APPENDIX 5A

Existing Conditions Model Update

Lower Charlotte Harbor Flatwoods Strategic Hydrologic Restoration Plan

Lower Charlotte Harbor Flatwoods Strategic Hydrologic Restoration Plan

5A – Existing Conditions Model Update

PREPARED FOR:

Coastal & Heartland National Estuary Partnership
1050 Loveland Boulevard
Port Charlotte, Florida 33980

PREPARED BY:

Water Science Associates
Coastal & Heartland National Estuary Partnership

IN CONJUNCTION WITH:

South Florida Water Management District
Florida Fish and Wildlife Conservation Commission
Southwest Florida Water Management District

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BACKGROUND

1.0 PROJECT DESCRIPTION

Water Science Associates (Water Science) was contracted by the Coastal & Heartland National Estuary Partnership (CHNEP) to develop a hydrologic restoration plan for the Lower Charlotte Harbor Flatwoods that will promote sheet flow enhancement, restore wetland hydroperiods in the Babcock Webb and the Yucca Pens Wildlife Management Areas (WMA), and improve the timing and magnitude of flows to tidal creeks west of Yucca Pens WMA.

Project tasks include:

1. Compilation of existing hydrologic data,
2. Installation of new surface and groundwater monitoring stations and rain gages,
3. Evaluation of vegetative indicators of wetland health,
4. Maintenance of the monitoring stations and management of manual and electronic data,
5. Development of an existing conditions hydrologic model of the study area,
6. Evaluation of alternative management scenarios, and
7. Development of a Lower Charlotte Harbor Flatwoods Strategic Hydrological Restoration Planning Tool and Report.

Work products for Task 1 - Data Compilation and Task 2 – Monitoring Station Installation including the Data Discovery Memorandum, the Groundwater Monitoring Plan, the Flow Monitoring Plan, and the Monitoring Equipment Acquisition and Installation Memoranda have been submitted to CHNEP. Groundwater and rainfall monitoring station locations were selected to complement existing monitoring stations and to address objectives identified during meetings of the Charlotte Harbor Flatwoods Initiative. The monitoring station locations were selected to provide water level data to define watershed boundaries on the eastern and northern portions of the study area, conveyances from Babcock Webb to Yucca Pens, and groundwater levels in Yucca Pens.

Task 3 includes ecologic monitoring to determine average wet season water depths at more than 50 locations in Babcock Webb and Yucca Pens and hydroperiod mapping. Dry season field work was completed in April and May 2020, and a memorandum for Task 3a was submitted to CHNEP. Wet season field work was completed in November 2020 to measure water depths at the locations inventoried in the 2020 dry season. The final memorandum was submitted in August 2021.

Task 4 activities include operational maintenance of the project monitoring stations and downloading of data from pressure transducers installed in surficial aquifer monitor wells on a quarterly basis for six consecutive quarters. Thus far, data has been downloaded for five consecutive quarters, with the final pressure transducer data download to be completed and analyzed in mid-November 2021.

Task 5 activities include the development of the existing conditions hydrologic model and calibration of that model to data collected as part of Task 4 and data readily available from other sources including the U.S. Geological Survey (USGS), the South Florida Water Management District (SFWMD), the Southwest Florida Water Management District (SWFWMD), Lee County, and Charlotte County. Task 5 deliverables include a) Update Model Files Technical Memorandum, b) Calibration Technical Memorandum, and c) Existing Conditions Model Output technical memo which will include ground water levels as well as surface water levels and flows and graphics This Technical Memorandum serves as the Task 5a deliverable and describes the development of the existing conditions hydrologic model and how model files were updated. Subsequent deliverables for Task 5 will include 50 percent calibration, 100 percent calibration, and a description of the results of the final existing condition model.

2.0 PRIOR MIKE SHE/MIKE 11 MODEL OF CHARLOTTE HARBOR FLATWOODS

The first MIKE SHE/MIKE 11 model that included Babcock Webb and Yucca Pens WMAs was developed in 2002 as part of the Tidal Caloosahatchee River Basin Model (DHI 2003). This model was updated in 2013 for the Florida Department of Transportation (FDOT) to assist FDOT in evaluating the hydrologic impact of widening I-75 between Tuckers Grade and the Charlotte/Lee County line (ADA 2013). That version was developed using twenty-nine surveyed cross sections with additional information from hydrologic studies conducted between the 2002 and 2013, including the 2010 Yucca Pens Hydrologic Restoration Plan (BPC 2010), the North Fort Myers Surface Water Management Plan (AECOM 2010), the Matlacha Pass Hydrologic Restoration Project (Boyle 2007), and information from the North Fort Myers Drainage Restoration Project, which modified channel dimensions for Gator Slough east of U.S. 41 and flow patterns for Prairie Pines Preserve and Powell Creek (ECT 2004).

The model was further enhanced for the City of Cape Coral Stormwater Master Plan (ADA 2015 and AIM 2015) and for the Northeast Irrigation Reservoir Basis of Design for Cape Coral (Tetra Tech 2016). Additional hydraulic information was added to the model in 2017 as part of a pilot water delivery project from inactive mining cells on the Southwest Aggregates mine on U.S. 41 in southern Charlotte County (Water Science Associates 2017).

This modeling effort used the latest version of the MIKE SHE/MIKE 11 software from 2017 and a number of the calibration simulation runs were conducted using the 2020 software version.

MIKE SHE SETUP SUMMARY

1.0 MODEL DOMAIN

The model domain originally developed in 2013 (ADA, 2013) was modified in 2016 (Tetra Tech & ADA, 2018). The 2016 domain was extended to the north up to CR 74, Bermont Rd, as shown in ***Figure 1***. The model grid cell size is 750 feet by 750 feet. The model has 25,753 active cells. The north boundary was extended to include areas of Babcock Webb WMA that drain north towards Charlotte Harbor. The eastern model boundary includes the Telegraph Slough watershed so that flows from Babcock Webb WMA under SR 31 towards Telegraph Slough can be properly represented in the model. The southern boundary was set as the Caloosahatchee River so that outflows from Babcock Webb WMA to North Fort Myers and to Cape Coral can be properly represented in the model.

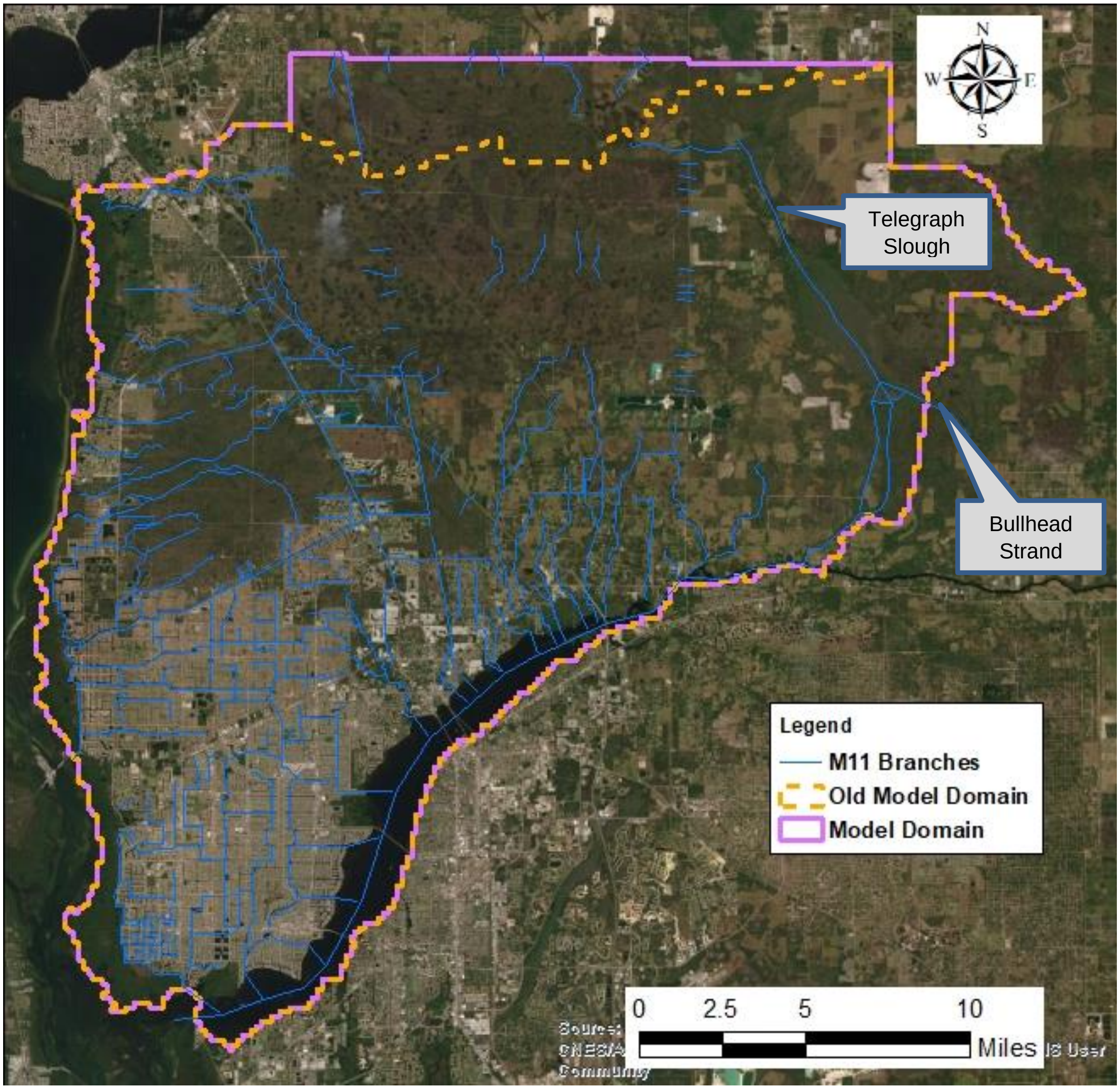

Figure 1. MIKE SHE model domain

2.0 TOPOGRAPHY

The topographic data set used for this project was developed by SFWMD in 2016 for the Charlotte Harbor Flatwoods Initiative. The topographic data includes Light Detection and Ranging (LiDAR) survey data from Lee County and Charlotte County. The LiDAR data was checked by SFWMD to determine that the LiDAR data did not include elevations of the canopy. Concerns regarding the accuracy of the elevations for a portion of the modeling domain surfaced during the physical survey of Surficial Aquifer monitoring wells in the southwest portion of Babcock-Webb WMA that is locally referred to as the “South Walk-In Area”. To address the discrepancies between the survey datasets, the Florida Fish and Wildlife Conservation Commission (FWC) hired Banks Engineering to survey ground surface elevations at fourteen transects in the “South Walk-In Area” (Banks Engineering 2021). The surveyed elevations were compared to LiDAR elevations in the 10-foot merged LiDAR dataset. This analysis indicated that the 10-foot resolution LiDAR-based Digital Elevation Model (DEM) generally over predicted the survey elevations at depressed and/or vegetated areas. LiDAR has difficulty penetrating through water surfaces and dense vegetation typical of the South Walk-In Area. Therefore, it was necessary to adjust the LiDAR-based DEM prior to being input as the topography in the MIKE SHE model.

The differences between survey and LiDAR DEM at the transect points are depicted in ***Figure 2***. Contour lines with the proposed LiDAR corrections were generated using the Banks Engineering survey data. It should be noted that the coverage and density of the survey data points are limited; therefore, contour lines were defined outside the transects by incorporating information from the vegetation land use/vegetation coverage as well as from the vegetation patterns visible in the aerial images.

Contour lines were also drawn at some depressed areas without transects, as depicted on ***Figure 2***, with the proposed elevational corrections interpolated using a TIN method and rasterized at a 10-foot resolution aligned with the existing LiDAR-based DEM. The grid operation between the LiDAR DEM minus the correction raster generated the corrected DEM. Some model cells located outside of the DEM without elevational data along the coast were populated by using a uniform elevation of -1.5-feet (this value was selected based on best-engineering judgement). The simulated topography was then utilized to create MIKE11 cross-sections using MIKE Hydro tools.

Two topographic maps have been generated for this project. A 50-foot DEM will be used to generate hydroperiod and water depth maps at a higher resolution than the MIKE SHE model grid. A 750-foot DEM is the basis for all MIKE SHE calculations. The 10-foot corrected DEM mentioned above was resampled by using the center cell value method to a 50-foot spatial resolution DEM, which is depicted on ***Figure 3***. The 50-foot DEM was further resampled by using an area-weighted average method to the 750-foot resolution and aligned to the model grid, as presented on ***Figure 4***. The center-cell value method used for the 50-foot DEM is deemed reasonable since topographic variations in the study area are not extreme. Accordingly, there are only minor differences in average cell elevation between the center-cell value and the area-weighted average methods when computing the average elevation of a 50-foot cell. The area-weighted average is the best method for the 750-foot grid cells since topographic variations are larger across the area of the 12.9 acres of a 750-foot grid cell. This 750-foot DEM is used as the topographic input in MIKE SHE.

3.0 CLIMATE

The climate component of MIKE SHE includes rainfall and evapotranspiration. Rainfall data available from SFWMD and reference evapo-transpiration data available from USGS are used to develop the model grid array. More information on these two types of data is provided in ***Section 3.1***.

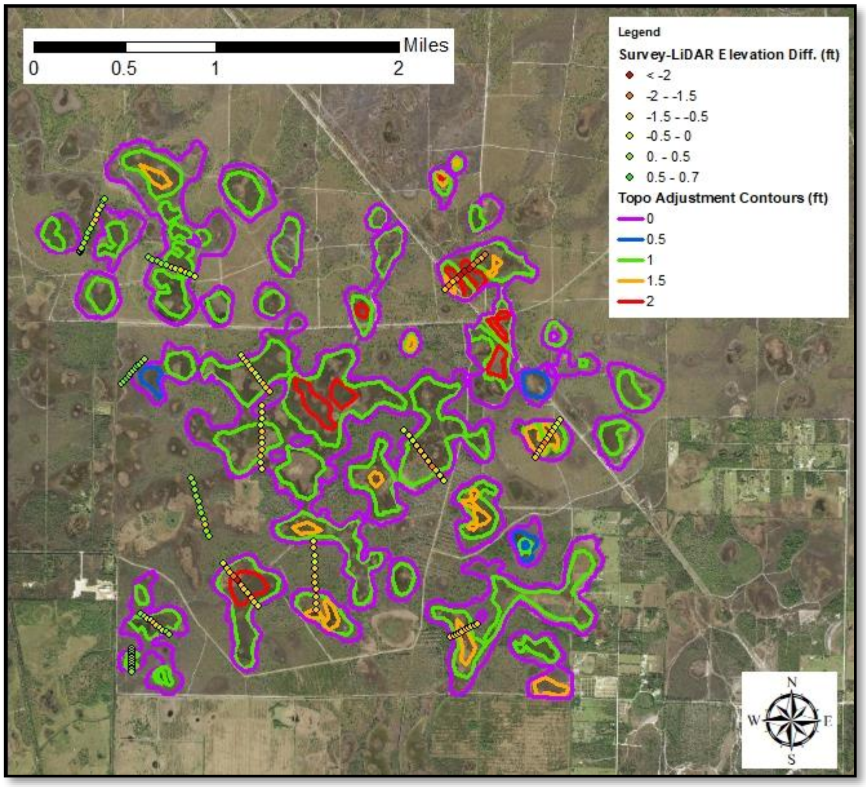

Figure 2. Contours to adjust LiDAR-based DEM in the South Walk-In Area

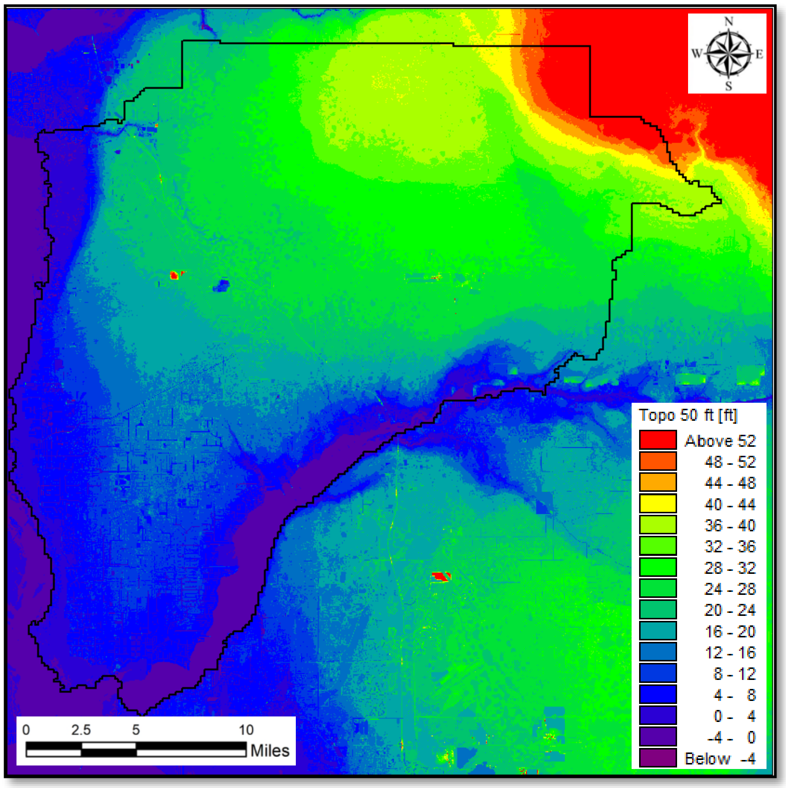

Figure 3. 50-foot topography for the model domain

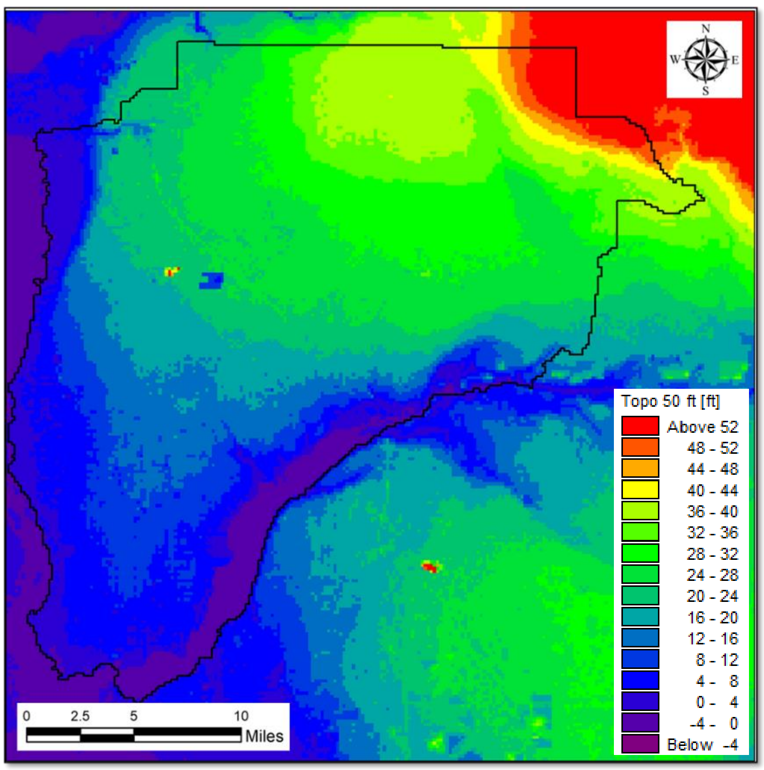

Figure 4. 750-foot topography in the model

3.1 Rainfall

Next Generation Weather Radar (NEXRAD) rainfall data is distributed at a 2-kilometer spatial resolution grid throughout the State of Florida. Each grid cell is referred to as a “pixel”, and it has a pixel and a hydroid number associated to it. The NEXRAD pixels around the Charlotte Harbor (CH) model domain are shown in ***Figure 5***.

