Re-Calibration and Application of the East Coast Floridan Model

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EXECUTIVE SUMMARY

The Upper East Coast (UEC) Planning Area of the South Florida Water Management District (SFWMD or District) faces several water management challenges, including increased freshwater demands, limited use of traditional water sources, increased levels of environmental protection, changing water quality, and sea level rise. These issues must be accounted for when evaluating and managing the region's water resources into the future. The SFWMD develops regional water supply plans that address water demands and availability issues for a 20-year planning horizon. As part of the planning process, alternative sources, including brackish water from the Floridan aquifer system (FAS), are evaluated for water supply use.

The East Coast Floridan Model (ECFM) is a three-dimensional, density-dependent groundwater flow and transport model that simulates changes in FAS water levels and water quality along the east coast of the District. Developed to evaluate potential impacts of additional FAS demands, the ECFM can simulate the response of the aquifers to the projected demands through wellfield pumpage, aquifer storage and recovery systems, reductions in recharge, increasing sea level, and climate change. Results of the model simulations can provide guidance for developing water management strategies, support periodic updates to the regional water supply plans, and be used in regulatory applications.

The ECFM domain extends from central Florida to the Florida Keys and from the approximate central line of the Florida peninsula to the Florida Straits and Atlantic Ocean. The model has seven primary layers representing the Upper Floridan aquifer, Ocala-Avon Park low-permeability zone, Avon Park permeable zone, middle confining unit, first permeable zone of the Lower Floridan aquifer, Boulder Zone confining unit, and Boulder Zone.

The ECFM originally was developed by HydroGeoLogic in 2006 and modified by Golder Associates in 2008. The model was peer reviewed in 2011 and the panel's comments and suggestions were incorporated into the 2014 version of the model. The current version of the model (2021) includes updated hydrostratigraphic (layer) information to synchronize the model layer elevations with the East-Central Florida Transient Expanded (ECFTX) Model where the two models overlap. In addition, new hydrogeologic data from aquifer tests were incorporated in localized areas across the model domain to improve model confidence.

The current version of the model was manually calibrated to water level and water quality (total dissolved solids concentrations) observations for transient conditions. The transient model was calibrated to the period from January 1989 through December 2012 using 143 water level targets and 208 water quality targets. The model calibration results indicated the simulated water levels and water quality values are in general agreement with field-observed measurements at most monitoring wells (targets). Simulated flow patterns and concentration distributions in major aquifers generally matched observed conditions.

The re-calibrated ECFM was used to evaluate the impacts of current (2019) and future proposed (2045) FAS demands within the UEC Planning Area. Only demands in or near the UEC Planning Area were altered for the 2019 and 2045 simulations. The ECFM results indicate the 2019 and 2045 FAS demands can be met without any widespread impacts to the aquifer system. However, there is potential for saltwater intrusion and upconing in localized areas due to projected increases in withdrawals. Continuous monitoring and adaptive planning strategies (e.g., increasing well spacing, rotation of operations) are recommended for users in the potentially vulnerable areas.

The ECFM was designed to provide a regional evaluation of the FAS in southeastern Florida. The model simulates FAS water levels, flow, and quality with reasonable accuracy. However, applying this tool at a local scale would require further modification. A more detailed representation of local hydrogeology and initial water level and water quality distribution would be required for predictions of water quality changes at existing or future wellfields.

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ACRONYMS AND ABBREVIATIONS

AFSIRS	Agricultural Field-Scale Irrigation Requirements Simulation
AG	Agriculture
APPZ	Avon Park permeable zone
BZ	Boulder Zone
CII	Commercial/Industrial/Institutional
District	South Florida Water Management District
ECFM	East Coast Floridan Model
ECFTX	East-Central Florida Transient Expanded (Model)
FAS	Floridan aquifer system
ft	foot
JEA	James E. Anderson (wellfield)
L/R	Landscape/Recreational
LFA	Lower Floridan aquifer
LF1	Lower Floridan aquifer– first permeable zone
MAE	mean absolute error
ME	mean error
mgd	million gallons per day
mg/L	milligrams per liter
NGVD29	North Geodetic Vertical Datum of 1929
PG	Power Generation
PS	Public Supply
R^2	coefficient of determination
RMSE	root mean square error
SAS	surficial aquifer system
SFWMD	South Florida Water Management District
TDS	total dissolved solids
UEC	Upper East Coast
UFA	Upper Floridan aquifer

1 INTRODUCTION

The South Florida Water Management District (SFWMD or District) updates its regional water supply plans every 5 years. Each water supply plan update identifies the region's existing water demands and projects demands at least 20 years into the future. The Upper East Coast (UEC) Planning Area includes all of St. Lucie and Martin counties and a portion of eastern Okeechobee County. Based on the 2021 UEC Water Supply Plan Update (SFWMD in press), the permanent resident population in the UEC Planning Area is projected to increase approximately 47% by 2045. The associated projected increase in public supply (i.e., water supplied by a utility) demand is approximately 65%. Most of the increased public supply demand is expected to be met through increased use of the Floridan aquifer system (FAS). As part of the planning process, the sustainability of existing and projected future FAS demands in the UEC Planning Area was evaluated using the East Coast Floridan Model (ECFM).

The ECFM is a three-dimensional, density-dependent groundwater flow and transport model that simulates changes in FAS water levels and water quality along the east coast of the District (**Figure 1-1**). The ECFM is based on the United States Geological Survey SEAWAT computer code, version 4 (Langevin et al. 2008, United States Geological Survey 2012). Originally developed by HydroGeoLogic, Inc. (2006), the ECFM was modified in 2008 (Golder Associates Inc. 2008), peer reviewed in 2011 (Jacobs et al. 2011), and re-calibrated and peer reviewed in 2014 (Giddings et al. 2014). This document describes the re-calibration and application of the ECFM to support the 2021 UEC Water Supply Plan Update (SFWMD in press).

The ECFM domain extends from central Florida near the southern border of Brevard County to the Florida Keys, and from the groundwater divide (along the spine of the Florida peninsula) to the Atlantic Ocean (**Figure 1-1**). The ECFM slightly overlaps with the West Coast Floridan Model (Giddings et al. 2020) on the western border, and the northern portion of the ECFM domain, including most of the UEC Planning Area, overlaps with the East-Central Florida Transient Expanded (ECFTX) Model (Central Florida Water Initiative Hydrologic Analysis Team 2020). The northern ECFM boundary was extended in 2014 (Giddings et al. 2014) to include the FAS recharge area in central Florida. The ECFM domain was divided into a uniform grid with spacing of 2,400 feet (ft). The 2014 ECFM (Giddings et al. 2014) was calibrated to observed water level and water quality targets based on criteria recommended by the peer-review panel (Jacobs et al. 2011). In this 2021 update, newly available hydrogeologic and hydrostratigraphic data were used to update the hydraulic properties and model layering, and the model was re-calibrated to meet the water level and water quality criteria established by the peer-review panel for the 2014 version of the ECFM.

The scope of this document includes updates to the previously calibrated and peer-reviewed version of the ECFM (Giddings et al. 2014), generally following the standard protocol for model development, as outlined by Anderson and Woessner (1992). The report is organized into six sections. **Section 1** includes the introduction and background of the report. **Section 2** illustrates the ECFM updates, including the incorporation of new hydrostratigraphic and hydrogeologic data. **Section 3** describes the re-calibration of the model based on the new data. **Section 4** describes water demand updates in the UEC Planning Area by use type for the current and future scenarios, and the application of the ECFM to simulate these scenarios. **Section 5** discusses the water demands in the UEC Planning Area for the current and future scenarios by county and by use type. Also, the modeling results of these scenarios are presented. **Section 6** concludes the report with a discussion on model capabilities, limitations, and general recommendations.

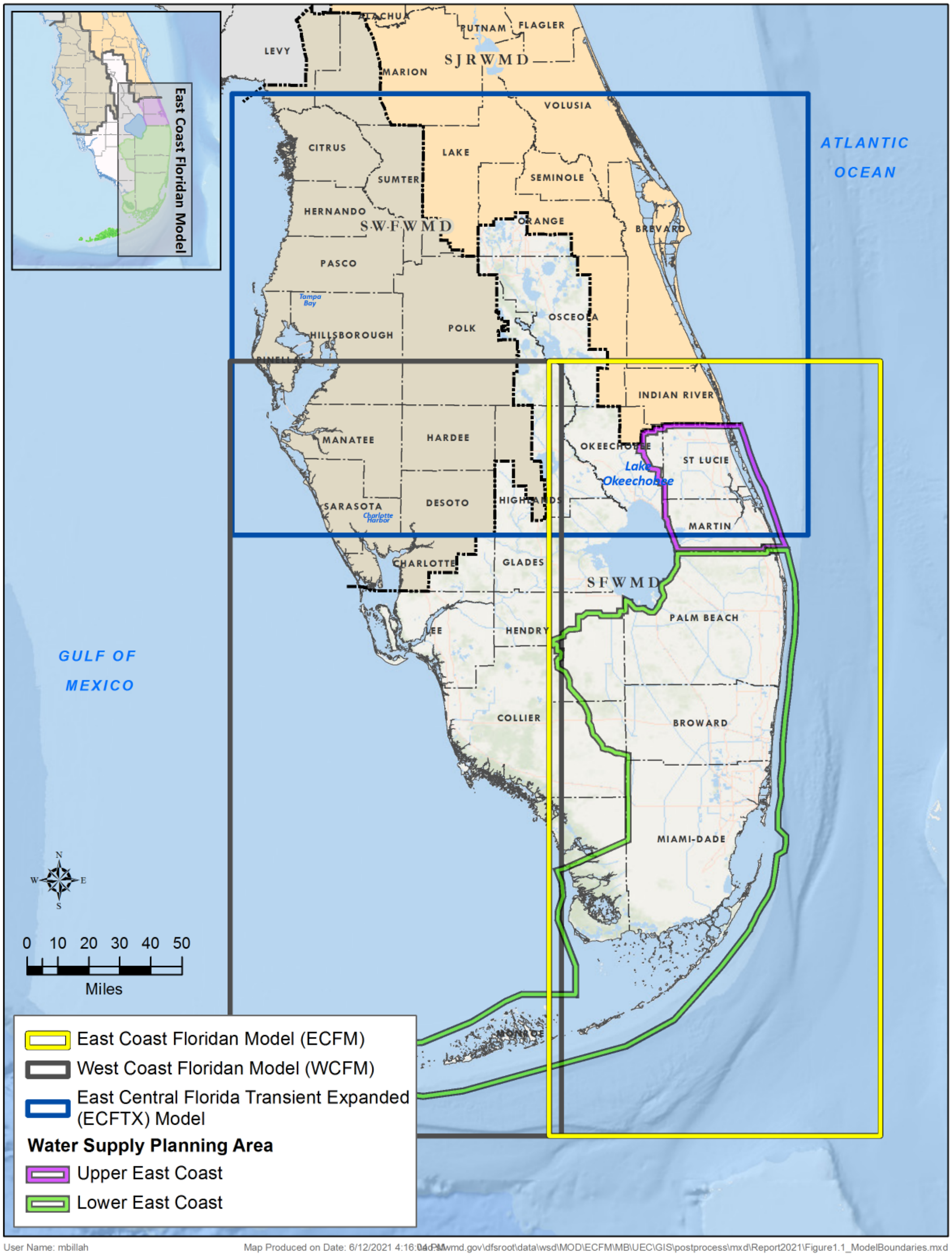

Figure 1-1. Boundaries of the East Coast Floridan Model domain compared with other Floridan aquifer system models in South Florida.

2 EAST COAST FLORIDAN MODEL UPDATES

2.1 Development of the East Coast Floridan Model

Numerous studies have focused on the FAS due to its importance as a major water resource for the southeastern region of the United States (e.g., Hickey 1982, Miller 1986, Bush and Johnston 1988, Meyer 1989, Tibbals 1990). In addition, several numerical models were recently developed by different agencies to simulate changes in the FAS. In the early 1990s, the SFWMD began developing groundwater flow models for most counties within its jurisdiction. The models mostly focused on the surficial aquifer system (SAS), but one addressed the Upper Floridan aquifer (UFA) in the UEC Planning Area (Lukasiewicz 1992). However, this model did not address the water quality and complete groundwater flow regime within the FAS. These shortcomings were overcome using a unified hydrogeologic framework that combined existing works into a single description of the upper three most productive zones of the FAS in South Florida (Reese and Richardson 2008).

The first density-dependent solute transport model of the FAS developed for the SFWMD was completed by HydroGeoLogic, Inc. (2006). This was the first phase of FAS model development and covered Miami-Dade, Broward, and Palm Beach counties. Phase II was completed by Golder Associates Inc. (2008) and expanded the model northward to include the UEC Planning Area. An independent peer-review panel reviewed both model versions and published their findings in 2011 (Jacobs et al. 2011). Based on the recommendations of the peer-review panel, the ECFM was updated in 2014 (Giddings et al. 2014). The United States Army Corps of Engineers (2010) also developed an FAS model as part of a regional aquifer storage and recovery modeling study for the Comprehensive Everglades Restoration Plan (CERP). The current version of the ECFM is a continuation of the 2014 version and was improved by incorporating new hydrostratigraphic and hydrogeologic information that became available after the 2014 model update.

The ECFM consists of 552 rows and 236 columns. The model has a north-south grid orientation, and the size of a model grid cell is 2,400 ft by 2,400 ft. The model coordinates are based on 1983 North American Datum Florida East State Planar Coordinates, and the northwest corner is set as follows:

X position: 565,465 ft

Y position: 1,280,352 ft

Vertically, the ECFM is composed of seven layers, each consisting of a confining unit or primary aquifer (**Table 2-1**).

Table 2-1. Model layers and corresponding hydrogeologic units of the East Coast Floridan Model.

Model Layer	Hydrogeologic Unit	Abbreviation
1	Upper Floridan aquifer	UFA
2	Ocala-Avon Park low-permeability zone	OCAPlpz
3	Avon Park permeable zone	APPZ
4	Middle confining unit	MCU
5	Lower Floridan aquifer – first permeable zone	LF1
6	Boulder Zone confining unit	BC
7	Boulder Zone	BZ

Miller (1990) illustrated the ECFM layers that include aquifers and confining units within the FAS, which generally consists of the UFA, the middle confining unit, and the Lower Floridan aquifer (LFA). Reese and Richardson (2008) refined these units to provide a more consistent hydrogeologic framework for groundwater model development. The framework they developed used multiple methods for identifying hydrostratigraphic units, including lithologic, stratigraphic, hydrogeologic, and geophysical methods. The results of their work were adhered to in this study and supplemented with additional data that have become available since their report was published. The top of the UFA includes portions of the Lower Hawthorn producing zone, the Suwannee Limestone, and the productive zone of the Ocala Limestone. Within the Avon Park Formation, there is a highly productive interval in the northern and central portion of the model domain referred to as the Avon Park permeable zone (APPZ). The APPZ separates the upper Ocala-Avon Park low-permeability zone and the lower middle confining unit. The LFA is a thick sequence of carbonate rocks that contains several permeable zones with thin and thick confining units between them. For this modeling effort, the LFA is divided into two producing zones: the uppermost permeable zone (LF1), located near the base of the Avon Park Formation, and the Boulder Zone (BZ), located within the Oldsmar Formation. Between the BZ and LF1 is a poorly understood sequence of permeable zones and confining units that are grouped into a single layer referred to as the Boulder Zone confining unit.

2.2 Hydrostratigraphic Data

The hydrostratigraphic information used to develop the ECFM was based on the primary water-producing units and confining units identified in Reese and Richardson (2008). The updated version of the ECFM incorporates additional data points from wells constructed after 2014 and synchronizes the model elevation with the ECFTX Model in the overlap area. The newly obtained sites were reviewed against the existing database and corrected as necessary to meet the conceptual model specifications.

The reviewed data from the well sites were used to create updated hydrostratigraphic units by kriging. For consistency with the ECFTX Model, hydrostratigraphic units from the UFA to the APPZ were updated (Central Florida Water Initiative Hydrologic Analysis Team 2016). Hydrostratigraphic data in the LFA were not considered for the ECFM update because available data are scarce in the overlap area with the ECFTX Model.

When developing this model update, aquifer and confining unit top and bottom elevations were considered static input parameters. These parameters were updated using the latest hydrostratigraphic information from well locations in the overlap area (**Figure 2-1**). The UFA's top elevation was updated using 446 well locations, and the UFA's bottom elevation was updated using 38 well locations. The bottom of the UFA is also the top of the Ocala-Avon Park low-permeability zone. The APPZ's top elevation was updated using 37 well locations. The bottom of the APPZ, which is also the top of the middle confining unit, was updated using 22 well locations. Details of these hydrostratigraphic data are included in **Appendix A**.

The hydrostratigraphic units show an increase in depth from the Polk County portion of the model to Miami-Dade County. The degree and extent of this elevation decline varies between hydrostratigraphic units. The UFA and APPZ show a relatively consistent increase in depth towards the southeastern portion of the model domain. The UFA and APPZ show greater thickness along the border of St. Lucie and Martin counties, and thickness decreases towards the ocean. Hydrostratigraphic unit thickness is a necessary piece of information to solve the flow and transport equations in the model. A minimum aquifer thickness of 10 ft was maintained to ensure numerical stability during model execution.

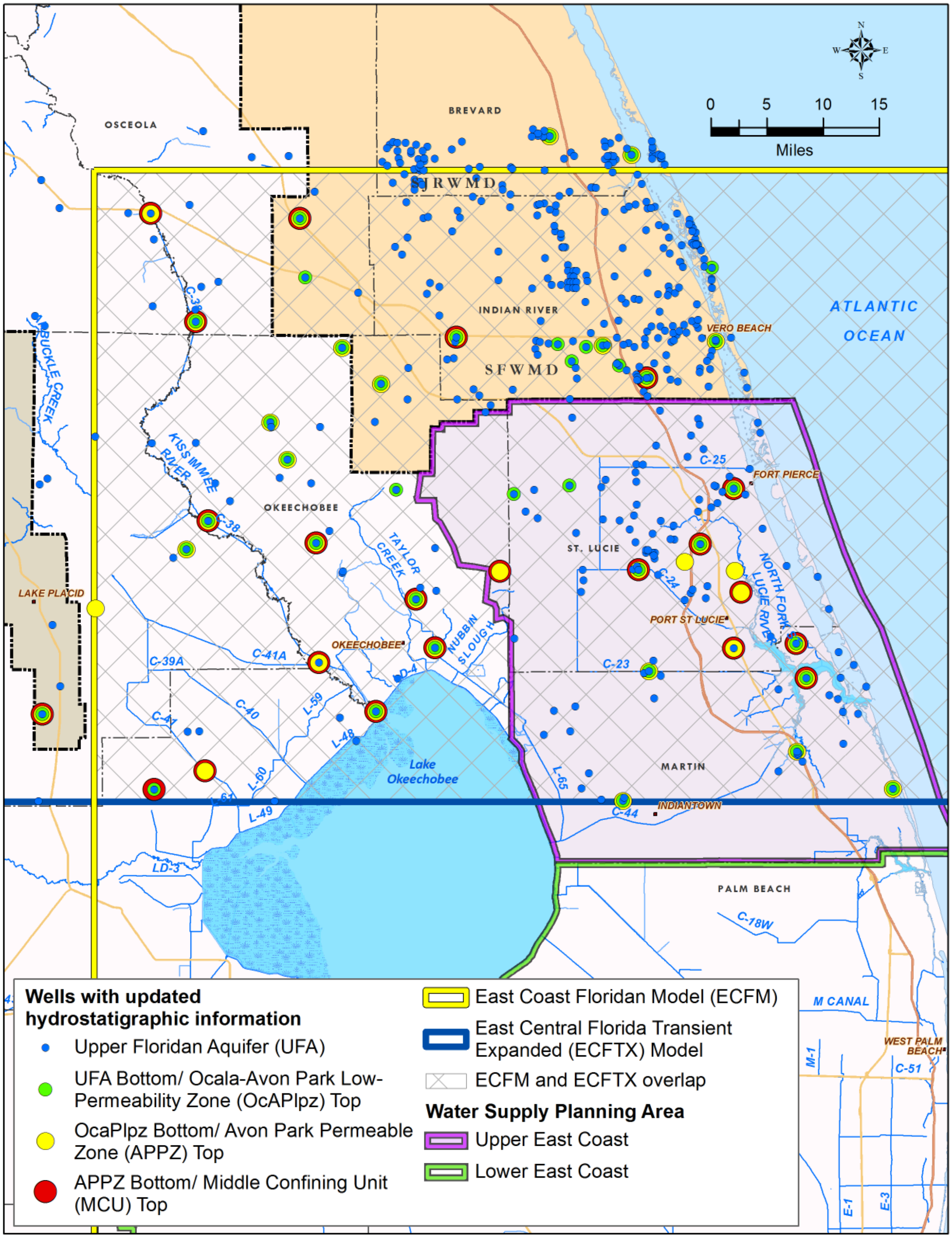

Figure 2-1. Well locations for the updated hydrostratigraphic information.

2.3 Hydrogeologic Data

The new hydrogeologic data used in the ECFM update were primarily horizontal hydraulic conductivity values, as discussed below.

2.3.1 Hydraulic Conductivity

Hydraulic conductivity is one of the most important parameters used to develop the ECFM. Hydraulic conductivity represents the aquifer's ability to transmit water under a hydraulic gradient. When multiplied by the aquifer thickness, the resulting term is called transmissivity, which can be obtained from aquifer performance tests. However, the model internally calculates transmissivity using the thickness of the aquifer and the horizontal hydraulic conductivities.

Several new aquifer performance, step, and packer test results became available since the 2014 model update (**Figure 2-2**). After detailed review of the new data and comparison with the previous model, it was found that vertical hydraulic conductivity and specific storage values used in the 2014 ECFM were similar to the new values at the aquifer test locations shown in **Figure 2-2**. However, horizontal hydraulic conductivity at seven locations were found to be significantly different from the 2014 ECFM information and considered for incorporation into the ECFM. Almost half of the data were from the UFA, which is the principal aquifer used throughout much of the state. There were three new horizontal hydraulic conductivity data values for the UFA and four new values for the APPZ. The new hydraulic information was incorporated such that only the immediate vicinity around these locations was updated in the model, leaving the remaining area with the previous horizontal hydraulic conductivity values. This approach preserved the quality of the model calibration in areas farther from the new data points.

The UFA includes the basal clastic zone of the Hawthorn Group, the upper portions of the Suwannee Limestone, and the upper part of the Ocala Limestone. Within the model domain, the UFA generally consists of several thin, highly permeable, water-bearing zones interbedded with thicker zones of lower permeability. The UFA is semi-confined in the northern portion of the model domain and more fully confined throughout the southern portion. The horizontal hydraulic conductivity of the UFA ranges from 0.8 ft/day (tri-zone well in Okeechobee County) to slightly more than 3,800 ft/day (north of the St. Lucie and Indian River counties border) throughout the model domain (**Figure 2-3**). The low horizontal hydraulic conductivity values are within the range of aquifer performance test values (0.45 to 3.7 ft/day) in the area (Giddings et al. 2014). The top of the UFA varies from approximately 200 ft below sea level in the northern area of the model domain to 1,200 ft below sea level in the western Florida Keys. The UFA thickness in most areas is between 250 and 500 ft and decreases towards the east. **Figure 2-4** shows the alignment of the high transmissivity with highly permeable areas as thickness shows less variation than the permeability. Within the UEC Planning Area, the highest transmissivity in the UFA varies between 200,000 and 500,000 ft^2/day at the border of St. Lucie and Indian River counties, which is 5 to 10 times higher than regional estimates (Miller 1990, Kuniansky et al. 2012).

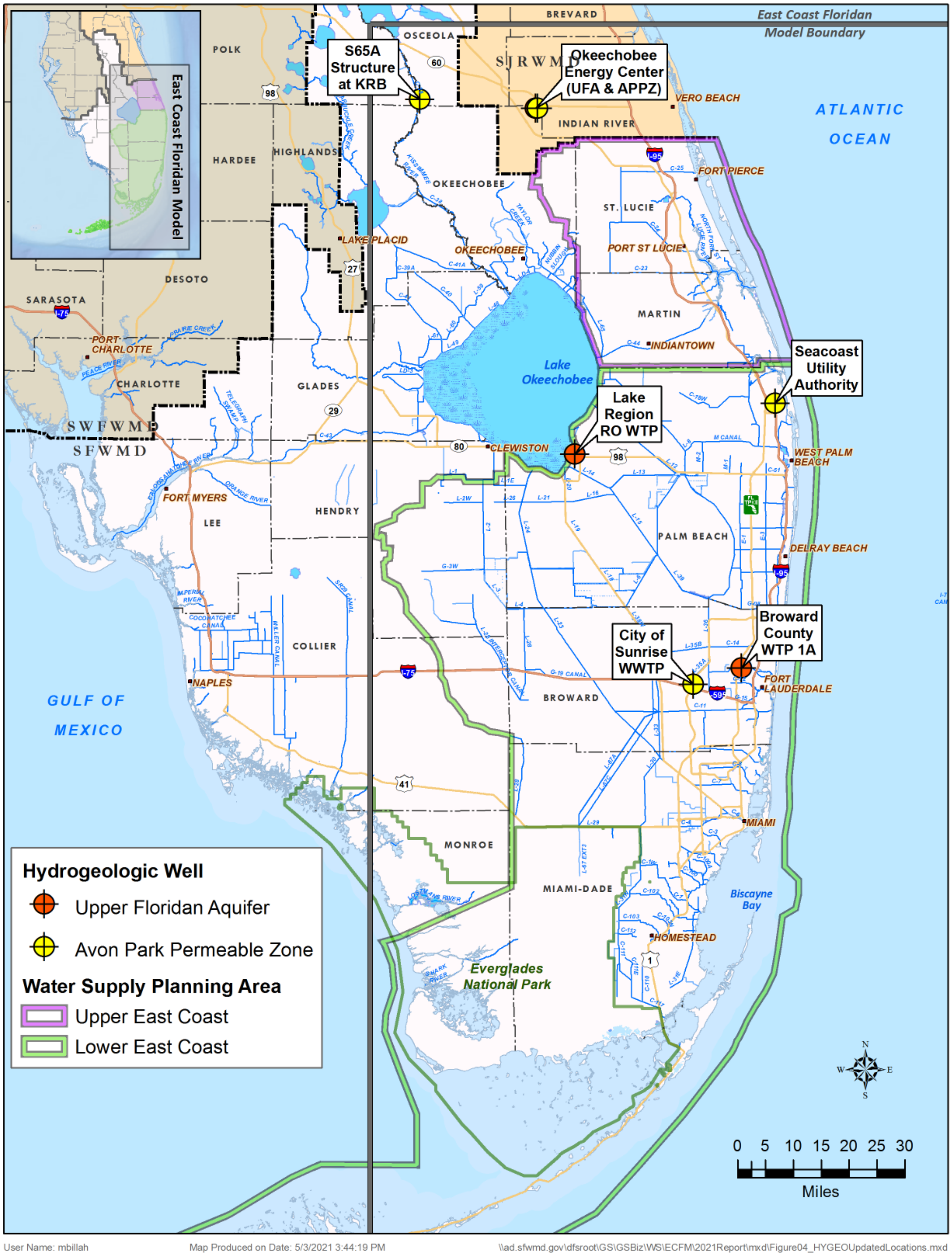

Figure 2-2. Locations with new hydrogeologic information used to update the East Coast Floridan Model.

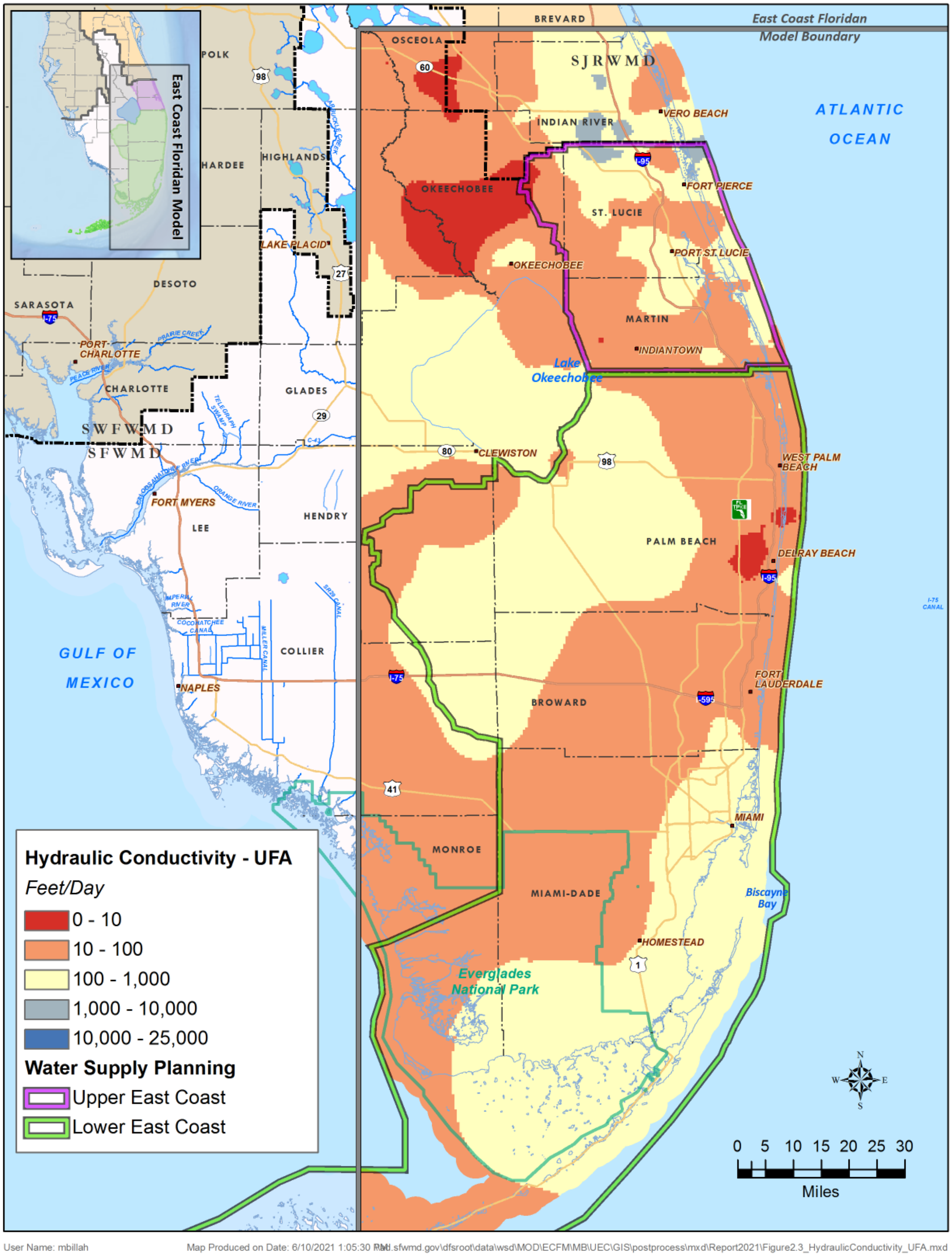

Figure 2-3. Distribution of horizontal hydraulic conductivity in the Upper Floridan aquifer.

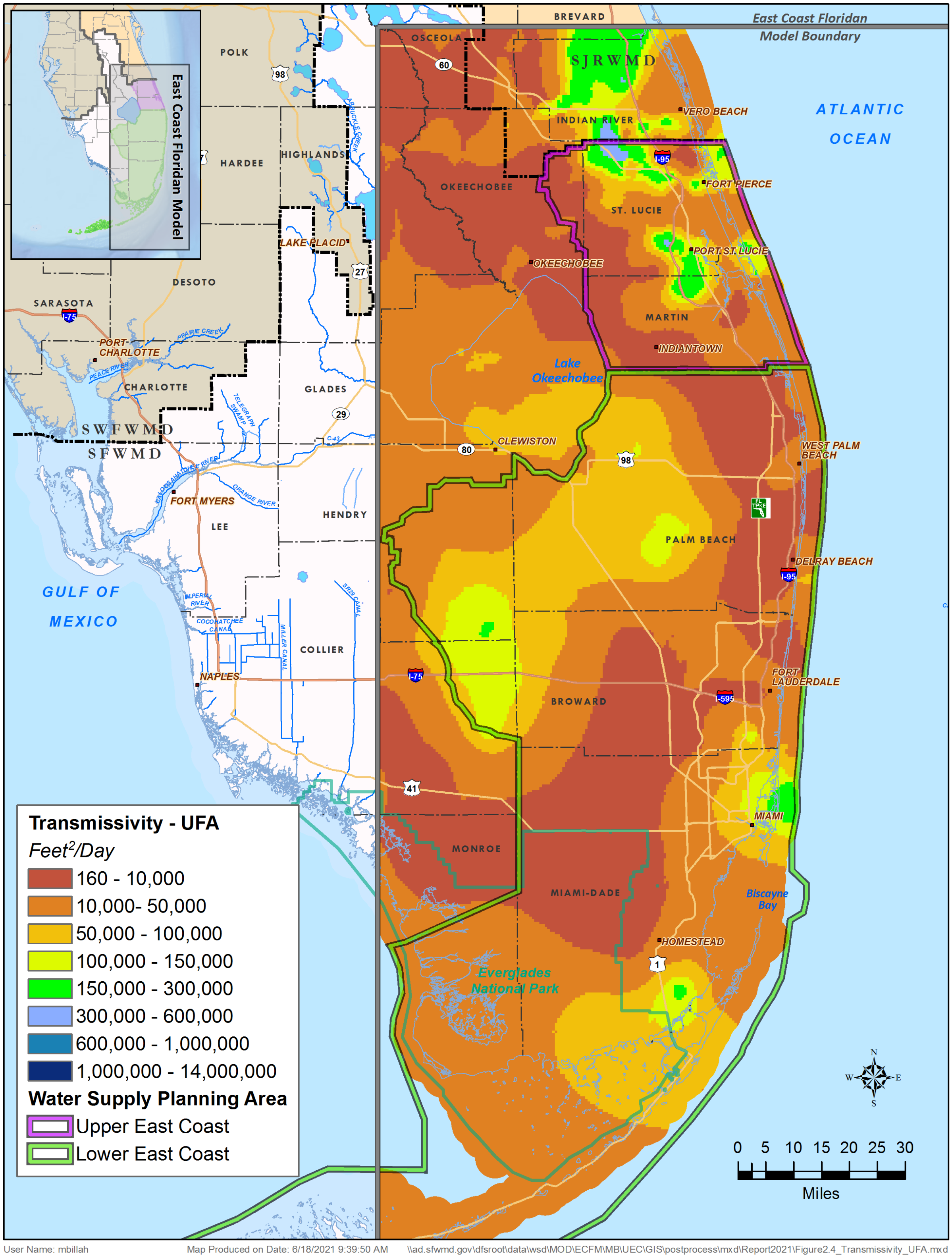

Figure 2-4. Distribution of transmissivity in the Upper Floridan aquifer.

Across the model domain, the APPZ is separated from the overlying UFA by the Ocala-Avon Park low-permeability zone. The layer is present throughout most of the model domain, except in portions of Collier and Monroe counties where it thins and may pinch out (Reese and Richardson 2008). Hydraulic conductivity of the APPZ generally is higher than the UFA, ranging from approximately 10 to 24,000 ft/day across the model domain (**Figure 2-5**). This more permeable area is located at the border of St. Lucie and Martin counties. In most of the northern model domain, the APPZ's thickness ranges between 300 and 500 ft. In the north, the top of the APPZ generally occurs 700 ft below sea level, while it is approximately 2,000 ft below sea level in the Florida Keys. A relatively greater thickness in the northern area of the model domain along with an average horizontal hydraulic conductivity of 250 ft/day results in a transmissivity range between 10,000 and 14,000 ft^2/day in this region (**Figure 2-6**). The highest APPZ transmissivity in the model domain occurs in northcentral Martin County and varies between 1.5 million and 14 million ft^2/day.

The LFA consists of a sequence of permeable zones separated by semi-confining units. The first permeable zone in the LFA (LF1) is located near the base of the Avon Park Formation and is somewhat contiguous throughout the ECFM domain. The horizontal hydraulic conductivity in the LF1 is based on seven aquifer performance tests and ranges from 3 to 2,200 ft/day (**Figure 2-7**). Most of the model domain has a horizontal hydraulic conductivity of less than 300 ft/day; the highly permeable area in LF1 is located southwest of Lake Okeechobee. Aligning with permeability, transmissivity also is higher southwest of Lake Okeechobee (**Figure 2-8**). Although permeability is low, the greater thickness of the LF1 results in moderate transmissivity in the northern portion of the model domain. Within the UEC Planning Area, transmissivity in the LFA is relatively low, varying between 160 and 10,000 ft^2/day.

Below the LF1 is the BZ, an extremely transmissive zone of cavernous and fractured dolomites and limestones of the Oldsmar Formation. The BZ occurs approximately 2,100 to 3,500 ft below sea level and can be several hundred feet thick with extremely high transmissivity values (Reese and Richardson 2008). Hydraulic conductivity in the BZ was irrelevant for the ECFM because the BZ is treated as a variable head/constant concentration boundary.

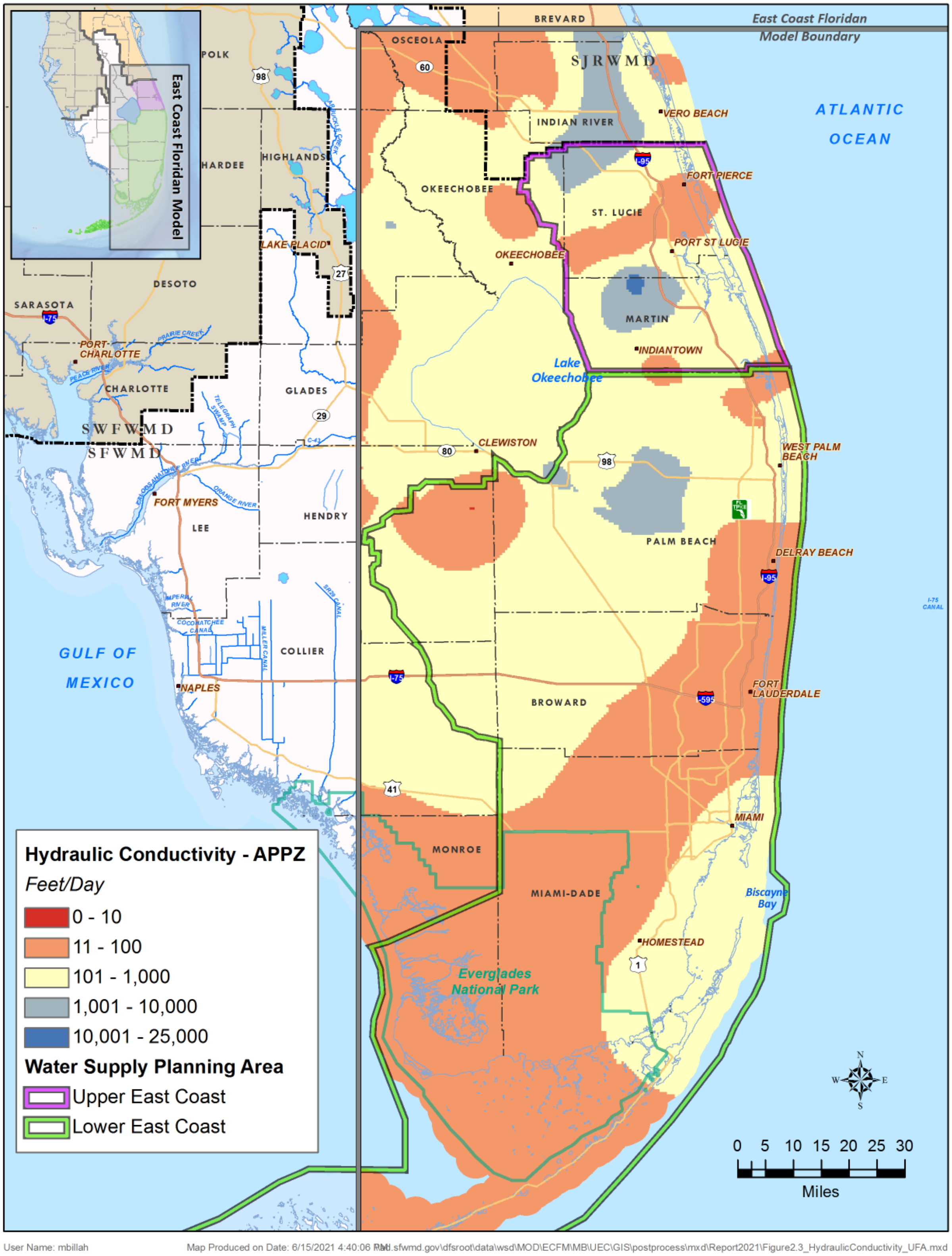

Figure 2-5. Distribution of horizontal hydraulic conductivity in the Avon Park permeable zone.

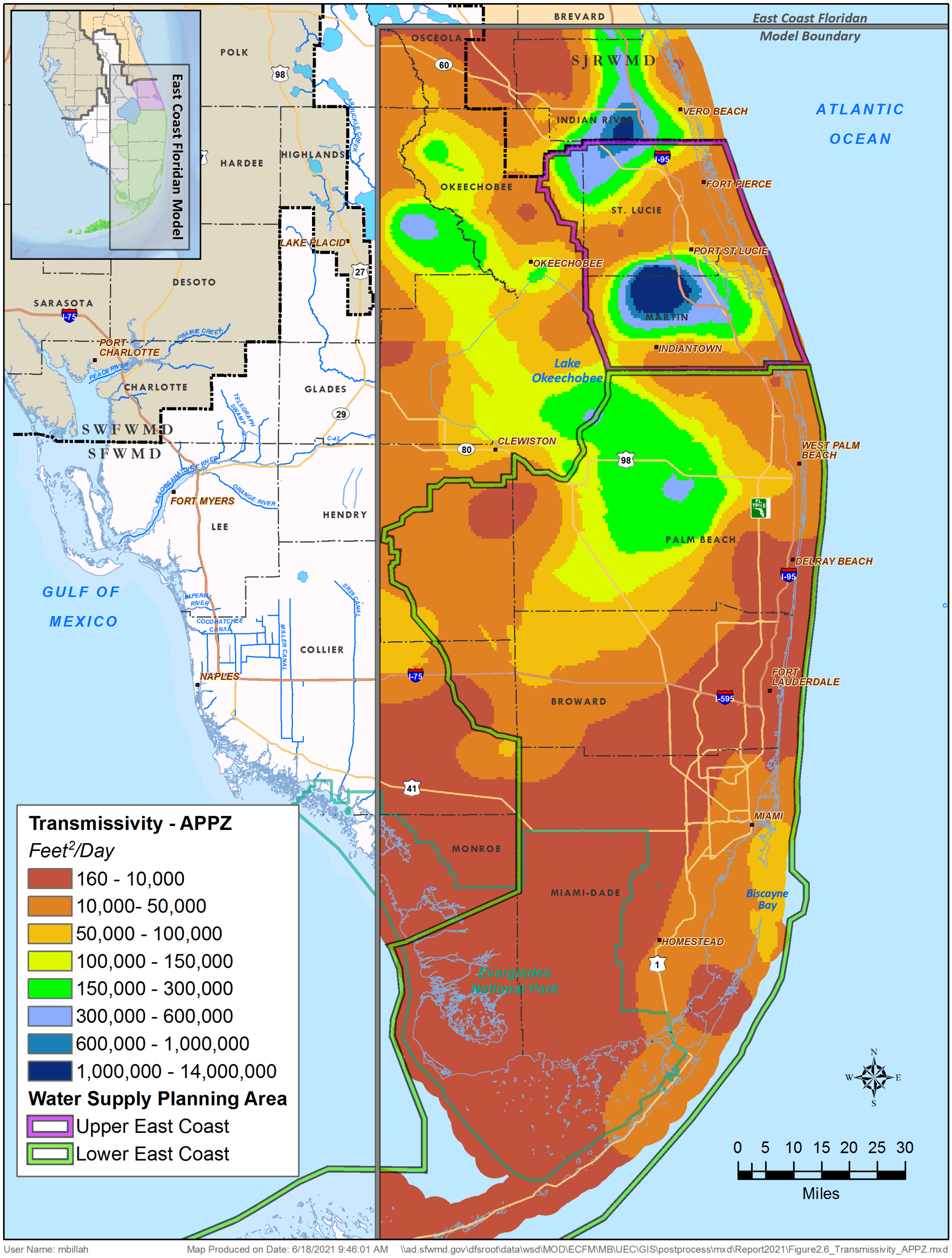

Figure 2-6. Distribution of transmissivity in the Avon Park permeable zone.

