APPENDIX 5C

Existing Conditions Model 100% Calibration

Lower Charlotte Harbor Flatwoods Strategic Hydrologic Restoration Plan

Lower Charlotte Harbor Flatwoods Strategic Hydrologic Restoration Plan

5C – Existing Conditions Model 100% Calibration

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SECTION A
BACKGROUND

1.0 PROJECT DESCRIPTION

As a result of hydrologic alteration to local coastal watersheds, the Charlotte Harbor Flatwoods Initiative (CHFI), comprised of multiple local, state and federal agencies, the Coastal & Heartland National Estuary Partnership, and other stakeholders, was formed to initiate efforts to restore natural drainage across the Gator Slough Watershed with water that has been unnaturally impounded on the Babcock-Webb WMA and diverted from the Yucca Pens WMA, Caloosahatchee, and tidal creeks to Charlotte Harbor. 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 conducted from July through November 2020 to measure water depths at the locations inventoried in the 2020 dry season (late fall rainfall resulted in high water levels in Babcock Webb into December, 2020, see STA-8 calibration plot in **Appendix A**). 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. All data have been downloaded for six consecutive quarters and were used in the model calibration.

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) 50% Calibration Technical Memorandum, c) 100% Calibration Technical Memorandum, and d) Existing Conditions Model Output technical memo which will include ground water levels as well as surface water levels and flows and graphics. Technical Memorandum Task 5a described the development of the existing conditions hydrologic model and how model input files were updated during the initial calibration effort. This memorandum describes the 100% calibration and as well as changes made to the Task 5c 50% Calibration Technical Memorandum. As such, this memorandum is a merging of Tasks 5a, 5b, and 5c. The final deliverable for Task 5 will describe the results of a multi-year continuous simulation representing baseline existing conditions.

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 and AIM, 2015), initial analysis of the Southwest Aggregates mining pit in 2015 (AECOM and ADA, 2015), and for the Northeast Irrigation Reservoir Basis of Design for Cape Coral (Tetra Tech and ADA, 2017). The 2017 update included changes to hydrogeology to include data from new boring data for Yucca Pens, changes to the MIKE 11 network in southwest Babcock Webb WMA, changes to vertical exchange between overland flow and the saturated zone in wetlands, and additional calibration to improve calibration statistics at monitoring stations in both Babcock Webb and Yucca Pens. 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).

3.0 MIKE SHE/MIKE 11 MODEL CALIBRATION APPROACH

The model calibration utilized data from the data collection effort (Task 4 described above in section 1.0) that commenced in mid-May 2020. Because the monitoring stations installed as part of this project greatly increased the density of calibration stations, the calibration period used for this project was May 2020 through November 2021. To minimize initial conditions issues, the model simulation period for calibration simulations was January 1, 2020 through November, 2021. 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.

1.0 MODEL DOMAIN

The model domain originally developed in 2013 (ADA, 2013) was modified in 2016 to extend the model domain north from Webb Lake outlet to Alligator Creek at Taylor Road in Punta Gorda (Tetra Tech and ADA, 2017). For this current modeling effort, the 2016 domain was extended to the north up to CR 74, Bermont Rd, as shown in ***Figure 1***. 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 reasonably well 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 accurately represented in the model. The model grid cell size is 750 feet by 750 feet. The model has 25,753 active cells.

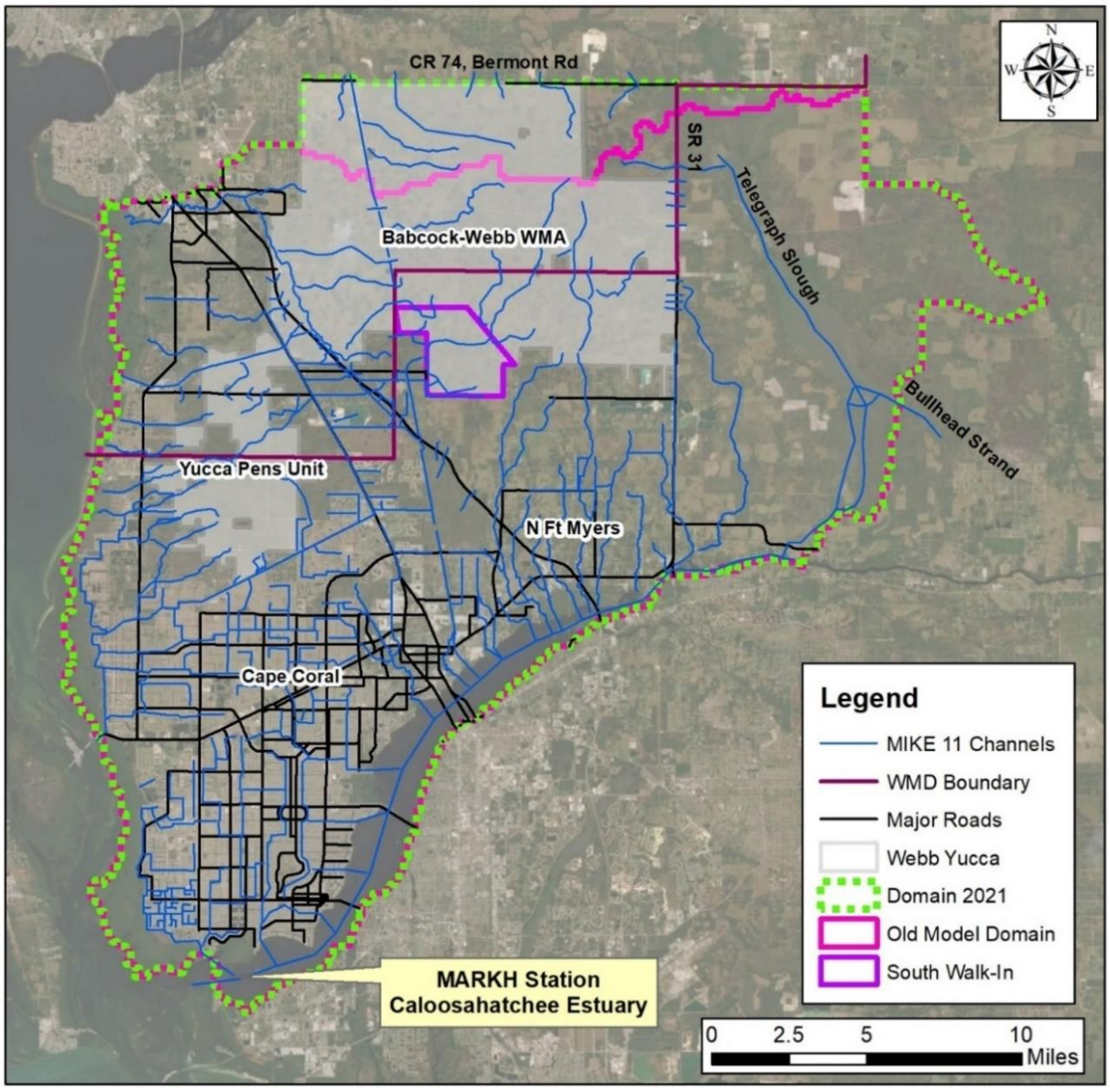


Figure 1. MIKE SHE model domain

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 southern portion of Babcock-Webb WMA that is east of I-75 is locally referred to as the “South Walk-In Area” (location shown in **Figure 1**). 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 for this current project 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.

During the calibration process, new LiDAR data from year 2018 was made available from the USGS that cover the lower half of the study area. This dataset include recent changes in the topography and provides greater detail in low lying areas and roadside ditches, and a decision was made to include new LiDAR data into the DEM used for this study. New cross sections were cut from this LiDAR source for those MIKE 11 branches that are within the coverage of the new LiDAR data.

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.

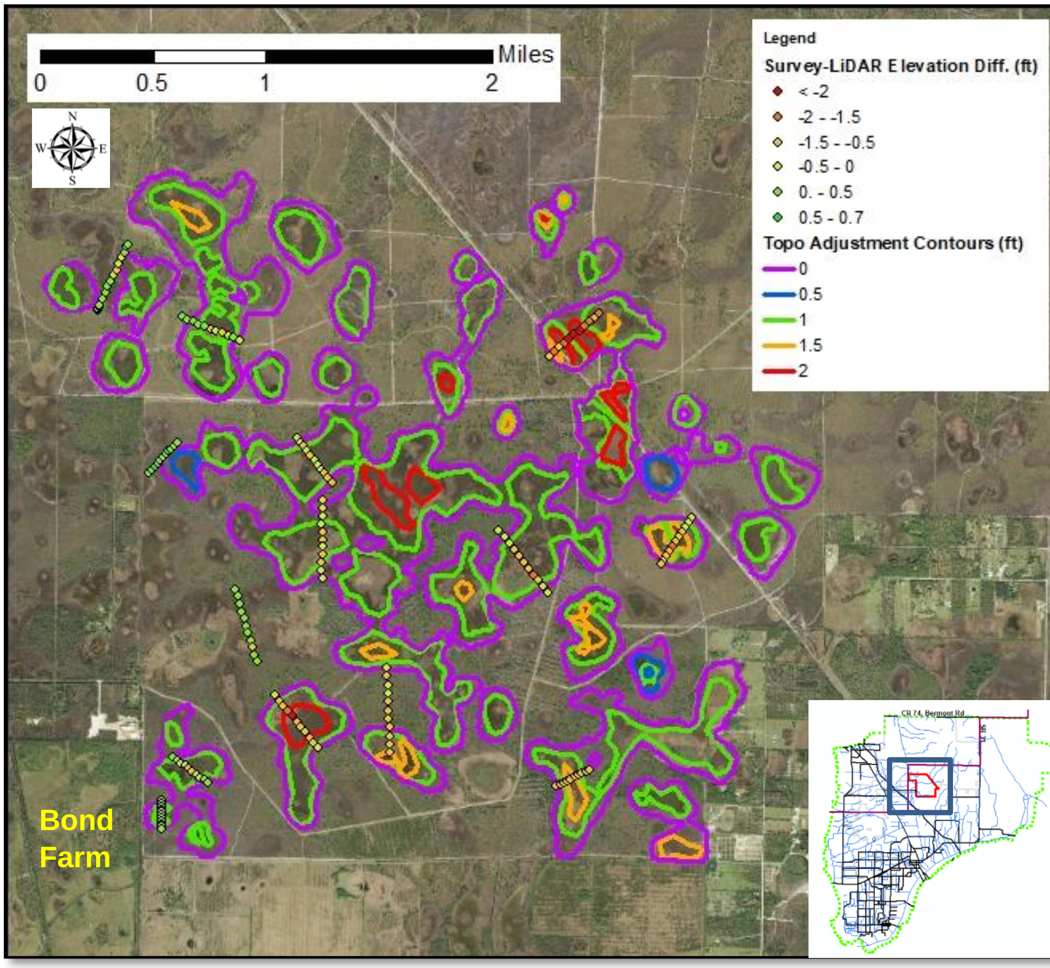


Figure 2. Contours to adjust LiDAR-based DEM in the South Walk-In Area

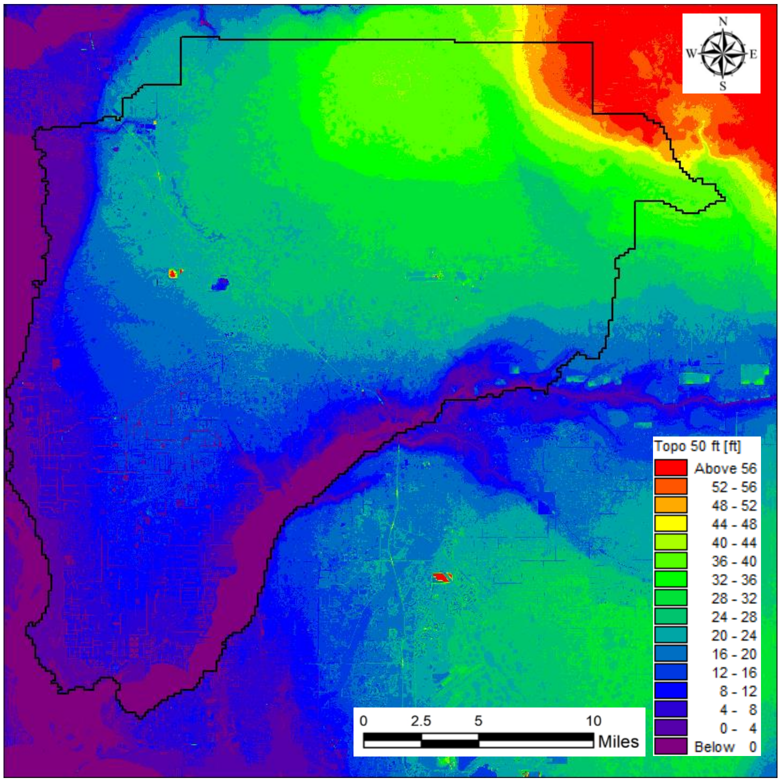


Figure 3. 50-foot topography for the model domain

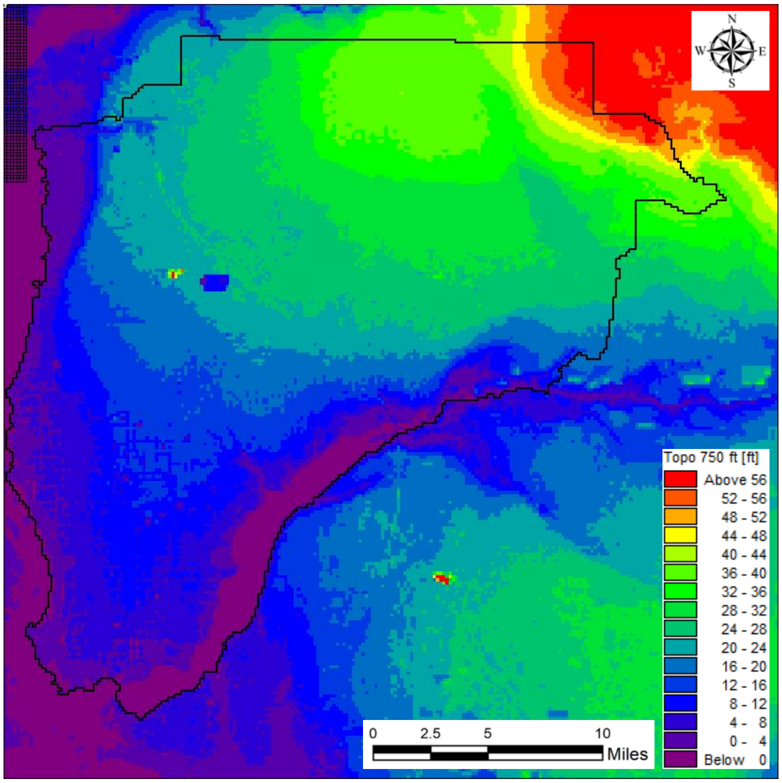


Figure 4. 750-foot topography in the model

3.0 CLIMATE

The climate component of MIKE SHE includes rainfall and evapotranspiration. Rainfall data available from SFWMD and reference evapotranspiration 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***.

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 was extended from a prior modeling effort and now covers the period from 1996 to 12/20/21. The raw NEXRAD rainfall data was converted to individual timeseries "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 for 2011 through 2021, which is the period that will be used for the baseline and proposed condition simulations conducted in Task 6. ***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.

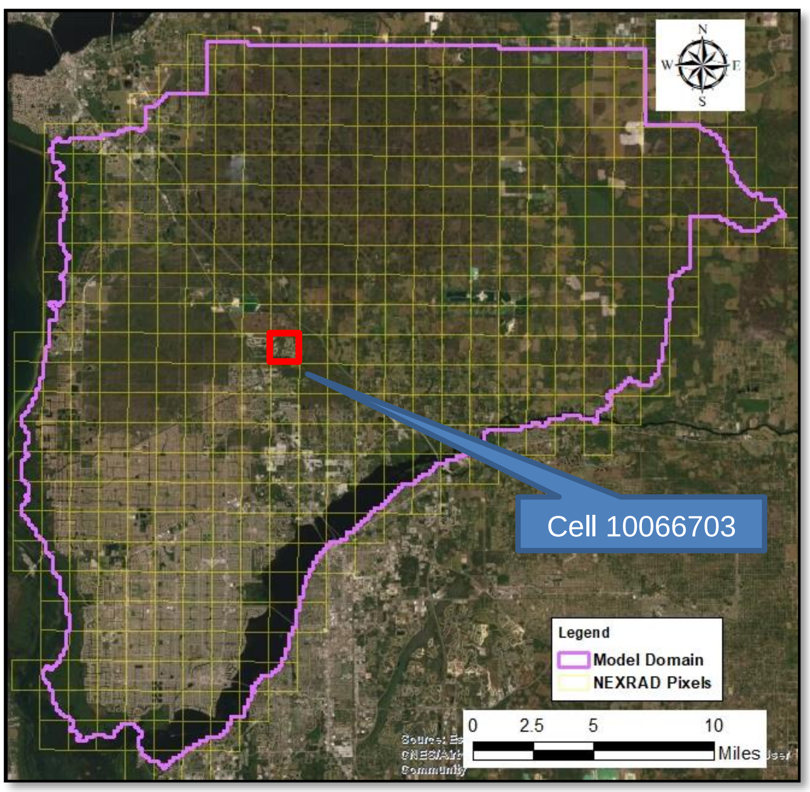


Figure 5. NEXRAD pixels within the model domain (red square indicates location of cell 10066703)

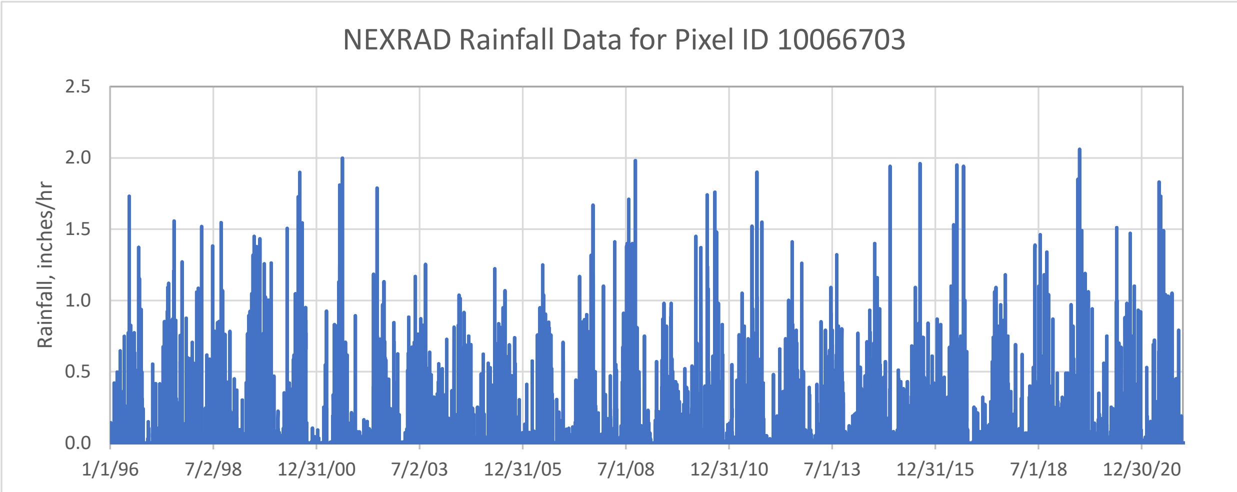


Figure 6. Hourly NEXRAD rainfall for pixel 66703

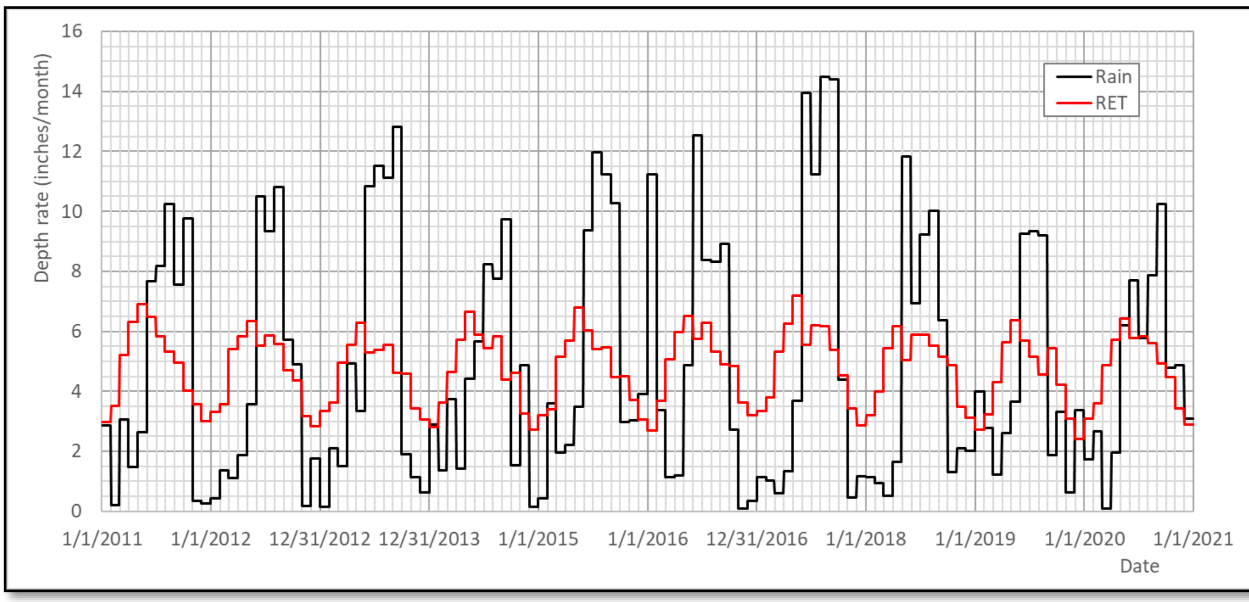


Figure 7. Spatial-averaged monthly NEXRAD rainfall and RET inside the model domain

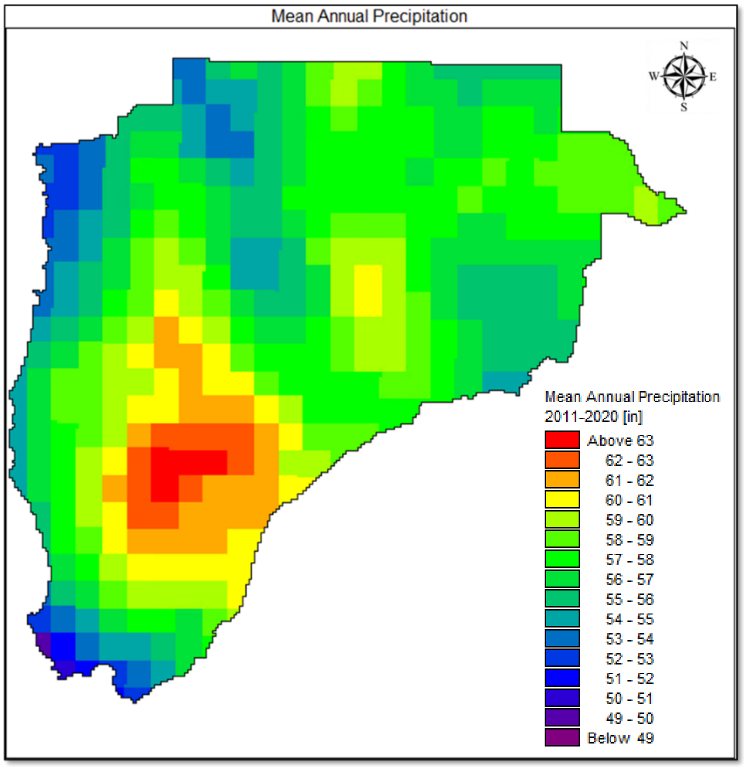


Figure 8. Average annual NEXRAD rainfall inside the model domain over 10-years (2011 to 2020)

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 timestep for the State of Florida. The data was extended from prior modeling efforts and now 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 timeseries 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 (location in Figure 5). Notice that the Julian Day average values for 2020 and 2021 do not have the typical daily oscillations, but they do capture the average seasonal RET dependence.

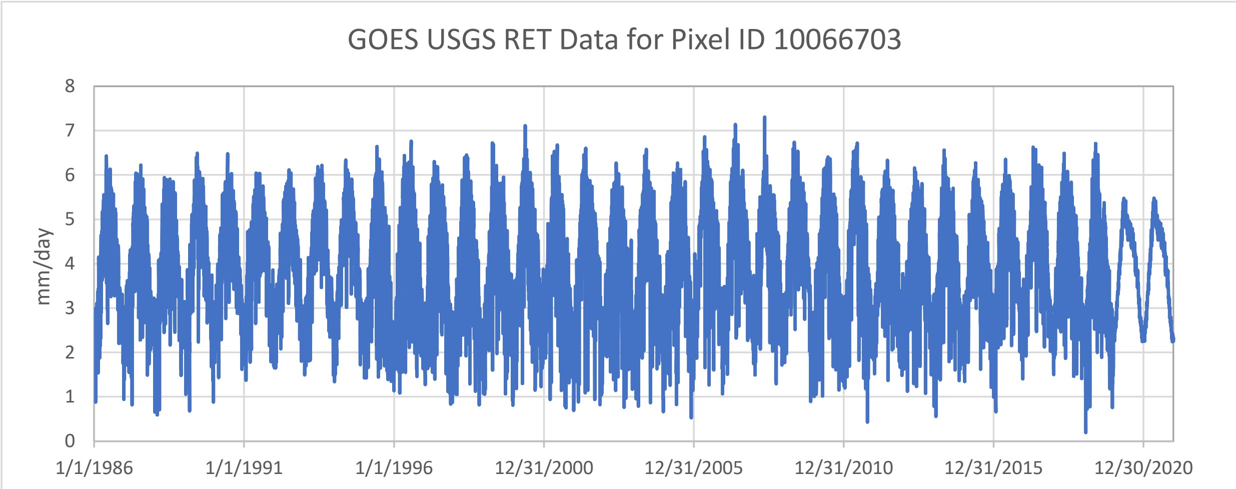


Figure 9. RET time series in mm/day for Pixel 66703 after processing

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. The mean annual RET is greater than precipitation because RET is Reference Evapotranspiration from an area that experiences continual flooding with weather conditions that are optimum for evapotranspiration. Since optimum conditions for evapotranspiration rarely exist for extended periods, actual ET will be less than rainfall.

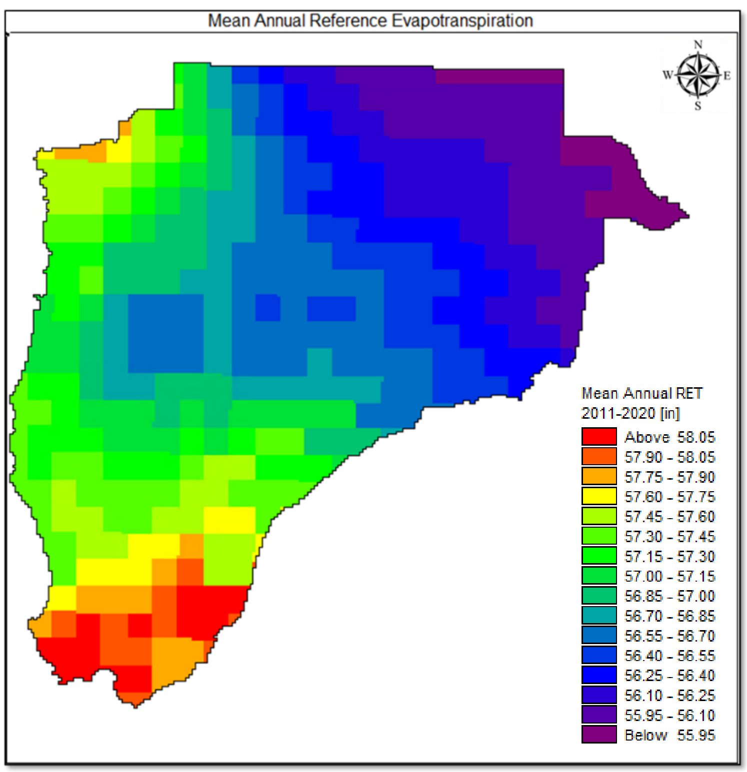


Figure 10. Annual average USGS RET data inside the model domain over 10-years (2011 to 2020)

4.0 LAND USE

4.1 Vegetation and Land Use

Prior MIKE SHE/MIKE 11 modeling efforts utilized 1995 land use data (DHI, 2003). Three sources of more recent land use/vegetation coverages 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.

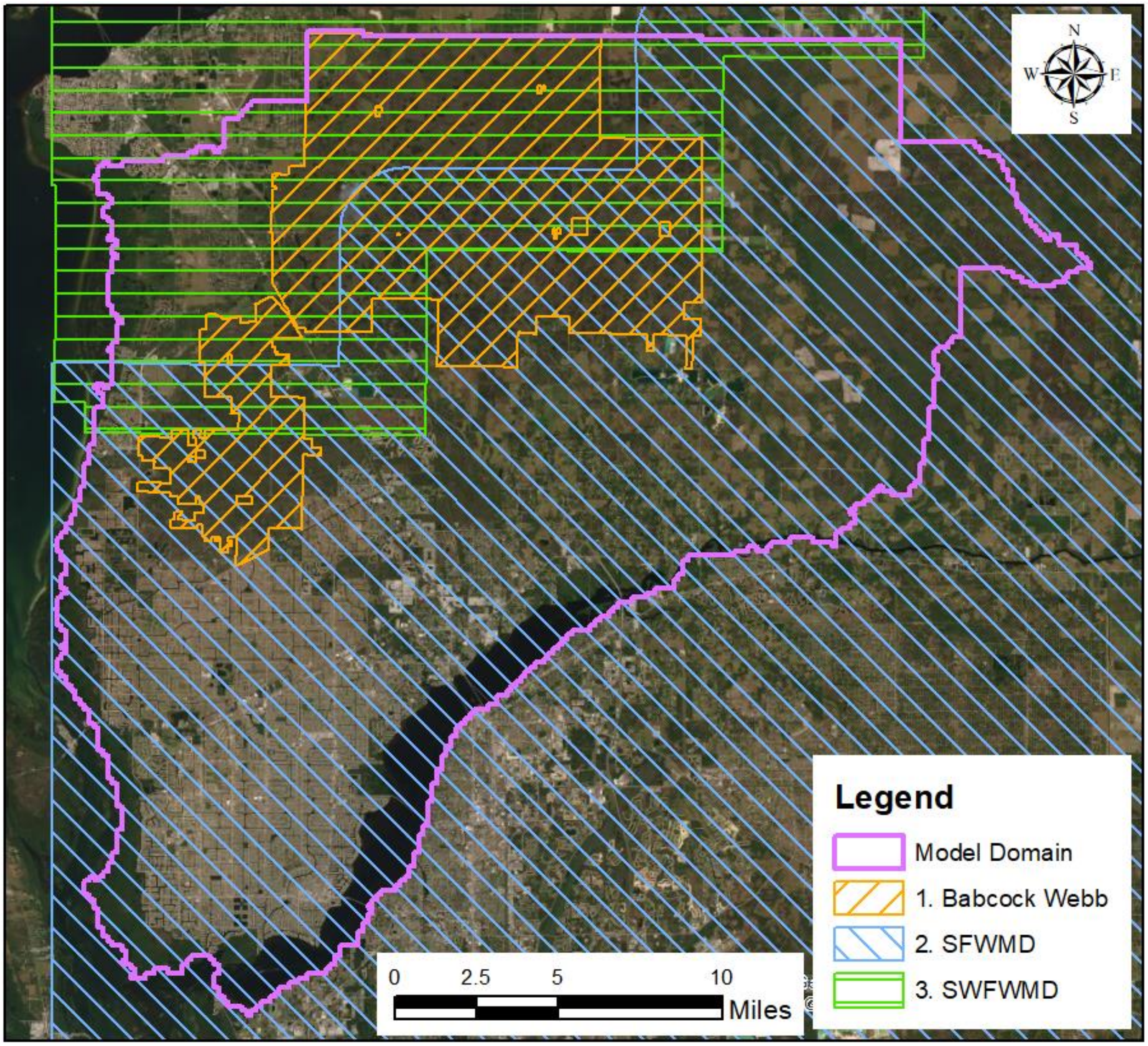


Figure 11. Land use/vegetation coverage source

1. Babcock Webb Wildlife Management Area and Yucca Pens Unit vegetation coverage from FWC.
2. 2014 to 2016 land use/vegetation coverage map from SFWMD. *WMD land use files boundaries may extend beyond their WMD boundary and overlap other files.*
3. 2017 land use coverage map from SWFWMD. *WMD land use files boundaries may extend beyond their WMD boundary and overlap other files.*

The primary land use data used was from SFWMD, and information from the other sources was used for areas not covered by the SFWMD data. 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

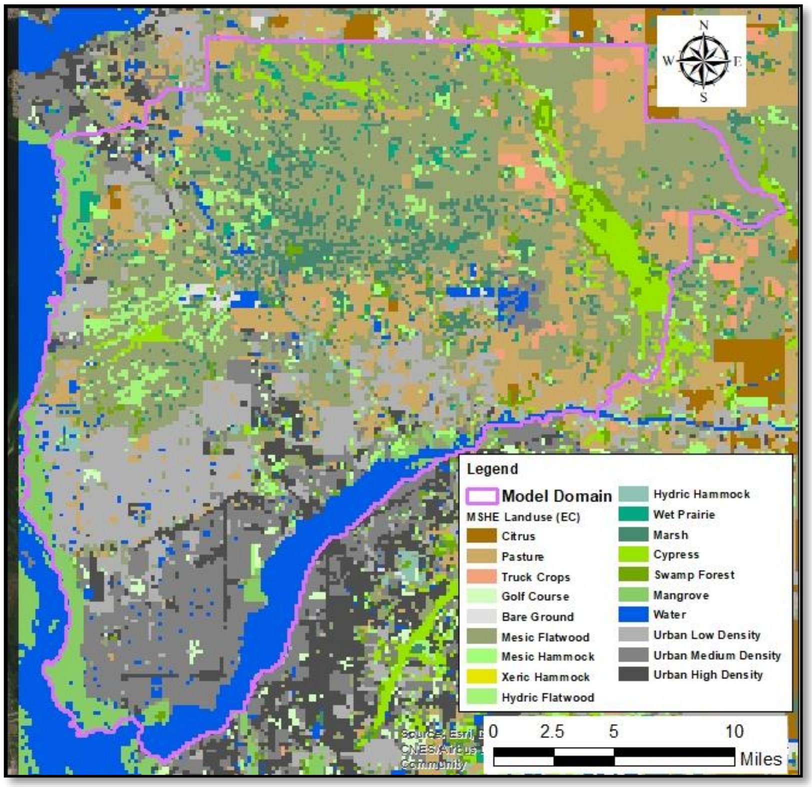


Figure 12. Existing conditions MIKE SHE vegetation codes in the Model

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** were a starting point and were taken from a recently calibrated model developed by this modeling team for South Lee County (Lago, 2021a). 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. Manning's n values in this range have been used in calibration reports for recent MIKE SHE models in South Lee County areas (Lago, 2021a) and (WSA, 2020). A previous study estimated Manning's n in the range [0.19-0.44] based on flow measurements at marsh vegetation types around Tree Islands in the Everglades (M. Lago, 2009). Sensitivity tests were conducted with varying levels of overland flow roughness. In the case of pasture coverage parameters, Drainage Depth/Time Constant values were set to "-0.5 feet" if they were irrigated, or "0" or "0.25 feet" if they were not irrigated.

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

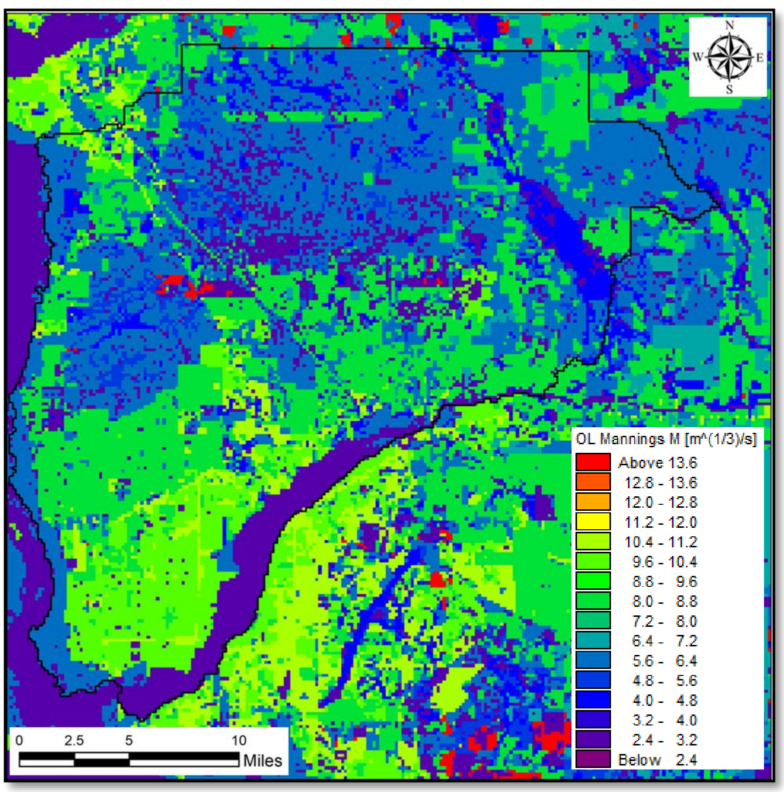


Figure 13. OL Manning's M map in the model

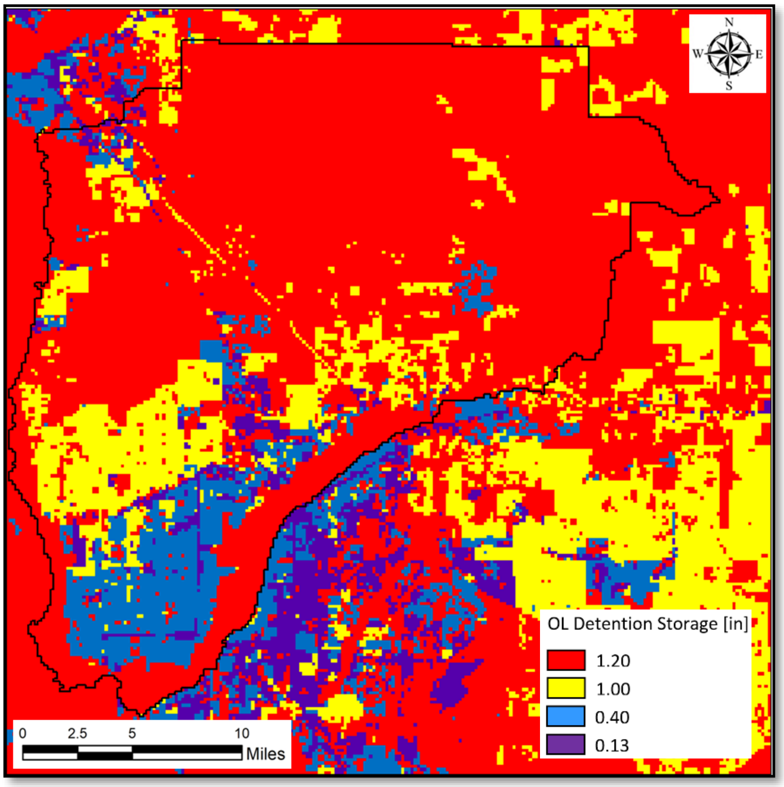


Figure 14. OL detention storage map in the model

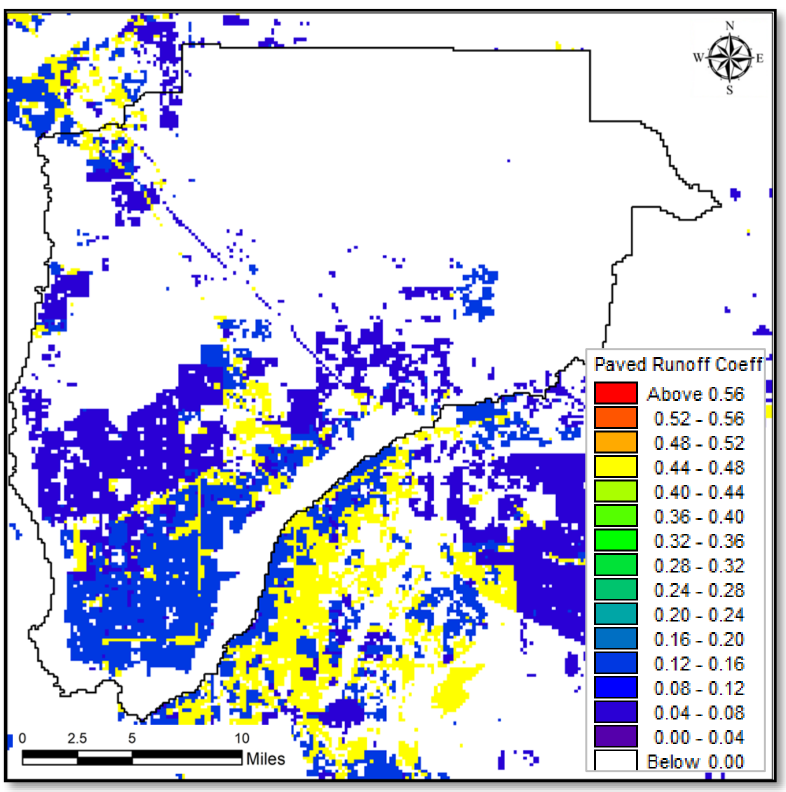


Figure 15. Paved runoff coefficient map in the model (fractional value ranging from 0-1)

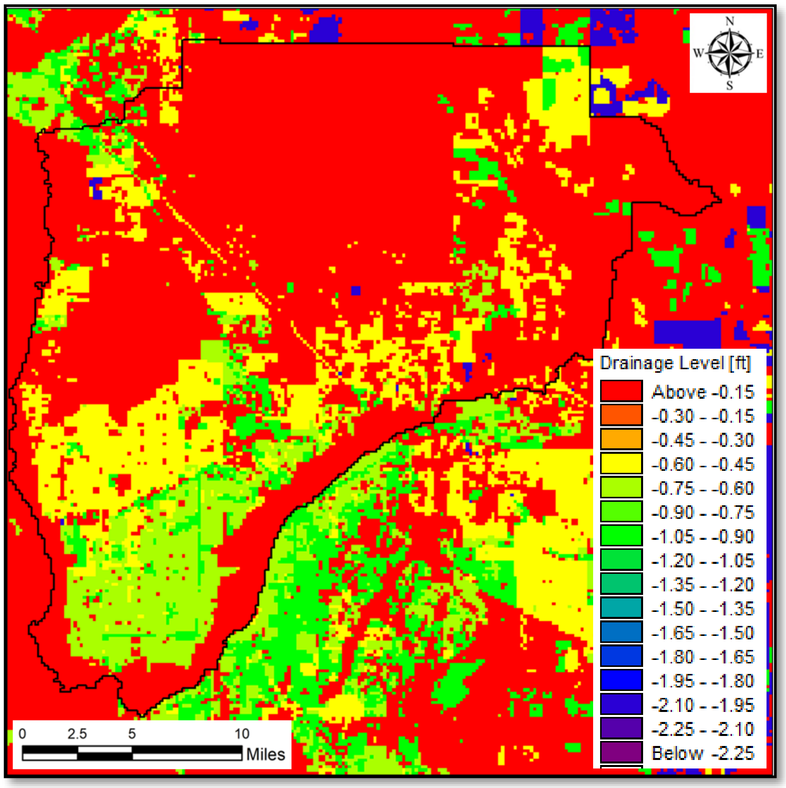


Figure 16. Drainage level map in the model

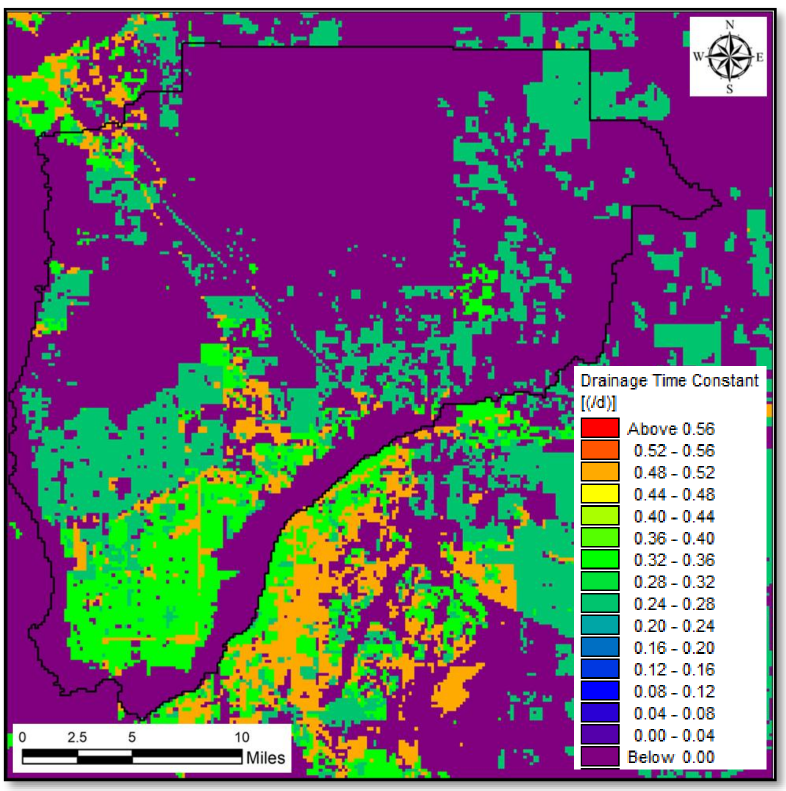


Figure 17. Drainage time constant map in the model

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 from the 2017 model based on more recent 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 (ADA, 2015).

