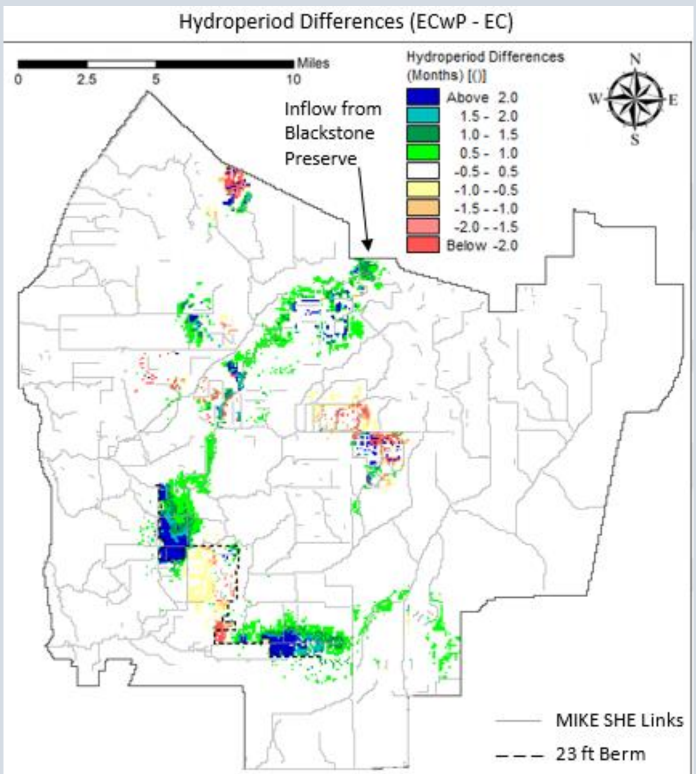
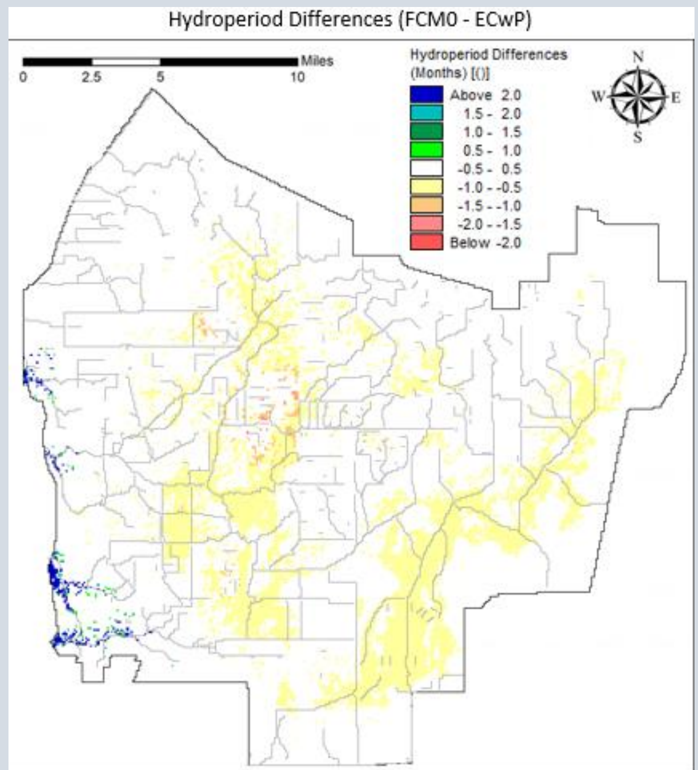
South Lee County Watershed Initiative Hydrological Modeling Project

Draft Report





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Consulting and Services

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Introduction

Project Origins

The South Lee County Watershed is comprised of the Estero River, Spring Creek, and Imperial River watersheds, all of which flow into the Estero Bay Aquatic Preserve. These riverine and tidal creek systems are primary nursery areas for fisheries, providing food and habitat to numerous species of fish and shellfish including snook, redfish, tarpon and oysters. Over the past 100 years, these wetland ecosystems have been heavily impacted by changes in hydrology. The conversion of native wetland habitats to agriculture or development, installation of drainage canals, surface mining, and construction of major roadways such as Corkscrew Road, SR. 82, US 41 and I-75, has significantly altered the historic sheet flow from the southern region of Lehigh Acres south to the Corkscrew Sanctuary and southwest to Estero Bay. As a result, the vast wetland ecosystems within the SLCW are susceptible to over-drainage, flooding, habitat changes, water quality degradation, and climate change stressors. The rivers and creeks in this area experience significant flooding during storm events and very low flow during the dry season.

To address these concerns, stakeholders in the region came together to form the South Lee County Watershed Initiative (SLCWI)-which aims to restore more natural water flows, improve water quality and environmental conditions, and increase natural water storage and moderation of flooding events. Stakeholders include the Coastal and Heartland National Estuary Partnership (CHNEP), South Florida Water Management District (SFWMD), Lee County, Collier County, City of Bonita Springs, Village of Estero, Conservancy of Southwest Florida, Water Science Associates, Lago Consulting, Bonita Springs Utilities, Florida Department of Transportation, Audubon Society, ECCL, ADA Engineering, Southwest Florida Regional Planning Council, AIM Engineering, Stantec, Waldrop Engineering, JR Evans Engineering, Audubon – Corkscrew Swamp Sanctuary, Hole Montes, Lehigh Acres MSLD, University of Florida Institute of Food and Agricultural Sciences (UF/IFAS), Calusa Waterkeeper, WSP, Estero Council of Community Leaders, Florida Gulf Coast University (FGCU), and Charlotte Soil & Water Conservation.

The SLCWI stakeholders identified the need for this project as the highest joint priority and at their April 5, 2017 meeting, drafted the following mission statement to guide the development of it: "To 'get the water right' in identifying what needs to happen to restore and maintain our water supply, flood protection, water quality and water-dependent resources in the face of existing degradation and depletion, sea level rise and continued regional growth.".

Project Purpose

The purpose of this project was to identify opportunities to restore more natural hydrology and water quality to improve environmental conditions, as well as increase storage and moderation of high flow events to provide greater flood protection in the region. It aims to restore wetland levels and hydroperiods (duration of inundation), improve water quality, improve habitat for wetland-dependent wildlife species, as well as the public drinking water supply.

The project involved developing a science-based, data-driven, strategic hydrologicalal planning tool to provide guidance to resource management agencies related to the appropriate restoration and management of surface waters currently flowing from the SLCW and discharging into the Estero Bay Aquatic Preserve. The Strategic Hydrologicalal Planning Tool provides SLCWI project partners and stakeholders with the needed information to determine the timing, distribution, quantity and quality of the water needed to improve the historic surface water flows of the Estero River, Spring Creek, and Imperial River to Estero Bay.

The project is intended to be additive to other local efforts in order to fill gaps and bridge various modeling efforts to create a regional watershed-scaled picture. The model has been coordinated and designed to complement the flood models recently completed for the Village of Estero, Lee County, and the Corkscrew Swamp Watershed Initiative Hydrologicalal Modeling Project, as well as integrates existing appropriate ecological data from the Density Reduction/Groundwater Resource (DRGR) studies in Lee County and Bonita Springs. This project generated an integrated surface/ground water hydrological model that is capable of simulating both dry and wet season water levels and flows in the Estero and Imperial River watersheds and will be sufficient for evaluating wetland hydroperiods and depth ranges in the wetlands in the basin.

Project Team

The project team consists of staff from the Coastal & Heartland National Estuary Partnership (CHNEP), including Jennifer Hecker, Nicole Iadevaia, Sarina Weiss and Andrew Webb; Lago Consulting including, Marcelo Lago and Maria C. Bravo; Water Science Associates (WSA), including Roger Copp and Kirk Martin; Church Environmental, including Church Roberts; and Southwest Engineering & Design (SED), including Gary Bayne. CHNEP served as the project managers and assisted in the drafting of this final report. Lago Consulting and WSA were the leads on data collection and modeling and assisted in the drafting of this final report. They also led the drafting of all Technical Memoranda that serve as appendices to this report. SED and Church Environmental assisted in field data collection and verification.

Data Collection and Model Building

This modeling effort is intended to be additive to existing regional flood mitigation and hydrologicalal restoration efforts underway in this basin. This includes the Lee County Stormwater Master Plan and Flood Mitigation Plan to address serious flooding that has occurred periodically in portions of South Lee County. Additionally, Bonita Springs has conducted a number of studies in response to flooding in the City of Bonita Springs during Hurricane Irma. To compliment these efforts in assisting to optimize those projects, as well as identifying other potential projects to improve natural resource protection, this hydrologicalal modeling effort was undertaken.

The initial steps were taken to gather and improve existing data sets, collect limited additional new data, and to conduct field verification. Once the data was sufficient, the model was refined and calibrated to be more sophisticated than its predecessors in this region, allowing for more accurate modeling analysis to be conducted. The updated model was then used to simulate existing conditions, natural conditions of what natural systems need in terms of water levels and flows, and three future condition scenarios (maximum restoration, maximum development, and intermediate restoration/development). From looking at these modeling results, recommendations were formulated for proposed future modeling and proposed hydrologicalal restoration projects. This section summarizes the aspects of the project involving the data collection and model-building activities.

Collection of Prior Model Information

Recent prior models in the South Lee County watersheds were reviewed and used as starting point to develop the new existing conditions MIKE SHE model, referred herein as SLCWI Model (details available in Appendix A: Gather Existing Data and Models Technical Memorandum).