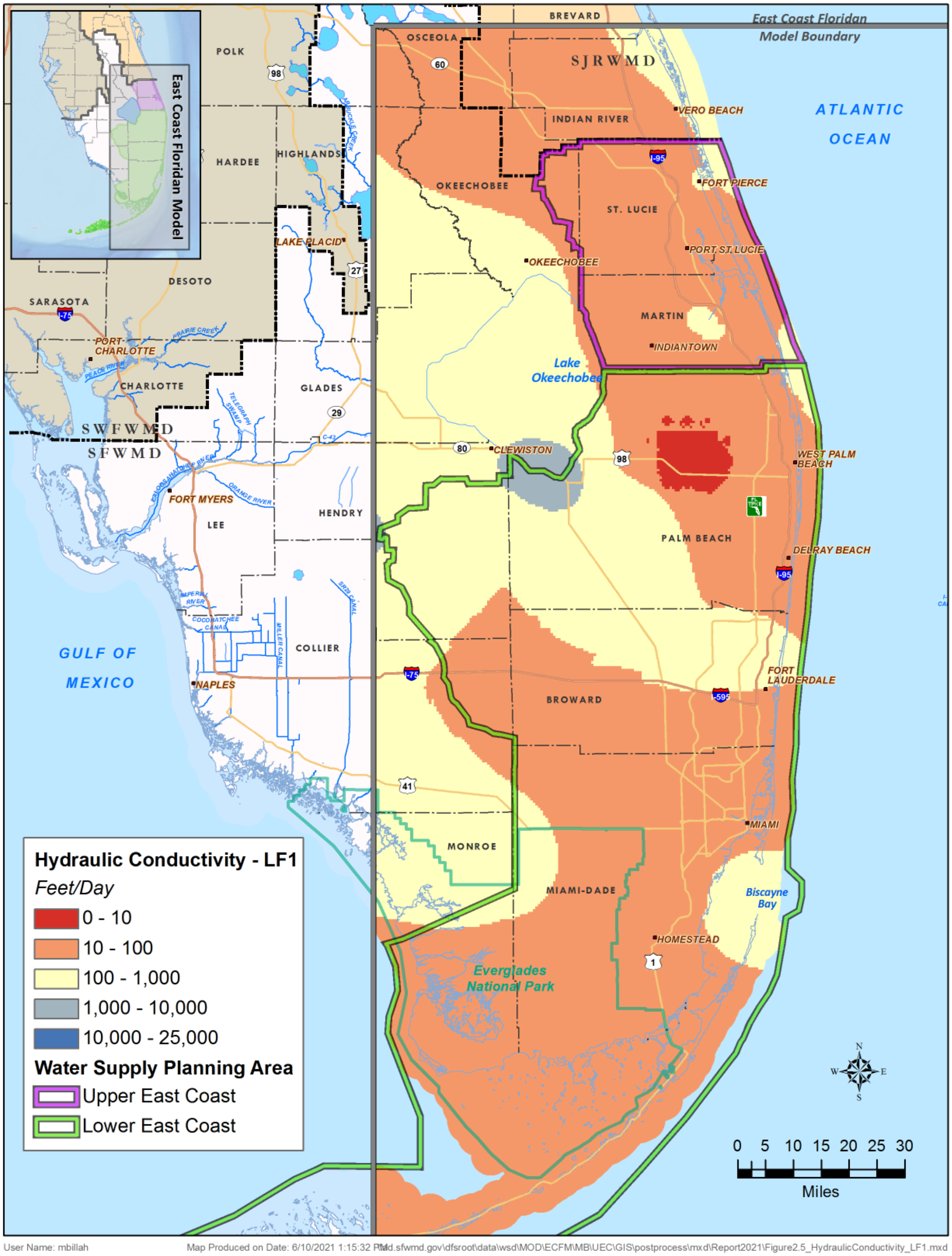

Figure 2-7. Distribution of horizontal hydraulic conductivity in the Lower Floridan aquifer – first permeable zone.

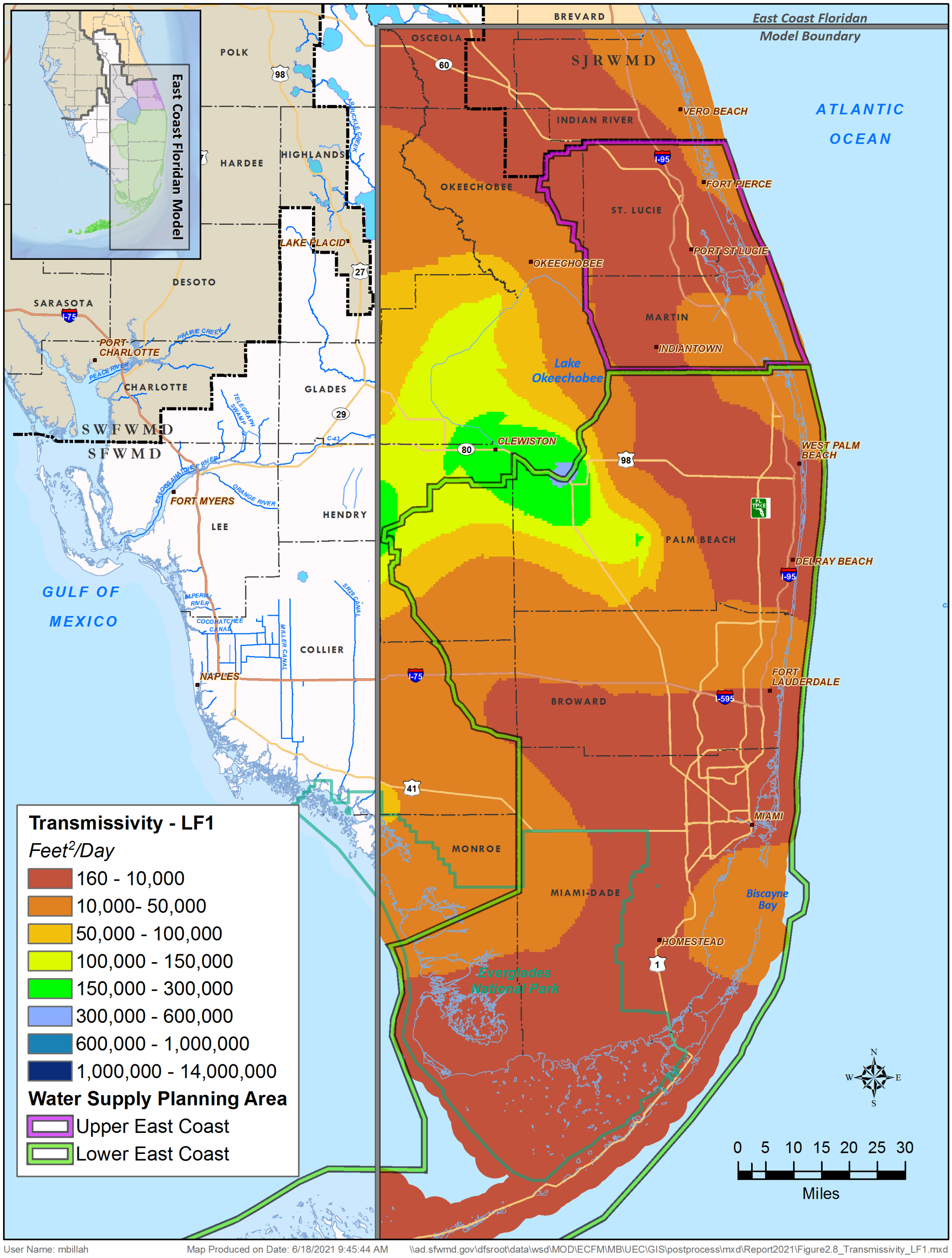

Figure 2-8. Distribution of transmissivity in the Lower Floridan aquifer – first permeable zone.

3 MODEL RE-CALIBRATION

3.1 Boundary Conditions

Model boundary conditions are used to control water entering and leaving the model domain and are engineered to be consistent with the conceptual model of the groundwater flow system. Boundary conditions are required to establish a regional flow gradient across the model domain. Where possible, boundary conditions coincide with natural elements (e.g., rivers, lakes, oceans, outcrops, regional flow fields). For example, one boundary is along the edge of the model where active and inactive cells meet and is simulated with the general head boundary (GHB) package. In the ECFM, water generally enters the system from the northwest corner of the model domain as areal recharge and exits at the offshore outcrops of the hydrostratigraphic units along the eastern and southern boundaries of the model domain (Giddings et al. 2014). The boundary conditions for water levels were adjusted between 0.25 and 1.0 ft at the west boundary in Highlands and Osceola counties to re-calibrate water levels in wells near that boundary.

3.2 Calibration Targets

Monitoring wells that measured water levels and/or water quality data were considered as calibration targets. The observation data at the target locations were compared with simulated heads (water levels) and total dissolved solids (TDS) concentrations (water quality) for the calibration period (1989 to 2012). The goal of the calibration process was to match the model's simulated heads and TDS concentrations to the observed data at the target locations.

The observed time-series data were collected and organized from numerous sources, notably the United States Geological Survey, Florida Department of Environmental Protection, and SFWMD. The ECFM considered 143 targets with monthly data for water levels and 208 targets for TDS concentrations. Of those target wells, 48 water level target wells and 66 water quality target wells were within the UEC Planning Area (**Table 3-1**; **Figures 3-1** and **3-2**).

Table 3-1. Monitoring wells with water level and water quality data within the East Coast Floridan Model domain and Upper East Coast Planning Area.

Aquifer	Water Level Monitoring Wells		Water Quality Monitoring Wells	
	ECFM Domain	UEC Planning Area	ECFM Domain	UEC Planning Area
UFA	110	42	102	37
APPZ	27	5	63	16
LF1	6	1	43	13
Total	**143**	**48**	**208**	**66**

APPZ = Avon Park permeable zone; ECFM = East Coast Floridan Model; LF1 = Lower Floridan aquifer – first permeable zone; UEC = Upper East Coast; UFA = Upper Floridan aquifer.

Some spatial and temporal data variability was expected for water level and TDS concentration observations. Spatially, the water level observations were mainly inland, whereas water quality observations were primarily along the coastline. On a temporal scale, monthly observations over the entire calibration period were not available for all monitoring wells. Some monitoring wells measured water level or water quality data early in the calibration period, while some monitoring wells measured data later in the calibration period. A few monitoring wells only collected seasonal water level or water quality data as part of separate projects and after completion of the project, water level or water quality were no longer monitored. Additionally, different sampling personnel and laboratories were involved in collecting and analyzing water quality data over the years. These variations in the data quality were considered when evaluating the accuracy of the model calibration, and a few calibration targets for water levels and TDS concentrations were excluded from the calibration (**Appendix B**). Insufficient observation data during the calibration period, inconsistent data within the aquifer, and proximity to nearby calibration targets with sufficient observations were factors for removal of some calibration targets. In some cases, when more than one calibration target was identified in one model grid cell, only the calibration target with the longest period of data or with more reliable data was kept. In addition, some water level and TDS concentration data were removed due to erroneous measurements (**Appendix B**).

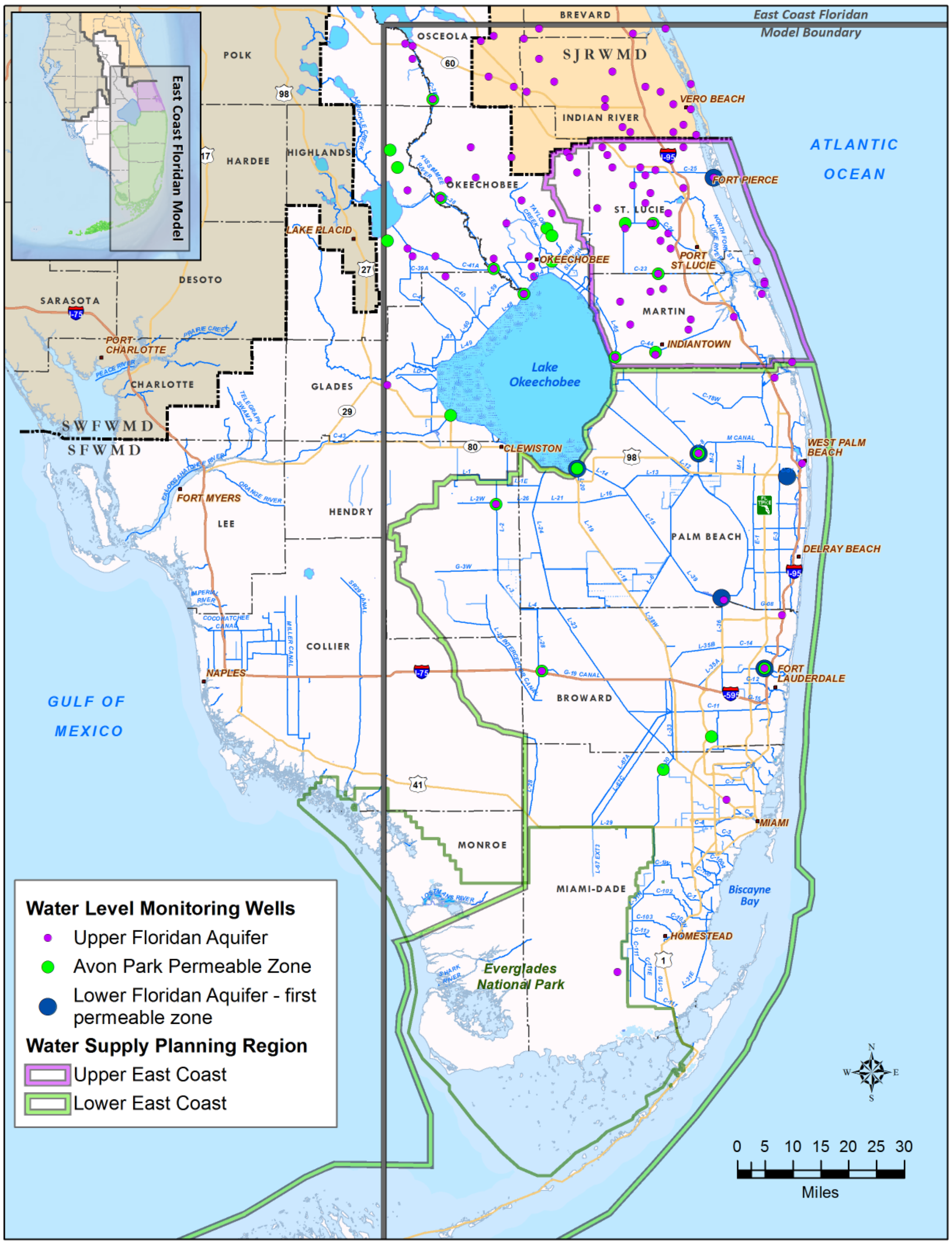

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Figure 3-1. Location of water level monitoring wells used for model calibration.

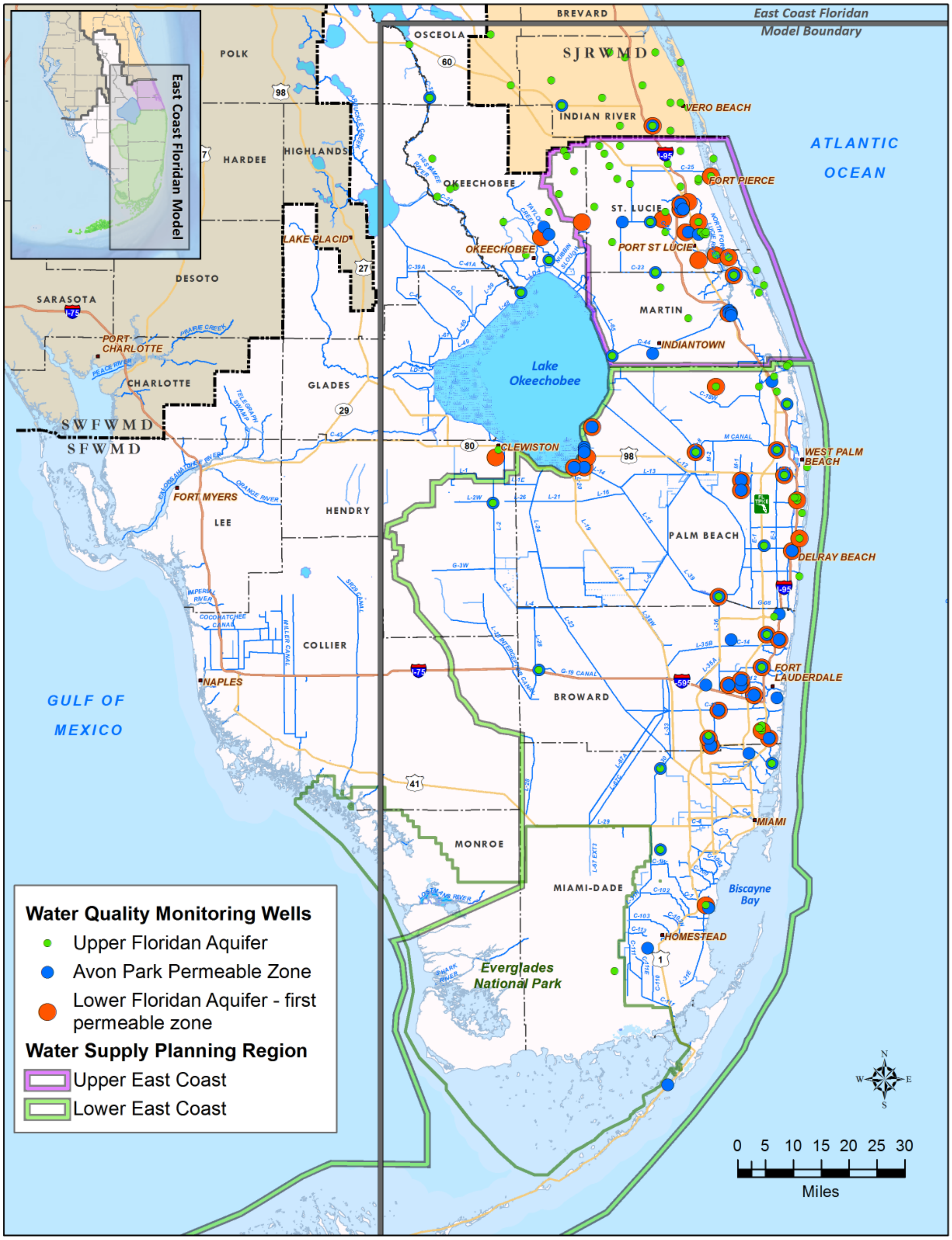

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Figure 3-2. Location of water quality monitoring wells used for model calibration.

3.3 Calibration Criteria

The ECFM's performance in matching historical conditions was evaluated by comparing simulated heads and TDS concentrations with observed values. Statistics of the errors and tolerance (or interval) criteria were used to objectively assess goodness of fit of the simulated behavior to the observed data. The monthly average heads and TDS concentrations from 1989 to 2012 were used to calibrate the transient model in the respective aquifers. The average monthly calibration criteria were used for the calibration targets in the UFA, APPZ, and LF1 aquifers. The comparison statistics served as benchmarks to evaluate successful transient calibration.

Residual statistics often are used to quantify the quality of model calibration (Anderson and Woessner 1992). The statistics criteria used for calibration were mean error (ME), mean absolute error (MAE), and root mean square error (RMSE). The ME indicated whether simulated values were overestimated or underestimated compared to historical measurements. This model calibration metric indicates the presence of systemic error in model predictions, showing values that deviate from the measured values by a consistent amount and in a consistent direction. The MAE was calculated using the absolute value of the error for each observation during the transient run and estimated the average error in the model. The RMSE, or standard error, provided an overall indication of the magnitude of a typical error. The closer the RMSE is to zero, the better the model simulates temporal changes.

Statistics calculations at each water level observation site included:

- ME: Mean of the difference between calculated and observed values

$$ME = \frac{1}{n}\sum_{i=1}^{n}(X_i - Y_i)$$

  where, n = number of data points, Xi = observation data points, and Yi = simulation data points.

- MAE: Mean of the absolute value of the residuals

$$MAE = \frac{1}{n}\sum_{i=1}^{n} ABS(X_i - Y_i)$$

  where, n = number of data points, Xi = observation data points, and Yi = simulation data points.

- RMSE: Measure of the standard deviation of the residuals

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_i - Y_i)^2}{n}}$$

  where, n = number of data points, Xi = observation data points, and Yi = simulation data points.

- ± Interval band or nominal error: Percentage of time when the simulated head is within a "desirable" band of the observed head for each observation site

Scatter plots (with accuracy interval criteria) and statistics were used to evaluate the performance of the ECFM calibration. Scatter plots were generated using observed versus simulated water levels and TDS concentrations. The plots were used to identify zones and points in the model that displayed anomalies as well as outliers, if present.

Specific water level calibration target criteria for the ECFM included the ME for each aquifer, with a target criterion of less than 1 ft for the combination of all wells; an RMSE of less than 4 ft from all wells within each aquifer; and an MAE within 5% of the total water level elevation range for each aquifer. Additionally, 80% of the mean absolute simulated water level residuals for each aquifer had to be within 2 ft of the observed value, and 90% of the mean absolute simulated water level residuals for all wells had to be within 4 ft of the observed values. These calibration criteria are similar to those applied in other regional modeling efforts and reflect the natural variability of water levels observed in the aquifers.

Jacobs et al. (2011) recommended broad salinity categories, which were used to provide a general understanding of the water quality calibration robustness. The outer error bands represent the minimum and maximum TDS concentration values for each category. For water quality, the interval calibration criteria bands were defined as ±500, ±750, ±3,000, and ±4,000 milligrams per liter (mg/L) of the observed values, depending on the TDS value and aquifer unit. The interval criteria were more restrictive in the UFA and less restrictive in deeper aquifers or when the TDS values were higher, which was in line with the 2014 ECFM (Giddings et al. 2014). It is generally acceptable to have higher uncertainty with higher TDS values (>10,000 mg/L) because its potential as a future source for water supply is limited. The selected water quality calibration criteria are listed on **Table 3-2**.

Table 3-2. Summary of calibration criteria for water quality (total dissolved solids) in the East Coast Floridan Model.

Criterion	Fresh to Brackish Water		Moderately Saline	Saline Water
Observed TDS (mg/L)	0 – 4,000	4,000 – 10,000	10,000 – 18,000	>18,000
Calibration Error Band (mg/L)	±500	±750	±3,000	±4,000

mg/L = milligrams per liter; TDS = total dissolved solids.

Using the above criteria, the overall ME for each well was evaluated within the designated interval criteria. However, 80% of the water quality monitoring wells in each aquifer were required to meet the MAE criterion.

3.4 Calibration Results

The calibration results were based on 143 water level and 208 water quality calibration targets.

3.4.1 Water Level and Water Quality Summary

Tables 3-3 and **3-4** summarize the calibration statistics of the ECFM. The desired 80% and 90% minimum error criteria were achieved for water levels as well as the ME for each aquifer and RMSE for all wells within each aquifer. The desired water quality criteria of 80% per aquifer was achieved for the UFA, LF1, and all aquifers combined.

Table 3-3. Summary of calibration statistics for water levels.

Aquifer	Number of Well Sites	Average Head Elevation (ft)	Mean Error (ft)	MAE (ft)	5% of Average Elevation Head (ft)	RMSE (ft)	MAE Within 2.0 ft	MAE Within 4.0 ft	RMSE Within 4.0 ft
UFA	110	43.51	-0.13	1.25	2.2	1.39	90%	100%	100%
APPZ	27	48.17	-0.27	1.04	2.4	1.19	96%	100%	100%
LF1	6	16.99	0.27	1.16	0.85	1.43	83%	100%	100%
All Aquifers	**143**	**36.22**	**-0.13**	**1.21**	**1.82**	**1.35**	**91%**	**100%**	**100%**

APPZ = Avon Park permeable zone; ft = foot; LF1 = Lower Floridan aquifer – first permeable zone; MAE = mean absolute error; RMSE = root mean square error; UFA = Upper Floridan aquifer.

Table 3-4. Summary of calibration statistics for water quality.

Aquifer	Number of Well Sites	Simulated Average (mg/L)	Observed Average (mg/L)	Calibration Criteria (mg/L)	Mean Average Difference (mg/L)	Mean Absolute Average Difference (mg/L)	Percent Met Criteria
UFA	102	2,321	2,376	500 – 750	32	251	90%
APPZ	63	5,190	5,858	500 – 4,000	549	1,012	73%
LF1	43	27,234	27,258	3,000 – 4,000	-384	2,344	84%
All Aquifers	**208**	**8,340**	**8,575**	**500 – 4,000**	**102**	**914**	**84%**

APPZ = Avon Park permeable zone; LF1 = Lower Floridan aquifer – first permeable zone; mg/L = milligrams per liter; UFA = Upper Floridan aquifer.

3.4.2 Water Level Statistics

Table 3-5 shows the simulated and observed minimum, average, and maximum water levels for each aquifer during the simulation period. Although the minimum and maximum observed water levels were not simulated within 1 ft for each aquifer (except minimum values in the APPZ), the average water levels were simulated within less than 0.5 ft. **Table 3-6** shows the percentage of records (observed versus simulated) within the desired error limit for the UFA, APPZ, and LF1. For all the aquifers, more than 80% of the records were within the ±2.0 ft error limit, and more than 98% of the records were within the ±4.0 ft error limit.

Table 3-5. Summary of simulated and observed water levels.

Aquifer	Observed (ft)			Simulated (ft)		
	Minimum	Average	Maximum	Minimum	Average	Maximum
UFA	25.11	43.51	67.65	21.86	43.76	79.99
APPZ	37.77	48.17	60.81	37.63	48.60	58.93
LF1	7.07	16.99	42.02	5.89	16.72	40.84

APPZ = Avon Park permeable zone; ft = foot; LF1 = Lower Floridan aquifer – first permeable zone; UFA = Upper Floridan aquifer.

Table 3-6. Percentage of water level observations within the interval criteria.

Aquifer	Number of Records	% of Records Within ±2.0 Feet	% of Records Within ±4.0 Feet
UFA	6,615	84%	98%
APPZ	1,889	90%	~100%
LF1	502	85%	99%

APPZ = Avon Park permeable zone; LF1 = Lower Floridan aquifer – first permeable zone; UFA = Upper Floridan aquifer.

The calibration criteria were based on individual well performance, with each well given an equal weight regardless of the number of observation points after the wells were filtered to meet the minimum requirements. In addition, scatter plots were generated to display overall performance and identify anomalies, if present. **Figures 3-3**, **3-4**, and **3-5** illustrate scatter plots for computed versus observed water levels in the UFA, APPZ, and LF1, respectively. The coefficient of determination (R^2) was used to understand the relationship between observed and simulated water levels.

The coefficient of determination (R^2) was calculated for each well using the following equation:

$$R^2 = \frac{\sum_{i=1}^{n}(Y_i - \bar{x})^2}{\sum_{i=1}^{n}(X_i - \bar{x})^2}$$

where, n = number of data points, Xi = observation data points, Yi = simulation data points, and $\bar{x}$ = mean of the observation points.

The R^2 was 0.93 for the UFA, 0.96 for the APPZ, and 0.99 for the LF1. The average R^2 value for all wells was 0.94. These high R^2 values indicated water level variation in the simulation was very close to the observed water level variation.

The UFA scatter plot in **Figure 3-3** indicates 2,762 of 3,350 (82%) observed water level values from 25 to 45 ft and 2,801 of 3,265 (86%) values from 45 to 70 ft were within the ±2.0 ft interval criteria. Furthermore, 98% of observed water level values were within the ±4.0 ft interval criteria. A summary of these water level values and statistics is shown in **Table 3-6**. Clusters of points outside the ±4.0 ft interval occurred at monitoring wells IRF-JOHN, IRF-USDA, and IRF-MACE in Indian River County, possibly due to pumpage reporting issues, and at well PBF-14 in Palm Beach County because the response to the injection and recovery cycling associated with aquifer storage and recovery testing was not fully realized.

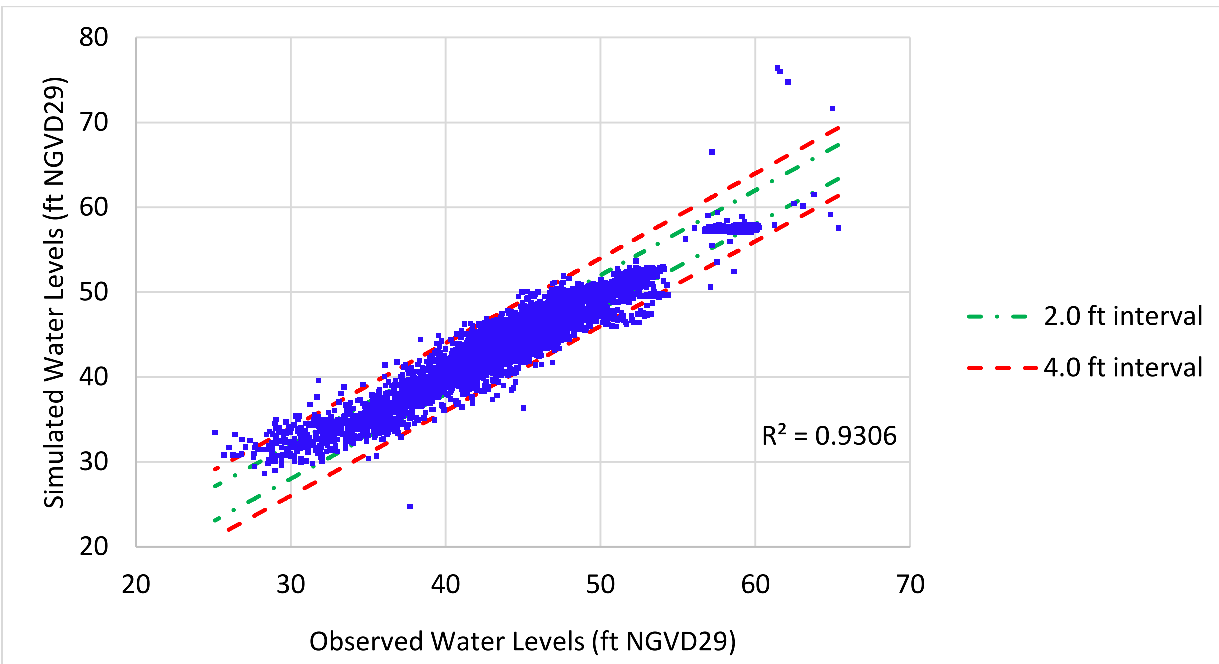


Figure 3-3. Observed versus simulated water levels in the Upper Floridan aquifer.

The APPZ scatter plot in **Figure 3-4** indicates 352 of 416 (85%) observed water level values from 35 to 45 ft and 1,349 of 1,473 (92%) values from 45 to 65 ft were within the ±2.0 ft interval criteria. Furthermore, almost 100% (1,881 of 1,889) of observed water level values were within the ±4.0 ft interval criteria. A summary of these water level values and statistics is shown in **Table 3-6**. The clusters of points outside the ±2.0 ft interval criteria at well G-2617 in Broward County may be due to initial conditions, and well PBF-15M in Palm Beach County is a tri-zone monitoring well, suggesting a potential issue unrelated to the model.

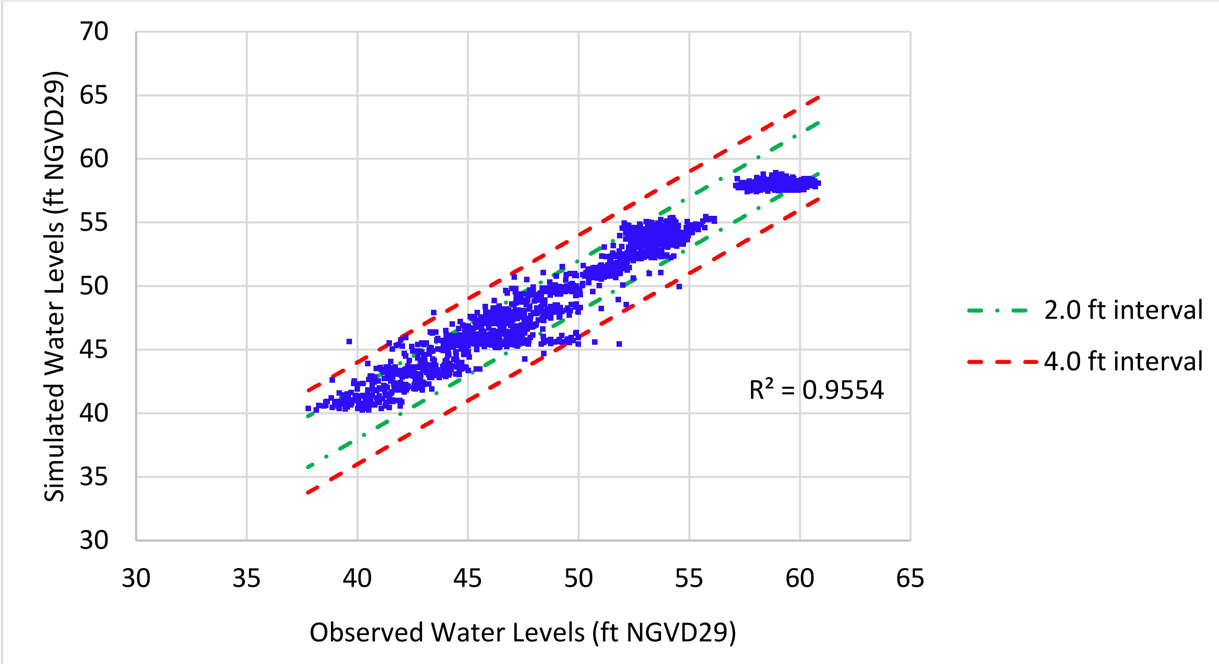


Figure 3-4. Observed versus simulated water levels in the Avon Park permeable zone.

The LF1 scatter plot in **Figure 3-5** indicates 302 of 371 (81%) observed water level values from 5 to 20 ft and 125 of 131 (95%) values from 20 to 45 ft were within the ±2.0 ft interval criteria. Furthermore, 99% of observed water level values were within the ±4.0 ft interval criteria; most of which were from BF-1 in Broward County. A summary of these water level values and statistics is shown in **Table 3-6**.

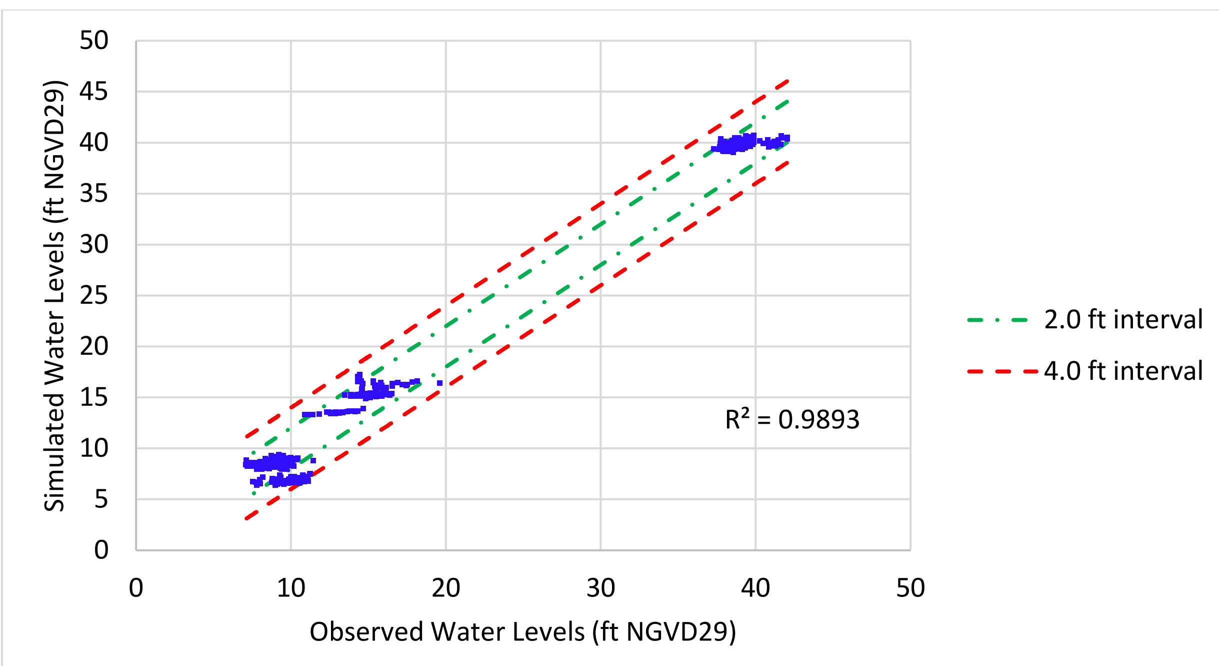
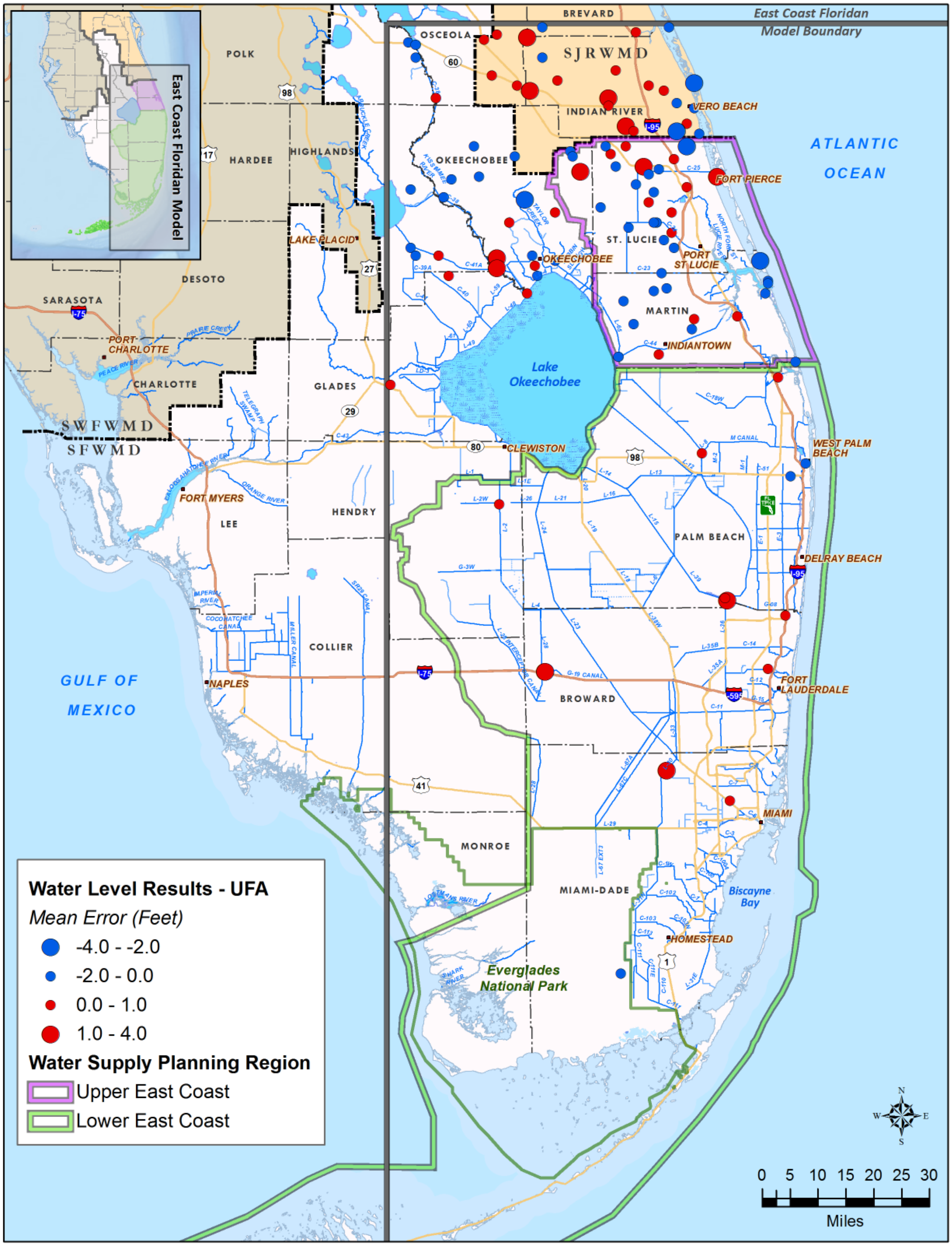


Figure 3-5. Observed versus simulated water levels in the Lower Floridan aquifer – first permeable zone.

Tables C-1, C-2, and C-3 of **Appendix C** summarize the water level calibration statistics for each observation site in the UFA, APPZ, and LF1, respectively. For all aquifers combined, the ME was -0.13 ft, the MAE was 1.15 ft, and the RMSE was 1.35 ft. The interval criteria for all wells indicate 91% of the wells have an ME within ±2.0 ft, and 100% of the wells have both the ME and RMSE within ±4.0 ft. Although combined statistics for all wells was not a necessary calibration criterion, the global statistics meet the requirements.

Figures 3-6, **3-7**, and **3-8** show the spatial distribution of average ME in each water level monitoring well in the UFA, APPZ, and LF1, respectively. Blue dots represent wells where average simulated water levels were higher than average historical water levels, indicating the wells were overpredicting in the model. Red dots represent wells where average simulated water levels were lower than average historical water levels, indicating the wells were underpredicting in the model. Dot size is proportional to the error at each point. Water level monitoring wells in the UFA were primarily located in the northern portion of the model domain, corresponding to where there is greater use of the UFA as a water supply source. Analysis of **Figure 3-6** indicated no clusters of wells with a large ME in the UFA. The model also showed no spatial bias towards overpredicting or underpredicting historical water levels. Compared to the UFA, there were substantially fewer monitoring wells within the APPZ, and the wells were evenly distributed across the model domain. This supports the UFA being the primary water supply source in the area. Analysis of **Figure 3-7** indicated no clusters of wells with a large ME in the APPZ. The wells appeared to slightly overpredict APPZ water levels within the UEC Planning Area. There were only six monitoring wells within the LF1 (**Figure 3-8**). Due to the low number of wells, spatial distribution for well clustering was not justifiable.



User Name: mbillah Map Produced on Date: 5/3/2021 4:34:41 PM \\ad.sfwmd.gov\dfsroot\GS\GSBiz\WS\ECFM\2021Report\mxd\Figure19_WaterLevelMeanError_UFA.mxd

Figure 3-6. Spatial distribution of mean error for water level monitoring wells in the Upper Floridan aquifer.

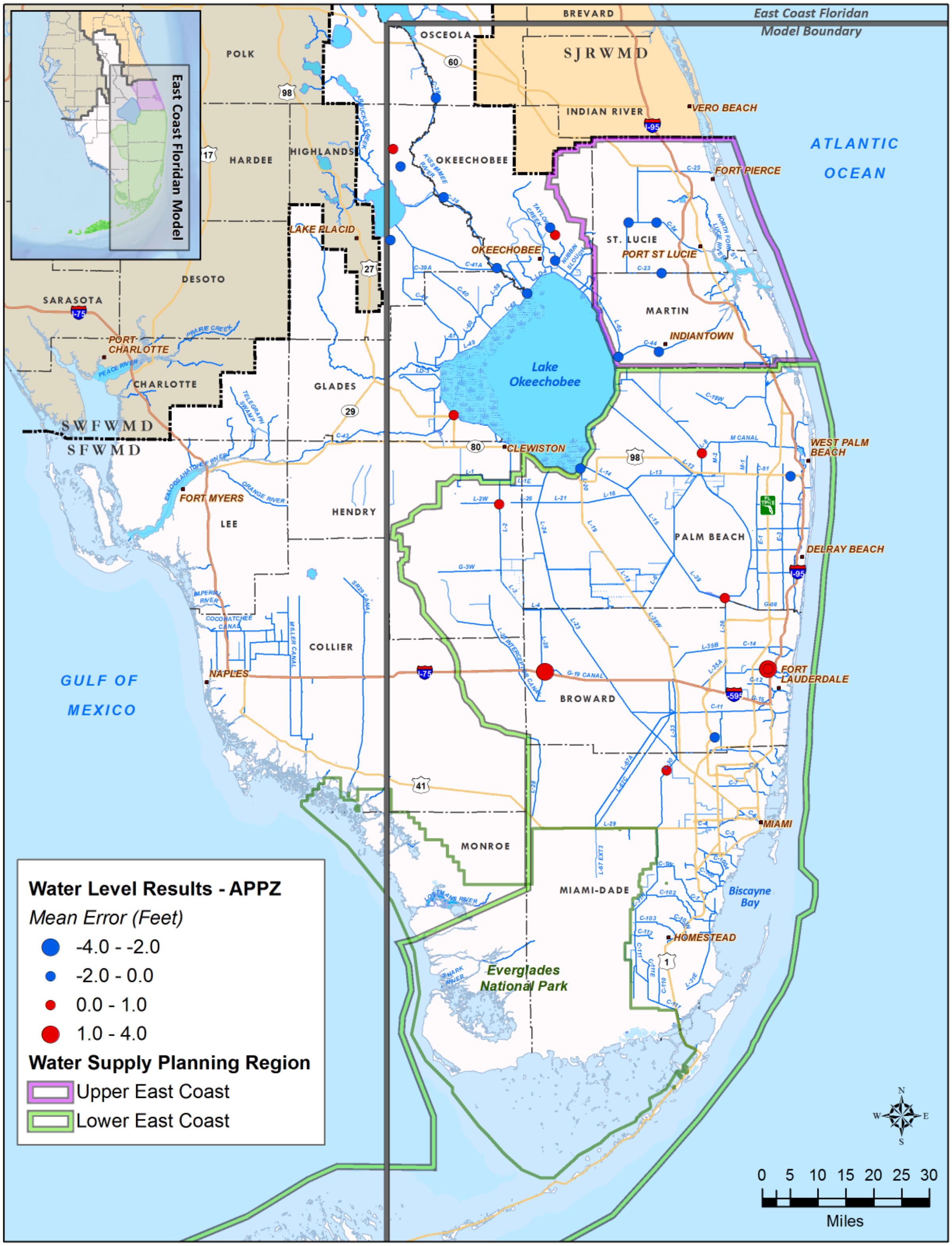


Figure 3-7. Spatial distribution of mean error for water level monitoring wells in the Avon Park permeable zone.

