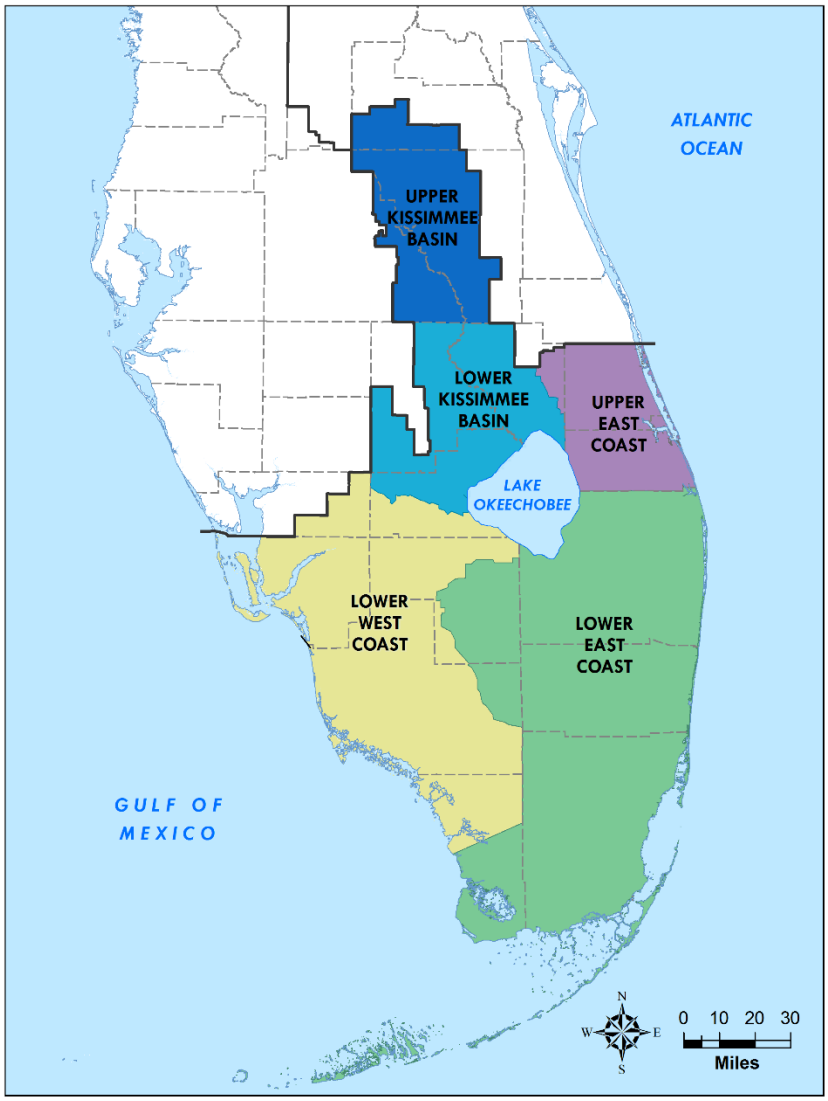
Physical Features and Water Resources of the South Florida Water Management District

December 2022



sfwmd.gov

South Florida Water Management District | 3301 Gun Club Road | West Palm Beach, FL 33406

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

C&SF Project	Central and Southern Florida Flood Control Project
CERP	Comprehensive Everglades Restoration Plan
CREW	Corkscrew Regional Ecosystem Watershed
District	South Florida Water Management District
EAA	Everglades Agricultural Area
FAS	Floridan aquifer system
ft	foot
HRS	Headwaters Revitalization Schedule
IAS	intermediate aquifer system
ICU	intermediate confining unit
KCOL	Kissimmee Chain of Lakes
LEC	Lower East Coast
LFA	Lower Floridan aquifer
LKB	Lower Kissimmee Basin
LOSA	Lake Okeechobee Service Area
LWC	Lower West Coast
MFL	minimum flow and minimum water level
mg/L	milligrams per liter
MSL	mean sea level
SAS	surficial aquifer system
SFWMD	South Florida Water Management District
SJRWMD	St. Johns River Water Management District
STA	stormwater treatment area
SWFWMD	Southwest Florida Water Management District
TDS	total dissolved solids
UEC	Upper East Coast
UFA	Upper Floridan aquifer
UKB	Upper Kissimmee Basin
USACE	United States Army Corps of Engineers
WCA	water conservation area
WMA	wildlife management area

Introduction

The South Florida Water Management District (SFWMD or District) is a regional government agency charged with safeguarding water resources and meeting the water needs across 16 counties, from Orlando to the Florida Keys (**Figure I-1**). Encompassing nearly 18,000 square miles, the SFWMD is divided into five water supply planning areas: Upper Kissimmee Basin (UKB), Lower Kissimmee Basin (LKB), Upper East Coast (UEC), Lower West Coast (LWC), and Lower East Coast (LEC). This document provides information about the physical features and water resources of these planning areas. Each chapter focuses on a particular planning area, highlighting the region's geography as well as the surface water and groundwater resources. The information herein is unlikely to change over time and provides reference for the water supply plan updates that are developed on a 5-year rolling cycle.

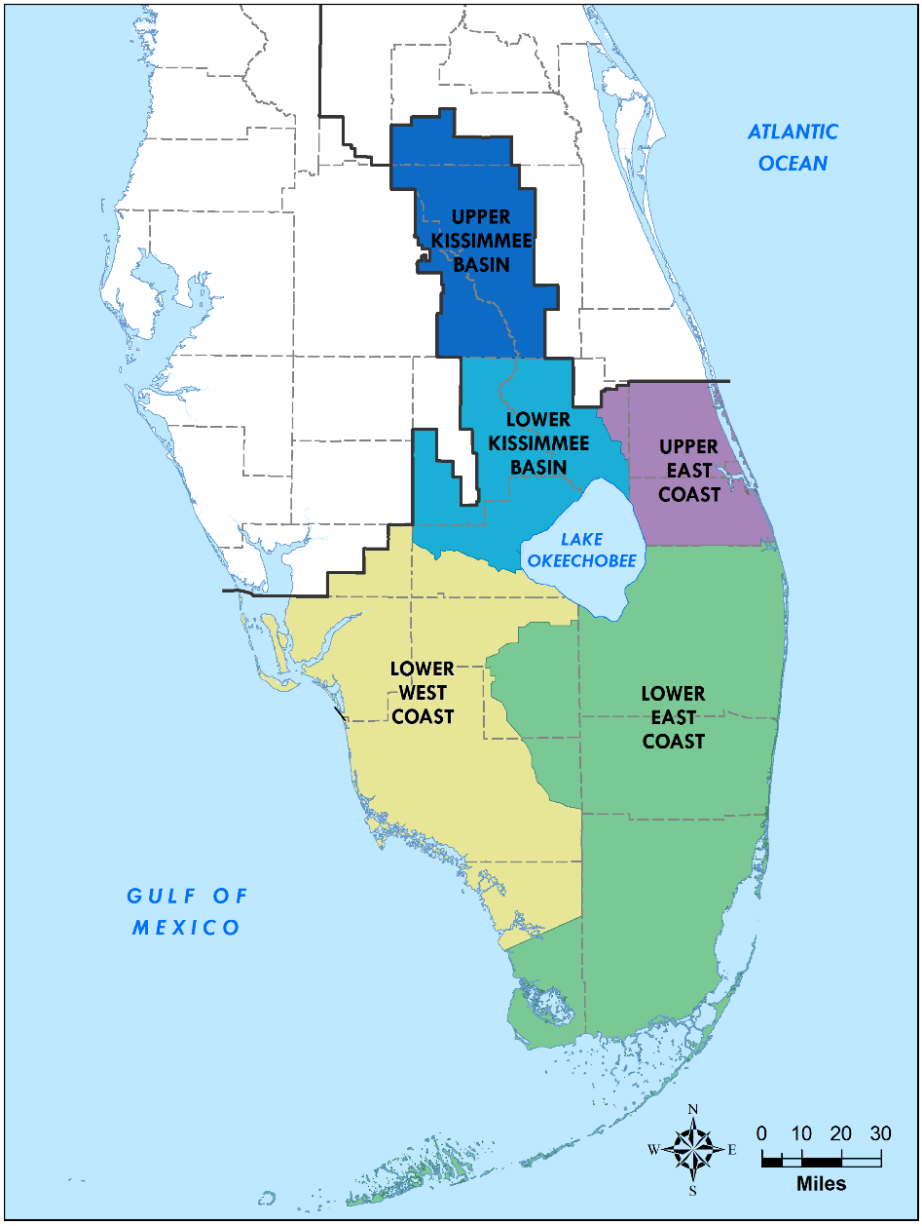


Figure I-1. Planning areas of the South Florida Water Management District.

Chapter 1: Upper and Lower Kissimmee Basin Planning Areas

This chapter describes characteristics of the combined Upper and Lower Kissimmee Basin planning areas. Since 2014, the Kissimmee Basin has been divided and addressed in two different water supply plans. The Upper Kissimmee Basin (UKB) is part of the Central Florida Water Initiative planning area, which includes Seminole, Orange, Osceola, Polk, and southern Lake counties. The Central Florida Water Initiative is a joint planning effort between the St. Johns River, South Florida, and Southwest Florida water management districts, among other agencies and stakeholders. The Lower Kissimmee Basin (LKB) includes portions of Glades, Highlands, and Okeechobee counties. Despite being addressed in separate water supply plans, the two regions are addressed together in this document because their physiography and hydrology are similar and connected.

Within the South Florida Water Management District (SFWMD or District), the UKB/LKB area extends from southern Orange County, south along the Kissimmee Chain of Lakes (KCOL) and the Kissimmee River, to the north shore of Lake Okeechobee (**Figure 1-1**). The area includes portions of Orange, Osceola, Polk, Highlands, Okeechobee, and Glades counties. The UKB/LKB boundaries generally reflect the drainage basin of the Kissimmee River. The northern and eastern portions of the combined basin are adjacent to the St. Johns River Water Management District (SJRWMD), while the western boundary is adjacent to the Southwest Florida Water Management District (SWFWMD).

Lake Kissimmee, S-65 Structure

1.1 PHYSICAL FEATURES

Water bodies and wetlands cover about a quarter of the UKB/LKB area. Most wetland systems drain into the Kissimmee River and, subsequently, into Lake Okeechobee. Major features include the KCOL, Kissimmee River and its floodplain, and Lake Istokpoga – Indian Prairie basin. Shingle Creek Swamp and Reedy Creek Swamp, two large, forested wetlands in the UKB Planning Area, start the headwaters of the KCOL.

Taylor Creek/Nubbin Slough Basin

Fisheating Creek, west of Lake Okeechobee, marks the southernmost boundary of the LKB Planning Area. The Fisheating Creek basin extends from west-central Highlands County (south of State Road 66) southward into the northern portion of Glades County. The creek collects runoff from the Lake Wales Ridge, located in Highlands County within the SWFWMD, as well as some runoff from Glades County. Fisheating Creek is the only remaining naturally flowing tributary to Lake Okeechobee.

The Taylor Creek/Nubbin Slough basin, located north and northeast of Lake Okeechobee, also is considered within the LKB Planning Area.

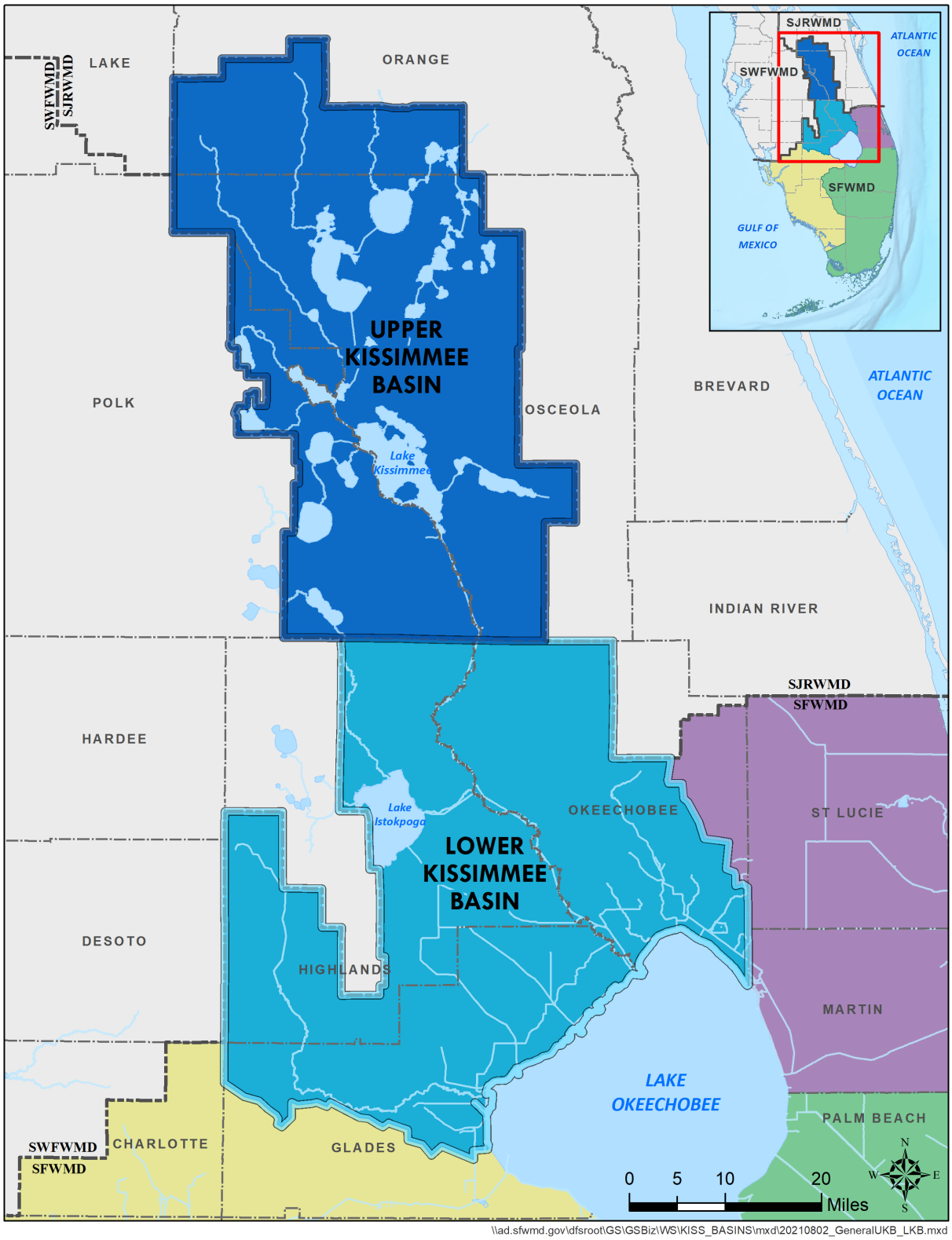
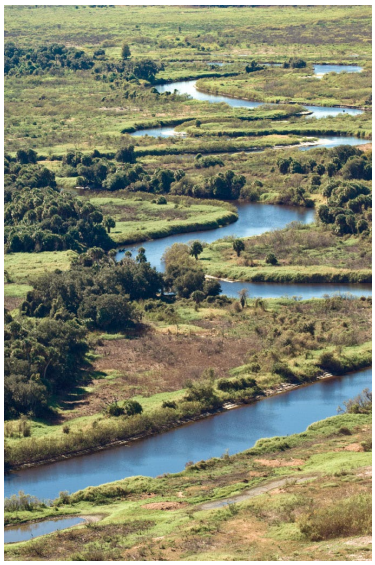


Figure 1-1. Upper and Lower Kissimmee Basin planning areas.

1.1.1 Water Bodies and Landscapes

The UKB Planning Area contains hundreds of lakes; however, the KCOL is the dominant hydrologic feature (see **Section 1.2.2.1**). Outflow from Lake Kissimmee enters the Kissimmee River and C-38 Canal before continuing southward to Lake Okeechobee (see **Section 1.2.2.2**).

The Kissimmee River and its floodplain are characterized by forested areas, wetland shrub, and marsh wetlands. Completed in July 2021, the federally authorized Kissimmee River Restoration Project re-established flow to approximately 40 miles of historical river channel and restored nearly 39 square miles of floodplain wetlands. More information about the Kissimmee River Restoration Project is provided in the annual updates of Chapter 9 of the *South Florida Environmental Report – Volume I*, available from www.sfwmd.gov/sfer.



Restored Kissimmee River

Located within the LKB Planning Area, Lake Istokpoga is 44 square miles and the fifth largest lake in Florida (see **Section 1.2.2.2**). Lake Istokpoga receives water from Arbuckle and Josephine creeks, which collect runoff from the western portion of the planning area and from areas within the SWFWMD.

Covering 730 square miles, Lake Okeechobee is the largest lake in the southeastern United States and a central component of the hydrology and environment of South Florida. Although the lake is adjacent to the LKB Planning Area, it is included in the Lower East Coast water supply plan updates and discussed in **Chapter 4** of this report.

Anhinga in Lake Istokpoga

1.1.2 Geography

Combined, the UKB and LKB planning areas encompass 3,488 square miles of central Florida, and the average elevation is 63 feet (ft) above mean sea level (MSL) (**Figure 1-2**).

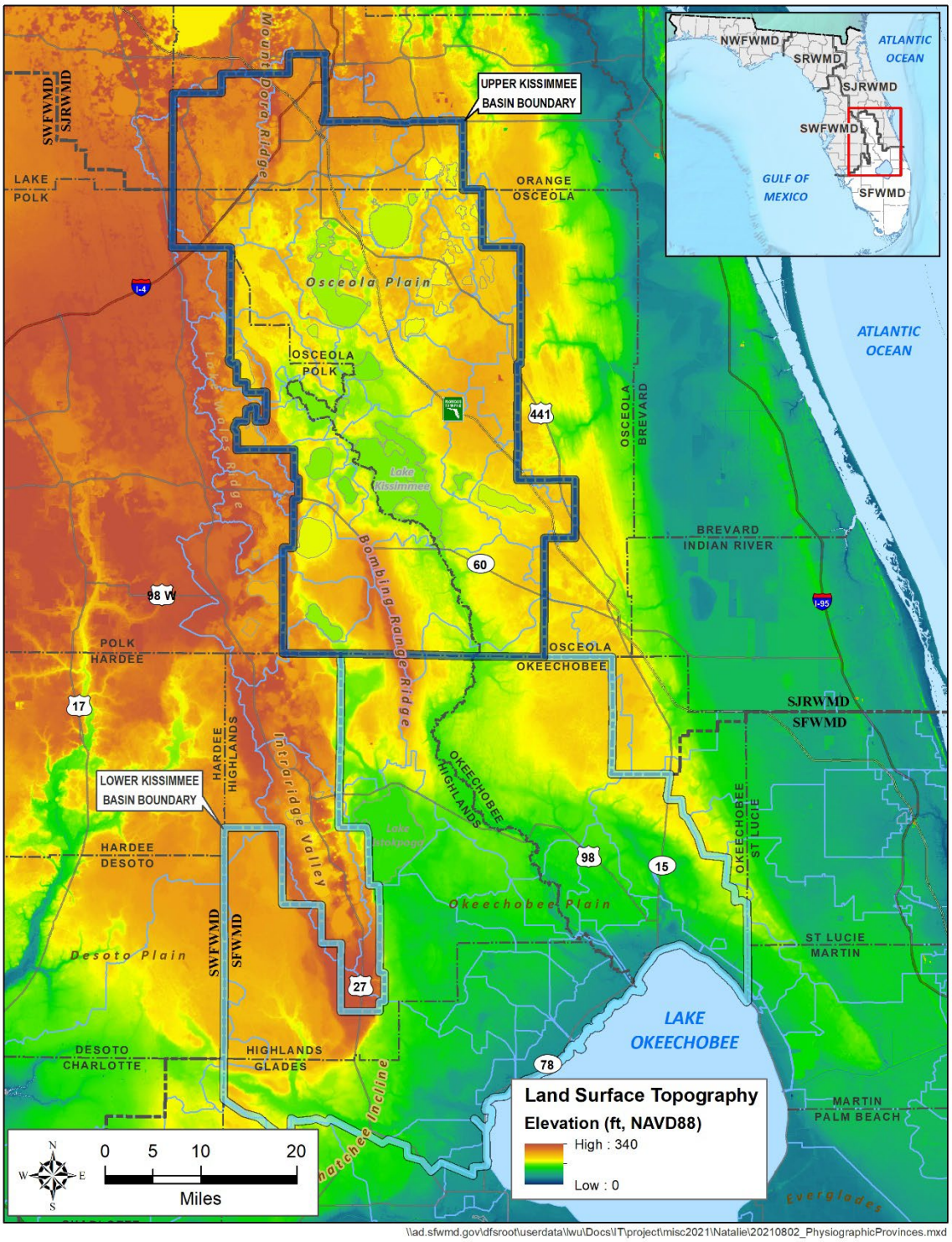


Figure 1-2. Topography of the Upper and Lower Kissimmee Basin planning areas.

1.1.3 Physiography

The UKB/LKB region is defined by three major physiographic zones: 1) Lake Wales Ridge, 2) Osceola Plain, and 3) Okeechobee Plain (**Figure 1-3**). In general, the physiographic features were formed as the Florida land mass gradually emerged from a receding ocean. Several million years ago, the Lake Wales Ridge was a peninsula that existed when much of Florida was under water.

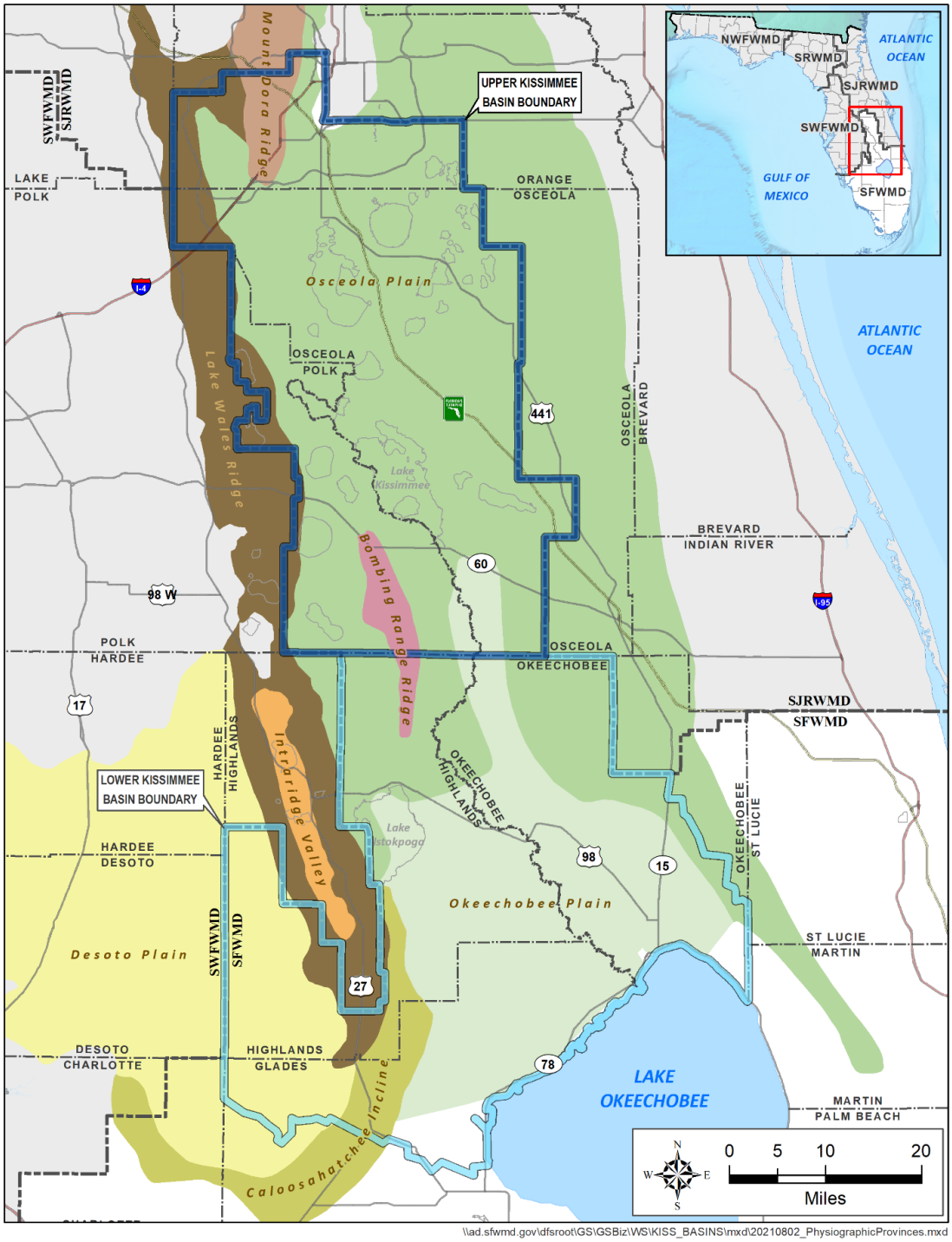


Figure 1-3. Physiography of the Upper and Lower Kissimmee Basin planning areas.

The Lake Wales Ridge is a relict beach and sand dune system that runs along the western edge of the UKB and LKB planning areas. Bounded on the east by the Osceola and Okeechobee plains, the ridge stretches approximately 100 miles from Orange County to southern Highlands County, and ranges from 4 to 10 miles in width.

Elevations generally exceed 100 ft above MSL and may reach more than 200 ft above MSL in portions of western Orange and Osceola counties and in eastern Polk County. The crest of the ridge forms the water divide between the SFWMD and SWFWMD, although the base of the ridge is used as the district boundary. Most surface waters east of the ridge drain toward the Kissimmee River.

Most of the UKB Planning Area lies within the Osceola Plain, a broad flat area approximately 40 miles wide and 100 miles long. The highest elevation of the Osceola Plain, near the southern portion of Orlando, ranges between 90 and 95 ft above MSL. Elsewhere, the Osceola Plain elevation is between 60 and 70 ft above MSL, with small local relief. The Osceola Plain narrows towards the southeast where it meets the northeastern edge of the Okeechobee Plain in the LKB Planning Area.

The Avon Park Bombing Range Ridge is a distinctive feature within the Osceola Plain and part of an important conservation and recreation area. This region is centrally located, linking the Three Lakes, Kissimmee Prairie, and Lake Wales Ridge conservation areas to create one of the largest preservation areas north of Lake Okeechobee. This north/south-trending sand ridge extends from southeastern Polk County into northeastern Highlands County, where it reaches its maximum elevation of 146 ft above MSL.

Numerous lakes are located within the Osceola Plain, including the KCOL (see **Section 1.2.2.1**). Most of the area's natural lakes may have formed from depressional areas in the original limestone deposition. The lakes on the Osceola Plain drain into the Kissimmee River. Water flows into the southern end of Lake Hatchineha, runs southward through Lake Kissimmee, and continues south through the Osceola and Okeechobee plains before entering Lake Okeechobee. Where the Kissimmee River flows across the Osceola Plain, it occupies a floodplain valley 1.5 miles wide. However, where the river flows in the Okeechobee Plain, the distinction between the valley and upland surface is difficult to perceive.

Lake Hatchineha

The Okeechobee Plain is adjacent to Lake Okeechobee and spans an area approximately 30 miles wide and 30 miles long, with less local relief than the Osceola Plain. The Okeechobee Plain gradually slopes southward from an elevation of 30 to 40 ft above MSL near the top of its boundary to approximately 20 ft above MSL at the north shore of Lake Okeechobee. The Fisheating Creek and Indian Prairie basins are within the Okeechobee Plain.

The Caloosahatchee Incline borders the southeastern portion of the Lake Wales Ridge and the western portion of the Okeechobee Plain. This long, narrow incline gently slopes eastward and ranges in elevation between 30 and 40 ft above MSL.

1.2 WATER RESOURCES AND SYSTEM OVERVIEW

1.2.1 Regional Hydrologic Cycle

The main components of the hydrologic cycle for the UKB and LKB planning areas include precipitation, evapotranspiration, and the flow of surface water and groundwater. The interaction between surface water and groundwater is expressed as either recharge to or discharge from the aquifer system.

1.2.1.1 Precipitation and Evapotranspiration

The region's wet season is May through October; the dry season starts in November and continues through April. Historical average annual rainfall is approximately 51 inches in the UKB Planning Area and 48 inches in the LKB Planning Area. On average, 72% of rainfall in the UKB Planning Area and 74% of rainfall in the LKB Planning Area occurs during the wet season. The heaviest rainfall month for both the UKB and LKB planning areas is June, when monthly rainfall averages 8.46 inches and 7.92 inches, respectively. The lightest rainfall month for both the UKB and LKB planning areas is November, when monthly rainfall averages 1.90 inches and 1.67 inches, respectively (SFWMD 2021). Average seasonal temperatures for the area range from 61°F in winter to 84°F in summer.

Hydrologic and meteorologic methods are available to measure and estimate the combined rate at which water is returned to the atmosphere by transpiration and evaporation. The combined processes are known as evapotranspiration. Precipitation minus evapotranspiration equals the combined amounts of surface water runoff and groundwater recharge. The estimate of potential evapotranspiration from open water and wetlands in the UKB/LKB region is 49 inches (Abtew et al. 2003). Potential evapotranspiration represents the total estimated passive water use of an area under maximum conditions. While actual evapotranspiration varies due to temperature, soil moisture, and other factors, potential evapotranspiration estimates are important landscape-level factors in water balance calculations to determine if enough water will be available for all uses during different environmental conditions.

1.2.1.2 Surface Water Inflow and Outflow

Surface water flow includes 1) inflow from areas adjacent to the basin, rainfall within the basin, and storage areas; and 2) outflow to Lake Okeechobee via the Kissimmee River, and to the Indian Prairie and Fisheating Creek basins. There are several primary water bodies that provide surface water drainage for the UKB and LKB planning areas. Located in the northern part of the UKB Planning Area, Reedy Creek, Shingle Creek, and Boggy Creek are the primary drainage features for Orange and northern Osceola counties. The KCOL includes the primary surface water bodies in northern Osceola County. Each of these hydrologic features eventually connects to the Kissimmee River, which is the primary drainage feature of the UKB/LKB region. Lakes located along the Lake Wales Ridge generally drain internally, providing important recharge for the surficial and Floridan aquifer systems.

In general, stormwater runoff within the UKB/LKB region is directed to one of the aforementioned surface water bodies. However, three sources of natural inflow come from adjacent areas: Josephine Creek and Arbuckle Creek, which flow into Lake Istokpoga, and surface water from the Horse Creek Basin, which flows into Lake Hatchineha via Lake Marion Creek. Additional information about surface water resources in the UKB/LKB region is provided in **Section 1.2.2**.

1.2.1.3 Groundwater Flow

Three major hydrogeologic units underlie the UKB and LKB planning areas: the surficial aquifer system (SAS), the intermediate confining unit (ICU), and the Floridan aquifer system (FAS). The SAS is primarily recharged by rainfall and interacts with surface water bodies such as rivers, canals, and lakes. The SAS also provides temporary storage for infiltrating water that eventually percolates down to the underlying aquifers or moves laterally to discharge areas. Additional information about groundwater resources in the UKB/LKB region is provided in **Section 1.2.3**.

1.2.2 Surface Water Resources

Hydrologically, the entire UKB/LKB area is within the Lake Okeechobee watershed, which consists of multiple tributary basins: Kissimmee (Upper and Lower), Taylor Creek/Nubbin Slough, Lake Istokpoga, Indian Prairie/Harney Pond, and Fisheating Creek. Except for Fisheating Creek, all major inflows to Lake Okeechobee are controlled by gravity-fed or pump-driven water control structures. For water management and flood control purposes, the Kissimmee Basin is divided into the UKB and LKB planning areas at the outlet of Lake Kissimmee (S-65) to the Kissimmee River (**Figure 1-4**).

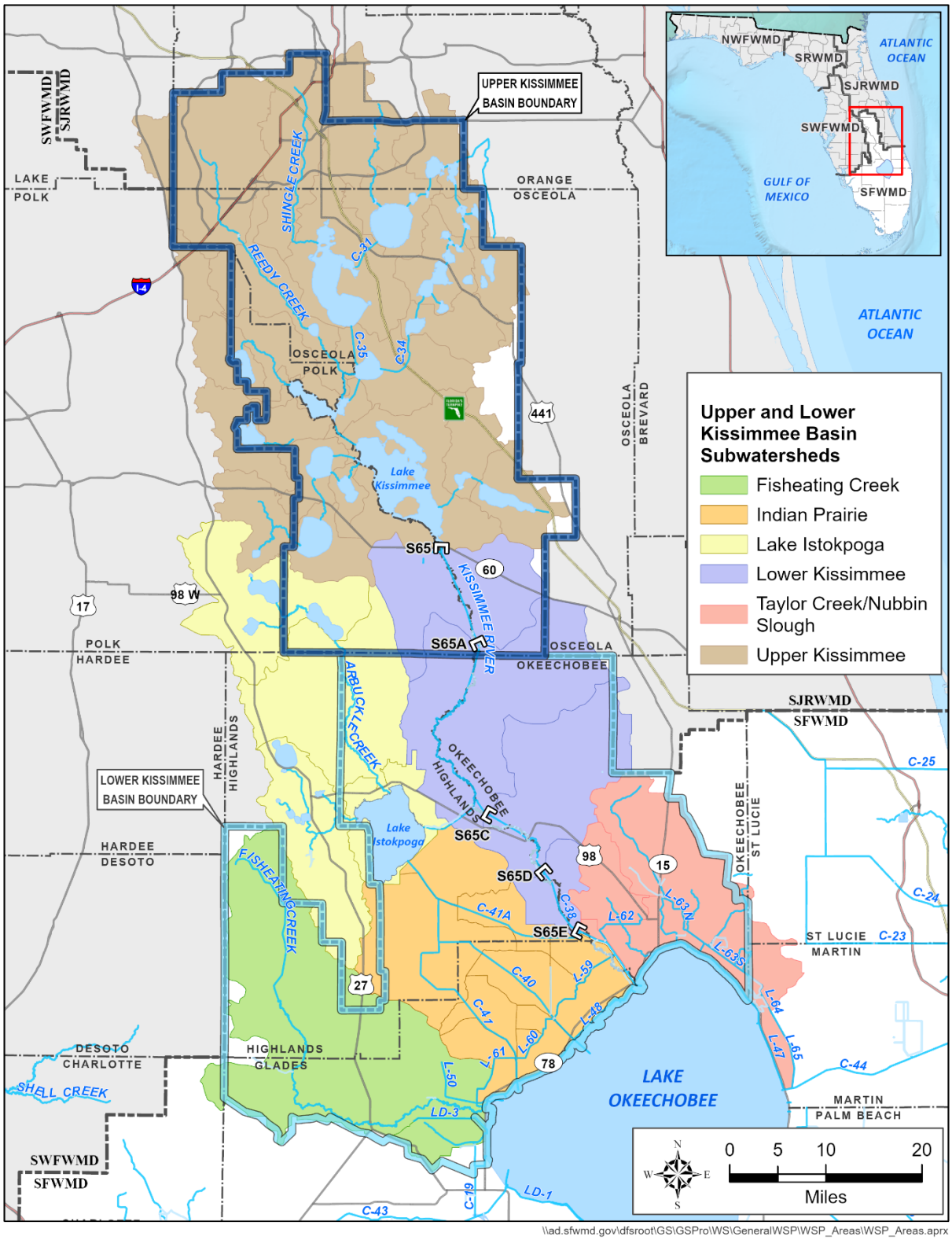


Figure 1-4. Upper and Lower Kissimmee Basin planning area subwatersheds.