The NEXRAD rainfall data covers the period from 1996 to the current date. The raw NEXRAD rainfall data was converted to individual time series “dfs0” files, one for each pixel number in the model domain. ***Figure 6*** shows the hourly rainfall for a pixel located at the center of the model domain during period of record. ***Figure 7*** presents the temporal dependence of spatially averaged rainfall monthly values inside the model domain area. ***Figure 8*** presents the spatial distribution of the annual average NEXRAD rainfall data for the 10-year period 2011 to 2020. The mean annual rainfall inside the model domain is 55.8 inches/year and the range of the spatial variation is about 25 percent.

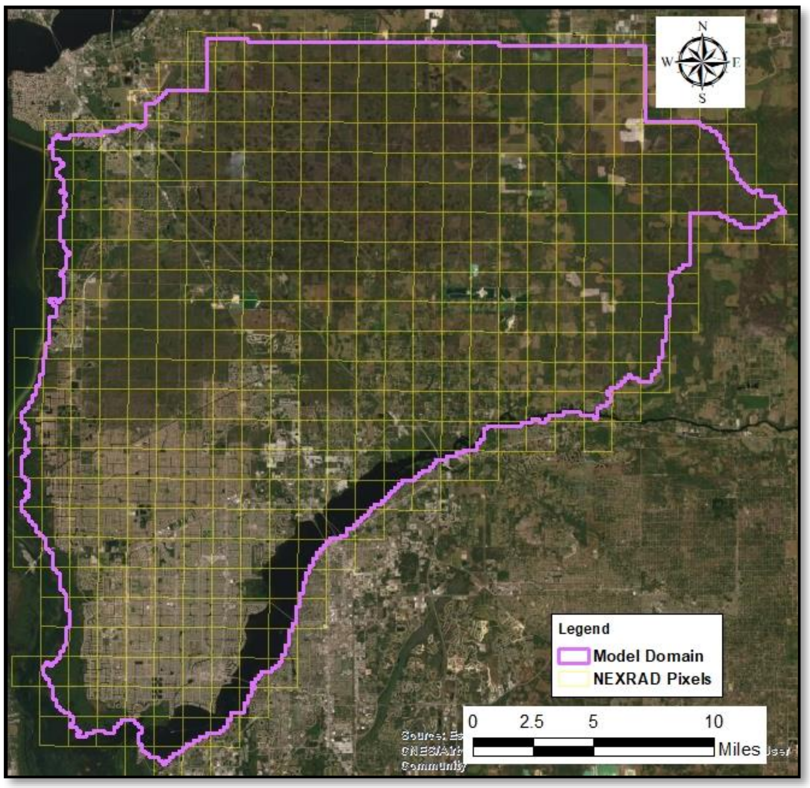

Figure 5. NEXRAD pixels within the model domain

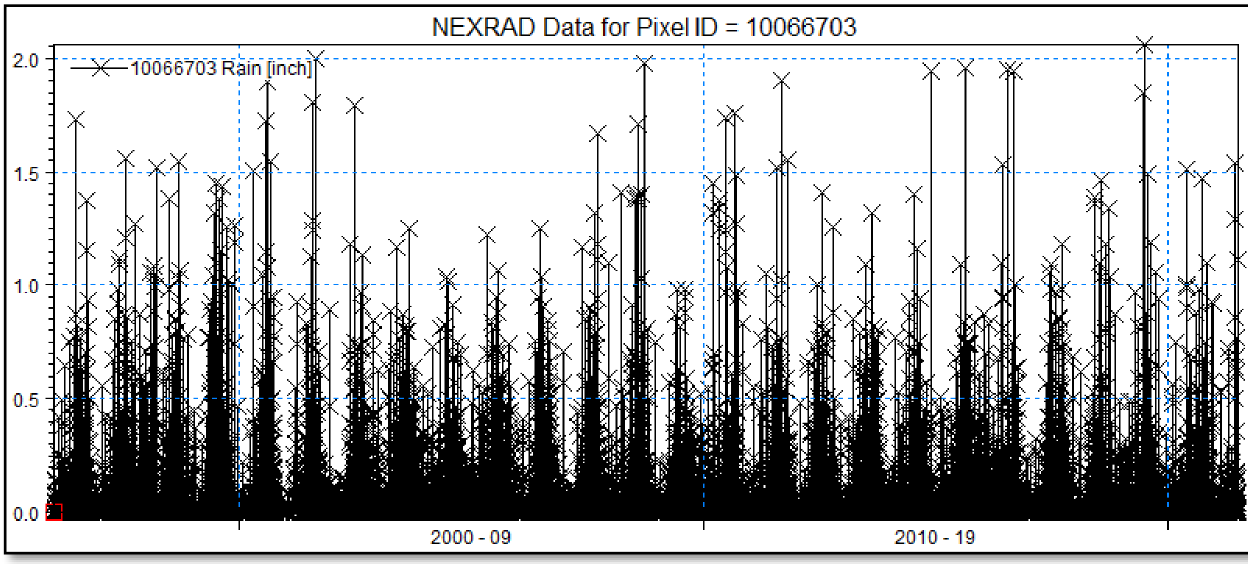

Figure 6. Hourly NEXRAD rainfall for pixel 66703

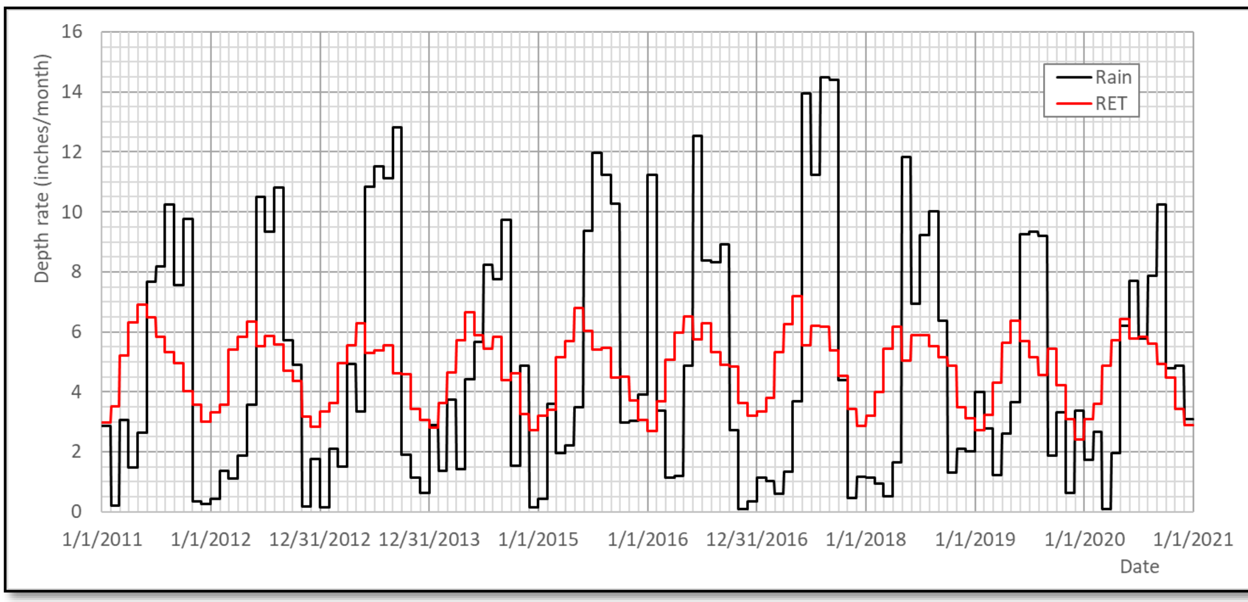

Figure 7. Spatial-averaged monthly NEXRAD rainfall and RET inside the model domain

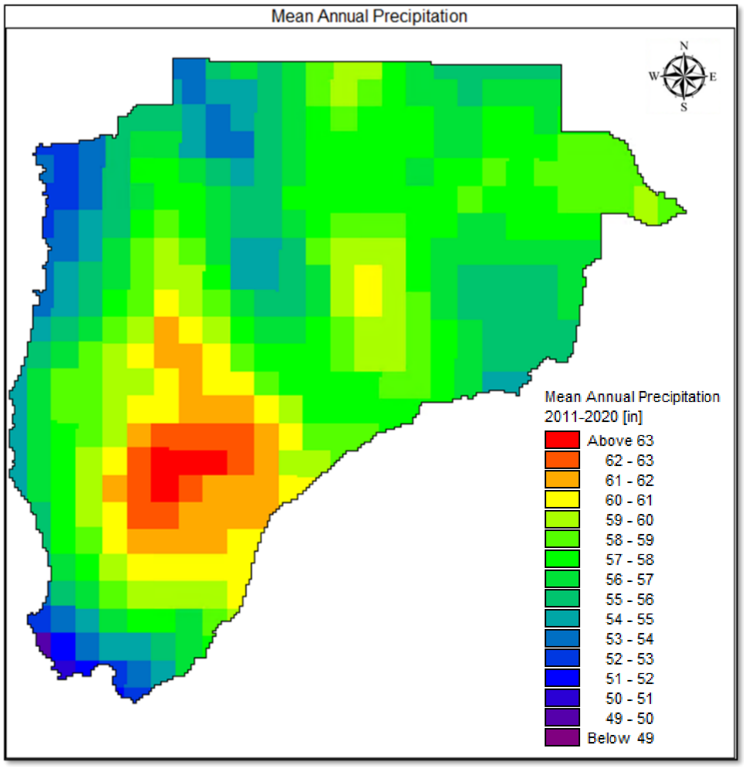

Figure 8. Average annual NEXRAD rainfall inside the model domain over 10-years (2011 to 2020)

3.2 Evapotranspiration

Reference Evapotranspiration (RET) data is available for downloading from the USGS webpage:

https://www.usgs.gov/centers/car-fl-water/science/reference-and-potential-evapotranspiration.

The methodology used to compute RET is described in reference [Mecikalski et al. 2018]. The data files available for download are separated by year and can be downloaded for specific counties or for the entire State of Florida.

The RET rates are computed at a 2-kilometer spatial resolution and a daily time step for the State of Florida. The data currently covers the period from the year 1985 through 2019. The 2- kilometer grid is the same grid used to report the NEXRAD rainfall by pixels, as presented in ***Figure 5***.

In the state file for 2018, the pixel numbering used was different. A crosswalk table was used to refer to the same NEXRAD pixel numbering as used for all the previous years. The data for 2019 were available as a NetCDF (*.nc) file, which was converted to the prior text file format using a MATLAB script.

The missing RET data for small data gaps (less than 6 days) were interpolated linearly by using the two days with data bookending the missing dataset. Julian day average values were used to extrapolate the data for two additional years (2020 and 2021) in each of pixel time series.

The processed daily RET data were converted to individual time series files, one for each pixel number. As an example, ***Figure 9*** presents the time series plot for a pixel located at the center of the model domain. Notice that the Julian Day average values at the end do not have the typical daily oscillations, but they do capture the average seasonal RET dependence.

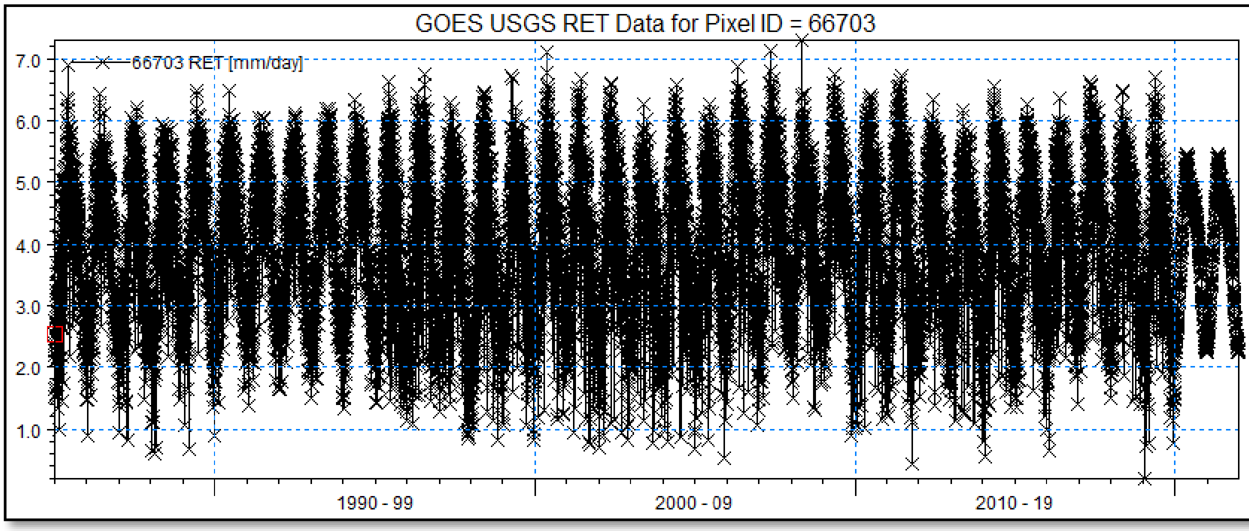

Figure 9. RET time series in mm/day for Pixel 66703 after processing

Figure 10 presents the spatial distribution of the annual average RET data for the 10-year period from 2011 through 2020. The mean annual RET inside the model domain is 57.3 inches/year and the range of the spatial variation is only 7.5 percent...

4.0 LAND USE

4.1 Vegetation and Land Use

Three sources of land use/vegetation coverage were available to update the MIKE SHE model land use input. Those coverage maps overlap in some areas, as shown in ***Figure 11***, and they were included in the MIKESHE land use map in the following order of priority.

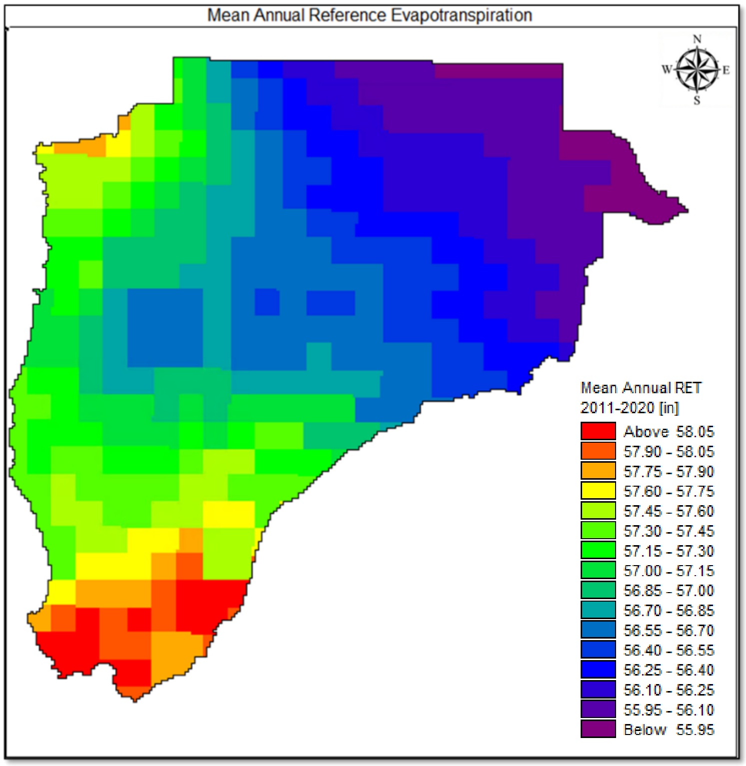

Figure 10. Annual average USGS RET data inside the model domain over 10-years (2011 to 2020)

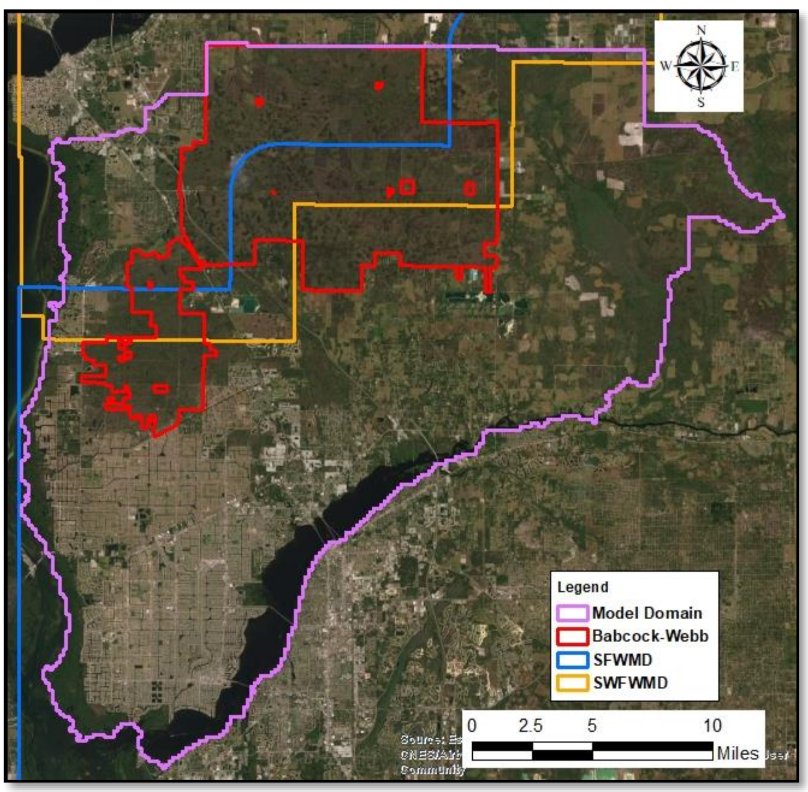

Figure 11. Land use/vegetation coverage source

1. Babcock Webb vegetation coverage from FWC.
2. 2014 to 2016 land use/vegetation coverage map from SFWMD.
3. 2017 land use coverage map from SWFWMD.