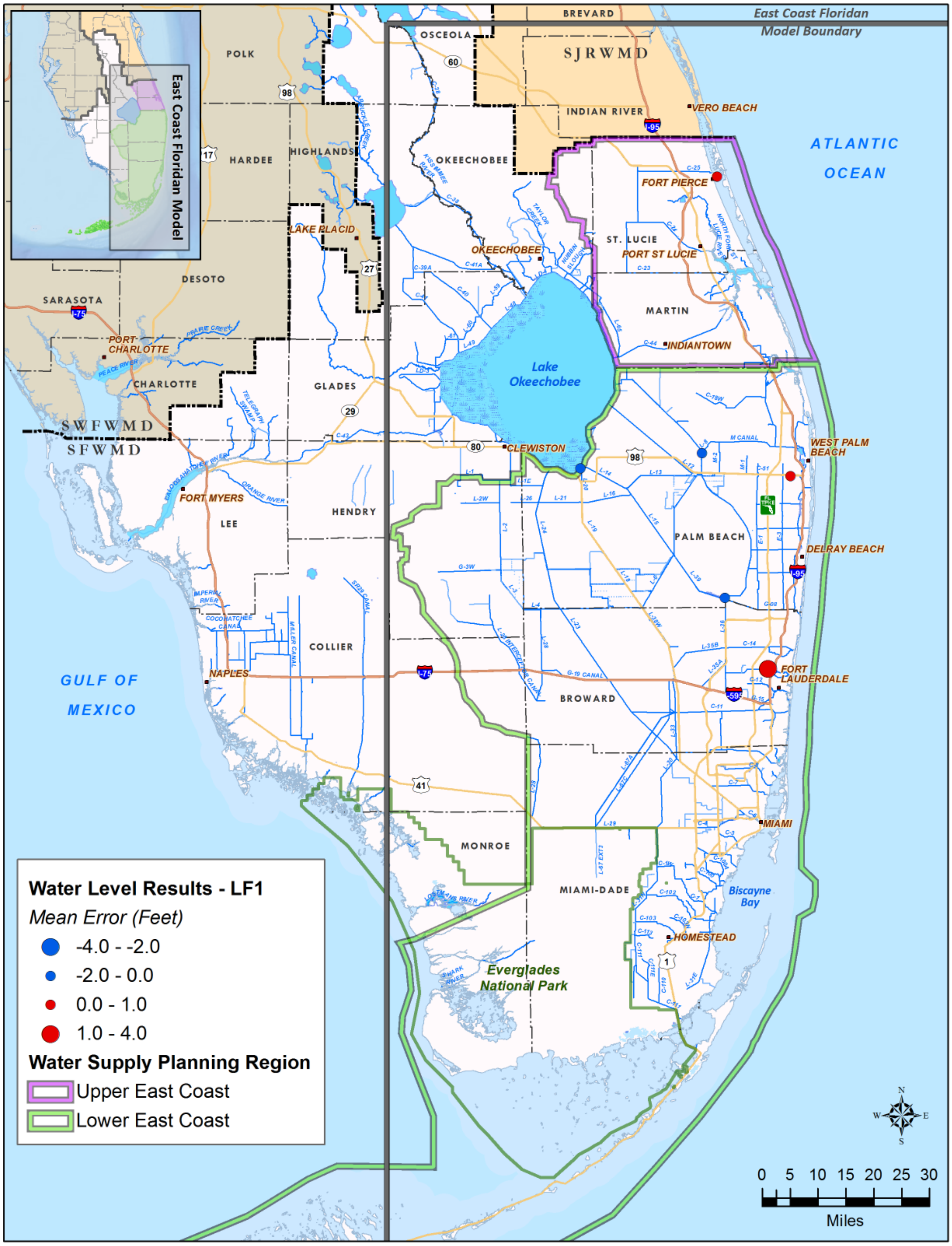


Figure 3-8. Spatial distribution of mean error for water level monitoring wells in the Lower Floridan aquifer – first permeable zone.

3.4.3 Water Quality Statistics

Table 3-7 shows the simulated and observed minimum, average, and maximum water quality values (i.e., TDS concentrations) for each aquifer during the simulation period. The UFA minimum, maximum, and average observed TDS concentrations were 185 mg/L, 8,780 mg/L, and 2,382 mg/L, respectively, indicating a fresh to brackish water environment. The APPZ minimum, maximum, and average observed TDS concentrations were 200 mg/L, 38,673 mg/L, and 5,858 mg/L, respectively, indicating greater water quality variability. The LF1 minimum, maximum, and average observed TDS concentrations were 7,967 mg/L, 42,900 mg/L, and 27,260 mg/L, respectively, suggesting primarily saltwater conditions.

Table 3-7. Summary of simulated and observed water quality values (total dissolved solids concentrations).

Aquifer	Observed (mg/L)			Simulated (mg/L)		
	Minimum	Average	Maximum	Minimum	Average	Maximum
UFA	185	2,382	8,780	201	2,321	8,400
APPZ	200	5,858	38,673	220	5,189	20,251
LF1	7,967	27,260	42,900	11,102	27,632	35,000

APPZ = Avon Park permeable zone; LF1 = Lower Floridan aquifer – first permeable zone; mg/L = milligrams per liter; UFA= Upper Floridan aquifer.

The minimum TDS concentrations were well simulated in the UFA and APPZ, while the maximum TDS concentration was well simulated only in the UFA. The minimum and maximum TDS concentrations were not well simulated in the LF1. The average TDS concentrations were well simulated in the UFA and LF1, while simulated TDS concentrations in the APPZ showed a difference of 700 mg/L compared with observed values. This indicated APPZ wells were not as well simulated as those in the UFA and LF1. **Table 3-8** shows the percentage of records (observed versus simulation) within the desired error limit for the UFA, APPZ, and LF1 aquifers. UFA records met the calibration criteria with 89% records within the desirable error interval. The statistics for the APPZ and LF1 show that records in the LF1 are closer to meeting the calibration criteria than the APPZ records. This was also the case for the average simulated values.

Table 3-8. Percentage of total dissolved solids observations within the interval criteria.

Aquifer	Number of Records	Desirable Interval Criteria (mg/L)	% of Records Within Desirable Interval
UFA	5,029	500 – 750	89%
APPZ	4,304	500 – 4,000	67%
LF1	4,166	3,000 – 4,000	77%

APPZ = Avon Park permeable zone; LF1 = Lower Floridan aquifer – first permeable zone; mg/L = milligrams per liter; UFA= Upper Floridan aquifer.

The scatter plot in **Figure 3-9** shows the observed versus simulated TDS concentrations for all wells in all aquifers. As recommended by Jacobs et al. (2011), a logarithmic transformation of TDS concentrations was applied to show values over several orders of magnitude. Because each point represents the composite values for a well, the plot provides a general understanding of the degree of calibration obtained by the ECFM. The plot indicates that 10,348 of 13,499 (77%) observed TDS concentration values were calibrated within the upper and lower error bands.

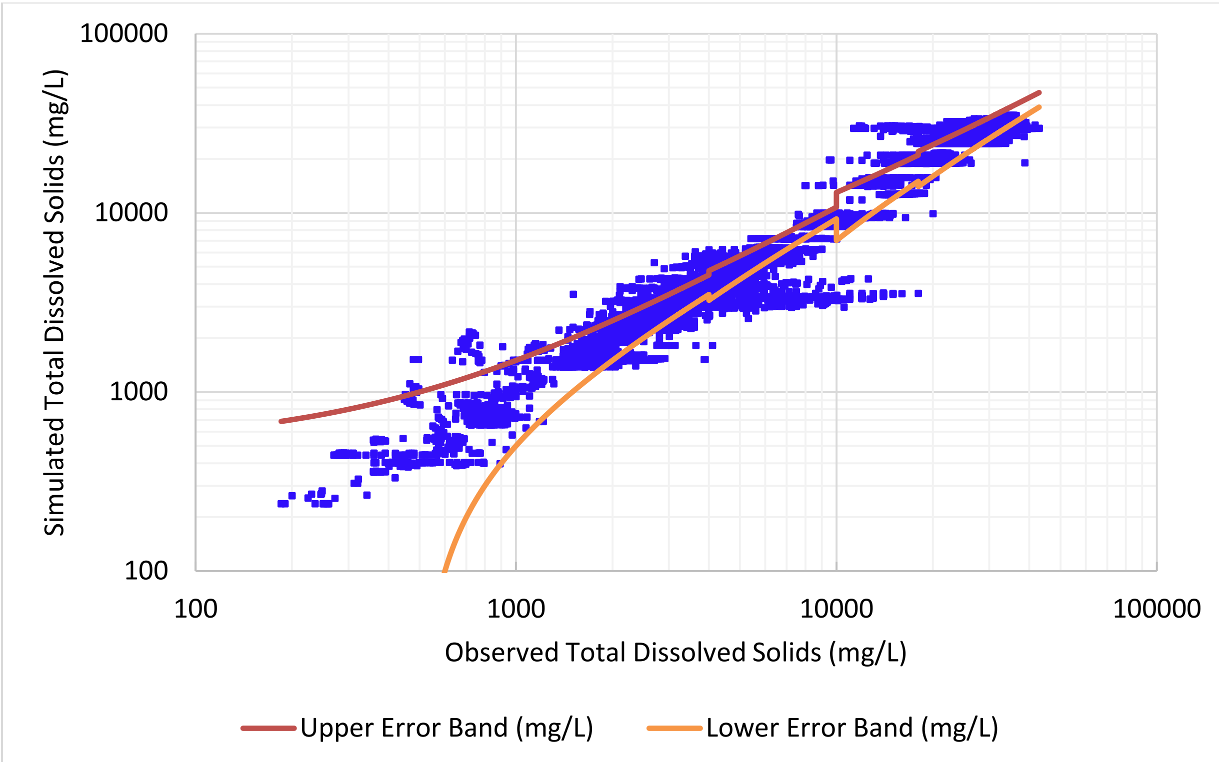


Figure 3-9. Observed versus simulated total dissolved solids concentrations in all aquifers.

Observed TDS concentrations in the UFA generally ranged between 100 and 10,000 mg/L (**Figure 3-10**). For values below 4,000 mg/L, 91% of observed TDS concentrations met the calibration criteria (±500 mg/L). For values between 4,000 and 10,000 mg/L, 86% of observed TDS concentrations met the calibration criteria (±750 mg/L). Of the 5,029 UFA observation points, 89% met the calibration criteria. Also, 92 of 102 UFA observation wells had an MAE less than the interval criterion. A summary of these values and statistics is provided in **Appendix D**. The UFA average ME and MAE values were 32 mg/L and 251 mg/L, respectively. Overall, 89% of the UFA wells were within the calibration criteria.

Observed TDS concentrations in the APPZ generally ranged between 200 and 20,000 mg/L (**Figure 3-11**). For values below 4,000 mg/L, 66% of observed TDS concentrations met the calibration criteria (±500 mg/L). For values between 4,000 and 10,000 mg/L, 71% of observed TDS concentrations met the calibration criteria (±750 mg/L). For values between 10,000 and 18,000 mg/L, 48% of observed TDS concentrations met the calibration criteria (±3,000 mg/L). When values exceeded 18,000 mg/L, 83% of the observed TDS concentrations were within the ±4,000 mg/L range. Of the 4,304 APPZ observation points, 67% met the calibration criteria. In the APPZ, 45 of the 63 APPZ wells had an MAE within the criteria. A summary of these values and statistics is provided in **Appendix D**, Table D-2. The APPZ average ME and MAE values were 549 mg/L and 1,012 mg/L, respectively. Overall, 73% of APPZ wells were within the calibration criteria.

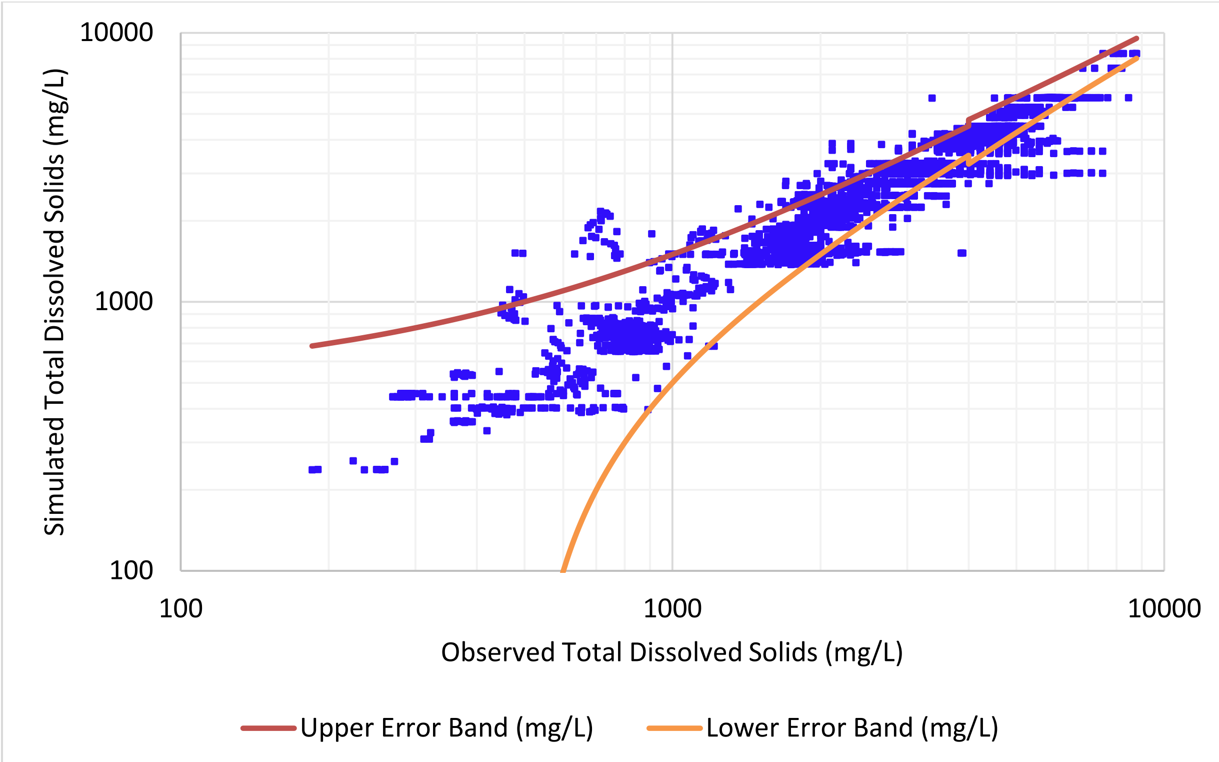


Figure 3-10. Observed versus simulated total dissolved solids concentrations in the Upper Floridan aquifer.

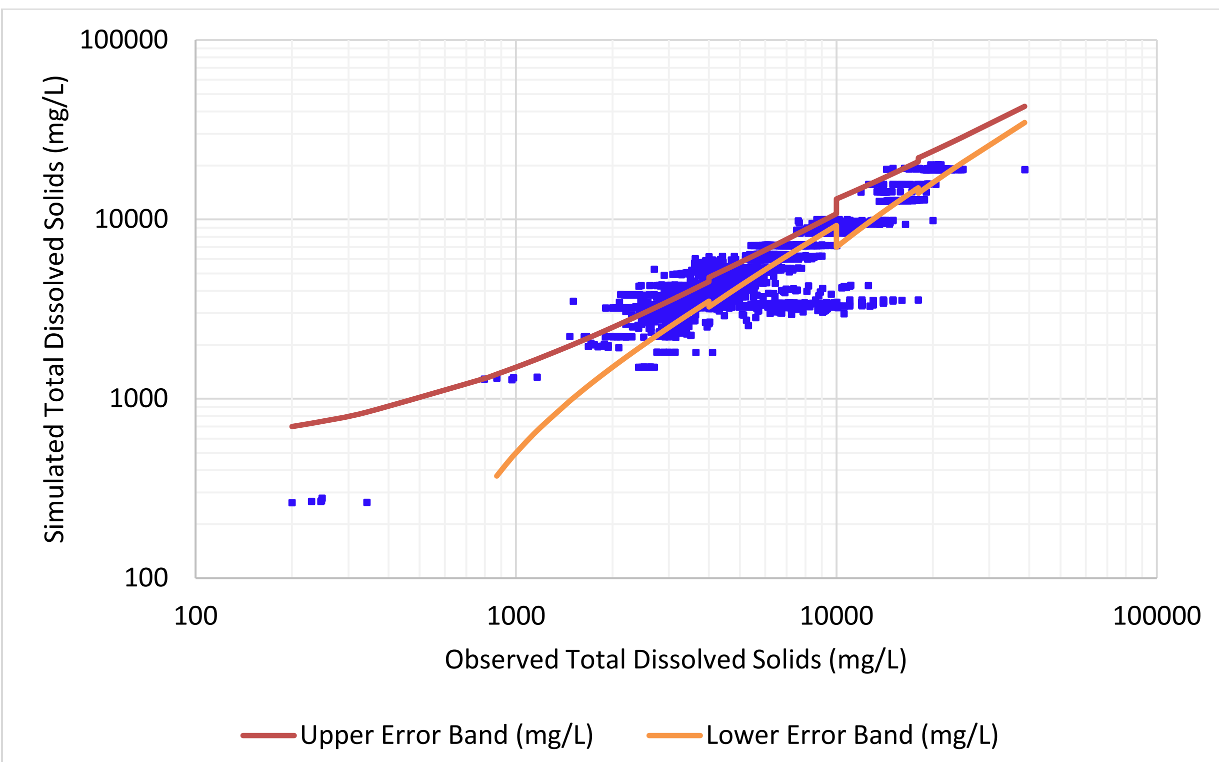


Figure 3-11. Observed versus simulated total dissolved solids concentrations in the Avon Park permeable zone.

Observed TDS concentrations in the LF1 generally were between 8,000 and 43,000 mg/L (**Figure 3-12**). Approximately, 77 of the simulated values met the calibration criteria. Many of the simulated values that did not meet the criteria were associated with hypersaline conditions. Because the purpose of this modeling effort was to evaluate fresh and brackish aquifers from a water supply perspective, it was deemed acceptable for the model to fall short of meeting calibration criteria for extreme (i.e., hypersaline) values. A summary of these values and statistics is provided in **Appendix D**, Table D-3. The LF1 average ME and MAE values were -382 mg/L and 2,344 mg/L, respectively. Overall, 84% of the LF1 wells were within the calibration criteria.

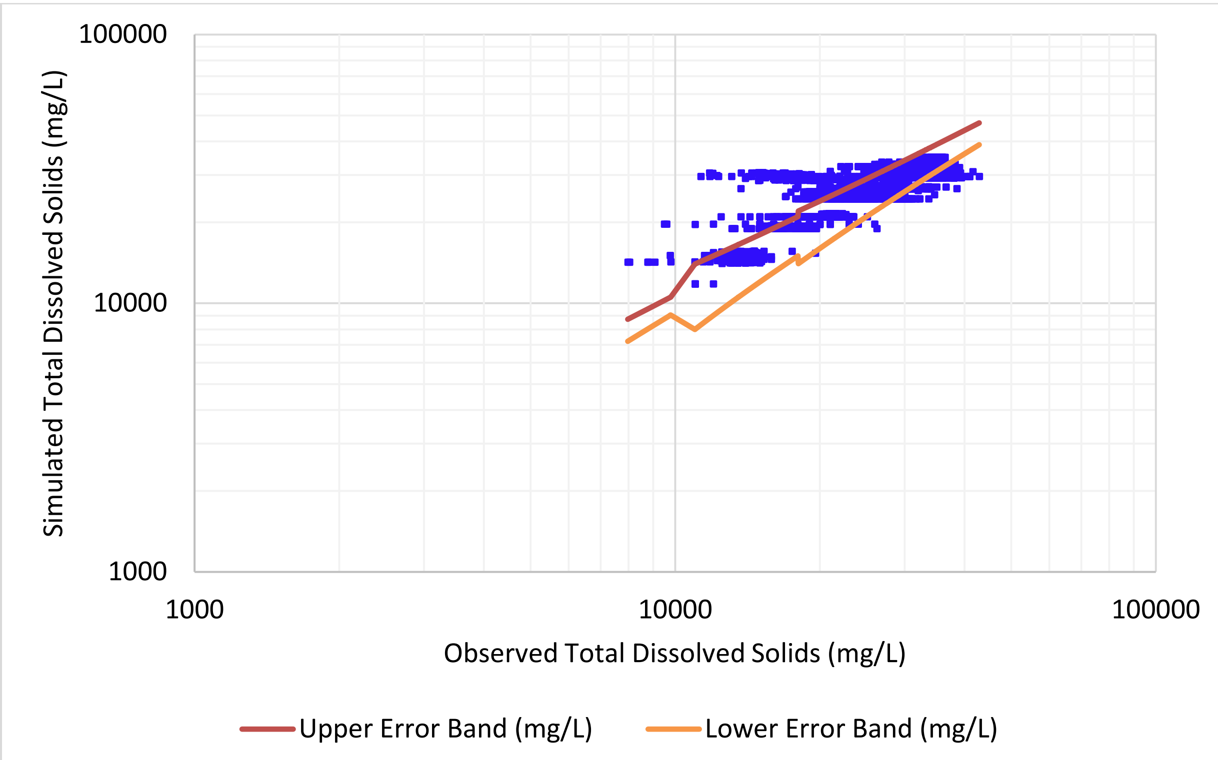


Figure 3-12. Observed versus simulated total dissolved solids concentrations in the Lower Floridan aquifer – first permeable zone.

Figures 3-13, **3-14**, and **3-15** show the spatial distribution of average ME in each water quality monitoring well in the UFA, APPZ, and LF1, respectively. Blue dots represent wells where the average simulated TDS concentrations were higher than the average historical TDS concentrations, indicating the wells were overpredicting in the model. Red dots represent wells where the average simulated TDS concentrations were lower than the average historical TDS concentrations, indicating the wells were underpredicting in the model. **Figure 3-13** shows the spatial distribution of water quality monitoring wells in the UFA. Within the UFA, most wells were calibrated, and no clustering of wells with a large ME appeared in the model domain. The model did not show any spatial bias towards overpredicting or underpredicting historical TDS concentrations. Within the APPZ, most wells met the calibration criteria and came close to meeting the 80% calibration criteria (**Figure 3-14**). The model did not show any spatial bias in overpredicting or underpredicting TDS concentrations within the APPZ. Within the LF1, 82% of monitoring wells met their respective calibration criteria, with no spatial bias in overpredicting or underpredicting TDS concentrations (**Figure 3-15**).

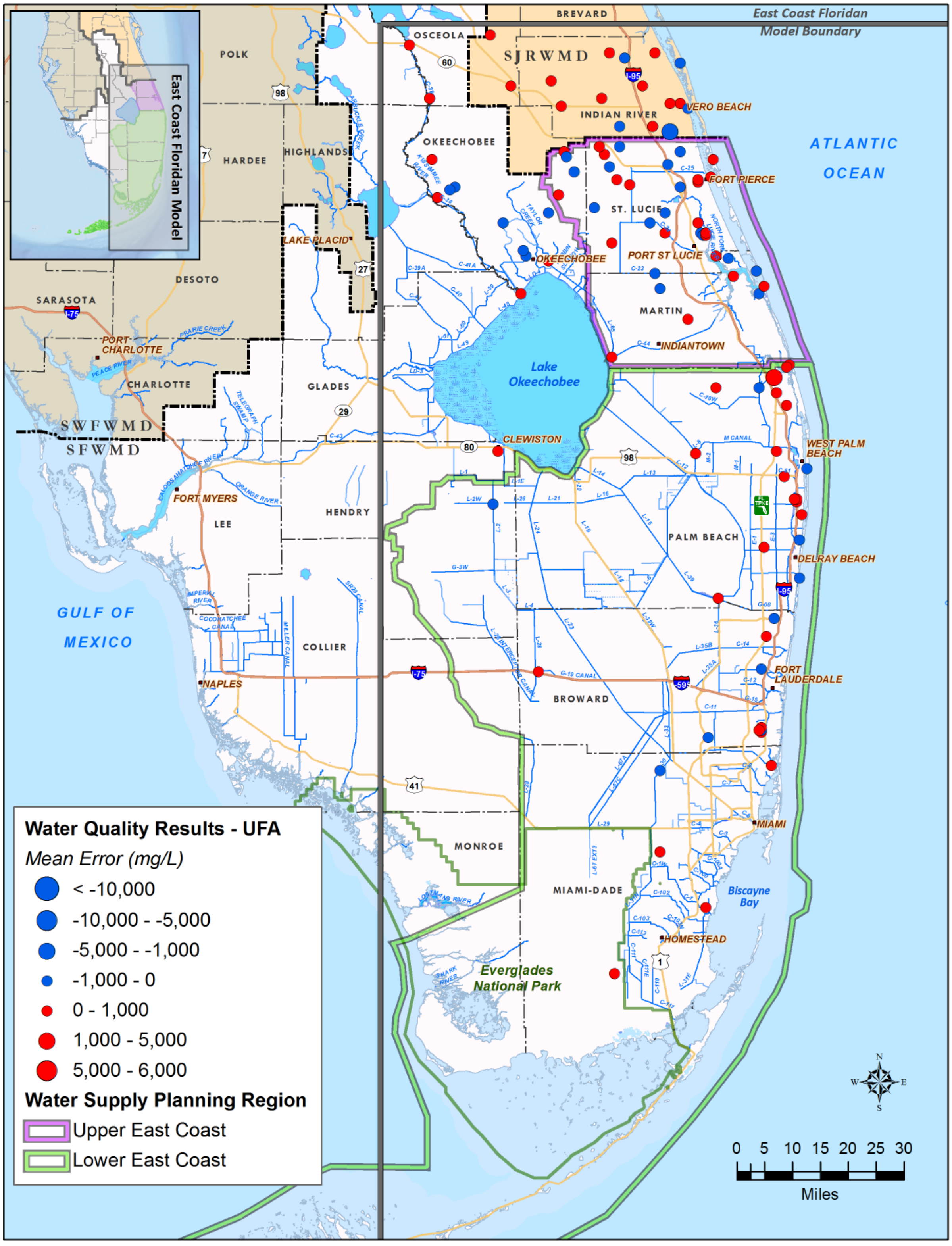


Figure 3-13. Spatial distribution of mean error in water quality monitoring wells in the Upper Floridan aquifer.

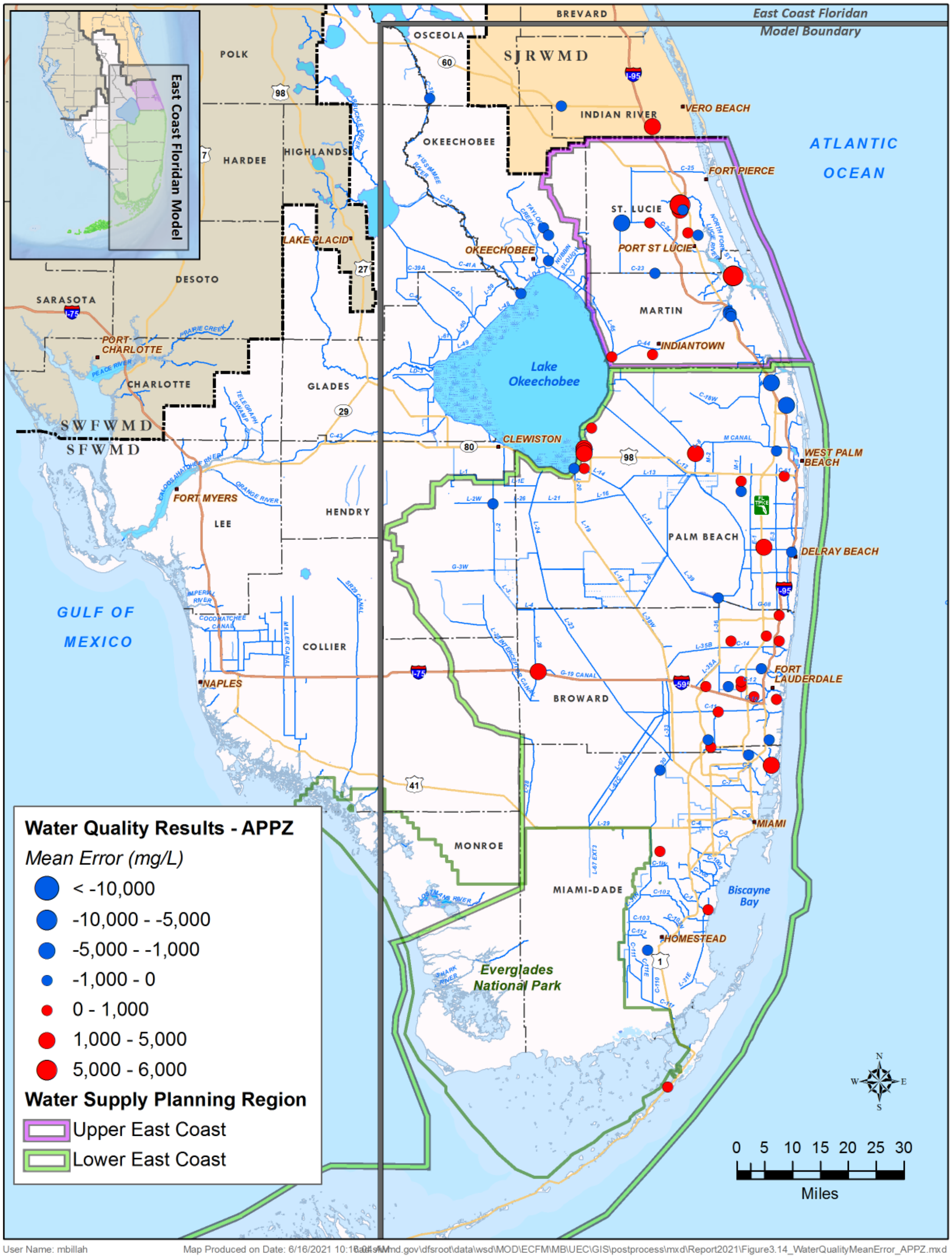


Figure 3-14. Spatial distribution of mean error in water quality monitoring wells in the Avon Park permeable zone.

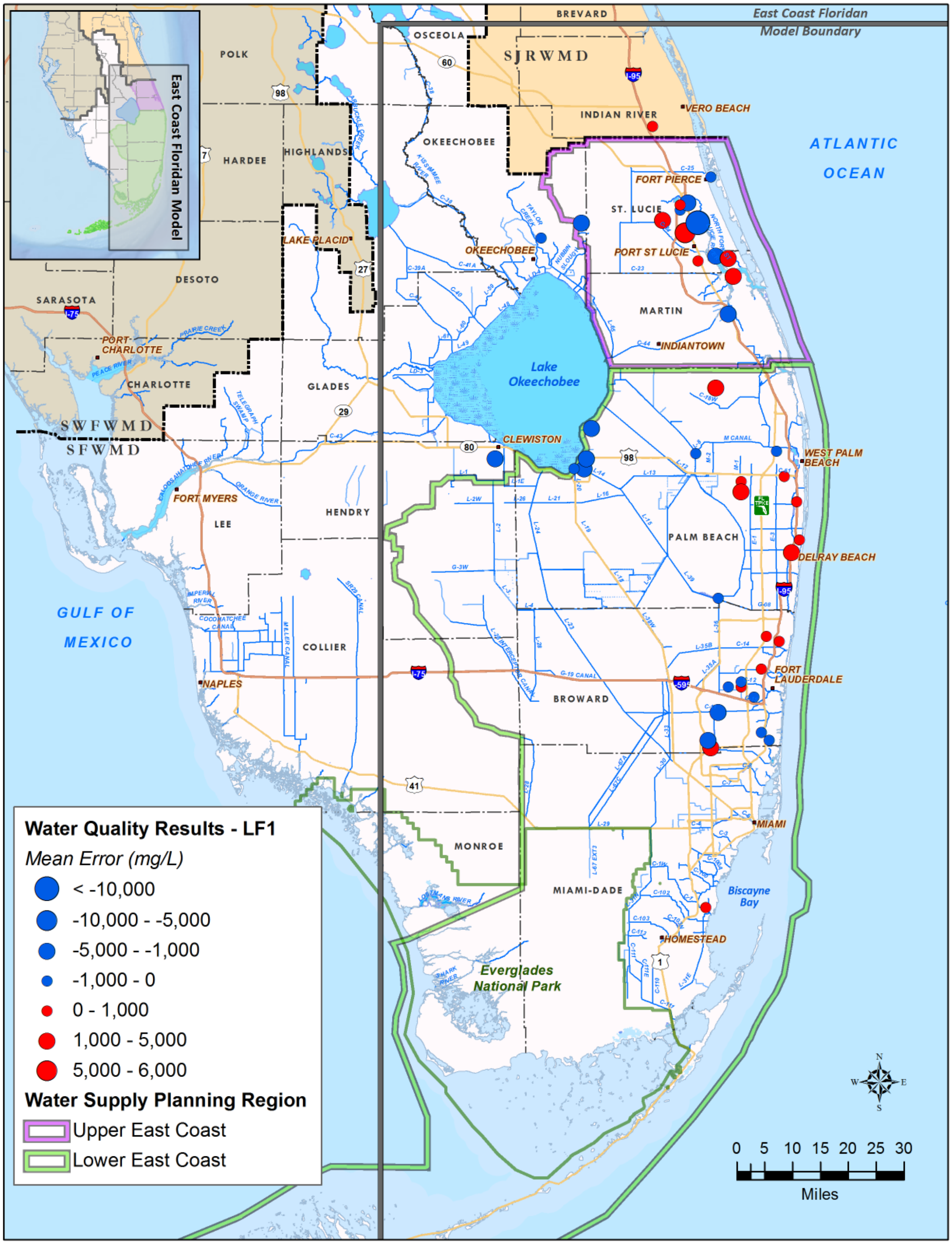


Figure 3-15. Spatial distribution of mean error in water quality monitoring wells in the Lower Floridan aquifer – first permeable zone.

3.5 Water Budget Analysis

There are some interactions between the FAS and the overlying SAS in the extreme northern portion of the model domain (Polk, Osceola, Okeechobee, and Highlands counties), where the model receives areal recharge. The southern and central portions of the model domain experience minimal to no water exchange between the FAS and SAS due to the thick confinement in the Hawthorn Group sediments that separate the two aquifer systems. Besides lateral freshwater recharge entering the model from the boundary conditions, recharge from rainfall is spatially accounted for using the recharge package only in the northwestern corner of the model (**Figure 3-16**; Giddings et al. 2014). The highest annual recharge (9.5 inches per year) was estimated along the western boundary in Highlands County. Annual recharge ranged between 1 and 2.5 inches per year from the northwestern boundary towards Osceola, Okeechobee, and Indian River counties.

The average rainfall for the simulation period was approximately 49.2 inches per year at the Bassinger rain gauge, which is located in the vicinity of the ECFM's primary recharge area. Simulated recharge rates varied monthly based on historical rainfall and spatial locations within topographic zones. The annual average recharge rate in the lowest recharge areas generally were between 0.1 and 1.0 inch per year, with the lower rates occurring in western Okeechobee County. Rates in the intermediate recharge zones of Highlands and Polk counties averaged between 1 and 5 inches per year except along high ridge areas where it could exceed 9 inches per year.

Fluxes into the model were determined by the conductance term of the general head boundary, the head of the general head boundary, and the simulated stages in the active model domain adjacent to the general head boundaries. Discharges along the Atlantic Ocean outcrops of the hydrostratigraphic units of the FAS and the BZ were also considered. In addition, the ECFM included monthly tidal variations along these boundaries using the time-variant constant head package of SEAWAT.

A water budget analysis determined vertical and horizonal water flow through the model. The model domain was divided into 10 zones of approximately equal size for each model layer for budget calculations. Generalized budget flow direction and magnitude for all layers by budget region are provided in **Figure 3-17**. The map shows a significant downward movement of water to the BZ (approximately 225 cubic feet per second) in the northwestern areas of the model domain. This is significantly different from the 2014 ECFM values, which indicated a slight upward movement of water from the BZ. Once the new hydrostratigraphy data were incorporated, additional calibration of leakance values between the LF1 and BZ was required to bring wells in the northwestern area of the model into calibration. The groundwater withdrawal (392 cubic feet per second) exceeded the recharge rate (89 cubic feet per second) by a large margin in these zones. The water budget for the southernmost portion of the model domain appeared relatively static, primarily due to the absence of stresses on the system. This upward movement of water along the coast from the BZ into the upper units of the FAS is consistent with Meyer's (1974, 1989) and Kohout's (1965) interpretation of the general flow patterns of the FAS in South Florida. Most of the upward movement from the BZ appeared related to the offshore Miami and Pourtales terraces, which have known sinkholes and other collapse features. The model also indicated that offshore discharge along the aquifer outcrops decreases southward.

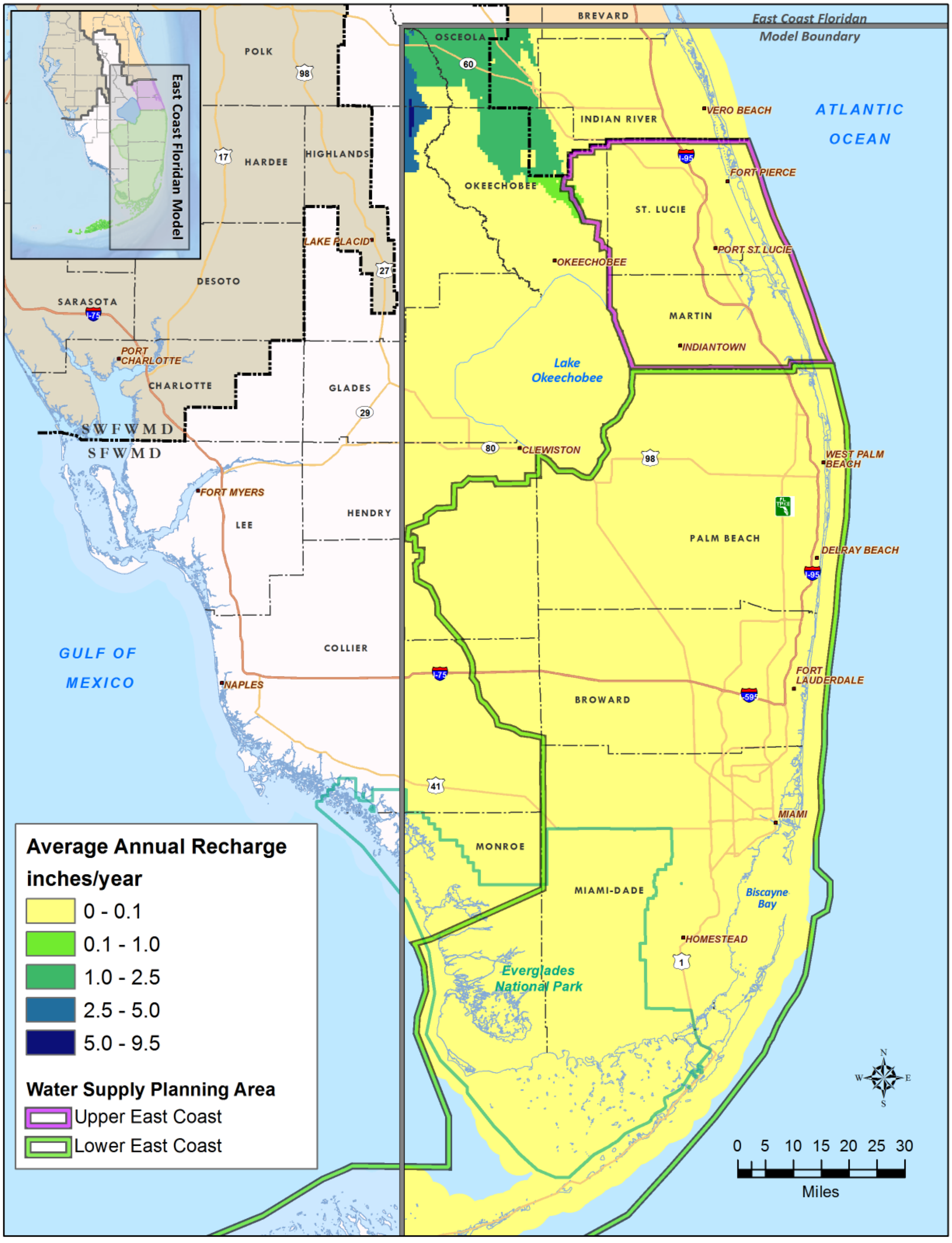


Figure 3-16. Average annual recharge rates (inches per year) from 1989 through 2012.

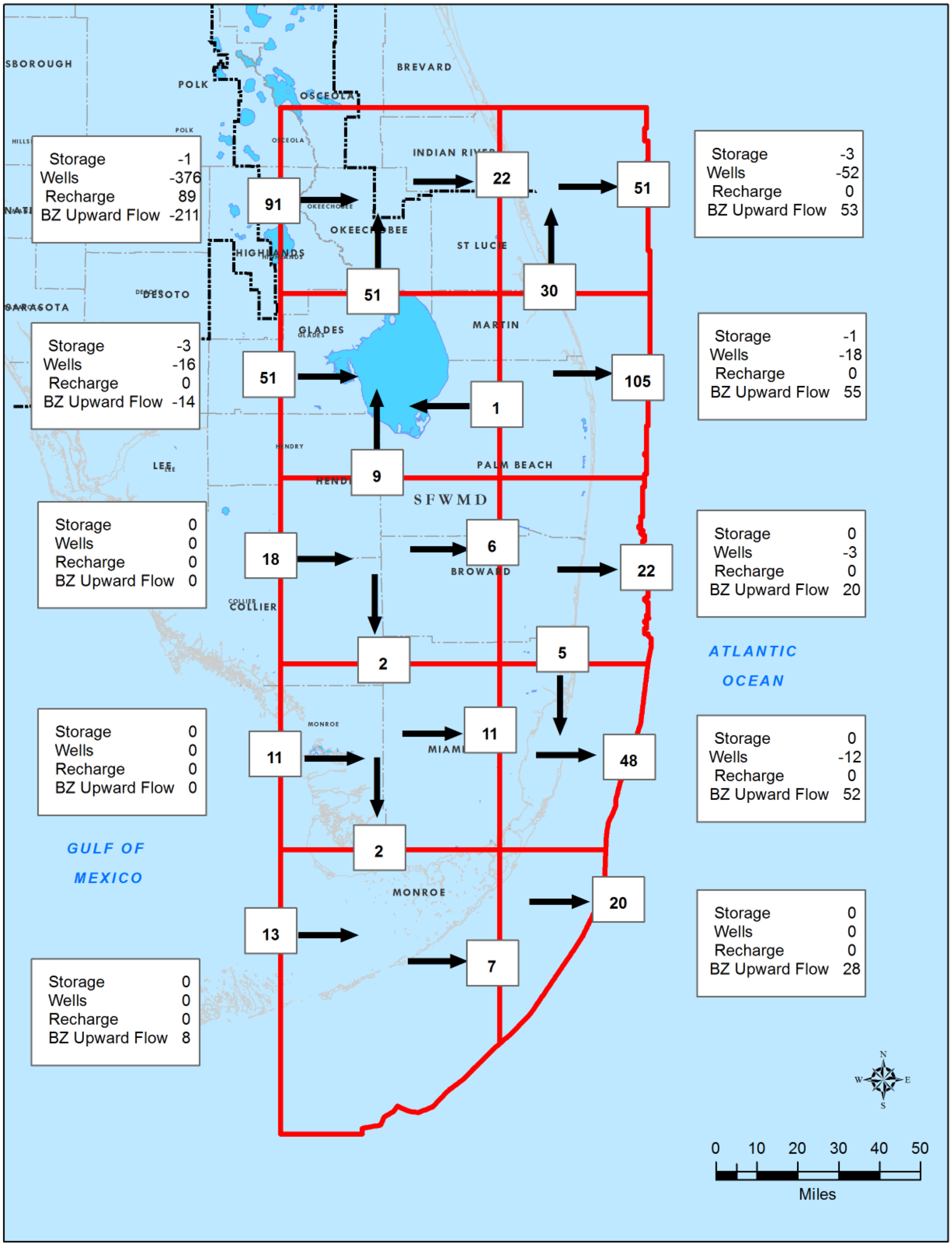


Figure 3-17. Flow budget for the calibrated East Coast Floridan Model.

4 DEMAND UPDATES AND MODEL SCENARIOS

4.1 Demand Updates

The 2021 ECFM was used to simulate the current (2019) and projected (2045) planning scenarios in support of the 2021 UEC Water Supply Plan Update (SFWMD in press). The following changes to the model from the 2014 version were made during development of the input files for the 2019 and 2045 simulations:

- Removal of wells (agricultural, public supply, golf courses, and landscape) with expired or canceled permits.
- Integration of additional data from public supply utilities in the planning area regarding new wellfields and wells that were permitted and installed, and wells that were permitted but not yet installed.

4.2 Model Scenarios

The 2021 ECFM was used to evaluate the water level and water quality impacts in the FAS due to current and projected groundwater withdrawals in the UEC Planning Area. Only the UFA and APPZ are used as FAS groundwater sources to meet demands.

The ECFM was used to simulate the 2019 and 2045 scenarios. The 2019 base condition scenario was based on historical and estimated demands, while the 2045 future simulation scenario was based on projected demands. Both scenarios were developed to simulate the aquifers' response if demands were applied over a 24-year period. The impacts of the projected demand increases were evaluated based on the difference in water levels and water quality between the 2019 and 2045 scenarios. **Table 4-1** provides a summary of 2019 and 2045 scenario pumping assumptions.

Table 4-1. Model scenario descriptions.