1.2.2.1 Upper Kissimmee Basin

The UKB Planning Area covers approximately 1,633 square miles and includes more than two dozen lakes in the KCOL, their tributary streams, and associated marshes. This basin forms the headwaters of Lake Okeechobee and the Everglades and is the uppermost section of the Kissimmee-Okeechobee-Everglades system. The KCOL (**Figure 1-5**) is the most prominent surface water feature in the basin. Water released from the KCOL flows southward to Lake Kissimmee, the southernmost and largest water body in the UKB Planning Area. Lake Kissimmee acts as a buffer for flows before their release into the Kissimmee River at the S-65 structure (**Figure 1-5**).

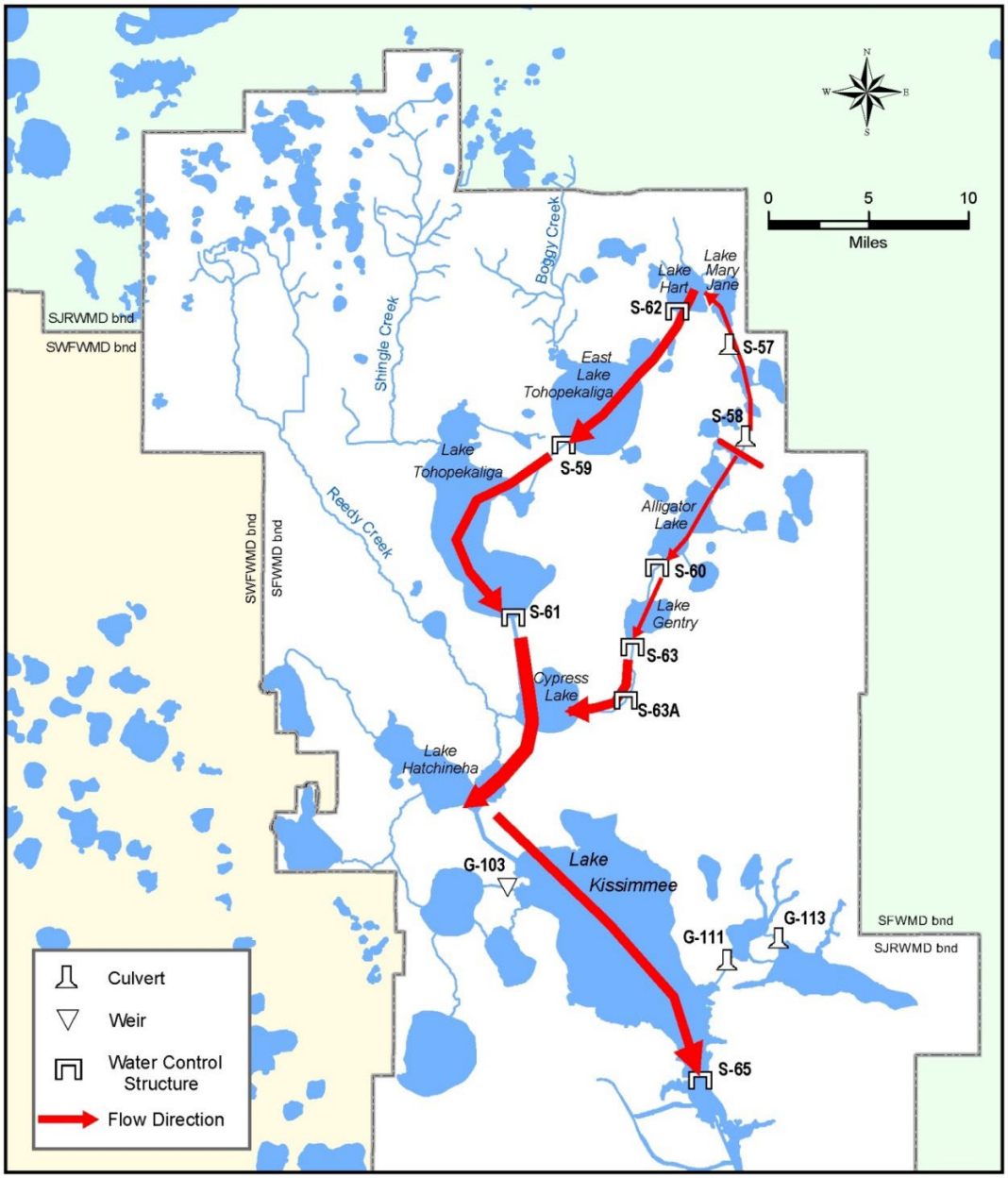


Figure 1-5. Water control structures that regulate flows in the Kissimmee Chain of Lakes. (Note: The line at the S-58 structure indicates where water is discharged south from the Alligator Chain of Lakes. The S-57 structure controls water levels north of the Alligator Chain of Lakes.)

Kissimmee Chain of Lakes

The KCOL forms an integrated system of lakes with interconnecting canals and water control structures operated by the SFWMD to maintain seasonal fluctuations in water levels. This lake system comprises 19 controlled water bodies, grouped into the following 7 Lake Management Areas, each of which is controlled by a single water control structure (**Figure 1-5**):

- **Alligator Chain of Lakes (Alligator, Brick, Lizzie, Coon, Center, and Trout)** – Located at the topographic top of the KCOL, these lakes are linked together by canals. Water control structures direct water from the Alligator Chain of Lakes to flow north or south, but generally water is discharged south through the C-33 Canal to Lake Gentry. The north end of Trout Lake acts as the drainage divide for flows through the KCOL.
- **Lake Gentry** – Inflows from the Alligator Chain of Lakes enter Lake Gentry through the C-33 Canal. Lake Gentry also receives surface water from the Big Bend Swamp along the eastern shore of the lake. Lake Gentry discharges through the C-34 Canal to Lakes Kissimmee, Hatchineha, and Cypress.
- **Lakes Kissimmee, Hatchineha, and Cypress** – This group composes the largest Lake Management Area and is tied to numerous secondary lakes—including Lake Russell, Tiger Lake, Lake Marion, Lake Pierce, Lake Rosalie, Lake Weohyakapka, Lake Jackson, and Lake Marian—through natural and artificial conveyances. These lakes receive inflows from Reedy Creek, the largest tributary, and from Lake Tohopekaliga via the C-35 Canal. Lake Kissimmee discharges to the LKB Planning Area through the C-38 Canal.

Lake Rosalie draining to Lake Kissimmee at structure G-103

- **Lakes Myrtle, Preston, and Joel** – At the northern end of the Alligator Chain of Lakes, the C-32 Canal connects Trout Lake to Lake Joel. However, the main source of water to these lakes is rainfall and runoff from the surrounding watershed. Water levels in these lakes are controlled to flow north through the C-30 Canal toward Lake Mary Jane.
- **Lakes Hart and Mary Jane** – Inflows from Lakes Myrtle, Preston, and Joel are directed through the C-30 Canal to Lakes Hart and Mary Jane. Water is discharged from these lakes through the C-29A Canal to East Lake Tohopekaliga, Fells Cove, and Lake Ajay.
- **East Lake Tohopekaliga, Fells Cove, and Lake Ajay** – Major inflows come from Boggy Creek, which enters East Lake Tohopekaliga in the northwestern corner, and the C-29A Canal from Lakes Hart and Mary Jane. Discharge is through the C-31 Canal to Lake Tohopekaliga.
- **Lake Tohopekaliga** – Inflows to this lake come from Shingle Creek and the C-31 Canal from East Lake Tohopekaliga. Lake Tohopekaliga discharges into Lakes Cypress, Hatchineha, and Kissimmee through the C-35 Canal.

Kissimmee Chain of Lakes Regulation Schedules

Water control structures in the KCOL direct flows according to regulation schedules established by the United States Army Corps of Engineers (USACE) and managed by the SFWMD. **Figure 1-5** shows the locations of the water control structures and the primary direction of the flow through the KCOL.

Outflows from the Alligator Chain of Lakes (Alligator, Brick, Lizzie, Coon, Center, and Trout) are controlled by the S-58 (northern) and S-60 (southern) structures. The S-58 structure in the C-32 Canal connects Trout Lake and Lake Joel. North of Trout Lake, the S-57 structure in the C-30 Canal regulates Lakes Joel, Myrtle, and Preston. The C-30 Canal connects Lake Myrtle to Lake Mary Jane in the next lake group. Lakes Mary Jane and Hart are regulated by the S-62 structure, located in the C-29 Canal, which discharges into Lake Ajay. East Lake Tohopekaliga and Lake Ajay are regulated by the S-59 structure, located in the C-31 Canal between East Lake Tohopekaliga and Lake Tohopekaliga. Lake Tohopekaliga is regulated by the S-61 structure, located in the C-35 Canal at the south shore of the lake.

At the southern end of the Alligator Chain of Lakes, the S-60 structure in the C-33 Canal connects Alligator Lake to Lake Gentry. Lake Gentry is regulated by the S-63 and S-63A structures, located in the C-34 Canal connecting Lake Gentry to Cypress Lake. Lakes Kissimmee, Hatchineha, and Cypress are regulated by the S-65 structure, located at the outlet of Lake Kissimmee and the head of the Kissimmee River (C-38 Canal).

C-38 Canal entering Lake Okeechobee

Operations for the Kissimmee Basin are described in the *Master Water Control Manual for Kissimmee River – Lake Istokpoga* (USACE 1994). After completion of Phase I of the Kissimmee River Restoration Project in 2001, a modification to the regulation schedule for S-65 was approved that provides for environmental releases to the Kissimmee River when water levels in the Headwaters Lakes (Lakes Kissimmee, Hatchineha, and Cypress) are within Zone B of the regulation schedule. The S-65 Interim Schedule has facilitated maintenance of flow through the restored portion of the Kissimmee River. Guidance for some structures that were included in USACE (1994) was revised in a partial update (USACE 2016) to address changes due to Kissimmee River Restoration Project construction. Construction for the Kissimmee River Restoration Project was completed in July 2021; the S-65 Interim Schedule will continue to be used until 2022, when partial, phased implementation of the Headwaters Revitalization Schedule (HRS) will begin. Projected to be fully implemented by 2026, the HRS allows additional water storage in Lakes Kissimmee, Cypress, and Hatchineha to provide sufficient flow for successful restoration of the Kissimmee River and its floodplain. Coupled with appropriate water management, the HRS will improve the quantity and timing of inflow to the Kissimmee River, and the higher stages allowed by the HRS are expected to increase the quantity and quality of shoreline habitat in the Headwater Lakes for the benefit of fish and wildlife. A new Kissimmee Basin System Operating Manual for all structures in the Kissimmee Basin will be completed prior to implementation of the HRS.

Tributary Creeks

The major streams feeding into the KCOL are Shingle Creek, Reedy Creek, and Boggy Creek. The headwaters for these creeks are in urbanized portions of the metro Orlando area. Flow moves southward through open channels and wetlands into lakes. In addition to these creeks, the Lakes Hart and Mary Jane basin contributes surface water flows to the KCOL for the most northeastern portion of the basin. Flows from these areas are directed to the Alligator Chain of Lakes or East Lake Tohopekaliga.

Shingle Creek

The headwaters of Shingle Creek form in the City of Orlando. The creek runs southward for 24 miles through Shingle Creek Swamp and the City of Kissimmee before discharging into Lake Tohopekaliga. Natural flow in Shingle Creek was substantially modified in the 1920s with channelization of 13 miles and subsequent crossing of utility transmission lines and access roads. The SFWMD began an aggressive land purchase program in the Shingle Creek basin in the 1980s after the State of Florida established the Save Our Rivers Program. The SFWMD has undertaken several successful restoration projects within Shingle Creek Swamp, funded as mitigation sites to offset wetland impacts associated with the construction of the Orlando Beltway. The SFWMD manages the Shingle Creek Management Area with Osceola County.

Shingle Creek – Lake Tohopekaliga

Reedy Creek

Reedy Creek in Osceola County is the least disturbed of the area's three major creeks. Originating on the grounds of Walt Disney World, Reedy Creek runs southeast for 29 miles before splitting into two branches near Cypress Lake. One branch enters Cypress Lake and the other enters Lake Hatchineha. For most of its course, the creek flows through Reedy Creek Swamp. Reedy Creek also receives water from the Butler Chain of Lakes during periods of high lake levels.

Boggy Creek

Boggy Creek consists of east and west branches. At 12 miles long, the east branch is the main watercourse, and its headwaters form in the metro Orlando area at the southern part of Lake Conway. The east branch runs through Boggy Creek Swamp and empties into East Lake Tohopekaliga. The headwaters of the west branch originate in Lake Jessamine, located in another highly urbanized area of Orlando, and extend to Boggy Creek Swamp.

1.2.2.2 Lower Kissimmee Basin

The LKB Planning Area covers 1,805 square miles and includes the tributary watersheds of the Kissimmee River between the outlet of Lake Kissimmee (S-65 structure) and Lake Okeechobee. The Kissimmee River is the major surface water body in the basin.

Re-established flow in Kissimmee River

Kissimmee River

The Kissimmee River was originally 134 miles long, including a 103-mile span between Lakes Kissimmee and Okeechobee. Construction of the Central and Southern Florida Flood Control Project (C&SF Project) to improve flood protection in the UKB/LKB area took place between 1962 and 1971. This effort resulted in channelizing the Kissimmee River into a 56-mile canal. Today, a series of combined locks and water control structures manage the canal's flow into Lake Okeechobee. Construction of the Kissimmee River Restoration Project was completed in July 2021, and the project ultimately will restore ecological integrity to a portion of the Kissimmee River and its floodplain through re-established historical hydrology and an equivalent pre-project level of flood control in the area.

Lower Kissimmee Basin Regulation Schedules

The LKB system (**Figure 1-6**) includes the Kissimmee River and C-38 Canal as well as three water control structures (S-65A, S-65D, and S-65E). The C-38 Canal structures are operated in conjunction with S-65 at the outlet of Lake Kissimmee. Structures S-65A, S-65D, and S-65E are operated to maintain optimum stages. As described above, a revised regulation schedule to operate the S-65 structure is expected to be implemented in 2026.

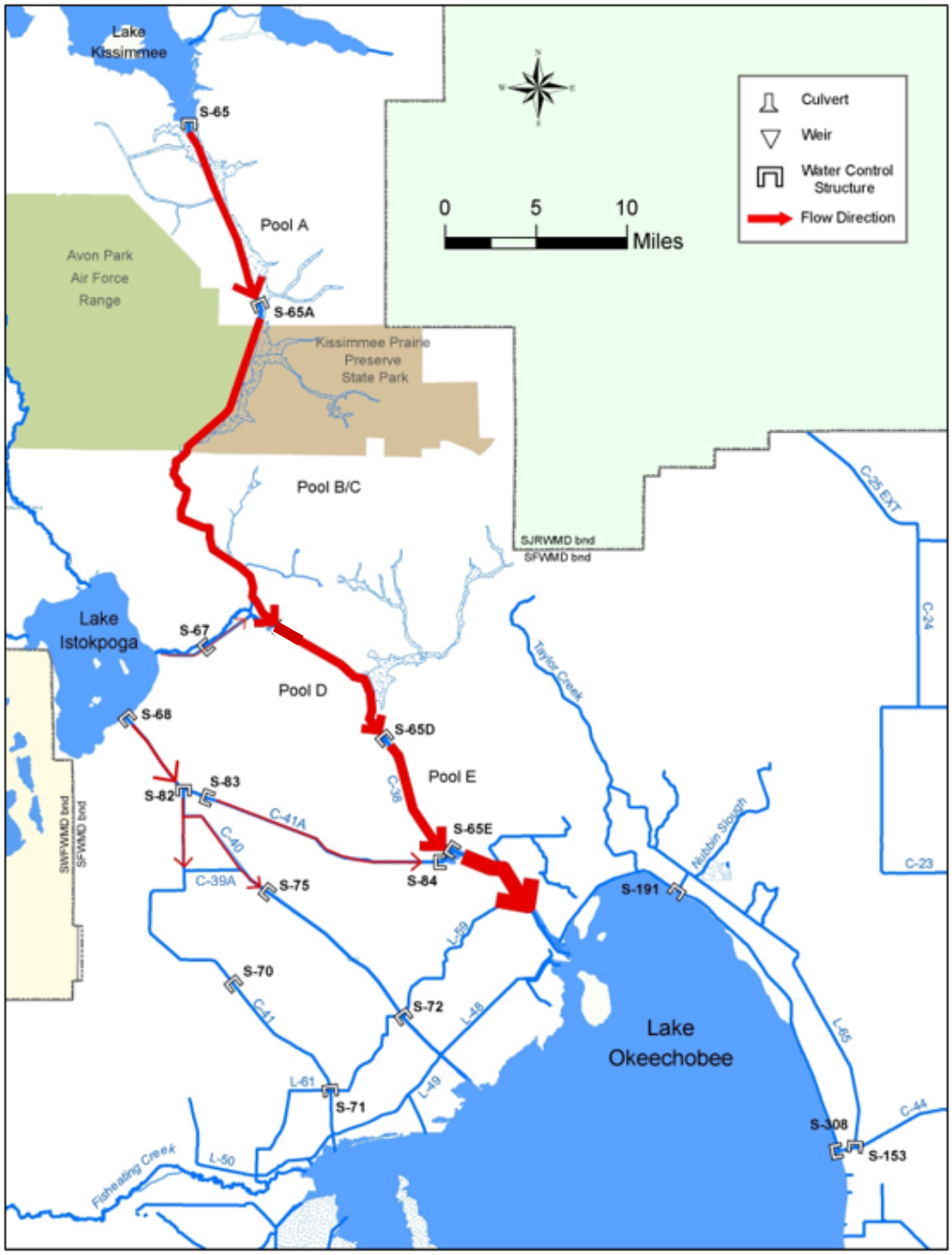


Figure 1-6. Water control structures that regulate flows out of Lakes Kissimmee and Istokpoga and into the Kissimmee River.

Lake Istokpoga and Indian Prairie Canal System

The Lake Istokpoga basin encompasses 607 square miles west and north of Lake Istokpoga and is the source of all surface water inflows to Lake Istokpoga, the fifth largest lake in Florida. Spanning 44 square miles, the lake is shallow, averaging between 4 and 6 ft in depth. Major tributaries to Lake Istokpoga are Josephine Creek and Arbuckle Creek, located in the northwestern and northern areas of the lake, respectively. Outflows from Lake Istokpoga are directed to the Kissimmee River or Lake Okeechobee through a system of canals and water control structures.

Lake Istokpoga

The Indian Prairie basin covers 622 square miles and drains the area south of Lake Istokpoga to Lake Okeechobee. Four canals connect Lake Istokpoga to Lake Okeechobee: C-39A, C-41A, C-40 (Indian Prairie Canal), and C-41 (Harney Pond Canal). The Istokpoga Canal connects Lake Istokpoga to the Kissimmee River.

Lake Istokpoga Regulation Schedule

Stages in Lake Istokpoga are primarily regulated by the S-68 structure at the southern end of the lake in accordance with a regulation schedule. The regulation schedule takes into consideration the Lake Istokpoga minimum flow and minimum water level (MFL) established by the SFWMD in December 2005. The S-68 structure discharges water from Lake Istokpoga to the C-41A Canal. The C-41, C-40, and C-39A canals provide secondary conveyance capacity for the regulation of floods in the Lake Istokpoga water management basin. The C-40 and C-41 canals flow into Lake Okeechobee, and the C-41A Canal discharges to the C-38 Canal south of S-65E, the southernmost structure in the Kissimmee River.

S-65E Tailwater Weir

When high water levels in the Kissimmee River restrict Lake Istokpoga basin discharges via the Istokpoga Canal, the S-68 structure offsets the loss of discharge capacity by re-routing flows down the C-41A Canal. The USACE also constructed the S-67 structure to replace the G-85 structure, which controls water discharges from Lake Istokpoga through the Istokpoga Canal to the C-38 Canal.

Taylor Creek/Nubbin Slough Basin

White Ibis at Taylor Creek

Taylor Creek and Nubbin Slough are interconnected basins that cover 104 and 84 square miles, respectively, and drain into Lake Okeechobee from the north and northeast. The Kissimmee River and its floodplain lie directly west of these natural systems. Surface water use in the basin is primarily for agriculture, including pasture and dairies. The Nubbin Slough Basin includes three tributaries: Lettuce Creek, Henry Creek, and Mosquito Creek, which, along with Nubbin Slough, are intercepted by the L-63, L-64, and C-59 canals and enter Lake Okeechobee through the S-191 structure. Chandler Hammock Slough is a small tributary in the northern part of the Taylor Creek Basin that allows water to flow eastward into Taylor Creek or westward to Popash Slough and is controlled by the G-80 structure. Taylor Creek provides drainage to an area just north of the City of Okeechobee, passes through the eastern part of the city, then flows south into the L-63N and C-59 canals and discharges to Lake Okeechobee via the S-191 structure.

Fisheating Creek Basin

Fisheating Creek, west of Lake Okeechobee, marks the southernmost boundary of the LKB Planning Area and is the second largest inflow to Lake Okeechobee. Much of the land surrounding the creek is publicly owned or under conservation easements. The Fisheating Creek basin, spanning 440 square miles, originates in western Highlands County and flows south through Cypress Swamp into Glades County. From central Glades County, water leaves the creek channel and flows east through Cowbone Marsh into Lake Okeechobee. Previous studies in the Fisheating Creek watershed have focused on creating water storage and improving water quality discharges to Lake Okeechobee. Fisheating Creek is the only basin with an uncontrolled "natural" discharge to Lake Okeechobee.

1.2.3 Groundwater Resources

There are three major hydrogeologic units underlying the UKB/LKB region: SAS, ICU, and FAS (**Figures 1-7** and **1-8**). The FAS includes the Upper Floridan aquifer (UFA), composed of two production zones separated by low-permeability strata (confining unit 1), and the Lower Floridan aquifer (LFA), composed of two or more productive units separated by less permeable materials. The UFA and LFA are separated by a much less permeable middle confining unit (confining unit 2). **Table 1-1** presents the groundwater systems, hydrogeologic units, and relative aquifer yields in the UKB/LKB region.

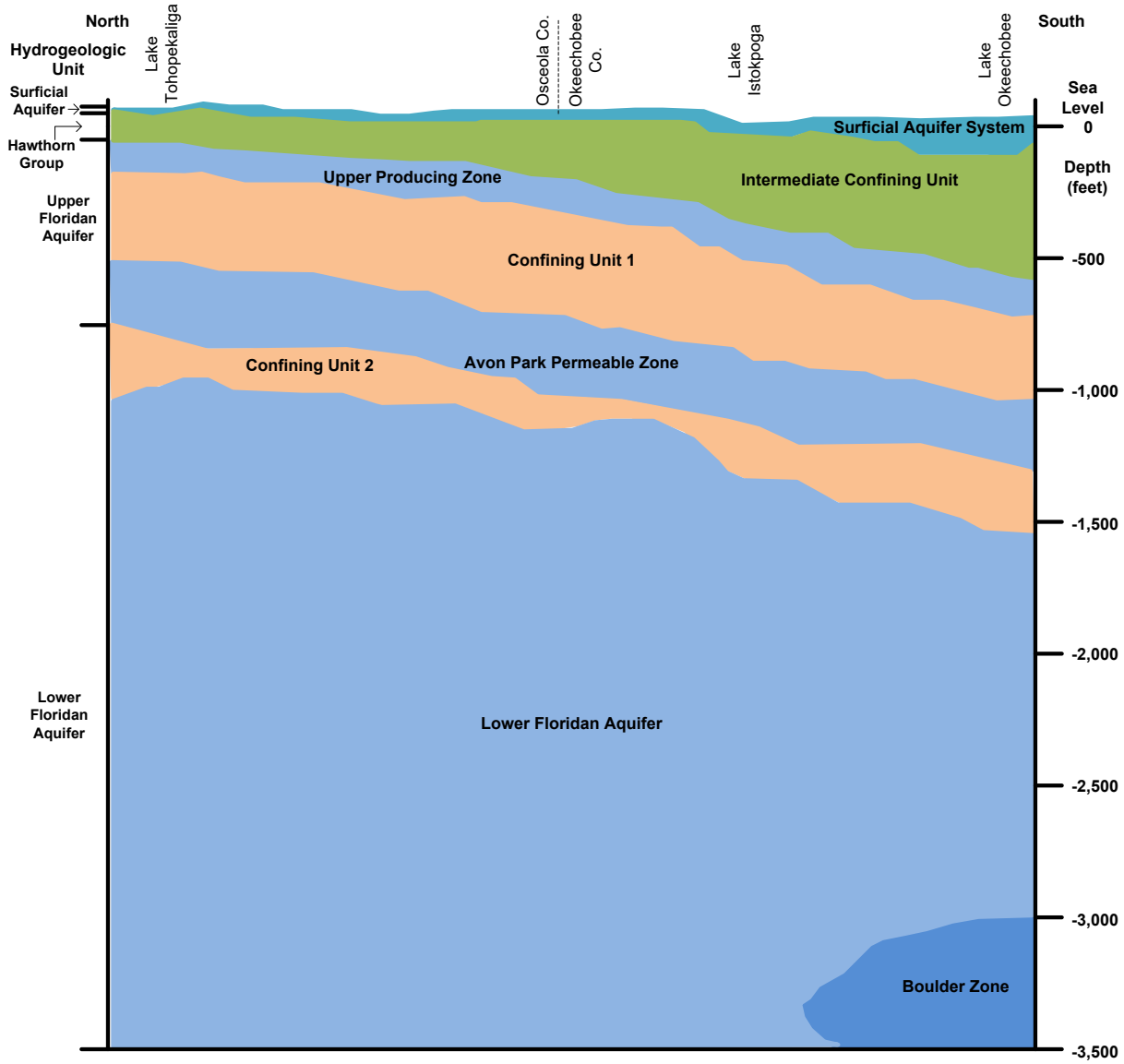


Figure 1-7. Generalized hydrogeologic cross-section (north to south) of the Upper and Lower Kissimmee Basin planning areas.

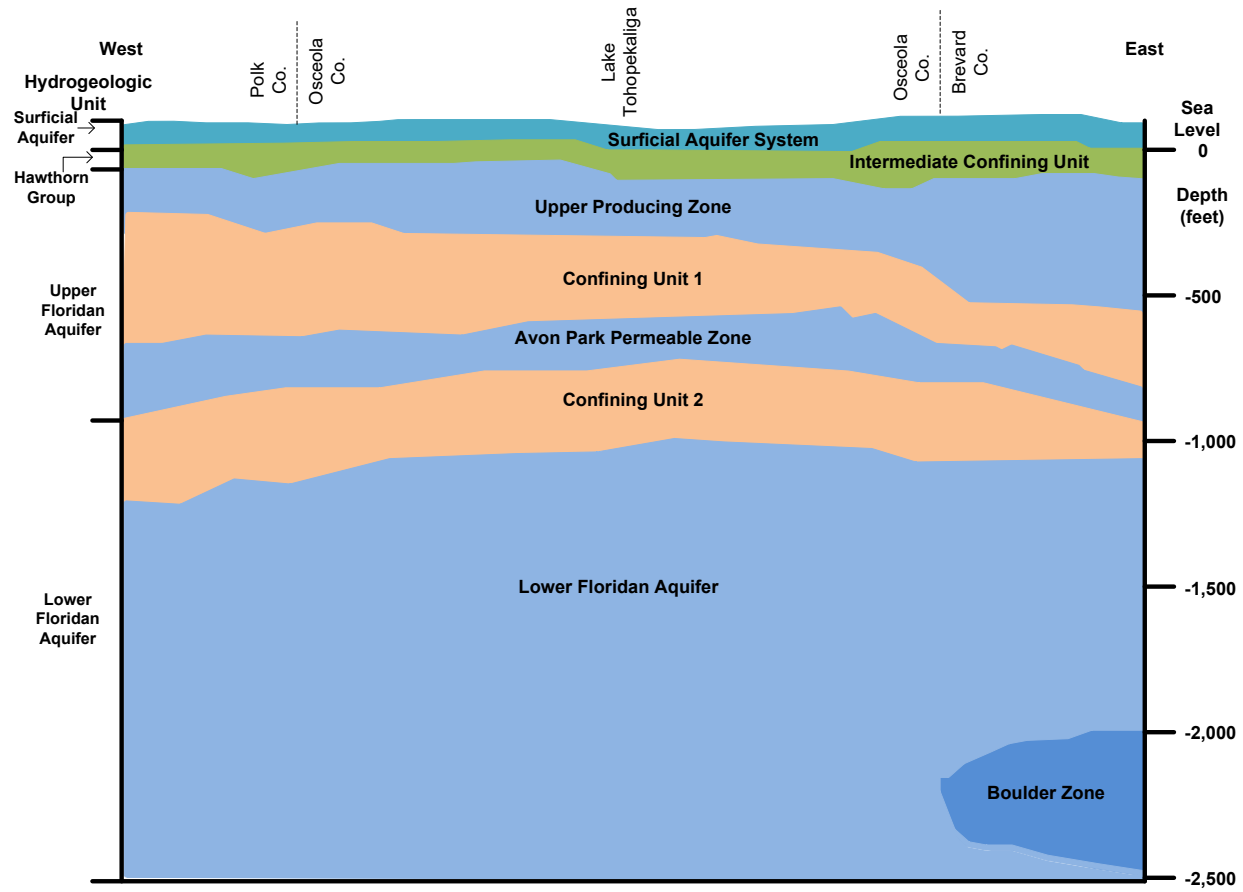


Figure 1-8. Generalized hydrogeologic cross-section (west to east) of the Upper Kissimmee Basin Planning Area.

Table 1-1. Groundwater systems in the Upper and Lower Kissimmee Basin planning areas.

Aquifer System	Hydrogeologic Unit	Aquifer Yield					
		Orange	Osceola	Polk	Highlands	Okeechobee	Glades
Surficial Aquifer System	Undifferentiated Clastic Deposits	L	L	L-M	L-M	L-M	L-M
Floridan Aquifer System	Upper Floridan Aquifer	H	H	H	H	H	H
	Lower Floridan Aquifer	H	M-H	M	M-H	M-H	M-H

A = absent; H = high; L = low; M = moderate.

1.2.3.1 Surficial Aquifer System

The SAS, also known as the Water Table aquifer, is unconfined and consists of fine- to medium-grained quartz sand with varying amounts of silt, clay, and crushed shell that range from Pliocene to Holocene in age. The thickness of the SAS generally ranges from less than 10 ft to 150 ft within the UKB/LKB region. The thickness of these sediments is generally less than 50 ft in the UKB Planning Area, thickening to the south and southwest. The thickness of SAS sediments reaches almost 300 ft in Polk County along the Lake Wales Ridge, but the depth to water may be several tens of feet below land surface in this region.

The SAS produces small quantities of good to fair quality water. It is generally soft, low in mineral content, slightly corrosive, and high in color and iron. This groundwater source contains relatively high chloride and dissolved solids concentrations toward the western part of Okeechobee County and near the Caloosahatchee River in Glades County. In the LKB Planning Area, and to a lesser extent in the UKB Planning Area, the SAS is primarily used for private residential wells, lawn irrigation, and small-scale agricultural uses.

1.2.3.2 Intermediate Confining Unit

Below the SAS lies a mixture of sands and clay collectively known as the ICU. The ICU consists of an interbedded sequence of sands, calcareous silts and clays, shell, and phosphatic limestone and dolomite of late to middle Miocene age (Hawthorn Group), although the top of the unit can include clayey sediments of early Pliocene age. The ICU restricts vertical movement of water between the SAS and FAS. The confining properties of the ICU are less effective near the Lake Wales Ridge due to geologic features that allow an enhanced connection between the SAS and FAS. West of the Lake Wales Ridge, multiple discrete producing zones can be found within the ICU, but these are mostly absent within the UKB and LKB planning areas. While a few locally occurring water-producing zones within the ICU exist in the UKB/LKB region, they generally do not produce large amounts of water. The thickness of the ICU ranges from less than 50 ft in the UKB Planning Area to more than 600 ft in parts of Okeechobee and Highlands counties in the LKB Planning Area.

1.2.3.3 Floridan Aquifer System

The FAS is an extensive and productive aquifer system that underlies Florida and portions of Alabama, Georgia, and South Carolina (**Figure 1-9**). Located below the ICU, the FAS acts as a confined or partially confined aquifer and the primary source for potable water in the UKB Planning Area. The FAS is traditionally divided into the UFA and LFA, which are separated by less permeable rocks (a middle confining unit) that restrict their interaction. The FAS is composed of a sequence of highly permeable carbonate rocks (limestone and dolomite) of Oligocene, Eocene, and late Paleocene age. The FAS has an average thickness of approximately 2,300 ft within the UKB/LKB area, but because of variability in productivity and water quality, only a portion of this thickness is useful for water supply.

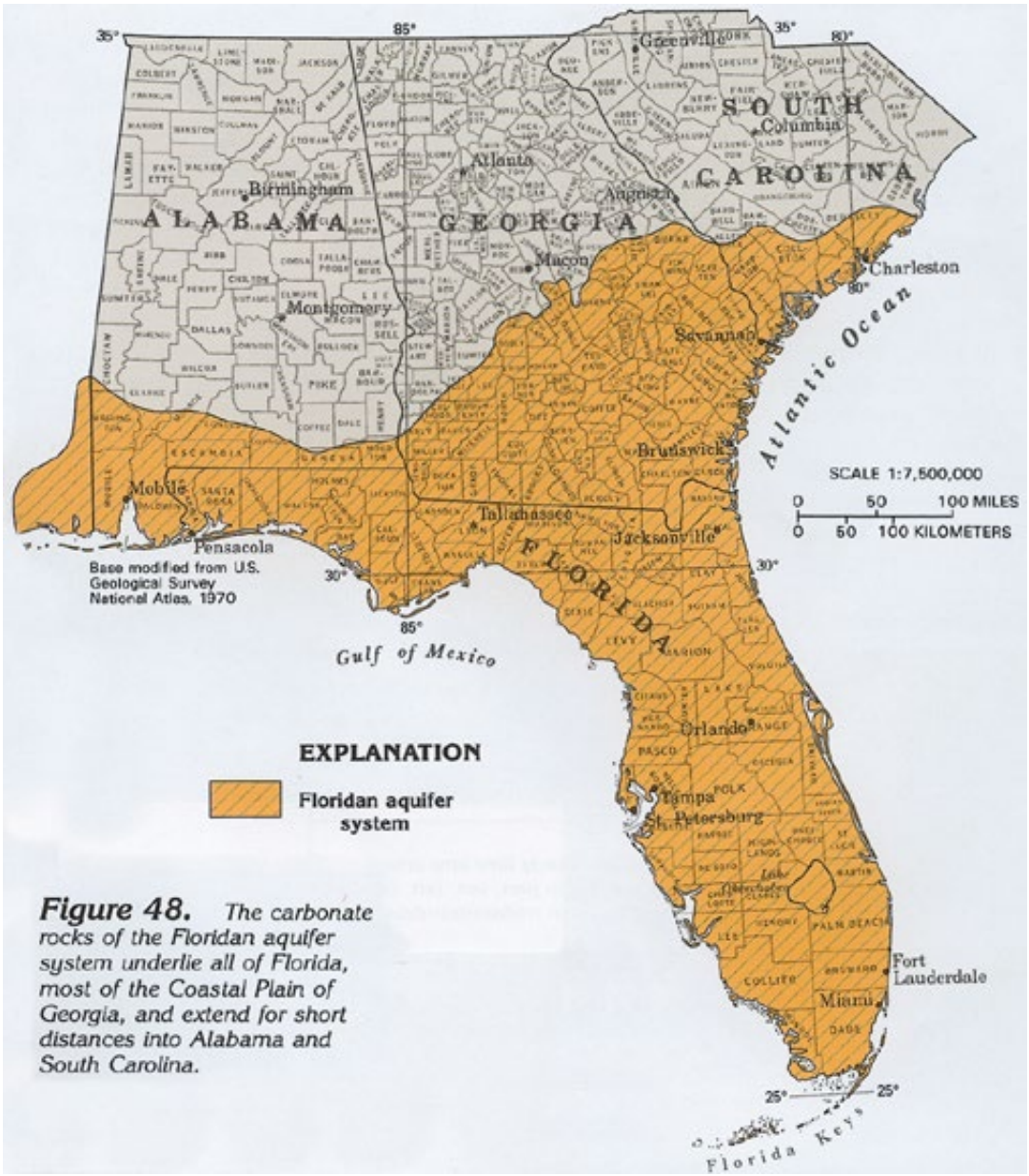


Figure 48. *The carbonate rocks of the Floridan aquifer system underlie all of Florida, most of the Coastal Plain of Georgia, and extend for short distances into Alabama and South Carolina.*

Figure 1-9. The extent of the Floridan aquifer system in the southeastern United States (From: Miller 1990).

