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## SUBSECTION 2.5.1 LIST OF FIGURES (CONT.)

## 2.5.1 BASIC GEOLOGIC AND SEISMIC INFORMATION

PTN COL 2.5-1 The geological and seismological information presented in this subsection was developed from a review of previous reports for the existing Turkey Point units, published geologic literature, and interpretations of data obtained as part of the surface and subsurface field investigations.

This subsection demonstrates compliance with the requirements of 10 CFR 100.23 (c).

Information on the geological and seismological characteristics of the Turkey Point site region (200-mile radius), site vicinity (25-mile radius), site area (5-mile radius), and site (0.6-mile radius) is presented in this subsection. Subsection 2.5.1.1 describes the geologic and tectonic characteristics of the site region and site vicinity. Subsection 2.5.1.2 describes the geologic and tectonic characteristics of the site area and site. The geological and seismological information was developed in accordance with NRC guidance documents RG 1.206 and RG 1.208.

### 2.5.1.1 Regional Geology

This subsection provides information on the physiography, stratigraphy, structures, geologic history, and tectonic setting within the site region. The nomenclature used in this subsection is consistent with terms used by the Florida Geological Survey (Reference 253).

The regional geologic map (Figure 2.5.1-201) contains information on the geology within the site region. Summaries of these aspects of regional geology are presented in the following subsections to provide the framework for evaluation of the geological and seismological hazards (Subsections 2.5.1.2.4 and 2.5.1.2.5).

#### 2.5.1.1.1 Regional Physiography and Geomorphology

Units 6 & 7 are located within the Atlantic Coastal Plain physiographic region as shown in Figure 2.5.1-202. The ground surface in the region ranges from 3 feet below sea level to 345 feet above. The region’s geologic and tectonic setting is the product of a complex history of continental collisions and rifting followed by deposition of sediments upon the newly formed Florida platform. Site regional stratigraphy consists of Paleozoic and Mesozoic igneous, metamorphic, and sedimentary basement rock overlain by up to 15,000 feet of additional Mesozoic carbonate and evaporite sedimentary rock units (Figure 2.5.1-203), which are in turn overlain by up to 6000 feet of Cenozoic carbonate and siliciclastic sediments (References 210, 235, and 300).

#### 2.5.1.1.1.1 Atlantic Coastal Plain Physiographic Province

The Atlantic Coastal Plain physiographic province extends eastward from the fall line (the physiographic and structural boundary between the Coastal Plain province and the Piedmont province) to the coastline. The Atlantic Coastal Plain province is a low-lying, gently-rolling terrain developed on an eastward-dipping wedge of Cretaceous, Tertiary, and Quaternary age deposits, which are unconsolidated and semi-consolidated sediments (gravels, sands, silts, and clays) that thicken towards the coast. In general, the Atlantic Coastal Plain physiographic province is an area of lower topographic relief (Reference 314).

The Atlantic Coastal Plain physiographic province formed during the Mesozoic and Cenozoic in response to crustal extension, thinning, and plate separation. The basement beneath the Atlantic Coastal Plain province consist of metamorphic and igneous crystalline rocks and Paleozoic and lower Mesozoic (Triassic) sedimentary rocks. The basement surface slopes seaward with variations due to orogenic episodes, isostatic adjustments, igneous intrusion, and preexisting surface irregularity. The basement slopes reaches depths of 5 to 7 miles beneath the North Atlantic shorelines (Reference 354).

The Atlantic coastal margin consists of a broad, slowly subsiding basin separated by broad arches (ridges). The central Georgia-Florida platform has been structurally defined by the Ocala arch (Peninsular arch). During the Cenozoic, the Ocala arch was the site of carbonate accumulation (Reference 354).

The Florida Geological Survey subdivides the Atlantic Coastal Plain into three physiographic zones (Figure 2.5.1-202) (Reference 357). The geomorphologic features within the site region are within the Central and Southern Zones and are characterized as slopes, plains, spurs, and ridges (Figure 2.5.1-202). Each of these physiographic subregions is shown in Figure 2.5.1-202. Each of the physiographic provinces present within the site region is described in the following subsections.

The Southern Zone physiographic subregion is a broad, gently sloping plain with poor drainage that is less than 33 feet above sea level. Most of the subregions within this zone are below the piezometric surface in saltwater marshes and swamps overlain by peat; this area is known as the Everglades (Reference 306).

It is bounded on the east by the Atlantic Coastal Ridge and extends westward to Cape Sable and Bay of Florida. The physiographic sub-provinces within the Southern Zone of Florida are the Atlantic Coastal Ridge, Florida Keys, Everglades, Big Cyprus Spur, Immokalee Rise, Southern Slope, Southwestern Slope, and Reticulate Coastal Swamps.

The Central Zone physiographic subregion includes discontinuous, subparallel ridges that rise 197 feet above MSL+, are parallel to the Florida peninsula and are separated by broad valleys. These broad valleys contain numerous lakes as the result of groundwater dissolution of the limestone (Reference 306). The physiographic sub-provinces within the Central Zone of Florida are the Gulf Coastal Lowlands, Eastern Valley, Caloosahatchee Valley, Okeechobee Plain, DeSoto Plain, Polk Upland, Central Highlands, and Osceola Plain.

##### 2.5.1.1.1.2 Southern Zone Physiographic Subregion

###### 2.5.1.1.1.2.1 Atlantic Coastal Ridge Physiographic Sub-Province

The Atlantic Coastal Ridge physiographic sub-province is a low ridge of sand over limestone that ranges in elevation from approximately 10 to 50 feet above sea level (Figure 2.5.1-202). It averages approximately 5 miles wide and is breached in places by shallow sloughs (Reference 298). It is comprised of single and multiple relict beach ridges and bars (Reference 357).

The Atlantic Coastal Ridge most likely formed when sea level was approximately 30 feet higher than today. The eastern slope of the ridge resembles the present Continental slope because of a sea level regression caused by a rapid onset of glaciation. Most of the eastern coast of Florida is an erosional shoreline rather than a prograding one (Reference 357).

The narrow part of the Atlantic Coastal Ridge is a relict beach ridge that surmounts the crest of the remnant Pamlico offshore scarp (steep slope). The ridge and scarp are essentially preserved in their original form (Reference 357). The wider and higher relief of the Atlantic Coastal Ridge is due in part to deposition from terrigenous local sources. The terrigenous local sources consist of quartz sand with broken fragments of contemporaneous shells in the beach sands. The structural feature, the Pamlico scarp, contributes quartzose sand along the Atlantic Coastal Ridge (Reference 357).

#### 2.5.1.1.1.2.2 Florida Keys Physiographic Sub-province

The Florida Keys physiographic sub-province (Figure 2.5.1-202) is a narrow chain of small islands at the southern tip of the Florida peninsula. The Florida Keys is composed of Pleistocene reef sediments. The Florida Keys extends for approximately 150 miles from Miami southwest to Key West. It is bounded by the Atlantic Ocean and the Bay of Florida, inland waters, and the Gulf of Mexico (Reference 271).

A topographic high beneath Key Largo was the focus of reef growth (Reference 325). The Late Tertiary siliciclastic sediments underlying the Quaternary carbonate rocks appears to control the position and arc shape of the recent shelf and slope of southern Florida (Reference 325). Additionally, the arc pattern of the Florida Keys is related to the bathymetry of the shelf edge and the Florida current. The growth of patch reefs is dependent upon nutrient availability, sea level, and topography.

#### 2.5.1.1.1.2.3 Everglades Physiographic Sub-Province

The Everglades physiographic sub-province (Figure 2.5.1-202) extends from Lake Okeechobee southward toward the Florida Bay. It consists of the Everglades, Big Cyprus Swamp, Florida Bay, and coastal mangroves (References 298 and 306). The Everglades is a wetland prairie created by the overflow of Lake Okeechobee, whose water spreads in a slow-moving sheet flow across a slope of less than 2 inches per mile from Lake Okeechobee to the mangrove lined margins of southwest Florida near the Florida Bay and the Gulf of Mexico (References 298 and 315).

Elevations in the Everglades range from 14 feet near Lake Okeechobee to sea level at Florida Bay. Before development of the canals in the northern potion of the Everglades, water discharged from the Everglades into the Florida Bay, the Gulf of Mexico, and the Atlantic Ocean through small rivers in the Atlantic Coastal Ridge or as seepage and spring flow into Biscayne Bay (Reference 298).

The vegetative wetland community and landscapes consist of a central core of peat that extended from Lake Okeechobee to the Florida Bay. Organic soils (peat) overlie the limestone throughout most of the Everglades. The fibrous peat accumulates on limestones because the limestone can be dissolved down to the water table. This results in swampy conditions for the growth of fibrous swamp plants and their preservation as fibrous peat (Reference 357).

The water flowing through the Everglades is only a few inches deep, but is 50 miles wide. The predominant vegetation, saw grass, is flooded during the wet season (summer) and burned during the dry season (winter/spring). During flood periods, the movement of water causes tree islands to develop an alignment pattern parallel to the lines of surface water flow (Reference 298). Interspersed through the saw grass are deeper water sloughs where tree islands or hammocks appear. The coastal mangrove swamps form very thick, dense thickets at the coastline where the saw grass and cypress swamps meet (References 298 and 306).

###### 2.5.1.1.1.2.4 Big Cypress Spur Physiographic Sub-province

The Big Cypress Spur physiographic sub-province (Figure 2.5.1-202) is west of the Everglades. The land surface is flat except for low mounded limestone outcrops and small, oval, elongated depressions in the limestone. Water drains to the south and southwest through cypress strands into the coastal mangroves (Reference 298). The elevations are below 16 feet, and the physiography consists of prairies, marshes, and stunted cypress (Reference 217). The swamp is dominated by cypress, pine, and wet prairie. The Big Cyprus Spur receives approximately 50 inches of rainfall per year but does not have overland flow similar to that of the Everglades (References 298 and 306).

###### 2.5.1.1.1.2.5 Immokalee Rise Physiographic Sub-province

The Immokalee Rise physiographic sub-province (Figure 2.5.1-202) is north of the Big Cypress Spur, west of the Everglades, and south of the Caloosahatchee Valley. It appears to be a southern extension of Pamlico marine sand because it exhibits several relicts of Pamlico shoreline features. According to White (Reference 357), the Immokalee Rise was built as a submarine shoal that extended southward from a mainland cape at the south end of the DeSoto Plain. The Immokalee Rise is ringed with small peripheral lakes that formed as a result of limestone dissolution (Reference 357). Elevations range between 30 and 40 feet (Reference 217).

###### 2.5.1.1.1.2.6 Southern Slope, Southwestern Slope, and Reticulate Coastal Swamps Physiographic Sub-Provinces

The Southern Slope, Southwestern Slope, and the Reticulate Coastal Swamps physiographic sub-provinces (Figure 2.5.1-202) are located along the eastern shore of the Gulf of Mexico and mainland Florida along Florida Bay south of the Everglades and the Big Cypress Spur. The topography is at or near sea level, and the area consists of broad bands of swamps and marshes that are flooded by tides or by freshwater run off. Tidal marshes, sea grass beds, and mangroves develop in this region of Florida because of the low wave energy (Reference 298).

#### 2.5.1.1.1.3 Central Zone Physiographic Subregion

##### 2.5.1.1.1.3.1 Gulf Coastal Lowlands Physiographic Sub-Province

The Gulf Coastal Lowland physiographic sub-province (Figure 2.5.1-202) can be subdivided by the terraces created by marine regression of the Gulf of Mexico. The topography is dominated by broad marine plains and gentle depositional slopes; the regional slope steepens and narrows northward and becomes terraced. The main terraces in the Gulf Coastal Lowlands of Florida, from oldest to youngest, are the Wicomico, Penholoway, Talbot, and Pamlico (Reference 319). According to Walker and Coleman (Reference 354), these four terraces and three intervening cemented ridges represent the late-Pleistocene near shore environments. However, it has been suggested by Alt and Brooks (Reference 201), Lichtler (Reference 288), and Healy (Reference 270) that the elevation of the terraces above 100 to 170 feet within Florida are not representative of the Pleistocene marine terraces but of older Pliocene and upper Miocene deposits.

##### 2.5.1.1.1.3.2 Eastern Valley Physiographic Sub-Province

The Eastern Valley physiographic sub-province (Figure 2.5.1-202) is a broad flat valley in Seminole and Indian River counties. Its elevation varies from 20 to 30 feet above sea level. There are relicts of beach ridges that at one time constituted a regressional or progradational beach ridge plain (Reference 357).

The head of the St. Johns River consists of a broad swampy valley with lakes. The river flows through each lake along its longest axis. This suggests that at one time there was a standing body of water that has been filled with sediments and vegetation between the upper levels of the lakes that eventually formed the flat, swampy flood plain; the unfilled places became the current chain of lakes in the St. Johns River's headwaters (Reference 357).

Southward of the St. Johns River, the topography has approximately 5 feet of local relief throughout the area. This topography is bounded by the headwaters of the St. Johns River at the north, the scarp on the west, the St. Lucie Canal on the south, and Ten Mile and Green Ridges on the east. The surface of the entire area has elevations close to 25 to 30 feet (Reference 357).

#### 2.5.1.1.1.3.3 Caloosahatchee Valley Physiographic Sub-Province

The Caloosahatchee Valley physiographic sub-province is in both the Central and Southern Zones (Figure 2.5.1-202) and is part of the "Caloosahatchee incline." This broad gentle incline forms the valley wall of the Caloosahatchee River, which runs through the valley. The Caloosahatchee incline slopes eastward from the eastern toe of the Lake Wales Ridge at 50 to 60 feet elevation down to 30 to 35 feet at the edge of the Okeechobee Plain. The Caloosahatchee incline is a remnant of a submarine shoal (Reference 357).

#### 2.5.1.1.1.3.4 Okeechobee Plain Physiographic Sub-Province

The Okeechobee Plain physiographic sub-province (Figure 2.5.1-202) is within Okeechobee County and includes part of Lake Okeechobee. The southern part of this plain abuts the Everglades with Lake Okeechobee bisecting the plain. The Okeechobee Plain is divisible from the Everglades by its slightly better drainage and slightly steeper slope and a higher mineral content in its soils. The Okeechobee Plain slopes gradually south to approximately El. 20 feet at the northern shore of Lake Okeechobee (Reference 357).

#### 2.5.1.1.1.3.5 De Soto Plain Physiographic Sub-Province

The De Soto Plain physiographic sub-province (Figure 2.5.1-202) in DeSoto County is approximately 45 to 50 miles in length and varies in width from 25 (at the southern edge) to 50 miles (at the northern edge). Its northern edge is adjacent to the Polk Uplands. This sub-province has low relief; the northern edge has elevations of 75 to 90 feet; the southern edge has an elevation of 60 feet (Reference 357). The De Soto Plain is a submarine plain formed during Wicomico time (Reference 357).

The Peace River transverses the De Soto Plain and entrenches into the plain 30 to 40 feet. The DeSoto Plain consists of a line of elongated cypress swamps underlain by clay deposits (Reference 217). The relict depositional environment is that of a lagoon that existed during the emergence of the De Soto Plain. The plain consists of Long Island Marsh, Rainsy Slough, and Valley of Fisheating Creek (Reference 357).

#### 2.5.1.1.1.3.6 Polk Upland Physiographic Sub-Province

The Polk Upland physiographic sub-province is within Polk County. It is surrounded by the De Soto Plain on the south, the Gulf Coastal Lowland on the west, the valley of the Hillsborough and upper Withlacoochee Rivers on the north, and by the Lake Wales Ridge on the east. The Winter Haven and Lakeland Ridges rise from its surface from the northeast. The elevation of the Polk Upland ranges from 100 to 130 feet (Reference 357).

From the south, a ridge separates the Polk Upland from the De Soto Plain. The ridge turns 90 degrees north at the southwestern corner of the Polk Upland and terminates approximately halfway on its western side. The edge of the ridge is approximately El. 75 to 85 feet, and the crest is above El. 100 feet (Reference 357). A second ridge is located at the northern end of the western boundary of the Polk Upland and a third irregular ridge is located at the southern boundary. These ridges are most likely erosional marine scarps formed as Gulf of Mexico shorelines during Wicomico sea level (Reference 357). The Peace, Manatee, Little Manatee, and Alafia streams all originate in the Polk Upland with their respective branching tributaries.

2.5.1.1.1.3.7 Central Highlands Physiographic Sub-Province

The Central Highlands physiographic sub-province consists of localized areas of high grounds such as the Lake Wales, Winter Haven, and Lake Hendry Ridges (Figure 2.5.1-202). These ridges surround the Polk, Lake, Sumter, and Marion Uplands; the St. Johns River; and the Central, and Western Valleys. The Central Highlands are comprised of parallel north-south ridges that are remnants of beach and sand dune systems associated with Miocene, Pliocene, or early Pleistocene shorelines (Reference 357). The larger areas of relief are the Lake Wales, Brooksville, Lakeland, Winter Haven, Lake Hendry, Mount Dora, and DeLand Ridges; and the Fairfield and Ocala Hills (Reference 357). The ridges are all long, narrow, and elongated in the same orientation of the relict beach ridges along the eastern shore of the peninsula. The region consists of xeric (arid) residual sand hills, beach ridges, and dune fields interspersed with numerous sinkhole lakes and basins caused by the dissolution of the underlying limestone bedrock (Reference 357).

2.5.1.1.1.3.8 Osceola Plain Physiographic Sub-Province

The Osceola Plain physiographic sub-province (Figure 2.5.1-202) extends southeasterly through eastern Okeechobee County, extreme southwestern St. Lucie County, and into western Martin County. It is bounded on the west and northwest by the Lake Wales Ridge and the southern ends of the Mount Dora and Orlando Ridges. On the northeast, east, and south it is bounded by an outward-facing erosional ridge (Reference 357). The Osceola Plain reaches approximately 90 to 95 feet in elevation near its northern edge. It reaches an elevation of 80 feet east and northeast of Lake Kissimmee. Its local relief is very small, encompassed within the 10 feet between elevations 60 and 70 feet (Reference 357).

The Kissimmee River passes roughly west of the Osceola Plain. South of Lake Kissimmee for 25 miles, the river occupies the valley. North of Lake Kissimmee, several lakes occupy most of the Osceola Plain (Reference 357). The Arbuckle Creek on the western side of the Osceola Plain (west of the Bombing Range Ridge) drains Lake Arbuckle into Lake Istokpoga below the southern bounding scarp of the Osceola Plain (Reference 357).

2.5.1.1.1.4 Suboceanic Physiographic Provinces

2.5.1.1.1.4.1 Continental Shelf

The Continental Shelf physiographic province (Figure 2.5.1-202) is the submerged continuation of the Atlantic Coastal Plain province and extends from the shoreline to the Continental Slope. The shelf is characterized by a shallow gradient to the southeast (Reference 335) and many shallow water features that are relicts of lower sea levels.

The Florida Platform portion of the Continental Shelf consists of shallow platforms covered with Pleistocene carbonate bedrock. The Holocene sediments vary in thickness and morphologic features. Due to fluctuation in sea level, suboceanic environments have been exposed, resulting in the dissolution of carbonates. The Continental Shelf within the Florida Platform consists of the narrow eastern Florida Shelf, the Bahamas Bank, and the West Florida Shelf (Reference 354).

The narrow eastern Florida Shelf merges southward into the Florida reef tract. On its seaward side is a steep, abrupt slope that forms the edge of the Straits of Florida. The Straits of Florida and Florida Bay morphology consist of a back reef environment composed of worm reefs, grass covered mud banks and algal flats. The active reef tract faces the Straits of Florida and is composed of reef facies. The reef facies are actively growing in response to Holocene sea level rise (Reference 354).