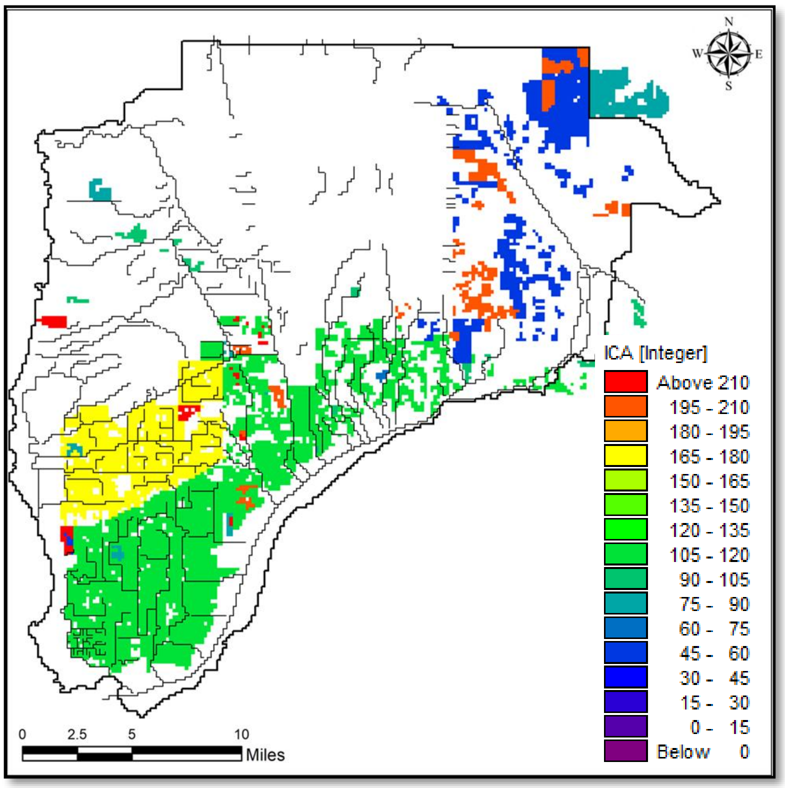


Figure 18. Updated ICA map in the model

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 during periods of high rainfall resulting from infiltration inputs from the overland flow routine to the water table aquifer and river/groundwater exchanges.

5.1 MIKE 11

The MIKE 11 component includes the following:

- A network file 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 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 10-foot resolution topographic data set. More information on cross-sections is provided below in the sub-section **Cross Sections**.
- A boundary file 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 describes initial conditions, bed roughness, and computational parameters.

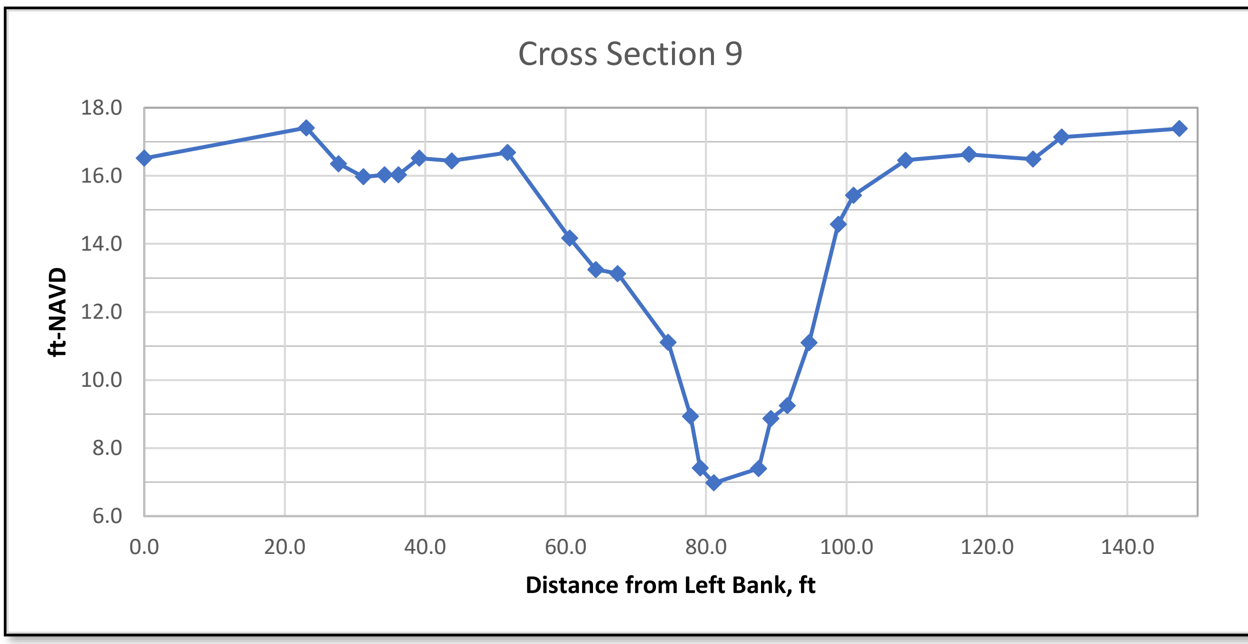


Figure 19. Cross-Section for Zemel Canal (CHNEP 2019)

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 typically have different hydraulic and geometric characteristics than rivers or creeks. Due to increased sinuosity, numerous tree deadfall, and dense vegetation, bed roughness is typically higher for these vegetated flow-ways due to low water velocities. 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 east from Babcock Webb WMA (see **Figure 1** for location). 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.

Numerous changes to the MIKE 11 network were made for this project to more completely represent flow patterns in Babcock Webb, Yucca Pens, and creeks draining the southern portion of Punta Gorda. The changes were made based on field site visits and a detailed review of drainage patterns using GIS and Google Earth.

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.

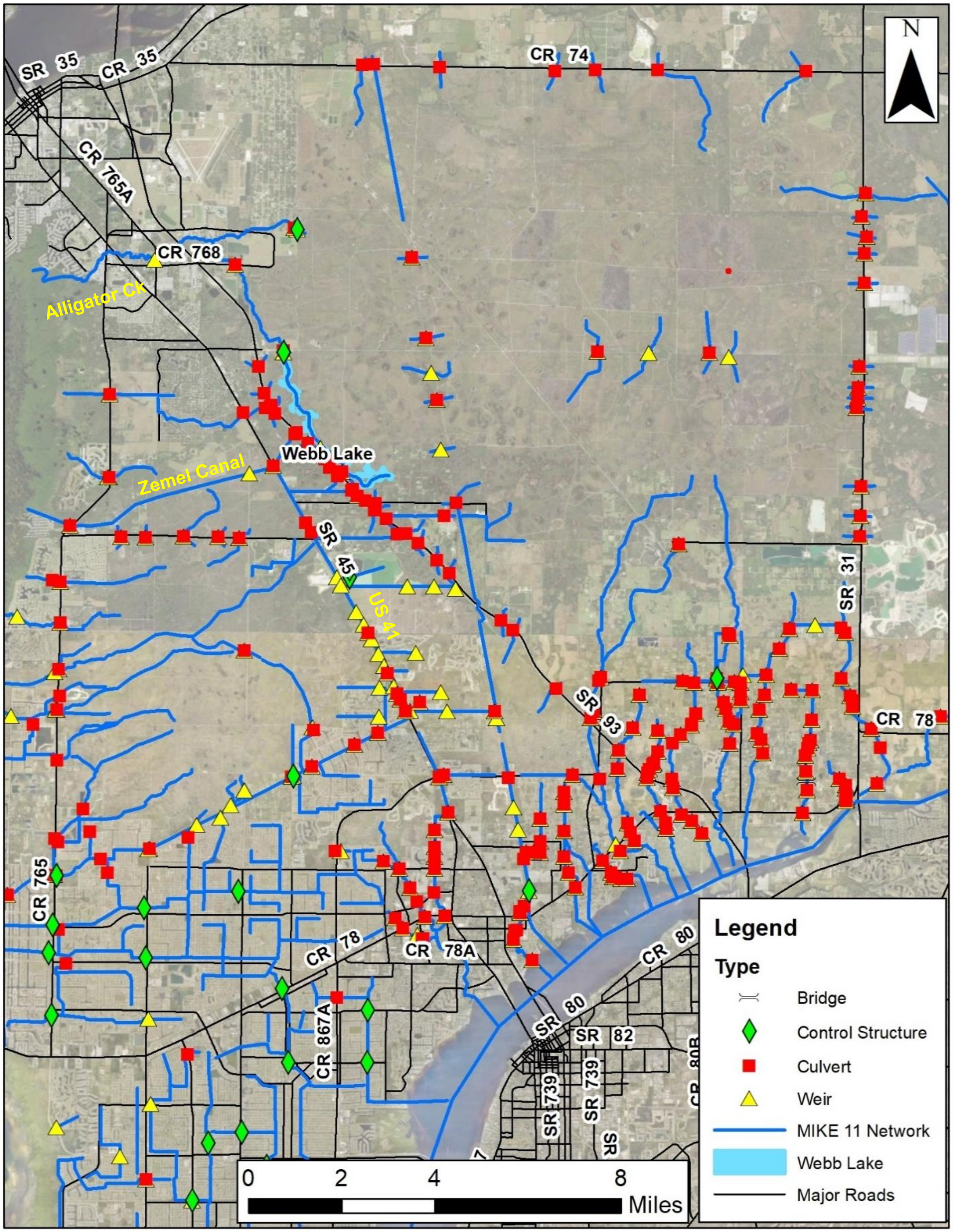


Figure 20. MIKE 11 branches and structures in the model

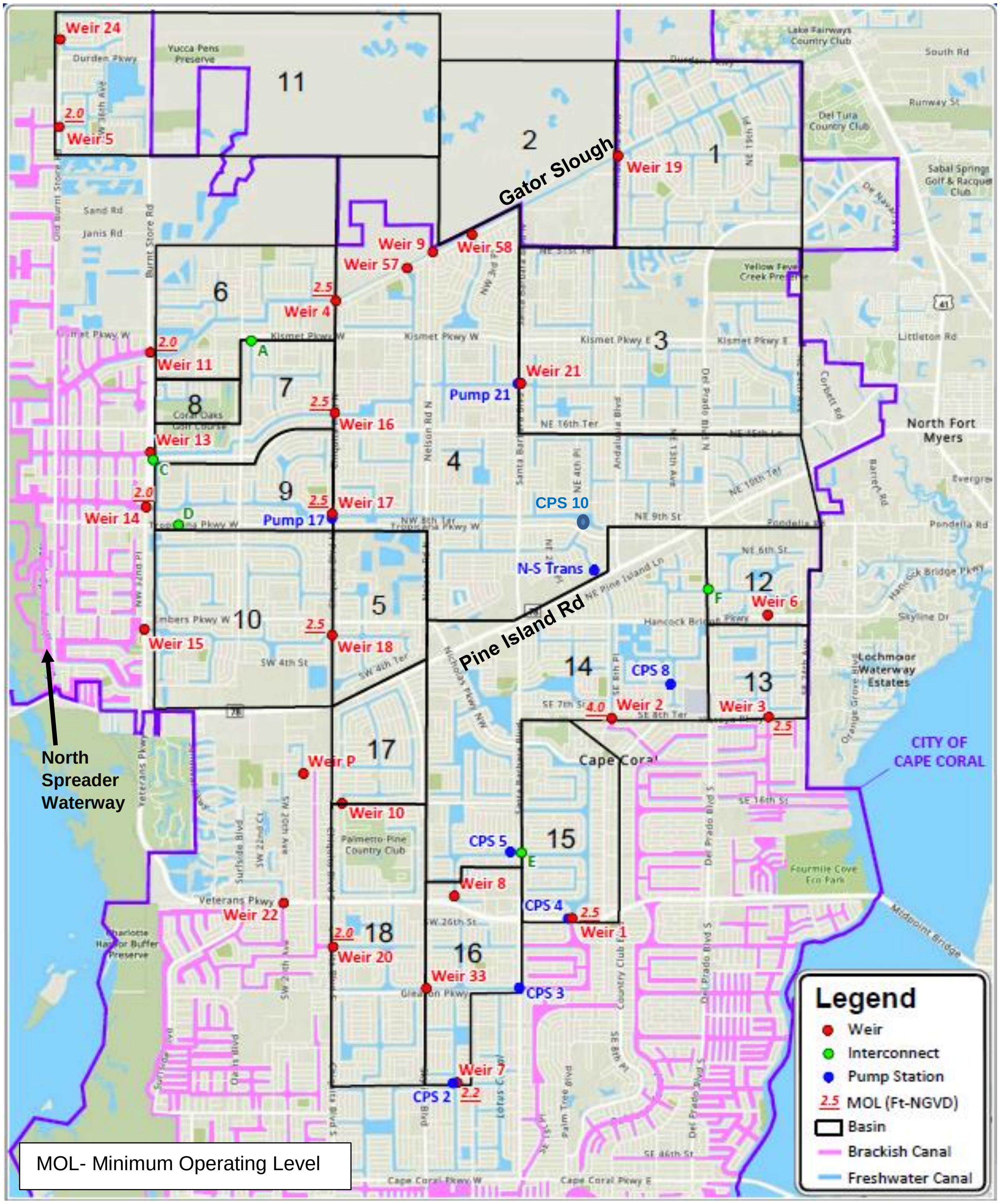


Figure 21. Cape Coral canals and structures

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 and SED 2019) and have been added to the cross-section file. **Figure 22** also illustrates the location of five additional cross sections were surveyed in November, 2021 to assist with model calibration efforts. 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 (ADA and AIM, 2015).

Boundaries. Tide level boundaries are applied to all creeks and canals that discharge to tide. The SFWMD MARKH station (location shown in Figure 1) is being used for the Cape Coral canals and all canals north to Alligator Creek in Punta Gorda. The modeling team attempted to identify a Charlotte Harbor tide water level time series that could be used for the tidal boundary on the northern portion of the model domain in future modeling efforts. The only available data is for the Peace River near Fort Ogden. Water levels from that station were compared to water levels at MARKH, and other than a 3-hour phase shift, there is little difference between tide data between the two stations. Accordingly, the MARKH station data has been used for all tidal boundaries north of the Caloosahatchee River estuary. The model boundary for Bullhead Strand (which flows east from Telegraph Slough, location shown in Figure 1) 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 (see Figure 42 for the location of these stations).

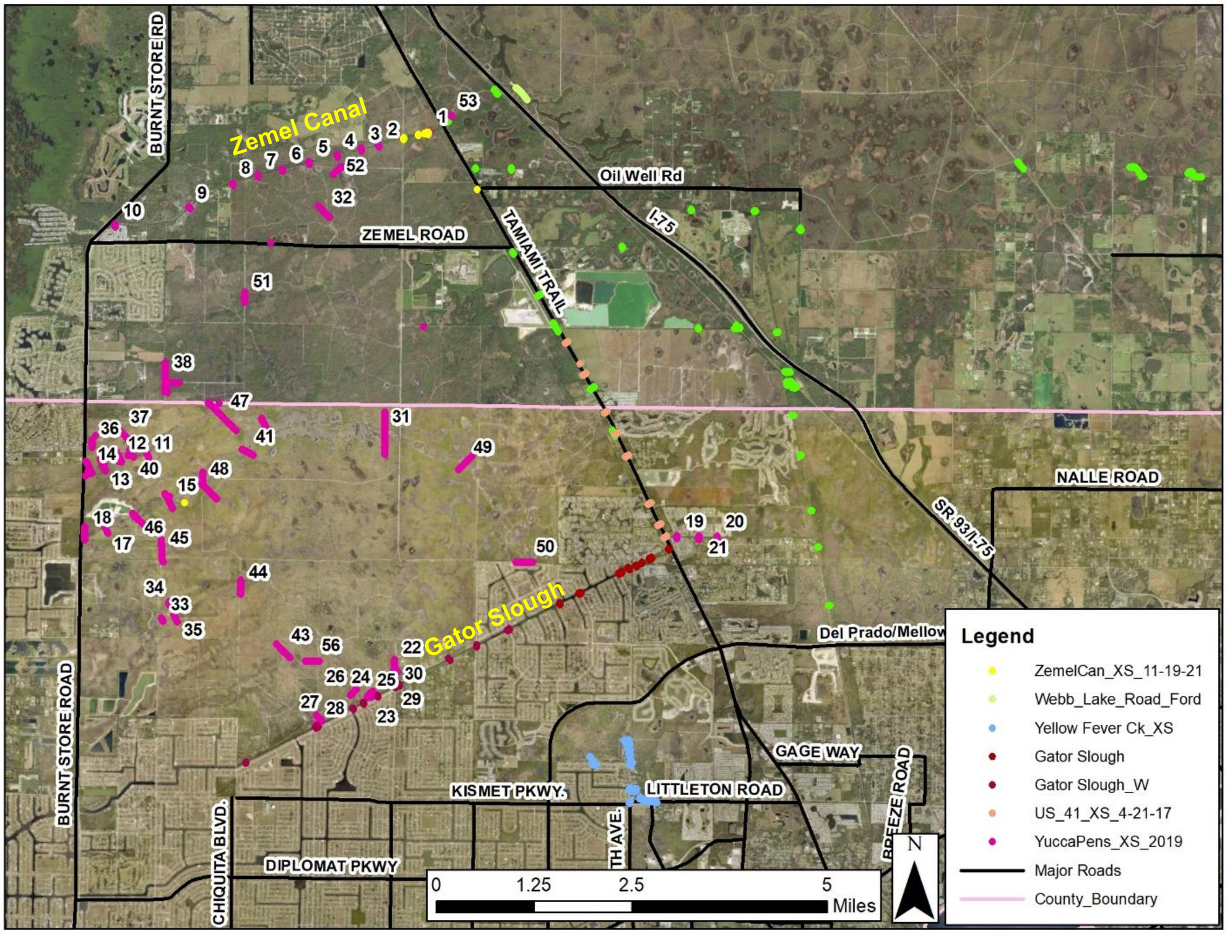


Figure 22. Cross section data used to update MIKE 11 cross-section file

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. Flood code assignment is based on the best professional experience of the modeling team. When there are exchanges on both sides of a MIKE 11 branch (e.g. Myrtle Slough), flood codes are assigned on both sides of the branch, however there are no rules on how many codes are on either side. Flood codes are only used on the east side of the SAL Grade Ditch since the

SAL Grade prevents exchanges for the west floodplain. Extensive field work during both dry and wet season conditions was conducted to understand the flow dynamics of the major streams and flow-ways within the model domain. The application of flood codes was therefore based on the knowledge gained from that extensive field work.

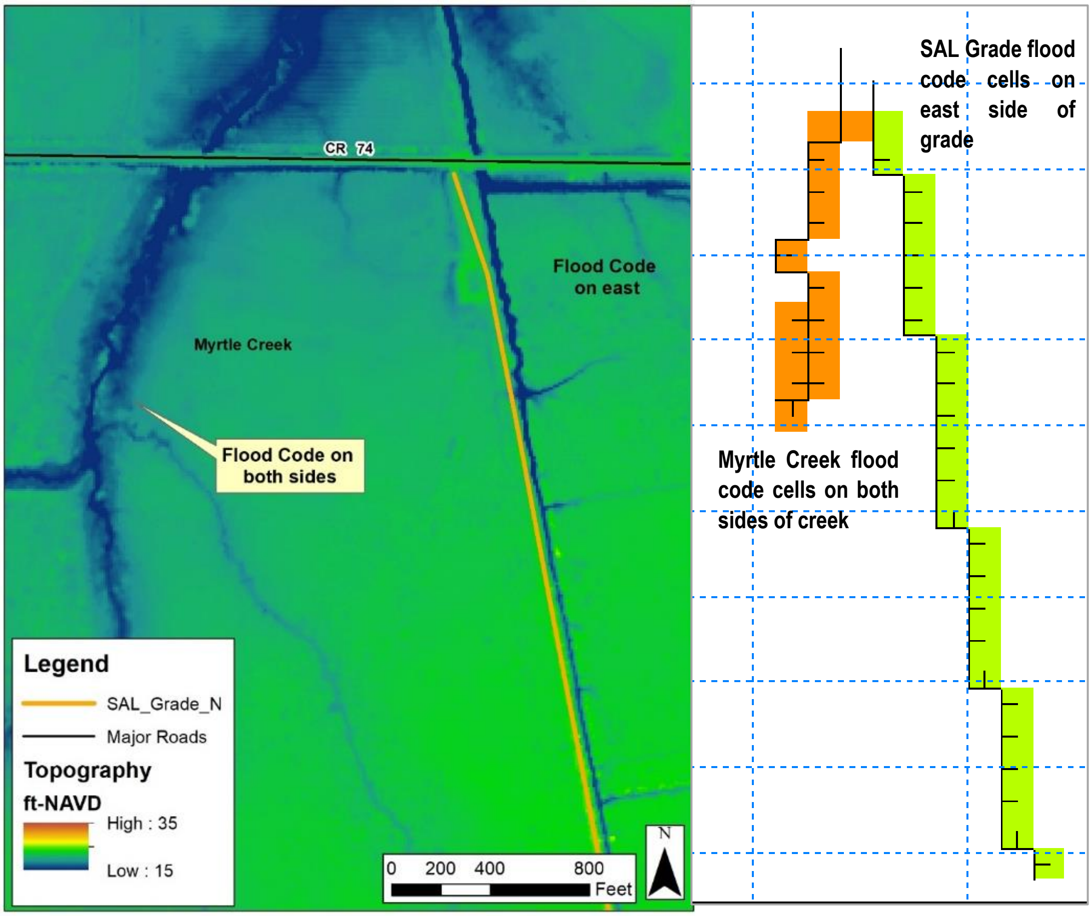


Figure 23. Flood code application along SAL in Charlotte County south of CR 74

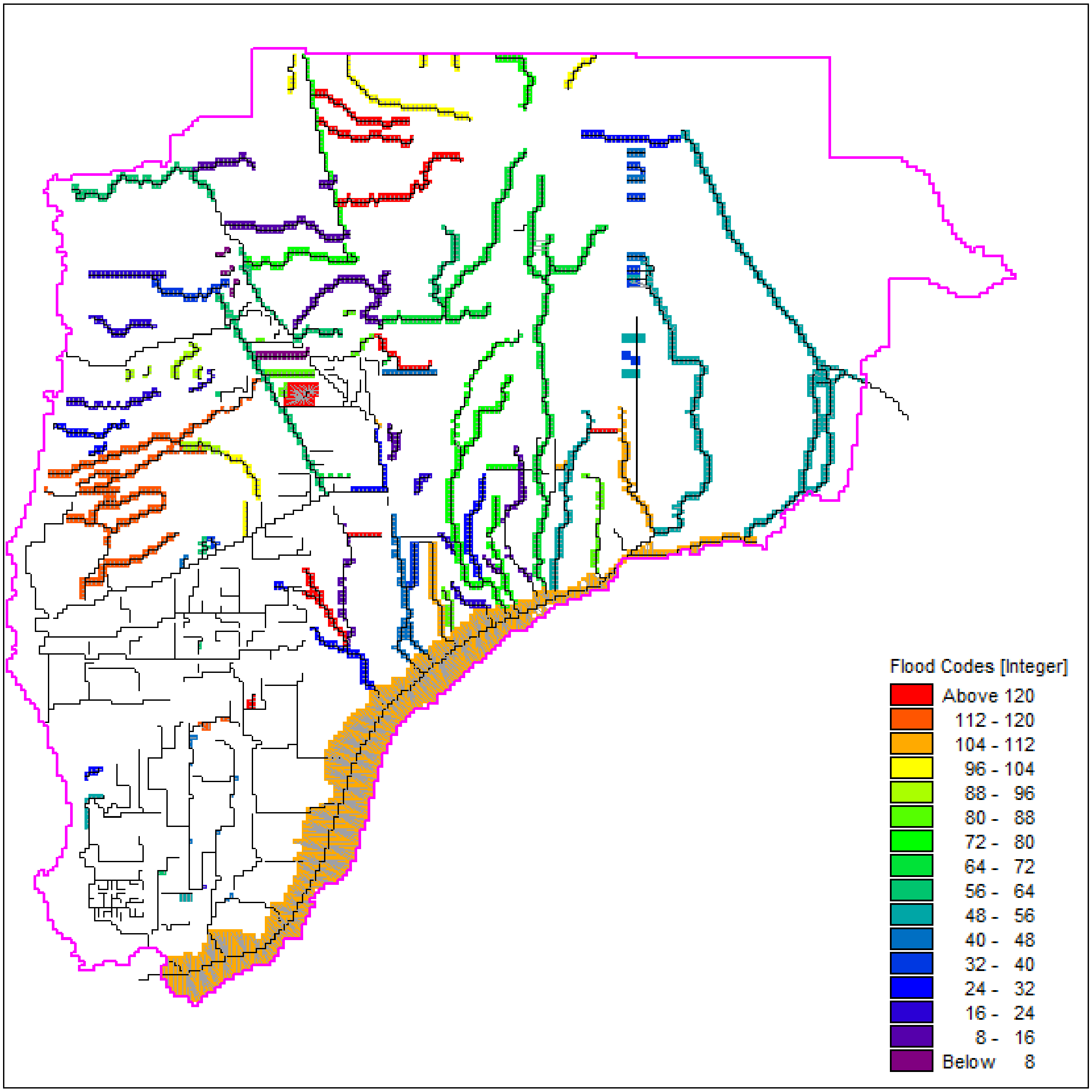


Figure 24. Flood code map in the Model.

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.
4. SOLFA #51 was added during calibration to better represent flows from north to south of Tuckers Grade on the eastern portion of Babcock Webb WMA (see location in **Figure 25**).

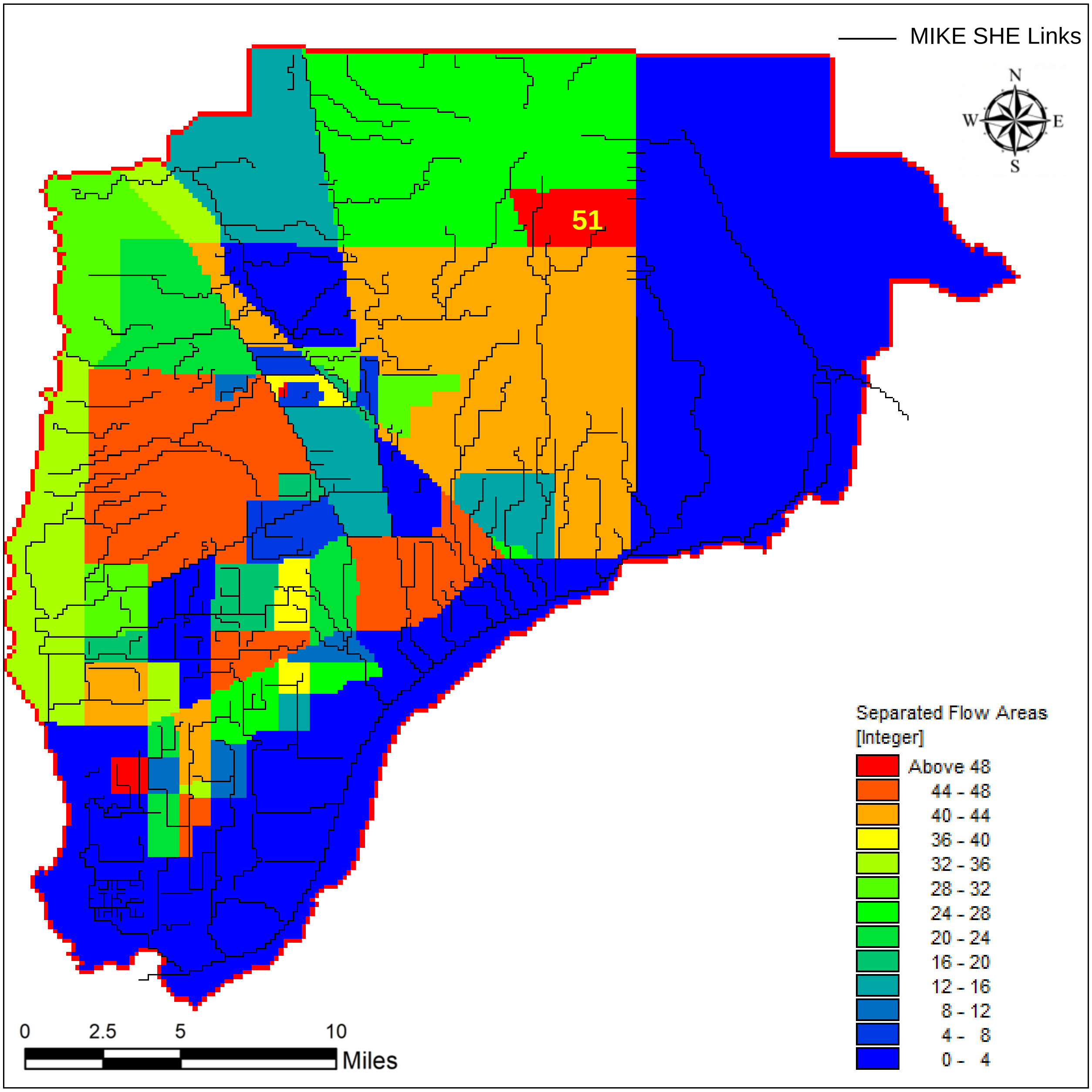


Figure 25. SOLFA map in the Model

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 affect the run time of the model. This MIKE SHE model **initially** used 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 they were not employed in the **preliminary** model version since irrigation is not a significant component of the water budget for this project (irrigation is 0.023% of rainfall in the model, which is insignificant). During the calibration, **we switched from the 2-layer to the Richards Equation method**, as stated elsewhere in the report (section 7.2, item 3, Section

C). The model predictions of irrigation and actual ET are relevant on deciding if using the 2-layer method or not, since the 2-layer method incorrectly turns off those processes when the water table level reach the bottom of the top numerical layer. 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 as the Gravity Flow method 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. An analysis of water balance results indicated that evapotranspiration (ET) was lower with the 2-layer method because ET is limited to the UZ zone with the 2-layer method. Accordingly, the model was modified to utilize the Richards Equation.

7.1 Soil Classes and Distribution

The previous model used a limited number of highly aggregated 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).

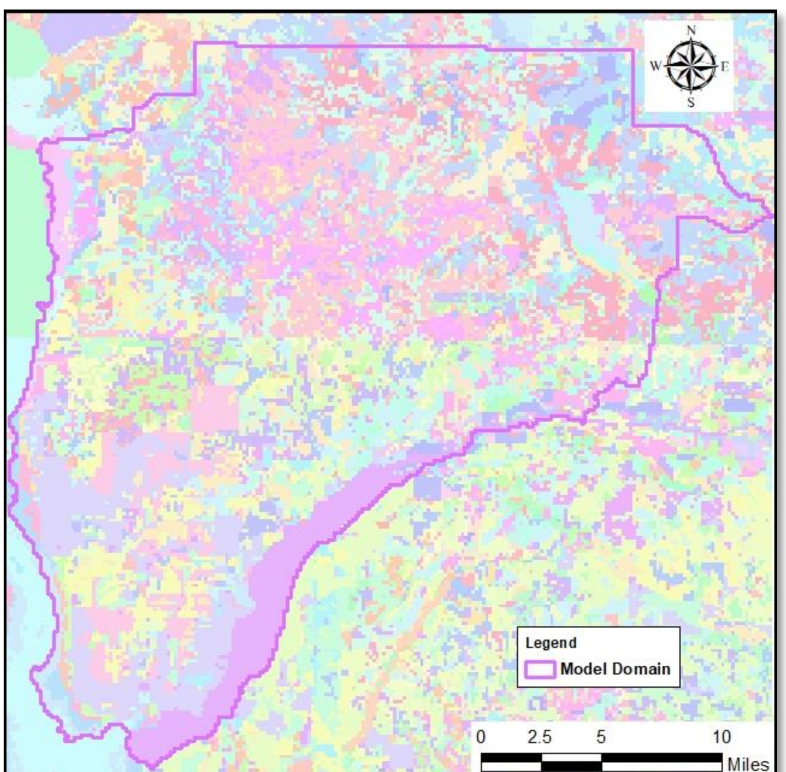


Figure 26. NRCS soil MUKey distribution around the model domain

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 NRCS soil classes. Note that each NRCS soil class is composed of layers or soil horizons, but the two-layer water balance method in MIKE SHE needs depth-averaged soil parameters. The two-layer method was replaced by the Richard's Equation Method during the calibration task, and these depth-averaged soil parameters from the two-layer method were reused in the new method.

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*** (Lago, 2021a). Soil parameter values in the model are vertically averaged. As a result, they do not correspond, in general, to the values for a specific horizon. The resulting five soil parameters necessary for UZ calculations 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 (Lago, 2021a)

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

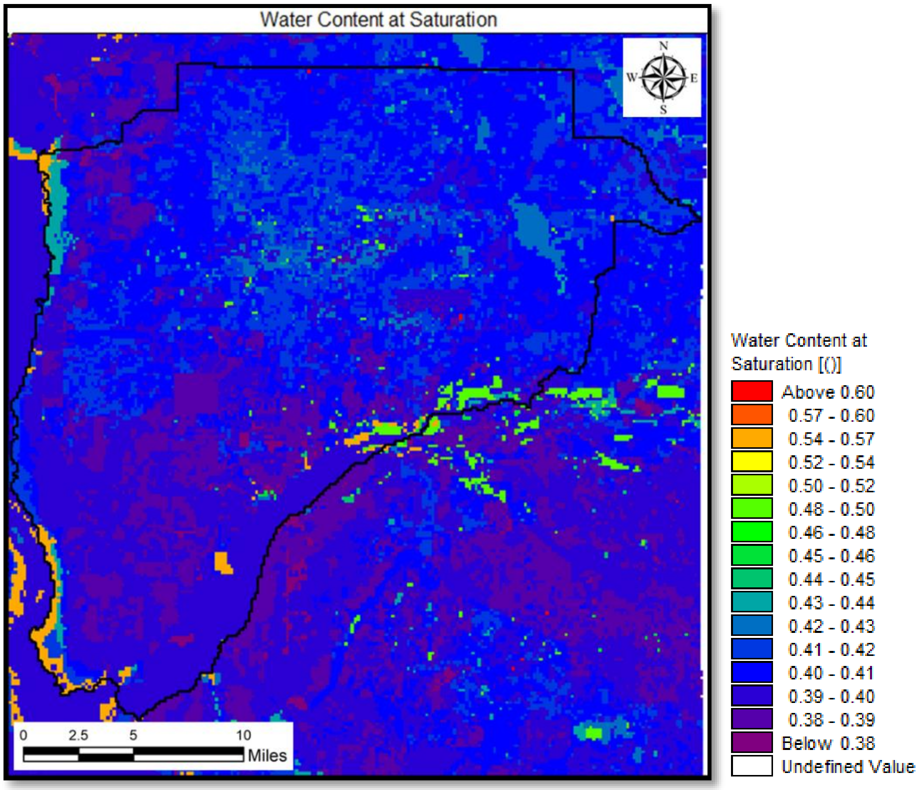


Figure 27. Soil water content at saturation

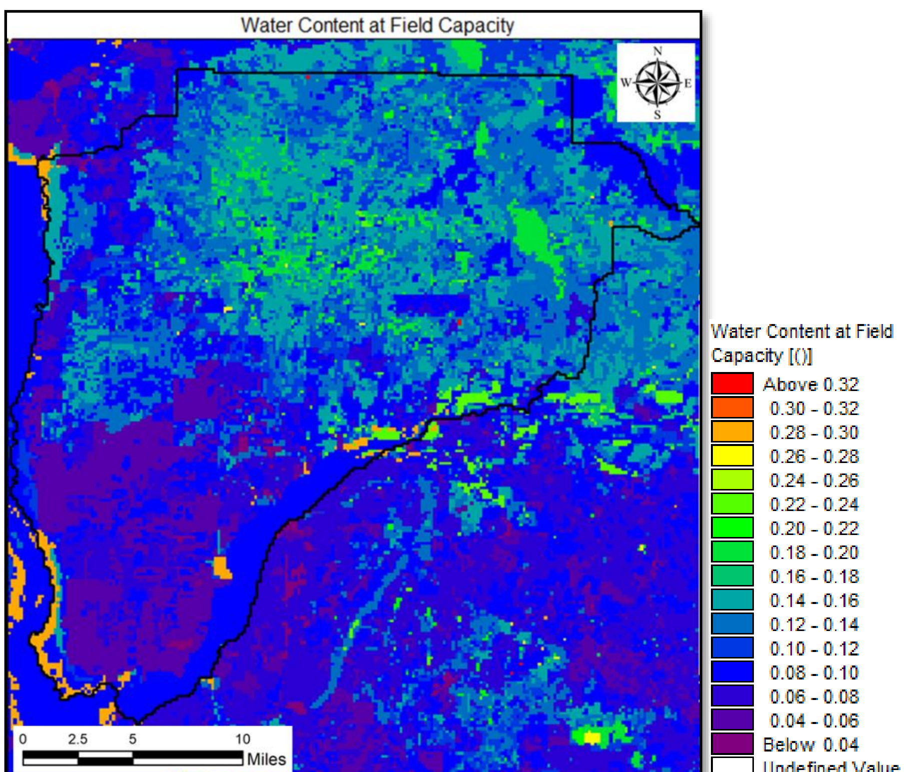


Figure 28. Soil water content at field capacity

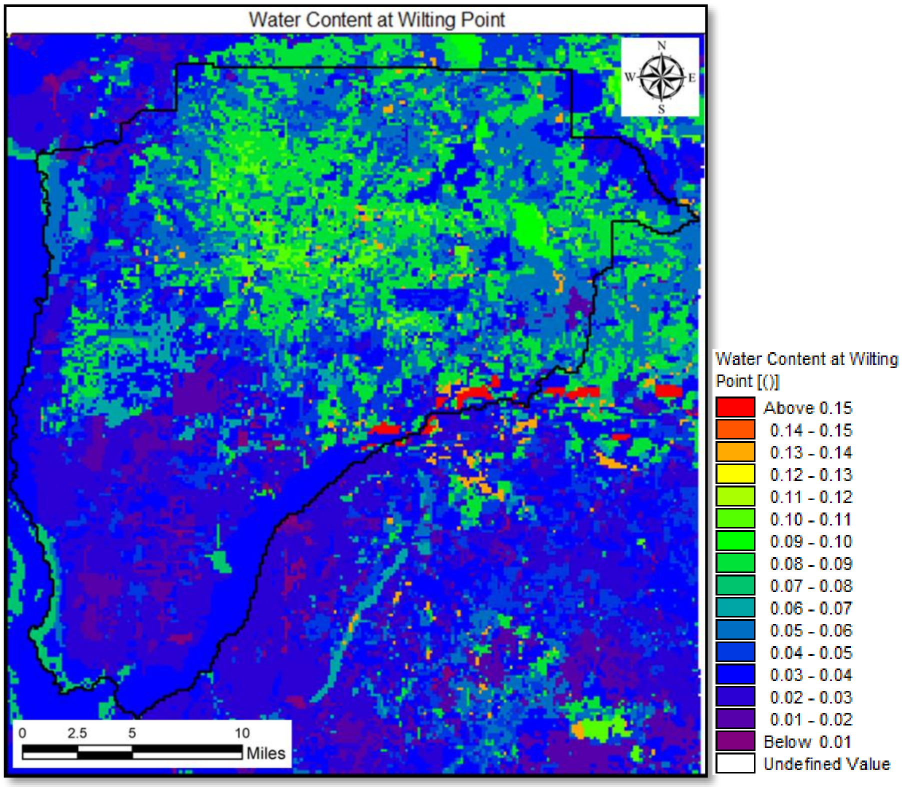


Figure 29. Soil water content at wilting point

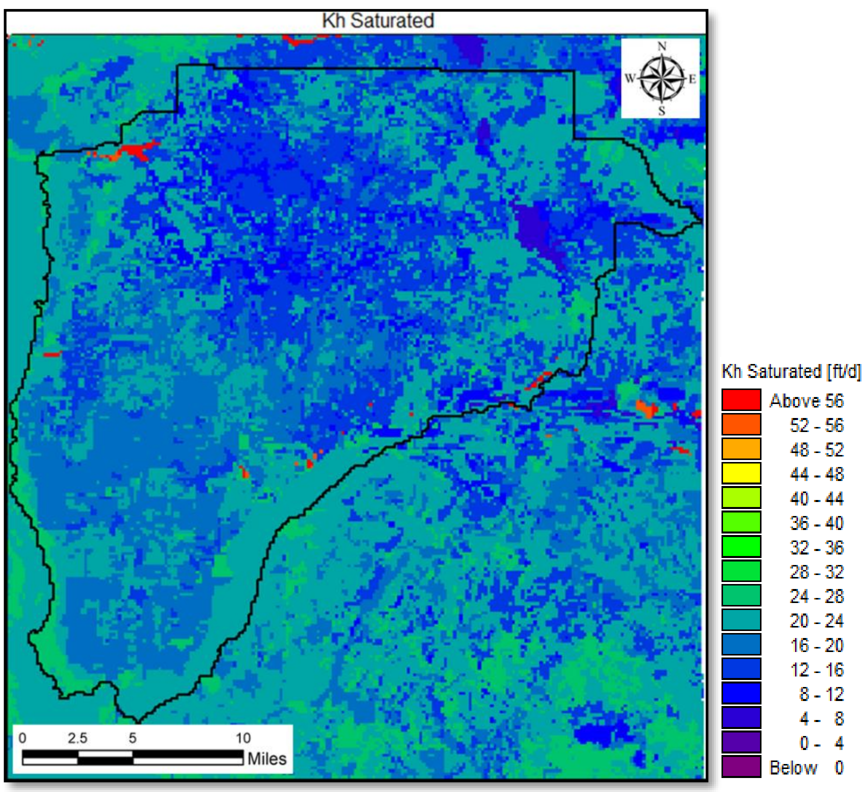


Figure 30. Soil hydraulic conductivity at saturation

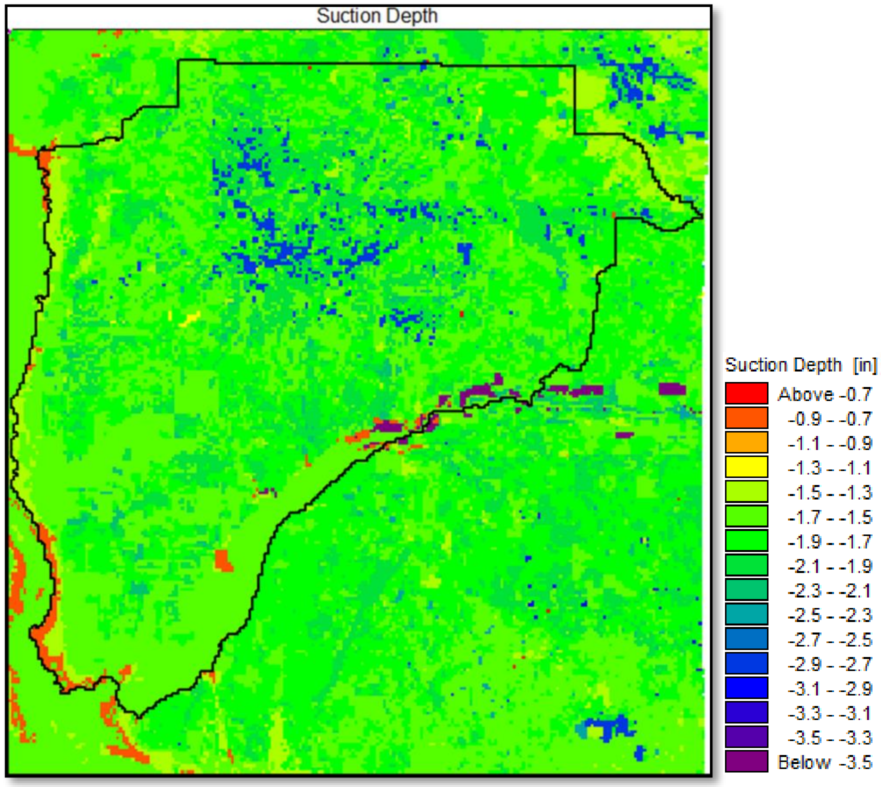


Figure 31. Soil suction depth

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. The drainage component is an empirical component that 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 (ADA and AIM, 2015) 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. The water table was split into two layers so that differences in conductivities for different components (e.g. sands, shell beds, and/or rock lenses) of the water table can be represented.

Hydraulic conductivity of the water table aquifer is initially set with uniform horizontal and vertical conductivities of 300 and 30 feet per day (ft. /day), respectively. After completion of the 50%

calibration effort, hydraulic conductivity values were adjusted in each model layer during the more detailed groundwater calibration effort (see Section C for more details). Well test or core analysis data were not existent to be able to establish an expected range of the hydraulic conductivity in the different geological layers. Furthermore, small-scale hydraulic conductivity tests such as slug tests often are not representative of groundwater hydraulic conductivity in large scale models (Schulze-Makuch & Cherkauer, 1995). The adjusted hydraulic conductivity median and range values are compared to the ones from a recent study (SFWMD, 2020) in ***Table 4***. Hydraulic conductivities in this model are higher than in the SFWMD LWCISM model. The SFWMD study did not use any observation station inside the study areas of Yucca Pens and Babcock-Webb. Given the greater number of stations used in this study, the conductivity values are felt to be appropriate.

Table 4. Hydraulic conductivity range in previous study and in the CH calibrated model

Hydrogeologic Unit	Parameter (ft./day)	[SFWMD, 2020] LWCISM Model	CH Partially Calibrated Model (after uniform values adjustment)	CH Calibrated Model (after spatial-variable adjustment)
Water Table (WT) Aquifer	Kh	50 [a], 50 – 445 [b]	Top : 800 Bottom: 240	Top : 806 [a], 456 – 1199 [b] Bottom: 297 [a], 125 – 521 [b]
Bonita Springs Marl (BSM)	Kv	3.1 [a], 0.2 – 91 [b]	12	10 [a], 6 – 15[b]
Lower Tamiami (LT)	Kh	4.8 [a], 0.9 – 69 [b]	420	289 [a], 178 – 393[b]
Upper Hawthorn Confining Unit	Kv	5.8 [a], 0.015 – 46 [b]	0.001	0.0018 [a], 0.0005 – 0.005 [b]
Sandstone (SS) Aquifer	Kh	50 [a], 0.001–135 [b]	420	1228 [a], 243–1500 [b]

Notes: a) median value
b) range from 5 to 95 percentile.

