2.0 SITE CHARACTERISTICS

Chapter 2, "Site Characteristics," of the Turkey Point Units 6 and 7 combined license (COL) final safety analysis report (FSAR) addresses the geological, seismological, hydrological, and meteorological characteristics of the Turkey Point Units 6 and 7 site and vicinity, in conjunction with present and projected population distribution and land use and site activities and controls.

2.0.1 Introduction

The site characteristics are reviewed by the U.S. Nuclear Regulatory Commission (NRC) staff to determine whether the applicant has accurately described the site characteristics and site parameters in accordance with Title 10 of the *Code of Federal Regulations* (CFR) Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." The review is focused on the site characteristics and site-related design characteristics needed to enable the staff to reach a conclusion on all safety matters related to siting of the Turkey Point Units 6 and 7. Because this COL application references a design certification (DC), this section focuses on the applicant's demonstration that the characteristics of the site fall within the site parameters specified in the DC rule or, if outside the site parameters, that the design satisfies the requirements imposed by the specific site characteristics and conforms to the design commitments and acceptance criteria described in the AP1000 design control document (DCD).

2.0.2 Summary of Application

Section 2.0 of the Turkey Point Units 6 and 7 COL FSAR, Revision 8, incorporates by reference Chapter 2 of the AP1000 DCD. AP1000 DCD Chapter 2 includes Section 2. This safety evaluation report (SER) refers to the Turkey Point Units 6 and 7 COL FSAR, Revision 8, and AP1000 DCD, Revision 19, unless otherwise specified.[1]

In addition, in the Turkey Point Units 6 and 7 COL FSAR Sections 2.1, 2.2, 2.4, and 2.5, the applicant provided the following:

Tier 2 Departures

- STD DEP 1.1-1

The applicant proposed numbering Sections 2.0, 2.1, 2.2, 2.4, and 2.5 of this chapter based on Regulatory Guide (RG) 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," down to the X.Y.Z level, rather than following the AP1000 DCD numbering and organization. In addition, Turkey Point Units 6 and 7 COL FSAR Part 7 requests an exemption from the numbering scheme in the AP1000 DCD. The applicant also requested other portions of the Turkey Point Units 6 and 7 COL FSAR be renumbered in STD DEP 1.1-1. The evaluation of STD DEP 1.1-1 can be found in SER Section 1.5.4.

[1] See Section 1.2.2 for a discussion of the staff's review related to verification of the scope of information to be included in a COL application that references a DC. This SER refers to the Turkey Point Units 6 and 7 COL FSAR, Revision 8, and AP1000 DCD, Revision 19, unless otherwise specified. This footnote will be referenced in several places throughout the chapter of this Safety Evaluation.

- PTN DEP 2.0-2

The applicant proposed a departure from the maximum normal wet-bulb (noncoincident) air temperature in Tier 2 material of the AP1000 DCD.

- PTN DEP 2.0-4

The applicant proposed a departure from the site parameter for the population distribution exclusion area (site) in Tier 2 material of the AP1000 DCD.

Tier 1 and 2 Departures

- PTN DEP 2.0-1

The applicant proposed a departure from the operating basis wind speed in both Tier 1 and Tier 2 material of the AP1000 DCD.

- PTN DEP 2.0-3

The applicant proposed a departure from the maximum safety wet-bulb (noncoincident) air temperature in both Tier 1 and Tier 2 material of the AP1000 DCD.

In addition, Turkey Point Units 6 and 7 COL FSAR Part 7 requests an exemption from the site parameter values described in PTN DEP 2.0-1, PTN DEP 2.0-2, PTN DEP 2.0-3, and PTN DEP 2.0-4.

Supplemental Information

- PTN Supplemental (SUP) 2.0-1

The applicant provided supplemental information in Turkey Point Units 6 and 7 COL FSAR Section 2.0, “Site Characteristics,” which describes the site characteristics of Turkey Point Units 6 and 7. The applicant also provided Turkey Point Units 6 and 7 COL FSAR Table 2.0-201, which provides a comparison of the AP1000 DCD site parameters and Turkey Point Units 6 and 7 site characteristics; Turkey Point Units 6 and 7 COL FSAR Table 2.0-202, provides control room atmospheric dispersion values expressed as χ/Q for all applicable accident analyses.

2.0.3 Regulatory Basis

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

In addition, the acceptance criteria associated with the relevant requirements of the NRC regulations for the site characteristics are given in Section 2.0, “Site Characteristics and Site Parameters,” of NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition.”

The applicable regulatory requirements for site characteristics are as follows:

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

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

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

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

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

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

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

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

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

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

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

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

- 10 CFR 50.12(a) – Specific Exemptions:

  > (a) The Commission may, upon application by any interested person or upon its own initiative, grant exemptions from the requirements of the regulations in Part 52, which are authorized by law, will not present an undue risk to the public health and safety, and are consistent with the common defense and security.

> The Commission will not consider granting an exemption unless special circumstances are present.

- 10 CFR 52.93(a) – Exemptions and variances:

> (a) Applicants for a combined license under Part 52, or any amendment to a combined license, may include in the application a request for an exemption from one or more of the Commission's regulations.

2.0.4 Technical Evaluation

The staff reviewed Section 2.0 of the Turkey Point Units 6 and 7 COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to site characteristics. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the Turkey Point Units 6 and 7 COL FSAR:

Tier 2 Departures

- STD DEP 1.1-1

The applicant's evaluation, in accordance with 10 CFR Part 52, Appendix D, Section VIII, Item B.5, determined that this departure did not require prior NRC approval. The numbering of Turkey Point Units 6 and 7 COL FSAR Chapter 2 is based on RG 1.206 down to the X.Y.Z level rather than following the AP1000 DCD organization for Chapter 2. The staff finds the Turkey Point Units 6 and 7 COL FSAR Chapter 2 numbering system proposed by the applicant to be acceptable because it provides for a logical presentation and review of the information in accordance with the guidance in RG 1.206.

The applicant renumbered the Turkey Point Units 6 and 7 COL FSAR Sections 2.0, 2.1, 2.2, 2.4 and 2.5 to include content consistent with RG 1.206, and NUREG-0800. The applicant identified the affected sections in Part 7 of the Turkey Point Units 6 and 7 COL FSAR. The departure and the exemption associated with the numbering scheme of the FSAR are closely related. The departure provided in Part 7 of the COL application provides the specific sections of the Turkey Point Units 6 and 7 COL FSAR that deviate from the DCD numbering scheme.

As required by 10 CFR 52.7, "Specific exemptions," and 10 CFR 52.93, "Exemptions and Variances," the applicant requested an exemption from 10 CFR Part 52, Appendix D, Section IV.A.2.a, to include "a plant-specific DCD containing the same type of information and using the same organization and numbering as the generic DCD for the AP1000 design…." In Part 7, "Departures and Exemptions," of the Turkey Point Units 6 and 7 COL FSAR, the applicant stated that the exemption will not result in any significant departures from the expected organization and numbering of a typical FSAR, and the information is readily identifiable to facilitate NRC review. The applicant stated that the subject deviations are considered to be purely administrative to support a logical construction of the document.

Furthermore, the revised organization and numbering generally follows the guidance provided in RG 1.206, and NUREG-0800.

As required by 10 CFR 52.7, the Commission may, upon application by any interested person or upon its own initiative, grant exemptions from the requirements of 10 CFR Part 52. The regulations in 10 CFR 52.7 further state the NRC's consideration will be governed by 10 CFR 50.12, which states that an exemption may be granted when:

> (1) the exemptions are authorized by law, will not present an undue risk to public health or safety, and are consistent with the common defense and security, and
>
> (2) special circumstances are present. Special circumstances are present whenever, according to 10 CFR 50.12(a)(2)(ii), "Application of the regulation in the particular circumstances would not serve the underlying purpose of the rule or is not necessary to achieve the underlying purpose of the rule."

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

Because there is not an applicable change provision in the referenced DC, and because 10 CFR 52.63(b)(1) does not apply to this exemption, the exemption cannot comply with the plain language of 10 CFR 52.93(a)(1). In this situation, the language of 10 CFR 52.93(a)(1) does not appear to serve the underlying purpose of the regulation as described by the Commission in the Statements of Consideration to the rule, in which the Commission stated that only changes to certification information must meet 10 CFR 52.63. Instead, this exemption should have fallen under 10 CFR 52.93(a)(2), and, thus, be analyzed under the requirements in 10 CFR 52.7. Therefore, the staff finds that, as required by 10 CFR 52.7, an exemption to Section 52.93(a)(1) should be granted.

This exemption is warranted because it meets the requirements in 10 CFR 50.12. First, because this is an administrative change regarding what exemption regulation applies, the exemption to 10 CFR 52.93(a)(1) is authorized by law, will not present an undue risk to public health or safety, and is consistent with the common defense and security. Additionally, application of the regulation in this case is not necessary to achieve the underlying purpose of the rule. The underlying purpose of the rule is to maintain the safety benefits of standardization

by requiring any exemption from certification information to meet the requirements in 10 CFR 52.63(b)(1). This underlying purpose does not apply to this exemption, because the form and organization of the application does not affect the safety benefits of standardization of the certification information. Therefore, for the purpose of determining the standards applicable to the exemption related to STD DEP 1.1-1, the staff finds an exemption to Section 52.93(a)(1) to be acceptable for the review of the exemption related to STD DEP 1.1-1.

In accordance with the exemption described above, the staff has reviewed the exemption related to STD DEP 1.1-1 to determine whether it meets the requirements in 10 CFR 52.7. This exemption would allow the applicant to provide an FSAR with numbering and topics more closely related to NUREG-0800 and RG 1.206. The staff finds that this administrative change of minor renumbering will not present an undue risk to the public health and safety and is consistent with the common defense and security. In addition, this exemption is consistent with the Atomic Energy Act of 1954, as amended, and is, therefore, authorized by law. Furthermore, the application of the regulation in these particular circumstances is not necessary to achieve the underlying purpose of the rule. Therefore, the staff finds that the exemption to 10 CFR Part 52, Appendix D, Section IV.A.2.a, is justified. Finally, for the same reasons the staff is granting the exemption request, the staff also finds the departure from the numbering scheme in the Turkey Point Units 6 and 7 COL FSAR to be acceptable.

- PTN DEP 2.0-2

The staff reviewed PTN DEP 2.0-2 in Turkey Point Units 6 and 7 COL FSAR Section 2.0, "Site Characteristics," describing the maximum normal wet-bulb (noncoincident) air temperature. The maximum normal wet-bulb (noncoincident) air temperature in AP1000 DCD Tier 1, Table 5.0-1 and DCD Tier 2, Table 2-1 is compared to the site-specific maximum normal wet-bulb (noncoincident) air temperature in Turkey Point Units 6 and 7 COL FSAR Table 2.0-201.

As required by 10 CFR Part 52, Appendix D, Section VIII.A.4 and 10 CFR 52.93, the applicant requested an exemption from 10 CFR Part 52, Appendix D, Section IV.A.2.d, to include "information demonstrating compliance with the site parameters and interface requirements," related to the maximum normal wet-bulb (noncoincident) air temperature. In Part 7, "Departures and Exemptions," of the Turkey Point Units 6 and 7 COL FSAR, the applicant stated that the exemption was evaluated in accordance with Section VIII.A.4 of the DC rule. Appendix D, Section VIII.A.4, 10 CFR 52.63(b)(1), 10 CFR 52.7, and 10 CFR 50.12 govern exemptions such as requested by the applicant here. These regulations require that: (1) the Commission will deny a request for an exemption from Tier 1 information if it finds that the design change will result in a significant decrease in the level of safety otherwise provided by the design (App. D, § VIII.A.4); (2) the Commission may grant the exemption if it is authorized by law, will not present an undue risk to the public health and safety, and is consistent with the common defense and security (§ 50.12(a)(1)); (3) the Commission will not grant the exemption unless special circumstances, as defined in § 50.12(a)(2), are present; and (4) the special circumstances that are required to be present outweigh any decrease in safety that may result from the reduction in standardization caused by the exemption (§ 52.63(b)(1)). The applicant's bases for satisfying each of the above criteria are shown below:

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

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

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

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

The staff's evaluation of the appropriateness of the 27.5 °Celsius (C) (81.5 °Fahrenheit (F)) value for the Turkey Point Units 6 and 7 site is discussed in SER Section 2.3. The staff's evaluation of the effects that this higher temperature has on the operation of the AP1000 design is addressed in SER Sections 2.3.1, 5.4, 6.2, 6.4, 9.1.3, 9.2.2 and 9.2.7.

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

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

- PTN DEP 2.0-4

The staff reviewed PTN DEP 2.0-4 in Turkey Point Units 6 and 7 COL FSAR Section 2.0, "Site Characteristics," describing the site parameter for the population distribution exclusion area (site). The site parameter for the population distribution exclusion areas (site) in AP1000 DCD Tier 1, Table 5.0-1 and DCD Tier 2, Table 2-1 is compared to the site-specific site parameter for

the population distribution exclusion areas (site) in Turkey Point Units 6 and 7 COL FSAR Table 2.0-201.

As required by 10 CFR 52.7 and 10 CFR 52.93, the applicant requested a Tier 2 departure from 10 CFR Part 52, Appendix D, Section IV.A.2.d, to include "information demonstrating compliance with the site parameters and interface requirements," related to the site parameter for the population distribution exclusion area (site).

The staff's evaluation of the appropriateness of using a minimum distance from the source boundary to the exclusion area boundary of 0.43 km (0.27 mi) rather than the AP1000 DCD site parameter of 0.80 km (0.5 mi) for the Turkey Point Units 6 and 7 site is discussed in SER Sections 2.1.2 and 2.3.4. Based on these evaluations, the staff has determined that the applicant's use of distances less than those provided in the AP1000 DCD would only result in more conservative (higher) χ/Q estimates. These atmospheric dispersion estimates are appropriate for the assessment of consequences from radioactive releases for design-basis accidents (DBA) in accordance with 10 CFR 52.79(a)(1)(vi), 10 CFR 100.21(c)(2), General Design Criterion (GDC) 19, "Control Room."

This departure will not affect the design or function of any structures, systems, and components (SSCs), the resolution of a severe accident issue identified in the plant-specific DCD, and will not adversely affect the common defense and security. Therefore, the staff finds that this departure to 10 CFR Part 52, Appendix D, Section IV.A.2.d and a departure from AP1000 DCD Table 2-1 is justified and meets the requirements of 10 CFR 52.7 and 10 CFR 52.93.

Tier 1 and Tier 2 Departures and Exemptions

- PTN DEP 2.0-1

The staff reviewed PTN DEP 2.0-1 in Turkey Point Units 6 and 7 COL FSAR Section 2.0, "Site Characteristics," describing the operating basis wind speed. The site parameter for the operating basis wind speed in AP1000 DCD Tier 1, Table 5.0-1 and DCD Tier 2, Table 2-1 is compared to the site-specific site parameter for the operating basis wind speed in Turkey Point Units 6 and 7 COL FSAR Table 2.0-201.

As required by 10 CFR Part 52, Appendix D, Section VIII.A.4 and 10 CFR 52.93, the applicant requested an exemption from 10 CFR Part 52, Appendix D, Section IV.A.2.d, to include "information demonstrating compliance with the site parameters and interface requirements," related to the operating basis wind speed. In Part 7, "Departures and Exemptions," of the Turkey Point Units 6 and 7 COL FSAR, the applicant stated that the exemption was evaluated in accordance with Section VIII.A.4 of the design certification rule. Appendix D, Section VIII.A.4, 10 CFR 52.63(b)(1), 10 CFR 52.7, and 10 CFR 50.12 govern exemptions such as requested by the applicant here. These regulations require that: (1) the Commission will deny a request for an exemption from Tier 1 information if it finds that the design change will result in a significant decrease in the level of safety otherwise provided by the design (App. D, § VIII.A.4); (2) the Commission may grant the exemption if it is authorized by law, will not present an undue risk to the public health and safety, and is consistent with the common defense and security (§ 50.12(a)(1)); (3) the Commission will not grant the exemption unless special circumstances, as defined in § 50.12(a)(2), are present; and (4) the special circumstances that are required to be present outweigh any decrease in safety that may result from the reduction in standardization caused by the exemption (§ 52.63(b)(1)). The applicant's bases for satisfying each of these four criteria are shown below:

1. As described in Section A.2 of Part 7 of the COL application, the exemption does not have an adverse impact on the AP1000 Standard Plant design and therefore will not result in a significant decrease in the level of safety otherwise provided by the design.

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

3. Special circumstances are present as specified in 10 CFR 50.12(a)(2). Specifically, application of 10 CFR Part 52, Appendix D, Section IV.A.2.d and the site parameters in Tier 1 of the DCD are not necessary to achieve the underlying purpose of the rules. The analysis described in SER Section 2.3.1, 3.3.1, and 3.3.3 shows that the increase in the operating basis wind speed does not affect the AP1000 Standard Plant design. Consequently, granting relief from the operating basis wind speed in the DCD would maintain the level of safety in the design, which is the underlying purpose of the rule.

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

The staff's evaluation of the appropriateness of the 150 mph operating basis wind speed for the Turkey Point Units 6 and 7 site is described in SER Sections 2.3.1, 3.3.1 and 3.3.3.

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

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

- PTN DEP 2.0-3

The staff reviewed PTN DEP 2.0-3 in Turkey Point Units 6 and 7 COL FSAR Section 2.0, "Site Characteristics," describing the maximum safety wet-bulb (noncoincident) air temperature. The

maximum safety wet-bulb (noncoincident) air temperature in AP1000 DCD Tier 1, Table 5.0-1 and DCD Tier 2, Table 2-1 is compared to the site-specific maximum safety wet-bulb (noncoincident) air temperature in Turkey Point Units 6 and 7 COL FSAR Table 2.0-201.

As required by 10 CFR Part 52, Appendix D, Section VIII.A.4 and 10 CFR 52.93, the applicant requested an exemption from 10 CFR Part 52, Appendix D, Section IV.A.2.d, to include "information demonstrating compliance with the site parameters and interface requirements," related to the maximum safety wet-bulb (noncoincident) air temperature. In Part 7, "Departures and Exemptions," of the Turkey Point Units 6 and 7 COL FSAR, the applicant stated that the exemption was evaluated in accordance with Section VIII.A.4 of the DC rule. Appendix D, Section VIII.A.4, 10 CFR 52.63(b)(1), 10 CFR 52.7, and 10 CFR 50.12 govern exemptions such as requested by the applicant here. These regulations require that: (1) the Commission will deny a request for an exemption from Tier 1 information if it finds that the design change will result in a significant decrease in the level of safety otherwise provided by the design (App. D, § VIII.A.4); (2) the Commission may grant the exemption if it is authorized by law, will not present an undue risk to the public health and safety, and is consistent with the common defense and security (§ 50.12(a)(1)); (3) the Commission will not grant the exemption unless special circumstances, as defined in § 50.12(a)(2), are present; and (4) the special circumstances that are required to be present outweigh any decrease in safety that may result from the reduction in standardization caused by the exemption (§ 52.63(b)(1)). The applicant's bases for satisfying each of these four criteria are shown below:

1. As described in Section A.2 of Part 7 of the Turkey Point Units 6 and 7 COL FSAR, the exemption does not have an adverse impact on the AP1000 Standard Plant design and therefore will not result in a significant decrease in the level of safety otherwise provided by the design.

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

3. Special circumstances are present as specified in 10 CFR 50.12(a)(2). Specifically, application of 10 CFR Part 52, Appendix D, Section IV.A.2.d and the site parameters in Tier 1 of the DCD are not necessary to achieve the underlying purpose of the rules. The analysis described in SER Section 2.3 shows that the increase in the maximum safety temperature does not affect the AP1000 Standard Plant design. Consequently, granting relief from the maximum safety air temperature in the DCD would maintain the level of safety in the design, which is the underlying purpose of the rule.

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

The staff's evaluation of the appropriateness of the 30.8 °C (87.4 °F) value for the Turkey Point Units 6 and 7 site is described in SER Section 2.3. The staff's evaluation of the effects that this

higher temperature has on the operation of the AP1000 design is addressed in SER Sections 2.3.1, 5.4, 6.2, 6.4, 9.1.3, 9.2.2 and 9.2.7.

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

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

Supplemental Information

- PTN SUP 2.0-1

The staff reviewed supplemental information PTN SUP 2.0-1 in Turkey Point Units 6 and 7 COL FSAR Section 2.0 describing the site characteristics of Turkey Point Units 6 and 7. The AP1000 DCD site parameters in DCD Table 2-1 are compared to the site-specific site characteristics in Turkey Point Units 6 and 7 COL FSAR Table 2.0-201. In addition, control room atmospheric dispersion factors for accident dose analysis are presented in Turkey Point Units 6 and 7 COL FSAR Table 2.0-202.

The staff reviewed and compared the site-specific characteristics included in the Turkey Point Units 6 and 7 COL FSAR Tables 2.0-201 against AP1000 DCD Table 2-1. The staff's evaluation of the site characteristics associated with air temperature, precipitation, wind speed, atmospheric dispersion values, and control room atmospheric dispersion values is addressed in SER Section 2.3. The staff's evaluation of site characteristics associated with flood level, groundwater level, and plant grade elevation is addressed in SER Section 2.4. The staff's evaluation of seismic and soil site characteristics is addressed in SER Section 2.5. The staff's evaluation of site characteristics associated with missiles is addressed in SER Section 3.5.

With the exception of the population distribution exclusion area (site), the operating basis wind speed, maximum safety wet-bulb (noncoincident) air temperature value, and maximum normal wet-bulb (noncoincident) air temperature value, the site-specific characteristics listed in Turkey Point Units 6 and 7 COL FSAR Table 2.0-201 are bounded by the AP1000 DCD site parameter values addressed in DCD Table 2-1.

2.0.5 Post Combined License Activities

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

2.0.6 Conclusion

The staff reviewed the application and checked the referenced DCD. The 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 Turkey Point Units 6 and 7 COL FSAR related to this section. The results of the staff's technical evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

As set forth above, the staff reviewed the application to ensure that sufficient information was presented in PTN DEP 2.0-1, PTN DEP 2.0-2, PTN DEP 2.0-3, PTN DEP 2.0-4, and VCS SUP 2.0-1 to demonstrate that the characteristics of the site fall within the site parameters specified in the DC and adequate justification has been provided for population distribution exclusion area (site), the operating basis wind speed, maximum safety wet-bulb (noncoincident) air temperature value, and maximum normal wet-bulb (noncoincident) air temperature value falling outside the DC site parameter. Accordingly, the staff concludes that the applicant has demonstrated that the requirements of 10 CFR 52.79(d)(1) have been met. The staff also concludes that PTN DEP 2.0-1, PTN DEP 2.0-2, PTN DEP 2.0-3, and PTN DEP 2.0-4 meet the requirements for departures in 10 CFR Part 52, Appendix D, and are, therefore, acceptable.

Regarding PTN DEP 2.0-1, PTN DEP 2.0-2, PTN DEP 2.0-3, and PTN DEP 2.0-4, the staff concludes that the exemptions meets the requirements in Appendix D to 10 CFR Part 52 and 10 CFR 50.12, and are, therefore, acceptable.

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 man-made features of the area, (2) site area map to determine the distance from the reactor to the boundary lines of the exclusion area, including consideration of the location, distance, and orientation of plant structures with respect to highways, railroads, and waterways that traverse or lie adjacent to the exclusion area, and (3) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts of 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 man-made hazards.

2.1.1.2 Summary of Application

Section 2.1 of the Turkey Point Units 6 and 7 COL FSAR incorporates by reference Section 2.1 of the AP1000 DCD.

In addition, in Turkey Point Units 6 and 7 COL FSAR Section 2.1, the applicant provided the following:

AP1000 COL Information Item

- PTN COL 2.1-1

The applicant provided additional information in PTN 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 Turkey Point Units 6 and 7 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 number, northing, easting), meters, and latitude and longitude.
- Site Area Map.

2.1.1.3 Regulatory Basis

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

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

The applicable regulatory requirements for identifying site location and description are set forth in the following:

- 10 CFR 50.34(a)(1) and 10 CFR 52.79(a)(1), as they relate to the inclusion in the safety analysis report (SAR) of a detailed description and safety assessment of the site on which the facility is to be located, with appropriate attention to features affecting facility design.
- 10 CFR Part 100, as it relates to the following: (1) defining an exclusion area and setting forth requirements regarding activities in that area (10 CFR 100.3, "Definitions"), (2) addressing and evaluating factors that are used in determining the acceptability of the site as identified in 10 CFR 100.20(b), (3) determining an exclusion area such that certain dose limits would not be exceeded in the event of a postulated fission product release as identified in 10 CFR 50.34(a)(1) and 10 CFR 52.79(a)(1), as it relates to site evaluation factors identified in 10 CFR Part 100, and (4) requiring that the site location and the engineered features included as safeguards against the hazardous consequences of an accident, should one occur, would ensure a low risk of public exposure.

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

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

- Site Area Map: The information submitted by the applicant is adequate and meets the requirements of 10 CFR 50.34(a)(1) and 10 CFR 52.79(a)(1) if it describes the site location, including the exclusion area and the location of the plant within the area, in sufficient detail to enable the reviewer to evaluate the applicant's analysis of a postulated fission product release, thereby allowing the reviewer to determine (in Safety Evaluation Report (SER) Sections 2.1.2 and 2.1.3, and Chapter 15) that the applicant has met the requirements of 10 CFR 50.34(a)(1) and 10 CFR Part 100.

- 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 NRC approval. This departure is subject to the requirements in Section VIII, which are similar to the requirements in 10 CFR 50.59.

2.1.1.4 Technical Evaluation

The staff reviewed Section 2.1 of the Turkey Point Units 6 and 7 COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the site location and description. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the Turkey Point Units 6 and 7 COL FSAR using the review procedures described in Section 2.1.1 of NUREG−0800.

<u>AP 1000 COL Information Item</u>

- PTN COL 2.1-1

The staff reviewed PTN COL 2.1-1 related to site location and description, including political subdivisions, natural and man-made features, population, highways, railways, waterways, and other significant features of the area included in Section 2.1.1 of the Turkey Point Units 6 and 7 COL FSAR. COL Information Item 2.1-1 in Section 2.1.1 of the AP1000 DCD states:

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

The staff reviewed the resolution to the site-specific items related to the site location and description included under Section 2.1of the Turkey Point Units 6 and 7 COL FSAR.

The staff independently estimated and verified the latitude and longitude and UTM coordinates of the proposed site as provided in the Turkey Point Units 6 and 7 COL FSAR (Table 2.1.1-1).

Table 2.1.1-1: NAD83 Coordinates of proposed site provided in Turkey Point Units 6 and 7 COL FSAR

	Northing; Easting UTM coordinates in meters (feet)	Latitude; Longitude (deg/min/sec)
Unit 6	Zone 17, 2,812,087 N; 567,179 E (9,226,007 N) (1,860,823 E)	25°25'27.1" N; 80°19'55.1" W
Unit 7	Zone 17, 2,812,087 N; 566,920 E (9,226,007 N) (1,859,973 E)	25°25'27.1 N; 80°20'04.3" W

On the basis of the staff's review of the information addressed in the Turkey Point Units 6 and 7 COL FSAR, and also the staff's confirmatory review of pertinent information generally available in literature and on the internet, as well as information collected during a site visit, the staff considers the information provided by the applicant with regard to the site location and description to be adequate and acceptable.

2.1.1.5 Post Combined License Activities

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

2.1.1.6 Conclusion

The staff reviewed the application and checked the referenced DCD. The 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 Turkey Point Units 6 and 7 COL FSAR related to this section. The results of the staff's technical evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

As set forth above, the applicant has presented and substantiated information to establish the site location and description. The staff has reviewed PTN COL 2.1-1, and for the reasons given above, concludes that it is sufficient for the staff to evaluate compliance with the siting evaluation factors in 10 CFR Part 100.3, as well as with the radiological consequence evaluation factors in 10 CFR 50.34(a)(1) and 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 conclusion, the applicant has provided sufficient information for satisfying 10 CFR Part 52.79(a)(1) and 10 CFR Part 100.

2.1.2 Exclusion Area Authority and Control

2.1.2.1 Introduction

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

2.1.2.2 Summary of Application

Turkey Point Units 6 and 7 COL FSAR Section 2.1 incorporates by reference Section 2.1 of the AP1000 DCD.

In addition, in Turkey Point Units 6 and 7 COL FSAR Section 2.1.2, the applicant provided the following:

Tier 2 Departure

- PTN DEP 2.0-4

The applicant proposed PTN DEP 2.0-4 in which the minimum distance from the source boundary to the exclusion area boundary of 0.43 km (0.27 mi) rather than the site parameter of 0.80 km (0.5 mi) specified in the AP1000 DCD be used for the Turkey Point Units 6 and 7 site. The applicant provided the distance from the Turkey Point Units 6 and 7 site's source boundary to the exclusion area boundary (EAB) at the atmospheric dispersion value (χ/Q) at the EAB in Turkey Point Units 6 and 7 COL FSAR Table 2.3.4-201.

AP1000 COL Information Item

- PTN COL 2.1-1

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

This site-specific information included in the Turkey Point Units 6 and 7 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 of the EAB,
- 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, and
- 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 in NUREG-1793 and its supplements.

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

The applicable regulatory requirements for verifying exclusion area authority and control are set forth in the following:

- 10 CFR 50.34(a)(1), and 10 CFR 52.79(a)(1), as it relates to the inclusion in the SAR of a detailed description and safety assessment of the site on which the facility is to be located, with appropriate attention to features affecting facility design (10 CFR 50.34(a)(1) and 10 CFR 52.79(a)(1)).
- 10 CFR Part 100, as it relates to the following: (1) defining an exclusion area and setting forth requirements regarding activities in that area (10 CFR 100.3), (2) addressing and evaluating factors that are used in determining the acceptability of the site as identified in 10 CFR 100.20(b), and (3) determining an exclusion area such that certain dose limits would not be exceeded in the event of a postulated fission product release as identified in 10 CFR 50.34(a)(1) and 10 CFR 52.79 (a)(1) as it relates to site evaluation factors identified in 10 CFR Part 100.

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

- Establishment of Authority for the Exclusion or Removal of Personnel and Property: The information submitted by the applicant is adequate and meets the requirements of 10 CFR 50.33, "Contents of Applications; General Information"; 10 CFR 50.34(a)(1); 10 CFR 52.79, "Contents of Applications; Technical Information in Final Safety Analysis Report"; and 10 CFR Part 100 if it provides sufficient detail to enable the staff to evaluate the applicant's legal authority 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 staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.1.2 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the exclusion area authority and control. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the Turkey Point Units 6 and 7 COL FSAR using the review procedures described in Section 2.1.2 of NUREG-0800.

Tier 2 Departure

- PTN DEP 2.0-4

The staff reviewed PTN DEP 2.0-4 related to the applicant's use of a minimum distance from the source boundary to the exclusion areas boundary of 0.27 mi (0.43 km) for the Turkey Point Units 6 and 7 site, rather than the site parameter of 0.80 km (0.5 mi) specified in the AP1000 DCD.

The distance from the Turkey Point Units 6 and 7 site's source boundary to the EAB and the atmospheric dispersion value (χ/Q) at the EAB are listed in Turkey Point Units 6 and 7 COL FSAR Table 2.3.4-201. The EAB for Turkey Point Units 6 and 7 lies primarily within the EAB for Turkey Point Units 3 and 4, with the exception of the eastern and southern portions. The combined EAB provides a minimum distance of 0.27 mi (43 km) from the source boundary for Turkey Point Units 6 and 7. All Turkey Point Units 6 and 7 site sector EAB distances, except for S, SSW, and SSE sectors are less than the 0.80 km (0.5 mi) site parameter, with the minimum being 0.43 km (0.27 mi) in the northeast sector. However, the Turkey Point Units 6 and 7 site's EAB resides within the current applicant's site boundary. A comparison of the Turkey Point Units 6 and 7 site boundary and EAB are shown in Turkey Point Units 6 and 7 COL FSAR Figures 2.1-202 and 2.1-204. Further evaluation of this departure is discussed in SER Section 2.3.4.

AP1000 COL Information Item

- PTN COL 2.1-1

The staff reviewed PTN COL 2.1-1 related to the exclusion area authority and control, including size of the area, exclusion area authority and control, and activities that may be permitted within the designated exclusion area included in Turkey Point Units 6 and 7 COL FSAR Section 2.1.2. COL Information Item in Section 2.1.1 of the AP1000 DCD states:

> Combined License applicants referencing the AP1000 certified design will provide site-specific information related to site location and description, exclusion

area authority and control, and population distribution. Site-specific information on the exclusion area will include the size of the area and the exclusion area authority and control. Activity that may be permitted within the exclusion area will be included in the discussion.

The applicant 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, and
- abandonment or relocation of roads.

Florida Power and Light (FPL) owns the property within the Turkey Point Units 6 and 7 exclusion area, subject to certain encumbrances on portions of the property, specifically, certain canal, drainage, reclamation, oil, gas and mineral rights reservations held by the Trustees of the Internal Improvement Fund of the State of Florida and a canal reservation held by Miami-Dade County. Also, a small parcel of submerged land in the southeast and south-southeast portions of the exclusion area is located in the Biscayne Bay waterway. Because of the location of the submerged land, this portion of the exclusion area cannot be reasonably accessed except through FPL property.

The staff reviewed the resolution to the site-specific items related to the exclusion area authority and control included under Turkey Point Units 6 and 7 COL FSAR Section 2.1. The 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 staff also verified for consistency that the EAB is the same as that being considered by the applicant for the radiological consequences in Turkey Point Units 6 and 7 COL FSAR Chapters 15 and 13.3. The staff concludes that the applicant has acquired authority to control all activities within the designated exclusion area and meets acceptance criteria of Section 2.1.2, Exclusion Area Authority and Control," of NUREG-0800.

There are no residences, commercial activities not associated with Turkey Point Units 6 and 7, or recreational activities within the exclusion area. No public highways or railroads traverse the exclusion area. The staff verified that no public roads cross the exclusion area; and, therefore, neither relocation nor abandonment of roads is needed.

2.1.2.5 Post Combined License Activities

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

2.1.2.6 Conclusion

The staff reviewed Section 2.1.2 of the Turkey Point Units 6 and 7 COL FSAR and checked the referenced DCD. The staff's review confirmed that the applicant addressed the required information relating to the exclusion area authority and control, and there is no outstanding information expected to be addressed in the Turkey Point Units 6 and 7 COL FSAR related to this section. The results of the staff's technical evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

As set forth above, the applicant has provided and substantiated information concerning its legal authority and control of all activities within the designated exclusion area. The staff has reviewed PTN COL 2.1-1, and for the reasons given above, concludes that the applicant's exclusion area is acceptable to meet the requirements of 10 CFR 50.33,10 CFR 50.34(a)(1), 10 CFR 52.79(a)(1), 10 CFR Part 100, and 10 CFR 100.3 with respect to determining the acceptability of the site. PTN DEP 2.0-4 is discussed and evaluated in SER Section 2.3.4. This conclusion is based on the applicant having appropriately described the plant exclusion area, the authority under which all activities within the exclusion area can be controlled, the methods by which the relocation or abandonment of public roads that lie within the proposed exclusion area can be accomplished, if necessary, and the methods by which access and occupancy of the exclusion area can be controlled during normal operation and in the event of an emergency situation. In addition, the applicant has the required authority to control activities within the designated exclusion area, including the exclusion and removal of persons and property, and has established acceptable methods for control of the designated exclusion area. This addresses COL Information Item 2.1-1. In conclusion, the applicant has provided sufficient information for satisfying the requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100.

2.1.3 Population Distribution

2.1.3.1 Introduction

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

2.1.3.2 Summary of Application

Turkey Point Units 6 and 7 COL FSAR Section 2.1 incorporates by reference Section 2.1 of the AP1000 DCD.

In addition, in Turkey Point Units 6 and 7 COL FSAR Section 2.1.3, the applicant provided the following:

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

- PTN COL 2.1-1

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

- 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 mi less than 500 people/square mile consistent with guidelines given in RG 4.7 Regulatory Position C.4,
- population data in the site vicinity including transient populations,
- a description of the population within 10 mi of the plant,
- a description of the population between 10 and 50 mi of the plant,
- a description of the seasonal and daily variations in population and population distribution from land uses,
- the low-population zone,
- the nearest population center, and
- a plot out to a distance of at least 20 mi showing the cumulative resident population (population density).

2.1.3.3 Regulatory Basis

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

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

The applicable regulatory requirements for identifying site location and description are set forth in the following:

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

- 10 CFR 100.20, “Factors To Be Considered When Evaluating Sites,” and 10 CFR 100.21, “Non-Seismic Siting Criteria,” as they relate to determining the acceptability of a site for a power reactor. In 10 CFR 100.3, 10 CFR 100.20(a), and 10 CFR 100.21(b), the NRC provides definitions and other requirements for determining an exclusion area, LPZ, and population center distance.

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

- Population Data: The population data supplied by the applicant in the SAR is acceptable under the following conditions: (1) the FSAR includes population data from the latest census and projected population at the year of plant approval and 5 years thereafter, in the geographical format given in Section 2.1.3 of RG 1.70 and in accordance with DG-1145, (2) the FSAR describes the methodology and sources used to obtain the population data, including the projections, and (3) the FSAR includes information on transient populations in the site vicinity.

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

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

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

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

2.1.3.4 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.1.3 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff’s review confirmed that the information in the application and incorporated by reference addresses the required information relating to population distribution. The results of the staff’s evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the Turkey Point Units 6 and 7 COL FSAR using the review procedures described in Section 2.1.3 of NUREG-0800.

AP1000 COL Information Item

- PTN COL 2.1-1

The staff reviewed PTN COL 2.1-1 related to the population distribution around the site environs included in Turkey Point Units 6 and 7 COL FSAR Section 2.1.3. COL Information Item in Section 2.1.1 of the AP1000 DCD states:

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

The staff reviewed the resolution to the COL specific items related to the population distribution around the site environs included under Section 2.1 of the Turkey Point Units 6 and 7 COL FSAR.

The staff reviewed the data on the population in the site environs, as presented in the Turkey Point Units 6 and 7 COL FSAR, to determine whether the exclusion area, LPZ, and population center distance for the proposed site comply with the requirements of 10 CFR Part 100. The staff evaluated whether, consistent with Regulatory Position C.4 of RG 4.7, the applicant should consider alternative sites with lower population densities. The staff also reviewed whether appropriate protective measures could be taken on behalf of the enclosed populace within the emergency planning zone (EPZ), which encompasses the LPZ, in the event of a serious accident. The staff compared and verified the applicant’s population data against U.S. Census Bureau and county population data. The staff reviewed the projected population data provided by the applicant, including the weighted transient population for 2020, 2030, 2040, 2050, 2060, 2070, 2080, and 2090.

The populations for the years 2020 through 2090 have been projected by calculating a growth rate using State populations (by county) as the base. The projected population for the expected first year of plant operation (2022 for Unit 6 and 2023 for Unit 7) is conservatively selected as that for the year 2030. The staff also independently performed and verified the population projections based on 2010 census data, and State and county population projection data. The staff reviewed the extensive transient population data provided by the applicant. Based on this information, the staff finds that the applicant’s estimate of the transient population is reasonable. The applicant stated in Turkey Point Units 6 and 7 COL FSAR Section 2.1.3.1 that Figures 2.1-207 through 2.1-215 show the total (resident and transient) population for the year 2010 through 2090. The applicant updated 2000 census data used for the original population distribution for the Turkey Point Units 6 and 7 COL FSAR Revision 0 with 2010 census data in the Turkey Point Units 6 and 7 COL FSAR Revision 5. The applicant also updated transient population data consistent with year 2010, and presented updated information in tables and figures.

The nearest population center (population of greater than 25,000 residents) to Turkey Point Units 6 and 7 site is the city of Homestead, which is 14.4 km (9 mi) west northwest of the site. Homestead’s population in 2010 was 60,512. The distance to the boundary of the population center is 1.6 times the radius of the 8 km (5 mi) LPZ. The staff verified the distance to the nearest population center to be greater than one and one third times the distance from the reactor center point to the boundary of the low population zone as required by NUREG-0800 and complies with the guidance provided by RG 4.7. Therefore, the staff concludes that the proposed site meets the population center distance requirement in 10 CFR 100.21(b).

The 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 population density in 2030 (more than 5 years after initial site approval), and whether it would exceed the criteria of 500 persons per square mile averaged over a radial distance of 20 mi (32 km) (cumulative population at a distance divided by the area at that distance). The applicant determined that the density based on both the land area and circular area at the 16.1 to 32.2 km (10 to 20 mi) radii exceeds the criterion of 500 people per square mile. Therefore, the applicant stated that in accordance with RG 4.7, Position C.4, it has evaluated alternative sites in Part 3 of the Turkey Point Units 6 and 7 COL FSAR and the Environmental Report. The staff has also independently verified and confirmed the applicant's calculated population density for the year 2030 exceeded the guideline value of 500 people per square mile. To adequately document the licensing basis, in a letter dated March 28, 2012, the staff requested the applicant in request for additional information (RAI) 6079, Question 02.01.03-2, to discuss the summary of results containing the rationale and justification for the selection of a high density site in the Turkey Point Units 6 and 7 COL FSAR in accordance with the guidance provided in RG 4.7 Position C.4.

In a letter April 25, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML121170467), the applicant provided the response with a general address of rationale and justification, and submitted a revision to the Turkey Point Units 6 and 7 FSAR Section 2.1.3.6. However, the applicant's response did not demonstrate the merits, benefits, or advantages of selecting the Turkey Point Units 6 and 7 site, despite a population density in excess of 500 people per square mile, over the other four alternative sites considered. Therefore, in letter dated May 20, 2014 (RAI 7467, Question 02.01.03-3), the staff requested the applicant provide supplemental information to RAI 6079, Question 02.01.03-2, to explain and document in the Turkey Point Units 6 and 7 COL FSAR, how the Turkey Point Units 6 and 7 site compared to the other four sites. In a letter dated June 18, 2014, the applicant provided discussion and rationale by clarifying the merits and advantages of Turkey Point Site over the other alternative sites considered and evaluated. The staff reviewed this information and found the applicant's address reasonable and acceptable as it meets the guidance provided in RG 4.7. The applicant also provided revision to Turkey Point Units 6 and 7 COL FSAR Section 2.1.3.6. The staff finds the proposed revisions acceptable and has confirmed that these changes have been incorporated into the Turkey Point Units 6 and 7 COL FSAR. Therefore, this RAI 7467, Question 02.01.03-03 is resolved.

2.1.3.5 Post Combined License Activities

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

2.1.3.6 Conclusion

The staff reviewed the application and checked the referenced DCD. The staff's review confirmed that the applicant addressed the required information relating to population distribution, and there is no outstanding information expected to be addressed in the Turkey Point Units 6 and 7 COL FSAR related to this section. The results of the staff's technical evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

As set forth above, the applicant has provided an acceptable description of current and projected population densities in and around the site. The staff has reviewed PTN COL 2.1-1,

and for the reasons given above, concludes that the population data with an exception population density guideline of 500 people per square mile, within 32 km (20 mi) from the site, meets the requirements of 10 CFR 50.34(a)(1), 10 CFR 52.79(a)(1), 10 CFR 100.20(a), 10 CFR 100.20(b), 10 CFR Part 100 based on the information provided in 10 CFR 100.3. This conclusion is based on the applicant having provided an acceptable description and safety assessment of the Turkey Point Units 6 and 7 site, which includes present and projected population densities in accordance with the guidelines of Regulatory Position C.4 of RG 4.7, and properly specified the LPZ and population center distance. In addition, the staff has reviewed and confirmed, by comparison with independently obtained population data, the applicant's estimates of the present and projected populations surrounding the Turkey Point Units 6 and 7 site, including transients. The applicant also has calculated the radiological consequences of design-basis accidents at the outer boundary of the low-population zone (SRP Chapter 15) and has provided reasonable assurance that appropriate protective measures can be taken within the low-population zone to protect the population in the event of a radiological emergency. This addresses COL Information Item 2.1-1. In conclusion, the applicant has provided sufficient information to satisfy the requirements of 10 CFR Part 52.79(a)(1), and 10 CFR Part 100.

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

The staff's review of Turkey Point Units 6 and 7 COL FSAR Section 2.2.1, "Locations and Routes," and Section 2.2.2, "Descriptions," is addressed in this SER section.

2.2.1.2 Summary of Application

Turkey Point Units 6 and 7 COL FSAR Section 2.2 incorporates by reference Section 2.2 of the AP1000 DCD.

In addition, in Turkey Point Units 6 and 7 COL FSAR Section 2.2, the applicant provided the following:

AP1000 COL Information Item

- PTN COL 2.2-1
- PTN COL 3.3-1

- PTN COL 3.5-1

The applicant provided additional information in PTN COL 2.2-1, PTN COL 3.3-1, and PTN COL 3.5-1 to resolve COL Information Item 2.2-1 (COL Action Item 2.2-1), which addresses information about industrial, military, and transportation facilities and routes to establish the presence and magnitude of potential external hazards.

The applicant identified and addressed the potential hazard facilities and routes within the vicinity, 8 km (5 mi) of the Turkey Point Units 6 and 7 site, and airports within 16 km (10 mi) of the Turkey Point Units 6 and 7 site along with other significant facilities beyond 8 km (5 mi), in accordance with RG 1.206 and relevant sections of 10 CFR Part 50 and 10 CFR Part 100.

The applicant addressed one significant industrial facility associated with a military installation, one natural gas transmission pipeline system, and one navigable waterway for assessment within 8 km (5 mi) of the site. In addition, potential hazard analysis included chemical storage associated with Units 1 through 5 and site-specific onsite chemical storage facilities associated with Turkey Point Units 6 and 7 along with an onsite transportation route. No additional facilities other than airway and military operation areas significant enough are identified within 16 km (10 mi) of the Turkey Point Units 6 and 7 site.

2.2.1.3 Regulatory Basis

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

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

The applicable regulatory requirements for identifying locations and routes are set forth in the following:

- 10 CFR 100.20(b), which requires that the nature and proximity of man-made related hazards (e.g., airports, dams, transportation routes, and military and chemical facilities) be evaluated to establish site parameters for use in determining whether plant design can accommodate commonly occurring hazards, and whether the risk of other hazards is very low.

- 10 CFR 52.79(a)(1)(iv), as it relates to the factors to be considered in the evaluation of sites, which require the location and description of industrial, military, or transportation facilities and routes, and of 10 CFR 52.79(a)(1)(vi) as it relates to the compliance with 10 CFR Part 100.

- In addition, in accordance with 10 CFR Part 52, Appendix D, Section VIII, the applicant identified a Tier 2 departure, which does not require prior NRC approval. This departure is subject to requirements in Section VIII, which are similar to the requirements in 10 CFR 50.59, “Changes, Tests and Experiments.”

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

- Data in the FSAR adequately describes the locations and distances from the plant for nearby industrial, military, and transportation facilities; and that such data are in agreement with data obtained from other sources, when available.

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

The regulatory requirement associated with the Tier 2 departure request is as follows:

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

2.2.1.4 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.2 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to nearby industrial, transportation, and military facilities. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the Turkey Point Units 6 and 7 COL FSAR:

AP1000 COL Information Items

- PTN COL 2.2-1
- PTN COL 3.3-1
- PTN COL 3.5-1

The staff reviewed PTN COL 2.2-1, PTN COL 3.3-1, and PTN COL 3.5-1 related to information about industrial, military, and transportation facilities and routes to establish the presence and magnitude of potential external hazards included in Turkey Point Units 6 and 7 COL FSAR Section 2.2. COL Information Item in AP1000 DCD Section 2.2.1 states:

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

The staff reviewed the information in the Turkey Point Units 6 and 7 COL FSAR using the review procedures described in Section 2.2.1-2.2.2 of NUREG-0800.

This SER section identifies and provides the information that would help in evaluating potential effects on the safe operation of the nuclear facility by industrial, transportation, mining, and military installations in the Turkey Point Units 6 and 7 site area. The evaluation of potential effects on the safe operation of the nuclear facility is described in SER Section 2.2.3.

Locations and Routes

The applicant identified and provided information regarding potential external hazard facilities and operations within a 5 mi (8 km) radius of the Turkey Point Units 6 and 7 site.

The location of these transportation routes and facilities are shown on Turkey Point Units 6 and 7 COL FSAR Figure 2.2-201, and include the following:

- industrial and military facilities within 8 km (5 mi),
- Turkey Point Units 1 through 5,
- Homestead Air Reserve Base,
- transportation routes within 8 km (5 mi),
- onsite transportation route,
- Miami to Key West, Florida Intracoastal Waterway,
- Florida Gas Transmission Company, Turkey Point Lateral Pipeline, and Homestead Lateral Pipeline,
- airport and airway routes within 16.2 km (10 mi),
- Turkey Point Heliport,
- Ocean Reef Club Airport, and
- Airway V-3.

The staff confirmed that no major industrial activities are within 16 km (10 mi) that are significant enough to be identified as potential hazard facilities.

Description of the Facilities

Turkey Point Units 1 through 5 are located on the approximate 11,000 acre property. Units 1 and 2 are gas/oil-fired steam electric generating units; Units 3 and 4 are nuclear-powered steam electric generating units; and Unit 5 is a natural gas combined cycle plant. Units 6 and 7 are located southwest of Units 1 through 5. The center point of the Unit 6 reactor building is approximately 65.5 m (215 ft) west and 1,105 m (3,625 ft) south of the center point of the Unit 4 containment.

The Homestead Air Reserve Base is located approximately 7.7 km (4.76 mi) north-northwest of Units 6 and 7. The Homestead Air Reserve Base is a fully combat-ready unit capable of providing F-16C multipurpose fighter aircraft, along with mission-ready pilots and support personnel, for short-notice worldwide deployment. In addition, the Homestead Air Reserve Base is home to the most active North American Aerospace Defense Command alert site in the continental United States, operated by a detachment of F-15 fighter intercepts from the 125th Fighter Wing Florida Air National Guard.

Description of Highways

Miami-Dade County, Florida, is traversed by several highways (i.e., Interstate 95, U.S. Highway 1, Florida Turnpike, and U.S. Route 41). However, there are no major highways within 8 km (5 mi) of Units 6 and 7. The transportation route that approaches closer than 8 km (5 mi) to Units 6 and 7 is for chemicals transported onto the plant property.

Description of Railroads

There are no railroads within 8 km (5 mi) of Units 6 and 7.

Description of Waterways

Turkey Point Units 6 and 7 site is on the western shore of south Biscayne Bay. The Biscayne Bay contains the Miami to Key West, Florida Intracoastal Waterway. The only commodity transported on the Miami to Key West, Florida Intracoastal Waterway is residual fuel oil. In 2005, there were 611,000 short tons of residual fuel oil transported, and the entirety of this commodity was delivered to the Turkey Point plant. Residual fuel oil is delivered exclusively by barges, having a size of barge transporting approximately 18,000 barrels of oil. The residual fuel oil is stored in two 268,000 barrel tanks. The hazard determined due to these tanks is bounding compared to the residual fuel oil transported by the barge, and, therefore, it is stated by the applicant that no further analysis for barge transport is warranted.

Description of Pipelines

There are two natural gas transmission pipelines operated by Florida Gas Transmission Company within 8 km (5 mi) of the plant. Two of the pipelines, the Turkey Point Lateral and Homestead Lateral, are located within 8 km (5 mi) of Turkey Point Units 6 and 7.

The Florida Gas Transmission Company Turkey Point Lateral is a 61 cm (24 in) diameter pipeline, operating at a maximum pressure of 722 psig, providing gas service to Turkey Point's gas-fired power plants. The pipeline is buried to an approximate depth of 107 cm (42 in) below grade. At the closest approach to Turkey Point Units 6 and 7, the Turkey Point Lateral pipeline passes within approximately 1,382 m (4,535 ft) of the Unit 6 auxiliary building.

The Florida Gas Transmission Company Homestead Lateral is a 16.8 cm (6.625 in) diameter pipeline that tees off of the 61 cm (24 in) Turkey Point Lateral pipeline approximately 4.8 km (3 mi) north of the Turkey Point Units 6 and 7 site and extends in a westward direction to provide gas to the city of Homestead. Because of the proximity and diameter of the Turkey Point Lateral pipeline compared to the Homestead Lateral pipeline, the Turkey Point Lateral pipeline presents a greater hazard, and is bounding. Therefore, the applicant stated that no further analysis of the Homestead Lateral pipeline is warranted.

Description of Airports and Airways

The Turkey Point site operates its own corporate heliport. The Turkey Point heliport is in the southeast corner of the Units 3 and 4 parking lot approximately 945 m (3,100 ft) north of Units 6 and 7. Due to the weight of the aircraft (signifying a low-penetration hazard), and infrequent use of the heliport, the applicant stated that no further analysis is considered.

Homestead Air Reserve Base is approximately 7.7 km (4.76 mi) north-northwest from the proposed Units 6 and 7. The U.S. Air Force owns the airport. The Homestead Air Reserve Base has approximately 36,429 annual operations, and this number is expected to remain the same over the life of the plant.

Ocean Reef Club Airport is a privately owned airport 11.9 km (7.41 mi) south-southeast from Units 6 and 7. There are approximately 25 aircraft on the site, and the number of flight operations reasonably falls within plant-to-airport distance criteria.

The site is approximately 9.6 km (5.98 statute mi) from the center of airway V3/G439. The edge of the closest airway is located closer than 3.2 km (2 statute mi) from Units 6 and 7. Because of the proximity of airway V43/G439 and the fact that Homestead Air Reserve base airport is within 8 km (5 mi) of the site, a calculation of the probability of an aircraft accident that could possibly result in radiological consequences was performed to determine whether the accident probability is less than an order of magnitude of 1×10^{-7} per year. The details of analysis for the determination of the aircraft crash probability are addressed in Turkey Point Units 6 and 7 COL FSAR Sections 2.2.2.7 and 3.5.1.6.

Based on the review of the information addressed by the applicant pertaining to locations and routes, and the staff's independent review of the information in public domain, the staff concludes that the information provided by the applicant is adequate and acceptable.

Projections of Industrial Growth

A review of Miami-Dade County's Comprehensive Development Master Plan does not indicate any future projections of new major industrial, military, or transportation facilities located with the vicinity of the Turkey Point Units 6 and 7 site.

2.2.1.5 Post Combined License Activities

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

2.2.1.6 Conclusion

The staff reviewed the application and checked the referenced DCD. The staff's review confirmed that the applicant addressed the required information relating to nearby industrial, transportation, and military facilities, and there is no outstanding information expected to be addressed in the Turkey Point Units 6 and 7 COL FSAR related to this section. The results of the staff's technical evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

As set forth above, the applicant has presented and substantiated information to establish an identification of potential hazards in the Turkey Point Units 6 and 7 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 Turkey Point Units 6 and 7 COL FSAR as well as information that the staff independently obtained, the staff has concluded that all potentially hazardous activities on site and in the vicinity of the plant have been identified. The hazards associated with these activities have been reviewed and are discussed in SER Sections 2.2.3, 3.5.1.5, and 3.5.1.6. This addresses PTN COL Information Item 2.2-1. In conclusion, the applicant has provided sufficient information for satisfying the relevant portions of 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities"; 10 CFR Part 52; and 10 CFR Part 100.

2.2.2 Descriptions

The staff's review of the Turkey Point Units 6 and 7 COL FSAR Section 2.2.2, "Descriptions," is addressed in SER Section 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

Turkey Point Units 6 and 7 COL FSAR Section 2.2 incorporates by reference Section 2.2 of the AP1000 DCD.

This section of the Turkey Point Units 6 and 7 COL FSAR addresses the need for evaluation of potential accidents.

In addition, in Turkey Point Units 6 and 7 COL FSAR Section 2.2, the applicant provided the following:

AP1000 COL Information Item

- PTN COL 2.2-1

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

- PTN COL 6.4-1

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

- STD COL 6.4-1

The applicant addressed STD COL 6.4-1 in the Turkey Point Units 6 and 7 COL FSAR, related to the onsite chemicals expected to be standard to all AP1000 COLs by providing Turkey Point Units 6 and 7 COL FSAR Table 6.4-201.

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 an 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.

2.2.3.3 Regulatory Basis

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

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

The applicable regulatory requirements for evaluation of potential accidents are set forth in the following:

- 10 CFR 100.20(b), which requires that the nature and proximity of man-made related hazards (e.g., airports, dams, transportation routes, military and chemical facilities) be evaluated to establish site parameters for use in determining whether plant design can accommodate commonly occurring hazards, and whether the risk of other hazards is very low.

- 10 CFR 52.79(a)(1)(iv), as it relates to the factors to be considered in the evaluation of sites, which require the location and description of industrial, military, or transportation facilities and routes, and the requirements of 10 CFR 52.79(a)(1)(vi) as they relate to compliance with 10 CFR Part 100.

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

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

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

In addition, the toxic gas evaluations should be consistent with appropriate sections from RG 1.78, "Evaluating the Habitability of a Nuclear Power Plant Control Room during a Postulated Hazardous Chemical Release," Revision 1 (December 2001).

2.2.3.4 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.2 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the evaluation of potential accidents. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the Turkey Point Units 6 and 7 COL FSAR:

AP1000 COL Information Item

- PTN COL 2.2-1
- PTN COL 6.4-1
- STD COL 6.4-1

The staff reviewed the resolution to the PTN COL 2.2-1 (related to COL Information Item 2.2-1), which addresses specific items related to the identification and evaluation of potential accidents resulting from external hazards or hazardous materials included in Turkey Point Units 6 and 7 COL FSAR Section 2.2.1.

The staff reviewed PTN COL 2.2-1 related to information about industrial, military, and transportation facilities and routes to establish the presence and magnitude of potential external

hazards, including the following accident categories: explosions, flammable vapor clouds (delayed ignition), toxic chemicals, fires, and airplane crashes included in Turkey Point Units 6 and 7 COL FSAR Section 2.2.3. COL Information Item in Section 2.2 of the AP1000 DCD states:

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

The applicant analyzed postulated accidents for various types considering the identified sources and locations in Turkey Point Units 6 and 7 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, and
- radiological hazards.

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 vicinity of the Turkey Point Units 6 and 7 site. The applicant evaluated potential explosions from nearby highways, navigable waterways, pipelines, or facilities using 1 psi overpressure as a criterion for adversely effecting plant operation or preventing safe shutdown of the plant. In accordance with RG 1.91, “Evaluations of Explosions Postulated To Occur at Nearby Facilities and on Transportation Routes near Nuclear Power Plants,” peak positive incident overpressures below 1 psi are considered to cause no significant damage.

The Turkey Point Units 6 and 7 site is close to existing Units 1 through 5 chemical storage locations. The applicant determined that the minimum safe distances for the storage of chemicals associated with Units 1 through 5 and Units 6 and 7 presented in Turkey Point Units 6 and 7 COL FSAR Table 2.2-213, are less than the minimum separation distance from the nearest safety-related structure, the Unit 6 auxiliary building to each chemical storage location. The staff performed independent confirmatory calculations and verified the applicant’s determined minimum safe distances for all chemicals stored onsite.

The applicant determined that the minimum safe standoff distances for hazardous chemicals gasoline, hydrazine, jet fuel, and propane stored at the Homestead Air Base are less than the minimum separation distance from the Unit 6 auxiliary building. Therefore, the overpressure resulting from an explosion due to chemicals stored at Homestead Air Base would not adversely affect the safe operation or shutdown of Units 6 and 7. The staff performed independent calculations and confirmed the applicant's determined values.

The applicant determined a minimum safe standoff distance of 81 m (266 ft), which is less than closest point of approach of 626 m (2,054 ft) to onsite truck transport, using conservative assumptions and RG 1.91 methodology. The staff performed independent calculations that confirmed the applicant's results. Therefore, the staff concludes that the applicant's assumptions and methodology are acceptable.

The applicant determined a minimum safe distance of 944 m (3,097 ft) to 1 psi overpressure due to an explosion from instantaneous release of natural gas from a pipeline at a separation distance of 1,382 m (4,535 ft) from the Unit 6 auxiliary building. Therefore, the overpressure from an explosion from a rupture in the Florida Gas Transmission Company Turkey Point Lateral natural gas transmission will not adversely affect the safe operation or shutdown of Units 6 and 7. The staff performed independent calculations and verified the applicant's results.

Flammable Vapor Clouds (Delayed Ignition)

The applicant evaluated potential flammable vapor clouds using the ALOHA air dispersion model to determine the distance that the chemical vapor cloud could exist in the flammable range between Lower Flammable Limit (LFL) to Upper Flammable Limit (UFL), thus having potential for ignition, explosion, or thermal hazard. The results of this evaluation are presented in Turkey Point Units 6 and 7 COL FSAR Table 2.2-214. The results of the analyses indicate that the calculated distance to LFL and minimum safe distance to 1 psi due to vapor cloud explosion is less than the distance to the nearest safety-related structure for each chemical from its source location. The maximum incident heat flux is less than level of concern 5 kW/m^2. The staff performed confirmatory calculations independently by using the ALOHA computer model, and found the applicant-determined values to be comparable. Based on the review and independent analyses, the staff finds the applicant's results acceptable.

Toxic Chemicals

Accidents involving the release of toxic or asphyxiating chemicals from onsite storage facilities and nearby mobile and stationary sources were considered and evaluated. The ALOHA air dispersion model was used to predict the concentrations of toxic or asphyxiating chemical clouds as they disperse downwind from all facilities and sources. The maximum distance a cloud could travel to reach the immediately dangerous to life and health (IDLH) concentration or other toxicity limit concentration level was determined by using the ALOHA model.

The effects of toxic chemical releases from standard AP1000 chemicals are summarized in Turkey Point Units 6 and 7 COL FSAR Table 6.4-201. The applicant stated that these standard AP1000 chemicals are stored at the Turkey Point Units 6 and 7 site at distances greater than the minimum safe distances indicated in Table 6.4-201. The effects of toxic chemical releases from the Turkey Point Units 6 and 7 site-specific chemicals, onsite chemicals (Units 1 through 5), and external nearby sources are summarized in Turkey Point Units 6 and 7 COL FSAR Table 2.2-215. The staff performed independent confirmatory analyses to determine the concentration of each chemical from the onsite storage sources and nearby facilities addressed

in Turkey Point Units 6 and 7 COL FSAR Table 2.2-215 using the ALOHA computer model. The staff's determined values are comparable to those that are presented by the applicant in Turkey Point Units 6 and 7 COL FSAR Table 2.2-215.

Based on the concentration information in Turkey Point Units 6 and 7 COL FSAR Table 2.2-215, the concentration of ammonium hydroxide (30 percent) and chlorine due to potential accidental release from onsite storage for Units 1 through 5; and the concentration of carbon dioxide (CO_2), hydrazine (35 percent), and sodium hypochlorite (10.8 percent) due to potential release from onsite storage for Units 6 and 7, is observed to exceed the respective chemical IDLH concentration at the inlet to the control room. Therefore, the staff requested the applicant in RAI 5655, Questions 02.02.03-2 and 02.02.03-3, to provide the ALOHA model determined concentration of these chemicals at the inlet to control room as well as the concentration inside the control room for easy comparison.

In a letter August 4, 2011 (ADAMS Accession No. ML11217A224), the applicant provided the response with adequate information. The applicant explained that the inlet to the control room is conservatively assumed to be ground level concentration. Although the concentration of these chemicals exceeds the respective IDLH concentration inlet to control room, the concentration inside the control room is lower than the respective IDLH concentration. However, these chemicals that exceed respective IDLH concentration at the inlet to the control room are further evaluated for concentration inside the control room in accordance with the criteria for the control room habitability in SER Section 6.4.

Fires

The heat fluxes determined from potential fires originating from accidents at any of the facilities are found to be much less than the level concern of 5 kW/m^2 for heat from fires. In addition, the safety zone around Units 6 and 7 greatly exceeds recommended distances of 30 to 100 ft, and therefore, the staff concludes that there will be no effect to Units 6 and 7 from fires and heat fluxes from fires.

Collision with Intake Structure

The Turkey Point Units 6 and 7 makeup water system consists of either reclaimed water provided from the Miami-Dade Water and Sewer Department or saltwater makeup water from the radial collector wells. There is no intake structure associated with either the reclaimed water pipeline or radial collector well system that would be damaged as a result of navigable waterway activities.

Liquid Spills

Only fuel oil shipped by barge may potentially spill, but has a specific gravity less than unity, will float on the surface of the Biscayne Bay, and is not likely to be drawn into the makeup water system. The staff agrees with the applicant's assumption and conclusion.

Radiological Hazards

The hazard due to the release of radioactive material from Turkey Point Units 3 and 4 as a result of normal operations or an unanticipated event will not threaten the safety of the new units. Smoke detectors, radiation detectors, and associated control equipment are installed at various plant locations as necessary to provide the appropriate operation of the systems.

Radiation monitoring of the main control room environment is provided by the radiation monitoring system. The habitability systems for Turkey Point Units 6 and 7 are capable of maintaining the main control room environment suitable for prolonged occupancy throughout the duration of the postulated accidents that require protection from external fire, smoke, and airborne radioactivity. The staff agrees that the applicant rationale reasonable and acceptable.

2.2.3.5 Post Combined License Activities

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

2.2.3.6 Conclusion

The staff reviewed the application and checked the referenced DCD. The staff's review confirmed that the applicant addressed the required information relating to evaluation of potential accidents, and there is no outstanding information expected to be addressed in the Turkey Point Units 6 and 7 COL FSAR related to this section. The results of the staff's technical evaluation of the information incorporated by reference in the COL application are documented in NUREG-1793 and its supplements.

As discussed above, the applicant has presented and substantiated information to identify potential hazards in the Turkey Point Units 6 and 7 site vicinity. The staff has reviewed the information provided and concludes that the applicant has provided sufficient information with respect to the identification of potential hazards in accordance with the requirements of 10 CFR 52.79(a)(1)(iv) and 10 CFR 52.79(a)(1)(vi). The nature and extent of activities involving potentially hazardous materials that are conducted at nearby industrial, military, and transportation facilities have been evaluated to identify any such activities that have the potential for adversely affecting plant safety-related structures. Based on an evaluation of information in the Turkey Point Units 6 and 7 COL FSAR as well as information that the staff independently evaluated, the staff has concluded that potentially hazardous activities on site and in the vicinity of the Turkey Point Units 6 and 7 site have been identified. This addresses and resolves COL Information Item 2.2-1. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR Part 50.34(a)(1), 10 CFR Part 52.79(a)(1)(iv), 10 CFR Part 52.79(a)(1)(vi), and 10 CFR Part 100.

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 NRC regulations, the staff evaluates regional and local climatological information, including climate extremes and severe weather occurrences that may affect the design and siting of a nuclear plant. The staff 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, comply with NRC regulations. The staff has prepared SER Sections 2.3.1 through 2.3.5 in accordance with the review procedures described in NUREG-0800, using information presented in Turkey Point Units 6 and 7 site COL FSAR Section 2.3 (which references 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

2.3.1.2 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.3.1, "Regional Climatology," addresses averages and extremes of climatic conditions and regional meteorological phenomena that could affect the safe design and siting of the plant, including information describing the general climate of the region, seasonal and annual frequencies of severe weather phenomena, and other meteorological conditions to be used for design- and operating-basis considerations.

This SER section also addresses the supplemental information in Turkey Point Units 6 and 7 COL FSAR Section 2.3.6 related to regional climatology.

2.3.1.2 Summary of Application

Turkey Point Units 6 and 7 COL FSAR Section 2.3 incorporates by reference Section 2.3 of the AP1000 DCD.

In addition, in Turkey Point Units 6 and 7 COL FSAR Section 2.3, the applicant provided the following:

Tier 2 Departure

- PTN DEP 2.0-2

Tier 1 and 2 Departures

- PTN DEP 2.0-1
- PTN DEP 2.0-3

The applicant proposed a departure (PTN DEP 2.0-1) from the operating basis wind speed in the AP1000 DCD Tier 2, Table 2-1. The 150 mph, 50-year return period, 3-second gust wind speed identified in Turkey Point Units 6 and 7 COL FSAR Table 2.0-201 exceeds the value in AP1000 DCD Tier 2 Table 2-1 of 145 mph. The applicant also proposed a departure (PTN DEP 2.0-2) from the maximum normal air temperature wet bulb (noncoincident) in the AP1000 DCD Tier 2, Table 2-1. The 81.5 °F maximum normal wet-bulb temperature (noncoincident) identified in Turkey Point Units 6 and 7 COL FSAR Table 2.0-201 exceeds the value in AP1000 DCD Tier 2, Table 2-1 of 80.1 °F. The applicant also proposed a departure (PTN DEP 2.0-3) from the maximum safety wet-bulb (noncoincident) air temperature in both Tier 1 and Tier 2 material of the AP1000 DCD. The 87.3 °F maximum safety wet-bulb (noncoincident) air temperature identified in Turkey Point Units 6 and 7 COL FSAR Table 2.0-201 exceeds the value in AP1000 DCD Tier 1 Table 5.0-1 and DCD Tier 2 Table 2-1.

AP1000 COL Information Item

- PTN COL 2.3-1

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

Supplemental Information

- PTN SUP 2.3-1

The applicant provided supplemental information in Turkey Point Units 6 and 7 COL FSAR Section 2.3, discussing regional climatology and local meteorological conditions, the onsite meteorological measurements program, and short-term and long-term diffusion estimates.

- PTN SUP 2.3.6-1

The applicant provided supplemental information in Turkey Point Units 6 and 7 COL FSAR Section 2.3.6.1, discussing climatological characteristics of the site region.

2.3.1.3 Regulatory Basis

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

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

The applicable regulatory requirements for identifying regional meteorology are:

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

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

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

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

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

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

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

- Data on severe weather phenomena should be based on standard meteorological records from nearby representative U.S. 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 consistent with Regulatory Guide (RG) 1.76, “Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants,” Revision 1. Alternatively, an applicant may specify any tornado parameters that are appropriately justified, provided that a technical evaluation of site-specific data is conducted.

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

- Consistent with RG 1.27, “Ultimate Heat Sink for Nuclear Power Plants,” Revision 2, the ultimate heat sink (UHS) meteorological data that would result in the maximum evaporation and drift loss of water and minimum water cooling should be based on long-period regional records that represent site conditions. (Not applicable to a passive containment system design that does not utilize a cooling tower or cooling pond).

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

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

- High air pollution potential information should be based on U.S. 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.

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

Interim staff guidance (ISG) document DC/COL-ISG-7, “Interim Staff Guidance on Assessment of Normal and Extreme Winter Precipitation Loads on the Roofs of Seismic Category I Structures,” was issued subsequent to the publication of NUREG-0800, Section 2.3.1. The ISG clarifies the staff’s position that the applicant should identify winter precipitation events as site characteristics and site parameters for determining normal and extreme winter precipitation loads on the roofs of seismic Category I structures.

2.3.1.4 Technical Evaluation

The staff reviewed Section 2.3.1 of the Turkey Point Units 6 and 7 COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed the information relating to regional climatology. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the Turkey Point Units 6 and 7 COL FSAR:

Tier 2 Departure

- PTN DEP 2.0-2

Tier 1 and 2 Departures

- PTN DEP 2.0-1
- PTN DEP 2.0-3

The staff reviewed PTN DEP 2.0-1 related to the applicant's use of an operating basis wind of a 150 mph, 50-year return period, 3-second gust wind speed which exceeds the value in the AP1000 DCD Tier 2 Table 2-1 of 145 mph. The staff's evaluation of the appropriateness of the applicant's values for the operating basis wind speed for the Turkey Point Units 6 and 7 site is in SER Sections 2.3.1, 3.3.1 and 3.3.3

In addition, the staff reviewed PTN DEP 2.0-2 related to the applicant's use the maximum normal air temperature wet bulb (noncoincident) of 81.5 °F which exceeds the value in AP1000 DCD Tier 2, Table 2-1 of 80.1 °F and PTN DEP 2.0-3 related to the applicant's use of a maximum safety wet-bulb (noncoincident) air temperature of 87.3 °F that exceeds the value in AP1000 DCD Tier 1 Table 5.0-1 and DCD Tier 2 Table 2-1. The staff's evaluation of the appropriateness of the applicant's values for the maximum normal and maximum safety wet-bulb (noncoincident) air temperature for the Turkey Point Units 6 and 7 site is in SER Section 2.3.1.4.5.

AP1000 COL Information Item

- PTN COL 2.3-1

The staff reviewed PTN COL 2.3-1 related to the provision of regional climatology included in Turkey Point Units 6 and 7 COL FSAR Section 2.3.1. The COL Information Item in Section 2.3.6.1 of the AP1000 DCD states:

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

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

Supplemental Information

- PTN SUP 2.3-1

The staff reviewed supplemental information in Turkey Point Units 6 and 7 COL FSAR Section 2.3, discussing regional climatological conditions and local meteorological conditions, the onsite meteorological measurements program, and short-term and long-term diffusion estimates.

- PTN SUP 2.3.6-1

The staff reviewed supplemental information in Turkey Point Units 6 and 7 COL FSAR Section 2.3.6.1, discussing climatological characteristics in the Turkey Point Units 6 and 7 site region.

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

2.3.1.4.1 Data Sources

The applicant used several sources of data in its discussion describing the regional climatology. They used a total of 16 stations within an approximately 50 mi radius of the Turkey Point Units 6 and 7 site, including the Miami International Airport, Florida's NWS first-order reporting station. The non-NWS sites were located in Broward, Collier, Miami-Dade, and Monroe Counties, FL. The applicant chose these sites to accurately depict the conditions that might be expected at the Turkey Point Units 6 and 7 site. The staff used the first-order NWS station at Miami International Airport to independently confirm the representativeness of the applicant's description of the regional climate.

2.3.1.4.2 General Climate

The applicant described the general climate of the Turkey Point Units 6 and 7 site by discussing the terrain in southern Florida, as well as the general synoptic conditions historically observed. The applicant noted that the Turkey Point Units 6 and 7 site is in the southern portion of Climate Division 6 (lower east coast), which includes a majority of Miami-Dade, Palm Beach, and Martin counties.

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

2.3.1.4.3 Severe Weather

Extreme Winds

Using the American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) Standard 7-05, "Minimum Design Loads for Buildings and Other Structures," the applicant found that the basic wind speed is about 150 mph. The staff confirmed this value using ASCE/SEI Standard 7-05. ACSE/SEI Standard 7-05 describes the basic wind speed to be the "[t]hree second wind gust speed at 33 ft (10 m) above the ground in Exposure Category C." Exposure Category C relies on the surface roughness categories as defined in Chapter 6, "Wind Loads," of ASCE/SEI Standard 7-05. Exposure Category C is acceptable at the Turkey Point Units 6 and 7 site due to scattered obstructions of various sizes in the immediate site area. Exposure

Category B specifies that there must be urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger, prevailing in the upwind direction for a distance of at least 792 m (2,600 ft) or 20 times the height of the building, whichever is greater. Exposure Category D specifies that there must be flat, unobstructed areas and water surfaces prevailing in the upwind direction for a distance greater than 1,525 m (5,000 ft) or 20 times the building height, whichever is greater. Neither Exposure Category B nor Exposure Category D accurately describes the conditions at the Turkey Point Units 6 and 7 meteorological tower. ASCE/SEI Standard 7-05 states that Exposure Category C shall apply for all cases where Exposures B or D does not apply.

Consistent with NUREG-0800, Section 2.3.1, the applicant chose the 100-year return period 3-second wind gust site characteristic based on ASCE/SEI Standard 7-05, “Minimum Design Loads for Buildings and Other Structures,” for the Turkey Point Units 6 and 7 site. The applicant stated that the 50-year return period 3-second gust is 150 mph. The applicant used a scaling factor of 1.07, consistent with ASCE/SEI Standard 7-05, Table C6-7, to determine the 100-year return period 3-second gust of 161 mph.

In RAI 5908, Question 02.03.01-2 (ADAMS Accession No. ML11276A100), the staff asked the applicant to update the Turkey Point Units 6 and 7 COL FSAR to include additional justification regarding how the proposed 100-year return period 3-second gust wind speed site characteristic value for safety-related structures suitably accounts for the historically reported hurricanes. The applicant responded by explaining that the highest recorded 3-second gust wind speed in the Turkey Point Units 6 and 7 site area was a result of Hurricane Andrew in 1992. Hurricane Andrew made landfall as a Category 5 storm with sustained 1-minute winds of 167 mph. Using a conversion factor from Figure C6-4 of ASCE/SEI Standard 7-05, the associated 3-second gust wind speed is estimated to be 204 mph. The applicant updated Turkey Point Units 6 and 7 COL FSAR Table 2.0-201 to include the maximum hurricane wind speed (as recorded during Hurricane Andrew [August 1992]) as a footnote (m) to the site characteristic tornado wind speed.

The staff accepts the applicant’s response to RAI 5908, Question 02.03.01-2 (ADAMS Accession No. ML11276A100) and the continued use of 161 mph as the site characteristic operating basis wind speed because the AP1000 operating basis wind speed is based on the 100-year return period wind, not the historic maximum wind. AP1000 design basis winds are the 10^{-2}/year and the 10^{-7}/year wind. The operating basis wind should be considered a severe environmental load that could infrequently be encountered during the plant life, and therefore, can be expected to be exceeded. The applicant, through the inclusion of footnote (m), has included the maximum historic wind gust of 204 mph in comparison to the maximum tornado wind speed. The AP1000 DCD site parameter tornado wind speed is 300 mph, and therefore bounds the maximum hurricane wind speed. The staff reviewed the changes proposed and based on the above discussion, finds them to be acceptable. Therefore, the staff considers RAI 5908, Question 02.03.01-2 to be resolved.

In RAI 6251, Question 02.03.01-3, the staff asked the applicant to describe how the Turkey Point Units 6 and 7 COL FSAR satisfies the Combined License Information requirement of AP1000 DCD Section 3.5.4 in consideration of RG 1.221, “Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants.” The applicant responded by providing an updated analysis of the design-basis missile spectrum for a hurricane wind speed of 260 mph. The applicant determined the 10^{-7} per year 3-second wind gust to be 260 mph. Based on this wind speed, the applicant updated Turkey Point Units 6 and 7 COL FSAR Section 3.5.1.4 with an analysis of the site-specific hurricane generated missiles. The applicant added Table 3.5-

201 to provide a comparison between the AP1000 DCD and site-specific hurricane-missile parameters. The applicant also added Section 3.5.2, "Protection from Externally Generated Missiles" as a discussion on the missile spectrum derived from RG 1.221. The staff reviewed the changes proposed and based on the above discussion, finds them to be acceptable. Therefore, the staff considers RAI 6251, Question 02.03.01-3 to be resolved.

A comparison between the AP1000 site parameters and the Turkey Point Units 6 and 7 site characteristics for the maximum 3-second wind gust is presented in Turkey Point Units 6 and 7 COL FSAR Table 2.0-201. The applicant's site characteristics for extreme winds were found to not be bounded by the AP1000 DCD site parameters.

The applicant has stated that an exemption from 10 CFR Part 52, Appendix D, Section IV.A.2.d, in accordance with 10 CFR 52.7 and 10 CFR 52.93, and a departure from AP1000 DCD Table 2-1 is necessary. Details on the departure (PTN DEP 2.0-1) and associated exemption from the 3-second gust wind speed value of 150 mph can be found in Part 7.A.2, of the Turkey Point Units 6 and 7 COL application. The staff has determined that the applicant's stated 50-year maximum 3-second gust wind speed value of 150 mph is appropriate for the Turkey Point Units 6 and 7 site. Additional staff evaluation of this departure and associated exemption is in SER Section 2.0. This departure is also discussed in the context of hurricane missiles in SER Section 3.5.

Tornadoes

Turkey Point Units 6 and 7 COL FSAR Section 2.3.1.3.2 lists the number of tornadoes by Fujita Scale strength for a 2-degree box surrounding the Turkey Point Units 6 and 7 site.

The applicant chose tornado site characteristics based on RG 1.76, Revision 1, and NUREG/CR-4461, "Tornado Climatology of the Contiguous United States," Revision 2. RG 1.76, Revision 1, provides design-basis tornado characteristics for three tornado intensity regions throughout the United States, each with a 10^{-7} per year probability of occurrence. The proposed COL site is in tornado intensity Region II. Tornado intensity Region II is primarily characterized by lower maximum wind speeds and lower pressure drops. The applicant proposed the following tornado site characteristics, which are listed in Turkey Point Units 6 and 7 COL FSAR Table 2.0-201:

Maximum Wind Speed	200 mi per hour

Because the applicant has correctly identified those design-basis tornado site characteristics presented in RG 1.76, Revision 1, the staff has verified and concluded that the applicant has chosen acceptable tornado site characteristics. RG 1.76, Revision 1 relies on the Enhanced-Fujita (EF) scale to relate the degree of damage from a tornado to the tornado maximum wind speed.

Tropical Cyclones

The applicant discussed a history of hurricanes that have passed within 100 nautical mi of the Turkey Point Units 6 and 7 site between 1851 and 2007. The applicant stated during this timeframe, 53 tropical cyclone (hurricanes and tropical storms) storm tracks have passed within 100 nautical mi of the Turkey Point Units 6 and 7 site. In addition to three historical extratropical cyclones, approximately 50 hurricanes have passed within 100 nautical mi of the Turkey Point

Units 6 and 7 site; 16 were Category 1, 8 were Category 2, 13 were Category 3, 10 were Category 4, and 3 were Category 5.

Section 3.3.1 of the AP1000 DCD states that the operating basis wind speed site parameter value of 145 mph (3-second gust) is based on an annual probability of occurrence of 0.02 (i.e., 50-year return period). Higher winds with an annual probability of occurrence of 0.01 (i.e., 100-year return period) were used in the design of seismic Category I structures by using an importance factor of 1.15. This is equivalent to designing the seismic Category I structures to a wind speed of 155 mph by using a 1.07 scaling factor from Table C6-7 of ASCE 7-05 to convert a 50-year return period gust wind speed to a 100-year return period gust wind speed. The most extreme tropical cyclone reported for the area was Hurricane Andrew (August 1992). This Category 5 storm is estimated to have had a 1-minute sustained wind speed of 167 mph. Using a conversion factor from ASCE/SEI 7-05, Figure C6-4, this is converted to a 3-second gust wind speed of 204 mph. As discussed in SER Section 2.3.1.4.3, this extreme wind speed associated with Hurricane Andrew is bounded by the 10^{-7} wind speed value of 260 mph derived from RG 1.221 for the FPL site. Both the wind speeds recorded during Hurricane Andrew and the wind speeds derived from RG 1.221 are bounded by the AP1000 10^{-7} wind speed site parameter value of 300 mph.

The staff evaluated data from NOAA Coastal Services Center for hurricanes making landfall in or passing near Homestead, FL, between 1851 and 2009. The staff finds hurricane totals acceptably close to what the applicant provided in Turkey Point Units 6 and 7 COL FSAR Section 2.3.1.3.3

Precipitation Extremes

The applicant stated that precipitation can vary significantly from one station to another because precipitation is a point measurement. The staff agrees with this assessment because extreme precipitation events are generally short lived and confined to a small region. Because of this, one station may report extreme precipitation; whereas, a nearby station may report much less. Based on observations from 17 nearby climatological observing stations, the applicant presented historical precipitation extremes for the region. The applicant stated that the highest 24-hour rainfall total in the area was 15.1 in on August 26, 2005, about 38 mi to the northwest of the Turkey Point Units 6 and 7 site. The highest monthly rainfall total in the Turkey Point Units 6 and 7 site area was 34.4 in recorded during October 1965, at a site about 57 mi to the north-northeast of the Turkey Point Units 6 and 7 site. Site characteristic values corresponding to the site parameter precipitation (rain) rates for 1-hour and 5-minute rainfall rates are addressed in Turkey Point Units 6 and 7 COL FSAR Section 2.4.2.

The applicant stated that winter storms that produce measurable amounts of frozen precipitation near the Turkey Point Units 6 and 7 site are rare. The record snowfall for the region was at Homestead, FL, which received a trace (0.05 in) of snow in January 1977. The staff issued DC/COL-ISG-007, which clarifies the staff's position on identifying winter precipitation events as site characteristics and site parameters for determining normal and extreme winter precipitation loads on the roofs of Seismic Category I structures. The ISG revises the previously issued staff guidance as discussed in NUREG-0800, Section 2.3.1.

The ISG states that normal and extreme winter precipitation events should be identified in NUREG-0800, Section 2.3.1 as COL site characteristics for use in NUREG-0800, Section 3.8.4 in determining the normal and extreme winter precipitation loads on the roofs of seismic Category I structures. The normal winter precipitation roof load is a function of the normal

winter precipitation event; whereas, the extreme winter precipitation roof loads are based on the weight of the antecedent snowpack resulting from the normal winter precipitation event plus the larger resultant weight from either: (1) the extreme frozen winter precipitation event, or (2) the extreme liquid winter precipitation event. The extreme frozen winter precipitation event is assumed to accumulate on the roof on top of the antecedent normal winter precipitation event; whereas, the extreme liquid winter precipitation event may or may not accumulate on the roof, depending on the geometry of the roof and the type of drainage provided. The ISG further states:

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

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

- The extreme liquid winter precipitation event is defined as the theoretically greatest depth of precipitation (in in of water) for a 48-hour period that is physically possible over a 25.9 km^2 (10 mi^2)) area at a particular geographical location during those months with the historically highest snowpacks.

The staff evaluated the normal winter precipitation event and the extreme frozen and liquid winter precipitation events in accordance with the ISG. Due to the location of the proposed units along Biscayne Bay, large snow and ice events are rare. The normal and extreme winter precipitation loads for the Turkey Point Units 6 and 7 site were determined to be significantly less than the AP1000 DCD site parameter value of 75 lb/ft^2. The staff agrees with the applicant that the normal and extreme winter precipitation roof loads are not significant; therefore the staff accepts the applicant's discussion as adequate.

<u>Hail, Snowstorms, and Ice Storms</u>

The following discussion on hail, snowstorms, and ice storms is intended to provide a general understanding of the severe weather phenomena in the Turkey Point Units 6 and 7 site region but does not result in the generation of site characteristics for use as design or operating bases.

The applicant stated that hail can occur any time of the year, but has been observed primarily during late spring and the summer months. Hail stone diameters greater than 0.75 in. have been recorded in the site area. Consistent with the guidance provided in NUREG-0800, Section 2.3.1, the applicant compiled this information from the NCDC. The applicant noted that the number of reported hail events is not consistent across each of the counties. This pattern in hail reports is likely due to the increased number of targets because of urbanization. This is because there are more targets damaged by hail in an urban area than in a rural area. The applicant stated that the largest hailstone observed in the surrounding counties was 4.0–4.5 in in diameter. Using data from the National Severe Storms Laboratory, the staff was able to confirm that the Turkey Point Units 6 and 7 site area experiences hail, on average, 0-1 days per year. The staff was able to confirm the applicant's hail statistics provided in Turkey Point Units 6 and 7 COL FSAR Section 2.3.1.3.5.

The applicant stated that the largest snow accumulation for the region was a trace (0.05 in.) at the Homestead Experiment Station. The applicant also stated that there have been no reports of ice storms in the counties surrounding the Turkey Point Units 6 and 7 site. The staff has confirmed these statements by using the NCDC Storm Events Database.

Thunderstorms and Lightning

The following discussion on thunderstorms and lightning is intended to provide a general understanding of the severe weather phenomena in the Turkey Point Units 6 and 7 site region but does not result in the generation of site characteristics for use as design or operating bases.

The applicant stated that thunderstorms have been observed on an average of 73 days per year. Thunderstorms have occurred most frequently during the months of June, July, and August. Consistent with NUREG-0800 Section 2.3.1, the applicant compiled this information from the 2009 Miami, FL, NCDC Local Climatological Data (LCD).

Using the 2009 NCDC LCD for Miami, FL, the staff confirmed that thunderstorms have been observed on an average of 73 days per year. The staff agrees with the applicant that thunderstorms have occurred most frequently in the months of June, July, and August at the observation location.

The applicant stated that there are approximately 14–16 flashes to Earth per year per square kilometer, based on the data from Miami, FL. The staff independently evaluated the applicant's estimate based on the 2009 LCDs from the same weather reporting station and a method attributed to the Electric Power Research Institute (8.3 flashes to Earth per square kilometer), a 10-year flash density map (Vaisala, 2009) (6–8 flashes to earth per square kilometer), and a 1999 paper by G. Huffines and R.E. Orville, titled "Lightning Ground Flash Density and Thunderstorm Duration in the Continental United States: 1989–96" (7–9 flashes to Earth per square kilometer). Thus, the staff concludes that the applicant has provided a reasonable and conservative estimate of the frequency of lightning flashes.

Based on a mean frequency of 23 flashes to Earth per year per square mile and an exclusion area for the proposed Units 6 and 7 of 0.047 square-mi, the applicant predicted that 1.1 lightning flashes per year can be expected within the exclusion area of the two proposed units. The staff has confirmed the applicant's calculation and finds it to be a reasonable estimate.

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

Droughts and Dust (Sand) Storms

Droughts are defined as a period of abnormally dry weather sufficiently long enough to cause a serious hydrological imbalance. The applicant stated that the southeastern coastal region of Florida is occasionally affected by drought conditions. Turkey Point Units 6 and 7 COL FSAR Subsection 2.4.11 describes the effects of droughts on the Turkey Point Units 6 and 7 site's cooling system and the historical frequency of droughts affecting the Turkey Point Units 6 and 7 site area.

Dust and sandstorms are an unusual severe weather condition characterized by strong winds and dust-filled air over an extensive area. Generally, a prerequisite for a dust storm is a period of drought over an area of normally arable land.

The applicant stated that the NCDC Storm Events database indicates that there have been no occurrences of dust storms near the Turkey Point Units 6 and 7 site dating back to 1950. Using the same NCDC database, the staff finds that there have been no dust storms reported in Miami-Dade County, FL during the period of January 1, 1950 through July 31, 2010.

2.3.1.4.4 Meteorological Data for Evaluating the Ultimate Heat Sink

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

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

2.3.1.4.5 Design-Basis Dry- and Wet-Bulb Temperatures

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

- Maximum Safety Dry-Bulb Temperature and Coincident Wet-Bulb Temperature: These site parameter values represent a maximum dry-bulb temperature that exists for 2 hours or more, combined with the maximum wet-bulb temperature that exists in that population of dry-bulb temperatures.

- Minimum Safety Dry Bulb Temperature: This site parameter value represents a minimum dry-bulb temperature that exists within a set of hourly data for duration of 2 hours or more.

- Maximum Safety Noncoincident Wet-Bulb Temperature: This site parameter value represents a maximum wet-bulb temperature that exists within a set of hourly data for duration of 2 hours or more.

- Maximum Normal Dry-Bulb Temperature and Coincident Wet-Bulb Temperature: The maximum normal value is the 1-percent seasonal exceedance temperature. The maximum temperature is for the months of June through September in the Northern Hemisphere. The 1-percent seasonal exceedance is approximately equivalent to the annual 0.4-percent exceedance.

- Minimum Normal Dry-Bulb Temperature: The minimum normal value is the 99-percent seasonal exceedance temperature. The minimum temperature is for the months of December, January, and February in the Northern Hemisphere. The 99-percent seasonal exceedance is approximately equivalent to the annual 99.6-percent exceedance.

- Maximum Normal Noncoincident Wet-Bulb Temperature: The maximum normal value is the 1-percent seasonal exceedance temperature. The maximum temperature is for the months of June through September in the Northern Hemisphere. The 1-percent seasonal exceedance is approximately equivalent to the annual 0.4-percent exceedance.

The applicant's safety temperature site characteristic values are based on conservative 100-year estimates. The ambient air temperatures used for comparison against the AP1000 site parameters are listed in Turkey Point Units 6 and 7 COL FSAR Table 2.0-201.

As shown in Turkey Point Units 6 and 7 COL FSAR Table 2.0-201, most of the applicant's site characteristics for ambient air temperature are conservatively bounded by the AP1000 DCD site parameters. The applicant stated that two departures were necessary regarding the site characteristic ambient temperatures. The two site-characteristic temperatures that did not fall within the bounds of the AP1000 DCD site parameters were the maximum normal noncoincident wet-bulb temperature (PTN DEP 2.0-2) and the maximum safety noncoincident wet-bulb temperature (PTN DEP 2.0-3).

The applicant stated that an exemption from 10 CFR Part 52, Appendix D, Section IV.A.2.d, in accordance with 10 CFR 52.7 and 10 CFR 52.93 and a departure from AP1000 DCD Table 2-1 is necessary. Details on the departure (PTN DEP 2.0-2) and associated exemption for the maximum normal wet-bulb (noncoincident) air temperature of 81.5 °F can be found in Turkey Point Units 6 and 7 COL FSAR Part 7.A.1. The staff has determined that the applicant's stated normal safety wet-bulb (noncoincident) air temperature of 81.5 °F is appropriate for the Turkey Point Units 6 and 7 site. Additional staff evaluation of this departure and associated exemption is in SER Section 2.0.

The applicant stated that an exemption from 10 CFR Part 52, Appendix D, Section IV.A.2.d, in accordance with 10 CFR 52.7 and 10 CFR 52.93 and a departure from AP1000 DCD Table 2-1 is necessary. Details on the departure (PTN DEP 2.0-3) and associated exemption for the maximum safety wet-bulb (noncoincident) air temperature of 87.4 °F can be found in Turkey Point Units 6 and 7 COL FSAR Part 7.A.2. The staff has determined that the applicant's stated maximum safety wet-bulb (noncoincident) air temperature of 87.4 °F is appropriate for the Turkey Point Units 6 and 7 site. Additional staff evaluation of this departure and associated exemption is in SER Section 2.0.

Using NCDC hourly data from Homestead AFB in Homestead, FL, (1973–2009) and climate data from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the staff was able to verify the applicant's site-characteristic temperatures presented in Turkey Point Units 6 and 7 COL FSAR Table 2.0-201.

2.3.1.4.6 Restrictive Dispersion Conditions

The following discussion on inversions and high air pollution potential is intended to provide a general understanding of the phenomena in the Turkey Point Units 6 and 7 site region but does not result in the generation of site characteristics for use as design or operating basis.

The applicant used model-derived mixing height data to characterize the potential for inversions at the Turkey Point Units 6 and 7 site. These data were determined by using an interactive, spatial database developed by the U.S. Department of Agriculture—Forest Service, referred to

as the U.S. Department of Agriculture (USDA) Ventilation Climate Information System (VCIS). Turkey Point Units 6 and 7 COL FSAR Table 2.3.1-204 lists the maximum, mean, and minimum monthly mixing depths during the AM and PM hours, as derived from the interactive database. The lowest mean monthly mixing height occurs during the morning hours of July (474 m) and the greatest mean mixing height occurs in afternoon hours of April (1,412 m). The staff verified the results in Turkey Point Units 6 and 7 COL FSAR Table 2.3.1-204 by using data published in documents referenced in NUREG-0800, Section 2.3.1 (Holzworth, 1972; Wang and Angell, 1999) and the VCIS database.

2.3.1.4.7 Climate Changes

The applicant presented a discussion on the potential effects of global climate change on the regional climatology of the Turkey Point Units 6 and 7 site. The applicant stated that any changes to the local climate are speculative and become even less certain for specific areas or locations.

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, ambient design temperatures were based on a minimum of 65 years of hourly data and an estimated 100-year return period value. Tornadoes were based on a 10^{-7} per year return interval and extreme winds were based on a 100-year return period, including 157 years of historical hurricane data (1851–2008).

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

The USGCRP report found that the average annual temperature of the Southeast (which includes the Florida coastline where the Turkey Point Units 6 and 7 site is located) did not change significantly over the past century as a whole, but the annual average temperature has risen about 2 °F since 1970 with the greatest seasonal increase in temperature occurring during the winter months. Climate models predict continued warming in all seasons across the Southeast and an increase in the rate of warming through the end of the 21st century. Average temperatures in the Southeast are projected to rise by 2—5 °F by the end of the 2050's, depending on assumptions regarding global greenhouse gas emissions.

The USGCRP report also states that there has been no discernable change in observed annual average precipitation from 1958 to 2008 in the region where the Turkey Point Units 6 and 7 site is located. Future changes in total precipitation are more difficult to project than changes in temperature. Model projections of future precipitation generally indicate that southern areas of the United States will become drier. Except for indications that the amount of rainfall from individual hurricanes will increase, climatic models provide divergent results for future precipitation for most of the Southeast.

The USGCRP reports that the power and frequency of Atlantic hurricanes has increased substantially in recent decades, but the number of North American mainland land-falling hurricanes does not appear to have increased over the past century. The USGCRP reports that

likely future changes for the United States and surrounding coastal waters include more intense hurricanes with related increases in wind and rain, but not necessarily an increase in the number of these storms that make landfall.

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

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

There is a level of uncertainty in projecting future conditions because the assumptions regarding the future level of emissions of heat trapping gases depend on projections of population, economic activity, and choice of energy technologies. If it becomes evident that long-term climatic change is influencing the most severe natural phenomena reported at the Turkey Point Units 6 and 7 site, the COL holders have a continuing obligation to ensure that their plants stay within the licensing basis.

2.3.1.5 Post Combined License Activities

There are no post COL activities associated with this FSAR section.

2.3.1.6 Conclusion

The staff reviewed the application and checked the referenced DCD. The staff's review confirmed that the applicant has addressed the relevant information relating to regional climatology, and no outstanding information related to this section remains to be addressed in the Turkey Point Units 6 and 7 COL FSAR. The staff's review confirmed that the applicant has addressed the relevant information relating to this section, and no outstanding information related to regional climatology remains to be addressed in the Turkey Point Units 6 and 7 COL FSAR. The results of the staff's technical evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL application are documented in NUREG-1793 and its supplements.

AP1000 DCD, Section 2.3.6.1 states that a COL applicant shall address the site-specific regional climatological information. As set forth above, the applicant has presented and substantiated information to establish the regional meteorological characteristics. The staff has reviewed the information provided in PTN COL 2.3-1 and PTN SUP 2.3-1 and concludes that the applicant has established the meteorological characteristics at the Turkey Point Units 6 and 7 site and in the surrounding area acceptable to meet the requirements of 10 CFR 100.20(c)(2) and 10 CFR 100.21(d) with respect to determining the acceptability of the Turkey Point Units 6 and 7 site. The staff has reviewed PTN DEP 2.0-1, PTN DEP 2.0-2, and PTN DEP 2.0-3 and has determined that the applicant's stated site characteristics are acceptable for the Turkey

Point Units 6 and 7 site. The staff finds that the applicant has provided a sufficient description to meet the requirements of the AP1000 DCD. PTN COL 2.3-1 has been adequately addressed by the applicant and is resolved.

The staff also finds that the applicant has considered the most severe natural phenomena historically reported for the Turkey Point Units 6 and 7 site and surrounding area in establishing the site characteristics. Specifically, the staff has accepted the methodologies used to analyze these natural phenomena and determine the severity of the weather phenomena reflected in these site characteristics. Because the applicant has adequately implemented these methodologies, as described above, the staff finds that the applicant has considered these historical phenomena with margin sufficient for the limited accuracy, quantity, and period of time in which the data have been accumulated in accordance with 10 CFR 52.79(a)(1)(iii).

2.3.2 Local Meteorology

2.3.2.1 Introduction

Section 2.3.2, "Local Meteorology," of the Turkey Point Units 6 and 7 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 Turkey Point Units 6 and 7 site and its environs.

2.3.2.2 Summary of Application

Turkey Point Units 6 and 7 COL FSAR Section 2.3 incorporates by reference Section 2.3 of the AP1000 DCD.

In addition, in Turkey Point Units 6 and 7 COL FSAR Section 2.3, the applicant provided the following:

AP1000 COL Information Item

- PTN COL 2.3-2

The applicant provided additional information in PTN COL 2.3-2 to address COL Information Item 2.3-2. PTN COL 2.3-2 addresses the provision of local meteorology.

2.3.2.3 Regulatory Basis

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

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

The applicable regulatory requirements for identifying local meteorology are:

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

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

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

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

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

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

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

2.3.2.4 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.3.2 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to local meteorology. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information contained in the Turkey Point Units 6 and 7 COL FSAR:

<u>AP1000 COL Information Item</u>

- PTN COL 2.3-2

The applicant provided additional information in PTN COL 2.3-2 to resolve COL Information Item 2.3-2, which addresses the provision of local meteorology.

The staff reviewed PTN COL 2.3-2, related to the provision of local meteorology included under Turkey Point Units 6 and 7 COL FSAR Section 2.3. The specific text of this COL Information Item in Section 2.3.6.2 of the AP1000 DCD states:

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

The 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, Mean, and Extreme Values of Meteorological Parameters

Local meteorology data for the Turkey Point Units 6 and 7 site was provided by the first-order NWS station at Miami, FL, and 16 other nearby cooperative network observing stations, and measurements from the onsite meteorological measurements program operated in support of Units 3 and 4.

Measurements from the tower-mounted meteorological monitoring system that supports Units 3 and 4 include wind direction, wind speed, and atmospheric stability. These measurements are used as the basis for determining and characterizing atmospheric dispersion conditions in the vicinity of the site. The measurements from this tower were taken over three annual cycles in 2002, 2005, and 2006.

<u>Average Wind Direction and Wind Speed Conditions</u>

The applicant produced monthly and annual wind summaries from the onsite meteorological data during 2002, 2005, and 2006. Turkey Point Units 6 and 7 COL FSAR Tables 2.3.2-205 and 2.3.2-206 presented the average joint frequency distribution of wind speed and direction by Pasquill Stability Category (i.e., stability class) for both the lower-level (10-m) and upper-level (60-m) measurement heights. The 3-year joint frequency distribution, based on the lower-level measurement height, was used as input to the atmospheric dispersion models discussed in Turkey Point Units 6 and 7 COL FSAR Sections 2.3.4 and 2.3.5. Using the hourly meteorological data provided by the applicant, the staff independently produced the 3-year joint frequency distributions at both the lower-level and upper-level measurement heights and has confirmed the applicant’s wind summaries as correct and acceptable.

Graphical illustrations of the wind summaries (i.e., wind roses) from the same observation period were also produced by the applicant in Turkey Point Units 6 and 7 COL FSAR Figures 2.3.2-201 through 2.3.2-212. These figures show the average monthly wind speed and direction for 16 radial compass directions over all stability classes during the 3-year period of record. Using the hourly meteorological data provided by the applicant, the staff independently produced the same wind roses and has confirmed the applicant’s figures as correct and acceptable.

<u>Wind Direction Persistence</u>

The applicant presented wind persistence data from the Turkey Point onsite meteorological monitoring program, as described in Turkey Point Units 6 and 7 COL FSAR Section 2.3.3, during 2002, 2004, and 2005. As the applicant stated, wind persistence is an indicator of the duration of atmospheric transport from a specific sector to a corresponding downwind sector that is 180 ° opposite. The applicant provided detailed information on the wind persistence that

was observed by the onsite meteorological measurements in Turkey Point Units 6 and 7 COL FSAR Tables 2.3.2-202 and 2.3.2-203. The staff has independently confirmed the wind persistence at the Turkey Point Units 6 and 7 site, and thus accepts the application's data and discussion.

Atmospheric Stability

The applicant classified atmospheric stability in accordance with the guidance provided in RG 1.23, Revision 1. Atmospheric stability is a critical parameter for estimating dispersion characteristics in Turkey Point Units 6 and 7 COL FSAR Sections 2.3.4 and 2.3.5. Dispersion of effluents is greatest for extremely unstable atmospheric conditions (i.e., Pasquill Stability Class A) and decreases progressively through extremely stable conditions (i.e., Pasquill Stability Class G). The applicant based its stability classification on temperature change with height (i.e., delta-temperature or $\Delta T/\Delta Z$) between the 60 m and 10 m height, as measured by the Turkey Point Units 6 and 7 onsite meteorological measurements program during 2002, 2005, and 2006.

Frequency of occurrence for each stability class is one of the inputs to the dispersion models used in Turkey Point Units 6 and 7 COL FSAR Sections 2.3.4 and 2.3.5. The applicant included these data in the form of a joint frequency distribution (JFD) of wind speed and direction data as a function of stability class. A comparison of a JFD developed by the staff from the hourly data submitted by the applicant with the JFD developed by the applicant showed reasonable agreement.

Based on the staff's past experience with stability data at various sites, a predominance of neutral (Pasquill Stability Class D) and slightly stable (Pasquill Stability Class E) conditions at the proposed Turkey Point Units 6 and 7 site is generally consistent with expected meteorological conditions. Using a JFD of wind speed, wind direction, and atmospheric stability, and comparing it against the applicants JFD, the staff was able to independently confirm that the 3-year statistics presented by the applicant are adequate.

Temperature

The applicant characterized normal and extreme temperatures for the site based on the 16 surrounding observation stations listed in Turkey Point Units 6 and 7 COL FSAR Table 2.3.2-207, as well as the Miami International Airport NWS reporting station. The extreme maximum temperatures recorded near the site range from 96 °F to 104 °F and the extreme minimum temperatures recorded near the site range from 21 °F to 42 °F. Annual average temperatures for the 17 surrounding sites range from 73.8 °F to 78.4 °F. The applicant stated that the annual average diurnal (day-to-night) temperature differences in the site vicinity range from 9.0 °F to 19.8 °F. The applicant stated that this difference in diurnal temperature ranges is due mainly to proximity of each station to the Atlantic Ocean.

Atmospheric Water Vapor

The applicant presented wet-bulb temperatures, dew-point temperatures, and relative humidity data summaries from the Miami International Airport NWS observation station to characterize the typical atmospheric moisture conditions near the proposed Turkey Point Units 6 and 7 site.

Based on a 25-year period of record, the applicant stated that the mean annual wet-bulb temperature is 69.6 °F. The highest monthly mean wet-bulb temperature is 76.4 °F during August and the lowest monthly mean wet-bulb temperature is 62.0 °F during January.

According to the applicant, the mean annual dew-point temperature at Miami International Airport is 67.7 °F, which also reaches its maximum during summer and minimum during winter. The applicant gives the highest monthly mean dew-point temperature as 74.4 °F during August and the lowest monthly mean dew point temperature as 59.1 °F during January.

Based on a 30-year period of record, the applicant indicates that relative humidity averages 73 percent on an annual basis. The average early morning relative humidity levels exceed 85 percent during August, September, October, and January. Typically, the relative humidity values reach diurnal maximum in the early morning and diurnal minimum during the early afternoon.

The staff reviewed the data listed in the NCDC "Miami, Florida 2008 Local Climatological Data, Annual Summary with Comparative Data" to verify the wet-bulb temperatures, dew-point temperatures, and relative humidity statistics presented by the applicant and discussed above. The staff concludes that the applicant's values are correct and appropriate.

Precipitation

Based on data from the 17 surrounding observation stations, the applicant stated that the average annual precipitation (water equivalent) totals vary by approximately 21.2 in, ranging from 44.8 in to 66.0 in. The applicant stated that there are two seasonal maximums, the highest during the early summer (June) and the second during the late summer and early autumn (August and September). The applicant stated that the long-term average annual total rainfall at the Turkey Point Units 6 and 7 site could reasonably be expected to be within this range.

Using daily snowfall and rainfall data from the NCDC, the staff has independently verified the precipitation statistics presented in Turkey Point Units 6 and 7 COL FSAR Section 2.3.2.1.6 and accepts them as adequate.

Fog

Miami International Airport is the closest station to the proposed Turkey Point Units 6 and 7 site that makes fog observations. The applicant stated that, based on a 45-year period of record, Miami International Airport averages about 4.7 days per year of heavy fog conditions (e.g., visibility is reduced to one-quarter mile or less).

According to the applicant, the frequency of typical fog conditions at Miami International Airport is expected to be similar to that at the proposed Turkey Point Units 6 and 7 site because of the proximity and similarity of topographic features between the two locations. Both sites are located in relatively flat terrain and are both located close to the Atlantic Ocean.

The staff confirmed the applicant's assertion that the Miami International Airport reports approximately 4.7 days per year with heavy fog observations. The staff agrees that the frequency of fog conditions at Miami International Airport is expected to be similar to that at the proposed Turkey Point Units 6 and 7 site because of the proximity and similarity of topographic features at both locations.

2.3.2.4.2 Potential Influence of the Plant and Related Facilities on Meteorology

The applicant stated that the potential exists for changes to the micrometeorology as a result of minor changes to the topography, vegetation, and the construction of additional building and

infrastructure. Wind flow may be altered immediately adjacent to and downwind of larger site structures, but these effects will likely dissipate within 10 structure heights downwind. SER Section 2.3.3 discusses the effects of these larger structures on wind flow.

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

Turkey Point Units 6 and 7 will use mechanical draft cooling towers to dissipate heat to the atmosphere. Potential meteorological effects due to operation of the cooling towers may include enhanced ground-level fogging and icing, cloud shadowing and precipitation enhancement, and increased ground-level humidity.

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

In response to RAI 02.03.02-2, the applicant provided a discussion of the effects of salt and moisture deposition on the Turkey Point Units 6 and 7 transformers, switchyard equipment, or transmission lines. The applicant provided an electronic copy of the input and output files from the AERMOD computer model. The staff reviewed the model input and output files to assure that the applicant made conservative assumptions. The AERMOD results indicate that nearly two months of salt accumulation would result in 0.08 mg/cm^2, which is the upper end of the "Light Contamination Level" range defined by the Institute of Electrical and Electronic Engineers (IEEE) standard. The applicant stated that the vapor plume from the mechanical draft cooling towers would only be expected to intersect the switchyard under high wind speeds (greater than 10 m/s) and with winds from the SSE, S, or SSW sectors. Turkey Point Units 6 and 7 COL FSAR Table 2.3.2-205 shows that these conditions exist for only about 7 hours per year. The staff has independently verified the sources and data cited by the applicant. The staff agrees that total salt accumulation reaching amounts that require mitigation is unlikely due to local precipitation removing any salt deposits before it reaches a level of concern.

The applicant also addressed the potential for the cooling tower plume to increase the temperature and humidity levels at the control room HVAC intakes. Since the cooling tower plumes are only marginally higher than the 100-year return period dry-bulb temperature at the site, the plume is not hot enough to exceed the HVAC design temperature, as shown in AP1000 DCD Table 2-1. The temperature difference, combined with the distance that the plume must travel, leads to the conclusion that there is little potential for the cooling tower plume to adversely impact the HVAC intakes.

Topographic Description

The applicant stated that the Turkey Point site and surrounding area is relatively flat, with no significant terrain features that will otherwise be expected to adversely or unusually impact natural dispersion downwind of the plant. In Turkey Point Units 6 and 7 COL FSAR Sections 2.3.4 and 2.3.5, the applicant discussed that due to the location of the site adjacent to Biscayne Bay, there is a potential for recirculation of flow due to land-water boundaries. The results of the short- and long-term atmospheric dispersion analyses are discussed in Turkey Point Units 6 and 7 COL FSAR Sections 2.3.4 and 2.3.5. Turkey Point Units 6 and 7 COL FSAR Figure

2.3.2-213, “Terrain Elevation Profiles Within 50 Miles of the Units 6 & 7 Site,” shows topographic features within an 80 km (50 mi) radius of the Turkey Point Units 6 and 7 site. The staff has independently verified the topographical assessment provided by the applicant and accepts the description as correct and adequate.

Fogging and Icing Effects Attributable to Cooling Tower Operation

Ground fogging could occur if ground elevations in the plant vicinity were comparable to expected heights of the cooling tower plumes. The applicant stated that the expected cooling towers for Units 6 and 7 are mechanical draft towers. The applicant stated that ground-level fogging could occur in the immediate vicinity of the mechanical draft cooling towers. However, those events would be expected only at on-site locations and under relatively cold and moist atmospheric conditions and when building wake and downwash effects have an adverse influence on the dispersion of the cooling tower plumes. The staff agrees and accepts the applicant’s discussion.

The applicant stated that there are no large safety-related plant structures or other nearby structures that are expected to be affected by icing from cooling tower plumes due to the meteorological conditions that could reasonably be expected to occur. Because of the small number of days with ambient temperatures below freezing at the Miami, FL, reporting station, the staff agrees that the threat of ice formation is sufficiently low. The staff agrees and accepts the applicant’s discussion.

Assessment of Heat Dissipation Effects on the Atmosphere

The topics discussed in this section of the Turkey Point Units 6 and 7 COL FSAR are addressed elsewhere in SER Section 2.3.2.4.2.

Current and Projected Site Air Quality

This section discusses Turkey Point Units 6 and 7 COL FSAR Sections 2.3.2.2.5 and 2.3.2.2.6. The applicant stated that the proposed Turkey Point Units 6 and 7 site is located in the Southeast Florida Intrastate Air Quality Control Region, which includes Broward, Miami-Dade, Indian River, Martin, Monroe, Okeechobee, Palm Beach, and St. Lucie counties. The Southeast Florida Intrastate Air Quality Control Region has been designated as being in attainment, or unclassified for all EPA criteria air pollutants (i.e., ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter, and lead) (40 CFR 81.310, “Florida,” and 40 CFR 81.49, “Southeast Florida Intrastate Air Quality Control Region”).

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

2.3.2.5 Post Combined License Activities

There are no post-COL activities related to this section

2.3.2.6 Conclusion

The staff reviewed the application and checked the referenced DCD. The staff's review confirmed that the applicant has addressed the relevant information relating to regional climatology, and no outstanding information related to regional climatology remains to be addressed in the Turkey Point Units 6 and 7 COL FSAR. The results of the staff's technical evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

COL Information Item 2.3-2 states that a COL applicant shall address the site-specific local meteorological information. As set forth above, the applicant has presented and substantiated information describing the local meteorological conditions and topographic characteristics important to evaluating the adequacy of 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 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). The staff finds that the applicant has provided a sufficient description to adequately address COL Information Item 2.3-2 (COL Action Item 2.3.2-1).

The staff also finds that the applicant has considered the appropriate site phenomena in establishing the site characteristics. Specifically, the staff has accepted the methodologies used to determine the meteorological and topographic characteristics. Because the applicant has correctly implemented these methodologies, as described above, the staff has determined that the site characteristics including margin, are 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).

2.3.3 Onsite Meteorological Measurements Program

2.3.3.1 Introduction

The Turkey Point Units 6 and 7 onsite meteorological measurement program addresses the need for onsite meteorological monitoring and the resulting data. The staff review covers the following specific areas: (1) meteorological instrumentation, including siting of sensors, sensor type and performance specifications, methods and equipment for recording sensor output, the quality assurance program for sensors and recorders, data acquisition and reduction procedures, and special considerations for complex terrain sites, and (2) the resulting onsite meteorological database, including consideration of the period of record and amenability of the data for use in characterizing atmospheric dispersion conditions.

This section verifies that the applicant successfully implemented an appropriate onsite meteorological measurements program and that data from this program provide an acceptable basis for estimating atmospheric dispersion for DBAs and routine releases from an AP1000 design.

2.3.3.2 Summary of Application

Turkey Point Units 6 and 7 COL FSAR Section 2.3 incorporates by reference Section 2.3 of the AP1000 DCD.

In addition, in Turkey Point Units 6 and 7 COL FSAR Section 2.3, the applicant provided the following:

AP1000 COL Information Item

- PTN COL 2.3-3

The applicant provided additional information in PTN COL 2.3-3 to address COL Information Item 2.3-3. PTN COL 2.3-3 addresses the onsite meteorological measurements program.

In addition, this Turkey Point Units 6 and 7 COL FSAR section addresses interface item No. 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 in NUREG-1793 and its supplements.

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

The applicable regulatory requirements for identifying onsite meteorological measurements 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 offsite, and (2) radiological dose consequences of postulated accidents meet prescribed dose limits at the exclusion area boundary (EAB) and the outer boundary of the low population zone (LPZ).

- 10 CFR Part 50, Appendix A, GDC 19, 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 50.47(b)(4), 10 CFR 50.47(b)(8), and 10 CFR 50.47(b)(9), as well as Section IV.E.2 of 10 CFR Part 50, Appendix E, “Emergency Planning and Preparedness for Production and Utilization Facilities,” with respect to the onsite meteorological information available for determining the magnitude and continuously assessing the impact of the releases of radiological materials to the environment during a radiological emergency.

- 10 CFR Part 50, Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As Is Reasonably Achievable for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," 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 reasonably achievable (ALARA).

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

The following RG is applicable to this section:

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

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

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

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

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

The applicant should identify and justify any deviations from the guidance provided in RG 1.23, Revision 1. Deviations from guidance are discussed in further detail in SER Chapter 1.

2.3.3.4 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.3.3 and checked the referenced DCD to ensure that the combination of the DCD and the COL applications represents the complete scope of information relating to this review topic.[1] The staff's review

confirmed that the information in the application and incorporated by reference addresses the required information relating to the onsite meteorological measurements program. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the Turkey Point Units 6 and 7 COL FSAR:

AP1000 COL Information Item

- PTN COL 2.3-3

The staff reviewed PTN COL 2.3-3 related to the onsite meteorological measurements program included under Section 2.3 of the Turkey Point Units 6 and 7 COL FSAR. The specific text of this COL information item in Section 2.3.6.3 of the AP1000 DCD states:

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

The staff's evaluation is based on the descriptions provided by the applicant in Turkey Point Units 6 and 7 COL FSAR Section 2.3.3 and a NRC site audit held June 7-11, 2010. The purpose of the site audit 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.

The 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 Preoperational and Operational Monitoring Programs

The onsite meteorological monitoring program at the Turkey Point site is a continuation of the current program supporting existing Turkey Point Units 3 and 4. Turkey Point Units 6 and 7 COL FSAR Figures 2.3.3-201 and 2.3.3-202 show the location of the 60 m (196 ft) and 10 m (33 ft) meteorological towers, respectively. Regulatory Guide 1.23, Revision 1, Section 3, describes an acceptable method for siting of the onsite meteorological observation tower. The Turkey Point Units 6 and 7 site is supported by two meteorological towers; the 60 m (196 ft) South Dade tower and the 10 m (33 ft) land utilization (LU) tower. The 60 m (196 ft) South Dade meteorological tower serves as the data collection system and source of onsite meteorological data for the COL application. As stated by the applicant, the 10 m (33 ft) wind speed and wind direction data from the LU tower is primarily used in emergency situations. Data from the South Dade tower is used as backup during a plant emergency.

The South Dade meteorology tower is a 60 m (196 ft), open latticed meteorological tower located approximately 8.9 km (5.5 mi) southwest of Turkey Point Units 3 and 4. The tower design is consistent with the guidance provided in RG 1.23, Revision 1; therefore, it is acceptable to the staff.

Meteorological Tower Location and Siting

General Location

Turkey Point Units 6 and 7 COL FSAR Figures 2.3.3-201 and 2.3.3-202 show the location of the 60 m (196 ft) South Dade tower and the 10 m (33 ft) LU tower in relation to the existing and proposed units. These figures also show the towers in relation to the Units 6 and 7 cooling towers, existing cooling canals, and Biscayne Bay.

The applicant stated that the South Dade tower is approximately 7.6 m (25 ft) below the elevation of the expected finished grade of the Turkey Point Units 6 and 7. However, because of the large distance between the proposed units and the South Dade tower, and the minimal terrain variations, the South Dade tower and the Turkey Point Units 6 and 7 will likely have similar meteorological exposures.

The applicant stated that the base of the LU tower is approximately 6.7 m (22 ft) below the finished grade of Units 6 and 7. However, due to the proposed location of Turkey Point Units 6 and 7, the LU tower requires relocation.

Tower Location Relative to Potential Obstructions to Airflow

According to RG 1.23, Revision 1, the wind sensors should be located over level, open terrain at a distance of at least 10 times the height of any nearby natural and man-made obstructions. There is an emergency generator shelter mound located approximately 6.6 m (21.5 ft) north of the tower. The height of the mound is 2.9 m (9.5 ft) above ground level, and the height of the shelter is 3.3 m. Combined, the height of the emergency generator shelter is 6.2 m (20.4 ft). Due to the location of the emergency generator shelter in relation to the South Dade tower, the shelter does not meet the guidance provided in RG 1.23, Revision 1. However, the staff finds this deviation from the regulatory guidance acceptable because of the relative infrequency of winds from the north (approximately 6.50 percent).

The applicant stated that at least 3 months before the start of Turkey Point Units 6 and 7, a replacement LU tower will be installed and made operational at an appropriate site location on the Turkey Point property.

Tower Location Relative to Potential Sources of Heat and Moisture

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

The applicant stated that the ground surrounding the South Dade tower is a grainy, light colored material with patches of low-cut grass or weeds that are typical of ground cover in the area. The applicant further stated that the heat reflection characteristics of the surface underlying the meteorological tower that could have localized influence on the measurements are expected to be minimal. Based on the NRC site audit, the staff agrees with the applicant’s characterization.

The applicant discussed the possibility that the extensive cooling canals may have some effect on the lower level temperature readings, which could affect the stability measurements. The applicant provided the average water temperatures recorded in the cooling basins and stated that warmer waters near the meteorological tower could create thermal instability. However, thermal instability would enhance the dispersion capability for releases occurring near the plant site.

Based on the applicant's description of the site, and the staff's site audit, the staff has confirmed that the applicant applied the siting guidance provided in RG 1.23, Revision 1, or has justified any deviations from the guidance. The staff, therefore, finds the siting of the meteorological towers acceptable.

Tower Location Relative to Biscayne Bay

The applicant stated that the South Dade tower is located approximately 4.8 km (3 mi) inland from Biscayne Bay. Due to the location of the tower near Biscayne Bay, it is frequently subjected to the land/sea breeze circulation, otherwise known as the thermal internal boundary layer (TIBL). The TIBL develops at or near the land-water interface based on the rate of differential heating between the land and water surfaces, wind conditions and other factors. The potential effects of the TIBL on the site's atmospheric dispersion estimates are discussed in Turkey Point Units 6 and 7 COL FSAR Sections 2.3.4 and 2.3.5.

The staff accepts the applicant's discussion on the location of the meteorological tower and its potential to be affected by the TIBL.

<u>Meteorological Instrumentation and Siting</u>

This section of the SER discusses Turkey Point Units 6 and 7 COL FSAR Sections 2.3.3.1.2.1, 2.3.3.1.2.2, and 2.3.3.1.2.3.

Turkey Point Units 6 and 7 COL FSAR Table 2.3.3-204 provides information on each of the meteorological instruments in the monitoring system. The meteorological parameters measured at the South Dade tower during 2002, 2005, and 2006 were wind speed, wind direction, air temperature, solar radiation, barometric pressure, and precipitation.

Ambient temperature and delta-temperature are monitored at both the lower- (10-m) and upper-level (60-m) of the tower. Two channels of differential temperature are monitored simultaneously between the lower- and upper-levels. The temperature probes are mounted in fan aspirated solar radiation shields attached to a 1.2-m retractable boom. There are no atmospheric moisture parameters recorded at the Turkey Point Units 6 and 7 site.

As shown in Turkey Point Units 6 and 7 COL FSAR Table 2.3.3-204, the temperature systems are based on RG 1.23, Revision 1; therefore the temperature systems are acceptable to the staff.

Wind direction, wind speed, and wind direction variance (i.e., sigma theta) are monitored at both the lower- (10-m) and upper-level (60-m) of the tower. The wind sensors are mounted on a 1.8-m retractable boom oriented perpendicular to the prevailing wind flow. As shown in Turkey Point Units 6 and 7 COL FSAR Table 2.3.3-204, these measurements are based on RG 1.23, Revision 1; therefore, the wind systems are acceptable to the staff.

Precipitation and solar radiation are measured near ground-level by a sensor located near the base of the tower. As shown in Turkey Point Units 6 and 7 COL FSAR Table 2.3.3-204, the precipitation sensor is based on RG 1.23, Revision 1. RG 1.23, Revision 1 does not provide specifications for solar radiation sensors. The RG states that solar radiation measurements are not required, but should be provided if available. These measurements are not required because they are not used as part of the application for any site parameter. Therefore, the staff

has no basis on which to evaluate a licensee's use of solar radiation sensors. In accordance with the current regulatory guidance, the precipitation and solar radiation systems are acceptable to the staff.

Turkey Point Units 6 and 7 COL FSAR Table 2.3.3-204 summarizes the accuracy of the measurements taken as part of the Turkey Point onsite meteorological measurements program. The accuracy of the 3-year record for the data provided was consistent with the requirements of RG 1.23, Revision 1. Therefore, the accuracy of the measurements is acceptable to the staff.

System Operation, Maintenance, and Calibration

This section of the SER discusses Turkey Point Units 6 and 7 COL FSAR Sections 2.3.3.1.3.1 and 2.3.3.1.3.2.

The applicant stated that the meteorological equipment is checked and calibrated on a routine basis in accordance with NRC guidance. To achieve the required level of system reliability, as specified in RG 1.23, Revision 1, the applicant employs the following maintenance techniques: (1) calibrating the datalogger input channels semiannually, (2) channel checks are performed daily in order to achieve maximum data recovery, (3) checking the consistency between the two ambient/differential temperature channels, (4) checking the guide wires and the tower anchors annually.

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

Data Acquisition and Recording

Data from each of the meteorological towers are processed through computers in the respective equipment shelters. These computers are used to receive, process, manage, and archive all of the data collected from the monitoring towers. The microprocessors used for data collection sample the meteorological processor modules once per second for each parameter measured, except for precipitation. Water from the precipitation gauge is automatically drained and counted each time an internal bucket fills with 0.01 in. of rainfall.

Data Processing and Validation

Data Reduction and Review

The applicant stated that the hourly average data is downloaded and formatted monthly for review and editing. Missing or invalid data from the 60-m tower, such as 10-m wind speed, wind direction, and ΔT data, are deleted or manually replaced with backup tower data.

Data Validation

The applicant described the rigid system of checks and procedures that are applied to the meteorological data on the monthly, quarterly, and annual data files. The applicant described the computer programs that are used to validate the data recorded at the meteorological towers. The applicant, in Turkey Point Units 6 and 7 COL FSAR Section 2.3.3.1.5.2, presented the acceptance criteria that are used for the onsite meteorological measurement system.

Data Recovery and Representativeness

This section of the SER addresses Turkey Point Units 6 and 7 COL FSAR Sections 2.3.3.1.5.3 and 2.3.3.1.6.

The applicant stated that historical data from the onsite meteorological monitoring system can be retrieved, archived, displayed, or printed as needed. This data includes the 15- and 60-minute averaged meteorological data that is recorded at the site.

As discussed in SER Section 2.3.2, the applicant provided JFDs of wind speed, wind direction, and atmospheric stability for both the 10-meter and 60-meter levels based on hourly measurements taken during 2002, 2005, and 2006.

The staff performed a quality review of the 2002, 2005, and 2006 hourly meteorological database using the methodology described in NUREG-0917, "Nuclear Regulatory Commission Staff Computer Programs for Use with Meteorological Data," issued July 1982. The staff used computer spreadsheets to perform further review. As expected, the staff's examination of the data revealed generally stable and neutral atmospheric conditions at night and unstable conditions during the day. Wind speed, wind direction, and stability class frequency distributions for each measurement channel were reasonable. As discussed in SER Section 2.3.2, the staff verified and accepts the lower- and upper-level JFDs and wind roses provided by the applicant.

Turkey Point Units 6 and 7 COL FSAR Table 2.3.3-205 summarizes the annual data recovery rate for the Turkey Point Units 6 and 7 site's meteorological monitoring system. The applicant has shown in the table, and stated, that the recovery rate meets the requirements of RG 1.23, Revision 1. Since the 3-year composite recovery rate for all of the parameters is above 90 percent for the period submitted, they are acceptable to the staff.

Emergency Preparedness Support

The applicant described the onsite meteorological monitoring system and stated that this data is also used to represent meteorological conditions in the 10-mile EPZ radius. The staff agrees with the information presented in this section of the Turkey Point Units 6 and 7 COL FSAR.

Need of Additional Data Sources for Airflow Projections.

The applicant described the local topographic features and how they may affect the dispersion characteristics determined through the use of the XOQDOQ computer model. The staff will discuss this information in SER Section 2.3.5.

2.3.3.5 Post Combined License Activities

Turkey Point Units 6 and 7 COL FSAR Part 10 describes proposed COL conditions, including inspection, test, analysis, and acceptance criteria (ITAAC). Table 3.8-1 in Part 10 of the COL application includes the emergency planning (EP) ITAAC. The following EP ITAAC involve demonstrating that the operational onsite meteorological monitoring program appropriately supports the Turkey Point Units 6 and 7 site's emergency plan:

- Acceptance Criteria 5.2.3: Radiological data identified in each Plan Annex, meteorological data, and plant system data pertinent to determining offsite protective measures are displayed in the Emergency Operations Facility (EOF), when activated.

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

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

The EP, including EP ITAAC, are addressed in SER Section 13.3, "Emergency Planning."

2.3.3.6 Conclusion

The staff reviewed the application and checked the referenced DCD. The 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 Turkey Point Units 6 and 7 COL FSAR related to this section. The results of the staff's technical evaluation of the information incorporated by reference in the COL application are documented in NUREG-1793 and its supplements.

COL Information Item 2.3-3 states that a COL applicant shall address the site-specific onsite meteorological measurements program. As set forth above, the applicant has presented and substantiated information pertaining to the onsite meteorological measurements program and the resulting database. The staff has reviewed the information provided in PTN COL 2.3-3 and, for the reasons given above, concludes that the applicant has established consideration of the onsite meteorological measurements program and the resulting database are acceptable and meet the requirements of 10 CFR 100.20 with respect to determining the acceptability of the site. The staff also finds that the onsite data provide an acceptable basis for making estimates of atmospheric dispersion for DBA and routine releases from the plant to meet the requirements of 10 CFR 100.21, GDC 19, 10 CFR Part 20, and Appendix I to 10 CFR Part 50. Finally, the equipment provided for measurement of meteorological parameters during the course of accidents is sufficient to provide reasonable prediction of atmospheric dispersion of airborne radioactive materials in accordance with Appendix E to 10 CFR Part 50. The staff finds that the applicant has provided a sufficient description to adequately address COL Information Item 2.3-3.

2.3.4 Short-Term Dispersion Estimates for Accident Releases

2.3.4.1 Introduction

The short-term diffusion estimates are used to determine the amount of airborne radioactive materials expected to reach a specific location during an accident situation. The diffusion estimates address the requirement for conservative atmospheric dispersion (relative concentration) factor (χ/Q value) estimates at the EAB, the outer boundary of the LPZ, and at the control room for postulated design-basis accidental radioactive airborne releases. The review covers the following specific areas: (1) atmospheric dispersion models to calculate atmospheric dispersion factors for postulated accidental radioactive releases, (2) meteorological

data and other assumptions used as input to atmospheric dispersion models, (3) derivation of diffusion parameters (e.g., σ_y and σ_z), (4) cumulative frequency distributions of χ/Q values, (5) determination of conservative χ/Q values used to assess the consequences of postulated design-basis atmospheric radioactive releases to the EAB, LPZ, and control room, and (6) any additional information requirements prescribed within the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.3.4.2 Summary of Application

Turkey Point Units 6 and 7 COL FSAR Section 2.3.4 incorporates by reference Section 2.3.4 of the AP1000 DCD.

Tier 2 Departure

- PTN DEP 2.0-4

The applicant proposed a departure from the population distribution exclusion area (site) of 0.5 mi in Tier 2 material of the AP1000. The 0.27-mi minimum distance from the source boundary to the exclusion area boundary identified in Turkey Point Units 6 and 7 COL FSAR Table 2.0-201 is less than the value in the AP1000 DCD Tier 2 Table 2-1. The evaluation of the appropriateness of the 0.27 mi value for the Turkey Point Units 6 and 7 site is in SER Section 2.3.4.4.3.1.

In addition, in Turkey Point Units 6 and 7 COL FSAR Section 2.3, the applicant provided the following:

AP1000 COL Information Item

- PTN COL 2.3-4

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

In addition, this Turkey Point Units 6 and 7 COL FSAR section addresses Interface Item No. 2.4 related to the limiting meteorological parameters (χ/Q) for DBAs.

2.3.4.3 Regulatory Basis

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

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

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

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

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

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

The following RGs are applicable to this section:

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

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

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

The related acceptance criteria from Section 2.3.4 of NUREG-0800 indicate that the following information should be provided:

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

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

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

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

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

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

2.3.4.4 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.3.4 and checked the referenced DCD to ensure that the combination of the DCD and the COL represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the short-term diffusion estimates. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information contained in the Turkey Point Units 6 and 7 COL FSAR:

Tier 2 Departure

- PTN DEP 2.0-4

The staff reviewed PTN DEP 2.0-4 related to the impact on the short-term dispersion estimates for accident releases potentially caused by applicant's use of a minimum distance from the source boundary to the exclusion areas boundary of 0.43 km (0.27 mi) rather than the site parameter of 0.80 km (0.5 mi) specified in the AP1000 DCD is used for the Turkey Point Units 6 and 7 site.

Evaluation of the information provided in PTN DEP-2.0-4 related to the impact of the applicant's use of a minimum distance from the source boundary to the exclusion area boundary of 0.43 km (0.27 km) on the short-term dispersion estimates for accident releases is discussed below.

AP1000 COL Information Item

- PTN COL 2.3-4

The staff reviewed PTN COL 2.3-4 related to the short-term diffusion estimates included under Section 2.3.4 of the Turkey Point Units 6 and 7 COL FSAR. The COL information item in Section 2.3.6.4 of the AP1000 DCD states:

> Combined License applicants referencing the AP1000 certified design will address the site-specific χ/Q values specified in subsection 2.3.4. For a site selected that exceeds the bounding χ/Q values, the Combined License applicant will address how the radiological consequences associated with the controlling design basis accident continue to meet the dose 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 that exceeds the median value (50-percent of the time).

The 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

Offsite Dispersion Estimates

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

The PAVAN code estimates χ/Q values for various time-average periods ranging from 2 hours to 30 days. The meteorological input to PAVAN consists of a JFD of hourly values of wind speed and wind direction by atmospheric stability class. The χ/Q values calculated through PAVAN are based on the theoretical assumption that material released to the atmosphere will be normally distributed (Gaussian) about the plume centerline. A straight-line trajectory is assumed between the point of release and all distances for which χ/Q values are calculated.

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

Using the same approach, PAVAN also combines all χ/Q values independent of wind direction into a cumulative frequency distribution for the entire site. An upper envelope curve is determined, and the program selects the χ/Q value that 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 (8,760-hour) χ/Q values for each of the 16 sectors and overall site. For each time period, the highest among the 16 sectors and overall site χ/Q values is identified and becomes the short-term site characteristic χ/Q value for that time period.

Control Room Dispersion Estimates

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

The ARCON96 code estimates χ/Q values for various time-averaged periods ranging from 2 hours to 30 days. The meteorological input to ARCON96 consists of hourly values of wind speed, wind direction, and atmospheric stability class. The χ/Q values calculated through ARCON96 are based on the theoretical assumption that material released to the atmosphere will be normally distributed (Gaussian) about the plume centerline. A straight-line trajectory is assumed between the release points and receptors. The diffusion coefficients account for enhanced dispersion under low wind speed conditions and in building wakes.

The hourly meteorological data are used to calculate hourly relative concentrations. The hourly relative concentrations are then combined to estimate concentrations ranging in duration from 2 hours to 30 days. Cumulative frequency distributions, 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

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 3-year period during 2002, 2005, and 2006. The wind data were obtained from the 10-m level of the onsite meteorological tower, and the stability data were derived from the vertical temperature difference (delta-temperature) measurements taken between the 60-m and 10-m levels on the onsite meteorological tower.

The staff has completed a detailed review related to the acceptability and representativeness of the hourly meteorological data as discussed in SER Sections 2.3.2 and 2.3.3. Based on this review, the staff considers the onsite meteorological database suitable for input to the PAVAN model.

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 3-year period during 2002, 2005, and 2006. The wind data were obtained from the 10 m and 60 m levels of the onsite meteorological tower, and the stability data were derived from the vertical temperature difference (delta-temperature) measurements taken between the 60 m and 10 m levels on the onsite meteorological tower.

The staff has completed a detailed review related to the acceptability and representativeness of the hourly meteorological data as discussed in SER Section 2.3.3. Based on this review, the staff considers the onsite meteorological database suitable for input to the ARCON96 model.

2.3.4.4.3 Diffusion Parameters

Offsite Dispersion Estimates

The applicant chose to implement the diffusion parameter assumptions outlined in RG 1.145, Revision 1, as a function of atmospheric stability for its PAVAN model runs. The staff evaluated the applicability of the PAVAN diffusion parameters and concluded that no unique topographic features (such as rough terrain, restricted flow conditions, or coastal or desert areas) preclude the use of the PAVAN model for the Turkey Point Units 6 and 7 site. However, in accordance with the guidance in RG 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors," Revision 1, terrain adjustment factors were used for the annual average calculations for the airflow recirculation effect generated by the local land-sea breeze circulation. Therefore, the staff finds that the applicant's use of diffusion parameter assumptions, as outlined in RG 1.145, Revision 1, acceptable.

The applicant stated that an exemption from 10 CFR Part 52, Appendix D, Section IV.A.2.d, in accordance with 10 CFR 52.7 and 10 CFR 52.93 and a departure from AP1000 DCD Table 2-1 is necessary. Details on the departure (PTN DEP 2.0-4) can be found in Part 7.B.3, of the Turkey Point Units 6 and 7 COL FSAR. This departure is a result of the applicant choosing an EAB distance less than the site parameter provided in AP1000 DCD Table 2.-1. The staff has determined that the applicant's use of distances less than those provided in the AP1000 DCD would only result in more conservative (higher) χ/Q estimates. The staff confirmed the resulting χ/Q estimates provided in PTN DEP 2.0-4 and determined that they are correct.

Control Room Dispersion Estimates

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

2.3.4.4.4 Relative Concentration for Accident Consequences Analysis

Conservative Short-Term Atmospheric Dispersion Estimates for EAB and LPZ

The applicant modeled one ground-level release point and used the AP1000 DCD dimensions for the minimum building cross section and containment heights for building wake effects. Including the building wake effects for a ground-level release has little influence on the predicted χ/Q values. A ground-level release assumption that assumes the appropriate building dimensions is acceptable to the staff. This is acceptable because the PAVAN model includes both plume meander and building wake effects, which are mutually exclusive. The applicant uses a source boundary that encloses all potential release points for both Turkey Point Units 6 and 7. As a result of this method, the minimum distance to the EAB and LPZ was used as input to PAVAN. The use of the shortest distance results in higher (more conservative) χ/Q values for ground level releases and is therefore acceptable to the staff.

In accordance with AP1000 DCD Section 2.3.6.4, Turkey Point Units 6 and 7 COL FSAR Section 2.3.4.2 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 EAB and LPZ χ/Q values conservatively bounded the site-specific values. The staff notes that 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 than the site parameter χ/Q value. The staff notes that such a comparison shows that the site has better dispersion characteristics than that required by the reactor design.

Using the information provided by the applicant, including the 10 m level joint frequency distributions of wind speed, wind direction, and atmospheric stability presented in Turkey Point Units 6 and 7 COL FSAR Table 2.3.2-205, the staff confirmed the applicant's χ/Q values by running the PAVAN computer code and obtaining consistent results. The staff accepts the short-term χ/Q values presented by the applicant.

Short-Term Atmospheric Dispersion Estimates for the Control Room

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

- Onsite Hourly Meteorological Data: 2002, 2005, and 2006,
- AP1000 DCD Table 15A-7: Control Room Source / Receptor Data,
- AP1000 DCD Figure 15A-1: Site Plan with Release and Intake Locations,
- Turkey Point Units 6 and 7 COL FSAR Table 2.3.4-205: Release/Receptor Azimuthal Angles, and
- Turkey Point Units 6 and 7 COL FSAR Figure 2.1-204: Plant Layout on the Turkey Point Units 6 and 7 Site.

Two receptor (i.e., air intake) points, the control room heating, ventilation, and air conditioning (HVAC) intake and control room door, were modeled for the following eight release points:

- containment shell,
- fuel building blowout panel,
- fuel building rail bay door,
- steam vent,
- power-operated relief valve (PORV)/safety valves,
- condenser air removal stack,
- plant vent, and
- PCS air diffuser.

Turkey Point Units 6 and 7 COL FSAR Tables 2.3.4-205 and 2.3.4-206 compared the site-specific control room χ/Q values to the corresponding site parameters provided in the DCD. This comparison showed that the AP1000 control room χ/Q values conservatively bounded the site-specific values. This comparison is reproduced in Turkey Point Units 6 and 7 COL FSAR Table 2.0-202.

The staff confirmed the applicant's atmospheric dispersion estimates by running the ARCON96 computer model and obtaining similar results (i.e., values on average within ± 0.14 percent). Both the staff and applicant used a ground-level release assumption for each of the

release/receptor combinations as well as other conservative assumptions. Based on its confirmatory analysis, the staff finds the applicant's control room χ/Q values acceptable.

2.3.4.4.5 Onsite and Offsite Hazardous Materials

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

2.3.4.5 Post Combined License Activities

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

2.3.4.6 Conclusion

The staff reviewed the application including PTN COL 2.3-4 and checked the referenced DCD. The staff's review confirmed that the applicant has addressed the relevant information relating to short-term diffusion estimates, and no outstanding information related to this section remains to be addressed in the Turkey Point Units 6 and 7 COL FSAR. The results of the staff's technical evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

COL Information Item 2.3-4 states that a COL applicant shall address the site-specific χ/Q values as specified in AP1000 DCD Section 2.3.4. The staff concludes that the applicant's atmospheric dispersion estimates are acceptable and meet the relevant requirements of 10 CFR 100.21(c)(2). This conclusion is based on the conservative assessments of post-accident atmospheric dispersion conditions that have been made by the applicant and the staff from the applicant's meteorological data and appropriate diffusion models. The staff has reviewed PTN DEP 2.0-4 and has determined that the applicant's use of distances less than those provided in the AP1000 DCD is acceptable for the Turkey Point Units 6 and 7 site.

The atmospheric dispersion estimates provided in this SER section are appropriate for the assessment of consequences from radioactive releases for DBAs in accordance with 10 CFR 52.79(a)(1)(vi), 10 CFR 100.21(c)(2), and GDC 19. The staff finds that the applicant has provided sufficient information to adequately address COL Information Item 2.3-4.

2.3.5 Long-Term Atmospheric Diffusion Estimates for Routine Releases

2.3.5.1 Introduction

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

2.3.5.2 Summary of Application

Turkey Point Units 6 and 7 COL FSAR Section 2.3 incorporates by reference Section 2.3 of the AP1000 DCD.

In addition, in Turkey Point Units 6 and 7 COL FSAR Section 2.3, the applicant provided the following:

AP1000 COL Information Item

- PTN COL 2.3-5

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

In addition, this Turkey Point Units 6 and 7 COL FSAR section addresses Interface Item No. 2.4 related to the limiting meteorological parameters (χ/Q values) for routine releases.

2.3.5.3 Regulatory Basis

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

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

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

- 10 CFR Part 20, Subpart D, with respect to demonstrating compliances with dose limits for individual members of the public.
- 10 CFR 50.34a, "Design Objectives for Equipment to Control Releases of Radioactive Material in Effluents—Nuclear Power Reactors." and Sections II.B.1, 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 area be kept ALARA.
- 10 CFR 100.21(c)(1) with respect to establishing atmospheric dispersion site characteristics such that radiological effluent release limits associated with normal operation can be met for any individual located offsite.

The following RGs are applicable to this section:

- RG 1.23, "Meteorological Monitoring Programs for Nuclear Power Plants," Revision 1
- RG 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," Revision 1
- RG 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors," Revision 1
- RG 1.112, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors," Revision 1

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

- A detailed description of the atmospheric dispersion and deposition models used by the applicant to calculate annual average concentrations in air and amount of material deposited as a result of routine releases or radioactive materials to the atmosphere.
- A discussion of atmospheric diffusion parameters, such as vertical plume spread (σ_z) as a function of distance, topography, and atmospheric conditions.
- Meteorological data summaries (onsite and regional) used as input to the dispersion and deposition models.
- Points of routine release of radioactive material to the atmosphere, including the characteristics (e.g., location, release mode) of each release point.
- The specific location of potential receptors of interest (e.g., nearest vegetable garden, nearest resident, nearest milk animal, and nearest meat cow in each 22½ degree direction sector within a 5-mi (8 km) radius of the site).

- The χ/Q and D/Q values to be used for assessment of the consequences of routine airborne radiological releases as described in Section C.I.2.3.5.2 of RG 1.206: (1) maximum annual average χ/Q values and D/Q values at or beyond the site boundary and at specified locations of potential receptors of interest utilizing appropriate meteorological data for each routine venting location, and (2) estimates of annual average χ/Q values and D/Q values for 16 radial sectors to a distance of 50 mi (80 km) from the plant using appropriate meteorological data.

2.3.5.4 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.3.5 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the long-term diffusion estimates. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

The staff reviewed the information contained in the Turkey Point Units 6 and 7 COL FSAR:

AP1000 COL Information Item

- PTN COL 2.3-5

The staff reviewed PTN COL 2.3-5 related to the long-term diffusion estimates included in Turkey Point Units 6 and 7 COL FSAR Section 2.3.5. The specific text of this COL information item in Section 2.3.6.4 of the AP1000 DCD states:

> Combined License applicants referencing the AP1000 certified design will address long-term diffusion estimates and χ/Q values specified in subsection 2.3.5. The Combined License applicant should consider topographical characteristics in the vicinity of the site for restrictions of horizontal and/or vertical plume spread, channeling or other changes in airflow trajectories, and other unusual conditions affecting atmospheric transport and diffusion between the source and receptors. No further action is required for sites within the bounds of the site parameter for atmospheric dispersion.
>
> With regard to environmental assessment, the COL applicant will also provide estimates of annual average χ/Q values for 16 radial sectors to a distance of 50 mi from the plant.

Evaluation of the information provided in PTN COL 2.3-5 related to the long-term diffusion estimates at the Turkey Point Units 6 and 7 site is discussed below.

2.3.5.4.1 Atmospheric Dispersion Model

The applicant used the NRC-sponsored computer code XOQDOQ (described in NUREG/CR-2919, "XOQDOQ Computer Program for the Meteorological Evaluation of Routine Releases at Nuclear Power Stations") to estimate χ/Q and D/Q values resulting from routine

releases. The XOQDOQ model implements the constant mean wind direction methodology outlined in RG 1.111, Revision 1.

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

2.3.5.4.2 Release Characteristics and Receptors

The applicant modeled one ground-level release point, assuming a minimum building cross-sectional area of 2,636 m^2 and a building height of 69.7 m, which is smaller than the height of the entire containment building at 71.4 m. This difference of height is acceptable to the staff because the applicant's use of a smaller building height directly leads to assuming a smaller building cross-section. This is a conservative assumption because a smaller building cross-section will lead to less air turbulence and higher χ/Q values.

The applicant assumed a ground-level release to model routine releases. A ground-level release is a conservative assumption at a relatively flat terrain site such as the Turkey Point Units 6 and 7 site, resulting in higher χ/Q and D/Q values when compared to a mixed-mode (e.g., part-time ground, part-time elevated) release or a 100-percent elevated release, as discussed in RG 1.111, Revision 1. A ground-level release assumption is therefore acceptable to the staff.

The distances to the receptors of interest (i.e., residence, meat animal, vegetable garden, school) were presented in Turkey Point Units 6 and 7 COL FSAR Section 2.3.5.2. Directional sectors without a receptor within 5 mi were not modeled. The applicant calculated the distances to each of the receptors from a location defined as the mid-point of the two proposed units. As depicted in Turkey Point Units 6 and 7 COL FSAR Figure 2.1-201, the Turkey Point Units 6 and 7 EAB does not extend beyond the Turkey Point plant boundary, except for in the SSE and SE sectors. However, the staff believed that because these sectors are located over Biscayne Bay they are not expected to have any long duration population near the boundary. These assumptions are acceptable to the staff.

2.3.5.4.3 Meteorological Data Input

The meteorological input to XOQDOQ used by the applicant consisted of a JFD of wind speed, wind direction, and atmospheric stability based on hourly onsite data from three 1-year periods including 2002, 2005, and 2006. The wind data were obtained from the 10-m level of the onsite meteorological tower, and the stability data were derived from the vertical temperature difference (delta-temperature) measurements taken between the 60-m and 10-m levels on the onsite meteorological tower.

As discussed in SER Section 2.3.3, the staff considers the 2002, 2005, and 2006 onsite meteorological database suitable for input to the XOQDOQ model.

2.3.5.4.4 Diffusion Parameters

The applicant chose to implement the diffusion parameter assumptions outlined in RG 1.111, Revision 1, as a function of atmospheric stability for the XOQDOQ model runs. The staff evaluated the applicability of the XOQDOQ diffusion parameters and concluded that no unique topographic features preclude the use of the XOQDOQ model for the Turkey Point site. Therefore, the staff finds that the applicant's use of diffusion parameter assumptions, as outlined in RG 1.111, Revision 1 was acceptable.

The applicant stated that in order to account for possible land-water recirculation effects due to the close proximity of Biscayne Bay, default correction factors were implemented in the XOQDOQ model. The staff agrees that these correction factors were necessary for the location of the plant and has implemented them for the independent confirmatory analysis.

2.3.5.4.5 Resulting Relative Concentration and Relative Deposition Factors

Turkey Point Units 6 and 7 COL FSAR Table 2.3.5-207 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. Turkey Point Units 6 and 7 COL FSAR Tables 2.3.5-203 through 2.3.5-206 also describe the applicant's long-term atmospheric dispersion and deposition estimates for 16 radial sectors from the site boundary to a distance of 50-mi from the proposed facility.

The χ/Q values presented in Turkey Point Units 6 and 7 COL FSAR Tables 2.3.5-203 through 2.3.5-207 reflect several plume radioactive decay and deposition scenarios. Section C.3 of RG 1.111, Revision 1, states that radioactive decay and dry deposition should be considered in radiological impact evaluations of potential annual radiation doses to the public, resulting from routine releases of radioactive materials in gaseous effluents. Section C.3.a of RG 1.111, Revision 1, states that an overall half-life of 2.26 days is acceptable for evaluating the radioactive decay of short-lived noble gases and an overall half-life of 8-days is acceptable for evaluating the radioactive decay for all iodine released to the atmosphere. Definitions for the χ/Q categories are as follows:

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

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

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

Using the information provided by the applicant, including the 10-m level JFDs of wind speed, wind direction, and atmospheric stability presented in Turkey Point Units 6 and 7 COL FSAR Table 2.3.2-205, the staff confirmed the applicant's χ/Q and D/Q values by running the XOQDOQ computer code and obtaining similar results (i.e., values on average within about 6-percent). In light of the foregoing, the staff accepts the long-term χ/Q and D/Q values presented by the applicant.

COL Information Item 2.3-5 also states that with regard to environmental assessment estimates of annual average χ/Q values for 16 radial sectors to a distance of 50-mi from the plant should be provided. The applicant provided these values in Turkey Point Units 6 and 7 COL FSAR Tables 2.3.5-203 through 2.3.5-206. Using the staff-generated JFDs and the XOQDOQ computer code, these χ/Q values were confirmed by the staff and were found to be adequate and acceptable.