The Bahamas Bank, consisting of the Greater and Little Bahama Banks, is separated from the Florida peninsula by the Straits of Florida. The Bahamas Bank is composed mostly of shallow Continental Shelf and lagoon sediments. The windward side is composed of a small percentage of active reefs. The reef pinnacles are found on the outer margin of the shelf. The sediment surface consists of grass flats of carbonate sands with relict sand bodies and oolite shoals (Reference 354).

The west Florida Shelf is a broad smooth shelf with widths of nearly 124 miles and little morphologic variability. Vertical relief is shown in the coral algae ridges (Reference 354).

#### 2.5.1.1.1.4.2 Continental Slope

The Continental Slope in the southern Florida region has three distinct physiographic units: the Florida-Hatteras Slope, the Blake Plateau, and the Blake Escarpment (Figure 2.4.6-203 and Figure 2.4.6-204). At depths of 131 to 262 feet, the shelf-edge breaks at the outer edge of the Florida-Hatteras slope. It has a gradient of less than 3 degrees. The next break in slope is at depths of 2625 to 4593 feet and is associated with the Blake Escarpment. It has a gradient of 2 to 6 degrees. Southward, the average gradient abruptly increases to a slope greater than 20 degrees (Reference 354). The Continental Slope in south Florida does not have a complex canyon morphology of mass wasting and canyon incisement. According to Popenoe et al. (Reference 323) and Cashman et al. (Reference 220), the slope is relatively smooth and erosional in nature. The slope consists of a thin layer of Pleistocene and Holocene sediments.

The Continental Slope at the southern tip of the Florida Platform is very steep. It connects with the ocean floor and has a depth of 4921 to 6562 feet. There are small carbonate fans on the floor of the Straits of Florida, which are derived from canyons cutting into the Continental Slope extending from the shelf-edge reef to the slope’s base (Reference 354).

The southwestern/western Continental Slope margin is defined by a double reef growth. The shallow reef lies between 427 and 492 feet and the deep reef ranges between 689 and 984 feet in depth. The slope increases in depths between 3281 and 6562 feet, exceeding 20 degrees, forming the West Florida escarpment. The West Florida escarpment is the result of sediments deposited in a shallow water, back reef, lagoon environment (Reference 354).

#### 2.5.1.1.1.5 Physiography of Cuba and the Bahamas

The geomorphology of the Bahama Platform involves the accumulation of carbonate sediments, which were deposited by currents, waves, and winds and the erosion of the land surfaces. The two major landforms which dominate the Bahamas are composed of marine and terrestrial deposits (Reference 260). Unlike the Bahama Platform, the physiography of Cuba involves mountainous terrain. Cuba's mountains are derived from several tectonic units that have different origins; these include the southern paleo-margin of the Bahama Platform, tectonic terranes derived from the Yucatan borderland, Cretaceous and Paleogene island arc complexes, Mesozoic ophiolites and Late Tertiary neoautochthonous (less deformed sedimentary rocks) units (Reference 215).

#### 2.5.1.1.2 Regional Stratigraphy and Geologic History

The stratigraphy described in this subsection has been developed from the analysis of surface and subsurface geologic and geophysical investigations performed at the site and reported in peer-reviewed publications. The stratigraphy of southern Florida is characterized by a thick sequence of Jurassic to Holocene sediments that lie unconformably on Jurassic basement volcanic rocks. Although most of the units in the sedimentary sequence are carbonates, deposition of Appalachian derived siliciclastic sediments occurred during the Miocene and Pliocene. The oldest stratum exposed at the surface in the southern Florida region is the Miocene-Pliocene Peace River Formation that outcrops in Hardee and Desoto counties (Reference 201).

##### 2.5.1.1.2.1 Basement

In Florida, the term "basement" refers to the suite of rocks below a regionally recognizable and tectonically significant unconformity that separates pre- to syn-rift rocks from overlying sedimentary rocks deposited during post-rift passive margin sedimentation. This designation accurately constrains the basement to rocks below the Mesozoic post-rift unconformity of the Florida subsurface (Reference 210). Two basement lithologic regions (Figure 2.5.1-214) are recognized in southern Florida: a suite of rocks collectively known as the Suwannee terrane and a southern early Middle Jurassic volcanic province (References 235 and 210). Figure 2.5.1-203 shows the south Florida basement stratigraphy.

The Suwannee terrane is composed of (a) the Osceola volcanic complex, (b) the Osceola Granite, (c) the St. Lucie complex of high-grade metamorphic rocks, and (d) a suite of Paleozoic sedimentary rocks (Figure 2.5.1-203).

The Osceola volcanic complex is a group of calc-alkaline, felsic, low-grade meta-igneous rocks (Reference 235). Dallmeyer (Reference 235) has correlated rock of this complex to a West African calc-alkaline meta-igneous sequence dated at 650 Ma.

The Osceola Granite is composed of undeformed diorite to batholithic granodiorite (Reference 250). This rock is described as having a granitic texture with coarse pink sodic plagioclase feldspar, abundant quartz, albite-oligoclase, and some potash feldspar, ilmenite, and apatite (Reference 300). Depth to the top of this granite is approximately 8000 feet in Osceola County (Reference 210). The granite records a Sr/Sr age of 530 million years ago (Ma) (Reference 235).

Immediately south of, and associated with, the Osceola Granite, is the St. Lucie metamorphic complex, which consists of an amphibolite-grade sequence composed of foliated amphibolite, schist, and quartz diorite. Depth to the amphibolite in St. Lucie County is approximately 12,500 feet. The rocks in this complex record Ar/Ar ages of 508 to 513 Ma (Reference 235).

The Paleozoic sedimentary suite is composed of a succession of undeformed, Lower Ordovician quartzitic sandstones and Middle Devonian black shales and siltstones overlying the Peninsular arch (Reference 210). Muscovite within the sandstone records an Ar/Ar age of 504 Ma (Reference 235). This suite of rocks is mapped in the subsurface just outside the site region.

A genetic relationship between the southern Florida basement (Figure 2.5.1-214) and West African rock sequences has been suggested by many investigators (References 210, 235, 333, and 338) based on:

- A correlation between lithology and radiometric age of calc-alkaline felsic igneous complex in central Florida and West Africa (Reference 235)
- A correlation between radiometric ages and petrography of the Osceola Granite with post-tectonic granite plutons in Guinea West Africa (Reference 235)
- A correlation of the Paleozoic sedimentary sequence overlying the Peninsular arch with the lithology, radiometric ages, paleontology, and paleomagnetic evidence found in rocks in Senegal and Guinea (Reference 235)
- A correlation between the stratigraphic, geochronologic, and geochemical data of the southern Florida tholeiitic volcanic sequence and Liberian tholeiites that indicates both may have had the same parental magma (Reference 210)

The lithologic and geochronologic characteristics described above suggest that these Florida basement provinces originated in West Africa and represent a fragment of Gondwana that accreted to Laurentia during the late Paleozoic formation of Pangaea (References 210, 333, 235, and 338). The Floridian piece of Africa remained attached to North America when Pangaea broke apart during the opening of the Atlantic Ocean in the Jurassic (References 333 and 235) (see Subsection 2.5.1.1.3.1). This fragment of the African plate provided the base for the development of a carbonate platform that included the Florida platform (Reference 338).

The second basement lithologic region, the southern Jurassic volcanic province (Figure 2.5.1-214) is composed of basalt and diabase and underlies most of the southern half of the Florida peninsula. Diabase and basalt samples contain approximately 50 percent plagioclase, 40 percent clinopyroxene (augite), 10 percent accessory minerals or alteration products, and occasional trace amounts of olivine. Depth to the top of the mafic volcanic rocks in the southern Florida basement ranges from 9500 to 15,000 feet (References 210 and 300). The K/Ar ages measured in the mafic volcanic rocks average 192 Ma, and the Ar/Ar ages average 194 Ma. Petrographic evidence (fine-grained and vesicular textures) suggests that emplacement and crystallization of these tholeiitic melts was at or near the surface. Similar differentiation patterns and fractionation assemblages, as well as proximity and age, suggest that the Florida tholeiite is part of the Eastern North American tholeiitic suite (Reference 210).

Similar to Florida, the base of the carbonate Bahama platform was formed in the Early Jurassic by the rifting of Pangaea and may rest on Jurassic-age volcanoclastics. A marked radial pattern of diabase dikes centered in the Bahama Platform has been interpreted to be the result of the rise of a mantle column or plume that may have been instrumental in initiating the breakup of Pangaea (Reference 333).

Due to the number of terranes identified on Cuba, Iturralde-Vinent (Reference 276) concludes that the geological framework of the Cuban archipelago is by far the most complex among the Caribbean islands. Although now part of the North American plate, Cuba contains several units that have different origins, including the southern paleomargin of the Florida-Bahama platform. Northern Cuba contains three domains: a volcanic arc terrane, a northern ophiolite belt, and the passive continental margin of North America. The continental margin of the North American plate collided with terranes previously belonging to the westernmost segment of the Cretaceous Greater Antilles volcanic arc in late Paleocene to early Eocene time (Reference 215). Subsurface investigations have shown that the basement varies beneath each of these domains. In northern Cuba, the basement for the passive North American continental margin is described by Cobiella-Reguera (Reference 223) as Jurassic terrigenous siliciclastic basinal deposits intruded in several places by diabasic sills.

Due to the fundamental differences in the geologic terranes of the Florida, Bahama, and Cuban basements, the following subsections focus on the regional stratigraphy and geologic history of the Florida platform only.

#### 2.5.1.1.2.2 Mesozoic

During the Early Mesozoic, the supercontinent of Pangaea began to split as new sea floor began to spread outwards on both sides of a mid ocean ridge to form the new Atlantic Ocean basin. This action forced the North American continental plate away from Africa (Reference 285). During the mid-Mesozoic, the basement rocks of Florida were a fragment of the African plate. As the Atlantic Ocean opened due to rifting, a portion of the African plate remained attached to the North American plate and became the base for the Bahama and Florida platforms. The Early Jurassic volcanic rocks in southern Florida are interpreted as transitional crust developed during this rifting (Reference 282). The basaltic crust shrank as it cooled. During the cooling and shrinking period, sediments were trapped in the basin. The weight of the sediments in the basin caused the crust beneath the basin to sink. This process of shrinking/cooling/sinking developed the Florida platform during the Cretaceous. The carbonate platform of Florida formed as the result of the build up of various marine organisms in shallow marine waters with exposures to light (Reference 285). By the beginning of the Late Cretaceous, the Bahama and Florida platforms were separated by the Straits of Florida. Subsequent to rifting, the area has generally been a stable site of carbonate deposition void of tectonic activity. During the Mesozoic and early Cenozoic, evaporites were intermixed with the carbonates. The presence of widespread evaporitic sediments, including gypsum, anhydrite, and some halite, indicates that water circulation within the carbonate environments was restricted periodically (Reference 338).

The oldest Mesozoic sediments in the site region are Late Jurassic-age clastics, possibly of continental origin; these basal clastics were deposited on the Jurassic basement. The Mesozoic sedimentary section in southern Florida averages approximately 10,000 to 12,000 feet thick and consists of approximately 7000 to 9000 feet of Late Jurassic through Early Cretaceous rocks and 3000 feet of Late Cretaceous rocks (References 322 and 363). The regional Mesozoic stratigraphic section is shown in Figure 2.5.1-203. Figures 2.5.1-204 and 2.5.1-206 provide geologic cross sections illustrating the regional Mesozoic stratigraphy.

Similar to Florida, the base of the carbonate Bahama platform was formed in the Early Jurassic by the rifting of Pangaea (Reference 333). Crustal spreading associated with the opening of the Atlantic Ocean in the mid Jurassic carried the Bahama platform westward on the trailing edge of the North American plate (Reference 352). Growth of the carbonate platform in the Bahamas was initiated as early as the Jurassic and has continued until the Holocene, controlled primarily by eustatic sea level changes (Reference 333). Shallow shelf and platform carbonate deposition continued essentially uninterrupted on the Bahama platform from the Early Cretaceous until the present. The carbonate shelves and platforms were often fringed along their basinal margins by high-energy shoals, rudist-dominated reef buildups, and barrier islands interrupted by tidal channels and passes. Behind the barrier islands, banks, patch reefs, and occasional evaporites were often formed in intrashelf basins and back-reef lagoons (Reference 333). Based on their similar depositional environments and marine physiography and geomorphology, Hoffmeister et al. (Reference 272) states that the geologic features of Florida and the Bahama platforms are mirror images of each other. Mesozoic sediments are largely shallow water carbonates with some evaporites. Based on deep drilling and seismic reflection data, the base of Upper Jurassic carbonates is at a depth of approximately 15,000 feet and the top of Mesozoic sediments ranges in depth from approximately 3200 to 8000 feet (References 244, 279, and 352).

Northern Cuba contains three Mesozoic domains: a volcanic arc terrane, a northern ophiolite belt, and a passive continental margin of North America. The volcanic arc terrane is mainly composed of Cretaceous volcanics with older tholeiitic lavas, while the northern ophiolite belt is a huge mélange of Upper Jurassic through Lower Cretaceous rock intermingled along the northern part of Cuba. The Mesozoic passive continental margin of North America consists mainly of Jurassic through Cretaceous, sedimentary sequences of neritic, slope, and basinal deposits. All begin with Middle Jurassic evaporites upon which are deposited a thick (4000 to 6000 feet) sequence of carbonates and anhydrites (Reference 223). Lopez Rivera et al. (Reference 289) confirm up to 6000 feet of carbonate Jurassic-Cretaceous sediments are present beneath northern Cuba. This northern Cuba Mesozoic carbonate complex can be correlated with the standard stratigraphic section in Florida. Based on subsurface geologic investigations, Winston (Reference 364) believes that (a) three anhydrite beds in Cuba correlate with the thick anhydrites in Florida's Punta Gorda Anhydrite, Pumpkin Bay Formation, and Bone Island Formation; (b) a limestone-anhydrite section in Cuba appears to correlate with the Pumpkin Bay Formation in Florida; and (c) three limestone intervals in Cuba seem to correlate with portions of the

Rattlesnake Hammock, Pumpkin Bay, and Bone Island Formations in Florida (Figure 2.5.1-203). Iturralde-Vinent (Reference 275) similarly correlates the Bahama Platform carbonate facies with Cuban sedimentary units. His generalized stratigraphic column for neoautochthonous units in northern Cuba shows basement rocks overlain by Lower to Middle Jurassic siliciclastics and in turn by Upper Jurassic evaporites. These units are overlain by shallow and deep water Cretaceous pelagic limestones with chert and calcareous shale that correspond to units of the Bahama platform. A lack of sediments indicates that a hiatus in deposition probably occurred at the end of the Mesozoic (Reference 275).

2.5.1.1.2.2.1 Triassic

No Triassic age units have been identified in the subsurface of southern Florida (Reference 338).

2.5.1.1.2.2.2 Jurassic

The Florida carbonate platform began to develop following the establishment of a continental base in North America. Knowledge of the Mesozoic sequence is principally derived from limited oil exploration borings and geophysical data reported in the literature (References 205, 207, 321, 322, and 363). Scott (Reference 338) indicates that no sedimentary rocks older than Middle Jurassic exist in southern Florida (Figure 2.5.1-203).

The Peninsular arch and other structural/topographic high points controlled the type and distribution of carbonate depositional facies of Jurassic and Cretaceous sediments including reef complexes that onlapped and wedged or pinched out against these bathymetric highs. A major barrier reef complex of continual reef growth existed in southern Florida from the Cretaceous to Holocene. The presence of nearly continuous carbonate-evaporite cyclical deposition from the Jurassic to the present indicates that sedimentation in the southern Florida basin kept pace with subsidence (Reference 322). Several wells have been drilled in the southern Florida basin through carbonate and evaporite sequences to depths as much as 5300 feet below the Punta Gorda Anhydrite. The deepest well penetrated igneous basement rocks at a total depth of 18,670 feet (Reference 207).

The Upper Jurassic and Lower Cretaceous Wood River Formation is the stratigraphically lowest sedimentary unit in southern Florida and rests unconformably on rhyolite porphyry dated at 189 Ma (Reference 321). A 100- to 150-foot-thick clastic unit forms the basal part of the Wood River Formation and consists of dark-red shale, sandy dolomite, and fine- to coarse-grained arkosic sandstone and calcareous sandstone. These basal clastic units may represent fan, fan-delta, and fluvial-lacustrine or marine deposits. Overlying these clastic rocks is a thick sequence of anhydrite, dolomite, and limestone with occasional interbedded salt stringers, indicating marine transgression. Marine beds are predominant in the formation, and the depositional environment, especially in the southern part of the depositional area, probably favored reef growth (Reference 321). The dolomite is microcrystalline and brown with relict oolitic texture (Reference 363). Interbedded anhydrite, salt stringers, and micritic limestones act as impermeable layers within the more porous dolomite (Reference 322). The thickness of the Wood River Formation ranges from 1700 to 2100 feet and is generally found at depths exceeding 15,000 feet (Reference 207).

2.5.1.1.2.2.3 Cretaceous

A major barrier reef complex of continual reef growth existed in southern Florida from the Cretaceous to Holocene (Reference 322). From the Late Jurassic (161 Ma) through the Early Cretaceous (99 Ma), the continental margin was occupied by a carbonate complex that restricted marine circulation in some areas. In the southeast, this barrier caused the deposition of lagoonal carbonates and anhydrites that formed the Bone Island and Pumpkin Bay Formations and the Glades, Ocean Reef, Big Cypress, and Naples Bay Groups (Figure 2.5.1-204). Carbonate-evaporite deposition in the south ended at the close of the Early Cretaceous and was followed by the deposition of chalk and chalky limestone of the Late Cretaceous Pine Key Formation. By the middle of the Late Cretaceous, the Rebecca Shoal barrier reef had appeared on the upthrown northern side of the straits. This barrier reef expanded to encircle the Florida peninsula completely. Winston (Reference 362) indicates that following this encirclement, the Paleocene (65 to 56 Ma) Cedar Keys Formation lagoonal dolomite-anhydrite appears to have been deposited within this enclosed environment.

The Lower Cretaceous Bone Island Formation conformably overlies the Upper Jurassic Wood River Formation. The Lower Cretaceous Bone Island Formation is a sparsely oolitic brown limestone with occasional similarly textured dolomites and anhydrites (Reference 207). Winston (Reference 363) and Applegate et al. (Reference 207) indicate the Bone Island Formation is capped by a regionally persistent 200-foot-thick anhydrite layer and contains a 100-foot-thick lens of dolomite in the type section (well). The Bone Island Formation is approximately 1300 to 2000 feet thick in southern Florida (References 207 and 363).

The Lower Cretaceous Pumpkin Bay Formation conformably overlies the Cretaceous Bone Island Formation. The Pumpkin Bay Formation is composed of limestone, except at its northern limit, where dolomite is the dominant lithology. A 350-foot-thick dolomite zone occurs in the middle and upper parts of the formation and exhibits pinpoint intercrystalline to vuggy porosity (Reference 322). The limestone is brown and sparsely oolitic with occasional oolitic textured dolomite and two thick (200 feet) anhydrite lenses (Reference 363). Pollastro and Viger (Reference 321) also describe organic-rich beds in the upper Pumpkin Bay Formation. Anhydrite and dolomite are predominant in the lower part of the formation (Reference 207). Within the Florida peninsula, the Pumpkin Bay Formation is as much as 1200 feet thick and thickens westward into the southern Florida basin depocenter. Onshore, the Pumpkin Bay Formation is found at depths from approximately 12,500 to more than 15,000 feet (Reference 321).