Model Run	Description
2019 Base Condition	2019 historical demands were used for public supply; commercial, industrial, and institutional; and landscape and recreational irrigation. Agricultural irrigation was estimated based on AFSIRS.
2045 Future Simulation	Projected demands for public supply; commercial, industrial, and institutional uses; landscape and recreational irrigation; and agricultural irrigation [AFSIRS-estimated demands based on Florida Department of Agriculture and Consumer Services (2019) acreage].

AFSIRS = Agricultural Field-Scale Irrigation Requirements Simulation.

The 2019 base condition represents the pumping required to meet 2019 water demands, and the 2045 future simulation represents the pumping required to meet projected 2045 demands. Both were simulated using climatic conditions that occurred from 1989 through 2012.

Historically, surface water bodies and the SAS were the primary water sources in the UEC Planning Area, and only a fraction of demands was met from the FAS. However, future use of the SAS is expected to be minor, and a significant increase in FAS use is projected for the future. **Table 4-2** summarizes the FAS demands by use type within the ECFM and UEC Planning Area for the 2019 base condition and 2045 future simulation. Pumping values outside of the UEC Planning Area were kept at historical values and not updated for the scenarios, except for a few utilities and wellfields near the northern and southern boundaries of the UEC Planning Area that may influence drawdown and water quality within the region. These include Indian River County Utilities (Hobart and Oslo wellfields), City of Vero Beach, FPL's Okeechobee Clean Energy Center, Town of Jupiter, Village of Tequesta, and Seacoast Utility Authority. Therefore, results of the 2021 ECFM simulations should not be interpreted for regions beyond the UEC Planning Area.

Table 4-2. Simulated water use demands from the Floridan aquifer system within the East Coast Floridan Model domain and Upper East Coast Planning Area for the 2019 base condition and 2045 future simulation.

Water Use Type	Simulated Average FAS Withdrawals (mgd)			
	2019 Base Condition		2045 Future Simulation	
	ECFM Domain	UEC Planning Area	ECFM Domain	UEC Planning Area
Public Supply	70.60	36.18	100.82	59.74
Power Generation	7.04	1.45	12.36	3.34
Agriculture	218.60	37.42	212.34	31.22
Landscape/Recreational*	29.60	2.72	31.05	4.17
Commercial/Industrial/Institutional	9.58	0.18	9.58	0.18
Total	**335.42**	**77.95**	**366.15**	**98.65**

FAS = Floridan aquifer system; mgd = million gallons per day; UEC = Upper East Coast.
* Includes water used for golf courses.

Figure 4-1 shows the spatial distribution of pumping wells by water use type across the UEC Planning Area. Agricultural wells typically are clustered in the northwestern portion of the planning area, primarily within St. Lucie County. A fraction of agricultural wells also appears in Okeechobee and Martin counties. The eastern portion of the planning area has predominantly public supply wells, with some golf course and landscape irrigation wells.

The spatial distribution of public supply wells simulated in the 2019 base condition and 2045 future simulation are illustrated in **Figure 4-1** with blue and red circles (with cross), respectively. In the UEC Planning Area, public supply wells are completed in the UFA and APPZ. The expansion of the City of Port St. Lucie Utility Systems Department's Southwest wellfield, proposed St. Lucie County wellfields, and proposed City of Stuart wellfield are recognizable within the UEC Planning Area in the 2045 future simulation.

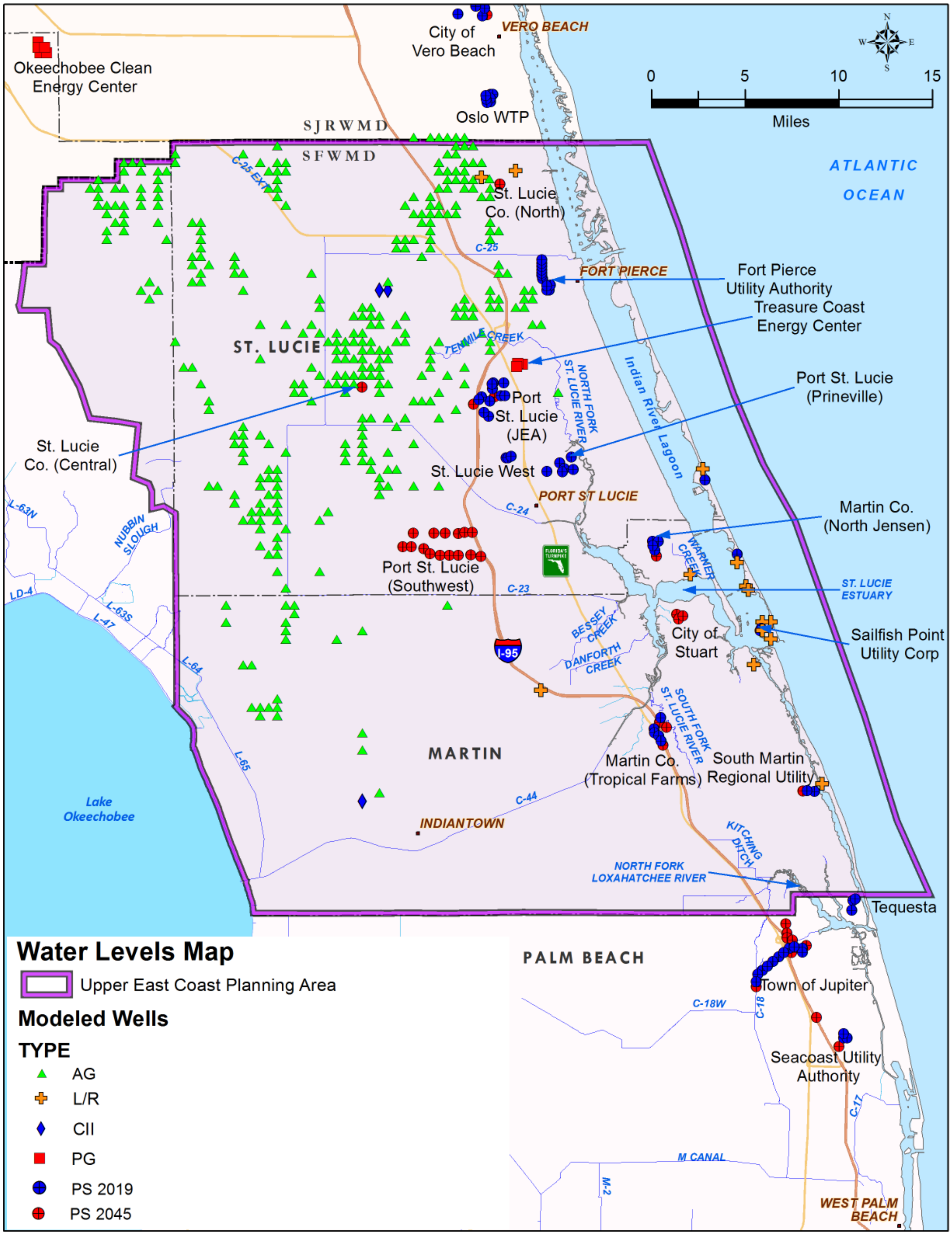


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Figure 4-1. Spatial distribution of production wells in the Upper Floridan aquifer.

5 SIMULATED DEMANDS AND MODEL RESULTS

Simulated water demands are grouped into five categories for the ECFM: public supply (PS), power generation (PG), agriculture (AG), landscape/recreational (including golf course irrigation; L/R), and commercial/industrial/institutional (CII). Domestic self-supply (DSS) wells in the UEC Planning Area do not use the FAS and, therefore, were not included in this modeling effort. In the UEC Planning Area, the total demand for all water use was estimated to be 77.95 million gallons per day (mgd) in 2019 and was predicted to be 98.65 mgd in 2045 (**Figure 5-1**). Rather than simulating a gradual increase in demands, the 2019 and 2045 demands were simulated as “instant on” (i.e., starting from the first stress period) for the two scenarios. The 2019 base condition simulated the aquifer response that would occur if the 2019 demands were applied to every year for the 24-year period. The 2045 future condition simulated the aquifer response that would occur if the projected 2045 demands were applied to every year for the 24-year period.

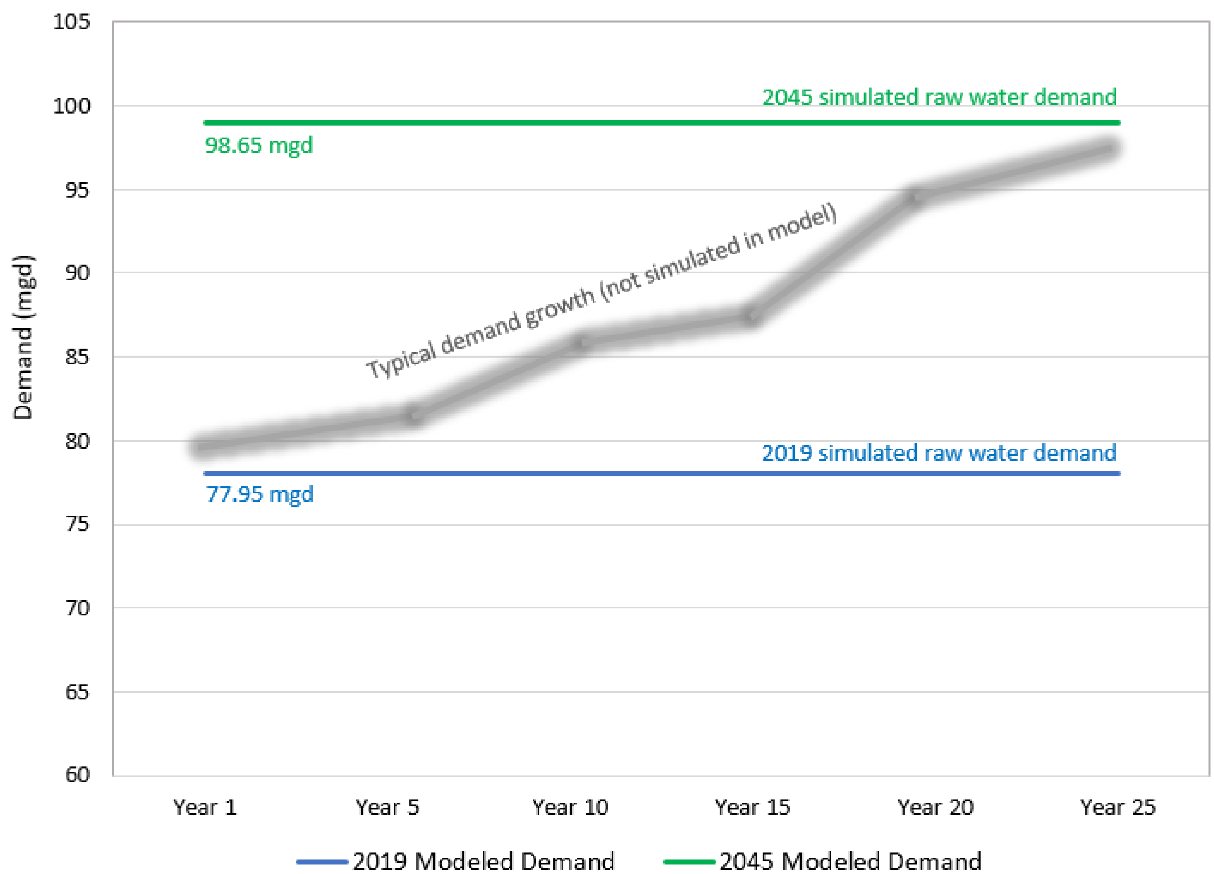

Figure 5-1. Total demand simulated in the 2019 base condition and 2045 future simulation within the Upper East Coast Planning Area.

The PS demands for 2019 were based on historical water use information collected from permittees by the SFWMD’s Water Use Bureau. The distribution of monthly water use among wells was also based on 2019 historical data. The simulated 2045 PS demands were estimated from historical per capita use and projected population growth rates by utility service area (SFWMD in press). The demands were further adjusted to reflect the SAS to FAS ratio for each utility. Monthly variations in simulated demands were based on historical use patterns from the utilities and variability associated with seasonal climatic conditions.

The simulated AG demands in the UEC Planning Area were based on the estimated total crop acreage and adjusted for irrigation type. The total crop acreage estimates were modified to reflect the percentage of acreage irrigated with water from the FAS. Irrigated acres for the 2019 base condition were obtained from the SFWMD's water use permit database. For the 2045 future simulation, irrigated acres and other information were obtained from the Florida Statewide Agricultural Irrigation Demand Report (Florida Department of Agriculture and Consumer Services 2019). Irrigation demands were based on the University of Florida's Agricultural Field-Scale Irrigation Requirements Simulation (AFSIRS) model (Smajstrla 1990). The SFWMD water use permit database contains crop type, acreage, irrigation efficiency, withdrawal facilities, and sources of irrigation water. Acreages were cross-checked against existing land use and land cover maps, and permits were checked to ensure they were still active.

Irrigation demands developed from AFSIRS were calculated using actual daily rainfall and evapotranspiration from 1989 through 2012. **Figure 5-2** shows average monthly rainfall for the City of Fort Pierce, in St. Lucie County. August was the wettest month, and average annual rainfall was approximately 54.1 inches from 1989 through 2012.

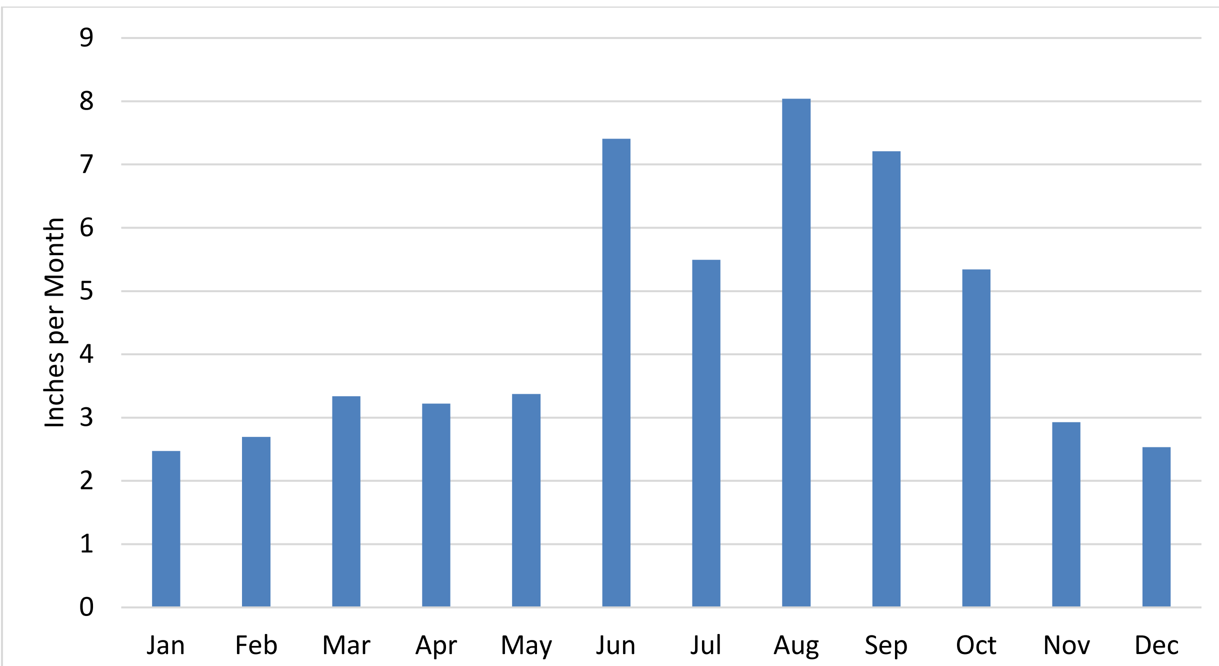

Figure 5-2. Average monthly rainfall in Fort Pierce, Florida, from 1989 through 2012.

Figure 5-3 represents average monthly demand variability for AG, PS, and L/R in the UEC Planning Area for the 2019 base condition. As expected, there was more variability in AG demand compared to PS due to the dependence of AG on climatic conditions, with lowest demands occurring during the wet season and highest demands occurring during the dry season. AG demands are expected to decrease slightly due to more efficient use of water and possible urbanization in the area (**Table 4-2**).

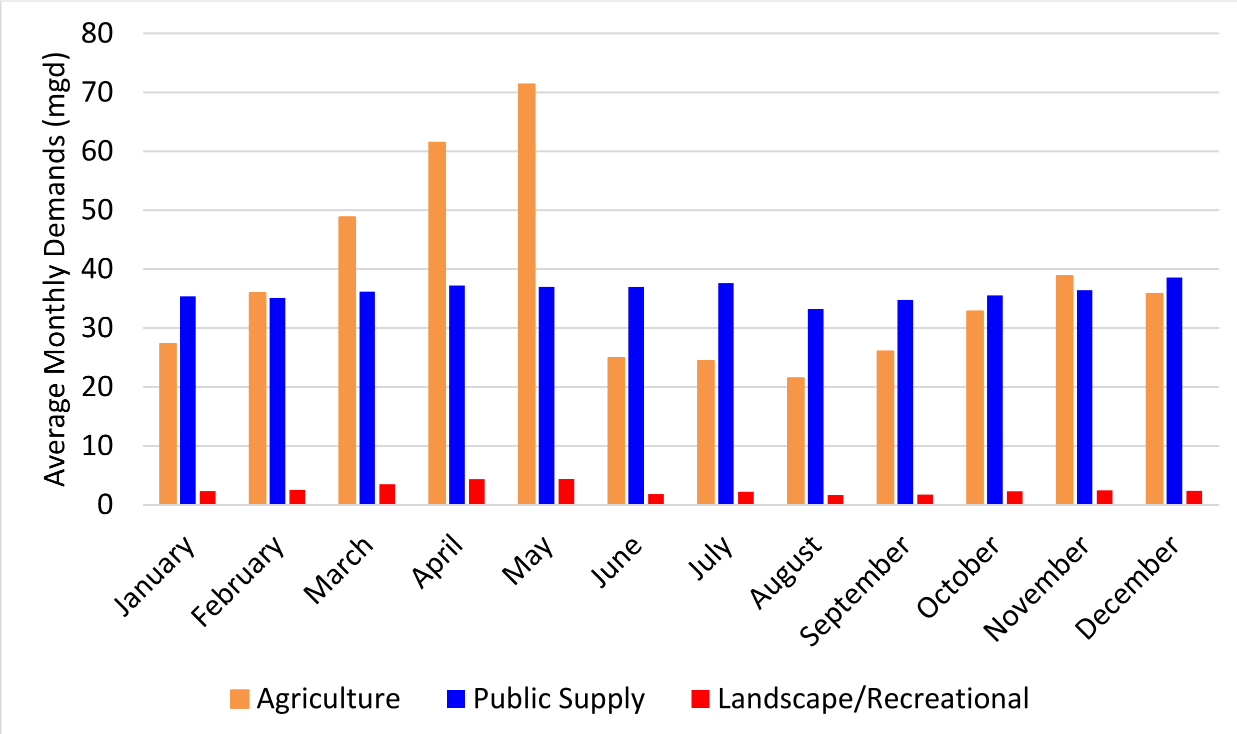

Figure 5-3. Monthly demand variability for water use (agriculture, public supply, and landscape/recreational) in 2019 within the Upper East Coast Planning Area.

Similar to AG demands, L/R demands heavily depend on climatic conditions, with drier months having significantly higher demand than wet season months. Although the L/R demands are much smaller than AG demands, the seasonal variation in L/R demands can still be seen in **Figure 5-3**. The 2019 L/R demands were based on historical pumping records. The 2045 L/R demands were estimated and provided by SFWMD planning staff (SFWMD in press).

Although CII water users typically do not use the FAS, there are a few CII permits for UFA withdrawals in the UEC Planning Area. FAS demands for CII were not expected to increase for the 2045 future simulation. Therefore, the demands for those permits were set at the FAS allocation in the current water use permit, or a ratio was developed based on individual permit facility information to determine the amount of water that likely would be withdrawn from the FAS.

5.1 Simulated Floridan Aquifer System Demands

5.1.1 Martin County

In Martin County, PS is the primary FAS user, with demands met from both the UFA and APPZ. Use of the FAS for irrigation is limited in Martin County because of the poor water quality compared to St. Lucie and Okeechobee counties. The two primary irrigation users are citrus and golf course/landscaping. Because of the proximity of agricultural areas to the C-44 Canal, most AG demand in Martin County is met with surface water directly or indirectly from the canal. AG demands from the FAS are met mainly from the UFA. The 2019 and 2045 scenarios showed almost constant AG demands in Martin County (**Table 5-1**). For the most part, the FAS is only used for golf courses and other L/R uses on the barrier islands or along Indian River Lagoon where the SAS is not productive or historically experienced saltwater intrusion. L/R uses were predicted to increase from 1.56 mgd in 2019 to 2.55 mgd in 2045.

Table 5-1. Irrigation demands in Martin County for the 2019 and 2045 scenarios.

Use Type	Simulated Average FAS Withdrawals (mgd)	
	2019 Base Condition	2045 Future Simulation
Agriculture	3.95	4.00
Landscape/Recreational*	1.56	2.55
Commercial/Industrial/Institutional	0.18	0.18
Total	**5.69**	**6.73**

FAS = Floridan aquifer system; mgd = million gallons per day.
* Includes water used for golf courses.

Several PS utilities in Martin County use water from the FAS (**Table 5-2**). Among them, Martin County Utilities is the biggest user of the FAS and has two wellfields: Tropical Farms and North Jensen Beach. At Tropical Farms, water is pumped mainly from the APPZ, while at North Jensen Beach, both the UFA and APPZ are used. Martin County Utilities used 9.98 mgd (6.83 mgd from the APPZ and 3.15 mgd from the UFA) in 2019, and demand was projected to increase to 10.63 mgd (7.06 mgd from the APPZ and 3.57 mgd from the UFA) in 2045. Compared to Martin County Utilities, the demands of the other utilities are lower (**Table 5-2**). The demands for the City of Stuart and South Martin Regional Utility are approximately 18% of the 2019 demands of Martin County Utilities, and approximately 48% of the 2045 demands of Martin County Utilities. Although PS demands are not strongly influenced by climatic conditions like AG and L/R are, there is a slight seasonal variation of water use among utilities (**Figure 5-4**).

Table 5-2. Public supply demands in Martin County for the 2019 and 2045 scenarios.

Utility	Simulated FAS Withdrawals (mgd)		
	2019	2045	Difference (2045 – 2019)
City of Stuart	0.00	2.62	+ 2.62
South Martin Regional Utility	1.78	2.43	+ 0.65
Martin County Utilities	9.98	10.63	+ 0.65
Sailfish Point	0.21	0.22	+ 0.01
Total	**11.97**	**15.90**	**+ 3.93**

FAS = Floridan aquifer system; mgd = million gallons per day.

The City of Stuart currently does not withdraw from the FAS and, therefore, has no demand in the 2019 base condition. However, demand is projected to be 2.63 mgd by 2045 and met with water from three proposed APPZ wells.

South Martin Regional Utility uses reverse osmosis to treat the FAS water pumped from its South wellfield. The two existing wells withdraw from both the UFA and APPZ. South Martin Regional Utility also has an SAS wellfield that supplies most of the water to the service area. In 2019, FAS water demand was approximately 1.78 mgd. The projected FAS water demand for 2045 is 2.43 mgd, which will be met with three wells.

Sailfish Point withdraws water solely from the UFA. There was no significant projected increase in demand for this utility between 2019 (0.21 mgd) and 2045 (0.22 mgd).

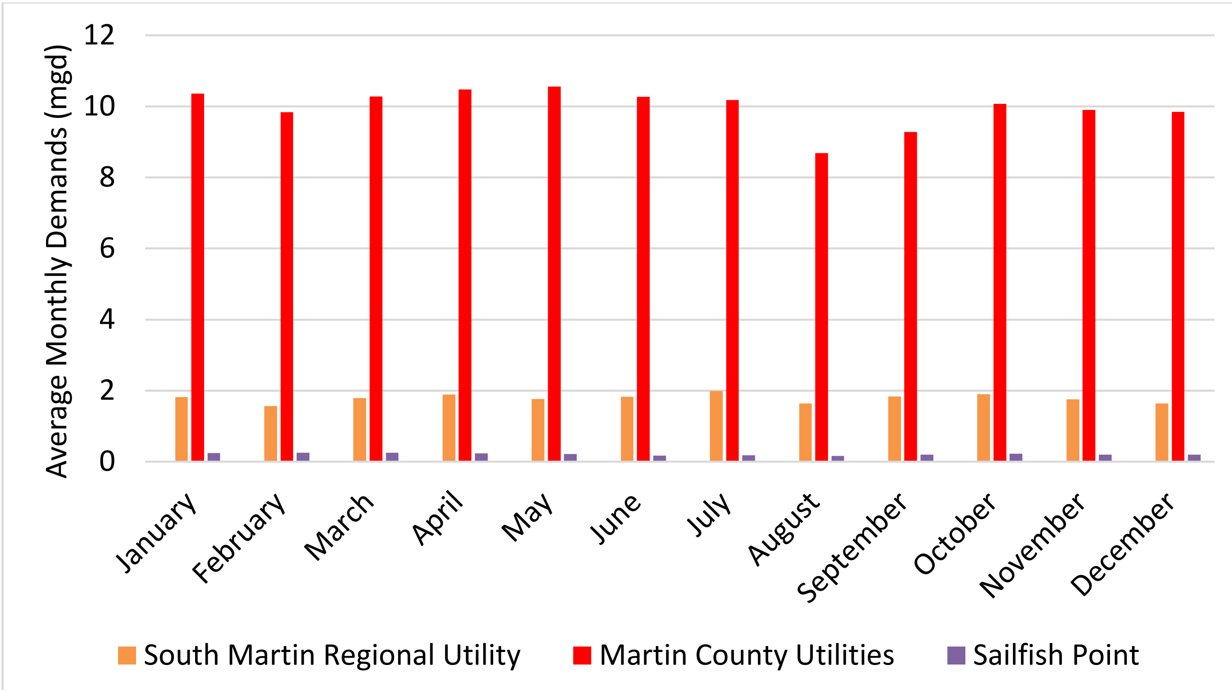

Figure 5-4. Monthly public supply demand variability, by utility, for the 2019 scenario in Martin County.

5.1.2 St. Lucie County

The FAS is a source of water for various water users in St. Lucie County (**Table 5-3**). AG demands in St. Lucie County are met primarily from the UFA and are projected to decrease 6.25 mgd due to more efficient water use, possible urbanization, and grove abandonment as a result of citrus disease. Use of the FAS for L/R and CII demands is limited because of the brackish water quality and the cost of constructing wells and treating the water. L/R demands are projected to increase slightly by 2045. PG users in the UEC Planning Area also use water from the UFA, and demand is projected to increase 1.89 mgd.

Table 5-3. Water supply demands, not including public supply, from the Floridan aquifer system in St. Lucie County for the 2019 and 2045 scenarios.

Use Type	Simulated Average FAS Withdrawals (mgd)	
	2019 Base Condition	2045 Future Simulation
Agriculture	29.73	23.48
Landscape/Recreational*	1.10	1.52
Commercial/Industrial/Institutional	0.001	0.001
Power Generation	1.45	3.34
Total	**32.28**	**28.34**

FAS = Floridan aquifer system; mgd = million gallons per day.
* Includes water used for golf courses.

PS demands met from the FAS in St. Lucie County use both the UFA and APPZ. Several major PS utilities in the county withdraw water from the FAS (**Table 5-4**). Among the utilities, the City of Port St. Lucie Utility Systems Department is the biggest user of the FAS, withdrawing 18.33 mgd in 2019 and projected to withdraw 30.08 mgd by 2045. The PS demands of the other utilities are much lower in comparison, with a combined demand of approximately 20% of the City of Port St. Lucie Utility Systems Department's demand (**Table 5-4**). Although PS demands are not strongly influenced by climatic conditions like AG and L/R are, there is a slight seasonal variation of water use among utilities (**Figure 5-5**). St. Lucie County Utilities did not withdraw from the FAS in 2019; however, it is projected to withdraw 5.40 mgd from the North and Central wellfields in 2045.

Table 5-4. Public supply demands from the Floridan aquifer system in St. Lucie County for the 2019 and 2045 scenarios.

Utility	Simulated FAS Withdrawals (mgd)		
	2019	2045	Difference (2045 – 2019)
Fort Pierce Utilities Authority	3.42	5.85	+ 2.43
Port St. Lucie Utility Systems Department, City of	18.33	30.08	+ 11.75
St. Lucie County Utilities	0.00	5.40	+ 5.40
St. Lucie West Services District	2.20	2.23	+ 0.03
Total	**23.95**	**43.56**	**+ 19.61**

FAS = Floridan aquifer system; mgd = million gallons per day.

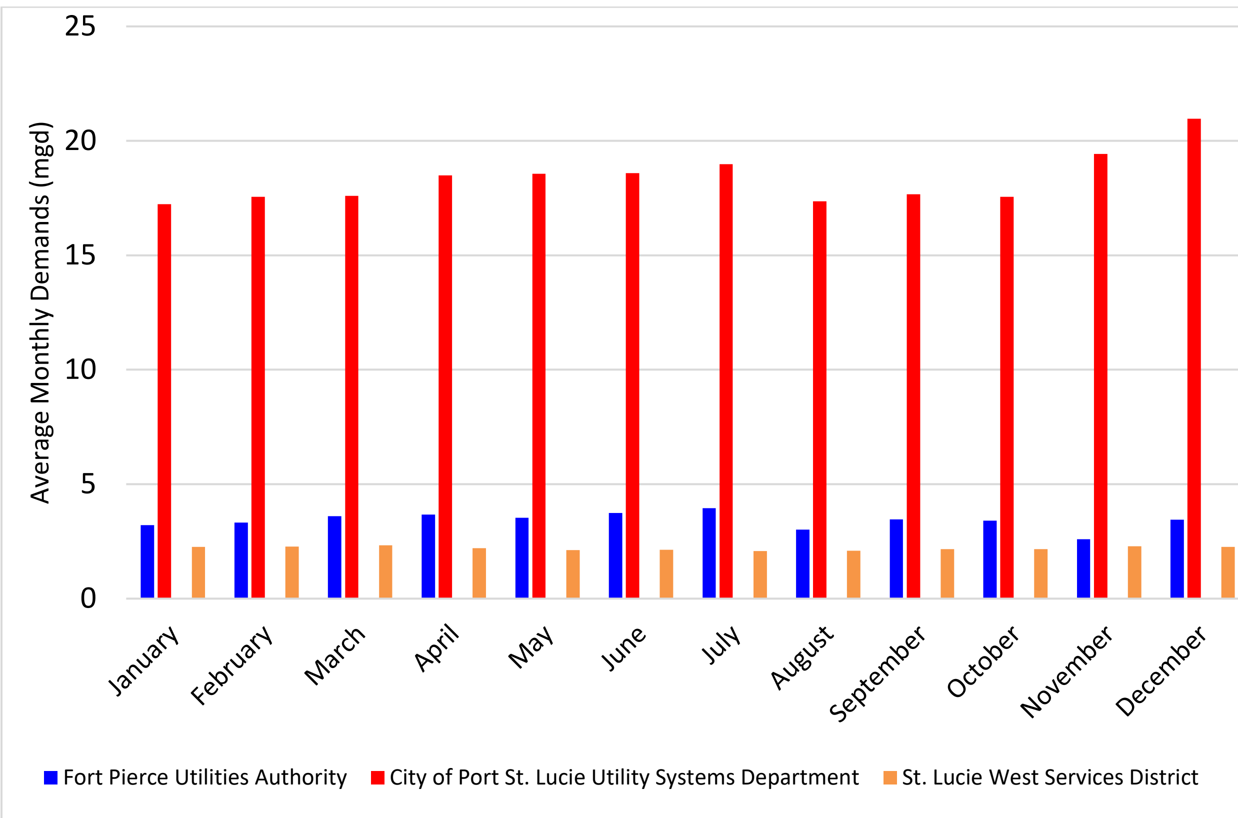

Figure 5-5. Monthly public supply demand variability, by utility, for the 2019 base condition in St. Lucie County.

The City of Port St. Lucie Utility Systems Department has three main FAS wellfields: James E. Anderson (JEA), Prineville, and Southwest. The Southwest wellfield is proposed and was not operational for the 2019 base condition. However, the wellfield is projected to have 17 operational wells by 2045, withdrawing 3.53 mgd from the UFA and 9.43 mgd from the APPZ. Production wells F1 to F6 are in the Prineville wellfield, wells F7 to F19 are in the JEA wellfield, and wells F20 to F36 are in the proposed Southwest wellfield. Over the last few years, the City of Port St. Lucie Utility Systems Department has partially backplugged wells F6 and F8 to F12 in the APPZ because of water quality issues; thus, several existing wells are not pumping water from the APPZ. For the 2019 base condition, five of six backplugged wells (F6 and F9 to F12) were not operational in the APPZ; however, well F8 was open to both UFA and APPZ because it was backplugged in November 2020. For the 2045 future simulation, all the wells were open only to the UFA.

St. Lucie County Utilities has a permit to construct four wellfields: North, Cloud Grove, Central, and Southern. None of the wellfields were operational in the 2019 base condition. However, St. Lucie County Utilities expects to meet future demands (5.4 mgd) from only the North and Central wellfields by 2045. By adding four wells in each wellfield, the North wellfield is projected to withdraw 4.0 mgd, while the Central wellfield is projected to withdraw 1.4 mgd. The exact well locations have not yet been determined by the utility; therefore, the well locations in the model were approximate.

The total FAS demand for the Fort Pierce Utilities Authority is approximately 3.42 mgd in the 2019 base condition. The utility uses a combination of SAS and FAS to meet demands. Historically, approximately 40% of the total demand came from the FAS, with the remaining 60% withdrawn from the SAS. The Fort Pierce Utilities Authority has two wellfields: 33rd Street and West. The combined 2019 demand for both wellfields was 3.42 mgd, with a projected increase to 5.85 mgd by 2045. The Fort Pierce Utilities Authority has 11 wells completed in the UFA; 10 of those wells extend to the APPZ, and demands were distributed equally for the 2019 and 2045 scenarios. Approximately 3 to 4 years ago, the utility began rotating some wells to avoid water quality degradation in the aquifer due to upconing. However, for the model scenarios, no well rotation was incorporated.

The St. Lucie West Services District has three wells (F-1, F-2, and F-3). Wells F-1 and F-2 are open to the UFA, whereas well F-3 is open to both UFA and APPZ. Only a slight demand increase (0.03 mgd) was projected to occur for the utility in 2045.

5.1.3 Eastern Okeechobee County

Demand estimates for Okeechobee County are separated into three water supply planning areas. Northeastern Okeechobee County is within the St. Johns River Water Management District, western Okeechobee County is within the SFWMD's Lower Kissimmee Basin Planning Area, and eastern Okeechobee County is included in the SFWMD's UEC Planning Area. For the ECFM scenarios conducted under this study, demands in western Okeechobee County remained at historical withdrawal volumes (2019), demands in the St. Johns River Water Management District portion of Okeechobee County came from their plan, and the demands in the UEC Planning Area (eastern Okeechobee County) are discussed here. In the UEC Planning Area, Okeechobee County water demands are for AG and L/R (**Table 5-5**). AG demands in Okeechobee County are not projected to change between 2019 and 2045.

Table 5-5. Floridan aquifer system demands in eastern Okeechobee County (portion within the Upper East Coast Planning Area) for the 2019 and 2045 scenarios.

Use Type	Simulated Average FAS Withdrawals (mgd)	
	2019 Base Condition	2045 Future Simulation
Agriculture	3.74	3.74
Landscape/Recreational	0.06	0.10
Total	**3.80**	**3.84**

FAS = Floridan aquifer system; mgd = million gallons per day.

5.2 Simulation Results

The ECFM simulation results are presented in four ways: 1) spatial variation and difference in water levels between scenarios, 2) spatial variation and difference in water quality between scenarios, 3) horizontal flow direction and magnitude in the aquifers, and 4) potential changes in groundwater head relative to land surface and the ability of a well to produce water under free-flowing conditions. The analysis between the 2019 base condition and 2045 future simulation identified potential areas of concern based on groundwater level drawdown, groundwater quality degradation, and groundwater flow direction. Simulated water levels (in feet National Geodetic Vertical Datum of 1929 [NGVD29]) and water quality (as TDS in milligrams per liter) at individual monitoring wells can be found in **Appendices C** and **D**, respectively. Discussion focuses on Martin and St. Lucie counties, where FAS demands are higher. When reviewing the graphics in this section, the maps show PS wells as blue dots for the 2019 base condition and red dots for the 2045 future simulation.

5.2.1 Water Level Spatial Variations and Differences Between Scenarios

The spatial variation and differences in water levels between the 2019 and 2045 scenarios in the UFA and APPZ are illustrated in **Figures 5-6** to **5-11**. Water level changes compare the last month (month 288) of the 2045 future simulation to the last month of the 2019 base condition. Because it takes time for changes in water quality to occur, the last month was selected for the standard evaluation. As a result, a lowering of the aquifer water level from 2019 to 2045 results in a negative change in head in the figures.

Figures 5-6 and **5-7** show the spatial variation of water levels in the UFA at the end of the 2019 and 2045 scenarios, respectively. Water levels in the UFA generally are higher in the west and southwest and lower in the east and northeast, and they typically vary between +25 and +50 ft of head, with some localized low areas around large wellfields across the UEC Planning Area. Both maps present the final condition of the water levels, applying the respective demands for a 24-year period.

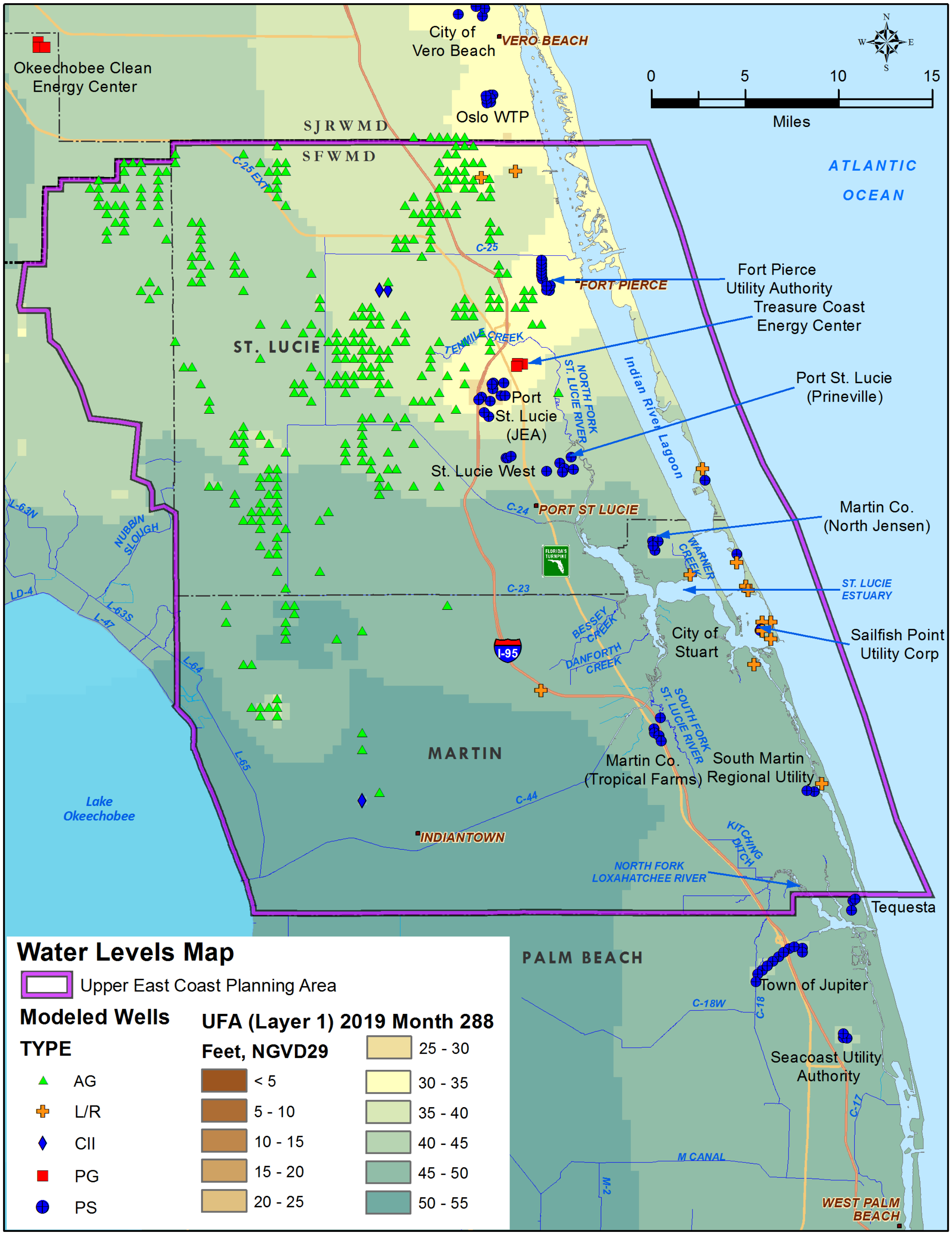

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Figure 5-6. Upper Floridan aquifer water levels for the final condition (month 288) of the 2019 base condition.

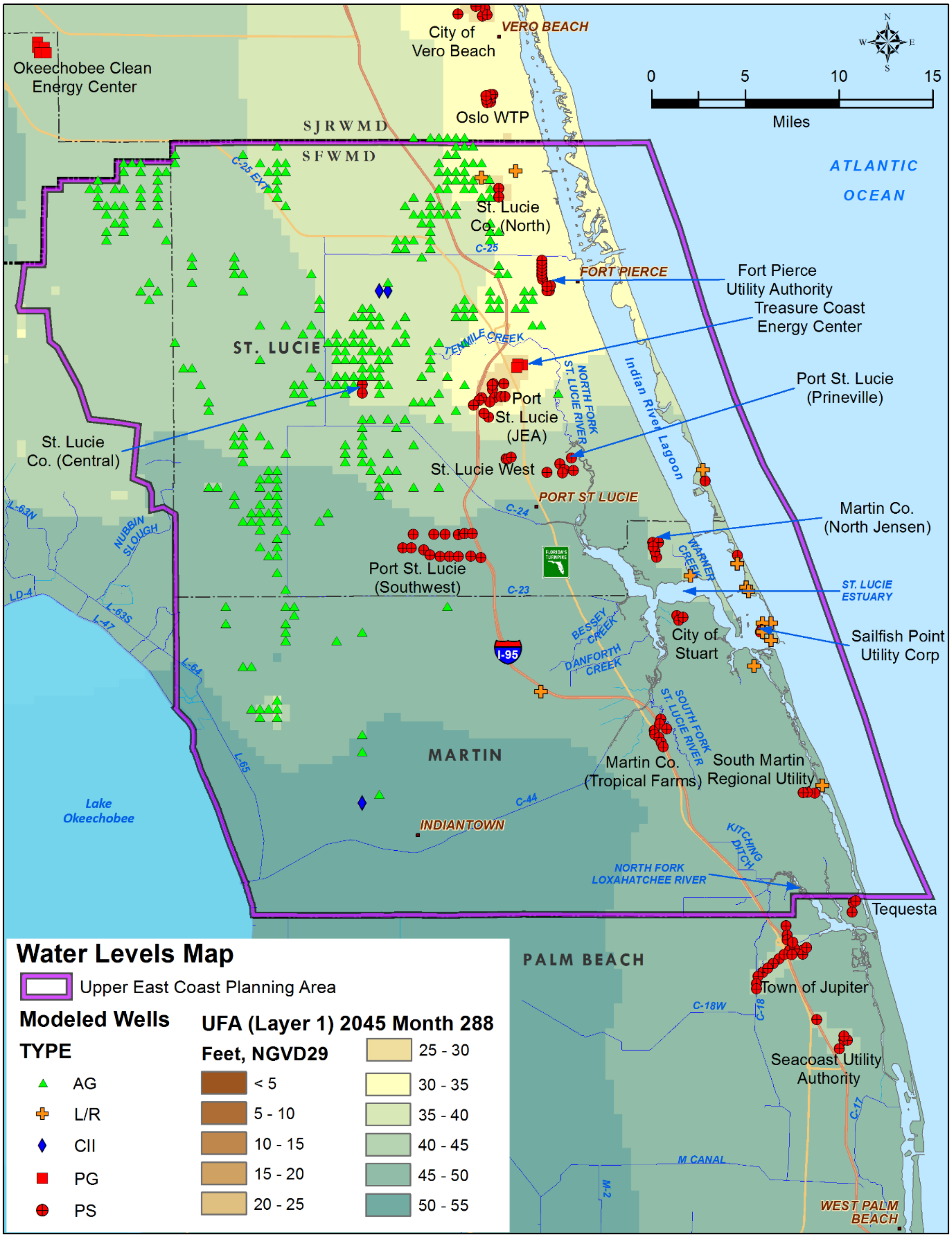

Figure 5-7. Upper Floridan aquifer water levels for the final condition (month 288) of the 2045 future simulation.

The spatial distribution of UFA water level differences for the end of simulation month (month 288) between the 2019 base condition and 2045 future simulation (2045 minus 2019) is shown in **Figure 5-8**. Water level changes are primarily related to differences in withdrawal quantities, followed by changes in withdrawal locations and demand distribution within individual wellfields. In the UFA, the largest decrease (approximately 17 ft) in water level occurred at St. Lucie County Utilities' North wellfield, where four proposed wells are projected to withdraw 4.00 mgd of water (two model cells and two wells in each neighboring model cell). This water level decrease demonstrates the cumulative impact of multiple pumping wells located relatively close to each other.