2.3.5.5 Post Combined License Activities

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

2.3.5.6 Conclusion

The staff reviewed the application including PTN COL 2.3-5 and checked the referenced DCD. The staff's review confirmed that the applicant has addressed the relevant information relating to long-term diffusion estimates, and no outstanding information related to this section remains to be addressed in the Turkey Point Units 6 and 7 COL FSAR. The results of the staff's technical evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

COL Information Item 2.3-5 states that a COL applicant shall address the site-specific diffusion estimates and χ/Q values as specified in AP1000 DCD Section 2.3.5. Based on the meteorological data provided by the applicant and an atmospheric dispersion model that is appropriate for the characteristics of the site and release points, the staff concludes that representative atmospheric dispersion and deposition factors have been calculated for 16 radial sectors from the site boundary to a distance of 50 mi (80 km) as well as for specific locations of potential receptors of interest. The characterization of atmospheric dispersion and deposition conditions are acceptable to meet the criteria described in RG 1.111, Revision 1, and are appropriate for the evaluation to demonstrate compliance with the numerical guides for doses in Subpart D of 10 CFR Part 20 and Appendix I to 10 CFR Part 50. The staff finds that the applicant has provided sufficient information to adequately address COL Information Item 2.3-5.

2.4 Hydrologic Engineering

To ensure that a nuclear power plant or plants can be designed, constructed, and safely operated on an applicant's proposed site and in accordance with the NRC regulations, the staff evaluates the hydrologic characteristics of the proposed site. These site characteristics describe the potential for flooding due to precipitation, riverine processes (runoff, dam breach discharge, channel blockage or diversion), coastal effects (storm surges and tsunamis), and combined events (e.g., from coincident wind waves). In addition, the staff reviewed the maximum elevation of surface water during floods and combined events, associated static and dynamic characteristics, minimum water-surface elevation during low-water events, maximum elevation of groundwater, and the characteristic ability of the site to attenuate a postulated accidental release of radiological material into surface water and groundwater. The surface water hydrologic site characteristics determine the design-basis flood for the proposed Turkey Point Units 6 and 7 site, and provide the basis for determining whether flood protection will be required. The groundwater hydrologic site characteristics determine the design-basis groundwater loadings and provide the basis for radiological dose analysis for a potential

receptor from the postulated accidental release of radioactive liquid effluents in surface and ground waters.

The staff has prepared SER Sections 2.4.1 through 2.4.14 in accordance with the review procedures described in NUREG-0800, using information presented in Section 2.4, "Hydrologic Engineering," of the Turkey Point Units 6 and 7 Final Safety Analysis Report (FSAR), responses to the staff RAIs, and generally available reference materials (e.g., as cited in applicable sections of NUREG-0800).

2.4.1 Hydrologic Description

2.4.1.1 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.4.1, "Hydrologic Description," describes the site and all safety-related elevations, structures, and systems from the standpoint of hydrologic considerations and provides a topographic map showing any proposed changes to natural drainage features.

This SER section provides hydrologic description of the of the following specific review areas: (1) the interface of the plant with the hydrosphere including descriptions of site location, major hydrological features in the site vicinity, characteristics related to surface water and groundwater, and the proposed water supply to the plant, (2) hydrological causal mechanisms that may require special plant design bases or operating limitations with regard to floods and water-supply requirements, (3) current and likely future surface-water and groundwater uses by the plant and water users in the vicinity of the site that may affect the safety of the plant, (4) available spatial and temporal data relevant for the site review, (5) alternate conceptual models of the hydrology of the site that reasonably bound hydrological conditions at the site, (6) potential effects of seismic and non-seismic data on the postulated design bases and how they relate to the hydrology in the vicinity of the site and the site region, and (7) any additional information requirements prescribed within the "Contents of Application" sections of the applicable Subparts of 10 CFR Part 52. These areas are reviewed in Sections 2.4.2 through 2.4.13.

2.4.1.2 Summary of Application

Turkey Point Units 6 and 7 COL FSAR Section 2.4.1 describes the site and elevations for safety related structures, systems and components from the standpoint of hydrologic considerations and provides a topographic map showing any proposed changes to natural drainage features. The applicant addressed these issues as follows:

AP1000 COL Information Item

- PTN COL 2.4-1 Hydrological Description

The applicant has referenced the AP1000 DCD in its application to comply with the requirements of Appendix D to 10 CFR Part 52. DCD Section 2.4.1.1 requires that COL applicants describe major hydrologic features on or in the vicinity of the site. It also requires the COL applicants to provide a specific description of the site, including critical elevations of the nuclear island and safety-related facilities.

2.4.1.3 Regulatory Basis

The relevant requirements of the NRC regulations for the site and all safety-related elevations, structures, and systems from the standpoint of hydrologic considerations, and the associated acceptance criteria are described in Section 2.4.1 of NUREG–0800.

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

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

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

The related acceptance criteria are as follows:

- Regulatory Guide 1.29, “Seismic Design Classification,” as it relates to those SSCs intended to protect against the effects of flooding’;

- Regulatory Guide 1.59, “Design Basis Floods for Nuclear Power Plants,” as supplemented by best current practices; and

- RG 1.102, “Flood Protection for Nuclear Power Plants,” as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

2.4.1.4 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.1 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic. The staff’s review confirmed that the information in the application and incorporated by reference addresses the required information relating to major hydrological features and descriptions of the site and safety-related elevations, structures, exterior accesses, equipment, and systems. The results of the staff’s evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

The staff reviewed the following information in the Turkey Point Units 6 and 7 COL FSAR:

AP1000 COL Information Items

- PTN COL 2.4-1

The staff reviewed PTN COL 2.4-1 related to the description of major hydrologic features included in Turkey Point Units 6 and 7 COL FSAR Section 2.4.1. The COL Information Item in Section 2.4.1.1 of the AP1000 DCD states:

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

Evaluation of the information provided in PTN COL 2.4-1 related to the description of major hydrologic features at the Turkey Point Units 6 and 7 site is discussed below.

2.4.1.4.1 Site and Facilities

This section describes the location of the proposed site and the major facilities of the proposed plant as relevant to hydrologic considerations.

<u>Information Submitted by Applicant</u>

The applicant stated that the Florida Power and Light Company (FPL) is proposing to build two new AP1000 reactors, designated Turkey Point Units 6 and 7, within its existing Turkey Point plant property boundaries, approximately 25 mi south of Miami, FL, in unincorporated southeast Miami-Dade County, FL. According to the applicant, the Turkey Point plant property consists of approximately 11,000 acres (45 square km) and is east of Florida City and the City of Homestead, bordered by Biscayne Bay to the east. The Turkey Point plant property includes five operating electric generating units: two gas/oil-fired steam electric generating units (Units 1 and 2), one natural gas combined cycle plant (Unit 5), and two nuclear powered steam electric generating units (Units 3 and 4). The site for Units 6 and 7 is immediately south of Units 3 and 4 on a tract of approximately 218 acres (0.9 square km). Most Units 6 and 7 plant features are located on an area bounded on all four sides by a network of industrial wastewater facility/cooling canals that serve as part of the closed-loop cooling water supply for Units 1 through 4 and receive blowdown discharged from Unit 5.

The plant area for the Turkey Point Units 6 and 7 site would be raised above surrounding grade to grade elevations varying from 19 ft (5.8 m) to 25.5 ft (7.8 mi) in North American Vertical Datum of 1988 (NAVD 88) with safety-related facilities at an elevation of 26 ft (7.9 m) NAVD 88. The area would be surrounded by a retaining wall structure with the top of wall elevation varying from 20 ft (6 m) to 21.5 ft (6.6 m) NAVD 88.

The NAVD 88 is the plant reference elevation datum for Turkey Point Units 6 and 7. The applicant notes that some reference documents and data sources for the area provide elevations referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29). In the site area, the applicant has determined that NGVD 29 is 1.6 ft (0.5 m) below NAVD 88, meaning that elevations referenced to NGVD 29 are decreased by 1.6 ft (0.5 m) to convert them to the NAVD 88 datum.

The FPL proposes to use the Westinghouse AP1000 certified plant design for Turkey Point Units 6 and 7. The design plant grade for all safety-related facilities is at El. 26.0 ft (7.9 m) NAVD 88, which is equivalent to the design plant grade elevation of 100 ft (30 m) in the DCD reference datum. The safety-related structures for the AP1000 design include the containment/shield building and the auxiliary building. Finished grade elevations at the plant area are shown in Figure 2.4.1-1. Before construction, the area where the plant is located was

occupied by sparsely vegetated, low-lying mudflats and was isolated by the surrounding cooling canals. The preconstruction elevations ranged from approximately El. -2.4 ft (-0.7 m) to 0.8 ft (0.2 m) NAVD 88.

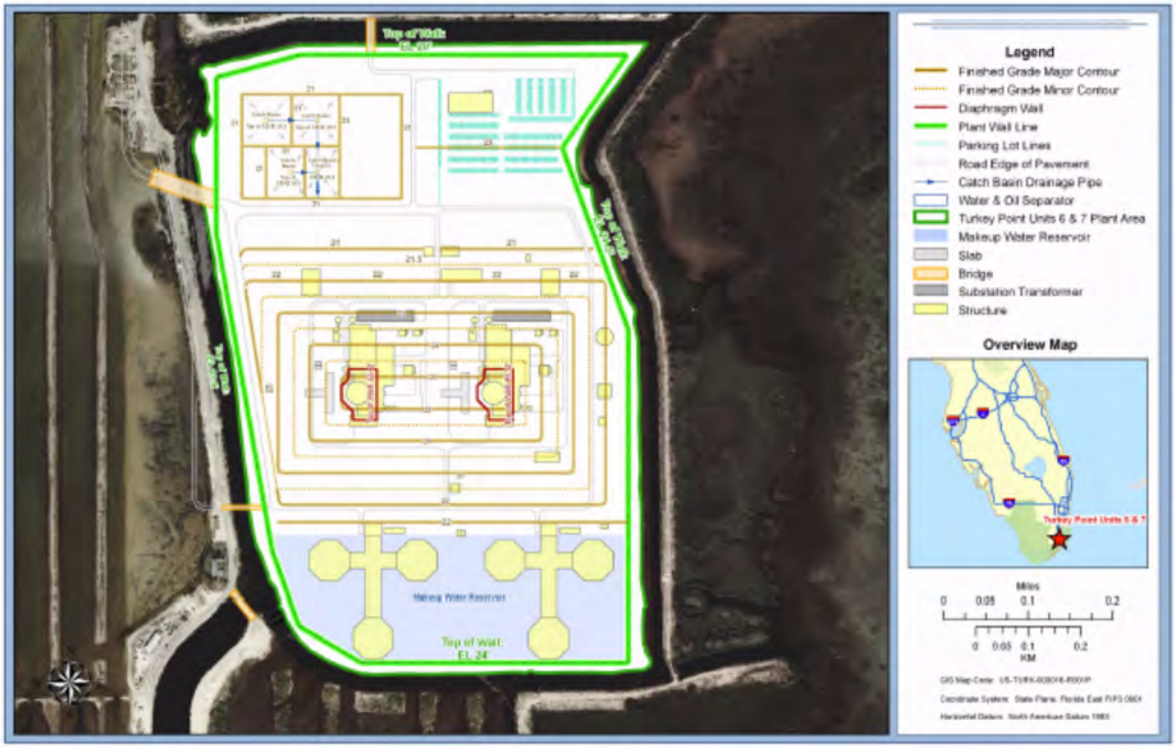


Figure 2.4.12.4.1-1 Turkey Point Units 6 and 7 power block layout and grading plan. (Source: COL FSAR Figure 2.4.2-202)

As described by the applicant, the AP1000 reactor design employs a safety-related passive containment cooling system that serves as the ultimate heat sink for design-basis accident events. This system does not require offsite water sources to perform its safety functions. Turkey Point Units 6 and 7 would use mechanical draft cooling towers for non-safety related circulating water system and service water system cooling, with makeup water from two independent water sources, each capable of supplying all of the makeup water demand for the circulating water system. The two independent sources of makeup water for the plant's non-safety related circulating water system are reclaimed water and saltwater. The reclaimed water would be supplied from Miami-Dade Water and Sewer Department wastewater treatment facilities via a pipeline system to the FPL reclaimed water treatment facility. Treated reclaimed water would be stored in a concrete makeup water reservoir to be located in the cooling tower area south of the power block (Figure 2.4.1-1). The top of the makeup reservoir wall is at El. 24.0 ft NAVD 88. The saltwater would be supplied to the cooling tower basins from radial collector wells; it would be used to supplement reclaimed water as needed to meet the makeup water demand. The applicant stated that the maximum makeup water requirement for the two units when the circulating water system is operating with reclaimed water is approximately 38,400 gallons per minute. When the circulating water system is operating with saltwater the applicant stated that the maximum makeup water requirement for the two units is approximately 86,400 gallons per minute. According to the applicant, the circulating water system is capable of operating on any combination of the two types of makeup water.

The applicant stated that none of the surrounding surface water bodies would be used as a water supply source, waste effluent discharge point, or heat sink for Turkey Point Units 6 and 7. Cooling tower blowdown and other plant wastewater streams are collected in a common collection sump for injection into a deep injection well.

In accordance with the requirements in Appendix A to 10 CFR Part 52, the applicant compared Turkey Point Units 6 and 7 hydrologic site characteristics with the respective envelopes of the AP1000 standard plant site design parameters specified in Section 2.4 of the reference AP1000 DCD.

Staff's Technical Evaluation

The staff conducted a hydrology site audit March 22–24, 2010. The site audit included visits to the site of Units 6 and 7 and to the Turkey Point cooling canals. The staff also observed Biscayne Bay and the general topographic and hydrologic setting of the area.

The staff compared the information presented by the applicant in Turkey Point Units 6 and 7 COL FSAR Section 2.4.1 with publicly available maps and data regarding the Turkey Point Units 6 and 7 site and its surrounding region. The staff finds the applicant's information on the site and facilities to be consistent with other sources and sufficient for the staff's review.

2.4.1.4.2 Hydrosphere

Information Submitted by Applicant

The Turkey Point Units 6 and 7 site is adjacent to the western edge of Biscayne Bay and is surrounded by the low-lying areas in the Everglades drainage basin. There are no major rivers, lakes, or dams located nearby, but the applicant stated that a network of drainage canals provides freshwater supply to the Everglades and controlled drainage from southeast Florida to Biscayne Bay. The site's hydrology is primarily controlled by Biscayne Bay.

Biscayne Bay

As described by the applicant, Biscayne Bay is a shallow coastal lagoon underlain by limestone, approximately 38 mi (61 km) long and 11.2 mi (18 km) wide, with an area of approximately 428 square mi (1,109 squire mi). According to the applicant, the Turkey Point Units 6 and 7 site is adjacent to a portion of Biscayne Bay known as South Bay or Lower Biscayne Bay. South Bay is bounded on the east and separated from the Atlantic Ocean by islands, including Elliott Key, which formed in the Pleistocene as coral reefs and are considered a part of the Florida Keys, making up the northern extent of the Florida reef tract (Swarzenski et al., 2004; Klein, 1970). As described by the applicant, Biscayne Bay is connected to the Atlantic Ocean by a wide and shallow opening of coral shoal near the middle of the bay that is known as the Safety Valve, and by several channels and cuts.

There is little sediment inflow to the bay from rivers and canals. Part of Biscayne Bay near the plant property is within the designated boundaries of Biscayne National Park, which contains a narrow fringe of mangrove forest along the mainland. Similar mangrove zones are present on islands of the Florida Keys including Elliott Key east of the Turkey Point site (U.S. National Park Service 2011—Reference 216—http://www.nps.gov/bisc/naturescience/keys.htm).

The applicant referenced Caccia and Boyer (2005) as reporting that Biscayne Bay has an average depth of approximately 6 ft (1.8 m) and a maximum depth of approximately 13 ft (4 m). According to the applicant, the volume at mean low water is approximately 1.5 x 10^{10} cubic ft (344,000 ac ft). NOAA maintains tidal stations in Biscayne Bay and surrounding areas (2008b). The applicant identified the following stations as currently operating and having more than 10 years of record: Virginia Key, FL (NOAA station 8723214; approximately 25 mi (40 km) north-northwest of Units 6 and 7); Vaca Key, FL (8723970; approximately 70 mi (113 km) southwest); and Key West, FL (8724580; approximately 110 mi (177 km) southwest). The applicant found that other stations have only short periods of tidal data or are no longer active. The locations of the tidal stations are shown on Figure 2.4.1-2. The mean low water datum at NOAA Virginia Key, FL, station is located at -1.9 ft (-0.6 m) NAVD 88 (NOAA, 2008a).

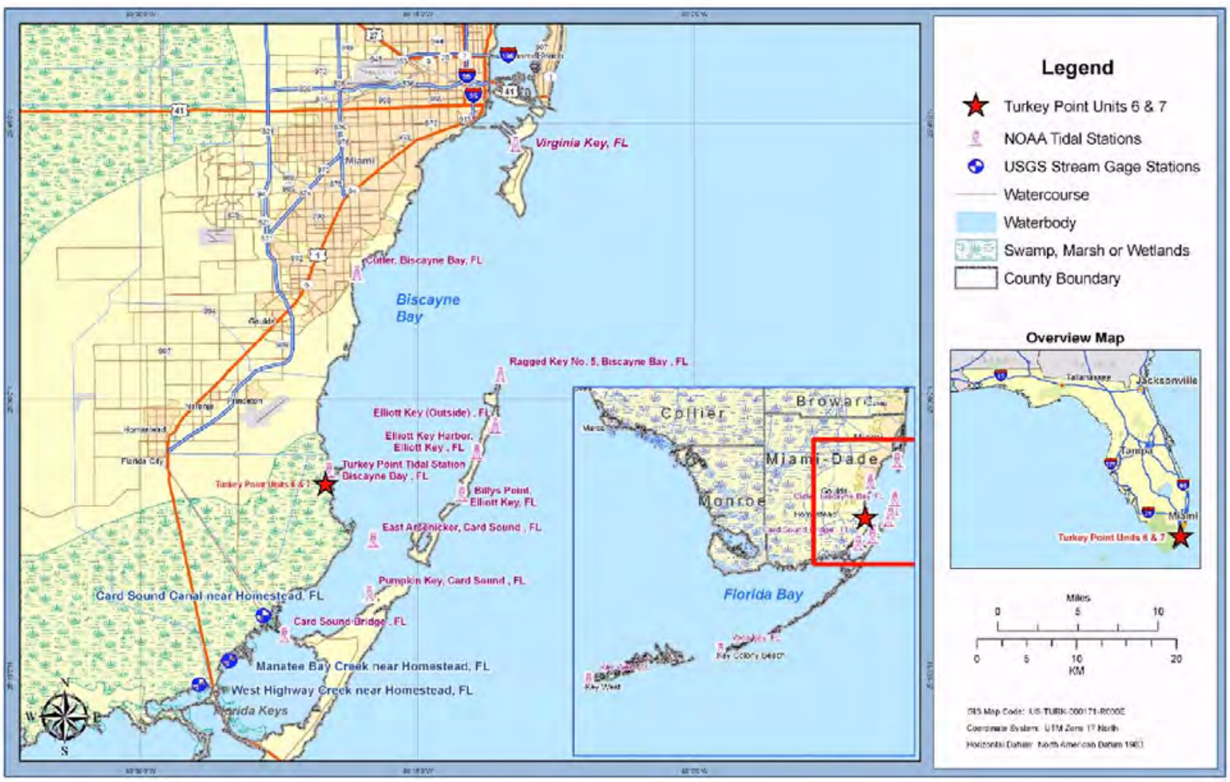


Figure -2.4.1-2 NOAA Tidal Stations and USGS Stream Gauges in the vicinity of Biscayne Bay (source: Turkey Point Units 6 and 7 COL FSAR Figure 2.4.1-212)

According to the applicant, the great diurnal tidal range, defined as the difference between the mean higher high and mean lower low tide levels, in Biscayne Bay is higher near the northern entrance of the bay. At Cutler station in Biscayne Bay, the great diurnal range is 2.13 ft (0.6 m); near the Turkey Point Units 6 and 7 site, the range is 1.78 ft (0.5 m); and at the Card Sound Bridge station to the south, the range is reduced to 0.63 ft (0.19 m).

The applicant stated that the principal circulation forces in Biscayne Bay are tidal, although winds that persist for longer than a complete tidal cycle (12 to 13 hours) cause relatively large water movements. The applicant stated that measurements of tidal flow past discrete points such as Cutter Bank (east of the cooling canals) average approximately 50,000 ac ft (61,674,092 m^3) per day, or a continuous flow of 60,000 ac ft (74,008,910 m^3) per half of a tidal

cycle. The applicant stated that tidal exchange between Biscayne Bay and the ocean is estimated to be less than 10,000 ac ft (12,334,818 m^3) per day.

The Everglades

The Everglades is the largest wetland in the continental United States. It was part of the larger, natural Kissimmee-Okeechobee-Everglades watershed that once extended south from Lake Okeechobee to the southernmost extremity of peninsular Florida. The Everglades were formed on limestone bedrock and have lower elevations than the Flatwoods and Atlantic Coastal Ridge physiographic provinces. The Everglades slope toward the south with an average gradient less than 2 in per mile (3 cm per km). The freshwater flow from Lake Okeechobee and the flat terrain of the basin supported the accumulation of layers of peat and mud that formed the historical Everglades wetlands over an area of approximately 4,500 mi^2 (11,655 km^2) (McPherson and Halley, 1997).

Before the beginning of drainage development in the late 1800s, overflows from Lake Okeechobee moved slowly through the Everglades as sheet flows. These flows provided the freshwater supply that sustained the ecosystem functions within the wetlands, which were dominated by sawgrass and tree islands. From the Everglades, water drained south to the Gulf of Mexico through a series of open-water sloughs.

The applicant stated that the Atlantic Coastal ridge that separates the Everglades from the Atlantic coastline has a maximum elevation of approximately 20 ft (6 m) above MSL (equivalent to NGVD 29), or approximately 18.4 ft (5.6 m) NAVD 88. Historically, nearly all of southeast Florida, except for the Atlantic Coastal ridge, was flooded annually, with the floodwater discharging to Biscayne Bay through the Miami, New, and Hillsborough rivers and other sloughs that formed transverse glades in the Atlantic Coastal ridge.

Beginning in the late 19th century, south Florida underwent substantial anthropogenic alterations that irreversibly changed its hydrology (McPherson and Halley, 1997). Causes included land reclamation for agriculture, construction of flood control levees and drainage canals, and urbanization. In the late 19th and early 20th centuries, canals were dug through the Everglades to drain water from the area south of Lake Okeechobee to enable agricultural development (McPherson and Halley, 1997). By the late 1920s, major canals were constructed and rivers in the transverse glades were modified to connect Lake Okeechobee with the Gulf of Mexico and Atlantic Ocean. In southeastern Florida, the West Palm Beach, Hillsborough, North New River, South New River, and Miami (River) Canals connected Lake Okeechobee with Biscayne Bay and the Atlantic Ocean (McPherson and Halley, 1997).

The Central and Southern Florida Flood Control Project (C&SF project) was authorized in 1948 with a mandate to provide flood protection, water supply, prevention of saltwater intrusion, and protection of fish and wildlife resources (McPherson and Halley, 1997). The State of Florida formed the Central and Southern Florida Flood Control District, which later became the South Florida Water Management District (SFWMD), to work with the C&SF project. The C&SF project adopted a water management plan for Lake Okeechobee and three water conservation areas (WCAs) to provide flood protection and water supply. As part of the water management plan, the Everglades Agricultural Area (EAA) was drained for agricultural development.

The construction of these flood control canals, levees, and structures by the C&SF project caused much of the runoff that once flowed to the Everglades from the Kissimmee River and Lake Okeechobee to be diverted directly to the Gulf of Mexico (via the Caloosahatchee Canal)

and the Atlantic Ocean (via the St. Lucie Canal). Under natural conditions, Lake Okeechobee overflowed its southern bank at El. 20 ft (6.1 m) to 21 ft (6.4 m)NGVD 29 (18.4 ft (5.6 m) to 19.4 ft (5.9 m) NAVD 88), but now the lake water level is maintained at approximately 13 ft (4 m) to 16 ft (4.9 m) NGVD 29 (11.4 ft (4.3 m) to 14.4 ft (4.4 m) NAVD 88) (U.S. Army Corps of Engineers 2007 page A-10). Surface water flows from the EAA into the WCAs are maintained by pumping. Water levels in the Everglades generally are shallower and have shorter hydroperiods than they had before development (McPherson and Halley, 1997).

Most of the undeveloped portions of the Everglades (about 50 percent of the original area) are now protected in public parks and other State lands (McPherson and Halley, 1997). The Everglades National Park, established in 1947, includes approximately 1.4 million acres (5666 km^2) (McPherson and Halley, 1997). The park is approximately 15 mi (24 km) west of the plant property and is adjacent to the southeast Florida drainage canal system.

The applicant described the Comprehensive Everglades Restoration Plan (CERP), which was authorized by Congress in 2000 to provide a framework and guide the restoration, protection, and preservation of the water resources of central and southern Florida, including the Everglades. CERP projects aim to capture some water that currently flows to the Atlantic Ocean and Gulf of Mexico, hold it in surface and subsurface reservoirs, and redirect it to the wetlands, lakes, rivers, and estuaries of southern Florida. The surface and subsurface reservoirs would mainly be located within the low-lying areas of the EAA and WCAs, whereas the proposed plant facilities will be located at an elevation of 26 ft (7.9 m) NAVD 88. The applicant stated that, due to elevation differences, failure of these reservoirs would not adversely affect the functioning of the Turkey Point Units 6 and 7 safety-related structures.

Everglades National Park-South Dade Conveyance System

The applicant described the systems of canals in the site area. According to the applicant, systematic construction of drainage canals in southern Miami-Dade County was initiated in the 1960s. The Federal Flood Control Act of 1962 authorized the C&SF project for southern Miami-Dade County. The C&SF project implemented a system of canals and structures to provide drainage for urban development, prevent over-drainage of agricultural lands, and prevent contamination of groundwater by saltwater intrusion. The conveyance system relies on gravity drainage through a primary network of 12 canals with outlets to serve a system of secondary canals.

The canal system was modified in the 1970s to meet the hydrologic needs of the Everglades National Park by implementing the Everglades National Park-South Dade Conveyance System (ENP-SDCS), which interconnected several drainage basins of the C&SF drainage project. Gated control structures were installed at the eastern (coastal) end of the primary canals to release excess storm water runoff to the coastal water bodies during wet seasons and to manage saltwater intrusion during dry seasons. Secondary controls were installed on the inland reaches of the canals to regulate flow eastward, control inland and agricultural flooding, and maintain higher water levels in the surficial aquifer system. The ENP-SDCS surface water canal system was fully developed in the 1980s. The existing north-south, borrow canals L-30 and L-31N/L-31W were enlarged to convey water from the Miami Canal (C-6) to the Everglades. The west-east running canals provide drainage from the southern Dade development corridor to Biscayne Bay by control structures at the mouth of the canals. The L-31 Canal, the western borrow canal of the L-31E Levee, runs parallel to the coastline of Biscayne Bay in southern Miami-Dade County, separating the coastal wetlands along the bay from the mainland. The

L-31E Levee, with a crest elevation of approximately 7 ft (2.1 m) NAVD 88, and L-31 Canal are located immediately west of the Turkey Point cooling canals.

The applicant stated that the United States Army Corps of Engineers (USACE) has delineated water management subbasins in southern Miami-Dade County. There are 17 subbasins that contribute flow to Biscayne Bay and Everglades. Surface water flows between the subbasin areas and from the drainage subbasins to Biscayne Bay or the Everglades are controlled by numerous flow control structures. Detailed flow and water level monitoring and measurements are performed by various agencies, including United States Geological Survey (USGS), SFWMD, and the Everglades National Park, as part of the operation of the structures in the ENP-SDCS. The applicant reports that a search of the SFWMD DBHYDRO database for flow and water level monitoring data returned approximately 700 records.

Units 6 and 7 Plant Area

As described by the applicant, the Turkey Point plant area is bounded by Biscayne Bay to the east, the Florida City Canal to the north, L-31E Canal to the west, and Card Sound Road and Card Sound to the south. Two flow control structures, S-20 and S-20F, control outflow from the canals north and west of Turkey Point Units 6 and 7. The applicant stated that remnants of east-west drainage ditches and shallow north-south “mosquito ditches” constructed in the early 1900s for mosquito control are present in the area. The SFWMD has undertaken the Biscayne Bay Coastal Wetlands Project to restore the Biscayne Bay ecosystem in the areas surrounding the Turkey Point plant property. The applicant stated that FPL maintains a wetland area in the northern area of the Turkey Point plant property and is implementing a wetland mitigation project (the Everglades Mitigation Bank) southwest of Turkey Point Units 6 and 7. According to the applicant, future hydrologic changes in the Biscayne Bay Coastal Wetlands project are not expected to have adverse flooding and water use impact on the safety-related functions of Turkey Point Units 6 and 7.

The Federal Emergency Management Agency (FEMA) flood insurance study for Miami-Dade County indicates that the most severe flooding in the county would result from hurricane storm surges (FEMA, 1994). FEMA estimated surge elevations (still water level) at transect locations along the shoreline of Biscayne Bay for different return periods. Turkey Point Units 6 and 7 lie between Transect 30 in the north to Transect 31 in the south. The maximum still water levels in these transects range from elevation 8.5 ft (2.6 m) NGVD 29 (6.9 ft (2.1 m) NAVD 88) for a 10-year return period to 12.4 ft (3.8 m) NGVD 29 (10.8 ft (3.3 m) NAVD 88) for a 500-year return period (FEMA, 1994).

Dams and Reservoirs

The applicant stated that there are no dams or reservoirs near Units 6 and 7. According to the applicant, the only flow regulation and control near Units 6 and 7 is for the ENP-SDCS, which regulates drainage from the Everglades and saltwater intrusion from Biscayne Bay. The applicant’s assessment of dam failure potential is provided in Turkey Point Units 6 and 7 COL FSAR Subsection 2.4.4.

Surface Water Users

The applicant stated that SFWMD, which administers water use permits for the south Florida region, reports that approximately 90 percent of all consumptive water use in southern Florida comes from groundwater sources, with just 10 percent supplied from surface water sources.

The applicant stated that SFWMD reports that there were 139 water-use permits in use within Miami-Dade County as of October 13, 2008. There are no surface water withdrawals permitted for potable water supply. Approximately 83 percent of the permitted surface water use is for landscape irrigation. The remaining use is for irrigation of golf courses, agriculture, aquaculture, nursery irrigation, industrial uses, and dewatering. The nearest surface water user to Turkey Point Units 6 and 7 is located approximately 6 mi to the west-northwest.

The applicant stated that the major non-consumptive surface water uses near Turkey Point Units 6 and 7 are recreation, fishing, and navigation, with nearly all of this use occurring in Biscayne National Park and Homestead Bayfront Park.

Groundwater

Turkey Point Units 6 and 7 COL FSAR Section 2.4.12 describes local and regional groundwater characteristics, groundwater users, groundwater well locations, and withdrawal rates. These are discussed further in SER Section 2.4.12.

Staff's Technical Evaluation

The staff reviewed the information provided by the applicant in Turkey Point Units 6 and 7 COL FSAR Section 2.4.1. The staff conducted a hydrology site audit on March 22–24, 2010. The site audit included visits to the site of Units 6 and 7 and to the Turkey Point cooling canals. The staff also observed Biscayne Bay and the general topographic and hydrologic setting of the area.

The staff compared the information presented by the applicant in Turkey Point Units 6 and 7 COL FSAR Section 2.4.1 with publicly available maps and data regarding the Turkey Point site and its surrounding region. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to site hydrologic description that the staff needs in order to perform safety assessment of the plant SSC and to consider the effects of any accidental release of radioactive effluent on public health and safety.

2.4.1.5 Post Combined License Activities

There are no post COL activities related to this section.

2.4.1.6 Conclusion

The staff reviewed the application and confirmed that the applicant provided sufficient information on the description of major hydrologic characteristics in the vicinity of the site and site regions as specified in the AP1000 Design Certification. The applicant has presented and substantiated information to establish the site description. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in SER Section 2.4.1, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the site safety. This addresses PTN COL 2.4-1. In conclusion, the applicant has provided sufficient information for the staff to determine whether it has met the applicable requirements of 10 CFR Part 52 and 10 CFR Part 100 pertaining to hydrologic engineering.

2.4.2 Floods

2.4.2.1 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.4.2 discusses historical flooding at the proposed site and in the region of the site. The information summarizes and identifies the individual types of flood-producing phenomena, and combinations of flood-producing phenomena, considered in establishing the flood design bases for safety-related plant features. The discussion also covers the potential effects of local intense precipitation.

Primary emphases of Section 2.4.2 are (1) flood history, (2) flood design considerations, and (3) effects of local intense precipitation.

2.4.2.2 Summary of Application

The staff reviewed Section 2.4.2 of the Turkey Point Units 6 and 7 COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic. The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the site-specific flooding description. The results of the staff's evaluation of the information incorporated by reference in the VCSNS COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the Turkey Point Units 6 and 7 COL FSAR:

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

- PTN COL 2.4-2 Floods

The applicant provided additional information in PTN 2.4-2 to resolve COL Information Item 2.4-1 (COL Action Item 2.4.1-2), which addresses the provision for site-specific information related to historical flooding and the potential for flooding at the plant site, including flood history, flood design considerations, and the effects of local intense precipitation.

The COL Information Item 2.4-2 also requires the COL applicant to provide sufficient information to verify that hydrologic-related events will not affect the safety basis for the AP1000. AP1000 DCD Tier 1 Table 5.0-1 site parameters related to hydrology are:

- maximum flood level less than plant elevation 100 ft, which is equal to the design grade elevation,

- 1 hr 1 mi^2 probable maximum precipitation (PMP) of 20.7 in/hr or less, and

- maximum groundwater level less than plant elevation 98 ft.

For Turkey Point Units 6 and 7, plant elevation 100 ft is equal to 26 ft NAVD 88. This SER section addresses the estimation of the first two hydrologic site parameters, while the SER Section 2.4.12 discusses the issue related to the maximum groundwater level.

2.4.2.3 Regulatory Basis

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

The applicable regulatory requirements for identifying floods are:

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

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

The related acceptance criteria are as follows:

- Regulatory Guide 1.29 as it relates to those SSCs intended to protect against the effects of flooding";

- Regulatory Guide 1.59 as supplemented by best current practices; and,

- RG 1.102 as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

2.4.2.2 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.2 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the site-specific flooding description. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

The staff reviewed the following information in the Turkey Point Units 6 and 7 COL FSAR:

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

- PTN COL 2.4-2

The staff reviewed PTN COL 2.4-2 related to the related to historical flooding and the potential for flooding at the plant site, including flood history, flood design considerations, and the effects

of local intense precipitation included in Turkey Point Units 6 and 7 COL FSAR Section 2.4.2. COL Information Item in Section 2.4.1.2 of the AP1000 DCD states:

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

Evaluation of the information provided in PTN COL 2.4-2 related to historical flooding and the potential for flooding at the Turkey Point Units 6 and 7 site, including flood history, flood design considerations, and the effects of local intense precipitation is discussed below.

2.4.2.4.1 Flood History

This subsection describes the historical floods at and in the vicinity of the proposed site.

Information Submitted by Applicant

Due to its location alongside the Atlantic Ocean, Florida Bay, and Biscayne Bay, the applicant stated that the area surrounding the Turkey Point Units 6 and 7 site is exposed to flooding from tsunami and from storm surge associated with tropical storms and hurricanes. In addition, ponding can occur in the very flat, poorly drained areas and drainage canals that characterize the area (FEMA 1994; Federal Emergency Management Agency, *Flood Insurance Study, Dade County, Florida and Incorporated Areas,* Revised March, 1994). The applicant summarized the most severe flooding events (up to 1992) in Miami-Dade County, as reported by the Federal Emergency Management Agency (FEMA) in the1994 flood insurance study for Miami-Dade County, FL, and incorporated areas (FEMA, 1994). The applicant also provided information on potential for local flooding in streams and canals and for flooding due to dam or levee breaches and, supplemented this information with more recent data as described below.

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.5, the applicant discusses major historical hurricanes near the Turkey Point Units 6 and 7 site. The maximum storm tide level in Biscayne

Bay reported by FEMA (1994) was 11.7 ft (3.6 m) NAVD 88, occurring at Coconut Grove between September 6 and 22, 1926. Hurricane Andrew caused the worst flooding on record for the area near Units 6 and 7. The FEMA flood insurance study (1994) did not report quantitative flood levels from Hurricane Andrew. During Hurricane Andrew, rainfall totals of more than seven in were recorded in southeastern Florida (Lovelace, 1996) and the peak storm surge on the southeast Florida coast occurred near the time of high astronomical tide. The height of the storm tide ranged from 4 to 6 ft (2.1 to 1.8 m) in northern Biscayne Bay and increased to a maximum value of 16.9 ft (5.2 m) NGVD 29 (15.37 ft (4.68 m) NAVD 88) at a location in Biscayne Bay approximately 13 mi north of Turkey Point Units 6 and 7. However, the height of the storm tide was 4 to 5 ft (1.2 to 1.5 m) in southern Biscayne Bay.

The applicant examined three USGS stream gages in the site vicinity for high water levels that occurred in years more recent than the FEMA flood insurance study. These gages are Card Sound Canal (USGS Gage 251816080232200), Manatee Bay Creek (USGS Gage 251549080251200), and West Highway Creek (USGS Gage 251433080265000), all located along the southeastern Florida shoreline south of the Turkey Point Units 6 and 7 site (Figure 2.4.1-2). The maximum gage water levels that the applicant identified in the records are 1.11 ft (0.34 m) NAVD 88 on November 12, 2003, at the Card Sound Canal gage; 2.27 ft (0.69 m) NAVD 88 on September 20, 2005, at the Manatee Bay Creek gage; and 2.59 ft (0.79 m) NAVD 88 on October 24, 2005 (during Hurricane Wilma), at the West Highway Creek gage.

The applicant also examined tide level measurements at two tide gage stations: the Virginia Key tide gage (Station ID: 8723214) 25 mi (40 km) north of the Turkey Point Units 6 and 7 site, and the Vaca Key tide gage (Station ID: 8723970) 70 mi south of Turkey Point Units 6 and 7 (Figure 2.4.1-2). According to the applicant, all peak tide levels at these stations are associated with tropical storm or hurricane events, and the maximum gage heights at both stations occurred on October 24, 2005, during Hurricane Wilma: 2.79 ft (0.85 m) NAVD 88 at the Virginia Key tide gage and 5.43 ft (1.7 m) NAVD 88 at the Vaca Key gage.

The applicant stated that the design grade elevation at 26 ft (8 m) NAVD 88 for all safety-related buildings of Units 6 and 7 is above the maximum recorded storm tide level of 11.7 ft NAVD 88, as reported in the 1994 FEMA flood insurance study for Miami-Dade County, FL.

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

An accurate description of the history of flooding in the site area and adjacent regions is required for the staff to perform its safety assessment. The staff reviewed the site-specific information related to historical flooding and the potential flooding at the plant site provided by the applicant, as well as references cited.

Based on the review of the information provided or cited by the applicant, the staff concludes that the applicant has provided a sufficient history of flooding in the site area, and that the historical flood levels, including the level cited in the applicant's comparison (11.7 ft (3.6 m) NAVD 88) and the highest storm tide level in Biscayne Bay (15.37 ft (4.7 m) NAVD 88), are well below the proposed plant grade (26.0 ft (7.9 m) NAVD 88) for safety-related facilities.

2.4.2.4.2 Flood Design Considerations

This section describes the scenarios used to determine the design basis flood at the Turkey Point Units 6 and 7 site.

Information Submitted by Applicant

The applicant stated that it considered and investigated the following potential flooding scenarios for Units 6 and 7: probable maximum flood (PMF) on streams and rivers, potential dam failures, probable maximum surge and seiche flooding, probable maximum tsunami, flooding due to ice effects, and potential flooding caused by channel diversions. The applicant stated that these flooding scenarios were investigated in conjunction with other flooding and meteorological events, such as wind generated waves and tidal levels, as recommended in ANSI/ANS-2.8-1992 (ANS, 1992).

The applicant stated that flooding from Biscayne Bay during severe storms, such as the PMP event, would be the most severe and controlling event among all scenarios because Turkey Point Units 6 and 7 are located on the Biscayne Bay shoreline and there are no major streams or rivers nearby. Therefore, the applicant did not perform detailed modeling analysis to determine the flood levels from PMF on streams and rivers.

The applicant stated that the maximum water level in the power block area due to a local PMP storm event is estimated to be at 24.5 ft (7.5 m) NAVD 88, which is lower than the design grade of 26.0 ft (7.9 m) NAVD 88 of the safety-related facilities by 1.5 ft (0.5 m). Thus, the applicant concludes that no safety-related facilities are affected due to flooding as a result of the local PMP.

The applicant estimated that the maximum flood water surface elevation at the Turkey Point Units 6 and 7 site would result from storm surge and wave run-up associated with a probable maximum hurricane storm. The applicant estimates this elevation to be 24.8 ft (7.6 m) NAVD 88, which the applicant determined to be the design basis flood elevation at the site. The applicant notes that the design basis flood elevation of 24.8 ft (7.6 m) NAVD 88 is lower by 1.2 ft (0.4 m) than the design grade of 26.0 ft (7.9 m) NAVD 88 of the safety-related facilities, including the elevation of floor entrances and openings of all safety-related facilities. Thus, the applicant concludes that no safety-related facilities are affected due to flooding as a result of the design basis flood.

Staff's Technical Evaluation

The staff reviewed the description of flooding mechanisms provided by the applicant in Turkey Point Units 6 and 7 COL FSAR Section 2.4.2. The staff determines that the applicant has considered all plausible flooding mechanisms at the Turkey Point 6 and 7 site. The staff's technical review of these individual flooding mechanisms and their flooding potential is described in appropriate sections of the SER.

2.4.2.4.3 Effects of Local Intense Precipitation

This section describes the estimation of local intense precipitation and its effects on the safety-related SSCs of Turkey Point Units 6 and 7.

Information Submitted by Applicant

Probable Maximum Precipitation Depths

The design basis for local intense precipitation is the all-season, 1 mi^2 (2.6 km^2) PMP, which the applicant obtained from NWS Hydrometeorological Reports (HMR) No. 51 and 52 (Schreiner et

al., 1982). The values of the PMP depths obtained by the applicant are reproduced in Table 2.4.2-1.

The applicant noted that the 1-hour local PMP depth of 19.4 in (49.3 cm) is 1.3 in (3.3 cm) less than the corresponding AP1000 DCD value of 20.7 in (52.6 cm).

Table 2.4.2-1. Local Intense Precipitation at the Turkey Point Site (Adapted from FSAR Table 2.4S.2-207).

PMP DURATION AND AREA	1-HR, POINT RATIO	SOURCE	PMP DEPTH (IN)
6 hr, 10 mi^2	–	HMR 51 - Fig. 18	32.0
1 hr, point	–	HMR 52 - Fig. 24	19.4
30 min, point	0.73	HMR 52 - Fig. 38	14.2
15 min, point	0.50	HMR 52 - Fig. 37	9.7
5 min, point	0.32	HMR 52 - Fig. 36	6.2

Local Drainage Components and Subbasins

As addressed in Turkey Point Units 6 and 7 COL FSAR Section 2.4.1, the plant area for Units 6 and 7 will be built up from the existing ground with backfill and surrounded by a retaining wall structure. The design grade for all safety-related facilities, which consist of the containment/ shields building and auxiliary building, is at 26 ft (7.9 m) NAVD 88. The grade elevation adjacent to the retaining wall is 19 ft (5.8 m) NAVD 88. The top of the retaining wall is at 21.5 ft (6.6 m) NAVD 88 along the eastern perimeter and the western perimeter and 20 ft (6.1 m) NAVD 88 along the northern perimeter. The southern portion of the plant area is occupied by the makeup water reservoir with the top of the reservoir wall at 24 ft (7.3 m) NAVD 88. The safety-related facilities are located in the center portion of the power block and the finish grade slopes away from the safety-related facilities at a minimum slope of 0.5 percent toward the retaining wall in the east and west and to the swales to the north and south of the power block.

The swales south of the power block collect overflow from the makeup water reservoir during extreme rainfall events, and the swales to the north of the power block collect storm water runoff from the switchyard (Clear Sky substation) and parking lot areas. The applicant determined water levels in the swales during the local PMP along their flow paths using the step-backwater methodology in the computer program HEC-RAS (USACE, 2009). For typical design storm events, runoff from the power block area is conveyed via catch basins and storm drains to a system of piping and swales that release to the industrial wastewater facility/cooling canal system (cooling canals). For the local PMP flooding analysis, the applicant assumed conservatively all storm drains, culverts, and catch basins are to be clogged and not functioning. All flow during PMP condition is assumed to be either overland or directed through the swales.

In the PMP flood analysis, the swales south of the power block are referred to as flow paths Cooling Tower East (CT-E) and West (CT-W). The swales north of the power block are referred to as flow paths Parking Lot East (PL-E) and Switchyard West (SY-W). The flow path SY-W consists of two parallel swales located in the switchyard and access road area north of the power block. These two parallel swales are modeled as one channel because during a PMP

event, the road is postulated to be overtopped. As shown in Figure 2.4.2-1, the plant area has been delineated into 22 drainage subbasins, with 19 subbasins for the power block area and 3 subbasins for the makeup water reservoir. The overflow from the makeup water reservoir during the PMP contributes to the flood flow discharges along flow paths CT-E and CT-W.

The northern half of the switchyard and the parking lot is graded down from the high-point elevations of 21.0 ft (6.4 m) and 23.0 ft (7 m) NAVD 88, respectively, toward the retaining wall along the northern perimeter of the plant site where grade elevation is at 19.0 ft (5.8 m) NAVD 88. Runoff from these areas would generally behave as sheet flows during the PMP condition. The runoff would flow along and over the swales on the northern perimeters of the plant area into the industrial wastewater facility. Therefore, the runoff from these areas does not contribute flood flow to the major flow paths defined in the PMP analysis.

Peak Discharges

The applicant used the Rational Method to determine PMP peak discharges at the outlet of each of the 22 subbasins. The whole site drainage area was conservatively assumed to be impervious at the start of and during the local PMP event, resulting in increasing the calculated peak discharges. The times of concentration for the subbasins were estimated using the U.S. Natural Resources Conservation Service (NRCS) methods (NRCS, 1986). In order to account for nonlinear effects during extreme floods, the estimated times of concentration were reduced by 25 percent, as recommended by the USACE Engineering Manual EM-1110-2-1417 (USACE, 1994).

The overflow PMP peak discharge on all sides of the makeup water reservoir is also calculated using the Rational Method. It is conservatively assumed that the reservoir, whose top of wall is at 24 ft (7 m) NAVD 88, is full at the beginning of the PMP event. The PMP peak runoff is computed based on the area of the reservoir, a runoff coefficient of 1.0, and the 5-minute PMP intensity of 74.5 in per hour for the 5-minute storm duration. The depth of the contributing overflow discharges from the makeup water reservoir to flow paths CT-E and CT-W is determined using the broad-crested weir equation and the length of reservoir wall.

The applicant calculated PMP peak discharges for all subbasin outlets, including overflow contributions from the makeup water reservoir. The calculated values are presented in Table 2.4.2-2.

Hydraulic Model Setup

The applicant used the USACE HEC-RAS model (USACE, 2005) to estimate the maximum water surface elevation during the local site flooding under a local PMP event. The HEC-RAS model simulated transient, subcritical flow conditions in the site drainage area with a critical flow depth boundary condition for each swale. This downstream boundary condition assumes a free overfall discharge at the downstream wall.

Inflow discharges in the HEC-RAS model were input based on estimates from the Rational Method. Peak discharge for each subbasin was distributed to the corresponding channel reach by drainage area proration.

Road crossings and retaining walls are modeled as inline structures with broad crested weirs with a discharge coefficient of 2.6 (USACE, 2005). Using this fairly low weir coefficient produces higher and, therefore, more conservative water levels over the structures.

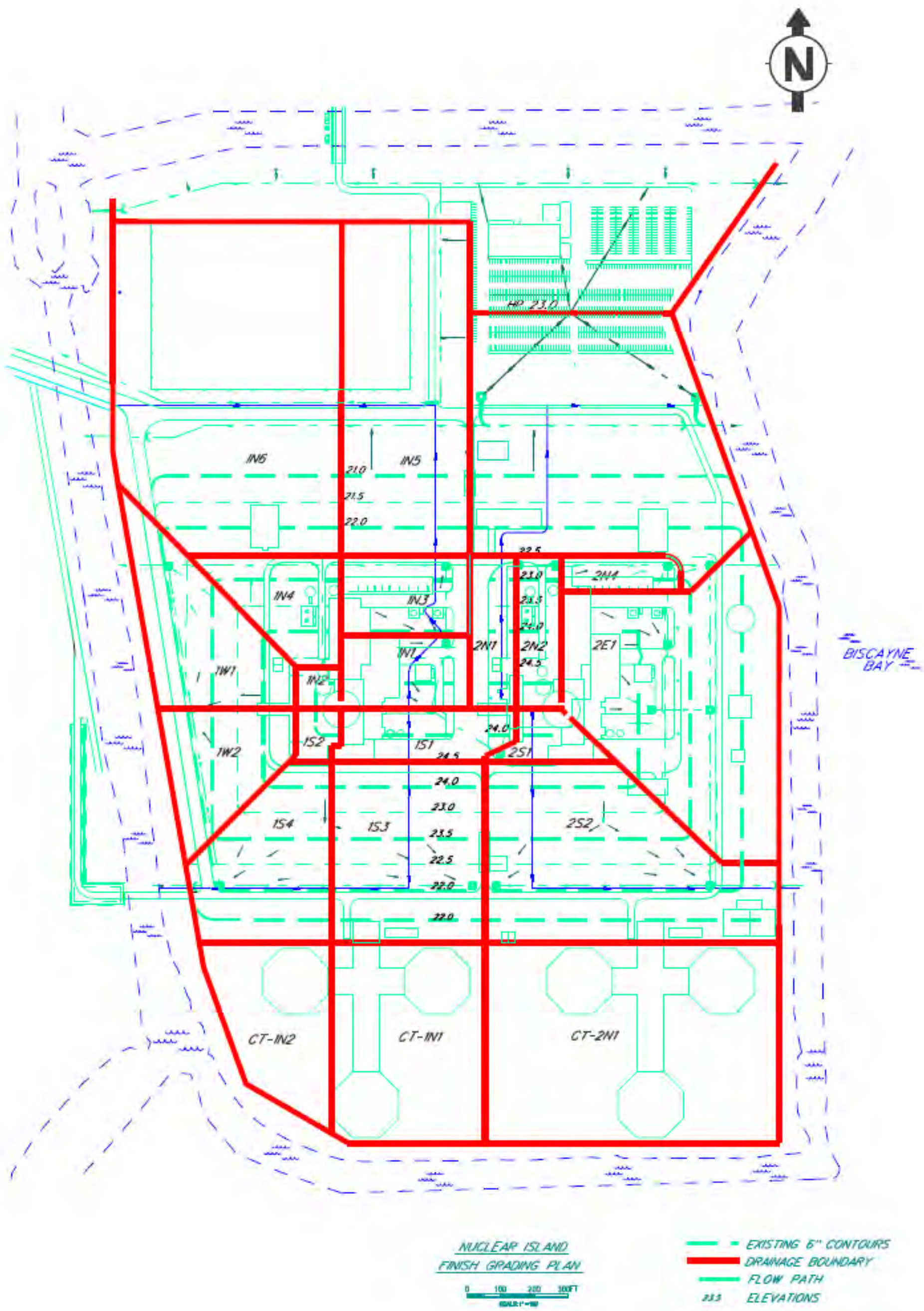


Figure 2.4.2-1. Units 6 and 7 Local PMP Analysis Subbasin Drainage Areas (Adapted from FSAR Figure 2.4.2-203)

Table 2.4.2-2. Units 6 and 7 Subbasin Local PMP Peak Discharges (Adapted from FSAR Table 2.4.2-211).

asin l	Drainage Area (acres)	Composite Runoff Coefficient	Time of Concentration (min)	Rainfall Intensity (in/hr)	without MWR Overflow (cfs)	MW Overfl (cfs
1	2.98	1	5.0	74.5	222.3	—
3	12.83	1	8.1	63.0	808.1	275.
4	20.45	1	10.0	56.0	1145.0	235.
1	1.39	1	5.0	74.5	103.7	—
2	15.40	1	10.3	56.0	862.3	534.
1	3.44	1	5.0	74.5	256.5	—
3	6.89	1	5.5	73.0	502.8	—
5	20.03	1	13.0	47.0	941.5	—
6	48.02	1	19.9	36.0	1728.6	—
1	2.36	1	5.2	74.0	174.7	—
3	26.56	1	13.6	45.0	1195.1	—
'1	6.55	1	5.0	74.5	487.7	—

The Manning's roughness coefficients (*n* values) for the channel and over bank areas are assigned based on guidance provided by Chow (Chow, 1959). A Manning's *n* of 0.033, the maximum value for dredged straight channel with short grass and few weeds, is used for the swales. The power block area is primarily paved with impervious surface. The area between the power block and the makeup water reservoir and the area between the power block and the parking lot/switchyard consist of grassy surfaces. These areas are represented by a Manning's *n* of 0.05, which is the maximum value for over bank areas with high grass.

All storm water inlets were assumed to be completely blocked during the local PMP event.

Flood Elevations

Based on this analysis, the applicant determined the maximum water surface elevation in the power block area to be 24.5 ft (7.5 m) NAVD 88. This elevation is approximately 1.5 ft (0.5 m) below the design grade of 26 ft (8 m) NAVD 88 for safety-related structures.

The applicant used the Rational Method to estimate peak discharges from the roofs of the safety-related structures. The flow depth was estimated using Manning's Equation by postulating that the runoff will flow over the sides of the safety-related buildings and then sheet flow away from the buildings. The applicant used a conservatively high Manning's *n* value of 0.05 to represent a rough surface and to account for an increased roughness influence on shallow flows over the surface. The applicant estimated a sheet flow depth near the safety-related facilities during a PMP to be in the range of 1.4 to 3.8 in (3.6 to 9.7 cm). The

highest finish grade elevation in the power block is at 25.5 ft (7.8 m) NAVD 88, which is 6 in below the design grade of 26 ft (7.9 m) NAVD 88 for safety-related facilities. Therefore the applicant concluded that safety-related facilities are not affected by PMP flooding.

Staff's Technical Evaluation

Probable Maximum Precipitation Depths

The staff reviewed the description of the local PMP analysis performed by the applicant. The staff finds that the applicant had made appropriate use of the guidance in HMR 51 and HMR 52. The staff noted that these reports are based on data collected in the 1970s and earlier, and questioned whether newer data could change conclusions regarding the applicability of these methods. Accordingly, in RAI 4806 Question 02.04.02-1, the staff asked the applicant to document how additional rainfall data compiled at locations throughout Florida in the years since the publication of HMR 51 and HMR 52 influences conclusions about the applicability of these methods. The applicant stated that in response to this RAI dated on September 1, 2010 (ADAMS Accession No. ML102450485), the applicant had examined data from 10 rainfall stations in southern Florida. Based on its review, the applicant reported that the records did not reflect significant rainfall events that would possibly influence the information presented in HMR 51 and HMR 52. The staff accepts this response as reasonable. Additionally, the staff observes that the applicant's PMP point estimates (Table 2.4.2-1) are higher than both the world record precipitation values for the relevant time periods (for example, the one-hour world record is 401 mm or 15.8 in) and the values predicted by analysis of the apparent scaling relationship between peak precipitation records and durations (NWS, 2009; Galmarini et al., 2004); this increases confidence in the conservatism of the estimates.

Local Drainage Components and Subbasins

The staff reviewed the description of site drainage components and subbasins provided by the applicant in Turkey Point Units 6 and 7 COL FSAR Section 2.4.2. The staff determined that this description matches staff's interpretation of the site grading plan depicted in Figure 2.4.2-1. The staff agrees, therefore, with the description of local drainage components and subbasins.

Peak Discharges

The applicant selected the Rational Method to estimate peak discharges in the site drainage area under a local PMP event. The staff determined that the Rational Method is an appropriate model to apply for the determination of peak discharge from local site drainages. The Rational Method is a conservative approach that is likely to overestimate peak discharges. The staff also determined the Rational Method was applied properly with conservative assumptions.

Hydraulic Model Setup

The applicant used USACE HEC-RAS model to estimate flood elevations at the site during the local PMP event. This model is one of the recommended models in the SRP. The staff determined that HEC-RAS is an appropriate model for this purpose.

The staff reviewed the details of the applicant's HEC-RAS analysis and found that the applicant did not demonstrate that its HEC-RAS analysis had bounded the flood elevations during the local PMP event. Accordingly, the staff issued RAI 4806 Question 02.04.02-2, requesting that the applicant explain whether a sensitivity analysis with HEC-RAS would verify the assumption

that additional interpolated cross-sections are not necessary. In particular, the applicant was asked to explain whether there would be any change in water surface elevations after adding interpolated cross-sections, confirm whether adding interpolated sections would establish a grid independent solution, and report on any changes to water surface profiles resulting from interpolated cross-sections. The applicant replied on September 17, 2010 (ADAMS Accession No. ML102640041), reporting that it had conducted a sensitivity analysis of the HEC-RAS model in which additional interpolated cross sections were added in such a way that the spacing between the cross sections was halved (i.e., the grid resolution is refined by a factor of two). The applicant stated that the analysis showed that adding interpolated cross sections did not change the elevation of the maximum water level.

Additionally, the applicant stated that these results were expected because there are no abrupt changes in the channel cross sections in the HEC-RAS model flow paths near the safety-related facilities, and the simulated water surface profile has a mild slope. Therefore, the applicant concluded that the HEC-RAS model used to obtain the maximum water level at the safety-related facilities due to local PMP is grid independent. The staff reviewed the applicant's modeling results and found that some of the added cross-sections resulted in water surface profiles that had elevations 0.1 to 0.3 ft (0.03 to 0.09 m) higher than in the original analysis. The staff interprets this result to mean that the HEC-RAS simulation is grid dependent, so the applicant has not demonstrated that its analysis bounds maximum water elevation from the local PMP. However, because the largest increment found in the sensitivity analysis (0.3 ft (0.09 m)) was well below the 1.5 ft (0.5 m) elevation margin indicated by the applicant's original analysis, the staff concludes that the applicant has satisfactorily demonstrated that flood elevations at the site due to local PMP would remain below the design grade for safety-related facilities.

2.4.2.4.4 Combined Flooding Events

Information Submitted by Applicant

The applicant did not provide an explicit discussion of combined flooding events in the initial version of Turkey Point Units 6 and 7 COL FSAR Section 2.4.2.

Staff's Technical Evaluation

The staff's review resulted in questions about whether combined flooding events related to hurricanes were sufficiently considered. Accordingly, the staff requested in RAI 4806, Question 02.04.02-2 that the applicant describe the reasons for selecting a particular combination of events that does not include a hurricane event. The section "Combined Events Criteria" in SRP Section 2.4.2 states: "The staff reviews the worst flooding at a site that may result from a reasonable combination of individual flooding mechanisms. Some or all of these individual mechanisms could be less severe than their worst-case occurrence but the combination may exceed the most severe flooding effects from the worst-case occurrence of any single mechanism." Consistent with that guidance, in RAI 4806, Question 02.04.02-2 asked the applicant to describe why the combination of events considered represents a conservative assessment that bounds the range of credible combinations of flooding events for Turkey Point Units 6 and 7.

In FPL Letter to NRC L-2010-087 Attachment 10, dated April 30, 2010 (ADAMS Accession No. ML102450485), associated with Hydrology Information Need HA-16, the applicant indicated that its local PMP flood analysis considers a coincident occurrence of a 500-year flood level in

Biscayne Bay. Because the 500-year flood in Biscayne Bay would be the result of a hurricane event, the applicant stated that hurricane events have been considered for combined flooding events. On September 1, 2010 (ADAMS Accession No. ML102450485), the applicant explained that it did not consider probable maximum storm surge (PMSS) flooding coincident with the peak discharge and flood level from the local PMP because it estimates the probability of such a combination to be near zero. The applicant estimated the probability of a PMSS (including 10 percent exceedance high tides) at a particular site to be on the order of 2.4×10^{-12} and estimated the probability of a PMP on a specific watershed to be on the order of 1.0×10^{-5}. Accordingly the applicant estimated the combined probability of a coincident event as 2.4×10^{-17}, which the applicant deems to be "not credible for design purposes." Additionally, the applicant stated that if the calculated PMSS water level of 21.2 ft (6.5 m) NAVD 88 (not including wave run-up) were to occur simultaneously with peak discharges from the local PMP, because the PMSS would not overtop the retaining wall (at elevation 21.5 ft (6.6 m) NAVD 88) on the east and west sides of the plant, it would not affect the discharge of local runoff flows over the wall. Thus, the applicant concluded that this unlikely combination of flooding events would not increase PMP-related flood levels in the power block area. The applicant revised the Turkey Point Units 6 and 7 COL FSAR to include a discussion of combined events. The staff accepts the applicant's reasoning as appropriately addressing the topic of combined flooding events.

The staff reviewed Section 2.4.2 of the Turkey Point Units 6 and 7 COL FSAR. The staff's review confirmed that the information contained in the application and incorporated by reference addresses the relevant information related to individual types of flood-producing phenomena, and combinations of flood-producing phenomena, considered in establishing the flood design bases for safety-related plant features. The information also covered the potential effects of local intense precipitation. The staff's technical review of this application includes an independent review of the applicant's information in the FSAR and in the responses to the RAIs. The staff supplemented this information with other publicly available sources of information.

2.4.2.5 Post Combined License Activities

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

2.4.2.6 Conclusion

The staff reviewed the application and confirmed that the applicant has addressed the information related to individual types of flood-producing phenomena, and combinations of flood-producing phenomena, considered in establishing the flood design bases for safety-related plant features. The information also covered the potential effects of local intense precipitation. The staff also confirmed that there is no outstanding information required to be addressed in the COL FSAR related to this section.

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

2.4.3 Probable Maximum Flood On Streams and Rivers

2.4.3.1 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.4.3 describes the hydrological site characteristics affecting any potential hazard to the plant's safety-related facilities as a result of the effect of the PMF on streams and rivers.

SER Section 2.4.3 provides a review of the following specific areas: (1) regional probable maximum precipitations and their losses, (2) runoff and stream course models, (3) PMF, (4) consideration of other site-related evaluation criteria, and (5) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts of 10 CFR Part 52.

2.4.3.2 Summary of Application

This section of the Turkey Point Units 6 and 7 COL FSAR addresses the information about site-specific PMFs on streams and rivers. In this section, the applicant provides site-specific supplemental information to address the COL specific information identified in DCD Tier 2 Revision 12, Section 2.4.1.2.

AP1000 COL Information Item

- PTN COL 2.4-2 Floods

COL License Information Item 2.4-2 requires COL applicants to provide site-specific information that will be used to determine the design basis flooding at the site. This information will include the PMF on streams and rivers.

2.4.3.3 Regulatory Basis

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

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

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

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

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

The related acceptance criteria are as follows:

- Regulatory Guide 1.29 as it relates to those SSCs intended to protect against the effects of flooding";

- Regulatory Guide 1.59 as supplemented by best current practices; and,

- Regulatory Guide 1.102 as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

2.4.3.4 Technical Evaluation

The staff reviewed Section 2.4.3 of the Turkey Point Units 6 and 7 COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the site-specific PMF on streams and rivers. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the Turkey Point Units 6 and 7 COL FSAR:

AP1000 COL Information Item

- PTN COL 2.4-2 Floods

The staff reviewed PTN COL 2.4-2 related to the site-specific information on PMF on streams and rivers included in Turkey Point Units 6 and 7 COL FSAR Section 2.4.3.

Evaluation of the information provided in PTN COL 2.4-2 related to PMF on streams and rivers is discussed below.

Information Submitted by the Applicant

The applicant notes that the site for Turkey Point Units 6 and 7 is adjacent to the Biscayne Bay shoreline, and there are no major natural streams or rivers nearby. There are several man-made canals located west of Units 6 and 7 extending from Florida City and Homestead to Biscayne Bay, as described in Subsection 2.4.1. The applicant notes that the topography of the area is extremely flat with natural elevations ranging from 2 to 5 ft (0.6 to 1.5 m) NAVD 88.

The applicant stated that during a storm event with the magnitude of the PMP, the floodwater level in the nearby canals would be controlled by the seawater level in Biscayne Bay. The applicant reasons that this extreme precipitation event would likely be associated with a tropical storm event and would be accompanied by a strong low-pressure system and a storm surge in Biscayne Bay.

The applicant reviewed the flood history of these canals, as reported by the FEMA Flood Insurance Study, Dade County, Florida, and Incorporated Areas (FEMA, 1994). That report provides still water elevations in Biscayne Bay at the Turkey Point plants and near the mouths for these canals for return period frequencies ranging from 10 years to 500 years. The highest still water elevation given in the FEMA study is 12.4 ft (3.8 m) NGVD 29 (10.8 ft (3.3 m) NAVD 88), for the 500-year return period, at the location identified as Transect 30 (FEMA, 1994, Table 2). The applicant notes that this is substantially below the flood elevation determined in the applicant's analysis of the probable maximum hurricane, presented in Turkey Point Units 6 and 7 COL FSAR Section 2.4.5 as a still water elevation of 20.3 ft (6.2 m) NAVD 88 with a wave run-up water level at elevation 24.8 ft (7.6 m).

The applicant notes that all flood elevations given in the FEMA report are higher than the ground elevations surrounding both the canals and Turkey Point Units 6 and 7. Floodwater levels from Biscayne Bay would extend landward a significant distance even during a 10-year flooding event on the bay. Additionally, the applicant stated that the flat topography that extends for many miles in all directions provides a large storage volume for canal flooding, with very little increase in water level.

Based on this large storage volume and the expectation that water levels in Biscayne Bay will control the water levels in the canals, the applicant stated that PMF water levels in canals most likely will not reach levels that would impact the site or that would be above the estimated probable maximum hurricane flood level resulting from PMSS, as presented in Turkey Point Units 6 and 7 COL FSAR Subsection 2.4.5. The applicant also stated that American National Standards/American Nuclear Society 2.8-1992 (USACE, 2005) indicates that flooding as a result of the PMP on adjacent streams or rivers need not be considered for nuclear power reactor sites located on shorelines because coastal water levels along a shoreline will control maximum water levels.

Based on this reasoning, the applicant did not perform a PMP runoff analysis on streams and rivers.

Staff's Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.3 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to probable maximum flooding. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

The staff conducted a hydrology site audit on March 22 – 24, 2010. The site audit included a visit to the Turkey Point Units 6 and 7 site, and observations of the topography and hydrology of the surrounding area. The staff reviewed the applicant's information in Turkey Point Units 6 and

7 COL FSAR Section 2.4.3, and safety conclusions regarding potential hazards from PMF on streams and rivers.

Based on its initial review, the staff finds that the applicant had provided a strong qualitative justification for its conclusion that the large storage volume on the surrounding land would prevent canal flooding from influencing the flood levels above the estimated probable maximum hurricane level that it has identified as the design basis flood, but the applicant had not provided quantitative reasoning to support this conclusion.

Accordingly, in RAI 4808, Question 02.04.03-1, the staff requested additional information concerning the analysis of probable maximum flooding on streams and canals. The RAI requested quantitative reasoning for the conclusion that canal flooding would not influence the flood levels above the estimated probable maximum hurricane level.

The applicant responded on September 2, 2010. In its response, the applicant calculated the storage in the Florida City Canal floodplain, based on the assumptions that the floodplain is more than 45,000 ft wide and land surface elevations range from 2 to 5 ft NAVD 88. Using this information, the applicant calculated that every 1,000 ft (305 m) reach of the Florida City Canal floodplain contains approximately 1,030 ac ft (1,270,484 m^3) of storage for every foot of vertical rise above elevation 5 ft (1.5 m) NAVD 88. In Turkey Point Units 6 and 7 COL FSAR Subsection 2.4.2, the applicant stated that this storage, combined with the flat topography of the region, would prevent the flood discharge from a 6 hour, 10 square mi (25.9 square km) probable maximum precipitation (PMP) depth of 32.0 in (81.2 cm) from reaching elevations approaching those produced by flooding events in the Atlantic Ocean and Biscayne Bay (referring to storm surge and tsunami flooding) or the Turkey Point Units 6 and 7 safety-related buildings design grade elevation of 26.0 ft (7.9 m) NAVD 88. The staff has confirmed the reasonableness of this conclusion by calculating that a 17 ft rise in water level on a 1,000 ft (304.8 m) reach of the canal floodplain would accommodate the runoff from a 32 in. rainfall over a 10 mi^2 (26 km^2) area.

The staff reviewed the applicant's quantitative reasoning and accepts the applicant's analysis of probable maximum flooding on streams and rivers, including canals.

2.4.3.5 Post Combined License Activities

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

2.4.3.6 Conclusions

The staff reviewed the application and confirmed that the applicant has addressed the information relevant to probable maximum flood (PMF) on streams and rivers, and that there is no outstanding information required to be addressed in the COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in SER Section 2.4.3. This addresses COL information item 2.4-2. In conclusion, the staff determines that the identified site characteristics meet 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.

2.4.4 Potential Dam Failures

2.4.4.1 Introduction

Section 2.4.4 of the Turkey Point Units 6 and 7 COL FSAR addresses potential dam failures to ensure that any potential hazard to safety-related structures due to failure of onsite, upstream, and downstream water-control structures is considered in the plant design.

This section of the SER presents the staff's review of the analysis of potential dam failures.

2.4.4.2 Summary of Application

This section of the Turkey Point Units 6 and 7 COL FSAR addresses the site-specific information about potential dam failures. In addition, in Turkey Point Units 6 and 7 COL FSAR Section 2.4.4, the applicant provides site-specific supplemental information to address COL License Information Items 2.4-2:

<u>AP1000 COL Information Item</u>

- PTN COL 2.4-2 Floods

COL License Information Item 2.4-2 requires COL applicants to provide site-specific information related to potential dam failures that will be used to determine the design basis flooding at the site.

2.4.4.3 Regulatory Basis

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

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

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

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

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

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

- RG 1.29 as it relates to those SSCs intended to protect against the effects of flooding";
- RG 1.59 as supplemented by best current practices; and,
- RG 1.102 as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

2.4.4.2 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.4 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to potential dam failures. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the Turkey Point Units 6 and 7 COL FSAR:

AP1000 COL Information Item

- PTN COL 2.4-2 Floods

The staff reviewed PTN COL 2.4-2 related to potential dam failures that will be used to determine the design basis flooding at the site included in Turkey Point Units 6 and 7 COL FSAR Section 2.4.4.

Failures of dams and impoundments are a concern for safety because they can result in downstream flooding or loss of access to water supplies. Evaluation of the information provided in PTN COL 2.4-2 related to potential dam failures is discussed below.

Information Submitted by Applicant

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.4, the applicant stated that there are no dams located either upstream or downstream of the site. The nearest embankment dam to the site is the Herbert Hoover Dike that surrounds Lake Okeechobee. The dike and lake are more than 90 mi (145 km) northwest of the Turkey Point Units 6 and 7 site, and there is no direct channel or stream path from Lake Okeechobee to the site. The applicant stated that any breach of the Herbert Hoover Dike would result in floodwaters from the breach quickly spreading out laterally from the breaching location, as the topography between the lake and Units 6 and 7 is relatively flat. Herbert Hoover Dike Breach Inundation Area maps published in the Unified Mitigation Strategy for Palm Beach County, FL, and produced by USACE (Palm Beach County 2009) indicate that flooding as a result of a Herbert Hoover Dike breach would not extend beyond the drainage canals along the Palm Beach-Broward County line between Lake Okeechobee and the site. Based on this information, the applicant concluded that flood water from a Herbert Hoover Dike breach would have no impact on the Units 6 and 7 site.

The applicant also reviewed the potential impact of the failures of dams or dikes controlling onsite reservoirs. The Turkey Point Units 6 and 7 concrete water storage reservoir, referred to

as the makeup water reservoir, would be located in the cooling tower area south of the power block. The top of the reservoir wall is at elevation 24.0 ft (7.3 m) NAVD 88, which is 2 ft (0.6 m) below the design grade elevation of the safety-related structures. The existing cooling water return canals for Units 1, 2, 3 and 4 surround the reservoir walls on the east, south, and west sides. The applicant stated that any breach along these three sides of the reservoir would result in water flowing away from the power block and into the canals, to Biscayne Bay, or to the low-lying natural topography south and west of Units 6 and 7. Therefore, the applicant concluded that breaches along these three sides would pose no flooding risk to the safety-related facilities.

A breach in the makeup water reservoir's northern wall could, however, result in water flowing toward the power block area. The applicant notes that the design grade elevation adjacent to the north wall of the makeup water reservoir is approximately elevation 22.0 ft (6.7 m) NAVD 88, meaning that the north reservoir wall extends only 2 ft (0.6 m) above grade. The maximum operating water level in the reservoir is approximately elevation 22.5 ft (6.9 m) NAVD 88, 1.5 ft (0.5 m) below the top of the reservoir. The applicant cites the combined events criteria in American National Standards/American Nuclear Society 2.8-1992 (NOAA, 2006) as indicating that a one-half PMF should be considered coincident with a breach of a reservoir wall. Given that the full PMP event maximum discharge over the reservoir walls is estimated to be 2,696 cfs, the applicant reasoned that a one-half PMP storm event would produce a peak discharge over the reservoir wall of 1,348 cfs (38 cm). Using the broad crest weir equation with a total wall length of 5,717 ft (1,743 m) around the four sides of the reservoir and a weir coefficient of 2.6, the applicant calculated the maximum water level to be 2.4 in (6 cm) above the top of the reservoir wall at elevation 24.0 ft (7.3 m) NAVD 88. Thus, the applicant determined the maximum one-half PMP water level in the reservoir to be approximately elevation 24.2 ft (7.4 m) NAVD 88. The applicant compared this value to the safety-related design grade elevation for Turkey Point Units 6 and 7, at 26.0 ft (7.9 m) NAVD 88. The applicant stated that because the flood wave from a breach in the north wall of the reservoir would be 1.8 ft (0.5 m) below the elevation of the safety-related facilities, it does not pose a flooding risk to the safety-related facilities. Additionally, the applicant points out that the 700 ft (213 m) distance between the makeup water reservoir wall and the nearest safety-related building (i.e., the auxiliary building for either Unit 6 or 7) would further reduce any potential for inundation of safety-related facilities.

In summary, the applicant found that there are no upstream or downstream dams that would pose a flooding potential to Turkey Point Units 6 and 7. Based on the result of a simple bounding analysis, the applicant concluded that the flood elevation during a breach of the makeup water reservoir would be lower than the design grade elevation of the safety-related facilities.

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

The staff reviewed the applicant's information in Turkey Point Units 6 and 7 COL FSAR Section 2.4.4 and found the methods and tools used in conjunction with or developed using this information to be reasonable.

The staff reviewed publicly available maps and reports and found that they confirm the applicant's information about dam and dike locations and the impacts of a failure of the Herbert Hoover Dike. The staff also reviewed the applicant's analysis of the potential breach of the makeup water reservoir, performed some confirmatory calculations for that analysis, and determined that the applicant's reasoning and supporting analysis are appropriate.

The staff finds that the applicant has considered the appropriate site phenomena for establishing the design bases for SSCs important to safety. The staff accepted the methodologies used to determine the potential for inundation due to dam breaks in the vicinity of the site. Accordingly, the staff also concludes that the use of these methodologies provides acceptable results. The staff concludes that the identified site characteristics meet the requirements of 10 CFR 52.79 and 10 CFR Part 100.20(c), with respect to establishing the design basis for SSCs important to safety.

2.4.4.5 Post Combined License Activities

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

2.4.4.6 Conclusion

As set forth above, the applicant presents and substantiates information relative to the potential for site inundation due to dam failure. The staff reviewed the available information and concluded, for the reasons given above, that the identification and consideration of the potential dam failure in the vicinity of the site and site regions are acceptable and meet the requirements of 10 CFR 52.79 and 10 CFR Part 100.20(c), with respect to determining the acceptability of the site.

The staff reviewed the application and confirmed that the applicant has addressed the information relevant to potential dam failures, and that there is no outstanding information required to be addressed in the Turkey Point Units 6 and 7 COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information to establish the site description. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in SER Section 2.4.4, 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 2.14.

2.4.5 Probable Maximum Surge and Seiche Flooding

2.4.5.1 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.4.5 addresses the probable maximum surge and seiche flooding to ensure that any potential hazard to the SSCs at the proposed site has been considered in compliance with the Commission’s regulations.

Section 2.4.5 of this SER presents evaluation of the following topics based on data provided by the applicant in the Turkey Point Units 6 and 7 COL FSAR and information obtained from site audits, RAI responses, and publicly available sources: (1) probable maximum hurricane (PMH) that causes the probable maximum surge as it approaches the site along a critical path at an optimum rate of movement, (2) probable maximum wind storm (PMWS) from a hypothetical extratropical cyclone or a moving squall line that approaches the site along a critical path at an optimum rate of movement, (3) a seiche near the site, and the potential for seiche wave oscillations at the natural periodicity of a water body that may affect flood water surface elevations near the site or cause a low water surface elevation affecting safety-related water

supplies, (4) wind-induced wave run-up under PMH or PMWS winds, (5) effects of sediment erosion and deposition during a storm surge and seiche-induced waves that may result in blockage or loss of function of SSCs important to safety, (6) the potential effects of seismic and nonseismic information on the postulated design bases and how they relate to a surge and seiche in the vicinity of the site and the site region, and (7) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.5.2 Summary of Application

This section of the Turkey Point Units 6 and 7 COL FSAR addresses the information related to probable maximum surge and seiche flooding in terms of impacts on structures and water supply. The applicant addressed these issues as follows:

AP1000 COL Information Item

- PTN COL 2.4-2 Floods

COL License Information Item 2.4-2 requires COL applicants to provide site-specific information related to probable maximum surge and seiche flooding that will be used to determine the design basis flooding at the site.

2.4.5.3 Regulatory Basis

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

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

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

- 10 CFR 100.23(d)(3) sets forth the criteria to determine the siting factors for plant design bases with respect to water levels at the site.

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

In addition, the staff used the regulatory positions of the following regulatory guides for the identified acceptance criteria:

- Regulatory Guide 1.29 as it relates to those structures, systems, and components (SSCs) intended to protect against the effects of flooding";

- Regulatory Guide 1.59 as supplemented by best current practices; and,

- Regulatory Guide 1.102 as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

2.4.5.4 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.3.5 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic. The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to PMSS. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the Turkey Point Units 6 and 7 COL FSAR:

AP1000 COL Information Item

- PTN COL 2.4-2

The staff reviewed PTN COL 2.4-2 related to probable maximum surge and seiche flooding included in Turkey Point Units 6 and 7 COL FSAR Section 2.4.5.

Because of the location of Turkey Point Units 6 and 7 on Florida's east coast, the site would be exposed to hurricane storm surge from hurricanes affecting that coast. Determination of the PMSS is, therefore, an important element of the safety evaluation for the site. Evaluation of the information provided in PTN COL 2.4-2 related to probable maximum surge and seiche flooding is discussed below.

2.4.5.4.1 Probable Maximum Winds and Associated Meteorological Parameters

An estimate of the probable maximum wind field for the site is necessary to perform the safety assessment because the potential for storm surge is related to the wind field of the PMH or PMWS. Subsection 2.4.5 of NUREG-0800 defines the PMSS as the surge that results from a combination of meteorological parameters of a PMH, a PMWS, or a moving squall line. NUREG-0800 indicates that the PMH, as defined by NOAA Technical Report NWS 23 (NOAA, 1979), should be estimated for coastal locations that may be exposed to hurricanes. The PMH is a hypothetical steady-state hurricane with a combination of meteorological parameters that will give the highest sustained wind speed that can probably occur at a specified coastal location. Meteorological parameters that define the PMH wind field include the hurricane peripheral pressure (p_n), central pressure (p_o), radius of maximum winds (R), forward speed (T), track direction (θ), and inflow angles of the hurricane winds (φ).

Information Submitted by Applicant

The applicant used guidance in NOAA NWS Report 23 (NOAA, 1979) as its basis for defining the combination of parameters of the wind field for the PMH at the location of Turkey Point Units 6 and 7. The PMH parameter values provided by NWS 23 are based on data from historical

hurricanes from 1851 to 1977. Table 2.4.5.4-1 summarizes the PMH characteristics determined by the applicant.

Table 2.4.5.4-1 Assumed PMH Characteristics for Turkey Point Units 6 and 7

Hurricane Parameter	Magnitude or range
Peripheral Pressure (p_n)	30.12 in. mercury (1020 millibar [mb])
Central Pressure (p_o)	26.12 in. mercury (884.5 millibar [mb])
Radius of Maximum Winds (R)	4 to 20 nautical miles (4.6 to 23.0 miles)
Forward Speed (T)	6 to 20 knots [kts] (6.9 to 23.0 mph)
Track Direction (θ)	72 to 185 ° clockwise from north
Inflow angle (φ)	2 to 9 ° (at a distance R from the hurricane center)

According to NWS 23, the pressure difference between the hurricane peripheral and central pressures, Δp, is the most important meteorological parameter in defining the hurricane wind field. The applicant notes that the Δp value in its analysis is 4 in. of mercury (135.5 millibar).

The applicant reviewed published information on historical trends in hurricane intensities and research on the effect of climate variability on hurricane intensity (NOAA, 2006, Blake et al., 2007). The applicant's review found that research on the effects of El Niño/Southern Oscillation on hurricane formation indicates that El Niño conditions tend to suppress hurricane formation in the Atlantic basin and La Niña conditions tend to favor hurricane development (NOAA, 2006). Additionally, hurricane activity increases during warm phases of the Atlantic Multi-decadal Oscillation, which is the variation of long-duration sea surface temperature in the northern Atlantic Ocean with cool and warm phases that may last for 20 to 40 years (NOAA, 2006). Historical hurricane data indicate that Atlantic hurricane seasons have been significantly more active since 1995 than they were in preceding decades, but earlier periods, such as from 1945 to 1970, were apparently as active the recent period (NOAA, 2006; Blake et al., 2007). Analysis by Blake et al. (2007) of historical trends from 1851 to 2006 found that the United States is affected by a Category 4 or stronger hurricane (based on the Saffir-Simpson scale, in which Category 4 corresponds to wind speeds over 130 mph (113 kts) and central pressure below 945 mb) approximately once every 7 years on average. The applicant stated that this suggests that the frequency of exceptionally strong hurricane landfalls during the last 35 years of the study period (from 1971 to 2006, when there were three storms of Category 4 or stronger at landfall) was less than average.

Based on this information, the applicant concluded that because NOAA Technical Report NWS 23 is based on historical data from 1851 to 1977 and includes the most recent active hurricane

period from 1945 to 1970, it is reasonable to assume that the PMH parameters derived from it are sufficiently conservative even in the consideration of future climate variability.

Staff's Technical Evaluation

The staff reviewed the basis for the applicant's conclusion that NOAA Technical Report NWS 23 is sufficiently conservative to bound the magnitude of the PMH, and found it to be reasonable. Although theoretical analyses (such as Bender et al., 2010) have projected an increase in the frequency of intense hurricanes due to global warming, they do not appear to project an increase in the intensity of the most severe individual storms.

The staff reviewed the applicant's application of NOAA Technical Report NWS 23 and concluded that it is acceptable.

The staff observed that the central pressure at landfall of the recommended PMH is lower than that for any storm included in the U.S. historical record documented by Blake et al. (2007), and the wind speed is higher than for any storm in the record. These observations are consistent with a finding that the PMH parameters are conservative.

2.4.5.4.2 Historical Hurricane Events and Storm Surges

The record of historical hurricane events and storm surges affecting the site, which is adjacent to the Biscayne Bay shoreline and approximately 8 mi west of the Elliott Key Barrier Island, helps to inform the analysis of PMSS.

Information Submitted by Applicant

The applicant reviewed the historical record of hurricanes that caused sustained wind damage to the Florida coast (including hurricanes that did not make landfall) between 1851 and 2006. The Labor Day hurricane of August/September 1935 (Category 5 on the Saffir-Simpson scale) was the most intense hurricane to affect the Florida coast during the period of record. With a central pressure of 892 mb (26.35 in.), this storm had the lowest central pressure at landfall for any hurricane to strike the U.S. coast during the period of record. It made landfall on the islands of Islamorada in the upper Florida Keys (roughly 40 mi south of the Turkey Point Units 6 and 7 site).

The most severe recent hurricane to make landfall near Units 6 and 7 was Hurricane Andrew in August 1992. Hurricane Andrew made landfall as a Category 5 hurricane (NOAA, 1993 and 2005) approximately 8 mi north of the plant area, at Fender Point, FL. At landfall, the hurricane had a central pressure of 922 mb (27.23 in.) and a maximum sustained wind speed (1-minute average, 33-ft-high) of 145 kts (167 mph). The applicant stated that, based on its central pressure, it is the fourth most intense hurricane to make landfall in the United States in the period of the historical record.

Observed high water elevations in Biscayne Bay associated with Hurricane Andrew storm surge are mapped in Figure 2.4.5-1 (NOAA, 1993 and 2005). The highest observed water level resulting from the combined effects of Hurricane Andrew storm surge and astronomical tide was 16.9 ft NGVD 29 (15.3 ft NAVD 88), on the western shoreline near the center of Biscayne Bay. In northern Biscayne Bay, high water levels were 4 to 6 ft NGVD 29, which is approximately

2.4 to 4.4 ft NAVD 88. In southern Biscayne Bay, the surge elevation ranged from 4 to 5 ft NGVD 29 (2.4 to 3.4 ft NAVD 88).

Staff's Technical Evaluation

The staff reviewed the applicant's information on the historical hurricane record and compared it with published sources cited by the applicant. The staff accepted this information as valid and appropriate for consideration in evaluating PMSS at the Turkey Point Units 6 and 7 sites.

2.4.5.4.3 Methodology for Storm Surge Analysis

Information Submitted by Applicant

The applicant selected the NOAA computer model "Sea, Lake, and Overland Surges from Hurricanes" (SLOSH) for simulation of the PMSS elevation from the PMH at Units 6 and 7 (Jelesnianski et al., 1992). SLOSH was developed by the NWS to forecast real-time hurricane storm surge levels, including inland routing of water levels. SLOSH is a depth-averaged two-dimensional finite difference model on curvilinear polar, elliptical, or hyperbolic grid schemes. Modification of storm surges due to the overtopping of barriers (including levees, dunes, and spoil banks), the flow through channels and floodplains, and barrier cuts/breaches are included in the model. The effects of local bathymetry and hydrography are also included in the SLOSH simulation (Jelesnianski et al., 1992). The developer of the SLOSH model conducted verification and validation testing of the SLOSH computer code.

The applicant used the PMH parameters (˜p, radius of maximum wind, forward speed, track direction) listed in Table 02.04.05.2-1 to define the physical attributes of the PMH in the model. The applicant ran model simulations with various combinations of the input PMH parameters to obtain the maximum storm surge elevation.

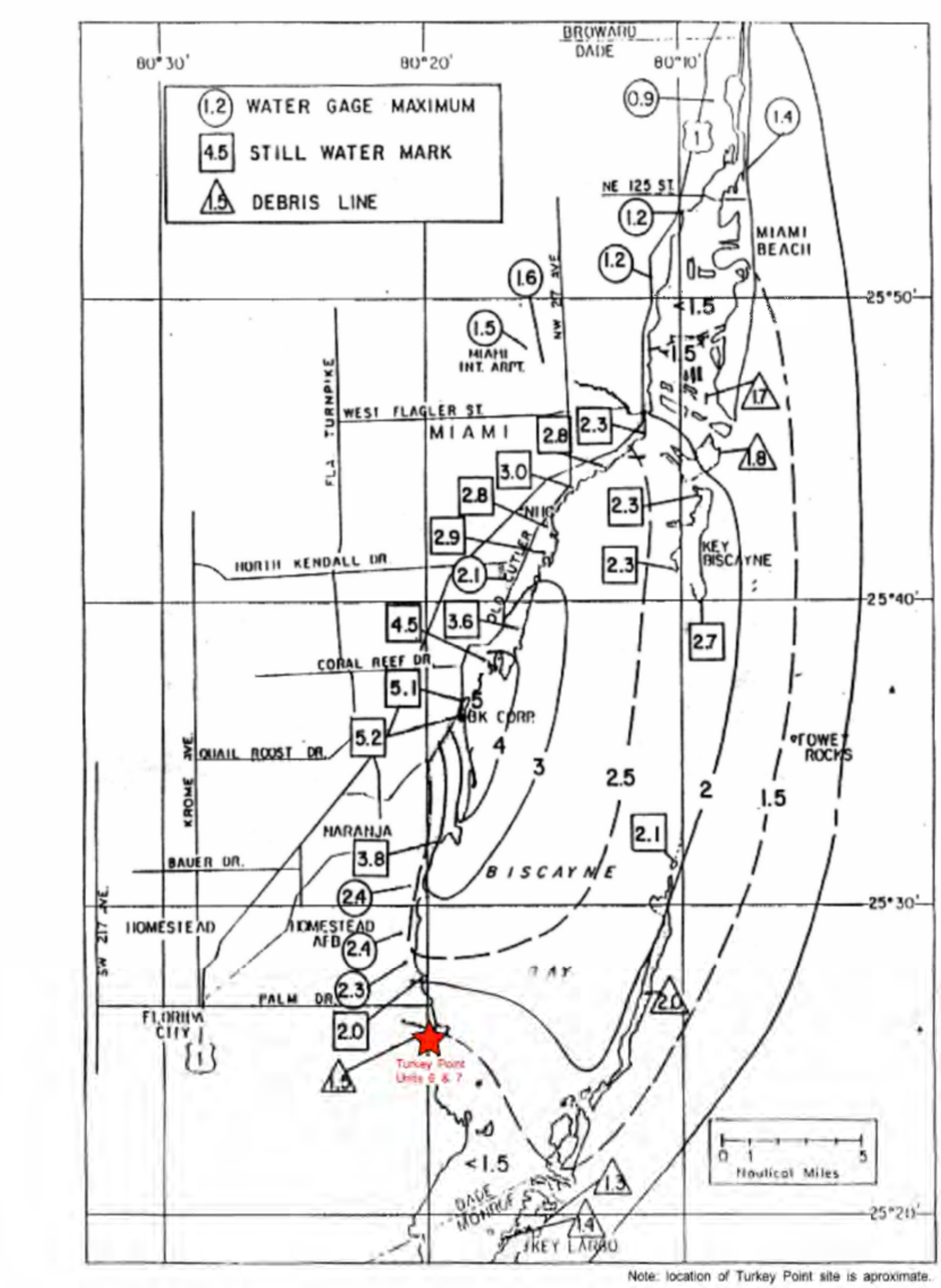


Figure 2.4.5-1 Observed high water elevations around Biscayne Bay during Hurricane Andrew
(Source: Turkey Point Units 6 and 7 COL FSAR Figure 2.4.5-203, based on NOAA, 1993 and 2005 http://www.nhc.noaa.gov/prelims/1992andfig7.gif). Labeled in meters above 1929 mean sea level (1 m = 3.28 ft).

In applying SLOSH, the applicant separately estimated the antecedent water level, as discussed below in Subsection 02.04.05.4.4, and used that estimated water level as the initial water level condition in the SLOSH model simulation.

Staff's Technical Evaluation

In evaluating the sufficiency of the methodology for analysis of storm surge, the staff reviewed the model documentation for the SLOSH model, the Section 02.04.05 of the Turkey Point Units 6 and 7 COL FSAR, the responses to relevant RAIs and published studies of modeling of hurricane storm surge.

Advances in computing technology since the development of SLOSH have led to development of more sophisticated modeling techniques for storm surge prediction. Among the capabilities provided by newer modeling tools are three-dimensional simulation, larger domain sizes, and finer discretization (Massey et al., 2007). Researchers who have compared different modeling approaches identify several advantages from the use of more sophisticated codes. For example, Blain et al. (1994) found that domain size influenced hurricane storm surge modeling results for the Gulf of Mexico. They modeled one actual storm at three scales, and found that modeling of a domain size similar to the domain sizes used in implementing SLOSH resulted in lower and less accurate estimates of peak storm surge than modeling at the scale of the entire Gulf of Mexico or the entire east coast of North America. They attributed the difference in results to the smaller-scale domain's inability to represent oscillatory behavior due to resonance within the semi-enclosed Gulf of Mexico basin, the boundaries of which lay outside the model domain. Weisberg and Zheng (2008) used two- and three-dimensional models to simulate the potential impact on the Tampa Bay, FL, area if Hurricane Ivan (September 2004) had made landfall there. They found that the 2-D model produced lower estimates than the 3-D model for the height of the storm surge as it moved up an inlet. They concluded that the 2-D model underestimated storm surge due to its inability to account accurately for bottom stresses.

Some studies of the accuracy of SLOSH predictions, including the applicant's validation run for Hurricane Carla, have found relatively large errors in predicting surge for storms striking various parts of the U.S. Gulf Coast, leading in some instances (e.g., Federal Emergency Management Agency, USACE and NOAA, 2005) to a recommendation that finer modeling grids are needed, together with updated bathymetric and topographic data.

The staff's review considered these findings, but did not identify any reason to reject SLOSH as an appropriately conservative tool for use in predicting PMSS at the Turkey Point Units 6 and 7 site on the shore of Biscayne Bay. The site does not have the characteristics that these studies identified as sources of error in SLOSH and similar models. The influence of domain size on modeling results that has been identified in the Gulf of Mexico and attributed to boundary-condition constraints is not a reason to reject the model for use at the Turkey Point Units 6 and 7 site because the site location faces the Atlantic Ocean, where it is not subject to the types of boundary-condition constraints that make larger-scale modeling desirable for Gulf Coast locations. Additionally, the model applications where researchers have identified a need for three-dimensional models, or for finer grid resolutions than are available in SLOSH are locations, where complex coastal geometry and topography are identified as important determinants of surge behavior. The coastal geometry of Biscayne Bay and the Florida coast near the Turkey Point Units 6 and 7 site is simple by comparison, and is further simplified in the case of an exceptionally large storm event (such as the PMH) that would overtop Elliott Key. Additionally, the staff noted that good agreement has been achieved in using the SLOSH

Biscayne Bay Model to simulate the storm surge from Hurricane Andrew. This increases confidence in the SLOSH implementation for Biscayne Bay.

Furthermore, the staff noted that the applicant accounted for the uncertainty of the SLOSH model simulations in determining the maximum storm surge level. That is, the estimated maximum surge level was adjusted conservatively by adding about 20 percent of the estimated surge level for the uncertainty of its SLOSH simulations as described in SER Subsection 2.4.5.4.5. The staff determined that this adjustment is sufficient to compensate for any effects of small SLOSH model domain, 3-D wave propagation, and the resonance of wind and wave.

Based on this review, the staff determined that the applicant's choice of methodology is appropriate for the analysis of PMSS at the Turkey Point Units 6 and 7 site.

2.4.5.4.4 Antecedent Water Level

To help ensure that modeling of PMSS does not underestimate storm surge elevation, it is necessary to consider the potential effects of tides, sea-level anomalies, and future sea-level changes on storm surge. These factors are combined in defining the antecedent water level. The extreme level of conservatism used in the analyses is included in the following discussion.

Information Submitted by Applicant

The applicant used guidance in RG 1.59 to determine the PMSS antecedent water level, following two different approaches described in the guidance.

The applicant notes that RG 1.59 states that the 10 percent exceedance high spring tide including initial rise should be used to represent the PMSS antecedent water level. The 10 percent exceedance high spring tide is the high tide level that is equaled or exceeded by 10 percent of the maximum monthly tides over a continuous 21-year period. For locations where the 10-percent exceedance high spring tide can be estimated from 21 years or more of observed tide data, RG 1.59 indicates this value can be used for antecedent water level without incorporating a separate estimate for initial rise (or sea-level anomaly).

The applicant identified three NOAA tide gauging stations in the area that have long-term tide-measurement records: Virginia Key (station number 8723214), Vaca Key (8723970), and Key West (8724580). The applicant reports that only the station at Key West has data records longer than a 21-year period that can be used to estimate the 10-percent exceedance high spring tide, consistent with the definition in RG 1.59. The estimated 10-percent exceedance high spring tide at Key West is 0.97 ft NAVD 88, based on 38 years of record. Closer to the Turkey Point Units 6 and 7 site, at the Virginia Key station (located north-northeast of the site), the corresponding value is 1.43 ft NAVD 88, based on 15 years of record.

The RG 1.59 also provides estimates of 10-percent exceedance high spring tide and initial rise (or sea-level anomaly) at the Miami Harbor Entrance on the Atlantic Ocean, which is located close to the NOAA tide gage station at Virginia Key. The 10 percent exceedance high spring tide and the initial rise at the Miami Harbor Entrance are given as 3.6 ft above mean low water and 0.9 ft, respectively. Using these values, the applicant determined that the combined height of the 10 percent exceedance high spring tide and initial rise is 3.6 ft + 0.9 ft = 4.5 ft above mean low water. The applicant stated that mean low water at Virginia Key is at -1.9 ft NAVD 88, so the antecedent water level at the Miami Harbor Entrance based on this approach is approximately 2.6 ft NAVD 88. The applicant used this value in its PMSS determinations. The

applicant stated that this is the highest, and thus most conservative, of the values determined by the alternative approaches described in RG 1.59.

In addition to the 10 percent exceedance high spring tide and initial rise, the applicant used the long-term trend in tide gage measurements to estimate the expected sea-level rise over the design life of the plant. The applicant identified the Miami Beach, FL, (8723170) station as the NOAA station nearest to Units 6 and 7 where long-term trend in sea-level rise is available. This station, which is located close to the Virginia Key station, is no longer active. The applicant cites a NOAA analysis of data from 1931 to 1981 that indicates that the long-term rate of sea-level rise at Miami Beach is 0.78 ft per century (NOAA, *Sea Levels Online*). To account for sea-level rise over the life of the plant, the applicant added a nominal long-term sea-level adjustment of 1 ft to the estimate of 10-percent high tide level and initial rise to arrive at an antecedent water level of 3.6 ft NAVD 88 (2.6 ft NAVD 88 + 1 ft).

Staff's Technical Evaluation

The staff reviewed the applicant's basis for determining the antecedent water level, and accepted the use of RG 1.59 values for 10 percent exceedance high tide and initial rise. The staff notes that the combined value of 4.5 ft above mean low water (2.6 ft NAVD 88) is higher than the highest value (1.43 ft NAVD 88) derived from available records, supporting the view that it is appropriately conservative.

The staff had questions about the applicant's analysis of long-term sea-level rise, which is based on a linear extrapolation of historical sea-level changes measured at Miami Beach, FL. Walton (2007) analyzed historical sea-level records for the State of Florida and found that a nonlinear model provided a better fit for the data, including some acceleration in sea-level rise. Using a second-order trend analysis and treating 2006 as the base year, Walton forecast sea-level rise through 2080 for five Florida coastal sites where long-term historical water level records exist. Predicted increases range from 0.82 ft (0.25 m) at Fernandina (in the northeastern corner of the State) to 1.15 ft (0.35 m) at St. Petersburg on the Gulf Coast. At Cedar Key, the location nearest to the Turkey Point Units 6 and 7 site, the forecast sea-level rise was 0.89 ft (0.27 m). All of these forecast values exceed the applicant's estimate of a sea-level rise of 0.78 ft in a century. Walton's predictions are generally consistent with average global sea-level increases of 0.6 to 1.9 ft (0.18 to 0.49 m) by 2100 that were projected by working group I of the Intergovernmental Panel on Climate Change in its 2007 report on the physical science basis (National Park Service, 2009), but some more recent studies suggest that these values may underestimate sea-level rise resulting from climate change (National Park Service, 2009). For example, the National Park Service (2009) cites a study that projected a global sea-level rise of 1.6 to 4.6 ft (0.5 to 1.4 m) between 1990 and 2100.

With this background, staff issued RAI 02.04.05-3 asking the applicant to provide analysis of the effect of a nonlinear model of the future rate of sea-level rise on PMF water levels at Units 6 and 7 resulting from PMH-related storm surge. In a March 22, 2011, response to RAI 02.04.05-3 (ADAMS Accession No. ML110840025), the applicant provided additional analysis of historical sea-level changes at Miami Beach, FL, including nonlinear modeling approaches, and provided analysis of the effect of a nonlinear model of the future rate of sea-level rise on PMF water levels at the Turkey Point Units 6 and 7 resulting from PMH-related storm surge. The applicant's analysis showed that a nonlinear analysis of Miami Beach water levels does not change the conclusion that the results of the linear approach are conservative. However, in reviewing the analysis, the staff found indications of shortcomings in the Miami Beach data set. The most recent measurements at Miami Beach were 30 years old (from 1981), so the data set

may not represent recent trends, and there are gaps in the record from earlier years. A data set exists for Key West, FL, that covers a longer period, continuing to the present time, and does not have gaps. In the applicant's analyses of the two data sets, R-squared values for both linear and nonlinear trend analyses of the Miami Beach data were much lower than those for trend analyses for Key West data (values of 0.32 to 0.35 for Miami Beach data (versus values of 0.45 and 0.46 for Key West data), which indicated a better fit for the Key West data. Also, the applicant's attempt to fit a second-order trend to the Miami Beach data counterintuitively predicts a large drop in sea level, suggesting problems with the data set. The applicant's linear regression analysis of the Miami Beach and Key West data sets did, however, find a close correlation between sea-level measurements at the two locations (R-squared of 0.85). To provide assurance that there is a technically valid basis for analysis of future sea-level rise, the staff issued RAI 5860, Question 02.04.05-05:

> Provide sufficient reasoning and analysis to demonstrate that reliance on the Miami Beach sea-level data is a valid and sufficient basis for predicting potential future sea-level rise, when a longer and more recent data set for the region is available from Key West.

In a November 4, 2011, response to RAI 5860, Question 02.04.05-5 (ADAMS Accession No. ML11312A049), the applicant provided comparisons of several linear and non-linear trend analyses of sea-level data for both Miami Beach and Key West. The applicant's analyses show that no alternative analytical approach provides a result that is more conservative than the sea-level rise of 1.0 ft that the licensee assumed based on the determination from linear trend analysis of the Miami Beach data. Staff noted that the applicant's analytical approach is consistent with the recommendations of NUREG/CR-7046 (NRC 2011) , which states that long-term sea-level rise for the expected life of the nuclear power plant should be derived from the trend in site or regional tide gage station data. Thus, the staff considers RAI 02.04.05-3 and RAI 02.04.05-5 resolved.

2.4.5.4.5 Analysis of Probable Maximum Storm Surge

Information Submitted by Applicant

The applicant used the NOAA SLOSH model to simulate PMSS. The model package used was the version obtained from NWS as of November 30, 2006. The applicant determined that the site of Turkey Points Units 6 and 7 is within the region of the SLOSH Biscayne Bay basin domain, which is simulated in SLOSH with a two-dimensional curvilinear hyperbolic grid, as illustrated in Figure 02.04.05-2. The applicant stated that the center of Units 6 and 7 (25.425 ° N, 80.333 ° W) is located in the SLOSH model grid cell (63, 40). Basin bathymetry data are included in the model and are referenced to NGVD 29. Modeling results were processed using Version 1.40 of the NOAA SLOSH Display Program (SLOSH, 2006). Output referenced to NGVD 29 was converted to a NAVD 88 basis using the -1.6 ft conversion determined for Virginia Key.

The applicant performed model simulations for different combinations of the PMH parameters given in Table 02.04.05.2-1 to obtain the maximum surge water level at Units 6 and 7. A total of 53 SLOSH model runs were performed to investigate the effects on the storm surge elevation using different combinations of PMH forward speed, size, direction, and track distance from Units 6 and 7. The applicant modeled two steady-state PMH forward speeds (the lower and upper bounds), three PMH radiuses of maximum wind (the mean, the lower bound, and upper bound), five PMH directions, and seven track distances. The five hurricane directions modeled

were 225, 247.5, 258.75, 270, and 315°, measured in a clockwise direction from the north. Storm tracks were modeled at distances of 0, 5.75, 11.5, 17.25, 23, 34.5, and 46 mi in a southerly direction from Turkey Point Units 6 and 7. All simulations were based on the PMH pressure differential (Δp) of 4.0 in of mercury (135.5 mb) given in Table 02.04.05.2-1 and used an antecedent water level of 4.2 ft NGVD 29 (this value includes the 10 percent exceedance high spring tide and initial rise, but not long-term sea-level rise) as an initial condition.

Figure 02.04.05-3 shows storm surge elevations at the Turkey Point Units 6 and 7 site that the applicant determined for different combinations of PMH forward speed and radius of maximum wind at three hurricane directions, 225, 270, and 315 ° from the north. From these simulation results, the applicant observed that:

- Higher PMH forward speed results in higher surge elevations.
- At the upper bound PMH forward speed, surge elevation increases with increasing storm radius.
- At the lower bound forward speed, the largest (upper bound) hurricane radius does not produce the highest surge elevation.
- Storm direction results in the largest differences in surge elevation at the upper bound PMH radius.

Figure 02.04.05-4 shows the results of the applicant's SLOSH analysis of the effect on surge elevation of different PMH directions and track distances for a storm with a RMW of 20 nautical mi. From this analysis, the applicant determined that the highest surge elevation occurs when the PMH direction is 258.75 ° from the north and the PMH track is at a distance approximately 0.75 times the PMH radius of maximum wind (i.e., 15 nautical mi) south from Turkey Point Units 6 and 7. Based on the results of the SLOSH model sensitivity runs, the applicant concluded that the PMSS would be generated by a PMH with the upper bound forward speed (20 kts or 23 mph) and size (radius of maximum wind of 20 nautical mi or 23 mi), a track direction of 258.75 ° from the north, and a track distance of approximately 15 nautical mi (17.25 mi) south of Units 6 and 7.

The applicant also investigated the effect of increasing the PMH size (radius of maximum wind) above the upper bound specified in NWS 23 for a PMH approaching at a direction of 270 °from the north. In this analysis, the hurricane track was assumed to be located at a distance from Turkey Point Units 6 and 7 equal to the PMH radius of maximum wind. The analysis for the effect of radius of maximum winds considered values of 4 (the lower end of the range indicated in NWS 23), 12, 20 (the upper end of the range in NWS 23), 25, 30, 40, and 100 nautical mi. Radius of maximum wind values of 25, 30, and 40 nautical mi all resulted in storm surge elevations higher than were determined for a radius of 20 nautical mi. The highest storm surge elevation found by the analysis resulted from a radius of 30 nautical mi (34.5 mi), at which value the predicted surge elevation at Turkey Point Units 6 and 7 was 19.4 ft (NAVD 29), approximately 2.6 percent (3.5 percent, as a percentage of the surge height) higher than the 18.9 ft surge predicted for the same conditions but with a radius of maximum wind of 20 nautical mi. The applicant did not determine whether other values between 25 and 35 nautical micould result in a higher estimated storm surge elevation than that calculated for a value of 30 nautical mi.

The applicant used SLOSH to simulate storm surge for four combinations of PMH characteristics using the full estimate of antecedent water level, 5.2 ft NAVD 29. With an antecedent water level of 5.2 ft NAVD 29, three of the four modeled combinations (storm directions of 247.5, 258.75, and 270 ° from north, all with RMW of 20 nautical mi, track distance of 15 nautical mi, and PMH forward speed of 20 knots) resulted in a storm surge of 19.8 ft NAVD 29.

Based on this analysis, the applicant concluded that the highest surge elevation at Turkey Point Units 6 and 7 is 19.8 ft NGVD 29 (18.2 ft NAVD 88) and is obtained from the SLOSH model simulation using PMH parameters of ∆p of 4 in mercury, forward speed of 20 knots, radius of maximum wind of 20 nautical mi, direction of 258.75 ° from the north, and track distance approximately 15 nautical mi south of Turkey Point Units 6 and 7, with antecedent water level of 5.2 ft NGVD 29 (3.6 ft NAVD 88). Figure 02.04.05-5 is a map display of SLOSH output for this set of conditions, including the storm track and maximum surge elevations over the model domain. The highest surge elevation predicted in this simulation occurs at a location northwest of the Turkey Point Units 6 and 7 site.

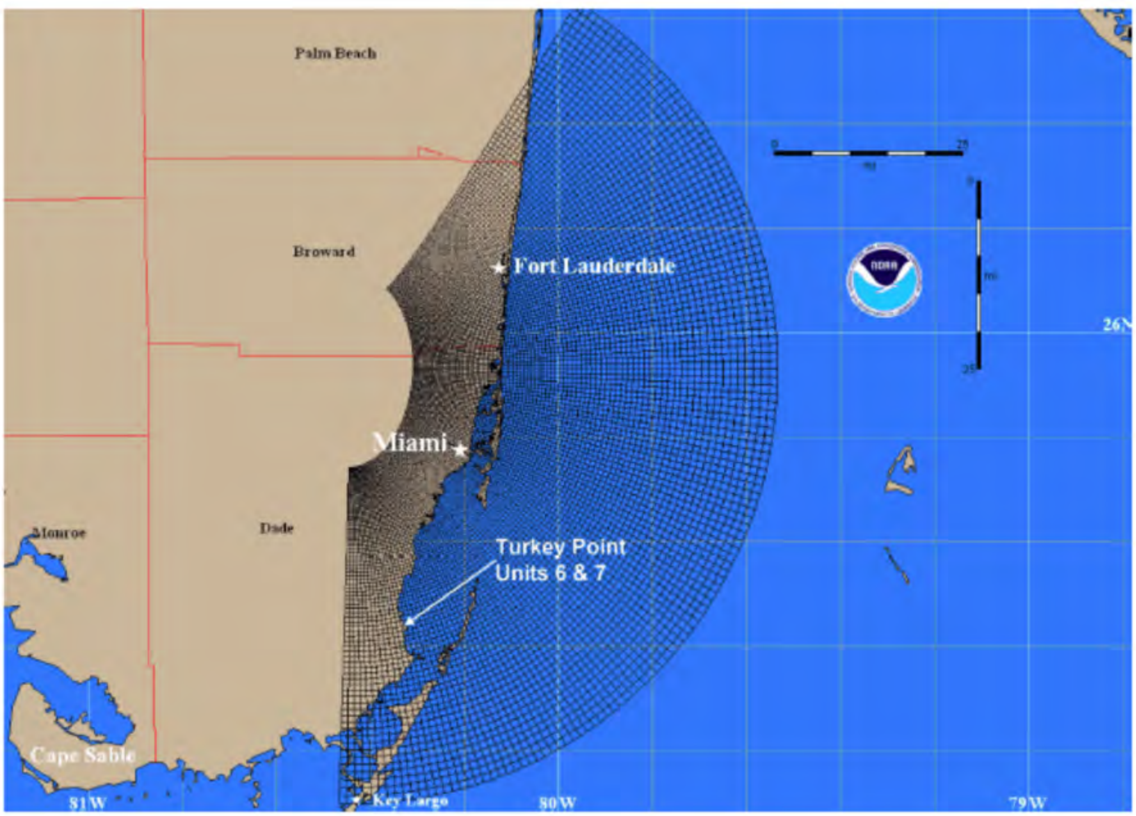


Figure 02.04.05-2 Biscayne Bay model grid used in applicant's implementation of SLOSH

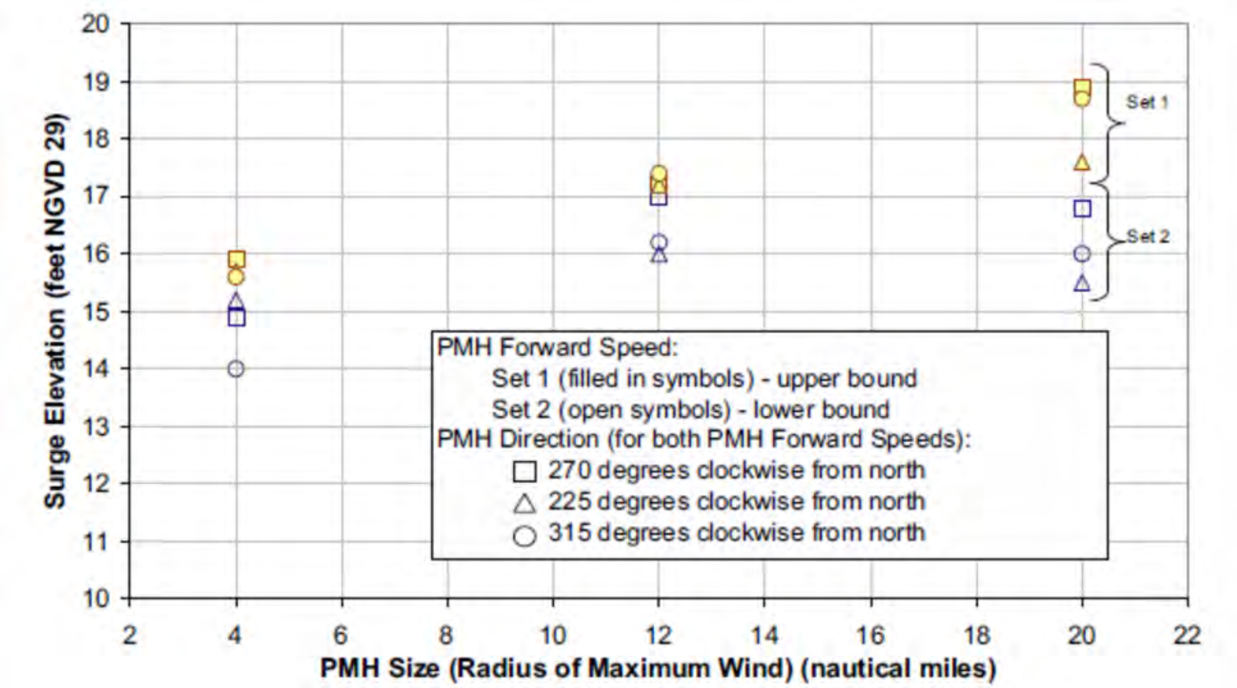


Figure 02.04.05-3 Surge elevations simulated for different combinations of PMH parameters (Source: Turkey Point Units 6 and 7 COL FSAR Figure 02.04.05-205)

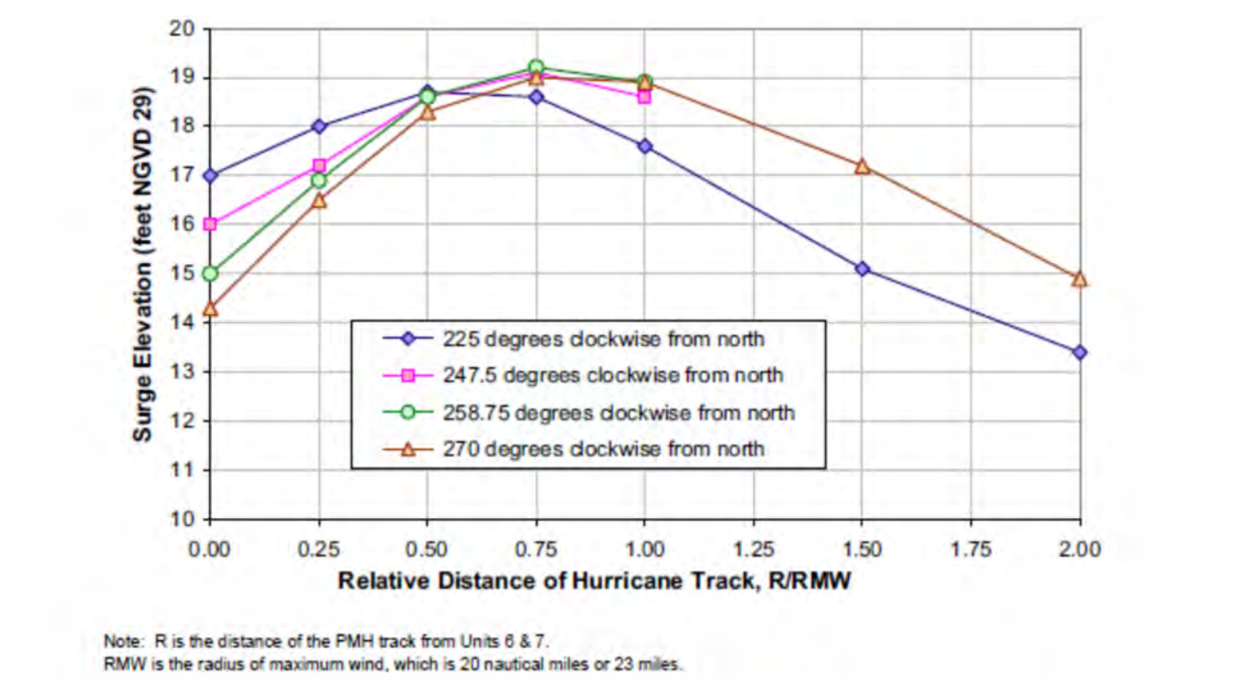
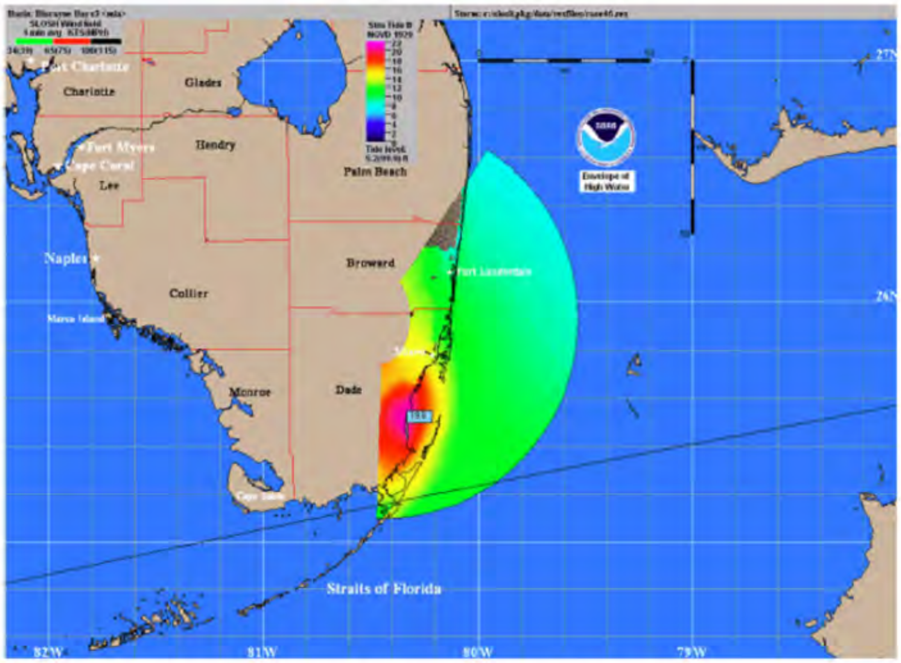


Figure 02.04.05-4 Applicant's analysis of surge elevation sensitivity to PMH direction and track distance. (Source: Turkey Point Units 6 and 7 COL FSAR Figure 02.04.05-206)



Note: Number in the flag indicates the maximum surge elevation (in NGVD 29) at Units 6 & 7.

Figure 02.04.05-5 Applicant's SLOSH output for the parameter combination producing the PMSS at Units 6 and 7. The black line is the storm track at 258.75 ° from north. (Source: Turkey Point Units 6 and 7 COL FSAR Figure 2.4.5-209)

To evaluate the uncertainty in SLOSH model predictions, the applicant reviewed published studies in which SLOSH was used to model actual storms and model predictions were compared with observed hurricane surge levels. Jarvinen and Lawrence (1985; NOAA, 1982) evaluated the error in SLOSH predictions for ten storms in eight SLOSH model basins. Based on a comparison of the SLOSH simulated surge heights against 523 observations, 90 percent of which were in the Gulf of Mexico, they reported a mean error of -0.09 m (-0.3 ft) and a range of errors from -2.16 m (-7.1 ft) to 2.68 m (8.8 ft) with a standard deviation of 0.61 m (2 ft). In that study, negative values for the error mean that SLOSH underpredicted the surge height. NOAA Technical Report NWS 48 (Jelesnianski et al., 1992) compared SLOSH model results with 570 observations for well-documented hurricanes in nine SLOSH basins. The applicant cited the report's finding that model results were "generally" within ± 20 percent for "significant surge heights." To illustrate that result, the applicant modified a graph from the report by adding a line to indicate a +20 percent margin above the "perfect forecast" line (Figure 02.04.05-6).

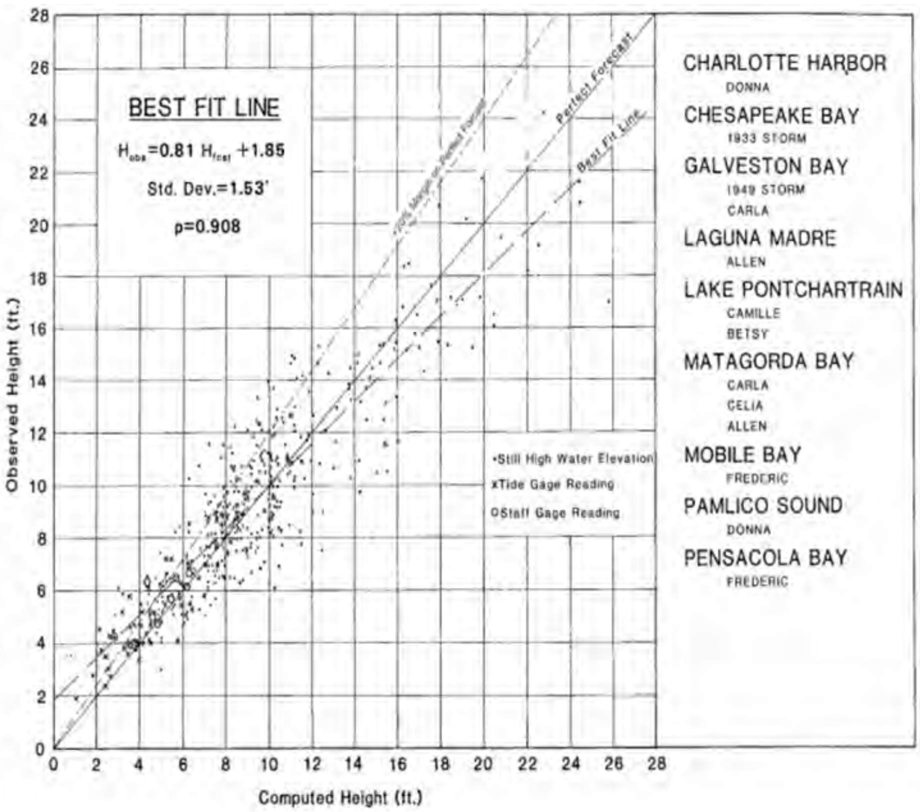


Figure 02.04.05-6 Comparison of SLOSH predictions with observed storm surge elevations (Source: Turkey Point Units 6 and 7 COL FSAR Figure 02.04.05-211, modified from Jelesnianski et. al, 1992)

The evaluation in NWS 48 (Jelesnianski et. al, 1992) considered only the storm surge height component of SLOSH predictions, not including contributions from antecedent water level. To apply the 20 percent model uncertainty indicated by NOAA NWS 48 to the modeling results for Turkey Point Units 6 and 7, the applicant determined the storm surge height component of the modeling results by subtracting the antecedent water level of 5.2 ft NGVD 29 (3.6 ft NAVD 88) from the model-simulated maximum surge level of 19.8 ft NGVD 29 (18.2 ft D 88), arriving at a modeled surge height of 14.6 ft. To account for model uncertainties, the applicant increased this value by 20 percent to arrive at an adjusted surge height of 17.5 feet. By adding the antecedent water level (5.2 ft NGVD 29 or 3.6 ft NAVD 88) to this adjusted maximum surge height, the applicant determined the PMSS elevation at Turkey Point Units 6 and 7 to be approximately 22.7 ft NGVD 29 or 21.1 ft NAVD 88.

The applicant concluded that no additional adjustment was needed to account for the greater surge elevation predicted by SLOSH when the radius of maximum wind was increased from 20 to 30 nautical mi. The applicant reasoned that the 20 percent adjustment to surge height to account for model uncertainties is much greater than the increase in surge elevation (approximately 2.6 percent of total surge elevation and 3.5 percent of the surge height component) calculated for the larger radius of maximum wind, so no additional adjustment in surge height is necessary to account for the potential effect of a larger radius (i.e., the 20 percent adjustment is sufficient to account for all sources of uncertainty).

The applicant compared its SLOSH model results with estimates of PMSS elevation provided in RG 1.59, which provides estimates of the PMSS elevation along the U.S. Gulf and Atlantic Coasts. The applicant stated that, from RG 1.59, the only location close to Units 6 and 7 where PMSS water level is available is Miami, FL, (25.787 ° N, 80.13 ° W). For this location RG 1.59 lists a wind set-up of 2.51 ft, a pressure set-up of 3.9 ft, an initial rise of 0.9 ft, and a 10 percent exceedance high spring tide of 3.6 ft above mean low water. These four components combine to give a total storm surge elevation of 10.91 ft above mean low water, which the applicant equates to approximately 9 feet NAVD 88 or 10.6 ft NGVD 29. The applicant stated that its implementation of the SLOSH Biscayne Bay basin model predicts a higher surge elevation of 11.2 ft NGVD 29, for Miami (represented in the model by grid cell [40, 88]), without accounting for long-term sea-level rise or adjusting for uncertainty in SLOSH predictions. Based on this comparison, the applicant concluded that the PMSS elevation obtained from the SLOSH model is more conservative than that presented in RG 1.59.

Staff's Technical Evaluation

Applicant SLOSH Simulations

In evaluating the applicant's analysis of PMSS, the staff reviewed the applicant's report of its application of the SLOSH model to predict storm surge from the PMH, the model documentation for the SLOSH model, the applicant's report of the verification and validation of the SLOSH model, and published studies of modeling of hurricane storm surge. The staff also performed limited confirmatory analysis using SLOSH.

The staff accepts the applicant's analysis as an appropriate implementation of the model. Additionally, the staff accepts the analysis as having adequately explored the sensitivity of model predictions to most of the factors potentially affecting storm surge elevation. The staff notes, however, that the applicant's analysis of the effect of PMH forward speed on storm surge considered only two values for PMH forward speed, 6 knots and 20 kts, the upper and lower end of the range specified in NWS 23. The analysis found that the higher value resulted in higher storm surge elevations. Research has shown, however, that storm surge height is not always correlated with storm forward speed; somewhat slower storms sometimes can result in higher surge elevations (Peng et al., 2004). The applicant's analysis does not demonstrate that a 20-kt forward speed is bounding for PMH storm surge at the Turkey Point Units 6 and 7 site, that is, that other values of forward speed between 6 kts and 20 kts would not result in higher storm surge at the Turkey Point Units 6 and 7 site. To resolve this omission, the staff issued RAI 5860, Question 02.04.05-4, which asked the applicant to provide sufficient reasoning and analysis to demonstrate that the effect of forward speed on storm surge elevation is bounded at Turkey Point Units 6 and 7 site.

In a November 16, 2011, response to RAI 5860, Question 02.04.05-4 (ADAMS Accession No. ML11321A3317), the applicant performed additional simulations with forward speeds of 6 knots, 13 knots, 16.5 knots, and 18.25 knots. The results show that the surge elevation at the site increases with increasing forward speed within the range specified in NWS 23 and is bounded by the forward speed of 20 knots. Thus, the staff considers RAI 02.04.05-4 resolved.

In its evaluation of the applicant's analysis of uncertainty and the sufficiency of the 20 percent increase in surge height that the applicant used to account for model uncertainty, the staff reviewed the applicant's SLOSH validation studies, the published information cited by the applicant, and evaluations by FEMA, USACE, and NOAA (2005) of the SLOSH model's accuracy in simulating surge levels for four hurricanes that occurred in 2004 (these are more

recent than the data set included in NWS 48). The staff observed that, for SLOSH estimates of storm surge less than about 14 ft NGVD 29, a significant number of observed surge levels exceed the SLOSH estimate by more than 20 percent, but for larger predicted surge elevations, no surge observations exceed the prediction by more than 20 percent. The staff accepts the applicant's determination that a 20 percent factor is sufficient to account for empirically determined uncertainty in SLOSH output.

The staff notes that the applicant had not provided clear technical justification, however, for the conclusion that the adjustment to storm surge height made to account for empirical uncertainty is sufficient to account for all uncertainty in PMH parameters. Of specific concern is the deterministically estimated effect on storm surge of a radius of maximum wind larger than 20 nautical mi. Although NWS 23 identified 20 nautical mi as the upper bound value of radius of maximum winds for a PMH, several major hurricanes striking the continental United States or the Caribbean in recent years had maximum winds at larger radial distances than 20 nautical mi. As summarized by Masters (undated), Hurricane Katrina in 2005 had a radius of maximum winds of about 30 mi (about 26 nautical mi) and Hurricane Ike of 2008 had a radius of 40 to 50 mi (about 35 to 43 nautical mi) one day before it made landfall. In 1995, Hurricane Luis in the Caribbean in 1995 had an eyewall radius of 60 km (32 nautical mi) and Hurricane Opal had an asymmetrical wind field as it approached its U.S. landfall, with maximum winds at 20 km (11 nautical mi) and a secondary maximum at a 60 km (32 nautical mi) radial distance (Powell and Houston, 1998). As discussed above, the highest storm surge elevation that the applicant found in its sensitivity analysis for the Turkey Point Units 6 and 7 site resulted from a radius of 30 nautical mi, at which value the predicted surge elevation at Units 6 and 7 was approximately 2.6 percent (3.5 percent, as a percentage of the surge height) higher than predicted when the radius of maximum wind was specified as 20 nautical mi. To address this issue, the staff issued RAI 02.04.05-6:

> Provide technical justification for the conclusion that the adjustment to storm surge height made to account for uncertainty in storm surge estimation is sufficient to account for the deterministically estimated effect on storm surge of a radius of maximum wind larger than 20 nautical mi.

In an October 21, 2011, response to RAI 02.04.05-6 (ADAMS Accession No. ML11298A089), the applicant described surge simulations using radius of maximum wind values of 25, 30, 40 and 100 nautical mi. The applicant stated that the highest storm surge elevation found by the analysis resulted from a radius of maximum winds of 30 nautical mi (3.5 percent of the surge height at a radius of maximum winds of 20 nautical mi). Furthermore, the applicant noted that the analysis arbitrarily assumed a constant value of Δp, but stated that when considering a larger radius of maximum wind, Δp should not be held constant (that is, a larger-radius hurricane would be associated with a lower pressure differential). In addition, the staff noted that the applicant's PMSS of 24.8 ft (using the 20 nautical mile radius of maximum winds) is within 0.1 ft of comparable USACE ADCIRC storms using a 30 nautical mile radius of maximum winds (exceedance probability10^{-7}) (details provided below). Thus, the staff considers RAI 02.04.05-6 resolved.

NRC and Army Corps of Engineers ADCIRC Simulations

In 2009, in order to specify acceptable methods for estimating design-basis floods that reflect changes in the state of the art flood estimation since 1977, especially for regions susceptible to

severe storm events, the NRC and USACE conducted a project to provide a technical basis for estimating probable maximum floods due to the storm surge from extreme storm events along the southern coast of the United States for consideration in evaluating flood protection for nuclear power plants.

As a result of the damaged caused by the 2005 hurricane season (e.g., Hurricane Katrina), USACE created the Interagency Performance Evaluation Task Force (IPET), a distinguished group of government, academic, and private sector scientists and engineers. IPET applied some of the most sophisticated capabilities available in civil engineering to understand what happened during Katrina and why. The IPET purpose was not just to acquire new knowledge, but also to improve engineering practice and policies. In addition, the Congress of the United States authorized the USACE to initiate two important and comprehensive planning efforts to address the impacts caused by the 2005 storms and to plan actions that would make the region more resilient and less susceptible to future risk from such disasters. One of the plans of actions was the Mississippi Coastal Improvements Program (MsCIP), which applied and further developed the technical approach and tools for estimating storm surge flood levels and waves established under IPET. The USACE studies, tools, and approach have all been extensively reviewed. Peer reviews have been conducted by distinguished External Review Panel (ERP) of the American Society of Civil Engineers, and the National Academy of Sciences. In the NRC/USACE project, these tools and approaches were applied to the South Texas Project, Levy County, and Turkey Point new reactor applications for the Estimation of Very-Low Probability Hurricane Storm Surges for Design and Licensing of Nuclear Power Plants in Coastal Areas (NUREG/CR-7134).

The USACE hurricane modeling system used for the Turkey Point storm surge analysis combines various wind models, the WAM offshore and STWAVE nearshore wave models, and the ADCIRC basin- to channel-scale unstructured grid circulation model. The modeling system is well validated and, in addition to being applied for Corps projects, has also been adopted by several FEMA regional offices for flood mapping.

Hurricane storm parameters (synthetic storms) are derived using the Joint Probability Method (JPM), which is extensively used by USACE and other agencies conducting storm hazard analyses (Resio and Irish, 2008; NUREG/CR-7134). For synthetic storms, the TC96 Planetary Boundary Layer (PBL) model (Thompson and Cardone, 1996) is applied to construct snapshots of wind and atmospheric pressure fields every 15 minutes for driving the surge and wave models. Storms are defined by a track and time-varying wind field parameters. For each storm, a unique set of input conditions is defined. The data file includes the track position in space and time, the forward speed and direction, central pressure, pressure scale radius (which is related to the radius to maximum winds), a rotation angle, and a pressure profile peakedness parameter termed the Holland B factor (Holland, 1980). The wind and pressure field is generated and positioned on a fixed longitude/latitude grid system covering the Gulf of Mexico. Based on the location of the storm center, these snapshots describe the temporal and spatial evolution of a hurricane. The final wind and pressure fields resulting from TC96 are targeted on a grid domain. The temporal variation in these fields is typically set to 1800 s (30 min) average wind. All wind-fields are marine-exposure (no effective roughness variations for land/sea changes), and generated at a 10 m elevation. The effect of ground cover on winds as the hurricane makes landfall is accounted for within the ADCIRC storm surge model.

The depth-integrated circulation model ADCIRC (Luettich et al., 1992; Westerink et al., 1994; Luettich and Westerink, 2004) was then run to compute the pressure- and wind-driven surge component. Imposing the wind and atmospheric pressure fields, the ADCIRC model could

replicate tide induced and storm-surge water levels and currents. In parallel with the initial ADCIRC runs, the large-domain, discrete, time-dependent spectral wave model WAM (Komen et al., 1994) was run to calculate directional wave spectra that serve as boundary conditions for the local-domain, near-coast wave model STWAVE (Smith et al., 2001; Smith, 2007). WAM generates the offshore wave field and directional wave spectra. The model solved the action balance equation for the spatial and temporal variation of wave action in frequency and direction over a fixed longitude-latitude geospatial grid. The numerical model STWAVE simulated nearshore wave transformation and generation. Using initial water levels from ADCIRC, winds that included the effects of sheltering due to land boundaries and reduction due to land roughness, and spectral boundary conditions from the large-domain wave model, STWAVE was run to produce wave fields and estimated radiation stress fields. The radiation stress fields were added to the estimated wind stresses, and applied as forcing in the ADCIRC model. ADCIRC estimates the water level across the entire grid at each time step.

Many coastal landscapes are characterized by complex bathymetry and topography. Natural features such as barrier islands, bays, inlets, marshes, lakes and rivers as well as man-made features such as levees, roadways, railways, navigation channels, gates, and seawalls all could influence surge and wave propagation. The surge and waves were not only influenced by the elevation of the landscape features, but also by the land cover, such as vegetation or buildings. The ADCIRC, TC96 PBL, and WAM model domains accurately capture basin-to-basin and shelf-to-basin physics, which is important in estimating high water levels that often occur well in advance of a hurricane's landfall.

The ADCIRC mesh contains over 2.3 million nodes with nodal spacing reaching as low as approximately 40 m in the most highly refined areas. Increased resolution across the coastal floodplain allows features such as inlets, rivers, navigation channels, levee systems and local topography/ bathymetry to be properly represented (Westerink et al., 1994). Levees and roadways are barriers to flood propagation that are generally below the defined grid scale. ADCIRC defines these structures as sub-grid scale parameterized weirs with a specified height (Westerink et al., 2001) within the domain. In addition, wave breaking zones are resolved to ensure that the grid scales of the surge and nearshore wave models are consistent. The nearshore wave forcing function is properly incorporated by adding resolution where significant gradients in the wave radiation stresses exist (IPET 2007; Bunya et al., 2009).

For a detailed, site-specific storm surge analysis, very extreme event storms are used that cover the range well beyond the annual exceedance probability of 10^{-6} (10^{-7} to 10^{-12}) (NRC, 1986). In the staff analysis, the period of record is chosen to be 1940–2009 (70 year) and considered east-to-west moving storms within a latitude-longitude box with boundaries at 77.4° W and 80.4° W longitude and 23.5°N and 27.5° N latitude. The staff analysis further limited the storms to those with central pressures, which are less than 990 mb in this box.

The Maximum Possible Intensity of a hurricane has been postulated as an upper limit for extreme tropical cyclone intensities at least since the late 1970's) (see for example: World Meteorological Organization, 1976 and Mooley, 1980). More recently, Emanuel (1986, 1991) and Holland (1997) formulated theoretical models for estimating maximum tropical cyclone intensity. The central pressures used in the analysis are 880 mb (lowest for the Atlantic) and 870 mb (lowest ever recorded worldwide) with radius of maximum winds 30 to 45 nautical mi. Note that by restricting the storm tracks to the paths shown in Figure 02.04.05-6, the exceedance probabilities could actually be lowered one order of magnitude (e.g., range 10^{-8} to 10^{-13}).

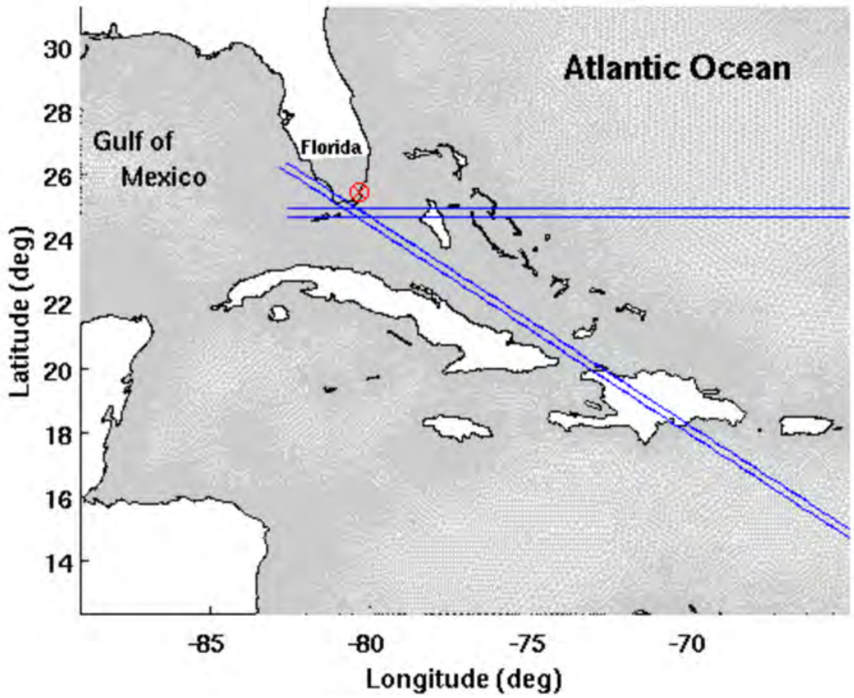


Figure 02.04.05-6 Storm tracks (blue lines) modeled in ADCIRC analysis for the Turkey Point site (shown with a red circle and x) in Florida.

Sea-level rise (1 ft NAVD88), initial rise (0.9 ft Mean Low Water) and the 10 percent exceedance high tide (3.6 ft Mean Low Water) were added to the ADCIRC still water level calculations, which included wind wave and wave setup (STWAVE/WAM). All Mean Low Water (MLW) heights were converted to NAVD88 (MLW = -1.9 ft NAVD88) and simulations were run at mean tide level. No adjustment was made equal to the difference between the 10 percent exceedance high tide and mean tide level, thus adding additional conservatism/margin.

Table 2.4.5.4-2 contains the USACE ADCIRC simulations adjusted for Turkey Point site-specific storm surge characteristics. The site characteristics were calculated in accordance with NRC guidance (RG 1.59 and NUREG-0800). In addition, the ADCIRC results were verified (December 2011 and January 2012) by the U.S. Army Engineer Research and Development Center's (ERDC) Coastal & Hydraulics Laboratory (CHL), which performed the original screening simulations. The PMSS for all 10^{-7} exceedance probability storms are 24.7 ft and below (site grade is 26 ft). Table 02.04.05.4-3 shows FPL SLOSH and comparable USACE ADCIRC simulations for storms having similar meteorological parameters. In summary, there was only a 0.1 ft difference (24.8 ft vs 24.7 ft), between the FPL SLOSH PMSS and the highest USACE ADCIRC PMSS for storms, respectively with a central pressure of 880 mb and probability of recurrence of 10^{-7}. This shows the very conservative nature of the applicant's storm surge analyses.

Table 02.04.05.4-2 USACE Turkey Point ADCIRC PMSS

PMSS (ft)	Surge (ft)	Wind (mph)	P (mb)	Rp (nm)	Vf (mph)	DeltaP (mb)	Exceedance Probability
27.0	20.4	138	870	30	6	141	10^{-8}
26.3	19.7	135	880	45	6	131	10^{-11}
26.1	19.5	134	870	45	6	141	10^{-12}
25.5	18.9	131	880	45	6	141	10^{-12}
25.5	18.9	138	870	45	13	141	10^{-12}
25.4	18.8	143	870	30	13	131	10^{-7}
24.9	18.3	135	880	45	13	141	10^{-12}
24.9	18.3	127	900	30	6	131	10^{-7}
24.7	18.1	140	880	30	13	131	10^{-7}
23.5	16.9	142	870	45	25	141	10^{-12}
23.2	16.6	137	870	30	6	131	10^{-7}
22.9	16.3	139	880	45	25	141	10^{-12}
22.7	16.1	133	880	30	6	131	10^{-7}
22.7	16.1	148	870	30	25	141	10^{-8}
22.2	15.6	145	880	30	25	131	10^{-7}
22.2	15.6	113	930	30	6	81	N/A
22.2	15.6	140	870	30	13	141	10^{-8}
22.1	15.5	132	870	45	6	141	10^{-12}
21.8	15.2	135	870	45	13	141	10^{-12}
21.7	15.1	129	880	30	6	131	10^{-7}
21.3	14.7	132	880	45	13	131	10^{-11}
21.3	14.7	137	880	30	13	131	10^{-7}
20.3	13.7	140	870	45	25	141	10^{-12}
20.0	13.4	146	870	30	25	141	10^{-8}
19.5	12.9	137	880	45	25	131	10^{-11}
19.5	12.9	143	880	30	25	131	10^{-7}
18.6	12.0	93	960	30	6	51	N/A

Table 02.04.05.3- FPL SLOSH vs USACE Turkey Point ADCIRC PMSS (880 mb, Rp=30 nm, 10^{-7} Exceedance Probability)

PMSS (ft)	Surge (ft)	Wind (mph)	P (mb)	Rp (nm)	Vf (mph)	DeltaP (mb)	Probability of Recurrence
FPL SLOSH							
24.8	17.5	159	880	30	23	135.5	N/A
USACE ADCIRC							
24.7	18.1	140	880	30	13	131	10^{-7}
22.7	16.1	133	880	30	6	131	10^{-7}
22.2	15.6	145	880	30	25	131	10^{-7}
21.7	15.1	129	880	30	6	131	10^{-7}
21.3	14.7	137	880	30	13	131	10^{-7}
19.5	12.9	143	880	30	25	131	10^{-7}

2.4.5.4.6 Wave Actions

Waves generated by hurricane winds increase water levels above the still-water levels resulting from storm surge, so the effect of wind-driven waves must be considered in determining the PMF elevation resulting from the PMSS.

Information Submitted by Applicant

The applicant investigated the effect of PMH wind field on the PMSS still-water level near Units 6 and 7 in order to estimate the PMH-induced waves, set-up, and run-up.

Hurricane Maximum Wind Speed

SLOSH model results were used to estimate the 1-minute average, 33 ft high wind speed at Units 6 and 7 during the PMH. The maximum wind speed corresponding to the PMH conditions that provide the maximum surge elevation is estimated to be 188.3 mph.

From SLOSH model results, the applicant estimated the maximum 1-minute average, 33-ft high wind speed at Units 6 and 7 as 188.3 mph. Following a procedure given in the Coastal Engineering Manual of USACE (USACE, 2005), the applicant converted this to the sustained 10-minute average, 33-ft-high wind speed. The converted 10-minute average wind speed is approximately 159 mph, which value the applicant used to calculate wind wave activities.

Wave Height, Period, and Run-up

The applicant notes that SLOSH model results indicate that a PMH surge elevation inundates the Elliott Key Barrier Island east of Biscayne Bay. Because the PMH maximum wind approaches from the Atlantic Ocean, the fetch length to produce wind waves during a PMH is very large. The applicant stated that wave heights at the retaining wall surrounding Units 6 and 7 would likely limited by the shallow water depth, with the breaking wave height representing the limiting wave condition beyond which waveforms cannot sustain. Because the breaking wave

condition would bound the maximum wave height, the applicant did not separately calculate the significant and 1 percent wave heights. Following procedures given in the Coastal Engineering Manual (USACE, 2005), the applicant calculated the breaking wave height and corresponding wave period in front of the retaining wall as approximately 15.4 ft and 5.1 seconds, respectively. To calculate wave run-up above the retaining wall (which would have a top of wall elevation of 21.5 ft NAVD 88 on the eastern side, and therefore could be overtopped by wind waves during a PMH), the applicant treated the ground above the wall as a berm with an equivalent slope based on the grade elevations between the retaining wall to the safety-related facilities. The surf similarity parameter, which defines wave breaking and run-up and depends on approach bottom slope and wave steepness, was calculated using equivalent deep-water wave parameters corresponding to the breaking waves at the retaining wall and the equivalent slope including the berm. By this approach, the applicant estimated the maximum wave run-up at the Turkey Point Units 6 and 7 sites as 3.7 ft.

Maximum Water Surface Elevation due to the PMH

Adding the wave run-up of 3.7 ft to the PMSS still water level of 21.1 ft NAVD 88, the applicant estimated the maximum water level due to a PMH at Units 6 and 7 as 24.8 ft NAVD 88.

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

The staff reviewed the applicant's analysis of wind conditions, formation of wind waves, and wave run-up during the PMH event, and accepts the analysis as sufficient to define the maximum wave height during this event.

2.4.5.4.7 Resonance

<u>Information Submitted by Applicant</u>

Turkey Point Units 6 and 7 are adjacent to the west shore of Biscayne Bay approximately 8 mi (13 km) west of the Elliott Key barrier island. The applicant reports that there are no records of seismic seiches within the bay. However, because the bay is a semi-enclosed body of water, seiche oscillation may occur due to atmospheric forcing. The applicant stated that it is likely that such oscillations would occur along the principal axis of the bay in the north-south direction. Assuming that the bay is approximately 25 mi (40 km) long, the natural period of oscillation for the bay is estimated to be approximately 36.8 minutes.

The applicant stated that because storm surges during a PMH event would overtop Elliott Key and other barrier islands, seiche oscillations within the bay would not be expected to coincide with large storm surge events like the PMSS.

In addition, the applicant noted that the natural period of oscillation is much greater than the period of wind-waves and shorter than the period of storm surge waves. Therefore, the applicant concluded that natural oscillations within the bay do not result in a resonance, and flooding of the plant area due to a seiche event in Biscayne Bay is precluded.

Staff's Technical Evaluation

The staff reviewed the applicant's reasoning regarding resonance in Biscayne Bay.

With an elevation of about 3 ft (0.8 m) above sea-level, the Elliott Key barrier island would be overtopped by the model-predicted storm surge from a PMH (Turkey Point Units 6 and 7 COL FSAR Figure 2.4.5-209 indicated a storm surge elevation at Elliott Key of about 15 ft (4.6 m) NGVD 29 in association the PMSS at Turkey Point Units 6 and 7) and inundated beneath more than 10 ft (3 m) of water (similar to the average depth of Biscayne Bay under normal conditions). Under those conditions, the staff finds that the barrier island would no longer function as a physical boundary that could contribute to a within-bay seiche, making it unlikely that such a seiche could add to the elevation of the PMSS from the PMH.

The staff reviewed the applicant's reasoning regarding the potential for natural oscillations within the Biscayne Bay to produce a resonance. The staff finds that the application discusses seismic forcing and acknowledges the possibility of atmospheric forcing as a contributor to seiche oscillation, but it does not discuss the possible role of ocean currents (such as the Florida Current) in contributing to oscillations (see Soloviev et al., 2003, and Davis et al., 2008).

Accordingly, the staff issued RAI 02.04.05-1 asking the applicant to provide sufficient reasoning and analysis to demonstrate that natural oscillations in the Biscayne Bay would not coincide with other phenomena to produce flooding that could adversely affect the safety-related facilities of Turkey Point Units 6 and 7. The RAI asked the applicant to demonstrate that all potential natural causes of oscillation are accounted for, and provide details for any quantitative analyses, calculations, and comparisons. The applicant responded on March 22, 2011, to RAI 02.04.05-1 (ADAMS Accession No. ML110840025).

In the response, the applicant described additional assessments that were conducted to examine other natural phenomena that might generate oscillations with periods close to the natural oscillation periods of the Biscayne Bay. The applicant stated that, in addition to seismic forcing and seiche oscillation induced by a PMSS, Florida Current and sea breeze forcing are the only phenomena identified to be capable of generating high frequency oscillations. The applicant's evaluations concluded that the Florida Current and sea breeze will not produce resonance responses in the Biscayne Bay and will have no safety-related flooding impact on the Turkey Point Units 6 and 7 site. The applicant noted that Florida Current is a major influence on the coastal circulation and current dynamics in the southeast Florida shelf, generating internal wave field and coastal ocean current oscillations with a dominant periodicity of about 10 hours (Refs. 1, 2, and 3). The applicant stated that Soloviev et al. (2003) illustrates that the presence of the Florida Current has no apparent effect on the sea-level and its oscillations near the shore, which still follows the tidal constituents with dominant periods near 12 and 24 hours. Therefore, the applicant concluded that there is no evidence to support a hypothesis that the Florida Current has any impact on the sea-level oscillations near the Turkey Point Units 6 and 7 site, despite its influence on the velocity and density fields. The staff accepts the applicant's assessments and considers RAI 02.04.05-1 resolved.

The applicant estimated the natural period of Biscayne Bay using methodology from Section 11-5-6 of the USACE Coastal Engineering Manual for open and closed basins. The analysis assumed that Biscayne Bay has an average depth of approximately 6 ft (1.8 m) (Caccia and Boyer; 2005) and is approximately 25 mi (40 km) long from north to south and 8 mi wide from east to west. In the north-south direction, the bay was postulated to be a closed basin, and an open basin in the east-west direction. The applicant estimated the natural oscillation periods of

Biscayne Bay during a normal sea condition as approximately 3.4 to 5.3 hours, which are much smaller than the observed oscillation period of 10 hours in the current and density fields. Therefore, the applicant determined that the potential for resonance in Biscayne Bay as affected by the Florida Current can further be precluded.