Upper Floridan Aquifer

The top elevation of the UFA ranges from less than 100 ft below MSL in northeastern Polk County to more than 500 ft below MSL in the southwestern portion of the LKB Planning Area. The UFA is thicker in Glades and Okeechobee counties, averaging approximately 1,000 ft. Chloride, total dissolved solids, and sulfate concentrations increase with depth and distance to the south and west. Water quality transitions from fresh to slightly brackish and aquifer productivity decreases toward the south.

The UFA can be subdivided into three hydrogeologic units: 1) a moderately productive, upper producing zone, 2) a semi-confining unit, and 3) a highly permeable, fractured crystalline dolostone in the Avon Park

Formation, referred to as the Avon Park permeable zone. The carbonate section of the Upper Avon Park Formation can be moderately productive as well (Spechler 2010).

West of the Highlands Ridge, the upper producing zone is largely composed of the Suwannee Limestone. East of the ridge, this unit is absent, having undergone significant aerial exposure and erosion during past glacial periods. In the SJRWMD, the top of the deeper Ocala Limestone often is used as a surrogate for the top of the UFA, and the Ocala Limestone can be quite productive in this area. The permeability of the Ocala Limestone diminishes to the south and west. In most of Polk and Osceola counties, it composes the semi-confining unit between the upper producing zone and Avon Park permeable zone. In these areas, where the Suwannee Limestone is also absent, the upper producing zone may be reduced to a thin region of enhanced dissolution around the contact between the Ocala Limestone and overlying units.

Lower Floridan Aquifer

The LFA is present throughout east-central Florida. The top of the LFA ranges from approximately 1,000 to 1,600 ft below MSL in the LKB Planning Area. The LFA consists of the lower part of the Avon Park and Oldsmar formations of middle Eocene age and the upper part of the Cedar Keys Formation of late Paleocene age. Like the UFA, the LFA is characterized by multiple productive zones with alternating lower-permeability beds of varying degrees of confinement. The production characteristics of the LFA are not well documented, but it is being investigated in the UKB Planning Area as an alternative water supply source, and initial tests indicate the aquifer should be able to yield large quantities of water. Use of the LFA as a water source has been limited in the region due to total dissolved solids concentrations that generally are too high for potable and irrigation uses without membrane treatment. In Orange County, the LFA is slightly brackish, but highly productive, characterized by abundant fractures and solution cavities. LFA water quality is saline throughout most of the LKB Planning Area; however, fresh water has been found in the northwestern portion of Highlands County close to the Lake Wales Ridge.

1.2.4 Surface Water and Groundwater Relationships

The relationship between a surface water feature and the underlying groundwater system is complex and affected by the hydraulic characteristics of the aquifer and the thickness and type of soils separating the two features. When a river, canal, or wetland has a higher water level than the water table, these surface water bodies provide seepage into the local shallow groundwater system. Conversely, when the water level of the surface water bodies is lower than the water table, groundwater discharge may occur. The rate at which this transfer occurs depends on the difference in the two levels and the permeability and thickness of the materials separating the surface water body and groundwater aquifer.

The SAS is primarily recharged by rainfall and interacts with surface water features such as rivers, canals, and lakes. The SAS provides temporary storage for infiltrating water that eventually recharges underlying aquifers or moves laterally to discharge areas.

In the UKB Planning Area, the UFA is recharged primarily by downward leakance from the SAS and, where present, through the ICU. Higher rates of recharge occur in areas with abundant sinkholes, where the ICU is thin or breached by collapse into underlying dissolution cavities. These areas represent locations where the differences in surface and UFA water levels are greatest, and the thickness of the ICU is thinnest or breached by karst activity.

1.2.4.1 Karst/Sinkhole Features

The chemical processes by which rock is dissolved through interactions with water are commonly referred to as solution processes. The past and continuing solution of the limestone beneath land surface by

groundwater results in a landform called karst (Schiffer 1998). The development of karst features is primarily expressed at the surface as "sinkhole lakes." These occur within the UKB Planning Area and along the eastern side of the Lake Wales Ridge. Surface water/groundwater exchange can occur through the bottom sediments of these lakes, depending on the thickness, composition, and porousness of the lake bottom/sinkhole collapse sediments. As a result, water can seep from lakes into the UFA (Florida Department of Environmental Protection 2006).

1.2.4.2 Drainage Wells

Hundreds of drainage wells in the metro Orlando area receive water from stormwater runoff as well as lake and wetland overflow. These drainage wells discharge into the FAS, providing recharge to the system. Constructed up until the 1970s, these wells are generally limited to closed drainage basins in the Orlando area.

Chapter 2: Upper East Coast Planning Area

St. Lucie Estuary and Indian River Lagoon

This chapter describes physical features and water resources in the Upper East Coast (UEC) Planning Area. For a comprehensive review of water supply status and issues in the UEC Planning Area, refer to the most recent UEC water supply plan update.

The UEC Planning Area includes Martin and St. Lucie counties and the northeastern portion of Okeechobee County (**Figure 2-1**). The planning area boundary generally reflects the drainage basins of the C-23, C-24, C-25, and C-44 (St. Lucie) canals. The northern boundary corresponds to the St. Lucie–Indian River county line, which is also the jurisdictional boundary between the South Florida Water Management District (SFWMD or District) and the St. Johns River Water Management District (SJRWMD). The planning area's southern boundary is the Martin–Palm Beach county line.

2.1 PHYSICAL FEATURES

Major water features in and adjacent to the UEC Planning Area include Lake Okeechobee, multiple canal systems (including the C-23, C-24, C-25, and C-44 canals), St. Lucie River and Estuary, Ten Mile Creek, and southern Indian River Lagoon. Although a small portion of the Loxahatchee River is in Martin County, most of the river is within Palm Beach County, which is part of the Lower East Coast Planning Area; therefore, the Loxahatchee River is briefly discussed here and more fully described in **Chapter 4**. Similarly, Lake Okeechobee borders the UEC Planning Area but is addressed as part of the Lower East Coast Planning Area.

2.1.1 Water Bodies and Landscapes

Lake Okeechobee is a key component of the south Florida hydrologic system. The lake has many functions, including flood protection, urban and agricultural water supply, navigation, and fisheries and wildlife habitat. Lake Okeechobee is critical for flood control during wet seasons and water supply during dry seasons. Releases from Lake Okeechobee flow into the C-44 (St. Lucie) Canal, which discharges to the South Fork of the St. Lucie River.

The St. Lucie River flows through Martin and St. Lucie counties. The river is 35 miles long and has two major forks, the North Fork and the South Fork (**Figure 2-1**). Danforth and Mapp creeks are tributaries to the South Fork downstream of the C-44 (St. Lucie) Canal. Ten Mile Creek is the major freshwater tributary to the North Fork of the St. Lucie River, which is approximately 10 miles long. Several miles downstream, Five Mile Creek contributes relatively limited inflows to the North Fork. The North Fork is a freshwater system upstream and a brackish system near the St. Lucie Estuary.

The North and South forks come together as a primary tributary to southern Indian River Lagoon. Indian River Lagoon extends approximately 155 miles through six coastal counties, from Ponce de Leon Inlet in Volusia County, southward to the Jupiter Inlet in Palm Beach County. Within the SFWMD boundaries, southern Indian River Lagoon (**Figure 2-1**) spans approximately 48 square miles from Fort Pierce to Jupiter Sound.

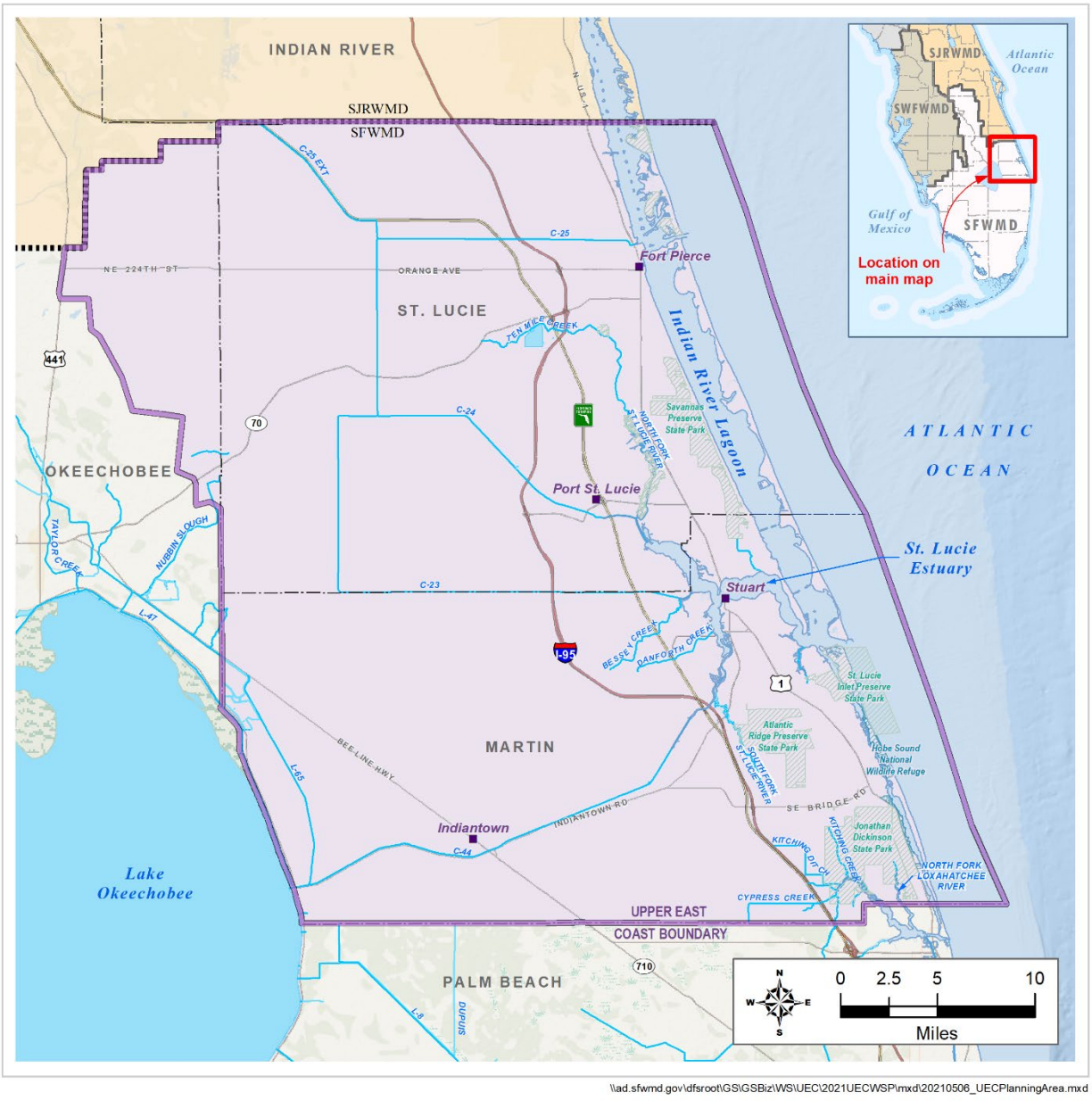


Figure 2-1. Upper East Coast Planning Area.

2.1.2 Geography

The UEC Planning Area encompasses approximately 1,231 square miles in southeastern Florida, and its average elevation is 20 feet (ft) above mean sea level (MSL) (**Figure 2-2**).

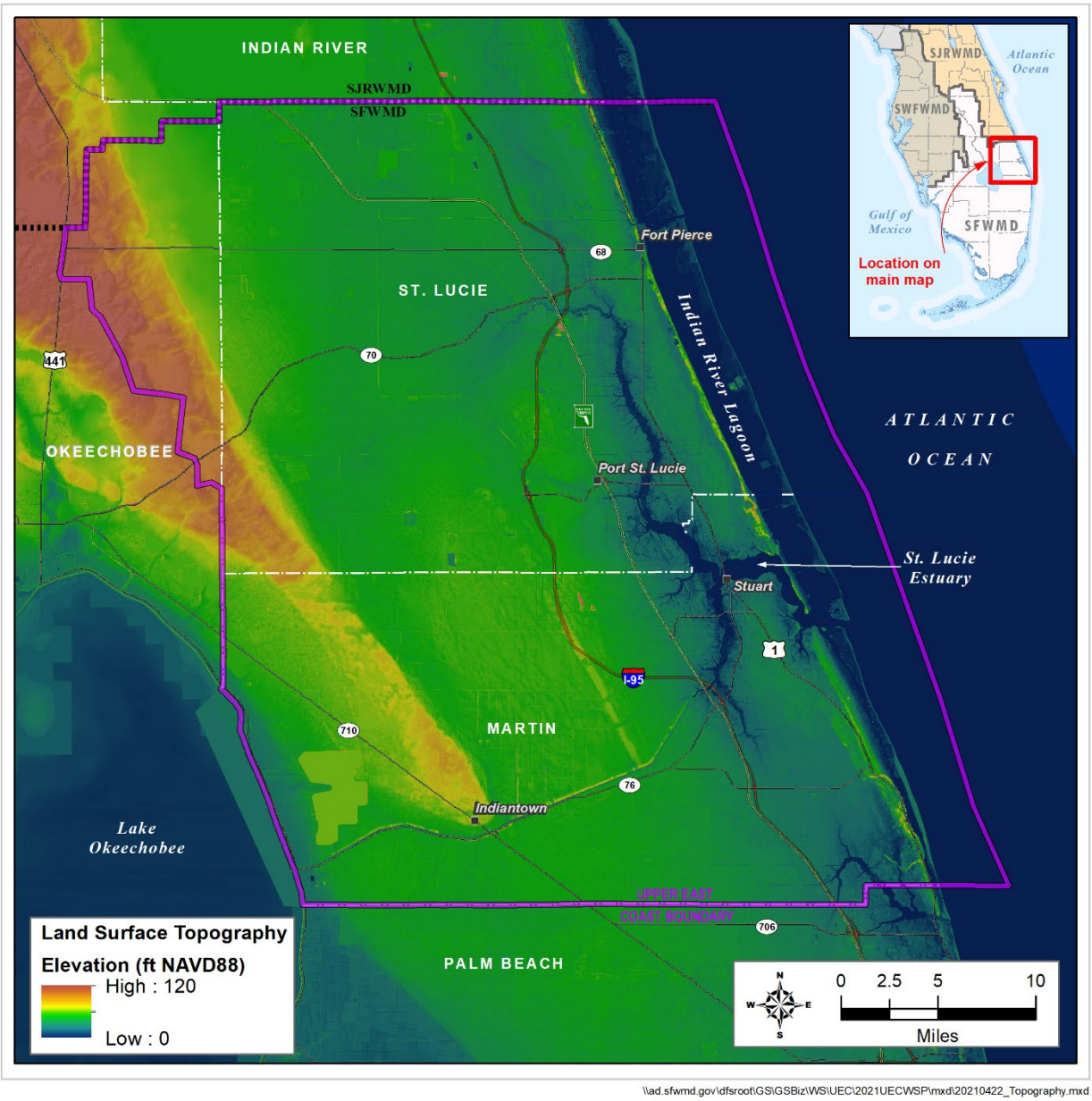


Figure 2-2. Topography of the Upper East Coast Planning Area.

2.1.3 Physiography

The UEC Planning Area is characterized by three principal physiographic zones with differing land characteristics (**Figure 2-3**), which generally trend from east to west. These zones are identified as 1) the Atlantic Coastal Ridge, 2) the Eastern Valley, and 3) the Osceola Plain.

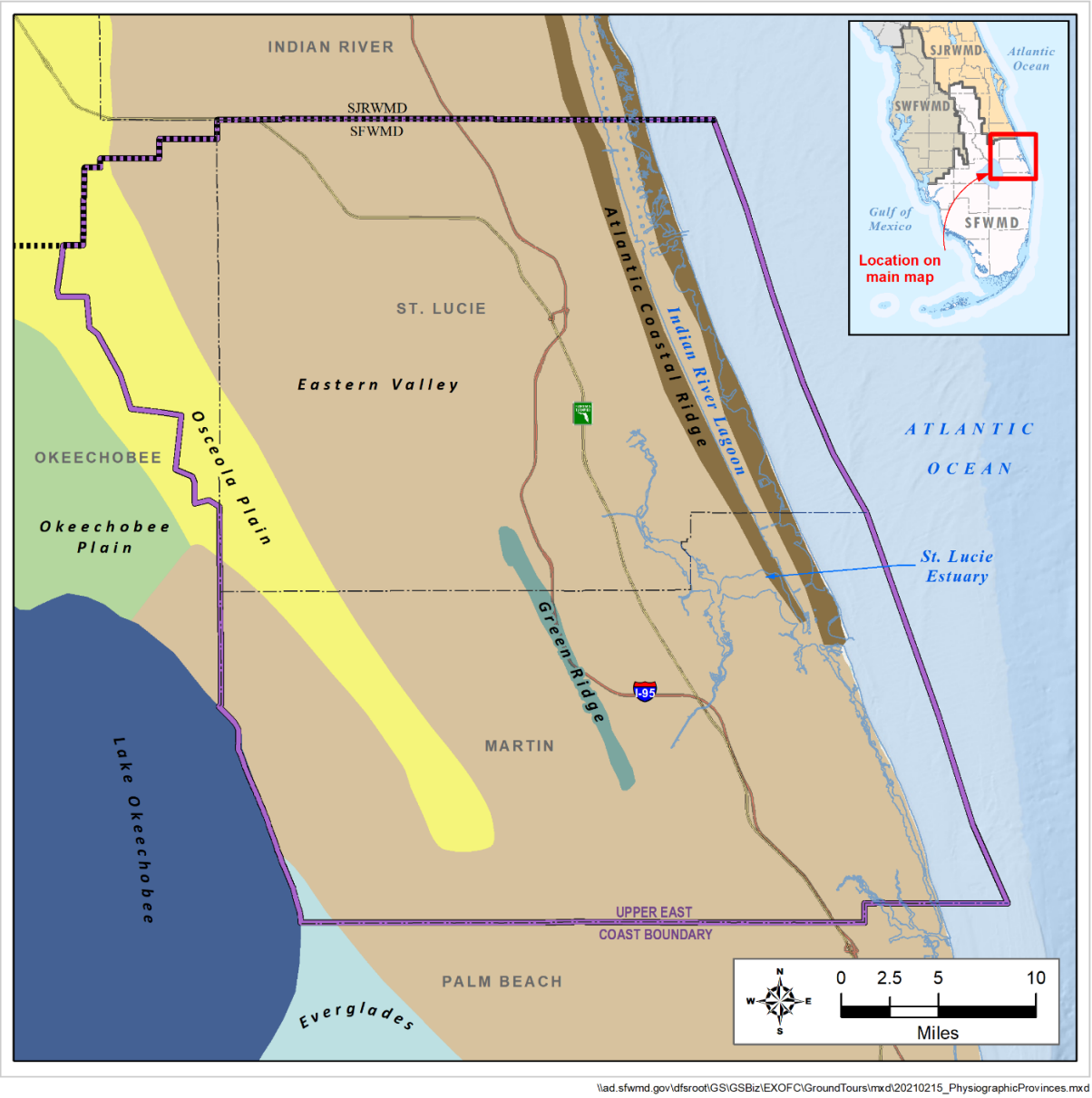


Figure 2-3. Physiography of the Upper East Coast Planning Area.

The Atlantic Coastal Ridge is composed of flatwoods, savanna-like wetlands, and relict beach ridges and sand bars. In the UEC Planning Area, the ridge varies in elevation from sea level to 86 ft above MSL at its highest point in Jonathan Dickinson State Park. The ridge's extensive upland/wetland systems provide a source of groundwater flow for the South Fork of the St. Lucie River and North Fork of the Loxahatchee River. This area is important for aquifer recharge and water supply to the coastal portion of Martin County, where groundwater and ground elevations are higher than the surrounding lands.

West of the Atlantic Coastal Ridge is the Eastern Valley (also known as the Eastern Flatwoods), which encompasses most of the UEC Planning Area. The Eastern Valley is a generally low plain between 1 and 5 ft above MSL, averaging 30 miles in width. The Eastern Valley features long, low, narrow ridges, ranging from 15 to 30 ft above MSL. The Green Ridge in south-central Martin County and the Ten Mile Ridge in north-central Martin County are two such ridges.

St. Lucie River Estuary

The Eastern Valley consists of wetland communities, including tidal and floodplain swamp and forest. These areas are characteristically pocketed with shallow lakes and marshes and have limited natural drainage. Prior to development and the construction of canals, the valley drained by a slow drift of water through multiple sloughs to the St. Lucie River, Loxahatchee River, and Everglades. This area contains the Savannas; Pal-Mar; Loxahatchee Slough; Allapattah, St. Lucie, and Osceola flats; and portions of St. Johns Marsh. The North Fork of the St. Lucie River is also located within the Eastern Valley.

The Osceola Plain lies west of the Eastern Valley in St. Lucie County and intrudes into the Eastern Valley in Martin County. The plain also extends into the eastern portion of Okeechobee County. The Osceola Plain is a relatively flat area that slopes from east to west. The elevation ranges from approximately 70 ft above MSL in northeastern Okeechobee County to 40 ft above MSL in Martin County. The landscape is a matrix of extensive open prairie, small ponds or depressions, swales, partially wooded sloughs, and hammocks.

2.2 WATER RESOURCES AND SYSTEM OVERVIEW

Before development, most of the UEC Planning Area was characterized by nearly level, poorly drained lands subject to frequent flooding. Most surface water systems, especially those with poor drainage, were altered to make the land suitable for development and to provide flood protection. The natural surface drainage systems included large expanses of sloughs and marshes, such as St. Johns Marsh, Allapattah Slough (also known as Allapattah Flats), Cane Slough, and the Savannas. Drainage systems with higher conveyance included the North and South forks of the St. Lucie River and a vast marsh system that included Ten Mile Creek, Five Mile Creek, Loxahatchee River, and Bessey Creek.

Allapattah Flats

2.2.1 Regional Hydrologic Cycle

The main components of the hydrologic cycle in the UEC Planning Area are precipitation, evapotranspiration, and the flow of surface water and groundwater. The interaction between surface water and groundwater is expressed as recharge to or discharge from the aquifer system.

2.2.1.1 Precipitation and Evapotranspiration

The region has a wet season from May through October, and a dry season from November through April. Annual rainfall in the UEC Planning Area averages 55 inches but varies considerably from year to year. Approximately 71% of the area's annual rainfall occurs during the wet season. Average seasonal temperatures for the area range from approximately 63°F to 81°F.

Hydrologic and meteorologic methods are available to measure and estimate the combined rate at which water is returned to the atmosphere by transpiration and evaporation. The combined processes are known as evapotranspiration. Precipitation minus evapotranspiration is equal to the combined amounts of surface water runoff and groundwater recharge. The estimate of potential evapotranspiration from open water and wetlands in the UEC Planning Area is 50 inches (Abtew et al. 2003). Potential evapotranspiration represents the total estimated passive water use of an area under maximum conditions. While actual evapotranspiration varies due to temperature, soil moisture, and other factors, potential evapotranspiration estimates are important landscape-level factors in water balance calculations to determine if enough water will be available for all uses during different environmental conditions.

2.2.1.2 Surface Water Inflow and Outflow

Almost all surface water inflows and outflows in the UEC Planning Area are derived from rainfall. The C-44 (St. Lucie) Canal is an exception, however, as it also receives water from Lake Okeechobee.

Most flows and stages in the region's canals are regulated for water supply and flood protection. The amount of stored water is critically important to natural ecosystems and developed areas in the UEC Planning Area. Surface water is mainly stored in canals. Management of surface water storage capacity involves balancing two conflicting extreme conditions: 1) providing flood protection during the wet season, and 2) meeting water supply needs during the dry season. Management of surface water systems and meteorologic events are key factors affecting the movement of water through the regional hydrologic cycle.

2.2.1.3 Groundwater Flow

Two aquifer systems, the surficial aquifer system (SAS) and the Floridan aquifer system (FAS), lie beneath the UEC Planning Area. Groundwater inflows from outside the planning area contribute insignificant recharge to the SAS; the main source of recharge to the SAS is rainfall. The FAS receives most of its recharge from central and northern Florida. The SFWMD has conducted regional groundwater flow modeling to represent a planning-level analysis of current (2019) and future (2045) groundwater flow regimes. Groundwater modeling reports for the UEC Planning Area are available on the District website at www.sfwmd.gov/uecplan.

2.2.2 Surface Water Resources

Surface water bodies in the UEC Planning Area include canals, natural water bodies, and wetlands. The St. Lucie watershed is hydrologically divided into 10 basins (**Figure 2-4**), each of which drains into a specific tributary or canal that connects to the St. Lucie Estuary. The C-23, C-24, C-25, and C-44 canals

are part of the Central and Southern Florida Flood Control Project (C&SF Project) and are important sources of irrigation water within their respective drainage basins. These canals also discharge directly to coastal waters.

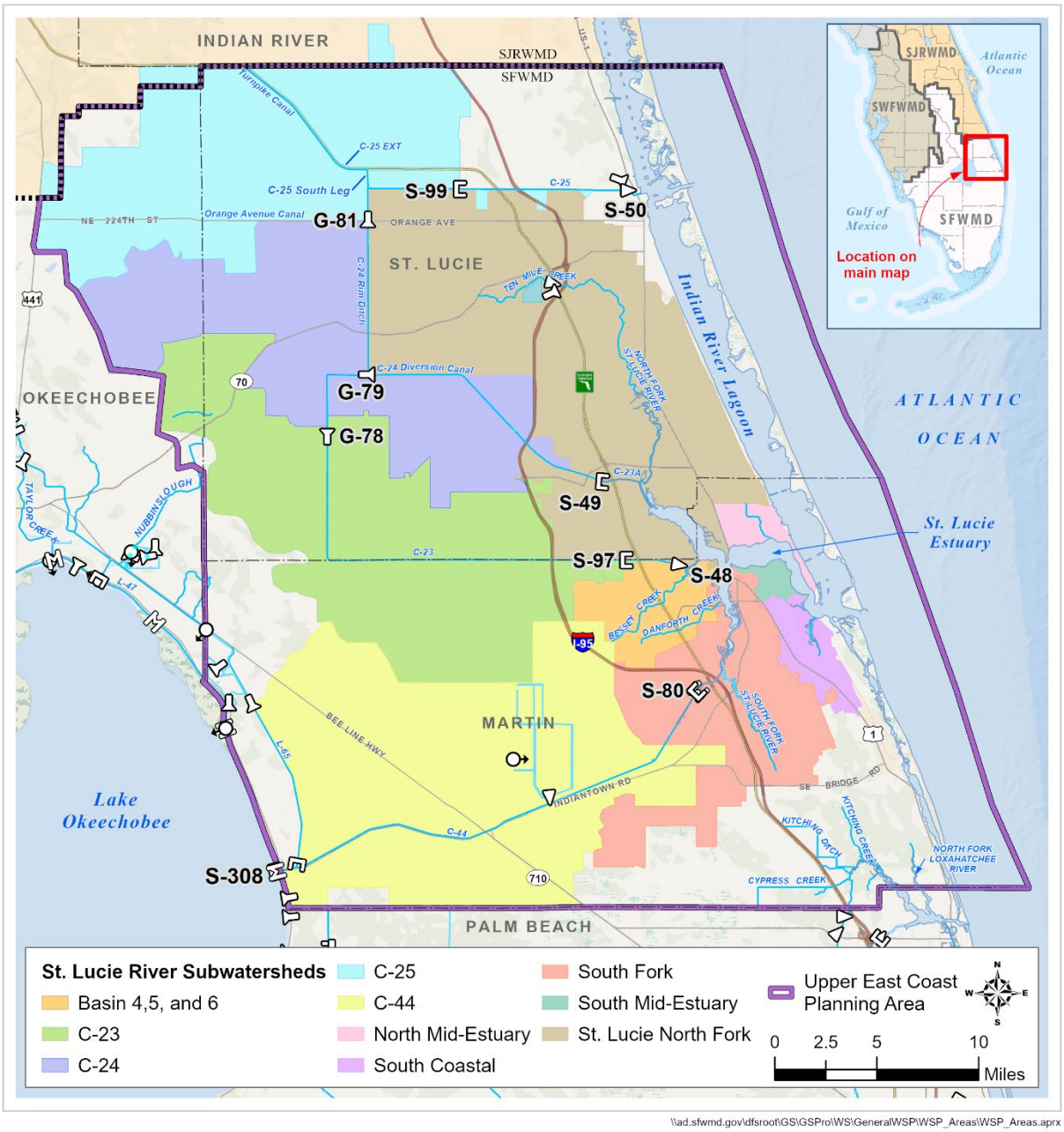


Figure 2-4. Upper East Coast Planning Area drainage basins.

2.2.2.1 Basins 4, 5, and 6

Basins 4, 5, and 6 collectively drain approximately 24 square miles in northeastern Martin County. The basins receive water from the C-23 Canal and C-23 basin via the S-48 structure, which also prevents saltwater intrusion into the local groundwater.

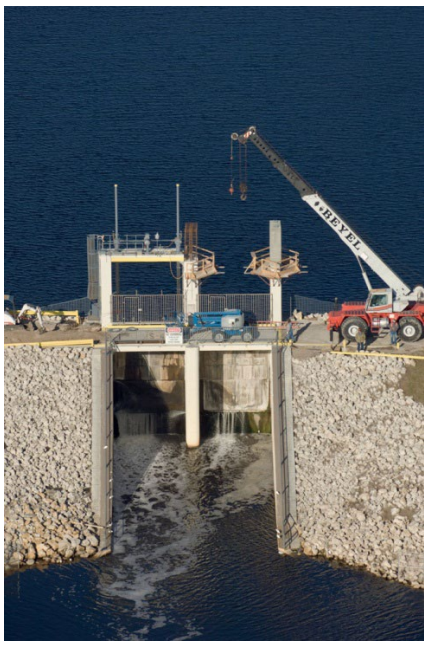
2.2.2.2 C-23 Basin

C-23 Canal in St. Lucie Agricultural Area

The C-23 basin comprises the C-23 canal system and basin, which has a total drainage area of approximately 176 square miles. Most of the C-23 basin is in southwestern St. Lucie County and northern Martin County, with a small portion in eastern Okeechobee County. The C-23 Canal is the main drainage canal. Water flows south from the C-24 basin to the Martin–St. Lucie county line, then heads east, discharging into the North Fork of the St. Lucie River. Three structures control flow in the C-23 basin: S-48, located at the outlet of the C-23 Canal to the North Fork of the St. Lucie River; S-97, located at the Florida Turnpike's crossing of the C-23 Canal; and G-78, located southwest of the convergence of the C-23 and C-24 canals. Water in the north-south leg of the C-23 Canal occasionally may be diverted to the C-24 basin for water supply and flood protection purposes (SFWMD et al. 2009).

2.2.2.3 C-24 Basin

The C-24 basin comprises the C-24 canal system and basin, which has a total drainage area of approximately 137 square miles. Most of the C-24 basin is in southwestern St. Lucie County, with a small portion in eastern Okeechobee County. The C-24 Canal is composed of two canal segments: Rim Ditch Canal and Diversion Canal, which are described below and shown in **Figure 2-4**. The major water control structures are the G-78, G-79, G-81, and S-49 structures. The G-78 structure is located at the confluence of the C-23 and C-24 canals and acts as a drainage divide. The G-79 structure also serves as a basin divide and allows discharge of water from the C-23 basin into the C-24 basin when conditions allow. The G-81 structure is at the drainage divide between the C-24 and C-25 basins. The S-49 structure discharges from the C-24 basin into the C-23A Canal, which is uncontrolled and is the point of discharge from the North Fork of the St. Lucie River to the St. Lucie Estuary.



S-49 Water Control Structure

The Rim Ditch Canal is the section of the C-24 Canal aligned north to south, parallel to and west of Rim Road, and connected to the C-25 South Leg Canal via the G-81 structure. At its south end, the Rim Ditch Canal is connected to the C-23 Canal via the G-79 structure and to the Diversion Canal by an open channel. Flow in the Rim Ditch Canal is usually to the south. If G-81 is open to discharge water to the C-25 basin, water in the Rim

Ditch Canal may flow to the north. The Diversion Canal extends from its intersection with the Rim Ditch Canal on the west to the North Fork of the St. Lucie River.

2.2.2.4 C-25 Basin

The C-25 basin is in northern St. Lucie County. A small portion of the basin also falls within the SJRWMD. The basin may be divided into two sub-basins (western and eastern) based on where water may be discharged. Together, these areas cover approximately 175 square miles.

The major drainage canals in the C-25 basin include the C-25, C-25 South Leg, and C-25 Extension (**Figure 2-4**). The C-25 South Leg is connected to the C-24 Canal via the G-81 water control structure. The C-25 Extension Canal parallels the Florida Turnpike, then turns south to the confluence of the C-25 and C-25 South Leg canals. Excess water is discharged from the basin to Indian River Lagoon west of the Fort Pierce Inlet via the S-99 and S-50 structures, or to a much lesser extent, to the C-24 Canal via the G-81 structure. The Turnpike Canal and Orange Avenue borrow canal provide flood protection and drainage in the western portion of the C-25 watershed. The Turnpike Canal is continuous with the C-25 Extension Canal and extends west along the Florida Turnpike. The Orange Avenue borrow canal makes an open-channel connection with the C-25 South Leg Canal (SFWMD 2010).

