# Model Calibration Report for the West Coast Floridan Model (WCFM)

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# EXECUTIVE SUMMARY

The Lower West Coast (LWC) Planning Area of the South Florida Water Management District (SFWMD) faces numerous water management challenges. Dwindling traditional water sources need to be addressed and managed to protect the area's water resources and provide an adequate water supply to meet the growing urban, agricultural, and environmental water needs. Regional water supply plans are the SFWMD's primary tool to address these issues. In general, the water supply plans recommend shifting future demands away from traditional water sources, such as surface water and shallow aquifers, to alternative sources, including brackish water from the Floridan aquifer system (FAS).

To evaluate the potential impacts of becoming more reliant on deeper, brackish aquifer systems in the LWC Planning Area, a density-dependent groundwater flow and transport model of the FAS was developed. This West Coast Floridan Model (WCFM) can simulate aquifer response to stresses such as proposed wellfield pumpage, aquifer storage and recovery systems, reductions in recharge, and increasing sea level rise. Results of the model applications can provide guidance when developing water management strategies, support periodic updates to the regional water supply plans, and be used in regulatory applications.

A three-dimensional groundwater flow and solute transport model was developed to simulate changes in water levels and water quality. The WCFM domain extends from central Florida to the Florida Keys and from the approximate central line of the Florida peninsula to the Gulf of Mexico. This area was divided into a uniform grid with spacing of 2,400 feet. The model has seven primary layers representing the Upper Floridan aquifer, Ocala-Avon Park low-permeability zone, Avon Park permeable zone, middle confining unit, the first permeable zone of the Lower Floridan aquifer, the Boulder Zone confining unit, and the basal Boulder Zone.

The original WCFM was developed in 2008 to support ongoing water supply management efforts in the LWC Planning Area. The model underwent an independent scientific peer review in 2008 and was revised in 2011 to address the peer-review comments and recommendations. The current model discussed in this report builds upon the 2011 version and incorporates updated information. As such, this report identifies the newest changes made to the model and discusses its ability to replicate observed water level and water quality information.

The WCFM previously was calibrated to water levels and water quality for steady-state and transient conditions using a combination of manual and automatic calibration methods iteratively during the model calibration process. This update to the model expanded the calibration period (January 1989 through December 2012), incorporated new aquifer property information, addressed additional peer-review comments received during development of the East Coast Floridan Model and the East Central Floridan Transient Expanded Model (including the addition of several new water level and water quality calibration targets), and simulated the model's response to several recently constructed Upper Floridan aquifer wellfields within the LWC Planning Area. Because of the limited scope of this update, the previous automated parameter estimation results generally were retained; however, some additional manual calibration was incorporated for this updated version. As this model is an update to the previously peer-reviewed model, a new peer-review was not considered necessary. The results of model calibration indicated the simulated water levels and water quality values are in general agreement with field-observed data at most monitoring targets. Simulated flow patterns and total dissolved solids concentration distributions in major aquifers generally matched observed conditions.

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AFSIRS | Agricultural Field-Scale Irrigation Requirements Simulation |
| APPZ | Avon Park permeable zone |
| APT | aquifer performance test |
| BZ | Boulder Zone |
| cfs | cubic feet per second |
| ECFM | East Coast Floridan Model |
| ECFTX | East-Central Floridan Transient Expanded Model |
| FAS | Floridan aquifer system |
| ft | foot |
| GHB | general head boundary |
| IAS | intermediate aquifer system |
| LF1 | Lower Floridan aquifer – first permeable zone |
| LFA | Lower Floridan aquifer |
| LWC | Lower West Coast |
| MAE | mean absolute error |
| MCU | middle confining unit |
| ME | mean error |
| mg/L | milligrams per liter |
| MODFLOW | Modular 3D Finite-Difference Groundwater Flow Model |
| OCAPlpz | Ocala-Avon Park low-permeability zone |
| $R^2$ | coefficient of determination |
| RMSE | root mean square error |
| SAS | surficial aquifer system |
| SFWMD | South Florida Water Management District |
| SWFWMD | Southwest Florida Water Management District |
| TDS | total dissolved solids |
| UFA | Upper Floridan aquifer |
| USGS | United States Geological Survey |
| WCFM | West Coast Floridan Model |

# 1 INTRODUCTION

This document describes the revisions and calibration of the West Coast Floridan Model (WCFM). The WCFM is a numerical model based on the United States Geological Survey (USGS) SEAWAT computer code version 4.0 (Langevin et al. 2008, USGS 2012) designed to simulate groundwater flow and solute transport. The model may be used to support analysis, permitting, and development of the Floridan aquifer system (FAS) in the western portions of the South Florida Water Management District (SFWMD). The WCFM is an update of the Lower West Coast Floridan Aquifer System Model originally developed by Restrepo et al. (2008) and subsequently modified by Guo et al. (2011). This model update integrates recent recommendations for model improvement and incorporates suggestions from two independent peer reviews of adjacent and similar models (Jacobs et al. 2011, Anderson et al. 2020).

The scope of this document includes updates to the previously calibrated and peer-reviewed WCFM, generally following the standard protocol for model development as outlined by Anderson and Woessnar (1992). The report is organized into five sections. **Section 1** includes the introduction and background of the report. **Section 2** provides a chronological history of the model development. **Section 3** describes the major revisions to the conceptual model, including data collection, hydrology, hydrogeology, water use, and other physical factors affecting model construction. The model's ability to simulate observed field conditions is discussed in the calibration and sensitivity analysis portions of **Section 4**. **Section 5** concludes the report with a discussion on model capabilities, limitations, and general recommendations.

# 2 WEST COAST FLORIDAN MODEL HISTORY

Restrepo et al. (2008) originally developed the WCFM to support ongoing water supply management efforts in the Lower West Coast (LWC) Planning Area. The model simulated 12 layers from ground surface down to the base of the FAS. The model had a uniform grid spacing of 3,000 feet (ft), oriented in a northwest-southeast direction, with a calibration period of 1997 through 2001. The model was peer reviewed by an independent panel with specific recommendations to reconceptualize and recalibrate the model (Leppert et al. 2008).

A revised version of the model was developed in 2011 to address the primary peer-review comments (Guo et al. 2011). In the 2011 version, the surficial aquifer system (SAS) and intermediate aquifer system (IAS) were removed, reducing the number of layers from 12 to 7, with the same grid spacing of 3,000 ft. A steady-state and a transient version of the model were developed and calibrated to wet and dry season conditions for the period of 2001 through 2010. The calibration process used manual and automated calibration processes iteratively to match observed water level and water quality conditions (Doherty 2010). The model was used to simulate a gradual rise in sea level conditions and the placement of a fictitious wellfield near the coast in Collier County to evaluate potential impacts.

During model construction and application of the seven-layer model developed by Guo et al. (2011), several concerns were identified. The first concern was the general lack of data in the Southwest Florida Water Management District's (SWFWMD's) portion of the model domain, including water level, water quality, hydrostratigraphic, hydraulic, and groundwater withdrawal data. Additionally, the grid needed to be refined to better simulate water quality conditions. These observations, along with new information from recently constructed test wells and wellfields and the incorporation of additional peer-review comments, are the focus of this update to the WCFM.

The model domain was modified to extend from Lake Wales south to offshore of Key West and from Dry Tortugas at the western edge to Lake Istokpoga on the east (**Figure 2-1**). The grid was designed to directly overlay the western edge of the East Coast Floridan Model (ECFM) to have a shared boundary condition and ultimately allow for one model to cover the entire southern peninsula of Florida, if needed.

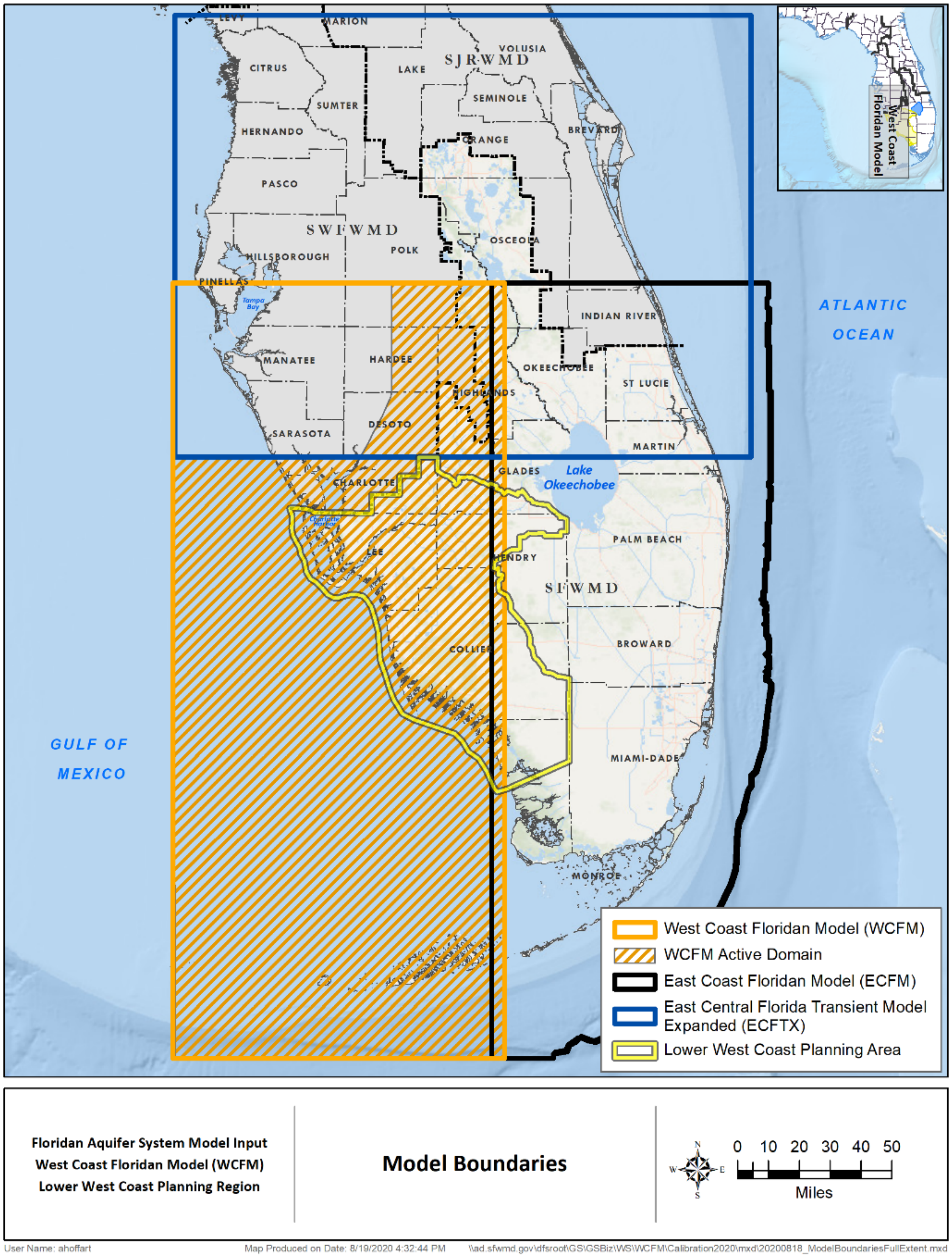


Figure 2-1. Boundaries of the West Coast Floridan Model active domain compared with other Floridan aquifer system models in South Florida.

The WCFM has 552 rows, 236 columns, and 7 layers. The orientation of the grid was modified to a north-south direction, and the grid size was revised to 2,400 ft to better simulate the transport component and match the ECFM. 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: 20,655 ft
Y position: 1,280,352 ft

Vertically, the WCFM is composed of seven layers, each consisting of either a confining unit or a primary aquifer (**Table 2-1**). Future revisions to the model for the development of local evaluations may require additional sub-layers to account for refined spatial resolution and aquifer heterogeneity.

Table 2-1. Model layers and corresponding hydrogeologic units.

| 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 |

The geologic framework of South Florida has been studied by numerous investigators, including Meyer (1989), Miller (1990), and Reese and Richardson (2008). The active model domain is underlain by approximately 20,000 ft of continuous carbonates, evaporites, and clastic sediments deposited relatively uninterrupted throughout the Cenozoic era (Smith and Lord 1997). The primary geologic formations include the Cedar Keys Formation, Oldsmar Formation, Avon Park Formation, Ocala and Suwannee Limestones, Hawthorn Group, Tamiami Formation, Fort Thompson Formation, and other undifferentiated Pleistocene and Holocene sediments. The Pliocene/Pleistocene deposits, the Tamiami Formation, and the carbonate and clastic zones within the Hawthorn Group form the SAS and IAS and are not included in this version of the model.

The WCFM layers only include aquifers and confining units within the FAS, which generally consists of the Upper Floridan aquifer (UFA), the middle confining unit (MCU), and the Lower Floridan aquifer (LFA; Miller 1990). 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 after 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). Where present, the APPZ separates the upper Ocala-Avon Park low-permeability zone (OCAPlpz) and the lower MCU. The LFA is a thick sequence of carbonate rocks that contains several permeable zones with thin and thick confining units between them. In this study, the LFA is divided into two producing zones, including the uppermost permeable zone (LF1) located near the base of the Avon Park Formation. A second highly permeable zone, called the Boulder Zone (BZ), is located within the Oldsmar Formation. Between the BZ and LF1 is a poorly understood sequence of permeable zones and confining units that are lumped into a single layer referred to as the Boulder Zone confining unit.

# 3 MODEL REVISIONS

The principal revisions to the WCFM were based on the peer-review comments provided for the ECFM (Jacobs et al. 2011) and the East-Central Floridan Transient Expanded Model (ECFTX; Anderson et al. 2020). Recommendations from the previous model update (Guo et al. 2011) also were addressed. The primary updates include expansion and incorporation of the water level and water quality database; creation of a pre-development model for the FAS, extension of the simulation period, refinement of the calibration criteria, justification for the primary recharge areas, incorporation of temperature changes within the BZ, and updated groundwater withdrawals and hydrogeologic properties.

## 3.1 Expansion of the Water Level and Water Quality Databases

The SFWMD reviewed and collected water quality and water level data for all FAS wells within the model domain from USGS and SFWMD databases. This information was added to the existing database originally developed by Restrepo et al. (2008) and augmented by Guo et al. (2011). Additional water quality data were assembled from the Florida Department of Environmental Protection's Underground Injection Control Program and the SFWMD's Water Use Regulation databases. All data were reviewed for quality and erroneous or questionable data, which, if found, were removed from the final model database. A third source of data was single, or several, point-in-time water quality values collected during initial aquifer testing at various wellfields, or data collected in support of short-term projects or publications. Water quality and water level data availability fell within two distinct time frames, although data at some wells occurred outside these dates. The first period generally occurred from 1989 through the early 1990s and corresponded to a severe drought. The second period of available data generally began in the early 2000s and continued through 2012. The second period corresponds to the introduction of telemetry and other methods for automated measurements. There are approximately 110 wells with water level readings useful for model calibration and more than 120 water quality wells, of which approximately half have single or several water quality observations. Water level readings from the Underground Injection Control Program monitor wells were not used because the data might be affected by the injection of freshwater effluent from the underlying, adjacent deep injection wells, meaning the water level data might not be indicative of natural conditions.

Numerous sites were sampled only sporadically for chloride values or total dissolved solids (TDS). Water quality simulated within the model domain was based on the TDS content. Therefore, it was necessary to develop an equation that could reasonably convert chloride concentrations into TDS values. **Figure 3-1** shows the equation developed for the conversion of chlorides to TDS values using only FAS water quality data. Although a 5$^{th}$ order polynomial equation provided a slightly better fit to the observed data, the linear equation was determined to be appropriate for this effort.

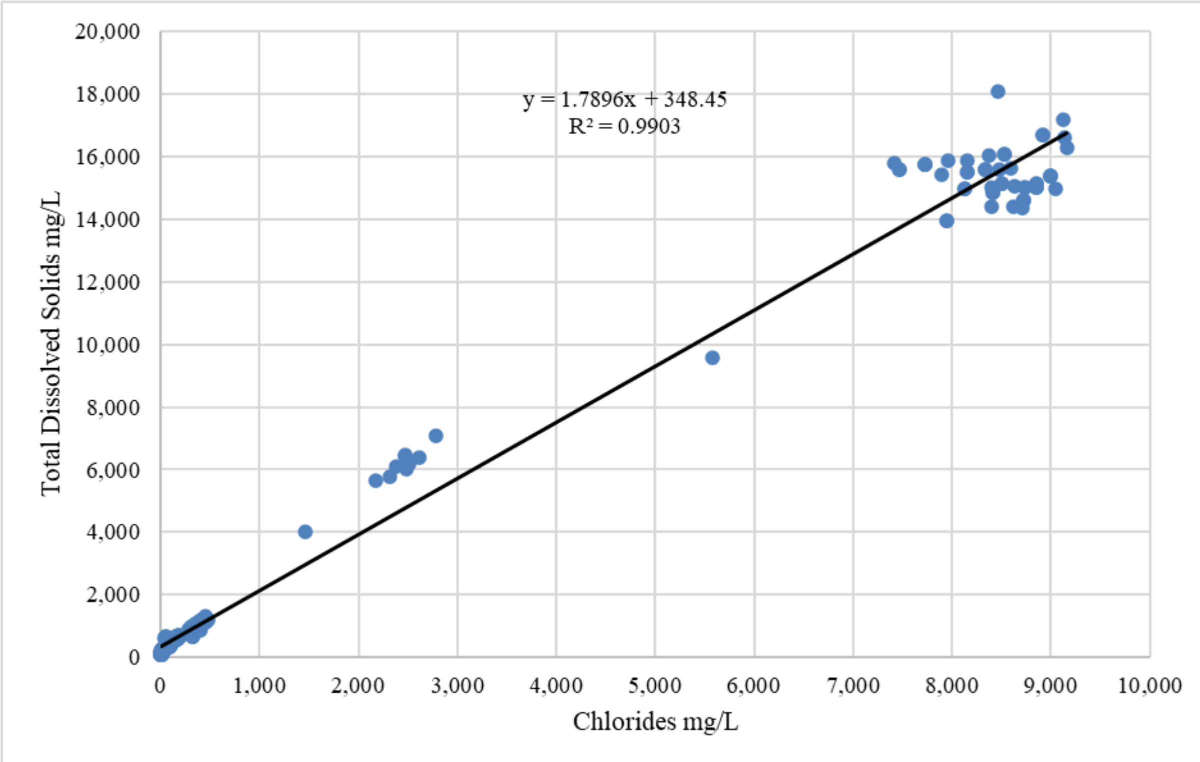


Figure 3-1. Equation to convert chloride concentrations into total dissolved solids for the Floridan aquifer system monitor wells in southwestern Florida.

**Table 3-1** compares the number of observation sites used in the calibration of the updated WCFM to the previous version. The model previously was calibrated to wet and dry season conditions, whereas the new version calibrated the model to monthly observations. Additionally, the calibration period was expanded from 2001 through 2010 to 1989 through 2012. Consequently, a review of the available data resulted in a significant increase in the number of water level and water quality observation sites.

Table 3-1. Comparison of data availability between the previous and current versions of the West Coast Floridan Model.

| Guo et al. (2011) | 2020 |
|---|---|
| 25 water level monitoring locations<br>• 17 UFA wells<br>• 6 APPZ wells<br>• 2 LF1 wells | 112 water level monitoring locations<br>• 91 UFA wells<br>• 18 APPZ wells<br>• 3 LF1 wells |
| 17 water quality monitoring locations<br>• 17 UFA wells | 120 water quality monitoring locations<br>• 79 UFA wells<br>• 18 APPZ wells<br>• 10 LF1 wells |

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

## 3.2 Development of a Pre-Development Transport Model

An interim, coupled transient flow and transport model was developed to evaluate changes in water level and water quality conditions during an approximately 500-year period before widespread development of the FAS occurred. Development of this version was used to assess water quality stability and evaluate general flow directions and, to a lesser extent, water levels over a long time period. For this simulation, all production wells were inactive. Although this tool represented pre-development conditions of the FAS in southwestern Florida, its utility in developing initial conditions for the transient model simulation was limited because of significant FAS use in certain areas of the model domain prior to initiation of the transient simulation. Additionally, rainfall and boundary conditions effectively were unknown during the early part of the long-term simulation period. The 1500s through the 1700s experienced an abnormal cooling period in the northern hemisphere, generally referred to as the Little Ice Age. This was followed by a noticeable shift in global climate around 1850, corresponding approximately with the end of the First Industrial Revolution. Therefore, the pre-development model is a hind-casting tool because the aquifer parameters and other model properties had to be developed spatially across the model domain from observed data and recorded system responses to the stresses imposed. However, it provides a general understanding of pre-development water quality and flow patterns of the system prior to widespread development.

## 3.3 Expansion of the Transient Calibration Period

The transient model was developed and extended for a 24-year period (1989 through 2012). The simulation period extends beyond the recommended 20-year period suggested by the peer-review panel for the ECFM (Jacobs et al. 2011) and represents a noticeable increase from the calibration period of the previous version of the model (2001 through 2010). The model was simulated using monthly stress periods, time steps, and solute transport time steps. The monthly solute transport time steps were computed by SEAWAT. When testing different lengths of transport time steps for a similar model, weekly or shorter transport steps did not change the solution but added considerable computational time (Giddings et al. 2014).

## 3.4 Revisions to Water Level and Water Quality Calibration Criteria

Water level, water quality, and flow budgets were used to calibrate the transient model. For water quality trends, the model may not respond to local changes in water quality due to local heterogeneities because data obtained from an aquifer performance test (APT) or longer-term monitor well data may not be accurate across an entire model layer. TDS distribution figures were generated following the ECFM peer-review panel's recommendation (Jacobs et al. 2011) for four broad water quality targets: potable (less than 1,000 milligrams per liter [mg/L]), brackish (1,000 to 10,000 mg/L), moderately saline (10,000 to 19,000 mg/L), and saline (greater than 19,000 mg/L). Calibration at individual wells followed a general calibration criterion, with the fresher portions of the aquifers having a tighter calibration criterion (approximately 500 mg/L) than more saline monitor wells (approximately 4,000 mg/L).

Water level calibration generally followed the outline by Anderson et al. (2020). The mean error (ME), mean absolute error (MAE), the root mean square error (RMSE), and various percent differences were generated for each well and aquifer. Scatter plots, spatial residuals, and a set of statistics are presented in **Appendix A** for each well and categorized by production zone to provide a clear picture and understanding of the model's response. Flow budgets were developed for each model layer as well as 10 sub-basins encompassing the model domain and reviewed for consistency with the conceptual model design. The coefficient of determination ($R^2$) was used to evaluate the transient response of water levels and the relative goodness of fit. A detailed discussion of the calibration criteria used for water levels, water budgets, flow directions, and water quality are provided in **Section 4.3**.

## 3.5 Primary Recharge Zones for the Upper Floridan Aquifer

Primary recharge to the FAS in South Florida occurs in the central part of the state along the Lake Wales Ridge and Polk uplands. Boundary conditions for this area were defined using the SEAWAT/MODFLOW General Head Boundary (GHB) package to control the magnitude of recharge entering the model domain from the recharge area to the north. Boundary conditions are discussed in more detail in **Section 4.1**. Recharge fluxes into the model domain can be estimated from studies conducted along the Lake Wales Ridge area (Stewart 1980, Tibbals 1990, Yobbi 1996, Sepulveda 2002). The studies, primarily been produced by the USGS and SWFWMD, attempted to estimate recharge from the SAS into the UFA as a result of rainfall and local stresses. Estimated recharge rates from these reports were used as calibration parameters during WCFM calibration.

Recharge into the FAS in the active portion of the model domain mainly occurs in Polk and Highlands counties where the Lake Wales Ridge is a predominant physiographic feature. Rainfall along the ridge infiltrates through the SAS and underlying intermediate confining unit into the UFA. No evapotranspiration occurs from the UFA in the area because of its depth below ground surface. Recharge infiltrates downward and then radiates outward from the ridge towards the east, south, and west. Discharge occurs to the south into the Florida Straits or to the west into the Gulf of Mexico, where it outcrops a significant distance offshore. Beyond the ridge area, little interaction occurs between the SAS and UFA because of the relatively impermeable clays of the Hawthorn Group in the intermediate confining unit that separates the two aquifer systems. Additional water is lost from the FAS due to pumping from water supply wells, which can be noticeable in some intense agricultural regions and around major public supply wellfields.

Freshwater recharge into the FAS within the model domain occurs primarily in Polk and Highlands counties and, to a lesser extent, Hardee County. The SAS is an important component of the overall water budget for the FAS because it provides temporary storage of fresh water that eventually can percolate down to the UFA, primarily in the northeastern portion of the model domain. The Lake Wales and Avon Park ridges are characterized by thick permeable deposits of sand and shell with deep water tables. The area allows for greater downward percolation of rainfall (that otherwise would be lost to evapotranspiration) compared to most areas of the state where the water table is closer to the surface. Surface water drainage networks are poorly developed along the ridges, restricting runoff and allowing for additional recharge. Several areas along the ridges are closed basins where no coastal runoff occurs and instead is redirected to sinkhole lake systems that are directly connected to the FAS. Recharge to the UFA beneath the Lake Wales and Avon Park ridges occurs where the intermediate confining unit is thin or permeable or where the overlying confining unit may be partially or totally breached by sinkhole development (Spechler 2010).

Location and rate are two factors required to estimate the quantity and distribution of recharge to the UFA. The recharge area is where the SAS is connected to the FAS and a downward gradient exists between them, while the rate is governed by the type and extent of the overlying sediments. Therefore, the rate and distribution of recharge to the FAS from the SAS depends on the head gradient and hydraulic connections between the two aquifer systems. Recharge areas primarily occur along the higher upland and ridge areas or in closed drainage basins that discharge runoff into karst sinkhole lakes.

Precipitation is the primary source of recharge to the UFA through downward leakance. Based on monthly average rainfall rates at local weather stations, monthly and seasonal rates vary greatly. Monthly rates can vary from near zero to as much as 10 inches per month during hurricanes or extreme rainfall events. However, rainfall itself is not the driving factor dictating the rate of recharge into the UFA; it is the head differential between the SAS and UFA that governs the recharge rate. A review of nested water level monitor wells in the SAS and UFA along the Lake Wales Ridge and away from major production centers showed the net head difference is relatively consistent throughout the year. This suggested that recharge rates should be relatively similar on a monthly basis when compared to monthly rainfall patterns.

The average annual high temperature for Sebring (near the UFA recharge area) is approximately 91° F in July, with an average low temperature of 48° F in January. Average rainfall from 1989 through 2012 was approximately 48.76 inches, with June being the wettest month (**Figure 3-2**). Recharge into the UFA from precipitation was simulated for 18 different zones/rates along the Lake Wales Ridge, southern Polk uplands, and northern Hardee County regions. Actual monthly rainfall was used with a delay function to replicate the thick sequences of unsaturated sediments located along the higher sections of the ridge to regulate flow from the SAS and intermediate confining unit above the UFA.

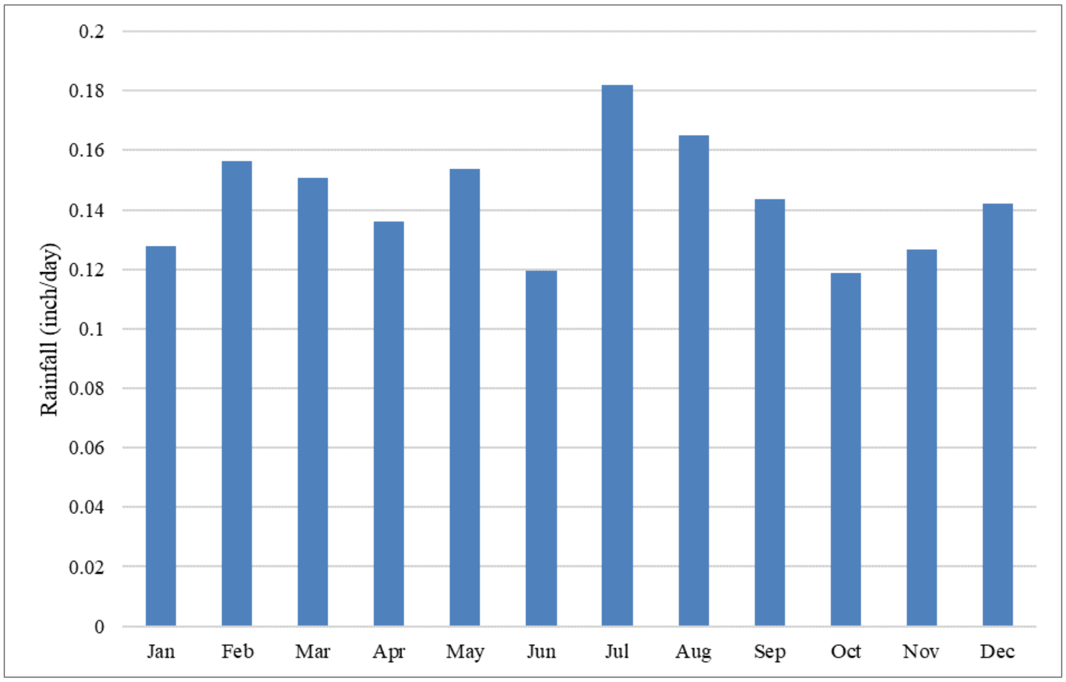


Figure 3-2. Average monthly rainfall in the city of Sebring, Highlands County, Florida, from 1989 to 2012.

The amount of rainfall available for recharge to the SAS is reduced by runoff and evapotranspiration. Evapotranspiration is the sum of evaporation from water bodies and transpiration losses from plant systems to the atmosphere. Evapotranspiration accounts for approximately 70% of rainfall, and the remaining 30% either runs off the land into drainage networks and streams/rivers or percolates into the ground as recharge. Stewart (1980) identified areas where natural recharge occurs to the FAS, primarily in Highlands, Polk, and Hardee counties. Elsewhere within the model domain, recharge to the UFA from rainfall is negligible. Stewart (1980), Tibbals (1990), and Yobbi (1996) calculated similar values, generally between 5 and 10 inches/year, with some areas greater than 10 inches/year in Polk County. Sepulveda (2002) estimated recharge rates along the Lake Wales Ridge in Highlands and Polk counties could reach values of 10 to 25 inches/year along the main ridge system and between 3 and 10 inches along the ridge flanks.

**Figure 3-3** shows where direct recharge was applied to the UFA. Simulated rates varied monthly based on historical rainfall and varied spatially within the recharge zones. The annual average recharge rate applied to the low recharge areas to the west of the ridge averaged 0.5 inches/year. Recharge rates around the Lake Wales Ridge and the Caloosahatchee Incline averaged approximately 2.5 inches/year. Where the topography exceeds approximately 90 ft National Geodetic Vertical Datum of 1929 (NGVD29), recharge rates can exceed 20 inches/year. Higher recharge rates along the Lake Wales Ridge can be directly related to 1) the lack of perennial and intermittent streams that would carry water towards the ocean, and 2) the existence of deep sinkhole lake systems that can extend downward into the intermediate confining unit and occasionally the FAS. In general, rainfall along the ridge directly infiltrates surficial sands or runs off to the isolated sinkhole lake systems. Additionally, the extreme depth from ground surface to the top of the water table can exceed typical vegetation root zone depths; therefore, evapotranspiration is limited compared to other regions of South Florida. The UFA recharge rates during average rainfall years is approximately to 1.25 inches/month along the ridge and decreases outward from the ridge (**Figure 3-3**). During dry years, recharge decreases to approximately 1 inch/month along the ridge, and during extremely wet years, it can increase to more than 1.5 inches/month (**Figures 3-4** and **3-5**).

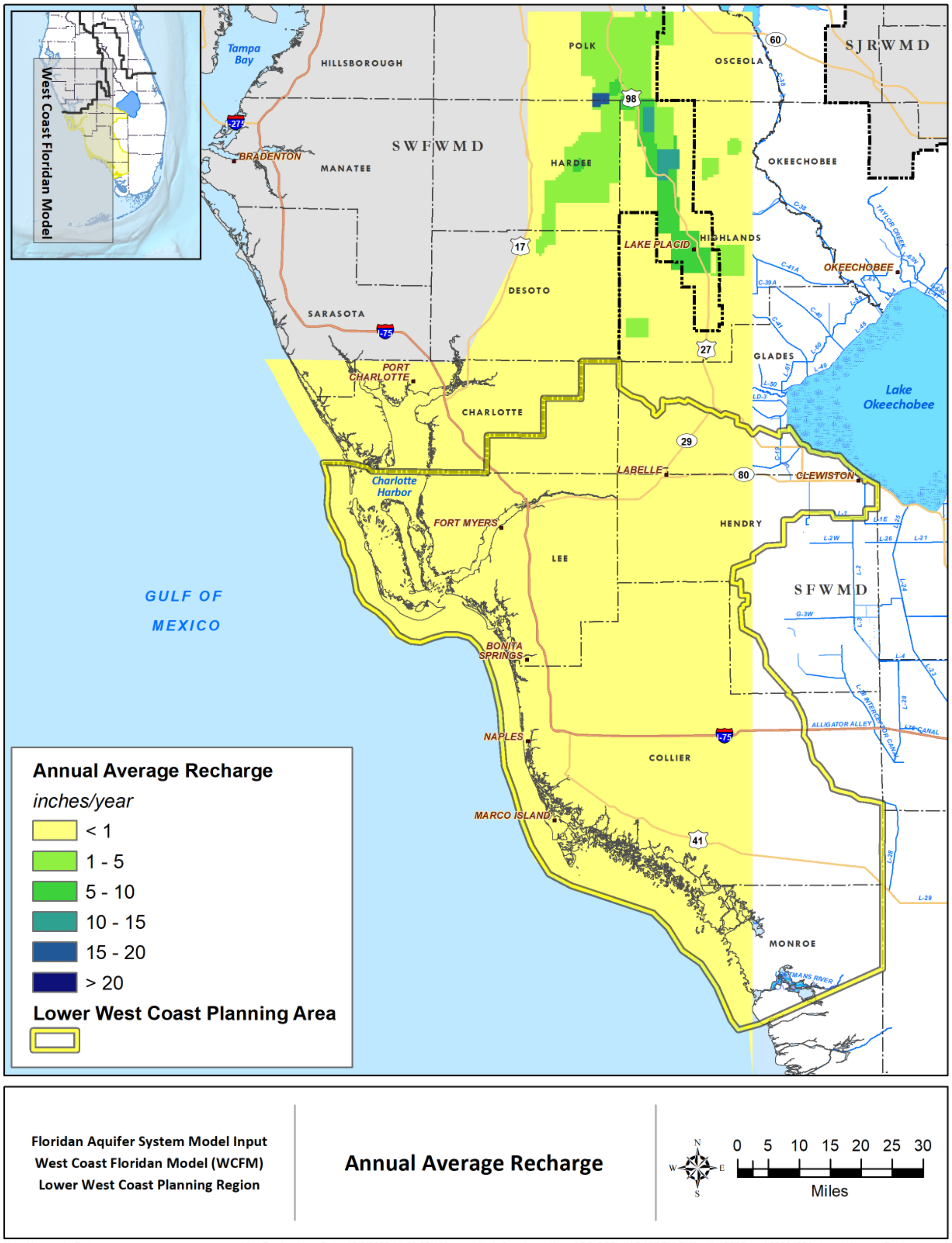


Figure 3-3. Average annual recharge rates (inches/year) from 1989 through 2012.

