COASTAL & HEARTLAND NATIONAL ESTUARY PARTNERSHIP
Lower Charlotte Harbor Flatwoods Strategic Hydrologic Restoration Plan

PREPARED FOR:

Coastal & Heartland National Estuary Partnership

1050 Loveland Boulevard
Port Charlotte, Florida 33980

PREPARED BY:

Water Science Associates

Coastal & Heartland National Estuary Partnership

IN CONJUNCTION WITH:

South Florida Water Management District · Protecting the Everglades Since 1949

Florida Fish and Wildlife Conservation Commission

Southwest Florida Water Management District

SEPTEMBER 2022

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ACRONYM LIST

Acronym	Definition
AOI	Area of Interest
ATV	All-Terrain Vehicle
bgs	Below ground surface
BSR	Burnt Store Road
BW	Babcock Webb
CCI	Charlotte Correctional Institute
CHFI	Charlotte Harbor Flatwoods Initiative
CHNEP	Coastal & Heartland National Estuary Partnership
CMP	Corrugated Metal Pipe
DEM	Digital Elevation Model
ET	Evapotranspiration
FDOT	Florida Department of Transportation
FWC	Florida Fish and Wildlife Conservation Commission
HEI	Hydrologic Enhancement Impoundment
LiDAR	Light Detection and Ranging
MAE	Mean absolute error
NAVD	North American Vertical Datum
NEXRAD	Next Generation Weather Radar
NFA	Non-Focus Area
NRCS	Natural Resources Conservation Service
NS	Nash-Sutcliffe
SFWMD	South Florida Water Management District
SGR	Seminole Gulf Railroad
SWIA	South Walk-In Area
SWFWMD	Southwest Florida Water Management District
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
UZ	Unsaturated zone
WMA	Wildlife Management Area
WSA	Water Science Associates

EXECUTIVE SUMMARY

The Charlotte Harbor Flatwoods project area encompasses over 90 square miles of land in the Charlotte Harbor, Gator Slough, and Caloosahatchee River watersheds, and includes the Fred C. Babcock/Cecil M. Webb Wildlife Management Area (Babcock Webb WMA), Yucca Pens Unit WMA (Yucca Pens), and numerous creeks that flow into eastern Charlotte Harbor and the Caloosahatchee River in southwest Florida's Lee and Charlotte Counties. The Florida Fish and Wildlife Conservation Commission (FWC) manages the Babcock Webb and the Yucca Pens WMAs. These riverine and tidal creek systems are essential fish habitat for fish and shellfish such as red drum, gray snapper, and pink shrimp. They also provide habitat for common snook, striped mullet, and blue crab, species which contribute to important recreational and commercial fisheries. The area's coastal creeks and freshwater wetlands also provide critical habitat to endangered Florida bonneted bat and threatened Florida manatee. Over the past 100 years, these wetland ecosystems have been heavily impacted by man-made changes in hydrology. The conversion of native wetland habitats to agriculture or development, surface mining, and construction of major roadways such as US-41 and I-75, have significantly altered the historic sheet flow from Babcock Webb to Yucca Pens. As a result, the vast wetland ecosystems within the Charlotte Harbor Flatwoods are susceptible to over-drainage, flooding, habitat changes, water quality degradation, and climate change stressors. In some instances, the rivers and creeks in this area experience too much flow during the wet season and too little flow during the dry season to support associated wetlands and downstream waterbodies. A project location map is on page 2 of the report (**Figure ES-1**).

As a result of the hydrological degradation and alteration to the area, the Charlotte Harbor Flatwoods Initiative (CHFI) was formed to initiate efforts to restore natural drainage across the project area with water that has been unnaturally impounded on the Babcock Webb WMA and diverted from the Yucca Pens, Caloosahatchee River, and tidal creeks to Charlotte Harbor. The CHFI is comprised of multiple local, state and federal agencies, the Coastal & Heartland National Estuary Partnership (CHNEP), and other stakeholders seeking synergies among agencies and landowners across multiple boundaries to restore hydrologic connections, improve water quality, enhance fish and wildlife habitat, restore groundwater recharge, enhance community resilience, and restore and revitalize the local economy.

In response to the 2010 Deepwater Horizon oil spill in the Gulf of Mexico, the Florida Department of Environmental Protection (FDEP) Florida Trustee Implementation Group (FL TIG) conducted a Natural Resource Damage Assessment (NRDA) to assess and determine restoration needs for damages to the Gulf of Mexico at both a local and regional scale. In March 2019, the FL TIG published their Final Restoration Plan and began dispersing funds from the Deepwater Horizon Oil Spill Coastal Protection Trust Fund for restoration projects. SFWMD was notified that the CHFI application for the Lower Charlotte Harbor Flatwoods Hydrologic Restoration Planning project was selected as one of only twenty-three projects in Florida approved for NRDA funding. The project was implemented by the FDEP FL TIG Trustee in coordination with the SFWMD who coordinates the CHFI and the CHNEP who administered the 2-year project contract. A project kick-off meeting was held March 30, 2020.

The goal of this planning project was to review existing data and identifying gaps; enhance existing data with additional monitoring devise installation, data collection and analysis; ecological field verification of data; synthesis of data using a data-driven integrated surface/groundwater hydrological model to determine the appropriate hydropattern, timing, and quantity of water flows required to improve hydrologic conditions and habitat; and document the results, derive conclusions and make recommendations in the Lower Charlotte Harbor Flatwoods Strategic Restoration Planning Tool and Report to provide guidance to resource management agencies related to the appropriate restoration and management of surface waters currently flowing through this area. This data collection, planning, and modeling effort was completed in July 2022 with this final report being produced in September 2022., This report and model serve as a planning 'tool' that will help guide the success of future regional restoration projects.

The initial step of data collection provided an extensive dataset for 40 monitoring stations in and around the Babcock Webb and the Yucca Pens WMAs. Combined with on-going FWC data collection efforts at 23 other stations, this project has established a comprehensive water level and flow monitoring database that was used for model development and calibration.

Field ecologic studies were conducted during the dry and wet seasons at 58 locations to identify and survey vegetation indicators of average wet season water elevation. This informed the identification of pre-development hydrologic conditions (natural conditions) and wetland extent in Babcock Webb and Yucca Pens. Pre-development hydrology was compared with recently collected groundwater and surface water elevation data to identify areas of altered hydrology or ecology. An updated integrated surface/ground water model was developed utilizing recent field data. Model calibration across the model domain is good with many stations substantially exceeding the targeted statistical thresholds for good calibration. Overall mean absolute error (MAE) for surface water and groundwater elevation 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 exceeded the 'good' threshold in key areas of interest for measuring drainage and implementing restoration. Based on the statistical analysis of the model calibration, it was determined that the model was appropriate for scenario analysis.

The final calibrated model was utilized to analyze three future conditions scenarios and compare to modeling of existing hydrology. Scenario 1 assumed that the 669-acre permitted Bond Farm Hydrological Enhancement Impoundment (Bond Farm HEI) project will be constructed on the southwest corner of the Babcock Webb WMA and will store a maximum of 2,400 acre-feet of excess waters from the Babcock Webb South Walk-In Area (SWIA) for discharge to the south towards Prairie Pines Preserve (PPP) during the dry season. Scenario 1 also assumed a combination of 26 new weirs in Yucca Pens to retain more water on Yucca Pens, reduce wet season discharges, and increase base flow discharges to tide. Please note, in this analysis, a weir may be a constructed weir or low-water ford such as shown in **Figure 3-17** of the report, or any structure utilized to raise the water level upstream or regulate its flow. A partial seepage barrier was also assumed along the south end of Yucca Pens adjacent to Gator Slough to retain more water on the Yucca Pens. The implementation of Scenario 1 provides hydrologic restoration by retaining more water on the Yucca Pens, reducing wet season discharges, and increasing base flow discharges to tide and can be implemented on lands currently under the FWC ownership and therefore can be implemented quickly. Modeling, design, permitting and construction of Scenario 1 should be considered for immediate implementation.

Scenario 2 was a refinement of Scenario 1 with additional storage of excess flows (approximately 7,100 acre-feet) from the Babcock Webb SWIA via the permitted but unconstructed Bond Farm HEI in the privately owned Southwest Aggregates mining property. The Scenario 1 Yucca Pens improvements were included in Scenario 2 with the location of one of the 26 weirs moved upstream to minimize impacts of higher water levels on private lands adjacent to the Yucca Pens. Scenario 2 is recommended for further refinement for restoration planning and design, which includes land acquisition, easements and/or agreements with several private landowners and the funding and construction of Bond Farm HEI. Scenario 2 would provide additional hydrologic restoration benefits in addition to the benefits provided by Scenario 1. Those benefits include:

- Improved restoration of hydroperiods and water depths in the SWIA of the Babcock Webb WMA due to greater storage capacity for wet season runoff from the SWIA in the Bond Farm HEI (up to 2,400 acre-ft) and the Southwest Aggregates mining property (approximately 4,700 acre-ft).
- Greater restoration of wetland hydroperiod and water depths in the Yucca Pens due to the late wet/early dry season flows of the 2,400 acre-feet of water stored on Bond Farm HEI. In turn, this would result in much needed increased late wet/early dry season discharges from the Yucca Pens to tidal creeks to Charlotte Harbor, which are primary nursery areas providing food and habitat to numerous species of fish and shellfish.

Scenario 3 included all features of Scenario 2 and assumed climate change impacts, consisting of higher tidal water level boundaries and higher ET rates.

Based on the data collection and analysis and the modeling conducted during this planning project several proposed projects and additional activities were recommended that would advance the work of the CHFI.

Recommended future data collection efforts include installation of additional monitoring stations, additional data collection, data analysis and formatting. Recommended future modeling activities include continued model calibration, updates and verification, continued refinement of scenarios, continued updates to climate data in scenarios, additional future conditions scenarios modeling, additional modeling to inform policy and operational protocol recommendations, and ongoing hydrological modeling tool updates.

Hydrological restoration projects modeled in the current project are recommended for implementation, including ATV ditch blocks, low-water fords or constructed weirs, partial groundwater seepage barrier, flow-way from Bond Farm HEI to Yucca Pens, box culvert under US-41, gated culverts on west side of Bond Farm HEI, acquisition of Southwest Aggregates Reservoir, gate on east side of Southwest Aggregates south ditch, gated weirs in US-41 ditches, and construction of Bond Farm HEI.

Finally, policy and operational protocol recommendations include the repair of riser structures in Babcock Webb WMA, modification of elevations at existing water control structures, Bond Farm HEI and Southwest Aggregates Pump Operations, and securing the flow-way from Bond Farm HEI to Yucca Pens.

A detailed narrative of these recommendations is provided in **Section 7** of the full report.

INTRODUCTION

Water Science Associates (WSA) was contracted by the Coastal & Heartland National Estuary Partnership (CHNEP) to develop a hydrologic restoration plan for the Lower Charlotte Harbor Flatwoods to enhance sheet flow and restore wetland hydroperiods in Babcock Webb and Yucca Pens WMAs and improve the timing and magnitude of flows to tidal creeks west of Yucca Pens WMA. Hydroperiod is defined as the number of days per year that water depths are more than 0.1 feet above ground surface. Hydroperiod units used in this memorandum are months, which is days/year divided by 30.

PROJECT LOCATION

The study area is in the Charlotte Harbor and Caloosahatchee watersheds with a primary focus on Babcock Webb, Yucca Pens, and the tidal creeks to Charlotte Harbor in Charlotte and Lee Counties, FL. Figure ES-1 provides a location map of the study area.

The 65,879-acre Fred C. Babcock/Cecil M. Webb WMA (Babcock Webb) contains the headwaters of several creeks that historically drained west-southwest, through the Charlotte Harbor Flatwoods, towards Matlacha Pass, via the 20,000-acre Yucca Pens. Surface water flow pathways from Babcock Webb to Yucca Pens have been altered by development of farms, mining, highways, and residential lands on either side of I-75. Many of these developments include perimeter berms that limit discharges from Babcock Webb, blocking the historic flow pathways to Yucca Pens. As a result of these flow restrictions, the southwestern portion of Babcock Webb - locally referred to as the South Walk-In Area (SWIA) - is inundated through much of the dry season reflecting a longer hydroperiod compared to the pre-development regime. Historical aerial photographs from 1980 show I-75 from Tucker's Grade down to the Caloosahatchee River, Bond Farm, excavation on the SLD Construction and Demolition (C&D) Landfill southwest of US-41 and Zemel Road, and agricultural development between I-75 and US-41. Near-continuous inundation of the SWIA shown in **Figures ES-2** and **ES-3** limits the capacity of the habitat to support a diverse wildlife community; in particular, nesting suitability is less than desired for Northern Bobwhite Quail *(Colinus virginianus),* an important game bird in Babcock Webb. Conversely, the Yucca Pens west of I-75 exhibits reduced wetland wet season water depths and hydroperiods due to blocked flow-ways from Babcock Webb (see **Figure ES-4**). Reduced water supply is compounded by accelerated outflows via eroded all-terrain vehicle (ATV) trails (see **Figure ES-5**). This modeling project is intended to confirm these observed hydrologic impacts in Babcock Webb and Yucca Pens WMAs as well as identify and quantify the benefit of restoration and interventions to alleviate these detrimental impacts.

PROJECT BACKGROUND

The Charlotte Harbor Flatwoods Initiative (CHFI) comprises multiple local, state and federal agencies, the CHNEP, and other stakeholders. The CHFI 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 and diverted from the Yucca Pens, Caloosahatchee, and tidal creeks of Charlotte Harbor.

The objectives of the CHFI include improvements to area sheet flow, restoration of natural flows to Charlotte Harbor and the Caloosahatchee River to the extent practicable, and improvements to area water quality, groundwater recharge, high water levels, flooding, and fish and wildlife habitats. This project includes development of an updated integrated surface-groundwater hydrological model to simulate potential future conditions scenarios in the Lower Charlotte Harbor Flatwoods area (commonly referred to in this report as the Charlotte Harbor Flatwoods). The outcomes from this work provide guidance to resource management agencies for restoration and management of surface waters flowing from Babcock Webb through Yucca Pens and into tidal creeks discharging into eastern Charlotte Harbor and the Caloosahatchee River.

PROJECT DESCRIPTION

The goal of the project is to reduce pollution and hydrologic degradation to coastal watersheds in lower Charlotte Harbor through development of a science-based and data-driven integrated surface-groundwater hydrological model and the Lower Charlotte Harbor Flatwoods Strategic Restoration Planning Tool and Report. Modeling work includes hydropattern mapping of natural, current, and potential future conditions scenarios in the Lower Charlotte Harbor Flatwoods area. The outcomes from the Future conditions modeled scenarios are components of the Lower Charlotte Harbor Flatwoods 'Strategic Hydrological Restoration Planning Tool' and Report. All data, models, and technical memos associated with this project along with the final report are publicly available through the CHNEP Water Atlas Charlotte Harbor Flatwoods Initiative page.

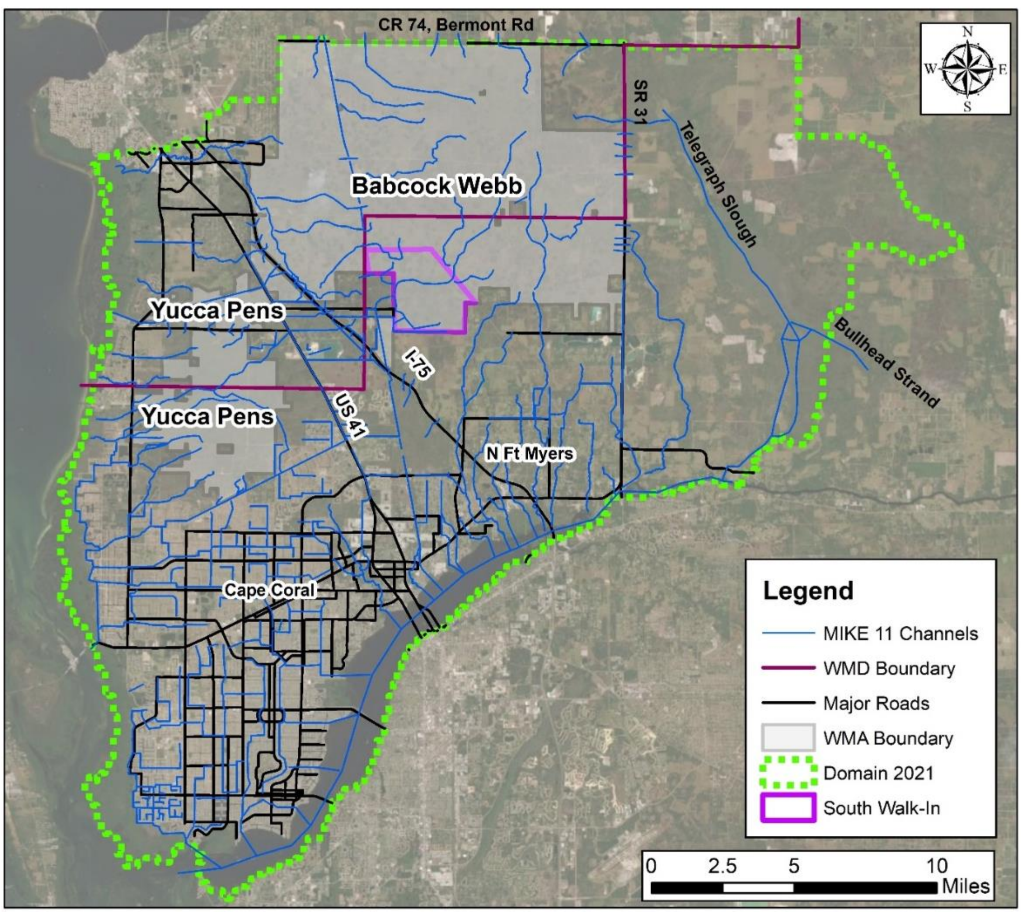

Figure ES-1. Location Map

The Report provides guidance to local governments and agencies for how best to restore connections and manage surface waters flowing from Babcock Webb and Yucca Pens through tidal creeks discharging into eastern Charlotte Harbor and the Caloosahatchee River.

Figure ES-2. South Walk-In Area, September 9, 2015

Figure ES-3. South Walk-In Area, July 2022

Figure ES-4. Very dry conditions in Yucca Pens, May 21, 2020

Figure ES-5. Localized flow in South Yucca Pens (left) and West Yucca Pens (right), October 15, 2020

PROJECT TASKS AND DELIVERABLES

1. Compilation of existing hydrologic data,
2. Installation of new surface and groundwater monitoring stations and rain gages,
3. Evaluation of vegetation indicators of wetland health,
4. Maintenance of the monitoring stations and downloading measured 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.

The remainder of this report includes four chapters:

- Data Collection and Model Building
- Modeling Existing Conditions
- Modeling Natural (Pre-Development) and Future Conditions
- Strategic Hydrological Restoration Planning Tool

The 'Data Collection and Model Building' chapter outlines the prior studies, existing monitoring and survey data which informed the groundwater and flow monitoring plan, device installation, data collection methods, and initial model building.

The 'Modeling Existing Conditions' chapter describes the model calibration process used to create the baseline existing conditions model which reflects the current hydrological and landscape conditions in the study area.

The 'Modeling Natural and Future Conditions' chapter describes the Natural Systems Analysis to create pre-development reference maps. It also describes development of the existing baseline conditions model, and future restoration and climate change scenario models. Hydroperiod and water level changes are compared between Natural Systems Analysis, the existing baseline conditions model, and modeled future potential management scenarios with the goal of meeting natural systems needs to the greatest extent possible.

Finally, the last chapter will summarize the results of the future conditions scenarios in meeting natural conditions (Pre-Development) and identify how to best address management concerns and support recommendations for management while accounting for future climate impacts.

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1) Gather Existing Data

1.1 Prior Studies

Several hydrologic studies have been completed for the CHNEP and surrounding areas. These include investigations by Florida Fish and Wildlife Conservation Commission (FWC), South Florida Water Management District (SFWMD), Southwest Florida Water Management District (SWFWMD), Florida Department of Transportation (FDOT), U.S. Army Corps of Engineers (USACE), and Lee County. This project used information from these various sources during the planning process. Typical information that is useful from previous studies include land use data, water level data, rainfall data, survey data including Light Detection and Ranging (LiDAR), point elevation measurements, and surveyed cross sections of existing water conveyances. Available hydrologic information provided a basis for identification of existing data gaps, new data acquisition efforts, and provides a platform for subsequent analysis of all available data.

See **Appendix 1** for the full Task 1 memorandum which identified and described existing data, studies, and modeling information, as well as data gaps in space, time, or type of information for the Charlotte Harbor Flatwoods Initiative (CHFI) project area. Note that only limited analyses of data were conducted in the Task 1 memorandum as those efforts were documented in subsequent technical reports.

Prior studies summarized in the Task 1 memorandum included:

- 1983 – Cecil Webb Water Management Study
- 1990 – Lee County Interim Surface Water Management Master Plan
- 2002 – Tidal Caloosahatchee Basin Model
- 2004 – South Charlotte, North Lee County, and Babcock Webb Surface Water Management Conceptual Plan
- 2005 – NW Lee County Surface Water Management Plan
- 2006 – North Fort Myers Drainage Restoration Project
- 2007 – Matlacha Pass Hydrologic Restoration Project
- 2008 – Lower Charlotte Harbor SWIM Plan
- 2008 – Conceptual Management Plan for Fred C. Babcock – Cecil M. Webb Wildlife Management Area 2003 – 2008
- 2010 – North Fort Myers Surface Water Management Plan
- 2010 – Yucca Pens Hydrologic Restoration Plan
- 2010 – Yucca Pens ATV Trails Restoration
- 2013 – FDOT I-75 Widening Permit, Initial Bond Farm Modeling
- 2015 – Southwest Florida Comprehensive Watershed Plan, US ACE, CHNEP, Sarasota County Estuary Program, Tampa Bay Estuary Program
- 2015 – City of Cape Coral Stormwater Model
- 2015 – A Management Plan for Fred C. Babcock – Cecil M. Webb Wildlife Management Area, 2014- 2024
- 2015 – Tidal Creeks Land and Conservation Prioritization Report
- 2016 – Basis of Design Report – Southwest Aggregates Storage Reservoir
- 2016 – SWFWMD LiDAR
- 2017 – Cape Coral Emergency Water Delivery from Southwest Aggregates
- 2018 – Bond Farm Acquisition

- 2018 – Yucca Pens Hydrological Study
- 2018 – SFWMD 2018-2023 Strategic Plan
- 2019 – RESTORE funding proposal for Bond Farm construction
- 2019 – Executive Order 19-12: “Focus on rapid improvement for water quality, quantity, and supply”
- 2019 – Yucca Pens Hydrogeological Assessment
- 2020 – Southwest Aggregates Water Use Permit Application
- 2020 – Bond Farm Environmental Resource Permit Application

1.2 Existing Monitoring Data

Existing monitoring stations (stations existing as of February 2020) within the Babcock Webb and Yucca Pens WMAs are described in **Table 1-1**. Stations installed in 2011 were monitored manually at bi-weekly intervals during periods when water levels were above ground until the stations were upgraded to have automatic data loggers. Data loggers recorded data typically at one-hour intervals. Monitoring stations outside of the WMAs are presented in **Table 1-2**. The location of existing monitoring stations in the vicinity of Babcock Webb and Yucca Pens WMAs are presented in **Figures 1-1** and **1-2**, respectively. Hydrologic data from existing monitoring stations and rain gages within the vicinity of the WMA are summarized in **Appendix 1**. Maps and additional information are also available in **Appendix 1**.

1.3 Survey Data

Surveyed cross-sections for some existing monitoring stations were available from the FDOT I-75 widening study (ADA, 2013), surveys of US-41 and Gator Slough for Cape Coral (WSA, 2017), and 58 cross sections in Yucca Pens surveyed for FWC and CHNEP (WSA and Southwest Engineering & Design, 2019). During a 2019 survey of monitoring wells in the Babcock Webb SWIA, five additional locations were surveyed, and the surveyed elevations were compared to LiDAR elevations. Surveyed ground elevations were, on average, one foot lower than LiDAR elevations (see **Appendix 1** for more detail). Based on these findings, additional surveying was conducted by Banks Engineering at 14 transects in the SWIA in February 2021 to check the accuracy of LiDAR elevation data (Banks Engineering, 2021). The Banks Engineering transect survey data was utilized during model development and is discussed further in **Section 5**. A map of the cross-sections is located in **Appendix 5A** Figure 22**.**

Table 1-1. Existing Monitoring Stations in Babcock Webb and Yucca Pens

Existing Station Name	Updated Station Name	Year Installed	Date When Data Logger Installed	Monitoring Type/Frequency
STA-6	No change	2017	2017	DL/hrly
STA-7	No change	2019	2019	DL/hrly
STA-8	No change	2019	2019	DL/hrly
SR-6	No change	2011	2019	M, biweekly
SR-10	No change	2017	2019	DL/hrly
SP-13	SP-13	2019	2019	DL/hrly
1	SP-15	2011	2019	M, biweekly
2	SP-16	2011	2019	M, biweekly
3	YP-1	2019	2019	M, biweekly
5	SR-7	2011	2019	M, biweekly
8	SR-8	2011	2017	M, biweekly
9	SR-9	2011	2017	M, biweekly
14	MW-14	2019	2019	DL/hrly
30S, 30D	No change	2019	2019	DL/hrly
YP-3	YP-8	2018	2018	DL/hrly
YP-1	YP-9	2018	2018	DL/hrly
23S, 23D	No change	2019	2019	DL/hrly
24S, 24D	No change	2019	2019	DL/hrly
29S, 29D	MW-29W, MW-29E	2019	2019	DL/hrly
30S, 30D	MW-30S, MW-30D	2019	2019	DL/hrly
YP-5	YP-5S	2019	2019	DL/hrly

Note: M: Manual, DL: Data Logger, see text above for explanation of manual monitoring

Table 1-2. Monitoring Stations near Babcock Webb and Yucca Pens

Station Name	Agency Maintaining Station	Year Installed
25100	SWFWMD	1989
25092	SWFWMD	1999
CH-323	USGS	2001
L-721	USGS	1970
Gator Slough, US-41	USGS/Lee County	2009
SW Aggregates wells	Cape Coral	2017
SW-1, -2, -3	Cape Coral	2017
CCI	Cape Coral	2020
Gator Slough Weir 11	USGS/Cape Coral	1992-2013
Gator Slough Weirs 19, 58, 11	Cape Coral	2014
Gator Slough Weir 4	Cape Coral	2018
1-GW1	Lee County	1991
5-GW1, 3, 5, 6, 8	Lee County	1991
17-GW3, 4, 18-GW2	Lee County	1991/1992
20-GW3, 22-GW1	Lee County	1992
27O-GW1, 28-GW2	Lee County	1997, 1993
Bayshore, Popash	Lee County	2011

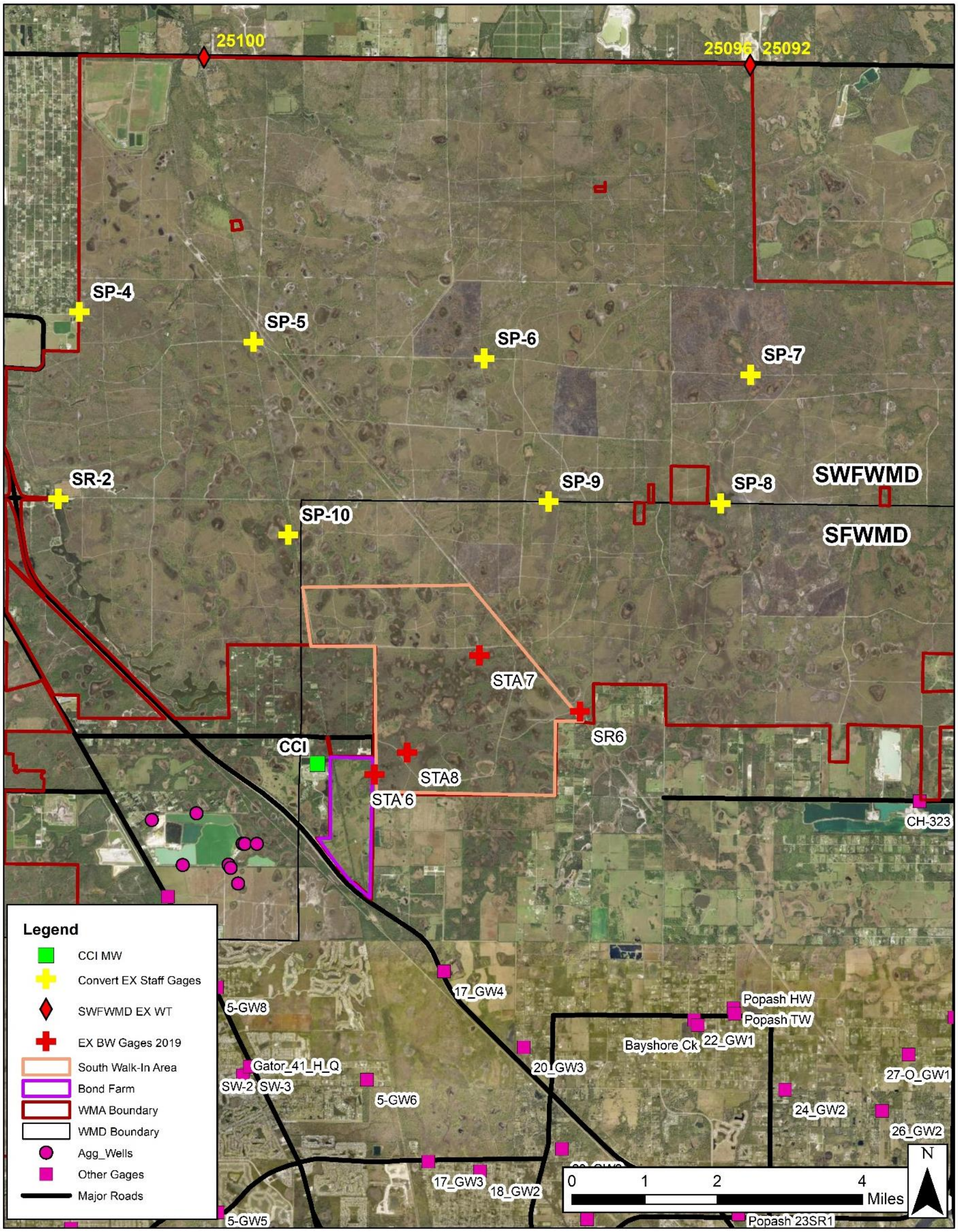


Figure 1-1. Existing Monitoring Stations in Vicinity of Babcock Webb

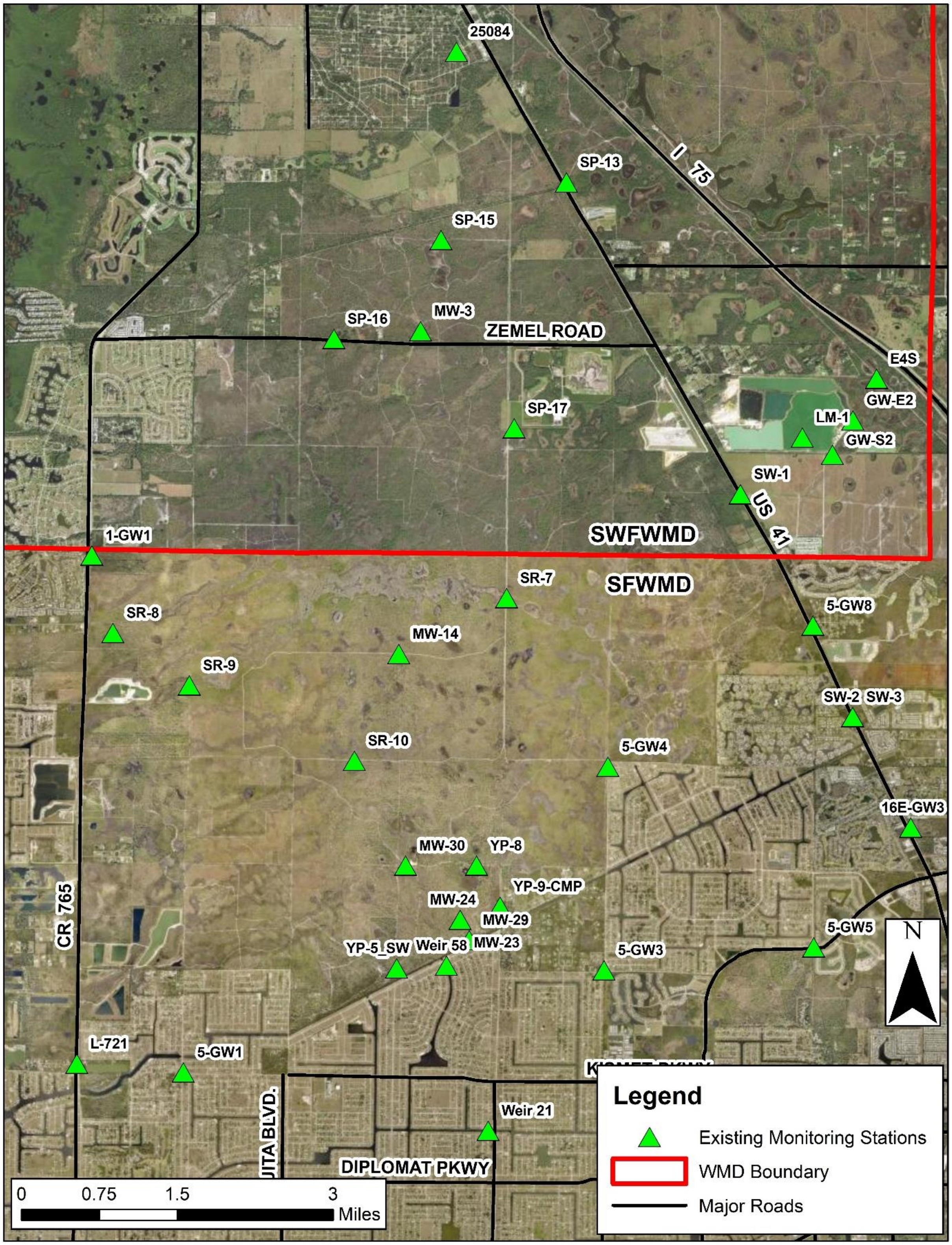


Figure 1-2. Existing Monitoring Stations in Vicinity of Yucca Pens

2) MONITORING, PLANNING, AND DEVICE INSTALLATION

The purpose of this task was to design and implement a monitoring plan to better understand the hydrology in the vicinity of Babcock Webb and Yucca Pens. The monitoring effort includes monitoring of groundwater, surface water, and rainfall.

2.1 GROUNDWATER MONITORING PLAN

A groundwater monitoring plan was implemented to improve understanding of groundwater elevations during the dry and wet seasons, particularly within the wetlands of the WMAs. The groundwater monitoring plan included installation of groundwater monitoring wells at eight existing staff water level gages in Babcock Webb, and establishment of 24 new monitoring stations in Babcock Webb and Yucca Pens. Station locations are shown in **Figure 2-1.**

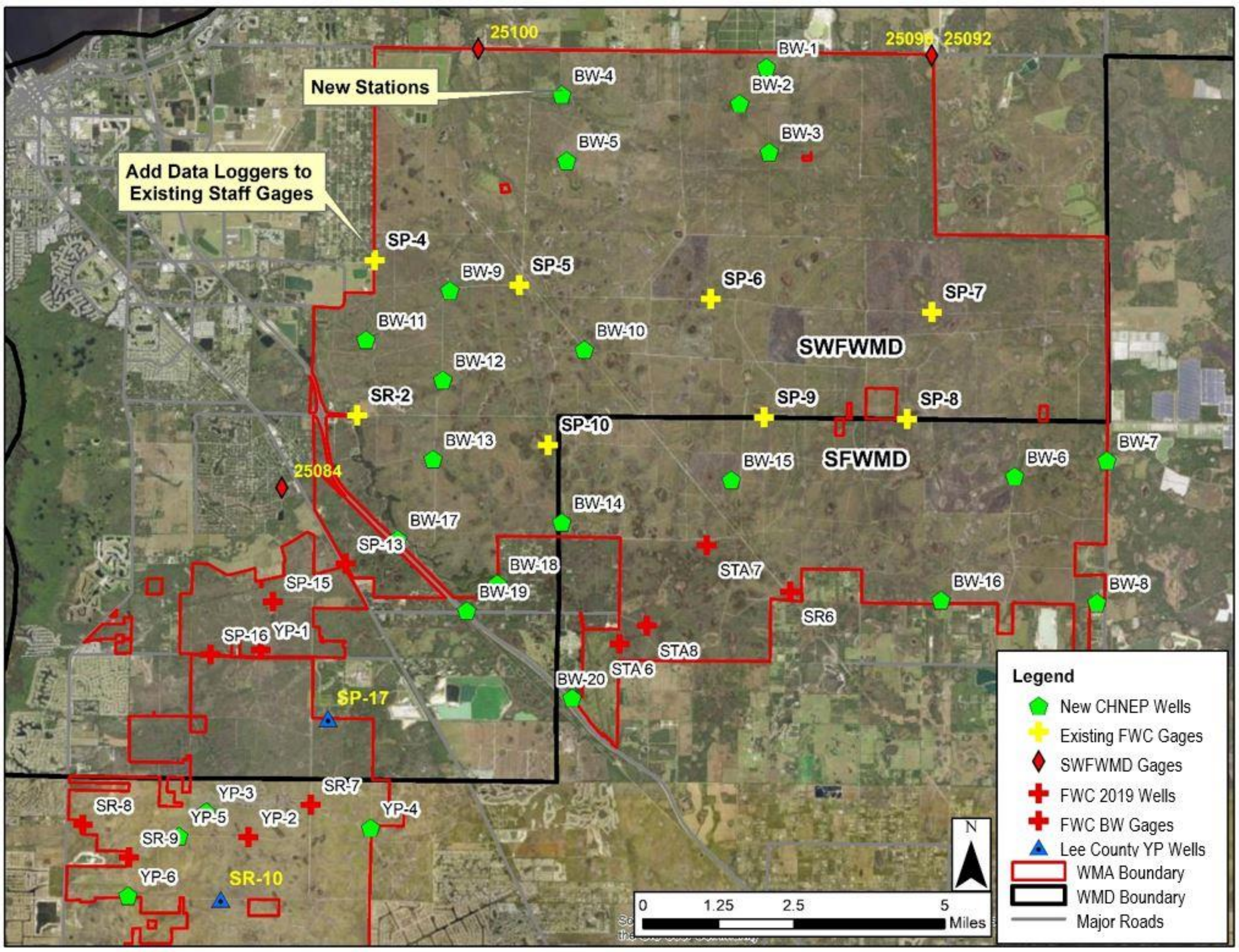


Figure 2-1. Groundwater Monitoring Stations in Babcock Webb and Yucca Pens

Each monitoring station consisted of an 8-ft deep monitoring well, screened casing in the bottom 5 ft, an aluminum protective cover, a 2x2 ft concrete base, and a water level data logger. In addition to the new groundwater monitoring stations, three rain gages were installed adjacent to groundwater monitoring stations SP-5, BW-18, and SR-7. Six quarterly data downloads were described in the plan. Full details of the groundwater monitoring plan and installation specifications are provided in **Appendix 2A**.

2.2 Flow Monitoring Plan

A flow monitoring plan was implemented to improve understanding of hydrologic conditions in Babcock Webb and Yucca Pens, including stream discharge within tidal creeks west of Yucca Pens WMA. Seven flow monitoring stations and one tidal flow monitoring station were identified in the plan. Station locations are presented in **Figure 2-2**.

At each monitoring location, a staff water level gage with elevations referenced to the North American Vertical Datum (NAVD) was installed and fitted with a Rugged Troll data logger to continuously measure water level. Flow velocity measurements were collected for ten wet season events using USGS-approved methods. (USGS, 2010; USGS, 2013) Flow rating curves were developed to generate a flow time series from measured water level data. Flow measurement techniques and flow rating curve development are detailed in **Appendix 2B**. The tidal flow monitoring station on Yucca Pens Creek west of Burnt Store Road (BSR) comprised a continuously recording side-looking velocity meter that measured tidal velocities for both in-coming and out-going tides.

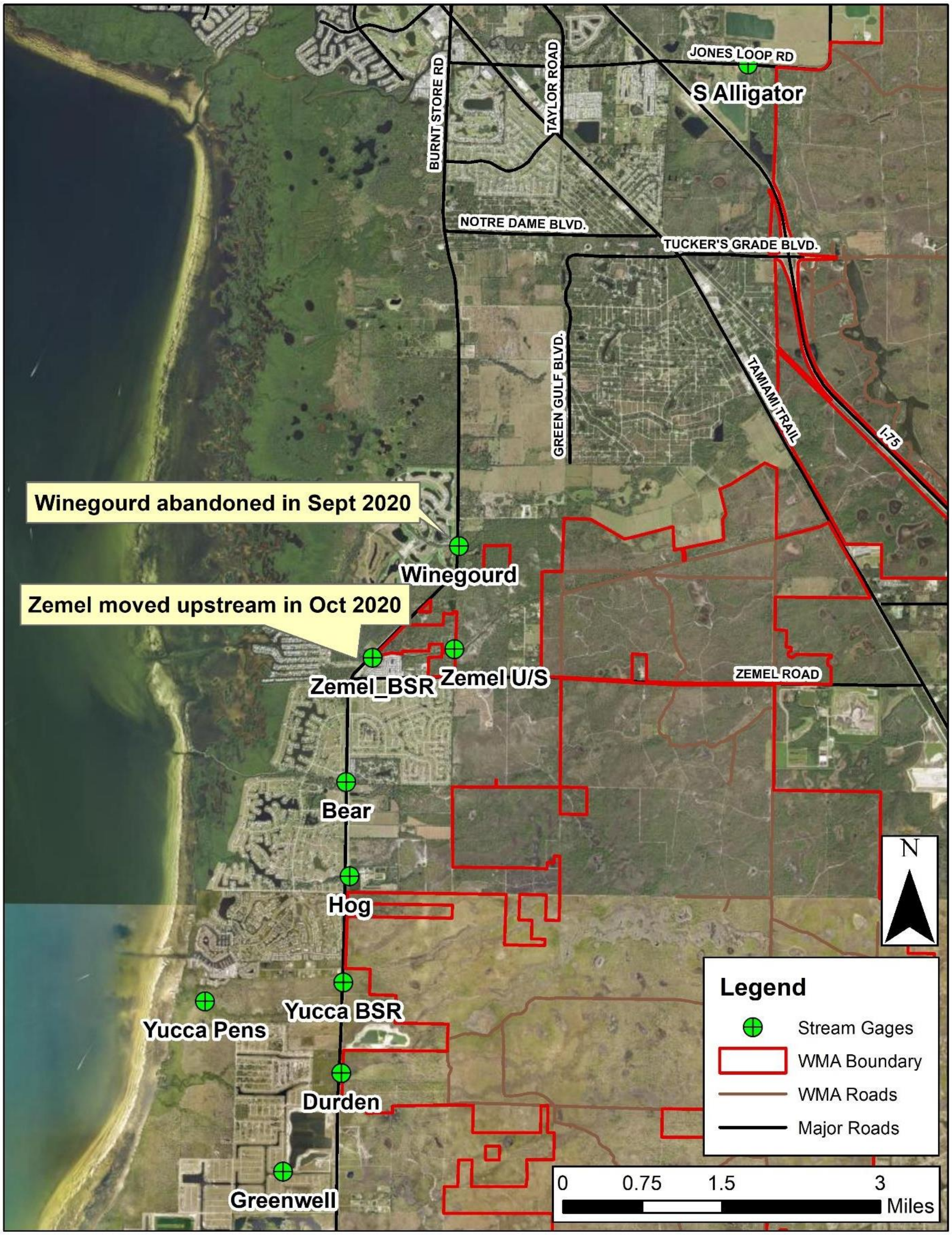


Figure 2-2. Flow Monitoring Stations

2.3 MONITORING DEVICE INSTALLATION

2.3.1 Groundwater Monitoring Stations

The new groundwater monitoring stations were installed during March and April 2020, and data loggers were installed at existing staff gages during late April and early May 2020. Stations were located according to the groundwater monitoring plan except where for minor adjustments where pockets of limestone close to the surface made installation cost prohibitive. Station location coordinates and elevations are outlined in **Table 2-1**. An example of a typical groundwater monitoring station is presented in **Figure 2-3**.

Table 2-1. Surveyed Results for Groundwater Monitoring Stations

Station	Y SPFLW_ft	X SPFLW_ft	Top of PVC ft-NAVD	Ground ft-NAVD	Well Depth from TOC, ft
BW-1	948379.12	704343.75	36.09	32.90	12.9
BW-2	945192.31	702023.08	36.24	32.84	13.0
BW-3	940953.57	704668.66	39.65	35.64	13.1
BW-4	945823.75	686455.97	28.85	25.07	9.7
BW-5	940050.69	686909.80	30.42	27.03	12.2
BW-6	912684.30	726381.91	34.34	30.63	12.4
BW-7	914128.41	734437.26	34.19	30.81	13.0
BW-8	901669.36	733662.51	31.50	27.96	13.0
BW-9	928576.49	676788.58	28.37	25.71	13.0
BW-10	923437.07	688558.69	31.80	28.63	damaged
BW-11	924202.65	669459.03	27.67	24.13	10.5
BW-12	920721.96	676220.07	29.25	25.80	13.0
BW-13	913774.91	675415.34	28.43	25.87	13.0
BW-14	908327.70	686748.91	29.53	25.90	13.0
BW-15	912146.89	701562.51	31.56	27.97	13.0
BW-16	901762.04	720001.19	31.78	28.19	12.7
BW-17	906721.59	672385.33	27.69	23.94	12.7
BW-18	902910.66	681128.22	28.84	25.18	13.2
BW-19	892905.42	687730.05	26.68	23.35	12.7
BW-20	900496.45	678486.91	27.74	24.10	12.8
YP-3	882666.23	655808.26	19.81	16.12	12.1
YP-4	881413.02	669859.20	20.29	17.30	10.0
YP-5	880534.76	653412.02	18.07	15.18	10.7
YP-6	875246.64	648951.91	15.16	11.72	12.3

Note: SPFLW_ft: Coordinates are in State Plane Florida West, ft
Top of PVC: Top of PVC casing; Ground: Ground Elevation Adjacent to Well; TOC: Top of Protective Cover

One monitoring station, YP-4, was not able to be installed in 2020 due to the presence of hard limestone five feet below ground surface. Since groundwater was encountered less than 4 feet below ground surface (bgs), a temporary shallow well was installed until a drill rig could be used to complete installation. The well was drilled in late April 2021, and the top of casing elevation of the temporary and new wells were surveyed so that data from the temporary well could be converted from depth below top of PVC to elevations in ft-NAVD. Station BW-10 was damaged in early November 2021 after which data was no longer collected at this location.

Water level data loggers were also installed at eight existing FWC staff gages shown in **Figure 2-1**. Location and elevation for those stations are provided in **Table 2-2**.

Table 2-2. List of Coordinates and Elevations for Babcock Webb Staff Gage Data Loggers

Station	Description	Horizontal Coordinates		Top of PVC
		Y_STFLW_ft	X_SPFLW_ft	ft-NAVD
SP-4	Cecil Webb, Alligator tributary	931175.41	670171.14	see note
SP-5	Cecil Webb NW	929092.49	682847.77	30.70
SP-6	Cecil Webb N	928021.84	699639.13	33.13
SP-7	Cecil Webb NE	926985.27	719013.80	38.88
SR-2	Webb Lake, Tuckers Grade Rd	917556.96	668748.81	see note
SP-8	Cecil Webb, TG, Telegraph HW	917606.91	716915.11	30.90
SP-9	Cecil Webb, TG, Gator HW	917642.90	704400.65	31.26
SP-10	Cecil Webb	915076.11	685486.06	30.10

Note: Because there is a permanent pool at SP-4 and SR-2, data loggers at those stations are programmed to water elevation observed at the staff gage

Figure 2-3. Groundwater Monitoring Station BW-11, August 2021

2.3.2 Flow Monitoring Stations

The flow monitoring stations were installed in April 2020 and were fully operational by early May 2020. These stations consisted of a staff gage (elevations on the gage are in ft-NAVD), conduit to the creek bottom, and a data logger to record water levels. **Figure 2-4** is a photograph of the flow monitoring station on the South Prong of Alligator Creek on South Jones Loop Road (see **Figure 2-2** for location). Details are provided in **Appendix 2C**.

Figure 2-4. Flow Monitoring Station, South Prong Alligator Creek, South Jones Loop Rd

Flow measurements were recorded at each station during the summer of 2020 and 2021, using standard USGS stream gaging techniques (References provided above. Measurement dates differed from station to station depending on local rainfall/runoff patterns in the upstream watershed of each monitoring station. Flows were measured on 5/21/20, 6/9/20, 7/21/20, 8/24/20, 8/28/20, 9/9/20, 9/14/20, 9/16/20, 9/30/20, 10/2/20, 11/12/20 and 7/8/21 Personnel recorded multiple velocity and depth measurements across the width of the streams/creeks. The flow monitoring equipment used at each station depended on the width and depth of the stream and creeks. Pygmy meters were used on the small streams, and Price AA or UVM meters were used on the larger streams or on smaller streams where the water velocities exceeded the range of the Pygmy meter. Flow measurements were obtained on an average of eight different wet weather events (6 at Durden Creek, 7 at Greenwell Branch, 8 or more at the remaining stations), and the stage/flow data were used to create a stage/discharge relationship that was used to generate a time series record of flows at the stations. Additional information on flow measurement techniques and equipment are provided in **Appendix 2C**.

2.3.3 Rainfall Monitoring Stations

Three rainfall monitoring stations were installed to augment existing rainfall data available from Lee County and City of Cape Coral operated rain gages. **Figure 2-5** shows new rain gages that were installed adjacent to groundwater monitoring stations SP-5, BW-18, and SR-7.