The prior models utilized (see **Figure 1** showing the various model boundaries/domains) include:

- The Corkscrew Swamp Sanctuary (CSS) MIKE SHE Model [WSA, 2020b]. Derived from the Big Cypress Basin (BCB) model [LAGO and Stanley, 2020] and the Edison Farm models.
- The Lehigh Acres Municipal Improvement District (LA-MSID) MIKE SHE Model [WSA, 2020a].
- Edison Farm MIKE SHE Model. Derived from the Village of Estero Model [WSA, 2018], which was based on the Density Reduction Groundwater Recharge (DRGR) Model of the South Lee County region [DHI, 2009].
- The South Lee County Flood Mitigation Plan (see SLCR in map below) MIKE SHE Model [AIM, 2020]. Derived from the Village of Estero and the LA-MSID models.
- The City of Bonita Springs ICPR Model [LAGO, 2019, domain not shown in map below].

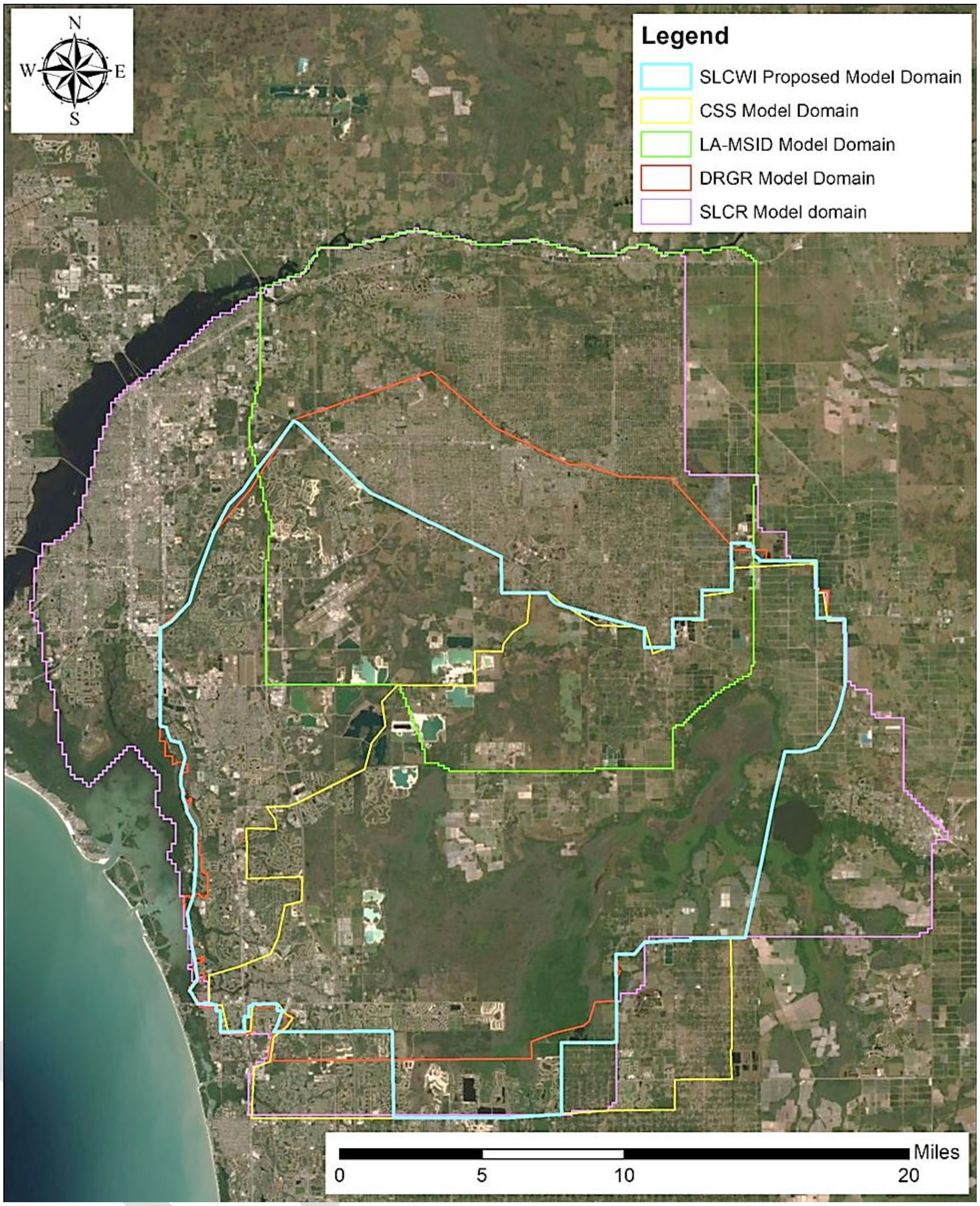


Figure 1. Model Domains for Models of South Lee County

A preliminary SLCWI Model for this project was built after merging information from these models.

Collection and Verification of Existing Field Data

This project collected and utilized data from a variety of existing sources. Once existing data sources were identified, efforts ensued to improve and expand existing data sets as well as to collected some limited additional data needed for the project modeling phase (all of this is outlined in detail in Appendix B: Monitoring Planning and Field Verifications Technical Memorandum, Appendix C: Field Investigations Technical Memorandum, Appendix D: Vegetation Coverage Data Compilation and Processing Technical Memorandum, Appendix E: Irrigation Data Compilation and Processing Technical Memorandum, and Appendix F: Time Series Update Technical Memorandum).

In summary, the project activities related to data collection and improvement of existing data included:

- Obtaining barometric pressure data from 10 wells at Kiker Preserve to improve accuracy of observed water levels
- Obtaining observed stages from 5 stations at Halfway Creek from private engineering firm
- Obtaining Bonita Springs Utilities observation water level data from 8 wells
- Obtaining Daniels Parkway monitoring well data at 2 deep wells from Lee County
- Obtaining Wild Blue observation water levels at 6 stations from a private engineering firm
- Obtaining Green Meadows observation water levels at 10 stations from Lee County Utilities
- Obtaining Panther Island Mitigation Bank observation water levels from 10 stations from Corkscrew Swamp Sanctuary
- Obtaining Lee County Port Authority Mitigation Bank observation water levels at 10 stations from Lee County Port Authority
- Obtaining Florida Gulf Coast University water level data at one station, as well as photographic records of water levels immediately preceding and following Hurricane Irma, from Florida Gulf Coast University
- Obtaining Corkscrew Swamp Sanctuary monitoring well and staff gage data, from the Sanctuary and as collected by the project consultant team
- Obtaining irrigation and reuse water application rates from Lee County and Bonita Springs Utilities
- Obtaining rainfall data from DBHYDRO and Lee County at 8 rain gage sites
- Obtaining Reference Evapotranspiration rates from the USGS
- Obtaining Potable Water Supply extraction well and injection well data
- Obtaining accurate ground elevations from four survey transects (total length 4.3 miles) in Corkscrew Swamp Sanctuary and Bird Rookery Swamp

Conversion of Existing Land Use Data

The SLCWI Florida Land Use Cover Classification System (FLUCCS) codes were converted to a smaller set of MIKE SHE codes for use in the SLCWI Model. Their polygon shape files were resampled to a finer 375-ft grid resolution as well as adjusted to reflect known recent land use changes not reflected in the original FLUCCs coding. For predevelopment conditions land use coding, the mapped land cover types established in the Southwest Florida Feasibility Study were utilized.

Figure 2 reflects the existing conditions MIKE SHE vegetation codes used in the SLCWI Model.

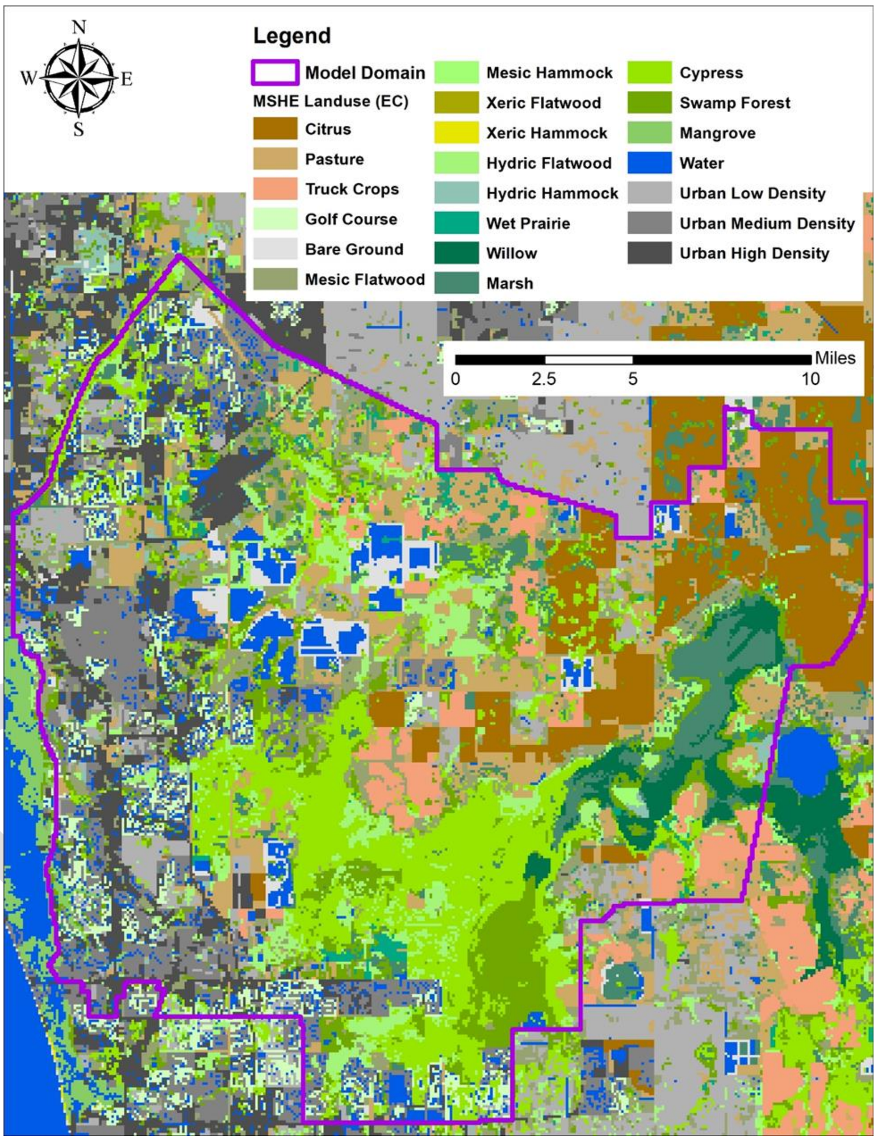


Figure 2. Land Use for the South Lee County Model

Collection of Additional Data

Additionally, there were some limited efforts to gather additional data, including:

- A number of ground elevation points were surveyed with a global navigation satellite system (GNSS) receiver (see ground elevations survey points outlined as symbols in **Figure 3**).