Maps of the bottom elevation, horizontal hydraulic conductivity, and vertical hydraulic conductivity for each geologic layer are presented in **Appendix A**. The contours shown for the depth of the water table aquifer presented in Appendix A are a result of a Simple Kriging method using all data available at the time of the analysis.

Lateral boundary conditions for the SZ computational layers were established by computing daily interpolated head maps for a calibration simulation run approximately one week prior to the final calibration, and the heads were extracted for March 3, 2021 since water levels on that date, on average, resulted in simulated water levels in May 2020 (start of the calibration period) that best matched observed water levels. The TIN interpolation method is conducted from observation stations inside and outside the model domain for the northern boundary. **Figures 32 - 34** present temporally-average spatially-interpolated head maps for the three aquifers in the model. The east model boundary is closed, and the western and southern boundaries use tidal water level data.

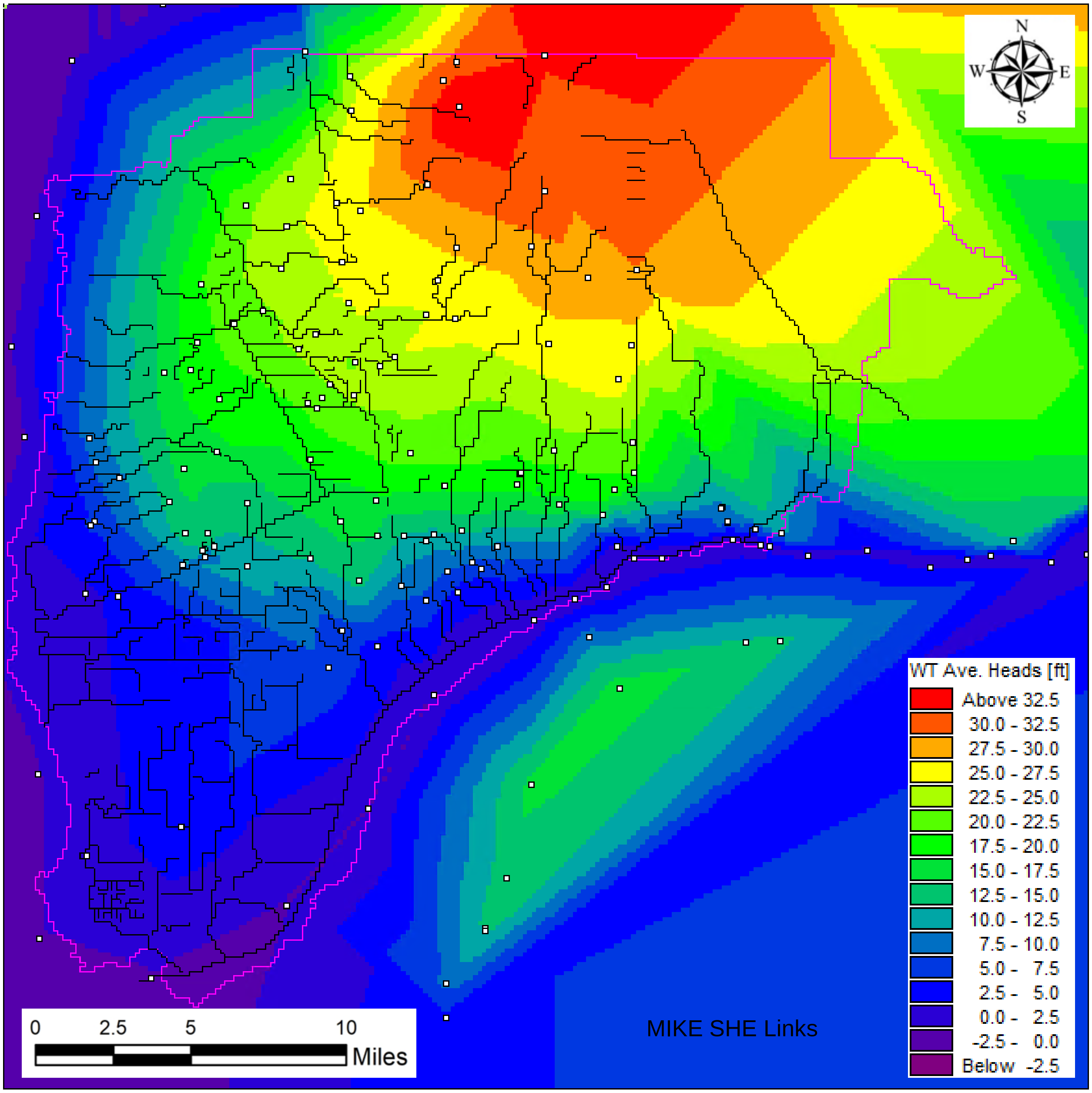


Figure 32. Interpolated heads in the Water Table Aquifer: temporal average from 1/1/20 through 12/1/21

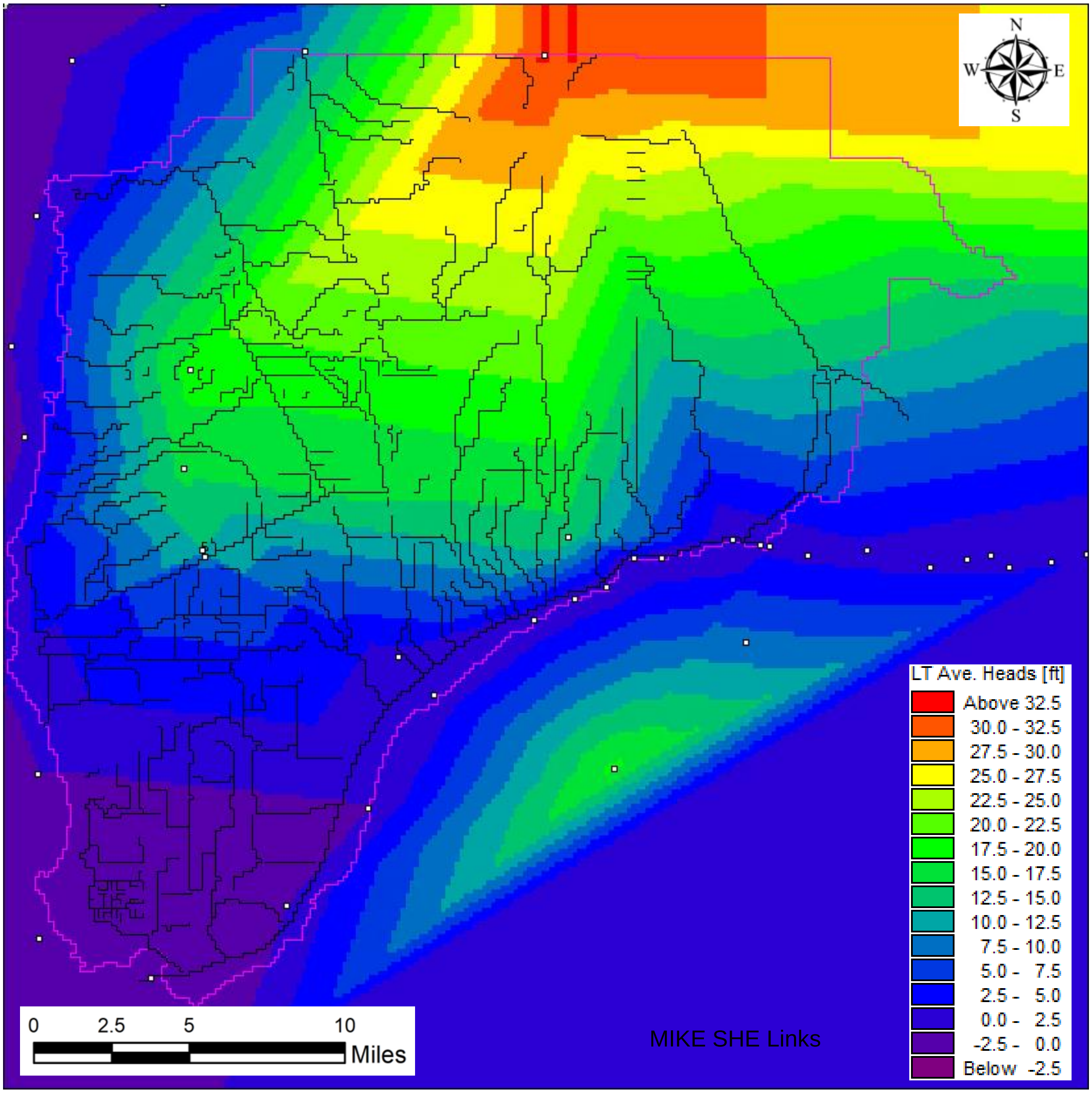


Figure 33. Interpolated heads in the Lower Tamiami Aquifer: temporal average from 1/1/20 through 12/1/21

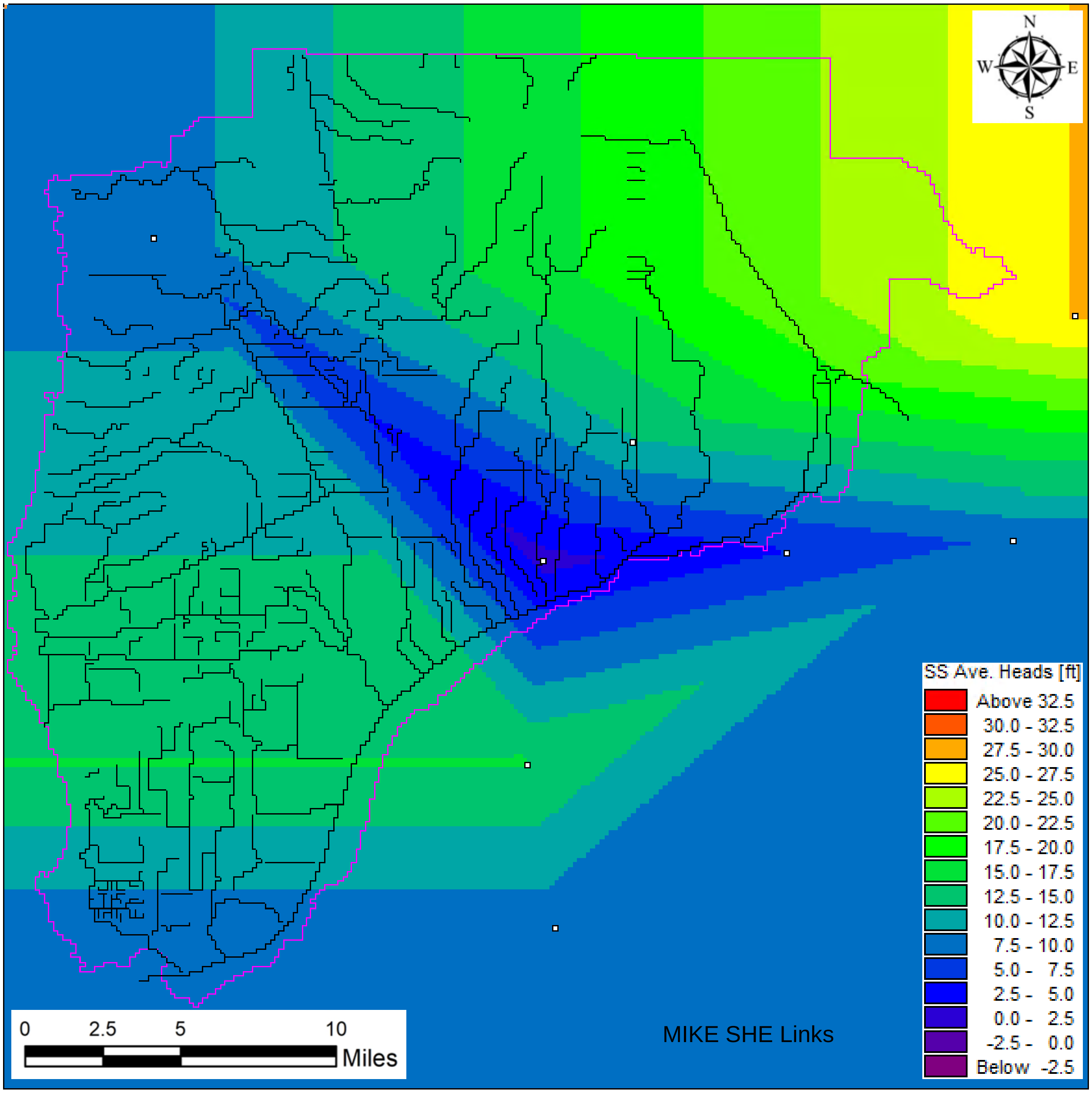


Figure 34. Interpolated heads in the Sandstone Aquifer: temporal average from 1/1/20 through 12/1/21

8.2 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*** (presented above in section 4.2). 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.

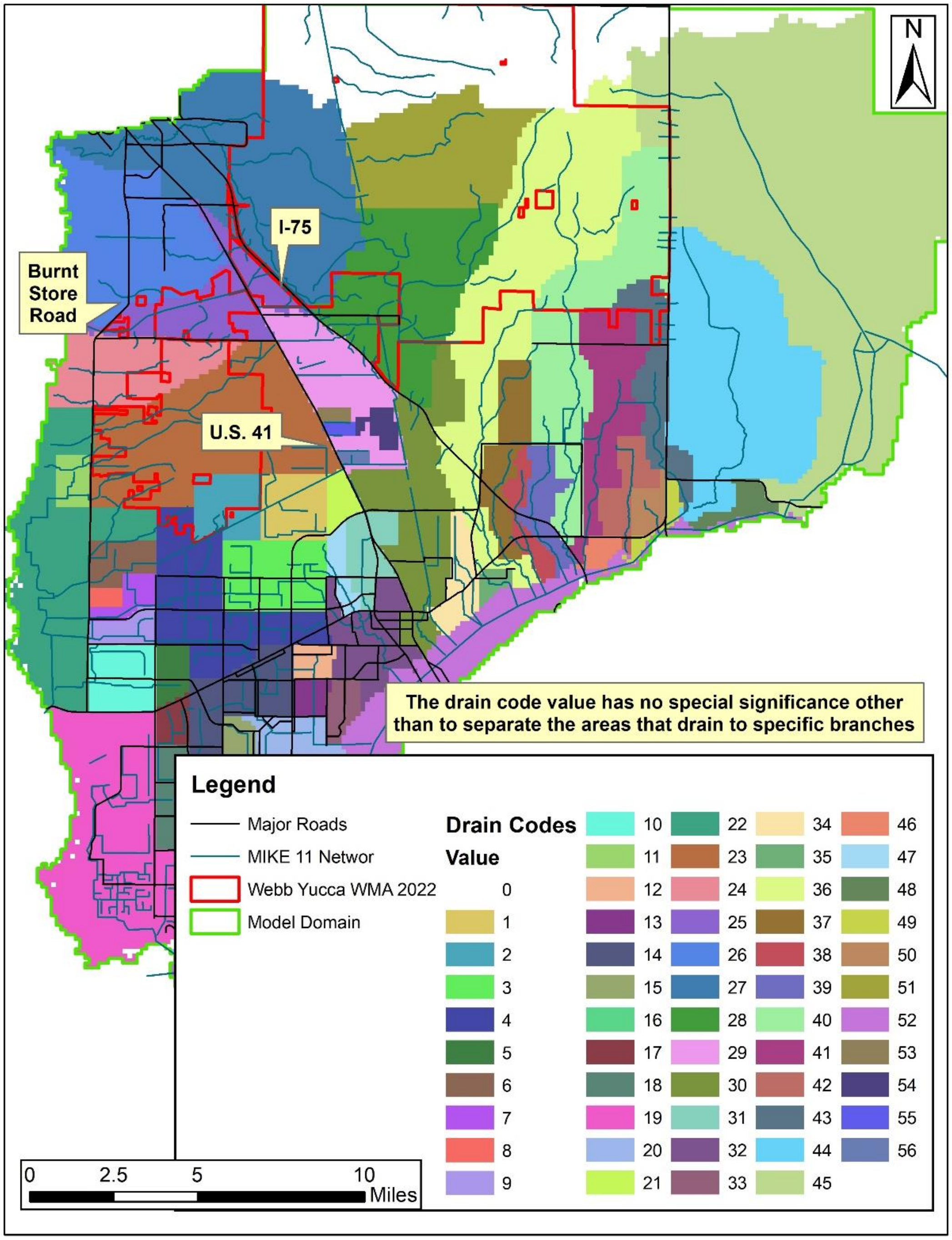


Figure 35. Drain codes

8.3 Leakage Coefficient

The overland (OL) flow module in MIKE SHE uses a leakage coefficient to reduce the infiltration rate at the ground surface and the seepage outflow rate across the ground surface. Conceptually, the leakage coefficient is used to account for soil compaction and fine sediment deposits on flood plains. Flood coded cells will use the leakage coefficient specified in the MIKE SHE links, though.

Initially, the Leakage Coefficient in the model was set to a uniform value of 1e-4 1/s. However, sensitivity tests showed that the model performance varied significantly if the coefficient was decreased. Thus, the leakage coefficient map shown in ***Figure 36*** was obtained during the calibration after adjusting spatially varying leakage coefficients in the typical range from 1e-6 to 1e-4 1/s.

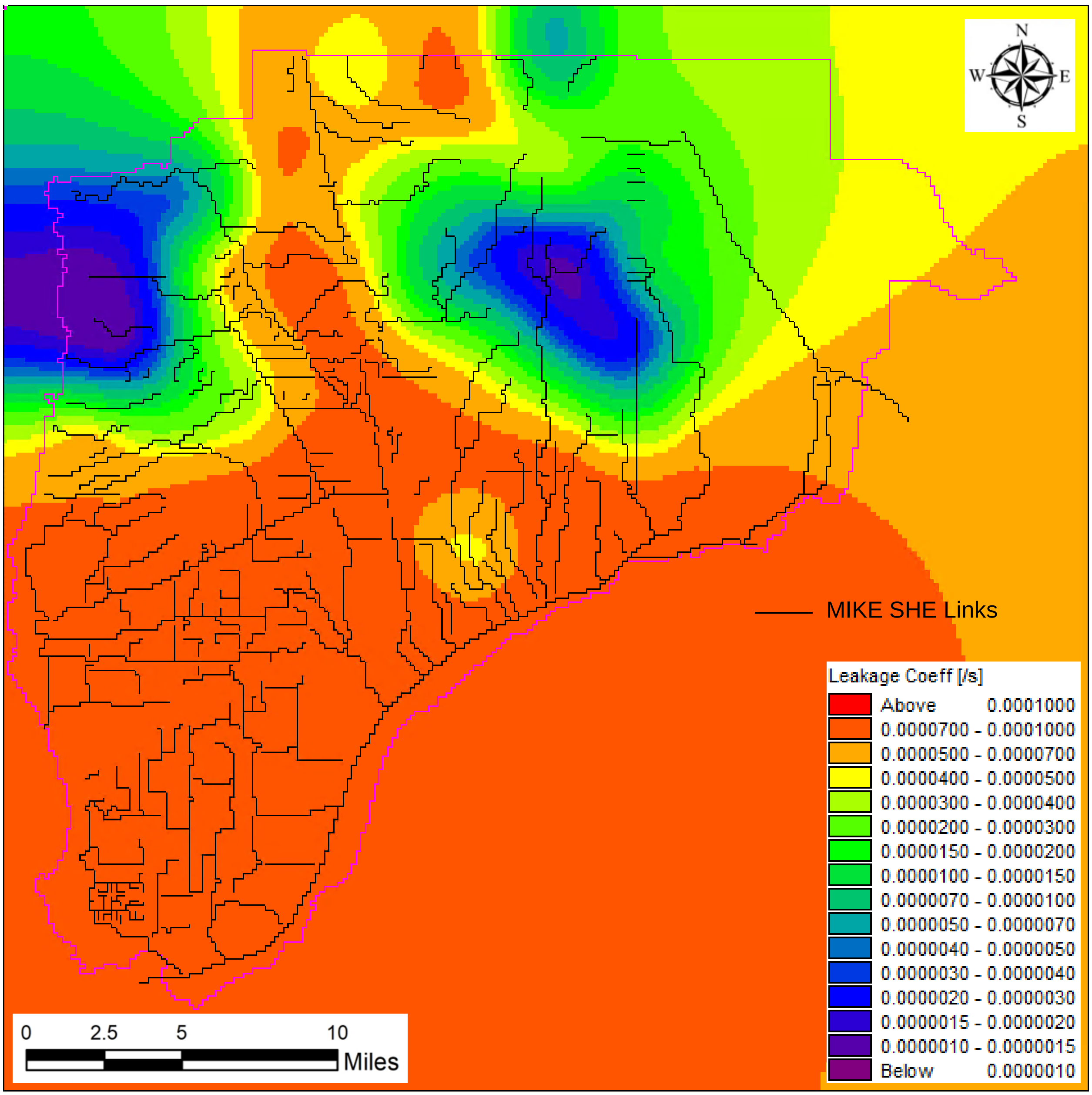


Figure 36. Leakage coefficient map

8.4 Water Supply Wells

The locations of the potable water supply (PWS) wells within the Charlotte Harbor Flatwoods (CHF) model domain are presented in ***Figure 37***. Monthly pumping data for PWS wells are available from SFWMD for the different water use permits (WUP). The period of record is from 1980 through 2020. The prior model developed in 2016 only included data through 2014. 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.

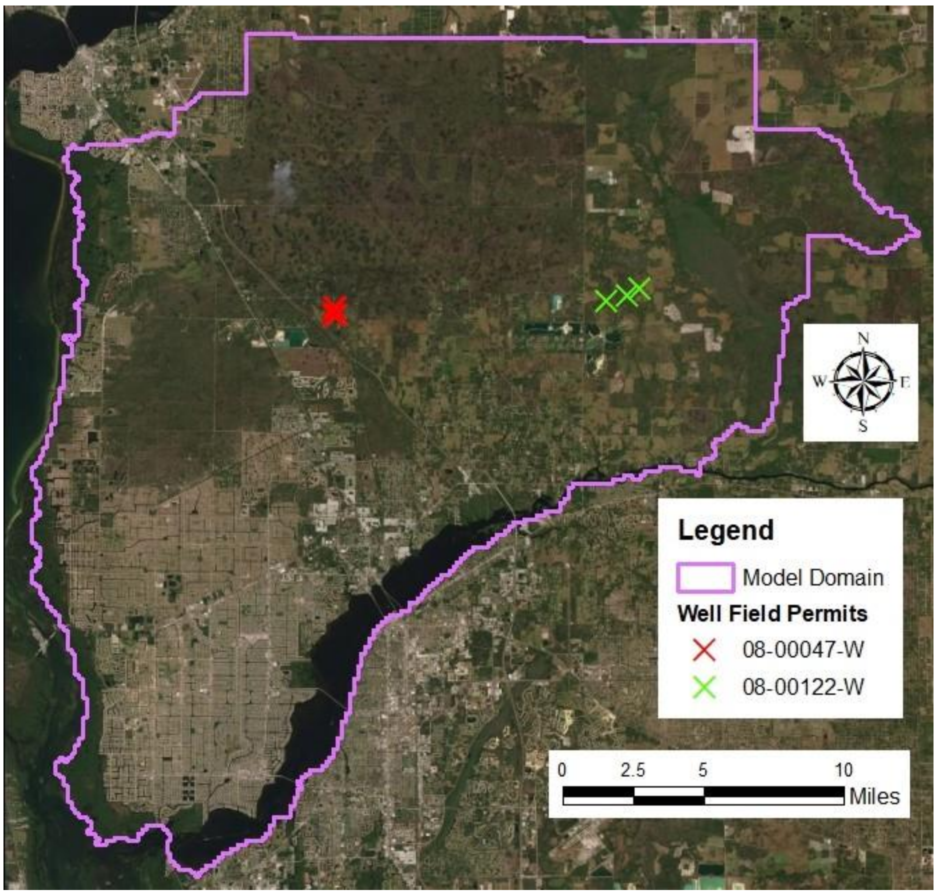


Figure 37. Water supply wells

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 38*** and ***39***. The available data for the Town and Country Utilities permit (08-00122-W) presented in ***Figure 39*** began in 2016. Note that 2021 was filled by repeating the data from the last reported year (i.e., 2020). Since groundwater pumping is a very small component of the water budget (0.23%), this approach to fill data gaps is deemed reasonable.

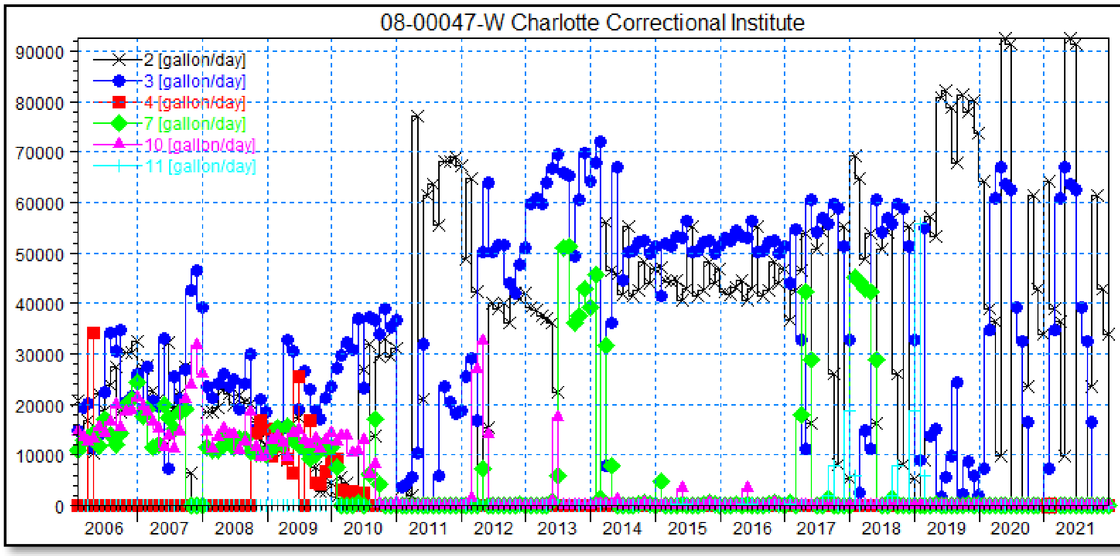


Figure 38. Monthly PWS pumping extraction rates from wells at Charlotte Correctional Institute

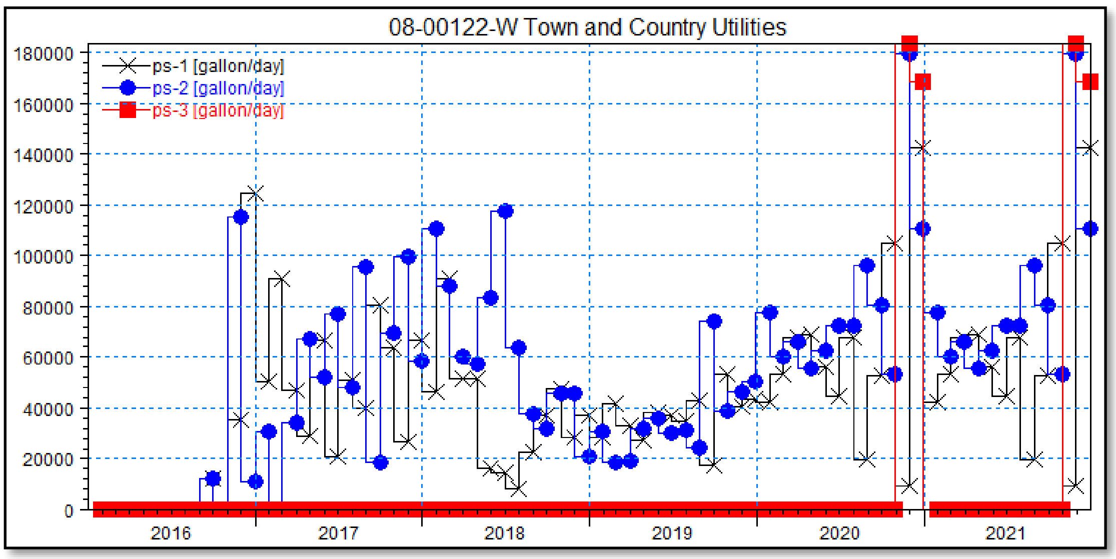


Figure 39. Monthly PWS pumping extraction rates from wells at Town and Country Utilities

Table 5 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 6***. The evolution of the total monthly pumping inside the model domain is plotted in ***Figure 40*****.**

Table 5. 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 6. 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

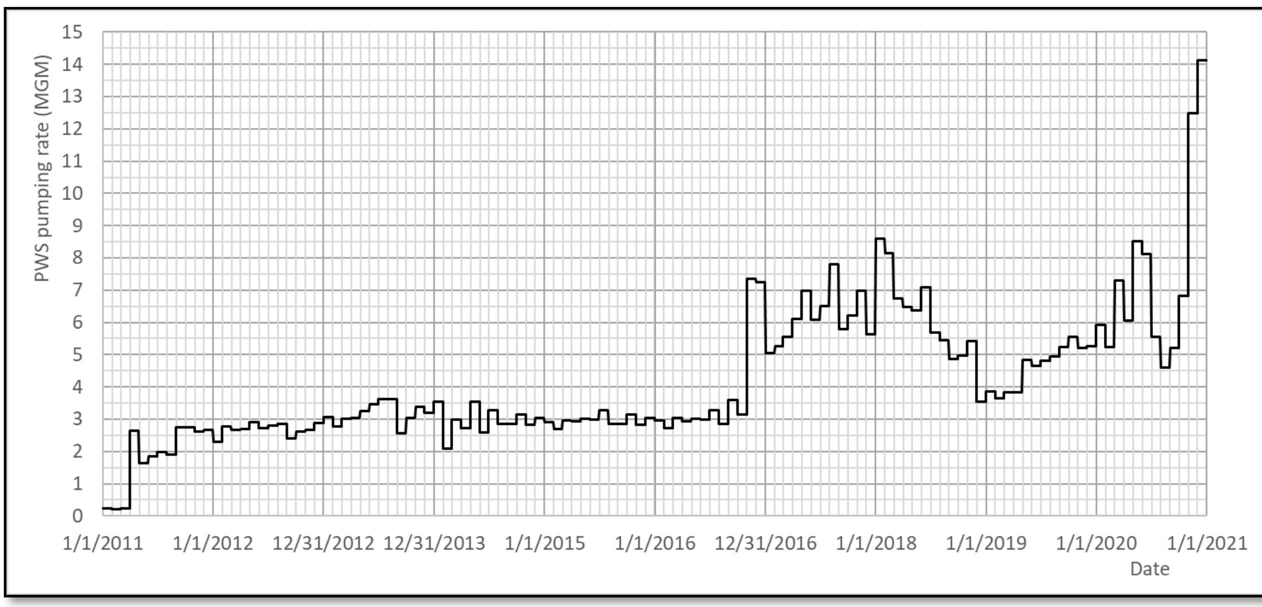


Figure 40. Total monthly PWS pumping inside the model domain

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. This modeling effort includes calibration data for many stations that were not available in prior calibration efforts, such as BW-1 through BW-20, YP-4 through YP-9, STA-6, STA-7, STA-8, MW-3, MW-14, MW-23, MW-24, MW-29, MW-30, SW-1, SW-2, SW-3, MW-CCI, Southwest Aggregates monitoring stations, and the 8 flow monitoring stations. In addition, manually-measured staff gages only recorded in the wet season in Babcock Webb and Yucca Pens were converted in 2019 and 2020 to automatic data logger monitoring stations, including SR-2, SP-4 through SP-13, SP-16, SP-17, SR-8, and SR-9.

Currently, the model calibration includes 110 groundwater and 34 surface water monitoring stations. The increase in the available data for model calibration greatly enhances the ability of the model to more accurate simulate overland runoff and groundwater flow processes within the study area. Model performance at these stations is used for calibration, verification, and to establish boundary conditions. Locations of calibration stations in the southern and northern portions of the model are presented below in Section C. The calibration period is May 15, 2020 through November 15, 2021, which is the period that data is available for the stations installed as part of this project. Calibration within Cape Coral is limited to improving model performance in Gator Slough. In addition, a number of calibration stations are located in North Fort Myers (see Figure 1 for the location of this area), and calibration in North Fort Myers was limited since this area does not have a significant effect on model performance in Babcock Webb WMA.

SUMMARY OF MODEL CALIBRATION

This section presents results of model calibration. The model development and calibration process initially consisted of reviewing simulation results and fixing any structural details that were 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 were 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 was conducted 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 obtained, and the dimensions and invert elevations of a number of culverts under Burnt Store Road were updated.

The initial focus of model calibration was fixing issues identified in the input files and updating parameters based on the latest available data. A summary of the model changes is provided below:

- Model instabilities were observed in calibration plots for the U.S. 41 ditches. These instabilities were corrected by merging the east and west U.S. 41 ditch branches, adding known culverts under driveway entrances, and utilizing field-verified channel dimensions to revise cross sections for side ditches east of U.S. 41.
- Invert elevations of several culverts were revised based on recent field checks, survey information, and recently obtained roadway plans.
- New branches and culverts were added for north-bound conveyances under CR 74, Bermont Road. Field measurements of culvert dimensions were obtained, and invert elevations were measured relative to the edge of pavement.
- Gate elevation data for Weir 11 was checked and was found to be entered using the 1929 NGVD datum. The data were converted to 1988 NAVD.
- The locations and well depths of a number of calibration stations were revised based on more detailed information.
- Cross sections and/or weirs were added to represent locations where channel deposits restricted outflows below the elevation of the channel deposit. Extensive field work during both dry and wet season conditions was conducted to understand the flow dynamics of the major streams and flow-ways within the model domain. Water was pooled upstream of apparent high points in channels, surveying data identified locations with higher channel invert elevations, etc. The MIKE 11 input files were modified where these obstructions were observed. Details on how obstructions were accounted for in the model with back-up information is presented in **Appendix B**.
- The water table aquifer was split into an upper and lower zone so that conductivities could be adjusted to represent localized differences in either the upper or lower portion of the aquifer. In some areas, fine-grained deposits are present that may restrict infiltration (e.g. in cypress domes), while in other areas permeable rock or shell deposits in the lower portion of the water table aquifer may allow easier flow of groundwater. The process of adjusting conductivities in the upper and lower portions of the water table aquifer is on-going.
- Horizontal and vertical conductivities were initially set to uniform values for all groundwater layers with horizontal conductivities 10X larger than vertical conductivities. Sensitivity tests

were conducted for those uniform groundwater hydraulic conductivities to determine the optimum starting point for the groundwater calibration process that will vary groundwater conductivity on a spatial scale.

Following the initial calibration phase, the following activities were conducted to further improve the calibration:

- Modifying groundwater hydraulic conductivities.
- Testing differing computation methods for the unsaturated zone
- Evaluating leakance coefficients that govern interactions between surface layer and the saturated zone. Leakance is lower in areas where surface water infiltration is reduced due to the presence of shallow layers of low permeability or in wetlands that have muck sediments.
- Additional improvements were made in the representation of surface water features (for example, additional surveyed cross sections were obtained for Zemel Canal west of U.S. 41).

The focus of calibration is matching simulated values to measured values of head elevation in the saturated zone, water elevations in MIKE 11 branches, and flows. Calibration performance was ranked according to the following criteria:

Good: MAE ≤ 0.75 ft., correlation coefficient r ≥ 0.8, and/or Nash Sutcliffe coefficient ≥ 0.3

OK: MAE 0.75- 1.0 ft., correlation coeff. r = 0.7 – 0.8, and/or Nash Sutcliffe coefficient = 0.2 - 0.3

Poor: MAE > 1.0 ft., correlation coeff. r ≤ 0.7 and Nash Sutcliffe coefficient < 0.0

The goal is to meet 2 of 3 calibration targets (MAE, r, NS). The criteria were developed based on professional experience in calibrating numerous MIKE SHE/MIKE 11 models in southwest Florida. A number of rankings were qualitative and did not adhere strictly to the criteria above based on a review of the calibration plots.

Groundwater hydraulic conductivities were varied spatially to improve calibration. Two simulations are run varying horizontal and vertical conductivity values by a factor of 1.2 and 0.8. A statistical comparison using MAE is made for the initial simulation and the two sensitivity tests (1.2 and 0.8) at all calibration stations. Note that correlation coefficient (r) and Nash Sutcliffe coefficient values were also checked throughout this effort. Typically, the correlation coefficient and Nash Sutcliffe coefficient values improved as MAE improved. However, performance for all three statistical measures was constantly checked throughout the calibration process.

At each station, hydraulic conductivities are unchanged if there is no change in calibration performance (as measured by MAE) between the starting simulation and the high and low sensitivity tests. When the calibration performance improves either by increasing or decreasing hydraulic conductivity, then the area surrounding that calibration station is modified accordingly using the Inverse Square Distance method. This process is repeated until there are no further improvements in overall model calibration. A summary of sensitivity tests conducted as part of this project are summarized below in ***Table* 7**. The selection of the parameters to be varied during sensitivity testing was based on results of sensitivity testing conducted in the South Lee County MIKE SHE/MIKE 11 model (Lago, 2021a).

The sequence of calibration activities is summarized below:

1. Initially the surface water conveyance system was refined (described above)
2. The unsaturated zone computation method was changed from the two-layer to Richard's Equation.
3. All K_c values in the vegetation database were decreased by 0.05. K_c values prior to the change typically ranged from 0.5 to 1.2, except for Water which had a value of 1.0 and was unchanged. After additional simulations, K_c values were further adjusted to values ranging from 0.65 to 0.7. Cumulative flow error at flow calibration stations decreased from 34% to 22%
4. A new branch was added to provide a second connection from Webb Lake to Zemel Canal based on field identification of culverts under Webb Lake Road
5. Sensitivity tests were conducted for Manning's n values used in MIKE 11 and overland flow (see Table 7 for details).
6. Sensitivity tests were conducted for MIKE 11 leakage coefficients (see Table 7 for details).
7. Additional changes were made to surface water conveyance based on additional information. A weir was added in Gator Slough east of U.S. 41 based on a review of design plans for the North Fort Myers Drainage Restoration project. Also modified MIKE 11 network and added a new SOLFA upstream of SP-8, the Big Water Ford on Tuckers Grade 9.8 miles east of I-75. Calibration improved at SP-8 and SP-7 north of SP-8.
8. Culverts under SR 31 were identified in Google Earth and culvert dimensions were obtained during a field visit. Additional MIKE 11 branches were added to the model.
9. Changes were made in the unsaturated zone to limit to soil horizon to the top 1.5 feet, and a new WT Generic soil horizon was created with a S_y reduced from 0.3 to 0.2. This change allowed the water table to rise more quickly at the beginning of the wet season. Initial conditions were established using simulation results from prior simulations, and it was not possible to perfectly match initial groundwater levels at all calibration stations. Accordingly, low initial water levels limited the ability of the model to simulate water levels during the initial portion of the dry season in 2020. Performance in the early portion of the 2021 wet season were represented more accurately at most stations.
10. Due to simulated peak stages at SP-13 (Zemel Canal at U.S. 41) being too low, additional field work was conducted. Newly surveyed cross sections were added to Zemel Canal west of U.S. 41, the low flow channel width was reduced based on field observations and overbank Manning's n values were increased to 0.33. Heavy vegetation growth increases water depths, and Manning's n values were increased to accomplish this.
11. Cross sections were updated using more detailed LiDAR data.
12. Sensitivity tests were conducted varying the multiplier factor between K_h and K_v from 10 to 20, 50, and 100. This sensitivity test confirmed that the multiplier factor = 10 was appropriate.
13. Hydraulic conductivity sensitivity tests (see paragraphs above)
14. Gated culverts were added in SAL Grade Ditch in vicinity of the Tram Grade (first east-west road north of Tuckers Grade).
15. East of I-75, a MIKE 11 branch south of Oil Well Road was connected to a culvert under Oil Well Road that has always been observed to flow north. This change was made since simulated water levels were significantly higher south of Oil Well Road than north of Oil Well Road, and more water was needed in the headwaters of Zemel Canal.
16. The MIKE 11 network was modified in Southwest Aggregates mine to represent dry mining

pit on west extent of property. A pump was added that discharges to the mining pits east of the dry mining pit. Information was obtained from the Southwest Aggregates water delivery project conducted for Cape Coral.

17. The MIKE 11 branch for Greenwell Branch was checked since flows seemed to be incorrect. MIKE 11 branch (originally from 2013 MIKE 11 network) was opposite the typical orientation from upstream to downstream. The net effect is that simulated flows from east to west are negative. Measured flows in dfs0 calibration time series file were changed from positive to negative, which fixed calibration problem at this flow monitoring station.
18. Culverts under east U.S. 41 ditch at McNew Ranch and the dimensions were incorrect. Based on survey from Southwest Aggregates project, the MIKE 11 network was modified to better represent actual conveyance.
19. Leakance was modified between the MIKE 11 branches and the water table aquifer to vary spatially. Sensitivity tests were conducted, which yielded Lc_CH_750ft_20211222.dfs2.

Model calibration improvements resulted from a number of actions that began with obtaining as much known information as possible, such as surveyed cross sections, field verification of channel bed roughness, identifying and measuring dimensions of culverts, bridges, and weirs that regulate surface water levels. In addition, all available hydrogeologic information was reviewed, including review of borings in Yucca Pens performed for CHNEP in 2019 (Southwest Engineering & Design and Water Science Associates, 2019). Adjustment of groundwater hydraulic conductivities was performed once all available information on surface water conveyance was added to the input files. Horizontal hydraulic conductivities resulting from that calibration exceed conductivities reported in other studies. However, the higher conductivities used in this model are consistent with the underlying geology of Charlotte County that has numerous isolated locations with lenticular beds of shell that have high hydraulic conductivity rates. In particular, measured dry season groundwater elevations at STA-6, STA-7, and STA-8 monitoring stations in the southern portion of Babcock Webb northeast of Bond Farm were lower than the invert elevations of surface water conveyances in the vicinity of those monitoring stations. The most likely explanation for the observed dry season groundwater elevations was drainage via the shallow aquifer.

Model performance gradually improved throughout the model calibration process, and the model calibration is currently considered to be **good with many stations performing substantially above the minimum standards for good calibration.** ***Figure 41*** presents a graph of the progression of model performance. ***Table 8*** provides explanations of key dates during calibration where significant improvements were realized. Overall mean absolute error (MAE) for surface water and groundwater calibration stations within the focus area of this study was 0.64 ft., the average correlation coefficient r was 0.87, and the average Nash-Sutcliffe (NS) coefficient was 0.34. Average r for flow stations was 0.82 and NS was 0.62. Model performance **far exceeding the good threshold in many key areas**, such as Gator Slough at Weir 19, Zemel Canal upstream of Burnt Store Road, SP-4 (outflow from Babcock Webb to North Alligator Creek), SR-2 (Webb Lake outlet), 16 of 20 Babcock Webb monitoring wells, STA-7 and -8 in the South Walk-In Area, SP-5 through 10, CH-323 south of Babcock Webb on Cook-Brown Road, Yucca Pens and Durden Creek stations SR-8 and SR-9, SR-7 in east Yucca Pens (a problem station in 2016), SR-10 in central Yucca Pens, YP-6 (next to eroded ATV trail on west Yucca Pens, YP-8 (south Yucca Pens outflow).

The improvements to the hydrologic model made as part of this project will enable the modeling team to evaluate restoration scenarios in both southwest Babcock Webb and in Yucca Pens west of U.S. 41 with greater accuracy and with a higher degree of confidence.

Table 7. Summary of Sensitivity Tests

Component	Parameter	Parameter Values		Model version	Difference (test - baseline) in Statistics Indicators		
		Baseline	Change		dMAE1	dMAE2+	dCFE
Vegetation	Crop Coeff. (Kc)	0.7 - 1.0	-0.05	20211105	-0.09	-0.02	-0.12
		0.65 - 0.95	-14 %	20211105r	0.02	-0.01	0.04
Overland	Manning's M	2.4 - 13.6	+20 %	20211111	0.00	0.00	-0.01
			-20 %		0.00	0.00	0.01
Rivers		(Banks, Center): Variable	(10, 20)		0.01	0.03	-0.37
			(6, 30)		0.00	0.01	0.28
			(5, 15)		0.00	0.01	0.18
Overland and Rivers	Leakance Coeff.	1e-4 (1/s)	*0.1	20211112	0.03	0.08	-0.05
			*0.3		0.00	0.01	0.00
			*0.01	20211122	0.25	0.41	0.03
Saturated Zone	Specific Yield (Sy)	Aq: 0.2 CU: 0.1	Aq: -0.05	20211213	-0.02	0.04	0.01
	Hydraulic Conductivity (Kh,Kv)	WT Kh: 300 ft./d	*2	20211013	0.01	-0.05	0.06
			/2		0.11	0.15	-0.05
		BSM Kv: 1 ft./d	*5		-0.01	-0.01	-0.01
			/5		0.00	-0.01	0.00
		LT Kh: 500 ft./d	*2		0.00	0.00	0.00
			/2		0.00	0.00	0.00
		For Calibrated Kh and Kv	+20 %	20211223r4	0.01	0.02	0.01
			-20 %		0.00	0.00	-0.01

Notes: WT – Water Table, BSM – Bonita Springs Marl, LT – Lower Tamiami, Aq - aquifer, CU – confining unit

dMAE1: difference (ft.) in stations-averaged Mean Absolute Error (MAE) for shallow (i.e., surface water and water table aquifer) water level stations.

dMAE2+: difference (ft.) in stations-averaged Mean Absolute Error (MAE) for deeper (i.e., bottom water table aquifer and below) water level stations.

dCFE: difference in stations-averaged absolute Cumulative Flow Error (CFE) divided by 30% for surface water flow stations.

Negative/positive indicator differences means that the performance is better/worse according to that indicator.