The Lower Cretaceous Glades Group conformably overlies the Pumpkin Bay Formation. The Glades Group consists of the Lehigh Acres Formation and Punta Gorda Anhydrite and continues a lagoonal carbonate depositional environment. The Lehigh Acres Formation conformably overlies the Cretaceous Pumpkin Bay Formation. The Lehigh Acres Formation is divided into the basal West Felda Shale Member, the Twelve Mile Member, and the uppermost Able Member. The members represent a backreef depositional cycle of limestone, dolomite, and anhydrite with a total thickness that varies from 530 to over 700 feet (References 207 and 363). The West Felda Shale Member consists of dark gray, micaceous, calcereous shale with thin interbeds of brown, micritic limestone up to 200 feet thick. The overlying Twelve Mile Member is composed of relatively thin limestone beds within the main thick, vugular, porous dolomite unit. The Able Member consists of a regionally persistent white to gray anhydrite interbedded with limestone and occasional dolomite beds (References 205 and 207). The Lower Cretaceous Punta Gorda Anhydrite of the Glades Group conformably overlies the Cretaceous Lehigh Acres Formation. Punta Gorda Anhydrite layers have been used as marker beds throughout the Gulf of Mexico and are divided into nine individual anhydrite beds traceable from southern Mississippi to southern Florida (Reference 317). Applegate et al. (Reference 207) describes the Punta Gorda Anhydrite as a series of anhydrite layers approximately 800 feet thick and indicates that it has been found at an elevation of –12,000 feet in Collier County. It serves as a regional impermeable seal for hydrocarbon deposits both above and below (Reference 207). Winston (Reference 363) also indicates the presence of salt stringers in the upper Punta Gorda Anhydrite.

The Punta Gorda Anhydrite beds appear to thicken and interfinger with carbonates of the Lower Cretaceous shelf edge reef. Paleontologic data indicate that these interbedded carbonates were deposited in water depths that ranged up to 300 feet. Carbonates and anhydrites were deposited simultaneously with carbonate patch reefs developing on crests of paleo highs while evaporites precipitated out of a hyper-saline solution on the flanks. Areas where poor anhydrite bed development occurs indicate areas of patch reefs. Some anhydrite beds are regional while others are more restricted. Isopach maps show that these beds were deposited with the long axis of the southern Florida basin parallel to the reef trend. Anhydrite deposition occurred where evaporation of restricted highstand waters was behind reefs that rimmed the shelf edge (Reference 317). The presence of micritic, calcareous mudstone immediately above the anhydrite provides evidence of the termination of marine regression (Reference 304).

The Lower Cretaceous Ocean Reef Group conformably overlies the Glades Group. The Ocean Reef Group consists of the Sunniland, Lake Trafford, and Rattlesnake Hammock Formations. The units of the Ocean Reef Group are typically composed of evaporites and carbonates formed during transgressive-regressive cycles (Reference 303). The units consist of limestones, anhydrites, and dolomites that have been subdivided into multiple formations and groups based on regionally persistent anhydrites that form the uppermost lithologic unit of each formation (Reference 363). Calcareous shales, mudstones, salt, and lignitic carbonaceous materials are also present, especially in the anhydrite and limestone intervals. The limestones range from white to gray to tan to dark brown and are usually micritic, chalky, and calcarenitic, with skeletal particles of gastropods, algae, and other fossils. The anhydrite is nodular, microcrystalline, or crystalline and is usually bedded. The dolomite crystals are euhedral to sucrosic and occur in approximately 30 percent of each formation (Reference 303).

The Sunniland Formation conformably overlies the Punta Gorda Anhydrite. The Sunniland Formation is the basal unit of the Ocean Reef Group. The formation is relatively uniform in thickness within the region and consists of limestone, dolomite, and anhydrite composed of reefs, shoals, carbonate mounds, bioherms, and related features (Reference 321). These shelf carbonates were deposited in beach and shoal-type environments along a high energy, reef-forming band between the shallow-water, low-energy chalky beds and the quiet, deep-water dark micrites to the southwest. Almost all of the effective porosity is on this northwest-southeast band where reef buildup occurred. Secondary dolitimization, which appears to be important in the higher porosity, decreases abruptly perpendicular from this band both to the northeast and the southwest (References 249 and 206). The upper Sunniland Formation represents a shoaling-upward depositional cycle that extends throughout onshore and offshore southern Florida. This slowly oscillating transgression-regression cycle continues to the top of the Sunniland Formation, where it gives way to a major marine regression with the deposition of the Lake Trafford Formation (Reference 304).

The lower Sunniland Formation is composed of brown and medium-dark-gray micritic and argillaceous limestones that are commonly algal laminated. The dark carbonate facies varies in thickness up to 150 feet and thins toward the eastern and southern margins of the southern Florida basin (Reference 321). The dark carbonate unit called the "rubble zone" in the lower Sunniland Formation is described as burrowed, fractured, and stylolitized. The lower zone is enclosed by impermeable, micritic, tidal-flat, calcareous mudstones above and sealed below by the Punta Gorda Anhydrite (Reference 320). At the base of the Sunniland Formation, at the top of the Punta Gorda Anhydrite, there is evidence of a slow marine transgression and the termination of a major regression (Reference 304).

The upper Sunniland Formation consist of isolated fossil-shell, skeletal-petal, porous, and permeable grainstone mounds enclosed by impermeable lagoonal mudstones, wackestones, nodular anhydrite beds, and micritic carbonates—some of which have been dolomitized (Reference 321). This facies may represent storm deposition as shoals in a regionally restricted, back-reef lagoonal area in a warm, shallow marine-shelf setting (References 249 and 302). Biotic abundance and content of the fragmented biotic material suggests that the debris mound facies were deposited on micritic tidal mud flats during a sea level rise (Reference 305). During a later regression, the upper portions of these porous shoal mounds were sub-aerially exposed, leached, and dolomitized during a low sea-level stand, further increasing the porosity of the upper Sunniland Formation carbonates. Individual mounds are between 40 and 100 feet thick (Reference 320). These highly porous bioclastic mounds accumulated along the southeastern coast of the Florida peninsula on subtle topographic/bathymetric highs that were probably related to underlying basement structure (Reference 320). Pollastro (Reference 320) also describes an anhydrite-cemented nonporous sabkha-like facies near the southern boundary of the upper Sunniland Formation that formed in supratidal arid conditions on restricted coastal plains above high tide level (Reference 321).

Pollastro et al. (Reference 322) indicates that the depth to the top of the Sunniland Formation in southern Florida is approximately 10,000 feet and increases to greater than 12,000 feet in the Florida basin to the southwest. The thickness of the Sunniland Formation in southern Florida is approximately 200 to 300 feet and increases toward the south (Reference 322).

The Lake Trafford Formation conformably overlies the Sunniland Formation. A major regression in the continuing oscillating transgression occurred with the deposition of the Lake Trafford Formation (Reference 304). The Lake Trafford Formation consists of a limestone-dolomite unit with a thin (<100 feet) anhydrite lens. Calcareous shales, mudstones, salt, and lignitic carbonaceous materials are also present. The Lake Trafford Formation is approximately 150 feet thick in southern Florida (Reference 363).

The Rattlesnake Hammock Formation conformably overlies the Lake Trafford Formation. The Rattlesnake Hammock Formation consists of a 200-foot-thick anhydrite cap underlain by cyclic deposits of limestone, anhydrite, dolomite, anhydrite, and limestone units successively. Calcareous shales, mudstones, salt, and lignitic carbonaceous materials are also present. The Rattlesnake Hammock Formation is approximately 600 feet thick in southern Florida (Reference 363).

The Lower Cretaceous Big Cypress Group conformably overlies the Rattlesnake Hammock Formation of the Ocean Reef Group. The Big Cypress Group consists of the Marco Junction, Gordon Pass, and Dollar Bay Formations. The units of the Big Cypress Group are typically composed of evaporites and carbonates formed during transgressive-regressive cycles (Reference 303). The units consist of limestones, anhydrites, and dolomites that have been subdivided into multiple formations and groups based on regionally persistent anhydrites that form the uppermost lithologic unit of each formation (Reference 363). Calcareous shales, mudstones, salt, and lignitic carbonaceous materials are also present, especially in the anhydrite and limestone intervals. The limestones range from white to gray to tan to dark brown and are usually micritic, chalky, and calcarenitic, with skeletal particles of gastropods, algae, and other fossils. The anhydrite is nodular, microcrystalline, or crystalline and is usually bedded. The dolomite crystals are euhedral to sucrosic and occur in approximately 30 percent of each formation (Reference 303).

The Lower Cretaceous Marco Junction Formation conformably overlies the Rattlesnake Hammock Formation. The Marco Junction Formation consists of a relatively thin (<100 feet) anhydrite cap underlain by a sequence of limestones and dolomites and a second thin anhydrite lens. The Marco Junction Formation is approximately 350 feet thick in southern Florida (Reference 363).

The Gordon Pass Formation conformably overlies the Marco Junction Formation. The Gordon Pass Formation consists of a thick (>100 feet) anhydrite cap underlain by a sequence of limestones and dolomites and a second thin anhydrite lens. Calcareous shales, mudstones, salt, and lignitic carbonaceous materials are also present. The Gordon Pass Formation is approximately 475 feet thick in southern Florida (Reference 363).

The Dollar Bay Formation is the uppermost unit of the Big Cypress Group; it conformably overlies the Gordon Pass Formation. The Dollar Bay Formation commonly consists of evaporite-carbonate beds of limestone, dolomite, and anhydrite formed during a transgressive-regressive cycle (Reference 321). The Dollar Bay Formation consists of reefs, shoals, carbonate mounds, bioherms, and related features, forming organic-rich calcareous units inter-bedded with the carbonates (Reference 322). The limestone, dolomite, and anhydrite units occur in a series of cycles that typically begin and end with anhydrite. Porous carbonate units were deposited as tidal shoal deposits and patch reefs in a tidal flat, lagoonal, restricted-marine setting and in a sub-tidal platform, open-marine setting (Reference 321). Environments from shallow shelf to euxinic are present (Reference 360).

The Dollar Bay Formation consists of a 55-foot-thick dark brown, fine crystalline dolomite with intercrystalline porosity that is typically found at the base of the formation. Above this lies a sedimentary cycle averaging 325 feet thick consisting characteristically of chalky dolomite and limestone interspersed with beds of fine-grained calcarenite (Reference 360). Leached limestone units (Reference 321) formed from isolated patch reefs (Reference 303) are present in the middle part of the Dollar Bay Formation. A porous dolomite unit forms the upper part of the formation (References 321 and 303). These units are capped with an impermeable tidal flat deposit of micritic, argillaceous lime mudstone and an uppermost anhydrite unit (Reference 321). The Dollar Bay Formation occurs at depths of more than 10,000 feet and averages 450 feet thick but ranges up to as much as 620 feet thick in some parts of the southern Florida basin (Reference 321). All contacts above, below, and within the Dollar Bay Formation are conformable (Reference 360).

The Lower Cretaceous Naples Bay Group conformably overlies the Big Cypress Group. The Naples Bay Group consists of the Panther Camp, Rookery Bay, and Corkscrew Swamp Formations. The units of the Naples Bay Group are typically composed of evaporites and carbonates formed during transgressive-regressive cycles (Reference 303). The units consist of limestones, anhydrites, and dolomites that have been subdivided into multiple formations and groups based on regionally persistent anhydrites that form the uppermost lithologic unit of each formation (Reference 363). Calcareous shales, mudstones, salt, and lignitic carbonaceous materials are also present, especially in the anhydrite and limestone intervals. The limestones range from white to gray to tan to dark brown and are usually micritic, chalky, and calcarenitic, with skeletal particles of gastropods, algae, and other fossils. The anhydrite is nodular, microcrystalline, or crystalline and is usually bedded. The dolomite crystals are euhedral to sucrosic and occur in approximately 30 percent of each formation (Reference 303).

The Panther Camp Formation conformably overlies the Dollar Bay Formation. The Panther Camp Formation consists of a thin (<100 feet) cap of anhydrite underlain by two limestone-dolomite units separated by an anhydrite layer. Calcareous shales, mudstones, salt, and lignitic carbonaceous materials are also present. The Panther Camp Formation is approximately 350 feet thick in southern Florida (Reference 363).

The Rookery Bay Formation of the Naples Bay Group conformably overlies the Panther Camp Formation. The Rookery Bay Formation consists of a thin (<100 feet) cap of anhydrite underlain by two limestone-dolomite units separated by a thin anhydrite layer. This, in turn, is underlain by a dolomite unit and a limestone unit. Calcareous shales, mudstones, salt, and lignitic carbonaceous materials are also present. The Rookery Bay Formation is approximately 500 feet thick in southern Florida (Reference 363).

The Corkscrew Swamp Formation of the Naples Bay Group conformably overlies the Rookery Bay Formation. The Corkscrew Swamp Formation consists of a thin (<100 feet) cap of anhydrite underlain by a dolomite unit and two limestone units separated by a second 100 feet thick anhydrite layer. Calcareous shales, mudstones, salt, and lignitic carbonaceous materials are also present. The Corkscrew Swamp Formation is approximately 450 feet thick in southern Florida (Reference 363).

The Upper Cretaceous Pine Key Formation conformably overlies the Corkscrew Swamp Formation of the Naples Bay Group and is the uppermost Mesozoic formation in southern Florida. Its lower contact is conformable in southern and eastern Florida, but unconformable to the west (Reference 333). The Pine Key Formation is essentially made up of two facies: (a) a white chalk and chalky limestone formed in a lagoonal environment that interfingers and is replaced by (b) the lower tongues of a regional barrier reef complex composed of tan, cream, light gray, and brown very fine microcrystalline to coarse crystalline euhedral and anhedral dolomite (References 366, 362, and 368). The reef facies is characterized by vugs and reports of cavities and wall collapse zones (References 369, 362, and 368). Neither evaporites nor dolomites are present within the lagoonal facies of the Pine Key Formation indicating that the Rebecca Shoals barrier-reef complex did not completely encircle Florida or otherwise restrict circulation during the Late Cretaceous (Reference 368). In the South Florida back-reef basin, deposition of the lagoonal chalk facies of the Pine Key Formation persisted until the barrier reef had completely encircled the Florida peninsula during the Paleocene (Reference 362). The Pine Key Formation is as much as 3000 feet thick in southern Florida at a depth of approximately 5500 to 6000 feet (References 363 and 367).

2.5.1.1.2.3 Cenozoic

The early part of the Cenozoic (the Paleogene, which consists of the Paleocene, Eocene, and Oligocene) consists of a depositional shallow marine environment of carbonate rocks (limestone, dolostone with some evaporites). These carbonate rocks include the Cedar Keys Formation, Oldsmar Formation, Avon Park Formation, Ocala Limestone, Suwannee Limestone, and part of the basal Arcadia Formation (Figure 2.5.1-205). The occurrence of gypsum and anhydrite during the Cenozoic indicates that seawater circulation in the shallow marine environment was periodically restricted (Reference 285). During the Cenozoic (65 Ma), sea level fluctuated +/- 100 feet above and below the present-day sea level (Reference 285).

The oldest Cenozoic sediment that outcrops in the site region is the Miocene-Pliocene Peace River Formation that outcrops in Hardee and Desoto counties (Figure 2.5.1-201). All deeper Cenozoic units occur only in the subsurface. The Cenozoic sedimentary section in southern Florida averages approximately 5000 to 6000 feet thick and consists of a thick sequence of carbonate deposition interrupted by Appalachian derived siliciclastic sediments during the Miocene and Pliocene (References 230, 251, 326, 328, 339, 341, 363, and 366). The regional Cenozoic stratigraphic section is shown in Figure 2.5.1-205. Figures 2.5.1-206, 2.5.1-207, 2.5.1-208, 2.5.1-209, and 2.5.1-210 provide geologic cross sections illustrating the regional Cenozoic stratigraphy.

The Cenozoic stratigraphy of southern Florida is described in the subsections below. The stratigraphy and geologic history of northern Cuba and the Bahama platform that fall within the site region are summarized in the following paragraphs. The generalized Cenozoic stratigraphy of northern Cuba (Reference 227) consists of synorogenic Paleocene and Early Eocene shales, clays, and limestone breccias that are in turn overlain by postorogenic sediments consisting of Late Eocene argillaceous limestones overlain by a thick sequence of Oligocene through Pliocene limestones (Reference 227). Iturralde-Vinent (Reference 275) identifies an unconformity that is followed by deposition of Paleocene submarine debris flows and Eocene calcareous shaly flysch. The Eocene-Oligocene contact is at a depth of approximately 4500 feet. The Oligocene unit consists of up to 600 feet of deep-water chalk and limestone that grades laterally into an arenaceous and shaly limestone deposited in marine water of intermediate depth. This is overlain by 400 to 1000 feet of Miocene sediments consisting of deep water marl, siltstone, and shaly limestone that grade into arenaceous and calcareous sediments with intercalated, fossiliferous sandy limestone deposited in a neritic environment (Reference 274). Late Tertiary deposits occur in the northern coastal area and dip gently toward the north. Miocene rocks are divided into marl and carbonate units. Late Miocene to Pliocene deposits are poorly developed and Pleistocene rocks include shelf and coastal carbonates that in places have been uplifted into terraces (Reference 276).

A review of paleogeography developed by Salvador (Reference 333) from a combination of seismic profiles and drilling data indicates that shallow shelf and platform carbonate deposition on the Bahama platform continued essentially uninterrupted from the Lower Cretaceous until the present. The carbonate shelves and platforms were often fringed along their basinal margins by high-energy shoals, rudist dominated reefal buildups, and barrier islands interrupted by tidal channels and passes. Banks, patch reefs, and occasional evaporites were often formed in intra-shelf basins and back-reef lagoons. Unlike Florida, there was no deposition of siliciclastics to interrupt carbonate deposition (Reference 333). Hoffmeister et al. (Reference 272) states that the geologic, stratigraphic, and topographic features of the Florida and Bahama platforms are mirror images of each other. Cenozoic sediments are dominated by low magnesium carbonates with varying amounts of aragonite and dolomite. Based on deep drilling and seismic reflection data, the base of Cenozoic sediments ranges in depth from approximately 3200 feet (References 244 and 352) to 8000 feet (Reference 279). The Great Bahama bank is considered to be an excellent indicator of sea-level changes in the Atlantic. Eberli et al. (Reference 244) report that deep core borings on the Great Bahama bank indicate that the frequency and amplitude of sea-level changes have had a significant effect on the progradation, thickness, and diagenesis of the platform strata (Figure 2.5.1-211).

#### 2.5.1.1.2.3.1 Paleocene

By the Paleogene, the Appalachian Mountains had been gradually lowered by erosion. This not only reduced the supply of siliciclastic material, but also resulted in a lower stream gradient that limited the transport of siliciclastic sediments to the Florida platform. In addition, the currents in the Suwannee Straits (also known as the "Gulf Trough") acted as a barrier to siliciclastic transport. These currents protected the carbonate depositional environment of the Florida platform from the influx of siliciclastic sediments resulting in predominantly carbonate deposition during the Paleogene (References 325 and 338) (Figure 2.5.1-205).

The oldest Cenozoic formation on the Florida platform is the Paleocene Cedar Keys Formation that conformably overlies the Late Cretaceous Pine Key Formation (Figure 2.5.1-205). The Cedar Keys Formation is a lagoonal facies that occurs within the confines of the Rebecca Shoal barrier reef (Reference 367). In southern Florida, the Cedar Keys Formation consists primarily of gray dolomite, gypsum, and anhydrite with a minor percentage of limestone. The upper part of the Cedar Keys Formation consists of coarsely crystalline, porous dolomite. The lower part of the Cedar Keys Formation contains more finely crystalline dolomite interbedded with anhydrite (Reference 367). The configuration of the Paleocene sediments in peninsular Florida reflects depositional controls inherited from pre-existing Mesozoic structures such as the Peninsular arch and the southern Florida basin. The upper unit of porous dolomite in the Cedar Keys Formation forms the base of the Floridan aquifer system (see Subsection 2.4.12) throughout southern Florida (Reference 338), where it is found at elevations ranging from –3000 to –4000 feet (Reference 299). The Cedar Keys Formation varies from approximately 500 feet up to 2000 feet thick in southern Florida (References 363 and 326).