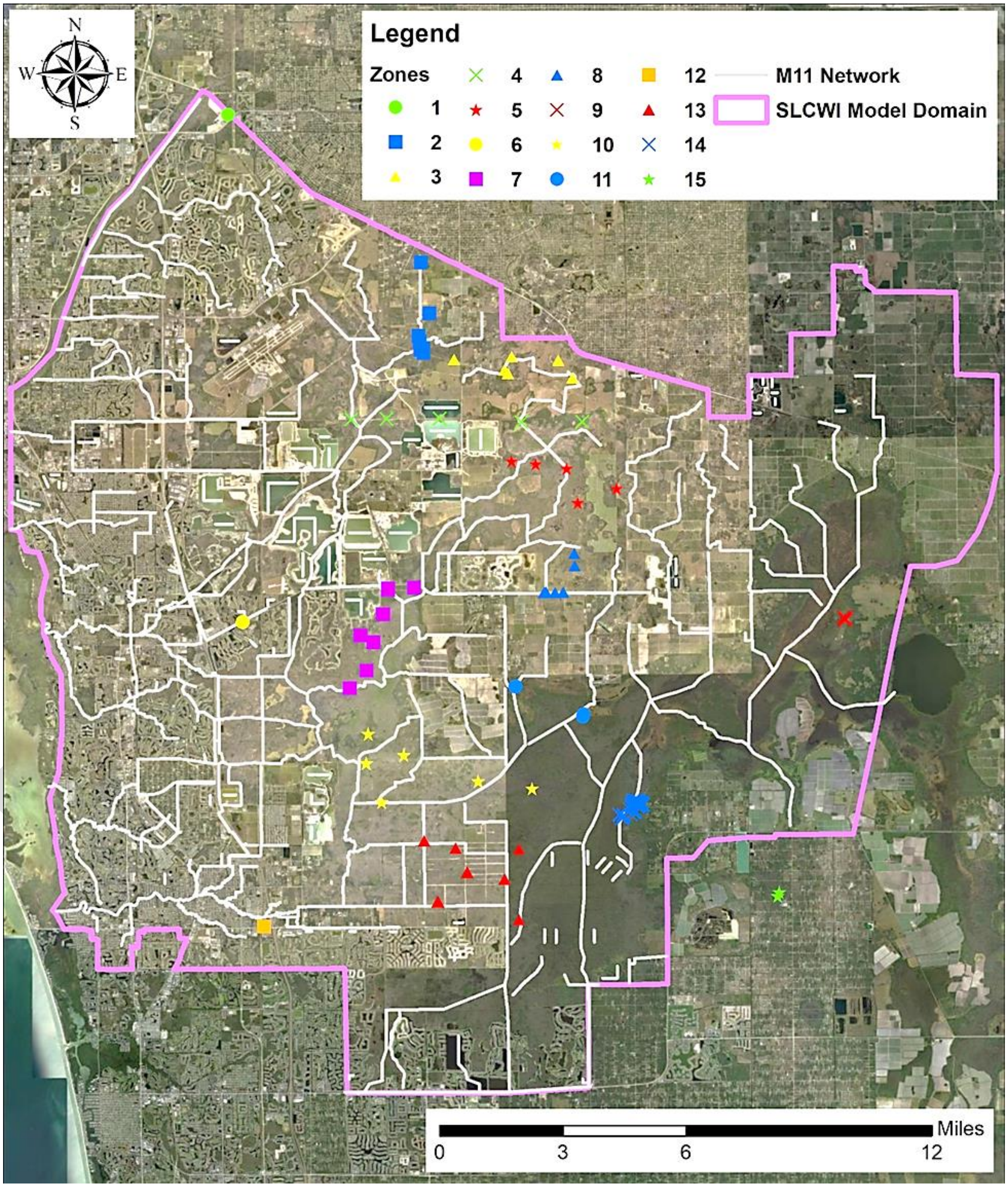


Figure 3. Locations of Surveyed Elevations of Vegetation Evaluation Sites

- A number of field visits were conducted to verify the presence, dimension, and invert elevation of hydraulic structures (hydraulic structure sites visited outlines as green stars in **Figure 4**).

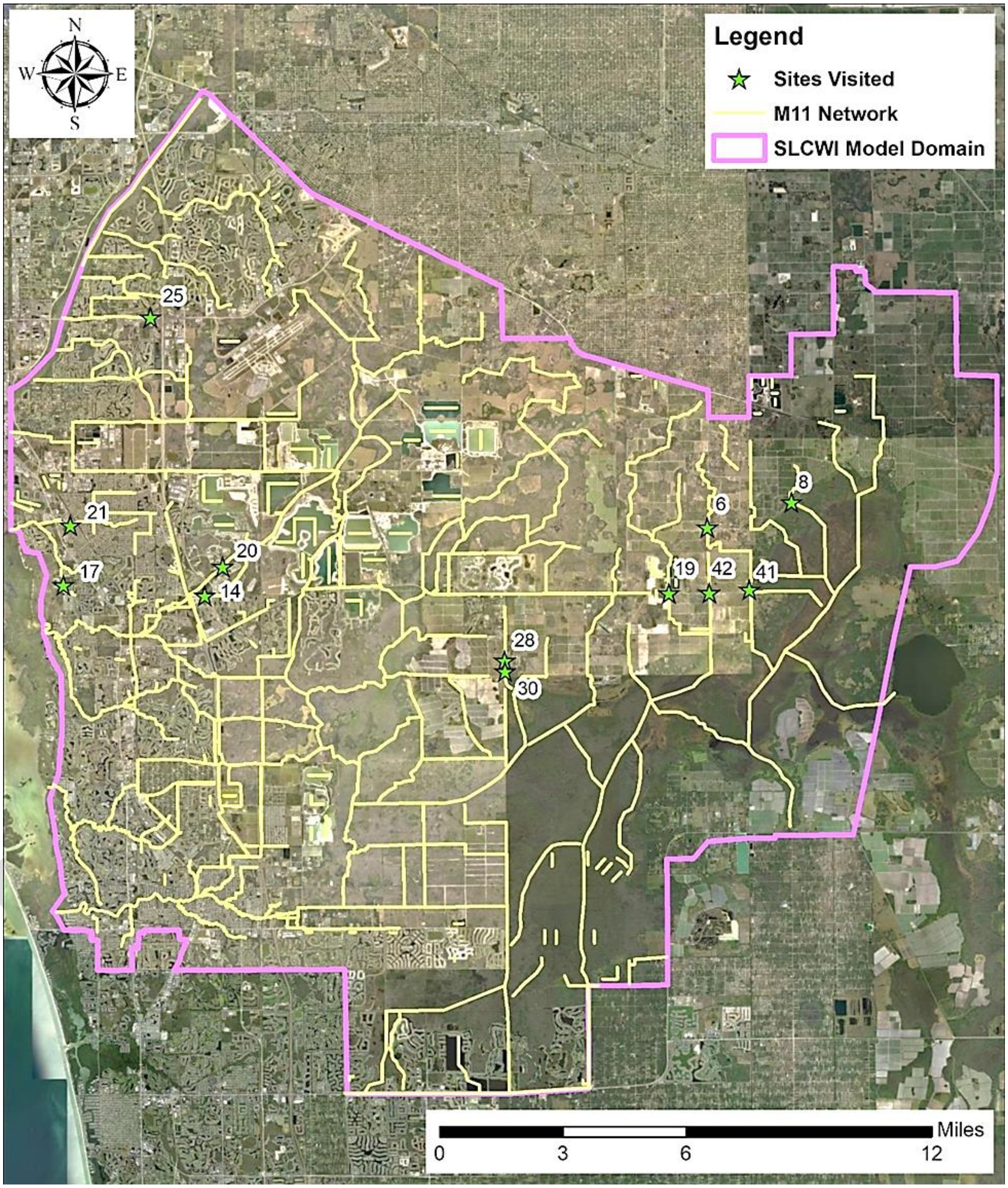


Figure 4. Field Surveyed Elevation Locations

- A number of field visits were conducted to assess a variety of vegetation indicators to estimate the average wet season water depth by the consulting team ecologist and survey crew (wet season water depth assessment sites outlined as yellow and peach stars in **Figure 5**).