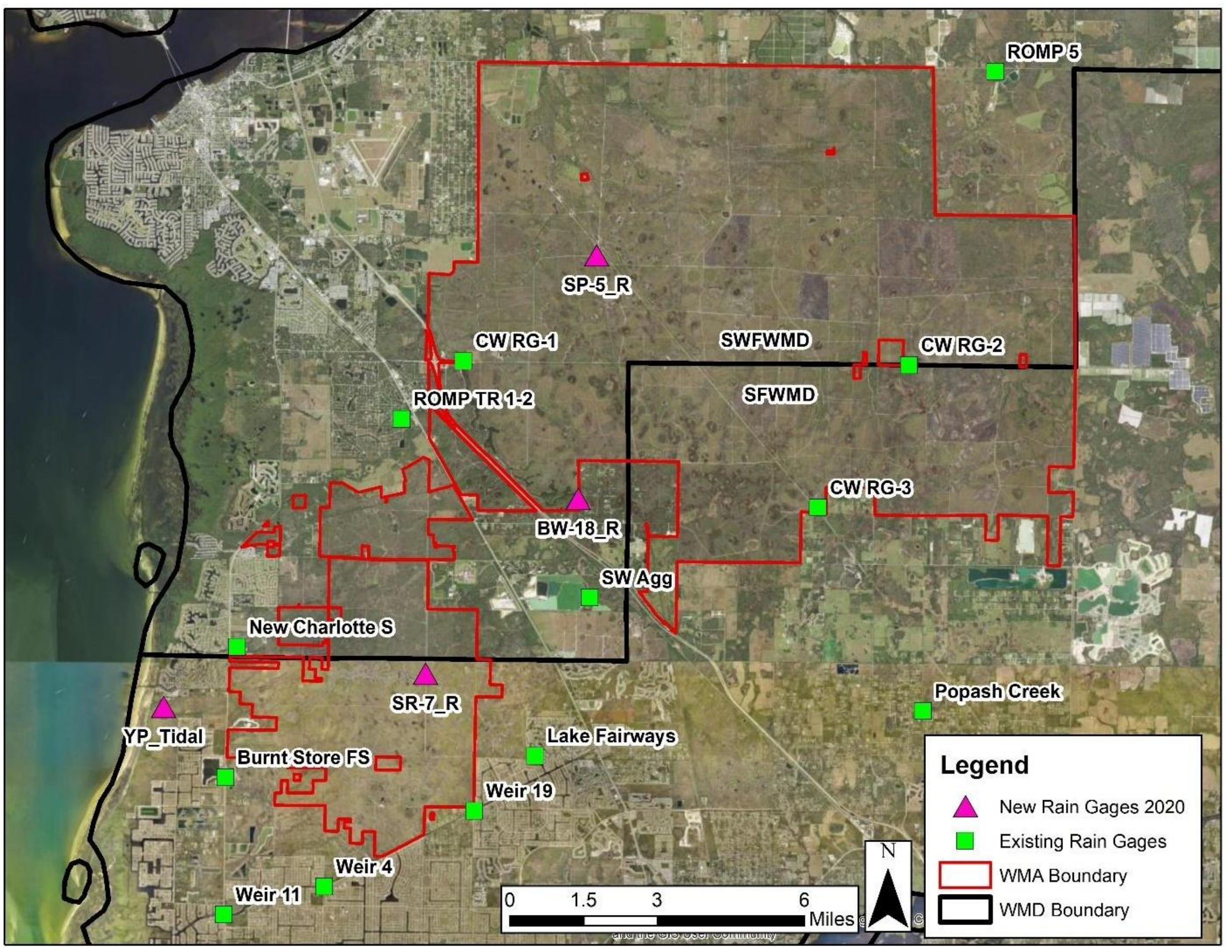


Figure 2-5. Rain Gages in Vicinity of Babcock Webb and Yucca Pens

3) Water Level Field Verification For Seasonal Highs And Historical Hydroperiod Mapping

Dry and wet season field investigations were conducted to identify vegetation indicators of average wet season water levels since the last major event and a map of historical (pre-development) hydroperiods. Results of these field investigations and estimated historic hydroperiods are provided below (see **Appendices 3A-C** for full detail of analyses and results). It is believed that Babcock Webb experiences extended wetland hydroperiods due to flow constrictions around developments within the historic flow-ways west and southwest of the WMA. Yucca Pens wetlands are drier than normal due to drainage via eroded ATV trails along the perimeter of the WMA as well as a lack of inflows from Babcock Webb. This section provides biologic information on water depths in wetlands that can be used to evaluate the overall hydrologic condition of the WMAs.

3.1 Dry Season Field Identification of Seasonal High and Low Water Levels

Dry season field work was conducted in March and April 2020 to identify field indicators of seasonal high and low water levels. Field methodologies for water elevations and biological indicators followed guidance from SWFWMD (Schultz, et. al., 2004). Special attention was made to evaluate the difference between vegetation indicators resulting from the high-water levels experienced during Hurricane Irma (September 2017) and vegetation indicators representing more typical wet season conditions. This was to establish where water levels are higher or lower than optimum levels for the plant community. Average wet season water elevations were established by a nail driven into a tree or bush at the high waterline mark at two to three locations across the extent of the wetland. Stakes were also often set to mark the edge of the wetland. Field studies were conducted at 58 locations with multiple stakes or nails set at each location. Approximately 240 elevations were established and surveyed. Results of the dry season field investigations are provided in **Appendix 3A**.

Biological indicators, which are longer term indicators, were identified and surveyed to estimate typical water level elevations for surveyed areas. Such indicators respond to an established pattern of seasonal high and low water over several years and are less influenced by recent extreme events. Discrepancy between measured seasonal water levels and those estimated from biological indicators may also indicate a shifting hydrologic regime. The biological indicators that primarily informed historic water level determination included the elevation of the inflection point of buttresses on pond-cypress (*Taxodium ascendens*), the lower elevation of epiphytic moss collars on pond-cypress, the elevation of root crown bases of wax myrtle (*Myrica cerifera*), the uppermost adventitious root of sandweed (*Hypericum fasciculatum*), and the ground elevation of the upland/wetland limit based on vegetation and its associated indicator status. Other vegetation indicators evaluated included:

- Presence of moss and lichen on tree trunks
- Water marks and dirt deposits on bark
- Elevation of cypress buttress inflection
- Elevation of the root crown base of Fetter bush (*Lyonia lucida)*
- Thinning of the diameter of tree trunks (see examples in **Figure 3-1**)

- Presence or absence of obligate and/or facultative wetland vegetation and presence of pond apple snail shells
- Abnormal branching
- Yellowing of leaves
- Presence or absence of hydric soils on the ground surface

The recorded average wet season depth was based on the preponderance of evidence utilizing all of the information described above. For further detailed methodology please refer to **Appendix 3A.** Overall, vegetation indicators aligned with measured water elevation to indicate that conditions were not optimal for the communities present.

In the vicinity of Tuckers Grade, observed water depths within wetlands correspond to markers of historical water levels. Water depths gradually increase south of Tuckers Grade Road, and, within the SWIA, significantly exceed the levels of longer-term water depth as indicated by biological indicators. In addition to excessively high seasonal water levels in the SWIA, there were also indications of optimum levels and causing a longer wetland hydroperiods and lower slowed recession rate of standing water (see **Figures 3-10 and 3-11** in **Section 3.3.2** for graphs of measured water levels in the SWIA and Yucca Pens that support these findings) of measured water levels in monitoring station STA-8). Indications of a prolonged hydroperiod included observations of apple snails (*Pomacea* spp.), vegetative stress, and lack of transitional plants near the wetland edge. Apple snails are considered a long hydroperiod taxon (Darby et. al., 2008) with limited capacity to survive prolonged periods of drought and were observed throughout the southwestern portion of Babcock Webb south of Tuckers Grade. Observations of apple snails in wetlands in the Yucca Pens study area, which appear to have a reduced hydroperiod, were less frequent. Stressed cabbage palm (*Sabal palmetto*) and slash pine (*Pinus elliottii var densa*) were noted in the central and southern portions of the Babcock Webb study area, presumably a result of prolonged inundation and saturation.

Figure 3-1. Stressed cabbage palms in South Walk-In Area, Babcock Webb

Yucca Pens wetlands also indicate varying levels of vegetative stress due to hydrologic alterations discussed above. However, vegetation indicators in the southern portion of Yucca Pens exhibit decreased wet season water depths and decreased wetland hydroperiods. Wet prairie and marsh habitat along the edge of cypress in west-central Yucca Pens and in southern Yucca Pens lacked facultative wet and obligate wetland vegetation. One explanation for altered hydroperiods is that numerous ATV trails on the property act as rapid-flow water conveyances during the wet season causing water to leave Yucca Pens too quickly. Babcock Webb vegetative communities also exhibit abnormalities such as the trees in the pine flatwoods community showing signs of stress and die off. Tree islands in Babcock Webb also exhibited water marks one foot above ground which is atypical.

3.2 Wet Season Confirmation of Seasonal High-Water Levels

Field work was conducted during the late summer and fall of 2020 to measure wet season water levels (**Figure 3-2**) and compare to typical wet season water level estimated from biological indicators during the dry season. Relatively normal rainfall in Babcock Webb was observed in late May and early June of 2020, which was then followed by less than normal rainfall during the remainder of June and early July. However, higher than normal rainfall occurred in Babcock Webb during the fall of 2020, as shown below in **Table 3-1**.

Table 3-1. Babcock Webb Observed and Average Rainfall for Fall 2020, Lee County Rain Gage Stations located in Charlotte County

Month	2020 Monthly Totals, Avg of RG-1, -2, -3 (Located in Charlotte County)	Lee County Historical Avg
October	9.30	2.68
November	5.14	1.81
December	4.27	1.72
Oct-Dec Total	18.71	6.21

As such, the wet season was defined as August – November in 2020 for the purposes of ecological field conditions investigations, and field survey of high water was timed for September and October to correspond to this later than normal peak. The relatively dry summer and wet fall resulted in water levels in November that were typical of "average" wet season water depths. Results and analysis of the wet season field investigations are provided in **Appendix 3B**.

Water depth in the SWIA ranged from 8 to 12 inches above vegetation indicators established during the dry season. Evidence of vegetative stress was common, including dead and stunted pine trees, reduced cabbage palm trunk and crown sizes (**Figure 3-1**), and hardwood leaf-cover reduction.

Across Yucca Pens, wetlands also indicated varying levels of vegetative stress due to hydrologic alternations. Vegetation indicators in portions of Yucca Pens exhibit decreased wet season water depths and decreased wetland hydroperiods. Specifically, observed average wet season water depths were less than anticipated.as indicated in the following locations below:

- Durden Creek (see points Y17A, Y19, Y-12, and Y-56 in **Figure 3-3**)
- Headwaters of Yucca Pens Creek (see point Y13 in **Figure 3-3**)
- Southern Yucca Pens (see red-circled area in **Figure 3-4**) was very dry with very little ponding of water above the land surface during the wet season.

In addition, numerous ATV and access trails act as shallow-water, rapid-flow conveyances during the wet season, contributing to the altered hydrologic conditions on the southern and western portions of Yucca Pens. Locations of these eroded ATV trails are identified in **Figure 3-5.** These locations were a focal issue during the initial scenario analysis, and proposed solutions are presented in **Section 6**.

Figure 3-2. Babcock Webb South of Tuckers Grade, September 10, 2020

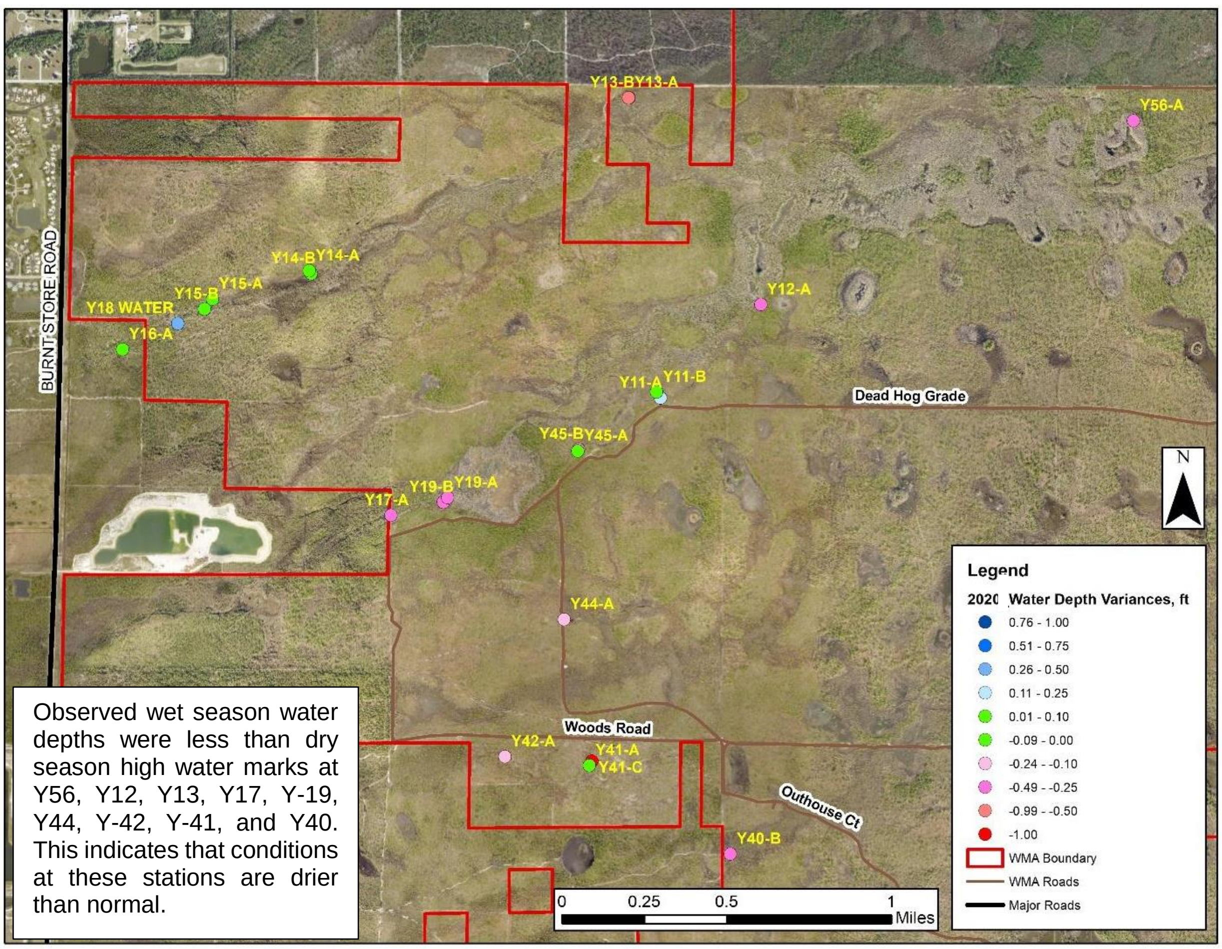


Figure 3-3. Map of Surveyed Wet Season Water Elevation Differences between Dry and Wet Season Vegetation Indicators on Western Yucca Pens WMA

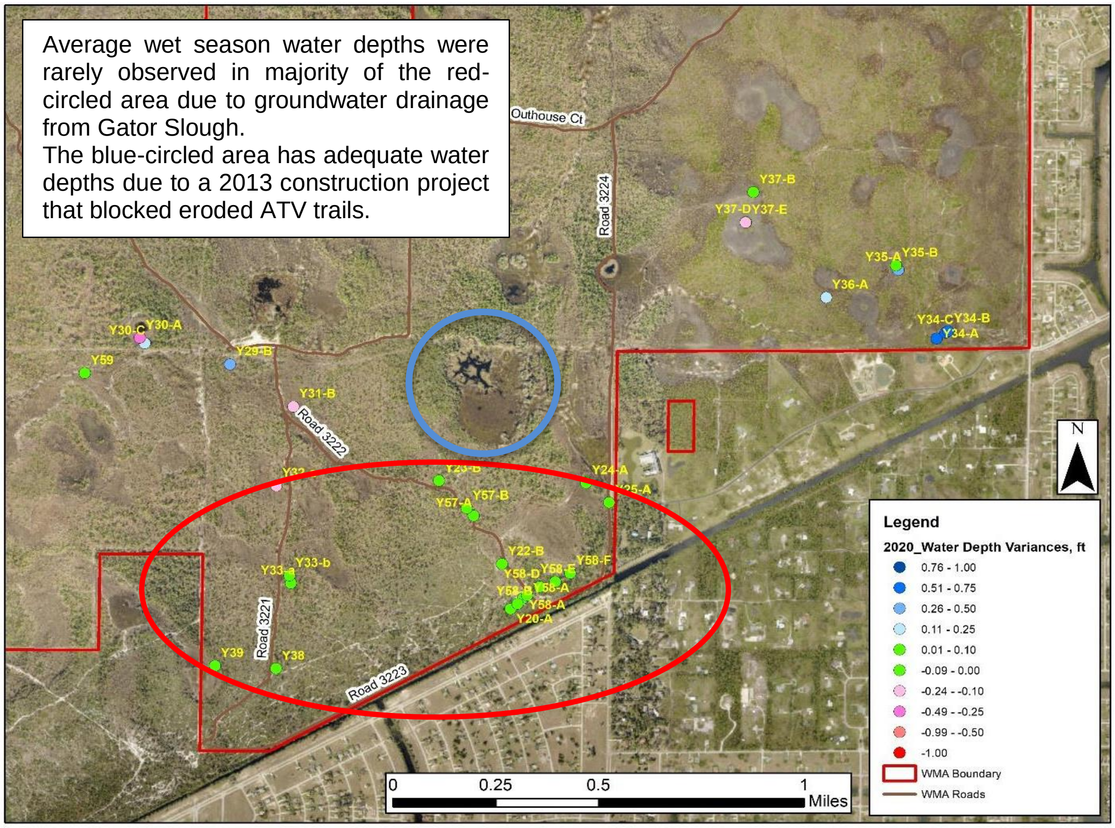


Figure 3-4. Map of Surveyed Wet Season Water Elevation Differences between Dry and Wet Season Vegetation Indicators on Southern Yucca Pens WMA

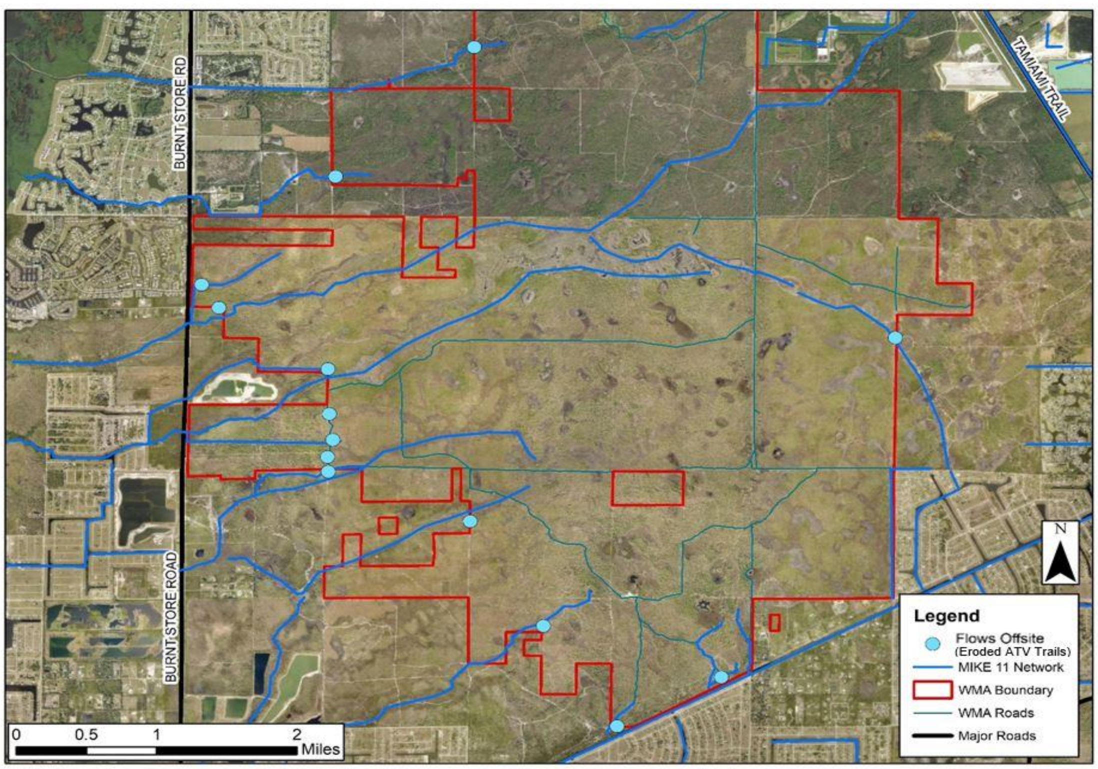


Figure 3-5. Map of Concentrated Outflow Locations from Yucca Pens via Eroded ATV Trails

3.3 Map of Historical Hydropatterns

Results from the ecologic field investigations and the hydrologic monitoring program were mutually supportive. These results were utilized to map historic hydropatterns, and identify areas where current water levels are higher or lower than optimum historic hydroperiods. Details of the analysis and the development of historic hydropattern maps are provided in **Appendix 3C**.

3.3.1 Historical Hydropatterns

Historic 1953 aerial photographs taken during the dry season for Babcock Webb and Yucca Pens were geo-referenced by Tim Lieberman (formerly of SFWMD, retired) and Mike Kemmerer of the Florida Fish and Wildlife Conservation Commission (FWC), (personal communication, Kemmerer, 2019. Lieberman and Kemmerer developed four ranks of hydrologic condition based on overlaying observable vegetation, drainage and inundation with USDA-NRCS soil survey maps (at a scale of 1:50,000 with some areas at a finer resolution). Hydro Rank 1 represents uplands and Hydro Rank 4 represents wetlands. Hydro Rank 2 was used for lands that experienced minor flooding, and Hydro Rank 3 was used for lands that were more often wet than dry.

The information in the Natural Resources Conservation Service Soil Survey Geographic Database (SSURGO) database used to assign a rank is explained below:

Hydro Rank 1. Uplands: 0% ponding frequency, no drainage limitations

Hydro Rank 2. Conifers: minor flooding, no drainage limitations

Hydro Rank 3. Marshland: frequent flooding, poorly drained

Hydro Rank 4. Wetlands: 98% ponding frequency, very poorly drained

Tonal differences in the historic aerial photographs are representative of soil moisture and inundation, with dark areas indicating inundation and light areas indicating dry conditions. **Figure 3-6** illustrates the visual signature within the aerial photographs and the corresponding hydrologic rank for a portion of southern Yucca Pens.

Hydrologic rank polygons were used to map historical wet season water depth. Water depth was assigned to hydrologic ranks based on ecologic surveys conducted across Southwest Florida by Mike Duever (see **Figure 3-7** and **Table 3-2**). This historical hydrological ranking system served as a reference for calculating differences between optimal historic water levels and observed water levels.

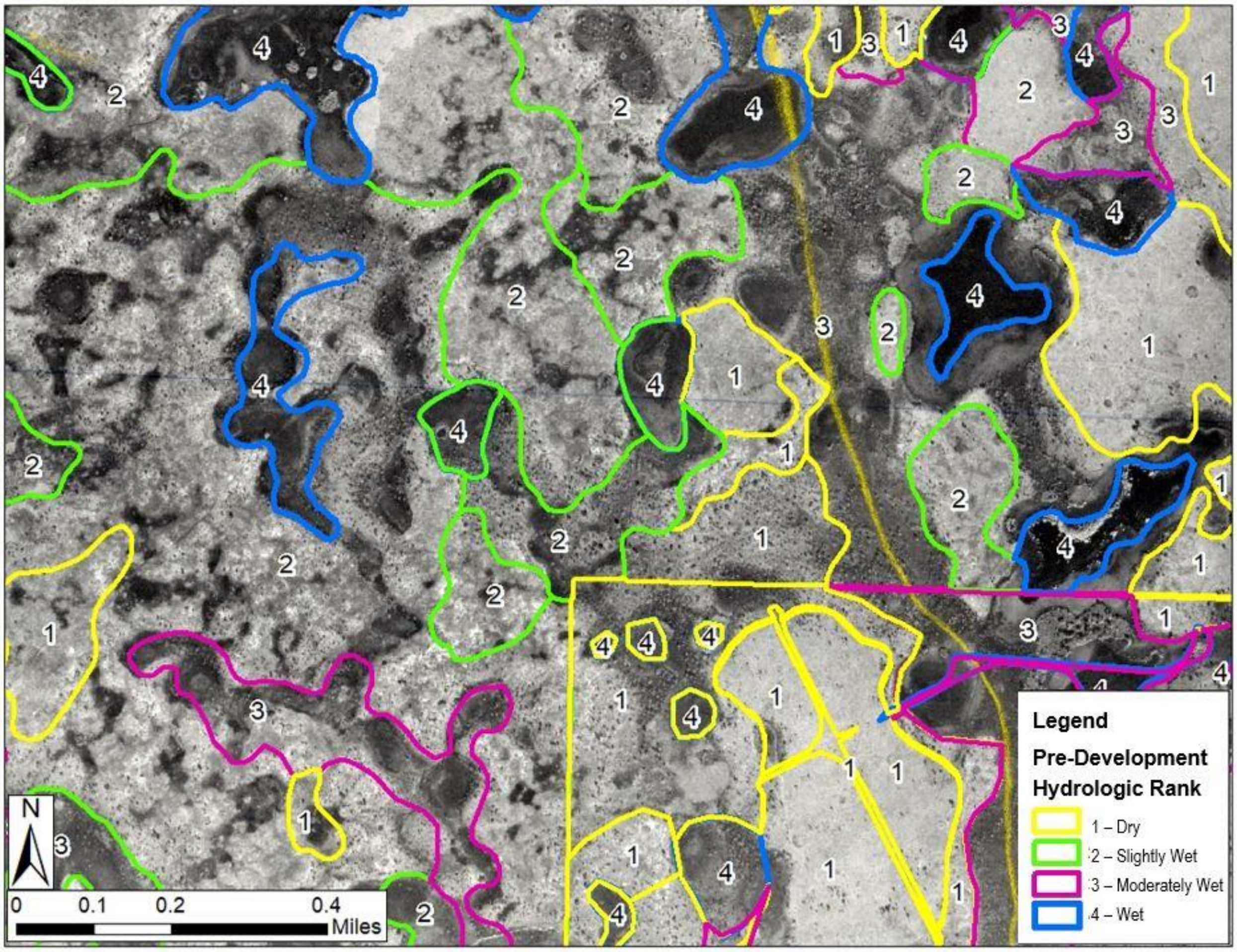


Figure 3-6. 1953 Geo-referenced Aerial Photos of Southern Yucca Pens and Pre-Development Hydrologic Rank Areas

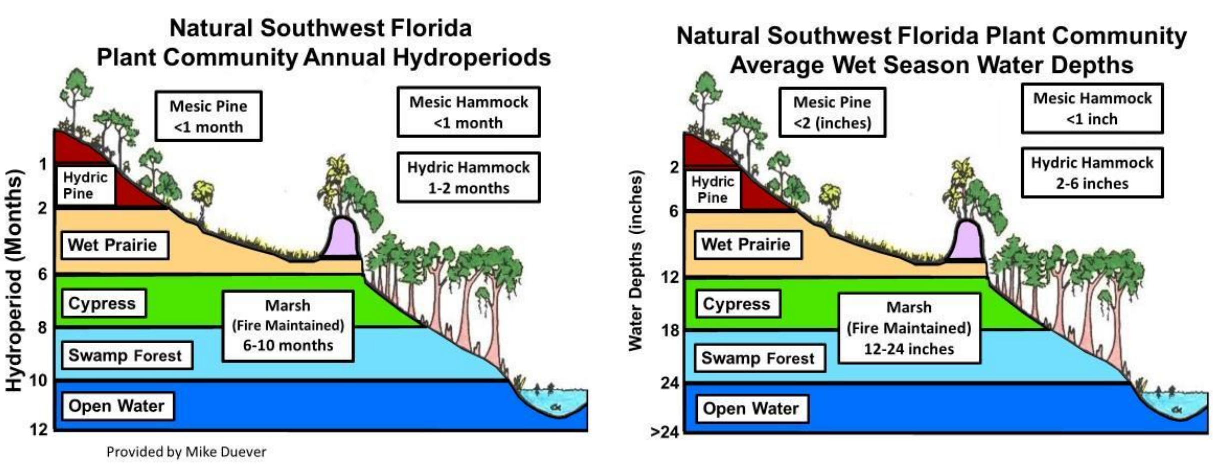


Figure 3-7. Optimum Wetland Hydroperiods and Average Wet Season Water Depths for South Florida Wetland Communities, Duever & Roberts (2013)

Table 3-2. Hydrologic Rank and Optimum Wet Season Average Depth, ft

Hydrologic Rank and Typical Land Cover	Optimum Wet Season Average Water Depth, ft
1 – Mesic Flatwoods	0.0
2 – Hydric Flatwoods	0.33
3 – Marsh	0.75
4 – Cypress/Slough	1.5

Note: Optimum Wet season Average Water Depths were taken from Duever & Roberts (2013)

3.3.2 Areas with Hydropatterns Higher or Lower than Optimum

Vegetation indicator points located within the SWIA in Babcock Webb, presented in **Figure 3-8,** generally had higher water depths than optimum (1.5 ft). Of the 14 points within the SWIA, the 10 locations where wet season water levels were observed during October 2020 were higher than optimum, with exceedances ranging from 0.3 to 1.6 feet (mean = 0.6 ft). Water levels in October 2020 were comparable to wet season conditions in recent years in Babcock Webb, according to FWC staff. The four locations with observed water depths less than optimum were in the northern portion of the SWIA, and those points were evaluated in September 2020, when it was drier than typical wet season conditions.

Average wet season water depths in Yucca Pens in September 2020 were comparable to wet season conditions in recent years in Yucca Pens, according to FWC staff. Observed wet season average water depths in Yucca Pens during 2020 were drier than optimum conditions at 60% of the vegetation stations. Observed depth was, on average, 0.62 feet lower than optimum average wet season water depths (see **Figure 3-9**). The greatest negative deviations from optimum wet season water depth (areas that were drier than optimum) were located on the southern and western areas of Yucca Pens. This pronounced difference in proximity to the area's boundaries suggests that drainage at ATV trail locations has a significant impact on wetland hydrology in Yucca Pens.

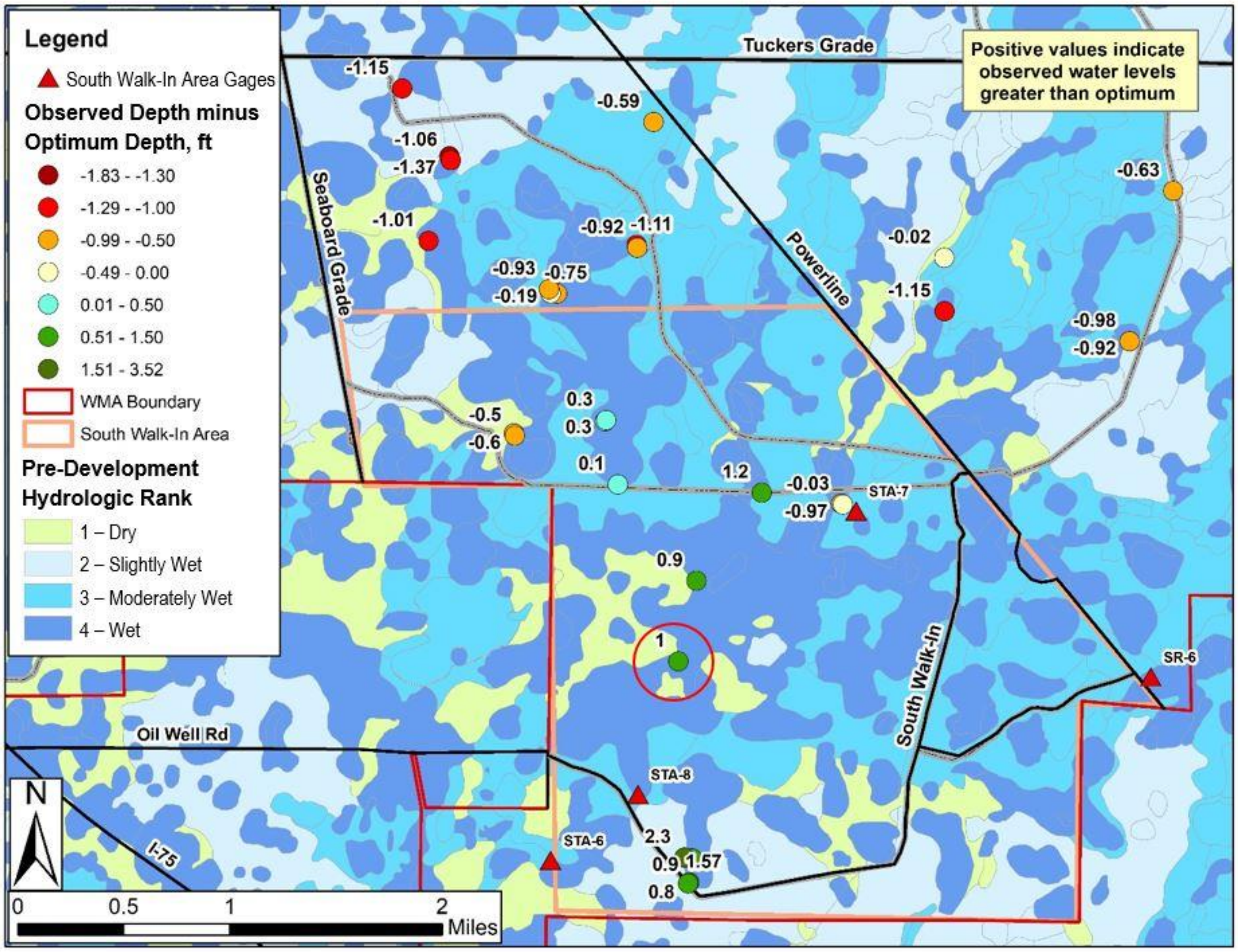


Figure 3-8. Comparison of Predevelopment Hydrologic Rank and Observed 2020 Wet Season Depths for the South Walk-In Area of Babcock Webb (in the legend, dots ranging from green to light blue have water depths higher than optimum)

> **Note:** In the **Figure 3-8** Legend, “Observed D minus Opt Depth” is Observed Depth minus Optimum Depth, which is equal to Average 2020 Wet Season Water Depth minus Optimum Depth. For example, see point in red circle above in **Figure 3-8.** Avg 2020 Wet Season Depth = 2.5 ft. Hydro Rank is 4, so optimum depth is 1.5 feet. Therefore, Observed Depth minus Optimum Depth = 1 ft

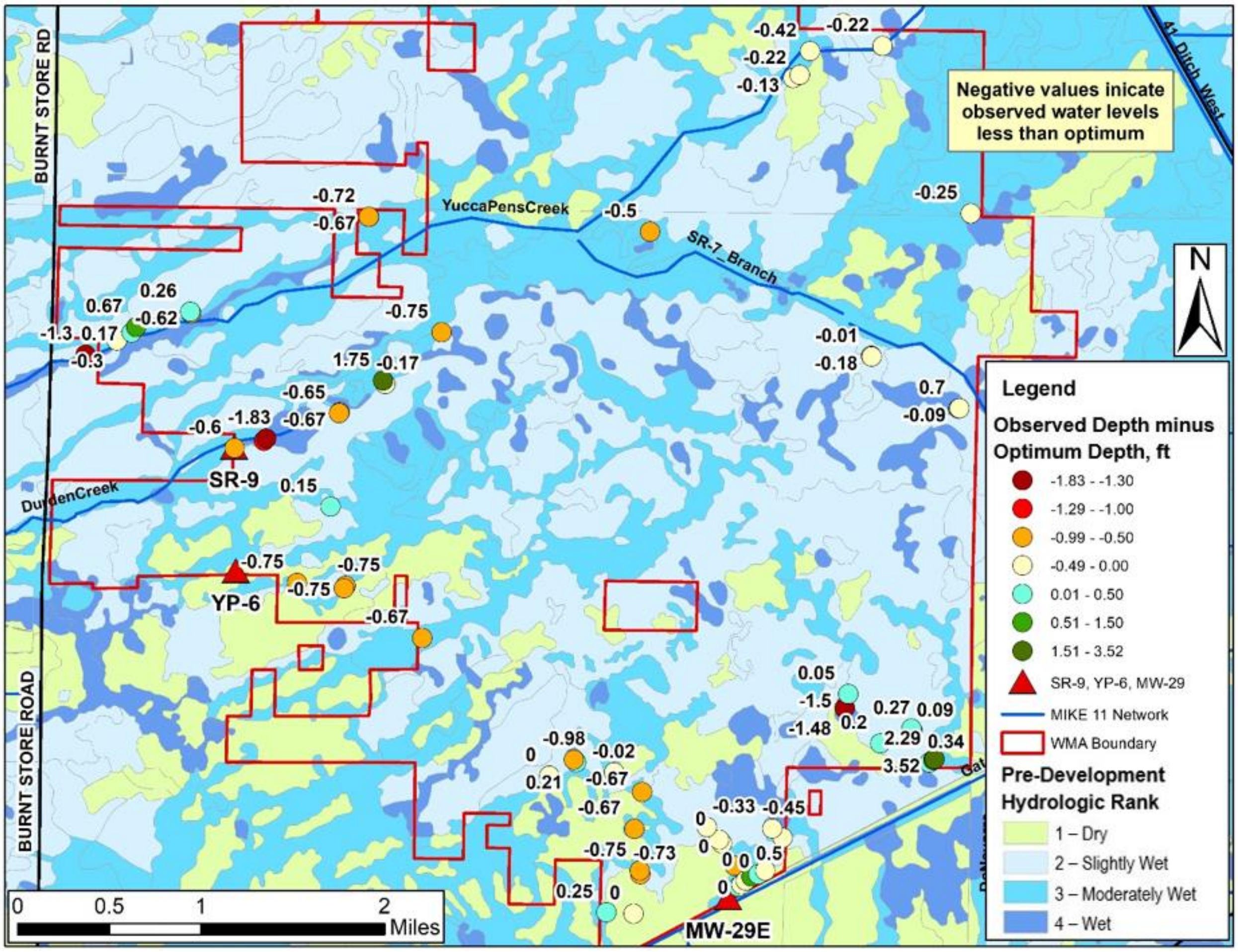


Figure 3-9. Comparison of Predevelopment Hydrologic Rank and Observed 2020 Wet Season Depths for Yucca Pens south of Zemel Road (in the legend, dots ranging from yellow to red have water depths less than optimum)

This analysis generally indicates that water depths are higher than optimum in the SWIA and less than optimum in portions of Yucca Pens. In addition to the observed wet season water depth used to compare to the optimum values assigned to hydrologic ranks, the measured water elevation data from monitoring stations in the vicinity of greatest deviation support these findings. **Table 3-3** presents average wet season water levels minus and the average wetland elevation for STA-7 and STA-8 in the SWIA and SR-9, YP-6, and MW-29 in Yucca Pens (station locations are shown in **Figures 3-8** and **3-9**). Note that MW-29E and MW-29W are deep and shallow monitoring wells installed prior to the start of this project.

Table 3-3. Average Wet Season Water Levels minus Average Wetland Elevation in 2020 and 2021

Station	Avg 7/1 to 11/15, 2020	Avg 7/1 to 11/15, 2021
STA-7	+1.7	2.0
STA-8	1.4	1.8
SR-9 (Durden Creek)	-0.5	-0.6
YP-6 (eroded ATV trail)	-0.7	-0.7
MW-29 (concrete weir)	-3.5	-3.0

Note that the elevation difference for MW-29 used the weir elevation for comparisons since there are no wetlands near this monitoring station.

Measured water levels in SWIA monitoring stations STA-7 and STA-8, presented in **Figures 3-10** and **3-11**), are consistently above wetland ground elevations during the wet season.

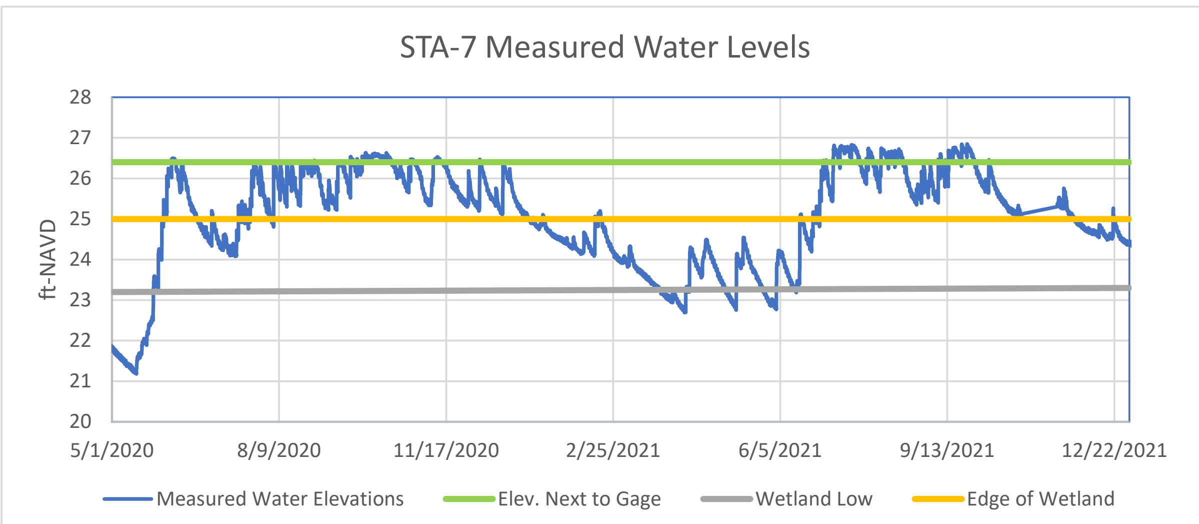


Figure 3-10. Measured Water Levels at STA-7 in North Portion of South Walk-In Area

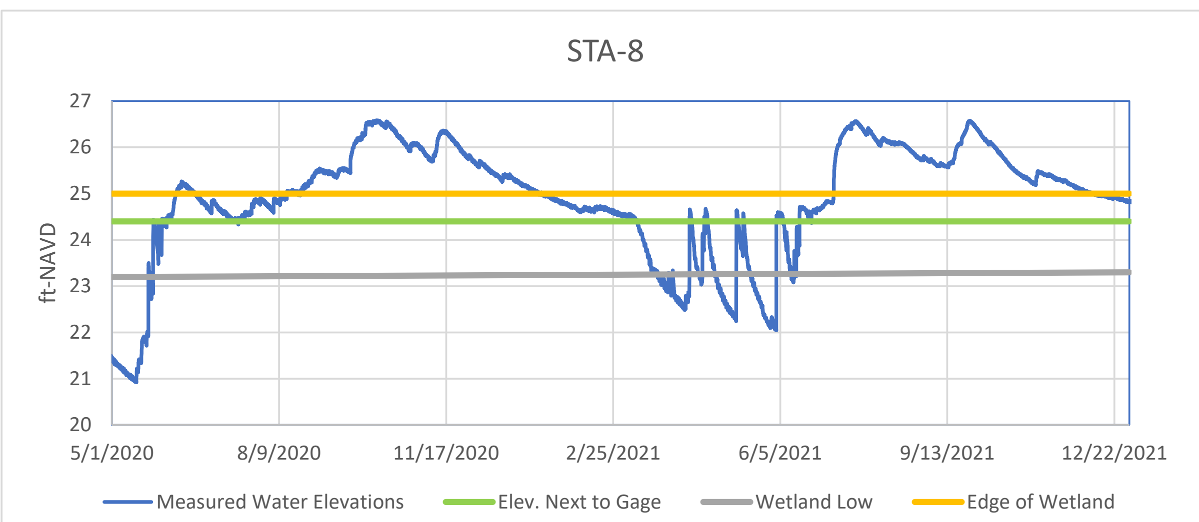


Figure 3-11. Measured Water Levels at STA-8 in South Portion of South Walk-In Area

Figure 3-12. Adjacent to STA-8, July 2022

Conversely, measured water levels in Yucca Pens monitoring stations SR-9, YP-6, and MW-29 are lower, as shown below in **Figures 3-13** through **3-17**. SR-9 water levels are above ground during most of the wet season but never reach the edge of the cypress wetlands of Durden Creek, which indicates that water levels at this location are below optimum conditions. YP-6 water levels are rarely higher than average wetlands elevations in the vicinity of the gage, evidence of the drainage effect of two eroded ATV trails adjacent to YP-6.

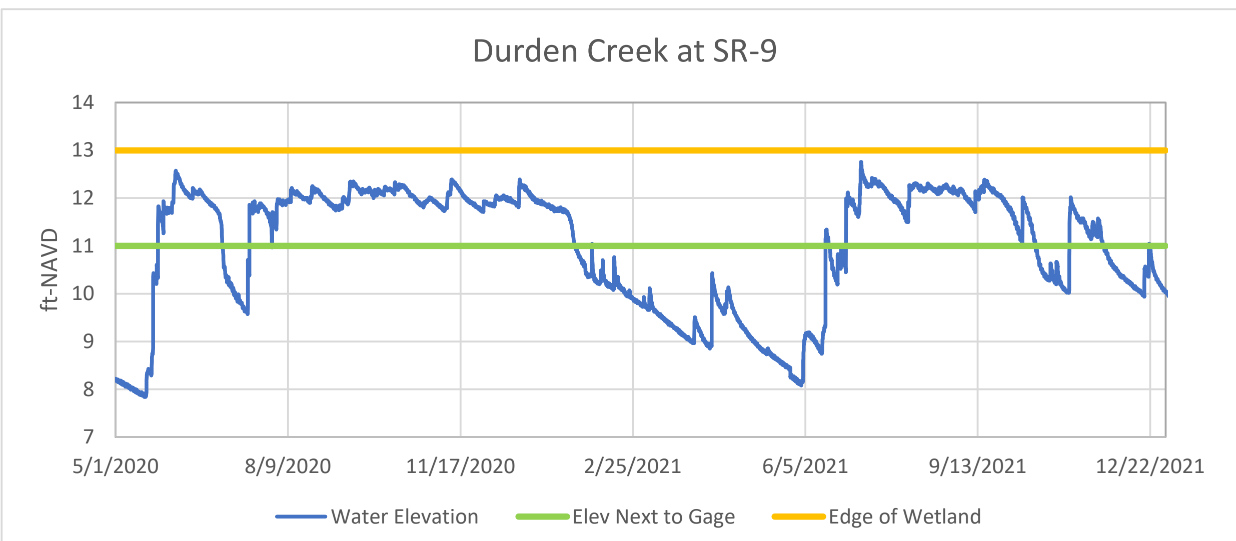


Figure 3-13. Measured Water Levels at SR-9 in Durden Creek at Western Limit of Yucca Pens

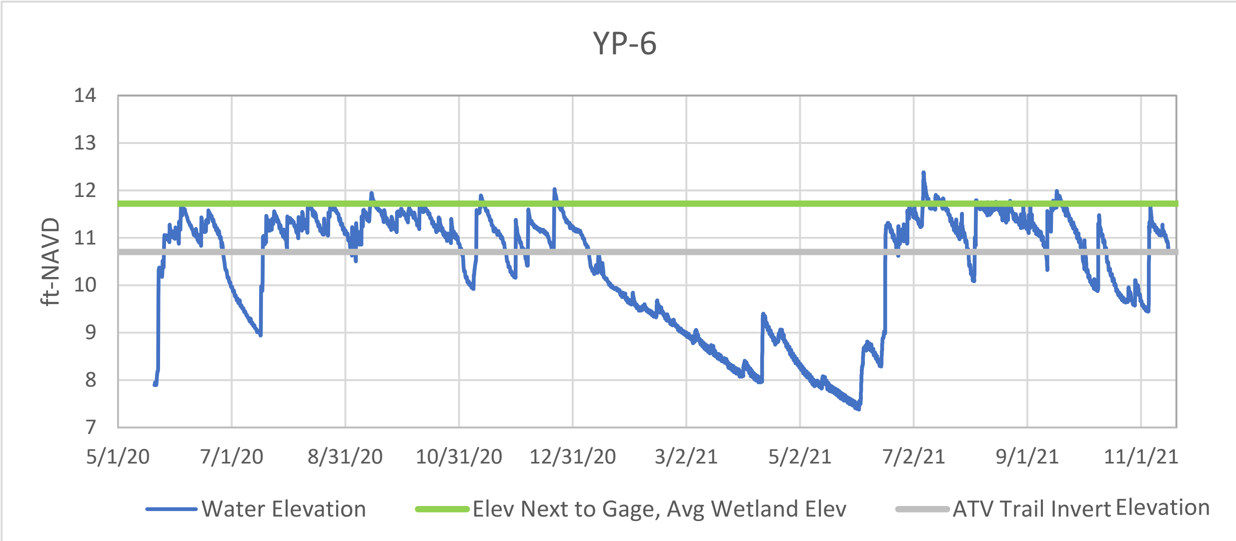


Figure 3-14. Measured Water Levels at YP-6 at Western Limit of Yucca Pens (south of SR-9)

NOTE: Invert elevation is the lowest point of ATV ditch

Figure 3-15. Station YP-6 and Eroded ATV Trail Just West of YP-6

Water level conditions are significantly lower at MW-29, suggesting negative impacts due to prevailing water levels (+/- 7.0 ft-NAVD) in nearby Gator Slough. MW-29W is a shallow well which has water levels that are consistently higher than the deep well levels (MW-29E). These monitoring wells are less than 120 feet from Gator Slough which has water levels in the range of 7.0 to 8.0 ft-NAVD, and the weir elevation of the low water ford adjacent to these two nested monitoring wells is 11.8 ft-NAVD. The top of limestone was encountered at elevation 7.0 ft-NAVD, and the bottom elevation was -6.0 ft-NAVD. The low water levels at both MW-29W and 29E, and the lower groundwater elevations in the deep well MW-29E, combined with limestone at depths similar to the water column depth in Gator Slough indicate that Gator Slough may be pulling water from southern Yucca Pens underground and a factor leading to low water levels in the southern portion of Yucca Pens. The complications of seepage combined with drainage from eroded ATV trails allow wet season water levels to drop quickly after rainfall events causing peak stages to rarely reach the overflow elevation of the concrete weir that is adjacent to the monitoring wells. The data collected from Yucca Pens monitoring wells indicate that Yucca Pens hydrology is below optimum conditions.