#### 2.5.1.1.2.3.2 Eocene

The Eocene Oldsmar Formation within southern Florida conformably overlies the Paleocene Cedar Keys Formation (Figure 2.5.1-205). The Oldsmar Formation primarily consists of a sequence of white, cream to gray, micritic to chalky limestones interbedded with tan to light-brown microcrystalline, vuggy dolomite. Dolomitization is usually more extensive in the lower part of the formation that is also noticeably unfossiliferous (References 286, 328, and 338). Gypsum and thin beds of anhydrite occur in some places. According to Winston (Reference 366), the top of the Oldsmar Formation in southern Florida is not identifiable or distinguishable on the basis of lithologic and faunal criteria. However, in southern Florida, the top of the uppermost thick dolomite unit is marked by glauconitic limestone (Reference 328). The so-called "Boulder Zone" forms part of the lower Oldsmar Formation and characteristically contains fractured dolomite (Reference 328). The Oldsmar Formation occurs in the subsurface at elevations ranging from –1950 to –2250 feet (Reference 326). It ranges from 500 to as much as 1500 feet thick in southern Florida (Reference 328).

The Eocene Avon Park Formation overlies the Eocene Oldsmar Formation (Figure 2.5.1-205). A regional unconformity in southern Florida has been proposed at the top of the Oldsmar Formation/base of the Avon Park Formation (Reference 326). The Avon Park Formation consists of cream to light-brown or tan, poorly indurated to well-indurated, variably fossiliferous, marine limestone (grainstone, packstone, and wackestone, with rare mudstone). These limestones are interbedded with light brown to orange-brown to dark brown or black, very poorly indurated to well indurated to dense, sucrosic to very fine to medium crystalline, fossiliferous (molds and casts), vuggy dolomites. Fine- to medium-grained calcarenite that is moderately to well sorted is intermittently present. Portions of the middle Avon Park Formation are very fine-grained with low permeability and act as confining beds separating the Avon Park Formation into upper and lower (formerly Lake City) parts (Reference 338). The fossils present include mollusks, foraminifera, echinoids, algae, and carbonized plant remains (References 339 and 328). The top of the Avon Park Formation is marked in some places by light-brown, finely crystalline to fossiliferous dolomitic limestone or dolomite, thinly interbedded with limestone. Thick intervals containing mostly dolomite, but in some places interbedded with limestone, are commonly present in the middle to lower part of the Avon Park Formation in southern Florida. High permeability due to fracturing is common, particularly in dolomite units. Gypsum and anhydrite also occur in the lower part of this formation in southwestern Florida, either as bedded deposits or more commonly as intergranular or pore filling material in the carbonate rocks. An upper marker horizon separates the more thinly bedded strata of the upper Avon Park Formation from more thickly bedded and massive units of the lower Avon Park Formation (Reference 328).

The shallow marine limestones and dolomites of the Avon Park Formation were deposited primarily on the inner part of a broad, flat-lying carbonate ramp that sloped gently toward the Gulf of Mexico during the Eocene (Reference 355). Carbonates of the Avon Park Formation are the oldest sediments exposed in the state and crop out in a limited area on the crest of the Ocala platform in the central peninsula (Reference 339). The Avon Park Formation varies from 400 feet up to

1200 feet thick in southern Florida (References 326 and 363) and occurs at elevations ranging from –1000 to –1300 feet (Reference 326).

The Eocene Ocala Limestone overlies the Eocene Avon Park Formation (Figure 2.5.1-205). A regional unconformity in southern Florida has been proposed at the top of the Avon Park Formation/base of the Ocala Limestone (Reference 326). The Ocala Limestone consists of white to cream, micritic or chalky marine limestones, calcarenitic limestone, coquinoid limestone, and occasional dolomites (References 328 and 254). Generally the Ocala Limestone is soft and porous, but in places it is hard and dense because of cementation of the particles by crystalline calcite. The deposit is unique in that it is composed of almost pure calcium carbonate from shells and micritic chalky particles (Reference 254). It can be subdivided into lower and upper facies on the basis of lithology. The lower unit is composed of a white- to cream-colored, fine- to medium-grained, poorly to moderately indurated, very fossiliferous limestone (grainstone and packstone). The lower facies may not be present throughout the areal extent of the Ocala Limestone and may be partially to completely dolomitized in some regions. The upper facies is a white, poorly to well indurated, poorly sorted, very fossiliferous limestone (grainstone, packstone, and wackestone). Silicified limestone is common in the upper facies. Fossils present in the Ocala Limestone include abundant large and smaller foraminifera, echinoids, bryozoans, and mollusks. Where the Ocala Limestone is at or near the surface, it exhibits extensive karstification (Reference 339). The limestone is characterized by abundant large benthic foraminifera, which have been used by various workers to distinguish the Ocala Limestone from the overlying Suwannee Limestone and the underlying Avon Park Formation (Reference 328). Other fossils present in the Ocala Limestone include abundant large and smaller foraminifera, echinoids, bryozoans, mollusks, and rare vertebrates (Reference 254).

The fine-grained carbonates of the Ocala Limestone were deposited on the middle to outer-ramp setting at water depths generally below storm wavebase (Reference 355). The Ocala Limestone occurs at the surface in a few locations, but appears to be absent even in the subsurface of the southernmost part of southeastern Florida (most of Miami-Dade County and southeastern Broward County). In the remainder of southern Florida, the thickness of the Ocala Limestone varies from 200 to 400 feet (References 328 and 363) and occurs at elevations ranging from –980 to –1100 feet (Reference 326).

#### 2.5.1.1.2.3.3 Oligocene

A significant increase of siliciclastic sediments occurred during the Oligocene, possibly due to renewed uplift of the Appalachians. The Suwannee Straits were filled with a flood of siliciclastic sediments as a possible result of longshore transport and currents. As a result of filling the Suwannee Straits, the carbonate depositional environment was replaced with sands, silts, and clays (Reference 338). The siliciclastic sediments appear in the early Miocene in northern Florida; however, in southern Florida, carbonates continued to be deposited until at least mid-Miocene. The siliciclastics spread southward along the east coast of Florida due to active transport conditions along the Atlantic coastline (Reference 285). The siliciclastic depositional environment moved further south due to longshore transport and currents until almost the entire Florida Platform was covered with sands and clays. The incursion of siliciclastics diminished during the later Pleistocene (Reference 338).

Karst features began to form at least as early as the latest Oligocene as determined from the occurrence of terrestrial vertebrate faunas (Reference 338). Karst features such as sinkholes, dissolution valleys, and collapse depressions formed when groundwater flowed through Florida's Eocene, Oligocene, and Miocene limestones and dissolved these carbonate sediments (Reference 285).

The Early Oligocene Suwannee Limestone overlies the Eocene Ocala Limestone (Figure 2.5.1-205). A regional unconformity in southern Florida has been described at the top of the Ocala Limestone/base of the Suwannee Limestone (References 326 and 356). The Suwannee Limestone consists of a white to cream, poorly to well indurated, fossiliferous, vuggy to moldic marine limestone (grainstone and packstone) with minor amounts of quartz sand and rare-to-absent phosphate mineral grains. The dolomitized parts of the Suwannee Limestone are gray, tan, light brown to moderate brown, moderately to well indurated, finely to coarsely crystalline, dolomite with limited occurrences of fossiliferous (molds and casts) beds. Silicified limestone and chert are common (References 254 and 339). Up to seven lithofacies have been identified in the Suwannee Limestone based on biotic content and texture (Reference 230). Characteristic porosity and permeability in the Suwannee Limestone is interparticle to moldic or vuggy. (Reference 328). Mollusks, foraminifers, corals, and echinoids are present in the Suwannee Limestone (Reference 254).

During deposition of the early Oligocene Suwannee Limestone, a series of clean siliciclastic shoreline deposits began to prograde onto the southern Florida platform that extended along the present west coast of Florida; however, these siliciclastic sediments did not affect the continued deposition of carbonate sediments in an open circulation shelf setting (Reference 301). The Suwannee Limestone represents the continued deposition in shallow marine conditions during the early Oligocene (Reference 355). The Suwannee Limestone exhibits numerous cycles of limestone capped by brecciated karst suggesting subaerial exposure; each cycle is overlain by a landward shift in sedimentary facies (marine flooding) (Reference 230). There have been opposing interpretations concerning the presence or absence of the Suwannee Limestone in southeastern Florida. The Suwannee Limestone may be absent from the eastern side of the Peninsular arch (Figure 2.5.1-213) due to erosion, nondeposition, or both (Reference 339). In southern Florida, the thickness of the Suwannee Limestone varies from 200 feet to as much as 600 feet in Lee and western Collier counties (References 363 and 328) and occurs at elevations ranging from –900 to –1300 feet (Reference 326).

The Oligocene-Miocene-Pliocene Hawthorn Group unconformably overlies the Oligocene Suwannee Limestone (Figure 2.5.1-205). The Hawthorn Group consists of an interbedded sequence of widely varying lithologies and components that include limestone, mudstone, dolomite, dolo silt, shells, quartz sand, clay, abundant phosphate grains, and mixtures of these materials. The characteristics that distinguish the Hawthorn Group from underlying units are (a) high and variable siliciclastic and phosphatic content; (b) color, which can be green, olive-gray, or light gray; and (c) a distinguishing gamma-ray log response. Intervals high in phosphate sand or gravel content are present and have high gamma-ray log activity, with peaks of 100 to 200 API standard units or more (Reference 328). In southern peninsular Florida, the Hawthorn Group consists of the basal Oligocene-Miocene Arcadia Formation, including the Tampa Member and the uppermost Miocene-Pliocene Peace River Formation with its Bone Valley Member (Reference 339). Zones of dissolution of Oligocene-age rocks indicate that post-Oligocene erosion was extensive (Reference 326). The complete Hawthorn Group varies from 500 to 800 feet thick in southern Florida (References 230 and 301).

The late Oligocene to middle Miocene Arcadia Formation of the Hawthorn Group unconformably overlies the Oligocene Suwannee Limestone. A regional unconformity in southern Florida has been proposed at the top of the Suwannee Limestone/base of the Arcadia Formation of the Hawthorn Group (References 230 and 301). Zones of dissolution of Oligocene-age rocks indicate that post-Oligocene erosion was extensive (Reference 326). The Arcadia Formation is predominantly a carbonate unit with a variable siliciclastic component, including thin beds of quartz sands. The Arcadia Formation (with the exception of the Tampa Member) is composed of yellowish gray to light olive gray to light brown, micro to finely crystalline, variably sandy, clayey, and phosphatic, fossiliferous limestones and dolomites. Thin beds of sand and clay are common. The sands are yellowish gray, very fine- to medium-grained, poorly to moderately indurated, clayey, dolomitic, and phosphatic. The clays are yellowish gray to light olive gray, poorly to moderately indurated, sandy, silty, phosphatic and dolomitic. Molds and casts of mollusks are common in the dolomites (Reference 339). Sediments within the Arcadia Formation show an upward and geographically northward (Reference 297) change from predominantly carbonate with some quartz sand to an equal mix of siliciclastics and carbonates (Reference 301). The Tampa Member is found near the base of the Arcadia Formation and is predominantly a white to yellowish gray fossiliferous marine limestone (mudstone, wackestone, and packstone) with subordinate dolomite, sand, clay, and phosphate. The Tampa Member is usually a hard, massive crystalline rock, and in some areas it contains small moldic cavities. Mollusks and corals, foraminifera, and algae are common in the Tampa Member.

Subsurface data show the Arcadia Formation as a gently sloping carbonate ramp upon which was deposited multiple high frequency, fining/coarsening upward, eustatically-driven, siliciclastic sequences. Fossil evidence suggests a shift from tropical to subtropical oceanic conditions during Arcadian deposition (Reference 230). The Tampa Member and the lower part of the Arcadia Formation form the upper part of the Floridan aquifer system (see Subsection 2.4.12) in parts of southern Florida (References 339 and 254). The thickness of the Arcadia Formation in southern Florida varies from 100 to 700 feet and occurs at elevations ranging from –300 to –650 feet (References 230 and 301).

#### 2.5.1.1.2.3.4 Miocene

During the Miocene, siliciclastics covered the Florida Platform providing a semipermeable barrier that reduced dissolution of the underlying carbonates. However, erosion of these siliciclastics during the early Pleistocene renewed the dissolution of the underlying limestones formations. This dissolution led to increased karst and an enhanced secondary porosity of the sediments of the Floridian aquifer system.

During the early Miocene a strong southward flood of terrigenous coarse clastics, presumably from the southern Appalachian Mountains, prograded over most of the Florida Platform (Figure 2.5.1-212) (References 333 and 356). The Hawthorn Group of shallow marine to non-marine coastal and deltaic sandstones and mudstones prograded out over the older carbonate platform during the late

Oligocene to Pliocene (Reference 355). By the end of the Oligocene, the influx of siliciclastic sediments, principally from the Appalachians, increased in volume and fines content. Carbonate production was significantly reduced in the east; however, the slow rate of sediment influx and lack of significant clay content allowed continued carbonate growth to continue into the mid-Miocene in the central portion of the Florida platform (Reference 301). This drowning/burial by siliciclastics is not the only interpretation for the reduction of the carbonate-producing organisms. McNeill et al. (Reference 297) suggest sea level rise, environmental deterioration, and the influence of local ocean currents as viable alternatives.

The Middle Miocene-Early Pliocene Peace River Formation of the Hawthorn Group unconformably overlies the Oligocene-Miocene Arcadia Formation. The base of the Peace River Formation is a regional unconformity that is identified by a thin, black phosphorite layer (Reference 297). The Peace River Formation is composed of interbedded sands, clays, and carbonates. The sands are generally light gray to olive gray, poorly consolidated, clayey, variably dolomitic, very fine- to medium-grained and phosphatic. The clays are yellowish gray to olive gray, poorly to moderately consolidated, sandy, silty, phosphatic and dolomitic. The carbonates are usually light gray to yellowish gray, poorly to well indurated, variably sandy, clayey, and phosphatic dolomites. Two distinct lithologies are present in the subsurface in southern Florida: a lower diatomaceous mudstone unit and an upper unit of mud-rich, very fine quartz sandstone. Fossil mollusks occur as reworked casts, molds, and limited original shell material. The Bone Valley Member of the Peace River Formation outcrops in a limited area on the southern part of the Ocala platform in Hillsborough, Polk, and Hardee counties. Where it is present, the Bone Valley Member is a poorly consolidated clastic unit consisting of sand-sized and larger phosphate grains in a matrix of quartz sand, silt, and clay. The lithology is highly variable, ranging from sandy, silty, phosphatic clays and relatively pure clays to clayey, phosphatic sands to sandy, clayey phosphorites. Colors range from white, light brown, and yellowish gray to olive gray and blue green. Vertebrate fossils occur in many of the beds within the Bone Valley Member. Shark's teeth are often abundant (Reference 339). The Peace River Formation may be, in part, correlative to the proposed Long Key formation (Reference 230).

Cunningham et al. (Reference 229), McNeill et al. (Reference 297), and Ward et al. (Reference 355) suggest that the Peace River Formation represents the southward transport and deposition of continental siliciclastics in a fluvial-deltaic system, which eroded and prograded out over the older carbonate platform environment. Well data show intervals of quartz sand localized as a wide north-south pathway from the central part of the peninsula to the middle Florida Keys (Figure 2.5.1-212 and Reference 356). This pathway is interpreted as a record of a strong, southward-moving shoreline and channeled deposition or a regional prograding spit (Reference 356). The ultimate source of these siliciclastics is considered to be the distant Appalachian highlands (References 297, 356, and 333). The Peace River Formation is widespread in southern Florida. It is part of the intermediate confining unit between the surficial and Floridan aquifer systems (References 328 and 339). The thickness of the Peace River Formation in southern Florida varies from 100 to 650 feet and occurs at elevations ranging from –100 to –250 feet (References 230 and 301).

2.5.1.1.2.3.5 Pliocene

The Pliocene Tamiami Formation unconformably overlies the Miocene-Pliocene Peace River Formation of the Hawthorn Group and interfingers with the contemporaneous Cypresshead Formation (Figure 2.5.1-205). The Tamiami Formation in southern Florida is a poorly defined lithostratigraphic unit containing a wide range of mixed carbonate-siliciclastic lithologies that include: (a) light gray to tan, unconsolidated, fine- to coarse-grained, fossiliferous sand; (b) light gray to green, poorly consolidated, fossiliferous sandy clay to clayey sand; (c) light gray, poorly consolidated, very fine- to medium-grained, calcareous, fossiliferous sand; (d) white to light gray, poorly consolidated, sandy, fossiliferous limestone; and (e) white to light gray, moderately to well indurated, sandy, fossiliferous limestone (Reference 339). Phosphatic sand- to gravel-sized grains are present in small quantities within virtually all the lithologies. Fossils present in the Tamiami Formation occur as molds, casts, and original material. The fossils present include barnacles, mollusks, corals, echinoids, foraminifera, and calcareous nannoplankton (Reference 339). The occurrence of limestone lenses in the Tamiami Formation appears to be related to fluctuations of the water table accompanied by cementation with calcium carbonate. The faunal assemblage of the Tamiami Formation commonly contains a variety of mollusks (Reference 337). The complex mix of permeable and impermeable lithologies makes the Tamiami Formation part of both the surficial aquifer system and the intermediate confining unit between the surficial and Floridan aquifer systems (see Subsection 2.4.12) (References 328 and 339). The Tamiami Formation may be, in part, correlative to the proposed Long Key formation (Reference 230).

Cunningham et al., (Reference 229) suggest that the presence of minor carbonate in the Tamiami Formation reflects a shift from the progradation of siliciclastics to aggradation of a vertical mix of carbonates and siliciclastics. The top of the

Tamiami Formation is an undulating surface that varies as much as 25 feet in elevation within a distance of 8 miles (Reference 337). This unevenness indicates that the upper part has been subjected to erosion. The deposition of the Caloosahatchee Formation on top of and along the flanks of erosional remnants indicates that the Tamiami Formation was dissected prior to Pliocene deposition and again during the Pleistocene. Apparently the deeper valleys were developed during the Pleistocene (Reference 337). The Tamiami Formation occurs at or near the land surface in Charlotte, Lee, Hendry, Collier, and Monroe counties (Reference 339). In Collier and Lee counties, Schroeder and Klein (Reference 337) found the Tamiami Formation to be approximately 50 feet thick, while in Miami-Dade County various reports indicate it to range in thickness from 25 to 220 feet (References 337 and 280).

The Pliocene Cypresshead Formation unconformably overlies the Miocene-Pliocene Peace River Formation of the Hawthorn Group and interfingers with the contemporaneous Tamiami Formation (Figure 2.5.1-205). The Cypresshead Formation consists of reddish brown to reddish orange, unconsolidated to poorly consolidated, fine- to very coarse-grained, clean to clayey sands. Cross-bedded sands are common within the Cypresshead Formation. Discoid quartzite pebbles and mica are often present. Clay beds are scattered and not really extensive. Original fossil material is not present in the sediments although poorly preserved molds and casts of mollusks and burrow structures are occasionally present. The Cypresshead Formation is at or near the surface from northern Nassau County southward to Highlands County forming the peninsular highlands (Lakeland Ridge, Lake Henry Ridge, Winter Haven Ridge, and Lake Wales Ridge) and appears to be present in the subsurface southward and to underlie the Florida Keys (Figure 2.5.1-202). The Cypresshead Formation formed in a shallow marine, near-shore environment and consists of deltaic and prodeltaic sediments (Reference 339). The Cypresshead Formation may be in part correlative to the proposed Long Key formation (Reference 230). The Cypresshead Formation is approximately 50 to 60 feet thick in Polk County (Reference 245).