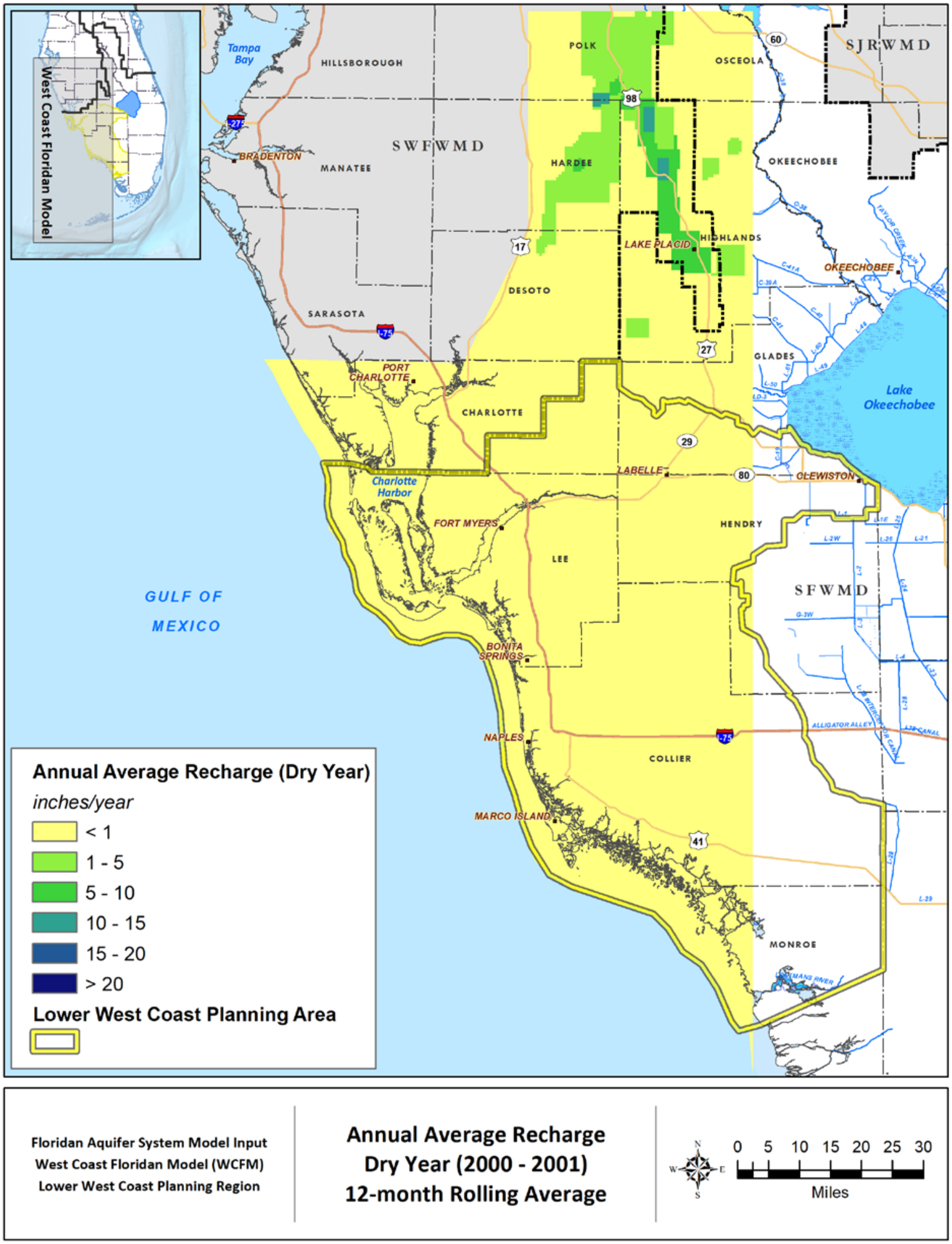


Figure 3-4. Average annual recharge rates (inches/year) from 2000 to 2001.

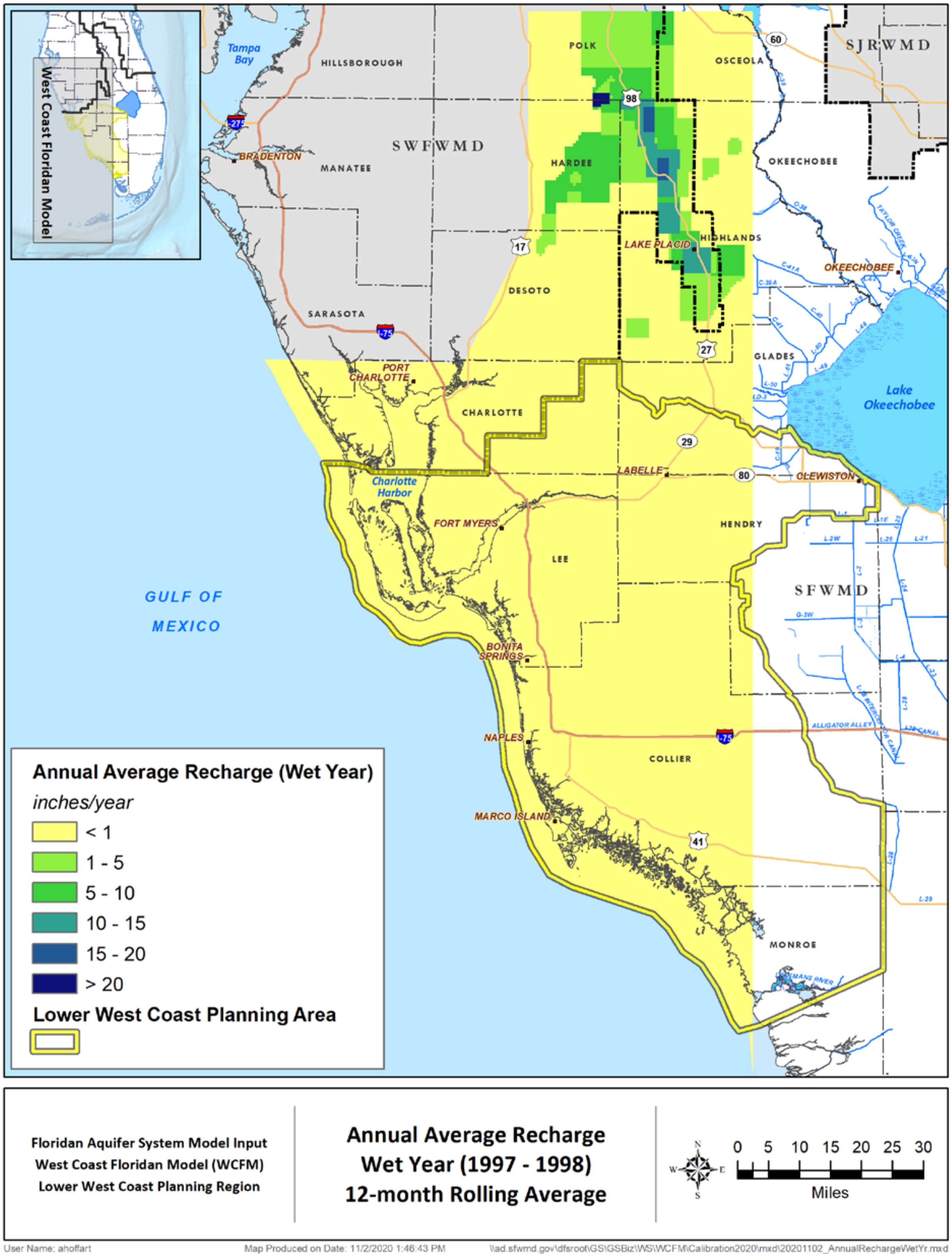


Figure 3-5. Average annual recharge rates (inches/year) from 1997 to 1998.

## 3.6 Temperature Changes Affecting Water Levels in the Boulder Zone

The lowermost unit in the WCFM is the BZ. Across much of the model domain, this is a highly productive aquifer that is rarely used, except for effluent disposal, because the water quality approaches that of seawater and it is several thousand feet below ground. Very few water level data are available due to the extreme depth below ground and the cost of installing monitor wells into a highly saline aquifer. To offset the lack of water level data for the BZ, water temperature data from deep well injection sites were analyzed to estimate the aquifer head. **Figure 3-6** shows the temperatures observed in the BZ at deep well injection or exploratory well sites. Water temperatures steadily increase from east to west across the southern peninsula of Florida. Temperatures can vary up to 45° F between Miami and Fort Myers. Assuming a constant density equal to seawater, **Figure 3-7** shows the calculated heads based on the temperature differential. The calculations suggest water levels in the BZ are near sea level along the southeastern coast of Florida and gradually increase to approximately 20 ft above sea level in the Boca Grande region.

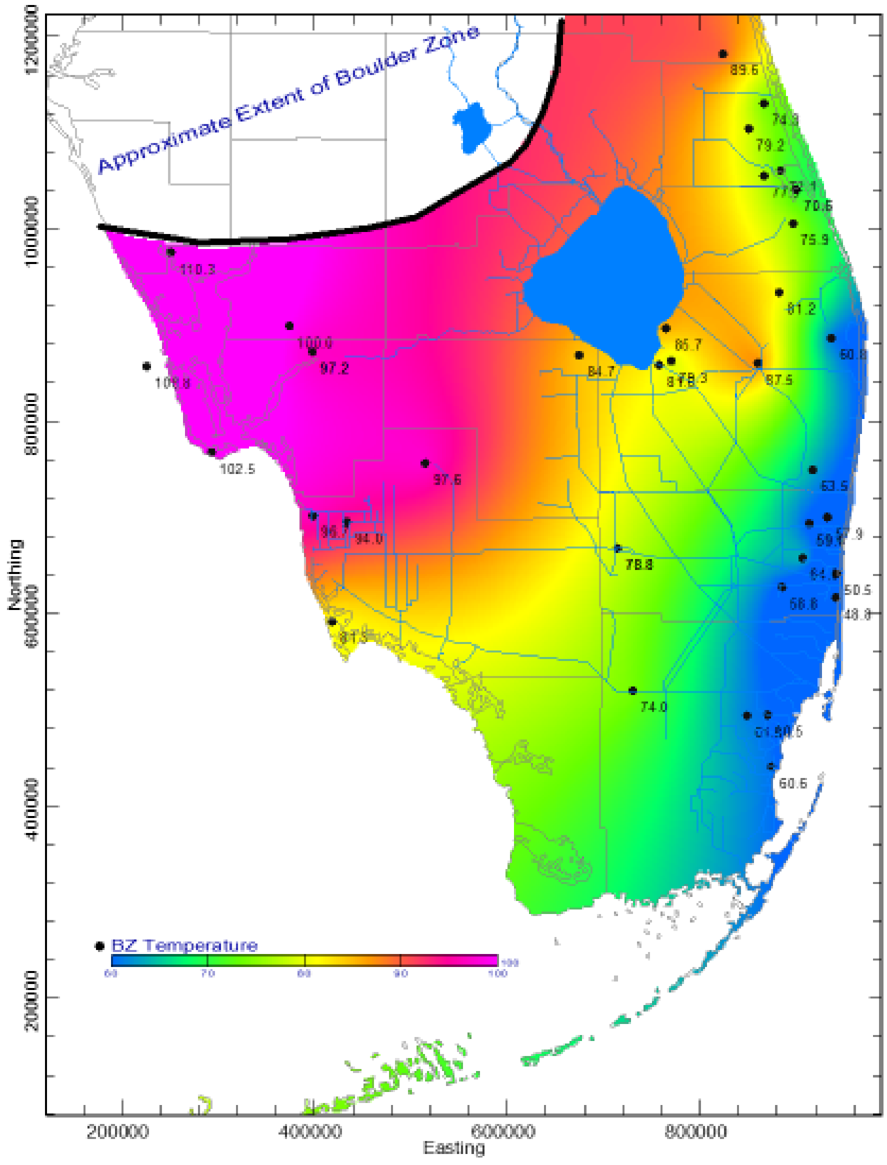


Figure 3-6. Temperature recorded in the Boulder Zone.

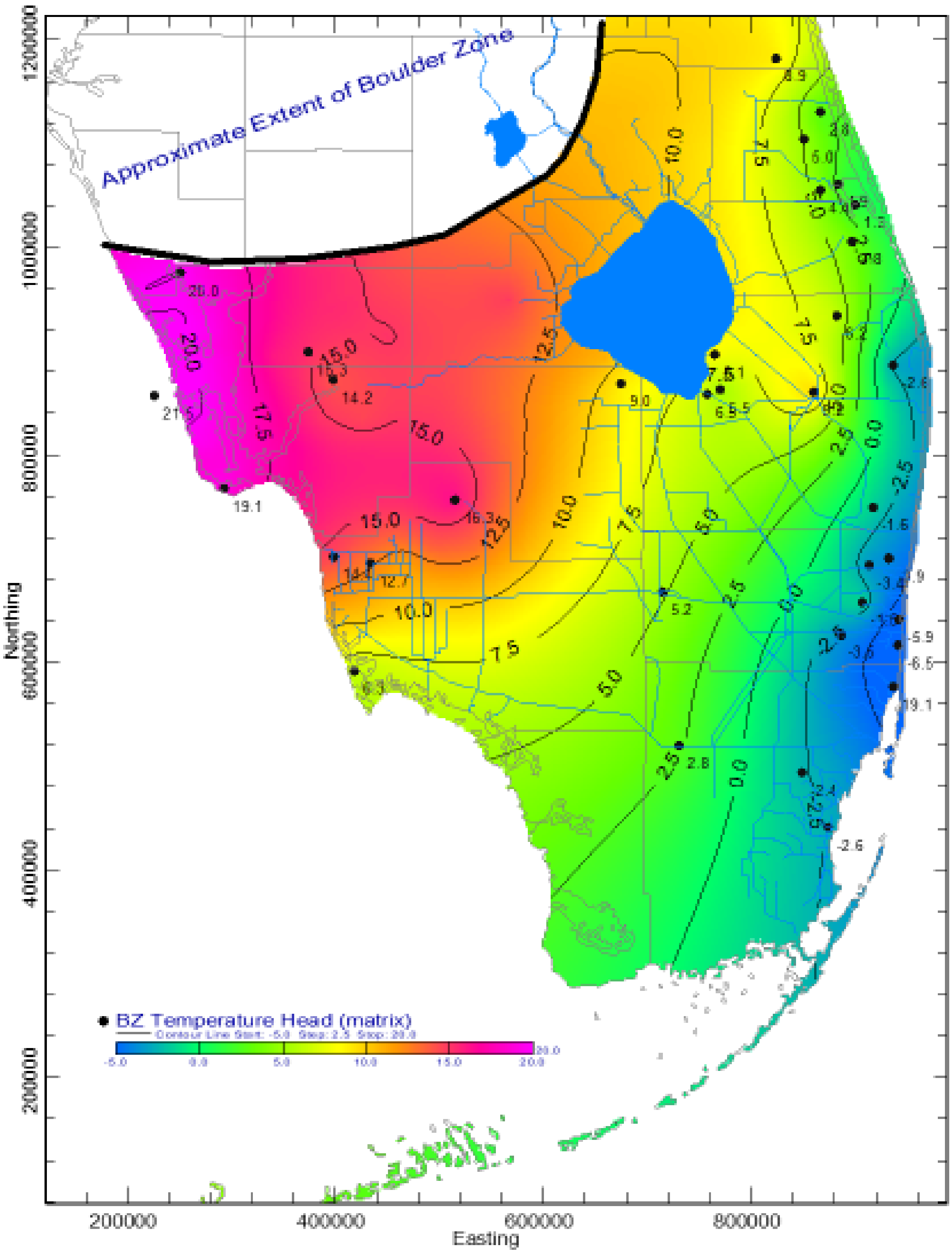


Figure 3-7. Calculated head based on temperature data for the Boulder Zone.

## 3.7 Groundwater Withdrawals

The FAS is a major water source in Florida, and numerous wells use the UFA or APPZ in the northern portion of the model domain for irrigation and public supply. The BZ is used for deep injection wells to dispose of secondary effluent or reverse osmosis concentrate throughout southeastern Florida, but not used as much in southwestern Florida. Few uses of the UFA occurred south of the Glades-Highlands county line in the early portions of calibration because most users tapped the IAS at that time. The two main exceptions to this were the Island Water Association, which supplies Sanibel Island, and the City of Cape Coral. Additional widespread use of the FAS in Lee and Collier counties did not occur until after 2000 when shallower aquifers began to experience excessive stress from continued development. Use of the FAS in the northern portion of the model domain began in the early 1900s in Polk County (Stewart 1966) and continues to present day. Kissengen Spring, located west of Lake Wales along the northern model boundary, provides an illustration of the impacts of groundwater withdrawals in the region. Recorded spring flow at this site extends back to 1898. From 1898 to approximately 1940, spring flow generally exceeded 20 cubic feet per second (cfs). After that, there was a steady decline in the spring flow until 1950 when it permanently stopped flowing, suggesting significant withdrawals had occurred in the region for the past 70 years or more (Spechler and Kroening 2007).

Average demands by county and water management district, in million gallons per day (mgd), are provided in **Table 3-2**. Demands in Polk, Hardee, Highlands, and DeSoto counties were not fully simulated in the active model domain; therefore, the numbers represent a fraction of the overall county demand. However, the table suggests that the vast majority of FAS demands occur in the northern portion of the model domain, with Highlands and DeSoto counties being the largest use areas. These northern demands are primarily for agricultural purposes, while demands in Collier and Lee counties are primarily for public supply.

Table 3-2. Simulated average Floridan aquifer system groundwater withdrawals, in million gallons per day, by county and water management district.

| County | SWFWMD | SFWMD | **Total** |
|---|---|---|---|
| Charlotte | 9.56 | 7.44 | **17.00** |
| Collier | 0.00 | 5.43 | **5.43** |
| DeSoto | 47.04 | 0.00 | **47.04** |
| Glades | 0.00 | 9.64 | **9.64** |
| Hardee | 35.65 | 0.00 | **35.65** |
| Hendry | 0.00 | 1.50 | **1.50** |
| Highlands | 0.00 | 55.68 | **55.68** |
| Lee | 0.00 | 28.85 | **28.85** |
| Polk | 23.92 | 2.77 | **26.69** |
| **Total** | **116.17** | **111.31** | **227.48** |

SFWMD = South Florida Water Management District; SWFWMD = Southwest Florida Water Management District.

Historical pumpage records for public supply utilities generally are available throughout the model domain and for the entire simulation period through utilities' monthly operating reports to the Florida Department of Environmental Protection or through regulatory requirements of the SFWMD and SWFWMD. The reports generally include the raw water pumped into a water treatment plant but may not include withdrawals from individual wells. Usually, more than one well provides water to a treatment plant. For the purposes of this study, in most cases, raw water volumes reported by the utility for an individual water treatment plant were distributed equally among all wells providing water to that plant. When available, individual well pumpage records were used to distribute demands.

Records of actual irrigation withdrawal volumes are rare and confined to the last several years of the simulation period, particularly in the SWFWMD. When pumpage data were available, sufficient quality assurances had to be conducted before the data were included in the data set. As a result, irrigation withdrawals needed to be estimated for the model domain. Irrigation demands were determined using the Agricultural Field-Scale Irrigation Requirements Simulation (AFSIRS) program developed by Smajstrla (1990). AFSIRS provides a reasonable estimate of daily irrigation requirements based on observed rainfall and evapotranspiration rates. For the SFWMD and SWFWMD, each district's water use permit database was used to determine the crop type, acreage, irrigation efficiency, and operation dates for each user. This information was fed into the AFSIRS program, and irrigation requirements were calculated for each day of the simulation period for each individual water use permittee. Some operations in the model domain use a combination of surface water, the IAS, and the FAS as their source of water. Based on permit information, only the percentage of irrigation demands estimated from the FAS was simulated. Demands were summed into monthly values and converted to average daily rates for input into the transient model simulation.

Aquaculture, livestock, industrial, and mining, users were included, but historical records for these users are not uniformly available. Therefore, the average permitted demand was used throughout the simulation period, adjusted for times when the users may not have been in operation based on available information. One additional use type was included, aquifer storage and recovery, although it is a relatively minor use in the model domain. Aquifer storage and recovery systems are primarily associated with public supply utilities and generally have detailed records of injected and recovered volumes. Water volumes used in such systems were included in the public supply category. **Table 3-3** provides a summary of the use types within the model domain.

Table 3-3. Simulated average Floridan aquifer system groundwater withdrawals, in million gallons per day, by use type, in the model domain, in the SFWMD, and in the Lower West Coast Planning Area.

| Use Type | WCFM | SFWMD | Lower West Coast Planning Area |
|---|---|---|---|
| Agriculture | 174.04 | 70.96 | 15.08 |
| Aquaculture | 0.05 | 0.05 | 0.05 |
| Golf Course | 2.67 | 2.67 | 2.39 |
| Industrial | 9.15 | 1.08 | 0.16 |
| Landscape | 2.09 | 2.09 | 2.09 |
| Livestock | 1.02 | 1.02 | 1.00 |
| Mining | 2.42 | 2.42 | 0.00 |
| Nursery | 0.78 | 0.78 | 0.26 |
| Public Water Supply | 35.26 | 30.24 | 29.42 |
| **Total** | **227.48** | **111.31** | **52.85** |

SFWMD = South Florida Water Management District; WCFM = West Coast Floridan Model.

## 3.8 Aquifer Properties

Hydraulic conductivity is one of the most important parameters used to develop and calibrate the WCFM Because it represents an aquifer's ability to transmit water under a hydraulic gradient. When multiplied by the aquifer's thickness, the resulting transmissivity term can be obtained from APTs. When developing the WCFM, aquifer and confining unit top and bottom elevations were treated as static input parameters. Aquifer thickness, and consequently transmissivity, was calculated internally via the model code. Therefore, vertical and horizontal hydraulic conductivities were used in place of transmissivity values.

Another important parameter needed for the transient simulations was the aquifer storage coefficient. Storage coefficients can be obtained from APTs. Similar to the relationship between hydraulic conductivity and transmissivity, the model code required a specific storage value, which is the quotient of the aquifer storativity divided by the aquifer thickness.

A large number of APT results were available for incorporation into the WCFM. Most data were available for the UFA, which is the principal aquifer used throughout much of Florida. The database was compiled from multiple sources, including the SFWMD, the SWFWMD, the USGS, the United States Army Corps of Engineers, various county governments, and several consultant reports. Horizontal hydraulic conductivity values and specific storage values for the UFA, APPZ, and LF1 were calculated. Approximately 250 tests were conducted, from short-term packer tests to long-term APTs. The aquifer test sites covered most of the model domain, but few sites exist within Big Cypress Basin and Hendry County. **Figure 3-8** shows the location of aquifer test sites, by test type and aquifer, and the test results are presented in **Appendix B**.

The UFA occurs at the base of the Hawthorn Group and includes the upper portions of the Avon Park Formation, the Suwannee Limestone, the basal clastic zone of the Hawthorn Group, 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 hydraulic conductivity of the UFA ranges from less than 10 to more than 100 ft/day throughout the model domain. The top of the UFA varies from approximately 200 ft below sea level in the northern areas of the model domain to 1,000 ft below sea level in the western Florida Keys. The UFA is semi-confined in the northern portion of the model domain and more fully confined throughout the southern portion.

The APPZ is present throughout most of the model domain, although it thins and may pinch out in portions of Collier and Monroe counties (Reese and Richardson 2008). In other parts of the model domain, the APPZ can be up to 500 ft thick. The top of the APPZ is quite variable and decreases from north to south. In the north, the top of the APPZ generally occurs 750 ft below sea level and is more than 1,500 ft below sea level in the Florida Keys. Hydraulic conductivity of the APPZ generally is higher than the UFA, ranging from less than 10 to more than 1,000 ft/day.

The LFA consists of a sequence of permeable zones separated by semi-confining units. The first permeable zone (LF1) is somewhat contiguous throughout the model domain and is located near the base of the Avon Park Formation. Only two aquifer tests exist for LF1, with an average hydraulic conductivity of 200 ft/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 in some areas with extremely high transmissivity values (Reese and Richardson 2008). Hydraulic conductivity in the BZ is extremely high but was not required for the WCFM because the BZ is treated as a variable head/constant concentration boundary; therefore, the hydraulic conductivity values assigned to the BZ do not affect the model results. However, a uniform horizontal hydraulic conductivity value of 1,000 ft/day was assigned to this model layer. Specific storage values for the top three model layers ranged from $10^{-3}$ to $10^{-8}$, with a constant value of $10^{-5}$ for the bottom model layers.

Initial aquifer properties were developed using values from the previous model update (Guo et al. 2011) and incorporating additional aquifer test information (**Appendix B**). Interpolation methods were used for the distributions shown in **Figures 3-9** to **3-11**. **Table 3-4** contains the artificial control points along the corners of the model that were used to contain the interpolation process. **Figures 3-9** to **3-11** show the calibrated horizontal hydraulic conductivity values and their distributions for the UFA, APPZ, and LF1. **Figures 3-12** to **3-14** show the distribution of storage values for the top layers. Vertical hydraulic conductivity values used in the WCFM were a tenth of the horizonal values, which is a common ratio for South Florida reflecting secondary porosity of the permeable horizontal layers.

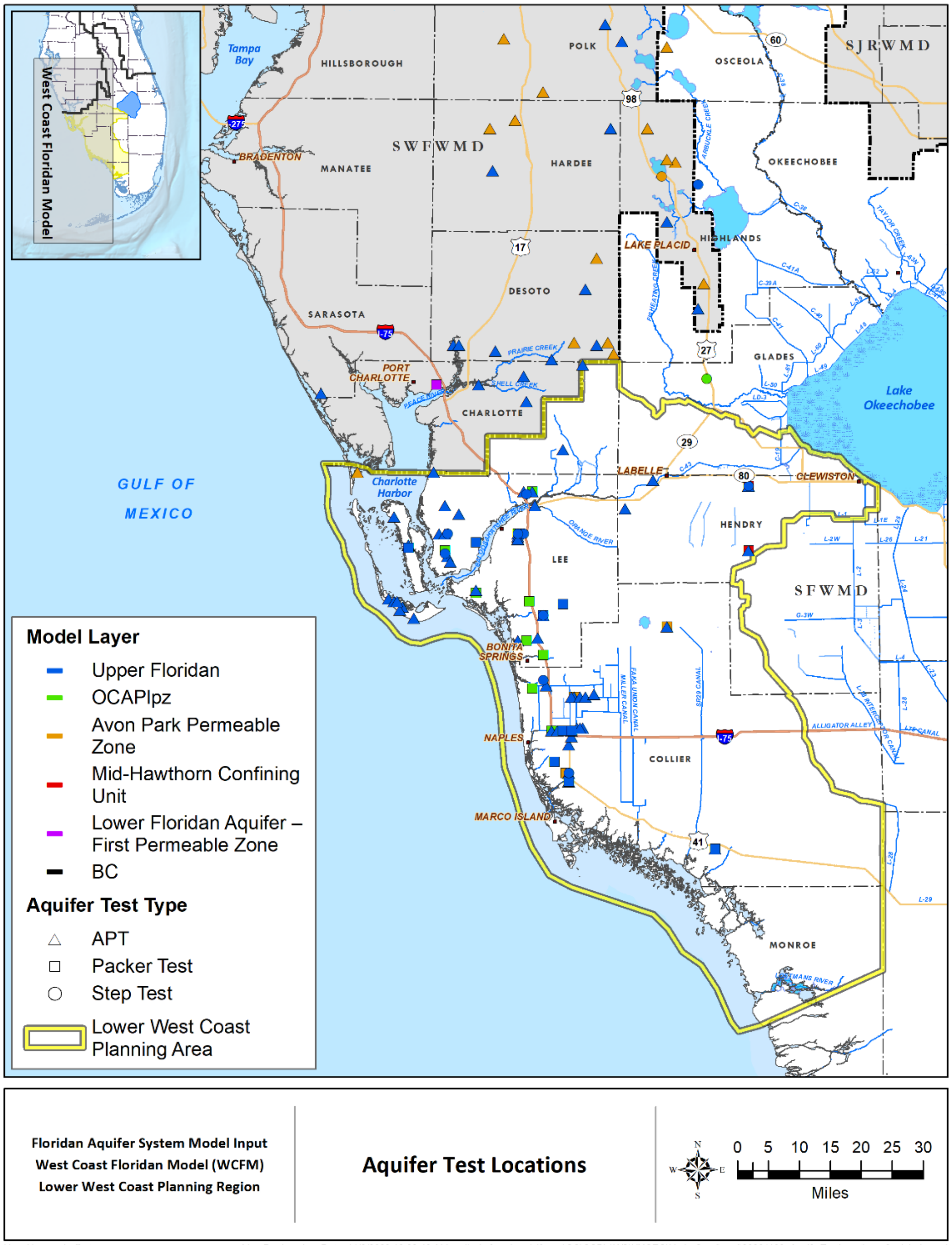


Figure 3-8. Location of aquifer tests within the model domain.

Table 3-4. Control points in the Upper Floridan aquifer.

| Well Name | X Coordinate | Y Coordinate | Elevation (feet NGVD29) |
|---|---|---|---|
| BR0920 | 741790.72 | 1279135.25 | -266.99 |
| BR1202 | 777335.24 | 1278500.90 | -284.20 |
| OS0231 | 669164.07 | 1270810.51 | -247.92 |

NGVD29 = National Geodetic Vertical Datum of 1929.

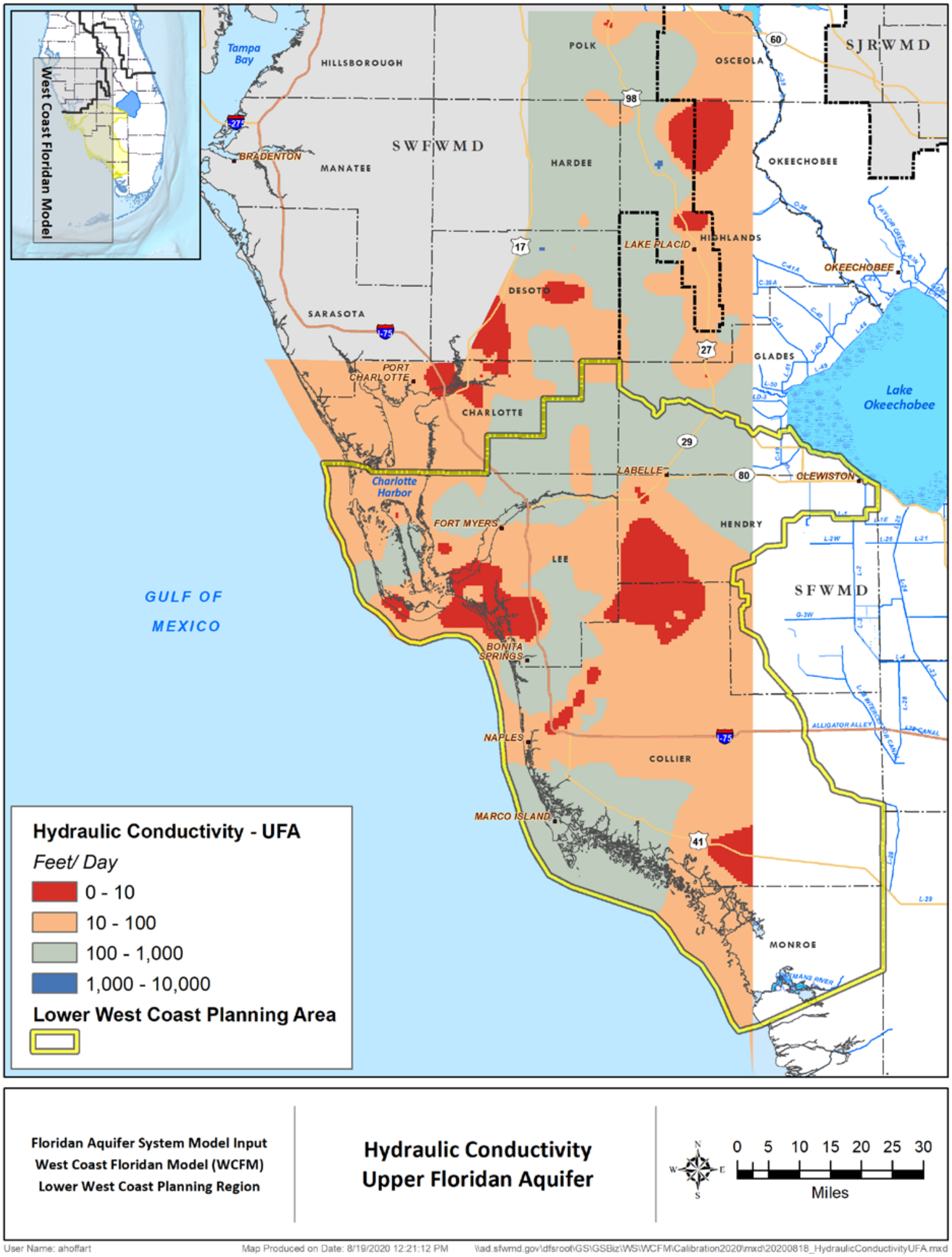


Figure 3-9. Distribution of horizontal hydraulic conductivity in the Upper Floridan aquifer.

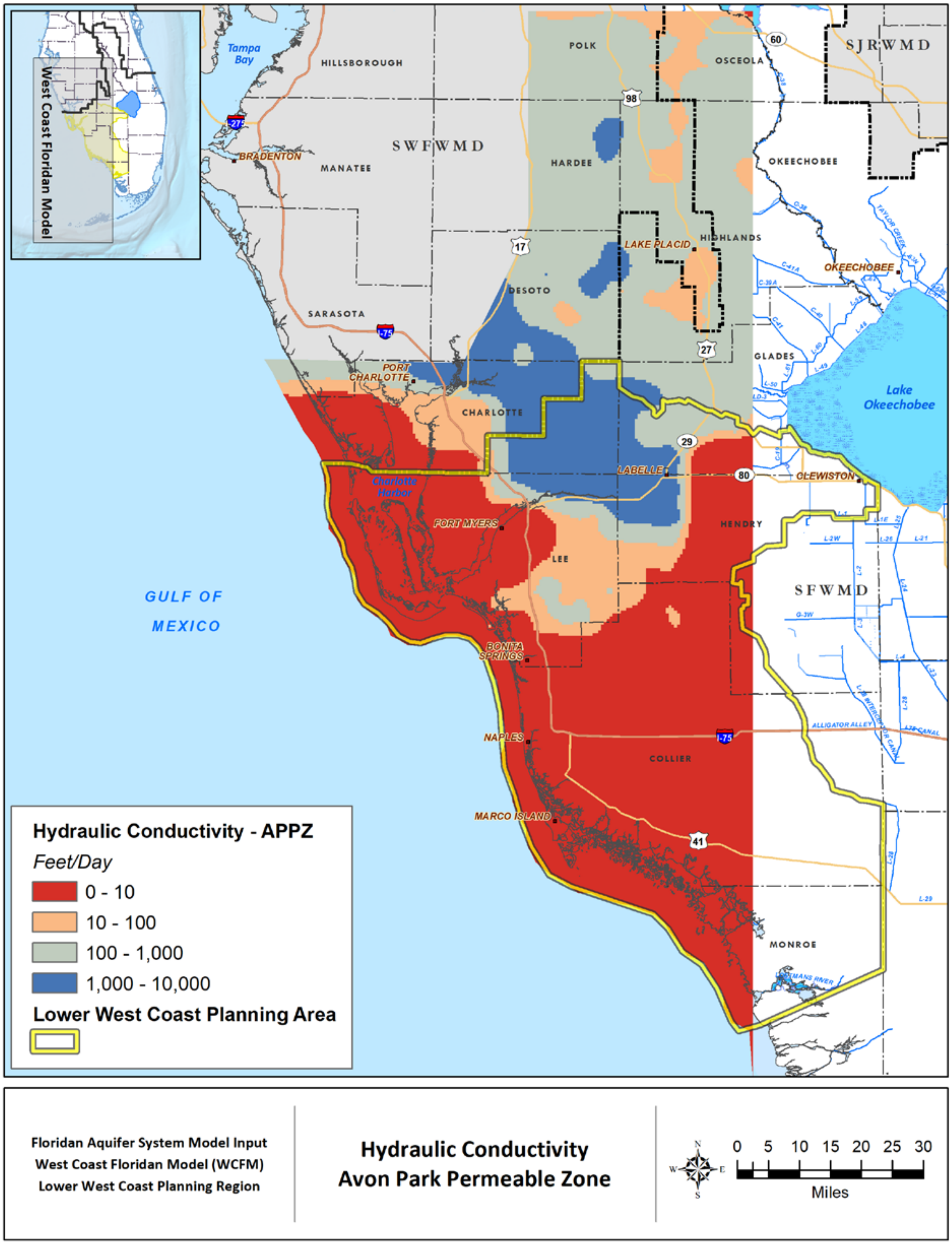


Figure 3-10. Distribution of horizontal hydraulic conductivity in the Avon Park permeable zone.