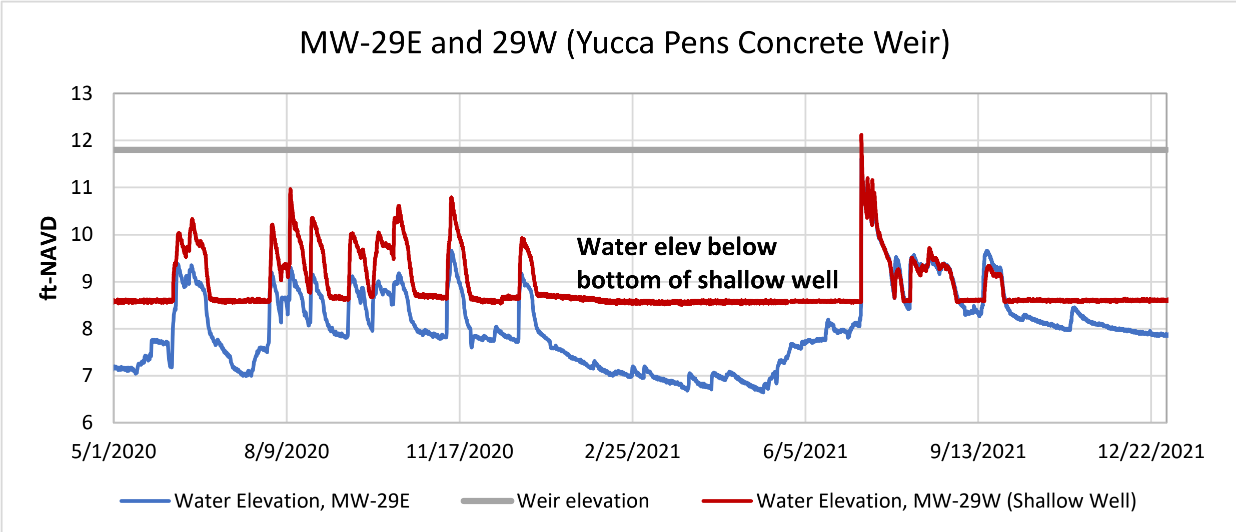


Figure 3-16. Measured Water Levels at MW-29 Adjacent to Concrete Weir in Southern Yucca Pens

Figure 3-17. Concrete Low-water ford in South Yucca Pens

4) DATA COLLECTION

4.1 DATA DOWNLOADS, QUARTERS 1 THROUGH 6

Groundwater monitoring was conducted from early May 2020 through mid-November 2021 at Babcock Webb groundwater monitoring stations BW-1 through BW-20 and at Yucca Pens stations YP-3 through YP-6. Water level monitoring was also completed at Babcock Webb staff gages SR-2, SP-4, -5, -6, -7, -8, -9, and SP-10 (for station locations, see **Figures 2-1** and **2-2**). The full monitoring data collected during each quarter with analyses and graphs of measured data and can be found in **Appendix 4A–F**. This analysis also includes data collected at monitoring stations installed by FWC prior to the initiation of this project, such as STA-6, STA-7, and STA-8.

Graphs of measured data for all stations are provided again in **Appendix 6A**. Graphs of measured data for a few select stations are provided below. The purpose of these graphs is to illustrate the range of water levels across Babcock Webb and Yucca Pens as well as to illustrate how anthropogenic changes to the landscape impact area hydrology.

The greatest variation between wet and dry season water levels was 6 ft at SP-4, the North Alligator Creek gated weir structure. Leakage through the underflow gates is the most likely reason for the higher variability observed at this station. **Figure 4-1** illustrates that water level variability at SP-4 (> 7 ft) is greater at than the upstream stations BW-9 (5 ft) and SP-5 (4 ft). Station SP-4 is located at a corrugated metal pipe (CMP) riser structure that likely minimizes water level variability.

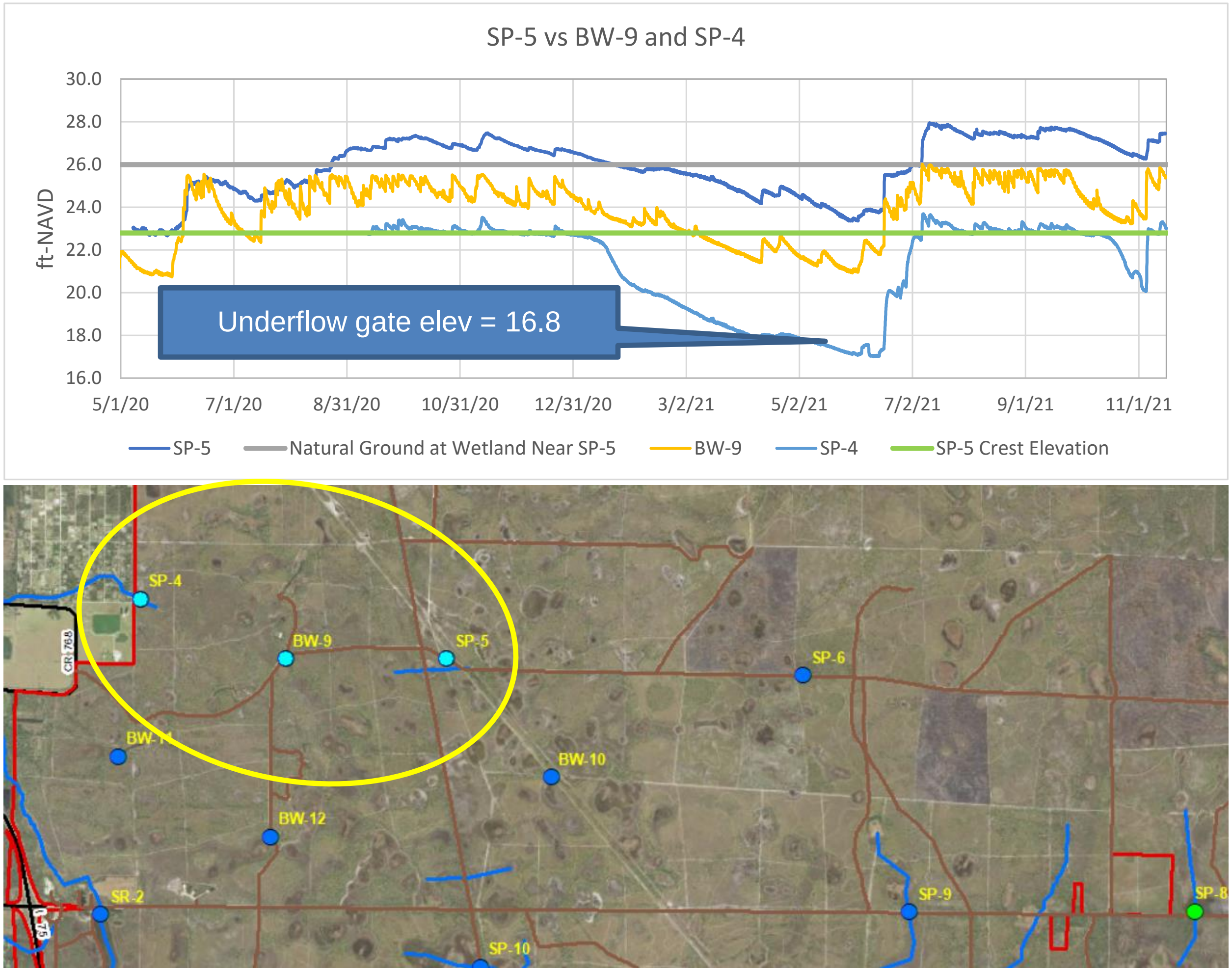


Figure 4-1. Measured Water Levels and Station Locations for SP-5, BW-9, and SP-4

Figure 4-2. Stations SP-4 (top left), SP-5 (top right), BW-9 (bottom left), and BW-10 (bottom right)

Babcock Webb water levels varied the least at stations located at the downstream limit of water storage areas, such as station SR-2 at the Webb Lake weir at Tuckers Grade (**Figure 4-3**). BW-12 wet season water levels (**Figure 4-4**) show greater short-term variability than water levels at SR-2. It is possible that the drainage effects of the North Prong Alligator Creek underflow gates impact dry season water levels at stations BW-9 (**Figure 4-1**) and BW-12.

Wet season water levels at station SP-8 at the Big Island Weir on eastern Tuckers Grade were relatively constant (**Figure 4-5**, see **Figure 4-1** for station locations). Dry season water levels at the Big Island Weir drop significantly due to the height of the CMP riser structure at SP-8. Water levels increase 5 feet from the dry to wet season at SP-8 due to the height of the riser and the elevation of the low water ford adjacent to the riser.

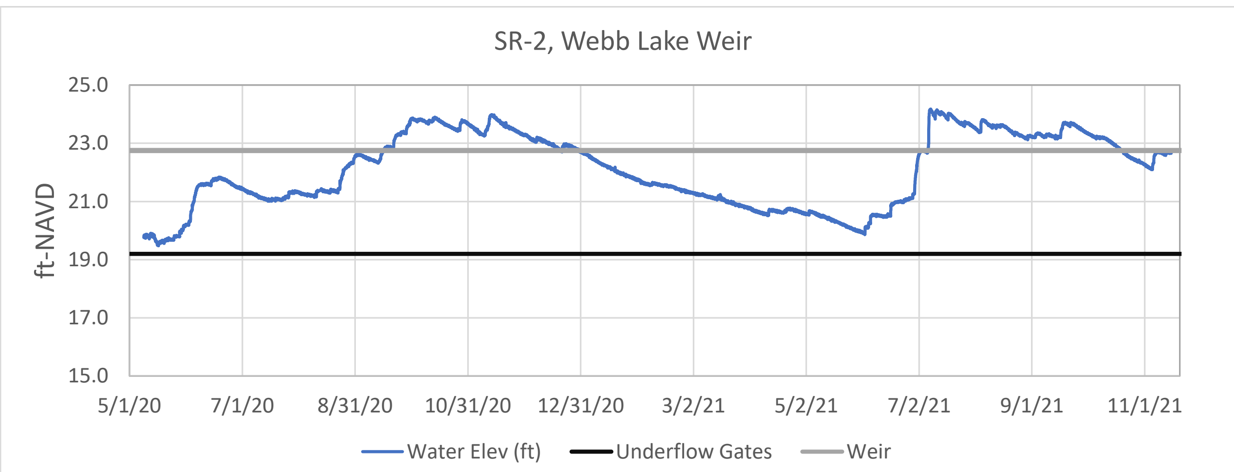


Figure 4-3. Measured Water Levels at Station SR-2 at the Webb Lake Weir

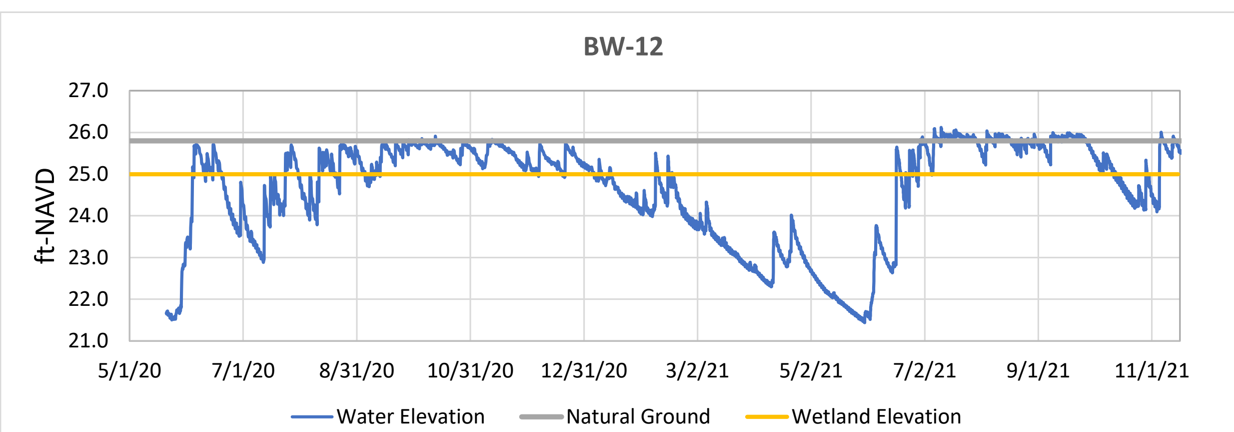


Figure 4-4. Measured Water Levels at Station BW-12, Northeast of SR-2

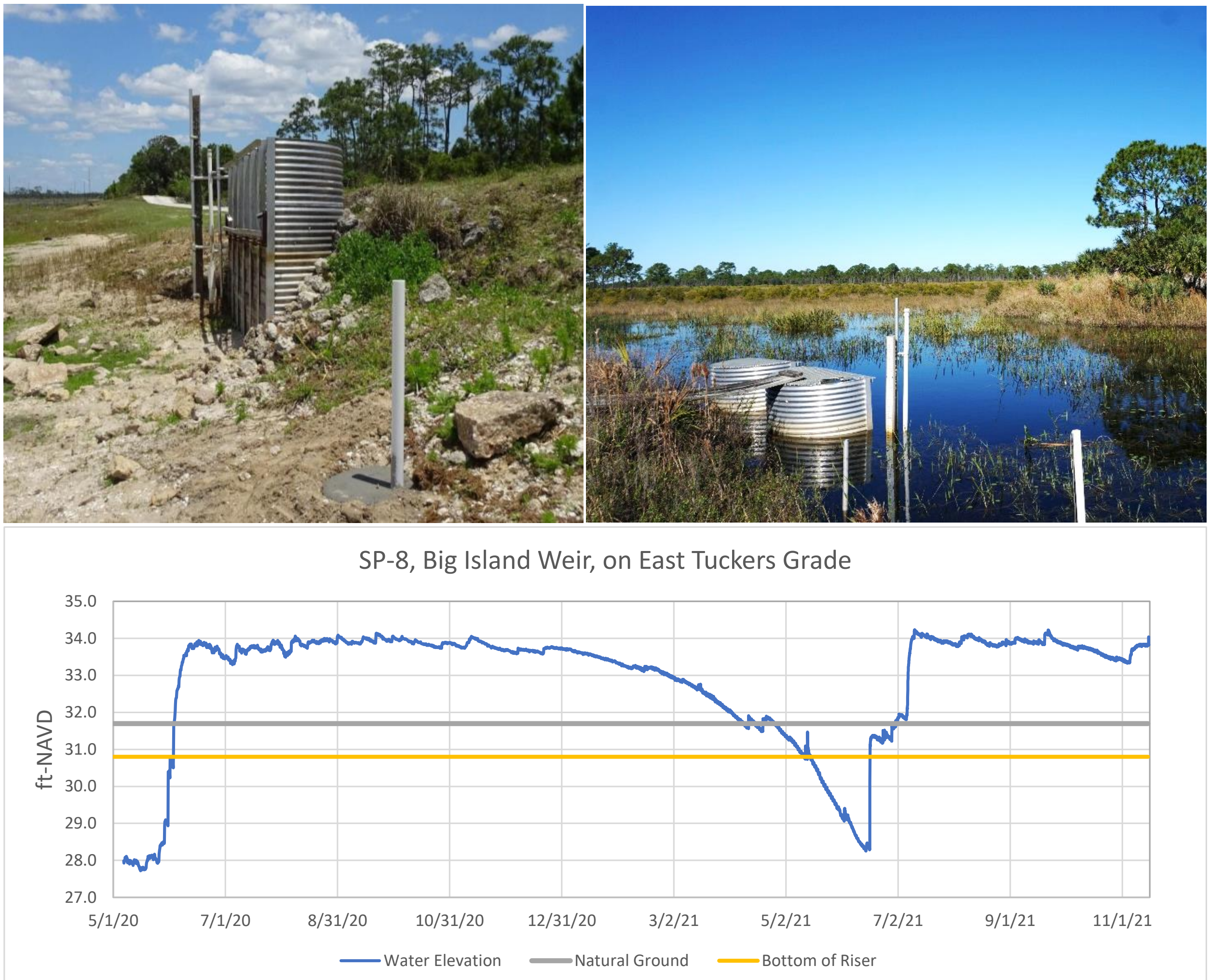


Figure 4-5. Measured Water Levels at Station SP-8 at the Big Island Weir

SP-9 is a CMP riser on the north side of Tuckers Grade, and BW-15, STA-7, STA-8, and STA-6 are located southwest of SP-9, with the STA stations located in the SWIA (data and locations shown in **Figure 4-5**). Wet season water levels vary least at SP-9, most likely due to the riser structure and impoundment effect of Tuckers Grade Rd. Water levels are all relatively similar at BW-15 and the STA stations, most likely due to the impounding effect of Stolle Ranch (south of SWIA), the current Bond Farm berm, and a general lack of outflow conveyances around the gun firing range north of Bond Farm and the Charlotte Correctional Institute (CCI) west of Bond Farm (MW-CCI is a monitoring well on the CCI).

The data presented for SP-9, BW-15, and the STA stations indicates the benefit of coordinated monitoring at existing FWC monitoring stations and monitoring stations described in **Section 2**.

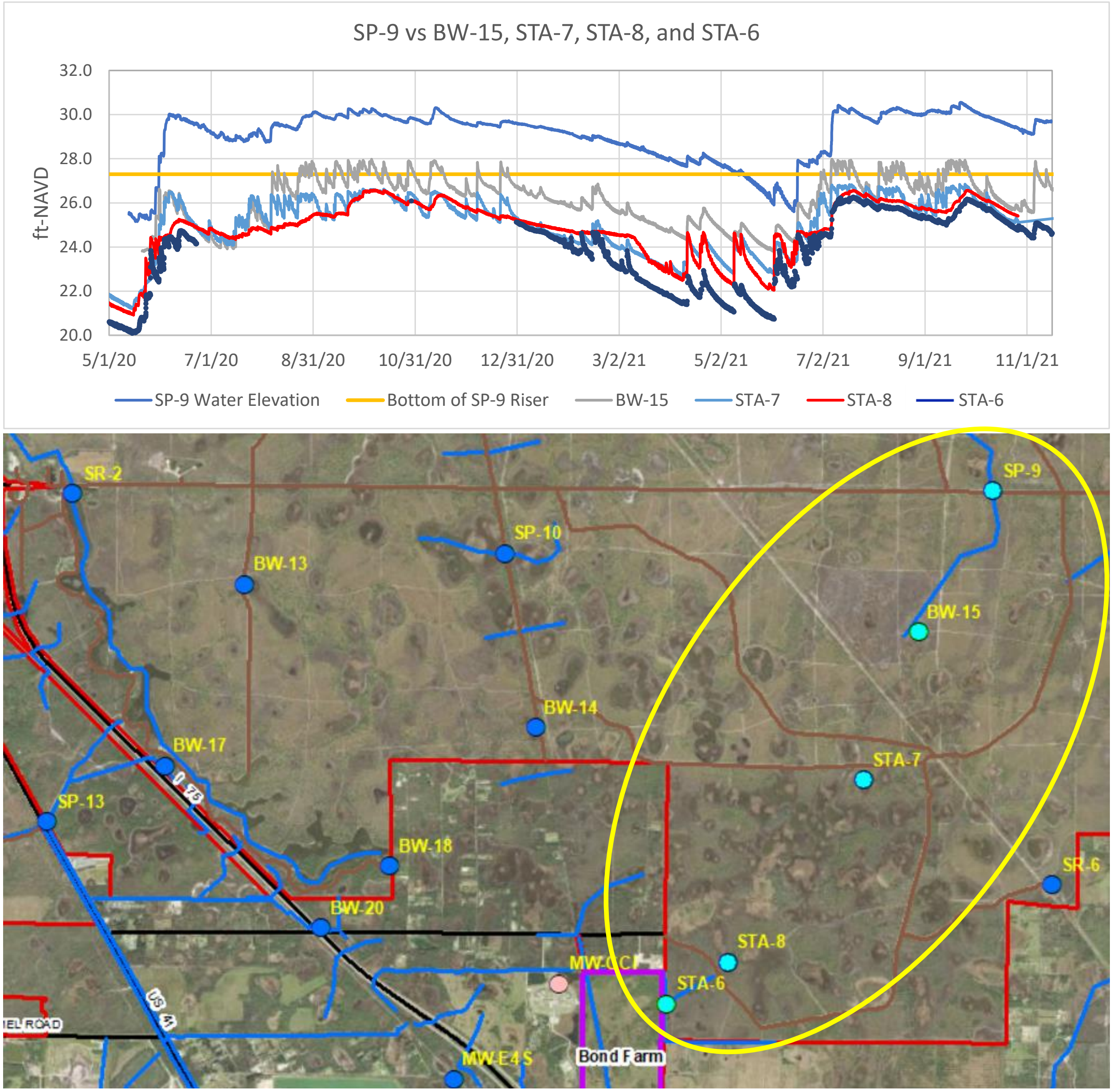


Figure 4-6. Measured Water Levels at Station Locations for SP-9, BW-15, and STA Stations

Figure 4-7. STA-6 (top left), BW-15 (top right), SP-9 CMP Riser Dry Season (bottom left), and SP-9 December 2021 (bottom right)

Water levels in Yucca Pens station YP-3 (**Figure 4-8**) were rarely above the edge of cypress at YP-3, which is also the ground elevation at YP-3. Data from this station confirms the findings above indicating that water levels in Yucca Pens cypress are below optimum conditions. Measured water levels at YP-4 (**Figure 4-9**), located on the eastern edge of Yucca Pens, exhibited water level variations of 1 to 2 feet in between rain events during the wet season, frequently dropping below the ground level of adjacent wetlands, suggesting hydrologic alteration due to off-site conveyance via ATV trails.

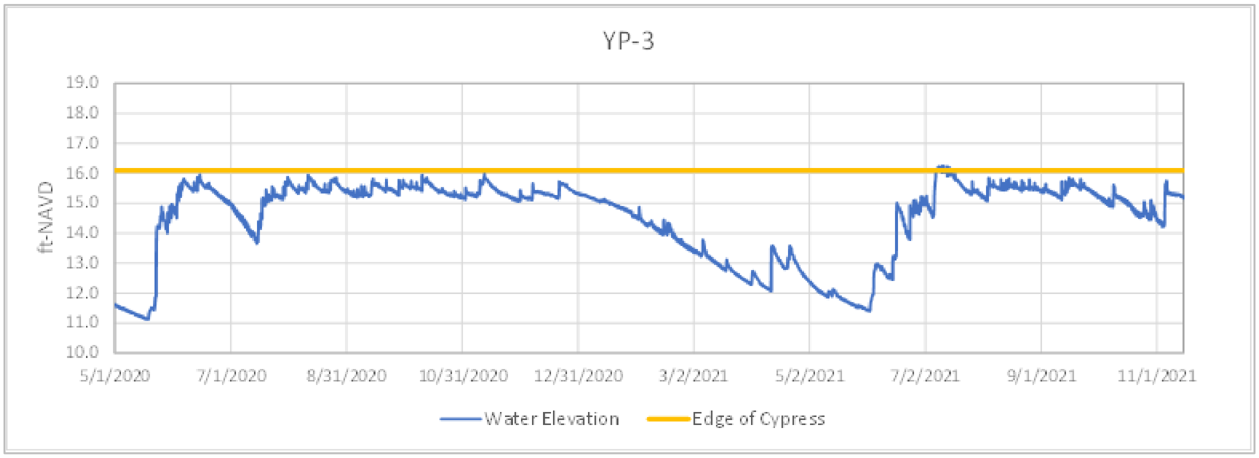


Figure 4-8. Measured Water Levels at Station YP-3

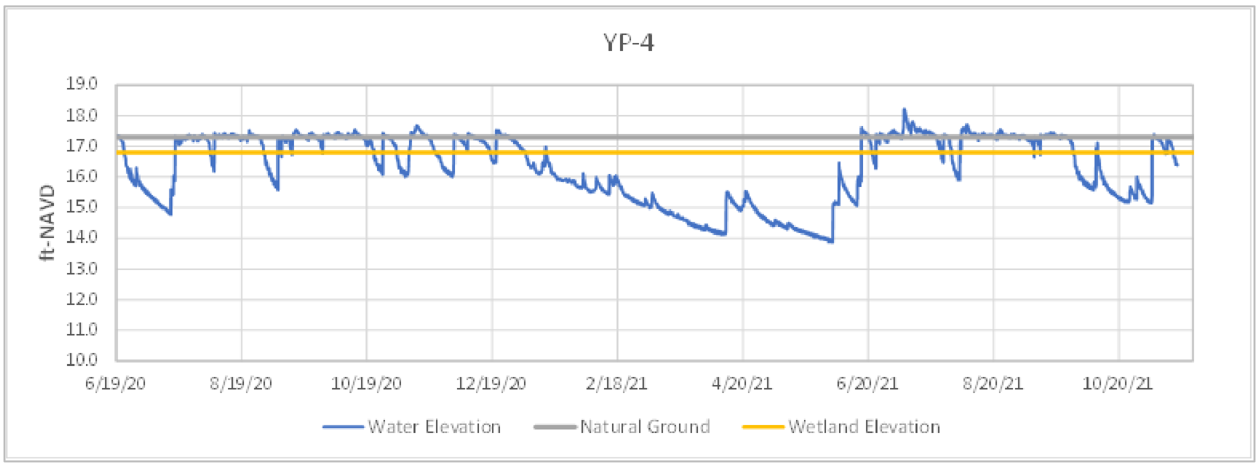


Figure 4-9. Measured Water Levels at Station YP-4

4.2 Flow Rating Curves

The collected flow measurement data yielded flow rating curves that were suitable for use in estimating stream flows. Flow rating curves were developed for Alligator Creek at South Jones Loop Road, Zemel Canal upstream of Burnt Store Road (BSR), Bear Branch at BSR, Hog Branch at BSR, Yucca Pens Creek at BSR, Yucca Pens Creek west of BSR (tidal station), Durden Creek at BSR, and Greenwell Branch at NW 36th Avenue in Cape Coral. Flow rating curves for all of the stations mentioned above are provided in **Appendix 4G**. The stage/discharge plots for Zemel Canal and Hog Branch presented in **Figures 4-10** and **4-11** are good examples of typical flow rating curves. **Figure 4-12** for Greenwell Branch is an example of a flow rating curve that is impacted by external factors. The Greenwell Branch station is located within the Cape Coral canal system and the canal dimensions both upstream and downstream are wider and deeper than the other flow monitoring stations that were part of the monitoring program. The additional channel storage associated with the Cape Coral canal system is the likely explanation for the atypical stage/discharge relationship. **Figure 4-13** provides photographs of selected flow monitoring stations.

Note: CFS = cubic feet per second

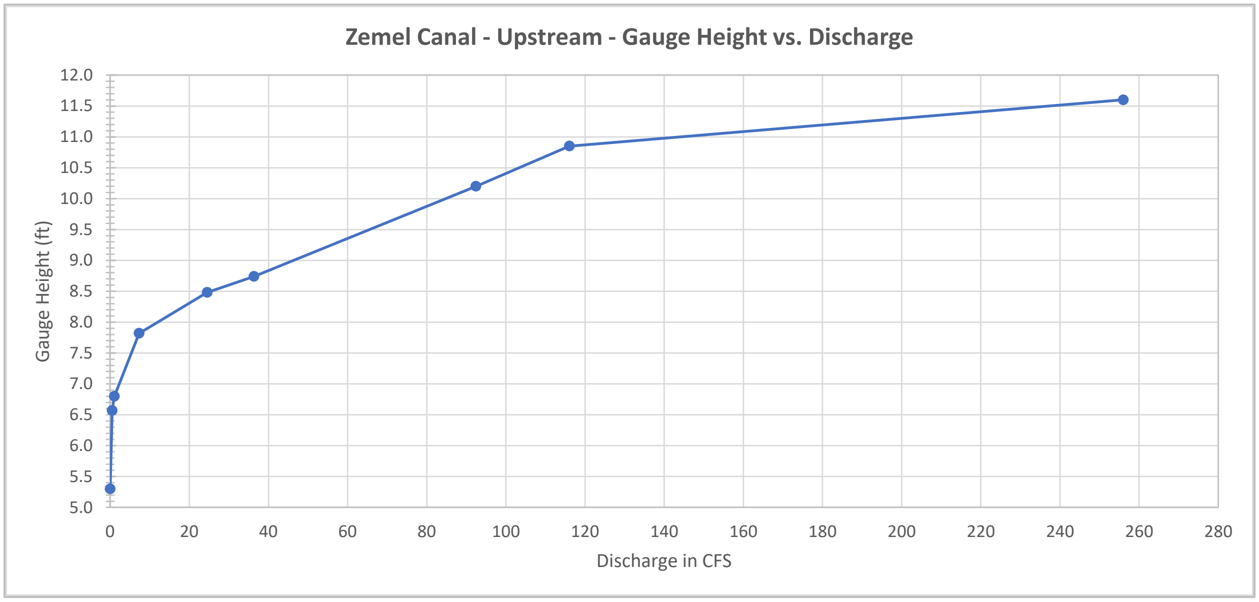


Figure 4-10. Stage/Discharge Relationship for Zemel Canal Upstream of Burnt Store Road

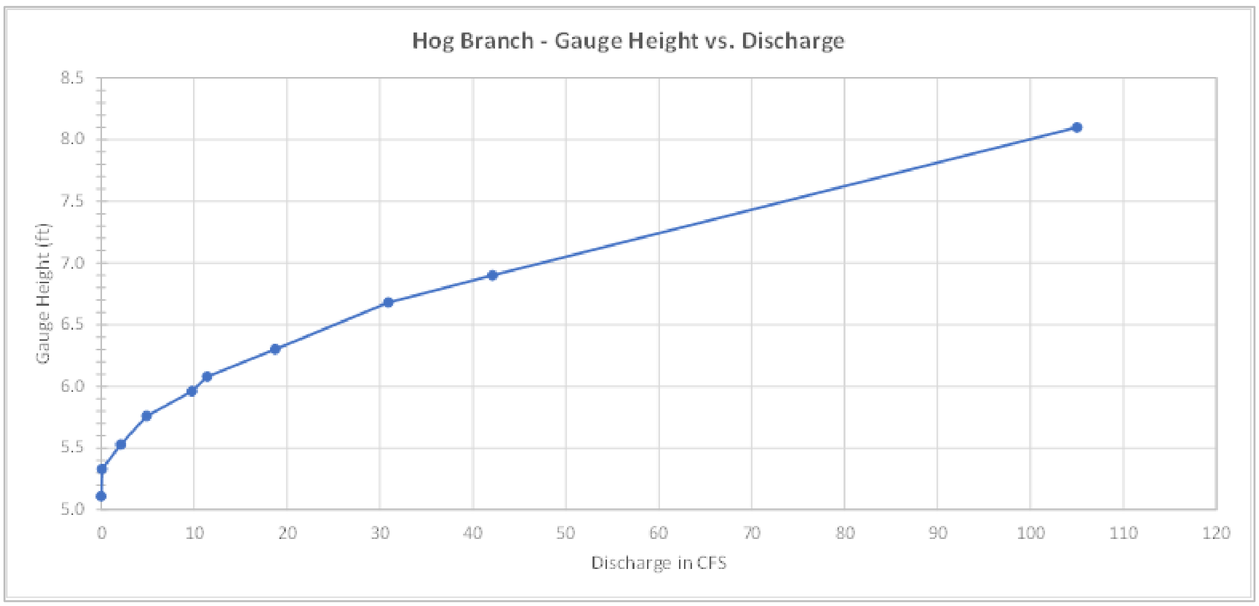


Figure 4-11. Stage/Discharge Relationship for Hog Branch Upstream of Burnt Store Road

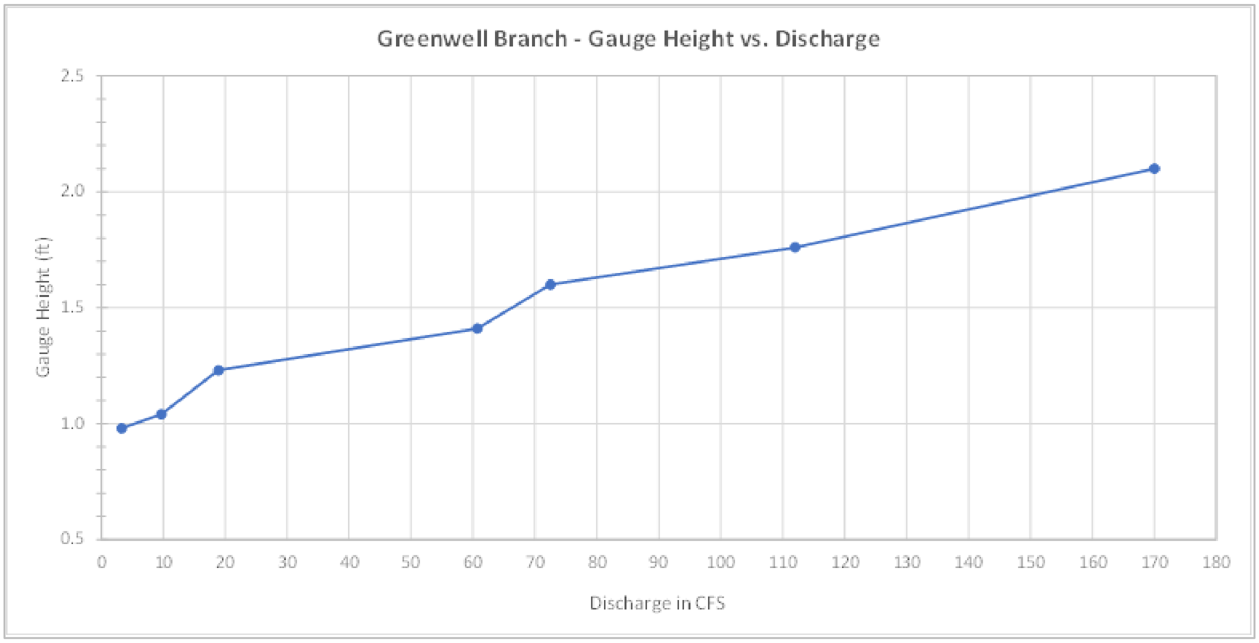


Figure 4-12. Stage/Discharge Relationship, Greenwell Branch, NW 36th Ave, Cape Coral

Figure 4-13. Hog Branch (top left), Bear Branch (top right), Yucca Pens Creek (bottom left), and Durden Creek (bottom right)

Rainfall Data. Rainfall data for the three stations installed as part of this project as well as data from nearby rainfall monitoring stations are presented below in Table 4-1 and Table 4-2. Rainfall data was used to assist the project team in interpreting results from the hydrologic monitoring program. For example, measured rainfall data were used to confirm that abnormal water levels corresponded to abnormal rainfall in 2020, when other factors did not indicate why water levels were atypical.

Table 4-1. Monthly Rainfall Totals for all Monitoring Stations in Vicinity of Babcock Webb and Yucca Pens. (Sum.-Monthly Total in inches)

	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.
Month	Lake Fairways	Popash Ck	Yellow Fev Ck	Big Is Weir	BSR FS #7	CW RG-1	CW RG-2	CW RG-3	N_Char	ROMP TR 1-2	Weir 19	Weir 4
5/2020	9.06	5.88	3.99	5.53	7.11	7.59	6.11	6.55	8.03	5.6	7.99	2.49
6/2020	9.73	5.96	8.48	5.18	11.21	7.26	7.89	6.48	8.05	6.94	8.7	N/A
7/2020	5.39	5.38	4.59	3.82	5.71	6.37	6.43	5.81	4.57	4.34	8	N/A
8/2020	7.9	6.11	7.93	7.32	4.89	8.99	9.73	8.23	4.86	9.41	8.51	N/A
9/2020	8.26	16.75	10.03	10.42	9.78	8.23	8.37	11.29	9.89	5.73	8.8	N/A
10/2020	5.02	5.23	3.73	3.94	3.44	6.32	4.31	4.8	4.26	4.97	5.13	3.98
11/2020	6.72	6.76	5.37	4.44	4.53	4.5	4.33	3.97	5.18	4.48	7.08	0.11
12/2020	4.5	4.29	2.55	2.81	4.08	3.07	2.63	3.37	4.19	3.06	4.7	1.24
1/2021	0.25	0.22	0.22	0.18	0.19	0.39	0.24	0.2	0.13	0.33	0.21	0.19
2/2021	1.32	2.13	1.05	1.85	0.39	1.23	2.04	1.32	0.81	1.09	0.83	0.65
3/2021	0.87	0.89	0.47	0.58	0.28	0.47	0.45	0.44	0.42	0.37	0.84	0.55
4/2021	4.1	3.74	2.9	4.87	3.14	3.62	3.44	3.31	3.61	3.2	3.95	3.01
5/2021	1.65	0.92	0.83	0.41	0.64	0.28	0.81	3.52	0.67	0.22	1.19	0.46
6/2021	9.71	11.74	6.74	9.12	11.32	10.85	7.9	8.62	12.24	14.02	8.79	7.69
7/2021	18.38	11.86	11.94	12.81	12.15	14.63	10.86	12.01	13.71	13.57	15.35	12.46
8/2021	10.53	8.37	7.92	10.55	8.11	7.65	7.28	4.64	10.43	8.75	9.03	10.43
9/2021	10.45	8.43	8.79	11.21	5.19	5.9	7.53	7.49	3.4	5.46	4.55	3.4
10/2021	1.99	3.07	3.03	3.53	2.84	2.07	1.37	2.14	3.56	0.94	2.22	3.56
11/2021	4.02	4.35	2.71	2.91	3.51	4.88	3.01	3.02	2.96	4.07	4.25	2.96

Table 4-2. Rainfall Data for installed BW-18, SR-7, and SP-5

	Sum, in	Sum, in	Sum, in	Sum, in
Month	Avg of Other Gages	BW-18_R	SR-7_R	SP-5_R
5/2020	6.33	6.76	1.64	3.28
6/2020	7.81	5.35	8.83	7.43
7/2020	5.49	3.73	7.51	5.56
8/2020	7.63	7.36	3.44	4.87
9/2020	9.78	9.20	N/A	2.56
10/2020	4.59	5.74	N/A	2.93
11/2020	4.79	4.67	N/A	1.85
12/2020	3.37	0.03	N/A	0.63
1/2021	0.23	0.00	N/A	N/A
2/2021	1.23	0.65	NR	0.44
3/2021	0.55	0.30	NR	0.31
4/2021	3.57	1.78	NR	0.03
5/2021	0.97	N/A	N/A	N/A
6/2021	9.90	N/A	N/A	N/A
7/2021	13.31	N/A	N/A	N/A
8/2021	8.64	N/A	N/A	N/A
9/2021	6.82	8.04	5	9.65
10/2021	2.53	0.97	1.21	1.21
11/2021	3.55	3.6	3.06	6.63

Note: Average values in yellow-highlighted cells do not include stations with incomplete information

4.3 Final Data Delivery

All data collected as part of this monitoring effort was delivered to the CHNEP in digital format and will continue to be made available upon request through the CHNEP Water Atlas. These data were also converted into a format required for model calibration. Details of the final data delivery are provided in **Appendix 4H**. The combination of data collected as part of this study as well as data available from other monitoring efforts provides a large dataset available for model calibration.

5) Model Calibration and Existing Conditions Model

The model calibration was an effort of Water Science Associates and Lago Consulting. While a formal independent peer review of the model was not performed for this project, Water Management District modeling staff conducted extensive review of model inputs and outputs as well as this final report and the model technical memos that serve as appendices to report.

5.1 Updated Model Files

The model calibration utilized data from the data collection effort that commenced in May 2020 along with data from existing stations. Because the new 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. The model uses estimates of initial water levels for all groundwater cells within the model domain. Since initial water levels were not known, the standard practice for model simulation is to begin the simulation well before the calibration period, and therefore this model simulation started on January 1, 2020 to minimize the impacts of estimating initial water levels. This modeling effort used the latest version of the MIKE SHE/MIKE 11 software from 2017 and the calibration simulation runs were conducted using the 2020 software version.

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 north to CR 74, Bermont Rd, as shown in **Figure 5-1**.

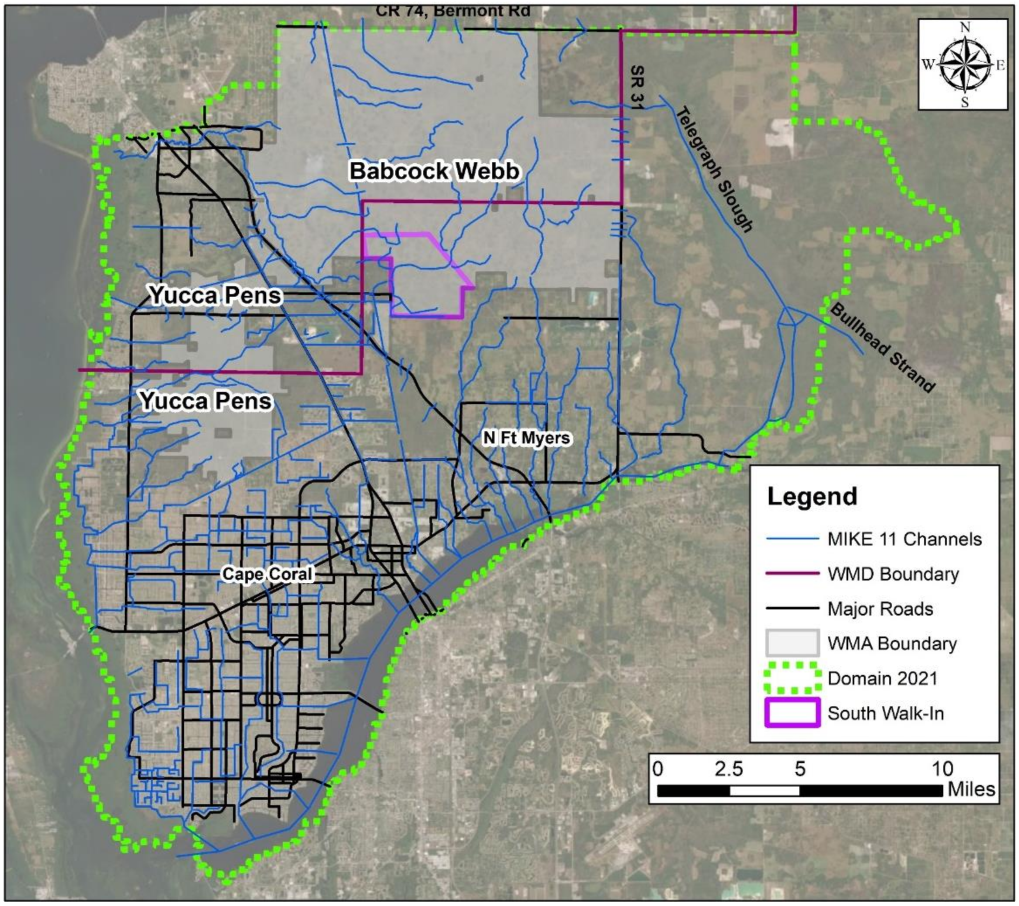


Figure 5-1. MIKE SHE Model Domain

Model Grid and Topographic Data. The model grid cell size is 750 feet by 750 feet with a total of 25,753 active cells. The topographic data set used for this project was developed by SFWMD in 2016 for the Charlotte Harbor Flatwoods Initiative (CHFI). The topographic data includes Light Detection and Ranging (LiDAR) survey data from Lee County and Charlotte County. LiDAR elevations in low-lying areas (which are frequently flooded) of the SWIA of Babcock Webb were inaccurate because LiDAR measures the water surface rather than ground elevations. Therefore, LiDAR elevations in low-lying portions in this area were lowered by 1.5 feet based on transect surveys performed for FWC. Details can be found in **Appendix 5A**. 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 includes recent changes in the topography and provides greater detail in low lying areas and roadside ditches. A decision was made to include new LiDAR data into the Digital Elevation Model (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.

Climate. Next Generation Weather Radar (NEXRAD) hourly rainfall data was used in the modeling effort. The grid size of this rainfall dataset is 2x2 kilometers. Reference evapotranspiration (ET) daily data were obtained from the United States Geological Survey (USGS) webpage. These data are also distributed in a 2-kilometer grid.

Vegetation and Land Use. Most of the model domain used 2014-2016 land use data available from SFWMD. Land use information for northern portions of the model domain were obtained from SWFWMD. FWC vegetation land cover information was used for the areas within Babcock Webb and Yucca Pens.

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. The MIKE 11 files include a network file that defines flow pathways, cross sections that define channel and flow-way dimensions, and channel roughness coefficients. Extensive field work was conducted to confirm the flow pathways within the study area. Over 120 surveyed cross sections were obtained from a variety of sources, including a study for FDOT (ADA, 2013), modeling work for Cape Coral that provided surveyed cross sections of Gator Slough and US-41 ditches (WSA, 2017), and investigations for FWC (SED and WSA, 2019).

Overland Flow Parameters. MIKE SHE uses a number parameters to manage communication between MIKE 11 and MIKE SHE, such as flood codes (used to govern exchanges during high flow periods), separated flow areas to limit overland flow across berms and roads, overland flow bed roughness, and detention storage. Details are provided in **Appendix 5A**.

Unsaturated Zone. 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. The Richards Equation method is used in this model, which is the most detailed computation approach for the infiltration process. Soils information was obtained from the Natural Resources Conservation Service (NRCS) Soil Survey webpage.

Saturated Zone. 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 hydrogeological 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.

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 accurately 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. Calibration station locations are shown in **Figures 5-2** and **5-3**. Note that the color of the monitoring station icons represents final calibration performance.

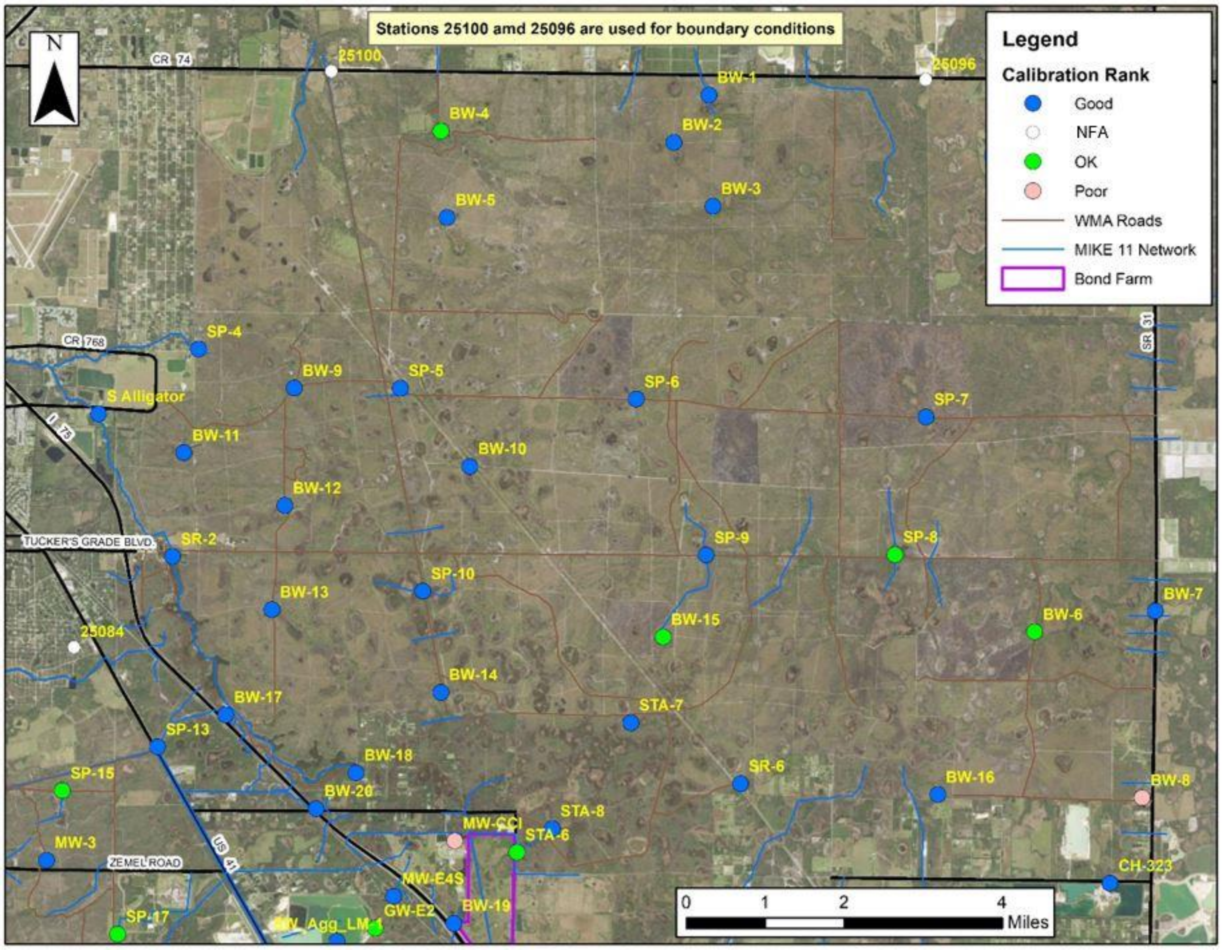


Figure 5-2. Calibration Stations and Model Performance in North Portion of Study Area

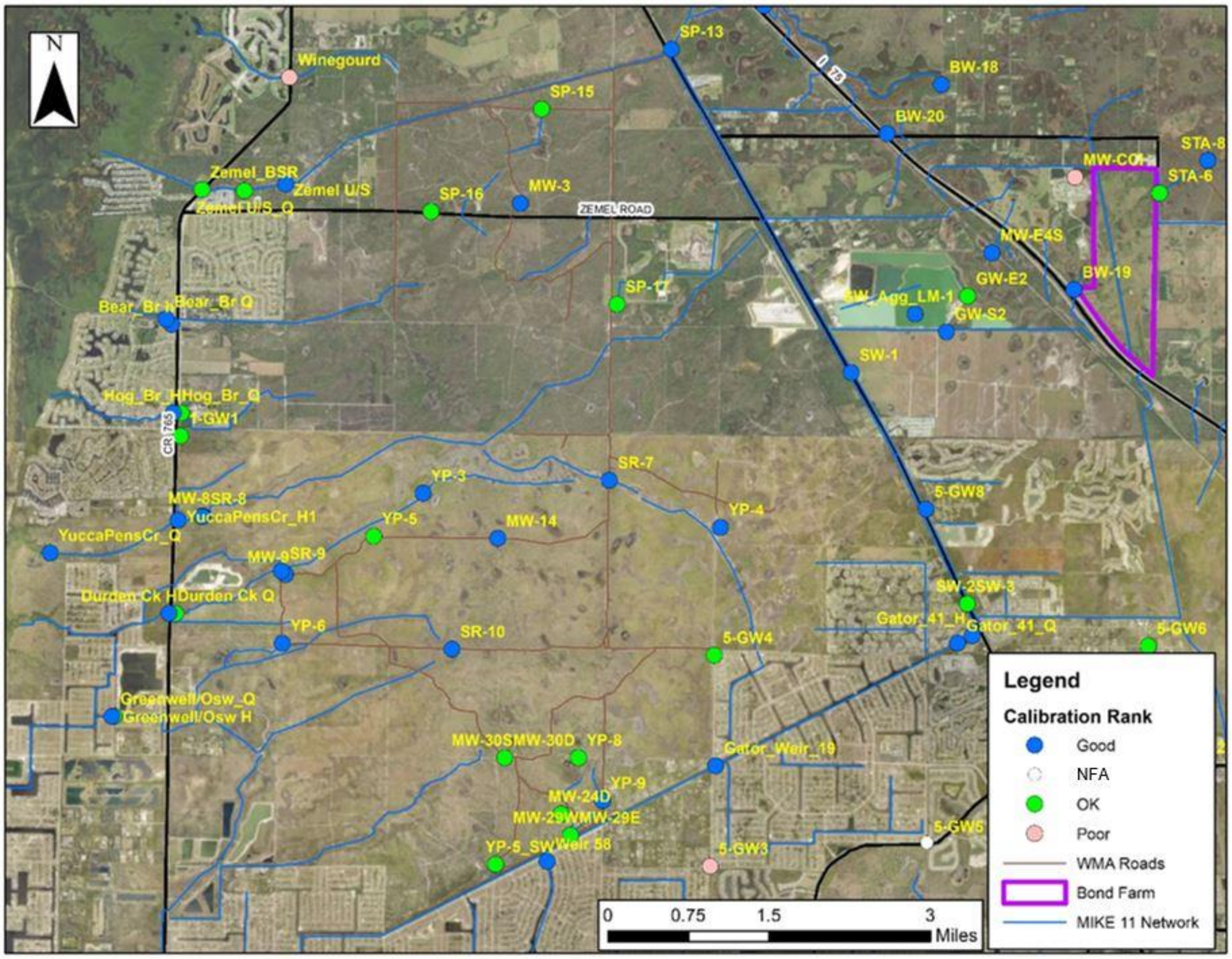


Figure 5-3. Calibration Stations and Model Performance in South Portion of Study Area

The calibration period was May 15, 2020 through November 15, 2021, which was the period that data were available for the stations installed as part of this project. Calibration within Cape Coral is limited to improving model performance in Gator Slough since hydrology of Cape Coral canals south of Gator Slough has limited to no impact on Yucca Pens hydrology. In addition, a number of calibration stations are located in North Fort Myers (see **Figure 5-1** for the location of this area). Calibration in North Fort Myers was limited since this area does not have a significant effect on model performance in the Babcock Webb WMA.