The Pliocene-Pleistocene shell beds have attracted much attention due to the abundance and preservation of the fossils but the biostratigraphy and lithostratigraphy of the units has not been well defined. The "formations" previously recognized within the latest Tertiary-Quaternary section of southern Florida include the Late Pliocene-Early Pleistocene Caloosahatchee Formation and the Late Pleistocene Fort Thompson Formation. Lithologically these sediments are complex, varying from unconsolidated, variably calcareous and fossiliferous quartz sands to well indurated, sandy, fossiliferous limestones (both marine and freshwater). Clayey sands and sandy clays are present. These sediments form part of the surficial aquifer system (Reference 339) (see Subsection 2.4.12). The identification of these units is problematic unless the significant molluscan species are recognized (Reference 339); over 680 species are presently recognized (Reference 337). Often the collection of representative faunal samples is not extensive enough to properly discern the biostratigraphic identification of the formation. In an attempt to alleviate the inherent problems in the recognition of lithostratigraphic units, Scott (Reference 338) has suggested grouping the latest Pliocene through late Pleistocene Caloosahatchee Formation and Fort Thompson Formation into a single lithostratigraphic unit. This unit may be in part correlative to a proposed Long Key formation (Reference 230). In mapping these shelly sands and carbonates, a generalized grouping termed the Tertiary-Quaternary shell-bearing units was used by Scott (Reference 339) in the preparation of the Geologic Map of Florida (Figure 2.5.1-201). A more detailed description of the units identified as the Caloosahatchee and Fort Thompson Formations follows.

The Pliocene-Pleistocene shell-bearing sediments also known as the Caloosahatchee Formation unconformably overlie the Pliocene Tamiami Formation (Reference 337). The Caloosahatchee Formation consists of fossiliferous quartz sand with variable amounts of carbonate matrix interbedded with variably sandy, shelly limestones. Freshwater limestones are commonly present within the Caloosahatchee Formation. Fresh unweathered exposures are generally pale cream-colored to light gray, although green clay marls have been included in the formation. Green silty sands or sandy silts in the Caloosahatchee Formation appear to be restricted to the flanks of the hills of the Tamiami Formation. The greenish clastics are considered redeposited green clay marls of the Tamiami Formation (Reference 337). Mollusks are typically the predominant fossils, along with corals, bryozoans, echinoids, and vertebrates (Reference 254). The sand and shell variations of the Caloosahatchee Formation can be separated from the Pleistocene marine formations by identification of the mollusk faunas (Reference 337).

Sediments identified as part of the Caloosahatchee Formation occur from the City of Tampa south to Lee County and to the east coast (Reference 338). The Caloosahatchee Formation is present in southern Florida as discontinuous erosion remnants. The most continuous exposures occur as thin beds along the Caloosahatchee River and other rivers along the southwest Florida coast (Reference 337). The Caloosahatchee Formation has not been identified on the southeast Florida mainland (Reference 356). The Caloosahatchee Formation is at least 10 feet thick along the Caloosahatchee River and may be as much as 20 feet thick near Lake Hicpochee (Reference 337).

The Pliocene-Pleistocene shell-bearing sediments, also known as the Fort Thompson Formation, appear to conformably overlie the Pliocene Tamiami Formation but lie unconformably on the Caloosahatchee Formation (Reference 337). The discontinuity surfaces within the Fort Thompson Formation can include dense, well-indurated laminated crusts (Reference 268). Both Sonenshein (Reference 345) and Wilcox et al. (Reference 358) split the Fort Thompson Formation into an upper and lower unit based on lithologic and core data. The Fort Thompson Formation is typically composed of interbedded marine limestone, minor gastropod-rich freshwater limestone, shell marl, sandy limestone, and sand. (References 281, 337, and 338). The shell beds are variably sandy and slightly indurated to unindurated. The sandy limestones were deposited under both freshwater and marine conditions. The sand present in the Fort Thompson Formation is fine- to medium-grained quartz sand with abundant mollusk shells and minor but variable clay content (Reference 338). Descriptions of core indicate that the Fort Thompson Formation is a vuggy, solution-riddled, well to poorly indurated, dense to friable limestone. Numerous vertical features in the formation are characteristic of shallow solution pipes or vugs. The features commonly penetrate through more than one horizon and may be conduits for vertical water flow through the formation (Reference 281).

The depositional environment of the Fort Thompson Formation can be related to late Quaternary sea level fluctuations (References 268 and 337). This formation is composed of a group of high-frequency depositional cycles within a progradational environment building on the Tamiami clastic ramp (Reference 232). According to Cunningham et al. (Reference 231), the depositional environments for the Fort Thompson Formation include (a) platform margin to outer platform, (b) open marine, restricted, and brackish platform interiors, and (c) freshwater terrestrial. The Fort Thompson Formation covers the greatest geographical area of all Quaternary formations in southern Florida (Reference 337). The thickness of the Fort Thompson Formation varies from approximately 40 to 80 feet in Miami-Dade, Broward, and Palm Beach counties, where it constitutes the highly productive zone of the Biscayne aquifer (References 268 and 337) (see Subsection 2.4.12). In southern Florida the thickness of Fort Thompson Formation ranges from approximately 50 to 100 feet (References 281 and 280).

2.5.1.1.2.3.6 Pleistocene

During the Pleistocene, glaciation and fluctuating sea levels occurred worldwide. Growth of continental glaciers resulted in a drop in sea level as water was retained in the ice sheets. As a result, Florida's land area increased significantly. Based on sea levels during peak glacial periods, Florida's Gulf of Mexico coastline was probably situated some 100 miles west of its current position. Warmer interglacial intervals resulted in the glacial melting and a rise in sea level that flooded Florida's land area. At the peak interglacial intervals, sea level stood approximately 100 feet above current sea level. During this time wave action and currents eroded the existing landforms that became filled with quartz sands originating from the erosion of the Appalachian Mountains and other upland areas. Due to a rise in sea level during the Pleistocene, nutrient rich waters flooded the southern portion of the Florida peninsula and broken shell fragments along with chemically precipitated particles became the main source of carbonate sediments (Reference 285).

The Pleistocene Anastasia Formation overlies the Pliocene-Pleistocene shell-bearing formations and transitions into the contemporaneous Key Largo Limestone and Miami Limestone. The Anastasia Formation is composed of interbedded sands and coquinoid limestones. The most recognized facies of the Anastasia Formation sediments is an orange-brown, unindurated to moderately indurated coquina of whole and fragmented mollusk shells in a matrix of sand often cemented by sparry calcite. Sands occur as light gray to tan and orange-brown, unconsolidated to moderately indurated, unfossiliferous to very fossiliferous beds. The Anastasia Formation forms part of the surficial aquifer system (see Subsection 2.4.12) (Reference 339).

The Anastasia Formation includes the coquina, sand, sandy limestone, and shelly marl of Pleistocene age that lies along both the east and west coasts of Florida. The typical coquina of the Anastasia Formation in the type locality does not occur in the western part of southern Florida. Sand, shell beds, marl, and calcareous sandstone are the most common materials. In southern Florida, molluscan faunas establish a Pleistocene age for the Anastasia Formation (Reference 337).

The Atlantic coastal ridge (Figure 2.5.1-202) is underlain by the Anastasia Formation from St. Johns County southward to Palm Beach County. The Anastasia Formation generally is recognized near the coast but extends inland as much as 20 miles in St. Lucie and Martin counties. To the south of Palm Beach County, the Anastasia Formation grades laterally into the Miami Limestone and is not present in southern Miami-Dade County (Reference 339). Thin marine sandstones of the Anastasia Formation are also present along the southwest coast and extend as a tongue into Collier and Hendry counties (Reference 337). The thickness of the Anastasia Formation varies up to a maximum of 140 feet in southern Florida (Reference 280).

The Pleistocene Key Largo Limestone overlies the Pliocene-Pleistocene shell-bearing sediments and transitions into the contemporaneous Anastasia Formation and Miami Limestone. The Key Largo Limestone is a white to light gray, moderately to well indurated, fossiliferous, coralline marine limestone composed of coral heads encased in a calcarenitic matrix (Reference 339). Some of these corals have been partially dissolved by groundwater, and the spaces remaining have been filled with crystalline calcite (Reference 254). Little to no siliciclastic sediment is found in these sediments. Fossils present include corals, mollusks, and bryozoans. The Key Largo Limestone is highly porous and permeable and is part of the Biscayne aquifer of the surficial aquifer system (Reference 339).

The Key Largo Limestone is a fossil coral reef that is believed to have formed in a complex of shallow-water shelf-margin reefs and associated deposits along a topographic break during the last interglacial period (Reference 266). The Key Largo Limestone is exposed at the surface in the Florida Keys from Soldier Key on the northeast to Newfound Harbor Keys near Big Pine Key on the southwest and from Big Pine Key to the mainland. On the mainland and in the southern Florida Keys from Big Pine Key to the Marquesas Keys, the Key Largo Limestone is replaced by the Miami Limestone (Reference 339). The thickness of the Key Largo Limestone varies widely and is more than 180 feet in southern Florida (Reference 266).

The Pleistocene Miami Limestone overlies the Pliocene-Pleistocene shell-bearing sediments and transitions into the contemporaneous Key Largo Limestone and Anastasia Formation. The Miami Limestone (formerly the Miami Oolite) is a Pleistocene marine limestone. Johnson (Reference 277) has identified six lithofacies in the Miami Limestone: ooid calcarenite, oomoldic-recrystallized, calcirudite, breccia, sandy, and microsparry-coralline. The oolitic facies is the most common and consists of white to orangish gray, oolitic limestone with scattered concentrations of fossils. Fossils present include mollusks, bryozoans, and corals; molds and casts of fossils are common (Reference 254).

The Miami Limestone occurs at or near the surface in southeastern peninsular Florida from Palm Beach County to Miami-Dade and Monroe counties. It forms the Atlantic Coastal Ridge and extends beneath the Everglades where it is commonly covered by thin sediments. The Miami Limestone occurs on the mainland and in the southern Florida Keys from Big Pine Key to the Marquesas Keys. From Big Pine Key to the mainland, the Miami Limestone is replaced by the Key Largo Limestone. To the north, in Palm Beach County, the Miami Limestone grades laterally northward into the Anastasia Formation (Reference 339). The depositional environment of the Miami Limestone can be related to late Quaternary sea level fluctuations (Reference 268). This formation is composed of a group of high-frequency depositional cycles within an aggradational environment (Reference 232). According to Cunningham et al. (Reference 231), the depositional environments for the Miami Limestone include both open marine platform interior and freshwater terrestrial. The highly porous and permeable Miami Limestone forms much of the Biscayne aquifer of the surficial aquifer system (Reference 339). The thickness of the Miami Limestone varies from 10 to 40 feet in southeastern Florida (References 266, 280, and 310). Undifferentiated Quaternary sediments overlie the Pliocene-Pleistocene shell-bearing sediments and the Pleistocene Anastasia Formation, Key Largo Limestone, and Miami Limestone. These undifferentiated sediments consist of siliciclastics, organics, and freshwater carbonates that vary in thickness. The siliciclastics are light gray, tan, brown to black, unconsolidated to poorly consolidated, clean to clayey, silty, unfossiliferous, variably organic-bearing sands to blue green to olive green, poorly to moderately consolidated, sandy, silty clays. Organics occur as plant debris, roots, disseminated organic matrix, and beds of peat. Freshwater carbonates, often referred to as "marls" are scattered over much of the region. In southern Florida, freshwater carbonates are nearly ubiquitous in the Everglades. These sediments are buff colored to tan, unconsolidated to poorly consolidated, fossiliferous carbonate muds. Sand, silt, and clay may be present in limited quantities. These carbonates often contain organics. The dominant fossils in the freshwater carbonates are mollusks (Reference 339).

Where these sediments exceed 20 feet in thickness, they are mapped by Scott (Reference 339) as discrete units. Those sediments occurring in flood plains are termed alluvial and flood plain deposits. Sediments exhibiting the surficial expression of beach ridges and dunes are shown separately. Terrace sands are not identified individually. The subdivisions of the undifferentiated Quaternary sediments are not lithostratigraphic units but are used to facilitate a better understanding of the geology (Reference 339).

2.5.1.1.2.3.7 Holocene

The Holocene sediments in Florida occur near the present coastline at elevations generally less than 5 feet. The sediments include quartz sands, carbonate sands and muds, and organics (Reference 339).

#### 2.5.1.1.3 Regional Tectonic Setting

The site region is located within the Central and Eastern United States (CEUS), a stable continental region characterized by low rates of crustal deformation and no active plate boundary conditions. In 1986, the Electric Power Research Institute (EPRI) developed a seismic source model for the CEUS that included the region (Reference 246). This seismic source model was developed using the interpretations provided by six independent Earth Science Teams (ESTs) and reflected the general state of knowledge of the earth science community as of 1986. The following subsection summarizes the current state of knowledge of the tectonic setting and tectonic structures in the site region with a focus on post-1986 geologic, seismologic, or geophysical information that is relevant to assessing potential for seismic activity in the region.

##### 2.5.1.1.3.1 Regional Tectonic History

The geologic history of the site region begins with the late Paleozoic Alleghany orogeny, in which Gondwana (including South America and Africa) and Laurentia (ancestral North America) collided to form the supercontinent Pangaea. Subsurface data indicate that the basement of central Florida is a composite terrane, known as the Suwannee terrane, which was part of West Africa until the Alleghany orogeny (Reference 222). Only after Pangaea broke up did the Florida peninsula become part of North America. This occurred during the Triassic Period, when the Gulf of Mexico opened as Pangaea was separated by sea floor spreading. In the Jurassic and Cretaceous Periods, the southern edge of the North American plate (now located south of the Florida platform) was subducting southwestward beneath the Caribbean Plate at the Greater Antilles volcanic arc. In the Cretaceous Period, shallow-water limestone deposition dominated a quiescent Florida platform, while the Bahama platform approached the Greater Antilles subduction zone (Reference 287). In the Eocene Epoch, the Greater Antilles arc collided with the Bahama platform and contractional structures developed north of Cuba (the Nortecubana fault system) to accommodate this strain. After the Eocene, Cuba had effectively been transferred to the southern edge of the North American plate, thus ending tectonic activity in the site region (Reference 318).

###### 2.5.1.1.3.1.1 Precambrian and Paleozoic Tectonic History

The oldest rocks that crop out in Florida are Eocene-age strata (Figure 2.5.1-201) (Reference 218). Therefore, the pre-Eocene history of the Florida peninsula is mostly based on subsurface datasets such as boring logs and cuttings, borehole geophysical logs, and gravity and magnetic data. Compilations of such data indicate that Mesozoic volcanic rocks underlie the southernmost portion of the peninsula and the central peninsula is underlain by the Suwannee terrane, a mixed-lithology Precambrian and Paleozoic terrane (Figure 2.5.1-214). The Bahamas fracture zone apparently trends subparallel to the boundary between the Mesozoic volcanic rocks and the Suwannee terrane (Figure 2.5.1-213 and 2.5.1-214) (References 333 and 351). Rock types of the Suwannee terrane include low-grade Late Proterozoic to Cambrian felsic metavolcanic rocks, the St. Lucie metamorphic complex of gneiss and amphibolite, the approximately 530 Ma Osceola Granite and undeformed Lower Ordovician-Middle Devonian sedimentary rocks of the Suwannee basin (Reference 236). The Suwannee terrane has been correlated to West Africa (References 222 and 236), and this exotic fragment was appended to Laurentia along the Suwannee suture, speculated to be located in southern Georgia and Alabama (Figure 2.5.1-214 and Reference 351). The timing of this collision is uncertain but generally considered to be during the Alleghany orogeny that formed Pangaea in the late Paleozoic (Reference 351).

2.5.1.1.3.1.2 Mesozoic and Cenozoic Tectonic History

During the Late Triassic to Middle Jurassic periods, the rifting that accomplished the break-up of Pangaea resulted in the opening of the Gulf of Mexico while leaving the Suwannee terrane stranded adjacent to the Laurentian margin (Reference 333). The Early Jurassic volcanic rocks beneath southern Florida are interpreted as transitional crust developed during this rifting (Reference 282). Seismic profiles indicate that subsurface normal faults were active in the Middle Jurassic to Cretaceous, and are interpreted to reflect this regional rifting event (Reference 333). Stratigraphic data indicate that by the Early Cretaceous, shallow-water carbonates and evaporites were deposited over most of the Florida platform (Reference 333). Subsequent to rifting and into the present, the Florida platform continues as a stable site of deposition devoid of tectonic activity.

To the south and west, Cuba was the site of Mesozoic calc-alkaline volcanism associated with the Greater Antilles volcanic arc as the North American plate subducted southwestward beneath the Caribbean plate. This island arc was generally active in the Cretaceous Period but volcanism may have varied spatially and temporally to potentially reflect multiple discrete volcanic events (Reference 213). During subduction and subsequent collision, many of the Jurassic to Cretaceous volcanic and sedimentary strata currently exposed in central and western Cuba underwent high-pressure, low-temperature metamorphism. This metamorphism and accompanying ophiolite emplacement occurred in mid-Cretaceous to Paleogene time (References 287 and 336). At approximately 50 Ma, the Bahama platform approached the Greater Antilles subduction zone and subduction ceased, resulting in the transfer of Cuba from the Caribbean plate to the North American plate (Reference 318). In western Cuba, this collision occurred in the latest Paleocene to early Eocene time (Reference 215). North to northeast directed thrusting and contraction related to this collision was widespread in the late Paleocene to middle Eocene along the Nortecubana fault system, which represents the ancestral plate boundary between the attenuated North America-affinity rocks, the Greater Antilles arc and related deposits, and ophiolitic assemblages that compose Cuba and the North American plate. After the northwestern portions of Cuba sutured to the Bahama platform along northwest-trending contractional structures, the plate boundary shifted southward in steps as new northeast-trending strike-slip faults initiated to the southeast (Reference 318). This process continued until Middle Eocene to Oligocene time, when collision ended in central Cuba. Hence, the post-middle Eocene history of western and central Cuba was generally tectonically quiescent, indicated by the deposition of thick limestone sequences (Reference 287). The southeasternmost portion of Cuba is adjacent to the active strike-slip plate boundary between the North American and Caribbean plates, and is currently the site of left-lateral deformation along the Oriente fault system (Reference 294).

#### 2.5.1.1.3.2 Tectonic Stress

Three types of forces are generally responsible for the stress in the lithosphere:

- Gravitational body forces or buoyancy forces, such as the ridge-push force resulting from hot, positively buoyant young oceanic lithosphere near the ridge against the older, colder, less buoyant lithosphere away from the ridge (Reference 233). This force is transmitted by the elastic strength of the lithosphere into the continental interior.
- Shear and compressive stresses transmitted across plate boundaries (such as strike-slip faults or subduction zones).
- Shear tractions acting on the base of the lithosphere from relative flow of the underlying asthenospheric mantle.

The ESTs that participated in the EPRI (Reference 246) evaluation of intra-plate stress concluded that tectonic stress in the CEUS region is primarily characterized by northeast-southwest-directed horizontal compression. In general, the ESTs concluded that the most likely source of tectonic stress in the mid-continent region is ridge-push force associated with the Mid-Atlantic ridge, transmitted to the interior of the North American plate by the elastic strength of the lithosphere. Other potential forces acting on the North American plate were judged to be less significant in contributing to the magnitude and orientation of the maximum compressive principal stress.