The available land use/vegetation coverage files have numerous classes that can be grouped into a manageable number of land use/land cover classifications. The original classes were converted to a smaller set of MIKE SHE codes by using the cross walk table presented in ***Table 1***. The polygon shapefile with the MIKE SHE land use/vegetation code coverage was resampled to the 750-foot model grid resolution by using the maximum combined area method. Then, manual adjustments of the MIKE SHE classification at some cells were completed based on aerial images and field observations. ***Figure 12*** presents the resulting 750-foot resolution land use/vegetation map for existing conditions.

Table 1. Cross reference table to convert to MIKE SHE Land use/Vegetation codes

MIKE SHE Code	MIKE SHE Land use / Vegetation Class	Babcock Webb vegetation	SFWMD Land Use FLUCCS Code	SWFWMD Land Use FLUCCS Code
1	Citrus		2210, 2230	2210, 2230
2	Pasture	Ruderal	1920, 2110, 2120, 2130, 2240, 2420,2510, 2520, 2610, 3100, 8320	1920, 2110, 2120, 2130, 2610, 8320
5	Truck Crops		2140, 2150, 2500	2140, 2150
6	Golf Course		1820	1820
7	Bare Ground		1610, 1620, 1630, 1670, 1810, 7200, 7400, 8120, 8350	1610, 1620, 1630, 1670, 1810, 7200, 7400, 8120, 8350
8	Mesic Flatwood	Dry Prairie, Mesic Flatwoods, Ruderal	1650, 1900, 2410, 2430, 3200, 3210, 3300, 4110, 4370, 4410, 4430, 7420, 7470	1650, 1900, 2240, 3100, 3200, 3210, 3300, 4110, 4370, 4410, 4430, 7470
9	Mesic Hammock	Mesic Hammock	4200, 4220, 4270, 4271, 4340	4200, 4220, 4270, 4271, 4300, 4340
10	Xeric Flatwood			4130
11	Xeric Hammock		3220, 4120	3220
12	Hydric Flatwood		6240, 6250	6240, 6250
13	Hydric Hammock	Hydric Hammock	4240, 4280, 6180, 7430	4240, 4280, 6180, 7430
14	Wet Prairie		6430	6430
16	Marsh	Basin Marsh, Depression Marsh	6410, 6411, 6440	6400, 6410, 6440
17	Cypress	Ruderal, Wet Flatwoods	6200, 6210, 6215, 6216	6200, 6210, 6215, 6216
18	Swamp Forest		6170, 6172, 6191, 6300	6170, 6172, 6191, 6300
19	Mangrove		6120, 6420	6120, 6420
20	Water	Ruderal	1660, 1840, 2540, 5110, 5120, 5200, 5300, 5410, 5420, 5430, 6510, 8360	1660, 1840, 2540, 5110, 5120, 5200, 5300, 5410, 5420, 5720, 6510, 8360
41	Urban Low Density	Ruderal	1110, 1120, 1130, 1180, 1190, 1480, 1850, 1860, 1890	1110, 1120, 1130, 1180, 1190, 1480, 1850, 1860, 1890, 2320, 2410, 2430, 2500, 2510
42	Urban Medium Density	Ruderal	1210, 1220, 1230, 1290, 1730, 1760, 1870, 8113, 8330, 8340	1210, 1220, 1230, 1290, 8330, 8340
43	Urban High Density	Ruderal	1310, 1320, 1330, 1340, 1390, 1400, 1411, 1423, 1460, 1490, 1540, 1550, 1700, 1710, 2320, 8110, 8115, 8140, 8200, 8300, 8310	1310, 1320, 1330, 1340, 1350, 1390, 1400, 1411, 1423, 1460, 1490, 1540, 1550, 1560, 1700, 1710, 1830, 8110, 8115, 8140, 8200, 8300, 8310

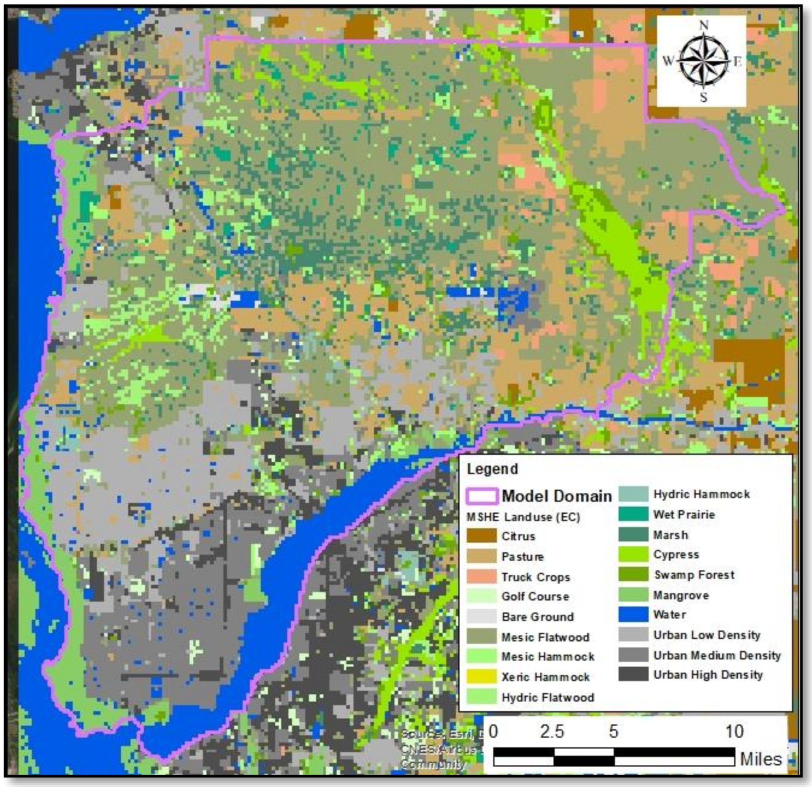

Figure 12. Existing conditions MIKE SHE vegetation codes in the Model

4.2 Land Use/Vegetation Related Parameters

The land use/vegetation map in the MIKE SHE model determines other input parameters in the model according to the parameter relationships presented in ***Table 2***. The resulting input parameter maps for the existing conditions are presented in ***Figures 13*** through ***17***. Manning's M values presented in Table 2 are a starting point and were taken from a recently calibrated model developed by this modeling team for South Lee County. The Manning's M value of 4 used for most of Babcock Webb and Yucca Pens is equivalent to a Manning's n value of 0.25, which is a typical value used for a flatwoods/marsh complex. Sensitivity tests will be conducted with varying levels of overland flow roughness. In the case of pasture coverage parameters, Drainage Depth/Time Constant were set to "-0.5" if they were irrigated or "0" or "0.25" if they were not irrigated.

4.3 Irrigation

The Irrigation Command Areas (ICAs) determine where irrigation is applied in the model as well as the application rate and the irrigation source. The ICA map and parameters were updated based on water use permit (WUP) information, vegetation land use coverage, and aerial images. Irrigation is only applied to land use grid cells classified as agricultural and urban. ***Figure 18*** shows the updated ICA code map.

The irrigation demand in the model is based on the soil moisture deficit estimated internally in the model, except for the City of Cape Coral area where the reported irrigation from canals and reuse water is applied.

5.0 RIVERS AND FLOW-WAYS

Conveyance in rivers, canals, creeks, and defined flow-ways is simulated with MIKE 11, which is directly linked to MIKE SHE. At each time step, surface water and groundwater data are delivered between MIKE SHE and MIKE 11. Communication between model components occurs at each time step and the model time step varies according to the amount of rainfall. The model setup includes a maximum amount of rainfall per the overland time step. This value was set at 25 mm (1 inch). If rainfall exceeds this amount, then the model time step for all layers (overland, unsaturated zone, saturated zone, and MIKE 11) reduces by the user-defined increment rate (varies between 0 and 1; 0.05 utilized in this model). The precipitation time series will then be re-sampled to see if the maximum precipitation depth criteria has been met. If it has not been met, the process will be repeated with progressively smaller time steps until the precipitation criteria is satisfied. This feature allows the model simulation to proceed quickly during dry conditions, while permitting the simulation to avoid instabilities resulting from infiltration inputs from the overland flow routine to the water table aquifer and river/groundwater exchanges.

Table 2. Land use associated model parameters and land use/vegetation classes [Lago 2021]

MIKE SHE Code	Land use / Vegetation Class	OL Manning's M	OL detention Storage (inches)	Paved Runoff Coefficient	Drain Depth (ft)	Drain Time Constant (1/day)
1	Citrus	7.1	1	0	2	0.25
2	Pasture	8.6	1.2	0	0 or 0.5	0 or 0.25
5	Truck Crops	7.1	1	0	1	0.25
6	Golf Course	8.6	1.2	0	1	0.25
7	Bare Ground	13.6	1.2	0	0	0
8	Mesic Flatwood	6.0	1.2	0	0	0
9	Mesic Hammock	4.0	1.2	0	0	0
11	Xeric Hammock	6.0	1.2	0	0	0
12	Hydric Flatwood	4.8	1.2	0	0	0
13	Hydric Hammock	3.0	1.2	0	0	0
14	Wet Prairie	4.0	1.2	0	0	0
16	Marsh	2.8	1.2	0	0	0
17	Cypress	4.0	1.2	0	0	0
18	Swamp Forest	3.0	1.2	0	0	0
19	Mangrove	6.0	1.2	0	0	0
20	Water	2.4	1.2	0	0	0
41	Urban Low Density	8.6	1	0.05	0.5	0.25
42	Urban Medium Density	10.0	0.4	0.15	0.75	0.35
43	Urban High Density	10.8	0.13	0.45	1	0.5

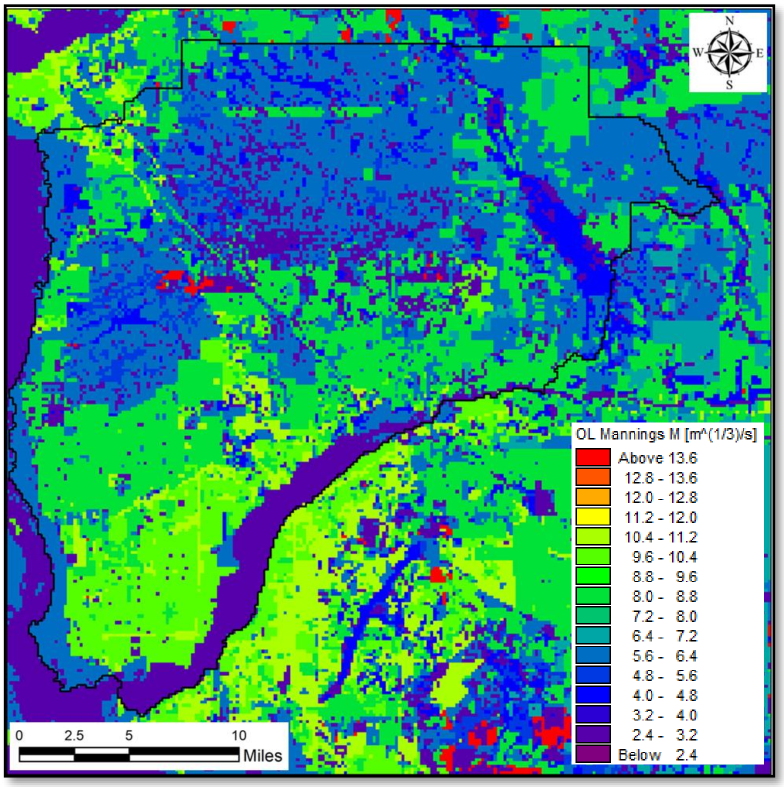

Figure 13. OL Manning's M map in the model

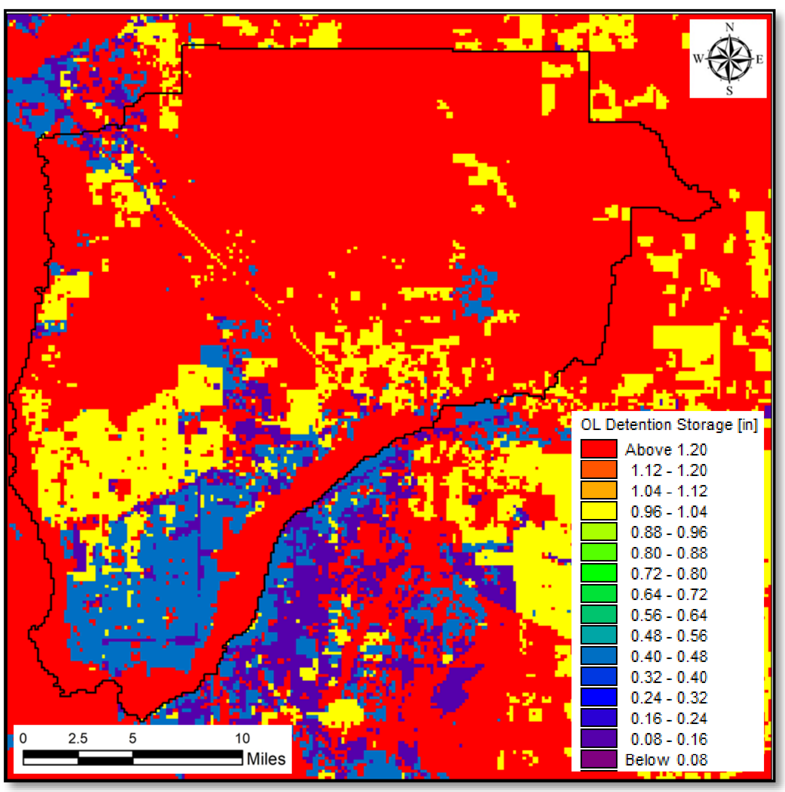

Figure 14. OL detention storage map in the model

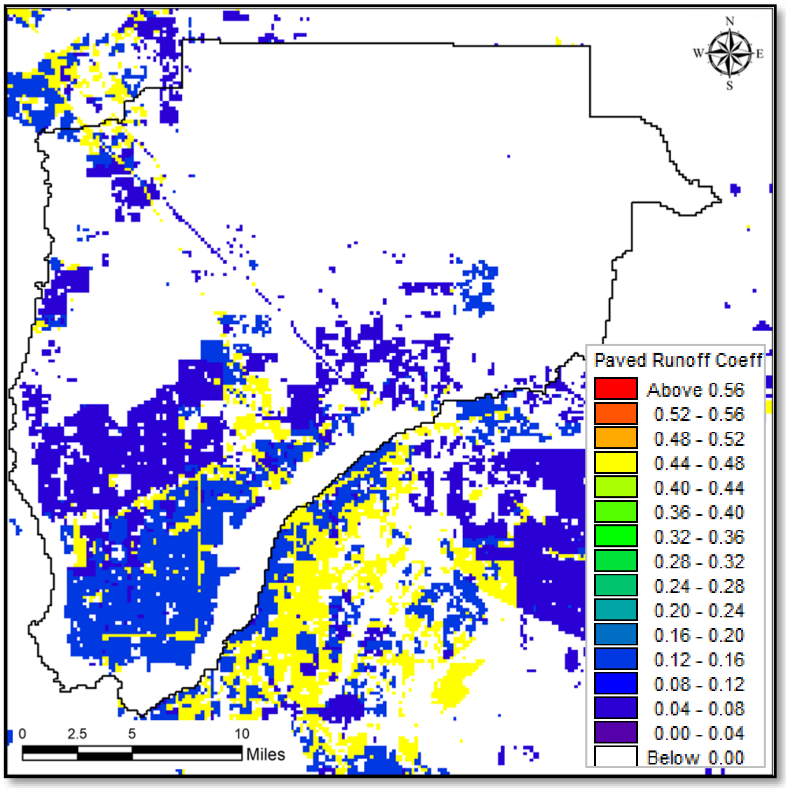

Figure 15. Paved runoff coefficient map in the model (fractional value ranging from 0-1)