The applicant also evaluated the potential of resonance within Biscayne Bay from the forcing from sea breeze, which is caused by the diurnal (24-hour period) heating and cooling of the land and sea. The applicant noted that this 24-hour period is much greater than the natural oscillation periods of the Biscayne Bay, which are estimated to be approximately 3.4 to 5.3 hours. Militello and Kraus, 2001 observed that sea breeze can introduce diurnal oscillations and generate higher harmonic motions into water bodies. Their study, using an analytical solution and numerical modeling developed for a simplified one-dimensional idealized basin, illustrates that (1) the amplitudes of wind-forced motions at the higher harmonics are orders of magnitude smaller than that at the fundamental period, and (2) the wind-forced motions near the resonant modes can be almost completely damped by relatively small bottom friction in the water body. Consequently, the applicant concluded that flooding from resonance within the Biscayne Bay due to sea breeze is not expected.

The staff determined that the Turkey Point Units 6 and 7 COL FSAR did not include an evaluation of the potential for resonance within the makeup water reservoir (MWR) resulting from the interaction of natural oscillations with storm-driven wind waves. Accordingly, the staff issued RAI 02.04.05-2 asking the applicant to provide this evaluation. The applicant responded to RAI 02.04.05-2 on February 28, 2011 (ADAMS Accession No. ML110610686). The applicant stated that resonance is not expected because the natural periods of the MWR are much longer than the wave periods generated from storms such as the probable maximum hurricane. To determine the natural wave periods of the MWR, the applicant approximated it as a rectangular basin and applied Equation 11-5-26 of the USACE Coastal Engineering Manual (Chapter 5) for a closed water body. The applicant stated that the dimensions along the two principal axes of the MWR are approximately 2,200 feet and 766 feet (a north side dimension of 2,260 feet is used for this evaluation). With the top of wall and bottom elevations at 24.0 ft (7.3 m) and -2.0 (0.6 m) ft NAVD 88, respectively, the applicant determined the natural periods of the MWR to be approximately 156 and 53 seconds, based on the two principal dimensions and a full reservoir with 26 ft of water to account for precipitation. The applicant stated that the corresponding wave height and wave period for the maximum PMH wind condition at the Turkey Point Units 6 and 7 site is 2.4 ft (0.7 m) (NAVD88) and 1.7 seconds, respectively, following procedures in the USACE Coastal Engineering Manual (Chapter 2). Because of the large difference in wave periods, the applicant concluded that resonance in the MWR due to storm-driven wind waves is not expected.

The staff accepts the applicant's reasoning and analysis related to resonance and considers RAI 02.04.05-2 resolved.

2.4.5.4.8 Protective Structures

Information Submitted by Applicant

The applicant noted that the estimated PMSS still-water level at Turkey Point Units 6 and 7, combined with coincidental wind-wave run-up, of approximately 24.8 ft (7.6 m) NAVD 88 is lower than the design plant grade elevation of 26 ft (7.9 m) NAVD 88 for safety-related facilities. Therefore, the applicant concluded that the postulated PMH event does not affect the safety

functions of the plant, and debris, waterborne projectiles, and sediment erosion and deposition are not of concern to the safety-related facilities.

Staff's Technical Evaluation

The staff reviewed and accepts the applicant's basis for determining that if the PMH event does not affect the safety functions of the plant, then debris, waterborne projectiles, and sediment erosion and deposition associated with that event are not of concern to the safety-related facilities.

2.4.5.5 Post Combined License Activities

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

2.4.5.6 Conclusion

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.5 and PTN COL 2.4-2 and confirmed that the applicant has addressed the information relevant to probable maximum surge and seiche flooding, and that there is no outstanding information required to be addressed in the COL FSAR related to this section.

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

2.4.6 Probable Maximum Tsunami Hazards

2.4.6.1 Introduction

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

2.4.6.2 Summary of Application

This section of the Turkey Point Units 6 and 7 COL FSAR addresses the site-specific information about tsunami hazards. The applicant addressed the information as follows:

AP1000 COL Information Item

- PTN COL 2.4-2 Probable Maximum Tsunami

The applicant provided additional information in PTN 2.4-2 to resolve COL Information Item 2.4-1 (COL Action Item 2.4.1-2), which addresses the provision for site-specific information related to tsunami loading.

2.4.6.3 Regulatory Basis

The relevant requirements of the NRC regulations for the identification of tsunami floods, tsunami flood design considerations and the associated acceptance criteria are described in Section 2.4.6 of NUREG-0800.

The applicable regulatory requirements for identifying the effects of tsunami flooding are:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).
- 10 CFR 100.23(d) sets forth the criteria to determine the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.
- 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

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

- Regulatory Guide 1.29 as it relates to those SSCs intended to protect against the effects of flooding”;
- Regulatory Guide 1.59 as supplemented by best current practices
- Regulatory Guide 1.102 as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

2.4.6.4 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.6 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the probable maximum tsunami hazards. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL application are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the Turkey Point Units 6 and 7 COL FSAR:

AP1000 COL Information Item

- PTN COL 2.4-2

The staff reviewed PTN COL 2.4-2 related to include tsunami loading in Turkey Point Units 6 and 7 COL FSAR Section 2.4.5.

Evaluation of the information provided in PTN COL 2.4-2 related to tsunami loading at the Turkey Point Units 6 and 7 site is discussed below.

2.4.6.4.1 Probable Maximum Tsunami

Information Submitted by the Applicant

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.6.1, the applicant qualitatively summarized potential tsunami sources and their effects for four submarine landslide regions and two submarine earthquakes regions. The primary reference for these source regions that the applicant cited was ten Brink et al. (2008). The landslide regions include the U.S. Atlantic margin as far south as the Blake Escarpment, the Gulf of Mexico (Mississippi Canyon and carbonate landslides off the West Florida shelf, and Campeche Escarpment), the Canary Islands (specifically, off the volcanic island of La Palma), and the North Atlantic Ocean (the Storegga landslide offshore Norway and the Grand Banks landslide offshore Canada). Earthquake source regions for PMT determination include the Azores-Gibraltar plate boundary between the African and Eurasian tectonic plates and the northern Caribbean subduction zones.

In terms of other sources, intraplate earthquakes are not considered by the applicant in terms of defining the PMT. The applicant also did not provide any information regarding seismically induced seiches in Biscayne Bay. Finally, the applicant indicated that the flat topography near the Turkey Point Units 6 and 7 site prevents the occurrence of subaerial slope failures that may generate tsunami-like waves. The applicant indicated that the most likely source for the PMT is an earthquake in the Azores-Gibraltar region and that the associated maximum tsunami runup will not exceed the proposed plant-grade elevation.

Staff's Technical Evaluation

The staff conducted independent confirmatory analyses to determine the PMT at the Turkey Point Units 6 and 7 site. The detail is described in the sections that follow. A general conclusion found from the modeling was that while the Bahamas do not necessary shield the

Turkey Point Units 6 and 7 site from large incident tsunami waves, the very shallow and irregular nature of the Biscayne Bay makes penetration of tsunami wave energy through the Bay to the shoreline difficult. The Puerto Rico Trench landslide source proved to have the largest impact at the Turkey Point Units 6 and 7 site, with maximum water surface elevations due to the tsunami of 10.5 ft (3.2 m). The Florida Straits and Mid-Atlantic landslide sources have the potential to produce multi-meter wave heights, but produce smaller waves than the Puerto Rico landslide source. The Florida Straits source produced, by far, the largest wave height just offshore of the Bay in a water depth of 250 m (820.2 ft), but due to the relatively short period of these waves they were rapidly damped and scattered within the Bay. The Canary Islands source, despite generating sea surface elevation of 1 km at the source, led to a tsunami crest elevation less than 1.6 ft (0.5 m) offshore of the Turkey Point Units 6 and 7 site. The earthquake source has the smallest effect on the site, with maximum water surface elevations less than 0.5 ft (0.15 m). Thus the Puerto Rico Trench landslide source is the PMT, however the effects of the PMT are below that of the PMSS.

2.4.6.4.2 Historical Tsunami Record

Information Submitted by the Applicant

The applicant identified 11 historical tsunamis along the U.S. and Canadian Atlantic Coast and divides the historical tsunami record into four regions: (1) the Nova Scotia margin offshore Newfoundland, (2) the Caribbean region, (3) the mid- to North U.S. Atlantic margin, and (4) far-field sources. The primary source that the applicant uses is the National Geophysical Data Center (NGDC) tsunami database (http://www.ngdc.noaa.gov/hazard/tsu.shtml), which is a compilation of original tsunami catalogs and sources. A secondary source of information is the catalog by Lockridge et al., (2002) for the Delaware-New York coast.

In terms of historical tsunami observations near the site, for the first region related to the 1929 Grand Banks earthquake and landslide the applicant indicated a reading of 12 cm near Charleston, SC.

For the second region related to Caribbean tsunami sources, that applicant indicated that observations along the Florida Atlantic coast from these sources are absent. A 6 cm wave-amplitude observation was reported near Atlantic City, New Jersey, from the 1918 Mona Passage earthquake and landslide.

For the third region, tsunami waves from the 1886 Charleston earthquake were reported in Jacksonville and Mayport, Florida. No amplitude measurements were recorded. No waves were reported along the Florida Atlantic coast from the New Jersey and New York events listed in the tsunami database.

For far-field events, the applicant reports a 23 ft (7 m) reading in the Lesser Antilles Islands from the 1755 Lisbon earthquake. In addition, a 0.56 ft (17 cm) reading at Trident Pier in Port Canaveral, FL, was reported from the 2004 Sumatra-Andaman earthquake.

For paleotsunami events, the applicant indicates that an extensive literature search and review of borehole logs from the site revealed no evidence for paleotsunami deposits (cf. RAI 02.04.06-3).

The staff issued RAI 4809, Question 02.04.06-3 to obtain detailed information regarding (1) evidence of tsunami deposits at the site, distinguishing characteristics of tsunami versus

storm deposits, and interpretation of the boring logs, (2) updated information on submarine landslides offshore of Puerto Rico and indicate how these sources are included in PMT determination, (3) clarification that seafloor offset from earthquake sources is not necessary to generate significant tsunamis, with regard to mid-plate earthquakes, and (4) correction regarding the phrase "wide continental shelf" offshore of the site in relation to the attenuating effect of tsunami waves. The applicant responded to the staff's RAI 4809, Question 02.04.06-3 in a letter dated September 2, 2010 (ADAMS Accession No. ML102500207). In its response to RAI 4809, Question 02.04.06-3 (ADAMS Accession No. ML102500207), the applicant cross-referenced a Subsection 2.5.1.1.5 that doesn't exist in the Turkey Point Units 6 and 7 COL FSAR. No reference to tsunami deposit can be found in Section 2.5.1.

In RAI 4089, Question 02.04.06-2 (ADAMS Accession No. ML102150446), the staff requested that the applicant provide a complete description of the numerical modeling methodology used for the revised tsunami analysis and supple water level results specific to the site. The staff also asked the applicant to take into account the regional and local (site-specific) bathymetry/topography. The staff noted that the applicant's assertion that the site is sheltered by the Bahamas Islands from landslide-generated tsunamis north of the Puerto Rico depended on the results from RAI 4809, Question 02.04.06-2.

In response to RAI 4809 Question 02.04.06-2 (ADAMS Accession No. Ml102670160), the applicant did not specifically model tsunamis from landslides north of Puerto Rico. Further evidence is needed to verify this assertion. Third, the assertion that the impact of a submarine landslide to the north (offshore of the Carolinas) would be considerably reduced depends on the results from RAI 4809, Question 02.04.06-2. In response to RAI 4809, Question 02.04.06-2, the applicant did not specifically model tsunamis from landslides offshore of the Carolinas. Further evidence was needed to verify this assertion. Finally, the applicant did adequately address the issued that seafloor offset from earthquake sources is not necessary to generate significant tsunamis, with regard to mid-plate earth. The staff issued RAI 4809, Question 02.04.06-06 to request the applicant to provide the following:

- Provide the correct COL FSAR cross-reference for paleotsunami deposits.
- Justify the assertion that the Bahamas Islands shelter the site from landslide-generated tsunamis north of the Puerto Rico.
- Justify the assertion that tsunami water levels from submarine landslides to the north (offshore of the Carolinas) would be negligible at the site.

The applicant responded to the staff's RAI 4809, Question 02.04.06-6 in a letter dated October 10, 2010 (ADAMS Accession No. ML11286A088). In its response, the applicant resolved Part (1) (Subsection 2.4.1.1.5 exists in Revision 2 of the Turkey Point Units 6 and 7 COL FSAR). For Parts (2) and (3) of this RAI, the applicant provides justification for its assertions described in the original COL FSAR. For Part (2), the applicant referred to coarse-grid modeling described in ten Brink et al. (2008). Finer grid modeling and modeling of shorter wavelengths associated with landslide tsunamis may affect the numerical results, but a physical basis for the assertion is now provided in the COL FSAR revision (resolved). For Part (3), the applicant referred to modeling described in Hornbach et al. (2007) to justify its assertion. However, the Hornbach et al. (2007) study did not use conservative estimates of the landslide source parameters for tsunami generation. Hornbach et al. (2007) only investigated the upper part of the Cape Fear slide, relying on very limited bathymetry coverage to determine the size of the evacuated mass (they only looked at the scars around the diapir, and did not include the larger scar further

downslope). In the Hornbach et al. (2007) paper (Section 4.3.3), the authors made special mention to note that they have very limited constraints on slide volume, timing (they separate the scars into multiple “failures”), and triggering. There are likely limited constraints on mobilization parameters as well. The 2007/2008 USGS reports contain information on the Cape Fear slide clearly different from that in the Hornbach et al. (2007) paper, yet the applicant appeared to not explain its rational for choosing the Hornbach et al. vs. USGS source information.

Because the applicant’s offshore tsunami amplitude estimate from the Cape Fear landslide is close to its PMT offshore tsunami amplitude (1.5 m (4.9 ft) vs. 2 m (6.6 ft), respectively) and because the Hornbach et al. (2007) study did not use the most conservative parameters for landslide tsunami generation, further justification was needed for the applicant’s assertion that landslides to the north would be negligible at the site (Part 3). The staff issued RAI 6225, Question 02.04.06-08 requesting the applicant to provide justification that source parameters for the Cape Fear landslide from Hornbach et al. (2007) are conservative, with regard to not only the upper part of the landslide, but also the downslope region of failure. If the source parameters for this potential PMT source are revised, the applicant was requested to discuss how the revised source affects PMT water levels at the site. In a January 20, 2012, response to RAI 6225, Question 02.04.06-8 (ADAMS Accession No. ML12025A2491), the applicant provided the requested information.

In response to RAI 6225, Question 02.04.06-8, the COL applicant provided a new COL FSAR Subsection 2.4.6.4.2 that evaluates the impact at the Turkey Point Units 6 and 7 site from a tsunami generated as a result of a hypothetical submarine landslide event at a site identified as the Cape Fear Slide. It concluded, based on COL applicant modeling results and assessments inferred from recent published literature on the subject, that the flood risk at the Units 6 and 7 site from the Cape Fear Slide will be bounded by the postulated PMT, i.e., the 1755 Lisbon Earthquake tsunami, as described in Subsection 2.4.6.4.1. An additional discussion on the source characteristics of the Cape Fear Slide including the downslope region of the failure was provided. Furthermore, the COL applicant provided a quantitative assessment of the tsunami generation at the Cape Fear Slide using a set of conservative source parameters, and its propagation toward the Turkey Point Units 6 and 7 site using the numerical models, NHWAVE (Version 1.1) and FUNWAVE (Version 1.1), developed and maintained by the University of Delaware, is described. Specifically, the COL applicant’s response explained how the postulated Cape Fear Slide was represented in the model and describes the estimation of the wave shape and size generated by this slide, The COL applicant’s numerical simulations of the tsunami wave propagation and coastal inundation at the Turkey Point Units 6 and 7 site based on two alternative assumptions for the initial wave, corresponding to a dynamic source and a static source generated by the Cape Fear Slide, was also presented.

The staff verified that the above information is included in Turkey Point Units 6 and 7 COL FSAR Section 2.4.6 and considers RAI 4809, Question 02.04.06-3, RAI 5818, Question 02.04.06-6, and RAI 6225, Question 02.04.06-8 resolved.

Staff’s Technical Evaluation

The staff’s assessment of the historical record is consistent with that of the applicant. The applicant has summarized the essential historical record of tsunamis in the region. The complete history of tsunamis and tsunami-like waves along the Atlantic seaboard of the U.S. is given by Lockridge and others (2002).

With regard to the 1918 Puerto Rico tsunami cited by the applicant, the source is most likely a landslide triggered by an earthquake (López-Venegas et al., 2008). It is not representative of a Greater Antilles subduction zone earthquake, but rather normal faulting within the arc from oblique extension (Chaytor and ten Brink, 2010).

With regard to the1755 Lisbon tsunami, it should be emphasized that tsunami amplitude estimates along the Florida coasts were derived from a numerical model (Mader, 2001a).

The source parameters for the earthquake that generated this tsunami are very uncertain and likely to be complex (e.g., possibly compound earthquake rupture). Barkan and others (2009) indicated that tsunami amplitudes from this earthquake are likely to be less than 1 m (39.4 ft) and demonstrated the effect that source parameter uncertainty had on computed tsunami amplitudes at the U.S. East Coast.

The most relevant tsunami observations near the site appeared to be from the 1886 Charleston, SC, earthquake. At Jacksonville, Florida, reports were of "a tidal wave smashed along the Jacksonville beaches and thrust itself up the St. John River past Mayport…sailors dashed ashore as their vessels rocked and heaved on violent waves that whipped against the shore." In Mayport, Florida, reports were of "a sudden wave dashed high over the beach." In addition, the 1946 Dominican Republic seismogenic tsunami was recorded on the Daytona Beach tide gauge station although no amplitude measurements were available as indicated by the applicant in the Turkey Point Units 6 and 7 COL FSAR. Large waves up to 6 m (19.7 ft) that struck Daytona Beach and St. Augustine, FL, in 1992 were included in the NGDC tsunami database, but are likely of meteorological origin. The applicant therefore indicated the most relevant historical tsunamis in the Turkey Point Units 6 and 7 COL FSAR.

Evaluation of Turkey Point Boring Logs

An independent analysis of the geotechnical boring logs provided was conducted. The boring are focused toward a geotechnical/engineering purpose. Lastly, no definitive, widespread evidence of paleotsunami-type deposits (borings with items of note listed below) is found.

<u>Stratigraphy (see Section 2.5.1.1.2.3 of the COL FSAR for detailed discussion of these units)</u>

Formations present in borings include (youngest to oldest): *Muck*—mix of organic material, shell fragments, silt; high water content; often present in the upper 1 m of the borings overlying limestone/boundstone units; *Miami Formation*—poorly to well indurated, sandy, fossiliferous limestone (oolitic and bryozoans facies); *Fort Thompson Formation*—alternating beds of marine, brackish and freshwater limestones; *Tamiami Formation*—Poorly graded, silty, carbonate sand (contains shell fragments); *Hawthorn Group*—interbedded limestone, mudstone, dolomite, sandstone.

<u>Boring of Note</u>

Several characteristics of individual boring should be noted.

#B-620 (DH): contains 3 m (10ft) of gravel (gravel/sand) at the base of a limestone layer at a depth of 39 m (117 ft).

#B-635: ~ 1m (3ft) of fat clay at the ground surface.

#B-734: ~0.7 m (2ft) of lean clay at ground surface (above muck layer).

#B-736: ~ 0.7 m (2ft) of fat clay at ground surface (above muck layer)

#B-738: ~ 0.7 m (2ft) of fat clay at ground surface (above muck layer)

#B-802: ~ 1.3 m (4ft) of fat clay at ground surface (above muck layer)

As boring #B-620 is the only occurrence of this type section in the boring logs, it is unlikely that it is the result of paleotsunami deposition. Similarly, the presence of clay layers of varying thicknesses (i.e., #B-635, 734, 736, 738, and 802) above the muck layer is likely to be due to anthropogenic causes, or localized depositional processes. Therefore, the staff has reasonable assurance that there has been no history of paleotsunami at the site.

2.4.6.4.3 Source Generator Characteristics

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

The applicant identified two regions that are likely to define the PMT source for the site: the Azores-Gibraltar plate-boundary zone between the African and Eurasian tectonic plates, and the northern Caribbean subduction zones. The source parameters necessary to define tsunami generation from ten Brink and others (2008), including magnitude, depth to fault plane, fault dimension, orientation, and average fault slip, are tabulated by the applicant for each of these source regions.

For the Azores-Gibraltar plate-boundary zone (Figure 2.4.6-1), the applicant considered a 200 km (124 mi) long by 80 km (50 mi) wide earthquake rupture zone with an average slip of 13.1 m (43 ft). The applicant did not indicate the earthquake magnitude for this scenario but from these rupture dimensions and slip, assuming a shear modulus of 50–70 GPA and using standard formulas for seismic moment (e.g., Lay and Wallace, 1995), the staff calculated an approximate moment magnitude of Mw = 8.6 to 8.7. However, for the estimated tsunami water levels, the applicant used the source specification of Mader (2001a) rather than tabulated values (See Turkey Point Units 6 and 7 COL FSAR Section 2.4.6.5).

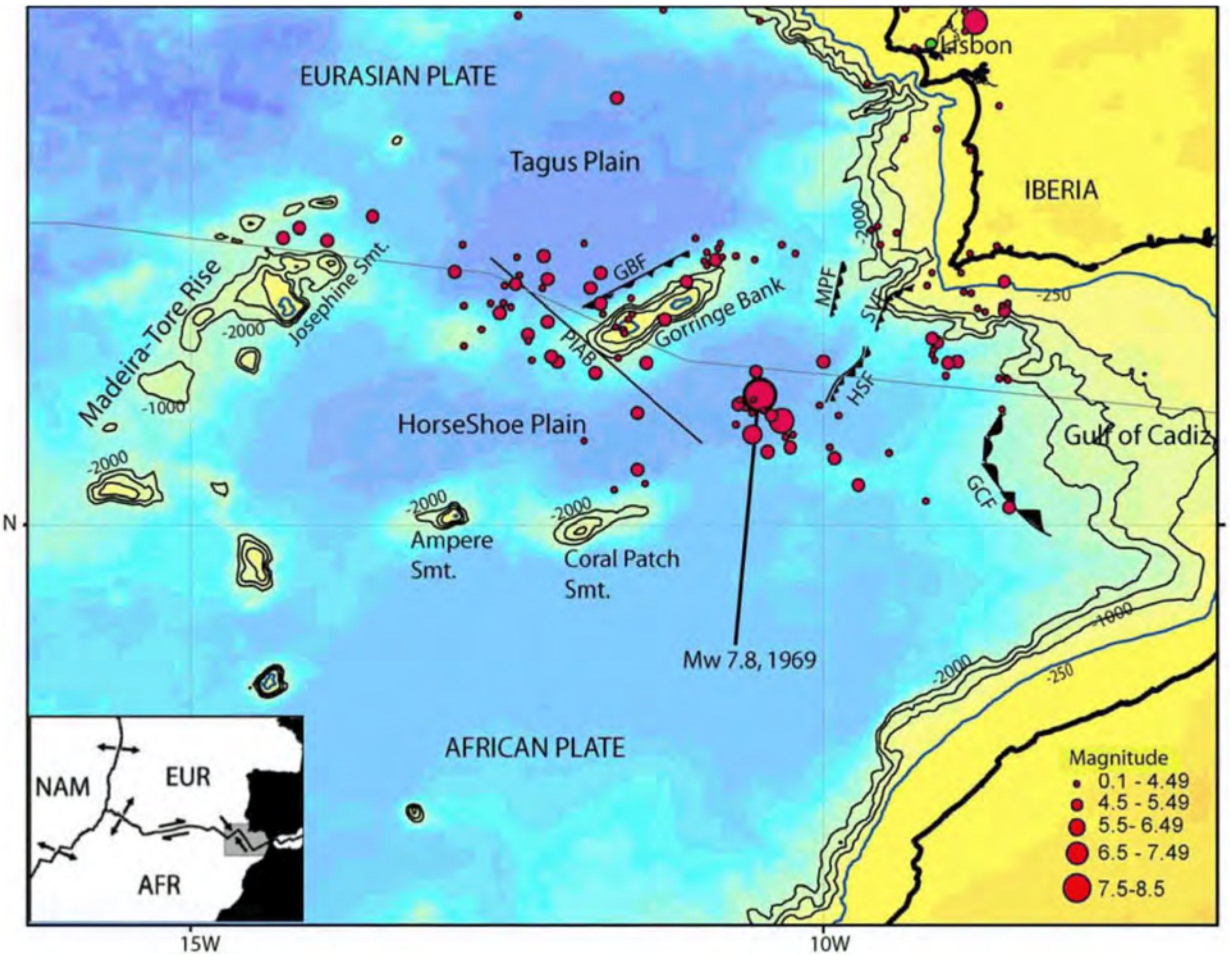


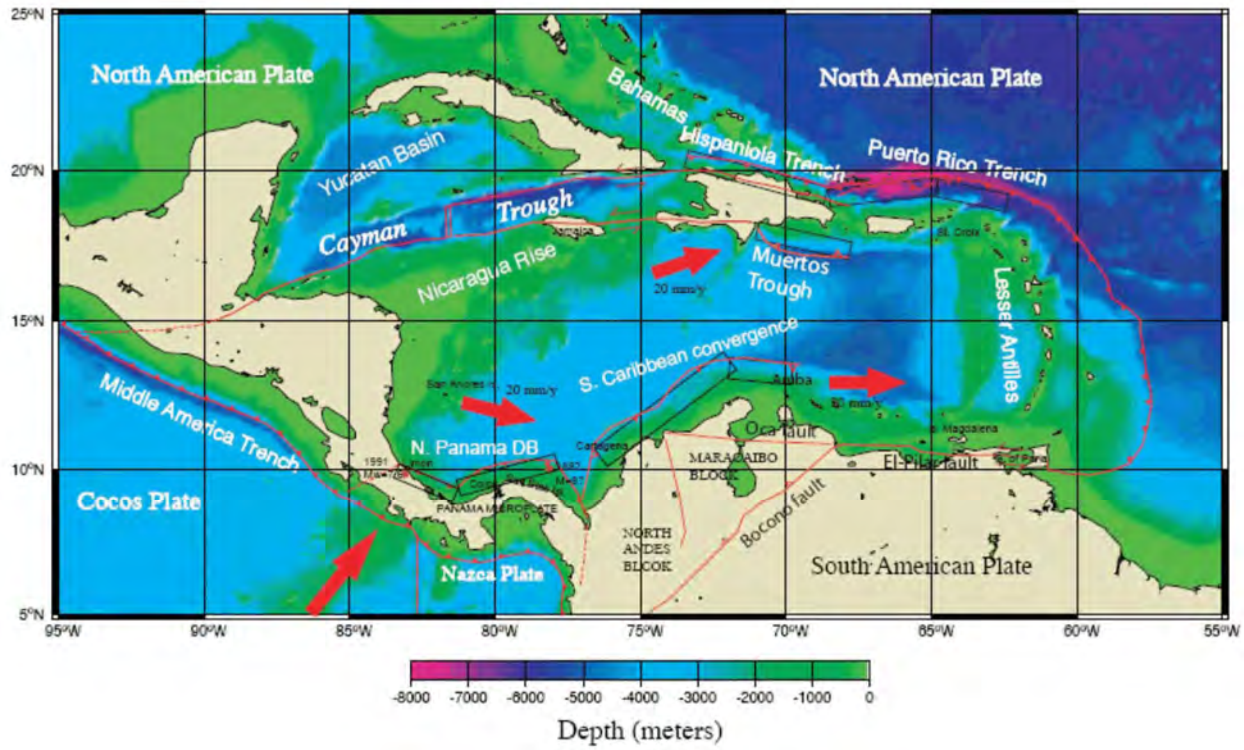
Figure 2.4.6-1: Azores-Gibraltar region showing various faults that make up the oceanic convergence zone boundary (Barkan and others, 2009).

For the northern Caribbean subduction zones (Figure 2.4.6-2), the applicant provided source parameters for both a Puerto Rico Trench and a Hispaniola trench earthquake rupture scenario. The magnitudes for each of these scenarios are *Mw* = 8.85 and *Mw* = 8.81, respectively.

However, in Turkey Point Units 6 and 7 COL FSAR Section 2.4.6.5 the applicant used the source specification by Knight (2006) for a Puerto Rico Trench earthquake only and not the tabulated values (i.e., a Hispaniola earthquake is not considered further).

Figure 2.4.6-2: The Caribbean Plate Boundary and its Tectonic Elements

To address submarine landslides in the Florida Straits/Bahamas/Cuba region as potential sources for PMT, the staff issued RAI 02.04.06-1 asking the applicant why these sources were not considered for the PMT and the justification for excluding them. The applicant responded to the staff's RAI 02.04.06-1 in a letter dated September 2, 2010 (ADAMS Accession



No. ML102500207). The applicant acknowledged evidence of Miocene debris flows in the Florida Straits region. However, it justified omission of Florida straits debris flows as potential tsunami sources for PMT determination on the basis of (1) absence of evidence for any correlated tsunami deposit along the southern Florida coast, and (2) the unlikelihood of debris flows similar to those that occurred in the Miocene under present-day sea-level-rise conditions. With regard to the first point, Miocene tsunami deposits would probably not be preserved over such a long period and in areas that are near sea-level now, given the changes in paleogeography since Miocene time. With regard to the second point, additional justification (e.g., past scientific studies) was needed to support this assertion. The staff also notes that the cross-referenced Subsection 2.5.1.1.5 did not exist in the Turkey Point Units 6 and 7 COL FSAR. The applicant might be referring in part to Subsection 2.5.1.1.1.5 with regard to Cuban geology.

The staff issued RAI 5818, Question 02.04.06-4 to request the applicant to provide justification for the assertion that debris flows in the Florida straits region, similar to those observed in the Miocene from drill-hole records, would not occur under present-day sea-level conditions, and to provide the correct cross-reference to Subsection 2.4.1.1.5, which does not exist in the Turkey Point Units 6 and 7 COL FSAR. The applicant responded to the staff's RAI 5818, Question 02.04.06-4 in a letter dated October 11, 2010 (ADAMS Accession No. ML11286A088).

The applicant evaluated the ocean circulation patterns and contourite/turbidite depositional regimes of the Florida Straits beginning in the Cretaceous, but still failed to justify ignoring the Florida Straits debris flows as a potential PMT source. Essentially, it said the sequence of events (contourite/turbidite deposition on the carbonate bank tops and falling sea level) responsible for the failure of the slope and deposition of the Miocene debris deposits observed in drill-hole records cannot occur today because of the ocean current regime and rising sea level. What was missing from its justification was a convincing explanation of the underlying cause of the slope instability; sea-level variations and the presence of an unknown thickness and composition of deposits on the bank tops did not provide a satisfactory description of the pre-conditioning/loading factors or triggers. The pre-conditioning factors and the triggering mechanism for the failure were unknown (could be any or all of the usual triggers: tectonic, sediment loading, current undercutting, underlying structure, pore pressure variations), so excluding them as possible PMT sources based on sea level and ocean currents alone was not a basis for determining if debris flows will happen again. Moreover, younger likely Pleistocene-age debris deposits occur at the western-most end of the Florida Straits near the Florida Slope/Escarpment and in a similar geologic environment (Holmes, 1985; Twichell and others, 1993), further suggesting the possibility of debris flows in the Florida Straits near the site.

As a result of insufficient justification provided by the applicant addressing why debris flows in the Florida straits region would not occur, the staff issued RAI 6225, Question 02.04.06-7. The staff requested the applicant to provide justification that triggering conditions for submarine mass failures in the Florida Straits are not currently present. If triggering and pre-conditioning factors/loading conditions such as those that caused the Miocene debris flows and likely Pleistocene-age failures at the western end of the Florida Straits (Holmes, 1985; Twichell and others, 1993) cannot be determined, the applicant requested to explain whether potential submarine mass failures can be conservatively excluded. If such failures are considered, the applicant was asked to discuss how inclusion of this source affects PMT water levels at the site.

In its January 20, 2012, response to RAI 6225, Question 02.04.06-7 (ADAMS Accession No. ML13100A104), the COL applicant elected to supplement the COL FSAR evaluation with numerical model simulations, using the NHWAVE and FUNWAVE codes developed and maintained by University of Delaware, to provide a quantitative estimate of the flood level at the site and reaffirm that the tsunami source of concern will not affect the probable maximum tsunami (PMT) flood level reported in the COL FSAR. The COL applicant's simulations of a tsunami generated by a conservatively large submarine mass failure at the Florida Escarpment suggested that the impact of such an event on water levels near Turkey Point Units 6 and 7 would be smaller than that of the postulated PMT presented in Subsection 2.4.6.4.1. The maximum predicted water level near Turkey Point Units 6 and 7 due to this tsunami event would be 1.71 m (5.6 ft) MLW or 1.14 m (3.7 ft) NAVD 88, representing a rise of only 0.02 meter (0.065 foot) above the initial sea water level. The assumed initial sea water level in the FUNWAVE model simulation includes the 10 percent exceedance high tide, an initial rise plus the long-term sea-level rise, all of which add up to 1.68 m (5.5 ft) MLW or 1.11 m (6 ft) NAVD 88. This water level was much smaller than the maximum tsunami water level of 4.5 m (14.76 ft) MSL (4.82 m (15.81 ft) MLW) reported for the PMT case in Subsection 2.4.6.5. This conclusion was also consistent with the results of the Florida Escarpment Slide evaluation described in Subsection 2.4.6.1.2.

The staff verified that the above information was included in Turkey Point Units 6 and 7 COL FSAR Section 2.4.6, and considers RAI 02.04.06-1, RAI 02.04.06-4 and RAI 02.04.06-7 resolved.

Staff's Technical Evaluation

Tsunami sources used for the independent confirmatory analysis were described in terms of their identification, characteristic, and tsunami generation parameters. Potential tsunamigenic sources are first discussed below, followed by parameters associated with the maximum credible earthquakes and submarine landslides around the Atlantic Ocean basin.

Potential Tsunamigenic Sources

Potential tsunami sources likely to determine the PMT at the Turkey Point site are as follows:

Subaerial Landslides

With regard to subaerial landslides, there are no major coastal cliffs along the Florida coast near the site that could be a location of large sub-aerial landslides. Thus, there are no areas of subaerial coastal landslides near the site that would produce tsunami-like waves exceeding the amplitude of those generated by other sources. Similarly, no major coastal cliffs exceeding 10 m (30 ft) are present along the western margins of the islands of the Bahamas.

Coastal elevations, which rarely exceeding 30 m (100 ft), are present along a segment of the north-central Cuban between Havana and Matanzas. Pliocene to Holocene age limestone formations (likely Matanzas and Jaimanitas formations; de la Torre y Callejas, 1966) crop out along the coast forming low coastal cliffs above extensive, shallowly submerged coastal platforms. Iturralde-Vinent (2009) noted the presence of boulders on coastal terraces along the north coast of Cuba, which he attributed to tsunami deposition, but, the emplacement mechanism of these boulders has not been well studied. Iturralde-Vinent (2009) described the presence of minor coastal rock falls originating from limestone cliffs along the south coast of Cuba, but did not identify any similar features along the north coast. Although coastal erosion leading to rock fall along the limestone cliffs is possible along the north coast of Cuba, the fractured nature of the limestone formations and the presence of shallow water platforms on to which they fall would likely limit any resulting water disturbance. See below for details of subaerial landslides associated with volcanogenic sources.

Volcanogenic Sources

According to the Global Volcanism Program of the Smithsonian Institution (http://www.volcano.si.edu/), there are three general regions of volcanic activity that have the potential to generate localized wave activity along the Florida coast and Caribbean Sea: (1) two Mexican volcanoes near the Gulf of Mexico coastline, (2) two volcanoes in the western Caribbean, and (3) volcanic activity along the Lesser Antilles island arc. Two Mexican volcanoes, (Cerro el Abra/Los Atlixos and San Martin) associated with the eastern Trans-Mexican Volcanic Belt, are near the Gulf of Mexico coastline. Basaltic flows associated with Los Atlixcos have reached as far as the coast. Capra et al. (2002) provided an inventory of major debris avalanches associated with the Trans-Mexican Volcanic Belt. In that study, there did not appear to be any major catastrophic failures that would reach the Gulf of Mexico. In the eastern Caribbean, Utila Island, located offshore Honduras, comprises primarily pyroclastic cones and rises 74 m (242.8 ft) above sea level. However, any flank failures are unlikely to generate significant wave activity in the Gulf of Mexico or Caribbean, owing to the size of the failures and obstructed propagation paths around the Yucatan Peninsula. Also in the western Caribbean, Volcán Azul on the coast of Nicaragua comprises three small cinder cones, but these were unlikely to generate significant tsunamigenic failures of sufficient size to affect the

site. There are many active volcanoes along the Lesser Antilles island arc, some of which have historically caused local tsunamis (Pelinovsky and others, 2004). However, because of their distance to the Turkey Point site and the obstructed propagation path created by the islands of the Greater Antilles, tsunami amplitudes from these volcanoes are unlikely to be significant (e.g., Smith and Shepherd, 1995).

In summary, catastrophic failures associated with volcanoes along the eastern coasts of Mexico and Central America were either too far inland or too small in size to generate significant wave activity near the Turkey Point site. Based on existing evidence, volcanoes along the Lesser Antilles or in the eastern Atlantic Ocean are too far away or unfavorably situated to generate significant wave activity along the east Florida coast near the Turkey Point site.

Canary Islands Region: The maximum credible landslide event is a catastrophic volcanic flank failure along the SW flank of La Palma Island. The maximum estimated landslide volume is 500 km^3 (Ward and Day, 2001), though Masson and others (2006) note that this volume is 2–3 times bigger than a typical Canary island landslide and that such landslides often fail as separate (in terms of tsunami generation) sub-events. The geologic age of these landslides range from 13,000–17,000 years before present (ybp) for the El Golfo landslide on El Hierro Island, to over a 1 million ybp (Masson et al., 2002; Masson et al., 2006). From these studies, the age of the Cumbre Nueva landslide for which the maximum credible landslide event is based is 125,000–536,000 ybp.

The initial research on the La Palma flank failure (Ward and Day, 2001) predicts wave heights of 10–25 m (32–82 ft) on the eastern shore of North America from the 500 km^3 landslide volume. The hydrodynamic model used by Ward and Day (2001), however, did not include the effects of non-linear advection or wave breaking. More recent research that incorporated these effects suggested wave heights along the eastern U.S. coast from this failure would be less than 3 m (9.8 ft) (Mader, 2001) or less than 1 m (3.3 ft) (Gisler and others, 2006).

Intra-Plate Earthquakes

Cuba: Low to moderate levels of seismicity has been recorded across most of Cuba, with an increase in intensity (occurrence and magnitude) in the vicinity of the Oriente Fault Zone along the south coast of the island. Potential tsunamigenic faults are present along the north coast of Cuba. Specifically, the offshore sections of the Nortecubana thrust fault system but the activity of these faults and their earthquake slip/tsunami generation potential are largely unconstrained. Significant amounts of slip on some of the faults of the Nortecubana system have been identified on seismic sections (Garcia and others, 2003), but Echerarvia-Rodriguez and others (1991) and Moretti and others (2003) found that the offshore sections of the faults are draped by an undisturbed Tertiary to Quaternary sedimentary section suggesting the system has been inactive for at least tens of thousands of years.

Inter-Plate Earthquakes

The Greater Antilles Subduction Zone: This fault represents the boundary between the North American and Caribbean tectonic plates (North American plate is subducted beneath the Caribbean plate). The earthquakes that are generated along subduction zones involve thrust motion with large amounts of vertical seafloor motion and are relatively efficient at generating tsunamis. In comparison, transform plate boundaries involve strike-slip motion and are much less efficient at generating tsunamis. Because the relative convergence direction between the two plates at the Greater Antilles subduction zone is highly oblique to the orientation of the fault

it is possible that there may be a mixed mode of thrust and strike-slip motion for earthquakes at this subduction zone.

The large surface area of subduction zone faults results in the occurrence of the world's largest earthquakes on these thrusts. As explained by Geist and Parsons (2009), there are several methods to determine the maximum magnitude that can occur on subduction zones. The most conservative method is a statistical fit to the frequency-magnitude distribution of earthquakes (known as the Gutenberg-Richter distribution) that occur on all of the world's subduction zones (Bird and Kagan, 2004). Because the length of the Greater Antilles subduction zone may limit the maximum earthquake magnitude possible, parametric and empirical methods are also considered.

The Azores-Gibraltar Oceanic Convergence Boundary: The offshore boundary between the African and Eurasian tectonic plates was classified as an oceanic convergence boundary (Bird, 2003). An M=8.4-8.7 earthquake along this plate boundary offshore of Lisbon in 1755, generated a transoceanic tsunami that was observed in the Caribbean and Canada (Barkan et al., 2009). The specific faults that make up this plate boundary in the Azores Gibraltar region are highly complex. Using the statistical analysis of Bird and Kagan (2004), the magnitude distribution of earthquakes along the world's oceanic convergence zones can be estimated. Because of a much smaller sample size in comparison to subduction zones, however, there is much greater uncertainty in the distribution curves for the earthquakes (Geist and Parsons, 2009).

Local Submarine Landslides

Currituck

The Currituck (also known as the Albemarle) landslide was approximately 60 km south of Norfolk Canyon, offshore of the Outer Banks of North Carolina.

The Currituck landslide likely occurred as two sub-events, which appear to have occurred contemporaneously (Locat et al., 2009). The total volume of the landslide was estimated to be 128 km^3 (30.7 mi^3) by Prior and others (1986) and 165 km^3 (39.6 mi^3) by Locat et al. (2009). The latter estimate was used as the maximum credible volume. In terms of the geologic setting of this landslide, Quaternary shelf edge delta deposits make up the bulk of the failed material, but some Pliocene strata may have been removed as well (Bunn and McGregor, 1980; Prior and others, 1986). There is approximately 4-9 m of sediment that has accumulated since the Currituck slope failure (Prior and others, 1986). The age of the failure is unknown, but might be approximately 25,000–50,000 ybp, based on average sedimentation rates of 5 cm/year (2 in/yr) for sediment burying the scar and deposits (Prior and others, 1986; Lee, 2009).

Cape Fear/Cape Lookout

The Cape Fear and Cape Lookout landslides are off the South Carolina and Georgia coasts, seaward of the Carolina Trough. These landslides occur in a different geologic setting to those landslides north of Cape Hatteras (such as the Currituck landslide), and therefore different processes contributed to their formation. The headwall scarps of these failures are near salt domes and the tectonic activity of the salt domes has been suggested as a triggering mechanism (Dillon et al., 1982; Popenoe et al., 1993; Cashman and Popenoe, 1985; Hornbach et al., 2007). The decomposition of gas hydrates due to changes in sea level has also been suggested to have contributed to triggering these failures (Popenoe et al., 1993; Schmuck and

Paull, 1993). The recent observation of small, shallow earthquakes along this section of the continental margin (Ekström, 2006) suggests that seismic activity may have also contributed to the formation of these landslides.

From an analysis of multi-beam bathymetry, the Cape Fear submarine landslide covers an area of 7,270 square kilometers (km^2) (1,817,500 acres) (excavation zone) and has an estimated volume of 342 km^3 (82.1 mi^3) (excavation zone). It has a stepped (potentially retrogressive) headwall, with mapped scarps at water depths of 930 m (3,051.2 ft) and 3,250 m (10,662.7 ft). The Cape Lookout submarine landslide has a more complex morphology, making calculation of its dimensions more difficult. It was estimated that the Cape Lookout landslide covers an area of approximately 3,630 km^2 (907,500 acres) (excavation zone) and has a volume (excavation zone) of approximately 216 km^3 (51.8 mi^3). The headwall of the Cape Lookout landslide as currently mapped is at a depth of 2,600 m (8,530.2 ft), although it may be significantly shallower.

Florida Straits Miocene Debris Flows

Ocean Drilling Program (ODP) Leg 101, Site 626 drilled in the Straits of Florida (Figure 2.4.6.4.3-2), penetrated a 50 m (164 ft) thick interval of mid-Miocene age, clast-heavy, carbonate debris flow sediments between 120 m (393.7 ft) and 170 m (557.7 ft) (below seafloor) (Fulthorpe and Melillo, 1988). The clasts and matrix material of this debris flow unit (Unit II of Austin et al., 1986) have a similar composition to the winnowed periplatform sediments found on the modern upper-slope along the eastern margin of the Straits of Florida (Mullins and Newmann, 1979). Based on analysis of seismic reflection profiles, the debris flow unit pinches out to the north and west, suggesting a source along the eastern margin of the Straits of Florida (Fulthorpe and Melillo, 1988). Although the true dimensions of this slope failure are unknown due to limited data, an estimate of the area and volume of failed material involved in this event is made based on the geometry of other platform-edge slope failures identified around the Bahamas (see below) and the estimated thickness of the modern-day periplatform deposits and winnowed sand units along the upper slope of the eastern margin of the Straits of Florida. Assuming a landslide headwall length of 5 km (3.1 mi), a downslope length of 1.7 km (1.1 mi), and a maximum thickness of 0.1 km, the area and volume of the excavation zone are 8.5 km^2 (2,125 acres) and 0.425 km^3 (0.1 mi^3), respectively.

Other Miocene gravity/debris flow and turbidite deposits were identified on seismic reflection profiles and drilled at ODP Leg 101 sites 627, 628, and 630, along the northern margin of Little Bahama Bank (LBB). Harwood and Towers (1988) provide estimates of the volumes of these deposits, although they appear to be erroneous (given Harwood and Towers (1988) measured areas of these deposits, the thickness of sediments required to achieve their stated volumes would need to be in the tens to hundreds of kilometers thick).

Modern (Holocene-late Pliestocene) debris flow and turbidite deposits have been identified throughout the Bahamas. These deposits have been found in the inter-island basins (Tongue of the Ocean, Columbus basin, Exhuma Sound) and associated with platform margin gully wall collapse. Turbidite deposits in Columbus basin occur every 3,000-6,000 years and have volumes on the order of 0.1 km^3 (0.02 mi^3) (Bornhold and Pilkey, 1971).

Far-Field Submarine Landslides

Puerto Rico Trench

Numerous landslide scarps of various sizes are present along the southern margin of the Puerto Rico Trench. They are primarily within the Arecibo and Loiza amphitheaters but also elsewhere along the edge of the PR-VI carbonate platform and within Mona Canyon. While the Aricebo and Loiza amphitheaters were initially considered to each be the result of large, potentially catastrophic slope failures (volume estimates of up to 1,500 km^3; Schwab and others, 1991; Mercado et al., 2002), recent analysis of high-resolution geophysical data and sediment cores suggests that the amphitheaters were created by numerous, smaller failure events (ten Brink et al., 2006). The largest of the landslides identified by ten Brink and others (2006) has a volume of 22 km^3 (5.8 mi^3). Lopez-Venegas and others (2009) identified a submarine landslide at the head of Mona Canyon northwest of Puerto Rico (volume of 10 km^3 (2.4 mi^3)) that may have been initiated by the 1918 Mona Passage earthquake and been the principle source of the tsunami that affected Puerto Rico and nearby coasts.

Summary

The following findings of the staff's independent confirmatory analysis of the tsunami source characteristics are provided below:

- There was sufficient evidence to consider submarine landslides in the Florida Straits and north of Puerto Rico as a present-day tsunami hazard for the purpose of defining the PMT at the Turkey Point site.

- Parameters for the maximum submarine landslide were determined for each of the provinces using regional data past: i.e., past landslides around the Bahamas and along the south wall of the Puerto Rico Trench.

- Important additional sources to determine the PMT include landslide sources along the mid-Atlantic margin and the Canary Islands and seismogenic sources along the northern Caribbean subduction zone.

2.4.6.4.4 Tsunami Analysis

Information Submitted by the Applicant

Several tsunami computational models are currently used in the National Tsunami Hazard Mitigation Program, sponsored by the National Oceanic and Atmospheric Administration, to produce tsunami inundation and evacuation maps for the states of Alaska, California, Hawaii, Oregon, and Washington. The computational models include MOST (Method of Splitting Tsunami), developed originally by researchers at the University of Southern California (Titov and Synolakis, 1998); COMCOT (Cornell Multi-grid Coupled Tsunami Model), developed at Cornell University (Liu et al., 28 1995); and TSUNAMI2, developed at Tohoko University in Japan (Imamura, 1996). All three models solve the same depth-integrated and 2D horizontal (2HD) nonlinear shallow-water (NSW) equations with different finite-difference algorithms. There are a number of other tsunami models as well, including the finite element model ADCIRC (ADvanced CIRCulation Model for Oceanic, Coastal, and Estuarine Waters) (e.g., Myers and Baptista, 1995). However, the shallow-water equation models lack the capability of simulating dispersive waves, which could be the dominating features in landslide-generated tsunamis and for tsunamis traveling a long distance. Several high-order depth-integrated wave hydrodynamics models (Boussinesq models) are now available for simulating nonlinear and weakly dispersive waves, such as COULWAVE (Cornell University Long and Intermediate Wave Modeling Package) (Lynett and Liu, 2002) and FUNWAVE (Kennedy et al., 2000). The major

difference between the two is their treatment of moving shoreline boundaries. Lynett et al. (2003) applied COULWAVE to the 1998 PNG tsunami with the landslide source: the results agreed well with field survey data.

Originally, the applicant did not perform hydrodynamic modeling according to any of the aforementioned methods in establishing tsunami water levels at the site. The applicant's tsunami analysis primarily consists of applying past studies to ascertain the tsunami-wave-propagation characteristics from the two source regions discussed in Section 2.4.6.3 and to estimate tsunami amplitudes offshore of the site. The applicant used different types of tsunami analysis to estimate tsunami water levels for each of the two source regions, as further described in COL FSAR Section 2.4.6.5.

For the Azores-Gibraltar earthquake scenario, the applicant cited the results of Mader (2001a). The Mader (2001a) study used the SWAN code based on nonlinear shallow-water wave equations that includes Coriolis and frictional effects. A 10 minute bathymetric grid was used in this study to calculate tsunami amplitudes. The applicant further cited studies by ten Brink et al. (2008) for this source zone.

For the Puerto Rico Trench earthquake scenario, the applicant cited an analysis of open-ocean propagation by Knight (2006). The tsunami analysis method used by Knight (2006) is generally a depth-averaged model from the University of Alaska, Fairbanks, but not further specified either by the applicant or by Knight (2006). The bathymetric grid spacing varies in Knight's (2006) study, depending on the resolution of the available data.

The staff issued RAI 4809, Question 02.04.06-2 requesting that the applicant provide a complete description of the numerical modeling methodology used for the revised tsunami analysis and supply water level results specific to the site, taking into account the regional and local (site-specific) bathymetry/topography. The applicant responded to the staff's RAI 4809, Question 02.04.06-2 in a letter dated September 22, 2010 (ADAMS Accession No. ML102670160).

The applicant provided a reasonable description of the site-specific numerical modeling they performed to determine water levels related to an offshore Lisbon earthquake tsunami source that they determine is the PMT source. The applicant used Delft3D, which includes the effects of nonlinearity but not dispersion (Stelling and van Kester, 1994; Stelling and Leendertse, 1991). This model is commonly used for a variety of hydrodynamic problems, including some forms of tsunami waves. Previous studies (Apotsos et al*.,* 2011a, 2011b, 2011c) indicate that this model can predict the run-up associated with benchmark-like tsunami experiments and analytical solutions well, and approximates the inundation for the 2004 tsunami at Kuala Meurisi, Sumatra well. The applicant also indicated that no wave breaking is included in the model. However, although the non-conservative form of the non-linear shallow-water equations (NLSWEs) has no unique solution at local discontinuities, the use of conservative properties, as is done with the Delft3D framework, is often sufficient to provide solutions that are acceptable in terms of the local energy losses in and the propagation speed of a bore. The PMT conducted under the independent confirmatory analysis primarily uses the COULWAVE model above that includes the effects of nonlinearity and dispersion.

In the applicant's response to RAI 4809, Question 02.04.06-2, there were some unresolved issues listed below that relate to theoretical basis of the model, its verification and the conservatism of all input parameters:

1. In terms of setting up the model, the applicant did not specify what type of offshore boundary condition is used. The applicant should verify that artificial reflections off this boundary do not influence its predictions (note there is a way to create a non-reflective boundary condition for sinusoidal waves but they do not mention using it).

2. It is unclear as to the effect of having a closed southwest boundary. There may be spurious reflections off this closed boundary. It would be reassuring if the applicant ran another simulation where the southwest boundary is extended a bit further into the Gulf of Mexico to show that shifting this boundary does not affect the model results, especially because the boundary is still fairly close to the site.

3. The applicant indicated that the water level at the site is larger when they used a Manning's *n* value of 0.02 instead of 0.025 that they prefer (pg. 14 of the RAI response). For conservatism, the applicant should use the lower *n*-value unless the water-level difference is negligible.

4. In the applicant's description of DEFLT3D on pg. 7 of the RAI response, the applicant indicated that the model does not included a wave breaking mechanism. This statement needs should be verified. Some discussion should be included in the FSAR as to the general conservatism of DELFT3D under the assumption listed in Section 2.4.6.4.1 of the FSAR revision.

5. It is unclear that the sinusoidal wave that the applicant uses is the most conservative waveform. Although they tune it to the wave amplitude and period obtained by Mader (2001) for the 1755 Lisbon tsunami at 238.7 m (783 feet) water depth, it is possible that a steeper non-sinusoidal wave would have larger run-up.

The staff issued RAI 5818, Question 02.04.06-5 to address the unresolved issues from RAI 4809, Question 02.04.06-2, requesting the applicant provide the following: (1) specify what type of offshore boundary condition is used and verify that any artificial reflections off this boundary do not influence water level predictions, (2) verify that shifting the southwest boundary of the model does not affect water level predictions at the site, (3) clarify whether a Manning's *n* value of 0.02 yields more conservative water level predictions at the site, compared to a Manning's *n* value of 0.025, (4) clarify whether DELFT 3D includes the effects of wave breaking as used to determine PMT water levels, and (5) determine whether alternate boundary conditions yield higher runup values compared to the sinusoid waveforms used for the model boundary conditions in the deep Atlantic Ocean.

The applicant responded to the staff's RAI 5818, Question 02.04.06-5 in a letter dated October 28, 2010 (ADAMS Accession No. ML11304A201), and acceptably responded to the issues. The applicant completed reasonably comprehensive sensitivity analysis, looking at the variation induced through changes in bottom friction, offshore boundary conditions, and incident wave forms. The applicant's new modeling results have led to greater wave heights at the site, and these larger wave heights are the new tsunami design water levels. Applicant's response was still unclear on whether the shallow water model was conservative as compared to a Boussinesq model (statement at the end of its Part 2 discussion on page 6 and its ending statement in the first paragraph on page 22 of the RAI 5818, Question 02.04.06-5 response). The basis of this statement is on the concept that dispersion spreads the wave energy out along the train, and so this dispersed energy should lead to lower wave heights. That is reasonable, but it practice in shallow water, the interplay between nonlinearity, dispersion, and viscous dissipation are too complex to make such a statement. Past experience suggests that the

differences are pretty well scattered about +/-10 percent, depending on bathymetry, height, etc. Thus, the additional detail provided by the applicant clarified the methodology and the staff considers RAI 02.04.06-2 and RAI 02.04.06-5 resolved.

Staff's Technical Evaluation

Earthquake-generated tsunamis, with their very long wavelengths, are ideally matched with NSW for transoceanic propagation. Models such as those by Titov and Synolakis (1995) and Liu et al. (1995) have been shown to be reasonably accurate throughout the evolution of a tsunami, and are in widespread use today. However, when examining tsunamis generated by submarine mass failures, the NSW can lead to significant errors (Lynett et al., 2003). The length scale of a submarine failure tends to be much less than that of an earthquake, and thus the wavelength of the created tsunami is shorter. To correctly simulate the shorter wave phenomenon, one needs equations with excellent shallow to intermediate water properties, such as the Boussinesq equations. Although Boussinesq models also have accuracy limitations on how deep (or short) the landslide can be (Lynett and Liu, 2002), they are able to simulate the majority of tsunami generating landslides.

Thus, for confirmatory analysis the staff used the Boussinesq-based numerical model COULWAVE (Lynett and Liu, 2002). This model solved the fully nonlinear extended Boussinesq equations on a Cartesian grid. A particular advantage of the model is the use of fully non-linear equations for both deep and shallow water. This avoided the common problem of "splitting" the analysis when the wave reaches shallow water. Applications for which COULWAVE has proven very accurate include wave evolution from intermediate depths to the shoreline, including parameterized models for wave breaking and bottom friction.

2.4.6.4.5 Tsunami Water Levels

Information Submitted by the Applicant

Offshore water-level estimates by the applicant were taken directly from previous studies by Mader (2001a), Knight (2006), and ten Brink et al. (2008).

For the Azores-Gibraltar earthquake scenario, the applicant compared the offshore tsunami amplitudes along the southern U.S. Atlantic margin between the studies by Mader (2001a) and ten Brink et al. (2008). The applicant concluded that for offshore tsunami amplitudes relevant to the site, Mader's (2001a) study has the larger estimate. The applicant also concluded that Mader's (2001a) offshore amplitude near the site for the Azores-Gibraltar earthquake scenario was larger than Knight's (2006) offshore amplitude near the site for the Puerto Rico Trench earthquake scenario. Therefore, the applicant concluded that the PMT offshore water levels were from Mader's (2001a) study of Azores-Gibraltar earthquake scenario.

The offshore PMT amplitude that the applicant used is 2 m (6.6 ft) at a location near Miami, FL, in 783 m (2 568.9 ft) water depth. The applicant then applied a runup amplification factor of 2, to obtain a PMT runup height at the site of 4 m (13.1 ft). The applicant added 0.8 m (2.6 ft) for the 10 percent exceedance high-tide and sea-level anomaly and 0.3 m (0.98 ft) for the long-term sea-level rise for the next 100 years to obtain a maximum PMT water level at the site of 5.1 m [16.7 ft] (NAVD88).

The applicant indicated that the design plant grade elevation is 7.9 m [26.0 ft] (NAVD88) and therefore the PMT water level will not impact safety-related facilities at the site.

Staff's Technical Evaluation

The staff performed numerical modeling of three different types of tsunami sources to determine their impacts on the Turkey Point site. Below, coarse-grid modeling is first conducted to determine the effects of tsunamis described in ten Brink (2008) near the site. The staff also included a local earthquake in the Florida Straits during the coarse-grid modeling phase to determine the order-of-magnitude impact at the site. The second phase of the water-level analysis is detailed hydrodynamic modeling of likely PMT sources using a finer computational grid near the site. This was described after the coarse-grid modeling sections. For all conditions, the most conservative source parameters were employed, even when arguably unphysical, to provide an absolute upper limit on the possible tsunami effects at the Turkey Point site.

Coarse-Grid Modeling: Caribbean Earthquake Sources

Regional tsunami propagation patterns offshore of the Turkey Point have been computed by the staff for a number of distant earthquake sources located in the Caribbean as reported in ten Brink and others (2008). In Chapter 8 of that study, earthquake scenarios along five fault systems were examined: (1) west Cayman oceanic transform fault (OTF), (2) east Cayman OTF, (3) northern Caribbean subduction zone, (4) north Panama Oceanic Convergence Boundary, and (5) the northern South America convergent zone. In that report, tsunami propagation was modeled using the leap-frog, finite-difference approximation to the linear-long wave equations computed using Cartesian coordinates. Bottom friction, wave breaking, and runup were not modeled—computations were restricted to water depths of 250 m (820.2 ft) or greater. Results for the western Gulf of Mexico indicate that offshore tsunami amplitudes were less than 1.0 m (3.3 ft) for each earthquake scenario.

For comparative purposes, the staff recalculated the offshore tsunami water levels for earthquake scenarios (3) and (5) using the COMCOT model on coarse computational grid, using the ETOPO1 DEM. The COMCOT model is more accurate than the model used in ten Brink and others (2008) because it includes non-linear terms in the propagation equations (hence, the computations can be carried into shallower water than in ten Brink and others, 2008), a moving boundary condition at the shoreline, and was computed in spherical coordinates. Bottom friction was also included, but was set at a low, conservative value ($f = 10^{-4}$) in this case. The results confirm that tsunami amplitudes from distant Caribbean earthquakes are less than 1.0 m (3.3 ft) near the Turkey Point site. Tsunami amplitudes from earthquakes along the Azores-Gibraltar oceanic convergence boundary were also of similar magnitude (Barkan and others, 2009).

Coarse-Grid Modeling: Local Earthquake Sources

Regional tsunami propagation patterns in the Florida Straits have been computed on a coarse computational grid for an intra-plate earthquake of expected maximum magnitude. For this scenario, probable maximum fault dimensions and slip similar to a *Mmax*=7.5 earthquake (Petersen and others, 2008; Wheeler, 2009; Mueller, 2010) was determined from the empirical scaling relationships for intra-plate earthquakes of Wells and Coppersmith (1994). Conservative values were allowed within one standard deviation of the empirical estimates of all fault types (empirical relationships for reverse faults only are not statistically reliable). This resulted in the following rupture parameters: length=150 km (93.2 mi), width=30 km (18.6 mi), up-dip fault depth=3 km (1.9 mi), average slip=5 m, dip=47 °, strike=N18.7 °E. The rupture was located in the deepest part of the Florida Straits to maximum shoaling amplification. The corresponding

magnitude, assuming a shear modulus of 30 GPa, is *Mw*=7.8—slightly greater than *Mmax*=7.5 because of the conservative assumptions. The geometric parameters of the earthquake were taken so as to maximize the tsunami amplitudes offshore of the Turkey Point site.

The offshore tsunami water levels for this local earthquake scenario were computed using the COMCOT model as previously described for the distant earthquake sources. Bottom friction was also included, but was set at a low, conservative value ($f = 10^{-4}$) in this case. In general, tsunami amplitudes from the local *Mw*=7.8 sources were larger than the distant M~9 earthquake sources, with peak offshore tsunami amplitudes near 1.2 m (3.9 ft). These amplitudes were significantly less than the tsunami amplitudes produced by the submarine landslide sources described below.

Detailed Hydrodynamic Modeling: Likely PMT Sources

Detailed numerical modeling of likely PMT sources has been performed to determine their impact on the Turkey Point Units 6 and 7 site. The sources include a near field landslide source immediately offshore of Biscayne Bay (the Florida Straits source), a number of far-field landslide sources with extremely large local waves (the Canary Islands source, the Mid-Atlantic source, and the Puerto Rico Trench source), and a far field earthquake source (the Puerto Rico Subduction Zone source). For all conditions, the most conservative source parameters were employed, even when arguably unphysical, to provide an absolute upper limit on the possible tsunami effects at the Turkey Point Units 6 and 7 site.

A general conclusion found from the modeling is that while the Bahamas do not necessarily shield the Turkey Point Units 6 and 7 site from large incident tsunami waves, and the very shallow and irregular nature of Biscayne Bay makes penetration of tsunami wave energy through the Bay to the shoreline difficult. The Puerto Rico Trench landslide source proved to have the largest impact at the Turkey Point Units 6 and 7 site, with maximum water surface elevations due to the tsunami of 3.2 m (10.5 ft). The Florida Straits and Mid-Atlantic landslide sources have the potential to produce multi-meter wave heights, but produce waves less than the Puerto Rico landslide source. Interestingly, the Florida Straits source produces, by far, the largest wave height just offshore of the Bay in a water depth of 250 m (820.2 ft), but due to the relatively short period of these waves they are rapidly damped and scattered within the Bay. The Canary Islands source, despite generating sea surface elevation of 1 km (0.6 mi) at the source, leads to a tsunami crest elevation less than 0.5 m (1.6 ft) offshore of the Turkey Point Units 6 and 7 site. The earthquake source has the smallest effect on the site, with maximum water surface elevations less than 0.15 m (0.5 ft). Thus the Puerto Rico Trench landslide source is the Probable Maximum Tsunami (PMT), however the effects of the PMT are below that of the maximum storm surge event.

Numerical Grid Development

The bathymetry/topography grid required by the hydrodynamic model is created via two main sources: (1) the GEBCO 1-minute global elevation database for open ocean simulations, and (2) relatively fine scale nearshore bathymetry and topography data in Biscayne Bay taken from NOAA Coastal Services Center's Digital Coast repository. Coastal waterways, Bay channels, and rivers are all well resolved.

Numerical Simulations – Physical Limits

The purpose of these simulations was to provide an absolute upper limit on the tsunami wave height that could be generated by the potential sources. Note that these limiting simulations used physical assumptions that are arguably unreasonable for landslide sources; the results of these simulations was used to filter out tsunami sources that are incapable of adversely impacting the Turkey Point Units 6 and 7 site under even the most conservative assumptions. Specifically, these assumptions were:

(1) Time scale of the seafloor motion was very small compared the period of the generated water wave (tsunami).

(2) Bottom roughness, and the associated energy dissipation, was negligible in locations that are initially wet (i.e., locations with negative bottom elevation, offshore).

Assumption (1) simplifies the numerical analysis considerably. With this assumption, the sea surface response matches the change in the seafloor profile exactly. This type of approximation was used commonly for subduction-earthquake-generated tsunamis, but was known to be very conservative for landslide tsunamis (Lynett and Liu, 2002). The modeling simplification arises because the need to include the landslide time evolution is removed. The initial pre-landslide bathymetry profile, as estimated by examination of neighboring depth contours, was subtracted by the post (existing) landslide bathymetry profile. This "difference surface" was smoothed and then used directly as a "hot-start" initial free surface condition in the hydrodynamic model.

Assumption (2) did not simplify the analysis significantly; however it does prevent the use of an overly high bottom roughness coefficient, which could artificially reduce the tsunami energy reaching the shoreline. Note that while the offshore regions are assumed to be without bottom friction, such an assumption is too physically unrealistic to accept for the inland regions where the roughness height may be the same order as the flow depth. For tsunami inundation, particularly for regions such as this project location where the wave might inundate long reaches of densely vegetated land, inclusion of some measure of bottom roughness was necessary.

For this tsunami hazard investigation, the simulation domain was divided into two separate, but coupled, components—an *offshore* domain and a *nearshore* domain. First, a simulation was performed to look at the waves near the offshore source and their evolution in shallow water approaching the Bay up to a water depth of 250 m. These simulations provided a time series of water surface elevation and fluid velocity near the Bay entrance. These time series were then used to force the nearshore domain, which encompassed the entire Biscayne Bay. For the far field sources (all sources except the Florida Straits landslide source), offshore modeling was performed utilizing two-horizontal-dimension (2HD) simulations. For each source, a time series of water surface elevation offshore of the Bay was created. For the near field source (Florida Straits), both one-horizontal dimension (1HD) and 2HD simulations were run. The 1HD simulations provided an absolute upper limit of the possible tsunami that might be generated by this source, and was conceptually equivalent to the entire length of the Bahamas shelf failing as a single landslide. A 2HD simulation of the Florida Straits landslide provided a quantitative measure of the conservatism of the 1HD simulation. With comparison of all the offshore simulation results, the PMT was chosen. Finally the offshore PMT time series was used with the nearshore domain to predict site-specific tsunami effects.

Currituck, Cape Fear, and Cape Lookout Landslide Sources

These three slide sources were grouped relatively close together off the Mid-Atlantic region. The Cape Fear Landslide is the closest to the Turkey Point Units 6 and 7 site, and has an average excavation depth of 50 m (164 ft). The Cape Lookout slide has a slightly larger excavation depth of 60 m (197 ft), but has smaller horizontal dimensions than the Cape Fear slide (approximately 50 percent of the volume). Currituck has the greatest excavation depth of 300 m (984.2 ft), but was further north and is oriented east-west. This directivity would yield a smaller level of energy at the southern Turkey Point Units 6 and 7 site. For purposes of conservatism, the various properties of these slides are combined to produce a "hybrid" slide yielding the greatest impact at the slide. The Mid-Atlantic slide would have an excavation depth of 300 m (984.2 ft) (from Currituck), a horizontal area of 7,300 km^2 (1,825,000 acres) (from Cape Fear), and will be located at the existing Cape Fear slide location with the orientation of the Cape Lookout slide. The horizontal dimensions of the slide source region were 75 km (46.6 mi) in width and 100 km (62.1 mi) in length. With this information, and knowledge of characteristic slide-generated waves taken from the literature (Lynett and Liu, 2002; Lynett and Liu, 2005), a hot-start initial condition was constructed.

A 2HD simulation was performed for the purpose of providing a time series of water surface elevation just offshore of the Bay. The wave energy that was directed toward the Turkey Point Units 6 and 7 site is relatively low. A time series of the ocean surface elevation at the 250 m (820.2 ft) depth contour offshore of Biscayne Bay shows the crest amplitude of the wave approaching the site was 1.5 m (4.9 ft).

Canary Islands Source

The Canary Islands landslide source has initiated significant debate within the tsunami research community. The initial tsunami assessment by Ward and Day (2001) due to a coherent failure of an entire island into the ocean, lead to runup predictions of 10–25 m (33–82 ft) along nearly the entire East Coast of the United States. Subsequent studies (e.g., Mader, 2001) have attempted to downplay the hazard, with reductions in runup by a factor of 10 for the most extreme case. In this study, the most conservative published source values are employed. Similar to the previous examinations, if this conservative setup has a damaging effect on the Turkey Point Units 6 and 7 site, the source parameters are given additional scrutiny and unreasonable conservatism relaxed.

Following Ward and Day (2001), a coherent La Palma collapse will generate an initial wave with amplitude approaching 1000 m (328.1 ft). For the simulations here, a hot start condition is placed just offshore of La Palma, with a crest elevation of +1000 m (+3280.8 ft)and a trough elevation of -1000 m (-3280.8 ft). The disturbance has a length of 50 km (31.1 mi) and a width of 25 km (15.5 mi), again taken approximately from the information in Ward and Day (2001). The wave propagation is modeled in the entire northern Atlantic Ocean in the *offshore domain*, using a grid spacing of 2 km (1.2 mi). The simulation is based on the fully nonlinear Boussinesq equations, with wave breaking included. The wave field 30 minutes after generation spreads radially, almost as a point source. Later in time, the wave spreads rapidly both through radial spreading and frequency dispersion. The tsunami transforms into a long train with the longest frequencies at the lead (the largest crest does not in fact occur with the first wave). When reaching the continental shelf break along the eastern U.S., the maximum crest elevation was much less than 10 m (32.8 ft).

Puerto Rico Trench Landslide Source

There was evidence of a pre-historical gigantic submarine slope failure in the Puerto Rico Trench with a displaced volume that has been estimated at approximately 1500 km^3 (359.9 mi^3) by Schwab and others (1991) and approximately 910—1,050 km^3 (210–251 mi^3) (by Grindlay (1998). The Puerto Rico Trench was the surface trace of a southward-dipping Benioff zone (Grindlay et al., 1997), and it included the deepest part of the Atlantic Ocean with depths up to 8.4 km (5.2 mi). The landslide was located along the southern slope of the Puerto Rico Trench. This was about 37 km off the north coast of Puerto Rico and is approximately 55 km (34.2 mi) across (east-west), has a crown in a water depth of approximately 3,000 m (9,842.5 ft), and extended to a water depth of approximately 6,000 m (19,685 ft). The maximum change in seafloor elevation of this slide was huge; the scarp depth was 800 m (2,624.7 ft).

Similar to the other landslide sources, an initial hot-start condition was created in the numerical model with the parameters given above. Note again the high conservatism of this approach; the initial height of the tsunami here was 800 m (2,624.7 ft), while in the analysis of Mercado and others (2002) who included time scales of motion and modeled the slide failure, a 15 minute slide event creates a wave with amplitude of 40 m (131.2 ft). Furthermore, the initial condition was angled counter-clockwise such that the directivity toward the Turkey Point Units 6 and 7 site is at a maximum. Along the eastern ridge of the Bahamas, wave energy was concentrated due to refraction. This concentrated energy then wraps around the northern extent of the Bahamas and bends to the south; again a result of refraction. The wave was then directed toward the Turkey Point Units 6 and 7 site, with surprisingly large amplitude, considering the distance of travel and the “protection” of the Bahamas. The most effective path of transit for wave energy to the Turkey Point Units 6 and 7 site from the Puerto Rico slide was not south through the Florida Straits or directly through the Bahamas, but around the Bahamas from the north and then bending to the south. A time series of the ocean surface elevation at the 250 m (820.2 ft) depth contour offshore of Biscayne Bay shows that this wave train with an amplitude of over 4 m (13.1 ft) and a long period of 30 minutes.

Puerto Rico Subduction Zone Source

The only earthquake source to be investigated for the CC site was the subduction zone that borders much of the northeastern and eastern extent of the Caribbean Islands. Here, the staff assumed that the entire fault zone ruptures during a single earthquake event. Seafloor displacements were taken as the expected maximum values that a subduction zone earthquake might generate. The initial sea surface condition is a direct mapping of the vertical seafloor displacement to the ocean surface. Based on the results, it was clear that the total rupture is composed by five individual regions; a simplification used to reasonably characterize the entire length. It is also evident that the largest waves would be directed toward the northeast Atlantic basin.

With a subduction zone earthquake, the generated waves are long in wavelength. This implied that the physics of the waves are simpler, relative to the dispersive waves created by the two landslide sources examined previously. To numerically model this source, the open-source tsunami model COMCOT was used. A grid covering the entire western Atlantic was generated with a spatial grid size of 1 minute (1/60 of a degree latitude or longitude). A single grid layer was used; there was no nesting of domains for refinement. The time step used by the model is 1 second. The linear version of the model was used, and there was no bottom friction applied anywhere in the domain. The linear version of the model was deemed acceptable because, as

will be shown, the wave height to water depth ratio was less than 0.1 at all areas of interest, and usually no greater than 0.01.

Once the wave exits the source area, the crest elevation of the main wave was about 2 m (6.6 ft) in the open ocean; Bermuda would experience an extreme and damaging wave. However, it was clear that the East Coast of the United States, while certainty feeling effects from this source, would see relatively minor wave impact. By the time the wave has reached the shelf offshore of the Turkey Point site in Biscayne Bay, the maximum crest elevation of the wave was approximately 0.15 m (0.5 ft).

Florida Straits Landslide Source

This source, given as “FS,” consisting of a landslide along the western Bahamas platform, was the only significant local source identified for the Turkey Point site. Based on the very limited geotechnical data for a prehistoric slide, the failure region was estimated to be 5 km (3.1 mi) in length. A maximum scarp depth of 150 m (492.1 ft) was used (100 m (328 ft) scarp depth was the best estimate given in Section 2.4.6.4.3), to account for uncertainty in the regional data and its importance for tsunami generation. For the analysis of local events, the modeling procedure was slightly different from that described above for the other sources. Here, for the initial, conservative estimation of tsunami impacts, the effects of lateral spreading are ignored. Thus, simulations in the one-horizontal-dimension (1HD) were performed. This was equivalent to specifying that the entire offshore shelf has failed simultaneously. Furthermore, due to the complexity of the bathymetry and topography of Biscayne Bay, the 1HD simulation was also likely to over-estimate the transmission of energy into the Bay due to a neglect of 2HD scattering.

Three 1HD simulations were undertaken for the FS source for three different values of bottom friction. All three simulations used no friction over initially submerged areas, but for initially dry areas use Manning’s “n” values of 0.0 (no friction), 0.02 (low friction), and 0.05 (high friction). Figure 2.4.6.4.5-18 provided a number of snapshots of the tsunami evolution for the no friction case. Due to the very shallow Bay and irregular topography, the wave height was significantly reduced by the time it reaches the Turkey Point Units 6 and 7 site. The no-friction simulation yielded a maximum tsunami water potential elevation (flow elevation of velocity head elevation) near the Turkey Point Units 6 and 7 site of 18 m (59 ft), while the low friction simulation predicted a potential elevation of 12 m (39.3 ft), and the high friction an elevation of 3 m (9.8 ft). Offshore (350 m (1,148.3 ft) contour), the time series from all three 1HD simulations were very similar; with the only differences due to friction-dependent reflections off of topography. The wave height at this depth was very large but the period is a relatively short: approximately 5 minutes.

PMT Determination and Nearshore, Site-Specific Modeling

Based on the above scoping analysis of the possible candidates for the PMT, it was clear that the FS source produces the largest offshore amplitude. However, the period of this generated wave was very short, and it might be expected that the wave height of this short period motion would be quickly damped out once entering the Bay. On the other hand, the Puerto Rico Landslide source, while producing a wave height that was ~1/5 of the FS source, had a period that is ~5 times larger. When considering the effect of bottom friction and scattering inside the Bay, it was plausible that the Puerto Rico source may in fact be the PMT despite the smaller offshore height. Thus, for the small-scale, 2HD site-specific modeling, both the FS and Puerto Rico source would be included.

For the site-specific modeling, a 10 m (32.8 ft) resolution sub-domain centered on the Bay was used. The offshore time series at the 250 m (820.2 ft) depth for the two sources would be forced into the domain. Note that the 1HD time series was used for the FS source. Compared with the 1HD simulations, the site-specific 2HD modeling to be presented here also included the effects of scattering inside the Bay. For the simulations, a Mannings “n” of 0.02 was used throughout the domain and is considered to be a conservative estimate of the friction in the system.

The tsunami evolution for the FS source clearly shows the offshore wave height was very large, but breaking, bottom friction, and scattering very quickly damp and disperse the wave energy. In fact, these effects transform the short period incident energy into a very slow, long period rise of the water level in the entire Bay. The maximum tsunami runup near the Turkey Point Units 6 and 7 site of the FS source is 1.2 m (3.9 ft); an order of magnitude reduction in elevation as compared with the incident time series signal.

For the Puerto Rico source, the increased period of motion was clearly evident, and the tsunami energy is better able to infiltrate the Bay. The crests break once they enter the very shallow water of the Bay, and they stack on top of each other. The wave was still slow to reach the site, but the runup for this source near Turkey Point Units 6 and 7 site was 3.2 m (10.5 ft). Thus, the PMT for the Turkey Point Units 6 and 7 site according to this analysis was due to the Puerto Rico Trench Landslide, with a maximum water elevation of 3.2 m (10.5 ft). Again, this estimate was conservative, and so it could be stated with some confidence that it is very unlikely that a tsunami might produce water levels greater than 3.2 m (10.5 ft) at the Turkey Point Units 6 and 7 site.

Considering an antecedent water level of 1.1 m (3.6 ft) (NAVD 88) that included 10 percent exceedance high tide and long-term sea-level rise for the next 100 years (0.3 m, 1 ft), the estimated PMT water level was 4.3 m (14.1 ft) (NAVD 88).

Summary

The Puerto Rico Trench landslide source proved to have the largest impact at the Turkey Point Units 6 and 7 site with maximum water surface elevations due to a tsunami of 3.2 m (10.5 ft). Even though the Florida Straits landslide source produces the largest wave height just offshore of Biscayne Bay in a water depth of 250 m, the relatively short period of these waves are rapidly damped and scattered within the Bay. Considering an antecedent water level of 1.1 m (3.6 ft) (NAVD 88) that included 10 percent exceedance high tide and long-term sea-level rise for the next 100 years (0.3 m, 1 ft), the estimated PMT water level was 4.3 m (14.1 ft) (NAVD 88). This PMT water level value was less than that determined by the applicant (5.1 m) (16.1 ft) (NAVD 88), was less than the PMSS water level, and was less than the design plant grade elevation. Therefore, the staff concluded that PMT water level is bounded by that of the PMSS.

2.4.6.4.6 Hydrography and Harbor or Breakwater Influences on Tsunami

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

The applicant mentioned the absence of breakwaters near the site and indicates that the hydrography of Biscayne Bay and Elliott Key Barrier Island has been considered in estimating of the PMT water level.

Staff's Technical Evaluation

The staff found the applicant's analysis reasonable in that the hydrography and harbor or breakwater influences are not expected to be severe enough to impact safety-related structures. The offshore hydrography and harbor or breakwater influences are specifically accounted for in the numerical modeling performed during the independent confirmatory analysis.

2.4.6.4.7 Effects on Safety-related Facilities

Information Submitted by the Applicant

The applicant indicated that the PMT is not expected to be large enough to affect the operation of safety-related SSCs. The applicant further indicated that consequently, debris, water-borne projectiles, and sediment erosion and deposition are not a concern to the functioning of safety-related SSCs for the site.

Staff's Technical Evaluation

The staff found the applicant's analysis reasonable in that the effects of the PMT are not expected to be severe enough to affect the operation of safety-related structures

2.4.6.5 Conclusions

The staff reviewed the Turkey Point Units 6 and 7 COL FSAR Section 2.4.6 and PTN COL 2.4-2 and confirmed that the COL applicant has addressed the information relevant to design basis for tsunami flooding. The staff also confirms that there is no outstanding information required to be addressed in the Turkey Point Units 6 and 7 COL FSAR Section 2.4.6.

The staff reviewed the information provided and, for the reasons given above, concludes that the COL applicant has provided sufficient details about the site description to allow a staff evaluation, as documented in Section 2.4.6 of this report. Based on the above, the staff concludes that the identified site characteristics meet the requirements of 10 CFR 52.79(a)(1)(iii), 10 CFR 100.20(c) and 10 CFR 100.23(d) with respect to establishing the design basis for SSCs important to safety. The information addressing the COL Information Item 2.4-6 is adequate and acceptable.

2.4.7 Ice Effects

2.4.7.1 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.4.7 addresses the ice effects to ensure that safety-related facilities and water supply are not affected by ice-induced hazards.

SER Section 2.4.7 presents an evaluation of the following topics based on data provided by the applicant in the Turkey Point Units 6 and 7 COL FSAR and information available from other sources: (1) regional history and types of historical ice accumulations (i.e., ice jams, wind-driven ice ridges, floes, frazil ice formation, etc.), (2) potential effects of ice-induced, high- or low-flow levels on safety-related facilities and water supplies, (3) potential effects of a surface ice-sheet to reduce the volume of available liquid water in safety-related water reservoirs, (4) potential effects of ice to produce forces on, or cause blockage of, safety-related facilities,

(5) potential effects of seismic and non-seismic data on the postulated worst-case icing scenario for the proposed plant site, and (6) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.7.2 Summary of Application

The applicant addressed the information related to ice effects as follows:

AP1000 COL Information Item

- PTN COL 2.4-2 Floods

COL License Information Item 2.4-2 requires COL applicants to provide site-specific information related to ice effects on the design basis flooding and safety-related the site.

2.4.7.3 Regulatory Basis

The relevant requirements of the NRC regulations for the identification and evaluation of ice effects, and the associated acceptance criteria, are described in Section 2.4.7 of NUREG-0800.

The applicable regulatory requirements for identifying ice effects are:

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

- 10 CFR 100.23(d) sets forth the criteria to determine the siting factors for plant design bases with respect to water levels at the site.

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

The related acceptance criteria are provided in the following Regulatory Guides:

- Regulatory Guide 1.29 as it relates to those SSCs intended to protect against the effects of flooding

- Regulatory Guide 1.59 as supplemented by best current practices;

- RG 1.102 as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

2.4.7.4 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.7 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to ice effects. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

The staff reviewed the information in the Turkey Point Units 6 and 7 COL FSAR:

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

- PTN COL 2.4-2 Floods

The staff reviewed PTN COL 2.4-2 related to ice effects on the design basis flooding and safety-related facilities at the site included in Turkey Point Units 6 and 7 COL FSAR Section 2.4.4.

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

Evaluation of the information provided in PTN COL 2.4-2 related to ice-induced hazards at the Turkey Point Units 6 and 7 site is discussed below.

2.4.7.4.1 Ice Conditions and Historical Ice Formation

<u>Information Submitted by Applicant</u>

Based on review of historical hydrometeorological data obtained from USGS and NOAA, the applicant described the climate near Turkey Point Units 6 and 7 as subtropical marine with occasional freezing air temperatures. Freezing or subfreezing air temperatures have been recorded, but the daily average temperatures on the days with freezing events always were well above freezing.

The applicant obtained water temperature data from 449 USGS stations within 30 mi (48 km) of the plant area. The applicant stated that data from 13 of the stations met quality requirements for use in analysis. Water temperatures measured at these stations between 1953 and 2007 were consistently well above the freezing point. The lowest water temperature in the records was 54.0 °F, recorded on April 3, 1959, in the Snapper Creek Canal at Miller Drive near S. Miami Station (USGS No. 02290610), 20 mi northwest of the Turkey Point plant.

The applicant obtained air temperature data from the NCDC of NOAA for two stations: the Homestead Experimental Station (12 mi (19 km) west of the plant area, Cooperative ID 084091, period of record from 1910 to 1988 with a continuous record starting in 1931) and the Miami International Airport Station (24 mi (38 km) north of the plant area, Cooperative ID 085663, period of record from 1948 to 2008). Both stations have recorded below-freezing air temperatures, with a minimum of 26°F measured on three occasions (December 13, 1934, March 2, 1941, and February 16, 1943) at the Homestead Experimental Station. All daily average temperatures at both stations are well above freezing. The lowest recorded daily average temperature was 38°F, on December 24, 1989, at Miami International Airport Station.

Staff's Technical Evaluation

The staff reviewed the hydrometeorological data provided by the applicant. Because subfreezing air temperatures have never been sustained for a full day and water temperatures have consistently been well above the freezing point, the staff concludes that ice formation near the Turkey Point site is an unlikely event.

2.4.7.4.2 Ice Jams

Information Submitted by Applicant

To obtain information on the historical occurrences of ice events, the applicant reported conducting a detailed search of the "Ice Jam Database" of the USACE. The applicant stated that the "Ice Jam Database" contains no records of ice jams in Florida. The applicant also stated that ice sheet formation, wind-driven ice ridges, and frazil or anchor ice formation are prevented because the available historical data indicate no occurrences of subfreezing water or subfreezing daily average air temperatures.

Staff's Technical Evaluation

The staff reviewed the applicant's hydrometeorological data, verified key items, and checked the "Ice Jam Database." Based on the review of hydrometeorological data, as well as the lack of historical records of ice jams in Florida, the staff concludes that other ice jams and other ice-related effects such as ice sheet formation, wind-driven ice ridges, and frazil or anchor ice formation are precluded.

2.4.7.4.3 Effect of Ice on Cooling Water Systems

Information Submitted by Applicant

The applicant noted that the design of the AP1000 reactor employs a passive containment cooling system that functions as the safety-related ultimate heat sink, and incorporates by reference a system description in Subsection 6.2.2 of the AP1000 DCD. The applicant stated that because the passive containment cooling system does not require an open surface water source to perform its safety-related function, it is not affected by surface water ice conditions.

Staff's Technical Evaluation

Because the passive containment cooling system does not require an open surface water source to perform its safety-related function and because hydrometeorological data indicate that ice formation is unlikely, the staff concludes that Units 6 and 7 would not be affected by surface water ice conditions.

2.4.7.5 Post Combined License Activities

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

2.4.7.6 Conclusions

As set forth above, the applicant presented and substantiated information relative to the ice effects important to the design and siting of this plant in Turkey Point Units 6 and 7 COL FSAR Section 2.4.7 and PTN COL 2.4-2. The staff reviewed the available information and concluded, for the reasons given above, that the identification and consideration of the potential for ice flooding, ice blockage of water intakes, ice forces on structures, and the minimum low water levels (from upstream ice blockage) are acceptable and meet the requirements of 10 CFR 52.79 and 10 CFR 100.20(c), with respect to determining the acceptability of the site.

The staff finds that the applicant has considered the appropriate site phenomena for establishing the design bases for SSCs important to safety. The staff accepted the methodologies used to determine the potential for ice formation and blockage reflected in these site characteristics, as documented in SERs for previous licensing actions. Accordingly, the staff concludes that the use of these methodologies results in site characteristics with a margin sufficient for the limited accuracy, quantity, and period of time in which the data were accumulated. The staff concludes that the COL applicant has provided sufficient information on ice-related hazards to satisfy the applicable requirements of 10 CFR Part 52 and 10 CFR Part 100.

The staff's review confirmed that the applicant has addressed the relevant information, and no outstanding information is expected to be addressed in the Turkey Point Units 6 and 7 COL FSAR related to this section.

2.4.8 Cooling Water Canals and Reservoirs

2.4.8.1 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.4.8 addresses the cooling water canals and reservoirs used to transport and impound water supplied to the SSCs.

SER Section 2.4.8 presents an evaluation of the following topics to verify its hydraulic design basis: (1) design bases postulated and used by the applicant to protect structures such as riprap, inasmuch as they apply to safety-related water supply, (2) design bases of canals pertaining to capacity, protection against wind waves, erosion, sedimentation, and freeboard and the ability to withstand a probable maximum flood (PMF) (surges, etc.), inasmuch as they apply to a safety-related water supply, (3) design bases of reservoirs pertaining to capacity, PMF design basis, wind wave and run-up protection, discharge facilities (e.g., low-level outlet, spillways, etc.), outlet protection, freeboard, and erosion and sedimentation processes inasmuch as they apply to a safety-related water supply, (4) potential effects of seismic and non-seismic information on the postulated hydraulic design bases of canals and reservoirs for the proposed plant site, and (5) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.8.2 Summary of Application

The applicant addressed the information related to cooling water canals and reservoirs in Turkey Point Units 6 and 7 COL FSAR Section 2.4.8.

<u>AP1000 COL Information Item</u>

- PTN COL 2.4-3 Cooling Water Supply

COL License Information Item 2.4-3 requires COL applicants to provide site-specific information related to canals and reservoirs that provide makeup water to the safety-related cooling systems. The design of the AP1000 reactor employs a passive containment cooling system, which is described in Subsection 6.2.2 of the certified AP1000 DCD.

2.4.8.3 Regulatory Basis

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

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

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

- 10 CFR 100.23(d) sets forth the criteria to determine the siting factors for plant design bases with respect to water levels at the site.

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

The related acceptance criteria are provided in the following Regulatory Guides:

- Regulatory Guide 1.59, “Design Basis Floods for Nuclear Power Plants,” as supplemented by best current practices.

- Regulatory Guide 1.102 as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

2.4.8.4 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.8 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff’s review confirmed that the information in the application and incorporated by reference addresses the required information relating to cooling water canals and reservoirs. The results of the staff’s evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

AP1000 COL Information Item

- PTN COL 2.4-3

This section addresses the following COL Information Item 2.4.3 (COL Action Item 2.4.2-1) identified in Section 2.4.1.3 of the DCD. Combined License applicants will address the water supply sources to provide makeup water to the service water system cooling tower.

Evaluation of the information provided in PTN COL 2.4-3 related to cooling water canals and reservoirs at the Turkey Point Units 6 and 7 site is discussed below.

2.4.8.4.1 Cooling Water Canals

Information Submitted by Applicant

The applicant stated that the design of the AP1000 reactor employs a passive containment cooling system that functions as the safety-related ultimate heat sink. The passive containment cooling system does not require an open surface water source to perform its safety-related function. As a result, the applicant stated that Units 6 and 7 are not designed to use cooling water canals for either normal plant cooling or emergency cooling and there are no safety-related cooling water canals or reservoirs related to the operation of Units 6 and 7.

The plant area of Units 6 and 7 is, however, surrounded by an existing system of industrial wastewater facility/cooling canals installed to perform the cooling function for the Turkey Point operating units. The cooling canals consist of 168 mi of recirculating canals that occupy an area approximately of 5,900 acres. The canals are 200 feet wide and are generally shallow, with water depths of 1 to 3 ft. The berms on the canals are approximately 90 ft wide. The cooling canals receive plant effluents from the operating units, as well as blowdown flow from the mechanical draft cooling towers of Unit 5, but there is no surface water discharge from the canals to other water bodies. Because the cooling canals are much lower in elevation than 26.0 ft NAVD 88, the design plant grade of Units 6 and 7, they do not cause any flooding concern to the safety-related SSCs of Units 6 and 7. In addition, there is no reliance of Units 6 and 7 on these existing canals for any plant water use.

Staff Technical Evaluation

The staff reviewed the information in Turkey Point Units 6 and 7 COL FSAR Section 2.4.8 and the function of the AP1000 UHS and confirmed that Units 6 and 7 are not designed to use cooling water canals for normal plant cooling, emergency cooling, or other safety-related purposes. Accordingly, the staff accepts the applicant's determination that there are no safety-related canals proposed for Turkey Point Units 6 and 7.

Additionally, the staff has determined that the large elevation difference between the design plant grade of Units 6 and 7 and the existing system cooling canals precludes any flooding concern from these canals for the safety-related SSCs of Units 6 and 7. The rationale for this determination is consistent with the staff reasoning regarding flooding on streams, rivers, and canals, which is presented in more detail in Section 2.4.3.

2.4.8.4.2 Makeup Water Reservoirs

Information Submitted by Applicant

The applicant described the systems and structures as follows: The mechanical draft cooling towers that function as the normal heat sinks for the circulating water system of the main condensers of Units 6 and 7 are designed to operate on two makeup water sources: reclaimed water and saltwater through radial collector wells. Each of the two makeup water sources can independently support full load operation of the station. Reclaimed water is supplied by the Miami-Dade Water and Sewer Department to the FPL reclaimed water facility and is delivered to an onsite makeup water reservoir (MWR) after treatment. Reclaimed water from the reservoir is then transferred to the cooling tower basins through a set of cooling tower makeup pumps when the system is running on reclaimed water. The MWR has no safety-related function. It provides makeup water inventory to support the continuous operation of the cooling towers for both units. When the cooling towers obtain makeup water from the radial collector wells, saltwater is transferred directly to the cooling tower basins, bypassing the MWR.

The MWR, which is made of concrete, is on the south side of the plant area. The north side of the reservoir is approximately 2,200 ft (671 m) long, and the south side is approximately 1,800 ft (549 m) long. The bottom of the reservoir is at elevation –2.0 ft (0.6 m) NAVD 88. The top of the concrete walls is at 24.0 ft NAVD 88, with the maximum storage level at 22.5 ft (6.9 m) NAVD 88. The six cooling towers, three for each unit and their common open channel flumes, occupy part of the footprint of the MWR.

The MWR is a self-contained reservoir with no other contributing drainage area. The only inflows are direct rainfall and reclaimed water. It does not receive effluents from the operation of Units 6 and 7; these effluents are directed to the blowdown sump before being discharged into the underground injection wells. The applicant noted that low flow conditions of the MWR are addressed in Turkey Point Units 6 and 7 COL FSAR Subsection 2.4.11 and the effects of potential breaching of the MWR are considered in Turkey Point Units 6 and 7 COL FSAR Subsection 2.4.4.

Staff's Technical Evaluation

The staff reviewed the information in Turkey Point Units 6 and 7 COL FSAR Section 2.4.8 and confirmed that proposed Units 6 and 7 are not designed to use reservoirs for safety-related purposes. Accordingly, the staff accepts the applicant's determination that there are no safety-related canals or safety-related reservoirs proposed for Turkey Point Units 6 and 7. Potential flooding impacts related to the non-safety-related makeup water reservoir are addressed in SER Section 2.4.4. The potential for seiche effects related to this reservoir is discussed in SER Section 2.4.5.4.

2.4.8.5 *Post Combined License Activities*

There are no post COL activities related to this subsection.

2.4.8.6 *Conclusions*

As set forth above, the applicant presents and substantiates information relative to the design bases of canals and reservoirs important to the design and siting of this plant. The staff reviewed Turkey Point Units 6 and 7 and PTN COL 2.4-3 and concluded, for the reasons given

above, that the identification and consideration of the design bases of canals and reservoirs are acceptable and meet the requirements of 10 CFR 52.79, 10 CFR 100.23(d), and 10 CFR 100.20(c), with respect to determining the acceptability of the site.

The staff's review confirmed that the applicant has addressed the relevant information relating to this section, and no outstanding information related to this section remains to be addressed in the Turkey Point Units 6 and 7 COL FSAR.

2.4.9 Channel Diversions

2.4.9.1 *Introduction*

Turkey Point Units 6 and 7 COL FSAR Section 2.4.9 addresses channel diversions. It evaluates plant and essential water supplies used to transport and impound water supplies to ensure that they will not be adversely affected by stream or channel diversions. The evaluation includes stream channel diversions away from the site (which may lead to a loss of safety-related water) and stream channel diversions toward the site (which may lead to flooding). In addition, in such an event, it must be ensured that alternate water supplies are available to safety-related equipment.

SER Section 2.4.9 presents an evaluation of the following specific areas: (1) historical channel migration phenomena including cutoffs, subsidence, and uplift, (2) regional topographic evidence that suggests a future channel diversion may or may not occur (used in conjunction with evidence of historical diversions), (3) thermal causes of channel diversion, such as ice jams, which may result from downstream ice blockages that may lead to flooding from backwater, or upstream ice blockages that can divert the flow of water away from the intake, (4) potential for forces on safety-related facilities or the blockage of water supplies resulting from channel migration-induced flooding (flooding not addressed by hydrometeorological-induced flooding scenarios in other sections), (5) potential of channel diversion from human-induced causes (i.e., land-use changes, diking, channelization, armoring, or failure of structures), (6) alternate water sources and operating procedures, (7) potential implications of seismic and nonseismic information on the postulated worst-case channel diversion scenario for the proposed plant site, and (8) any additional information requirement prescribed in the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52.

2.4.9.2 Summary of Application

The applicant addressed the information related to channel diversions in Turkey Point Units 6 and 7 COL FSAR Section 2.4.9.

*AP1000 COL Information Item*

- PTN COL 2.4-3 Cooling Water Supply

COL License Information Item 2.4-3 requires COL applicants to provide site-specific information related to the potential for channel diversions and their effects on the safety-related cooling systems.

2.4.9.3 *Regulatory Basis*

The relevant requirements of the NRC regulations for the identification and evaluation of channel diversions, and the associated acceptance criteria, are described in Section 2.4.9 of NUREG-0800.

The applicable regulatory requirements for identifying and evaluating channel diversions are:

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

- 10 CFR 100.23(d) sets forth the criteria to determine the siting factors for plant design bases with respect to water levels at the site.

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

The related acceptance criteria are provided in the following RG:

- Regulatory Guide 1.59, “Design Basis Floods for Nuclear Power Plants,” as supplemented by best current practices

- Regulatory Guide 1.102 as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

2.4.9.4 ***Technical Evaluation***

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.9 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic. The staff’s review confirmed that the information in the application and incorporated by reference addresses the required information relating to channel diversions. The results of the staff’s evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

AP1000 COL Information Item

- PTN COL 2.4-3

This section addresses COL Information Item 2.4.3 (COL Action Item 2.4.2-1), which is identified in Section 2.4.1.3 of the DCD and states:

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

The staff reviewed the application information in the Turkey Point Units 6 and 7 COL FSAR and supplemented it with observations made during the staff's site visit on March 22, 2010. The staff also used publicly available data to determine the likelihood of channel diversion and other geomorphic changes near the Turkey Point site. To complete the review, the staff needed an accurate description of the history of channel diversions and other geomorphic changes and the potential for future channel diversions and geomorphic changes, as they relate to the functioning of safety-related SSCs. The descriptive information and the staff review are described below.

2.4.9.4.1 Stream Channel Diversions

By providing evidence of past channel diversion and other geomorphic changes, the geologic record can be one indicator of changes that could occur in the future. The historical record of channel diversion and other geomorphic changes also can be an indicator of changes that could occur in the future.

Information Submitted by Applicant

The applicant reviewed the site's geologic setting, including the seismic and stratigraphic properties, as described in Turkey Point Units 6 and 7 COL FSAR Subsection 2.5.1. The applicant described the geologic setting as follows: Turkey Point Units 6 and 7 are located within the Southern Slope subprovince of the Southern Zone physiographic subregion of the Florida Platform (a partly submerged peninsula of the continental shelf) within the Atlantic Coastal Plain physiographic province. The geology was influenced by sea-level fluctuations, processes of carbonate and clastic deposition, and erosion. The Paleogene (early Cenozoic) was dominated by the deposition of carbonate rocks, while the Neogene (late Cenozoic) is primarily characterized by the deposition of quartzitic sands, silts, and clays. Flat, planar bedding predominates. Before site development, the Turkey Point site was within 3 ft of sea level (preconstruction elevations ranged from -2.4 ft to 0.8 ft NAVD 88) and was uniformly flat with the exception of a few isolated vegetated depressions. The local terrain was covered with a thin (less than 6 ft) veneer of organic muck overlying the Pleistocene Miami Limestone. The applicant reported finding no geological or topographic evidence that indicates historical channel diversions in the general area.

The applicant refers to discussion in Turkey Point Units 6 and 7 COL FSAR Section 2.4.1, which indicates that there are no major natural rivers or channels located near Units 6 and 7. The applicant stated as follows: An extensive system of canals was built between Lake Okeechobee and the Atlantic Ocean, Biscayne Bay, and the Gulf of Mexico during the last century for the purposes of drainage, flood protection, and water supply. Consisting of multiple waterways with locks and gates for controlling flow and water levels, the canal system has elevated levees along both of its banks to contain flood flow during storm events. As a controlled system, it is not susceptible to channel migration or cutoff. The applicant reported that there is no evidence of channel diversions in the area as a result of natural flooding events since the canal system was built.

Staff's Technical Evaluation

The staff reviewed the information provided by the applicant and supplemented it with observations of the topography and surficial geology of the site and vicinity made during the staff's site visit on March 22, 2010. The staff observations confirm the absence of natural rivers and channels and the minimal topographic relief in the surrounding landscape. In addition, the

staff has determined that the applicant's interpretation of the geologic evidence is consistent with observed site conditions and published references on the geology of the area. The staff has also determined that the applicant's statement that the canal system is not susceptible to channel migration or cutoff is consistent with observed site conditions and the engineering design of these systems. For these reasons, the staff concludes that there is no geologic and historic evidence of stream channel diversion in the area of the Units 6 and 7 site.

2.4.9.4.3 Shoreline Changes

Due to the site's location adjacent to a marine shoreline, the potential effects on SSCs from changes in the shoreline need to be considered.

Information Submitted by Applicant

The applicant stated as follows: Biscayne Bay is bounded by mainland Florida to the west; by barrier islands and a wide, shallow opening of coral shoal near the middle of the bay; and by several channels and cuts to the east. The barrier islands are between the bay and the Atlantic Ocean. Biscayne Bay is a shallow subtropical lagoon with a natural depth ranging from 3 to 9 ft. However, much of the bay has been dredged and the current depth ranges from 6 to 10 ft (Florida Department of Environmental Protection, 2008). There is historical evidence of shoreline changes along the Florida coasts, including the western shore of Biscayne Bay where Turkey Point Units 6 and 7 are located.

The applicant incorporated Turkey Point Units 6 and 7 COL FSAR Section 2.5 by reference in Turkey Point Units 6 and 7 COL FSAR Section 2.4.9. In Turkey Point Units 6 and 7 COL FSAR Section 2.5, the applicant discusses the characteristics of the Florida Keys physiographic sub-province, which is the narrow chain of small islands at the southern tip of the Florida peninsula that also forms the eastern boundary of Biscayne Bay. The applicant stated that the Florida Keys comprise Pleistocene reef sediments. The applicant cited research indicating that a topographic high beneath Key Largo was the focus of reef growth. The applicant indicated further that Late Tertiary siliciclastic sediments underlying the Quaternary carbonate rocks appear to control the position and arc shape of the recent shelf and slope of southern Florida. Additionally, the applicant indicated that the arc pattern of the Florida Keys is related to the bathymetry of the shelf edge and the Florida current. According to the applicant, the growth of patch reefs is dependent upon nutrient availability, sea level, and topography.

The applicant described natural shoreline changes along east Florida as being due to hurricanes, tropical storms, northeasters, and tidal and wave actions, which erode sandy beaches and barrier islands, especially around inlets (Morton and Miller, 2005). The applicant stated as follows: Artificial coastal protection structures amplify shoreline fluctuations by changing the natural longshore sediment transport pattern. Barrier islands protect lagoons such as Biscayne Bay from some of these effects, but wakes generated by boats in the lagoons can contribute to local shore erosion in some areas (Morton and Miller, 2005).

Morton and Miller (2005) summarized long- and short-term shoreline change for the southeast Atlantic coast. Long-term rates of shoreline change were estimated based on surveys of shoreline positions from the 1800s to 1999, and short-term rates of shoreline change were estimated based on 1970s and 1999 shoreline positions. The average long- and short-term shoreline-change rates for east Florida are 0.2 ±0.6 m/year (0.66 ±2.0 ft/year) and 0.7 m/year (2.3 ft/year), respectively (plus sign indicates accretion and minus sign indicates erosion). This long-term shoreline rate of change is relatively small compared to shoreline changes for the

other parts of the southeast Atlantic coast because tidal and wave energy levels are low and beach nourishments are common where shore erosion persists. Nevertheless, at least 39 percent of the east Florida shoreline experienced erosion, at a long-term average erosion rate of 0.5 m/year (1.6 ft/year). The study did not estimate the long- and short-term shoreline change rates specifically for Biscayne Bay. However, the applicant's discussion of this topic states that shoreline changes in Biscayne Bay, especially along the western shore, are expected to be smaller than for the open coast because of the protection provided by the barrier islands.

The applicant provided a figure, based on data from the NOAA Shoreline Data Explorer, showing the shorelines near Units 6 and 7 for the years 1928, 1946, and 1971/1972 (Figure 2.4.9-1). The figure indicates that there was some shoreline erosion during the 43-year period between 1928 and 1971/1972, although some areas also experienced accretion. During the latter 25 years of this period, from 1946 through 1971/1972, only minor shoreline changes were observed.

The applicant stated that any shoreline changes that would occur near Units 6 and 7 as a result of long-term tidal and wave actions would be relatively gradual with sufficient warning for mitigating actions to be implemented before the safety facilities will be adversely impacted.

Shoreline changes as a result of hurricanes or tropical storms occur on a shorter time scale, however. The applicant cites a study by Tilmant et al. (1994) on the effects of Hurricane Andrew in 1992 on the mainland coast of Biscayne Bay, from Rickenbacker Causeway to Turkey Point. According to the source, lower beach slope erosion from the hurricane seldom exceeded 0.3 to 1 m (1 to 3.3 ft) and lateral erosion of the shoreline did not exceed 10 m (33 ft). The same source also indicates, however, that earlier slower-moving hurricanes, such as Hurricane Donna in 1960, caused more beach erosion than Hurricane Andrew (Tilmant et al., 1994). The applicant stated that the Units 6 and 7 plant area would be built up to higher elevations from the adjacent grade and protected by a retaining wall structure with the top of

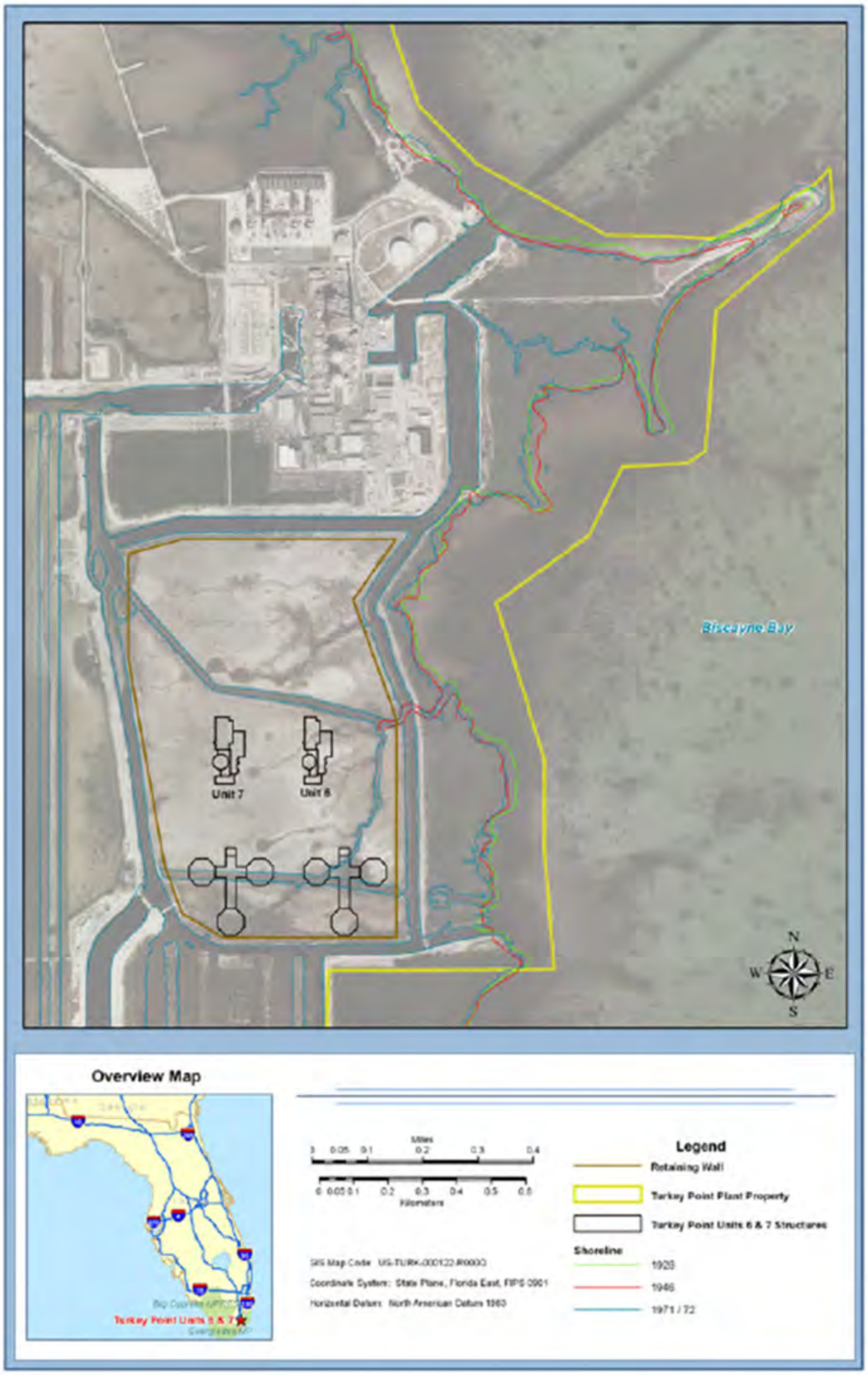


Figure 2.4.9-1 Historical Shoreline Changes at Units 6 & 7 (Modified after Turkey Point Units 6 and 7 COL FSAR Figure 2.4.9-201)

wall elevation varying from 20 ft to 21.5 ft NAVD 88. The retaining wall, though not a safety-related structure, is designed to withstand the hydrostatic and hydrodynamic forces from hurricane surge up to the PMSS and coincidental wave run-up actions. Accordingly, the applicant expected no adverse impact on the structures, systems, or components as a result of shoreline erosion caused by hurricane or tropical storm surges.

The applicant stated that long-term sea-level rise will cause a landward shift of the shoreline position, inundating low-lying areas along the coast. As discussed in Subsection 2.4.5, the applicant estimated that the long-term average sea-level rise at the plant property is expected to be approximately 0.78 ft per century (0.094 in/yr), similar to the sea-level rise rate at Miami Beach, FL. The applicant stated that this rate of the sea-level rise is too slow to cause any significant short-term shoreline change and points out that this sea-level rise is accounted for in determining the flood level from the probable maximum hurricane storm surge.

Additionally, the applicant stated that any erosion or inundation of the barrier islands due to long-term wave action would be gradual with sufficient warning for mitigating actions to be implemented before the safety-related facilities are adversely impacted. Similarly, the applicant indicated that any migration of the shoreline due to coastal protection structures, dredging, and other human activities near and around the plant site would be gradual and will be addressed before the safety-related facilities are adversely impacted.

Staff's Technical Evaluation

The staff reviewed the information supplied by the applicant and supplemented it with observations of the site and vicinity topography made during the staff's site visit on March 22, 2010, and review of information in published references. Regarding the potential for shoreline change, the staff confirmed that the historical record of shoreline changes at the Turkey Point site indicates that the long-term shoreline rate of change is relatively small. Additionally, the staff observes that most of the historical changes recorded at that site before development of the Turkey Point plant (as illustrated by Figure 2.4.9-1) can be attributed to human actions such as canal development, rather than to natural phenomena. Furthermore, long-term shoreline changes on the western shore of Biscayne Bay would be moderated by the protection provided by the barrier islands. Because the barrier islands on the eastern shore of the bay were formed from reef sediments, unlike most eastern U.S. barrier islands that formed as spits, shoals, or dunes (Morton and Miller, 2005), they are less susceptible to erosion or breaching by storm events than typical barrier islands, and therefore can be expected to remain relatively stable throughout the operating life of the proposed units. Additionally, erosion or inundation of the barrier islands due to long-term wave action, coastal protection structures, dredging, and other human activities are gradual processes, and there would be sufficient warning for mitigating actions to be implemented before the safety-related facilities are adversely impacted.

The applicant's information on the effects of Hurricane Andrew and other hurricanes indicates that dramatic changes in shoreline position can occur in a short time as a result of storm events. However, the staff agrees that an engineered retaining wall surrounding the built-up site of Units 6 and 7 that is designed to withstand the hydrostatic and hydrodynamic forces associated with hurricanes and tropical storm surges and wave action would be sufficient to prevent adverse impacts on the structures, systems, or components as a result of shoreline erosion caused by such events. The staff notes that the distance between the shoreline and the SSCs (i.e., at least 690 ft from the top of the retaining wall to the SSCs) is large in comparison with the maximum lateral erosion reported from Hurricane Andrew, which helps to support the conclusion that shoreline erosion would not affect the SSCs.

Regarding long-term sea-level rise, the reported long-term average rate of sea-level rise (which is approximately 0.78 foot in 100 years) determined from Miami Beach records is too slow to cause significant short-term shoreline change. Any shoreline changes associated with this rate of sea-level rise would occur with sufficient warning that mitigating actions could be implemented before the safety-related facilities are adversely impacted. As discussed in

Section 2.4.5.4, the staff requested and received additional information and analysis regarding the rate of sea-level rise and, for the reasons stated in that SER section, accepted the licensee's analysis.

2.4.9.4.4 Flooding of the Site due to Channel Diversion

Flooding can be caused by phenomena that divert streams, such as landslides and ice jams.

Information Submitted by Applicant

Because the plant property is flat and no major rivers are located nearby, the applicant found that there is no potential for subaerial landslide-generated flooding. Potential impacts on the site from underwater landslides (that is, submarine landslide-generated tsunamis) are addressed in Section 2.4.6.

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.7, the applicant indicates that there are no records of ice jams in the region of South Florida where Turkey Point Units 6 and 7 are located. Therefore, the applicant concluded that there is no potential for flooding or low water concerns as a result of channel diversions both upstream and downstream of Turkey Point Units 6 and 7 from ice blockage or breaching of ice jams.

Staff's Technical Evaluation

As described in Section 2.4.7, the staff reviewed information related to the potential for ice jams and concluded that ice jams and other ice-related effects are precluded. Based on this conclusion, the minimal topographic relief of the site and vicinity, and the absence of rivers and streams, the staff accept the applicant's reasoning regarding flooding due to stream diversion by phenomena such as landslides and ice jams. For the reasons given by the applicant, these phenomena are not concerns for Turkey Point Units 6 and 7.

2.4.9.4.5 Potential for Impacts to Safety-Related Water Supply

Low water conditions caused by channel diversion or shoreline migration events have the potential to disrupt access to surface-water sources.

Information Submitted by Applicant

On the consideration of the plant's safety-related water supply, the applicant noted that the design of the AP1000 reactor employs a passive containment cooling system that functions as the safety-related ultimate heat sink. Because this passive containment cooling system does not rely on an open surface water source or groundwater source to perform its safety-related function, its operation could not be adversely affected by the interruption of plant water supply as a result of low water conditions caused by channel diversion or shoreline migration events.

Staff's Technical Evaluation

Because the AP1000 passive containment cooling system does not credit an open surface water source to perform its safety-related function, the staff accepts the applicant's reasoning regarding potential for impacts to safety-related water supply due to channel diversion or shoreline migration events. For the reasons given by the applicant, this is not a concern for Turkey Point Units 6 and 7.

2.4.9.5 Post Combined License Activities

There are no post COL activities related to this subsection.

2.4.9.6 Conclusions

The staff reviewed the application and confirmed that the applicant has adequately addressed the information related to the potential for and effects of channel diversions on safety-related cooling systems, and that there is no outstanding information required to be addressed in Turkey Point Units 6 and 7 COL FSAR Section 2.4.9.

As set forth above, the applicant has presented and substantiated information to establish the site description ensuring that the plant and essential water supplies will not be adversely affected by potential channel diversions. The staff has reviewed the information submitted by the applicant in Turkey Point Units 6 and 7 COL FSAR Section 2.4.9 and PTN COL 2.4-3 and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in SER Section 2.4.9, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. In conclusion, the applicant has satisfied 10 CFR Part 52 and 10 CFR Part 100 with respect to channel diversions. This addresses the part of COL Information Item 2.4-3 related to channel diversions.

2.4.10 Flooding Protection Requirements

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.10 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to flooding protection requirements. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

2.4.10.1 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.4.10 addresses the locations and elevations of safety-related facilities and those of structures and components required for protection of safety-related facilities. These requirements are then compared with design-basis flood conditions to determine whether flood effects need to be considered in the plant's design or in emergency procedures.

Section 2.4.10 of this SER presents an evaluation of the following specific areas: (1) safety-related facilities exposed to flooding, (2) type of flood protection (e.g., "hardened facilities," sandbags, flood doors, bulkheads, etc.) provided to the SSCs exposed to floods, (3) emergency procedures needed to implement flood protection activities and warning times available for their implementation reviewed by the organization responsible for reviewing issues related to plant emergency procedures, (4) potential implications of seismic and non-seismic information on the postulated flooding protection for the proposed plant site, and (5) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.10.2 Summary of Application

This subsection of the Turkey Point Units 6 and 7 COL FSAR addresses the needs for site-specific information on flooding protection. The applicant addressed the information as follows:

<u>COL License Information Items</u>

- PTN COL 2.4-2 Floods
- PTN COL 2.4-6 Flood Protection Emergency Operation Procedures

COL License Information Item 2.4-2 and 2.4-6 require COL applicants to provide site-specific information related to any flood protection measures needed to protect the plant facilities from potential floods.

2.4.10.3 Regulatory Basis

The relevant requirements of the NRC regulations for the identification and evaluation of flooding protection measures, and the associated acceptance criteria, are described in Section 2.4.10 of NUREG-0800.

The applicable regulatory requirements for identifying and evaluating flooding protection measures are:

- 10 CFR Part 100, as it relates to identifying and evaluating hydrological features of the site. The requirement to consider physical site characteristics in site evaluations is specified in 10 CFR 100.20(c).
- 10 CFR 100.23(d) sets forth the criteria to determine the siting factors for plant design bases with respect to water levels at the site.
- 10 CFR 52.79(a)(1)(iii), as it relates to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The related acceptance criteria are provided in the following Regulatory Guides:

- Regulatory Guide 1.59, "Design Basis Floods for Nuclear Power Plants," as supplemented by best current practices
- Regulatory Guide 1.102 as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

2.4.10.4 Technical Evaluation

Turkey Point Units 6 and 7 COL FSAR Section 2.4.10 addresses the needs for site-specific information on flooding protection. The applicant addressed the information as follows:

AP1000 COL Information Item

- PTN COL 2.4-2

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

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

- PTN COL 2.4-6

In addition, this section addresses the following COL Information Item 2.4-6 (COL Action Item 2.4.1-1) identified in Section 2.4.1.6 of the DCD.

> Combined License applicants referencing the AP1000 certified design will address any flood protection emergency procedures required to meet the site parameter for flood level.

Evaluation of the information provided in PTN COL 2.4-2 and PTN-COL 2.4-6 related to any flood protection measures needed to protect the plant facilities from potential floods at the Turkey Point Units 6 and 7 site is discussed below.

Information Submitted by Applicant

The applicant identified the design-basis flood elevation for Units 6 and 7 as 24.8 ft NAVD 88, determined by PMSS. The elevations of floor entrances and openings of all safety-related structures are at 26 ft NAVD 88. Because the design-basis flood elevation is below the entrance floor elevations of the safety-related structures, the applicant stated that the safety functions of the plant are not affected by the design basis flood event.

Additionally, the applicant referred to the analysis in Turkey Point Units 6 and 7 COL FSAR Subsection 2.4.2.3 regarding the flood elevation resulting from local intense precipitation (also referred to as local PMP) at Units 6 and 7. The applicant's analysis, which conservatively assumes that all underground storm drains and culverts are clogged, found the maximum flood water level of 24.5 ft (7.5 m) NAVD 88 in the Units 6 and 7 power block area where safety-related SSCs are located. Consequently, the applicant stated that local PMP storm event does not cause flooding impacts to the safety-related SSCs.

The applicant stated that because none of the Units 6 and 7 safety-related SSCs are impaired by any of the postulated flood events, no flood protection measures are required. Thus, the applicant finds that no technical specifications or emergency procedures to implement flood protection activities are required.

The applicant noted that the Units 6 and 7 plant area would be surrounded by a non-safety-related retaining wall structure with the top of the wall elevation varying from 20 ft (6 m) to 21.5 ft (6.6 m) NAVD 88. This is a retaining wall with earthen material behind it; it is not a dike or seawall. Accordingly, as described in Section 2.4.5.4.6, storm waves that reach shore at elevations above the top of the wall would dissipate as they move up the sloping surface above the wall. The applicant stated that the safety-related structures of Unit 6 and Unit 7 are

(respectively) at least 750 ft (229 m) and 690 ft (210 m) away from the nearest retaining wall. The applicant stated that the retaining wall is designed to withstand the hydrostatic and hydrodynamic forces from hurricane surge up to the PMSS and coincidental wave run-up actions.

Staff's Technical Evaluation

The staff reviewed the applicant's information regarding flood protection requirements. The staff finds that the applicant's analysis is adequate to address flood protection requirements. The maximum floodwater surface elevation of 24.8 ft (7.6 m) NAVD 88 is below 26.0 ft (7.9 m) NAVD 88, which is equivalent to the design plant grade elevation of 100 ft in the DCD reference datum. The staff concluded therefore, that the DCD maximum flood level parameter would not be exceeded. Therefore, no additional flood protection is needed for Turkey Point Units 6 and 7.

2.4.10.5 Post Combined License Activities

There are no post COL activities related to this subsection.

2.4.10.6 Conclusions

The staff reviewed the application and confirmed that the applicant has addressed the information to demonstrate that the characteristics of the site fall within the site parameters specified in the DC rule, and that there is no outstanding information in regard to flood protection remaining to be addressed in the Turkey Point Units 6 and 7 COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information relative to the flood protection measures important to the design and siting of this plant. The staff finds that the applicant has considered the appropriate site phenomena in establishing the flood protection measures for SSCs. The staff has reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.10, PTN COL 2.4-2, and PTN COL 2.4-6, and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.10, of this SER, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1)(iii) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses the part of COL Information Item 2.4-2 related to flood protection requirements and COL Information Item 2.4-6.

2.4.11 Low Water Considerations

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.11 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to low water considerations. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

2.4.11.1 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.4.11 addresses natural events that may reduce or limit the available safety-related cooling water supply. The applicant ensures that an adequate water supply will exist to shut down the plant under conditions calling for safety-related cooling.

Section 2.4.11 of this SER presents an evaluation of the following specific areas: (1) low water conditions due to the worst drought considered reasonably possible in the region, (2) effects of low water surface elevations caused by various hydrometeorological events and a potential blockage of intakes by sediment, debris, littoral drift, and ice because they can affect the safety-related water supply, (3) effects of low water on the intake structure and pump design bases in relation to the events described in SER Sections 2.4.7, 2.4.8, 2.4.9, and 2.4.11, which consider the range of water supply needed by the plant (including minimum operating and shutdown flows during anticipated operational occurrences and emergency conditions) compared with availability (considering the capability of the UHS to provide adequate cooling water under conditions calling for safety-related cooling), (4) use limitations imposed or under discussion by Federal, State, or local agencies authorizing the use of the water, (5) potential implications of seismic and non-seismic information on the postulated worst-case low water scenario for the proposed plant site, and (6) any additional information requirements prescribed in the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52.

2.4.11.2 Summary of Application

The applicant addressed the information related to low water considerations in Turkey Point Units 6 and 7 COL FSAR Section 2.4.10.

AP1000 COL Information Item

- PTN COL 2.4-3 Cooling Water Supply

COL License Information Item 2.4-3 requires COL applicants to provide site-specific information related to the water supply resources to provide makeup water to the service water system cooling tower.

2.4.11.3 Regulatory Basis

The relevant requirements of the NRC regulations for low water considerations, and the associated acceptance criteria, are described in Section 2.4.11 of NUREG-0800.

The applicable regulatory requirements for identifying the effects of low water are:

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

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

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

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

- Regulatory Guide 1.59 as supplemented by best current practices; and

- Regulatory Guide 1.102 as it relates to providing assurance that SSCs important to safety have been designed to withstand the effects of natural flooding phenomena likely to occur at the site

2.4.11.4 Technical Evaluation

Information Submitted by Applicant

The applicant referred to the AP1000 DCD and incorporated it by reference. The applicant noted that the passive containment cooling system for Turkey Point Units 6 and 7 does not need an open surface water source to perform its safety-related function, and, therefore, its operation is not impaired by low flow conditions in surface water bodies. The applicant referred to AP1000 DCD Subsection 6.2.2 for a detailed description of the UHS design.

The applicant stated that for the AP1000 design, the passive containment cooling system serves as the ultimate heat sink for design basis accident events The passive containment cooling system is not reliant on the source of water from the cooling towers' makeup water system. In the Turkey Point Units 6 and 7 design, makeup for the passive containment cooling system is provided by means of a connection to the municipal water supply.

Additionally, the applicant stated that the non-safety-related raw water system has 100 percent redundancy because either of its two makeup water sources (i.e., reclaimed water supplied by the Miami-Dade County Water and Sewer Department and saltwater withdrawn from radial collector wells) could fully supply the need for makeup water.

Based on this information, the applicant stated that no warning of impending low flow from the cooling tower makeup water system is required, and makeup water supply during low flow conditions would not affect the ability of the safety-related UHS to provide the necessary cooling for emergency conditions.

Staff's Technical Evaluation

The staff reviewed the information supplied by the applicant. The staff accepts the applicant's conclusion that because the passive containment cooling system for Turkey Point Units 6 and 7 does not depend on an open surface water source to perform its safety-related function, its operation is not adversely affected by low flow conditions in surface water bodies. There are no site characteristics in the DCD associated with low water conditions.

The applicant has provided the information needed to address the water supply sources to provide makeup water to the service water system cooling tower. The staff confirmed that the raw water system for Units 6 and 7 is designed with redundancy, as either of its two raw water sources could fully supply the need for makeup water for the service water system cooling tower. These two water sources can also provide makeup to the passive containment cooling system tank. Staff also notes that neither of these two sources would be sensitive to low-water conditions in a surface water body. Therefore, the staff finds that low water conditions would not affect the safety of Turkey Point Units 6 and 7.

2.4.11.5 *Post Combined License Actions*

There are no post COL activities related to this subsection.

2.4.11.6 *Conclusions*

The staff reviewed the application and confirmed that the applicant has addressed the information related to low water conditions and the water supply resources to provide makeup water to the service water system cooling tower, and that there is no outstanding information remaining to be addressed in the Turkey Point Units 6 and 7 COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated information relative to the low water effects important to the design and siting of this plant. The staff finds that the applicant has considered the appropriate site phenomena in establishing the design bases for SSCs. The staff has reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.11, PTN COL 2.4-3, and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.11, of this SER, whether the applicant has met the relevant requirements of 10 CFR Part 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR Part 52 and 10 CFR Part 100 in regard to low water concerns.

2.4.12 Groundwater

2.4.12.1 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.4.12 describes the hydrogeological characteristics of the site. The most significant objective of groundwater investigations and monitoring at this site is to evaluate the effects of groundwater on safety-related plant facilities. The evaluation is performed to assure that the maximum groundwater elevation remains below the AP1000 DCD site parameter value. The other significant objectives are to examine whether groundwater provides any safety-related water supply; to determine whether dewatering systems are necessary to maintain groundwater elevation below the maximum specified level; to measure characteristics and properties of the site needed to develop a conceptual site model of groundwater movement; and to estimate the direction and velocity of movement of potential radioactive contaminants.

This section presents an evaluation of the following specific areas: (1) identification of the aquifers, types of onsite groundwater use, sources of recharge, present withdrawals and known and likely future withdrawals, flow rates, travel time, gradients and other properties that affect the movement of accidental contaminants in groundwater, groundwater levels beneath the site, seasonal and climatic fluctuations, monitoring and protection requirements, and manmade

changes that have the potential to cause long-term changes in local groundwater regime, and (2) effects of groundwater levels and other hydrodynamic effects of groundwater on the design.

2.4.12.2 Summary of Application

This section of the Turkey Point Units 6 and 7 COL FSAR addresses groundwater conditions in terms of influences on structures and water supply.

The applicant submitted Turkey Point Units 6 and 7 COL FSAR Section 2.4.12 as a site-specific supplement designed to address COL Information Item 2.4-4.

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

- PTN COL 2.4-4

COL Information Item 2.4-4 requires COL applicants to provide site-specific information on groundwater.

This COL item is addressed by Turkey Point Units 6 and 7 COL FSAR Section 2.4.12. In particular, this section addresses the site-related parameter for groundwater level that is specified in Table 2-1 of Revision 19 of the DCD, and is defined and discussed in Section 2.4.1.4 of Revision 19 of the DCD. Section 2.4.1.4 states:

> Combined License applicants referencing the AP1000 certified design will address site-specific information on groundwater. No further action is required for the sites within the bounds of the site parameter for groundwater.

2.4.12.3 Regulatory Basis

The relevant requirements of the NRC regulations for groundwater, and the associated acceptance criteria, are described in Section 2.4.12 of NUREG-0800.

The applicable regulatory requirements are:

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

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

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

2.4.12.4 Technical Evaluation

The NRC staff reviewed Section 2.4.12 of the COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic. The NRC staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to groundwater. The results of the NRC staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL application are documented in NUREG-1793 "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design" and its supplements.

2.4.12.4.1 Regional Hydrogeologic Description

Information Submitted by Applicant

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.12.1.2, the applicant described the geologic formations, regional and local groundwater aquifers, aquifer recharge and discharge regions, and onsite groundwater use. The hydrogeologic conceptual model of the Turkey Point Units 6 and 7 site was formulated by the applicant using data sources that included:

- A desktop study of the regional groundwater system derived from State, Federal, and other sources of information;
- A review of Florida Power and Light FSAR Units 3 and 4 documentation with regard to groundwater;
- The evaluation of site-specific geotechnical and geologic data collected during characterization of the Turkey Point Units 6 and 7 site;
- The evaluation of regional and local hydrogeology through review of studies, data and information, such as proximal deep-well injection sites; and
- The evaluation of site-specific hydrogeology through review of data and information obtained during construction and testing of Class V Exploratory Well EW-1 and Dual Zone Monitoring Well DZMW-1.

The site-specific Turkey Point Units 6 and 7 data were considered by the applicant along with data from existing Units 3 and 4 to formulate the conceptual groundwater and transport model for the site with a focus on the proposed location for Turkey Point Units 6 and 7.

In Turkey Point Units 6 and 7 COL FSAR, Section 2.4.12.1.1, the applicant described the Turkey Point Units 6 and 7 site, which is in Miami-Dade County, FL, as follows: The site is in the Southern Slope subprovince of the Southern Zone of the Florida Platform, which is a partly submerged peninsula of the continental shelf, in the Atlantic Coastal Plain physiographic province. The subprovince is characterized by relatively flat topography ranging from sea level at the coast to 2.4 to 0.8 ft mean sea level (MSL) NAVD 88 along the northern and western inland boundaries of the sub-province. The plant is bordered on the east by Biscayne Bay, on the west by FPL Everglades Mitigation Bank, and on the north by Biscayne Bay National Park. The applicant stated that the plant area consists primarily of coastal mangroves and tidal flats along the western margin of Biscayne Bay that have been modified to accommodate the industrial wastewater facility consisting of cooling canals for Turkey Point Units 3 and 4. The applicant stated that the canals contain approximately 4 billion gallons of water, and are unlined. Additionally, there is an interceptor ditch between the western side of the cooling canals and the

L-31E canal in which the water level is carefully controlled as to inhibit landward movement of shallow saline groundwater from the site. The water levels in all canals are carefully controlled to maintain static groundwater-surface water interactions. Underlying the Turkey Point Units 6 and 7 site are 4,000 to 15,000 feet of sedimentary deposits including clastics consisting of quartz sands, silt, marl, and clay and nonclastics consisting of carbonate materials such as shell beds, calcareous sandstone, limestone, dolostone, dolomite, and anhydrite.

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.12.1.2, the applicant stated that there are three regional aquifer systems (or hydrogeologic units) that are present at the Turkey Point Units 6 and 7 site. The applicant stated that these systems include the surficial aquifer system, the intermediate aquifer system/confining unit, and the Floridan aquifer system (Southeastern Geological Society, 1986). Regional thicknesses and depths are presented in Turkey Point Units 6 and 7 COL FSAR Figure 2.4.12-202 and site thicknesses and depths for upper units are presented in Turkey Point Units 6 and 7 COL FSAR Figure 2.4.12-204.

The applicant indicated that the surficial aquifer system consists of unconsolidated quartz sands, shell beds, and carbonates ranging in age from Upper Miocene (Tamiami Formation) to Holocene. The applicant indicated further that the surficial aquifer system consists of the lower Tamiami aquifer, which is in some cases overlain by confining beds of the Tamiami Formation; and the overlying water table aquifer, which is referred to as the Biscayne aquifer. The entire surficial aquifer system is often referred to as the Biscayne aquifer, and in this report and the Turkey Point Units 6 and 7 FSAR, the terms Biscayne aquifer and surficial aquifer are used interchangeably. In the region, the thickness of the Biscayne aquifer ranges from approximately 20 to 400 ft (6 to 122 m). Detailed geological, physiographical, and geomorphological information are presented in Turkey Point Units 6 and 7 COL FSAR Subsections 2.5.1.1 and 2.5.1.2.

The applicant stated the intermediate aquifer system/confining unit underlies the Biscayne and consists of a thick sequence (around 900 feet) of fine-grained siliciclastics interbedded with carbonate strata of late Oligocene to Miocene age of the Hawthorn Group. The intermediate aquifer/confining unit comprises the Hawthorn Group sediments (composed of the Peace River and the Arcadia Formations) at elevations starting at 100 to 200 ft (30 to 61 m) below ground surface (bgs) and continuing to 700 to 1,250 ft (213 to 381 m) bgs MSL in the region of the Turkey Point Units 6 and 7 site. The applicant indicated that the unit is defined by the Southeastern Geological Society (1986) as the system of rocks that collectively retards exchange of water between the overlying surficial aquifer system and the underlying Floridan aquifer system. The applicant stated that transmissive units may occur within the intermediate confining unit and be used as local aquifers where they are present. As a result, the applicant stated that this hydrogeologic unit may be referred to locally as either the “intermediate confining unit” or the “intermediate aquifer system,” which is a consequence of its observed variability in permeability throughout the State. The applicant stated that overall, this unit provides good confinement for the underlying Floridan aquifer system.

The applicant described the Floridan aquifer system in southern Florida as a thick sequence (2,300–3,400 ft (701-1036 m)) of permeable, Tertiary age interbedded carbonate rocks underlying approximately 100,000 mi^2 (258,999 km2) in the southeastern coastal U.S. The applicant described the Floridan aquifer system as follows: The Floridan aquifer comprises three different hydrogeologic units, the Upper Floridan aquifer, the middle confining unit, and the Lower Floridan aquifer. The Floridan aquifer comprises (from oldest to youngest) the Paleocene age Cedar Keys Formation, the Eocene age Oldsmar Formation, the Avon Park Formation, the Ocala Limestone (where it occurs), the early Oligocene age Suwannee

Limestone, and in some areas, the lower Hawthorn Group. The Upper Floridan aquifer is described by the applicant as thin water-bearing zones of high permeability interlayered with thick zones of low permeability, which could be between 100 to 400 ft (30 to 122 m) thick (Turkey Point Units 6 and 7 COL FSAR Figure 2.4.12-208).

The applicant indicated that the middle confining unit of the Floridan aquifer system underlies the Upper Floridan aquifer. In the Turkey Point Units 6 and 7 COL FSAR, the applicant reports that in the vicinity of the site, the top of the MCU occurs around 1,200 ft (366 m) deep and is greater than 1,000 ft (305 m) thick. The applicant states in the Turkey Point Units 6 and 7 COL FSAR that the middle confining unit can often occur as an upper and lower low permeability unit separated by a higher permeability zone (the Avon Park permeable zone).

Based on regional studies, the applicant estimated the top of the Lower Floridan aquifer to be at depths greater than 2,400 ft (732 m) bgs in the vicinity of the site. The applicant indicated that this unit consists of a thick sequence of low permeable zones that are similar in lithology to the middle confining unit. The applicant indicated that a highly permeable zone in the Lower Floridan aquifer known as the Boulder Zone occurs beneath the top of the Lower Floridan aquifer and can be up to 700 ft (213 m) thick. The applicant reports that based on previous studies in southern Florida, the Boulder Zone top elevation may vary from 2,000 to 3,400 ft (610 to 1,036 m) below ground surface. The applicant also stated that Boulder Zone contains saltwater and is used widely in Florida for wastewater disposal through deep injection wells. The applicant indicated further that the base of the Lower Floridan aquifer is marked by massive impermeable anhydrite beds of the Cedar Keys Formation.

Staff's Technical Evaluation

The staff reviewed subsections 2.4.12.1.1 "Physiography and Geomorphology" and 2.4.12.1.2 "Regional Groundwater Aquifers" of the Turkey Point Units 6 and 7 COL FSAR as well as supporting site studies, such as reports from the construction and testing of on-site wells EW-1 and DZMW-1 (McNabb HCI, 2012a and 2012b). The staff's review confirmed that the applicant addressed relevant information. In its review of the application, staff also reviewed documents on the hydrology and aquifers of the region by the United States Geological Survey (USGS) (Cunningham, 2015; Williams and Kuniansky, 2015; Reese and Richardson, 2008; Klein and Hull, 1978; Miller, 1986), and the Southeastern Geological Society (Southeastern Geological Society, 1986). The staff also reviewed studies detailing the hydrogeology of the vicinity including sites where deep well injection occurs (Maliva, Guo, and Missimer 2007; Walsh and Price, 2010; Starr, Green and Hull 2001; and, EPA 2003). The staff determined that the variability in depths and thicknesses of important hydrogeologic units reported from regional, local and site studies cited by the applicant and summarized above are reasonable and are consistent with observations made by others in the vicinity of the site and the region. Because the staff verified the applicant's description of the regional hydrogeologic setting and groundwater aquifers consistent with the data and information cited in the studies and literature above, the staff determined that the applicant's description is acceptable.

2.4.12.4.2 Hydrogeologic Site Description and Characteristics

Information Submitted by Applicant

In Turkey Point Units 6 and 7 COL FSAR, Sections 2.4.12.1.3 and 2.4.12.1.4, the applicant described site-specific data from the major geological and hydrogeological units shown in Turkey Point Units 6 and 7 COL FSAR Figure 2.4.12-202.

Biscayne Aquifer

The applicant indicated that the surface consists of a muck layer from 2-7 feet thick, followed by sediments and rocks comprising the Biscayne aquifer, including the Miami Limestone, the Key Largo Limestone, the Fort Thompson Formation, and the Tamiami Formation (Turkey Point Units 6 and 7 COL FSAR Fig. 2.4.12-204). The applicant indicated that at the site, the most productive parts of the Biscayne aquifer are composed of the Miami Limestone, Key Largo Limestone, and Fort Thompson Formation. The applicant stated that the surficial (Biscayne) aquifer extends to an elevation of -10 ft NGVD 29 in the southern portions of Miami-Dade County to more than -240 ft (-73 ft) NGVD 29 in the northern portions of Palm Beach and Broward Counties. The applicant indicated further as follows: Site specific boring data and characterization data from exploratory well EW-1 indicate that the Biscayne aquifer could be around 115 ft (35 m) thick with a base elevation of around 140 ft (43 m), as indicated by the presence of a dark greenish-gray, clay rich silt marker bed (EW-1 drilling report (McNabb HCI, 2012a and 2012b). The EW-1 drilling report (McNabb, 2012a) referenced by the applicant, indicates that the base of the Tamiami Formation is located at a depth of 210 ft (64 m) at the site. The applicant stated that at the Turkey Point Units 6 and 7 site, the Biscayne aquifer is saline due to seawater intrusion.

The applicant stated further as follows: A subsurface investigation of the geological and hydrogeological environment from the ground surface to 615 ft below ground surface (bgs) was conducted by the applicant at the Turkey Point Units 6 and 7 site from February 2008 through June 2008. Results from 94 geotechnical borings, 4 cone penetrometer tests, 22 groundwater observation wells, and 2 test pits from the MACTEC (2008) report are incorporated into the Turkey Point Units 6 and 7 COL FSAR. Boring logs, core photographs, and soil testing data are presented in Turkey Point Units 6 and 7 COL FSAR, Section 2.5.4. Ten paired observation wells (20 individual wells) were completed in the Miami Limestone/Key Largo Limestone (screened from 15–28 ft (4.6–8.5 m) bgs) and the Fort Thompson Formation (screened from 98 to110 ft (30 to 34 m) bgs). Two deep geotechnical piezometers (at Turkey Point Units 6 and 7, respectively) were installed at 135 ft (41 m) bgs to monitor pressure in the Tamiami Formation. Pressure transducers were installed in two surface water stations in cooling canals surrounding the Turkey Point Units 6 and 7 plant area. Groundwater levels were monitored hourly using piezometers beginning in June 2008 and through July 2010. Based on the investigations, the applicant divided the Biscayne aquifer into five targeted aquifer test zones:

- The upper aquitard (Miami Limestone);
- The upper Biscayne aquifer test zone (Key Largo Limestone);
- The middle aquitard (freshwater limestone unit);
- The lower Biscayne aquifer test zone (Fort Thompson Formation); and,
- The lower aquitard (Upper Tamiami Formation).

The applicant conducted thirty-one in situ hydraulic conductivity slug tests in these wells, and reported estimates of hydraulic conductivity ranging from 3–319 ft/d (0.9-97 m/d) (geometric mean, 61.3 ft/d) in the upper aquifer (Key Largo Limestone) wells; and 1–20 ft/d (0.3-6 m/d) (geometric mean, 20.1 ft/d) in the lower aquifer (Fort Thompson Formation) wells. Results are

presented in Turkey Point Units 6 and 7 COL FSAR Table 2.4.12-208. The applicant stated that the estimates for the Fort Thompson Formation interval are lower than regional averages and local aquifer tests. The applicant suggested that the filter pack surrounding the screened interval may have artificially depressed the observed hydraulic conductivity.

The applicant performed four aquifer pump tests in the Biscayne aquifer from January to March 2009 in order to determine the properties and performance of the Biscayne aquifer and the overlying and underlying aquitards for evaluation of construction dewatering, modeling of groundwater flow, postulated release of liquid radionuclides, and simulation of radial collector well performance. The applicant stated that it "amended" the usual definition of the term "aquitard" from a "low permeability unit" to one which "has a lower permeability than the aquifer units." The applicant indicated as follows: The resolution within the Biscayne aquifer is finer in the pump test study than in the slug test study above. Four test wells and 50 temporary observation wells were monitored during the pump tests. Two open-hole pumping wells (30 in (76 cm) diameter) were located at each reactor site, one each in the upper Biscayne aquifer (Key Largo Limestone) and the lower Biscayne aquifer (Fort Thompson Formation). Following the convention of upper ("U") and lower ("L"), the applicant designated pumping wells as PW-6U, PW-6L, PW-7U, and PW-7L. The upper aquifer wells were 45 ft (13.7 m) deep, PW-6L was 105 ft, and PW-7L was 87 ft (26.5) deep. The observation wells at each reactor site consisted of five well clusters containing five temporary wells each. For each pumping well at each unit, two well clusters were located at right angles to and approximately 10 ft (3 m) away. An additional shared well cluster was located 25 ft (7.6 m) away and positioned between the two pump test wells at each unit. The wells were installed in each aquifer or aquitard zone.

The results of the pump tests were discussed in detail by the applicant in Turkey Point Units 6 and 7 COL FSAR Appendix 2BB and were presented in Turkey Point Units 6 and 7 COL FSAR Table 2.4.12-209 . The applicant's aquifer test results and a summary of regional studies are summarized in SER Tables 2.4.12-1 and 2.4.12-2 below for the confining or low permeability intervals (Table 2.4.12-1) and the aquifer or permeable intervals (Table 2.4.12-2).

Table 2.4.12-1. Representative Properties of Confining (Low Permeability) Layers in the shallow Turkey Point Units 6 and 7 site Hydrogeologic Strata (from Turkey Point Units 6 and 7 COL FSAR).

Hydrogeologic Unit	Property	Units	Representative Value *	Range	FSAR Source
Muck	Thickness	ft	3	3-5	Figure 2.4.12-204
	Vertical hyd cond	gpd/ft^2			
	Horizontal hyd	Cm/s	3.5e-3		Langevin, 2001
	cond	Cm/s	3.5e-5		Langevin, 2001
	Vertical hyd cond	Cm/s	3.5e-3		Merritt, 1996
	Horizontal hyd	Cm/s	3.5e-4		Merritt, 1996
	cond	Pcf			

Hydrogeologic Unit	Property	Units	Representative Value *	Range	FSAR Source
	Vertical hyd cond				
	Bulk (dry) density				
	Total porosity	%			
Miami Limestone	Thickness	Ft	25	7-25	Figure 2.4.12-204
	Vertical hyd gradient	-			
	Vertical hyd cond	gpd/ft2	138	103-173	Table 2BB-207
	Vertical hyd cond	Cm/s	7.9e-2		Dames and Moore, 1971
	Bulk (dry) density	pcf			
	Total porosity	%			
Freshwater limestone	Thickness	Ft	15	11-19	Table 2BB-207
	Thickness	Ft	11, 19, 11, 19		Table 2.4.12-209
	Thickness	Ft	<= 9		Appendix 2.3
	Vertical hyd cond	gpd/ft2	26	2-54	Table 2BB-207
	Vertical hyd cond	Cm/s	0.17		Fish and Stewart, 1991
	Vertical hyd cond	cm/s	0.2, 0.4, 6, 7		Table 2.4.12-209
	Bulk (dry) density	pcf			
	Total porosity	%			
Tamiami limestone	Thickness	Ft	105		Figure 2.4.12-204
	Vertical hyd cond	gpd/ft2	4340	740-7940	Table 2BB-207
	Vertical hyd cond	Cm/s	5.6e-2		Fish and Stewart, 1991
	Bulk (dry) density	pcf			
	Total porosity	%		0.1-0.31	Table 2.4.12-205

* Values are arithmetic mean except where noted

gm = geometric mean, am = arithmetic mean

Table 2.4.12-2. Representative Properties of Aquifers (Permeable Intervals) in the shallow Hydrogeologic Strata (from Turkey Point Units 6 and 7 COL FSAR)

Hydrogeologic Unit	Property	Units	Representative Value *	Range	FSAR Source
Upper Biscayne (Key Largo Limestone)	Thickness	ft	22	24-33	Figure 2.4.12-204
	Transmissivity	gpd/ft	2,265,500	2,200,000-2,331,000	Table 2BB-207
	Transmissivity	Gpd/ft	3,000,000		App 2BB Dames and Moore, 1971
	Storage coefficient	-	0.0012	0.00015-0.0022	Table 2BB-207
	Horizontal hyd cond	gpd/ft2	81,500	71,000-92,000	Table 2BB-207
	Horizontal hyd cond	Ft/d	61.3 (gm)	3-319	Table 2.4.12-209
	Horizontal hyd cond	Cm/s	5.1		Dames and Moore, 1971
	Horizontal hyd gradient				
	Bulk (dry) density	pcf			
	Total porosity	%	0.31		Table 2.4.12-205
	Effective porosity	%			
Lower Biscayne (Fort Thompson Formation)	Thickness	ft	65		Figure 2.4.12-204
	Transmissivity	gpd/ft	126,600	122,000-131,200	Table 2BB-207
	Transmissivity	Gpd/ft	1,000,000		App. 2BB, Dames and Moore, 1971
	Storage coefficient	-	0.00158	0.00016-0.0003	Table 2BB-207
	Storage coefficient	-	2.4e-4		Table 2.4.12-209
	Horizontal hyd cond	Ft/d	20.1(gm)	1-120	Table 2.4.12-209
	Horizontal hyd cond	Cm/s	1.6		Dames and Moore, 1971

Hydrogeologic Unit	Property	Units	Representative Value *	Range	FSAR Source
	Hydraulic gradient				
	Bulk (dry) density	pcf			
	Total porosity	%	0.31		Table 2.4.12-205
	Effective porosity	%			

* Value = arithmetic mean except where noted

gm = geometric mean, am = arithmetic mean

Based on the aquifer testing, the applicant determined that there is an Upper Higher Flow Zone (UHFZ) within the Miami/Key Largo Limestone boundary and a more localized and discontinuous Lower Higher Flow Zone (LHFZ) in the Fort Thompson Formation within the area of the site. The applicant stated that the UHFZ and LHFZ are relatively thin layers of high secondary porosity.

Intermediate Aquifer/Confining Unit

Turkey Point Units 6 and 7 COL The applicant described the intermediate confining unit as follows: The unit lies between the Biscayne aquifer and the Floridan aquifer system. It is described by the applicant as a thick unit with very low saturated hydraulic conductivity of the confining units that provides good confinement for the Upper Floridan aquifer. Site-specific studies conducted as part of the drilling, construction and testing of exploratory well EW-1 and monitoring well DZMW-1 at the Turkey Point 6 and 7 site (McNabb HCI, 2012a and 2012b) indicate that the unit is slightly less than 900 ft (274 m) thick, which is consistent with regional thicknesses discussed in the section above. The unit is not exposed at the ground surface at the Turkey Point Units 6 and 7 site, and recharge occurs via infiltration from the overlying surficial aquifer and/or from the underlying Upper Floridan aquifer.

Floridan Aquifer

The applicant described the unit beneath the intermediate confining unit as follows: Below the intermediate confining unit is the Floridan aquifer system, comprising the Upper Floridan aquifer, the Middle Confining Unit, and the Lower Floridan aquifer (Turkey Point Units 6 and 7 COL FSAR Figure 12.4-202). The Floridan aquifer is found at depth around 1010 ft bgs and is approximately 3,000 ft thick in the vicinity of the Turkey Point Units 6 and 7 site.

The Upper Floridan consists of several thin water-bearing zones of higher permeability interbedded with zones of low permeability. The primary geologic units associated with the Upper Floridan include the Suwannee Limestone and the top of the Avon Park Formation. The Upper Floridan is a major aquifer in Florida. However, water in Miami-Dade County and in the area of the site is brackish and of variable quality. The aquifer has an upward hydraulic gradients in the vicinity of the Turkey Point Units 6 and 7 site. Site-specific information obtained by the applicant at well EW-1 indicates that the Upper Floridan aquifer thickness at the site is approximately 400 ft (122 m) (McNabb HCI, 2012a and 2012b).