In general, the ESTs focused on evaluating the state of stress in the mid-continent and Atlantic seaboard regions, for which stress indicator data were relatively abundant. Fewer stress indicator data were available for the Gulf of Mexico, Gulf Coastal Plain, and Florida peninsula, and thus these areas received less scrutiny in the EPRI (Reference 246) studies. Since 1986, an international effort to collate and evaluate stress indicator data culminated in publication of a new *World Stress Map* in 1989 (References 371 and 372) that has been periodically updated (Reference 329). Plate-scale trends in the orientations of principal stresses were assessed qualitatively based on analysis of high-quality data (Reference 370), and previous delineations of regional stress provinces were refined (Reference 373). Statistical analyses of stress indicators confirmed that the trajectory of the maximum compressive principal stress is uniform across broad continental regions at a high level of confidence (Reference 224). In particular, the northeast-southwest orientation of principal stress in the CEUS inferred by the EPRI ESTs is statistically robust and is consistent with the theoretical orientation of compressive forces acting on the North American plate from the Mid-Atlantic ridge (Reference 370).

According to the continental United States stress map of Zoback and Zoback (Reference 371), most of the CEUS is in the Mid-Plate stress province, which displays a consistent northeast-southwest maximum compressive stress orientation. However, coastal regions of Texas, Louisiana, Mississippi, Alabama, and northwestern Florida can exhibit down-to-the-gulf growth faulting. Hence, this area has been designated as the Gulf Coast stress province, characterized by northeast-southwest to north-northeast to south-southwest horizontal tension (Reference 371). The boundary between the Mid-Plate and Gulf Coast stress provinces terminates in the northern Florida peninsula, but there is a lack of stress data from areas near the Florida peninsula and most of Cuba. Because the southern Florida peninsula doesn’t exhibit the geologic features (such as salt-rooted normal faults) associated with the Gulf Coast stress province, the site region is generally interpreted to be part of the Mid-Plate stress province (Figure 2.5.1-215 and Reference 373).

The Mid-Plate stress province may exhibit reverse or strike-slip faulting under east-northeast- to west-southwest- to northwest-southeast-oriented compressive stress. This region extends from an approximately north-south-oriented line through Texas, Colorado, Wyoming, and Montana east all the way to the Atlantic margin and potentially into the Atlantic Ocean basin (Reference 371). Within this province, the orientation of maximum compressive stress is generally parallel to plate velocity direction (Reference 372). Richardson and Reding (Reference 331) concluded that the observed northeast-southwest trend of principal stress in the Mid-Plate stress province of the CEUS dominantly reflects ridge-push body forces associated with the Mid-Atlantic ridge. They estimated the magnitude of these forces to be approximately 2E12 to 3E12 N/m (Newton per meter), or 2.9 to 4.4x10 psi, (i.e., the total vertically integrated force acting on a column of lithosphere 3.28 feet wide), which corresponds to average equivalent stresses of approximately 40 to 60 MPa (megaPascals), or 5800 to 8700 psi, distributed across a 30-mile-thick elastic plate. Humphreys and Coblentz (Reference 273) evaluated the contribution of shear tractions on the base of the North American lithosphere to intra-continental stress and concluded that the dominant control on the northeast-southwest orientation of the maximum compressive principal stress in the CEUS is ridge-push force from the Atlantic basin.

Research on the state of stress in the continental United States since publication of the EPRI (Reference 246) studies has confirmed observations that stress in the CEUS is characterized by relatively uniform northeast-southwest compression. Few new data have been reported since the EPRI (Reference 246) study that better determine the orientations and relative magnitudes of the principal stresses in the site region. Given that the current interpretation of the orientation of principal stress is similar to that adopted in EPRI (Reference 246) a reevaluation of the seismic potential of tectonic features based on a favorable or unfavorable orientation to the stress field would yield similar results. Thus, there is no significant change in the understanding of the static stress in the site region and site area since the publication of the EPRI source models in 1986, and there are no significant implications for existing characterizations of potential activity of tectonic structures. The Mid-Plate stress province is the most likely characterization of the tectonic stress at the site region and site area (Figure 2.5.1-215).

#### 2.5.1.1.3.3 Principal Tectonic Features

The site region is covered in a thick blanket of sedimentary rocks and deposits that obscure any Precambrian to Paleozoic tectonic features associated with the formation of Pangaea. In fact, this region has generally recorded only sedimentary processes since Mesozoic rifting, with the exception of the tectonic activity associated with the migration of the plate boundary from northern Cuba to south of Cuba during Cretaceous to Eocene time. The Florida peninsula has been a site of stable carbonate platform deposition continually since the Cretaceous, and the adjacent Gulf of Mexico and Atlantic basins have been sites of sedimentary deposition since the Jurassic Period. The dominantly carbonate strata of the subsurface Florida peninsula exhibits variations in thickness that have been interpreted as a series of arches, uplifts, basins, or embayments from geophysical or borehole data. Generally, these features are sedimentary responses to minor warping, regional tilting, sedimentary compaction, or sea level changes and are not considered associated with faulting or tectonic events (Reference 365). In some cases, the highs or lows seen in the stratigraphy may be mimicking Mesozoic paleotopography. No tectonic features younger than Miocene have been identified within the site region or site area.

2.5.1.1.3.3.1 Precambrian to Paleozoic Tectonic Features

Very few tectonic features older than those associated with Mesozoic rifting have been identified within the site region, because they are buried beneath thousands of feet of carbonate. However, the Suwannee terrane, part of the Florida basement, includes Paleozoic strata and Early Cambrian granites (Reference 236). Boreholes in northern Florida, southern Georgia, and southeastern Alabama have penetrated lower Paleozoic rocks with African affinity flora and fauna, indicating that the Suwannee terrane is exotic to North America (References 234 and 313). The timing of the construction of the Suwannee terrane is uncertain, but its suturing to North America occurred during the late Paleozoic Alleghany orogeny (Reference 269). The hypothesized Suwannee suture has been proposed to occur in southern Georgia. This suture separates former African Suwannee terrane from ancestral North America and is mapped near the Brunswick magnetic anomaly (Reference 351). This suture is interpreted as active in the late Paleozoic Alleghany orogeny during the continental collision and construction of Pangaea (Reference 269).

2.5.1.1.3.3.2 Mesozoic Tectonic and Structural Features

The characteristic event of Mesozoic time in the site region was rifting associated with the opening of the Atlantic Ocean and Gulf of Mexico basins, during the Triassic to Early Jurassic periods. The Gulf of Mexico is approximately 1000 miles in diameter and filled with sedimentary rocks that are Triassic to Holocene in age. Near its eastern flank, essentially the western edge of the Florida platform, the basin is filled with dominantly carbonates and minor amounts of evaporites, indicating dominantly shallow-water conditions (Reference 333). Normal faulting and volcanic activity associated with this rifting was widespread and ended in the Jurassic, but occurred mostly outside of the site region (Reference 333).

The Florida platform is the term for the flat, slowly subsiding region dominated by carbonate deposition from northern Cuba to Georgia and between the Florida escarpment in the eastern Gulf of Mexico to the Bahama platform in east. This platform subsided slowly from the Early Mesozoic to Middle Eocene, but differential rates of subsidence resulted in minor arches and lows (such as the Peninsular arch, Sarasota arch) (Reference 359).

The Peninsular arch is a northwest-trending feature that was a high until the Cretaceous Period (Reference 324) (Figure 2.5.1-213). East-west cross sections across northernmost Florida show that Triassic/Jurassic and lower Cretaceous strata are truncated against this basement high (Reference 208; Figure 2.5.1-216 and 2.5.1-217). Upper Cretaceous beds were deposited over the crest of this arch, indicating it had ceased to be a high by that time as the sea-level rose (References 208 and 324). Although, Oligocene deposition may have been affected by the Peninsular arch, Neogene to Holocene sediments are unaffected (Reference 325). The Sarasota arch is a northeast-trending basement high extending to the southwest from the Peninsular arch and mapped in Jurassic and early Cretaceous strata (Reference 365). It formed during or shortly after the Pangaea rifting began (Reference 365). The Broward syncline is a northwest-southeast trending syncline mapped in the subsurface Cretaceous strata (References 209 and 324) but its presence cannot be "unequivocally demonstrated because of lack of drilling" (Reference 359). This feature is located in Broward and Palm Beach counties, outside of the site vicinity.

The South Florida basin is a sedimentary basin filled with 3 to 8 miles of Jurassic to Holocene strata (Reference 342) that slowly subsided at the southern end of the Florida platform. These deposits are the thickest of the Atlantic coastal plain. The Upper Jurassic and younger strata are shallow-water limestones and dolomites, evaporites, and deep-water limestones. The thickening to the southwest displayed in Cretaceous strata is sometimes referred to as the South Florida shelf (Reference 209). Seismic lines more than 100 miles south of Units 6 & 7 indicate that the Upper Cretaceous and older strata are sometimes cut by faults related to Late Cretaceous to Tertiary Cuban tectonic activity (Reference 342).

A series of fracture zones emanates from the spreading center of the Mid-Atlantic ridge into the site region (Figure 2.5.1-213). These northwest-trending fracture zones developed as the Atlantic opened. These fracture zones, including the

Jacksonville, Bahamas, and Cuban fracture zones, have not accommodated any significant differential movement between portions of the North American plate since the Jurassic or Cretaceous (Reference 282 and Figure 2.5.1-213). Some authors have pointed out the coincidence of the Bahamas fracture zone with the transition from the Suwannee terrane to Jurassic volcanic rocks on the Florida peninsula and also with a gravity gradient and/or magnetic anomalies (Reference 282); however, others have contested any relationship (Reference 212).

2.5.1.1.3.3.3 Cenozoic-Tertiary Tectonic and Structural Features

The Ocala uplift, or Ocala platform, is a south-southeast trending anticlinal feature characterized by thickness variations in the Eocene strata in northwest Florida approximately 300 miles from Units 6 & 7. The stratigraphic variations are interpreted to result from either compaction shortly after deposition or sedimentary build-ups and do not have a fault-controlled origin (References 299 and 361). The Ocala platform was also subaerially exposed during the Eocene to Miocene, but the cause of this is uncertain. Mid-Miocene and younger deposition is undisturbed across the Ocala platform (Reference 325).

The Suwannee channel, also referred to as the Suwannee Straits or Gulf trough, is a Middle Cretaceous to Late Paleogene channel that separated southeastern North America from the Florida carbonate platform (References 296 and 221; Figure 2.5.1-213). The currents from the Gulf of Mexico that flowed through the Suwannee channel to the Atlantic Ocean might have prevented clastics from the Appalachians and southeastern North America from reaching the platform (Reference 299). After the Late Eocene, this trough had been filled, which allowed for clastic deposition on the central peninsula in the late Early Miocene (Reference 299). There is no faulting or tectonic activity associated with this feature, which is located approximately 400 miles to the north of Units 6 & 7.

The Nortecubana fault is the arcuate east-west- to northwest-striking, north- and northeast-directed thrust system located north of Cuba that represents the former suture between the Caribbean and North American plates (Figure 2.5.1-213 and 2.5.1-218). This thrust system accommodated crustal shortening between the Bahama platform and Cuba until the middle Eocene. This feature is located approximately 140 miles south of Units 6 & 7. Onshore in western Cuba, mapping indicates that north- and northeast-directed thrusting and deformation does not affect rocks younger than middle Eocene (Reference 261). This provides the best estimate for the tectonic history of the Nortecubana system.

#### 2.5.1.1.3.4 Potentially Significant Seismic Sources Outside the Site Region

The absence of active structures and seismicity within the site region and site area may increase the contribution to site-specific seismic hazard from more active features outside the 200-mile radius (Figure 2.5.3-201). There are two potential seismic sources for the site: (1) the Caribbean-North America plate boundary, and (2) the Charleston, South Carolina. These potential sources of seismic hazard are briefly described below.

##### 2.5.1.1.3.4.1 Cuba and Caribbean-North America Plate Boundary Seismic Sources

Located more than 450 miles south of Units 6 & 7, structures along the Caribbean-North America plate boundary are potential sources of ground motion for the site (Figure 2.5.1-218). A summary of the geologic structures is provided here, but full description of the seismic hazard parameters for each structure is presented in Subsection 2.5.2.2.

The Caribbean plate is presently moving relative to the North American plate at a rate of approximately 0.8 inch (20 mm) per year along an azimuth of roughly 075 degrees (References 237, 238, and 293). In the Cuba and Caribbean-North America plate boundary region, the relative plate motion is accommodated by the mid-Cayman spreading center and several subvertical, left-lateral transform faults extending from offshore of the northern coast of Honduras eastward through the Cayman trough and through the islands of Jamaica and Hispaniola. The Cayman spreading center itself is located southwest of the Cayman Islands and is characterized by a north-south-trending axis of spreading with an average rate of approximately 0.6 inch (15 mm) per year since approximately 25 to 30 Ma (Reference 332). West of the Cayman trough, Caribbean-North America plate motion is accommodated offshore on the left-lateral Swan Islands fault (Figure 2.5.1-218). East of the Cayman trough, on Hispaniola, the orientation of the plate-bounding structures changes and motion is partitioned between strike-slip faults (e.g., Septentrional and Enriquillo faults), minor oblique-reverse faults, and subduction on low-angle thrust faults (e.g., Northern Hispaniola thrust fault) (References 240, 241, and 294). East of Hispaniola, the Caribbean-North America plate boundary becomes an oblique subduction zone or zones at the Puerto Rico trench and Muertos trough, and finally a more pure dip-slip west-dipping subduction zone in the Lesser Antilles.

The kinematics of crustal deformation and faulting on the island of Cuba are poorly understood. Geodetic data show that the current plate boundary is mostly south of Cuba along the Oriente and Plantain Garden-Enriquillo faults and that modern strain rates across the island are likely <0.1 inch (3 mm) per year relative to North America (References 237 and 239). Some strike-slip faults have been mapped, but none are adequately characterized with late Quaternary slip rates or timing or recurrence of large earthquakes (Reference 226).

The Oriente fault zone is a left-lateral transform fault extending from the northern tip of the Mid-Cayman spreading center 500 miles to the southeastern tip of Cuba. The remainder of Caribbean-North America plate motion not accommodated along the southern Cayman trough boundary, or approximately 0.3 to 0.5 inches (8 to 13 mm) per year, is attributed to this fault. Again, variation in historical seismicity and geometry of the Oriente fault warrants its division into eastern and western segments. The largest historical earthquakes on the western Oriente fault are the 1992 moment magnitude ($M_w$) 6.8 to 7.0 event and a $M_w$ 7.0 to 7.1 event that occurred offshore of the southern tip of Cuba (References 374, 259, and 295). The eastern Oriente fault along southern Cuba is characterized by more intense seismic activity and focal mechanisms indicating strike-slip, oblique, and reverse mechanisms (References 307 and 374).

The Septentrional fault is a left-lateral strike-slip fault that extends for roughly 400 miles west from the Mona Passage to the Windward Passage, where it merges with the Oriente fault (References 219 and 240). Strain is partitioned on this structure and on the gently south-dipping Northern Hispaniola thrust fault (References 242 and 292).The best estimate of a slip rate for the fault is 0.2 to 0.5 inches (6 to 12 mm) year (Reference 293), and it has been suggested that large historical earthquakes ($M_w$ 7.75 to 8.0) occurred on this structure (Reference 295).

The Northern Hispaniola fault is an east-west-striking, north-directed thrust system. Geodetic data indicate a strain accumulation rate of 0.2 inches (5 mm) year on this structure (Reference 377). Historical seismic events of up to surface-wave magnitude ($M_s$) 8.1 have been attributed to a shallowly south-dipping thrust fault plane (Reference 242). Variations in seismicity and crustal structure along strike indicate the fault is segmented and best described by a more seismically active eastern segment and a quieter western segment that roots at the Septentrional fault.

The Swan Islands fault is a left-lateral oceanic transform fault extending 450 miles west of the mid-Cayman spreading center. Geodetic data indicate that essentially the entire 0.7 to 0.8 inches (18 to 20 mm) per year Caribbean-North America plate motion is accommodated on the Swan Islands fault (References 237 and 238). A historical earthquake with a estimated magnitude of 8.3 is attributed to the western portion of the Swan Islands fault (Reference 295).

East of the Mid-Cayman spreading center, the Walton, Plantain Garden, and Enriquillo faults are left-lateral strike-slip faults that collectively form the southern margin of the Cayman trough. The estimated slip rate for the system is approximately 0.3 inch (8 mm) per year (Reference 239). Slip is transferred more than 600 miles across these structures (causing a restraining bend on Jamaica) and eventually feeds into the Muertos trough. The Jamaican restraining bend is interpreted as a boundary between a western portion of the system (the Walton-Duanvale fault) and an eastern portion (Plantain Garden-Enriquillo fault). Multiple historical events of magnitude ~7.5 have ruptured on the Enriquillo fault (Reference 295).

2.5.1.1.3.4.2 The Charleston, South Carolina Seismic Source

The August 31, 1886, earthquake that occurred in Charleston, South Carolina, 500 miles north of Units 6 & 7, is the largest historical earthquake in the eastern United States. The event produced Modified Mercalli Intensity (MMI) X shaking in the epicentral area and was felt as far away as Chicago (Reference 278). As a result of this earthquake and the relatively high risk in the Charleston area, government agencies funded numerous investigations to identify the source of the earthquake and the recurrence history of large magnitude events in the region. Because no primary tectonic surface deformation was identified with the 1886 event, a combination of geology, geomorphology, and instrumental seismicity data have been used to suggest several different faults (East Coast fault system, Ashley River fault) as the source for Charleston seismicity. However, the source of the 1886 earthquake has not been definitively attributed to any particular fault.

Johnston (Reference 278) estimates $M_w$ 7.3±0.26 for the 1886 Charleston event. More recently, Bakun and Hopper (Reference 211) estimate a smaller magnitude of $M_w$ 6.9 with a 95 percent confidence level corresponding to a range of $M_w$ 6.4 to 7.1. Both of these more recent estimates of maximum magnitude (Mmax) are similar to the upper-bound maximum range of Mmax values used in EPRI (Reference 246) (using body wave magnitudes [$m_b$] 6.8 to 7.5). However, significant new information regarding the source geometry and earthquake recurrence of the Charleston seismic source warrants an update of the EPRI (Reference 246) source models. The updated Charleston seismic source parameters are presented in Subsection 2.5.2.

Three zones of elevated seismic activity have been identified in the greater Charleston area. These include the Middleton Place–Summerville, Bowman, and Adams Run seismic zones. The Middleton Place–Summerville seismic zone is an area of elevated microseismic activity located approximately 12 miles northwest of Charleston (References 214, 290, 291, 347, and 349). Between 1980 and 1991, 58 events with duration magnitude (Md) 0.8 to 3.3 were recorded in a 7- by 9-mile area, with hypocentral depths ranging from approximately 1 to 7 miles (Reference 291). The elevated seismic activity of the Middleton Place–Summerville seismic zone has been attributed to stress concentrations associated with the intersection of the Ashley River and Woodstock faults (References 258, 291, 346, and 347). Some investigators speculate that the 1886 Charleston earthquake occurred within this zone (References 211, 346, and 349). The Bowman seismic zone is located approximately 50 miles northwest of Charleston, South Carolina, outside of the meizoseismal area of the 1886 Charleston earthquake. The Bowman seismic zone is identified on the basis of a series of local magnitude ($M_L$) $3<M_L<4$ earthquakes that occurred between 1971 and 1974 (References 214 and 350). The Adams Run seismic zone, located within the meizoseismal area of the 1886 Charleston earthquake, is identified on the basis of four M < 2.5 earthquakes, three of which occurred in a two-day period in December 1977 (Reference 349). Bollinger et al. (Reference 214) downplay the significance of the Adams Run seismic zone, noting that, in spite of increased instrumentation, no additional events were detected after October 1979.