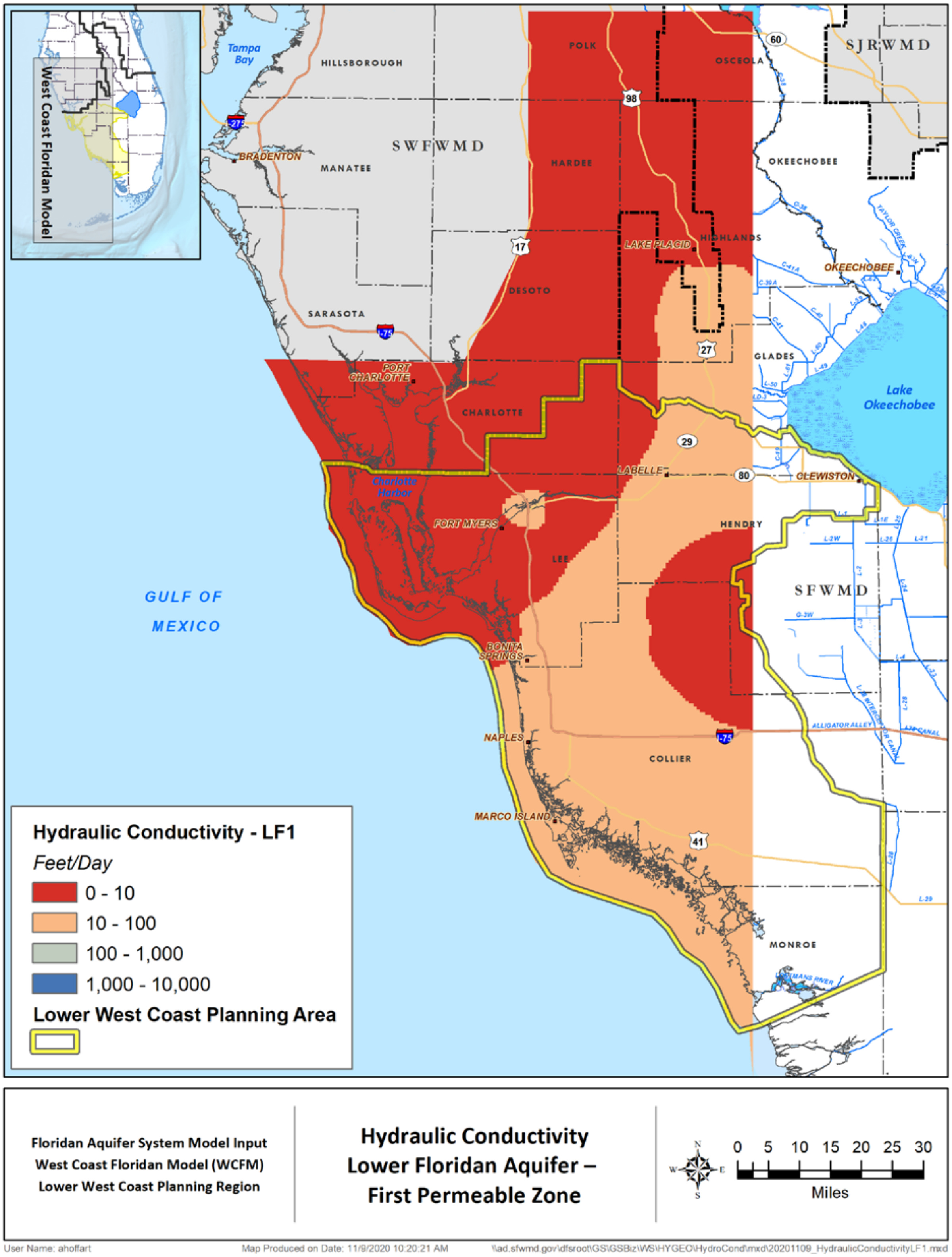


Figure 3-11. Distribution of horizontal hydraulic conductivity in the Lower Floridan aquifer – first permeable zone.

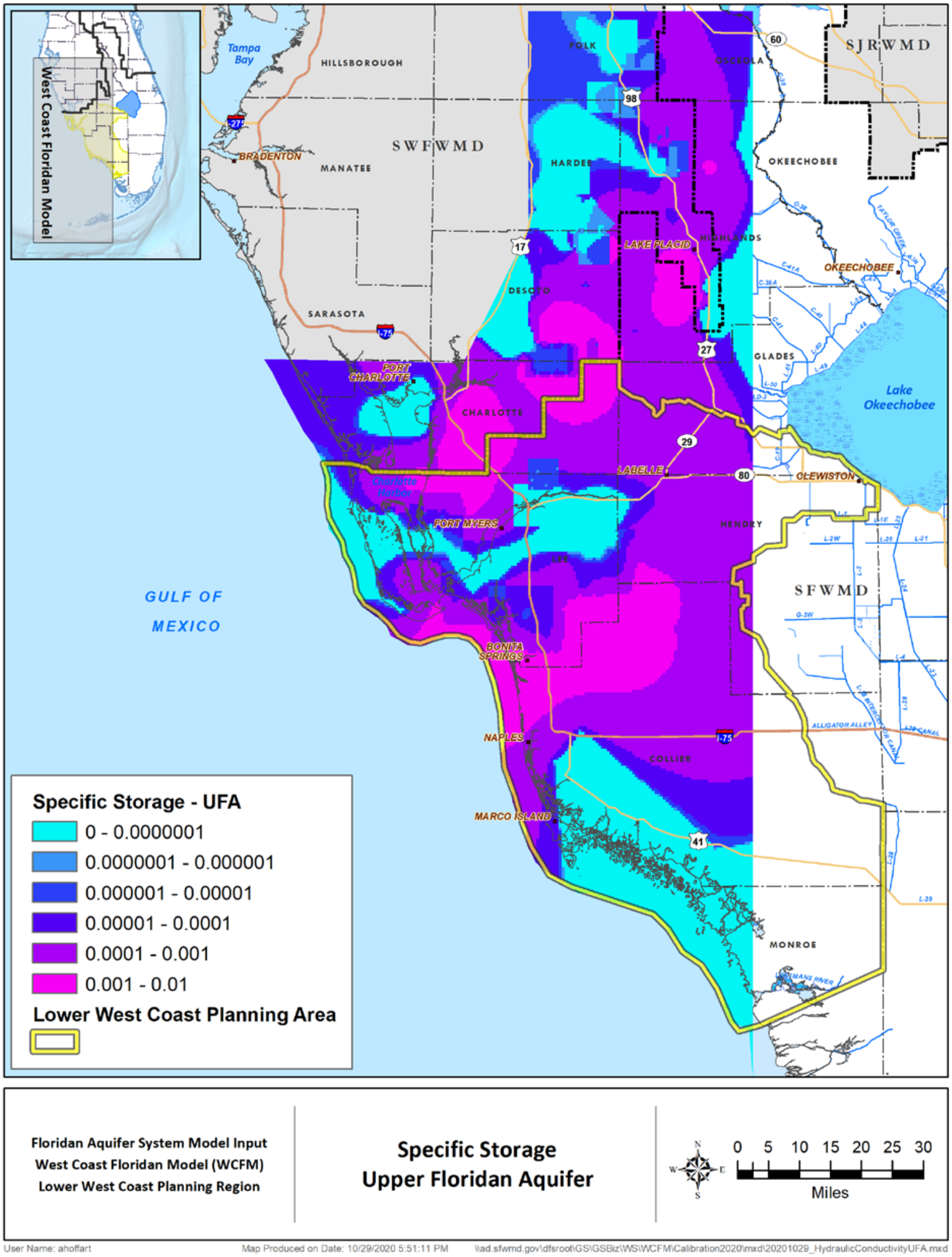


Figure 3-12. Distribution of specific storage in the Upper Floridan aquifer.

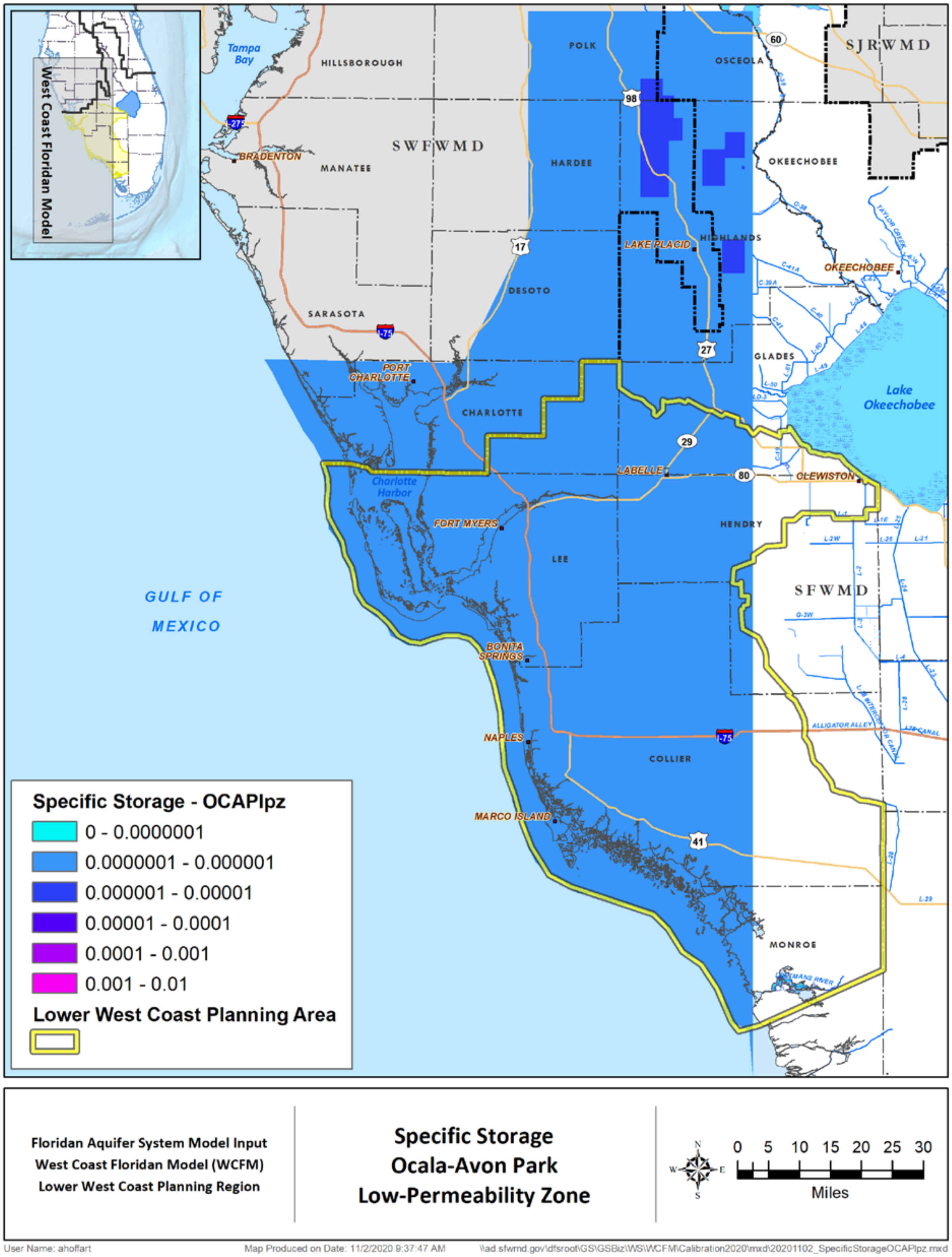


Figure 3-13. Distribution of specific storage in the Ocala-Avon Park low-permeability zone.

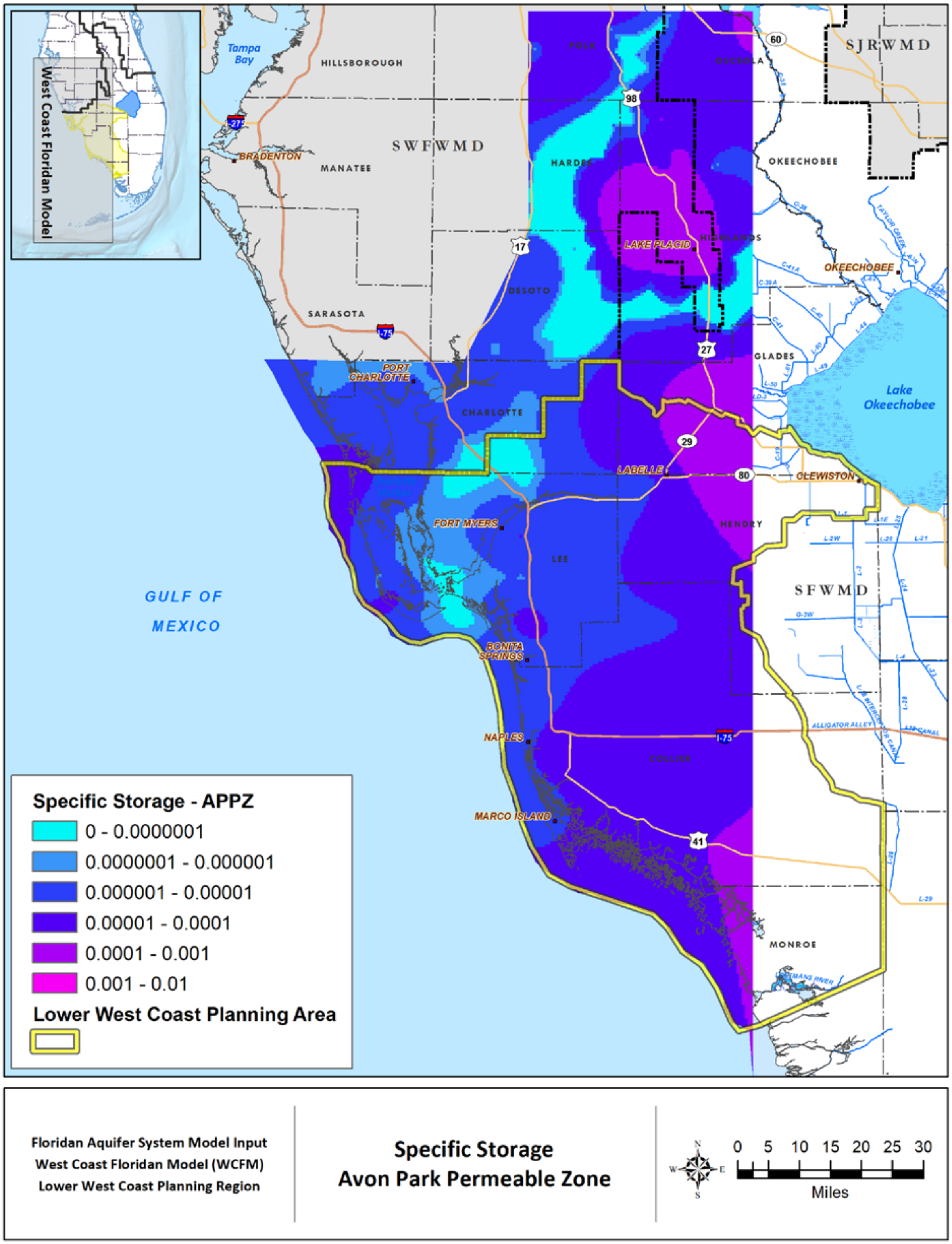


Figure 3-14. Distribution of specific storage in the Avon Park permeable zone.

Aquifer properties were obtained from numerous tests conducted in the region. Tests included long-term APTs, specific capacity and step tests performed on public supply production wells, and packer tests in isolated zones conducted during well construction to answer a site-specific question. For example, a packer test may have been conducted during construction of a deep injection well to determine if a specific zone was tight enough to prohibit upward migration of the injected effluent; therefore, data from that site may not be representative of conditions throughout the entire model layer. **Appendix B**, Tables B-1 to B-4, provides the results of various aquifer tests and the calibrated values used in the WCFM for specific aquifers and confining units. Because of their higher test quality, APT data were relied upon more than data from shorter-term or smaller tested intervals, including specific capacity and packer tests. The minimum and maximum values shown in **Appendix B** were determined from the screened interval of the test well (maximum value) or calculated using the entire unit/aquifer thickness (minimum value). If multiple aquifer tests were conducted for a test site, the value presented is the range for all tests.

The WCFM incorporates transport parameters that need to be quantified. One of those parameters is dispersivity, which is a scale-dependent term accounting for water mixing (dispersion) within an aquifer. HydroGeoLogic (2006) suggested longitudinal dispersity should range between 1,250 and 5,000 ft and a transverse value of one-tenth the longitudinal dispersity. Guo et al. (2011) used a longitudinal value of 100 ft, a transverse value of 20 ft, and a vertical dispersivity of 10 ft for the previous version of the model. Sensitivity analysis conducted by Guo et al. (2011) indicated the previous model was not sensitive to variations in these parameters, on the order of five times and one-tenth the initial values. Similar transport modeling conducted for the FAS in South Florida used longitudinal dispersity values between 3 and 1,000 ft, with the lower values reported by the United States Army Corps of Engineers (2010). Additional analysis conducted by Giddings et al. (2014) for the ECFM suggested using a longitudinal value of approximately 100 ft for dispersivity.

Longitudinal dispersivity in the WCFM was set at 100 ft for most areas of the model domain, with some values set at approximately 1,000 ft in the UFA around sensitive wellfields. The transverse dispersivity was set at 20 ft and the vertical dispersivity at 10 ft across each model layer. Effective porosities were assigned a value of 0.25 for each layer, which is a typical value used in previous models for aquifers in South Florida, including the FAS. A sensitivity analysis, discussed in **Section 4.7**, indicated the model has some sensitivity to these parameters in some local wellfield areas.

# 4 MODEL CALIBRATION

The SEAWAT, version 4.0, computer code (USGS 2012), which couples MODFLOW (McDonald and Harbaugh 1988) for the groundwater flow with MT3DMS (Zheng and Wang 1999) for the variable-density component, was used for this project. SEAWAT solves two coupled partial differential equations for flow and transport (Guo and Langevin 2002). In SEAWAT, flow and solute transport can be coupled in implicit and explicit coupling procedures. TDS concentration was selected as the species parameter for fluid density calculation and solute transport simulation. The advection process was solved using an implicit finite-difference scheme, and the solute transport equation was solved using the generalized conjugate gradient (Guo et al. 2011).

Model calibration involved adjusting model input parameters within the error bands of hydraulic properties observed from APTs or other information until model results (simulated water levels and/or solute concentrations) closely matched water level and water quality data observed in the field. For the WCFM, calibration was achieved by adjusting parameters manually and automatically. In the automatic calibration process, originally done by Guo et al. (2012), the model parameters were adjusted using the computer software parameter estimation code referred to as PEST (Doherty 2010) for multiple parameters during a single run. The initial PEST arrays were manually adjusted by changing one or more parameters for each calibration model run and then kriging, which is a Gaussian regression technique for interpolating irregular points.

The current version of the WCFM was manually calibrated by adjusting horizontal hydraulic conductivity values within the major aquifers and vertical hydraulic conductivity values in the confining units. Flow and transport processes are dominated by horizontal hydraulic conductivity of an aquifer and vertical hydraulic conductivity of a confining unit. Parameters selected for calibration included horizontal hydraulic conductivity in the UFA, APPZ, and LF1; vertical hydraulic conductivity in the confining units; and recharge zones and rates. Secondary calibration parameters included GHB conductance rates, pumpage distribution with wellfields, storage values, and other less sensitive parameters.

Calibration targets were monitor wells with available observed data. Two types of targets were used: head (or water levels) and water quality (TDS). Simulated head and water quality values were compared to field data at the target locations. The calibration priority was set first for head and then for TDS. The goal of model calibration was to match the model-calculated head levels and TDS values to measured data at the target locations. Time-series data were collected and organized from numerous head and water quality targets, primarily from the USGS, Florida Department of Environmental Protection, and SFWMD. Observed data consisted of monthly water levels and TDS concentrations at the monitor wells. Approximately 110 wells had useful water level readings and approximately 120 wells had useful water quality observations. Locations of head and water quality target wells are shown in **Figures 4-1** and **4-2**, respectively. Some spatial and temporal data variability was expected because water quality data depend on the level of quality assurance/quality control implemented during sampling and laboratory analysis by the entity collecting the data. Additionally, data were collected and analyzed over many years by different sampling personnel and different laboratories. Variability in the field data quality was considered when evaluating the accuracy of the model calibration.

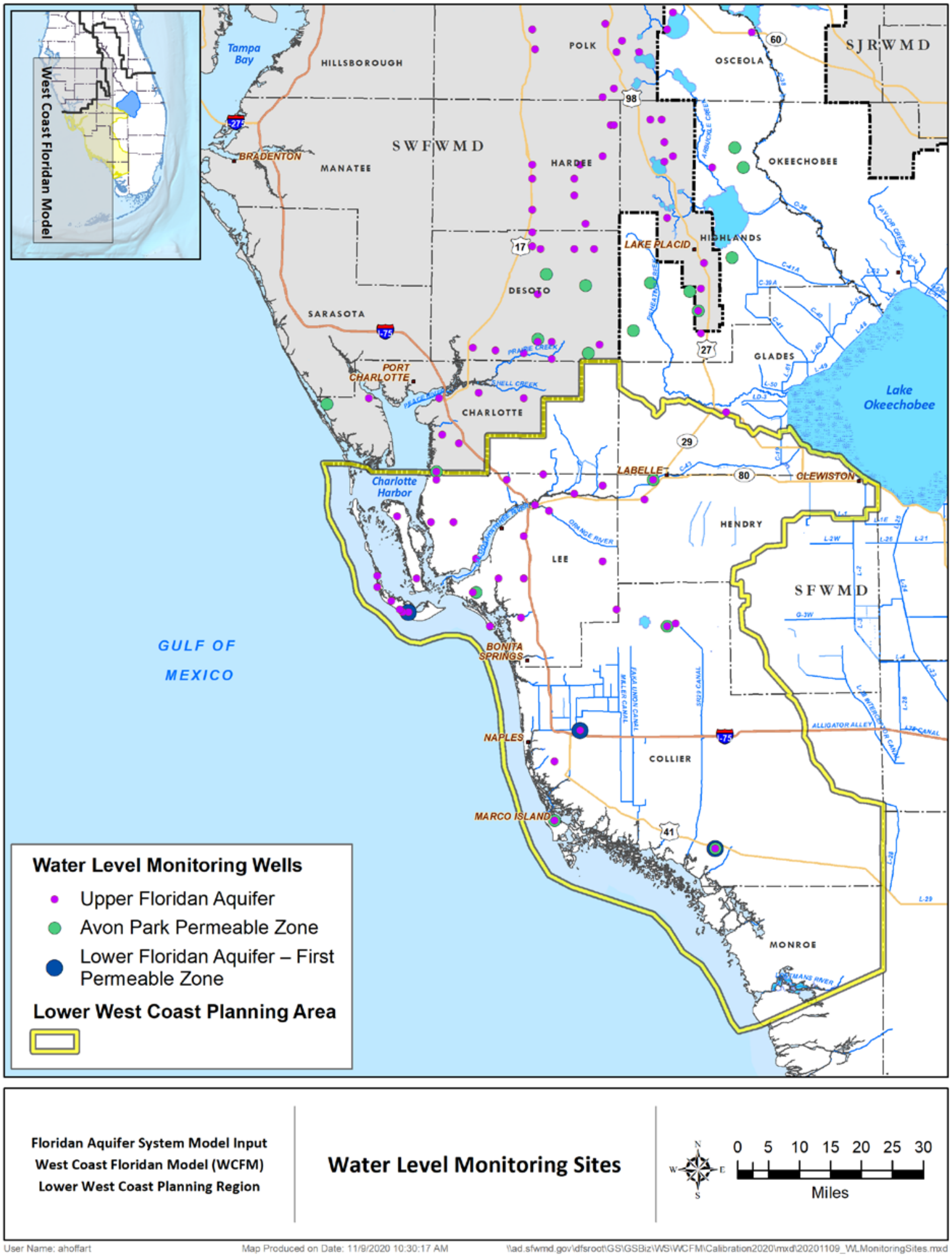


Figure 4-1. Location of water level monitoring wells used for model calibration.

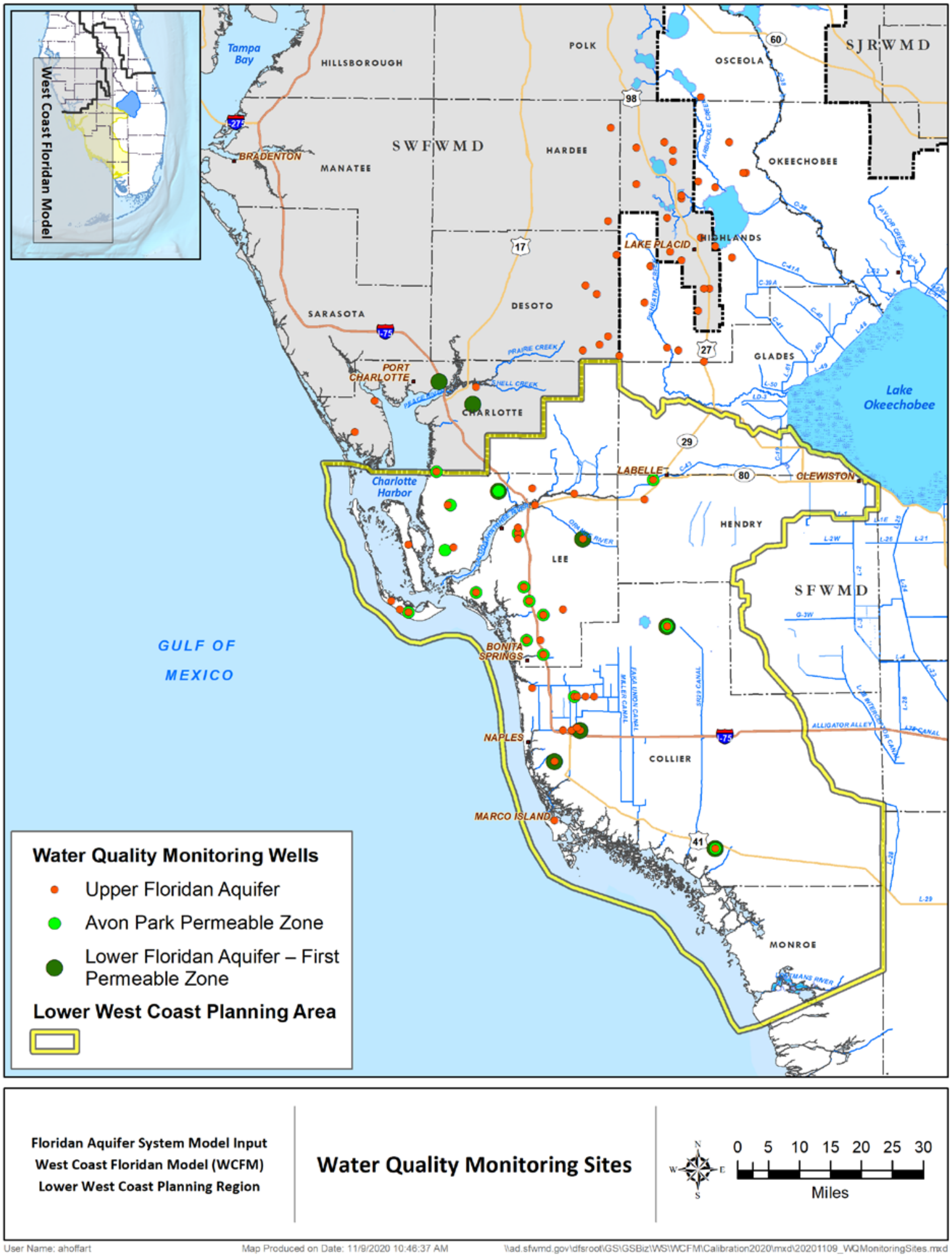


Figure 4-2. Location of water quality monitoring wells used for model calibration.

## 4.1 Boundary Conditions

The boundary conditions along the edge of the model (i.e., where active and inactive model cells meet) are where water can enter or leave the model domain. Water generally enters the system from the northern and eastern boundaries (i.e., recharge areas) and exits at the offshore outcrops along the western and southern boundaries into the Gulf of Mexico or the Straits of Florida (i.e., discharge areas). Along the eastern edge of the model domain, water can flow eastward towards the southeastern coast of Florida or westward into southwestern Florida, depending on the specific location.

Potentiometric surface maps of the UFA were generated by the USGS in May and/or September for several years during the calibration period. The maps were used to initially develop boundary conditions in areas not affected by ocean conditions. Use of maps south of Lake Okeechobee was suspect because the observed water levels used to generate the map were limited; therefore, the map is of little value with the exception of understanding general flow directions. Additionally, where there was a reasonable distribution of observed data points, the USGS did not differentiate between the UFA and APPZ, but instead grouped the two zones together to create the potentiometric surface maps. Because potentiometric maps were unavailable for the APPZ, these boundary heads were adjusted from UFA values by an offset determined from observed water levels at cluster sites, which monitor multiple zones within the FAS. Because the WCFM is a transport model, the boundary conditions require an uncorrected head value with no need to develop equivalent freshwater head calculations at each site. In general, water quality degrades with depth between aquifers at a specific location and southward within each aquifer. Therefore, heads in the UFA at a specific location generally are higher than deeper APPZ heads. Data between May and September of each year were further adjusted based on nearby observation wells where data may have been collected more frequently than the biannual potentiometric maps to develop a time series for the monthly stress period transient calibration. If wells with monthly data were not available along the boundary, water levels were linearly interpolated between dates or between cells to develop the monthly time series. Water levels were included in the model as GHBs, which allowed them to vary between stress periods for the UFA and APPZ. From the shoreline seaward, a constant head and concentration boundary was set for these two aquifers. There is no LFA potentiometric map for any time frame because of the lack of monitor wells, so the boundaries for this layer were set at a constant value for the entire simulation. **Figure 4-3** shows the location of the GHB and constant head cells along the model boundary.

Water quality assigned along the northern boundary was based on observed water quality data and generally considered fresh to slightly brackish depending on the aquifer. Water quality rapidly deteriorated southward and westward along the model boundaries. In the Gulf of Mexico, the boundaries were set to ocean water conditions, and along the eastern boundary from Lake Okeechobee southward, water quality slowly transitioned to ocean conditions. Water quality along the boundaries were set at a constant value throughout the simulation.

The LF1 boundaries were set to constant head and constant TDS concentration along the active model edges. For the BZ, heads across the entire model domain varied depending on the temperature changes discussed in **Section 3.6**. Additionally, heads in the BZ were adjusted monthly to simulate the seasonal tidal component, with higher ocean levels occurring in the fall and lower levels occurring in the spring. TDS concentrations were set to ocean water conditions (35,000 mg/L), although some observed values indicated hypersaline conditions in the lower aquifers.

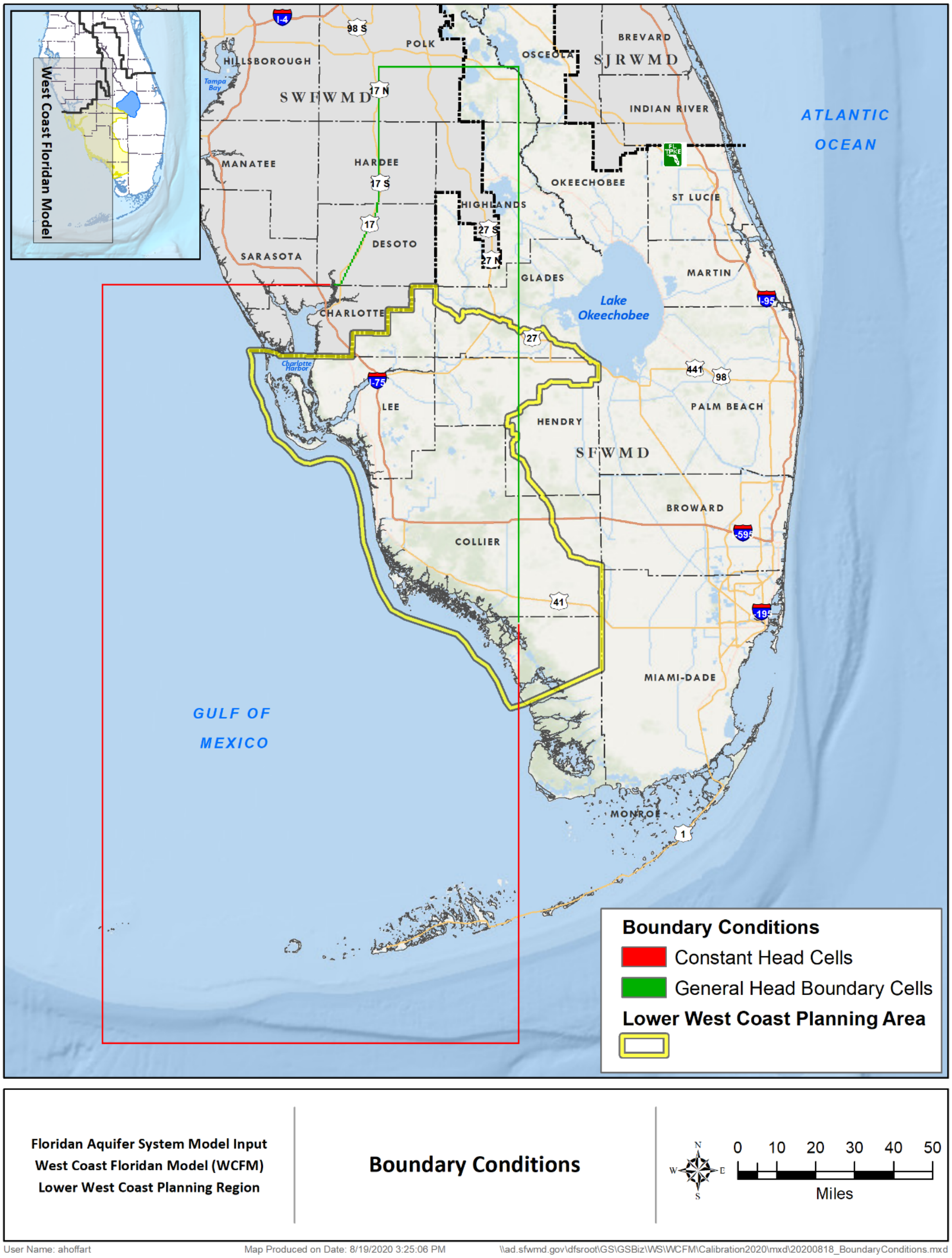


Figure 4-3. Boundary conditions for the Upper Floridan aquifer and Avon Park permeable zone.

## 4.2 Initial Conditions

The initial water level and water quality arrays to begin the simulation were estimated from Guo et al. (2012). However, several issues with the data needed to be resolved. First, the Guo et al. (2012) model commenced in 1999, whereas the current version of the WCFM commenced in 1989. In addition, the updated WCFM has a different model grid orientation and size. Therefore, 1) data from the older version of the model was resampled at selective points in the model grid, 2) observed values or estimates from observation wells were added from the water level and water quality databases, and 3) additional points from the 1989 USGS potentiometric surfaces for the UFA (Barr 1989) were used to develop the initial conditions. This information was kriged for the aquifer layers to develop the initial head and concentration arrays. Water levels and water quality in the confining units were calculated by averaging the values for each aquifer cell above and below the confining unit and adjusting as appropriate.

Because most of the data used in the kriging process to generate the initial heads and concentration values were estimates from various sources and time frames, they may not represent a reasonable starting condition. Therefore, an initial model run was conducted to stabilize the starting conditions. This was accomplished by developing a pseudo steady-state model, which used the transient model, turned off all the pumping wells, and ran the first stress period over and over again until the water quality and water levels stabilized and matched observed values. Water levels and TDS concentrations at the end of the pseudo steady-state model run were used as the initial condition for the transient simulation.

## 4.3 Calibration Criteria

The WCFM was evaluated by comparing simulated and observed heads and water quality values. Statistics of the errors and tolerance (or interval) criteria were used to provide an objective assessment of goodness of fit of the simulated behavior to the observed data. Monthly average aquifer water levels and TDS values were obtained from recorded observations or estimated during the 1989 through 2012 period to calibrate the transient model. Average monthly heads or TDS values for observation wells for the UFA, APPZ, and LF1 were assigned as calibration target criteria, which served as measuring sticks for a successful transient calibration.

Three of the statistics used in the calibration were the ME, MAE, and RMSE. Residuals often are used to quantify the quality of the model calibration (Anderson and Woessner 1992). The ME globally indicates whether simulated values tend to be disproportionately overestimated or underestimated compared to historical measurements. However, if the ME was close to zero, that does not necessarily imply a better calibration. This model calibration metric may indicate 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 RMSE, or standard error, of the estimate gives an overall indication of the magnitude of a typical error. The closer the RMSE is to zero, the better the model simulates temporal changes. MAE was calculated using the absolute value of the error for each observation during the transient run. Unlike ME, by which positive and negative errors could be cancelled out, this value measures the average error in the model. Statistics calculations at each water level observation site included:

- ME: Mean of the difference between calculated and observed values
- MAE: Mean of the absolute value of the residuals
- RMSE: Measure of the standard deviation of the residuals
- Coefficient of determination ($R^2$) for each well
- ± interval band or nominal error: Percentage of time when simulated head lies within a “desirable” band of the observed head for each observation site

Other metrics for WCFM calibration performance were scatter plots (with accuracy interval criteria) and statistics at each monitoring site. Scatter plots were generated using observed versus simulated heads and TDS values, including every measured value. Scatter plots were used to identify zones and points in the model that display anomalies as well as outliers that do not seem to fit with the rest of the points. Another use of scatter plots was to identify the tendency of the values. If the points aligned along a straight line from the lower left to the upper right of the plot area, the two variables had a positive correlation.