The Middle Confining Unit of the Floridan separates the Upper Floridan aquifer from the Lower Floridan aquifer and consists primarily of the Avon Park Formation, which is over 1,000 ft (305 m) thick in the vicinity of the Turkey Point Units 6 and 7 site. In the Turkey Point Units 6 and 7 COL FSAR, the applicant reports that in the vicinity of the site, the top of the MCU occurs around 1,200 ft (366 m) deep (based on regional mapping) or as deep as 1,930 ft (588 m) bgs (based on data from well EW-1 at the site). This variation in depths is likely because, as the applicant states in the Turkey Point Units 6 and 7 COL FSAR, the middle confining unit can often occur as both an upper and lower unit separated by a higher permeability zone (the Avon Park permeable zone). The EW-1 report indicates that the top confining unit may occur around 1,450 ft (442 m) bgs, where the TDS increases above 10,000 mg/L and the Avon Park Formation becomes more confining, while the top of the bottom confining unit occurs at 1,930 ft (588 m) deep, as discussed above. Based on this, the total estimated thickness of this unit could be nearly 1,500 ft (457 m), including the Avon Park Permeable Zone, if it is present.

The Lower Floridan aquifer is a sequence of thin permeable zones interbedded with thicker less permeable zones, and is comprised of the Oldsmar Formation and the upper portion of the Cedar Keys Formation. Based on information from well EW-1, the applicant indicates that at the site, the Lower Floridan aquifer top is located at 2,915 ft (888 m) bgs. The applicant indicates further as follows: The Lower Floridan aquifer unit consists of a thick sequence of low permeable zones with a highly permeable (Boulder Zone) near the base. The “Boulder Zone” is used extensively by coastal municipalities and industries for disposal of treated sewage and other wastewaters via injection wells. In Table 2.4.12-205, which is summarized from an EPA relative risk assessment for management of treated wastewater in south Florida, FPL reports that the top of the Boulder Zone is located between 2,750 and 3,250 ft (838 and 991 m) bgs (FPL 2015). Data collected from well EW-1 indicate that the top of the Boulder Zone at the site is 3,030 ft (924 m) bgs, which is within this range. The base of the Floridan was not encountered in well EW-1 at the Turkey Point site.

The applicant provided typical values of hydraulic parameters for different formations in Miami-Dade County as compiled by EPA in COL FSAR Table 2.4.12-205. Values from tests within a radius of 15 mi (24 km) of the site, including the 1971 Dames and Moore investigation for Turkey Point Units 3 and 4 and data from the South Florida Water Management District (SFWMD) are presented in Turkey Point Units 6 and 7 COL FSAR Table 2.4.12-206.

<u>Staff’s Technical Evaluation</u>

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Sections 2.4.12.1.3 “Local Hydrogeology” and Section 2.4.12.1.4 “Site-Specific Hydrogeology” of the Turkey Point Units 6 and 7 COL FSAR on hydraulic site characteristics. The staff examined site-specific geotechnical borings, observation well data, geophysical data, and test pit data collected by the applicant to characterize the Biscayne aquifer in the vicinity of the site (MACTEC, 2008). Staff reviewed the applicant’s data and results from aquifer tests conducted within multiple intervals of the Biscayne aquifer and determined that the applicant’s assessment of the influence on the filter pack during aquifer slug tests is reasonable, as follows: Slug tests, although useful, are limited to testing an aquifer volume in the immediate area of the well screen and are subject to the influences of the well filter pack. Aquifer pumping tests sample a much larger volume of the aquifer during the test and better represent aquifer parameters over a larger area of the aquifer. Therefore, the staff concludes that the applicant’s assessment of a better resolution of aquifer parameters from the pumping tests to be acceptable.

The applicant performed four aquifer pumping tests with two tests performed adjacent to locations of each proposed reactor building, one in the Key Largo Limestone and the other in the Fort Thompson formation. Staff confirmed that the parameters pumping test results were within the ranges of other studies in the vicinity of the site (e.g., Fish and Stewart, 1991) and that the highest permeabilities in the limestones (Miami and Key Largo Limestones) and calcareous sandstones (Fort Thompson Formation) of the Biscayne aquifer determined by the applicant are also consistent with the study findings. The UHFZ designated by the applicant is located at the boundary of the Miami/Thompson Limestones while the LHFZ as designated by the applicant is within the Fort Thompson Formation. As Fish and Stewart (1991) note, clayey or silty sands, such as those in the upper clastic unit of the Tamiami Formation, are less permeable. The staff confirmed that the silt, clay, and mixtures of lime mud, shell, and sand in the upper and lower clastic units of the Tamiami Formation have relatively low permeabilities, consistent with the results of the applicant's pumping test results (e.g., transmissivities in Tables 2.4.12-1 and 2.4.12-2 above).

The applicant described an intermediate aquifer/confining unit below the Biscayne aquifer consisting of the Hawthorn Group as low permeability and providing good confinement for the Upper Floridan aquifer. The staff notes that the low permeability bottom portion of the Tamiami Formation is also included in this unit in southeastern Florida (Meyer, 1989), which would be consistent with characterization of this group as a confining unit in the area of the site. Scott (1988, 1990) has described the lithology of the Hawthorn as varying greatly between areas, but consisting primarily of phosphatic clay, silt, and sand. A joint SFWMD/USGS cooperative study has characterized the intermediate confining unit as a confining unit or aquifer system depending on the variable lithology of this unit (Reese and Richardson, 2008). However, in east-central and southeastern Florida, the intermediate aquifer system, which includes the Hawthorn Group, has been characterized as an intermediate confining unit (Reese and Richardson, 2008). Based on the information cited above, the staff finds the applicant's characterization of the intermediate confining unit acceptable.

The applicant described the Floridan aquifer in the vicinity of the site as comprised of the Upper Floridan, Middle Confining Unit, and the Lower Floridan. The applicant's estimate of the thickness of the unit is consistent with USGS studies (Meyer, 1989) showing thicknesses of over approximately 3,000 ft in southeastern Florida. The applicant's characterization of the Upper Floridan containing thin water-bearing zones of high permeability interlayered with thick zones of low permeability is consistent with USGS descriptions (e.g., Reese and Richardson, 2008, Reese, 1994) of this interval. Staff notes that USGS studies (Meyer, 1989) confirm the applicant's description of the brackish water quality of the Upper Floridan. The applicant's description of the Avon Park Formation within the Middle Confining Unit and extending into the Lower Floridan in places agrees with USGS (i.e., Meyer, 1989 and Reese, 1994) descriptions. The base of the Lower Floridan has been characterized as being at approximately 4,000 ft bgs, which is in general agreement with the applicant's estimate of greater than 4,000 ft bgs. As the applicant states, the highly permeable Boulder Zone is used for disposal of wastewater as governed by the FDEP Underground Injection Control Program (Chapter 62-528 Florida Administrative Code). Accordingly, and for the reasons stated above, the staff finds the applicant's description of the Floridan aquifer to be acceptable.

The FPL constructed wells EW-1 and DZMW-1 at the Turkey Point site to confirm and refine geology, hydrogeologic parameters, and general expectations for groundwater movement at the site. This was performed primarily to evaluate the feasibility of disposal of plant blowdown through proposed deep injection wells. Lithologic, hydrogeologic, and geophysical data was gathered at each well (McNabb HCI, 2012a and 2012b). Injection testing was also performed to

test the ability of the Boulder Zone to receive proposed effluent and the ability of the Middle Confining Unit to confine the injected effluent (FPL 2015). Staff evaluated data from these wells and confirmed that the depths, thicknesses, hydrogeologic properties, and potential results of injection at the site were reasonable and consistent with results determined through more recent studies at other sites in the vicinity and region (e.g., Cunningham, 2015; Williams and Kuniansky, 2015; and, Reese and Richardson, 2008). Reese and Richardson (2008) recognized that the Avon Park Permeable Zone in southeastern Florida, which is part of the Middle Confining Unit, had been identified in previous studies as, "…the lower part of the Upper Floridan Aquifer" (Reese, 1994). As a result, the later studies do not treat the Upper Floridan aquifer as thick as presented in earlier studies, while the later studies treat the Middle Confining Unit as more vertically extensive than earlier studies (including Starr et al 2001, EPA 2003). Reese and Richardson (2008) and later reports also confirm that the Middle Confining Unit in southeastern Florida may occur as two lower permeability units, with a more permeable zone known as the Avon Park Permeable Zone, in between. Staff's review of the reports from on-site exploratory wells indicate that the brackish Upper Floridan aquifer is separated from the Lower Floridan aquifer and Boulder Zone by a thick section of less permeable rocks with elevated TDS which is identified as the Middle Confining Unit. This is consistent with the description of the Middle Confining Unit provided in the sources mentioned above.

Documents on the hydrology and aquifers of the region reviewed by staff include those by the USGS (Klein and Hull, 1978; Meyer, 1989; Johnston and Bush, 1988; Fish and Stewart, 1991; Starr et al., 2001; Reese and Richardson, 2008) and site-specific documents on the hydrology and aquifers of the site developed by the applicant (Dames and Moore, 1971, 1975, for Turkey Point Units 3 and 4) including the applicant's observation well data, aquifer test results, and hydrologic and geotechnical investigations of the site. As described above, the staff reviewed analysis, data, and reports compiled by the applicant, and confirmed that the applicant's evaluation and characterization of the aquifer system is acceptable and addressed the relevant information.

2.4.12.4.3 Groundwater Sources and Sinks

Information Submitted by Applicant

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.12.1.5, "Groundwater Sources and Sinks," the applicant described the regional, local, and site-specific sources of recharge and locations of discharge. The applicant stated that recharge to the Biscayne aquifer occurs over most of Miami-Dade County. The applicant stated that recharge to the Biscayne aquifer occurs through four major sources:

- Directly from rainwater and irrigation water infiltrating surface materials;
- Infiltration of surface water imported by run-off from the north in water conservation areas or by canals;
- Infiltration of urban runoff via drains, wells, and ponds; and,
- Groundwater inflow from southwestern Broward County located directly to the north of the site.

The applicant indicated that recharge by rainfall is greatest during the wet season from June through November, and recharge by canal seepage is greatest from December through May during the dry season.

The applicant stated that discharge from all aquifers occurs as baseflow to the Florida Bay and Biscayne Bay. The applicant stated that discharge of groundwater in the Biscayne aquifer is through seepage into streams, canals, or the ocean, evaporation, transpiration by plants, and through groundwater pumping. The applicant notes that the regional canal systems exert a major influence on groundwater levels and pathways, and most of the water that circulates in the Biscayne aquifer system is discharged into the canals and into the ocean, accounting for 15 to 25 in (38 to 64 cm) of equivalent precipitation per year. The applicant indicated that of the 60 in of annual precipitation, approximately 20 in (51 cm) per year are lost due to evapotranspiration, 16 to 18 in (41 to 46 cm) per year to discharge through canals and by coastal seepage, and the remainder to human consumption. The applicant also stated that recharge was typically on the order of 38 in (97 cm) per year.

The applicant stated that the water in the 5,900 acre (24 km^2) industrial wastewater cooling canals for the existing and operating Turkey Point Units condenser cooling water interacts with groundwater because the canals are not lined. The applicant described the canals as follows: Most cooling water canals are 3 ft (0.9 m) deep. Major, deeper canals (18 ft (5.5 m)) are the eastern return canal, the northern discharge canal, the south collector canal, and the main return canal (“grand canal”). A steady-state hydraulic head difference of 3 ft (0.9 m) is maintained between the Turkey Point Units 3 and 4 discharge location at the western side and the intake location on the eastern side, which promotes full circulation throughout the canal system. The applicant stated that canals convey warm waters away from and return cool water back to the currently operating units. The canals in the industrial wastewater facility do not discharge directly to surface water. Evaporative loss from the canals is significant and is replenished by inflow from the Biscayne aquifer, discharge of operating unit process water, rainfall, and storm water run-off. The applicant stated that there is net inflow from the saline Biscayne aquifer into the canal system, and that due to evaporation, water in the canals is more saline than Biscayne groundwater. The applicant stated further as follows: An interceptor ditch on the western side of the canal system was constructed to limit westward migration of water infiltrated into the Biscayne aquifer from the cooling canals. During the wet season a natural freshwater gradient is maintained, while during the dry season, water is pumped from the interceptor ditch into the westernmost cooling canal (Canal 32). The L-31E Canal located to the west of the interceptor ditch provides delivery of water to farmlands and wetlands to the south, and is designed to impede inland migration of saline groundwater.

In regard to the deeper Floridan units, the applicant stated as follows: The intermediate aquifer/confining unit is not exposed at the surface locally and recharge is believed to occur via downward leakage through the overlying Biscayne aquifer. Recharge to the Floridan aquifer system is therefore related to the extent of confinement by the intermediate aquifer/confining unit, and also the extent of karst drainage through this system. At the site, the Floridan system does not directly outcrop and is considered to be confined with an upward hydraulic gradient. Regional flow in the deeper Floridan aquifer involves deep circulation over long time periods where seawater is drawn into the Lower Floridan aquifer and is heated as it migrates landward, as shown in Turkey Point Units 6 and 7 COL FSAR Figure 2.4.12-243. The regional flow direction in the Upper Floridan and Biscayne aquifers is from west to east in southeastern Florida, and ultimately results in discharge into Biscayne Bay.

Staff's Technical Evaluation

The staff reviewed Section 2.4.12.1.5 "Groundwater Sources and Sinks" of the Turkey Point Units 6 and 7 COL FSAR. The staff independently reviewed the data, information and studies used by the applicant and confirmed that the applicant's evaluation adequately describes the aquifer conditions addressing the relevant information.

Staff reviewed the recharge to the Biscayne aquifer and determined that the applicant's characterization is in agreement with Biscayne aquifer hydrogeologic framework and modeling studies conducted by the USGS (e.g., Langevin, 2001; Klein and Hull, 1978; Reese and Richardson, 2008). These studies describe recharge sources and groundwater sinks within the Biscayne aquifer and characterize groundwater discharges and interactions with canals and discharge to the ocean during the wet and dry seasons. The staff reviewed additional documents on hydrology and aquifers of the region by USGS (Klein and Hull, 1978; Meyer, 1989; Fish and Stewart, 1991; Starr et al., 2001; Maliva et al 2007), which characterize the hydrology. The staff determined the applicant's evaluation of groundwater sources and sinks to be consistent with these independent studies and therefore acceptable.

The staff reviewed and confirmed historical, current, and projected groundwater use provided in the FSAR and checked the provided data through reviews of the reports and electronic databases available from the SFWMD (http://www.sfwmd.gov/watersupply). The staff confirmed the data described by the applicant to be acceptable. The applicant stated that the Floridan aquifer is considered a confined aquifer in the site vicinity, which is consistent with USGS studies (Johnson and Bush, 1988), and slow upward groundwater migration in the site vicinity as described by the applicant is consistent with USGS studies (e.g., Meyer, 1989). Accordingly, the staff concludes that the applicant's description of groundwater sources and sinks is consistent with independent studies and that the description of on-site hydrologic features is acceptable and adequate.

2.4.12.4.4 Plant Groundwater Use

Information Submitted by Applicant

In Turkey Point Units 6 and 7 COL FSAR, Sections 2.4.12.2.1.2, 2.4.12.2.1.3, and 2.4.12.2.1.6, the applicant described current and planned groundwater use for plant water supply and liquid waste disposal. In Turkey Point Units 6 and 7 COL FSAR, Section 2.4.12.2.1.2, the applicant stated that cooling water for the operating units is supplied via a closed loop system that includes the cooling canal system (or IWF) adjacent to the proposed Units 6 and 7 site. The applicant stated that non-cooling water supply for Units 3 and 4 is provided by the Miami-Dade Water and Sewer District (MDWASD) municipal water supply system. The applicant stated that cooling water for Unit 5 and process water for Units 1, 2, and 5 is tapped from the Upper Floridan aquifer production wells (PW-1, PW-3, and PW-4) at an average production rate of 170 million gallons per month. The maximum pumping rate is limited to a 90-day average of 14.06 million gallons per day and an average annual supply of 4,599 million gallons per year.

The applicant described the use of cooling water for the main condenser in Units 6 & 7 as follows: In Turkey Point Units 6 and 7 COL FSAR, Section 2.4.12.2.1.3, the applicant stated that for planned Units 6 and 7, makeup water for cooling the main condenser is expected to be supplied by two potential sources: the primary supply from reclaimed waste water provided by MDWASD South District Wastewater Treatment Plant, and a backup supply obtained through a system of four radial collector wells installed beneath Biscayne Bay at the Turkey Point

peninsula. Use of reclaimed water provided by MDWASD would eliminate the need for make-up water for Units 6 and 7 to be obtained from water resources near the site. In the FSAR, the applicant stated that radial collector wells would only be used "when reclaimed water cannot supply the quantity and/or quality of water needed for the circulating water system" (FPL 2015). When reclaimed water is used, the mechanical draft cooling towers for units 6 & 7 will use a maximum rate of 38,400 gallons per minute (gpm) based on four cycles of concentration. Due to the difference in water quality, fewer cycles on concentration could be achieved if radial collector wells were used. The reclaimed water from MDWASD will be temporarily stored within an onsite makeup water reservoir (MWR) and transferred to the cooling tower basins via a set of cooling tower makeup pumps.

The radial collector well laterals are expected to be located within the Upper Higher Flow Zone (a relatively thin layer of high secondary porosity) of the Biscayne Aquifer and are designed and located to pull water into the wells from the overlying Biscayne Bay (FPL 2015). The radial collector wells consist of a central concrete caisson from which a number of lateral lines extend at a depth of approximately 25 – 40 ft (8 to 12 m) bgs to approximately 900 ft (274 m) away from the caisson. At the end of each lateral line, a minimum of 300 feet will be screened. The exact dimensions of the wells will be based on site-specific conditions. The total makeup flow needed is estimated at 86,400 gallons per minute, and four radial collector wells capable of producing 45 million gallons per day will be installed. Four wells are planned to be drilled and three operated, leaving one in reserve. The applicant stated that aquifer pumping tests were performed on the Turkey Point peninsula at anticipated installation depths to evaluate the hydrogeologic suitability of that area for installation and operation of radial collector wells. Pump test results were evaluated using industry standard software and techniques to determine aquifer transmissivity values. Makeup supplied from the radial collector well system is delivered directly to the cooling towers basins and is not stored in the MWR.

The applicant stated that the raw water system is designed to supply 100 percent of the makeup water from either source (FPL 2015). The applicant stated that there are no safety-related cooling water canals or reservoirs (including the MWR) related to the operation of Turkey Point Units 6 and 7.

For Turkey Point Units 6 and 7, the applicant proposed to drill 12 Class I Industrial deep injection wells into the Boulder Zone within the Lower Floridan aquifer to dispose of cooling water blowdown and other plant effluents. The applicant described the injection wells and process as follows: Ten of these would be used as the primary injection wells and two would be used as backup wells (FPL 2015). Injection in the Boulder Zone is permitted through the Florida Department of Environmental Protection (FDEP) Underground Injection Control (UIC) process for disposal because of its characteristics, which indicate a natural ability to accept and confine the waste. This includes; (1) a depth of 3,030 ft (924 m) at Units 6 and 7, (2) confinement by more than 1,000 ft of overlying lower permeability limestone and dolomite beds between the Boulder Zone and the base of the Underground Source of Drinking Water (USDW), (3) significant secondary permeability and high transmissivity up to 2.46×10^7 ft^2/d in the Boulder Zone, which resulted in a slight increase in pressure during injection testing, and (4) total dissolved solids concentrations in the Boulder Zone exceeding 10,000 mg/L. Deep injection wells are regulated by and must fully comply with the requirements of Rule 62-528 F.A.C. administered by FDEP. As mentioned previously, FPL received a permit (0293962-001-UC) to construct a Class V exploratory well (EW-1) and associated Dual Zone Monitoring Well (DZMW-1) at the proposed site. FPL indicated that since that time, EW-1 was converted to DIW-1 as one of the Class I Industrial deep injection wells after demonstrating the geology and hydrogeology of the site was appropriate for deep well injection, as required by the permit (FPL

2015; pursuant to the provisions of Rule 62-528.603 of the Florida Administrative Code (FAC) (*www.dep.state.fl.us/legal/rules/shared/62-528/62-528.doc)).*

The applicant estimates the wastewater disposal needs at Turkey Point Units 6 and 7 at approximately 18 million gallons per day when using only reclaimed water from MDSAWD, and as high as approximately 85 million gallons per day when using only saltwater from the radial collector wells. The actual volume will be dependent on the use of makeup water sources but the higher estimate is used for conservative design purposes. The applicant stated that this capacity will call for the installation of 10 primary and 2 backup deep injection wells.

Staff's Technical Evaluation

The staff reviewed Section 2.4.12.1.6, "Plant Groundwater Use," and Appendix 2CC of the Turkey Point Units 6 and 7 COL FSAR, and the applicant response to RAI 5190 Questions 02.04.012-1 to 02.04.12-4 (ADAMS Accession No. ML11129A058) and RAI 5643 Questions 02.04.12-5 and 02.04.12-6 (ADAMS Accession No. ML11180A062), in addition to EPA (2000, 2003), and USGS investigations (Reese, 1994; Reese and Richardson, 2008, Cunningham 2015, Williams and Kuniansky 2015), and FDEP UIC permit requirements (http://www.dep.state.fl.us/water/uic/index.htm). While the FSAR did not quantify usage expected for the primary reclaimed water and backup RCW sources, these amounts have been specified in the FDEP Conditions of Certification (COCs) for the UIC permit, which was reviewed by the staff. The staff notes that these COCs state that "it is expected that the reclaimed water will be a reliable primary source of water for this project" (Section B.IV.C.1.a) and that, as the applicant states, "only in the event that reclaimed water is not available in the quantity or the quality required by Licensee for cooling water purposes shall Licensee be authorized to withdraw cooling water from the RCW system" (Section B.VI.C.2.ii.(1)). In that event, the COCs authorize use of the RCWs for up to 60 days per 12 month period at a maximum volume of 7,465 million gallons. The staff also reviewed studies related to deep well injection performed by public, local and Federal agencies (Maliva et al., 2007; EPA, 2003; Maliva and Walker 1998; Haberfield, 1990) including those relating to the MDWASD (Starr et al., 2001; Walsh and Price 2010) as well as UIC permit requirements related to construction, testing and monitoring of injection wells. Staff's evaluation of the anticipated releases from the deep well injection are documented in FSER Section 11.2.

The staff confirmed that the applicant's evaluation is adequate and addressed the relevant information in the application. The staff finds that the applicant's description of the plant groundwater use is acceptable and adequate.

2.4.12.4.5 Historical and Projected Groundwater Use

Information Submitted by Applicant

In Turkey Point Units 6 and 7 COL FSAR Sections 2.4.12.2.1 and 2.4.12.2.1.3, the applicant summarized information from USGS and SFWMD to determine the historical, current, and projected groundwater use in Miami-Dade County). The applicant stated that the only freshwater source in the immediate vicinity of Turkey Point Units 6 and 7 is the Biscayne aquifer, which has been increasingly used since the 1960s. As the applicant explains: The Biscayne aquifer is designated in the region by EPA as a sole-source aquifer. A sole-source aquifer is defined by EPA as "an underground water source that supplies at least 50 percent of the drinking water in the area overlying the aquifer. These areas have no alternative drinking water sources that could physically, legally, and economically supply all those who depend on

the aquifer for drinking water." In Turkey Point Units 6 and 7 COL FSAR Rev. 3 Section 2.4.12.1.2.1, the applicant stated that the water is saline in the immediate vicinity of the plant due to seawater intrusion (Turkey Point Units 6 and 7 COL FSAR Fig. 2.4.12-206) and that Biscayne aquifer groundwater is not used locally as a source of drinking water. The applicant stated that although the Upper Floridan aquifer is a major source of potable groundwater in much of Florida, water withdrawn from the unit in southeastern Florida, including Miami-Dade County, is brackish and variable in quality (Turkey Point Units 6 and 7 COL FSAR Fig. 2.4.12-229).

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.12.2.1, the applicant stated that the primary consumers of Biscayne groundwater are the public water supply (400 million gallons per day in 2005) and agriculture (100 million gallons per day in 2005) (Turkey Point Units 6 and 7 COL FSAR Table 2.4.12-202). With the addition of seven power plants in the Lower East Coast Planning area, (which includes Palm Beach, Broward, Miami-Dade and Monroe Counties), since 2005, the applicant stated that power generation needs for water from all groundwater sources are projected to increase to a maximum of 70 million gallons per day by 2025. In the Turkey Point Units 6 and 7 COL FSAR, the applicant stated that radial collector wells would only be used "when reclaimed water cannot supply the quantity and/or quality of water needed for the circulating water system" (FPL 2015).The applicant estimated total makeup flow needed at 86,400 gallons per minute, and indicated that four radial collector wells capable of producing 45 million gallons per day will be installed. The central caisson for each radial collector well will extend below the ground surface to around 40-ft depth, and multiple laterals will extend from each well up to 900 ft from the caisson. The wells are designed to induce infiltration from Biscayne Bay. At any one time, one well will be reserved in the event of unplanned or scheduled outages.

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.12.2.1, the applicant stated that the Upper Floridan contains saline water (greater than 250 milligrams per liter of chloride) or saltwater (greater than 19,000 milligrams per liter of chloride), and that no groundwater use was reported in Miami-Dade County in 1990 or 1995. The applicant indicated that in 2000, 3.68 million gallons per day were used for industrial processes including mining and power generation. The applicant stated that Unit 5 obtains cooling water from the Upper Floridan at the rate of a 90-day average of 14.06 million gallons per day.

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.12.2.1.3, the applicant stated that in southern Florida, an additional use of groundwater is for aquifer storage and recovery wells and for disposal of municipal and industrial wastewater through Class I injection wells. In this regard, the applicant further indicated as follows: Aquifer storage and recovery wells are typically within the Upper Floridan, and Class I injection wells are typically within the Boulder Zone of the Lower Floridan. The FDEP permits all subsurface injection wells and FDEP has determined that the Boulder Zone meets the Florida Department of Environmental Regulations criteria for Class I injection wells. Over 125 Class I wells are permitted in Florida releasing over 200 million gallons per day of secondary treated wastewater (Turkey Point Units 6 and 7 COL FSAR Figure 2.4.12-215).

Deep injection wells are regulated by the State of Florida and must fully comply with the requirements of Rule 62-528 F.A.C. administered by FDEP. As mentioned previously, FPL received a permit (0293962-001-UC) to construct a Class V exploratory well (EW-1) and associated Dual Zone Monitoring Well (DZMW-1) at the proposed site. FPL indicated that since that time, EW-1 was converted to DIW-1 as one of the Class I Industrial deep injection wells after demonstrating the geology and hydrogeology of the site was appropriate for deep well

injection, as required by the permit (FPL 2015; pursuant to the provisions of Rule 62-528.603 of the Florida Administrative Code (FAC) (*www.dep.state.fl.us/legal/rules/shared/62-528/62-528.doc)).*

The applicant stated that dual zone monitoring wells are required at a deep well injection site. The applicant described the monitoring wells as follows: These wells consist of two screened intervals; one within the confining unit above the injection zone and also within the USDW, above the confining unit. The USDW is defined as an aquifer that contains water with dissolved solids concentration of less than 10,000 mg/L. The purpose of these wells is to detect upward migration of fluid out of the injection zone at deep well injection sites. (Turkey Point Units 6 and 7 COL FSAR Figure 2.4.12-244). Regulations and monitoring requirements are described in Chapter 62-528 of the FAC. The applicant stated that monitoring will be focused primarily on fluid buoyancy as indicated by temperature and total dissolved solids (TDS).

In the Turkey Point Units 6 and 7 COL FSAR, the applicant also provided information on the impacts of deep well injection in southeast Florida from a report by Maliva et al (2007) that evaluated the confining capability of the Middle Confining Unit of the Floridan Aquifer System. The applicant stated out of the 32 injection well systems in southeastern Florida, 7 have experienced fluid movement into the lowest monitoring zone (within the MCU) and 3 facilities have experienced upward migration into a monitoring zone within the overlying USDW. The applicant stated that these failures are potentially related to well failure and well construction methods (e.g., leaking from well joints, etc.) and not the subsurface geology (e.g., fractures of the confining unit between Floridan and underlying aquifers). The applicant indicated that injected fluid buoyancy as determined by temperature and TDS is the most important control on fluid density and therefore upward migration, in the absence of well construction issues. The applicant stated that the density of the fluid in the Boulder Zone is estimated to be 1,028.5 kilograms per cubic meter with an average temperature of 50 °F and average TDS of 37,000 milligrams per liter. The applicant indicated further that the temperature of the injected water is projected to vary seasonally in the range from 65 ºF to 91 ºF. The applicant also indicated that variations in TDS range from 2,721 milligrams per liter when makeup cooling water is sourced exclusively from MDSAWD to 57,030 milligrams per liter when makeup cooling water is sourced exclusively from the radial collector wells. The applicant stated that the resultant fluid density variations are 996.8 kilograms per cubic meter (100 percent reclaimed water in the summer) to 1,042.4 kilograms per cubic meter (100 percent salt water in the winter).

The applicant stated that State of Florida regulations (FAC Section 62-528.415(1)(f)2) dictate that the hourly peak injection flow rate must not exceed 10 ft per second and the applicant concurred with this limit based on a review of other deep well injection systems in southern Florida. The applicant indicated that the blowdown discharge rate from the cooling towers is 10,000 gpm. The applicant identified the disposal needs for Units 6 and 7 as 18 million gallons per day when using reclaimed water from MDWASD and up to 85 million gallons per day when using a combination of reclaimed and salt water. Based upon the maximum estimate, the applicant stated that the injection well gallery will consist of 10 primary and two backup wells.

Staff's Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.12.2.1 "Historical and Projected Groundwater Use" and Appendix 2CC. The staff reviewed the information provided in the Turkey Point Units 6 and 7 COL FSAR on current and projected groundwater use, and checked the provided data through reviews of the reports and electronic databases available from the SWFWMD for permitted wells. The staff verified that the data were accurate.

Accordingly, the staff's review confirmed that the applicant's evaluation of historical and projected groundwater use is acceptable, and that it addressed relevant information. The staff independently reviewed the characterization of the Biscayne and Floridan Aquifer Systems in the vicinity of the site as characterized by the USGS (Sonenshein, 1995 and Meyer, 1989), and verified the applicant's evaluation of saline conditions and non-potable groundwater in the vicinity of the site to be consistent with USGS studies and therefore acceptable.

The staff reviewed the construction characteristics of the radial collector wells to be constructed in the Biscayne aquifer in regard to the design of horizontal laterals to induce infiltration from Biscayne Bay. The staff reviewed aquifer test data and results conducted by the applicant to support the estimated capacity of these wells and confirmed the methods used to estimate the capacity of these wells reasonable and acceptable.

In its review of the application, the staff reviewed documents on Florida water law governing use by SFWMD (SFWMD, 2008) and on disposal of wastes via underground injection control (UIC) by the Florida Department of Environmental Protection (FDEP) (http://www.dep.state.fl.us/water/uic/index.htm), EPA (EPA, 2000, 2003), USGS (Reese and Richardson, 2008, Cunningham 2015), MDWASD (MDWASD, 1981, Walsh and Price 2010), and academic researchers (Maliva et al., 2007; Maliva and Walker 1998; Haberfield, 1990, INEEL 2001). The staff reviewed the data obtained from exploratory well EW-1 constructed under an FDEP permit, and determined the stratigraphy and subsurface hydrogeologic properties obtained from the well boring to be consistent with the applicant's characterization of the aquifer sequence and properties described in their site-specific (Section 2.4.12.1.4) assessment of hydrogeologic conditions. As the applicant stated, vertical migration of wastewater has occurred in a minority of deep injection well locations. Based on the staff's review of the studies cited above for deep injection wells in south Florida, the staff confirmed the applicant's statement that vertical migration of effluent constituents depends on two major components: injection pressure and injectate buoyancy (i.e., temperature and TDS).

The staff notes that vertical migration is also related to the degree of confinement offered by the Middle Confining Unit of the Floridan Aquifer System, which is a thick assemblage of competent, low permeability limestone and dolomites at the site. The staff notes that while Maliva et al (2007) indicates that impact to the USDW has occurred at three locations in southeast Florida (Seacoast, North District WWTP and South District WWTP), more recent studies such as Walsh and Price (2010) conclude that this migration did not reach the Upper Floridan Aquifer despite this finding in older reports (EPA 2003, Starr et al 2001). This is because of two factors: 1) in many areas, the bottom of the USDW (where TDS exceeds 10,000 mg/L) may be within the top of the Middle Confining Unit beneath the Upper Floridan Aquifer and, 2) more recent hydrogeologic studies of the Floridan Aquifer System (beginning with Reese and Richardson, 2008) recognize that the Middle Confining Unit is more vertically extensive that previously thought in Southeastern Florida, and includes an upper and lower confining zone separated by the more permeable Avon Park Permeable Zone. As a result, migration previously thought to have reached the base of the Upper Floridan Aquifer is now recognized to be within the Avon Park Permeable Zone. This is further discussed in the Staff's Technical Evaluation in Section 2.4.12.4.2 above.

Maliva et al (2007) indicated that migration at these sites is not likely the result of matrix flow through a competent MCU due to low vertical hydraulic conductivity values, but rather channelized flow due to improper well construction or fracture related pathways. This is supported by Starr et al. (2001), who earlier evaluated a limited hydrologic data set and concluded that the unit offered better confinement in reality than their limited data set

suggested. While Cunningham (2015) indicated that vertical migration pathways could be created by karst collapse structures mapped using seismic geophysical techniques, Walsh and Price (2010) concluded that migration seen at the SDWWTP was due in part to well related issues. The staff notes that regulations, requirements, and permits for these injection wells are governed by the State of Florida (FAC Section 62-528.415). Evaluation of the expected impacts of deep well injection are discussed in Section 11.2 of this FSER.

Accordingly, and for the reasons stated above, the staff concludes that the applicant's description of the historical and projected groundwater use is acceptable and reasonably represents current and projected groundwater use and, aquifer conditions in the vicinity of the Turkey Point Units 6 and 7 site.

2.4.12.4.6 Groundwater Flow Directions

Information Submitted by Applicant

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.12.2.2, the applicant reviewed USGS data to determine that regional flow in the Biscayne aquifer is toward the south and southeast in Miami-Dade County (Turkey Point Units 6 and 7 COL FSAR Figures 2.4.12-219 and 2.4.12-220). The applicant stated that minor seasonal changes are observed and cones of depression indicate large withdrawals of groundwater in the vicinity of Miami. The applicant stated that irrigation canals exert a major influence on the shape of the water table. The applicant stated that the regional hydraulic gradient is seaward and estimated at 0.00002 ft/ft.

The applicant monitored on-site wells from June 2008 to January 2010 and measured local-scale potentiometric changes during high and low tides in the Upper Biscayne (Miami and Key Largo Limestones) and Lower Biscayne (Fort Thompson Formation) aquifers. The applicant indicated as follows: All well pairs indicate either upward or minimal hydraulic gradient from the Lower to Upper Biscayne. Specifically, of the 10 well pairs, 4 well pairs consistently indicate upward gradient, 3 well pairs indicate upward gradient until January 2009 and minimal gradient from January 2009 to January 2010, 1 well pair consistently indicates minimal gradient, and 2 wells show only data from the Lower Biscayne. Some data gaps are observed in the raw transducer data due to instrument malfunction or lack of agreement between manual and automated measurements. Vertical hydraulic gradients were calculated by the applicant by comparing hydraulic heads in the Upper and Lower Biscayne, which can be generalized as 0.02 ft/ft and range from 0.009 to 0.042 ft/ft.

The applicant described the flow regimes in the Biscayne aquifer as follows: In the Upper Biscayne, the flow is generally toward the center of the Florida peninsula from the northwest and from the southeast. From the center, flow direction is toward the southwest. Horizontal hydraulic gradients in the Upper Biscayne, are estimated as 0.0003 ft/ft. Potentiometric surface maps, as a function of season, tidal stage, and monitoring interval, are shown in Turkey Point Units 6 and 7 COL FSAR Figures 2.4.12-221 through 2.4.12-228. In the Lower Biscayne, a high point of the potentiometric surface extends from the center of the peninsula toward the south to southwest. Horizontal hydraulic gradients in the Lower Biscayne are estimated as 0.001 ft/ft.

The applicant indicated that seasonal fluctuations were less than 3.5 ft (1.1 m) in all wells. The applicant stated that differences are observed in the Upper and Lower Biscayne potentiometric surfaces with high and low tide, but overall, flow directions are similar regardless of tidal influence. The applicant stated that vertical heads indicate upward flow potential, are consistent

regardless of tidal or seasonal variation, and are an order of magnitude greater than horizontal gradients in the Lower Biscayne and two orders of magnitude greater in the Upper Biscayne.

The applicant investigated the effects of the makeup water reservoir (MWR) on the direction and measurement of hydraulic gradient. The applicant described the MWR and cooling towers as follows: The MWR is constructed of concrete and is on the south side of the proposed plant area around 600 ft from the power block, and is approximately 2,200 ft (671 m) long on the northern side and 1,800 ft long on the southern side. The bottom elevation of the reservoir is approximately -2.0 ft (-0.6 m) NAVD 88, the top elevation of the concrete wall is 24.0 ft (7.3 m) NAVD 88, and the maximum water level is 22.5 ft (6.9 m) NAVD 88. The top of the concrete wall is 2 ft (0.6 m) below the design grade elevation of the safety-related structures. The six cooling towers occupy part of the MWR footprint. The MWR is self-contained and neither contributes to outflow nor receives input of drainage. Based on a simulation of the 3-D groundwater model with the MWR operational, the applicant concluded that any impact to groundwater levels and hydraulic gradients from an overflow of the MWR would be negligible, and that normal operation, catastrophic failure, or overflow of the MWR would not raise water table elevation in a manner that would warrant a permanent dewatering system.

Regarding the Floridan aquifer, the applicant reviewed USGS data to describe flow directions because the pre-construction monitoring program does not include the Floridan. Geochemical and pressure monitoring will be conducted in the Floridan aquifer in accordance with the State of Florida's underground injection control regulations (62-528 FAC).

The applicant indicated that a groundwater divide runs the length of Florida, resulting in flow on the eastern side being toward the east. The applicant calculated the horizontal hydraulic gradient as 0.00006 ft/ft. The applicant stated that determination of groundwater flow directions and hydraulic heads in the Boulder Zone has been unreliable due to the lack of good head data and the transitory effect of tides (FPL 2015). The regional circulation pattern within the Floridan aquifer system is considered to be very slow—on the order of thousands of years (Meyer, 1989) and is conceptualized to involve:

- Horizontal movement of seawater in the deepest reaches of the Lower Floridan;
- Heating of seawater resulting in decreased density;
- Upwelling through the Middle Confining Unit;
- Dilution and seaward migration through the Upper Floridan;

The applicant's conceptual model, shown in Turkey Point Units 6 and 7 COL FSAR Figure 4.12-243, does not suggest movement of Floridan water through the intermediate confining unit and into the Biscayne.

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

The staff reviewed Section 2.4.12.2.2 "Groundwater Flow Directions" of the Turkey Point Units 6 and 7 COL FSAR, Appendices 2BB and 2CC, and the applicant's response to RAI 5190, Question 02.04.12-2 (ADAMS Accession No. ML11129A058), and studies cited by the applicant. Data and information in the staff's review included the applicant's observation well data and, aquifer pumping test data and results. The staff's review confirmed that the applicant's evaluation of groundwater flow direction is acceptable and addressed relevant information topics. The staff reviewed documents by USGS (Klein and Hull, 1978; Meyer, 1989;

Fish and Stewart, 1991; Langevin, 2001) and databases from the USGS (e.g., http://131.247.143.93/index.html).

To assess the influence of water use in the plant on the regional groundwater flow directions, the staff took an east-west cross section from the applicant's 3-dimensional groundwater model grid (row 260, east-west across the plant) and constructed a 2-dimensional groundwater model using a publicly available spreadsheet tool (Anderson and Bair 2001). The boundary conditions in the east and west were modeled as fixed head boundaries. The results (Figure 2.4.12-1) confirm that the regional hydraulic gradient from the west (inland) to the east (ocean) is controlled by the water levels in the cooling and L-31E irrigation canals. The vertical gradient is even smaller and the variations near the canals are significant only in the first layer (Miami Limestone) and dampen out with depth in the underlying layers 2–4 (Key Largo Limestone, freshwater limestone, and Fort Thompson Formation, respectively). These results show that as long as the water level in the canals is maintained at the designed level, water use at the plant is not expected to alter the regional groundwater flow direction (from the west to the east, and from underground to the ground surface). This is due to the relatively permeable subsurface geologic formations and small hydraulic gradient at the site.

The staff performed an independent confirmatory analysis of the potential impact of the maximum water level of 22.5 ft (6.9 m) in the MWR on the subsurface potentiometric head distribution at Turkey Point Units 6 and 7, as described below. The staff calculated the lateral head losses from the MWR through the 3 ft (0.9 m) thick concrete floor and then through 100 ft of the Miami Limestone aquifer. According to Darcy's law, discharge rate, q, is estimated as $q = k_1 \Delta h_1 / L_1 = k_2 \Delta h_2 / L_2$, and $\Delta h = \Delta h_1 + \Delta h_2$, where k, Δh, and L are the hydraulic conductivity, head loss, and length, and subscripts 1 and 2 stand for the concrete layer and aquifer layer, respectively. It can be derived that $\Delta h_1 / \Delta h = (L_1 / k_1)/(L_1/k_1 + L_2/k_2)$. Using conservative values for k_1 and k_2, *i.e.*, $k_1 = 10^{-8}$ cm/s (Turkey Point Units 6 and 7 COL FSAR 2.4.13.1.3.1 assumes 8.25×10^{-9} cm/s, which is an order of magnitude higher than that of intact concrete in included reference) and $k_2 = 10^{-4}$ cm/s (less than the smallest calibrated value in Turkey Point Units 6 and 7 COL FSAR Table 2CC-205), the calculated head loss in the concrete floor is 22.4 ft (6.8 m). This result indicates that most of the head is expected to be lost over the concrete floor of the MWR due to its low permeability. Therefore, the water in the MWR, even at maximum level, is not expected to raise the groundwater table under Turkey Point Units 6 and 7 significantly (less than a few feet, comparing with the 23.5 ft (7.2 m) design elevation). Accordingly, the staff's review of the studies and reports described above and the staff's evaluation of the applicant's analysis described above confirmed that the applicant's description of the groundwater flow directions is acceptable and adequate.

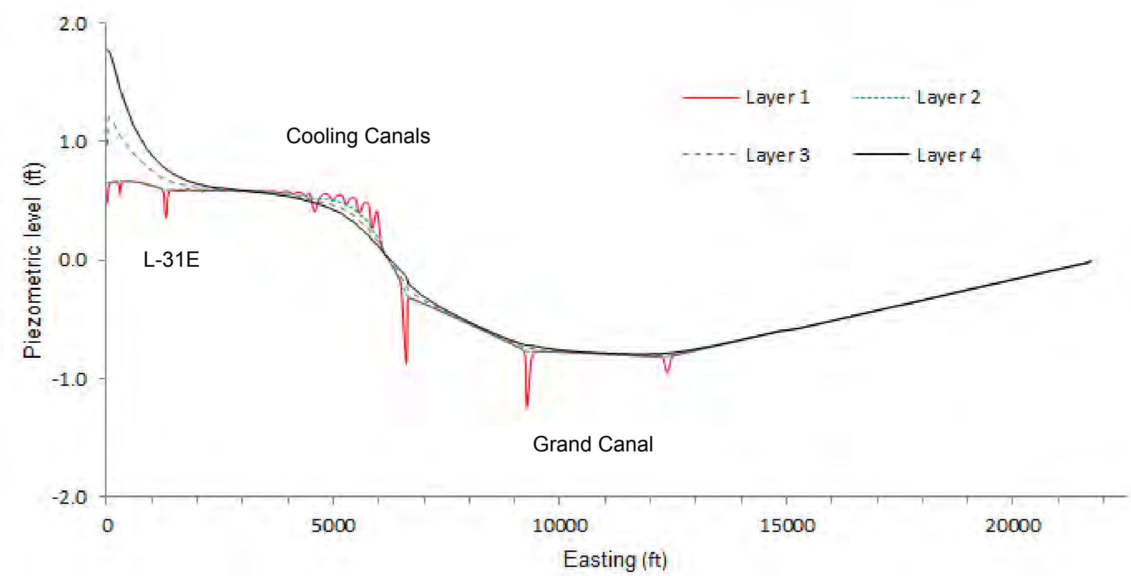


Figure 2.4.12-1. Simulated piezometric levels across the plant area (Layer 1-4 correspond to the four layers: Miami Limestone, Key Largo Limestone, Freshwater Limestone, and Fort Thompson Formation in the numerical model).

2.4.12.4.7 Temporal Groundwater Trends

Information Submitted by Applicant

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.12.2.3, the applicant presented temporal groundwater trends gleaned from regional- and local-scale data. The applicant stated that regional monitoring of the Biscayne aquifer occurs via a network of SFWMD and USGS wells and surface water/canal locations. Hydrographs presented by the applicant in the Turkey Point Units 6 and 7 COL FSAR indicate steady water levels and short-term fluctuations associated with tides and precipitation in the typical range of 3.5 ft (1.1 m) with a maximum of 6.5 ft (2 m) for wells in the last 15 to 35 years, and typically less than 2.5 ft (0.8 m) for canals in the last 19 years.

The applicant presented limited local monitoring (18 months from June 2008 to June 2010) of the Turkey Point Units 6 and 7 network in the Upper and Lower Biscayne that indicates that seasonal fluctuations are less than 3.5 ft (1 m), and fluctuations resulting from individual larger events are around 1.5 ft (0.5 m). The applicant stated that maximum groundwater elevation in the Upper Biscayne aquifer observed at the Turkey Point Units 6 and 7 site was 0.62 ft (0.19 m) NAVD 88 and the minimum was -3.42 ft (-1 m) NAVD 88. The maximum groundwater level in the Lower Biscayne observed was 2.15 ft NAVD 88 and the minimum was -2.45 ft (-0.75 m) NAVD 88.

For the Upper Floridan aquifer, the applicant presented data obtained from 1965–1997 in one USGS well 17 mi (27.4 km) to the west of Turkey Point Units 6 and 7. These data show a dramatic drop in water levels from 1965 to 1969, followed by a large rebound and steady state from 1970–1986, followed by dropping levels until monitoring stopped in 1997. Head levels inside the well ranged from 30 to 42.6 ft (9.1 to 13.0 m) MSL (NGVD 29) with a wellhead elevation of 4.5 ft (1.4 m) MSL (NGVD 29).

Staff's Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.12.2.3, "Temporal Groundwater Trends". The staff's independent review of observation well data, well hydrographs, and aquifer tests presented by the applicant confirmed that the applicant's evaluation of temporal groundwater trends was adequate and addressed relevant information topics. The staff also reviewed databases maintained by USGS (USGS, http://131.247.143.93/index.html) and SFWMD (www.sfwmd.gov) for the Biscayne and Floridan aquifers and verified the information consistent with the applicant's evaluation of temporal trends. Therefore the staff concludes the applicant's analysis is acceptable.

2.4.12.4.8 Aquifer Properties

Information Submitted by Applicant

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.12.2.4, the applicant presented hydrological parameters including transmissivity, storativity, specific yield, hydraulic conductivity, and leakage coefficients obtained from the Biscayne and Floridan aquifers and from the various confining layers. Hydrologic data was compiled from Miami-Dade County, the EPA, the SFWMD DBHYDRO database, the Dames and Moore Turkey Point Units 3 and 4 site investigation, USGS investigations, and municipal water supply information. In addition, the applicant presented data from the Turkey Point Units 6 and 7 site investigation for the Biscayne aquifer from pump testing and from the MACTEC investigation (MACTEC, 2008). The applicant also presented anisotropy parameters obtained by physical core testing by USGS at a site to the northwest of the Turkey Point Units 6 and 7 site. Physical parameters obtained with relevance to the Turkey Point Units 6 and 7 COL FSAR include horizontal and vertical permeability.

As a part of the Turkey Point Units 6 and 7 site investigation, the applicant conducted four pumping tests in the Upper and Lower Biscayne aquifer in 2009. The applicant used the results in the design and implementation of the construction dewatering system, development of the site groundwater model, and simulation of the radial collector wells in the site groundwater model. The wells and naming conventions are as described in Section 2.4.12.4.2 (Site Specific Hydrology), and monitor in order from youngest to oldest the Miami Limestone, the Key Largo Limestone, the freshwater limestone unit, the Fort Thompson Formation, and the Tamiami Formation. The applicant indicated that the Key Largo and Fort Thompson are interpreted in the site conceptual model as aquifers, and the Miami, freshwater limestone, and Tamiami are interpreted as aquitards, where the definition of aquitard implies significantly lower permeability than surrounding aquifer units. The applicant stated that each pumping test was conducted at a constant discharge rate of 3,300 to 5,100 gpm for eight hours and was followed by an eight hour recovery period. The applicant used a background well to correct for the influences of the tidal cycle.

Biscayne aquifer

The applicant summarized the results of the aquifer pumping testing analyses for the site in Turkey Point Units 6 and 7 COL FSAR Table 2.4.12-209. From the Theis solution to the pump tests in the aquifer intervals, the applicant determined that the transmissivity of the Upper Biscayne aquifer (Key Largo) was 2.3×10^6 gallons per day per foot (gal/d/ft) with a mean storage coefficient of 1.0×10^{-3}, and transmissivity of the Lower Biscayne aquifer (Fort Thompson) was 1.3×10^5 gal/d/ft with a mean storage coefficient of 2.4×10^{-4}. The applicant

cited regional investigations that did not distinguish between the Upper and Lower Biscayne aquifers and found the transmissivity of the Biscayne aquifer ranged from 4×10^5 to 4×10^6 gallons per day per foot (gal/d/ft), storage coefficients ranged from 0.05 to 0.34, and specific yields of 20–25 percent (Turkey Point Units 6 and 7 COL FSAR Table 2.4.12-206). In the undifferentiated shallow Biscayne aquifer, Dames and Moore (1971, 1975) found transmissivities ranging from 1×10^6 to 3×10^6 gal/d/ft, and the applicant also cited results from Broward County on the order of 4×10^5 to 4×10^6 gal/d/ft.

The EPA compiled hydraulic conductivities of the Biscayne aquifer and found vertical conductivities around 15 ft/d and horizontal conductivities around 1,500 ft/d, which corresponds to 2.6 E6 gal/d/ft (Turkey Point Units 6 and 7 COL FSAR Table 2.4.12-205). The applicant stated that municipal water supply wells typically yield 500–7,000 gpm with minimal drawdowns. The applicant suggested that its estimates for the Lower Biscayne were somewhat lower than other investigations in the region, and proposed that a low conductivity filter pack in the wells may have depressed its measured hydraulic conductivity values.

The applicant's estimates of formation anisotropy from the Biscayne aquifer units were obtained from two studies to the northwest of Turkey Point Units 6 and 7 site performed by USGS. The applicant described the studies as follows: Core samples were tested for horizontal and vertical air permeability, porosity, grain density, lithology, and fossil assemblages. These studies subdivided the aquifer on the basis of depositional cycles ranging from marine to fresh water. The freshwater portions tended to have a lower permeability (less than 1000 milliDarcies) and porosity (less than 20 percent) than the marine portions (greater than 1000 milliDarcies and 20–40 percent porosity) of the aquifer. The aquifer sediments were found to be approximately isotropic. This information was used as a starting point in the applicant's groundwater model calibration.

Aquitard units in Biscayne aquifer

The applicant interpreted the pumping test data and information using two different analytical solutions, the Theis method and the Hantush leaky aquifer solution with aquitard storage. The applicant stated as follows: Because the Theis method does not consider leakage it was applied to the time-drawdown data to provide an upper bound on transmissivity for the aquifer units. The Hantush method was used to evaluate distance-drawdown and time-drawdown relationships in the Key Largo Limestone and Fort Thompson Formation aquifers and aquitards. The results are summarized in Turkey Point Units 6 and 7 COL FSAR Table 2.4.12-209.

The applicant obtained Information on the aquitard units (Miami Limestone, freshwater limestone, and Tamiami Formation) using the Hantush method, which the applicant asserts allows calculation of the extent of leakage through over- and underlying aquitards. For the Miami limestone and the freshwater limestone that bracket the Upper Biscayne (Key Largo), the applicant stated that several responses were inconsistent with the site conceptual model, as follows: Responses in three wells in the Miami (C6-1A, C6-3A, C6-4A) and three wells in the freshwater (C6-1B, C6-2B, C6-4B) at the Unit 6 well field were identical to those in the Key Largo pumped zone. The applicant stated that this may suggest that a portion of the screened interval of the aquitard is actually located in the aquifer, and/or that the vertical hydraulic conductivity of the aquitard is the same as that of the pumped aquifer, indicating the absence of an aquitard in this location. The applicant stated that responses in Well C6-3B in the freshwater showed less drawdown than in the underlying unpumped aquifer indicating a possible connection between the pumped (Upper Biscayne Key Largo Limestone) and unpumped aquifers (Fort Thompson Formation that constitutes the Lower Biscayne aquifer). The applicant

indicated that this suggests that responses in the Unit 6 well field may have been detected in only one well in the Miami (C6-2A) and potentially in no wells in the freshwater limestone. The applicant stated that the average vertical hydraulic conductivity of the Miami Limestone is 14 ft per day (ft/d), and that of the freshwater limestone is 6 ft/d.

The applicant stated that the Lower Biscayne pump tests in the Fort Thompson Formation yielded anomalous results for the freshwater limestone aquitard and for the Upper Biscayne aquifer (Key Largo Limestone) for Wells C6-2B and C6-2D. The applicant stated that these results indicate that a portion of the screened interval of the aquitard is actually located in the aquifer, or that the vertical hydraulic conductivity of the aquitard is the same as that of the pumped aquifer, indicating the absence of an aquitard in this location. The applicant stated that the average vertical hydraulic conductivity of the freshwater limestone is 0.2 ft/d, and that of the Tamiami Formation is 1,061 ft/d.

The applicant observed identical responses beneath Unit 7 in the Upper Biscayne aquifer Wells C7-1B (freshwater limestone) and C7-1E (Fort Thompson aquifer), and for Wells C7-4B (freshwater limestone) and C7-4E (Fort Thompson aquifer). The applicant stated that these responses indicate again that a portion of the screened interval of the aquitard is actually located in the aquifer, or that the vertical hydraulic conductivity of the aquitard is the same as that of the pumped aquifer, indicating the absence of an aquitard in this location. The applicant stated that neither Wells C7-1A (Miami Limestone) nor C7-1D (Key Largo Limestone) had sufficiently detailed measurements for determining the drawdown. The applicant indicated that time-drawdown and distance-drawdown data were successfully obtained for well clusters C7-2 and C7-3 and for well cluster C7-4 with the exception noted above. The applicant stated that data from the C7-1 well cluster were only acceptable for distance-drawdown comparisons. The applicant stated that the average vertical hydraulic conductivity of the Miami was 123 ft/d, and that of the freshwater limestone was 7 ft/d.

The applicant stated that legible and usable data was recorded from the transducers in the Lower Biscayne aquifer at Unit 7 produced for well clusters C7-3, C7-4, and C7-5, with the exception of wells C7-4B (freshwater limestone), C7-4D (Key Largo Limestone) and C7-5C (Tamiami Formation). The applicant stated that the average vertical hydraulic conductivity of the freshwater limestone was 0.4 ft/d and that of the Tamiami Formation was 100 ft/d (30 m/d).

Intermediate confining unit

The applicant cited a regional USGS water supply investigation for information regarding the Intermediate aquifer system/confining unit (Bush and Johnston 1988). The applicant stated that the hydraulic conductivity of the intermediate confining unit is "very low and provides good confinement for the underlying Floridan aquifer system," implying that at the Turkey Point Units 6 and 7 site, the intermediate aquifer system/confining unit acts as a confining unit and not as an aquifer. The applicant did not perform site-specific hydrogeological investigations on the intermediate confining unit because the applicant believes flow and transport for the radioactive release scenario, construction dewatering, and water supply through the radial collector wells will occur exclusively in the Biscayne aquifer. EPA compiled information from sources in Miami-Dade County and estimated the horizontal hydraulic conductivity as 90 ft/d and the vertical hydraulic conductivity as 0.1-0.24 ft/d, and porosities ranging from 0.1-0.31 (Turkey Point Units 6 and 7 COL FSAR Table 2.4.12-205). The applicant stated that the modeled leakage coefficient was variable, and ranges from 0.01 to 1 in/yr/ft, but that measured leakage coefficients range from 0.44 to 88 in/yr/ft, according to Bush and Johnston. The applicant stated that the large measured leakage coefficients indicate a combination of sources including

leakage from the overlying surficial (Biscayne) aquifer and upward leakage from permeable rocks beneath and within the pumped interval.

Floridan aquifer

No new data has been generated in the Turkey Point Units 6 and 7 investigation from the Floridan aquifer and the applicant relies upon regional data sources and site-specific investigations at the Turkey Point site for Units 1-5. This is primarily because the applicant believes flow and transport for the radioactive release scenario, construction dewatering, and water supply (from Biscayne Bay) to the radial collector wells occur exclusively in the Biscayne aquifer. The applicant described the Upper Floridan as approximately 3,000 ft thick with porosity and permeability varying widely depending on the location and formation. For instance, the applicant stated that confinement by clay and low permeability layers tends to inhibit formation of secondary porosity, particularly in southern Florida. Specifically, the applicant stated as follows: Transmissivity tends to be lowest in southern and panhandle Florida with values typically less than 50,000 ft^2/d, and highest in central and northern Florida with values typically greater than 1 million ft^2/d (Turkey Point Units 6 and 7 COL FSAR Table 2.4.12-206). EPA found the transmissivity from the Upper Floridan was 3.8E5 gal/d/ft (Turkey Point Units 6 and 7 COL FSAR Table 2.4.12-205). Regional storage coefficients range from 1×10^{-1} to 1×10^{-4} (Bush and Johnson, 1971, 1975). From the Turkey Point Units 1 and 2 investigation, site-specific data from a 90-day continuous pump test in production wells of 1130–1400 feet deep indicates transmissivity of 53,600 ft^2/d (4×10^5 gal/d/ft), a storage coefficient of 6×10^{-3}, and leakance of 2×10^{-3} gal/d/ft^2 in the Upper Floridan. Parameters obtained for Turkey Point Unit 5 and Turkey Point Units 1 and 2 cooling and process water wells indicated transmissivity of 2.4E5 gal/d/ft, storage coefficient of 2×10^{-3}, and leakance of 0.005 gal/d/ft^2.

The applicant stated that the Middle Confining Unit of the Floridan aquifer consists of the Avon Park Formation and the top of the Oldsmar Formation, with the base being the top of the highly transmissive units constituting the top of the Lower Floridan. The applicant explained as follows: In MDWASD Well MDS-I12, the base of the MCU is found at 2,460 ft bgs and is 230 ft below the top of the Oldsmar Formation (Reese, 1994). The horizontal hydraulic conductivity is 3×10^{-3} to 3 ft/d and vertical hydraulic conductivity measured from core samples in eastern Broward county ranges from 1×10^{-3} to 2 ft/d (Reese, 1994), and 1.7×10^{-8} cm/s in Palm Beach County (Maliva et al., 2007). The porosity in the Palm Beach County core samples was less than 15 percent. EPA found the transmissivity of the middle confining unit was 1.7×10^{-4} (Turkey Point Units 6 and 7 COL FSAR Table 2.4.12-205).

The applicant stated that the Lower Floridan aquifer is discussed here primarily because it contains a unit of extremely high transmissivity that is used in southern Florida for disposal of treated industrial and sewage wastewaters, the “Boulder Zone.” In regard to the Boulder Zone, the applicant stated as follows: At Turkey Point Units 6 and 7, blowdown will be disposed within the Boulder Zone as described in Section 2.4.12.4.5. The Boulder Zone is not composed of boulders but rather of massively bedded dolostones with extensive secondary porosity. Regionally, the Lower Floridan is encountered around 2,400 ft bgs and extends to over 4,000 ft bgs, and because of its depth is not well characterized. The Boulder Zone is typically located above the top of the Cedar Keys Formation in the lower portions of the Oldsmar Formation, but locally the Boulder Zone may extend upward to the middle of the Oldsmar Formation or downward to the top of the Cedar Keys Formation. At the Turkey Point site, the Boulder Zone is believed to begin at around 3,030 ft bgs. Transmissivity ranges from 3×10^6 to 24×10^6 ft^2/d and hydraulic conductivity was estimated as 4,250 ft/d at an injection well at MDWASD, which is around two orders of magnitude higher than the overlying Lower Floridan aquifer and the Middle

Confining Unit of the Floridan aquifer. EPA found the transmissivity of the Lower Floridan was 1.5×10^1 ft^2/d, and the Boulder Zone was 2.5×10^7 ft^2/d (Turkey Point Units 6 and 7 COL FSAR Table 2.4.12-205).

Staff's Technical Evaluation

The staff reviewed Section 2.4.12.2.4 "Aquifer Properties" of the Turkey Point Units 6 and 7 COL FSAR and associated appendices containing observation well records and data and pumping test data and analysis. The staff also reviewed documents on the properties of aquifers in the vicinity of the Turkey Point Units 6 and 7 site by USGS (e.g., Johnston and Bush, 1988; Bush and Johnston, 1988; Reese, 1994; Reese and Richardson, 2008; Merritt, 1996; and, Fish and Stewart, 1991), EPA (US EPA, 2003), the SFWMD DBHYDRO database (http://www.sfwmd.gov/portal/page/portal/xweb environmental monitoring/dbhydro application), and previous studies conducted on the site (Dames and Moore, 1971, 1975). The staff verified the applicant's description of the aquifer properties and testing methods and results from on-site investigations to be reasonable and consistent with the independent studies cited. Therefore, the staff concludes that the applicant's description of the aquifer properties is adequate and acceptable.

2.4.12.4.9 Hydrogeochemical Characteristics

Information Submitted by Applicant

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.12.2.5, the applicant presented data regarding aquifer water quality in the vicinity of Turkey Point Units 6 and 7. The applicant presented water quality data from the Turkey Point Units 6 and 7 investigation, and local and regional data from USGS and SFWMD for the Biscayne and Floridan aquifers and local surface water bodies.

The applicant stated that groundwater from the aquifers in the vicinity of the Turkey Point Units 6 and 7 site was not potable because of excess salinity. The applicant stated that the State of Florida has classified these waters as Class G-III indicating there is no reasonable chance of their use as drinking water. The applicant indicated that Class G-III is defined by the State of Florida as non-potable groundwater in unconfined aquifers that has TDS content of 10,000 mg/L or greater; or which has total dissolved solids of 3,000–10,000 mg/L and either has been reclassified by the Commission as having no reasonable potential as a future source of drinking water, or has been designated by the Department as an exempted aquifer according to Rule 62-528.300(3), F.A.C. The applicant provided two tables (Turkey Point Units 6 and 7 COL FSAR Tables 2.4.12-210 and 2.4.12-211) showing major water quality indicators including TDS, dissolved cations, pH, temperature, dissolved oxygen, specific conductance, turbidity, and redox potential in the site-specific investigation wells at the Turkey Point Units 6 and 7 site, median values of the Surficial and Floridan aquifers obtained from SFWMD, mean values from the Upper Floridan production well at the Turkey Point Units 6 and 7 site, and average values in Biscayne Bay, the L-31N canal, and precipitation at the Everglades National Park. The applicant also provided a Piper trilinear diagram in the FSAR indicating similarities between Biscayne groundwater, Floridan groundwater, Biscayne Bay seawater, and cooling canal water, all of which are classified as a sodium-chloride type.

The tables provided by the applicant suggest that TDS in the Biscayne (surficial) aquifer at Turkey Point Units 6 and 7 ranges from 30,000 to 65,000 mg/L. According to the applicant, the Upper Floridan in the vicinity of the site as monitored by SFWMD contains TDS concentrations

greater than 1000 mg/L, and the Turkey Point Unit 5 production wells have an average concentration of 5,400 mg/L TDS. The applicant stated that the groundwater in the Middle Confining Unit is variable and is a mixture of freshwater from the Upper Floridan and upwelling saline water from the Lower Floridan. The applicant cites a USGS regional water investigation report to suggest that groundwater in the Boulder zone contains approximately 37,000 mg/L TDS. The applicant noted a low temperature anomaly found within the Boulder Zone (50 °F) along Florida's southeastern coast, suggesting recharge of the Boulder Zone by seawater infiltration. The applicant presented a conceptual model (Turkey Point Units 6 and 7 COL FSAR Figure 2.4.12-243) developed by the USGS (Meyer, 1989) describing deep circulation in the Floridan aquifer and the mixing of seawater with groundwater in coastal areas.

Staff's Technical Evaluation

The staff reviewed Turkey Point COL FSAR Section 2.4.12.2.5 "Hydrogeochemical Characteristics" including: site-specific data collected by the applicant (MACTEC, 2008), regional data from FDEP (http://www.dep.state.fl.us/water/monitoring/); reports containing a discussion of chemical characteristics of aquifers in the region by the USGS (Merritt, 1996, Sonenshein, 1995 and Meyer, 1989) and the Florida Geological Survey (FGS, 1992). Based on the staff's review of these data and reports, the staff confirmed that the applicant's evaluation of the hydrogeochemical characteristics of the groundwater in the vicinity of the site is consistent with independent reports by state and federal agencies and is an acceptable description. Additionally, the staff reviewed the State of Florida's criteria for waters classified as Class G-III (https://www.flrules.org/gateway/RuleNo.asp?ID=62-520.430), and considers the applicant's characterization to be reasonable. The staff confirmed that the applicant's conceptual description of the Floridan aquifer (including the Boulder Zone) circulation is consistent and based on USGS studies (e.g., Meyer, 1989) and is an acceptable and adequate representation of the aquifer system.

2.4.12.4.10 Subsurface Pathways

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.12.3, the applicant presented an evaluation of subsurface pathways to an offsite receptor. Information provided by the applicant included an evaluation of alternative pathways, an assessment of advective travel times, and results from a model of post-construction groundwater flow conditions.

The applicant described the pre-construction condition of Turkey Point Units 6 and 7, in which the ground surface at Turkey Point Units 6 and 7 is approximately at sea level (2.5 to 0.8 ft (0.8 to 0.24 m) NAVD 88 MSL) and the Biscayne aquifer is within 5 ft (1.5 m) of the ground surface. The applicant indicated the following: The muck layer found in the first 7 ft (2.1 m) will be removed during construction. The excavation will be -35 ft NAVD 88. Engineered fill will be used to raise the finish grade to 25.5 ft (7.8 m) NAVD 88. The walls of the excavation will be reinforced with concrete grouting to reduce the rate of infiltration of groundwater into the excavation. Reinforced concrete diaphragm walls of thickness 3 ft (0.9 m) will also be emplaced to a depth of -65 ft (-19.8 m) ft NAVD 88 to control groundwater flow into the excavation.

The applicant indicated further, as follows: The effluent holdup tanks will be located within the auxiliary containment building. The building will contain a radioactive tank that is modeled as leaking, for which 80 percent of the simulated leakage is assumed to be released (22,400 gal) in accordance with NUREG-0800 and Branch Technical Position (BTP) 11-6. Instantaneous release into the saturated structural fill adjacent to the building is assumed, which the applicant stated is conservative because it assumes failure of the floor drain system, penetration of the

3 ft (0.9 m) thick exterior concrete walls and 6 ft (1.8 m) thick basemat, and flow of effluent outward into the saturated zone of the water table.

Alternative Pathways Evaluation

Information Submitted by Applicant

The applicant described one potential physical pathway for offsite migration of a postulated accidental release of radionuclides. The applicant used regional groundwater potentiometric surface measurements, which are describe above in Sections 2.4.12.4.6 and 2.4.12.4.7 above, to infer that flow is toward the east and southeast in Miami-Dade County in the Biscayne aquifer. Expanding on this, the applicant stated as follows: Onsite measurements of hydraulic head suggest an upward gradient from the Lower to the Upper Biscayne aquifers, and that the hydraulic gradient in the Upper Biscayne aquifer is also in the upward vertical direction. Local monitoring suggests that flow is generally toward the center and to the southwestern corner of the Turkey Point Units 6 and 7 island in the Upper Biscayne and generally away from the center of the island and toward the cooling canals, i.e., the industrial wastewater facility (IWF), that surround the island in the Lower Biscayne. The most likely release pathway is from the Turkey Point Unit 6 or 7 reactor through the Key Largo Limestone, followed by discharge into the IWF and release into Biscayne Bay through the Biscayne aquifer. Multiple alternate pathways involved exactly the same physical pathway, but alternatively assumed for simulation purposes that the radial collector wells (RCW) at the Turkey Point peninsula were either pumping or were *not* pumping during the release. The RCW system, when fully operational, would pump 87,000 gallons per minute (gpm), which is assumed for the primary advective flowpath. The applicant stated that the RCW will only be fully operational 90 days per year.

The applicant described further as follows: Discharge into the subsurface is within the Key Largo Limestone, followed by discharge to the IWF and dilution, and, ultimately, discharge with regional groundwater flow into Biscayne Bay. This scenario would also not threaten surface water supplies, because public access to the 5,900 acre IWF is entirely restricted. The IWF is engineered to function as a groundwater discharge zone, as the eastern canals are continuously maintained at a lower head than Biscayne Bay to the east and the western canals are continuously maintained at a lower head than fresh groundwater located to the west of TP. Thus, multiple alternate pathways also involved a functional, circulating IWF, or an inactive IWF. The IWF circulates around 4 billion gallons at a rate of 4,000 cubic feet per second (cfs). Thus, a total of four scenarios were investigated:

- IWF operational, RCW off (Case 1)
- IWF operational, RCW on (Case 2)
- IWF non-operational, RCW off (Case 3)
- IWF non-operational, RCW on (Case 4)

Calculations of advective radionuclide travel times after accidental release are presented in Section 2.4.13.1.4. The receptor calculation is based upon using an artificial (i.e., nonexistent) well at a point in the Biscayne aquifer in Biscayne Bay, but the applicant concluded that human consumption of groundwater is not a plausible receptor scenario because the groundwater at the Turkey Point Units 6 and 7 site is saline, is not used for human consumption, and is not likely to be used for human consumption at any point in the future. Instead, a dose calculation is performed to determine the risk of human consumption of seafood in Biscayne Bay that has become contaminated by radionuclides.

The applicant stated that there is no vertical transport downwards from the Biscayne aquifer into the Floridan aquifer, thus the applicant did not consider discharge into the Floridan aquifer in the postulated radionuclide release scenario.

Staff's Technical Evaluation

The staff reviewed Section 2.4.12.3.1 "Biscayne Aquifer", Section 2.4.12.3.2 "Floridan Aquifer System", Section 2.4.13.1 "Groundwater", Section 2.4.13.1.2.1 "Primary Conceptual Model", and Section 2.4.13.1.2.2 "Alternate Conceptual Model" of the Turkey Point Units 6 and 7 COL FSAR, RAI 5643, Question 02.04.12-6, and BTP 11-6 (NRC, 2007) for information on Alternative Pathways Evaluation. The staff's review confirmed that the applicant addressed relevant information topics. Initially, the staff determined that the applicant's description of alternate subsurface pathways in Turkey Point Units 6 and 7 COL FSAR, Revision 2, was not conservative because all pathways traveled through the 19 ft (5.7 m) thick concrete fill layer constructed as the lower portion of the containment building, and because breaches of neither the 19 ft (5.7 m) concrete base layer nor the 3-ft thick reinforced concrete diaphragm walls (neither of which are seismic Category I structures) were considered to provide a pathway to groundwater. Accordingly, the staff sent RAI 5643, Question 02.04.12-6 to the applicant to which the applicant responded June 27, 2011 (ADAMS Accession No. ML11180A062). The staff evaluated the responses and determined that the applicant considered the four scenarios identified above, eliminated any credit for delayed transport through the concrete layer and walls, and revised and recalibrated the groundwater model accordingly. Based on the review of the responses to the alternative scenarios and the groundwater model, the staff concludes that the applicant's evaluation of potential pathways was adequate and addressed each unresolved question and the RAI is closed. Accordingly, the staff finds that the applicant's evaluation of alternative pathways is acceptable.

Advective Travel Times

Information Submitted by Applicant

In Turkey Point Units 6 and 7 COL FSAR Revision 2 Section 2.4.13.1.4 "Radionuclide Transport Analysis," the applicant provided analysis of contaminant transport along a plausible alternative pathway to determine a travel time assuming advective transport (fluid transport that causes changes in density or other physical properties). In Turkey Point Units 6 and 7 COL FSAR Section 2.4.13.1.3 "Pathway Analysis" and in Appendix 2CC, the applicant provided analysis of contaminant transport along a plausible alternative pathway to determine a travel time assuming advective transport using the particle tracking method. The applicant stated that for the analyses, it is assumed the contaminant moves with the groundwater and is not retarded by geochemical reactions. The average velocity of the pore water in a porous media is estimated using the following equation:

$v = (K\ dh/dx) / n_e$

Where

- v = average pore water velocity (ft/d)
- K = saturated hydraulic conductivity (ft/d)
- dh/dl = hydraulic gradient (ft/ft)
- n_e = effective porosity (scalar decimal).

Travel time (T in days) is then estimated as the distance from source release point to receptor (D in feet) divided by the pore-water velocity (v in ft/d).

In the conceptual model for the release scenario in Turkey Point Units 6 and 7 COL FSAR Revision 2, the applicant considers flow into the IWF and through the Key Largo Limestone. To be conservative, the applicant does not consider residence time in the IWF. To calculate travel time, the applicant uses a travel distance (D) of 810 ft (247 m), the horizontal hydraulic conductivity of 12,000 ft/d, an average hydraulic gradient of 4 x 10^{-3}, and an effective porosity of 0.20. The applicant stated that the calculated travel time through groundwater in the Key Largo Limestone to Biscayne Bay is 0.09 years.

In the conceptual model for the release scenario in Turkey Point Units 6 and 7 COL FSAR, the applicant considers particles released into the structural fill around the Units 6 and 7 nuclear islands as shown in Turkey Point Units 6 and 7 COL FSAR Revision Figure 2.4.13-201, and in Appendix 2CC Figure 2CC-255. The resultant travel times to the IWF obtained by the applicant are shown in Turkey Point Units 6 and 7 COL FSAR Table 2.4.13-202. The applicant modeled particle movement through the system until they reach a boundary where flow will occur outside of the system, and calculated the time for particles to reach that point. The applicant stated that for instances where the IWF is operational, Case 1 (RCW off) modeled particle movement was faster than for Case 2 (RCW on), thus, Case 1 (3911 d) is subjected to further evaluation. For Cases 3 and 4 the IWF is not operational, and the RCW is either off (Case 3), or on (Case 4). The applicant stated that Case 3 produced an estimated transport time of 3778 d and Case 4 (IWF-non-operational, RCW-on) an estimated time of 4079 d.

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

The staff reviewed Section 2.4.13.1.3 "Pathway Analysis," and Appendix 2CC of the Turkey Point Units 6 and 7 COL FSAR and the applicant's response to RAI 5643, Question 02.04.12-6 for information on advective transport (ADAMS Accession No. ML11180A062). The staff's review confirmed that the applicant used the parameters and inputs consistent with the hydrogeologic characteristics of the site as discussed in SER Sections 2.4.12.12.6, 2.4.12.4.7 and 2.4.12.4.8 above, and that the applicant's conceptualization and evaluation of the advective transport travel times used accepted transport models. Accordingly, the applicant's results are acceptable.

Three-Dimensional Numerical Groundwater Flow Model

<u>Information Submitted by Applicant</u>

In Turkey Point Units 6 and 7 COL FSAR Appendix 2CC, the applicant describes a three-dimensional, steady-state, constant density, numerical groundwater model that was developed to better understand pre-construction and post-construction groundwater conditions within the Biscayne aquifer at the Turkey Point Units 6 and 7 site (ADAMS Accession No. ML110610729). The applicant described the model as follows: In Turkey Point Units 6 and 7 COL FSAR, the model effort is split into Phase I, involving determining groundwater control options for construction and to simulate the operation of the RCW system for production of make-up water; and Phase II, involving specific post-construction issues, e.g., splitting the top model layer into two layers, revision of the top elevation of diaphragm walls to 2 ft (0.6 m) NAVD 88, incorporation of structural backfill into the top model layer, and incorporation of the MWR as an active feature. The model uses the user interface Visual MODFLOW and is based on the USGS-developed MODFLOW 2000 code. Fourteen layers of the Biscayne aquifer were

included in the model framework, as described above beginning in the muck layer and extending to the Tamiami Formation. The layers are as follows:

- Layer 1: Muck layer: organic soils onshore, offshore sand and sediment
- Layers 2, 3: Marine limestone, upper aquitard (Miami Limestone)
- Layer 4: Marine limestone, Upper Higher Flow Zone (RCW source)
- Layers 5, 6: Marine limestone, Upper Biscayne aquifer (Key Largo Limestone)
- Layer 7: Freshwater limestone unit, and where absent = Key Largo Limestone
- Layers 8, 9, 11, 12, 13: Marine limestone, Lower Biscayne aquifer (Fort Thompson Formation)
- Layer 10: Marine limestone, Lower Higher Flow Zone
- Layer 14: Marine limestone or sandstone, lower aquitard (Upper Tamiami Formation)

The Upper Higher Flow Zone and Lower Higher Flow Zone are identified as a result of mud loss during drilling at the contact between the Miami Limestone and the Key Largo Limestone, and 15 ft below the top of the Fort Thompson Formation. Additionally, enlarged boring diameters were observed. Revision 3 of the Turkey Point Units 6 and 7 COL FSAR included these layers.

The applicant obtained hydraulic parameters for parameterization and calibration from three historical onsite pump tests in the Biscayne aquifer on the Turkey Point Units 6 and 7 property, regional groundwater models that include the Turkey Point Units 6 and 7 site in their domain, recent onsite pumping tests at Turkey Point Units 6 and 7 for the development of the Turkey Point Units 6 and 7 COL FSAR, and literature values.

The applicant based precipitation estimates on the 2008 water year, in which 45.47 in (13.9 m) were received, which the applicant found to be close to the long term average (1968–2008) of 45.77 in (116.26 cm). The applicant treated recharge assuming 100 percent of precipitation is allowed for surface water bodies and for wetland areas, while buildings and paved areas allow no recharge. The applicant used evapotranspiration rates of 54.52 in/yr (16.6 m/yr) in the calibration runs.

The applicant indicated as follows: Spatially variable recharge and evaporation were assigned to the top layer of the model based on land use. Biscayne Bay was represented by the long-term average elevation of -0.81 ft (-0.25 m) NAVD 88. The elevation of various surface water bodies were specified by adjustment to the elevation of Biscayne Bay. For example, the elevation of the IWF is specifically maintained with respect to the actual surface elevation of Biscayne Bay. Groundwater-surface water interactions are simulated in the model by including Biscayne Bay, the IWF, L-31E Canal, Cardinal Sound Canal, Florida City Canal, and the Model Land Canal (C-107). The river boundary condition was used for surface water features. Evapotranspiration and recharge boundaries were used at the ground surface for the land area. A general head boundary was used for Biscayne Bay and model sides. The horizontal flow barrier boundary was used for the mechanically stabilized earth retaining wall and for the cut-off walls for Turkey Point Units 6 and 7. The bottom of the Tamiami Formation and the bottom of the Turkey Point Units 6 and 7 excavations are represented as no-flow boundaries.

The applicant described model calibration and input data as follows: Calibration of the model was approached by using the response to pumping tests (PW-7L, PW-1, and PW-7U) to adjust the hydraulic conductivities of the units of the Biscayne aquifer, and the conductance of the various head-dependent boundary conditions. Hydraulic conductivity input data from pump tests are summarized in Table 2.4.12-1, and site hydraulic parameters are summarized in Table

2CC-204. To test the efficacy of the model, three tests were employed: (1) the modeled groundwater flow directions were compared to historical data, (2) the calculated groundwater discharge and recharge between cooling water canals and groundwater beneath Biscayne Bay was qualitatively compared to results from surface water modeling, and (3) the response to pumping in test well PW-6U was matched to model predictions.

The applicant concluded that the model was correctly calibrated because (1) observations of regional flow patterns and groundwater levels were reasonably matched by the simulations, (2) the modeled flow exchanges between the cooling water canals and the underlying groundwater agreed between independently developed ground and surface water models, and (3) the 2009 pump test (PW-6U) results.

The applicant subsequently used the model to determine estimates of discharge rates for the construction excavation for the power block, which is expected to extend to a depth of -35 ft (-10.7 m) NAVD. The applicant stated further as follows: A concrete cut-off wall will be installed around the excavation for Turkey Point Units 6 and 7 at a depth of -65 ft (-20 m) NAVD to assist in the dewatering process. To determine dewatering pumping rates, the calibrated base model was used with the following changes: (1) horizontal flow was assumed to occur between the ground surface and the base of the cut-off wall, (2) the interior of the excavation was defined as inactive to flow, and (3) pumping wells were added around the interior perimeter of the excavation between the base of the excavation and the base of the simulated cut-off wall in the lower portion of the Key Largo Limestone, freshwater limestone, and the Fort Thompson Formation. The pumping wells were represented as constant head cells represented as a thin uniform layer with a head of -35 feet NAVD 88. The applicant stated that the results of Phase I calibration suggested that construction dewatering would be aided by grouting within the cut-off walls to produce discharge rates ranging from 100 to 1,000 gpm in the excavation. Grouting was represented using a new hydraulic conductivity of 1×10^{-4} cm/s, while additional tests ranging from 1×10^{-3} to 1×10^{-6} cm/s were also tested. The grouting program is discussed in greater detail in Sections 2.5.4.5.4 and 2.5.4.6.2.

The applicant stated that model simulations demonstrated that the IWF and other regional canals exert a major influence on groundwater levels in the vicinity of Turkey Point Units 6 and 7. The applicant described the canals as follows: The canals in the IWF are engineered for circulation through maintenance of constant head levels at opposing ends of the system. After cooling water passes through Units 1-4 condensers and gains heat, the water is discharged to the northern end of the 32 westernmost canals, which are ~3 ft (0.9 m) deep and are oriented north to south. The warm water flows toward the southern end of the westernmost canals where it is collected and flows eastward across the southern end of the canals. The easternmost canals provide the cooling water return. The circulating pumps on the return side in the northeastern corner maintain a drawdown of about 3 ft (0.9 m) relative to the discharge location. The operation results in higher water levels in the discharge versus return canals, regardless of tidal influences. In the westernmost canals, the head level is always higher than that of Biscayne Bay; in the easternmost canals, the head level is always lower than that of Biscayne Bay; and in the southernmost canals, the head level is approximately equal to that of Biscayne Bay. Based on the surface water elevations for Biscayne Bay, the elevation of the discharge side is assumed to be 0.95 ft (0.3 m) NAVD 88, and that of the intake structure is -2.05 ft (0.6 m) NAVD 88. The canals are assumed to be in steady-state with respect to salinity and chemistry.

The L-31E Canal (SFWMD Salinity Structure) located to the west of the industrial wastewater cooling canals was constructed to act as a barrier to prevent salinity intrusion to locations west

of the canal. The elevation of the water level of the L-31E Canal was assumed to be 0.02 ft (0.61 cm) NAVD 88. The Interceptor Ditch lies between the industrial wastewater cooling canals and the L-31E Canal and is designed to limit the influence of water from the cooling canals on groundwater quality west of the canals in the upper portion of the aquifer. Water levels in the Interceptor Ditch are maintained by pumping to induce a seaward hydraulic gradient. The Interceptor Ditch is about 1,000 ft to the southeast of the L-31E Canal. The Interceptor Ditch is approximately 30 ft (9.1 m) wide, 19 ft (5.8 m) deep, has a total length of approximately 29,000 ft (8,839 m), and the water surface elevation is -0.28 ft (-0.02 m) NAVD 88 and transitions to -1.05 ft (-0.32 m) at the southern end. The westernmost discharge cooling canal surface elevation is assumed to be 1.08 ft (0.33 m) NAVD 88 at the northern end and drops linearly to -1.05 ft (-0.32 m) at the southern end.

The post-construction elevation of the ground surface is expected to be 25.5 ft (7.8 m) NAVD 88. The applicant used the model to determine the elevation of the groundwater table once construction is complete. The applicant made the following assumptions for the simulations: (1) the cut-off walls remain in place, (2) concrete added within the cut-off walls between -35 ft (-11 m) NAVD 88 and -16 ft NAVD 88 has a hydraulic conductivity of 1 x 10^{-7} cm/s, (3) a concrete “mud mat” for the reactor building having a hydraulic conductivity of 1 x 10^{-7} cm/s was added within the cut-off walls between -16 and -14 ft NAVD 88, (4) the reactor building is impermeable to flow, (5) zero recharge occurs on the island due to pavement, grass is 2 in/yr, and gravel is 10 in/yr, (6) backfill added between the reactor building and the cut-off walls has a hydraulic conductivity of 0.01 cm/s, and (7) muck is removed entirely and replaced with backfill having hydraulic conductivity of 0.01 cm/s. The applicant indicated further as follows: Simulations resulted in water table elevations at Turkey Point Units 6 and 7 were sufficient to meet the criteria of the Design Control Document (DCD) of the AP1000 (i.e., a water table elevation of less than 3 ft (0.91 m) NAVD 88 given a power block elevation of 25.5 ft (7.8 m) NAVD 88) . Test cases included sea-level rise of 1 ft/yr, failure of the north wall of the MWR, and a variety of recharge rates on the island.

The applicant also used the model to simulate the performance of the radial collector wells and to determine the source of the water. The applicant indicated as follows: A new 1-ft thick layer was added into the model of the Key Largo Limestone to represent the lateral wells, effectively splitting the Key Largo into three layers, one of which is located above -26.5 ft NAVD 88 and the other below -27.5 ft NAVD 88. The model predicted that four pumping wells on each lateral would produce a total of 28,800 gallons per minute per radial collector well, with three of the four radial wells operational. The applicant used the particle tracking model to predict that 92 percent of the water would originate in Biscayne Bay and would be filtered through the muck layer, while 8 percent of the water would originate inland. The applicant subsequently revised the modeled shoreline to include the submerged mangrove forest, resulting in an estimate of 95 percent of the water sourcing from Biscayne Bay. The applicant stated that the radial collector wells are not a safety issue because the AP1000 reactor does not credit a water source for cooling.

Staff’s Technical Evaluation

The applicant has provided a description of the methods and outcomes of three-dimensional numerical groundwater flow modeling in Section 2.4.12.3.1 “Biscayne Aquifer” and Turkey Point Units 6 and 7 COL FSAR Appendix 2CC. The staff examined the model to determine pre-construction and post-construction groundwater conditions at the Turkey Point Units 6 and 7 site, including the impacts and efficacy of construction dewatering, considering both the increase in site grade and the emplacement of diaphragm walls for groundwater control.

For dewatering simulation for Turkey Point Units 6 and 7 excavations, the staff conducted a bounding analysis to determine the efficacy of planned construction dewatering. The staff assumed an impermeable cutoff wall and the pumping rate was approximated by one-dimensional steady-state flow to the portion of the aquifer contained in the cutoff wall as $Q = kiA$, with k as the hydraulic conductivity, i as the gradient, and A as the cross-sectional area. From Figure 2CC-222 of the Turkey Point Units 6 and 7 COL FSAR Revision 2, A is approximately 54,000 ft^2 (300 ft × 180 ft). To keep the groundwater level below the excavation elevation of -35 ft, the total head loss is about 35 ft. For the three formations in the cylinder (Figure 2CC-226), the hydraulic conductivity of the freshwater limestone $4x10^{-4}$ cm/s is orders of magnitudes less than that of the Key Largo Limestone (4 cm/s) and the Fort Thompson Formation (0.2 cm/s) (Turkey Point Units 6 and 7 COL FSAR Table 2CC-205). Therefore, most of the head loss is expected to occur in the freshwater limestone (similar to the MWR case described in Section 2.4.12.4.2 of this SER). According to Turkey Point Units 6 and 7 COL FSAR Appendix 2CC, the freshwater limestone is a thin unit (less than 9 ft). The gradient in this layer will be greater than 1 (9 ft of the 35 ft head loss on a 9 ft layer). The vertical hydraulic conductivity must be less than 32 ft/day (0.01 cm/s). Considering that the freshwater limestone can be absent (Turkey Point Units 6 and 7 COL FSAR Appendix 2CC), a 35-ft total head loss, and the hydraulic conductivity of these formations can be much greater than 0.01 cm/s, the staff determined that the 9,000 gpm pumping rate for dewatering listed in Turkey Point Units 6 and 7 COL FSAR Revision 2 (FPL, 2010b) per excavation was inadequate.

The staff determined that the reasons for this initial underestimation are: (1) use of a calibrated horizontal (10 times greater than vertical) hydraulic conductivity of 0.0004 cm/s for the freshwater limestone (Turkey Point Units 6 and 7 COL FSAR Revision 2 Table 2CC-205) while the geometric mean was reported to be 0.17 cm/s (Turkey Point Units 6 and 7 COL FSAR Revision 2 App. 2CC 5.7.1), and (2) the thickness of this low permeable formation appears to be significantly greater under the excavation sections than elsewhere (Turkey Point Units 6 and 7 COL FSAR Revision 2 Figure 2CC-225). Accordingly, the staff posed RAI 5643, Question 02.04.12-5 (April 28, 2011) to ask the applicant to revise the dewatering estimate to demonstrate more conservatism. In a June 27, 2011, response (ADAMS Accession No. ML11180A062), the applicant revised the groundwater model and changed the dewatering design by proposing to inject approximately 25 ft of grout plug into the rock beneath the base of the excavation. The applicant estimated the hydraulic conductivity of the formation plugged with grout as 1×10^{-4} cm/s, and the applicant tested the efficacy of dewatering by performing calculations with a range of hydraulic conductivity from 1×10^{-3} to 1×10^{-6} cm/s. Furthermore, the staff in its calculations used the conductivity of the Key Largo Limestone with freshwater limestone absent, which was conservative (i.e., the hydraulic conductivity will be higher) and the staff results were in agreement with the applicant's estimates. The accordingly staff finds the revised model to be acceptable and that the applicant had addressed the questions in the RAI and the staff considers the RAI closed.

As described above, based on the results of staff's analysis and the applicant's conceptualization and implementation of the groundwater flow model, input parameters and simulations are acceptable and sufficient to represent the transport processes and dewatering estimates for the aquifer system.

2.4.12.4.11 Monitoring or Safeguard Requirements

Information Submitted by Applicant

In Turkey Point Units 6 and 7 COL FSAR, Section 2.4.12.4, the applicant discussed "monitoring and safeguard requirements." The applicant stated that it will comply with RG 4.21 and the Nuclear Energy Institute (NEI) groundwater initiatives. The applicant stated that many measurements will be made during construction and after plant start-up, including water level and geochemical measurements (e.g., pH, temperature, specific conductance, oxidation-reduction potential, dissolved oxygen, major anions and cations, total dissolved solids, and silica at minimum). The applicant indicated that wells will include selected observation wells retained from the Turkey Point Units 6 and 7 site investigation, radial collector wells, and on-site water supply wells. The applicant stated that the long-term groundwater monitoring program would involve periodic water level measurements and geochemical sampling and analysis of the radial collector wells to determine changes in the Biscayne aquifer that could impact groundwater supply or the accidental release analysis.

In regard to injection into the Boulder Zone, the applicant stated that it will comply with underground injection control (UIC) regulations determined by the State of Florida in Chapter 62-528 FAC (FDEP, www). The applicant described this as follows: The UIC permit requires monthly reporting of the average, minimum, and maximum injection pressure, flow rate, volume, and annular pressure of each injection well. Mechanical integrity is required to be tested every 5 years. Dual-zone wells are required to be located less than 150 ft from the injection wells in order to detect vertical migration of injected fluids. The upper monitoring zone is above or at the base of the USDW and the lower zone is below the base of the USDW and just above the primary confining unit.

Operational and accident monitoring will be initiated in the event of an accidental release of liquid effluent from the plant. Measurements will be taken quarterly in the downgradient direction of flow.

Staff's Technical Evaluation

The staff reviewed Section 2.4.12.2.4 "Monitoring and Safeguard Requirements" of the Turkey Point Units 6 and 7 COL FSAR. As discussed below, the staff finds the monitoring program components acceptable as described in the FSAR:

- Periodic monitoring of Biscayne aquifer water level and geochemical sampling of radial collector wells;

- Geochemical and pressure monitoring of the Floridan aquifer in accordance with mandates by the State of Florida (Chapter 62-528 FAC); and,

- An effluent and process monitoring program (as described in SER Section 11.5)

For the Biscayne and Floridan aquifers, the staff notes that the applicant will perform analysis during and after construction of pH, temperature, specific conductance, oxidation-reduction potential, and dissolved oxygen, major cations, major anions, total dissolved solids, silica, and any additional water use or injection well permit-required parameters. Sampling is performed in site water supply wells, selected observation wells, and dual-zone monitoring wells as part of

the underground injection control (UIC) permit. The State of Florida regulates monitoring associated with the UIC permit.

The staff also reviewed documents on the use of the Boulder Zone for the disposal of Class I industrial wastes via Underground Controlled Injection (UIC) by USGS (Reese and Richardson, 2008), MDWASD (MDWASD, 1981), academic researchers (Maliva et al., 2007; Maliva and Walker, 1998; Haberfield, 1990), EPA (EPA, 2000, 2003), and FDEP regulations concerning UIC (http://www.dep.state.fl.us/water/uic/index.htm). In its review of the application, the staff also reviewed sections of the environmental report addressing groundwater monitoring (FPL, 2010c) and the applicant's approved application to FDEP for a Class V exploratory well and transition to a Class I deep injection well (ADAMS Accession Nos. ML093310169, ML110070251). The information addressing groundwater monitoring in the environmental report is consistent with that in the Turkey Point Units 6 and 7 COL FSAR. Accordingly, and for the reasons described above, the staff concludes that the applicant's Turkey Point Units 6 and 7 site monitoring program and its components are acceptable.

2.4.12.4.12 Site Characteristics for Subsurface Hydrostatic Loading

Information Submitted by Applicant

In Turkey Point Units 6 and 7 COL FSAR, Section 2.4.12.5, the applicant described subsurface hydrostatic loading estimates, defined plant grade, and defined the site characteristic maximum groundwater level for the Turkey Point Units 6 and 7 site.

The applicant indicated as follows: The current elevation of the proposed location of the nuclear island for Units 6 & 7 is approximately 2.5 to 0.8 ft (0.8 to 2.4 m) MSL (NAVD 88). The muck layer found in the first 7 ft will be removed during construction, and the initial excavation will extend to -35 ft (-11 m) NAVD 88. Engineered fill will be used to raise the finish grade to 25.5 ft (7.8 m) NAVD 88. Reinforced concrete diaphragm walls of thickness 3 ft (0.9 m) will be emplaced at a depth of -65 ft (-20 m) NAVD 88 to control groundwater flow into the excavation. The applicant stated that the Biscayne aquifer is within 5 ft of the current ground surface.

The applicant calculated the estimates of subsurface hydrostatic loading for the projected maximum groundwater level. The maximum groundwater level must be lower than 2 ft below the plant grade (e.g., 23.5 ft (7.2 m) NAVD 88) as specified in Table 5.0-1 (Site Parameters) in Tier 1 Chapter 5 of the AP1000 Design Control Document (DCD). The applicant groundwater model simulations (Turkey Point Units 6 and 7 COL FSAR, Appendix 2CC) predicted a maximum groundwater elevation of 2 ft (0.6 m) NAVD 88 in the power block area. The applicant stated that the estimated maximum groundwater elevation is therefore over 20 ft lower than the DCD site parameter.

The applicant calculated the maximum hydrostatic load using the depth below groundwater and the unit weight of water measured at the site (64.4 pounds per cubic ft (2,274 pounds per cubic m). The results were shown in Turkey Point Units 6 and 7 COL FSAR, Fig. 12.4.12-247, and the results indicated that the estimated hydrostatic pressure beneath the power block will not exceed the corresponding hydrostatic pressure computed using the maximum groundwater level of 2 ft (0.6 m) below grade as specified in the DCD. The applicant stated that as a result of these analyses a permanent dewatering system is not a design feature for Turkey Point Units 6 and 7.

The applicant stated that subsurface hydrostatic loading on safety-related structures during construction will be less than predicted above because the applicant will implement groundwater control measures. That is, the applicant will perform dewatering to 35 ft (11 m) below the pre-construction grade for the reactor building, as described in Turkey Point Units 6 and 7 COL FSAR Subsections 2.5.4.5.4 and 2.5.4.6.2. The applicant stated that before the excavation is initiated, a groundwater control and recovery plan will be prepared for the system design, installation, and removal.

Staff's Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.12.2.5 Site Characteristics for Subsurface Hydrostatic Loading." The staff's review confirmed that the applicant addressed relevant information.

The staff conducted independent bounding analyses for a steady-state flow scenario and a transient flow scenario with a 72-hour probable maximum precipitation (55.7 in) (NOAA, 1982). For both scenarios, the power block was simplified as a circular island with constant head (0 ft) at the boundary.

For the steady-state flow scenario with Dupuit's assumption for an unconfined aquifer, the flow rate (Q) is expressed as

$$Q = 2\pi k r b \frac{db}{dr} = -\pi r^2 w,$$

Where k = hydraulic conductivity, b = thickness of the unconfined aquifer, r = distance from the center, and w = infiltration rate. The equation can be rewritten as

$$\frac{db^2}{dr^2} = -\frac{w}{2k}$$

The general solution is

$$b^2 = -\frac{w}{2k} r^2 + c$$

Assuming a boundary condition of $b(r = R) = b_0$ at the edge of the island,

$$b^2 = b_0^2 + \frac{w}{2k}(R^2 - r^2)$$

The maximum groundwater level (h_{max}) in the center (r = 0) is

$$h_{max} = \sqrt{b_0^2 + \frac{w}{2k} R^2} - b_0$$

Let R = 1,330 ft (405 m), and h_{max} is dependent on the hydraulic conductivity, recharge rate, and aquifer thickness. A hydraulic conductivity of less than 3-4 ft/day (0.9-1.2 m/day) is necessary for the mounding to be over the 23.5 ft (7.2 m) maximum groundwater level (Figure 2.4.12-2) with a recharge equal to the annual precipitation w = 3.79 ft/year = 0.01 ft/day and an assumed aquifer thickness of 25 ft (freshwater limestone as the aquitard). As the vertical hydraulic conductivity of the surficial Biscayne aquifer is approximately 15 ft/day (4.6 m/day) (Turkey Point Units 6 and 7

COL FSAR Revision 2, Table 2.4.12-205), the maximum water level is not likely to be exceeded under steady-state flow conditions, given expected conductivity of the fill material used to build up the island. Accordingly, the staff finds that that the maximum groundwater level meets the criteria of the Design Control Document (DCD) of the AP1000 at a maximum of 2 ft (0.6 m) below grade.

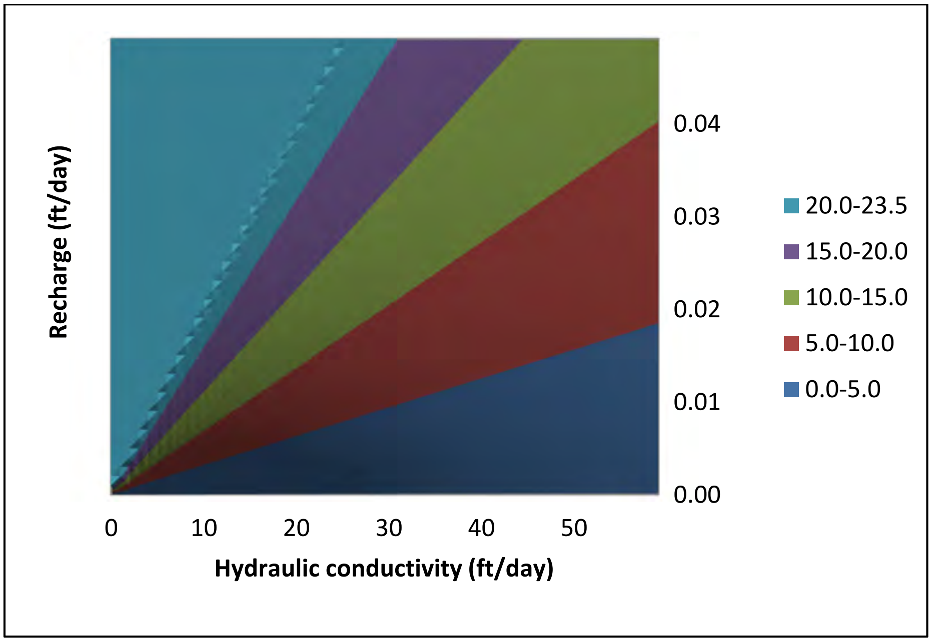


Figure 2.4.12-2. Maximum groundwater mounding under steady-state flow condition with aquifer thickness of 25 ft (7.6 m) (freshwater limestone as the aquitard).

The staff also estimated maximum groundwater elevation under a transient flow scenario. The 72-hour probable maximum precipitation of 55.7 in. for areas of 10 mi^2 or less in the Florida peninsula was considered. The approximate analytical solution by Basak (1982) was used to calculate the groundwater table mounding. The results (Figure 2.4.12-3) show that the maximum water level of 23.5 ft (7.2 m) is not likely to be exceeded, even when the maximum precipitation occurs for 5 days (R = 1,330 ft (405 m), k = 15 ft/day (4.6 ft/day), b_0 = 50 ft (15.2 m), and specific yield = 0.3). Even though the Basak (1982) solution is accurate only for a small mounding level (say 5 ft (1.5 m) of a 25 ft (7.6 m) thick unconfined island aquifer) and for a hydraulic conductivity greater than the recharge rate, the possible maximum mounding level would be expected to be much less than 23.5 ft (7.2 m) for an expected recharge rate less than 1 ft/day, and hydraulic conductivity greater than 10 ft/day (Figure 2.4.12-4). Accordingly, the staff finds that that the maximum groundwater level under a transient flow scenario meets the criteria of the Design Control Document (DCD) of the AP1000 at a maximum of 2 ft (0.6 m) below grade.

The applicant's analysis assumed that the nuclear island would be fully (100 percent) paved. Because infiltration could enhance or induce groundwater mounding, the staff issued RAI 5190, Question 02.04.12-3 (December 10, 2010) to discern if the zero infiltration scenario was consistent with an absence of groundwater mounding. In a May 5, 2011 response (ADAMS Accession No. ML11129A058), the applicant revised the infiltration rate distribution by including infiltration estimates for grass and gravel, conducted numerical simulations, and confirmed that alternative infiltration scenarios will not raise the mounding level close to the 23.5 ft (7.2 m)

design level. In the staff's analysis, no coverage of ground surface with pavement was assumed. The results of the staff analysis confirmed that the extent of pavement did not influence groundwater mounding

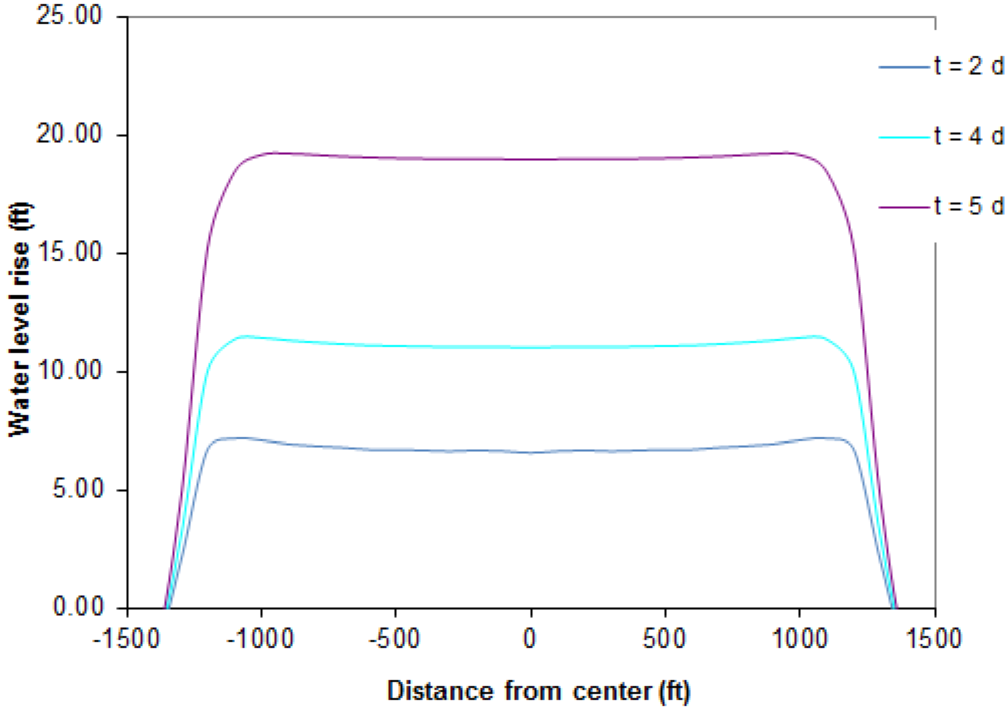


Figure 2.4.12-3. Groundwater mounding calculated using Basak (1982) for the 72-hour probable maximum precipitation of 55.7 in.

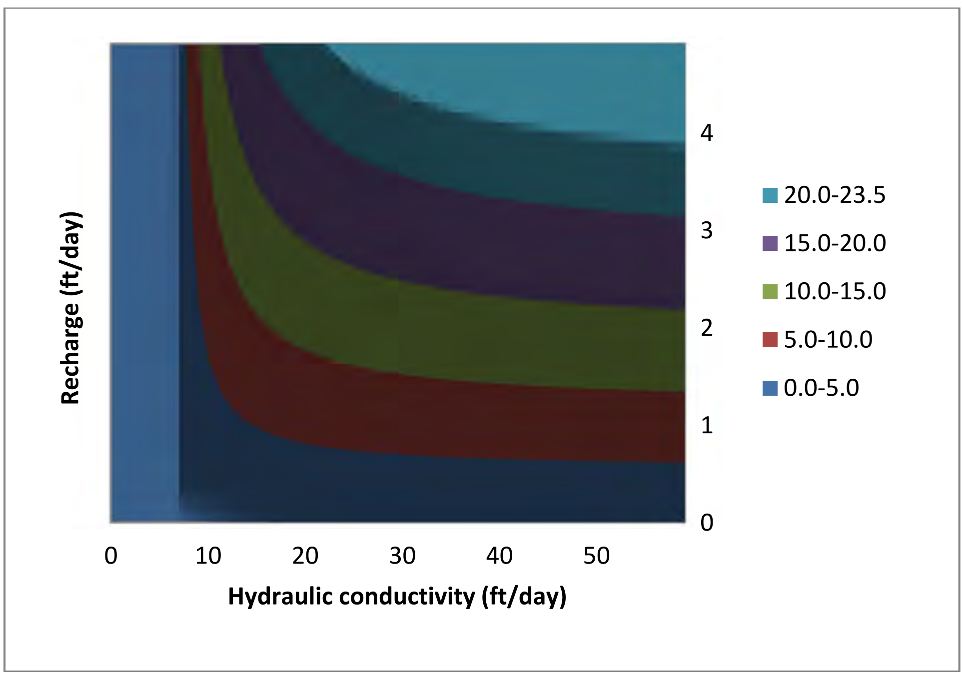


Figure 2.4.12-4. Maximum groundwater mounding due to 3-day recharge with different hydraulic conductivity and recharge rate for a 25 ft (7.6 m) unconfined island aquifer.

beneath the nuclear island, which is consistent with applicant response and revised simulations (ADAMS Accession No. ML11129A058). Accordingly, the staff finds that that the maximum groundwater level for this scenario meets the criteria of the Design Control Document (DCD) of the AP1000 at a maximum of 2 ft (0.6 m) below grade.

The applicant's analysis did not consider changes in groundwater elevations due to sea-level rise associated with climate change. In a May 5, 2011 response (ADAMS Accession No. ML11129A058) to RAI 5190, Question 02.04.12-1 (December 16, 2010), to account for sea level rise, the applicant conducted additional numerical simulations. The applicant results indicated that the long-term sea-level change can at most raise the water table by 1-2 ft, far below the designed level of 23.5 ft (7.2 m) . The small increase in water level due to sea level rise would have little impact on the more that 20 ft of margin between maximum groundwater level (less than 3 ft (0.91 m) NAVD88) and the nuclear island site grade of 25.5 ft (7.8 m) NAVD88. Accordingly, the staff finds that that the maximum groundwater level, including consideration of sea level rise, meets the criteria of the Design Control Document (DCD) of the AP1000 of a maximum of 2 ft (0.6 m) below grade.

Based on the foregoing, the staff concludes that the applicant's evaluations for the scenarios described above for a permanent dewatering system to meet the requirements of the DCD and are acceptable.

2.4.12.5 Post Combined License Activities

There are no post COL activities related to this subsection.

2.4.12.6 Conclusions

The staff has reviewed the application and has confirmed that the applicant addressed the information relevant to groundwater, and that there is no outstanding information required to be addressed in the Turkey Point Units 6 and 7 COL FSAR. As set forth above, the applicant presented and substantiated information to establish the site description. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.12, 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 2.4-4. In conclusion, the applicant has provided sufficient information for satisfying 10 CFR Part 52 and 10 CFR Part 100.

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

2.4.13.1 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.4.13 analyzes the potential effects of accidental releases from the Radwaste Management Systems that handle liquid effluents generated during normal plant operations. Such releases would have relatively low levels of radioactivity, but could be large in volume. Normal and severe accidental releases are also considered in the applicant's ER and Turkey Point Units 6 and 7 COL FSAR Chapter 15. The

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

Section 2.4.13 of this SER presents an evaluation of the following specific areas: (1) alternative conceptual models of the hydrology at the site that reasonably bound hydrogeological conditions at the site inasmuch as these conditions affect the transport of radioactive liquid effluent in the groundwater and surface water environment; (2) a bounding set of plausible surface and subsurface pathways from potential points of an accidental release to determine the critical pathways that may result in the most severe impact on existing uses and known and likely future uses of groundwater and surface water resources in the vicinity of the site; (3) ability of the groundwater and surface water environments to delay, disperse, dilute, or concentrate accidentally released radioactive liquid effluents during transport; and (4) assessment of scenarios wherein an accidental release of radioactive effluents is combined with potential effects of seismic and non-seismic events (e.g., assessing effects of hydraulic structures located upstream and downstream of the plant in the event of structural or operational failures and the ensuing sudden changes in the regime of flow); and (5) any additional information requirements prescribed in the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

2.4.13.2 Summary of Application

Section 2.4.13 of the Turkey Point Units 6 and 7 COL FSAR addresses the accidental release of radioactive liquid effluents in ground and surface waters. The AP1000 Finality Matrix calls for Section 2.4.13 of the Turkey Point Units 6 and 7 COL FSAR to address COL Information Item 2.4-5 on the accidental release of radioactive liquid effluents in ground and surface waters by (1) providing information about the ability of the surface- and subsurface-water environment to disperse, dilute, or concentrate accidental releases, and by (2) describing the effects of these releases on existing and known future uses of water resources.
The applicant submitted Section 2.4.13 as a site-specific supplement designed to address COL Information Items 2.4-5 and 15.7-1. The applicant addressed these issues as follows:

<u>AP1000 COL Information Item</u>

- PTN COL 2.4-5 and PTN COL 15.7-1

COL License Information Item 2.4-5 requires COL applicants to provide site-specific information on the ability of the ground and surface water to disperse, dilute, or concentrate accidental releases of liquid effluents. COL applicants are required to perform an analysis of the consequences of potential release of radioactivity to the environment due to a liquid tank failure. Effects of these releases on existing and known future use of surface water resources will also be addressed.

Turkey Point Units 6 and 7 COL FSAR Section 15.7.6 states that PTN COL 15.7-1 is addressed in Turkey Point Units 6 and 7 COL FSAR Section 2.4.13 where the applicant performed the consequence analysis of a postulated liquid waste tank failure. The staff's review of the applicant's analysis in FSAR Section 2.4.13 is limited to these COL Information Items as described below.

2.4.13.3 Regulatory Basis

The relevant requirements of the NRC regulations for the pathways of liquid effluents in ground and surface waters, and the associated acceptance criteria, are described in Section 2.4.13 of NUREG-0800.

The applicable regulatory requirements for liquid effluent pathways for groundwater and surface water are as follows:

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

- 10 CFR Part 20, as it relates to effluent concentration limits.

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

Appropriate sections of the following documents are used for the related acceptance criteria:

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

- RG 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose Of Implementing Appendix I"

2.4.13.4 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.13 and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to accidental release of radioactive liquid effluent in ground and surface waters. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 ("Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design, Rev 19") and its supplements.

To improve readability, the staff's discussion of the accidental release of radioactive liquid effluents is organized into the following technical areas as described below which include:

- Direct Release to Groundwater;
- Accident Scenario;
- Conceptual Model;
- Analysis of Accidental Releases to Groundwater;
- Compliance with 10 CFR Part 20; and
- Direct Releases to Surface Waters.

The staff notes that Section 2.4.13 considers a postulated release from a catastrophic tank failure scenario considering the transport through the hydrologic system with the resulting radiological dose evaluated in SER Section 11. Additionally, normal operational radiological releases are addressed in SER Section 11 and not considered in SER Section 2.4.13.

2.4.13.4.1 Direct Release to Groundwater

Information Submitted by Applicant

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.13.1, the applicant provided an analysis of the postulated accidental liquid release to groundwater at the Turkey Point Units 6 and 7 site (FPL 2015). The applicant included in the pathway analysis the processes of advection, radionuclide decay, adsorption, dilution, and dispersion. As described in Turkey Point Units 6 and 7 COL FSAR Section 2.4.12.4.10, "Subsurface Pathways," the applicant applied a simplified model for a single physical pathway, but with slightly different hydraulic controls (RCW system on and off; IWF circulation system on and off). The applicant indicated the following: The physical pathway considers the release of liquid effluent below the auxiliary building to instantaneously enter the structural fill surrounding the building. Once in the groundwater, the effluent migrates upward according to the hydraulic gradient into the IWF, where mixing and dilution occur. Water from the IWF then migrates through the Key Largo Limestone unit of the Biscayne aquifer and is released into Biscayne Bay.

Staff's Technical Evaluation

The staff reviewed the Turkey Point Units 6 and 7 COL FSAR, Section 2.4.13.1, "Direct Release to Groundwater" and confirmed that the applicant's revised analysis included in a June 27, 2011 response to RAI 5643, Question 02.04.12-6 (ADAMS Accession No. ML110610729) regarding instantaneous transport pathway release scenarios was adequately addressed in the Turkey Point Units 6 and 7 COL FSAR, as discussed below, and the staff considers the RAI closed. The staff's review confirmed that the applicant addressed relevant information considering conservative release scenarios. The staff evaluated the applicant's assumptions and parameters to confirm that the applicant's description of the groundwater pathway was conservatively represented by the processes of advection, dispersion, dilution, and decay, in accordance with the guidance of NUREG-0800, Section 2.4.13. As discussed in the Alternative Pathways Evaluation Subsection of Subsection 2.4.12.4.10, "Subsurface Pathways," the staff concludes that the applicant's description of alternate subsurface pathways was conservative because all non-seismic Category I structural features of the buildings and excavation (sealed 3 ft (0.9 m) thick exterior walls, the 6 ft (1.8 m) thick basemat, and floor drains, along with the 3 ft (0.9 m) thick reinforced concrete diaphragm walls and a 19 ft (5.8 m) thick concrete layer beneath the building) were postulated to be instantaneously permeated for a tank failure scenario. The staff confirmed that the release scenario is sufficiently conservative and that the pathway described is considered acceptable and a plausible pathway to groundwater.

2.4.13.4.2 Accident Scenario

<u>Information Submitted by Applicant</u>

In Turkey Point Units 6 and 7 COL FSAR, Section 2.4.13.1.1, the applicant postulated a release to groundwater (and surface water via the groundwater pathway) from a liquid radwaste effluent holdup tank rupture in the auxiliary building at Turkey Point Units 6 and 7. The applicant considered the various radioactive sources and concluded that the volume and radionuclide concentrations of a single effluent holdup tank would be the most conservative choice for accident scenario analyses (Turkey Point Units 6 and 7 COL FSAR Table 2.4.13-201). The applicant explained that the volume of a single effluent holdup tank is 28,000 gallons and, based on NUREG-0800 and BTP 11-6, the postulated rupture of the effluent holdup tank is assumed to release 80 percent of its liquid volume (22,400 gallons) to the groundwater environment. The applicant estimated that radionuclide concentrations resulting from effluent holdup tank rupture would be 101 percent of the reactor coolant activity, which is representative of the effluent holdup tank contents (Turkey Point Units 6 and 7 COL FSAR, Table 2.4.13-201).

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

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.13.1.1, "Source Term" (FPL 2015). The staff reviewed the postulated release and finds the postulated effluent holdup tank rupture in the lowest level of the auxiliary building to be consistent with the AP1000 DCD information and BTP 11-6 (NRC 2007). Consistent with the AP1000 DCD Rev 19, Table 11.1-2, the staff confirmed that the applicant conservatively selected the radwaste system tank with the highest radionuclide concentration inventory and with the highest volume for the postulated tank failure scenario consistent with BTP 11-6 for determining the radionuclide source term. Therefore, the staff accepted the radionuclide concentrations reported in Turkey Point Units 6 and 7 COL FSAR Table 2.4.13-201 as the highest for the radwaste tank system for the reactor AP1000 DCD.

2.4.13.4.3 Conceptual Model

<u>Information Submitted by Applicant</u>

In Turkey Point Units 6 and 7 COL FSAR, Section 2.4.13.1, the applicant described the conceptual model used to evaluate the plausible groundwater pathways that an accidental release of radioactive liquid effluent could follow at the proposed Turkey Point Units 6 and 7 site. The applicant used regional groundwater potentiometric surface measurements to infer that flow is toward the east and southeast in Miami-Dade County in the Biscayne aquifer. Local monitoring suggests that flow is generally toward the center and to the southwestern corner of the Turkey Point Units 6 and 7 island in the Upper Biscayne aquifer and generally away from the center of the island and toward the canals that surround the island in the Lower Biscayne aquifer. Onsite measurements of hydraulic head suggest an upward gradient from the Lower to the Upper Biscayne aquifers, and that the hydraulic gradient in the Upper Biscayne aquifer is also in the upward vertical direction.

The applicant described a single plausible physical groundwater pathway, with slightly different hydraulic controls on the flow and transport characteristics of system components (RCW system on and off; IWF circulation system on and off). The applicant indicated as follows: The physical pathway considers the release of liquid effluent below the auxiliary building to instantaneously enter the structural fill surrounding the building, and subsequently flow through the Key Largo

Limestone in the upper interval of the Biscayne aquifer to the IWF, which serves as the area of groundwater discharge for the plant. Dilution occurs in the IWF, followed by exchange between groundwater and the cooling canal water since the canals are unlined, with final discharge with regional groundwater flow into Biscayne Bay. The water levels within the cooling canals are engineered to function as a groundwater discharge zone. The eastern canals are continuously maintained at a lower head than Biscayne Bay to the east and the western canals are continuously maintained at a lower head than fresh groundwater located to the west of the Turkey Point Units 6 and 8 site. The primary groundwater pathway would not threaten groundwater or surface water supplies, a conclusion primarily based on the lack of receptors that use ground or surface water for drinking water supply. In this scenario, the radionuclides associated with a postulated liquid release would enter the cooling water canals and be diluted. The IWF has an estimated total volume of 4 billion gallons. The cooling water canals also act as a groundwater sink based on cooling water canal water balance studies and local groundwater modeling. For exposure assessment purposes, the applicant assumed the radionuclide concentrations in the cooling canal water are transferred along the overall regional groundwater flow easterly toward Biscayne Bay.

The applicant stated there are no water-supply wells between the postulated effluent holdup tank release point and the IWF or Biscayne Bay that withdraw water from the Biscayne aquifer. The applicant indicated further as follows: The Biscayne aquifer groundwater in the site region is brackish to saline, limiting its potential as a potable water source, and the freshwater/saltwater boundary is located over 6 mi to the west of the Turkey Point Units 6 and 7 site (FPL 2011b). The use of groundwater in the area for domestic purposes is unlikely, thus the applicant identified exposure to groundwater in the vicinity of the site as an incomplete pathway. Within Biscayne Bay, a theoretical well is located, which allows radionuclide concentrations to be estimated at that discharge point. Subsequently, the applicant used an indirect consumption pathway involving human ingestion of contaminated seafood (fish and crustaceans/mollusks).

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

The staff has reviewed the conceptualization of the primary and alternative groundwater pathways, which include analyses of potential exposure pathways in the Biscayne aquifer. The conceptualization provides a reasonable assessment of groundwater flow that the staff considered consistent with the hydrogeologic setting. Based on the site conditions described above, there are no direct drinking water receptors for the groundwater and surface water exposure pathways at the Turkey Point Units 6 and 7 site and the surrounding area. The staff's review of the applicant's information and data supporting the conceptual model confirms that the applicant addressed relevant information. Accordingly, the staff concludes that the applicant's description of the conceptual model is acceptable and an adequate representation.

2.4.13.4.4 Analysis of Accidental Releases to Groundwater

<u>Information Submitted by Applicant</u>

In Turkey Point Units 6 and 7 COL FSAR, Section 2.4.13.1.4 (FPL 2011b), the applicant described an approach for estimating radioactive contaminant concentrations resulting from the postulated release from an effluent holdup tank in the auxiliary building into groundwater surrounding the lower portion of the containment building. The applicant presented several calculations for estimating advection, radionuclide decay, adsorption, dilution, and dispersion through subsurface materials to the IWF, and subsequently discharging within Biscayne Bay.

The applicant considered parent and progeny radionuclides expected to be present in the effluent holdup tank. The applicant also presented a hypothetical dose assessment for human ingestion of marine organisms after biological uptake of radionuclides, which are transported to Biscayne Bay via groundwater.

The applicant indicated the following: The particle tracking method terminates in the IWF, and it is at this point that the applicant evaluates changes to radionuclide concentrations during transport through the subsurface. The shortest travel time (3,778 d) of the four alternative cases (Turkey Point Units 6 and 7 COL FSAR Table 2.4.13-202) for hydraulic conditions in the subsurface is Case 3, in which the IWF is not operational and the RCW are off. The applicant compared simulated concentrations to the effluent concentration limits (ECL) of 10 CFR Part 20, Appendix B, Table 2, Column 2.

The applicant described the analysis as follows: First, the applicant allowed the radionuclides in the effluent holdup tank (Turkey Point Units 6 and 7 COL FSAR Table 2.4.13-201) to decay for 3,800 d, which is similar to Case 3. However, the primary conceptual model for release assumes that the IWF is functional (i.e., Case 1, with RCWs off). Travel time in the Upper Higher Flow Zone (model layer 4) is neglected. The results were shown in Turkey Point Units 6 and 7 COL FSAR, Table 2.4.13-203, where the concentration of radionuclides is calculated with respect to the ECL. Only radionuclides with ratios of their concentrations to ECL exceeding 1 x 10^{-6} are of concern, and these were carried forward for additional analysis.

Second, the applicant considered adsorption of these radionuclides. Derived from laboratory tests of site-specific fill, native aquifer material and concrete, the applicant provided values of the distribution coefficient (K_d) representing the linear adsorption coefficient of sorption (Turkey Point Units 6 and 7 COL FSAR, Table 2.4.13-204). The applicant evaluated the mean and skewness of its measured K_d to determine that the geometric mean is representative, with the exception of Fe-55. The applicant assumed the Kd of Fe-55 was zero for conservatism (i.e., no sorption/retardation). The applicant indicated further as follows: For daughter products with short half-lives, their K_d was assumed to be equivalent to that of the parent. Retardation coefficients were calculated using site-specific values from the Miami Limestone. The effective porosity of 0.15 and a bulk density of 1.59 g/cm^3 were consistent with and somewhat lower than those published in Merritt (1996) and measured total porosities at the site (Turkey Point Units 6 and 7 COL FSAR Table 2.4.13-206). A lower effective porosity and bulk density is more conservative for adsorption. Only radionuclides with ratios of their concentrations to ECL exceeding 1 x 10^{-6} are of concern, and these were carried forward for additional analysis (Turkey Point Units 6 and 7 COL FSAR, Table 2.4.13-205).

Third, the applicant considered dilution of these radionuclides. The applicant explained as follows: Dilution was inferred to be 5.6E-6 in accordance with a release of 22,400 gal into an IWF volume of 4 billion gal. The background concentration of the IWF was considered since it contains H-3 from current operations at a concentration of approximately 5250 pCi/L. The applicant assumed the IWF is completely mixed because circulation occurs at a rate of 4,000 ft^3/s (113 m^3/s). The ratio of the radionuclide concentrations to the ECL after dilution is shown in Turkey Point Units 6 and 7 COL FSAR Table 2.4.13-207. The applicant used the sum of fractions approach and determined the sum after the release scenario is 0.7 and therefore conforms to 10 CFR Part 20 effluent concentration limits of less than 1.0 (Turkey Point Units 6 and 7 COL FSAR, Table 2.4.13-207).

The applicant stated that the IWF itself is not accessible to the public and is not potable due to its salinity. The applicant presented a dose assessment for the biological uptake of key

radionuclides and potential consumption of fish, crustaceans, and mollusks following discharge of groundwater from the IWF to Biscayne Bay (FPL, 2011). The applicant stated that Biscayne Bay is also saline and not potable, and that the underlying Biscayne aquifer is also saline, consequently there are no potential receptors of drinking water. The applicant calculated the fish and invertebrate bioaccumulation (update) of the radionuclides at the concentrations remaining after the dilution calculation (Turkey Point Units 6 and 7 COL FSAR Table 2.4.13-207) following the guidance in Table A-1 of Regulatory Guide 1.109 (NRC, 1977). The applicant did not consider I-129 due to its low concentration (Turkey Point Units 6 and 7 COL FSAR Table 2.4.13-207). The applicant state further as follows: Uptake is influenced by the salinity of Biscayne Bay, which is discussed in Appendix 2AA (FPL, 2011). The dose via each consumption pathway (crustaceans/mollusks and fish) was determined assuming a yearly consumption of 5.4 kilograms (11.9 pounds) of fish and 0.9 kilograms (2 pounds) of crustaceans/mollusks. The resultant dose rate was estimated as 8 mrem/y, which was below the exposure level of 100 mrem per year given in 10 CFR 20.1301, “Dose Limits for Individual Members of the Public.”

The applicant describes an alternate conceptual model assuming that the IWF was not operational, i.e., Case 3. The applicant adjusted the model so that the IWF is represented by cells having a high hydraulic conductivity of 100 cm/s to simulate open water where flow is not restricted by the conductivity of the cells. The applicant stated as follows: The advective travel time of 3800 d is still used, and after advection, radioactive decay, and adsorption, several radionuclides still exceed the ECL (Turkey Point Units 6 and 7 COL FSAR Table 2.4.13-205). Flow in the Upper Higher Flow Zone is still neglected. Particle tracking was used to determine that travel time from Unit 6 to Biscayne Bay. However, without making changes to the numerical grid, the model overestimated total activity and also included an adsorption coefficient. The applicant provides the results in Turkey Point Units 6 and 7 COL FSAR Table 2.4.13-209. As before, the applicant stated that the analysis is still conservative because a failure of the auxiliary building exterior walls and the effluent holdup tank would result in groundwater infiltration into the auxiliary building, rather than leakage of tank contents into groundwater; because groundwater infiltration would dilute the tank waste; because the radionuclides would sorb onto the structural fill material; and because a postulated release would occur over time and would not occur instantaneously.

The applicant then calculated parameters for subsurface transport modeling (effective porosity, bulk density, longitudinal and transverse dispersivity, and adsorption), and predicted radionuclide concentrations at a simulated receptor well in Biscayne Bay. The applicant-predicted peak concentrations at the theoretical well CW-2s are shown in Turkey Point Units 6 and 7 COL FSAR, Table 2.4.13-210. The applicant indicated as follows: Cs-137 contours at 10 y are shown in Turkey Point Units 6 and 7 COL FSAR, Fig. 2.4.13-213. A biological uptake calculation similar to the primary conceptual model scenario was subsequently employed for model layer 1 radionuclides at the concentrations in Turkey Point Units 6 and 7 COL FSAR, Table 2.4.13-210, and is shown in Table 2.4.13-211. The sum of fractions method produced a maximum dose of 65 mrem/y, which is again below the 100 mrem/y limit in 10 CFR 20.1301.

<u>Staff’s Technical Evaluation</u>

The staff reviewed Turkey Point Units 6 and 7 COL FSAR, Section 2.4.13, “Analysis of Accidental Releases to Groundwater and Surface Water” (FPL 2011b) and confirmed that the applicant addressed relevant information. The analysis of an accidental release to groundwater for the Turkey Point Units 6 and 7 site described by the applicant in Turkey Point Units 6 and 7 COL FSAR Revision 2 Section 2.4.13.1, focuses on physical pathways in the upper interval of

the Biscayne aquifer to the IWF, followed by mixing in the IWF because it is operating, and discharge to Biscayne Bay. The alternative pathway is physically identical, but the IWF is not operational, therefore dilution by mixing in the IWF is minimal. For both cases, the dose to humans is calculated through biological uptake of seafood contaminated in Biscayne Bay. There are no potential receptors of groundwater, because the Biscayne aquifer groundwater in the site region is brackish to saline and unsuitable for potable use.

The staff initially performed an independent calculation of effluent wastewater travel time through the basemat of the containment structure and the underlying 19 ft (5.8 m) of concrete and confirmed the estimated travel time of 1,480 years. The staff confirmed the modeled decay in radionuclide activity for this 1,480-year travel time presented in Turkey Point Units 6 and 7 COL FSAR Revision 2 (Kennedy 1992; USDOH 1970). Progeny radioisotopes are shown in Turkey Point Units 6 and 7 COL FSAR Revision 2, Table 2.4.13-202, and include members of each decay chain (ICRP 1983; USDOH 1970). Confirmation of hydraulic properties in the Key Largo Limestone and Fort Thompson Formation indicate groundwater travel time through the Key Largo Limestone and the cooling water canals (primary pathway) to be conservatively modeled as instantaneous for radionuclide transport calculations. The staff analysis of these pathways confirmed that the applicant-modeled radionuclide decay and transport through the concrete fill is consistent with the guidance in BTP 11-6 and that the resultant radionuclide concentrations conformed to the ECL and sum of fraction criteria in 10 CFR Part 20, Appendix B, Table 2.

However, as discussed in the Alternative Pathways Evaluation subsection of Subsection 2.4.12.4.10 “Subsurface Pathways”, the staff determined that the applicant’s description of alternate subsurface pathways was potentially not conservative because all pathways traveled through the 19 ft (5.8 ft) thick concrete layer beneath the containment building, and because breaches of neither the 19 ft (5.8 ft) concrete layer nor the 3 ft (0.9 m) thick reinforced concrete diaphragm walls (neither of which are seismic Category I structures) were considered a plausible pathway to groundwater.

The staff conducted analysis for a bounding case in which the concrete layer is breached. For that bounding case, the staff calculated that the travel time to the IWF would be reduced to 0.09 year. Using the same method as the applicant, the calculated concentrations for Cs-134 and Cs-137 would exceed the corresponding ECLs. Neither adding a retardation factor of 1.3, which corresponds to a partition coefficient of 0.04 (Turkey Point Units 6 and 7 COL FSAR Revision 2, Table 2.4.13-204), nor adding dilution by groundwater result in Cs-134 and Cs-137 concentrations below the ECLs. The IWF dilution (dilution factor 1.75 E5) used in the applicant’s calculations reduces the Cs-137 concentration from 0.242 μCi/cm^3 in the canal to 1.38 x 10^{-6} μCi/cm^3 (0.242/1.75 x 10^5). With a first order decay, it will take 14 years, with a decay coefficient of 0.00063/day from Turkey Point Units 6 and 7 COL FSAR, Table 2.4.13-203 to further reduce the concentration to the ECL (1.0 x 10^{-6} μCi/cm^3).

Accordingly, the staff requested additional information on this subject in RAI 5643, Question 02.04.12-6 (December 16, 2010) to which the applicant responded on June 27, 2011 (ADAMS Accession No. ML11180A062). In its response, the applicant considered four scenarios that did not credit the 19 ft (5.7 m) concrete fill layer. Using particle tracking analysis, the applicant calculated a groundwater travel time of 3,911 days to the cooling canal. The applicant used the geometric mean of Kd for Cs-137 of 0.17 g/cm^3, bulk density of 1.59 g/cm^3, and effective porosity of 0.15 to calculate a retardation coefficient equivalent to Rd = 2.8. The applicant calculated the Cs-137 concentration arriving at the canal to be 0.124 μCi/cm^3. The applicant further assumed instantaneous complete mixing/dilution of the release of 22,400 gallons with

total volume of 4 × 10^9 gallons of water in the canal system, which would reduce the Cs-137 concentration to 0.69 × 10^{-6} µCi/cm^3, which is less than the ECL (1.0 x 10^{-6} µCi/cm^3).

The staff calculated the residence time in the cooling canal to be 1.5 days (4 x 10^9 gallons / (4000 cfs x 646,317 gallon/day/cfs) = 1.5 days). As the actual groundwater travel time to the cooling canal ranges from months to years, the staff confirmed that the simulated instantaneous complete mixing assumption is conservative. The staff noted that even though use of an effective porosity of 0.15 is conservative for the groundwater travel time calculation it is not conservative for the retardation factor. Using an effective porosity of 0.3, Rd = 1 + 1.59 × 0.17 / 0.3 = 1.4. The staff noted that more conservative scenarios such as using the minimum Cs-137 K_d from the measurements or increasing the hydraulic conductivity would result in exceedance of the Cs-137 ECL in water of the cooling canal.

The applicant stated that the water in the cooling canal is hypersaline, non-potable, and is not accessible by the public. Thus, the applicant postulated the nearest publicly accessible point to be east of the Turkey Point Units 6 and 7 site in Biscayne Bay, and the most likely exposure is through consumption of seafood from an area of the bay affected by a release of radioactive liquid effluent. The staff reviewed the information provided by the applicant and determined that the public does not have access to the cooling canals. Accordingly, the staff finds the likely exposure routes reasonable and acceptable. The staff confirmed the estimated total dose rate from radionuclides in the bay would be below the maximum exposure level of 100 mrem/y given in 10 CFR 20.1301(a).

The applicant evaluated an alternative pathway scenario for accidental release of radioactive liquid effluent and transport via groundwater to Biscayne Bay without dilution in the water of the IWF and without influence of the IWF on groundwater flow pathways. The staff confirmed the radionuclide migration simulations into the bay, with no additional dilution in the IWF, and the estimated maximum Cs-137 concentration exceeded the ECL while the maximum concentration of Cs-134, Fe-55, H-3, Sr-90, and Y-90 did not exceed their respective ECLs. The staff estimated biological uptake of the modeled radionuclides in the bay by marine organisms and conducted an offsite receptor dose assessment.

As described above, based on the staff's independent review of the applicant's analysis, response to RAIs, the results of the staff's calculations as described above, and the staff's evaluation described in SER Section 11.2.4 where the staff discussed their independent dose analysis performed to account for the consumption of fish and invertebrates, the staff determined that the doses were below the 10 CFR 20.1301(a) 100 mrem limits. Accordingly, the staff finds that the potential doses to an offsite receptor from a postulated accidental release of liquid effluents are within acceptable limits.

2.4.13.4.5 Compliance with 10 CFR Part 20

Information Submitted by Applicant

In Turkey Point Units 6 and 7 COL FSAR, Section 2.4.13.1.4 (FPL 2011b), the applicant described the comparison of the analysis results to the requirements of 10 CFR Part 20. The applicant's analysis (FPL 2011b) evaluated the postulated accidental release of radioactive liquid wastewater from the effluent holdup tank in the auxiliary building along two plausible groundwater pathways. In the both pathways, groundwater and radionuclides travel in groundwater of the Key Largo Limestone followed by mixing in the IWF (before subsurface discharge to Biscayne Bay. In the alternative conceptual model), the pathway was identical but

the IWF did not serve to dilute radionuclide concentrations as it was assumed to be not operational. A requirement of 10 CFR Part 20, Appendix B, Table 2, is that the sum of the ratios of radionuclide concentrations to ECLs for known analytes in the mixture, and each individual ratio for the concentration established in 10 CFR Part 20, Appendix B, Table 2, for specified radionuclides not in a mixture, may not exceed 1, or unity. The applicant has taken the sum of fractions approach and using the estimated radionuclides concentrations asserts that the sum of fractions is below 1 for each pathway.

The applicant stated the nearest, plausible off-site receptor for the site is located to the east of Turkey Point Units 6 and 7 site in Biscayne Bay. The applicant indicated as follows: A dose assessment considering uptake of radionuclides by marine organisms followed by consumption was modeled for a hypothetical receptor located in Biscayne Bay. Doses for key radionuclides in groundwater following the accidental release and subsequent travel in groundwater along the two plausible groundwater pathways were modeled. The applicant concludes that resultant doses based on consumption of crustaceans/mollusks and fish for both the primary and alternative groundwater pathways are below the exposure level of 100 millirem per year given in 10 CFR 20.1301.

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

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.13.1.4, "Compliance with 10 CFR 20" and confirmed that the applicant addressed relevant information. The staff reviewed the representative and sensitivity cases presented by the applicant for the accidental release of radioactive liquid effluent in groundwater and found these cases reasonable with the exception of the issues described in the following discussion.

Upon review of Turkey Point Units 6 and 7 COL FSAR Revision 3, Section 2.4.13, the staff determined that the dose assessment did not meet the criteria of 10 CFR 20.1301, which are only valid for concentrations of radionuclides in well or groundwater, and determined that the applicant's description of alternate subsurface pathways was potentially not conservative because all pathways traveled through the 19 ft (5.8 m) thick concrete layer (lower portion of the containment building), and because breaches of neither the 19 ft (5.8 m) concrete layer nor the 3 ft (0.9 m) thick reinforced concrete diaphragm walls (neither of which are seismic Category I structures) were considered as plausible pathways to groundwater. The staff conducted analysis for a bounding case in which the concrete fill layer is breached and found the ECL is exceeded for Cs-134 and Cs-137.

In a June 27, 2011 response (ADAMS Accession No. ML11180A062) to the staff's RAI 5643, Question 02.04.12-6 (April 28, 2011), the applicant evaluated four scenarios of accidental release of radioactive liquid effluent to groundwater. One scenario considered release and subsequent transport to the industrial waste water cooling canals in the absence of the 19 ft (5.8 m) concrete layer. Once reaching the cooling canals, the applicant further assumed instantaneous complete mixing/dilution of the release of 22,400 gallons with the total volume of 4×10^9 gallons of water in the canal system, thus reducing the concentration of Cs-137, H-3, Sr-90, Cs-134, Y-90, Fe-55 to I-129 to below their respective ECLs (Turkey Point Units 6 and 7 COL FSAR Table 2.4.13-207). In addition, the applicant has taken the sum of fractions approach and using the estimated radionuclide concentrations in the water of the cooling canal has shown the sum of radionuclide concentrations is 0.7, which is below unity (1.0) indicating compliance with 10 CFR 20.1301. For this scenario, the applicant calculated the dose to a hypothetical offsite receptor following consumption of the marine organisms to be 3.78 millirem per year. The staff confirmed the radionuclide transport simulations and the staff's calculated

dose was below the exposure level of 100 millirem per year given in 10 CFR 20.1301 as is evaluated and described in SER Section 11.2.

In further response (ADAMS Accession No. ML11180A062) to the staff's RAI 5643, Question 02.04.12-6, the applicant evaluated an alternative pathway based on the release of radioactive liquid effluent from Unit 6 with subsequent migration in groundwater that reaches Biscayne Bay. The applicant simulated radionuclide transport in groundwater to the bay and subsequent bioaccumulation by marine organisms (fish and crustaceans/mollusks). The applicant calculated the dose to a hypothetical offsite receptor following consumption of the marine organisms to be 65 millirem per year. The staff confirmed the radionuclide transport simulations and the staff's calculated dose from consumption of marine organisms was below the exposure level of 100 millirem per year given in 10 CFR 20.1301 as evaluated and described in SER Section 11.2.

The staff confirmed the analyses of the alternative groundwater pathways and concluded that the applicant provided relevant information. In view of the foregoing, the applicant's analyses of plausible radioactive liquid effluent releases to groundwater and simulated radionuclide concentrations in onsite groundwater, water in the cooling canals, and offsite marine waters of Biscayne Bay are acceptable and indicate compliance with 10 CFR 20.1301.

2.4.13.4.6 Direct Releases to Surface Waters

<u>Information Submitted by Applicant</u>

In Turkey Point Units 6 and 7 COL FSAR Section 2.4.13.2, the applicant stated that there are no outdoor tanks that contain licensed radioactive material in the Turkey Point Units 6 and 7 design. Because no outdoor tanks contain radioactivity, the applicant stated that an accident scenario will not result in the release of liquid effluent directly to the surface water.

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

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.13.2, "Direct Releases to Surface Waters" (FPL 2011b), and concludes that the applicant included relevant information, and that since the design does not include outdoor tanks that contain radioactivity, no release scenario would result in release of liquid effluent directly to surface waters. Accordingly, the staff finds the application acceptable in this regard.

2.4.13.5 Post Combined License Activities

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

2.4.13.6 Conclusions

The staff has determined that the applicant provided complete and sufficient information and that there is no outstanding information remaining to be addressed in the COL FSAR related to this section. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description, and about the design of the liquid waste management system, to allow the staff to evaluate, as documented in this section, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site, and with respect to 10 CFR 20.1301 as it relates to radionuclide dose limits. This addresses COL

Information Item 2.4-5 and 15.7-1. In conclusion, the applicant provided sufficient information for satisfying 10 CFR Part 20, 10 CFR Part 52, and 10 CFR Part 100 in regard to accidental radionuclide releases.

2.4.14 Technical Specification And Emergency Operation Requirements

2.4.14.1 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.4.14 describes the technical specifications and emergency operation requirements as necessary. The requirements described implement protection against floods for safety-related facilities to ensure that an adequate supply of water for shutdown and cool-down purposes is available.

SER Section 2.4.14 presents an evaluation of the following specific areas: (1) controlling hydrological events, as determined in previous hydrology sections of the Turkey Point Units 6 and 7 COL FSAR, to identify bases for emergency actions credited during these events, (2) the amount of time available to initiate and complete emergency procedures before the onset of conditions while controlling hydrological events that may prevent such action, (3) reviewing technical specifications related to all emergency procedures required to ensure adequate plant safety from controlling hydrological events by the organization responsible for the review of issues related to technical specifications, (4) potential implications of seismic and nonseismic information on the postulated technical specifications and emergency operations for the proposed plant site, and (5) any additional information requirements prescribed in the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52.

2.4.14.2 Summary of Application

This subsection of the Turkey Point Units 6 and 7 COL FSAR addresses technical specifications and emergency operation requirements. The applicant addressed the information as follows:

AP1000 COL Information Item

- PTN COL 2.4-6

Combined License applicants referencing the AP1000 certified design will address any flood protection emergency procedures required to meet the site parameter for flood level.

2.4.14.3 Regulatory Basis

The relevant requirements of the NRC regulations for consideration of emergency protective measures, and the associated acceptance criteria, are described in Section 2.4.14 of NUREG-0800.

The applicable regulatory requirements are:

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

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

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

- 10 CFR 50.36, "Technical Specifications," as it relates to identifying technical specifications related to all emergency procedures required to ensure adequate plant safety from controlling hydrological events by the organization responsible for the review of issues related to technical specifications.

2.4.14.4 Technical Evaluation

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.4.13, and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to technical specification and emergency operation requirements. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

<u>Information Submitted by Applicant</u>

The applicant stated that analysis of design features of the AP1000, as documented in the DCD, and site-specific analysis of hydrologic conditions and phenomena, as documented in Turkey Point Units 6 and 7 COL FSAR Sections 2.4.1 through 2.4.14, led to a conclusion that no emergency protective measures need to be designed to minimize the impact of adverse hydrology-related events on safety-related facilities for Turkey Point Units 6 and 7.

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

The NRC staff has concluded in previous sections of this SER that floods caused by natural phenomena at and near the Turkey Point Units 6 and 7 site would not result in inundation of the plant grade. The AP1000 design does not use a safety-related cooling-water system. Therefore, the staff concluded that no technical specification or emergency procedures related to hydrologic events are required at the Turkey Point Units 6 and 7 site.

2.4.14.5 Post Combined License Activities

There are no post COL activities related to this section.

2.4.14.6 Conclusions

The staff reviewed the application and confirmed that the applicant has addressed the information relevant to technical specification and emergency operations requirements, and there is no outstanding information remaining to be addressed in the COL FSAR related to this section.

As set forth above, the applicant has presented and substantiated site-specific information related to technical specifications and emergency operations. The staff has reviewed the information provided and, for the reasons given above, concludes that the applicant has provided sufficient details about the site description to allow the staff to evaluate, as documented in Section 2.4.14 of this SER, whether the applicant has met the relevant requirements of 10 CFR 52.79(a)(1) and 10 CFR Part 100 with respect to determining the acceptability of the site. This addresses COL Information Item 2.4-6.

2.5 Geology, Seismology, and Geotechnical Engineering

In Turkey Point Units 6 and 7 COL FSAR Section 2.5, “Geology, Seismology, and Geotechnical Engineering,” the applicant described geologic, seismic, and geotechnical engineering characteristics of the proposed Turkey Point Units 6 and 7 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 Turkey Point Units 6 and 7 site and conducted technical investigations in those zones that became progressively more detailed passing from site region to site location:

- Site region – Area within a 320 kilometer (km) (200 mi) radius of the site location.
- Site vicinity – Area within a 40 km (25-mi) radius of the site location.
- Site area – Area within an 8 km (5 mi) radius of the site location.
- Site location – Area within a 1 km (0.6 mi) radius of proposed site.

Since the Turkey Point Units 6 and 7 site is adjacent to Turkey Point Units 3 and 4, the applicant used information acquired during the previous site investigations for the Units 3 and 4 facilities as the starting point for characterization of the geologic, seismic, and geotechnical engineering properties of the Turkey Point Units 6 and 7 site. The material in Turkey Point Units 6 and 7 COL FSAR Section 2.5 focuses on information published since the Turkey Point Units 3 and 4 FSAR, which was issued in the 1970s. The Turkey Point Units 6 and 7 COL FSAR Section 2.5 also focuses on recent geologic, seismic, geophysical, and geotechnical investigations performed specifically for the Turkey Point Units 6 and 7 site.

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.5, interacted with the applicant during public meetings and site audits, and issued RAIs to support the conclusions presented by the applicant in the Turkey Point Units 6 and 7 COL FSAR. As a result of NRC actions implemented after the March 2011 Fukushima Dai-ichi nuclear power plant accident following the Great Tohoku earthquake and subsequent tsunami in Japan, the NRC formed a Near-Term Task Force (NTTF) that issued a series of recommendations for reevaluating the safety of nuclear power plant facilities located in the United States. Consequently, on March 12, 2012 (ADAMS Accession No. ML12053A340), the NRC issued an information letter requesting that licensees of all operating nuclear power plants in the United States reevaluate seismic hazard at their respective plant sites using the most recent data and evaluation methodologies available. The information request letter also stated that licensees of operating nuclear power plant sites in the Central and Eastern United States (CEUS) should use the new seismic source model provided in NUREG-2115, “Central and Eastern United States Seismic Source Characterization for Nuclear Facilities,” to characterize seismic hazard for their respective plants.

Consistent with existing guidance in RG 1.208, pertaining to the need to consider the latest information in the evaluation of seismic hazard, the staff also issued RAIs to all COL and early site permit (ESP) applicants requesting that they reassess seismic hazard using the newly published NUREG-2115 seismic source model and modify their respective GMRS, if necessary. The staff issued this request for the Turkey Point Units 6 and 7 COL FSAR in RAI 01.05-1. In the February 12, 2013, response to RAI 01.05-1, the applicant stated that it performed sensitivity analyses to compare the results from the older Electric Power Research Institute (EPRI) (1986, 1989) base seismic source models for seismic hazard analysis, with those from the new seismic source characterization model for the CEUS published in NUREG-2115, "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities." These analyses are described in detail in SER Section 2.5.2.

The SER Section 2.5 is divided into five main parts, SER Sections 2.5.1 through 2.5.5, which parallel the five main FSAR sections prepared by the applicant for the Turkey Point Units 6 and 7 COL application. The five sections are: Section 2.5.1, "Basic Geologic and Seismic Information"; Section 2.5.2, "Vibratory Ground Motion"; Section, 2.5.3 "Surface Faulting"; Section, 2.5.4 "Stability of Subsurface Materials and Foundations"; and Section 2.5.5, "Stability of Slopes" (including information regarding embankments and dams). These SER sections follow and summarize the content of the Turkey Point Units 6 and 7 COL FSAR, and present the evaluations, conclusions, and findings of the staff in regard to the geologic, seismic, and geotechnical engineering characteristics of Turkey Point Nuclear Site Units 6 and 7.

2.5.1 Geologic Characterization Information

2.5.1.1 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1 describes basic geologic and seismic information collected by the applicant during site characterization investigations. This information addresses both regional and site-specific geology and seismicity. The investigations included surface and subsurface field studies, performed at progressively greater levels of detail closer to the site, within each of four circumscribed areas corresponding to the site region, site vicinity, site area, and site location, as previously defined. The applicant conducted these investigations to assess geologic and seismic suitability of the Turkey Point Units 6 and 7 site; to determine whether there is significant new information on tectonic features or ground motion that could impact seismic design bases as determined by a probabilistic seismic hazard analysis (PSHA); and to provide the bases for plant design. Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1, "Regional Geology," describes the geologic and tectonic setting within the Turkey Point Units 6 and 7 site region. Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2, "Site Geology," describes the geology and tectonic setting within the site vicinity and site area and at the site location.

2.5.1.2 Summary of Application

Section 2.5 of the Turkey Point Units 6 and 7 COL FSAR incorporates by reference Section 2.5.1 of the AP1000 DCD.

In addition, in Turkey Point Units 6 and 7 COL FSAR Section 2.5.1, the applicant provided site-specific supplemental information to address the following:

AP1000 COL Information Item

- PTN COL 2.5-1

The applicant provided additional information in PTN COL 2.5-1 to address COL Information Item 2.5-1 (COL Action Item 2.5.1-1). PTN COL 2.5-1 addresses the provision of regional and site-specific geologic, seismic, and geophysical information, as well as conditions caused by human activity. This information specifically includes the following topics: structural geology, 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 physical properties, and the effect of human activities in the site area.

The Turkey Point Units 6 and 7 COL FSAR Section 2.5.1 is divided into two main sections. Section 2.5.1.1 discusses physiography, geomorphic processes and stratigraphy; and regional tectonic setting, including tectonic structures that are possibly Quaternary in age (i.e., 2.6 million years ago, or 2.6 Ma, to present); and seismicity and paleoseismicity within a 320 km (200 mi) radius of the site. The Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1 also describes specific seismic sources inside the site region. The Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2, describes the physiography, geomorphology, stratigraphy, structural geology, site geologic hazards and engineering geology (including the effects of human activities), seismicity and paleoseismicity, and groundwater conditions in the site area.