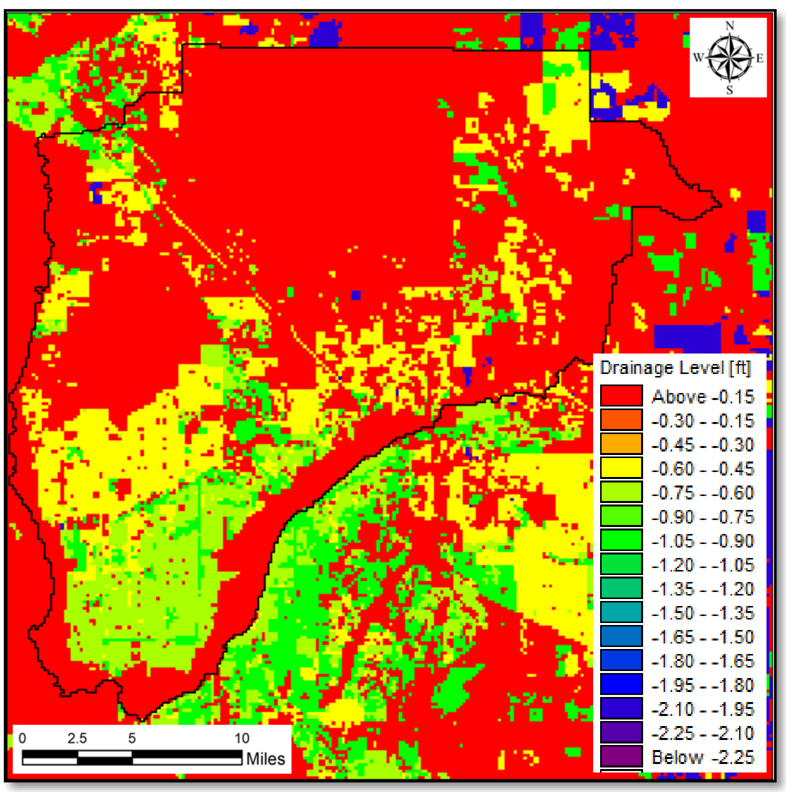

Figure 16. Drainage level map in the model

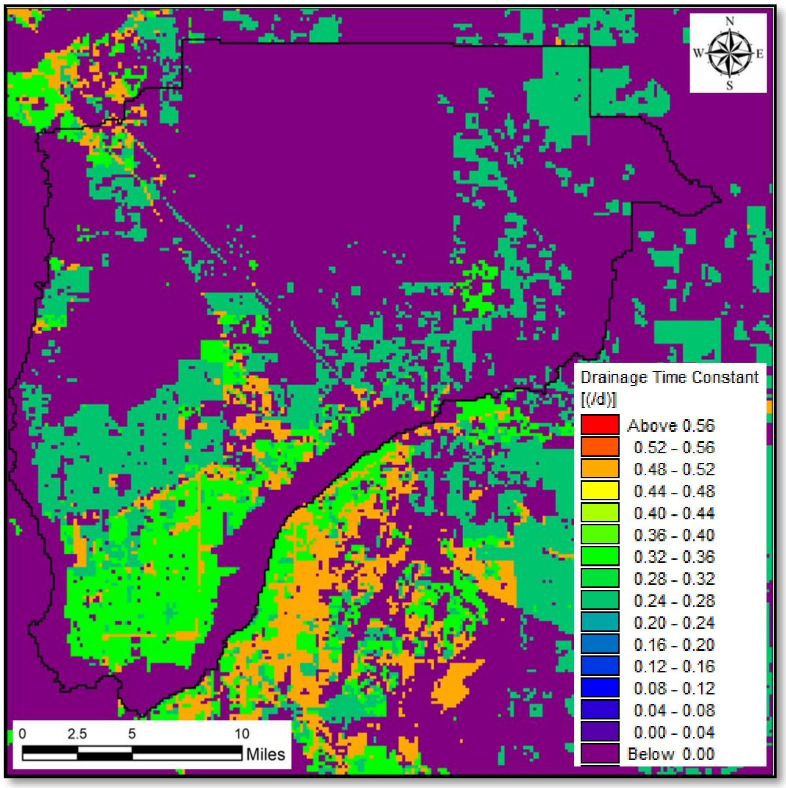

Figure 17. Drainage time constant map in the model

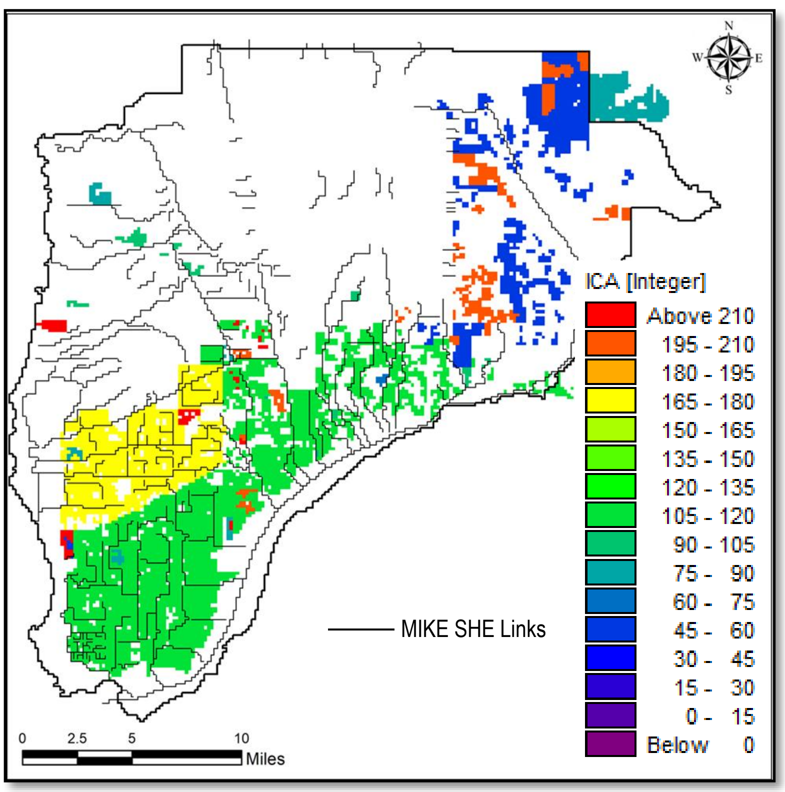

Figure 18. Updated ICA map in the model

5.1 MIKE 11

The MIKE 11 component includes the following:

- A network file that has line features (referred to as "branches") representing rivers, creeks, and flow-ways. More information is presented below in the sub-section **Network**.
- A cross-section file that defines the dimensions of the rivers, creeks, and flow-ways. A typical cross-section added to the model from surveyed data is shown in ***Figure 19***. The cross-section file includes both surveyed cross-sections and cross-sections cut from the topographic data file described above. More information on cross-sections is provided below in the sub-section **Cross Sections**.
- A boundary file that provides information at the beginning and ends of network branches that are not connected to other branches. The boundary file also includes any inputs along a branch, such as a pump station that either adds or removes flows from a river branch.
- A hydrodynamic file that describes initial conditions, bed roughness, and computational parameters.

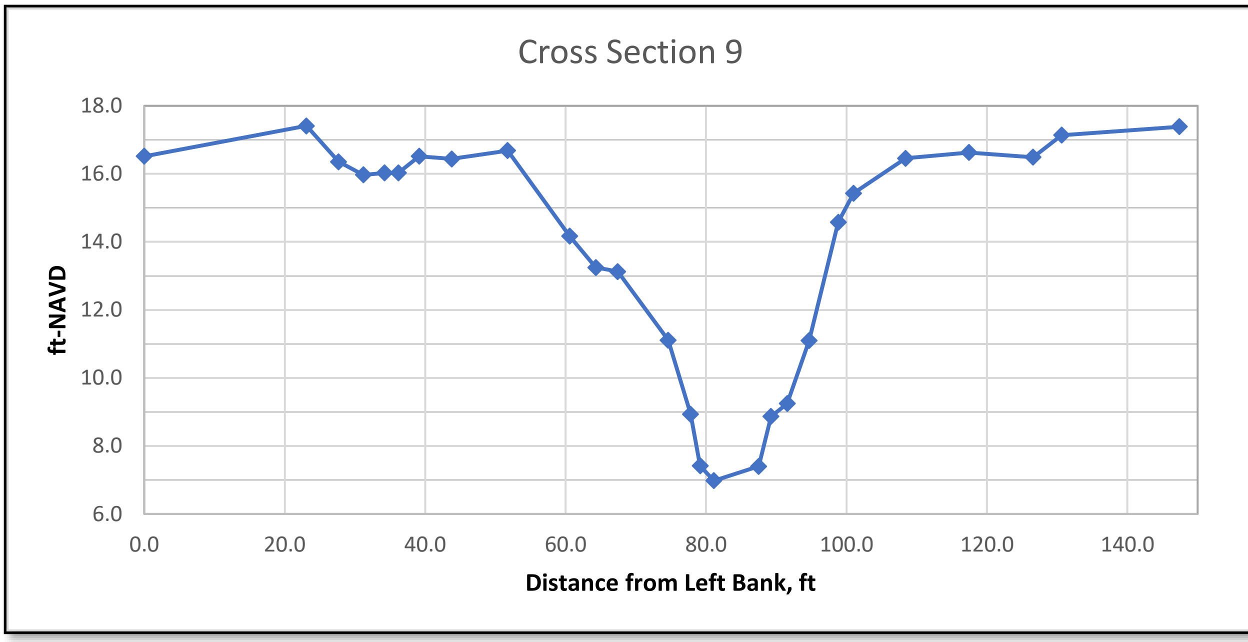

Figure 19. Cross-Section for Zemel Canal (CHNEP 2019)

Network. The network file presented in ***Figure 20*** has continuous branches for rivers, creeks, and ditches such as Zemel Canal or Alligator Creek. The network file also has branches for flow-ways with lower velocities, such as cypress sloughs and marshes that have been connected via excavated ditches. These flow-ways are typically characterized by differing hydraulic and geometric characteristics than rivers or creeks. In addition to increased sinuosity, numerous tree deadfall, and dense vegetation bed roughness is typically higher for these vegetated flow-ways where velocities are typically quite low. Short branches have been included in the MIKE 11 network to represent existing culverts that connect wetlands that are on both sides of gravel roads within Babcock Webb and Yucca Pens WMAs. The model domain includes Telegraph Slough (location shown in ***Figure 1***) since several culverts under SR 31 discharge water from Babcock Webb WMA to Babcock Ranch. Though the representation of Telegraph Slough is less detailed than for most of the model, including it in the model minimized boundary condition errors on the east border of Babcock Webb WMA.

Cape Coral canals presented in ***Figure 21*** are included in the model domain since Gator Slough, located at the northern end of Cape Coral, is adjacent to the southern boundary of Yucca Pens. Outflows into the Cape Coral canal system are routed through a series of weirs, pump stations, and pipelines. Cape Coral Weir 58 conveys water from Gator Slough into Basin 4 of the Cape Coral canal system. The North-South Transfer Station, located at the south end of Basin 4, conveys water from Basin 4 to the Cape Coral canals south of Pine Island Road. Several Canal Pump Stations (CPS 2, 3, 4, 5, and 8) located south of Pine Island Road pump water into an irrigation distribution system that delivers a mix of treated wastewater and canal water to irrigate residential land primarily south of Pine Island Road. CPS 10, located in Basin 4 north of Pine Island Road, was constructed in 2020 with initial operation beginning in 2021. This irrigation pipeline delivery system is gradually being expanded into neighborhoods north of Pine Island Road.

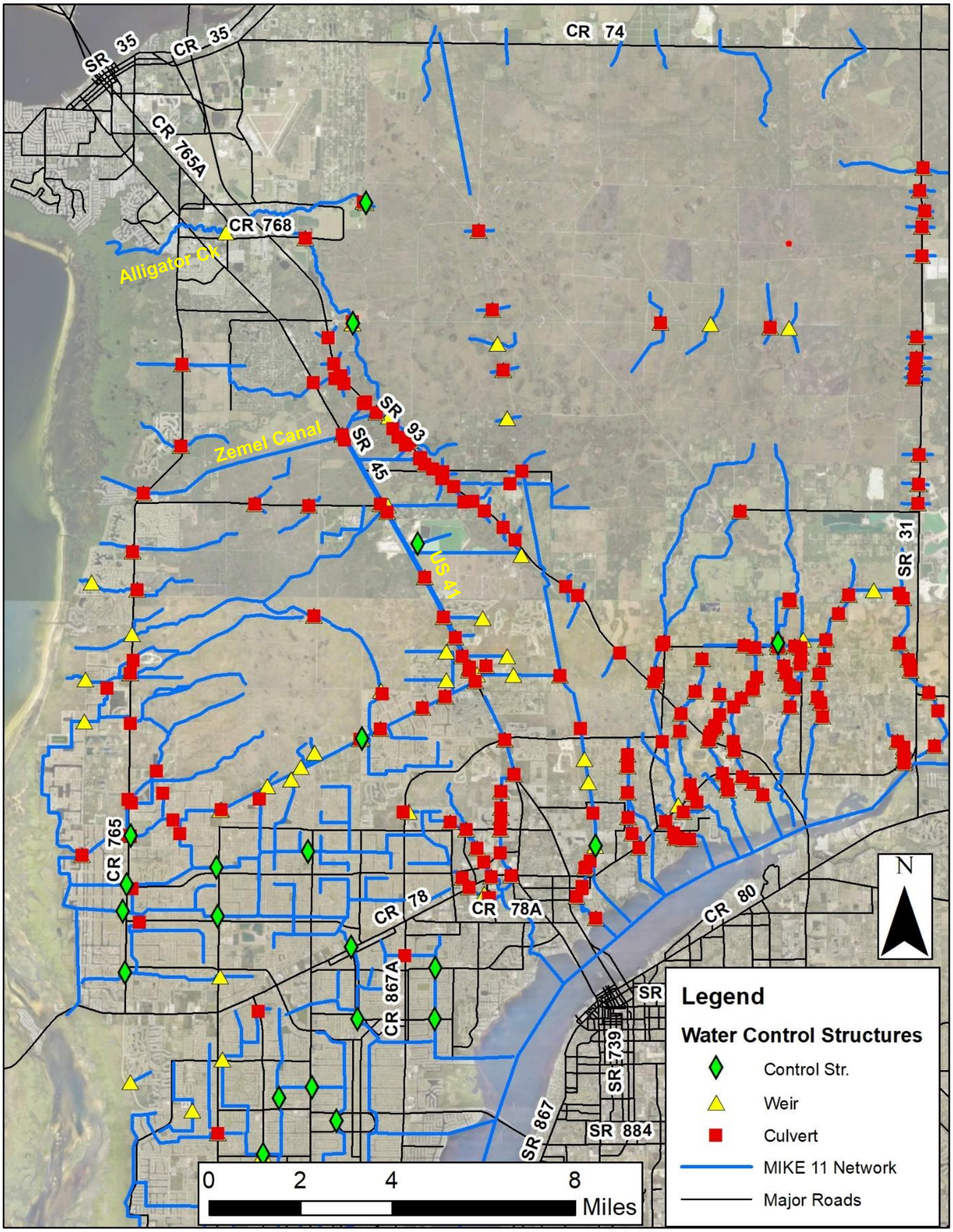

Figure 20. MIKE 11 branches and structures in the model

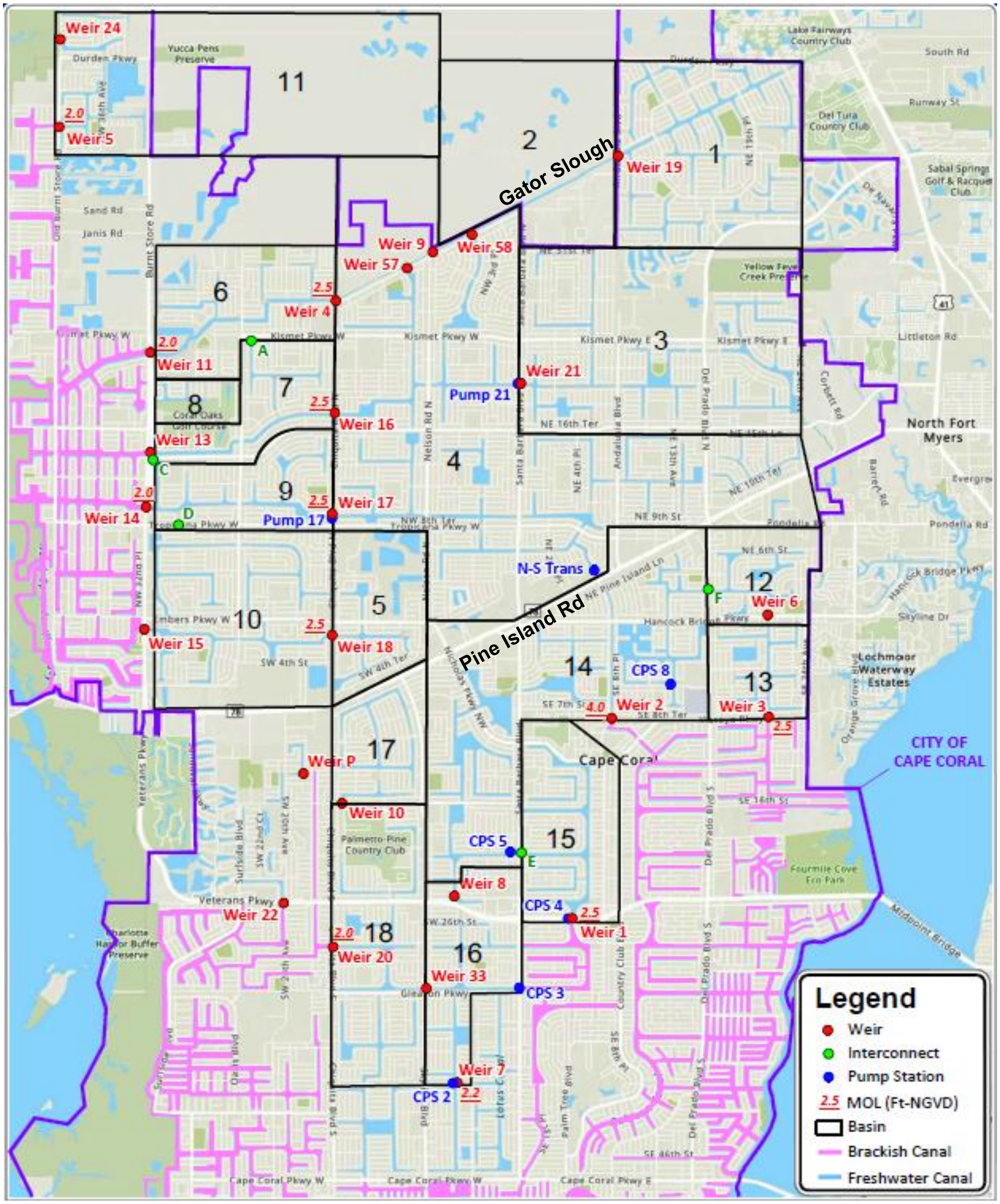

Figure 21. Cape Coral canals and structures

Water levels in Gator Slough are maintained by a number of weirs, gated and ungated, between U.S. 41 and Burnt Store Road. Including the Cape Coral canals within the model domain provides a more robust representation of the groundwater dynamics along the southern border of Yucca Pens. Reported gate operations for Weir 11, Weir 13, and Weir 19 have been incorporated into the model. Other gates in Cape Coral canals north of Pine Island Road (Weirs 14, 15, 16, and 17) are operated according to control logic and are fully open during the summer wet season period (June 15 through October 14). Pump stations (North-South Transfer, Weir 21 forward pump, Weir 17 back-pump, and CPS 10) in Cape Coral canals north of Pine Island Road impact water levels in northern Cape Coral canals and reported flows for those pump stations are used to define when those pumps are operating. All gates south of Pine Island Road are operated according to control logic. CPS 2, 3, 4, 5, and 8, south of Pine Island Road, are configured in the MIKE 11 network to operate according to reported information. Calibration of water levels in Cape Coral canals south of Pine Island Road will be limited by the gap in information regarding operation of key structures.