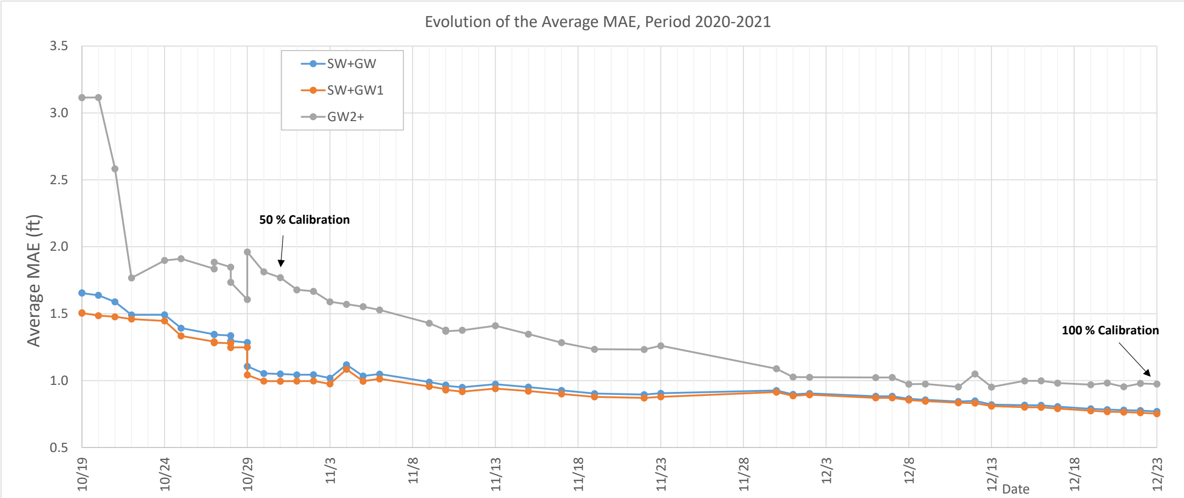


Figure 41. Progression of Model Performance During Calibration

Table 8. Actions Associated with Key Dates Where Calibration Improved

Date	Changes in Input Files Resulting in MAE Improvements
10/22/21	• Topography and NSM topo resampled from 50 ft. using spatial average with the MIKESHE overland. NSM topo used to convert layer bottom from Height Above Ground to elevation. • WT geological layer divided in two. The dividing line between the WT layers was found from the maximum among the top of the rock lens, 10 ft. below the ground surface, and the center elevation of the aquifer. • The conductivities for all layers were updated using uniform adjustments.
10/29/21	• Using SLCWI vegetation database in place of the vegetation database from the 2017 MIKE SHE model. The previous database Kc values were higher, which seem to result in less water levels and flows.
11/30/21	• New MIKE11 cross sections were cut from LiDAR DEM with a 1 meter resolution. All the structure Q/H table were recomputed. • Various improvements in MIKE11 culverts and weirs. • Flood code file was updated.

Calibration performance is presented in **Table 9** and **Table 10**. Locations of calibration stations are presented in ***Figures 42*** and ***43***. A number of stations in the figures are shown as NFA (Not Focus Area). Those stations are either stations used to establish boundary conditions or are stations in North Fort Myers or Cape Coral that are far removed from the primary focus area of this modeling study (Babcock Webb and Yucca Pens) that do not affect the ability of the model to properly represent conditions in the WMAs. Calibration plots are presented in **Appendix C**. A summary of calibration performance is presented below, which indicates that 64% of the stations have Good calibration and 31% have OK calibration. Overall, model performance is good with many stations performing substantially above the minimum standards for good calibration.

Statistic	Good	OK	Poor
Meeting Target	62	30	5
Number of Calibration Stations	97	97	97
Percent Meeting Target	64%	31%	5%

Table 9. Calibration Performance Statistics

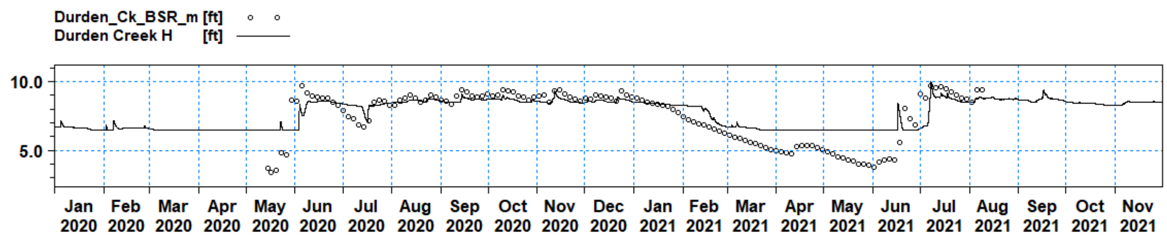
Name	ME	MAE	RMSE	STDres	R_Corr	R2 NS	Overall
Bear Branch H	0.34	0.36	0.4473	0.2858	0.82	0.11	G
Durden Creek H	-0.32	0.84	1.1442	1.0999	0.87	0.61	OK
Gator_Weir11_H	0.45	0.53	0.6956	0.5327	0.61	-5.11	Poor
Gator_41_H	0.45	0.46	0.5008	0.2233	0.95	0.37	G
Gator_Weir_19	-0.13	0.17	0.1997	0.1480	0.96	0.87	G
Greenwell/Osw H	0.41	0.47	0.5420	0.3547	0.80	-0.62	OK
Hog Branch H	0.39	0.40	0.4962	0.3013	0.72	-0.36	OK
S Alligator	-0.54	0.67	0.8364	0.6370	0.88	0.61	G
SP-4	0.19	0.45	0.8879	0.8674	0.93	0.85	G
SP-8, BigWaterFord	0.75	0.97	1.1287	0.8456	0.88	0.54	OK
SP-13, Zemel at 41	-0.47	0.63	0.7820	0.6277	0.81	0.44	G
SR-2, WebbLake	0.27	0.46	0.5149	0.4406	0.94	0.83	G
SW-1, US_41	0.49	0.51	0.5549	0.2514	0.92	0.14	G
SW-2, US_41 E	0.52	0.62	0.6903	0.4530	0.88	-1.03	OK
SW-3, US_41 W	0.22	0.42	0.5157	0.4657	0.85	-0.04	OK
YuccaPensCr_H1	0.37	0.71	0.9766	0.9025	0.77	0.48	G
Weir 58	0.09	0.18	0.2216	0.2033	0.86	0.68	G
Winegourd	1.24	1.33	1.6633	1.1055	0.03	-5.43	Poor
Zemel U/S	-0.09	0.43	0.60	0.59	0.86	0.67	G
Zemel_BSR	-0.52	0.58	0.67	0.43	0.63	-1.25	OK
17-GW4	-0.14	0.80	1.0340	1.0249	0.76	0.48	OK
BW-1	-0.07	0.47	0.5821	0.5778	0.94	0.84	G
BW-2	-0.03	0.65	0.8106	0.8101	0.90	0.67	G
BW-3	0.36	0.50	0.7359	0.6409	0.94	0.73	G
BW-4	0.62	0.91	1.2609	1.0956	0.88	0.49	OK
BW-5	0.06	0.67	0.8994	0.8972	0.80	0.59	G
BW-6	-0.78	0.89	0.9985	0.6219	0.91	0.50	OK
BW-7	-0.20	0.53	0.6453	0.6122	0.94	0.81	G
BW-8	-1.14	1.15	1.4172	0.8439	0.90	0.33	Poor
BW-9	-0.31	0.66	0.8094	0.7491	0.87	0.71	G
BW-10	0.09	0.29	0.3903	0.3799	0.96	0.90	G
BW-11	0.05	0.69	0.9296	0.9280	0.86	0.58	G
BW-12	-0.17	0.45	0.6024	0.5783	0.90	0.80	G
BW-13	0.30	0.42	0.6191	0.5420	0.93	0.80	G
BW-14	-0.02	0.31	0.3830	0.3823	0.96	0.91	G
BW-15	-0.82	0.84	0.9600	0.5070	0.90	0.22	OK
BW-16	-0.42	0.46	0.5641	0.3759	0.96	0.80	G
BW-17	0.29	0.45	0.5915	0.5141	0.92	0.79	G
BW-18	0.26	0.38	0.5280	0.4569	0.95	0.86	G
BW-19	-0.36	0.57	0.6360	0.5253	0.93	0.74	G
BW-20	0.41	0.46	0.5646	0.3917	0.97	0.80	G
MW-23S	0.92	1.01	1.2912	0.9074	0.92	0.51	OK
MW-24S	0.84	1.00	1.3054	1.0024	0.89	0.30	OK
MW-29W	-0.21	0.54	0.6494	0.6155	0.43	-0.28	OK
MW-30S	0.44	0.82	1.0856	0.9913	0.82	0.04	OK
SP-5	-0.21	0.35	0.3938	0.3303	0.97	0.90	G
SP-6	-0.28	0.45	0.5087	0.4269	0.94	0.81	G
SP-7	-0.23	0.54	0.6241	0.5803	0.88	0.69	G

Table 10. Calibration Performance Statistics, Continued

Name	ME	MAE	RMSE	STDres	R_Corr	R2 NS	Overall
SP-9	-0.11	0.26	0.3419	0.3231	0.97	0.92	G
SP-10	0.59	0.59	0.6462	0.2715	0.97	0.56	G
SP-16	-0.31	0.84	1.0115	0.9620	0.85	0.37	OK
SP-17	-0.77	0.93	1.0676	0.7438	0.56	-1.36	OK
STA-6	-0.92	1.07	1.1928	0.7568	0.82	0.19	OK
STA-7	-0.46	0.63	0.7761	0.6232	0.96	0.67	G
SW_Agg_LM-1	-0.47	0.51	0.7741	0.6135	0.83	0.50	G
YP-5_SW	1.13	1.13	1.2578	0.5622	0.97	0.55	OK
YP-8	0.88	0.91	1.2549	0.8924	0.91	0.22	OK
YP-9	0.31	0.63	0.8165	0.7564	0.96	0.77	G
1-GW1	0.79	0.95	1.1913	0.8924	0.87	0.20	OK
5-GW3	0.69	1.04	1.2936	1.0924	0.91	-0.18	Poor
5-GW4	-1.06	1.14	1.2980	0.7424	0.91	0.22	OK
5-GW6	-0.74	0.78	0.8841	0.4840	0.95	0.66	OK
5-GW8	0.59	0.65	0.8549	0.6229	0.92	0.47	G
16E-GW3	0.43	0.70	0.8819	0.7691	0.90	0.34	G
20-GW3	-0.38	0.64	0.7707	0.6699	0.97	0.82	G
CH-323	-0.01	0.58	0.7206	0.7206	0.81	0.65	G
L-721	-0.29	0.54	0.6533	0.5877	0.97	0.49	G
L-3207	0.08	0.21	0.2563	0.2441	0.91	0.82	G
MW-3	0.36	0.63	0.8621	0.7856	0.85	0.54	G
MW-8	0.57	0.64	0.9024	0.6963	0.89	0.40	G
MW-9	0.05	0.38	0.6883	0.6865	0.89	0.74	G
MW-14	0.28	0.48	0.6774	0.6154	0.89	0.70	G
MW-23D	0.81	0.94	1.2103	0.9031	0.93	0.55	OK
MW-24D	0.42	0.96	1.1185	1.0356	0.90	0.44	OK
MW-29E	-0.63	0.77	0.8818	0.6128	0.87	0.21	OK
MW-30D	0.45	0.76	1.0437	0.9409	0.84	0.18	OK
SP-15	0.73	0.89	1.0982	0.8222	0.89	0.36	OK
SR-6	-0.30	0.42	0.5505	0.4610	0.94	0.84	G
SR-7	-0.68	0.71	0.7859	0.4009	0.94	0.55	G
SR-8	0.00	0.54	0.6983	0.6983	0.91	0.73	G
SR-9	-0.09	0.42	0.5742	0.5672	0.92	0.83	G
SR-10	-0.10	0.37	0.4925	0.4823	0.90	0.79	G
STA-8	0.02	0.39	0.5123	0.5119	0.94	0.86	G
SW_Agg_MW-CCI	-1.50	1.50	1.5602	0.4369	0.95	-0.38	Poor
SW_Agg_MW-E4S	0.17	0.39	0.5407	0.5147	0.92	0.82	G
SW_Agg_GW-E2	-0.30	0.80	0.9057	0.8552	0.78	-0.01	OK
SW_Agg_GW-S2	-0.22	0.46	0.5956	0.5548	0.94	0.49	G
YP-4	-0.25	0.57	0.7829	0.7404	0.78	0.53	G
YP-6	0.16	0.62	0.9019	0.8868	0.84	0.55	G
Bear Branch Q	3.41	4.16	10.3116	9.7328	0.76	0.48	G
Durden Creek Q	0.17	3.00	7.1565	7.1545	0.86	0.72	G
Gator_41_Q	2.72	6.17	15.3197	15.0764	0.89	0.78	G
Greenwell/Osw_Q	-2.02	6.11	14.9905	14.8543	0.76	0.50	G
Hog_Q	2.20	2.49	7.5517	7.2249	0.81	0.53	G
NS Transfer	1.65	2.56	7.0252	6.8276	0.90	0.81	G
YuccaPensCr_Q	1.90	6.91	12.5021	12.3565	0.86	0.72	G
Zemel U/S_Q	-5.59	11.33	29.78	29.25	0.69	0.45	OK

A number of stations with an **OK** rating do not meet the **Good** calibration target for reasons that are due primarily to input data issues. In most of these stations, wet season calibration is good. Model performance at these stations is acceptable, as explained below:

- Water level in Durden Creek at Burnt Store Road has an **OK** rating because the minimum elevations are set by the bottom of the MIKE 11 cross section. Water levels at that station drop below ground, which cannot be represented in the calibration plot for the cross section at the gaging station. As can be seen in the calibration plot below, model performance is acceptable at this location with good calibration during the wet season.



- Greenwell Branch calibration is rated as **OK** due to a negative NS value. MAE and correlation coefficient r both meet calibration targets. Simulated water levels are lower than measured water levels, most likely due to uncertainty in tailwater elevations in the tidally influenced brackish canal in the northwestern portion of Cape Coral north of Pine Island Road. The MARKH boundary condition is applied at the downstream end of the North Spreader Waterway, which may not be correct, plus discharges from numerous Cape Coral Canals to that waterway likely influence water levels along the Waterway. Since the model calibration did not focus on Cape Coral canals, performance is negatively affected at this station.
- Water level calibration in Hog Branch at Burnt Store Road is good for MAE and OK for correlation coefficient r, but is below 0.0 for the NS coefficient. There is a lake upstream of the monitoring station, and a lack of knowledge regarding this lake is a likely explanation for the low NS coefficient value.
- Water level calibration at SP-8, Big Water Ford, is **OK** due to a high MAE (0.97). Correlation coefficient r and NS both meet Good model performance. There are 3 corrugated metal pipe (CMP) risers at this location with wooden flashboard that are leaky.
- NS values are negative for U.S. 41 ditch stations SW-2 and SW-3 (located immediately upstream of the ditch confluence with Gator Slough). The east and west ditches are merged into one MIKE 11 branch to reduce MIKE 11 model instabilities. Since MAE and correlation coefficient values meet good ratings, model performance is acceptable in the U.S. 41 ditches even though the rating at these two stations is only **OK**.
- Zemel Canal at Burnt Store Road calibration is **OK** due to a negative NS value. This is a tidal station, and the tidal influence due to wetlands west of the monitoring station may not be appropriately represented in the model.
- Calibration at 17-GW4 (on I-75 just east of Prairie Pines Preserve) is only slightly out of **Good** performance (MAE = 0.8, r and NS are both good). The model performs adequately at this station.
- Calibration is **OK** at Babcock Webb groundwater monitoring stations BW-4, BW-6, and BW-15. MAE is higher than 0.75 ft. at all three stations.
  - BW-4 initial conditions have a negative effect on calibration and simulated water

levels rise too slowly in the early 2021 wet season. There is an excavated low area next to this station that likely maintains higher water levels. Overall, these calibration problems are considered to be minor.

    - BW-6 simulated wet season water levels are approximately 0.5 – 0.75 ft. too high in the wet season and approximately 1.5 feet too high in the dry season. A nearby ATV trail drains to the southwest, which may provide a drainage route that is not represented in the model.
    - BW-15 simulated water levels are too high, most likely due to overland flows draining to the southwest that are not represented appropriately or ET may be higher in this area than represented in the model.

- Calibration is **OK** at Yucca Pens stations MW-23S, -24S, -29W, and -30S. MAE is too high at MW-23S and 24S, and NS is too low at MW-29W and -30S. Simulated water levels do not rise quickly enough in the early wet season. This area will be evaluated further prior to initiating scenario analysis.
- Yucca Pens stations SP-16 and SP-17 have **OK** calibration due to MAE > 0.75 and a negative NS value for SP-17. The SP-16 data logger was calibrated incorrectly, which was discovered at the end of calibration. SP-17 is adjacent to a seepage pit on the Charlotte County Landfill and the groundwater impacts of that seepage pit are unknown.
- STA-6 is in the southwestern corner of the South Walk-In Area (see Figure 1 for location), and simulated dry season water levels are slightly high. Incorrect initial conditions have a significant negative impact on simulated 2020 dry season water levels. Since simulated 2021 dry season water levels are closer to measured values, this station would likely in the Good category if a longer time series of data were available for model calibration.
- YP-5_SW and SP-8 are located on the southern portion of Yucca Pens and have similar issues to other south Yucca Pens calibration stations (MW-23S, etc.). This area will be evaluated further prior to initiating scenario analysis.
- Simulated dry season recession rates at 1-GW1 are higher than measured, and initial conditions are too low. Due to these factors, model performance in this area of the model is believed to be acceptable.
- Simulated water levels do not drop quickly enough at 5-GW4. This station is adjacent to Andalusia Parkway in Northern Cape Coral. Drainage associated with the road may be draining water away from this area quicker than represented in the model.
- Station 5-GW6 is located in a rural residential area just west of Prairie Pines and south of the eastern extent of Gator Slough. This station is rated as **OK**, however MAE is 0.78, r = 0.95, and NS = 0.66. Given the minor calibration issues associated with this station, model performance is deemed acceptable at this location.
- Station GW-E2 adjacent to the Southwest Aggregates mining pit has MAE = 0.8, and a negative NS value. Since this station is adjacent to a mining pit with varying water levels during the simulation period, this is not a significant problem. This calibration issue would likely be fixed with a model with a smaller grid size.
- Flow at the upstream Zemel Canal monitoring station has an OK rating due to a correlation coefficient = 0.69. The simulated flows during two wet weather events in 2021 are higher than measured flows. It is possible that bed roughness (Manning's n) in the overbank is too low for extreme high flow events.

Model performance is **Poor** at a number of stations due to the following factors:

- Water level in Gator Slough at Weir 11 (just upstream of Burnt Store Road) has a poor rating. Little effort was made to calibrate water levels in Cape Coral, and water levels at this station are influenced by water levels in Cape Coral canals south of Gator Slough. Since little effort was expended calibrating canals in Cape Coral, and simulated water levels in Gator Slough at Weir 19 are excellent, this problem is not considered to be an issue of concern.
- Measured water levels in Winegourd Creek at Burnt Store Road are higher than measured. It is believed that there are significant obstructions to flow in the residential area west of Burnt Store Road, however information on these obstructions could not be identified and added to the model.
- Simulated water levels in BW-8, located in southeast Babcock Webb WMA, are too high during the early wet season in 2020 and the dry season of the spring 2021. Field investigations of culverts along SR 31 did not identify culvert invert elevations that are sufficiently low to drain southeast Babcock Webb to the observed dry season elevations. Groundwater abstractions are a possible cause for the poor simulation performance.
- Model performance at 5-GW3 is rated at **Poor**. This station is located in Cape Coral, and as such, it is not concern for this project.
- Model performance is **Poor** at Charlotte Correctional Institute monitoring well MW-CCI. This station is located adjacent to a water supply wellfield for the Institute, which may affect model performance.

Summary of Calibration. Model performance is good at a majority of the calibration stations in the vicinity of Babcock Webb and Yucca Pens WMAs with performance at many stations far exceeding the good threshold. The model is suitable for use in scenario analysis. As discussed above, 94% of the stations have calibration performance ranging from good to OK.

Recommendations for Future Modeling Efforts. While the model is suitable for the scenario analyses as part of this project, there are some areas where model performance can be improved. The key issue is inaccurate topography, which is most apparent in areas with extended hydroperiods, such as the South Walk-In Area. Topography in the South Walk-In Area wetlands was improved, but more ground surveying is needed in other wetland areas not surveyed as well as areas with higher ground elevations that still experience inundation. More information on surface water conveyances and hydrogeology in the vicinity of Bond Farm (located west of the South Walk-In Area, see location in ***Figure 42***). A full-scale seepage study that fills in the gaps of existing geotechnical reports for Bond Farm and provides new information on the project site conditions is recommended to verify hydraulic conductivity rates. Additional surveying is also needed in the cypress wetlands of Yucca Pens. Additional survey may be needed of channel dimensions in some streams such as upstream and downstream of the gaging stations on Burnt Store Road. Also, additional geotechnical field work is recommended in southern Yucca Pens to provide new data for modeling to better understand the interaction between the Yucca Pens and Gator Slough Canal hydrology.

Initial conditions issues also affected model calibration. This can be resolved by having a longer time period of data available for calibration, and efforts are underway to continue data collection at the Babcock Webb and Yucca Pens monitoring stations. Once additional data are available, model calibration can be extended into 2022 to confirm that the model can properly represent the increase in groundwater elevations during the late dry season and early part of the wet season.

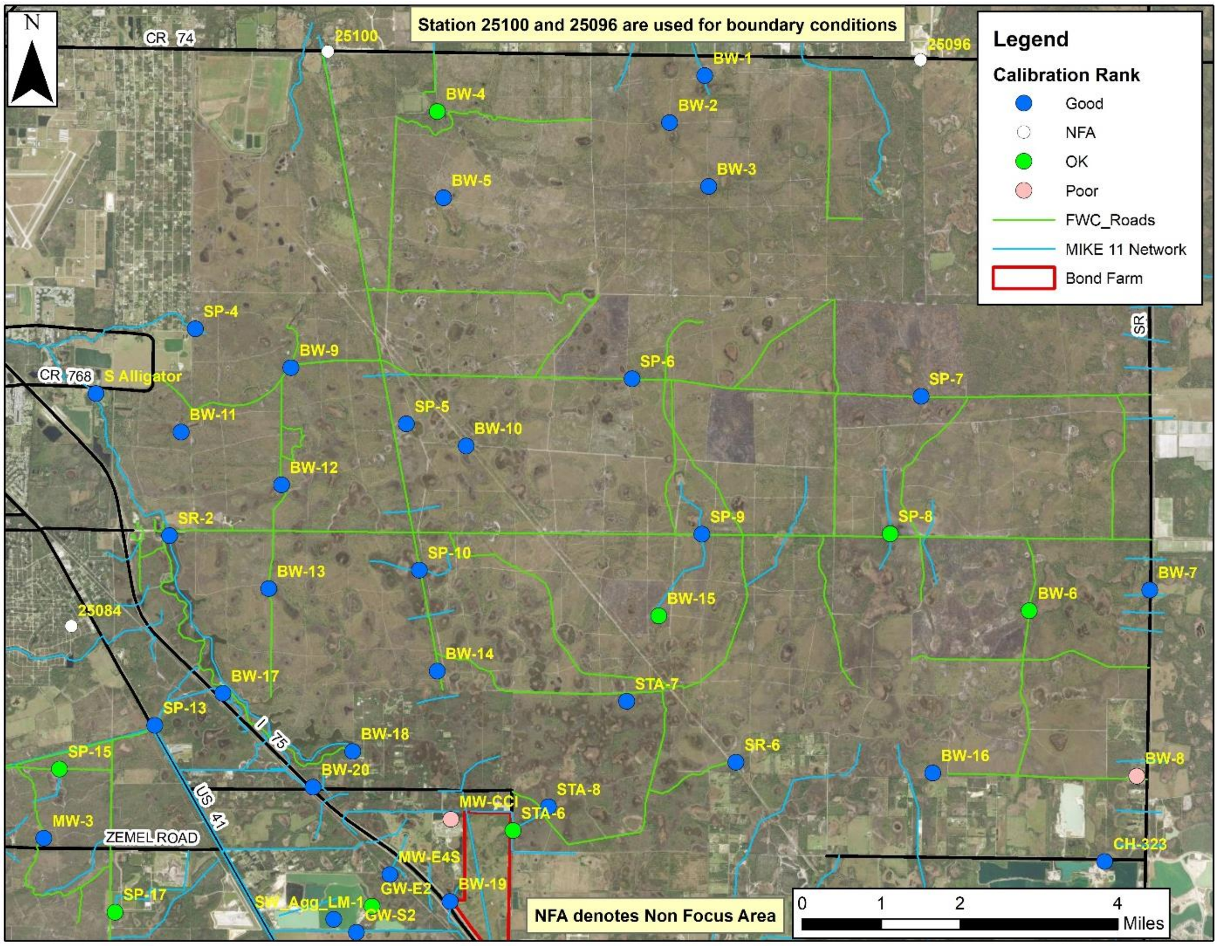


Figure 42. Map of Calibration Stations in the Northern Portion of the Study Area

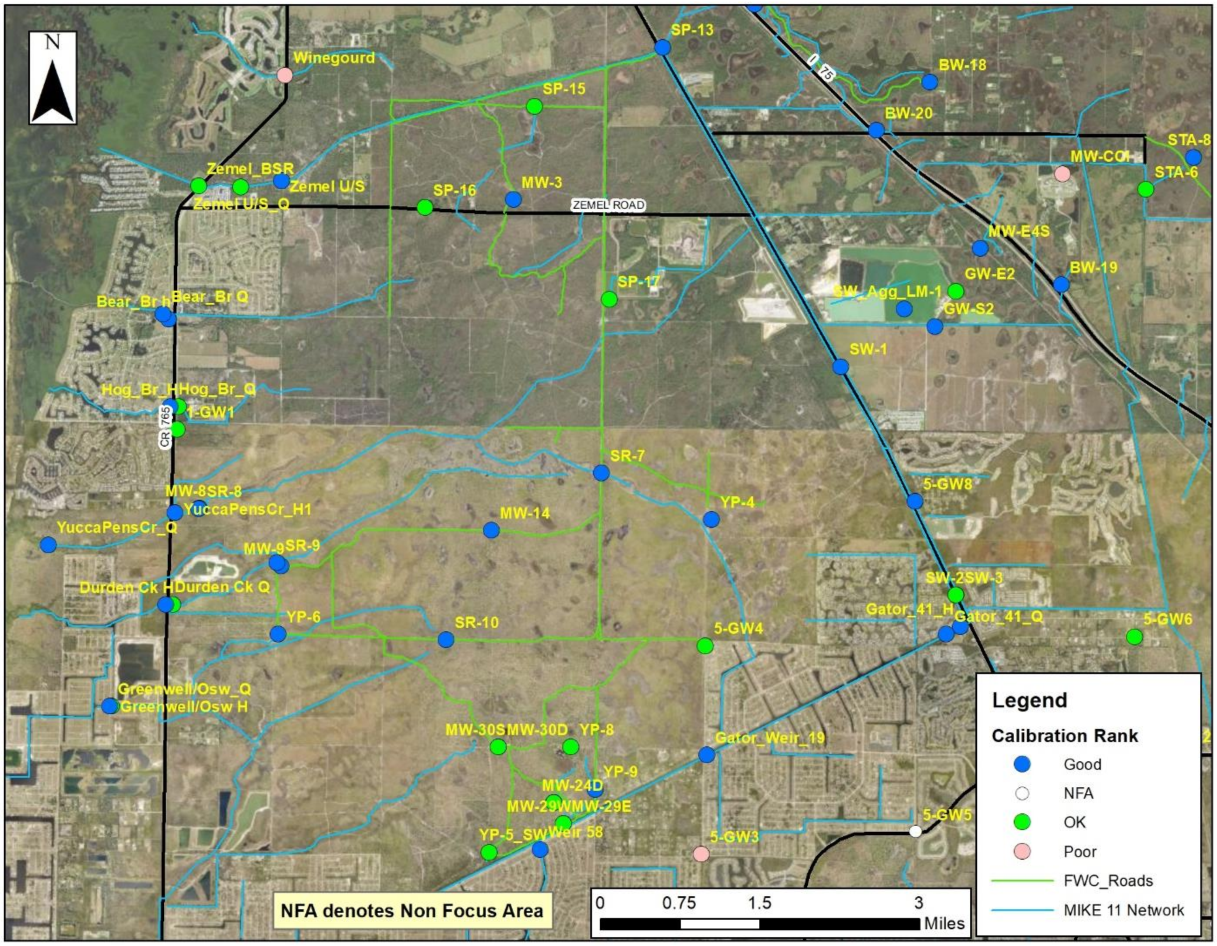


Figure 43. Calibration Station Performance for Western Portion of the Study Area

DURATION OF INUNDATION AND WET SEASON WATER DEPTHS

1.0 Hydroperiods

Simulated hydroperiods for calendar years 2020 and 2021 for the study area are presented in **Figure 44** and **Figure 45**. Hydroperiods are greatest in the South Walk-In Area of southwestern Babcock Webb WMA and are below optimum conditions in Yucca Pens. Optimum hydroperiod conditions for cypress are 6 – 8 months (Duever and Roberts, 2013). Hydroperiods in Yucca Pens are rarely greater than 5 months which is less than optimum, especially for the cypress strands of Yucca Pens. The southern portion of Yucca Pens has hydroperiods less than one month, and the western cypress strands of Yucca Pens have hydroperiods ranging from 2 – 5 months. The simulated hydroperiods are consistent with the findings of the Task 3 ecologic investigations. Conversely, hydroperiods in Babcock Webb are above nine months in much of the South Walk-In Area.

All of the flow monitoring stations were ephemeral (no flow during the dry season). Positive flows ceased in Alligator Creek in early February, and in Yucca Pens Creek in December. Positive flows ended in January for Bear Branch, Hog Branch, Yucca Pens Creek, Durden Creek, and Greenwell Branch. Restoration of hydroperiods in Yucca Pens would have a positive effect on extending the duration of dry season discharges to tidal creeks west of Yucca Pens.

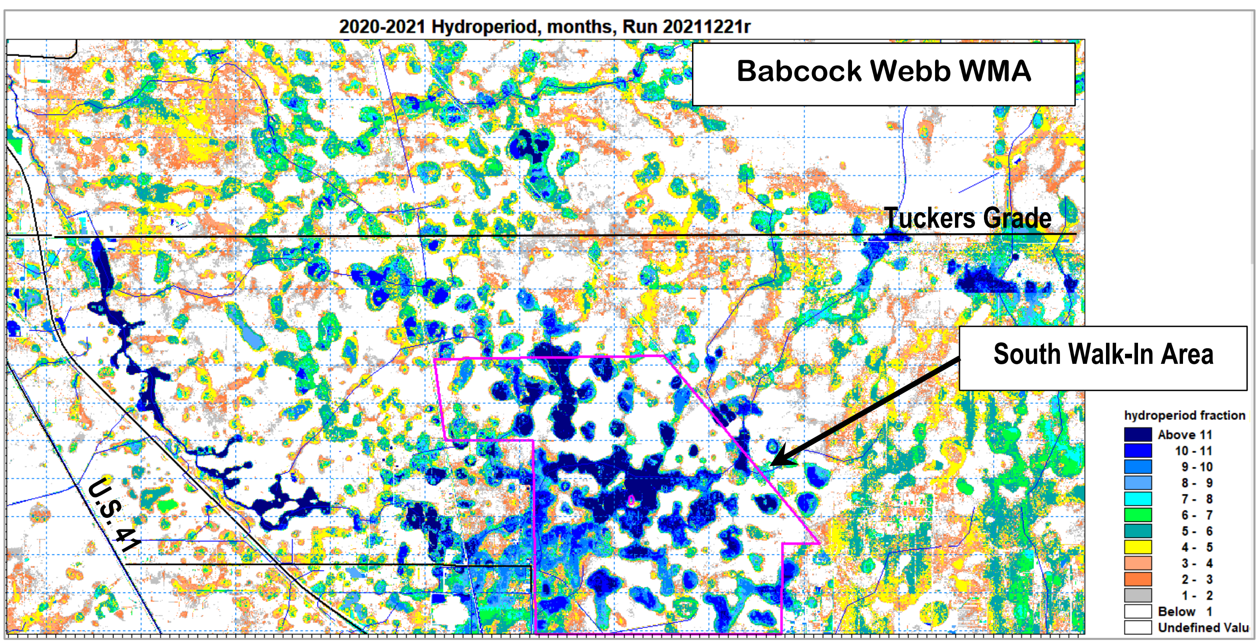


Figure 44. Simulated Babcock Webb Hydroperiod, 2020-2021, 1221r simulation

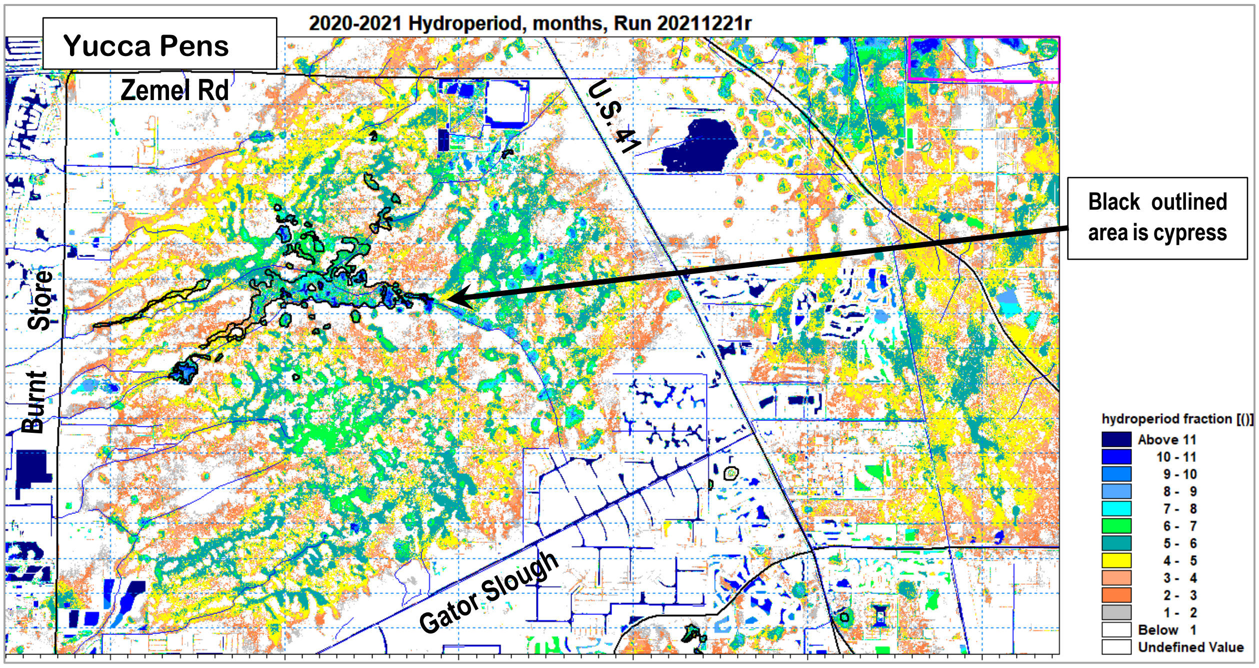


Figure 45. Simulated Yucca Pens Hydroperiod, 2020-2021, 1221r simulation

1.1 Wet Season Water Depths

Figure 46 illustrates the average wet season (July 1 – November 30) water depths in the Babcock Webb area for the 2020 – 2021 simulation period. **Figure 47** illustrated the average wet season water depths in the Yucca Pens area for the 2021 simulation period. Depths in excess of one foot are common in the South Walk-In Area of Babcock Webb while they are rare in Yucca Pens. Of particular concern, Yucca Pens average wet season water depths in excess of one foot are relatively rare in the cypress wetlands of Yucca Pens. These simulation results suggest that increased conveyance from the South Walk-In Area is needed, and that water levels in Yucca Pens wetlands need to be increased. On average, simulated wet season water depths are not observed in Yucca Pens immediately north of Gator Slough. The average water depth in the cypress wetlands is 0.33 ft. (standard deviation = 0.45 ft.). Depths in excess of 1 foot are found in 7.5 % of the cypress wetlands. Of those cells with depths greater than one foot, the average depth was 1.66 ft. This analysis of average wet season water depths indicates that the cypress wetlands of Yucca Pens have water levels significantly less than are typically observed in cypress wetlands. Combined with the hydroperiod results presented above, it is clear that management efforts for Yucca Pens should include measures to either increase flows or reduce discharges to these wetlands.

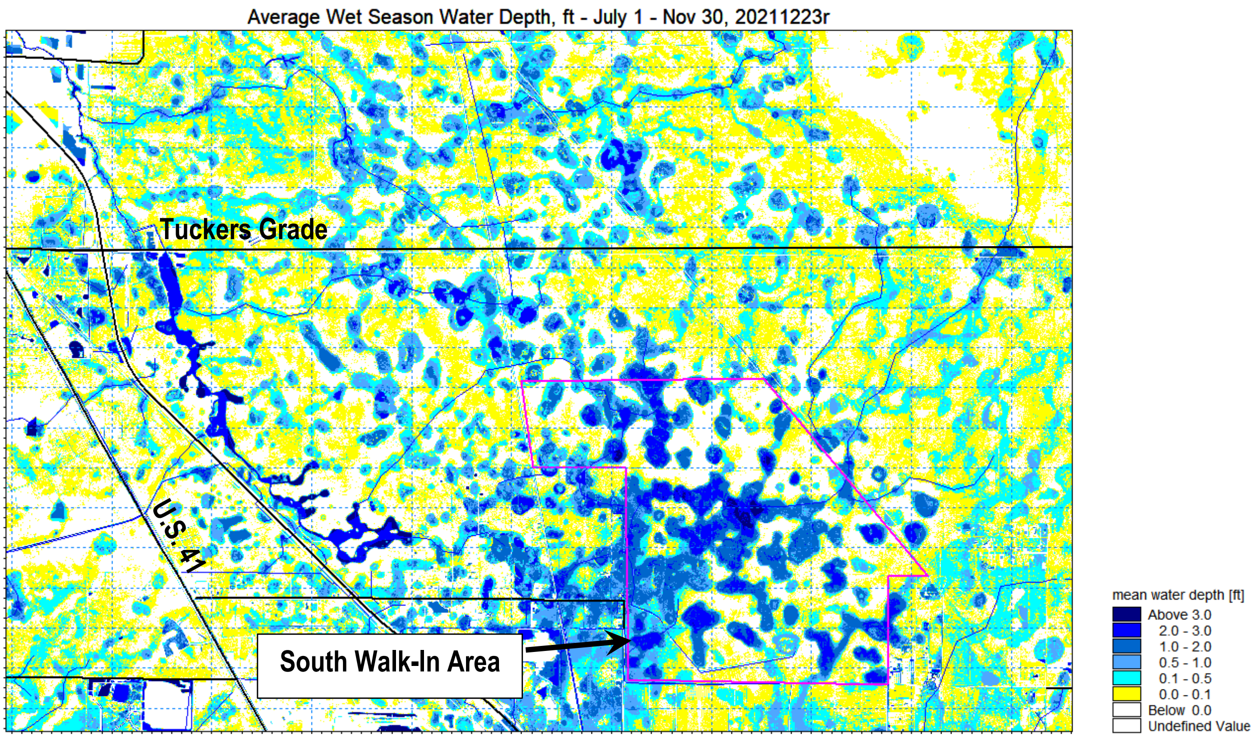


Figure 46 - Average Wet Season Water Depth in Babcock Webb WMA Area

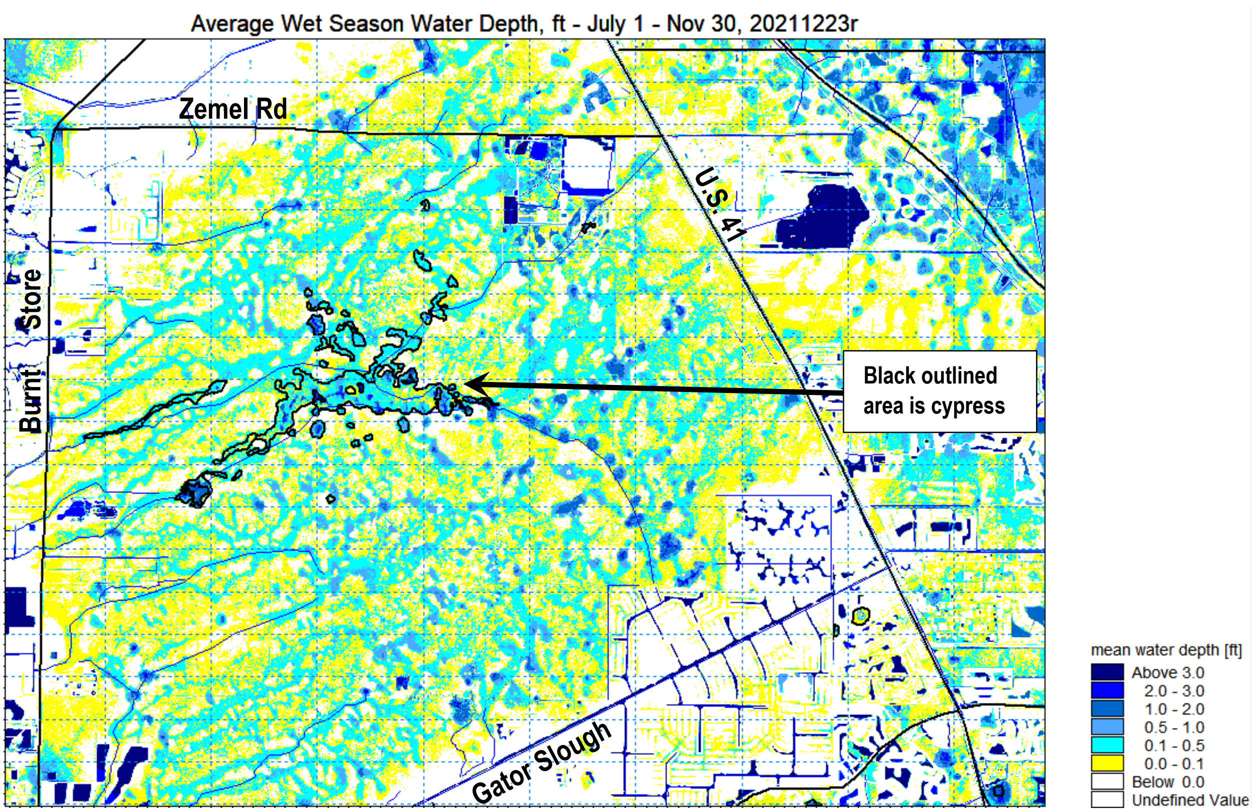


Figure 47 - Average Wet Season Water Depth for Yucca Pens Area

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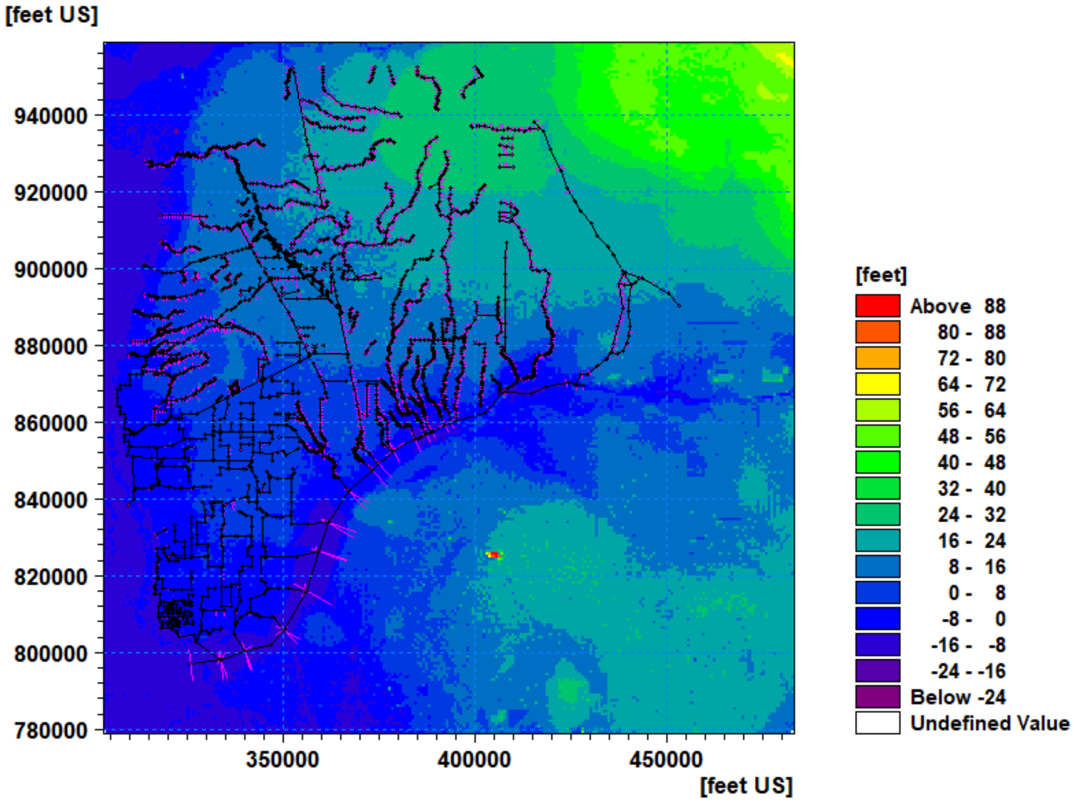
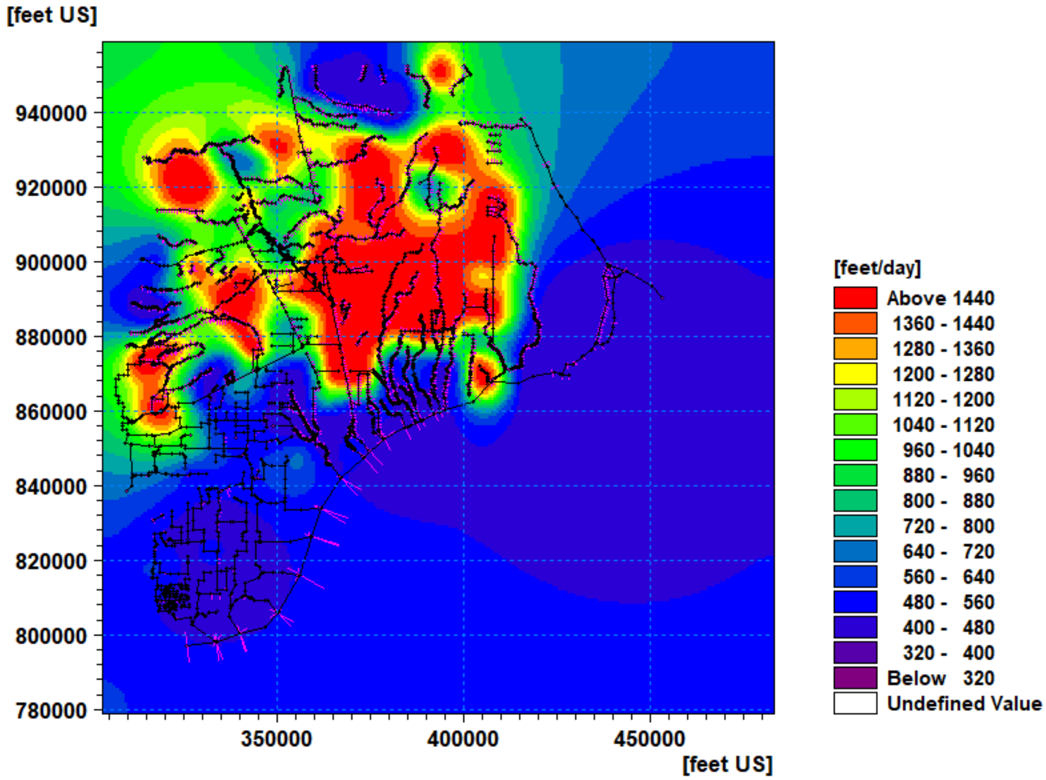
SATURATED ZONE MAPS

All model files use the State Plane East coordinate system with the model origin (southeast corner of the domain) equal to X = 303303.525 ft., Y = 778855.349 ft.