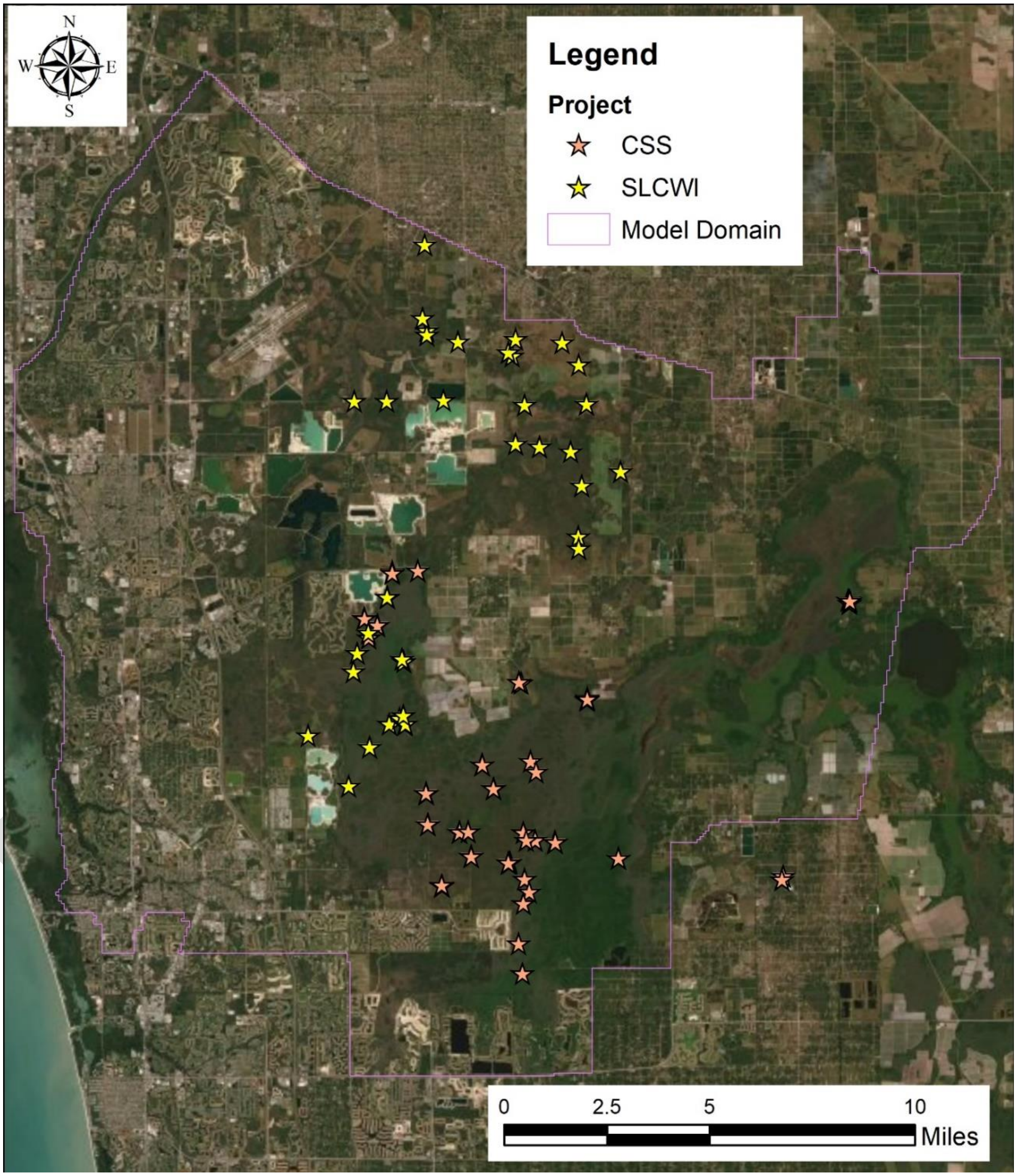


Figure 5. Locations Visited To Estimate Average Wet Season Water Depth From Vegetation Indicators.

The improved and collected data sets were later used in the integrated surface/groundwater modeling using the SLCWI Model.

Model Calibration

A preliminary version of the SLCWI Model was built using the MIKE SHE input files from recent models and conducting a number of necessary updates (details available in Appendix G: Preliminary Model Performance Technical Memorandum). The new model domain covers an area of 363 square miles, south of the SR-82 and north of the Cocohatchee Canal (located just north of Immokalee Road). The calibrated model was developed from the preliminary model based on input from the SFWMD review team and additional calibration effort.

Model calibration focused on improving the model input data and better representing the existing surface water movement in the watershed during the simulation period 2013-2019 (details available in Appendix H: Model Calibration Technical Memorandum). The calibration was further refined by adjusting model parameters to better match the observation data.

In summary, the project activities related to model calibration included:

- Redrawing MIKE11 branch paths and introducing new branches to better represent the channelized flow network
- Adding or revising hydraulic structures based on surface water management permit information and field visits
- Recutting cross-sections from the latest LiDAR-based DEM
- Defining short branches to represent storage and outfall structures within urban developments
- Modifying Separated Overland Flow Area (SOLFA), flood, and drain code maps accordingly
- Obtaining corrected LiDAR-based topographic maps at 50-ft and 375-ft spatial resolutions
- Enhancing the vertical distribution of the specific yield (S_y) by dividing the Water Table Aquifer in two computational layers
- Adjusting the crop coefficient (K_c) and moisture deficit start/stop values to improve predicted flow at observation stations and predicted irrigation amounts at some large water use permits
- Adjusting the maximum allowable irrigation application rate

Sensitivity tests were conducted on several model input parameters during the second part of the calibration task. The model sensitivity was evaluated using statistical measures at observation stations. The tests concluded that model results were most sensitive to saturated zone (SZ) hydraulic conductivities, vegetation crop coefficient, irrigation maximum application rate, and overland and river Manning's coefficient M. Accordingly, hydraulic conductivities in the SZ component were adjusted consistently within the range of variations from previous models and other literature sources. The iterative procedure generated conductivity maps for each geologic layer that produced lower overall mean absolute error (MAE) at water level observation stations. In terms of vegetation-related parameters, the crop coefficient (K_c) and the moisture deficit start/stop values were adjusted to improve predicted flow at observation stations and predicted irrigation amounts at some large water use permits with reported irrigation data. The maximum allowable irrigation application rate was also adjusted for the same purpose. Finally, the Manning's M (i.e., reciprocal of Manning's n) was increased by 20% in order to increase the predicted surface water flows at observation flow stations.

Comparisons of preliminary and calibrated model results at observation stations showed an overall improvement in the model performance after the calibration. There were visible improvements in the hydroperiod and water depth maps from the preliminary to the calibrated models. Lowering the LiDAR-based DEM in wetlands areas according to recent survey elevation data produced longer hydroperiods and higher water depths in those areas. Moreover, implementing a pump-driven drainage in some of the agricultural areas corrected many of the unrealistic ponded water as predicted in the preliminary model. The average wet season water depths estimated from vegetation indicators at field investigation sites were underestimated (in average by around 0.5 ft) by water depth estimations that used water levels from the calibrated model or from observation station data. An underestimation of 0.2 ft was obtained from the calibrated model with the subset of points within areas with LiDAR-based DEM corrections. Thus, lowering the LiDAR-based DEM in those wetland areas produced a significant improvement in the wet season water depth model predictions.

The model performance was evaluated by comparing the observation station data for 146 monitoring stations with the model results by using statistical measures, with the final calibrated model having 88% with okay to good calibration (above industry standard).

The calibrated model was more accurate than predecessor models and appropriate to conduct scenario evaluations.

Hydroperiod and wet season water depth maps were generated from the model results. Average annual hydroperiod duration as predicted from the SLCWI Model is presented in **Figure 6**.