Cross-Sections. The 2013 MIKE SHE/MIKE 11 model developed for FDOT (ADA 2013) included approximately thirty-five surveyed cross-sections. ***Figure 22*** presents a map of surveyed cross sections that have been added to the MIKE 11 network. Survey data was obtained for North Fort Myers from a 2010 stormwater management plan (AECOM 2010). The cross-sections were created from the raw survey data for the FDOT model. Cross-sections for U.S. 41 ditches south of Zemel Road (ten locations) and Gator Slough west of U.S. 41 to Weir 4 (twenty-two locations) were surveyed in 2017 and were appended to the cross-section file. Cross-sections were surveyed at fifty-eight locations in Yucca Pens in 2019 for CHNEP and FWC (WSA & SED 2019) and have been added to the cross-section file. Cross-sections for the remaining areas have been cut from the DEM. Edits were made to some of the DEM-cut cross-sections to represent ground surface elevations with the main channel, where more detailed information was obtained either from field work or permit files.

Culvert and bridge dimensions have been obtained from numerous sources including Charlotte County DOT, FDOT, Lee County DOT, and Cape Coral. In addition, culvert information and cross-section data were obtained from the Matlacha Pass Hydrologic Restoration Project – Phase 1 (Boyle Engineering 2007), Yucca Pens Hydrologic Restoration Plan (BPC 2010), North Fort Myers Surface Water Restoration Project (ECT 2004), North Fort Myers Surface Water Management Plan (AECOM 2010), and the Cape Coral Stormwater Model Draft Final Report (AIM/ADA 2015).

Boundaries. Tide level boundaries are applied to all creeks and canals that discharge to tide. The SFWMD MARKH station is being used for the Cape Coral canals and all canals north to, and including Alligator Creek in Punta Gorda. The modeling team is seeking a Charlotte Harbor tide water level time series that can be used for the tidal boundary on the northern portion of the model domain in future modeling efforts. Data from a tidal monitoring station at the mouth of the Caloosahatchee Estuary will be used if tidal water level data for Charlotte Harbor cannot be secured. Flowing east from Telegraph Slough to Cypress Creek, the model boundary for Bullhead Strand was generated from simulated water levels from simulated water levels for the Four County Corners MIKE SHE/MIKE 11 model, a MIKE SHE/MIKE 11 model for the County Line Drainage District (WSA 2018a). Boundary time series files for creeks and ditches on the northern model boundary were estimated based on the range of water levels observed in monitoring well BW-1 and the SWFWMD groundwater monitoring stations 25100 and 25096.

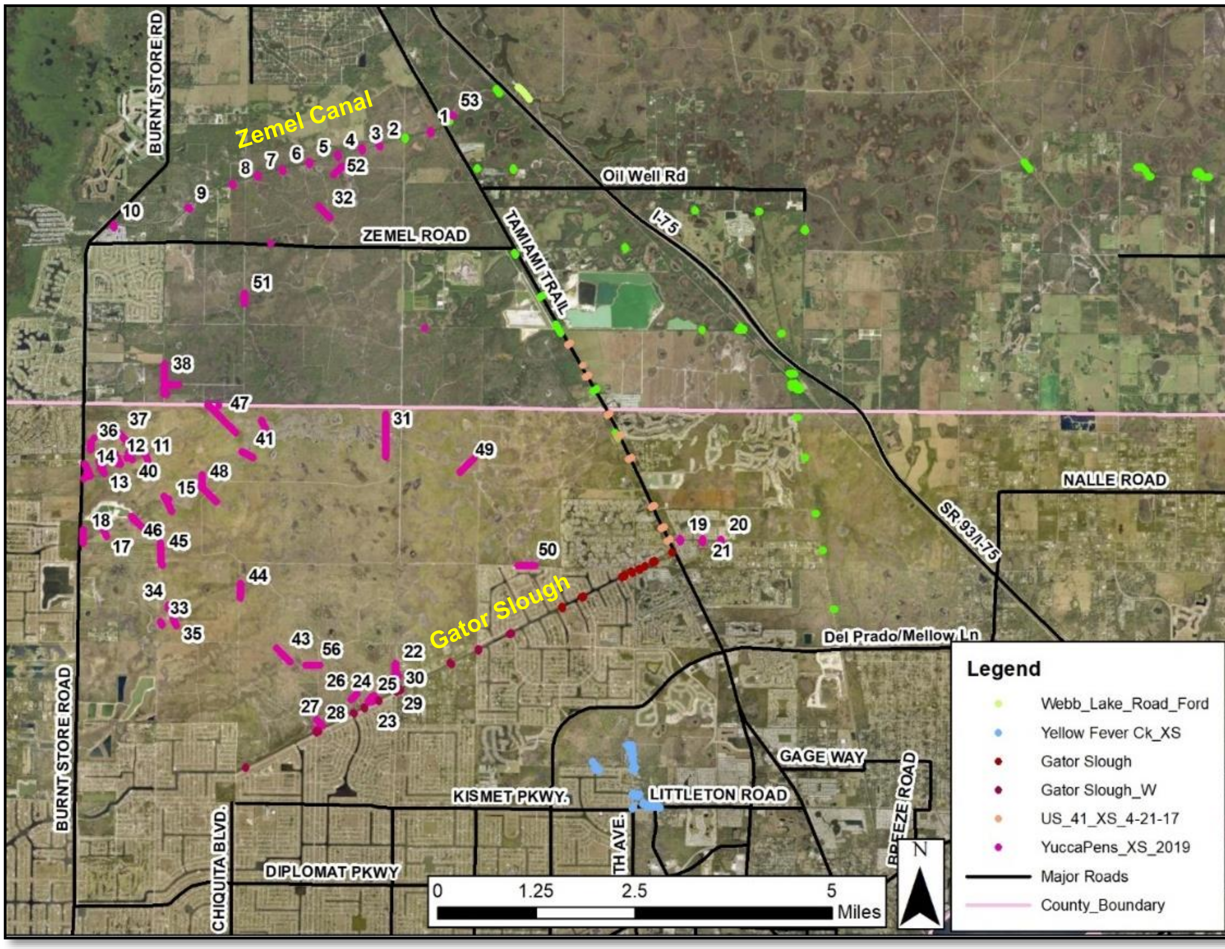

Figure 22. Cross section data used to update MIKE 11 cross-section file

5.2 Flood Codes

Flood codes provide a method to allow water out of the MIKE11 branches into the overland (OL) component. Flood codes are used in conjunction with wide MIKE11 cross-sections so the ponded water storage is considered in MIKE11 and not in the OL component. As described in the following section, overland flow occurs when rainfall rates exceed the infiltration rate or when groundwater elevations reach the land surface and additional rainfall is experienced. Flood codes are used to either allow or prevent movement between the two model components. A good example of flood code usage is the Seaboard Atlantic (SAL) Grade and Myrtle Creek just south of CR 74 in Charlotte County line presented in ***Figure 23***. The SAL Grade is an abandoned railroad grade that prevents flows to the west, while allowing flows into the SAL Grade Ditch located just east of the SAL Grade. Conversely, Myrtle Creek does not have any berms or levees on either side, which allows for flows to move into and out of the creek and exchange with water ponded on the land surface.

Figure 24 presents the flood codes map in the model. In general, a different flood code was chosen for each MIKE11 branch to assure that the flood-coded cells are linked to the correct branch.

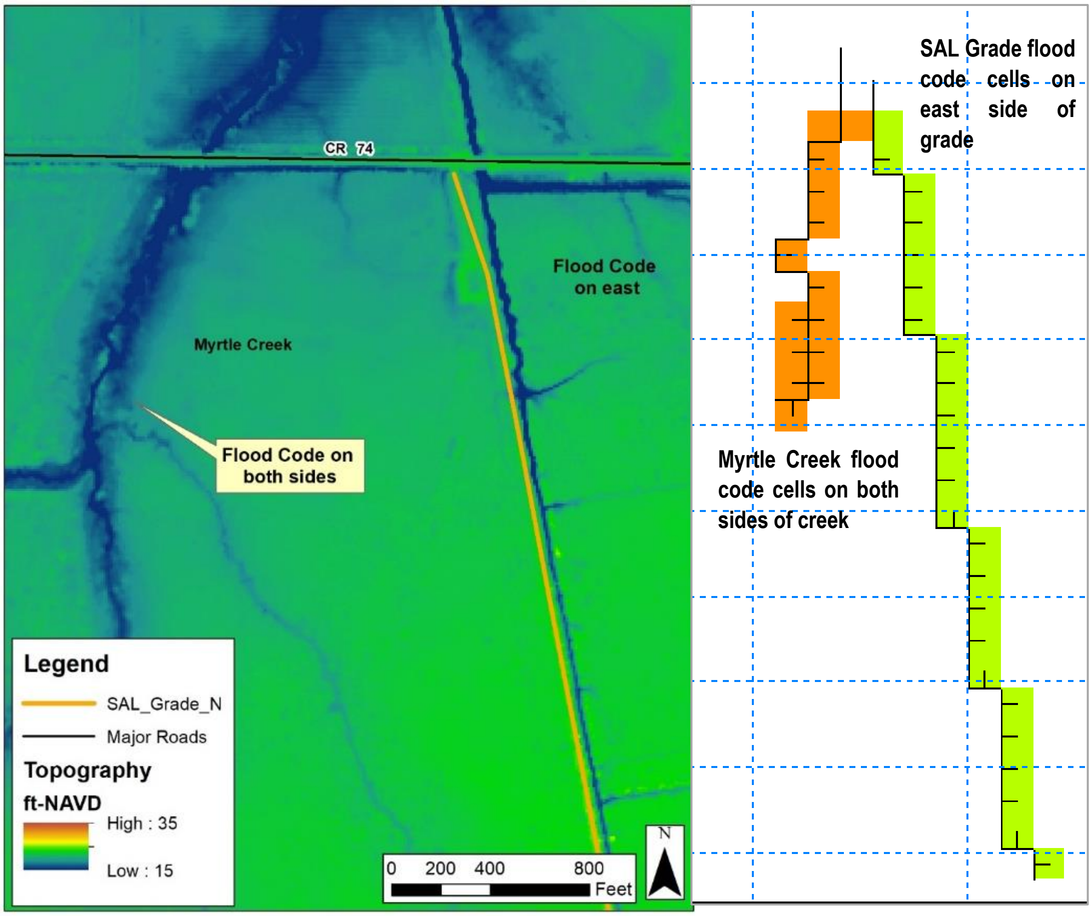

Figure 23. Flood code application along SAL in Charlotte County south of CR 74

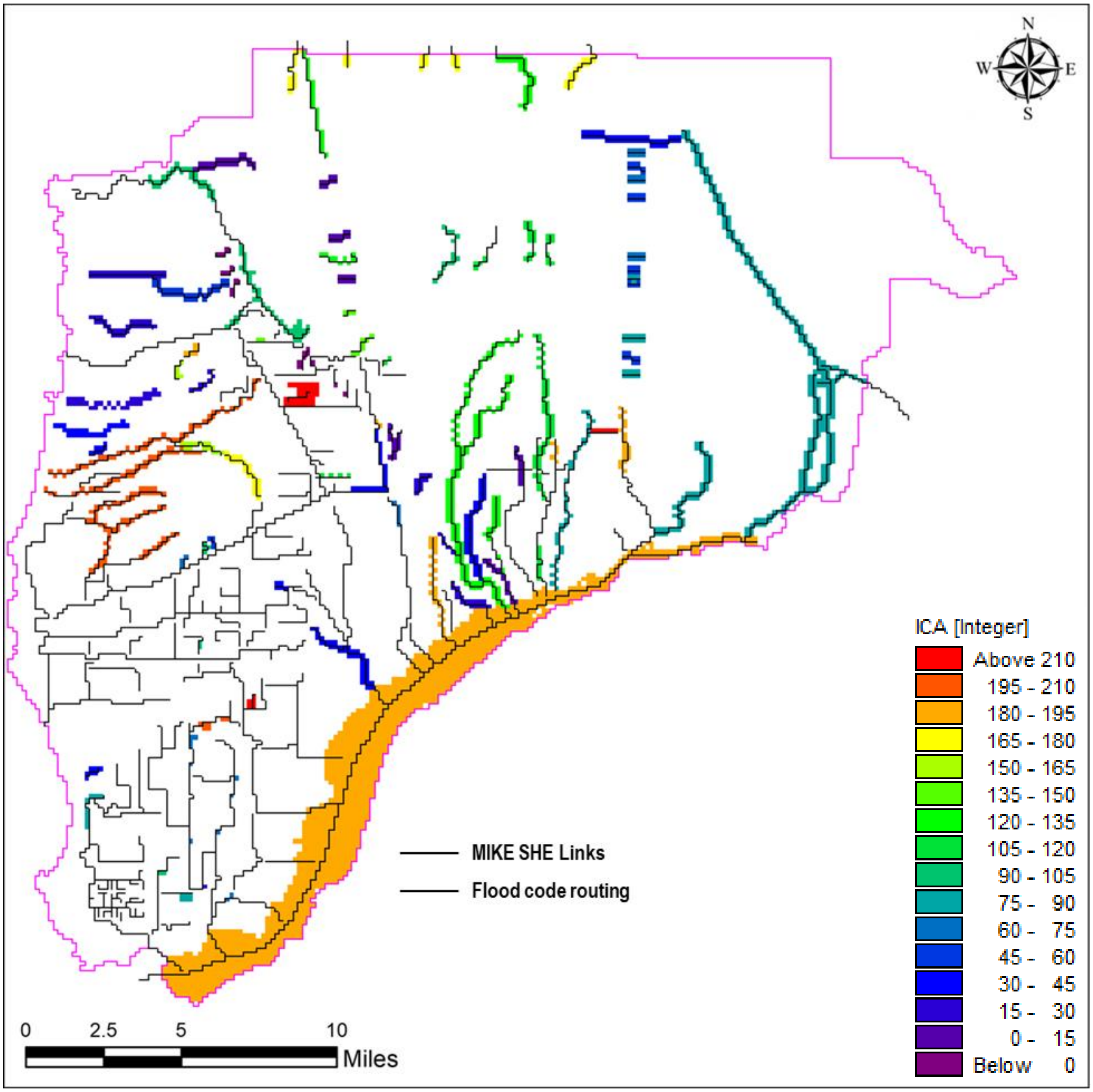

Figure 24. Irrigation command areas used in the model

6.0 OVERLAND FLOW COMPONENT

The overland (OL) flow module in MIKE SHE uses a separated overland flow area (SOLFA) map to limit the overland flow across berms and roads. This option is useful when the road or berm width is smaller than the grid cell size and the increase in the ground elevation does not show up in the topographic grid map. This is a common occurrence with a model cell size of 750-feet.

The OL component allows flow only between cells with the same SOLFA grid code. Therefore, different SOLFA grid codes are assigned on the different sides of the surface water divide to suppress OL flows. ***Figure 25*** shows the SOLFA map used in the model.

The following OL flow divides are represented in the SOLFA map of ***Figure 25***:

1. Along some major street, railroad, and berm segments; where MIKE11 branches are the only way for the surface water to flow across those impediments.
2. Around the model boundary, where the boundary conditions imposed in MIKE11 and in the saturated zone (SZ) computational layers are controlling the flows across the boundary.
3. Along some MIKE SHE link segments. This is redundant since MIKE SHE links already prevent OL flow to cross MIKE SHE link segments.

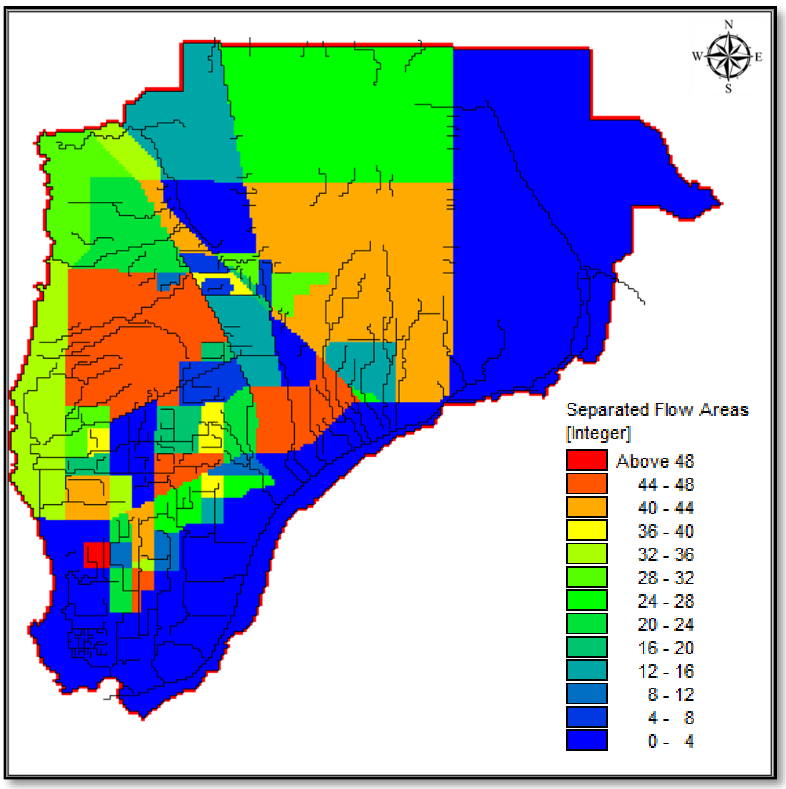

Figure 25. SOLFA map in the Model

7.0 UNSATURATED ZONE COMPONENT

The unsaturated zone (UZ) component governs vertical movement of water through the soil horizons. There are a number of methods for calculating water movement in the unsaturated zone that vary in complexity and affects run time of the model. This MIKE SHE model uses the two-layer water balance method in combination with the Green-Ampt method to compute the infiltration. Other methods such as the Richards Equation and the Gravity Flow methods have been used in past projects but are not employed here since irrigation is not a significant component of the water budget for this project. The Gravity Flow method divides the soil horizon into multiple horizons, each with its own soil properties. The Richard's Equation method uses the same discretization of the soil column but includes capillary rise in the equations used to solve the infiltration process. The most accurate method is the Richards Equation. However, simulation run time is longer with this method. Based on prior experience with all three methods, the modeling team feels that the two-layer water balance method is the best approach to take on this project, however the calculation method may be changed during the calibration process.