However, a noticeable increase (or rebound) in water levels (up to 3 ft) is projected west of the City of Port St. Lucie Utility Systems Department's JEA wellfield. The predicted rebound is the result of a large decrease (almost half) in AG demands and a slight decrease and rearrangement of the pumping distribution at the JEA wellfield. In 2019, 11 wells at the JEA wellfield pumped 9.05 mgd, while 13 wells are projected to pump 8.62 mgd in 2045. The projected PS demands of 3.53 mgd in the UFA at the utility's Southwest wellfield is predicted to cause a maximum of 2 ft of additional drawdown when the new wells become operational. The nearly constant PS demands at the Prineville wellfield (5.88 mgd in 2019 and 5.72 mgd in 2045) cause almost no change in water levels, as expected.

The Fort Pierce Utilities Authority's UFA demands are anticipated to significantly increase between the planning scenarios (2.96 mgd in 2019 and 5.07 mgd in 2045). This increase in demands resulted in a water level decrease of 2.5 ft in both the 33rd Street and West wellfields. The Treasure Coast Energy Center also is projected to noticeably increase its use of the UFA, from 1.45 mgd in 2019 to 3.35 mgd in 2045, which is predicted to result in a water level drawdown up to 7 ft.

Figures 5-9 and **5-10** show the spatial variation of water levels in the APPZ at the end of the 2019 and 2045 scenarios, respectively. APPZ water levels typically are between +25 and +50 ft NGVD29, with lower water levels along the coast in the northeastern corner of the UEC Planning Area. The spatial distribution of APPZ water level differences for the end of simulation month (month 288) between the 2019 base condition and 2045 future simulation is shown in **Figure 5-11**. Changes in APPZ water levels are related to differences in withdrawal quantities, changes in withdrawal locations, distribution of demands within individual wellfields, and impacts from UFA wellfields at selected locations.

In the APPZ, the largest water level decrease (approximately 3 ft) appeared at St. Lucie County Utilities' North wellfield. Although there are no wells in the APPZ at that location, the impact of pumping the UFA wellfield extends down to the APPZ due, in part, to a lack of confinement between the two layers. However, a decrease in AG demands results in a water level increase (or rebound). This area coincides with the area of water level rebound in the UFA (discussed earlier).

A large area extending from St. Lucie County Utilities' North wellfield to north of the City of Port St. Lucie Utility Systems Department's JEA wellfield is predicted to experience drawdown of 2 ft in the APPZ, mainly caused by UFA demands. In addition, APPZ demands slightly increase in this region. The Fort Pierce Utilities Authority's 10 APPZ wells are projected to nearly double their pumping (0.46 mgd in 2019 and 0.79 mgd in 2045).

The projected APPZ demands of 9.43 mgd from the City of Port St. Lucie Utility Systems Department's Southwest wellfield are expected to cause a maximum 2-ft water level decrease when new wells become operational. Despite the increase in APPZ demands, water level does not decrease as much as in other areas due to a highly transmissive (360,000 ft^2/day) area near the wellfield and good spatial distribution of the wells. The water level decrease is expected to expand towards the east coast where several Martin County Utilities wellfields are located. The greatest water level decline is expected in the City of Stuart's wells. PS demand is projected to be 2.62 mgd in 2045 when three wells are operational.

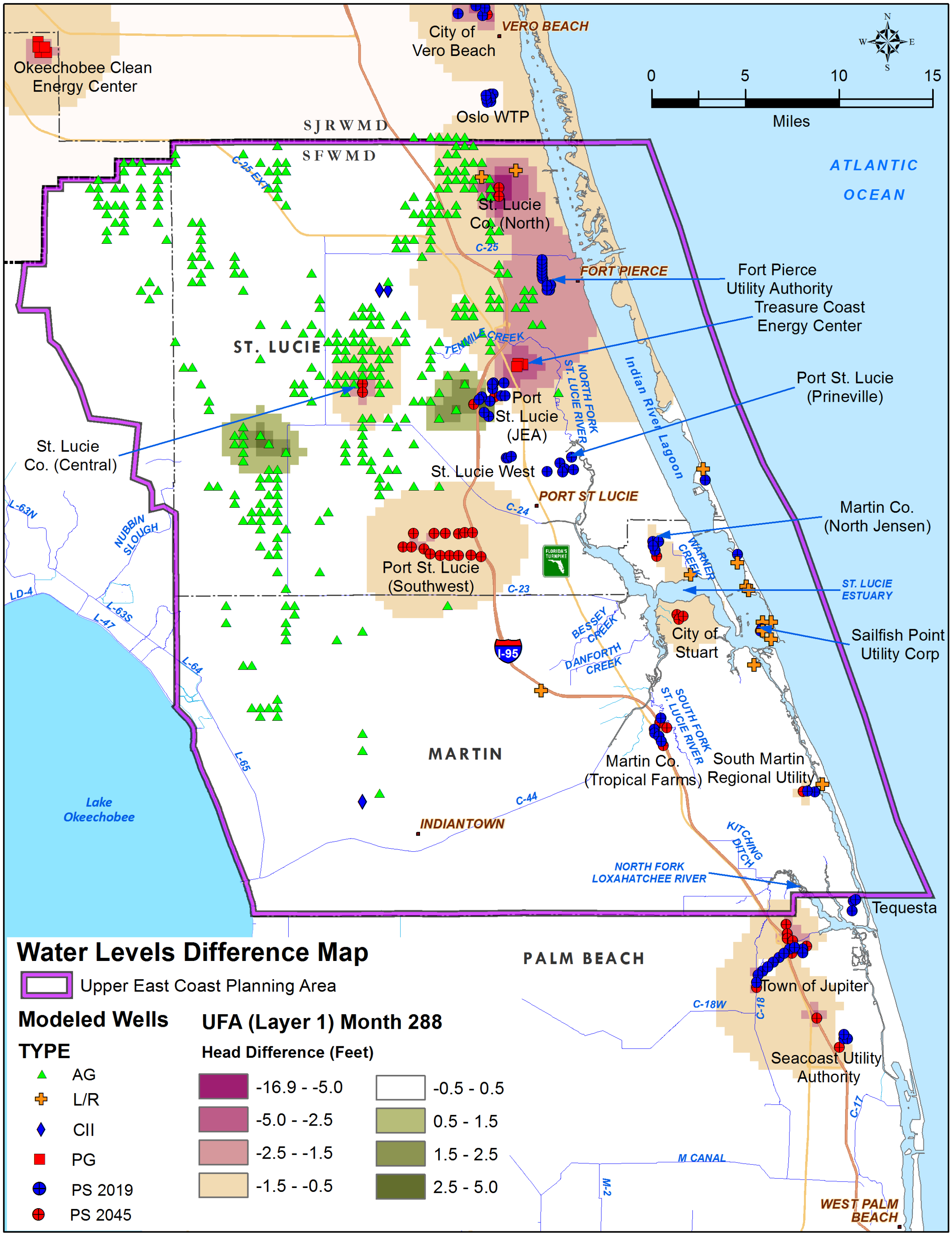

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Figure 5-8. Upper Floridan aquifer water level (head) differences between the 2019 base condition and 2045 future simulation (2045 minus 2019) for the final condition (month 288).

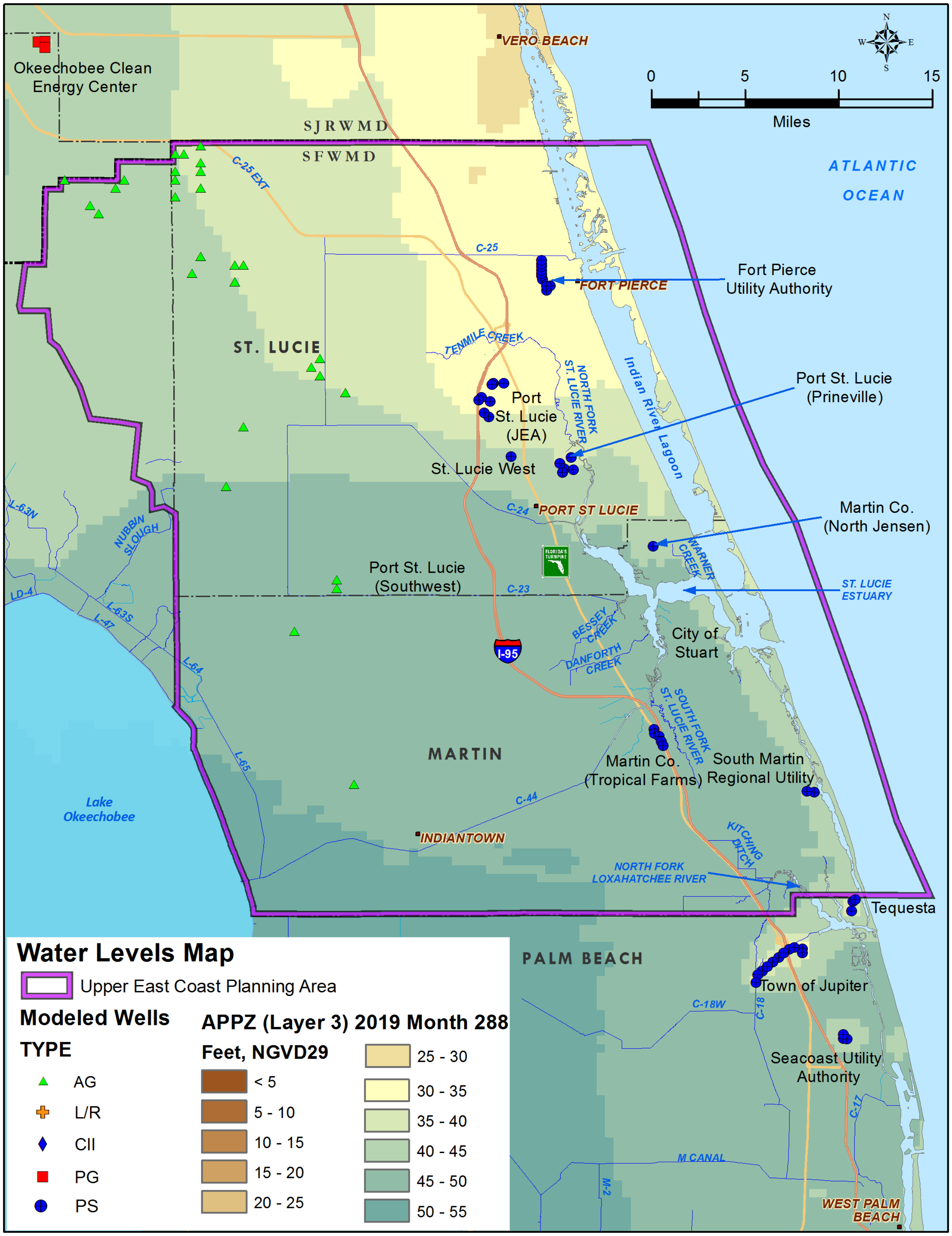

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Figure 5-9. Avon Park permeable zone water levels for the final condition (month 288) of the 2019 base condition.

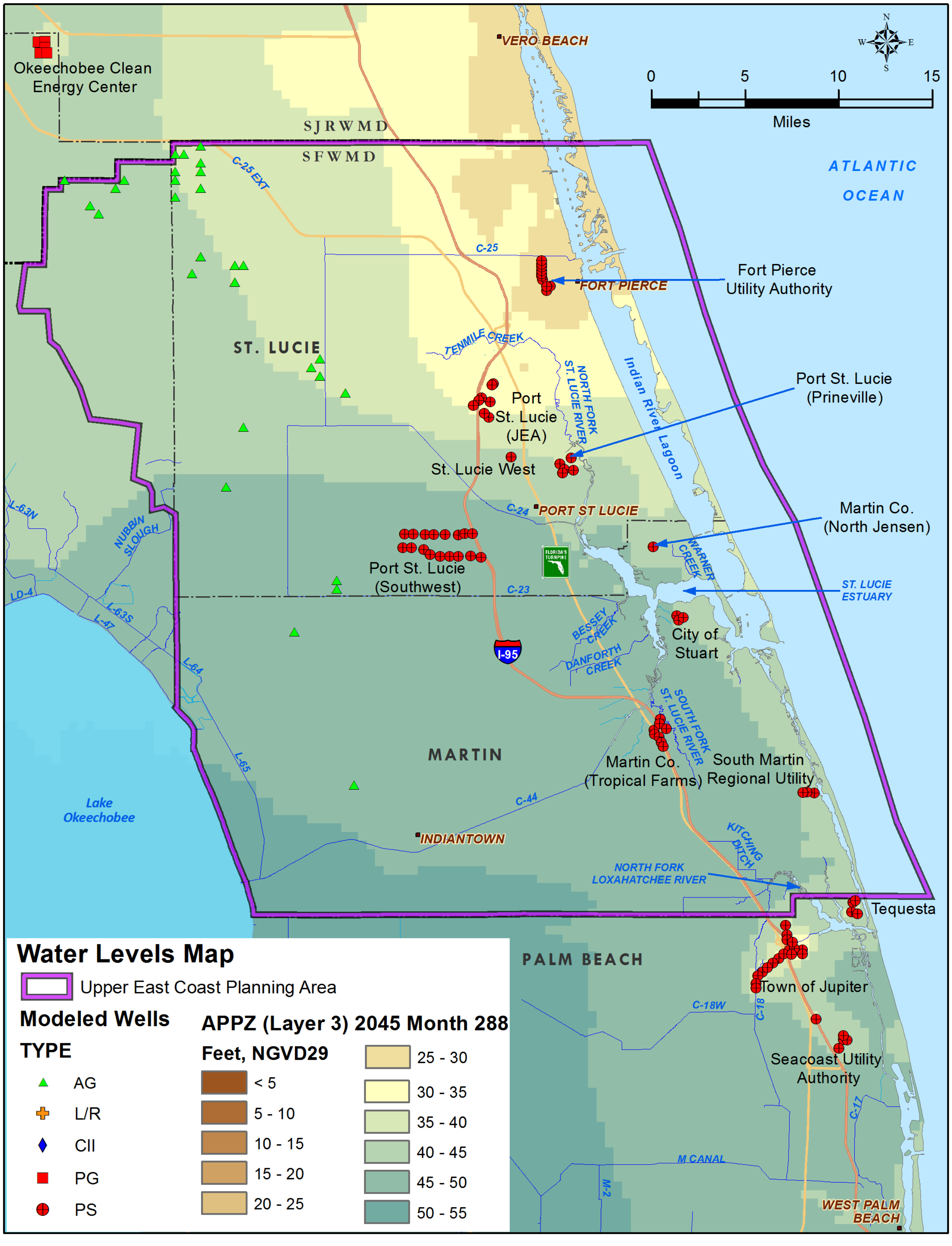

Figure 5-10. Avon Park permeable zone water levels for the final condition (month 288) of the 2045 future simulation.

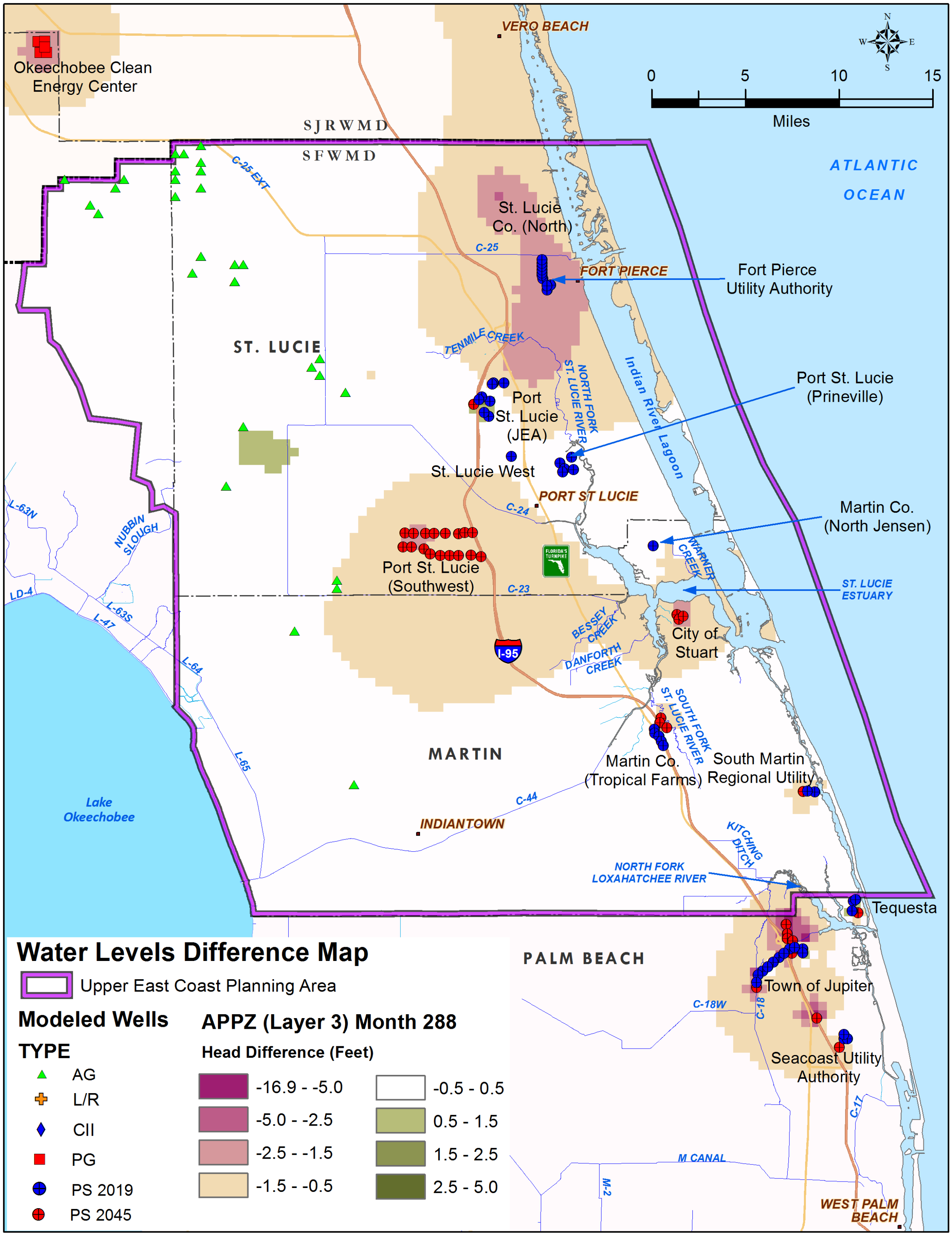

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Figure 5-11. Avon Park permeable zone water level (head) differences between the 2019 base condition and 2045 future simulation (2045 minus 2019) for the final condition (month 288).

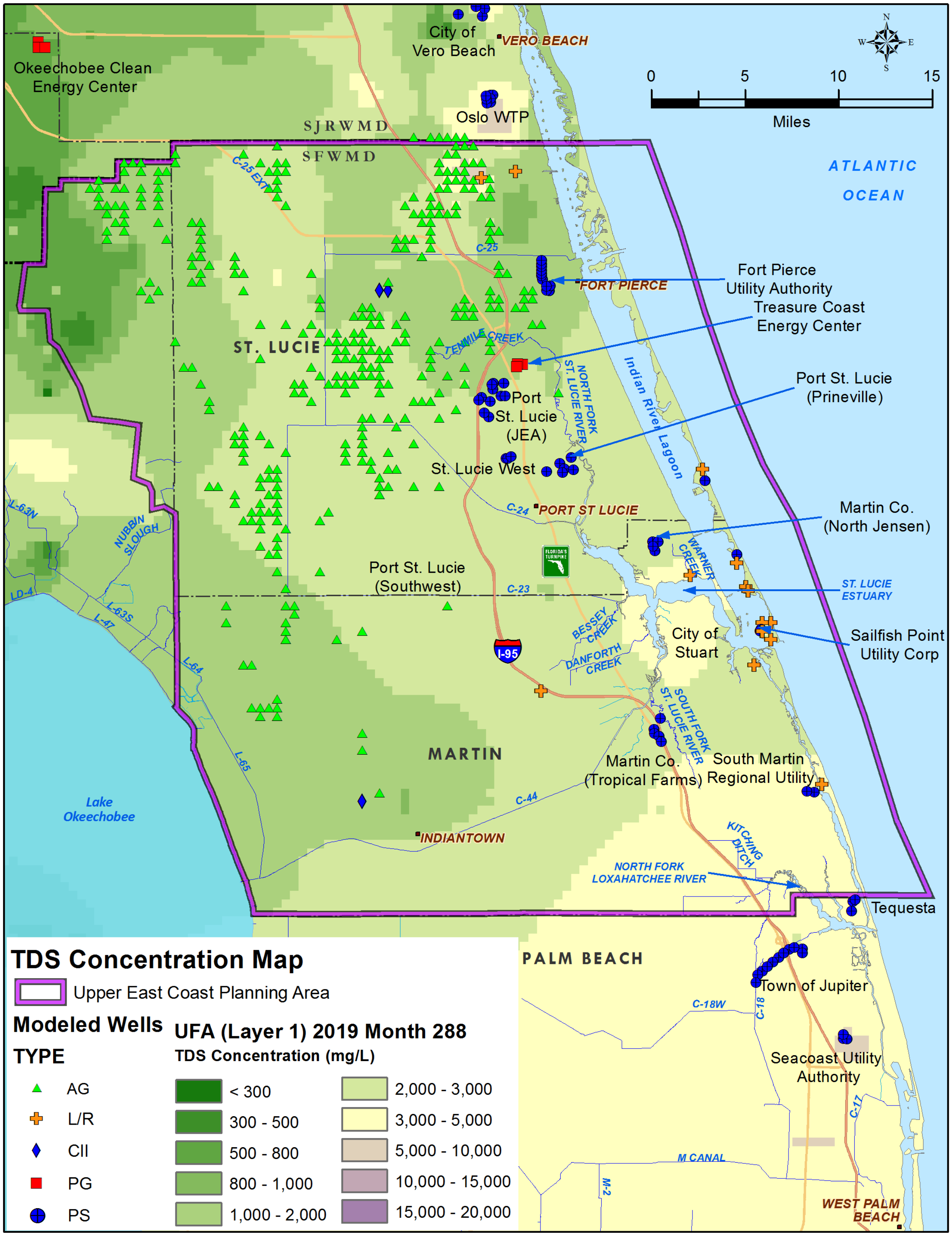
5.2.2 Water Quality Spatial Variations and Differences Between Scenarios

In general, TDS concentrations in the UFA are predicted to remain steady or slightly increase with the projected 2045 demands for most of the UEC Planning Area. Changes in water quality compare the last simulation month (month 288) of the 2045 future simulation and the last month of the 2019 base condition. As a result, increasing withdrawals and lowering aquifer water levels from 2019 to 2045 may increase TDS concentrations, which indicates degrading water quality. **Figures 5-12** and **5-13** show the spatial distribution of UFA water quality (represented by TDS concentrations in milligrams per liter) for the 2019 and 2045 scenarios, respectively. Both maps illustrate the final condition of TDS concentrations with the respective demands in place for the 24-year period of simulation. In general, simulated TDS concentrations remain steady throughout the UEC Planning Area and vary between 1,000 and 6,000 mg/L. The highest TDS concentration appears near the boundary between St. Lucie and Indian River counties. Compared with other parts of the UEC Planning Area, a higher TDS concentration appears around the City of Stuart wellfield.

Spatial distribution of the water quality differences for the 2019 base condition and 2045 future simulation in the UFA is shown in **Figure 5-14**. Changes in water quality are represented by comparison of the final conditions (month 288) of the two scenarios. Changes in TDS concentrations are predicted to be 100 mg/L or less for most of the UEC Planning Area, suggesting no major FAS water quality changes, even with the increase in demand. The greatest change in TDS concentration is predicted to occur at St. Lucie County Utilities' North wellfield. Water quality degradation is also projected to occur at Fort Pierce Utilities Authority's 33rd Street and West wellfields and around the Treasure Coast Energy Center. **Appendix E** contains water level hydrographs and water quality time series for the 2019 base condition and 2045 future simulation at these locations.

The water quality degradation around St. Lucie County Utilities' North wellfield is between 300 to 4,800 mg/L. Causes of the degradation include the increase in demands (4.00 mgd) when the wellfield becomes operational by 2045 and the impact of the Oslo wellfield withdrawal just outside the UEC Planning Area's northern boundary. Water quality degradation of this magnitude might not be a major concern to a PS utility but could be detrimental to nearby AG users, especially if the FAS is used to irrigate less salt-tolerant plants.

Fort Pierce Utilities Authority's two wellfields are close to the saltwater interface along the east coast of Florida. With an increase in demand of 2.11 mgd from 2019 to 2045, the model results show lateral flow of water from the coast towards the wellfields. Despite the increase in demands and lateral intrusion of saltwater, water quality is predicted to degrade only 200 mg/L at most within the vicinity of the wellfields. This may be because of the fresh regional flow from the northwestern portion of the model domain replacing the pumped water. Water quality degradation near the Treasure Coast Energy Center wellfield is predicted to be between 100 and 200 mg/L and is the result of the increase in demand (1.89 mgd), which almost doubles from 2019 to 2045. Water quality degradation the Fort Pierce Utilities Authority or Treasure Coast Energy Center wellfields is not expected to cause concern for PS utilities or nearby AG users.



User Name: mbillah   Map Produced on Date: 6/7/2021 3:25:02 PM \\ad.sfwmd.gov\dfsroot\data\wsd\MOD\ECFM\MB\UEC\GIS\postprocess\mxd\Report2021\Figure5.12_WaterQualityUFA2019.mxd

Figure 5-12. Upper Floridan aquifer water quality (total dissolved solids concentrations) for the final condition (month 288) of the 2019 base condition.

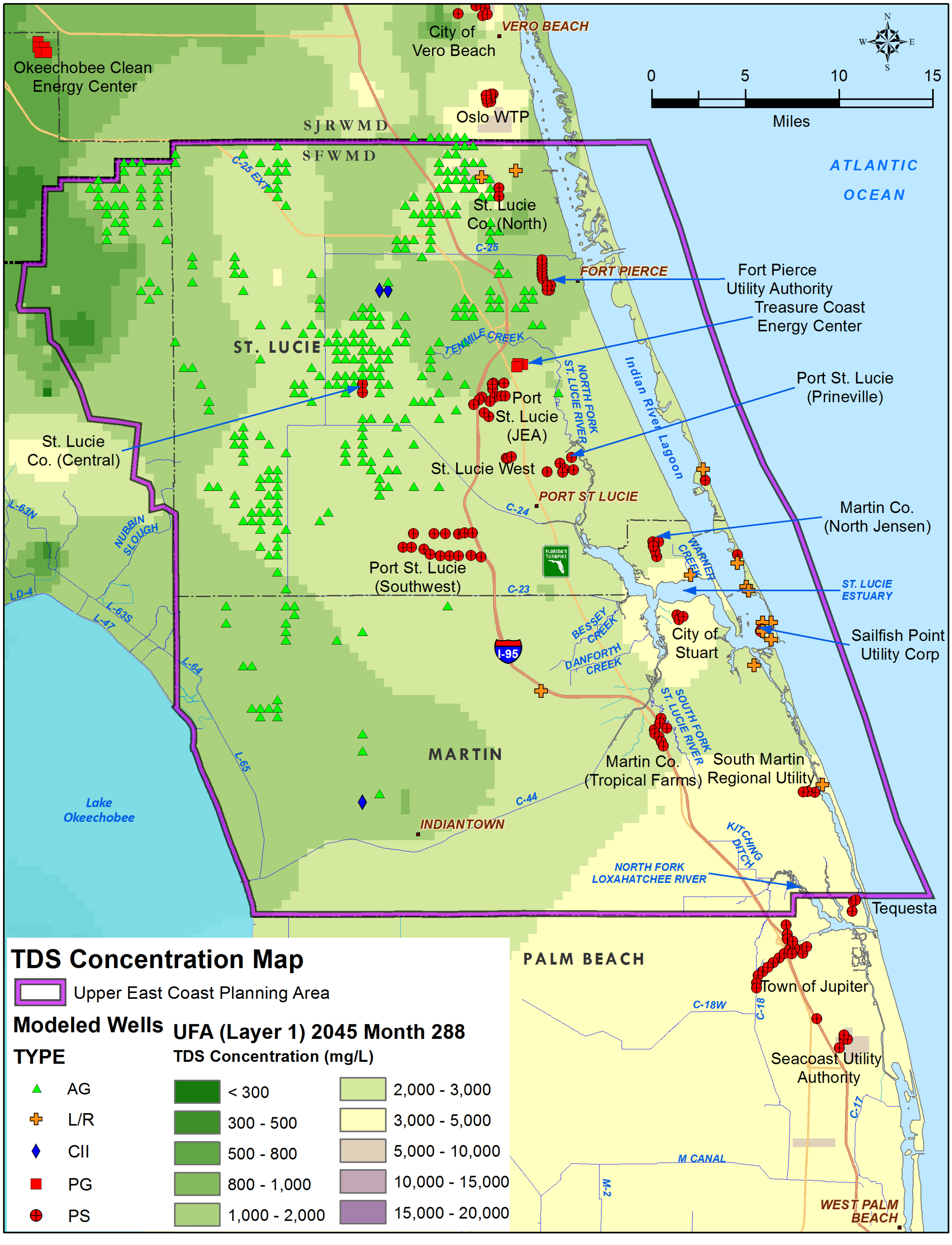


Figure 5-13. Upper Floridan aquifer water quality (total dissolved solids concentrations) for the final condition (month 288) of the 2045 future simulation.

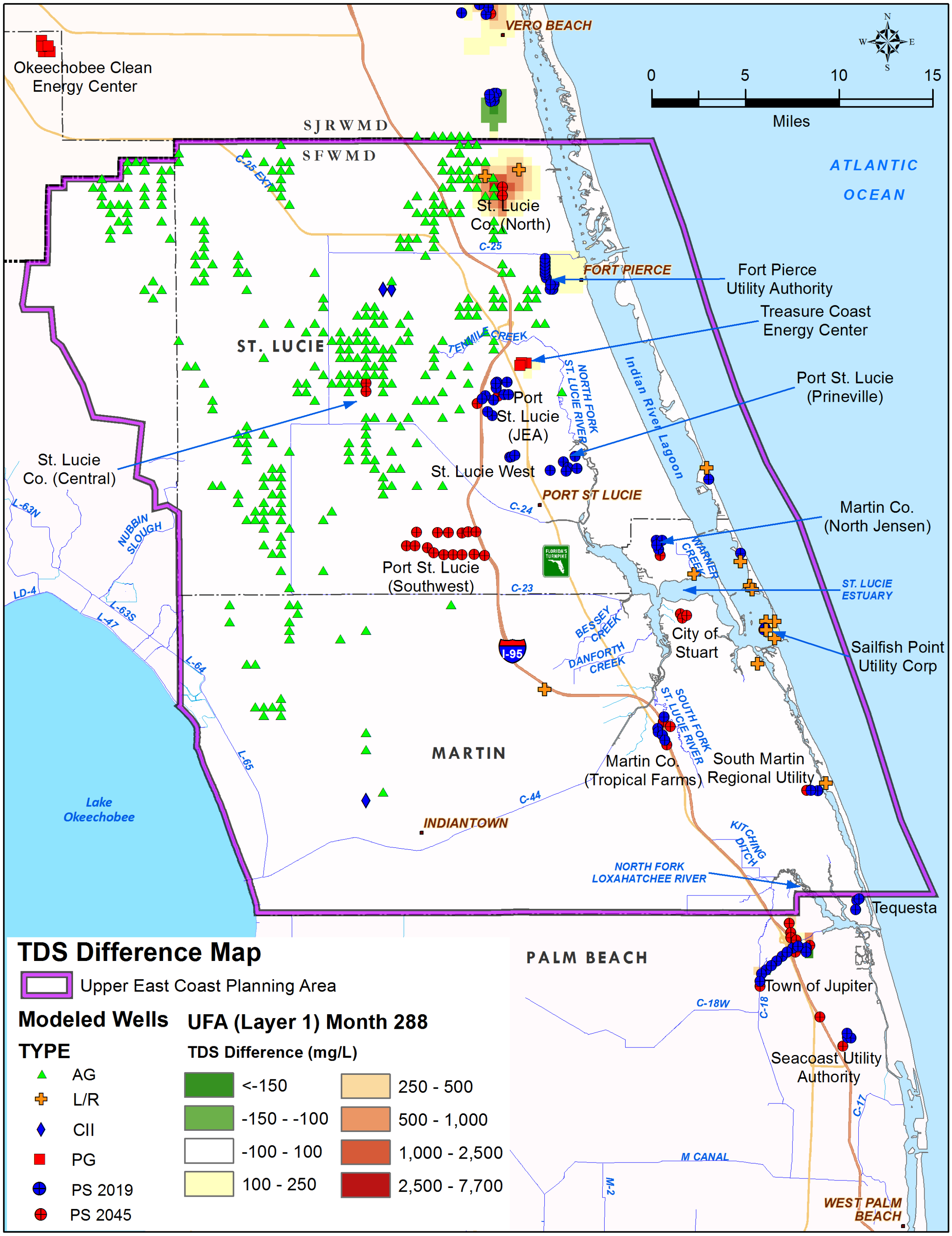


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Figure 5-14. Upper Floridan aquifer water quality (total dissolved solids concentration) difference between the 2019 base condition and 2045 future simulation (2045 minus 2019) for the final condition (month 288).

Figures 5-15 and **5-16** show the spatial distribution of APPZ water quality for the 2019 and 2045 model scenarios, respectively. Both maps represent the final condition (month 288) of the TDS concentration from the respective model simulations for the 24-year period. Within the UEC Planning Area, TDS concentrations in the APPZ vary between 3,000 and 12,000 mg/L. TDS concentrations range between 5,000 and 10,000 mg/L along the coastline while inland TDS concentrations range between 2,000 and 5,000 mg/L. The highest TDS concentration (12,000 mg/L) appears around St. Lucie County Utilities' North wellfield.

Spatial distribution of the water quality differences for the 2019 base condition and 2045 future simulation in the APPZ is shown in **Figure 5-17**. Changes in water quality are represented by comparing the final conditions (month 288) of the 2019 and 2045 scenarios. TDS concentration is predicted to change 100 mg/L or less for most of the UEC Planning Area. The greatest change in TDS concentration is predicted to occur at St. Lucie County Utilities' North wellfield and the City of Port St. Lucie Utility Systems Department's Southwest wellfield.

The water quality degradation around St. Lucie County Utilities' North wellfield ranges between 500 and 1,000 mg/L. Despite no withdrawal of water from the APPZ, the TDS concentration degradation is projected to be as high as 1,000 mg/L at four wells in two neighboring model cells, while the remaining area shows an average degradation of 500 mg/L.

Water quality degradation at the City of Port St. Lucie Utility Systems Department's Southwest wellfield ranges between 300 and 600 mg/L and expands toward the coast. Although APPZ demand increases 9.43 mgd from 2019 to 2045, the water quality degradation is not significant, primarily due to the wellfield location, which is far from the saltwater interface. TDS concentrations at the City of Stuart wellfield increase approximately 1,000 mg/L in the APPZ layer as a result of the projected increase in PS demands (2.6 mgd). The change in TDS concentration is high compared to the change in PS demands because of the wellfield's proximity to the saltwater interface. Lateral saltwater movement and increased demands by Martin County Utilities may contribute to the increase in TDS concentrations at City of Stuart's wellfield.

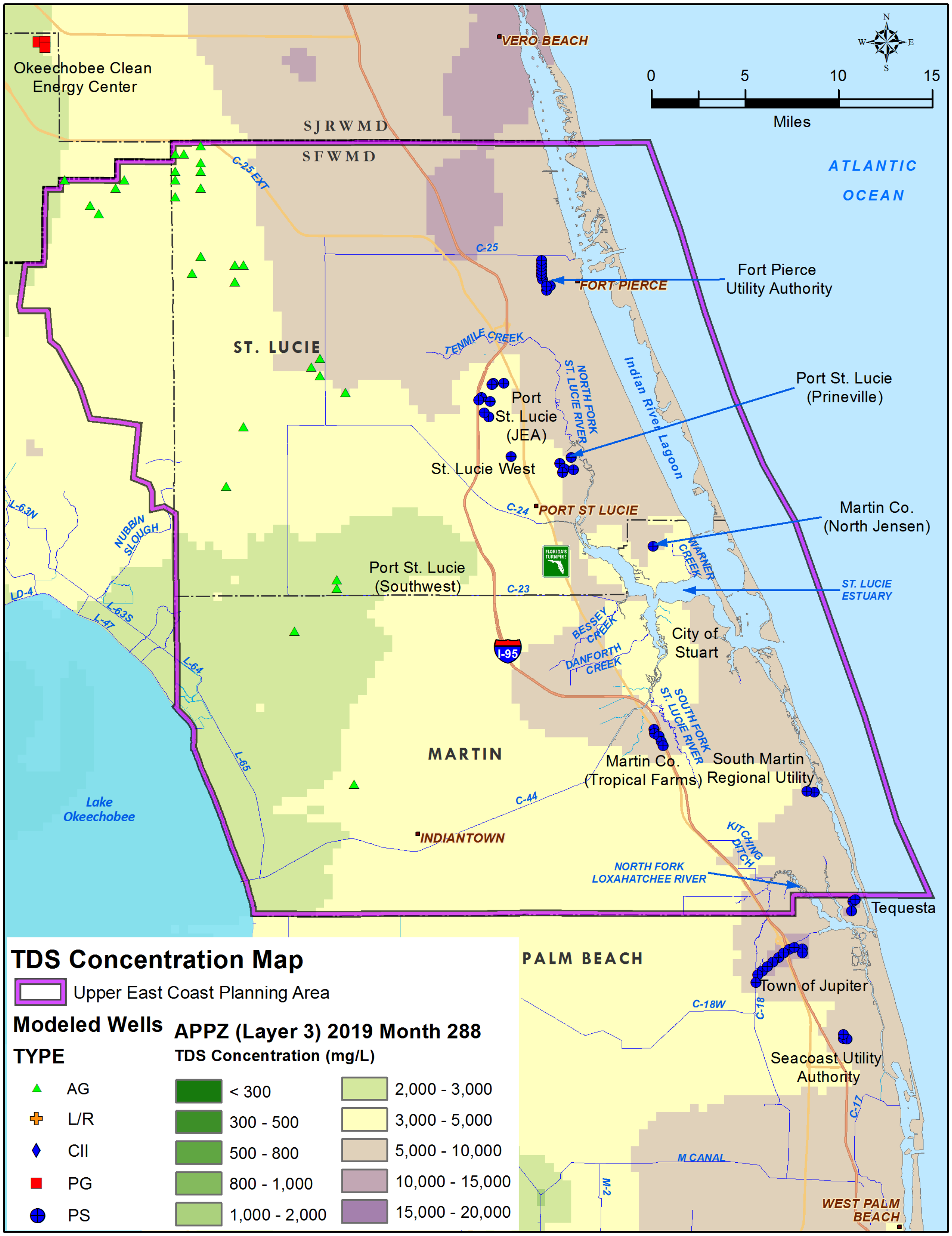

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Figure 5-15. Avon Park permeable zone water quality (total dissolved solids concentrations) for the final condition (month 288) of the 2019 base condition.

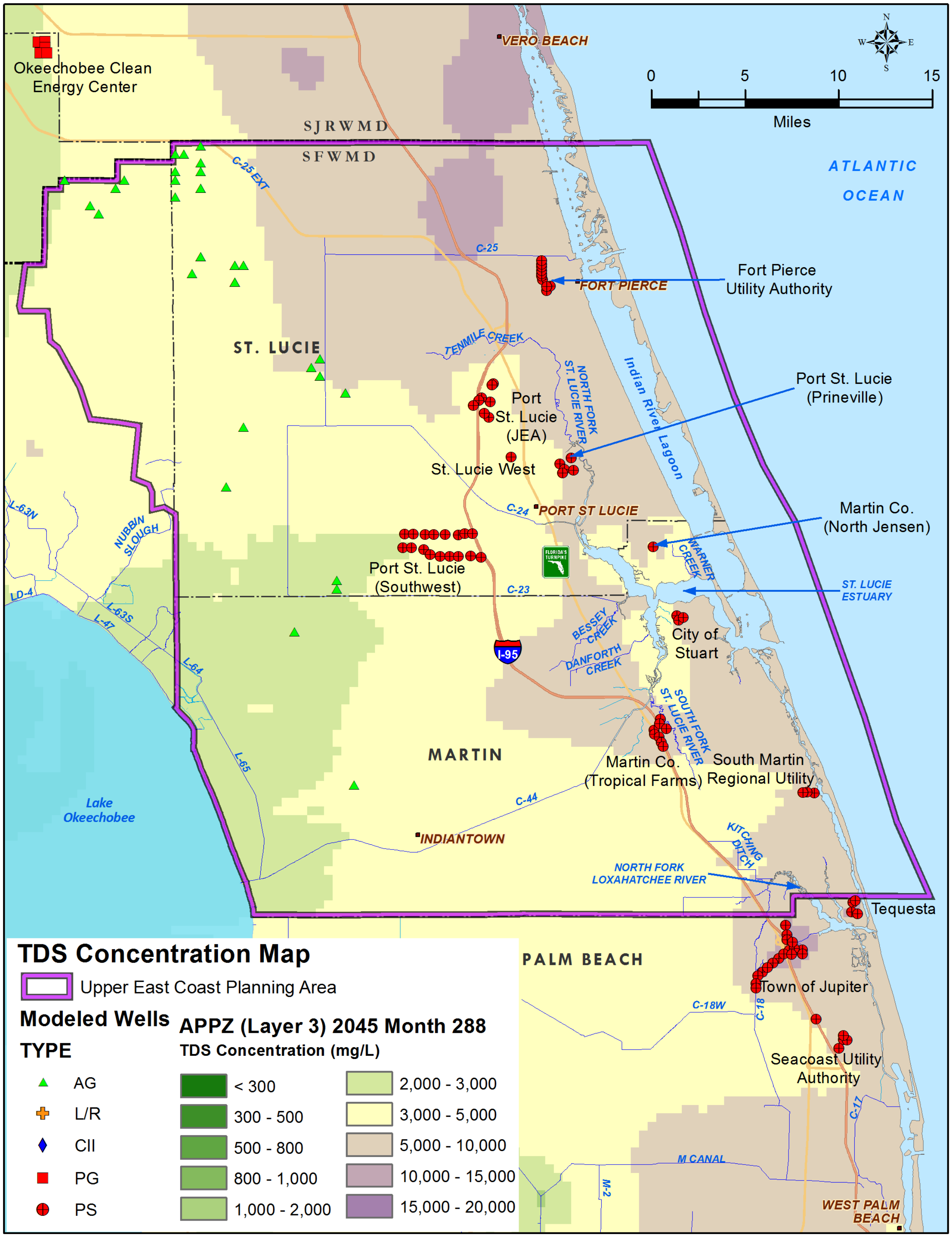
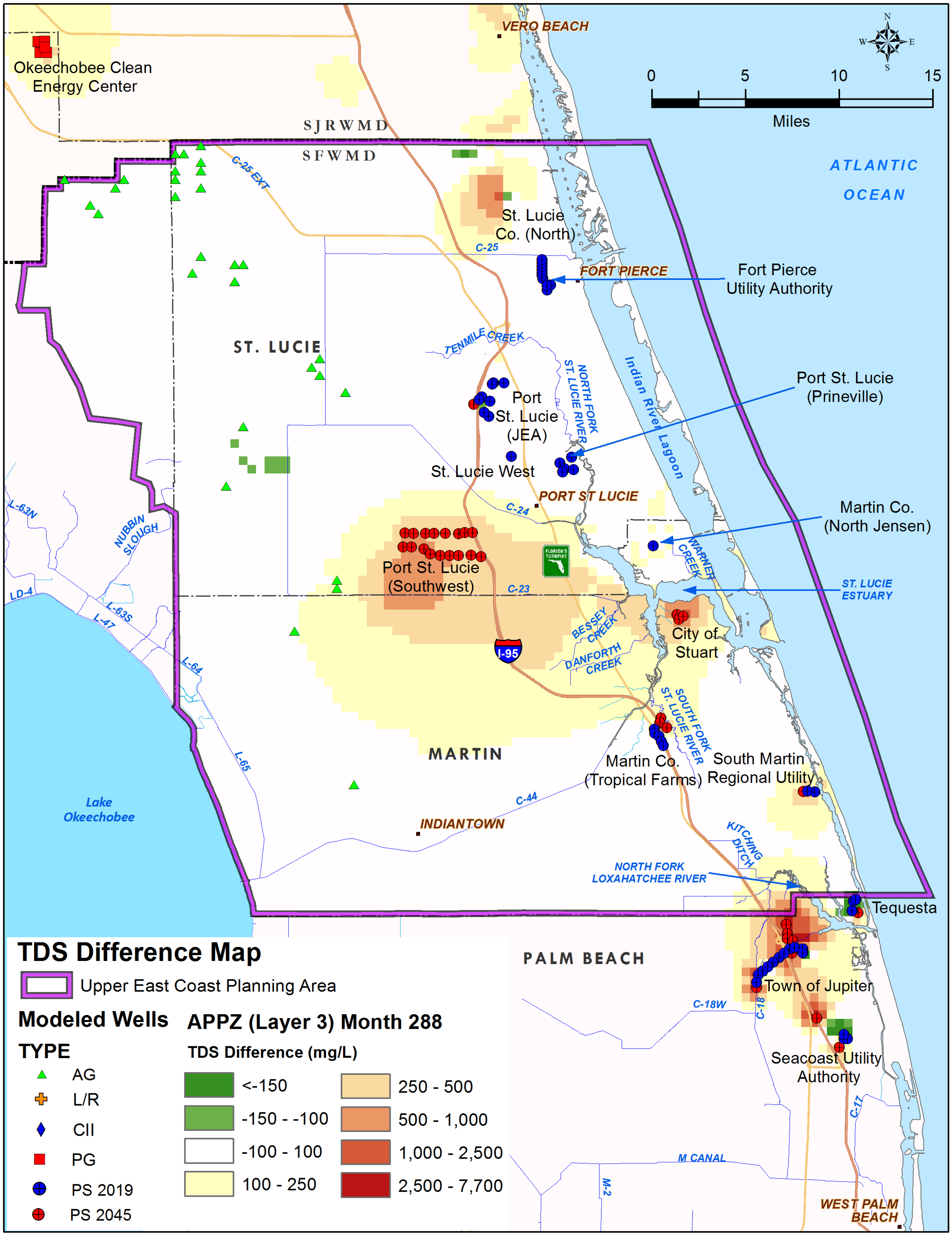


Figure 5-16. Avon Park permeable zone water quality (total dissolved solids concentrations) for the final condition (month 288) of the 2045 future simulation.