The applicant developed Turkey Point Units 6 and 7 COL FSAR Section 2.5.1 based on information derived from geologic maps and reports published by State and Federal agencies and research scientists; aerial photographs; communications with experts in geology, seismology, and tectonics of the site region and site area; and geologic field investigations completed as part of the COL application. These field investigations included geologic field reconnaissance, geophysical surveys, and new borehole data collected at the Turkey Point Units 6 and 7 site.

Based on the results of the geologic and seismic investigations performed for Turkey Point Units 6 and 7, the applicant concluded that the in Turkey Point Units 6 and 7 COL FSAR Section 2.5.1 that no geologic or seismic conditions exist at the site that would negatively affect construction or operation of safety-related structures. The following SER Sections 2.5.1.2.1 (“Regional Geology”) and 2.5.1.2.2 (“Site Geology”) summarize the basic geologic and seismic information provided by the applicant in the Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.

Supplemental Information

- PTN SUP 2.5-1

The applicant also provided supplemental information in Turkey Point Units 6 and 7 COL FSAR Section 2.5, “Geology, Seismology, and Geotechnical Engineering,” which provides summary information of detailed information in Turkey Point Units 6 and 7 FSAR Section 2.5.1, “Basic Geologic and Seismic Information,” for the Turkey Point Units 6 and 7 site.

2.5.1.2.1 Regional Geology

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1 describes the physiography, geomorphic processes, stratigraphy, tectonic setting, stress regime, and geologic history within a 320-km (200-mi) radius from the site as those features may be relevant when evaluating the geologic hazards at the Turkey Point Units 6 and 7 site. The following SER sections summarize the information provided by the applicant in Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.

Regional Physiography

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1 the applicant described the physiography and geomorphic processes of the Florida Peninsula, the Florida Platform, and the Florida portion of the Atlantic Continental Shelf and Slope, including the Blake Plateau, the Bahama Platform and its western continuation through the Straits of Florida, and Cuba. The applicant stated that the Florida Peninsula and continental margin consist of three physiographic areas: Florida Peninsula, the Florida Platform and the Atlantic Continental Shelf and Slope. As shown on Figure 2.5.1-1 the Turkey Point Units 6 and 7 site is in the southern tip of the Florida Peninsula, and its site region encompasses the southern half of the Florida Platform. The applicant indicated that the Florida Peninsula is a stable carbonate platform with Neogene (23 to 2.6 million years ago, or Ma) and Quaternary (2.6 Ma to present) age land derived sediments that accumulated asymmetrically, that is, moderately thick on the east coast of Florida and thinning toward the west. The applicant identified the Florida Peninsula as the emergent portion of the Florida Platform, which forms a rampart between the waters of the Gulf of Mexico and the Atlantic Ocean. The Florida Platform is part of the larger Florida-Bahama Platform, which represents a massive shallow-water, carbonate sedimentary province approximately 900 km (600 mi) long, 1,000 km (620 mi) wide, and over 12 km (7.5 mi) thick.

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.1.1.1, the applicant stated that the Turkey Point units 6 and 7 site is within the Atlantic Coastal Plains physiographic region, which is characterized by a low-lying, gently rolling topography. The applicant indicated that the Florida Department of Environmental Protection along with the Florida Geological Survey reorganized and subdivided the physiographic zones of Florida into seven primary physiographic provinces. The Turkey Point Units 6 and 7 site region encompasses four of the primary physiographic provinces: the Atlantic Coastal Lowlands, Intermediate Coastal Lowlands, Gulf Coastal Lowlands, and Central Highlands. Figure 2.5.1-2 shows these primary physiographic provinces and the secondary and tertiary provinces. The Turkey Point Units 6 and 7 site is situated within the Southern Slope of the Intermediate Coastal Lowlands province.

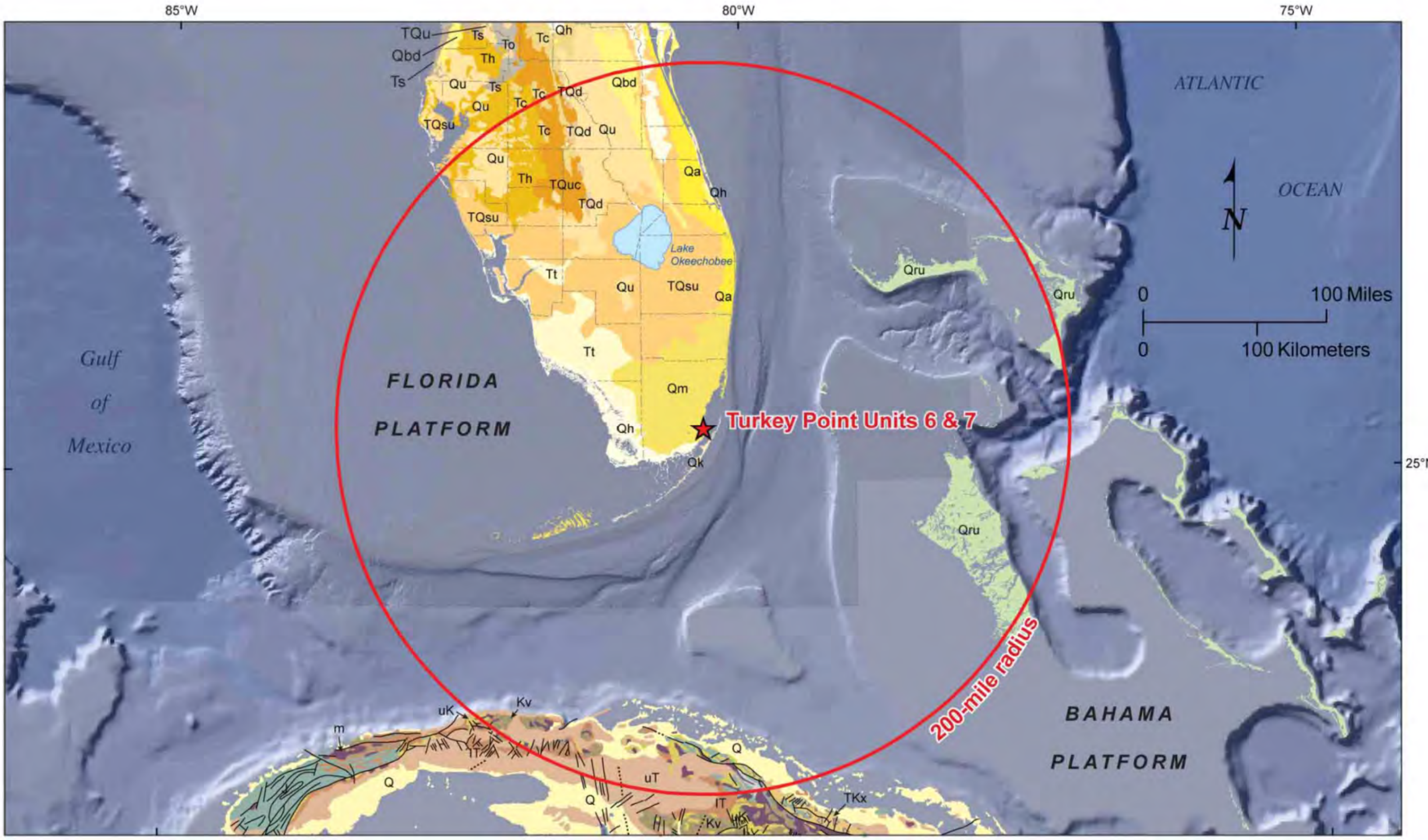


Figure 2.5.1-1. Turkey Point Units 6 and 7 site region (Source: Turkey Point Units 6 and 7 FSAR Figure 2.5.1-201)

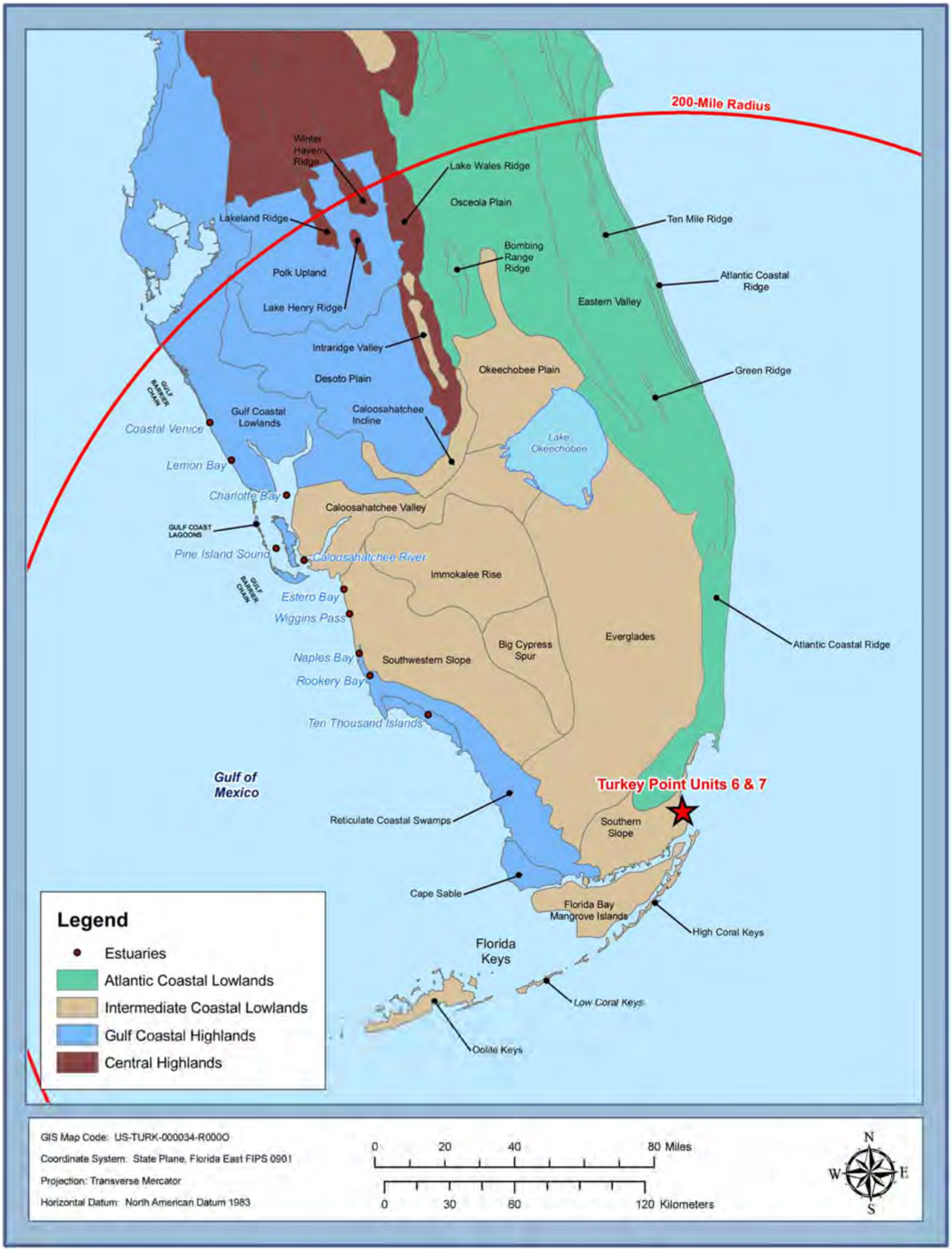


Figure 2.5.1-2. Physiography of Florida
(Source: Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-217)

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.1.1.1 also describes limestone dissolution features within the Turkey Point Units 6 and 7 site region and site vicinity, which include the dry caves along the Atlantic Coastal Ridge; vegetated surface depressions; freshwater springs in Biscayne Bay; submarine paleo sinkhole in Key Largo National Marine Sanctuary; and submarine paleo sinkholes in Biscayne Bay. The applicant described the different processes that lead to the development of these features, such as freshwater/saltwater mixing zones in the water table aquifer, surficial rain water dissolution, and deep pore water upwelling from the confined Floridan Aquifer. The applicant indicated that the Turkey Point Units 6 and 7 site is not located in a zone of fresh groundwater discharge or mixing zone of fresh and saltwater, moreover, the interface is approximately 9.6 km (6 mi) west from the site. Therefore, the applicant stated that carbonate dissolution or formation of large solution cavities is not likely to occur at the site. Turkey Point Units 6 and 7 COL FSAR Appendix 2.5AA provides additional details on the potential for carbonate dissolution and karst development at the Turkey Point Units 6 and 7 site.

The applicant indicated that the principal geomorphic features in southern Florida are represented by the barrier island system of the Gulf Coastal Lowlands, the Reticulated Coastal Swamps of southwest Florida, and the swales and swamps of the Everglades as shown on Figure 2.5.1-2. The applicant indicated that, due to changes in sea level and associated erosion patterns, southern Florida is characterized by a broad, flat, gently sloping, and poorly drained plain that is limited on the east by the Atlantic Ridge.

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.1.3, the applicant explained that Cuba lies approximately 240 km (150 mi) south of Turkey Point Units 6 and 7. Cuba covers 107,500 square km (44,000 square mi) of which 20 percent is mountainous. The remaining 80 percent consists of gently rolling hills and extensive lowlands, containing sandy clays and fertile alluvial soils in the flood plains. The applicant indicated that nearly two-thirds of the island consists of limestone and thus karst features are well developed, mostly in the eastern section of the island.

<u>Regional Stratigraphy</u>

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.2 indicates that southern Florida is characterized by a thick sequence of Jurassic (201 to 145 Ma) to Holocene sediments lying unconformably on basement volcanic rocks of Jurassic age. Basement rocks in the Florida Peninsula are overlain by up to 4,570 m (15,000 ft) of relatively flat-lying Mesozoic (252 to 66 Ma) evaporate and carbonate units, which are overlain by up to 1,830 m (6,000 ft) of Cenozoic carbonate and siliciclastic sediments. The applicant indicated that most of the units in the sedimentary sequence are carbonates, however, deposition of Appalachian derived siliciclastic sediments occurred during the Miocene (23 to 5.3 Ma) and Pliocene (5.3 to 2.6 Ma).

Cenozoic Stratigraphic Units

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.2 the applicant indicated that the Florida Peninsula section includes Cenozoic (66 Ma to present) carbonate rocks (limestone, dolostone and evaporates) of the Cedar Keys Formation, Oldsmar Formation, Avon Park Formation, Ocala Limestone, Suwannee Limestone, and part of the Arcadia Formation. Figure 2.5.1-3 (Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-231) shows that the location of the oldest Cenozoic strata observed in the site region is the Miocene-Pliocene Peace River Formation, while the oldest Cenozoic formation on the Florida Platform is the Paleocene (66 to 23 Ma) Cedar Keys Formation.

In the Late Oligocene (28.1 to 23 Ma), karst features such as sinkholes, dissolution valleys, and collapse depressions started to form. The applicant indicated that during the Miocene, siliciclastic sediments deposited on the Florida Platform reduced the dissolution of the underlying carbonates. During the Pleistocene, worldwide glaciation resulted in a drop in sea level, which increased Florida's land area. The applicant indicated that sea-level fluctuations during the Quaternary resulted in the deposition of the Fort Thompson Formation, which covers the greatest geographical area of all Quaternary formations in southern Florida. The applicant indicated that during the Pleistocene, the Miami Limestone transitioned into the contemporaneous Key Largo Limestone and Anastasia Formation, although the latter is not present in southern Miami-Dade County (site vicinity).

The Miami Limestone, a highly porous and permeable stratum, constitutes much of the surficial aquifer system of the Biscayne aquifer. The applicant indicated that undifferentiated sediments such as siliciclastics, organic material, and freshwater carbonates of various thicknesses overlie the Pliocene-Pleistocene Anastasia Formation, Key Largo Limestone, and Miami Limestone.

Regional Tectonic Setting

Principal Tectonic Structures

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.3 discusses the principal tectonic structures and features within the site region, including principal tectonic structures and features of the Bahamas and Cuba, which are partly within the site region. The applicant addressed gravity and magnetic data of the site region with a focus on anomalous features in the gravity and magnetic fields. The applicant explained that the Florida Platform is cut by the Central Florida Gravity Lineament, which is defined as a northwest-southeast-oriented linear gravity high. The Central Florida Gravity Lineament exhibits a contrasting character in the gravity and magnetic fields with the northeast portion of the lineament having low gravity field values while the southwest portion has high values. In addition, the licensee correlated the location of the lineament to basic changes in the nature of the crust, such as composition or thickness.

1. Late Proterozoic Paleozoic Mesozoic Tectonic Structures

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.3.2, the applicant stated that all Precambrian (4,000 to 541 Ma) to Paleozoic (541 to 252 Ma) features associated with Pangea are covered by a thick sequence of sedimentary strata in the site region. The applicant stated that tectonic and structural features recognized in the Florida Platform are mostly a series of gentle highs and lows that possibly reflect the original basement topography.

The applicant indicated that because Mesozoic rifting is associated with the opening of the Atlantic Ocean, the site region has only recorded sedimentary processes with the exception of the possible tectonic activity of the Straits of Florida normal faults, the Santaren anticline, the Walkers Cay fault, the Cuban Fold and Thrust Belt, and the possibly active faults in northern Cuba. Figure 2.5.1-4 shows the locations of these features relative to the Turkey Point Units 6 and 7 site. The applicant noted that hypothetical faults have been described in various tectonic maps that show the pre-Mesozoic Florida Platform lithology. The applicant stated that if these

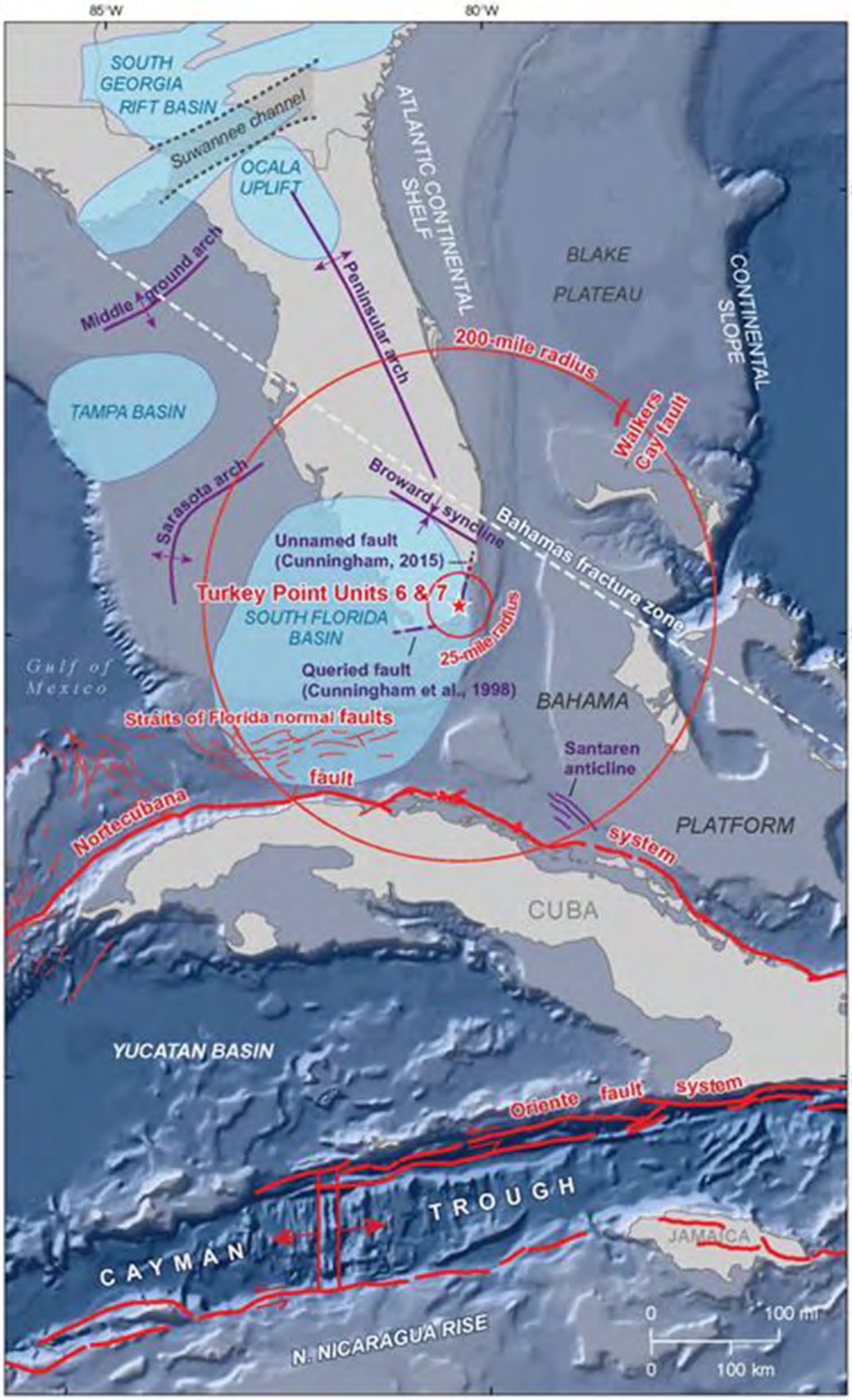


Figure 2.5.1-4. Tectonic features in the site region
(Source: Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-229)

structures exist, they have been inactive since the end of the Jurassic as there is no offset observed in younger strata.

A. Florida Peninsula and Platform Tectonic Structures

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.3.2.1 discusses the tectonic and structural features of the Florida Peninsula and Platform. The applicant stated that seismic reflection data indicate that the basement beneath the Bahama and Florida Platforms is faulted; however, several regional-scale cross sections reveal a smooth varying basement surface beneath the Florida Platform.

The applicant described the following tectonic features on the Florida Peninsula and Platform within the site region: basement faults of the Florida Peninsula Platform, Peninsular Arch, the Sarasota Arch, the Tampa Basin, Broward Syncline, the South Florida Basin, the Ocala Uplift, the South Georgia Rift Basin, the Suwanee Channel, and the Queried Fault from Cunningham et al. (1998). The only tectonic feature within the site vicinity is a possible subsurface unnamed fault (Cunningham et al., 1998), which the applicant described as a 50- to 60-km (30- to 37-mi) long structure located 41 km (25 mi) west of the Turkey Point Units 6 and 7 site. Cunningham et al. (1998) suggested that a fault or paleotopography could be responsible for the elevation variations in the Arcadia Formation. The applicant indicated that the thickness and variations in elevation could be related to paleotopography because the top of the Arcadia Formation is known to be a regional erosional unconformity.

B. Bahama Platform

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.3.2.2 the applicant described the Bahama Platform as a largely undeformed, shallow marine platform. From Late Jurassic to Early Cretaceous, the Bahama Platform was attached to the Florida Platform, the Yucatan Platform and the Gulf of Mexico carbonate platform, forming an extensive carbonate system. Figure 2.5.1-4 shows the main structural features in the Bahama Platform within the site region: the Santaren anticline, normal faults in the Straits of Florida, the Walkers Cay fault, and the eastern Bahama Platform.

Based on seismic reflection data, the applicant indicated that the Walkers Cay fault is a basement structure about 33-km (21-mi) long located about 320 km (200 mi) northeast of the Turkey Point Units 6 and 7 site. The applicant considered seismic and borehole data in the vicinity of these seismic profiles and concluded that only one of five seismic lines that cross the Walkers Cay fault was a fault reaching the seafloor with minimal impact on sediments younger than middle Miocene. The applicant noted that these data do not preclude Quaternary offset on this fault.

The Santaren anticline, as shown on Figure 2.5.1-4, is a structure located about 240 km (150 mi) southeast of the Turkey Point Units 6 and 7 site that corresponds to the northernmost limit of the Cuban Fold and Thrust Belt. The applicant indicated that data from multiple sources revealed that this structure was mainly active in the Eocene, with declining activity throughout the Miocene, and possible deformation into the Quaternary. However, the applicant explained that strata younger than 1 Ma show no evidence of deformation.

The applicant described the Straits of Florida Normal Faults as a set of steep normal faults located in the western Straits of Florida, to the southwest of the Turkey Point Units 6 and 7 site. The applicant indicated that this faulting was the result of the collision of the Cuban foreland basin with the Florida-Bahama Platform. The applicant added that seismic lines in the site

region show unfaulted strata above a late middle Eocene unconformity. However, Moretti and others (2003) concluded that there was a reactivation of the faults in the Late Tertiary.

C. Cuban Fold and Thrust Belt

The applicant described the Cuban Fold and Thrust Belt as an area along the northern edge of Cuba where rocks associated to the North American margin are deformed in a series of overlapping thrusts and anticlines. The applicant indicated that the thrust faulting is Eocene in age and that seismic lines show post-tectonic Tertiary and Quaternary sediments undeformed by the thrusts. However, the applicant noted that research by Moretti et al. (2003) demonstrates Miocene reactivation of some of the early Tertiary thrusts and Jurassic normal faults.

2. Cuba Structures

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.3.2.4, the applicant described 12 faults throughout the island of Cuba classified as active by Cotilla-Rodriguez et al. (2007) as shown on Figure 2.5.1-5 (Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-247). Of the 12, the applicant noted that 6 of the faults occur within the 320-km (200-mi) radius of the Turkey Point Units 6 and 7 site: the Domingo fault, the Cochinos fault, the Hicacos fault, the Las Villas fault, the Nortecubana fault system, and the Pinar fault. The applicant added that although the Oriente fault zone is located more than 644 km (400 mi) southeast of the Turkey Point Units 6 and 7 site along the southeast coast of Cuba, it is the most seismically active area and, as discussed in SER Section 2.5.2, a major contributor to the seismic hazard at the Turkey Point Units 6 and 7 site. The Oriente fault zone is a left-lateral transform fault that forms the northern boundary of the Gonâve microplate and is part of the active North America-Caribbean Plate boundary. The Oriente fault zone has a slip rate of 8 and 13 millimeters/year and is divided into eastern and western segments based on historical seismicity variation and geometry. The largest historical earthquakes on the western Oriente fault are M_W 6.8 to 7.0 events in 1992. The largest historical earthquake on the eastern Oriente fault is the June 1766 M_W 7.53 earthquake. The applicant indicated that the eastern Oriente fault in southern Cuba is characterized by more seismic activity and focal mechanisms that indicate strike-slip, oblique, and reverse motion.

The Domingo fault is located 282 km (175 mi) south of the Turkey Point Units 6 and 7 site. The applicant indicated that the Domingo fault can be considered the former suture between North American and Caribbean plates. The applicant stated that the fault does not cut the uppermost Eocene and younger overlying sedimentary units and, thus concluded that the Domingo fault is not Quaternary in age.

The Cochinos fault is located in south-central Cuba and is mapped as close as 282 km (175 mi), to more than 320 km (200 mi), from the Turkey Point Units 6 and 7 site. The applicant pointed out that Mann et al. (1990) considered the Cochinos fault as the only onshore intraplate fault that is neotectonic. Mann et al. (1990) also mapped the Cochinos fault as two parallel, north-northwest-striking normal faults that form a graben between the faults.

The Hicacos fault (also called Matanzas fault) is located about 250 km (155 mi) south of the Turkey Point Units 6 and 7 site. The applicant indicated that Cotilla-Rodríguez et al. (2007) concluded this fault is active based on associated seismicity. Cotilla-Rodriguez et al. (2007)

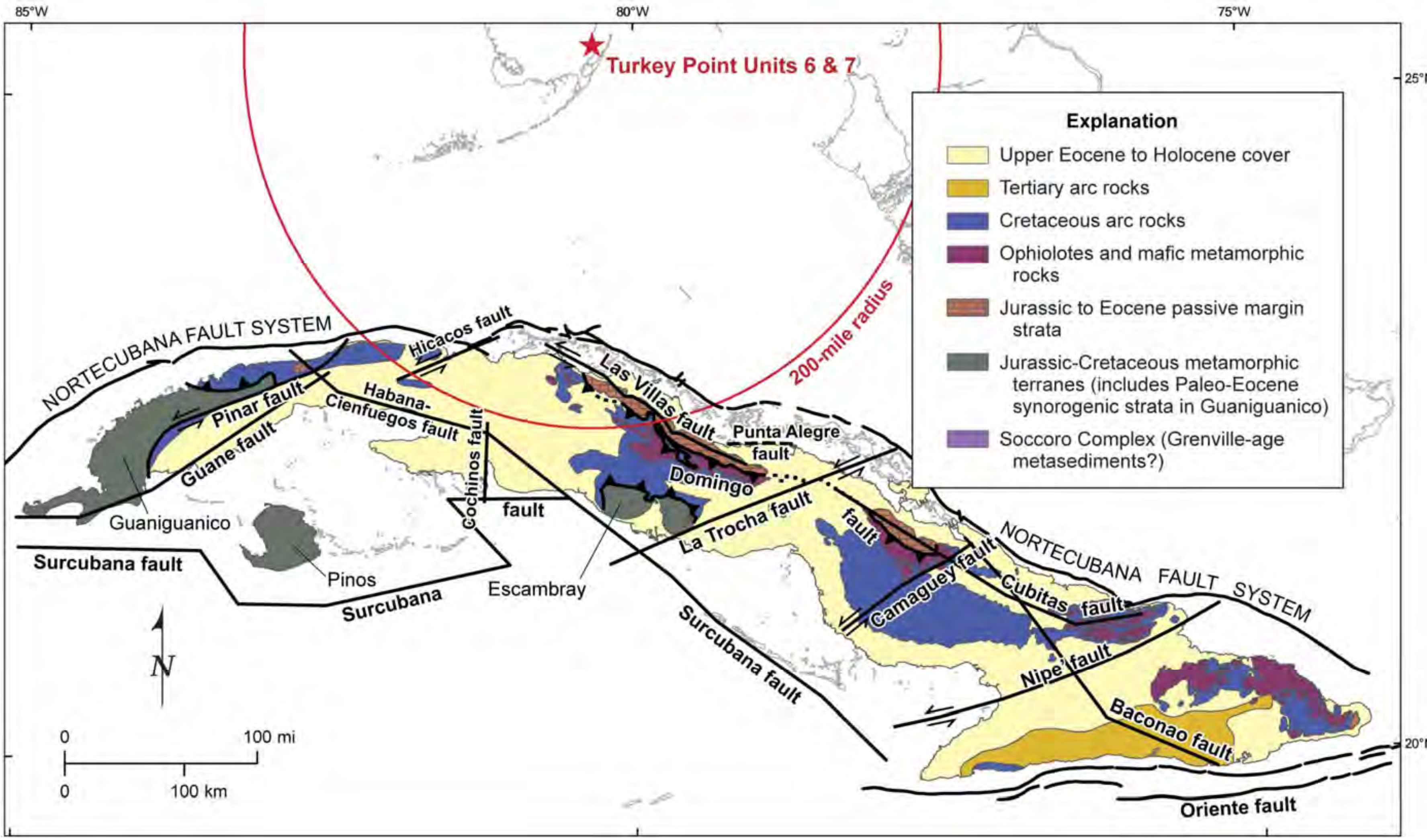


Figure 2.5.1-5. Tectonic features of Cuba (Source: Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-247)

indicate that historical records suggest ten earthquakes of less than or equal to intensity V on the Medvedev-Sonheuer-Karnik seismic intensity scale that occurred in the vicinity of the Hicacos fault. However, the applicant argued that the direct association of these earthquakes to the Hicacos fault is uncertain because of poorly located earthquakes in Cuba.

The Las Villas fault is located in central Cuba about 250 km (155 mi) south of the Turkey Point Units 6 and 7 site. Pardo (2009) indicates that the Las Villas fault displaces middle Eocene units while Cotilla-Rodríguez et al. (2007) suggests that this fault is Pliocene-Quaternary based on seismicity and geomorphic expression. The applicant indicated that both studies provided minimal description of the fault and did not support its interpretations with other publications. The applicant added that although geologic mapping of the area did not reveal faulting of Quaternary units, recent activity cannot be ruled out due to the small scale of the maps.
The Nortecubana fault system is the main structure within the Cuban Fold and Thrust Belt and is located 240 km (150 mi) south of the Turkey Point Units 6 and 7 site. The research of Cotilla-Rodríguez et al. (2007) links the seismic activity of this structure to the modern plate boundary and suggests that a 1914 Mw 6.29 earthquake off the north coast of Cuba occurred on the Nortecubana fault. The applicant indicated that due to the lack of permanent seismic monitoring networks in Cuba and the poorly located epicenter of this earthquake, it could not rule out the possibility that the 1914 earthquake occurred on a fault other than the Nortecubana. However, the applicant added that because of uncertainties in both the location of the 1914 earthquake and the mapped location of the Nortecubana fault, it could not rule out the possibility that the 1914 earthquake occurred on the Nortecubana fault.

The Pinar fault is located in western Cuba, approximately 320 km (200 mi) south of the Turkey Point Units 6 and 7 site. The applicant indicated that there are conflicting opinions in the literature regarding whether the Pinar fault is active. Garcia et al. (2003) suggests that the Pinar fault is expressed as a prominent surface escarpment, was reactivated in the Neogene-Quaternary, and may have produced the Mw 6.13, 1880 earthquake. Alternatively, Cotilla-Rodríguez et al. (2007) indicates that the Pinar fault has a relief surface expression but conclude that it is inactive and suggest that the 1880 earthquake occurred on the Guane fault (Figure 2.5.1-5).

The applicant noted the limited availability of studies indicating the most recent timing of faulting in Cuba and the conflicting ages for the structures discussed therein. The applicant concluded that, with the exception of the Oriente fault, most faults in Cuba were active during the Cretaceous to Eocene time due to the subduction of the Bahama Platform beneath the Greater Antilles Arc of Cuba and the later southward migration of the plate boundary to its current position.

Sources beyond the 200 mi (320 km) radius of the site

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.2 the applicant discussed relevant the geologic and seismic information on tectonic structures outside the 320 km (200 mi) radius of the Turkey Point Units 6 and 7 site. The applicant included information on physiography, stratigraphy, structure, and seismicity of portions of the North American Plate and the Caribbean Plate.

2.5.1.2.2 Site Geology

Turkey Point Units 6 and 7 COL FSAR Sections 2.5.1.2 describes the geologic characteristics of the Turkey Point Units 6 and 7 site area defined as the area lying within an 8-km (5-mi) radius of the site. These characteristics include physiography and geomorphology, stratigraphy and lithology, structural geology, and geologic hazards. The following SER sections summarize the information provided by the applicant in Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.

<u>Site Area Physiography and Geomorphology</u>

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.1, the applicant described physiography and geomorphology of the Turkey Point Units 6 and 7 site area. As shown on Figure 2.5.1-2, the site area is located within the Southern Slope subprovince of the Florida Platform. The site surface geology is characterized by organic peat/muck sediments and the Miami Limestone. The applicant described the organic peat muck as the dominant surficial sediment type in the area characterized by decomposed organic peat soil with trace amounts of shell fragments. The Miami Limestone is a marine carbonate unit, consisting of oolitic facies with fossils exposed in the northern and western parts of the site area. The applicant stated that the site is mostly flat with the exception of vegetated depressions caused by dissolution within the Miami Limestone.

<u>Site Area Stratigraphy</u>

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.2 describes the site area stratigraphy. As part of the site characterization program for the Turkey Point Units 6 and 7 site, 97 geotechnical borings were drilled providing detailed information about the near-surface geologic characteristics and composition of sediments underlying the site. The Holocene units at the site are classified as marl, saprist wetland soils (muck), and peat. The applicant defined saprist soils as those with two-thirds or more of decomposed material with less than one-third of identifiable plant fibers. The applicant explained that the surficial layers within the vegetated surface depressions at the Turkey Point Units 6 and 7 site were peat, while the flat areas outside the depressions were classified as marl, peat sediments and organic rich elastic silts. The applicant added that laminated surficial deposits outside the vegetated depressions could be the result of cyclical changes in oxidation-reduction conditions. The applicant stated that the bedrock surface through the Turkey Point Units 6 and 7 site consists of the Miami Limestone overlain by muck/peat. Underlying the Miami Limestone is the coralline vuggy Key Largo Limestone beneath, which is the Pleistocene Fort Thompson Formation, a sandy limestone with vugs and zones of interbedded uncemented sand as shown in Figure 2.5.1-3.

<u>Site Area Structural Geology</u>

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.3 describes the structural geology of the site area. Previous reports for the Turkey Point Units 3 and 4 UFSAR, new geologic mapping and the supplemental exploration program are the basis for the applicant’s characterization. The applicant indicated that the site is located on the Florida carbonate platform where no faults or folds are mapped within more than 40 km (25 mi). The applicant indicated that field investigations, interpretation of aerial photography, review of published literature, and analysis of the results of the subsurface exploration did not reveal evidence for tectonic deformation within the site vicinity and site area. Boring data in the site vicinity revealed several feet of vertical relief along the contact of the Miami Limestone and the underlying Key Largo

ERA	SYSTEM		SERIES	STRATIGRAPHIC UNIT		LITHOLOGY	APPROXIMATE THICKNESS (ft)
CENOZOIC	QUATERNARY		PLEISTOCENE	Miami Limestone / Key Largo Limestone/ Anastasia Formation		sandy, oolitic, coralline, shelly limestone	10-180
				Caloosahatchee Formation/ Fort Thompson Formation		poor/well indurated sandy, fossiliferous limestone	50-100
	TERTIARY	NEOGENE	PLIOCENE	Tamiami Formation/ Cypresshead Formation (Long Key Formation)		fossiliferous sand & silt with limestone	25-220
			MIOCENE	Hawthorn Group	Peace River Formation	sands, clays, & phosphatic carbonates	100-650
					Arcadia Formation	fine crystalline limestone with sand/clay, phosphatic fossiliferous limestone, & dolomite	100-700
		PALEOGENE	OLIGOCENE	Suwannee Limestone		poor/well indurated fossiliferous vuggy to moldic limestone	200-600
			EOCENE	Ocala Limestone		poor/well indurated fossiliferous limestone	200-400
				Avon Park Formation		poor/well indurated fossiliferous limestone & vuggy dolostone	400-1200
				Oldsmar Formation		vuggy limestone & dolomite	500-1500
			PALEOCENE	Cedar Keys Formation		dolomite, gypsum, & anhydrite	500-2000
TOTAL THICKNESS							5000-6000

Figure 2.5.1-3. Cenozoic Stratigraphy of southern Florida

Limestone. After further consideration, the applicant concluded that the relief is not due to tectonic or non-tectonic deformation, but considered to be a primary sedimentary feature associated with the reef origin of the Key Largo Limestone.

Site Area Geologic Hazard

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.4 the applicant explained that there is no evidence of active tectonic features, tsunami deposits, evidence for seismically induced paleoliquefaction features indicative of paleoseismic activity, and no known sinkholes in the underlying karst terrane within the Turkey Point Units 6 and 7 site. The applicant particularly described dissolution features at the site as well as tsunami-related features.

The Florida Geological Survey mapped sinkhole zones into four distinct areas (I through IV) based on the predominant type of sinkholes. Area I develops in bare or thinly covered limestone dominated by shallow solution sinkholes. Area II develops in regions of 9.1 to 61 m (30 to 200 ft) thick mostly permeable incohesive sand and is characterized by small cover-subsidence sinkholes. Area III develops in regions of 9.1 to 61 m (30 to 200 ft) thick of mostly cohesive sediments with low permeability and is dominated by cover collapse sinkholes. In Area IV, cover is more than 61 m (200 ft) thick consisting mostly of cohesive sediments interlayered with discontinuous carbonate beds. Turkey Point Units 6 and 7 site is located in Area I, which is characterized by few, generally shallow and broad, gradually developed sinkholes. The applicant explained that if sinkholes were to occur at the site they will be solution sinkholes, as are commonly observed in Area I. Solution sinkholes are bowl-shaped depressions that occur near or at land surface where limestone is exposed or covered with a thin layer of material.

The applicant stated that zones of secondary porosity (i.e., porosity developed in a rock after its deposition or emplacement, through such processes as solution or fracturing) are present beneath the site where microkarst features have developed. These microkarst zones were possibly formed by the enlargement of sedimentary structures caused by groundwater dissolution. The applicant explained that touching-vug porosity, a subdivision of secondary porosity, occurs at the site near the contact of the Miami Limestone and Key Largo Limestone at a depth interval of 6.1 to 10.1 m (20 to 35 ft). The applicant explained that touching-vug porosity develops by the enlargement of fossil molds and that these features are numerous and could form a laterally continuous zone of interconnected voids. The applicant also stated that drilling and coring within these touching-vug porosity zones revealed these features to be generally on a centimeter scale and laterally persistent and that there were few indications, such as rod drops, of possible larger voids. The applicant explained that limestone dissolution in the upper secondary porosity zone possibly occurred during the Wisconsinan glacial stage in the Pleistocene, when sea level was lower than when the Miami Limestone and Key Largo Limestone were formed and mixed fresh groundwater and seawater discharged through the zone. The applicant stated that the freshwater/saltwater interface is about 9.6 km (6 mi) inland from the Turkey Point Units 6 and 7 site; therefore, the groundwater within the touching-vug porosity zone is saline and there is no freshwater shoreline flow near the site. Based on this, the applicant stated that the possibility of further dissolution of the limestone within the touching-vug zone of porosity does not exist and the possibility of caverns developing and potential collapse is unlikely. The applicant added that this secondary porosity zone will be completely removed during excavation of the nuclear island foundations. The applicant committed to perform a grouting program under the Nuclear Island area to limit the voids between elevation -10 to -18 m (-35 to -60 ft) within the Key Largo and Fort Thompson

Formations, and to limit the size of potential voids between elevation -18 and -33 m (-60 and -110 ft) in the Fort Thompson Formation.

Site Area Engineering Geology

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.5, the applicant discussed engineering geology of the Turkey Point Units 6 and 7 site including engineering soil properties and behavior of foundation materials, zones of alteration, weathering, dissolution, and structural weakness, prior earthquake effects and effects of human activities at the site. The applicant indicated that no zones of unusual alteration, weathering profiles, or structural weakness in the surface or subsurface of the site were identified during field reconnaissance and evaluation of published literature. Ground and aerial field reconnaissance investigations revealed no evidence of active folding and faulting or earthquake-induced features like liquefaction-related sand blows, lateral spread fractures or other geomorphic, stratigraphic features indicative of recent tectonic deformation within the site vicinity. The applicant cross-referenced FSAR Section 2.5.4 for additional details related to engineering geology of the site area and site location.

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.5.4, the applicant explained that numerous anthropogenic activities, such as, agriculture, construction of drainage canals, limestone mining, among others, have affected the regional groundwater table in southeastern Florida. However, the applicant stated that there are no indications that human activities affected the groundwater table at the Turkey Point Units 6 and 7 site.

2.5.1.3 Regulatory Basis

NUREG-1793 and its supplements address the regulatory basis for information incorporated by reference.

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

The applicable regulatory requirements for reviewing geologic and seismic information are:

- 10 CFR 52.79(a)(1)(iii), “Contents of Applications: Technical Information in Final Safety Analysis Report,” as it relates to including in the FSAR information on seismic and geologic characteristics of the proposed site with appropriate consideration of the most severe natural phenomena that have been historically reported for the site and surrounding area and with sufficient margin for the limited accuracy, quantity and period of time in which the historical data have been accumulated.

- 10 CFR 100.23, “Geologic and Seismic Siting Criteria,” for evaluating suitability of a proposed site based on consideration of geologic, geotechnical, geophysical, and seismic characteristics of the proposed site. Geologic and seismic siting factors must include the safe shutdown earthquake (SSE) for the site; and the potential for surface tectonic and non-tectonic deformation.

In addition, the acceptance criteria associated with the relevant requirements of NRC regulations for basic geologic and seismic information are given in NUREG-0800, Section 2.5.1, as follows:

- Regional Geology: Requirements of General Design Criterion (GDC) 2 of 10 CFR Part 50, Appendix A, 10 CFR 52.17 and 10 CFR 100.23(c) are met and guidance in RG 1.206, 1.208, and 4.7 followed for this area of review if a complete and documented discussion is presented for the geologic setting, tectonic framework and conditions caused by human activities, that have potential to affect the safe siting and design of the plant. This section should contain a review of regional stratigraphy, lithology, structural geology, geologic and tectonic history, tectonic features (with emphasis on the Quaternary period), seismology, geomorphology, paleoseismology, and physiography within the 320 km (200 mi) site region or beyond as necessary to provide a framework within which significance to safety can be evaluated concerning geology, seismology, and conditions caused by human activities. Geologic maps and cross-sections constructed at scales adequate to illustrate relevant regional features should be included in the application.

- Site Geology: Requirements of GDC 2 and 10 CFR Part 50, Appendix A, 10 CFR 52.17 and 10 CFR 100.23(c) are met and the guidance in RGs 1.206, 1.208, and 4.7 followed for this area of review if it contains a description and evaluation of geologic (including tectonic and non-tectonic) features, and conditions caused by human activities at appropriate levels of detail for determining any potential natural hazards that might affect the design and operation of the proposed facility. This subsection should contain the following information:

    a. structural geology, including identification and characterization of faults, joints, and other tectonic deformation features and discussion of the relationships between these features and regional tectonic structures

    b. geologic maps and cross-sections constructed at scales adequate to clearly illustrate pertinent features in the site vicinity, area, and location shall be included in the application

    c. stratigraphy and lithology of rock units and discussion of their relationships to the regional lithostratigraphic framework

    d. geomorphologic features as tectonic strain markers or indicators of other potentially hazardous natural phenomena (e.g., landslides, karst development, and dissolution collapse, growth faults)

    e. geologic and tectonic history, particularly for the Quaternary Period, and discussion of the relationship to regional geologic and tectonic history

    f. tectonic framework description, including identification of historical and instrumentally recorded earthquakes; identification and characterization of any local tectonic features as they might be related to seismicity; discussion of the relationships between local and regional tectonic structures and any relationship to seismicity; and the nature of the crust beneath the site

    g. evidence for paleoseismic features, including a description of investigations performed by the applicant to verify the presence or absence of the features

h. geologic features that have significance for geotechnical engineering:

(1) zones of mineralization, alteration, irregular or deep weathering, or structural weakness in surface or subsurface materials

(2) surface and subsurface dissolution features in soluble rock such as limestone, gypsum, or salt

2.5.1.4 Technical Evaluation

The staff reviewed Section 2.5.1 of the Turkey Point Units 6 and 7 COL FSAR and the referenced DCD to ensure that the combination of information presented in the FSAR and the DCD completely represents the required information related to this review topic.[1] The staff confirmed, as described below, that information contained in the application or incorporated by reference addresses the information required relating to basic geologic and seismic characteristics. NUREG-1793, and its supplements (2005, 2011) document the results of the staff's evaluation of information incorporated by reference into the Turkey Point Units 6 and 7 COL FSAR.

The staff reviewed the following information in the Turkey Point Units 6 and 7 COL FSAR:

AP1000 COL Information Item

- PTN COL 2.5-1

The staff reviewed PTN COL 2.5-1 regarding the geologic, seismic, and geophysical information included in Section 2.5.1 of the Turkey Point Units 6 and 7 COL FSAR. The COL information item in Section 2.5.1 of the AP1000 DCD states the following:

> Combined License applicants referencing the AP1000 certified design will address the following regional and site-specific geological, seismological, and geophysical information as well as conditions caused by human activities: (1) structural geology of the site, (2) seismicity of the site, (3) geological history, (4) evidence of paleoseismicity, (5) site stratigraphy and lithology, (6) engineering significance of geological features, (7) site groundwater conditions, (8) dynamic behavior during prior earthquakes, (9) zones of alteration, irregular weathering, or structural weakness, (10) unrelieved residual stresses in bedrock, (11) materials that could be unstable because of mineralogy or physical properties, and (12) effect of human activities in the area.

Based on the discussion of the basic geologic and seismic information presented in Turkey Point Units 6 and 7 COL FSAR Section 2.5.1, the staff concludes that the applicant provided the information required satisfying PTN COL 2.5-1.

COL FSAR Section 2.5.1

The technical information presented in COL FSAR Section 2.5.1 resulted from the applicant's review of published geologic literature; personal communications with experts in geology and seismotectonics of the site region; aerial photograph analysis, and geologic fieldwork performed

as part of the COL application (including a site subsurface investigation, a geologic field reconnaissance, and a geophysical survey). COL FSAR Section 2.5.1 contains geologic and seismic information presented in support of the vibratory ground motion analysis and the site GMRS provided in COL FSAR Section 2.5.2 as well as the determination for potential future tectonic and non-tectonic deformation in COL FSAR 2.5.3. 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. Through the review of COL FSAR Section 2.5.1, the staff determines whether the applicant had complied with all applicable NRC regulations and conducted its investigations at the appropriate levels of detail within the 320 km (200 mi) radius site region, 40 km (25 mi) site vicinity, 8 km (5 mi) radius site area, and 1 km (0.6 mi) site, as designated in RG 1.208. To evaluate the original geologic, seismic, and geophysical information submitted by the applicant thoroughly, the staff obtained additional assistance from experts at USGS.

Site Visits

The staff visited the Turkey Point Units 6 and 7 site on May 24 and 25, 2011 (ADAMS Accession No. ML111881052), and on August 22 and 23, 2013 (ADAMS Accession No. ML13248A497), and interacted with the applicant and its consultants in regard to the geologic, seismic, geophysical, and geotechnical investigations conducted at the Turkey Point Units 6 and 7 site for the COL application. The purpose of the May 2011 visit was to acquaint the staff with the proposed site, examine drill cores, dissolution features, and calculation packages. The staff examined drill cores from selected intervals of various boreholes completed within the nuclear island footprint and focused on the Key Largo Formation and Fort Thompson Formation cores. These boreholes include B-730, B-704DH, B-701DH, and B-703 from Unit 7 and B-629, B-604DH, B-601DH, and B-606 from Unit 6. Specific runs within these boreholes were examined based on low rock quality designation (RQD) and low recovery. The staff also visited shallow surface depression dissolution features that support distinct woody vegetation at Units 6 and 7 and along the interceptor canal road, near the western plant boundary. The surficial dissolution features along the canal road are in a more natural pristine condition than the ones at Unit 6 and 7 building site. The natural condition of these features can reveal some aspects of their origin.

The August 2013 site visit was an audit of the subsurface investigation work performed at the Turkey Point Units 6 and 7 site by Paul C. Rizzo Associates, Inc. (ADAMS Accession No. ML13248A497). The staff interviewed individuals representing the applicant and Paul C. Rizzo Associates at the Unit 7 drilling site for the new supplemental boring program that included specific sampling of the vegetated depressions at the site. The on-site individuals discussed with the staff the decision to use a Macaulay sampler, a half cylinder barrel with a rotating shuttle that has a cutting edge, to retrieve undisturbed peat samples from the peat filled surface dissolution pits located at the drilling site. The sampler is advanced to the target depth and the operator turns the shuttle to cut a sample of peat, and retrieves an enclosed, protected sample. The undisturbed peat samples were later examined for the presence of tsunami and storm surge deposits from prehistoric events.

The staff also examined newly extracted core from the Miami, Key Largo, and Fort Thompson Limestone formations. This was the first opportunity to directly observe Miami Limestone because the heavily weathered nature of this surface unit previously prevented sufficient RQD. The staff observed the increasing clastic content with depth in the Fort Thompson formation and the open reef like fabric in the Key Largo formation. Terminated calcite crystals were observed covering open surfaces indicating a precipitating, rather than dissolving in situ environment.

The following SER Sections 2.5.1.4.1, "Regional Geology," and 2.5.1.4.2, "Site Geology," present the staff's technical evaluation of the information provided by the applicant in Turkey Point Units 6 and 7 COL FSAR Section 2.5.1 and the applicant's responses to RAIs for Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.

2.5.1.4.1 Regional Geology

The staff reviewed the Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1 and the applicant's description of the regional physiography, geomorphology, stratigraphy, and tectonic setting within the 320 km (200 mi) radius site region around the Turkey Point Units 6 and 7 site (Figure 2.5.1-1). The applicant needed to characterize offshore Florida, Cuba seismic sources, and the active Caribbean–North American plate boundary. Therefore, the staff performed a detailed review of the new information that was not part of the previously endorsed model (NUREG-2115) in addition to conducting its own independent literature review. This resulted in the development of several RAIs evaluated in this section of the review.

The staff focused its review on the structures, stratigraphic relationships, and tectonic interpretations pertaining to geologically young features and characteristics that might have implications for the site PSHA. Geologically young in this context refers to the Cenozoic era (65 Ma) and in particular the Quaternary period (2.6 Ma through today). This includes the characterization of the Florida peninsula, Biscayne Bay, the offshore Straits of Florida and terraces, the Bahama Banks, and the island of Cuba, as its north central portion resides within the Turkey Point site region. In addition, because the Florida platform is essentially a carbonate bank, the staff also focused on the applicant's characterization of carbonate dissolution features and processes found in the site region that have implications for the site area.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1 describes Large Igneous Province (LIP) magmatic events and the East Coast Margin Igneous Province (ECMIP), which includes the eastern edge of the offshore Blake Plateau and Bahamas Platform. The crustal structure of LIPs are comprised of an extrusive upper crust and a lower crust characterized by high seismic velocities (Vp 7.0-7.6 km/s) and are different from "normal" oceanic or continental crust. In RAI 02.05.01-10, the staff asked the applicant to further describe the location of the ECMIP with respect to transitional continental, thickened and normal oceanic crust and the impact of crustal thickness variations on the ground motion models from Caribbean sources.

In an October 3, 2014, response to RAI 02.05.01-10, the applicant explained that the ECMIP (also called the East Coast Magnetic Anomaly (ECMA)) and its southeast conjugate, the Blake Spur Magnetic Anomaly (BSMA) are part of an LIP located along the North American continental margin that marks the boundary between continental and oceanic crust. Located between rifted continental crust and normal ocean crust, this 100 km (62 mi) wide zone of thick (up to 25 km (15 mi)), high velocity crust is interpreted as massive mafic igneous rock emplaced during the Triassic-Jurassic rifting of Pangea. The applicant indicated that the Appalachian intracrustal reflectivity largely disappears across the boundary, implying that the reflectivity is disrupted by massive intrusion and very little, if any, continental crust can be found east of it. The BSMA underlies the Bahamas and implies that the Bahamas overlie seamounts produced by the LIP magmatic event.

The applicant explained that development of the Caribbean GMPEs was based on the regional attenuation parameters estimated from an empirical dataset of earthquakes recorded in and around the island of Puerto Rico (Motazedian and Atkinson, 2005). The final Caribbean GMPEs

included a variation of the anelastic Q model. This Q variation and resulting variation in the suite of recommended Caribbean GMPEs is intended to capture the range in ground motions from the noted variation in the crust in the region and is consistent with the GMPEs used for the EPRI - Seismicity Owners Group (EPRI-SOG) seismic sources.

Based on review of the response and the fact that the GMPEs included a range of values to account for variation in the crust in the Turkey Point Units 6 and 7 site region, the staff finds that the applicant explained how crustal variations are accounted for. Accordingly, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 02.05.01-10, resolved.

Regional Physiography and Geomorphology

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.1, the applicant described regional physiography and geomorphic processes. In this section, the staff focused on the applicant's characterization of carbonate dissolution processes and features on the Florida Platform because subsurface open cavities and karst could impact site safety from the perspective of surface deformation hazard.

Limestone Dissolution in Southern Florida

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.1.1 describes limestone dissolution features within the site region and the Turkey Point Units 6 and 7 site vicinity, including: the dry caves along the Atlantic Coastal Ridge; the vegetated surface depressions (solution sinkholes) at the Turkey Point Units 6 and 7 site; zones of secondary porosity in the Miami/Key Largo limestone formations and the deeper Fort Thompson Formation (touching vug and moldic porosity) beneath the Turkey Point Units 6 and 7 site; freshwater springs in Biscayne Bay; the paleo-sinkholes at Jewfish Creek and the submarine paleo-sinkhole in the Key Largo National Marine Sanctuary; and submarine paleo-sinkholes in Biscayne Bay (Figure 2.5.1-6). The applicant described the different processes that led to the development of these features. The staff notes that the processes that impact the Turkey Point Units 6 and 7 site vicinity include freshwater/saltwater-mixing zones in the water table aquifer, surficial rainwater dissolution, and deep pore water upwelling from the confined Floridan Aquifer.

The staff issued several RAIs (Question 02.05.01-1, Question 02.05.01-2, and Question 02.05.01-37), discussed in detail in the following paragraphs, regarding limestone dissolution in the site region and vicinity based on: review of material in the Turkey Point Units 6 and 7 COL FSAR, including referenced publications; RAI responses from the applicant; independent review of publications not previously included in the Turkey Point Units 6 and 7 COL FSAR; and questions arising from the site visits. In response, the applicant provided more detail in the Turkey Point Units 6 and 7 COL FSAR, completed additional field work at the site and submitted supplemental reports including Turkey Point Units 6 and 7 COL FSAR Appendix 2.5AA titled "Potential for Carbonate Dissolution and Karst Development at the Turkey Point Units 6 and 7 site" and Turkey Point Units 6 and 7 COL FSAR Enclosure 9 titled "Surficial Muck Deposits Field and Laboratory Investigation Data Report"

1. Sinkhole Types

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.1.1.1 provides a classification of Florida sinkhole types and ranking of collapse risk based on geographic distribution of known sinkholes (Sinclair and Stewart, 1985). The applicant indicated that for the Turkey Point Units 6

and 7 site, sinkholes are typically solution sinkholes. The staff independently reviewed Sinclair and Stewart (1985) and notes that solution sinkholes occur where limestone is exposed at the ground surface or is covered with only a thin veneer of unconsolidated material. Dissolution comes from rainfall that soaks into the ground and slowly dissolves the limestone, resulting in generally lowering the elevation of the landscape. In places, perhaps underlain by fractures or jointing, shallow, bowl-shaped depressions form that are typically filled with peat deposits and supporting vegetation distinct from surrounding sawgrass savannahs as shown on Figure 2.5.1-7. Photo compilation of vegetated surface depressions and discussed in Section 2.5.1.4.2 of this evaluation. The staff reviewed Sinclair and Stewart (1985) and notes that areas in central and northern Florida contain cover collapse and cover subsidence sinkholes (distinguished from solution sinkholes) formed from dissolution at the water table/vadose zone interface beneath more substantial, unconsolidated clastic/organic cover layers. The dissolving water is derived from local rainwater percolating through a relatively thick vadose zone, forming significant open cavities at or near the water table interface. Based on the material from the Turkey Point Units 6 and 7 COL FSAR and the staff's independent consideration of Sinclair and Stewart (1985) staff agrees with the applicant that this type of sinkhole is not found in the Turkey Point Units 6 and 7 vicinity with the possible exception of the features at Jewfish Creek and Key Largo.

2. Mixing Zones

The staff noted that there is a different mechanism or process of carbonate dissolution in coastal areas that is linked to mixing disequilibria at freshwater-brine interfaces (i.e., where the freshwater lens contacts saltwater in the Biscayne Bay aquifer). A zone of brackish water forms in the contact area that is under-saturated with respect to calcium carbonate. This was not discussed in the earlier versions of the Turkey Point Units 6 and 7 COL FSAR. Therefore, in RAI 41, Question 02.05.01-1, the staff asked the applicant to discuss any evidence for the potential of limestone dissolution associated with freshwater/saltwater interfaces in southern Florida, and to specifically consider the linking of open, water-filled passages in the subsurface to sub-sea springs in Biscayne Bay that may have formed from past freshwater/saltwater interfaces. The staff also asked the applicant to discuss how freshwater/saltwater mixing zones of dissolution would be expected to migrate in response to sea-level changes.

In an October 3, 2014, response to RAI 41, Question 02.05.01-1 (ADAMS Accession No. ML14282A073), the applicant explained that seawater saturated with calcium carbonate contains far less mass than fresh groundwater saturated with calcium carbonate, and the mixing waters become under-saturated with respect to calcium carbonate and thereby promote the dissolution of carbonate rock. The freshwater/saltwater interface within the Biscayne Aquifer is located approximately 9.6 km (6 mi) inland from the site (Turkey Point Units 6 and 7 COL FSAR Figure 2.4.12-207) and groundwater at the site is saline (Lanevin, 2001). Current groundwater withdrawals from constructed drainage canals and pumping from the freshwater aquifer for agriculture and urban population use has contributed to inland migration of the freshwater/saltwater interface. Furthermore, the

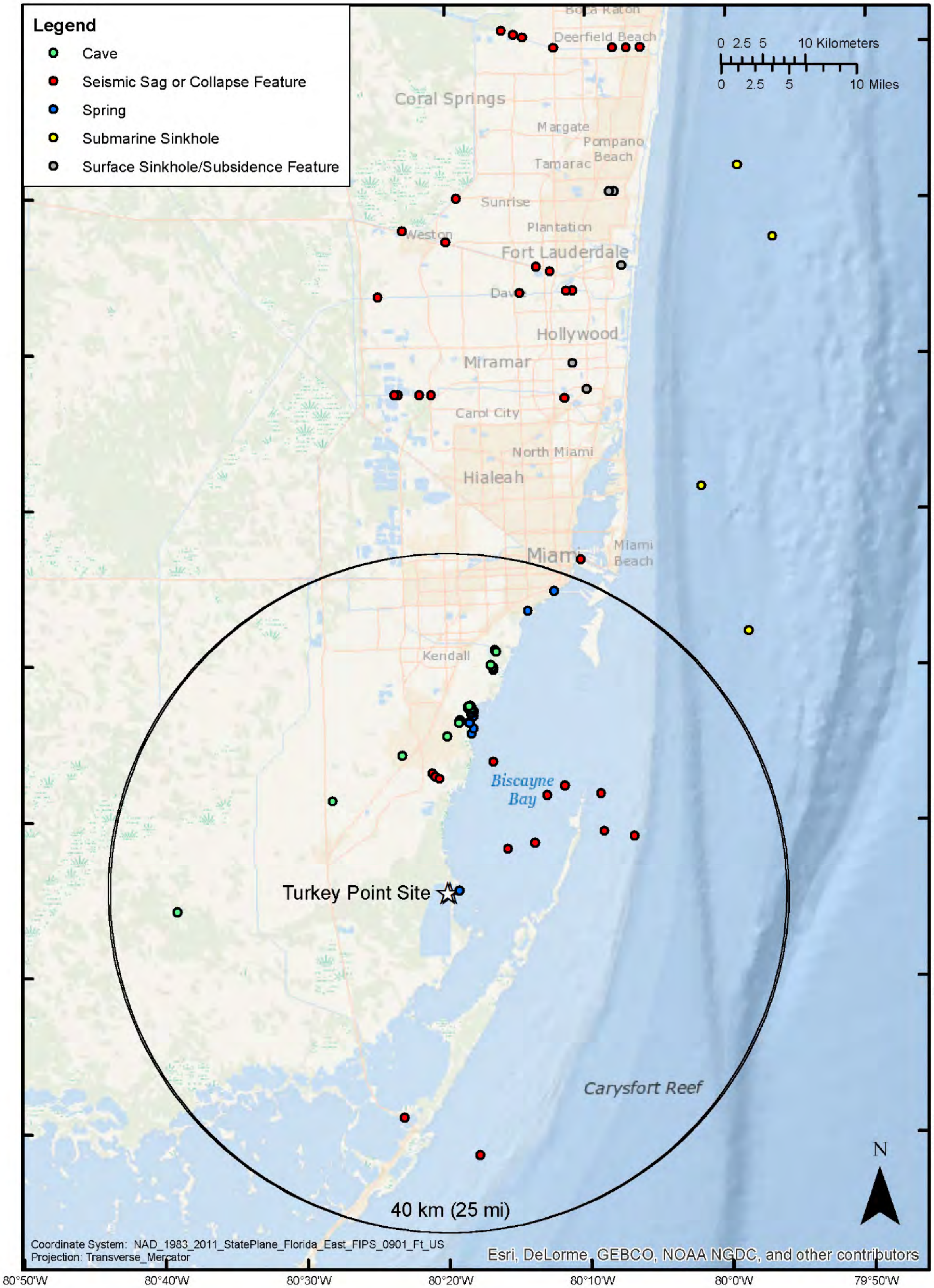


Figure 2.5.1-6. Map of karst features in the Turkey Point Units 6 and 7 site vicinity

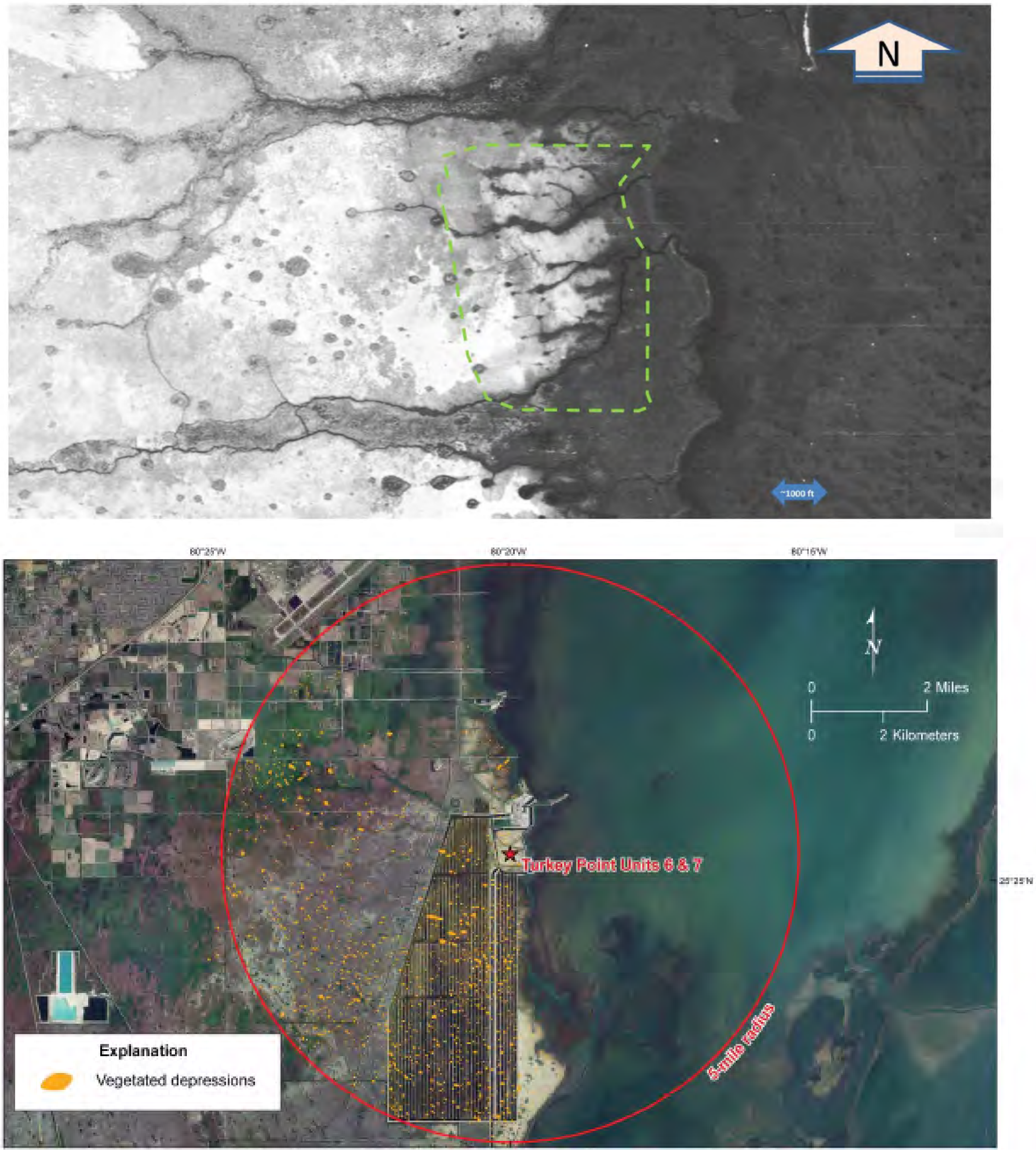


Figure 2.5.1-7. Photo of vegetated surface depressions in the site and site area.

long-term sea-level rise trend at Miami Beach, FL, currently estimated at 0.2 m (0.78 ft) per century, will increase the ocean hydrostatic head and move the freshwater/saltwater interface further inland and away from the site.

The applicant explained that dissolution features associated with mixing zones might occur at groundwater discharge sites and seafloor discharge zones. The applicant described freshwater springs on the floor of Biscayne Bay as a manifestation of a freshwater aquifer discharge zone driven by an inland hydraulic head. Dissolution of carbonate rock occurs along the aquifer flow path, where fresh and seawater mix. Before drainage canals were built and prior to substantial lowering of groundwater levels in southeast Florida, fresh groundwater discharged along the shoreline and offshore as submarine springs. The groundwater flow conduits still exist as dissolution features within the Biscayne Aquifer. However, due to current diminished aquifer flow and saline conditions, freshwater springs in the Bay are not active. The applicant also suggested that the 20 caves in Miami-Dade County along the flanks of the northeast trending Atlantic Coastal Ridge, located west of the Turkey Point Units 6 and 7 site (Cressler, 1983) are channels of past groundwater flow formed in a mixing zone along the paleo-shoreline of the coastal ridge.

The applicant concluded that there is no current fresh groundwater mixing with saltwater in the Biscayne Aquifer and, therefore, the mechanism necessary to form solution cavities does not appear to be active at or near the site.

The staff notes that the applicant, in response to RAI 41, Question 02.05.01-2 (ADAMS Accession No. ML14282A073) (discussed in more detail below), concluded that the zones of secondary porosity, found in the subsurface at Turkey Point Units 6 and 7 site, are the result of former mixing zone dissolution (now inactive). The staff also notes that groundwater discharge sites near the Turkey Point Units 6 and 7 site include freshwater drainage canals and outfalls, the closest of which are the Model Land Canal (C107) outfall, approximately 8 km (5.0 mi) south of the site, and the Florida City Canal outfall, approximately 1.9 km (1.2 mi) north of the site. The staff agrees with the applicant’s characterization that there are mixing zone features in the site vicinity but these are derived from previous conditions and they are not actively forming now.

3. Zones of Secondary Porosity at the Turkey Point Units 6 and 7 Site

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.4 describes subsurface limestone dissolution features in the Key Largo Limestone and in the Fort Thompson Formation as zones of secondary porosity. These intervals have been identified via down-hole televiewer, caliper logs and rod drops. The upper zone at the contact between Miami and Key Largo Limestone will be removed during construction. The zone in the Fort Thompson Limestone is beneath the bearing layer for SCC buildings. In RAI 41, Question 02.05.01-2, the staff asked the applicant to discuss the origins of the subsurface secondary porosity.

In an October 3, 2014, response to RAI 41, Question 02.05.01-2, the applicant explained that two zones of secondary porosity are found beneath the site; near the contact of the Miami and Key Largo Limestones and in the Fort Thompson Formation. The zones of secondary porosity provide preferential conduits for groundwater flow. The applicant suggested that micro-karst formed by solution enlargement of primary sedimentary structures as fresh groundwater flowing from inland areas, mixed with sea water (mixing zone disequilibria), and dissolved carbonate rock as it flowed through the zones to the sea. The staff notes that groundwater within the

Biscayne aquifer, where both zones of secondary porosity are located, is currently saline and thus not conducive to further dissolution of the limestone host rock.

The applicant described two categories of secondary porosity: touching-vug porosity and moldic porosity. Touching-vug porosity occurs at the Turkey Point Units 6 and 7 site within the approximate depth interval of 6.1 to 10.7 m (20 to 35 ft) near the contact of the Miami and Key Largo Limestones as a result of solution enlargement of burrows, inter-burrow vugs, moldic fossils, root molds, and vugs between root casts. Drilling and coring during the site subsurface investigation show the zone of touching-vug porosity to be a laterally continuous zone of interconnected voids that are generally of centimeter scale with very few indications of larger voids such as those that could cause a rod drop (Figure 2.5.1-8). The staff notes that this zone will be completely removed during excavation of the nuclear island foundations.

Moldic porosity occurs at the Turkey Point Units 6 and 7 site in pockets within the approximate depth interval of 18.3 to 22.8 m or (60 to 75 ft), within the Fort Thompson Formation. Moldic porosity results from the dissolution of fossil shells and organic structures rather than the enveloping matrix rock. Void spaces of less than centimeter scale are located within shell molds. Drilling and coring during the site subsurface investigation within the zone of moldic porosity indicates that the zone is not laterally persistent, but exists in isolated sandy pockets with few indications of larger voids.

The staff notes that geologic features such as zones of secondary porosity, fractures, bedding planes and voids can provide potential pathways for water to flow. The staff notes that the applicant will construct a grouted zone for construction groundwater control and constraint of open voids, via grout injections into the rock mass between the bottom of the excavation at -10.7 m (-35 ft) and -33.5m (-110 ft) elevation in the Key Largo and Fort Thompson Formations. In Part 10 of the Turkey Point Units 6 and 7 COL FSAR Appendix B Table 3.8-6, the applicant provided a grouting ITAAC that establishes a set of actions and criteria for the grouting activity necessary to provide assurance that, when met, the stability of Category I structures are in conformance with the combined license (refer to SER Section 2.5.4.2.5).

The staff considered the characterization of mixing zone dissolution of limestone in the site vicinity provided by the applicant and concludes that the response adequately describes the dissolution process and the features likely associated with that process, namely the zones of secondary porosity in the subsurface units, the springs in Biscayne Bay and the caves along the coastal ridge. The staff agrees that there are mixing zone features in the site vicinity but these are derived from previous conditions and the features are not actively forming now. Accordingly and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 41, Questions 02.05.01-1 and 02.05.01-2 resolved.

The applicant proposed a revision to the Turkey Point Units 6 and 7 COL FSAR to include portions of RAI 41, Questions 02.05.01-1 and -2 responses. The applicant's proposed revisions to the Turkey Point Units 6 and 7 COL FSAR are found in the response to RAI 41, Question 02.05.01-17 (not Questions 02.05.01-1 or -2). The staff finds the proposed revisions acceptable and has confirmed that these changes have been incorporated into the Turkey Point Units 6 and 7 COL FSAR.

Figure 2.5.1-8. Photograph of core boring from the Key Largo Formation taken during NRC site audit at the Turkey Point Units 6 and 7 site

4. Key Largo Paleo-sinkhole

The applicant described a large, offshore paleo-sinkhole in Key Largo Marine Sanctuary (Shinn et al., 1996) approximately 13 km (8 mi) south of the site. The sinkhole is sediment-filled, with little bathymetric expression, about 600 m (1,970 ft) in diameter and at a depth likely to exceed 100 m (328 ft). The oldest Radiocarbon age from the bottom sample at 54.5 m (179 ft) is 5,650 +/-90 years before present, and the youngest age (just below the overlying carbonate sand cap) is 3,260 +/-60 years before present. The staff notes that the sediment infilling of this sinkhole is geologically recent, within Holocene time. The applicant concluded that the Key Largo sinkhole was formed through shoreline flow under freshwater/saltwater mixing zone conditions, and since these mixing zone conditions no longer exist in this location, development of cavernous limestone is unlikely at this site. However, because of the large dimensions of this sinkhole, especially the depth, the staff concludes that this feature might be an expression of hypogenic dissolution.

5. Deep Pore Water Upwelling

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.1.1.1 introduces the concept of deep pore water upwelling as one type of submarine groundwater discharge where fresh groundwater

flows 'beyond the shoreline on the continental shelf through deeper confined permeable shelf sediments and rocks driven by buoyancy and pressure gradients'. The applicant provided two examples of this: submarine paleo-karst sinkholes beneath Biscayne Bay (approximately 13 km [8 mi] northeast of the site); and Crescent Beach Spring and Red Snapper Sink (approximately 320 km (200 mi) north of the site). The applicant also stated in the response to RAI 41, Question 02.05.01-1, that "deep pore water upwelling generally occurs well off shore, where the slope of the shelf is steeper and erosion of this thickness of confining sediments is more likely." The applicant concluded that carbonate dissolution associated with deep pore water upwelling from the Floridan Aquifer is not likely to pose a threat of surface collapse or sinkhole hazard at the site. The staff notes that there are 12 features in Biscayne Bay, described as seismic sags in Cunningham and Walker (2009) and Cunningham et al. (2012) that are interpreted as hypergenic dissolution. In addition, the staff notes that the seismic sags in Biscayne Bay are actually near-shore examples (not out on the shelf break) that likely represent a hypogenic karst mechanism (Klimchouk, 2009), rooted in the Floridan Aquifer that might affect the Turkey Point Units 6 and 7 site. This type of dissolution was not previously described in the Turkey Point Units 6 and 7 COL FSAR.

6. Hypogenic Dissolution

For the staff to have a complete understanding of all likely limestone dissolution processes that might impact the Turkey Point Units 6 and 7 site, the staff independently reviewed several southern Florida investigations that pertain to limestone dissolution in coastal areas that were not previously included in the Turkey Point Units 6 and 7 COL FSAR. The staff reviewed and considered the interpretations in Klimchouk (2009), who describes the process and features associated with hypogenic speleogenesis worldwide. Then the staff considered the correspondence of dissolution features identified in southern Florida within the site vicinity and the Keys as described by various researchers such as: Cunningham and Walker (2009), Cunningham et al. (2012), Land and Paull (2000), Land et al. (1995), and possibly a feature at Jewfish Creek (Technos, 2009). Klimchouk (2009) describes hypogenic speleogenesis, or cave formation, as occurring in confined to semi-confined groundwater conditions with recharge coming from deeper confined aquifers and moving vertically upward through aquifer and overlying confining units. The dissolving mechanisms including both physical and chemical conditions. This process forms vertically stacked or chimney-like voids; is active over large spans of geologic time and can reactivate.

The staff reviewed Land et al. (1995), which describes a Quaternary-aged, large, deep sinkhole offshore Key West on the edge of the Portales Terrace that formed under persistent submarine circumstances as hypogenic karst. Land and Paull (2000) located and investigated several more sinkhole-like features offshore along the entire stretch of the Florida Keys to Miami. The authors interpreted these features as hypogenic karst rooted in the Floridan aquifer, some likely active today. These features have diameters that range from about 350 to 960 m (1,148 to 3,150 ft) and vertical dimensions of about 31 to 260 m (101 to 853 ft). The staff notes that the applicant did not include these features in the FSAR discussion of deep porewater upwelling. More recently and close to the Turkey Point Units 6 and 7 site, Cunningham and Walker (2009) describe 12 seismic sags, capped by Miocene strata, in Biscayne Bay and the shelf margin, interpreted to be collapsed paleocaves or paleocave systems formed by hypogenic dissolution processes. These features range between 355 and 2,479 m (1,165 and 8,133 ft) in diameter and at least 730 m (2,395 ft) vertically. The staff also reviewed the Technos (2009), "Geophysical Survey for Karst Characterization at Proposed Units 6 and 7 Turkey Point Nuclear Power Plant," Appendix A, that describes a filled sinkhole at Jewfish Creek, within 16 km (10 mi) of the Turkey Point Units 6 and 7 site. This sinkhole is about 579 m (1,900 ft) across and

estimated to be more than 183 m (600 ft) deep, based upon seismic reflection and microgravity data. Borings and geophysical logging indicated open cavities within this paleocollapse feature up to 2.7 m (9 ft) in diameter. The staff notes that a 183 m (600 ft) deep sinkhole is far deeper than typical cover collapse sinkholes found in central and northern Florida and well below the -107 m (-350 ft) sea-level lowstand from Late Pleistocene glacial maxima.

Because of the staff's concern regarding the possibility of hypogenic dissolution in the Turkey Point Units 6 and 7 site vicinity and area, the on February 18, 2015 staff asked the applicant in RAI 81, Question 02.05.01-37 (ADAMS Accession No. ML15050A155), to (a) provide more details regarding the sinkhole at Jewfish Creek, (b) provide a discussion of hypogenic dissolution processes in southern Florida and include features in the site vicinity such as the seismic sags in Biscayne Bay, and (c) provide a map showing locations of all limestone dissolution features found in the Turkey Point Units 6 and 7 site vicinity.

In a May 18, 2015, response to RAI 81, Question 02.05.01-37, Part a, (ADAMS Accession No. ML15142A463) the applicant described the data) available for characterizing the Jewfish Creek and adjacent shallow marine Lake Surprise karst features available in the five Technos reports issued from 1995 through 2009. The features are located 27 km (17 mi) south of the Turkey Point Units 6 and 7 site. Based on geotechnical borings with geophysical logs, seismic reflection surveys (high resolution as well as deep seismic reflection), microgravity surveys, and analysis of aerial imagery to support design work for the Jewfish Creek Bridge, Technos identified seven discrete collapse structures beneath Jewfish Creek and Lake Surprise, filled with sediments from overlying materials. The structures are associated with vertical, closely spaced, enlarged dissolution joints. Technos modeled the data, locating the collapse within the Arcadia Formation. Subsidence in overlying, dipping layers is interpreted as shallow as 21 m (70 ft), possibly into the Fort Thompson and Key Largo Formations. Technos concluded that the features were not actively forming features although no specific basis was provided for this conclusion. Since the bridge was completed in May 2008, no structural damage or differential settlement has been reported. The staff asked the applicant if the Jewfish Creek feature was an indication of hypogenic dissolution. Although Technos Inc. never suggested a formation mechanism, the applicant suggested two causative mechanisms for the collapse features: either epigenetic or eogenetic or a combination of both.

The staff notes that epigenic dissolution occurs at or near the water table because of fresh rainwater dissolving limestone as it percolates through the vadose zone. Examples are the commonly known sinkholes of northern Florida. Eogenetic dissolution occurs along the freshwater/saltwater interface in a shallow coastal marine setting, typically in the water table aquifer, due to carbonate under-saturation in the mixed zone.

The applicant compared the Jewfish Creek feature with the collapse structures in Biscayne Bay and onshore Miami-Dade County. The applicant stated that the collapse structures at Jewfish Creek/Lake Surprise are not entirely inconsistent with the narrow seismic sag features described by Cunningham and Walker (2012); Reese and Cunningham (2014) and Cunningham (2013, 2014, and 2015). However, the seismic sag features are generally vertically stacked (multi-storied) and are not closely spaced or distributed horizontally as is the case at Jewfish Creek/Lake Surprise. Furthermore, the applicant stated that the Jewfish Creek/Lake Surprise feature and the nearby Key Largo submarine sinkhole (Shinn et al., 1996) appear to have formed in the Pleistocene, coincident with sea-level lowstands. The applicant concluded that given sea-level rise since that time, the Jewfish Creek/Lake Surprise structures are not relevant analogs for active surface collapse near the Turkey Point Units 6 and 7 site.

In response to RAI 81, Question 02.05.01-37, Part b, the applicant cited the description of hypogenic speleogenesis in Klimchouk (2007 and 2009) as dissolution-enlarged permeability (flow) structure development via ascending waters, driven by regional and/or more localized hydraulic potentials or other convective circulation mechanisms (e.g., thermal or density). The upward groundwater flow implies some hydrological confinement rather than surface recharge. Therefore, potential for hypogenic speleogenesis exists in the confined Floridan Aquifer system, which includes the Cedar Keys up to the lower Arcadia formations. The applicant cited Kohout (1967 and 1965), which stated that thermally induced convective circulation (and by inference hypogenic dissolution) was occurring in the Floridan Aquifer system in southern Florida. Meyer (1989) substantiated Kohout convection within the Floridan Aquifer, and suggested that inland flows associated with the circulation pattern were as high as 52 m (172 ft) per year in the early Holocene, but estimated modern Kohout circulation inland flows to be about 1.5 m (5 ft) per year.

The applicant stated that hypogene karst features are not typically seen at the surface because hypogenic dissolution is not associated with meteoric recharge. Therefore, direct (observational) evidence for hypogenic dissolution (i.e., from cave morphology) is not readily available for southeastern Florida, and very few studies from southeastern Florida explicitly address hypogenic dissolution processes as a cave or cavity/void forming mechanism.

The applicant cited Cunningham and Walker (2009) who propose two hypogenic mechanisms to explain structural sags in Biscayne Bay and the Atlantic Ocean: (1) upward groundwater flow via Kohout convection and subsequent carbonate dissolution by mixed fresh and saline waters, and (2) upward flow and dissolution from hydrogen-sulfide-rich groundwater, sourced from calcium sulfates in deeper Eocene (or Paleocene) age rocks. Cunningham and Walker (2009) also suggested that upward flow and dissolution via Kohout convection was responsible for the submarine sinkholes on the Portales and Miami terraces. However, the applicant stated that Cunningham and Walker (2009) did not present tangible evidence to support a hypogenic origin for these mechanisms. The applicant concluded that a hypogenic dissolution mechanism is not required to explain the collapse structures in Biscayne Bay and onshore Miami-Dade County or the Jewfish Creek/Lake Surprise collapse complex, but it cannot be ruled out as a formative mechanism.

The staff considered what the applicant concluded regarding the seismic sags and compared that to what others concluded (Cunningham, 2015; Reese and Cunningham, 2014; Cunningham et al., 2012; Cunningham and Walker, 2009). The staff acknowledges that both conclusions are possible alternatives, but considers that these features are likely hypogenic dissolution, in whole or in part, because: (1) the physical characteristics of the structural features compare favorably to Klimchouk's description of hypogenic dissolution systems, and (2) Cunningham et al. (2009) presents striking seismic reflection images of deep seated, vertically stacked, chaotic, truncated and broken reflectors within the Floridan Aquifer. Cunningham (2015) continues subsurface exploration (seismic reflection, drill hole and borehole tele-viewer data) to conclude that these karst collapse features are common structural features beneath southeastern Florida in the Floridan Aquifer, and that they range from about 122 m (400 ft) to 4.8 km (3 mi) in diameter (Figure 2.5.1-9).

In response to the staff's question about the timing and reactivation potential of hypogenic dissolution, the applicant stated that Cunningham and Walker (2009) suggested that Kohout circulation and hypogenic speleogenesis were likely initiated in the Eocene, and at least one structure indicates four cave formation and collapse cycles in middle Eocene to middle Miocene rocks. Deformation associated with the structural sags does not seem to extend beyond

(above) the Oligocene to Miocene age Arcadia Formation. The applicant identified one collapse feature extending upward into the Peace River and Tamiami formations located below the North New River and Hillsboro canals, located approximately 77 and 101 km (48 and 63 mi) from the site (Reese and Cunningham, 2014). It is possible then that cave formation and/or collapse deformed rock units as young as the Pliocene.

In reviewing these papers, the staff notes that the extent of collapse structures revealed in these data appears to be mostly limited to the upper Floridan Aquifer. Stratigraphically, these features appear to be capped by the upper contact of the Arcadia Formation with the overlying Peace River Formation (Miocene). This stratigraphic interval is positioned about 450 ft (137 m) below the surface at the Turkey Point Units 6 and 7 site. However, in Broward County, the staff observe one seismic sag that extends beyond the top of the Arcadia Formation into the Peace River Formation in a seismic reflection image (Reese and Cunningham, 2014).

The staff also notes that in response to RAI 82, Question 02.05.04-26 (ADAMS Accession No. ML14282A079), the applicant will develop a grouting program based on its test program for the subsurface beneath the nuclear island for dewatering and constraining open voids in the Key Largo and Fort Thompson Formations. The applicant will also perform analyses to confirm that this grouting will result with the condition that any remaining potential voids would not impact the safety of any Category I structure. The staff's evaluation of this plan and the associated ITAAC are in SER Section 2.5.4.4.4. In addition, for the depth of the subsurface explorations for safety related foundations, RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants," Appendix D, "Spacing and Depth of Subsurface Explorations for Safety-Related Foundations," states that, "Where soils are very thick, the maximum required depth for engineering purposes, denoted d_{max}, may be taken as the depth at which the change in the vertical stress during or after construction for the combined foundation loadings is less than 10% of the effective in situ overburden stress." Staff further noted that in an October 3, 2014 response to RAI 6006, Question 02.05.04-19 (ADAMS Accession No. ML14283A312), the applicant provided a PLAXIS 3D finite element analysis that incorporates advance constitutive models (stress vs. strain relationship) that simulates the response of soils to external loading for construction sequence. The applicant used an analysis depth of El. –450 feet, which is greater than 2B (B is equal to the least dimension of the foundation), and assumed it to be adequate to meet the aforementioned RG 1.132 criterion. The applicant results indicated that the changes in effective vertical stresses are less than 10 percent of the effective in situ stress for each phase of the construction sequence, demonstrating that the model depth is appropriate and in compliance with RG 1.132 criterion. The staff's evaluation of this RAI response is in SER Section 2.5.4.4.10. As such, the staff accepts the applicant's conclusion for RAI 81, Question 02.05.01-37, Parts a and b.

In response to RAI 81, Question 02.05.01-37, Part c, the applicant provided two new figures to illustrate the various limestone dissolution features in the Turkey Point Units 6 and 7 site vicinity and beyond as discussed in the RAI responses. In a July 15, 2009 response to RAI 85, Question 02.05.01-39 (ADAMS Accession No. ML15198A060), the applicant provided a table of coordinates of all limestone dissolution features in the site vicinity and beyond to include the Florida Keys.

The staff accepts the applicant's response for RAI 81, Question 02.05.01-37, Parts a, b and c as indicated in preceding paragraphs. Accordingly, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 81, Questions 02.05.01-37 and -39, resolved. The applicant provided a proposed COL revision to include portions of the RAI 81, Question 02.05.01-37, response in a future revision of the Turkey Point Units 6 and 7 COL FSAR. The staff finds the

proposed revisions acceptable and has confirmed that these changes have been incorporated into the Turkey Point Units 6 and 7 COL FSAR.

Marine Terraces and Ridges in Florida

Turkey Point Units 6 and 7 COL FSAR Subsection 2.5.1.1.1.1.1.1 describes a statewide model and maps of marine terraces in the State of Florida (Turkey Point Units 6 and 7 COL FSAR Table 2.5.1-203). More recent studies refined the ages of previously mapped marine terraces in Florida, particularly the Pleistocene record of marine terrace development in southern Florida and the Florida Keys. Turkey Point Units 6 and 7 COL FSAR Table 2.5.1-203, "Florida's Marine Terraces, Elevations, and Probable Ages," characterizes nine marine terraces in Florida; however, the staff notes that the source of these data is 40 years old. In RAI 41, Question 02.05.01-4, the staff asked the applicant to provide more recent information regarding the age and elevations of southern Florida's marine terraces to characterize regional and local geomorphology and integrate these features with sea-level history through past interglacial periods.

In an October 3, 2014, response to RAI 41, Question 02.05.01-4 (ADAMS Accession No. ML14282A073), the applicant explained that the marine terraces of southern Florida, once thought to be the direct result of sea-level fluctuations through the last glacial cycles, are now understood to be a result of complex interactions between sea-level oscillation, sub-aerial exposure, precipitation karstification, and isostatic uplift. The Miami and Key Largo limestones, along with the coastal terraces and ridges, preserve the record of Pleistocene sea-level changes in southern Florida including periods of sub aerial exposure and isostatic uplift.

The applicant described a model (Adams et al., 2010) of two coastal terraces and one ridge along the Atlantic shoreline of northern Florida that were determined to be Pleistocene aged based on the ages of sea-level highstands, lithospheric uplift as a result of decrease in bulk crustal density due to precipitation karstification and the elevations of the terraces and ridge. The applicant described the ages of cores recovered from sites in the Florida Everglades that revealed at least ten separate sea-level highstands within the Pleistocene, one of which is the youngest Pleistocene sub aerial exposure in the Florida Keys and represents peak sea level of the last interglacial substage QE5 (Hickey et al., 2010) (Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-377).

Based on review of the applicant's response that included several new investigations, maps and correlation tables of sea-level oscillations and ages of morphostratigraphic units, the staff finds that the applicant sufficiently explained the ages of geomorphic features in southern Florida. Accordingly, in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 41, Question 02.05.01-4 resolved.

The applicant proposed to include portions of the response to RAI 41, Question 02.05.01-4, in a future revision of the Turkey Point Units 6 and 7 COL FSAR. The staff finds the proposed revisions acceptable and has confirmed that these changes have been incorporated into the Turkey Point Units 6 and 7 COL FSAR.

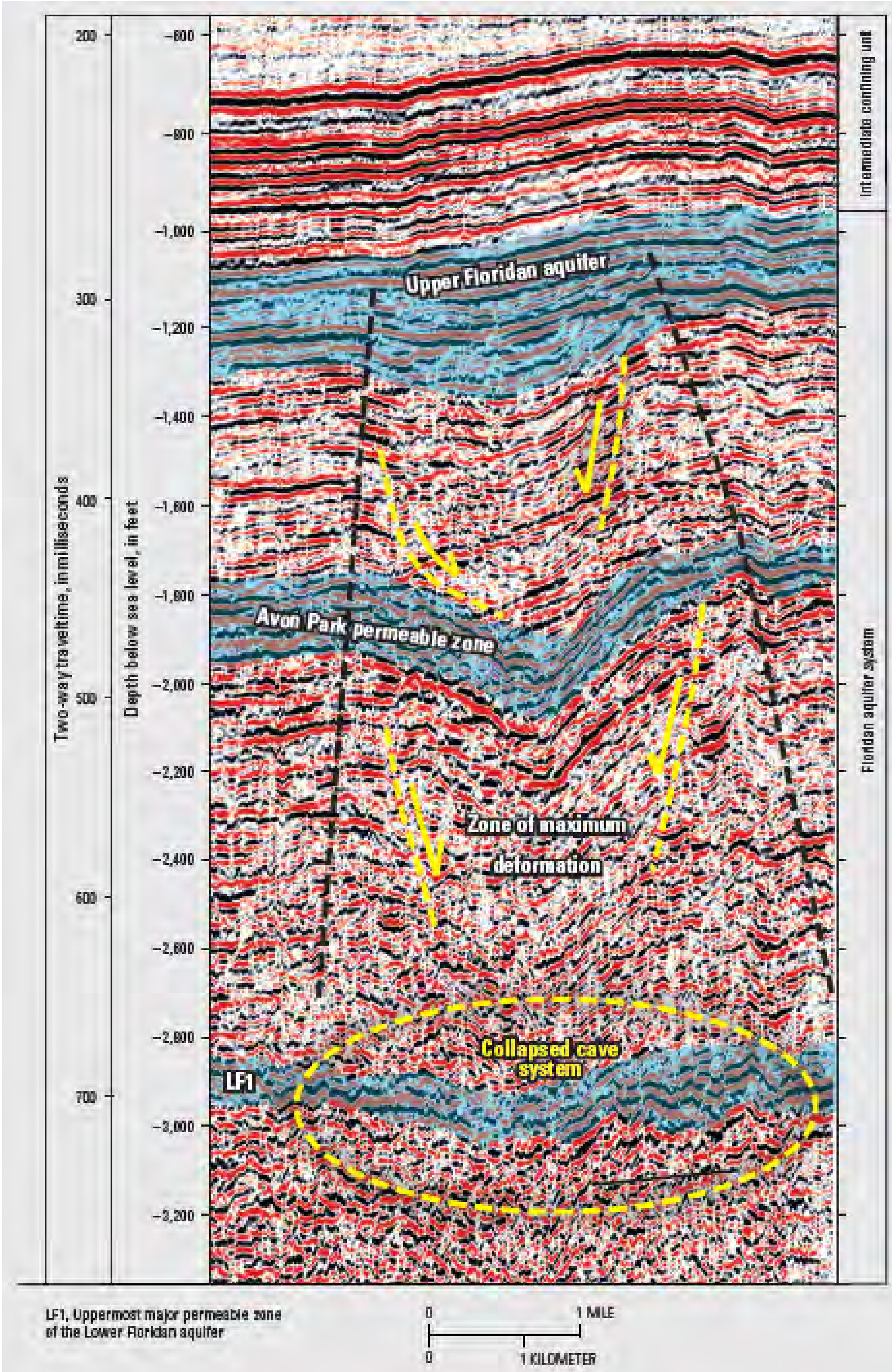


Figure 2.5.1-9. Cunningham (2015) Seismic Sag structure

Regional Stratigraphy

Turkey Point Units 6 and 7 CO FSAR Section 2.5.1.1.1.2 describes regional stratigraphy in the site region covering Florida, the Bahamas Platform, and Cuba. The staff focused the review on the Cenozoic stratigraphy of Florida, which includes the peninsula, the platform, and the offshore continental slope and shelf. The staff focused in particular on the Quaternary and Holocene stratigraphy.

Florida Stratigraphy

1. Quaternary Formations

The applicant described Quaternary formations in southern Florida including the Pliocene-Pleistocene Thompson Formation with the overlying Pleistocene Key Largo Limestone. The Key Largo Limestone is the highly porous, permeable, and part of the Biscayne surficial aquifer system. The Pleistocene Miami Limestone, which overlies the Key Largo Limestone, is the uppermost Quaternary unit in the Site area and is mostly marine limestone.

2. Holocene Sediments

The staff focused its review of Florida stratigraphy on the youngest units in the site region. Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.2.1.1 states that the Holocene sediments in Florida occur near the present coastline at elevations generally less than 1.5 m (5 ft) above sea level. Because of the scouring effect of hurricanes in southern Florida, Holocene sediment sequences are preserved only in protected depositional environments. The applicant described the Holocene record of southern Florida based on: deposits preserved in Blackwater Bay on the southwest Gulf coast of Florida; deposits preserved in Sarasota Bay and Little Sarasota Bay on the west-central Gulf coast of Florida; deposits preserved in Whitewater Bay near Cape Sable, on the southern tip of Florida; and the hurricane-disrupted deposits of Biscayne Bay, on the southeastern coast of Florida. In RAI 41, Question 02.05.01-7 (ADAMS Accession No. ML11293A202) dated October 20, 2011, the staff asked the applicant to provide a figure that illustrates the location of these deposits. In an October 3, 2014 response to RAI 41, Question 02.05.01-7 (ADAMS Accession No. ML14282A073), the applicant provided a map showing the distribution around the southern tip of Florida where these study sites are located with respect to the Turkey Point Units 6 and 7 site. Accordingly, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 41, Question 02.05.01-7, resolved.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.2.1.1 indicates that the general history of sea-level transgression and regression during the Holocene is based on deposits preserved in Blackwater Bay on the southwest Gulf coast of Florida and that a significant sediment layer (Unit D) (1000–1090 years before present) is found in all these cores at the same elevation, and that this may be the result of a storm deposit or series of storm deposits. In RAI 41, Question 02.05.01-6 (ADAMS Accession No. ML11293A202) dated October 20, 2011, the staff asked the applicant to provide more detail to confirm that these deposits are storm deposits rather than a Holocene tsunami deposit.

In an October 3, 2014 response to RAI 41, Question 02.05.01-6 (ADAMS Accession No. ML14282A073), the applicant stated that there are no reliable sedimentological criteria for distinguishing paleo-tsunami and paleo-storm deposits in various environments, as both can generate identical depositional processes and related sedimentary features. Southern Florida

Holocene sediment sequences are preserved only in protected depositional environments (i.e., in areas that have a dense mangrove forest), and the Turkey Point site does not have that protected depositional environment, therefore, erosion (wave action) would have likely removed any "paleostorm" deposit(s). Studies by Tuttle et al. (2004), Morton et al. (2007), and Lowery (2002) in southwest Florida, in protected Blackwater Bay, identified a Unit D sediment layer. The applicant interpreted Unit D as a possible storm deposit or a series of storms that date 1,090 years before present. The radiometric age dates of the sediments correspond to the Medieval Warm Period. The interpretation is that the warm conditions are associated with increased hurricane activity or a higher frequency of major hurricanes in the tropical North Atlantic and Caribbean Sea.

The staff reviewed the response and notes the lack of dense mangrove forest and the conditions to preserve paleostorm deposits are not present in the Turkey Point Units 6 and 7 area. In regard to paleo-storm or -tsunami deposits in the Holocene deposits at the Turkey Point Units 6 and 7 site, the staff reviewed the Turkey Point Units 6 and 7 site exploration data provided in SER Section 2.5.1.4.2 and concurs that distinguishing paleo-storm from paleo-tsunami is difficult because similar sedimentary features can arise under both conditions. Accordingly, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 41, Question 02.05.01-6, resolved.

<u>Regional Tectonic Setting</u>

The regional tectonic setting for the Turkey Point Units 6 and 7 site and beyond includes the long standing, stable carbonate/siliciclastic continental margin (Florida Peninsula and Platform and the Bahamas Platform); the complex orogenic terranes of Cuba; the intervening Straits of Florida and Santaren channel; and the complex and distant Caribbean plate boundary. The staff focused its review on the tectonic structures that are within the 320 km (200 mi) radius of the site region, the structures that are the most relevant to the hazard assessment, and the tectonic structures that are potentially Quaternary-aged (Figure 2.5.1-4).

As stated previously, the applicant used the EPRI-SOG model for the PSHA, and developed a unique seismic source model for Turkey Point Units 6 and 7 to include the North American-Caribbean plate boundary and the island of Cuba as an areal source. The northern flank of Cuba is the site of a relict plate boundary from the Eocene and has small to moderate size earthquakes. Cuba also has many mapped faults of various age, some of which might be Quaternary. The staff conducted its own independent literature review of the geology and tectonics of Cuba. This information led the staff to develop several RAIs regarding tectonic setting in Cuba and nearby offshore regions.

<u>Contemporary Stress Regime in Region</u>

The Turkey Point Units 6 and 7 COL FSAR describes the two contemporary stress provinces within the site region: the mid-plate province and the Gulf Coast Province. Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.4 states that the boundary between the mid-plate and Gulf Coast stress provinces terminates in the northern Florida Peninsula, and there is a lack of stress data from areas near the Florida Peninsula and most of Cuba. Because the southern Florida Peninsula does not reveal the salt-rooted normal growth faults associated with the north and northwest portions of the Gulf Coast, the site region is generally interpreted to be part of the mid-plate stress province.

In RAI 41, Question 02.05.01-20, the staff asked the applicant to address questions about boundaries of contemporary stress within the site region between the mid-plate, Gulf Coast stress provinces and the area of Cuba. Specifically, the staff asked the applicant to:
(a) address the focal mechanism for the September 2006 Gulf of Mexico earthquake with respect to the Gulf Coast stress province, (b) indicate the boundary between the Gulf Coast and mid-plate stress provinces as currently interpreted, and (c) indicate on a map how the Gulf Coast and mid-plate stress provinces resolve in the vicinity of northern Cuba.

In an October 3, 2014, response to RAI 41, Question 02.05.01-20, Part a, the applicant explained that the Gulf Coast stress province is characterized by northeast-southwest to north-northeast to south-southwest horizontal tension, driven by sediment loading and subsidence of the gulf. The resulting "typical" faults in this regime are down-to-the-gulf growth faults in Cenozoic cover sediments that glide over a weak salt layer, the Louann formation (e.g., Wu et al., 1990). The focal mechanism for the September 10, 2006, Gulf of Mexico earthquake is representative of a thrust fault along a steep northwest-striking fault plane, with a compression principal stress direction oriented at 214 °, plunging 19 °. The staff notes that this is consistent with the mid-plate stress province of the CEUS, characterized by northeast-southwest compression driven by forces originating at the mid-Atlantic Ridge, rather than the Gulf Coast stress province. The applicant stated that the September 10, 2006, earthquake was produced by basement faulting beneath the Louann salt formation (Angell and Hitchcock, 2007). The earthquake epicenter is at 22 to 31 km (13.6 to 19.2 mi), beneath the 5 to 14 km (3.1 to 8.7 mi) of sedimentary cover in the gulf (with its associated stresses). Therefore, stress orientation on basement faults in the Gulf of Mexico would align with the rest of the CEUS. The original EPRI-SOG seismic source zones within the site region were updated to account for the September 10, 2006, Emb 5.90 Gulf of Mexico earthquake.

In response to part b, the applicant replied that there is little stress data available near the Florida peninsula and Cuba to determine a stress province boundary, and the Florida Peninsula and platform lack the growth fault features characteristic of the Gulf Coast stress province. The applicant stated that the Gulf Coast stress province does not extend to the Turkey Point Units 6 and 7 site region. The staff notes that given the lack of stress orientation data, and Florida and bathymetric features that do not indicate growth fault systems, the extension of Zoback and Zoback's (1991) Gulf Coast boundary into the Florida Peninsula is not justified and thus agrees with the applicant that there is insufficient evidence to determine the boundary of the stress province.

In response to part c, the applicant stated that based on the absence of growth fault systems they would not interpret the Gulf Coast stress province to extend further south toward Cuba. The applicant also stated that focal mechanisms associated with north Cuba seismicity are lacking, therefore, the applicant concluded that the stress orientation data are inadequate in the site region to reliably determine if stress differences exist between Cuba and the Florida platforms.

The staff concludes that there is insufficient stress orientation data within the Turkey Point Units 6 and 7 site region to justify drawing a distinct boundary between the Gulf Coast and the Mid-plate stress provinces as well as a boundary between Florida and Cuba. In addition, based on the bathymetric character of the Florida platform (no growth fault systems), there is no justification to extend the Gulf coast stress province into the Turkey Point Units 6 and 7 site region. Accordingly and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 41, Question 02.05.01-20, resolved.

Principal Regional Tectonic Structures

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.3.2 originally stated that the site region has generally recorded only sedimentary processes since Mesozoic rifting, with exception of tectonic activity associated with the collision of the Greater Antilles Arc with the Bahamas Platform during Cretaceous to Eocene (~34 Ma) time. The staff notes that the Walkers Cay fault, the Santaren Anticline, and the Straits of Florida normal faults all occur within the site region and show evidence for post-Eocene tectonic activity. Therefore, the staff asked the applicant in RAI 41, Question 02.05.01-11, to update the discussion to clarify the timing and location of all tectonic features in the site region and place them into the regional tectonic setting. In response to RAI 41, Question 02.05.01-11 (ADAMS Accession No. ML14282A074), the applicant replied with a brief description of each feature and referred to further details in additional RAI responses that are specific to each feature (Questions 02.05.01-14, -15, -16, -34, and -36). The staff provides its evaluation of these structures and features in the following paragraphs.

1. Structures in southern Florida Peninsula

The staff independently sought out and reviewed many publications pertaining to the Turkey Point Units 6 and 7 COL FSAR review and found a recent short paper (Cunningham et al., 2012) that reveals normal and reverse faults in Biscayne Bay and the shelf margin, within 11.3 km (7 mi) of the site, based on approximately 210 km (130 mi) of high-resolution marine seismic data. One of these faults is identified on 5 seismic lines and extends about 16 km (10 mi), striking N, NE (Figure 2.5.1-10). The authors interpret this fault as a vertical normal fault offsetting the top of the Arcadia Formation. The staff notes that the fault projects directly toward the Turkey Point Units 6 and 7 site. Because the fault appears to offset the top of the Arcadia Formation, the age of movement might be as young as early Pliocene (5.3 Ma). The staff also notes that this tectonic structure is not included in the Turkey Point Units 6 and 7 COL FSAR. In RAI 81, Question 02.05.01-36, the staff asked the applicant to discuss this tectonic feature with respect to the Turkey Point Units 6 and 7 site, and integrate the information into the regional tectonic setting. The staff also asked the applicant to address the possibility that the fault is strike-slip and finally to address the possibility that this fault underlies the Turkey Point Units 6 and 7 site, and what impact if any does this have on potential surface deformation.

In a May 19, 2015, response to RAI 81, Question 02.05.01-36 (ADAMS Accession No. ML15156A616), the applicant cited a recent USGS Scientific Investigations Report (Cunningham, 2015) that includes additional information about the fault identified in Biscayne Bay. Cunningham (2015) extends the fault, as uncertain, an additional 30 km (20 mi) northward through a data gap to connect with a possible offset identified in seismic profiles at the Miami-Dade North District Boulder Zone Water Field. Cunningham (2015) now interprets this fault as strike-slip with a characteristic normal, dip-slip component (up to the east), with typically about 12 m (40 ft) of vertical separation. The youngest faulted strata are the Arcadia Formation (Miocene age). The author interprets the top of Peace River and Tamiami formation (Pliocene) strata as unfaulted. Movement on the fault is thus interpreted to be within mid Miocene to early Pliocene, meaning no movement in the last 3.6 Ma.

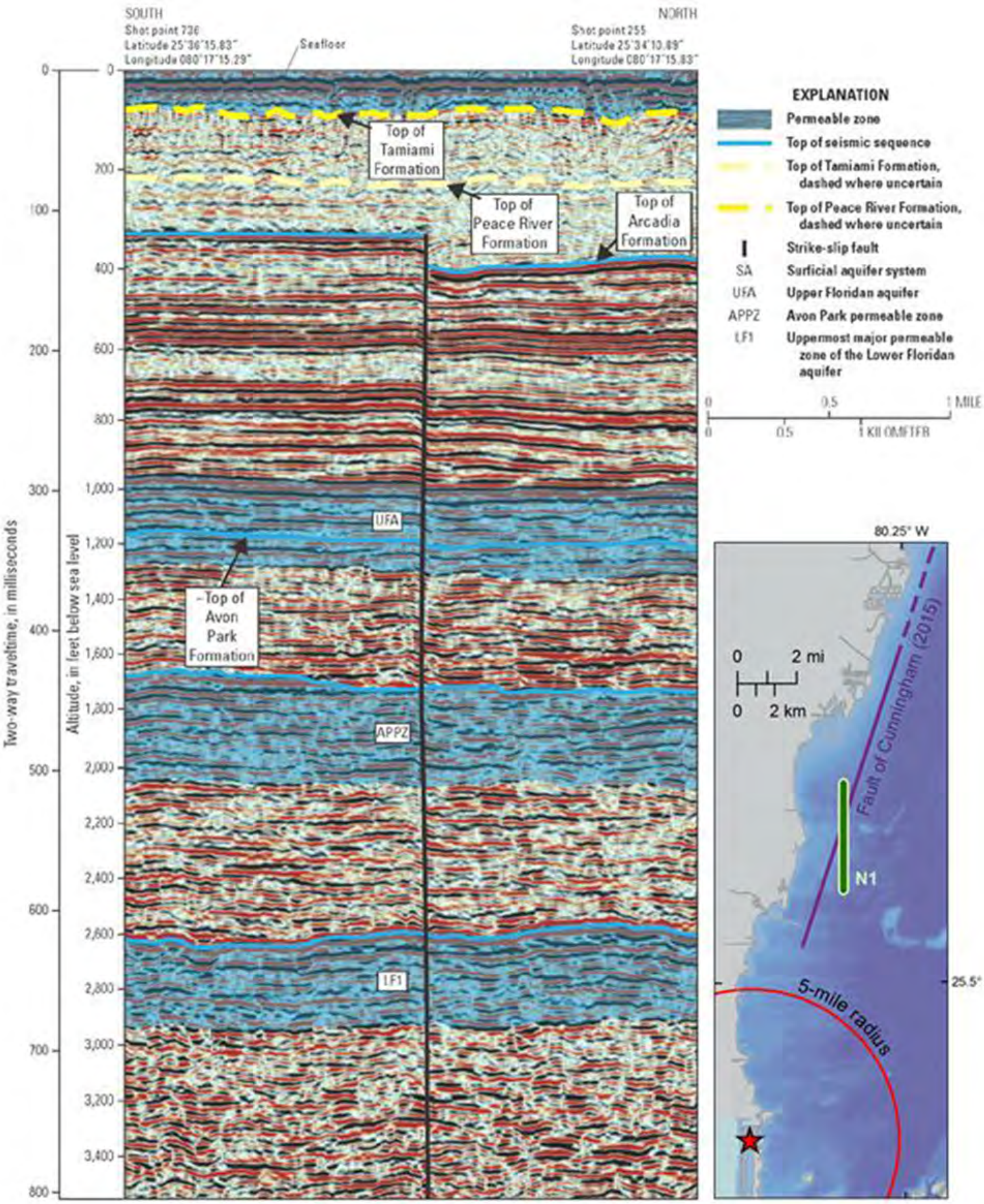


Figure 2.5.1-10. Strike-slip fault (unnamed) in Biscayne Bay (Source: Turkey Point Units 6 and 7 FSAR Figure 2.5.1-393, Cunningham et al., 2012 and Cunningham, 2015).

The applicant acknowledged that insufficient information exists to definitively exclude the possibility that this fault underlies the Turkey Point Units 6 and 7 site. The applicant stated that

Cunningham (2015) indicates the fault does not cut post-Arcadia strata, indicating no movement in the last 3.6 Ma. The applicant also stated that there are no earthquakes associated with the fault trace and no nearby potential Quaternary tectonic structures or capable faults. The applicant concluded that even if the fault underlies the Turkey Point Units 6 and 7 site, it is not a capable tectonic source and does not pose a surface rupture hazard at the site.

The staff notes that pure strike-slip faults will not show offset strata in cross-section, which might be a challenge with determining the final age of movement. However, in the case of this fault, there is a persistent characteristic of a slip component of normal offset in the seismic reflection images. The staff considers that fault movement more recent than 3.6 Ma would also likely reveal some dip-slip offset in younger strata, therefore, the staff concurs with the applicant that fault movement is no younger than about 3.6 Ma.

The staff consider tectonic structures younger than the Quaternary boundary (greater than 2.6 Ma) to be more likely to move or deform in the future than older tectonic structures (SRP 2.5.1), therefore, the staff focus on the technical bases for any conclusion regarding Quaternary tectonic features. This consideration is also rooted in the capable tectonic source definition in RG 1.206 where a structure known to be at least pre-Quaternary, in the absence of other conflicting evidence, can be taken as not a capable tectonic source. The staff notes that Cunningham's seismic reflection images consistently show a fault that does not disturb or deform sediments younger than the Peace River and Tamiami Formations. The staff also notes that the offset on the top of the Arcadia Formation would be positioned about 137 m (450 ft) below the surface of the Turkey Point Units 6 and 7 site. Therefore, the staff concludes that the fault is likely older than Quaternary and is not a surface deformation hazard to the Turkey Point Units 6 and 7 site, a finding in SER Section 2.5.3. The staff examined the earthquake catalog and agrees there is no seismic activity associated with the fault in Biscayne Bay. Therefore, in accordance with 10 CFR 100.23 and 10 CFR 52.79, RAI 81, Question 02.05.01-36, is resolved.

2. Miami Terrace anticline and reverse faults

The staff independently reviewed Cunningham (2015) and observed a tectonic anticline, located east of Miami, on the Miami Terrace, about 48.2 km (30 mi) from the Turkey Point Units 6 and 7 site that has not been previously discussed in the Turkey Point Units 6 and 7 COL FSAR. Cunningham (2015) clearly shows a tectonic anticline with uplifted truncated seismic reflections assigned to the top of the lower Arcadia Formation (Figure 2.5.1-11). Horizontal, buried wave-cut terraces on the flank of the anticline indicate uplift and erosion of the lower Arcadia Formation followed by deposition of late Pliocene or early Pleistocene-age sediments. The author suggests that this compression event is consistent with the timing of tectonic movement of the Santaren anticline, also considered a potential Quaternary structure. The staff also notes that this young tectonic structure is close to the Turkey Point Units 6 and 7 site and has not been previously characterized in the Turkey Point Units 6 and 7 COL FSAR. Therefore, in RAI 85, Question 02.05.01-38, the staff asked the applicant to discuss this tectonic feature with respect to the Turkey Point Units 6 and 7 site, to integrate the feature into the regional tectonic setting for the Turkey Point Units 6 and 7 site COLA, and, finally, to discuss how this feature might affect the PSHA at the Turkey Point Units 6 and 7 site in light of sensitivity analyses completed for the Santaren Anticline and the Walker's Cay fault, 274 and 320 km (170 and 200 mi) from the Turkey Point Units 6 and 7 site, respectively.

In a July 15, 2015, response to RAI 85, Question 02.05.01-38, the applicant replied that Cunningham et al. (2012) and Cunningham (2015) report a group of five reverse faults and an anticline interpreted in seismic-reflection data on the offshore Miami Terrace, north-northeast of

the Turkey Point Units 6 and 7 site. The anticline is 43 km (27 mi) north-northeast of the Turkey Point Units 6 and 7 site and deforms strata through the Oligocene or early Miocene lower Arcadia Formation. The fold introduces approximately 152 m (500 ft) of relief on the top of the Avon Park Formation over a distance of approximately 2.4 km (1.5 mi) along one seismic profile. It is only imaged on one seismic line, therefore, the strike and extent are not determined. The reverse faults are 47 km (29 mi) northeast of the site, two of which offset seismic reflections in middle Eocene-age strata. Cunningham (2015) indicates that the reverse-fault movement occurred sometime within the Oligocene to early Pleistocene. Because the reverse faults were only imaged at one location, the strike and extent of these faults is undetermined.

The staff independently reviewed Cunningham (2015) and notes that he interprets late Pliocene- or early Pleistocene-age overlying sediments that downlap onto and overstep horizontal wave-cut terraces on the top of the lower Arcadia unconformity. He concludes that the contractional uplift and reverse faulting occurred sometime during the Oligocene to early Pleistocene. The staff notes that this indicates the possible age of deformation to be within the Quaternary Period (2.6 Ma to present). The staff also notes that Cunningham (2015) links these structures to the regional tectonic setting in that the timing of uplift and reverse faulting in southeastern Florida postdates intense northerly directed thrust movement during the Cuba orogeny, but may coincide with later possible contractional deformation episodes recorded in the Bahamian foreland of the Cuban Fold and Thrust Belt. Furthermore, Missimer and Maliva (2004) report tectonic folding deformation in southern Florida and attribute that to episodic interactions between the Caribbean and North American plates southeast of the Florida Platform during the late Miocene and early Pliocene. The staff notes that the timing of reverse-fault movement into early Pleistocene is also compatible with the timing of the majority of fold uplift of the Santaren Anticline (Masaferro et al., 1999 and 2002), which is considered by some investigators as part of the Cuban Fold and Thrust Belt and is discussed in the staff's evaluation of RAI 41, Question 02.05.01-15 (Santaren Anticline).

In addressing the staff's question regarding the Miami Terrace structures' effect on the Turkey Point Units 6 and 7 site's PSHA (RAI 85, Question 02.05.01-38), the applicant cited Appendix A to RG 1.208 definition of a capable tectonic source and stated that because the uppermost deformed strata observed in the anticline and reverse faults is the Oligocene to Miocene Arcadia Formation, the structures are not considered to be capable tectonic features. The applicant pointed out that there is only one Emb 2.70 earthquake in the project Phase 1 earthquake catalog, including dependent events, located approximately 10 km away from the Miami terrace structures. Thus, there does not appear to be an association of seismicity with these structures. Therefore, the applicant stated that the reverse faults and fold reported by Cunningham et al. (2012) and Cunningham (2015) are not capable tectonic sources and would not affect, and should not be included in, the PSHA for the Turkey Point Units 6 and 7 site.

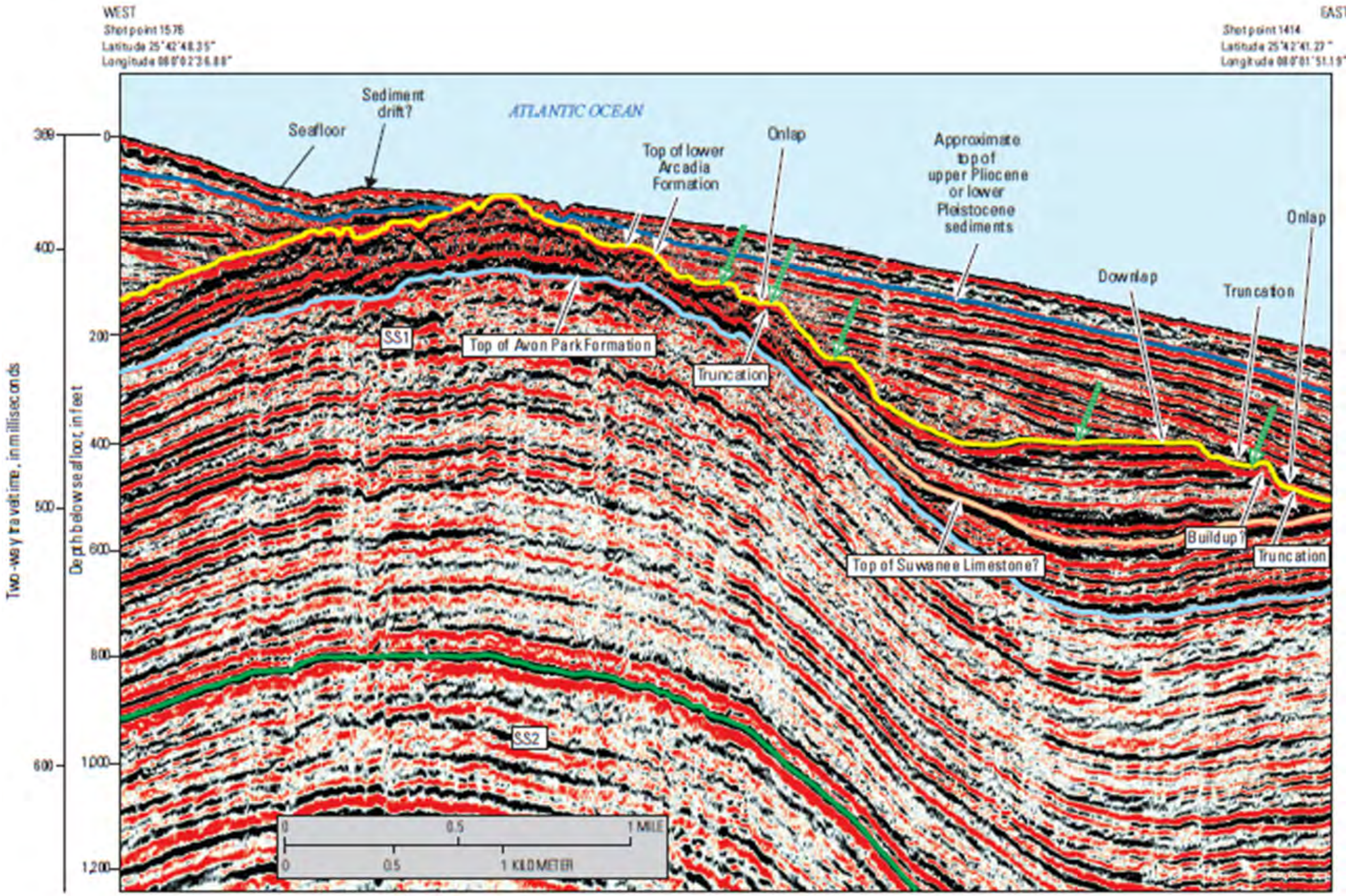


Figure 2.5.1-11. Miami Terrace anticline from Cunningham, 2015 (Source: Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-395)

The staff points out that Cunningham concluded that the structures were formed sometime during the Oligocene to early Pleistocene. The Pleistocene Epoch (2.6 Ma to 10,000 years before present) is part of the Quaternary Period (2.6 Ma to the present). Cunningham associates this deformation event with other Oligocene through Pliocene, and into Quaternary-age, deformation in the region that researchers have suggested for structures such as: the Santaren Anticline and associated structures; the Bahamian contraction and tilting (Masafero et al., 1999; Mulder et al., 2015; Austin et al., 1988; Bergman, 2005), and Miocene through Pliocene folding deformation in scattered locations in southern Florida (Missimer and Maliva, 2004). Missimer and Maliva report fold relief on the order of 70 m. The staff notes that this group of geologically young structures within the Turkey Point Units 6 and 7 site region should also include Walkers Cay fault off of Little Bahama Bank (discussed in the staff's evaluation of RAI 41, Question 02.05.01-14). Thus the staff notes that there are several tectonic structures within the Turkey Point Units 6 and 7 site region that indicate Oligo-Pleistocene tectonism that is not directly related to the current North American-Caribbean plate boundary.

Based on Cunningham's (2015) conclusion of Plio-Pleistocene deformation, the staff does not agree with the applicant's determination that the structures on Miami Terrace are definitively "not capable tectonic sources." To assess the potential significance of the Miami Terrace anticline for the site-specific seismic hazard, the staff conducted a PSHA sensitivity analysis using the NRC-endorsed ground motion models (EPRI, 2013). The details of this sensitivity analysis are provided in SER Section 2.5.2.4.4. The staff developed hazard curves using a wide range of alternative slip rates that could be considered small-to-large for this tectonic region (e.g., 0.01, 0.05, 0.1, 1.0, 10.0 mm/yr). A slip rate of 10 mm/yr would be expected along a plate boundary, such as the North American-Caribbean plate boundary and is not a realistic slip rate for this region. An uplift rate of 0.05 mm/yr was determined for the Santaren Anticline (Massaferro et al., 2002), and the applicant translated this to a slip rate of 0.071 mm/yr (assuming a fault dip angle of 45 °) for its sensitivity analysis of the Santaren anticline. For the Miami Terrace anticline, assuming it is cored by a vertical fault, with 152 m (500 ft) of vertical uplift in 1 Ma, the rate might be about 0.15 mm/yr, and for a 2 Ma time period the slip rate would be about 0.07 mm/yr (or 0.1 mm/yr on a 45-degree dipping fault). A fault length of 15 km (9.3 mi) is based the thickness of the seismogenic crust, and the closest distance to Turkey Point Units 6 and 7 site is 43 km (27 mi). The calculated seismic hazard from these slip rates was compared to the seismic hazard for the Turkey Point Units 6 and 7 site over a range of frequencies (0.5 to 100 Hz). Based on these assumed slip rates and geometries, the fault cored anticline would not affect the Turkey Point seismic hazard significantly (greater than 1 percent of total hazard) unless slip rates on this fault far exceed 1 mm/yr. Estimated slip rates on nearby tectonic structures appear to be much less than 1 mm/yr, which is consistent with the staff's understanding of the tectonic setting of this region. Based on the results of the sensitivity analysis, the staff concludes that the Miami Terrace anticline and associated reverse faults are not a contributor to site hazard. Accordingly, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 85, Question 02.05.01-38, resolved.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.3.2.1 originally stated that variations in pre-Miocene stratigraphy, as recorded in boreholes, is due to erosion-based paleotopography or karst rather than possible faulting (e.g., the queried fault in Cunningham et al. (1998)). The staff notes that the fault, on the southern tip of the Florida peninsula, strikes essentially east to west, toward the Turkey Point Units 6 and 7 site. Cunningham et al. (1998) indicates that the Long Key Formation is offset against the Arcadia Formation, and the Arcadia Formation is offset against the Avon Park Formation. A structural contour map of the top of the Arcadia formation and a map of net thickness of Miocene-to-Pliocene siliciclastic sand appears to be consistent

with faulting. In RAI 41, Question 02.05.01-12, the staff asked the applicant to substantiate its interpretation with specific evidence that the stratigraphic relations across the queried fault shown by Cunningham et al. (1998) are a result of paleo-topographic or karst processes, rather than tectonic offset.

In an October 3, 2014, response to RAI 41, Question 02.05.01-12 (ADAMS Accession No. ML14282A074), the applicant replied that although Cunningham et al. (1998) shows a possible fault in a borehole-based cross section, a structure contour map on top of the Arcadia Formation, and an isopach map, there is no specific discussion of the fault in the text. Of the two wells on either side of the fault that show about 100 m (328 ft) of offset on top of the Arcadia Formation, one well has critical data gaps in intervals including the Arcadia Formation. Furthermore, the top of the Arcadia Formation is a known regional unconformity with geologic formation thickness and relief variations of 200 m (656 ft) and 90 m (295 ft), respectively (Warzeski et al., 1996; Missimer, 2001). The influence of the Arcadia Formation paleotopography on subsequent carbonate and clastic deposition in southernmost Florida is recognized in McNeil et al. (2004) and Hine et al. (2009). Hine et al. (2009) attributes as much as 100 m (328 ft) of relief over distances of kilometers to tens of kilometers on the top of the Arcadia Formation in west-central Florida to a mid to late Miocene sea-level lowstand that caused dissolution in the deeper carbonates, such as the Arcadia Formation, and formed paleotopographic depressions and non-tectonic deformation in the Arcadia Formation. The applicant concluded that while the fault in Cunningham et al. (1998) is a potential explanation of the cause of thickness variations, paleotopography is a possible alternate explanation.

The staff independently reviewed Cunningham et al. (1998), the applicant's assessment of it and more recent publications. Because the fault was not discussed within the text as an investigated structure, the staff concludes that the fault was not presented as a confirmed, newly identified fault in southern Florida. Furthermore, the staff acknowledges that regional unconformities, such as the top of the Arcadia Formation, indicate subaerial erosion that can modify the original depositional surfaces and result in significant thickness variation and topographical relief along the contact surface. Accordingly, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 41, Question 02.05.01-12, resolved.

The applicant provided a proposed revision to the Turkey Point Units 6 and 7 COL FSAR to include portions of the RAI 41, Question 02.05.01-12 response. The staff finds the proposed revisions acceptable and has confirmed that these changes have been incorporated into the Turkey Point Units 6 and 7 COL FSAR.

3. Structures in the Straits of Florida, the Santaren Channel and the Bahamas Platform

Offshore southern Florida, within the 320 km (200 mi) radius of the site, includes the regional features of the Straits of Florida and the Florida peninsula submarine terraces, the Bahamas Bank, the drowned Cay Sal Bank, and the Santaren Channel, which is located between the Bahamas and Cal Sal banks.

A. Walkers Cay Fault

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.3.2.2 originally stated that Walkers Cay Fault is interpreted in seismic sections as both faulted and unfaulted above the Oligocene horizon, yet the Walkers Cay fault has minimal effect on middle Miocene and younger strata. The applicant concluded that because of the minor deformation of Miocene and younger strata, the Walkers Cay fault is a Tertiary structure, and consequently, not a capable tectonic structure.

In RAI 41, Question 02.05.01-14, the staff asked the applicant to provide further details for its conclusions, discuss fault offset up to the sea floor in light of the Austin et al. (1988a, 1988b) papers and discuss the seismic reflection profiles interpreted to be displacing the seafloor.

In response to RAI 41, Question 02.05.01-14 dated October 3, 2014 (ADAMS Accession No. ML14282A074), the applicant replied that there are five seismic reflection lines published in various papers that show the Walkers Cay fault or fault zone, located 320 km (200 mi) northeast of the Turkey Point Units 6 and 7 site: Van Buren and Mullins (1983), Harwood and Towers (1988), and Austin et al. (1988a, 1988b). In general, the fault strikes north to northeast and in some interpretations extends about 33 km (20 mi) and appears to be a normal fault. Van Buren and Mullins (1983) describe the fault as vertically displacing the Oligocene reflector by about 75 to 100 m (246 to 328 ft). The applicant stated that the fault does not appear to extend upwards to the seafloor. The data resolution near the surface, however does not allow for a definitive assessment of the fault tips. Harwood and Towers (1988) interpret the Walkers Cay fault on all five seismic reflection profiles. One seismic reflection line shows the Walkers Cay fault reaching the seafloor, but the majority of seismic lines appear to show fault deformation terminating at 1.3 to 1.5s (two-way travel time) just below the seafloor. Harwood and Towers (1988) indicate that the resolution of the data is 10 m (33 ft). Austin et al. (1988a) interprets brittle faulting in Profile LBB-17, within sequence G, and deformation continuing upwards as monoclinal folding into the upper stratigraphy, which they attribute to “synsedimentary movement.” They interpret the monocline to be the result of tectonic deformation that extends activity at least into the late Paleocene-early Eocene. In Profile LBB-18, a normal fault extends from above the carbonate platform top to the seafloor. This is the only profile that interprets faulting to the seafloor. The applicant noted that Austin et al. (1988a) does not discuss the amounts of offset in Quaternary strata.

Borehole data in the vicinity of these seismic profiles indicate that the Quaternary section is limited to a thin veneer. Pleistocene sediments are limited to approximately the uppermost 15.5 m, 3.6 m, and 18.2 m (51 ft, 12 ft, and 60 ft) (Austin et al., 1986a, 1986b, and 1986c, respectively). Thus, to definitively determine if the Walkers Cay fault is a Quaternary structure, seismic data would need to resolve displacement within approximately the uppermost 20 m (66 ft) of seafloor sediments.

The staff notes that the thickness of the Quaternary section, as measured in three Ocean Drilling Project (ODP) borings, ranges from 3.6 to 18.2 m (12 to 60 ft), and in conjunction with seismic reflection data resolution of about 10 m (33 ft), makes it difficult to accurately assess the presence or absence of Quaternary deformation on the Walkers Cay fault in those data.

The applicant concluded that considering all the data published to date, the possibility of Quaternary slip on the Walkers Cay fault cannot be precluded by the available data. For this reason, the applicant performed a hazard sensitivity calculation to assess the potential effect of a Walkers Cay fault source on the PSHA for the Turkey Point site.

As input parameters to the hazard sensitivity calculation, the applicant used a probability of activity of 1.0, a length of 33 km (20.5 mi), vertical dip angle and a rupture depth from 0 to 15 km (0 to 9 mi), maximum magnitude of Mw 6.8 with 0.2 uncertainty, and an upper, median, and lower bound slip rate distribution of 0.05 mm/yr, 0.01 mm/yr and 0.001 mm/yr, respectively. The largest weight in this slip rate distribution is accorded to a slip rate of 0.01 mm/yr, which appears to represent a limiting rate beyond which there would be a significant likelihood that vertical separations of Quaternary and Pliocene deposits would be sufficiently large to be observable within the presently available data.

The applicant stated that the results show that adding the Walkers Cay fault to the total hazard results in 10^{-4} mean annual frequency of exceedance (MAFE) amplitudes that are 0.3 percent higher at 1 Hz and 0.5 percent higher at 10 Hz, and annual frequencies of exceedance, at the Turkey Point Units 6 and 7 COL FSAR 10^{-4} MAFE amplitudes, that are 0.7 percent higher at 1 Hz and 1.0 percent higher at 10 Hz. The applicant concluded that the results of the hazard sensitivity calculation, based on the conservative seismic source characterization of the Walkers Cay fault, indicate that further consideration of the Walkers Cay fault for the Turkey Point site hazard is unwarranted due to its insignificant contribution to site seismic hazard, discussed in more detail in Section 2.5.2 of this SER.

The staff notes the research that reveals the Walkers Cay fault does not provide clear evidence of age of last movement on the fault. Although some authors indicate faulting to the sea floor, which would suggest Quaternary age for the fault, the resolution of the data and the continuity of seismic reflectors do not allow for a determination of the age of the last strata that the tip of the fault deforms in most seismic lines. In addition, the fault is about 320 km (200 mi) from the Turkey Point Units 6 and 7 site. The staff considers the results of the sensitivity analysis completed by the applicant to be a sufficient indication that the Walkers Cay fault is not a significant contributor to site seismic hazard. Accordingly, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 41, Question 02.05.01-14, resolved.

The applicant proposed a revision to the Turkey Point Units 6 and 7 COL FSAR to include portions of the RAI 41, Question 02.05.01-14 response. The staff finds the proposed revisions acceptable and has confirmed that these changes have been incorporated into the Turkey Point Units 6 and 7 COL FSAR.

B. Straits of Florida faults

The deep Straits of Florida, which also include the distinctive submarine Miami, Portales, and Mitchel terraces on the Florida side of the strait, separate Florida from Cuba. Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.3.2.2 originally stated that a series of short, steep normal faults exist in the western Straits of Florida southwest of the Turkey Point Units 6 and 7 site, and that middle to late Eocene to early middle Miocene strata were deposited uniformly over most of the southern Straits of Florida and also the edges of the Florida and Bahamas Platforms along the Straits of Florida. In RAI 41, Question 02.05.01-16, the staff asked the applicant to provide more details with respect to the timing and location of the faults located in the Straits of Florida.

In response to RAI 41, Question 02.05.01-16 (ADAMS Accession No. ML15065A070), the applicant provided a map of the Straits of Florida with the faults and the locations of seismic lines, and replied that deformation within the Straits of Florida is characterized by a series of short, steep, normal faults buried by Eocene sediments. Malloy and Hurley (1970) hypothesized faulting along some of the geomorphic escarpments in the central Straits of Florida, particularly the Pourtales escarpment and the Mitchell escarpment.

The applicant explained that more recent, higher resolution seismic imaging reveals the Pourtales escarpment and similar steep-sided escarpments throughout the Straits of Florida and Bahamas to be relict carbonate platform margins, sometimes modified by erosion, and associated with younger sediment drift, resting adjacent to the scarp. Along the base of the Pourtales escarpment, large drifts of sediment overlie the toe margin and have been prograding along the Straits of Florida since the Miocene. Where these drift deposits rest against the paleo-reef face, discordant dips are observed that were previously interpreted as potentially

fault-related. Two seismic lines that obliquely cross the Mitchell escarpment also display similar stratigraphic characteristics near the toe of the escarpment, with drifts resting against each other in the shallow stratigraphy and erosional truncations in the seismic reflectors that do not extend to depth. The applicant stated that little detail is available with respect to the hypothesized Las Villas and Sierra de Jatibonico structures offshore in Northern Cuba drawn by Malloy and Hurley on the basis of bathymetric data. More recent compilations generally do not depict offshore interpretations of these faults.

The applicant concluded that the Straits of Florida normal faulting is likely syntectonic deformation of the Cuban foreland basin during its Eocene collision with the Florida-Bahama Platform, and the undeformed Miocene and younger strata overlying these faults constrain deformation to Eocene. The staff notes that throughout the seismic reflection profiles provided by the applicant, the youngest faulting is constrained below a middle Miocene unconformity. Furthermore, the staff notes that Miocene and younger drift deposits are clearly expressed in the seismic reflection data as both geomorphological elements as well as discordant layering against the base of escarpments, but are not faulted contacts. Accordingly, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 41, Question 02.05.01-16, resolved.

C. Santaren Anticline

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.3.2.2 originally stated that the Santaren Anticline is Tertiary in age, predominantly active during the Eocene, with diminishing activity throughout the Miocene. The staff notes that Masaferro (1997), Masaferro et al. (2002), and Ball et al. (1985) present evidence that the Santaren Anticline, within the 320 km (200 mi) radius of the site, is cored by a thrust fault, and is potentially undergoing present-day shortening. The authors used stratigraphic analysis to infer Pliocene or potential Quaternary activity on the structure.

In RAI 41, Question 02.05.01-15, the staff asked the applicant to address evidence for possible ongoing deformation, to discuss rates of shortening calculated across the anticline (Masaferro et al., 1999), to examine regional seismicity on a close-up view of the Santaren Anticline, and to comment on whether the Santaren Anticline is a capable tectonic structure.

In response to RAI 41, Question 02.05.01-15 (ADAMS Accession No. ML15169A845), the applicant summarized the data and interpretations presented in the literature for ongoing deformation; rates of shortening; and the possible existence of a thrust fault that cores the Santaren anticline. The applicant cited Ball et al. (1985), which identifies the Santaren anticline as an approximately 10 km (6 mi) wide, 70 km (43 mi) long, northwest-trending structure and concludes that the structure was initiated during the Late Cretaceous and that maximum topographic relief occurred in the early Cenozoic. The authors further speculate that the Santaren Anticline is a hanging-wall anticline on the northern limit of thrusting in the Cuban arc, based on age, location, and asymmetry of the anticline, and the interpretation of a fault below 4 km (2.5 mi) depth.

Masaferro et al. (1999) uses seismic reflection data with well logs acquired during the ODP to provide a more detailed stratigraphic and structural analysis of the Santaren anticline, and conclude the Santaren anticline experienced fold growth from the Mid-Eocene to Pliocene and perhaps to the present day, although the youngest beds might be post-tectonic.

Masaferro et al. (2002) interprets the Santaren anticline to have had episodic tectonic growth and sedimentation since at least Oligocene time, with the most recent episode of tectonic uplift interpreted to have occurred in the early Quaternary (between deposition of beds M2 and M3, with a fold uplift rate of 0.05 mm/yr). The same study recognizes previous interpretations of the Santaren anticline as a fault-related fold or a detachment fold but do not provide any additional discussion or interpretation of fold-growth models for the Santaren anticline.

The applicant provided a close-up map view of the Santaren anticline and three unnamed fold axes directly to its southwest (Masaferro et al., 1999) along with earthquake epicenters from the Phase 2 earthquake catalog. Only two small earthquakes (Mw 3.26 and 3.1) with three dependent events (aftershocks) are indicated on the seismicity map, and there does not appear to be a spatial association with the Santaren anticline or the unnamed fold axes directly to the southwest. The applicant stated that Masaferro et al. (2002) shows no uplift on the structure in the last 1 million years and that, in conjunction with the sparse seismicity, would suggest that the Santaren Anticline does not represent a capable tectonic structure.

The staff notes that earthquake activity is sparse within about a 50 km (31 mi) radius of the Santaren anticline, and different structural frameworks to explain the Santaren anticline are found in the publications cited by the applicant. Masaferro et al. (2002) notes that Ball et al. (1985) suggests the Santaren anticline may be cored by a steeply dipping thrust fault, whereas Masaferro et al. (1999) interprets the Santaren anticline as a detachment fold but provide no further discussion of any postulated fault. However, the staff reviewed Bergman (2005) and finds that new data and interpretations regarding the Santaren anticline show thrust faulting in the core of the anticline as interpreted in the new seismic reflection data. Therefore, in RAI 81, Question 02.05.01-34, the staff asked the applicant to update and include the interpretation of the Santaren Anticline based on Bergman (2005).

In a July 15, 2015, response to RAI 81, Question 02.05.01-34 (ADAMS Accession No. ML15198A059), the applicant provided additional information on the Santaren anticline and other structural features in the Santarn channel based on recent publications, and conducted a sensitivity analysis of the Santaren anticline on the PSHA.

Masaferro (1997) and Masaferro et al. (1999 and 2002) quantified the fold geometry, growth strata, uplift history, and timing of deformation, suggesting that the Santaren anticline has been active at least since Mid-Eocene time to possibly Pliocene/present day. They indicate that the Santaren anticline is not an isolated structure, as a second anticline located to the south of the Santaren anticline has also folded much of the same sedimentary section. Echevarria-Rodriquez et al. (1991) interpreted a similar type of anticline to be an extension of the Santaren anticline.

The applicant assessed Bergman's dissertation work (Bergman, 2005), which describes the Santaren anticline as a detachment growth fold that "is underlain by a detachment horizon over which reflections are folded." Bergman interprets two imbricated thrust blocks located directly northwest of the Santaren anticline. Further to the northwest, at the northern margin of Cay Sal Bank, Bergman (2005) interprets steep normal faults bounding the drowned carbonate bank margins and a large, northeast trending, broad fold underlying the Cay Sal Bank region. Bergman (2005) concludes that loading of the North American plate migrated northward away from the Cuba collision zone and caused differential subsidence along the margins of the Santaren Channel. Later, Bergman (2015) concludes that thrust faulting and other compressional features associated with the late stage Cuba collision propagated as far north as the central Santaren Channel, which is farther north than previously estimated. These

compressional features of the Cuba-Bahama thrust belt were long-lived and one structure appears to be active into the late Miocene and possibly Pliocene.

The applicant stated that while a fault has yet to be imaged in the core of the relatively symmetrical Santaren anticline, this structure is a candidate for a potential seismic source because fold deformation appears to be Quaternary in age (Jo, 2013; Jo et al., 2015) and a fold uplift rate was determined for this structure (Masaferro et al., 2002). New high-resolution seismic data and subbottom profiles illustrate Quaternary growth strata and steeply dipping secondary faults associated with the Santaren anticline, further suggesting ongoing deformation of the anticline (Jo et al., 2015) (Figure 2.5.1- 12).

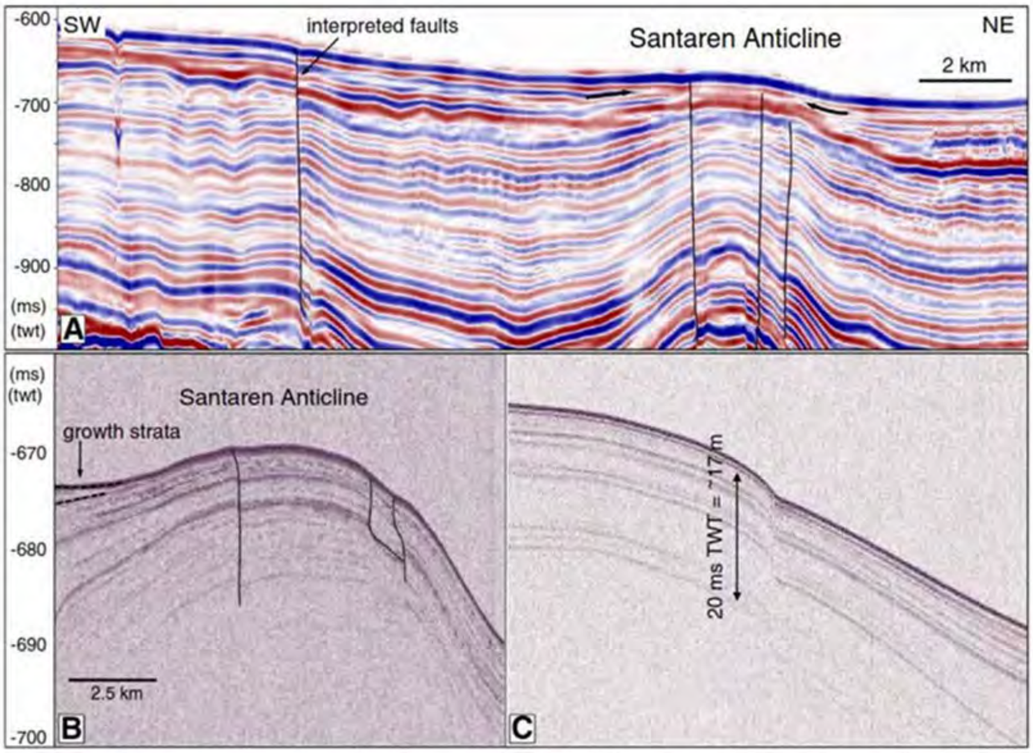


Figure 2.5.1-12. Santaren anticline and faults from Jo et al., 2015.

D. Santaren Anticline Fault Source Sensitivity Analysis

The applicant conducted a sensitivity analysis to assess the effect to the PSHA results from a Santaren anticline fault source. Details of the calculation are evaluated in SER Section 2.5.2. For the sensitivity analysis, the applicant conservatively assumed that the anticline is cored by a seismogenic fault and the fault source follows the northernmost surface trace of the Santaren anticline, as depicted in Masaferro et al. (1999).

The results of the sensitivity analysis consist of quantification of the increase in hazard and ground motion amplitude at annual frequencies of exceedance (AFEs) of 10^{-4} and 10^{-5}, for frequencies of 1 Hz and 10 Hz. The applicant used the Hicacos fault source in Cuba as a proxy for magnitude and distance to assess the sensitivity of the Turkey Point Units 6 and 7 COL FSAR PSHA to a Santaren anticline seismic source. The applicant's assessment determined a slip rate of 0.037 mm/yr for the Hicacos fault source and a 0.071 mm/yr for the Santaren

anticline fault source. The applicant found that the ground motion amplitudes at AFEs of 10^{-4} and 10^{-5} increase by 0.8 to 3.5 percent, with increases in ground motion amplitudes ranging from approximately 0.0006 to 0.003 g for AFEs of 10^{-4} and 10^{-5}. The staff concludes that based on this limited effect on the Turkey Point Units 6 and 7 PSHA total hazard, the Santaren Anticline is not a seismic hazard to Turkey Point Units 6 and 7 site.

E. Possible Quaternary faults off Cay Sal Bank

The staff reviewed Kula (2014) and notes that the author includes interpretations regarding possible Quaternary tectonic faults along the western bank of the northern Santaren Channel (northeast of the Cay Sal Bank). High resolution seismic reflection, multibeam bathymetry and sub-bottom parasound profiles reveal Quaternary-aged tectonic structures in the Santaren Channel and the Straits of Florida within about 50 mi of the Turkey Point Units 6 and 7 site (Figure 2.5.1-13). Although there is no seismicity in the area beneath Cay Sal Bank and the Santaren Channel, distinct seafloor scarps suggest recent and significant displacement on faults imaged on seismic reflection. In RAI 81, Question 02.05.01-34, the staff asked the applicant to discuss and integrate these tectonic features into the regional tectonic setting for the Turkey Point Units 6 and 7 site. The staff asked the applicant to provide an analysis of how a northward extension of the Cuban Fold and Thrust Belt terrane with associated Quaternary fault displacement and seafloor scarps on at least two faults impacts the site seismic hazard assessment and seismotectonic boundaries. The staff also asked the applicant to update interpretations of the Santaren Anticline

In a July 15, 2015, response to RAI 81, Question 02.05.01-34 (ADAMS Accession No. ML15198A059), the applicant (1) reviewed Kula (2014), including interpretations and data (high resolution shallow seismic reflection and bathymetry) data, (2) obtained and interpreted six deep seismic reflection lines in the same area as Kula's interpretation, (3) completed a solicitation of expert opinion through a Senior Seismic Hazard Analysis Committee (SSHAC) level II study regarding a Quaternary tectonic fault off the northern Cay Sal Bank, and (4) discussed the Cuban areal source term for the Turkey Point Units 6 and 7 site in conjunction with different concepts of the Cuba Fold and Thrust Belt. The applicant specifically contacted Dr. Gregor Eberli, from University of Miami (Florida) who is an expert in carbonate bank research and is also D. Kula's thesis advisor. The applicant concluded that (1) Kula's interpretations are not technically defensible, (2) the deep seismic reflection lines show unfaulted seismic reflectors where Kula interpreted faults in the shallow section, and (3) that Dr. Eberli concurs with its position that there are no seismogenic faults in this area.