7.1 Soil Classes and Distribution

The previous model used a few soil classes. The updated model uses the soil classification from the most current Natural Resources Conservation Service (NRCS) soil database based on the MUKey code.

Polygon shape files with the Soil Survey Area (SSURGO) for Lee, Collier and Hendry counties were downloaded from the NRCS Web Soil Survey webpage. The polygons with MUKey codes are combined and resampled to the 750-foot model grid by using the maximum combined area method (see ***Figure 26***). The MUKey codes are unique for each county, and there is a total of 174 codes around the model grid area. Due to the large number of soil codes, ***Figure 26*** does not include a legend defining each MUKey code. The location of each soil code can be viewed within the MIKE SHE graphical user interface (GUI).

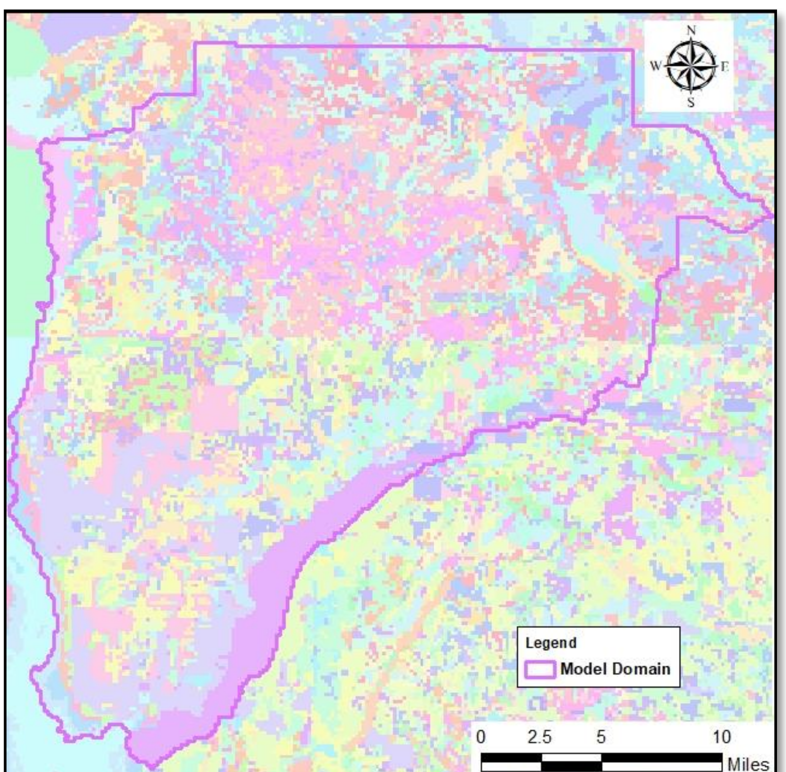

Figure 26. NRCS soil MUKey distribution around the model domain

7.2 Soil Parameters

Soil parameter values were obtained from the NRCS Soil Survey webpage. The Interconnected Channel and Pond Routing (ICPR) model software documentation offers a methodology to find depth average soil parameters for the different NCRS soil classes. Note that each NCRS soil class is composed of layers or soil horizons, but the two-layer water balance method in MIKE SHE needs depth-averaged soil parameters.

Depth-averaged soil parameters for each MUKey code are found by following the Green-Ampt Template Worksheet procedure from the ICPR documentation [ICPR 2021]. Mean, minimum, and maximum values from the soil parameters inside the model domain are also summarized in ***Table 3***. The resulting five soil parameters necessary for the two-layer method are mapped in ***Figure 27*** through ***31***. The soil parameter maps show a discontinuity at the county boundaries, which is not expected to significantly affect the model results.

Table 3. Soil parameter values and ranges within the model domain

Soil Parameters	Minimum	Mean	Maximum
Water Content at Saturation	0.372	0.405	0.672
Water Content at Field Capacity	0.013	0.114	0.495
Water Content at Wilting Point	0.004	0.051	0.168
Hydraulic Conductivity (Kh) at Saturation (ft/day)	7.00	18.3	55.2
Suction Depth (inches)	-6.38	-1.79	-0.59

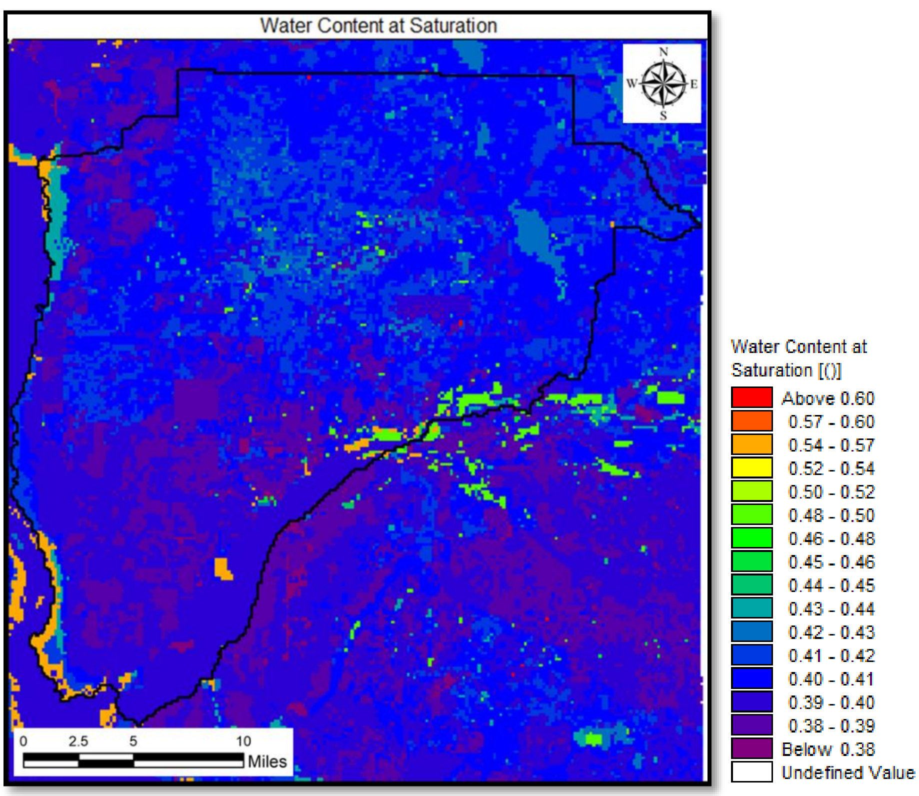

Figure 27. Soil water content at saturation

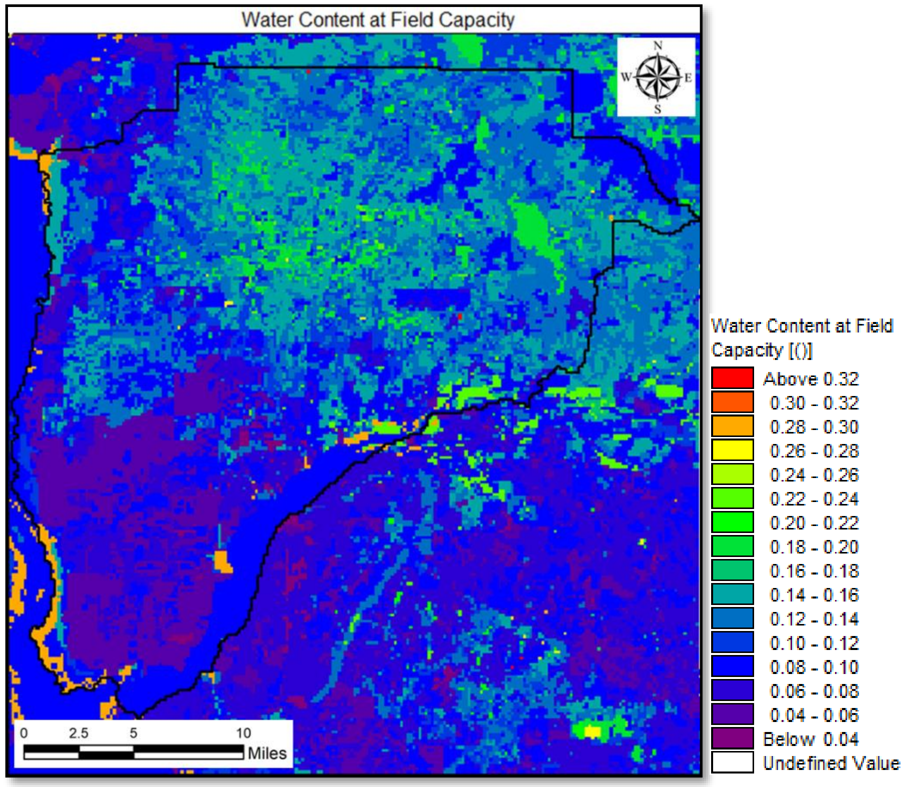

Figure 28. Soil water content at field capacity

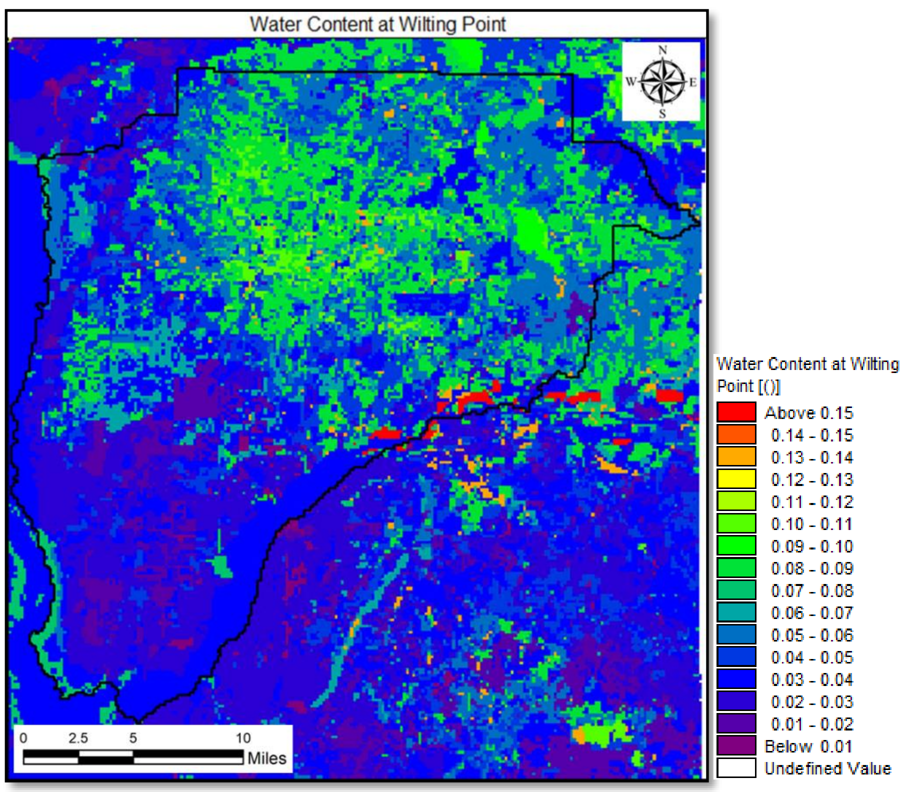

Figure 29. Soil water content at wilting point

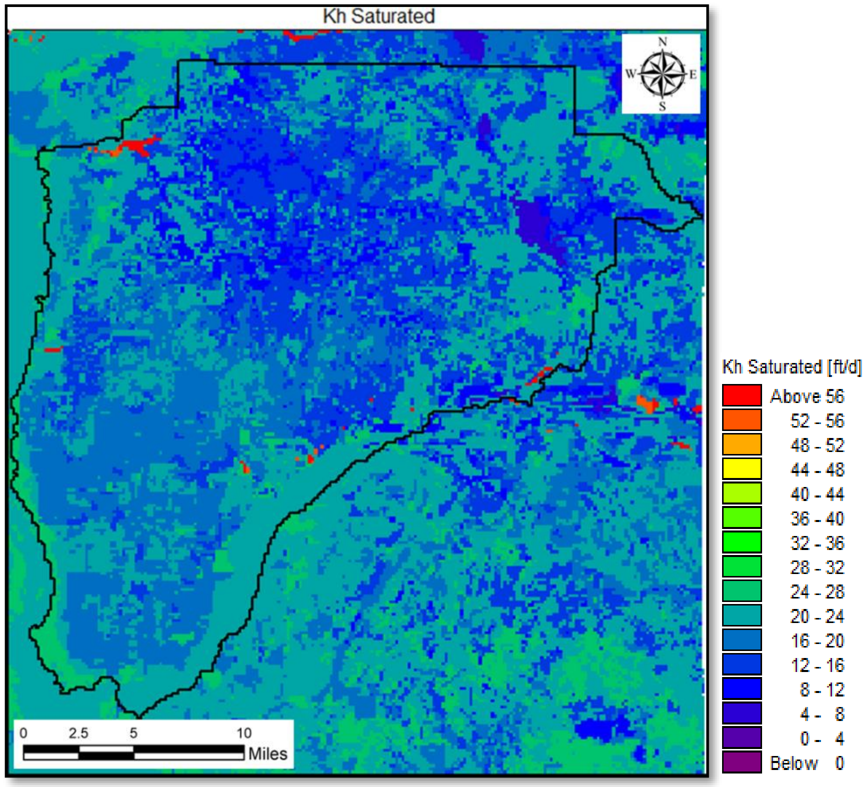

Figure 30. Soil hydraulic conductivity at saturation

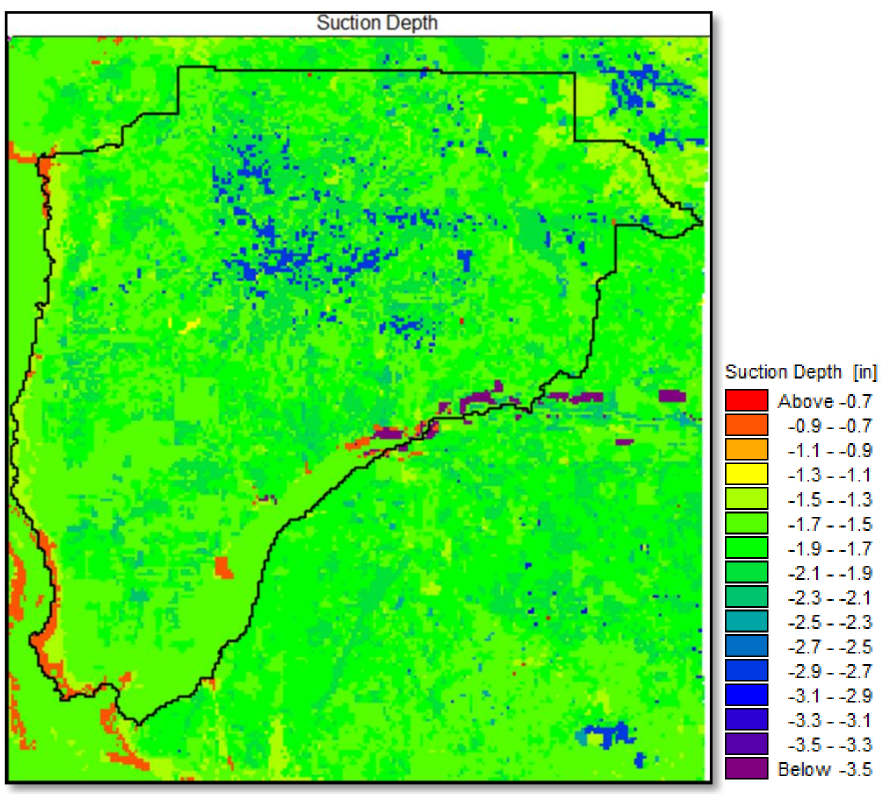

Figure 31. Soil suction depth

8.0 SATURATED ZONE COMPONENT

The saturated zone (SZ) component of the model handles movement within the groundwater system. The hydrogeologic layers (e.g. water table aquifer, confining units, etc.) and respective bottom elevations are defined. Horizontal and vertical conductivities are defined, which govern groundwater flow between layers and horizontal movement across the model domain. The SZ component also handles drainage from groundwater to adjacent ditches, creeks, and rivers. This empirical component is needed since the MIKE 11 network does not include every field ditch, roadside ditch, and minor ditches that convey flows to larger ditches, creeks, or river. Pumping from aquifers for public water supply is also handled by the SZ component. The following sections describe the details associated with the SZ utilized in the Charlotte Harbor Flatwood MIKE SHE/MIKE 11 model.

8.1 Geologic Layers

The geological layers definition in the previous MIKE SHE model were mostly retained in the updated model together with their top and bottom elevations. The bottom elevation of the Water Table Aquifer was regenerated utilizing information from recent hydrogeologic studies, and a new lens labeled as “Rock” was introduced. Hydrogeological parameters, such as the hydraulic conductivities, may be adjusted during the calibration task.