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Map Produced on Date: 8/9/2021 12:12 \\ad.sfwmd.gov\dfsroot\data\wsd\MOD\ECFM\MB\UEC\GIS\postprocess\mxd\Report2021\Figure5.17_ALT_DIFF_WaterQualityAPPZ.mxd

Figure 5-17. Avon Park permeable zone water quality (total dissolved solids concentration) difference between the 2019 base condition and 2045 future simulation (2045 minus 2019) for the final condition (month 288).

5.2.3 Horizontal Flow Direction and Magnitude in the Aquifers

Horizontal flow vectors show the magnitude and direction of lateral flow for the final condition (month 288) of the 2019 and 2045 scenarios. A comparison of superimposed flow vectors is necessary to understand the subtle changes in flow magnitude and direction resulting from the difference in water use demand. The horizontal flow vectors represent a resampling of horizontal flows in an area of five model cells by five model cells. Thus, the vectors represent average flow conditions for each grouping of 25 cells. **Figures 5-18** and **5-19** show the resampled horizontal flow vectors for the 2019 base condition and 2045 future simulation in the UFA and APPZ, respectively. As illustrated in each figure, water moves into the model domain from the northern recharge area along the Lake Wales Ridge and the potentiometric high in Polk and Osceola counties, which provide the primary FAS recharge in South Florida. Overall, the flow pattern shows a general northwest to southeast movement, as expected based on historical, regional potentiometric levels (Meyer 1989, Miller 1990).

There are apparent differences in the magnitude and direction of flow vectors in the UFA for 2019 and 2045 (**Figure 5-18**). A distinct increase in the magnitude of lateral flow can be seen from the northern recharge area into the vicinity of St. Lucie County Utilities' North wellfield and Fort Pierce Utilities Authority's wellfields. This increase in flow from an area of higher head and fresher water could minimize drawdown and water quality degradation due to increased PS demand. A noticeable change in flow direction for the 2045 future simulation is apparent across the City of Port St. Lucie Utility Systems Department's three wellfields. The 2045 flow vectors at St. Lucie County Utilities' North wellfield and Fort Pierce Utilities Authority's wellfields show higher magnitude and movement towards the wellfields than the 2019 flow vectors. There are flows with increased magnitude coming from the Atlantic Ocean towards the Fort Pierce Utilities Authority's wellfields, indicating potential lateral saltwater intrusion. However, at the City of Port St. Lucie Utility Systems Department's JEA wellfield, the flow vectors drift away from the wellfield. This is likely is a response to the decrease in water demand and is consistent with the water level and water quality difference maps.

Changes in the flow vectors between the 2019 and 2045 are less apparent in the APPZ. **Figure 5-19** shows a slight increase in the magnitude of horizontal flow from the east due to UFA withdrawals at St. Lucie County Utilities' North wellfield. There is inland flow movement towards the City of Port St. Lucie Utility Systems Department's Southwest wellfield and the City of Stuart's wellfield due to increased PS demand.

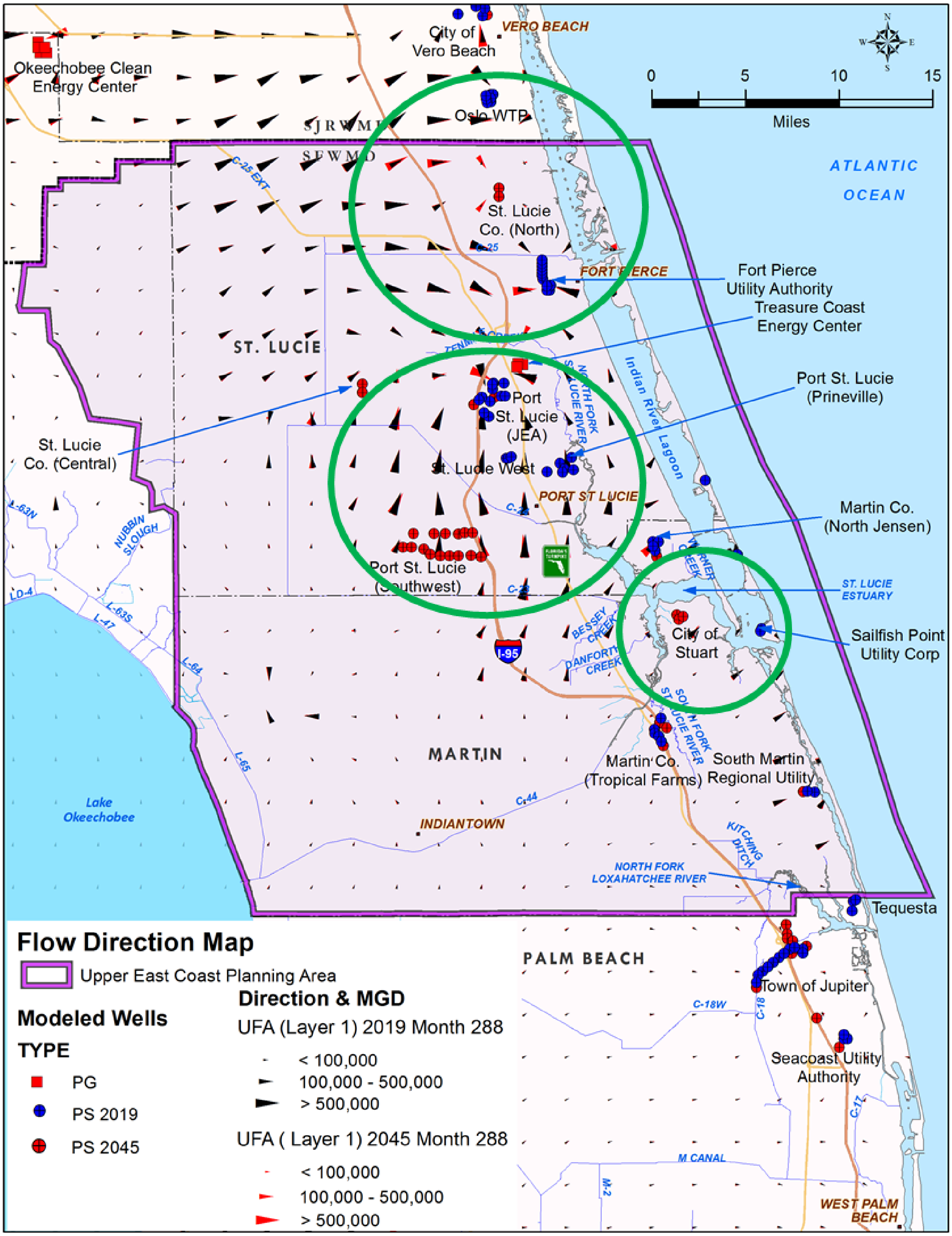

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Figure 5-18. Resampled horizontal flow vectors (flow direction) for the final condition (month 288) of the 2019 base condition and 2045 future simulation in the Upper Floridan aquifer.

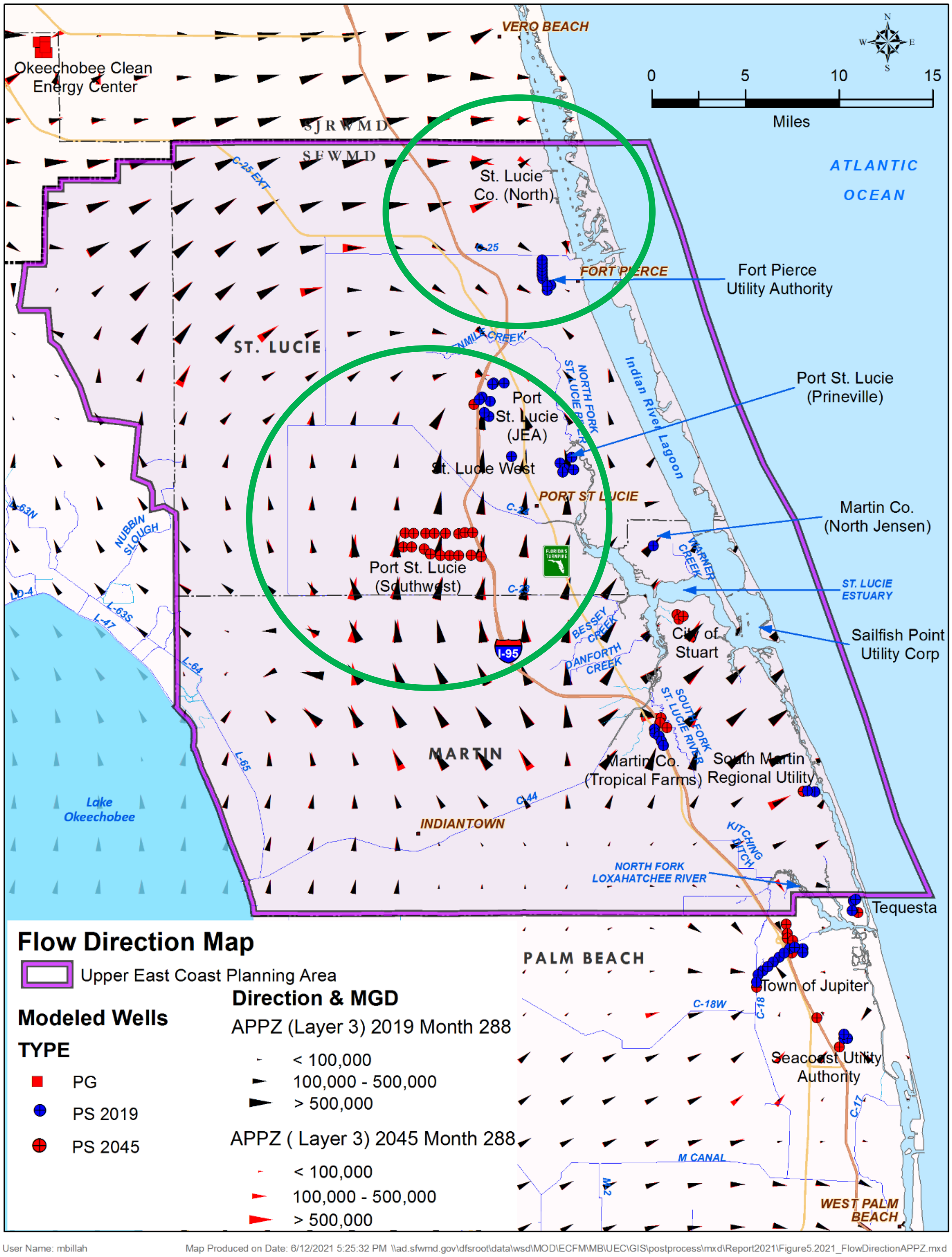


Figure 5-19. Resampled horizontal flow vectors (flow direction) for the final condition (month 288) of the 2019 base condition and 2045 simulation in the Avon Park permeable zone.

5.2.4 Reduction in Heads of Free-Flowing Wells

The final graphics illustrate changes in artesian head above land surface. Current SFWMD water use rules protect flowing FAS wells in Martin and St. Lucie counties (SFWMD 2021). The rules are designed to protect legal users that rely on a sufficient head above land surface to supply enough water to meet crop demands without a pump. Proposed demand increases from 2019 to 2045 may cause additional drawdowns, which may reduce or eliminate flow from these wells.

Figures 5-20 and **5-21** show the artesian heads above land surface for a dry month (month 218, which corresponds to February 2007, a 1-in-10-year drought condition) in the 2019 and 2045 scenarios, respectively. Generally, artesian heads above land surface increase from north to south and can be up to 50 ft NGVD29. **Figure 5-22** illustrates the difference in artesian heads above land surface for a dry month (month 218) between the 2019 base condition and 2045 future simulation. The most impacted area is near St. Lucie County Utilities' North wellfield, where there is a 10- to 15-ft reduction in artesian head above land surface. This is approximately a 100% reduction in artesian head above land surface from the 2019 base condition to the 2045 future simulation (**Figure 5-23**), indicating a complete diminishing of free-flowing wells in the area. Additionally, around Fort Pierce Utilities Authority's wellfields, the simulated reduction in artesian head above land surface is approximately 2.5 ft (**Figure 5-22**). This is approximately a 22% reduction in artesian head above land surface between the 2019 and 2045 scenarios (**Figure 5-23**). Finally, in some parts of central St. Lucie County the artesian head above land surface increases up to 5 ft, associated with projected reduction in AG demands.

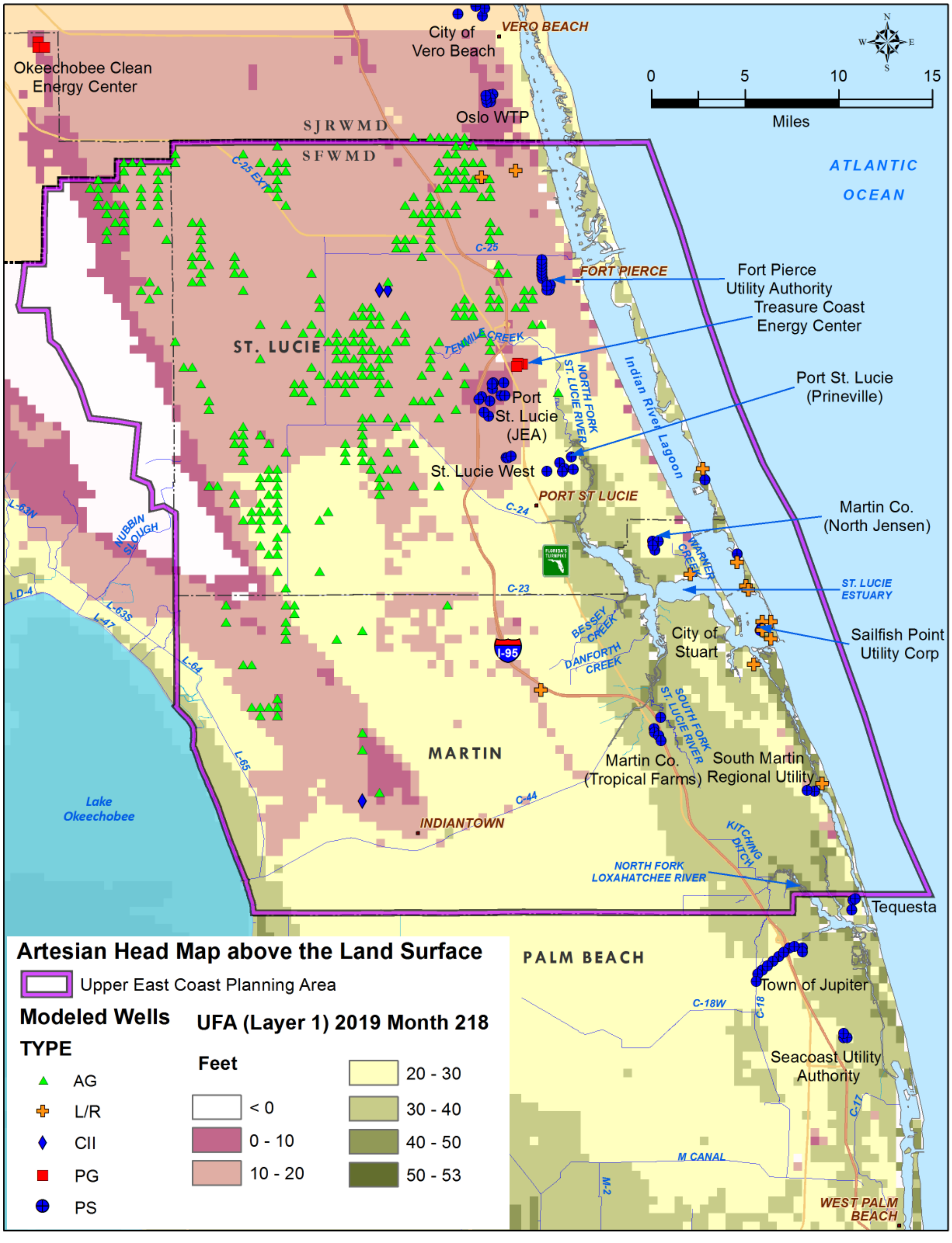
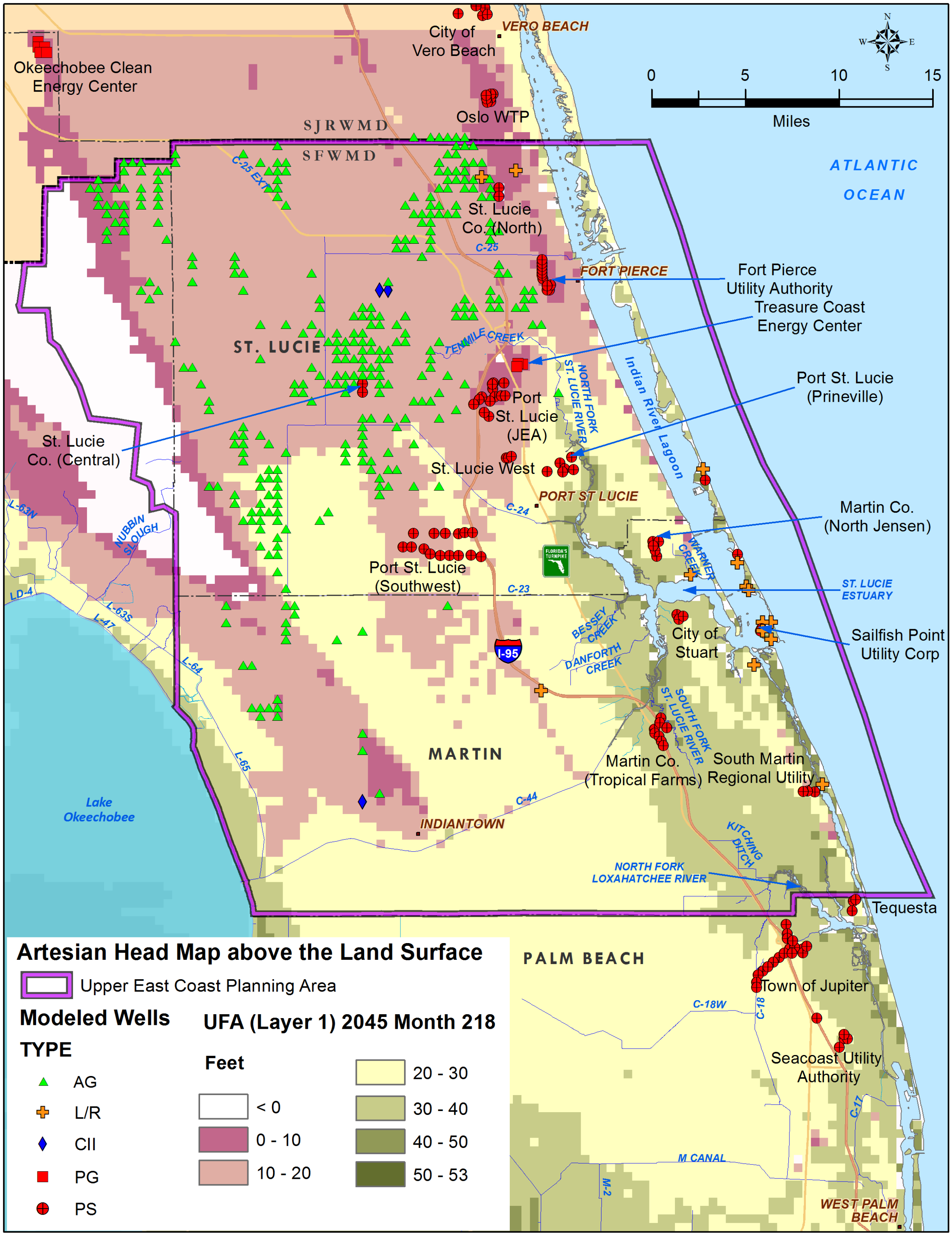


Figure 5-20. Artesian head above land surface in the Upper Floridan aquifer during a dry month (month 218) of the 2019 base condition.



User Name: mbillah Map Produced on Date: 7/27/2021 5:25:53 PM \\ad.sfwmd.gov\dfsroot\data\wsd\MOD\ECFM\MB\UEC\GIS\postprocess\mxd\Report2021\Figure5.23_ArtesianFlow2045.mxd

Figure 5-21. Artesian head above land surface in the Upper Floridan aquifer during a dry month (month 218) of the 2045 future simulation.

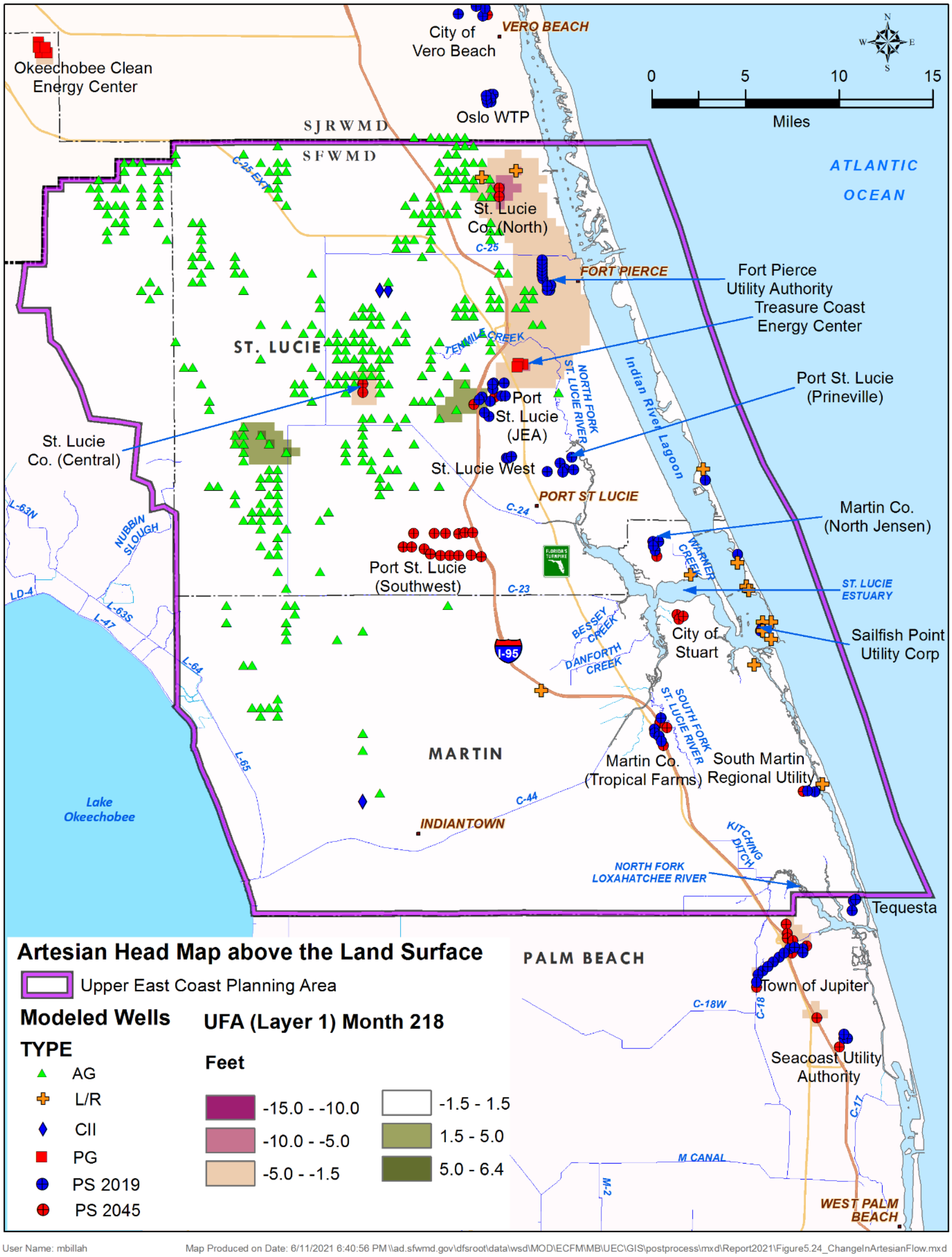


Figure 5-22. Difference in artesian head in the Upper Floridan aquifer during a dry month (month 218) between the 2019 base condition and 2045 future simulation (2045 minus 2019).

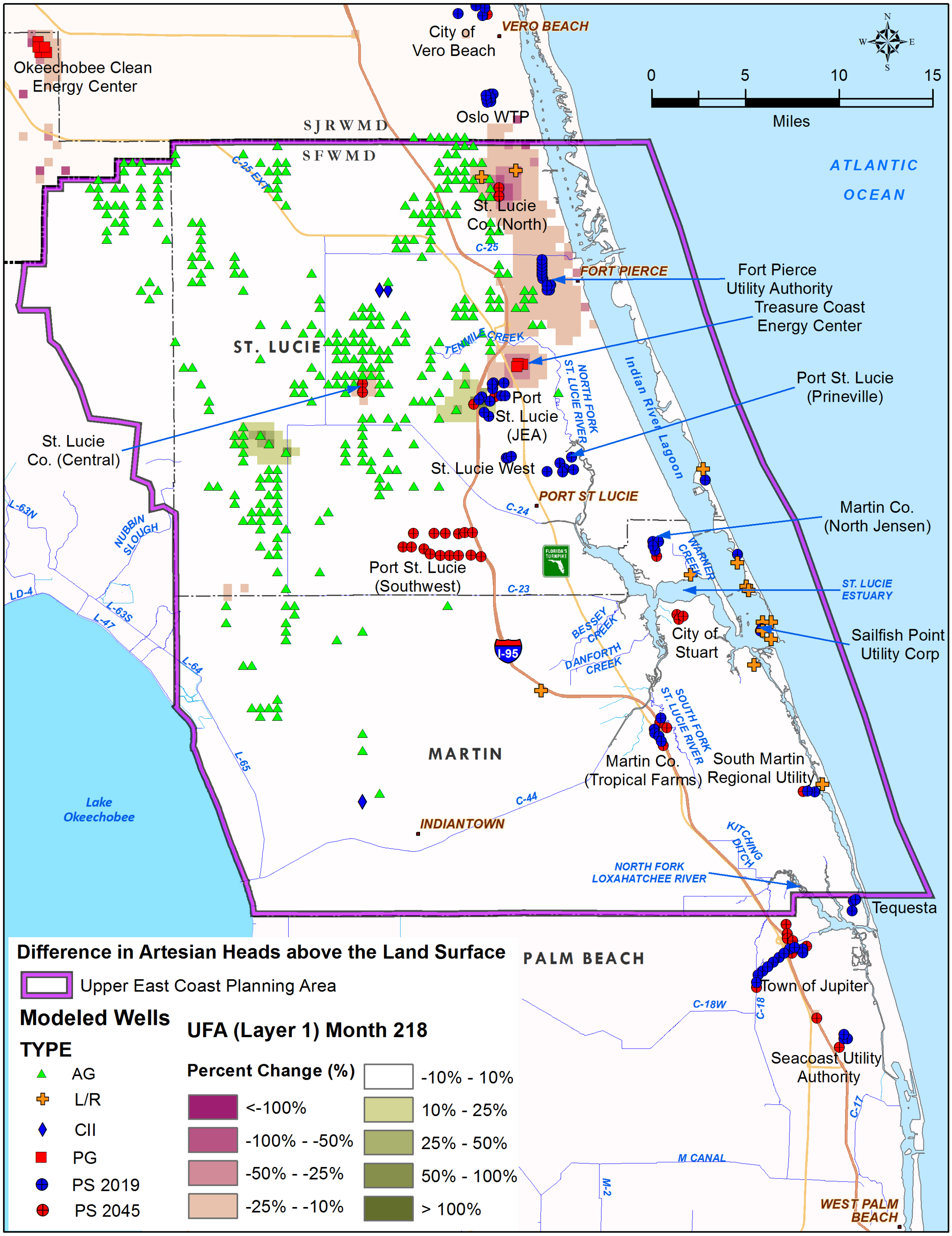


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Figure 5-23. Percent change in artesian head in the Upper Floridan aquifer during a dry month (month 218) between the 2019 base condition and 2045 future simulation (2045 minus 2019).

6 CONCLUSIONS AND RECOMMENDATIONS

The 2014 version of the ECFM was updated with new hydrostratigraphic (layering) data from the ECFTX Model and with new hydrogeologic data from aquifer tests conducted across the model domain. The newly refined 2021 ECFM model was re-calibrated to meet calibration criteria established by the peer-review panel for the 2014 ECFM. After re-calibration, the ECFM was used to simulate 2019 (base condition) and 2045 (future simulation) demands from the FAS within the UEC Planning Area. AG and L/R demands on the FAS are projected to decrease approximately 12% within the region, from 40.14 mgd in 2019 to 35.39 mgd in 2045. PS demands on the FAS are projected to increase approximately 65%, from 36.18 mgd in 2019 to 59.74 mgd in 2045. Overall, FAS demands in the UEC Planning Area are projected to increase approximately 26%, from 77.95 mgd in 2019 to 98.65 mgd in 2045.

Planning-level groundwater model simulations were conducted to evaluate changes in potentiometric surfaces (i.e., water levels) and water quality (i.e., TDS concentrations) as a result of the UEC Planning Area's overall net increase in FAS use. These results may not be observed if wellfield spacing and design/operation plans are implemented to minimize potential impacts. The primary findings, with recommendations when appropriate, are as follows:

1) St. Lucie County Utilities' proposed North wellfield is projected to cause localized issues in the UFA that may be of concern. In the presently proposed configuration, the wellfield could cause upconing of poor-quality water into the wellfield and surrounding areas and reduce the ability of nearby wells to naturally flow. The water quality degradation could prevent nearby AG users from being able to directly use groundwater for irrigation. St. Lucie County Utilities should provide a clear picture of the actual wellfield designs and the number, capacity, depth, location, and spacing of wells at each proposed site. With this information, further analysis can be conducted to determine potential interference between the proposed wellfields and the adjacent existing permitted users.

2) A conservative approach is recommended for future users targeting the APPZ as their primary source of water in Martin and St. Lucie counties. ECFM simulations and observed data suggest that sustained withdrawals from the APPZ generally result in water quality degradation in these coastal areas, sometimes reaching or exceeding TDS concentrations of 8,000 to 10,000 mg/L. PS utilities have had to backfill wells, install additional wells to improve well spacing, implement adaptive management strategies for well rotation, and undertake other costly measures to address the worsening water quality issues associated with prolonged withdrawals from the APPZ. Exploratory well drilling and aquifer testing at the time of construction should be conducted to better understand the water quality beneath the target zone. Furthermore, wellfields that minimize well interference should be constructed, even at higher pipeline transmission costs, and flexibility should be built into the design of water treatment plants to accommodate higher TDS concentrations.

3) The City of Port St. Lucie Utility Systems Department should continue construction of the Southwest wellfield, targeting the UFA when possible, and continue evaluation of source options other than the FAS as its demands increase. The Southwest wellfield appears to be in a highly transmissive area of the UFA and APPZ, and the ECFM simulations indicate minimal drawdown and water quality changes as a result of increased withdrawals.

4) Because of the potential for impacts in the UEC Planning Area, additional analysis of the interaction among the Town of Jupiter, Village of Tequesta, and Seacoast Utility Authority is suggested.

5) The projected increases in withdrawals from St. Johns River Water Management District's Oslo wellfield and the St. Lucie County Utilities' North wellfield are likely to have a cumulative impact on free-flowing wells near the border of Indian River and St. Lucie counties. In some places, especially along the coast, the model indicates there will no longer be any artesian heads above land surface due to increased withdrawals at these two wellfields. The simulation results highlight the different regulatory processes of St. Johns River Water Management District and SFWMD, suggesting a need to develop a more robust and consistent framework.

6) Reduction in AG demand in St. Lucie County caused rebound in UFA water levels, up to 3 ft near the City of Port St. Lucie Utility Systems Department's JEA wellfield and the agricultural wellfields for Vero Producers, Inc.; Circle I Ranch; and LTC Ranch.

Based on the results of this modeling effort, the projected 2045 demands for the UEC Planning Area do not cause widespread concerns regarding water level and water quality; however, there are isolated areas where minor issues are projected to occur. These areas need continued monitoring and adaptive planning strategies, such as increased spacing between pumping wells and rotating operations between pumping wells, to best manage the FAS.

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APPENDIX A: UPDATED HYDROGEOLOGIC AND HYDROSTRATIGRAPHIC INFORMATION

Table A-1. Hydrostratigraphic information for the overlap area between the East Coast Floridan Model (ECFM) and East-Central Florida Transient Expanded (ECFTX) model domains.

SFWMD ID	SJRWMD Name	X Plane	Y Plane	Upper Floridan Aquifer		Avon Park Permeable Zone	
				Top	Bottom	Top	Bottom
Brevard County – SJRWMD							
BR0004	BR0004	833875	1282955	-296			
BR0015	BR0015	816162	1290556	-270			
	BR0080	828259	1287438	-314			
BR0082	BR0082	828098	1290201	-311			
	BR0083	828154	1291278	-309			
	BR0377	718708	1280244	-229			
	BR0398	827777	1293956	-291			
BR0404	BR0404	809296	1279417	-265			
BR0405	BR0405	757428	1273293	-259			
	BR0409	831948	1285843	-285			
	BR0410	832033	1286447	-284			
BR0625	BR0625	832408	1285876	-295			
	BR0696	818312	1287596	-306	-623	-668	
	BR0782	704497	1292243	-161			
BR0783	BR0783	717999	1285535	-171			
	BR0803	716000	1280749	-254			
	BR0805	716187	1275800	-203			
	BR0806	716102	1273273	-212			
	BR0807	716105	1271055	-242			
	BR0808	719141	1280953	-380			
	BR0809	718333	1281760	-206			
BV3-PW	BR0811	720522	1280283	-228			
	BR0814	720687	1284635	-181			
	BR0815	720762	1286007	-174			
	BR0816	725596	1285817	-213			
W-13076	BR0817	714497	1288252	-156			
	BR0818	714444	1289342	-155			
	BR0825	716886	1292302	-152			
	BR0835	722209	1291396	-171			
	BR0850	761445	1281741	-234			
	BR0918	745183	1276562	-263			
BR0920	BR0920	741793	1281032	-253			
	BR1012	786444	1285666	-270			
	BR1125	762134	1280946	-233			
	BR1158	708090	1289322	-192			
	BR1159	703243	1290628	-166			
BR1198	BR1198	743618	1267910	-246			
BR1200	BR1200	828029	1285653	-317			
BR1201	BR1201	733785	1290208	-193			
BR1202	BR1202	777336	1280316	-287			

SFWMD ID	SJRWMD Name	X Plane	Y Plane	Upper Floridan Aquifer		Avon Park Permeable Zone	
				Top	Bottom	Top	Bottom
BR1203	BR1203	761301	1268961	-260			
	BR1204	746873	1281918	-231			
	BR1205	831042	1287753	-285			
	BR1206	708635	1285987	-181			
	BR1207	718704	1274894	-204			
	BR1289	706056	1293543	-162			
BR1293	BR1293	776811	1296037	-279			
BR1323	BR1323	701041	1284301	-165			
BR1324	BR1324	708117	1293195	-161			
	BR1325	711943	1293162	-134			
	BR1326	703341	1282449	-217			
BR1327	BR1327	705990	1274409	-192			
	BR1328	709354	1283769	-198			
BR1329	BR1329	711458	1278452	-172			
BR1330	BR1330	719814	1273516	-225			
	BR1382	718960	1282975	-381			
	BR1387	719935	1289440	-194			
	BR1393	832391	1287156	-281			
	BR1401	808167	1293050	-242			
	BR1419	812342	1295551	-269			
	BR1461	757582	1271140	-241			
	BR1500	805532	1293812	-248			
	BR1503	779680	1296345	-257	-546	-696	
	BR1504	776719	1296234	-244			
	BR1505	774238	1296523	-245			
	BR1506	777159	1298964	-245			
	BR1507	771954	1299555	-222			
	BR1508	774294	1297540	-228			
	BR1509	771426	1296221	-227			
BR1521	BR1521	784288	1268219	-309			
	BR1522	800225	1272282	-317			
BR-1559	BR1559	799266	1272164	-268			
BR1627	BR1627	738534	1293851	-225			
	BR1671	789844	1288606	-293			
	BR1690	805899	1291488	-260			
	BR1696	810858	1285449	-256			
	BR1701	808344	1285745	-246			
	BR1706	809457	1284018	-236			
	BR1736	789099	1270221	-301			
	BR1745	808426	1287254	-258			
	BR1762	809683	1287057	-263			
	BR1786	791226	1286985	-331			
	BR1819	805666	1285626	-246			
	BR1820	807291	1282705	-267			
	BR1935	806903	1287051	-235			
	W-17520	801423	1272019	-314			

SFWMD ID	SJRWMD Name	X Plane	Y Plane	Upper Floridan Aquifer		Avon Park Permeable Zone	
				Top	Bottom	Top	Bottom
Glades County – SFWMD							
BREX-1	BREX-1	617755	997563			-1,168	-1,418
GLF-1	GL00012	681155	1022611	-610			
GLF-0002	GL00013	650436	983227	-653			
W-5439	GL0013	688753	1011715	-610			
W-15880	GL0029	593659	988826	-654	-784		-1,674
W-14780	W-14780	609458	1016047	-536			
W-16281	W-16281	614893	1016139	-573			
Highlands County							
Highlands County – SFWMD							
HI00009	HI00009	543527	1135149	-361			
HIF-42	HI0090	671208	1048459	-520		-1,281	-1,521
IMWI-NO2	IMWI-NO2	566172	1074042			-1,128	
W-15163	W-15163	539772	1132418	-361			
W-17042	W-17042	565860	1154965	-269			
W-17092	W-17092	602608	1097853	-397			
HI00014	W-17415	608838	1101883	-367	-502	-1,012	
W-5132	W-5132	539185	983227	-547			
Highlands County – SWFWMD							
HIF-5_G	HI0005	549487	1037485	-464			
W-17001	HI0072	541167	1024291	-502	-580	-1,306	-1,654
ROMP28F	W-15644	545854	1066254	-447			
Indian River County – SJRWMD							
IR0011	IR0011	835719	1225672	-311			
IR0024	IR0024	856218	1224858	-610			
	IR0034	783506	1198405	-308	-450		
	IR0035	848341	1247871	-379			
IR0167	IR0167	836119	1223184	-307			
	IR0189	712813	1248731	-301			
IR0198	IR0198	856215	1195202	-437			
IR0314	IR0314	734697	1191749	-355			
IR0319	IR0319	762354	1177073	-391			
IR0320	IR0320	872500	1177919	-614			
IR0322	IR0322	871292	1184982	-527			
IR0323	IR0323	812493	1188408	-399	-450		
IR0325	IR0325	790205	1190279	-408	-460		
IR0327	IR0327	772916	1196285	-317			
IR0328	IR0328	779204	1198727	-304			
IR0329	IR0329	796841	1197073	-417	-450		
IR0330	IR0330	816802	1198963	-397			
IR0332	IR0332	824528	1200913	-346			
IR0333	IR0333	830822	1201346	-326			
IR0334	IR0334	825591	1204352	-331			
IR0335	IR0335	849595	1206078	-352			
IR0336	IR0336	843025	1207457	-362			
IR0337	IR0337	819503	1219679	-350			
W-13958	IR0338	838820	1222488	-311			
IR0339	IR0339	778751	1229426	-298			

SFWMD ID	SJRWMD Name	X Plane	Y Plane	Upper Floridan Aquifer		Avon Park Permeable Zone	
				Top	Bottom	Top	Bottom
IR0340	IR0340	814104	1243788	-266			
	IR0341	849470	1244720	-445			
IR0342	IR0342	849497	1245258	-427			
	IR0343	848374	1250976	-407			
	IR0344	814915	1261832	-260			
	IR0345	820113	1264176	-281			
	IR0346	821131	1278321	-277			
IR0354	IR0354	836129	1241156	-279			
	IR0392	712377	1265226	-193			
IR-154F	IR0406	848870	1245698	-401			
IR0458	IR0458	743906	1177230	-374			
IR0463	IR0463	746703	1174309	-372			
	IR0469	820442	1184201	-417			
	IR0473	804734	1197874	-375	-550	-750	
IR0490	IR0490	855329	1192773	-368			
IR0498	IR0498	852421	1234973	-424			
	IR0553	821735	1219344	-330			
IR0572	IR0572	850498	1187096	-344			
IR0573	IR0573	850235	1185179	-344			
	IR0576	841420	1237106	-322			
IR0578	IR0578	841000	1237040	-318			
IR0615	IR0615	773812	1259102	-298			
IR0623	IR0623	799155	1203643	-369			
IR0624	IR0624	825883	1262318	-272			
IR0625	IR0625	782515	1260539	-283			
IR0627	IR0627	736358	1261228	-285			
IR0628	IR0628	779729	1261747	-297			
	IR0629	773854	1264011	-330			
IR0630	IR0630	777205	1264766	-289			
IR0631	IR0631	775052	1264353	-303			
IR0632	IR0632	846218	1254231	-324			
	IR0633	846185	1254901	-342			
IR0634	IR0634	837632	1206932	-319			
IR0636	IR0636	828893	1189524	-353			
IR0638	IR0638	814465	1198149	-395			
IR0639	IR0639	773355	1200027	-336			
IR0640	IR0640	826854	1182744	-418			
IR0696	IR0696	790714	1199876	-385			
IR0698	IR0698	855956	1229236	-392			
IR0699	IR0699	856018	1228494	-400			
IR0700	IR0700	839510	1202764	-328			
IR0701	IR0701	789276	1172609	-378			
IR0706	IR0706	792017	1187155	-401			
IR0707	IR0707	854498	1178530	-357			
IR0709	IR0709	848660	1207857	-343			
IR0711	IR0711	846612	1209393	-331			
IR0716	IR0716	853809	1190548	-366			
	IR0718	821958	1187837	-392			

SFWMD ID	SJRWMD Name	X Plane	Y Plane	Upper Floridan Aquifer		Avon Park Permeable Zone	
				Top	Bottom	Top	Bottom
	IR0723	836855	1199554	-310			
IR0730	IR0730	811305	1201464	-390			
IR0732	IR0732	815555	1217743	-337			
IR0733	IR0733	771573	1224759	-381			
IR0734	IR0734	780648	1226302	-337			
IR0735	IR0735	755656	1228455	-319			
IR0736	IR0736	777553	1238918	-389			
IR0737	IR0737	755623	1241983	-280			
IR0738	IR0738	761048	1262804	-243			
IR0739	IR0739	747661	1265895	-252			
IR0740	IR0740	733952	1251632	-296			
IR0742	IR0742	796496	1218274	-337			
IR0743	IR0743	805253	1208107	-369			
IR0744	IR0744	810202	1230444	-315			
IR0745	IR0745	721963	1222226	-327			
IR0746	IR0746	723394	1227273	-278			
IR0747	IR0747	727917	1211835	-293			
IR-1001	IR0748	825417	1182435	-421	-515	-716	-954
IR0751	IR0751	839999	1180886	-362			
IR0756	IR0756	846707	1246151	-343			
IR0761	IR0761	840514	1225120	-306			
	IR0763	720345	1257835	-273			
IR0772	IR0772	737621	1257900	-264			
	IR0773	722590	1258340	-265			
	IR0778	782745	1263736	-306			
IR0779	IR0779	811351	1189249	-419			
	IR0786	815922	1186203	-406			
	IR0799	838249	1200223	-328			
	IR0801	831187	1254428	-269			
IR0805	IR0805	839634	1260060	-293			
IR0806	IR0806	831876	1206800	-325			
	IR0807	835378	1221326	-285			
IR0808	IR0808	864997	1201510	-488			
	IR0831	842358	1234822	-319			
	IR0838	849063	1217145	-377			
	IR0841	812082	1209446	-338			
	IR0842	830642	1221943	-297			
	IR0844	784980	1248632	-321			
IR0854	IR0854	735403	1199528	-328			
IR0878	IR0878	834042	1204792	-327			
IR0885	IR0885	835913	1248731	-289			
	IR0904	824002	1176068	-416			
	IR0906	822056	1181982	-419			
	IR0907	821190	1181306	-422			
	IR0908	820973	1182790	-390			
	IR0909	820799	1181575	-426			
IR0921	IR0921	782364	1251553	-308			
IR0927	IR0927	837915	1203702	-319			