Based upon all the material that the staff reviewed related to this question, the staff decided to conduct its own seismic hazard sensitivity analysis. The applicant provided a synopsis of Kula's (2014) interpretation of four tectonic faults along the eastern margin of Cay Sal Bank, and her interpretation that these faults represent an extension of the Cuba Fold and Thrust Belt a few hundred kilometers farther north and east than previously mapped by others. Kula suggests neotectonic activity on two of these faults (Fault A and B) along the eastern margin of Cay Sal Bank and north to the Straits of Florida. Kula (2014) interprets that the faults extend in length

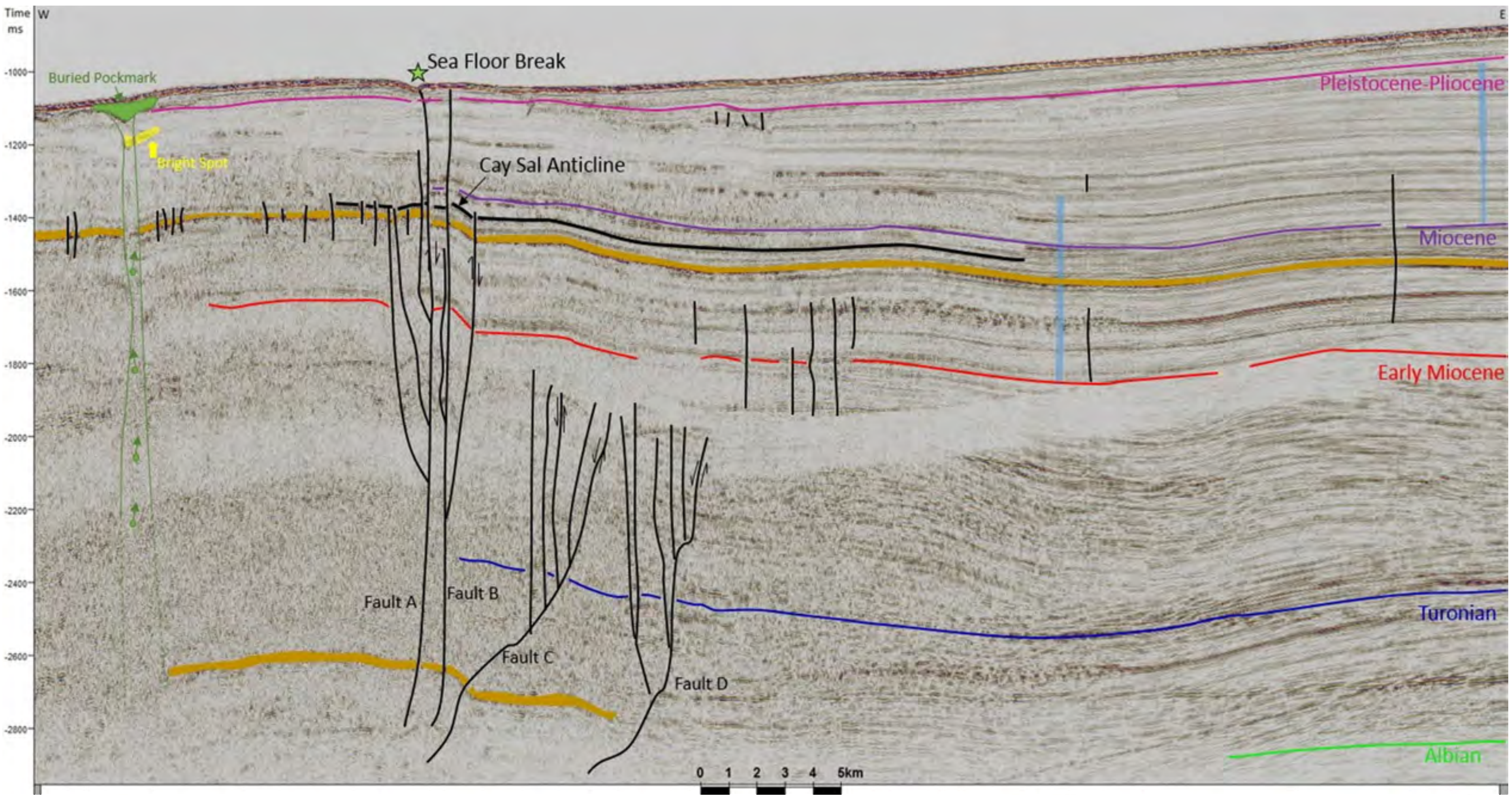


Figure 2.5.1-13. Profile 20 as interpreted from Kula, 2014.

from 41 km (25 mi) (Fault A) to 115 km (71 mi) (Fault B). Kula (2014) cites seafloor breaks in seismic profiles (profile 20, 22 and 24) and breaks in multibeam bathymetry data as evidence for neotectonic activity.

In addition, the applicant obtained and reviewed six high-energy, deep-penetration 2D industry seismic lines acquired from USGS National Archive of Marine Seismic Surveys that are located close to the high resolution lines used by Kula. These public domain data, collected during commercial survey cruises in 1981 and 1982, have somewhat lower resolution, in comparison to the new high resolution shallow 2013 data, but provide a much deeper view (up to 10 km (6.2 mi)) of potential fault structure. Images of some of these data are interpreted in prior publications in the region (e.g., Ball et al., 1985; Masaferro, 1997; Masaferro et al., 1999 and 2002; Bergman, 2005). The staff notes that vertical resolution is about 15 to 30 m (50 to 100 ft) in these seismic data.

The applicant completed a SSHAC Level II study of the potential Quaternary faults proposed by Kula as part of the response to Question 02.05.01-34b. As part of the SSHAC study, the Technical Integration (TI) team attempted to engage more than 20 researchers with potential knowledge of the new offshore data in the region. The TI team formed as part of the SSHAC Level II study examined the deep seismic lines from USGS and concluded that these data do not support Quaternary active faults along the eastern margin of Cay Sal Bank because continuous, unfaulted seismic reflections across the Santaren Channel and along the eastern flank of Cay Sal Bank are clearly apparent on seismic profiles that cross the faults mapped by Kula. The TI team further concluded that minor faults along the axis of the Cay Sal anticline (Bergman, 2005) do not penetrate below the top of the Miocene, which is less than 1 km below the seafloor (not seismogenic depth).

The staff audited the SSHAC material that the applicant provided in a reading room (April through July, 2015) (ADAMS Accession Nos. ML15321A134 and ML15243A420) and carefully considered remarks provided by Dr. Eberli in response to the TI team's expert solicitation, examined the extra seismic reflection lines provided by Dr. Eberli, and also examined USGS 1980 public domain seismic reflection lines evaluated by the applicant. The staff notes that Dr. Eberli was the only researcher who responded to the TI Team with detailed written statements and a report. The staff also independently reviewed several relevant publications including Kula (2014); Bergman (2005); Masaferro et al. (2002 and 1999); Jo et al. (2015); Mulder et al. (2013); Tourndour et al. (2015); and Missimer and Maliva (2004).

Dr. Eberli provided a written review of the preliminary TI Team interpretations of USGS deep seismic reflection profiles; answered the TI Team questionnaire; and provided additional, zoomed-in, high-resolution seismic profiles not presented in Kula's thesis. As part of his review of the TI team's interpretation of the deep seismic reflection from USGS, Dr. Eberli pointed out various small faults and anticlines in those data, not breaking the seafloor and not necessarily lining up with Kula's interpreted faults. Dr. Eberli stated that Kula's structural and neotectonic interpretations allow for some reinterpretations and provided comments on Kula's profile lines 20, 22 and 24.

Dr. Eberli re-interprets seafloor breaks interpreted as fault scarps by Kula on Profile 24 as the headscarp of a mass transport complex (MTC). The staff notes that Dr. Eberli made no specific re-interpretation of the vertical fault-like feature immediately to the west of the MTC. While the TI Team asserted that subsurface reflections are continuous and unbroken beneath the seafloor break, indicating the absence of a fault at that location, the staff observes broken reflectors and

tightly folded strata from the surface to the bottom of the profile, based on the additional seismic profiles that Dr. Eberli provided as part of his written statement (ADAMS Accession Nos. ML15321A134, and ML15243A420).

Dr. Eberli supports the fault interpretation for seismic profile 20. The TI team acknowledged that this fault zone of small displacement faults extends to the seafloor but stated that there is little apparent vertical separation of the Plio-Pleistocene horizon and concluded the feature in seismic Profile 20 is non-tectonic, and non seismogenic. However, the staff notes that strike-slip fault zones are not likely to show a lot of vertical separation in the strata.

The staff notes that Dr. Eberli stated in his written report to the TI team that: "The high resolution seismic lines shot in 2013 display reflection offsets that are indicative of Quaternary folding and faulting. Three lines (15, 20, and 22) image an asymmetrical anticlinal feature (Cay Sal anticline) that partly grows in the Quaternary strata. In conjunction with this anticline, faults extend into younger starta and at least in one location break the sea floor."

The staff also notes that Dr. Eberli concluded that Fault A on Line 20 is a wrench fault (strike-slip) with some dip slip motion that cuts to the seafloor and he considers this fault active. Dr. Eberli interprets the fault-cored fold of the Cay Sal anticline apparent on Profile 20 as part of a wrench fault system with components of both local compression and strike slip motion, and suggests it may be the far field expression of a lateral stress component along the American-Caribbean plate boundary. Dr. Eberli also noted that three seismic lines show anticlines within the Quaternary section thus indicating deformation in the Quaternary. Finally, Dr. Eberli stated that due to low resolution, USGS deep seismic reflection is not able to resolve faults with small offsets and, therefore, does not allow for precise interpretation of reflection offsets.

Based on its review, the staff cannot rule out the possibility that some of the features identified in Kula (2014) are tectonic in origin and Quaternary-age, particularly Fault A. To assess the potential significance of Fault A and the Cay Sal anticline for the site-specific seismic hazard, the staff conducted a PSHA sensitivity analysis using the most recent NRC-endorsed ground motion models (EPRI, 2013). The details of this sensitivity analysis are provided in SER Section 2.5.2.4.4. The staff developed hazard curves using a wide range of alternative slip rates along these faults (0.01, 0.05, 0.1, 1.0, 10.0 mm/yr). However, regional examples of slip rates of 10 mm/yr would only be expected along active plate boundaries, such as the Caribbean and North American plate boundary. A slip rate of 0.071 mm/yr is used by the applicant for the nearby Santaren anticline. The staff estimated a range of 0.15, 0.1, or 0.07 mm/yr for the Miami Terrace anticline.

For Kula's Fault A, the staff considered a vertical fault with 150 m (492 ft) of dip slip offset over a 2.6 Ma period resulting in an estimated slip rate of 0.057 mm/yr. In its sensitivity analysis, the staff used a fault length of 40 km (24.8 mi) and assumed the thickness of the seismogenic crust to be 15 km (9.3 mi). The closest distance of this fault to the Turkey Point Units 6 and 7 site is 77 km (48 mi). The staff then calculated the hazard contribution from this source using alternative slip rates and compared the calculated seismic hazard from the range of slip rates to the seismic hazard for the Turkey Point Units 6 and 7 site over a range of frequencies (0.5 to 100 Hz) and found that Fault A would not significantly affect the Turkey Point seismic hazard (greater than 1 percent of total hazard) unless slip rates on this fault far exceed 1 mm/yr. Since estimated slip rates on nearby Santaren anticline also appear to be less than 1 mm/yr, the staff considers the results of the sensitivity analysis to be a sufficient indication that the features as interpreted by Kula (2014) are not a contributor to site seismic hazard.

4. Cuba Fold and Thrust Belt and the Cuban Areal source term

In response to RAI 81, Question 02.05.01-34 (ADAMS Accession No. ML15198A059), specifically in regard to the boundary of the Cuba Fold and Thrust Belt, the applicant indicated that there does not appear to be a strict definition or boundary to the Cuba Fold and Thrust Belt in the literature, in terms of style, intensity, and magnitude of deformation. Two general views suggest the Cuba Fold and Thrust Belt as either an arcuate belt largely restricted to the island of Cuba or a broader interpretation that extends the margin eastward to the southern Santaren Channel to include the Santaren anticline. Bergman (2005 and 2015) extended this boundary northward in the Santaren Channel and Kula (2014) proposes that the boundary be expanded further to include the Cay Sal Bank.

The applicant stated that tectonic terranes and areas of similar geologic histories can assist in subdividing the crust into regional seismic source zones; however, the criteria for defining areal source zones are primarily the size, rate, and characteristics of future earthquake production. The Cuba areal source zone was defined to capture the higher rate of seismicity in Cuba and distinguish it from the very low rates of seismicity in the surrounding offshore regions of the site region covering the Bahamas and Straits of Florida (and the Cay Sal Bank), which are included in separate supplemental background zones. Therefore, the applicant concluded that there is no justification for expanding the Cuba areal source to include either the northern Santaren Channel or the Cay Sal Bank.

Based on the staff's hazard sensitivity on Kula's interpreted fault and the applicant's hazard sensitivity of the Santaren Anticline, the staff finds that there is sufficient indication that these features are not contributors to the site seismic hazard. With respect to the Cuba Fold and Thrust Belt, the staff notes that the specific boundary of the Cuba Fold and Thrust Belt would not necessarily define the Cuban areal source zone for the Turkey Point Units 6 and 7 site's PSHA. Based on distinct differences in seismicity rates, the staff agrees with the applicant that there is no justification for expanding the Cuba areal source to include the northern Santaren Channel and Cay Sal Bank. Accordingly and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 81, Question 02.05.01-34, resolved.

5. Tectonic Structures in Cuba

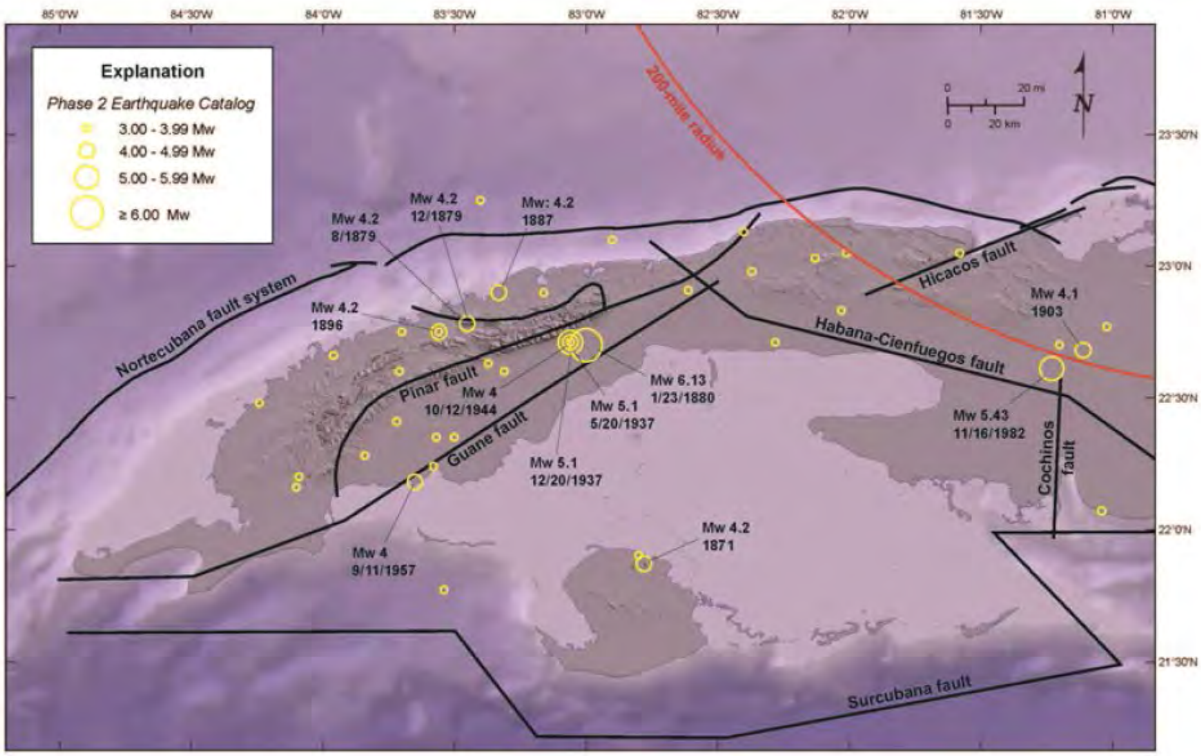
Within the 320 km (200 mi) radius of the site there are many mapped, potentially active faults on the island of Cuba and immediately offshore to the north as identified and discussed in various publications. There are also many small to moderate magnitude earthquakes that reveal a persistent history of recorded seismicity along the northern portion of Cuba separate from the modern plate boundary further south. However, the staff notes that the northern boundary of Cuba is the location of a Miocene age relict plate boundary. In addition to reviewing the references provided in the Turkey Point Units 6 and 7 COL FSAR, the staff independently reviewed other publications pertaining to tectonic features in Cuba that were not initially in the Turkey Point Units 6 and 7 COL FSAR and that became the basis of several RAIs.

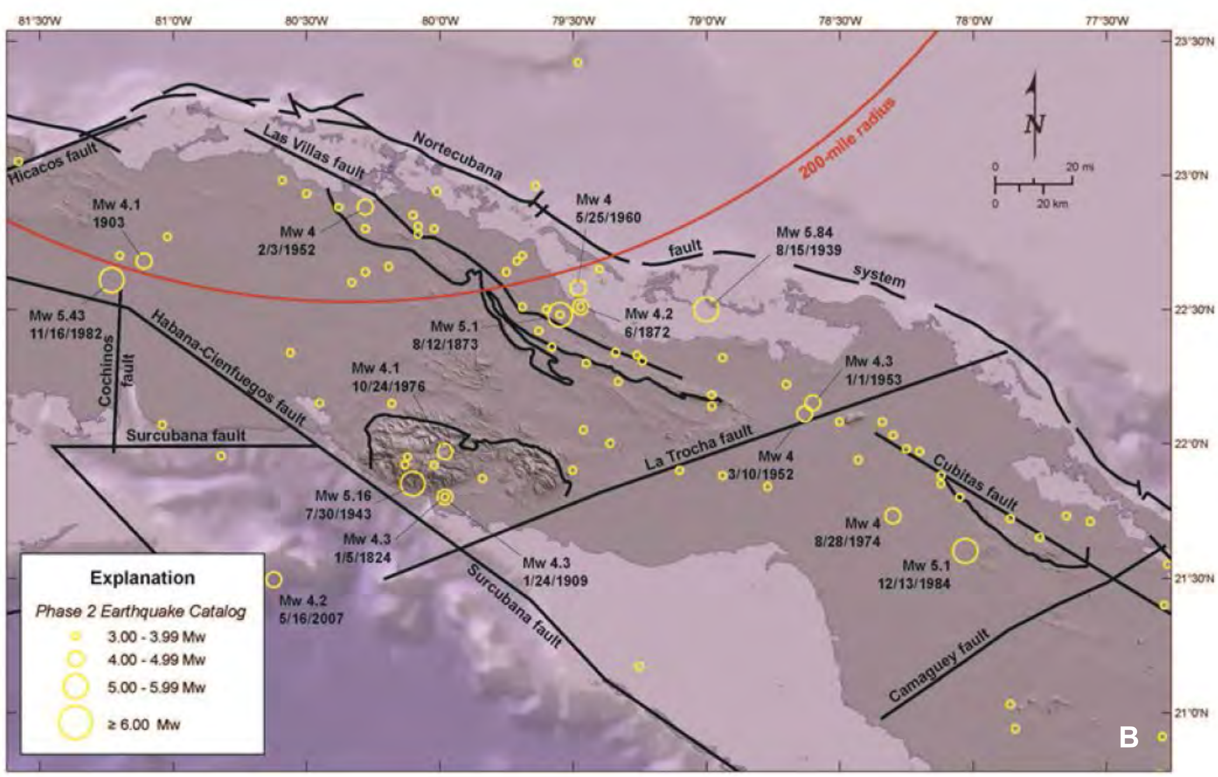
In response to several RAIs regarding Cuba faults and seismicity (RAI 41, Questions 02.05.01-21, -24 through 30) (ADAMS Accession Nos. ML14282A078. ML14282A079, and ML14282A079) dated October 3, 2014, the applicant made a general statement that the lack of permanent seismic recording stations in Cuba, especially for lower-magnitude earthquakes, limits the accuracy of earthquake locations; that earthquakes in Cuba do not appear to correlate strongly with faults; and the Phase 2 earthquake catalog was used to consider the possibility of seismicity associated with a specified fault (Figure 2.5.1-14). The staff notes that the Phase 2

catalog is declustered and includes earthquakes of Mw 3 and above. The staff also notes that aftershocks of an earthquake can be used to determine an image of a fault's subsurface rupture plane and subsequently used to identify the acting fault for the event. In RAI 81, Question 02.05.01-35, the staff asked the applicant to describe the rationale to use a declustered Phase 2 earthquake catalog to determine seismic activity associated with any Cuban faults, rather than the complete catalog.

In a June 8, 2015 response to RAI 81, Question 02.05.01-35 (ADAMS Accession No. ML15160A574) the applicant responded that a declustered or mainshock Phase 2 earthquake catalog was used to compute recurrence parameters for the Cuba seismic source characterization. The applicant agrees with the staff that in the Cuba region that mapping seismicity before the declustering earthquake process could be used in identifying potentially active, previously unidentified structures, if the earthquake association were unambiguous. Therefore, the applicant revised FSAR Figure 2.5.1-368 (Sheets 1 through 3) to include mainshock events of Mw and above 3.0, and foreshocks, aftershocks, and cluster events of Mw and above 3.0, and all small events mainshock and dependent events of Mw less than 3.0. The applicant also stated that the relevant text in Turkey Point Units 6 and 7 COL FSAR Section 2.5.1 will be revised accordingly. The applicant also stated that while the majority of the small-magnitude (Mw less than 3) seismicity is scattered and diffuse, seismicity patterns do show several clusters that are not part of the Phase 2 mainshock earthquake catalog Mw of 3 and above. Some of these earthquakes are not of sufficient size and definition to merit their consideration as fault sources. Other earthquake clusters are near faults that were included in a PSHA sensitivity study of the modeling of Cuba as a seismic source. The applicant concluded that when specific faults were considered as alternatives to the Cuba seismic source, they produced negligible impact on the total seismic hazard at the Turkey Point Units 6 and 7 site, as compared to the modeling of Cuba as a single areal seismic source zone (see FSAR Section 2.5.2.4.4.3.4.2.1). The staff evaluates the sensitivity analysis for the Cuba seismic source in RAI 41, Question 02.05.01-21 and RAI 5896, Question 02.05.02-4. Staff considers the revised Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-368 showing the total earthquake catalog of independent and dependent earthquakes sufficient response to this question and thus considers RAI 81, Question 02.05.01-35 resolved.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.4.4.3.2 states that an area source model is used for Cuba because of the lack of knowledge on fault behavior and slip rates for Cuban faults with which to support assessment of fault-specific sources. To evaluate the possibility of capable tectonic sources within the site region, in RAI 41, Question 02.05.01-21, the staff asked the applicant to provide a detailed geologic discussion of tectonic features of Cuba and their potential impact on the PSHA. In an October 3, 2014 response to RAI 41, Question 02.05.01-21 (ADAMS Accession No. ML14282A078), the applicant discussed the uncertainty and alternate interpretations of faults and tectonic features of Cuba, presented information on faults located within intraplate Cuba, and provided a hazard sensitivity calculation using Cuba faults as sources. The applicant also characterized the faults in intraplate Cuba including: Baconao fault, Camaguey fault, Cochinos fault, Cubitas fault, Guane fault, Habana-Cienfuegos fault, Hicacos fault, La Trocha fault, Las Villas fault, Nipe fault, Nortecubana fault, Pinar fault and Surcubana Fault.


Explanation
Phase 2 Earthquake Catalog
3.00 - 3.99 Mw
4.00 - 4.99 Mw
5.00 - 5.99 Mw
≥ 6.00 Mw
200-mile radius
Nortecubana fault system
Pinar fault
Guane fault
Habana-Cienfuegos fault
Hicacos fault
Cochinos fault
Surcubana fault
Mw 4.2 8/1879
Mw 4.2 12/1879
Mw: 4.2 1887
Mw 4.2 1896
Mw 4 10/12/1944
Mw 6.13 1/23/1880
Mw 5.1 5/20/1937
Mw 5.1 12/20/1937
Mw 4 9/11/1957
Mw 4.2 1871
Mw 4.1 1903
Mw 5.43 11/16/1982


Hicacos fault
Las Villas fault
Nortecubana fault system
200-mile radius
Mw 4.1 1903
Mw 4 2/3/1952
Mw 4 5/25/1960
Mw 5.84 8/15/1939
Mw 5.43 11/16/1982
Mw 5.1 8/12/1873
Mw 4.2 6/1872
Habana-Cienfuegos fault
Cochinos fault
Surcubana fault
Mw 4.1 10/24/1976
Mw 4.3 1/1/1953
Mw 4 3/10/1952
La Trocha fault
Cubitas fault
Mw 5.16 7/30/1943
Mw 4.3 1/5/1824
Mw 4.3 1/24/1909
Mw 4 8/28/1974
Mw 5.1 12/13/1984
Mw 4.2 5/16/2007
Camaguey fault
Explanation
Phase 2 Earthquake Catalog
3.00 - 3.99 Mw
4.00 - 4.99 Mw
5.00 - 5.99 Mw
≥ 6.00 Mw
B

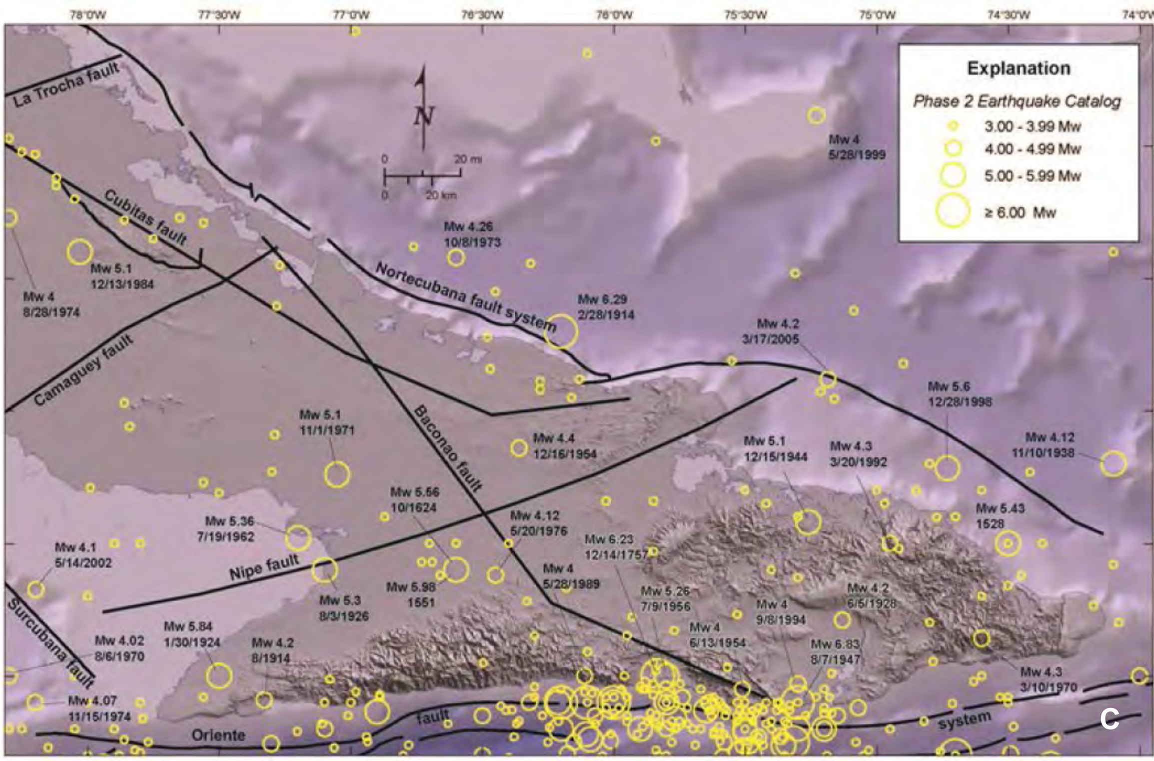


Figure 14. Fault Maps of Cuba Showing Earthquakes from the Project Phase 2 Earthquake Catalog (Sheet 1 of 3) (Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-368). Multiple sources used to compile this map, including Turkey Point Units 6 and 7 COL FSAR Refs. 439, 448, 492, and 494.

Finally, the applicant described the SSHAC Level II study completed to address the tectonic features in Cuba and the development of input parameters for the hazard sensitivity calculation and thus the potential impact of Cuba faults on the Turkey Point Units 6 and 7 site's PSHA.

The applicant modeled intraplate Cuba as a single areal source, as opposed to multiple fault sources or a combination of fault and areal sources, because of the coarse scale of geologic mapping; the poor location of earthquakes and uncertain estimates of magnitude; and the lack of fault-specific paleoseismic studies. The applicant indicated that the large scale maps that are available are developed for geologic rather than neotectonic purposes. The staff independently reviewed geologic maps of Cuba held at USGS library in Reston, VA, and notes that most maps are small scale, ranging from 1:250,000 to 1: 2,250,000.

The applicant stated that the accuracy of the instrument-derived earthquake locations is limited by lack of permanent recording stations in Cuba and the accuracy of intensity-based locations is a function of the number and reliability of felt reports, the population density and distribution and other factors. There are no known historical observations of surface rupturing earthquakes in Cuba and no fault-specific neotectonic studies that would theoretically provide recurrence interval and slip rate. The staff notes that the number of stations in the Cuban network started increasing after 1998 when broadband seismometers were installed along the island of Cuba (Moreno Toiran, 2002). According to recent news from Cuban newspaper, Cubasi (2015), the Cuban government plans to expand its seismic network with new seismometers in the central region. This is not only to improve the monitoring of the regional seismicity but to share the data

of their stations with the international community. The staff concludes that, in the near future, it may be possible to use seismic data from Cuba as a reliable constraint for the seismotectonic interpretations in the region.

The applicant indicated that several faults are identified in intraplate Cuba and after a detailed review of literature and geologic maps, concluded that no late Quaternary activity was revealed for many of the intraplate Cuba faults. However, some authors, such as Cotilla-Rodriguez et al. (2007), assert Quaternary activity. Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-368 (Sheets 1 through 3) shows the fault map locations and earthquakes in Cuba from the Phase 2 earthquake catalog. According to these figures, the faults in Cuba that are within the 320 km (200 mi) radius of the Turkey Point Units 6 and 7 site and described in the response to RAI 41, Question 02.05.01-21 (ADAMS Accession No. ML14282A078), are the Hicacos fault, Nortecubana fault, Las Villas fault, and Domingo fault. Although the applicant stated that earthquakes in Cuba do not appear to correlate strongly with faults, the staff notes that Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-368 shows a spatial association between some faults and seismic activity in Cuba. In addition, the staff looked at additional literature and current research not cited by the applicant to evaluate these features.

Hicacos Fault

In response to RAI 41, Question 02.05.01-21, the applicant characterized the Hicacos fault also known as Matanzas fault (Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-247). This fault is also discussed in response to RAI 41, Question 02.05.01-29. The applicant described the Hicacos fault as the closest fault to the Turkey Point Units 6 and 7 site that is identified as active by Cotilla-Rodríguez et al., (2007), based on associated seismicity. Based on the Phase 2 earthquake catalog, seismicity in the vicinity of the Hicacos fault is sparse and. Cotilla-Rodriguez et al. (2007) indicated that there are no earthquake focal mechanisms associated with the Hicacos fault. The applicant concluded that the association of these earthquakes with the Hicacos fault or another mapped or unmapped fault is problematic due to the uncertainties associated with the accurate locations of both faults and earthquakes in Cuba and the paucity of available focal plane solutions.

The staff notes that the number of stations in the Cuban network started increasing after 1998 when broadband seismometers were installed along the island of Cuba (Moreno Toiran, 2002). According to recent news from Cuban newspaper, Cubasi (2015), the Cuban government plans to expand its seismic network with new seismometers in the central region. This is not only to improve the monitoring of the regional seismicity but to share the data of its stations with the international community. The staff concludes that, in the near future, it may be possible to use seismic data from Cuba as a reliable constraint for the seismotectonic interpretations in the region.

Nortecubana Fault Zone and Domingo Fault

In response to RAI 41, Question 02.05.01-21, the applicant also described the Nortecubana fault zone (Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-247), located approximately 240 km (150 mi) of the Turkey Point Units 6 and 7 site, is the main structure within the Cuban Fold and Thrust belt, which falls offshore of, and nearshore to, northern Cuba dipping south with a various dip angle along the strike.

In RAI 41, Question 02.05.01-24 the staff asked the applicant to explain how the Nortecubana fault is expressed in the offshore bathymetry. In response to RAI 41, Question 02.05.01-24

dated October 3, 2014 (ADAMS Accession No. ML14282A079), the applicant indicated that Cotilla-Rodriguez et al. (2007) as well as other researchers, suggests the possibility that the Nortecubana is expressed in the bathymetry; however, none of these studies provide sufficient information to determine the nature of the bathymetric expression of the fault. Cotilla-Rodriguez et al.'s (2007) description of the Nortecubana fault as expressed "in the sea" is their indication that this fault is located offshore, as opposed to onshore, not that there is a geomorphic expression on the seafloor. Along much of its length, the surface projection of the Nortecubana fault is roughly associated with the continental slope off northern Cuba and, as such, is approximately spatially associated with this gross feature in the bathymetry. A continental slope is a bathymetric feature common to many nearshore areas and is not typically produced by faulting. Based on independent review of literature, the staff agrees with the applicant's conclusion that studies of the Nortecubana fault do not provide in depth description of the bathymetric expression of this fault.

In an October 3, 2014 response to RAI 41, Question 02.05.01-21 (ADAMS Accession No. ML14282A078), the applicant described the Domingo fault. The applicant indicated that the Domingo fault is considered the former suture between North American and Caribbean plates and is Late Eocene in age. The staff reviewed the information provided on the Domingo fault and based on several experts and maps from Cuba, the staff agrees with the applicant's conclusion that because the fault does not cut the uppermost Eocene and younger sedimentary units, it is not considered of Quaternary age.

<u>Las Villas Fault</u>

The Las Villas fault is located approximately 250 km (155 mi) south of the Turkey Point Units 6 and 7 site. In an October 3, 2014 response to RAI 41, Question 02.05.01-21 (ADAMS Accession No. ML14282A079), the applicant characterized the Las Villas fault as either middle Eocene age (Pardo, 2009) or Pliocene-Quaternary age outlined by young eroded scarps (Cotilla-Rodríguez et al., 2007). The applicant indicated that the Phase 2 earthquake catalog shows a total of 33 earthquakes located about 10 km (6 mi) from Las Villas fault, the largest being a MW 5.1 in 1873. Cotilla-Rodríguez et al. (2007) indicates that it is difficult to determine if these epicenters occurred on the Las Villas fault or another fault as there are no focal mechanisms available.

In RAI 41, Question 02.05.01-27 dated October 20, 2011 (ADAMS Accession No. ML11293A202), the staff asked the applicant to evaluate Cotilla-Rodríguez et al. (2007) statement about young eroded scarps of Pliocene-Quaternary age associated with the Las Villas fault, to discuss the bathymetric evidence that suggests recent faulting along the Las Villas fault, and to address alignment of earthquakes with respect to tectonic activity of Las Villas fault. In response to RAI 41, Question 02.05.01-27, the applicant explained that Cotilla-Rodríguez et al. (2007) does not provide additional details or references regarding their statement of young eroded scarps, therefore, it is not clear if the fault scarps formed by recent slip on the Las Villas fault, formed by erosion along the fault trace or formed by preferential erosion of sheared rocks within the fault zone. Although geologic maps of the area (Case and Holcombe 1980; Perez-Othon and Yarmoliuk 1985; Pushcharovskiy et al., 1988) reveal no faulted units of Quaternary age, the coarse scale of the mapping (1:250,000 to 1:2,500,000) does not preclude recent activity. The applicant stated that the Las Villas fault is depicted differently in several maps and Malloy and Hurley (1970) and Pardo (2009) are the only researchers that show Las Villas fault as an offshore feature. The applicant stated that Malloy and Hurley (1970) also indicated that the Las Villas fault appears to be reflected in the bathymetry as a scarp, but presented no additional information in support of this interpretation.

Furthermore, Malloy and Hurley's depiction of the Las Villas fault roughly coincides with the Nortecubana fault of other authors.

Review of geologic mapping (Case and Holcombe 1980; Perez-Othon and Yarmoliuk 1985; Pushcharovskiy et al., 1988) reveals no faulted units of Quaternary age, but the coarse scale of the mapping (1:250,000 to 1:2,500,000) does not preclude recent activity. The applicant stated that the Las Villas fault is depicted differently in several maps and possibly the name "Las Villas" was applied to different geologic structures. Malloy and Hurley (1970) and Pardo (2009) are the only researchers that show Las Villas fault as an offshore feature. Therefore, the applicant concluded that the bathymetric expression that exists for the offshore Las Villas is not relevant to assess latest movement of this fault but rather for the Nortecubana fault. The staff notes that although Malloy and Hurley (1970) did not provide additional detail on the Las Villas scarp it was recognized in their bathymetric studies as a noticeable feature associated with the Las Villas fault, and north of the Las Villas fault, a scarp extends along the Sierra de Jatibonico fault for 37 km (20 nautical mi). The staff concludes that the applicant adequately characterized the Las Villas fault, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, staff considers RAI 41, Question 02.05.01-27 resolved.

Pinar Fault

The Pinar fault is outside the 320 km (200 mi) radius of the Turkey Point Units 6 and 7 site and is covered in RAI 41, Question 02.05.01-21 and -28. The staff evaluated the characterization of the Pinar fault within the context of RAI 02.05.01-28.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.3.2.4, "Seismicity of Cuba," states that two of the largest earthquakes in the central and western region of Cuba occurred in January 1880 (MMI VIII and magnitude 6.0 to 6.6) near the Pinar fault in western Cuba. Therefore, in RAI 41, Question 02.05.01-28 the staff asked the applicant to provide more information on the Pinar fault particularly in regards to the January 22, 1880, M 6.0-6.6, San Cristobal earthquake. In response to RAI 41, Question 02.05.01-28 (ADAMS Accession No. ML14282A079) the applicant explained that the Pinar fault is located in western Cuba around 330 km (205 mi) from the Turkey Point Units 6 and 7 site. The northeast-striking, southeast-dipping fault is mapped inconsistently in the published literature including geologic maps with respect to location and extent (Garcia et al., 2003; Cotilla-Rodríguez et al., 2007; and Rosencratz 1990). Garcia et al. (2003) states that the Pinar fault is expressed as a scarp in the Sierra del Rosario mountain range, was reactivated in the Neogene-Quaternary, and considers Pinar fault the most important fault system in western Cuba, whose surface expression is clearly observed from satellite images. Cotilla-Rodríguez et al. (2007) agrees that the fault has a prominent relief but concludes it is inactive. The applicant explained that the Pinar fault is depicted on many geologic maps of Cuba (scales: 1:250,000 to 1:1,000,000). One map shows Jurassic-age limestones in fault contact against upper Pliocene to lower Pleistocene alluvial and marine deposits, which suggest fault activity. Another map places Jurassic-age rocks in fault contact against Eocene to Miocene rocks. The applicant stated that due to the map scale it is not possible to constrain an age with confidence. The applicant concluded that the Sierra del Rosario mountain range scarp associated to Pinar fault could be a result of differential erosion or a result of Miocene normal faulting that occurred in western Cuba.

The applicant stated that there are also conflicting opinions regarding the association of the 1880 earthquake event with the Pinar fault: Garcia et al. (2003) suggests that the Pinar fault produced the 1880 earthquake; Cotilla-Rodríguez et al. (2007) classifies the Pinar fault as inactive and attribute the 1880 earthquake to the Guane fault along with 19 other earthquakes,

the largest one being the 1880 Mw 6.13 earthquake; and Cotilla-Rodriguez and Cordoba-Barba (2011) conclude that historical accounts of the 1880 earthquake suggest that the most severe and concentrated damage was near the Guane fault and not in the vicinity of the Pinar fault. The applicant stated that the Phase 2 earthquake catalog shows sparse seismicity in the vicinity of the Pinar fault but moderate-magnitude earthquakes within 32 km (20 mi) of the Guane fault. However, the applicant stated that these studies are inconclusive because no focal mechanisms are available to identify the causative fault and no paleoseismic trench studies or detailed tectonic geomorphic assessments are available for either the Guane or Pinar fault.

The staff notes that in 2011 the Cuban National Centre for Seismological Research (CENAIS), along with eight institutions of Cuba, started an investigation on the Pinar fault to identify areas that may have evidence of past earthquakes. In the applicant's SSHAC Level 2 questionnaire José Alejandro Zapata Balanqué, director of the CENAIS project, indicated that the trenching results from the Pinar and possibly other faults are expected in 2014 or later.

Based on the applicant's response to RAI 41, Question 02.05.01-28 and independent examination of the literature and various geologic maps of Cuba, the staff concludes that the applicant summarized the various point of views regarding the Pinar fault presented by experts in the area, published literature and available maps. The staff acknowledges that various interpretations exist regarding the Pinar fault and that specific kinds of data to precisely constrain the age of movement are not available at this time. The staff considers that ongoing investigation along the Pinar fault will reveal more information on this feature particularly the studies that the Cuban National Centre for Seismological Research (CENAIS) is developing in the vicinity of the Pinar fault. The staff concludes that the applicant adequately characterized the Pinar fault given the available information. Accordingly, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 41, Question 02.05.01-28 resolved.

Cochinos Fault

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.3.2.4 originally stated that Cotilla Rodriguez et al. (2007) provided no geologic evidence for activity in this fault and described it as covered by young sediments. The Turkey Point Units 6 and 7 COL FSAR also indicates that the Cochinos fault appears to be geographically associated with sparse instrumental seismicity, but that these earthquakes are poorly located and no focal mechanisms are available. In RAI 41, Question 02.05.01-26 the staff asked the applicant provide a map of to the Cochinos fault and to discuss geologic evidence for fault activity. The staff also asked the applicant to map the seismicity of the Cochinos fault. In response to RAI 41, Question 02.05.01-28, the applicant indicated that the Cochinos fault is a north-northwest-striking fault in south-central Cuba depicted and interpreted differently by various researchers and on several maps. The applicant's Phase 2 earthquake catalog shows the Cochinos fault approximately 330 km (205 mi) from the Turkey Point Units 6 and 7 site. The length of the fault taken from the publications ranges from 60 to 140 km (37 to 90 mi). Some studies conclude that the fault is neotectonic (includes the Neogene and Quaternary periods), that it is expressed geomorphically in the landscape as a graben and bathymetrically in the Bahia de Cochinos, and that the fault cuts a Quaternary-age marine erosional platform. The applicant indicated that the morphology of Cochinos basin suggests the possibility of a fault-controlled landscape. The staff reviewed the cited publications and maps and notes that the fault is most likely a normal fault or set of parallel faults with an intervening graben that is between 280 to 340 km (175 to 210 mi) from the Turkey Point Units 6 and 7 site. The staff notes that the neotectonic map of the Caribbean region from Mann et al. (1990) shows the Cochinos fault as two parallel north-northwest-striking

normal faults that form a graben. The staff notes that these publications do not provide specific data to support a case that the fault is active.

With respect to seismicity possibly associated with the fault, the applicant indicated that seismicity in the vicinity of the Cochinos fault is sparse as observed in the Phase 2 earthquake catalog. The Phase 2 earthquake catalog shows a November 1982 Mw 5.4 earthquake about 5 km (3 mi) northwest of the Cochinos fault trace; four other earthquakes, the largest Mw 4.1, are observed within 32 km (20 mi) of the Cochinos fault. The staff notes that Cotilla-Rodríguez et al. (2007) classified the Cochinos fault as active based on associated seismicity and the most important earthquake detected on this fault was a December 1982 Ms 5.0 event. The applicant concluded that the association of seismicity with the Cochinos fault is problematic due to the uncertainties associated with the locations of both faults and earthquakes in Cuba.

The staff notes that the Cochinos fault is described and depicted differently by several researchers and on various maps; however, most acknowledge that the southern portion of the Cochinos fault is expressed in the topography on land and bathymetry in the Bahia de Cochinos. Seismicity associated with this fault is of low intensity, with the strongest event an Mw 5.4 in 1982. Based on the staff's review of the response to RAI 41, Question 02.05.01-26 and independent examination of references and map products cited by the applicant, the staff concludes that the applicant appropriately characterized the Cochinos fault. Accordingly, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 41, Question 02.05.01-26 resolved.

Hazard Sensitivity Calculation for Cuba Areal Source

In response to RAI 41, Question 02.05.01-21, the applicant conducted a hazard sensitivity calculation to assess the potential effect of intraplate Cuba fault sources on the PSHA for the Turkey Point Units 6 and 7 site because the possibility of Quaternary activity on intraplate Cuba faults cannot be precluded. The SSHAC Level II study assessed the hazard sensitivity of various modeling decisions regarding Cuba seismic sources and determined conservative source parameters for use in hazard sensitivity calculations for: (1) possible intraplate Cuba fault sources, and (2) alternative depictions of areal seismic sources for intraplate Cuba.

Eleven experts including geologists, seismologists, and hazard analysts from Cuba and elsewhere were contacted by the TI team with questions related to sensitivity calculations. The responses varied as many experts declined to participate, others provided only brief responses, and other experts provided detailed responses. The applicant explained that most of the contacted experts acknowledge the importance of considering possible fault sources in the hazard sensitivity calculations and most of them recognized the limitations from the lack of data with which to determine active faults in intraplate Cuba. There is disagreement among the experts, for example: Cotilla-Rodriguez does not consider the Pinar fault active but suggests that the Guane fault is active and produced the January 23, 1880, earthquake in western Cuba; however, Garcia et al. (2003) considers the Pinar fault active and the source of the 1880 earthquake but does not describe the Guane fault as a potential seismic source. Because of the uncertainty regarding whether the Pinar or Guane faults are active, the TI team elected to include both of these faults as sources in the hazard sensitivity calculation with a probability of activity of 1.0 for each.

The applicant indicated that using median modeled slip rates on fault sources, the predicted recurrence of Mw 7 earthquakes in intraplate Cuba is approximately one every 500 years. Table 3, from the RAI 41, Question 02.05.01-21 response dated October 3, 2014 (ADAMS

Accession No. ML14282A078), provides the input parameters for the hazard calculations (fault, dip, rupture depth, length, Mw, slip rate). The response to RAI 37, Question 02.05.02-04, discussed in detail in Section 2.5.2 of this SER, describes the alternative areal source approaches for Cuba, as well as the results of both fault source and alternative areal source hazard sensitivity calculations.

Based on review of the scientific literature, including maps and the applicant's response to the preceding RAI questions about Cuba faults, including RAI 41, Question 02.05.01-21, the staff acknowledges that there is insufficient information regarding specific parameters (slip rate, recurrence, length, depth) to model specific faults as seismic sources. The staff notes that the applicant incorporated information from different sources, including relatively recent publications as well as interviews with outside experts, providing a comprehensive overview of the tectonic geologic features of Cuba and their potential impact on the PSHA. The staff notes that the applicant justified modeling intraplate Cuba as a single areal source, as opposed to multiple fault sources. The staff acknowledges that the sensitivity results conducted to compare hazard from fault seismic sources, and different configurations of Cuba areal sources show that the Cuba areal source hazard is equivalent to the hazard for fault sources. Therefore, the staff concludes that the applicant assessed sufficient information to characterize the tectonic features of Cuba, particularly those within the 320 km (200 mi) radius of the Turkey Point Units 6 and 7 site. The staff further concludes that using the areal source for the Turkey Point Units 6 and 7 site PSHA is appropriate. Accordingly, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 41, Questions 02.05.01-21, -24, -27, resolved.

The applicant proposed a revision to the Turkey Point Units 6 and 7 COL FSAR to include portions of the response to RAI 41, Question 02.05.01-21. Staff notes this includes Enclosure A to the RAI response titled "SSHAC Level 2 Questionnaire in Support of Cuba Hazard Sensitivity Calculations." The staff finds the proposed revisions acceptable and has confirmed that these changes have been incorporated into the Turkey Point Units 6 and 7 COL FSAR.

Uplifted Marine Terraces

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.2.3 states that "Late Miocene to Pliocene deposits are poorly developed and Pleistocene rocks include shelf and coastal carbonates that in places have been uplifted into terraces." The staff notes that this implies Pleistocene tectonic uplift. The staff further notes that Agassiz (1894) described the extensive marine terraces along the northern coast of Cuba and very young elevated patch reef corals in growth position, forming the lowest terraces. In addition, a suite of Quaternary terraces along the northern edge of Cuba is clearly depicted in available 1:500,000 scale geologic maps of the region. In RAI 41, Question 02.05.01-22, the staff asked the applicant to explain the tectonic context of these uplifted terraces in light of continued seismicity along the northern coast of Cuba and to discuss the implication for assessments of active faulting in the site region.

In an October 3, 2014 response to RAI 41, Question 02.05.01-22 (ADAMS Accession No. ML14282A079), the applicant explained that the elevated marine terraces along Cuba's north coast may have formed as the result of both fluctuations in sea level and epeirogenic uplift. Early research suggests reactivation of a regional scale anticline or differential tectonic uplift may be partly responsible for formation of the terrace surfaces near Matanzas, along the north coast of Cuba. However, later research suggests that these differences in elevation could be the result of erosion or miscorrelation of surfaces as well as worldwide changes in sea level.

The staff notes that there are about three Pleistocene marine terraces in the Havana-Matanzas coastal region. The youngest, and therefore lowest, is Terraza de Seboruco, which is 3 to 4 m (10 to 13 ft) above sea level, is approximately 120,000 to 142,000 years old (ka) (Toscano et al., 1999), and is linked, because of age dating, with the global substage 5e sea-level highstand at 122 ka. This terrace is similar in elevation to other 5e reef deposits in stable portions of the Caribbean, thus its position can be explained by changes in sea level. The applicant indicated that the Terraza de Seboruco is the only terrace in northern Cuba for which radiometric age control is available. There is not sufficient data on other marine terraces in northern Cuba to assess the implications for active faulting.

A more recent investigation (Pedoja et al., 2011) examines late Quaternary coastlines worldwide and reports minor uplift relative to sea level of approximately 0.2 mm/yr, even along passive margins, outpacing eustatic sea-level decreases by a factor of four. The authors suggest that since the Late Cretaceous, there is an increase in the average magnitude of compressive stress in the lithosphere producing low rates of uplift even along passive margins. Their data suggest that the Substage 5e terrace in the Matanzas area (i.e., the Terraza de Seboruco) has been uplifted at an average rate that, when accounting for eustatic changes in sea level, ranges from approximately 0.00 to 0.04 mm/yr over the last approximately 122 ka accounting for about 4.9 m (16 ft) uplift.

The staff notes that based on the most recent studies, active faulting is not required to explain the elevation of the Terraza de Seboruco along Cuba's north coast in the site region. Worldwide uplift of even passive margins is revealed in the most recent study for global coastlines. If there is ongoing uplift of terraces in northern Cuba, the rate of this uplift is very low and approaching the limit of detection by recent studies. Accordingly, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 41, Question 02.05.01-22, resolved.

The applicant proposed a revision to the Turkey Point Units 6 and 7 COL FSAR to include portions of the response to RAI 02.05.01-22. The staff finds the proposed revisions acceptable and has confirmed that these changes have been incorporated into the Turkey Point Units 6 and 7 COL FSAR.

Cuban Fold and Thrust Belt

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.3.2 discusses the Cuban Fold and Thrust Belt and Turkey Point Units 6 and 7 COL FSAR Figure 02.05.01-279 shows mapped basement faults of the Cuban Fold and Thrust Belt with overlying and laterally continuous reflectors that appear to be deformed and folded up to and including the seafloor. Also, in Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-282, the staff notes that Tertiary, post-tectonic deposits are faulted, and the uppermost Tertiary deposits appear to lap-onto, rather than drape, an underlying fold on the same figure. Both relations are consistent with deformation that continues to present day. In RAI 41, Question 02.05.01-23, the staff asked the applicant to discuss the tectonic implications of the seismic reflection features above the mapped faults for Plio-Pleistocene activity in the Cuban Fold and Thrust Belt.

In an October 3, 2014, response to RAI 41, Question 02.05.01-23 (ADAMS Accession No. ML14282A079), the applicant stated that in Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-279 the visible irregularities in the Oligocene and Pleistocene reflectors in the seismic profile, as discussed by Saura et al. (2008), are "bright, irregular, internally chaotic reflections above the front of the Cuban thrust belt" typical of the Cenozoic section in this area; and the irregular

reflectors correspond to olistostromic sediments, on the basis of their seismic character and published borehole and seismic data. The staff notes that olistostromic sediments (or mélange) are described as mapable lens-like stratigraphic units lacking true internal bedding because it is a result of a submarine gravity slide. The applicant stated that Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-282 shows a schematic cross section of the evolution of the northern edge of Cuba wherein a topographic high in the lower Tertiary post-tectonic strata is shown as not completely covered by the later Tertiary post-tectonic strata. The applicant concluded that there are no indications of faulting or folding in the later Tertiary post-tectonic strata depicted on either FSAR Figure 2.5.1-279 or 2.5.1-282.

The staff agrees that there is no faulting or folding in late Tertiary strata in Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1- 279 or -282. The staff notes that Moretti et al. (2003) does not specifically address Quaternary activity, but conclude that thrusting ceased in the Eocene, whereas infilling of the basin continued to the Quaternary because of sediment influx with few minor reactivations occurred during the Tertiary. Accordingly, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, the staff considers RAI 41, Question 02.05.01-23, resolved.

<u>Seismic Zones Defined by Regional Seismicity</u>

The staff focused its review on elements that contributed most to the hazard finding. Based on hazard assessment, the Cuba areal source and the Oriente East and Oriente West faults contribute the most to the hazard from sources in Cuba and the Caribbean (details in SER Section 2.5.2).

Cuba Seismic Source

As part of the geological characterization of Cuba, the applicant described many features on the island of Cuba including faults, geologic terranes, stratigraphy, and geologic history. In response to RAI 41, Question 02.05.01.-21, the applicant ran a sensitivity analysis comparing hazard results from a Cuba areal source versus individual fault sources and concluded that the total hazard for the Turkey Point Units 6 and 7 site does not change significantly between the areal source and individual fault sources. Additional discussion of the hazard analysis is presented in SER Section 2.5.2. The staff concludes that the Cuba areal source is an acceptable and plausible alternative approach to modeling the SSC individual faults on the island of Cuba based on the staff's previous evaluation of RAI 41, Question 02.05.01.-21.

North American and Caribbean Plate Boundary

The plate boundary sources in the Caribbean contribute to the total seismic hazard at the Turkey Point Units 6 and 7 site. However, due to their large distance from the Turkey Point Units 6 and 7 site their contribution levels are relatively low. The staff identified that the Oriente West and Oriente East faults, off the coast of southern Cuba, contribute the most to the total seismic hazard among the identified plate boundary sources. The Oriente fault zone forms part of the boundary between the modern North American plate and the Caribbean plate, including the Gonave microplate. It is located directly off the southern coast of Cuba about 690 km (430 mi) from the Turkey Point Units 6 and 7 site and is a left-lateral strike-slip fault with 8 to 13 mm/year slip, hence the applicant classified this as a capable tectonic source. The staff did not ask RAIs for this section and conclude the applicant adequately characterized this seismic zone outside the 200 mile radius of the site. The range of slip provided for this fault zone is consistent with the published literature. The Oriente fault parameters in the Cuba and northern

Caribbean seismic source model is further described in Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.4.4.3.

Staff Conclusions on Regional Geology and Tectonic Setting

Based on review of Turkey Point Units 6 and 7 COL FSAR Sections 2.5.1.1.2, "Regional Tectonic Setting," and 2.5.1.1.3, "Regional Seismicity and Paleoseismology," the applicant's responses to RAIs on those two FSAR sections, as well as independent examination of references cited by the applicant in those two sections, the staff finds that the applicant provided a complete and accurate description of the regional tectonic setting and regional seismicity and paleoseismology for the Turkey Point Units 6 and 7 site, including regional geologic setting, tectonic stress, gravity and magnetic data in the site region and site vicinity, principal regional tectonic structures, and seismic sources defined by regional seismicity in the CEUS both inside and outside the site region. The staff also finds that the descriptions provided in the Turkey Point Units 6 and 7 COL FSAR Sections 2.5.1.1.2 and 2.5.1.1.3 reflect the current literature and state of knowledge and meet the requirements of 10 CFR 52.79 and 10 CFR 100.23.

2.5.1.4.2 Site Geology

Site Area Physiography and Geomorphology

The large physiographic features bordering the plant property include the Everglades, Florida Keys, and the Atlantic Continental Slope, including Biscayne Bay and the submarine Miami Terrace. Site features include vegetated surficial depressions and patches on the floor of Biscayne Bay.

Vegetated Surface Depressions

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.8.2.1 concludes that shallow depressions preserved at the surface, observed at the site and in the site vicinity, are formed by gradual top-down, subaerial dissolution. The applicant stated that these features are unlikely to have underlying cavity voids with potential for sudden collapse. The applicant refers to these site features as vegetated surficial depressions. As a result of discussions during public meetings, site visits by the staff and RAI questions pertaining to Turkey Point Units 6 and 7 COL FSAR Sections 2.5.1 and 2.5.3 (RAI 41, Questions 02.05.01-1, -2, and -17, and 02.05.03-1) and Turkey Point Units 6 and 7 COL FSAR Section 2.5.4 (RAI 40, Questions 02.05.04-1, and -25), the applicant conducted a supplement field investigation of the vegetated depressions on the Turkey Point Units 6 and 7 site and vicinity, as described in Turkey Point Units 6 and 7 COL FSAR Enclosure 9, "Surficial Muck Deposits Field and Laboratory Investigation Data Report"; and Enclosure 8, "Supplemental Field Investigation Data Report Turkey Point Nuclear Power Plant Units 6 and 7." In addition, the applicant developed FSAR Appendix 2.5 AA, "Potential for Carbonate Dissolution and Karst Development at the Turkey Point Units 6 and 7 Site." In these three subsequent submittals, the applicant responded in a general manner to multiple RAI questions and provided more data and described, in more detail, vegetated depressions at the Turkey Point Units 6 and 7 site and throughout southern Florida (Willard and Bernhardt, 2011). The staff notes that these features also fit the description of solution sinkholes from Stewart and Sinclair (1985), as described in SER Section 2.5.1.1.

Enclosure 9 describes the additional geotechnical borings conducted to describe surficial soil and sediment layers which include muck and peat deposits and to specifically characterize the vegetated surficial depressions. Core runs extended from ground surface to the Miami

Limestone contact at all sample locations (nine sample locations, Turkey Point Units 6 and 7 COL FSAR Enclosure 9, Figure 2-1). Peat was found primarily in depressions, natural water drainages, and as the basal deposits on Miami Limestone. Surficial layers within vegetated surficial depressions were characterized as peat and as thick as 2 m (6.68 ft) (borehole M-7-2a). Enclosure 8 describes the three inclined borings through hard rock that were intended to intersect zones of fractures beneath surface features such as the vegetated depressions and natural drains (see the applicant's response to RAI 44 ,Question 02.05.04-25). These borings were also aimed at finding potential cavities. No cavities of significant sizes were found under the targeted vegetated depression area or the drainage channels.

Vegetated Patches on the floor of Biscayne Bay

The staff notes the presence of the apparent semi-circular alignments of individual offshore depressions on the sea floor of Biscayne Bay within 3 km (1.8 mi) to the east of Units 6 and 7. In RAI 5875, Question 02.05.03-1, in SER Section 2.5.3.4, the staff asked the applicant to discuss these offshore features and their age of formation. In closely related RAI 41, Question 02.05.01-2, staff asked the applicant to discuss the possibility that the zones of secondary porosity found at the Turkey Point Units 6 and 7 site in the subsurface are in the same stratigraphic interval that contains the circular depressions or vegetated patches on the floor of Biscayne Bay.

In an October 3, 2014 response to RAI 43, Question 02.05.03-1 (ADAMS Accession No. ML14281A177), the applicant suggested that the vegetated patches on the floor of the bay appear to be paleo-dissolution features that formed subaerially, during the last glacial stage when sea level was approximately 328 ft (100 m) lower than today, exposing the bay floor to surficial dissolution by fresh rainwater. The staff agrees with the applicant's conclusion that the process of subaerial dissolution ended in Biscayne Bay when sea level rose and flooded the bay but continued on emergent areas, including the vegetated depressions at Turkey Point Units 6 and 7 site. In response to RAI 41, Question 02.05.01-2, The applicant replied that based on stratigraphic data and bathymetry in Biscayne Bay, the touching-vug porosity zone at the site (within the Miami and Key Largo Limestones) correlates with the stratigraphic interval in which the vegetated patches occur on the floor of Biscayne Bay. However, the applicant indicated that the vegetated patches in the bay formed by subaerial dissolution, similar to the surficial vegetated depressions on the site, rather than by groundwater mixing zones. This suggests that the vegetated patches in Biscayne Bay are not linked to the touching-vug porosity zone beneath the Turkey Point Units 6 and 7 site. The applicant concluded that the features on the floor of Biscayne Bay do not appear to have the capacity for development of large underground caverns with the potential for collapse and formation of sinkholes. The staff notes that based on stratigraphic data and bathymetry in the bay provided by the applicant that the moldic porosity zone in the Fort Thompson Formation is too deep to be expressed on the floor of Biscayne Bay. Therefore, the staff considers RAI 41, Question 02.05.01-2, and RAI 5875, Question 02.05.03-1, resolved.

Site Area Stratigraphy

The applicant described the upper 183 m (600 ft) of the Turkey Point Units 6 and 7 site stratigraphy as consisting of eight soil and rock formations including: a surficial muck layer (Holocene section), Miami Limestone, Key Largo Limestone, the Fort Thompson Formation, the Upper Tamiami Formation, the Lower Tamiami Formation, the Peace River Formation, and the Arcadia Formation. The staff focused its review on the surficial deposits that reveal the most recent geologic history of the site along with possible indications of tsunami and hurricane storm

deposits. The staff also considered the characterization of the bearing layer for Units 6 and 7, the Fort Thompson Formation.

Holocene Section

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.2 describes the Holocene section at the Turkey Point site. In response to RAI 41, Question 02.05.01-17, in part, and RAI 40, Question 02.05.04-1, in part, the applicant collected additional data and provided an analysis of the surficial sediment layers at the Turkey Point Units 6 and 7 site based on the supplemental field investigations (Turkey Point Units 6 and 7 COL FSAR Enclosures 8 and 9). These reports include a description of the muck layers and peat deposits and an evaluation for the lack of hurricane and tsunami deposits.

The applicant stated that surface sediments at the Turkey Point Units 6 and 7 site are indicative of fresh water conditions at the Turkey Point Units 6 and 7 site, formed after the area emerged with the drop in sea level during the last glacial period. The laminations in the organic-rich elastic silt and peat deposits at the site (Muck report) likely resulted from cyclical changes in redox conditions, with organic rich laminae deposited under low oxygen conditions and light colored, carbonate-rich laminae deposited under open marsh, shallow water and less anaerobic conditions (Flugel, 2009). In coastal Florida wetlands, marl deposition is typically associated with freshwater conditions. Within the Turkey Point Units 6 and 7 site cores, evidence for historic freshwater conditions is provided by the presence of intact specimens of Planorbella spp., a freshwater gastropod (Easton et al., 2012). The applicant pointed out (Enclosure 9) that the surficial deposits described at the Turkey Point Units 6 and 7 site generally correspond to the surficial sediment sequences described within other coastal wetland systems adjacent to Biscayne Bay (Willard and Bernhardt, 2011; Robles et al., 2005; Schroeder et al., 1958). Based on radiocarbon age determinations, the basal peat deposits from these locations generally date to between 4,400 and 1,100 years before present.

The applicant concluded that based on the boreholes and surface samples, the surficial sediment record or Holocene section at the site provides no direct evidence for material and sedimentary structures that could be interpreted as evidence for high-energy depositional events (e.g., hurricane or tsunami landfalls). That is, no storm bed, tsunamigenic deposits (upward fining clastic sequences), peaks in sand content (sand sheets), nor erosive surfaces, were identified in any borings at the site.

Staff concludes that the additional field investigation provided in Enclosure 9 provides the data to support the applicant’s conclusion that there is no evidence in surficial peat depressions of tsunami or hurricane deposits. Staff also concludes that the applicant has characterized the youngest geologic layers at the Turkey Point Units 6 and 7 site sufficiently to determine the most recent geologic history.

Pleistocene Section

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.2 describes the Pleistocene section at the Turkey Point Units 6 and 7 site, which includes the Miami and Key Largo Limestones and the Fort Thompson Formation, and is about 31 to 38 m (102 to 125 ft) thick. In RAI 41, Question 02.05.01-17, staff asked the applicant to provide additional information and clarification on the isopach and structure contour maps of the Key Largo Limestone and the Fort Thompson Formation in order to verify that there is no deformation in those stratigraphic units. In response to RAI 41, Question 02.05.01-17, the applicant provided revised structure contour

and isopach maps and cross sections. The staff examined the isopach map of the Key Largo Limestone in comparison with the structure contour map of the top of the Fort Thompson Formation and notes that there is no strong correlation between the thickness of the Key Largo Limestone and the topography at the top of the Fort Thompson Formation suggesting the absence of a large collapse feature within the Fort Thompson Formation that extends upward into the Key Largo Limestone. The staff notes that the structure contour map of the top of the Key Largo Limestone does not correlate strongly with the locations of the vegetated surficial depressions, suggesting that any dissolution associated with the vegetated surficial depressions has not fully penetrated the Miami Limestone to affect the top of the underlying Key Largo Limestone. Staff examined both structure contour and isopach maps for the Key Largo and the Fort Thompson Formation and compared these to the geotechnical cross sections to verify essentially flat lying layers with no indication of disturbed, inclined layers or anomalous thicknesses to suggest collapsed cavities in the subsurface. Accordingly, the staff considers RAI 41, Question 02.05.01-17, resolved.

Structural Geology

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.3, describes the structural setting for the Turkey Point Units 6 and 7 site that considers published literature and maps, Units 3 and 4 UFSAR (FPL, 1992), and the supplemental exploration programs (MACTEC, 2008; Enclosure 8; Enclosure 9). The staff notes that these data indicate generally flat, planar bedding in Pleistocene and older units and an absence of geologic structures within the site area (see discussion in SER Section 2.5.1.4.2 Site Area Stratigraphy).

The applicant also stated that the site lies on the stable Florida carbonate platform, and that no faults or folds are mapped within more than 40 km (25 mi). The staff notes that there is a tectonic structure located in the subsurface in the Biscayne Bay within 40 km (25 mi) of the Turkey Point Units 6 and 7 site. In previously discussed and resolved RAI 81, Question 02.05.01-36, the staff asked the applicant to discuss this tectonic feature with respect to the Turkey Point Units 6 and 7 site and integrate it into the regional tectonic setting. Based on the applicant's response and conclusions in SER Section 2.5.1.4.1.3.1, the staff determines that this feature is neither a seismic hazard nor a surface deformation hazard to the Turkey Point Units 6 and 7 site.

Analysis of Lineaments and Fracture Patterns

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.3 analyzes lineaments and fracture patterns in the Turkey Point Units 6 and 7 region and site based on a response to RAI 40, Question 02.05.04-1. The 1940's aerial photographs (USGS, 2004) were used for the interpretation and analysis of the lineaments. This photo set shows the surface features of the site area prior to any significant modification of the landscape.

The staff examined the orientations of the lineaments at the site area and notes that they are consistent with large-scale, regional lineament trends identified in other studies, which linked these features to subsurface fracture orientations (Bond et al., 1981). The documented vertical or near-vertical fracture orientations in Florida (USACE, 2004) supported the initial assumption that the lineaments identified in the Turkey Point site area were associated with fractures in the subsurface. The staff notes that this is corroborated by results of the inclined boreholes completed by the applicant as part of the supplemental field program as documented in Enclosure 8. The staff notes that these subvertical fractures or joints in the region, and in particular at the Turkey Point Units 6 and 7 site, are possibly initiation points for the

development of the vegetated surface depressions. The staff also notes that there is no indication in the data that there are offsets along the joints to suggest faulting.

Site Geologic Hazard Evaluation

The applicant examined the Turkey Point Units 6 and 7 Units 6 and 7 site area and found no evidence of active tectonic features, no known tsunami deposits, no evidence for seismically induced paleoliquefaction features or other indicators of paleoseismic activity, and no known sinkholes in the underlying karst terrane. For site geologic hazard evaluation at the Turkey Point Units 6 and 7 site, the staff focused on carbonate dissolution features in the site area, past evidence of storm or tsunami deposits, and a Miocene tectonic fault in Biscayne Bay. The staff independently reviewed relevant publications, supplemental reports from the applicant, including the field and laboratory investigation report provided in Turkey Point Units 6 and 7 COL FSAR Enclosure 9, as well as the applicant's responses to RAI 41, Questions 02.05.01-1, -2, -17; RAI 81, Questions 02.05.01-36 and 02.05.01-37, and RAI 40, Question 02.05.04-1, that pertain to carbonate dissolution features. The staff also notes that in response to RAI 82, Question 02.05.04-26, the applicant will develop a grouting program based on its test program for the subsurface beneath the nuclear island, which will grout the zone between EL -10.7 m and EL -18.3 m (EL -35 ft and EL -60 ft) and constrain any remaining voids not having potential to exceed 6.1 m (20 ft) equivalent diameter between EL -18.3 m and EL -33.5 m (EL -60 ft and EL -110 ft). Also, the applicant performed a sensitivity analysis to demonstrate the void size (6.1 m (20 ft)) constrained by the grouting program is not critical to the stability of subsurface materials and the integrity of SSCs. The staff's evaluation of the grouting plan and testing program, the sensitivity analysis, and the associated ITAAC are discussed in SER Section 2.5.4.4.4.

The staff finds that the Turkey Point Units 6 and 7 site has no known geologic hazards that would affect the safe operation of the proposed Units 6 and 7. Therefore, the staff concludes that the applicant provided a thorough and accurate description of site geologic hazard evaluation in support of the Turkey Point Units 6 and 7 application.

Site Area Engineering Geology

Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.5 addresses site engineering soil properties and behavior of foundation materials, zones of alteration, weathering, dissolution, and structural weakness, prior earthquake effects, and effects of human activities. Detailed discussions on earthquake effects are found in Turkey Point Units 6 and 7 COL FSAR Section 2.5.2 and details on soil properties and foundation materials are found in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4. The applicant stated that the foundation bearing strata will be evaluated and geologically mapped as the subgrade excavation is completed to confirm that the observed properties are consistent with those used in the design and that any deformation features discovered during construction do not have the potential to compromise the safety of the plant. The staff will be notified when safety-related excavations are open for inspection.

The applicant stated that its review and interpretation of aerial photography, the published literature, its field reconnaissance and the results of the subsurface exploration completed in support of the Turkey Point Units 6 and 7 COL FSAR found no unusual zones of alteration, weathering profiles, or structural weakness in the surface or subsurface. Additional discussion of the staff evaluations of the subsurface with respect to geotechnical engineering are found in SER Section 2.5.4. Based on the staff's review of the Turkey Point Units 6 and 7 COL FSAR, RAI responses and staff's own independent review of the published literature, the staff agrees with the applicant's conclusion. The staff concludes that the applicant provided a thorough and

accurate description of site engineering geology in support of the Turkey Point Units 6 and 7 application.

2.5.1.5 Post-Combined License Activities

There are no post-COL activities related to FSAR Section 2.5.1. However, SER Section 2.5.3.5 identifies a geologic mapping License Condition for Turkey Point Site Units 6 and 7 as the responsibility of the applicant. SER Section 2.5.3.5 defines the applicant's responsibility for geologic mapping at Turkey Point Units 6 and 7 as License Condition (2-1). In addition, SER Section 2.5.4.5 identifies an ITAAC for seismic Category I structures foundation grouting for Turkey Point Site Units 6 and 7 as the responsibility of the applicant and which establishes a set of actions and criteria for the grouting activity necessary to provide assurance that, when met, the stability of seismic Category I structures are in conformance with the combined license.

2.5.1.6 Conclusion

The staff reviewed the Turkey Point Units 6 and 7 COL FSAR and referenced DCD. Based on these reviews, the staff confirms that the applicant addressed the required information related to basic geologic and seismic characteristics, and there is no additional outstanding information that must be discussed in the Turkey Point Units 6 and 7 COL FSAR related to these characteristics. NUREG-1793 and its supplements document the results of the staff's technical evaluation of the information incorporated by reference into the Turkey Point Units 6 and 7 COL FSAR.

As set forth above, the staff has reviewed the information in PTN COL 2.5-1 and PTN SUP 2.5-1 finds that the applicant provided a thorough characterization of basic geologic and seismic information for the Turkey Point Units 6 and 7 site, as required by 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii). In addition, the staff concludes that the applicant identified and appropriately characterized all seismic sources significant for determining the GMRS, or SSE, for the COL site, in accordance with NRC regulations provided in 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii) and the guidance provided in RG 1.208. Based on the applicant's geologic investigations of the site region, site vicinity, site area, and site location, 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 Turkey Point Units 6 and 7 site. The staff also concludes that there is no potential for the effects of human activity (i.e., mining activity or groundwater injection or withdrawal) to compromise the safety of the site. Therefore, the staff concludes that the Turkey Point Units 6 and 7 site is acceptable from the standpoint of geologic and seismic information and meets the requirements of 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii).

PTN COL 2.5-1 addresses the provision of regional and site-specific geologic, seismic, and geophysical information, as well as conditions caused by human activity. Based on the discussion of the basic geologic and seismic information presented in Turkey Point Units 6 and 7 COL FSAR Section 2.5.1, and the technical evaluation presented above in SER Section 2.5.1.4, the staff concludes that the applicant provided the information required to satisfy PTN COL 2.5-1.

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 ground motion response spectrum (GMRS), which must meet the regulations for the safe shutdown earthquake provided in 10 CFR 100.23. The GMRS is defined as the free-field horizontal and vertical ground motion response spectra at the plant 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. The specific investigations necessary to determine the GMRS include the seismicity of the site region and the correlation of earthquake activity with seismic sources. Seismic sources are identified and characterized, including the rates of occurrence of earthquakes associated with each seismic source. Seismic sources that have any part within 320 km (200 mi) of the site must be identified. More distant sources that have a potential for earthquakes large enough to affect the site must also be identified. Seismic sources can be capable tectonic sources or seismogenic sources. The staff’s review covers the following specific areas: (1) Seismicity, (2) geologic and tectonic characteristics of the site and region, (3) correlation of earthquake activity with seismic sources, (4) PSHA and controlling earthquakes, (5) seismic wave transmission characteristics of the site, (6) site-specific GMRS, and (7) any additional information requirements prescribed in the “Contents of Application” sections of the applicable subparts to 10 CFR Part 52 Subparts.

2.5.2.2 Summary of Application

Section 2.5.2 of the Turkey Point Units 6 and 7 COL FSAR incorporates by reference Section 2.5.2 of the AP1000 DCD.

In addition, in Turkey Point Units 6 and 7 COL FSAR Section 2.5.2, the applicant provided supplemental, site-specific information to address the following:

AP1000 COL Information Items

- PTN COL 2.5-1

The applicant provided additional information in PTN COL 2.5-1 to address COL Information Item 2.5-1. PTN COL 2.5-1 addresses the provision of regional and site-specific geologic, seismic, and geophysical information, as well as conditions caused by human activities. This information includes: structural geology; seismicity of the site; geologic history; evidence of paleo-seismicity; 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 effects of human activities in the area.

- PTN COL 2.5-2

The applicant provided additional information in PTN COL 2.5-2 to address COL Information Item 2.5-2. PTN 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, PSHA, seismic wave transmission characteristics and the SSE ground motion.

- PTN COL 2.5-3

The applicant provided additional information in PTN COL 2.5-3 to resolve COL Information Item 2.5-3, which addresses the provision for performing site-specific evaluations, if the site-specific GMRS at foundation level exceed the response spectra in AP1000 DCD Figures 3.7.1-1 and 3.7.1-2 at any frequency, or if soil conditions are outside the range evaluated for the AP1000 DC.

Supplemental Information

- PTN SUP 2.5-1

The also applicant provided supplemental information in Turkey Point Units 6 and 7 COL FSAR Section 2.5, “Geology, Seismology, and Geotechnical Engineering,” which provides summary information of detailed information in Turkey Point Units 6 and 7 FSAR Section 2.5.2, “Vibratory Ground Motion,” for the Turkey Point Units 6 and 7 site.

2.5.2.2.1 Seismicity

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.1 describes the development of an up-to-date earthquake catalog for the Turkey Point Units 6 and 7 site. Following guidance in RG 1.208, “A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion,” the applicant used the CEUS) Electric Power Research Institute (EPRI)-Seismicity Owners Group (SOG) earthquake catalog as a starting point and updated it through February 2008, since the EPRI-SOG catalog is complete through 1984. However, the applicant noted that the seismic hazard at the Turkey Point Units 6 and 7 site is also affected by earthquakes in Cuba and the Caribbean region. The EPRI-SOG earthquake catalog does not cover this region. Therefore, the applicant developed a separate earthquake catalog primarily covering the regions of Cuba and the Caribbean. The applicant referred to the EPRI-SOG earthquake catalog update as the Phase 1 update, and to the development of the new earthquake catalog covering the regions of Cuba and the Caribbean as the Phase 2 update.

The Phase 1 earthquake catalog update covered a window from 22 ° to 35 ° N latitude and 100 ° to 65 ° W longitude. The applicant identified all earthquakes from 1984 to 2008 within this window using 34 regional catalogs and eliminated dependent events using the criteria described in EPRI (1988). For earthquakes with available body-wave magnitudes (m_b), the applicant adopted that magnitude directly. Otherwise, the applicant converted available magnitude measurements to m_b using procedures defined in the 1988 EPRI study. Since both the EPRI-SOG earthquake catalog and recurrence characterization of the EPRI-SOG seismic sources use the m_b scale, the applicant constrained the Phase 1 earthquake catalog update to maintain the magnitude scale in m_b. However, since modern seismic hazard analyses describe magnitudes in terms of moment magnitude (M_w) rather than m_b, the applicant also scaled m_b to M_w using established relationships to enable a consistent comparison between magnitude scales.

The Phase 2 earthquake catalog update covered a window from 15 ° to 24 ° N latitude and 100 ° to 65 ° W longitude. The applicant used 22 regional earthquake catalogs to compile this catalog. This region has variable seismic network data coverage, and therefore, variable quality data sets that cover different time spans. In addition, the applicant identified 19 different scales describing earthquake magnitudes in the Cuba and Caribbean regions. The applicant converted the different magnitude scales to moment magnitude (M_w or **M**) to obtain an earthquake catalog with a uniform magnitude scale. The earthquake catalogs compiled by the applicant contain both independent (e.g., mainshocks) and dependent (e.g., foreshocks, aftershocks, etc.) events. In order to ensure that the final Phase 1 and Phase 2 earthquake catalogs contain only independent events, the applicant declustered the catalogs to include only mainshock events in the final catalog. Figures 2.5.2-1 and 2.5.2-2 show the final updated earthquake catalog used in the Turkey Point Units 6 and 7 site's seismic hazard assessment. After the establishment of the updated earthquake catalog to be used in the Turkey Point Units 6 and 7 site's seismic hazard calculations, and in accordance with the 1988 EPRI-SOG PSHA study, the applicant also developed the earthquake completeness assessments in the zones not initially covered by the EPRI-SOG models.

2.5.2.2.2 Geologic and Tectonic Characteristics of the Site and Region

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.2 describes original EPRI-SOG seismic source models and the need to update these models based on new data and information prior to using them in the Turkey Point Units 6 and 7 site's seismic hazard assessments.

Consistent with RG 1.208, the applicant used the 1986 EPRI-SOG seismic source model as a starting point for its seismic source characterization of the Turkey Point Units 6 and 7 site. The 1986 EPRI-SOG seismic source model comprises input from six independent earth science teams (ESTs): the Bechtel Group, Dames and Moore, Law Engineering, Rondout Associates, Weston Geophysical Corporation, and Woodward-Clyde Consultants. Figure 2.5.2-1 illustrates seismic sources located within 320 km (200 mi) of the Turkey Point Units 6 and 7 site that were delineated by each of these six ESTs.

Because of the time elapsed since the publication of these models, the applicant reviewed available geological, seismological, and geophysical data since the late 1980s to evaluate the need for modifications to the original EPRI-SOG ESTs' seismic source models. The applicant described various modifications including maximum magnitude (M_{max}) updates due to recent earthquakes, the addition of supplemental source zones to cover the entire 320 km (200 mi) radius of the site region, an update of the Charleston seismic source, and the addition of new sources outside the EPRI-SOG model coverage to include potential hazard impacts from seismic sources in the regions of Cuba and the North American-Caribbean plate boundary region. SER Section 2.5.2.2.4 discusses these updated seismic source models and their parameters.

2.5.2.2.3 Correlation of Earthquake Activity with Seismic Sources

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.3 describes the correlation seismicity with the seismic source models used in the PSHA calculations. The FSAR states that the Turkey Point Units 6 and 7 site's PSHA included the updated EPRI-SOG seismic sources along with new supplementary sources specifically developed for this application. The applicant compared seismicity from the Phase 1 catalog update described above with the known geologic features described in the EPRI-SOG seismic source models and concluded that there was no clear

association of seismicity with any known geologic structures within EPRI-SOG seismic sources. Using the updated earthquake catalog, the applicant further concluded: (1) there is no unique seismicity cluster in the region requiring new sources, (2) the updated earthquake catalog does not show a pattern of seismicity, and (3) the Phase 1 earthquake catalog does not imply a significant change in seismicity parameters. The applicant, however, noted that the Phase 1 earthquake catalog requires updates to many of the EPRI-SOG seismic source models' M_{max} values. The applicant further stated that correlation of seismicity with Cuban and Caribbean seismic sources are discussed in the PSHA and controlling earthquakes section of the FSAR; a summary of which is discussed in SER Section 2.5.2.2.4.

2.5.2.2.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.4 describes the results of the applicant's PSHA for the Turkey Point Units 6 and 7 site. In performing its PSHA, the applicant followed the guidance provided in RG 1.208 to determine the seismic hazard curves and controlling earthquakes for the Turkey Point Units 6 and 7 site. The applicant based its analyses on the original EPRI hazard study (1989) and used the seismic sources identified in EPRI-SOG's 1986 study and updated them as necessary. In addition, the applicant determined that seismic sources in Cuba and the northern Caribbean region also contributed to the total seismic hazard and established new seismic source models for these regions, because these regions were not covered in the 1986 EPRI-SOG study. Similarly, because the existing ground motion prediction models do not cover the Caribbean region, the applicant developed new ground motion prediction models to be used for seismic sources in Cuba and the Caribbean using a SSHAC Level II process.

The PSHA seismic hazard curves generated by the applicant represent generic hard rock conditions characterized by a shear wave velocity (V_S) in excess of 2.8 km per second (9,200 ft per second). In addition, the applicant described the earthquake potential for the site in terms of a Uniform Hazard Response Spectra (UHRS) and controlling earthquakes, the most likely earthquake magnitudes and source-site distances. The applicant determined the low- and high-frequency controlling earthquakes by deaggregating the PSHA seismic hazard curves at selected probability levels. The following sections describe the applicant's entire PSHA process.

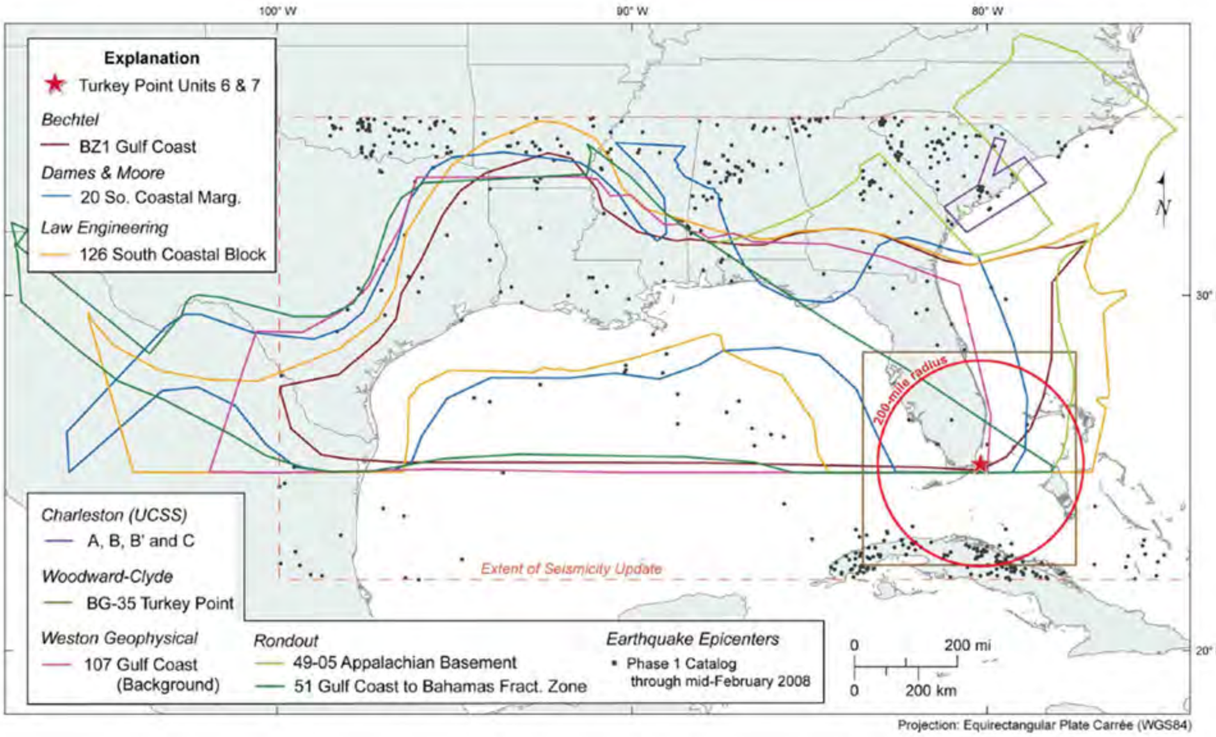


Figure 2.5.2-1. Map showing the updated EPRI earthquake catalog and CEUS seismic sources used for the Turkey Point Units 6 and 7 site (Reference Turkey Point Units 6 and 7 COL FSAR Figure 2.5.2-203).

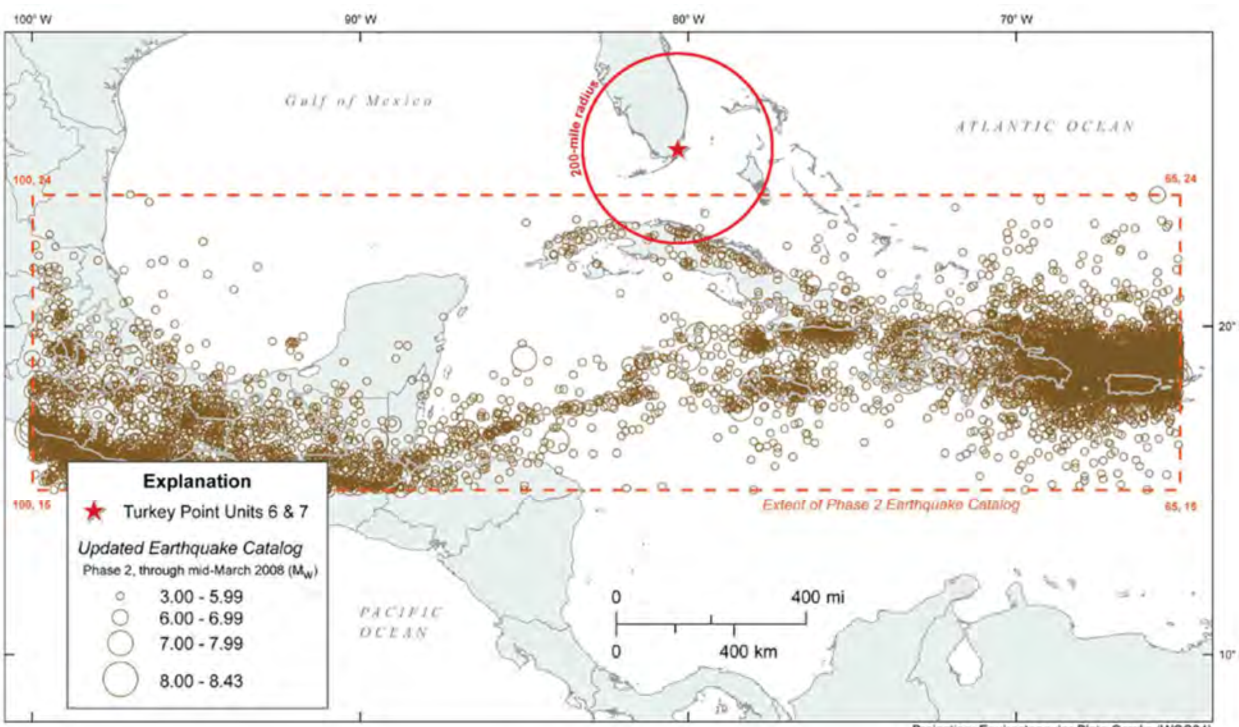


Figure 2.5.2-2. Map showing earthquakes included in the Phase 2 update (Reference Turkey Point Units 6 and 7 COL FSAR Figure 2.5.2-216).

PSHA Inputs

Before performing the PSHA, as outlined in RG 1.208, the applicant addressed the potential significant new information on seismic source characterization and developed new seismic source models for the Cuba and Caribbean regions. The following sections describe the applicant's efforts in developing a complete seismic source model to be used in the Turkey Point Units 6 and 7 site's PSHA.

Original EPRI PSHA Calculations and Updates to EPRI-SOG Seismic Sources

Initially, before conducting new PSHA calculations, the applicant first tested its own seismic hazard calculation code by re-calculating the 1989 PSHA results at the Crystal River Nuclear Generating Plant, approximately 450 km (280 mi) northeast of the Turkey Point Units 6 and 7 site, since the original EPRI PSHA study did not incorporate the Turkey Point site. The applicant showed that it could duplicate the original mean total seismic hazard curves at the Crystal River Nuclear Generating Plant site. Then, in accordance with the guidance in RG 1.208, the applicant assessed potential updates to the original seismic source model parameters following an extensive review of recently published information. The applicant primarily discussed the effects of the Phase 1 earthquake catalog updates on the published seismicity rates as well as the M_{max} estimates for the selected EPRI-SOG seismic sources. The following provides a summary of the applicant's assessments.

1. Seismicity Rates

To evaluate potential effects of the updated EPRI-SOG earthquake catalog, the applicant selected a region covering the Florida Peninsula within the boundaries of the EPRI study region. The applicant then calculated earthquake recurrence parameters using both the original EPRI earthquake catalog and the updated catalog. The applicant compared the two results to show that the updated earthquake catalog produces slightly lower recurrence rates than those calculated using the original EPRI catalog. Based on this analysis, the applicant chose not to update the seismicity rates and used the original published rates in its seismic hazard analysis.

2. New Maximum Magnitude Information

Using the updated earthquake catalog, the applicant identified four moderate-sized earthquakes within the EPRI-SOG seismic source models that impact the seismic source model's original M_{max} assignments. The earthquakes identified by the applicant are the **M**5.9 September 10, 2006, Gulf of Mexico earthquake, the **M**5.58 February 10, 2006, earthquake, the **M**5.0 October 24, 1997, earthquake, and the approximately **M**6.0 January 23, 1880, Cuba earthquake. The applicant stated that maximum magnitude values assigned to all but one of the EST sources within the site region needed to be updated because of these earthquakes.

Development of New Seismic Source Zones

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.4.4 describes the need to develop new seismic source models to fully characterize the seismic hazard at the Turkey Point Units 6 and 7 site. The applicant specifically addressed three types of new seismic source models that needed to be developed. Since the original EPRI-SOG models do not cover the 320 km (200 mi) site area completely, the applicant stated that additional models needed to be developed to

cover the entire area. Secondly, since the publication of the EPRI-SOG models in 1986, new information indicated that the Charleston seismic source needed to be exclusively defined in the seismic source models. Lastly, the applicant indicated that since the Turkey Point Units 6 and 7 site is relatively close to Cuba and some of the active plate boundary seismic sources in the Caribbean region, these sources' seismic hazard contributions needed to be incorporated into the total seismic hazard calculations. The following sections summarize the applicant's new seismic source model development efforts in these regions.

Development of Supplemental Sources

Since not all the EPRI seismic source zones cover the entire 320 km (200 mi) radius site region (Figure 2.5.2-1), the applicant added supplemental seismic source zones to fill the uncovered areas within the site region to the south and east of offshore the Florida peninsula. The applicant explained that these areas of the site region not covered by the original EPRI model are mostly devoid of seismicity and therefore simply expanding the EPRI seismic zones to cover the site region would smooth the earthquake rates and unrealistically decrease them. Therefore, the applicant created new source zones covering the offshore region south and east of the Florida peninsula to supplement each EPRI seismic source zone using model parameters obtained from the updated earthquake catalog.

Updated Charleston Seismic Source Model

The site of the 1886 Charleston, SC, earthquake with a magnitude of about **M**7.0 lies approximately 800 km (500 mi) north of the Turkey Point Units 6 and 7 site. The applicant explained that the original EPRI-SOG seismic source model included an assessment of the Charleston seismic source; however studies post-dating this characterization required an updated Charleston Seismic Source Model (UCSS). The applicant used the UCSS model developed through a SSHAC Level II process for the Vogtle ESP application (SNC, 2008). The USSC model accounts for updated information regarding the location, size, and rate of earthquake occurrence for large magnitude earthquakes in the vicinity of Charleston, SC. The UCSS model includes four possible alternative source scenarios as limited information exists on the location and causative structure for these earthquakes. The size of the characteristic earthquake is assumed to vary from **M**6.7 to **M**7.5 in each of these four alternative source zones and the recurrence rates vary from about 550 years to 950 years.

Cuba and Northern Caribbean Source Models

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.4.4.3, the applicant described the seismic source models developed for Cuba and the North American-Caribbean plate boundary region through a SSHAC Level II study. Earthquake data for these sources were compiled through the development of the Phase 2 earthquake catalog (Figure 2.5.2-2). Through the SSHAC study, the applicant identified an areal seismic source for Cuba and nine seismic fault sources in the Caribbean region (Figure 2.5.2-3).

The applicant stated that to accommodate the potential seismic hazard from Cuba, which is partly within the 320 km (200 mi) site region, an areal source is appropriate. The applicant justified its use of an areal source based on the fact that limited information exists about fault behavior and slip rates for any of the faults in Cuba. The applicant further stated that the Cuban areal source is associated with a moderate level of seismicity with concentrations of earthquakes occurring along its northern boundary as well as along its southeastern boundary, closer to an active plate tectonic boundary in the region. The applicant listed the largest

historical earthquake in this areal source to be the 1914 earthquake with a magnitude of about **M**6.3 located along the northeastern portion of the areal source. The applicant stated that it used the Phase 2 earthquake catalog to estimate the earthquake recurrence rates within the areal source. The applicant also indicated that earthquakes with a M_{max} of **M**7.0 to **M**7.25 are expected in this source and used these values in defining the areal source's M_{max} values.

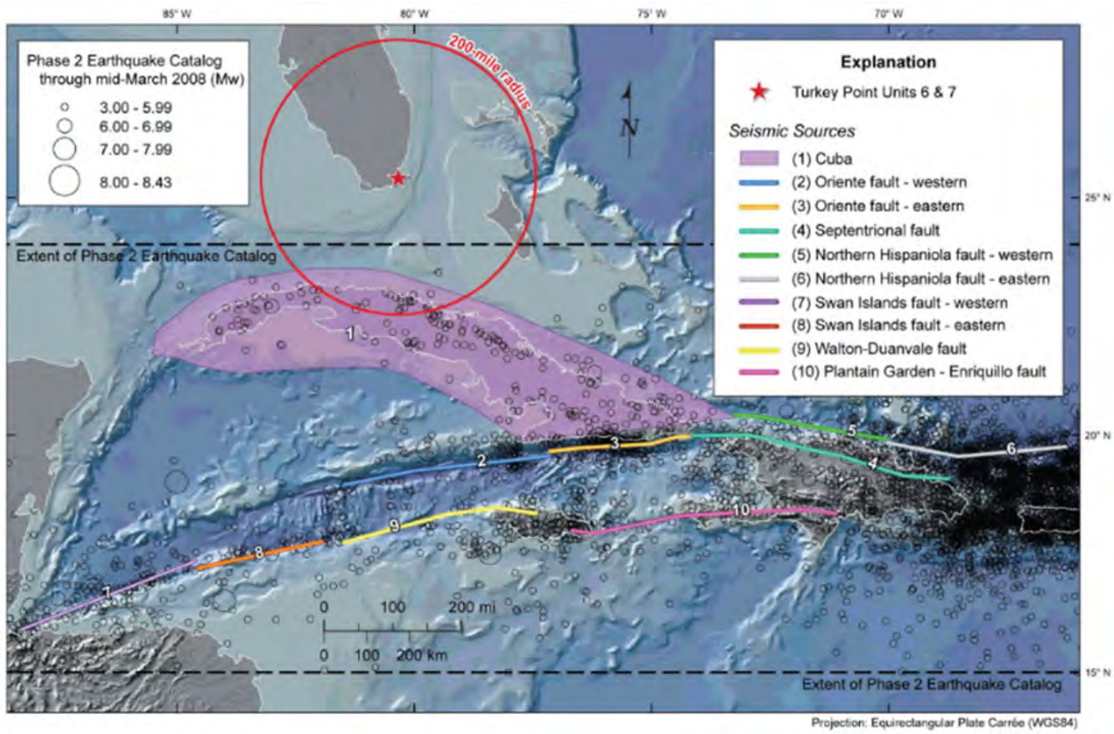


Figure 2.5.2-3. Map showing new seismic sources developed in the region of Cuba and the Caribbean. Phase 2 earthquake catalog data also plotted as black circles (Source: Turkey Point Units 6 and 7 COL FSAR Figure 2.5.2-217)

To accommodate the remaining seismic sources in the Caribbean region, the applicant developed nine major fault sources that could potentially affect the Turkey Point Units 6 and 7 site. These seismic sources along the North American-Caribbean plate boundary zone are: Oriente fault – western, Oriente fault – eastern, Septentrional fault, Northern Hispaniola fault – western, Northern Hispaniola fault – eastern, Swan Islands fault – western, Swan Islands fault – eastern, Walton Duanvale fault, and Enriquillo-Plantain Garden fault (Figure 2.5.2-3). These fault sources are located approximately 670 km (420 mi) to 1,200 km (760 mi) from the Turkey Point Units 6 and 7 site. Through its SSHAC level II study, the applicant developed a range of seismic source parameters for these fault sources along with their uncertainties.

As a confirmatory check, the applicant compared the seismic source model parameters of some its newly developed seismic sources with those used in USGS Initial Seismic Hazard Maps for Haiti by Frankel et al. (2010). The applicant explained that four seismic sources in the Frankel et al. (2010) model are incorporated into the Caribbean Seismic Source Model for the Turkey Point Units 6 and 7 site and their source model parameters are comparable.

Ground Motion Models

The applicant used two ground motion prediction models in conducting its PSHA analysis based on the geographic location of the seismic sources. For the EPRI-SOG seismic sources, the applicant used the NRC-endorsed EPRI (2004, 2006) Ground Motion Prediction Equations (GMPEs). The applicant stated that Cuba and the Caribbean region do not have any published GMPE that could be used in the Turkey Point Units 6 and 7 site's PSHA. For these seismic sources, the applicant developed a new ground motion model using a SSHAC level II process. Since observational data is very limited, the applicant used a simulation procedure to develop the Caribbean region GMPEs. Using region-specific information such as lithospheric velocity models, seismic quality factor (Q), and established seismic waveform calculation programs and procedures, the applicant simulated many different alternative earthquake scenarios and used these results to develop ground motion propagation models for the Caribbean region. The applicant then compared the new GMPEs with the limited amount of observational data available in the region to show that the new models are, in general, conservative compared to the observational data and used the new GMPEs in its PSHA calculations

PSHA Methodology and Calculation

The applicant performed PSHA calculations for peak ground acceleration (PGA) and spectral acceleration at ground motion frequencies of 0.5, 1.0, 2.5, 5, 10, and 25 hertz (Hz). Because the ground motion prediction models are valid at generic hard rock site conditions with shear wave velocities equal to 2.8 km/s (9,200 fps), the applicant's PSHA calculations are valid for hard rock conditions.

PSHA Results

The applicant performed the PSHA calculations using the EPRI-SOG and Caribbean seismic sources described in SER Section 2.5.2.2.2, EPRI (2004, 2006) GMPEs, GMPEs developed for Cuba and the Caribbean region, and the earthquake recurrence rates described in EPRI (1989) as well as those calculated using the Phase 2 earthquake catalog. In addition, the applicant incorporated the UCSS model (SNC, 2006) into its PSHA calculations. The applicant tested hazard contributions of the New Madrid seismic zone and small earthquakes in the updated UCSS and determined that these sources did not contribute to the total hazard at the Turkey Point Units 6 and 7 site. Using the total seismic hazard curves, the applicant developed UHRS, which are the spectral accelerations that have an equal likelihood of exceedance at different natural frequencies. Figure 2.5.2-4 shows the mean UHRS for the 10^{-4}, 10^{-5}, and 10^{-6} annual frequencies of exceedance for hard rock conditions at the Turkey Point Units 6 and 7 site.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.4.6 describes the earthquake potential for the site in terms of the most likely earthquake magnitudes and source-to-site distances, which are referred to as 'controlling earthquakes'. The applicant determined the controlling earthquakes that dominate low frequencies (LF) and high frequencies (HF), 1 and 2.5 Hz and 5 and 10 Hz, respectively. To determine the controlling earthquakes, the applicant deaggregated the PSHA at selected probability levels using the procedures outlined in RG 1.208. The applicant performed the deaggregation of the mean 10^{-4}, 10^{-5}, and 10^{-6} PSHA seismic hazard curves. The resulting parameters are listed in Figure 2.5.2-1. The deaggregation results indicate that local earthquakes are the primary contributors to the HF seismic hazard, while far away earthquakes also contribute. Low frequency seismic hazard is primarily controlled by far away sources, such as the Cuba areal source, UCSS, and some of the Caribbean sources.

Table 2.5.2-1. Controlling Earthquakes Magnitudes and Distances (Reference FSAR Table 2.5.2-225)

Struct. Frequency	Annual Freq. Exceed.	Overall Hazard		Hazard from R > 100 km	
		M	R, km	M	R, km
1 & 2.5 Hz	1E-04	7.1	400	7.3	570
5 & 10 Hz	1E-04	5.9	110	6.5	290
1 & 2.5 Hz	1E-05	6.7	190	7.2	560
5 & 10 Hz	1E-05	5.5	31	6.7	250
1 & 2.5 Hz	1E-06	6.3	61	7.2	600
5 & 10 Hz	1E-06	5.5	17	6.9	180

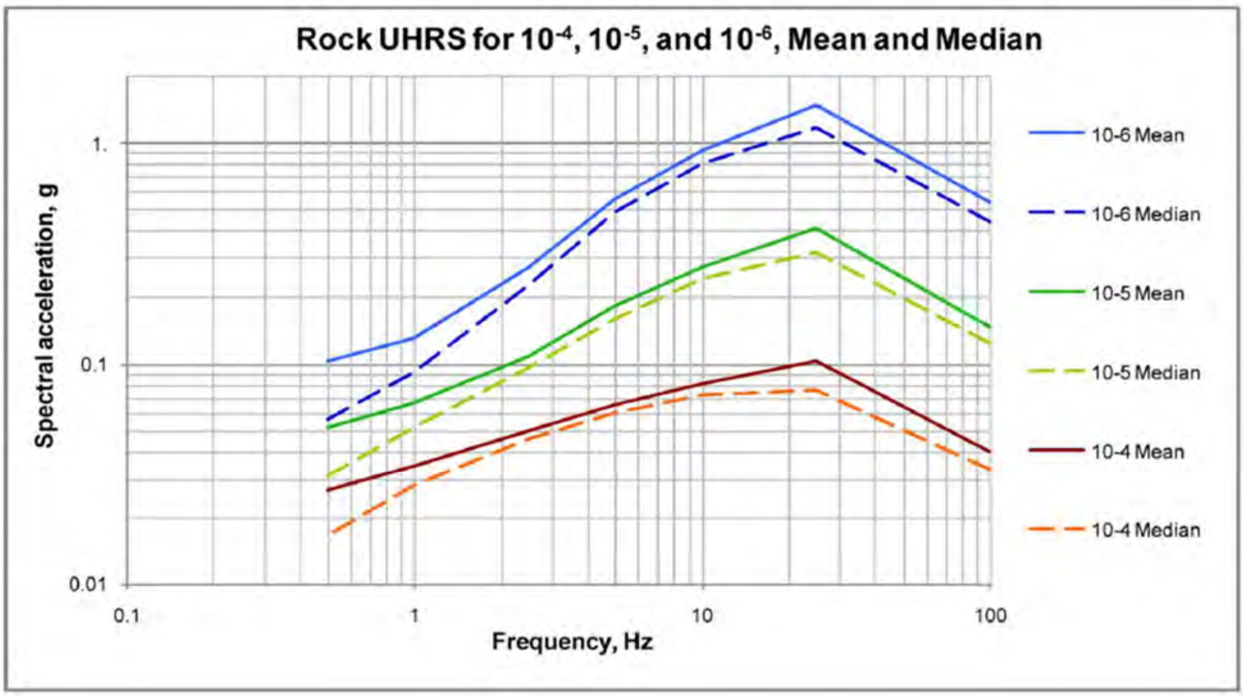


Figure 2.5.2-4. Uniform hazard respond spectra curves calculated for the Turkey Point site at the annual frequencies of exceedances of 10^{-4}, 10^{-5}, and 10^{-6}. These curves represent uniform hazard spectra at the hard rock levels beneath the site (Source: Turkey Point Units 6 and 7 COL FSAR Figure 2.5.2.-225)

PSHA Sensitivity Analysis

The applicant submitted its original COL application in 2010. In 2012, the NRC issued NUREG-2115 describing new seismic source models to be used in future PSHA calculations. Consistent with RG 1.208, the applicant compared its PSHA results calculated based on the updated EPRI-SOG model to the results obtained based on the NUREG-2115 model (the

CEUS-SSC model). For both hazard calculations, the applicant held hazard from Cuba and Caribbean sources constant. The applicant stated that the EPRI-SOG PSHA results were comparable to the results obtained using the CEUS-SSC model, therefore, the applicant decided to maintain the original results in its PSHA analysis.

2.5.2.2.5 Seismic Wave Transmission Characteristics of the Site

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.5 describes the procedure the applicant used to assess the effects of near surface rocks on seismic wave transmission beneath the site. As defined above, the hazard curves generated by the PSHA are defined for generic hard rock conditions characterized by a shear-wave velocity (V_S) of 2.8 km/s (9,200 ft/s). For the Turkey Point Units 6 and 7 site, these hard rock conditions exist at a depth of 3,500 m (10,000 ft) beneath the ground surface, while materials with lower velocities exist in the upper 3,500 m (10,000 ft). To determine the near-surface UHRS, the applicant used Approach 2A procedures outlined in NUREG/CR-6728, “Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines”. Following Approach 2A, the applicant: (1) developed velocity models for the Turkey Point Units 6 and 7 site, (2) randomized the models to account for variability, and (3) performed the final site response analysis.

Site Response Model

The applicant developed site-specific shallow V_S models for the upper 194 m (636 ft) of the subsurface based on the results of compression (P) and shear (S) wave measurements from P-S suspension logging and cone penetration testing (CPT). The applicant estimated velocities from a depth of 194 m (636 ft) to 3,660 m (12,000 ft) using deep velocity profiles taken from eight deep sonic logs located within 125 mi of the site. The applicant combined the median V_S data from the upper 194 m (636 ft) at the site with the median V_S data from the regional sonic logs to estimate an initial velocity profile for the upper 3,050 m (10,000 ft) of the subsurface for site response analysis.

The applicant also estimated the parameter kappa (κ) as input into the site response analysis. Kappa is a measure of seismic energy dissipation in near-surface rocks. The applicant used modulus reduction and damping relationships to account for the potential of nonlinear behavior in the upper 194 m (636 ft) of the profile. The applicant assumed that the remaining rock layers behave linearly during seismic shaking. In order to ensure physically realistic damping parameters for the site, the applicant calculated a total site κ and ensured that the total damping from the profile remained within this maximum κ.

The applicant’s analysis resulted in the V_S profiles for the Turkey Point Units 6 and 7 site illustrated in Figure 2.5.2-5, which were used in the applicant’s GMRS analysis.

Site Response Methodology and Results

The applicant used RG 1.208 to define the site-specific GMRS at elevation -10.7 m (-35 ft) within the Key Largo Limestone. Turkey Point Units 6 and 7 COL FSAR Section 2.5.4 states that material above the GMRS elevation (Miami Limestone and “muck”) will be replaced with concrete and structural fill.

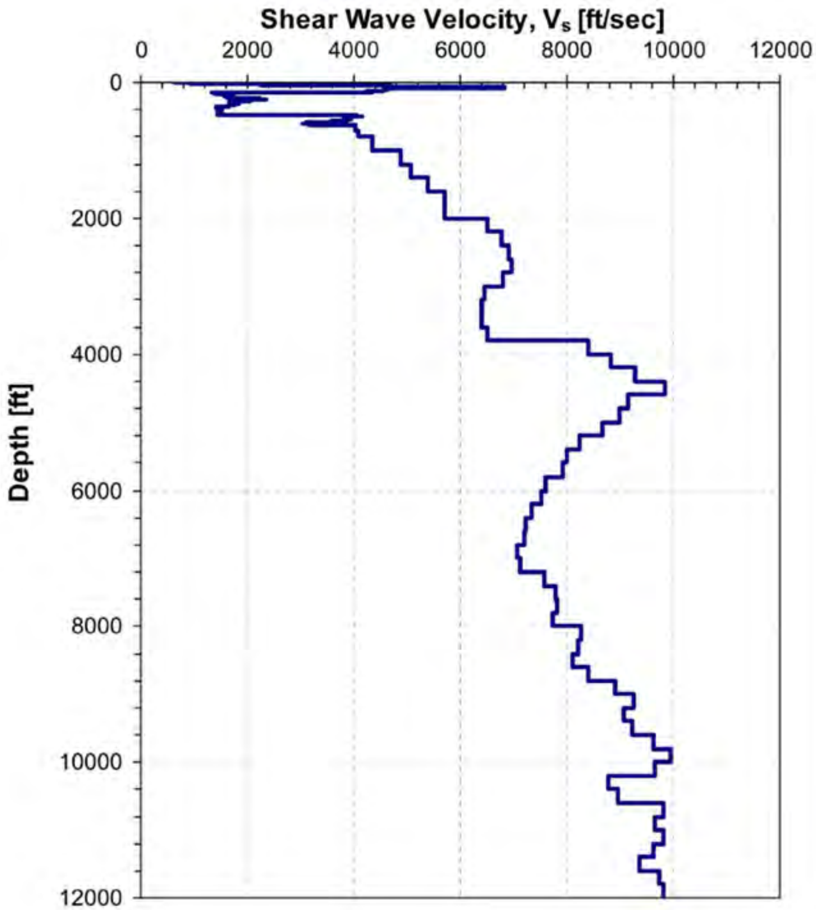


Figure 2.5.2-5. Base case shear velocity profile developed for the Turkey Point site. Hard rock conditions are observed at a depth of about 12,000 ft (3,658 m) (Source: Turkey Point Units 6 and 7 COL FSAR Figure 2.5.2-235)

The applicant determined the appropriate soil and rock dynamic properties and then modeled the variability in the site data by randomizing the soil and rock V_S profiles, shear modulus reduction, and damping values. The applicant generated 60 randomized profiles using the V_S correlation model developed by Silva et al. (1996). These artificial profiles represent potential variability in the soil column from the top of bedrock to the ground surface.

The applicant developed response spectra for each controlling earthquake for two frequency ranges, HF (5 to 10 Hz) and LF (1 to 2.5 Hz), as defined in RG 1.208. The applicant then developed input ground motions using the controlling earthquake's magnitudes and distances and the hard rock spectral shapes for CEUS earthquake ground motions recommended in NUREG/CR-6728. These input ground motions were then used as input to a random vibration theory process to calculate site response. The applicant's site response calculations indicate that, in general, local site conditions amplify reference hard rock motions at frequencies lower than about 7 to 8 Hz, and de-amplify seismic energy at higher frequencies.

2.5.2.2.6 Ground Motion Response Spectra

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.6 describes the method the applicant used to develop the horizontal and vertical site-specific GMRS. To obtain the horizontal GMRS, the applicant used the performance-based approach described in RG 1.208. The applicant developed the GMRS by scaling the rock UHRS by the site amplification functions. The site-specific GMRS is defined at the elevation of -10.7 m (-35 ft). The applicant developed the vertical GMRS by applying vertical-to-horizontal response spectral ratios, based on RG 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," to the horizontal 10^{-4} and 10^{-5} UHRS values and calculating a site-specific vertical GMRS.

Horizontal GMRS

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.6.1, the applicant developed a horizontal, site-specific, performance-based GMRS using the method described in RG 1.208. The performance-based method achieves the annual target performance goal (P_F) of 10^{-5} per year for frequency of onset of significant inelastic deformation. This damage state represents a minimum structural damage state, or essentially elastic behavior, and falls well short of the damage state that would interfere with functionality. The horizontal GMRS for each spectral frequency, which meets the P_F, is obtained by scaling the smooth rock 10^{-4} UHRS by the design factor (DF) (SER Equation 2.5.2-1):

$$DF = max(1.0, 0.6(A_R)^{0.8}) \quad \text{Equation (2.5.2-1)}$$

In SER Equation 2.5.2-1, the amplitude ratio, A_R, is given by the ratio 10^{-5} UHRS and the 10^{-4} UHRS spectral accelerations for each spectral frequency. When A_R exceeds 4.2, RG 1.208 specifies that the value of the GMRS is to be no less than 45 percent of the 10^{-5} UHRS. The resulting horizontal GMRS is shown as the green line in Figure 2.5.2-6

Vertical GMRS

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.6.2, the applicant calculated the vertical GMRS by applying the V/H ratios listed in RG 1.60 to the 10^{-4} and 10^{-5} UHRS and using SER Equation 2.5.2-1. Figure 2.5.2-6 shows the resulting GMRS as a violet line.

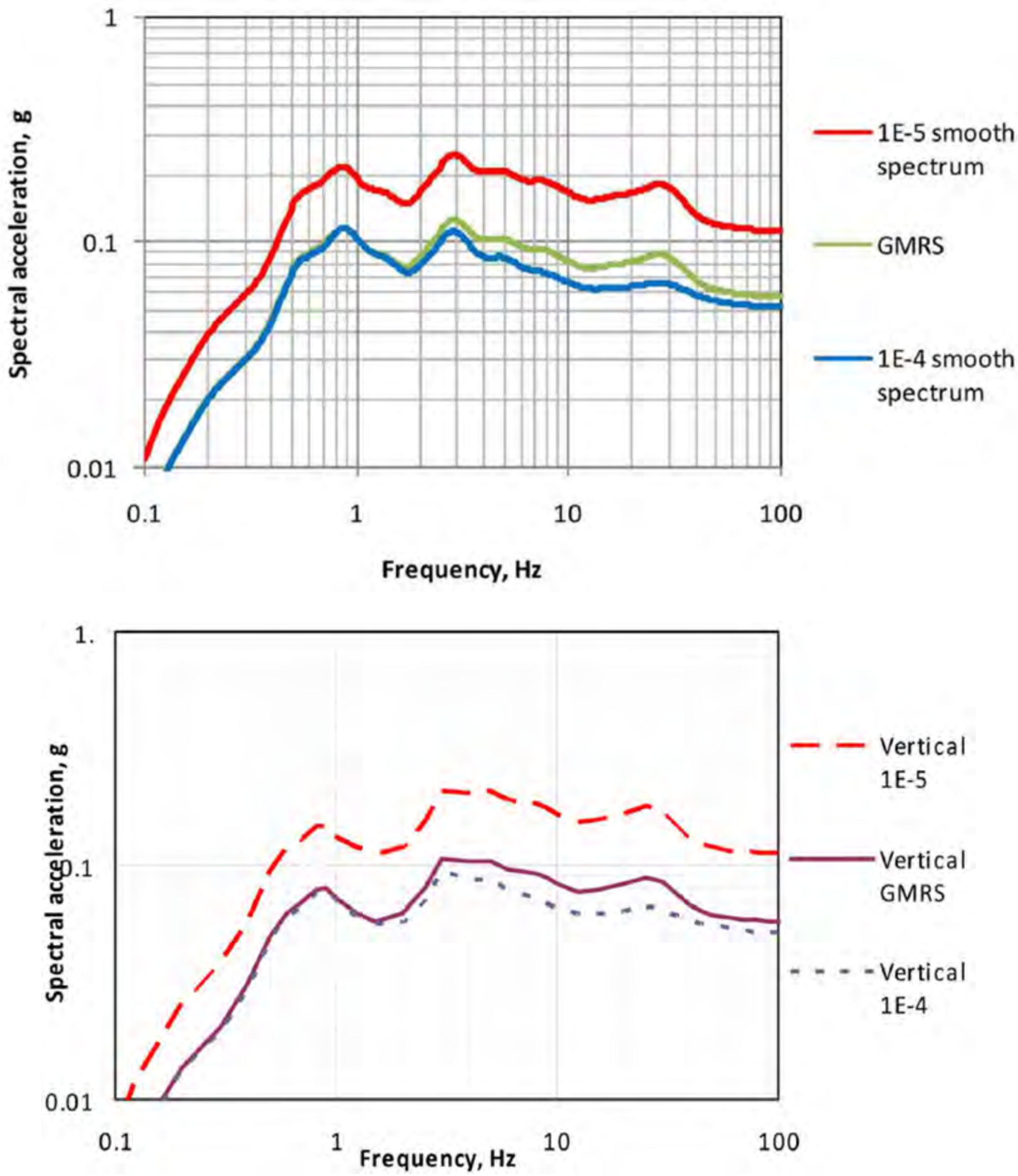


Figure 2.5.2-6. Horizontal (top) and vertical (bottom) GMRS curves calculated for the Turkey Point Units 6 and 7 site (Source: Turkey Point Units 6 and 7 COL FSAR Figures 2.5.2-253 and Figure 2.5.2-254)

2.5.2.3 Regulatory Basis

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

In addition, the applicable regulatory requirements for reviewing the applicant’s discussion of vibratory ground motion are:

- 10 CFR 100.23 with respect to obtaining geologic and seismic information necessary to determine site suitability and ascertain that any new information derived from site-specific investigations does not impact the GMRS derived by a PSHA. In complying with this regulation, the applicant also meets guidance in RG 1.132, Revision 2 and RG 1.208.

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

The related acceptance criteria NUREG-0800, Section 2.5.2 are summarized as follows:

- Seismicity: To meet the requirements in 10 CFR 100.23, this section is accepted when the complete historical record of earthquakes in the region is listed and when all available parameters are given for each earthquake in the historical record.

- Geologic and Tectonic Characteristics of Site and Region: Seismic sources identified and characterized by NUREG-2115 were used.

- Correlation of Earthquake Activity with Seismic Sources: To meet the requirements in 10 CFR 100.23, acceptance of this section is based on the development of the relationship between the history of earthquake activity and seismic sources of a region.

- Probabilistic Seismic Hazard Analysis and Controlling Earthquakes: For CEUS sites relying on the NUREG-2115 seismic source characterization model, 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 these site investigation results 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.

- Ground Motion Response Spectra: In this section, the staff reviews the applicant's procedure to determine the GMRS.

In addition, the geologic and seismic characteristics should be consistent with appropriate sections from: RG 1.60, RG 1.206, and RG 1.208.

2.5.2.4 Technical Evaluation

The staff reviewed Section 2.5.2 of the Turkey Point Units 6 and 7 COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represent the complete scope of information relating to this review topic.[1] The review confirmed that the information contained in the Turkey Point Units 6 and 7 COL FSAR and incorporated by reference addresses the required information relating to the vibratory ground motion. The staff's

technical evaluation of the information incorporated by reference related to vibratory ground motion are documented in NUREG-1793 and its supplements.

The staff review of the information contained in the Turkey Point Units 6 and 7 COL FSAR is discussed as follows:

AP1000 COL Information Items

- PTN COL 2.5-2

The staff reviewed COL Information Item 2.5-2, which addresses the provision for site-specific information related to the vibratory ground motion aspects of the site including: seismicity, geologic and tectonic characteristics, correlation of earthquake activity with seismic sources, PSHA, seismic wave transmission characteristics and the SSE ground motion.

- PTN COL 2.5-3

The staff reviewed COL Information Item 2.5-3, 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.

SER Section 2.5.2.4 of this report provides the 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 Turkey Point Units 6 and 7 site. The applicant developed of the GMRS based on a detailed evaluation of earthquake potential, taking into account the regional and local geology, Quaternary tectonics, seismicity, and site-specific geotechnical engineering characteristics of the Turkey Point Units 6 and 7 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 Turkey Point Units 6 and 7 COL FSAR. To evaluate the original geologic, seismic, and geophysical information submitted by the applicant thoroughly, the staff obtained additional assistance from experts at USGS.

In addition to RAIs addressing specific technical issues discussed below, the staff also prepared clarification and data request RAIs (RAI 19, Question 02.05.02-1 and RAI 37, Question 02.05.02-13) to help its review. Because the information provided by the applicant in response to those clarification RAIs did not substantively change information in the Turkey Point Units 6 and 7 COL FSAR, these RAIs are resolved.

2.5.2.4.1 Seismicity

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.1 describes the seismicity and earthquake catalog used by the applicant to calculate the seismic ground motion hazard for the Turkey Point Units 6 and 7 site. The applicant used the CEUS EPRI-SOG earthquake catalog as a starting point and updated it through February 2008 (Phase 1 catalog). The applicant supplemented the updated EPRI-SOG catalog with seismicity in Cuba and the Caribbean because the applicant identified seismic sources in these regions affect the total seismic hazard

at the Turkey Point Units 6 and 7 site (Phase 2 catalog). The applicant's combined Phase 1 and Phase 2 earthquake catalog covers the seismicity in the Turkey Point Units 6 and 7 site region through 2008 and provides data to assess seismic source model parameters used in the Turkey Point Units 6 and 7 site's PSHA study. Seismic source model parameters, such as maximum magnitudes and earthquake recurrence rates, are primarily determined based on information available in the earthquake catalog. The staff's technical evaluation of COL FSAR Section 2.5.2.1 focused on (1) development of the Caribbean earthquake catalog and updates to the EPRI-SOG earthquake catalog, (2) whether earthquakes that have occurred since completion of the applicant's catalog affect the seismic sources and their parameters, and (3) the methodology used by the applicant to convert earthquake magnitudes into a consistent magnitude scale.

Staff Confirmatory Seismicity Analysis

As part of its review of Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.1, the staff developed its earthquake catalog for the Caribbean region and the CEUS region covering the time period from February 1985 to January 2015. The staff used this supplemental earthquake catalog to determine whether the applicant's updated earthquake adequately characterized the seismicity in the region and that there are no new earthquakes in the entire region since the development of the applicant's catalog that might impact the parameters of seismic sources used in the Turkey Point Units 6 and 7 site's PSHA.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.1.2 describes the updated Phase 1 and Phase 2 earthquake catalogs. The staff recognized that 15 of the 34 earthquake catalogs used by the applicant cite USGS National Earthquake information Center (NEIC) "Earthquake Search" Web site. In RAI 37, Question 02.05.02-10, the staff asked the applicant to clarify how it identified the contribution from each sub-catalog in USGS NEIC database. In response to this RAI, the applicant provided the staff with clarifying information, indicating that the appropriate catalog reference in the Turkey Point Units 6 and 7 COL FSAR should have been the National Geophysical Data Center (NGDC). Because the NGDC catalog reference lists a table, which indicates the contribution from each sub-catalog and the applicant updated the Turkey Point Units 6 and 7 COL FSAR accordingly, the staff considers RAI 37, Question 02.05.02-10, resolved.

The staff's independent confirmatory earthquake catalog for the region is primarily from USGS NEIC earthquake catalog. Figure 2.5.2-7 depicts the earthquakes identified in the staff's earthquake catalog and the applicant's earthquake catalog from February 1985 to December 2007. The comparison of these data sets illustrates that the applicant's updated earthquake catalog adequately characterizes the seismicity within the site region.

Since the applicant's earthquake catalog is complete through 2007, the staff also searched for significant seismic events that have occurred since 2007 that would potentially impact the seismic hazard. The yellow circles in Figure 2.5.2-7 illustrate the seismicity documented in USGS catalog from December 2007 through January 2015. Overall, the pattern of seismicity occurring in the period after the end of the applicant's catalog is consistent with the information contained in the catalog. The staff noted only one moderate magnitude (M_w = 5.1) earthquake that occurred within the 200 mile (320 km) site region in Cuba on January 9, 2014. The staff concludes that the applicant's seismic hazard models encompass this event because similar sized earthquakes have previously occurred in the region and the minimum M_{max} defined by the applicant for the Cuba areal source is 7.0.

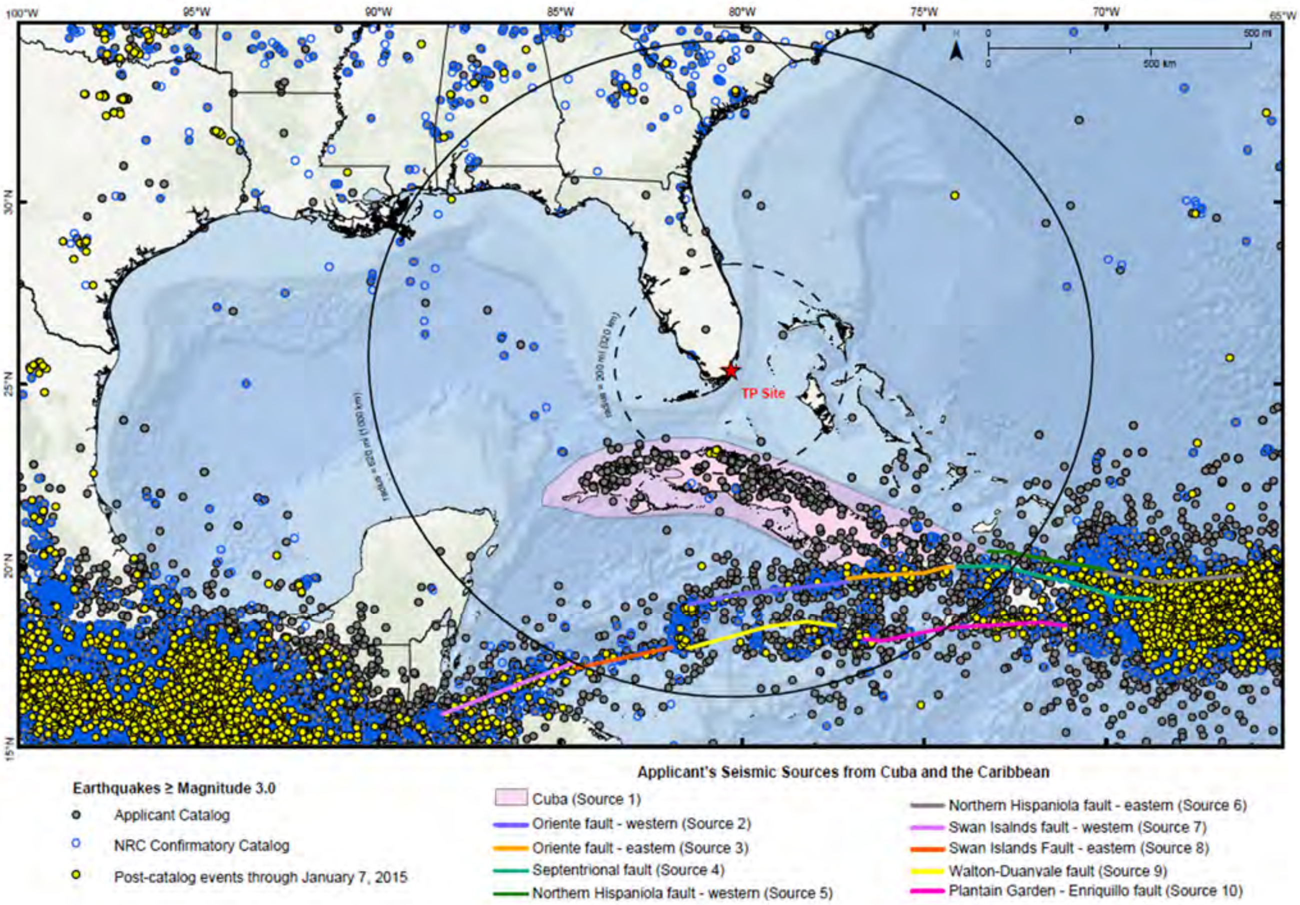


Figure 2.5.2-7. Comparison of the applicant's earthquake catalog with staff's confirmatory catalog for events with moment magnitudes (M) equal to or greater than 3.0 in the CEUS, Cuba, and the Caribbean. The applicant's seismic sources for Cuba and the Caribbean are also illustrated.

Magnitude Conversions

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.1.3.1 states that moment magnitude (M_w) was used as the uniform magnitude measure in the Phase 2 earthquake catalog (Cuba and Caribbean region update) development efforts, however, the applicant's Phase 1 earthquake catalog (EPRI-SOG earthquake update) uses body-wave magnitudes (m_b) as the uniform magnitude measure. In RAI 37, Question 02.05.02-5, the staff asked the applicant to explain if this would pose an issue since the Phase 1 catalog is based on m_b (body wave magnitude) and the Phase 2 catalog is based on M_w (moment magnitude). In an October 3, 2014 response to RAI 37, Question 02.05.02-5 (ADAMS Accession No. ML14282A014), the applicant provided the staff with its rationale for selecting two alternative magnitude scales. The applicant stated that it used m_b for the Phase 1 catalog update, since both the EPRI-SOG seismicity catalog and recurrence calculations used the m_b scale. The applicant stated that, in general, the m_b scale adequately characterized the seismic energy released by sources in the central and eastern United States. However, M_w was more appropriate for the Caribbean because it provided a better measure of the energy released for a greater range of magnitudes, especially for large magnitude earthquakes characterized by large fault dimensions or complex rupture

mechanisms expected in the Caribbean. The applicant further explained that m_b saturates the energy release for earthquakes greater than magnitude 5.0 due to the difference in period and the seismic-wave type used to determine the magnitude size and is therefore not appropriate for seismicity in the Caribbean.

The applicant explained that the total number of earthquakes greater than or equal to magnitude 3.0 using m_b or M_w as the uniform magnitude measure could vary depending on the details of the magnitude conversion. However, the applicant confirmed that it did not exclude any earthquakes of m_b 3.0 or greater by their conversion to M_w for the Caribbean region. The applicant also evaluated the effect on the number of Phase 2 catalog earthquakes of M_w 3.0 and greater calculated using the CEUS-SSC magnitude scale conversion relations in EPRI et al. (2012) instead of the relations presented in the Turkey Point Units 6 and 7 COL FSAR. The applicant concluded that if it implemented the CEUS-SSC magnitude conversion methodology, there would be an increase in the number of small magnitude events and a decrease in the magnitude for all events with M_w 4.5 and greater. As a result of RAI 37, Question 02.05.02-5, the applicant added a discussion and the rationale for selecting M_w as the uniform magnitude scale for the Phase 2 catalog and their magnitude conversion process for earthquakes in the Caribbean to Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.1.3.1. Since the applicant used both the EPRI-SOG and Caribbean seismic source models, and each model is based exclusively on either m_b or M_w magnitudes, the staff finds that having two different types of base magnitudes is justified. Furthermore, because the applicant showed in its RAI response that when applied, the most recent m_b to M_w conversion methodology results in somewhat less conservative results (as it provides fewer number of events greater than magnitude 4.5), the staff considers RAI 37, Question 02.05.02-5 resolved.

Staff Conclusions Regarding Seismicity

Based upon the staff's confirmatory earthquake catalog, a review of Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.1, and the resolution of RAI 37, Questions 02.05.02-5 and 02.05.02-10, the staff concludes that the applicant developed a completed and accurate earthquake catalog for the region surrounding the Turkey Point Units 6 and 7 site. The staff concludes that the earthquake catalog as described by the applicant in the Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.1 forms an adequate basis for the seismic hazard characterization of the site.

2.5.2.4.2 Geologic and Tectonic Characteristics of the Site and Region

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.2 describes the seismic sources used by the applicant to calculate the seismic ground motion hazard for the Turkey Point Units 6 and 7 site. This SER section provides the staff's evaluation of the seismic source models the applicant used as part of its PSHA. Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.2 describes that the applicant used the original EPRI-SOG seismic source models (EPRI-SOG, 1986) as a starting model and updated them using new data and information. Consistent with RG 1.208, the applicant evaluated more recent seismic hazard studies and new data available for the region surrounding the site for comparisons to the 1986 EPRI-SOG seismic source models. As a result of this evaluation, the applicant updated several of the original source models developed by the EPRI-SOG ESTs. In its geologic and tectonic site characterization, the applicant also determined that several of the Caribbean seismic sources that are outside the 320 km (200 mi) site region might also contribute to the seismic hazard at the site. In COL FSAR Section 2.5.2.4, the applicant described the development of a new seismic source model for the Caribbean region. The following sections describe the staff's evaluation of updates to

the EPRI-SOG seismic source models and the newly developed Caribbean seismic source models.

2.5.2.4.1.2 EPRI Seismic Sources

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.2, the applicant stated that, consistent with RG 1.208, it chose to use the EPRI-SOG seismic models in its seismic hazard calculations and updated them to be consistent with new geologic, tectonic, and earthquake information available in the region. The applicant stated that recent earthquakes in the Gulf of Mexico and U.S. Gulf Coast required modifications to M_{max} distributions of several of the EPRI-SOG seismic sources. In addition, the applicant stated that the EPRI-SOG model did not cover the site region fully, and it would develop supplemental seismic sources to cover the entire site region adequately. In Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.4, the applicant described these updates to the EPRI-SOG model. Because RG 1.208 specifically mentions the EPRI-SOG model as a potential seismic source model in new reactor seismic hazard assessments in the CEUS, the staff focused its review on the updates the applicant conducted to bring this model up-to-date.

Update of the Charleston Seismic Source

New scientific evidence available after the publication of the EPRI-SOG model in 1986 indicates that the models representing two of the largest seismic sources in the CEUS, the New Madrid Seismic Zone and Charleston seismic source, needed updating. The original EPRI-SOG model incorporates these two seismic sources, however, in the time since its publication; researchers have discovered evidence for higher earthquake recurrence rates for large magnitude earthquakes in these seismic sources. The applicant evaluated the impacts of such updates to these two seismic sources in the CEUS region and determined that due to the distance of the New Madrid Seismic Zone to the Turkey Point Units 6 and 7 site, the updates did not impact the total seismic hazard at the Turkey Point Units 6 and 7 site. However, the proposed updates to the Charleston seismic source model impacted the total seismic hazard estimates at the Turkey Point Units 6 and 7 site. Hence, the applicant discussed the new evidence, revised the seismic sources of the EPRI-SOG model, and added an updated Charleston Seismic Source (UCSS) to accommodate increased hazard estimates from this source in its seismic hazard calculations.

The applicant updated the original EPRI-SOG Charleston seismic source models with a model originally presented in the SSAR for the Vogtle ESP site (SNC, 2008). This update was based on the results of several post-EPRI PSHA studies (e.g., Frankel et al., 2002; Chapman and Talwani, 2002) and the availability of paleoliquefaction data (Talwani and Schaeffer 2001). The Site Safety Analysis Report (SSAR) for the Vogtle ESP Site (SNC, 2008) provides the details of the UCSS model and NUREG-1923, "Safety Evaluation Report for an Early Site Permit (ESP) at the Vogtle Electric Generating Plant (VEGP) ESP Site," describes the staff's review of the UCSS. The UCSS model development followed the guidelines provided in RG 1.208 and used a SSHAC Level II (SSHAC, 1997) expert elicitation method to incorporate current literature and data and the understanding of experts into an update of the Charleston seismic source model. During the review of the Turkey Point Units 6 and 7 COL FSAR, there was an additional update to the Charleston seismic source model developed as part of the most recent CEUS regional seismic source model published in NUREG-2115. The NUREG-2115 model modified the UCSS model, and SER Section 2.5.2.4.4 discusses the staff's evaluation of the impact of this new model at the Turkey Point Units 6 and 7 site.

Cuba and Caribbean Seismic Source Models

The 320 km (200 mi) site region of the Turkey Point Units 6 and 7 site extends beyond the physical boundaries of the EPRI-SOG seismic model, which ends just south of the Florida peninsula. The 320 km (200 mi) site region extends into Cuba, as seen in Figure 2.5.2-7. In accordance with RG 1.208, the applicant should analyze all seismic sources within the 320 km (200 mi) site region for potential contributions to the seismic hazard. In addition, RG 1.208 also recommends that an applicant must expand the area of investigation beyond the site region, if capable seismic source zones outside the site region affect the seismic hazard at the site of interest. There are large seismic sources in the Caribbean region associated with the plate boundary between North American and the Caribbean. These sources extend from just outside the 320 km (200 mi) site region to greater than 1,000 km (620 mi) from the site. Despite these sources' large distances, the applicant stated that several have the potential to contribute to the total seismic hazard at the Turkey Point Units 6 and 7 site. Figure 2.5.2-7 shows the large seismic sources in the Caribbean used in the applicant's PSHA. Through a SSHAC Level II study, the applicant conducted a seismic source characterization study and developed new seismic source models for several of these large seismic sources for use in the Turkey Point Units 6 and 7 site's PSHA study. SER Section 2.5.1.4.1 provides a detailed description of the geologic and tectonic characterization of these Cuba and Caribbean sources. Potential impacts of these structures on the seismic hazard is evaluated in SER Section 2.5.2.4.4.

Staff Conclusions of the Geologic and Tectonic Characteristics of the Site and Region

Based upon its review of Turkey Point Units 6 and 7 COL FSAR Sections 2.5.2.2 and 2.5.2.4, and the resolution of RAIs, the staff concludes that the applicant adequately described the geologic and tectonic characterization of potential seismic sources in the region of the Turkey Point Units 6 and 7 site. The staff finds the applicant's characterization of the updated EPRI-SOG models and the newly developed Caribbean seismic source models adequate and consistent with the guidance provided in RG 1.208.

2.5.2.4.3 Correlation of Earthquake Activity with Seismic Sources

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.3, the applicant described the correlation between the seismicity and the EPRI-SOG seismic source model. Consistent with RG 1.208, the applicant updated the EPRI-SOG earthquake catalog (1627 to 1984) to include events recorded through December 2007. The applicant described this earthquake catalog as the Phase 1 catalog. From this updated catalog, the applicant concluded that seismicity in the CEUS site region did not correlate with any known geologic structures and that there were no patterns of seismicity that required a significant revision to the geometry of the EPRI-SOG seismic sources.

The applicant provided information on correlations of earthquakes with just the EPRI seismic source models, but not with other seismic sources, such as the Cuba areal source and the Caribbean seismic sources used in its hazard estimates for the Turkey Point Units 6 and 7 site. In RAI 37, Question 02.05.02-7, the staff requested for the applicant to provide a thorough, detailed description in the COL FSAR of the correlations of seismicity with all of the seismic sources used in the Turkey Point Units 6 and 7 site's PSHA study. In response to this RAI, the applicant provided additional information on the correlation of seismicity (described in its Phase 2 earthquake catalog) with the Cuba and Caribbean seismic sources in COL FSAR Section 2.5.2.4.4.3.

In its evaluation, staff examined its confirmatory earthquake catalog and maps of tectonic features in the study area. The staff agrees with the applicant that seismicity in the CEUS region does not show any correlation with any known tectonic features. In Cuba, the staff determines that establishing a discernable correlation between seismicity and known tectonic structures, such as faults, is quite difficult. Local seismicity in Cuba indicates that although some earthquakes concentrate along known faults, both the quality and quantity of data do not permit a clear determination of correlation. However, for the larger seismic sources in the Caribbean, fault activity is very clear as evidenced by concentration of seismicity along the faults sources (Figure 2.5.2-7).

The staff further evaluated the applicant's use of the updated earthquake catalog in seismic sources' maximum magnitude (M_{max}) assignments. Using its confirmatory earthquake catalog, the staff confirmed that the M_{max} assignments were adequate for each seismic source. This assessment showed that the M_{max} values used by the applicant were consistent with the seismic observations and that there were no observed earthquakes within each of the seismic sources with magnitudes greater than the assigned M_{max} values. Therefore, the staff concludes that the M_{max} values used by the applicant are acceptable for use in the Turkey Point Units 6 and 7 site's PSHA calculations.

Based on the staff's own independent earthquake catalog and confirmatory analyses of earthquake sources, the staff concludes that the Turkey Point Units 6 and 7 site's earthquake catalog adequately characterizes regional and local seismicity. Furthermore, the staff agrees with the applicant's conclusion that the spatial distribution of earthquakes in the region had not changed significantly since the publication of the EPRI-SOG earthquake catalog and that there are no substantial changes in seismicity patterns identified by the Phase 1 catalog. In addition, the staff agrees that seismicity demonstrated in the Phase 2 catalog adequately represented the Cuba and northern Caribbean seismic sources. Therefore, the staff concludes that the applicant has adequately evaluated the potential for new seismic sources or for revisions to existing source geometries based on seismicity patterns. Accordingly, the staff considers RAI 37, Question 02.05.02-7, resolved.

2.4.6.4.5 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.4 presents the applicant's PSHA results and its estimate of the earthquake potential for the Turkey Point Units 6 and 7 site in terms of the controlling earthquakes. The applicant determined the high- and low-frequency controlling earthquakes by deaggregating the PSHA results at selected probability levels following the guidance provided in RG 1.208. Before conducting PSHA calculations and determining the controlling earthquakes, the applicant investigated the local and regional geologic and tectonic features, updated existing seismic sources and their model parameters, and developed new seismic source models for the Caribbean seismic sources as described in Section 2.5.2.4.2 of this report. Since there were no applicable ground motion prediction equations (GMPE) to the Cuba and Caribbean seismic sources, the applicant also developed a new GMPE for the Cuba and Caribbean seismic sources. The staff focused its review on the applicant's EPRI-SOG source model updates, development of new seismic source models for Cuba and the Caribbean and the GMPEs specifically developed for the Cuba and Caribbean regions.

PSHA Calculations

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.4.1, the applicant stated that it used the 1989 EPRI–SOG seismic source model and the procedures outlined therein as the starting point for probabilistic seismic hazard calculations at the Turkey Point Units 6 and 7 site.

Since the EPRI-SOG model covers the entire CEUS region and it may be unnecessary to use very far away seismic sources with lower activity rates in its PSHA calculations, the applicant first identified a subset of the EPRI-SOG seismic sources that will impact the seismic hazard calculations at the Turkey Point Units 6 and 7. In addition, because the EPRI-SOG model does not cover the entire site region, and large seismic sources exist in Cuba and the Caribbean region outside the site region, the applicant supplemented the EPRI-SOG seismic models within the site region and developed new seismic source models for Cuba and the Caribbean following the SSHAC Level II study guidelines. Using the EPRI-SOG seismic sources and the newly developed Cuba and Caribbean seismic source models along with the EPRI (2004, 2006) GMPEs and the newly developed Caribbean GMPEs, the applicant calculated generic hard rock seismic hazard curves. Using the hard rock seismic hazard curves, the applicant then obtained uniform hazard response spectra (UHRS) at the mean annual frequency of exceedances of 10^{-4}, 10^{-5}, and 10^{-6}. Using the procedures outlined in RG 1.208, the applicant also determined the controlling earthquakes for the site along with their magnitudes and distances. The following sections describe the staff's assessment of the applicant's PSHA calculations and the determination of the controlling earthquakes and their parameters.

PSHA Inputs

To conduct a PSHA study, three essential data sets are needed: seismic sources, earthquake activity rates in these sources, and ground motion prediction models. Figure 2.5.2-1 shows the relevant seismic sources the applicant extracted from the CEUS EPRI-SOG model impacting the Turkey Point Units 6 and 7 site's seismic hazard. The applicant stated that it used the criterion described in the EPRI (1989) study to select these seismic sources. The EPRI (1989) study's seismic source selection criterion was that only those seismic sources that contributed at least 1 percent to the total seismic hazard would be used in a PSHA study. Because seismicity is relatively low in Florida, and the geology and tectonics of the site region are uniform, hazard contributing seismic sources are mainly the background seismic sources (seismic sources that incorporate the site). The applicant stated that none of the nearby CEUS EPRI-SOG seismic sources contributed more than 1 percent to the total seismic hazard. Since the original EPRI (1989) study used an older set of GMPEs to calculate percent contributions for each of the seismic sources in the EPRI-SOG model, in RAI 37, Question 02.05.02-6, the staff asked the applicant to clarify whether it used the newer EPRI (2004, 2006) GMPEs in its seismic source screening for the 1 percent contribution limit criterion. In its response, the applicant stated that its 1 percent contribution assessment used the newer EPRI (2004, 2006) GMPEs. Since the applicant used the process defined in the EPRI (1989) study with newer GMPEs to estimate seismic sources' contribution levels, the staff considers RAI 37, Question 02.05.02-6 resolved.

Following the seismic source selection process, the applicant investigated whether it needed to update the original earthquake recurrence rates provided for the selected EPRI-SOG seismic sources. To determine this, the applicant conducted a sensitivity study. First, the applicant defined a rectangular geographic area bounded by 25 to 30 ° North latitudes and 80 to 83 ° West longitudes. This region is large enough to cover the site and much of its vicinity. Using

the original EPRI-SOG earthquake catalog and the updated earthquake catalog, the applicant conducted two separate rate calculations within this zone and compared the results. The comparison showed that the original earthquake catalog produced recurrence rates slightly higher than the rates obtained using the updated earthquake catalog. The applicant stated that because the original rates are higher, it opted to use them in its Turkey Point Units 6 and 7 site's PSHA. Since the higher rates will result in higher hazard calculations, the staff concludes that the use of the older catalog rates are adequate and will result in more conservative hazard estimates at the Turkey Point Units 6 and 7 site.

Since the EPRI-SOG seismic sources did not cover the entire site region of the Turkey Point Units 6 and 7 site, the applicant also developed supplementary seismic sources as shown in Turkey Point Units 6 and 7 COL FSAR Figures 2.5.2-204 through 2.5.2-209. Since there is little seismicity in these supplementary seismic sources, using the updated earthquake catalog, the applicant estimated earthquake recurrence rates in a larger region. Once the applicant calculated the earthquake recurrence rates in a larger zone, it converted them into a total rate for each of the supplementary source zones using sources' areas. The staff evaluated the applicant's process and concluded that this is a conservative approach compared with the alternative of distributing the original rates calculated within the background sources to these supplementary sources. Extending existing rates to the supplementary zones would dilute the rates and would result in slightly lower hazard calculations. The applicant's process added earthquake rates into the total earthquake rate budget in the site region and will result in slightly more conservative seismic hazard estimates. The applicant, however, did not discuss the *a*- and *b*-values it calculated for these new supplementary seismic sources. In RAI 37, Question 02.05.02-11, the staff asked the applicant to provide the *a*- and *b*-values for these new supplementary sources. The applicant responded by stating that average *a*- and *b*-values were -2.28 and 1.03, respectively. The *a*-value is $\log_{10}$ of the annual rate of earthquakes with m_b between 3.3 and 3.9, per equatorial square degree. The applicant assigned these *a*- and *b*-values to the supplementary sources after scaling them using the individual sources' areas. Since the applicant provided numerical values of the *a*- and *b*-values, the staff considers RAI 37, Question 02.05.02-11, resolved.

Another seismic source model parameter that might need updating based on the new earthquake catalog is the maximum magnitudes defined for each of the selected EPRI-SOG seismic sources. M_{max} values represent the magnitude of the largest expected earthquake in a given source. Because of the uncertainty in determining the largest expected earthquake magnitudes in any region, rather than assigning a single M_{max} value, seismic source models usually provide a range of possible M_{max} values for each source. Each possible M_{max} value is also associated with a weight representing the degree of confidence on that value. The applicant stated that six out of the seven EPRI-SOG seismic source models required updates to at least one of the assigned M_{max} values. The applicant identified four moderate sized earthquakes in the updated earthquake catalog with magnitudes greater than the lower bound M_{max} values assigned to these sources. Using the process identified in EPRI-SOG (1986), the applicant updated several of the lower bound M_{max} values. Table 2.5.2-2 shows the names of the sources along with older and updated M_{max} distributions. To evaluate this update, the staff also conducted its own confirmatory study using its own earthquake catalog update and determined that the updates applied by the applicant are adequate and there are no other larger observed earthquakes in any of the selected seismic sources than the M_{max} magnitudes listed in Table 2.5.2-2.

As Figure 2.5.2-7 shows, while the Turkey Point Units 6 and 7 site region is devoid of significant earthquake activity, there is substantial seismic activity beyond the 320 km (200 mi) site region. Specifically, in Cuba and along the active plate boundaries of the Caribbean region, seismicity levels are elevated relative to the surrounding region (Figure 2.5.2-7). The applicant stated that despite their significant distances to the Turkey Point Units 6 and 7 site, some of these seismic sources contributed to total seismic hazard at the Turkey Point Units 6 and 7 site. Because there are no seismic source models for Cuba and the Caribbean seismic sources applicable for nuclear power plant applications, following the guidance in RG 1.208, the applicant conducted a SSHAC Level II study to develop new seismic source models for Cuba and the Caribbean regions. The applicant stated that the SSHAC study produced 10 new seismic sources, which included an areal source for the region of Cuba and nine fault sources. Figure 2.5.2-7 shows the locations of these seismic source models. Using these newly created models along with the EPRI-SOG models described above form the basis of the applicant's PSHA study to determine the total seismic hazard at the Turkey Point Units 6 and 7 site.

Table 2.5.2-2. Updated M_{max} (m_b) values of the seismic sources and associated weights (Revised from Turkey Point Units 6 and 7 COL FSAR Table 2.5.2-207)

Source Name	Original M_{max} Distribution	Updated M_{max} Distribution
Bechtel Group - Gulf Coast	5.4 [0.10] 5.7 [0.40] 6.0 [0.40] 6.6 [0.10]	6.1 [0.10] 6.4 [0.40] 6.6 [0.10] 6.7 [0.40]
Dames & Moore – S. Costal Margin	5.3 [0.80] 7.2 [0.20]	5.6 [0.80] 7.2 [0.20]
Law Engineering – S. Coastal Block	4.6 [0.90] 4.9 [0.10]	5.6 [0.90] 5.7 [0.10]
Rondout Assoc. – Appalachian Basement	4.8 [0.20] 5.5 [0.60] 5.8 [0.20]	5.0 [0.20] 5.5 [0.60] 5.8 [0.20]
Rondout Assoc. – Gulf Cost to Bahamas Fracture Zone	4.8 [0.20] 5.5 [0.60] 5.8 [0.20]	6.1 [0.30] 6.3 [0.55] 6.5 [0.15]
Weston Geophysical – Gulf Coast	5.4 [0.71] 6.0 [0.29]	6.6 [0.89] 7.2 [0.11]

As Figure 2.5.2-7 shows, while the Turkey Point Units 6 and 7 site region is devoid of significant earthquake activity, there is substantial seismic activity beyond the 320 km (200 mi) site region. Specifically, in Cuba and along the active plate boundaries of the Caribbean region, seismicity levels are elevated relative to the surrounding region (Figure 2.5.2-7). The applicant stated that despite their significant distances to the Turkey Point Units 6 and 7 site, some of these seismic sources contributed to total seismic hazard at the Turkey Point Units 6 and 7 site. Because there are no seismic source models for Cuba and the Caribbean seismic sources applicable for nuclear power plant applications, following the guidance in RG 1.208, the applicant conducted a SSHAC Level II study to develop new seismic source models for Cuba and the Caribbean regions. The applicant stated that the SSHAC study produced 10 new seismic sources, which

included an areal source for the region of Cuba and nine fault sources. Figure 2.5.2-7 shows the locations of these seismic source models. Using these newly created models along with the EPRI-SOG models described above form the basis of the applicant's PSHA study to determine the total seismic hazard at the Turkey Point Units 6 and 7 site.