5.2 Initial Model Calibration

Model calibration initially focused on refinement of input data, such as identifying areas where flows were restricted due to heavy vegetation in channels or revising culvert dimensions based on more recent information. Several field visits were conducted during this period to confirm field conditions. Details of these efforts can be found in **Appendix 5C**.

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

- Testing differing computation methods for the unsaturated zone

- Modifying groundwater hydraulic conductivities
- Evaluating leakance coefficients that govern interactions between the 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 US-41).

Water balance tests were conducted to test several different unsaturated zone computation methods, and it was decided that the most advanced method (Richards Equation) should be used. Groundwater horizontal and vertical hydraulic conductivities were initially set to uniform values since most efforts were focused on improving the physical representation of hydrologic conditions. Once the majority of input file refinements had been completed, 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.

5.3 Analysis of Calibration Performance

The focus of calibration was to match simulated values to measured values of head elevation (also referred to as water elevation) in the saturated zone, water elevations in MIKE 11 branches, and flows. The primary calibration metrics were Mean Absolute Error (MAE), correlation coefficient (r or R_Corr), and Nash Sutcliffe coefficient (R2 NS). Calibration performance was ranked according to the following criteria that were agreed to in consultation with staff from SFWMD and SWFWMD during the initial calibration effort:

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

Groundwater hydraulic conductivities were varied spatially to improve calibration. Two simulations were run varying horizontal and vertical conductivity values by a factor of 1.2 and 0.8. A statistical comparison using mean absolute error (MAE) was made for the initial simulation and the two sensitivity tests (1.2 and 0.8) at all calibration stations. After a review of the results, conductivities in the vicinity of each station that demonstrated improved calibration were modified to be either 0.8 or 1.2 times the original estimated conductivity. Successive sensitivity test simulations were conducted again using 0.8 and 1.2 multipliers of conductivities. Conductivities were adjusted throughout this series of simulations until there were no further improvements in calibration. Further explanation of the calibration effort is provided below. Note that correlation coefficient (r) and Nash Sutcliffe (NS) coefficient values were also checked throughout this effort. Typically, the correlation coefficient and NS coefficient values improved as MAE improved. However, performance for all three statistical measures was taken into account throughout the calibration process.

At each station, hydraulic conductivities were unchanged if there was no change in calibration performance (as measured by MAE) between the starting simulation and the high and low sensitivity tests. When the calibration performance improved either by increasing or decreasing hydraulic conductivity, the area surrounding that calibration station was modified accordingly using the Inverse Square Distance method. This process was repeated until there were no further improvements in overall model calibration. Note that calibration was only considered good when 2 of 3 metrics (MAE, correlation coefficient, NS coefficient) met the calibration criteria. If MAE improved but correlation deteriorated, this was an indication of an incorrect representation of either surface or ground water dynamics, which led to further review of model input data.

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, as described above. Overall, average 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 NS coefficient was 0.34. Average r for flow stations was 0.82 and NS was 0.62. Model performance far exceeded the good threshold in many key areas near Babcock Webb and Yucca Pens, such as Gator Slough at Weir 19, Zemel Canal upstream of Burnt Store Road (BSR), 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 SWIA, 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).

Model calibration performance is summarized in **Table 5-1**. In this table, blue highlighting indicates good calibration, green indicates OK, and pink indicates poor. A number of stations in **Figure 5-2** and **5-3** are shown as NFA (Non Focus Area). Those stations are either stations used to establish boundary conditions for the model 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) and do not affect the ability of the model to properly represent conditions in the WMAs. The summary of calibration performance indicates that 64% of the stations have **Good** calibration and 31% have **OK** calibration. More detailed information on model calibration is presented in **Tables 5-2** and **5-3** (ME: Mean Error; RMSE: Root Mean Square Error; STDres: Standard Deviation residual; G: Good; other statistics defined above).

Overall, model performance is **Good** with many stations performing substantially above the minimum standards for good calibration (minimum standards for good calibration outlined above). Based on the statistical analysis of the model calibration, it was determined by the modeling team that the model was ready for scenario analysis.

Table 5-1. Summary of Model Calibration Performance

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

Table 5-2. 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 5-3. 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

5.4 Existing Conditions Model Results

5.4.1 Baseline Model Modifications

The final calibrated model was converted to a baseline existing-conditions model by incorporating the modifications described below. Results from the baseline existing-conditions model will be used to better understand areas of current management concerns and to compare current conditions to results from proposed future alternative management scenarios.

The calibrated model input files were used as a starting point for this analysis, with modifications to allow the model to simulate conditions outside of the May 2020 – November 2021 calibration period as described below:

- To minimize initial conditions issues, a 2-year model simulation period was run for January 2020 through November 2021.
- The 2-year simulation period was increased to 10 years. The calibrated model ran for May 2020 through November 2021, and the baseline model ran from January 2011 through January 2021. This longer period includes 9 more years of climate variability data inputs.
- Time series files were extended to cover the new simulation period (e.g. rainfall, ET), pumpage files for groundwater withdrawals, rooted depth and leaf area index values).

For Gator Slough Weirs 11 and 19, the calibrated model utilized known gate level positions provided by the City of Cape Coral. The gates at these two weir structures were modified to operate according to known gate operation protocols (Personal Communication, J. Walter, City of Cape Coral, 2020). Other specifications were made to Cape Coral structures to enable the simulation to run for the 10-year period listed above, which are outlined in **Appendix 5D**.

5.4.2 Hydroperiods and Wet Season Depths

Hydroperiod is defined as the number of days per year that water depths are more than 0.1 feet above ground surface. Hydroperiod units used in this study are months, which is days/year divided by 12 months. **Figures 5-4** and **5-5** present the spatial distribution of simulated hydroperiod durations in Babcock Webb and Yucca Pens in the baseline existing-conditions model. **Figures 5-6** and **5-7** present mean water depth during the wet season (i.e., from July 1st through October 15th) in Babcock Webb and Yucca Pens, respectively. These maps were produced at a finer spatial resolution by comparing the simulated water levels each day in the 750-ft model grid with the 50-ft resolution topography. Note that the definition of the wet season differs from the definition used in calibration (July 1st through November 30th) associated with this project. The hydroperiod used in calibration was based on observed rainfall patterns for 2020 and 2021 which experienced a late initiation of the wet season with rainfall continuing into December for 2020 and November for 2021. The analysis for the baseline simulation of 2011 through 2020 uses a more common definition of the wet season (i.e., from July 1st through October 15th) since rainfall patterns varied across the simulation period and did not always have the patterns observed in 2020 and 2021.

Currently, hydroperiods in the SWIA are commonly greater than 10 months, meaning that water depths are more than 0.1 feet above ground surface for at least 10 months out of the year. The optimal hydroperiod for these wetlands is between 6 to 10 months (optimal conditions defined in Section 3), and therefore the SWIA is currently too wet. Conversely, the optimal wet season water depth in southern Yucca Pens is between 0.5 to 0.8 ft and therefore the southern portion of Yucca Pens is currently too dry, with current peak wet season water depths less than 0.3 ft. In the cypress wetlands of Yucca Pens, current wet season water depths are commonly less than 1 foot. Ideally, the wet season water depth in cypress wetlands would be around 1.5 ft, indicating that Yucca Pens cypress wetlands are also too dry.

These results confirm and quantify stated management concerns and hypotheses that hydroperiods in Babcock Webb are longer than optimal due to blocked historic (pre-development) flow-ways, especially in the SWIA of Babcock Webb, resulting in negative impacts to vegetation as well as quail and other species. Additionally, hydroperiods in Yucca Pens are shorter than optimal due to the blocked flow-ways from Babcock Webb as well as accelerated outflows via eroded ATV trails. Yucca Pens reduced wetland wet season water depths negatively impact existing vegetation, including cypress domes.

The next section of the report will compare changes in hydrology from the existing baseline conditions model to modeled future potential management scenarios to identify how to best address management concerns outlined above and support recommendations for management while accounting for future climate impacts. These hydroperiods will also be compared to pre-development reference maps created in a Natural Systems Analysis with the goal of meeting natural systems need to the extent possible.

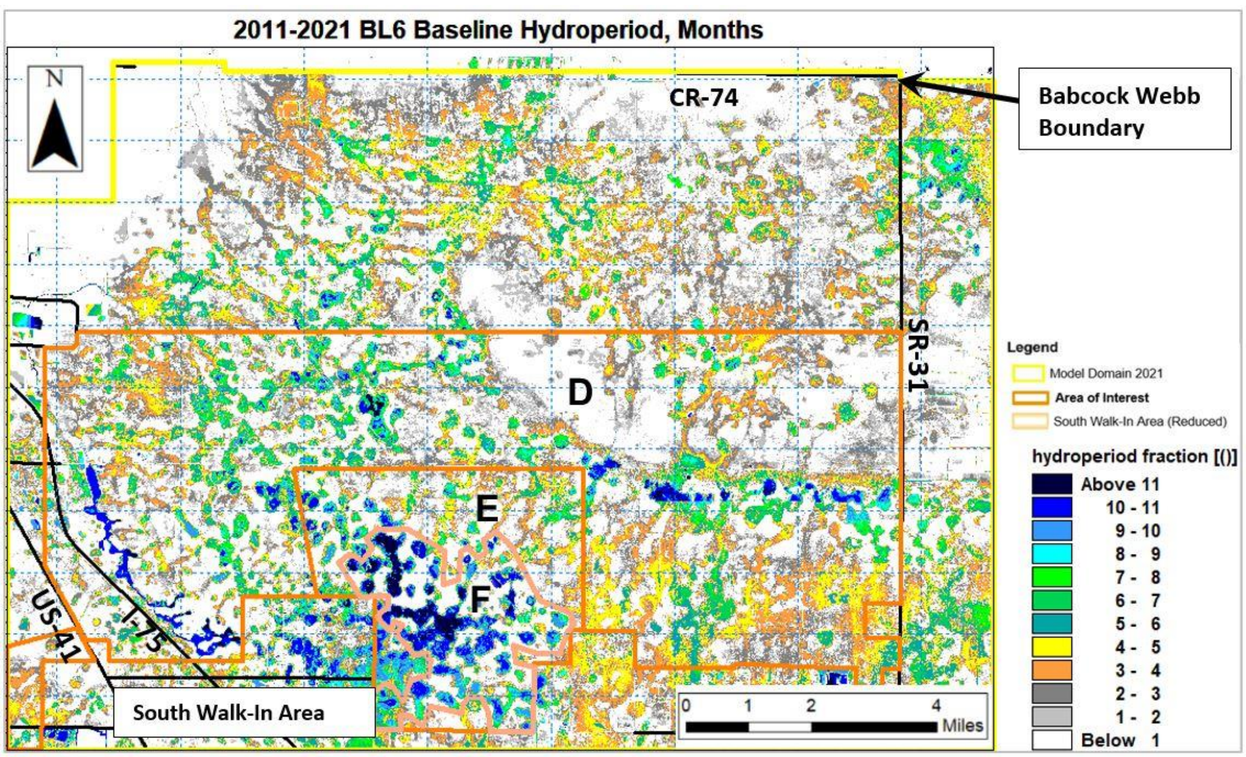


Figure 5-4. Average annual hydroperiod duration in Babcock Webb as predicted by the baseline existing conditions model during the period 2011-2021, at a 50-ft resolution.

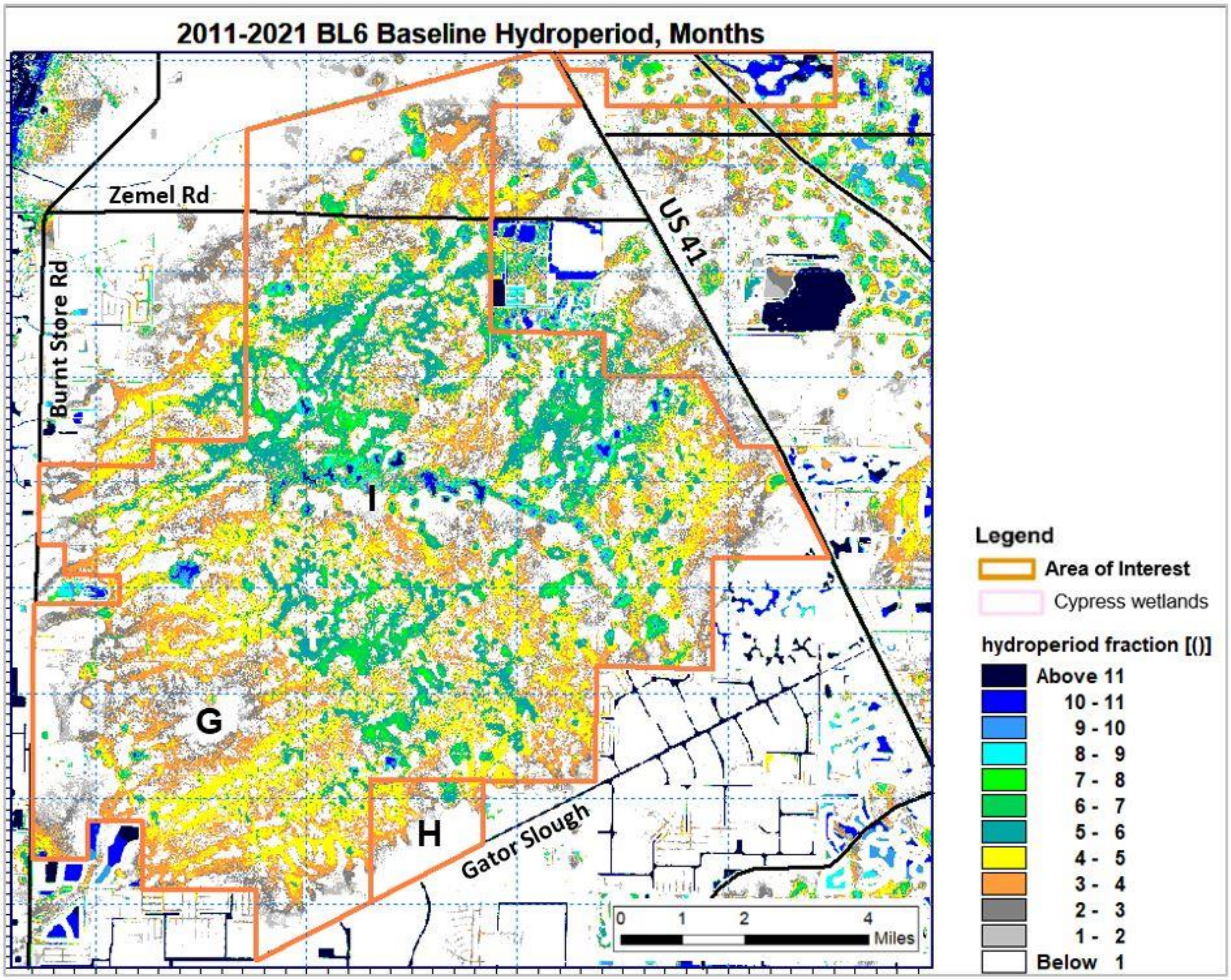


Figure 5-5. Average annual hydroperiod duration in Yucca Pens as predicted by the baseline existing conditions model during the period 2011-2021, at a 50-ft resolution.

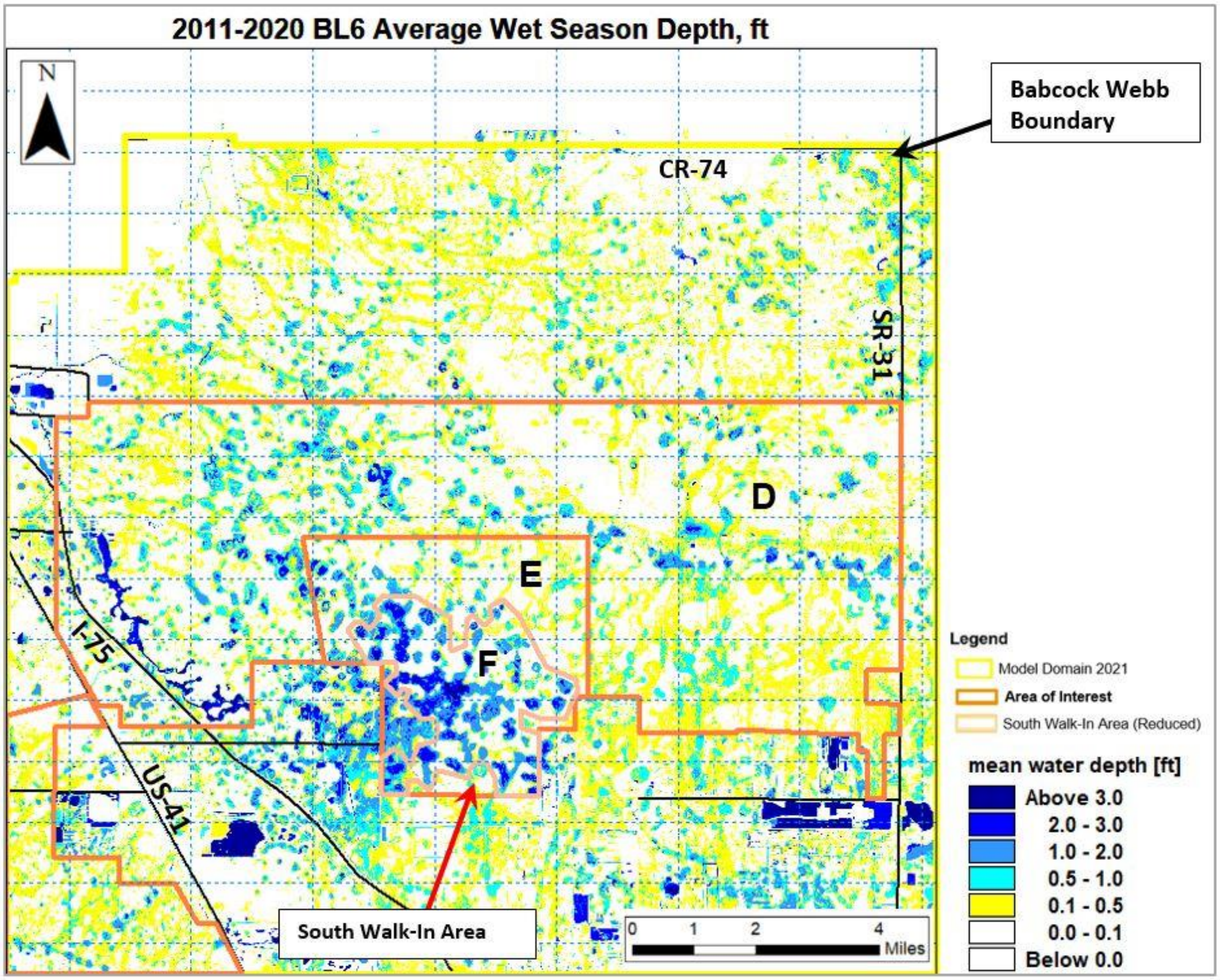


Figure 5-6. Mean water depth in Babcock Webb during the wet season (July 1 – Oct. 15) as predicted by the baseline existing conditions model during the period 2011-2020, at a 50-ft resolution.

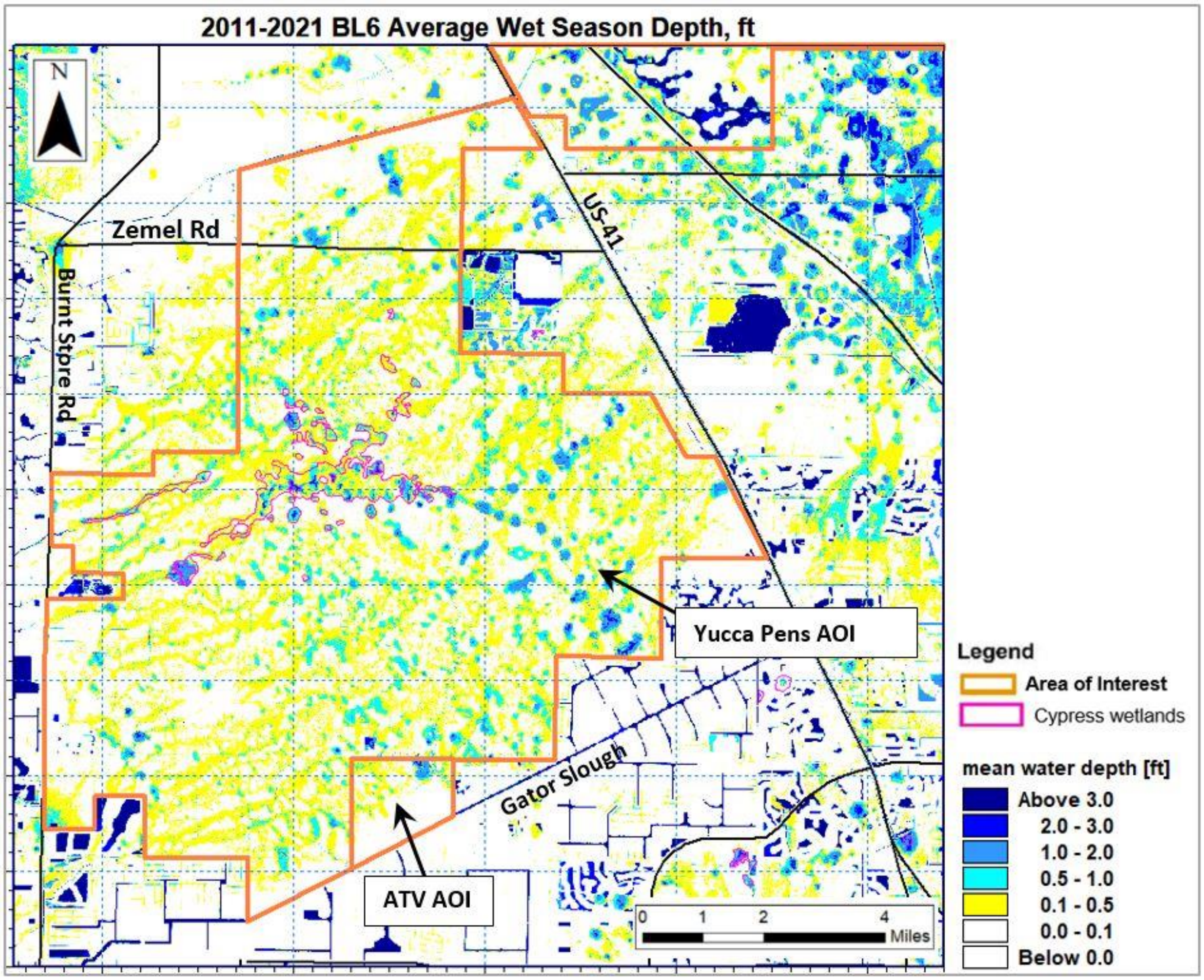


Figure 5-7. Mean water depth in Yucca Pens during the wet season (July 1 – Oct. 15) as predicted by the baseline existing conditions model during the period 2011-2021, at a 50-ft resolution.

6) NATURAL SYSTEMS ANALYSIS AND FUTURE CONDITIONS MODELS

The Natural Systems Analysis involved mapping pre-development conditions as represented by maps of hydrological rank and the assigned optimal hydroperiod and wet season water depth (see Section 3). This was compared to the results of the existing conditions model to ascertain the extent of hydrological alteration and identify areas of management concern. To address management concerns, three future management/conditions scenarios were selected by stakeholders and modeled. Future conditions scenarios include restoration projects that are set to be completed in the near future including the Bond Farm Hydrological Enhancement Impoundment (Bond Farm HEI) which is a permitted project (FDEP ERP No. 0375475-001 EI & State 404 Program Individual Permit No. 0375475-004 SFI). At the time of this report, construction has not commenced. The scenarios also include other potential projects to address additional concerns. However, implementation of some of the unpermitted modeled projects is contingent upon several factors including funding and stakeholder agreement to secure property easements or publicly acquire land and/or permits. The results of the future conditions scenarios were compared to the baseline existing conditions model results to evaluate hydrological changes and scenario benefits. This evaluation informs management recommendations which appear in the final section of this report. The simulation period for future conditions scenarios was the 10-year period of 2012 – 2021.

The three future conditions scenarios include the following:

1. Scenario 1 modeled ATV ditch blocks, low-water fords, and constructed weirs in Yucca Pens to minimize excessive drainage caused by eroded ATV trails. The Bond Farm HEI was assumed in Scenario 1 to store water pumped from the southwestern portion of Babcock Webb WMA during the wet season and to release water south towards Prairie Pines Preserve (PPP) during the dry season only. Scenario 1 also included a partial groundwater seepage barrier at the Gator Slough Canal for further restoration in southern Yucca Pens.
2. As management needs for Babcock Webb and Yucca Pens were not fully met in Scenario 1, Scenario 2 included all Scenario 1 improvements plus additional features to increase hydrological restoration and ecosystem benefits. Additional features added in Scenario 2 include 1) a flow-way from Bond Farm HEI to Yucca Pens to direct Bond Farm HEI outflows west to Yucca Pens during the dry season, 2) more storage for flooded areas of Babcock Webb in the Southwest Aggregates Reservoir during the wet season, 3) outflows from the Southwest Aggregates Reservoir were conveyed via the existing US-41 ditches to Gator Slough in the late dry season only when freshwater flows are needed (future studies will be needed to better understand conveyance methods and stakeholder input will be needed to proportionately allocate any excess water), and 4) modification of one weir in Yucca Pens.
3. Scenario 3 modeled Scenario 2 improvements along with future evapotranspiration (ET) and sea level rise assumptions associated with climate change.

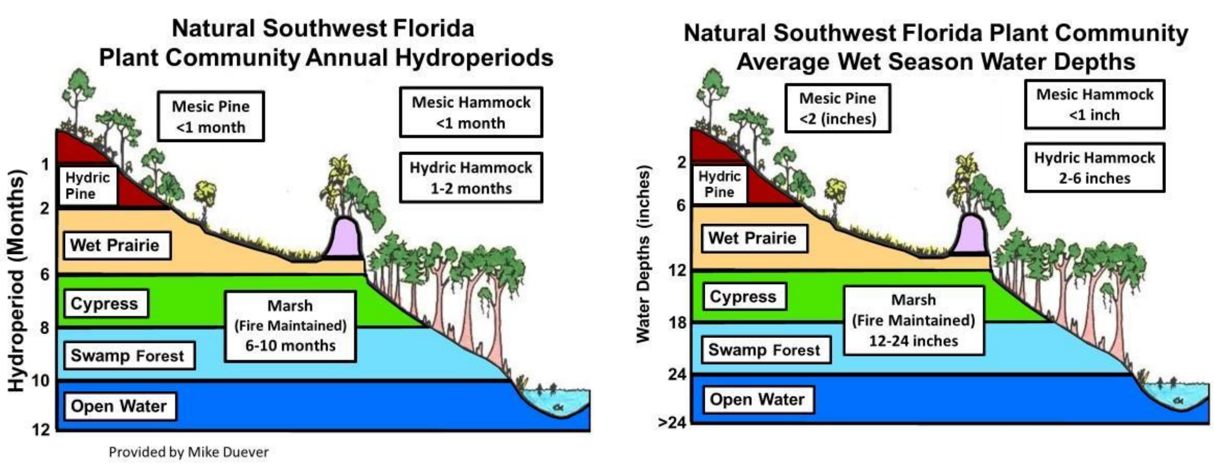
The following sub-sections of this section describe the results of the scenario analysis.

6.1 Natural Systems Analysis

Pre-development Conditions. A GIS analysis was conducted to compare the results for the existing conditions model to a natural systems GIS shapefile of optimum hydroperiods and average wet season water depths. Methodology is discussed in further detail later in this section. Kemmerer and Liebermann (2018) collated a group of 1953-vintage aerial photographs for the Babcock Webb and Yucca Pens area and geo-referenced the photographs to a horizontal datum using ArcGIS. A GIS NRCS soils database was then overlain on top of the aerial photos and was modified to determine the hydroperiod in each of the 500x500 ft grid cells of the model domain and create a map of likely pre-development hydrologic and landscape conditions, ranked from dry to wet (Kemmerer and Liebermann, 2018). The four hydrologic rank categories along with typical vegetation, hydroperiods, and average wet season depths from Duever and Roberts (2013) are listed below in **Table 6-1**. Pre-development wetland hydroperiods from Duever and Roberts (2013) are presented in **Figure 3-5**.

Table 6-1. Pre-Development Hydrologic Regimes (Duever and Roberts, 2013)

Rank	Hydrologic Condition	Typical Vegetation	Typical Hydroperiod, months	Typical Wet Season Depth, ft
1	Dry	Mesic Flatwoods	0-1	0
2	Slightly wet	Hydric Flatwoods	1-2	0.2 – 0.5
3	Moderately wet	Wet Prairie, Cypress, Marsh	2-6	0.5 – 0.8
4	Wet	Cypress, Marsh	6-10	1 - 2



A MIKE SHE/MIKE 11 natural systems model was not developed because flow patterns have been altered by man-made canals that have significantly re-aligned drainage basin divides and hydrologic conveyance. Modification of the existing conditions MIKE SHE/MIKE 11 model would have required many assumptions including extensive changes to the ground topography and an entirely new network of surface water conveyances. The changes were so significant that stakeholders agreed resulting hydrologic simulation outcomes would have a high level of uncertainty. Therefore, at a Charlotte Harbor Flatwoods Initiative (CHFI) meeting, partners made the decision to use a GIS analysis rather than development of a MIKE SHE/MIKE 11 model.

The mapped pre-development hydrologic ranks (established in Section 3) are presented in **Figure 6-1**. Babcock Webb wetlands appear as a series of isolated wetlands connected by narrow flow-ways. The northern portion of Babcock Webb flows northwest towards what is now known as Myrtle Creek. Several wide, moderately wet, flow-ways flow southwest from Babcock Webb toward Yucca Pens and the historic headwaters of Yellow Fever Creek. In addition, there is a wide flow-way to the south towards Powell Creek and Nalle Road (North Fort Myers). Yucca Pens wetlands appear as relatively narrow strands that flow west towards Burnt Store Road (see Durden Creek on **Figure 6-1**). The southeastern portion of Yucca Pens flows south towards Yellow Fever Creek, the western portion flow towards Burnt Store Road, and the southern portion of Yucca Pens drains south into the artificially channelized Gator Slough, which then flows west.

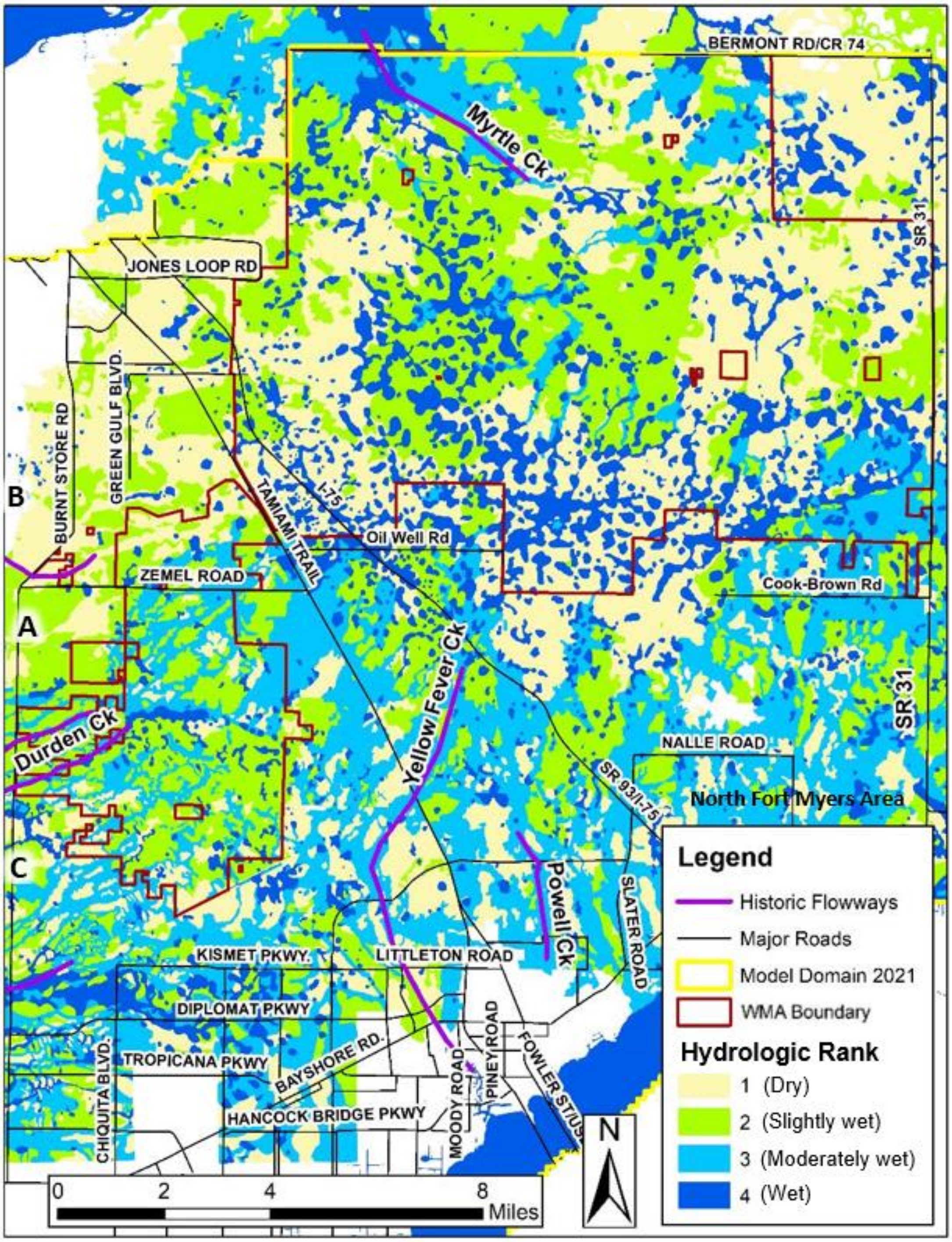


Figure 6-1. Pre-Development Hydrologic Ranks

Hydroperiods and Wet Season Water Depths. Key focal areas or Areas of Interest (AOI) were defined to assist in the comparison of simulated hydroperiods and water depths to historic hydrologic rank areas. AOIs are discussed in detail in **Appendix 6A**. This discussion will focus on hydroperiods and water depths in the South Walk-In Area (Reduced) in Babcock Webb, Yucca Pens Cypress, and Yucca Pens ATV AOIs as shown in **Figure 6-2**. The South Walk-In Area (Reduced) AOI is an area of Babcock Webb with updated topography based on results from field surveys (discussed in **Section 5** and **Appendix 5D**) and that reduced area is a further refinement of the SWIA. These three AOI's are discussed herein because these areas demonstrate the most significant hydrologic alterations compared to previously established optimum conditions and are the focus of the hydrologic restoration efforts evaluated as part of Scenarios 1, 2, and 3.

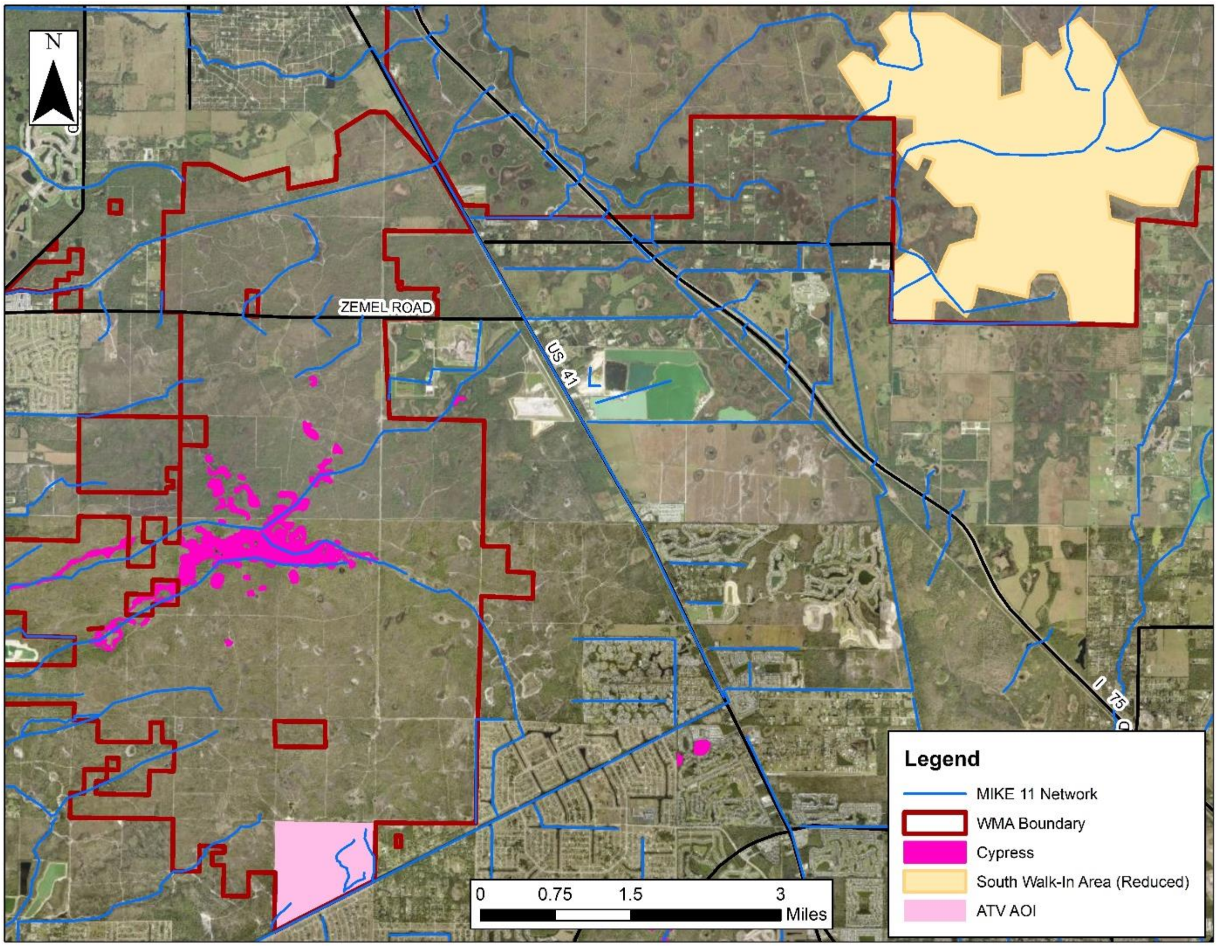


Figure 6-2. AOI's for Babcock Webb South Walk-In Area (Reduced), Yucca Pens Cypress, and Yucca Pens ATV

Expanded views of natural pre-development Hydro Rank classes for the Babcock Webb South Walk-In Area (Reduced), Yucca Pens Cypress, and Yucca Pens ATV are shown below in **Figures 6-3** through **6-5**, respectively. Under natural pre-development conditions, wetland hydroperiods in the South Walk-In Area (Reduced) and Yucca Pens cypress are commonly between 6 to 10 months and average wet season water levels are between 1 to 2 feet (Hydro Rank 4). Wetland hydroperiods in the Yucca Pens ATV area are commonly between 2 to 6 months and average wet season water levels are between 0.5 to 0.8 feet.

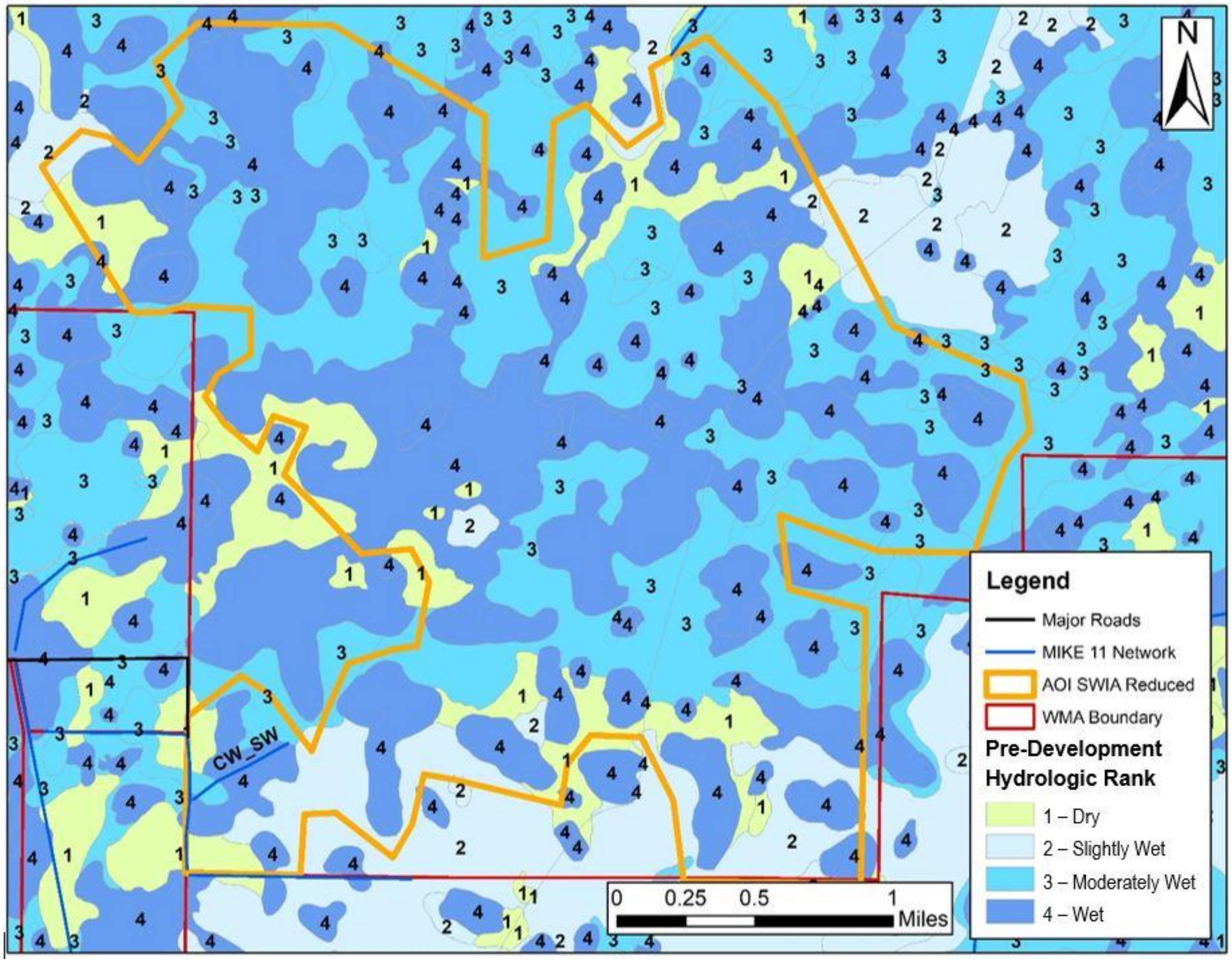


Figure 6-3. AOI for Babcock Webb South Walk-In Area (Reduced)

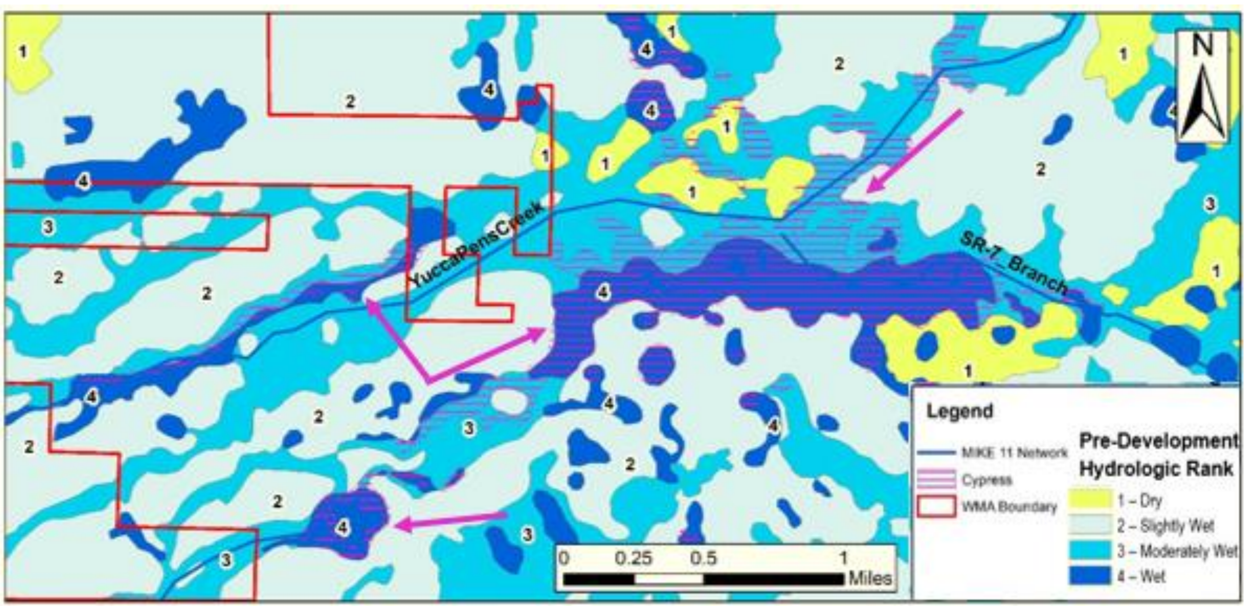


Figure 6-4. AOI for Yucca Pens Cypress (Note: arrows indicate cross-hatched cypress areas)

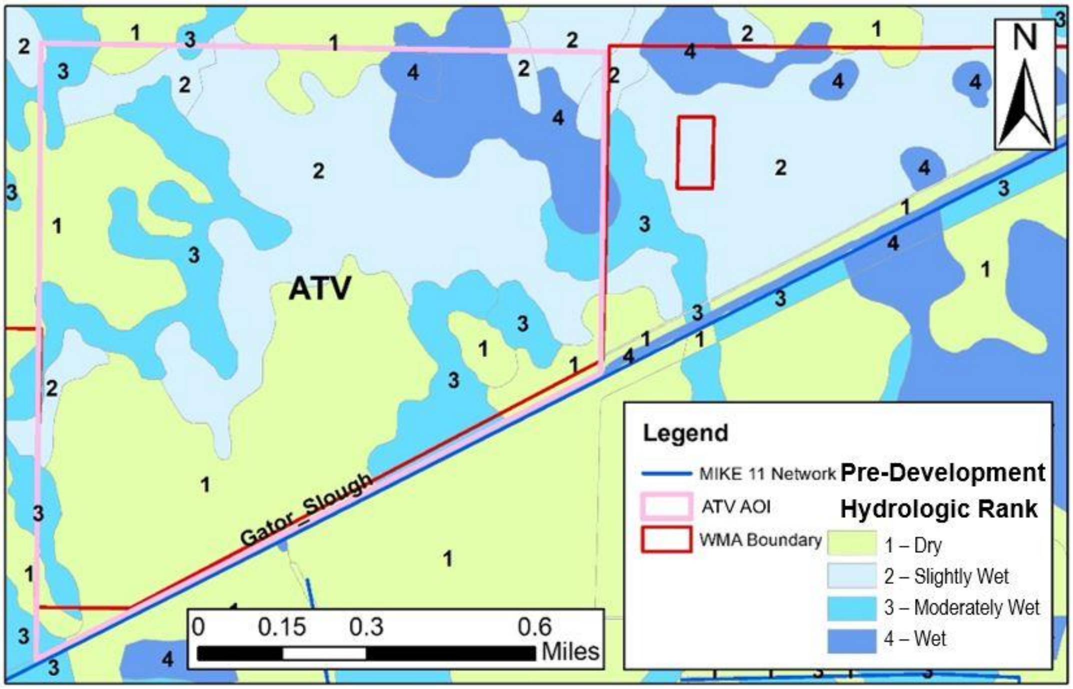


Figure 6-5. AOI for Yucca Pens ATV area

Simulated hydroperiods from the baseline existing conditions model outputs were compared to natural pre-development hydroperiods using the methodology summarized below:

- Converted the hydrologic rank shape file to a 50-ft resolution grid file. This is then compared with similar output files of simulated hydroperiods from baseline existing conditions model.
- In each selected AOI, the simulated baseline hydroperiod value was matched to the corresponding Hydrologic Rank.
- Histograms are made to compare the distribution of hydroperiod values under current baseline existing conditions to the optimal hydrologic ranks inside each AOI.
- This same procedure was also used for average wet season water depths.