SFWMD ID	SJRWMD Name	X Plane	Y Plane	Upper Floridan Aquifer		Avon Park Permeable Zone	
				Top	Bottom	Top	Bottom
W-3022	IR0930	851328	1201339	-394			
IR0932	IR0932	823143	1273923	-296			
	IR0934	825302	1265410	-277			
IR0938	IR0938	836664	1181680	-392			
	IR0950	819595	1197053	-411			
IR0954	IR0954	792571	1182311	-396			
IR0956	IR0956	775485	1209321	-349			
IR0963	IR0963	813569	1219955	-357			
	IR0964	805774	1260697	-291			
W-17725	IR0968	727890	1225416	-268			
IR0970	IR0970	827560	1206781	-330			
	IR0972	785033	1250418	-279			
	IR0980	829355	1263106	-346			
	IR0986	855178	1186715	-357			
	IR0989	849470	1209879	-333			
IR0991	IR0991	857902	1199856	-500	-700	-800	
IR0998	IR0998	796900	1230700	-287			
	IR1001	816992	1263191	-295			
IR-1006	IR1006	840790	1204575	-336			
	IR1008	857807	1200414	-499			
	IR1014	774094	1193364	-344			
	IR1015	806730	1198018	-376			
	IR1016	782000	1254061	-291			
	IR1017	834656	1193200	-338			
	IR1019	797471	1228159	-318			
	IR1021	844052	1203807	-352			
	IR1025	788318	1235583	-349			
	IR1028	788324	1232958	-324			
	IR1030	791022	1232964	-358			
	IR1031	792279	1232866	-331			
	IR1033	789683	1230332	-318			
	IR1034	791032	1230240	-350			
	IR1036	788344	1227601	-310			
	IR1037	789690	1227608	-326			
	IR1038	791039	1227615	-327			
	IR1039	792299	1227615	-324			
	IR1040	788262	1224976	-356			
	IR1042	790960	1224884	-358			
	IR1043	792217	1224891	-345			
	IR1047	827393	1262594	-300			
	IR1050	736220	1172491	-378			
	IR1058	851033	1242698	-431			
	IR1064	787031	1244057	-300			
	IR1066	785682	1244057	-339			
	IR1071	833300	1243631	-306			
	IR1074	845457	1257021	-357			
	IR1076	847183	1253089	-365			
	IR1077	847580	1245114	-379			

SFWMD ID	SJRWMD Name	X Plane	Y Plane	Upper Floridan Aquifer		Avon Park Permeable Zone	
				Top	Bottom	Top	Bottom
	IR1078	846832	1251573	-342			
	IR1079	848568	1245423	-423			
	IR1080	786221	1244057	-316			
	IR1082	852555	1238471	-404			
	IR1083	845378	1254796	-363			
	IR1084	841922	1244983	-320			
	IR1090	824702	1197952	-378			
	IR1091	834994	1186584	-348			
	IR1092	785111	1226282	-343			
	IR1093	825804	1232091	-291			
	IR1096	825781	1173922	-430			
	IR1111	834121	1253654	-300			
	IR1118	775246	1199475	-304			
	IR1127	831397	1213719	-298			
IR1163	IR1163	735935	1201700	-386	-726	-886	-1,041
	IR1183	825030	1252170	-292			
	IR1228	856107	1234438	-500	-720		
W-3021	W-3021	731461	1191237	-349			
W-3033	W-3033	710342	1240585	-252			
W-3783	W-3783	707014	1244313	-266			
Martin County – SFWMD							
MF-1	MF-1	824173	1043550	-627			
MF-4	MF-4	928690	1037248	-755			
MF-9	MF-9	828909	1031656	-512			
MT00052	MR0031	803969	983995	-715			
W-16067	MR0039	895776	1057452	-711	-1,226	-1,436	-1,656
TFIW-2	MR0069	896799	1005846	-695			
TFRO-3	MR0072	896265	1004829	-693			
TFRO-2	MR0073	896258	1005741	-704			
TFRO-1	MR0074	896163	1006746	-685	-956	-1,136	
TFRO-5	MR0075	898631	1002020	-659			
ICW-1	MR0076	814301	983503	-713	-919	-1,469	
WA-1151	MR0077	831945	1042270	-620			
M-1359	MR0078	941306	989161	-861	-1,116	-1,285	
M-1352	MR0079	900538	1041233	-772	-1,039	-1,222	-1,642
M-1332	MR0080	814921	984947	-711			
MF-36B	MR0086	917748	1025361	-801			
WA-1155	MR0088	777038	1014603	-697			
MF-6	MT00006	791721	1027980	-668			
MF-10	MT00010	887370	997405	-627			
MF-3	MT00012	922776	1047508	-722			
MF-23	MT00023	798252	996539	-748			
MF-20	MT00044	781793	1025925	-645			
MT00045	MT00045	911375	1033198	-764			
MT00046	MT00046	915658	1053520	-811			
MT00053	MT00053	915270	1031301	-775			
MF-31	MT00054	924778	1024357	-835			
MF-34	MT00055	887426	1035883	-607			

SFWMD ID	SJRWMD Name	X Plane	Y Plane	Upper Floridan Aquifer		Avon Park Permeable Zone	
				Top	Bottom	Top	Bottom
MF-33	MT00056	789503	1016158	-670			
M-1364	MT-1364	794744	989312	-750			
M-1366	MT-1366	916560	1041508	-807			
MF-40	W-18726	826444	1044449	-702	-942	-1,072	
WA-546	MR0087	917922	1010317	-701			
Okeechobee County							
Okeechobee County – SFWMD							
OKF-2	OE0002	749601	1166439	-377			
OKF-6A	OE00041	676144	1110455	-479			
OKF-7	OE00042	725823	1102434	-606			
OKF-54	OE00049	682160	1196830	-279	-731	-891	
OKF-34	OE00051	648425	1161687	-342	-726	-896	
OKF-5	OE00052	718911	1083845	-564			
OE00054	OE00054	682104	1090770	-553			
OKF-19	OK0017	667483	1132970	-353			
OKF-18	OK0018	652711	1135497	-416			
OKF-37	OK0022	656403	1144181	-378	-698	-878	
OKF-36	OK0026	648661	1159527	-313			
OKF-42	OK0037	592651	1151802	-368			
W-15813	OK0064	669836	1104902	-436	-795	-1,201	-1,381
OKF-100	OK0098	698136	1025453	-543	-786	-1,336	-1,511
OKF-101	OK0101	708356	1041095	-593			
OKF-17	OK0102	682590	1091460	-558			
OKF-105	OK0105	619123	1115300	-340	-638	-1190	-1,438
OKF-29	OKF-29	707592	1129871	-371	-795		
LKOKEE_ASR	OKF-77	725757	1055562	-676	-726	-1,284	-1,606
OLI-IW1	OLI-IW1	756443	1091568			-1,123	-1,523
OUA-EW1	OUA-EW1	716866	1078246	-671	-671	-1,181	-1,541
OKF-81	W-16539	613308	1152064	-371			
W-16579	W-16579	629317	1124483	-408			
W-16977	W-16977	671743	1159416	-292			
W-17423	W-17423	726341	1082323	-577			
W-17541	W-17541	622386	1132970	-352			
Okeechobee County – SJRWMD							
OK0002	OK0002	700529	1179783	-304	-782	-897	
OK0003	OK0003	713296	1187273	-391			
OK0005	OK0005	751931	1169773	-366			
OK0006	OK0006	697578	1161903	-329			
	OK0047	712833	1172392	-325			
Osceola County							
Osceola County – SFWMD							
OS00001	OS00001	616783	1298630	-251			
OS00009	OS00009	656885	1286998	-171			
OSF-3	OS00010	639530	1286467	-258			
OSF-52	OS00019	592047	1259988	-223		-803	-1,143
OSF-104	POF-20	613203	1208993	-244	-546	-891	-1,236
W-9132	W-9132	623813	1227890	-259			
W-9133	W-9133	613016	1214572	-283			

SFWMD ID	SJRWMD Name	X Plane	Y Plane	Upper Floridan Aquifer		Avon Park Permeable Zone	
				Top	Bottom	Top	Bottom
W-9144	W-9144	615904	1225370	-281			
W-9151	W-9151	610374	1264057	-241			
Osceola County – SJRWMD							
OSF-0042	OS00011	664884	1229846	-314	-662		
FLA-OS4	OS0002	662182	1257612	-228	-521	-791	-961
OSF-60	OS0075	689662	1222652	-218			
OS0231	OS0231	669186	1270136	-289			
Polk County – SFWMD							
POF-18	W-10808	593465	1247766	-209			
W-17022	W-17022	593058	1216312	-344			
W-1726	W-1726	581479	1260113	-235			
POF-9	W-381	542273	1206899	-259			
	W-437	537632	1211638	-215			
W-4503	W-4503	549221	1262607	-188			
W-9251	W-9251	540471	1275767	-183			
St. Lucie County – SFWMD							
FPU_RO-IW1	FPU_RO-IW1	866323	1130449	-482	-701	-958	-1,332
NRCS121-1	NRCS121-1	820487	1133613	-491			
NRCS2-1	NRCS2-1	812611	1115365	-481			
NRCS29-8	NRCS29-8	831646	1167168	-421			
PSL-DMW	PSL-DMW	869842	1081666			-1,079	-1,436
PSL-F14	PSL-F14	843271	1096021			-1,211	
SLF-11	SL00011	790294	1163925	-389			
SL00033	SL00033	829782	1150751	-463			
SLF-42	SL00042	878827	1156744	-599			
SLF-45	SL00045	877630	1161483	-612			
SLF-50	SL0073	819089	1092405	-602			
PSLLTC-IW1	SL0089	850626	1104239	-537	-1,037	-1,199	-1,531
PSLWPT-IW1	SL0090	866389	1055240	-714		-1,210	-1,784
SLF-70	SL0091	849529	1163308	-391			
WA-1000	SL0094	829185	1100308	-486			
WA-1001	SL0095	827924	1100196	-513			
WA-1002	SL0096	829017	1097479	-508			
WA-1003	SL0097	828650	1098988	-482			
WA-1004	SL0098	825040	1100288	-476			
WA-1005	SL0099	825033	1101601	-479			
WA-1006	SL0100	825936	1101502	-486			
WA-1009	SL0102	852030	1148986	-404			
WA-1014	SL0103	838446	1106504	-582			
WA-1016	SL0104	836553	1106596	-495			
WA-1033	SL0107	850353	1160591	-371			
WA-1083	SL0108	828154	1109287	-461			
WA-1087	SL0110	774048	1116566	-478			
WA-1119	SL0114	768364	1119678	-458			
WA-1134	SL0115	857974	1131539	-430			
WA-1136	SL0116	817422	1111263	-439			
WA-1139	SL0117	846238	1155517	-375			
WA-1140	SL0118	820149	1105112	-454			

SFWMD ID	SJRWMD Name	X Plane	Y Plane	Upper Floridan Aquifer		Avon Park Permeable Zone	
				Top	Bottom	Top	Bottom
WA-1144	SL0120	844666	1145310	-434			
WA-1147	SL0121	794537	1081896	-556			
WA-1158	SL0122	832007	1115260	-524			
WA-1186	SL0123	873786	1139803	-614			
WA-1192	SL0124	820826	1093809	-516			
WA-547	SL0125	792099	1109655	-572			
WA-562	SL0128	846120	1081312	-484			
WA-580	SL0132	853878	1084462	-513			
WA-582	SL0134	847029	1082913	-498			
WA-638	SL0135	806067	1134650	-439			
WA-699	SL0136	855768	1121634	-506			
WA-708	SL0137	871870	1127673	-473			
WA-820	SL0138	837964	1112963	-451			
WA-823	SL0139	820451	1141975	-422			
WA-825	SL0140	858732	1123669	-483			
WA-826	SL0141	820107	1138135	-489			
WA-827	SL0142	763024	1127843	-441	-824		
WA-829	SL0143	830675	1089910	-529			
WA-877	SL0145	857252	1131841	-431			
WA-878	SL0146	804783	1115963	-471			
WA-887	SL0147	861138	1128933	-464			
SLF-14	SLF-14	795305	1092195	-557			
SLF-17	SLF-17	795584	1087364	-556			
SLF-21	SLF-21	850166	1125342	-441			
SLF-23	SLF-23	828574	1049523	-557			
SLF-26	SLF-26	879874	1111571	-586			
SLF-28	SLF-28	891155	1093967	-595			
SLF-31	SLF-31	852050	1068112	-610			
SLF-4	SLF-4	823517	1141687	-441			
SLF-40	SLF-40	820711	1122888	-429			
SLF-44	SLF-44	911122	1073789	-642			
SLF-47	SLF-47	905884	1089005	-848			
SLF-48	SLF-48	843340	1077964	-537			
SLF-53	SLF-53	803992	1131119	-521			
SLF-54	SLF-54	763188	1059900	-696			
SLF-6	SLF-6	849546	1119697	-459			
SLF-9	SLF-9	789050	1131959	-441	-850		
STL-386	STL-386	883688	1060714	-689			
STL-422	STL-422	864384	1136035	-462			
W-16039	W-16039	866993	1091916			-1,215	
W-16543	W-16543	821554	1092293	-488	-835	-1,055	-1,425
WA-1107	WA-1107	772390	1129793	-476			
WA-565	WA-565	853274	1078903	-577			
WA-875	WA-875	819470	1117735	-501			

SFWMD = South Florida Water Management District; SJRWMD = St. Johns River Water Management District; SWFWMD = Southwest Florida Water Management District.

Table A-2. Location of the new hydrogeologic information to update the East Coast Floridan Model calibration.

Test Site	Well Name	Type of Test	Layer	Test Value (feet/day)	Model Simulated Value (feet/day)
Broward County WTP 1A	BCWTP1FW-1	Packer Test	UFA	96	96
City of Sunrise WWTF	SUN-SGF1	Packer Test	APPZ	15	24
Lake Region RO WTP	LRRO-PW3	APT	UFA	47	54
Okeechobee Energy Center	OCEC-FA1	APT	UFA	310	280
Okeechobee Energy Center	OCEC-FA2	Step Test	APPZ	400	402
S-65A Structure at Kissimmee River Basin	OSF-109	APT	APPZ	1,260	190
Seacoast Utility Authority	SUA-F3	APT	APPZ	137	135

APPZ = Avon Park permeable zone; APT = aquifer performance test; RO = reverse osmosis; UFA = Upper Floridan aquifer; WTP = water treatment plant; WWTF = wastewater treatment facility.

APPENDIX B: TARGETS REMOVED FROM CALIBRATION

Table B-1. Target stations that were removed from the calibration analysis.

Station	County	Reason(s)
Heads – Upper Floridan Aquifer		
MF-10	Martin	Only 1 data point
STL-219	St. Lucie	Station used for analyzing water level from kriging of rasters
STL-224	St. Lucie	Station used for analyzing water level from kriging of rasters
STL-244	St. Lucie	Station used for analyzing water level from kriging of rasters
STL-346	St. Lucie	Station used for analyzing water level from kriging of rasters
STL-353	St. Lucie	Station used for analyzing water level from kriging of rasters
STL-354	St. Lucie	Station used for analyzing water level from kriging of rasters
STL-355	St. Lucie	Station used for analyzing water level from kriging of rasters
Total Dissolved Solids Concentration		
Total Dissolved Solids Concentration – Upper Floridan Aquifer		
SUN-RO1	Broward	37 data points; no monitoring well for water level
ORC-PW5	Monroe	2 data points; no monitoring well for water level
OKF-105U	Okeechobee	Water level monitoring well although calibrated within mean absolute error <1 foot, only 2 water quality monitoring data available
PBC-3W	Palm Beach	6 data points; no monitoring well for water level; neighboring water quality monitoring site (PBC-SR1A) is calibrated within desirable interval
SLF-76	St. Lucie	23 data points; no monitoring well for water level; site is calibrated within desirable interval; however, water quality monitoring site (SLF-75) is calibrated within desirable interval in the same cell
STL-381	St. Lucie	2 data points; no monitoring well for water level; site is calibrated within desirable interval; however, water quality monitoring site (SLF-75) is calibrated within desirable interval in the same cell
STL-385	St. Lucie	2 data points; no monitoring well for water level; site is calibrated within desirable interval; however, water quality monitoring site (FP-FB1) is calibrated within desirable interval in the same cell
Total Dissolved Solids Concentration – Avon Park Permeable Zone		
MCSU-F1	Martin	61 data points; no monitoring well for water level
MCSU-F2	Martin	62 data points; no monitoring well for water level
NMC-F1	Martin	33 data points; no monitoring well for water level; water quality monitoring sites NMC-F2, NMC-F3, and NMC-F4 in the neighboring cell also are not considered
NMC-F2	Martin	44 data points; no monitoring well for water level; water quality monitoring sites NMC-F1, NMC-F3, and NMC-F4 in the neighboring cell also are not considered
NMC-F3	Martin	45 data points; no monitoring well for water level; water quality monitoring sites NMC-F1, NMC-F2, and NMC-F4 in the neighboring cell also are not considered
NMC-F4	Martin	42 data points; no monitoring well for water level; water quality monitoring sites NMC-F1, NMC-F2, and NMC-F3 in the neighboring cell also are not considered
MCTF-F5	Martin	54 data points; no monitoring well for water level; water quality monitoring site within the same cell (MCTF-F4)
OKF-105M	Okeechobee	Water level monitoring well although calibrated within mean absolute error <1 foot, only 2 water quality monitoring data available
LW-MW1A	Palm Beach	2 data points; no monitoring well for water level
PBF-6	Palm Beach	3 data points; water quality monitoring site (PBF-4) is calibrated within desirable interval in the same cell; 1 water level monitoring well calibrated

Station	County	Reason(s)
JUP-RO6	Palm Beach	22 data points; no monitoring well for water level; nearby water quality monitoring site within a mile radius (EN-MW1A) calibrated outside desirable interval, however, with correct trend
PB-1196L	Palm Beach	2 data points; no monitoring well for water level
PSL-F10	St. Lucie	52 data points; water quality monitoring site (PSL-7) is calibrated within desirable interval in the neighboring cell
Total Dissolved Solids Concentration – Lower Floridan Aquifer		
SG-MW1B	Broward	79 data points; no monitoring well for water level
EN-MW1B	Palm Beach	103 data points; no monitoring well for water level
PBC-FPL	Palm Beach	20 data points; no monitoring well for water level
SCU-MW1B	Palm Beach	200 data points; no monitoring well for water level; erroneous data

Table B-2. Inconsistent data that were removed from calibration targets.

Station	Date	Water Level (ft)	Total Dissolved Solids (mg/L)
Water Level			
FPU-MZL	6/1/2006	9.068	--
FPU-MZL	12/1/2011	25.211	--
FPU-MZL	1/1/2012	21.759	--
FPU-MZL	2/1/2012	24.566	--
FPU-MZL	9/1/2012	20.868	--
Water Quality			
OS-MW1C	7/1/1996	--	20,000
FP-MW1A	6/1/2003	--	2,800
BCN-MW1B	2/1/2005	--	3,625
PH-MW1A	2/1/2006	--	1,510
MDN-FA1B	1/1/2008	--	38,673
SEA-F2	8/1/2010	--	5,577
CL-MW1	11/1/2011	--	26,280
MCTF-F1	10/1/2012	--	2,120

ft = foot; mg/L = milligrams per liter.

APPENDIX C:
WATER LEVEL CALIBRATION STATISTICS

Table C-1. Statistics (in feet) at each head monitoring site in the Upper Floridan aquifer.

Well	Mean Error	MAE	RMSE	MAE Within 2.0 feet	MAE Within 4.0 feet	RMSE Within 4.0 feet
Brevard County						
BEF-1559	0.36	0.50	0.66	Y	Y	Y
BEF-INLET	-0.57	0.69	0.81	Y	Y	Y
BEF-T6	-0.68	1.10	1.31	Y	Y	Y
Broward County						
BR-4S	0.64	0.80	0.98	Y	Y	Y
BR-6	0.05	0.52	0.62	Y	Y	Y
G-2618	1.57	1.57	1.63	Y	Y	Y
G-2619	1.87	1.87	1.92	Y	Y	Y
Glades County						
GLY-155	0.12	1.01	1.28	Y	Y	Y
GLY-CLE	0.27	0.59	0.80	Y	Y	Y
Hendry County						
L2-PW2	0.40	0.58	0.69	Y	Y	Y
Highlands County						
HIF-13	-0.83	1.60	1.91	Y	Y	Y
HIF-37	-0.42	1.06	1.27	Y	Y	Y
HIF-40	-0.13	0.74	1.01	Y	Y	Y
HIF-42U	1.08	1.19	1.41	Y	Y	Y
HIF-6	0.07	1.26	1.59	Y	Y	Y
Indian River County						
IR-368	-1.70	1.86	2.10	Y	Y	Y
IR-370	0.06	1.21	1.43	Y	Y	Y
IR-373	0.66	1.22	1.39	Y	Y	Y
IRF-1006	-0.48	1.04	1.30	Y	Y	Y
IRF-1008	-0.42	1.54	2.00	Y	Y	Y
IRF-189	-0.19	1.42	1.62	Y	Y	Y
IRF-210	0.08	1.19	1.56	Y	Y	Y
IRF-365	1.72	1.76	1.95	Y	Y	Y
IRF-954	2.21	2.21	2.50	N	Y	Y
IRF-955	1.71	1.76	2.11	Y	Y	Y
IRF-963	0.55	1.04	1.35	Y	Y	Y
IRF-968	0.68	1.32	1.57	Y	Y	Y
IRF-BERRY	0.82	1.38	1.75	Y	Y	Y
IRF-JOHN	-2.58	2.66	2.97	N	Y	Y
IRF-MACE	2.98	3.05	3.57	N	Y	Y
IRF-RO	0.25	1.52	1.80	Y	Y	Y
IRF-USDA	-2.15	2.54	2.94	N	Y	Y

Well	Mean Error	MAE	RMSE	MAE Within 2.0 feet	MAE Within 4.0 feet	RMSE Within 4.0 feet
Martin County						
MF-2	-1.34	1.34	1.47	Y	Y	Y
MF-23	-1.60	1.65	1.82	Y	Y	Y
MF-31	-1.02	1.30	1.73	Y	Y	Y
MF-33	-1.89	1.89	2.00	Y	Y	Y
MF-35B	0.96	1.01	1.14	Y	Y	Y
MF-37	0.50	0.73	0.83	Y	Y	Y
MF-37U	-0.03	0.42	0.51	Y	Y	Y
MF-40U	-0.87	0.92	1.11	Y	Y	Y
MF-51	-0.86	0.88	1.09	Y	Y	Y
MF-52	0.04	0.72	0.91	Y	Y	Y
MF-53	-0.44	0.44	0.71	Y	Y	Y
MF-54	-0.48	0.89	1.19	Y	Y	Y
MF-55	-3.30	3.30	3.66	N	Y	Y
MF-9	-1.24	1.46	2.01	Y	Y	Y
TFRO-5	0.03	0.44	0.59	Y	Y	Y
Miami-Dade County						
DF-4	1.09	1.09	1.16	Y	Y	Y
ENP-100	-1.38	1.38	1.46	Y	Y	Y
G-3061	0.16	0.43	0.51	Y	Y	Y
Okeechobee County						
OKF-1	1.24	1.52	1.75	Y	Y	Y
OKF-100U	0.15	1.37	1.82	Y	Y	Y
OKF-101	-0.22	0.77	0.93	Y	Y	Y
OKF-105U	-0.13	0.93	1.30	Y	Y	Y
OKF-106	-1.77	1.77	1.99	Y	Y	Y
OKF-17	0.14	1.03	1.33	Y	Y	Y
OKF-23	-0.08	1.20	1.57	Y	Y	Y
OKF-31	0.65	1.94	2.32	Y	Y	Y
OKF-34	-1.82	2.08	2.42	N	Y	Y
OKF-42	0.54	0.94	1.20	Y	Y	Y
OKF-7	0.05	1.13	1.38	Y	Y	Y
OKF-71	-0.50	0.81	1.00	Y	Y	Y
OKF-72	-0.83	0.89	1.19	Y	Y	Y
OKF-BAS	-0.65	1.14	1.35	Y	Y	Y
OKF-MAC	-2.02	2.02	2.56	N	Y	Y
OKF-UNK1	-0.02	0.66	0.83	Y	Y	Y
OKF-UNK2	2.31	2.51	2.78	N	Y	Y
OKF-WIL	-0.01	0.57	0.67	Y	Y	Y
TCRK_GW1	-0.56	0.87	1.10	Y	Y	Y

Well	Mean Error	MAE	RMSE	MAE Within 2.0 feet	MAE Within 4.0 feet	RMSE Within 4.0 feet
Osceola County						
OSF-104U	0.40	1.17	1.42	Y	Y	Y
OSF-231	0.01	1.01	1.15	Y	Y	Y
OSF-42	0.95	1.87	2.40	Y	Y	Y
OSF-52	-1.09	1.23	1.47	Y	Y	Y
OSF-60A	0.17	1.13	1.47	Y	Y	Y
OSF-HAY	0.04	1.15	1.45	Y	Y	Y
OSF-65	-0.90	1.34	1.75	Y	Y	Y
Palm Beach County						
PBF-1	-0.78	0.94	0.89	Y	Y	Y
PBF-10R	0.13	1.62	3.28	Y	Y	Y
PBF-14	2.54	2.61	2.96	N	Y	Y
PBF-15U	0.66	0.76	0.90	Y	Y	Y
PBF-2	-0.59	1.18	1.32	Y	Y	Y
PBF-3	-0.78	0.82	0.94	Y	Y	Y
PBF-747	0.81	1.03	1.22	Y	Y	Y
Polk County						
POL_IF	-0.78	1.20	1.52	Y	Y	Y
POL-RR	-0.54	1.11	0.83	Y	Y	Y
POL_20	0.46	1.30	1.57	Y	Y	Y
St. Lucie County						
SLF-11	0.00	0.92	1.17	Y	Y	Y
SLF-17	-0.36	1.22	1.76	Y	Y	Y
SLF-21	0.33	1.08	1.50	Y	Y	Y
SLF-36	-1.13	1.16	1.47	Y	Y	Y
SLF-40	-0.15	0.91	1.10	Y	Y	Y
SLF-61	-1.07	1.28	1.51	Y	Y	Y
SLF-62	-1.48	1.69	1.74	Y	Y	Y
SLF-62B	0.13	0.72	0.91	Y	Y	Y
SLF-63	-1.04	1.08	1.36	Y	Y	Y
SLF-64	0.25	0.80	0.94	Y	Y	Y
SLF-65	-0.94	1.11	1.78	Y	Y	Y
SLF-66	-0.82	1.31	1.57	Y	Y	Y
SLF-67	-0.32	0.84	1.10	Y	Y	Y
SLF-69	0.18	1.65	2.29	Y	Y	Y
SLF-70	-3.37	3.37	3.94	N	Y	Y
SLF-75	-0.27	0.64	0.85	Y	Y	Y
SLF-76	-0.15	0.65	0.88	Y	Y	Y
STL-215	0.17	1.26	1.68	Y	Y	Y
STL-216	-1.01	1.03	1.34	Y	Y	Y
STL-229	0.49	1.15	1.45	Y	Y	Y
STL-251	1.15	1.34	1.67	Y	Y	Y
STL-352	0.64	1.60	1.82	Y	Y	Y
C24GW	-0.69	0.93	1.17	Y	Y	Y
FPU-MZU	1.23	1.28	1.49	Y	Y	Y

MAE = mean absolute error; RMSE = root mean square error.

Table C-2. Statistics (in feet) at each head monitoring site in the Avon Park permeable zone.

Well	Mean Error	MAE	RMSE	MAE Within 2.0 feet	MAE Within 4.0 feet	RMSE Within 4.0 feet
Broward County						
BR-2	1.97	3.17	3.39	N	Y	Y
BR-4M	0.33	0.72	0.90	Y	Y	Y
G-2617	1.84	1.84	1.89	Y	Y	Y
MIR-MZU	-0.22	0.79	0.89	Y	Y	Y
Glades County						
GLF-6	0.02	0.48	0.58	Y	Y	Y
Hendry County						
L2-PW1	0.39	0.56	0.68	Y	Y	Y
Highlands County						
HIF-14	-0.05	1.23	1.51	Y	Y	Y
HIF-3	0.21	1.20	1.66	Y	Y	Y
HIF-4	-1.18	1.45	1.81	Y	Y	Y
HIF-42L	-1.42	1.47	1.72	Y	Y	Y
Martin County						
MF-35	-1.20	1.22	1.53	Y	Y	Y
MF-37L	-0.11	0.44	0.55	Y	Y	Y
MF-40L	-0.93	0.96	1.15	Y	Y	Y
Miami-Dade County						
DF-5	0.05	0.29	0.36	Y	Y	Y
Okeechobee County						
OKF-100	0.59	0.90	1.03	Y	Y	Y
OKF-100L	-0.38	0.95	1.13	Y	Y	Y
OKF-105M	-0.55	0.65	0.82	Y	Y	Y
OKF-73	-0.74	0.85	1.11	Y	Y	Y
OKF-74	0.21	0.61	0.71	Y	Y	Y
TCRK_GW2	-0.65	1.11	1.33	Y	Y	Y
Osceola County						
OSF-104M	-1.61	1.61	1.79	Y	Y	Y
Palm Beach County						
PBF-11	0.17	0.53	0.67	Y	Y	Y
PBF-15M	0.17	0.58	0.67	Y	Y	Y
PBF-4	-1.38	1.38	1.46	Y	Y	Y
PBF-7U	-1.00	1.16	1.29	Y	Y	Y
St. Lucie County						
SLF-14	-1.20	1.20	1.28	Y	Y	Y
SLF-74	-0.49	0.81	1.04	Y	Y	Y

MAE = mean absolute error; RMSE = root mean square error.

Table C-3. Statistics (in feet) at each head monitoring site in the Lower Floridan aquifer – first permeable zone.

Well	Mean Error	MAE	RMSE	MAE Within 2.0 feet	MAE Within 4.0 feet	RMSE Within 4.0 feet
Broward County						
BR-1	2.99	2.99	3.12	N	Y	Y
Palm Beach County						
PBF-12	-0.29	0.57	0.80	Y	Y	Y
PBF-15L	-0.75	0.90	1.12	Y	Y	Y
PBF-5	0.25	0.62	0.79	Y	Y	Y
PBF-7L	-0.67	1.05	1.17	Y	Y	Y
St. Lucie County						
FPU-MZL	0.09	0.84	1.06	Y	Y	Y

MAE = mean absolute error; RMSE = root mean square error.

APPENDIX D:
WATER QUALITY CALIBRATION STATISTICS

Table D-1. Statistics (in milligrams per liter) at each water quality monitoring site in the Upper Floridan aquifer.

Well Name	Simulated Average TDS	Observed Average TDS	Calibration Criteria	Mean Average Difference	Mean Absolute Average Difference	Met Criteria
Broward County						
BCN-MW1A	4,326	4,334	750	8	127	Y
HW-MW1A	4,195	4,242	750	48	121	Y
PP-MW1A	3,262	3,183	500	-78	233	Y
BF-4S	8,392	8,259	750	-127	405	Y
G-2619	1,899	2,131	500	232	232	Y
HOLLY-F5	4,058	4,043	750	-21	288	Y
HOLLY-F6	3,940	4,022	750	25	213	Y
HOLLY-F13	3,922	4,281	750	317	326	Y
DEER-FA2	4,841	4,690	750	-152	167	Y
Hendry County						
L2-PW2	1,750	1,714	500	-36	138	Y
CL-PW1	2,636	2,650	500	8	50	Y
Indian River County						
VB-MW1	2,088	2,555	500	303	303	Y
OS-MW1A	1,633	1,480	500	-39	91	Y
OS-MW1B	1,633	1,741	500	129	170	Y
IR-312	1,387	729	500	-1,087	1,087	N
IR-916	1,005	1,052	500	-12	45	Y
IR-921	1,647	1,753	500	80	98	Y
IR-954	443	574	500	-23	62	Y
IR-955	733	819	500	56	56	Y
IR-963	1,040	1,174	500	10	73	Y
IR-968	1,385	1,457	500	75	91	Y
IR-988	650	472	500	-471	471	Y
IR-1006	454	641	500	131	131	Y
IR-1058	1,448	1,169	500	-593	593	N
IR-1183	328	460	500	67	67	Y
IR-1202	328	735	500	339	339	Y
Martin County						
NMC-MW1A	2,302	2,103	500	-193	228	Y
ST-UFA	4,489	4,681	750	191	255	Y
MF-31	2,650	2,301	500	-352	369	Y
MF-37U	1,405	1,571	500	162	162	Y
MF-40U	2,398	2,297	500	-100	142	Y
MF-52	2,300	2,329	500	30	142	Y
MF-9	2,799	2,756	500	-43	229	Y
SAIL-2	2,226	2,764	500	331	456	Y
IRP-1	2,531	2,263	500	-417	438	Y

Well Name	Simulated Average TDS	Observed Average TDS	Calibration Criteria	Mean Average Difference	Mean Absolute Average Difference	Met Criteria
Miami-Dade County						
MDASR-MW1A	1,871	1,681	500	264	586	N
MDS-FA1A	1,510	1,805	500	301	302	Y
MDN-FA1A	4,202	4,248	750	45	272	Y
DF-4	3,796	3,703	500	-91	119	Y
ENP-100	4,927	5,414	750	472	483	Y
Okeechobee County						
OK-0001	522	375	500	-162	162	Y
TCRK_GW1	402	600	500	195	195	Y
OKF-42	403	417	500	15	27	Y
OKF-100U	766	843	500	40	112	Y
OKF-17	563	546	500	-5	30	Y
OKF-23	1,097	942	500	-82	82	Y
OKF-7	266	248	500	-8	25	Y
OKF-71	1,494	1,622	500	163	186	Y
OKF-72	1,024	802	500	-159	159	Y
OKF-81	407	421	500	14	14	Y
OKF-94	309	316	500	7	7	Y
OKF-39	1,051	995	500	-14	32	Y
FOURK-E	456	452	500	-4	172	Y
FOURK-W	443	382	500	-62	107	Y
Osceola County						
OSF-104U	239	217	500	-21	30	Y
OSF-52	768	801	500	9	105	Y
OSF-60	365	381	500	32	36	Y
OS-231	356	375	500	15	16	Y
Palm Beach County						
PBC-RRF1A	4,402	4,435	750	34	140	Y
PW-MW1A	3,002	3,087	500	84	190	Y
SCU-MW1A	5,740	6,053	750	312	411	Y
BB-MW1A	3,895	3,832	500	-66	168	Y
PBC-SR1A	5,100	5,200	750	100	184	Y
PB-1196U	3,604	3,685	500	81	205	Y
PBF-10R	5,166	5,388	750	97	323	Y
PBF-15U	3,340	3,338	500	5	86	Y
PBF-3	4,416	4,565	750	151	360	Y
ECF-W1	3,203	3,165	500	-39	127	Y
HIGH-FA6	7,383	7,155	750	-233	1017	N
TEQ-RO1	3,609	4,208	750	492	769	N
TEQ-RO3	3,565	3,740	500	57	515	N
JUP-RO1	2,916	4,208	750	1,140	1,194	N
JUP-RO12	4,203	4,161	750	-66	422	Y
LW-F1	3,900	4,107	750	206	213	Y
LW-F2	3,935	4,128	750	191	196	Y
LW-F3	3,939	4,183	750	243	243	Y
MAN-15	3,786	4,752	750	851	1,006	N

Well Name	Simulated Average TDS	Observed Average TDS	Calibration Criteria	Mean Average Difference	Mean Absolute Average Difference	Met Criteria
Polk County						
POF-20R	239	255	500	17	17	Y
St. Lucie County						
FP-MW1A	1,929	1,986	500	72	96	Y
PSLSP-MW1A	2,753	3,009	500	256	327	Y
PSLNP-MW1A	2,250	2,413	500	163	221	Y
STL-376	1,424	934	500	-497	497	Y
STL-215	2,451	2,280	500	-162	162	Y
STL-352	2,504	2,505	500	3	36	Y
SLF-11	2,041	2,043	500	-11	173	Y
SLF-21	918	872	500	-51	99	Y
SLF-60	2,306	2,405	500	99	372	Y
SLF-62B	2,475	2,977	500	494	529	N
SLF-63	2,221	1,849	500	-372	489	Y
SLF-64	2,494	2,670	500	169	330	Y
SLF-65	2,151	2,395	500	244	276	Y
SLF-66	1,621	1,691	500	169	695	N
SLF-67	1,328	943	500	-363	363	Y
SLF-69	1,787	1,644	500	-146	193	Y
SLF-75	2,503	2,130	500	-374	420	Y
SLF-9	3,016	3,097	500	76	266	Y
FP-FB1	682	774	500	11	96	Y
FP-FB3	669	855	500	142	143	Y
PSL-F1	1,781	1,762	500	-92	111	Y
PSL-F2	2,111	2,097	500	-65	95	Y
PSL-F4	2,183	2,206	500	1	62	Y
PSL-F5	2,035	2,165	500	111	126	Y

TDS = total dissolved solids.

Table D-2. Statistics (in milligrams per liter) at each water quality monitoring site in the Avon Park permeable zone.

Well Name	Simulated Average TDS	Observed Average TDS	Calibration Criteria	Mean Average Difference	Mean Absolute Average Difference	Met Criteria
Broward County						
BCN-MW1B	6,052	6,629	750	560	599	Y
FTL-MW1B	9,045	9,490	750	456	574	Y
CC-MW1A	4,356	4,599	750	172	544	Y
CS-MW1A	5,325	5,767	750	447	560	Y
DF-MW1A	7,213	7,837	750	609	676	Y
FTL-PD1A	5,024	5,175	750	131	208	Y
HAL-MW1A	5,588	5,903	750	-133	430	Y
MIR-RO1A	6,239	6,497	750	207	589	Y
MIR-MW1A	4,404	4,262	750	-221	367	Y
PLC-MW1A	4,359	4,522	750	-15	117	Y
PLE-MW1A	4,063	4,330	750	208	281	Y
PL-MW2A	3,770	3,793	500	15	101	Y
PB-MW1A	5,233	5,532	750	282	492	Y
SG-MW1A	3,203	3,460	500	218	227	Y
BF-4M	5,153	4,952	750	-390	390	Y
G-2617	1,502	2,558	500	1,055	1,055	N
Hendry County						
L2-PW1	2,218	1,993	500	-236	246	Y
Indian River County						
OS-MW1C	9,680	12,342	3,000	2,616	2,902	Y
IR-1163	1,520	1,851	500	-130	166	Y
Martin County						
ST-MW1B	3,330	9,218	750	5,867	6,182	N
MF-35B	3,497	3,598	500	102	228	Y
MF-37L	2,688	3,461	500	720	720	N
MF-40L	2,185	2,489	500	-44	134	Y
MCTF-F1	3,286	3,623	500	-74	359	Y
MCTF-F2	3,342	3,494	500	-307	447	Y
MCTF-F3	3,353	3,730	500	-70	272	Y
MCTF-F4	3,422	3,345	500	-572	588	N
Miami-Dade County						
MDASR-MW1B	5,007	5,234	750	110	288	Y
MDS-BZB	8,673	8,881	750	172	515	Y
MDN-FA1B	19,360	20,677	4,000	1,534	2,471	Y
FKAA-MW1A	14,155	14,284	3,000	-1	645	Y
NMB-MW1A	15,839	15,427	3,000	-320	1,848	Y
DF-5	3,194	3,307	500	-90	123	Y
Monroe County						
LARGO-MW1B	20,127	20,600	4,000	357	574	Y

Well Name	Simulated Average TDS	Observed Average TDS	Calibration Criteria	Mean Average Difference	Mean Absolute Average Difference	Met Criteria
Okeechobee County						
TCRK_GW2	4,906	4,738	750	-121	754	N
OKF-100L	1,144	956	500	-348	348	Y
OKF-73	5,056	4,495	750	-515	515	Y
OKF-74	4,281	3,929	500	-292	292	Y
Osceola County						
OSF-104M	245	252	500	-18	43	Y
Palm Beach County						
PH-MW1A	3,450	3,731	500	284	350	Y
BG-MW1A	2,800	3,082	500	294	486	Y
WE-MW1A	8,583	9,149	750	730	880	N
PBC-SC1A	9,998	9,673		-324	548	Y
PBC-RRF1B	7,185	7,056	750	-127	662	Y
EN-MW1A	4,927	3,917	500	-1,497	1,505	N
ACME-1A	5,084	5,058	750	-31	446	Y
PBC-SR1B	12,736	16,312	3,000	3,533	3,533	N
PBF-11	2,777	2,552	500	-344	385	Y
PBF-15M	1,811	3,182	500	1,359	1,359	N
PBF-4	3,488	4,084	750	560	560	Y
PBF-7U	2,570	2,818	500	-36	103	Y
SEA-F2	4,070	3,086	500	-1,201	1,277	N
LR-TP1	2,877	7,129	750	3,324	3,362	N
LR-PW4	2,664	5,700	750	2,624	2,671	N
LR-PW7	2,654	8,071	750	4,989	4,989	N
St. Lucie County						
PSLJA-MW1A	3,308	6,319	750	2,952	2,952	N
TP-MW1A	3,312	9,047	750	5,647	5,647	N
STL-380	3,710	4,265	750	556	556	Y
SLF-14	3,802	2,467	500	-1,335	1,335	N
SLF-74	3,710	4,554	750	840	872	N
SLW-F2	3,081	3,636	500	401	489	Y
PSL-F6	3,999	3,570	500	-481	519	N
PSL-F7	3,306	3,362	500	-4	459	Y

TDS = total dissolved solids.

Table D-3. Statistics (in milligrams per liter) at each water quality monitoring site in the Lower Floridan aquifer – first permeable zone.

Well Name	Simulated Average TDS	Observed Average TDS	Calibration Criteria	Mean Average Difference	Mean Absolute Average Difference	Met Criteria
Broward County						
BCN-MW1C	30,337	30,628	4,000	311	2,402	Y
CC-MW1B	32,311	28,724	4,000	-3,592	4,965	N
FTL-PD1B	33,854	33,257	4,000	-510	1,051	Y
HAL-MW1B	33,535	33,216	4,000	-345	1,611	Y
HW-MW1B	35,000	34,976	4,000	-24	609	Y
MIR-RO1B	32,024	33,033	4,000	1,003	1,428	Y
MIR-MW1B	30,989	28,562	4,000	-2,424	2,886	Y
PLC-MW1B	21,350	21,100	4,000	-425	550	Y
PLE-MW1B	28,466	28,807	4,000	353	509	Y
PL-MW2B	27,378	26,944	4,000	-470	693	Y
PB-MW1B	32,960	33,313	4,000	376	1,820	Y
BF-1	34,313	34,388	4,000	135	1,136	Y
Hendry County						
CL-MW1	18,978	16,964	3,000	-2015	2,368	Y
Indian River County						
OS-MW1D	30,780	31,406	4,000	570	1,774	Y
Martin County						
NMC-MW1B	29,674	32,565	4,000	2,894	6,851	N
TF-MW1A	25,776	21,270	4,000	-4,747	4,759	N
ST-MW1A	30,003	31,434	4,000	1,440	1,731	Y
Miami-Dade County						
MDS-FA1B	33,025	33,711	4,000	687	1,213	Y
Okeechobee County						
OKU-MW1A	11,471	11,125	3,000	-691	737	Y
OKLF-MW1A	19,388	17,964	3,000	-1,759	3,896	N
Palm Beach County						
PH-MW1B	21,001	19,371	4,000	-1,630	2,287	Y
BG-MW1B	14,932	13,701	3,000	-1,156	1,290	Y
LR-MW1A	19,587	17,259	3,000	-2,160	2,171	Y
WE-MW1B	25,434	25,976	4,000	590	2,275	Y
PBC-SC1B	31,398	34,078	4,000	2,743	2,817	Y
LW-MW1B	34,191	34,200	4,000	260	900	Y
PBC-RRF2A	25,007	24,063	4,000	-947	1,839	Y
PW-MW1B	30,887	31,973	4,000	1,104	1,621	Y
BB-MW1B	27,169	27,415	4,000	184	865	Y
ACME-1B	24,503	25,629	4,000	1,126	3,132	Y
PBF-12	30,299	29,550	4,000	-750	1,250	Y
PBF-15L	34,275	33,663	4,000	-104	652	Y
PBF-5	32,490	32,692	4,000	207	1,424	Y
PBF-7L	14,118	13,936	3,000	-246	549	Y

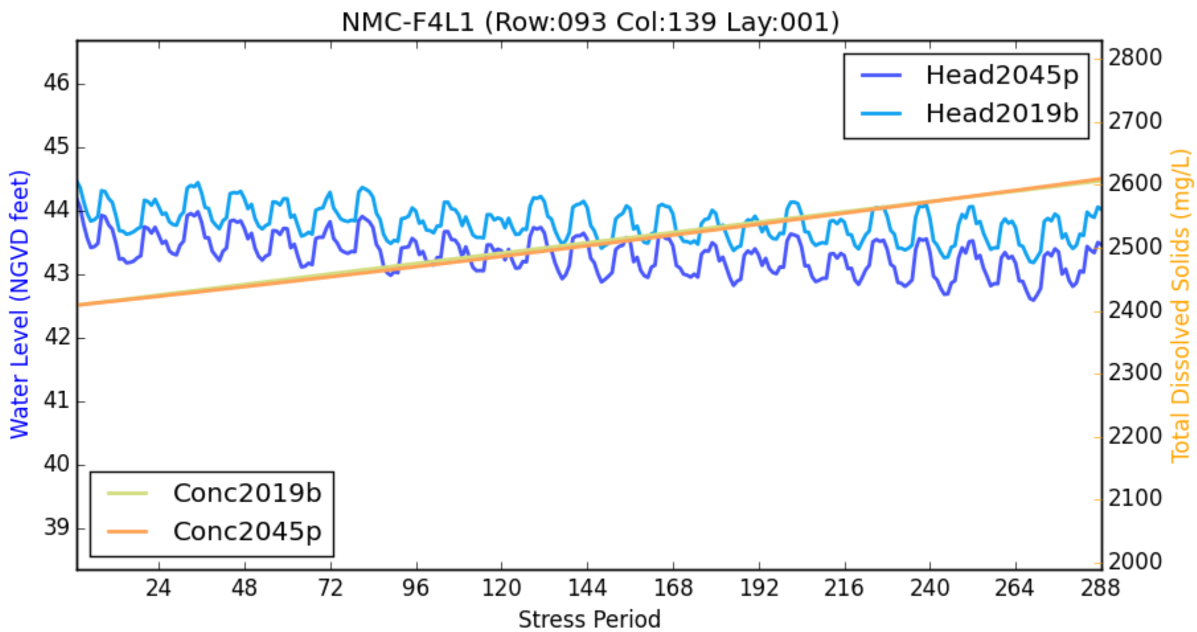
Well Name	Simulated Average TDS	Observed Average TDS	Calibration Criteria	Mean Average Difference	Mean Absolute Average Difference	Met Criteria
St. Lucie County						
PSLJA-MW1B	27,084	26,595	4,000	-534	3,058	Y
FP-MW1B	24,980	24,820	4,000	-173	1,769	Y
FPML-MW1B	25,941	25,039	4,000	-1,011	1,326	Y
TP-MW1B	26,257	26,583	4,000	289	1,367	Y
PSLG-MW1B	30,931	33,300	4,000	2,333	3,496	Y
SLW-MW1B	30,662	35,737	4,000	5,129	5,129	N
WP-MW1B	29,384	29,771	4,000	415	4,028	N
PSLSP-MW1C	26,556	25,130	4,000	-1,505	3,285	Y
PSLNP-MW1B	29,466	18,223	4,000	-11,339	11,339	N

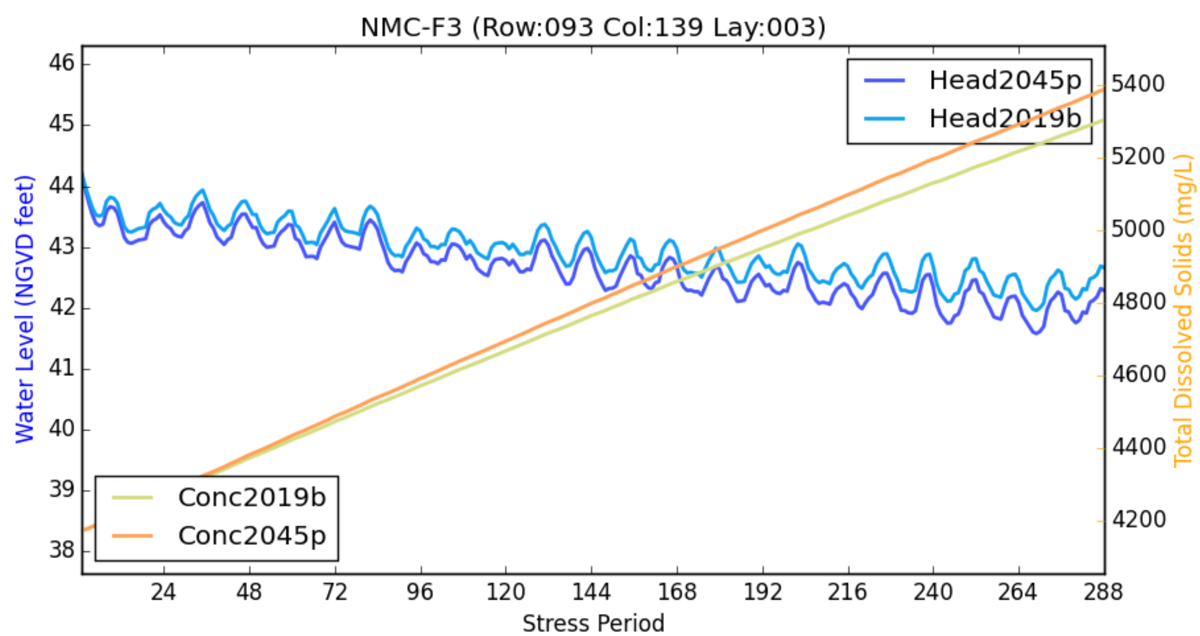
TDS = total dissolved solids.