Water Table Top Layer – Bottom Elevation:



Water Table Top Layer – Horizontal Hydraulic Conductivity:



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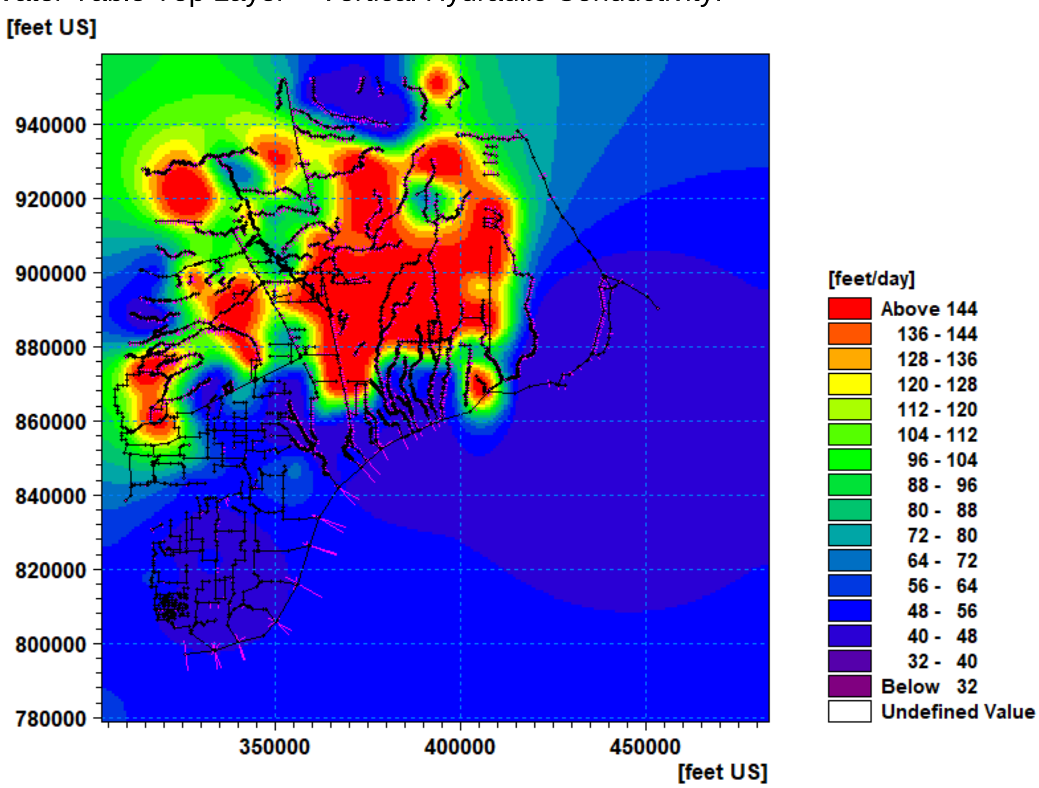

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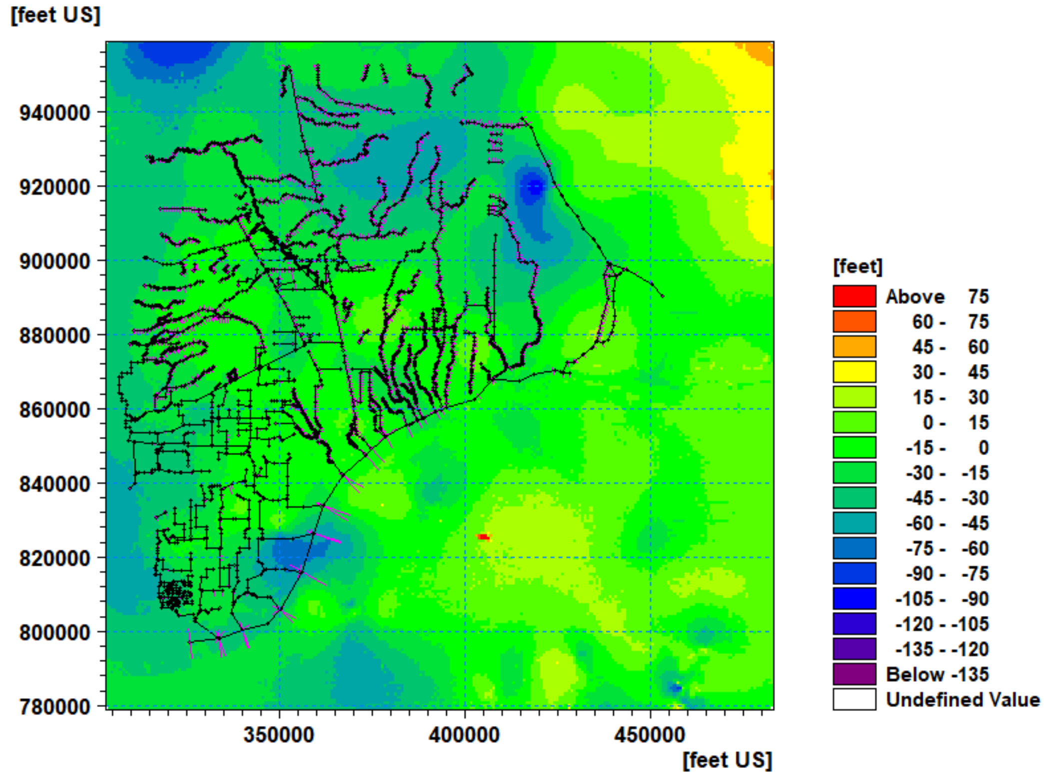

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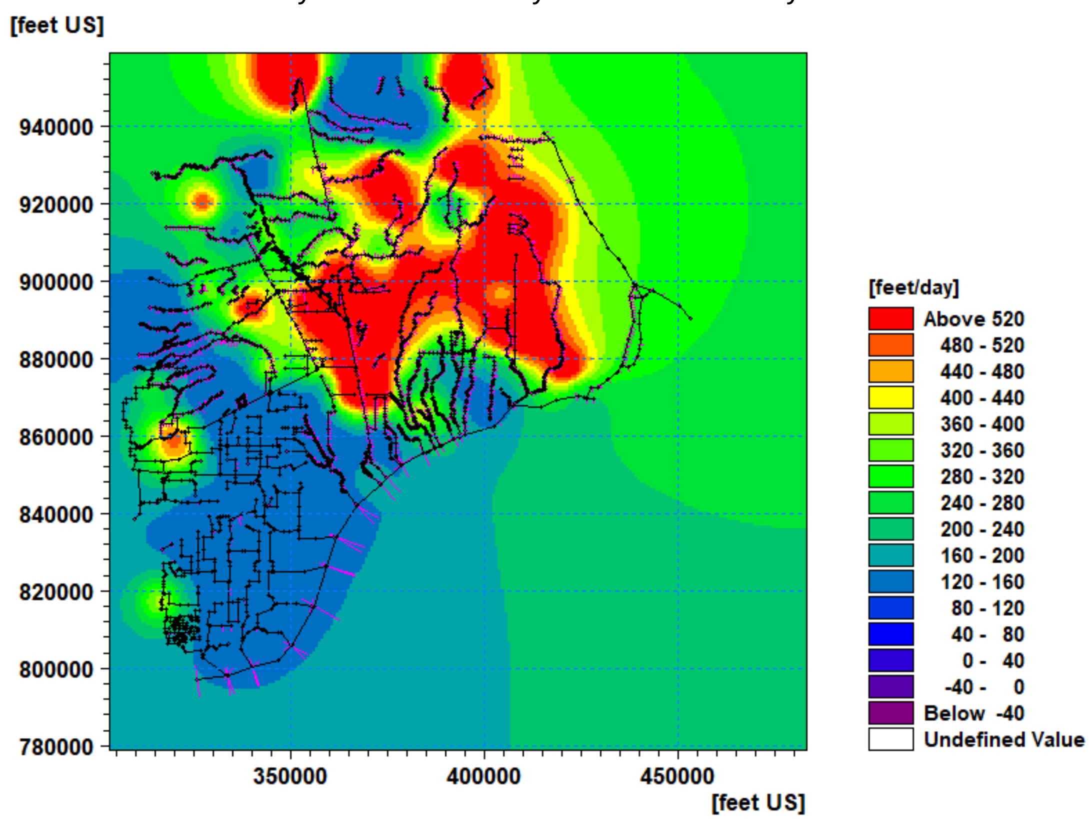

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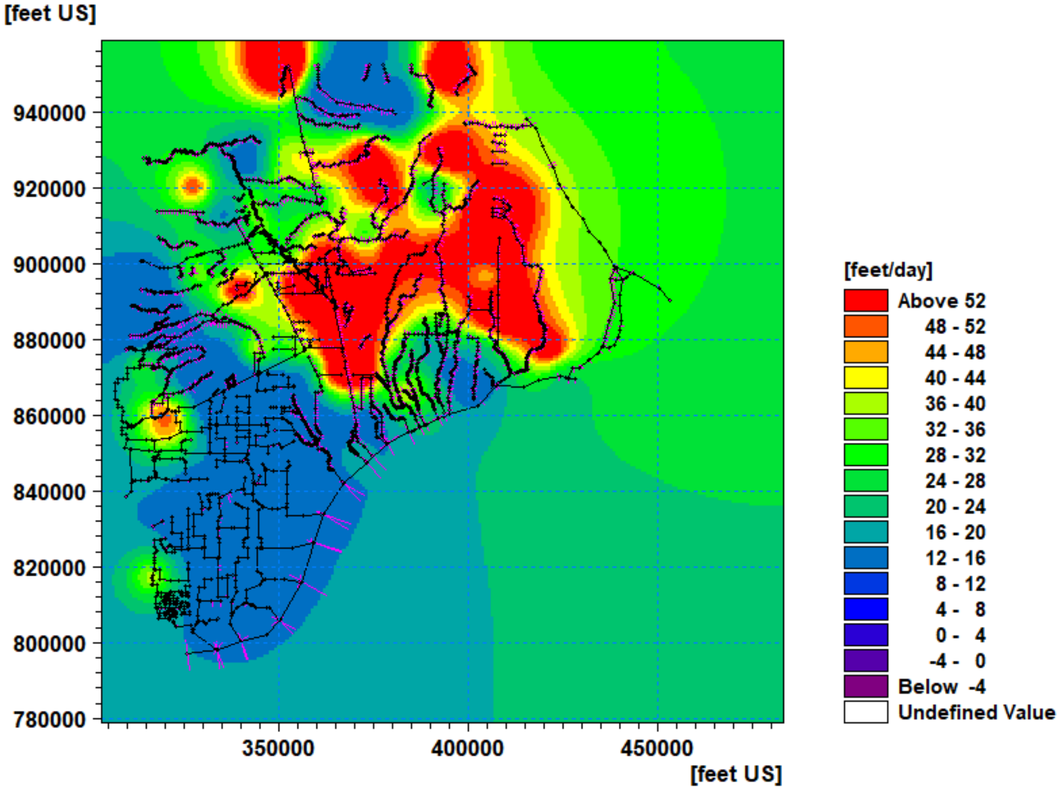
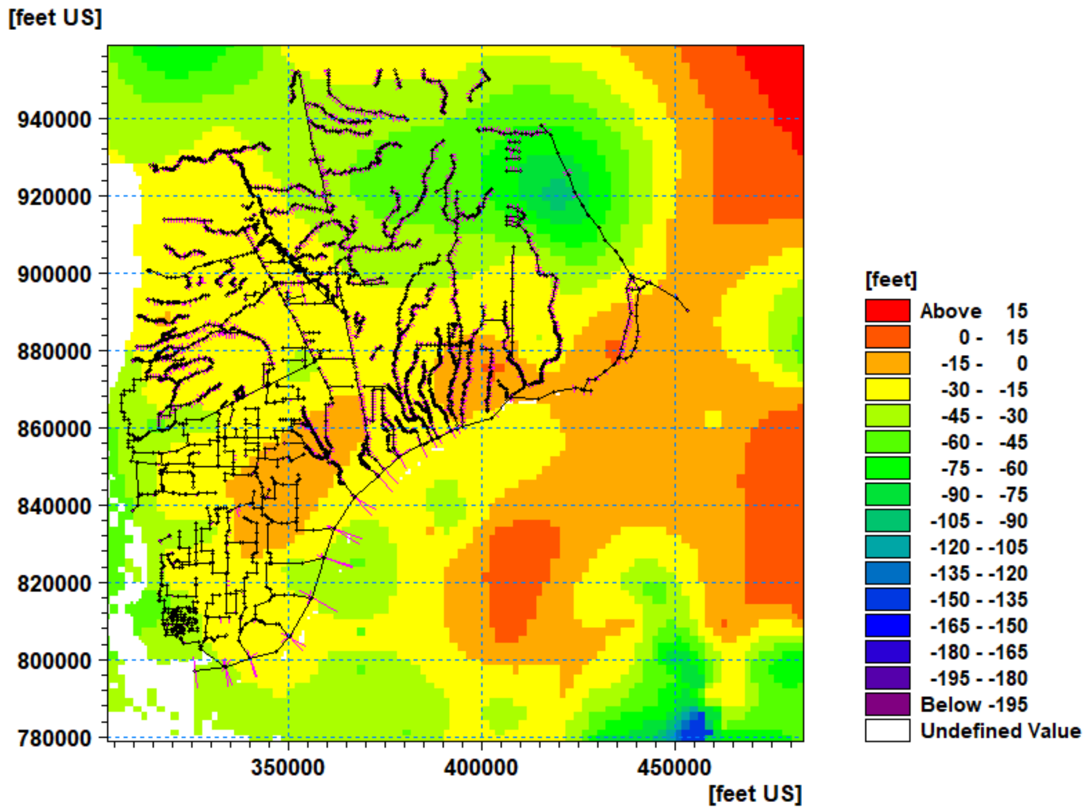
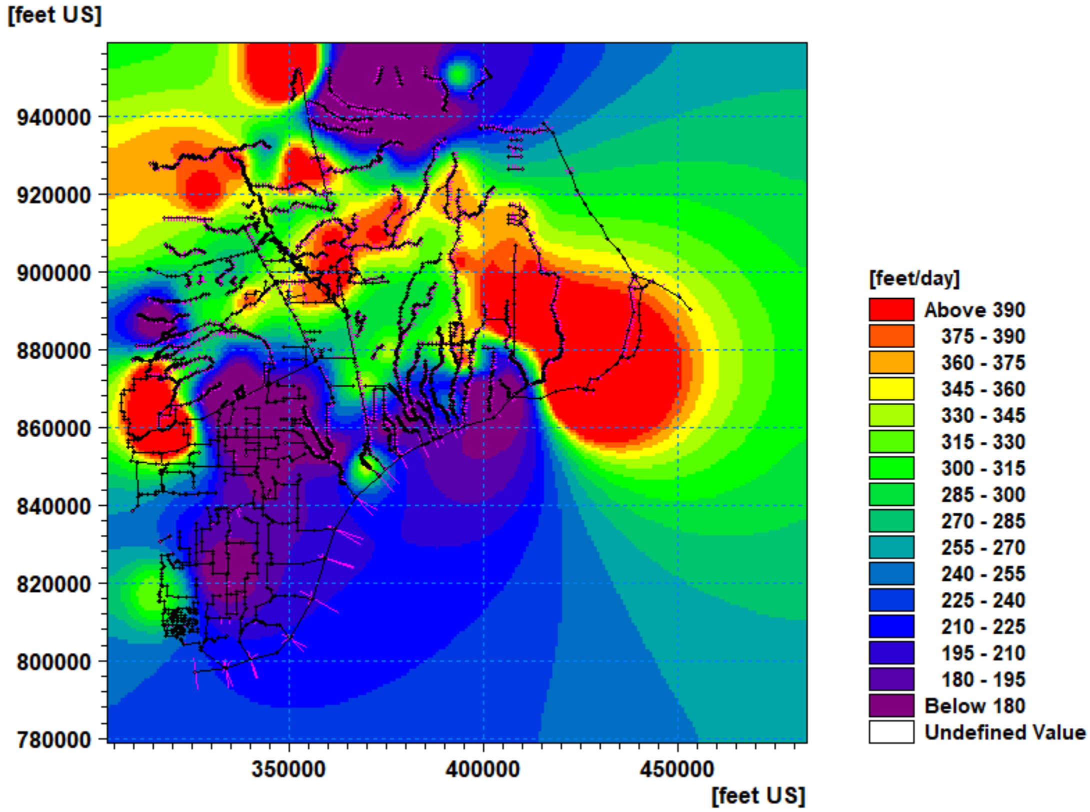


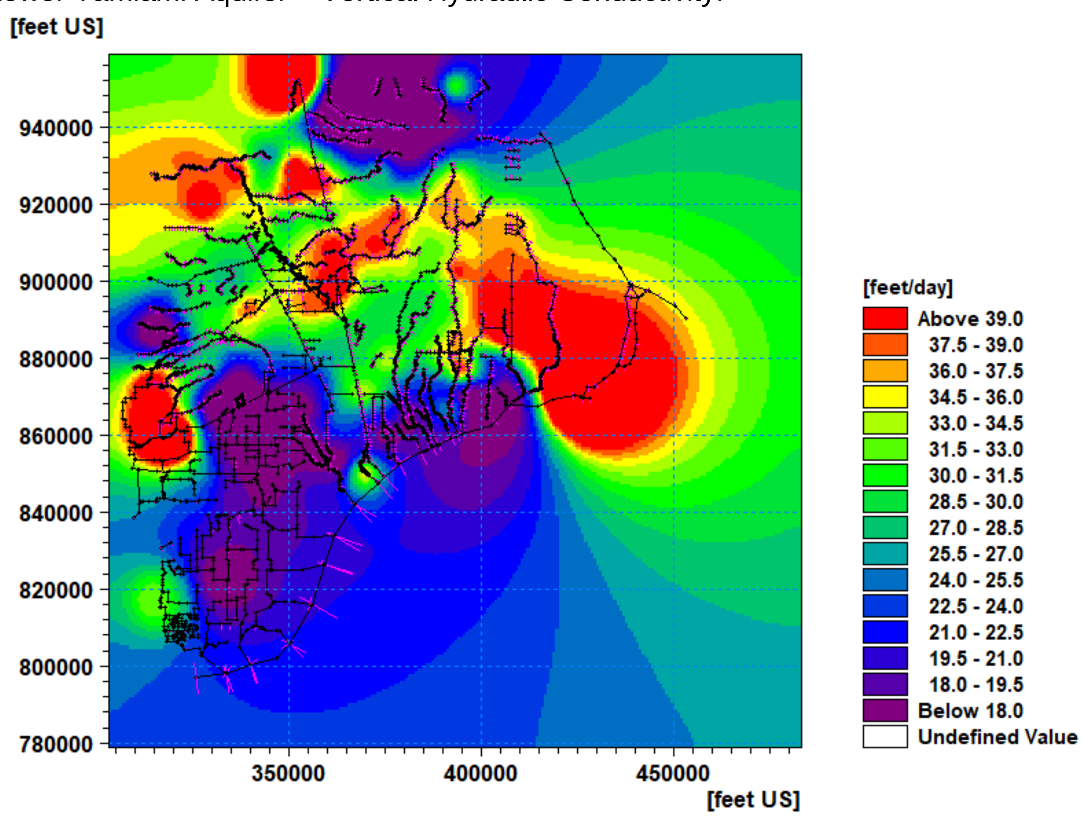
Lower Tamiami Aquifer – Bottom Elevation:



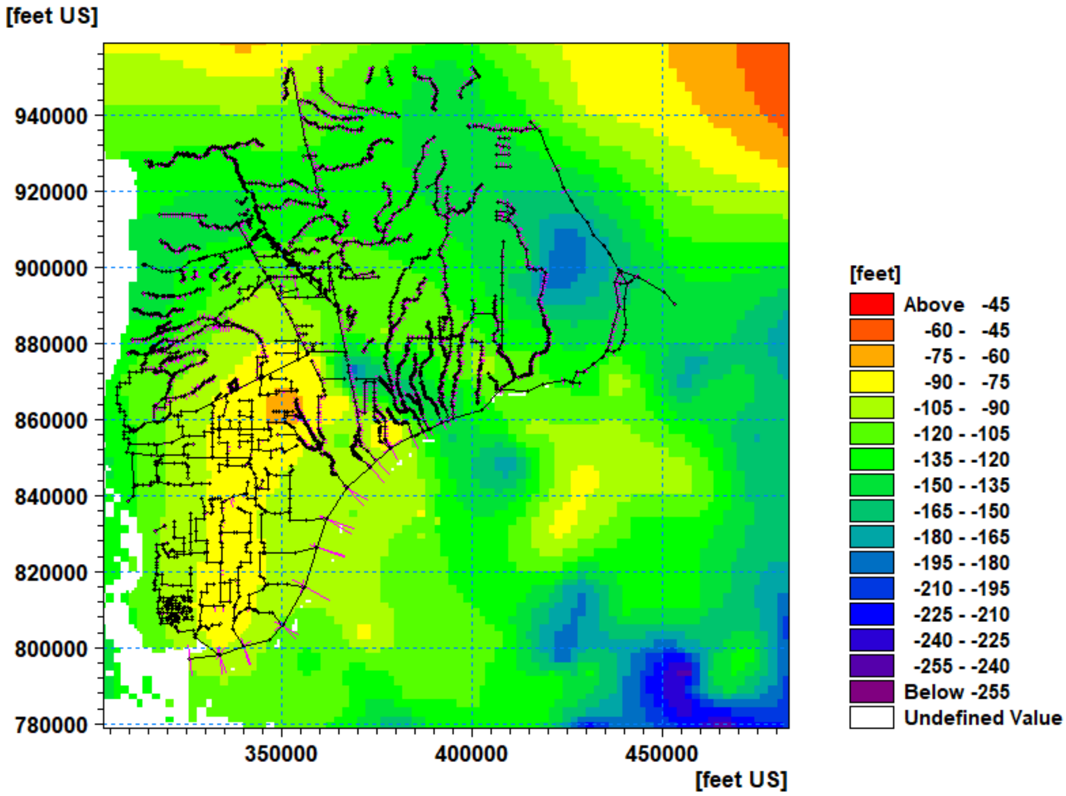
Lower Tamiami Aquifer – Horizontal Hydraulic Conductivity:



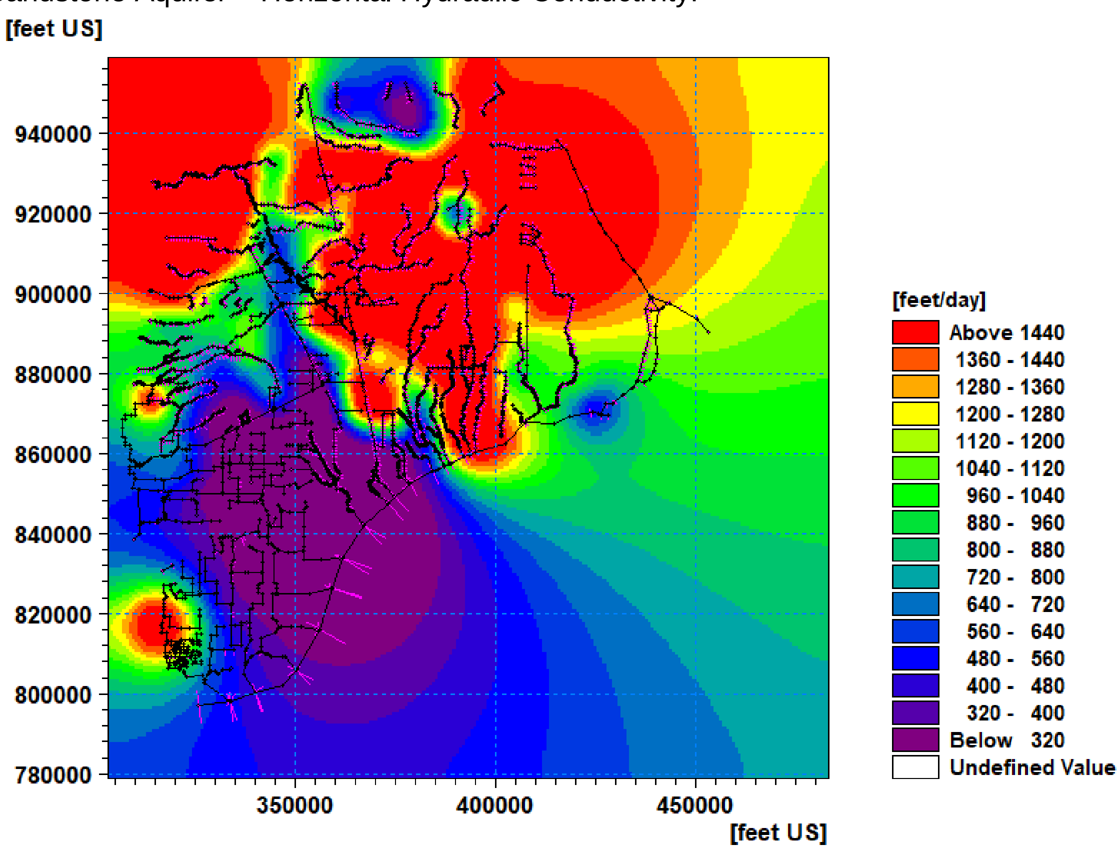
Lower Tamiami Aquifer – Vertical Hydraulic Conductivity:



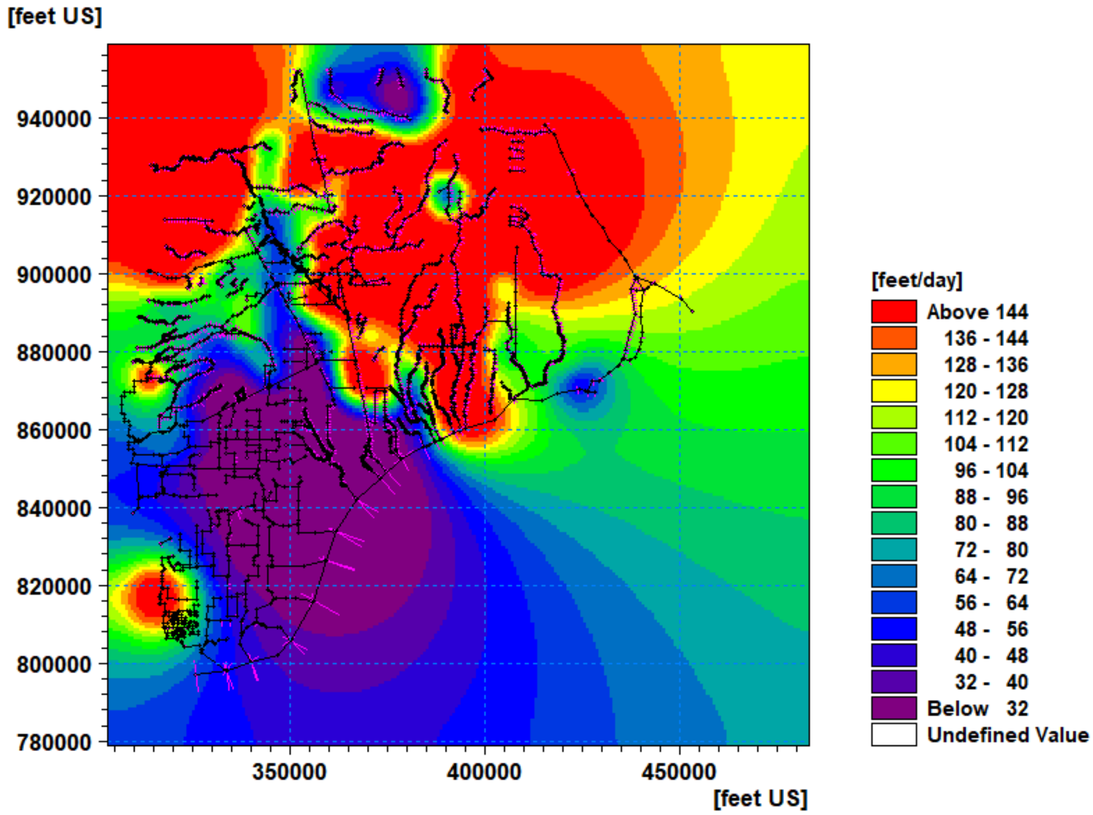
Sandstone Aquifer – Bottom Elevation:



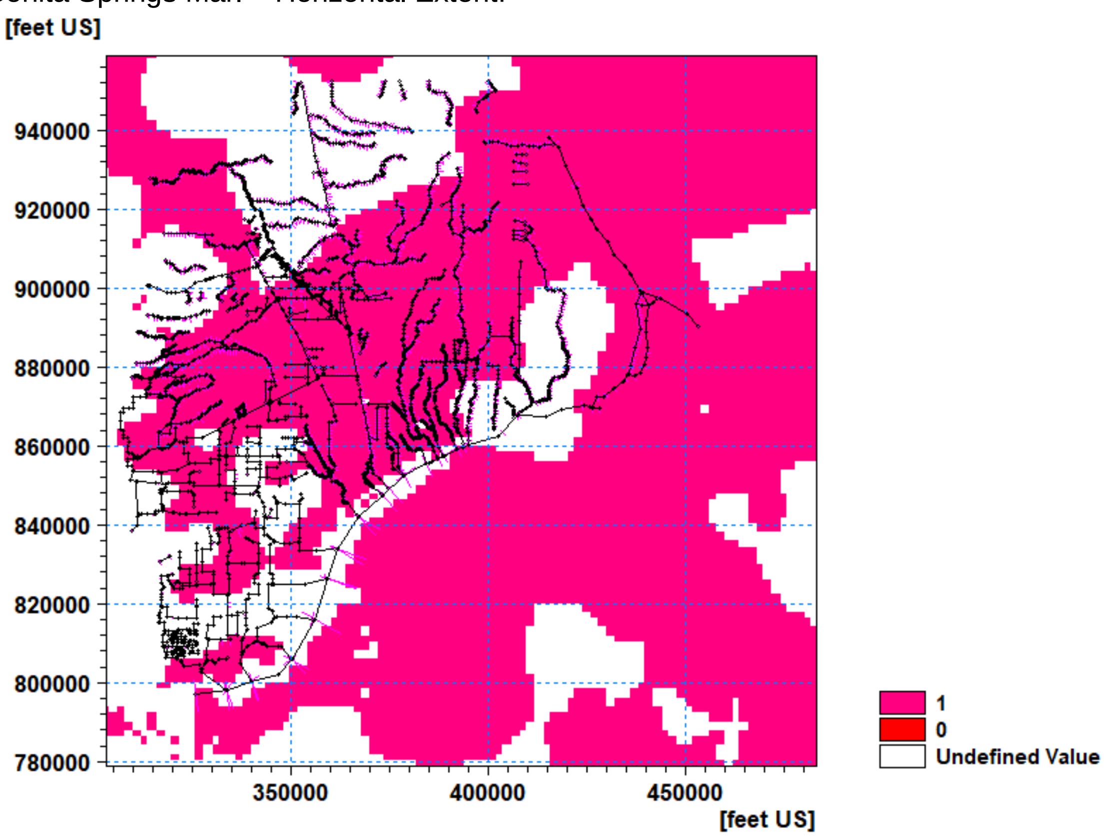
Sandstone Aquifer – Horizontal Hydraulic Conductivity:



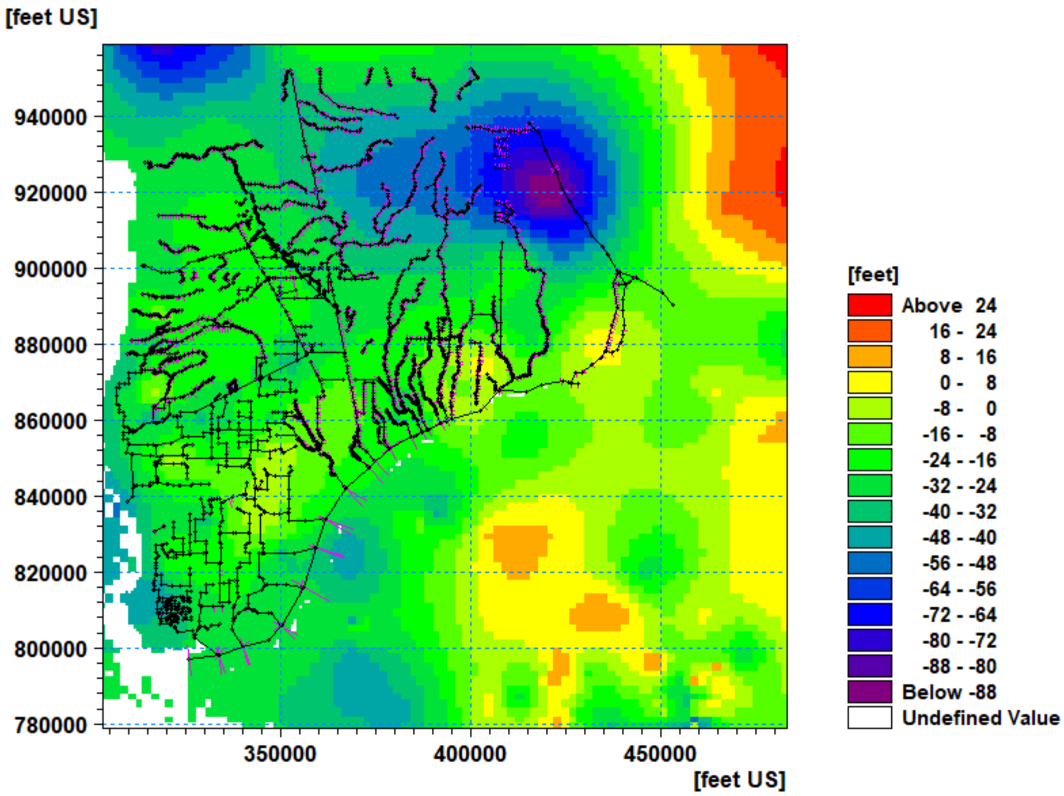
Sandstone Aquifer – Vertical Hydraulic Conductivity:



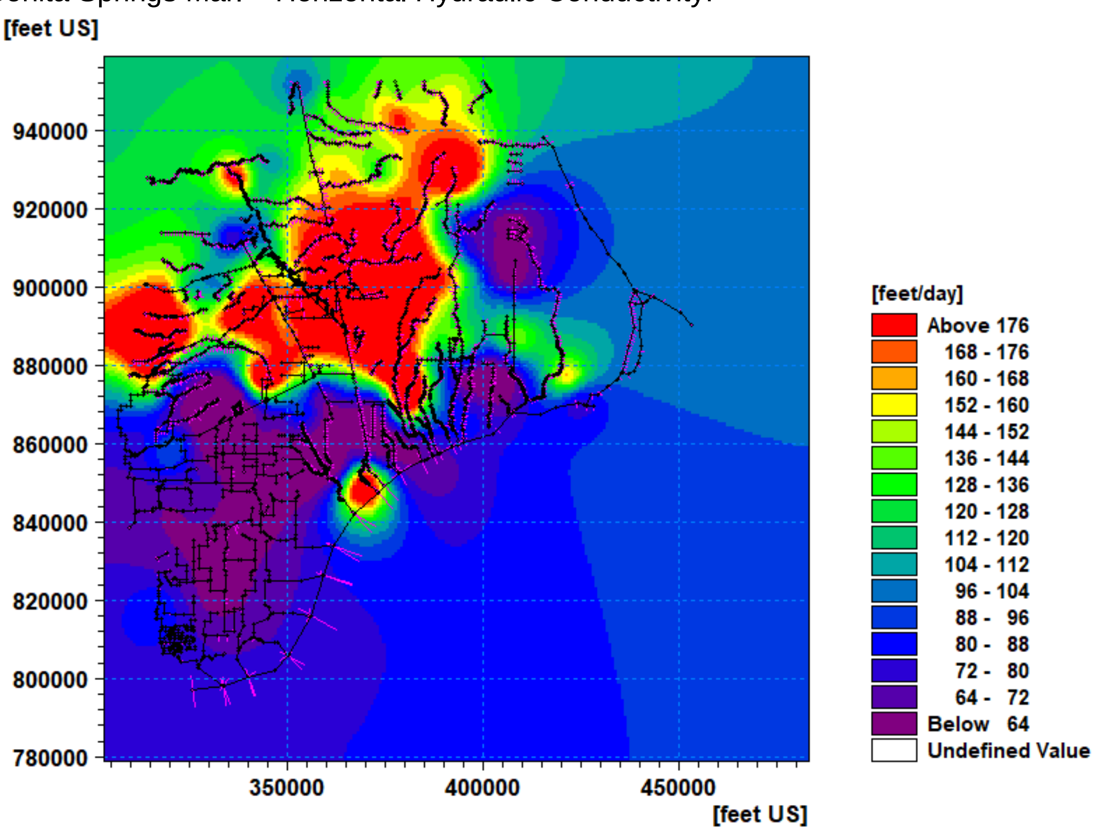
Bonita Springs Marl – Horizontal Extent:



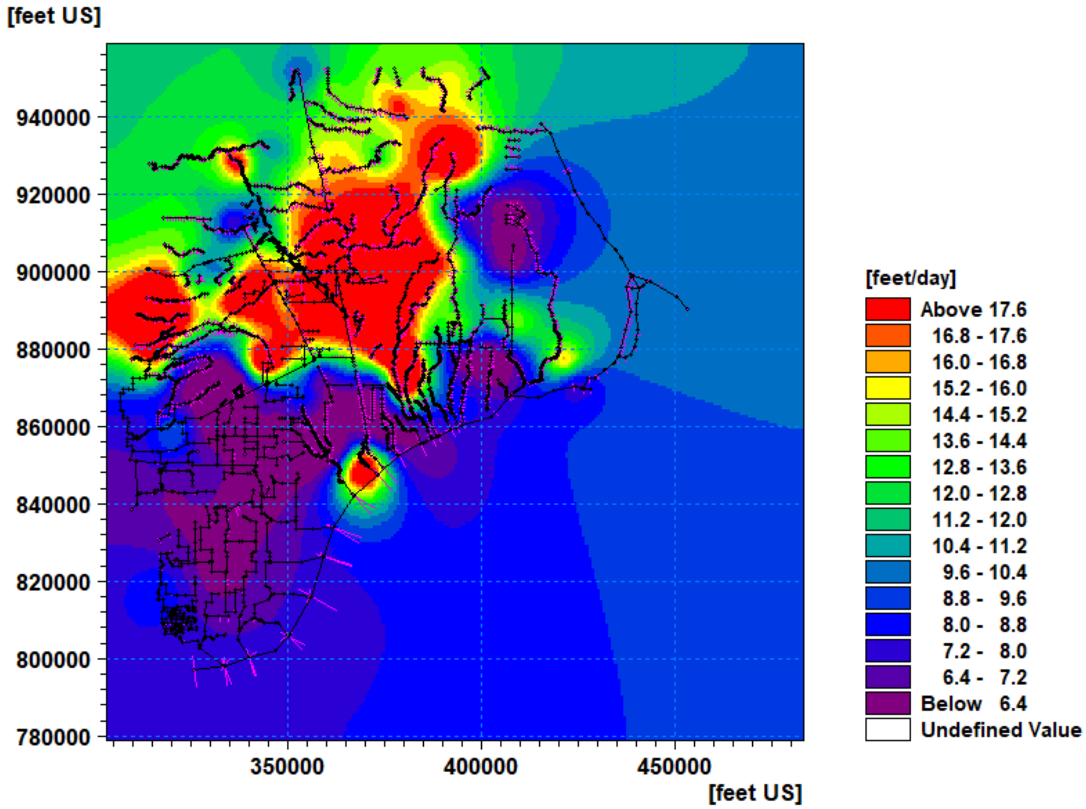
Bonita Springs Marl – Lower Level:



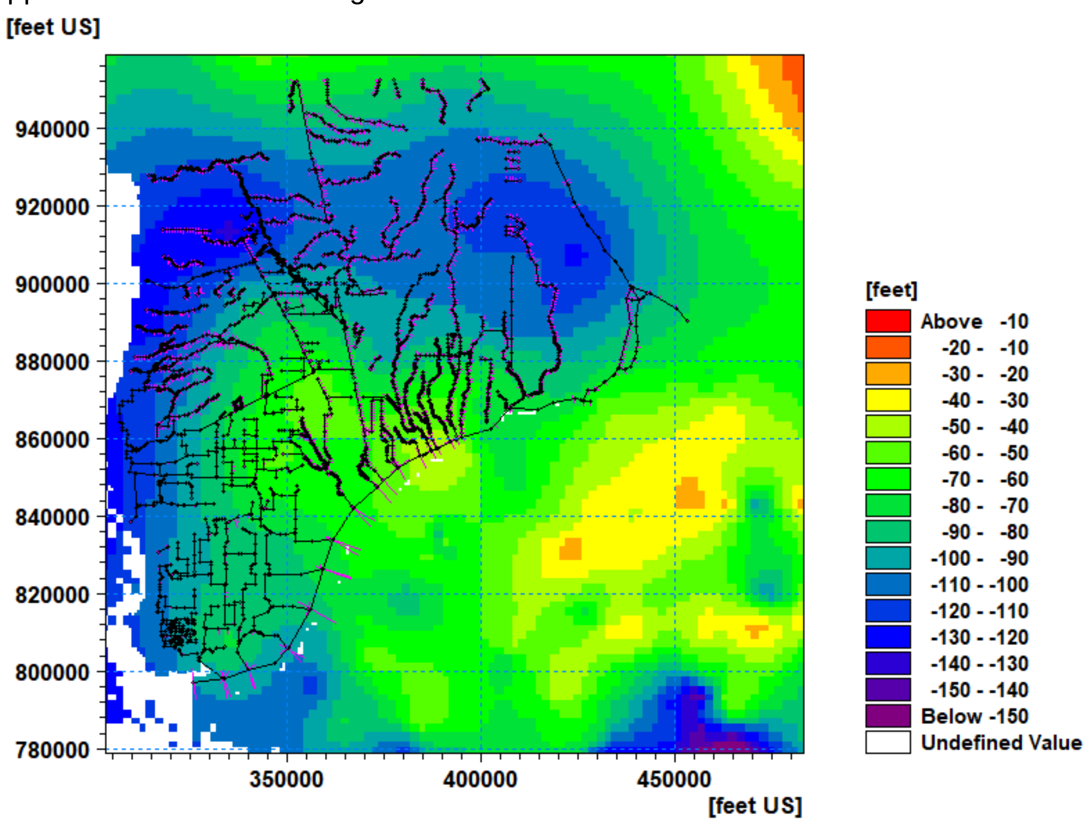
Bonita Springs Marl – Horizontal Hydraulic Conductivity:



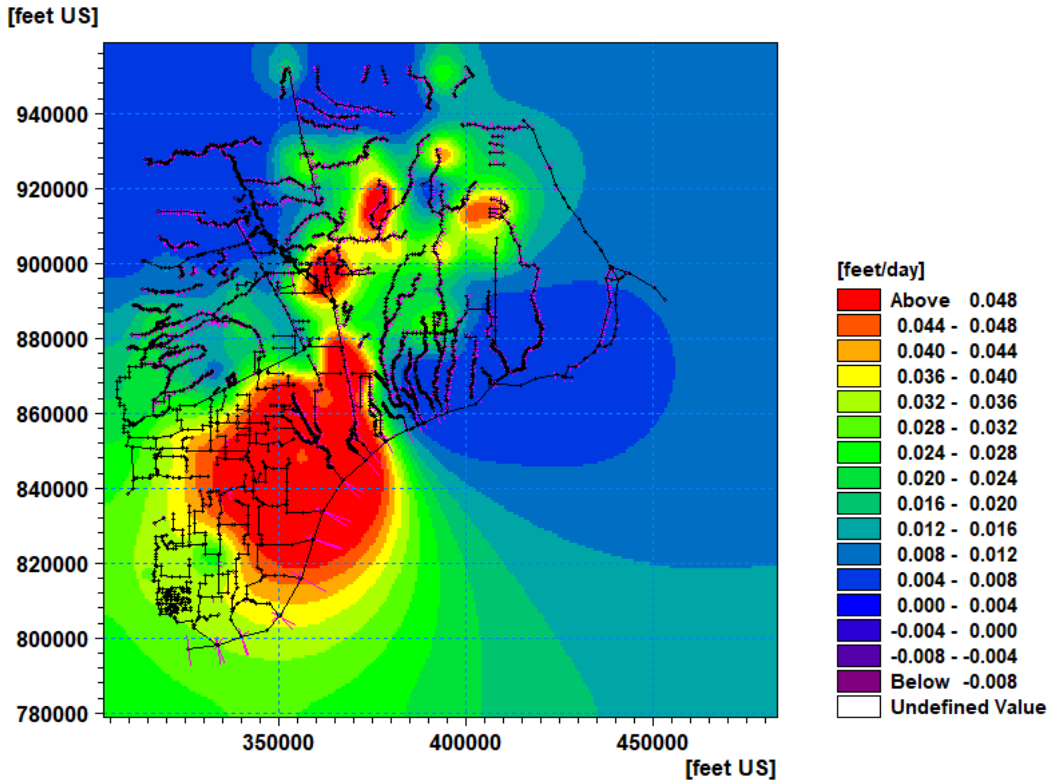
Bonita Springs Marl – Vertical Hydraulic Conductivity:



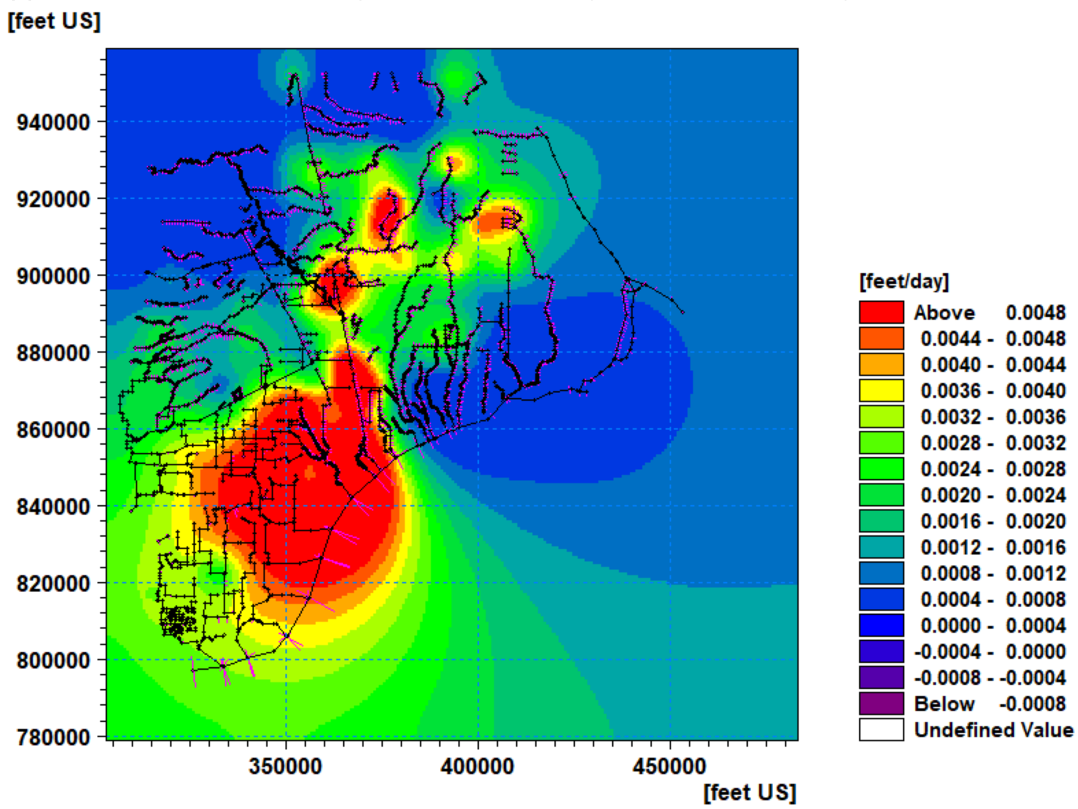
Upper Peace River Confining Unit – Lower Level:



Upper Peace River Confining Unit – Horizontal Hydraulic Conductivity:



Upper Peace River Confining Unit – Vertical Hydraulic Conductivity:



APPENDIX B

MIKE 11 WEIRS ADDED TO REPRESENT CHANNEL OBSTRUCTIONS

Weirs are used rather than representing the obstruction as a cross section in order to reduce model instabilities since MIKE 11 instabilities occur at the location of cross sections that are higher than cross sections located upstream and downstream of the cross section with the higher invert elevation. Details on the obstructions with back-up information is provided below.