Hydroperiod histogram results are presented in **Figures 6-6** through **6-8**. General observations are summarized below:

- Under baseline existing conditions, Hydro Rank 4 simulated hydroperiods in the South Walk-In Area (Reduced) commonly are greater than 10 months. The optimum hydroperiod for these wetland areas (Hydro Rank 4) is 6 to 10 months, meaning that the baseline hydroperiod in this AOI is longer than optimum for even the wettest habitats.
- Under baseline existing conditions, Hydro Rank 3 and 4 simulated hydroperiods in the cypress area of Yucca are most commonly 5.5 and 6 months. Most of the Scenario 2 Hydro Rank 3 and 4 wetlands now have hydroperiods greater than five months, which is a significant improvement relative to baseline existing conditions. However, the optimum hydroperiod for cypress wetlands (Hydro Rank 4) is 6 to 8 months, meaning that the baseline simulated hydroperiod in this AOI is shorter than optimum for these cypress wetlands.
- Under baseline existing conditions, Hydro Rank 3 simulated hydroperiods in the ATV area

of Yucca Pens are commonly in the range of 4 to 5 months. The optimum hydroperiod for these wet prairies (Hydro Rank 3) is 2 to 6 months, meaning that the baseline hydroperiod in this AOI is shorter than optimum for these wet prairies. Note: The LiDAR elevations of Hydro Rank 3 polygons are likely too high, which means that there was not much change in that hydro rank. The topography in the SWIA was improved, but more detailed survey of the SWIA is needed to come up with more accurate estimates of hydroperiod and water depth.

Note for hydroperiod histograms below:

- light blue bar is the optimum hydroperiod for Hydro Rank 3
- dark blue bar is the optimum hydroperiod for Hydro Rank 4

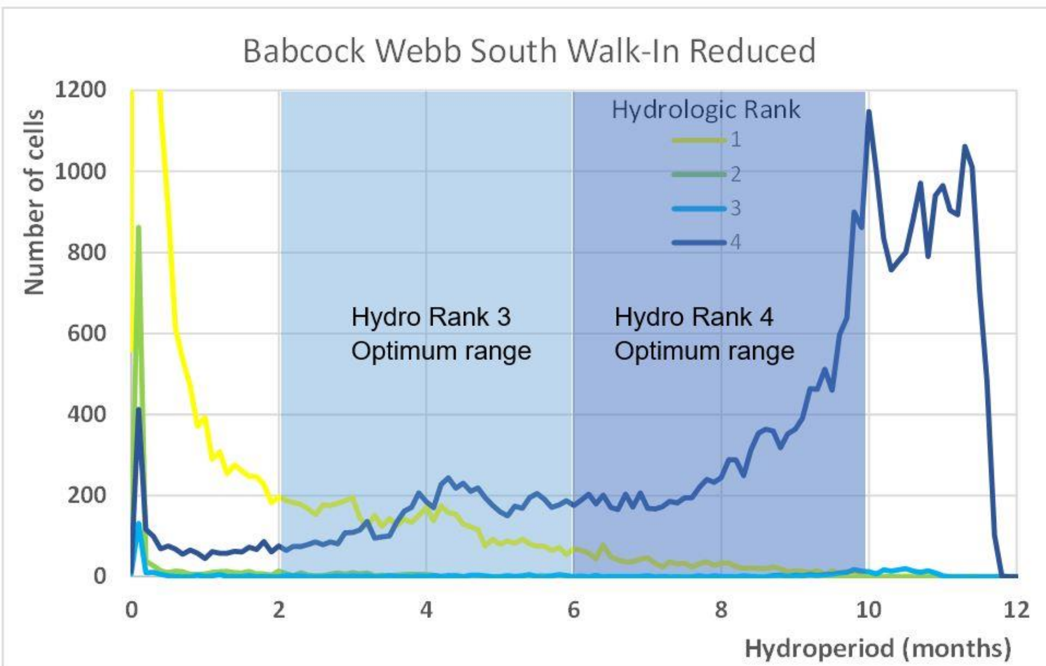


Figure 6-6. Hydroperiod Histogram for Babcock Webb South Walk-In Area (Reduced)

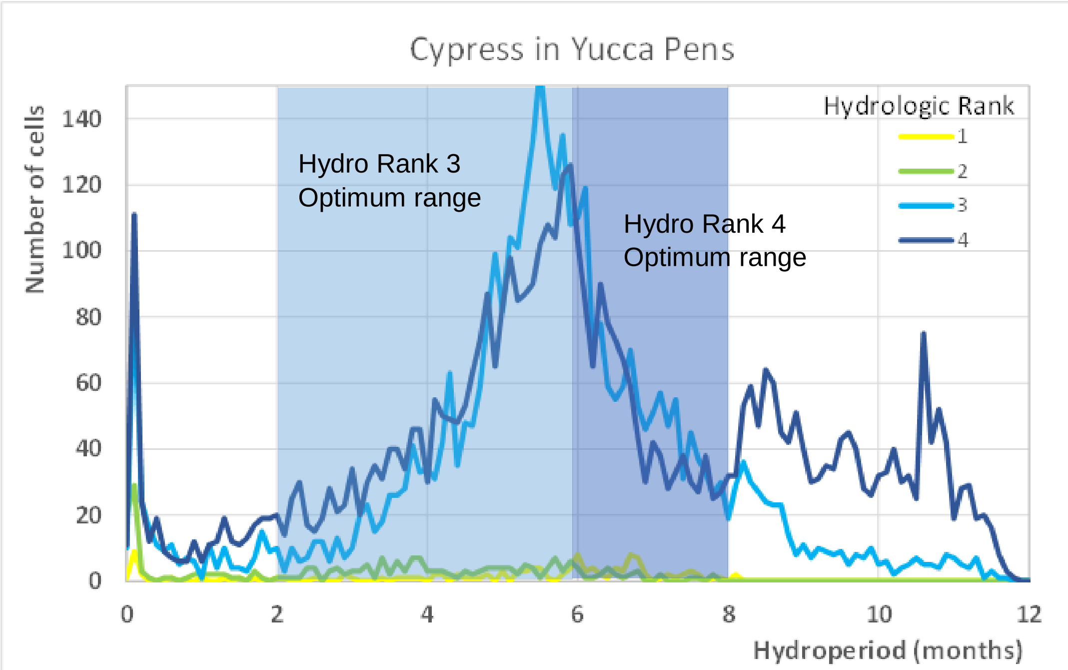


Figure 6-7. Hydroperiod Histogram for Yucca Pens Cypress

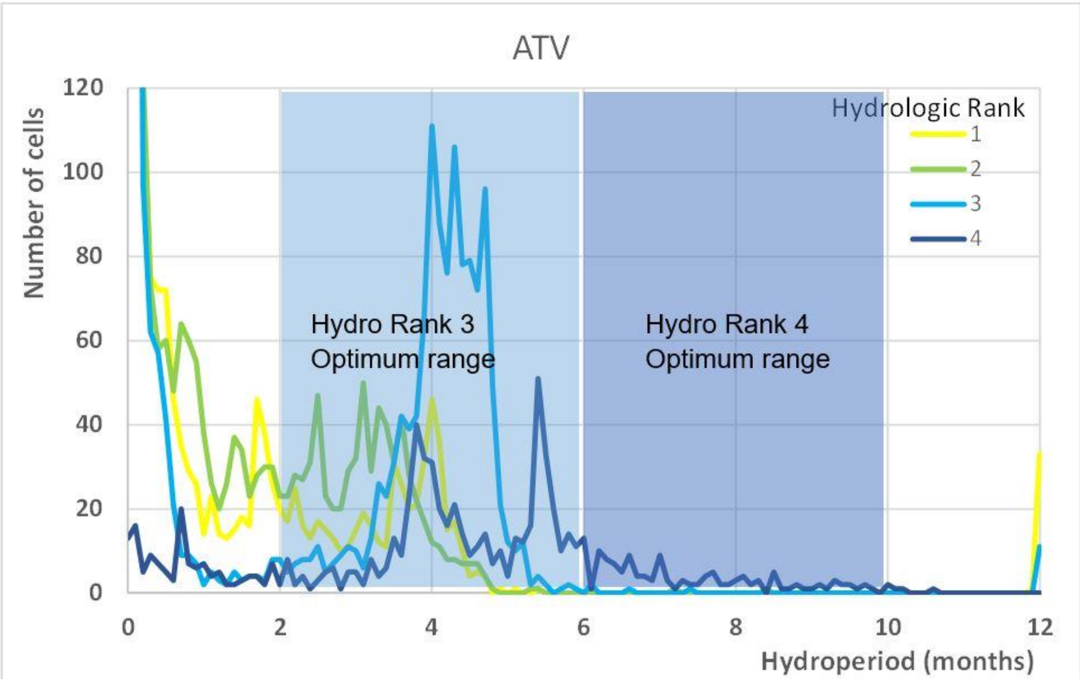


Figure 6-8. Hydroperiod Histogram for Yucca Pens ATV

Water depth histograms are presented in **Figures 6-9** through **6-11**. Observations are summarized below:

- Under baseline existing conditions, Hydro Rank 4 simulated water depths in the Babcock Webb South Walk-In Area (Reduced) range from approximately 1.5 to 2.5 feet. The optimum depth range for these Hydro Rank 4 wetlands is 1 to 2 feet, and thus the South Walk-In Area (Reduced) is too wet.
- Under baseline existing conditions, Hydro Rank 3 simulated water depths in the Yucca Pens cypress and ATV area are less than 0.5 feet. The optimum depth range for Hydro Rank 3 cypress and wet prairies is 0.5 to 0.8 feet, and thus these areas are too dry.
- Under baseline existing conditions, Hydro Rank 4 simulated water depths in the Yucca Pens cypress and ATV area are commonly less than 1 foot. The optimum depth range for Hydro Rank 4 wetlands is 1 to 2 feet, and thus these areas are too dry.

The histogram analysis confirms the findings of the ecologic analysis and water level findings in Sections 3 and 4, which is that there is too much water in the SWIA and more water is needed in Yucca Pens cypress and the southern Yucca Pens ATV AOI. These results guided the development of future conditions scenarios 1, 2, and 3.

Note for water depth histograms below:

- light blue bar is the optimum depth range for Hydro Rank 3
- dark blue bar is the optimum depth range for Hydro Rank 4

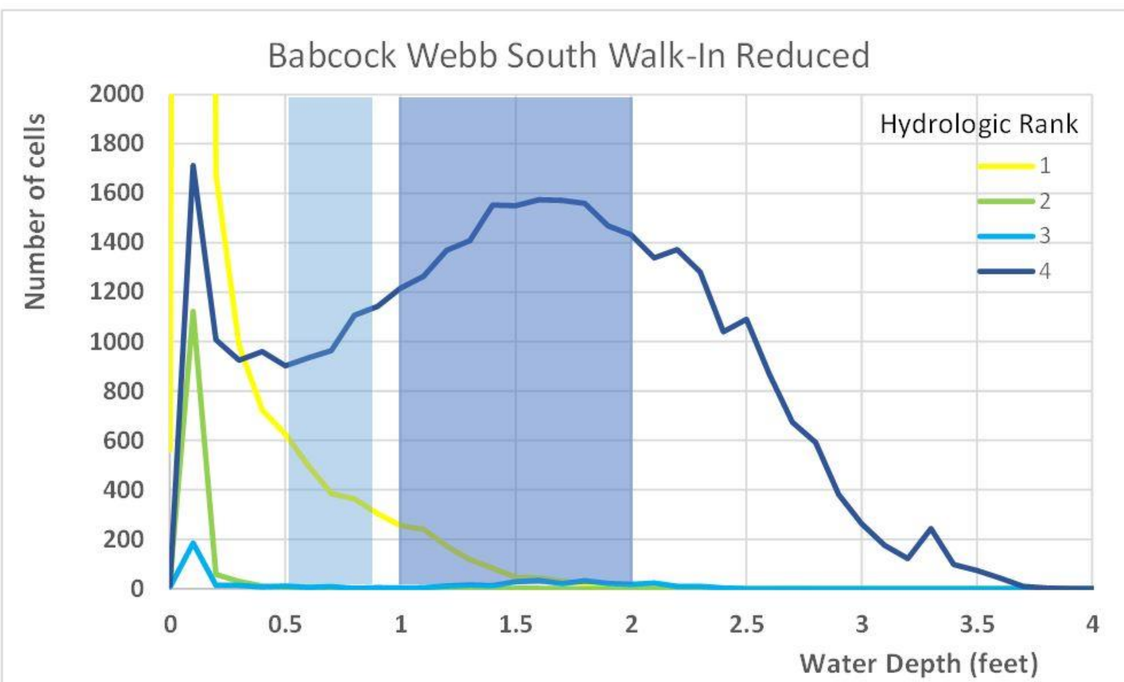


Figure 6-9. Wet Season Water Depth Histogram for Babcock Webb South Walk-In Area (Reduced)

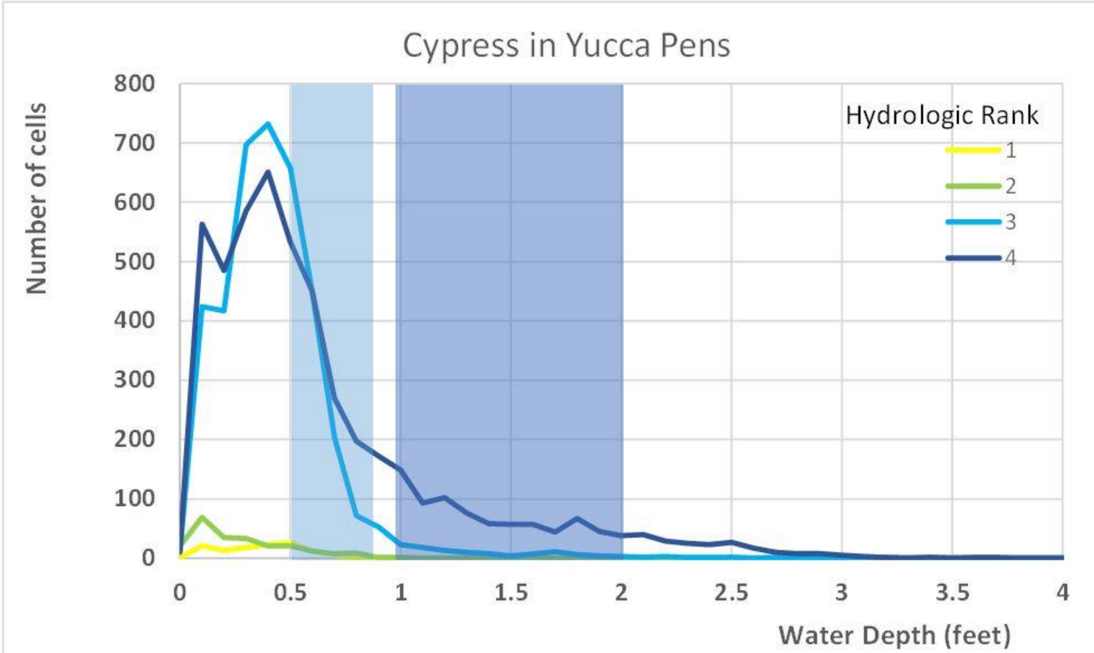


Figure 6-10. Wet Season Water Depth Histogram for Yucca Pens Cypress

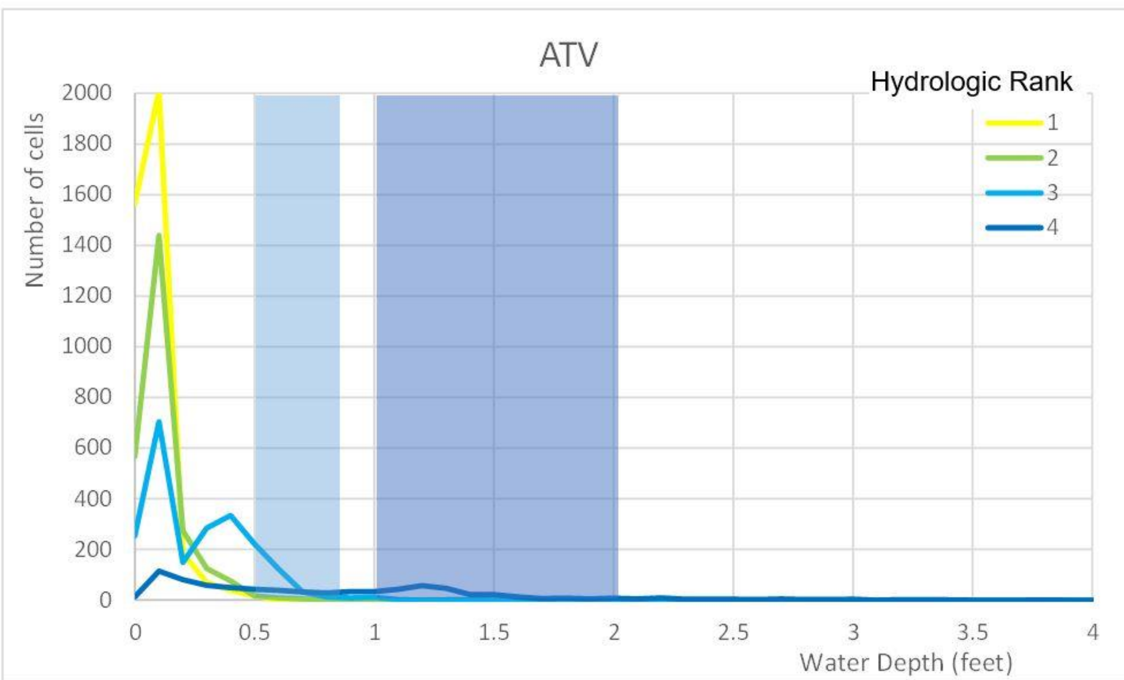


Figure 6-11. Wet Season Water Depth Histogram for Yucca Pens ATV

6.2 Future Conditions Scenario 1

Scenario 1 modeled ATV ditch blocks, low-water fords, and constructed weirs (example low water ford shown in **Figure 3-17**) in Yucca Pens to minimize excessive drainage caused by eroded ATV trails. The Bond Farm HEI was assumed in Scenario 1 to store water pumped from the southwestern portion of Babcock Webb WMA during the wet season and to release water during the dry season. The initial conceptual restoration plan developed in 2013 (ADA, 2013) included a proposed flow-way from Bond Farm HEI west to Yucca Pens with the intention that outflows would be released during the early part of the dry season (December and January) to extend hydroperiods in Yucca Pens. However, Scenario 1 excluded flow deliveries from Bond Farm HEI to Yucca Pens so that Scenario 1 could clearly identify the hydroperiod benefits from reducing over-drainage of Yucca Pens via eroded ATV trails. In addition, securing property easements or purchasing a flow-way west of US-41 was expected to be difficult. Therefore, Scenario 1 was designed to evaluate the impacts of discharging water south under I-75 towards PPP in the dry season only. Since a portion of the water discharged from Bond Farm HEI to the south ultimately would flow during the early dry season towards the Caloosahatchee River estuary via Powell Creek, these flows could have a beneficial impact on restoration of the salinity regime in the Caloosahatchee estuary. The aforementioned management efforts did not achieve full restoration in Yucca Pens, and therefore a partial groundwater seepage barrier was also included in Scenario 1 at the Gator Slough Canal. The potential future projects and management efforts modeled in Scenario 1 were identified as high priority by stakeholders and are likely to be completed in the near future.

During the development of Scenario 1, the following model assumptions were made:

1. As permitted, the Bond Farm HEI will have a maximum storage depth of 4 feet, which translates to a storage volume of 2,400 acre-feet.
2. The Bond Farm HEI inflow pump station will be located on the east side of Bond Farm HEI approximately 1,300 feet south of the northern property line (locations shown in **Figure 6-12**).
3. The Bond Farm HEI inflow pump station operation will gradually increase from no flow (0 cfs) to 20 cfs between upstream stages of 24.5 and 25.0 ft-NAVD. No flow will be permitted if water levels within the impoundment are above 28.0 ft-NAVD. The pump will only operate between June and November (wet season), as indicated by the Bond Farm HEI permit (FDEP ERP No. 0375475-001 EI & State 404 Program Individual Permit No. 0375475-004 SFI). Assumed stages to turn on the pump were based on measured and simulated wet season water levels at monitoring station STA-6 located just east of the proposed pump.
4. The Bond Farm HEI outflow will be directed south towards PPP at a constant flow of 20 cfs during the early part of the dry season in December and January. No outflow will be permitted during the wet season unless a major storm event is anticipated. When Bond Farm HEI is constructed and discharges south to PPP as currently permitted, the period of discharges and the discharge rate should be based on optimal hydroperiod conditions in PPP and flow augmentation needs during the dry season in the ultimate receiving waters (Powell Creek/Caloosahatchee Estuary or Gator Slough/Matlacha Pass) without reducing flood protection to nearby or downstream communities.

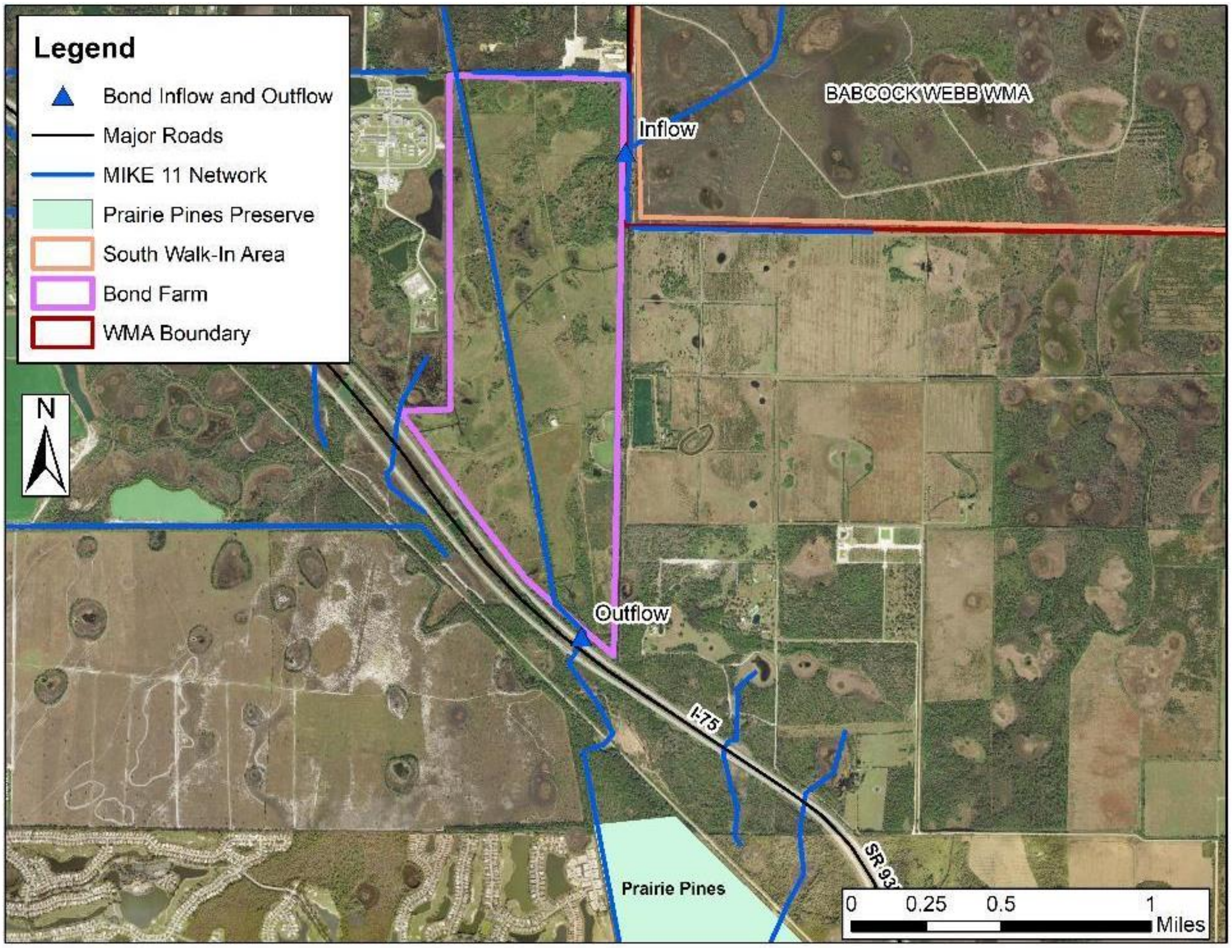


Figure 6-12. Bond Farm Hydrologic Enhancement Impoundment (HEI) Project

5. A number of weirs representing either low-water fords or constructed weirs were added in Yucca Pens. Locations are presented in **Figure 6-13**. Proposed weirs range from 30 ft wide to as much as 600 ft wide. A 5 to 20 ft wide low-flow notch is assumed at most locations with the invert of the notch 2 to 4 ft above the channel invert. It is anticipated that the principal flow width would be concrete (say 30 ft wide) with rock armoring of the wider portions of the weir. Additional information is provided in **Appendix 6B**.
6. ATV ditch blocks were modeled to increase water detention in isolated wetlands on Yucca Pens that are drained by existing ATV trails. The location of those identified isolated wetlands is presented in **Figure 6-13**.
7. Initial testing of ATV ditch blocks in south Yucca Pens indicated that higher groundwater levels as a result of the increased detention was resulting in higher groundwater elevations in private lands west of southern Yucca Pens (see **Figure 6-14** for location of the private lands). As a result, a partial groundwater seepage barrier was included in the model along the southern portion of Yucca Pens as shown in **Figure 6-14**. The partial seepage barrier would be created by drilling boreholes at a predefined spacing (e.g. 10 feet) and grouting the borehole with cement, which will flow into the permeable rock forming a partial flow barrier. The assumed horizontal hydraulic conductivity was 30 ft/day to a depth of 15 – 20 feet below ground, approximately 10% of the prevailing hydraulic conductivity of the area north of the proposed barrier. Additional information is presented in **Appendix 6B**.

8. If a limited response is seen in Babcock Webb and Yucca Pens key areas and management needs are not met, then Scenario 2 will model additional storage and other solutions.

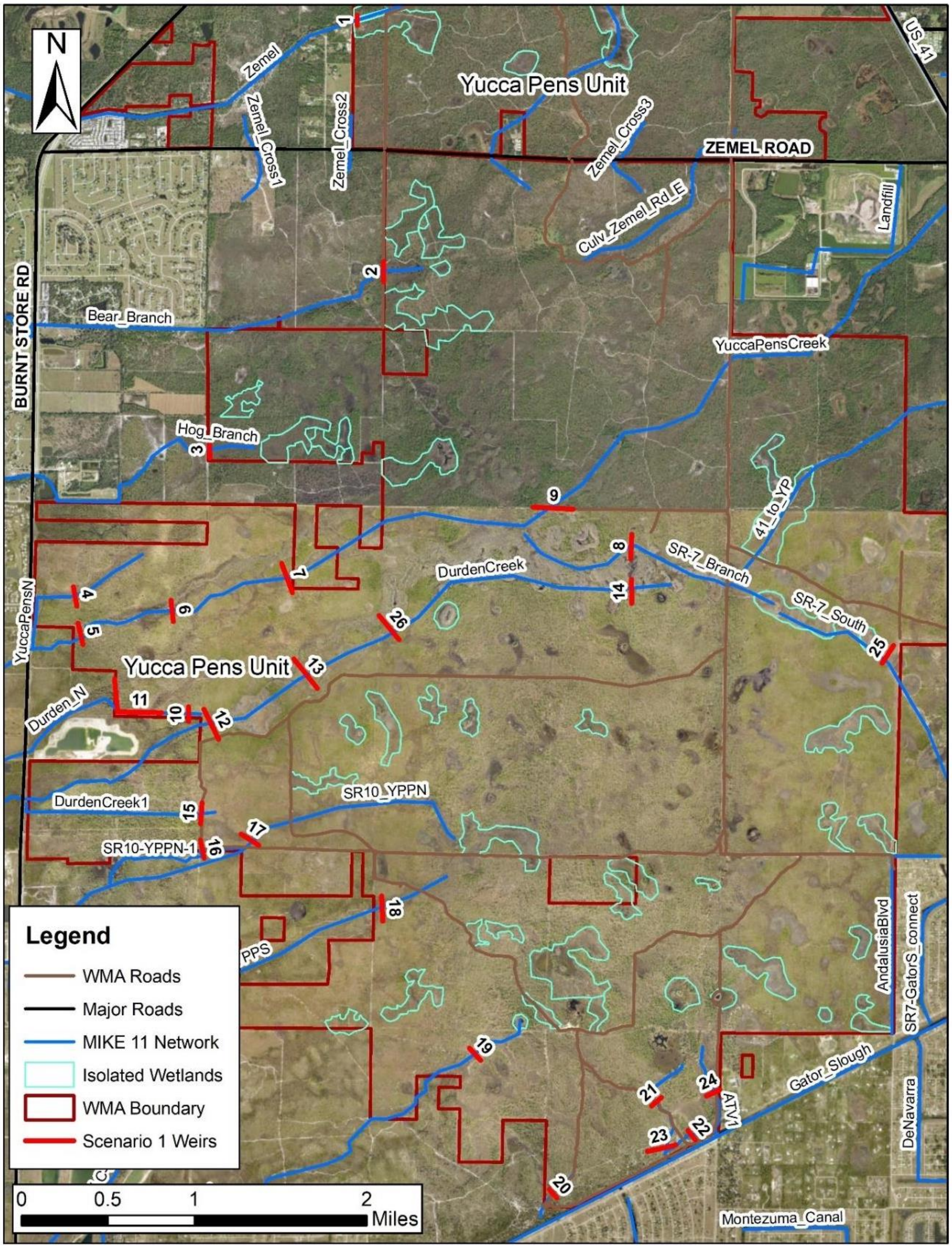


Figure 6-13. Map of Proposed Weirs/Low Water Fords in Yucca Pens

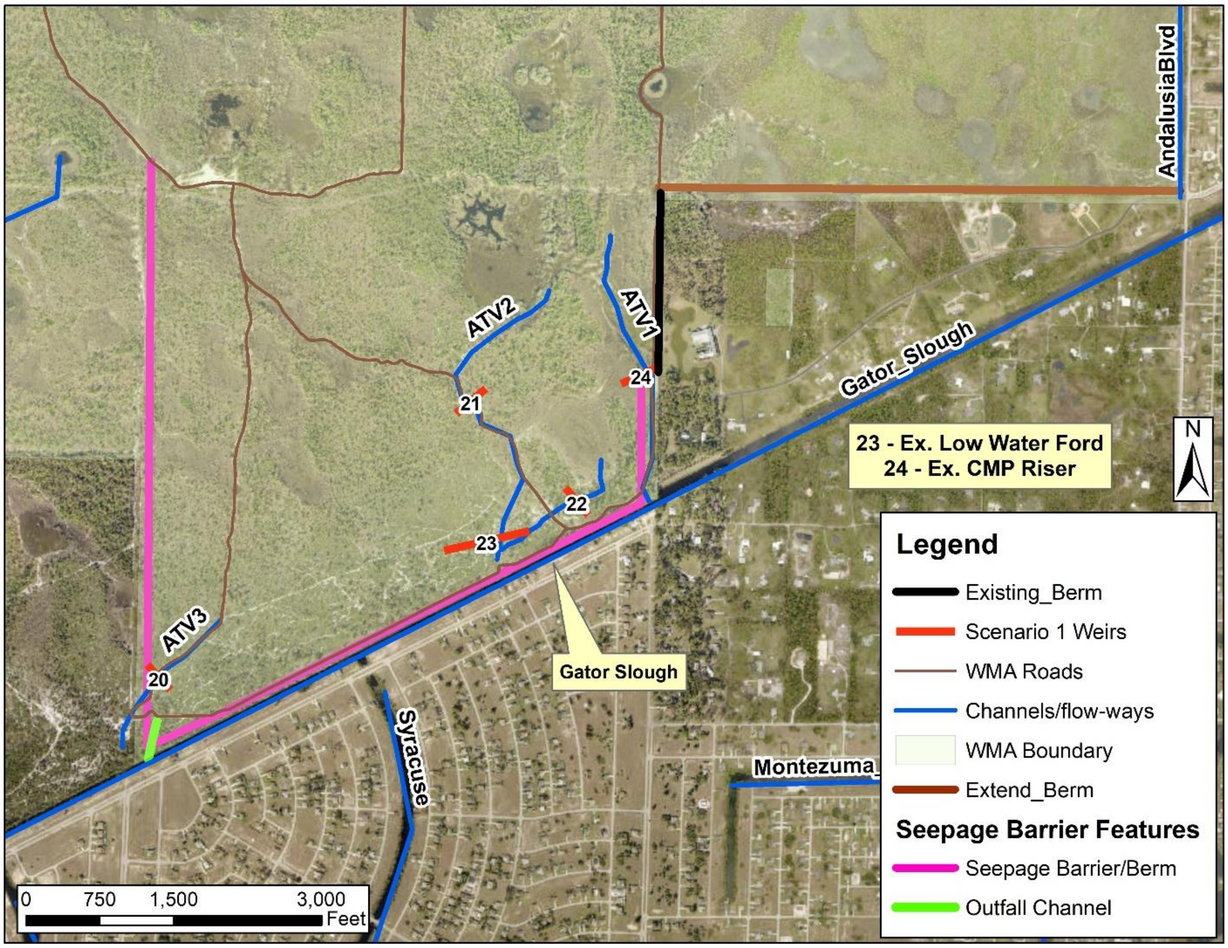


Figure 6-14. Restoration Measures in South Yucca Pens

Scenario 1 Results. Scenario 1 resulted in substantially improved wetland hydroperiods and water depths in Yucca Pens as well as some improvements in Babcock Webb, as shown in **Figure 6-15**, **6-16** and **6-17**. Note, all positive changes to hydroperiods in Babcock Webb are shown in the areas presented in **Figure 6-15**. Quantitative summaries of the Scenario 1 changes are presented below in **Table 6-2**. Although specific quantitative acreage targets were not identified as a project goal, acreage totals are presented below to further demonstrate the magnitude of hydrologic restoration performance. Scenario 1 positive changes to wetland hydroperiods and water level changes in the SWIA of Babcock Webb are summarized below:

- Water level decreases of 0.1 to 0.25 feet were experienced in 94 acres, with the average difference for those 94 acres equal to -0.14 ft.
- Hydroperiod decreases of 0.25 to 0.5 months were experienced in 121 acres, with the average difference for those 121 acres equal to -0.35 months.
- Hydroperiod decreases of 0.5 to 1 month were experienced in 42 acres, which the average difference for those 42 acres equal to -0.66 months.

Hydroperiod increases of greater than one month are predicted for 2,554 acres of Yucca Pens. Water table levels in March and April (end of dry season) are predicted to be greater than 1 foot for 410 acres and to increase by more than 0.25 feet for 4,672 acres in Yucca Pens.

Table 6-2. Summary of Scenario 1 Hydroperiod and March – April Water Level Improvements in Yucca Pens

Hydroperiod Difference	Area, ac.	Avg months
> 2 months	726	+2.86
1 - 2 months	1,828	+1.38
0.5 - 1 months	2,601	+0.72
0.25 - 0.5 months	2,333	+0.36
Water Level Difference	**Area, ac.**	**Avg, ft**
> 1.5 ft	131	+1.66
1 - 1.5 ft	279	+1.24
0.5 - 1 ft	838	+0.65
0.25 - 0.5 ft	3,424	+0.32
0.1 - 0.25 ft	8,422	+0.16

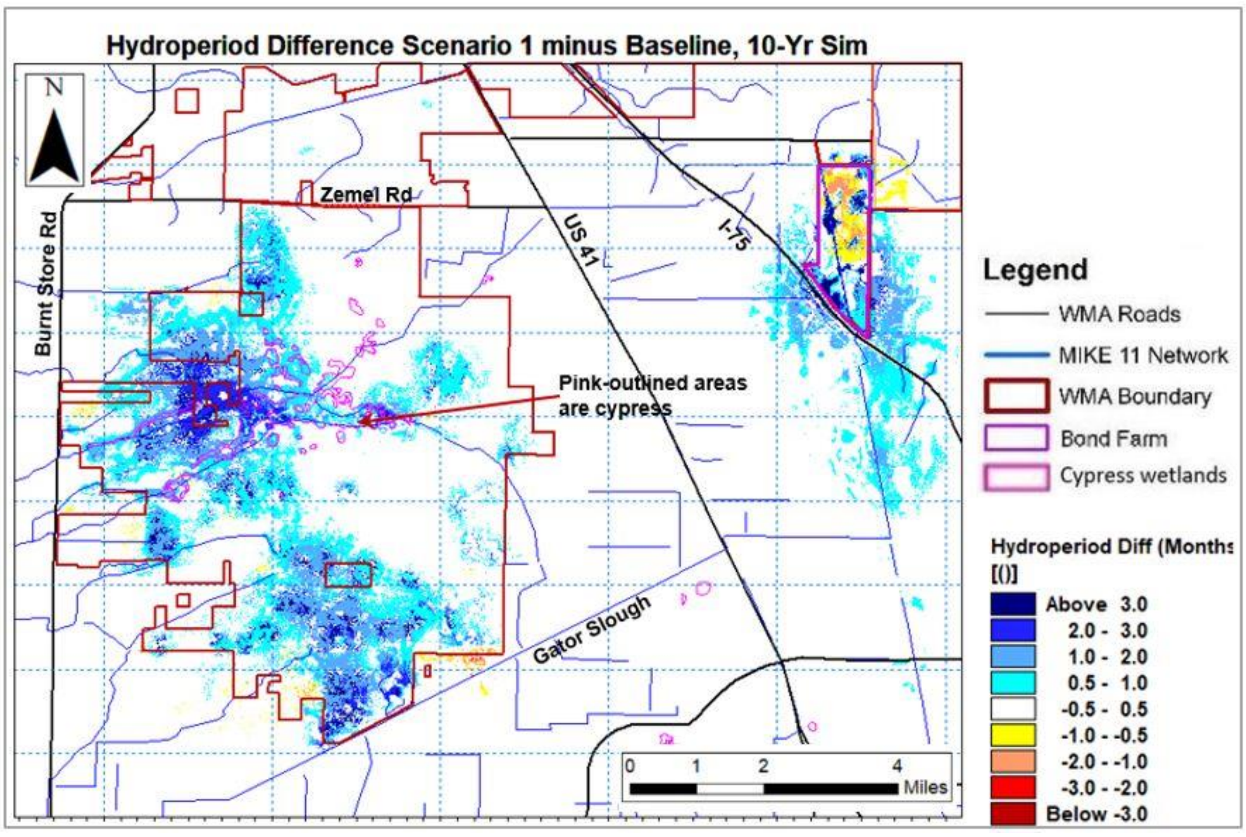


Figure 6-15. Scenario 1 minus baseline existing conditions average annual hydroperiod difference during the period 2012-2021, at a 50-ft resolution. Note: All positive changes in Babcock Webb are shown here.

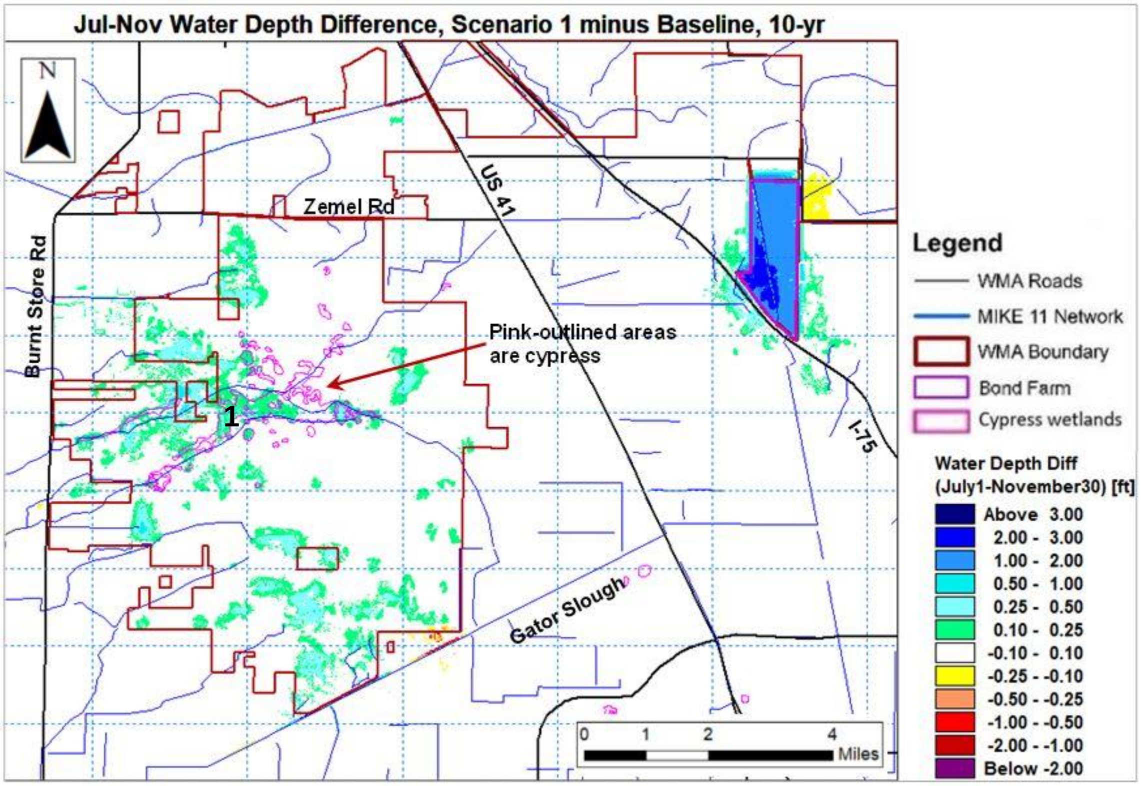


Figure 6-16. Scenario 1 minus baseline existing conditions average water depth differences for the wet season (July 1 – November 30) during the period 2012-2021

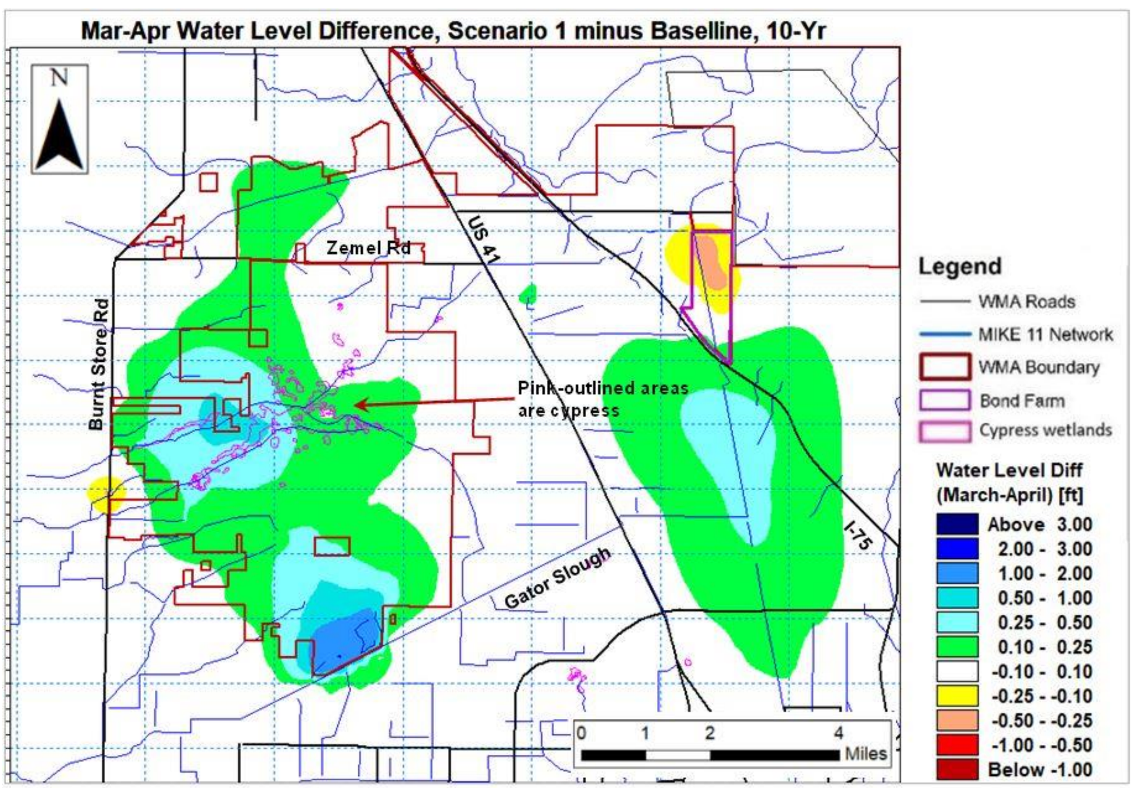


Figure 6-17. Scenario 1 minus baseline existing conditions water table level difference during the dry season months of March and April during the period 2012 – 2021

To evaluate the performance of Scenario 1 improvements, simulated results were compared to the baseline existing conditions results for hydrologic ranks 3 and 4. Comparisons are presented for Yucca Pens Cypress and ATV AOIs for Hydro Ranks 3 and 4 in **Figure 6-18** histograms. The most common hydroperiod in Yucca Pens Cypress Hydro Rank 3 was approximately 5.5 months for the baseline existing condition scenario, while the distribution of hydroperiods for Scenario 1 was wider with peaks at 5.6 months and 7.7 months. The optimum hydroperiod for cypress in Hydro Rank 3 should be 2 to 6 months. This means that the hydroperiod range in this AOI is now closer to optimum conditions for these cypress wetlands.

The Cypress Hydro Rank 4 baseline most common hydroperiod was 5.9 months and increased in Scenario 1 to 8.9 and 10.8 months in some areas. The optimum hydroperiod range for cypress in Hydro Rank 4 should be 6 to 10 months. This means that the hydroperiod range in this AOI is now closer to optimum conditions for these cypress wetlands.

The most common hydroperiod in Yucca Pens ATV Hydro Rank 3 was approximately 4.5 months for the baseline existing condition scenario, while the distribution of hydroperiods for Scenario 1 increased to 6.3 months. Again, the optimum hydroperiod range for Hydro Rank 3 should be 2 to 6 months. This means that the hydroperiod range in this AOI is now closer to optimum conditions for these wetlands. The ATV Hydro Rank 4 baseline common hydroperiods were at 3.9 and 5.7 months. The Scenario 1 most common hydroperiod was 4.9 to 9 months.