Because the Turkey Point Units 6 and 7 COL FSAR did not provide details of the SSHAC process, in RAI 37, Question 02.05.02-3, the staff asked the applicant to provide specific details of the SSHAC process including the makeup of the TI team, experts interviewed, peer reviewers, how differing views of the experts were integrated into the final models and why the final models represented the consensus of the informed community. In its response, the applicant stated that the SSHAC level II project started with a comprehensive literature review performed by the TI team. The TI team initially came up with a draft seismic source model. The TI team also identified resource experts and conducted interviews with these resource experts to determine whether the draft seismic models represented the region adequately and if any additional seismic sources and/or source parameters were needed. During the entire process, the TI team also consulted with the project's technical advisory group composed of five additional seismic hazard experts about the applicability of the draft seismic source models for the Turkey Point Units 6 and 7 site's PSHA study. After the interviews with the identified resource experts and comments from the technical advisory group, the TI team modified the initial models and finalized them for use in the Turkey Point Units 6 and 7 site's PSHA study. The applicant stated that there were a few conflicting opinions among the resource experts on the nature and makeup of the seismic source models. Specifically, the issue of how to represent seismic activity in Cuba in seismic source models was of apparent debate. Some resource experts stated that rather than simply using an areal source for Cuba, which was in the initial model of the TI team, perhaps it was more appropriate to model seismicity with both areal and fault sources, as there are several mapped faults in Cuba. The TI team considered all the input and retained the single areal seismic source for the region of Cuba in its PSHA because there is very little known about the activity rates of the mapped faults. In the absence of observational evidence, the TI team opted to use an areal source and background seismicity in its Cuba seismic source model.

The applicant stated that the fault sources developed as part of the SSHAC Level II process for the Caribbean region are in agreement with the published literature and expert judgements as well. During the site audit conducted by the staff on May 24 and 25, 2011 (ADAMS Accession No. ML111881052), the staff also had the opportunity to review the full details of the SSHAC documents and concluded that the applicant conducted the SSHAC Level II process properly as established in NUREG/CR-6372. Based on new information provided by the applicant in response to this RAI and the staff's audit results the staff closes RAI 37, Question 02.05.02-3.

In RAI 37, Question 02.05.02-4, the staff asked the applicant to further discuss the rationale for using a single areal source exclusively for the seismic sources zones in Cuba. The staff specifically asked if an areal source would result in more conservative hazard estimates, whether a uniform seismicity model or smoothed seismicity model is used for the Cuba areal source, further details on the earthquake catalog's completeness, and whether large earthquakes in this areal source are modeled using finite faults. In a March 15, 2015 response to RAI 37, Question 02.05.02-4 (ADAMS Accession No. ML15077A177), the applicant stated that the use of individual faults would require the knowledge of fault activity and recurrence parameters. The lack of adequate data to evaluate and characterize the faults as potential distinct faults prevented the use of individual faults as potential seismic sources. However, the applicant conducted a sensitivity study in which it allowed certain fault sources to be active. Since there is lack of information about the fault slip rates, the applicant used a large uncertainty

on fault slip rates to show that the potential impact of using individual faults in its PSHA is minimal. The staff performed a confirmatory sensitivity study using a subset of scenarios considered by the applicant and concluded that the use of discrete faults has little impact on the site hazard. A detailed discussion of the staff's evaluation of this sensitivity study is in the 'PSHA Methodology and Calculation' section of this SER.

The applicant also stated that it used a spatially uniform seismicity rate model calculated using the Phase 2 earthquake catalog. In its response to the staff's RAI, the applicant presented the results of a sensitivity study in which it divided the single areal source into two areal sources to address a potential impact of non-uniform seismicity distribution in the area. The northern portion of the areal source includes a larger number of earthquakes, which would result in higher rate calculations in the region closer to the Turkey Point Units 6 and 7 site and may result in higher seismic hazard contributions from this region. Through its sensitivity study the applicant showed that seismicity rates in the northern portion of the areal source would be about 10 percent higher than rates calculated using the single areal source. Using these higher rates for the entire areal source, the applicant calculated the amount of increases in seismic hazard estimates for the 10^{-4} mean annual frequency of exceedance UHRS and showed that the higher rates would result in less than 2 percent increase in the UHRS values.

In response to the question regarding the earthquake catalog's completeness, the applicant stated that it took the completeness periods for Cuban earthquakes directly from the published literature. Garcia et al. (2008) provided earthquake completeness periods for a series of earthquake magnitudes ranges for the Cuba region. The applicant stated that earthquakes with magnitudes larger than 6 are complete since the year 1500, earthquakes with magnitudes within the range of 5 and 6 are complete since the year 1850, earthquakes with magnitudes in the range of 4 to 5 and magnitudes between 3 and 4 are compete since 1940 and1960, respectively. The staff also evaluated the work published by Garcia et al. (2008) and concluded that the completeness periods used by the applicant are consistent with the available published data.

With regard to the question of whether the earthquakes are modeled as finite faults in the Cuba areal source, the applicant stated that earthquakes are modeled using point sources rather than finite sources, and that the impact of using the point source approximation for Cuba earthquake is minimal due to the distances involved. The staff notes that larger magnitude earthquakes require larger fault sizes, and at short distances, the use of a finite fault approximation can be shown to influence hazard calculations. Although the point source assumption is not valid for large magnitude earthquakes, considering the distances of these seismic sources to the Turkey Point Units 6 and 7 site are on the order of 320 km (200 mi) or greater and the orientation of the tectonic features that are likely to cause such large earthquakes are preferentially oriented in the east-west direction, the staff concludes that this approach will result in adequate seismic hazard estimates at the Turkey Point Units 6 and 7 site. Therefore, the staff considers RAI 37, Question 02.05.02-4, resolved.

As part of its technical evaluation regarding the seismic source model development efforts for the overall Cuba and Caribbean regions, the staff also conducted its own review of the seismotectonics of the Cuba and the Caribbean regions. The section titled 'Principal Tectonic Structures' of SER Section 2.5.1.4.1 describes the details of the staff's evaluation of the applicant's seismic source characterization efforts in the Cuba and Caribbean region. The staff asked several RAIs regarding the acceptability of the Cuban and Caribbean seismic sources for the Turkey Point Units 6 and 7 site's PSHA calculations. In this SER Section, the staff describes the details of the staff's efforts. Upon resolution of all related RAIs regarding the

development of seismic source models to be input into the Turkey Point Units 6 and 7 PSHA study, the staff concludes that the Cuba and Caribbean seismic sources are appropriate for the Turkey Point Units 6 and 7 site's PSHA.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.4.4.3.2 discusses the existence of additional several large distance seismic sources that the applicant did not incorporate into its seismic source model. Regarding these sources, the applicant stated that they do not significantly contribute to the site hazard. In RAI 37, Question 02.05.02-12, the staff asked the applicant whether this conclusion was based on sensitivity studies or on best judgement. In its response, the applicant stated that it used a combination of judgement and sensitivity studies to exclude some of the large distance seismic sources in its PSHA inputs. The applicant indicated that it based the rationale to exclude seismic sources, such as the Puerto Rico Trench and the Muertos Trough, on their great distances from the Turkey Point site. The applicant stated that in an earlier sensitivity study it calculated hazard contributions from the New Madrid Seismic Zone and shown that this source did not contribute to the total seismic hazard. Because these additional sources are at least the same distance to the site with comparable or lower recurrence levels, the applicant stated that they would not contribute to the total seismic hazard at the Turkey Point Units 6 and 7 either. The staff analyzed these additional seismic sources, confirmed their distances to the Turkey Point Units 6 and 7 site, and agrees with the applicant that their contribution to the total seismic hazard will be insignificant based on the applicant's earlier sensitivity analysis results conducted for the New Madrid Seismic Zone. Therefore, the staff considers RAI 37, Question 02.05.02-12, resolved.

Ground Motion Models

After identifying appropriate seismic sources and model parameters, in COL FSAR Section 2.5.2.4.5, the applicant described the ground motion models (GMM) it used to conduct a PSHA for the Turkey Point Units 6 and 7 site. For sources in the CEUS, including the updated and extended EPRI-SOG sources and the UCSS, the applicant used a GMM previously approved by the NRC (EPRI, 2004 and 2006). For sources in the Caribbean, the applicant stated that the EPRI (2004, 2006) GMM was not appropriate due to the tectonic setting of the Caribbean sources. Therefore, the applicant stated that it developed a new GMM for the Caribbean for use in the Turkey Point Units 6 and 7 site's PSHA.

The applicant began its GMM development study with a literature survey to find potential candidate GMMs for the region, finding one developed for Puerto Rico (Motazedian and Atkinson, 2005). The applicant stated that this model, developed for soft rock conditions consistent with Puerto Rico, represented the starting point for its GMM development effort. Because the Motazedian and Atkinson (2005) model did not incorporate distance and magnitude ranges, the applicant performed stochastic simulations for earthquakes with magnitudes between **M**4.75 and **M**8.75 and a distance range of 150 to 2,000 km (93 to 1,253 mi) using the regional anelastic attenuation and source parameters of Motazedian and Atkinson (2005). The applicant explored the model space within the simulation by varying the stress parameter, anelastic attenuation constant, and source model.

The staff reviewed information in the Turkey Point Units 6 and 7 COL FSAR and noted that the model of Motazedian and Atkinson (2005) was developed for a subduction zone plate boundary, a tectonic setting distinct from the seismic sources relevant to the Turkey Point Units 6 and 7 site. Additionally, the applicant provided limited information about the process it followed in developing the GMM. Therefore, in RAI 37, Question 02.05.02-2, the staff requested that the applicant to explain why GMM based on Puerto Rico settings are applicable to the Caribbean

generally, provide more information about the SSHAC process used to develop the Caribbean GMM, compare the Caribbean GMM with EPRI (2004, 2006), and discuss any evidence that seismic source scaling varies systematically in the Caribbean. In a letter dated November 16, 2011 (ADAMS Accession No. ML11321A319), the applicant provided its first response and later, on October 3, 2014 (ADAMS Accession No. ML14282A015), the applicant provided a revised, more comprehensive response. In its response, the applicant provided additional information regarding the development and applicability of the Caribbean GMM to seismic sources used in the Turkey Point Units 6 and 7 site's PSHA, additional information regarding the SSHAC process, and a comparison between the Caribbean GMM and the EPRI (2004, 2006) GMM, including the results of two sensitivity studies.

In its revised RAI response, the applicant stated that no GMM were currently available that directly address the impact of earthquakes in the Caribbean on the CEUS. Therefore, the applicant selected the model of Motazedian and Atkinson (2005) as a starting point. The applicant noted that it did not use this model directly, but as a starting point to develop a new model. The applicant further noted that there were insufficient strong motion recordings in Cuba and the northern Caribbean to develop a GMM from observations directly. The applicant also stated that Motazedian and Atkinson (2005) took pains to ensure that subduction zone earthquakes minimally affected their strong motion dataset by limiting the depth of earthquakes used in their study and by comparing their results to GMM for regions such as California and the CEUS. The applicant stated that because these comparisons are favorable, and there is a lack of other candidate models, that the model of Motazedian and Atkinson (2005) represents a reasonable starting model for developing the Caribbean GMM.

In its initial response to the staff's RAI requesting the details of the SSHAC Level II study conducted in the development of GMM, the applicant stated that it did not conduct a formal SSHAC Level II study for the development of the Caribbean GMM. The staff evaluated this initial response and found it inadequate, and requested that the applicant to follow a SSHAC Level II process, consistent with the guidance provided NUREG/CR-6728. After the staff's request, the applicant conducted additional studies to bring the level of its initial work to a level compatible with a SSHAC Level II study and provided its results in the revised RAI response. The applicant's revised response stated that the applicant contacted outside technical experts, requested their reviews of what had already been developed and conducted new sensitivity studies to address the experts' concerns. In its updated RAI response, the applicant further justified the use of a GMM based on the Motazedian and Atkinson (2005) study. The applicant stated that two individuals with significant experience in GMM development conducted its initial study and that the study participants reached out to several other experts throughout the process of model development. The applicant also noted that the lack of GMM for the Caribbean region meant that finding proponent experts, individuals who are able to advocate for a particular technical conclusion or position, was difficult. Therefore, the applicant reached out more broadly to experts in GMM development. These experts provided feedback to the study participants and served as a peer review group. The applicant's revised response stated that this effort broadly met the guidance for a SSHAC Level II study and was consistent with current industry practice.

As part of its revised response to the staff's RAI, the applicant also conducted two studies to assess if the Caribbean GMM were appropriate for use with seismic sources in the Caribbean and Cuba. In the first study, the applicant compared the Caribbean GMM with the EPRI (2004) GMM and with limited observational data available in the region (Figure 2.5.2-8). As Figure 2.5.2-8 indicates, the Caribbean GMM produce spectral accelerations lower than the EPRI (2004) Midcontinent GMM, but higher than the EPRI (2004) Gulf Coast models. Comparisons

with limited observational data available from an earthquake that occurred south of Cuba on February 4, 2007, indicate that observations fall in between the Caribbean and Gulf Coast EPRI (2004) models, suggesting that, for this event, the Caribbean GMM are slightly more conservative, and the EPRI stable continental GMM are overly conservative.

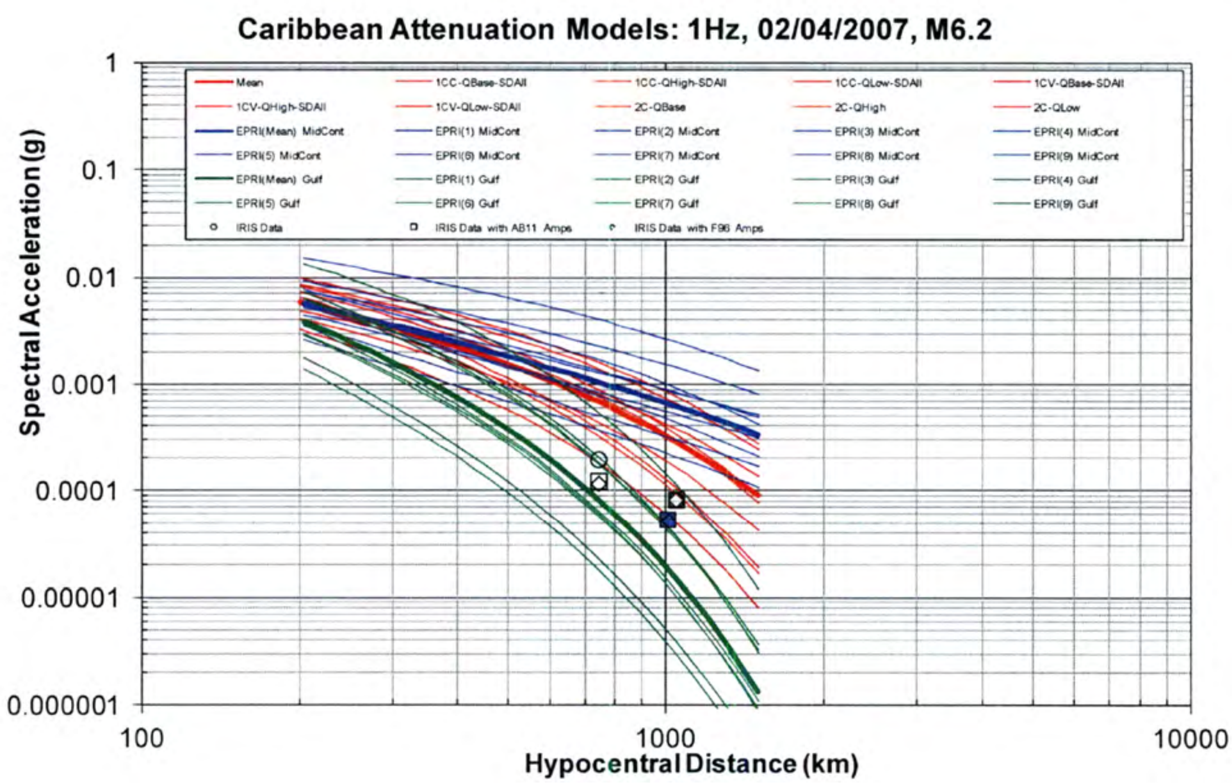


Figure 2.5.2-8. Comparison of observed earthquake ground acceleration (circles and squares) with predictions from the Caribbean GMM (Red) and Midcontinent (Blue) and Gulf (Red) versions of the EPRI (2004, 2006) GMM (Source: Turkey Point Units 6 and 7 COL FSAR Figure 2.5.2-260b)

In the second study, the applicant considered, as a sensitivity study, the effect of using alternative GMM for the Caribbean sources on the Turkey Point GMRS. The applicant calculated a GMRS for five alternative ground motion model scenarios. The applicant performed its GMRS sensitivity analysis so that the only thing that changed was which GMM it used to calculate the contribution to hazard from the Caribbean seismic sources. The base case GMRS is the one calculated using the Caribbean GMM. The remaining four alternative GMRS curves represent results obtained by using the midcontinent and gulf versions of the EPRI (2004, 2006) GMM either as published or with modifications. The modified versions of the EPRI GMM were obtained by eliminating the highest ground motion producing equation at large distances from the published model. Figure 2.5.2-9 shows the results of the applicant's sensitivity study. The applicant stated that the results of its analysis reveal the GMRS that results from the Caribbean GMM is intermediate between the midcontinent and gulf versions of the EPRI (2004) GMM and the midcontinent versions are not realistic representations of the site-specific GMRS. The applicant concluded based on this study and results of the observed ground accelerations that the Caribbean GMM is appropriate for use for Caribbean sources

because it results in higher ground motions than using the gulf version of the EPRI GMM and is more consistent with observations.

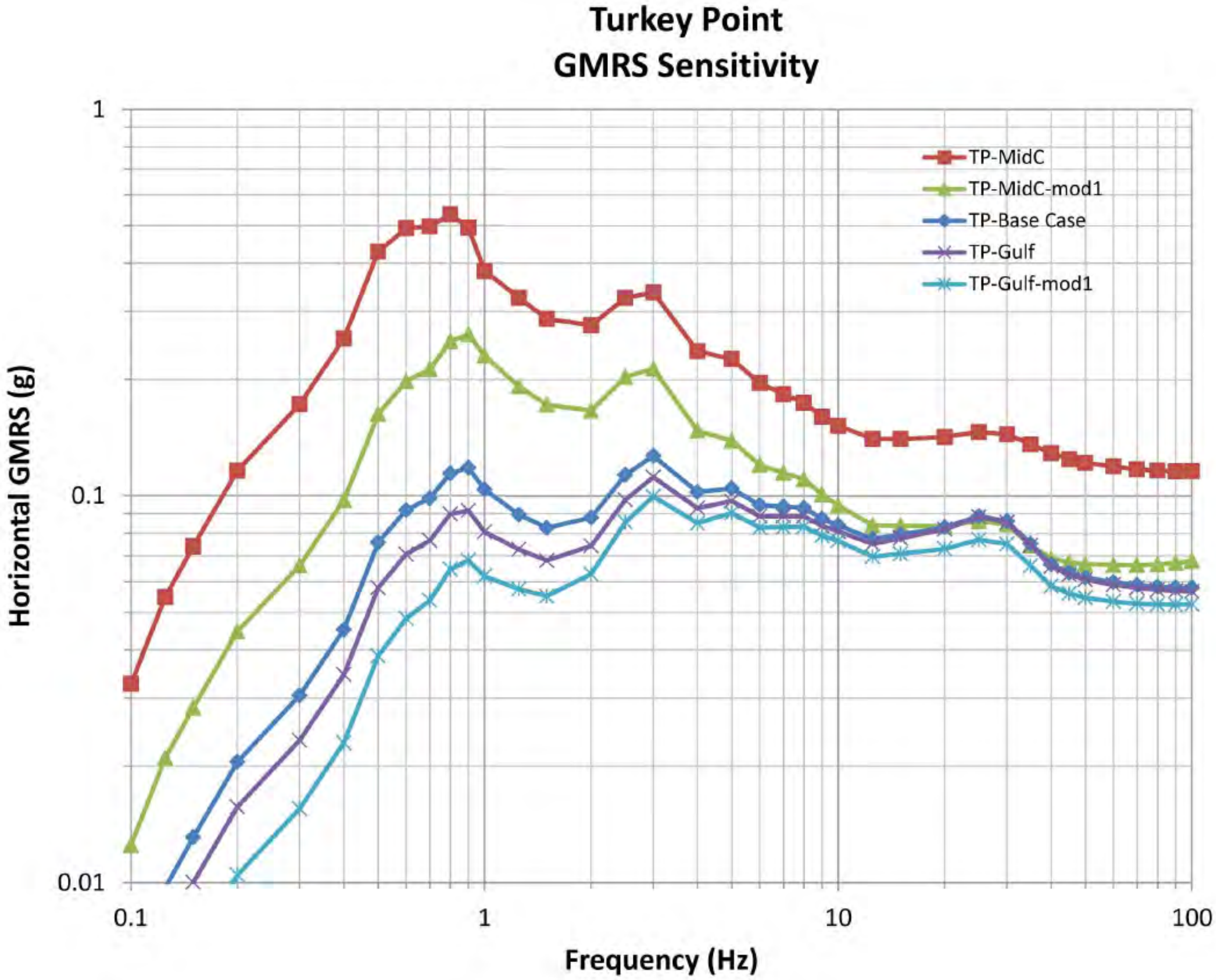


Figure 2.5.2–9. GMRS sensitivity to GMM selection for Caribbean Seismic Sources (Source: Turkey Point Units 6 and 7 COL FSAR Figure 2.5.2-263)

In addition to providing the results of these two additional studies that examined the differences between the Caribbean GMM and the EPRI GMM for Caribbean seismic sources, the applicant also compared the expected ground motions from the two GMMs for a variety of distances and earthquake magnitudes. Earthquake distances ranged from 200 to 1,000 km (124 to 621 mi) and earthquake magnitudes ranged from **M**6 to **M**8. The applicant showed that expected ground motions for the Caribbean GMM were generally lower than those for the midcontinent version of the EPRI GMM, except at a frequency of 1 Hz for a **M**6 earthquake 200 km (124 mi) away.

Based on the results of these sensitivity studies conducted by the applicant in response to RAI 37, Question 02.05.02-2, the staff finds that the use of the Caribbean GMM is conservative relative to observed data. Therefore, the staff finds that the applicant's Caribbean GMM is

adequate for use in the PSHA for at the Turkey Point Units 6 and 7 site and considers RAI 37, Question 02.05.02-2, resolved.

PSHA Methodology and Calculation

In COL FSAR Section 2.5.2.4.6, the applicant described its approach to performing a PSHA for the Turkey Point Units 6 and 7 site. The applicant considered the impact of multiple potential seismic sources including updated EPRI-SOG sources, Cuba and North American-Caribbean plate boundary faults as well as the updated Charleston seismic source.

As described above in this section and in SER Section 2.5.1.4.1, the applicant modeled seismic sources in Cuba as a single areal source despite the presence of several large faults in the region. The applicant stated that there is little geologic or seismic evidence to constrain the parameters (e.g., slip rate, M_{max}, fault length, etc.) on these faults important to conducting a PSHA. Based on the presence of these faults and the fact that they represent potentially tectonically capable faults within 320 km (200 mi) of the Turkey Point Units 6 and 7 site, in RAI 37, Question 02.05.02-4, the staff requested further justification on the use of a single areal source to represent seismic hazard from Cuba.

In a response to RAI 37, Question 02.05.02-4 dated October 3, 2014 (ADAMS Accession No. ML14282A014), and updated on March 16, 2015 (ADAMS Accession No. ML15077A177), the applicant addressed the staff's concerns regarding the treatment of the Cuba areal source in its PSHA. The applicant conducted a sensitivity study using the SSHAC Level II guidelines to model the effect of subdividing the Cuba areal source into several areal sources or treating the source as a number of discrete faults. The applicant selected several potential seismic source models for the Cuba region ranging from the single areal source model currently implemented in the PSHA to a full fault (FF) model that modeled all seismic sources as discrete fault sources. Figure 2.5.2-3 summarizes the models considered by the applicant in its sensitivity study. Shaded models are those that the SSHAC Level II participants deemed technically defensible interpretations of the available data and were included in the applicant's sensitivity analysis. The applicant discarded the other scenarios for a number of reasons. The FF model results in a greater seismic moment release than is observed in the seismicity catalog. Therefore, the applicant did not consider any scenario that incorporates the FF model because it deemed this interpretation overly conservative. The remaining discarded models were not used either because they include the FF model, arrive at an answer within the range of the acceptable models (e.g., Z6+SF), or are based on an arbitrary increase in background seismicity (Z11). Of the scenarios selected by the applicant for conducting its sensitivity study, none results in an increase in seismic hazard greater than 0.004 g, which is insignificant compared to the overall hazard at the site.

The applicant did not include the effect of the FF model on the site hazard as it was considered overly conservative. However, because very limited data are available on the activity of the faults, the staff determines that these alternative models should also be considered in the uncertainty analysis. To better assess the effect of incorporating the FF model into the Turkey Point Units 6 and 7 site's PSHA analysis, the staff conducted a confirmatory study and considered two scenarios discarded by the applicant as viable options. The staff used the hazard curves for the FF model to assess the effect on Turkey Point Units 6 and 7 site seismic hazard by considering the FF scenario and the Z1+FF scenario in Table 2.5.2-3. Figure 2.5.2-10 shows the staff's results for these two scenarios and indicates that the inclusion of the FF model results in a relatively small increase to the total hazard at the Turkey Point Units 6 and 7 site. At 1 Hz, the increase in hazard is less than 0.004 g at the 10^{-4} mean annual frequency of

exceedance and 0.008 g at the 10^{-5} hazard level for the Z1+FF model (the most conservative scenario considered). These increases are small relative to the hazard at the site (less than 12 percent of the total hazard). In its sensitivity analysis, the staff ignored the fact that seismic moment attributed to Cuba faults would need to be removed from the Cuba areal source when calculating *a*- and *b*-values, leading to additional conservatism in the sensitivity results. Because the applicant's sensitivity study and the staff's confirmatory calculations have shown that consideration of alternative seismic source models do not impact the total hazard significantly, the staff agrees that the One Areal Source Zone (Z1) model used by the applicant adequately addresses the contribution to seismic hazard at the Turkey Point Units 6 and 7 site from Cuba.

Table 2.5.2-3: Scenarios Selected for Cuba Seismic Source Sensitivity Study (Z1* used as basis for PSHA) (Modified from Turkey Point Units 6 and 7 COL FSAR Table 2.5.2.-233)

		Areal Source Zone Scenarios (Hazard Increases →)			
		No Areal Source Zones	Six Areal Source Zones (Z6)	One Areal Source Zone (Z1)	One Areal Source Zone with 11% Increase in Seismicity Rate (Z11)
Fault Source Scenarios (Hazard Increasing ←)	No Fault Sources		Z6	Z1*	Z11
	Scaled Fault Sources (SF)	SF	Z6+SF	Z1+SF	Z11+SF
	Full Fault Sources (FF)	FF	Z6+FF	Z1+FF	Z11+FF

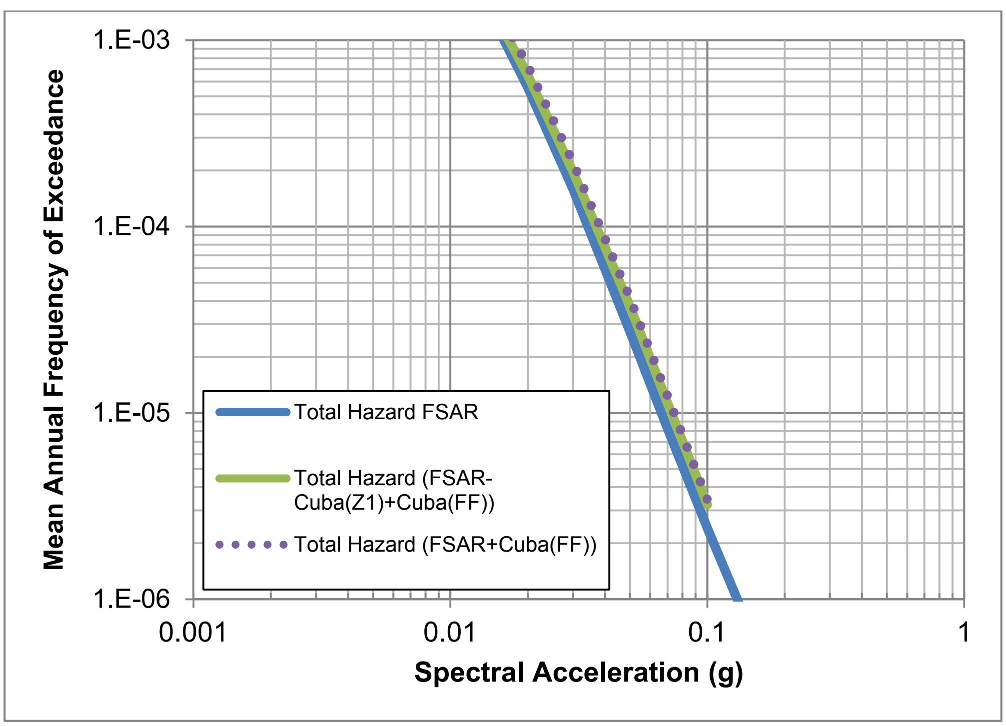


Figure 2.5.2-10. Comparison of 1 Hz hazard curves when including Cuba full fault (FF) scenario or the Cuba FF and One Areal Source Zone (Z1) scenario in the Turkey Point Units 6 and 7 site's PSHA

As discussed in Section 2.5.1.4.1.3.1 of this report, the staff also conducted a couple of sensitivity studies for two possible active strike-slip faults identified within the site region. Seismic reflection data collected by a recent research cruise in the Santaren Channel (Kula, 2014) identified a potential Quaternary fault. Based on information provided by the applicant in its response to RAI 81, Question 02.05.01-34, the applicant reached the conclusion that structures identified by Kula (2014) do not represent Quaternary faulting. However, the staff considered that based on data available at hand, it was not conclusive that the faults are not active. To assess the potential impact of this structure on the Turkey Point Units 6 and 7 site's PSHA analysis, the staff conducted a sensitivity study.

In its sensitivity study, the staff used the most recent NRC approved GMPEs (EPRI, 2013) for the midcontinent region of the CEUS and a simplified magnitude distribution to calculate potential seismic hazard curves at the Turkey Point Units 6 and 7 site from the possible faults. The staff calculated mean seismic hazard curves using a fault length (40 km) and distance (155 km) consistent with seismic reflection profiles identified in Kula (2014) for Fault A at a variety of slip rates ranging from 0.01 to 10 mm/yr. The staff compared these seismic hazard curves to the PSHA results in the Turkey Point Units 6 and 7 COL FSAR to determine the impact of a possible Fault A on the PSHA for the site. Figure 2.5.2-11 shows the impact of the this sensitivity study on the PSHA results and indicates that the possible existence of Fault A has a minor impact on overall hazard at reasonable slip rates (less than 1.0 mm/yr). The staff's sensitivity analysis includes several conservative assumptions, including a single seismogenic thickness of 15 km (9 mi) and the use of the midcontinent version of the EPRI (2013) GMPEs. The small increase in overall hazard due to the potential Fault A and the conservative assumptions used in the staff's sensitivity analysis provide assurance that the applicants PSHA for the Turkey Point Units 6 and 7 site would not change, even if this fault were active.

In addition to analyzing the impact of a potential Quaternary fault within the Santaren Channel (Fault A discussed above), the staff analyzed the potential impact of a fault within the Miami Terrace anticline, discussed in SER Section 2.5.1.4.1. The staff considered the impact of this fault on the hazard at the Turkey Point Units 6 and 7 site in a manner consistent with the analysis above. Based on a lack of information about the fault size, the staff assumed a fault length of 15 km (9 mi), consistent with the assumed seismogenic thickness of the crust, and a distance from the site of 50 km (31 mi). Based on these parameters, the staff calculated hazard curves for a number of possible slip rates and compared these results to the hazard at the Turkey Point Units 6 and 7 site reported in the COL FSAR. As shown in Figure 2.5.2-12, the contribution to seismic hazard from the Miami Terrace anticline fault is moderate at frequencies above 5 Hz for slip rates greater than 0.05 mm/yr. The staff notes that its analysis incorporates a number of simplifications and conservatisms, including the use of a single seismogenic thickness and the use of the midcontinent version of the EPRI (2013) GMPEs. Based on the staff's analysis and the lack of geologic and geophysical evidence to provide constraints on the fault length, dip, and slip rate, the staff concludes that the applicant's PSHA adequately incorporates the hazard from the potential Miami Terrace anticline fault.

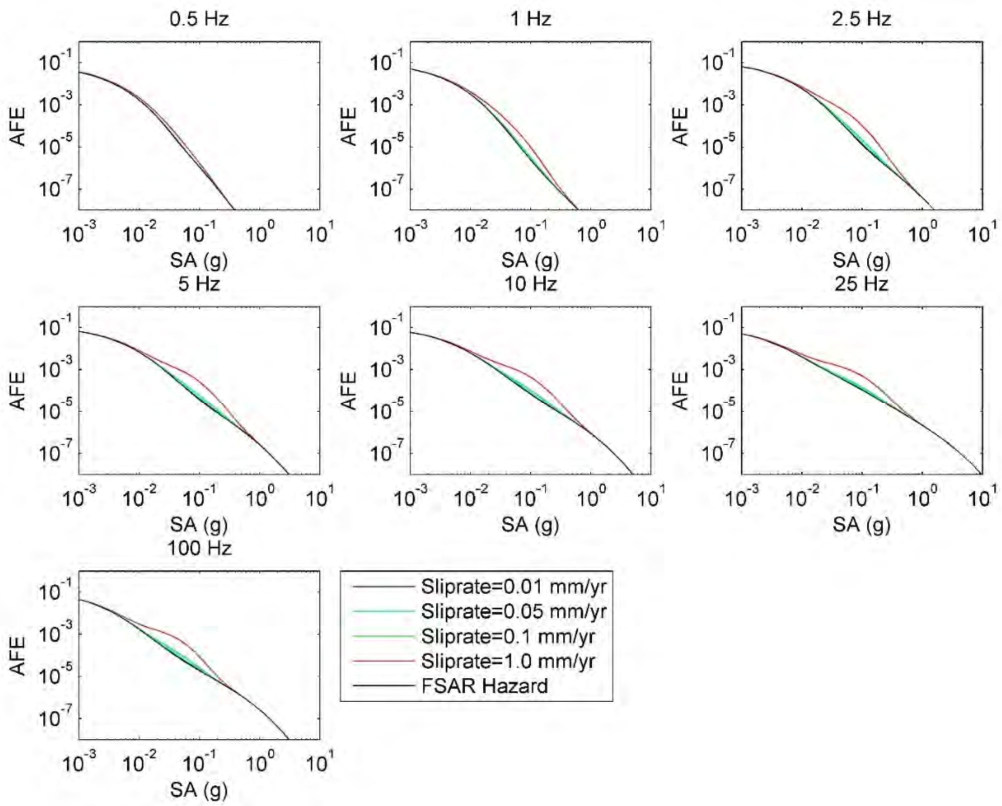


Figure 2.5.2-11. Sensitivity of COL FSAR hazard (black) to Fault A under a number of different slip rate scenarios. The inclusion of Fault A has a minor potential impact on PSHA results at slip rates less than 1 mm/yr, which is not supported by geologic evidence. The x-axis for each plot shows the spectral acceleration (SA) in g and the y-axis shows the annual exceedance frequency. The hazard levels important for the GMRS are 10^{-4} and 10^{-5} mean annual frequency of exceedance.

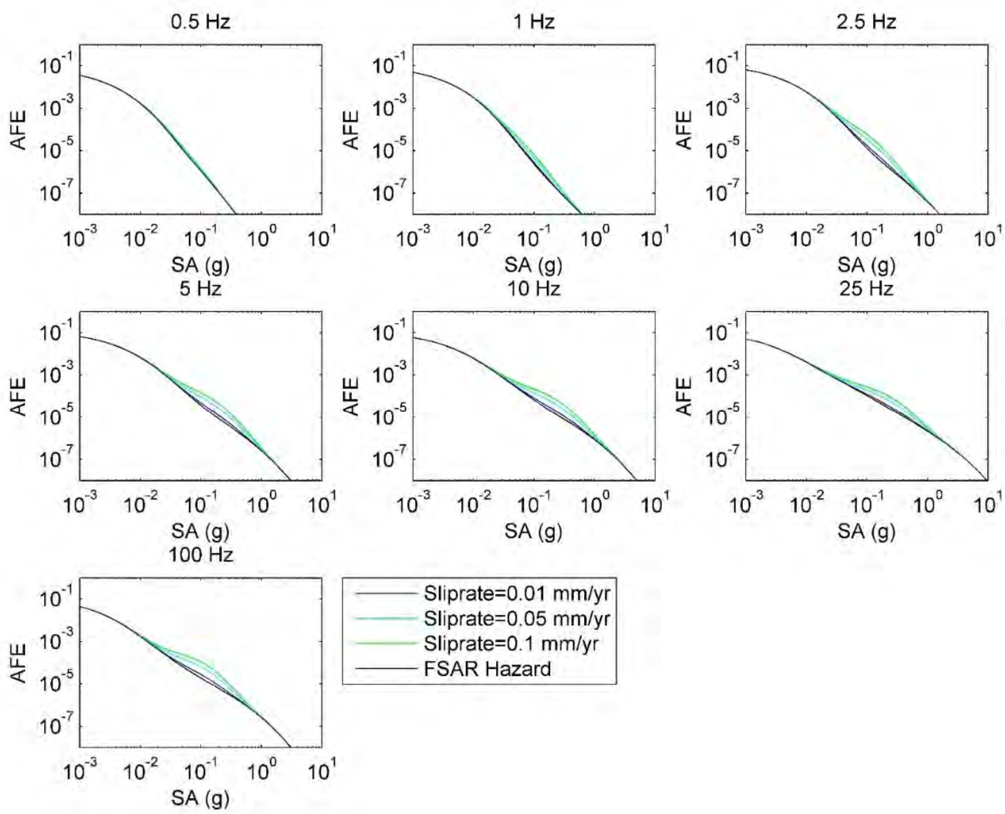


Figure 2.5.2-12. Sensitivity of COL FSAR hazard (black) to Miami Terrace Anticline Fault under a number of different slip rate scenarios. The inclusion of the fault has a minor potential impact on PSHA results. The x-axis for each plot shows the spectral acceleration (SA) in g and the y-axis shows the annual exceedance frequency. The hazard levels important for the GMRS are 10^{-4} and 10^{-5} mean annual frequency of exceedance.

After the 2011 Fukushima Dai-ichi nuclear power plant accident in Japan, which occurred because of the Great Tohoku earthquake and the subsequent tsunami, the NRC Near-Term Task Force (NTTF) issued a series of recommendations for reevaluating and improving nuclear power plant safety in the United States. Consequently, on March 12, 2012, the NRC issued an information letter requesting that licensees of all operating nuclear power plants in the United States reevaluate the seismic hazard at their respective plants using the most recent data and evaluation methodologies available. That information letter also requested that licensees of operating plants in the CEUS use the seismic source model provided in NUREG-2115 to characterize seismic hazard at their respective plants. Consistent with existing guidance in RG 1.208 pertaining to the need to consider the latest information in the evaluation of seismic hazard, the NRC also requested that all COL and ESP applicants in the CEUS address seismic hazard for their respective proposed plant sites using information in NUREG-2115 and modify the ground motion response spectra (GMRS), if needed. The staff issued this request to the applicant in RAI 47, Question 1.5-1.

In responses to RAI 47, Question 01.05-1 dated February 12, 2013 (ADAMS Accession No. ML13044A570) and March 31, 2015 (ADAMS Accession No. ML15092A222), the applicant stated that it conducted a sensitivity study to determine that the EPRI-SOG model, as updated and modified in the Turkey Point Units 6 and 7 COL FSAR, is acceptable for use at the Turkey

Point Units 6 and 7 site. In its sensitivity study, the applicant combined seismic hazard curves developed using the CEUS-SSC model described in NUREG-2115 with hazard curves for the Caribbean region and compared these to the hazard curves that result from combining the updated EPRI-SOG model with the Caribbean. The applicant's sensitivity shows that the EPRI-SOG model results in slightly higher hazard at frequencies greater than 1 Hz, and slightly lower hazard less than 1 Hz. Based on the results of the sensitivity study, the applicant chose to continue using the EPRI-SOG model for its PSHA.

To confirm the applicant's sensitivity study results presented in the Turkey Point Units 6 and 7 COL FSAR, the staff performed an independent confirmatory analysis. The staff used the CEUS-SSC, as published in NUREG-2115, along with the midcontinent version of the EPRI (2004, 2006) GMM to calculate hazard for all sources within 1,000 km (620 mi) of the site. The staff compared its results for the CEUS-SSC with hazard curves developed by the applicant for the CEUS using the EPRI-SOG model and UCSS. The staff did not consider the effect of the Caribbean sources for its confirmatory analysis because the contribution of the Caribbean sources to the total hazard remains the same regardless of which seismic source model is used for the CEUS. Figure 2.5.2-13 shows the results of the staff's confirmatory analysis along with the applicant's results. The staff's PSHA results obtained using the CEUS-SSC model are lower than the applicant's results at 10 Hz and peak ground acceleration (PGA), and slightly higher at 1 Hz. Based on the results of the applicant's sensitivity study and the staff's confirmatory analysis, the staff considers the use of the EPRI-SOG model is adequate to represent the total seismic hazard at the site and the staff considers RAI 47, Question 1.5-1, resolved.

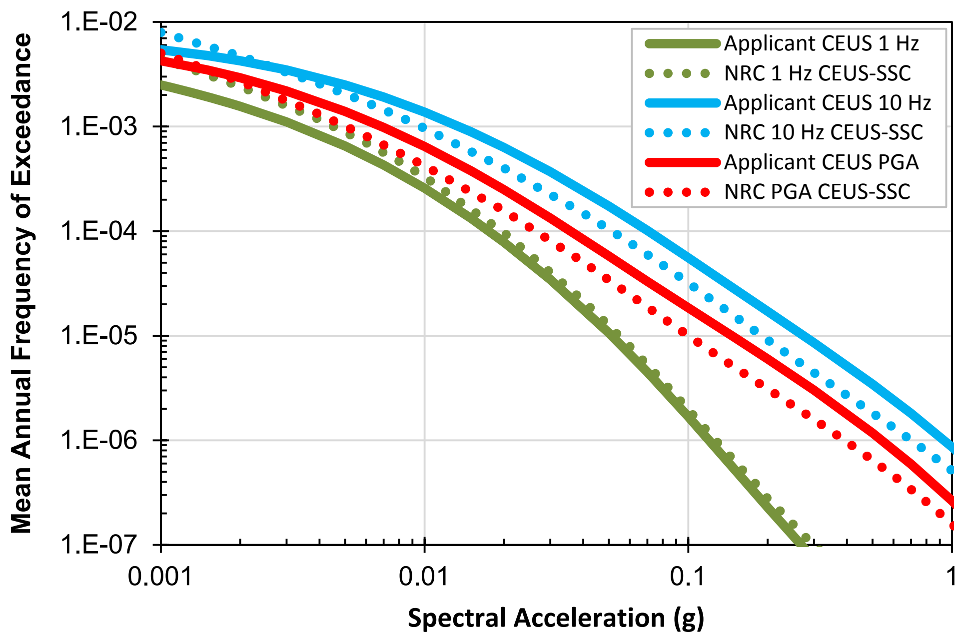


Figure 2.5.2-13. Comparison of Applicant's PSHA Results Using EPRI-SOG and UCSS Sources to Staff's Confirmatory Analysis Using CEUS-SSC at 1 , 10, and 100 Hz (PGA)

<u>Controlling Earthquakes</u>

To determine the LF and HF controlling earthquakes, the applicant used a procedure called deaggregation of the seismic hazard. The applicant followed the deaggregation procedures

outlined in RG 1.208, Appendix D. The deaggregation results showed that local seismic sources within 60 km (38 mi) of the Turkey Point Units 6 and 7 site are the primary contributors to the high-frequency seismic hazard at the site, while the large Caribbean fault sources and the Charleston source are a significant source of low-frequency seismic hazard at the Turkey Point Units 6 and 7 site. Table 2.5.2-1 of this report shows the applicant's deaggregation results for the mean 10^{-4}, 10^{-5}, and 10^{-6} annual frequencies of exceedance results. The applicant calculated the controlling earthquakes for two different cases: overall hazard and hazard from earthquakes located beyond 100 km (62 mi). As shown in Table 2.5.2-4, for the HF hazard, the controlling earthquakes are those with magnitudes less than **M**6 occurring at distances 110 km (68 mi) or less. For the LF hazard, the controlling earthquakes are several hundred kilometers away with magnitudes greater than **M**7. The applicant selected the gray shaded values shown in Table 2.5.2-1 of this report as representative of the controlling earthquakes for the Turkey Point Units 6 and 7 site.

During its review, the staff noted that figures of deaggregation results for Turkey Point Units 6 and 7 showed only a minor contribution form the distance range of the Cuba seismic source zone in contrast to COL FSAR Section 2.5.2.4.5, which states that the Cuba seismic source zone contributes significantly to seismic hazard at Turkey Point Units 6 and 7. In RAI 37, Question 02.05.02-8, the staff requested that the applicant explain this apparent discrepancy and provide a detailed breakdown of the contribution of the Cuba seismic source zone to seismic hazard at the Turkey Point Units 6 and 7 site.

In a response dated November 16, 2011, and supplemented on October 3, 2014, the applicant provided a breakdown of the contribution of the Cuba seismic source zone to the total hazard. The applicant stated that it contributed, on average, 22 percent to the low-frequency seismic hazard at the 10^{-4} mean annual frequency of exceedance. The applicant further stated that the contribution of the Cuba seismic zone is distributed across a wide range of distance and magnitude bins and provided a table detailing the contribution of the Cuba seismic source zone within a number magnitude and distance bins at the 10^{-4} and 10^{-5} annual frequencies of exceedance.

On the basis of the applicant's response, the staff agrees that the contribution from Cuba source zone earthquakes is distributed across a number of distance and magnitude bins and is properly accounted for in the applicant's deaggregation results. Therefore, staff considers RAI 37, Question 02.05.02-8, resolved.

Staff Conclusions Regarding PSHA and Controlling Earthquakes

After fully evaluating the applicant's PSHA and controlling earthquakes determinations, the staff concludes that the applicant's PSHA adequately characterizes the seismic hazards for the region surrounding the Turkey Point Units 6 and 7 site, and that the controlling earthquakes determined by the applicant are representative of earthquakes that would be expected to contribute the most to the hazard. The staff concludes that the applicant's PSHA and controlling earthquake analysis meets the guidance in RG 1.208.

2.5.2.4.5 Seismic Wave Transmission Characteristics of the Site

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.5 describes the method used by the applicant to develop the Turkey Point Units 6 and 7 site soil UHRS. The seismic hazard curves calculated by the applicant are defined for generic hard rock conditions characterized by a shear wave (V_s) velocity of at least 2.8 km/s (9,200 ft/s). The applicant stated that these hard rock

conditions exist at a depth of more than 4,572 m (15,000 ft) beneath the ground surface at the Turkey Point Units 6 and 7 site. To determine the effect of the soil column between the hard rock and the surface, the applicant performed a site response analysis. The output of the applicant's site response analysis are the site amplification functions, which are then used to determine the soil UHRS at three uniform hazard levels of 10^{-4}, 10^{-5}, and 10^{-6} mean annual frequency of exceedance.

Site Response Inputs

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.5, the applicant summarized the low strain S-wave velocity, material damping, and strain-dependent properties of the base case soil and rock profile, which the applicant used as the input model to its site response calculations. The applicant stated that it investigated the upper 185 m (611 ft) of the Turkey Point Units 6 and 7 site's subsurface using test borings, cone penetration testing, test pits, and geophysical methods. For the deeper sedimentary rocks (greater than 185 m (611 ft)), the applicant obtained the information from nearby wells and geological data sets.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.2.5.1 states that the applicant used P-wave velocities from eight deep wells to develop the deeper sections of the site response model. These wells are approximately 100 km (62 mi) to 180 km (112 mi) away from the Turkey Point Units 6 and 7 site. In RAI 37, Question 02.05.02-9, the staff asked the applicant to provide additional information on the applicability of seismic velocity information at these long distances from the site, including how it considered the variation in geology in the projection of these datasets to the site. The staff also asked the applicant to provide individual velocity profiles for each of the eight wells used in estimating the average profiles and for further details on how it accounted for larger uncertainties in deeper layers, thicknesses, and depths in the randomization of the site profile. In response to RAI 37, Question 02.05.02-9, the applicant provided the velocity profile data used to develop the deeper site profile. The applicant stated that based on its review of relevant publications, regional geologic cross sections, and the sonic logs, there is minimal variation in the stratigraphy in the upper 1,829 m (6,000 ft) between the deep well logs and the Turkey Point Units 6 and 7 site. The applicant also stated that alternative models used in the randomization process in site response input models accommodate any potential variations in the deeper velocities. Since the applicant showed in the RAI response that the variability between the site and the well log locations was minimal, the staff considers the applicant adequately used the available data and RAI 37, Question 02.05.02-9, resolved.

The applicant used the Random Vibration Theory (RVT) methodology to calculate the site response amplification function at the Turkey Point Units 6 and 7 site. RG 1.208 mentions the use of RVT in site response calculations as an acceptable alternative to the time series approach. RG 1.208 specifically states, "…RVT methods are acceptable as long as the strain dependent soil properties are adequately accounted for in the analysis." Hence, the staff focused its review on the input parameters used in the site response calculations. Inputs to the RVT method include response spectra that are based on the hard rock UHRS, shear wave velocity and density profiles, degradation and damping curves, effective strain ratio, and strong motion duration. The applicant estimated the strong-motion durations using the site-specific controlling earthquakes' magnitudes and distances and the formulation provided in American Society of Civil Engineers report ASCE 4-98, titled "Seismic Analysis of Safety-Related Nuclear Structures and Commentary" (ASCE, 2000). Since the applicant used published reference tables in ASCE 4-98 to estimate the strong motion ground durations and also the staff's determination that site response is only slightly dependent on the duration used, the staff

concludes that the applicant's selection of duration values are within range and adequate for site response calculations at the Turkey Point Units 6 and 7 site.

The applicant stated that it calculated the effective strain ratios using the formulation provided in Idriss and Sun (1992) and the program P-SHAKE (Der Kiureghian, 1980; Rathje and Ozbey, 2006), which uses a procedure based on RVT. The applicant used an effective strain ratio of 0.65, defined by the applicant as the ratio between the peak acceleration of earthquake time history and the equivalent harmonic wave going through the layers. The staff confirmed these values and concluded that the input effective strain ratios determined by the applicant are within the acceptable values commonly used by the engineering community.

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1, the applicant discussed its site-specific soil and rock column. In that section, the applicant stated that it used site-specific RCTS-based shear modulus degradation and damping ratio curves for the site amplification function analysis for the Key Largo Limestone, Fort Thompson Formation, and upper and lower Tamiami Formation. In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.3.16, the applicant detailed the strain-dependent properties developed for the Turkey Point Units 6 and 7 site by comparing the generic EPRI (1993) shear modulus and damping curves to the site-specific data from RCTS tests. The applicant developed site-specific curves from the RCTS tests on 14 undisturbed soil samples down to approximately 55 m (180 ft). The applicant used the site-specific data to choose the best fit EPRI generic curves in characterizing the strain-dependent properties above 55 m (180 ft). These curves were used as input to the site response analysis for the Key Largo Limestone, Fort Thompson Formation, and natural soils above (Lower Tamiami Formation) and below (Peace River and Arcadia Formations) 46 m (150 ft). Based on the data provided, the staff confirmed that the applicant's use of site-specific and generic EPRI curves to characterize the strain-dependent properties beneath the Turkey Point Units 6 and 7 site is adequate.

Another primary input to the RVT site response calculations is the response spectra calculated for the generic hard rock conditions beneath the site. The applicant used the low- and high-frequency UHRS spectra at the 10^{-4} and 10^{-5} mean annual frequency of exceedance levels to estimate input ground motions. Consistent with DC/COL-ISG-017, "Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses," the applicant also stated that it conducted the calculations using the full soil column including the soils above the GMRS horizon, and estimated the strain-compatible properties associated with each of the input rock motions and repeated the process again after removing the soil layers above the GMRS horizon, and calculated site responses and obtained the mean amplification function for the site.

Staff Site Response Confirmatory Analyses

To determine the adequacy of the applicant's site response calculations, the staff performed its own confirmatory site response calculations. As input, the staff used the static and dynamic soil properties provided in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4. To represent the input rock motions, the staff used the applicant's low- and high-frequency 10^{-4} and 10^{-5} rock spectra. The staff performed its site response calculations using the STRATA software (Kottke and Rathje, 2008).

As shown in Figure 2.5.2-14, the applicant's amplification functions are similar to the staff's confirmatory amplification functions across the frequency range typically important for engineering purposes (i.e., 0.5 Hz to 10 Hz) and they are within the limits of uncertainties

expected from these calculations. In addition to confirming the applicant's calculations, the staff also conducted sensitivity studies to test the impacts of the strong motion duration. The staff's confirmatory calculations showed that the Turkey Point Units 6 and 7 site response is not strongly sensitive to duration of strong motion.

Staff Conclusions Regarding Seismic Wave Transmission Characteristics of the Site

Based on its review of the applicant's site response methodology and results, the applicant's response to RAIs related to site response, and the staff's independent confirmatory analysis, the staff concludes that the applicant's site response analysis adequately characterizes the expected response of the Turkey Point Units 6 and 7 site to input ground motions. The staff concludes that the applicant's site response analysis meets the guidance in RG 1.208.

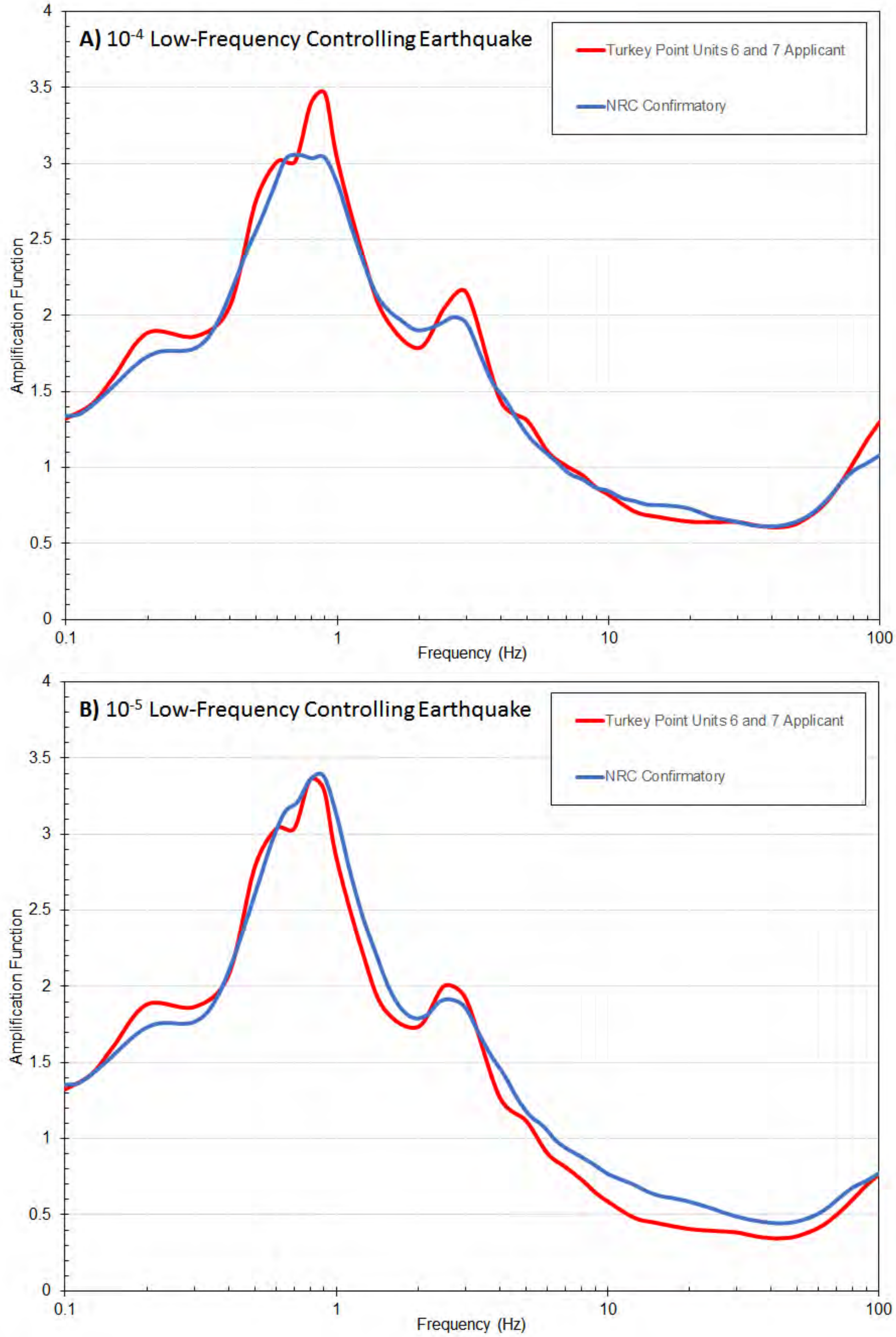


Figure 2.5.2-14 Comparisons of the staff's site response amplification function with the amplification function determined by the applicant for the A) 10^{-4} and B) 10^{-5} mean annual frequency of exceedance for low-frequency controlling earthquake at the Turkey Point Units 6 and 7 site

2.5.2.4.5 Ground Motion Response Spectra

Turkey Point Units 6 and 7 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 American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) Standard 43-05, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities. COLFSAR Section 2.5.2.4.6 states that the horizontal GMRS (for each spectral frequency), is obtained by scaling the soil 10-4 UHRS by the design factor specified in RG 1.206.

In COL FSAR Section 2.5.2.4.7, the applicant stated that it multiplied the horizontal GMRS by a frequency-dependent scaling factor in order to obtain the vertical GMRS. The applicant used the envelope of three V/H ratios calculated using three different methods as its final V/H ratio to calculate the vertical GMRS.

<u>Staff Conclusions Regarding Ground Motion Response Spectra</u>

Since the applicant used the standard procedures outlined in RG 1.208 and NUREG/CR-6728 to develop both the horizontal and vertical GMRS, the staff concludes that the applicant's GMRS adequately represents the site ground motion. This information addresses and resolves PTN COL 2.5-2 and PTN COL 2.5-3.

2.5.2.5 Post Combined License Activities

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

2.5.2.6 Conclusion

The staff reviewed the Turkey Point Units 6 and 7 COL FSAR and checked the referenced DCD. The staff's review confirmed that the applicant has addressed the relevant information relating to vibratory ground motion, and no outstanding information related to this section remains to be addressed in the Turkey Point Units 6 and 7 COL FSAR.

As set forth above, the staff reviewed the seismic information submitted by the applicant in Turkey Point Units 6 and 7 COL FSAR Section 2.5.2, PTN COL 2.5-1, PTN COL 2.5-2, PTN COL 2.5-3, and PTN SUP 2.5-1. On the basis of its review, the staff finds that the applicant has provided a thorough characterization of the seismic sources surrounding the site, as required by 10 CFR 100.23. In addition, the staff finds that the applicant has adequately addressed the uncertainties inherent in the characterization of these seismic sources through a PSHA, and this PSHA follows the guidance provided in 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, the staff finds that the applicant's GMRS, which was developed using the performance-based approach, adequately represents the regional and local seismic hazards and accurately includes the effects of the local site subsurface properties. The staff concludes that the proposed Turkey Point Units 6 and 7 COL site is acceptable from a geologic and seismologic standpoint and meets the requirements of 10 CFR 52.79 and 10 CFR 100.23.

2.5.3 Surface Deformation

2.5.3.1 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3 evaluates the potential for tectonic and non-tectonic surface deformation within a 40 km (25 mi) radius of the Turkey Point Units 6 and 7 site. The applicant addressed the following topics: geologic, seismic, and geophysical investigations; geologic evidence, or absence of evidence for tectonic surface deformation; correlation of earthquakes with capable tectonic sources; ages of most recent deformation; relationship of tectonic structures in the site area to regional tectonic structures; characterization of capable tectonic sources; designation of zones of Quaternary deformation in the site region; and potential for surface tectonic deformation at the site.

2.5.3.2 Summary of Application

Turkey Point Units 6 and 7 COL FSAR Section 2.5 incorporates by reference Section 2.5.3 of the AP1000 DCD In addition, in Turkey Point Units 6 and 7 COL FSAR Section 2.5.3, the applicant provided the following information:

AP1000 COL Information Item

- PTN COL 2.5-4

The applicant provided additional information in PTN COL 2.5-4 to address COL Information Item 2.5-4 (COL Action Item 2.5.3-1). PTN COL 2.5-4 addresses the evaluation of site-specific surface and subsurface geologic, seismic, and geophysical information related to the potential for surface or near-surface faulting affecting the site.

The applicant developed Turkey Point Units 6 and 7 COL FSAR Section 2.5.3 for the Turkey Point Units 6 and 7 site based on information derived from its review of published literature and geologic maps; interpretation of aerial photographs and satellite images, interpretation of aerial photographs and satellite images; and field geologic and aerial reconnaissance investigations performed specifically for the Turkey Point Units 6 and 7 site COL FSAR. The applicant also used information presented in the Updated Final Safety Analysis Report (UFSAR) for Turkey Point Units 3 and 4, Revision 7.

Based on the information derived from these sources, the applicant concluded in Turkey Point Units 6 and 7 COL FSAR Section 2.5.3 that there are no capable tectonic fault sources or bedrock faults and there is no potential for tectonic fault rupture within the site area or vicinity. The applicant noted that the only non-tectonic surface deformation features within the Turkey Point Units 6 and 7 site area are features related to surficial dissolution of carbonate strata in the site area.

The following SER Sections 2.5.3.2.1 through 2.5.3.2.8 summarize the information provided by the applicant in Turkey Point Units 6 and 7 COL FSAR Section 2.5.3 related to surface and near-surface tectonic deformation due to faulting, as well as surface and near-surface non-tectonic deformation.

Supplemental Information

- PTN SUP 2.5-1

The applicant also provided supplemental information in Turkey Point Units 6 and 7 COL FSAR Section 2.5, "Geology, Seismology, and Geotechnical Engineering," which provides summary information of detailed information in Turkey Point Units 6 and 7 FSAR Section 2.5.3, "Surface Faulting," for the Turkey Point Units 6 and 7 site.

2.5.3.2.1 Geologic, Seismic, and Geophysical Investigations

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.1 describes geological, seismological, and geophysical investigations performed by the applicant to assess the potential for tectonic and non-tectonic surface and near-surface deformation in the Turkey Point Units 6 and 7 site vicinity and site area. The following SER sections summarize these investigations and conclusions made by the applicant based on them in regard to tectonic and non-tectonic surface and near-surface deformation at the Turkey Point Units 6 and 7 site.

Previous Investigations

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.1.1 discusses investigations conducted at the Turkey Point Units 6 and 7 site. The applicant used information presented in the UFSAR for Turkey Point Units 3 and 4 to assess information about the stratigraphy and structures within the site area. The applicant stated that previous geological and seismological investigations presented in the UFSAR for Turkey Point Units 3 and 4 as well as for Turkey Point Units 6 and 7 revealed no tectonic or non-tectonic surface deformation hazards existing at the site. However, the applicant identified local depressions in the surface of the limestone bedrock at the site that the applicant classified as surficial erosion or solution features created by solution activity from groundwater during periods of low sea level. The applicant cross-referenced FSAR Section 2.5.4.4.5 and the UFSAR for Turkey Point Units 3 and 4 for a discussion on how bedrock beneath the site is competent and capable of supporting heavy loads.

Regional and Local Geological Studies Geologic Mapping

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.1.2 discusses the results of geologic mapping conducted in the site area by the Florida Geological Survey and other researchers. The applicant indicated that no faults are identified at the surface on the Florida peninsula within the 320 km (200 mi) radius of the Turkey Point Units 6 and 7 site region. In addition, the applicant reported that USACE used Landsat satellite data to identify possible linear features across central and southern Florida. The Landsat satellite data identified around 500 lineaments (linear patterns) in sinkholes and solution depressions, ponds or lakes and streams. The applicant stated that the features exhibited a northwest and northeast orientations, which are typical for all of Florida; in addition the lineaments are recognized as reflecting joint or fracture patterns in the limestone, which are enhanced by karstic dissolution.

Seismicity Data

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.1.3, the applicant discussed the seismicity data of the Turkey Point Units 6 and 7 site and region. The applicant indicated that Florida peninsula is an area of low seismicity and based on the original EPRI catalog, three earthquakes occurred within the 320 km (200 mi) radius of the site region. The applicant

clarified that the original EPRI catalog did not cover parts of the Gulf of Mexico and Cuba. The applicant indicated that the EPRI earthquake catalog for the Turkey Point Units 6 and 7 COL investigation includes earthquakes that occurred after the publication of the EPRI catalog; this update covers the entire site region, including Cuba and beyond. The applicant indicated that the catalog for the Phase 1 seismicity investigation contains a total of 700 earthquakes; 66 of them are located within the 320 km (200 mi) radius of the Turkey Point Units 6 and 7 site and no earthquakes inside the 40 km (25 mi) radius of the site location. The applicant stated that most of these earthquakes are concentrated in a zone of seismicity in and around Cuba as shown on Turkey Point Units 6 and 7 COL FSAR Figure 2.5.3-203.

Current Aerial and Field Reconnaissance

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.1.4 discusses the current aerial and field reconnaissance for the Turkey Point Units 6 and 7 site. The applicant stated that aerial photography, satellite imagery, and topographic maps revealed no evidence indicative of the potential for tectonic surface deformation (i.e., faulting or folding).

During aerial and field reconnaissance the applicant identified three north south trending vegetation lineaments located around 8 km (5 mi) west of the Turkey Point Units 6 and 7 site. The applicant explained that it found no evidence for surface rupture or geomorphic features indicating active faulting. Four other features identified in southern Florida were further investigated: a rock reef approximately 32 km (20 mi) northwest of the Turkey Point Units 6 and 7 site in Everglades National Park; tree lineaments located 29 km (18 mi) west of the Turkey Point Units 6 and 7 site near the intersection of Flamingo Road and Ingram Highway in Everglades National Park; a linear segment about 55 km (34 mi) west of the site in the Shark River channel in Everglades National Park; postulated faults from borehole data in the McGregor Isles about 193 km (120 mi) northwest of the Turkey Point Units 6 and 7 site. The applicant indicated that geologic field and aerial reconnaissance did not identify evidence for surface rupture or offset of geomorphic features indicative of active faulting within the site or site area. The applicant stated that it identified vegetated depressions during field and aerial reconnaissance. Aerial photographs indicate that the construction of Turkey Point Units 3 and 4 cooling canals removed many of the surficial depressions.

2.5.3.2.2 Geologic Evidence, or Absence of Evidence, for Surface Deformation

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.2 the applicant indicated that a review of published literature did not reveal any evidence for active tectonic deformation within the Turkey Point Units 6 and 7 site vicinity or site area. The applicant indicated that the site vicinity lies in the Florida carbonate platform, characterized by horizontal and undisturbed bedding and low rates of seismicity. Furthermore, the applicant did not report any features such as salt domes, Quaternary volcanic features, and glacial related deformation in the Turkey Point Units 6 and 7 site vicinity.

The applicant identified the only geomorphic feature possibly related to faulting within the site vicinity, as the Grossman's Hammock also called "rock reef." The applicant described the Grossman's Hammock as a 13 km (8 mi) long ridge, similar to other ridges found in southern Florida. Steinen et al. (1995) interpreted a fault due to the apparent offset of a buried Quaternary erosion surface identified in some boreholes beneath Grossman's Hammock. However, the applicant stated that in a more recent work, a ground-penetrating radar study shows no offset on the on the underlying Quaternary surface. Proposed explanations for Grossman's Hammock include fracture-related preferential cementation, and preservation of

paleoshorelines or paleo-mud banks. Grossman's Hammock was classified as a Class D feature by Crone and Wheeler (2000), meaning that geologic evidence demonstrates that the feature is not a tectonic fault or structure.

The applicant stated that it did not identify any geomorphic features or lineaments associated with faulting within the site area during analysis of aerial imagery, but did observe numerous linear and ellipsoidal/circular features associated with changes in vegetation. The applicant stated that these features are the result of surficial dissolution of the limestone bedrock.

Aerial photographs from the 1940s revealed three main lineament orientations are east-west, northeast-southwest, and northwest-southeast with two minor orientations of east-northeast-west-southwest and north-northeast-south-southeast. Through fieldwork, the applicant determined that three north-south trending vegetation lineaments located 8-10 km (5-6 mi) west of the site are wide swaths of cut down vegetation. The applicant stated that these features show no geomorphic expression or other evidence that would indicate tectonic faulting associated with these vegetation lineaments.

As part of the field investigations, the applicant examined two features beyond the site vicinity. The first feature is a linear segment on the Shark River channel approximately 55 km (34 mi) west of the site on Everglades National Park. The applicant stated that field investigation showed no evidence that suggest a tectonic origin in the linear segment, and possibly the linearity of this feature was likely human controlled. Another featured found about 193 km (120 mi) northwest of the Turkey Point Units 6 and 7 site, are possible faults in the McGregor Isles area near Fort Myers. The applicant identified these features from borehole data. Based on gamma-ray logs from several wells, Sproul et al. (1972) interpreted faulting on mid-Miocene (~16–11.6 Ma) strata. However, field reconnaissance and inspection of aerial photography, in addition to more recent studies by Scott and Missimer (2001), revealed no evidence of surficial faulting in the area.

2.5.3.2.3 Correlation of Earthquakes with Capable Tectonic Sources

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.3 of the Turkey Point Units 6 and 7 site discusses correlation of earthquakes with capable tectonic sources. The applicant updated the original EPRI earthquake catalog to incorporate earthquakes that occurred between 1985 and February 2008. The applicant explained that the updated Phase 1 earthquake catalog contained no earthquakes within the Turkey Point Units 6 and 7 site vicinity. The applicant concluded that there is no seismicity or capable tectonic sources within the Turkey Point Units 6 and 7 site vicinity or site area, and thus, no spatial correlation of earthquake epicenters or capable tectonic sources.

2.5.3.2.4 Ages of Most Recent Deformation

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.4 discusses the ages of most recent deformations within the Turkey Point Units 6 and 7 site. Based on field reconnaissance, review of published literature and interpretation of aerial photography, the applicant indicated that there is no evidence for tectonic deformation within the Turkey Point Units 6 and 7 site vicinity. In addition the applicant stated that there is no correlation of geologic structures to ages of recent deformation.

2.5.3.2.5 Relationships of Site Area Tectonic Structures to Regional Tectonic Structures

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.5 of the Turkey Point Unit 6 and 7 site discusses the relationship of tectonic structures within the site area. The applicant stated that field reconnaissance, review of published literature and interpretation of aerial photography within the Turkey Point Units 6 and 7 site showed no evidence for tectonic deformation. The applicant indicated that subsurface exploration program at the site revealed continuous, horizontal stratigraphy that precludes the existence of faults, folds, or structures related to tectonic deformation, therefore the applicant stated that there is no correlation of geologic structures in the Turkey Point Units 6 and 7 site to capable tectonic structures.

2.5.3.2.6 Characterization of Capable Tectonic Sources

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.6 of the Turkey Point Units 6 and 7 site addresses the characterization of capable tectonic sources. Based on review of published literature, interpretation of aerial photography, and field reconnaissance, the applicant concluded that no evidence exists for capable tectonic sources within the Turkey Point Units 6 and 7 site vicinity. The applicant supported this conclusion by the results of the subsurface exploration program, which indicates continuous, horizontal stratigraphy that precludes the presence of faults, folds, or structures related to tectonic deformation. The applicant stated that based on these data there are no capable tectonic sources within the site vicinity or site area.

2.5.3.2.7 Designation of Quaternary Deformation Zones in the Site Region

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.7 characterizes the zones of Quaternary (2.6 Ma to present) deformation in the Turkey Point Unit 6 and 7 site region. The applicant concluded that review and interpretation of aerial photography, review of published literature and field reconnaissance, revealed no evidence for Quaternary tectonic deformation, including paleoliquefaction, within the Turkey Point Units 6 and 7 site area, or site vicinity. The applicant, however, indicated that within the site region, potential Quaternary deformation and seismicity are limited to the faults within the Cuba areal source zone, located about 225 km (140 mi) south of the Turkey Point Units 6 and 7 site. In addition, the applicant stated that other areas that may exhibit possible deformation are the Walkers Cay fault located approximately 320 km (200 mi) northeast of the site and the Santaren anticline located about 240 km (150 mi) southeast of the Turkey Point Units 6 and 7 site. The applicant indicated that published literature does not identify any sand blows or paleoliquefaction features. The applicant noted that karstic dissolution is a source of non-tectonic Quaternary deformation found in Florida and the Bahamas within the Turkey Point Units 6 and 7 site region.

2.5.3.2.8 Potential for Surface Tectonic Deformation at the Site

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.8 of the Turkey Point Units 6 and 7 site addresses the potential for surface tectonic and nontectonic deformation at the site. The applicant stated that there are no sources for potential tectonic deformation at the site; however, they noted that the only evidence for non-tectonic deformation at the site is potholes attributed to surficial dissolution. The applicant referred to Appendix 2.5AA of the Turkey Point Units 6 and 7 COL FSAR for a detailed discussion on potential for carbonate dissolution and karst development at the Turkey Point Units 6 and 7 site.

2.5.3.3 Regulatory Basis

The regulatory basis of the information incorporated by reference is addressed in NUREG-1793, and its supplements. The applicable regulatory requirements for surface faulting are as follows:

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

- 10 CFR 100.23, as it relates to determining the potential for surface tectonic and nontectonic deformation at and in the region surrounding the site.

In addition, the related acceptance criteria associated with relevant requirements of NRC regulations for surface deformation are given in NUREG-0800, Section 2.5.3, as follows:

- Geologic, Seismic, and Geophysical Investigations: Requirements of GDC 2 in Appendix A of 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi),or 10 CFR 52.79(a)(1)(iii) and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), are met and the guidance in RG 1.208 and RG 4.7 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 reasonably well with studies conducted by others in the same area, and are supported by detailed investigations performed by the applicant. Site vicinity, site area, and site location-specific geologic maps and cross-sections constructed at scales adequate to clearly illustrate surficial and bedrock geology, structural geology, topography, and relationship of power plant foundations and site boundaries to these features should be included in the application. For sites located near bodies of water, the application should address how investigations have been conducted to detect possible surface deformation features that might be located beneath water.

- Geologic Evidence for Surface Deformation: Requirements of GDC 2 in Appendix A to 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi) or 10 CFR 52.79(a)(1)(iii), 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), are met and guidance RG 1.208, and RG 4.7 followed for this area of review if the applicant provides sufficient surface and subsurface information for the site vicinity, area, and location to confirm and characterize presence or absence of surface deformation (e.g., faulting, growth faulting, subsidence or collapse related to dissolution of limestone, salt or gypsum deposits, or salt diapirism and paleoliquefaction) features. The applicant should also take into account the potential for blind faults.

- Timing of Deformation: Requirements of GDC 2 in Appendix A to 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi) or 10 CFR 52.79(a)(1)(iii), and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), are met for this area of review if recognized surface deformation features (e.g., tectonic faults and non-tectonic features including growth faults) and features associated with a blind fault, are investigated in sufficient detail to constrain the age of the most recent surface deformation event, and, if applicable, the ages of preceding deformation events. The application shall also provide an acceptable evaluation of sensitivity and resolution of the exploratory geologic and geophysical

techniques used to determine whether or not appropriate techniques were applied to assess the age of the most recent displacement.

- Correlation of Earthquakes with Tectonic Feature: Requirements of GDC 2 in Appendix A to 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi or 10 CFR 52.79(a)(1)(iii)), and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), are met for this area of review if the applicant evaluates all reported historical earthquakes within the site vicinity with respect to accuracy of hypocenter location and source of origin, and with respect to correlation to tectonic features. The applicant shall evaluate the potential for historical activity on tectonic features in the site vicinity. The application should include a plot of earthquake epicenters superimposed on a map showing tectonic features in the site vicinity.

- Relationship of Geologic Features in the Site Vicinity to Regional Geologic Features: Requirements of GDC 2 in Appendix A to 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi) or 10 CFR 52.79(a)(1)(iii), and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), are satisfied for this area of review if the applicant evaluates the relationships between faults or other deformation features in the site vicinity and the regional framework. The application should provide an acceptable evaluation of the relationships between the regional (tectonic and non-tectonic) framework and deformation features in the site vicinity, including growths faults and growth fault systems. The applicant should show how this information is used in the evaluation of potential for future surface deformation at the site.

- Potential for Surface Deformation at the Site: To meet requirements of GDC 2 in Appendix A to 10 CFR Part 50, 10 CFR 52.17(a)(1)(vi) or 52.79(a)(1)(iii), and 10 CFR 100.23(c) and 10 CFR 100.23(d)(2), for this area of review, the applicant shall assess the potential future tectonic and nontectonic surface deformation at the site. The applicant should provide sufficient geological, seismological, and geophysical information to clearly establish whether there is potential for future surface deformation at the site. If the potential for future surface deformation exists at the site, the application must provide information that demonstrates the potential effects of surface deformation are within the design basis of the proposed facility. NRC regulations do not restrict building in an area with surface faulting potential, but if that potential exists, the regulations require that surface deformation must be taken into account in the design and operation of the proposed nuclear power plant. It is questionable whether it might be feasible to design for surface deformation with any degree of confidence that safety-related SSCs would maintain their safety functions if surface displacements occur in the future. Consequently, it is NRC policy (e.g., RG 1.208) to recommend that any site located on a surface or near-surface feature with a potential for future displacement be re-located to an alternate site.

2.5.3.4 Technical Evaluation

The staff reviewed Section 2.5.3 of the Turkey Point Units 6 and 7 site COL FSAR and the referenced DCD to ensure that the combination of information presented in the FSAR and the DCD completely represents the required information related to tectonic (i.e., faulting) and non-tectonic surface and near-surface deformation. The staff's review confirmed that information contained in the application or incorporated by reference addresses the information required for this review topic.[1] NUREG-1793 and associated supplements document the results of the staff's evaluation of information incorporated by reference into the Turkey Point Units 6 and 7

Site COL FSAR. The staff reviewed the following information in the Turkey Point Units 6 and 7 Site COL FSAR:

AP1000 COL Information Item

- PTN COL 2.5-4

The staff reviewed PTN COL 2.5-4 included in Section 2.5.3 of the Turkey Point Units 6 and 7 COL FSAR. Turkey Point Units 6 and 7 Site COL FSAR Section 2.5.3 addresses the potential for surface or near-surface tectonic and non-tectonic deformation within the site vicinity and site area and at the site location. The COL information item from AP1000 DCD, Section 2.5.3, states:

> Combined License applicants referencing the AP1000 certified design will address the following surface and subsurface geological, seismological, and geophysical information related to the potential for surface or near-surface faulting affecting the site: (1) geological, seismological, and geophysical investigations, (2) geological evidence, or absence of evidence, for surface deformation, (3) correlation of earthquakes with capable tectonic sources, (4) ages of most recent deformations, (5) relationship of tectonic structures in the site area to regional tectonic sources, (6) characterization of capable tectonic sources, (7) designation of zones of Quaternary deformation in the site region, and (8) potential for surface tectonic deformation at the site.

Based on the discussion of the potential for tectonic and non-tectonic surface deformation at the site presented in Turkey Point Units 6 and 7 Site COL FSAR Section 2.5.3, the staff concludes, as described below, that the applicant provided the information required to satisfy PTN COL 2.5-4.

SER Section 2.5.3.2 above specifies the data sources used by the applicant to develop Turkey Point Units 6 and 7 Site COL FSAR Section 2.5.3, which contains information related to the potential for tectonic and non-tectonic surface and near-surface deformation within the site vicinity, area and location. Through the review of the Turkey Point Units 6 and 7 Site COL FSAR Section 2.5.3, the staff determined whether the applicant had complied with the applicable regulations and conducted the investigations at an appropriate level of detail in accordance with RG 1.208. To evaluate the original geologic, seismic, and geophysical information submitted by the applicant thoroughly, the staff obtained additional assistance from experts at USGS.

Site Visits

The staff visited the Turkey Point Units 6 and 7 site on May 24 and 25, 2011 (ADAMS Accession No. ML111881052), and on August 22 and 23, 2013 (ADAMS Accession No. ML13248A497), to meet with the applicant and its consultants regarding the geologic, seismic, geophysical, and geotechnical investigations conducted at the Turkey Point Units 6 and 7 site for the Turkey Point Units 6 and 7 COL FSAR. The purpose of the May 2011 visit was to acquaint the staff with the nuclear station site, examine drill cores, dissolution features, and calculation packages. The staff examined drill cores from selected intervals of various boreholes completed within the nuclear island footprint and focused on the Key Largo Formation and Fort Thompson Formation cores. These boreholes include B-730, B-704DH, B-701DH and B-703 from Unit 7 and B-629, B-604DH, B-601DH and B-606 from Unit 6. The staff also visited

shallow surface depression dissolution features that support distinct woody vegetation at Units 6 and 7 and along the interceptor canal road, near the western plant boundary. The surficial dissolution features along the canal road are in a more natural pristine condition than the ones at Units 6 and 7 building site.

The August 2013 site visit was an audit of the subsurface investigation work being performed by Paul C. Rizzo Associates, Inc. at the Turkey Point Units 6 and 7 site (ADAMS Accession No. ML13248A497). The staff interviewed individuals representing the applicant and Rizzo Associates at the Unit 7 drilling site for the new supplemental boring program that included specific sampling of the vegetated depressions at the site. The applicant used the Macaulay sampler to provide undisturbed peat samples for the basis of Holocene stratigraphy at the site. The applicant examined undisturbed peat samples for presence of tsunami and storm surge deposits from prehistoric events.

The staff also examined newly extracted core from the Miami, Key Largo, and Fort Thompson Limestone Formations. This was the first opportunity to directly observe Miami Limestone because the heavily weathered nature of this surface unit previously prevented sufficient RQD. The staff observed the increasing clastic content with depth in the Fort Thompson formation and the open reef like fabric in the Key Largo Formation. Terminated calcite crystals cover open surfaces indicating a precipitating, rather than a dissolving in situ environment.

The following SER Sections 2.5.3.4.1 through 2.5.3.4.8 present the staff's evaluation of information provided by the applicant in Turkey Point Units 6 and 7 site COL FSAR Section 2.5.3 and the applicant's responses to RAIs for Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.

2.5.3.4.1 Geologic, Seismic, and Geophysical Investigations

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.1 describes the geologic, seismic, and geophysical investigations performed by the applicant to support the Turkey Point Units 6 and 7 COL FSAR and specifically to assess the potential for tectonic and nontectonic surface or near-surface deformation within a 40 km (25 mi) radius (site vicinity) of Turkey Point Units 6 and 7. The applicant considered information from various investigations and sources that include the following:

- compilation and review of existing data and literature,
- interpretation of old and new aerial photography that include pre a post construction photos to look especially for both tectonic and non-tectonic surface deformation,
- review of seismicity data based on the historical earthquakes,
- field and aerial reconnaissance to examine geomorphic features and lineations,
- geologic reconnaissance and aerial photograph analysis of vegetated surficial depressions, and
- integrated Multi-method Geophysical Survey to locate possible subsurface dissolution features.

The applicant concluded that there are no capable tectonic fault sources or bedrock faults, no potential for tectonic fault rupture, and no evidence of Quaternary tectonic surface faulting or tectonic deformation within the site, site area, or site vicinity. The applicant further concluded that there are non-tectonic surface deformation features within the site area and the site. Site investigations relate these features to surficial dissolution of carbonate strata in the site area.

For the Section 2.5.3 review, the staff considers the evidence provided by the applicant to assess the potential for surface deformation from tectonic and non-tectonic features, structures, or processes. Because tectonic features that are Quaternary age or younger are more likely to be formed in the current tectonic regime, and more likely to move in the future, the staff focused on tectonic features that are potentially Quaternary aged. The staff also focused on non-tectonic sources of surface deformation such as limestone dissolution processes or features.

The staff evaluated several RAI responses in SER Section 2.5.1 that pertain to the evaluation of surface deformation at the Turkey Point Units 6 and 7 site. The following SER Sections present the staff's evaluations of the geologic, seismic, and geophysical investigations performed by the applicant for the Turkey Point Units 6 and 7 site and refer back to related and previously evaluated RAI responses found in SER Section 2.5.1.

Previous Site Investigations

The applicant referred to results of previous geologic and seismologic investigations in the 1992 UFSAR for Turkey Point Units 3 and 4 and in a more detailed study of the 8 km (5 mi) radius site area (Grupton and Berry, 1976). Both studies conclude that no tectonic or non-tectonic surface deformation hazard exists at the site. The 1992 UFSAR identified the vegetated surface depressions at the site and suggested that these depressions are not sinkholes associated with collapse above an underground solution channel, but rather potholes, which are surficial erosion or solution features. The 1992 UFSAR concluded that the Miami Limestone and Fort Thompson Formations have been susceptible to solution activity from groundwater during periods of low sea level (Pleistocene glacial advances), but that the "bedrock beneath the site is competent with respect to foundation conditions and is capable of supporting heavy loads."

Staff asked several RAIs regarding limestone dissolution in the site region and area. SER Sections 2.5.1, 2.5.3.4.2, and 2.5.3.4.6 evaluate the responses. The staff also notes that SER Section 2.5.4 addresses the stability of the subsurface with respect to supporting SSCs.

Regional and Local Geological Studies

The applicant described three geological studies that pertain to this review area. None of these studies concludes or indicates surface faulting in southern Florida. Results of regional and local geologic mapping by the Florida Geological Survey and other researchers do not indicate any faults at the surface on the Florida peninsula. USGS compiled a catalog of all known or suggested Quaternary faults, liquefaction features, and possible tectonic features in CEUS (Crone and Wheeler, 2000; Wheeler, 2006). The applicant stated that these compilations identify no Quaternary tectonic faults or tectonic features in the site region or site area. The applicant also summarized the USACE study (2004), which identified lineations in central and southern Florida using Landsat satellite data and digital orthophoto quadrangles. The applicant concludes that the lineaments are typical for all of Florida and are the surface expression of joint or fracture patterns in the underlying limestone. USACE reports no offsets along any of these lineaments, nor are any designated as faults.

In reviewing Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.3, staff notes that the applicant also provided new geologic information from the 2008 geologic mapping and exploration program performed as part of the Turkey Point Units 6 and 7 COL FSAR (MACTEC, 2008), the supplemental field investigation (Rizzo, 2014a), sampling performed in surficial muck deposits using a McCauley Sampler (Rizzo, 2014b) and Turkey Point Units 6 and 7 COL FSAR Appendix 2.5AA, The potential for carbonate dissolution and karst development at the Turkey Point Units 6 and 7 site.

Seismicity Data

The applicant stated that the Florida Peninsula is an area of low seismic activity. The Phase 1 earthquake catalog contains a total of about 700 earthquakes with Rmb greater than or equal to 3.0 or intensity I0 greater than or equal to IV for all years through mid-February 2008. Approximately 66 out of about 700 earthquakes are located within the 320 km (200 mi) radius site region. Most of these earthquakes are concentrated in a zone of seismicity in and near Cuba, which is greater than about 257 km (160 mi) south of the Turkey Point Units 6 and 7 site. The applicant cited Turkey Point Units 6 and 7 COL FSAR Figure 2.5.3-203, which shows that there are no earthquakes from the updated Phase 1 earthquake catalog inside the 40 km (25 mi) radius site vicinity.

The staff examined the seismicity maps in Turkey Point Units 6 and 7 COL FSAR Figures 2.5.3-201 and 2.5.3-203 and agrees with the applicant that there are no earthquakes within 40 km (25 mi) of the site. The staff notes that SER Section 2.5.2 evaluates the regional seismicity and the development of the Turkey Point Units 6 and 7 site's earthquake catalog.

Current Aerial and Field Reconnaissance

The applicant examined various aerial photography, satellite imagery, and topographic maps of varying scales (1:20,000 and 1:40,000) and vintages (from 1940 through 2004) and concluded that no evidence is revealed in these data of geomorphic features indicative of the potential for tectonic surface deformation (e.g., faulting or folding) within the site area.

The applicant referred to an analysis of lineations in Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.3. Staff reviewed and evaluated this analysis of lineaments in southern Florida in Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.3 and found no evidence of surface faulting or surface deformation. Staff also considered the lineament analysis the applicant provided in its response to RAI 40, Question 02.05.04-1. The staff notes that results documented from area studies such as the USACE report and the lineaments studied at Turkey Point Units 6 and 7 site support the idea that lineaments are associated with near vertical fractures (or joints) in the subsurface.

Staff examined the orientations of the lineaments at the site area and note that they are consistent with large-scale, regional lineament trends identified in other studies, which linked these features to subsurface fracture orientations (Bond et al., 1981). The vertical or near-vertical fracture orientations found in the USACE study (2004) support the assumption that the lineaments identified in the Turkey Point site area are associated with fractures in the subsurface. The staff notes that the results of the inclined boreholes the applicant completed as part of the supplemental field program (Turkey Point Units 6 and 7 COL FSAR Enclosure 8) corroborate this assumption. The staff notes that these sub-vertical fractures or joints in the region and at Turkey Point Units 6 and 7 site are possibly initiation points for the development of

the vegetated surface depressions. The staff also notes that there is no indication in the site data that there are offsets along the joints to suggest faulting.

Based on review of Turkey Point Units 6 and 7 COL FSAR Sections 2.5.3.1 and 2.5.1 and field observations made during the site visits, the staff finds that the applicant presented a complete description of the geologic, seismic, and geophysical investigations performed to assess the potential for tectonic and non-tectonic surface and near-surface deformation within the site vicinity, area and location in compliance with 10 CFR 100.23 and 10 CFR 52.79, and in support of the Turkey Point Units 6 and 7 COL FSAR.

2.5.3.4.2 Geologic Evidence for Surface Deformation

For this area of review, staff consider if the applicant has provided sufficient surface and subsurface information for the site vicinity, area, and location to confirm and characterize the presence or absence of surface deformation features following guidance in RG 1.208 and 4.7, and SRP 2.5.3. This area of review corresponds to Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.2.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.2 originally stated that published geologic mapping results show no bedrock faults mapped within the site vicinity. However, the staff notes that FSAR Figure 2.5.1-253 depicts a strike-slip fault within 40 km (25 mi) of the site; Figure 2.5.3-204 also shows this feature as a high-rank lineament. In RAI 43, Question 02.05.03-3, staff asked the applicant to discuss the high-rank lineament shown on Turkey Point Units 6 and 7 COL FSAR Figure 2.5.3-204, and clarify its relationship with the strike-slip fault north of the Turkey Point Units 6 and 7 site shown on Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-253.

In an October 3, 2014, response to RAI 43, Question 02.05.03-3 (ADAMS Accession No. ML14281A177), the applicant stated that USACE (2004) mapped a variety of lineaments in southern Florida, including the high-rank lineament shown on Turkey Point Units 6 and 7 COL FSAR Figure 2.5.3-204, using Landsat imagery. Although the USACE report suggested that some lineaments could be related to fractures or faults, it did not present evidence for tectonic displacement along the high-rank lineament under discussion, nor did it interpret this feature as a fault. Furthermore, the lineaments were generally not field checked. The applicant assigned the lineament a high rank due to its alignment with a linear portion of the Shark River toward its southwestern end. The applicant stated that field and air photo reconnaissance conducted to support the Turkey Point Units 6 and 7 COL FSAR found no positive evidence for faulting associated with the linear portion of the Shark River.

The applicant clarified the interpretation of a subsurface strike-slip, east-west striking basement fault near the Turkey Point Units 6 and 7 site. Turkey Point Units 6 and 7 COL FSAR Figure 2.5.1-253 shows faults drawn to accommodate potential misfits in plate tectonic reconstruction models and thus, little evidence directly indicates actual displacement occurred on these postulated structures. Barnett (1975) placed the northeast-striking basement fault in order to align magnetic anomalies on Andros Island in the Bahamas with the Peninsular Arch. Barnett states that the evidence for the actual presence of major shear faults in the basement of the Florida-Bahama Platform is interpretive.

Staff considered the USACE study and Barnett (1975) and concludes that there is no specific evidence to link the surficial lineament with the postulated basement fault based on the following reasoning. Staff notes that the north to northeast striking surficial lineament is mapped only on

shore and terminates against the Atlantic coastal ridge. The USACE did not consider this feature tectonic. In contrast, the basement fault extends many kilometers to the east and west of the Florida peninsula, offshore, has a more easterly strike, and is located more than 5 km north of the surficial lineament. In addition Barnett (1977) postulated a structure to accommodate misfits in regional plate tectonic models. There is no real evidence of a basement fault. Therefore, staff considers RAI 43, Question 02.05.03-3 resolved.

Limestone Dissolution Features

Staff notes that within the Turkey Point Units 6 and 7 site vicinity there are several different kinds of limestone dissolution features that developed due to different processes including: dry caves along the Atlantic ridge, peat lined surface dissolution depressions, subsurface zones of secondary porosity due to mixing zones of fresh and salt waters, submarine springs in Biscayne Bay, large submarine sinkholes that are considered to extend very deep into the subsurface (Key Largo and Jewfish creek and others further away from Turkey Point Units 6 and 7 site), subsurface seismic sags (also referred to as structural collapse features) located in Biscayne Bay, and onshore in Miami-Dade and Broward counties. The only dissolution features observed at the surface in the site vicinity are the dry caves along the Atlantic Coastal ridge (west of the Turkey Point Units 6 and 7 site), widely distributed vegetated surface depressions and eroded joints expressed as surface lineaments. Staff concludes in SER Section 2.5.1 that these are not a surface deformation hazard to the Turkey Point Units 6 and 7 site. Staff evaluated and closed several RAIs in its assessment of the potential for limestone dissolution at Turkey Point Units 6 and 7 site in SER Section 2.5.1.4.1, including RAI 41, Questions 02.05.01-1, -2, -17, and -37.

Staff also notes that in response to RAI 82, Question 02.05.04-26, the applicant will develop a grouting program based on its test program for the subsurface beneath the nuclear island, which will grout the zone between -10.7 m and -18.3 m (-35 ft and -60 ft) elevation and constrain any remaining voids not having potential to exceed 6.1 m (20 ft) equivalent diameter between -18.3 m and -33.5 m (-60 ft and -110 ft) elevation. Also, the applicant performed a sensitivity analysis to demonstrate the void size (6.1 m (20 ft)) constrained by the grouting program is not critical to the stability of subsurface materials and the integrity of SSCs. The staff's evaluation of the grouting plan and testing program, the sensitivity analysis and the associated ITAAC are discussed in SER Section 2.5.4.4.4.

Consistent with RG 1.208, RG 4.7, and SRP Section 2.5.3, staff considered the information provided in the Turkey Point Units 6 and 7 COL FSAR related to surface and subsurface information for the site vicinity, area, and location to confirm the applicant's conclusions regarding the absence of surface deformation features. Based on that review, as well as independent review of publications and observations made during site field audits, staff finds that there is no surface faulting evidence within the site vicinity and the applicant will mitigate the potential for subsurface limestone dissolution through the grouting plan.

2.5.3.4.3 Timing of Deformation

Turkey Point Units 6 and 7 COL FSAR Sections 2.5.3.4 and 2.5.3.7 discuss the ages of most recent deformation, particularly Quaternary (2.6 Ma to present) deformation in the Turkey Point Units 6 and 7 site region. Based on information presented in Turkey Point Units 6 and 7 COL FSAR Section 2.5.1 and cross-referenced in Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.7, the applicant concluded that no zones of Quaternary deformation requiring further investigation occur in the site region. Staff also notes that FSAR Section 2.5.3.7 originally

stated that “within the site region, seismicity and potential Quaternary tectonic deformation are restricted to the Cuba areal source zone, approximately 160 mi (258 m) south of the site.”

After reviewing the Turkey Point Units 6 and 7 COL FSAR and independently considering relevant publications, the staff noted that other tectonic features outside the Cuba areal zone were not included in the Turkey Point Units 6 and 7 COL FSAR. These tectonic features are interpreted by the various investigators as being younger than the end of the Cuban orogeny (Eocene 33.9 Ma) and some possibly as young as Pleistocene. Therefore, staff asked the applicant several RAI questions regarding these features including RAI 43, Question 02.05.03-2; RAI 41, Questions 02.05.01-3, 02.05.01-14, 02.05.01-15, 2.5.1-16, and RAI 81, Questions 02.05.01-34, -36, and -38, the latter two RAIs of which are discussed and evaluated by staff in SER Section 2.5.1.

In RAI 43, Question 02.05.03-2, staff asked the applicant to describe the Walkers Cay Fault, the Santaren Anticline, and the Straits of Florida normal faults, which are tectonic features all located outside the Cuba areal source but within the site region. Staff also asked the applicant to provide a figure that reflects all potentially active Quaternary features in the site region.

In an October 3, 2014, response to RAI 43, Question 02.05.03-2 (ADAMS Accession No. ML14281A177), the applicant addressed the specific tectonic features outside the Cuba areal source and within the 320 km (200 mi) radius of the site. The applicant summarized the publications available that identified these features. The applicant also cited previous RAI responses that contain more detail.

The staff reviewed related material provided by the applicant in response to RAI 41, Question 02.05.01-14 (evaluated in SER Section 2.5.1.4.1), regarding Quaternary deformation on the Walkers Cay Fault. The applicant acknowledged that, considering all the data published to date, it cannot preclude the possibility of Quaternary slip on the Walkers Cay Fault by the available data. Therefore, the applicant completed a hazard sensitivity calculation to assess the potential effect of a Walkers Cay Fault source on the PSHA (see SER Section 2.5.1.4.1 and 2.5.2 for details of this seismic hazard sensitivity analysis). The applicant concluded that the hazard sensitivity calculation, based on a conservative seismic source characterization of the Walkers Cay Fault, indicates a total hazard of less than 1 percent of the total site seismic hazard. The applicant further concluded, and staff agrees, that it is an insignificant contributor to site seismic hazard.

The staff reviewed additional related material provided by the applicant in response to RAI 41, Question 02.05.01-15 dated June 17, 2015 (ADAMS Accession No. ML15169A845), and RAI 81, Question 02.05.01-34 dated July 15, 2015 (ADAMS Accession No. ML15198A059) (evaluated in SER Section 2.5.1.4.1), regarding details of Quaternary deformation of the Santaren Anticline. The staff evaluated the sensitivity analysis of the Santaren Anticline fault source completed by the applicant and concludes that these calculated increases from the sensitivity analysis are not significant enough to revise the PSHA (see SER Section 2.5.1.4.1 and 2.5.2 for details of this seismic hazard sensitivity analysis).

The staff reviewed additional related material for the Straits of Florida normal faults provided in response to RAI 41, Questions 02.05.01-3 and -16, as discussed in Section 2.5.1.4 of this SER. Because the Straits of Florida normal faults are overlain by undeformed Miocene and younger strata and detailed seismic data indicate a non-fault origin for these geomorphic features, the applicant concluded that the Straits of Florida normal faults are not Quaternary age. The

applicant provided supporting details to conclude that the undeformed Miocene and younger strata overlying these faults constrain deformation to Eocene. Staff notes that in the seismic reflection profiles provided by the applicant, the youngest faulting is constrained below a middle Miocene unconformity, thus constraining the age to about 13.8 Ma.

Because the applicant completed a hazard sensitivity analysis of the Walkers Cay Fault and the Santaren Anticline, staff concludes that the applicant adequately considered these features with respect to seismic hazard. Furthermore, the staff notes that the Straits of Florida normal faults show no evidence of Quaternary deformation. Accordingly, and in compliance with 10 CFR 100.23 and 10 CFR 52.79, staff considers RAI 43, Question 02.05.03-2, resolved.

In RAI 81, Question 02.05.01-34, staff asked the applicant to provide a discussion of possible Quaternary tectonic faults along the western bank of the northern Santaren Channel (northeast of the Cay Sal Bank), within about 80 km (50 mi) of the Turkey Point Units 6 and 7 site (Kula, 2014) and integrate into the regional tectonic setting for the Turkey Point Units 6 and 7 COLA. In response, the applicant concluded that there are no through-going structures along the eastern margin of Cay Sal Bank capable of producing large crustal earthquakes and that the features in Kula's data are non-tectonic and non-seismogenic. Based on its evaluation (SER Section 2.5.1.4.1), the staff cannot rule out the possibility that some of the features identified in Kula (2014) are tectonic in origin and Quaternary-age, in particular Fault A, therefore, staff conducted a PSHA sensitivity analysis of Fault A using the most recent NRC-endorsed ground motion models (EPRI, 2013). SER Section 2.5.1.4.1 and 2.5.2.4.4 provide the details of this sensitivity analysis. Based on the results, Fault A or a fault cored anticline would not affect the Turkey Point seismic hazard significantly (greater than 1 percent of total hazard). The staff considers the results of the sensitivity analysis to be a sufficient indication that the features as interpreted by Kula (2014) are not a significant contributor to site hazard.

In RAI 85, Question 02.05.01-38 (evaluated in SER Section 2.5.1), staff asked the applicant to provide a discussion of a newly identified tectonic anticline located on the submarine Miami Terrace, about 30 mi from the Turkey Point Units 6 and 7 site, to integrate this structure into the regional tectonic setting for the Turkey Point Units 6 and 7 COL FSAR and, to discuss how this feature might affect the PSHA at the Turkey Point Units 6 and 7 site. The applicant concluded that the anticline is not a capable tectonic source because it is older than 1.8 Ma with no associated seismicity. Therefore, it should not be included in the PSHA for the Turkey Point Units 6 and 7 site. Staff reviewed Cunningham (2015) and notes that he concludes that the folding and the reverse faulting occurred sometime during the Oligocene to early Pleistocene. Because the documented tectonic activity falls within the Quaternary period, in order to assess the potential significance of the Miami Terrace anticline for the site-specific seismic hazard, staff conducted a PSHA sensitivity analysis to show that hazard contribution from this source is negligible. SER Section 2.5.2.4.4 and 2.5.1.4.1 provide the details of this sensitivity analysis. Hence, the staff considers the results of the sensitivity analysis to be a sufficient indication that the Miami Terrace anticline and associated reverse faults are not a contributor to site hazard.

The applicant revised the Turkey Point Units 6 and 7 COL FSAR Figure 02.05.03-205 to include tectonic structures within the site region with potential Quaternary deformation, including the Walkers Cay fault, the Santaren anticline, and faults on Cuba within the site region. The applicant did not include Fault A and the Cay Sal anticline nor the Miami Terrace reverse anticline and reverse faults in this figure.

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.4, the applicant stated that results of the surface and subsurface exploration program at the site indicate continuous, horizontal stratigraphy that precludes the presence of faults, folds, or structures related to tectonic deformation in the site vicinity. Therefore, the applicant concluded, there is no correlation of geologic structures to ages of recent deformation. However, in SER Section 2.5.1, staff evaluated the applicant's response to RAI 81, Question 02.05.01-36, regarding a submarine, subsurface strike slip fault in Biscayne Bay (Cunningham et al., 2012 and Cunningham, 2015) that is within 11 km (7 mi) of the site, extends greater than 16 km (10 mi), strikes north to northeast, and projects directly toward the Turkey Point Units 6 and 7 site. Staff examined the earthquake catalog and notes there is no seismic activity associated with the fault in Biscayne Bay. The staff concludes that the fault is older than Quaternary and is not a surface deformation hazard to the Turkey Point Units 6 and 7 site.

The staff focused the review of Turkey Point Units 6 and 7 COL FSAR Sections 2.5.3.4 and 2.5.3.7 on the information provided by the applicant, primarily in Turkey Point Units 6 and 7 COL FSAR Section 2.5.1, to confirm where Quaternary deformation might occur in the site region. Staff asked several RAI questions to clarify submarine structures within the site region, such as the Walkers Cay fault, Santaren anticline and faults, Fault A off of Northeast Cay Sal Bank, and Miami Terrace reverse faults and anticline, where investigators have concluded these structures might be Quaternary tectonic structures. Staff evaluated these structures and concluded that all could be Quaternary age tectonic structures. However, based on the sensitivity analysis that the applicant completed for the Walkers Cay fault and the Santaren anticline, and the staff's seismic hazard sensitivity completed for the Miami Terrace anticline and Fault A and the Cay Sal anticline, none of these structures impact the PSHA greater than 1 percent of the total hazard.

Based on the review of Turkey Point Units 6 and 7 COL FSAR Sections 2.5.3.7, 2.5.3.4, and 2.5.1, the responses to RAI questions, and independent review of relevant publications, the staff finds that the applicant provided a complete characterization of known Quaternary deformation in the site region. Based on the seismic hazard sensitivity analyses completed by the applicant and staff, staff finds that there are no known Quaternary age tectonic features in the site region that will impact Turkey Point Units 6 and 7 Site PSHA.

2.5.3.4.4 Correlation of Earthquakes with Tectonic Features

This area of review combines Turkey Point Units 6 and 7 COL FSAR Sections 2.5.3.3, "Correlation of Earthquakes with Capable Tectonic Sources," and 2.5.3.6, "Characterization of Capable Tectonic sources." The staff notes that acceptance criteria associated with relevant requirements of the NRC regulations for surface deformation as given in Section 2.5.3 of NUREG-0800, no longer contains a section for "characterization of capable tectonic sources" or "correlation of earthquakes with capable tectonic sources."

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.3, the applicant stated that no seismicity or capable tectonic sources exist within the site vicinity or site area; therefore, there is no spatial correlation of earthquake epicenters or capable tectonic sources. The staff examined the earthquake catalog and agrees with the applicant that there are no earthquakes in the site vicinity. The staff finds that there are no Quaternary age tectonic features within the site vicinity based on its review of Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.1.1.3 and independent review of relevant publications. Staff asked and evaluated several RAI questions related to this topic in SER Section 2.5.1.4.1 and 2.5.1.4.2. These are all resolved. Staff finds

that the applicant met the guidance in RG 1.208 and RG 4.7 for this area of review, because the applicant evaluated the earthquake catalog for the Turkey Point Units 6 and 7 site within the site vicinity and with respect to potential correlation to tectonic features.

2.5.3.4.4 Correlation of Earthquakes with Tectonic Features

This area of review combines Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.3, “Correlation of Earthquakes with Capable Tectonic Sources,” and Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.6, “Characterization of Capable Tectonic sources.”

2.5.3.4.5 Relationship of Geologic features in the Site Vicinity to Regional Geologic Structures

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.5 discusses the relationships of tectonic structures in the site area to regional tectonic structures. The applicant stated that there is no evidence of tectonic deformation within the site area and therefore there is no correlation of geologic structures in the site area to regional capable tectonic structures.

Staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.5.1 for the identification of geologic features at the regional and site scale to verify the validity of the applicant’s conclusion. Staff also independently reviewed many publications as part of the Turkey Point Units 6 and 7 COL FSAR Section 2.5.1 review. The only tectonic feature within the site vicinity is the Miocene-age strike-slip fault in Biscayne Bay (Cunningham, 2015) but this feature is not structurally linked nor related to any regional tectonic feature, as discussed in SER Sections 2.5.1.4.1 and 2.5.1.4.2. Staff confirms that the applicant considered or evaluated relationships between faults or other deformation features in the site vicinity and the regional framework. Staff finds that there are no Quaternary age tectonic features in the site area.

2.5.3.4.6 Potential for Surface Deformation at the Site

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.8.1 discusses the potential for surface and near-surface tectonic and non-tectonic deformation at the Turkey Point Units 6 and 7 site. The applicant stated that there are no sources for potential tectonic deformation at the site. The applicant evaluated possible Quaternary age tectonic structures outside the site vicinity, including the Miami terrace anticline and reverse faults, Walkers Cay fault, Santaren anticline, and Fault A off of Cay Sal Bank, but concluded that the structures have no significant effect on the Turkey Point Units 6 and 7 site’s PSHA. The only tectonic fault within the site vicinity is a subsurface, strike-slip fault in Biscayne Bay (Cunningham, 2015) but the staff concludes that the fault is older than Quaternary with no associated seismic activity. The only evidence for non-tectonic deformation at the site is the presence of “potholes” that appear to be caused by surficial dissolution (Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.4 and FSAR Appendix 2.5AA).

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.8.2.1 indicates that deformation related to karst is observed in southern Florida and limestone dissolution is evident in stratigraphic units, such as the Miami and Key Largo Limestones, which underlie the site. The applicant stated that this is not expected to pose a significant surface deformation hazard at the Units 6 and 7 site and that no collapse or settlement problems associated with karst-type dissolution of underlying limestones have been associated with Turkey Point Units 3 and 4. Appendix 2.5 AA of the Turkey Point Units 6 and 7 Site FSAR provides details regarding the potential for carbonate

dissolution and karst development at the site. The applicant concluded that although subject to spatial resolution and detection limits inherent in a subsurface investigation, the available borehole and geophysical data indicate there is minimal hazard posed by sinkholes and no evidence for potential surface collapse due to the presence of large underground openings at the site.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.3.8.2.1 originally stated that shallow depressions preserved at the surface and recognized in the site vicinity are formed by gradual top-down, subaerial dissolution and are unlikely to have underlying cavity voids with potential for rapid collapse. The staff notes the presence of similar-sized and -shaped features on the sea floor of Biscayne Bay within 3 km (1.9 mi) to the east of Units 6 and 7 in publically available satellite images. In RAI 43, Question 02.05.03-1, staff asked the applicant to discuss how the apparent semi-circular alignments of offshore depressions may be consistent with incipient collapse into a larger underlying void. Staff also asked the applicant to discuss the time of formation and whether these features have formed at similar elevations below Units 6 and 7, such as the zones of secondary porosity.

In an October 3, 2014, response to RAI 85, Question 02.05.03-1 (ADAMS Accession No. ML14281A177), the applicant stated that the seafloor of Biscayne Bay, east of the Turkey Point Units 6 and 7 site, includes many vegetated patches that appear to be similar to the vegetated patches mapped subaerially at the site. The features at the site are thought to be the result of a subaerial, epigenic, gradual, top-down process of carbonate dissolution caused by downward seepage of slightly acidic meteoric water following fractures, joints and bedding planes. The applicant identified features within 3 km (1.9 mi) of the site in Biscayne Bay, compared them to the subaerial depressions at the site, and concluded that the subaerial depressions at the site are slightly larger than the submarine patches in Biscayne Bay. The applicant further noted that the patches on the floor of Biscayne Bay likely formed during the Wisconsinan glacial advance, at which time both the floor of the bay and the area of the Turkey Point Units 6 and 7 site were subject to subaerial weathering and surficial dissolution. However, the site area remained above sea level since the Wisconsinan and has been subject to weathering and surficial dissolution for several thousand years longer than the floor of the bay.

The applicant explained that the upper zone of secondary porosity beneath the site is located near the contact of the Miami and Key Largo Limestones at an approximate elevation of -8.5 m (-28 ft). Because the stratigraphic units are relatively flat, it appears that the upper zone of secondary porosity at the site corresponds to the same stratigraphic interval where the submarine vegetated patches are in Biscayne Bay. However, the site subsurface investigations show an absence of large solution features at this stratigraphic interval beneath the site. In addition, the dissolution features such as the vugs in the upper zone of secondary porosity likely developed in a subsurface freshwater/saltwater mixing zone, whereas, the vegetated patches on the floor of the bay appear to be subaerial, paleo-dissolution features that formed during the Pleistocene when sea level was approximately 100 m (328 ft) lower than the present day sea level.

Staff notes that during the Quaternary, multiple glacial periods affected eustatic sea levels that would have exposed the limestone strata in Biscayne Bay to subaerial weathering and erosion. Staff agrees with the applicant that the patches in Biscayne Bay have similar physical characteristics to the vegetated surface depressions on site and in the general southern Florida area around the site that would suggest a similar origin of formation. Accordingly, and in

compliance with 10 CFR 100.23 and 10 CFR 52.79, staff considers RAI 85, Question 02.05.03-1, resolved.

Staff notes that within the Turkey Point Units 6 and 7 site vicinity there are several types of limestone dissolution features that developed due to different processes including: dry caves along the Atlantic ridge, peat lined surface dissolution depressions, subsurface zones of secondary porosity due to mixing zones of fresh and salt waters, submarine springs in Biscayne Bay, large submarine sinkholes that are considered to extend very deep into the subsurface (Key Largo and Jewfish creek and others further away from the Turkey Point Units 6 and 7 site), subsurface seismic sags (also referred to as structural collapse features) located in Biscayne Bay and onshore in Miami-Dade and Broward counties. SER Section 2.5.1.4.1 evaluates and resolves several RAIs related to the applicant's assessment of the potential for limestone dissolution at the Turkey Point Units 6 and 7 site and vicinity.

Staff also notes that in response to RAI 82, Question 02.05.04-26, the applicant developed a drilling and grouting plan for the subsurface beneath the nuclear island, and also performed analyses to confirm that any remaining potential voids would not impact the safety of any Category I structure. The staff's evaluation of this plan and the associated ITAAC are in SER Section 2.5.4.4.4. For the depth of the subsurface explorations for safety related foundations, RG 1.132, Appendix D, states that, "Where soils are very thick, the maximum required depth for engineering purposes, denoted dmax, may be taken as the depth at which the change in the vertical stress during or after construction for the combined foundation loadings is less than 10 percent of the effective in situ overburden stress." Staff further noted that in response to RAI 6006, Question 02.05.04-19, the applicant provided a PLAXIS 3D finite element analysis that incorporates advance constitutive models (stress vs. strain relationship) that simulates the response of soils to external loading for construction sequence. The applicant used an analysis depth of El. –450 feet, which is greater than 2B (B is equal to the least dimension of the foundation), and assumed it to be adequate to meet the aforementioned RG 1.132 criterion. The applicant results indicated that the changes in effective vertical stresses are less than 10 percent of the effective in situ stress for each phase of the construction sequence, demonstrating that the model depth is appropriate and in compliance with RG 1.132 criterion. The staff's evaluation of this RAI response is in SER Section 2.5.4.4.10.

Based on the staff's finding about limestone dissolution features and processes in SER Section 2.5.1.4.1, and staff's evaluation of the applicant's response to RAI 82, Question 02.05.04-26, regarding the void size, location and depth that needs to be considered for integrity of Category I structures, staff concludes that the potential for tectonic and non-tectonic surface deformation at Turkey Point Units 6 and 7 site has been adequately addressed in compliance with 10 CFR 100.23 and 10 CFR 52.79.

2.5.3.5 Post-Combined License Activities

Staff identifies the following geologic mapping License Condition as the responsibility of the COL licensee:

- License Condition (2-1) – The licensee shall perform detailed geologic mapping of the excavation for Turkey Point Units 6 and 7 Site safety-related structures; examine and evaluate geologic features discovered in excavations for safety-related structures other than those for the Units 6 and 7 nuclear islands; and notify the Director of the Office of

New Reactors, or the Director's designee, once excavations for Turkey Point Units 6 and 7 safety-related structures are open for examination by NRC staff.

2.5.3.6 Conclusion

Staff reviewed the Turkey Point Units 6 and 7 Site COL FSAR and the referenced DCD. Based on these reviews, staff confirmed that the applicant addressed the required information related to surface and near-surface tectonic (i.e., due to faulting) and non-tectonic deformation and that no additional outstanding information must be discussed in the Turkey Point Units 6 and 7 COL FSAR in regard to tectonic and non-tectonic surface or near-surface deformation. NUREG-1793 and associated supplements document the results of the staff's technical evaluation of information incorporated by reference into the Turkey Point Units 6 and 7 Site COL FSAR.

As set forth above, staff has reviewed the information in PTN COL 2.5-4 and PTN SUP 2.5-1 and concludes that the applicant thoroughly characterized the potential for surface and near-surface tectonic and non-tectonic deformation at the Turkey Point Units 6 and 7 Site, as required by 10 CFR 100.23 and 10 CFR 52.79 (a)(1)(iii). Based on the applicant's geologic investigations performed for the site vicinity, site area, and site location, the staff also concludes that the applicant properly addressed information related to the following specific topics for the Turkey Point Units 6 and 7 Site: Geologic, seismic, and geophysical investigations; geologic evidence, or absence of evidence, for surface deformation; correlation of earthquakes with capable tectonic sources; ages of most recent deformations; relationships between tectonic structures in the site area and regional tectonic structures; characterization of capable tectonic sources; designation of zones of Quaternary (2.6 Ma to present) deformation in the site region; and the potential for surface tectonic and non-tectonic deformation at the site. In addition, staff concludes that the applicant performed all investigations in accordance with10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii) and followed guidance provided in RG 1.208. Finally, staff concludes that the applicant established an adequate basis to state that no known capable tectonic sources exist that would cause surface or near-surface tectonic deformation at the Turkey Point Units 6 and 7 Site and no known sources exist for non-tectonic deformation at the site. Therefore, the staff finds that the Turkey Point Units 6 and 7 site is acceptable in regard to surface and near-surface tectonic and non-tectonic deformation and meets the requirements of 10 CFR 100.23 and 10 CFR 52.79(a)(1)(iii).

2.5.4 Stability of Subsurface Materials and Foundations

2.5.4.1 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4 presents the applicant's evaluation of the stability of subsurface materials and foundations that relate to the Turkey Point Units 6 and 7 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 Turkey Point Units 6 and 7 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 to affect the loading and stability of foundation materials, (7) responses of site

soils or rocks to dynamic loading, (8) liquefaction potential and consequences of liquefaction of all subsurface soils, including the settlement of foundations, (9) earthquake design bases, (10) results of investigations and analyses conducted to determine foundation material stability, deformation and settlement under static conditions, (11) criteria, references, and design methods used in static and seismic analyses of foundation materials, and (12) techniques and specifications to improve subsurface conditions, which are to be used at the site to provide suitable foundation conditions, and any additional information deemed necessary in accordance with 10 CFR Part 52.

2.5.4.2 Summary of Application

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4, the applicant describes the subsurface materials and foundation. In particular, the site-specific information provided in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4 addresses the following COL-specific information identified in Section 2.5 of the AP1000 DCD.

In addition, in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4, the applicant provided the following:

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

- PTN COL 2.5-1

The applicant provided additional information in PTN COL 2.5-1 to address COL Information Item 2.5-1. PTN COL 2.5-1 addresses the provision of regional and site-specific geologic, seismic, and geophysical information, as well as conditions caused by human activities. This information includes: structural geology; seismicity of the site; geologic history; evidence of paleo-seismicity; 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 effects of human activities in the area.

- PTN COL 2.5-2

The applicant provided additional information in PTN COL 2.5-2 to address COL Information Item 2.5-2. PTN COL 2.5-2 addresses the provision for site-specific information related to vibratory ground motion aspects of the site including: seismicity, geologic and tectonic characteristics, correlation of earthquake activity with seismic sources, PSHA, seismic wave transmission characteristics and the SSE ground motion.

- PTN COL 2.5-3

The applicant provided additional information in PTN COL 2.5-3 to resolve COL Information Item 2.5-3, 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 the AP1000 DCD.

- PTN COL 2.5-5

The applicant provided additional information in PTN COL 2.5-5 to address COL Information Item 2.5-5 (COL Action Item 2.5.1-1). PTN 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.

- PTN COL 2.5-6

The applicant provided additional information in PTN COL 2.5-6 to resolve COL Information Item 2.5-6 (COL Action Item 2.6-3). PTN COL 2.5-6 addresses the properties of the foundation soils to be within the range considered for design of the nuclear island basemat.

- PTN COL 2.5-7

The applicant provided additional information in PTN COL 2.5-7 to resolve COL Information Item 2.5-7 (COL Action Item 2.5.4-1). PTN COL 2.5-7 addresses the information concerning the extent (horizontal and vertical) of Seismic Category I excavations, fills, and slopes.

- PTN COL 2.5-8

The applicant provided additional information in PTN COL 2.5-8 to resolve COL Information Item 2.5-8 (COL Action Item 2.4.1-1). PTN COL 2.5-8 addresses the groundwater conditions relative to the foundation stability of the safety-related structures at the site.

- PTN COL 2.5-9

The applicant provided additional information in PTN COL 2.5-9 to resolve COL Information Item 2.5-9 (COL Action Item 2.5.4.3-1). PTN COL 2.5-9 addresses the provision of demonstration that the potential for liquefaction is negligible.

- PTN COL 2.5-10

The applicant provided additional information in PTN COL 2.5-10 to resolve COL Information Item 2.5-10 (COL Action Item 2.6-4). PTN COL 2.5-10 addresses the verification that the site-specific allowable soil bearing capacities are equal to or greater than the values documented in the standard design, or will provide a site-specific evaluation as described in the AP1000 DCD Section 2.5.4.2 under all combined loads, including the safe shutdown earthquake, for static and dynamic loads.

- PTN COL 2.5-11

The applicant provided additional information in PTN COL 2.5-11 to resolve COL Information Item 2.5-11 (COL Action Item 2.5.2-2). PTN 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.

- PTN COL 2.5-12

The applicant provided additional information in PTN COL 2.5-12 to resolve COL Information Item 2.5-12 (COL Action Item 2.5.5-1). PTN COL 2.5-12 addresses soil characteristics affecting the stability of the nuclear island including foundation rebound, settlement, and differential settlement.

- PTN COL 2.5-13

The applicant provided additional information in PTN COL 2.5-13 to resolve COL Information Item 2.5-13 (COL Action Item 2.6-5). PTN 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.

- PTN COL 2.5-16

The applicant provided additional information in PTN COL 2.5-16 to resolve COL Information Item 2.5-16. PTN 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, Turkey Point Units 6 and 7 COL FSAR Section 2.5.4 addresses Interface Item 2.12 related to peak ground acceleration, response spectra, shear wave velocity (V_s) and Interface Item 2.13 related to the required bearing capacity of foundation materials.

- PTN COL 2.5-17

The applicant provided additional information in PTN COL 2.5-17 to resolve COL Information Item 2.5-17. PTN COL 2.5-17 addresses the provision of information regarding waterproofing system used for the foundation mat (mudmat) and below grade exterior walls exposed to flood and groundwater under seismic Category I structures. The applicant referred to Turkey Point Units 6 and 7 COL FSAR Sections 3.8.5.1 and 14.3.3.4 where this COL information item is addressed.

Supplemental Information

- PTN SUP 2.5-1

The applicant provided supplemental information in Turkey Point Units 6 and 7 COL FSAR Section 2.5, "Geology, Seismology, and Geotechnical Engineering," which provides summary information of detailed information in Turkey Point Units 6 and 7 FSAR Section 2.5.4, "Stability of Subsurface Materials and Foundations," for the Turkey Point Units 6 and 7 site.

2.5.4.2.1 Geologic Features

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.1 presents a synopsis of the subsurface conditions on Turkey Point Units 6 and 7, followed by descriptions of the foundations soil and rock properties and the stability of these materials. This section also summarizes the non-tectonic processes and geologic features that could relate, if present, to permanent ground deformations or foundation instability at the Turkey Point Units 6 and 7 safety-related facilities.

Subsurface Conditions

Turkey Point Units 6 and 7 COL FSAR Figures 2.5.4-201 and 2.5.4-202 present the locations of Turkey Point Units 6 and 7 on the east coast of the Florida platform and the drilling locations of the two subsurface investigation programs performed by the applicant. The applicant stated that it drilled and sampled a total of 88 geotechnical borings and 2 geophysical borings during the initial investigation. During the supplemental investigation, the applicant drilled 9 additional borings, three of which were inclined toward surface depressions to study potential fractures. The applicant collected surficial muck samples at nine locations. The applicant also referred to Turkey Point Units 6 and 7 COL FSAR Figures 2.5.4-203 through 2.5.4-209 for geologic cross sections and their locations relative to the units.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.1.1.1 describes the surficial soil and rock at the site. The applicant stated that the dominant surface cover is organic muck although the Miami Limestone is present in the northwestern portion of the site. The applicant stated that the site is at or near sea level and that, other than berms and vegetative depressions, the site is flat and uniform. The applicant indicated that the site is within the Southern Slope sub-province of the Atlantic Coastal Plain in a geologic setting characterized by broad bands of swamps and marshes flooded by tides or freshwater runoff.

Subsidence, Dissolution Activity, Uplift, or Collapse

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.1.2, the applicant indicated that it did not identify any geologic hazards within the site or site area, nor any geomorphic disturbances or fault-related features within the site vicinity.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.1.2.1 evaluates the dissolution activity present in the limestone rock near-surface geologic units. The applicant observed outside the vegetated depressions and drainages a total of 6.1 m (20.1 ft) of rod drops during approximately 2,413.5 m (7,918.4 ft) of rock coring, ranging in magnitude from 0.1 to 1.2 m (0.4 to 4.0 ft), with a maximum of 0.5 m (1.5 ft) within the Turkey Point Units 6 and 7 building footprints. While performing the three inclined borings, the applicant noted a total of 4.6 m (15.2 ft) rod drops during 108.6 m (356.4 ft) of rock coring, ranging in magnitude from 0.1 to 0.8 m (0.3 to 2.5 ft). The applicant indicated that the downhole geophysical data obtained from the caliper and acoustic logs do not indicate the presence of large voids and support the interpretation of two preferential secondary porosity flow zones.

The applicant stated that it does not anticipate any uplift due to natural forces or human development and noted that there is no evidence of tectonic surface deformation and/or karst related collapse.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.1.2.3 describes the history of deposition and erosion of the site. The applicant described the site area as flat and planar bedding of late Pleistocene age (10,000 to 2.8 million years ago). The applicant stated that, during the Pleistocene, erosion increased resulting in clastic deposition; while the warm interglacial periods produced an increase in the sea level leading to an increase in the carbonate buildup.

2.5.4.2.2 Properties of Subsurface Materials

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2 presents the static and dynamic engineering properties of subsurface materials based on the applicant’s field investigation, sampling program, and the laboratory testing.

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.1, the applicant provided an overview of the subsurface profile and materials. The applicant indicated that the natural ground surface at and around the power block, at the time of the subsurface investigation, had an average of El. -0.3 m (-1.0 ft) North American Vertical Datum of 1988 (NAVD88). The applicant stated that the power block finish grade elevation will be at 7.8 m (25.5 ft) NAVD88.

The applicant derived the shear strength parameters and rock mass modulus for two separate masses at the site: the fractured density (FD) 1 zone (very slightly fractured) and the FD4 zone (slightly to moderately fractured).

Soil and Rock Strata

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.2 describes each soil stratum encountered in the subsurface investigation. The applicant investigated to a maximum depth of 187.8 m (616 ft) below ground surface (bgs) in the power block area and 45.7 m (150 ft) bgs in the makeup water reservoir and perimeter areas. The applicant identified and categorized eight stratum at the Turkey Point Units 6 and 7 site: Stratum 1 is surficial muck, Stratum 2, 3, 4 and 8 are predominantly rock and Stratum 5, 6, and 7 are predominantly soil. The applicant further identified the eight strata as Muck (Stratum 1), Miami Limestone (Stratum 2), Key Largo Limestone (Stratum 3), Fort Thompson Formation (Stratum 4), Upper Tamiami Formation (Stratum 5), Lower Tamiami Formation (Stratum 6), Peace River Formation (Stratum 7), and Arcadia Formation (Stratum 8).

The applicant indicated that the Muck ranges in thickness from 0.6 to 3.4 m (2 to 11 ft) and consists of elastic silt, organic-rich elastic silt, or peat sediments. The applicant indicated that the muck has a very soft to medium stiffness consistency. The applicant described plans to remove this stratum from the plant area at the beginning of construction.

The applicant described the Miami Limestone as a soft rock consisting of pale yellow, light brownish gray and white limestone with a soft to very hard consistency depending on the degree of cementation. The thickness of the Miami Limestone ranges from 4.0 to 9.1 m (13 to 30 ft).

The applicant described the Key Largo Limestone as a coralline, porous formation with recrystallized calcite infill resulting in a rock of medium hardness and strength. The thickness of the Key Largo Limestone varies between 4.5 to 8.2 m (14.6 and 26.9 ft).

The applicant described the Fort Thompson Formation as white limestone with varying amounts of vugs, shells, and some sand, resulting in a varying consistency, medium to hard above El. -18.3 m (-60.0 ft) and medium hard to soft below El. -18.3 m (-60.0 ft). The applicant indicated that the thickness of the stratum varies between 15.6 to 23.5 m (51.3 to 77.0 ft).

The applicant characterized the Upper Tamiami Formation as light gray to greenish gray silty sands, with varying amounts of gravel and a dense to very dense consistency. The applicant encountered the top of the Upper Tamiami Formation between El. -31.0 and -38.0 m (-101.6 and -124.7 ft).

The applicant described the Lower Tamiami Formation as light gray to greenish gray silty sands, with minor amounts of silty clay resulting in a very stiff to hard consistency. The applicant indicated that the Lower Tamiami Formation starts at approximately El. -51.1 m (-167.6 ft).

The applicant described the Peace River Formation as a very dense light gray to olive gray silty sand. The applicant indicated that the stratum thickness is 73.7 m (241.7 ft), based on three fully penetrated borings.

The applicant described the Arcadia Formation as different types of limestone with occasional dolostone and thin silty sand layers resulting in hardness from soft to hard. The applicant indicated that the Arcadia Formation starts at approximately El. -138.6 m (-454.8 ft). The applicant stated that the formation was not fully penetrated by the borings, which ended at El. −188.1 m (−617.0 ft).

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.2.9 describes the compacted limerock fill, which will replace the muck layer underneath the power block area.

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.2.10, the applicant used published data from the Gas Division of the Florida Geological Survey (FGS) and from USGS to evaluate the properties of the subsurface material below 183 m (600 ft). The applicant indicated that the compression wave velocity (V_p) data was incomplete between El. −549 m (−1,800 ft) and El. −610 m (−2,200 ft), and between El. −716 m (−2,350 ft) and El. −1,082m (−3,550 ft). The applicant overcame this situation by estimating and converting V_p to V_s using a Poisson ratio of 0.3. Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-211 shows the subsurface average V_s in the southern Florida region. Initially, the applicant observed a high average V_s, of 3,048 m/s (10,000 feet per second (fps)) occurring at a depth of 183 m (600 ft), before decreasing to 2,134 m/s (7,000 fps) at 2,057 m (6,750 ft) and; thereafter fluctuating between 2,591 and 3,048 m/s (8,500 and 10,000 fps).

Evaluation of Properties of In Situ Materials

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.3 presents the properties of in situ materials of the site evaluated using the field and laboratory testing. FSAR Table 2.5.4-209 presents the recommended geotechnical engineering parameters in each stratum.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.3.2 indicates that the applicant took standard penetration test (SPT) samples at 0.8 m (2.5 ft), 1.5 m (5.0 ft), and 3.0 m (10.0 ft) intervals depending on the depth. Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-202 presents a summary of all uncorrected N-values measured in the field. During the initial investigation, the applicant encountered very low SPT N-values in the Upper and Lower Tamiami and Peace River Formations. The applicant obtained additional SPT N-values from its supplemental investigation. The applicant stated that the values from its supplemental investigation were consistently higher than those obtained during the initial investigation. The applicant indicated that the difference between the initial and supplemental field investigation can be attributed to the drilling and sampling requirements and to the fact that the supplemental investigation target was to reduce disturbance effects. The applicant considered overwashing as the cause of the lower N-values in its initial investigation. The applicant stated that it used the SPT N-values from investigations to develop engineering parameters such as friction angle and modulus of deformation, and also for input into the liquefaction assessment.

The applicant adjusted the SPT N-values for SPT hammer energy, borehole diameter, sampler, and rod length. Turkey Point Units 6 and 7 COL FSAR Tables 2.5.4-204 and 2.5.4-209 present a summary of all the corrected N-values defined as N60 and the N60 values selected for the design of each stratum, respectively.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.3.3 indicates that the applicant performed six CPTs; three in the power block areas. Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-214 summarizes the tip resistance, sleeve friction and friction ratio. The applicant performed rock sampling using HQ3 and PQ3 core barrel equipment. Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-215 shows a rock quality designation (RQD) by elevation. The RQD provides an index of rock strength for a general characteristic of a rock mass. The applicant stated that the rock quality appears to be at its maximum in the Key Largo formation. Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-206 summarizes the recovery and RQD for the three rock strata cored. Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-205 shows the testing results of natural moisture content and Atterberg limits on samples.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.3.6 describes the grain size distribution. The applicant recognized a difference in fines content between the Upper and Lower Tamiami Formations. Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-205 presents all of the results for the grain size distribution tests. The applicant recorded the unit weight for each rock sample tested for unconfined compressive strength, Resonant Column Torsional Shear (RCTS) and triaxial shear strength. Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-209 shows the recommended unit weights for use in each stratum.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.3.8 describes selection of the shear strength parameters for the soil formations. The applicant conducted triaxial testing on five samples from the Lower Tamiami, one sample from the Upper Tamiami and 15 samples from the Peace River Formation. The applicant considered the amount of triaxial tests sufficient to characterize the shear strength of the Lower Tamiami and Peace River Formations. For the Upper Tamiami Formation, the applicant established the parameters by analyses and correlations using SPT and CPT results. The applicant used the equation Su = N60/8 (in kips per square foot (ksf)) to obtain the undrained shear strength. The applicant performed rock unconfined strength testing on 31 samples from the Key Largo Limestone, 50 samples from the Fort Thompson Formation, and three samples from the Arcadia Formation.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.3.11 describes the relationship used for the evaluation of the elastic modulus (E) and shear modulus (G) high strain. The applicant used data from pressuremeter tests as well as SPT, CPT, compressional and shear (P-S) suspension logging and triaxial tests, and also used several different methods to address natural variability and the variability involved in the conversion of measured parameters to stiffness.

The applicant related the shear modulus (G) to the elastic modulus (E) as follows:

$$G = E/(2[1 + \mu])$$

where

μ = Poisson’s ratio
E=static elastic modulus
G=static shear modulus

The applicant used Poisson (μ) values for the rock strata of 0.37, 0.31, and 0.34, and a value of 0.35 for the soil strata. The applicant concluded that the shear and elastic modulus values based on V_s, and an E of 18,600 megapascals (MPa; 2,700 kips per square inch (ksi)) for the

Key Largo sample and 20,000 MPa (2,900 ksi) for the Fort Thompson sample, are more representative than the laboratory results because the laboratory results were derived from samples with higher than average RQD values.

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.3.12, the applicant used the Rankine theory (Coduto, 2001) to estimate the active, passive, and at-rest static earth pressure coefficients. Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-209 presents the calculated coefficients. The applicant indicated that it will not construct foundations below the Fort Thompson Formation. The applicant defined the coefficient of sliding as the tangent of the friction angle between the soil and the concrete. The applicant selected 0.6 as the coefficient of sliding for the Miami Limestone Formation, and 0.7 for the Key Largo Limestone and Fort Thompson Formations.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.3.14 refers to Turkey Point Units 6 and 7 COL FSAR Sections 2.5.4.4 and 2.5.4.7 in order to address the measurement and interpretation of V_s. The applicant measured the V_s and V_p with suspension logging in six boring hole locations for each unit, and with downhole velocity logging at one borehole location for each unit. Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-209 provides the V_s values for each stratum recommended by the applicant.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.3.15 discusses elastic modulus and low strain shear modulus. Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-209 shows the recommended value of low strain shear modulus for each stratum derived from the recommended V_s.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.3.16 presents an overview for the shear modulus degradation and damping ratio; Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.7 provides a more detailed description. The applicant obtained the measured values of shear modulus at increasing shear strain by performing 14 RCTS test on intact samples from the Key Largo, Fort Thompson, and Upper and Lower Tamiami formations.

The applicant conducted in situ testing including P-S suspension soundings and pressuremeter tests to investigate the high strain rock stiffness. The applicant used P-S suspension testing to produce the shear wave velocity profile, and converted it to low strain and high strain stiffness. The applicant stated that the pressuremeter test produces two types of stiffness: the initial modulus and the unload/reload modulus. The applicant calculated the stiffness for the moderately fractured zones using the Rock Mass Rating (RMR), and for the slightly fractured zones using RMR, P-S suspension, Unconfined Compressive Strength (UCS) and pressuremeter tests. The applicant provided the design stiffness values in Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-209.

The applicant indicated that the low strains represent the levels corresponding to the site response analysis or seismic soil-structure interaction analysis. The applicant stated that the median strain profile obtained from the site response analysis indicates that the maximum strain are less than 0.005 percent shear strain for the Key Largo and Fort Thompson formations, indicating that for this strain range, stiffness degradation is negligible.

Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-221 provides the lower bound soil/rock parameters used for sensitivity analyses regarding settlement, bearing capacity, and bearing pressure uniformity.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.3.20 describes the use of the rock mass classification system to estimate properties of the bearing strata as a whole from characteristics of individual rock, cores, core samples, and boring logs.

The applicant used the Hoek-Brown (Hoek, 2006) criterion to define the shear strength of a rock mass.

Chemical Properties of Soils and Rock

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.4 evaluates the chemistry of the soil and rock strata in order to consider corrosion and aggression effects toward buried steel and buried concrete. The applicant analyzed 23 sets of samples from the power block area for pH, as well as chloride and sulfate content. The applicant measured an average pH of 8.5, indicating a mildly corrosive soil; and a chloride content of 1,833 to 70,400 parts per million (ppm), indicating very corrosive soils. The applicant measured a sulfate content of 198 to 7,590 ppm (0.034 to 0.76 percent), indicating mild to moderate aggression toward concrete. The applicant will remove the muck stratum, which exhibited severe aggression toward exposed concrete. In addition, the applicant indicated that any potential sulfate or chlorine attack on the concrete will be minimized by complying with AP1000 DCD Tier 1, Table 3.3-6, which provides ITAAC to ensure that the exterior walls and the basemat of the nuclear island have a water barrier up to the site grade. The applicant also conducted tests for calcium carbonate content and concluded that the rock strata have higher calcite content than the soil strata.

Field and Laboratory Testing Program

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.5 refers to Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.2 for details on the field testing program. The applicant performed the initial field subsurface investigation from February 2008 through June 2008 and a supplemental field subsurface investigation from July 2013 to October 2013. Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.6 refers to Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.3 for details on the laboratory testing program.

Subsurface Investigation/Exploration

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.2, the applicant, following the guidance in RG 1.132, adjusted the subsurface investigation program in order to tailor it to site-specific conditions. The applicant conducted 88 geotechnical borings, 22 groundwater wells, 4 cone penetrometer tests and 2 test pits as part of the initial subsurface investigation. The applicant conducted a supplemental site investigation, including nine additional borings with: geophysical testing performed in two borings, pressuremeter testing performed in three borings to obtain in situ deformation, two inclined borings toward the center of vegetated surface depressions to study potential fractures or potential karstic features and two additional CPTs performed in the footprint of safety-related structures. In addition, the applicant collected surficial muck deposits to provide additional information related to recent geologic history at the site. Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.2 refers to two reports (MACTEC Engineering and Consulting Inc., 2008; Rizzo Associates Inc., 2014) for the complete results of the subsurface investigation. During the initial investigation, the applicant used 11 drill rigs, 10 for SPT sampling, and one for CPT at the site. The applicant used three drill rigs and one CPT truck during its supplemental investigation. The applicant logged each sample into an inventory system and followed the guidance of ASTM D 4220 (ASTM, 1995) for material storage and handling.

The applicant stated that it followed the guidance RG 1.132 on spacing and depth of borings, sampling, in situ testing and geophysical investigation methods. The applicant extended borings beneath each building up to a depth of 38.1 m (125 ft), borings beneath the reactor and other key structures up to a depth of 76.2 m (250 ft), and two borings beneath each reactor, one to at least 122 m (400 ft) and other to at least 137 m (450 ft). The applicant extended the deepest boring, B-701(DH), to a maximum depth of 188 m (616 ft).

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.2.3 describes the boring and sampling methods used by the applicant. During the initial investigation, the applicant drilled 88 geotechnical borings, ranging in depth from 30.5 to 88.4 m (100 to 290 ft). The applicant drilled two deeper borings: one to 128 m (420 ft) in the Turkey Point Unit 6 power block and the other to 188 m (616 ft) in the Turkey Point Unit 7 power block. The applicant advanced the borings using mud rotary drilling techniques until SPT refusal was found, and then used triple tube wire-line rock coring equipment and followed the ASTM D 2113 (ASTM, 2008) procedure. When the subsurface material transitioned from the Fort Thompson Formation limestone to the Upper Tamiami Formation sand, the applicant used SPT sampling at 3.1 m (10 ft) intervals. The applicant changed the sampling method to rock coring as the stratum progressed from the Peace River Formation to the Arcadia Formation.

During the supplemental investigation, the applicant drilled nine additional borings. For boring R-6-1b, the applicant conducted PQ (85 mm (3.35 in.) inside diameter) coring in the shallow limestone layer up to a depth of 36.7 m (120.5 ft) and conducted SPT and sampling in the Tamiami and Peace River formations to a depth of 141.5 m (464.1 ft). For boring R-7-1, the applicant conducted PQ coring in the shallow limestone layer up to a depth of 36.2 m (118.7 ft) and conducted SPT in the Tamiami and Peace River formations to a depth of 140.0 m (459.4 ft). For the additional borings, the applicant performed PQ coring and destructive drilling up to a depth of 38.1 m (125 ft).

The applicant collected intact samples for testing according to ASTM D1587 (ASTM, 2012). Turkey Point Units 6 and 7 COL FSAR Appendix A of Rizzo Associates Inc. (2014) and Appendix B of MACTEC Engineering and Consulting Inc. (2008) include the boring logs, core photographs, and test pit logs for the initial and supplemental subsurface investigations.

The applicant conducted a total of six CPTs, three in each of the unit power block areas. The applicant also used the CPTs to perform 29 pore pressure dissipation tests at varying depth intervals ranging from 1.5 to 15.2 m (5 to 50 ft) and 41.2 to 88.4 m (135 to 290 ft) based on the encountered stratum. FSAR Appendix C of Rizzo Associates Inc. (2014) and Appendix E of MACTEC Engineering and Consulting Inc. (2008) include the results of the CPT testing.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.2.5 describes the exploratory test pits. The applicant excavated two test pits two feet into Miami limestone rock in order to collect bulk samples and to test for laboratory compaction.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.2.6 refers to Turkey Point Units 6 and 7 COL FSAR Section 2.4.12 for a detailed description of groundwater well installation, observation, and in situ hydraulic conductivity testing. The applicant installed a total of 22 observation wells, which it developed using a submersible pump until the pumped water was relatively clear and free of suspended sediment. Additionally, the applicant installed data loggers and telemetry units at each of the observation well locations in order to measure the

depth to the water table. In the Turkey Point Units 6 and 7 COL Appendix G, includes the well development and sampling records collected by Rizzo Associates Inc. (2014).

The applicant collected soft, surficial soil and sediment layers (muck/peat deposits) to develop additional information related to the recent geologic history at the site. FSAR Reference 291 provides results of the muck and peat sampling. In addition, Turkey Point Units 6 and 7 COL FSAR Section 2.5.1.2.2 provides detailed information about the recent geologic history.

Laboratory Testing

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.2.2, the applicant indicated that it followed the guidance provided in RG 1.138, "Laboratory Investigations of Soils And Rocks for Engineering Analysis and Design of Nuclear Power Plants," to plan its laboratory testing. Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.3 describes the laboratory tests that the applicant performed at the Turkey Point Units 6 and 7 site. During the initial investigation, the applicant conducted soil laboratory testing on 178 disturbed, 7 intact and 2 bulk samples. In the supplemental investigation, the applicant conducted laboratory tests on 4 special care rock samples, 14 muck samples and 48 Shelby tube samples. The applicant stated that due to the fragility of the rock and the porosity of the limestone, it was not possible to attach strain gages to most of the samples for determination of stress-strain characteristics. During the initial investigation, the applicant attached strain gages to only two samples. The applicant performed the laboratory tests for identification, compaction, shear strength, modulus and damping, and chemical testing of soil. Appendix E to FSAR Reference 257 contains the geotechnical laboratory test reports from the initial investigation and Appendix C to FSAR Reference 290 contains the results of the supplemental investigation.

2.5.4.2.3 Foundation Interfaces

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.3 describes the foundation interface conditions at the Turkey Point Units 6 and 7 site. Turkey Point Units 6 and 7 COL FSAR Figures 2.5.4-203 through 2.54-208 show the subsurface profiles illustrating the stratigraphy at each power block area. Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-22 illustrates the power block foundation excavation geometries, and locations and depth of the units' Seismic Category I structures, as well as the relationship of the structure foundations to the subsurface strata.

2.5.4.2.4 Geophysical Surveys

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4, the applicant summarized the geophysical survey methods and analyses performed. In the initial investigation, the applicant performed downhole geophysical testing and logging in 12 boreholes in the power block areas. In the supplemental investigation, the applicant performed P-S suspension and acoustic televiewer testing in two borings in the power block areas.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4.1 presents the three types of geophysical borehole logging performed by the applicant, which are Natural Gamma (N-Gamma), normal resistivity, and three-arm caliper logging. The applicant performed the natural gamma testing following the guidelines of ASTM D6274 (ASTM, 2004). The applicant collected N-Gamma data using the caliper probe system and used the resulting data to identify strata changes. The applicant conducted normal-resistivity logs with a spacing of 41 cm (16 in.) for short-normal resistivity and 163 cm (64 in.) for long-normal resistivity in order to record the electrical

resistivity of the borehole environment and surroundings. The applicant indicated that this method provided poor demarcation of different lithological units at the site due to the influence of saltwater intrusion. The applicant used the three-arm caliper logs to measure borehole diameters with depth, which generally showed diameters of less than 15 cm (6 in.) below 9.1 m (30 ft).

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4.2 describes the P-S velocity and downhole velocity suspension logging. The applicant performed P-S suspension logging tests in twelve boreholes, and downhole testing in two P-S holes, in order to obtain the V_p and V_s as a function of depth at the Turkey Point Units 6 and 7 site. The applicant stated that it followed GeoVision procedures for both logging methods. The applicant stated that the P-S velocity logging determines the average velocity of a 1.0 m (3.3 ft) high segment of the soil column surrounding the boring of interest by measuring the elapsed time between arrivals of a wave propagating upward to the soil column. Turkey Point Units 6 and 7 COL FSAR Figures 2.5.4-218 and 2.5.4-219 show the measured shear and compression wave velocity profiles. Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4.2.2 provides an overview for the downhole testing and compares those results to the P-S suspension logging results, which show that both V_s and V_p were consistent with depth; and refers to Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.7 for a detailed discussion of the results.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4.3 describes the 12 borehole acoustic televiewer logging tests the applicant performed at the Turkey Point Units 6 and 7 site. The applicant measured borehole wall features using a high resolution acoustic televiewer probe that produces images of the boring wall based on the amplitude and travel time of an ultrasonic beam reflected from the formation wall. The applicant found many borings exhibiting zebra striping caused by rapidly reaming down the boring with new core bits, which may conceal small dikes but does not conceal fractures. The applicant stated that it did not observe any large vugs or cavities in the logs.

The applicant used the suspension logging results summarized in Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-215 to develop the V_s profiles shown in Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-220. The applicant collected the Turkey Point Unit 6 data to a depth of 137.2m (450 ft), and the Turkey Point Unit 7 V_s data to a depth of 182.9 m (600 ft).

<u>Geophysical Exploration for Possible Dissolution Features</u>

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4.5 describes the geophysical survey conducted to evaluate the potential for carbonate dissolution features at the site. The applicant applied three non-invasive geophysical techniques including: microgravity, seismic refraction and Multi-channel Analysis of Surfaces Waves (MASW).

The applicant conducted microgravity surveys to develop profiles that identify lateral variation in subsurface density. The applicant measured each station along 11 survey lines as part of the microgravity survey, excluding an existing data gap between stations 500 through 640 along line 2. The applicant indicated that the data gap is due to localized flooding.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4.5.2 describes the seismic refraction survey encompassing twenty-three arrays and covering a total length of 70.1 m (230 ft). The applicant developed two-dimensional cross sections using a modeled average V_p for the contact between the muck and Miami Limestone of 1,305 m/s (4,280 fps) and between the Miami

Limestone and Key Largo Limestone of 2,917 m/s (9,570 fps). The applicant used a vertical resolution of 20 percent and a lateral resolution of 6.1 m (20 ft).

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4.5.3 describes the MASW survey as one producing Rayleigh surface waves. Rayleigh surface waves are produced by the interaction of V_p and V_s waves with the earth's surface, which involves both vertical and horizontal particle motion. The applicant collected data along each of the eleven survey lines, excluding the existing data gap between station 460 and 640 along line 2. The applicant developed two-dimensional cross sections using a modeled average P-wave velocity for the contact between the muck and Miami Limestone of 134 m/s (440 fps) and between the Miami Limestone and Key Largo Limestone of 1,116 m/s (3,660 fps). The applicant concluded that the MASW surveys are not accurate at capturing the absolute V_s of the rock, but velocity models are accurate to within 15 percent compared to the borehole measurements.

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4.5.4, the applicant indicated that the three largest low gravity anomalies are centered on the surface depressions containing vegetation outside the Units 6 and 7 power block areas. The applicant concluded that the low density measurements are associated with the presence of peat in shallower depressions and density variations within more weathered Miami Limestone. The applicant also concluded that the site does not present sinkhole hazards and underground openings that could result in surface collapse.

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4.5.5 the applicant committed to conduct a subsurface grouting program to constrain the potential sizes of subsurface voids. The applicant stated that the zone between El. −10.7 m (−35 ft) and El. −18.3 m (−60 ft) within the diaphragm walls (the grouted zone) will be grouted in accordance with the closure criteria that will be developed as part of the grout test program. In addition, for the zone between El. −18.3 m (−60 ft) and El. −33.5 m (−110 ft) within the diaphragm walls, (the extended grouted zone), the applicant will perform grouting in every primary grout borehole. The applicant will space primary grout holes less than or equal to 6.1 m (20 ft) on center as shown on Figure 2.5.4-1. The applicant stated that this configuration constrains the maximum void size to approximately 6.1 m (20 ft). In Part 10 of the Turkey Point Units 6 and 7 COL FSAR, Appendix B, Table 3.8-6, the applicant provided a grouting ITAAC, which establishes a set of actions and criteria for the grouting activity necessary to provide assurance that, when met, the stability of Category I structures are in conformance with the combined license. The applicant indicated that successful grouting ITAAC execution results in any remaining voids in the grouted zone being structurally insignificant and any remaining voids in the extended grouted zone having a maximum equivalent spherical diameter of equal or less than 6.1m (20 ft). Turkey Point Units 6 and 7 COL FSAR Sections 2.5.4.10.3.2 and 2.5.4.10.8 and SER Section 2.5.4.2.10 describes the sensitivity analysis performed in PLAXIS 3D to consider the stability of Category I structures with postulated voids in the subsurface.