Specific water level calibration target criteria for the WCFM 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 5 ft from all wells within each aquifer; and an MAE of within 5% of the total head elevation range for each aquifer. Additionally, 50% of the mean absolute simulated head residuals for each aquifer had to be within 2.5 ft of the observed value, and 80% of the mean absolute simulated head residuals for all wells had to be within 5 ft of the observed values. These calibration criteria were reviewed and applied for the ECFTX (Anderson et al. 2020). The only exception to the criteria is that for the LF1, the MAE within 5% of the total head elevation range was not included because the LF1 only had three observation wells, which were located in the same general area and therefore are not representative of the aquifer heads across the model domain. Additionally, the $R^2$ criterion was that 40% of the observation wells needed to have an $R^2$ value of 0.4 or higher.

For water quality, broader categories identified by Jacobs et al. (2011) were used to provide a general understanding of the robustness of the water quality calibration. The outer error bands represent the minimum and maximum value for each category. For this report, potable water had a TDS concentration between 0 and 1,000 mg/L, brackish was between 1,000 and 10,000 mg/L, moderately saline was between 10,000 and 18,000 mg/L, and saline was between 18,000 and 35,000 mg/L. However, the calibration criteria for TDS were used as an alternative target for model performance.

For water quality, the interval calibration criteria bands were defined as ±500, 750, 2,000, 3,000, and 4,000 mg/L of the observed values, depending on the TDS value and the aquifer unit location. The interval criteria were more restrictive in the UFA and less restrictive in deeper aquifers or when the TDS values were higher, which is consistent with the ECFM (Giddings et al. 2014). For TDS calibration criteria, low values were more important for water supply purposes. It generally is acceptable to have higher uncertainty with higher TDS values because its potential as a future source for water supply is limited.

The selected water quality calibration criteria were as follows:

- In the UFA, if the observed TDS value was from 0 to 4,000 mg/L, an interval criterion of ±500 mg/L was used; if the observed TDS value was higher than 4,000 mg/L, an interval criterion of ±750 mg/L was used.
- In the APPZ (classified into three intervals due to the variability of the values), if the observed TDS value was from 0 to 2,000 mg/L, an interval criterion of ±750 mg/L was used; if the observed TDS value was from 2,000 to 8,000 mg/L, an interval criterion of ±2,000 mg/L was used; if the observed TDS value was higher than 8,000 mg/L, an interval criterion of ±4,000 mg/L was used.
- In the LF1, an interval criterion of ±4,000 mg/L was used. The maximum value in the model simulation was limited to 35,000 mg/L. However, bottom layers of the LFA had observed values greater than 36,000 mg/L.

Utilizing the above criteria, the overall ME for each well was within the designated interval criteria for all wells and aquifers combined, with at least 80% of the wells meeting the criteria. Additional qualitative calibration criteria results for the model water budget and conceptual pre-development flow model are presented in **Sections 4.5** and **4.6**, respectively.

## 4.4 Water Level and Water Quality Calibration Results

During the calibration process, a few observation sites were not used for one of the following reasons: no data during the calibration period, the data were not consistent with the unit or aquifer, the monitor site crossed multiple confining units and/or aquifers, or a specific site better fit the spatial and temporal variations of the model cell results (where there was more than one site in a cell).

### *4.4.1 Water Level and Water Quality Summary*

**Tables 4-1** and **4-2** summarize the calibration statistics achieved in the calibrated WCFM. These data confirm the desired 50% and 80% minimum error criteria were achieved.

Table 4-1. Summary of calibration statistics for water levels.

| Aquifer | Number of Well Sites | Mean Error (ft) | Mean Absolute Error (ft) | Root Mean Square Error (ft) | Mean Absolute Error Within 2.5 ft | Mean Absolute Error Within 5.0 ft | Root Mean Square Error Within 5.0 ft |
|---|---|---|---|---|---|---|---|
| UFA | 91 | 0.14 | 2.16 | 2.60 | 65% | 100% | 100% |
| APPZ | 18 | 0.99 | 2.01 | 2.38 | 72% | 100% | 100% |
| LF1 | 3 | 0.59 | 0.68 | 0.81 | 100% | 100% | 100% |
| **All Aquifers** | **112** | **0.27** | **2.13** | **2.52** | **66%** | **100%** | **100%** |

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

Table 4-2. Summary of statistics for water quality.

| Aquifer | Number of Well Sites | Simulated Average | Observed Average | Calibration Criteria (mg/L) | Mean Average Difference | Mean Absolute Average Difference | Met Criteria |
|---|---|---|---|---|---|---|---|
| UFA | 77 | 3,500 | 3,683 | 500 – 4,000 | -115 | 601 | 88% |
| APPZ | 18 | 25,364 | 25,721 | 2,000 – 4,000 | -390 | 1,807 | 89% |
| LF1 | 8 | 30,895 | 31,175 | 500- 4000 | -282 | 2,369 | 100% |
| **All Aquifers** | **103** | **9,449** | **9,669** | **500 – 4,000** | **-176** | **949** | **89%** |
| Confining Units | 14 | 17,787 | 20,184 | 500 – 4,000 | -2421 | 3,990 | 71% |
| **All Model Layers** | **117** | **10,169** | **10,541** | **500 – 4,000** | **-320** | **1,172** | **87%** |

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

### *4.4.2 Water Level Statistics*

**Table 4-3** shows the simulated and observed minimum, average, and maximum water levels for each aquifer for the simulation period. **Figures 4-4**, **4-5**, and **4-6** show scatter plots for computed versus observed head for each measured value in the UFA, APPZ, and LF1, respectively. $R^2$ was 0.97 for the UFA, 0.98 for the APPZ, and 0.72 for the LF1. The $R^2$ value was calculated for each well, with 42% of the wells achieving the calibration criteria of 0.4. The average $R^2$ value for all wells was 0.40. This criterion was applied to all wells regardless of aquifer.

Table 4-3. Summary of simulated and observed extreme water levels (in feet).

| Aquifer | Observed | | | Simulated | | |
|---|---|---|---|---|---|---|
| | Minimum | Average | Maximum | Minimum | Average | Maximum |
| UFA | -24.60 | 41.67 | 97.69 | -23.55 | 41.66 | 98.03 |
| APPZ | 7.82 | 35.54 | 57.39 | 10.10 | 34.64 | 52.75 |
| LF1 | 6.64 | 9.14 | 11.25 | 5.36 | 8.00 | 11.10 |

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

The UFA scatter plot in **Figure 4-4** indicates 64% of observations were within the ±2.5 ft interval criterion. Furthermore, 92% of matching head values were within the ±5.0 ft interval criterion. The APPZ scatter plot in **Figure 4-5** indicates 65% of observations were within the ±2.5 ft interval criterion and 95% were within the ±5.0 ft interval criterion. For the LF1, 100% of observations were within the ±5.0 ft interval criterion and 85% were less than the ±2.5 ft interval criterion (**Figure 4-6**). A summary of the head values and statistics is provided in **Table 4-4**.

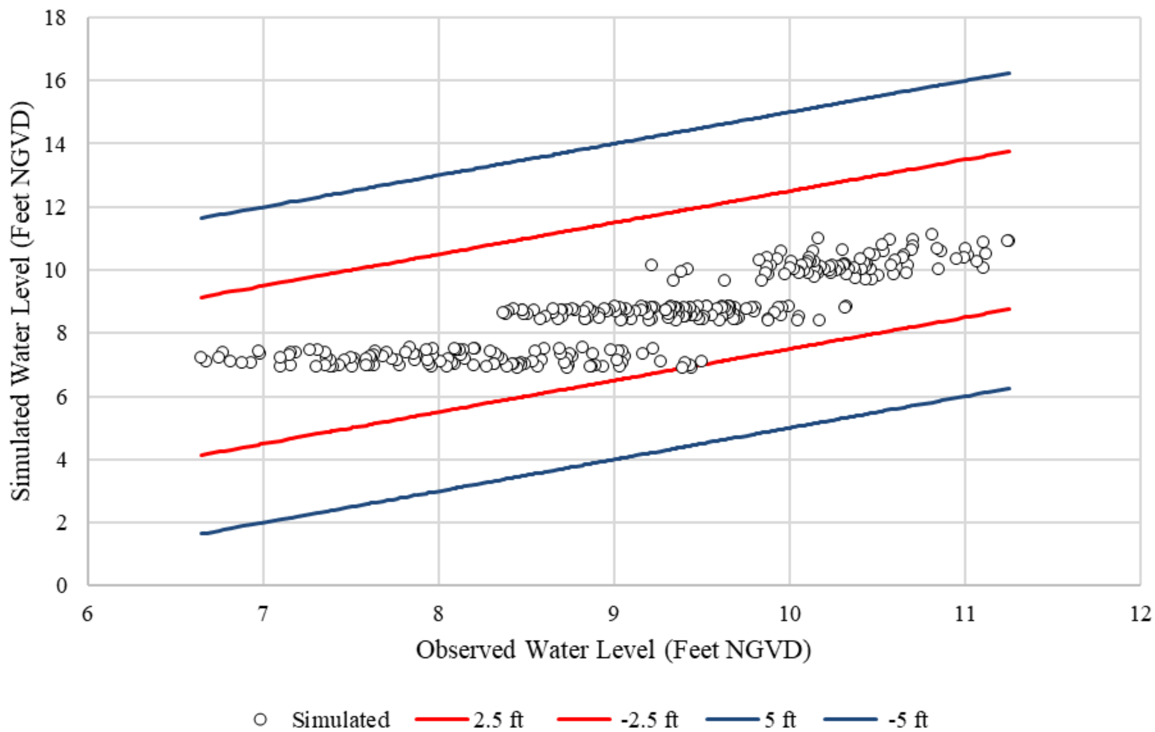


Figure 4-4. Scatter plot of observed versus simulated heads in the Upper Floridan aquifer.

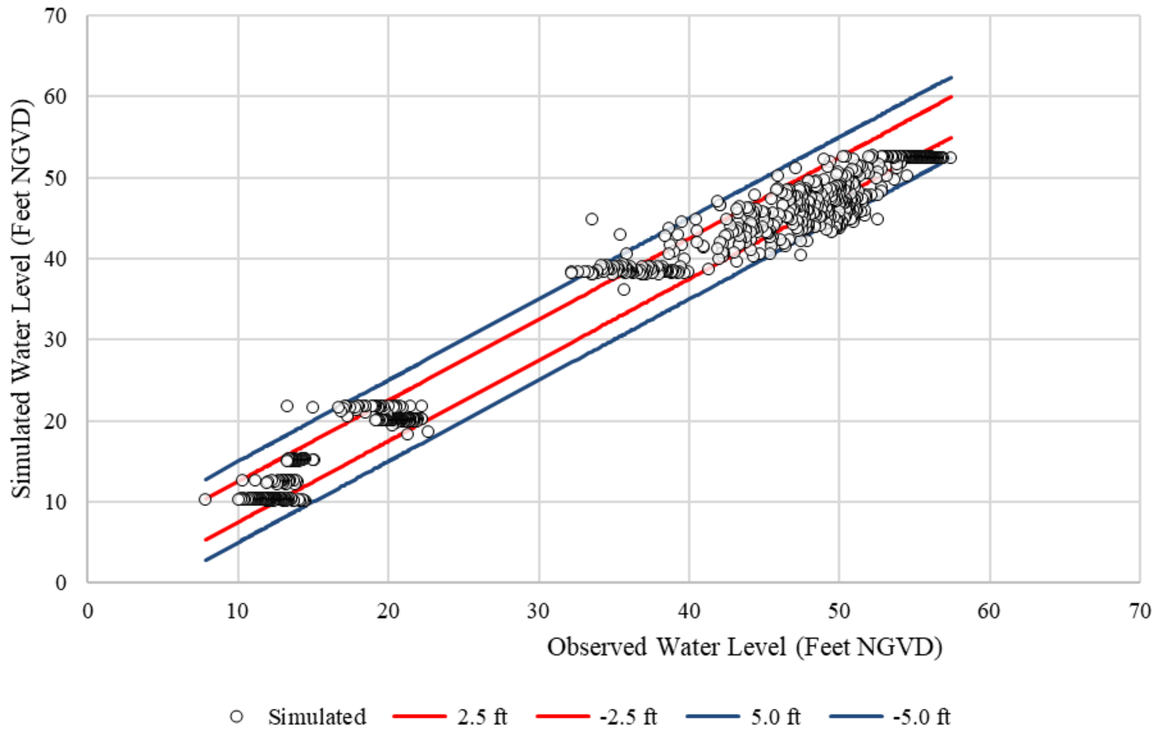


Figure 4-5. Scatter plot of observed versus simulated heads in the Avon Park permeable zone.

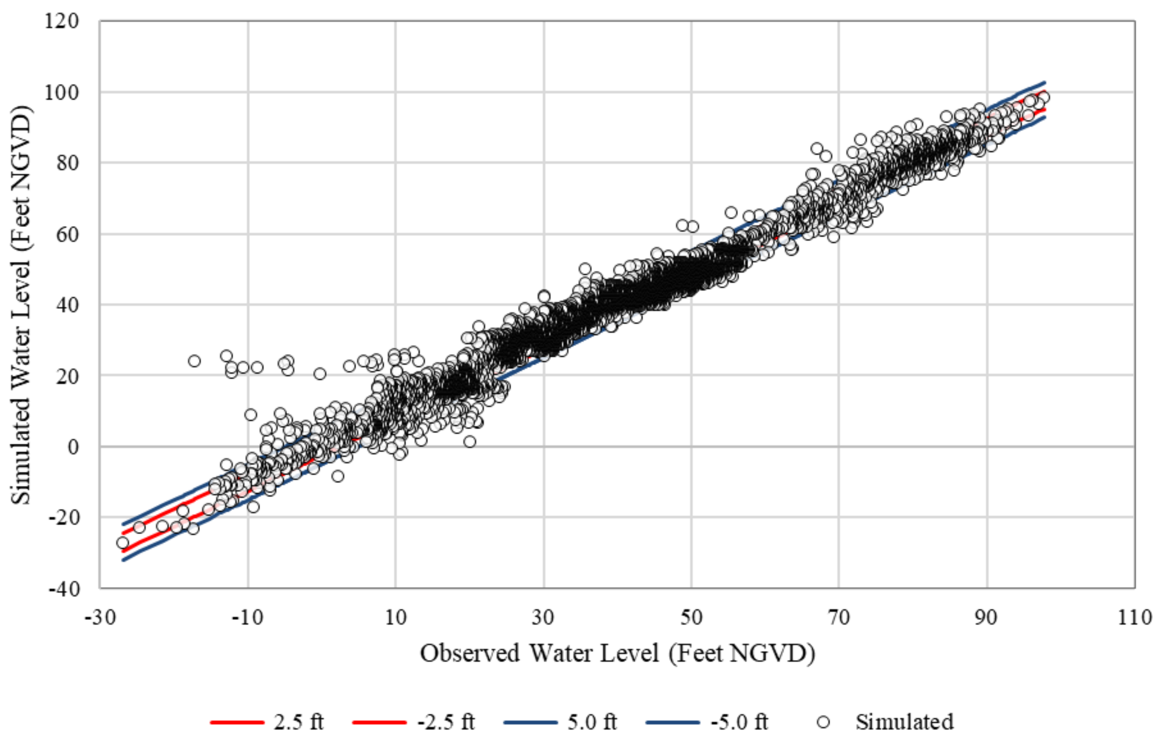


Figure 4-6. Scatter plot of observed versus simulated heads in the Lower Floridan aquifer – first permeable zone.

Table 4-4. Percentage of head observations within the interval criteria.

| Aquifer | Number of Records | % of Records Within ±2.5 Feet | % of Records Within ±5.0 Feet |
|---|---|---|---|
| Upper Floridan aquifer | 9,678 | 64% | 92% |
| Avon Park permeable zone | 871 | 65% | 95% |
| Lower Floridan aquifer–first permeable zone | 326 | 85% | 100% |

The scatter plots provide a general understanding of overall performance, but the calibration criteria are based on individual well performance, with each well given an equal weight regardless of the number of observation points after the wells have been filtered to meet the minimum requirements. **Appendix A**, Tables A-1, A-2, and A-3, summarize the head calibration statistics for each observation site in the UFA, APPZ, and LF1, respectively. For all aquifers combined, the ME was 0.27 ft, the MAE was 2.13 ft, and the RMSE was 2.52 ft. The interval criteria for all wells indicate 66% of the wells have an ME within ±2.5 ft and 100% of the wells have both the ME and RMSE within ±5.0 ft. Statistics for all wells combined was not a necessary calibration criterion; nonetheless, the global statistics meet the requirements.

**Appendix A**, Table A-1, shows that for all UFA wells combined, the ME was 0.14 ft, the MAE was 2.16 ft, and the RMSE was 2.60 ft. The interval criteria for all wells indicate 65% of the wells had an MAE within 2.5 ft and 100% of the wells had both the MAE and the RMSE within 5.0 ft. Statistics for the summation of UFA wells indicate all calibration criteria were met.

**Appendix A**, Table A-2, shows that for all APPZ wells combined, the ME was 0.99 ft, the MAE was 2.01 ft, and the RMSE was 2.38 ft. The interval criteria for all wells indicated 72% of the wells had an MAE within 2.50 ft and 100% of the wells had both the MAE and the RMSE within 5.0 ft. Statistics for the summation of APPZ wells indicate all calibration criteria were met.

**Appendix A**, Table A-3, shows that for all LF1 wells combined, the ME was 0.59 ft, the MAE was 0.68 ft, and the RMSE was 0.81 ft. The interval criteria for all wells indicate 100% of the wells had an MAE within 2.5 ft and had both the MAE and the RMSE within 5.0 ft. Statistics for the summation of LF1 wells indicate all calibration criteria were met.

**Figures 4-7**, **4-8**, and **4-9** show the spatial distribution of average ME in each water level monitoring well in the UFA, APPZ, and LF1, respectively. Each map shows the ME, with blue representing locations where average simulated water levels were higher than average historical water levels, indicating the wells were overpredicting. Wells shown in red represent locations where average simulated water levels were lower than average historical water levels, indicating the wells were underpredicting. Dot size is proportional to the error at each point. Water level monitoring wells in the UFA were spatially distributed primarily across the northern and central portions of the model domain. Analysis of **Figure 4-7** indicated that within the UFA, there did not appear to be any clustering of wells with a large ME, and the model did not appear to be biased towards overpredicting or underpredicting historical water levels. Compared to the UFA, there were substantially fewer monitoring wells within the APPZ, and most of the wells were within the northern portion of the model domain. Analysis of **Figure 4-8** indicated that within the APPZ, there did not appear to be any clustering of wells with a large ME. Within most of the APPZ, the wells appeared to be underpredicting water levels. Within the LF1 (**Figure 4-9**), there were only three monitoring wells; therefore, based on the spatial distribution, it was not possible to look for well clustering. Wells within the LF1 were well calibrated, and there did not appear to be any bias towards overpredicting or underpredicting.

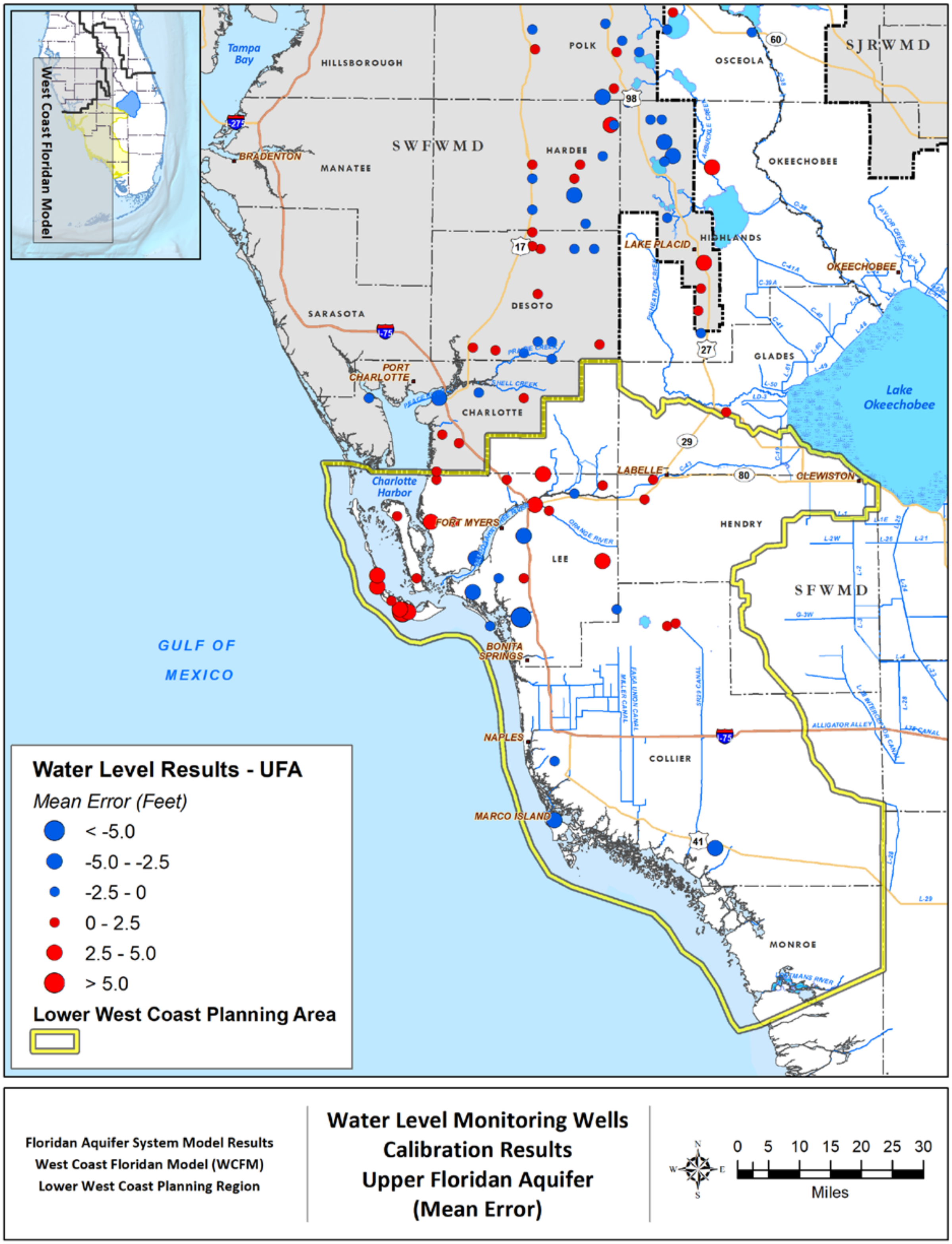


Figure 4-7. Spatial distribution of mean error for water level monitoring wells in the Upper Floridan aquifer.

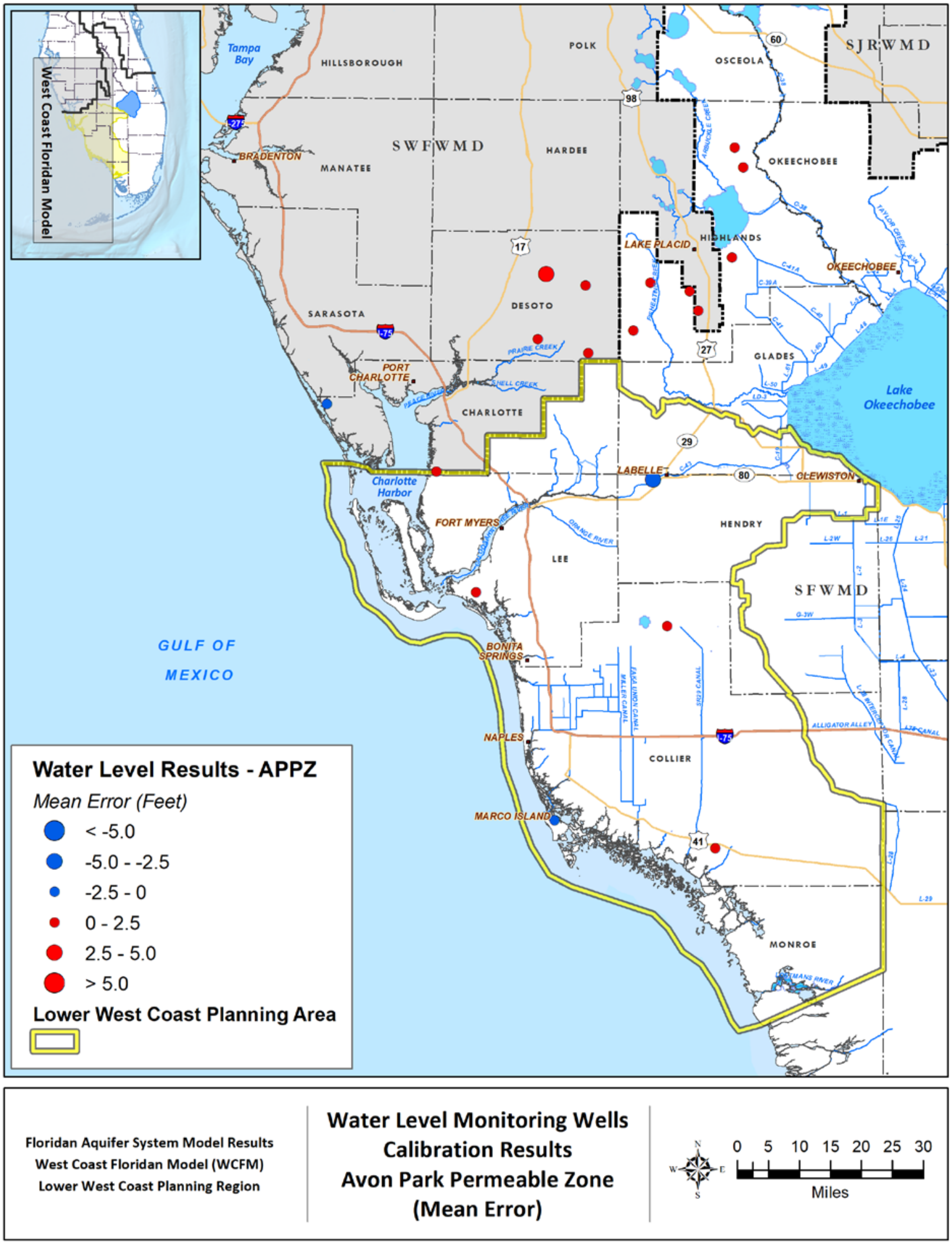


Figure 4-8. Spatial distribution of mean error for water level monitoring wells in the Avon Park permeable zone.

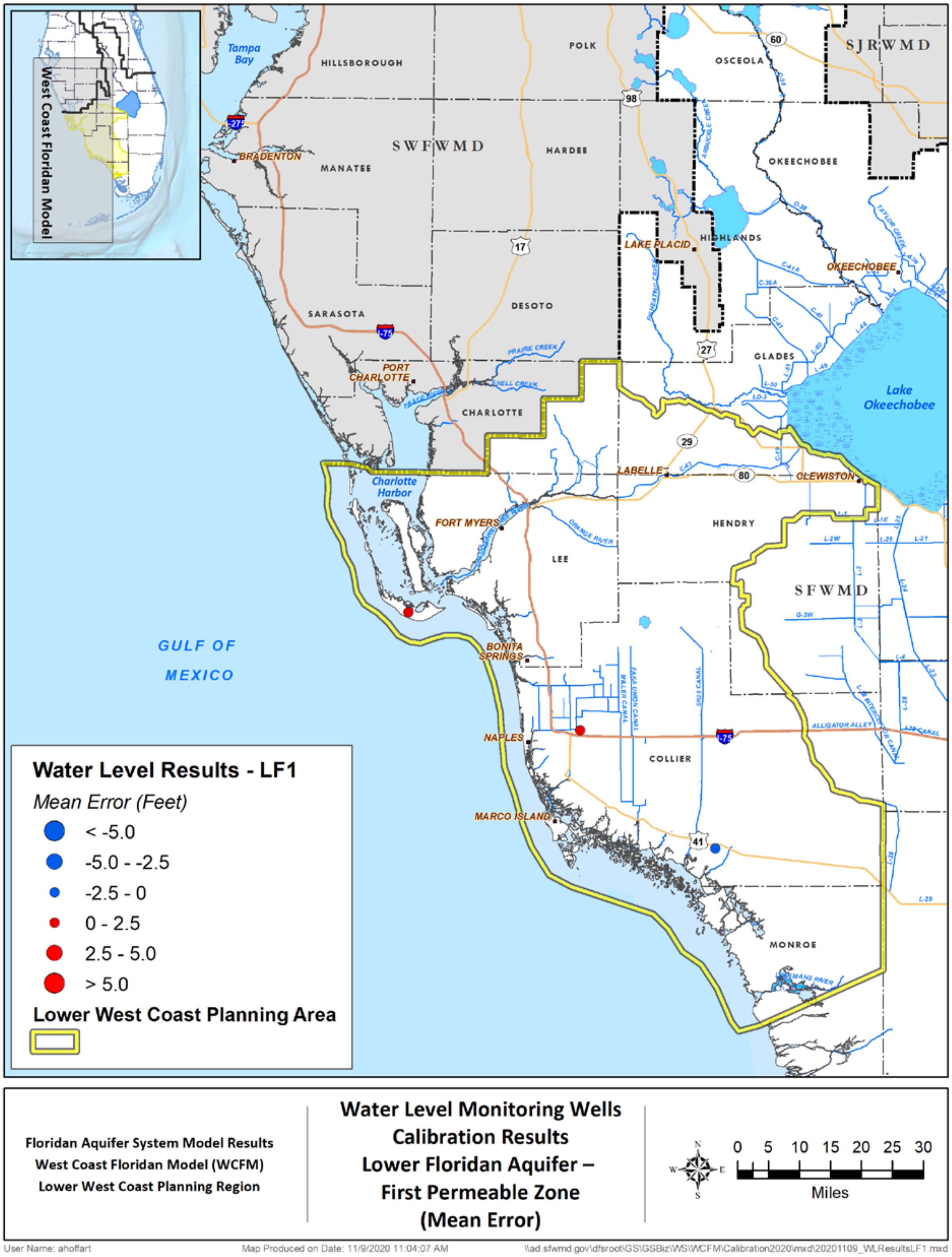


Figure 4-9. Spatial distribution of mean error for water level monitoring wells in the Lower Floridan aquifer – first permeable zone.

### 4.4.2 Water Quality Statistics

**Figure 4-10** shows the average observed versus simulated TDS values for each well. 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 model. The plot indicates approximately 91% of the wells were within the calibration range for this statistic.

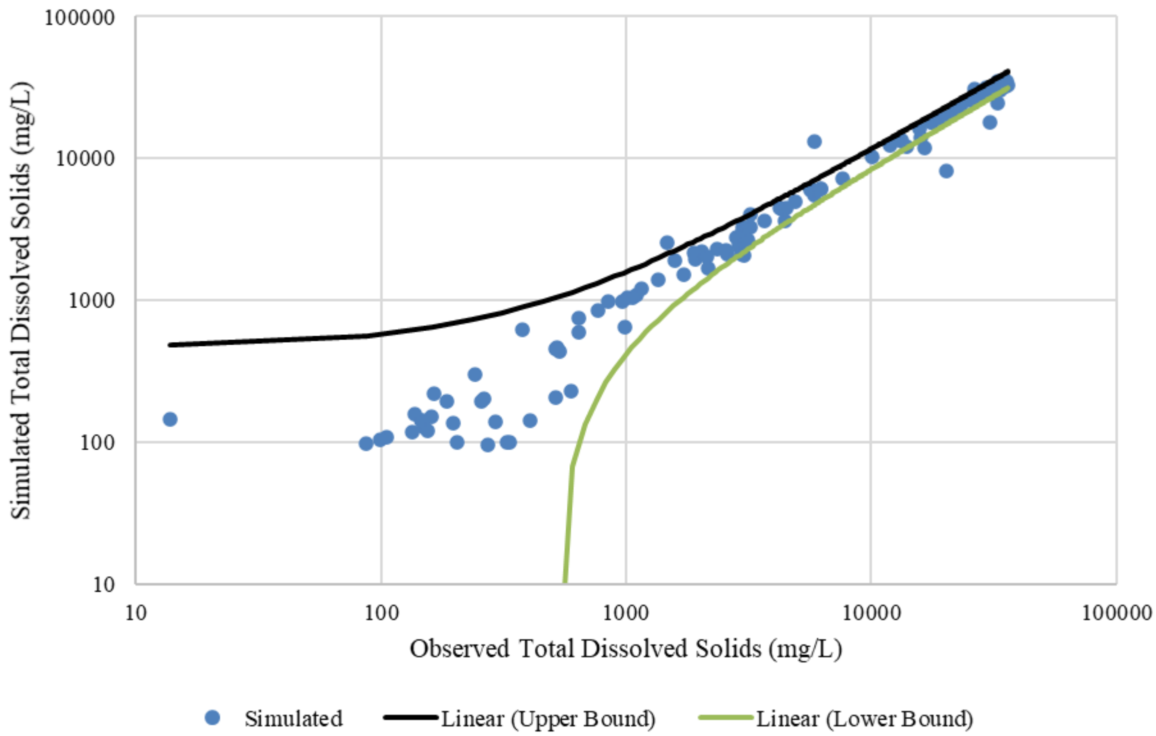


Figure 4-10. Scatter plot of observed versus simulated total dissolved solids concentrations for each well in all aquifers.

The minimum, maximum, and average water quality observed and simulated values for each aquifer are shown in **Table 4-5**. It should be noted that the maximum simulated TDS value was restricted to 35,000 mg/L and the WCFM is not set up to simulate hypersaline conditions like those observed in both the APPZ and LF1 monitoring wells. Additionally, there is no long-term water quality monitoring of the APPZ and LF1 in the northern portion of the model domain where the APPZ is fresh to slightly brackish, which slightly skews the minimum and average observed values.

Table 4-5. Summary of simulated and observed extreme water quality total dissolved solids (in milligrams per liter).

| Aquifer | Observed | | | Simulated | | |
|---|---|---|---|---|---|---|
| | Minimum | Average | Maximum | Minimum | Average | Maximum |
| UFA | 96 | 5,058 | 34,680 | 14 | 5,064 | 34,680 |
| APPZ | 2,470 | 27,638 | 42,000 | 4,511 | 27,486 | 33,873 |
| LF1 | 14,397 | 29,253 | 43,300 | 23,110 | 29,651 | 35,000 |

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

**Figure 4-11** indicates that for TDS values between 0 and 4,000 mg/L, 79% of observations were within the ±500 mg/L criterion, and for TDS values between 4,000 and 10,000 mg/L, the percentage fell to 51% within the ±750 mg/L criterion. When the observed TDS readings exceeded 10,000 mg/L, the percentage increased back to 79% of the observation points within the ±4,000 mg/L range. Of the 3,643 UFA observation points, 70% met the various calibration criteria. Sixty-nine of the 77 UFA observation wells had an MAE less than the interval criterion or 88% of the wells had an MAE within the criteria. A summary of these values and statistics is provided in **Appendix A**, Table A-4. The UFA average ME and MAE values were -115 mg/L and 601 mg/L, respectively. Overall, 88% of the UFA wells were within the calibration criteria.

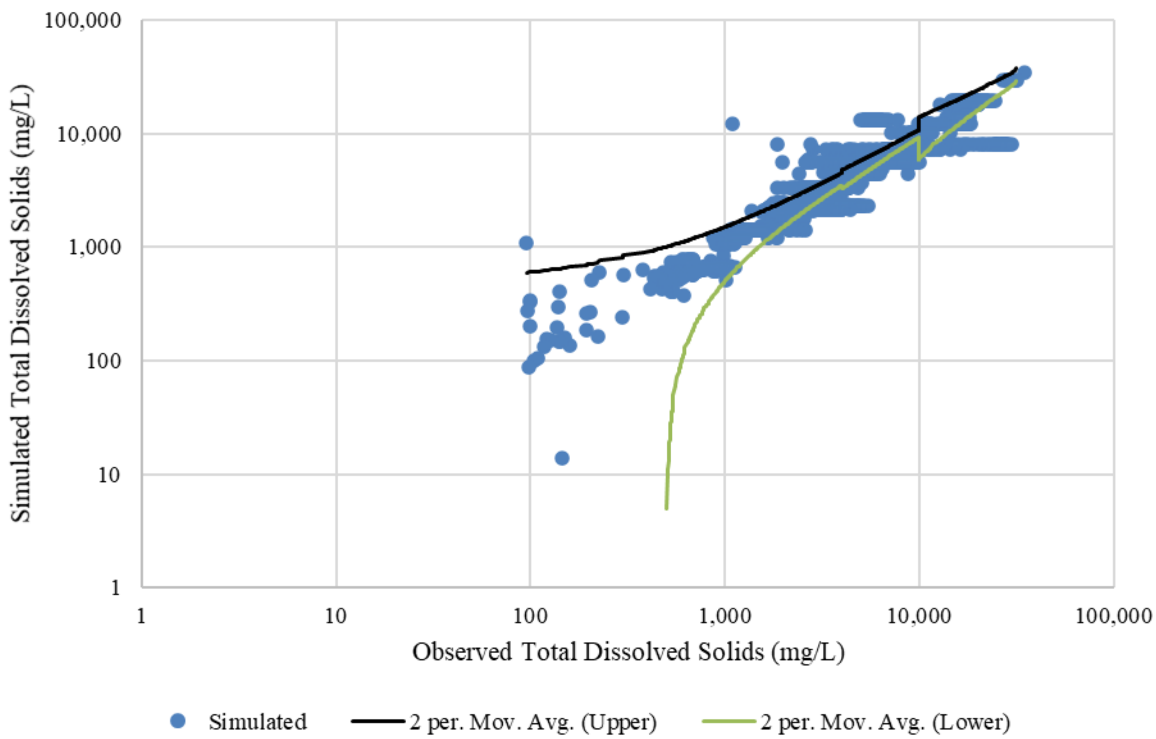


Figure 4-11. Scatter plot of observed versus simulated total dissolved solids concentrations in the Upper Floridan aquifer.