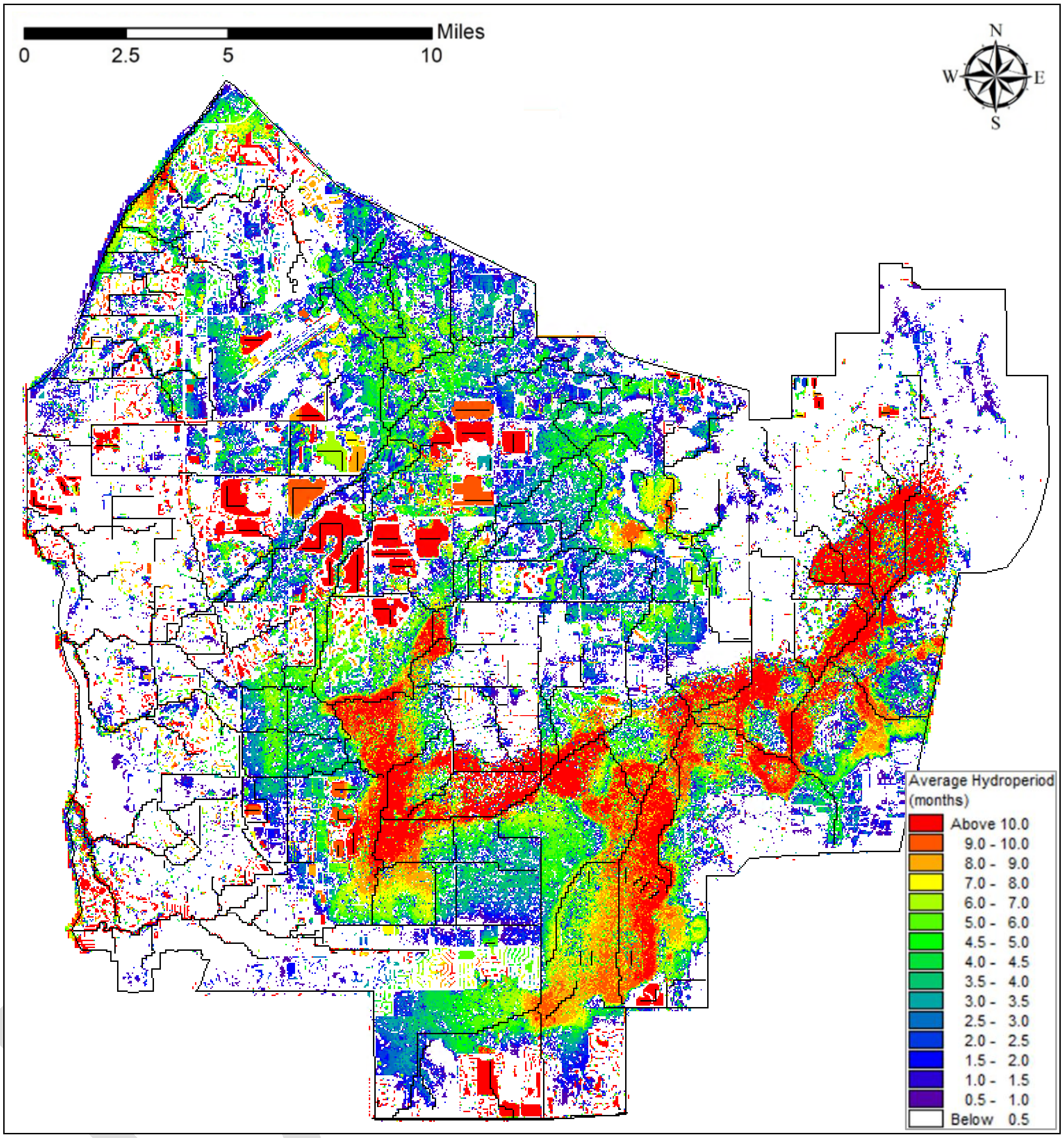


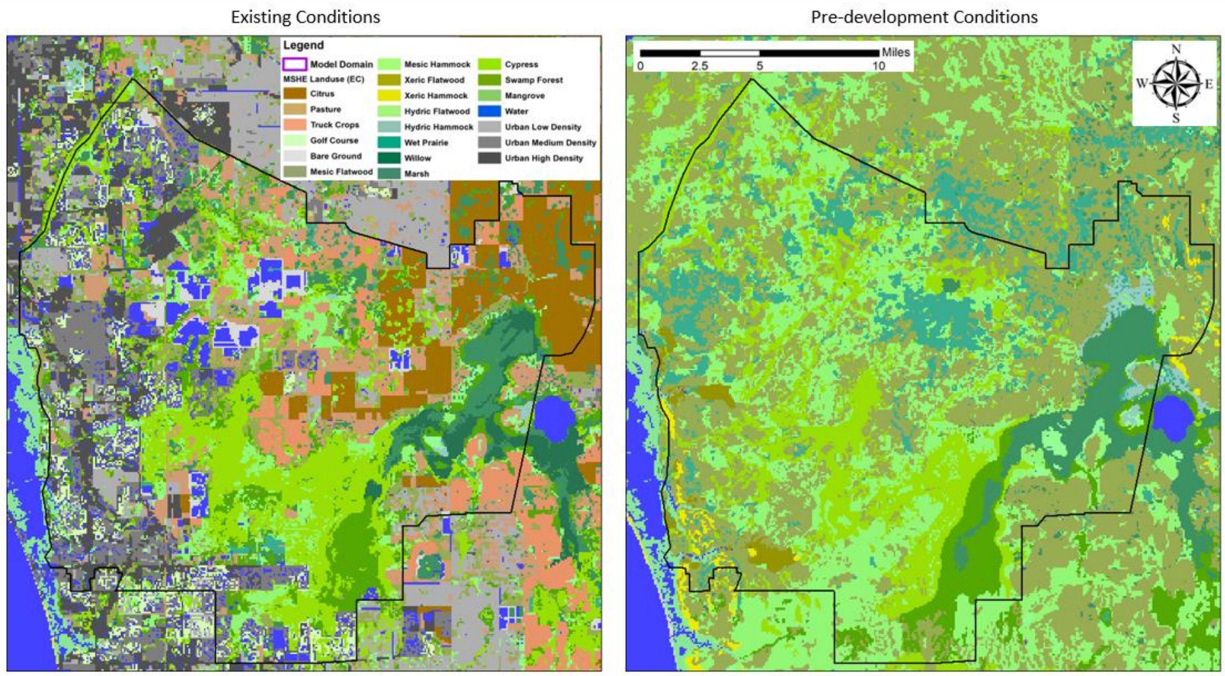
Figure 6. Average Annual Hydroperiod Duration for the Calibrated Model

Natural Systems Model

The Natural Systems Model was designed to accurately simulate historical and existing conditions to determine changes to natural systems in the South Lee County Watershed (detailed explanation of methodology and results are contained in Appendix I: Natural Systems Model Technical Memorandum).

The procedure used to build the Natural Systems Model (NSM) from the baseline existing conditions model consists of removing all anthropogenic alterations made in the watershed. This included man-made changes in the topography, vegetation, soil, and SOLFA maps; as well as in the MIKE11 hydraulic network. Irrigation, drainage, and pumping well components were turned off. The model simulation was launched for a 10-year period and the results were processed.

The resulting natural system model maps comparing existing conditions to pre-development conditions show the vegetative community shifts, levels of water level changes and level of hydroperiod changes that have occurred in different areas throughout this basin. Below is a map of existing and the pre-development conditions vegetation coverage maps at 375-ft spatial resolution.



In general, the results comparing pre-development and existing conditions show extensive drainage in lowering water levels and shortening hydroperiods throughout all the developed portions of the watershed. This lack of water storage has negatively affected some remaining natural areas that are needed to recharge groundwater drinking water supplies, provide freshwater flows to downstream rivers and estuaries, as well as to support habitats (particularly wetlands) needed by area wildlife. Understanding where and how exactly these changes have affected remaining natural areas allows for understanding of what natural system needs exist in guiding potential restoration activities.

Existing Conditions	Pre-development Conditions

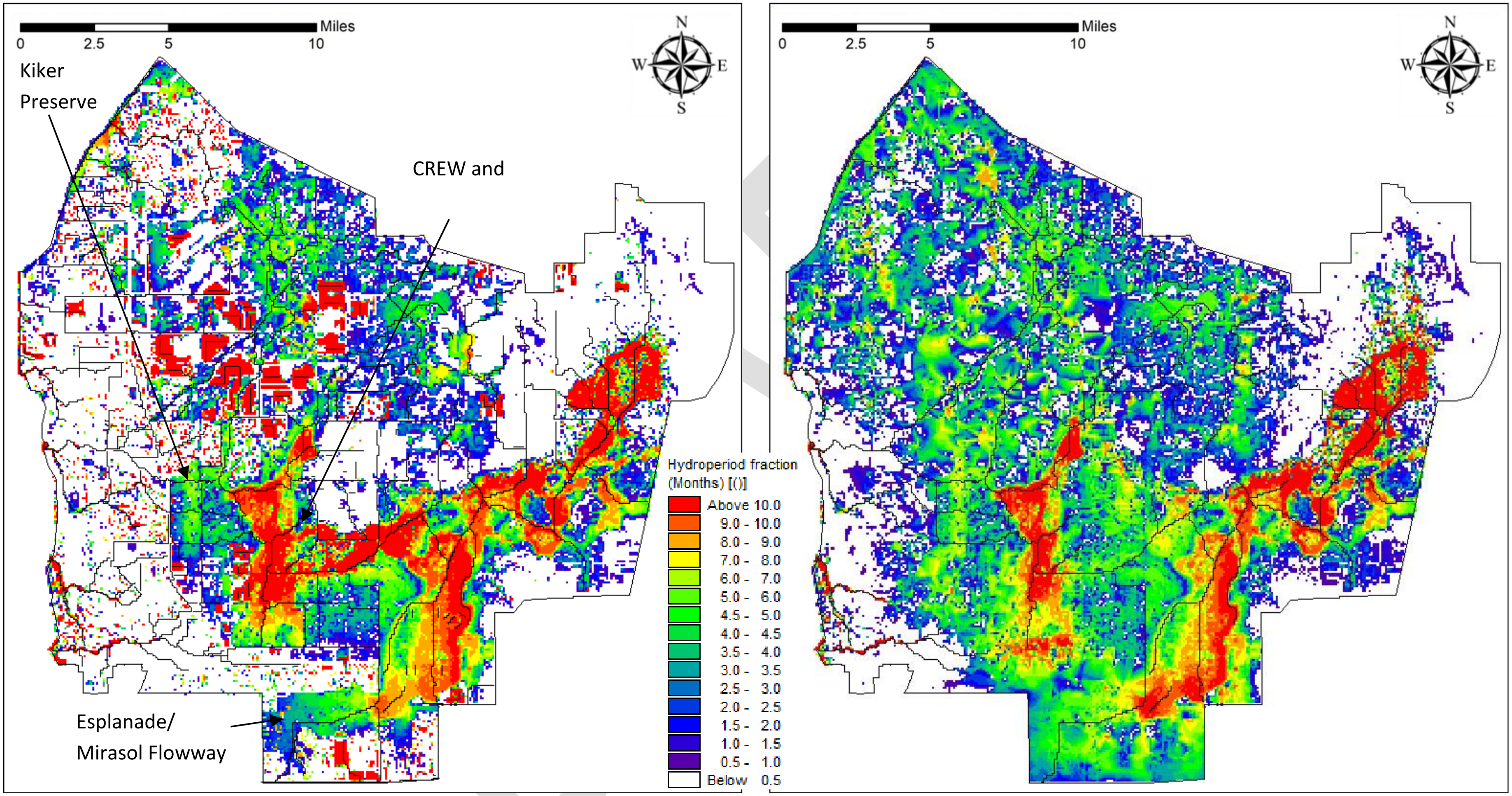
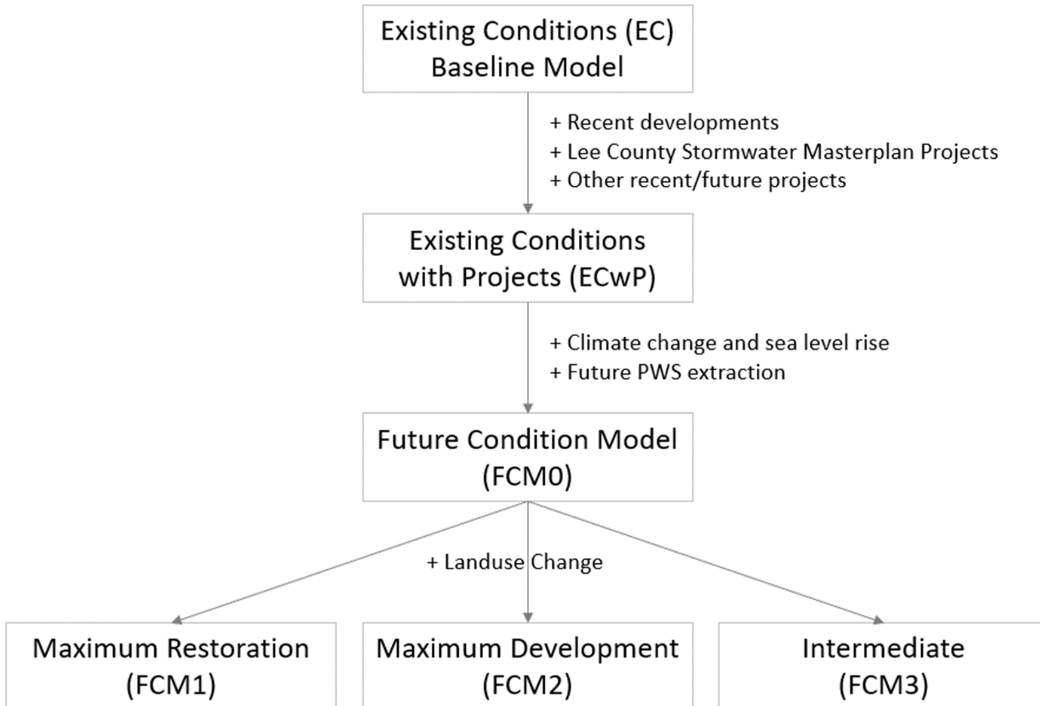