2.2.2.5 C-44 Basin

The C-44 basin includes the S-153 sub-basin and has a drainage area of approximately 203 square miles. The C-44 (St. Lucie) Canal connects Lake Okeechobee to the South Fork of the St. Lucie River. Two control structures are located along the C-44 Canal: S-80 (St. Lucie lock and spillway), and S-308 (Port Mayaca lock and spillway/dam). The C-44 Canal is a primary outlet from Lake Okeechobee for flood control. Water levels in the C-44 basin are regulated by the S-80 structure, and regulatory releases from Lake Okeechobee are through the S-308 structure (SFWMD et al. 2009). The S-153 sub-basin discharges into the western end of the C-44 Canal. Secondary drainage in the basin is provided by natural streams.

2.2.2.6 North Fork and North Mid-Estuary Basins

The North Fork and North Mid-Estuary basins are in eastern St. Lucie County and northeastern Martin County. The basins have a total drainage area of approximately 186 square miles. The C-24 and C-23A canals, along with the S-49 structure, regulate water levels in the North Fork and C-24 basins (SFWMD et al. 2009). The sub-basin tributaries within the North Fork basin are as follows: Winters Creek, Howard Creek, Elkcam Waterway, Five Mile Creek, Ten Mile Creek (Gordy Road structure), Britt Creek, Port St. Lucie ditches 1 to 6, C-105, C-106, C-107, C-108, and Hog Pen Ditch.

2.2.2.7 South Fork and South Mid-Estuary Basins

The South Fork and South Mid-Estuary basins have a total drainage area of approximately 78 square miles. Located east of the C-44 basin, the South Fork basin includes the South Fork of the St. Lucie River from south of the Roosevelt Bridge, including the City of Stuart, to a portion of the area to the southwest and upstream of the S-80 structure. The C-44 Canal is the only major drainage canal in the basin.

2.2.2.8 South Coastal Basin

The South Coastal basin has a drainage area of approximately 24 square miles and is located in southeastern Martin County, east of the North Fork basin. The northern portion of the South Coastal basin drains into the St. Lucie Estuary and the southern portion drains into Hobe Sound. There are no major canals or control structures in the South Coastal basin. Most surface water in this basin is tidal and not used for water supply.

2.2.3 Groundwater Resources

The major hydrogeologic units underlying the UEC Planning Area are as follows: 1) the SAS, 2) the intermediate confining unit (ICU) (low-permeability sediments of the Hawthorn Group), and 3) the FAS (**Figure 2-5**). The SAS extends to the top of the ICU, and the ICU extends to the top of the FAS. **Table 2-1** lists the groundwater systems, hydrogeologic units, and relative aquifer yields for each county in the UEC Planning Area.

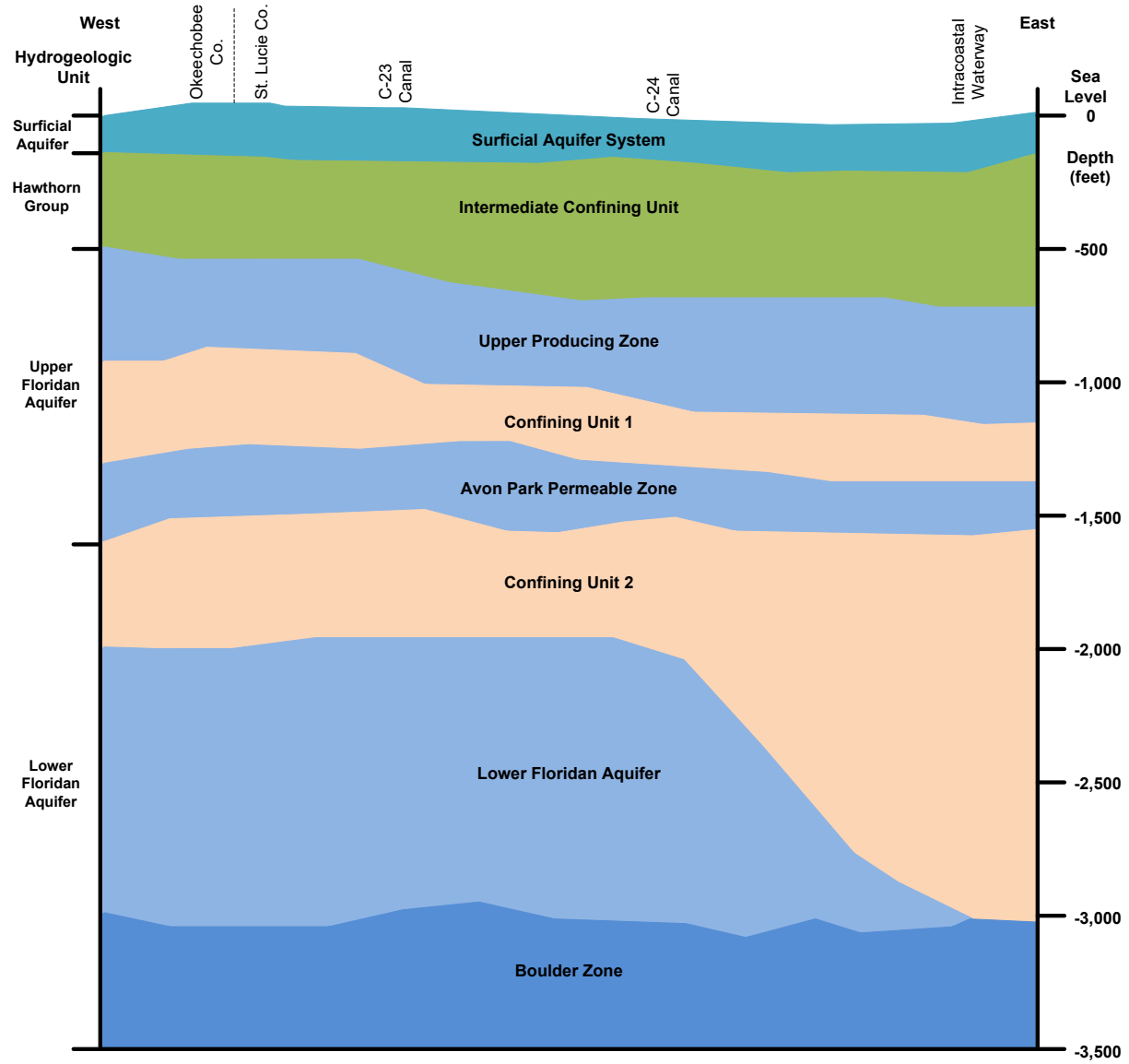


Figure 2-5. Generalized hydrogeologic cross-section of the Upper East Coast Planning Area.

Table 2-1. Groundwater systems in the Upper East Coast Planning Area.

Aquifer System	Hydrogeologic Unit	Aquifer Yield		
		Martin	St. Lucie	Okeechobee
Surficial Aquifer System	Surficial Aquifer System	M	L–M	L
Intermediate Confining Unit	Hawthorn Group	L	L	L
Floridan Aquifer System	Upper Floridan Aquifer and Avon Park Permeable Zone	H	H	M–H
	Lower Floridan Aquifer	H	H	H

A = absent; H = high; L = low; M = moderate.

2.2.3.1 Surficial Aquifer System

The SAS is a water source for urban uses, including potable water, within the UEC Planning Area. The SAS includes all saturated rock and sediment from the water table to the top of the underlying ICU, and ranges in thickness from 50 to 250 ft in this area (Brown and Reece 1979). Its lithology consists of quartz sand, silts, clay, shell beds, coquina, calcareous sandstone, and limestone with shells. The geologic units that make up the aquifers range are (from youngest to oldest): the Pamlico Sand (Pleistocene), the Anastasia Formation (Pleistocene), the Fort Thompson Formation (Pliocene), and possibly part of the Tamiami Formation (Pliocene).

The SAS is generally unconfined to semi-confined (Adams 1992). Permeability of the SAS typically increases to the south and east in the UEC Planning Area (Butler and Padgett 1995). Productivity in the SAS tend to improve from west to east. Throughout most of the UEC Planning Area, water in the SAS meets national drinking water standards with respect to chloride, total dissolved solids (TDS), and sulfate concentrations (Lukasiewicz and Switanek 1995).

2.2.3.2 Intermediate Confining Unit

Within the UEC Planning Area, the ICU comprises relatively impermeable phosphatic clays, silts, and limestones of the Hawthorn Group. In the northwestern corner of St. Lucie County, the top of this confining unit lies approximately 80 ft below MSL. It dips slightly to the southeast, reaching a maximum depth of more than 200 ft below MSL in southeastern Martin County. Thickness also varies, ranging from less than 300 ft in northern St. Lucie County to more than 600 ft at the extreme southern end of the planning area. The ICU has low permeability, does not yield significant quantities of water, and separates the overlying SAS from the underlying FAS.

2.2.3.3 Floridan Aquifer System

The FAS ranges in thickness from 2,700 to 3,400 ft within the UEC Planning Area. The top of the FAS lies approximately 300 ft below MSL in the northwest corner of the planning area. It then dips to more than 900 ft below MSL in southeastern Martin County. The elevation of the top of the FAS corresponds to the top of the Hawthorn/Suwannee basal unit. The FAS includes rocks of middle Eocene (Oldsmar and Avon Park), Upper Eocene (Ocala Limestone), Oligocene (Suwannee Limestone), and Miocene (Hawthorn Group) age (Parker et al. 1955).

The FAS is divided into the Upper and Lower Floridan aquifers (UFA and LFA). The UFA and LFA are separated by a low-permeability interval, labeled the middle confining unit by Miller (1986) (**Figure 2-5**, confining unit 2).

Upper Floridan Aquifer

The UFA is an artesian aquifer (i.e., it flows at land surface without the aid of pumping) more than 500 ft thick within the UEC Planning Area. It is characterized by two distinct and regionally correlated producing zones: the upper producing zone and the Avon Park permeable zone. Although these units occur together, they are not homogenous because both are composed of multiple smaller producing zones with intervening semi-confining units.

The upper producing zone is highly developed along the lithologic contacts between the Suwannee Formation and the Ocala Group, and the Ocala Group and the Avon Park Formation. A lower-permeability semi-confining unit (**Figure 2-5**, confining unit 1) separates the upper producing zone from the Avon Park permeable zone. The Avon Park permeable zone is 1,300 ft or more below land surface (Rupert 1992) and associated with fractured and solutioned dolomites within the Avon Park Formation.

The Avon Park permeable zone is generally more productive than the upper producing zone, but its productivity is also less predictable and varies widely across the UEC Planning Area. Lower-permeability rock separating the upper producing zone from the Avon Park permeable zone allows for variations in water quality between the two units. In most cases, the Avon Park permeable zone is more brackish than the upper producing zone. Many users of the UFA within the UEC Planning Area construct wells open to both the upper producing and Avon Park permeable zones but must balance water quality with improved productivity.

The productivity of the UFA is considerably greater than that of the SAS throughout most of the UEC Planning Area; however, TDS concentrations in the UFA are also much greater than in the SAS. TDS concentrations in the upper producing zone average approximately 1,500 milligrams per liter (mg/L), while TDS concentrations in the Avon Park permeable zone average approximately 3,000 mg/L in Martin and St. Lucie counties.

The UFA is an important source of agricultural irrigation water, particularly in the northern portion of the UEC Planning Area where surface water availability is limited. However, in many areas, water from the UFA requires blending with surface water prior to irrigation because of high chloride concentrations. In Martin and St. Lucie counties, the UFA is used for drinking water, and as the area continues to grow, use of the UFA to augment urban supply is expected to increase. The UFA's chloride concentrations are within a reasonable range for current desalination technology. Where chloride concentrations are sufficiently low, UFA water can be blended with SAS water for use by public water supply utilities. Most utilities use desalinated UFA water to supply a portion of their service area, and many are planning to increase withdrawals to meet future growth in demands. In addition, several golf courses use the UFA for all or some of their water supply needs, with most using reverse osmosis treatment.

Lower Floridan Aquifer

The deeper producing zones of the FAS are composed of hard, porous, crystalline dolomitic limestone, with stringers of chalky fossiliferous limestone. There are multiple flow zones within the upper part of the LFA, but these are generally not used as supply sources in the UEC Planning Area due to the high salinity (greater than 10,000 mg/L) and mineral content of the water.

An area of extremely high transmissivity, known as the Boulder Zone, occurs at the base of the LFA. A thick confining layer of dense limestones and dolomites impedes flow between the Boulder Zone and the transmissive zones at the top of the LFA. The base of the LFA generally coincides with the top of the evaporite beds in the Cedar Keys Formation (Miller 1986). The Boulder Zone is used to dispose of wastewater effluent that is not reused and concentrate from desalination water treatment facilities.

2.2.4 Surface Water and Groundwater Relationships

In many ways, surface water and groundwater resources are interdependent. Although surface water management systems are a major source of water supply, in terms of interaction with groundwater, the systems within the UEC Planning Area function primarily as aquifer drains. Surface water management systems also affect aquifer recharge by diverting rainfall from an area before it has time to percolate down to the water table. Once diverted, this water may contribute to aquifer recharge elsewhere in the system, supply a downstream consumptive use, be lost to evapotranspiration, or be discharged to tide.

Although the FAS is not hydraulically connected to surface water bodies within the UEC Planning Area, FAS water has become a primary source for public water supply. In addition, the FAS is used a secondary or backup source for agriculture. The FAS is usually diluted with surface water to achieve an acceptable quality for agricultural irrigation.

Chapter 3: Lower West Coast Planning Area

This chapter describes physical features and water resources, including surface water and groundwater sources, in the Lower West Coast (LWC) Planning Area. For a comprehensive review of water supply status and issues in the LWC Planning Area, refer to the most recent LWC water supply plan update.

The LWC Planning Area includes all of Lee County, most of Collier County, and portions of Charlotte, Glades, Hendry, and Monroe counties (**Figure 3-1**). The boundaries of the LWC Planning Area generally reflect the drainage patterns of the Caloosahatchee River basin to the north and the Big Cypress National Preserve to the south. The northern boundary corresponds roughly to the Caloosahatchee River watershed, which is the South Florida Water Management District (SFWMD or District) and Southwest Florida Water Management District (SWFWMD) jurisdictional boundary in Charlotte County. The eastern boundary of the LWC Planning Area is along the western edge of the historical Everglades watershed, dividing the Big Cypress and Lake Okeechobee drainage basins. At the southern end of the region, the LWC Planning Area encompasses a coastal portion of Everglades National Park and ends just north of Shark River Slough.

Figure 3-1. Lower West Coast Planning Area.

3.1 PHYSICAL FEATURES

Major features in and adjacent to the LWC Planning Area include the Caloosahatchee River and Estuary; Lake Okeechobee; Lake Trafford; Corkscrew Regional Ecosystem Watershed (CREW); Big Cypress Swamp; and along the west coast, Southern Charlotte Harbor, Estero Bay, Naples Bay, Ten Thousand Islands and Rookery Bay, and Fakahatchee Estuary.

Fisheating Creek basin in the adjacent Lower Kissimmee Basin Planning Area (**Chapter 1**) impacts the northeastern boundary of the LWC Planning Area. Flows from Fisheating Creek basin affect surface water flows in the LWC Planning Area through lake and river discharges and sheetflow events.

Big Cypress National Preserve

3.1.1 Water Bodies and Landscapes

Lake Okeechobee is one of the largest freshwater lakes in the nation and provides substantial surface water storage in South Florida. The lake is east of the LWC Planning Area and discharges west to the Gulf coast through the C-43 Canal and Caloosahatchee River.

The Caloosahatchee River receives inflows from Lake Okeechobee (via the C-43 Canal) and runoff from its own watershed. West of the S-79 structure, the river mixes freely with estuarine water as it empties into the Gulf of Mexico, forming an important tidal estuary (see **Section 3.1.1.1**). A canal connects Lake Hicpochee and Lake Okeechobee, creating an avenue for lake water discharges to the west coast through the Caloosahatchee River. Later modifications to the Caloosahatchee River and C-43 Canal allowed development in the watershed, resulting in a network of local secondary and tertiary canals. This network provides conveyance for drainage, flood control, and irrigation to accommodate agricultural and urban needs.

Located in the LWC Planning Area, Lake Trafford is the largest lake south of Lake Okeechobee and forms the inland headwaters of the Corkscrew Swamp, Imperial River, and Cocohatchee River watersheds that drain into the Ten Thousand Islands and Estero Bay estuary systems on the coast.

Surrounding most of Lake Trafford's shores is CREW, which extends west-southwest through Lee and Collier counties toward Naples. Pine flatwoods, marshes, and slough areas characterize the CREW area, with small bald cypress stands interspersed throughout. Of the approximately 94 square miles of watershed area, about 78 square miles are designated as preserve. The *South Florida Environmental Report* – Volume II, Chapter 6B (available from www.sfwmd.gov/sfer) annually updates the status of this ecosystem restoration project.

Okaloacoochee Slough is an important surface water flow-way in Collier County, covering approximately 21 square miles. The headwaters of this slough originate in northern Hendry County. The slough runs north to south through the Okaloacoochee Slough State Forest (50 square miles). Composed largely of herbaceous plants with trees and shrubs scattered along its fringes and central portions, Okaloacoochee Slough provides a large contiguous habitat for a variety of wildlife species. The forest is home to listed, threatened, and endangered species, such as the Florida panther, Florida black bear, sandhill crane, wood stork, and gopher tortoise. The natural systems of the Fakahatchee Strand Preserve and Big Cypress Preserve depend on the water supplied by Okaloacoochee Slough.

South of Lake Trafford and CREW, roughly from west to east, are the Picayune Strand State Forest, Fakahatchee Strand Preserve State Park, Big Cypress Natural Preserve, and the Florida Panther National Wildlife Refuge, which sits on the north end of Fakahatchee Strand. Picayune Strand State Forest is in the heart of the greater Big Cypress Basin. The forest encompasses two major tracts of land, Belle Meade and Southern Golden Gate Estates.

Picayune Strand State Forest

Fakahatchee Strand is a long, narrow forest with an unusual natural slough. The park covers approximately 100 square miles between Picayune Strand State Forest and Big Cypress National Preserve. Within a dense bald cypress and royal palm canopy, Fakahatchee Strand shelters a slow-flowing river, several lakes, and a range of wet and dry landscapes. The trees and slough create a microclimate that is more temperate than surrounding areas. Because of this, a large diversity of rare tropical plants, such as the ghost orchid, can be found. Prairie Canal currently defines the western border of Fakahatchee Strand, which has hastened the drainage of water from the natural areas.

Big Cypress National Preserve protects almost half of the Big Cypress Swamp, which is mainly in Collier County. The preserve spans approximately 1,125 square miles of the 2,400-square-mile swamp basin. Dominated by cypress trees, the swamp and its fresh waters are essential to the health of the Everglades, supporting multiple estuaries along Florida's southwestern coast. Fresh water from the preserve flows south and west into the Ten Thousand Islands region.

3.1.1.1 Coastal Ecosystems

Coastal areas are dominated by large estuarine systems where the waters of the Gulf of Mexico mix with freshwater inflows from numerous river systems, sloughs, and overland sheetflow. These estuarine areas are characterized by shallow bays, extensive seagrass beds, and sand flats. Extensive mangrove forests dominate undeveloped areas of the shoreline. Coastal areas subject to tidal inundation support extensive mangrove forests and salt marsh areas. These brackish water communities were once commonly distributed along the entire coastline but are now found in greatest abundance in southwestern Collier County and southern Lee County.

Two large open water estuarine systems, Charlotte Harbor and the Caloosahatchee River Estuary, dominate the northwestern portion of the LWC Planning Area (**Figure 3-2**). Charlotte Harbor is Florida's second-largest open water estuary, characterized by a broad barrier island chain. Within the District's boundaries lies the southern portion of the system, including the Caloosahatchee Estuary, San Carlos Bay, and most of Pine Island Sound and Matlacha Pass. Southern Charlotte Harbor is mostly preserve and adjoins the J.N. "Ding" Darling National Wildlife Refuge on Sanibel Island. The harbor consists of mangroves, salt flats, oyster bars, and seagrasses. The area is monitored regularly as part of a national aquatic preserve program. Economically important fisheries thrive in southern Charlotte Harbor, and numerous endangered and threatened species can be found here.

Figure 3-2. Coastal features of the Lower West Coast Planning Area.

At the tip of southern Charlotte Harbor and north of Estero Bay is the Caloosahatchee River Estuary, a large estuarine ecosystem where the waters of the Gulf of Mexico mix with the freshwater inflows from the Caloosahatchee River and its watershed (C-43 basin) as well as the largely urban tidal basin surrounding the estuary.

Mangroves in Estero Bay

Estero Bay is a long, narrow, and very shallow body of water (**Figure 3-2**). Estero Bay's northwestern border begins at Bowditch Point on Estero Island and extends as far south as Bonita Beach. Estero Island, Black Island, Long Key, Lover's Key, and Big Hickory Island are the barrier islands that separate the bay from the Gulf of Mexico. The major wetland and associated upland systems are in the central and eastern parts of the basin. The Estero Bay watershed includes central and southern Lee County as well as parts of northern Collier and western Hendry counties. The watershed contains Estero Bay and its adjacent barrier islands. The Estero Bay Aquatic Preserve protects the water, inlets, and islands along 10 miles of Estero Bay. Hendry Creek, Mullock Creek, Estero River, portions of CREW, Spring Creek, and Imperial River are major surface water features and principal sources of freshwater inflows in the basin. The natural flow path between the Estero and Imperial river watersheds is through the Flint Pen Strand, part of CREW. Flint Pen Strand has been disrupted by urban and agricultural development that hampers aquifer recharge and affects these natural systems. Restoring sheetflow through the region is part of the restoration effort for this watershed.

Naples Bay originates at the mouth of the Gordon River in downtown Naples (**Figure 3-2**). Several miles to the south, the bay connects to the Gulf of Mexico through Gordon Pass. South of Gordon Pass, at the southern lobe of the Naples Bay system, Dollar Bay connects to Rookery Bay and the Marco River through a shallow waterway with a dredged channel.

The 120-square-mile Naples Bay basin lies within the greater Big Cypress basin, and shares borders with the Corkscrew-Cocohatchee basin to the north, the Faka-Union Canal basin to the east, and the Henderson Creek basin and Rock Creek, Winter Park Outlet, Haldeman Creek, Lely Canal, and Eagle Creek sub-basins along the southeast. Fresh water flows into Naples Bay from the Golden Gate Canal, Gordon River, Rock Creek, and Haldeman Creek and via runoff from the urban areas that surround the bay.

Rookery Bay, just south of Naples Bay, is on the northern edge of the Ten Thousand Islands estuary region in Collier County, between Naples and Marco Island. The bay is part of a national estuary preserve program and is downstream of the Comprehensive Everglades Restoration Plan (CERP) Picayune Strand Restoration Project.

Ten Thousand Islands

The Ten Thousand Islands estuarine ecosystem, located in the southern portion of Collier County (**Figure 3-2**), contains bays, interconnected tidal embayments, lagoons, and tidal streams. Sources of freshwater drainage include sloughs, strands, a series of tidal creeks and channels, surface and subsurface sheetflow, and canals. Ten Thousand Islands is one of the world's largest remaining intact mangrove forests. The habitat extends from just south of Marco Island to Flamingo and Florida bays. Two-thirds of the area is within the Everglades National Park's Whitewater Bay. Cape Romano/Ten Thousand Islands Aquatic Preserve and Ten Thousand Islands National Wildlife Refuge protect the areas outside the Everglades National Park boundaries.

For scientific study, the Fakahatchee Estuary may include Rookery Bay, the Ten Thousand Islands National Wildlife Refuge, and smaller embayments south through to Fakahatchee Bay. However, for the sake of water supply planning, Fakahatchee Estuary is narrowed to the north-to-south region beginning at Blackwater Bay and extending through Fakahatchee Bay into the northern coastal regions of Everglades National Park.

3.1.2 Geography

The LWC Planning Area extends approximately 5,129 square miles across southwestern Florida, and its average elevation is about 16 feet (ft) above mean sea level (MSL). The landscape slopes gently westward, in keeping with the overall topography of the state, which slopes away from the peninsular ridge that extends from the Georgia border and ends just above Lake Okeechobee (**Figure 3-3**). Within the LWC Planning Area, fresh water historically drained across the landscape from the Everglades and Lake Okeechobee and from the Immokalee Rise to the estuaries on the west coast.

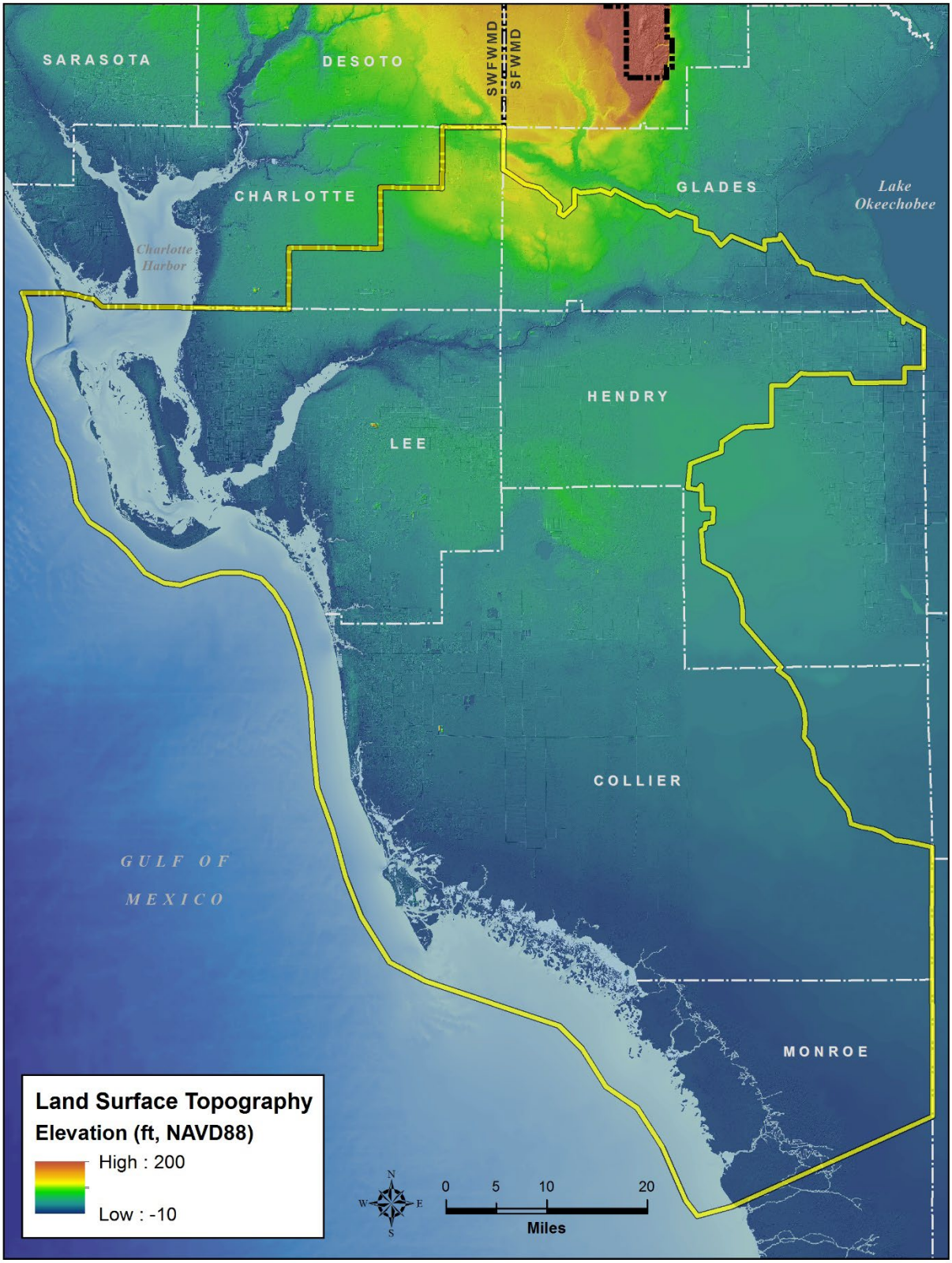


Figure 3-3. Topography of the Lower West Coast Planning Area.

3.1.3 Physiography

South Florida is characterized by low topographic relief and a high water table. With this type of flat terrain, a few vertical feet may have a profound effect on surface water drainage, vegetation, and settlement patterns.

Physiographically, the LWC Planning Area includes the Caloosahatchee River and Big Cypress watersheds (**Figure 3-4**). The Caloosahatchee River watershed encompasses the Caloosahatchee River Valley (the watershed's dominant physiographic feature), Caloosahatchee Incline, DeSoto Plain, and Immokalee Rise (Drew and Schomer 1984). The Big Cypress watershed contains all or parts of the Immokalee Rise, Big Cypress Spur, Southwestern Slope, and coastal swamps and lagoons (Drew and Schomer 1984). The valley follows the Caloosahatchee River from Lake Okeechobee to San Carlos Bay.

The valley "wall," known as the Caloosahatchee Incline, slopes gradually upward to the north of the river (Drew and Schomer 1984). At the peak of the valley wall lies the DeSoto Plain, a very flat terrace extending down from central Florida. The Immokalee Rise forms the valley wall south of the Caloosahatchee River.

The Immokalee Rise is an elevated flat area of predominantly sandy soils (Drew and Schomer 1984). This area is primarily in Hendry County but extends into eastern Lee County and northeastern Collier County. The Immokalee Rise is bounded on the east by the Everglades, on the south-southeast by the Big Cypress Spur, and on the southwest by the Southwestern Slope. The Immokalee Rise ranges in elevation from 25 to 42 ft above MSL (Campbell 1988).

The Big Cypress Spur is a sloping, transitional area between the Immokalee Rise, the Everglades to the east, and the Southwestern Slope to the west (Drew and Schomer 1984). This area receives runoff from the Immokalee Rise and drains to the Everglades and Southwestern Slope. Elevations are only slightly higher than 25 ft above MSL.

Big Cypress Swamp

The Southwestern Slope lies at elevations below approximately 25 ft above MSL between the Gulf of Mexico and the western edges of the Immokalee Rise and Big Cypress Spur (Campbell 1988). This area is a northwest-southeast trending area that tilts toward the Gulf of Mexico (Drew and Schomer 1984).

The Collier County coastline consists of quartz sand-dominated barrier islands and lagoons, with Cape Romano forming the southern end of the barrier islands. The Ten Thousand Islands are located south of Cape Romano and are transitional between the barrier islands and shoreline to the south. The Reticulate Coastal Swamps border the Gulf Coast in the southern portion of Collier County. These swamps consist of channeled mangrove swamps and coastal marshes (Campbell 1988).

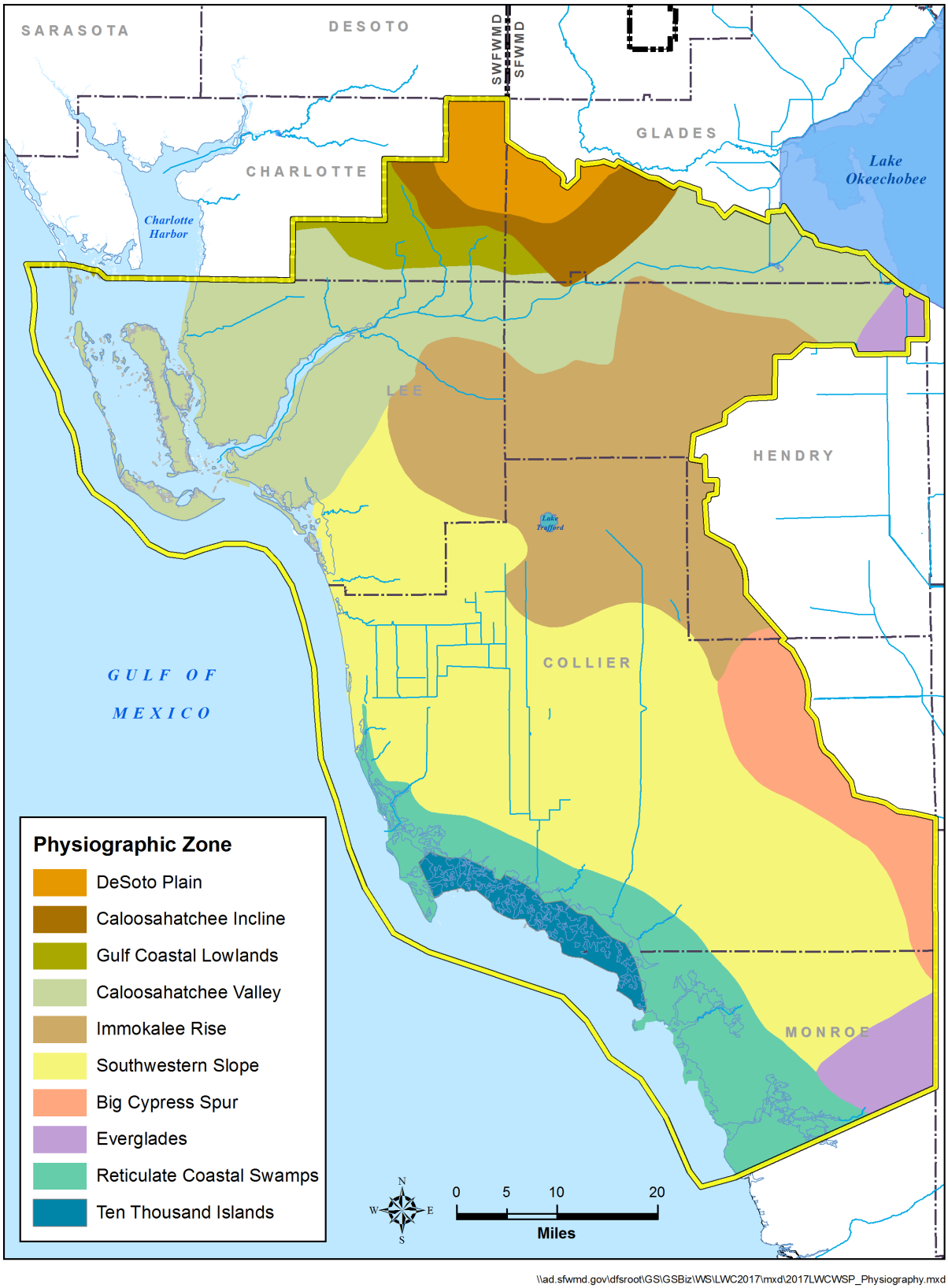


Figure 3-4. Physiography of the Lower West Coast Planning Area.

3.2 WATER RESOURCES AND SYSTEM OVERVIEW

Prior to development, most of the LWC Planning Area was characterized by nearly level, poorly drained lands subject to frequent flooding. The natural surface drainage systems included large expanses of sloughs and marshes, such as Telegraph Cypress Swamp, Corkscrew Swamp, Flint Pen Strand, Camp Keais Strand, Six Mile Cypress Slough, Okaloacoochee Slough, and Twelve Mile Slough.

3.2.1 Regional Hydrologic Cycle

The main components of the hydrologic cycle in the LWC Planning Area are precipitation, evapotranspiration, and the flow of surface water and groundwater.

3.2.1.1 Precipitation and Evapotranspiration

Estimated annual rainfall in the LWC Planning Area averages 53 inches. Nearly two-thirds of the area's rainfall occurs during the wet season (May through October). Average seasonal temperatures for the area range from approximately 65°F to 83°F.