**Figure 4-12** indicates that for TDS values, very few observed values were below 3,000 mg/L, so the lower two calibration criteria are not applicable. For TDS values between 3,000 and 8,000 mg/L, 100% of observations were within the criterion. When observed TDS readings exceeded 8,000 mg/L, 83% of the observation points were within the ±4,000 mg/L range. In total, there were 1,370 APPZ observation points, 84% of which met the various calibration criteria. Only two of the 18 APPZ observation wells had an MAE that exceeded the interval criteria; 16 of the 18 APPZ wells had an MAE within the criteria. A summary of these values and statistics is provided in **Appendix A**, Table A-5. The APPZ average ME and MAE values were -390 mg/L and 1,807 mg/L, respectively. Overall, 89% of UFA wells were within the calibration criteria.

The LF1 scatter plot is shown in **Figure 4-13**. A review of the model results indicated 83% of the observed values met the ±4,000 mg/L calibration criterion. Many of the observations not meeting the criterion were associated with hypersaline conditions. A summary of these values and statistics is provided in **Appendix A**, Table A-6. The LF1 average ME and MAE values were -638 mg/L and 2,102 mg/L, respectively. Overall, 100% of the LF1 wells were within the calibration criteria.

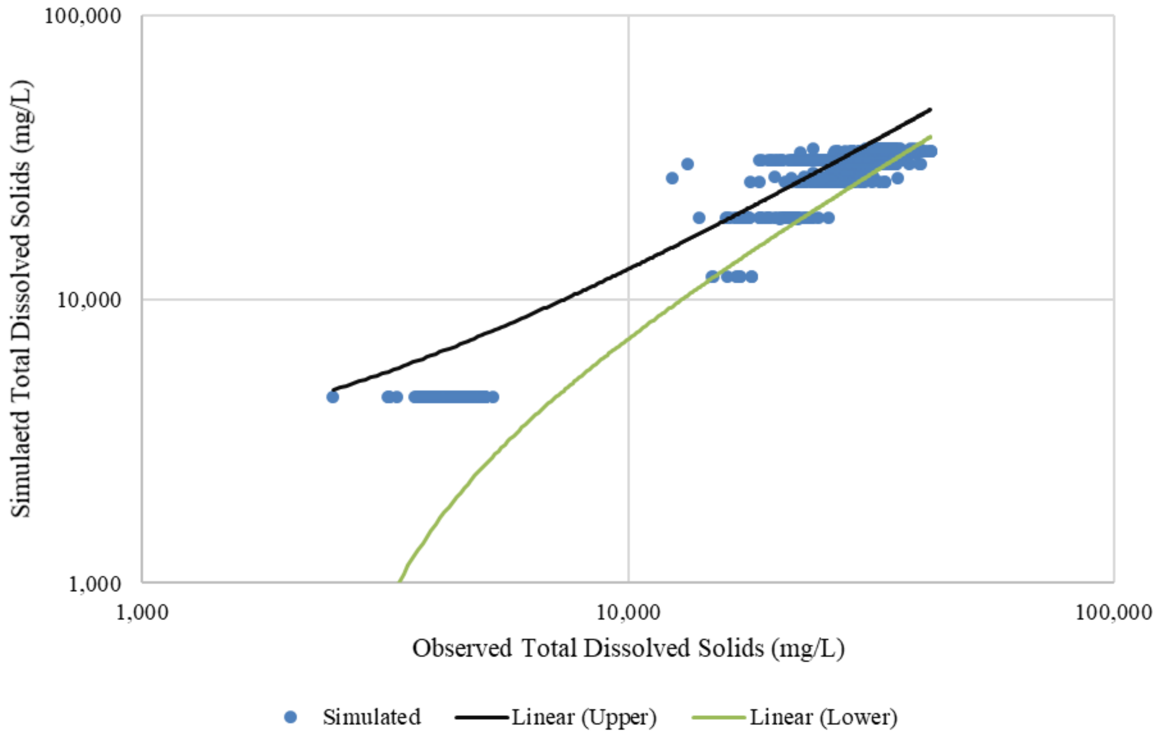


Figure 4-12. Scatter plot of observed versus simulated total dissolved solids concentrations in the Avon Park permeable zone.

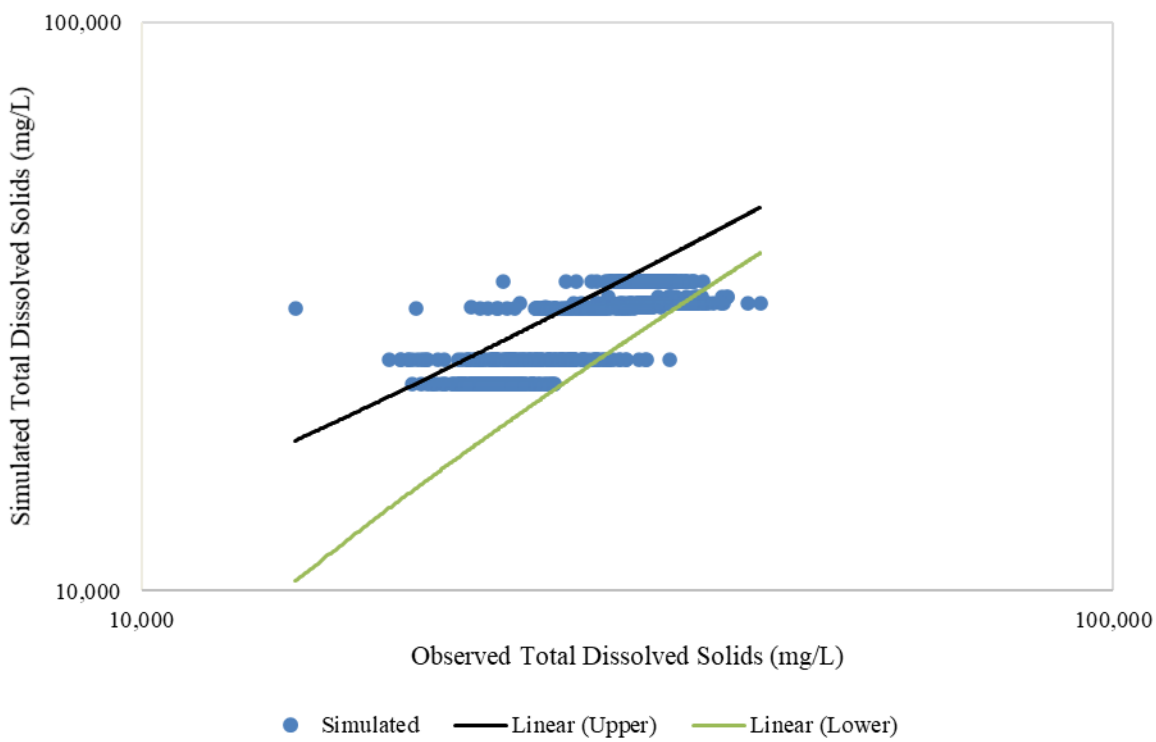


Figure 4-13. Scatter plot of observed versus simulated total dissolved solids concentrations in the Lower Floridan aquifer – first permeable zone.

**Figures 4-14**, **4-15**, and **4-16** show the spatial distribution of average ME in each water quality monitoring well in the UFA, APPZ, and LF1, respectively. Each map shows the wells that met calibration criteria in green. For wells that did not meet the calibration criteria, the ME is shown, with wells shown in blue representing locations where the average simulated TDS value was higher than the average historical TDS value, indicating the wells were overpredicting. Wells shown in red represent locations where the average simulated TDS value was lower than the average historical TDS value, indicating the wells were underpredicting. **Figure 4-14** shows the spatial distribution of water quality monitoring wells in the UFA. Within the UFA, a large majority of wells were calibrated, there did not appear to be any clustering of wells with a large ME, and the model did not appear to be biased towards overpredicting or underpredicting historical TDS values. Within the APPZ, all but one well met the calibration criteria (**Figure 4-15**). The well that did not meet the calibration criteria is in Hendry County near the LaBelle wellfield and slightly overpredicted the TDS value. Overall, within the LF1, there were a limited number of monitoring wells and all of them met their respective calibration criteria (**Figure 4-16**).

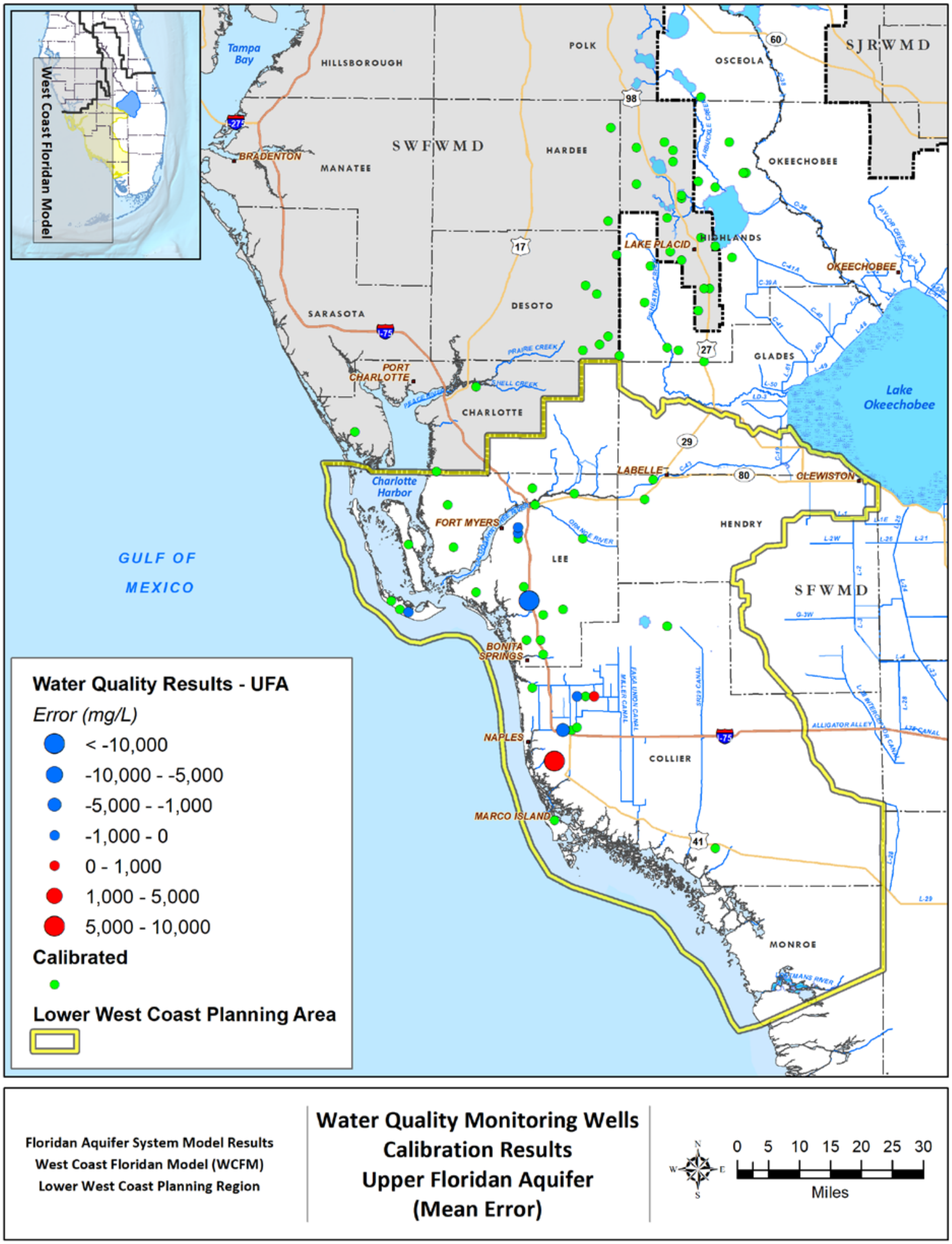


Figure 4-14. Spatial distribution of mean error in water quality monitoring wells in the Upper Floridan aquifer.

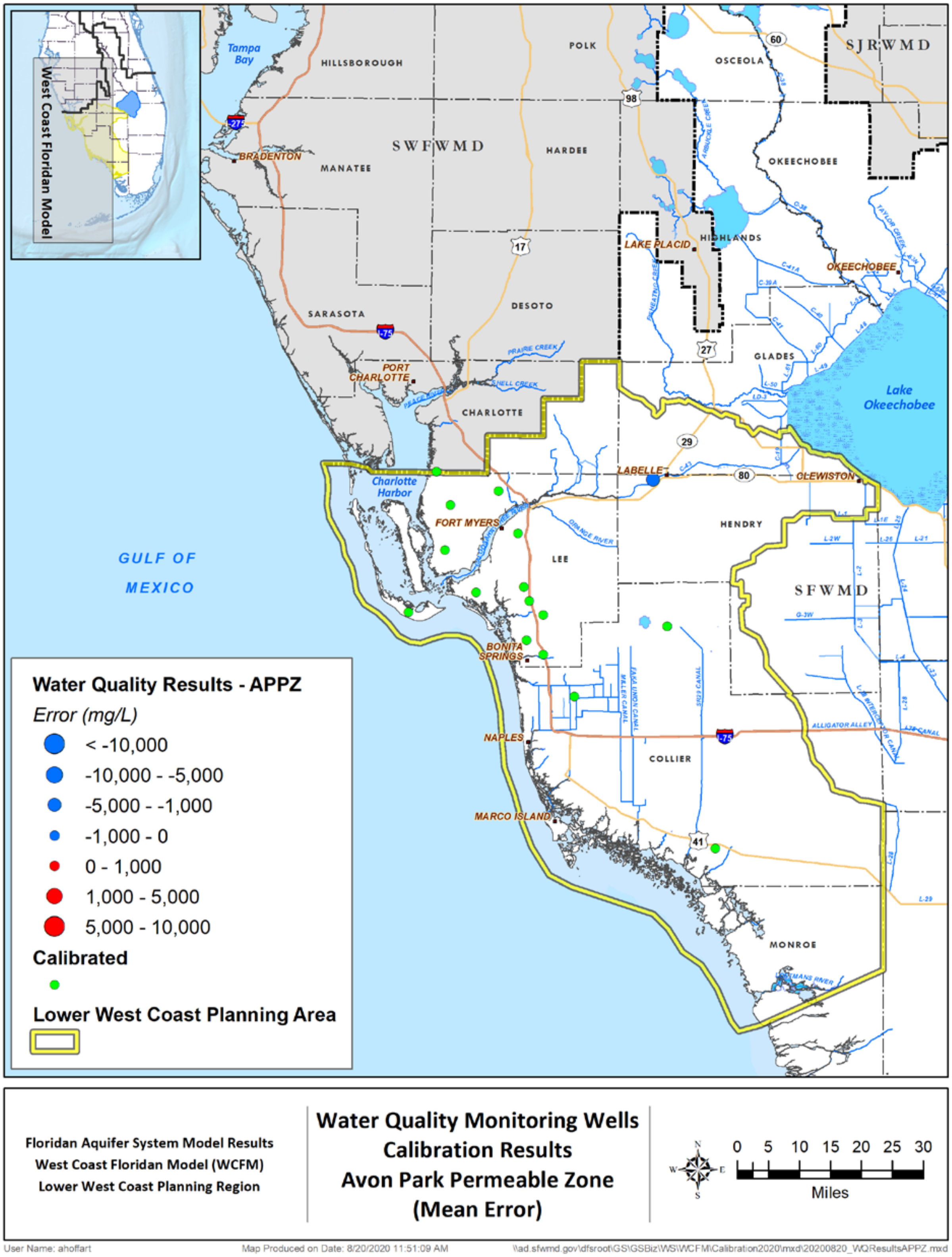


Figure 4-15. Spatial distribution of mean error in water quality monitoring wells in the Avon Park permeable zone.

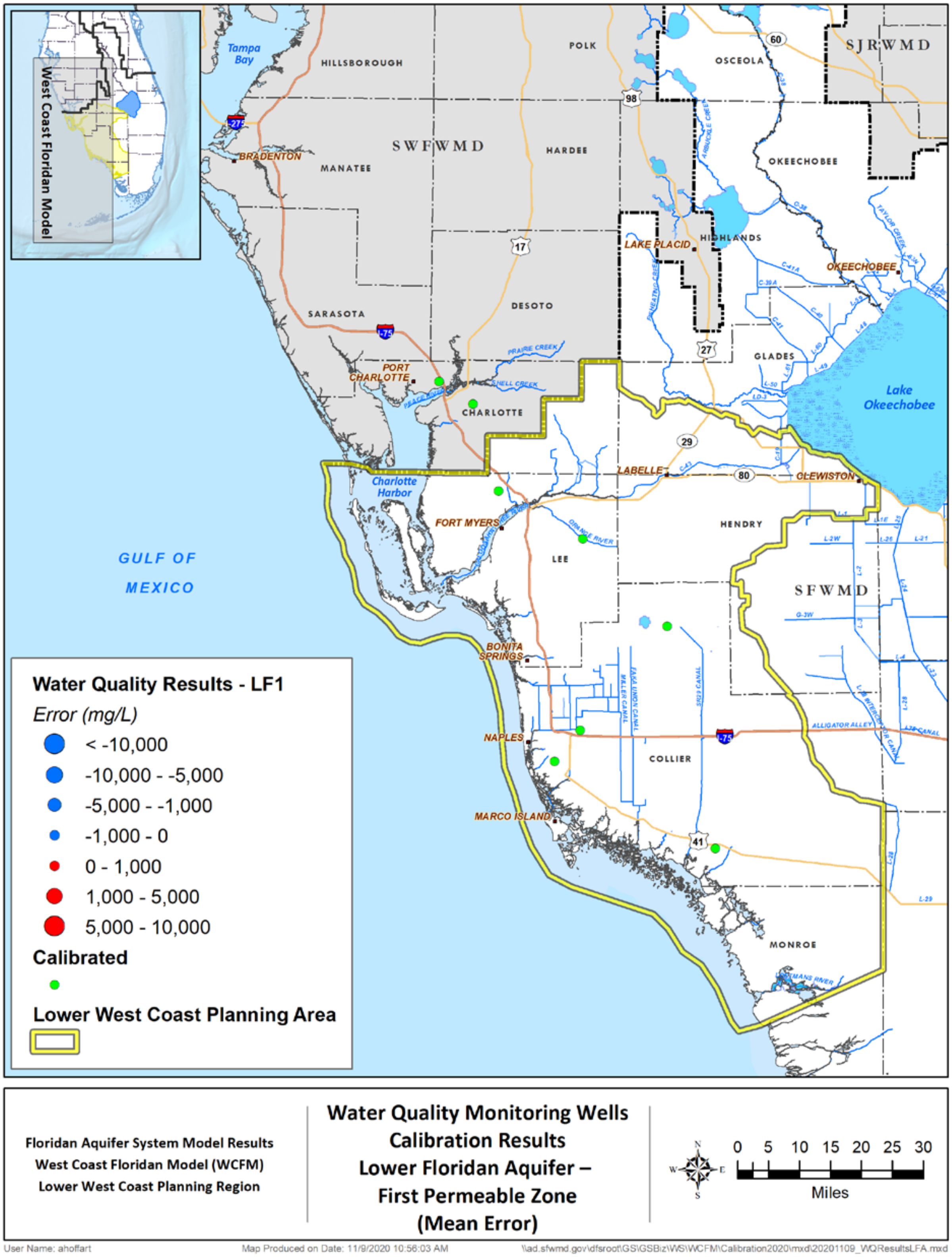


Figure 4-16. Spatial distribution of mean error in water quality monitoring wells in the Lower Floridan aquifer – first permeable zone.

## 4.5 Water Budget Analysis

There is minimal to no water exchange between the FAS and overlying SAS throughout the southern and central portions of the model domain due to confinement of the Hawthorn Group sediments that separate these aquifer systems. Some interaction between the FAS and SAS occurs in the northern portion of the model domain (i.e., Polk, Hardee, and Highlands counties). Lateral freshwater recharge enters the model domain from the boundary conditions specified along the northern portion of the model, and brackish water enters the model domain along the east-central portion or the western coast of the model. Recharge from rainfall was spatially accounted for in the model along the Lake Wales Ridge and adjacent upland regions.

Average rainfall for the simulation period at the City of Sebring rain gauge near the model domain's primary recharge area was approximately 48.76 inches/year. Simulated recharge rates varied monthly based on historical rainfall and spatially within topographic zones. The annual average recharge rate applied to the lowest recharge areas generally were between 0.1 and 1.0 inches/year, with lower rates occurring in Hardee County. Rates in the intermediate recharge zones of Highlands and Polk counties averaged between 1 and 5 inches/year, except along the high ridge areas where it could exceed 10 inches/year.

Volumetric influxes to the model along the northern boundary were difficult to quantify. Fluxes into the model were determined by the conductance term of the GHB, the head of the GHB, and the simulated stages in the active model domain adjacent to the GHBs. Heads along the boundaries were determined from the USGS potentiometric maps for May and September conditions. The maps were not available for every year of the simulation period. Observation well data adjacent to the model boundary were used for years when maps were not produced and for the development of monthly water levels for all years of the simulation period.

Model recharge and discharge can occur along the Gulf of Mexico and the Atlantic Ocean outcrops off the Florida Keys and from the deeper BZ. Tidal variations were included in the model within the BZ from historical average monthly tides obtained from Key West. Average tides generally were higher in the fall and lower in the spring.

**Figures 4-17**, **4-18**, and **4-19** show the flow vectors for the UFA, APPZ, and LF1, respectively, and provide a general direction and magnitude of the simulated flow in December 2012, which includes some of the more recent public supply wellfields becoming operational. The vectors were resampled over a 5 × 5 model grid, and each vector represents approximately 4.5 square miles. The flow volume is illustrated by the vector size, and the direction of flow is symbolized by the arrow track.

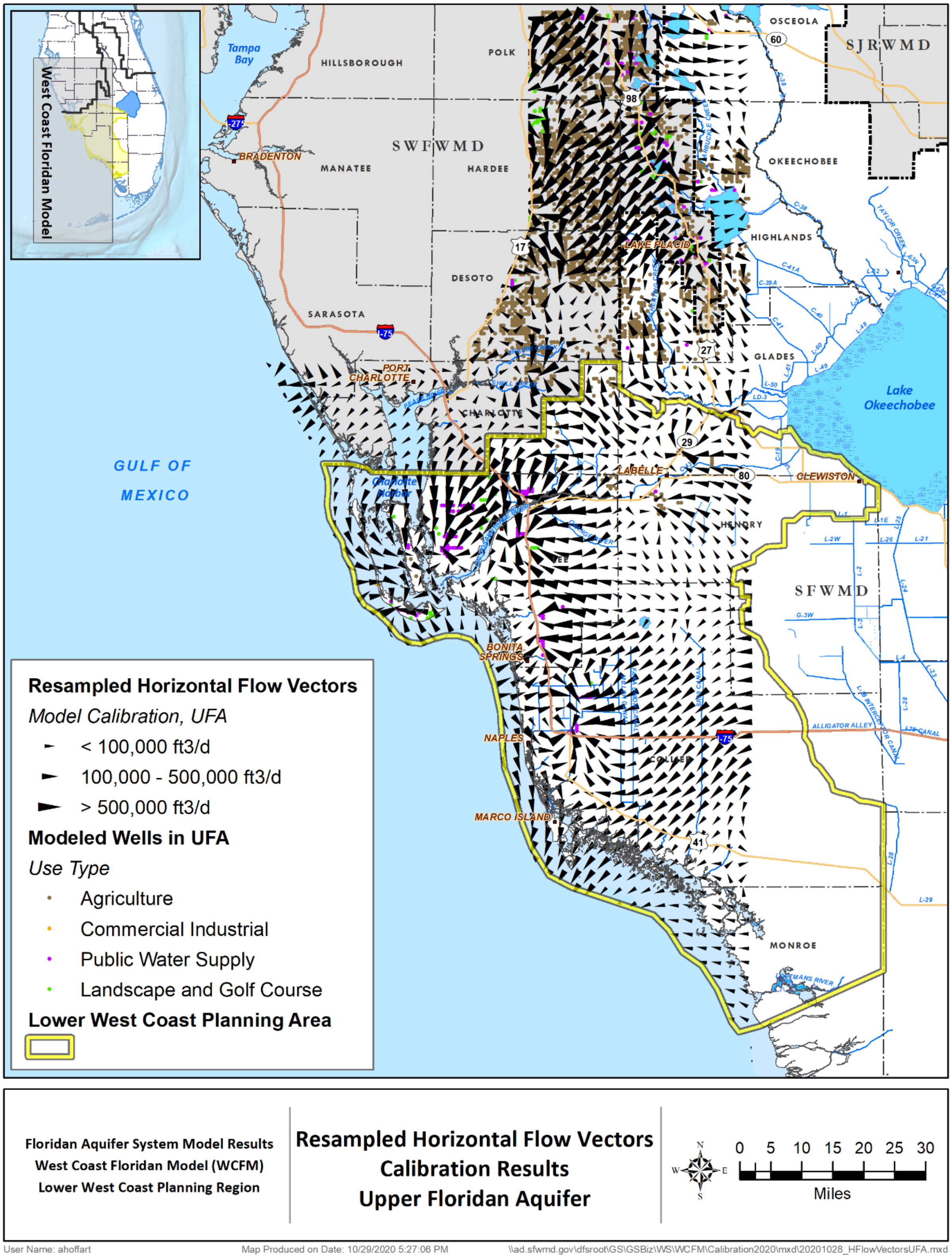


Figure 4-17. Simulated flow direction in the Upper Floridan aquifer, December 2012.

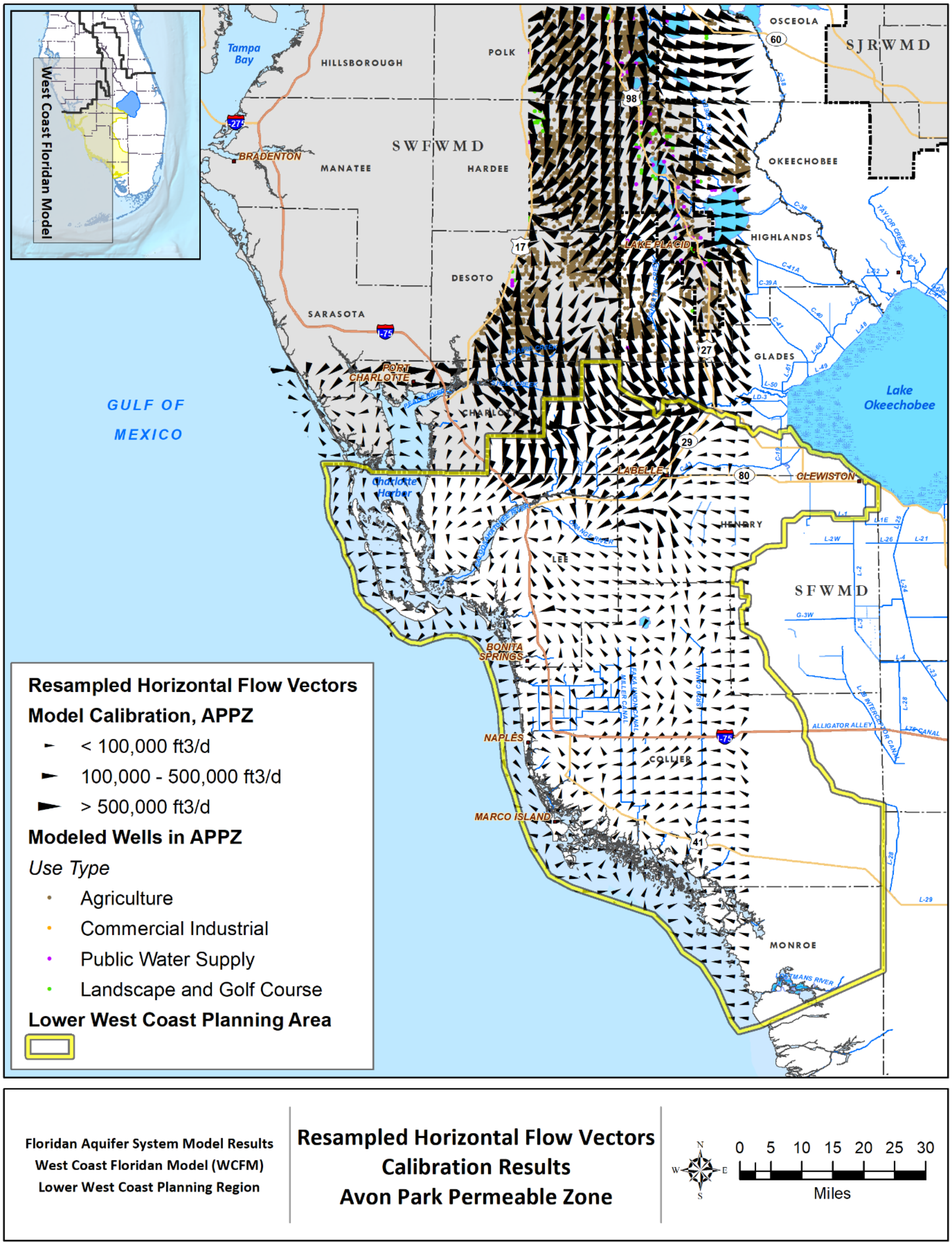


Figure 4-18. Simulated flow direction in the Avon Park permeable zone, December 2012.

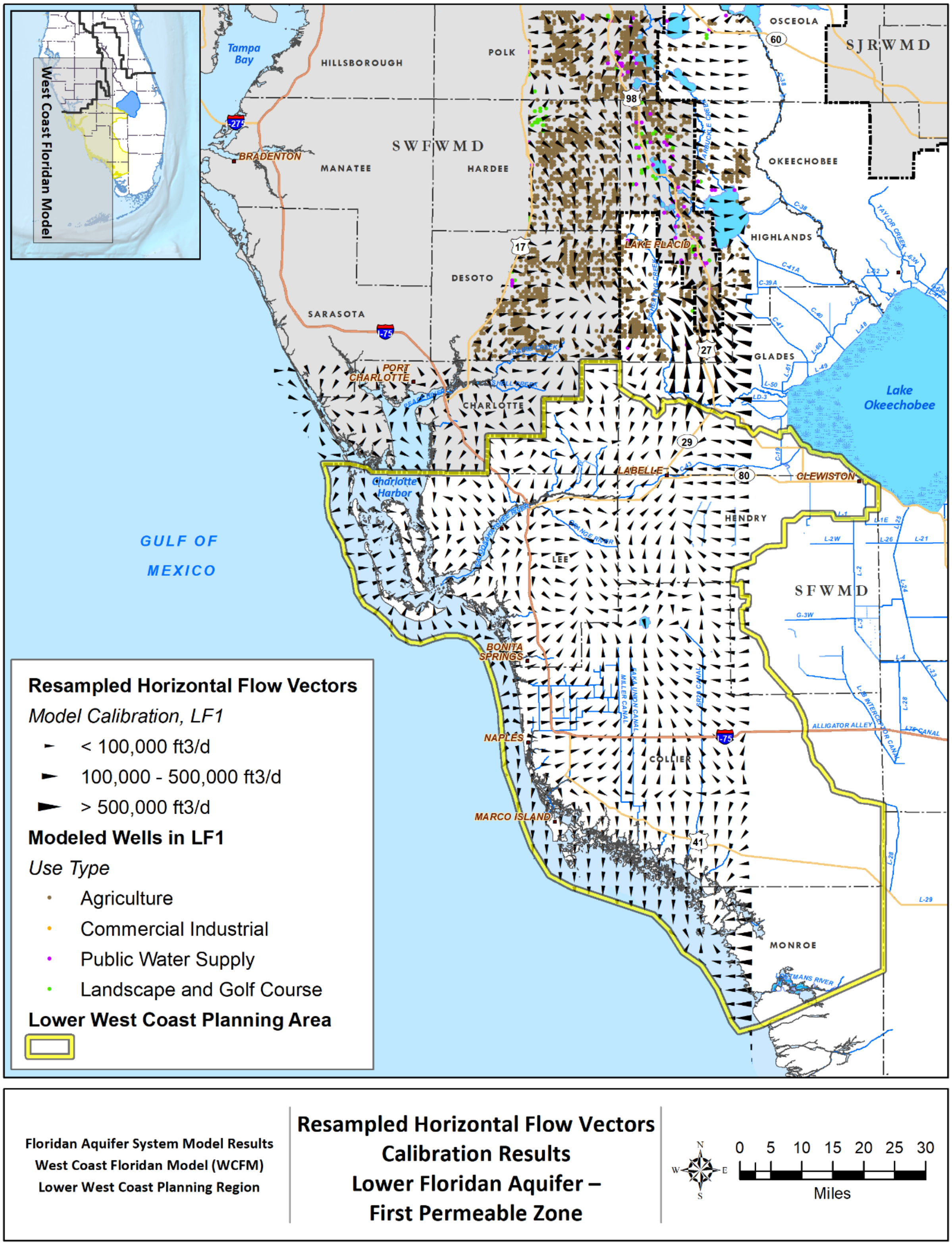


Figure 4-19. Simulated flow direction in the Lower Floridan aquifer – first permeable zone, December 2012.

Flow in Polk, Osceola, Hardee, DeSoto, and Highlands counties generally radiates outward from the Polk uplands and the Lake Wales Ridge, which runs south through Highlands County. The size and density of the large flow vectors in these counties are especially prominent, particularly in the UFA and APPZ, indicating this was the primary source of water within the model domain. Flow within the LF1 in this region was not as pronounced compared to the other two aquifers.

Besides the impacts of recharge in the northern area on flow direction, the vectors also are governed by the large pumpage centers in the region. Vectors tend to rotate toward these large withdrawals. This is evident in the APPZ and, to a lesser extent, the LF1 in Highlands County. A series of large agricultural water users that withdraw water from the APPZ and UFA are congregated along western Highlands and eastern DeSoto counties. The pinwheel features in this region are an example of a series of large groundwater withdrawals redirecting flow into the wellfields. Similarly, the large vectors exiting along the western side of Polk, Hardee, and DeSoto counties are the result of extremely large withdrawals occurring in Sarasota and Manatee counties to the west (within the SWFWMD). Although these withdrawals were not explicitly simulated by the model, their effects were imposed via the GHB package, which simulated the drawdowns along the model boundary via head-dependent boundary conditions.

In Charlotte, Glades, Hendry, and Lee counties, another pinwheel feature was observed in the UFA around the City of Fort Myers. This feature is related to groundwater withdrawals from the City of Fort Myers, where water levels have decreased nearly 40 ft between 1999 and 2012, as illustrated by water levels in well L-2292 (**Figure 4-20**). Beneath the Caloosahatchee River, which only partially penetrates the SAS, additional large flow vectors were observed flowing into the City of Cape Coral as a result of the city's large UFA withdrawals. Flow direction in the APPZ for this region was dominated by a very specific feature. Although the general flow was towards the southwest, there was a prominent redirection of flow towards the northwest through Charlotte County. This flow appeared to be heading towards the large groundwater withdrawals occurring in Sarasota County, as mentioned previously. The ECFTX reported a similar observation, which may be related to the high transmissivity of the APPZ in the area (Central Florida Water Initiative 2020). Flow in the LF1 was of much lower magnitude but suggested landward movement of saltwater along the coast particularly in the Bonita Springs area.

In Collier and Monroe counties, flow in the UFA was generally to the southwest, except around the Collier County Utilities wellfield along the coast, which redirected flow into the wellfield. Flow in the APPZ was of much lower magnitude than elsewhere in the model because it is not productive in the southern portion of the model domain. The LF1 showed an inland flow direction along the coast of Collier County.