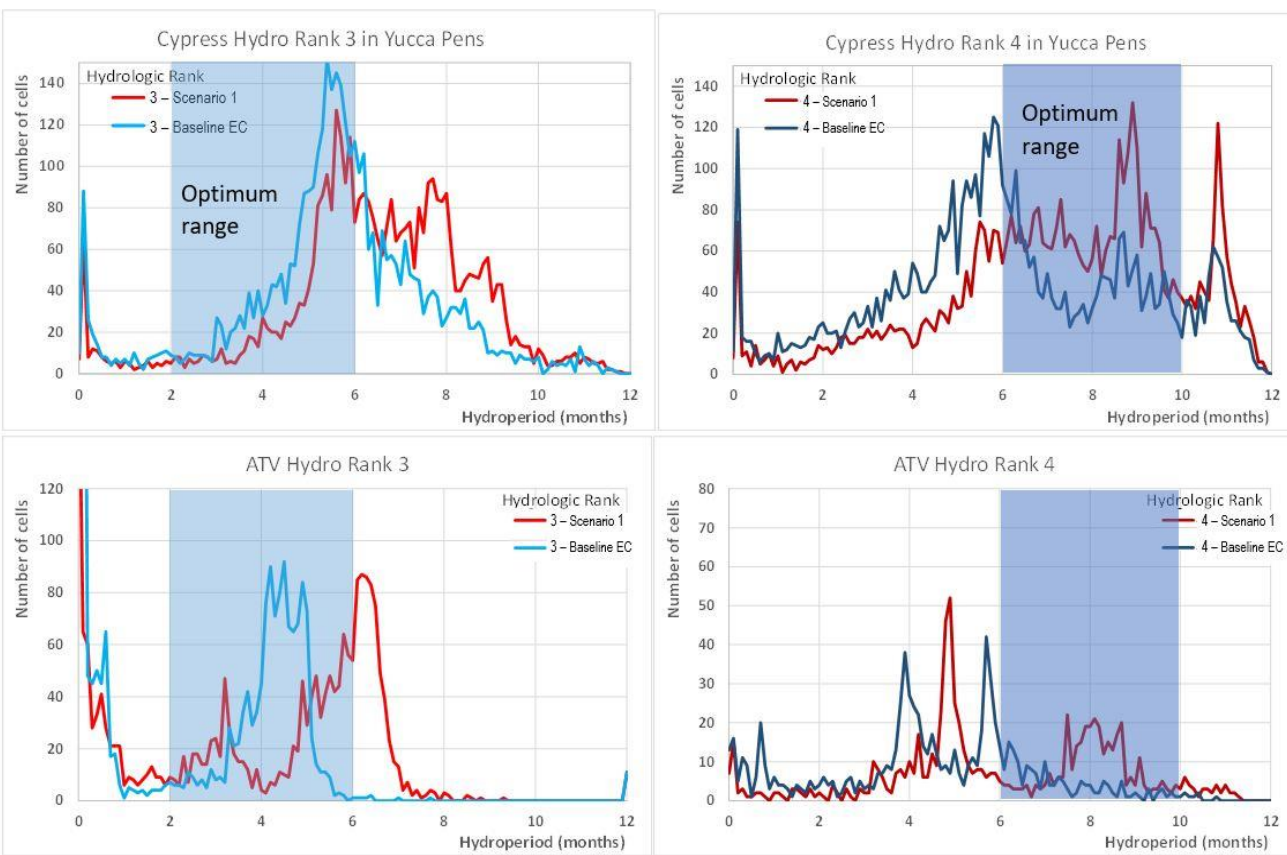


Figure 6-18. Scenario 1 and baseline existing conditions Hydro Rank 3 & 4 Hydroperiods for Yucca Pens Cypress and ATV AOIs

The Bond Farm HEI was assumed to store water pumped from the southwestern portion of Babcock Webb WMA during the wet season and to release water during the dry season. Water removed from Babcock Webb would be limited to only what is needed to restore the SWIA to historic water levels. The initial conceptual restoration plan developed in 2013 (ADA, 2013) included a proposed flow-way from Bond Farm HEI west to Yucca Pens with the intention that outflows would be released during the early part of the dry season (December and January) to extend hydroperiods in Yucca Pens. Scenario 1 did not include flow deliveries from Bond Farm HEI to Yucca Pens so that Scenario 1 could clearly identify the hydroperiod benefits from reducing over-drainage of Yucca Pens via eroded ATV trails. In addition, securing property easements or purchasing a flow-way west of US-41 was expected to be difficult. Therefore, Scenario 1 was designed to send water south under I-75 towards PPP in the dry season only (location shown in **Figure 6-15**). Since a portion of the water discharged from Bond Farm HEI to the south ultimately would flow during the early dry season towards the Caloosahatchee River estuary via Powell Creek, these flows could have a beneficial impact on restoration of the salinity regime in the Caloosahatchee estuary (Barnes et al., 2006).

Scenario 1 simulated inflows and outflows for Bond Farm HEI during the period of 2012 – 2021 are summarized below in **Table 6-3**. Outflows using the Final Calibration model were 37% of inflows for the 10-year simulation period and 35% for 2013 due primarily to seepage from the reservoir. Because this high level of seepage was unexpected, sensitivity tests were conducted to determine the amount of seepage using lower rates of hydraulic conductivity. **Table 6-3** also presents results for a sensitivity test with water table horizontal hydraulic conductivities around Bond Farm HEI capped at 297 ft/day (see **Exhibit 1** for discussion of Scenario 1 analysis using the sensitivity test model files). The sensitivity test indicates lower overall losses to groundwater, with simulated outflows in 2013 being 81% of simulated inflows and an average of 66% for the 10-year period. The final calibrated model assumed lower water table hydraulic conductivity in Bond Farm HEI only. Outflows are less than 50% of inflows for the final calibrated model and the majority of the losses (i.e., difference between inflows and outflows) are due to groundwater seepage due to the likely presence of permeable limestone in some areas around Bond Farm.

Table 6-3. Scenario 1 simulated annual inflows and outflows from Bond Farm HEI

	Final Calibration		Sensitivity Test (Reduced Hydraulic Conductivity)	
Period	**Inflow, Ac-ft**	**Outflow, Ac-ft**	**Inflow, Ac-ft**	**Outflow, Ac-ft**
10-yr Avg	4,080	1,528	2,842	1,877
Year 2013	3,675	1,313	2,183	1,762

Note: final calibration model described in Appendix 5C. Sensitivity tests changed any horizontal hydraulic conductivity values greater than 297 ft/day to 297 ft/day.

Flows from tidal creeks in Yucca Pens under Burnt Store Road (Greenwell Branch, Durden Creek, Yucca Pens Creek, and Hog Branch) for Scenario 1 are less than they are for the baseline existing conditions scenario, and the recession limb of the flow after many storm events has been extended due to the restoration measures. One example of this is the ATV ditch blocks which slow flow out of Yucca Pens wetland areas and help retain water. This demonstrates that flashiness in streams is reduced and that there is more moderate flow in these streams rather than extreme high and low flow events. The median reduction in peak flows for 74 modeled rain or storm events over the 10-year period was 16% (25th percentile = 8%, 75th percentile = 22%).

All graphs presented below in **Figure 6-19** represent flows under Burnt Store Road. Overall combined response for Hog Branch, Yucca Pens Creek, Durden Creek North, Durden Creek, and Greenwell Branch are presented in the top left graph. Graphs of Scenario 1 versus baseline existing conditions for each of the creeks is presented in the remaining graphs in the figure. Hog Branch (top right graph) flows do not change significantly due to the proposed weirs. This is expected since most of the Hog Branch watershed is outside the boundaries of Yucca Pens WMA. Yucca Pens Creek peak flows in the early part of the wet season (June through September) are less for Scenario 1 than for the baseline existing condition scenario. Scenario 1 flow reductions are most effective in the North Branch of Durden Creek. Performance in Durden Creek was similar to Yucca Pens Creek with reductions during peak flow periods and higher flows during the recession limb of hydrographs. Peak flow reductions in Greenwell Branch were minimal due to the urban nature of the watershed east and west of Burnt Store Road.

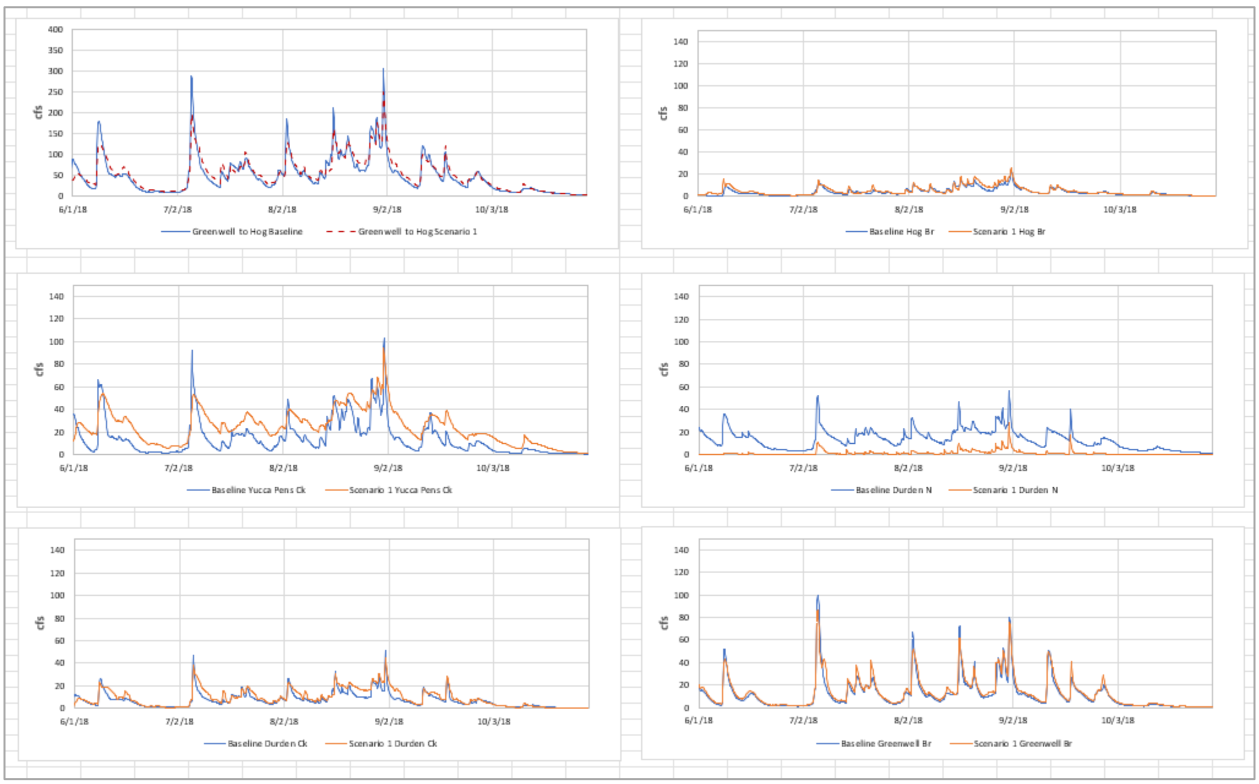


Figure 6-19. 2018 Flows for Scenario 1 and baseline existing conditions for Burnt Store Road Creeks

Summary of Scenario 1 Results. Scenario 1 assumed that the Bond Farm HEI would be used to store water up to a depth of 4 feet with water discharged south through PPP only during the early dry season. Scenario 1 also assumed addition of 26 weir-structures in Yucca Pens to increase on-site detention in the historic wetlands of Yucca Pens. Such structures will include, but not be limited to, ditch blocks in eroded ATV trails, low water fords, and concrete weirs. The design details at each of the proposed weir locations will be determined during subsequent design studies. It is recommended that in future work the weirs be prioritized for available funding, so that if, for example, funding is only available for 10-15 weirs then a plan would be in place already for implementing construction of weirs that would have the most beneficial impact. Similarly, consideration should be given to model results if all 26 proposed weirs are not completed. Scenario 1 also includes a partial groundwater seepage barrier along the southern portion of

Yucca Pens just north of Gator Slough. It is anticipated that this seepage barrier will not be a complete barrier to groundwater flow, but it will reduce seepage rates to the degree that hydroperiods are increased in Yucca Pens wetlands north of Gator Slough.

SWIA hydroperiods decreased by 0.35 months for 121 acres and by 0.66 months for 42 acres. Additional storage will be needed to accomplish hydrologic restoration in Babcock Webb and will be explored further as part of the Scenario 2 analysis.

Yucca Pens hydroperiods and dry season water table levels will increase substantially because of the proposed restoration measures described above. Hydroperiod increases of greater than 1 month are predicted for 2,554 acres of Yucca Pens. Relative to the baseline existing condition, water table levels in March and April are predicted to be increase by more than 1 foot for 410 acres, and water depths are predicted to increase by more than 0.25 feet for 4,672 acres. Histogram analysis predicted hydroperiod improvements in the Yucca Pens Cypress and ATV areas (see **Figure 6-18**).

Flows from Yucca Pens tidal creeks under Burnt Store Road (Greenwell Branch, Durden Creek, Yucca Pens Creek, and Hog Branch) in Scenario 1 are less than flows in the baseline existing conditions scenario, and the recession limb of the flow after each storm event has been extended due to the restoration measures in Scenario 1.

6.3 Future Conditions Scenario 2

Scenario 2 includes the Scenario 1 improvements that provided substantial ecosystem benefits and includes additional features to increase restoration performance. Additional features added in Scenario 2 include 1) a flow-way from Bond Farm HEI to Yucca Pens to direct Bond Farm HEI outflows west during the dry season, 2) more wet season storage for flooded areas of Babcock Webb in the Southwest Aggregates Reservoir, 3) water deliveries from the Southwest Aggregates Reservoir to deliver freshwater flows to Gator Slough in the late dry season, and 4) modification of one weir in Yucca Pens.

Implementation of modeling assumptions made in Scenario 2 are contingent upon a number of key factors: first this scenario can only be implemented if private and public landowners in the region of the proposed flow-way are willing to work with regional partners to secure property easements, publicly acquire land and/or permits in order to allow water to move from Bond Farm HEI to Yucca Pens through the SLD property south of the SLD Construction and Demolition (C&D) Landfill, second stakeholder agreements are needed to conveyance water from the Southwest Aggregates Reservoir to Gator Slough. Finally, stakeholders will need to formally acquire use of the Southwest Aggregates Reservoir to potentially store additional freshwater in the wet season. The new features of Scenario 2 are described below:

1. In the model, the Bond Farm HEI outflow was directed west towards Yucca Pens at a constant flow of 20 cfs during December and January. Note that a western discharge from the Bond Farm HEI is not part of the approved engineering plans. No outflow will be permitted during the wet season. The flow-way from Bond Farm HEI to Yucca Pens was modeled along the southern border of the Southwest Aggregates Reservoir property, passed under US-41, and was routed west through a new flow-way south of the SLD C&D Landfill. A new 7-ft x 3-ft box culvert was assumed under US-41. Dimensions of this culvert were approximated using best engineering judgment and it may be appropriate to modify

the dimensions during the design phase.

2. In the model, the Southwest Aggregates mine was used as a ‘reservoir’ to store additional water from Babcock Webb (shown in **Figure 6-20**). A proposed flow-way was modeled along the southern border of that property and used to convey water from Bond Farm HEI to Yucca Pens as well as used as an inflow canal for water that could potentially be routed around Bond Farm HEI into the existing pits on the Southwest Aggregates property in the wet season. The depth range modeled was 15.0 to 25.0 ft-NAVD. The modeled inflow rate to the Southwest Aggregates Reservoir was limited to 35 cfs between June and November, and the outflow rate between March and May was limited to 26 cfs. Inflow rate was determined by iteratively testing inflow rates in the model to maximize storage in both Bond Farm HEI and the Southwest Aggregates Reservoir (by running pumps simultaneously it allows water to continuously be removed from Babcock Webb during the wet season to achieve desired restoration goals). The outflow rate was selected based upon prior water deliveries from Southwest Aggregates Reservoir to US-41 ditches during 2017, 2020, 2021, and 2022.
3. In the model, the outflow was directed from the Southwest Aggregates Reservoir via existing US-41 ditches to Gator Slough just west of US-41.
   - Gated culverts in a proposed seepage control ditch on the west side of Bond Farm HEI will open during the wet season to allow water from Babcock Webb to flow west into the Southwest Aggregates Reservoir using the above-mentioned flow-way. The dimensions of the culverts associated with this structure were taken from the Bond Farm HEI design plans (HDR, 2020), however gates on the culverts were not part of the Bond Farm HEI design plans. Filling of Bond Farm HEI will have priority over filling of the Southwest Aggregates Reservoir. More information on filling recommendations is provided in **Section 7**. The western discharge is conceptually discussed and design, modeling and permitting would be required to construct it.
   - A proposed gate on the east side of the Southwest Aggregates south ditch will open during wet season flow deliveries to the Reservoir or during flow routing from Bond Farm HEI to Yucca Pens in the early dry season. The following specifications were used in the model and may be changed or reduced in the design phase. It was assumed that this gate will be 24.0 feet wide with a sill elevation of 22.0 ft-NAVD, and a maximum elevation of 26.0 ft-NAVD.
   - Gated weirs will be needed in the US-41 ditches north and south of the flow-way to direct the Bond HEI outflows to Yucca Pens. These gates will be closed blocking flow north and south to these US-41 ditches, instead directing water west via the proposed flow-way during the time period that the flows would be directed to Yucca Pens (typically December and January). Gates would be at an added 6'x4' box culvert. A schematic of the flow routing from Babcock Webb to Bond Farm HEI and Southwest Aggregates Reservoir is provided in **Figure 6-21**.
4. A number of proposed weirs representing either low-water fords or constructed weirs were modeled in Future Conditions Scenario 1 to minimize excess drainage from eroded ATV trail in Yucca Pens (see **Appendix 6B** for details). The proposed weirs for Scenario 2 are identical to those included in Scenario 1 with the exception of Yucca Pens New Weir 3. Yucca Pens New Weir 3 was moved 1,325 meters (4,347 feet) upstream (east) from the location used in Scenario 1 for two reasons: a) the Scenario 1 location was too close to private lands, and b) the new Scenario 2 location is along an existing firebreak that is already disturbed and would be easier to access, so the construction of the new weir 3 will

result in significantly reduced wetland disturbance. It should be noted that there will still be some potential direct and secondary wetland disturbance with any weir installation in Yucca Pens. The location of this weir is #7 in **Figure 6-22**.

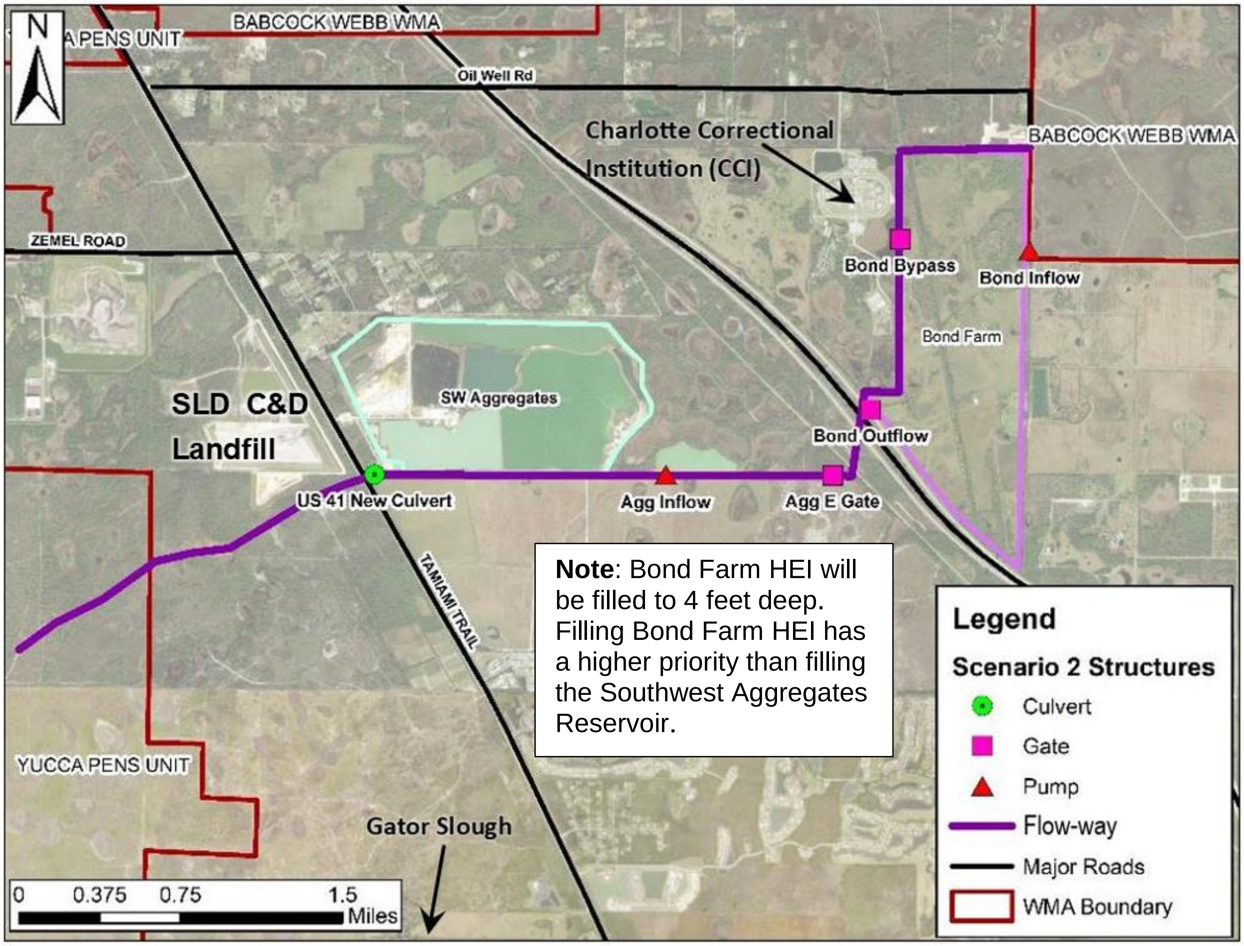


Figure 6-20. Scenario 2 Modeled Storage Areas and Flow-ways

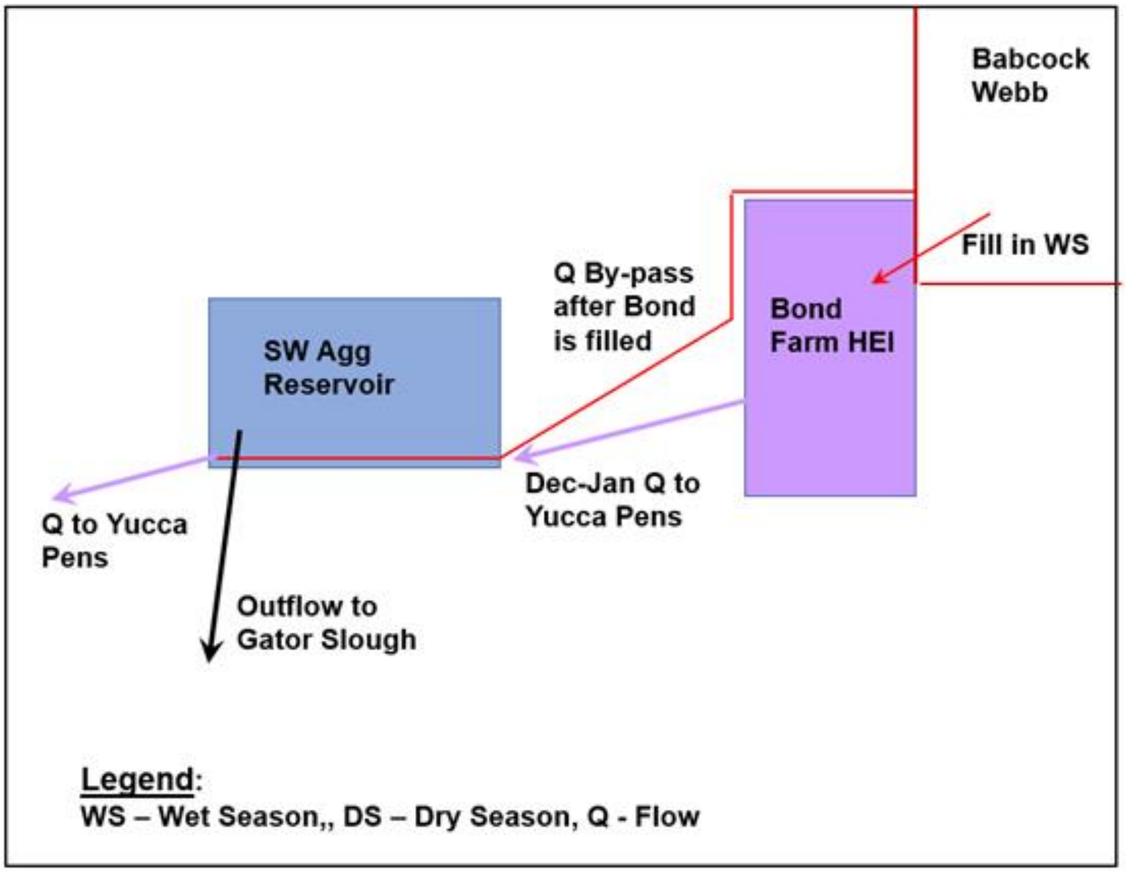


Figure 6-21. Schematic of Flow Routing, Babcock Webb to Bond Farm HEI and Southwest Aggregates Reservoir

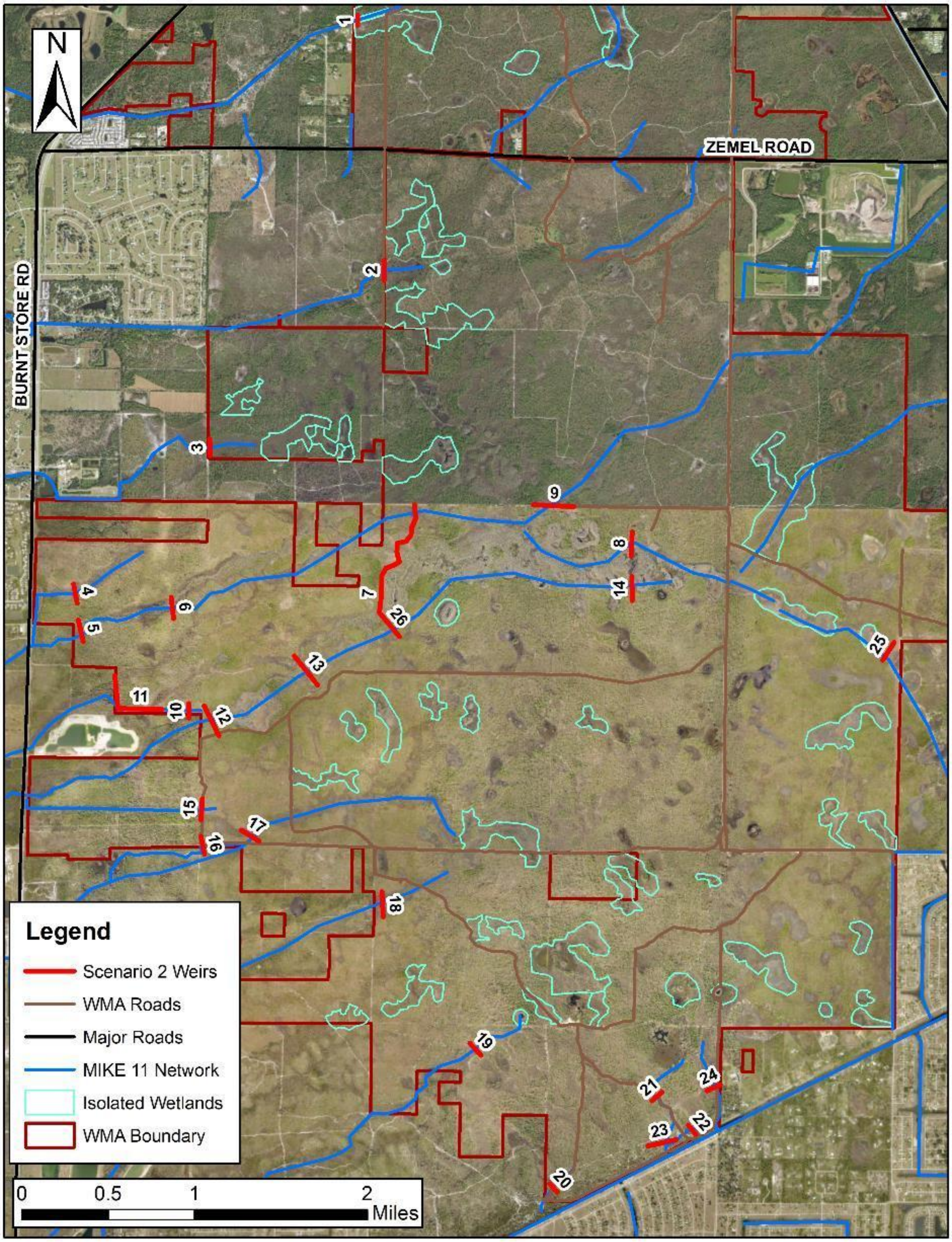


Figure 6-22. Map of Proposed Weirs/Low Water Fords in Yucca Pens

Scenario 2 simulations were run for 2012 – 2021. The simulation results were compared to the baseline existing conditions model results (also run for 2012 – 2021) and the Scenario 1 model results were used to determine the hydrologic response of the Scenario 2 restoration measures as described above. The difference between simulated hydroperiods in Yucca Pens for Scenario 1 and 2 is presented in **Figure 6-23**. The additional benefits of Scenario 2 (in comparison to Scenario 1) are primarily located in the Yucca Pens Creek and Durden Creek systems. The March – April water level difference between Scenario 2 and baseline existing conditions is presented in **Figure 6-24**. Please note that this figure also shows increased water levels around US-41 drainage ditches in the late dry season March – April when it is anticipated that these drainage ditches can handle this amount of added water. The July – November water level difference between Scenario 2 and baseline existing conditions is presented in **Figure 6-25**. Substantial decreases in water levels are observed in the SWIA of Babcock Webb and substantial increases in water levels are observed in Yucca Pens.

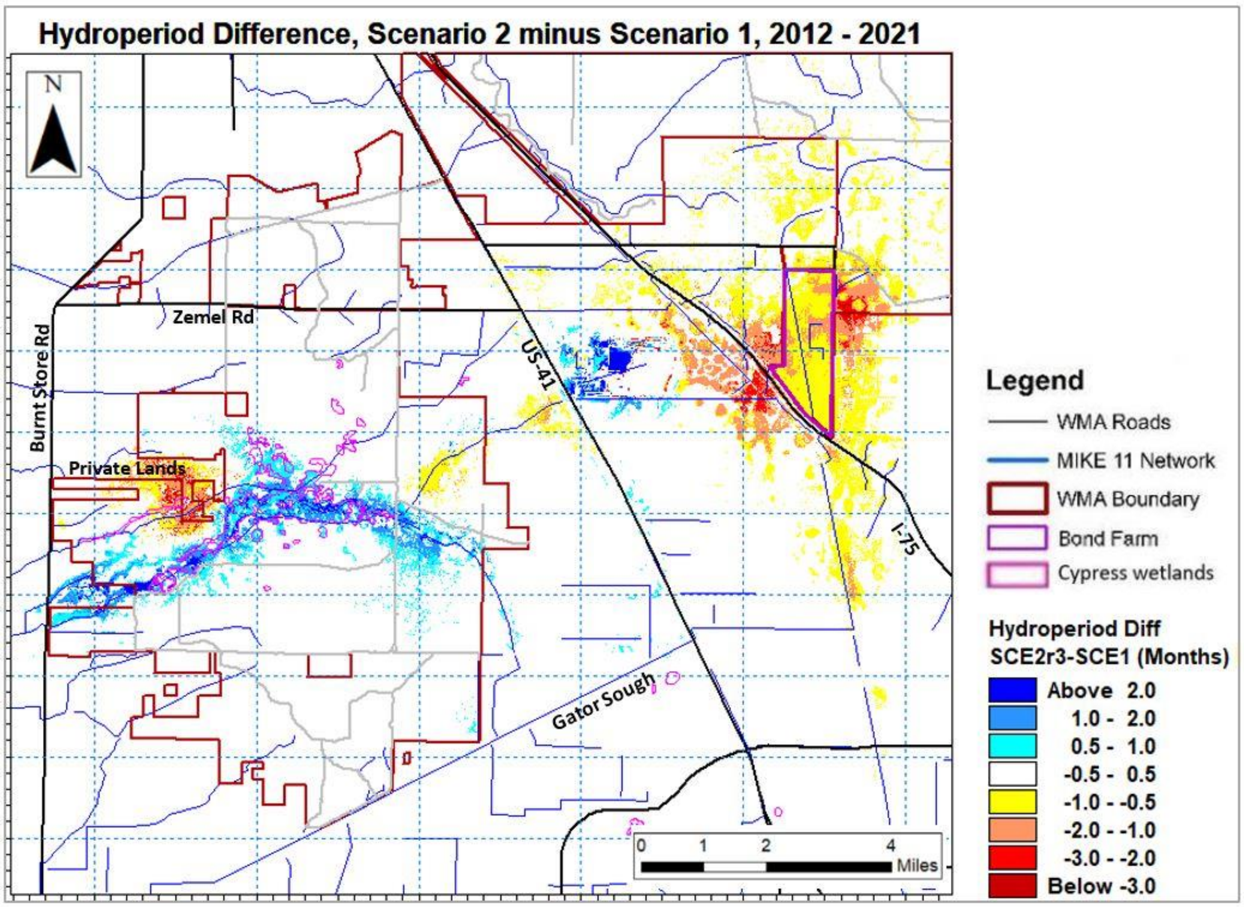


Figure 6-23. Scenario 2 minus Scenario 1 Hydroperiod Difference at a 50-ft resolution during the period 2012 - 2021

Quantitative summaries of the Scenario 2 improvements/changes in Yucca Pens are presented below in **Table 6-4**. Although specific quantitative acreage targets were not identified as a project goal, acreage totals are presented below in order to further demonstrate hydrologic restoration. Hydroperiod increases of greater than one month are predicted for 3,466 acres of Yucca Pens in Scenario 2 model results (improvements were seen in 2,554 acres for Scenario 1). Water levels in March and April are predicted to increase for more than 15,000 acres (78%) of the 20,000 acre Yucca Pens WMA. The improvement area includes 431 acres with more than one foot of improved water level, and 5,440 acres where water levels increased by 0.25 to 0.5 feet. This means that the hydroperiod range and water levels in Yucca Pens are now closer to optimum conditions for these areas.

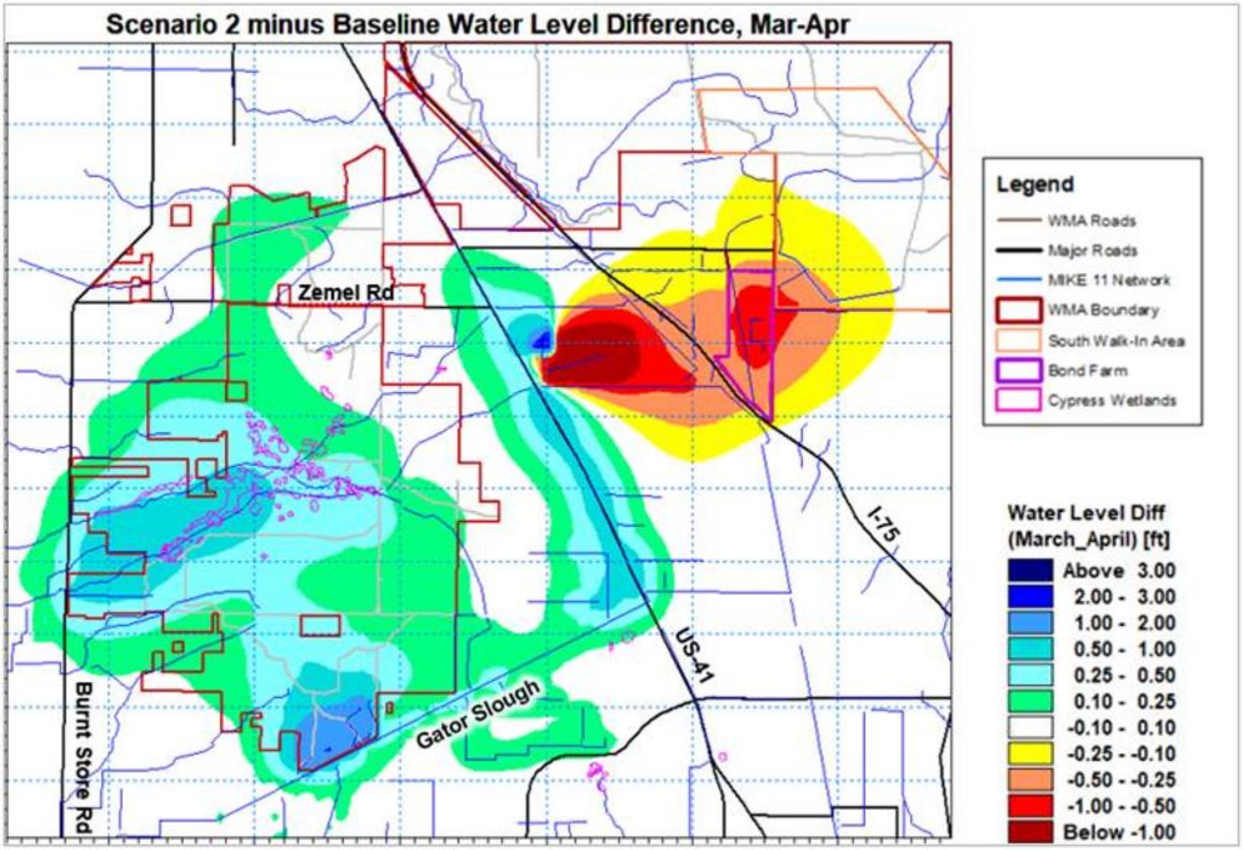


Figure 6-24. Scenario 2 minus baseline Water Level Differences during March – April during the period 2012 – 2021

Table 6-4. Summary of Scenario 2 Hydroperiod and March – April Water Level Improvements in Yucca Pens

Hydroperiod Difference	**Area, ac. (S2-Baseline)**	**+/- from S1, ac.**	**Avg Hydroperiod Change, months**
> 2 months	+1,081	+355	+2.89
1 - 2 months	+2,385	+557	+1.4
0.5 - 1 months	+2,799	+198	+0.72
0.25 - 0.5 months	+2,435	+102	+0.37
> 0.25 months	+8,700	+1,212	+1.08
Water Elevation Difference, March - April	**Area, ac. (S2-Baseline)**	**+/- from S1, ac.**	**Avg Elevation Change, ft**
> 2.0 ft	+2	+1	+2.04
1.0 – 2.0 ft	+429	+20	+1.38
0.5 – 1.0 ft	+2,210	+1,549	+0.65
0.25 - 0.5 ft	+5,440	+2,016	+0.34
0.1 - 0.25 ft	+7,550	-872	+0.17
> 0.1 ft	+15,631	+2,714	+0.33

Quantitative summaries of Babcock Webb hydroperiod and water level changes due to the modeled Scenario 2 restoration measures are presented below in **Table 6-5**. Although specific quantitative acreage targets were not identified as a project goal, acreage totals are presented below in order to further demonstrate hydrologic restoration. Reduced wetland hydroperiods and decreased water levels are predicted in a portion of the Babcock Webb SWIA because of water deliveries to both the Bond Farm HEI and the proposed Southwest Aggregates Reservoir. Hydroperiods in the SWIA have dropped below 10.5 months for a larger percentage of the Hydro Rank 4 wetlands and the percentage of Hydro Rank 3 wetlands with hydroperiods above 10.5 months has decreased significantly. However, the Scenario 2 results suggest that additional off-line storage will be needed to achieve more optimal hydrologic restoration of the Babcock Webb SWIA.

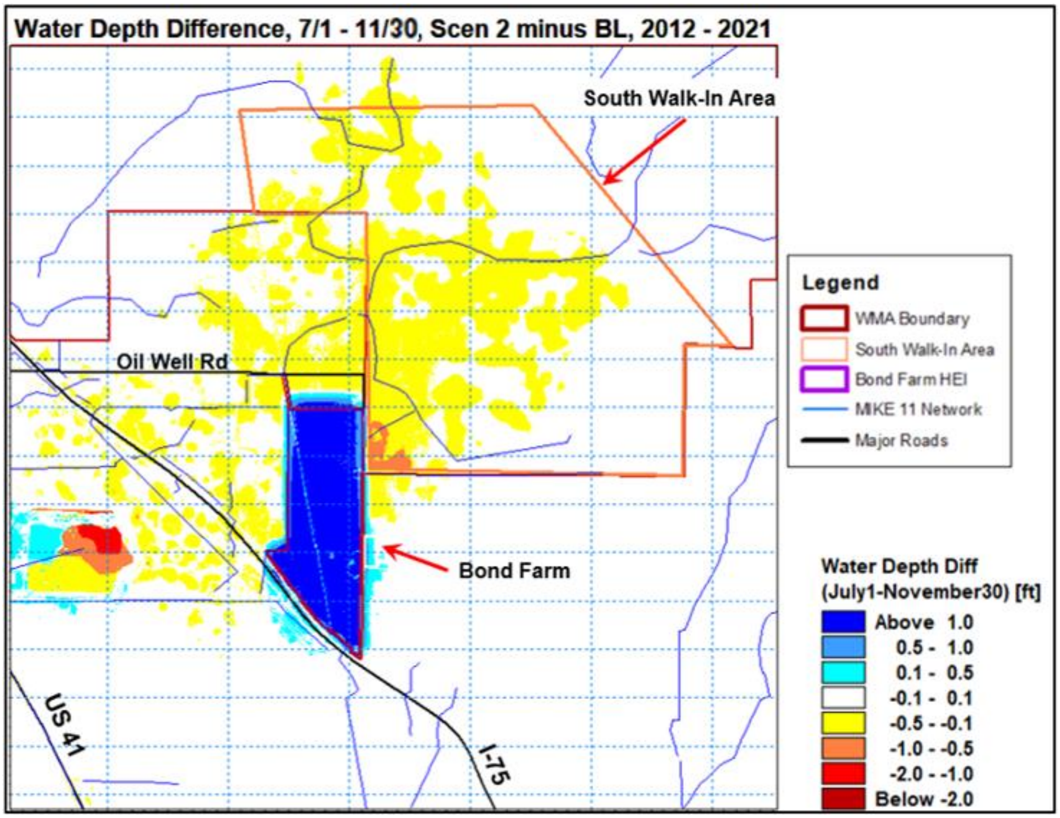


Figure 6-25. Scenario 2 minus baseline Water Level Differences in Babcock Webb SWIA during July 1 – November 30 during the period 2012 – 2021

Table 6-5. Babcock Webb SWIA hydroperiod and water level changes

Hydroperiod Decrease	Area, ac. (S2-Baseline)	+/- from S1, ac.	Average Hydroperiod Change, months
> 2 months	89	+89	-2.5
1 - 2 months	208	+208	-1.4
0.5 - 1 months	440	+398	-0.7
0.25 - 0.5 months	935	+766	-0.36
Water Elevation Difference, July 1 – Nov 30	**Area, ac. (S2-Baseline)**	**+/- from S1, ac.**	**Average Elevation Change, ft**
0.5 – 1.0 ft	40	+40	-0.61
0.25 - 0.5 ft	123	+123	-0.36
0.1 - 0.25 ft	1,674	+1,580	-0.18

Scenario 2 simulated flows at Burnt Store Road for Greenwell Branch, Durden Creek, Yucca Pens Creek, and Hog Branch were compared to Scenario 1 simulated flows for these same creeks. A statistical comparison of the changes in peak flows for both Scenarios 1 and 2 is presented in **Table 6-6**. Current model results show that there is less reduction of peak flows in Scenario 2 as compared to Scenario 1 due to additional water flowing out of US-41 ditches into Yucca Pens during the wet season, future modeling would need to occur to refine measures identified in Recommendations section to mitigate this. However, Scenario 2 recession limb of the flow after many storm events has been extended due to the restoration measures. One example of this is the ATV ditch blocks which slow flow out of Yucca Pens wetland areas and help retain water. This essentially demonstrates that flashiness in streams is attenuated or reduced so that there is more moderate flow in these streams rather than extreme high and low flow events. The attenuation of freshwater flows is beneficial for sport fish diet as prey species in these tidal creeks can be positively impacted by mimicking a more natural freshwater flow.

Table 6-6. Comparison of changes in peak flows for 74 rain or storm events as compared to baseline, 2012 – 2021

Statistic	Scenario 1	Scenario 2
Median Change in Peak Flow, %	-16%	-1%
25th Percentile Change in Peak Flow, %	-8%	+8%
75th Percentile Change in Peak Flow, %	-22%	-10%

A detailed evaluation of simulated flows during the late wet/early dry seasons (November 1 through January 31) was conducted to highlight the differences between Scenarios 1 and 2. Flows for November 1 through January 31 for each simulation year under Burnt Store Road from Greenwell Branch, Durden Creek, Yucca Pens Creek, and Hog Branch for Scenarios 1 and 2 are compared in **Table 6-7**, and locations of the stations are shown in **Figure 6-26**. There is less reduction of peak flows in Scenario 2 during the wet season due to more water being delivered to Yucca Pens. In addition, in Scenario 2, high water levels in US-41 ditches route water west to Yucca Pens during the wet season. However, due to the additional conditions in Scenario 2 (added storage, additional delivery of water via flow-way to Yucca Pens, modified Weir 3 location), the recession limb of the flow after each storm or rain event has been extended in Scenario 2. Thus, Scenario 2 provides further restoration benefit by extending the duration of positive discharges from Yucca Pens to tidal creeks during the early dry season. On average, Scenario 2 provides 87% more freshwater flow from Yucca Pens to tidal creeks during the early dry season than Scenario 1, which will have beneficial impacts to coastal ecosystems. Future refinement of Scenario 2 to include a gate west of US-41 is needed to achieve the desired goal of reducing peak wet season discharges to tide.

Table 6-7. Simulated flows under Burnt Store Road for Scenarios 1 and 2, Greenwell Branch to Hog Branch

Flows November 1 to January 31, acre feet			
Year	**Scenario 1**	**Scenario 2**	**S2 – S1**
2012	199	1,538	+1,339
2013	138	1,041	+903
2014	1,450	2,905	+1,455
2015	10,018	13,590	+3,572
2016	84	678	+594
2017	563	2,155	+1,592
2018	173	1,373	+1,200
2019	469	1,552	+1,083
2020	4,947	8,925	+3,978
Averages	**2,005**	**3,751**	**+1,746**

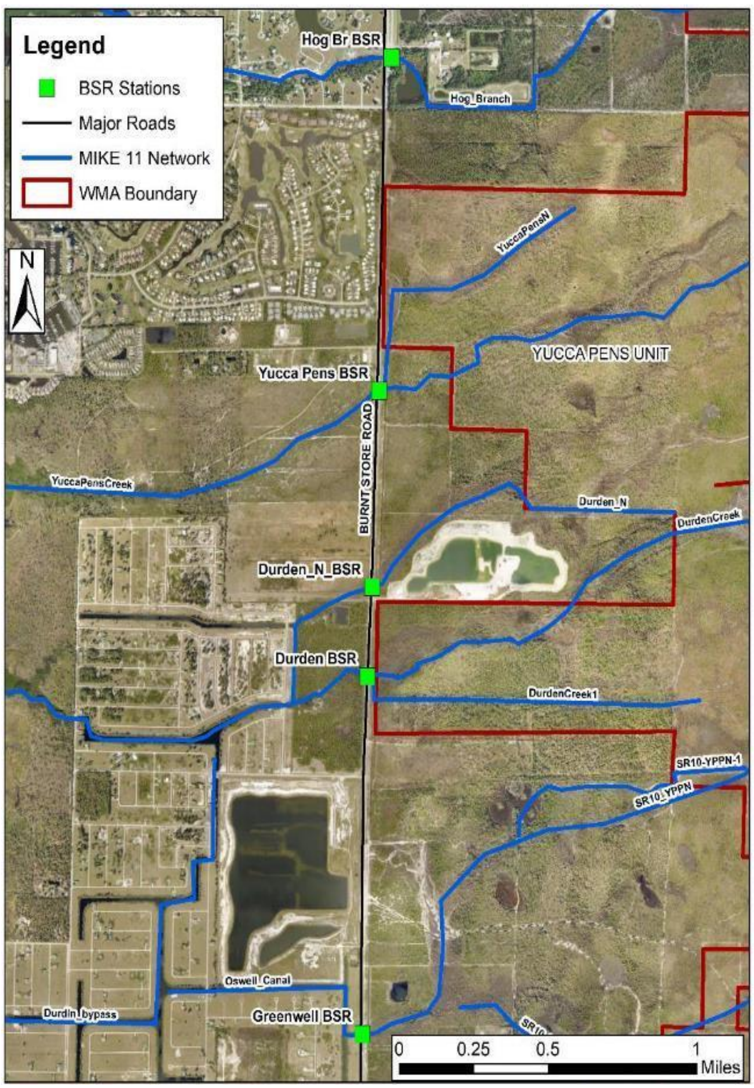


Figure 6-26. Map of Stations, Hog Branch to Greenwell Branch

Histogram Analysis of Scenario 2. The Natural Systems Analysis presented in **Appendix 6A** provided a comparison of the baseline existing conditions simulated hydroperiods and average wet season water depths to optimum hydroperiods and depths expected under pre-development conditions. The Natural Systems Analysis results were presented as a series of histograms for AOIs within Babcock Webb and Yucca Pens.

In order to evaluate the performance of Scenario 2, simulated Scenario 2 results were compared to the Scenario 1 and baseline existing condition results for Hydro Ranks 3 and 4. Comparisons are presented for Babcock Webb South Walk-In (Reduced) for Hydro Rank levels 3 and 4 in **Figure 6-27**. Results for Yucca Pens Cypress and the Yucca Pens ATV AOIs are also presented in **Figure 6-27**.

Scenario 2 simulated hydroperiods in the Babcock Webb South Walk-In Area (Reduced) decreased for both Hydro Ranks 3 and 4. This is an improved result compared to Scenario 1 outcomes. The most common hydroperiod for the baseline existing conditions scenario for Hydro Rank 3 was 10.8 months, which was decreased to 10.1 months in Scenario 2. The most common hydroperiod for the baseline existing conditions for Hydro Rank 4 was 11.5 months, and the Scenario 2 hydroperiods were more broadly distributed with two peaks at 9.5 and 11.4 months. These results suggest that some of the wetlands in the Babcock Webb South Walk-In Area (Reduced) experienced reduced hydroperiods while the remaining wetlands throughout Babcock Webb did not change substantially. This is consistent with the hydroperiod difference map shown above in **Figure 6-23**.

The most common hydroperiod in Yucca Pens Cypress for the baseline existing condition scenario for Hydro Rank 3 was approximately 5.5 months, and Scenario 2 hydroperiods were more broadly distributed with two peaks at 5.4 months and 8.5 months. The most common hydroperiod for the baseline existing conditions scenario for Hydro Rank 4 was 5.9 months in Yucca Pens Cypress, Scenario 2 hydroperiods were more broadly distributed with peaks at 9.1 and 10.9 months. Scenario 2 simulated hydroperiods were longer than Scenario 1 simulated hydroperiods for Yucca Pens. This means that the hydroperiod ranges in Yucca Pens Cypress are now closer to optimum conditions for these areas, which is a significant improvement to baseline existing conditions. This also suggests that the hydrologic benefits of moving water from Bond Farm are concentrated in the Durden Creek area.