Figure 7. Existing and the pre-development hydroperiod at 375-ft resolution as predicted during the period 2010-201

Future Conditions Scenarios



The Future Conditions model was built in phases (methodology and results of which are detailed in Appendix J: Future Condition Scenarios Technical Memorandum). Starting with the baseline calibrated model, existing known development projects that were permitted and/or underway, the priority projects anticipated to be implemented from the Lee County Stormwater Master Plan and other recent and future known projects (ex. permitted mines) were included to create an Existing Conditions with Projects Model (ECwP). Then anticipated near-term climate change factors such as increased evapotranspiration and sea level rise, as well as future potable water supply demands, were included to create the baseline Future Conditions Model (FCM0).

This Future Conditions Model served as the basis for modeling three primary future conditions scenarios: maximized development, maximized restoration and an intermediate development /restoration scenario. The maximized development scenario assumed all highest land use intensities allowed in local land development code occurred, and that the only preservation/conservation opportunities outlined in the CHNEP Habitat Restoration Needs (HRN) Plan being preserved would be those outside of where further development was allowed in addition to existing conservation properties. The maximized restoration scenario assumed all CHNEP HRN preservation/conservation opportunities lands were conserved with natural being fully publicly protected and the non-natural opportunities being a public conservation easement that allowed their continued land uses to continue. Finally, the intermediate scenario assumed that all non-natural preservation/conservation opportunity lands were developed to highest allowed land use intensity, as well as all lands not designated preservation/conservation opportunities – with only natural preservation/conservation opportunity lands being conserved in addition to existing conservation lands. Below is further explanation of these differed iterations of modeling.

Existing Condition with Projects (ECwP) Model

The Existing Conditions (ECwP) Model included urban developments that have been permitted and have started construction, as well as some of the high-priority projects from the Lee County's Stormwater Master Plan including:

- **1.3.4: Alico Mine Lake Interconnects (West)**. This project consists of connection of an existing stormwater pond on the Southwest Florida International Airport to a number of mining pits north and south of Alico Road. This project is intended to reduce flooding by capturing stormwater in the pond and mining pits.
- **1.3.7: Blackstone Drive to Alico Mine Lakes Drainageway**. The proposed conceptual project 1.3.7 conveys excess stormwater drainage flow from Blackstone Drive area in Lehigh Acres lying south of SR 82 to the existing Alico Mine Lakes. The originally proposed project is conceived with a control structure that would allow the gravity-driven flows. There is not always a positive hydraulic gradient for the surface water to flow south, so for this study, the original proposed structure has been replaced by a 10-cfs pump as a refinement modification to the proposed project.
- **1.3.8: Alico Mine Lake to Halfway Creek Drainageway**. The proposed conceptual project 1.3.8 utilizes the existing mine lakes in the WildBlue development currently under construction lying north of Corkscrew Road for storage, conveys water into the Flint Pen Strand preservation area, and directs excess flow towards the Halfway Creek bridge under the I-75. The replacement of some culverts under Corkscrew Roads is proposed as part of this project.
- **1.3.11: East I-75 Overland Flow Collection Drainageway**. The proposed conceptual project 1.3.11 connects existing borrow pit lakes (also referred to here as ponds) east of I-75 to the conveyance structures under I-75. The project consists of creating a collector drainageway that would direct overland flow and equalize water levels at each I-75 crossing to fully utilize each structure. Control structures with overflow elevations ranging from 18 to 19 ft-NAVD would be installed in the 23-ft high berm.
- **1.3.13 CREW-Flint Pen Strand Hydrological Restoration**. The proposed conceptual project 1.3.13 would develop a water storage area located within the boundaries of Kiker Preserve, Flint Pen Strand, and the Southern Corkscrew Regional Ecosystem Watershed (Southern CREW). The project objective is to hold excess stormwater upstream of the proposed berm until downstream developed areas have drained following a large storm event. This area would be contained within a 23-ft high perimeter berm and will have remotely operated control outflow gated structures to maintain the water level within desirable ranges. The berm configuration used in this modeling effort was obtained from a second berm alignment proposed as part of additional flood mitigation studies conducted for Lee County.

Figure 8 illustrates the location of the projects listed above. The proposed projects listed above were modified to reflect recent development. In addition, some hydraulic structures were modified, removed, or added in this study to maintain and/or enhance hydrologicalal restoration of natural areas, including wetlands. Finally, two other future projects (namely the new Corkscrew Crossing conveyance and hydroperiod restoration at the south end of Corkscrew Swamp Sanctuary) were added in the ECwP model.