In addition to the vector plots, a review of the water budget, by model layer and region, helped understand how water flows vertically and horizontally through the model. **Table 4-6** shows the water budget by layer, averaged over the simulation period. Additionally, the model domain was divided into 10 budget zones of approximate equal size (in relation to land mass), and the volumes presented are the average for the calibration period. Generalized budget flow direction and magnitude for all layers combined is provided in **Figure 4-21**. The table and figure provide a general understanding of the degree of water movement between the regions or layers and also provides the amount of water entering or leaving the system through recharge, well withdrawals, changes in storage, and flow from the BZ up into the shallower aquifers.

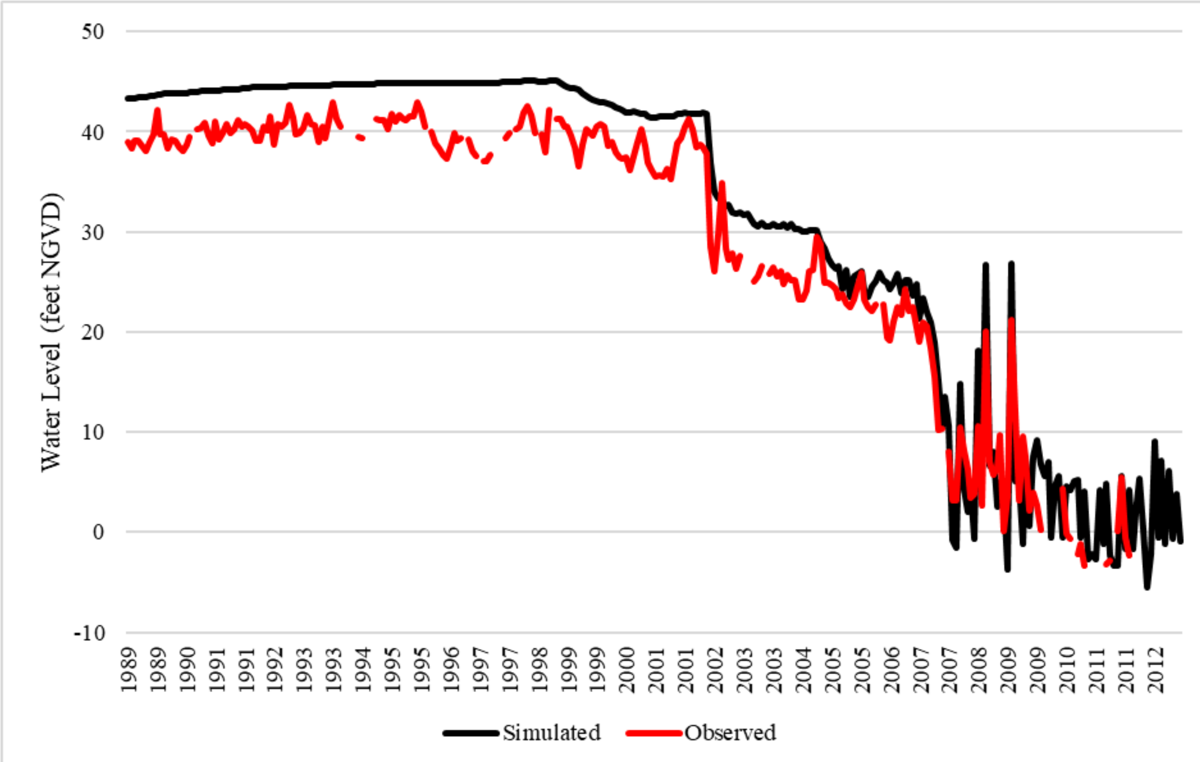


Figure 4-20. Observed and simulated water levels at well L-2292 located at the City of Fort Myers wellfield in Lee County.

Table 4-6. Calibrated flow budget (in cubic feet per second), by model layer.

| Layer | Storage | Constant Head | Upper Flow | Lower Flow | Wells | Recharge | GHB |
|---|---|---|---|---|---|---|---|
| UFA | 35.02 | 9.78 | 0.00 | -40.33 | -216.16 | 213.60 | -0.95 |
| OCAPlpz | -0.25 | -0.17 | 40.33 | -39.15 | 0.00 | 0.00 | 0.00 |
| APPZ | -4.36 | 2.76 | 39.15 | 148.01 | -123.76 | 0.00 | -59.64 |
| MCU | -0.37 | -0.20 | -148.01 | 144.92 | 0.00 | 0.00 | 0.00 |
| LF1 | 0.03 | 35.29 | -144.92 | 109.54 | 0.00 | 0.00 | 0.00 |
| BZCU | -0.24 | -0.21 | -109.54 | 110.63 | 0.00 | 0.00 | 0.00 |
| BZ | 0.00 | 110.58 | -110.63 | 0.00 | 0.00 | 0.00 | 0.00 |

APPZ = Avon Park permeable zone; BZ = Boulder Zone; BZCU = Boulder Zone confining unit; GHB = general head boundary; LF1 = Lower Floridan aquifer – first permeable zone; MCU = middle confining unit; OCAPlpz = Ocala-Avon Park low-permeability zone; UFA = Upper Floridan aquifer.

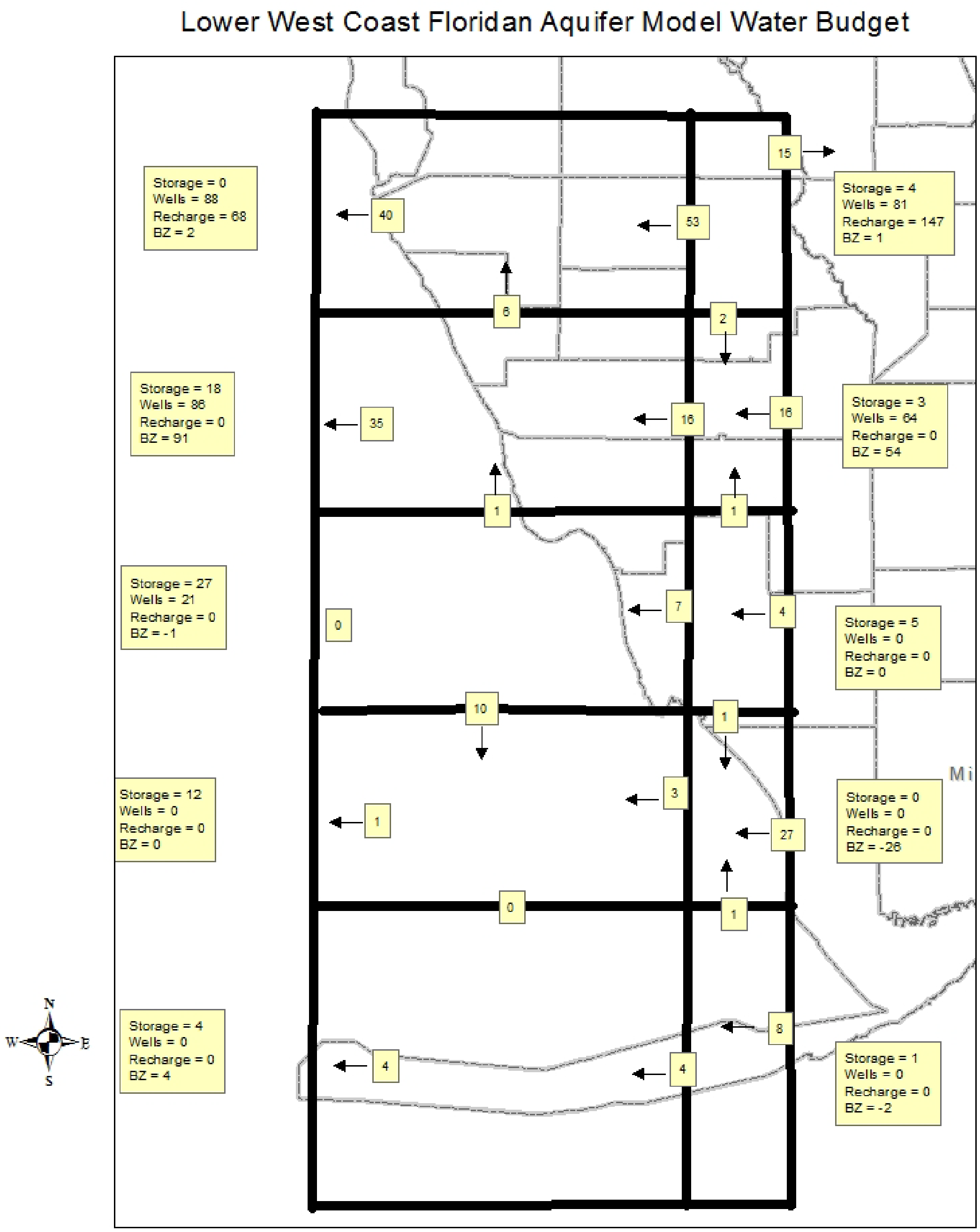


Figure 4-21. Calibrated flow budget (in cubic feet per second) for the West Coast Floridan Model.

The water budgets suggested approximately 215 cfs, on average, infiltrates into the FAS from recharge in Polk, Highlands, and Hardee counties. Horizonal flow into the model domain from the north appeared to be offset by discharges from the Lake Wales Ridge and large withdrawals to the west. The net outflow of water through the APPZ is shown by the GHB term in **Table 4-6**. Groundwater withdrawals easily exceed average recharge rates and account for approximately 340 cfs on average. It should be noted that groundwater withdrawals were biased to the low side because they represent an average over the entire calibration period and several large public supply users in Lee and Collier counties were not operational for at least half of the simulation period. The water budget for the southern portion of the model appeared relatively static, primarily because there were no stresses on the system in the area.

An interesting situation occurred in the central portion of the model domain (Charlotte, Hendry, Glades, Lee, southern DeSoto, and southern Highlands counties). The water budget suggested there was significant upward movement of water from the BZ (approximately 145 cfs) in the central portion of the model domain and a slight downward flux of water into the BZ in the southern portion of the model (**Figure 4-21**). A review of the flows between the model layers in **Table 4-6** confirmed this and provided additional information in that the upper flux appeared to be towards the APPZ, with a net downward flow from the UFA into the APPZ. The upward circulation from the BZ into the middle units of the FAS in some areas was consistent with Kohout's (1965) and Meyer's (1989) interpretations of the general flow patterns of the FAS in South Florida. As discussed in **Section 3.6**, the temperature of the BZ increases noticeably from east to west across South Florida and reaches its warmest temperature near Cape Coral. In combination with APPZ withdrawals, this temperature increase may be the driving force for the upward component in portions of the model domain. A secondary model run was conducted to determine if the upward flux was related to increasing temperature across the model domain or if it was related to the groundwater withdrawals. For the secondary model run, production wells were turned off and the water budget for those regions was evaluated. The results indicated approximately 113 cfs of upward flux in the central portion of the model domain occurred from the BZ under a no-pumping condition, suggesting some of the upward movement was related to the groundwater withdrawals. Taking this into account, in addition to the fact that groundwater withdrawal volumes exceed recharge rates and that recent large production wells have experienced water quality degradation, care should be taken when designing future FAS wellfields in the region.

## 4.6 Simulation of the Conceptualized Groundwater Flow System

Flow in the UFA generally radiates outward from four prominent high water level areas observed on the potentiometric map of Florida (Miller 1990). Two of these areas are in northwestern Florida near the Georgia border, one northeast of Gainesville and the other around Polk City in central Florida. The Polk City high water level area generally dictates the direction of flow within the UFA for central and southern Florida. The high water level area is oblong in shape and trends north-south from northern Polk County into Highlands County, generally following the Lake Wales Ridge. Although not as pronounced, this local high water level feature in the potentiometric surface continues southward into Glades and eastern Hendry counties (**Figure 4-22**). Johnston et al. (1980) created a pre-development UFA map for the southeastern United States, covering portions of Georgia, South Carolina, and Alabama as well as all of Florida. The pre-development map provided a general understanding of the conceptual groundwater flow regime in the region. Meyer (1989) expanded on the concept and suggested that in addition to the general flow patterns, the BZ provides some upward migration of water into the upper portions of the FAS.

A pre-development simulation was conducted to determine if the general flow patterns were consistent with the conceptual groundwater flow system of Johnston et al. (1980) and Meyer (1989). The 2011 model was modified to run for an extended period of time. In addition to understanding the general flow patterns, the pre-development model was used to determine the stability of the initial condition salinity of the FAS. Additional objectives of the simulation were to understand the potential contribution of the BZ to the upper aquifers under non-stressed conditions.

The model was simulated from 1492 through 2020 to allow sufficient time for long-term changes to occur within the salinity regime of the FAS. The 2011 model was modified to include pre-development heads along the boundary conditions. The estimated pre-development water levels were obtained from Johnston et al. (1980). Slight variations in water levels along the boundaries of the UFA and APPZ were incorporated to reflect longer duration, regular climate cycles such as the El Niño Southern Oscillation and Atlantic Multi-decadal Oscillation. Available rainfall data sets do not extend back to the 1500s, so an average rainfall rate of 50 inches/year was applied throughout the simulation and adjusted annually, similar to the boundary conditions. Historical annual rainfall rates were used from 1902 through 2020. The rainfall rate was adjusted to net FAS recharge values using the methods discussed earlier in the report.

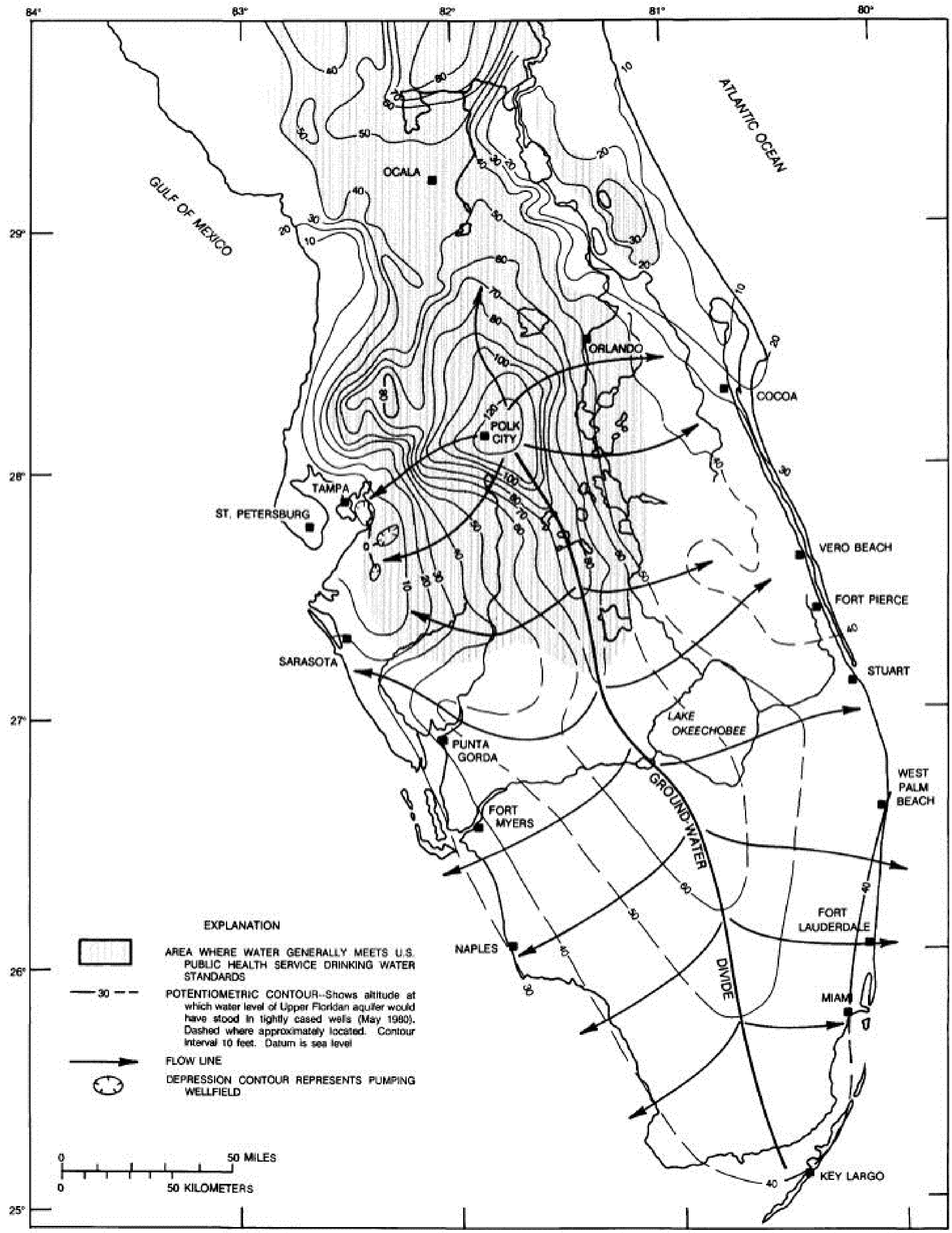


Figure 4-22. Flow patterns in the Upper Floridan aquifer, May1980 (From: Meyer 1989).

Flow pattern vectors in the UFA changed significantly between the calibrated model (**Figure 4-17**) and the pre-development model (**Figure 4-23**). Besides the lack of pinwheel features associated with the major withdrawal centers, flow direction appeared more in line with Meyer's (1989) May 1980 version. All flow vectors were moving seaward in the pre-development model, whereas in the calibrated model, several vectors suggested inland migration of water. Additionally, Johnston et al. (1980) and Meyer (1989) suggested westward movement of water from the groundwater divide towards the coast south of Lake Okeechobee, whereas the pre-development model showed a significant southerly flow component through eastern Lee and western Hendry and Collier counties. Flows from the Polk County high water level area and the Lake Wales Ridge were systematically radiating outward in a more general pattern compared to the radical direction changes shown in **Figure 4-17**, which were clearly influenced by localized groundwater withdrawals.

There were major water level differences between the pre-development model and the calibrated model (**Figure 4-24**). Head declines in the UFA were estimated to be on the order of 20 to 40 ft between the two simulations, primarily within the northern portions of the model domain. Heads in the vicinity of Kissengen Spring, which is now an extinct flowing spring but was once a magnitude 2 spring (around 20 cfs), showed a decrease in water level on the order of 30 ft, supporting the historical data. Early analysis of the spring reduction was placed on an adjacent phosphate mining operation (Stewart 1966), but the model suggested it may have been the result of increased use of the FAS causing widespread water level reductions in the region. **Figure 4-24** shows the head difference between the calibrated and pre-development runs at the end of each simulation period. The reduction of heads along the Lake Wales Ridge was on the order of 40 ft and between 20 and 30 ft elsewhere in the northern portions of the model domain. Head changes were more muted in the central and southern portions of the model domain, except near major wellfields where widespread use of the UFA has not been pursued until recently.

Changes in water quality were less dramatic than water levels, with the exception of the UFA (**Figure 4-25**). The deeper aquifers appeared to have retained their water quality values compared to the calibrated model, suggesting the initial water quality arrays for the units were reasonable. The primary change in water quality between the two simulations occurred in the UFA and OCAPlpz, where the increase in heads in the northern region changed the water quality from brackish to fresh, forcing those wells out of calibration criteria (**Table 4-7**).

Another component of the conceptual model was Kohout's (1965) and Meyer's (1989) contention that the increase in temperature within the BZ from east to west across South Florida caused a noticeable increase in flow from the BZ to the upper aquifers of the FAS. As discussed in **Section 4.5**, the upward flux from the BZ was 141 cfs for the calibrated run and 97 cfs for the calibrated run with wells turned off in the central region. The flow budget from the pre-development model indicated this BZ upward flux was even lower under pre-development conditions (41 cfs). This suggested that the pumpage incurred over the last 100 years has caused a steady increase in the migration of poorer water quality from the BZ into the upper aquifers.

In summary, the pre-development model generally matches the conceptual flow patterns suggested by Johnston et al. (1980) and Meyer (1989) for the flow direction and internal forcing mechanisms between the FAS aquifers. The primary differences were that the heads along the Lake Wales Ridge appeared higher than suggested and that there was a more southerly flow component in the FAS for Collier County and eastern Lee County than the suggested westerly flow. Additionally, Kissengen Spring appeared to be flowing under pre-development conditions, which is consistent with historical observations.

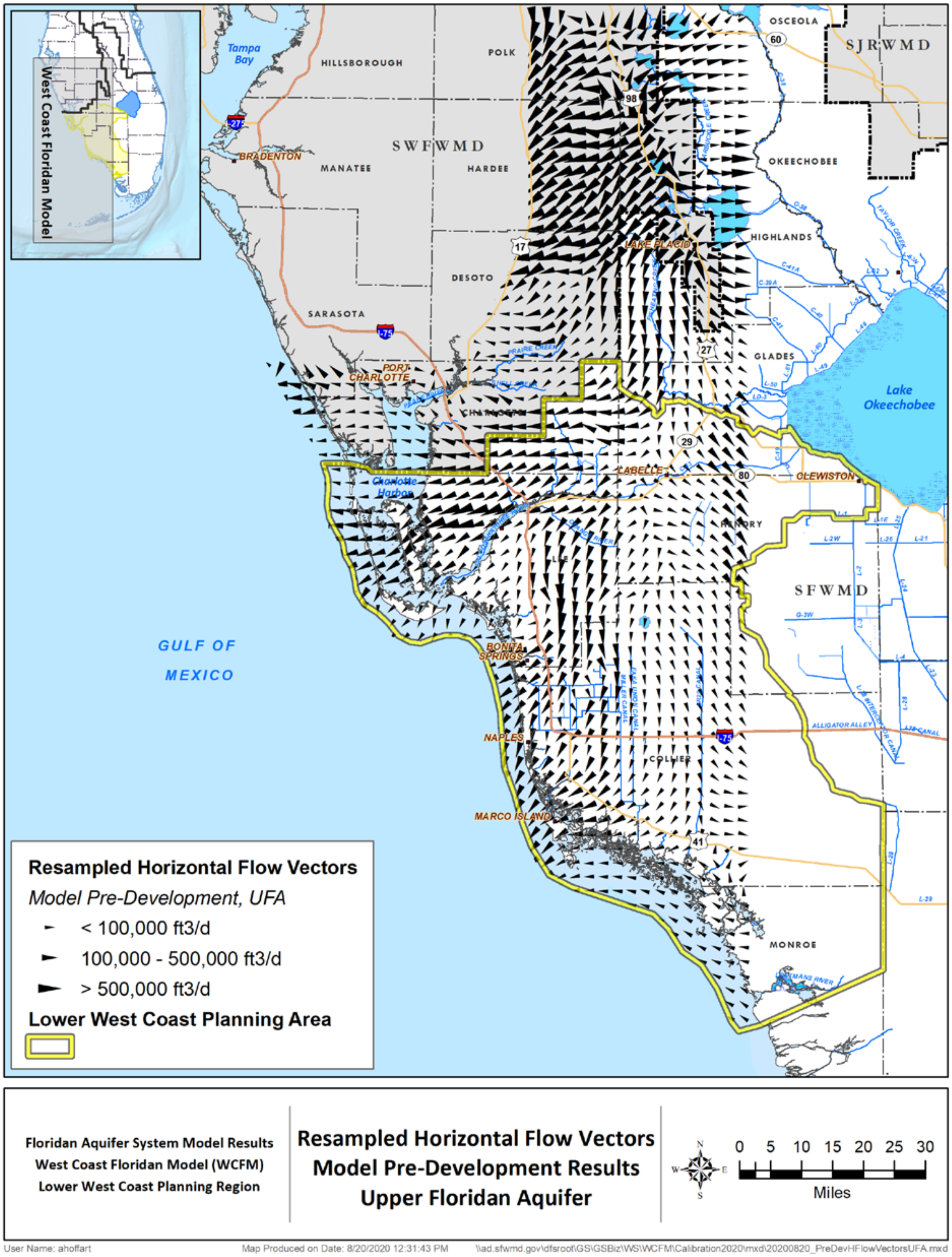


Figure 4-23. Flow vectors for the pre-development model.

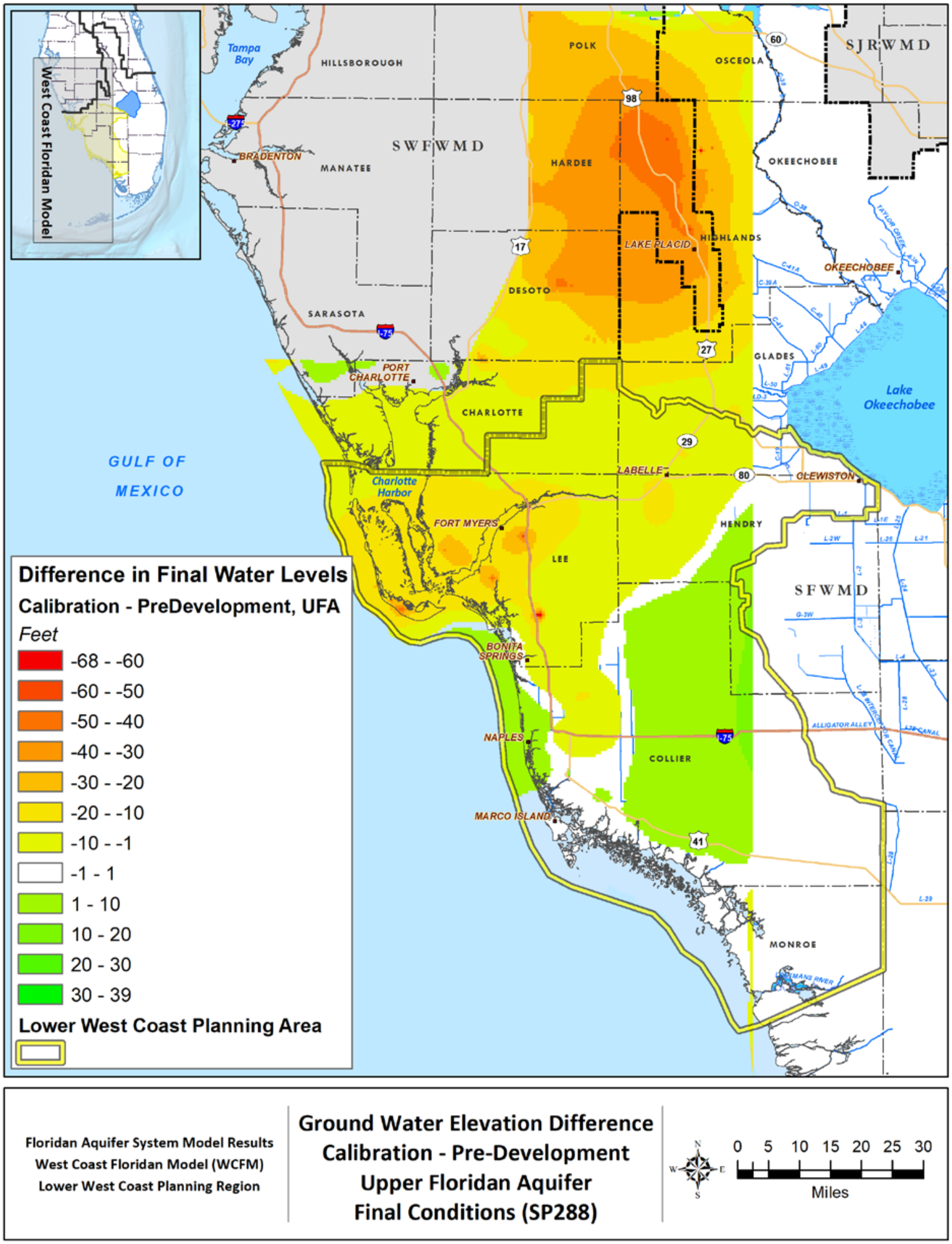


Figure 4-24. Difference in groundwater levels in the calibrated model and the pre-development model in the Upper Floridan aquifer.

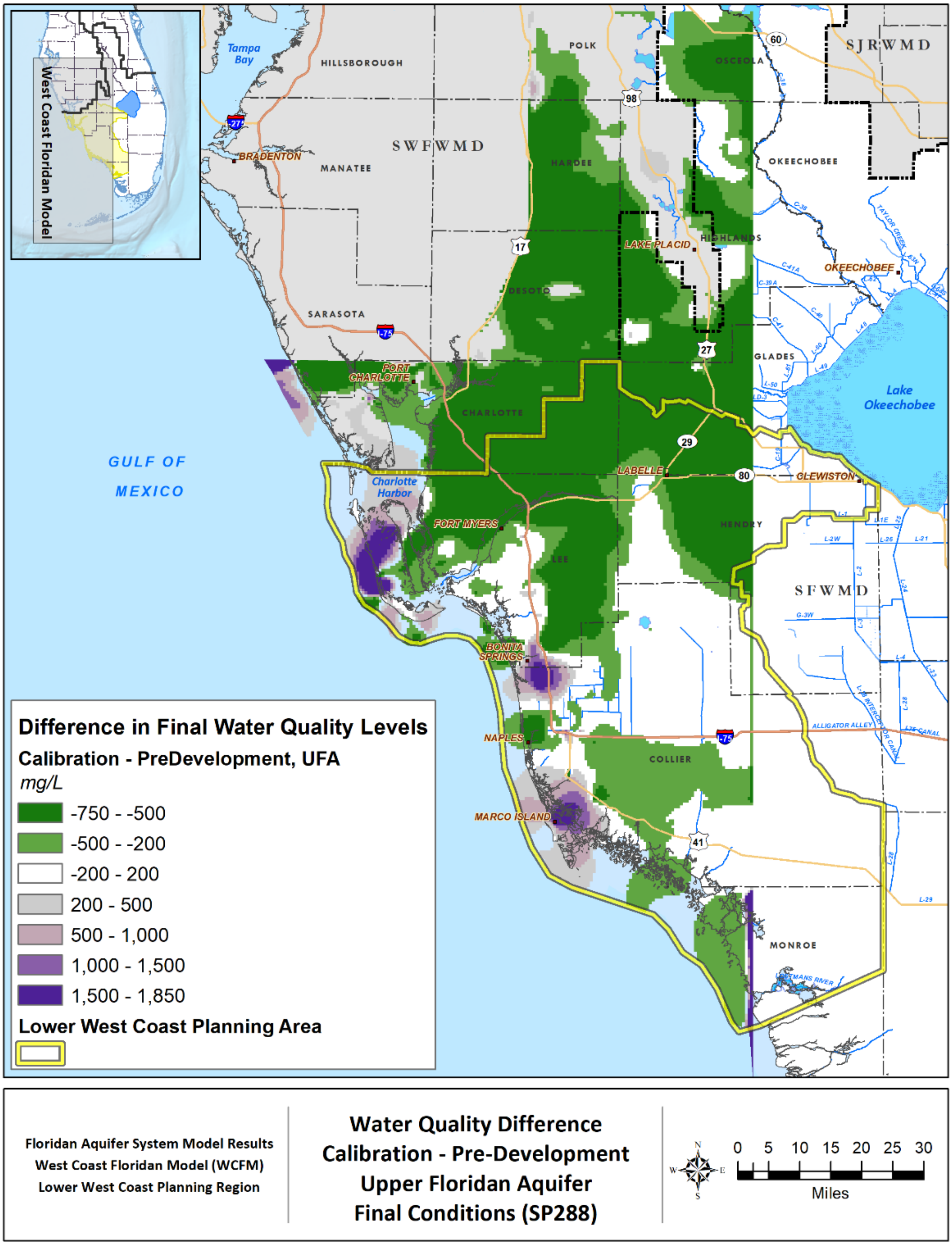


Figure 4-25. Difference in water quality between the calibrated model and the pre-development model in the Upper Floridan aquifer.

Table 4-7. Percentage of wells that met the water quality criteria in the calibrated model and the pre-development model.

| Aquifer | Calibrated Model | Pre-development Model |
|---|---|---|
| Upper Floridan aquifer | 88% | 55% |
| Avon Park permeable zone | 89% | 94% |
| Lower Floridan aquifer – first permeable zone | 100% | 100% |
| **All Aquifers** | **89%** | **65%** |
| Confining units | 71% | 50% |
| **All Model Layers** | **87%** | **64%** |

## 4.7 Sensitivity Analysis

Sensitivity analysis is a quantitative evaluation of the impact of variability or uncertainty in model inputs (e.g., heads, concentrations, flows) on the degree of model calibration and its results or conclusions. The analysis is essential to understand how the simulated system conforms with the conceptual model, and the results can be used to determine which model input parameters are more significant in adjusting the simulated heads and flows and how they relate to the observed values (Reilly and Harbaugh 2004).

Automated and manual techniques can be implemented during sensitivity analysis. Due to the transient nature of the WCFM, a manual approach was used for the sensitivity analysis to determine which model input parameters were most sensitive within the model domain. In this approach, one parameter was changed at a time so the effect of its variations on the model could be individually assessed. Parameters were varied within acceptable ranges based on a predetermined data range for each parameter from the calibrated values. The sensitivity analysis was used to determine which parameters were most sensitive to simulated heads and TDS concentrations.

**Table 4-8** shows the model input parameters used in the sensitivity analysis and the different multipliers that were applied for each parameter. The tested parameters include vertical hydraulic conductivity, horizontal hydraulic conductivity, specific storage, variations in the GHB cells, gross recharge, dispersivity, and effective porosity. For each parameter, several model runs were completed using the identified multipliers. The simulation period for the sensitivity analysis was from January 1, 1989 to December 31, 2012, same as the calibration period. A total of 129 sensitivity runs were conducted. The disadvantage of manual sensitivity analysis compared to automated global sensitivity analysis is that because the parameters varied by layer and not by region within the layers, local variations of parameter sensitivities were not captured. It should be noted that the sensitivity runs were conducted on an earlier version of the WCFM; therefore, the model calibration criteria referenced in this section are significantly different than the results of the final model.

Table 4-8. Parameters and multipliers of sensitivity analysis.

| Parameter | Multiplier | | | |
|---|---|---|---|---|
| Vertical hydraulic conductivity for model layers 1 to 6 | 0.1 | 0.2 | 5 | 10 |
| Horizontal hydraulic conductivity for model layers 1 to 6 | 0.1 | 0.2 | 5 | 10 |
| Specific storage for model layers 1 to 6 | 0.01 | 0.1 | 10 | 100 |
| General head boundary conductance for model layers 1 and 3 | 0.01 | 0.1 | 10 | 100 |
| Dispersivity for model layers 1 to 6 | 0.001 | 0.01 | 100 | 1,000 |
| Gross recharge for model layer 1 | 0.8 | 0.9 | 1.1 | 1.2 |
| Porosity for model layers 1 to 6 | 0.5 | 0.8 | 1.2 | 1.5 |

### 4.7.1 Sensitivity Results

After each sensitivity run, simulated heads were compared to observed heads for the simulation period at 112 groundwater monitoring wells and 117 water quality monitoring sites. The MAE was calculated for each well, while the average MAE of all sites was calculated for the groundwater monitoring wells and water quality wells separately. The average MAE at a multiplier of 1 showed the value for the calibrated model, from an earlier version, which was used to compare the sensitivity run performance to the model calibration. **Appendix C**, Tables C-1 to C-4, show the average MAE for the groundwater monitoring wells and the water quality sites as well as the overall MAE for each sensitivity run and the model calibration. The tables also provide the frequency distribution of the number of wells meeting specific water level intervals related to the calibration criteria. For example, if the sum of the wells with an MAE of 2.5 ft or less for a specific sensitivity run is greater than that of the calibration run, it suggests a better calibration fit. Conversely, a significant increase in the number of wells exceeding an MAE of 5.0 ft suggests a significant deterioration of model performance. **Figures 4-26**, **4-27**, and **4-28** provide composite views of each parameter's effect on overall performance. The effective porosity and longitudinal dispersivity values were not included because the change was insignificant.

Horizontal hydraulic conductivity values for Layers 1, 2, and 3 varied between 0.1 and 10 times the calibrated values. Changes in model performance can be seen in **Appendix C**, Tables C-1 and C-2. **Figure 4-26** shows the sensitivity of the performance of groundwater monitoring wells to changes in horizontal hydraulic conductivity values for the top six dynamic layers of the WCFM. Layer 7 is not included in the sensitivity analysis because it is a constant density and variable head boundary condition. Hydraulic conductivity of layer 1 was the most sensitive parameter analyzed, with the reduction in this variable showing the largest change. Water level changes also were noticeable when vertical hydraulic conductivity was altered in the confining units (**Figure 4-27**). Changes in the storativity values had minimal influence on the calibration results (**Figure 4-28**). Slight changes in water quality were observed when the hydraulic conductivity of layer 1 was modified (**Figure 4-29**).