Hydrologic and meteorologic methods are available to measure and estimate the combined rate at which water is returned to the atmosphere by transpiration and evaporation. The combined processes are known as evapotranspiration. Precipitation minus evapotranspiration is equal to the combined amounts of surface water runoff and groundwater recharge. The estimate of potential evapotranspiration from open water and wetlands in the LWC Planning Area is 52 inches (Abtew et al. 2003). Potential evapotranspiration represents the total estimated passive water use of an area under maximum conditions. While actual evapotranspiration varies due to temperature, soil moisture, and other factors, potential evapotranspiration estimates are important landscape-level factors in water balance calculations to determine if enough water will be available for all uses during different environmental conditions.

3.2.1.2 Surface Water Inflow and Outflow

Except for the Caloosahatchee River and C-43 Canal, most surface water in the LWC Planning Area originates from rainfall. The Caloosahatchee River also receives water from Lake Okeechobee. Historical flow-ways in the region were natural drainage features, consisting of a series of flat wetlands or swamps connected by shallow drainage ways or sloughs separated by low ridges. These features were dry for a portion of the year and overtopped by water in periods of seasonal high rainfall.

Mouth of Caloosahatchee River and San Carlos Bay

Most of the canals in the LWC Planning Area were constructed as surface water drainage systems. The C-43 Canal and Caloosahatchee River are key sources of fresh water for the estuary and for consumptive use. The amount of stored water is critically important to natural ecosystems and developed areas in the LWC Planning Area. Management of surface water storage capacity involves balancing two conflicting conditions: 1) drought conditions may occur during periods of deficient rainfall, and 2) flooding may occur due to excessive rainfall, especially during the wet season.

3.2.1.3 Groundwater Flow

Three major aquifer systems underlie the LWC Planning Area: the surficial aquifer system (SAS), the intermediate aquifer system (IAS), and the Floridan aquifer system (FAS). Rainfall is the main source of recharge to the SAS. The IAS is partially recharged from the SAS. The FAS receives its recharge from central and northern Florida. Groundwater flow within these aquifer systems is generally from the north to south and southwest toward the coast. The SFWMD has conducted regional groundwater flow modeling to represent a planning-level analysis of current (2020) and future (2040) groundwater flow regimes in these aquifer systems. Groundwater modeling reports for the LWC Planning Area are available on the District website at www.sfwmd.gov/lwcplan.

3.2.2 Surface Water Resources

Surface water bodies in the LWC Planning Area include rivers and canals that provide storage and conveyance of surface water. However, the area's two largest lakes, Lake Trafford and Lake Hicpochee, are not considered suitable water supply sources. Lake Hicpochee changes dramatically in size on a seasonal basis as it receives overflows from Lake Okeechobee during times of high lake levels. The dynamic nature of inflows and the shallowness of Lake Hicpochee makes it unsuitable for water storage. In addition, construction of the C-43 Canal through the center of Lake Hicpochee has resulted in lower lake water levels. Lake Trafford has experienced a decline in the viability of the lake ecosystem and has been undergoing extensive restoration activities to return the lake to its natural condition. The lake remains on the state's list of impaired water bodies.

The Caloosahatchee River, the region's most important surface water source, extends across 7 of the 10 drainage basins in the LWC Planning Area. The river receives runoff from its own basin and supplemented inflows from Lake Okeechobee. The freshwater portion of the river (C-43 Canal) extends eastward from the S-79 structure (Franklin lock and dam) towards Lake Okeechobee and the cities of LaBelle and Moore Haven. West of the S-79 structure, the river mixes with estuarine water as it empties into the Gulf of Mexico. The remaining rivers and canals in the LWC Planning Area drain into Estero Bay, the Caloosahatchee River, or the Gulf of Mexico.

3.2.2.1 Drainage Basins

The LWC Planning Area is divided into 10 major drainage basins according to their respective hydrologic characteristics (**Figure 3-5**):

- North Coastal
- Tidal Caloosahatchee
- Telegraph Swamp
- West Caloosahatchee
- East Caloosahatchee
- S-4
- S-236
- Estero Bay
- West Collier
- East Collier

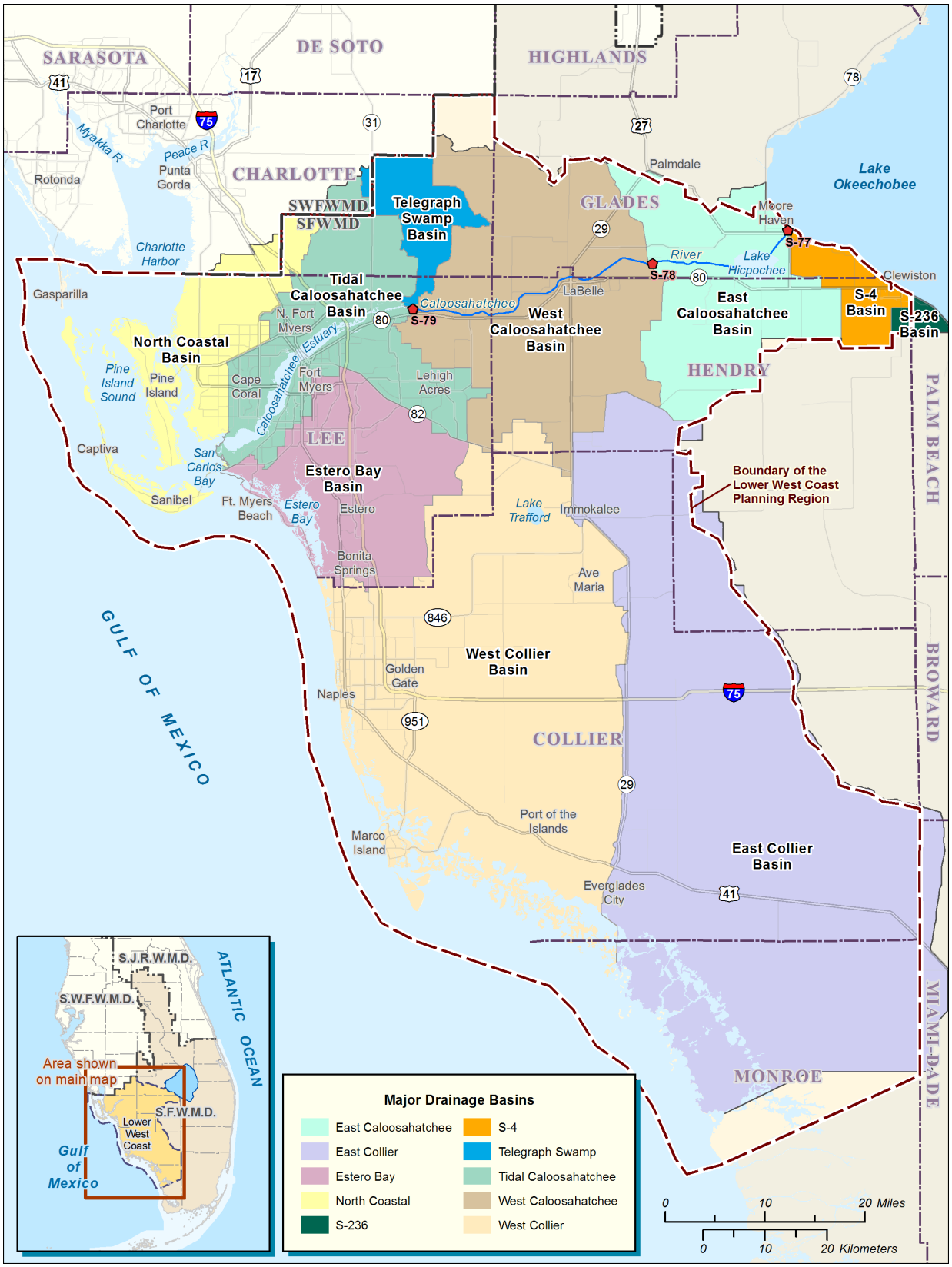


Figure 3-5. Lower West Coast Planning Area drainage basins.

North Coastal Basin

The North Coastal basin, in southwestern Charlotte County and northwestern Lee County, contains numerous creeks. The basin drains via overland flow from the Fred C. Babcock/Cecil M. Webb Wildlife Management Area in Charlotte County into the Gator Slough watershed within northwestern Lee County. Most of this basin drains through the Gator Slough Canal into the Cape Coral canal system. The 400-mile canal system flows through Cape Coral, which is 115 square miles and Florida's third-largest city (as measured by land mass). Approximately 295 miles of the canal system are considered fresh water and about 105 miles are brackish water. The system drains a large area, affecting the hydrology of the Matlacha Pass and Caloosahatchee estuaries.

Tidal Caloosahatchee Basin

The Tidal Caloosahatchee basin extends from both sides of the saltwater portion of the Caloosahatchee basin and north into Charlotte County. Numerous creeks in this basin drain into the Caloosahatchee River.

Telegraph Swamp Basin

The Telegraph Swamp basin extends from Charlotte County southward to the Caloosahatchee River. Telegraph Cypress Swamp, which drains via sheetflow into Telegraph Creek in Lee County, is the basin's major feature. The approximately 92-square-mile watershed with sheetflow discharge is potentially suitable as a water supply recharge area (Johnson Engineering et al. 1990).

West and East Caloosahatchee Basins

The West and East Caloosahatchee basins are located along the freshwater portion of the C-43 Canal. The basins include parts of Lee, Collier, Hendry, Glades, and Charlotte counties. The C-43 Canal is the major surface water resource within the basins. The canal has multiple purposes, including navigation, water supply, drainage, and regulatory releases of excess water from Lake Okeechobee.

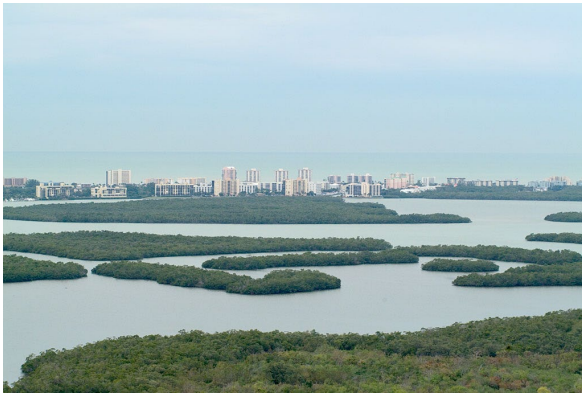
In the East Caloosahatchee basin, Lake Hicpochee was severely impacted by the construction of the C-43 Canal through the lake's center, which resulted in lower lake water levels. The C-43 Canal provides drainage for numerous private drainage systems and local drainage districts within the combined drainage basins. The C-43 Canal also provides water for agricultural irrigation projects within the basins and water supply for Lee County's Olga Wastewater Treatment Facility.

Three structures (S-77, S-78, and S-79) provide navigation and water level control in the C-43 Canal. These structures are operated by the United States Army Corps of Engineers, who controls the water stages in the C-43 Canal from Lake Okeechobee (S-77 structure) to Franklin lock (S-79 structure). Upstream of the S-78 structure, water levels are maintained at approximately 11 ft above MSL and water levels downstream of the structure are maintained around 3 ft above MSL. The S-79 structure also serves as a saltwater barrier. The operation schedule for these structures depends on rainfall conditions, agricultural practices, the need for regulatory releases from Lake Okeechobee, and the need to provide water quality control.

S-4 and S-236 Basins

The S-4 and S-236 basins adjoin the southwestern edge of Lake Okeechobee, including the City of Clewiston. Land use within these basins is predominantly agriculture. Water levels in the basins are controlled by operation of the S-4 pump station for agricultural irrigation and hurricane protection purposes.

Estero Bay Basin



Estero Bay

The Estero Bay basin is in southern Lee County and includes Hendry Creek, Mullock Creek/Ten Mile Canal/Six Mile Cypress Slough, Kehl Canal/Imperial River, Estero River, and Spring Creek. These waterways are influenced, to varying degrees, by tides. Within the Estero Bay basin, a twofold water management problem exists: 1) over-drainage in areas due to development, and 2) lack of conveyance in other areas, resulting in flooding. The Estero Bay basin does not have a major source of surface water available for water supply. The Estero River east of U.S. Highway 41 and the Imperial River east of Interstate 75 are both considered good recharge areas. The Kehl Canal is connected to this river and drains the water levels within this basin.

West Collier Basin

The West Collier basin extends west from State Road 29 to the Gulf of Mexico, and north to the Lee County border. The basin also includes a portion of Hendry County. The West Collier basin does not have an external source of surface water for year-round water supply. Lake Trafford, in the northern section of the basin, has a drainage area of approximately 30 square miles.

The West Collier basin flows into the Gulf of Mexico near the Ten Thousand Islands. The Gordon and Cocohatchee rivers are two remnant natural rivers in this basin. Both rivers are tidally influenced and connect to the canal system within this basin. The canal system, operated and managed by the Big Cypress Basin Board, serves primarily as a drainage network. The Big Cypress Basin Board retrofitted many old weirs and constructed new water control structures in the canals to prevent over-drainage of the basin. Because the primary source of water for this system is rainfall, the canals have little or no flow during the dry season but produce considerable freshwater discharge during wet conditions.

The West Collier basin has extensive wetland systems, including CREW, Picayune Strand State Forest, Fakahatchee Strand Preserve State Park, and Collier-Seminole State Park.

East Collier Basin

The East Collier basin extends east from State Road 29 to the LWC Planning Area boundary, north approximately 3 miles into southern Hendry County, and south into Monroe County. Sheetflow from this basin flows south-southwest into Everglades National Park and the Gulf of Mexico. The Big Cypress National Preserve forms most of this basin. There are no major rivers or sources of surface water for year-round water supply use in the East Collier basin.

3.2.3 Groundwater Resources

Three major aquifer systems—SAS, IAS, and FAS—lie beneath southwestern Florida. As **Figure 3-6** illustrates, these systems are composed of multiple, discrete aquifers separated by confining units with low permeability. Because hydraulic properties (i.e., ability to yield water) and water quality may vary vertically and horizontally within each aquifer, groundwater supply potential is uneven throughout the LWC Planning Area. **Table 3-1** lists the aquifer systems, hydrogeologic units, and aquifer yields in the planning area.

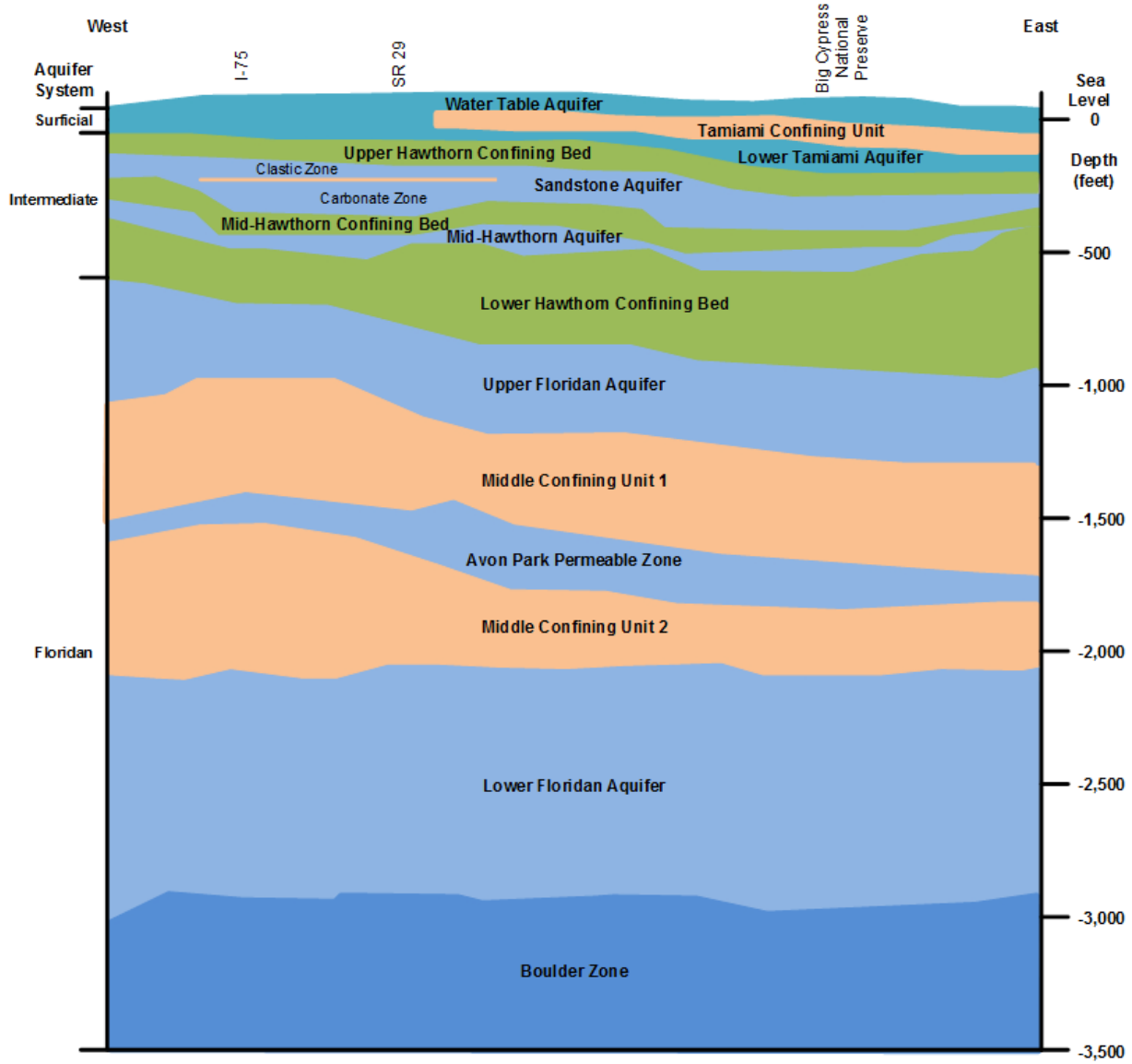


Figure 3-6. Generalized hydrogeologic cross-section of the Lower West Coast Planning Area.

Table 3-1. Groundwater systems in the Lower West Coast Planning Area.

Aquifer System	Hydrogeologic Unit	Aquifer Yield				
		Charlotte	Glades	Lee	Hendry	Collier
Surficial	Water Table Aquifer	L	L-M	L-M	L-M	M-H
	Lower Tamiami Aquifer	A	A-L-M	A-M	A-M-H	H
Intermediate	Sandstone Aquifer	A-L	A-L-M	A-L-M	A-L-M	A-L
	Mid-Hawthorn Aquifer	L	A-L	L	L	M
Floridan	Upper Floridan Aquifer	H	H	H	M-H	M-H
	Middle Confining Unit 1	L	L	L	L	L
	Avon Park Permeable Zone	H	H	H	H	H
	Middle Confining Unit 2	L	L	L	L	L
	Lower Floridan Aquifer	H	H	M	M	M

A = absent; H = high; L = low; M = moderate.

3.2.3.1 Surficial Aquifer System

In the LWC Planning Area, the SAS consists of the Water Table aquifer, confining beds, and the Lower Tamiami aquifer with Holocene- to Pliocene-age materials. The thickness of the system ranges from 200 ft in southwestern Collier County to less than 25 ft in northern Lee County (Reese 2000). The SAS is recharged by precipitation, seepage from canals and other surface water bodies, and upward leakance from the IAS.

Water Table Aquifer

The Water Table aquifer is composed of sediments from land surface to the top of the Tamiami confining beds. Within Lee County, several major public water supply wellfields, all located in areas where the confining beds are absent, pump water from the Water Table aquifer. The aquifer also furnishes water for agricultural and landscape irrigation in addition to supporting natural hydroperiods in wetland systems.

Although the Water Table aquifer in Hendry County may yield abundant quantities of water in isolated areas, it generally is used only where no suitable alternative is available. The aquifer produces potable quality water; however, near LaBelle and the Caloosahatchee River, chloride and total dissolved solids concentrations may be higher than drinking water standards. High iron concentrations also exist in some isolated areas. In some locations, the Water Table aquifer may not be appropriate for irrigation.

Lower Tamiami Aquifer

The Lower Tamiami aquifer is a water producer in the western and southern portions of the LWC Planning Area, though its thickness varies. The aquifer supplies water to several public water supply wellfields, agricultural uses, and domestic self-suppliers (i.e., private residential wells) in the region. The potential for saltwater intrusion and water level drawdowns in wetland areas exists in the Lower Tamiami aquifer along the Collier County coast. However, protection against detrimental withdrawals (and associated drawdown) is provided by water use permitting criteria and the Lower West Coast Aquifers minimum flow and minimum water level (MFL) (Rule 40E-8.331, Florida Administrative Code).

3.2.3.2 Intermediate Aquifer System

The IAS consists of the units underlying the SAS and overlying/confining the FAS. The IAS consists of three relatively impermeable confining units and the Sandstone and Mid-Hawthorn aquifers (Oligocene to Pliocene age). Recharge to the Sandstone aquifer occurs indirectly through downward leakance from the SAS. Leakance between the Sandstone and Mid-Hawthorn aquifers within the IAS is minimal. Recharge to the Mid-Hawthorn aquifer comes from areas where the stratum is exposed at the surface in DeSoto and Osceola counties (within the SWFWMD). In Lee and Hendry counties, the IAS is a source of fresh water. In Collier County, the IAS is brackish and requires desalination to meet drinking water standards. Protection against detrimental withdrawals (and associated drawdown) from the Sandstone and Mid-Hawthorn aquifers is provided by the Lower West Coast Aquifers MFL (Rule 40E-8.331, Florida Administrative Code).

Sandstone Aquifer

The Sandstone aquifer has variable thickness and production. Near Immokalee and portions of central Lee County, the aquifer's average thickness is approximately 100 ft. In Lee County, the Sandstone aquifer provides water to several public water supply wellfields and is a source for domestic self-supply wells. In western Hendry County, where the Lower Tamiami aquifer is absent, the Sandstone aquifer is an important source of water for agricultural irrigation. Water from the Sandstone aquifer is only marginally acceptable for potable uses in Hendry and Collier counties due to salinity. Near LaBelle, flowing FAS wells have raised salinity levels in the Sandstone aquifer, making water unsuitable for irrigation in some locations.

Mid-Hawthorn Aquifer

Although the Mid-Hawthorn aquifer is present throughout the LWC Planning Area, it is not always productive. The Mid-Hawthorn aquifer is used for domestic self-supply, landscape irrigation, and some agricultural irrigation, depending on location. The aquifer's thickness is variable and relatively thin, and in some areas, the aquifer may include interbedded low-permeability layers, which results in the aquifer's low productivity. In addition to its low productivity, the Mid-Hawthorn aquifer experiences water quality degradation as the aquifer dips to the south and east, yielding only brackish water in much of the planning area.

3.2.3.3 Floridan Aquifer System

In southwestern Florida, the FAS is situated between 800 and 3,500 ft below MSL. The top of the FAS coincides with the top of a vertically continuous permeable carbonate sequence. The FAS contains several thin, highly permeable, water-bearing zones, which define the Upper Floridan aquifer (UFA), middle confining unit, and Lower Floridan aquifer (LFA). The FAS produces brackish water throughout most of the LWC Planning Area. Salinity and water hardness in the FAS increase from north to south and vertically with depth.

Upper Floridan Aquifer

The UFA may include portions of the lower part of the Hawthorn Group, Suwannee Limestone, Ocala Limestone, and upper part of the Avon Park Formation. Production zones in the lower part of the Hawthorn Group and Avon Park permeable zone are not always present. The UFA consists of multiple thin, water-bearing zones interlayered with thick zones of much lower permeability.

With reverse osmosis treatment, the UFA is a principal source of potable water in the LWC Planning Area. The UFA also supplies water for frost and freeze protection for some agricultural users and irrigation water (blended with other water sources) for landscape and golf courses.

Middle Confining Unit

The middle confining unit (**Figure 3-6**, confining unit 2) is less permeable than the UFA and LFA. This portion of the FAS separates the brackish water of the UFA from the more saline water of the LFA.

Lower Floridan Aquifer

Like the UFA, the LFA is characterized by multiple thin producing zones (fractured or solutioned rock) sandwiched between lower-permeability carbonate confining units. The lower portion of the LFA contains a highly transmissive fracture-riddled dolomite known as the Boulder Zone, typically about 2,800 ft below MSL, in a section of rock approximately 400 ft thick (Reese 2000). This unit serves as a primary repository for residual brines from reverse osmosis treatment and a backup disposal of effluent from wastewater treatment facilities. The base of the LFA ranges between 3,500 and 4,000 ft below MSL (Miller 1986).

3.2.4 Surface Water and Groundwater Relationships

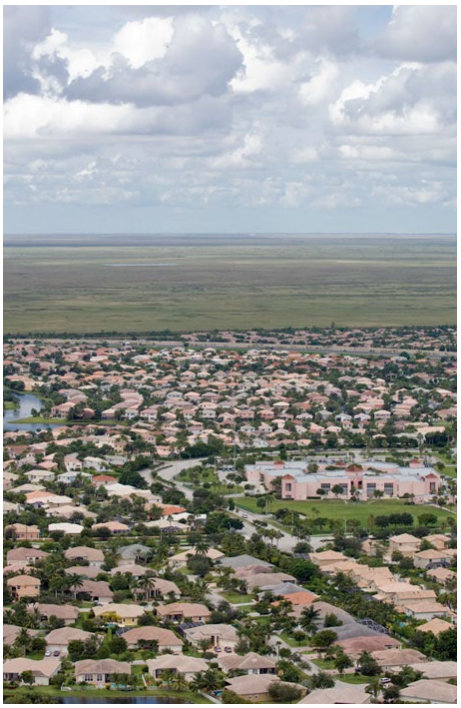
The construction and operation of surface water management systems affect the quantity and distribution of recharge to the SAS. Surface water management systems within the LWC Planning Area function primarily as SAS drains, because ambient groundwater levels generally exceed surface water elevations. The Caloosahatchee River and the Gulf of Mexico act as regional groundwater discharge points. Groundwater seepage represents part of the inflow to the Caloosahatchee River. During the wet season, some recharge to the SAS may occur after a rain event from drainage canals, small lakes and stormwater ponds, Lake Trafford, and low-lying areas.

Surface water management systems also affect aquifer recharge by diverting rainfall from an area before it has time to percolate down to the Water Table aquifer. Once diverted, this water may contribute to aquifer recharge elsewhere in the system, supply downstream consumptive uses, be lost to evapotranspiration, or be discharged to tide.

Chapter 4: Lower East Coast Planning Area

This chapter describes physical features and water resources, including surface water and groundwater, of the Lower East Coast (LEC) Planning Area. For a comprehensive review of water supply status and issues in the LEC Planning Area, refer to the most recent LEC water supply plan update.

Within the South Florida Water Management District (SFWMD or District), the LEC Planning Area includes Palm Beach, Broward, and Miami-Dade counties, most of Monroe County, and the eastern portions of Hendry and Collier counties (**Figure 4-1**). The planning area boundaries follow the north-to-south sheetflow pattern of the historical Everglades, draining to Florida Bay at the southern tip of the peninsula, and encompassing the Florida Keys island chain. Most of the Lake Okeechobee Service Area (LOSA) (see **Section 4.2.2.1**) is within the LEC Planning Area. For consistency, all Lake Okeechobee and LOSA analyses are performed within the LEC planning process.



Western Broward County

4.1 PHYSICAL FEATURES

Major features in the LEC Planning Area include Lake Okeechobee and hydraulically connected surface water bodies, the Loxahatchee River and Estuary, Lake Worth Lagoon, the Everglades Agricultural Area (EAA), water conservation areas (WCAs), portions of the Everglades, Biscayne Bay, and Florida Bay. Two national parks (Everglades and Biscayne), a federally designated Wild and Scenic River (Northwest Fork of the Loxahatchee River), and five national wildlife refuges are also within the LEC Planning Area boundary.

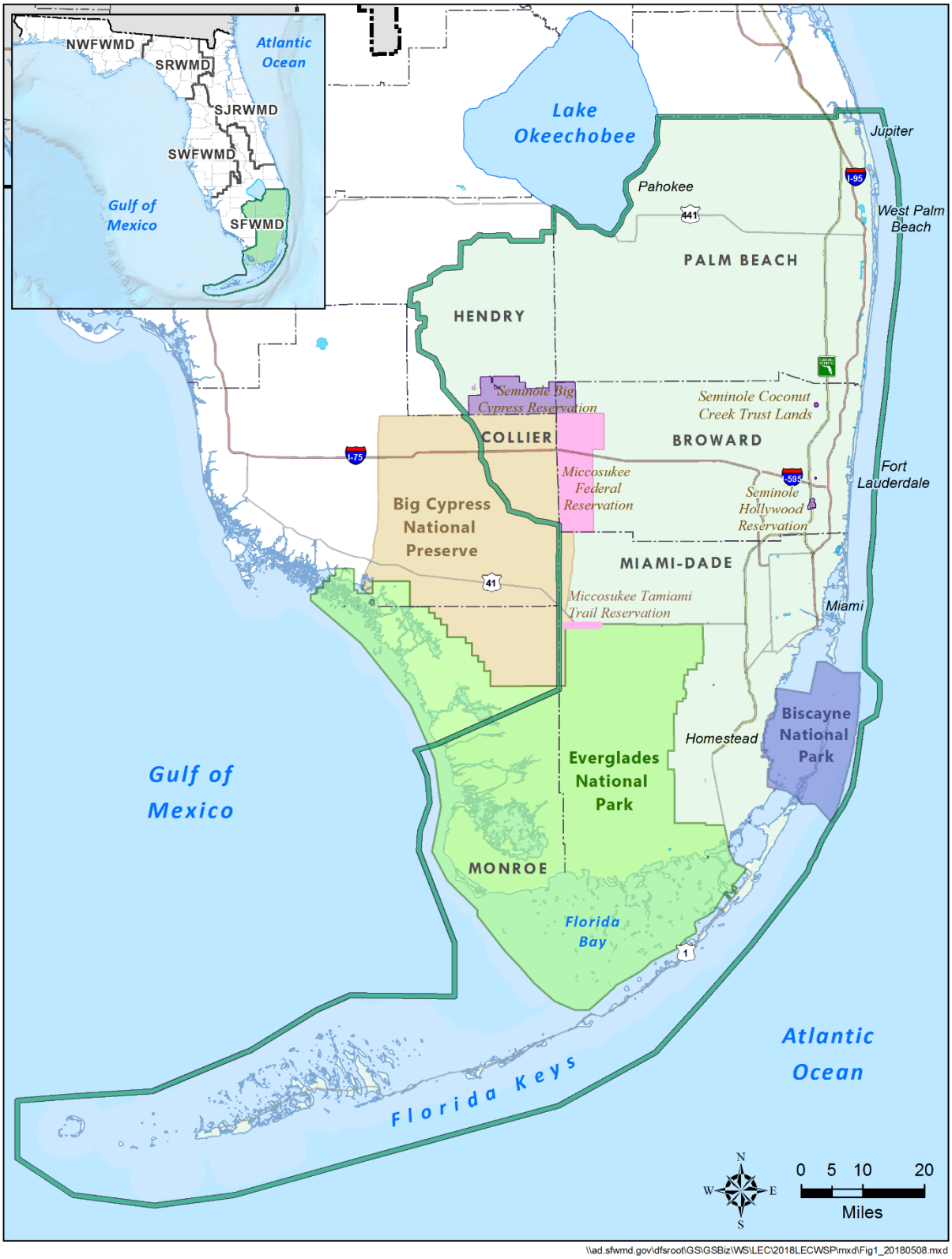


Figure 4-1. Lower East Coast Planning Area.

4.1.1 Water Bodies and Landscapes

The Central and Southern Florida Flood Control Project (C&SF Project) links Lake Okeechobee and the Everglades with agricultural and urban areas as well as other major ecosystems. The LEC Planning Area contains the following freshwater systems and coastal ecosystems.

4.1.1.1 Freshwater Systems

Lake Okeechobee is the largest lake in the southeastern United States and a major source of water storage and supply for the LEC Planning Area. Lake Okeechobee receives water from rainfall and its major tributaries: the Kissimmee River, Fisheating Creek, and Taylor Creek/Nubbin Slough. Downstream of the lake, outflows from Lake Okeechobee are received by the C-43 and C-44 canals (and ultimately the Caloosahatchee and St. Lucie estuaries), EAA, Everglades stormwater treatment areas (STAs), C-139 and L-28 basins, and WCAs in the LEC Planning Area.

The Everglades Protection Area lies south of the EAA, west of the Atlantic Coastal Ridge, and east of the Big Cypress Preserve. It comprises numerous management areas that have different operational needs and priorities, including five WCAs, the Holey Land and Rotenberger wildlife management areas (WMAs), and most of the Everglades National Park.

The C&SF Project divided the remaining Everglades south of Lake Okeechobee and north of Tamiami Trail (U.S. Highway 41) in Palm Beach, Broward, and Miami-Dade counties into hydrologic units known as WCAs (WCA-1, WCA-2A/WCA-2B, and WCA-3A/WCA-3B). These diked areas are operated and maintained for flood control, environmental habitat, and water supply to the LEC Planning Area. The WCAs serve as the first source of supplemental water to the coastal canals that recharge the Biscayne aquifer (USACE 2011).

The Rotenberger WMA is a conservation area in the southern EAA. The WMA contains sawgrass marsh, tree islands, sloughs, wet prairies, and cattail marsh. East of the Rotenberger WMA, the Holey Land WMA is composed of marsh and scattered tree island communities, including a red maple forest on the western edge, providing essential habitat for many plant and wildlife species.

Regulatory discharges from Lake Okeechobee and runoff from the EAA are treated by STAs before being delivered to the WCAs. Water from the WCAs then enters Everglades National Park and flows through Shark River Slough to Whitewater and Florida bays and the Ten Thousand Islands area. Some water enters Everglades National Park and Taylor Slough, which is an important tributary to northeastern Florida Bay.

C&SF Project canals in the LEC Planning Area move water from Lake Okeechobee and the Everglades to coastal counties to recharge the surficial aquifer system during dry times. The canals are also a crucial component of the flood control system for the region, discharging water to tide.

Wetlands extend across 5,000 square miles of the LEC Planning Area. Approximately 3,125 square miles are freshwater wetlands and 1,875 square miles are generally classified as estuarine or marine. The remnant Everglades represent the majority of the region's wetlands. In addition to Everglades National Park and the WCAs, key wetlands in the LEC Planning Area include the Holey Land and Rotenberger WMAs, Grassy Waters Preserve, and wetlands in the Loxahatchee River watershed. The region also has extensive constructed wetlands within the Everglades STAs. Finally, isolated wetlands can be found throughout the LEC Planning Area.

4.1.1.2 Coastal Ecosystems

Significant coastal ecosystems in the LEC Planning Area include the Northwest Fork of the Loxahatchee River, Lake Worth Lagoon, the North Fork of the New River, Biscayne Bay, Florida Bay, and the Florida Keys (**Figures 4-2** and **4-3**).

The Loxahatchee River and Estuary extend across approximately 200 square miles of southern Martin and northern Palm Beach counties, overlapping slightly into the Upper East Coast Planning Area. A system of inland wetlands, including Grassy Waters Preserve and the Loxahatchee and Hungryland sloughs, forms the headwaters of the watershed that drains into the Northwest Fork of the Loxahatchee River, federally designated as a Wild and Scenic River. The Loxahatchee River has two other branches—the North Fork and the Southwest Fork, which receives water from the C-18 Canal. All three branches discharge in the central embayment area, which flows through the Jupiter Inlet into the Atlantic Ocean. The downstream section of each fork contains brackish water. Flows from all three forks drain into the Loxahatchee River Estuary—the southernmost tributary to Indian River Lagoon. More information about Indian River Lagoon is provided in **Chapter 2**.