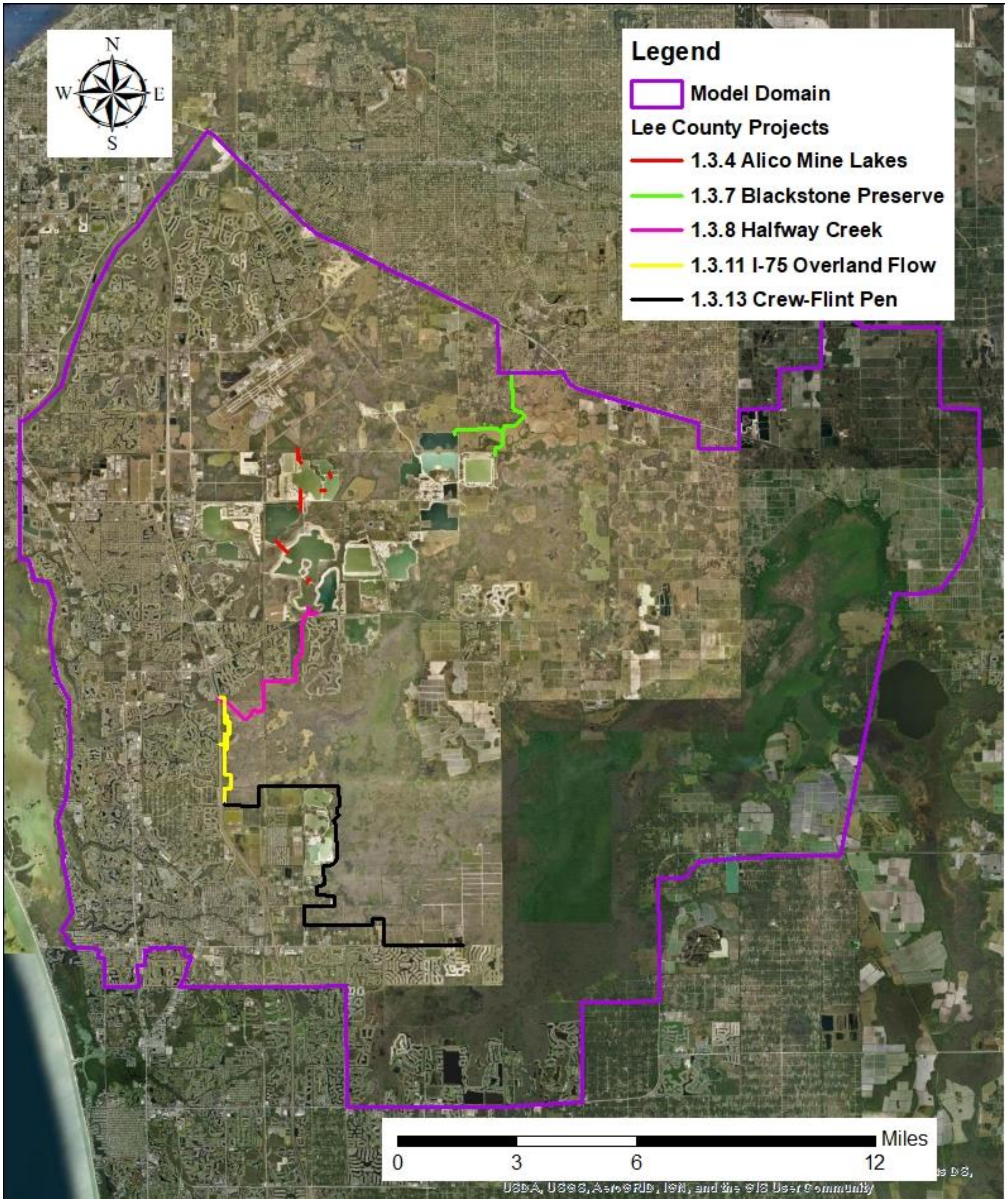


Figure 8. Lee County Flood Mitigation Projects Included in the ECwP Model

The model mapped the hydroperiod differences between existing conditions with projects (ECwP) versus existing conditions (EC, without projects) – see Figure 9. The comparison between the EC baseline and the ECwP models indicates altered hydroperiods and wet season water depths resulting from the projects introduced in the model. Hydroperiods were typically shorter in the urban developed areas and higher in receiving waters outside of the developed lands. Longer hydroperiods were predicted due to inflows from the Blackstone Preserve. Longer hydroperiods were also seen typically at upstream areas of proposed berms (see Kiker Preserve area in map). As a result, longer hydroperiods are seen along a northeast-southwest linear alignment from the Blackstone inflow to Kiker Preserve and the east-west section of the proposed berm.

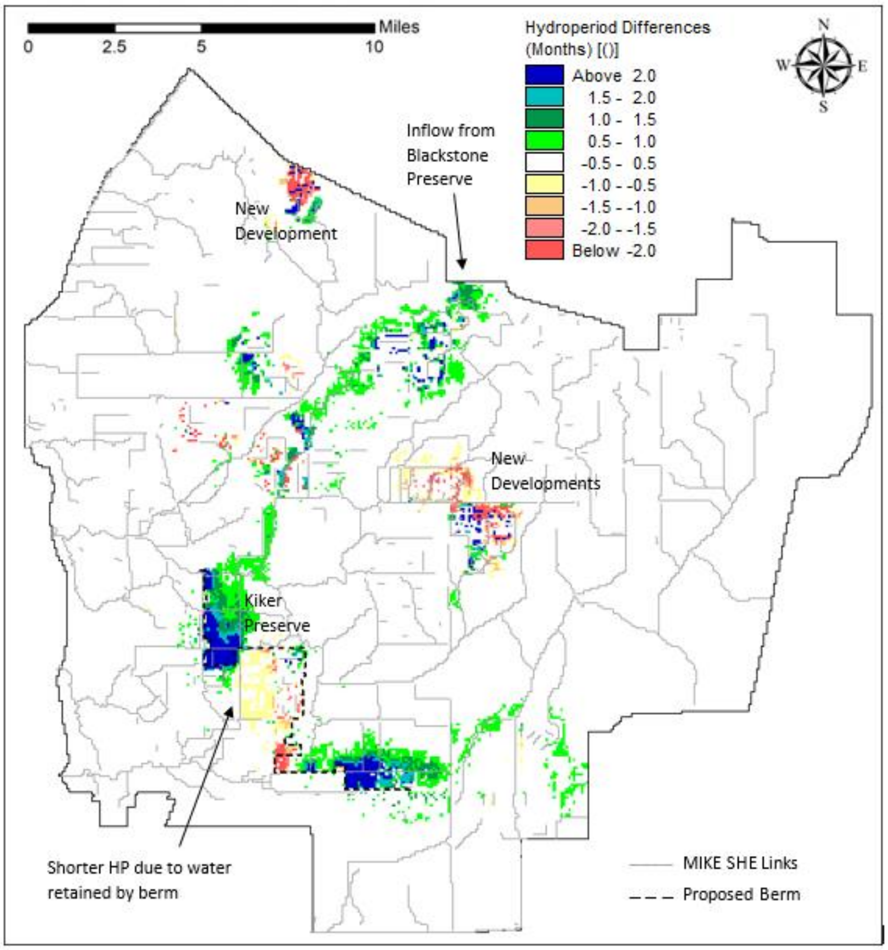


Figure 9. Hydroperiod Difference for EC minus ECwP

Future Condition Model without Landuse Change Scenarios (FCM0)

The anticipated near-term climate change factors such as increased evapotranspiration and sea level rise, as well as future potable water supply demands, were included to create the baseline Future Conditions Model (FCM0). Sea level rise was based on sea level rise projections by NOAA for year 2050, assuming Intermediate/High Sea Level Rise with Low Accretion Rate (of 2 mm/year). Evapotranspiration rates were obtained from the DHI climate change tool. Since there is not scientific consensus in the literature on anticipated future changes in rainfall, the rainfall input time series were not modified. In addition to the climate factors, an increase in public water supply (PWS) pumping was included using the maximum extraction rates as specified in the water use permits, which represents an increase of 34% above the existing condition baseline model (i.e., period 2010-2019).

The FCM0 results showed a decrease in hydroperiods (as shown in map below) and wet season water depths with respect to the ECwP model in the regional scale. Hydroperiods are predicted to decrease by up to 1 month and the wet season water depths will decrease by up to 0.4’ due to increases in temperatures and ET. Water budget calculations showed that the increase in ET by 5% will create drier conditions and will reduce river outflows.

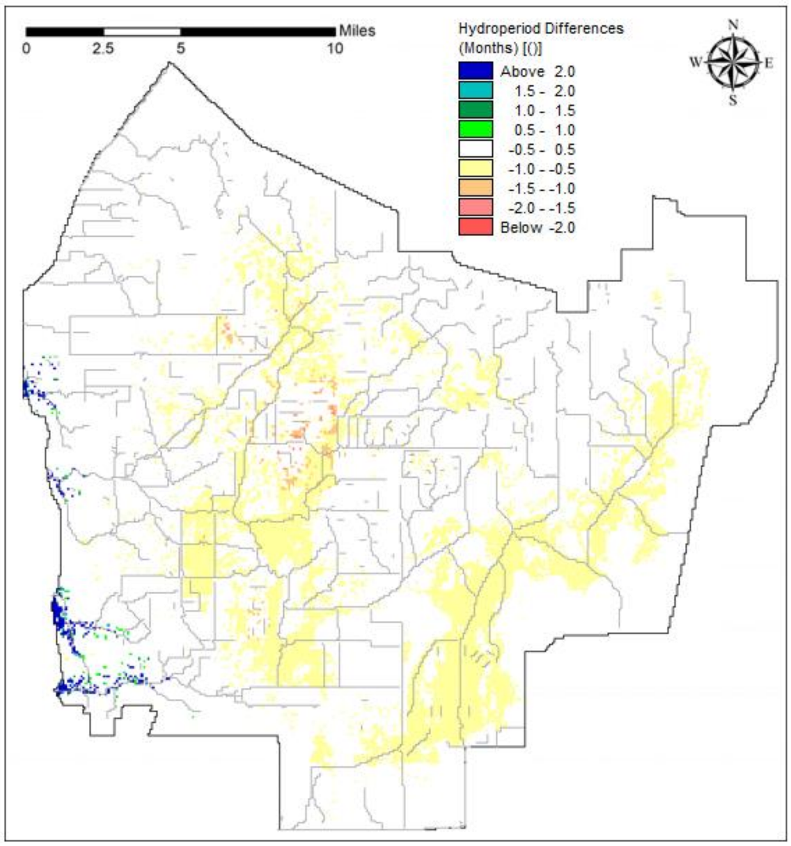


Figure 10. Hydroperiod differences (FCM0 minus ECwP) after including climate change and groundwater pumping

The FCM0 results showed an increase in hydroperiod and water depth along the tidal portions of all rivers in the model (i.e., Imperial River, Spring Creek, Estero River, and Mullock Creek) as a consequence of the sea level rise. This is shown in **Figure 9** and is shown in greater detail in Appendix J. The model also predicted increase in the water depth by about 7 inches along mangrove areas, which will likely result in changes in vegetation along the coastal boundary. This landward migration of brackish tidal water along the rivers (due to higher tidal levels and reduced river outflows) may have negative impacts on the freshwater resources near the coast.

Future Condition Models (FCM1, FCM2, and FCM3)

Three future condition scenarios were evaluated in this study with different landuse/vegetation coverages, which were built based on the CHNEP Habitat Restoration Needs mapped preservation and conservation opportunities (PCO) and the Lee County simplified future landuse map. The first scenario (FCM1) represented maximum restoration, the second scenario (FCM2) represented maximum development, and the third scenario (FCM3) incorporated landuse changes intermediate between the maximum restoration and development scenarios. Changes in the landuse maps were propagated to the topography and ICA maps, as well as to the other correlated maps obtained from the landuse.