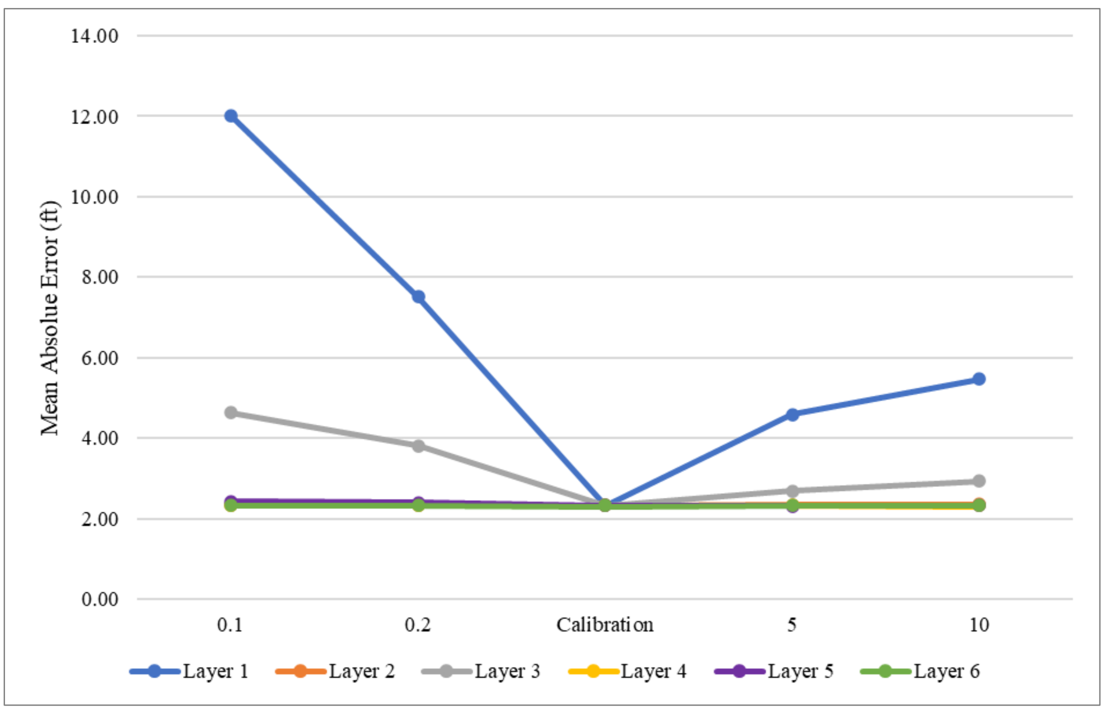


Figure 4-26. Sensitivity of simulated heads in groundwater monitoring wells to changes in horizontal hydraulic conductivity.

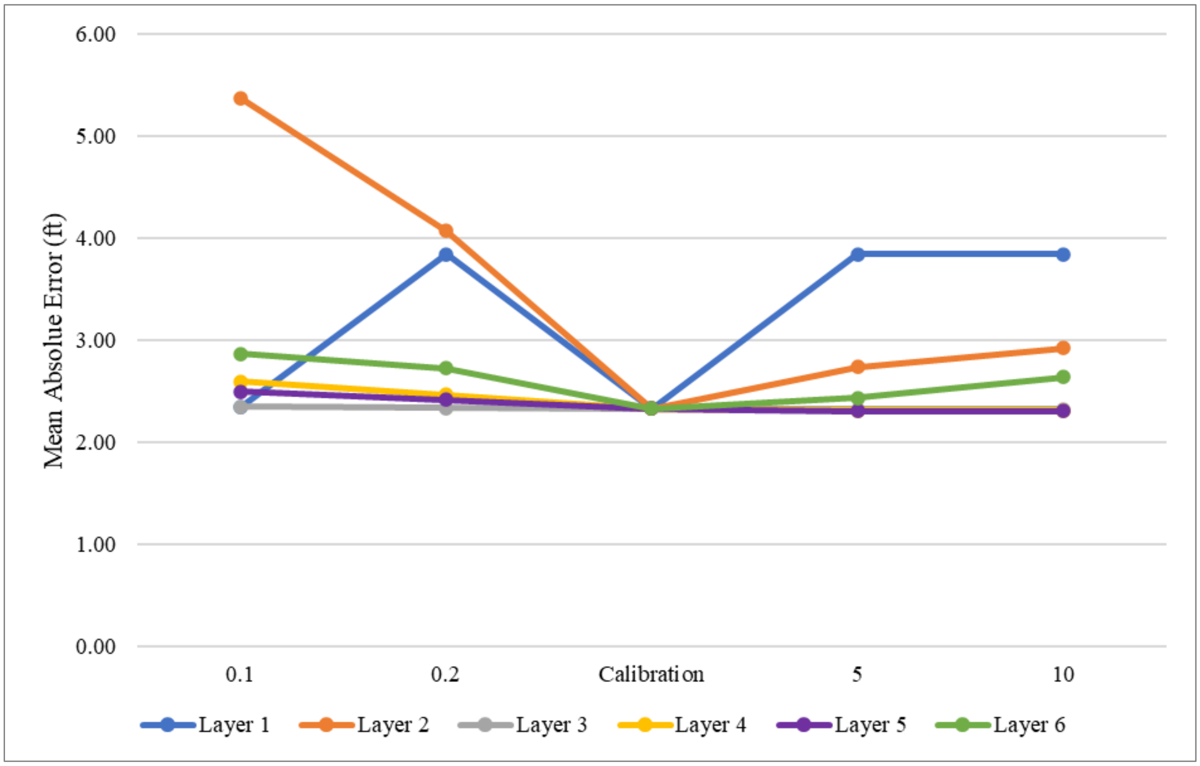


Figure 4-27. Sensitivity of simulated heads in groundwater monitoring wells to changes in vertical hydraulic conductivity.

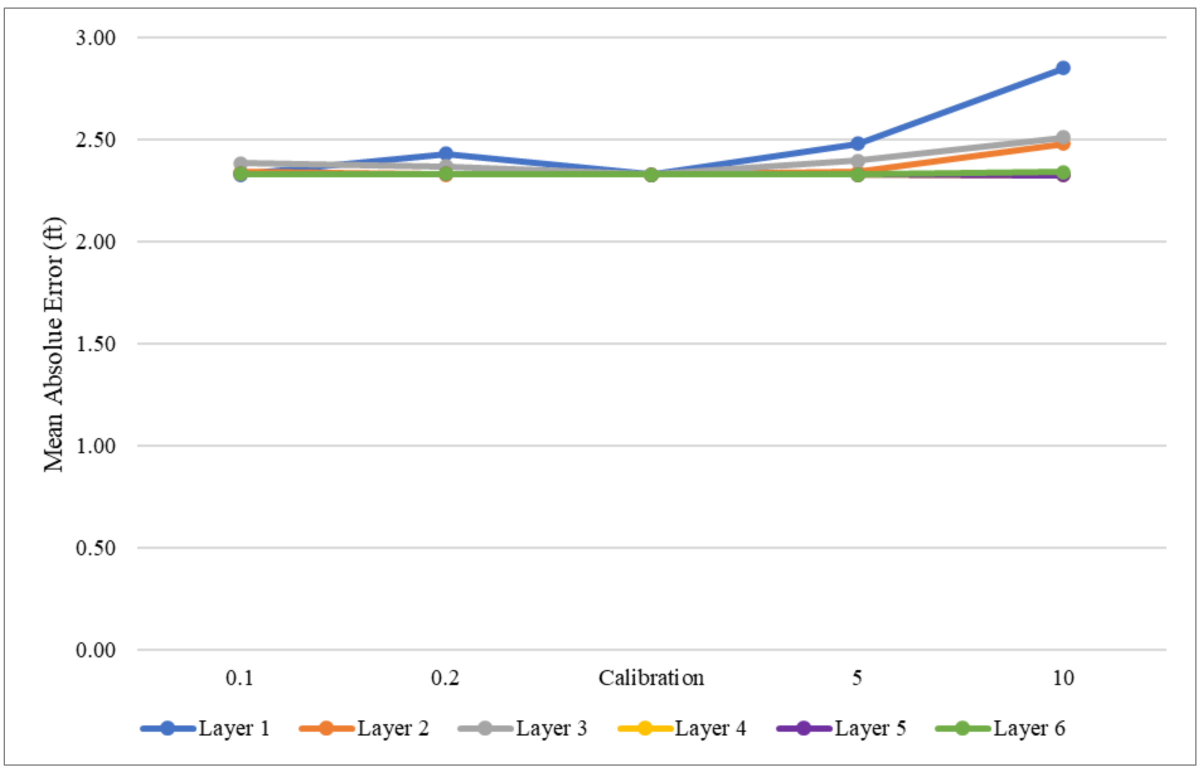


Figure 4-28. Sensitivity of simulated heads in groundwater monitoring wells to changes in aquifer storage.

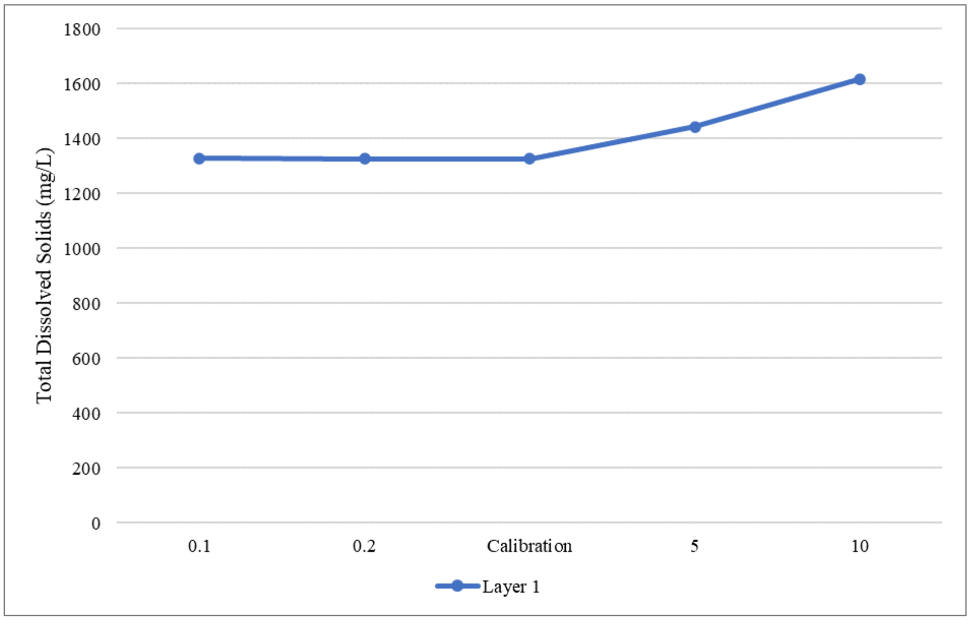


Figure 4-29. Sensitivity of simulated total dissolved solids concentrations in water quality monitoring wells to changes in the layer 1 hydraulic conductivity.

GHB conductance values for layers 1 and 3 varied between 0.01 and 100 times the calibrated conductance values. The UFA and APPZ were the only model layers with the GHB active. Changes in model performance can be seen in **Appendix C**, Tables C-3 and C-4, for the GHB conductance terms and the variations in recharge. **Figure 4-30** shows the sensitivity of the groundwater monitoring wells to changes in GHB conductance values across the model domain. Generally, GHB conductance caused little change in the overall MAE of the groundwater monitoring wells, with the slight decrease in layer 3 conductance causing a slight increase and the decrease in layer 1 causing the most deviation from the calibrated model. Changes in GHB conductance did not impact any water quality locations.

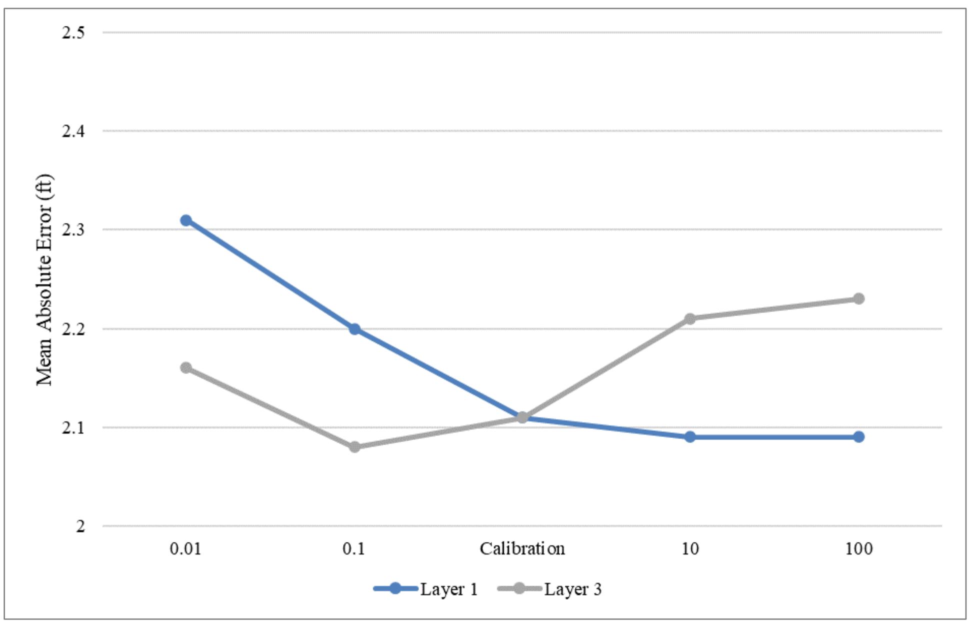


Figure 4-30. Sensitivity of simulated heads in groundwater monitoring wells to changes in the general head boundary conductance term.

Recharge changes across the northern portion of the model domain varied between 0.8 and 1.2 times the calibrated values. Changes in groundwater recharge caused noticeable degradation in the MAE of the groundwater monitoring wells and little change in water quality, primarily because the water is already fresh in the recharge areas. The pattern of changes in recharge followed a classic "U" shape, in that the more the variable was modified, the more intense the change from the calibrated model (**Figure 4-31**).

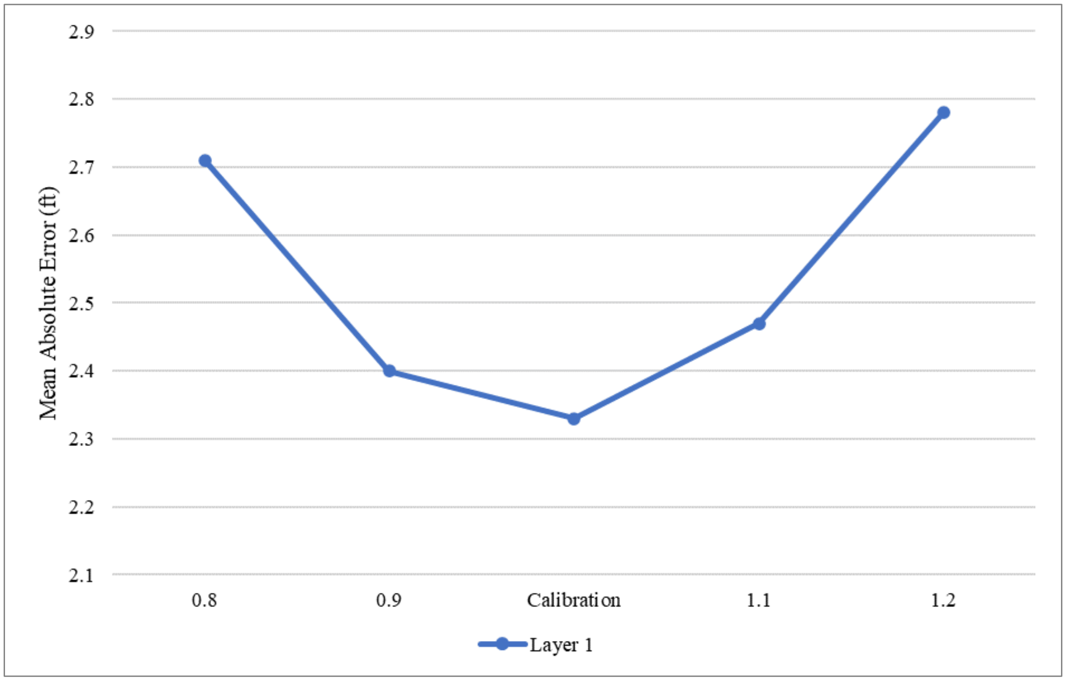


Figure 4-31. Sensitivity of simulated heads in groundwater monitoring wells to changes in recharge.

Sensitivity analysis was performed for two transport parameters: effective porosity and longitudinal dispersivity. The analysis was conducted manually by increasing and decreasing values. The calibrated effective porosity value used in the model was 0.25 for all layers. Effective porosity values were increased to 0.375 and decreased to 0.125. The average MAE per well change from the calibration run was minimal when the effective porosity was changed in water level calibration statistics. The water quality changes to the calibration wells when the effective porosity was varied also did not change significantly, suggesting a change to the value used in the model was unwarranted at a regional level. Changes in longitudinal dispersivity were insignificant, with the exception of dispersivity in layer 1. Variations in the transverse and horizonal dispersivity were evident during the calibration process, and further analysis of these parameters should be explored in future updates.

No global change for any parameter evaluated provided better overall calibration statistics than what is presently within the WCFM. This suggests the current calibrated model parameters are the optimum parameter set resulting in the best calibration. Some localized improvements were observed, and potential improvements may be achieved by making site-specific parameter changes. The most sensitive parameters that primarily affected water levels, and rarely water quality, include horizonal and vertical hydraulic conductivities of the UFA, horizonal hydraulic conductivity of the APPZ, vertical hydraulic conductivities for the three confining units, and GHB and recharge boundary conditions. Dispersivity and effective porosity values appear to be reasonable based on actual field data and the sensitivity analysis results.

# 5 CONCLUSIONS

The WCFM is a well calibrated groundwater flow and solute transport hydrologic model using the flow and transport code SEAWAT (USGS 2012). The WCFM can be used to support planning-level analysis of system responses for formulation and evaluation of water supply plans, regulatory analysis, and regional applications. This report serves as documentation of the model updates and calibration process. Application of the model to projects will depend on several factors, including a project's modeling objectives, and should be reviewed on a case-by-case-basis for each modeling request. The WCFM more than adequately met the calibration targets selected for this project's goals. Model results should be evaluated comparatively (i.e., evaluating the relative difference between two simulations) for predictions; results from a particular simulation should not be taken as absolutes.

The WCFM was designed to provide a regional evaluation of FAS conditions in southwestern Florida. The model reasonably simulates groundwater level and water quality conditions in the FAS. Caution is advised when attempting to use this tool for evaluations of small-scale withdrawals or where water quality in aquifers beneath a wellfield is unknown. Predictions of water quality changes at an existing or future wellfield may require a more detailed delineation of the local hydrogeology and initial water quality distributions. Care should be taken when evaluating large groundwater withdrawals when the production wells are closely spaced. The WCFM may underpredict water quality changes at individual production wells under these circumstances. The model can be used to evaluate water supply planning options and impacts of larger groundwater withdrawals. This regional model may be used to develop boundary conditions for a local model to evaluate existing or proposed FAS withdrawals associated with water use permit applications.

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# APPENDIX A
# MODEL CALIBRATION STATISTICS

Table A-1. Statistics at each monitoring site for heads in the Upper Floridan aquifer.

| Well | Mean Error (ft) | MAE (ft) | RMSE (ft) | MAE Within 2.5 ft | MAE Within 5.0 ft | RMSE Within 5.0 ft | $R^2$ |
|---|---|---|---|---|---|---|---|
| Charlotte | | | | | | | |
| BSU-MZU | 0.99 | 1.13 | 1.34 | Y | Y | Y | 0.01 |
| O_FAITH | 0.28 | 1.20 | 1.40 | Y | Y | Y | 0.03 |
| Browns | -3.40 | 3.40 | 3.72 | N | Y | Y | 0.02 |
| ROMP TR1-2 | 0.40 | 1.84 | 2.39 | Y | Y | Y | 0.02 |
| ROMP TR3-1 | -1.94 | 1.99 | 2.35 | Y | Y | Y | 0.13 |
| WEBB MW4 | 2.81 | 2.92 | 3.36 | N | Y | Y | 0.03 |
| CR74 | -0.26 | 1.50 | 1.67 | Y | Y | Y | 0.14 |
| Collier | | | | | | | |
| BICY-GW2 | 0.48 | 0.62 | 0.74 | Y | Y | Y | 0.00 |
| IWSD-MZ2 | 0.88 | 1.00 | 1.18 | Y | Y | Y | 0.00 |
| MIU-MZ1 | -2.17 | 2.17 | 2.22 | Y | Y | Y | 0.21 |
| SCC-MZU | 0.27 | 0.71 | 0.85 | Y | Y | Y | 0.33 |
| C-258 | 0.08 | 0.92 | 1.17 | Y | Y | Y | 0.01 |
| DeSoto | | | | | | | |
| Romp 13 | 2.37 | 3.39 | 3.84 | N | Y | Y | 0.12 |
| Romp 12 | 0.24 | 1.68 | 2.00 | Y | Y | Y | 0.34 |
| Cromwell | -0.61 | 2.21 | 2.64 | Y | Y | Y | 0.29 |
| Wolf | -0.79 | 1.29 | 1.64 | Y | Y | Y | 0.63 |
| Nichols UFA | -1.87 | 2.08 | 2.47 | Y | Y | Y | 0.65 |
| Romp 16.5 | 2.51 | 3.60 | 4.01 | N | Y | Y | 0.00 |
| Morgan | 0.55 | 0.75 | 0.92 | Y | Y | Y | 0.94 |
| TRG18 | 0.36 | 1.86 | 2.03 | Y | Y | Y | 0.68 |
| Romp 16 | 2.05 | 3.17 | 3.76 | N | Y | Y | 0.22 |
| S Tomato | 1.19 | 3.44 | 4.13 | N | Y | Y | 0.46 |
| FPL | 1.58 | 2.36 | 2.91 | Y | Y | Y | 0.66 |
| Romp 26 | 0.22 | 2.25 | 2.85 | Y | Y | Y | 0.71 |
| Marshal | -0.59 | 1.96 | 2.63 | Y | Y | Y | 0.80 |
| Glades | | | | | | | |
| CLEMONS | 0.13 | 1.03 | 1.26 | Y | Y | Y | 0.06 |
| Hardee | | | | | | | |
| Flint | 0.37 | 2.44 | 2.90 | Y | Y | Y | 0.94 |
| Marrls | -1.23 | 2.03 | 3.02 | Y | Y | Y | 0.97 |
| Hass | 2.11 | 3.63 | 4.71 | N | Y | Y | 0.69 |
| Robertson | 1.28 | 2.42 | 2.79 | Y | Y | Y | 0.93 |
| Smith | -0.13 | 3.65 | 4.72 | N | Y | Y | 0.71 |
| Romp 43 | 3.69 | 4.01 | 4.41 | N | Y | Y | 0.93 |
| Shear | 0.09 | 2.96 | 3.64 | N | Y | Y | 0.72 |
| Romp 30 | -1.39 | 1.39 | 1.48 | Y | Y | Y | 1.00 |
| Griffin | -1.44 | 1.48 | 1.81 | Y | Y | Y | 1.00 |
| Zolfo Springs | 0.41 | 0.74 | 0.85 | Y | Y | Y | 1.00 |

| Well | Mean Error (ft) | MAE (ft) | RMSE (ft) | MAE Within 2.5 ft | MAE Within 5.0 ft | RMSE Within 5.0 ft | $R^2$ |
|---|---|---|---|---|---|---|---|
| Hendry | | | | | | | |
| LAB-MZ1 | 2.94 | 2.98 | 3.08 | N | Y | Y | 0.14 |
| BRY-MW | 2.98 | 2.98 | 3.08 | N | Y | Y | 0.18 |
| Highlands | | | | | | | |
| HIF-26 | -1.41 | 1.54 | 2.09 | Y | Y | Y | 0.64 |
| HIF-32 | -1.35 | 2.78 | 3.41 | N | Y | Y | 0.00 |
| HIF-23 | 2.82 | 3.12 | 3.42 | N | Y | Y | 0.63 |
| RMP14U | 0.22 | 1.63 | 1.83 | Y | Y | Y | 0.72 |
| PLACID | -0.30 | 1.86 | 2.39 | Y | Y | Y | 0.45 |
| RMP28X | 3.13 | 3.51 | 4.17 | N | Y | Y | 0.18 |
| RMP28 | -0.34 | 2.00 | 2.55 | Y | Y | Y | 0.31 |
| SEBR | 0.11 | 2.18 | 2.66 | Y | Y | Y | 0.77 |
| MARAN | -2.93 | 3.50 | 4.48 | N | Y | Y | 0.65 |
| BONETT | -1.59 | 3.24 | 4.12 | N | Y | Y | 0.43 |
| RMP43XX | 0.05 | 2.14 | 2.39 | Y | Y | Y | 0.71 |
| CLEN | -0.48 | 2.69 | 3.40 | N | Y | Y | 0.73 |
| DRESS | -1.56 | 3.37 | 4.27 | N | Y | Y | 0.14 |
| Lee | | | | | | | |
| L-1634 | -0.94 | 1.30 | 1.88 | Y | Y | Y | 0.13 |
| L-5641 | 0.56 | 1.70 | 2.13 | Y | Y | Y | 0.00 |
| L-5708 | 2.83 | 3.14 | 3.48 | N | Y | Y | 0.27 |
| L-5766 | 2.35 | 2.38 | 2.62 | Y | Y | Y | 0.19 |
| Simulated | -3.55 | 4.11 | 4.49 | N | Y | Y | 0.97 |
| L-2295 | -2.18 | 2.48 | 3.25 | Y | Y | Y | 0.25 |
| L-2311 | 2.93 | 2.94 | 3.24 | N | Y | Y | 0.00 |
| L-2313 | -0.58 | 1.11 | 1.60 | Y | Y | Y | 0.19 |
| L-2315 | 2.63 | 2.81 | 3.17 | N | Y | Y | 0.51 |
| L-2328 | 2.80 | 2.86 | 3.19 | N | Y | Y | 0.06 |
| L-2341 | 1.44 | 2.11 | 2.50 | Y | Y | Y | 0.01 |
| L-2435 | -3.94 | 3.98 | 4.39 | N | Y | Y | 0.13 |
| L-2524 | 1.92 | 3.77 | 4.68 | N | Y | Y | 0.63 |
| L-2525 | 0.37 | 0.88 | 1.07 | Y | Y | Y | 0.26 |
| L-2526 | 1.48 | 1.82 | 2.24 | Y | Y | Y | 0.02 |
| L-2527 | -0.39 | 1.38 | 1.73 | Y | Y | Y | 0.00 |
| L-2528 | 0.18 | 1.18 | 1.57 | Y | Y | Y | 0.24 |
| L-2529 | -3.39 | 3.41 | 3.86 | N | Y | Y | 0.12 |
| L-2530 | -0.84 | 1.82 | 2.42 | Y | Y | Y | 0.01 |
| L-2531 | -0.76 | 1.55 | 1.99 | Y | Y | Y | 0.09 |
| L-5734 | -3.29 | 3.71 | 4.75 | N | Y | Y | 0.00 |
| L-5737 | -0.71 | 2.85 | 3.92 | N | Y | Y | 0.89 |
| L-5801 | -0.09 | 1.57 | 1.94 | Y | Y | Y | 0.00 |
| L-6436 | 0.43 | 0.79 | 0.93 | Y | Y | Y | 0.29 |
| L-652 | 0.24 | 1.13 | 1.39 | Y | Y | Y | 0.11 |
| FPL-MW | 3.53 | 3.53 | 3.66 | N | Y | Y | 0.33 |
| IWA-MZU | -0.94 | 1.29 | 1.63 | Y | Y | Y | 0.12 |
| L-331 | -0.85 | 2.59 | 3.10 | N | Y | Y | 0.24 |

| Well | Mean Error (ft) | MAE (ft) | RMSE (ft) | MAE Within 2.5 ft | MAE Within 5.0 ft | RMSE Within 5.0 ft | $R^2$ |
|---|---|---|---|---|---|---|---|
| Monroe | | | | | | | |
| KW-MZL | 1.57 | 1.57 | 1.58 | Y | Y | Y | 0.04 |
| Polk | | | | | | | |
| POL-IL | -0.24 | 0.24 | 0.27 | Y | Y | Y | 1.00 |
| Burnett | 0.76 | 2.30 | 2.91 | Y | Y | Y | 0.30 |
| Romp CL2 | -0.30 | 2.07 | 2.51 | Y | Y | Y | 0.72 |
| WEO | -0.99 | 1.40 | 1.82 | Y | Y | Y | 0.63 |
| Altman | -1.23 | 2.97 | 3.83 | N | Y | Y | 0.64 |
| Romp CL3 | 0.24 | 2.34 | 2.88 | Y | Y | Y | 0.85 |
| Romp 55 | 0.18 | 2.15 | 2.71 | Y | Y | Y | 0.86 |
| Romp 44 | -0.41 | 1.71 | 2.16 | Y | Y | Y | 0.89 |
| Lake Wales | 0.09 | 0.24 | 0.28 | Y | Y | Y | 1.00 |
| Romp 45 | 0.37 | 0.54 | 0.62 | Y | Y | Y | 1.00 |
| Homeland | -0.30 | 0.51 | 0.69 | Y | Y | Y | 1.00 |
| Average | | | | | | | |
| | 0.14 | 2.16 | 2.60 | 65% | 100% | 100% | 0.42 |

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

Table A-2. Statistics at each monitoring site for heads in the Avon Park permeable zone.

| Well | Mean Error (ft) | MAE (ft) | RMSE (ft) | MAE Within 2.5 ft | MAE Within 5.0 ft | RMSE Within 5.0 ft | $R^2$ |
|---|---|---|---|---|---|---|---|
| Charlotte | | | | | | | |
| BSU-MZL | 1.80 | 1.85 | 2.11 | Y | Y | Y | 0.10 |
| ROMP TR3-3 | -0.29 | 1.55 | 2.11 | Y | Y | Y | 0.10 |
| Collier | | | | | | | |
| IWSD-MZ3 | 2.49 | 2.58 | 2.78 | N | Y | Y | 0.36 |
| BICY-GW3 | 0.82 | 0.87 | 1.05 | Y | Y | Y | 0.04 |
| MIU-MZ2 | -0.85 | 0.88 | 0.94 | Y | Y | Y | 0.18 |
| DeSoto | | | | | | | |
| Emerald | 1.44 | 1.52 | 1.87 | Y | Y | Y | 0.35 |
| Nichols APPZ | 2.34 | 2.46 | 2.84 | Y | Y | Y | 0.51 |
| ROMP 15 | 2.25 | 3.25 | 3.79 | N | Y | Y | 0.45 |
| Bevis | 2.96 | 3.64 | 4.15 | N | Y | Y | 0.64 |
| Hendry | | | | | | | |
| LAB-MZ3 | -2.11 | 2.33 | 2.88 | Y | Y | Y | 0.00 |
| Highlands | | | | | | | |
| HIF-14 | 0.05 | 1.53 | 1.83 | Y | Y | Y | 0.49 |
| HIF-3 | 1.01 | 1.69 | 2.16 | Y | Y | Y | 0.28 |
| HIF-4 | 0.66 | 1.35 | 1.78 | Y | Y | Y | 0.76 |
| RMP14L | 0.33 | 1.67 | 1.97 | Y | Y | Y | 0.87 |
| HIF-5 | 0.13 | 2.15 | 2.51 | Y | Y | Y | 0.21 |
| HIF-8 | 1.63 | 3.03 | 3.80 | N | Y | Y | 0.27 |
| HIF-23 | 2.82 | 3.12 | 3.42 | N | Y | Y | 0.63 |
| Lee | | | | | | | |
| FMB-MZL | 0.39 | 0.75 | 0.91 | Y | Y | Y | 0.01 |
| Average | | | | | | | |
| | 0.99 | 2.01 | 2.38 | 72% | 100% | 100% | 0.35 |

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

Table A-3. Statistics at each monitoring site for heads in the Lower Floridan aquifer – first permeable zone.

| Well | Mean Error (ft) | MAE (ft) | RMSE (ft) | MAE Within 2.5 ft | MAE Within 5.0 ft | RMSE Within 5.0 ft | $R^2$ |
|---|---|---|---|---|---|---|---|
| Collier | | | | | | | |
| BICY-GW4 | 0.13 | 0.33 | 0.40 | Y | Y | Y | 0.26 |
| I75-MZ3 | 0.72 | 0.74 | 0.86 | Y | Y | Y | 0.00 |
| Lee | | | | | | | |
| IWA-MZL | 0.91 | 0.98 | 1.17 | Y | Y | Y | 0.01 |
| Average | | | | | | | |
| | 0.59 | 0.68 | 0.81 | 100% | 100% | 100% | 0.09 |

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

Table A-4. Statistics (in milligrams per liter) at each monitoring site for water quality in the Upper Floridan aquifer.

| Well | Simulated Average Total Dissolved Solids | Observed Average Total Dissolved Solids | Calibration Criteria | Mean Average Difference | Mean Absolute Average Difference | Met Criteria |
|---|---|---|---|---|---|---|
| Charlotte | | | | | | |
| GPISL-MZL | 19,249 | 19,152 | 4,000 | 90 | 1575 | Y |
| SC-ASR | 1,209 | 1,161 | 500 | 54 | 125 | Y |
| BSU-MZU | 1,526 | 1,715 | 500 | -176 | 176 | Y |
| Brown 36 | 642 | 988 | 500 | -332 | 332 | Y |
| Romp TR3-3 | 13,984 | 15,831 | 3,000 | -1,849 | 1,860 | Y |
| Hollingsworth | 437 | 537 | 500 | 100 | 100 | Y |
| Collier | | | | | | |
| SCO-MZU | 13,023 | 5,889 | 750 | 7,140 | 7,140 | N |
| GG-MZU | 12,016 | 13,993 | 3,000 | -1,941 | 3,195 | N |
| IMM-MZU | 2,790 | 2,806 | 500 | -16 | 94 | Y |
| NCWR-MZU | 17,859 | 17,523 | 3,000 | 347 | 1,442 | Y |
| BICY-GW2 | 6,003 | 5,745 | 750 | 259 | 259 | Y |
| MIU-MZ1 | 29,631 | 29,230 | 4,000 | 344 | 1,156 | Y |
| IWSD-MZ2 | 2,790 | 2,864 | 500 | -74 | 109 | Y |
| CC-R10N | 5,937 | 5,675 | 750 | 170 | 534 | Y |
| CC-R15N | 3,252 | 3,232 | 500 | 88 | 587 | N |
| CC-R5N | 7,182 | 7,680 | 750 | -437 | 1,709 | N |
| CC-R10S | 6,142 | 6,245 | 750 | 172 | 660 | Y |
| CC-R40S | 6,075 | 6,204 | 750 | 60 | 592 | Y |
| DeSoto | | | | | | |
| Emerald | 747 | 639 | 500 | 115 | 115 | Y |
| Romp 13 | 468 | 524 | 500 | -8 | 59 | Y |
| 4N1 Groves | 1,079 | 1,099 | 500 | 20 | 20 | Y |
| Sunpure | 2,044 | 2,123 | 500 | 79 | 79 | Y |
| Bright Hour | 450 | 519 | 500 | 69 | 69 | Y |
| Romp15 | 100 | 327 | 500 | 227 | 227 | Y |
| Rutland Ranch | 616 | 376 | 500 | -240 | 240 | Y |
| Hardee | | | | | | |
| Bentley Grove | 848 | 764 | 500 | -84 | 84 | Y |
| Romp 43 | 121 | 155 | 500 | 34 | 34 | Y |
| Hendry | | | | | | |
| LAB-MZ1 | 1,963 | 1,913 | 500 | 52 | 145 | Y |
| BRY-MW | 2,422 | 2,871 | 500 | -448 | 448 | Y |
| Highlands | | | | | | |
| Sherley Deep | 227 | 597 | 500 | 370 | 370 | Y |
| Southern Farms | 1,050 | 1,060 | 500 | 10 | 10 | Y |
| Romp 14 | 150 | 160 | 500 | 10 | 10 | Y |
| Perry | 138 | 293 | 500 | 155 | 155 | Y |
| Sunshine | 127 | 149 | 500 | 22 | 22 | Y |
| Lake Placid | 141 | 145 | 500 | 4 | 4 | Y |
| Carlton | 100 | 204 | 500 | 104 | 104 | Y |
| Placid Lakes | 158 | 137 | 500 | -21 | 21 | Y |

| Well | Simulated Average Total Dissolved Solids | Observed Average Total Dissolved Solids | Calibration Criteria | Mean Average Difference | Mean Absolute Average Difference | Met Criteria |
|---|---|---|---|---|---|---|
| Hif-14 | 146 | 14 | 500 | -132 | 132 | Y |
| Westby | 298 | 242 | 500 | -56 | 56 | Y |
| Windy Point | 141 | 149 | 500 | 8 | 8 | Y |
| Tropical Harbor | 117 | 134 | 500 | 17 | 17 | Y |
| Romp 28 SUW | 100 | 334 | 500 | 234 | 234 | Y |
| Griffin | 194 | 258 | 500 | 64 | 64 | Y |
| Desoto Tower | 96 | 272 | 500 | 176 | 176 | Y |
| Spring Lake | 204 | 264 | 500 | 60 | 60 | Y |
| Country Club | 206 | 516 | 500 | 310 | 310 | Y |
| Sebring Airport | 136 | 196 | 500 | 60 | 60 | Y |
| Donley-Myers 4 | 980 | 964 | 500 | -16 | 16 | Y |
| Donley-Myers 1 | 980 | 844 | 500 | -136 | 136 | Y |
| Maranatha | 98 | 87 | 500 | -11 | 11 | Y |
| Highlands Landfill | 194 | 185 | 500 | -9 | 9 | Y |
| Sun and Lakes | 141 | 406 | 500 | 265 | 265 | Y |
| Avon AFB | 221 | 164 | 500 | -57 | 57 | Y |
| Bonnett Lake | 109 | 105 | 500 | -4 | 4 | Y |
| Avon Park Corr | 104 | 99 | 500 | -5 | 5 | Y |
| Lee | | | | | | |
| ABIO-MZU | 3,262 | 2,981 | 500 | 280 | 280 | Y |
| BSWW-MZU | 6,094 | 5,652 | 750 | 710 | 719 | Y |
| BSRU-MZU | 10,219 | 10,058 | 3,000 | 171 | 633 | Y |
| FMB-MZU | 4,412 | 4,345 | 750 | 106 | 594 | Y |
| OLGA-MZU | 1,406 | 1,355 | 500 | 64 | 244 | Y |
| Lehigh-MZU | 2,315 | 2,357 | 500 | -27 | 59 | Y |
| Pwood - MZU | 4,908 | 4,898 | 750 | 25 | 299 | Y |
| Oakw - MZU | 8,086 | 20,224 | 4,000 | -12,452 | 12,632 | N |
| FPL-MW | 2,197 | 2,043 | 500 | 250 | 250 | Y |
| LC-CS40 | 1,044 | 1,009 | 500 | 68 | 76 | Y |
| IW-S8 | 2,370 | 2,902 | 500 | -431 | 436 | Y |
| IW-S7 | 2,112 | 2,576 | 500 | -345 | 355 | Y |
| IW-S1 | 3,623 | 4,439 | 750 | -765 | 765 | N |
| FM-P1 | 2,116 | 2,966 | 500 | -708 | 917 | N |
| FM-P12 | 2,075 | 3,031 | 500 | -886 | 891 | N |
| FM-P7 | 2,108 | 1,924 | 500 | 244 | 280 | Y |
| PI-RO6 | 2,144 | 1,884 | 500 | 368 | 368 | Y |
| CAC-15N | 1,688 | 2,149 | 500 | -216 | 223 | Y |
| CAC-R18 | 589 | 638 | 500 | -43 | 71 | Y |
| NLC-PW1 | 2,251 | 2,563 | 500 | -306 | 423 | Y |
| BS-30 | 2,678 | 3,125 | 500 | -197 | 271 | Y |
| Monroe | | | | | | |
| KW-MZL | 34680 | 34680 | 4000 | 0 | 0 | Y |
| Average | | | | | | |
| | 3,500 | 3,683 | 844 | -115 | 601 | 88% |