Lake Worth Lagoon drains into the Lake Worth and South Lake Worth inlets in Palm Beach County. The lagoon is a long, narrow body of brackish water, divided into three geographical segments (north, central, and south), and located along the heavily urbanized Intracoastal Waterway. The north segment includes waters from PGA Boulevard south to Flagler Memorial Bridge. The central segment includes waters from Flagler Memorial Bridge south to Lake Worth Bridge, and the south segment includes waters from Lake Worth Bridge south to Boynton Beach Bridge at Ocean Avenue. Sources of freshwater runoff include primary and secondary canal systems. The major sources of fresh water are the C-17, C-51, and C-16 canals.

The North Fork of the New River is a remnant tributary that drained the eastern Everglades and now flows through the City of Fort Lauderdale, where it joins the river's main branch and empties into the Atlantic Ocean via the inlet at Port Everglades.

Biscayne Bay covers approximately 428 square miles along the southeastern coast near Miami-Dade County. Everglades National Park shares some of the watershed along the southwestern boundary. The bay is an aquatic preserve and an Outstanding Florida Water. The southern half of the bay is within Biscayne National Park. This is the largest marine park in the National Park System and supports diverse flora and fauna, including many endangered species.

Florida Bay is a large, shallow, marine-estuarine lagoon between the Everglades and the Florida Keys. Most of the bay is within Everglades National Park.

The chain of islands known as the Florida Keys runs south and west from the southeastern tip of the state. Because of the unique marine ecosystems, the Florida Keys area is protected by the Florida Keys National Marine Sanctuary, three national parks (Everglades, Biscayne, and Dry Tortugas), and several state parks.

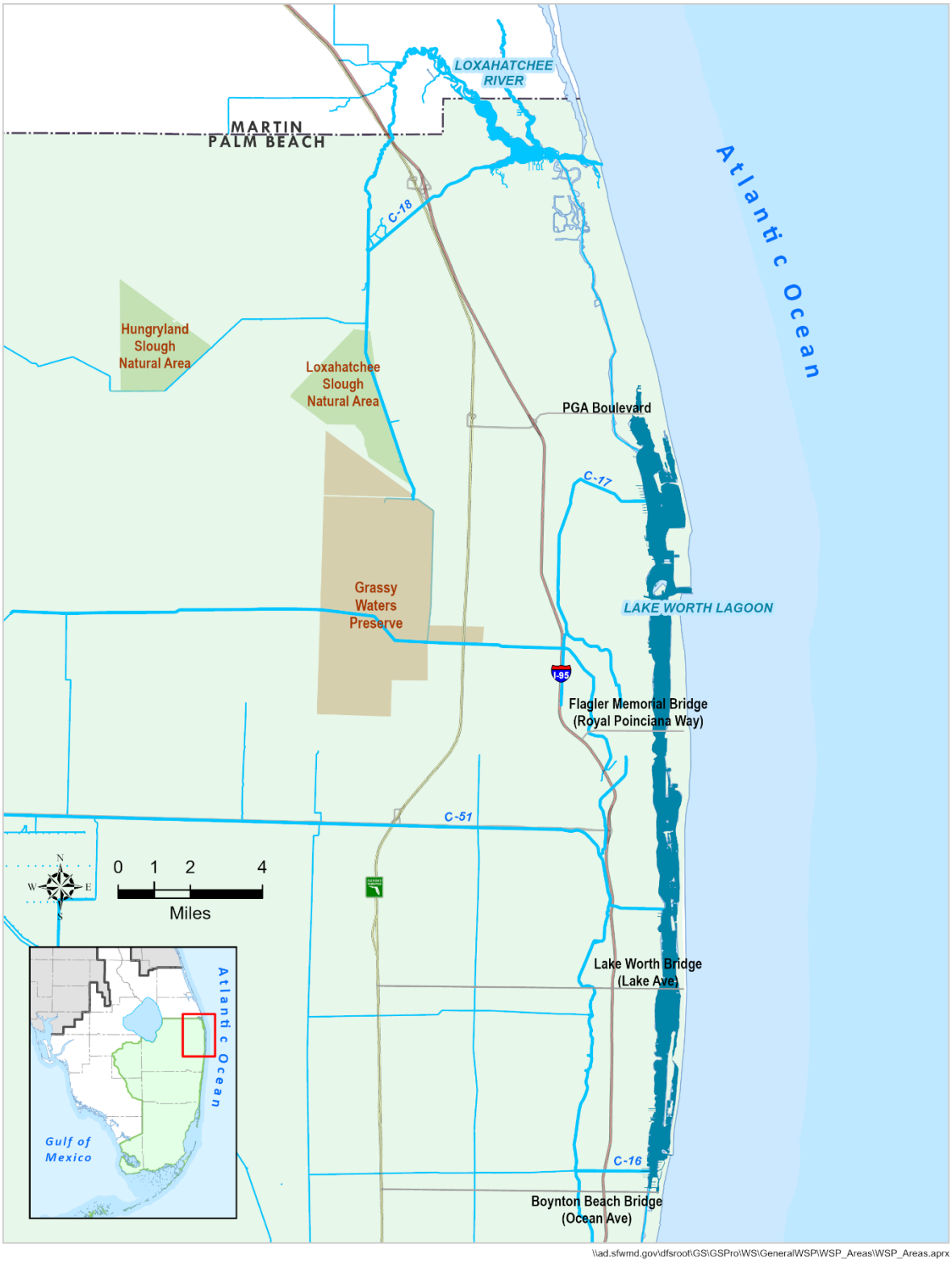


Figure 4-2. Coastal features in the northern portion of the Lower East Coast Planning Area.

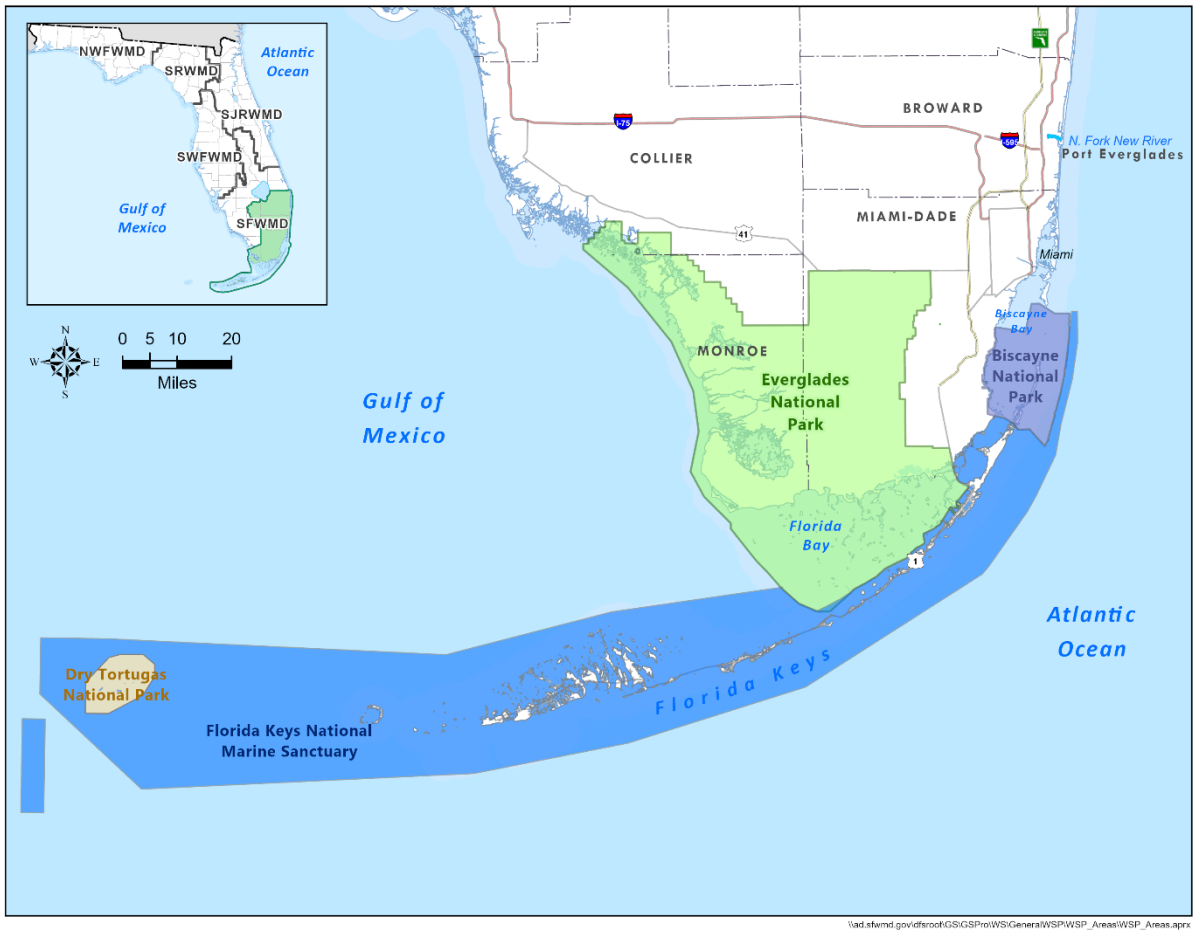


Figure 4-3. Coastal features in the southern portion of the Lower East Coast Planning Area.

4.1.2 Geography

The LEC Planning Area encompasses approximately 6,500 square miles of southeastern Florida. Elevation differences in the LEC Planning Area are slight. The bottom of Lake Okeechobee is approximately at sea level and the land immediately surrounding Lake Okeechobee ranges from 20 to 25 feet (ft) above mean sea level (MSL) (**Figure 4-4**). The highest elevations are along the Atlantic Coastal Ridge, with some locations higher than 25 ft above MSL. The lowest elevations are along the southern coastline, where mangrove and coastal glades are at or below sea level and often flooded by tides or freshwater runoff.

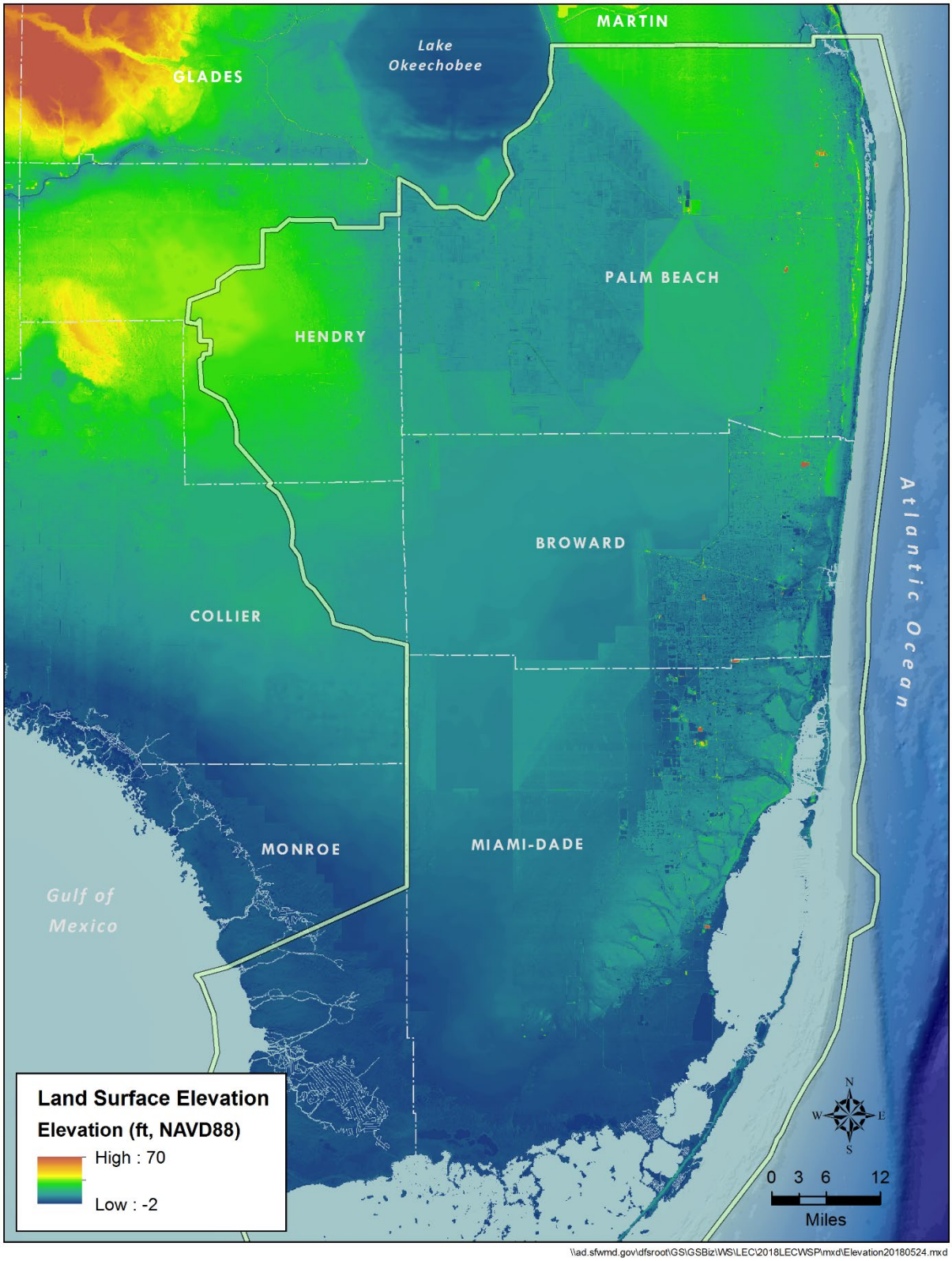


Figure 4-4. Topography of the Lower East Coast Planning Area.

Land elevations in the WCAs generally range from 16 ft above MSL at the northern end of WCA-1 to approximately 10 ft above MSL at the southern end of WCA-3. The topography of Everglades National Park is extremely low and flat, with most of the area lying 4 ft below MSL. The land surface generally slopes from 8 to 9 ft above MSL at the northern end to below sea level as the freshwater wetlands of the Everglades merge with the saltwater wetlands of Florida Bay.

4.1.3 Physiography

The LEC Planning Area is characterized by lakes (including Lake Okeechobee), rivers, canals, coastal ridges, remnant Everglades and wetlands, and coastal swamps and bays (including Biscayne and Florida bays). Except for the coastal and beach ridges, the region is flat in appearance, and slopes gradually from approximately 25 ft above MSL near Lake Okeechobee to sea level or below at the coastline. Physiographic regions include the Eastern Valley, Atlantic Coastal Ridge, Everglades, Immokalee Rise, Big Cypress Spur, Reticulate Coastal Swamps, Florida Bay Mangrove Islands, and combined High Coral, Low Coral, and Oolite Keys (**Figure 4-5**).

The Eastern Valley consists of wetland communities, including tidal and floodplain swamp and forest. These areas are characteristically pocketed with shallow lakes and marshes and have limited natural drainage. Prior to development and the construction of canals, the valley drained by a slow drift of water through multiple sloughs to the St. Lucie River, Loxahatchee River, and Everglades.

The Atlantic Coastal Ridge, composed of relict beach ridges and sand bars, is mostly underlain by thin sand and Miami Limestone that are highly permeable and moderately to well drained. West of the coastal ridge, soils contain fine sand and loamy material and have poor natural drainage. Rockland areas on the Atlantic Coastal Ridge in Miami-Dade County are characterized by weathered limestone surfaces and karst features such as solution holes and sinkholes. The Atlantic Coastal Ridge covers nearly 20 square miles of diverse community types, including scrub, pine flatwoods, and forested sloughs. The southern slope of the Atlantic Coastal Ridge contains small, pine-covered hammocks. Elevations range from 25 to 50 ft above MSL in Palm Beach County, declining to a maximum of 29 ft above MSL in Broward County.

West of the Atlantic Coastal Ridge, the Everglades extends southward from Lake Okeechobee and Loxahatchee Slough to the mouth of Shark River Slough at Florida Bay. The Everglades has an almost imperceptible slope to the south, which averages less than 2 inches per mile. Elevations range from 14 ft above MSL near Lake Okeechobee to sea level at Florida Bay. Prior to development, the Everglades was seasonally inundated, and water drained slowly to the south. Much of the Everglades is underlain by peat and muck soils that developed in a shallow basin with poor natural drainage under prolonged conditions of flooding. Beneath the surface layers of organic material is the Fort Thompson Formation of interbedded sand, shell, and limestone. Bedrock in the Everglades is almost entirely limestone. Higher elevation marshes in the southern Everglades on either side of Shark River Slough are characterized by calcitic marl soils deposited by algal mats and exposed limerock surfaces with karst features.

The Immokalee Rise is bounded on the east by the Everglades, on the south-southeast by the Big Cypress Spur, and on the southwest by the Southwestern Slope. This area, predominantly composed of sandy soils, ranges in elevation from 25 to 42 ft above MSL (Campbell 1988).

The Big Cypress Spur is a sloping, transitional area between the Immokalee Rise, the Everglades to the east, and the Southwestern Slope to the west (Drew and Schomer 1984). This area receives runoff from the Immokalee Rise and drains to the Everglades and Southwestern Slope. Elevations are only slightly higher than 25 ft above MSL.

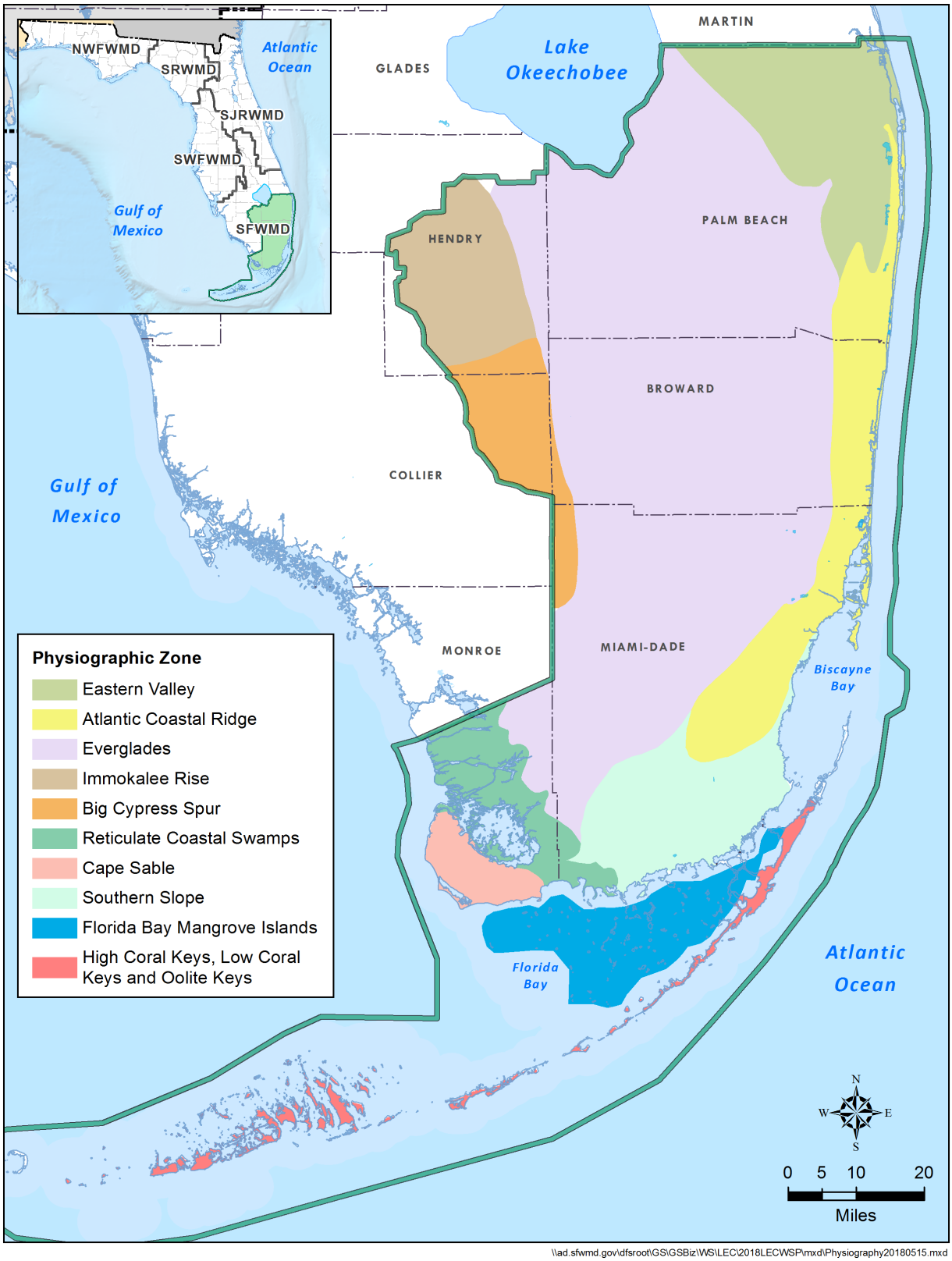


Figure 4-5. Physiography of the Lower East Coast Planning Area.

Mangrove swamps occupy a zone between the open waters of the coast and the uplands and freshwater wetlands of the Everglades interior. These mangroves form small, densely packed islands and shoreline jungles, which together form the Reticulate Coastal Swamps of northern Florida Bay.

Florida Bay

Along the southern shores of Everglades National Park, Florida Bay is underlain by Miami Limestone, with variable sediment cover of sand, exposed bedrock, and mudbanks. The bay has an average depth of approximately 3 ft, and consists of shallow, interconnected basins. It is subject to rapid salinity changes due to mainland Everglades runoff and regional droughts, and it is an important habitat for many species. Sand shoals and ancient corals underlie small mangrove keys throughout the bay, identified as Florida Bay Mangrove Islands (**Figure 4-5**).

The Florida Keys are a chain of 882 charted island remnants of ancient coral reefs and sand bars. They consist of highly permeable Key Largo Limestone in the High Coral Keys (northernmost key to Upper Matecumbe Key) and less permeable Miami Limestone in the middle Oolite Keys and Low Coral Keys (Lower Matecumbe Key to the southwestern end of the Florida Keys). The average elevation is 3 to 4 ft above MSL, with the highest land elevation at 18 ft above MSL on Key Largo, Windley Key, and Key West (White 1970).

4.2 WATER RESOURCES AND SYSTEM OVERVIEW

4.2.1 Regional Hydrologic Cycle

The main components of the LEC Planning Area's hydrologic cycle are precipitation, evapotranspiration, and the flow of surface water and groundwater.

4.2.1.1 Precipitation and Evapotranspiration

Annual precipitation in the LEC Planning Area averages 57 inches. Nearly 75% of rainfall occurs during the wet season (May through October). Average seasonal temperatures for the area range from approximately 69°F in the winter to 84°F in the summer.

Hydrologic and meteorologic methods are available to measure and estimate the combined rate at which water is returned to the atmosphere by transpiration and evaporation. The combined processes are known as evapotranspiration. Precipitation minus evapotranspiration is equal to the combined amounts of surface water runoff and groundwater recharge. The estimate of potential evapotranspiration from open water and wetlands in the LEC Planning Area is 53 inches (Abtew et al. 2003). Potential evapotranspiration represents the total estimated passive water use of an area under maximum conditions. While actual evapotranspiration varies due to temperature, soil moisture, and other factors, potential evapotranspiration estimates are important landscape-level factors in water balance calculations to determine if enough water will be available for all uses during different environmental conditions.

4.2.1.2 Surface Water Inflow and Outflow

The C&SF Project canals provide drainage and flood control, agricultural irrigation, municipal and industrial water supply, fish and wildlife preservation, water supply to and preservation of Everglades National Park, prevention of saltwater intrusion, groundwater recharge, recreation, and navigation. The project was designed and constructed by the United States Army Corps of Engineers (USACE), and the SFWMD serves as the local sponsor. Flows and stages in Lake Okeechobee and most of the region's C&SF Project canals are operated under regulation schedules or master water control manuals. The amount of stored water is critically important to natural ecosystems and developed areas in the LEC Planning Area. Managing surface water storage capacity involves balancing two conflicting conditions: 1) drought conditions may occur during periods of deficient rainfall, and 2) flooding may occur due to excessive rainfall, especially during the wet season.

Tree Island in Water Conservation Area 1

A regional system of canals in the LEC Planning Area provides a means to move water from one location to another (see **Section 4.2.2.4**). Surface water inflows to the LEC Planning Area come through C&SF Project canals. Water is transported from north to south and west to east, from Lake Okeechobee through water control structures to the EAA canals and WCAs. South of Lake Okeechobee and north of the Everglades, STAs reduce excess phosphorus from stormwater runoff through the natural filtering of native vegetation before water enters protected wetlands (i.e., WCAs). Water moves from the WCAs via structures and canals to Everglades National Park and urbanized coastal basins. Outflows of surface water in the LEC Planning Area are largely directed through water control structures, many of which were constructed as part of the C&SF Project. When canal elevations are greater than surrounding groundwater, water in coastal canals provides recharge to the Biscayne aquifer, enhancing groundwater supplies and replenishing water in lakes, rivers, and wetlands.

4.2.1.3 Groundwater Flow

Two principal aquifer systems underlie the LEC Planning Area: the surficial aquifer system (SAS) and the Floridan aquifer system (FAS). Rainfall is the main source of recharge to the SAS. Groundwater inflows from the Everglades to the coast form a substantial portion of recharge to the SAS. The FAS receives most of its recharge from central and northern Florida. Groundwater flow within these aquifer systems is generally from the north to south and southeast toward the coast. The SFWMD has conducted regional groundwater flow modeling to represent a planning-level analysis of current (2016) and future (2040) groundwater flow regimes. Groundwater modeling reports for the LEC Planning Area are available on the District website at www.sfwmd.gov/lecplan.

4.2.2 Surface Water Resources

South of Lake Okeechobee, the southern Everglades is divided into surface water management basins. For water management purposes, the SFWMD divides the LEC Planning Area into four hydrologically related areas: 1) Lake Okeechobee Basin/Lake Okeechobee Service Area (encompassing portions of Martin, Okeechobee, Palm Beach, Hendry, Glades, and Lee counties), including the EAA; 2) Everglades Protection Area (WCAs and Everglades National Park); 3) Western Basins; and 4) Lower East Coast Service Areas (**Figure 4-6**).

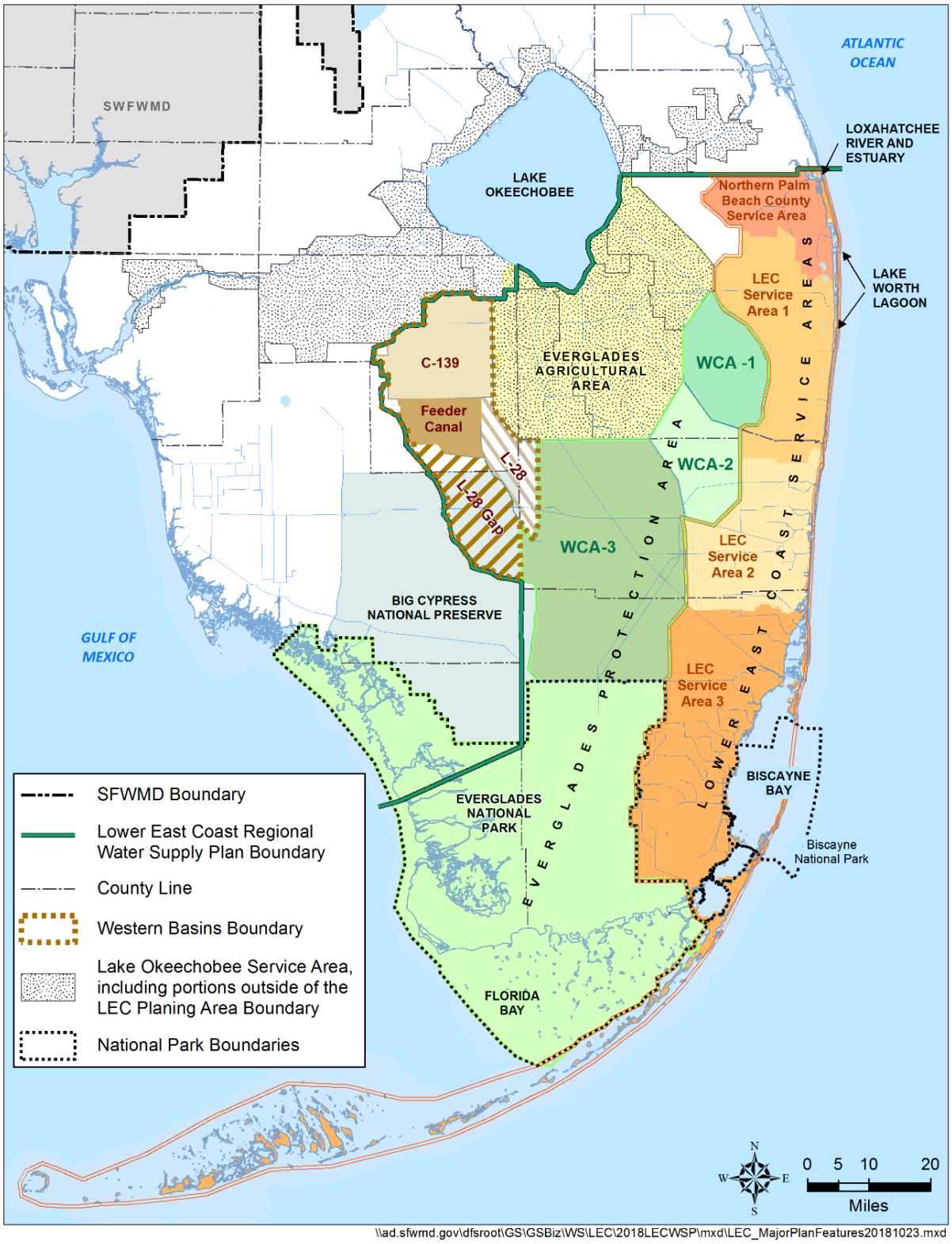


Figure 4-6. Major features of the Lower East Coast Planning Area.

4.2.2.1 Lake Okeechobee Basin/Lake Okeechobee Service Area

Lake Okeechobee is a major surface water body for storage and supply in the LEC Planning Area. Surrounded by the 143-mile long Herbert Hoover Dike to protect neighboring communities from flooding, Lake Okeechobee is a central component of the C&SF Project and an interconnected regional aquatic ecosystem. The lake serves multiple functions, including flood control, agricultural and urban water supply, fulfillment of Seminole Tribe of Florida water rights, navigation, recreation, and fish and wildlife preservation and enhancement. Operation of the lake affects a wide range of environmental and economic issues. Lake operations must carefully consider all, and sometimes conflicting, purposes of the C&SF Project as well as highly variable rainfall conditions throughout the wet and dry seasons.

Lake Okeechobee has multiple inflows from a watershed encompassing a drainage area of more than 5,500 square miles and is dominated by agricultural land uses (more than 50% of the total area). Based on hydrologic and geographic boundaries, the Lake Okeechobee watershed includes the following basins: Upper and Lower Kissimmee, Lake Istokpoga/Indian Prairie, Taylor Creek/Nubbin Slough, Fisheating Creek, EAA, and Lake Okeechobee (including the C-43 and C-44 basins). The Upper and Lower Kissimmee, Lake Istokpoga/Indian Prairie, Taylor Creek/Nubbin Slough, Fisheating Creek basins are described in **Chapter 1**. Lake Okeechobee also has several outlets for flood control purposes, including the C-44 Canal and St. Lucie River to the eastern coast of Florida, the C-43 Canal and Caloosahatchee River to the southwestern coast of Florida, and the EAA canals to the WCAs and southeastern coast of Florida.

Lake Okeechobee provides recharge to coastal aquifers, mainly during the dry season, and is the primary source of supplemental irrigation for numerous adjacent agricultural basins, including Northeast Lake Shore, St. Lucie (C-44), West Palm Beach (C-51) Canal and L-8, East Beach and East Shore water control districts, North New River and Hillsboro Canal, Miami Canal, C-21 and S-236, Caloosahatchee (C-43), Northwest Lakeshore and Southern Indian Prairie, and North Lake Shore. The EAA is also part of the Lake Okeechobee basin and LOSA (**Figure 4-6**). Although LOSA extends beyond the LEC Planning Area, it is considered during the LEC water supply planning process because of its reliance on Lake Okeechobee for water supply.

Lake Okeechobee

Lake Okeechobee is a key ecological component of the Greater Everglades ecosystem (Zhang and Sharfstein 2013). In 2001, minimum flow and minimum water level (MFL) criteria and a prevention strategy were adopted for Lake Okeechobee to protect this important resource from significant harm. MFL criteria regarding significant harm were based on the relationship between water levels in the lake and the ability of the lake to 1) protect the coastal aquifer against saltwater intrusion, 2) supply water to Everglades National Park, 3) provide littoral zone habitat for fish and wildlife, and 4) ensure navigational and recreational access (SFWMD 2000).

Everglades Agricultural Area

In 1948, the C&SF Project designated approximately 1,100 square miles of the northern Everglades as the EAA, which today includes agricultural land, STAs, and the Rotenberger and Holey Land WMAs. Located south of Lake Okeechobee in eastern Hendry and western Palm Beach counties (**Figure 4-6**), the EAA is

composed of rich, organic peat or muck soils. Agriculture within the EAA, primarily sugarcane, requires extensive drainage, which is accomplished via canals and water control components of the C&SF Project. The canals are also used to provide irrigation water to the EAA. In addition to C&SF Project canals, there is an extensive network of local canals and farm ditches in the EAA.

Stormwater from the EAA is moved south through the District's STAs and into the Everglades Protection Area. STAs use vegetation to uptake phosphorous and supply treated water to the WMAs, which provide essential habitat for many plant and wildlife species. STAs are also a critical step in supplying fresh water from Lake Okeechobee to the Everglades Protection Area. There are six STAs: STA-1 East, STA-1 West, STA-2, STA-3/4, STA-5, and STA-6.

4.2.2.2 Everglades Protection Area

The Everglades Protection Area is defined by the Everglades Forever Act (Section 373.4592, Florida Statutes) and encompasses the WCAs and Everglades National Park (**Figure 4-6**). The area is managed for flood control, water supply, regional groundwater control (including prevention of saltwater intrusion), recreation, and enhancement of fish and wildlife, including endangered and threatened species (Abtew et al. 2013). As a natural ecosystem, the Everglades Protection Area contains marl marshes, coastal mangrove forests, tree islands, and the globally rare ridge-and-slough patterned peatlands that are important habitat for subtropical and tropical plant and animal species, including fish and other aquatic species, reptiles, amphibians, wading birds, and migratory birds. Because of its ecological importance, the Everglades system is the focus of one of the largest ecological restoration projects in the world, the South Florida Ecosystem Restoration Program, which includes the Comprehensive Everglades Restoration Plan (CERP) and the Central Everglades Planning Project (USACE 2011).

The landscape pattern of the Everglades Protection Area is oriented parallel to water flow. Prior to human development, water flowed unimpeded out of Lake Okeechobee through what is now the EAA, bounded by the coastal ridge to the east and the higher lands west of WCA-3A and Big Cypress National Preserve (McVoy et al. 2011). Historically, water discharged to the Gulf of Mexico, Biscayne Bay, and Florida Bay. Under natural flows, water levels across the landscape generally were uniform in depth. However, the C&SF Project divided the Everglades into shallow, diked marshes that changed wetland depths and altered the historical ridge-and-slough landscape.