The most common hydroperiod for the baseline existing condition scenario for Hydro Rank 3 was approximately 4.5 months in the Yucca Pens ATV areas, while the most common hydroperiod for Scenario 2 increased to 5.6 months. The most common hydroperiods for the baseline existing conditions scenario were 3.9 and 5.7 months in the Yucca Pens ATV area, while the most common hydroperiod for Scenario 1 was 4.7 months with more broadly distributed peaks between 4.7 and 7.7 months. The Yucca Pens ATV AOI performed relatively similar in both Scenarios 1 and 2, with a slight improvement for Scenario 2 as evidenced by the difference map presented in **Figure 6-28**. This means that the hydroperiod ranges in Yucca Pens ATV AOI are now closer to optimum conditions for these areas.

Note for hydroperiod histograms below:

- light blue bar is the optimum hydroperiod for Hydro Rank 3
- dark blue bar is the optimum hydroperiod for Hydro Rank 4

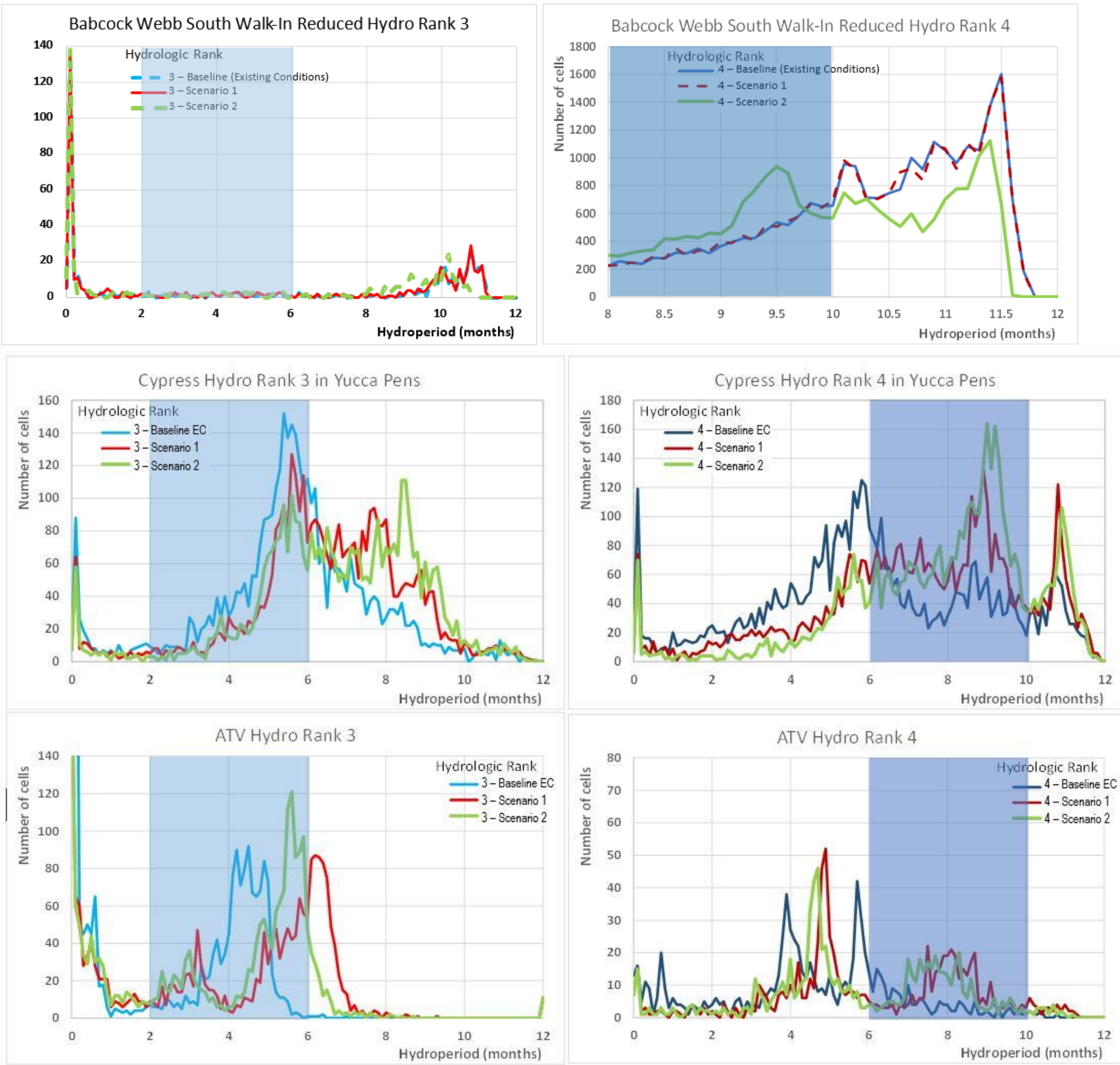


Figure 6-27. Comparison of Scenarios 1 and 2 for Babcock Webb South Walk-In Area (Reduced), Yucca Pens Cypress, and Yucca Pens ATV AOIs, for Hydro Rank 3 and Hydro Rank 4

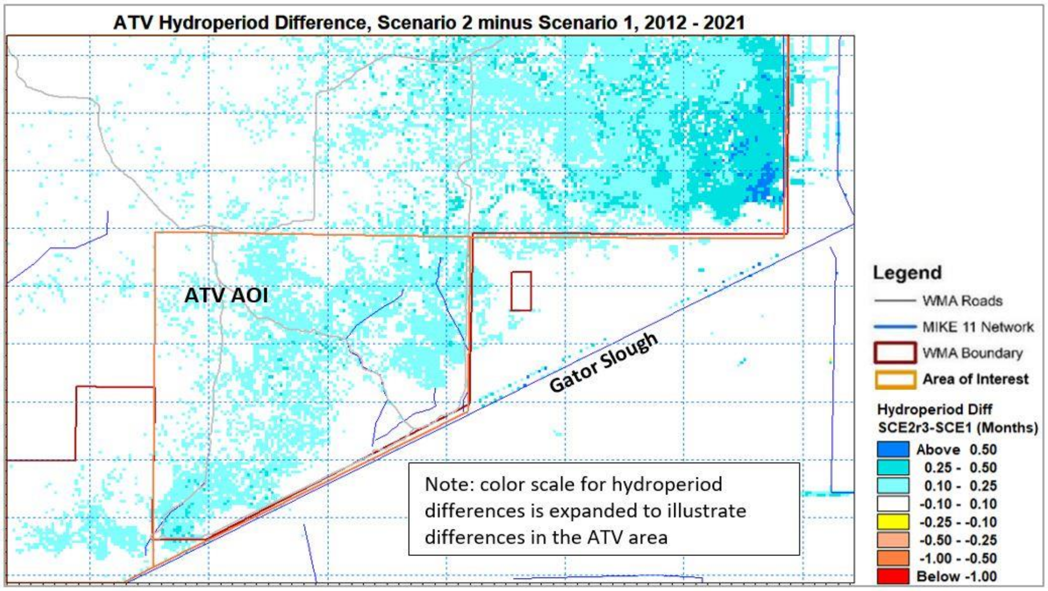


Figure 6-28. Scenario 2 minus Scenario 1 Yucca Pens ATV hydroperiod differences during the period 2012-2021 (note finer color scale than prior figures)

Simulated Performance for the Bond Farm HEI and the Southwest Aggregates Reservoir. The Bond Farm HEI was assumed to store water pumped from the southwestern portion of Babcock Webb with water depths up to 4 feet during the wet season and to release water during the dry season. Scenario 2 includes a flow-way west from Bond Farm HEI to Yucca Pens. Scenario 2 also includes storage of up to 4,744 acre-feet (from simulated model performance based on low seepage/transmissivity and 10-foot storage depth across 474 acres) in the proposed Southwest Aggregates Reservoir. Please note that these dimensions will need to be verified and refined during future modeling efforts. The Scenario 2 simulated inflows and outflows for Bond Farm HEI and Southwest Aggregates Reservoir during the period of 2012 – 2021 are summarized below in **Table 6-8**. Outflows are less than 50% of inflows for the final calibrated model (assumed lower water table hydraulic conductivity in Bond Farm HEI only). Much of the difference between inflows and outflows is due to groundwater seepage (72%), with a small percentage due to evaporation (28%). The simulation with capped conductivities indicates lower overall losses to groundwater due to seepage. On average, simulated Bond Farm HEI outflows were 62% of simulated inflows for the sensitivity test (reduced hydraulic conductivity simulation).

Table 6-8. Simulated Inflows and outflows for Bond Farm HEI and Southwest Aggregates Reservoir (in acre-feet)

Year	Bond Farm HEI In	Bond Farm HEI Out	Southwest Aggregates In	Southwest Aggregates Out
Average, Final Calibration	3,299	1,042	6,800	4,744
Average, Sensitivity Test	2,448	1,524	6,413	4,744

Note: final calibration model described in Appendix 5C (WSA & CHNEP, 2022b). Sensitivity test assumptions described in Appendix 6B (WSA & CHNEP, 2022). Additional discussion in **Exhibit 1**.

Summary of Scenario 2 Results. Scenario 2 includes storage of excess water from Babcock Webb in Southwest Aggregates in addition to storage in Bond Farm HEI (also included in Scenario 1). The analysis of Scenario 2 simulation results indicated that hydroperiod decreases greater than 0.5 months are predicted for 737 acres in the SWIA of Babcock Webb, meaning hydroperiods are closer to optimum conditions due to increased removal of water from Babcock Webb. However, hydroperiods in Babcock Webb were still not optimal and additional storage may be needed to provide greater restoration of the Babcock Webb SWIA.

In Yucca Pens, hydroperiods and water depths will increase as a result of the proposed restoration measures described above in Scenario 2. Hydroperiod increases of greater than one month are predicted for 3,465 acres of Yucca Pens, which closer to optimum conditions and therefore a greater level of restoration than predicted for Scenario 1. Water table levels in March and April (dry season) are predicted to be greater than one foot for 431 acres, and water levels are predicted to increase by more than 0.25 feet for 8,082 acres in Yucca Pens.

A comparison of discharges to tidal creeks during the late wet/early dry season was conducted for Scenarios 1 and 2. There is less reduction of peak flows in Scenario 2 during the wet season due to more water being delivered to Yucca Pens. In addition, in Scenario 2, high water levels in US-41 ditches route water west to Yucca Pens during the wet season. However, due to the additional conditions in Scenario 2 (added storage, additional delivery of water via flow-way to Yucca Pens, modified Weir 3 location), the recession limb of the flow after each storm or rain event has been extended in Scenario 2. Thus, Scenario 2 provides further restoration benefit by extending the duration of positive discharges from Yucca Pens to tidal creeks during the early dry season. On average, Scenario 2 provides 87% more freshwater flow from Yucca Pens to tidal creeks during the early dry season than Scenario 1, which will have beneficial impacts to coastal ecosystems. Future refinement of Scenario 2 to include a gate west of US-41 is needed to achieve the desired goal of reducing peak wet season discharges to tide.

Based on the analysis described herein, Scenario 2 is recommended for implementation due to hydrologic improvements in both Babcock Webb and Yucca Pens. Further model refinements of Scenario 2 are recommended during subsequent restoration planning and design efforts. Additional calibration is recommended to decrease uncertainties regarding groundwater hydraulic conductivities, and this effort may indicate that greater restoration can be achieved by Scenario 2. Recalibration may indicate more substantial Yucca Pens peak flow reductions at Burnt Store Road. In addition, refinements are recommended for the operating protocols for the Bond Farm HEI and Southwest Aggregates Reservoir and are described in **Section 7**. Further explanation on the need for these model refinements can be found in **Section 7**.

6.4 FUTURE CONDITIONS SCENARIO 3

Scenario 3 includes Scenario 2 improvements along with rainfall, ET and sea level rise assumptions associated with climate change. A detailed discussion of the climate change assumptions is provided in **Appendix 6D**. A summary of climate change assumptions is provided below:

- During the development of this model there were too many uncertainties to confidently assume how rainfall will change either in quantity or distribution. Therefore, rainfall will remain unchanged in the model and results should be interpreted carefully before being used for decision making and planning. These assumption should be revisited in future climate change scenario analyses when scientific investigations are able to reduce the uncertainty in predicting how rainfall will change due to climate change as it is near certain that future rainfall will be different.
- Sea levels will rise 1.64 feet by 2050, based on the NOAA case of Intermediate/High Sea Level Rise with Low Accretion Rate (ESA & CHNEP, 2020). This assumption is similar to other recent regional studies.
- ET will increase by 6.3% by 2050. This assumption is similar to other regional studies (ESA & CHNEP, 2020).

Implementation of modeling assumptions made in Scenario 2 are contingent upon a number of key factors: First this scenario can only be implemented if private and public landowners in the region of the proposed flow-way are willing to work with regional partners to secure property easements, publicly acquire land and/or permits in order to allow water to move from Bond Farm HEI to Yucca Pens; Second stakeholders will need to formally acquire use of the Southwest Aggregates Reservoir to potentially store additional freshwater in the wet season; Finally, stakeholders will need to agree to routing water from the Southwest Aggregates Reservoir to transport freshwater flows to Gator Slough in the late dry season only when freshwater flows are needed.

Scenario 3 Hydroperiods and Wet Season Water Depths. Scenario 3 and baseline simulations were run for 2012 – 2021 and the simulation results were analyzed to determine the hydrologic response of the Scenario 3 climate change assumptions. **Figure 6-29** presents the difference between Scenario 3 and the baseline existing conditions scenario, simulated wetland hydroperiods for 2012 – 2021 appear below. Scenario 3 simulated hydroperiods are predicted to decrease slightly across much of Babcock Webb, and hydroperiod changes in the Babcock Webb SWIA are more prominent than for either Scenario 1 or 2. This may or may not be a beneficial change in hydroperiods to the SWIA. The difference between Scenarios 2 and 3 was evaluated as well, and overall hydroperiods are reduced in both Babcock Webb and Yucca Pens by 0.5 -1 month due to projected changes in climate (primarily increased ET). These are the kinds of results that may vary if a different input rainfall time series is used for the climate change scenario. If ET is increased, it could also increase rainfall amounts. Scenario 3 simulated hydroperiods are increased in tidally influenced areas west of Burnt Store Road and adjacent to the Caloosahatchee Estuary as compared to both baseline existing conditions and Scenario 2 simulations (primarily due to sea level rise).

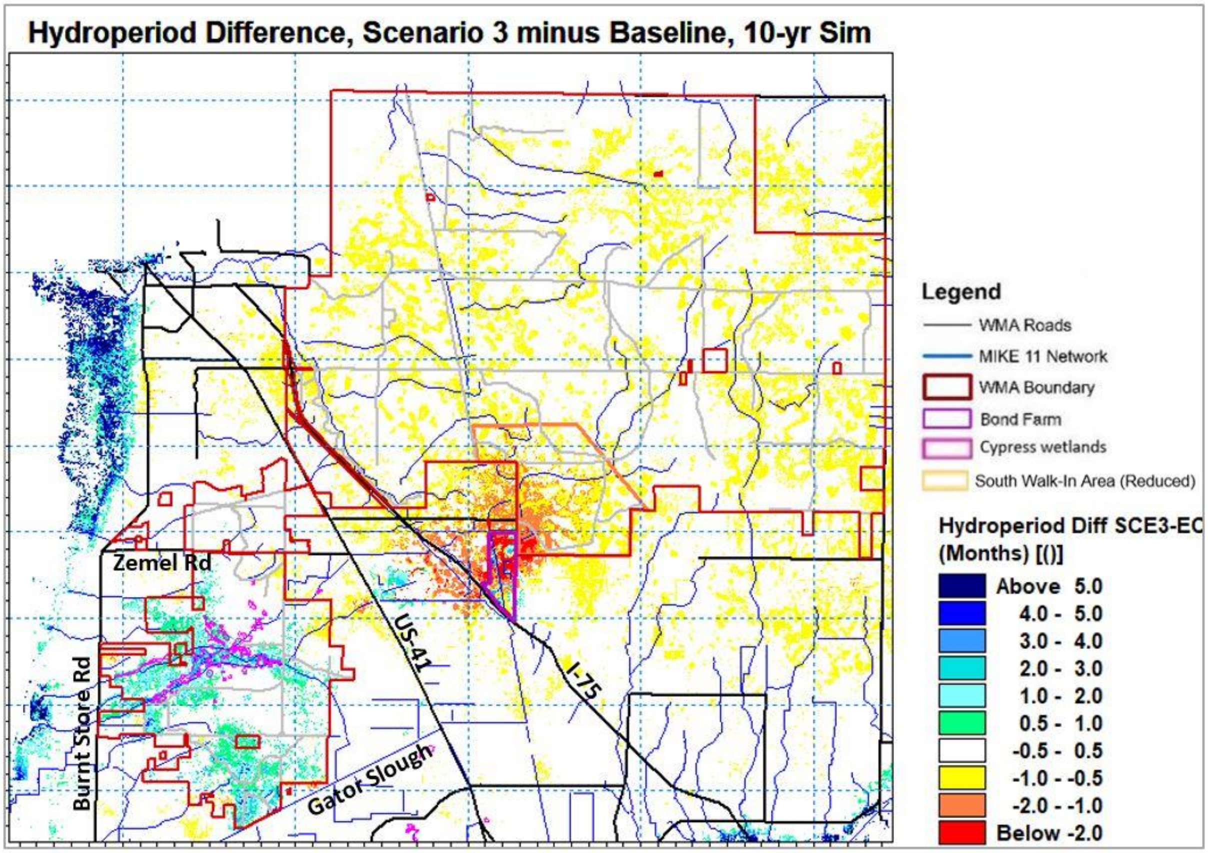


Figure 6-29. Scenario 3 minus baseline Average Hydroperiod Difference for 2012-2021, at a 50-ft Resolution

Wet season water depth differences associated with Scenario 3 relative to baseline conditions are presented in **Figure 6-30**. The restoration goals of reduced water depths in the Babcock Webb SWIA and increased water depths in Yucca Pens that were achieved in Scenario 2 were still maintained in Scenario 3 with slight differences. The most significant difference between Scenario 2 and Scenario 3 is the increased water depths predicted in tidally influenced lands west of Burnt Store Road. Minor decreases in water depths are predicted for the Babcock Webb SWIA. Wet season water levels for Scenarios 3 are less than 0.1 feet lower than Scenario 2 levels in Yucca Pens Cypress and the most southern area of Yucca Pens.

Dry season groundwater level differences between Scenario 3 and baseline existing conditions are presented in **Figure 6-31**. Groundwater levels are predicted to increase in the tidally influenced lands west of Burnt Store Road and adjacent to the Caloosahatchee Estuary. Decreases in water levels are predicted in most of Babcock Webb in Scenario 3, with groundwater levels decreasing by an average of 0.25 – 0.5 feet in the dry season during the months of March and April. Although hydroperiods in Babcock Webb appear to be improving due to climate factors, decreased groundwater levels during the dry season will have deleterious impacts on habitat conditions in Babcock Webb. Additionally, groundwater levels can impact fire potential which will become very important as the area is increasingly developed and prescribed fire becomes a concern to surrounding residents. Scenario 3 Yucca Pens dry season groundwater levels are still predicted to be higher than baseline existing conditions in the southern portion and in the Durden and Yucca Pens Creek watersheds. Yucca Pens Scenario 3 groundwater levels are predicted to decrease between 0.1 and 0.25 feet in the vicinity of Zemel Road and along the eastern border of Yucca Pens.

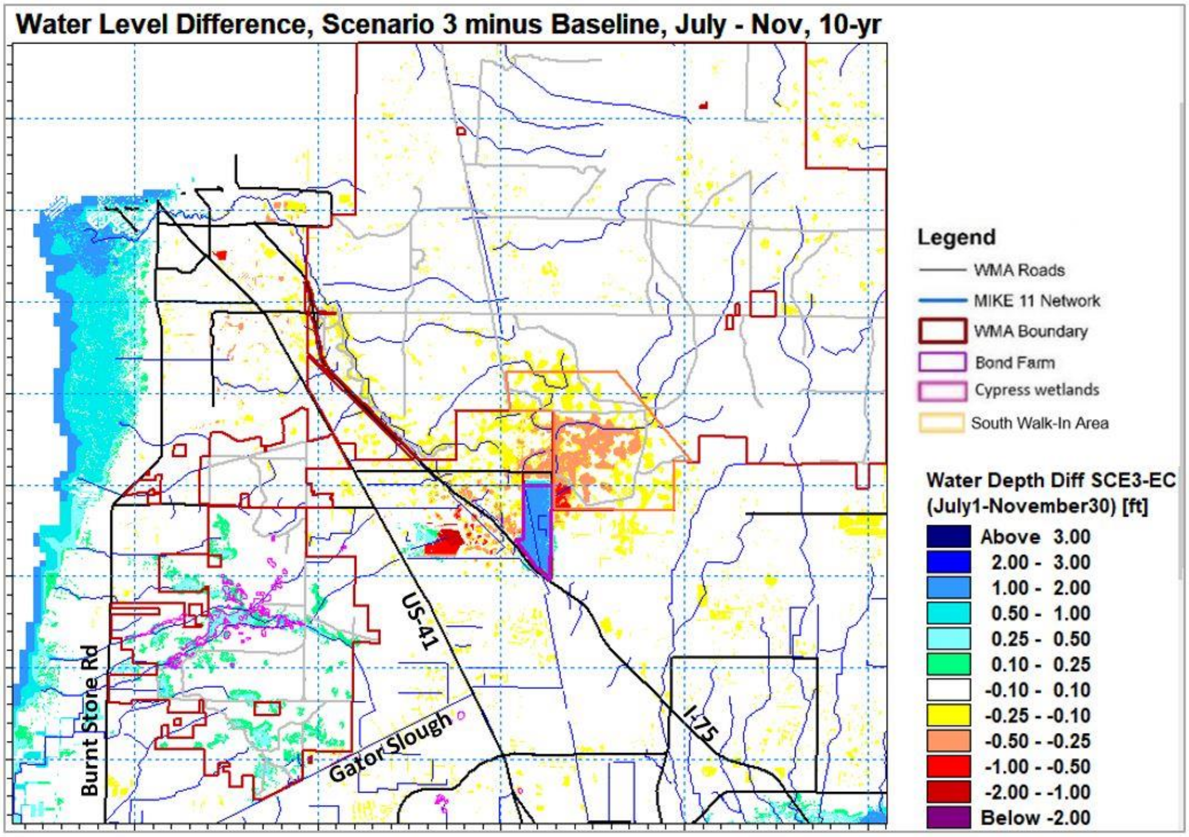


Figure 6-30. Scenario 3 minus baseline Average Annual Wet Season Surface Water level Difference for 2012-2021, at a 50-ft Resolution

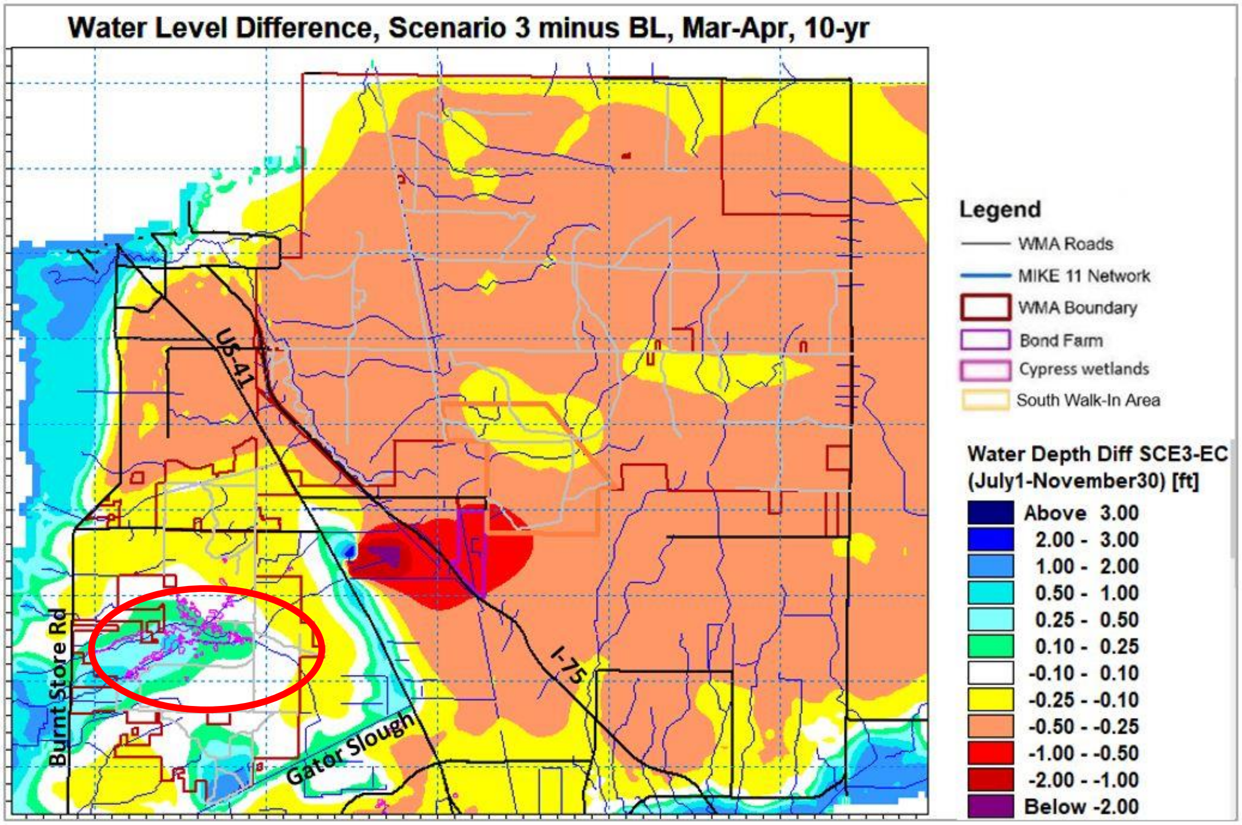


Figure 6-31. Scenario 3 minus baseline Groundwater level difference March - April during the period 2012 – 2021 (red ellipse indicates Yucca Pens Creek and Durden Creek watersheds)

Quantitative summaries of the changes in Yucca Pens are presented below in **Table 6-9**. In Yucca Pens, 2,163 acres saw hydroperiod improvements greater than one month, compared to 3,465 acres that were improved for Scenario 1. This is a 38% **decrease** in area improved in Yucca Pens. Water levels in the late dry season of March and April are still predicted to improve by greater than 1 foot for 304 acres.

Quantitative summaries of the changes in Babcock Webb in Scenario 3 are presented in **Table 6-10**. Scenario 2 improvements in hydroperiods and water levels were maintained and slightly increase overall in Scenario 3. Hydroperiod and water depth increases in Yucca Pens for Scenario 3 are still better than for the baseline existing condition scenario, however the improvements are less significant than for Scenarios 1 and 2. This is because Scenario 3 evapotranspiration rates are higher than for either Scenarios 1 or 2 (due to the climate change assumptions). Improvements gained from Scenario 2 projects in Yucca Pens continue to provide restoration benefits in Scenario 3. Hydroperiod and water depth decreases in the SWIA of Babcock Webb are more pronounced for Scenario 3 than for Scenario 2, again due to the increased evapotranspiration associated with climate change. This is a benefit for the SWIA, but is a negative impact in the remainder of Babcock Webb where reductions in hydroperiods and water depths are not desired. In Scenario 3, wetland hydroperiods and water depths were reduced throughout most of Babcock Webb. Hydroperiods in Scenario 3 will be 1 - 2 months shorter than baseline existing conditions in 692 acres. Hydroperiods in Scenario 3 will be 0.5 - 1 month shorter than baseline existing conditions for 14,155 acres. Water depths in Scenario 3 will decrease by 0.25 - 0.5 feet for 56,364 acres in Babcock Webb as compared to baseline existing conditions.

Simulated combined flows at Burnt Store Road for Greenwell Branch, Durden Creek, Yucca Pens Creek, and Hog Branch are presented in **Table 6-11**. The peak flow reduction in Scenario 1 is greater than Scenario 2. In Scenario 3, peak flows are less reduced for most rainfall or storm events, demonstrating a slight decrease in benefits gained in Scenario 1, due to the extra water retained by the proposed 26 water control structures in Yucca Pens counteracting climate change adverse impacts. In addition, the recession limb of each rain or storm event has been extended due to restoration measures from Scenario 1 and 2 and this overall benefit appears to continue for Scenario 3. Despite climate change impacts on the hydrology of both Babcock Webb and Yucca Pens, restoration measures continue to provide additional hydrologic benefits in Yucca Pens in extending the duration of positive discharges to tide during the early dry season. The attenuation of freshwater flows is beneficial for sport fish diet as prey species in these tidal creeks can be positively impacted by mimicking a more natural freshwater flow (Adams et al. 2009). Continued pursuit of extension of the recession limb in tidal creeks will provide the most benefits to downstream habitats and sport fish. Additionally, increased freshwater availability will help to buffer sea level rise and saltwater intrusion.

Table 6-9. Summary of Scenario 3 hydroperiod and March – April water level improvements in Yucca Pens relative to baseline existing conditions

Hydroperiod Difference	**Area, ac. (S3-Baseline)**	**+/- from S2, ac.**	**Avg Hydroperiod Change, months**
> 2 months	+754	-327	+2.87
1 - 2 months	+1,409	-975	+1.39
0.5 - 1 months	+1,850	-949	+0.73
0.25 - 0.5 months	+1,508	-928	+0.36
Total (> 0.25 months)	**+5,463**	**-3,237**	**+1.07**
Water Elevation Difference, March - April	**Area, ac. (S3-Baseline)**	**+/- from S2, ac.**	**Avg Elevation Change, ft**
> 2 ft	0	-2	0.00
1 - 2 ft	+304	-124	+1.24
0.5 - 1 ft	+963	-1,248	+0.66
0.25 - 0.5 ft	+2,285	-3,155	+0.36
0.1 - 0.25 ft	+2,761	-4,789	+0.17
Total (> 0.1 ft)	**+6,313**	**-9,318**	**+0.36**

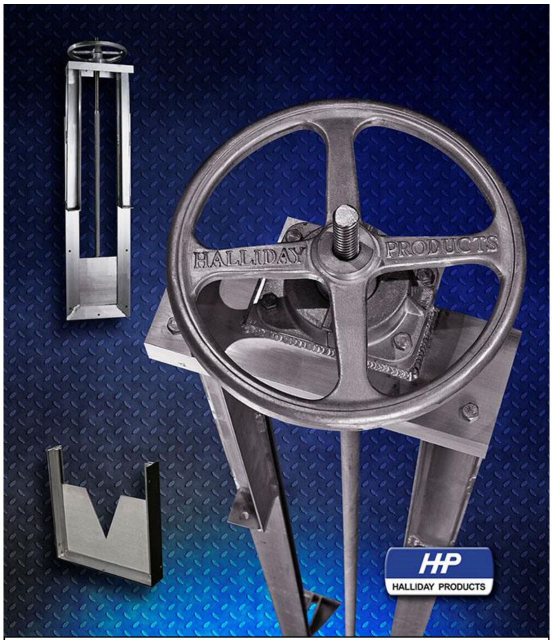
Table 6-10. Summary of Scenario 3 hydroperiod and March – April water level improvements in Babcock Webb relative to baseline existing conditions

Hydroperiod Difference	Area, ac. (S3-Baseline)	+/- from S2, ac.	Avg Hydroperiod Change, months
< -2 months	+94	+5	-2.65
-2 to -1 months	+692	+484	-1.23
-1 to -0.5 months	+14,155	+13,715	-0.63
Water Elevation Difference, March - April	**Area, ac. (S3-Baseline)**	**+/- from S2, ac.**	**Avg Elevation Change, ft**
-1 to -0.5 ft	+319	+279	-0.62
-0.5 to -0.25 ft	+56,364	+56,241	-0.29
-0.25 to -0.1 ft	+10,839	+9,165	-0.22

Table 6-11. Changes in peak flows for 74 rain or storm events as compared to baseline, 2012 – 2021

Statistic	Scenario 1	Scenario 2	Scenario 3
Median Change in Peak Flow, %	-16%	-1%	-13%
25^{th} Percentile Change in Peak Flow, %	-8%	+8%	-2%
75^{th} Percentile Change in Peak Flow, %	-22%	-10%	-20%

Mitigation Efforts to Address Climate Change. The most significant dry season water level reductions occur in Babcock Webb. There are several corrugated metal pipe (CMP) risers and two gated weirs in Babcock Webb that are not actively managed, and changes to those structures could be implemented to adopt different control elevations during the wet and dry seasons. In order to mitigate climate change impacts, it is recommended that the structures remain in open or partially open positions during the wet season and gate elevations be raised at the end of the wet season to hold water on the landscape for the coming dry season. Additionally, there is potential to retrofit leaking riser structures with metal lift gates that can be installed on the upstream side of existing CMP risers (Halliday Products, Orlando, FL). Structures SR-2, SP-4, SP-5, SP-6, SP-7, SP-9, SP-9, and SP-10 as well as a number of other risers are candidates for this type of operation.



Lift Gates, https://www.hallidayproducts.com/

Simulated Performance for the Bond Farm HEI and the Southwest Aggregates Reservoir. Bond Farm HEI and Southwest Aggregates Reservoir operations for Scenario 3 are unchanged from Scenario 2. The Scenario 3 simulated inflows and outflows for Bond Farm HEI and

Southwest Aggregates Reservoir during the period of 2012 – 2021 are summarized below in **Table 6-12**. Outflows are less than 50% of inflows for the final calibrated model which assumed lower water table hydraulic conductivity in Bond Farm HEI only. The majority of the difference between inflows and outflows is due to groundwater seepage (72%), with a small percentage due to evaporation (28%).

Table 6-12. Simulated Inflows and outflows for Bond Farm HEI and Southwest Aggregates Reservoir (in acre-feet)

Year	Bond Farm HEI In	Bond Farm HEI Out	Southwest Aggregates In	Southwest Aggregates Out
Average, Final Calibration	3,066	943	6,016	4,744
Average, Sensitivity Test	2,353	1,418	5,719	4,744

Note: final calibration model described in Appendix 5C (WSA & CHNEP, 2022b). Sensitivity test assumptions described in Appendix 6B (WSA & CHNEP, 2022).

The simulation with capped conductivities indicates lower overall losses to groundwater. On average, simulated Bond Farm HEI outflows were 62% of simulated inflows for the sensitivity test (reduced hydraulic conductivity simulation). Scenario 3 assumptions result in a 10% decrease in the volume of water stored in Bond Farm HEI and the Southwest Aggregates Reservoir as shown below:

Total Stored Bond Farm plus SW Agg Scenario 2: 10,099 acre-feet (final calibration)

Total Stored Bond Farm plus SW Agg Scenario 3: 9,082 acre-feet (final calibration)

The climate change scenario analysis of year-by-year water budgets for the two storage areas indicated that Bond Farm would not fill during 2014, a year with low wet season rainfall. Refinements are recommended in **Section 7** for the operating protocols for the Bond Farm HEI and Southwest Aggregates Reservoir inflow pumps so that the priorities for turning on both pumps may be varied through a series of sensitivity tests to obtain simulation results where Bond Farm HEI is filled to full capacity before the Southwest Aggregates Reservoir is filled during all simulation years. One possible approach is to have different operating rules for dry years where the Southwest Aggregates Reservoir inflow pump turns on at a higher trigger elevation, which will maximize inflows to the Bond Farm HEI.

Summary of Scenario 3 Results. The Scenario 3 simulation results suggest that:

- Improved wet season water depths from Scenario 2 will not change substantially in either Babcock Webb or Yucca Pens due to Scenario 3 climate change assumptions.
- Dry season water levels will decrease by 0.25 to 0.50 feet in most of Babcock Webb due to Scenario 3 climate change assumptions.
- Scenario 3 dry season water levels will still be higher than baseline existing conditions in most of Yucca Pens south of Zemel Road, however the water level improvements will be lower than for Scenario 2.
- Scenario 3 discharges under Burnt Store Road are 12% less than Scenario 2 between November 1 and January 31. However, discharges under Burnt Store Road during this period are still 65% higher than baseline existing conditions.
- Scenario 3 assumptions result in a 10% decrease (relative to Scenario 2) in the combined volume of water stored in Bond Farm HEI and the Southwest Aggregates Reservoir.

Based on the analysis described herein, while restoration benefits will be maintained, climate change assumptions will present additional challenges to future restoration planning and design efforts. Significant uncertainties exist when attempting to predict the changes in rainfall due to climate change. Climate change assumptions should be reviewed throughout the preliminary and final design of proposed restoration projects and effects of climate change on restoration measures should be evaluated using the best available information on future changes in tidal fluctuations, rainfall, and evapotranspiration (ET).

Dry season control elevations at existing water control structures are recommended for further consideration to mitigate the potential changes associated with climate change. There are several corrugated metal pipe (CMP) risers and two gated weirs in Babcock Webb that are not actively managed, and changes to those structures could be implemented to adopt different control elevations during the wet and dry seasons. In order to mitigate climate change impacts, it is recommended that the structures remain in open or partially open positions during the wet season and gate elevations be raised at the end of the wet season to hold water on the landscape for the coming dry season. Additionally, there is potential to retrofit leaking riser structures with metal lift gates that can be installed on the upstream side of existing CMP risers (Halliday Products, Orlando, FL). Structures SR-2, SP-4, SP-5, SP-6, SP-7, SP-9, SP-9, and SP-10 as well as a number of other risers that are not actively managed are candidates for this type of operation.

6.5 Summary of Scenario Analysis

The scenario analysis task defined optimum conditions for Babcock Webb and Yucca Pens. Baseline existing condition model hydroperiods and average wet season water depths for a 10-year simulation period were compared to optimum conditions. The analysis confirmed the findings of the ecologic analysis in Section 3, and the water level findings in Section 4, which is that there is too much water in the SWIA, and more water is needed in Yucca Pens Cypress and southern Yucca Pens. These results guided the alternatives analysis for Scenarios 1, 2, and 3.

Scenario 1 assumed that the 600-acre Bond Farm HEI parcel on the southwest corner of Babcock Webb will be used to store a maximum of 4 feet of excess waters from the SWIA. However, outflows resulting from the Bond Farm HEI storage are assumed to be directed south to the Caloosahatchee River providing no benefit to Yucca Pens. Scenario 1 also included 26 weirs in Yucca Pens to retain more water, reduce wet season discharges, and increase baseflow discharges to tide. A partial groundwater seepage barrier was also assumed along the south end of Yucca Pens adjacent to Gator Slough to retain water lost to Gator Slough.

Scenario 2 was a refinement of Scenario 1 with additional storage of excess flows in the Southwest Aggregates Reservoir and redirection of water stored in Bond Farm HEI and Southwest Aggregates to Yucca Pens. The Yucca Pens improvements from Scenario 1 were included in Scenario 2 with the location of one of the 26 weirs moved upstream to minimize impacts of higher water levels on private lands adjacent to Yucca Pens.

Scenario 3 included all features of Scenario 2 but also assumed climate change impacts, consisting of higher tidal water level boundaries and higher ET rates.

For Scenario 1, SWIA hydroperiods decreased by 0.35 months for 121 acres and by 0.66 months for 42 acres. Yucca Pens hydroperiods and dry season water table levels will increase substantially because of the proposed restoration measures described above. Hydroperiod increases of greater than 1 month are predicted for 2,554 acres of Yucca Pens. Relative to the baseline existing condition, water table levels in March and April are predicted to be increase by more than 1 foot for 410 acres, and water depths are predicted to increase by more than 0.25 feet for 4,672 acres.

Scenario 2 provided decreases in wetland hydroperiods and wet season water depths in the SWIA of Babcock Webb. Scenario 2 also provided additional restoration benefits in Yucca Pens above and beyond the Scenario 1 hydrologic benefits. This was due primarily to the additional storage of wet season runoff from Babcock Web. Scenario 2 discharges to tide during the early dry season (November 1 through January 31) are greater than for Scenario 1. Wet season peak flow discharges are less significant for Scenario 2 than for Scenario 1. Scenario 2 has higher peak wet season flows than Scenario 1 because US-41 ditch levels are higher than water levels in eastern Yucca Pens. A gate west of US-41 may be needed to achieve the desired goal of reducing peak wet season discharges to tide.

Scenario 3 results in lower wet season hydroperiods and decreased dry season water depths across most of the model domain except for portions of Yucca Pens (Yucca Pens and Durden Creek watersheds). In order to mitigate climate change impacts, it is recommended that the structures remain in open or partially open positions during the wet season and gate elevations be raised at the end of the wet season to hold water on the landscape for the coming dry season. Recommended locations of structures to be considered for wet/dry season gate operation improvements are presented in **Figure 6-32**.

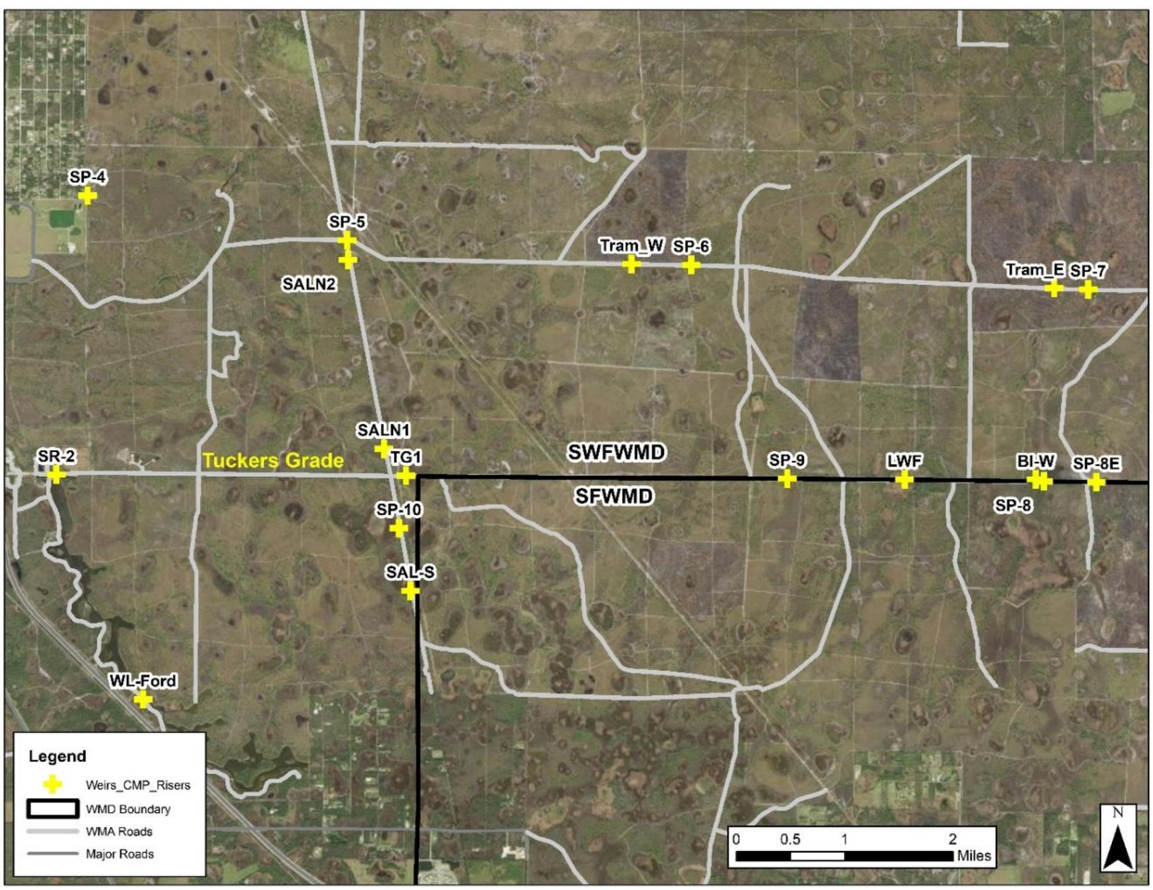


Figure 6-32. Babcock Webb existing CMP Risers to be considered for structural retrofits

7) RECOMMENDATIONS, CONCLUSIONS AND ACKNOWLEDGEMENTS

7.1 RECOMMENDATIONS

To meet project objectives as outlined in the introduction of this report and to advance the work of the Charlotte Harbor Flatwoods Initiative, recommended activities related to data collection, model refinement, projects, and operational protocol are outlined in this section. These proposed activities are based on stakeholder input and modeling results. Based on the analysis described herein, Scenario 2 is the ultimate recommended course of action however Scenario 1 restoration measures serve as an important first step and therefore it is recommended to focus on rapid implementation of elements that are common to both Scenario 1 and 2, including the Bond Farm HEI, Yucca Pens weirs and Yucca Pens partial groundwater seepage barrier. Specific measures taken to implement facets of Scenario 2 will require further model and project refinement during subsequent restoration planning and design efforts. Scenario 2 provides additional hydrologic restoration benefits to those benefits provided by Scenario 1 and buffers climate impacts as discussed in Scenario 3 results. Those benefits include:

- Improved restoration of hydroperiods and water depths in the SWIA of Babcock Webb due to greater storage capacity for wet season runoff from the SWIA.
- Greater restoration of wetland hydroperiod and water depths in Yucca Pens
- Increased discharges from Yucca Pens to tide during the late wet/early dry season

The objective of the recommendations presented below is to restore hydrology to natural systems in Babcock Webb and Yucca Pens WMAs while providing flood protection to communities south of this region. Stored water and operational water control structures should be designed to increase wetland hydroperiods and water depths to match, but not exceed, optimum conditions for these natural areas. Restoration strategies and projects below are needed presently to address near-term climatic conditions. It should be noted that water will only be sent to Gator Slough in the dry season when freshwater flows would be needed in these areas. One aspect of this solution would contribute what is historically needed for freshwater flows to Yellow Fever Creek and would offset the impact of development activities that reduced the Yellow Fever Creek drainage area. This would also reduce wet season discharges to Prairie Pines Preserve (PPP) and the Caloosahatchee estuary. Additionally, it would maintain flood protection for the same reasons mentioned above. This project and all future phases are modeled with the understanding that flood protection for communities is integral to project outcomes.

Recommended Future Data Collection

Through the course of the project, it was determined it would be useful for the overall project to collect additional information to continue to refine the model calibration and thereby improve the confidence of proposed future condition scenarios.

The following additional data collection efforts are summarized below:

1. Installation of Additional Monitoring Stations

To continue to understand the ecological restoration progress, it will be important to continue to document freshwater flows in upstream areas of tidal creeks as well as discharges from Gator

Slough and the tidal creeks to Matlacha Pass and Charlotte Harbor Aquatic Preserves and estuaries. One example would be to monitor the southern tributary of Hog Branch which is not currently included in the model as there is insufficient flow and survey data at this time. Three flow monitoring stations have already been added by FWC in late 2021 in the north portion of Babcock Webb in the North SAL Grade ditch.

To better understand flows from Bond Farm HEI south to the PPP and the impacts to Gator Slough and Powell Creek, installation of additional flow monitoring stations is recommended at two wooden trestle bridges under the Seminole Gulf Railroad (SGR) on the east side of PPP, as well as at SAL Grade culverts from PPP to Gator Slough, and south end of PPP at Powell Creek upstream of Del Prado Blvd. Note that permission is needed from SGR to install monitoring stations at the trestle bridges.

Combined with continued monitoring in Yucca Pens Creek, installation of tidal flow monitoring equipment is also recommended at the tidal interface in two additional creeks in Yucca Pens. Tentative locations of the two additional creeks are Durden Creek and Bear Branch.

Installation of more groundwater monitoring stations in northern Babcock Webb in the Southwest Florida Water Management District (SWFWMD) jurisdiction has also been recommended by SWFWMD to fill data gaps and improve model calibration.

Finally, installation of evapotranspiration monitoring stations is recommended at one location each in Babcock Webb and Yucca Pens to monitor evapotranspiration rates.

2. Additional Data Collection

While the model is suitable for the scenario analyses as part of this project, there are some areas where model performance could be improved and refined with additional data and analysis, these are listed below:

Topography. LiDAR elevations in low-lying areas of the SWIA, which are frequently flooded, can be inaccurate because LiDAR measures the water surface rather than ground elevations. Field surveys were conducted by FWC during the execution of the current project and topography data in the SWIA wetlands was improved during model calibration due to these efforts. However, more ground surveying is recommended in other wetland areas not surveyed as well as in upland areas in Babcock Webb with higher ground elevations that still experience inundation. Specifically, additional ground elevation and ecological surveying is recommended in the Babcock Webb SWIA, north Babcock Webb, the northwest corner of Bond Farm HEI where a conceptual western discharge is proposed, west of US-41 south of the SLD Construction and Demolition (C&D) Landfill, and in Yucca Pens cypress wetlands.

Channel Cross Sections. Additionally, more data should be collected to better understand surface water conveyances and sub-surface hydrogeology throughout the project area. Surveying is recommended to determine the outflow conveyances from the SWIA to augment the previous field survey effort. Field observations are recommended at the end of the wet season both at the outflow conveyances as well as in locations between the lowest elevations of wetlands within the SWIA. Stream cross section surveys are also recommended west of the SWIA and upstream and downstream of gaging stations on Burnt Store Road to better understand channel conveyance restrictions. It will be important to continue to collect data on freshwater flows upstream as well as discharges from Gator Slough and the tidal creeks to Matlacha Pass and Charlotte Harbor

Aquatic Preserves and estuaries. Additional flow monitoring is recommended at the tidal interface and throughout other Yucca Pens creeks and in the South Prong of Alligator Creek.

Hydrogeology. Hydrogeological studies are recommended in Babcock Webb and Yucca Pens to better understand variations in hydraulic conductivity in key areas, such as the SWIA and south Yucca Pens. There was high uncertainty around both saturated and unsaturated hydraulic conductivity values, which were also highly sensitive in the model. Specifically, 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 throughout Bond Farm HEI and the project area

Additional geotechnical field work is also recommended in southern Yucca Pens to provide new data for finer-scale modeling to better understand the depth and strata of surficial aquifer and the interaction between the Yucca Pens and Gator Slough Canal hydrology. Borings are recommended in Yucca Pens north of Gator Slough to identify the depth and effect of low and high permeable strata within the surficial aquifer. This data will also be critical to evaluation and design of any seepage barrier needed to control water losses to Gator Slough Canal through the groundwater system.

High Water Marks during Extreme Events. It is recommended to continue to collect field survey data related to extreme storm and rainfall events, including recording high water marks during and after such events. This data can be used to verify and improve model performance for multi-year seasonal evaluations.