Branch Name	Chainage	Description	Figure #
CW_SW	-25	Berm near STA-8	B-1
GSlough_to_US_41	1810	Block in the south of South Agg mine	B-2
GSlough_to_US_41	881.2	Bump in the canal	B-3
GSlough_to_US_41	100	High topo	B-4
Zemel	30.48	Road	B-5
Culverts_Zemel_Rd	-1337.42	Woods Road acting as berm	B-6
Zemel_Cross1	168	High topo	B-7
Hog_Branch	4220	New dirt Driveway	B-8
Zemel Canal	3121	Concrete in channel	B-9
YuccaPens	10744	Dense vegetation west of Burnt Store Rd	B-10
Durden	6750	higher invert elevations in LiDAR data	B-11
CCI_N	140	High ground evident in LiDAR data	B-12

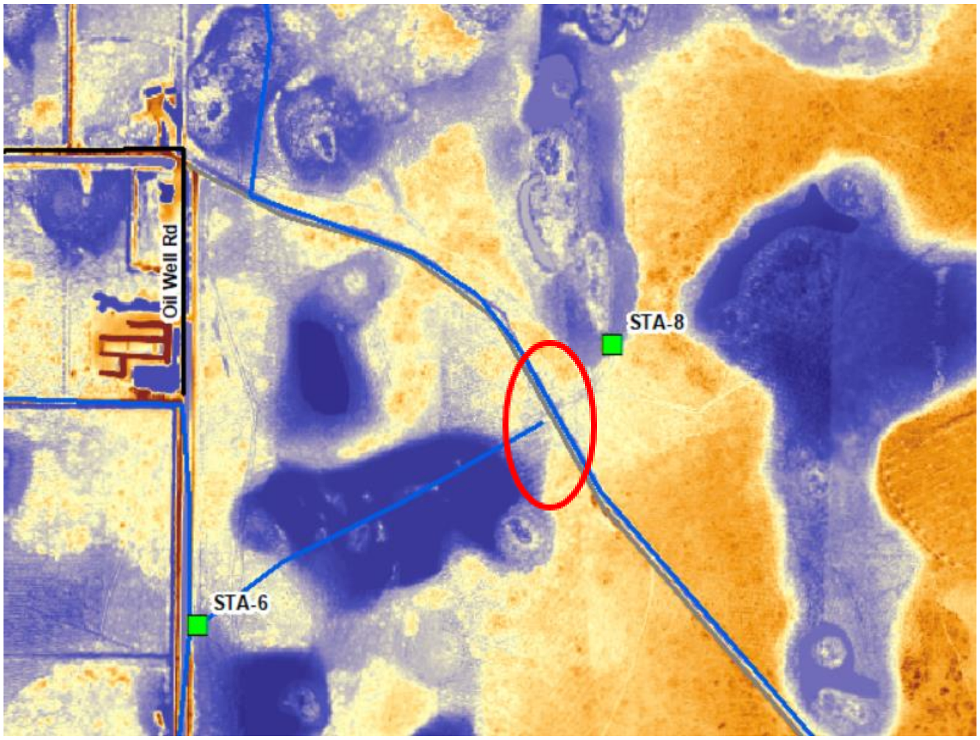


Figure B-1. Branch CW-SW, just southwest of STA-8

Figure B-2. Branch GSlough_to_US_41, chainage 1810, south side of Southwest Aggregates, rock in ditch

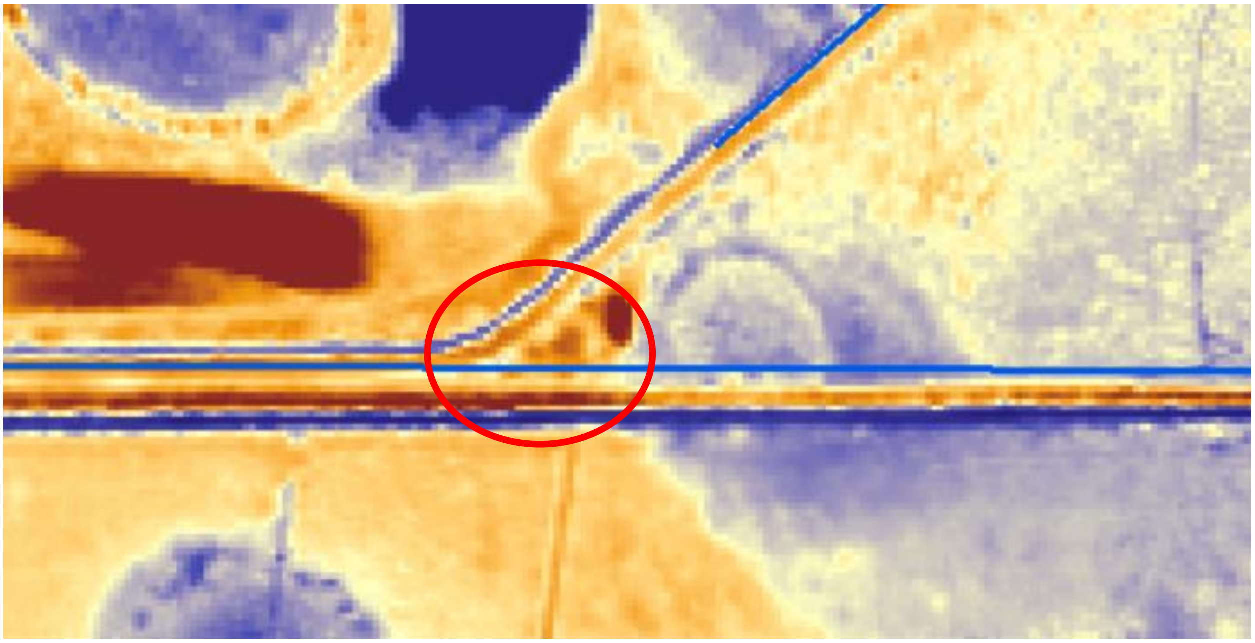


Figure B-3. Branch GSlough_to_US_41, chainage 881.1, dirt in channel prevents flow to west

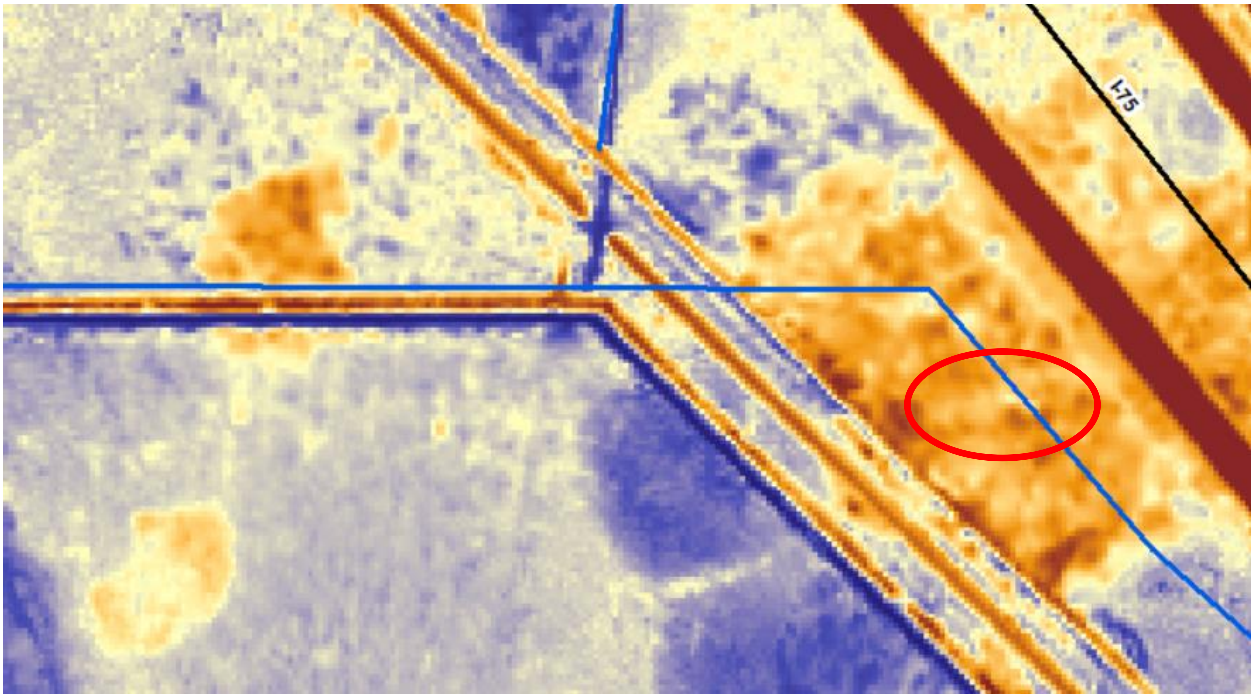


Figure B-4. Branch GSlough_to_US_41, chainage 100, high ground evident in LiDAR data

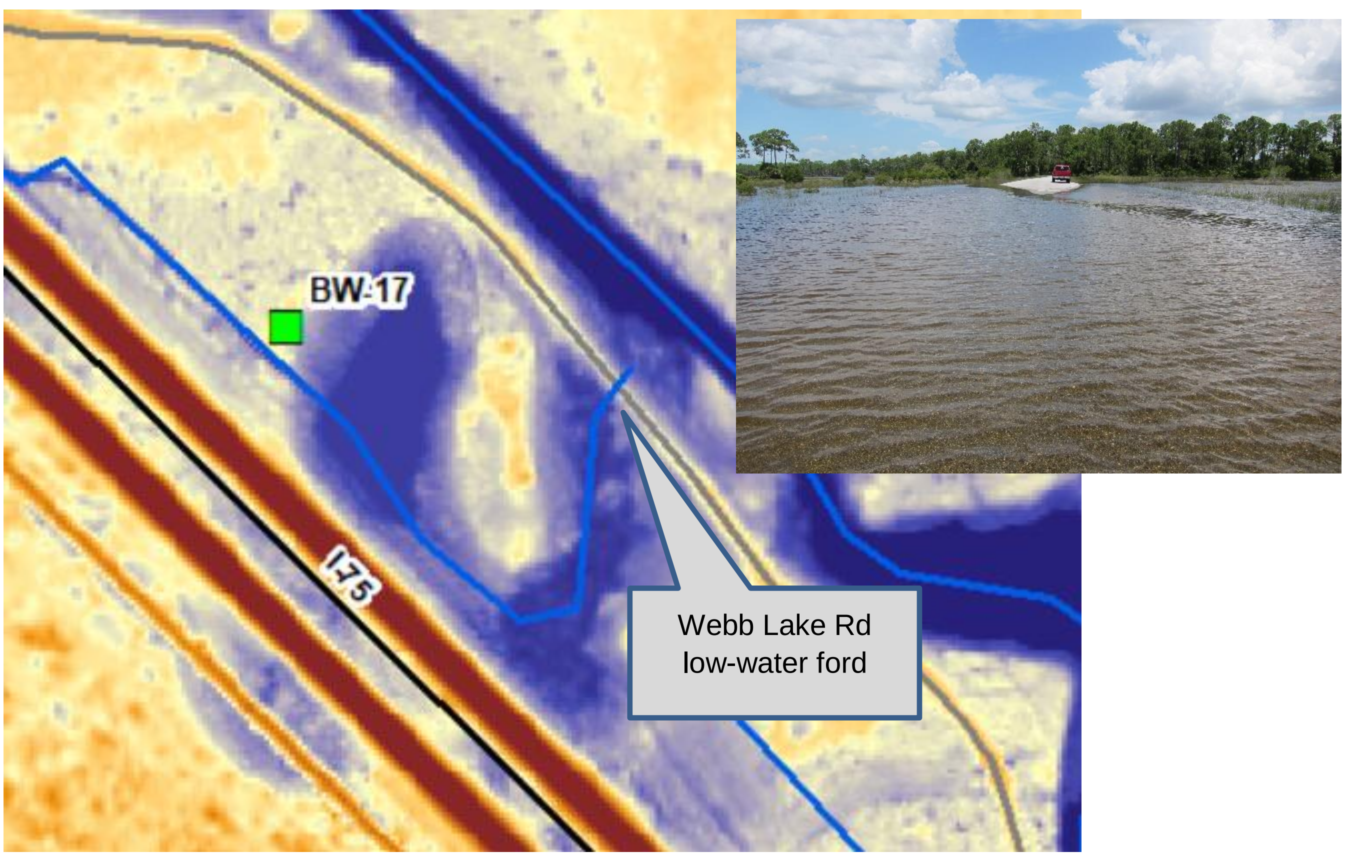


Figure B-5. Branch Zemel, chainage 30.48, Webb Lake Road low-water ford

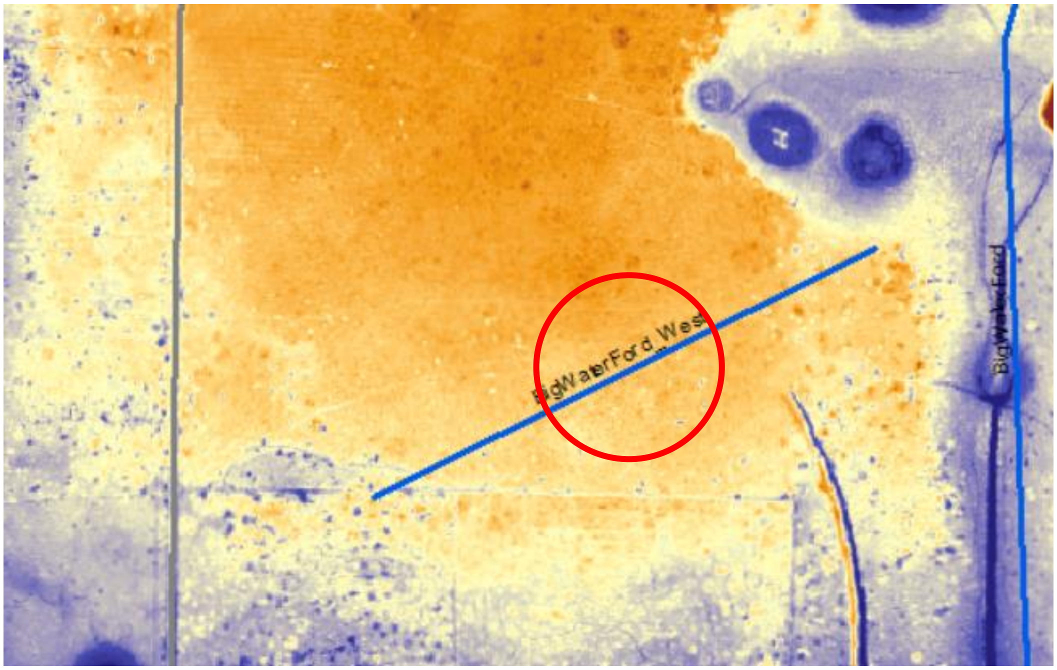


Figure B-6. BigWaterFord_West, chainage 300, high elevations evident in LiDAR

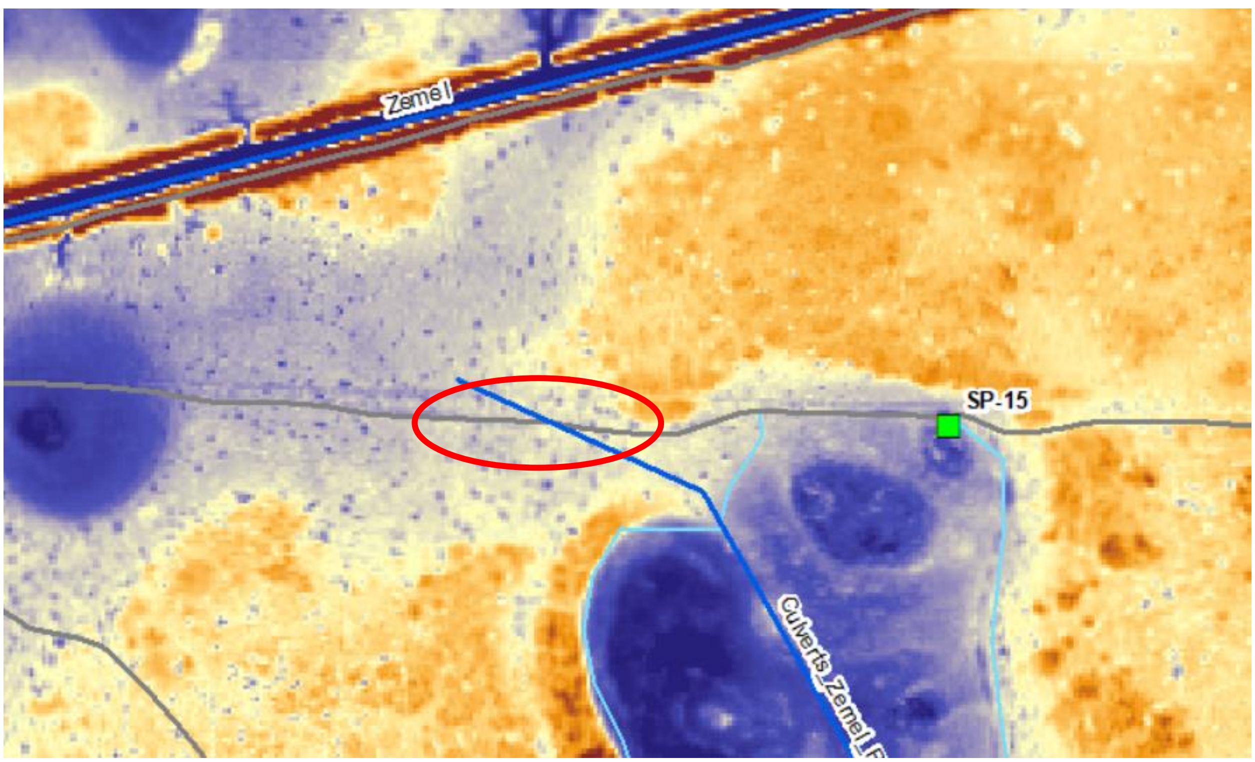


Figure B-7. Culverts_Zemel_Rd, chainage -1337.42, Woods Road and berm along Zemel Canal, both which constrict flows

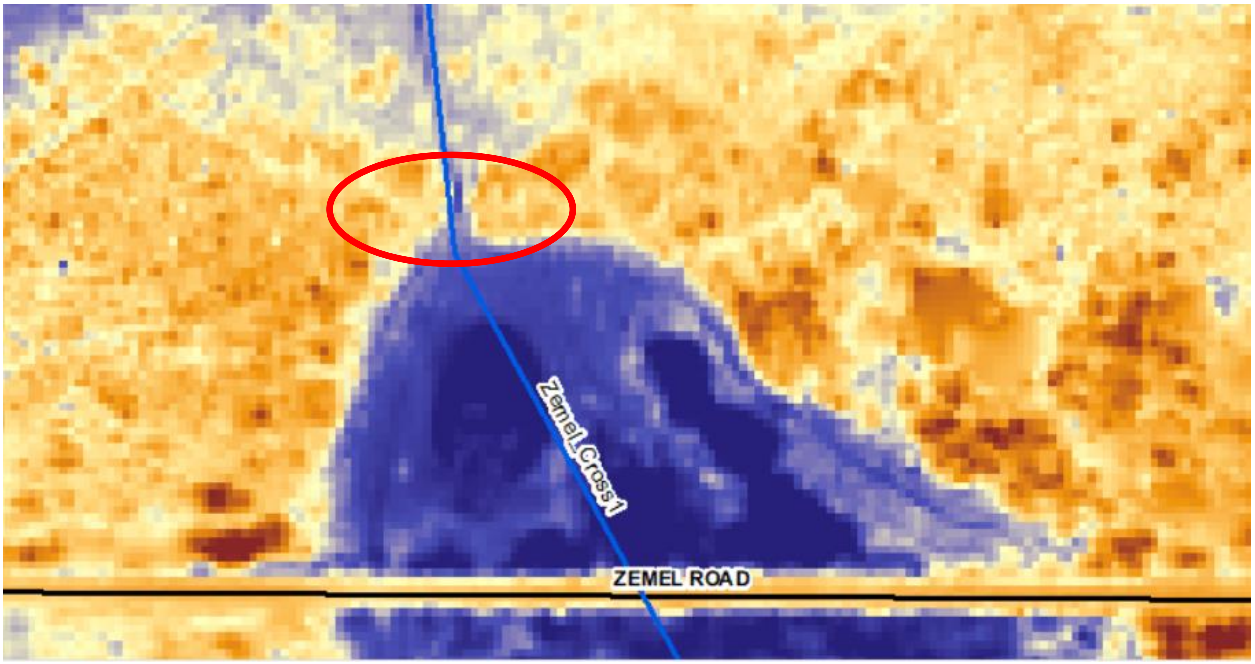


Figure B-8. Zemel_Cross1, chainage 168, high ground constricting flows

Figure B-9. Hog_Branch, chainage 4220, dirt road crossing

Figure B-10. Zemel Canal, chainage 3121, concrete low-water ford in Zemel Canal, survey indicated higher elevation due to concrete

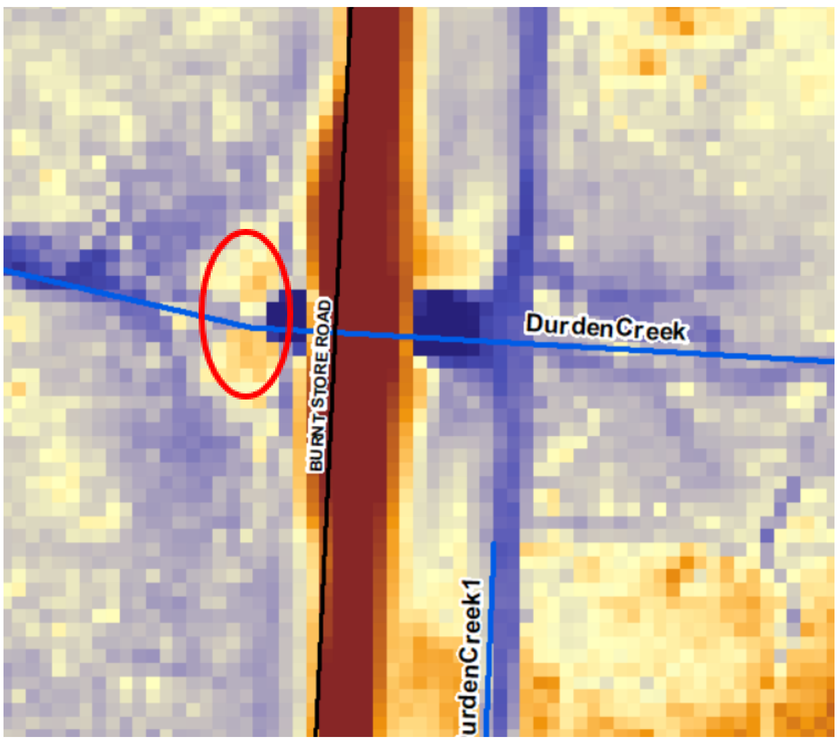


Figure B-11. Durden Creek, just west of Burnt Store Road

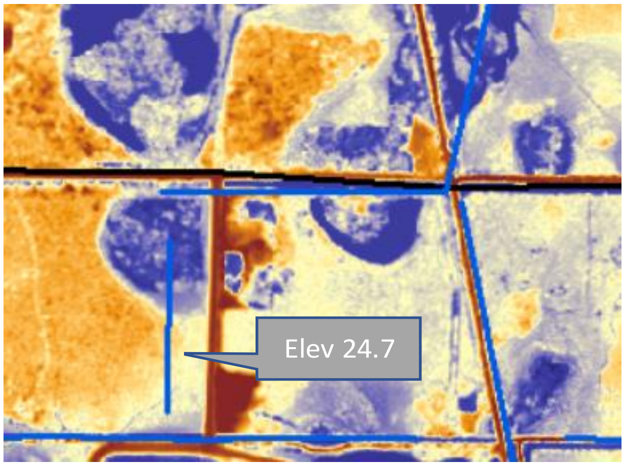


Figure B-12. Branch CCI_N, south of Oil Well Rd, east of I-75

MODEL CALIBRATION PLOTS

Open circles are measured data at calibration stations, and the solid line is simulated data. Calibration statistics for individual stations are provided in Tables 9 and 10 above. Calibration rankings included for each station and delineated within the categories:

Good **OK** **Poor** **NFA**

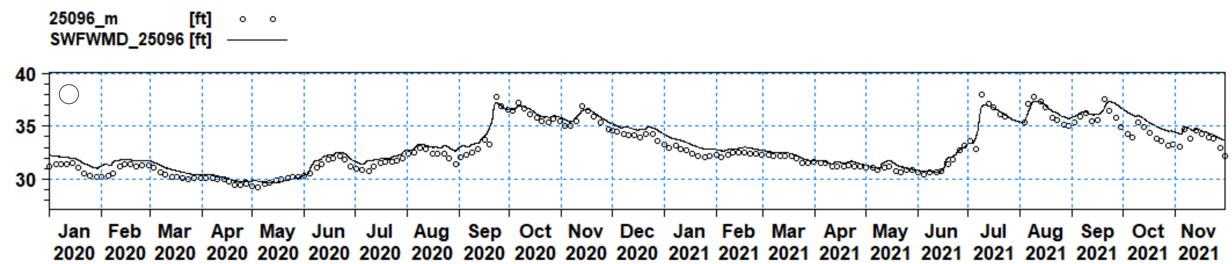
Good: MAE ≤ 0.75 ft., correlation coefficient r ≥ 0.8, and/or Nash Sutcliffe coefficient ≥ 0.3

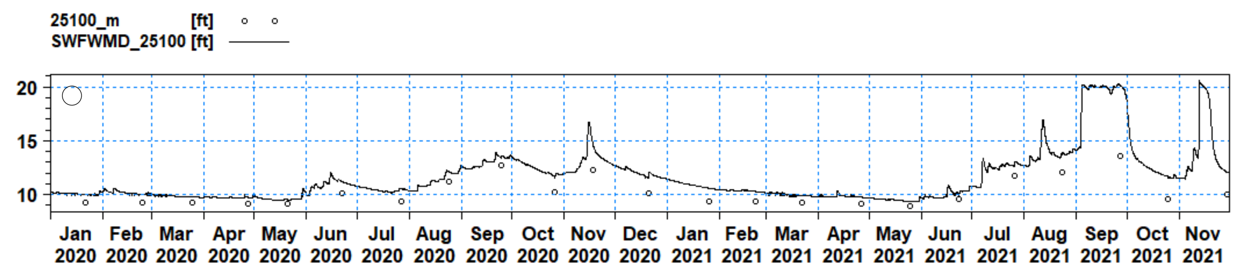
OK: MAE 0.75- 1.0 ft., correlation coeff. r = 0.7 – 0.8, and/or Nash Sutcliffe coefficient = 0.2 - 0.3

Poor: MAE > 1.0 ft., correlation coeff. r ≤ 0.7 and Nash Sutcliffe coefficient < 0.0

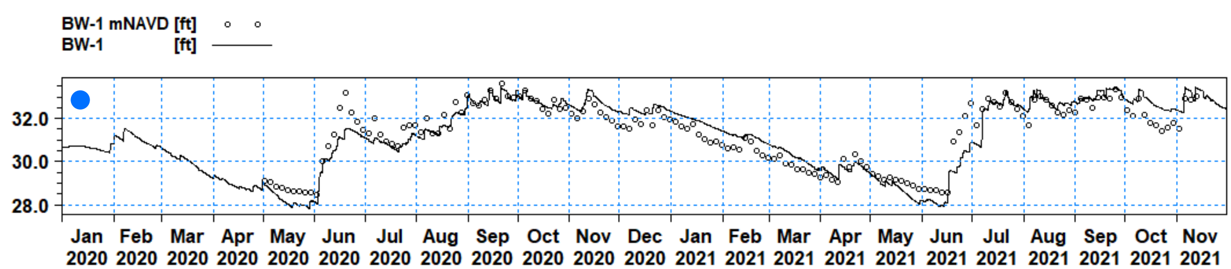
NFA: denotes Non Focus Area.

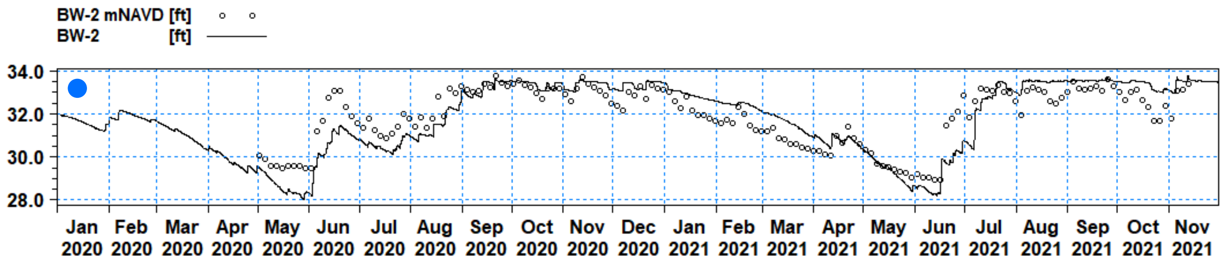
North Boundary Condition Stations:

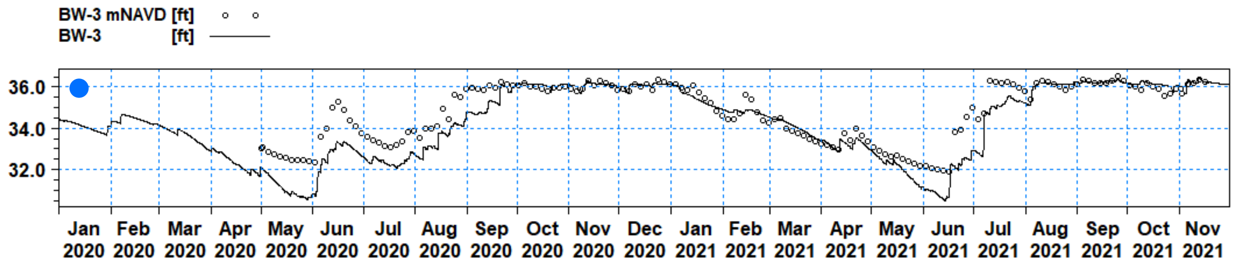


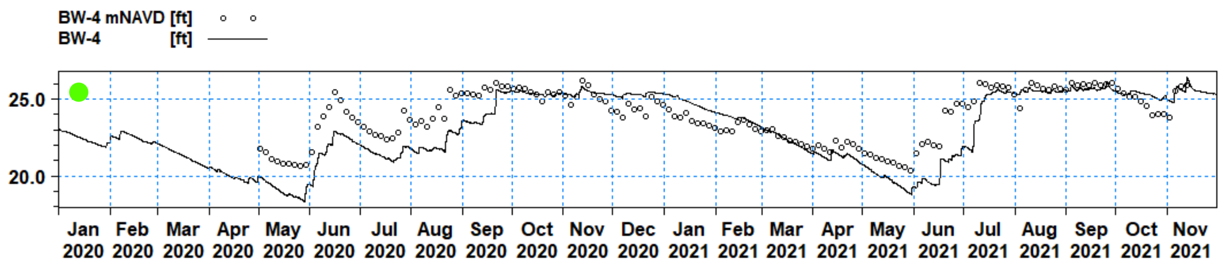


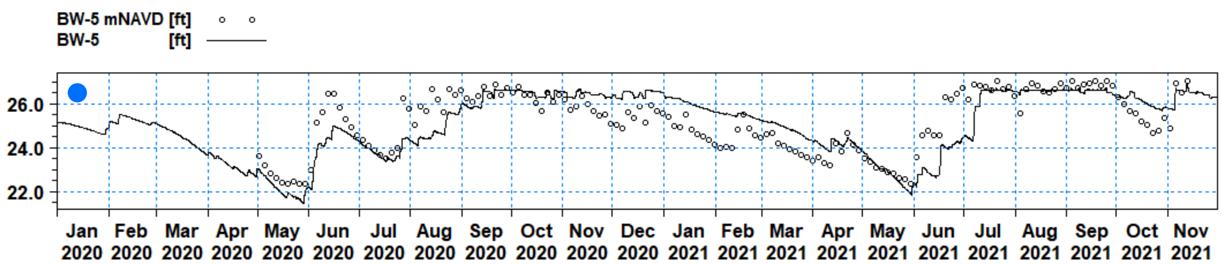
North Babcock Webb WMA Stations North of Tuckers Grade:

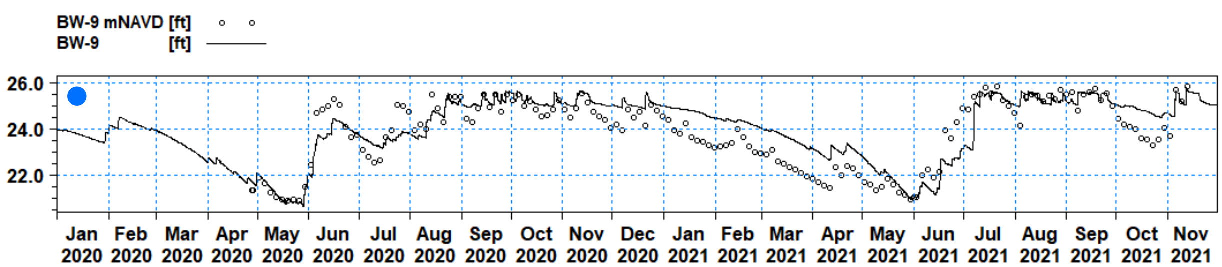


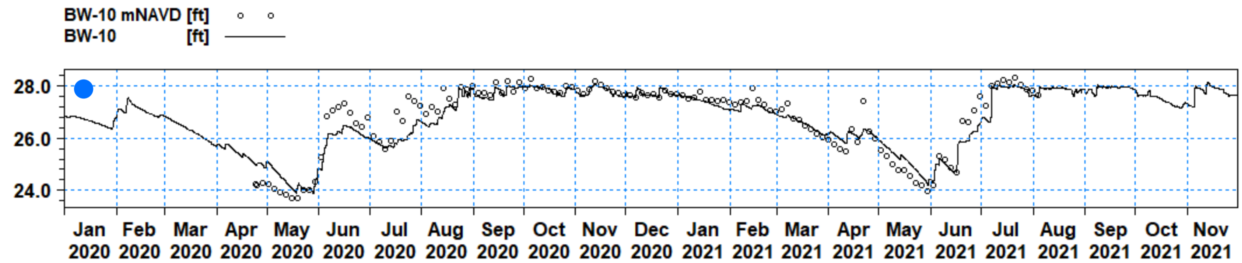

BW-2 mNAVD [ft]
BW-2 [ft]
34.0
32.0
30.0
28.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

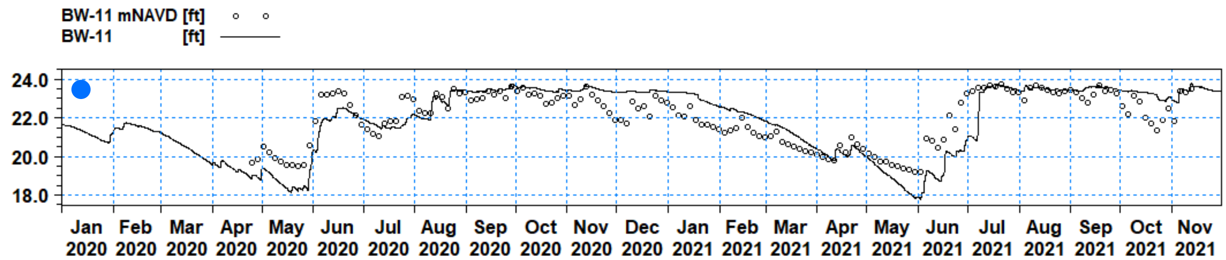

BW-3 mNAVD [ft]
BW-3 [ft]
36.0
34.0
32.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

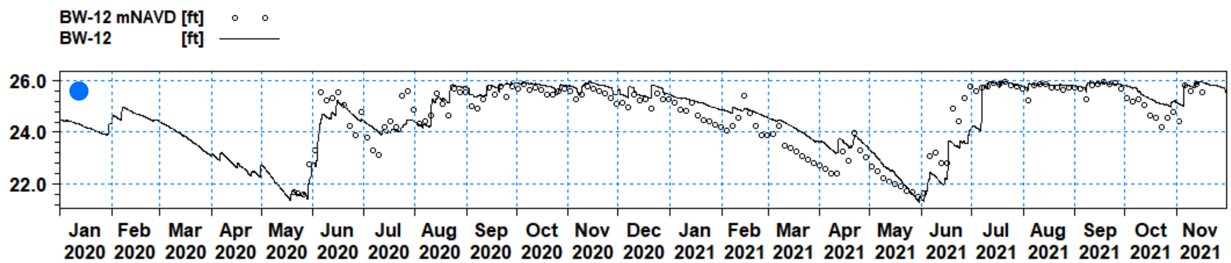

BW-4 mNAVD [ft]
BW-4 [ft]
25.0
20.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

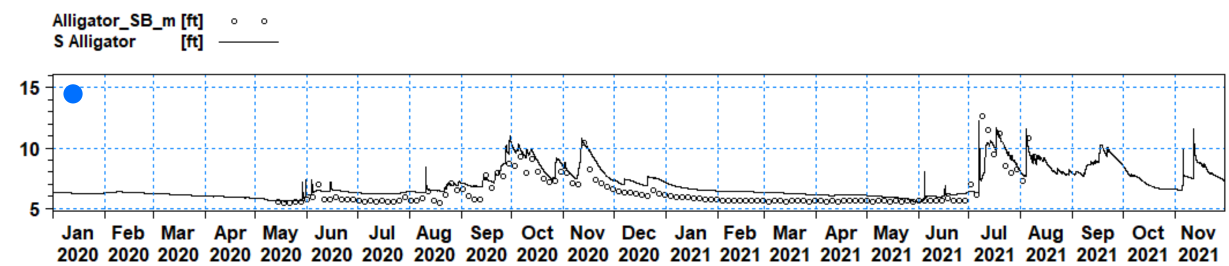

BW-5 mNAVD [ft]
BW-5 [ft]
26.0
24.0
22.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

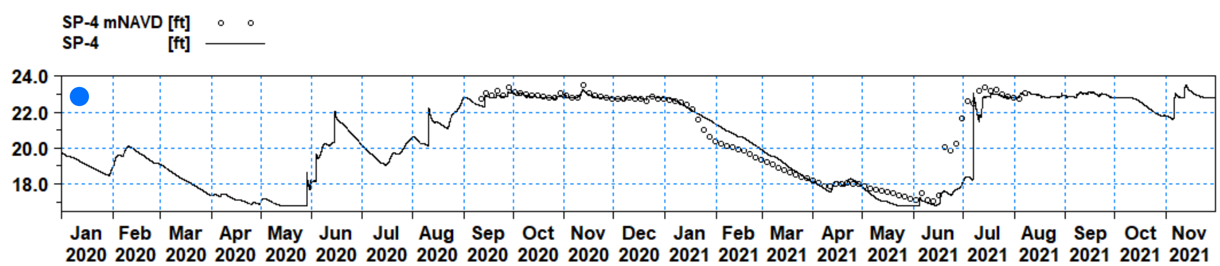

BW-9 mNAVD [ft]
BW-9 [ft]
26.0
24.0
22.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

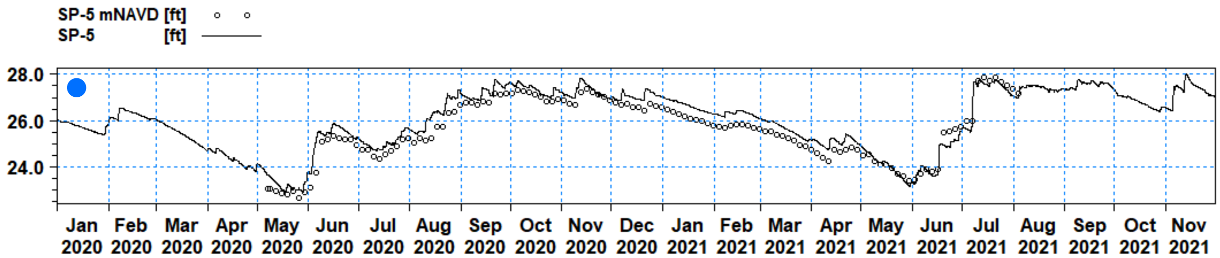

BW-10 mNAVD [ft]
BW-10 [ft]
28.0
26.0
24.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

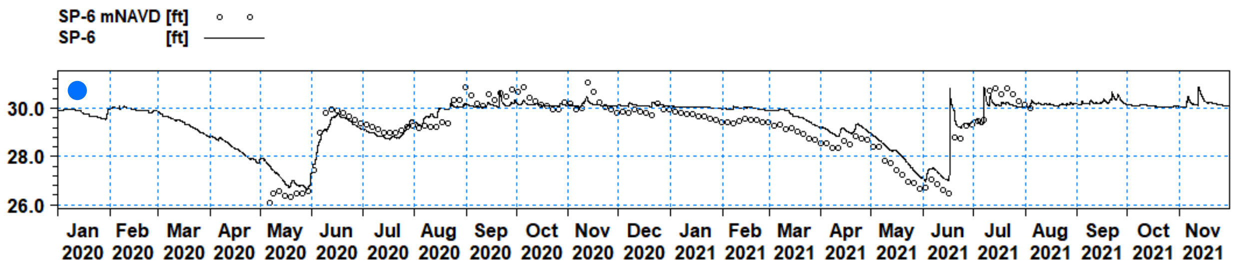

BW-11 mNAVD [ft]
BW-11 [ft]
24.0
22.0
20.0
18.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