Table A-5. Statistics (in milligrams per liter) at each monitoring site for water quality in the Avon Park permeable zone.

| Well | Simulated Average Total Dissolved Solids | Observed Average Total Dissolved Solids | Calibration Criteria | Mean Average Difference | Mean Absolute Average Difference | Met Criteria |
|---|---|---|---|---|---|---|
| Charlotte | | | | | | |
| PG-MZU | 30,959 | 26,365 | 4,000 | 4,573 | 4,911 | N |
| BSU-MZL | 31,415 | 33,520 | 4,000 | -2,132 | 2,318 | Y |
| Collier | | | | | | |
| IMM-MZM | 4,511 | 4,232 | 2,000 | 280 | 419 | Y |
| NCO-MZL | 33,300 | 34,219 | 4,000 | -918 | 2,111 | Y |
| BICY-GW3 | 27,800 | 27,354 | 4,000 | 446 | 1,044 | Y |
| IWSD-MZ3 | 4,511 | 4,480 | 2,000 | 32 | 238 | Y |
| Hendry | | | | | | |
| LAB-MZ3 | 11,971 | 16,600 | 4,000 | -4,642 | 4,642 | N |
| Lee | | | | | | |
| ABIO-MZL | 16,193 | 15,743 | 4,000 | 451 | 451 | Y |
| BSWW-MZL | 26,000 | 25,967 | 4,000 | 33 | 1,710 | Y |
| CCSW-MZL | 32,537 | 32,554 | 4,000 | -28 | 1,643 | Y |
| CCN-MZL | 33,876 | 33,887 | 4,000 | -15 | 1,676 | Y |
| FTMY-MZL | 26,912 | 26,833 | 4,000 | -17 | 1,636 | Y |
| BSRU-MZL | 31,590 | 31,679 | 4,000 | -96 | 1,653 | Y |
| FMB-MZL | 29,997 | 33,411 | 4,000 | -3,415 | 3,655 | Y |
| N Ft M -MZM | 19,560 | 20,443 | 4,000 | -1,094 | 2,384 | Y |
| Pwood - MZL | 33,195 | 33,351 | 4,000 | -276 | 632 | Y |
| San I - MZl | 32,947 | 32,945 | 4,000 | 1 | 633 | Y |
| Oakw - MZl | 29,285 | 29,397 | 4,000 | -195 | 772 | Y |
| Average | | | | | | |
| | 25,364 | 25,721 | 3,778 | -390 | 1807 | 89% |

Table A-6. Statistics (in milligrams per liter) at each monitoring site for water quality in the Lower Floridan aquifer – first permeable zone.

| Well | Simulated Average Total Dissolved Solids | Observed Average Total Dissolved Solids | Calibration Criteria | Mean Average Difference | Mean Absolute Average Difference | Met Criteria |
|---|---|---|---|---|---|---|
| Charlotte | | | | | | |
| PG-MZL | 25,508 | 25,406 | 4,000 | 106 | 2,825 | Y |
| CHEP-MZL | 23,112 | 23,055 | 4,000 | 60 | 1,154 | Y |
| Collier | | | | | | |
| SCO-MZL | 35,000 | 32,942 | 4,000 | 2058 | 2,140 | Y |
| IMM-MZL | 32,000 | 35,296 | 4,000 | -3296 | 3,501 | Y |
| BICY-GW4 | 32,975 | 36,239 | 4,000 | -3277 | 3,622 | Y |
| I75-MZ3 | 35,000 | 35,094 | 4,000 | -94 | 1,729 | Y |
| Lee | | | | | | |
| Lehigh-MZL | 32,083 | 32,060 | 4,000 | 6 | 1,195 | Y |
| NFtM-MZL | 31,487 | 29,305 | 4,000 | 2185 | 2,784 | Y |
| Average | | | | | | |
| | 30,895 | 31,175 | 4,000 | -282 | 2,369 | 100% |

# APPENDIX B
# AQUIFER TESTS AND PROPERTIES

Table B-1. Upper Floridan aquifer test values and model calibrated values.

| Test Site | Type of Test | Minimum Test Value (ft/day) | Maximum Test Value (ft/day) | Model Simulated Value (ft/day) |
|---|---|---|---|---|
| Charlotte | | | | |
| Shell Creek ASR | APT | 3 | 1 | 10 |
| Shell Creek ASR | APT | 30 | 20 | 10 |
| Babcock | APT | 10 | 8 | 19 |
| ROMP 5 Cecil Webb (MW-4) | APT | 10 | 8 | 23 |
| Englewood Injection Well IW-1 | APT | 86 | 68 | 26 |
| Burnt Store Wellfield - RO15 | APT | 66 | 27 | 38 |
| Collier | | | | |
| IMWSD APT | APT | 448 | 75 | 50 |
| Big Cypress Test 3 | Packer | 7 | 2 | 1 |
| Big Cypress APT 2 | APT | 65 | 27 | 1 |
| I-75 APT1 | APT | 173 | 35 | 3 |
| I-75 APT2 | APT | 44 | 16 | 3 |
| Marco Manatee C-1102 | Packer | 188 | 24 | 136 |
| Marco Manatee C-1102 | Packer | 74 | 11 | 136 |
| Marco Manatee C-1102 | Packer | 158 | 10 | 136 |
| Marco Lakes | APT | 759 | 89 | 136 |
| GGWWTP | Packer | 111 | 6 | 84 |
| GGWWTP | Packer | 110 | 8 | 84 |
| NCCWWTP (MC-5005) | APT | 3794 | 643 | 13 |
| SCCWWTP (MC-5060) | APT | 27 | 7 | 10 |
| SCCWWTP (MC-5068) | APT | 282 | 66 | 104 |
| Marco Lakes ASR-5 | APT | 217 | 19 | 124 |
| Marco Lakes ASR-6 | Step | 74 | 4 | 124 |
| Marco Lakes ASR-6 | Step | 194 | 15 | 124 |
| Pelican Bay ASR (PELBAYASR1) | Step | 125 | 16 | 165 |
| SCRWTP IW1 | Packer | 5 | 0 | 92 |
| South Collier WWTPIW1 | Packer | 5 | 0 | 200 |
| South Collier WWTPIW1 | Packer | 5 | 0 | 200 |
| South Collier WWTPPW1 | Packer | 4 | 0 | 200 |
| Collier County | APT | 138 | 14 | 136 |
| Marco | APT | 218 | 16 | 124 |
| Collier County | APT | 46 | 19 | 56 |
| Collier County | APT | 4 | 2 | 92 |
| Collier County | APT | 10 | 6 | 92 |
| Collier County | APT | 232 | 66 | 81 |
| Collier County | APT | 9 | 3 | 100 |
| Collier County | APT | 696 | 113 | 28 |
| Collier County | APT | 25 | 8 | 3 |
| Collier County | APT | 49 | 13 | 12 |
| Collier County | APT | 1 | 0 | 41 |

| Test Site | Type of Test | Minimum Test Value (ft/day) | Maximum Test Value (ft/day) | Model Simulated Value (ft/day) |
|---|---|---|---|---|
| DeSoto | | | | |
| ROMP 12 Prairie Creek (Suwannee) | APT | 38 | 28 | 180 |
| ROMP 12 Prairie Creek (Upper Fldn Shallow) | APT | 191 | 167 | 180 |
| ROMP 16.5 Ft. Ogden | APT | 2 | 2 | 10 |
| Peace River Well #0414-5847 | APT | 11 | 36 | 10 |
| ROMP 13 Tippen Bay (WRAP S-4) | APT | 21 | 19 | 29 |
| Fort Ogden | APT | 12 | 31 | 10 |
| Fort Ogden Test Site (Test 15) Well LL-1 | APT | 14 | 46 | 10 |
| ROMP 15 Long Island Marsh | APT | 12 | 19 | 31 |
| Hardee | | | | |
| Farmland Industries Well FIS 1 | APT | 19 | 49 | 166 |
| Hendry | | | | |
| Clewiston RO PW2 | APT | 26 | 25 | 247 |
| Clewiston RO PW3 | APT | 43 | 47 | 247 |
| Clewiston RO PW4 | Step | 31 | 32 | 247 |
| Caloosahatchee ASR (EXBRY-1) | APT | 113 | 7 | 42 |
| L-2 | APT | 10 | 17 | 106 |
| LaBelle LAB-PW2 | APT | 52 | 68 | 11 |
| Highlands | | | | |
| HIF-41 | Step | 7 | 47 | 63 |
| ROMP 14 Hicoria (Well No.2) | APT | 82 | 19 | 58 |
| ROMP 28 Kuhlman (Suwannee) | APT | 3 | 3 | 307 |
| ROMP 43 Bee Branch (Suwannee) | APT | 84 | 97 | 118 |
| Lee | | | | |
| CC RO-10 | Step | 54 | 19 | 5 |
| CC RO-225 | Step | 23 | 9 | 89 |
| CC RO-9 | APT | 12 | 7 | 16 |
| CC WWTP | Packer | 0 | 0 | 76 |
| Ft Myers Beach | APT | 211 | 60 | 14 |
| FPL Ft Myers | APT | 23 | 30 | 150 |
| Ft Myers P13 | Step | 17 | 4 | 40 |
| Ft Myers P15 | Step | 38 | 15 | 40 |
| Ft Myers P1 | Step | 4 | 3 | 40 |
| Ft Myers P3 | APT | 25 | 16 | 40 |
| Ft Myers P4 | APT | 24 | 17 | 40 |
| Ft Myers P5 | APT | 43 | 29 | 40 |
| Ft Myers P6 | APT | 59 | 41 | 40 |
| Ft Myers P7 | APT | 60 | 41 | 40 |
| LM-3249 CC | APT | 28 | 31 | 28 |
| LM-3513 Sanibel | APT | 84 | 3 | 7 |
| LM-3680 Pine Island | APT | 137 | 29 | 550 |
| LM-3681 Pine Island | APT | 116 | 33 | 550 |
| Corkscrew WTP | Packer | 382 | 24 | 419 |
| Pinewood | Step | 903 | 245 | 250 |
| Pinewood | Packer | 158 | 14 | 250 |

| Test Site | Type of Test | Minimum Test Value (ft/day) | Maximum Test Value (ft/day) | Model Simulated Value (ft/day) |
|---|---|---|---|---|
| Pinewood | Packer | 50 | 4 | 250 |
| Pine Island | Packer | 0 | 0 | 624 |
| Pine Island | Packer | 0 | 0 | 624 |
| Pine Island | Packer | 5 | 1 | 624 |
| North Lee Co. PW11 | APT | 510 | 324 | 58 |
| North Lee Co. PW16A | Step | 187 | 71 | 68 |
| North Lee Co. PW8 | APT | 169 | 74 | 62 |
| Sanibel | APT | 75 | 4 | 3 |
| Royal Tee GC | APT | 28 | 18 | 73 |
| Sanibel | APT | 59 | 11 | 9 |
| Pelican landing | APT | 26 | 35 | 109 |
| Cape Coral | APT | 26 | 4 | 238 |
| Bonita Springs | APT | 102 | 44 | 260 |
| Pelican Bay | APT | 22 | 28 | 109 |
| Pinewood | APT | 859 | 170 | 250 |
| IWA | APT | 19 | 4 | 16 |
| Seascape | APT | 56 | 17 | 15 |
| IWA | APT | 17 | 4 | 2 |
| GPI | APT | 153 | 32 | 550 |
| Cape Coral | APT | 22 | 12 | 38 |
| Cape Coral | APT | 26 | 10 | 79 |
| Alden | APT | 49 | 11 | 12 |
| Cape Coral | APT | 25 | 10 | 157 |
| Polk | | | | |
| ROMP 55 Crooked Lake Coca Cola (SUW) | APT | 106 | 30 | 110 |
| ROMP 55 Crooked Lake Coca Cola Foods (UFA) | APT | 50 | 126 | 110 |
| ROMP 44 Warner Southern College | APT | 8 | 7 | 250 |

APT = aquifer performance test; ft = foot.

Table B-2. Avon Park permeable zone test values and model calibrated values.

| Test Site | Type of Test | Minimum Test Value (ft/day) | Maximum Test Value (ft/day) | Model Simulated Value (ft/day) |
|---|---|---|---|---|
| Collier | | | | |
| IMWSD Test 1 | Packer | 1.49 | 0.48 | 1.50 |
| IMWSD Test 2 | Packer | 20.23 | 6.48 | 1.50 |
| Big Cypress Test 5 | Packer | 4.03 | 1.09 | 0.01 |
| I-75 Packer 2 | Packer | 28.39 | 5.18 | 0.01 |
| Marco Manatee C-1102 | Packer | 21.84 | 10.07 | 0.39 |
| Marco Packer 1 IW C-1104 | Packer | 0.34 | 0.01 | 0.22 |
| Marco Packer 1 IW C-1104 | Packer | 11.83 | 1.51 | 0.22 |
| NCCWWTP | Packer | 0.60 | 0.04 | 0.01 |
| NCWRF IW | Packer | 0.36 | 0.08 | 0.01 |
| SCRWTP IW1 | Packer | 0.03 | 0.00 | 0.01 |
| SCRWTP IW2 | Packer | 0.02 | 0.00 | 0.01 |
| SCRWTP IW2 | Packer | 0.02 | 0.00 | 0.01 |
| South Collier WWTPIW1 | Packer | 0.20 | 0.01 | 0.20 |
| South Collier WWTPIW1 | Packer | 0.01 | 0.00 | 0.20 |
| South Collier WWTPIW2 | Packer | 0.08 | 0.00 | 0.20 |
| South Collier WWTPIW2 | Packer | 0.02 | 0.00 | 0.20 |
| South Collier WWTPPW1 | Packer | 0.03 | 0.01 | 0.20 |
| DeSoto | | | | |
| ROMP 12 Prairie Creek (Avon Park) | APT | 5860.81 | 4177.55 | 4000.00 |
| Tropical River Groves Well 1715-3746.2 | APT | 543.48 | 1607.72 | 893.00 |
| DeSoto Land & Cattle | APT | 294.12 | 293.38 | 717.00 |
| Sunpure Groves Well 101 | APT | 330.92 | 785.38 | 311.00 |
| North Grove PW1 | APT | 125.17 | 289.14 | 228.00 |
| Hardee | | | | |
| Farmland Industries Well FIF-1 | APT | 76.08 | 176.06 | 429.00 |
| CF Industries (Avon Park) | APT | 1188.35 | 586.36 | 839.00 |
| ROMP 41 Torrey (Avon Park-UFA) | APT | 431.10 | 536.26 | 746.00 |
| Mobil South Fort Meade | APT | 218.27 | 335.72 | 388.00 |
| Hendry | | | | |
| L-2 | APT | 3.35 | 4.96 | 0.01 |
| LaBelle LAB-PW2 | APT | 5612.58 | 1822.27 | 2000.00 |
| Highlands | | | | |
| Layne Atlantic | Step | 8.98 | 94.39 | 88.00 |
| ROMP 14 Hicoria (Well No.1) | APT | 11.36 | 35.75 | 97.00 |
| Consolidated Tomoca | APT | 56.15 | 185.31 | 79.00 |
| ROMP 29A Sebring | APT | 34.42 | 178.57 | 91.00 |
| Sebring | APT | 30.38 | 117.79 | 89.00 |
| FPC Avon Park (Test #3) | APT | 65.15 | 286.09 | 320.00 |
| ROMP 43 Bee Branch (Avon Park) | APT | 693.88 | 1168.38 | 1564.00 |
| ROMP 43 Bee Branch (Composite UFA) | APT | 388.89 | 1202.75 | 1564.00 |

| Test Site | Type of Test | Minimum Test Value (ft/day) | Maximum Test Value (ft/day) | Model Simulated Value (ft/day) |
|---|---|---|---|---|
| Lee | | | | |
| 3 Oaks | Packer | 86.82 | 20.89 | 75.00 |
| 3 Oaks | Packer | 1.68 | 0.32 | 75.00 |
| Bonita WTP | Packer | 0.07 | 0.01 | 0.01 |
| Bonita WTP | Packer | 0.11 | 0.04 | 0.01 |
| Bonita WTP | Packer | 0.00 | 0.00 | 0.01 |
| Bonita WTP MW | Packer | 0.01 | 0.00 | 0.01 |
| CC WWTP | Packer | 0.20 | 0.04 | 0.04 |
| CC WWTP | Packer | 0.08 | 0.01 | 0.04 |
| Ft Myers WWTP | Packer | 0.29 | 0.22 | 0.25 |
| North Lee Co. IW | Packer | 20.97 | 2.61 | 15.40 |
| Ft Myers Beach | Packer | 0.37 | 0.05 | 540.00 |
| Ft Myers Beach | Packer | 0.02 | 0.00 | 540.00 |
| Ft Myers Beach | Packer | 0.57 | 0.35 | 540.00 |
| Gasparilla Island Injection Well IW-1 | APT | 285.88 | 500.29 | 256.00 |
| Polk | | | | |
| Hines Energy Complex (P-1) | APT | 1192.76 | 1164.75 | 1033.00 |
| Southeast Polk County (SE-UFA-MW 11) | APT | 52.87 | 115.81 | 102.00 |

APT = aquifer performance test; ft = foot.

Table B-3. Lower Floridan aquifer – first permeable zone test values and model calibrated values.

| Test Site | Type of Test | Minimum Test Value (ft/day) | Maximum Test Value (ft/day) | Model Simulated Value (ft/day) |
|---|---|---|---|---|
| Collier | | | | |
| IMWD | APT | 75 | 489 | 307 |
| I-75 | APT | 65 | 381 | 166 |

APT = aquifer performance test; ft = foot.

Table B-4. Confining units test values and model calibrated values.

| Test Site | Type of Test | Minimum Test Value (ft/day) | Maximum Test Value (ft/day) | Model Simulated Value (ft/day) |
|---|---|---|---|---|
| Charlotte | | | | |
| East Port WWTP | Packer | 51.375 | 6.775 | 1.700 |
| Collier | | | | |
| NCWRF IW | Packer | 0.232 | 0.836 | 1.700 |
| Big Cypress Test 4 | Packer | 0.901 | 1.766 | 0.070 |
| I-75 Packer 1 | Packer | 19.470 | 3.979 | 1.200 |
| Marco Composite | Packer | 0.766 | 0.003 | 0.700 |
| NCCWWTP Composite | Packer | 1.725 | 0.012 | 0.900 |
| SCRWTP Composite | Packer | 0.235 | 0.003 | 1.300 |
| South Collier Composite | Packer | 3.049 | 0.001 | 1.300 |
| Big Cypress Test 1 | Packer | 0.021 | 0.006 | 0.003 |
| I-75 Composite | Packer | 30.988 | 0.468 | 0.004 |
| NCWRF Composite | Packer | 0.226 | 0.005 | 0.030 |
| SCRWTP Composite | Packer | 1.355 | 0.001 | 0.001 |
| Glades | | | | |
| Lykes SI1 | Step | 8.158 | 7.333 | 0.600 |
| Hendry | | | | |
| LaBelle LAB-PW2 | APT | 10.099 | 4.351 | 0.500 |
| Lee | | | | |
| 3 Oaks Composite | Packer | 4.821 | 0.011 | 1.200 |
| Bonita WTP MW | Packer | 0.073 | 0.014 | 0.050 |
| CC WWTP | Packer | 0.039 | 0.002 | 0.150 |
| Pine Island | Packer | 0.011 | 0.028 | 0.020 |
| North Lee Composite | Packer | 0.042 | 0.001 | 0.080 |
| Cape Coral Composite | Packer | 0.178 | 0.001 | 0.010 |
| Bonita WTP | Packer | 0.133 | 0.017 | 0.240 |
| Bonita WTP MW | Packer | 0.270 | 0.063 | 0.070 |
| Cape Coral Composite | Packer | 2.418 | 0.004 | 0.001 |
| Ft Myers Composite | Packer | 1.315 | 0.298 | 0.130 |
| 3 Oaks Composite | Packer | 0.135 | 0.001 | 0.100 |
| Bonita WTP Composite | Packer | 0.774 | 0.001 | 0.003 |
| Bonita MW Composite | Packer | 0.713 | 0.001 | 0.100 |
| CC WWTP | Packer | 0.167 | 0.018 | 0.040 |
| Ft Myers Composite | Packer | 0.771 | 0.001 | 11.000 |
| Pine Island Composite | Packer | 0.586 | 0.001 | 1.280 |
| North Lee Co. IW | Packer | 0.395 | 0.026 | 0.780 |
| Cape Coral SWWTP Composite | Packer | 0.424 | 0.003 | 0.500 |
| Ft Myers Beach Composite | Packer | 0.665 | 0.000 | 0.700 |

APT = aquifer performance test; ft = foot.

# APPENDIX C
# SENSITIVITY ANALYSIS RESULTS

Table C-1. Sensitivity water level and water quality results for aquifer parameters.

| Transport Parameter Modified | Multiplier | Number of Wells with MAE: | | | | | MAE for All Wells (ft) | Percent of Wells Meeting Water Quality Criterion | Water Quality MAE in TDS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| | | <1.5 ft | Between 1.5 and 2.5 ft | Between 2.5 and 4.0 ft | Between 4.0 and 5.0 ft | >5.0 ft | | | |
| Calibration | 1 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| Layer 1 | | | | | | | | | |
| Kh | 0.1 | 23 | 26 | 21 | 4 | 39 | 12.01 | 81% | 1,329 |
| | 0.2 | 23 | 27 | 24 | 8 | 31 | 7.51 | 80% | 1,326 |
| | 5 | 25 | 25 | 28 | 5 | 30 | 4.59 | 70% | 1,443 |
| | 10 | 21 | 28 | 23 | 5 | 36 | 5.47 | 66% | 1,618 |
| Kv | 0.1 | 27 | 36 | 43 | 7 | 0 | 2.35 | 79% | 1,334 |
| | 0.2 | 25 | 26 | 32 | 11 | 19 | 3.84 | 79% | 1,334 |
| | 5 | 25 | 26 | 32 | 11 | 19 | 3.84 | 79% | 1,335 |
| | 10 | 23 | 28 | 32 | 11 | 19 | 3.85 | 78% | 1,336 |
| Storage | 0.01 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 0.1 | 24 | 36 | 45 | 8 | 0 | 2.43 | 79% | 1,326 |
| | 10 | 27 | 37 | 35 | 11 | 3 | 2.48 | 77% | 1,331 |
| | 100 | 27 | 29 | 33 | 14 | 10 | 2.85 | 76% | 1,340 |
| Layer 2 | | | | | | | | | |
| Kh | 0.1 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,328 |
| | 0.2 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,328 |
| | 5 | 27 | 38 | 42 | 4 | 2 | 2.35 | 79% | 1,327 |
| | 10 | 27 | 38 | 42 | 3 | 3 | 2.35 | 79% | 1,328 |
| Kv | 0.1 | 23 | 25 | 26 | 8 | 31 | 5.37 | 79% | 1,327 |
| | 0.2 | 26 | 24 | 27 | 13 | 23 | 4.07 | 79% | 1,326 |
| | 5 | 25 | 35 | 36 | 8 | 9 | 2.74 | 79% | 1,335 |
| | 10 | 25 | 34 | 35 | 6 | 13 | 2.92 | 78% | 1,341 |
| Storage | 0.01 | 27 | 35 | 44 | 7 | 0 | 2.34 | 79% | 1,327 |
| | 0.1 | 27 | 35 | 44 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 10 | 28 | 34 | 44 | 7 | 0 | 2.34 | 79% | 1,327 |
| | 100 | 26 | 35 | 37 | 13 | 2 | 2.48 | 79% | 1,327 |
| Layer 3 | | | | | | | | | |
| Kh | 0.1 | 25 | 24 | 23 | 9 | 32 | 4.64 | 79% | 1,320 |
| | 0.2 | 26 | 24 | 24 | 14 | 25 | 3.81 | 79% | 1,322 |
| | 5 | 26 | 32 | 37 | 9 | 9 | 2.69 | 79% | 1,338 |
| | 10 | 27 | 29 | 35 | 7 | 15 | 2.93 | 78% | 1,351 |
| Kv | 0.1 | 27 | 38 | 40 | 6 | 2 | 2.35 | 79% | 1,327 |
| | 0.2 | 27 | 36 | 43 | 7 | 0 | 2.34 | 79% | 1,327 |
| | 5 | 27 | 38 | 41 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 10 | 27 | 38 | 41 | 7 | 0 | 2.32 | 79% | 1,327 |
| Storage | 0.01 | 25 | 36 | 43 | 8 | 1 | 2.38 | 79% | 1,327 |
| | 0.1 | 25 | 36 | 44 | 8 | 0 | 2.37 | 79% | 1,327 |
| | 10 | 28 | 35 | 40 | 10 | 0 | 2.40 | 79% | 1,327 |
| | 100 | 24 | 42 | 29 | 13 | 5 | 2.51 | 78% | 1,336 |

| Transport Parameter Modified | Multiplier | Number of Wells with MAE: | | | | | MAE for All Wells (ft) | Percent of Wells Meeting Water Quality Criterion | Water Quality MAE in TDS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| | | <1.5 ft | Between 1.5 and 2.5 ft | Between 2.5 and 4.0 ft | Between 4.0 and 5.0 ft | >5.0 ft | | | |
| Layer 4 | | | | | | | | | |
| Kh | 0.1 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 0.2 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 5 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 10 | 27 | 37 | 42 | 7 | 0 | 2.33 | 79% | 1,327 |
| Kv | 0.1 | 22 | 36 | 39 | 12 | 4 | 2.60 | 79% | 1,325 |
| | 0.2 | 22 | 38 | 42 | 10 | 1 | 2.47 | 79% | 1,325 |
| | 5 | 29 | 40 | 36 | 6 | 2 | 2.31 | 79% | 1,328 |
| | 10 | 29 | 41 | 34 | 6 | 3 | 2.31 | 79% | 1,329 |
| Storage | 0.01 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 0.1 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 10 | 27 | 37 | 42 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 100 | 28 | 36 | 41 | 8 | 0 | 2.33 | 79% | 1,326 |
| Layer 5 | | | | | | | | | |
| Kh | 0.1 | 26 | 35 | 43 | 8 | 1 | 2.43 | 79% | 1,327 |
| | 0.2 | 26 | 35 | 43 | 8 | 1 | 2.40 | 79% | 1,327 |
| | 5 | 28 | 41 | 38 | 6 | 0 | 2.31 | 79% | 1,326 |
| | 10 | 29 | 37 | 40 | 7 | 0 | 2.34 | 79% | 1,325 |
| Kv | 0.1 | 25 | 36 | 39 | 10 | 3 | 2.50 | 79% | 1,326 |
| | 0.2 | 25 | 36 | 44 | 8 | 0 | 2.42 | 79% | 1,326 |
| | 5 | 26 | 40 | 40 | 7 | 0 | 2.31 | 79% | 1,327 |
| | 10 | 28 | 38 | 40 | 7 | 0 | 2.31 | 79% | 1,327 |
| Storage | 0.01 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 0.1 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 10 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 100 | 27 | 39 | 39 | 8 | 0 | 2.33 | 79% | 1,326 |
| Layer 6 | | | | | | | | | |
| Kh | 0.1 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 0.2 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 5 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 10 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| Kv | 0.1 | 21 | 28 | 46 | 8 | 10 | 2.87 | 79% | 1,327 |
| | 0.2 | 22 | 31 | 45 | 6 | 9 | 2.72 | 79% | 1,327 |
| | 5 | 28 | 33 | 44 | 5 | 3 | 2.44 | 79% | 1,327 |
| | 10 | 28 | 24 | 45 | 11 | 5 | 2.64 | 79% | 1,327 |
| Storage | 0.01 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,325 |
| | 0.1 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,325 |
| | 10 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,329 |
| | 100 | 27 | 36 | 42 | 8 | 0 | 2.34 | 79% | 1,327 |

ft = foot; Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity; MAE = mean absolute error, mg/L = milligrams per liter; TDS = total dissolved solids.

Table C-2. Results of water quality parameter sensitivity simulations.

| Layer Modified | Multiplier | Number of Wells with MAE: <1.5 feet | Between 1.5 and 2.5 ft | Between 2.5 and 4.0 ft | Between 4.0 and 5.0 ft | >5.0 ft | MAE for All Wells (ft) | Percent of Wells Meeting Water Quality Criterion | Water Quality MAE in TDS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| Porosity | | | | | | | | | |
| L1 | 0.5 | 27 | 36 | 41 | 9 | 0 | 2.34 | 74% | 1,370 |
| | 0.8 | 27 | 36 | 42 | 8 | 0 | 2.33 | 77% | 1,337 |
| | 1.2 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,320 |
| | 1.5 | 27 | 37 | 42 | 7 | 0 | 2.33 | 78% | 1,315 |
| L2 | 0.5 | 27 | 36 | 42 | 8 | 0 | 2.34 | 78% | 1,325 |
| | 0.8 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 1.2 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,329 |
| | 1.5 | 27 | 37 | 42 | 7 | 0 | 2.33 | 79% | 1,329 |
| L3 | 0.5 | 27 | 36 | 43 | 7 | 0 | 2.34 | 79% | 1,332 |
| | 0.8 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,328 |
| | 1.2 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,326 |
| | 1.5 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,325 |
| L4 | 0.5 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,326 |
| | 0.8 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,326 |
| | 1.2 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 1.5 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| L5 | 0.5 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 0.8 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 1.2 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 1.5 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| L6 | 0.5 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 0.8 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 1.2 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 1.5 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| Dispersivity | | | | | | | | | |
| L1 | 0.001 | 27 | 37 | 42 | 7 | 0 | 2.33 | 78% | 1,344 |
| | 0.01 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,341 |
| | 10 | 25 | 38 | 40 | 9 | 1 | 2.39 | 70% | 1,472 |
| | 100 | 23 | 37 | 42 | 7 | 4 | 2.55 | 60% | 2,002 |
| L2 | 0.001 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,319 |
| | 0.01 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,320 |
| | 100 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 1,000 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| L3 | 0.001 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,324 |
| | 0.01 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,324 |
| | 100 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 1,000 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| L4 | 0.001 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 0.01 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 100 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 1,000 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |

| Layer Modified | Multiplier | Number of Wells with MAE: <1.5 feet | Between 1.5 and 2.5 ft | Between 2.5 and 4.0 ft | Between 4.0 and 5.0 ft | >5.0 ft | MAE for All Wells (ft) | Percent of Wells Meeting Water Quality Criterion | Water Quality MAE in TDS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| L5 | 0.001 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 0.01 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 100 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 1,000 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| L6 | 0.001 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 0.01 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 100 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| | 1,000 | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |

ft = foot; MAE = mean absolute error, mg/L = milligrams per liter; TDS = total dissolved solids.

Table C-3. Sensitivity results for the recharge model fluxes.

| Transport Parameter Modified | Multiplier | Number of Wells with MAE: <1.5 ft | Between 1.5 and 2.5 ft | Between 2.5 and 4.0 ft | Between 4.0 and 5.0 ft | >5.0 ft | MAE for All Wells (ft) | Percent of Wells Meeting Water Quality Criterion | Water Quality MAE in TDS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| Calibration | | 27 | 36 | 43 | 7 | 0 | 2.33 | 79% | 1,327 |
| Recharge | 0.8 | 26 | 30 | 35 | 15 | 7 | 2.71 | 79% | 1,326 |
| | 0.9 | 27 | 31 | 47 | 6 | 2 | 2.40 | 79% | 1,326 |
| | 1.1 | 25 | 37 | 38 | 9 | 4 | 2.47 | 79% | 1,327 |
| | 1.2 | 24 | 38 | 36 | 4 | 11 | 2.78 | 79% | 1,327 |

ft = foot; MAE = mean absolute error, mg/L = milligrams per liter; TDS = total dissolved solids.

Table C-4. Sensitivity results for the general head boundary (GHB) conductance term model fluxes.

| Transport Parameter Modified | Multiplier | Number of Wells with MAE: <1.5 ft | Between 1.5 and 2.5 ft | Between 2.5 and 4.0 ft | Between 4.0 and 5.0 ft | >5.0 ft | MAE for All Wells (ft) | Percent of Wells Meeting Water Quality Criterion | Water Quality MAE in TDS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| Calibration | | 33 | 42 | 36 | 2 | 0 | 2.11 | 87% | 1,172 |
| Layer 1 | | | | | | | | | |
| GHB | 0.01 | 26 | 42 | 38 | 6 | 1 | 2.31 | 87% | 1,172 |
| | 0.1 | 30 | 42 | 39 | 2 | 0 | 2.19 | 87% | 1,172 |
| | 10 | 33 | 42 | 37 | 1 | 0 | 2.09 | 87% | 1,172 |
| | 100 | 33 | 42 | 37 | 1 | 0 | 2.09 | 87% | 1,172 |
| Layer 3 | | | | | | | | | |
| GHB | 0.01 | 30 | 38 | 42 | 3 | 0 | 2.16 | 87% | 1,172 |
| | 0.1 | 32 | 37 | 41 | 3 | 0 | 2.08 | 87% | 1,173 |
| | 10 | 33 | 41 | 34 | 4 | 1 | 2.20 | 87% | 1,172 |
| | 100 | 31 | 43 | 33 | 5 | 1 | 2.23 | 87% | 1,172 |

ft = foot; MAE = mean absolute error, mg/L = milligrams per liter; TDS = total dissolved solids.