The presence of liquefaction features in the geologic record may be indicative of past earthquake activity in a region. Liquefaction features are recognized throughout coastal South Carolina and are attributed to both the 1886 Charleston and earlier unidentified moderate to large earthquakes in the region. Liquefaction features predating the 1886 Charleston earthquake are found throughout coastal South Carolina. The spatial distribution and ages of paleoliquefaction features in coastal South Carolina constrain possible locations and recurrence rates for large earthquakes (References 202, 203, 204, 311, and 312). Talwani and Schaeffer (Reference 348) combine previously published data with their own studies of liquefaction features in the South Carolina coastal region to derive possible earthquake recurrence histories for the region. They estimate recurrence intervals of approximately 550 to 1000 years with varying magnitudes (roughly $M_w$ 6+ to $M_w$ 7+) and sources.

In summary, instrumental seismicity strongly indicates the presence of zones of increased seismicity in the greater Charleston, South Carolina area. Field and instrumental evidence have identified a variety of potential faults, but none have clear surface expression. However, the historical 1886 event had a magnitude of greater than magnitude 7 and caused liquefaction throughout coastal South Carolina. Paleoliquefaction features provide evidence for repeated large earthquakes with a recurrence interval of 500 to 1000 years, and these earthquakes appear to be confined to the Charleston, South Carolina area. Refinements of the estimate of Charleston area earthquake recurrence are presented in detail in Subsection 2.5.2.

#### 2.5.1.1.4 Regional Gravity and Magnetic Fields

Gravity and magnetic data for the site region are described in this subsection, with a focus on anomalous features in the gravity and magnetic fields. Data for the gravity and magnetic fields for the site region were obtained from the National Geophysical Data Center. The gravity (Reference 262) and magnetic data (Reference 225) were originally produced for the Decade of North America Project (DNAG). The original DNAG gravity data were presented on a 6 km grid (and subsequently regridded by the National Geophysical Data Center to a 2.5-minute grid spacing [References 283 and 308]), which represented free-air gravity anomalies over the ocean and Bouguer anomalies on land. Terrain corrections were only computed and applied in high relief areas of the continent. Large portions of the site region are located offshore and, as a result, Subsection 2.5.1.1.4.1 describes both free-air and Bouguer anomalies for the offshore and onshore portions of the site region, respectively.

The DNAG magnetic data were originally presented on 1.2-mile grid spacing based on a spherical North American Transverse Mercator projection. These data were subsequently also re-gridded on a 2.5-minute grid spacing by the National Geophysical Data Center. These data sets were chosen because they extend farther and give better coverage off shore in southern portions of the site region than more current alternatives such as those presented by the U.S. Geological Survey.

##### 2.5.1.1.4.1 Regional Gravity Field

The gravity field for the site region is shown in Figure 2.5.1-219, which indicates locations of representative field profiles that run through the site region: one oriented north-south parallel to and along the Florida peninsula and one oriented east-west across the southern portions of the Florida platform to the northern portions of the Bahama platform (cross sections A-A’ and B-B’ in Figure 2.5.1-220). The first-order pattern of the anomalous gravitational field correlates well with bathymetry. Higher gravitational field values are in the range from approximately –20 up to +20 to +40 mGals. These higher values generally are surrounded by steep gravity gradients that generally outline and coincide with the exposed land and surrounding shallow waters of the Florida platform and Bahama platform. Intervening deep-water areas such as the Straits of Florida and deep-water channels and basins in the Bahamas banks are characterized by negative values of the gravity field. In addition to the low-density water column, the deep-water channels of the Straits of Florida, Providence Channel, and Tongue of the Ocean have been shown to be floored by thick sequences of low density sediment, compared to the surrounding platform carbonates (Reference 343). This density contrast and the steep nature of the escarpments that form the boundaries of the Bahama platform (Reference 343) provide the well-defined nature of the platforms in the gravity field.

The overall positive anomaly associated with the Bahama platform exhibits a positive gradient to the east from approximately +20 to +40 mGals to over +100 mGals, roughly 225 miles east of Units 6 & 7, except where modified by bathymetric effects as described above. The easterly increasing gradient is interpreted as the result of the decreasing importance of transitional crust with more mafic and denser oceanic crust progressively occurring at shallower levels (Reference 343) towards the Atlantic basin. This long wavelength, easterly increasing gradient is locally modified by relatively subdued, low amplitude circular to elongate anomalies with amplitudes up to 10 mGals.

The Florida platform occupies the northwest quadrant of the site region. This portion of the Florida platform is transected by the Central Florida Gravity Lineament, a well defined northwest-southeast-oriented linear gravity high with an amplitude of a little over +30 mGals in central Florida, at a location approximately 100 miles north of Units 6 & 7 on gravity profile A-A’ (Figures 2.5.1-219 and 2.5.1-220). However, the amplitude of this anomaly is not constant along strike. It appears to decrease slightly to the northwest of profile A-A’ and shows higher anomalous values near the coast line to the southeast of profile A-A’. Subsection 2.5.1.1.4.3 contains an interpretation of this linear anomaly.

Northeast of the Central Florida Gravity Lineament the Florida platform is characterized by relatively low values of the gravity field down to a little less than –20 mGals, with the exception of a short wavelength (approximately 12 miles) circular gravity high located at approximately mile 40 on profile A-A’, which reaches a maximum of a little less than +40 mGals. In contrast, the gravity field associated with the Florida platform southwest of the Central Florida Gravity Lineament is characterized by relatively long wavelength, on the order of 62 to 93 miles, gravitational anomalies that range from 0 to approximately 30 mGals on gravity profile B-B' (Figure 2.5.1-220). These observations indicate that the Central Florida Gravity Lineament effectively forms a boundary that separates the Florida platform into a northern portion characterized by relatively low gravity field values and short wavelength anomalies and a southern portion characterized by a relatively high anomalous field with broader longer wavelength anomalies.

To the south-southeast of Units 6 & 7 a positive anomalous field of approximately 40 mGals is associated with the Cay Sal bank, which exhibits similar field characteristics with the Bahama platform just to the east. In the extreme, southern portions of the site region a positive anomalous field occurs in association with the Cuban mainland resulting from relatively dense igneous, metamorphic, and sedimentary basement rocks and their carbonate cover at shallow levels.

A gravitational low anomaly, whose minimum gravity field value of approximately –15 mGals, occurs just north of the site on gravitational profile A-A'.

#### 2.5.1.1.4.2 Regional Magnetic Field

The regional aeromagnetic field for the site region is shown in Figure 2.5.1-221 and 2.5.1-222, which also indicates the location of magnetic profile A-A' (Figure 2.5.1-223). In distinct contrast to the gravity field in the site region, the magnetic field shows no strong correlation with bathymetry. This is the result of thick carbonate successions that cap the Florida and Bahama platforms that are essentially nonmagnetic. The magnetic field sources all lie in the sub-Cretaceous basement. However, the fundamental nature of the Central Florida Gravity Lineament (Figure 2.5.1-220) is reflected in the nature and anomalous patterns of the magnetic field in the site region (Central Florida Magnetic Lineament in Figure 2.5.1-221).

The Central Florida Gravity Lineament is associated with similar trending and coincident low values in the magnetic field that exhibit values of –500 nanoteslas (nT) on magnetic profile A-A' (Figure 2.5.1-223) approximately 100 miles north of Units 6 & 7. An anomalous magnetic high area on its northwest extension complicates the pattern of this feature, which generally is coincident with the area where the gravitational field associated with this linear feature is also diminishing (Figure 2.5.1-219).

The Florida platform to the southwest of the Central Florida Gravity and Magnetic Lineament and the Bahamas bank exhibit magnetic anomalous features that are circular to ellipsoidal in shape, have relatively long wavelengths, are relatively subdued, and generally trend northwest. Conversely, in central Florida, in the site region and in areas north of the site region, the magnetic field is characterized by relatively high gradient, short wavelength anomalies that are more elongate and linear in shape. In addition, these elongated and linear anomalies are oriented more or less uniformly northeasterly in concert with the structural grain of the Appalachian tectonic province. These trends are truncated by the Central Florida Gravity and Magnetic Lineament. These relationships in the magnetic field further support the fundamental nature of the Central Florida Gravity and Magnetic Lineament, and indicate that it separates two crustal provinces, each of which exhibits different gravity and magnetic field characteristics.

The circular anomalous gravity high noted at mile 40 on gravity profile A-A' (Figure 2.5.1-219 and 2.5.1-220) described in the previous subsection is associated with an apparent magnetic dipole source with a magnetic field high of +300 to +400 nT to the south of a magnetic low of –400 nT. The close association of a dense and magnetic source at this location would suggest that the potential field source for this feature is probably a mafic intrusion in the basement (Reference 282).

Within the site vicinity, a steep northerly increasing magnetic gradient marks the transition from a magnetic field minimum of approximately –200 nT to the south to a magnetic field high of approximately +200 nT to the north. This relationship is opposite of that expected for a magnetic dipole in the northern hemisphere so the significance of the magnetic field is uncertain in terms of a primarily induced field interpretation. However, the occurrence of several magnetic high and low anomalous field regions in the vicinity most probably indicates a magnetized basement with a significant mafic component. However, as noted, the site vicinity is located in association with a gravity low anomaly indicating that the basement in the vicinity is less dense than would be expected from a purely mafic composition and possibly reflects basement lithologic variation.

#### 2.5.1.1.4.3 Summary

Klitgord et al. (Reference 282) and Sheridan et al. (Reference 343) present a synthesis and discussion of the anomalous gravitational and magnetic fields for the Florida platform and Bahama platform including the site region. The following description summarizes the pertinent points that relate to the site region presented in these sources.

In addition to the contrasting character exhibited by the gravity and magnetic fields on either side of the Central Florida Gravity and Magnetic Lineament, the location of the lineament is also correlated with other basic changes in the nature of the crust. The lineament marks a transition in the composition of the crust in the subsurface. In addition, the top of the basement surface becomes much deeper to the southwest. North of the lineament, in the site region, the basement of the Florida platform is relatively shallow and characterized by Paleozoic igneous and metamorphic rocks that compose the Central Florida basement complex, which roughly corresponds with the Suwannee terrane (Figure 2.5.1-222). On the southwestern side of the central Florida lineament the carbonate platform cap becomes much thicker, and the composition of the crust becomes more "transitional" in nature and is composed of Jurassic volcaniclastic sequences.

Klitgord et al. (Reference 282) noted the fact that the Central Florida Gravity and Magnetic Lineament aligns with the Bahamas fracture zone (Figure 2.5.1-222) and suggested that it likely represents a Jurassic transform that separates a Late Jurassic spreading center in the Gulf of Mexico from the Central Atlantic spreading center. North of this transform plate boundary the crust is continental in nature and exhibits structural features associated with Appalachian tectonics as shown in the distinct northeast trend in the potential field anomalies. The relatively shallow basement and consequent relatively thin carbonate cap results in little attenuation of the high frequency components of the potential field anomalies; consequently, the high gradient characteristics of the gravity and magnetic sources are preserved.

In contrast, the basement of the Florida platform and other areas southwest of the transform boundary is much deeper, with a correspondingly thicker carbonate cap on the Florida and Bahama platforms. The basement in these areas contains rotated and tilted blocks of volcaniclastic rocks. These deeply buried volcaniclastic sources result in subdued potential field anomalies whose high-frequency components have been attenuated and the field gradients subdued; consequently, they exhibit broad long wavelength characteristics. Also, detailed interpretation of the magnetic field anomalous sources associated with the volcaniclastic basement to the southwest of the transform boundary is complicated by the fact that some of these volcanic rocks may contain a component of remnant magnetization that may significantly modify the potential anomaly produced by the induced field.

### 2.5.1.2 Site Geology

Units 6 & 7 are located within the Southern Slope subprovince of the Atlantic Coastal Plain physiographic province. The site vicinity geology (Figure 2.5.1-224) was influenced by sea level fluctuations, processes of carbonate and clastic deposition, and erosion. The Paleogene (early Tertiary) is dominated by the deposition of carbonate rocks while the Neogene (late Tertiary) is more influenced by the deposition of quartzitic sands, silts, and clays (Reference 285). Deposition of carbonate rock resumed again during the Pleistocene. Within the site area the dominant rock types are limestones of the Arcadia Formation, Fort Thompson Formation, Key Largo Limestone, and Miami Limestone and the sands and silts of the Peace River and Tamiami Formations (Figure 2.5.1-225). Minor units of alluvial soils, organic muck, and silt cover the surface. During the Pleistocene, worldwide glaciation and fluctuating sea levels influenced the geology in the site vicinity. Drops in sea level caused by growth of glaciers increased Florida's land area significantly, which led to increased erosion and clastic deposition. Warm interglacial periods resulted in a rise in sea level and an increase in nutrient-rich waters leading to an increase in carbonate build-up (Reference 285). The geology within the site area is dominated by flat, planar bedding in late Pleistocene and older units. No geologic tectonic or physiographic structures such as sinkholes have been identified within the site area.

#### 2.5.1.2.1 Site Physiography and Geomorphology

Units 6 & 7 are located within Miami-Dade County, Florida, approximately 25 miles south of Miami, 8 miles east of Florida City, and 9 miles southeast of Homestead, Florida. The site area is located within the Southern Slope sub-province 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 (Figure 2.5.1-202). The Southern Zone physiographic subregion is a broad, gently sloping plain with poor drainage. Most of this zone is below the piezometric surface in saltwater marshes and swamps overlain by peat. Units 6 & 7 are bordered on the east by Biscayne Bay, on the west by Florida City and Homestead, on the south by Key Largo, and on the north by Miami. There are numerous canals to the west within an Everglades mitigation bank. The physiographic features bordering the plant property are the Everglades, Florida Keys, and the Continental Slope (Figure 2.5.1-202).

The site area is characterized by organic muck and the Miami Limestone (Figure 2.5.1-227). The organic muck is the dominant surficial sediment type, whereas the Miami Limestone is exposed in the northern and western parts of the site area (Figure 2.5.1-227). The Miami Limestone is a marine carbonate consisting predominately of oolitic facies of white to gray limestone with fossils (mollusks, bryozoans, and corals). The overlying organic muck located near the rivers in the site area is a light gray to dark gray to pale brown sapric muck with trace amounts of shell fragments that have little or no reaction to hydrochloric acid. Close to the rivers, it consists of black to brown fiberous muck with a strong reaction to hydrochloric acid. The muck varies in thickness across the site from 2 to 6 feet.

The site is at or near sea level with an existing elevation of –2.4 to 0.8 feet (NAVD 88) and is generally flat. The site is flat and uniform throughout with the exception of vegetated depressions, as seen in Figure 2.5.1-226 and 2.5.3-202. The vegetative depressions are dissolution features within the Miami Limestone, described in Subsection 2.5.3.

#### 2.5.1.2.2 Site Area Stratigraphy

A geologic map of the site area is presented in Figure 2.5.1-227. As part of the site characterization program, subsurface information was collected from 88 geotechnical borings, 22 separate groundwater borings, and four CPTs. Of the 88 geotechnical borings drilled, 32 are located within the boundary of the Unit 6 power block (600-series borings) and 32 are located within the boundary of the Unit 7 power block (700-series borings). The locations of the boreholes are shown in Figure 2.5.1-228. Subsection 2.5.4 contains a more detailed description of the comprehensive geotechnical investigation employed to characterize the subsurface of the site. The rock core descriptions on the boring logs described in Subsection 2.5.4 and in Reference 381 are based on the carbonate classification system described by Dunham (Reference 243) that is commonly used in Florida. The geologic formations encountered in the geotechnical exploration were identified in the field. The upper and lower Fort Thompson formations identified on the boring logs are reinterpreted in this subsection as the Key Largo Limestone and Fort Thompson Formation. This is based on a broad review of geologic publications, the predominance of coralline structure in the Key Largo Limestone and moldic porosity in the lower Fort Thompson Formation.

Of the 88 geotechnical borings drilled and sampled as part of the site investigations, only two were advanced to a depth greater than 290 feet below ground surface (bgs): B-701 was advanced to a depth of 615.5 feet bgs and B-601 was advanced to a depth of 419.2 feet bgs. The remaining 86 borings ranged in depth from 100 to 290 feet bgs with a median of approximately 125 feet bgs. This subsurface investigation obtained detailed information about the near-surface geologic characteristics and composition of sediments underlying the site. Information gathered from the regional investigation coupled with specific data obtained from borings that were drilled as part of the subsurface investigation were used to develop the site stratigraphic column presented in Figure 2.5.1-225.

Geophysical logs were obtained for 10 of the 88 borings. A suite of nine different geophysical logs was prepared for each of the ten borings in which geophysical logging was accomplished. Natural gamma logs were recorded as part of the electric log suite and as a correlation tool with the caliper log. Gamma logs are used to identify lithology, with gamma counts of shale, silt, and clay generally higher (moving to the right) because clays adsorb radioactive particles more readily than other materials. A spontaneous potential (SP) log was also taken to identify lithology, but SP is not as sensitive to changes in lithology as the natural gamma curves. Three different resistivity logs were taken to record the resistivity of the formation at various intervals away from the boring wall and to track the effects of the drilling fluid at different levels. These three logs are also used to identify lithology with sandy units moving the curve to the right and clays moving the curve to the left. A caliper log was taken to record changes to the diameter of each borehole. Suspension shear (S) and compression (P) wave velocity logs were completed in each of the ten designated borings. Finally, an acoustic televiewer log was taken to provide a visual inspection of the interior walls of the boring. The key at the top of each log identifies each of the curves. A more detailed description of the down-hole geophysical logging is available in the geotechnical data report in Reference 381.

Figure 2.5.1-224, 2.5.1-227, and 2.5.1-229 show the geology of the site vicinity, site area, and site. The site stratigraphic column (Figure 2.5.1-225) presents the lithologic and hydrostratigraphic units encountered during the site subsurface investigation. Hydrogeologic units are described in more detail in Subsection 2.4.12. These strata are described below as they occur from the ground surface to depth beneath the site. Most borings drilled for the site subsurface investigation penetrate the Miami Limestone, Key Largo Limestone, and Fort Thompson Formation to a depth of over 100 feet. Thirty-four deeper borings penetrated into the underlying Tamiami Formation at approximately 115 feet and continued to a depth of around 150 feet; ten of these borings continued to depths in excess of 215 feet and penetrated the Peace River Formation of the Hawthorn Group. One boring, B-701 (DH), penetrated the Arcadia Formation of the Hawthorn Group at a depth of 455 feet before terminating at a final depth of 615.5 feet. The description and characteristics of the geologic units encountered in the site investigation are described below. Boring logs are included in Reference 381.

The surface of the site consists of approximately 2 to 6 feet of organic soils called muck. The muck is composed of recent light gray calcareous silts with varying amounts of organic content. The surface elevations for the top of the organic soil ranged from +0.2 to –1.8 feet MSL (Figure 2.5.1-229 and 2.5.1-230).

The bedrock surface throughout the site consists of the Pleistocene Miami Limestone overlain by muck. At the site, the Miami Limestone is a white, porous, sometimes sandy, fossiliferous, oolitic limestone (grainstone) with vugs that are typically oriented in either the horizontal or the near vertical direction. The formation is mostly soft to medium hard throughout, but typically very hard at the base. The top of the Miami Limestone was generally encountered at a depth of 3 to 6 feet bgs. The Miami Limestone is approximately 25 feet thick beneath the site.

The Pleistocene Key Largo Limestone underlies the Miami Limestone at Turkey Point. The contact between the Miami Limestone and the Key Largo Limestone is generally an irregular gradational contact primarily inferred from changes in hardness and oolite content. Based on previous investigations by others (Reference 265), the Key Largo Limestone was initially identified and logged as the upper Fort Thompson Formation. Subsequent investigation, including a review of recent publications and a reexamination of the rock core, indicated that the coralline limestone facies should be identified as the Key Largo Limestone, not the upper Fort Thompson Formation. The Key Largo Limestone is a coralline limestone characterized by the presence of vuggy porosity with a high degree of interconnectivity. The coralline vugs within the Key Largo Limestone typically exhibit evidence of precipitation of secondary minerals (i.e., calcite). The contact between the Key Largo Limestone and the underlying Fort Thompson Formation has been identified at the site as a marker layer of dark gray, fine-grained limestone occurring at the base of the Key Largo Limestone. The dark gray limestone encountered in most of the site borings is generally 2 feet or more thick and often possesses a sharp color change from light to dark gray at its base marking the transition from the Key Largo Limestone to the Fort Thompson Formation.