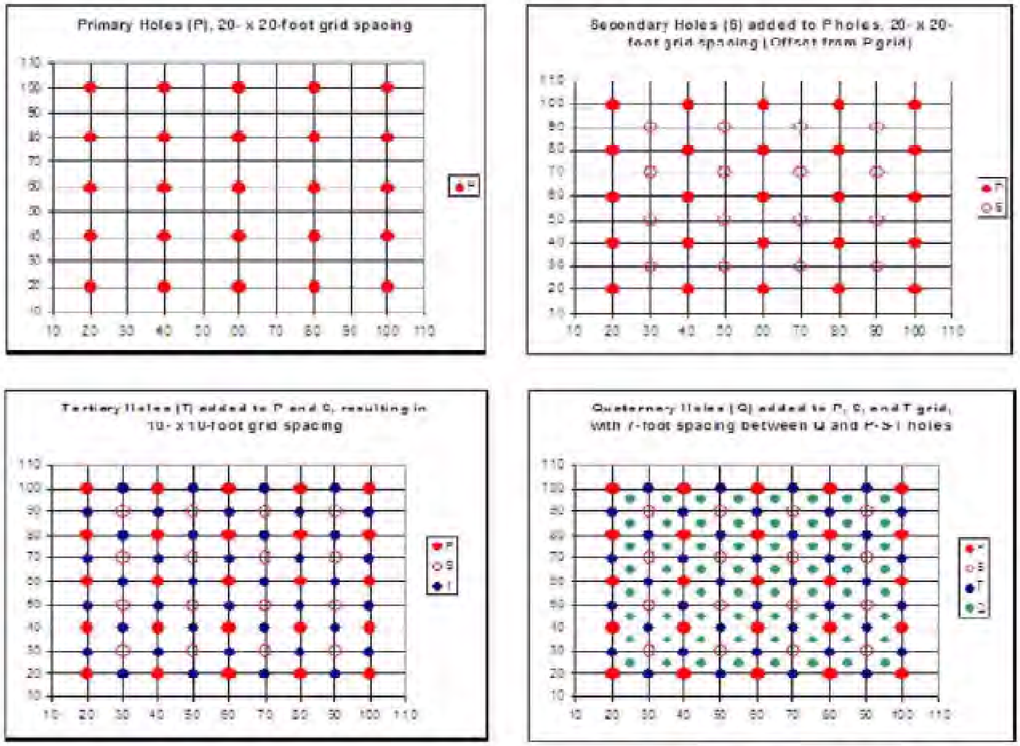


Figure 2.5.4-1. Grouting holes spacing and frequency during proposed grouting method (Source: Turkey Point Units 6 and 7 COL FSAR Appendix 2CC Figure 2CC-239)

<u>Pressuremeter Testing</u>

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4.6 describes the procedure and instruments used for the pressuremeter testing performed at the site. During the supplemental investigation, the applicant performed pressuremeter testing in three boreholes at the site to obtain large strain shear modulus for the subsurface materials of the Key Largo, Fort Thompson, Upper and Lower Tamiami and Peace River formations. The applicant attempted a total of 96 pressuremeter tests; however, only approximately 64 tests produced useful data for stiffness characterization. The applicant stated that the remaining tests resulted in oversized test pockets due to the combination of drilling conditions and the deformation limit of the pressuremeter. Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-220 presents the pressuremeter test results.

2.5.4.2.5 Excavations and Backfill

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.5.1 describes the earthwork required in order to establish finish grades at the Turkey Point Units 6 and 7 site areas. The applicant stated that it plans to completely remove Stratum F1 (muck) because of its poor soil properties. After removing the muck, the applicant described plans to raise the grade to El. 0 m (0 ft) through the placement and compaction of Miami Limestone fill material and limerock material from other sources. In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.5.1.2 the applicant stated that approximately 7.6 million cubic meters (m^3) (10 million cubic yards (yd^3)) of structural fill will be necessary to fill the site to finish grade. Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-201 illustrates the finish grade.

The applicant stated that it will construct a mechanically stabilized earth (MSE) retaining wall around the perimeter of the plant area to establish finish grades and to provide for backfilling. The applicant stated that the distance from the retaining wall to any seismic Category I structures of Turkey Point Units 6 and 7 is greater than 152.4 m (500 ft) and thus failure of the wall would not affect the seismic Category I structures. The applicant described plans to excavate into the Key Largo Limestone formation to approximately El. −10.7 m (−35 ft) and place structural fill around the power block area and lean concrete between the bottom of the mudmat and the bottom of the excavation. The applicant indicated the lean concrete fill between the mudmat and the Key Largo Limestone will have a compressive strength of 10.3 MPa (1.5 ksi). The applicant stated that the first lift of concrete fill (bottom lift) will follow American Concrete Institute (ACI) 201.2R-08, “Guide to Durable Concrete,” (2008) to improve concrete fill resistance to sulfate attack from groundwater. The applicant developed a thermal control plan to minimize thermal cracking of the 5.9 m (19 ft) thick lean concrete. The applicant stated that will follow ACI 207,” “Guide to Mass Concrete” and Nuclear Quality Assurance-1 for construction of lean concrete. In Part 10 of the Turkey Point Units 6 and 7 COL FSAR, Appendix B, Table 3.8-5, the applicant provided a concrete fill ITAAC, which establishes a set of actions and criteria for the concrete fill compressive strength, methods to control thermal cracking and sulfate attack resistance, necessary to provide assurance that, when met, the stability of Category I structures are in conformance with the combined license. The applicant indicated that successful concrete fill ITAAC execution ensures that the concrete fill placed underneath seismic Category I structures meets the specifications in ACI 207.1R-05 and that the first lift of concrete placed underneath Seismic Category I structures meets the ACI 201.2R-08 durability requirements.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.5.2 presents foundation data for the reactor and auxiliary building. The applicant identified the foundation dimensions as 26.8 m to 48.5 m (88 to 159 ft) by 77.4 m (254 ft) with the deepest excavation at an El. −10.7 m (−35 ft). The applicant stated that it will place the base of the makeup water reservoir at El. −0.6 m (−2 ft) and the excavation bottom at El. −1.2 m (−4 ft). Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-222 presents the extent of excavation, filling, and limits of temporary ground support for major structures. The applicant stated that it will not create any permanent or temporary safety-related excavation or fill slopes in the power block area.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.5.3 describes the compaction criteria applied. The applicant indicated that structural fill used as backfill around the nuclear island structures and beneath nonsafety-related power block structures will be compacted to a minimum of 95 percent of the modified Proctor maximum dry density. The applicant indicated that the general fill at power block non-structure areas will be compacted to a minimum of 92 percent of the modified Proctor maximum dry density. The applicant stated that it will address the fill placement and compaction control procedures during the detailed design stage.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.5.4 specifies that, because the deepest excavation level extends 10.7 m (35 ft) below the groundwater level, a complete construction dewatering level system will be required. The applicant stated that it will conduct the power block excavations as open cuts with a reinforced concrete diaphragm wall surrounding the excavation area. The applicant stated its intentions of conducting inspection, geologic mapping, and surveying during excavation to ensure the complete removal of the Miami Limestone and that the required depth is reached. The applicant stated that it plans to develop a detailed excavation and foundation preparation plan prior to the construction stage.

The applicant indicated that seepage will be controlled using sumps and discharge pumps. The applicant does not anticipate subgrade rebound at the Key Largo Limestone, either at the base of the excavation or in the underlying Fort Thompson Formation.

2.5.4.2.6 Groundwater Conditions

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.6, the applicant described the periodic measurements of groundwater levels it conducted to provide a basis for engineering design and for the conceptual construction design for dewatering.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.6.1 describes the amount and types of instruments installed by the applicant to help define the aquifer parameters. The applicant installed four pumping wells and 50 observations wells in order to accurately perform an aquifer pumping test. In addition, the applicant installed two pumping wells and five well clusters at each reactor site. Turkey Point Units 6 and 7 COL FSAR Section 2.4.12 provides descriptions and locations of the aquifer pumping test wells and observation wells and describes the results for hydraulic conductivity testing and the groundwater elevation gradients.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.6.2 describes the construction dewatering method and the grout test program. The applicant indicated that will surround the excavation with a reinforced concrete diaphragm wall that will act as a cut-off for horizontal groundwater flow into the excavation. The applicant stated that the bottom of the wall will be at El. −18.3 m (−60 ft), just below a limestone layer encountered between the Key Largo limestone and the Fort Thompson Formation. The applicant indicated that geologic features such as zones of secondary porosity, fractures, bedding planes and voids can provide potential pathways for water to flow. The applicant stated that zones of secondary porosity contain vugs on the order of centimeter scale. The applicant indicated that within the slightly to moderate fractures zones, the openness discontinuities vary from tight, which indicates no visible separation, to moderately wide, which indicates 9 mm (0.03 ft) to 30 mm (0.1 ft), all with an average of less than 1 mm (0.003 ft). Based on the field information described above, the applicant defined a void being as equal to or greater than 0.15 m (0.5 ft) in diameter. The applicant indicated that potential voids or sediment infills that were found are limited in size and extent. The applicant stated that for construction groundwater control, a grouted zone will be constructed via grout injections into the rock mass between the bottom of the excavation at El. −10.7 m (−35 ft) and the bottom of the diaphragm wall In Part 10 of the Turkey Point Units 6 and 7 COL FSAR, Appendix B Table 3.8-6, the applicant provided a grouting ITAAC, which establishes a set of actions and criteria for the grouting activity necessary to provide assurance that, when met, the stability of Category I structures are in conformance with the combined license. The applicant conducted a groundwater model sensitivity simulation assuming various hydraulic conductivities for the grout plug and concluded that grouting can significantly reduce the amount of discharged water generated during excavation. The applicant indicated that a grout test program will be performed to validate the grout design and grouting techniques. The applicant stated that the grouting is not classified as safety related and is to be performed to facilitate construction dewatering.

The applicant did not anticipate adverse conditions due to seepage or piping through earthwork structures because it does not plan to use such structures during construction of Turkey Point Units 6 and 7.

2.5.4.2.7 Response of Soil and Rock to Dynamic Loading

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.7 presents the site subsurface profile characterization with respect to the properties of strata pertinent for dynamic loading. The applicant referred to Turkey Point Units 6 and 7 COL FSAR Section 2.5.2 for a detailed description of the development of the ground motion response spectrum (GMRS) and the PSHA, as well as for the seismic history of the site area.

P and S Wave Velocity Profiles

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.7.2, the applicant stated that it measured the V_s and V_p at the site in the upper 183 m (600 ft) and obtained the velocities deeper than 183 m (600 ft) from Arthur (1988) and Reese and Richardson (2008) to complete the velocity profile for seismic ground response analyses with consideration of the significant depth of unconsolidated sediments at the site. Figure 2.5.4-2 shows a plot of all of the measured shear wave velocities to depths of 137 m (450 ft) and 183 m (600 ft) at Turkey Point Unit 6 and Unit 7, respectively.

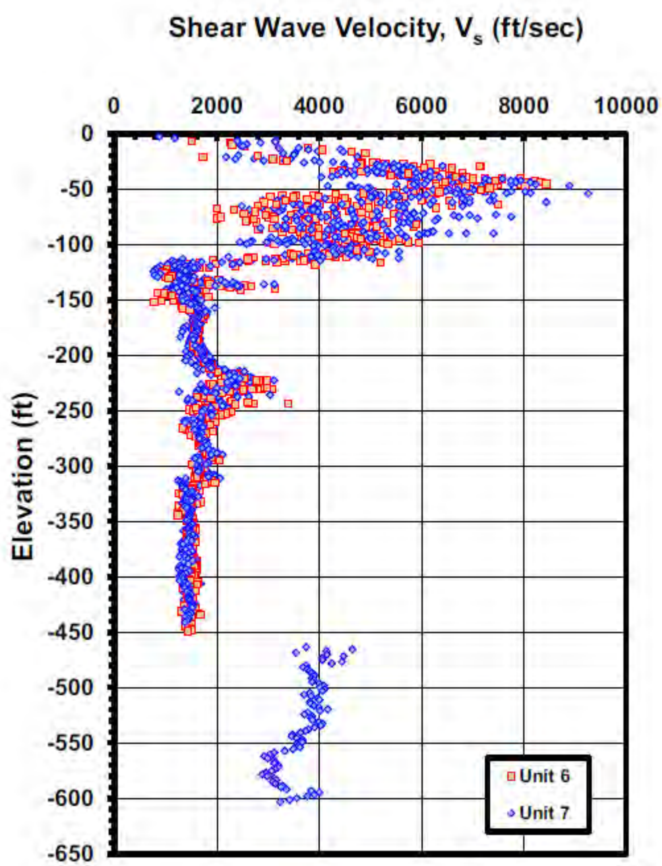


Figure 2.5.4-2. Plot of shear wave velocity measurements with elevation (Source: Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-218)

For the seismic velocities in the upper 183 m (600 ft), the applicant stated that it obtained geophysical measurements by performing P-S logging in 12 dedicated boreholes, 6 in each of

the 2 power blocks, and downhole geophysical testing up to 121.9 m (400 ft) deep. The applicant observed a variation of V_s and V_p within the Miami Limestone, Key Largo Limestone, and Fort Thompson formations and attributed this variation to the different degrees of degradation of these materials. The applicant concluded that the velocities measured in the Upper Tamiami Formation, Lower Tamiami Formation and Peace River Formation are more consistent than the overlying formations. The applicant compared results between the two power block areas and noted that the velocities are similar. Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4.4 summarizes the design/average V_s.

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.7.2.2, the applicant described the seismic velocities deeper than 183 m (600 ft). The applicant stated, following Arthur (1988), that the Cenozoic bedrock occurs at a depth of at least 4,570 m (15,000 ft) and that eight sonic logs previously performed within the site region for oil field exploration contain data ranging in elevation from approximately -152 to -3,627 m (-500 to -11,900 ft) in elevation. The applicant calculated the average V_s for the eight sonic logs. The applicant noted that the sonic data shows that the V_s of strata deeper that 183 m (600 ft) below the finish grade increased from approximately 1,220 m/s (4,000 fps) at 183 m (600 ft) to between 2,590 m/s (8,500 fps) and 3,048 m/s (10,000 fps) below 3,048 m (10,000 ft).

Static and Dynamic Laboratory Testing

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.7.3 states that the applicant conducted RCTS testing on 14 samples on the power block area from the Key Largo, Fort Thompson, Upper and Lower Tamiami, and Peace River Formations to obtain data on shear modulus degradation (G/G_{max}) and damping characteristics of site soils. Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-233 presents the selected values of G/G_{max} versus shear strain for the five strata tested in the power block area.

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.7.3.1, the applicant stated that because it will remove the muck stratum, the shear modulus degradation properties are not relevant. The applicant also obtained values of damping ratio (D) for soils at increasing shear strain levels from the RCTS tests. Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-249 presents the damping data for tests performed on natural soils.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.7.3.3 describes the shear modulus and damping curves for rock. The applicant stated that it considered the Key Largo and Fort Thompson Formations (Stratum 3 and 4) to have non-strain dependent shear modulus based on the competency of the rock. The applicant considered the Miami Limestone (Stratum 2) weak and to have a strain dependent shear modulus. Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-235 presents the selected values of damping versus the shear strain for the tested data, to include the rock curve for the Key Largo Limestone and Fort Thompson Formation and the natural soil curve used for the Upper and Lower Tamiami and Peace River formations (Stratum 5, 6 and 7).

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.7.3.4 describes the dynamic properties of the compacted structural fill. The applicant stated that will replace the muck layer with compacted limerock fill. The applicant estimated the V_s for structural limerock fill using a coefficient of variation of 1.5 applied to the shear modulus. As part of a nonsafety-related investigation of the compacted limerock fill at existing Turkey Point Unit 5, the applicant measured V_s values in the top 3.6 m (12 ft) of the fill, which average between 442 m/s and 457 m/s (1,450 and 1,500 fps). Therefore, the applicant concluded that the increase in V_s due

to cementation of the fill is more pronounced on the surface, and that the increase in confining pressure with depth in the fill results in a higher V_s with depth.

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.7.4, the applicant stated that it could calculate the small strain shear modulus values using V_s and other established parameters. The applicant referred to Section 2.5.4.2 for a stratum by stratum description of the derivation of shear modulus and other design parameters.

2.5.4.2.8 Liquefaction Potential

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.8 provides an overview of the liquefaction potential at the Turkey Point Units 6 and 7 site and discusses the geologically based and state-of-the-art methodology assessments (Youd et al., 2001), such as liquefaction analyses using CPT, V_s and SPT data.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.8.1 states that the Upper and Lower Tamiami Formation and Peace River Formation (Strata 5, 6, 7) are the soil strata considered for liquefaction potential analyses. The applicant stated that liquefaction is unlikely due to the depth of the unconsolidated deposits. The applicant estimated peak ground acceleration at the site of 0.1 g.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.8.2 presents the liquefaction resistance based on SPT data. The applicant stated that due to the effect of overwashing, the SPT N- values from the initial investigation are too low and not representative of the actual soil conditions. The applicant based its liquefaction analysis on results from the supplemental investigation. For the supplemental investigation, the applicant used a 24-inch sampler to allow observation of the second and third (2+3) blow counts and the third and fourth (3+4) blow counts. The applicant stated that the summation of the 3+4 blow count is consistently higher than the summation of the 2+3 blow count. The applicant considered the soil zone penetrated by the 3+4 blow count less influenced by overwashing and more representative of the in situ soil conditions. The applicant considered both blow counts for the liquefaction analysis and reported nine points with factors of safety raging between 1.06 and 3.21 for the analysis performed for 3+4 blow counts. The applicant stated that the value of 1.06 is the only value under 1.4 and that it corresponds to the transition between the Fort Thompson and Upper Tamiami formations. Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-250 presents a comparison between the liquefaction analysis results using the SPT N-values (blow counts 2+3) and the results using the sum of the 3+4 blow counts, both from the supplemental investigation.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.8.3 presents results of the calculated factor of safety (FOS) for the potentially liquefiable materials based on measured cone penetration parameters such as tip resistance sleeve friction. The applicant stated that the deepest CPT soundings penetrated 88.1 m (289 ft) below the ground surface, encountering refusal at that depth. The applicant performed 2 cm (0.79 in) interval tip resistance measurements during the initial investigation and 5 cm (2 in) interval measurements during the supplemental investigation. Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-238 presents the FOS results against liquefaction using CPT data. The applicant stated that FOS are consistently higher than 1.1 across the full depth of the testing at the site.

The applicant also calculated the FOS against liquefaction based on V_s data collected from P-S logging and downhole measurements. The applicant stated that it performed P-S velocity measurements at 0.5 m (1.64 ft) intervals and that the deepest measurement extended to 182.9

m (600 ft) below ground surface. Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-251 shows results for the FOS against liquefaction using shear wave velocity data. The applicant reported two values between 1.1 and 1.4 and one value below 1.1. The applicant stated that the 1.07 value corresponds to a tributary thickness to its measured point equal to 0.5 m (1.64 ft) and that it is a localized exception and does not represent a weak zone.

The applicant stated that a negligible portion of the data at isolated locations indicate the potential for liquefaction, but that factors that tend to increase the liquefaction resistance, such as the effects of age, overconsolidation and cementation are ignored in the analysis, and that the earthquake acceleration and the magnitude levels adopted for liquefaction analysis are conservative. Therefore, the applicant concluded the soils at the site are not likely to liquefy and that liquefaction is not a concern for the Turkey Point Units 6 and 7 site.

2.5.4.2.9 Earthquake Site Characteristics

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.9 refers to FSAR Sections 2.5.2 for a description of possible earthquake site characteristics.

2.5.4.2.10 Static Stability

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.10 addresses the stability of foundations for the nuclear islands to include the reactor and auxiliary buildings.

Table 2.5.4-1 summarizes the properties for the site Seismic Category I Structures**.**

Table 2.5.4.1. Site Properties for Seismic Category I Structures (Source: Turkey Point Units 6 and 7 COL FSAR Section 2.5.10.1)

Structure	**Approximate Foundation Dimensions m(ft)**	**Approximate Foundation El. m(ft)**	**Average Required Bearing Capacity (Static) kPa (ksf)**	**Maximum Required Dynamic Bearing Capacity kPa (ksf)**
Reactor and auxiliary buildings (Units 6 and 7)	26.8 to 48.5 by 77.4 (88 to 159 by 254) [irregular]	-4.3 (–14.0)	426.1 kPa (8.9)	1675.8 kPa (35)

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.10.2 refers to Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2 for a description of the power block subsurface conditions and the geotechnical engineering parameters.

<u>Bearing Capacity Evaluation</u>

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.10.2, the applicant calculated the local shear failure ultimate bearing capacity (q_{ult}) for a footing on weak rocks with little fracturing with the following formula:

$$q_{ult} = cN_cC_{f1} + 0.5\gamma BN_\gamma C_{f2}$$

and calculated the q_{ult} for a foundation on soils with Vesic's formula:

$$q_{ult} = cN_c\zeta_c + 0.5\gamma B N_\gamma \zeta_\gamma$$

where,

c = rock mass cohesion
γ = effective unit weight rock

B = width of foundation
N_c and N_γ = bearing capacity factors for rock
C_{f1} ,$C_{f2,}$ ζ_c and ζ_γ = shape factors

In addition to local shear failure, the applicant evaluated bearing capacity using the Hoek-Brown methodology for punching failure and performed a SLOPE/W analysis. The applicant presented a summary of cases evaluated and the allowable bearing capacities in Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-217. The applicant used a FOS of 3 for the allowable bearing capacities for the Seismic Category I structures. The applicant concluded that the minimum allowable static bearing capacity is 1870 kPa (39 ksf), which exceeds the average required in the AP1000 DCD, Tier 2, Table 2-1. The applicant stated that, using normal loading plus seismic conditions with 0.3 g peak ground acceleration, the maximum dynamic bearing capacity required by the AP1000 DCD of 1680 kPa (35 ksf) is satisfied.

Settlement

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.10.3 discusses the settlement analyses employed at the Turkey Point Units 6 and 7 site. The applicant estimated settlement of the foundations through hand calculations using stress distributions appropriate for layered systems, and by a three-dimensional finite element model using PLAXIS 3D Foundation (PLAXIS 3D). For the hand calculation, the applicant considered two cases: the best estimate using the design stiffness for each layer and a sensitivity analysis using the lower-bound stiffness for the two layers that impact settlement the most, Upper Tamiami and Peace River Formations. Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-219 presents the results for the hand calculation. For the three-dimensional model, PLAXIS 3D calculates displacements with the use of numerical integration methods and incorporates advanced constitutive models that are capable of simulating the response of soil to external loading. The applicant stated that the PLAXIS 3D model included the following phases: initial conditions, dewatering, excavation and lean concrete placement, construction of power block structures, construction of the nuclear island and re-watering. Table 2.5.4-2 compares the settlements estimated by the hand calculation and the PLAXIS 3D model to the DCD requirements. The applicant indicated that the lower bound and best estimate cases for the hand calculation and the PLAXIS 3D model are within the acceptable limits provided by the DCD.

Table 2.5.4-2. Comparison of Limits of Acceptable Settlement without Additional Evaluation (Source: Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-224)

		Differential Across Nuclear Island Foundation Mat (inch per 50 feet)	Total for Nuclear Island Foundation Mat (inch)	Differential Between Nuclear Island and Turbine Building[a] (inch)	Differential Between Nuclear Island and Other Buildings[a] [b] (inch)
DCD Requirement		0.5	6	3	3
Best Estimate[c]	PLAXIS 3D	0.20	2.5	0.8	1.6
	Hand Calculation	0.22	2.4	0.6	2.0
Lower Bound[c]	PLAXIS 3D	0.23	3.4	1.2	2.2
	Hand Calculation	0.26	3.2	0.9	2.7

(a) Differential settlement is measured at the center of the nuclear island and the center of adjacent structures.
(b) Maximum differential settlement occurs between nuclear island and radwaste buildings.
(c) Settlements presented exclude the rewatering phase.

Earth Pressures

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.10.4 describes the static and seismic active and at-rest lateral earth pressures acting on the underground structure below grade walls. The applicant stated that vertical ground accelerations are negligible for seismic active and at rest earth pressure cases, but accounted for horizontal ground acceleration by employing a factor of k_h g, where $k_h = 0.1$ and g = acceleration.

The applicant calculated the static active earth pressure as the product of the Rankine coefficient of static active lateral earth pressure, unit weight of the structural fill and general fill, and the depth.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.10.4.2 describes how the applicant calculated the active seismic pressures. The applicant used the Mononobe-Okabe equation as defined in Seed and Whitman (1970).

The applicant calculated the lateral earth pressure due to surcharge using the relationship between earth pressure coefficient and uniform surcharge pressure. The applicant developed sample earth diagrams with uniform surcharge loads of 24 kPa (500 psf) and 190 kPa (4,000 psf), a unit weight for compacted limerock fill of 2080 kilograms per cubic meter (kg/m^3; 130 pounds per cubic foot (pcf)) and a drained friction angle of 33 °.

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.10.6, the applicant stated that the results of the investigation indicate that the site is underlain by rock overlying unconsolidated deposits, and that the risk of subsidence due to karst and the risk associated with settlement are insignificant.

Lateral Variability

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.7 describes the applicant's evaluations for stratigraphic uniformity and bearing pressure uniformity. The applicant correlated the geologic and stratigraphic features at depths less than 36.6 m (120 ft) below grade from one boring to another with relatively smooth variation in thickness. The applicant developed a

two-dimensional plane-strain PLAXIS 2D model to evaluate the bearing pressures for site-specific conditions. The applicant indicated that for all cases, the maximum bearing pressure difference is less than 20 percent. The applicant stated that the AP1000 DCD criterion for lateral uniformity is satisfied.

Sensitivity Analysis with Postulated Voids in the Subsurface

Turkey Point Units 6 and 7 COL FSAR 2.5.4.10.8 describes the sensitivity analysis performed in PLAXIS 3D to consider the stability of Category I structures with postulated voids in the subsurface. The applicant indicated that the void size of 6.1 m (20 ft) constrained by the grouting program is much larger than the estimated void sizes present on the site. The applicant modeled a postulated tunnel-shaped void with a 6.1 m (20 ft) diameter circular cross section where the void extends east-west across the nuclear island and with the top of the void below the grout plug, which is at El. −60 ft. The applicant stated that it selected this direction because the maximum dynamic bearing demand occurs under the west edge of the shield building primarily because of the east-west component of the earthquake. The applicant modeled the postulated water-filled void and performed static and dynamic analyses. For the static stability analysis results, the applicant stated that the presence of a 6.1 m (20 ft) wide tunnel does not present stability concerns, that the total and differential settlements from the PLAXIS 3D model indicated that the presence of the void has no impact on settlement, and that the AP1000 DCD criteria are still met. In addition, the applicant stated that the factor of safety for bearing capacity is greater than 3, that no plastic points or tension cut off points were observed during the loading phase and that the tensile capacity of concrete fill was not reached. For the pseudo-dynamic analysis results, the applicant stated that subsurface collapse is not anticipated under the combination of seismic and static nuclear island loads, indicating that no plastic points or tension cut off points were observed during the pseudo dynamic loading conditions, the effective vertical compressive stresses were smaller than the ultimate bearing capacity of concrete and that the tensile capacity of concrete fill was not reached.

2.5.4.2.11 Design Criteria and References

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.11 summarizes the geotechnical-related design criteria that pertain to the design. The applicant selected a factor of safety against liquefaction of 1.25. The applicant stated that it computed an allowable bearing capacity of 1870 kPa (39 ksf) using a FOS of 3, which exceeds the AP1000 DCD maximum static loading of 430 kPa (8.9 ksf). Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-219 presents the estimated settlements of Turkey Point Units 6 and 7. The applicant stated that it complies with the threshold in the AP1000 DCD. The applicant calculated the lateral earth pressures with a FOS of 1.0 and recommended FOS of 1.10 for sliding and overturning due to lateral loads when the seismic component is included.

2.5.4.2.12 Techniques to Improve Subsurface Conditions

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.12, the applicant stated that it will limit its ground treatment to over-excavation of unsuitable materials, and their replacement with compacted limerock fill and lean concrete fill. The applicant stated that the muck of Stratum 1 will be removed and replaced with compacted limerock fill. The applicant stated that groundwater control is required as part of the over-excavation of unsuitable materials and that it will be achieved by grouting. The applicant stated that grouting will also be used to constrain the sizes of potential voids. The applicant stated that because the zone between El. −10.7 m (−35 ft) and El. −18.3 m (−60 ft) will be grouted in accordance with the closure criteria that will

be developed as part of the grout test program, any remaining voids in this zone that will remain would be structurally insignificant. In addition, for the zone between El. −18.3 m (−60 ft) and El. −33.5 m (−110 ft), the applicant will perform grouting in every primary grout borehole. The applicant stated that the primary grout boreholes will be spaced less than or equal to 6.1 m (20 ft) on center, constraining the maximum undetected void size to approximately 6.1 m (20 ft). In Part 10 of the Turkey Point Units 6 and 7 COL FSAR, Appendix B, Table 3.8-6, the applicant provided a grouting ITAAC, which establishes a set of actions and criteria for the grouting activity necessary to provide assurance that, when met, the stability of Category I structures are in conformance with the combined license. The applicant indicated that successful grouting ITAAC execution results in any remaining voids in the grouted zone being structurally insignificant and any remaining voids in the extended grouted zone having a maximum equivalent spherical diameter of equal or less than 6.1 m (20 ft).

The applicant stated that it will prepare a thermal control plan, following ACI 207 (2006) guidelines, to minimize thermal cracking of the lean concrete to be placed under the nuclear island.

2.5.4.3 Regulatory Basis

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

In addition, the acceptance criteria associated with the relevant requirements of the NRC regulations for the stability of subsurface materials and foundations are given in Section 2.5.4 of NUREG-0800.

The applicable regulatory requirements for reviewing the applicant’s discussion of stability of subsurface materials and foundations are as follows:

- 10 CFR Part 50, Appendix A, GDC 1, “Quality Standards and Records,” as it relates to the requirement 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 B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants,” as it relates to quality assurance requirements for the design, fabrication, construction, and testing 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 without loss of capability to perform their safety functions.

- 10 CFR 100 provides the criteria that guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors.

- 10 CFR 100.23 provides the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability, and identify geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants.

The related acceptance criteria from Section 2.5.4 of NUREG-0800 are as follows:

- Geologic Features: To meet the requirements of 10 CFR Parts 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: To meet the requirements of 10 CFR Parts 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 to sufficient depth that impact behavior during construction and over the life of the facility, including during postulated seismic events.

- Foundation Interfaces: To meet the requirements of 10 CFR Parts 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 an early site permit or COL.

- Geophysical Surveys. To meet the requirements of 10 CFR 100.23, the presentation of the dynamic characteristics of soil or rock is acceptable if geophysical investigations have been performed at the site and the results obtained there from are presented in detail.

- Excavation and Backfill: To meet the requirements of 10 CFR Part 50, the presentation of the data concerning excavation, backfill, and earthwork analyses is acceptable if:

  (1) The sources and quantities of backfill and borrow are identified and are shown to have been adequately investigated by borings, pits, and laboratory property and strength testing (dynamic and static); long term solubility properties and dissolution behavior during the life of the facility have been determined; and these data are included, interpreted, and summarized.

(2) The extent (horizontally and vertically) of all seismic Category I excavations, fills, and slopes are clearly shown on plot plans and profiles.

(3) Compaction specifications and embankment and foundation designs are justified by field and laboratory tests and analyses to ensure stability and reliable performance over the life of the plant.

(4) The impact of compaction methods are incorporated into the structural design of the plant facilities.

(5) Quality control methods are discussed and the quality assurance program described and referenced. If backfill is to be placed under safety-related structures, proper ITAAC should be specified in the applicant's technical submittal to ensure that the static and dynamic properties of in-place backfill material will be the same as, or better than the design parameters. In case cementitious construction material is to be placed under safety-related structures, proper ITAAC should be specified in the applicant technical submittal to ensure that the cementitious backfill placed underneath any seismic Category I structures to a thickness greater than five ft, meets the design, construction and testing of applicable ACI standards.

(6) Control of groundwater during excavation to preclude degradation of foundation materials and properties is described and referenced. In addition, the long-term behavior of the backfill subjected to any aggressive groundwater characteristics is evaluated.

(7) For sites where deeply embedded structures are involved, deep excavation techniques will likely utilize wall retaining systems rather than a sloped excavation of the soil. A description of the planned excavation technique(s) and design of the wall retention system with sufficient details is provided and it should be able to demonstrate that the excavation technique used will not significantly affect the surrounding soil properties that are relied upon in the analysis and design of the foundation and plant structures.

- Groundwater Conditions: To meet the requirements of 10 CFR Parts 50 and 100, the analysis of groundwater conditions is acceptable if the following are included in this subsection or cross-referenced to the appropriate subsections in Section 2.4 of the applicant's technical submittal:

(1) Discussion of critical cases of groundwater conditions relative to the foundation settlement and stability of the safety-related facilities of the nuclear power plant.

(2) Plans for dewatering during construction and the impact of the dewatering on temporary and permanent structures. This includes consideration of the potential for substantial head and volume of water due to the deep excavation for the plant structures.

(3) Analysis and interpretation of seepage and potential piping conditions during construction.

(4) Records of field and laboratory permeability tests as well as dewatering induced settlements.

(5) History of groundwater fluctuations as determined by periodic monitoring of an adequate number of local wells and piezometers. Flood conditions should also be considered.

(6) Evaluation of chemical properties of the groundwater that may impact long-term behavior of the rock/soil/fill materials as well as structural elements (concrete and steel materials).

- Response of Soil and Rock to Dynamic Loading: To meet the requirements of 10 CFR Parts 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 at the site. Evidence of liquefaction and sand cone formation should be included, (2) field seismic surveys (surface refraction and reflection and in-hole and cross-hole seismic explorations) have been accomplished and the data presented and interpreted to develop bounding P and S wave velocity profiles, (3) dynamic tests have been performed in the laboratory on undisturbed samples of the foundation soil and rock sufficient to develop strain-dependent modulus-reduction and hysteretic damping properties of the soils and the results included. If generic soil degradation properties are used in the related preliminary analyses (e.g., site seismic response and soil structure interaction analyses), then reconciliation of the generic properties and laboratory testing results should be performed. The section should be cross-referenced with Section 2.5.2.5.

- Liquefaction Potential: To meet the requirements of 10 CFR Parts 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 and Dynamic Stability: To meet the requirements of 10 CFR Parts 50 and 10 CFR Parts 100, the discussions of static and dynamic analyses are acceptable if the stability of all safety-related facilities has been analyzed from a static and dynamic stability standpoint including bearing capacity, rebound, settlement, and differential settlements under dead loads of fills and plant facilities, dynamic loads including “live” and seismic loads with consideration of loading sequences and combinations.

- Design Criteria: To meet 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: To meet the requirements of 10 CFR Part 50, the discussion of techniques to improve subsurface conditions is acceptable if plans, summaries of specifications, and methods of quality control are described for all techniques to be used to improve foundation conditions (such as grouting, vibroflotation, bridging mats, dental work, rock bolting, or anchors).

In addition, the geotechnical characteristics should be consistent with appropriate sections from: RG 1.27; RG 1.28, "Quality Assurance Program Requirements (Design and Construction)"; RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants", RG 1.138, "Laboratory Investigations of Soils 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," and RG 1.206.

2.5.4.4 Technical Evaluation

The staff reviewed Section 2.5.4 of the Turkey Point Units 6 and 7 COL FSAR and checked the referenced DCD to ensure that the combination of the DCD and the COL application represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and incorporated by reference addresses the required information relating to the stability of subsurface materials and foundations. The results of the staff's evaluation of the information incorporated by reference in the Turkey Point Units 6 and 7 COL FSAR are documented in NUREG-1793 and its supplements.

AP1000 COL Information Items

- PTN COL 2.5-1, PTN COL 2.5-2, PTN COL 2.5-3, PTN 2.5-5, PTN COL 2.5-6, PTN COL 2.5-7, PTN COL 2.5-8, PTN COL 2.5-9, PTN COL 2.5-10, PTN COL 2.5-11, PTN COL 2.5-12, PTN COL 2.5-13, PTN COL 2.5-16, and PTN COL 2.5-17

The staff reviewed all of the information presented in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4 related to the PTN COL Information Items 2.5-1, 2.5-2, 2.5-3, 2.5-3, 2.5-5, 2.5-6, 2.5-7, 2.5-8, 2.5-9, 2.5-10, 2.5-11, 2.5-12, 2.5-13, 2.5-16, and 2.5-17. Based on the discussion related to the stability of subsurface materials and foundation presented in Turkey Point Unit 6 and 7 COL FSAR Section 2.5.4, the staff's detailed review and evaluation of the information, and the staff's independent analyses, the staff concludes that the applicant provided the information required satisfying PTN COL Information Items 2.5-1, 2.5-1, 2.5-3, 2.5-5, 2.5-6, 2.5-7, 2.5-8, 2.5-9, 2.5-10, 2.5-11, 2.5-12, 2.5-13, 2.5-16, and 2.5-17. The staff's detailed review of this information is presented below.

2.5.4.4.1 Geologic Features

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.1 refers to Turkey Point Units 6 and 7 COL FSAR Section 2.5.1 and 2.5.3 for a complete description of the regional and site geology and surface faulting. Section 2.5.1.4 and 2.5.3.4 of this SER presents the staff's evaluation of the site geology and surface faulting. The staff's review of Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.1.1 focused on the applicant's description of the subsurface conditions, foundation soil, and rock properties and stability of materials, along with non-tectonic processes and geologic features that could relate, if present, to permanent ground deformation or foundation instability. Turkey Point Units 6 and 7 COL FSAR Sections 2.5.4.1.2 and 2.5.4.4.5 describe the dissolution activity in the limestone formation, including potential cavities at depths. The staff reviewed the microgravity data presented by the applicant and issued several RAIs regarding the subject. Section 2.5.4.4.4 of this SER presents the staff's evaluation of the applicant's responses to related RAIs.

2.5.4.4.2 Properties of Subsurface Materials

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2 describes the field investigation and subsurface material properties at the Turkey Point Units 6 and 7 site. Section 2.5.4.2.2 of this report provides a summary of the information presented in the Turkey Point Units 6 and 7 COL FSAR. The staff reviewed the geotechnical data presented and evaluated the Turkey Point Units 6 and 7 site's exploration and laboratory testing programs in accordance with the guidelines presented in RG 1.132 and RG 1.138. The main focus of the review was to ensure that the applicant adequately characterized the soil and rock profile in order to evaluate the ability of the subsurface to support the nuclear island statically and dynamically.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2 describes the static and dynamic engineering properties of subsurface materials as well as the methods the applicant used to determine the site engineering properties including field investigation and laboratory testing. The applicant performed two field subsurface investigations: the initial field subsurface investigation from February through June 2008 and a supplemental field subsurface investigation from July to October 2013. The staff conducted a site visit and regulatory audit of the applicant's initial and supplemental field investigations, from May 24 to May 25, 2011, and August 21 to August 23, 2013, as documented in ADAMS Accession Nos. ML111881052 and ML13248A297, respectively. During the 2011 site visit, the staff visually examined drill cores from selected intervals in the Key Largo Formation and Fort Thompson Formation cores and reviewed the geotechnical engineering calculation packages. During the 2013 site audit, the staff examined core samples, the sample storage facility, and sample storage procedure, examined the field test data storage and transfer procedure, interviewed the Paul C. Rizzo Associates, Inc. personnel in charge of the field investigation and evaluation, and reviewed the on-site documentation to include resumes, qualifications, and training records. The staff concludes that applicant collected the samples in accordance with RG 1.132 and industrial standards, adequately stored the soil and rock samples, effectively preserved the test data for future use, and the site personnel have adequate knowledge in their specific field and meet the qualification criteria specified in relevant procedures.

The staff observed site investigation activities, including: Cone Penetration Tests (CPT); PQ drilling with core sample collection; and the standard penetration test (SPT) testing procedure and sampling in the top of the Tamiami formation. During the observations, the staff asked technical personnel to explain the field test purpose and procedures for each site investigation activity. The staff confirmed that the applicant conducted all observed field testing following the industrial standards procedures.

During the Turkey Point Unit 6 and 7 application review, the staff issued several RAIs addressing specific technical issues related to the Turkey Point Unit 6 and 7 site investigations. The staff's evaluations of the applicant's responses to these RAIs are discussed below. The staff also issued a number of editorial RAIs and clarification RAIs, which are not discussed in this SER.

<u>Soil and Rock Strata</u>

The staff reviewed the applicant's description of each soil and rock strata encountered during the subsurface investigation. The staff noted that Stratum 1 is surficial muck to be removed and replaced with compacted limerock fill; Strata 2, 3, 4 and 8 are predominantly rock; and Strata 5, 6, and 7 are predominantly soil. The staff focused its review on the identification and characterization of the soil and rock strata based on physical and engineering methods

conducted by the applicant. The staff's technical evaluation of the methods the applicant used in identification and characterization of the investigated soil and rock strata is further discussed in the subsequent "Subsurface Investigation/Exploration" and "Geophysical Surveys" sections of this SER.

Evaluation of Properties of In Situ Materials

The staff reviewed the applicant's results of field and laboratory testing for Turkey Point Units 6 and 7. The staff noted, while reviewing the information regarding the SPT blow counts, that the applicant obtained the N_{60} by applying a correction factor, C_ε, to the energy ratio. Since field SPT N-values are generally adjusted to be standardized to a specific energy level by applying correction factors, including energy correction (C_ε), borehole diameter (C_B), sampler type (C_S), rod length (C_R), and overburden pressure (C_n), in RAI 6006, Question 02.05.04-2, the staff asked the applicant to clarify if it included other correction factors (e.g., overburden pressure, borehole diameter, rod length and sampling method) in the N-value correction process. In addition, the staff asked the applicant to describe how it obtained the recommended SPT design values and how each single value for each stratum could properly and statistically reflect the entire layer variations.

In its response to RAI 6006, Question 02.05.04-2, dated October 3, 2014, the applicant clarified that corrections for the SPT N-values included energy correction (C_ε), borehole diameter (C_B), sampler type (C_S), and rod length (C_R) for N_{60} values that are typically used in correlations to derive friction angle and other engineering properties. The applicant further clarified that one additional N-value correction, which is only used for the liquefaction analysis, is the overburden pressure correction factor (C_n) that converts N_{60} to $(N_1)_{60}$. To explain why blow counts obtained from the initial site investigation turned out to be lower than anticipated, the applicant examined the blow counts by using the 61-cm (24-in.) sampler in the supplemental investigation, rather than the 46-cm (18-in) sampler used in the initial site investigation. In the response, the applicant compared the blow counts obtained from the initial and supplemental investigations, and noted that the SPT N-values from the supplemental investigation at R-6-1b and R-7-1 are consistently higher than those from the initial investigation at B-601 (DH) and B-701 (DH). Furthermore, for the supplemental investigation the applicant observed that the summations of the 3rd and 4th blow counts obtained at R-6-1b and R-7-1 are consistently higher than the summation of the 2nd and 3rd blow counts (SPT N-values). Accordingly, the applicant attributed the lower SPT N-values to overwashing and concluded that the overall SPT N-values are conservative. The applicant also clarified that it accounted for variation within each layer by using conservative SPT N-values in conjunction with other in situ and laboratory tests to determine engineering parameters. Therefore, the applicant concluded that the average SPT blow count per layer is a conservative representation of the value for that layer.

The staff reviewed the applicant's response to RAI 6006, Question 02.05.04-2, and the applicant's results of SPT blow counts from both initial and supplemental site investigation reports. The staff concludes that the applicant corrected the SPT N-values to N_{60}-values and $(N_1)_{60}$-values in accordance with ASTM D 1586 (ASTM International, 2011). The staff agrees that overwashing is attributed to lower N-values based on the applicant's demonstration of the soil zone penetrated by the 3rd and 4th blow counts influenced less by the washing and drilling conditions in its supplemental investigation. The staff also agrees that the SPT N-values are conservative. The staff noted that the applicant derived the associated engineering parameters by combination of average SPT N-values per stratum and other tests/measurements. The staff concludes that variation within each layer is statistically reflected by combination of conservative SPT N-value and other conservative test results and measurements.

However, comparing test results of SPT N-values between initial and supplemental investigations, it was not clear to the staff why the SPT N-values from the supplemental investigation are consistently higher than those from the initial investigation, given the similar condition of overwashing ahead of casing for both 457 mm (18 in.) sampler and 610 mm (24 in.) sampler. In RAI 7811, Question 02.05.04-28, the staff asked the applicant to discuss the difference between the original and supplemental SPT N-values.

In its response to RAI 7811, Question 02.05.04-28, dated April 10, 2015 (ADAMS Accession No. ML15103A544), the applicant stated that SPT N-values from the initial investigation associated with the soil formations were lower than the expected values based on their depth (greater than 30.5 m [100 ft]) and high shear wave velocity (greater than 45.7 m/s [1,500 ft/s]). The applicant attributed that exposure to the effects of overwashing and disturbance due to stress relief effects for the depths ranging from 35.1 m (115 ft) to 140.2 m (460 ft). The applicant stated that it used a longer split barrel (610 mm [24 in.]) sampler during the supplemental investigation with special attention paid to the overwashing effect, and controlled bentonite-water mix to provide a heavy mud to reduce the effect of stress relief. The applicant observed that a discontinuous sampling method, as compared to a continuous sampling method, will have lower blow counts because of its longer exposure to the effects of overwashing.

The staff reviewed the applicant's response to RAI 7811, Question 02.05.04-28. The staff notes that disturbance of the soils can be gradually mitigated depending on drilling/sampling requirements and approach; however, the degree of disturbance due to overwashing and stress relief cannot be fully eliminated. The staff also notes that the applicant used a targeted approach during the supplemental investigation to mitigate the degree of disturbance, which in general resulted in higher SPT N-values. The staff agreed that the continuous sampling method has less influence on the blow counts because of a shorter duration to overwashing exposure. Based on shear wave velocity measured at the site and the demonstration of higher summation of 3rd and 4th blow counts than SPT N-values (summation of 2nd and 3rd blow counts), the staff agrees that SPT N-values are lower than the expected values. The staff concludes that the applicant's explanation of the difference between the original SPT N-values and the supplemental SPT N-values is appropriate. Accordingly, the staff considers RAI 6006, Question 02.05.04-2, and RAI 7811, Question 02.05.04-28, resolved.

The staff also concentrated its review on the elastic modulus of subsurface materials, an important parameter in the subsurface stability evaluation. In RAI 6006, Question 02.05.04-5, the staff asked the applicant to describe the test methods, results and correlations used to develop the high strain elastic modulus for fine and coarse grained soils.

In an October 3, 2014, response to RAI 6006, Question 02.05.04-5 (ADAMS Accession No. ML14283A311), the applicant stated that for the supplemental field investigation program conducted in 2013, the determination of the high strain elastic modulus of the soil formations took into account all available data from five different test methods including pressuremeter tests, SPT, CPT, shear wave velocity from P-S suspension, and triaxial tests. The applicant provided five empirical correlations between test data and high strain elastic modulus of soil and calculated the corresponding modulus for the Upper Tamiami, Lower Tamiami, and Peace River Formations. Additionally, the applicant presented statistical parameters (minimum, maximum, median, average, standard deviation, and coefficient of variation) for each method. The applicant demonstrated that the total mean modulus and total median modulus are similar.

Based on the above, the applicant selected the design high strain elastic modulus of the soil formations.

The staff reviewed the applicant's response to RAI 6006, Question 02.05.04-5. The staff acknowledged that the empirical correlations applied by the applicant to develop the high strain elastic modulus for fine and coarse grained soils are state-of-the-practice. The modulus for the Upper Tamiami Formation by SPT method reasonably agreed with the values by other methods but the modulus for Peace River Formation by SPT method is relatively higher than the values by other methods. The staff also acknowledges that the data and methods used by the applicant are adequate for deriving the soil high strain elastic modulus. However, the staff noted that the SPT based modulus for the Lower Tamiami Formation was not included in the assessment. In RAI 7811, Question 02.050.4-29, the staff asked the applicant to provide the calculation of the SPT based modulus for the Lower Tamiami Formation and explain why it ignored the SPT based modulus for the Lower Tamiami Formation. In addition, since the applicant indicated in its response to RAI 6006, Question 02.05.04-2, and in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.1.3.2.1 that it used the overall pool of SPT N-values from both the initial and supplemental investigations in the development of engineering parameters or engineering analyses, the staff asked the applicant to clarify the engineering parameters or engineering analyses it developed based on the overall pool of SPT N-values.

In its response to RAI 7811, Question 02.05.04-29, dated April 17, 2015, the applicant provided the calculation of SPT based stiffness for the Lower Tamiami Formation with both overall data pool and supplemental test data to demonstrate that the average values are about 6 to 15 percent of the average stiffness obtained from the CPT, pressuremeter, shear wave velocity, and CU triaxial methods. The applicant noted that it did not consider the suggested correlations it used to obtain the stiffness based on SPT data for silty soil applicable for the site-specific conditions of the Lower Tamiami Formation. The applicant further clarified that it based the engineering parameters or engineering analyses on SPT results.

The staff reviewed the applicant's response to RAI 7811, Question 02.05.04-29. The staff noted that SPT based stiffness for the Lower Tamiami Formation is approximately an order of magnitude less than the average stiffness obtained from other methodologies. The staff also notes that the suggested correlations the applicant used to obtain the stiffness based on SPT data are empirically based on nonspecific data, therefore, there is considerable uncertainty associated with these correlations. The staff agrees that these correlations should be checked and confirmed based on site-specific data. The staff further agrees that four methodologies other than SPT are more reliable for stiffness characterization because these methodologies lead to similar stiffness results and are adequate to estimate the stiffness for the Lower Tamiami Formation. Accordingly, the staff considers RAI 6006, Question 02.05.04-5, and RAI 7811, Question 02.05.04-29 resolved.

During its review of the shear strength parameters of the soil, the staff noted that before the supplemental field investigation program was conducted in 2013, only one triaxial test was completed on an intact soil sample from Tamiami Formation sandy silt, and the recommended effective cohesion and effective friction value for the Lower Tamiami was based solely on the result of this sample. For the computation of effective friction angle in each sand stratum, the SPT N-values from the initial investigation were questionable due to difficulties of sampling; only four CPT profiles were available for use and no direct shear testing results were provided. In RAI 6006, Question 02.05.04-7, the staff asked the applicant to justify why additional triaxial tests are not needed to characterize the shear strength parameters of these soils. Furthermore,

in RAI 6006, Question 02.05.04-8, the staff specifically asked the applicant to justify the adequacy of the friction angle determination.

In its response to RAI 6006, Question 02.05.04-7, and RAI 6006, Question 02.05.04-8 dated October 3, 2014, the applicant stated that it performed additional triaxial tests on intact soil samples from the Upper and Lower Tamiami and Peace River formations. The applicant indicated that it performed triaxial testing on a total of five samples from the Lower Tamiami Formation, one sample from the Upper Tamiami Formation, and fifteen samples from the Peace River Formation. Since the quantity of triaxial samples tested for the Upper Tamiami was insufficient to characterize the shear strength parameters of the soil, the applicant established the shear strength parameters for this stratum by analyzing and corroborating data including: Atterberg testing, SPT and CPT. The applicant also presented the effective friction angles for the Upper Tamiami Formation based on triaxial testing of one sample, CPT testing, and SPT testing and demonstrated that the effective friction angles obtained from correlations of SPT and CPT are in agreement with the result of one triaxial test. For the Lower Tamiami and Peace River Formations, the applicant considered the number of triaxial tests for these formations sufficient to estimate the effective friction angle.

The staff reviewed the applicant's responses to RAI 6006, Question 02.05.04-7, and RAI 6006, Question 02.05.04-8, and concludes that the applicant's use of Atterberg testing, SPT and CPT to characterize the shear strength parameters, including friction angle, of the Upper Tamiami Formation in the absence of additional triaxial test data is acceptable. The staff also agrees with the applicant that there are sufficient triaxial test data for the Lower Tamiami and Peace River Formations to estimate the effective friction angle. Based on the review of the geotechnical information the applicant obtained from both the initial and supplemental investigations, the staff concludes that the soil shear strength parameters are adequately and reasonably characterized. Consequently, the staff considers RAI 6006, Question 02.05.04-7, and RAI 6006, Question 02.05.04-8 resolved.

The staff reviewed the dynamic backfill properties selected by the applicant to ensure that the material used for backfill will have equivalent or better properties as assumed in the analysis. For the dynamic properties of the crushed limestone backfill, the staff noted that the applicant selected the generic shear modulus degradation and damping curves from Seed et al. (1984). Since the nature of this material is unique and potentially not conducive to dynamic testing, in RAI 6006, Question 02.05.04-15, the staff asked the applicant to provide additional evaluations to justify the use of these generic curves.

In its response to RAI 6006, Question 02.05.04-15, dated October 3, 2014, the applicant conducted a further literature review using curves proposed by Menq (2003) to evaluate the assumptions made for the dynamic properties and assigned uncertainty through randomization. The applicant concluded that the shear modulus degradation and damping curves for backfill, as provided in Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-216, are appropriate based on its additional literature review.

The staff reviewed the applicant's response to RAI 6006, Question 02.05.04-15, and Menq's method cited by the applicant. The staff acknowledges that Menq's method represents the state-of-the-art knowledge on dynamic properties of sandy and gravelly soils, and therefore, the staff notes that it is appropriate to use Menq's method to validate the structural fill curve developed from the generic curves by Seed et al. (1984). The staff notes that the applicant selected reasonable soil parameters, the curves by Menq's equations are in good agreement with the structural fill curve at low strains and at higher strains, and these curves are enveloped

by the randomization boundaries of the structural fill curve up to the strain at 0.02 percent. The staff further observes that the applicant reported the highest strain in the structural fill to be less than 0.02 percent as obtained from the site response analysis. Because the applicant provided additional acceptable evaluations to validate the use of the generic curves from Seed et al. (1984), the staff considers RAI 6006, Question 02.05.04-15, resolved.

Chemical Properties of Soils and Rock

The staff's review of Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.4 focused on the applicant's evaluation of the chemistry of the soil and rock strata for consideration of corrosive effects on buried steel and aggressiveness toward buried concrete. During its review, the staff noted that the applicant did not provide any general physical and chemical property laboratory testing results for the Fort Thompson Formation in Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-205. In RAI 6006, Question 02.05.04-4, the staff asked the applicant to provide these results or to justify why these results are not needed.

In its response to RAI 6006, Question 02.05.04-4, dated October 3, 2014, the applicant updated Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-205 with the testing results obtained from both the initial and supplemental investigation, including the laboratory test results of the Fort Thompson Formation.

The staff reviewed the applicant's response to RAI 6006, Question 02.05.04-4, and confirmed that the applicant revised the general physical and chemical properties test results in the updated Turkey Point Units 6 and 7 COL FSAR and provided the testing results for the Fort Thompson Formation in Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-205. In addition, the staff noted and confirmed that the applicant updated Turkey Point Units 6 and 7 COL FSAR Tables 2.5.4-207 and 2.5.4-209, and Turkey Point Units 6 and 7 COL FSAR Figures 2.5.4-216 and 2.5.4-217 in accordance with the supplemental laboratory testing results. Consequently, the staff considers RAI 6006, Question 02.05.04-4, resolved.

Field and Laboratory Testing Program

The staff reviewed the field and laboratory testing program and participated in a site visit on May 24 and May 25, 2011, to observe the results of the initial field subsurface investigation performed by the applicant from February 2008 through June 2008. In addition, the staff participated in a regulatory audit from August 21 to August 23, 2013, of the supplemental site investigation performed from July 2013 through October 2013 at the Turkey Point Units 6 and 7 site. The staff focused its review on results from laboratory tests conducted on soil and rock samples recovered during the field investigation. The following sections of this SER address the staff technical evaluation of the field and laboratory testing program.

Subsurface Investigation/Exploration

The staff reviewed the applicant's site investigation and exploration of subsurface materials for providing data to define the static and dynamic engineering properties of soil and rock materials at the site and their spatial distribution, in accordance with RG 1.132. During its review, the staff noted that Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.2 indicates that the applicant made adjustments to the subsurface investigation including changes to the locations and types of field testing. In RAI 6006, Question 02.05.04-3, the staff asked the applicant to provide further information on how and to what extent these adjustments vary from the

recommendations provided in RG 1.132 and to justify its acceptance for characterizing site subsurface conditions.

In its response to RAI 6006, Question 02.05.04-3, dated October 3, 2014, the applicant explained that some adjustments were required to tailor the subsurface investigation to the site-specific conditions as outlined in RG 1.132. The applicant described the necessary adjustments and clarified that none of the adjustments made to the field testing locations, test methods, testing frequencies, and test depths varied from the recommendations in RG 1.132. The applicant stated that it met the guidelines of RG 1.132, with the exception that it continuously sampled only one boring for the site, instead of one per unit, in the deeper soils. The applicant considered the variation in field testing to be acceptable because it found the soil and rock strata to be uniform in depth and thickness across the site.

The staff reviewed the applicant's response to RAI 6006, Question 02.05.04-3, and its site investigation programs including both initial and supplemental site investigations. The staff notes that the adjustments are mainly to comply with environmental regulations related to the difficulties in access to the drilling or sampling locations, or adopting more suitable methods for the conditions encountered in situ. The staff also agrees with the applicant's conclusion that the adjustments made to the field testing locations, test methods, testing frequencies, and test depths meet the guideline of RG 1.132. The staff notes that although RG 1.132 suggests that at least one continuously sampled boring should be used for each unit, continuous sampling was only conducted in the Turkey Point Unit 6 footprint during the supplemental site investigation, not in the Turkey Point Unit 7 footprint. For the discontinuously sampled boreholes conducted during the initial site investigation for both units, the staff noted that the applicant continuously cored the Key Largo and Fort Thompson limestone formations and sampled the soil at an increased interval at greater depths. Based on the review and comparison of the material descriptions from field and laboratory classifications for soil layers in the continuously sampled borehole and the discontinuously sampled boreholes, the staff agrees that the materials encountered in the former are generally consistent with the materials encountered in the latter with reasonable minor variations in the material descriptions. Therefore, the staff agrees with the applicant that there is no impact on quality due to continuous sampling at one location instead of two or more as suggested in RG 1.132. Because the applicant's exploration program met the intent of RG 1.132, the staff considers RAI 6006, Question 02.05.04-3, resolved.

Laboratory Testing

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.2.3 related to the laboratory testing program the applicant performed to identify, classify, and evaluate the physical and engineering properties of the soil and rock. Before the applicant conducted the supplemental field investigation program in 2013, it tested only two rock core samples in a laboratory for stress-strain characteristics. The applicant stated that due to the fragility and the porosity of the subsurface materials it was not possible to attach strain gages to most of the samples for determination of stress-strain characteristics. In RAI 6006, Question 02.05.04-6, the staff asked the applicant to justify why two samples are sufficient to characterize the Fort Thompson and Key Largo Formations, especially since the Key Largo will be the bearing layer. In addition, the staff asked the applicant to validate the assumption that for rocks the elastic and shear modulus values generally remain constant at both small and large strains.

In its response to RAI 6006, Question 02.05.04-6, dated October 3, 2014, the applicant stated that the data collected during the supplemental investigation contributed additional information to more adequately characterize the Fort Thompson and Key Largo Formations. In addition to

the two rock core samples tested for stress-strain characteristics in initial field investigation, the applicant performed the additional tests on the Key Largo and Fort Thompson Formations during its supplemental field investigation to assess small strain and large strain rock behavior. Specifically, four UCS tests with stress-strain measurements, four RCTS tests to assess the low strain behavior and the potential for strain dependency within the materials, 26 pressuremeter tests, 9 on the Key Largo Formation and 17 on the Fort Thompson Formation, and 2 P-S suspension loggings to determine the shear wave velocity and small strain modulus for these rock formations.

The applicant validated its linear assumptions previously made for both the Key Largo and Fort Thompson Formations by demonstrating the behavior as obtained from RCTS tests for the small strain range (less than 0.005 percent). For this strain range, the applicant concluded that stiffness degradation is negligible. The applicant also assessed the large strain rock stiffness based on in situ tests including P-S suspension tests, reduced to account for large strain using RQD, and pressuremeter tests, and laboratory tests including UCS test results. To estimate the rock mass stiffness, the applicant used the RMR and the Geological Strength Index (GSI) classifications. The applicant demonstrated that it evaluated the potential fractures in the drainage and vegetated depression areas based on the observation within the three inclined boreholes from the supplemental investigation.

The staff reviewed the applicant's response to RAI 6006, Question 02.05.04-6. The staff noted that strain degradation for the Key Largo and Fort Thompson Formations is minor within the small strain range (less than 0.005 percent) from RCTS test results, which confirmed linear assumptions for the limestone formations for small strain range. Since small strains represent the levels corresponding to the site response analysis or seismic soil-structure interaction (SSI) analysis, and shear wave measurements characterize the nature of low strain and dynamicity, the staff agrees that the small strain rock stiffness values calculated from shear wave velocities are reasonable and justifiable. For the large strain rock stiffness assessment, the staff agrees with the applicant's description in the revised Turkey Point Units 6 and 7 COL FSAR that the small strain rock stiffness is not the same as the large strain rock stiffness previously assumed. The staff also acknowledges that the data from in situ and laboratory tests and methods used by the applicant are reasonably adequate for deriving the large strain rock stiffness. The staff further notes that the applicant accounted for rock mass conditions including rock quality, fracture and discontinuities and orientation of fracture in evaluating the large strain rock stiffness. The staff reviewed the design rock stiffness selected by the applicant and agrees that these values are rational since the rock stiffness from different methods are comprehensively considered. Consequently, the staff considers RAI 6006, Question 02.05.04-6, resolved.

Staff's Conclusions Regarding the Properties of Subsurface Materials

The staff finds the applicant's description of the subsurface materials acceptable in that the applicant followed the guidance provided in RG 1.132, Revision 2, and RG 1.138, Revision 2. The applicant investigated and tested the subsurface materials to determine the geotechnical engineering properties of the soil and rock at the planned Turkey Point Units 6 and 7 site. The staff concludes that the applicant obtained sufficient undisturbed samples to allow for the adequate characterization of each of these soil/rock groups and determined the extent, thickness, hardness, density, consistency, strength, and engineering and static design properties. Furthermore, the staff also concludes that the applicant provided sufficient information in the form of plots, plans, boring logs, and laboratory test results that enabled the staff to determine that the applicant adequately characterized the subsurface soil and rock materials and adequately determined the engineering and design properties. Therefore, the

staff concludes that the applicant's description of the subsurface materials and properties at the proposed Turkey Point Units 6 and 7 site is acceptable and meets the requirements of 10 CFR 100.23.

2.5.4.4.3 Foundation Interfaces

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Figures 2.5.4-201 and 2.5.4-221, which show the final plant grade plan and profile, respectively, Figures 2.5.4-203 through 2.54-208, which show the subsurface profiles illustrating the stratigraphy at each power block area, Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-209, which shows the subsurface profile locations and Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-222, which illustrates the power block foundation excavation geometries, locations, and depth of the units Seismic Category I structures as well as the relationship of the structure foundation to the subsurface strata.

The staff concludes that the applicant adequately investigated the subsurface materials beneath the nuclear island construction zone for the Turkey Point Units 6 and 7 site. In reaching this conclusion, the staff reviewed and evaluated: (1) the plot plans showing the locations of all site explorations, such as borings, seismic and non-seismic geophysical explorations, piezometers, geologic profiles, and the locations of the safety-related facilities, (2) the profiles the applicant presented, illustrating the detailed relationship of the foundations of all Seismic Category I and other safety-related facilities to the subsurface materials, and (3) core borings, SPT borings, V_s profiles and non-seismic geophysical logging results. Accordingly, the staff concludes that plot plans, subsurface profiles and results of subsurface investigations, as described in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.3, form an adequate basis for the characterization of the foundation interfaces at the

2.5.4.4.4 Geophysical Survey

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4 focusing on the applicant's description of the geophysical surveys performed to identify the dynamic characteristics of soils and rocks. The staff concentrated its review on the shear and compressive wave velocities which are important dynamic parameters of soil and rock. Before the applicant conducted the supplemental field investigation program in 2013, it performed only two borings over the deeper portion of the profile. In RAI 6006, Question 02.05.04-10, the staff asked the applicant to justify its estimated variations in shear wave velocity based on only two boring readings over the deeper portion of the soil profile.

In its response to RAI 6006, Question 02.05.04-10, dated October 3, 2014, the applicant stated that it performed two additional P-S suspension borings during the supplemental field investigation program; one boring (R-7-1) to a depth of 134.1 m (440 ft), and the other (R-6-1b) to 137.2 m (450 ft). The staff reviewed the information, and concludes that the applicant's estimate of the mean shear wave velocity and its variation for the deeper portion of the soil profile within the Peace River Formation based on four V_s profiles is reasonable and acceptable. Accordingly, the staff considers RAI 6006, Question 02.05.04-10, resolved.

In RAI 6006, Question 02.05.04-9, the staff requested the applicant to describe how it selected shear and compressive wave velocity values for design, and explain how the selected single value for each stratum statistically reflects the entire layer given the large deviations, especially in the Key Largo and Fort Thompson Formations. In RAI 6006, Question 02.05.04-11, the staff

asked the applicant to explain the uniformity in shear wave velocity below the Fort Thompson Formation considering the varied descriptions as silty sands or silts and clays.

In its responses to RAI 6006, Questions 02.05.04-9 and 02.05.04-11, dated October 3, 2014, the applicant stated that, based on data obtained during the initial and supplemental investigations, the recommended shear wave velocities reflect the average velocity associated with each layer. The applicant's investigations demonstrated small V_s variations for the Upper Tamiami, Lower Tamiami, and Peace River Formations. The applicant clarified that it developed 60 randomized V_s profiles for the site response analysis, and as such, the site response analysis does not use a single V_s value within each layer. The applicant also stated that in addition to direct wave velocity measurements, it used other methods to determine the rock and soil stiffness. The applicant discussed the methodology to obtain recommended shear wave velocities in detail. The applicant further discussed uniformity requirements for an AP1000 design plant by providing in-depth site-specific evaluations of stratigraphic uniformity, bearing pressure uniformity, and shear wave velocity variability.

The staff reviewed the applicant's responses to RAI 6006, Questions 02.05.04-9 and 02.05.04-11, and noted that the recommended V_s reflect the average velocity associated with each layer based on data obtained during the initial and supplemental investigations. The staff notes that the applicant conducted the site response analysis on a set of 60 randomized profiles to account for the variability in the dynamic soil properties. The staff also notes that the applicant's methodology to obtain recommended wave velocities is the state-of–the–practice. During the review of the site uniformity, the staff reviewed the applicant's sensitivity study on bearing pressure uniformity. For the laterally variable case, the staff notes the applicant assumed a scenario, in which, half of the foundation rests on the softer soil/rock column with lower bound (LB) parameters and half of the foundation rests on the stiffer soil/rock column with the best estimated (BE) parameters. In RAI 7811, Question 02.05.04-30, the staff asked the applicant to justify why it did not consider upper bound (UB) parameters for the stiffer soil/rock column in the evaluation for the worst-case scenario.

In its response to RAI 7811, Question 02.05.04-30, dated April 17, 2015, the applicant evaluated the worst-case scenario using a two-dimensional finite element PLAXIS model and assuming half of the foundation on a softer soil/rock column with LB properties and half of the foundation on a stiffer soil/rock column with UB properties. The applicant demonstrated that even for this conservative case, the maximum difference in bearing pressures is less than 20 percent, which indicates that soils supporting the nuclear island do not have extreme variations in subgrade stiffness, as required by the DCD criterion

The staff reviewed the applicant's response to RAI 7811, Question 02.05.04-30, and its calculation and assumptions for the worst-case scenario. The staff confirms that the applicant's evaluation of site uniformity is sufficient and conservative based on the cases and conditions selected. Because the applicant demonstrated that the bearing pressures for the laterally variable ground models do not differ more than 15 percent, the staff further confirms that therefore the criterion in the AP1000 DCD for lateral uniformity of bearing pressures to be less than 20 percent different is satisfied. Consequently, the staff considers RAI 6006, Questions 02.05.04-9 and 02.05.04-11, and RAI 7811, Question 02.05.04-30, resolved.

<u>Geophysical Exploration for Possible Dissolution Features</u>

The staff reviewed the applicant's evaluation of the potential for carbonate dissolution features at the Turkey Point Units 6 and 7 site. The applicant used three non-invasive geophysical

techniques (microgravity, seismic refraction, and MASW) to investigate the site. While reviewing the microgravity data, which provide insights into the existence of potential cavities at the site, the staff notes that the applicant based its conclusion that there are no large cavities underneath the site on gravity data analyses. The staff further notes that these measurements may not be sufficient to determine that there are no large cavities, because the applicant only made profile measurements and large gaps remain between profiles throughout the site area. Accordingly, in RAI 6006, Question 02.05.04-1, the staff asked the applicant to justify the assumption that no large cavities exist throughout the site and provide additional references and data sources used to reach this conclusion.

In its response to RAI 6006, Question 02.05.04-1 dated October 3, 2014, the applicant stated that the 6.1-m (20-ft) station spacing along the survey lines was chosen to provide a high-degree of lateral resolution to map gravity anomalies related to potential karst features beneath the survey lines, which include the footprints of the Turkey Point Units 6 and 7 power blocks. The applicant monitored the data quality by re-acquiring data at stations throughout the survey and checking the repeatability of the measurements to assure that the quality of the gravity data was appropriate to use based on the level of repeatability, which indicates a low level of noise. The applicant also described the supplemental subsurface investigations and reevaluation of geophysical data to assess the potential for subsurface voids, and performed a lineament analysis to evaluate fracture density and distribution at the Turkey Point Units 6 and 7 site.

The staff reviewed the result of the original microgravity survey and the remodeled microgravity survey and its data analyses. The staff also reviewed related information presented in the response from initial and supplemental field investigation to support the microgravity assessment. Based on the staff's interpretations of the existing gravity survey anomalies discussed in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4.5.1, the staff notes that the applicant will remove shallow soil layers with uncertainties related to significant lateral variations prior to construction of Turkey Point Units 6 and 7. The staff further notes that in Revision 6 of FSAR Section 2.5.4.4.5.5, the applicant had planned to perform microgravity surveys on the excavation surfaces of the proposed Turkey Point Units 6 and 7 to detect the presence, or verify the absence, of potential water-filled dissolution features (or voids) beneath the power block. An earlier version of Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4.5.5 states that the planned microgravity survey would be designed to detect 7.6-m (25-ft) diameter spherical voids and cylindrical voids as small as 3.7 m (12 ft) in diameter at the base of the 7.6 m (25 ft) thick grout plug at an elevation of approximately −18.3 m (−60 ft) NAVD88. In RAI 7811, Question 02.05.04-26, the staff further asked the applicant to provide additional details of the planned microgravity gravity survey, the information on potential void size, location and depth in the limestone layers that need to be considered and detected, and a description of the type of inspection and test program to be followed to reasonably ensure that gravity anomalies resulting from potential underground voids (both within the grouted zones and deeper levels) that are critical to the stability of subsurface materials and the integrity of SSCs are to be appropriately detected, investigated, evaluated, and, if necessary, remediated.

In its response to RAI 7811, Question 02.05.04-26, dated October 29, 2015, the applicant indicated that utilization of microgravity methods to determine the critical void size may not be feasible because microgravity methods can only detect large voids at depth. Instead of microgravity methods, the applicant decided that the subsurface grouting program, which was planned only for dewatering purposes, would be revised such that void sizes will be physically filled and constrained. The applicant committed through an ITAAC to ensure that the Grouted Zone will be grouted, which will result in any remaining voids in the Grouted Zone between El.

10.7 m (-35 ft) to −18.3 m (−60 ft) being structurally insignificant, according to the grout closure criteria that will be developed as part of the grout test program. The applicant also committed through the ITAAC that for the Extended Grouted Zone between El. −18.3 m (−60 ft) to −33.5 m (−110 ft), grouting will be performed in every primary grout borehole, which will result in any remaining voids being less than 6.1 m (20 ft) in diameter, which is not large enough to be critical to the stability of safety-related structures.

The applicant provided a detailed discussion of its grouting plans. In its response to the RAI, the applicant stated that the grout closure criteria described in the ITAAC will be developed based on results of the grout test program. For the Grouted Zone, grouting will be performed in a series of split spaced borings starting with primary order grout boreholes, and continuing through secondary order grout boreholes at a minimum. The water pressure test results from verification borings and grout takes from the primary and secondary grout boreholes will be evaluated to determine the need for tertiary and higher order grout boreholes. The applicant also stated that higher-order grout boreholes will be assigned until the grout takes in the highest order grout boreholes drilled and grouted are acceptably low. The applicant further stated that for the Extended Grouted Zone, primary grout boreholes will be extended above the interface between the Fort Thompson Formation and Upper Tamiami formation. Primary grout boreholes will be spaced less than or equal to 6.1 m (20 ft) on center. This configuration, with a conservative grout radius of influence of 4 ft, as shown in Figure 2.5.4-1 constrains the maximum undetected void size to approximately 6.1 m (20 ft) in diameter.

The applicant justified that the 6.1 m (20 ft) void size constrained by the grouting program is conservatively much larger than the estimated void sizes present on site. The applicant emphasized the geological conclusion (Turkey Point Units 6 and 7 COL FSAR Appendix 2.5AA) that large voids and karst features are considered unlikely to be present at the site. The geological evaluation of the site based on all boring data from both the initial and supplemental site investigations reveals that the maximum length of interpreted tool drop (due to voids or voids filled with soft sediments) is limited to 0.5 m (1.5 ft) within the Unit 6 and 7 building footprints, and the frequency of encountering an interpreted tool drop is less than 0.5 percent site-wide.

Furthermore, the applicant provided the sensitivity analysis through a 3D finite element model using software PLAXIS 3D foundation for a postulated cylindrical void with a 6.1 m (20 ft) diameter extending east-west across the nuclear island with the top of the void just below the Grouted Zone. This direction was selected because the maximum dynamic bearing demand occurs under the west edge of the shield building and is primarily due to the response to the east-west component of the earthquake. The applicant stated that the sensitivity analysis considers extremely unlikely and conservative cases that are only assessed to show the safety margin provided by the rock mass. The applicant discussed the modeling approach by considering a construction sequence, model size, and boundary. The applicant evaluated the effects of the postulated void on settlement, bearing capacity, and potential tension in the concrete fill. The applicant also evaluated the impact of the potential voids on stability of concrete fill under dynamic conditions using pseudo-dynamic method to simulate dynamic conditions. The applicant therefore concluded that the presence of a 6.1 m (20 ft) diameter cylindrical tunnel does not present stability concerns to the subsurface material at the site, and therefore is not critical to the stability of safety-related structures.

The applicant proposed a grouting ITAAC, which is accomplished through drilling and pressure grouting of grout boreholes in accordance with the grout closure criteria and grout borehole spacing. The applicant stated that the that execution of ITAAC will result in any remaining voids

in the Grouted Zone being structurally insignificant and any remaining voids in the Extended Zone having a maximum equivalent spherical diameter of equal to or less than 20 ft.

During the process of the review, staff conducted several public meetings and conference calls to discuss with the applicant its grouting plans, methods, and grout closure criteria. During a staff audit on seismic design parameters and seismic subsystem analysis and stability of materials and foundations held during June 22 to 25, 2015, the staff discussed comprehensively with the applicant the grouting ITAAC, grouting plan, and finite element modeling and stability analysis for a postulated void.

The staff reviewed the applicant's responses to RAI 7811, Question 02.05.04-26, particularly the geotechnical investigation, the grouting methodology, the grout test program, the sensitivity analysis, and the ITAAC. The staff also reviewed related information presented in the response from the initial and supplemental field investigation to support the microgravity assessment. The staff notes from the geotechnical investigation that that the maximum individual drops in the borings are 1.2 m (4 ft) at the site and 0.5 m (1.5 ft) within the Unit 6 and 7 building footprints. The staff also notes that in a total of 2,522.2 m (8,275 ft) cored in 96 borings, the frequency of encountering an interpreted tool drop is less than 0.5 percent site-wide including the tool drops under vegetated depressions and drainages. Based on above finding from geotechnical investigation at the site, the staff agrees that large voids are not expected.

The staff also reviewed the applicant's grout plan. The staff acknowledges that with current grouting technology, the purposes of dewatering and constraining voids are achievable through this plan. The staff notes that before Seismic Category I Structure foundation grouting, a grout test program will be developed and implemented for the purpose of validating the grout design and grouting techniques, determining the approximate grout takes for the Key Largo Limestone and Fort Thompson Formations, and determining the grout closure criteria for individual grout stages and for completed areas of the Grouted and Extended Grouted Zones. The staff also notes that spacing for primary and secondary grout boreholes, suitability of the formation for grouting via downstages, upstages, or a combination of upstages and downstages, inclination of grout boreholes to best intercept the dominant features in the treatment area, effective grout mixes, drilling and flushing of grout boreholes, injection rates and pressure, and monitoring grouting conditions will be carefully tested and studied through the grout test program. The staff acknowledges that the grout test program will be used to optimize and finalize grouting program with the grout closure criteria and dewatering specifications.

The staff notes that the applicant proposed the ITAAC for Seismic Category I Structure foundation grouting. The staff also notes that primary grout boreholes will be spaced less than or equal to 6.1 m (20 ft) on center, and spacing of primary and secondary grout boreholes may be reduced based on results from the grout test program. For the Grouted Zone, the grout test program will identify and define grout closure criteria for identifying when each grout borehole has been filled and pressurized with grout and filling may cease or tertiary or quaternary grout boreholes are necessary. For the Extended Grouted zone, grouting will be performed in every primary grout borehole. The grout test program will identify and define grout closure criteria for identifying when each grout borehole has been filled and pressurized with grout and filling may cease or secondary grout boreholes are necessary. The applicant further noted that inspections and analysis will be performed of the as-built locations, depth and spacing of all grout boreholes, both with respect to the Grouted Zone and the Extended Grouted Zone, and the grout data associated with each grout borehole and zone. The staff agrees with the applicant that with successful implementation of the ITAAC will ensure that any voids

remaining in the Grouted Zone are structurally insignificant and ensure that any voids remaining in the Extended Grouted Zone are equal to or less than 20 ft.

The staff reviewed the applicant's sensitivity analysis and assessed its potential effect on the stability of the overlying soils and the structure foundations. SER Section 3.7.1.4 presents the staff evaluation on the effect of the postulated presence of 20 foot diameter void beneath the NI and assessment on its potential impact on the structure foundations. Based on the geological and geotechnical findings, the staff agrees that it is conservative to assume a cylindrical void with a 6.1 m (20 ft) diameter extending east-west across the nuclear island with the top of the void just below the Grouted Zone. The staff notes that computational simulation considers a loading sequence including the activities of initial gravity loading without the void, gravity loading with the void, dewatering, excavation and fill placement, loading, and rewatering. The staff acknowledges that this loading sequence reflects a real construction order and progression. The staff also notes that the model size is adequate. For vertical extent, it meets the criterion of the maximum required depth d_{max} defined by RG 1.132, Appendix D; for lateral extent, the sufficiency is confirmed by settlement computations by demonstrating that maximum settlement predicted for the buildings does not vary with the extended boundaries. The staff further notes from the sensitivity analysis that the effects of the postulated void on stability of concrete fill including settlement, bearing capacity, and potential tension in the concrete fill are not critical to the static and dynamic stability of the concrete fill. The staff therefore agrees with the applicant that the presence of a 6.1 m (20 ft) diameter cylindrical tunnel under the Grouted Zone does not present stability concerns to the subsurface material at the site.

In summary, the staff concludes that with a careful development of the grout test program including grout closure criteria and the specified borehole spacing, and implementation of the ITAAC, the limestone (Key Largo and Fort Thompson formations) under the concrete fill will be grouted to fill or constrain voids so that the stability of subsurface materials will not be a concern. Consequently, the staff considers RAI 6006, Questions 02.05.04-1 and RAI 7811, Question 02.05.04-26 resolved. The incorporation of the grouting information in RAI 7811, Question 02.05.04-26, into the FSAR is being tracked as a Confirmatory Item 2.5.4-1 pending the appicant's update of the FSAR.

Resolution of Turkey Point Confirmatory Item 2.5.4-1

Confirmatory Item 2.5.4-1 is an applicant commitment to include the grouting information and the ITAACs for grouting and concrete fill in the Turkey Point Units 6 and 7 COL FSAR Section 2.5.4. The staff verified that the Turkey Point Units 6 and 7 COL FSAR, Revision 8, was revised in accordance with the applicant's response to RAI 7811, Question 02.05.04-26. As a result, Confirmatory Item 2.5.4-1 is now closed.

Pressuremeter Testing

The staff reviewed the pressuremeter testing program and evaluated the results presented by the applicant, specifically Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-220 and Figures 2.5.4-220 and 2.5.4-245, which present initial shear modulus and unload/reload shear modulus results. The staff concludes that the applicant adequately applied the pressuremeter program and obtained reasonable values for the high strain shear modulus for the subsurface materials of the Key Largo, Fort Thompson, Upper Tamiami, Lower Tamiami, and Peace River formations.

Staff's Conclusions Regarding Geophysical Surveys

Based on the staff's review of the geophysical surveys that the applicant conducted at the Turkey Point Unit 6 and 7 site, as part of the applicant's overall subsurface investigation program to identify dynamic characteristic of the soil and rocks, and the applicant's responses to several questions related to RAIs 6006 and 7811, the staff concludes that the applicant's geophysical surveys are acceptable and in accordance with the guidance provided in RG 1.132.

2.5.4.4.5 Excavation and Backfill

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.5 related to the engineering granular backfill requirements, the extent of excavation fills and slopes, excavation methods, and stability at the Turkey Point Units 6 and 7 site.

The applicant stated in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.5.2 that it will found the Turkey Point Units 6 and 7 nuclear islands directly on a 5.8 m (19 ft) thick lean concrete layer above the Key Largo Formation. In Part (a) of RAI 02.05.04-12, the staff asked the applicant to define "lean concrete" with the ACI standard(s) it plans to follow.

In its response to RAI 6006, Question 02.05.04-12, dated October 3, 2014 (ADAMS Accession No. ML14282A311), the applicant defined lean concrete as unreinforced concrete with a lower cement to aggregate ratio than typical concrete. The applicant clarified that Controlled Low Strength Material (CLSM) will not be used. The applicant stated that it will follow ACI 207 standard, "Guide to Mass Concrete." The staff reviewed the applicant response and applicable changes in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.5.1. The staff acknowledge that the applicant plans to follow industry guidance for construction and placement methods of the lean concrete fill, such that the mechanical properties of the lean concrete fill are consistent with the properties used for the design analyses.

In Part (b) of RAI 6006, Question 02.05.04-12, the staff asked the applicant to evaluate the potential for cracking of the lean concrete due to loading/overstressing and thermal conditions. In its response to RAI 6006, Question 02.05.04-12, the applicant stated that the concrete fill will have an estimated compressive strength of 10.3 MPa (1,500 psi or 216 ksf). The applicant further explained that the design bearing capacity of this strength of concrete is over 4.8 MPa (100 ksf), while the maximum applied bearing pressure is 0.4 MPa (8.9 ksf) according to the AP1000 DCD. The applicant indicated that it will develop a thermal control plan following ACI 207 during detailed design to minimize thermal cracking of the concrete fill. Because the bearing demand is less than 9 percent of the bearing capacity of the concrete and ACI 207 will be followed to address to the issue of thermal cracking of the concrete fill, the applicant concluded that the cracking of the concrete fill due to loading/overstressing is not expected, and thermal cracking of the concrete fill will be controlled and minimized. The staff reviewed the applicant's responses to Part (b) of RAI 6006, Question 02.05.04-12. The staff performed a confirmatory calculation based on ACI standard to ensure the bearing capacity for concrete fill is sufficient. The staff also notes that the thermal control plan will follow ACI 207 to include elements of controls on cementitious material content, precooling, and construction management. Based on its review, the staff agreed that the cracking due to due to loading/overstressing and heat generated from mass concrete is not an issue.

In Part (c) of RAI 6006, Question 02.05.04-12, the staff asked the applicant to describe the load transfer mechanism between the base of the nuclear island structures and the concrete fill as well as the load transfer between the concrete fill and the surrounding supporting soils. In its

response to RAI 6006, Question 02.05.04-12, the applicant stated that stress levels will remain low and within the elastic range for transfer of vertical load from the foundation to the concrete fill and from the concrete fill to the underlying rock because of the strength of the concrete fill and the underlying rock. The applicant also stated that for transfer of lateral loading, the frictions against sliding between the foundation mat and mudmat, between the mudmat and concrete fill, and between the concrete fill and rock give the resistance to sliding among the materials. The staff reviewed the applicant's responses to Part (c) of RAI 6006, Question 02.05.04-12. The staff agrees that vertical stress levels for concrete fill and underlying rock remain low and elastic based on their material properties. The staff also checked the coefficient of friction against sliding between concrete and rock and between concrete and concrete to ensure these values generate enough force to prevent sliding. Based on its review, the staff finds that load transfer from the foundation to subsurface materials will not cause overstressing and sliding concerns.

Since the chemical tests of soil and rock indicated that that the chemistry of soil and rock is considered to be aggressive toward cementitious materials, in Part (d) of RAI 6006, Question 02.05.04-12, the staff asked the applicant to provide test results on groundwater chemistry including pH, chlorides, and sulfates, to evaluate the potential aging effects, and to address the concrete durability for lean concrete backfill and sub-foundation due to aggressive soil and/or groundwater conditions. In its response to RAI 6006, Question 02.05.04-12, the applicant provided its measured values of chemical tests on groundwater samples from observation wells, indicating that the pH values measured were essentially neutral, the measured chloride concentration level can affect the reinforcing steel of concrete, and the sulfate values measured classify the concrete exposure to sulfate attack as severe according to ACI codes. However, the applicant stated that since the concrete fill is non-structural and unreinforced, the chloride concentration will not affect the concrete fill at the Turkey Point Units 6 and 7 site. The applicant also proposed to use sulfate resisting Type V cement with a maximum C3A content of 5 percent as specified in ACI 318-05/318R-05 (ACI, 2005) in combination with fly ash to improve the sulfate resistance and the thermal control to make the first, bottom lift of concrete fill. The applicant further stated that the extensively grouted Key Largo Limestone layer under the concrete fill, permanent diaphragm cut-off walls surrounding the concrete fill, and the nuclear island and structural fill covering the surface of the concrete fill will help to reduce groundwater incursions to concrete fill. The applicant also concluded that the effects of high sulfate content, erosion, or leaching of the cement will have no effect on total or differential settlement.

The staff reviewed the applicant's responses to Part (d) of RAI 6006, Question 02.05.04-12, particularly the test results on groundwater chemistry including pH, chlorides, and sulfates, and agrees that the chloride concentration will not affect the concrete fill because the concrete fill is not reinforced. However, for concrete to resist a sulfate attack, the staff notes, that in addition to the type of cement, ACI 318-05 and ACI 318R-05 also specify the maximum water-cementitious material ratio and the minimum concrete strength. In RAI 7811, Question 02.05.04-31, the staff asked the applicant to specify the water-cementitious material ratio and the concrete strength it will use for the first lift of concrete fill, and to provide corresponding updates in the Turkey Point Units 6 and 7 COL FSAR to reflect the evaluation and prevention of groundwater chemicals attacking concrete fill.

In its response to RAI 7811, Question 02.05.04-31, dated July 13, 2015, the applicant committed that the concrete mix for the first lift will contain a maximum water-cementitious material ratio by mass of 0.45 and a sulfate resisting Type V cement or equivalent as defined in Sections 6.2.5, 6.2.7, and 6.2.9 of ACI 201.2R-08 (ACI, 2008). The applicant committed to prepare the delivery tickets in accordance with ACI 311.5 (ACI, 2004) and inspect to ensure that

the water cementitious material ratio and the type of cementitious materials for the first lift of concrete mix meet durability requirements of ACI 201.2R-08 for Class 2 sulfate exposure. The applicant voluntarily indicated that for additional protection it will use Type V cement or its equivalent, according to ACI 201.2R-08, for all the lifts. The applicant proposed an ITAAC that will be used to ensure that the first lift of concrete fill with minimum thickness of 0.8 m (2.5 ft) meets the ACI 201.2R-08 durability requirements.

The staff reviewed the applicant's response to RAI 7811, Question 02.05.04-31. The staff acknowledges that ACI 201.2R-08 is a code that addresses issues specific to concrete durability, including the concrete exposure to sulfate attack; while ACI 318-05/318R-05 is a design code for reinforced concrete in general. The staff reviewed ACI 201.2R-08 and confirms that the applicant classified the severity of potential exposure to groundwater as Class 2 exposure for concrete exposure to sulfate attack. The staff also reviewed ACI 311.5-04, which is a guide for concrete plant inspection and testing of ready-mixed concrete. The staff notes that the requirements in ACI 201.2R-08 to protect against damage to concrete by sulfate attack from external sources of sulfate exposure, and the requirements by ACI 311.5-04 for inspection at the concrete plant when such inspections are required by specifications or the owner are followed, and committed through the ITAAC to ensure the first lift of concrete fill meets the ACI 201.2R-08 durability requirements. The staff found that the related information is properly documented in the Turkey Point Units 6 and 7 FSAR. Accordingly, the staff considers RAI 6006, Question 02.05.04-12, and RAI 7811, Question 02.05.04-31, resolved.

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.5.1.2 and the response to RAI 6006, Question 0.2.05.04-12, indicated that the applicant will place a 19-foot thick layer of concrete fill beneath the nuclear islands. In RAI 7811, Question 02.05.04-33, the staff asked the applicant to provide the ITAAC it will use to ensure that the concrete fill placed underneath any Category I structures meet the design, construction and testing of applicable ACI standards.

In its response to RAI 7811, Question 02.05.04-33, dated July 13, 2015, the applicant committed through an ITAAC that the design and construction of the concrete fill will follow ACI 207 (ACI, 2006) to control thermal cracking, and testing of the strength of concrete, and ACI 311.5 to ensure that the compressive strength is equal to or greater than 10.3 MPa (1,500 psi).

The staff reviewed the applicant's response to RAI 7811, Question 02.05.04-33. The staff acknowledges that ACI 207 is a code that addresses measures to be taken for mass concrete to cope with the generation of heat from hydration of the cement and the attendant volume change to minimize cracking. The staff also acknowledges that ACI 311.5 recommends requirements for field and laboratory testing of concrete. The staff notes that the measures to be taken for mass concrete in ACI 207 to minimize cracking of concrete fill due to its heat from hydration of the cement and the attendant volume change, and testing by ACI 311.5-04 to ensure the mean 28-day compressive strength of the concrete fill is equal to, or greater than, 10.3 MPa (1,500 psi) are followed, and committed through the ITAAC to ensure the concrete fill meets the ACI 207.1R-05 thermal cracking controlling methods and ACI 311.5-04 testing requirements. The staff found that the related information is properly documented in the Turkey Point Units 6 and 7 FSAR. Accordingly, the staff considers RAI 02.05.04-33 resolved.

The applicant stated in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.5.1 that it will place the structural fill consisting of excavated fill material around but not below any of the nuclear island structures, and that the replacement material below the nuclear islands consists of lean concrete fill. In RAI 4975, Question 03.07.01-2, the staff asked the applicant to describe the fill to be placed above the concrete supporting the foundation (referred by the applicant as Part (1)

in its response to the RAI), as well as to provide information on whether any long-term serviceability issues should be considered when judging the adequacy of this material for use in providing support to the nuclear power plant (referred by the applicant as Part (2) in its response to the RAI), and to also provide information on the development of the best estimate, lower bound, and upper bound shear and compression wave velocities for the NEAR and FAR site soils given in Appendix 3KK (referred by the applicant as Part (3) in its response to the RAI). The applicant's response to Part (3) of RAI 4975, Question 03.07.01-2, and the staff's evaluation are discussed and documented in Section 3.7.1.4 of this SER.

In response to RAI 4975, Question 03.07.01-2, dated December 11, 2014, the applicant described the limerock fill placed around the nuclear island structures as crushed limestone that has particle gradations from small to large in granular form and is used in the Florida aggregate industry as a compacted base layer beneath roads and buildings as well as in other structural earth fill applications. The applicant indicated that the limerock material intended for Turkey Point Units 6 and 7 is granular in nature, and is derived from the excavated portions of the onsite Miami Limestone and/or obtained from offsite sources. The applicant committed that structural fill used to backfill against the nuclear island is compacted to a minimum of 95 percent modified Proctor maximum dry density. The applicant also discussed the long-term serviceability of fill from major factors such as suitability of material aggregates and minerals, control during material production, and/or placement and compaction control, indicating that there are no long term serviceability issues.

The staff reviewed the applicant's response to Part (1) and Part (2) of RAI 4975, Question 03.07.01-2, as well as Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.5. The staff notes that the limerock fill placed around the nuclear island structures is crushed limestone that has particle gradations from small to large in granular form. The staff also notes that structural fill used as backfill around the nuclear island structures and beneath nonsafety-related power block structures will be compacted to a minimum of 95 percent of modified Proctor maximum dry density. The staff further notes that the limerock fill will be from onsite excavated Miami Limestone and offsite sources qualified by testing for index properties, chemical properties, and engineering properties, especially: grain size and plasticity characteristics; soil pH, sulfate content, chloride content characteristics; and moisture-density relationships. For long-term serviceability of crushed limestone, the staff notes that approximately 55 million tons of rock from the Lake Belt Region (area between the Everglades and the urbanized Miami-Dade County) is processed into aggregate products each year and is a major supplier for the construction industry, and that the Florida Department of Transportation (FDOT) establishes requirements for hardness, durability, and chemical content. In addition, the staff notes that quality control is an integral part of material verification and acceptance at its source in the Lake Belt Region of Miami-Dade County, and its practice is well-developed and regulated by the FDOT for state-owned projects. Based on the above information and measures, the staff concludes that the applicant provided reasonable assurance that it will place a quality structural fill around the nuclear island structures. However, it is possible that the properties of offsite sources of limerock may differ from those of onsite excavated limestone. In RAI 7811, Question 02.05.04-32, the staff asked the applicant to clarify material tests for offsite structural fill sources, to discuss similarities and differences of offsite limerock with onsite Miami Limestone, and to evaluate the adequacy of fill material to borrow for Category I engineered fill.

In its response to RAI 7811, Question 02.05.04-32, dated July 13, 2015, the applicant reiterated that borrow sources are qualified before earthwork operations by testing for index properties, chemical properties, and engineering properties. The applicant reconfirmed that it will obtain any offsite backfill material, or limerock, necessary for Category I engineered fill from local

quarries. The applicant indicated that the quarries identified as likely offsite structural fill sources are all located within Miami-Dade County, and will be crushed and graded into a variety of grain size distributions. As for adequacy of on-site fill material, the applicant stated that approximately 51,200 m^3 (67,000 yd^3) of limestone or limerock will be excavated for each unit, and 49,500 m^3 (64,700 yd^3) of Category I fill is required for each unit. The applicant stated that onsite limerock is likely adequate in terms of amount, but that offsite sources may be necessary for Category I fill. Because the limerock from both onsite and offsite sources may contain chemicals including chloride and sulfate that may adversely impact the safety-related concrete, the applicant stated that the AP1000 DCD Tier 1, Table 3.3-6 provides ITAAC to ensure that the exterior walls and the basemat of the nuclear island have a water barrier up to site grade, and therefore, the water barrier will eliminate contact between the fill and the nuclear island exterior walls and basemat, any potential sulfate or chloride attack on the concrete will be minimized.

The staff reviewed the applicant's response to RAI 7811, Question 02.05.04-32. The staff notes that the applicant will qualify the backfill material from both onsite and offsite sources by testing of index properties, chemical properties, and engineering properties for Category I engineered fill. The staff also notes that a dense backfill material adjacent to the Seismic Category I structure is assured by the expected compaction specifications of backfill material. The staff further notes that the safety-related concrete is not in contact with the limerock backfill because of installation of a sheet-type HDPE waterproofing material on the vertical surfaces under Seismic Category I structures; therefore, the staff concludes that the chloride and sulfate contents in the backfilling limerock will not be a concern for concrete durability.

Since the applicant suitably described the sources, quantities, and static and dynamic engineering properties of borrow materials and specified the compaction requirement for Category I engineered fill, the staff concludes that the applicant met the intent of backfill in the AP1000 DCD described in Tier 2 Section 2.5.4.6.3. The staff also confirms that the related information is properly documented in the revised version of the Turkey Point Units 6 and 7 COL FSAR. Therefore, the staff considers Part (1) and Part (2) of RAI 4975, Question 03.07.01-2 resolved.

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.5.1, the applicant stated that it will construct a mechanically stabilized earth (MSE) retaining wall around the perimeter of the plant area that it will design to retain the soil mass and resist loading resulting from the probable maximum hurricane. In RAI 6006, Question 02.05.04-13, the staff asked the applicant to indicate whether the safety of any Seismic Category I structure is dependent on the MSE retaining wall, and describe this wall's design in the Turkey Point Units 6 and 7 COL FSAR.

In its response to RAI 6006, Question 02.05.04-13, dated October 3, 2014, the applicant provided a general description of the MSE retaining wall. The applicant clarified that the MSE retaining wall is not required to maintain the function of any Seismic Category I structure. The applicant further clarified that the distance from the MSE wall to SSCs of interest for Turkey Point Units 6 and 7 is greater than 152.4 m (500 ft), and thus a failure of the wall could not affect the SSCs of interest.

The staff reviewed the applicant's response to RAI 6006, Question 02.05.04-13. The staff noted that the MSE wall is not required to maintain the function of any Seismic Category I structures and that the distance from the retaining wall to SSCs of interest is greater than 152.4 m (500 ft) and thus a failure of the wall could not affect the SSCs of interest. However, the staff noted these statements were not included as part of the proposed FSAR revisions. In RAI 7811, Question 02.05.04-34, the staff requested the applicant to document these statements in the

FSAR. In its response to RAI 7811, Question 02.05.04-34, dated March 20, 2015, the applicant clarified that it would include these statements in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4, and identified changes that it would make in a future revision of the Turkey Point Units 6 and 7 COL FSAR. The staff reviewed the applicant's response to RAI 02.05.04-34 and confirmed these statements were documented in the Turkey Point Units 6 and 7 COL FSAR. Accordingly, the staff considers RAI 6006, Question 02.05.04-13, and RAI 7811, Question 02.05.04-34 resolved.

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-222, which shows a general concept of the excavation cross-section. In RAI 6006, Question 02.05.04-14, the staff asked the applicant to describe the procedures that will be followed during site excavation and construction activities to ensure that the appropriate strata for the proposed foundation locations are confirmed through objective measures and the exposed foundation laying surface is uniform. In addition, the staff asked the applicant to provide the vertical and horizontal extent of all Seismic Category I excavations, fills, and slopes, including the locations and limits of excavations, fills, and backfills on plot plans and geologic sections and profiles.

In its response to RAI 6006, Question 02.05.04-14, dated October 3, 2014, the applicant provided general descriptions of the upper three strata at the Turkey Point Units 6 and 7 site including muck, the Miami Limestone, and the Key Largo Limestone based on its subsurface investigation for the power block areas. The applicant expected to directly observe these near-surface strata during the excavation process. The applicant also stated that during the excavation process, onsite geotechnical engineers and geologists will visually inspect and verify complete removal of the Miami Limestone to the Key Largo Limestone. In regards to the Key Largo Formation, the applicant stated that the onsite geotechnical engineers and geologists will identify and excavate the zones that are softer than moderately hard. The applicant updated Turkey Point Units 6 and 7 COL FSAR Figures 2.5.4-203 through 2.5.4-209 to show the vertical and horizontal extent of all Seismic Category I excavations, fills, and slopes, including the locations and limits of excavations, fills, and backfills. In addition the applicant revised Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-222 to show the extent of excavation in plain view.

The staff reviewed the applicant's response to RAI 6006, Question 02.05.04-14. The staff notes that the applicant clearly described the procedures to confirm the appropriate strata during site excavation and construction activity. The staff examined updated Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-203 through Figure 2.5.4-209 and Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-222, and finds that these figures adequately provide the vertical and horizontal extent of all Seismic Category I excavations, fills, and slopes, including the locations and limits of excavations, fills, and backfills. The staff also confirms that the applicant updated these figures on the revised Turkey Point Units 6 and 7 COL FSAR. Accordingly, the staff considers RAI 6006, Question 02.05.04-14, resolved.

<u>Staff's Conclusions Regarding Excavation and Backfill</u>

The staff concludes that the applicant has (1) provided detailed information on engineered granular backfill and fill concrete properties and compaction requirements, (2) provided applicable methods and procedures used for the verification and quality control of engineered granular backfill and concrete fill, (3) described concrete fill properties that will ensure that the proposed fill concrete meet the strength and stability requirements, and (4) provided detailed information and applicable methods and procedures for Seismic Category I structure foundation grouting. In addition the applicant provided two site-specific ITAAC. One is concrete fill ITAAC that will ensure that the first lift off concrete fill material placed under Seismic Category I

structures is resistant to sulfate attack and that the static and dynamic properties of the material will be the same as, or better than the design parameters. Therefore, the proposed concrete fills for this site are adequate for meeting design and engineering standards. The other ITAAC is for Category I Structure foundation grouting that will ensure that any voids remaining in the Grouted Zone are structurally insignificant and ensure that any voids remaining in the Extended Grouted Zone are equal to or less than 20 ft and therefore would not result in any structural instabilities. The staff concludes that the supporting foundation materials, qualified fill concrete, and/or foundation grouting will result in a solid foundation for the nuclear island that meets the requirements specified in AP1000 DCD Tier 1, Table 5.0-1 and 10 CFR Part 50.

2.5.4.4.6 Groundwater Conditions

The staff focused its review of Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.6, groundwater conditions at the Turkey Point Units 6 and 7 site relative to foundation stability for the safety-related structures. The applicant indicated that a reinforced concrete diaphragm wall will surround the excavation and act as a cut-off for horizontal groundwater flow into the excavation. The applicant also stated that a construction groundwater control will form a grouted zone between the bottom of the excavation at El. −10.7 m (−35 ft) and the bottom of the diaphragm wall at El. −18.3 m (−60 ft). The applicant further stated that primary grout boreholes will be extended from El. −18.3 m (−60 ft) to −33.5 m (−110 ft) to form “the extended grouted zone.” The staff reviewed the groundwater model simulation sensitivity analysis that assumes various hydraulic conductivities for the grout plug and agrees with the applicant that grouting can significantly reduce the amount of discharged water generated during the excavation.

The staff reviewed the groundwater information in the Turkey Point Units 6 and 7 COL FSAR including the conditions before, during, and after excavation and the associated groundwater control. The staff concludes that the applicant’s assessment of groundwater conditions satisfies the relevant requirements of 10 CFR Part 50 and 10 CFR Part 100 and is acceptable.

2.5.4.4.7 Response of Soil and Rock to Dynamic Loading

Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.7 presents the site subsurface profile characterization with respect to the properties of the strata pertinent for dynamic loading. Turkey Point Units 6 and 7 COL FSAR Sections 2.5.4.7.3.3, Revision 5, states that the damping for rock is 1 percent, while Turkey Point Units 6 and 7 COL FSAR Figure 2.5.2-249 indicates that the applicant used a damping value of 0.5 percent to develop the GMRS. In RAI 6006, Question 02.05.04-16, and RAI 6432, Question 03.07.01-19, the staff asked the applicant to clarify the actual level of damping used in the analyses and to provide a basis for its selection. In RAI 4975, Question 03.07.01-10, the staff asked the applicant to provide information on the selection of the best estimate profile and associated sigma variation of both shear wave velocity and hysteretic damping used in the randomization process for the calculation of the surface and Foundation Input Response Spectra (FIRS).

In its response to RAI 4975, Question 03.07.01-10, dated December 11, 2014, the applicant stated that it used the base case shear wave velocity profile as the best estimate profile for the randomization process. The applicant clarified that it developed the base case profile and its associated sigma variation for the top 183 m (600 ft) of in situ soils and rock using seismic velocity data generated from the site-specific subsurface investigation. However, the applicant noted that for structural fill and concrete fill layers, it developed the base case shear wave velocity profile and its sigma variation from the dynamic properties using other available geotechnical information and not determined by direct measurements. For deep soil layers

below 183 m (600 ft) depth, the applicant stated that sonic logs obtained from borings made in the vicinity of the site provided the necessary data. In its responses to RAI 6006, Question 02.05.04-16, dated May 6, 2016 (ADAMS Accession No. ML16131A673) and RAI 6432, Question 03.07.01-19, dated December 11, 2014 (ADAMS Accession No. ML14349A372), the applicant clarified the actual levels of damping used for the existing site response analysis. The applicant adopted a damping ratio of 1 percent in the analysis for both the Key Largo and Fort Thompson Formations. The applicant further stated that the measured damping ratio from four resonant column torsional shear tests (RCTS), which were conducted on the Key Largo and Fort Thompson Formations as part of the supplemental field investigation in 2013, is first constant around 0.8 percent, and then increases toward 1 percent as the shear strain approaches 0.005 percent. The applicant also took into account the uncertainties and variation in the damping ratios (reflected in the variations in parameters such as RQD) in the randomization process. As a result of supplement investigation, the applicant revealed that dynamic soil and rock properties changed slightly by displaying Figures 6 through 13 in the applicant's response to RAI 02.05.04-16. Based on its sensitivity analysis presented in Turkey Point Units 6 and 7 COL FSAR Appendix 3JJ.7, the applicant demonstrated that the newly acquired RCTS data has a small effect on the site amplification results. The applicant also demonstrated that the increase in seismic response due to the change in material properties is enveloped by the safe-shutdown earthquake (SSE) at all frequencies for the FIRS near nuclear island site conditions. Accordingly, the applicant concluded that the Turkey Point Units 6 and 7 SSE is not impacted by the new data, and the existing site response analysis in Turkey Point Units 6 and 7 COL FSAR Section 2.5.2 is still valid.

The staff reviewed the applicant's response to RAI 6006, Question 02.05.04-16, RAI 4975, Question 03.07.01-10, and RAI 6432, Question 03.07.01-19, as well as the sensitivity assessment presented in Turkey Point Units 6 and 7 COL FSAR Appendix 3JJ.7. The staff notes that the applicant conducted four RCTS tests on the Key Largo and Fort Thompson Formations as part of the supplemental field investigation. The staff also notes that the applicant updated Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-235 to include the best fit damping curve labeled as "Key Largo and Fort Thompson" based on the RCTS results. The staff agrees that even though the assumed damping ratio of 1 percent is slightly higher than the measured values of 0.8 to 1 percent, the test results are in good agreement with the assumptions made for layers and the difference is within the uncertainty involved in determining the damping ratio from the test results. The staff acknowledges that the applicant's selection of the best estimate profile and associated sigma variation of both shear wave velocity and damping used in the randomization process meet the intent of Standard Review Plan (NUREG-0800) Section 3.7.2. For the sensitivity analysis, the staff notes that two site column locations and characterization were considered and studied: 1) near nuclear island site conditions, and 2) far from nuclear island conditions. The staff also notes the first profile used in the initial (existing) SSI evaluations is referred to as the "initial" analysis that services as the reference condition to which the changes are compared; and the second profile set considered is referred to as "updated" based on data collected by the initial and supplemental site investigation. From Figure 3JJ-262 (Figure 2.5.4-3) in Turkey Point Units 6 and 7 COL FSAR Appendix 3JJ, the staff further notes that the applicant calculated the design response spectrum level motion for the "initial" and "updated" response to estimate the potential effect of the new strain-dependent property curves from the newly acquired RCTS tests by supplemental field investigation on the design level earthquake. Based on the sensitivity analysis demonstrated on Figure 3JJ-262 in Turkey Point Units 6 and 7 COL FSAR Appendix 3JJ, the staff agrees with the applicant that new RCTS data has a small effect on the site amplification results, and a large margin exists between the site-specific motions and the adopted broadband SSE response spectrum. Therefore, the staff concludes that the Turkey Point Units 6 and 7 SSE is not affected by the

new data, and no further analyses are required. Accordingly, the staff considers RAI 6006, Question 02.05.04-16, RAI 4975, Question 03.07.01-10, and RAI 6432, Question 03.07.01-19, resolved.

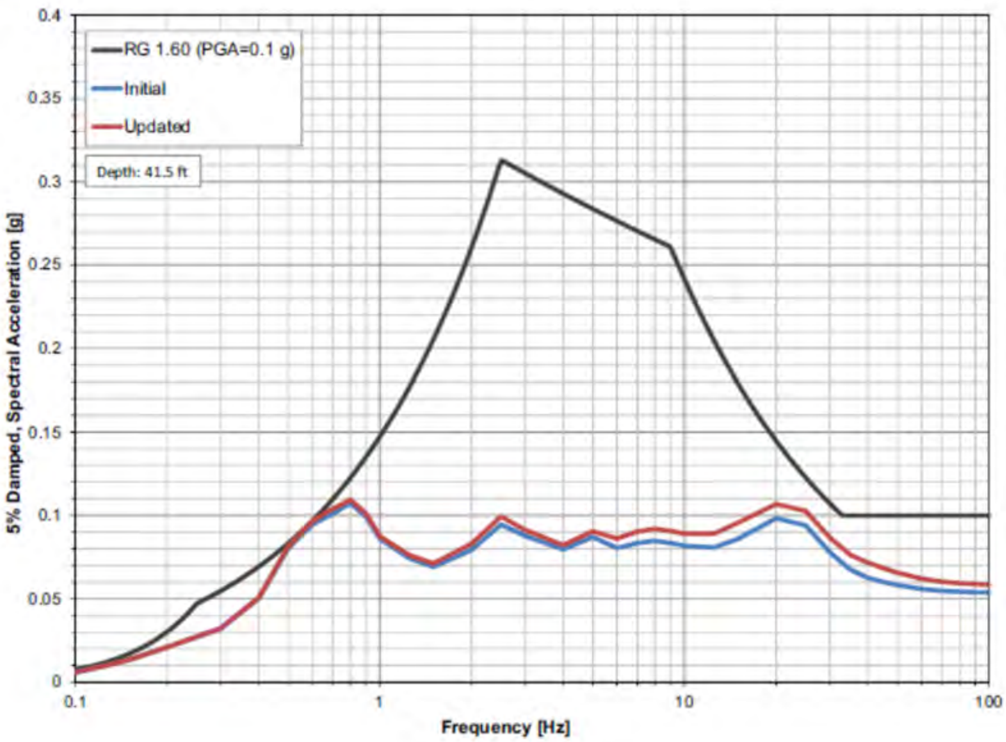


Figure 2.5.4-3 Comparison between the FIRS Computed with the Sensitivity Analysis and the Initial Analysis, near nuclear island site conditions (Reprint of Figure 3JJ-262 in Turkey Point Units 6 and 7 COL FSAR Appendix 3JJ)

P and S Wave Velocity Profiles

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.5.4-218 and 2.5.4-219, which show plots of all of the measured shear wave velocities and compression wave velocities to depths of 137 m (450 ft) and 183 m (600 ft) at Turkey Point Units 6 and Unit 7, respectively. The staff also reviewed FSAR Section 2.5.4.7.2.2, in which the applicant described the selection of seismic velocities deeper than 183 m (600 ft). The staff noted that the applicant obtained the velocities deeper than 183 m (600 ft) from Arthur (1988) and Reese and Richardson (2008) to complete the velocity profile for seismic ground response analyses with consideration of the significant depth of unconsolidated sediments at the site. The staff concludes that the applicant properly and adequately performed a detailed investigation of P and S wave velocity profiles in accordance with RG 1.132 “Site Investigations for Foundations of Nuclear Power Plants.”

Static and Dynamic Laboratory Testing

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Table 2.5.4-209 and Section 2.5.4.2.1.3, which summarize the static laboratory testing of representative soil samples obtained from the subsurface investigation. The staff also reviewed Turkey Point Units 6 and 7 COL FSAR Figures 2.5.4-232 and 2.5.4-235, which present the selected values of G/Gmax

versus shear strain for the five strata (the Key Largo, Fort Thompson, Upper and Lower Tamiami, and Peace River formations) tested in the power block and the damping versus the shear strain for the tested data. In addition, the staff reviewed the dynamic properties of compacted structural fill. The staff concludes that the applicant properly and adequately performed static and dynamic laboratory testing in accordance with RG 1.138.

Staff's Conclusions Regarding the Response of Soil and Rock to Dynamic Loading

Based on the above review, the staff concludes that the applicant developed soil and rock dynamic properties for the Turkey Point Units 6 and 7 site based on field and laboratory tests that are in accordance with RG 1.132 and RG 1.138. In addition, the staff concludes that the applicant conducted sufficient tests and considered the variations of soil and rock properties to determine appropriate soil and rock dynamic properties to satisfy the applicable requirements of 10 CFR Part 50 and 10 CFR Part 100.

2.5.4.4.8 Liquefaction Potential

During the review of Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.8, the staff evaluated the applicant's description of the liquefaction potential at the Turkey Point Units 6 and 7 site. The staff focused on the applicant's discussion of the geologically based and state-of-the-art methodology assessments (Youd et al., 2001), such as liquefaction analyses using CPT, V_s and SPT data.

As a result of its review, the staff raised several issues in RAI 6006, Question 02.05.04-17, regarding the method by Idriss and Boulanger (2008) and some factors and parameters selected for this method in the applicant's calculation. However, the applicant revised the methodology for the liquefaction analysis of the Turkey Point Units 6 and 7 site based on its field data obtained from both the initial and the supplemental field investigations. The applicant evaluated soil liquefaction following RG 1.198, which corresponds to the methodology found in Youd et al. (2001). Therefore, issues raised by Parts (a) to (d) of RAI 6006, Question 02.05.04-17, are no longer relevant and are not discussed in this FSAR.

In Part (e) of RAI 6006, Question 02.05.04-17, the staff asked the applicant to justify use of equations from Idriss and Boulanger (2008) for determining normalized clean sand cone penetration resistance (q_{c1Ncs}) values, and how the resulting values are conservative compared to the methods outlined in RG 1.198 using the calculated soil behavior type index (I_c) values.

In its response to Part (e) of RAI 6006, Question 02.05.04-17, dated October 3, 2014, the applicant stated that it revised the liquefaction analysis to follow RG 1.198. The applicant described this methodology, indicating that the methodology considers the evaluation of data from CPT, V_s, and SPT data. The applicant indicated that it scaled up the peak ground acceleration (PGA) to 0.1 g for the liquefaction analysis per RG 1.208. The applicant also generated plots to demonstrate the factor of safety (FOS) against liquefaction based on in situ test data from CPT, V_s, and SPT to display ample FOSs for most data points obtained from the power block area. The applicant concluded that liquefaction is not a concern for the Turkey Point Units 6 and 7 site.

The staff reviewed the applicant's response to RAI 6006, Question 02.05.04-17, and the associated calculation. The applicant acknowledged that RG 1.198 recommends application of relationships from Youd et al. (2001) when using empirical procedures to assess the potential for liquefaction triggering. The staff notes from Figure 2 in the response (FSAR Figure 2.5.4-

238) that the FOS against liquefaction based on CPT results is higher than 1.1 across the full depth of testing at the site with many points in the range of 1.1 and 1.4 within the layers of Upper Tamiami and Lower Tamiami. The staff also notes that of the 1,247 data points for FOS against liquefaction based on V_s results, all but 3 are above 1.4. The staff further notes that the liquefaction analysis based on SPT data considers only the results of the supplemental investigation because the original SPT N-values are too low due to the effect of overwashing and, therefore, are not representative of the actual soil conditions at the NRC site. The staff considered Figure 5 in the response (added as Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-250) and found that 44 out of 79 SPT N value data points obtained from the supplemental investigation are directly classified as non-liquefiable given that the parameter $(N_1)_{60}$ results in values equal to or higher than 30, the FOS from 33 of the 79 SPT N-values are above 1.4, and FOS for the remaining 2 data points are within the 1.1 to 1.4 range. Noting the use of only supplemental test data for the SPT liquefaction evaluation and the fact that many values from the CPT liquefaction evaluation were within the range necessitating further justification (FOS between 1.1 and 1.4), in RAI 7811, Question 02.05.04-35, the staff asked the applicant to provide a further evaluation of the potential for soil liquefaction.

In its response to RAI 7811, Question 02.05.04-35, dated April 27, 2015, the applicant emphasized that it considered the reported FOS to have a significant safety margin since it did not consider a scaled up PGA and the effects of deposit age. The applicant indicated that the scaled up PGA used in the liquefaction assessment is 0.1 g, while the PGA for the GMRS is 0.0579 g. Because the scaled up PGA used in the analysis is approximately 1.73 times higher than the calculated PGA at the site, the applicant concluded that it maintained conservatism in the approach. The applicant also cited Youd et al. (2001), which relates liquefaction susceptibility to the age and type of geologic deposit and indicates that pre-Pleistocene formations are not prone to liquefaction. The applicant noted that although the Pliocene age Upper Tamiami and Lower Tamiami Formations, and the Miocene-Pliocene age Peace River Formation are older than pre-Pleistocene, no consideration of strength gain as a function of age is made in the liquefaction assessment at Turkey Point Units 6 and 7. Accordingly, the applicant concluded that it maintained conservatism in the approach.

The staff reviewed the applicant's response to RAI 7811, Question 02.05.04-35. Given the enhanced quality of SPT in the supplemental field investigation, the staff agrees with the applicant that the liquefaction analysis based on supplemental SPT data is acceptable. Based on the RG 1.198 endorsed approach of Youd et al. (2001), and other literature, the staff further agrees that the effects from scaled up PGA, as well as the fact that the applicant did not credit the influence of the geologic age of the deposit on cyclic shear strength, provides sufficient conservatism in the liquefaction assessment. Therefore, the staff concludes that the applicant's further justification for the values of FOSs between 1.1 and 1.4 for the Upper Tamiami and Lower Tamiami is adequate and acceptable. Consequently, the staff considers RAI 6006, Question 02.05.04-17, and RAI 7811, Question 02.05.04-35, resolved.

Based on the staff's review of the information in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.8 and the applicant's responses to RAIs described in SER Section 2.5.4.4.8, the staff concludes that that the assessment of the liquefaction potential at the planned Turkey Point Units 6 and 7 site is adequate and satisfies the applicable requirements of 10 CFR Part 50 and 10 CFR Part 100.

2.5.4.4.9 Earthquake Site Characteristics

Turkey Point Units 6 and 7 COL FSAR Sections 2.5.2.9 refers to FSAR Section 2.5.2 for a description of possible earthquake site characteristics. Section 2.5.2.4 of this SER provides the staff's technical evaluation of the earthquake potential taking into account the regional and local geology, Quaternary tectonics, seismicity, and site-specific geotechnical engineering characteristics of the site's subsurface material. SER Section 2.5.2.4 also presents the staff's evaluation of the specific investigations necessary to determine the GMRS, including the seismicity of the site region and the correlation of earthquake activity with seismic sources.

2.5.4.4.10 Static Stability

The staff reviewed of Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.10 focusing on the determination of the representativeness of the soil and rock properties used in the analyses, the applicability of the methods of analysis used, and the applicant's statement that the estimated performance was within the AP1000 bounding criteria. The applicant presented the assumptions, methodologies, and technical references used for its evaluation of the foundation conditions relative to the proposed demands created by excavation, structure and backfill loads, and lateral pressures exerted against the exterior walls of the nuclear island.

Bearing Capacity

During the review of the applicant's bearing capacity evaluation, the staff asked the applicant in RAI 6006, Question 02.05.04-18, to clarify the methodology used to calculate the ultimate bearing capacity and to justify its applicability.

In its response to RAI 6006, Question 02.05.04-18, dated October 3, 2014, the applicant described the methodologies used to obtain the bearing capacity of the foundation materials underlying the nuclear island. The applicant discussed rock failure modes including general shear failure, local shear failure, general shear failure without cohesion, compressive failure, splitting failure, Hoek-Brown evaluation, punching failure, and beam tension failure. Based on realistic and/or conservative considerations, the applicant identified local shear failure, Hoek-Brown evaluation, punching failure, and beam tension failure as probable rock failure modes at the site. The applicant's evaluation included hand calculations, limit-equilibrium and finite element 2D models. The applicant recommended a static bearing capacity at Turkey Point Units 6 and 7 of 1,870 kPa (39 ksf) and a dynamic bearing capacity of 1,960 kPa (41 ksf).

The staff reviewed the applicant's response to RAI 6006, Question 02.05.04-18, including the hand calculations, but also limit-equilibrium and finite element 2D models used in the evaluation. The staff agrees with the applicant that these are the most plausible rock failure modes at the site because the applicant based its determination on the site condition with comprehensive and conservative considerations. For example, local shear failure represents a conservative variation of general shear failure because the depth of embedment does not contribute to the total bearing capacity in the local shear failure mode. The staff also notes that the applicant's foundation material and configuration for calculation of bearing capacity are comprehensive and include consideration of combinations of rock and/or soil layers, the degree of rock fracture, and variations of soil properties based on both the initial and supplemental field investigations. The staff determines that these configurations for calculation are acceptable because they reflect comprehensive and conservative assumptions. Because the applicant reasonably and conservatively demonstrated that the lowest allowable static bearing capacity of 1,870 kPa (39 ksf) and the minimum allowable dynamic bearing capacity of 1,960 kPa (41 ksf) exceed the 430

kPa (8.9 ksf) static bearing demand and the 1,680 kPa (35 ksf) dynamic bearing demand required by the AP1000 DCD, respectively, the staff concludes that the bearing capacities at the site are adequate. Accordingly, the staff considers RAI 6006, Question 02.05.04-18, resolved.

Settlement

During review of the applicant's settlement evaluation, the staff requested in RAI 6006, Question 02.05.04-19, that the applicant update its calculation based on the change made in AP1000 DCD Revision 18 on the applied contact pressure for the Reactor Building and provide additional information regarding the differential settlement calculations across the nuclear island foundation mat. In RAI 6006, Question 02.05.04-20, the staff noted that the Boussinesq stress distribution for calculation of settlement is based on the assumption that the soil is a homogeneous, linear elastic, isotropic half-space media, and asked the applicant to justify how the Boussinesq method is applicable to site-specific conditions with variation in elastic modulus from rock strata and soil strata.

In its response to RAI 6006, Question 02.05.04-19, dated October 3, 2014, the applicant revised the settlement analyses to consist of a hand calculation that uses stress distributions appropriate for layered systems, as well as a three-dimensional finite element model (FEM) using PLAXIS 3D. The applicant also stated that the settlement analyses use the revised best estimate material properties based on laboratory data from both the initial and supplemental field investigations. The applicant clarified that the FEM utilizes specific foundation pressures for the shield and auxiliary buildings rather than assuming one value for the entire nuclear island, which results in an equivalent average pressure of 440 kPa (9.2 ksf) for the FEM, as well as for the hand calculation for consistency. The applicant considered two cases, including a best estimate case using the design stiffness for each layer and a lower bound case for a sensitivity analysis using the lower bound stiffness defined as the 16th percentile for two soil layers (the Upper Tamiami and Peace River). For the hand calculation, the applicant considered the assumed loading conditions to include heave for the excavation below the nuclear island, dewatering prior to the construction process to an elevation of -11.5 m (-38 ft) under the nuclear island, and no buoyancy up to the construction of the lean concrete layer. For the FEM analysis, the applicant considered the actual construction sequence to involve simultaneous dewatering and excavation, as well as simultaneous building construction and re-watering. The applicant also discussed its four sensitivity analyses within the FEM analysis including mesh sensitivity, fracture density, soil constitutive behavior, and lower bound. Based on its revised settlement hand calculation and three-dimensional FEM analyses, the applicant demonstrated the predicted maximum differential settlement of 0.66 cm (0.26 in.) in 15.2 m (50 ft) across the nuclear island foundation mat, a maximum total settlement of 8.6 cm (3.4 in.) for the nuclear island foundation mat, a maximum differential settlement of 3.1 cm (1.2 in.) between the nuclear island and turbine building, and a maximum differential settlement of 4.1 cm (1.6 in.) between nuclear island and other buildings.

In its response to RAI 6006, Question 02.05.04-20, dated October 3, 2014, the applicant discussed its detailed stress distribution approaches in the hand calculations for a two-layered system (Milovic, 1992) and a three-layered system (Poulos and Davis, 1974). The applicant used the two layered system approach to represent the Key Largo and Fort Thompson limestone layers and the Upper Tamiami, Lower Tamiami, and Peace River soil layers to imitate the subsurface conditions under the nuclear island. The three-layered system represents the structural fill, in addition to the same limestone and the soil layers, to simulate the subsurface conditions beneath the turbine, first bay, annex, and radwaste buildings. The applicant compared the results from the hand calculation with the results from the FEM using PLAXIS 3D

and the results based on Boussinesq stress distribution. The applicant concluded that because the Boussinesq approach estimated higher stresses in both the rock and soil layers, it is the most conservative. The applicant further demonstrated that the stress distributions determined from the two- and three-layered systems, Milovic (1992) and Poulos and Davis (1974), respectively, are generally similar to the PLAXIS 3D stress distribution.

The staff reviewed the applicant's responses to RAI 6006, Questions 02.05.04-19, and 02.05.04-20. The staff notes that the applicant revised the settlement hand calculation to use stress distributions appropriate for layered systems instead of the Boussinesq distribution. Specifically, the applicant used the stress distribution for a two-layered system (Milovic, 1992) for the nuclear island, and a stress distribution for a three-layered system (Poulos and Davis, 1974) for the remaining buildings (turbine, first bay, annex, and radwaste). The staff agrees with the applicant that it is appropriate to use the FEM model and the hand calculation based on layered stress distribution for the revised settlement calculation because the stiffness between soil and rock strata is reasonably assumed and accounted for. The staff concludes that the conditions assumed during loading in the hand calculation, construction sequence and sensitivity analyses by FEM analysis are rational and comprehensive. The staff finds that the settlements calculated by the applicant are within the acceptable limits of the AP1000 DCD, which cites 1.3 cm (0.5 in.) per 15.2 m (50 ft) differential across the nuclear island foundation mat, 15.2 cm (6 in.) total for the nuclear island foundation mat, and 7.6 cm (3.0 in.) differential between the nuclear island and turbine building, as well as between the nuclear island and other buildings. The staff also noted that for the settlement hand calculation, the applicant used a best estimate case using the design stiffness for each layer and a lower bound case using the lower bound stiffness for the Upper Tamiami and Peace River formations.

The staff noted that the lower bound case, calculated by the applicant, may not necessarily represent the most conservative case since the stress distribution is also dependent on the stiffness contrast between the harder and softer layers. In RAI 7811, Question 02.05.04-36, the staff asked the applicant to provide a settlement calculation to including all layers using lower bound stiffness because the stiffness of the harder layer is less, and therefore more settlement is expected.

In its response to RAI 7811, Question 02.05.04-36, dated April 29, 2015, the applicant stated that, although it considered the scenario extremely unlikely, it performed another settlement sensitivity analysis using a hand calculation and three-dimensional FEM (using PLAXIS 3D) to consider the scenario of all layers with lower bound stiffness. Despite the conservatism involved in the analysis, the applicant demonstrated that the FEM results for the settlement sensitivity analysis using lower bound stiffness for all layers meets all AP1000 DCD criteria. For its hand calculation, the applicant indicated that the only exception to this is the differential settlement of 8.6 cm (3.4 in) between the nuclear island and the radwaste buildings. The applicant further indicated that if the differential settlement, as calculated by the PLAXIS 3D model, is reduced to 2.8 cm (1.1 in) for all the layers of the lower bound case, it is within the AP1000 DCD criteria.

The staff reviewed the applicant's response to RAI 7811, Question 02.05.04-36, and notes that it is conservative because for the nuclear island and other adjacent buildings, it does not account for the influence of the nuclear island loads on the settlement of adjacent buildings, and is therefore conservative. The staff further notes that the differential settlement between the nuclear island and the radwaste buildings calculated by the PLAXIS 3D model is reduced to 2.8 cm (1.1 in.) if nuclear island loads are considered in the settlement of the radwaste building. Based on this information, the staff concludes that the differential settlement between the

nuclear island and radwaste buildings calculated by hand calculation is very conservative because the applicant did not consider the nuclear island loads in the settlement of adjacent structures. The staff also compared the FEM with the hand calculation, and notes that the FEM is more accurate for modeling of rock/soil material properties, more capable of computation of stress and strain, and therefore produces more reasonable results, while the hand calculation involves significant simplifications.

Because the stress distribution found using Milovic (1992) for the hand calculation is similar to but more conservative than the PLAXIS 3D stress distribution, the staff concludes that the hand calculation is conservative to some extent, and can be calibrated by the FEM result. With a rational extrapolation of reduced differential settlement by FEM to include nuclear island loads in the settlement analysis of the radwaste building, the staff applied the same reduction rate from the result by FEM to the result by hand calculation, and finds that the differential settlement between the nuclear island and the radwaste building is within the AP1000 DCD criteria. Finally, since the lower bound rock and soil properties represent a 16 percent probability of that or a lower stiffness occurring, the staff acknowledges that the probability of having all layers with lower bound stiffness is low; and therefore, the settlement analyses based on this assumption are conservative. Because the applicant reasonably and conservatively demonstrated the FEM results for the settlement sensitivity analysis using lower bound stiffness for all layers and met all the applicable AP1000 DCD criteria, the staff concludes that settlement is not a concern at the Turkey Point Unit 6 and 7 site. Accordingly, the staff considers RAI 6006, Questions 02.05.04-19 and 02.05.04-20, and RAI 7811 Question 02.05.04-36, resolved.

Earth Pressures

The staff reviewed the static and seismic active and at-rest lateral earth pressures acting on underground structure below-grade walls. The staff noted that that the pressure developed using the American Society of Civil Engineers (ASCE) 4-98 methodology uses the zero period acceleration (zpa) value from the GMRS. Since the GMRS was developed for El. −10.7 m (-35 ft), the elevation of the GMRS is considerably lower than the surface of the soils adjacent to the basement walls that are to be evaluated for seismic lateral earth pressures. In RAI 6006, Question 02.05.04-22, the staff asked the applicant to clarify the definition of the design ground motion for the active seismic pressure using the Mononobe-Okabe equation and at-rest seismic pressure using ASCE 4-98, and explain how that motion is consistent with Appendix S to 10 CFR Part 50.

In its response to RAI 6006, Question 02.05.04-22, dated October 3, 2014, the applicant confirmed that the zpa value of 0.058 g was not considered appropriate when computing lateral earth pressures because it was developed for −10.7 m (-35 ft) elevation. The applicant clarified that the design response spectra at 5 percent damping, calculated at the ground surface using the envelope of low frequency and high frequency acceleration response spectra at 10^{-4} and 10^{-5} annual probability of exceedance, gives the PGA of 0.0824 g and PGA of 0.0806 g for the near nuclear island and far from nuclear island soil sites, respectively. For active seismic pressure, the applicant used an acceleration of 0.1 g, rather than the PGA of 0.0824 g for the near nuclear island or 0.0806 g for far from nuclear island, in the Mononobe-Okabe equation, which commonly use the acceleration at the surface of the backfill or an average between the surface and the base of the wall. Similarly, for the computation of at-rest seismic pressure using ASCE 4-98, an acceleration of 0.1 g, rather than the PGA of 0.0824 g for the near nuclear island or 0.0806 g for far from nuclear island, is conservatively used.

The staff reviewed the applicant's response to RAI 6006, Question 02.05.04-22. The staff noted that the acceleration of 0.1 g is used for computing lateral earth pressure, while the PGAs calculated at the ground surface are 0.0824 g for the near nuclear island or 0.0806 g for far from the nuclear island. The staff concludes that the ground motion for computing the active seismic pressure using the Mononobe-Okabe equation and at-rest seismic pressure using ASCE 4-98 is appropriately applied since this value is also consistent with the minimum peak ground acceleration of 0.1 g as defined in the Standard Review Plan 3.7.2 Section II.2 and 10 CFR 50 Appendix S. Consequently, the staff considers RAI 6006, Question 02.05.04-22, resolved.

While conducting its review, the staff noted that the applicant included a surcharge pressure of 24 kPa (500 psf) in the lateral earth pressure calculation, however, the applicant did not consider the adjacent building loads and the equipment loads. In RAI 02.05.04-23, the staff asked the applicant to explain the selection of surcharge loads for consideration of lateral earth pressure calculations.

In its response to RAI 6006, Question 02.05.04-23, dated October 3, 2014, the applicant confirmed that an area-wide surcharge pressure of 24 kPa (500 psf) is included in the earth pressure calculations to represent the temporary construction loading, and does not include the permanent adjacent building loads. The applicant stated that this temporary loading is conservatively twice the typical design pressure for heavy truck loading. The applicant adopted an additional case considering a surcharge of 190 kPa (4,000 psf) that is the highest expected building bearing pressure for the buildings founded on fill around the nuclear island to represent adjacent building loads. The applicant developed the recommended diagrams for use in calculating lateral active and at-rest earth pressures against walls based on strata thicknesses and lateral earth pressure coefficients for both 24 kPa (500 psf) surcharge and 190 kPa (4,000 psf) surcharge.

The staff reviewed the applicant's response to RAI 6006, Question 02.05.04-23. The staff agrees that the additional case considering a surcharge of 190 kPa (4,000 psf) is appropriate and conservative to address the loads from the adjacent buildings because 190 kPa (4,000 psf) is the highest expected building bearing pressure for the buildings founded on fill around the nuclear island. The staff also reviewed the recommended diagrams that contain surcharge, static and dynamic lateral earth pressures, and hydrostatic groundwater pressures acting on plant safety-related below-grade walls. Since all the loading conditions and combinations are considered in evaluating the static and seismic lateral earth pressures acting on plant safety-related below-grade walls, the staff concludes that its concern regarding surcharge pressure from adjacent buildings acting on nuclear island below-grade walls is addressed. Accordingly, the staff considers RAI 6006, Question 02.05.04-23, resolved.

<u>Lateral Variability</u>

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.10.7 and related RAIs (RAI 6006, Question 02.05.04-9 and RAI 02.05.04-11 and RAI 7811, Question 02.05.04-30), as discussed in Section 2.5.4.4.4 of this SER. The staff's review concentrated on the applicant's evaluation of lateral variability in terms of stratigraphic and bearing pressure uniformity. The staff noted that the maximum bearing pressure difference is less than 20 percent. The staff concludes that soils supporting the nuclear island do not contain extreme variations in subgrade

stiffness. Consequently, the staff concludes that the AP1000 DCD criterion for lateral uniformity is satisfied.

Staff's Conclusions Regarding Static Stability

Based on the staff's review of the information in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.10 and the applicant's responses to the RAIs described in Section 2.5.4.4.10 of this SER, the staff concludes that the applicant has provided sufficient information in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.10, which includes a static and dynamic bearing capacity evaluation; total and differential settlement evaluation; and a lateral earth pressure evaluation to meet the standard design values and to satisfy the applicable requirements of 10 CFR Part 50 and 10 CFR Part 100.

2.5.4.4.11 Design Criteria and References

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.11 summarizes the AP1000 DCD site parameter criteria and compares them to the site-specific parameters presented in the Turkey Point Units 6 and 7 COL FSAR. Figure 2.5.4-3 of this report summarizes the critical parameters.

The staff reviewed the section of the Turkey Point Units 6 and 7 COL FSAR containing the geotechnical design criteria and determined that they contained sufficient details to meet the relevant requirements of 10 CFR Part 50 and Part 100. Based on its review the staff concludes that the applicant's design criteria and references for the Turkey Point Units 6 and 7 site are acceptable and meet the requirements of the applicable regulations.

Figure 2.5.4-3. Comparison of AP1000 Design Criteria to Turkey Point Units 6 and 7 Site Characteristics

	AP1000 DCD	Turkey Point Units 6 and 7	Turkey Point FSAR	Turkey Point within Site Parameter
Static Bearing Capacity	425 kPa (8,900 psf)	1,867 kPa minimum (39 ksf minimum)	2.5.4.10.2	Yes
Dynamic Bearing Capacity	1,675 kPa 35,000 psf	1,963 kPa minimum (41 ksf minimum)	2.5.4.10.2.1	Yes
Shear Wave Velocity	305 m/s (1,000 fps) over the footprint of the nuclear island at its excavation depth	1,759 m/s average with 1,392 m/s lower bound and 2,309 m/s upper bound (5,770 fps average with 4,566 fps lower bound and 7,575 fps upper bound)	2.5.4.7.2.1	Yes
Lateral Variability	Condition 2, site-specific assessment of subsurface conditions demonstrates that the bearing pressures below	Condition 2, the maximum bearing pressure difference is less than 20 percent.	2.5.4.10.7	Yes

	the nuclear island do not exceed 120% of those from the generic analyses of the nuclear island at a uniform site			
Liquefaction Potential	No liquefaction considered beneath the SC I and SC II structures and immediate surrounding area.	None: nuclear Island founded on concrete fill over rock; adjacent structures founded on compacted fill (to a minimum of 95 percent of modified Proctor maximum dry density) above rock; Soil under rock have negligible liquefaction potential.	2.5.4.8	Yes
Minimum Angle of Internal Friction of Foundation Soils	Greater than 35 degrees.	Nuclear Island founded on concrete fill over rock meeting the criteria	Not applicable	Yes

2.5.4.4.12 Techniques to Improve Subsurface Conditions

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.12, the applicant stated that its ground treatment will include over-excavation of unsuitable materials, and their replacement with compacted limerock fill and concrete fill. The applicant stated that groundwater control is required as part of the over-excavation of unsuitable materials and that it will be achieved by grouting. The applicant stated that grouting will be used to constrain the sizes of potential voids. The applicant provided details of the subsurface grouting program in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.4.5.5. The applicant stated that will prepare a thermal control plan, following ACI 207 guidelines, to minimize thermal cracking for the concrete fill to be placed under the nuclear island. The staff reviewed this information and concludes that the plan for subsurface improvements will ensure the stability of the foundation and the structures built at this site. The staff therefore concludes that the techniques presented to improve subsurface conditions of the Turkey Point Units 6 and 7 site are acceptable. Accordingly, the applicant's improvements satisfy the requirements of 10 CFR Part 100.

2.5.4.5 Post Combined License Activities

The applicant identifies the following ITAAC:

- ITAAC Table 3.8-5–ITAAC for Concrete Fill under Seismic Category I Structures
- ITAAC Table 3.8-6–ITAAC for Seismic Category I Structure Foundation Grouting

2.5.4.6 Conclusion

Staff reviewed the application and confirmed that the applicant has addressed the required information, and no outstanding information is expected to be addressed in Turkey Point Units 6 and 7 COL FSAR related to this section.

In addition, the staff compared the additional information in the Turkey Point Units 6 and 7 COL FSAR to the relevant NRC regulations, the guidance in Section 2.5.4 of NUREG–0800, and applicable NRC regulatory guides. The staff's review concludes that the applicant has provided sufficient information to satisfy the requirements of relevant NRC regulations. The staff determines that the applicant has adequately addressed COL Information Items PTN COL 2.5-1 through PTN COL 2.5-3, PTN COL 2.5-5 through PTN COL 2.5-13, PTN COL 2.5-16, and PTN COL 2.5-17 as it relates to the stability of subsurface materials and foundations.

The staff's review concludes that the applicant has adequately determined the engineering properties of soil and rock conditions underlying the Turkey Point Units 6 and 7 site through field and laboratory investigations. The applicant used the latest field and laboratory methods in accordance with the guidance in RG 1.132, RG 1.138, and RG 1.198 to determine the required site-specific engineering properties for the Turkey Point Unit 6 and 7 site and to ensure that those properties meet the design criteria outlined in the AP1000 DCD. In addition, the applicant will use the techniques including excavation, limerock fill and concrete fill, and grout to improve subsurface conditions. Accordingly, the staff concludes that the applicant has performed sufficient field investigations and laboratory testing to determine the overall subsurface profile and the properties of the soil and rock underlying the Turkey Point Unit 6 and 7 site. Specifically, the staff concludes that the applicant has adequately determined (1) the soil and rock static and dynamic properties through field investigations and laboratory tests, (2) the response of the soils and rocks to static and dynamic loading, and (3) the liquefaction potential of the soils.

As set forth above, the applicant presented and substantiated the necessary information to establish the geotechnical engineering characteristics of the Turkey Point 6 and 7 site. The staff reviewed the information and concluded that the applicant has performed sufficient investigations at the site to justify the soil and rock characteristics used in the AP1000 design, and the design analyses contain adequate margins of safety for the construction and operation of the nuclear power plant and meet the relevant requirements of 10 CFR Part 50, 10 CFR Part 52, and 10 CFR 100.23.

2.5.5 Stability of Slopes

2.5.5.1 Introduction

Turkey Point Units 6 and 7 COL FSAR Section 2.5.5 addresses the stability of all earth and rock slopes, both natural and manmade (cuts, fill, embankments, dams, etc.), whose failure, under any of the conditions to which they could be exposed during the life of the plant, could adversely affect the safety of the plant. The staff evaluated the following topics based on data provided by the applicant in the Turkey Point Units 6 and 7 COL 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 deemed necessary in accordance with 10 CFR Part 52.

SER Section 2.5.5 addresses slope stability information related to the Turkey Point Units 6 and 7 site. Section 2.5.5.2 of this report provides a summary of relevant geologic and seismic information contained in Section 2.5.5 of the Turkey Point Units 6 and 7 application.
Section 2.5.5.3 of this report provides a summary of the regulation and guidance used in its

application and by the staff to review the application. Section 2.5.5.4 of this report provides a review of the staff's evaluation Section 2.5.5. Section 2.5.5.5 of this report discusses any post combined license activities. Finally, Section 2.5.5.6 of this report provides an overall summary of the applicant's conclusions, as well as the staff's conclusions, restates any bases covered in the application, and confirms that the application meets the requirements defined in NRC regulations.

2.5.5.2 Summary of Application

Section 2.5.5 of the Turkey Point Units 6 and 7 COL FSAR addresses COL Information Items 2.5-14, "Stability of Slopes," and 2.5-15, "Embankments and Dams," of the AP1000 DCD.

- PTN COL 2.5-14

The applicant provided additional information in PTN COL 2.5-14 to address COL Information Item 2.5-14, 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 seismic Category I structures.

- PTN COL 2.5-15

PTN COL 2.5-15 addresses the provision of site-specific information about the static and dynamic stability of embankments and dams, the failure of which could adversely affect seismic Category I structures.

The applicant developed Turkey Point Units 6 and 7 COL FSAR Section 2.5.5 for the evaluation of slope stability at the Turkey Point Units 6 and 7 site based on information derived from site investigations, geotechnical characterization studies, and excavation and backfill profiles presented in Turkey Point Units 6 and 7 COL FSAR Sections 2.5.4.1 through 2.5.4.5. These investigations and studies included consideration of geologic features and characteristics, site exploration involving soil and rock boring and sampling, groundwater monitoring, surface geophysical testing, in situ testing, geotechnical test pits, geologic trench excavations, and laboratory testing; and geophysical surveys.

Supplemental Information

- PTN SUP 2.5-1

The applicant provided supplemental information in Turkey Point Units 6 and 7 COL FSAR Section 2.5, "Geology, Seismology, and Geotechnical Engineering," which provides summary information of detailed information in Turkey Point Units 6 and 7 FSAR Section 2.5.5, "Stability of Slopes," for the Turkey Point Units 6 and 7 site.

2.5.5.2.1 Slope Characteristics

Turkey Point Units 6 and 7 COL FSAR Section 2.5.5.1 presents information about the permanent and temporary slopes for plant construction. Figure 2.5.5-1 (Turkey Point Units 6 and 7 COL FSAR Figure 2.5.4-221) presents a profile of the finished site grade. The applicant stated that the current site is relatively flat with an approximate elevation at sea level and that the grade of the site will be raised to avoid the effects of design storm surge. The applicant

stated that the permanent finished slopes at the site are directed away from the power block, have a maximum grade of 0.5 percent and that significant movement or failure of these slopes will not adversely affect the safety of the nuclear power plant facilities. The applicant indicated that the grade change from the existing grade to the finished grade around the power block will be made with an MSE retaining wall. The applicant indicated that the MSE wall is no closer than 152 m (500 ft) away from the Seismic Category I structures and that failure of the MSE wall will not affect safety-related structures. The applicant indicated that Turkey Point Units 6 and 7 do not use safety-related dams or embankments.

Turkey Point Units 6 and 7 COL FSAR Subsection 2.5.5.1.2 indicates that a temporary reinforced diaphragm wall will provide support to the excavation and aid with groundwater control. The applicant indicated that failure of the temporary slope will not adversely affect the safety of the nuclear power plant facilities due to its distant location from seismic Category I structures and cooling canals.

2.5.5.2.2 Design Criteria and Analyses

The applicant stated that no slopes require analyses for stability.

2.5.5.2.3 Result of the Investigations

Turkey Point Units 6 and 7 COL FSAR Section 2.5.5.3 references FSAR Section 2.5.4 and a MACTEC report (MACTEC Engineering and Consulting, Inc., 2008) for the data, investigation and summary of the results of the subsurface investigation used for consideration of stability of the structures.

2.5.5.2.4 Properties of Borrow Material, Compaction and Excavation Specification

The applicant referenced Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.5 for information related to borrow material and compaction requirements. The applicant stated that it will develop the excavation specifications during the detailed design stage.

2.5.5.3 Regulatory Basis

The regulatory requirements for reviewing the applicant's discussion of stability of slopes are:

- 10 CFR 50.55a, "Codes and Standards," as it relates to the requirement 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," as it relates to the requirement 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. This regulation 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 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 100.23, “Geologic and Seismic SitingCriteria,” 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: To meet 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: To meet 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: To meet the requirements of 10 CFR Parts 50 and 10 CFR Part100, the applicant should describe the borings and soil testing carried out for slope stability studies and dam and dike analyses.

- Compacted Fill: To meet 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 geotechnical engineering characteristics should be consistent with appropriate sections from: RG 1.27, “Ultimate Heat Sink for Nuclear Power Plants,” RG 1.28, “Quality Assurance Program Requirements (Design and Construction),” RG 1.132, “Site Investigations for Foundations of Nuclear Power Plants,” RG 1.138, , “Laboratory Investigations of Soils 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,” and RG 1.206, “Combined License Applications for Nuclear Power Plants (LWR Edition).”

2.5.5.4 Technical Evaluation

The staff reviewed Sections 2.5.5 of the Turkey Point Units 6 and 7 site related to the stability of slopes as follows:

AP1000 COL Information Item

- PTN COL 2.5-14

The staff reviewed PTN COL 2.5-14 included under Section 2.5.5 of the Turkey Point Units 6 and 7 COL FSAR, related to the stability of all earth and rock slopes both natural and manmade (cuts, fill, embankments, dams, etc.) whose failure, under any of the conditions to which it could be exposed during the life of the plant, could adversely affect the safety of the plant. The COL information item in AP1000 DCD Section 2.5.5 states:

> Combined License applicants referencing the AP1000 design will address site-specific information about the static and dynamic stability of soil and rock slopes, the failure of which could adversely affect the nuclear island.

- PTN COL 2.5-15

The staff reviewed PTN COL 2.5-15 included under Section 2.5.6 of the Turkey Point Units 6 and 7 COL FSAR, related to the stability of embankments and dams, the failure of which could adversely affect the plant. The COL information item in AP1000 DCD Section 2.5.6 states:

> Combined License applicants referencing the AP1000 design will address site-specific information about the static and dynamic stability of embankments and dams, the failure of which could adversely affect the nuclear island.

The staff's evaluation of COL Information Item PTN COL 2.5-14 and COL 2.5-15 is presented below.

2.5.5.4.1 Slope Characteristics

Turkey Point Units 6 and 7 COL FSAR Section 2.5.5.1 provides the applicant's general discussion of the slope characteristics including information for permanent slopes and temporary slopes for plant construction. The applicant noted that the permanent finished slopes at the site are directed away from the power block, have a maximum grade of 0.5 percent and that significant movement or failure of these slopes will not adversely affect the safety of the nuclear power plant facilities.

The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.5.5.1, the site grade plan and foundation excavation sections as provided in Turkey Point Units 6 and 7 COL FSAR Section 2.5.4. The staff also examined the site during the site visit in May 2011 (ADAMS Accession No. ML111881052) and site audit in August 2013 (ADAMS Accession No. ML13248A497). The staff also reviewed the site boring logs and the site subsurface soil profile. The staff's evaluation of these inputs is in Section 2.5.4 of this SER.

The staff determines that (1) failure of the MSE wall will not affect safety-related structures because the MSE wall is not required to maintain the function of any Seismic Category I

structure, and there will be an ample distance of greater than 152 m (500 ft) between the MSE wall and the Seismic Category I structures to ensure that collapse of the MSE wall could not affect the SSCs of interest, and (2) failure of the temporary slope will not adversely affect the safety of the nuclear power plant facilities because of its distant location from seismic Category I structures and cooling canals. Based on these findings, the staff concludes that no slope failure at the site will adversely affect the safety of the nuclear power plant structures; and the applicant has provided sufficient information in Turkey Point Units 6 and 7 COL FSAR Section 2.5.5.1 to satisfy the applicable criteria of 10 CFR Part 50 and 10 CFR Part 100.

2.5.5.4.2 Design Criteria and Analyses

In Turkey Point Units 6 and 7 COLFSAR Section 2.5.5.2, the applicant noted that no slopes require analyses for stability. The staff considered the permanent slopes to be stable because the maximum permanent grade slope is 0.5 percent (0.3 °) and are directed away from the power block area. Based on this finding, the staff concludes that no slope failure at the site will adversely affect the safety of the nuclear power plant structures. Therefore, no slope stability analysis is necessary for the Turkey Point Units 6 and 7 site.

2.5.5.4.3 Results of the Investigations

Turkey Point Units 6 and 7 COL FSAR Section 2.5.5.3 provides references for the data, investigation and summary of the results of the subsurface investigation used for consideration of stability of the structures. SER Section 2.5.4 presents the staff evaluation of the applicant's subsurface investigation program and results. The staff concludes that the applicant's information satisfies the relevant requirements of 10 CFR Part 50 and Part 100.

2.5.5.4.4 Properties of Borrow Material, Compaction and Excavation Specification

In Turkey Point Units 6 and 7 COL FSAR Section 2.5.5.4, the applicant referred to Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.5 for information related to borrow material and compaction requirements. The applicant stated that it will develop the excavation specifications during the detailed design stage. The staff reviewed Turkey Point Units 6 and 7 COL FSAR Section 2.5.4.5, which describes the specific property requirements, site preparation, extent of excavation, fill and slopes, compaction requirements, and dewatering and excavation methods. The staff concludes that this information satisfies the relevant requirements of 10 CFR Part 50.

2.5.5.5 Post Combined License Activities

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

2.5.5.6 Conclusion

Staff reviewed the application and confirmed that the applicant addressed the required information, and no outstanding information is expected to be addressed in the Turkey Point Units 6 and 7 COL FSAR related to this section. In addition, the staff compared the additional information in the Turkey Point Units 6 and 7 COL FSAR to the relevant NRC regulations, the guidance in Section 2.5.5 of NUREG–0800, and applicable NRC regulatory guides. The staff conducted independent reviews of the investigations performed for slope stability studies and concluded that the applicant has provided sufficient information to satisfy the requirements of NRC regulations. The staff determines that the applicant adequately addressed COL

Information Items PTN COL 2.5-14 and PTN COL 2.5-15, as it relates to the stability of slopes, which met the design criteria and requirements specified in the AP1000 DCD.

The staff's review concluded that the applicant has presented and substantiated information to assess the stability of all earth and rock slopes, both natural and man-made, at the Turkey Point Units 6 and 7 site. The staff reviewed the site investigations related to slope stability and concludes that (1) there are no natural or man-made slopes that could adversely affect the Turkey Point Units 6 and 7 Seismic Category I structures, (2) failure of the MSE walls would not affect the safety-related structures (3) there are no dams or embankments on the site that could adversely affect the safety of the nuclear plant facilities, and (4) failure of temporary slopes will not adversely impact the safety of the nuclear power plant facilities. The staff therefore further concludes that the result of slope stability assessment performed by the applicant meets the requirements of 10 CFR Part 50, Appendix A (GDC 1 and GDC 2); 10 CFR Part 50, Appendices B and S; and 10 CFR 100.23. Accordingly, the staff concludes that the Turkey Point Units 6 and 7 site is suitable with respect to the criteria governing the stability of slopes and, therefore, considers Turkey Point Units 6 and 7 COL FSAR Section 2.5.5 acceptable.