Beginning in the 1950s and 1960s, the C&SF Project compartmentalized approximately half of the original Everglades sawgrass marsh, wet prairies, and hardwood swamps into three shallow, diked WCAs. The WCAs 1) store excess water; 2) supply water for Everglades National Park, agricultural lands, and use during the dry season; 3) provide flood control during the wet season; and 4) recharge the Biscayne aquifer.

Water levels in most of the WCAs are managed through inflow and outflow structures using a set of regulation schedules established by the USACE (1996). These schedules allow for different water levels under different conditions (e.g., wet season, dry season), balancing the needs of the natural system and other water users. The water level ranges can provide flood control and storage of runoff during the wet season for use during the dry season. Current regulation schedules and daily water levels are available at http://www.saj.usace.army.mil. More information about the WCAs can be found in Chapter 2 of the *South Florida Environmental Report – Volume I*, available at www.sfwmd.gov/sfer.

WCA-1

WCA-1, also known as the Arthur R. Marshall National Wildlife Refuge, encompasses 221 square miles of south-central Palm Beach County and includes some sawgrass marshes, wet prairies, and hardwood swamps of the remnant Everglades system. WCA-1 is enclosed by 58 miles of canals and levees. The

WCA-1 regulation schedule varies from high stages in the late fall and winter to low stages at the beginning of the wet season (Abtew et al. 2007). Inflows to WCA-1 are primarily rainfall and discharges from STA-1W and STA-1E. Outflows from WCA-1 are received by WCA-2, the Hillsboro Canal, and a canal system monitored and controlled by the Lake Worth Drainage District.

WCA-2A and WCA-2B

WCA-2A and WCA-2B encompass approximately 208 square miles of southwestern Palm Beach and northwestern Broward counties. WCA-2A is much larger than WCA-2B and provides 167 square miles of shallow impoundment for excess water storage. These WCAs provide wellfield recharge and water supply for urban areas in Broward County. Inflows to WCA-2A/2B primarily come from WCA-1, STA-2, and STA-3/4. Outflows from WCA-2A/2B generally enter WCA-3A through the S-11 structures. The regulation schedule for WCA-2A was established by the USACE (1996). A regulation schedule is not used for WCA-2B because of high seepage rates into the underlying SAS.

WCA-3A and WCA-3B

Together, WCA-3A and WCA-3B are the largest of the WCAs, spanning 915 square miles. Water stored within WCA-3A/3B is used to meet the principal water supply needs of adjacent areas, including water supply and salinity control requirements for Miami-Dade County, irrigation requirements for agriculture, and environmental water supply for Everglades National Park. The Miami Canal traverses WCA-3A from northwest to southeast. WCA-3A receives most of its water from direct rainfall, WCA-2, STA-5, STA-3/4, and regulatory releases from Lake Okeechobee on a case-by-case basis. This area also receives excess runoff from Big Cypress Swamp to the west and flood control discharges from pump stations S-9 and S-9A in western Broward County. WCA-3B inflows are through the S-151 and S-152 structures, and outflows are limited to evaporation and seepage along the L-30 Canal. Flows from WCA-3A enter the northern boundaries of Everglades National Park through the S-21 and S-333 structures and Tamiami Trail (U.S. Highway 41) culverts. The regulation schedule for WCA-3A was established by the USACE (1996). A regulation schedule is not used for WCA-3B because of high seepage rates.

Everglades National Park

Established in 1947 and expanded in 1989, Everglades National Park is the nation's second-largest national park, covering more than 2,300 square miles. The park is home to a wide variety of species, including federally threatened or endangered species, and has several international preserve designations.

Much of the water that enters Everglades National Park from the WCAs flows in a southwestern arc through Shark River Slough to Whitewater Bay and the Ten Thousand Islands area. Some water enters through the S-12, S-333, S-343A, S-343B, and S-344 structures. Additional water enters the panhandle of Everglades National Park via the S-332D pump station and Taylor Slough or through intentional breaches in the lower C-111 Canal, which were created downstream of the S-18C structure.

Water can be forced to remain in Taylor Slough, an important tributary to northeastern Florida Bay, using a series of pumped seepage management features east of the park's eastern boundary, collectively known as the C-111 South Dade Project. Constructed between 1974 and 1983, the South Dade Conveyance System was designed to transfer water from WCA-3A to Everglades National Park for natural resource benefits (**Figure 4-7**). The system, including SFWMD canals (e.g., C-6, C-4, C-102, C-103, C-111, L-31N, L-31W), also provides water to wellfields and canals to minimize saltwater intrusion in southern Miami-Dade County.

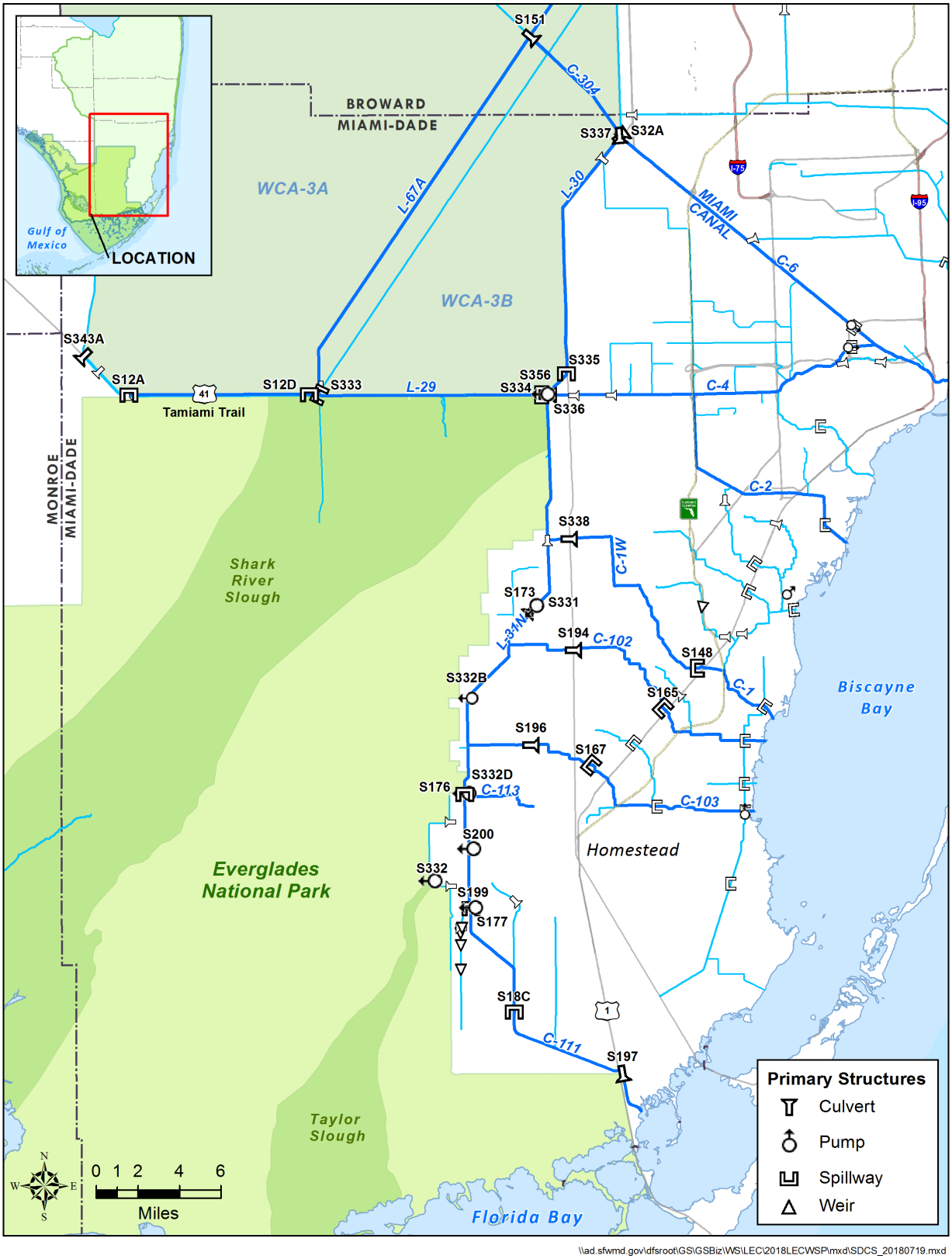


Figure 4-7. South Dade Conveyance System canals and water management structures.

In addition to Whitewater Bay and the Ten Thousand Islands area, much of the water entering Everglades National Park ends up in Florida Bay. Florida Bay receives water that passes though the park's numerous tidal creeks and coastal wetlands, including mangrove and buttonwood forests, salt marshes, and coastal prairies, all of which are subject to the influence of salinity from tidal action.

Covering a triangular area of 850 square miles, Florida Bay is a shallow (average 3.3 ft deep) estuarine system between the Everglades and the Florida Keys (**Figure 4-8**). Approximately 80% of the bay is within Everglades National Park. A major premise of Everglades restoration efforts is that freshwater flow from the Everglades to Florida Bay has decreased, causing salinity increases and detrimental ecological changes (e.g., seagrass and sponge die-offs, algal blooms, declines in fish species abundance) in the bay (Rudnick et al. 2005).

While Florida Bay is not managed by the SFWMD, it is an important natural resource affected by and considered when making water management decisions. The SFWMD has monitoring, research, and modeling programs in place for Florida Bay to better 1) understand the importance of water management as a driver of ecological changes, 2) forecast the impacts of changing water management strategies, and 3) operate water control structures for the protection and restoration of the ecosystem. Results from major monitoring, research, and modeling projects can be found in Chapter 6 of the *South Florida Environmental Report – Volume I*.

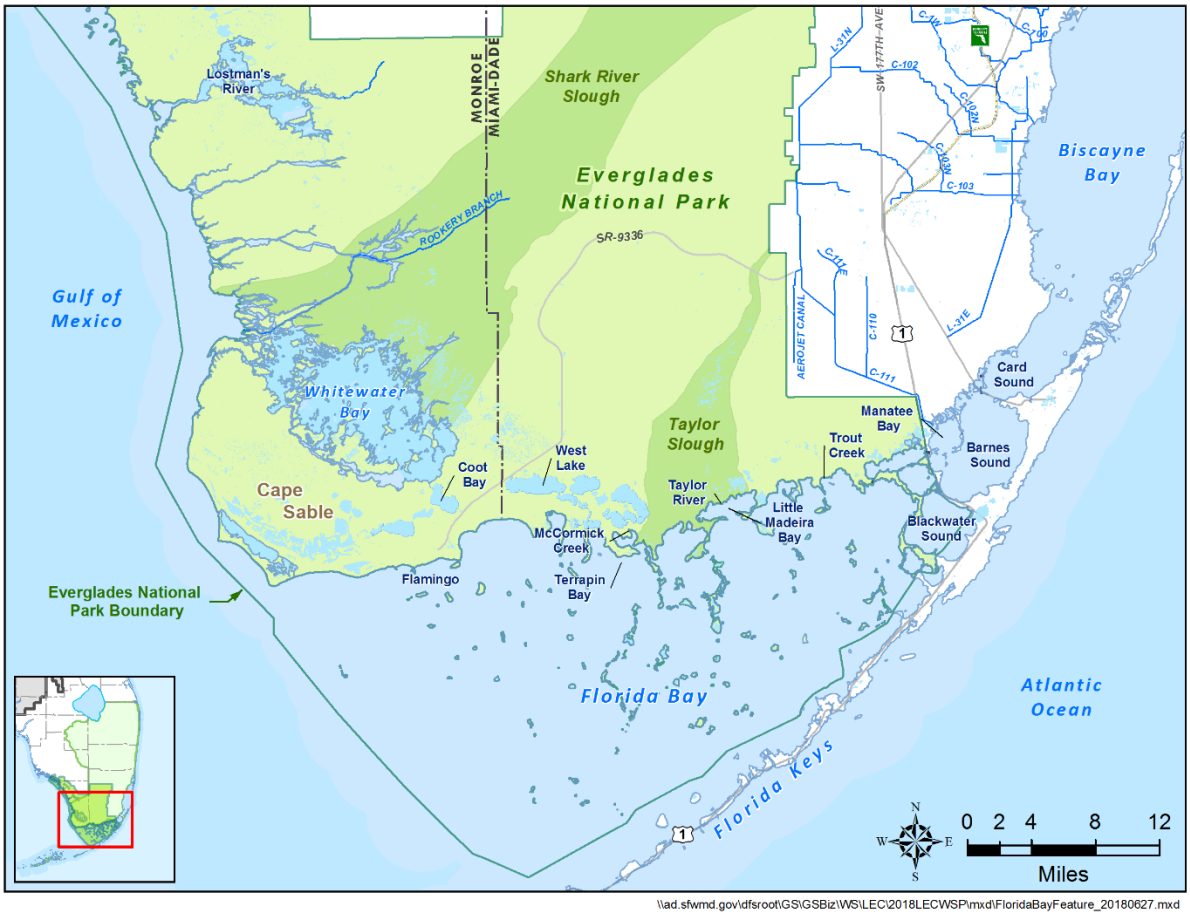


Figure 4-8. Major features of Florida Bay.

4.2.2.3 Western Basins

Encompassing nearly 690 square miles, the C-139, Feeder Canal, L-28, and L-28 Gap drainage basins along the western edge of the Everglades are collectively known as the Western Basins (**Figure 4-9**). The Seminole Tribe of Florida and Miccosukee Tribe of Indians of Florida have reservations in the Western Basins, with water supply needs for residents, agriculture, and wetlands. Water supply and water quality of stormwater runoff are challenges to development of the Western Basins.

C-139 Basin

The C-139 basin is 266 square miles of agricultural land in Hendry County and the second largest discharging tributary, by volume, to the Everglades Protection Area, behind the EAA. Under the 1994 Everglades Forever Act (Section 373.4592, Florida Statutes), landowners within the C-139 Basin must implement water quality best management practices and collectively not exceed average annual total phosphorus loads, adjusted for rainfall, to protect water quality in the Everglades Protection Area. Stormwater runoff from the C-139 basin enters WCA-3A via STA-5/6.

Feeder Canal Basin

The Feeder Canal basin is the third largest discharging tributary to the Everglades Protection Area and is divided into three areas: 1) the West Feeder sub-basin (50 square miles); 2) the North Feeder sub-basin (36 square miles); and 3) a portion of the Seminole Tribe of Florida Big Cypress Reservation (22 square miles). The two major canals in this basin are the North Feeder and West Feeder canals, which merge in the southeastern corner of the basin and discharge south to the L-28 Interceptor Canal and WCA-3A.

L-28 Basin

The L-28 Basin includes the C-139 Annex and portions of the Seminole Tribe of Florida Big Cypress Reservation, the Miccosukee Federal Reservation (in WCA-3A), and Big Cypress National Preserve. The C-139 Annex is 27 square miles south of Lake Okeechobee purchased by the SFWMD from the United States Sugar Corporation. The SFWMD plans to use the annex for water storage, water quality improvement, and wetland restoration projects. Restoration activities will improve the quality, timing, and distribution of water flowing into the Everglades Protection Area. Flows from the C-139 Annex are diverted to STA-5/6 with mandatory best management practices to reduce total phosphorus loads.

L-28 Gap Basin

The L-28 Gap Basin consists of natural and undisturbed wetland marsh and slough systems within Big Cypress National Preserve and a portion of the Seminole Tribe of Florida Big Cypress Reservation south of the Feeder Canal Basin. Runoff from the L-28 Gap Basin flows southeast and drains into WCA-3A. The region is low lying and nearly level, resulting in poorly drained soils.

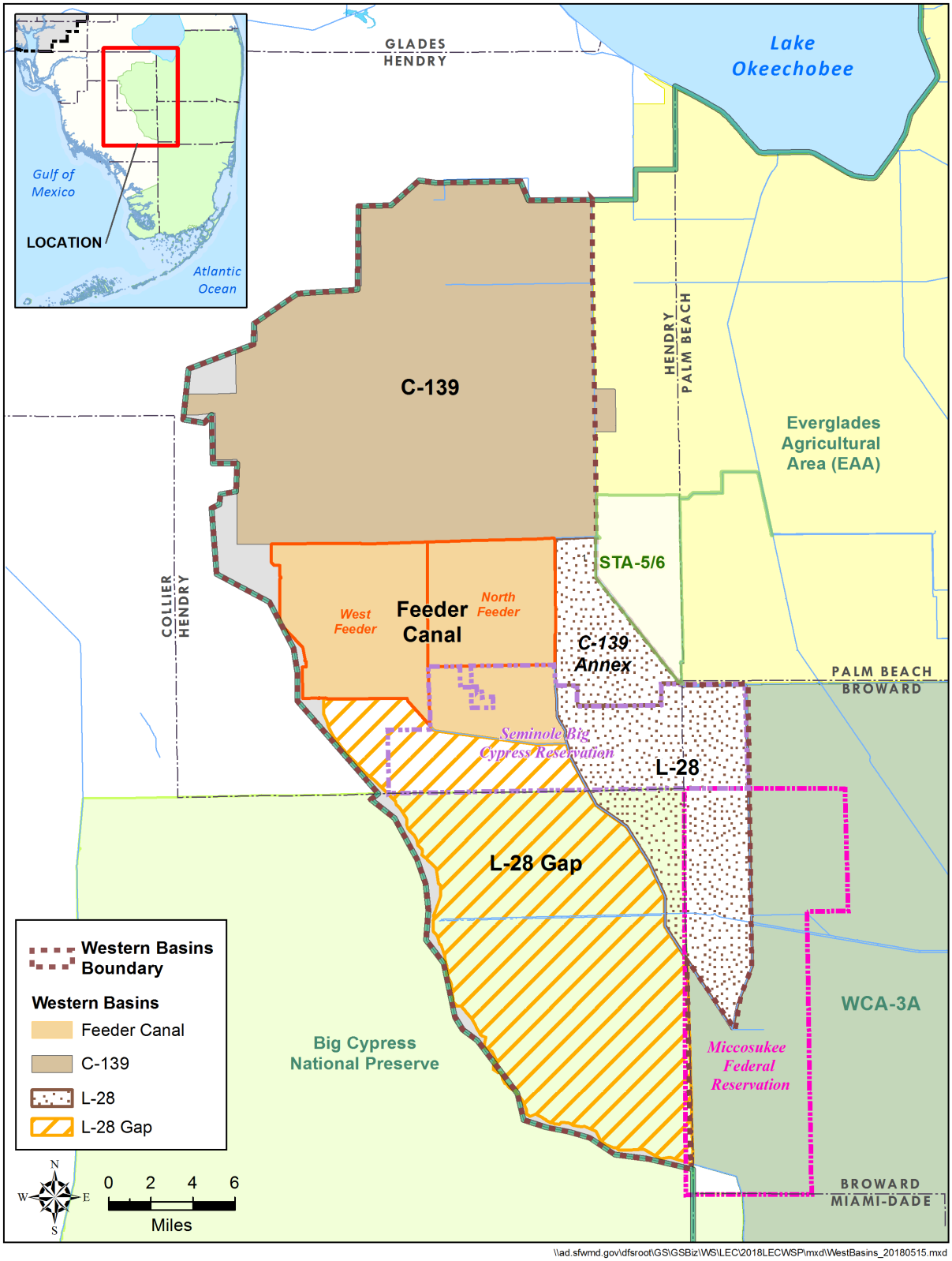


Figure 4-9. Western Basins within the Lower East Coast Planning Area.

4.2.2.4 Lower East Coast Service Areas

C&SF Project flood control components were constructed in the early 20th century and have altered historical freshwater flows to coastal ecosystems in the LEC Planning Area, including the Loxahatchee River, Lake Worth Lagoon, and Biscayne Bay. Flood control and water management structures, including coastal canals, throughout Palm Beach, Broward, and Miami-Dade counties are designed to rapidly remove stormwater in adjacent drainage areas. The degree of flood protection provided by outlet capacity depends on whether the protected area is urban or agricultural. Although the canals have altered historical flows, they also provide many benefits, including flood, regional groundwater level, and salinity control; enhancement of fish and wildlife; and water supply for agricultural irrigation, municipalities, and industry.

For water supply planning, operations, and water shortage, the SFWMD divides the coastal, urban portion of the LEC Planning Area into four service areas that generally reflect the historical sources of water delivered from the regional system (**Figure 4-10**):

- **North Palm Beach**: All coastal and inland portions of northern Palm Beach County east of the EAA and north of the C-51 (West Palm Beach) basin. The southern L-8 and M-Canal/Water Catchment Area basins are also in this service area. Natural areas include DuPuis Reserve, J.W. Corbett WMA, Grassy Waters Preserve, Loxahatchee Slough, Loxahatchee River, and Pal-Mar.
- **LEC Service Area 1**: The portion of Palm Beach County east of WCA-1 and a small portion of northern Broward County, which includes the C-51 and Hillsboro Canal basins and receives water from WCA-1.
- **LEC Service Area 2**: The portion of Broward County east of the WCAs that includes the C-9, C-11, C-13, and C-14 basins and receives water from WCA-2A and WCA-2B.
- **LEC Service Area 3**: The portion of Miami-Dade County east of WCA-3B that receives water from WCA-3A/3B. This service area also includes the Florida Keys because the primary source of drinking water for those users is a wellfield near Florida City.

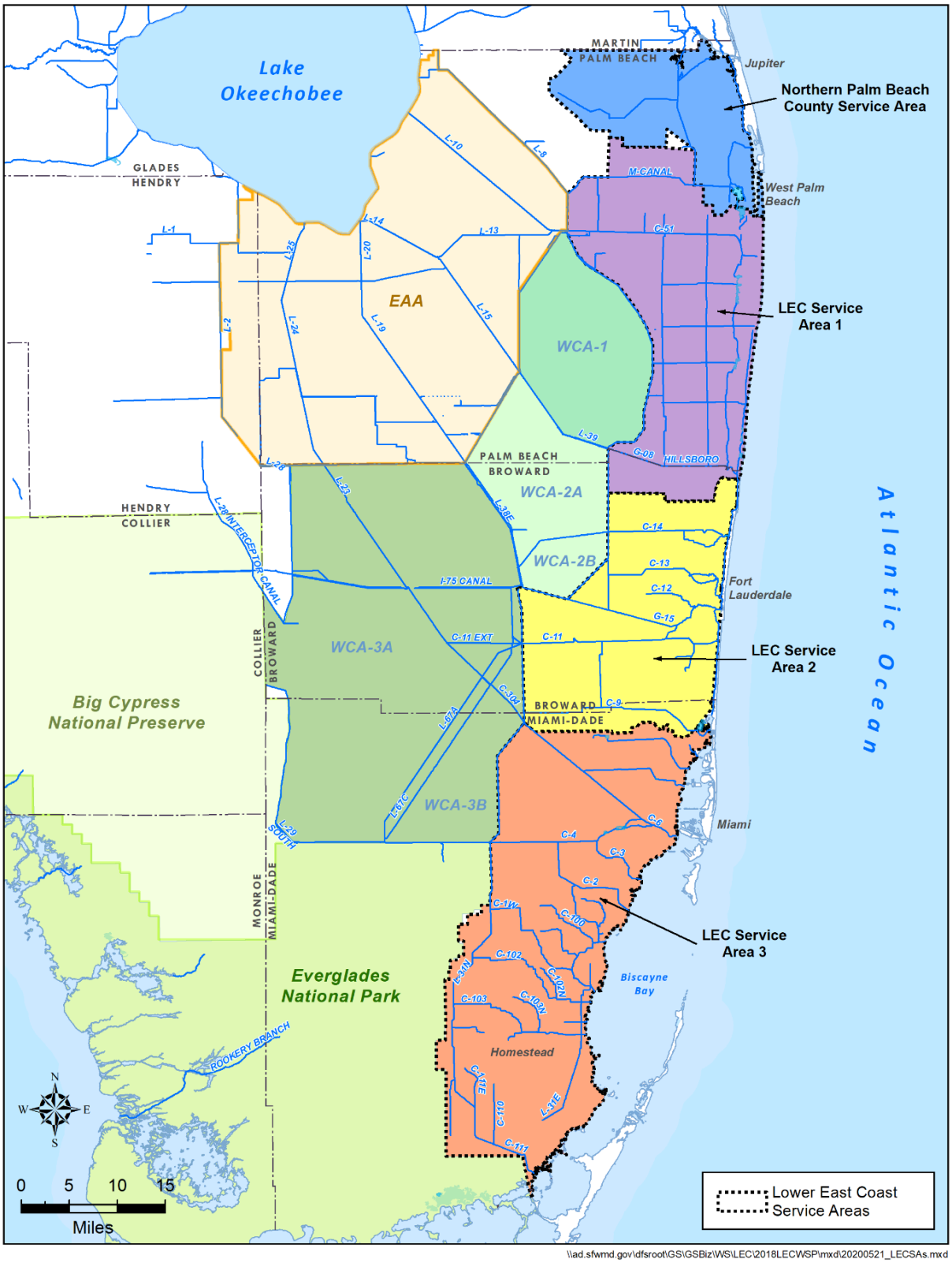


Figure 4-10. Lower East Coast service areas.

Loxahatchee River and Estuary

The Northwest Fork of the Loxahatchee River is hydrologically considered in the LEC Planning Area because the river's watershed includes a broad area of northern Palm Beach County. Grassy Waters Preserve and the Loxahatchee and Hungryland sloughs form the headwaters of the Loxahatchee watershed and drain into the Northwest Fork of the river. The Northwest Fork of the Loxahatchee River flows north into Martin County and continues east through Jonathan Dickinson State Park. It then flows southeast back into Palm Beach County, where it enters the central embayment area of the Loxahatchee Estuary. The Northwest Fork receives important inflows from three major tributaries: Cypress Creek, Hobe Grove Ditch, and Kitching Creek. Grassy Waters Preserve provides public water supply for the City of West Palm Beach, Town of Palm Beach, Town of South Palm Beach, and surrounding unincorporated areas.

Floodplain plant communities, soils, and salinity regimes characterize three distinct reaches within the Loxahatchee River and Estuary: 1) riverine (790 acres), which generally is unaffected by salinity; 2) upper tidal (59 acres), which experiences some saltwater intrusion during the dry season; and 3) lower tidal (111 acres), which is highly influenced by tides and salinity (**Figures 4-11** and **4-12**; SFWMD et al. 2006). However, increased saltwater intrusion from the opening of the Jupiter Inlet in 1947 and decreased freshwater inflow due to drainage canals have impacted the riverine and upper tidal ecosystems. To address these issues and as part of the Wild and Scenic River designation, the Florida Department of Environmental Protection and SFWMD (2010) were required to jointly develop, administer, and implement a Wild and Scenic River Management Plan.

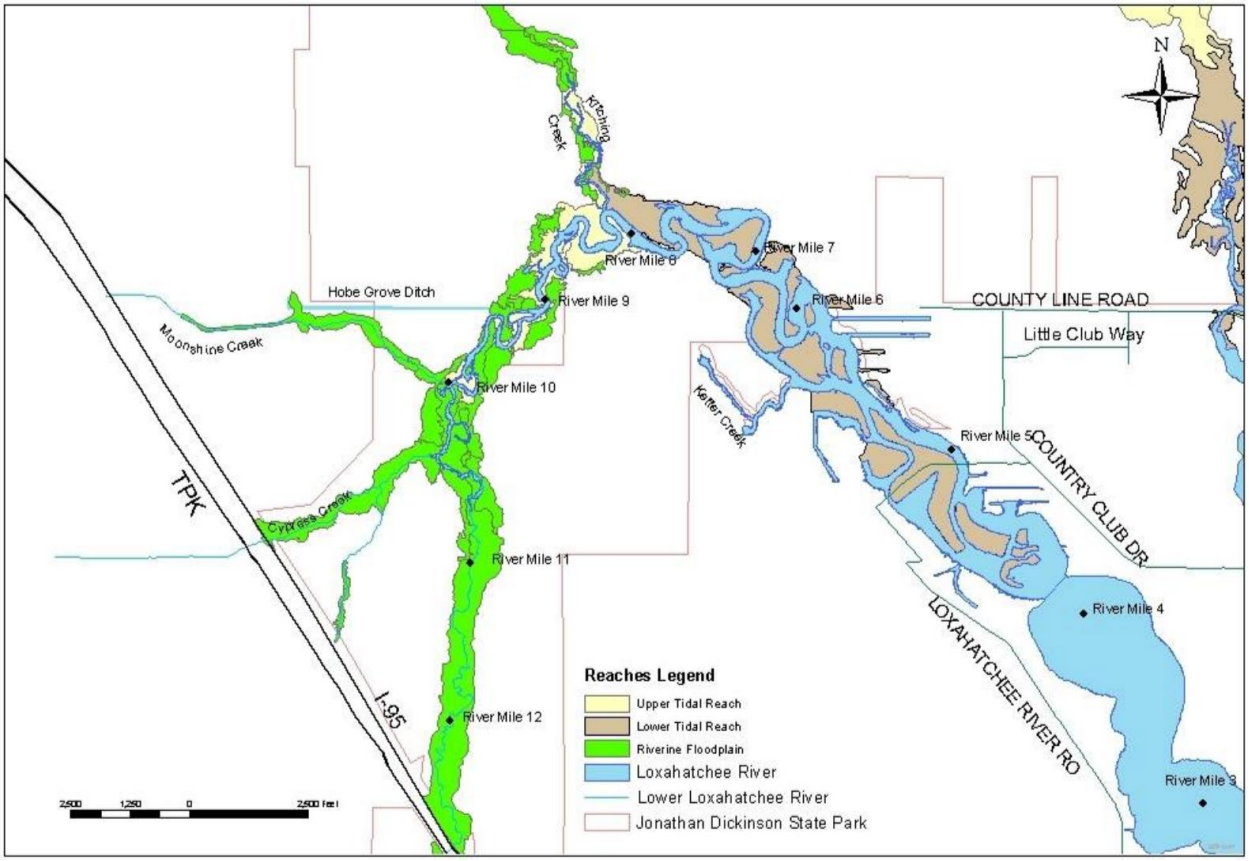


Figure 4-11. Reaches of the Northwest Fork of the Loxahatchee River between River Mile 4.5 and I-95 (River Mile 12.76) (From: SFWMD et al. 2006).

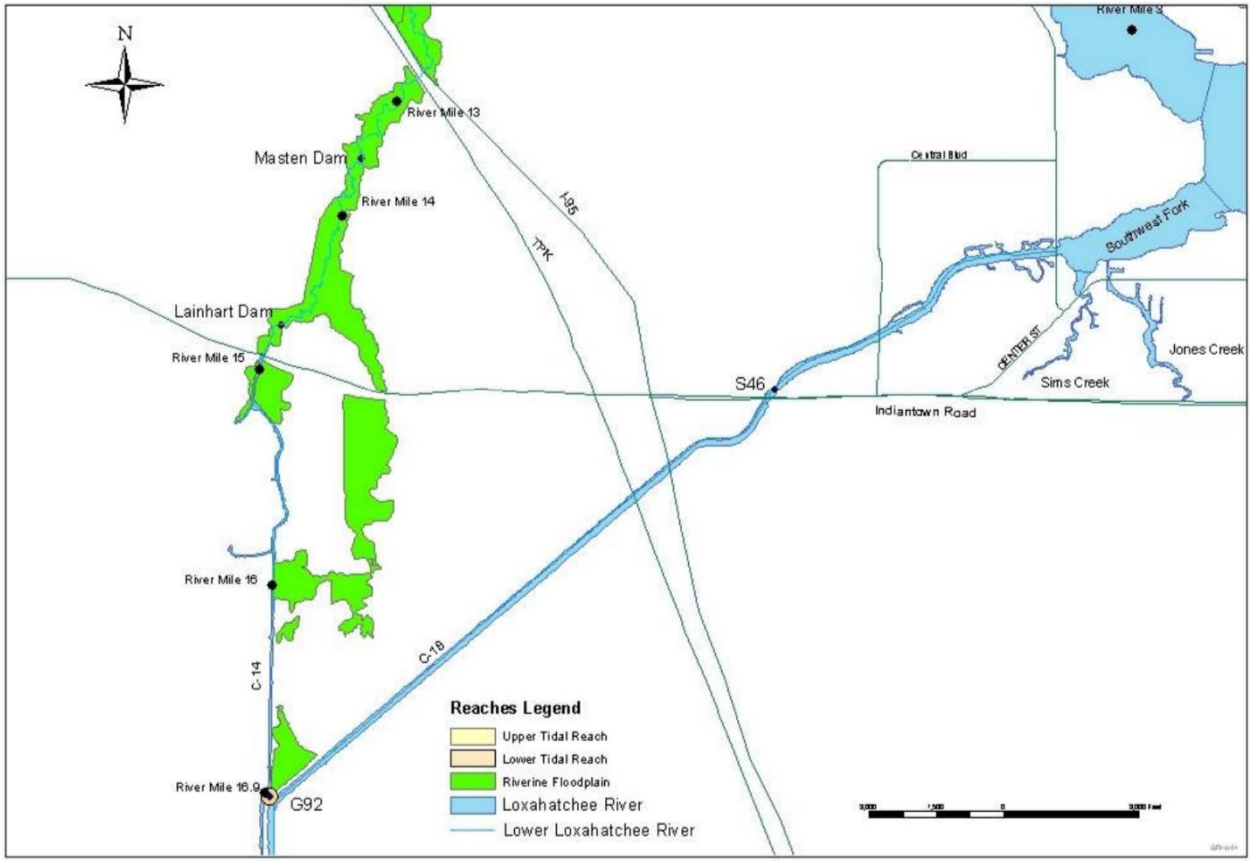


Figure 4-12. Upper riverine reach of the Northwest Fork of the Loxahatchee River between I-95 (River Mile 12.76) and the G-92 structure (From: SFWMD et al. 2006).

Lake Worth Lagoon

Lake Worth Lagoon is a 22-mile long, 6- to 10-ft deep estuary between mainland Palm Beach County and offshore barrier islands. While Lake Worth Lagoon is not a water supply source and not managed by the SFWMD, it is an important natural resource affected by and considered when making water management decisions. The lagoon is managed by the county under the Lake Worth Lagoon Management Plan (Palm Beach County Department of Environmental Resources Management 2008), in cooperation with other agencies, including the SFWMD. Management plan performance measures target freshwater discharges and resulting salinities during the wet season to provide optimal conditions for key species (e.g., oysters, seagrass).

The Lake Worth Lagoon watershed encompasses approximately 450 square miles of predominantly urbanized land in Palm Beach County (**Figure 4-13**). The watershed receives fresh water from the C-17 Canal (Earman River), West Palm Beach (C-51) Canal, and Boynton (C-16) Canal. Freshwater runoff from the watershed drains to canals and is discharged to the lagoon. Excessive fresh water discharged into the lagoon reduces salinity and increases turbidity, which can negatively affect the estuarine ecosystem. Tidal exchange with the Atlantic Ocean occurs at the Palm Beach and Boynton inlets. Harmful discharges to Lake Worth Lagoon can be reduced by diverting watershed runoff to the CERP Environmental Preserve at the Marjorie Stoneman Douglas Habitat and to STA-1E for nutrient reduction before discharge to WCA-1.