APPENDIX E: SELECT SIMULATED VERSUS OBSERVED WATER LEVEL HYDROGRAPHS AND WATER QUALITY TIME SERIES

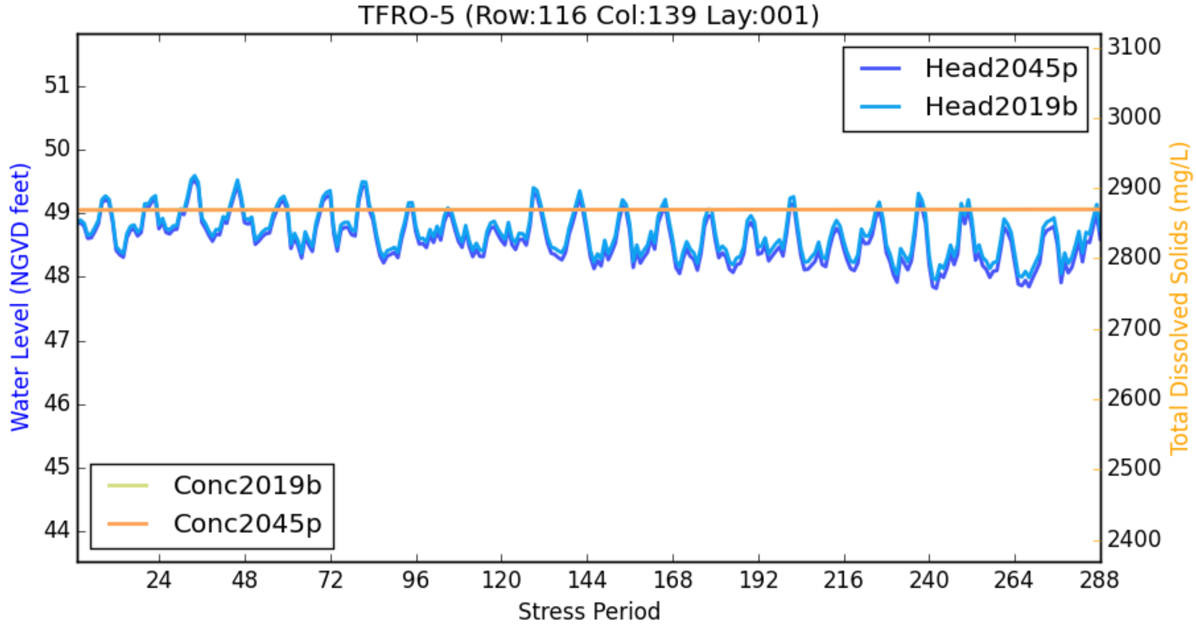
Martin County

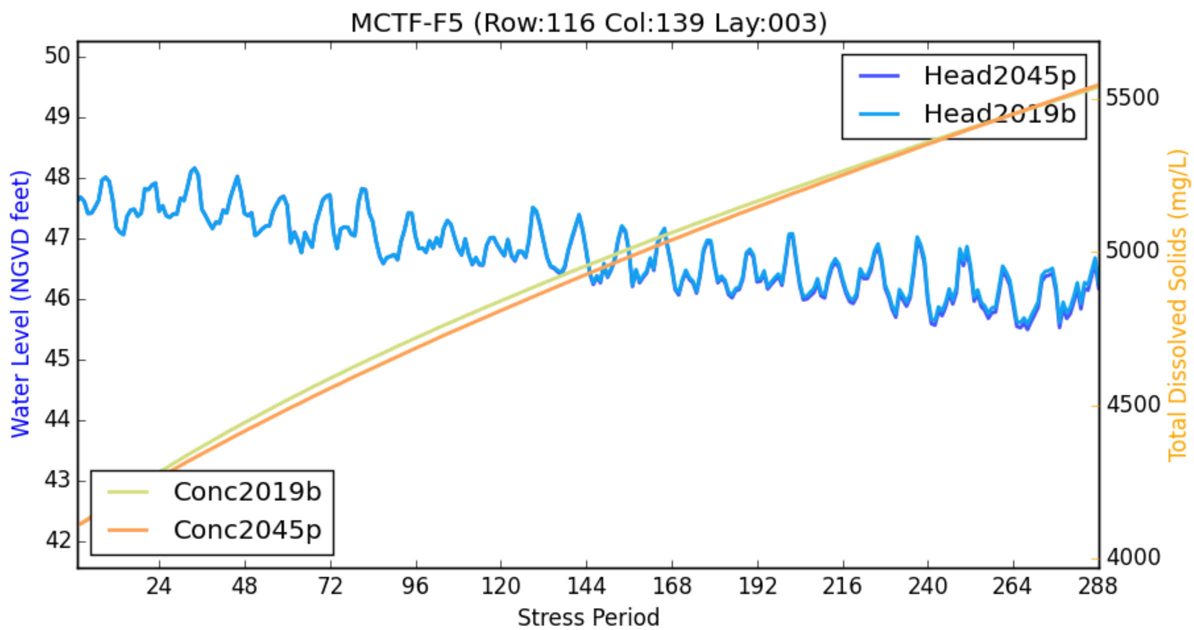
Martin County Utilities (North Jensen Beach Wellfield)



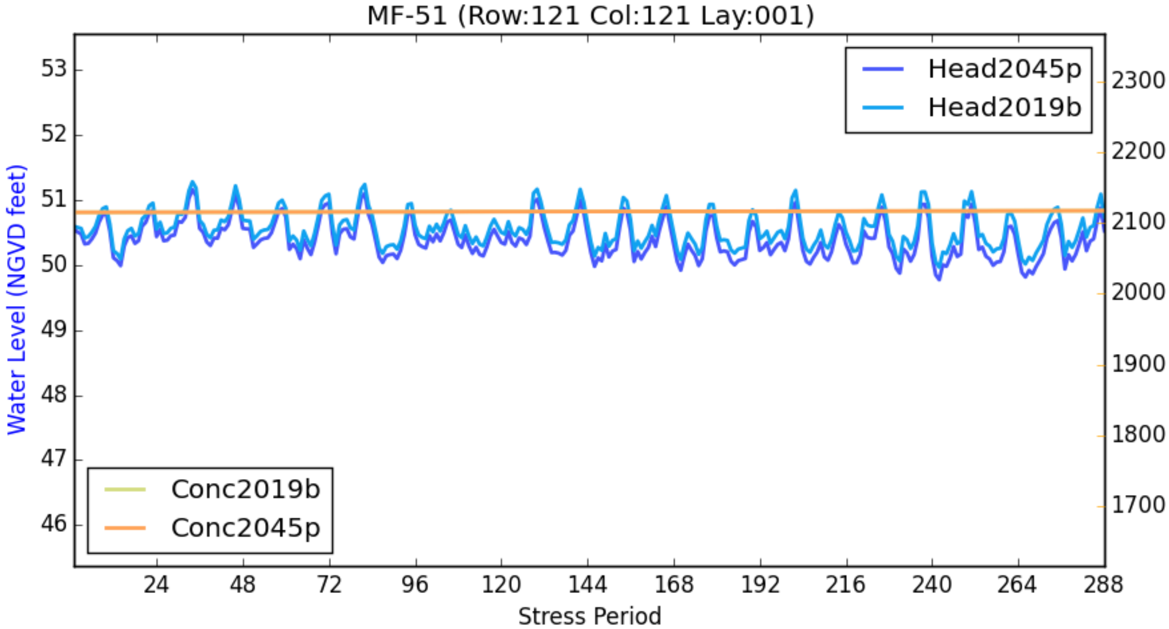


Martin County Utilities (Tropical Farms Wellfield)

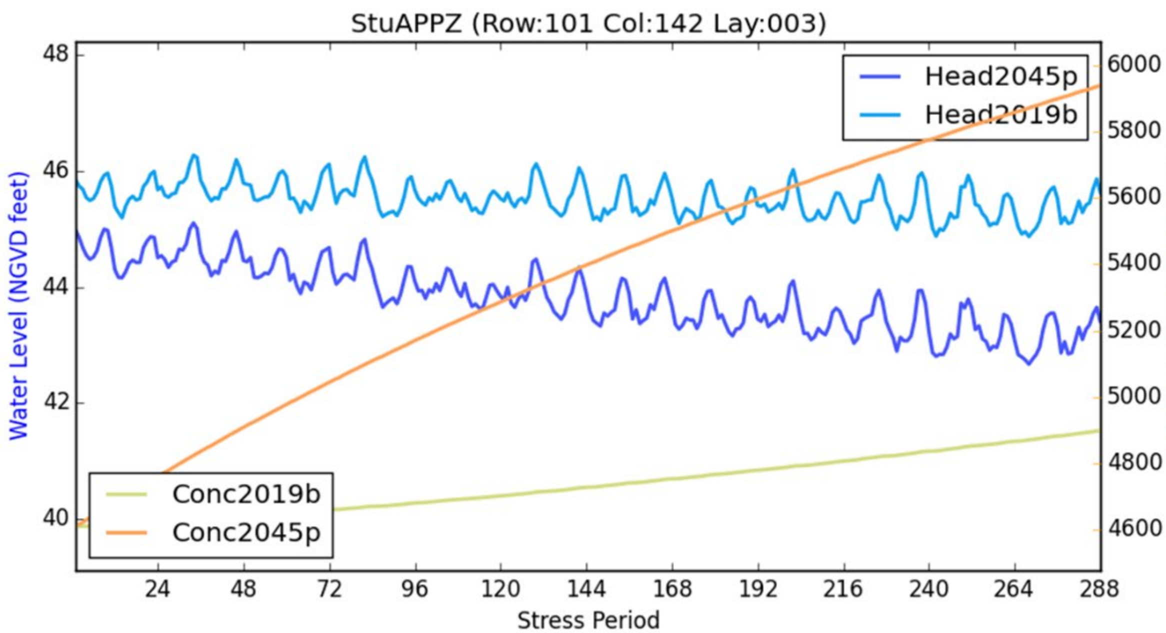




South Martin Regional Utility

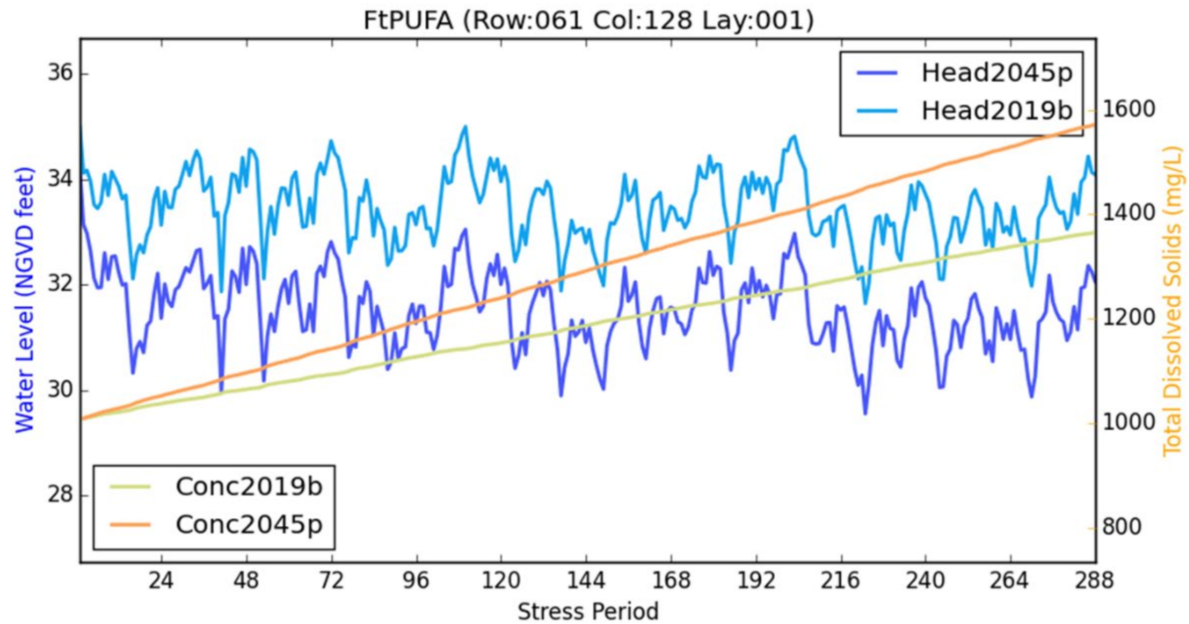


City of Stuart

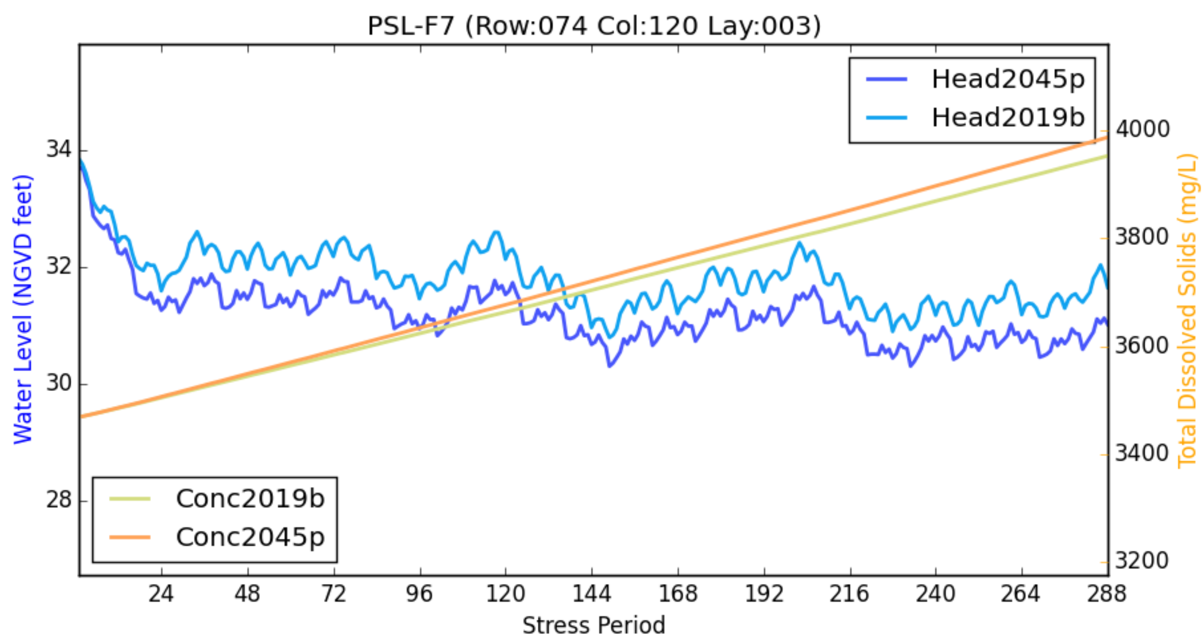


St. Lucie County

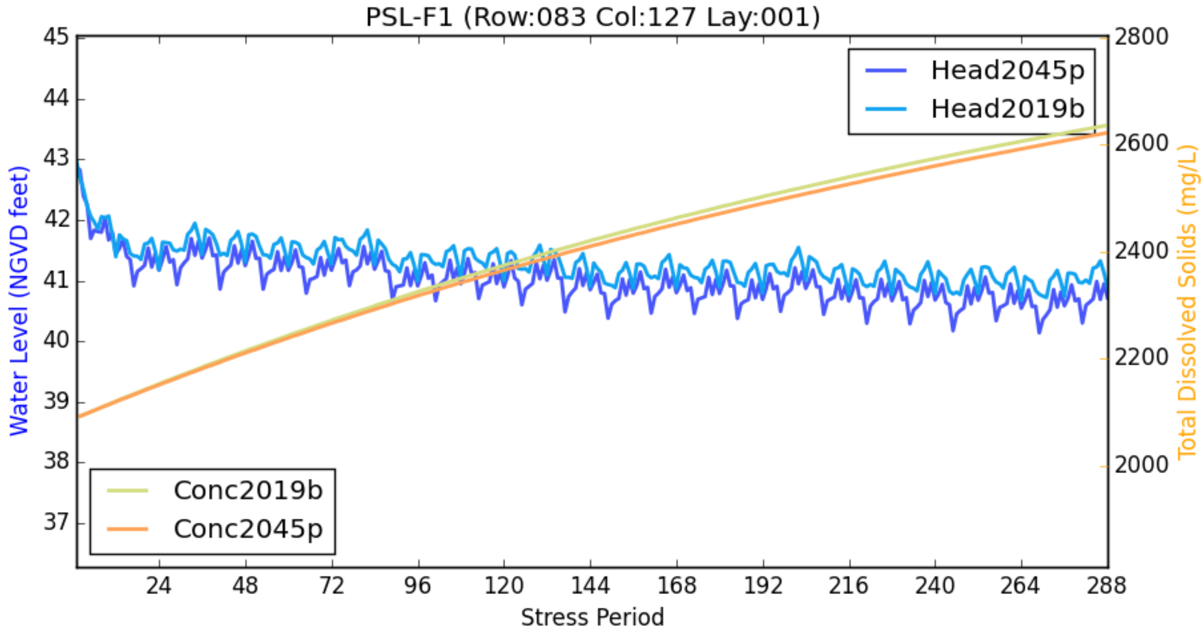
Fort Pierce Utilities Authority

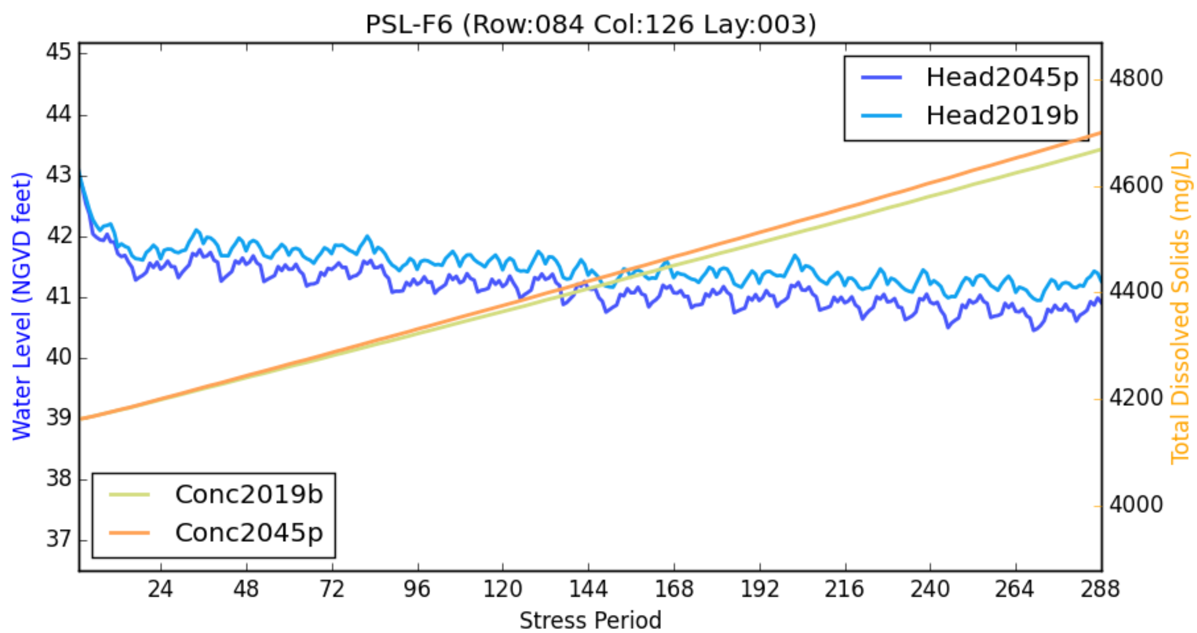


City of Port St. Lucie Utility Systems Department (James E. Anderson Wellfield)

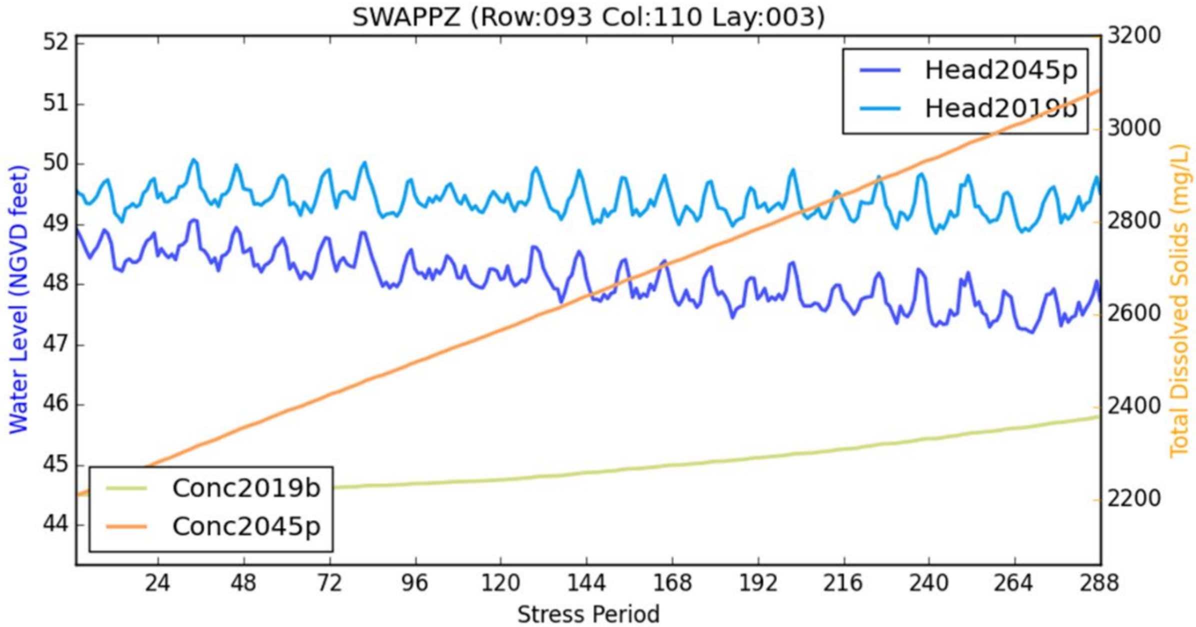


City of Port St. Lucie Utility Systems Department (Prineville Wellfield)

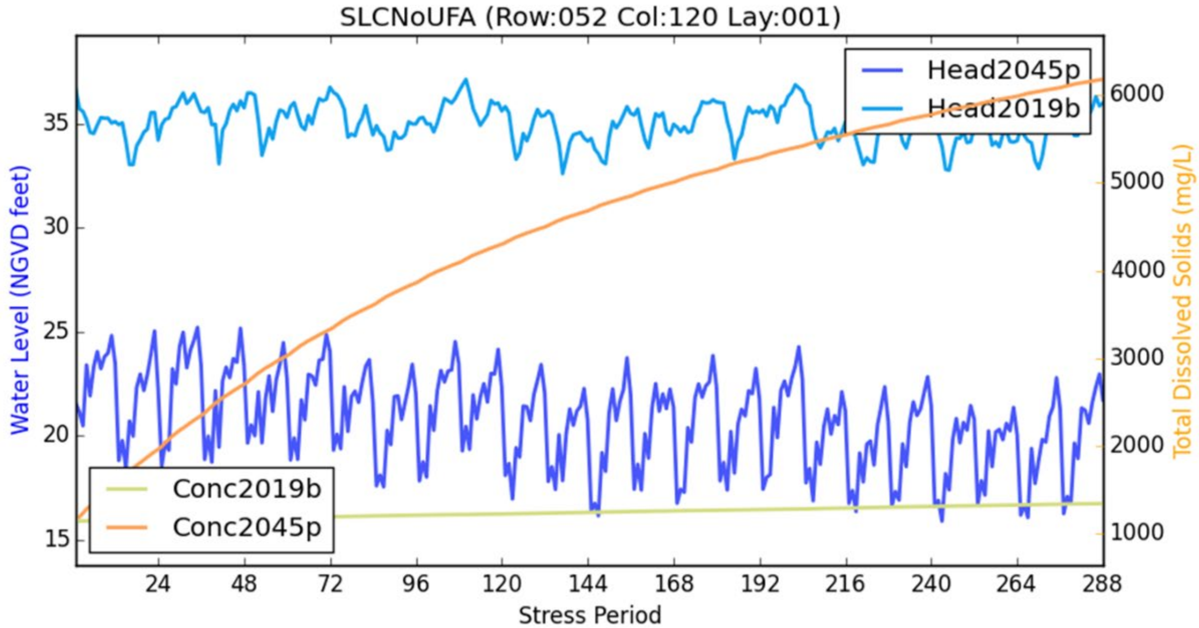


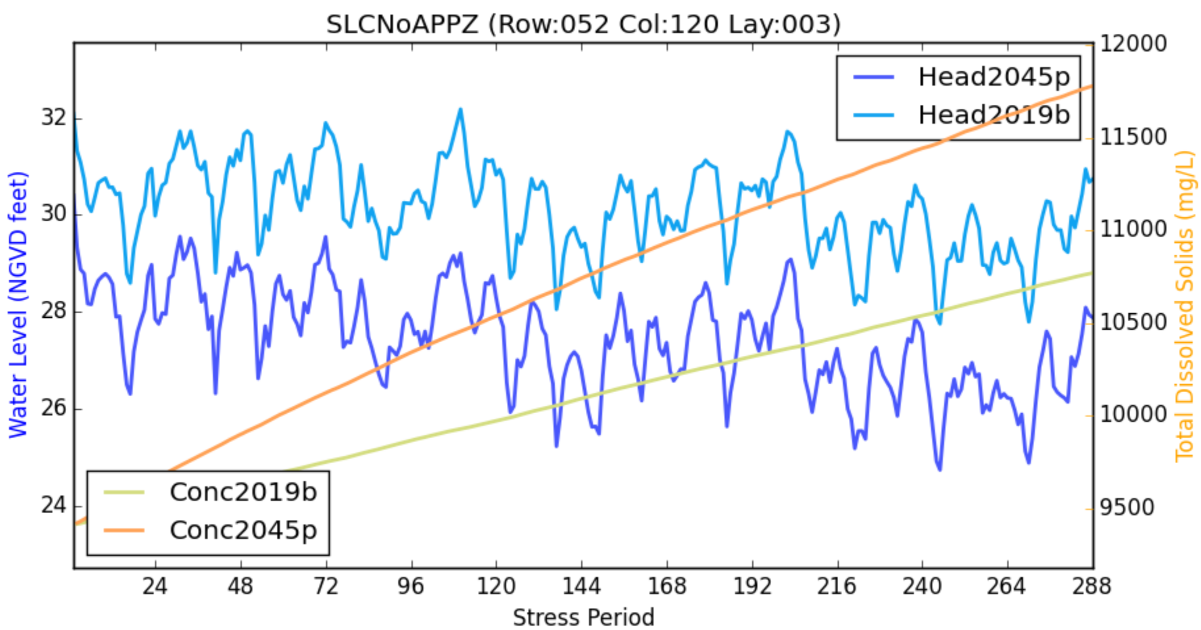


City of Port St. Lucie Utility Systems Department (Southwest Wellfield)

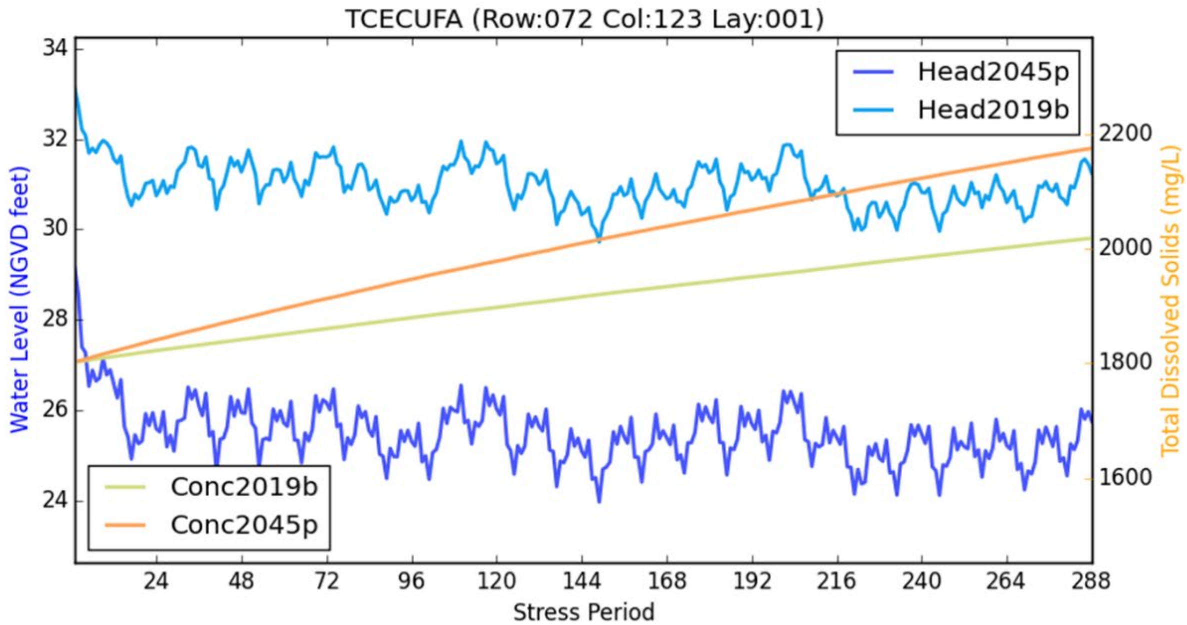


St. Lucie County Utilities (North Wellfield)



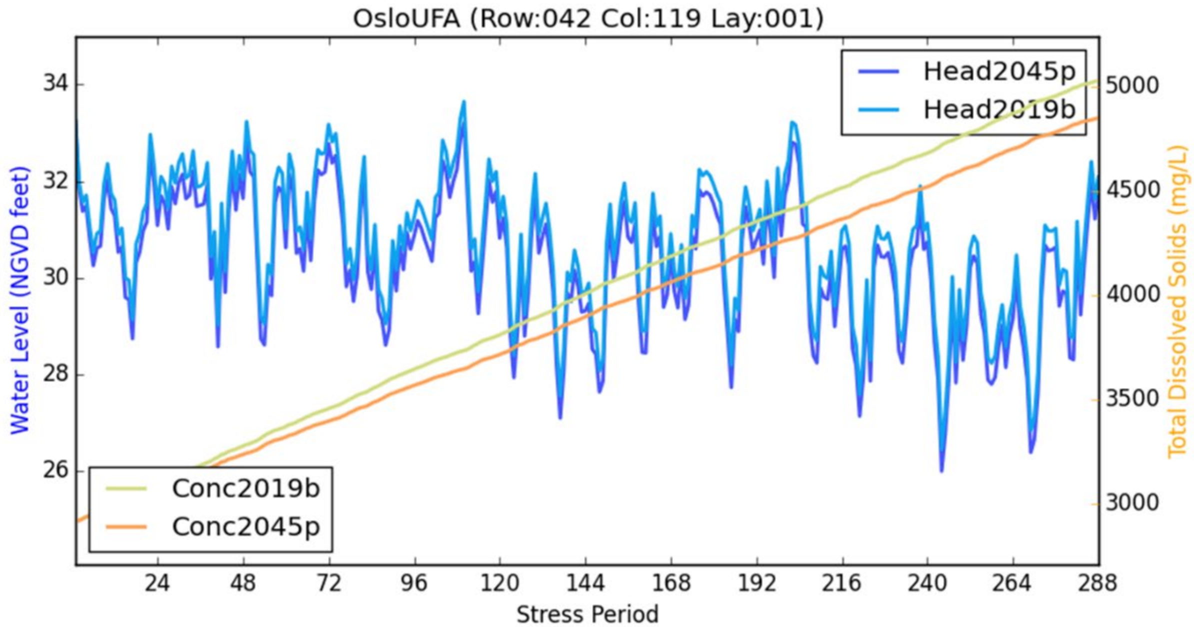


Treasure Coast Energy Center



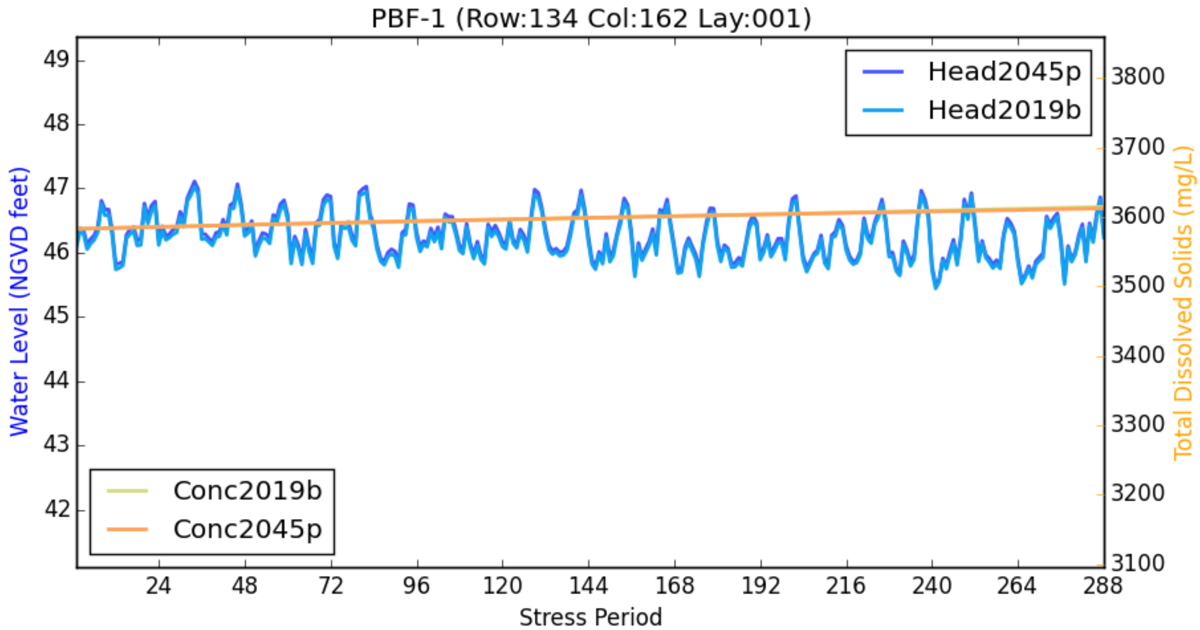
Indian River County

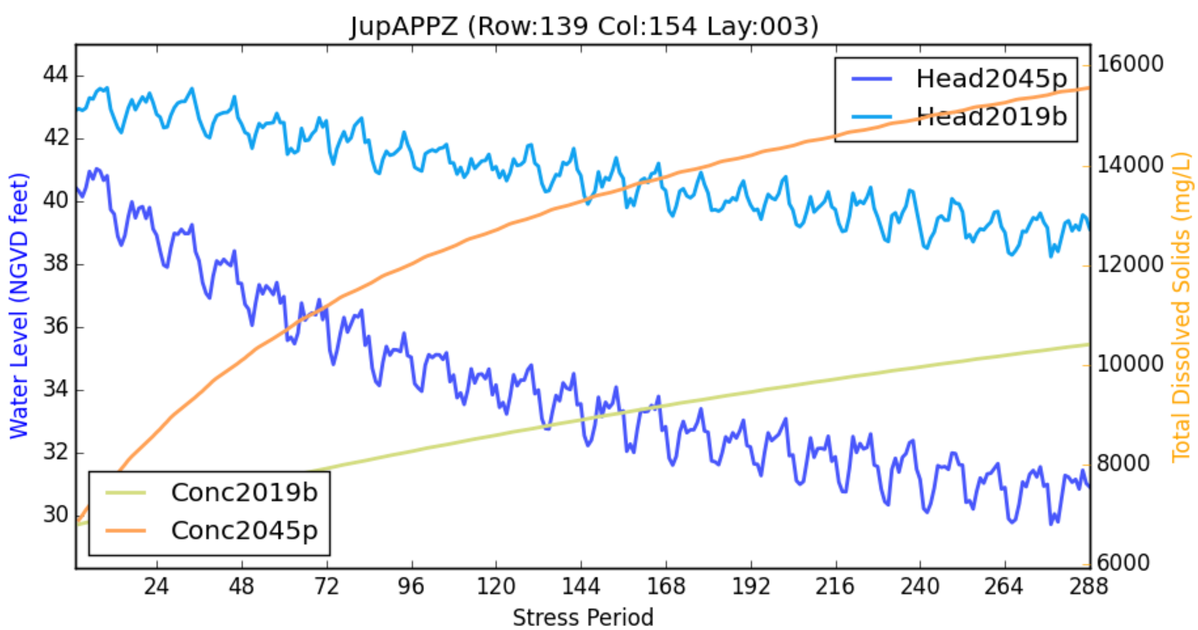
Oslo Wellfield



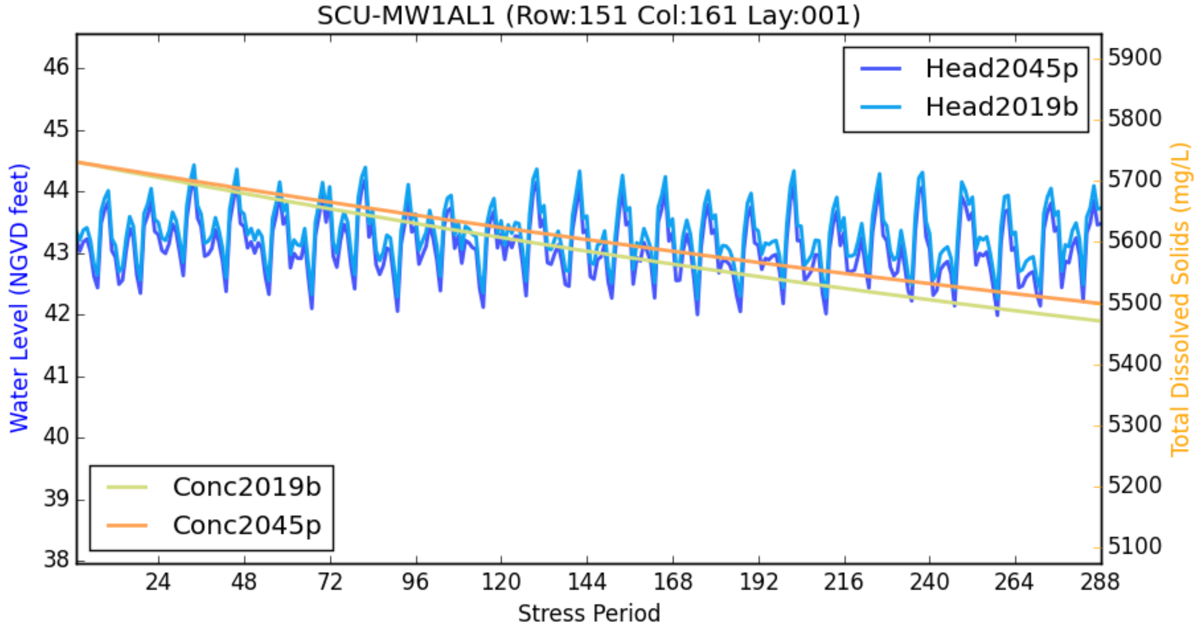
Palm Beach County

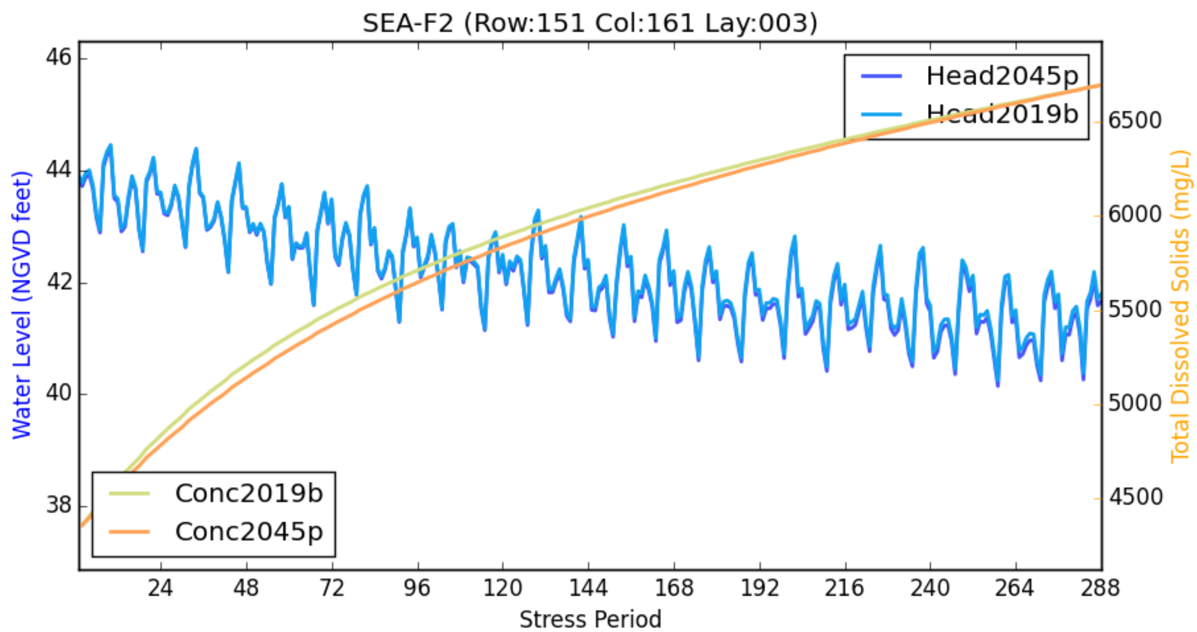
Town of Jupiter





Seacoast Utility Authority





Village of Tequesta