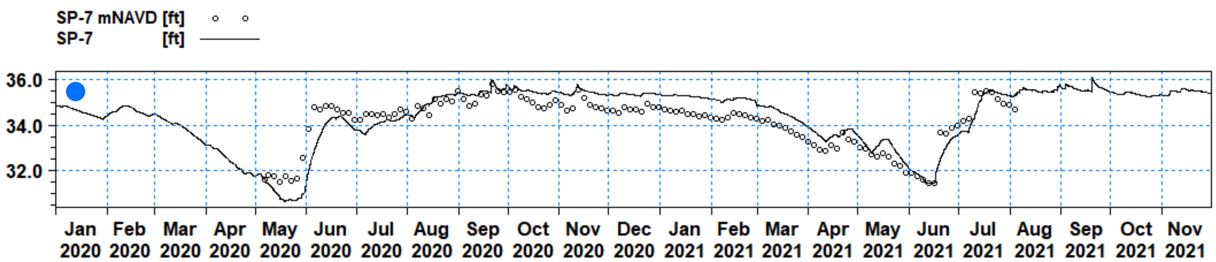

BW-12 mNAVD [ft]
BW-12 [ft]
26.0
24.0
22.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

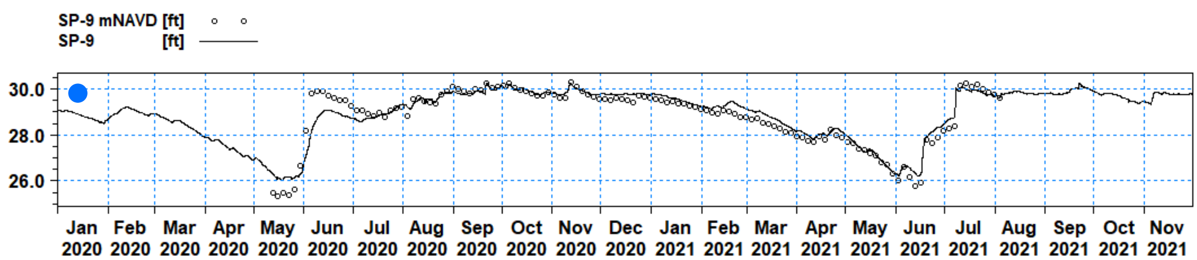

Alligator_SB_m [ft]
S Alligator [ft]
15
10
5
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

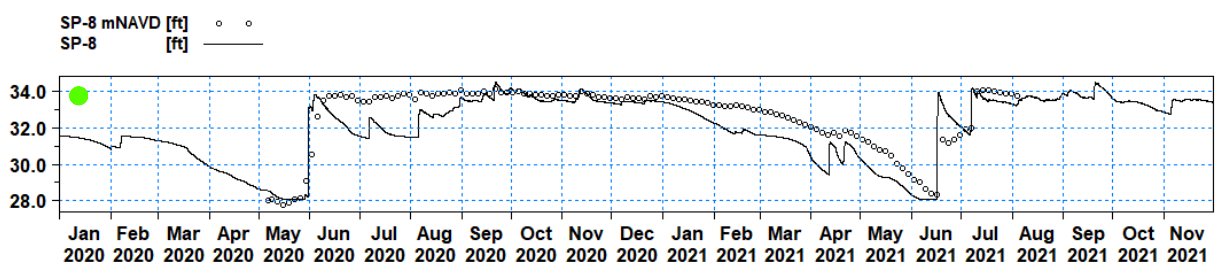

SP-4 mNAVD [ft]
SP-4 [ft]
24.0
22.0
20.0
18.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021


SP-5 mNAVD [ft]
SP-5 [ft]
28.0
26.0
24.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

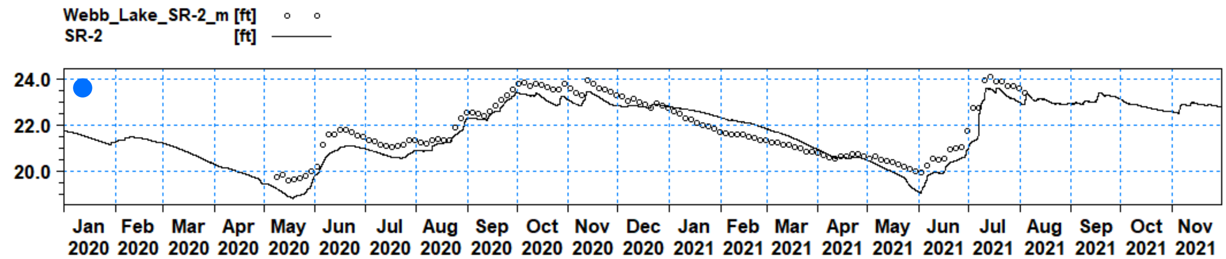

SP-6 mNAVD [ft]
SP-6 [ft]
30.0
28.0
26.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

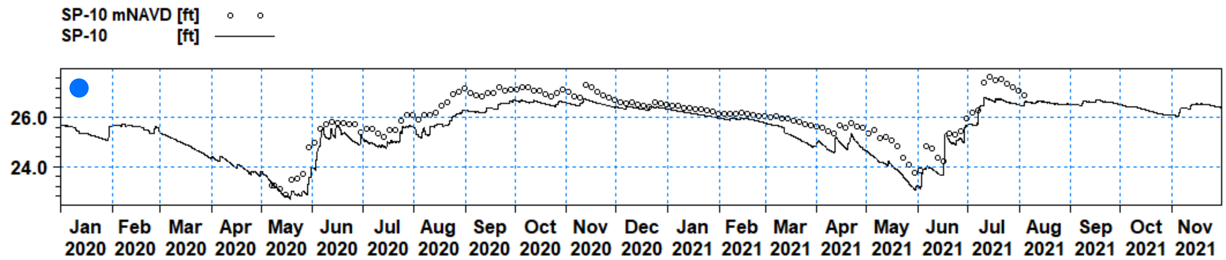

SP-7 mNAVD [ft]
SP-7 [ft]
36.0
34.0
32.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

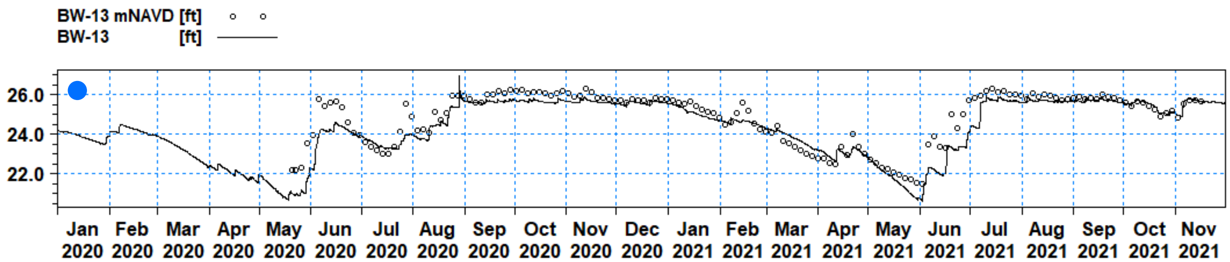

SP-9 mNAVD [ft]
SP-9 [ft]
30.0
28.0
26.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

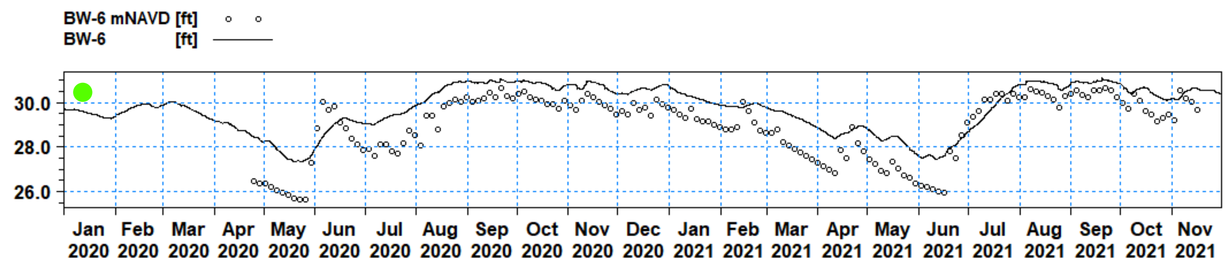

SP-8 mNAVD [ft]
SP-8 [ft]
34.0
32.0
30.0
28.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

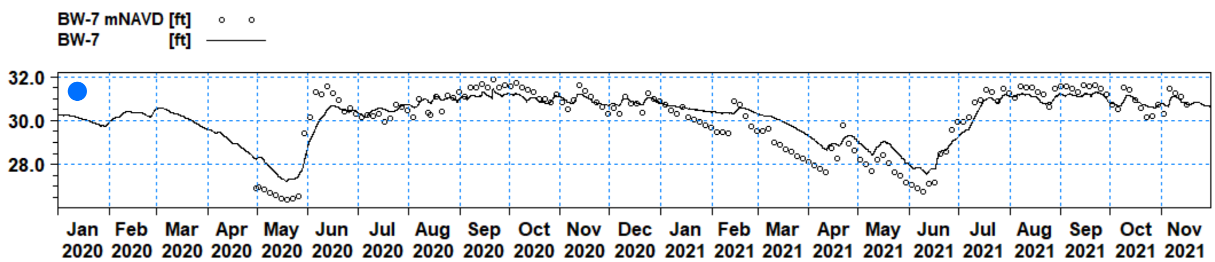
Babcock Webb from Tuckers Grade South

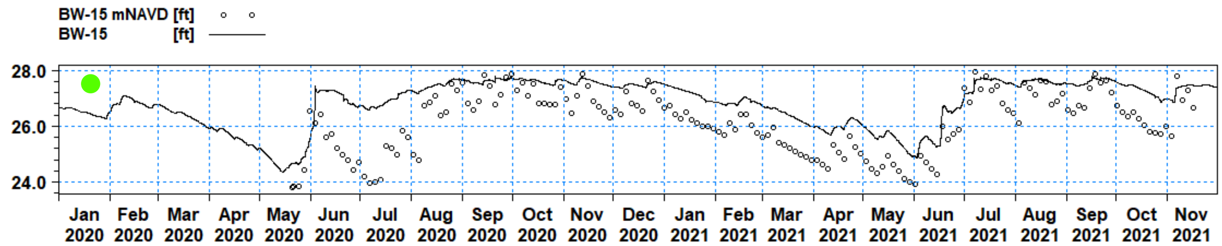




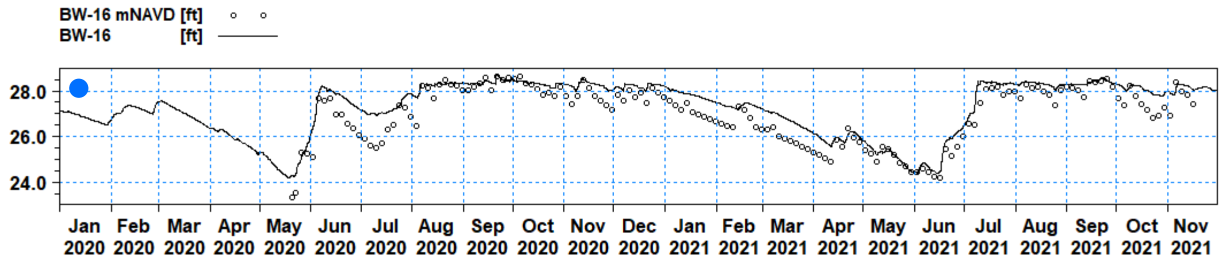


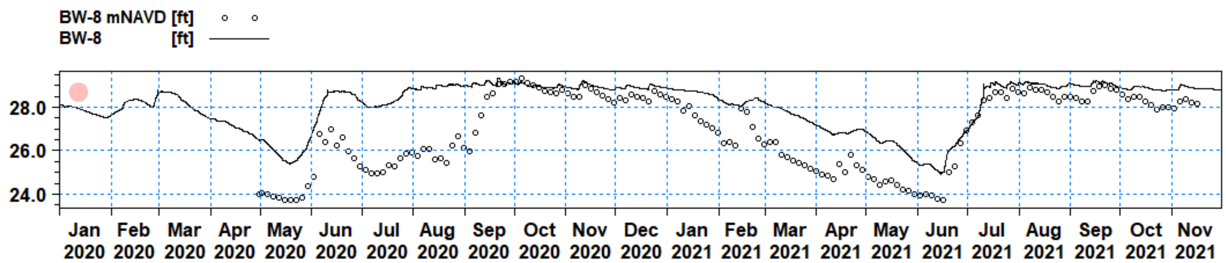


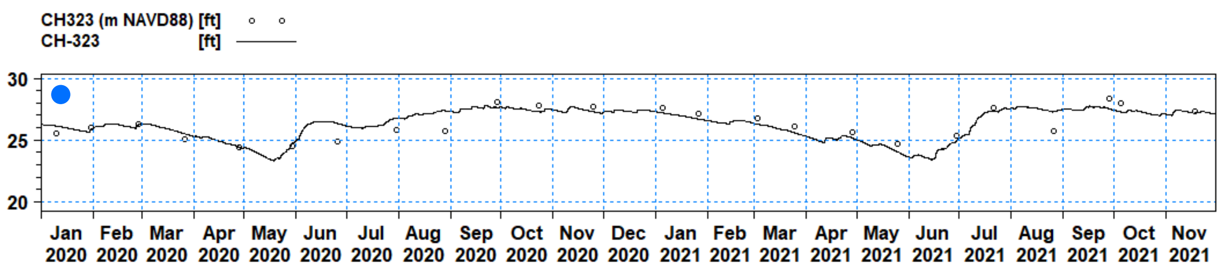


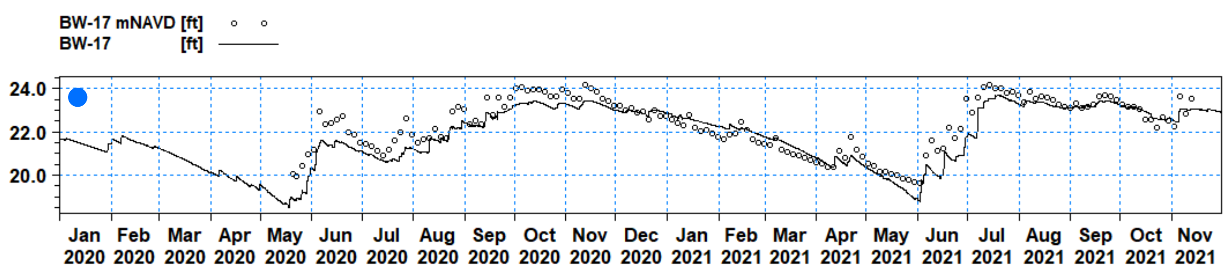


Though it visually appears to significantly differ, the statistics support that it has OK calibration.

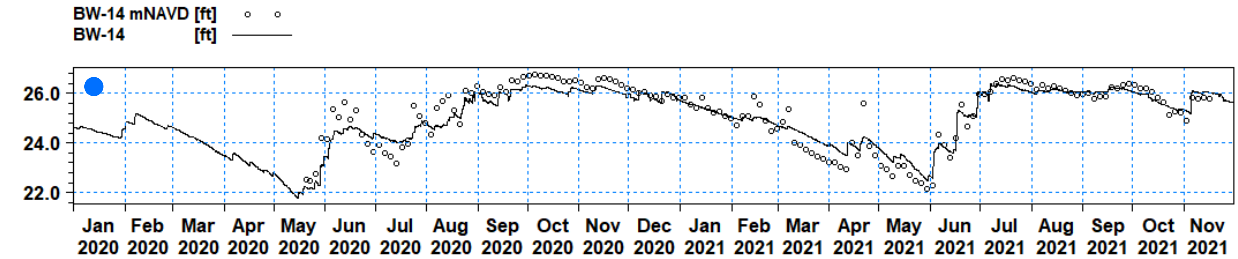


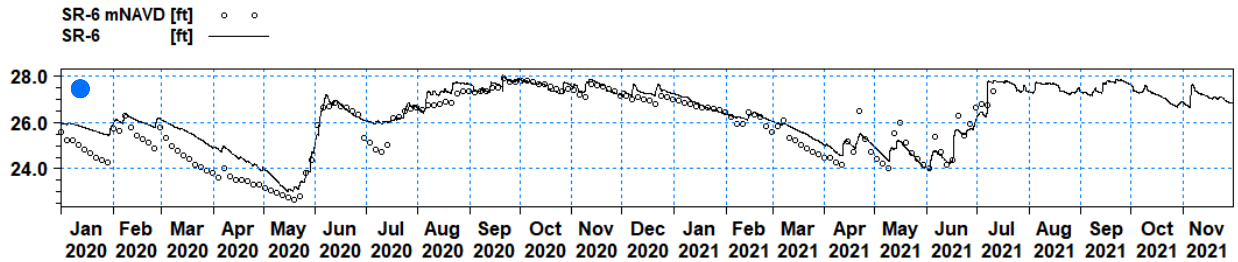


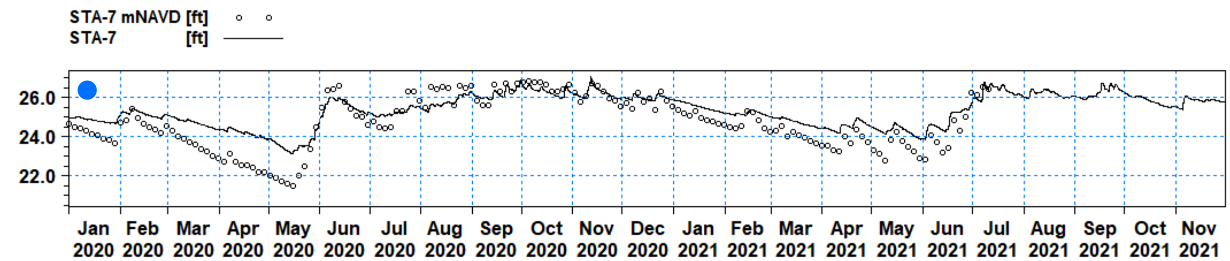


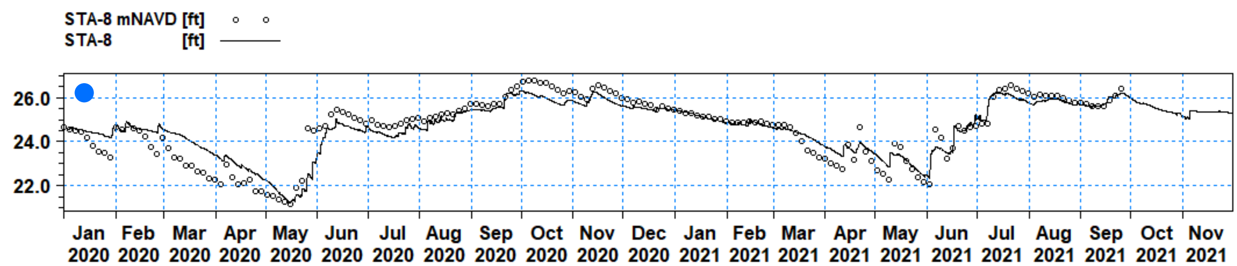


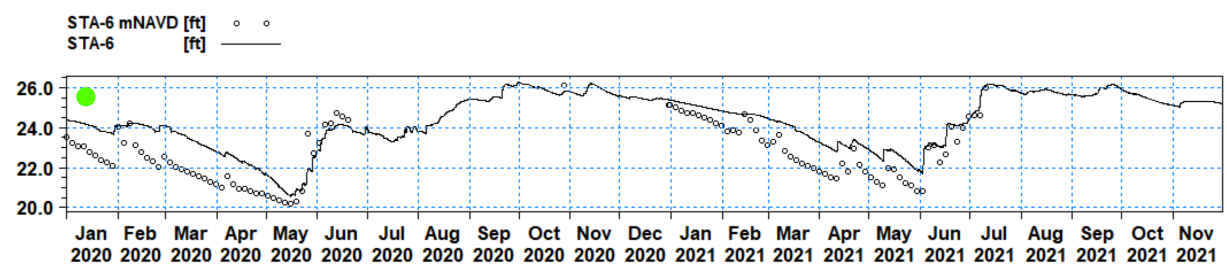
South Walk-In Area of Babcock Webb:



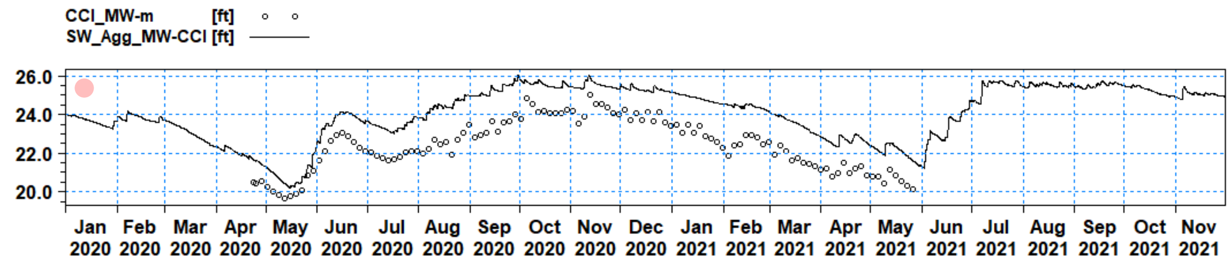


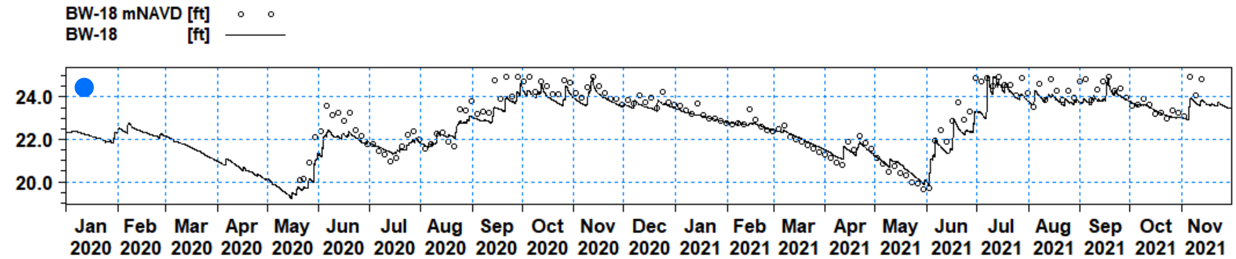


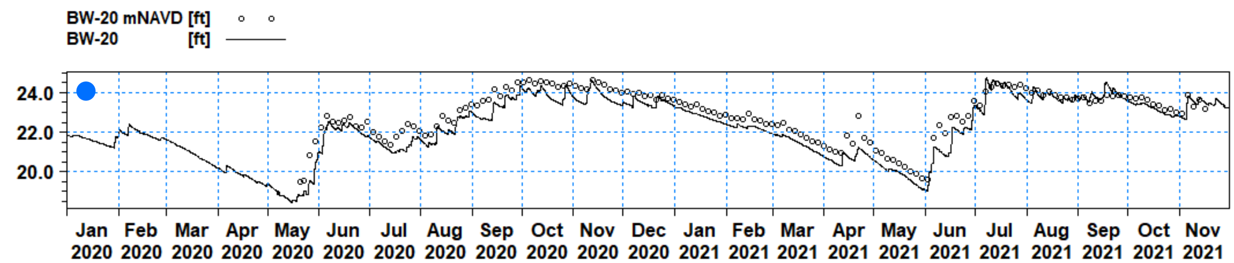


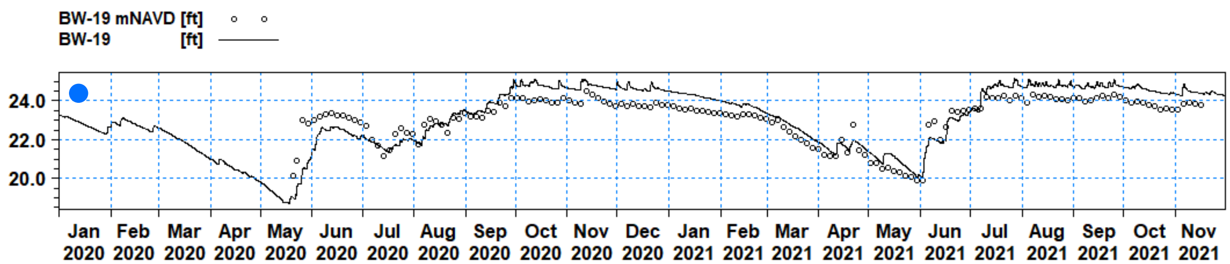


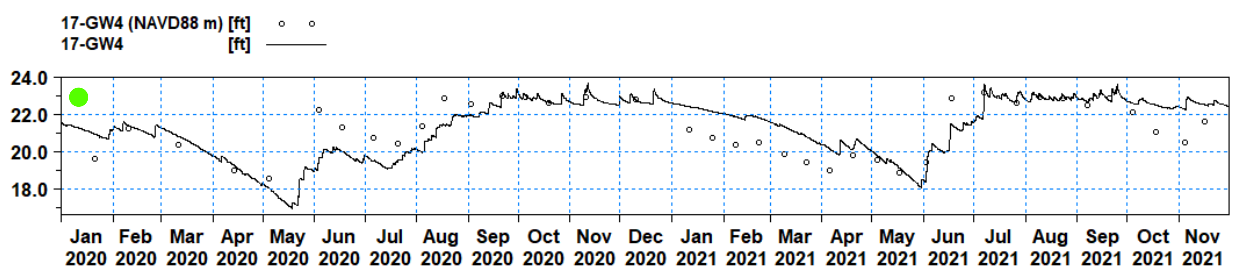
West of South Walk-In Area, East of I-75:

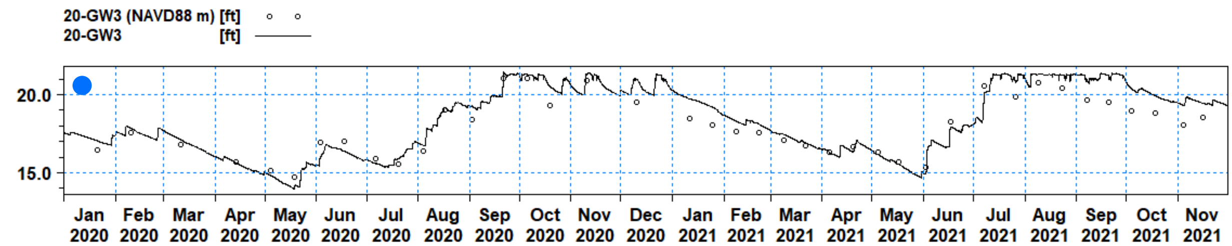


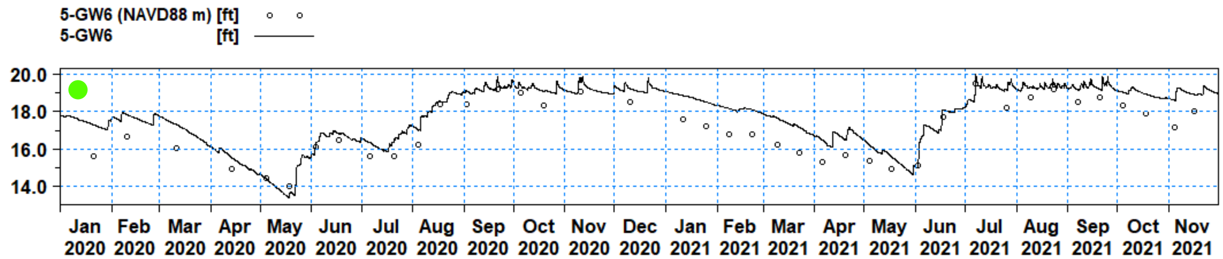


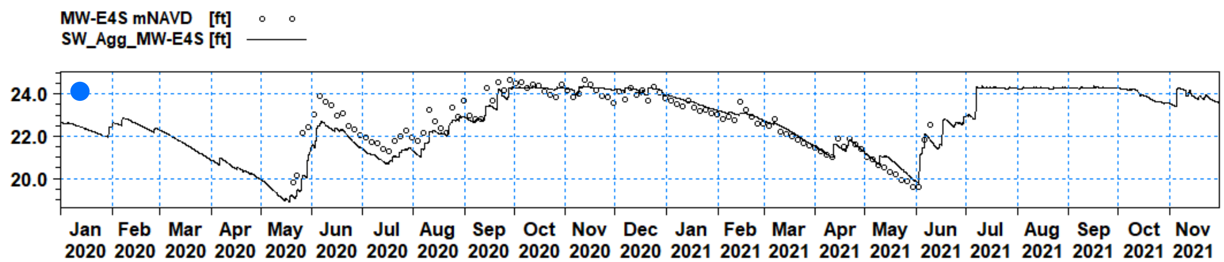


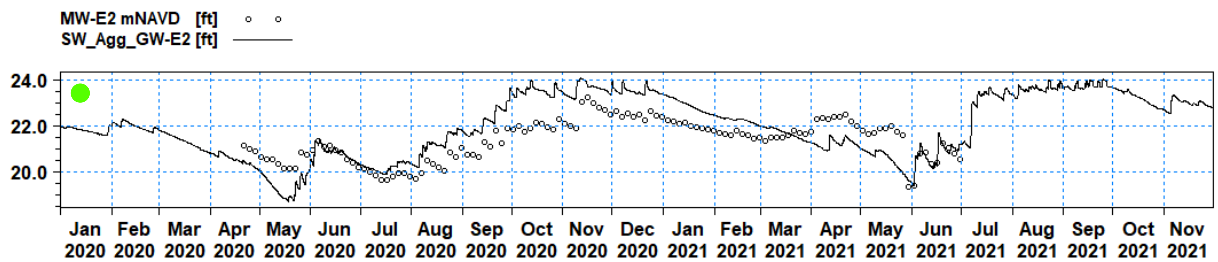


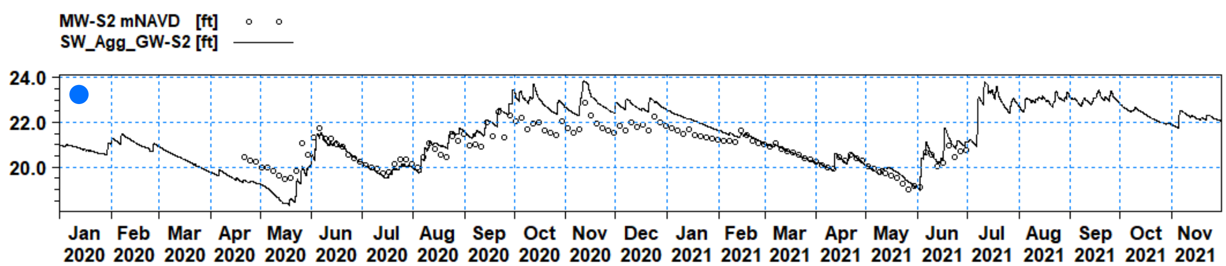


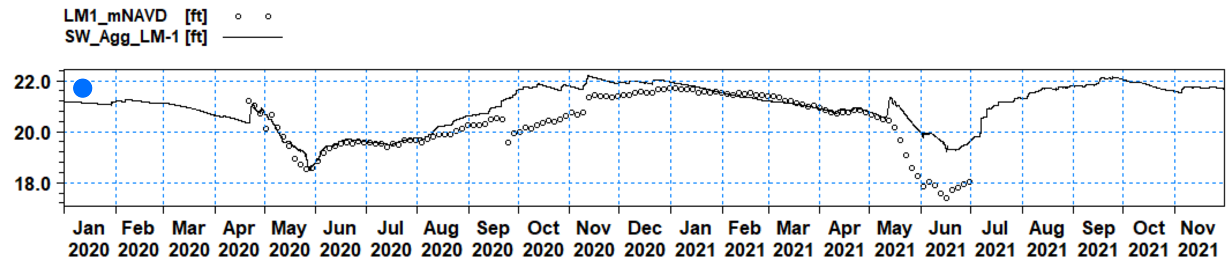

20-GW3 (NAVD88 m) [ft]
20-GW3 [ft]
20.0
15.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021


5-GW6 (NAVD88 m) [ft]
5-GW6 [ft]
20.0
18.0
16.0
14.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

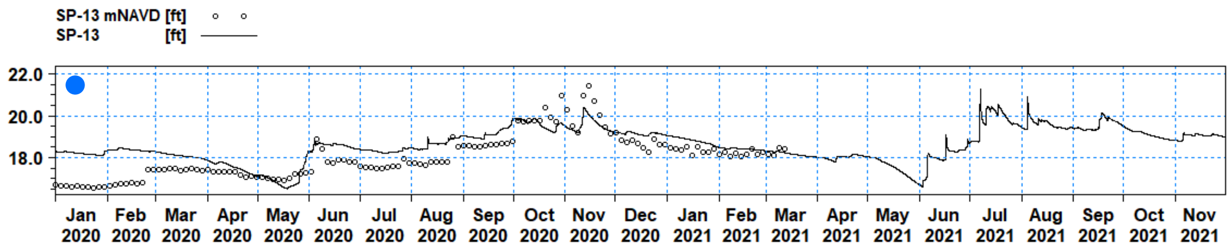

MW-E4S mNAVD [ft]
SW_Agg_MW-E4S [ft]
24.0
22.0
20.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

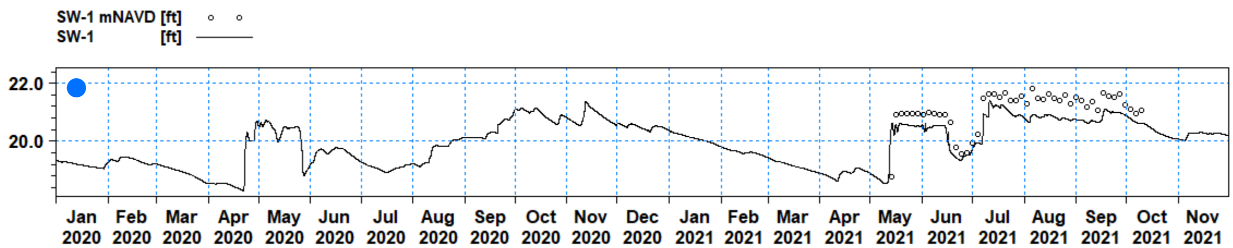

MW-E2 mNAVD [ft]
SW_Agg_GW-E2 [ft]
24.0
22.0
20.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

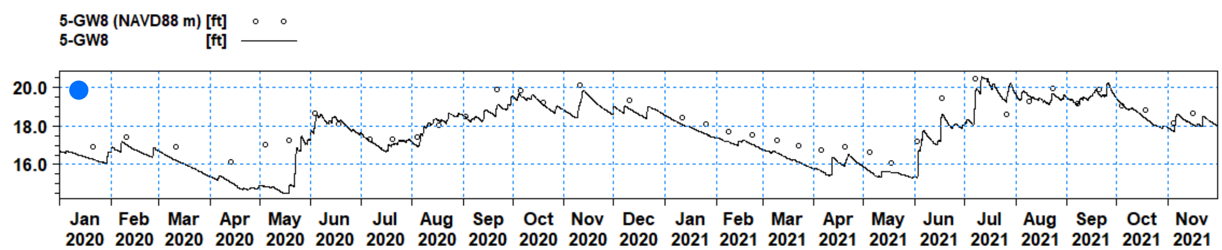

MW-S2 mNAVD [ft]
SW_Agg_GW-S2 [ft]
24.0
22.0
20.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

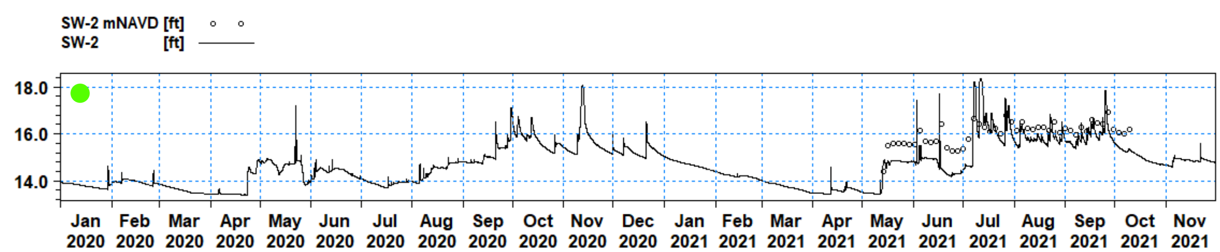


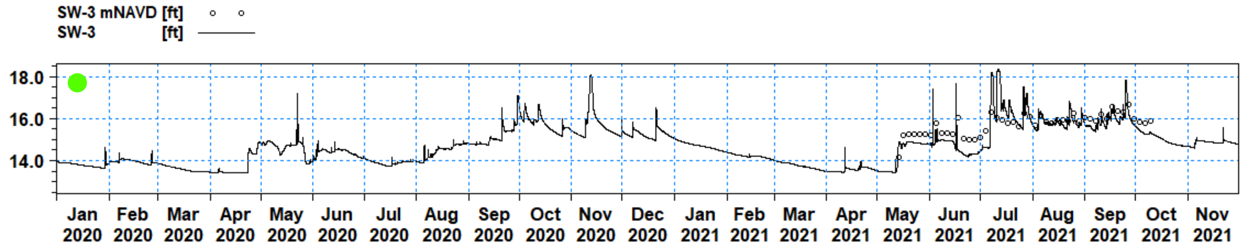
Vicinity of U.S. 41:

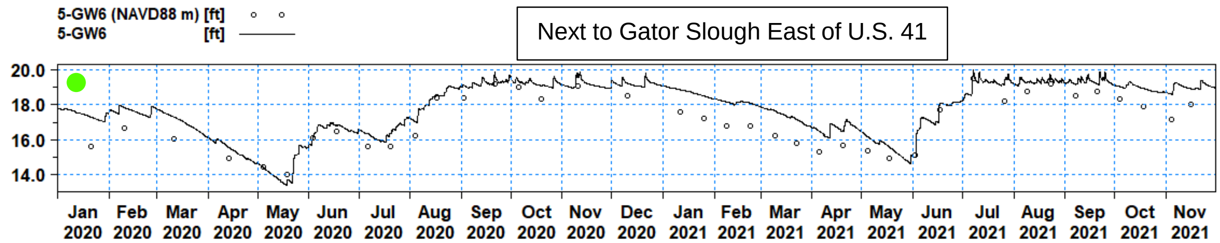


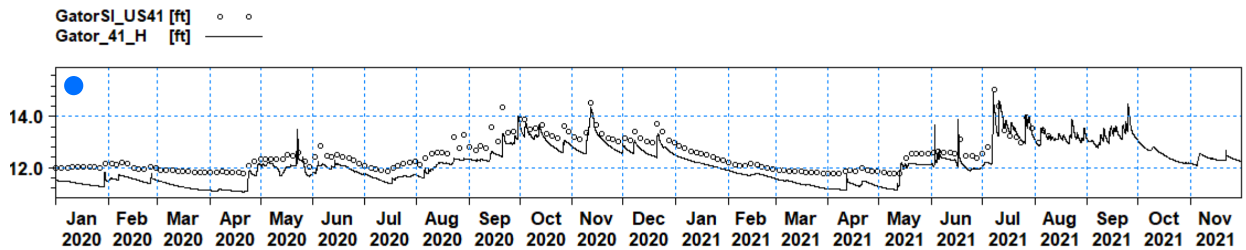


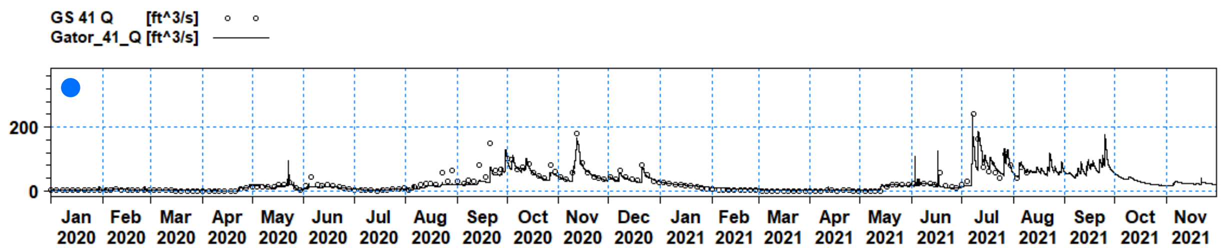


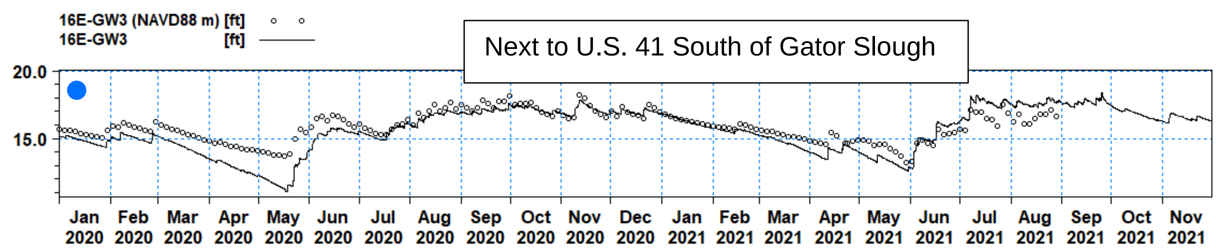


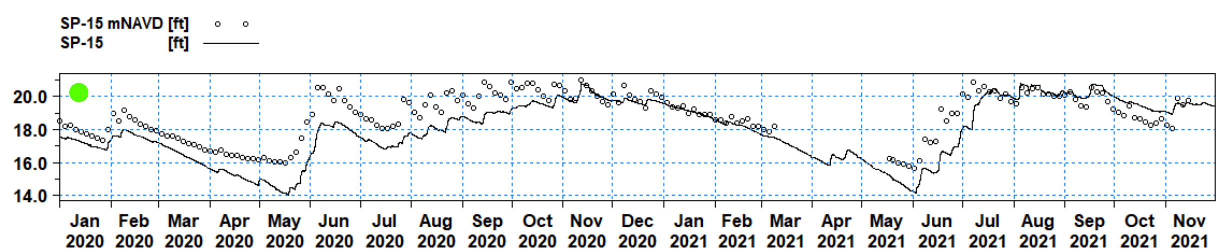

SW-3 mNAVD [ft]
SW-3 [ft]
18.0
16.0
14.0

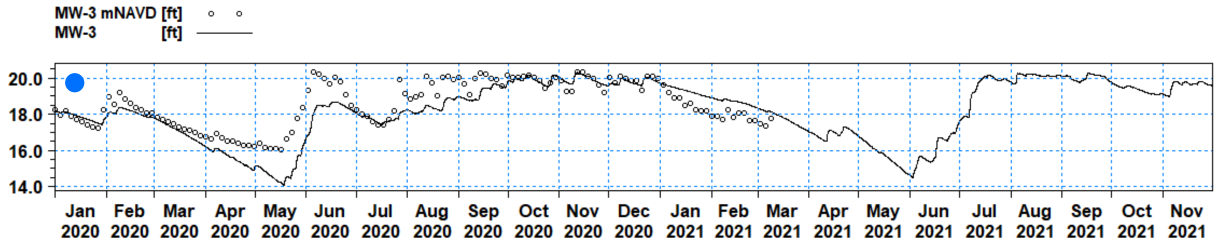

5-GW6 (NAVD88 m) [ft]
5-GW6 [ft]
Next to Gator Slough East of U.S. 41
20.0
18.0
16.0
14.0

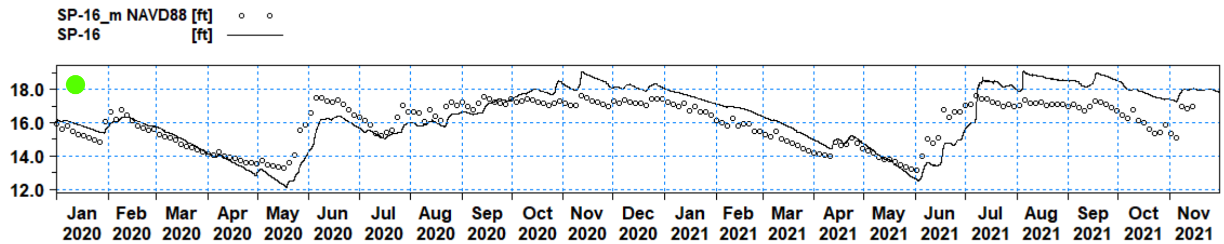

GatorSl_US41 [ft]
Gator_41_H [ft]
14.0
12.0

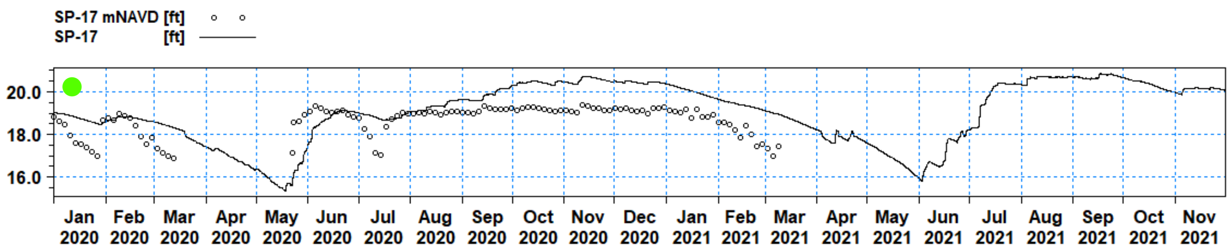

GS 41 Q [ft^3/s]
Gator_41_Q [ft^3/s]
200
0

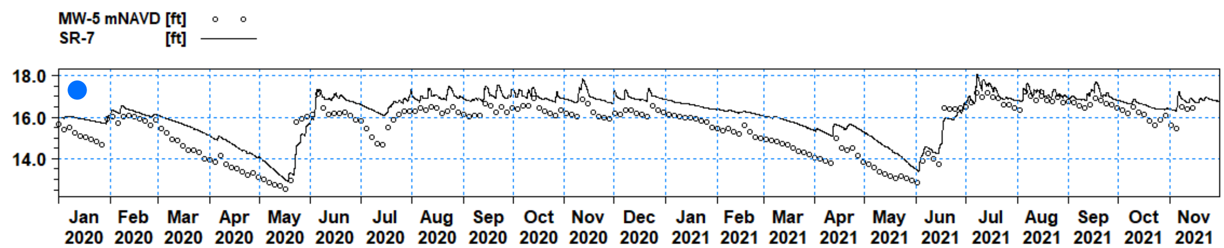

16E-GW3 (NAVD88 m) [ft]
16E-GW3 [ft]
Next to U.S. 41 South of Gator Slough
20.0
15.0