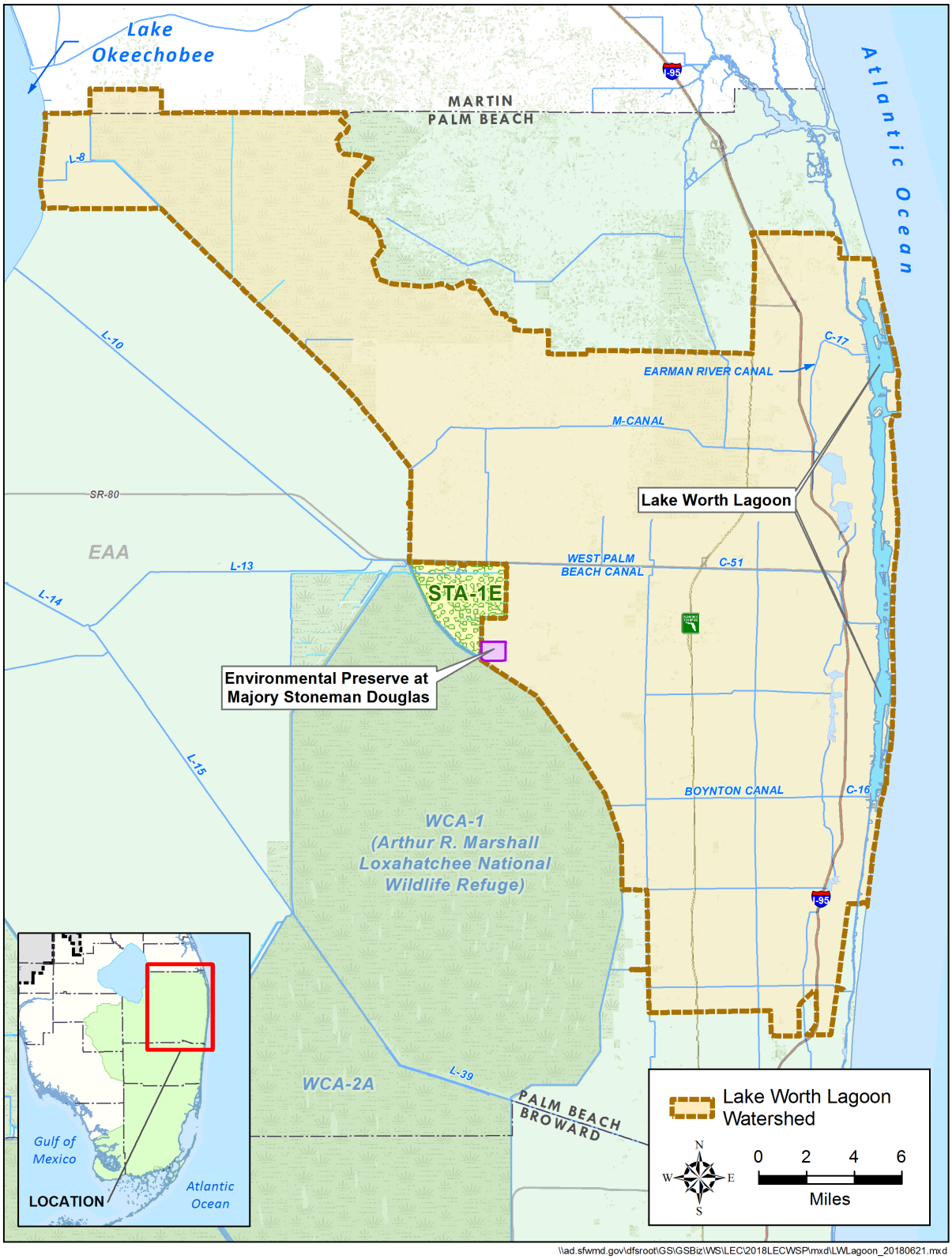


Figure 4-13. Major features of the Lake Worth Lagoon watershed.

Biscayne Bay

Located along the southeastern coast of Florida, Biscayne Bay is a shallow, subtropical estuary spanning nearly 430 square miles, with 270 square miles of the bay in Biscayne National Park (**Figure 4-14**). While Biscayne Bay is not a water supply source and not managed by the SFWMD, it is an important natural resource affected by and considered when making water management decisions. The Biscayne Bay watershed encompasses approximately 940 square miles of urban and agricultural land in Miami-Dade County. Water levels within the watershed are managed for flood control and water supply, and there are 16 drainage outfalls into Biscayne Bay. Drainage of the watershed has altered the location and timing of freshwater inputs to the bay, while construction of artificial inlets and channels has allowed seawater to move farther into the bay. These two factors have contributed heavily to the bay's transition from a freshwater estuary to a more saline environment. Other factors that may be contributing to the bay's increased salinity include reduced rainfall from historical levels and sea level rise.

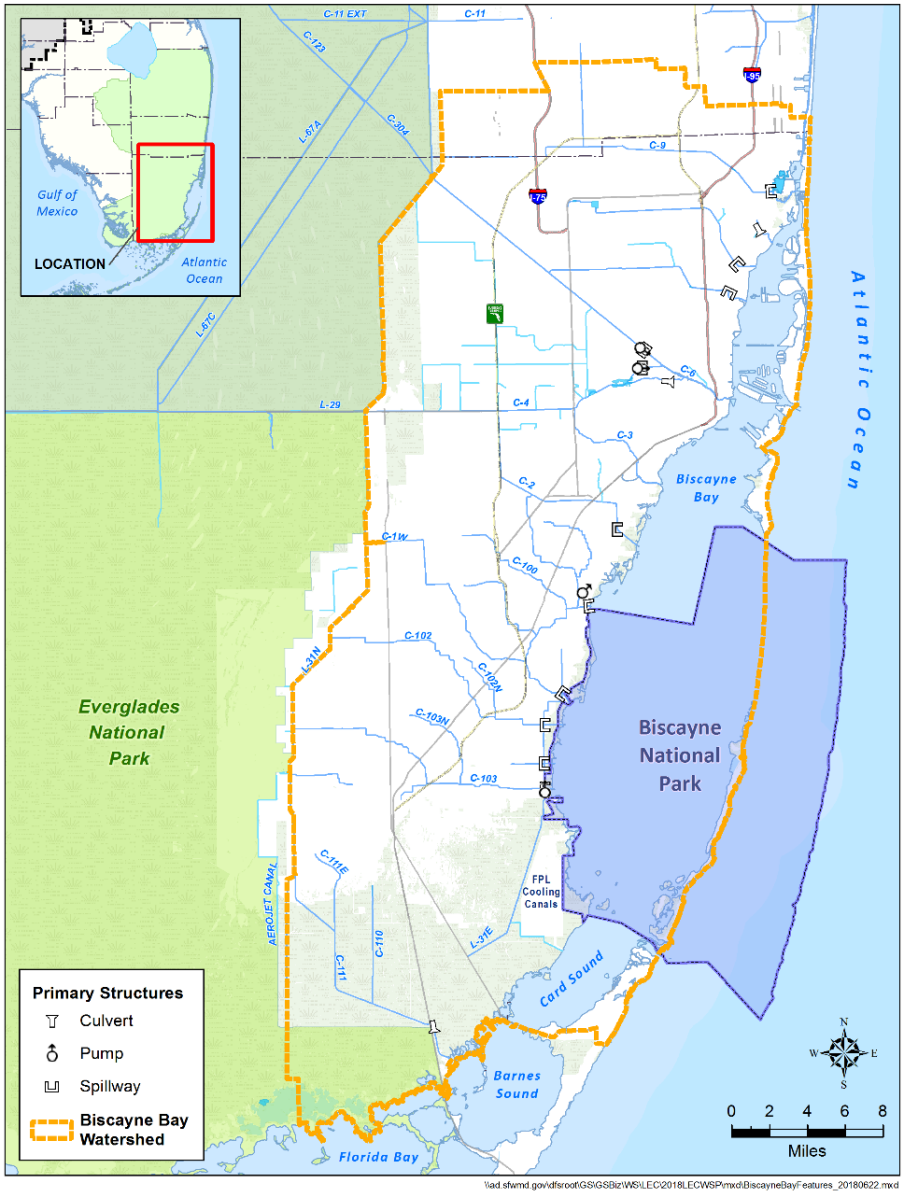


Figure 4-14. Major features of Biscayne Bay and its watershed.

4.2.2.5 Basins with Significant Relationship to the LEC Planning Process

St. Lucie Canal and Caloosahatchee River

The C-44 (St. Lucie) Canal in the Upper East Coast Planning Area (**Chapter 2**) and the C-43 Canal (Caloosahatchee River) in the Lower West Coast Planning Area (**Chapter 3**) are outside the boundaries of the LEC Planning Area. However, because of their hydraulic connection to Lake Okeechobee, these basins are included in the LEC water supply planning process in addition to the Upper East Coast and Lower West Coast planning processes.

4.2.3 Groundwater Resources

The SAS and FAS are the two principal aquifer systems in the LEC Planning Area (**Figure 4-15**). The intermediate aquifer system is absent or has low yield in the planning area (**Table 4-1**) and therefore is not discussed. The SAS provides fresh groundwater from the Biscayne aquifer underlying Broward and Miami-Dade counties, undifferentiated surficial aquifers underlying Palm Beach County, and the Lower Tamiami aquifer underlying Hendry County. The FAS provides brackish groundwater from the Upper Floridan aquifer (UFA) throughout the planning area (Shine et al. 1989).

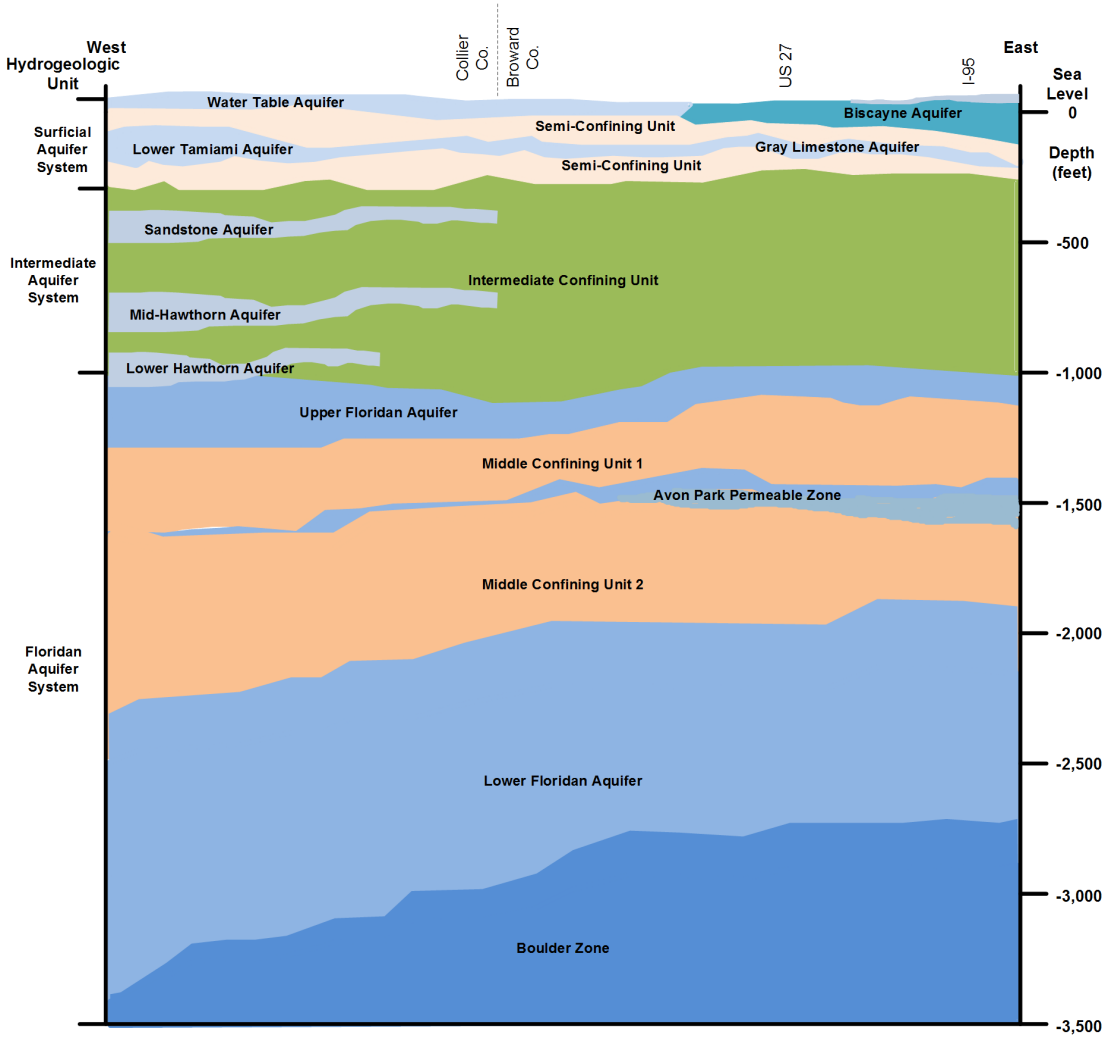


Figure 4-15. Generalized hydrogeologic cross-section of the Lower East Coast Planning Area.

Because hydraulic properties (i.e., ability to yield water to wells) and water quality may vary vertically and horizontally within each aquifer system, the potential for groundwater supply varies throughout the planning area. **Table 4-1** lists the aquifer systems, hydrogeologic units, and general aquifer yields in the LEC Planning Area. Groundwater use is minimal within the LEC Planning Area portions of Collier and Monroe counties; therefore, they are not listed in **Table 4-1**.

Table 4-1. Groundwater systems in the Lower East Coast Planning Area.

Aquifer System	Hydrogeologic Unit	Aquifer Yield by County			
		Miami-Dade	Broward	Palm Beach	Hendry*
Surficial	Biscayne aquifer	H	H	M	A
	Undifferentiated surficial aquifer system	M	M	L-M	L-M
	Lower Tamiami aquifer/Gray Limestone	L-M	L-M	A	M-H
Intermediate	Sandstone aquifer	A	A	A	L
	Mid-Hawthorn aquifer	A	A	A	L
Floridan	Upper Floridan aquifer	M	M	M-H	M
	Avon Park Permeable Zone	L	L-M	M-H	L-H
	Lower Floridan aquifer	M-H	M-H	M-H	M

A = absent; H = high; L = low; M = moderate.
* Values listed for Hendry County are only for the area within the LEC Planning Area boundary.

4.2.3.1 Surficial Aquifer System

The SAS, which extends throughout southeastern Florida, provides fresh water for potable and supplemental irrigation uses in the LEC Planning Area. The SAS is an unconfined to semi-confined aquifer system composed of solutioned limestone, sandstone, sand shell, and clayey sand. It includes sediments from the water table down to the intermediate confining unit (ICU; Hawthorn Group) and ranges from 150 to 300 ft below land surface (**Figure 4-15**). SAS sediments have a wide range of permeability and are locally divided into aquifers separated by less permeable units. The best known of these aquifers is the Biscayne aquifer, which extends south from coastal Palm Beach County through most of Broward and Miami-Dade counties and into portions of southeastern Monroe County. In Palm Beach County, a highly productive portion of the SAS is referred to locally as the Turnpike aquifer (**Figure 4-16**) and is thickest and most productive in the vicinity of the Florida Turnpike (Reese and Wacker 2009).

Transmissivity in the SAS varies from 10,000 ft^2/day in sandy, shelly portions to more than 1 million ft^2/day in open, solutioned cavity portions of the Biscayne aquifer. Estimated values generally are 300,000 ft^2/day or greater in nearly all central and eastern Miami-Dade County. Transmissivity is lower to the west, decreasing to less than 75,000 ft^2/day in western Miami-Dade County (Fish and Stewart 1991).

The SAS produces high-quality fresh water from relatively shallow wells in most of the LEC Planning Area. In some cases, the ambient water quality meets primary and secondary drinking water quality standards. However, some coastal areas in the LEC Planning Area have chloride concentrations greater than 250 milligrams per liter (mg/L) in the SAS. In central and western Palm Beach and Broward counties, high salinities in the SAS are attributed to relict seawater (connate water) in less transmissive portions of the SAS (Fish 1988; Reese and Wacker 2009). Higher salinities also are found in EAA canals where portions of the canals are within the SAS (Restrepo et al. 1992).

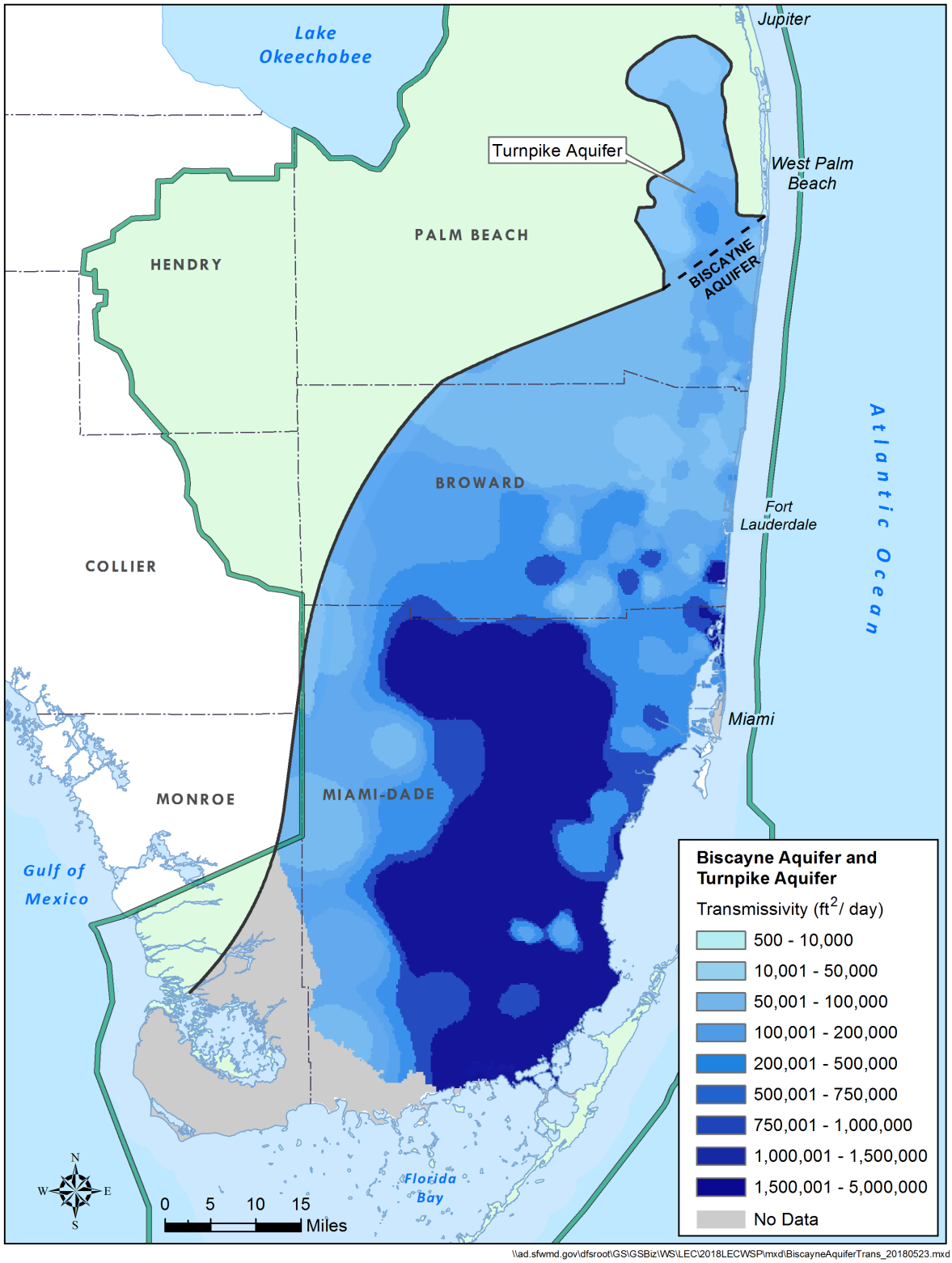


Figure 4-16. Location and transmissivity of the Biscayne and Turnpike aquifers.

Biscayne Aquifer

The Biscayne aquifer (**Figure 4-16**) is composed of interbedded, unconsolidated sands and shell units with varying thicknesses of consolidated, highly solutioned limestone and sandstone. In general, the Biscayne aquifer contains less sand and more solutioned limestone than most of the SAS. The major geologic deposits composing the Biscayne aquifer include the Miami Limestone, Fort Thompson Formation, Anastasia Formation, and Key Largo Limestone. The base of the Biscayne aquifer is generally the contact between the Fort Thompson Formation and the underlying Tamiami Formation of Plio-Miocene age. However, where the upper unit of the Tamiami Formation contains highly permeable limestones and sandstones, the zones are also considered part of the Biscayne aquifer if the thickness exceeds 10 ft. The Biscayne aquifer has been designated by the United States Environmental Protection Agency as a sole source aquifer because it is the principal drinking water source for the LEC area and if the aquifer was contaminated, it would be a significant hazard to public health.

Gray Limestone Aquifer

The Gray Limestone aquifer lies below and west of the Biscayne aquifer, extending into Hendry and Collier counties. For most of its extent, the Gray Limestone aquifer is confined by sand, clayey sand, mudstone, and clays of low hydraulic conductivity (Reese and Cunningham 2000). The thickness of the aquifer is comparatively uniform, ranging from 30 to 100 ft. West of Miami-Dade and Broward counties, transmissivity values of the aquifer are commonly greater than 50,000 ft^2/day. Hydraulic conductivity of the Gray Limestone aquifer generally increases from east to west, and ranges from approximately 200 to 12,000 ft/day.

Lower Tamiami Aquifer

The Lower Tamiami aquifer is the major source of groundwater in eastern Hendry County and extends east into the LEC Service Areas as the Gray Limestone aquifer (Reese and Cunningham 2000). The aquifer is composed of shelly sand, course-grained sandy limestone, and sandstone occurring from 25 to 200 ft below land surface. It is overlain by the water table and an intermittent clayey layer (leaky confining zone). Below the Lower Tamiami aquifer, the Sandstone and Mid-Hawthorn aquifers in the intermediate aquifer system are not productive in the LEC Planning Area. Transmissivity of the Lower Tamiami aquifer increases from north to south in eastern Hendry County. The aquifer produces high-quality fresh water from relatively shallow wells in the Western Basins (see **Section 4.2.2.3**).

4.2.3.2 Intermediate Confining Unit

The ICU consists of beds of clay, sand, sandy limestone, limestone, and dolostone that dip and thicken to the south and southwest. In much of South Florida, the ICU separates the SAS from the FAS. This massive confining unit also serves as a protective barrier, isolating surface features from the drawdown effects of FAS withdrawals. The ICU achieves its maximum development within the LEC Planning Area, ranging from 600 to more than 900 ft thick.

4.2.3.3 Floridan Aquifer System

The FAS is a thick (more than 2,700 ft), multi-layered sequence of predominantly carbonate rocks that underlies Florida and parts of Alabama, Georgia, and South Carolina. It is a confined aquifer system separated from the SAS by the low-permeability sediments of the ICU. Although the FAS is under artesian pressure (potentiometric head is 40 to 55 ft above MSL), the ICU prevents upward migration of saline waters into shallower aquifers.

The FAS is composed of many discrete aquifers separated by lower-permeability confining units. Traditionally, the FAS is subdivided into two major, regionally continuous producing zones: the brackish UFA and the more saline Lower Floridan aquifer (LFA), separated by a middle confining unit (**Figure 4-15**, confining unit 2).

Upper Floridan Aquifer

The top of the FAS, which coincides with the top of the UFA, is approximately 800 to 1,100 ft below land surface in the LEC Planning Area. The FAS is shallowest in the northwestern corner of Palm Beach County and deepens to the south and east. The UFA is composed of limestones from the Suwannee, Ocala, and upper Avon Park formations. Permeability is primarily due to the dissolution of rock material. Carbonate dissolution occurs most rapidly where waters of different chemistry meet.

The Avon Park permeable zone is a deeper water-bearing interval (1,400 to 1,600 ft below land surface) separated from the UFA by an intervening confining unit (**Figure 4-15**, confining unit 1). Heads in the UFA and Avon Park permeable zone are similar, but productivity and salinity may vary considerably. In the LEC Planning Area, water from the FAS typically contains chloride concentrations greater than 1,000 mg/L, and desalination is required before this water supply source is suitable for most uses, including human consumption. Several utilities and golf courses in the LEC Planning Area use UFA water with reverse osmosis treatment for all or some of their needs. Generally, salinity within the FAS increases with depth; however, in some coastal regions of the LEC Planning Area, this relationship is inverted due to the presence of relict seawater, with greater salinity in the UFA than the Avon Park permeable zone.

Lower Floridan Aquifer

The LFA comprises the limestones and dolostones of the lower Avon Park, Oldsmar, and Upper Cedar Keys formations. The total dissolved solids concentration (a measure of salinity) within the LFA is greater than 10,000 mg/L, which is the threshold for an underground source of drinking water. Though not generally considered useful as a water supply source in the LEC Planning Area, the LFA is a repository for underground injection of residual brine from reverse osmosis treatment and effluent disposal for several wastewater treatment facilities. At the base of the LFA (approximately 2,700 ft below MSL), a cavernous and highly transmissive layer known as the Boulder Zone is the target storage interval for these deep injection wells.

4.2.4 Surface Water and Groundwater Relationships

Surface water and groundwater resources are interconnected as many surface waterbodies recharge aquifers, and both types of resources provide regional water supply. Although surface water management systems are a major source of water supply, in terms of interaction with groundwater, the systems within the LEC Planning Area function primarily as aquifer drains during the dry season. Surface water management systems also affect aquifer recharge by diverting rainfall from an area before it percolates down to the water table. Once diverted, this water may contribute to aquifer recharge elsewhere in the system, supply a downstream consumptive use, be lost to evapotranspiration, or be discharged to tide.

The groundwater hydrology of the LEC Planning Area has been permanently altered by the C&SF Project as well as urban and agricultural development. Canals have drained the upper portion of the Biscayne aquifer and the freshwater mound behind the Atlantic Coastal Ridge. This has resulted in a significant decline in groundwater flow towards the ocean and, consequently, has allowed inland migration of the saltwater interface in some areas. The inland movement of salt water is a major concern in coastal areas of the LEC Planning Area. Coastal water control structures help stabilize or slow the advance of saltwater intrusion; however, isolated areas of Broward and Miami-Dade counties show evidence of continued inland migration of salt water. The diversion of surface water into water control (298) districts west of the water control structures recharges groundwater sources, reduces impacts of irrigation and public water supply withdrawals from aquifers, and helps slow saltwater intrusion.

Literature Cited

Abtew, W., L. Cadavid, and V. Ciuca. 2013. Chapter 2: South Florida Hydrology and Water Management. In: *2013 South Florida Environmental Report – Volume I*. South Florida Water Management District, West Palm Beach, FL.

Abtew, W., R.S. Huebner, C. Pathak, and V. Ciuca. 2007. Appendix 2-6: Regulation Schedules. In: *2007 South Florida Environmental Report – Volume I*. South Florida Water Management District, West Palm Beach, FL.

Abtew, W., J. Obeysekera, M. Irizzary-Ortiz, D. Lyons, and A. Reardon. 2003. *Evapotranspiration Estimation for South Florida*. Technical Paper EMA #407. South Florida Water Management District, West Palm Beach, FL.

Adams, K.M. 1992. *A Three-Dimensional Finite Difference Ground Water Flow Model of the Surficial Aquifer in Martin County, Florida*. Technical Publication 92–02. South Florida Water Management District, West Palm Beach, FL.

Ali, A. and W. Abtew. 1999. *Regional Rainfall Frequency Analysis for Central and South Florida*. Technical Publication WRE #380. South Florida Water Management District, West Palm Beach, FL.

Brown, M.P. and D.E. Reece. 1979. *Hydrogeologic Reconnaissance of the Floridan Aquifer System, Upper East Coast Planning Area.* Technical Map Series 79-1, Plates 1-10B. South Florida Water Management District, West Palm Beach, FL.

Butler, D.E. and D.G.J. Padgett. 1995. *A Three-Dimensional Finite-Difference Ground Water Flow Model of the Surficial Aquifer in St. Lucie County, Florida.* Technical Publication 95-01. South Florida Water Management District, West Palm Beach, FL.

Campbell, K.M. 1988. *The Geology of Collier County, Florida*. Open File Report 25. Florida Geological Survey, Tallahassee, FL.

Drew, R.D. and N.S. Schomer. 1984. *An Ecological Characterization of the Caloosahatchee River/Big Cypress Watershed*. FWS/OBS-82/58.2. United States Fish and Wildlife Service, United States Department of the Interior, Washington, D.C.

Fish, J.E. 1988. *Hydrogeology, Aquifer Characteristics, and Ground-Water Flow of the Surficial Aquifer System, Broward County, Florida*. Water-Resources Investigations Report 87-4034. United States Geological Survey, Reston, VA.

Fish, J.E. and M. Stewart. 1991. *Hydrogeology of the Surficial Aquifer System, Dade County, Florida*. Water-Resources Investigations Report 90-4108. United States Geological Survey, Tallahassee, FL.

Florida Department of Environmental Protection. 2006. *Water Quality Assessment Report – Kissimmee River and Fisheating Creek*. Division of Water Resource Management, Florida Department of Environmental Protection, Tallahassee, FL.

Florida Department of Environmental Protection and SFWMD. 2010. *Loxahatchee River National Wild and Scenic River Management Plan Update*. Florida Department of Environmental Protection, Tallahassee, FL and South Florida Water Management District, West Palm Beach, FL.

Johnson Engineering; Camp, Dresser, & McKee; Hole Montes & Associates; W. Dexter Bender & Associates; Darby & Way; and Greiner Engineering Sciences. 1990. *Lee County Interim Surface Water Management Plan*. Volumes I, II A&B, and III. Prepared for the Board of County Commissioners of Lee County, FL.

Lukasiewicz, J. and M.P. Switanek. 1995. *Ground Water Quality in the Surficial and Floridan Aquifer Systems Underlying the Upper East Coast Planning Area.* Technical Publication WRE-329 95-04. South Florida Water Management District, West Palm Beach, FL.

McVoy, C.W., W. Park Said, J. Obeysekera, J.A. VanArman, and T.W. Dreschel. 2011. *Landscapes and Hydrology of the Predrainage Everglade*s. University Press of Florida, Gainesville, FL.

Miller, J.A. 1986. *Hydrogeologic Framework of the Floridan Aquifer System in Florida and in Parts of Georgia, South Carolina, and Alabama*. Professional Paper 1403-B. United States Geological Survey, Washington, D.C.

Miller, J.A. 1990. *Ground Water Atlas of the United States: Segment 6, Alabama, Florida, Georgia, South Carolina*. Hydrologic Investigations Atlas 730-G. United States Geological Survey, Washington, D.C.

Palm Beach County Department of Environmental Resources Management. 2008. *Lake Worth Lagoon Management Plan Revision*. West Palm Beach, FL.

Parker, G.G., G.E. Ferguson, and S.K. Love. 1955. *Water Resources of Southeastern Florida*. U.S. Geological Survey Water-Supply Paper 1255. United States Geological Survey, Washington, D.C.

Reese, R.S. 2000. *Hydrogeology and the Distribution of Salinity in the Floridan Aquifer System, Southwestern Florida*. Water-Resources Investigations Report 98-4253. United States Geological Survey, Tallahassee, FL.

Reese, R.S. and K.J. Cunningham. 2000. *Hydrogeology of the Gray Limestone Aquifer in Southern Florida.* Water-Resources Investigations Report 99-4213. United States Geological Survey, Tallahassee, FL.

Reese, R.S. and M.A. Wacker. 2009. *Hydrogeologic and Hydraulic Characterization of the Surficial Aquifer System, and Origin of High Salinity Groundwater, Palm Beach County, Florida*. Scientific Investigations Report 2009-5113. United States Geological Survey, Reston, VA.

Restrepo, J.I., C. Bevier, and D. Butler. 1992. *A Three-Dimensional Finite Difference Ground Water Flow Model of the Surficial Aquifer System, Broward County, Florida*. Technical Publication 92-05. South Florida Water Management District, West Palm Beach, FL.

Rudnick, D.T., P.B. Ortner, J.A. Browder, and S.M. Davis. 2005. *A conceptual model of Florida Bay*. Wetlands 25(4):870-883.

Rupert, F.R. 1992. *Geomorphology, Geology, and Hydrogeology of the Savannahs State Reserve, Martin and St. Lucie Counties, Florida*. Open File Report 51. Florida Geological Survey, Tallahassee, FL.

Schiffer, D.M. 1998. *Hydrology of Central Florida Lakes – A Primer*. Circular 1137. United States Geological Survey, Reston, VA.

SFWMD. 2000. *2000 Lower East Coast Regional Water Supply Plan*. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2010. *Canals in South Florida: A Technical Support Document*. Appendix C: Primary Water Management Features. South Florida Water Management District, West Palm Beach, FL.

SFWMD. 2021. *SFWMD 30-Year Historical Average Rainfall (1991-2020)*. South Florida Water Management District, West Palm Beach, FL. Available online at https://www.sfwmd.gov/weather-radar/rainfall-historical/normal.

SFWMD, Florida Department of Environmental Protection, and Florida Department of Agriculture and Consumer Services. 2009. *St. Lucie River Watershed Protection Plan*. South Florida Water Management District, West Palm Beach, FL.

SFWMD, Florida Department of Environmental Protection, and Florida Park Service. 2006. *Restoration Plan for the Northwest Fork of the Loxahatchee River*. South Florida Water Management District, West Palm Beach, FL; Florida Department of Environmental Protection, Tallahassee, FL; and Florida Park Service, Loxahatchee River District.

Shine, M.J., D.G.J. Padgett, and W.M. Barfknecht. 1989. *Groundwater Resource Assessment of Eastern Palm Beach County, Florida*. Technical Publication 89-4. South Florida Water Management District, West Palm Beach, FL.

Spechler, R.M. 2010. *Hydrogeology and Groundwater Quality of Highlands County, Florida*. Scientific Investigations Report 2010-5097. United States Geological Survey, Reston, VA.

USACE. 1994. *Master Water Control Manual for Kissimmee River – Lake Istokpoga*. United States Army Corps of Engineers, Jacksonville District, Jacksonville, FL.

USACE. 1996. *Master Water Control Manual–Water Conservation Areas, Everglades National Park, and ENP-South Dade Conveyance System*. United States Army Corps of Engineers, Jacksonville District, Jacksonville, FL.

USACE. 2011. *Everglades Restoration Transition Plan Final Draft Environmental Impact Statement and Water Control Plan*. United States Army Corps of Engineers, Jacksonville District, Jacksonville, FL.

USACE. 2016. *Central and Southern Florida Project Water Control Plan for S-67, S-67X, S-68X, S-83X, S-84X, S-65C, S-65D, S-65DX1, S-65DX2, and S-65EX1*. United States Army Corps of Engineers, Jacksonville District, Jacksonville, FL.

White, W.A. 1970. *The Geomorphology of the Florida Peninsula.* Geological Bulletin No. 51. Florida Department of Natural Resources Bureau of Geology, Tallahassee, FL.

Zhang, J. and B. Sharfstein. 2013. Chapter 8: Lake Okeechobee Watershed Protection Program. In: *2013 South Florida Environmental Report – Volume I*. South Florida Water Management District, West Palm Beach, FL.