The Key Largo Limestone is a fossil coral reef that is believed to have formed in a complex of shallow-water, shelf-margin reefs and associated deposits along a topographic break during the last interglacial period (Reference 266). The Key Largo Limestone is exposed at the surface in the Florida Keys from Soldier Key on the northeast to Newfound Harbor Keys near Big Pine Key on the southwest. At the site, the Key Largo Limestone is generally encountered at a depth of 23 to 33 feet bgs and is approximately 22 feet thick.

The Pleistocene Fort Thompson Formation directly underlies the Key Largo Limestone. The Fort Thompson Formation is generally a sandy limestone with zones of uncemented sand interbeds, some vugs, and zones of moldic porosity after gastropod and/or bivalve shell molds and casts. Overall, the vugs and molds within the Fort Thompson Formation create a secondary porosity with a lower degree of interconnectivity than the vugs within the Key Largo Limestone. The top of the Fort Thompson Formation is generally encountered at a depth between 48 and 52 feet bgs and has a thickness of approximately 65 feet at the site.

The Pliocene Tamiami Formation directly underlies the Fort Thompson Formation. The contact between the Tamiami Formation and the Fort Thompson Formation is an inferred contact picked as the bottom of the last lens of competent limestone encountered. The placement of this inferred contact in each boring was primarily determined from core recoveries and drill rates. The Tamiami Formation is a poorly defined lithostratigraphic unit containing a wide range of mixed carbonate-siliciclastic lithologies. The Tamiami Formation generally consists of well-sorted, silty sand, but locally it is interlayered with clayey sand, silt, and clean clay. The top of the Tamiami Formation is generally encountered at a depth between 113 and 117 feet bgs with an average thickness of 105 feet at the site.

The Miocene-Pliocene Peace River Formation of the Hawthorn Group directly underlies the Tamiami Formation. The Peace River Formation is composed of interbedded sands, clays, and carbonates. The contact between the Peace River Formation and the Tamiami Formation is inferred based an increase in activity on the gamma ray log (Reference 381). The Peace River Formation is penetrated in only the eight deepest borings and generally consists of well-sorted, silty sand down to approximately 460 feet bgs. The top of the Peace River Formation is encountered at a depth between 216 and 224 feet bgs with an average thickness of 235 feet.

The Oligocene-Miocene Arcadia Formation of the Hawthorn Group underlies the Peace River Formation. The Arcadia Formation consists of carbonate rock ranging from packstone to wackestone to mudstone, with a few isolated lenses of silty sand. The Arcadia formation varies in hardness from soft (friable) to hard (well indurated), with colors ranging from pale yellow to greenish gray. The Arcadia Formation is fossiliferous with shell molds and casts of bivalves and gastropods found in some locations within the core. The unit was capped by a gray, hard, indurated dolostone/grainstone with sugary texture containing a few gastropod shell molds and casts. The Arcadia Formation is encountered in a single deep boring (B-701 DH) at a depth of 455 feet bgs and extended to the bottom of the boring to a depth of 615.5 feet bgs where the boring was terminated.

Consequently, the thickness of the Arcadia Formation at the site exceeds 161 feet. Four geologic cross sections, two isopach (thickness) contour maps, one structural contour map, and a site geologic map were prepared from the information obtained from the site subsurface investigation. Figure 2.5.1-228 shows the location and orientation of the four cross sections at the site developed from borings, CPTs, and geophysical logs.

Geologic cross section A-A' (Figure 2.5.1-231) extends east-west through the power blocks and eight borings, including the two deepest borings B-601 and B-701. Cross section B-B' (Figure 2.5.1-232) extends west-east through the southern edge of the site and contains 8 borings, the deepest at 153 feet bgs. Cross section C-C' (Figure 2.5.1-233) extends diagonally northwest–southeast through the entire site and passes through the western power block. Cross section C-C' contains seven borings including the deepest boring, B-701(DH), at a depth of 615.5 feet bgs. Cross section D-D' (Figure 2.5.1-234) also extends diagonally northwest–southeast through the entire site but passes through the eastern power block. Cross section D-D' contains six borings; the deepest at a depth of 215 feet bgs. The cross sections indicate that geologic contacts beneath the site are relatively flat and undeformed. This reflects the environment of deposition and subsequent erosion of the paleosurface. This is represented by isopach (thickness) maps of the Key Largo Limestone (Figure 2.5.1-235) and the Fort Thompson Formation (Figure 2.5.1-236) that indicate a relatively uniform thickness across the site with no abrupt changes. A structural contour map of the top of the Fort Thompson Formation shows a relatively flat paleosurface (Figure 2.5.1-237). Boring logs and descriptions of the lithology are included in the geotechnical data report in Reference 381.

#### 2.5.1.2.3 Site Area Structural Geology

This subsection provides a review of the structural geologic setting from published maps and literature and the Units 3 & 4 UFSAR (Reference 256), which is supplemented by new information from the 2008 geologic mapping and exploration program performed as part of this COL Application project. The site lies on the stable Florida carbonate platform, and no faults or folds are mapped within more than 25 miles (Figure 2.5.1-224). New data include geologic mapping and bedding attitudes interpreted from lithologic contacts in boreholes. Taken together, these data indicate generally flat, planar bedding in Pleistocene and older units and an absence of geologic structures within the site area.

The site area geologic and surficial maps and cross sections (Figures 2.5.1-227, 2.5.1-229, 2.5.1-230, 2.5.1-231, 2.5.1-232, 2.5.1-233, and 2.5.1-234) present basic structural information. Figure 2.5.1-237 is a structure contour map of the top of the Late Pleistocene Fort Thompson Formation. Isopach maps of the Key Largo Limestone and the Fort Thompson Formation are also shown in Figure 2.5.1-235 and 2.5.1-236. Geologic field reconnaissance was performed to verify general structural interpretations presented in literature describing southern Florida and observations of that work are presented herein. The reconnaissance effort generally increased with increasing proximity to the site.

The entire site area was inspected using both pre-construction (1940 black-and-white stereo paired) and more recent (1999 color infrared and 2004 true color) 1:40,000-scale aerial photography acquired from the U.S. Geological Survey and the Florida Department of Environmental Protection. Interpretations of the photographs did not identify any structural features to be studied further within the site area. Field reconnaissance within the site area included detailed mapping of the site and inspection of available outcrops of Miami Limestone along the banks of the cooling canals. The Late Pleistocene Miami Limestone underlies the entire site area, and is mapped at the surface throughout large portions of southern Florida (Figure 2.5.1-224). However, this unit rarely outcrops and is often covered by recent unconsolidated soil or other deposits (Figure 2.5.1-230). The portions of the site that have not been disturbed by the construction of cooling canals are covered by a thin (roughly 3 feet thick) veneer of organic-rich mud and silt, generally referred to as organic muck (Figure 2.5.1-229). Field reconnaissance, a review and interpretation of aerial photography, a review of published literature, and an analysis of the results of the subsurface exploration (Reference 381) that were all performed for this COL Application did not reveal any evidence for tectonic deformation within the site vicinity or site area. No folds, fractures, faults or geomorphic features indicative of faulting, or other tectonic structures have been observed or mapped (Figures 2.5.1-224, 2.5.1-227, and 2.5.1-229 through 2.5.1-234) in the site vicinity or site area.

Regional structural information from borings across southern Florida indicates that Cretaceous to Pleistocene strata are generally flat-lying or have shallow dips (<1 degree) that likely reflect paleotopography (References 221, 247, and 327) (Figures 2.5.1-216 and 2.5.1-217). For example, the base of the Fort Thompson Formation has a dip of 0.06 degrees to the southeast in the vicinity of the existing cooling canals (from Reference 263). Data presented in Figures 2.5.1-231 through 2.5.1-234 and Reference 381 confirm that planar, undisturbed bedding persists beneath the site. Based upon local boring data, vertical relief of several feet is found in the contact of the Miami Limestone with the underlying Key Largo Limestone in the site vicinity. However, upon examination during the field reconnaissance, this relief is considered to be a primary sedimentary feature related to the reef origin of the Key Largo Limestone and not due to tectonic or non-tectonic deformation. Field reconnaissance, a review and interpretation of aerial photography, a review of published literature, and an analysis of the results of the subsurface exploration (Reference 381) that were all performed for this COL Application indicate that the Miami Limestone and older strata are consistently oriented and are not measurably offset or deformed by faulting within the site area (see Figures 2.5.1-227 and 2.5.1-229 through 2.5.1-234).

Additionally, previous site and regional investigations (References 256 and 263) and work performed as part of this project have identified no systematic jointing patterns within bedrock underlying the site area. Geologic field reconnaissance also included inspection of aerial imagery for lineations and possible hazards within the site area. No lineations were identified within the site area, other than minor local alignments of the vegetated depressions developed in the organic muck that covers the site (Figure 2.5.3-202). Field reconnaissance, a review and interpretation of aerial photography, a review of published literature, and an analysis of the results of the subsurface exploration (Reference 381) that were all performed for this COL Application found no geomorphic evidence to suggest differential uplift across any of the lineaments or any structural or stratigraphic evidence to suggest lateral displacement across any of the lineaments. These lineations are interpreted as tidally-influenced channels (see description in Subsection 2.5.3.2, and Figures 2.5.1-227 and 2.5.1-229 through 2.5.1-235) and do not correlate with any potential joints, folds, faults, or other structures within the site area.

#### 2.5.1.2.4 Site Geologic Hazards

No geologic hazards have been identified within the site area. However, because the near-surface geologic rock units in the site area are primarily composed of limestone, it was considered essential to assess the potential for solution hazards related to karst. The term “karst” is used to describe areas where the landscape and its subsurface have been modified by the dissolution of soluble rock. Such areas are characterized by a variable group of features, which include cavities and sinkholes, that can represent a geologic subsidence or collapse hazard. Cavities, as related to karst, are subsurface voids created due to the dissolution and removal of soluble rock. Sinkholes are topographic depressions formed as the result of processes such as dissolution and removal of bedrock, collapse of cave roofs, or flushing and/or collapse of unconsolidated sediment into a void within the bedrock. There are three main types of sinkholes common to Florida (Reference 344):

- Solution sinkholes occur where limestone is exposed at the ground surface or is thinly covered. Dissolution is concentrated at the limestone surface and along joints, fractures, or other openings in the rock. Their development is typified by a slow downward movement of the ground surface that results in the formation of a depression that is commonly filled with organic sediments. These sinkholes typically manifest themselves as bowl-shaped depressions at the ground surface.

- Cover-collapse sinkholes occur where a solution cavity develops in the limestone to a size such that the overlying material cannot support its own weight. The result is generally a sudden collapse of the overburden into the cavity. These sinkholes are common in areas where limestone bedrock is near the ground surface and under water-table conditions, with accelerated dissolution occurring in limestone zones at and just below the water table.

- Cover-subsidence sinkholes occur where the overburden is comprised of unconsolidated and permeable sands. They form when the sand slowly moves downward into space formerly occupied by other sediments, which have already moved downward into space formerly occupied by limestone that has been removed by dissolution. These sinkholes generally develop gradually.

The Florida Geological Survey classifies sinkhole occurrences into four type areas (Reference 344) (Figure 2.5.1-238):

- Area I: Bare or thinly covered limestone. Sinkholes are few, generally shallow and broad, and develop gradually. Solution sinkholes dominate.

- Area II: Cover is 30 to 200 feet thick and consists mainly of incohesive and permeable sand. Sinkholes are few, shallow, of small diameter, and develop gradually. Cover-subsidence sinkholes dominate.

- Area III: Cover is 30 to 200 feet thick and consists mainly of cohesive clayey sediments of low permeability. Sinkholes are numerous, of varying size, and develop abruptly. Cover-collapse sinkholes dominate.

- Area IV: Cover is more than 200 feet thick and consists of cohesive sediments interlayered with discontinuous carbonate beds. Sinkholes are few in number. However, the ones that do occur are generally large in diameter and deep. Cover-collapse sinkholes dominate.

Units 6 & 7 are located in Area I where sinkholes, if they occur, are typically solution sinkholes. Their gradual development is explained by the relatively slow rate at which limestone dissolution and removal occurs. The maximum rate of wall retreat in limestone is estimated to be on the order of 0.04 inches per year (Reference 380). The maximal potential dissolution for the Lower Suwannee River basin in Florida, which is located approximately 300 miles northwest of the site, is calculated to be less than 0.002 inches per year (Reference 379). Thus, active dissolution of limestone at the site is not considered to present a geologic hazard.

While large cavities and collapses are not expected in Area I where Units 6 & 7 are located (Reference 340), localized factors can influence whether or not cavities and the potential for collapse exists. Catastrophic collapse is not known to occur in southern Florida. In addition to the fact that cavities in this area are generally small in size, a stress mechanism, such as a rising or falling water table, is necessary to trigger the collapse of overburden into preexisting cavities that may have taken eons to form (Reference 284). Such a natural triggering mechanism is not prevalent in south Florida because the water table is generally very close to the surface with little fluctuation (Reference 378).

According to Renken et al. (Reference 330), sinkholes and caves have been found in Miami-Dade County along the Atlantic coastal ridge, where limestone is present at a relatively high elevation, extending southward from south Miami toward Everglades National Park (Figure 2.5.1-202). The Atlantic coastal ridge is up to 50 feet high and trends north-northeast to south-southwest into the site vicinity (Reference 357). Further discussion of the Atlantic coastal ridge is found in Subsection 2.5.1.1.1.2.1. Parker (Reference 316) states that the Miami Limestone and Fort Thompson Formation have significant permeability and solution features that have created turbulent flow conditions in some wells. According to Cunningham et al. (Reference 228), topographic relief related to karst dissolution is well documented in the Lake Belt area of north-central Miami-Dade County approximately 90 miles northwest of Units 6 & 7. These studies contain no suggestion of the presence of buried sinkholes, caverns, or other large-scale underground karst features in the vicinity of the site (Reference 308).

A Florida Geological Survey Investigation (Reference 353) concludes that most of Miami-Dade County is underlain by limestone containing solution cavities. It indicates that a few general localities in the Homestead/Turkey Point area may be underlain by open and sand-filled cavities in a zone occurring between depths of about 18 to 31 feet. However, the locations of any such cavities have not been determined. The indicated depth interval correlates roughly with that of the Miami Limestone beneath Units 6 & 7, which will be removed during plant construction.

Personal communication with the Florida Geological Survey (Reference 340) indicates that dissolution present in the site area is generally considered to be micro-karst with numerous small cavities as observed in the rock core from the site. Small dissolution features in the form of vugs and moldic secondary porosity were observed in limestone drill core obtained at Units 6 & 7, particularly in the Miami Limestone and Key Largo Limestone. During the course of the site subsurface investigation (Reference 381), the following observations were made with respect to the presence of subsurface solution activity:

- No large dissolution features were encountered.
- Rod drops during drilling were negligible, as described in Subsection 2.5.4.1.2.1.
- No unusual loss of drilling fluid occurred.
- Caliper logs did not reveal the presence of any large voids.
- Acoustic logs did not indicate the presence of any large voids.

An investigation of small surface depressions identified within the site (Figure 2.5.1-226) and site area is discussed in Subsection 2.5.3. The UFSAR for Turkey Point Units 3 & 4 concludes that "Such depressions are not sinkholes associated with collapse above an underground solution channel, but rather potholes, which are surficial erosion or solution features" (Reference 256). These solution potholes are not expected to form large voids beneath the surface that would pose a hazard to the site (Reference 344).

An integrated geophysical survey focused on the Units 6 & 7 power block area and the small surface depressions identified within the site is discussed in Subsection 2.5.4.4.5. Based on all of the site characterization data collected from the site, there is no evidence for sinkhole hazards or for the potential of surface collapse due to the presence of large underground openings.

Based on the absence of Quaternary volcanic features in the site region, no volcanic activity is anticipated in the site vicinity.

#### 2.5.1.2.5 Site Area Engineering Geology Evaluation

##### 2.5.1.2.5.1 Engineering Soil Properties and Behavior of Foundation Materials

Engineering soil properties, including index properties, static and dynamic strength, plasticity and compressibility, are described in Subsection 2.5.4. The foundation bearing strata will be evaluated and mapped as the subgrade excavation is completed to confirm that the observed properties are consistent with those used in the design.

##### 2.5.1.2.5.2 Zones of Alteration, Weathering, Dissolution, and Structural Weakness

Field reconnaissance, a review and interpretation of aerial photography, a review of published literature, and an analysis of the results of the subsurface exploration (Reference 381) that were all performed for this COL Application found no unusual zones of alteration, weathering profiles, or structural weakness in the surface or subsurface. No zones of alteration, weathering profiles, or structural weakness were encountered during subsurface drilling. Downhole geophysics, caliper logs and acoustic logs did not indicate any zones of alteration, weathering, dissolution, or other structural weakness. An investigation of small surface depressions in the site area due to surficial limestone dissolution is described in Subsection 2.5.3.

In addition, FPL conducted an integrated geophysical survey focused on the Units 6 & 7 power block areas to further evaluate the potential for carbonate dissolution features occurring at the site, which is described in Subsection 2.5.4.4.5. Any noted desiccation, dissolution, weathering zones, joints, or fractures will be evaluated and mapped as the subgrade excavation is completed to confirm that the mapped characteristics, such as fracture frequency, are consistent with the borehole data used in the design.

##### 2.5.1.2.5.3 Prior Earthquake Effects

A ground and aerial field reconnaissance investigation and literature review were conducted in 2008 to identify potential earthquake-related deformation at the site. These investigations included a review of aerial photography to evaluate anomalous features including depressions, topographic highs and lineaments. The geologic and geomorphic study found no evidence for active folding or faulting, or other past earthquake activity. No features were identified during this investigation that may be related to earthquake induced ground shaking including liquefaction-related sand blows or lateral spread fractures. The field reconnaissance augmented and verified aspects of previous geologic maps and publications by the U.S. Geological Survey, the Florida Geological Survey, and other researchers. A detailed search for evidence of prehistoric earthquakes along the Atlantic seaboard by Amick et al. (Reference 203) found no evidence of paleoliquefaction features south of the South Carolina border. These investigations have recognized no geomorphic, stratigraphic, or other features indicating recent tectonic deformation within the site vicinity. In addition to this field reconnaissance, a review and interpretation of aerial photography, a review of published literature, and an analysis of the results of the subsurface exploration (see Reference 381, and Figure 2.5.1-227 and 2.5.1-229 through 2.5.1-234) that were all performed for this COL Application found no evidence of past earthquake activity or liquefaction-related features within the site area or site vicinity.

#### 2.5.1.2.5.4 Effects of Human Activities

The anthropogenic effects in southeastern Florida of urban development, water mining, limestone mining, oil and gas development, agriculture, and construction of drainage canals have affected the regional groundwater table and associated saltwater intrusion. There are no indications that the groundwater table has been affected at the site due to those activities. Subsection 2.4.12 contains a more detailed description of the groundwater characteristics.

No oil, gas, or metallic mineral resources have been reported in the site area. There is no present mining or excavation of nonmetallic mineral resources within the site area. The closest quarrying activities are located 8 miles from the site. No oil or gas production activities occur within the site or site area. Some oil and gas exploration has been performed in southern Florida, and approximately six dry holes were drilled within the site vicinity (Reference 376).

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