New stratigraphic data was available from borings in the Yucca Pens area that have been obtained since 2013 (Tetra Tech & ADA, 2017; Water Science Associates, 2018; Water Science Associates & SED, 2019) and are depicted on ***Figure 32***. Most of the borings were drilled until a confining low permeability layer was encountered. The depth to confinement ranged from 25 to 45 feet with most depths of confinement ranging from 25 to 30 feet below ground surface. The depth to the bottom of the Water Table Aquifer in those wells was merged to the Hydrogeologic Unit Mapping Update for the Lower West Coast Water Supply Planning Area (LWCSASIAS) [SFWMD 2015]. The combined dataset was converted to an interpolated surface by using a Simple Kriging method, and the regenerated Water Table Aquifer bottom elevation is depicted on ***Figure 33***.

Hydraulic conductivity of the water table aquifer is initially set with uniform vertical and horizontal conductivities of 30 and 300 feet per day (ft. /day), respectively. Hydraulic conductivities will be modified during calibration within defined acceptable ranges.

8.2 Geological and Conceptual Lenses

The vertical extent of the new Rock lens in Yucca Pens was obtained from the hydrostratigraphic information of boring wells in the area. Contour lines of the top and bottom elevation below the ground surface were obtained by using a Kriging interpolation method. Then, the elevations at well points and contour lines were used to create a TIN, then a raster, and finally, a dfs2 file that is used as a MIKE SHE input. The map of the interpolated top and bottom elevations is presented in ***Figure 34***. The hydraulic conductivity of the rock layer is expected to be higher than the conductivity of the unconsolidated material in the Water Table Aquifer.

8.3 Computational Layers

The previous model version used three computational layers corresponding to the three geological layers defined in the model. This updated model split the top geological layer into two computational layers to increase the vertical resolution and to delineate the two different lithologies within the Water Table Aquifer where they occur.

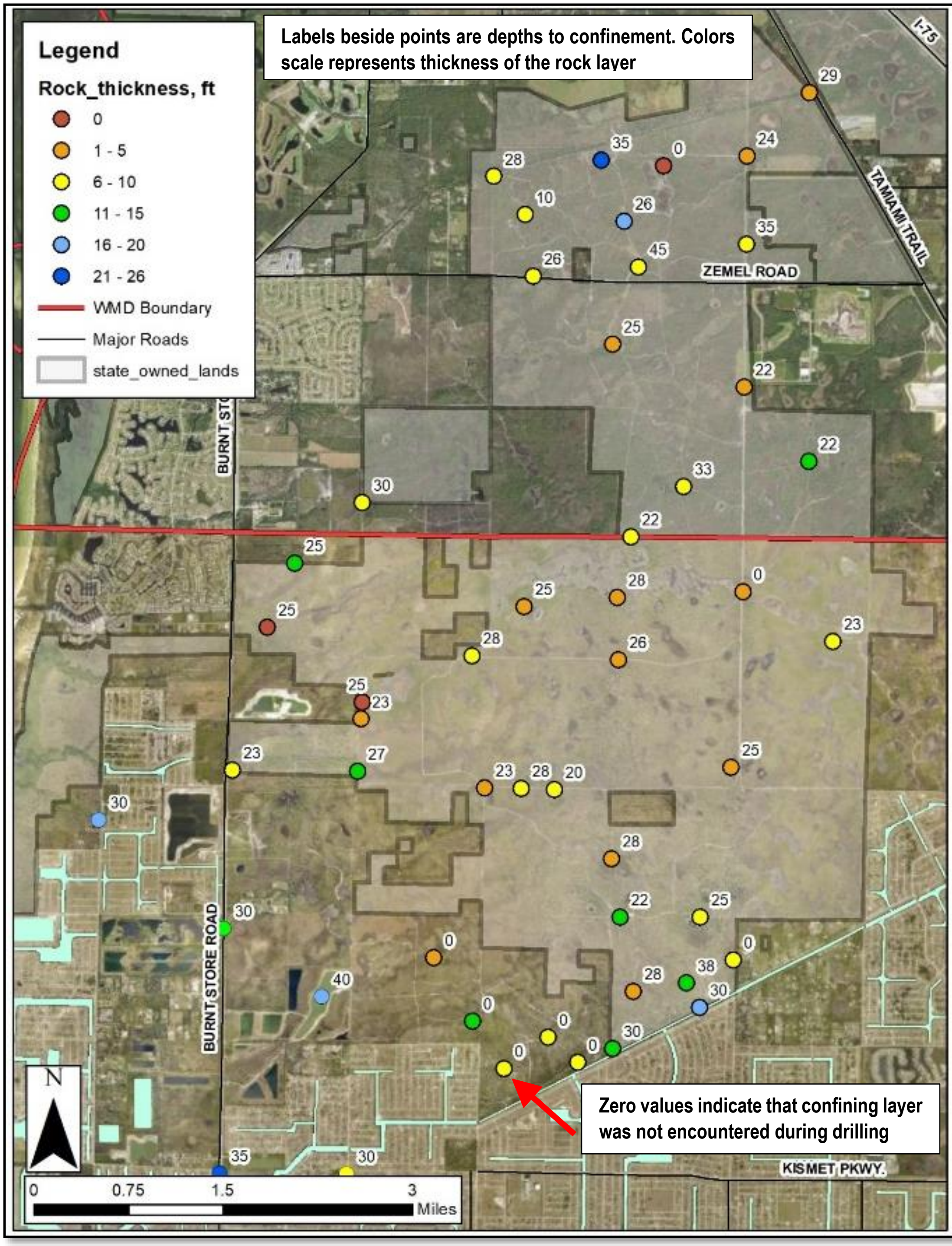

Figure 32. Locations of borings used to refine hydro-stratigraphy (labels associated with points indicate depth to confinement)

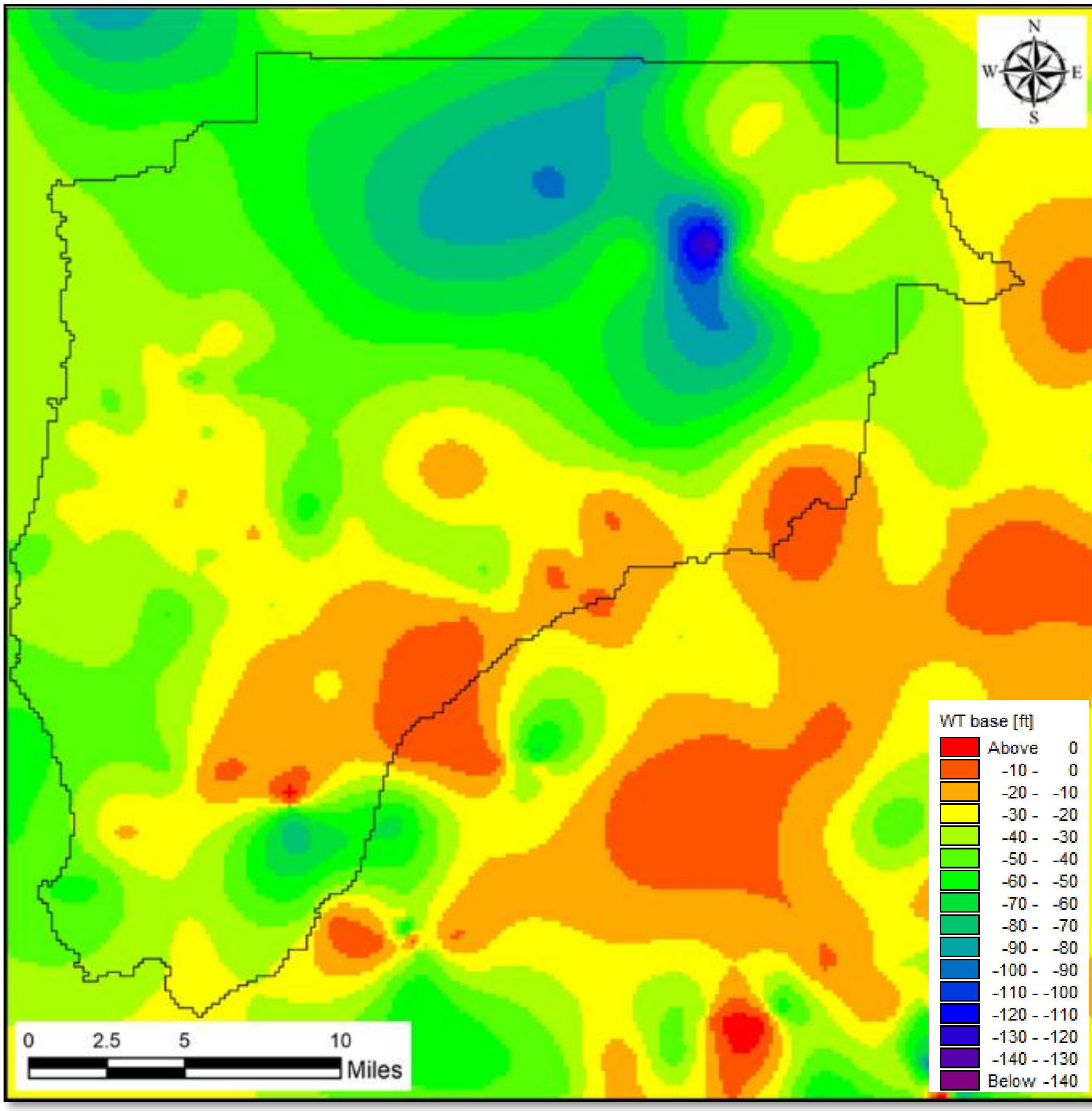

Figure 33. Water Table Aquifer bottom elevation relative to the ground surface in the model

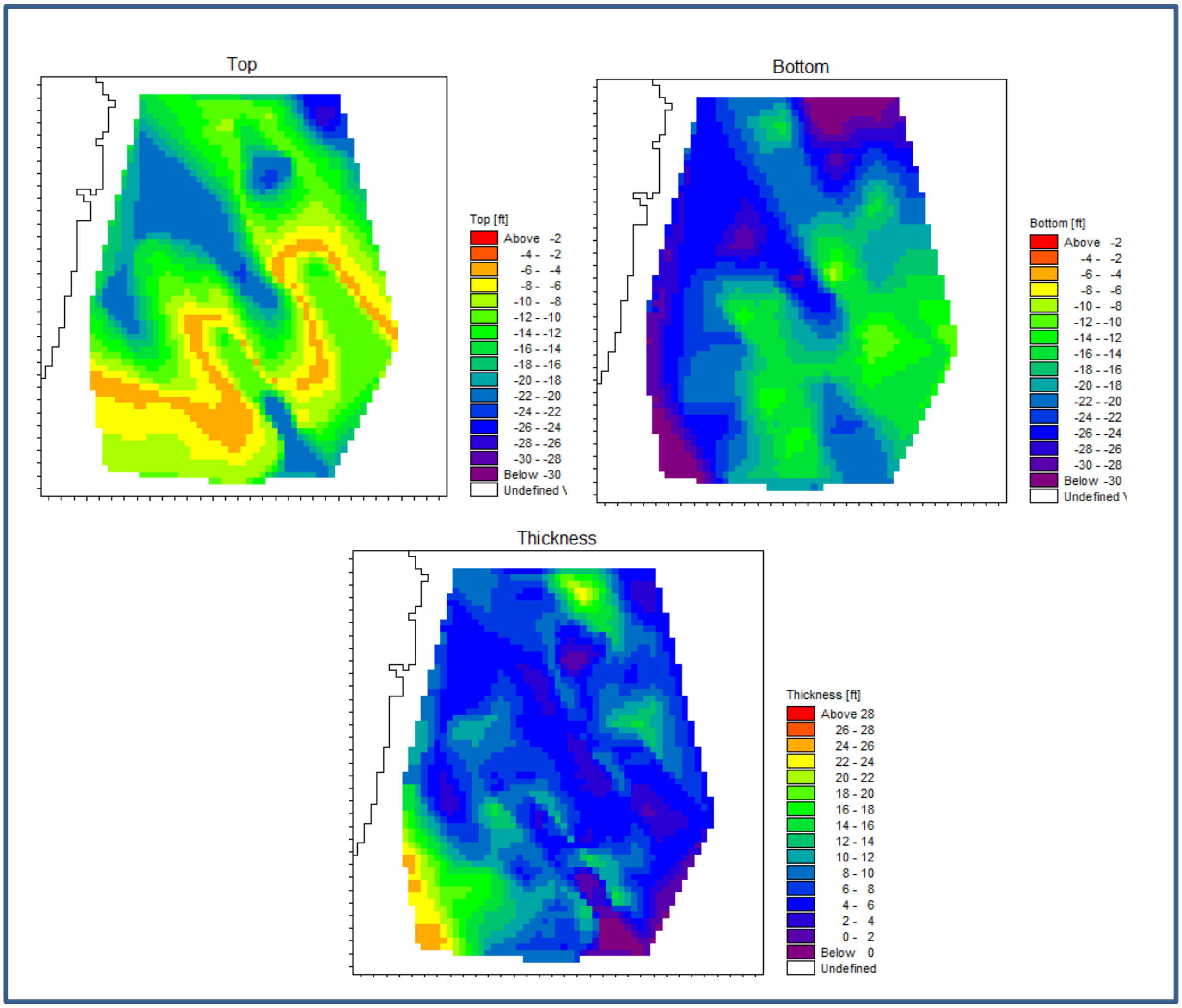

Figure 34. Depth to top, bottom, and thickness of the Rock lens at Yucca Pens

Lateral boundary conditions for the SZ computational layers were established by computing daily interpolated head maps. The TIN interpolation method is conducted from observation stations inside and outside the model domain for the northern boundary. The east model boundary is closed, and the western and southern boundaries use tidal water level data. Temporal average head maps computed for the different aquifers are being developed and will be provided once they have been subjected to internal quality control checks.

8.4 Drainage

The MIKE SHE model uses the Drainage component to represent the drainage from agricultural and urban areas. This model component is one of the few empirical components in MIKE SHE. The Drainage component is part of the geologic model set-up because it routes shallow groundwater to the drainage destination (i.e., MIKE11 branches, local depressions, or model boundary).

The input parameters for drainage levels and time constants are found from correlations with the MIKE SHE land use codes, as shown in ***Table 2***. They are utilized for agricultural and urban areas and set as zero elsewhere to suppress the drainage. The resulting parameter maps are shown in previous ***Figures 16*** and ***17***, respectively.

Drainage codes presented in ***Figure 35*** are based on the SOLFA codes presented before. Areas with negative drain code drain to a local depression. Other areas with positive codes drain to the nearest MIKE11 branches inside the drain code area.

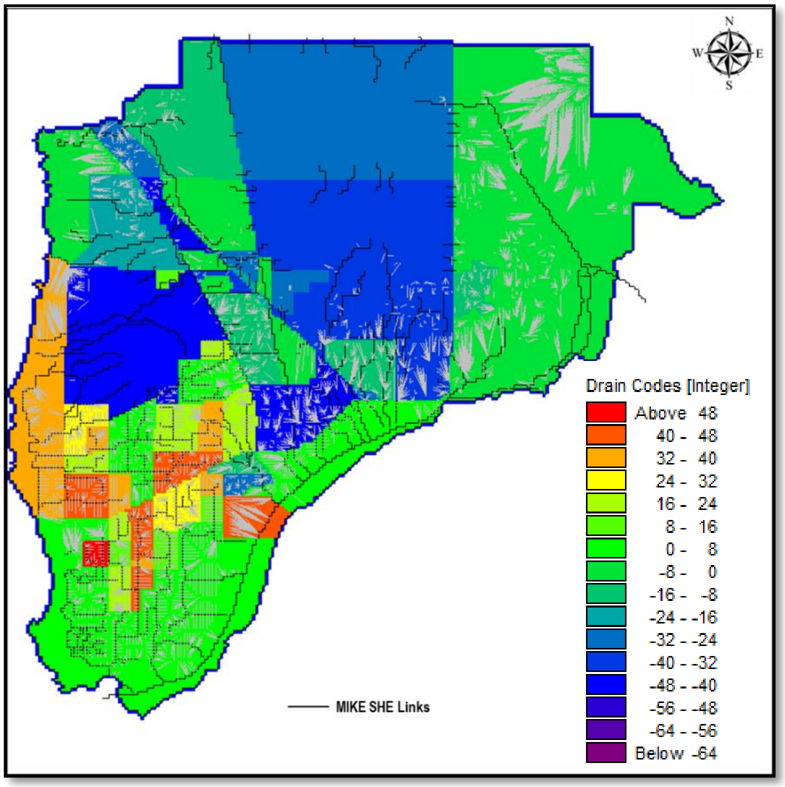

Figure 35. Drain codes

8.5 Water Supply Wells

The locations of the potable water supply (PWS) wells within the Charlotte Harbor Flatwoods (CHF) model domain are presented in ***Figure 36***. Monthly pumping data for PWS wells are available from the SFWMD for the different water use permits (WUP). The period of record is from 1980 through 2020.

The data processing starts by creating individual files for each desired permit number. Then, the sequential report is separated by wells, while considering that the specific label used for the wells may change throughout the period of record.

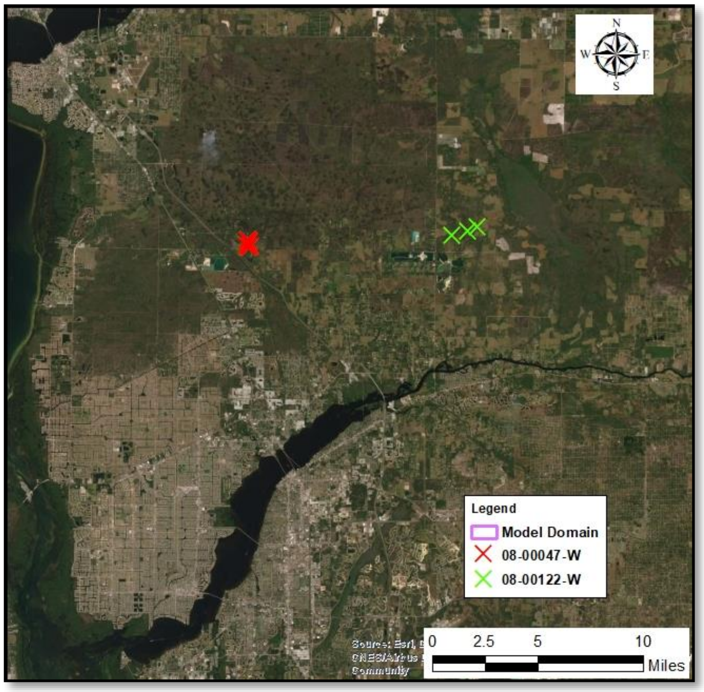

Figure 36. Water supply wells

Some early monthly reports include the extraction of the entire well field and not from individual wells. In such cases, a well pumping percentage from the well field total was obtained from the first year with individual well reporting and applied to previous well field total amounts. Finally, input “dfs0” files are created for each well field containing the monthly pumping from each individual well, as shown in ***Figures 37*** and ***38***. Note that 2021 was filled by repeating the data from the last reported year (i.e., 2020).