Minor Tributaries. The current model did not include all the smaller tributaries in the area in the MIKE 11 flow-way network. The southern Hog Branch tributary is one example, as more information will need to be collected regarding tributary conveyances (e.g. known cross sections) and road crossings so they can be more accurately represented. Therefore, it is recommended that more data on this and any new or additional tributary identified as pertinent to future project modeling.

Lastly, SWFWMD has recommended to conduct ecological field studies and ground surveys immediately north and east of the SWIA, and in the vicinity of Tucker's Grade, to determine if hydrological conditions align with optimal natural conditions. Furthermore, identifying areas where flow is artificially channeled toward the SWIA may provide opportunity to attenuate flows and reduce wet season inundation.

3. Data Analysis and Cleaning

It is also important to address here that additional formatting can be done with data collected for the current project to improve data accessibility for stakeholders to conduct supplementary analyses. Future data collection protocols should align with the quality control and data formatting required for inclusion in District and FDEP databases.

Recommended Future Modeling

A comprehensive surface and ground water integrated model of the Charlotte Harbor Flatwoods project area has been developed in this study by incorporating updated available information with spatial resolution higher than the earlier models of the watershed formulated in the MIKE SHE platform during the last two decades. The model is now robust enough to be applied as a useful tool for evaluating water and land management measures to restore natural drainage and hydrology and enhance fish and wildlife habitat within the region. However, this developed model will need to be treated as a living model with periodic updates and verifications to be consistent with changes in land and water use features of the project area. Therefore, the following activities are recommended for future modeling efforts:

1. Continued Model Calibration, Updates and Verification

It is recommended that the model be re-calibrated when more detailed ground survey or topography information is available throughout the project area. Data collection at the Babcock Webb and Yucca Pens monitoring stations (both existing and those installed for the current project) has continued without interruption via an on-going FWC monitoring contract at all stations except BW-10 (which was destroyed in November 2021). It is recommended to extend the calibration period and incorporate additional data collected after November 2021 to verify that the model can properly represent the increase in groundwater elevations during the late dry season and early part of the wet season in 2021.

Additional calibration is recommended to decrease uncertainties regarding groundwater hydraulic conductivities, and this effort may indicate that greater restoration can be achieved by Scenario 2. Specifically, it recommended to use hydrogeological studies mentioned above to assist in better representation of groundwater hydraulic conductivity. Recalibration may also indicate more substantial Yucca Pens peak flow reductions at Burnt Store Road.

2. Continued Refinement of Scenarios

Fine scale refinement of projects in Scenarios 2 and 3, which are modeled at a larger scale in the current project, will be necessary as proposed projects move closer to engineering and design, permitting, and construction phases to detail how those can be best accomplished. A list of these recommended refinements is provided below:

In Scenario 2, flows from Bond Farm HEI south towards PPP were not modeled for this conceptual effort. To modify the current Bond Farm HEI permits for the inclusion of a future western discharge towards the Yucca Pens, more detailed modeling of flows from Bond Farm HEI south to PPP will need to occur to understand the impacts and amount of flow to Gator Slough and Powell Creek. Additional modeling will be useful to address wetland hydroperiod and water depth issues in PPP while continuing to keep in mind that flood protection in all areas further south is of utmost importance when modeling and designing any future projects.

Development of a local-scale model in Yucca Pens is recommended (grid size of approximately 100 ft.) to determine exact number and location of proposed Yucca Pens ATV ditch blocks, weirs, and low-water fords and evaluate their performance. Sensitivity studies should be conducted to refine dimensions and locations of proposed weirs, gates, and culverts assumed for Scenarios 2 and 3. If funding is not available in the future for all 26 proposed weirs, future work could involve ranking/prioritizing the weirs and creating a plan for construction of weirs. Similarly, consideration should be given to modeling scenarios with only a portion of the 26 proposed weirs. Modeling is also recommended to evaluate the freshwater/tidal interactions and drainage impacts from Yucca Pens to tidal creeks in greater detail. It is also suggested to use the localized sub-model to determine the amount and locations of additional culverts to be added underneath the Florida Power and Light (FPL) Powerline in the Yucca Pens since the ecologic studies indicated that inundation is greater east of the Yucca Pens Powerline Grade.

A local-scale model of southern Yucca Pens is also needed to better understand the depth and strata of surficial aquifer and the interaction between the Yucca Pens and Gator Slough Canal hydrology and to inform the design assumptions and determine the effectiveness of the proposed partial groundwater seepage barrier at Gator Slough.

Scenarios 2 and 3 currently include a flow-way to send water from Bond Farm HEI west to Yucca Pens only during the dry season (December – January). This flow-way from Bond Farm HEI to Yucca Pens was modeled along the southern border of the Southwest Aggregates Reservoir property, where a proposed gate would allow the Bond Farm HEI outflows to pass under US-41. This water was simulated to flow west through a new flow-way south of the SLD C&D Landfill. It is recommended that future refinement of modeling of conveyances from Bond Farm HEI to Yucca Pens use the additional survey data collected at the SLD C&D Landfill to fully capture best practices for moving water across the land south of the SLD C&D Landfill. It is also recommended that structure dimensions along the conveyances from Bond Farm HEI to Yucca Pens are refined during subsequent modeling of Scenarios 2 and 3. More specifically, gated weirs in the US-41 ditches north and south of the flow-way were included in the current model to help direct the Bond HEI outflows to Yucca Pens. These gates will be closed blocking flow north and south to these US-41 ditches, instead directing water west via the proposed flow-way during the time period when water is needed to hydrate Yucca Pens (typically December and January) in the dry season. Modeling to determine specifications and dimensions for these structures may be appropriate during the design phase. Finally, the simulations conducted as part of this project assumed a new 7-ft x 3-ft box culvert under US-41 along the flow-way. Dimensions of this culvert were approximated using best engineering judgment and it may be appropriate to modify the dimensions during the design phase.

Scenarios 2 and 3 modeled delivery of freshwater flows from the Southwest Aggregates Reservoir to Gator Slough in the late dry season only. It is recommended that stakeholders explore formally acquiring use of the Southwest Aggregates Reservoir to potentially store additional freshwater for hydrological restoration in the wet season. Please note that dimensions for existing mining pits will need to be verified and those values will need to be included in future model refinement.

Scenarios 2 and 3 also include a gate on the east side of the Southwest Aggregates Reservoir south ditch which opens during wet season flow deliveries to the Reservoir or during flow routing from Bond Farm HEI to Yucca Pens in the early dry season. In the current model it is assumed that this gate will be 24 feet wide with a sill elevation of 22.0 ft-NAVD, and a maximum elevation of 26.0 ft-NAVD. However, the width of this gate may be able to be reduced during the design phase based on further modeling of dimensions. The model input files should also be revised to maintain US-41 ditch flows in their current alignment to minimize any diversion of wet season flows from the US-41 ditches to Yucca Pens via the proposed conveyance west of US-41.

The current model did not include the southern Hog Branch tributary in the MIKE 11 flow-way network, as there was insufficient data available at the time of modeling. Once survey and flow data in this branch become available, it is recommended to update the model to add the southern Hog Branch tributary for better representation of this region in future model efforts and to explore if there is a need for restoration upstream of Hog Branch and Burnt Store Road.

3. Continued Updates to Climate Data in Scenarios

Scenario 3 modeled how projects from Scenarios 1 and 2 might be impacted by future climate conditions using the best available data at the time of modeling. Given the current uncertainty of rainfall predictions with climate change in the region, Scenario 3 does not include changes to rainfall. However, it is known that climate change will impact the frequency and intensity of rainfall, and therefore it is recommended that future projects model a theoretical spectrum of changes, including different combinations of extreme wet and dry events throughout a year, that could occur with increased or decreased rainfall amounts and/or patterns to understand the relative role of rainfall and evapotranspiration (ET) in changes to hydroperiods and wetland water depths. This tool can be used now effectively to quantify hypothetical changes in rainfall; for example, a 5 or 10% increase in rainfall, a 5% decrease in rainfall, or a different rainfall distribution (increased rainfall in wet season and less rainfall in dry season).

As there is more certainty around how rainfall will change in the future, it is recommended that Scenario 3 input files be updated to use the latest available scientific information on rainfall and climate change predictions. Due to the significant ecological impacts of reduced hydroperiod to wetlands in the Charlotte Harbor Flatwoods area, the findings could be used to form specific guidance on measures that can be taken in advance (in management, engineering, and/or policy) to buffer climate change impacts (e.g., options for water storage and additional restoration measures). It is also recommended that future modeling utilize data collected from proposed evapotranspiration monitoring stations in Babcock Webb and Yucca Pens to continue to refine evapotranspiration rates.

The model was calibrated in this study to perform well for multi-year seasonal evaluations. However, due to the evolving climate conditions and intensity and duration of storm events continually contributing to increased flooding, the model should periodically be updated to incorporate new storm event data, including recorded high-water marks during and after such events. Thus, it is recommended to further verify the model performance during extreme rainfall events, to include available high-water marks in the evaluation, and to perform model recalibration to those extreme conditions as needed without diminishing the model performance for multi-year seasonal evaluations.

4. Additional Future Conditions Scenarios Modeling

One of the benefits from the creation of the current modeling tool is that it can continue to be refined and utilized by all stakeholders in the region to explore additional proposed measures to restore hydrology throughout the region. Below are a few such projects as identified by Charlotte Harbor Flatwoods Initiative stakeholders:

It was recommended evaluate the impact of reducing the maximum storage depth of Bond Farm HEI from 4 to 2 feet, and explore alternative storage options, such as increasing storage in Southwest Aggregates by 1,200 acre-feet. Reducing the maximum storage depth of Bond Farm HEI may reduce seepage-related costs, resulting in a more feasible and cost-efficient effort. Note that increasing storage in Southwest Aggregates Reservoir will require coordination with other planned uses of this property. This proposed study could also be used to simulate suggested controls that can be applied to reduce seepage in Bond Farm HEI.

Scenario 2 discharges to tide during the early dry season (November 1 through January 31) are greater than for Scenario 1. This is a beneficial aspect of Scenario 2. However, peak wet season flows are greater for Scenario 2 than for Scenario 1. Further modeling is suggested to decide how to best reduce peak flows to tide during the wet season. Scenarios 2 and 3 in the current model include a flow-way to send water from Bond Farm HEI west to Yucca Pens only during the dry season (December – January), and thus, the flow-way is blocked at the east side of US-41 so that water cannot pass throughout the remainder of the year. However, there is potential for high water levels in US-41 ditches to route water west into Yucca Pens during the wet season, minimizing the improvements to hydroperiods in Yucca Pens. Installation of a gate on the west side of US-41 that can be closed in the wet season to prevent this outflow may be needed to reduce peak wet season discharges to tide from Yucca Pens. Therefore, it is recommended that conveyances from Bond Farm HEI to Yucca Pens are refined during subsequent modeling of Scenarios 2 and 3 to include this gate to better understand and quantify the benefits to inform potential future gate design and implementation.

It is recommended to continue to utilize the model to evaluate other hydrological restoration measures if considered to be feasible. Finally, analyses on long-term climate predications are recommended to help identify appropriate actions, projects, or adaptive management strategies needed to address long-term climatic changes.

5. Additional Modeling to Inform Policy and Operational Protocol Recommendations

Additional modeling will be needed to better determine specifications for potential modifications to dry season control elevations at existing water control structures in Babcock Webb WMA and Yucca Pens to minimize impacts to the surrounding wetlands. Operational protocol recommendations for modification of elevations at existing water control structures could be made based on results from this modeling effort.

6. Ongoing Hydrological Modeling Tool Updates

It is recommended to update the model with data collected after the completion of the last model update (Spring 2022), and to verify model performance during extreme wet and dry season periods in the future.

Lastly, it is recommended to update the model at least every five years to include water conveyance improvements, future development, and changes in land use.

Recommended Hydrological Restoration Projects Modeled in Current Project

At the outset of modeling of future restoration scenarios for the current study, several potential feasible hydrological restoration projects were identified by stakeholders for inclusion in Scenarios 1 and 2 (Scenario 3 was examining how future climate predications may impact restoration form previous Scenarios). As stated previously, all projects identified and modeled at a larger scale for the current work may need localized model refinement to further evaluate how they can best be implemented prior to design, engineering, permitting and construction. These projects are listed below:

1. ATV Ditch Blocks

It is recommended to construct ATV ditch blocks in existing ATV trails that drain isolated wetlands in Yucca Pens. The location of those identified isolated wetlands is presented in **Figure 6-13** and a map of potential locations for these appears in **Appendix 6A Figure 13**. The exact number, locations, and design specifications of these ditch blocks will need to be determined through a localized model to further evaluate how they can be implemented.

2. Low-Water Fords or Constructed Weirs

It is recommended to construct the 26 weirs representing either low-water fords or constructed weirs in Yucca Pens to minimize excess drainage from eroded ATV trail in Yucca Pens (see **Appendix 6B** for details). It should be noted that there will be some potential direct and secondary wetland disturbance with any weir installation in Yucca Pens. The locations of the proposed 26 weirs are represented in **Figure 6-20**. If funding is not available in the future for all 26 proposed weirs, future work could involve ranking/prioritizing the weirs and creating a plan for construction of weirs. Similarly, consideration should be given to model results if all 26 proposed weirs are not completed.

3. Partial Groundwater Seepage Barrier

It is recommended to construct a partial groundwater seepage barrier in southern Yucca Pens. The model assumed a seepage barrier created by drilling boreholes at predefined spacing (e.g. 10 feet) and grouting the boreholes with cement or some other type of material, which will flow through permeable rock to form a partial flow barrier. The location of the proposed partial seepage barrier is presented in **Figure 6-14** and additional information is presented in **Appendix 6B**. After completion of additional geotechnical field work and local-scale modeling previously recommended to better understand the depth and strata of surficial aquifer and the interaction between the Yucca Pens and Gator Slough Canal hydrology, the most appropriate seepage control system should be implemented.

4. Construction of Bond Farm HEI

Scenarios 1, 2 and 3 are dependent upon the construction of Bond Farm HEI. Funding is needed to construct the fully permitted Bond Farm HEI. The FWC may benefit from contracting with an engineering firm to evaluate potential value engineering aspects for the current Bond Farm HEI design to reduce costs that would be within the current obtained permits which at most might require a permit modification. The evaluation would determine any data required, if any, to implement feasible value engineering approaches.

5. Flow-way from Bond Farm HEI to Yucca Pens

It is recommended to construct a flow-way from Bond Farm HEI to Yucca Pens along the southern border of the Southwest Aggregates Reservoir property, passing under US-41 and I-75, and routed west through the flow-way south of the SLD C&D Landfill. The recommended flow-way would be used to convey water from Bond Farm HEI to Yucca Pens as well as used as an inflow canal for water that could potentially be pumped into the existing pits on the Southwest Aggregates property in the wet season. The location of the proposed flow-way is presented in **Figure 6-19**. This flow-way is conceptually modeled. However, more refined modeling and permitting would be required prior to implementation.

6. Box Culvert under US-41

It is recommended to add a culvert under US-41 where the flow-way intersects US-41 to enhance flows west. It was assumed in the current model the dimensions of the culvert were 7-ft x 3-ft, however, the dimensions may be changed in the design phase.

7. Discharge Structure on West Side of Bond Farm

It is recommended to add either a pump station or gated culverts on the west side of Bond Farm HEI which will be utilized during the late wet and early dry season to deliver water to Yucca Pens.

In addition, a flow-way around Bond Farm HEI may be the best solution to delivering water from the SWIA to Southwest Aggregates. The dimensions of the seepage ditch culverts associated with this structure were taken from the Bond Farm HEI design plans (HDR, 2020).

8. Acquisition of Southwest Aggregates Reservoir

It is recommended to formally acquire use of the Southwest Aggregates Reservoir to potentially store additional freshwater from Bond Farm HEI in the wet season.

9. Gate on East Side of Southwest Aggregates South Ditch

It is recommended to construct a gate on the east side of the Southwest Aggregates south ditch that will open during wet season flow deliveries to the Reservoir or during flow routing from Bond Farm HEI to Yucca Pens in the early dry season. It was assumed in the current model that this gate will be 24 feet wide with a sill elevation of 22.0 ft-NAVD, and a maximum elevation of 26.0 ft-NAVD, however, the dimensions may be changed or reduced in the design phase.

10. Gated Weirs in US-41 Ditches

It is recommended to add gated weirs in the US-41 ditches north and south of the flow-way in order to direct the Bond HEI outflows to Yucca Pens. It is recommended that these gates be closed, blocking flow north and south to these US-41 ditches, and instead directing water west to Yucca Pens via the proposed flow-way during the early dry season (typically December and January). Details and specifications for these structures may be modified during the design phase.

Policy and Operational Protocol Recommendations

A few of the recommended hydrological restoration measures will need input or guidance from the appropriate stakeholder and managing authority for implementation. This report recommends the consideration of the following policy and operational protocol changes for existing and new structures:

1. Retrofit Existing Riser Structures in Babcock Webb

Retrofits of existing water control structures in Babcock Webb are recommended for further consideration. This could involve the installation of metal risers that are available from Halliday Products or some equivalent type of structure. Structures SR-2, SP-4, SP-5, SP-6, SP-7, SP-9, SP-9, and SP-10 as well as several other risers are not actively managed and are candidates for this type of operation.

2. Modification of Elevations at Existing Water Control Structures

As previously stated, dry season control elevations at existing water control structures are recommended for further modeling and consideration of operational changes to mitigate the potential changes associated with climate change. There are several corrugated metal pipe (CMP) risers and two gated weirs in Babcock Webb that are not actively managed, and changes to those structures could be implemented to adopt different control elevations during the wet and dry seasons. The abovementioned two gated weirs are located at Webb Lake and the North Prong of Alligator Creek. It is recommended that the structures remain in open or partially open positions during the wet season and gate elevations be raised at the end of the wet season to hold water on the landscape for the coming dry season. This will continue to be an important change to help buffer impacts from future climate conditions.

3. Bond Farm HEI and Southwest Aggregates Pump Operations

It is recommended to consider modification of operating protocols, based on modeling, for inflow pumps for Bond Farm HEI and Southwest Aggregates so that the priorities for turning on both pumps may be varied through a series of sensitivity tests to obtain simulation results where Bond Farm HEI is filled to full capacity before the Southwest Aggregates Reservoir is filled during all simulation years. One possible approach is to have different operating rules for dry years where the Southwest Aggregates Reservoir inflow pump turns on at a higher trigger elevation, which will maximize inflows to the Bond Farm HEI.

4. Securing the Flow-way from Bond Farm HEI to Yucca Pens

Scenario 2 recommended projects are contingent upon a number of key factors: first this scenario can only be implemented if private and public landowners in the region of the proposed flow-way are willing to work with regional partners to secure property easements, publicly acquire land and/or permits in order to allow water to move from Bond Farm HEI to Yucca Pens via the proposed flow-way. Finally, it is recommended that stakeholders explore formally acquiring use of the Southwest Aggregates property to be converted to a reservoir to potentially store additional freshwater for hydrological restoration in the wet season.

7.2 Conclusions and Acknowledgements

The outcomes of this modeling effort and report support objectives set forth by Coastal & Heartland National Estuary Partnership (CHNEP) and members of the Charlotte Harbor Flatwoods Initiative (CHFI) to guide reduction of pollution and hydrologic degradation to coastal watersheds in lower Charlotte Harbor through development of a science based and data driven integrated surface-groundwater hydrological model and the Lower Charlotte Harbor Flatwoods 'Strategic Restoration Planning Tool' Report.

The report provides guidance to local governments and agencies for how best to restore hydrologic connections and manage surface waters flowing from the Babcock Webb and Yucca Pens WMAs through tidal creeks discharging into eastern Charlotte Harbor and the Caloosahatchee River. The restoration of appropriate freshwater flow across the landscape will help to sustain healthy wetlands, rivers, and estuaries and to provide adequate aquifer recharge and freshwater volume and timing of flow for healthy natural systems as well as to moderate flooding events. Benefits from identified restoration projects and pathways for future data collection modeling and design work and project implementation are outlined in the Results and Recommendations sections above. This project also accounts for factors that would inform likely future conditions in the region such as anticipated restoration projects and climate change.

Special thanks to the South Florida Water Management District and the Southwest Florida Water Management District, as well as Florida Fish & Wildlife Conservation Commission- Wildlife Management Area, Fish & Wildlife Research Institute, and Habitat and Species Conservation Sections, Lee and Charlotte Counties, and other members of the Charlotte Harbor Flatwoods Initiative (CHFI) for their invaluable contributions to the project and production of this report. CHFI members include: Coastal and Heartland National Estuary Partnership (CHNEP), South Florida Water Management District (SFWMD), Southwest Florida Water Management District

(SWFWMD), Water Science Associates, Florida Fish and Wildlife Conservation Commission (FWC), Florida Department of Environmental Protection (FDEP), Florida Department of Transportation (FDOT), Lee County, Charlotte County, City of Cape Coral, Charlotte Harbor Buffer Preserve State Park, Babcock Webb Yucca Pens Unit Wildlife Management Area, Charlotte Harbor Aquatic Preserve, numerous NGOs, private stakeholders, and many others who are planning and implementing projects for this multi-phased, 90-square mile regional hydrological restoration of Babcock Webb, Yucca Pens, Charlotte Harbor, and the impaired Caloosahatchee Estuary Watershed.

REFERENCES

A.D.A. Engineering, Inc. (2013) Design Services for I-75 from Lee County to Tuckers Grade in Charlotte County, prepared by Roger Copp and Maria Loinaz for Carlos Lopez, HDR; Carl Spirio, FDOT; and Brent Setchell, FDOT.

A.D.A. Engineering, Inc. and AIM Engineering & Surveying, Inc. (2015) City of Cape Coral Stormwater Model, Draft Final Report, prepared for AIM Engineering, Inc. and the City of Cape Coral.

Adams, Aaron J., R. Kirby Wolfe, and Craig A. Layman (2009) "Preliminary examination of how human-driven freshwater flow alteration affects trophic ecology of juvenile snook (*Centropomus undecimalis*) in estuarine creeks." Estuaries and Coasts 32, no. 4 (2009): 819-828.

Banks Engineering, Inc. (2021) Specific Purpose Survey, Babcock Webb Wildlife Management Area, February 25, 2021, Project 4473.

Barnes, Tomma & Rumbold, Darren & Salvato, Mark. (2006). CALOOSAHATCHEE ESTUARY AND CHARLOTTE HARBOR CONCEPTUAL MODEL.

Darby, P.C, R.E. Bennetts, and H.F. Percival (2008). Dry down impacts on apple snail demography: implications for wetland water management. Wetlands 28:204-214.

Duever, Michael J. and Richard E. Roberts (2013) Successional and Transitional Models of Natural South Florida, USA, Plant Communities. Fire Ecology Volume 9, Issue 1, pages 110 – 123.

ESA & CHNEP (2020) CHNEP Habitat Restoration Needs Plan (HRN) Phase II Report Addendum for the CHNEP Expansion Area. Report prepared for CHNEP by ESA, October 2020.

HDR (2020) Bond Farm Hydrological Enhancement Impoundment (HEI) Ready to Advertise, Design Report, Appendix T, Geotechnical Engineering Report, prepared for Florida Fish and Wildlife Conservation Commission, August 5, 2020.

Kemmerer, Michael, and Tim Liebermann (2018). 1953 Babcock Webb Wildlife Management Area Aerial Photographs and Hydrologic Mapping, Maps presented to the Charlotte Harbor Flatwoods Initiative by Mike Kemmerer, Florida Fish and Wildlife Conservation Commission Babcock Webb Wildlife Management Area and Tim Liebermann, South Florida Water Management District (retired), December 13, 2018.

Schultz, R., M. Hancock, J. Hood, D. Carr, and T. Rochow (2004). Use of Biologic Indicators for the Establishment of Historic Normal Pool. SWFWMD Technical Memorandum NTB II, July 21, 2004.

Southwest Engineering & Design and Water Science Associates (2019) Hydrogeologic Survey of Yucca Pens Wildlife Management Area to Assist with Charlotte Harbor Flatwoods Initiative. Prepared for Charlotte Harbor National Estuary Program, July 11, 2019.

USGS (2010). Discharge Measurements at Gaging Stations, Techniques and Methods 3-A8, D. P. Turnipseed and V.B. Sauer.

USGS (2013). Measuring Discharge with Acoustic Doppler Current Profiles from a Moving Boat, Techniques and Methods 3-A22, Mueller, D.S. C.R. Wagner, M.S. Rehmel, K.A. Oberg, and F.

Rainville, December 2013, in Chapter 22 of Section A, Surface-Water Techniques, Book 3, Applications of Hydraulics.

Water Science Associates (2017) City of Cape Coral Utilities Pilot Pumping Test of the Southwest Aggregates Reservoir, Lee/Charlotte County, Florida, prepared for the City of Cape Coral.

EXHIBIT 1

Explanation of Modified Hydraulic Conductivities Referenced in Table 3 Bond Farm HEI Inflows/Outflows

All results in the scenario analysis memoranda (**Appendices 6B–D**) use the final calibration with horizontal hydraulic conductivity capped only under Bond Farm HEI at 35 ft/day. Results from the sensitivity test with reduced hydraulic conductivities were only presented for Bond Farm HEI and Southwest Aggregates Reservoir water balance results presented in **Table 6-3 and 6-8** as a comparison.

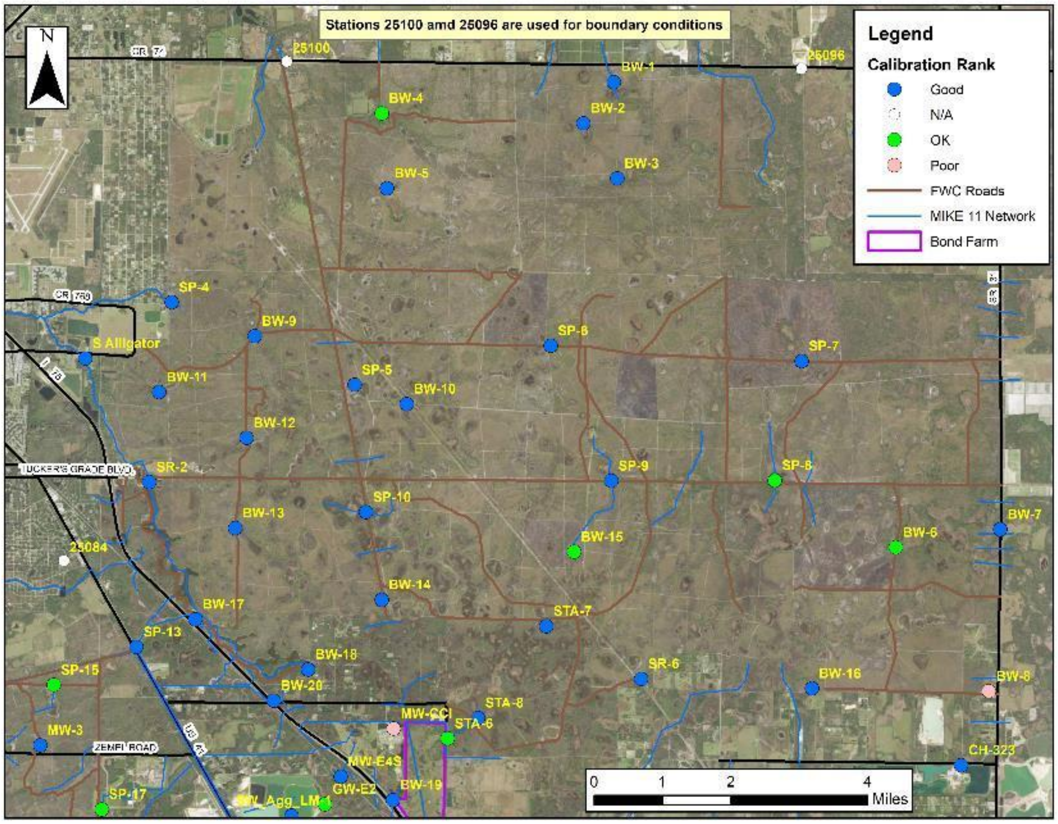
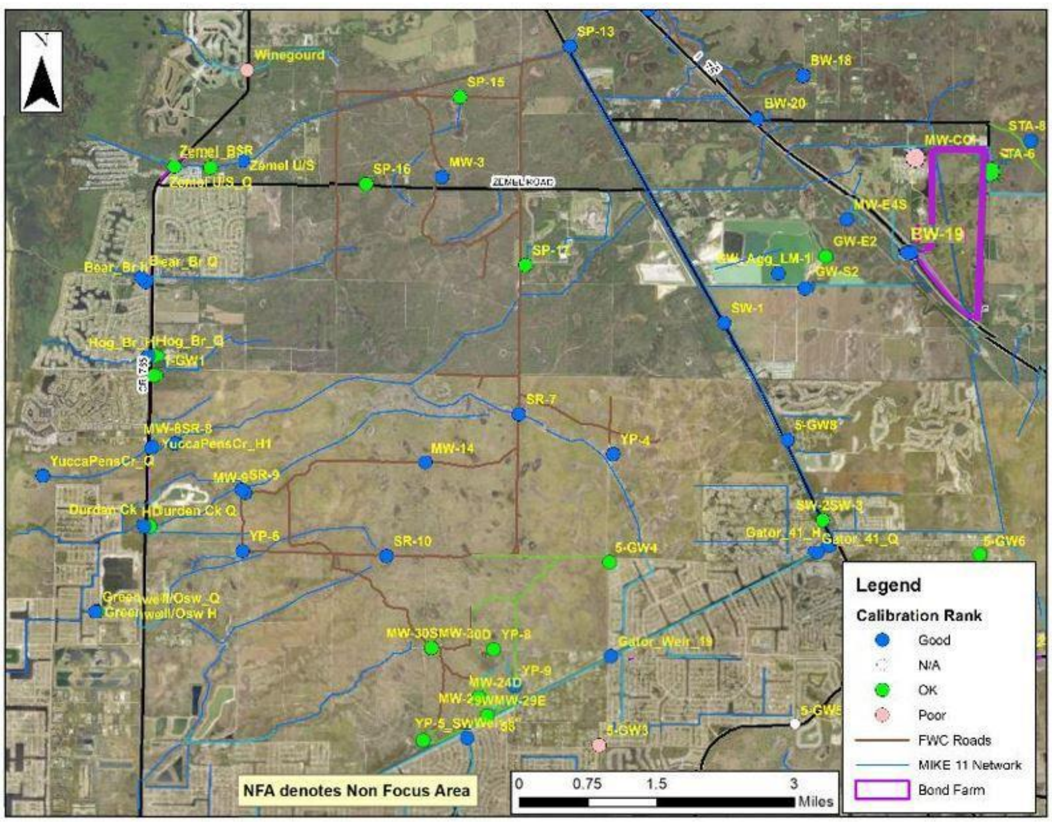
During scenario analysis of Bond Farm HEI, seepage rates from Bond Farm HEI were significantly greater than expected. The project area and larger Charlotte County is known to have porous shell layers. Hydrogeologic studies of the Bond Farm HEI area included lithologic descriptions of multiple borings around the perimeter of the proposed impoundment as well as field permeability measurements. Field permeability testing in Bond Farm HEI estimated a permeability rate of 40 ft/day for the limestone layer (HDR, 2020), however there have not been any full scale studies looking at seepage throughout Bond Farm. These additional studies will provide insight on varied hydraulic conductivity throughout Bond Farm. A zone of lower water table horizontal hydraulic conductivity (35 ft/day) was used for only the area of Bond Farm HEI based on the Bond Farm hydrologic investigation, along with findings from a previous study in the nearby Southwest Aggregates mining cells which calculated horizontal hydraulic conductivities of 35 ft/day (WSA, 2017). Therefore, these conservative hydraulic conductivities were used to avoid over-estimating the capacity of Bond Farm HEI to hold water. Additional studies are recommended to quantify groundwater seepage rates throughout Bond Farm HEI and the project area (see RECOMMENDATIONS section for more information).

The initial analysis of Scenario 1 used the final calibrated model (see TM 5c, WSA & CHNEP, 2022b). Maps of calibration stations are shown below, and tables comparing the final calibrated model to a sensitivity test with lower hydraulic conductivities follow the maps of calibration station locations. The final calibrated model had upper water table horizontal hydraulic conductivities ranging from 456 to 1,500 ft/day with vertical conductivity values 10 times less than horizontal values. Lower water table horizontal hydraulic conductivity values ranged from 123 to 543 ft/day. Model calibration was best with these lower water table hydraulic conductivities, and resulted from an effort to match measured dry season water levels at numerous stations, most notably at stations STA-6, -7, and -8 northeast of Bond Farm. The adjustment of hydraulic conductivity values was performed after all surface water conveyance details had been added to the model and all other model input files had been vetted and sensitivity testing had been completed.

Seepage losses from Bond Farm HEI were higher than what was deemed to be appropriate in additional testing of Scenario 1, therefore it was decided to perform a sensitivity test on Scenario 1 with lower hydraulic conductivities. Two iterations of the entire model domain were conducted, one with a maximum horizontal hydraulic conductivity of 35 ft/day and another with the maximum set to 300 ft/day. Then, two iterations were simulated that varied horizontal hydraulic conductivity between 35 and 300 ft/day, and the resulting best calibration was for a simulation with the maximum horizontal hydraulic conductivity value of 297 ft/day for the upper water table. The resulting lower water table aquifer horizontal hydraulic conductivities ranged from 70 to 292 ft/day.

Comparison of the final calibration and the sensitivity test is presented in the tables shown below. Calibration improved at 14 stations. Slight reductions in calibration performance were observed at stations SP-4, BW-19, and 20-GW3 in the sensitivity test. Performance changed from either Good to OK or OK to Poor in the sensitivity test at the following stations: MW-29W, SP-17, SP-17, STA-6, 5-GW4, L-721, MW-29E, SW_Agg_GW-E2 and SW_Agg_GW-S2. (NOTE: Performance deteriorated at Gator Slough at Weir 19 because the revised model used program logic (gates open according to prescribed rules) rather than known gate operations. Therefore, the drop in performance at this station is not considered valid. Gator Slough at US-41 was also affected because it is upstream of Weir 19).

Additional model calibration is proposed once additional hydrologic surveys are performed for this area and that information is available (see RECOMMENDATIONS section for more information).


Stations 25100 amd 25096 are used for boundary conditions
N
Legend
Calibration Rank
Good
N/A
OK
Poor
FWC Roads
MIKE 11 Network
Bond Farm
25100
25096
BW-1
BW-2
BW-3
BW-4
BW-5
SP-4
BW-9
S Alligator
BW-11
SP-5
BW-10
SP-8
SP-7
BW-12
TUCKER'S GRADE BLVD
SR-2
SP-9
SP-8
SP-10
BW-13
BW-15
BW-6
BW-7
25084
BW-14
BW-17
STA-7
SP-13
BW-18
SR-6
BW-16
SP-15
BW-20
BW-8
STA-8
MW-CCI
STA-6
MW-3
ZEMEL ROAD
MW-E4S
CH-323
GW-E2
BW-19
SP-17
0 1 2 4
Miles

N
Winegourd
SP-13
BW-18
SP-15
BW-20
STA-8
MW-CCI
STA-6
Zemel_BSR
Zemel U/S
SP-16
MW-3
ZEMEL ROAD
MW-E4S
GW-E2
BW-19
SP-17
GW-S2
Bear_Br_Q
SW-1
Hog_Br_Q
SR-7
YP-4
MW-14
YuccaPensCr_H1
YuccaPensCr_Q
YP-6
SR-10
5-GW4
Gator_41_Q
5-GW6
MW-30S
MW-30D
YP-8
YP-9
Gator_Weir_19
MW-24D
5-GW3
NFA denotes Non Focus Area
0 0.75 1.5 3
Miles
Legend
Calibration Rank
Good
N/A
OK
Poor
FWC Roads
MIKE 11 Network
Bond Farm

	Final	Test	Final	Test	Final	Test		
Name	MAE	MAE	R_Corr	R_Corr	R2 NS	R2 NS	Overall	Change
Bear Branch H	0.36	0.37	0.82	0.84	0.11	0.11	Good	Same
Durden Creek H	0.84	0.95	0.87	0.88	0.61	0.57	OK	Same
Gator_Weir11_H	0.53	0.62	0.61	0.50	-5.11	-6.05	Poor	Same
Gator_41_H	0.46	0.60	0.95	0.94	0.37	-0.08	Good	Worse
Gator_Weir_19	0.17	0.63	0.96	-0.10	0.87	-1.04	Good	See note
Greenwell/Osw H	0.47	0.57	0.80	0.75	-0.62	-1.37	OK	Same
Hog Branch H	0.40	0.38	0.72	0.71	-0.36	-0.28	OK	Same
S Alligator	0.67	0.57	0.88	0.91	0.61	0.71	Good	Same
SP-4	0.45	0.82	0.93	0.87	0.85	0.71	Good	Worse
SP-8, BigWaterFor	0.97	0.65	0.88	0.88	0.54	0.75	OK	Better
SP-13, Zemel at 41	0.63	0.61	0.81	0.88	0.44	0.50	Good	Same
SR-2, WebbLake	0.46	0.58	0.94	0.92	0.83	0.72	Good	Same
SW-1, US_41	0.51	0.40	0.92	0.93	0.14	0.45	Good	Better
SW-2, US_41 E	0.62	0.62	0.88	0.86	-1.03	-1.19	OK	Same
SW-3, US_41 W	0.42	0.45	0.85	0.84	-0.04	-0.39	OK	Same
YuccaPensCr_H1	0.71	0.67	0.77	0.89	0.48	0.52	Good	Same
Weir 58	0.18	0.26	0.86	0.83	0.68	0.39	Good	Same
Winegourd	1.33	1.11	0.03	0.00	-5.43	-3.75	Poor	Same
Zemel U/S	0.43	0.41	0.86	0.90	0.67	0.72	Good	Same
Zemel_BSR	0.58	0.48	0.63	0.70	-1.25	-0.74	OK	Same
17-GW4	0.80	0.91	0.76	0.74	0.48	0.39	OK	Same
BW-1	0.47	0.55	0.94	0.93	0.84	0.81	Good	Same
BW-2	0.65	0.61	0.90	0.91	0.67	0.74	Good	Same
BW-3	0.50	0.33	0.94	0.96	0.73	0.91	Good	Better
BW-4	0.91	0.66	0.88	0.89	0.49	0.79	OK	Better
BW-5	0.67	0.66	0.80	0.84	0.59	0.68	Good	Better
BW-6	0.89	0.82	0.91	0.89	0.50	0.60	OK	Same
BW-7	0.53	0.54	0.94	0.93	0.81	0.80	Good	Same
BW-8	1.15	1.20	0.90	0.90	0.33	0.28	Poor	Same
BW-9	0.66	0.71	0.87	0.90	0.71	0.67	Good	Same
BW-10	0.29	0.29	0.96	0.96	0.90	0.90	Good	Same
BW-11	0.69	0.68	0.86	0.85	0.58	0.65	Good	Same
BW-12	0.45	0.48	0.90	0.91	0.80	0.79	Good	Same
BW-13	0.42	0.42	0.93	0.92	0.80	0.84	Good	Same
BW-14	0.31	0.34	0.96	0.96	0.91	0.89	Good	Same
BW-15	0.84	0.72	0.90	0.90	0.22	0.40	OK	Better
BW-16	0.46	0.45	0.96	0.96	0.80	0.82	Good	Same
BW-17	0.45	0.42	0.92	0.92	0.79	0.82	Good	Same
BW-18	0.38	0.31	0.95	0.96	0.86	0.92	Good	Same
BW-19	0.57	0.98	0.93	0.85	0.74	0.22	Good	Worse
BW-20	0.46	0.37	0.97	0.94	0.80	0.80	Good	Same
MW-23S	1.01	0.86	0.92	0.91	0.51	0.61	OK	Better
MW-24S	1.00	0.98	0.89	0.89	0.30	0.35	OK	Better
MW-29W	0.54	0.82	0.43	0.46	-0.28	-1.71	OK	Worse
MW-30S	0.82	0.73	0.82	0.81	0.04	0.29	OK	Better
SP-5	0.35	0.30	0.97	0.97	0.90	0.92	Good	Same
SP-6	0.45	0.56	0.94	0.93	0.81	0.68	Good	Same
SP-7	0.54	0.63	0.88	0.80	0.69	0.55	Good	Same

	Final	Test	Final	Test	Final	Test		
Name	MAE	MAE	R_Corr	R_Corr	R2 NS	R2 NS	Overall	Change
SP-9	0.26	0.33	0.97	0.95	0.92	0.89	Good	Same
SP-10	0.59	0.60	0.97	0.96	0.56	0.53	Good	Same
SP-16	0.84	1.09	0.85	0.83	0.37	-0.01	OK	Worse
SP-17	0.93	1.24	0.56	0.47	-1.36	-3.21	OK	Worse
STA-6	1.07	1.24	0.82	0.80	0.19	-0.09	OK	Worse
STA-7	0.63	0.56	0.96	0.96	0.67	0.74	Good	Same
SW_Agg_LM-1	0.51	0.75	0.83	0.79	0.50	0.18	Good	Same
YP-5_SW	1.13	0.68	0.97	0.96	0.55	0.78	OK	Better
YP-8	0.91	0.79	0.91	0.90	0.22	0.40	OK	Better
YP-9	0.63	0.70	0.96	0.96	0.77	0.74	Good	Same
1-GW1	0.95	0.90	0.87	0.85	0.20	0.31	OK	Same
5-GW3	1.04	1.33	0.91	0.84	-0.18	-0.66	Poor	Same
5-GW4	1.14	1.49	0.91	0.89	0.22	-0.25	OK	Worse
5-GW6	0.78	0.97	0.95	0.94	0.66	0.47	OK	Same
5-GW8	0.65	0.73	0.92	0.85	0.47	0.18	Good	Same
16E-GW3	0.70	0.71	0.90	0.88	0.34	0.25	Good	Same
20-GW3	0.64	0.99	0.97	0.94	0.82	0.55	Good	Worse
CH-323	0.58	0.54	0.81	0.82	0.65	0.66	Good	Same
L-721	0.54	1.37	0.97	0.92	0.49	-2.20	Good	Worse
L-3207	0.21	0.29	0.91	0.90	0.82	0.70	Good	Same
MW-3	0.63	0.54	0.85	0.87	0.54	0.70	Good	Same
MW-8	0.64	0.62	0.89	0.88	0.40	0.52	Good	Same
MW-9	0.38	0.46	0.89	0.89	0.74	0.74	Good	Same
MW-14	0.48	0.50	0.89	0.88	0.70	0.70	Good	Same
MW-23D	0.94	0.83	0.93	0.92	0.55	0.64	OK	Same
MW-24D	0.96	0.99	0.90	0.90	0.44	0.44	OK	Same
MW-29E	0.77	1.08	0.87	0.87	0.21	-0.49	OK	Worse
MW-30D	0.76	0.69	0.84	0.83	0.18	0.40	OK	Better
SP-15	0.89	0.72	0.89	0.89	0.36	0.63	OK	Same
SR-6	0.42	0.49	0.94	0.95	0.84	0.81	Good	Same
SR-7	0.71	0.80	0.94	0.94	0.55	0.46	Good	Same
SR-8	0.54	0.67	0.91	0.90	0.73	0.61	Good	Same
SR-9	0.42	0.44	0.92	0.93	0.83	0.82	Good	Same
SR-10	0.37	0.42	0.90	0.88	0.79	0.72	Good	Same
STA-8	0.39	0.43	0.94	0.94	0.86	0.84	Good	Same
SW_Agg_MW-CCI	1.50	1.72	0.95	0.95	-0.38	-0.77	Poor	Same
SW_Agg_MW-E4S	0.39	0.45	0.92	0.91	0.82	0.79	Good	Same
SW_Agg_GW-E2	0.80	1.09	0.78	0.71	-0.01	-0.69	OK	Worse
SW_Agg_GW-S2	0.46	0.92	0.94	0.92	0.49	-0.80	Good	Worse
YP-4	0.57	0.57	0.78	0.79	0.53	0.52	Good	Same
YP-6	0.62	0.67	0.84	0.82	0.55	0.60	Good	Same
Bear Branch Q	4.16	3.92	0.76	0.83	0.48	0.53	Good	Better
Durden Creek Q	3.00	4.28	0.86	0.89	0.72	0.59	Good	Same
Gator_41_Q	6.17	6.84	0.89	0.89	0.78	0.78	Good	Same
Greenwell/Osw_Q	6.11	6.02	0.76	0.79	0.50	0.59	Good	Same
Hog_Q	2.49	2.32	0.81	0.81	0.53	0.61	Good	Same
NS Transfer	2.56	4.36	0.90	0.82	0.81	0.63	Good	Same
YuccaPensCr_Q	6.91	7.66	0.86	0.83	0.72	0.60	Good	Same
Zemel U/S_Q	11.33	10.46	0.69	0.74	0.45	0.51	OK	Better

EXHIBIT 2

Information on Retrofits to Existing CMP Metal Riser Structures in Babcock Webb

Retrofits of existing water control structures in Babcock Webb are recommended for further consideration. This could involve the installation of metal risers that are available from Halliday Products or some equivalent type of structure. Structures SR-2, SP-4, SP-5, SP-6, SP-7, SP-9, SP-9, and SP-10 as well as several other risers are not actively managed and are candidates for this type of operation.

In order to retrofit the existing corrugated metal pipe (CMP) riser structures to easily set wet and dry season control elevations, the Halliday lift gates can be attached onto the front of an existing concrete headwall or to the front of a CMP riser. A photo of a typical gate and a diagram of a G1A gate are attached. Their web site is: https://www.hallidayproducts.com/ssg.html.

Halliday lift gates are designed for no more than 5 feet of elevation head on the upstream side of the gate. Thus, gates may need to be installed above the absolute minimum elevation of channels upstream of a given riser. Lift gate retrofit assembly has gate dimensions of 3-ft wide by 5-ft high and includes the frame and the threaded rod/hand wheel to raise and lower the gate. Halliday makes gates with user-specified widths up to 5-ft wide. The height of the metal riser plate is also user-specified, and thus, it is recommended to install a gate with a 3-ft wide x 2-ft high design in order to hold water at the end of the wet season. The gates are supplied with anchor screws to attach the assembly to an upstream concrete face. However, existing risers in Babcock Webb WMA have metal I-beams and the appropriate nuts and bolts will be needed. It is recommended to install enough risers to retrofit one CMP riser structure to determine the appropriate installation specifications and assess the effectiveness of lift gates to inform further retrofits.

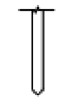
SERIES G1A AND G1B
SLIDE GATES

HALLIDAY PRODUCTS

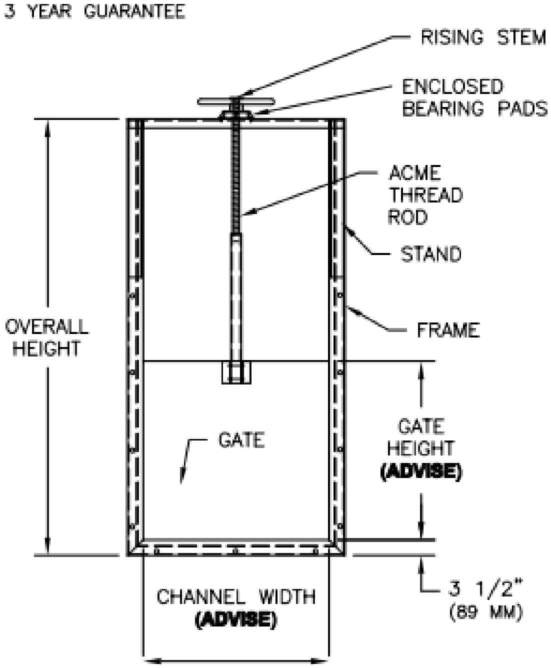
www.HallidayProducts.com
Phone 800–298–1027
Fax 407–298–4534
Sales@HallidayProducts.com

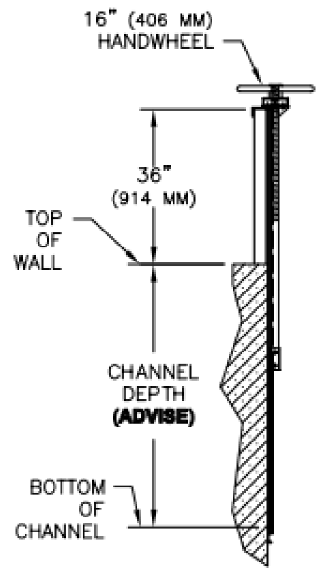
STANDARD FEATURES:

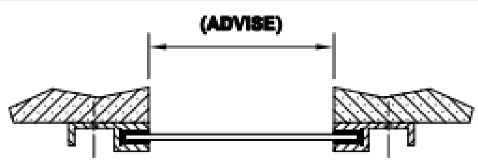
- ONE–PIECE 6061–T6 EXTRUDED ALUMINUM FRAME
- ONE–PIECE POLYMER GUIDE
- 1/4" (7 MM) THICK 6061–T6 ALUMINUM GATE REINFORCED AS REQUIRED TO DEFLECT NO MORE THAN 1/360th OF SPAN
- LOW COEFFICIENT OF FRICTION
- DEEP SEATING FOR OPTIMUM TRACKING
- STANDARD 16" (406 MM) ALUMINUM HANDWHEEL
- POLYMER BEARING PADS
- ø1 1/8" (ø29 MM) S.STL. TRIPLE LEAD ACME ROD
- BRASS LIFTING NUT
- STAINLESS STEEL HARDWARE THROUGHOUT
- NON–OZONE DEPLETING BITUMINOUS COATING
- OPTIONAL CLEAR STEM COVER
- 3 YEAR GUARANTEE



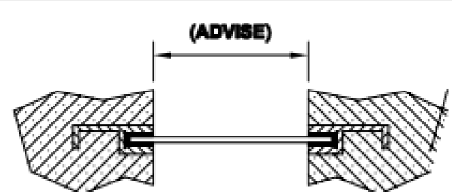
GATE BOTTOM







SERIES G1A
(WALL MOUNTED)



SERIES G1B
(EMBEDDED)

SER–GAB–N 07/27/05