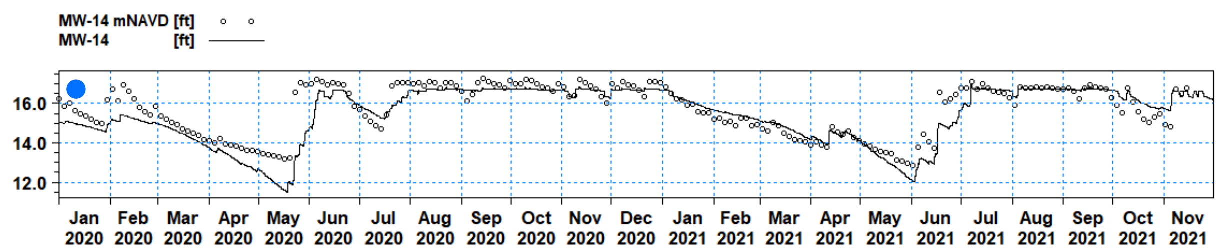

SP-15 mNAVD [ft]
SP-15 [ft]
20.0
18.0
16.0
14.0

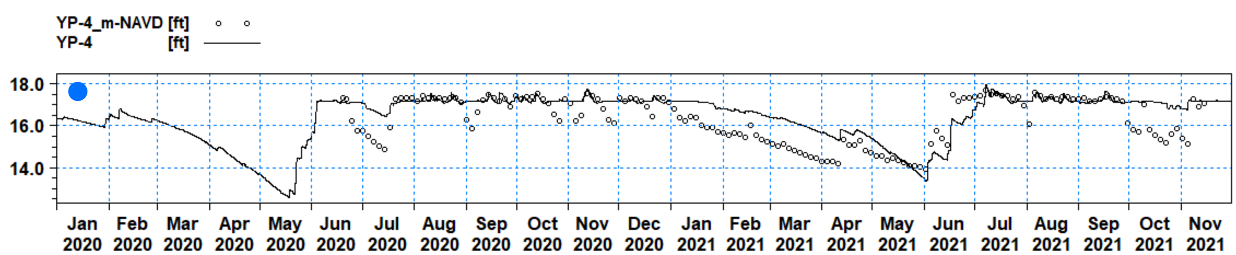

MW-3 mNAVD [ft]
MW-3 [ft]
20.0
18.0
16.0
14.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

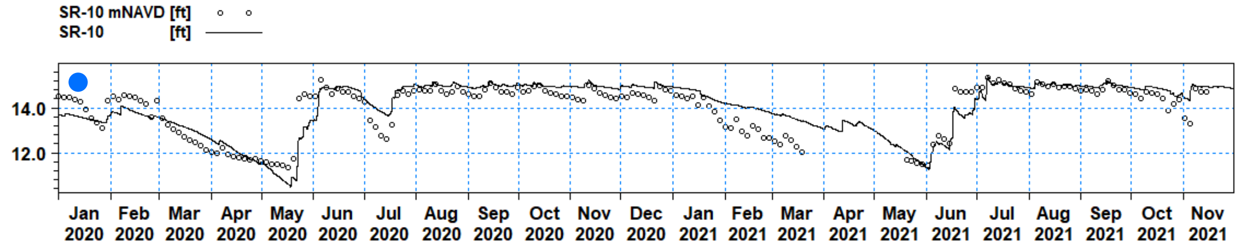

SP-16_m NAVD88 [ft]
SP-16 [ft]
18.0
16.0
14.0
12.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

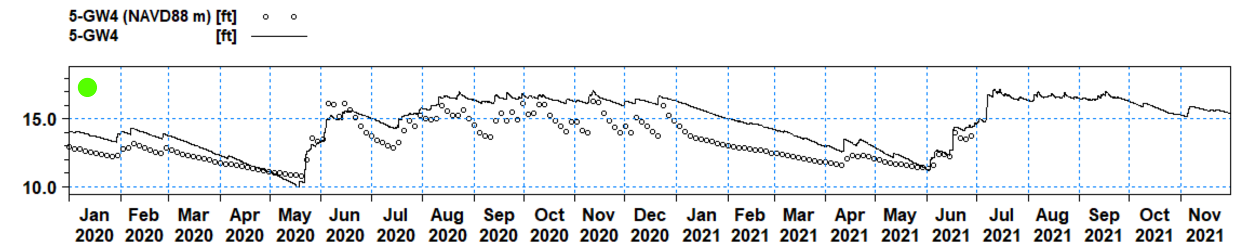

SP-17 mNAVD [ft]
SP-17 [ft]
20.0
18.0
16.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021


MW-5 mNAVD [ft]
SR-7 [ft]
18.0
16.0
14.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

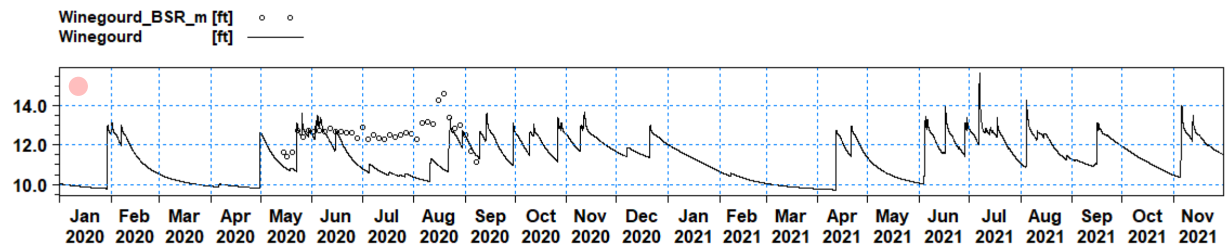

MW-14 mNAVD [ft]
MW-14 [ft]
16.0
14.0
12.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

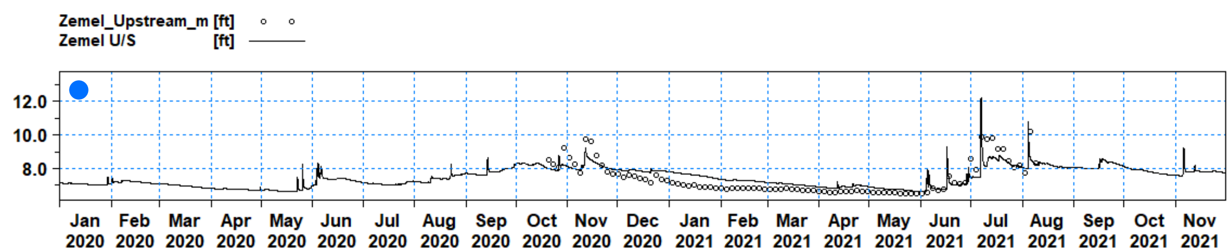

YP-4_m-NAVD [ft]
YP-4 [ft]
18.0
16.0
14.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

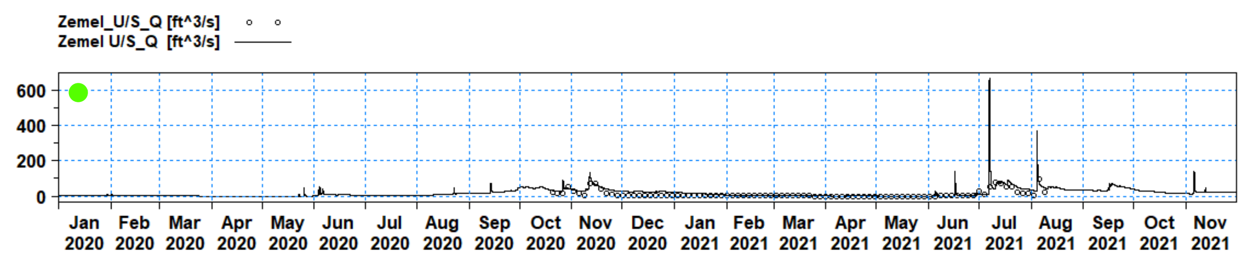


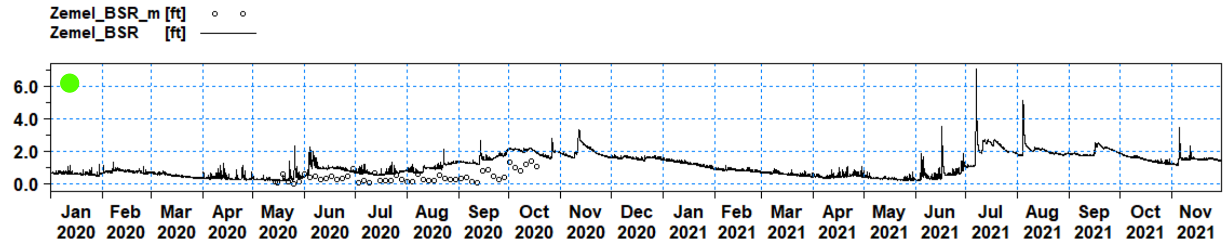


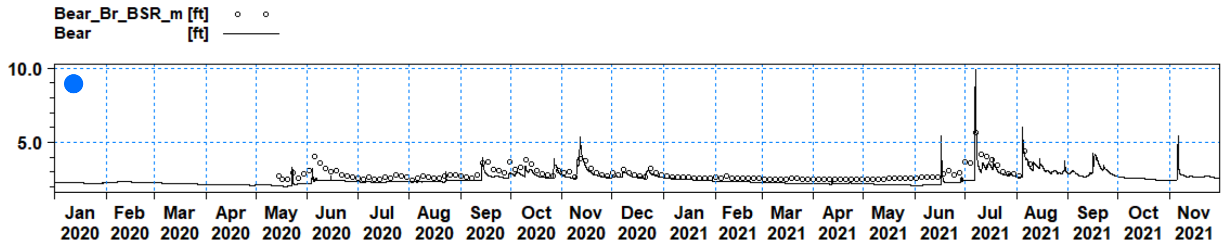
West Yucca Pens and Along Burnt Store Road, North to South

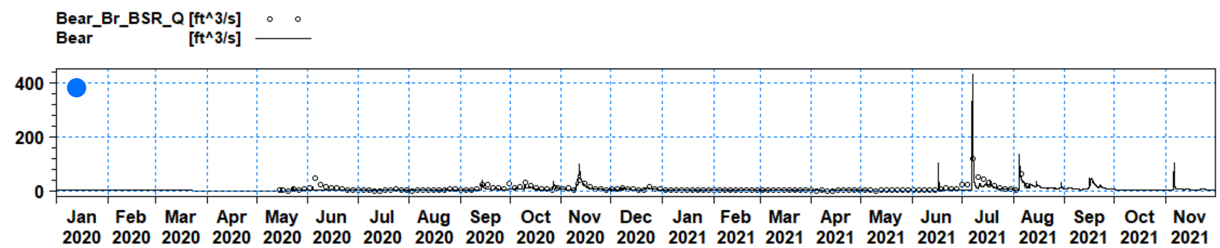


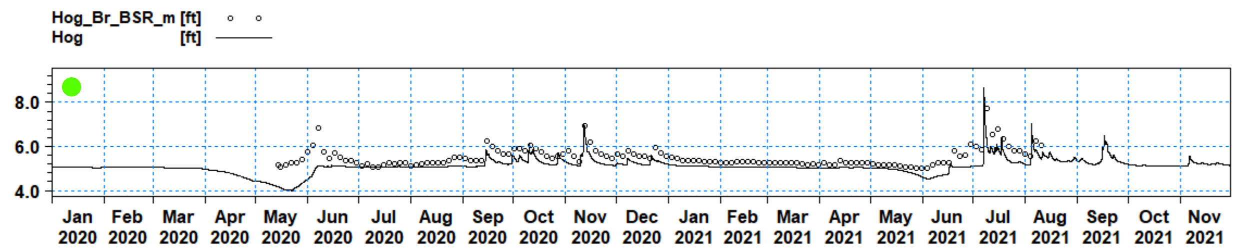


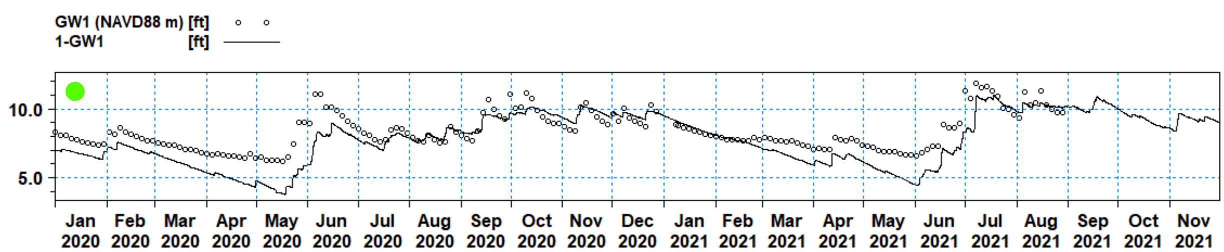


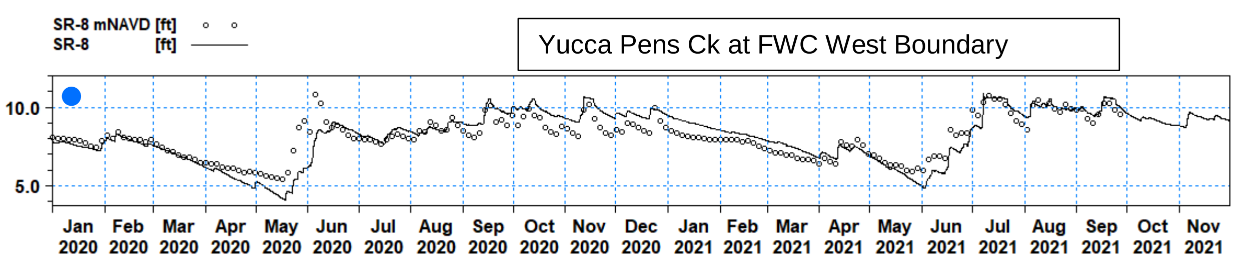

Zemel_BSR_m [ft]
Zemel_BSR [ft]

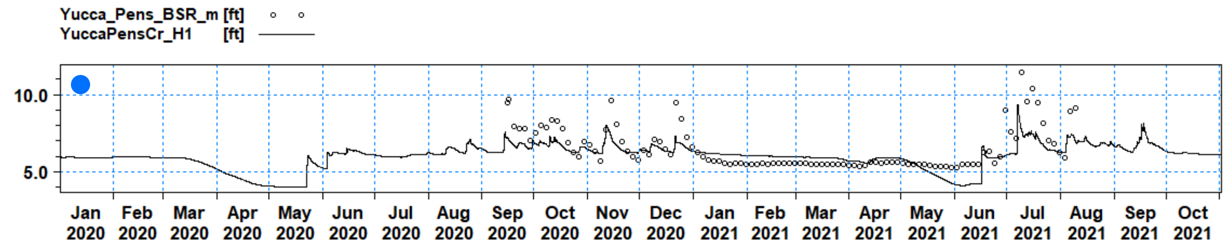

Bear_Br_BSR_m [ft]
Bear [ft]

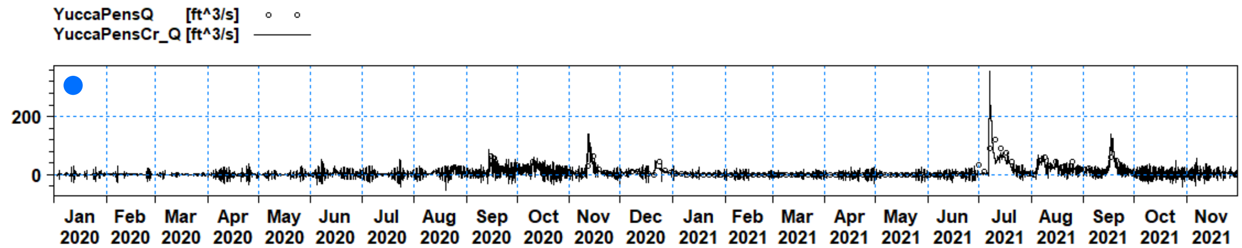

Bear_Br_BSR_Q [ft^3/s]
Bear [ft^3/s]

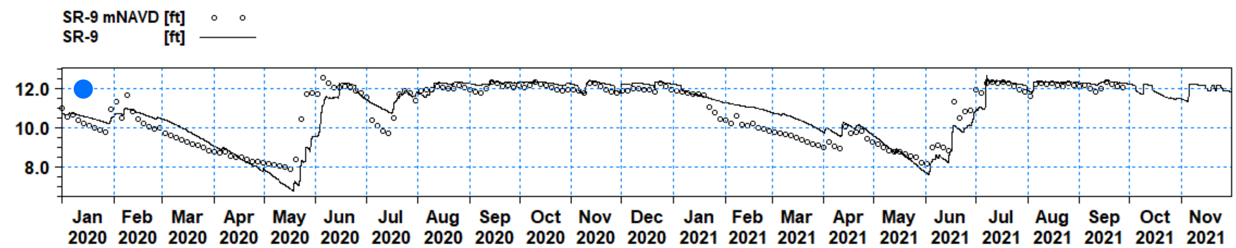

Hog_Br_BSR_m [ft]
Hog [ft]

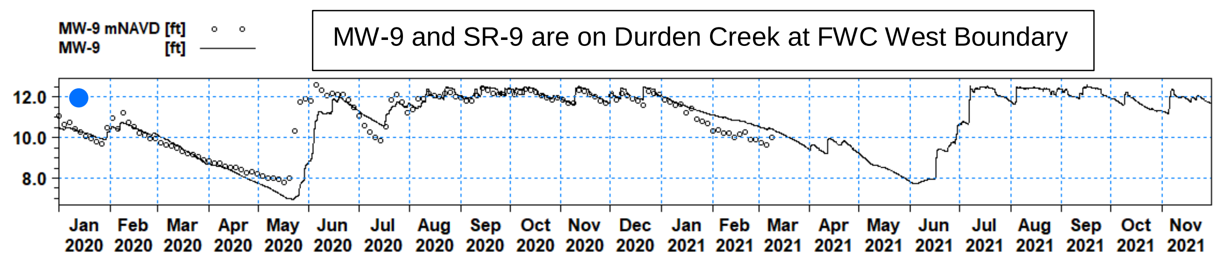

GW1 (NAVD88 m) [ft]
1-GW1 [ft]

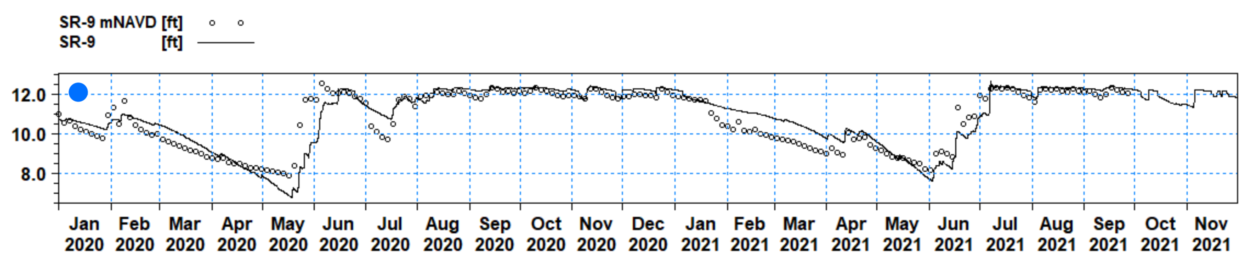

SR-8 mNAVD [ft]
SR-8 [ft]
Yucca Pens Ck at FWC West Boundary

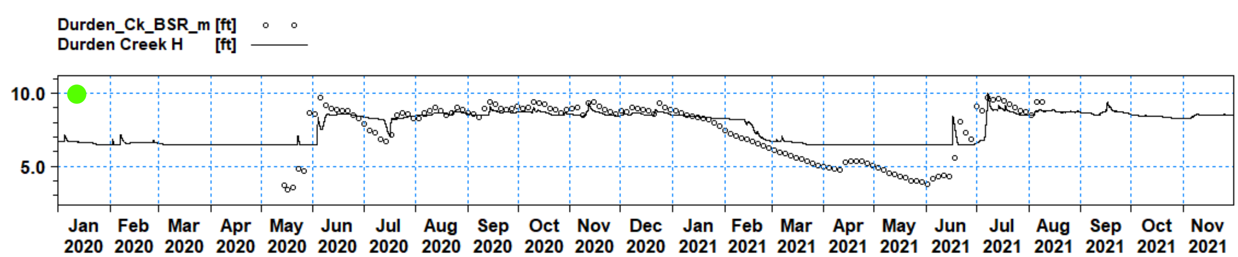

Yucca_Pens_BSR_m [ft]
YuccaPensCr_H1 [ft]
10.0
5.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021

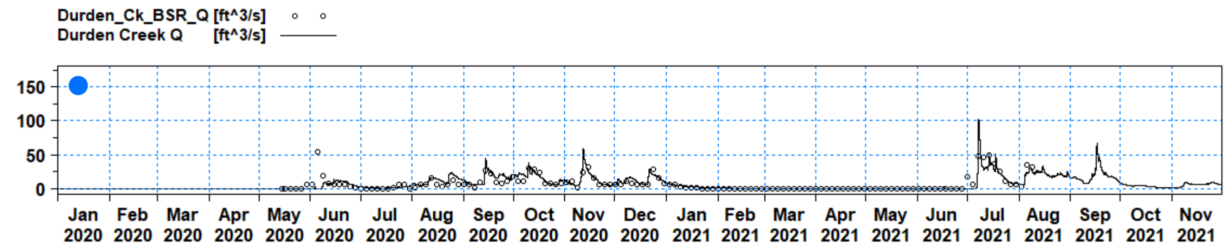

YuccaPensQ [ft^3/s]
YuccaPensCr_Q [ft^3/s]
200
0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

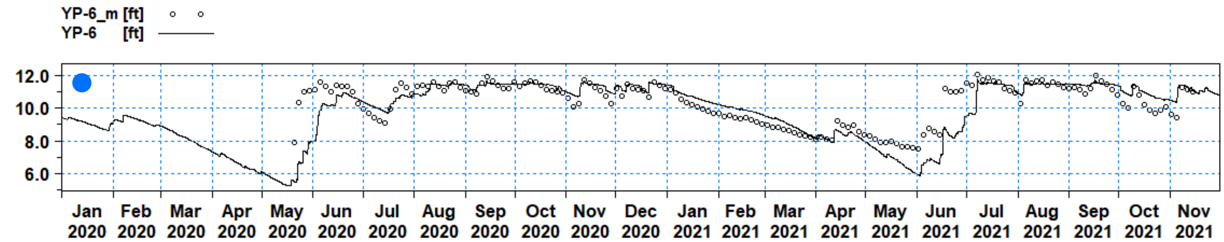

SR-9 mNAVD [ft]
SR-9 [ft]
12.0
10.0
8.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

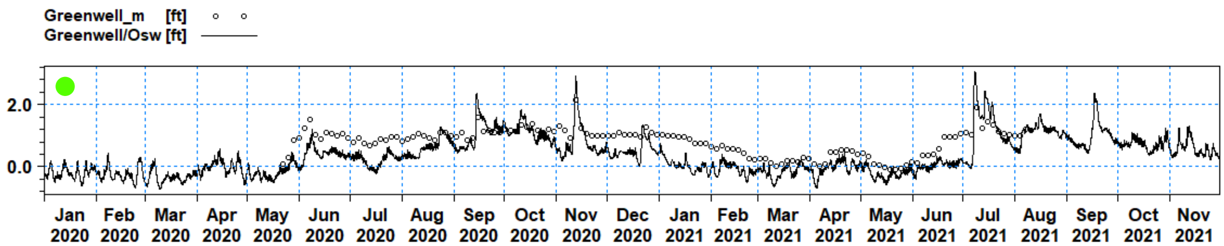

MW-9 mNAVD [ft]
MW-9 [ft]
MW-9 and SR-9 are on Durden Creek at FWC West Boundary
12.0
10.0
8.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

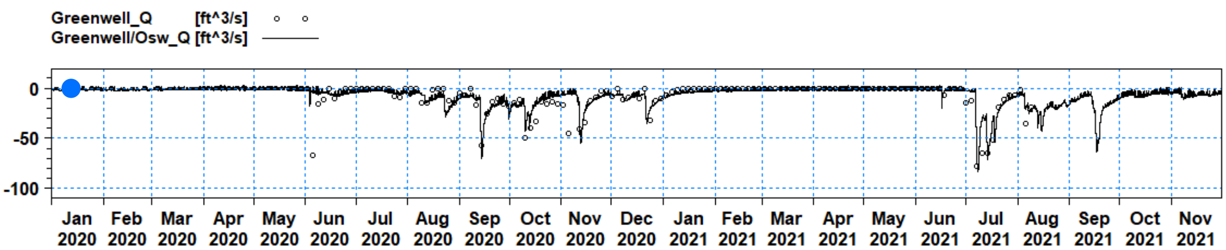

SR-9 mNAVD [ft]
SR-9 [ft]
12.0
10.0
8.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021


Durden_Ck_BSR_m [ft]
Durden Creek H [ft]
10.0
5.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

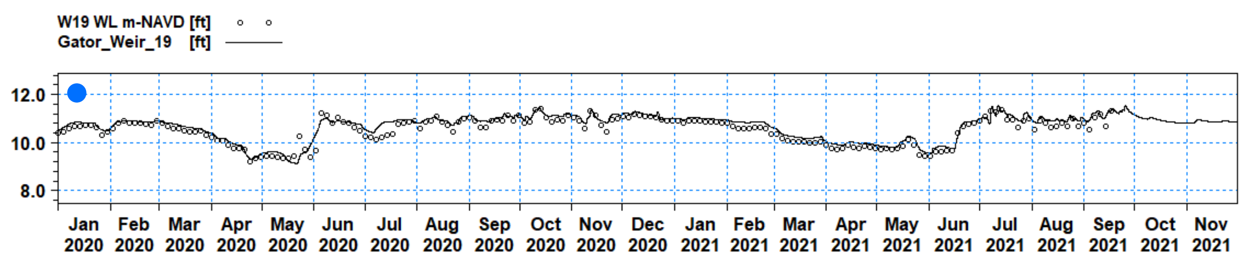




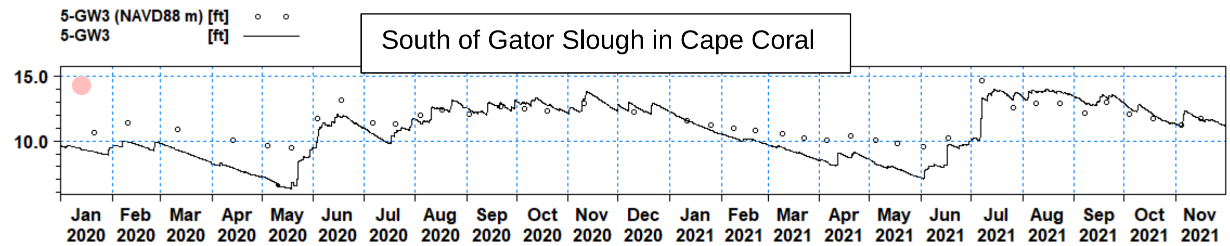


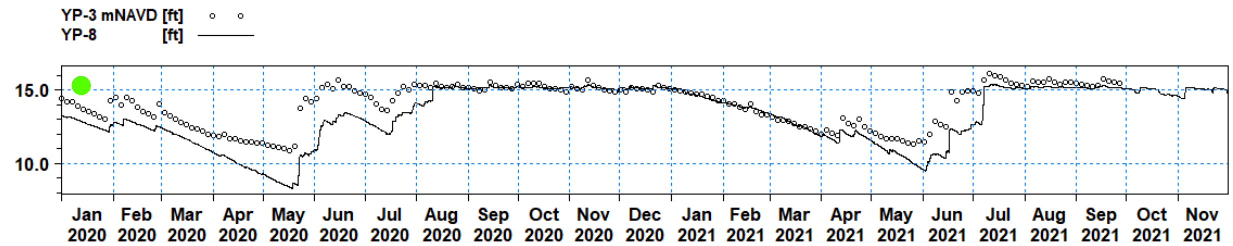


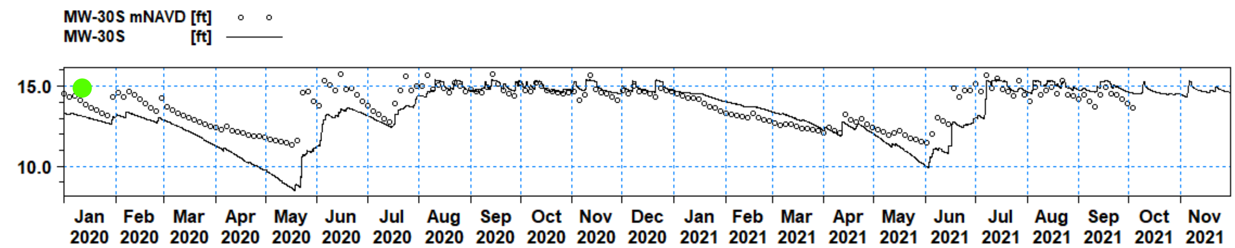
South Yucca Pens/Gator Slough

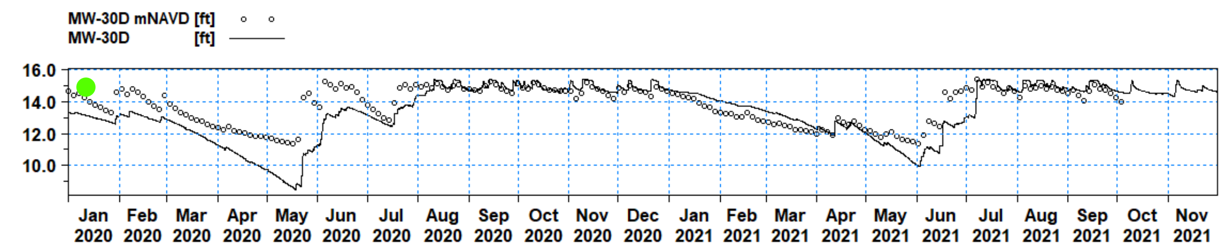


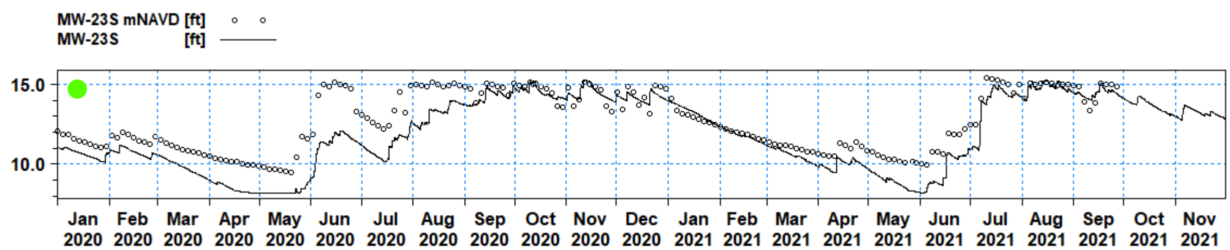
South of Gator Slough in Cape Coral

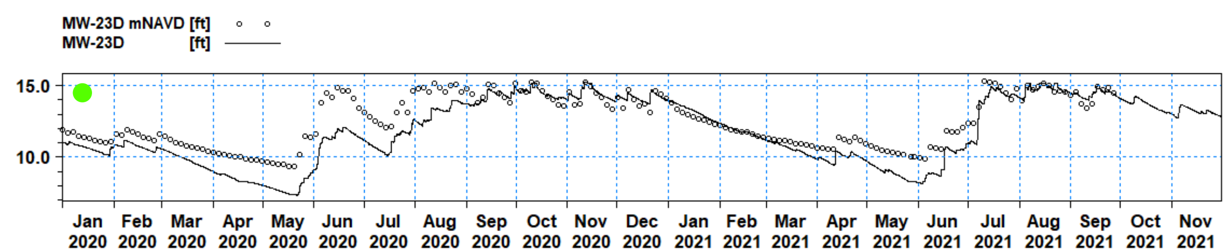


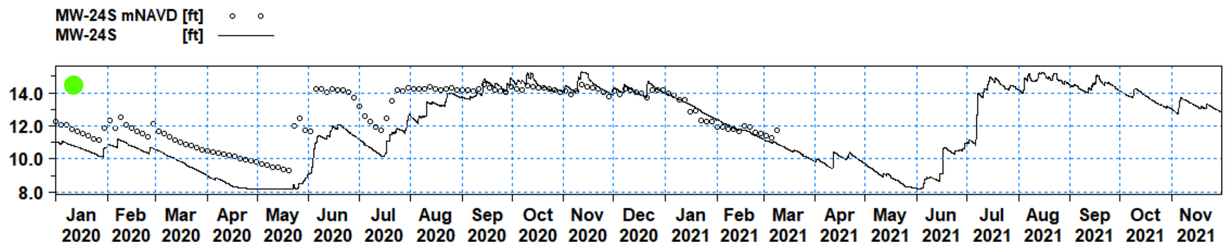


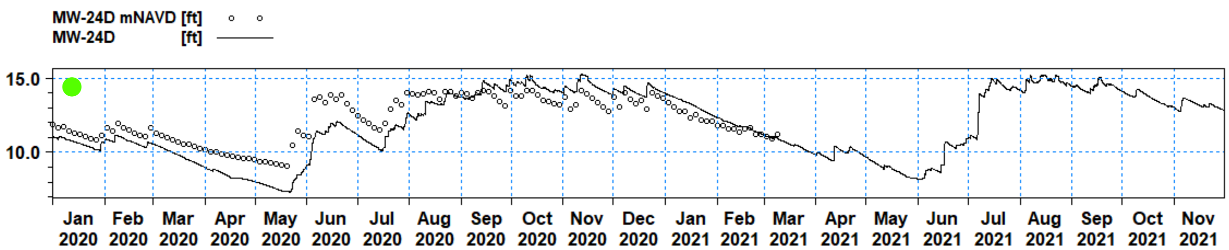


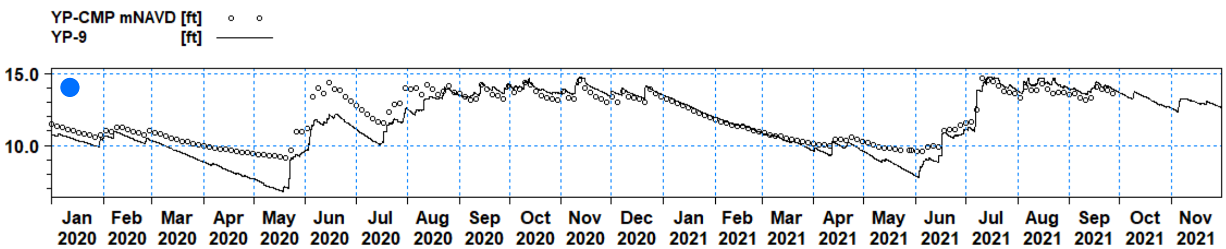


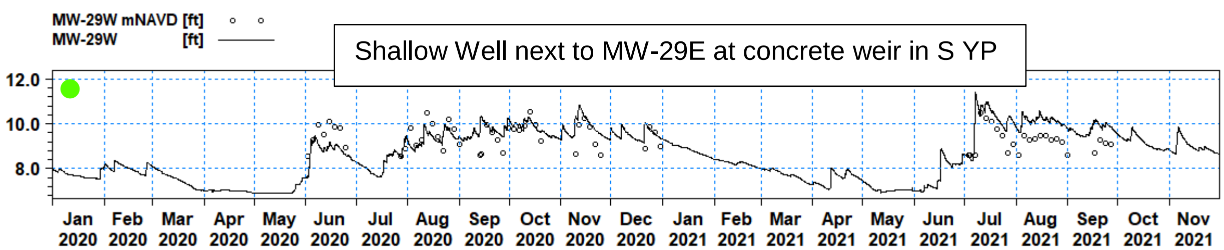


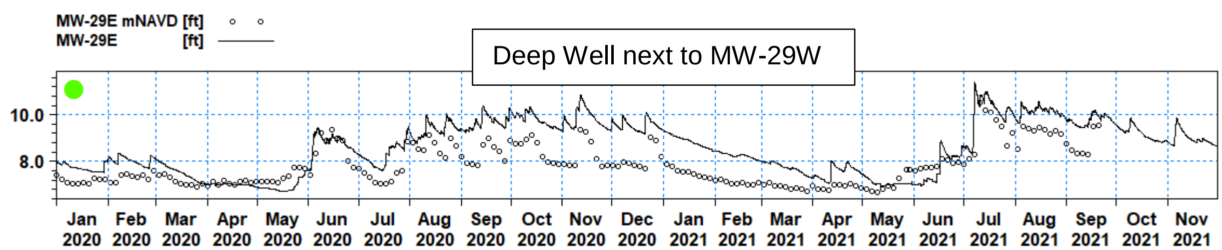


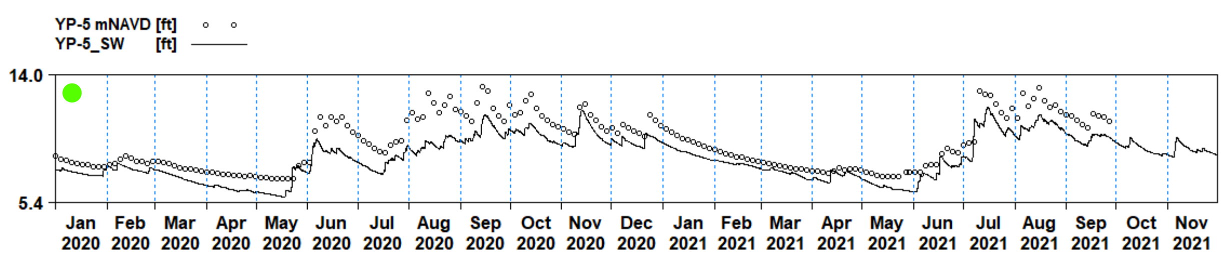

MW-24S mNAVD [ft]
MW-24S [ft]
14.0
12.0
10.0
8.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

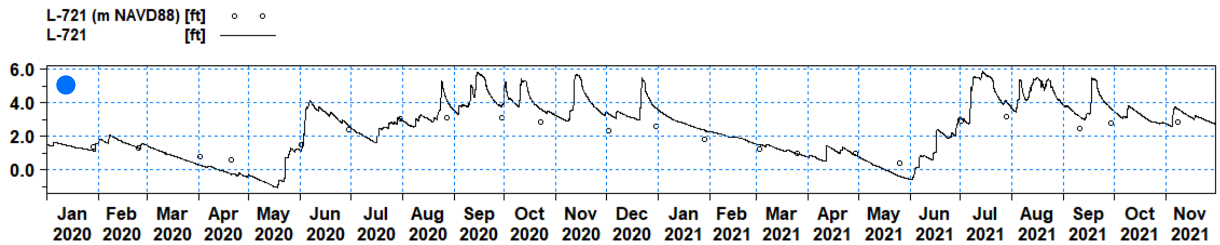

MW-24D mNAVD [ft]
MW-24D [ft]
15.0
10.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

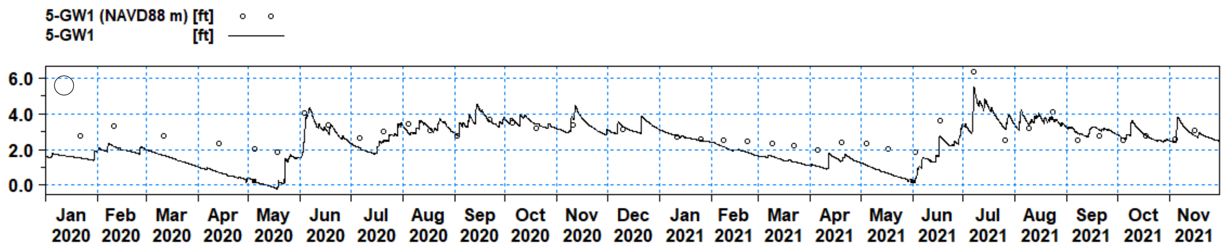

YP-CMP mNAVD [ft]
YP-9 [ft]
15.0
10.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

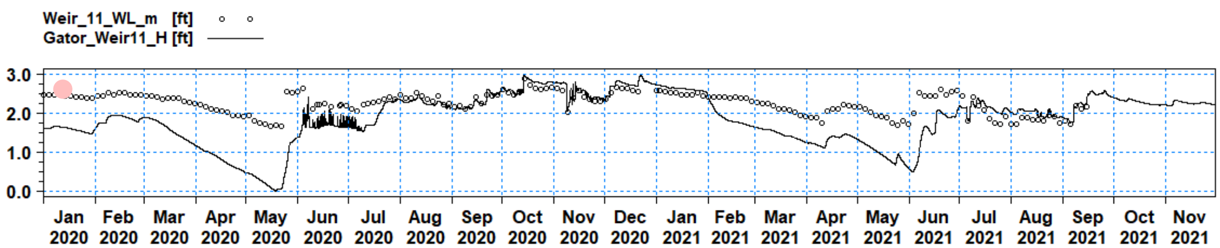

MW-29W mNAVD [ft]
MW-29W [ft]
Shallow Well next to MW-29E at concrete weir in S YP
12.0
10.0
8.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021


MW-29E mNAVD [ft]
MW-29E [ft]
Deep Well next to MW-29W
10.0
8.0
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

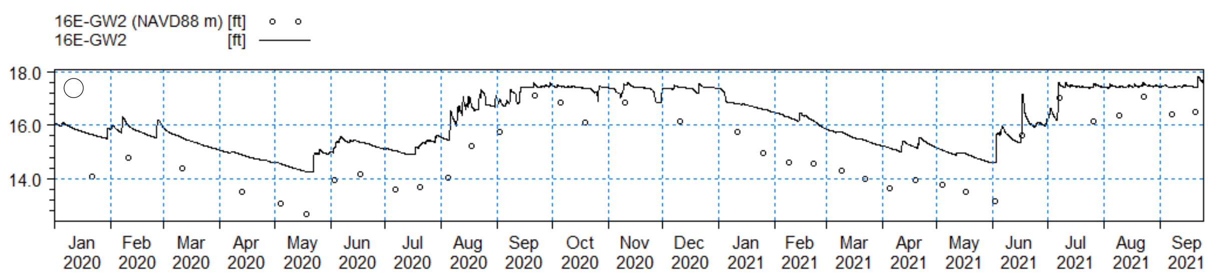

YP-5 mNAVD [ft]
YP-5_SW [ft]
14.0
5.4
Jan 2020 Feb 2020 Mar 2020 Apr 2020 May 2020 Jun 2020 Jul 2020 Aug 2020 Sep 2020 Oct 2020 Nov 2020 Dec 2020 Jan 2021 Feb 2021 Mar 2021 Apr 2021 May 2021 Jun 2021 Jul 2021 Aug 2021 Sep 2021 Oct 2021 Nov 2021

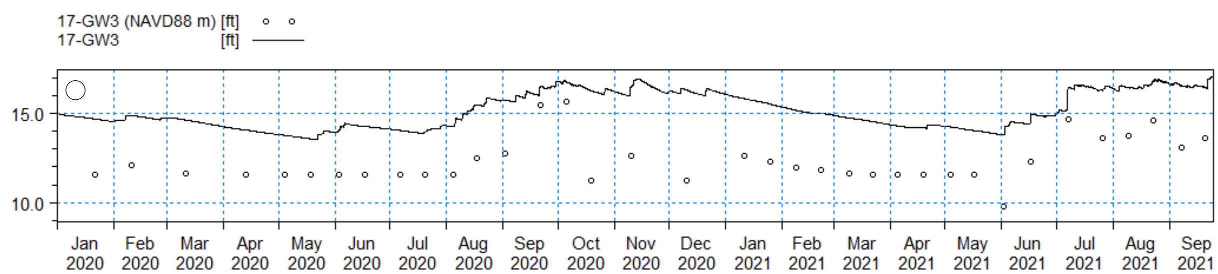


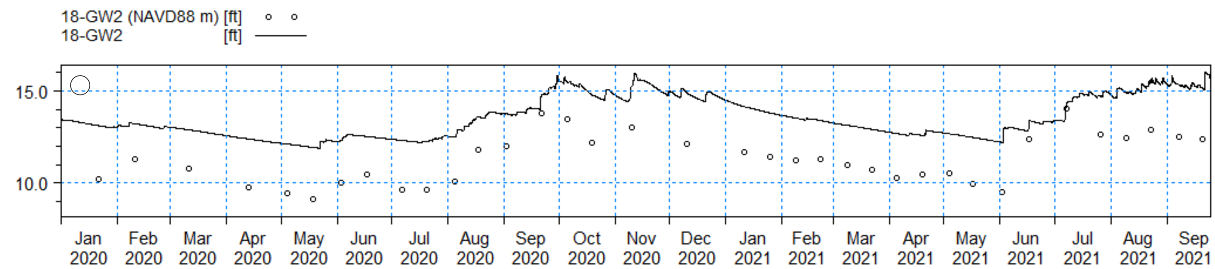




North Fort Myers, West of I-75, East of U.S. 41:







Sandstone Well, Punta Gorda