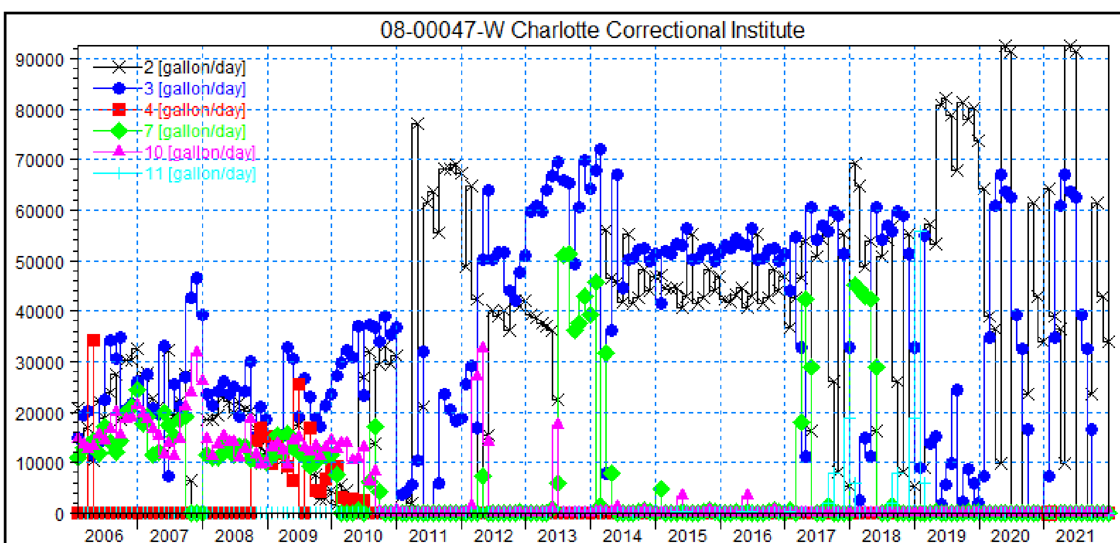

Figure 37. Monthly PWS pumping extraction rates from wells at Charlotte Correctional Institute

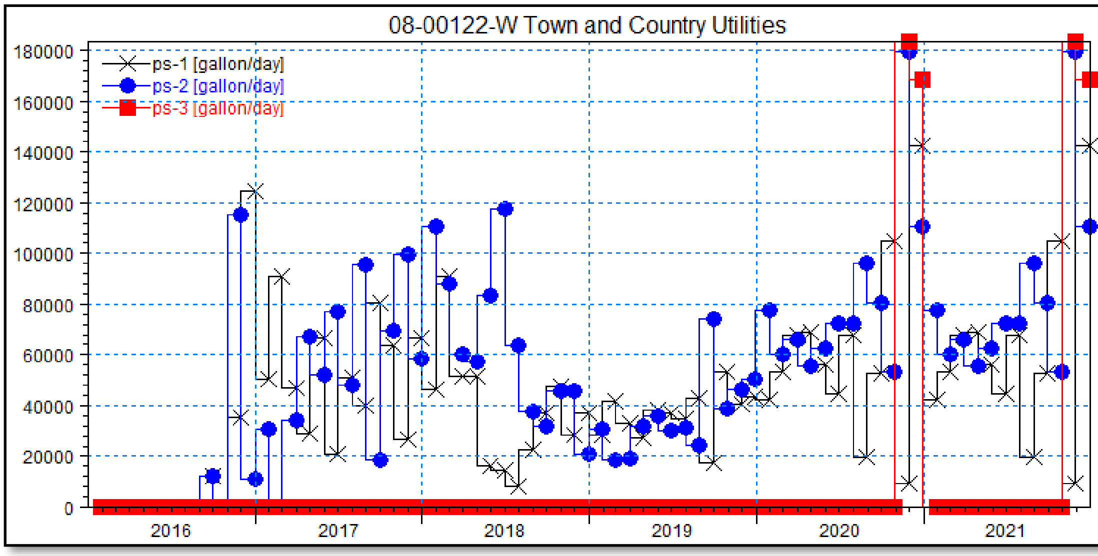

Figure 38. Monthly PWS pumping extraction rates from wells at Town and Country Utilities

Table 4 lists the PWS wellfields inside the model domain with their corresponding average pumping extraction rate. Here, "WT" refers to the Water Table Aquifer, "LT" to the Lower Tamiami Aquifer, and "SS" to the Sandstone Aquifer. A more detailed list by individual wells and their average pumping is also presented in ***Table 5***. The evolution of the total monthly pumping inside the model domain is plotted in ***Figure 39.***

Table 4. PWS wellfields in the Model

WUP Number	Well Field Name	Aquifer	Number of Wells	Annual Allocation (MGD)	2020 Annual Pumping (MGD)
08-00047-W	Charlotte Correctional Institute	WT	6	0.124	0.0731
08-00122-W	Town and Country Utilities	SS	3	1.036	0.1755
	Total:		9		0.2486

Table 5. PWS wells in the Model

WUP Number	Well Name	Aquifer	2020 Annual pumping (MGD)
08-00047-W	2	WT	0.0412
08-00047-W	3	WT	0.0319
08-00047-W	4	WT	0.0000
08-00047-W	7	WT	0.0000
08-00047-W	10	WT	0.0000
08-00047-W	11	WT	0.0000
08-00122-W	ps-1	SS	0.0611
08-00122-W	ps-2	SS	0.0822
08-00122-W	ps-3	SS	0.0293

9.0 OBSERVATION STATION DATA

Water level and flow data are available from a number of sources, including the USGS, SFWMD, SWFWMD, Lee County, and stations monitored as part of this study. Currently, the model calibration includes 121 groundwater and 40 surface water monitoring stations. Model performance at these stations is used for calibration, verification, and to establish boundary conditions. Calibration stations in the southern and northern portions of the model are presented in ***Figures 40*** and ***41***, respectively. Calibration within Cape Coral is limited to improving model performance in Gator Slough.

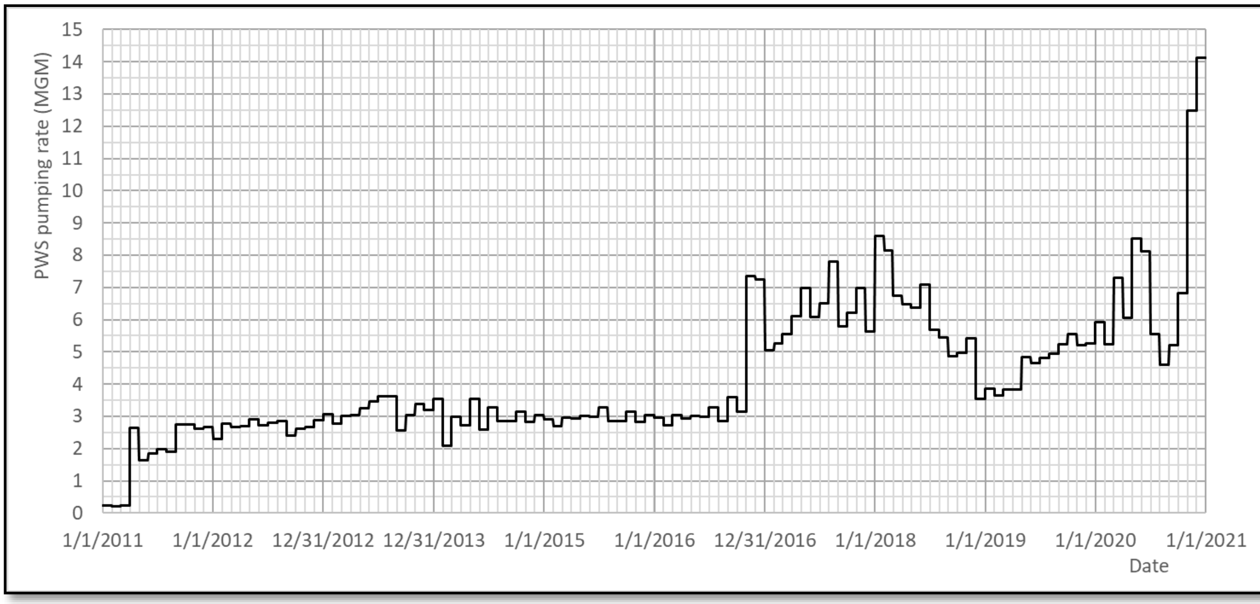

Figure 39. Total monthly PWS pumping inside the model domain

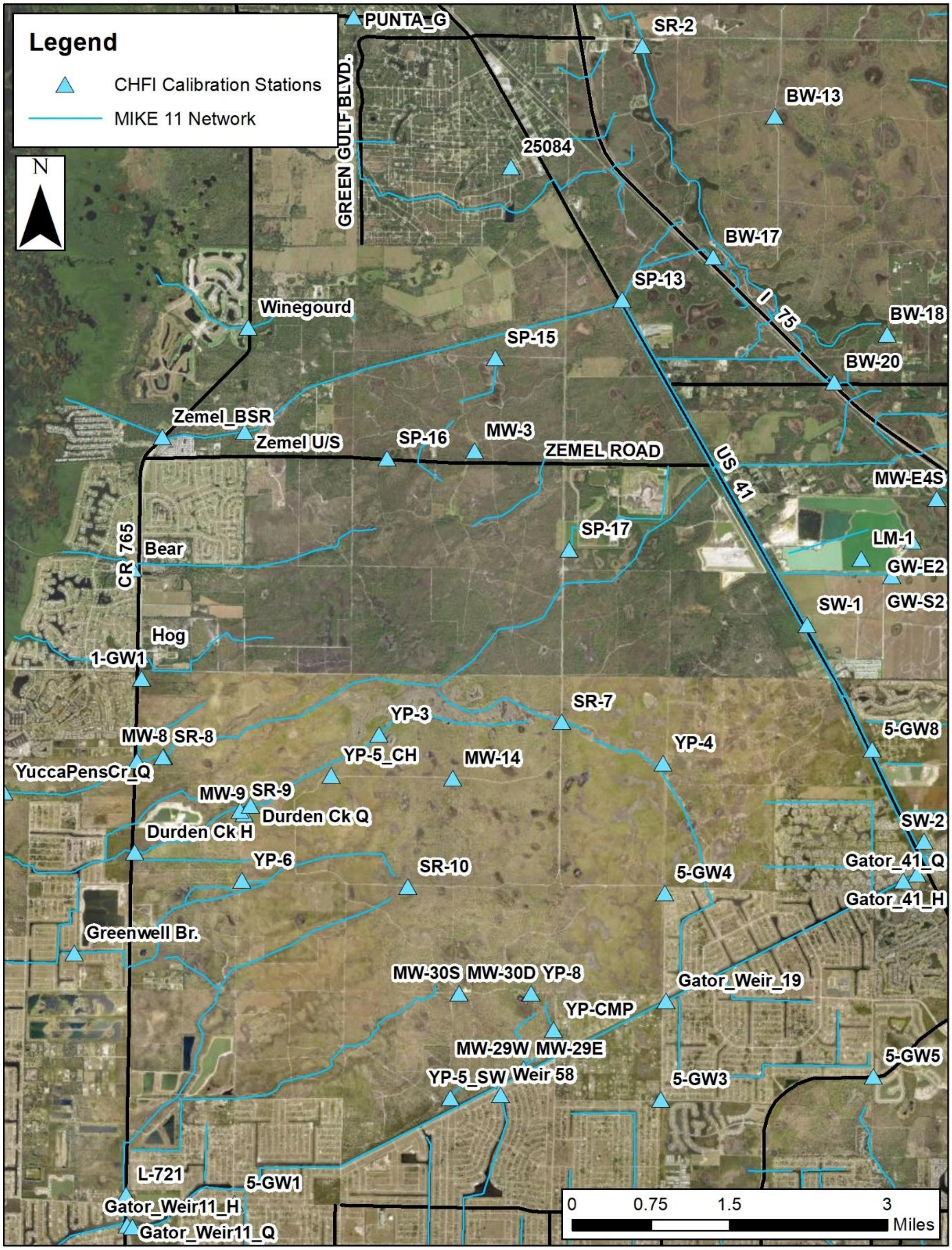

Figure 40. Calibration stations in southern portion of the model domain

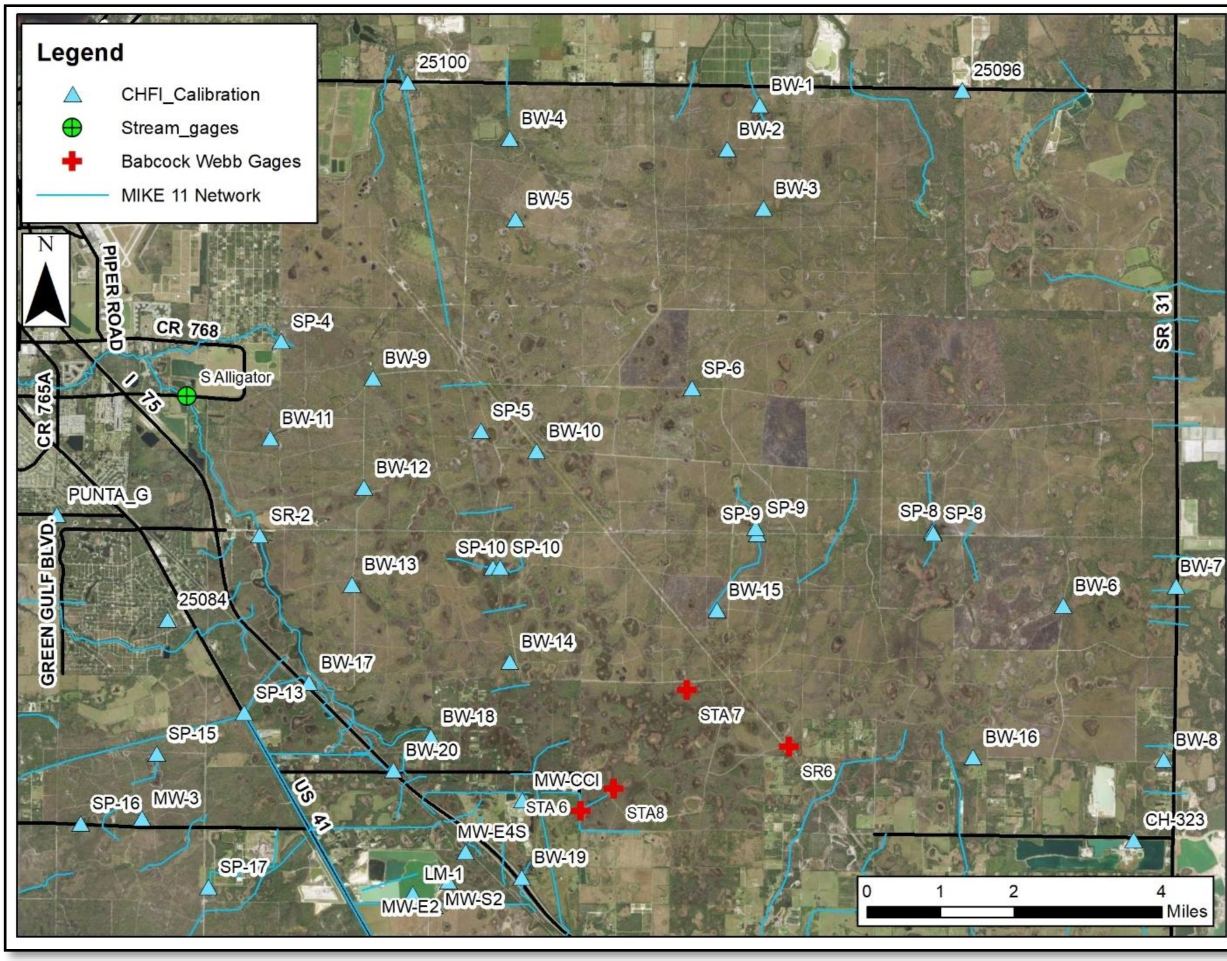

Figure 41. Calibration stations in the northern portion of the model domain

SECTION C

SUMMARY OF MODEL DEVELOPMENT

The model development is complete and the simulation is running without errors. Simulation time is ranging between 2.5 and 4.3 hours per year, depending on the selected iteration time steps, which are being varied as part of the development/calibration process. Currently, the model development process involves a review of simulation results and fixing any structural details that are impacting model performance. For example, if measured data are consistently higher or lower than simulated data near a road culvert, then the dimensions of the culverts are checked to make sure that the information in the model is accurate. Since the model has been updated from a prior version, a thorough review of input files is underway to make sure that the most up-to-date information is being used. For example, engineering plans for the widening of Burnt Store Road in Charlotte County were recently obtained, and the dimensions and invert elevations of a number of culverts under Burnt Store Road were updated. The model has estimated dimensions of culverts under CR 74, and dimensions will be field measured if engineering drawings for CR 74 cannot be located. This process of checking input data files will be continued until no further improvements in model performance are realized. At that point, calibration of groundwater hydraulic conductivities will begin.

Upcoming memoranda include a 50% and 100% calibration report. Meetings during the calibration process will be held with interested review staff to discuss the status of the model calibration process and to solicit creative input to improve the calibration. Following the completion of the calibration, an existing condition model simulation will be conducted for an extended period (likely 2011 – 2021) to serve as a baseline for comparison to proposed condition simulations.

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