Developed areas showed typically shorter hydroperiods due to increased land elevations and increased drainage from those developed lands. In addition, the adjacent natural areas receiving runoff from developed lands showed typically longer hydroperiods.

FCM1, Maximum Restoration. Hydroperiod increases for FCM1 were predicted for agricultural lands such as 6Ls and Troyer Brothers shown in **Figure 11** that were assumed to be restored in the 2020 CHNEP Habitat Restoration Needs study. Both areas have subsequently been approved for development either for residential development or mining, and therefore, most of these areas will not experience hydroperiod increases.

FCM2, Maximum Development. **Figure 12** indicates that hydroperiod are predicted to decrease in lands assumed to be converted to development with hydroperiod changes ranging from -1 to -2 months. Undeveloped lands adjacent to the developed lands receiving runoff from the newly developed lands are predicted to have hydroperiod increases, ranging from 0.5 to 2.5 months. These increases are predicted to occur both north and south of Corkscrew Road east of Alico Road as well as in the Lee County Port Authority (LCPA) mitigation lands.

FCM3, Intermediate Restoration. Figure 13 presents the predicted hydroperiod changes associated with this scenario. The spatial extent of lands predicted to have hydroperiod changes was less than for FCM2 since less land was assumed to be developed. Hydroperiod increases are predicted to increase for undeveloped lands adjacent to developed lands that will receive additional runoff from those developed areas (such as 6Ls and Troyer Brothers).

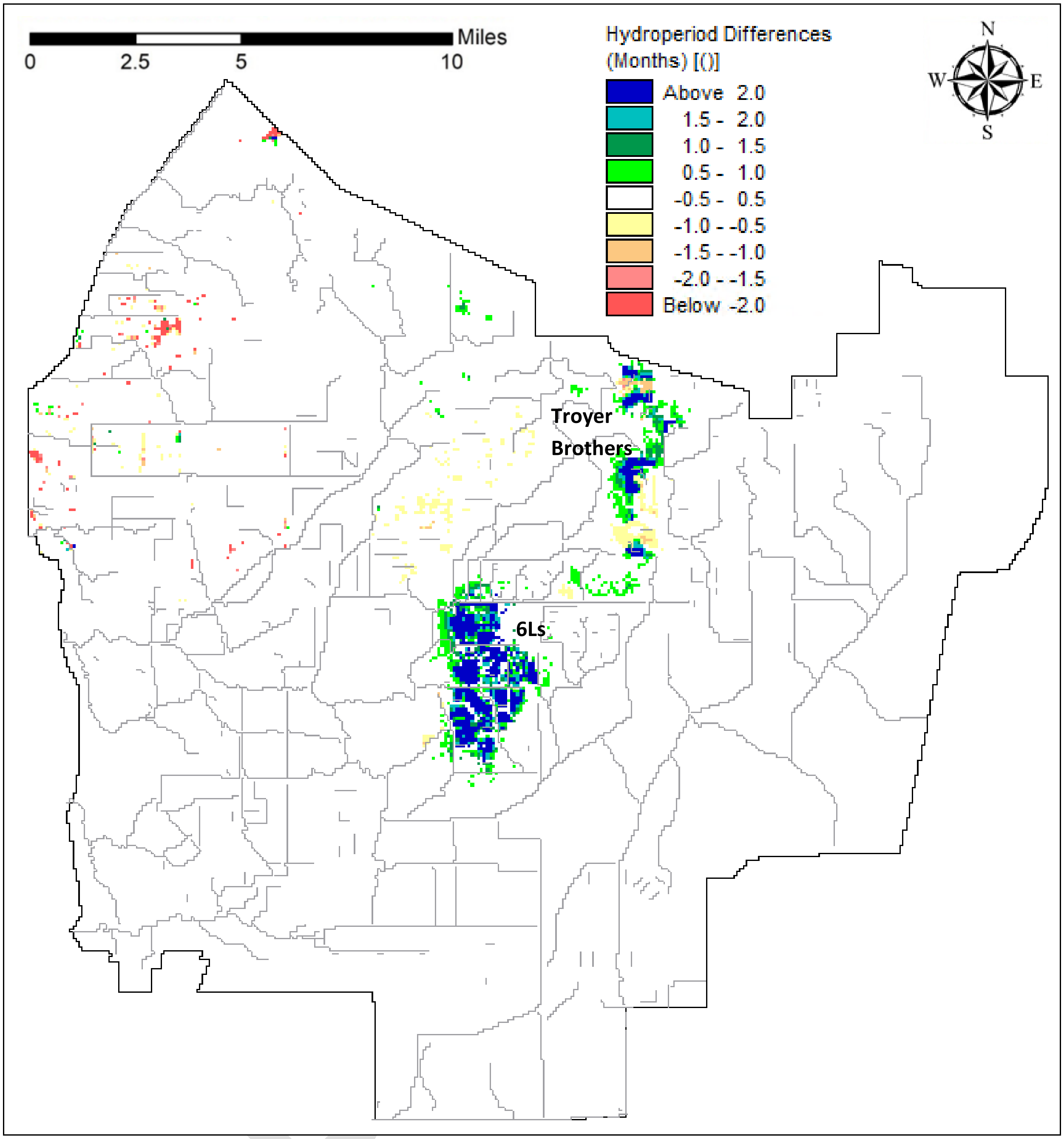


Figure 11. Future condition hydroperiod differences after the landuse changes in the scenarios: Max. Restoration (FCM1) – Future Condition Baseline (FCM0)

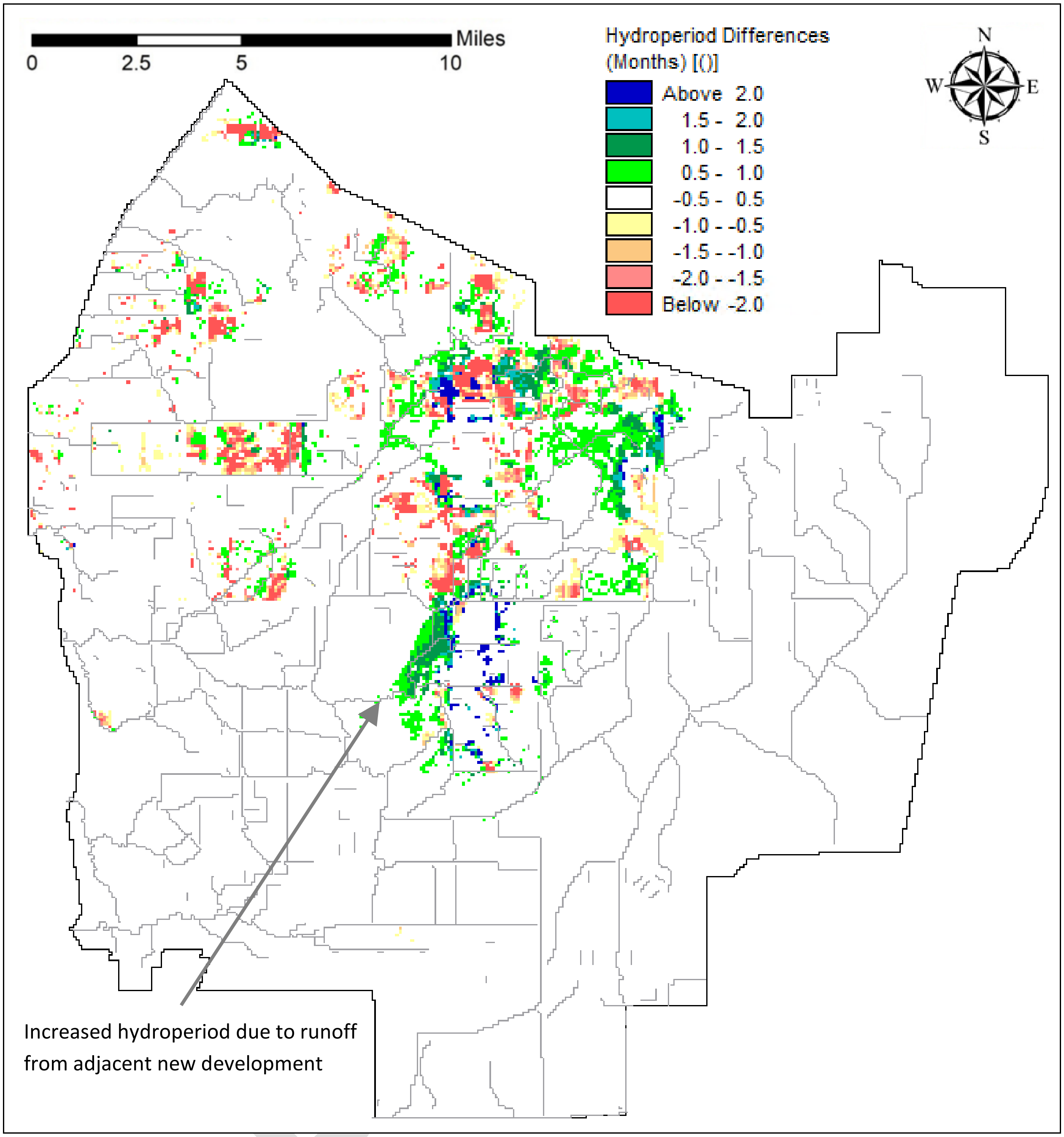


Figure 12. Future condition hydroperiod differences after the landuse changes in the scenarios: Max. Development (FCM2) – Future Condition Baseline (FCM0)

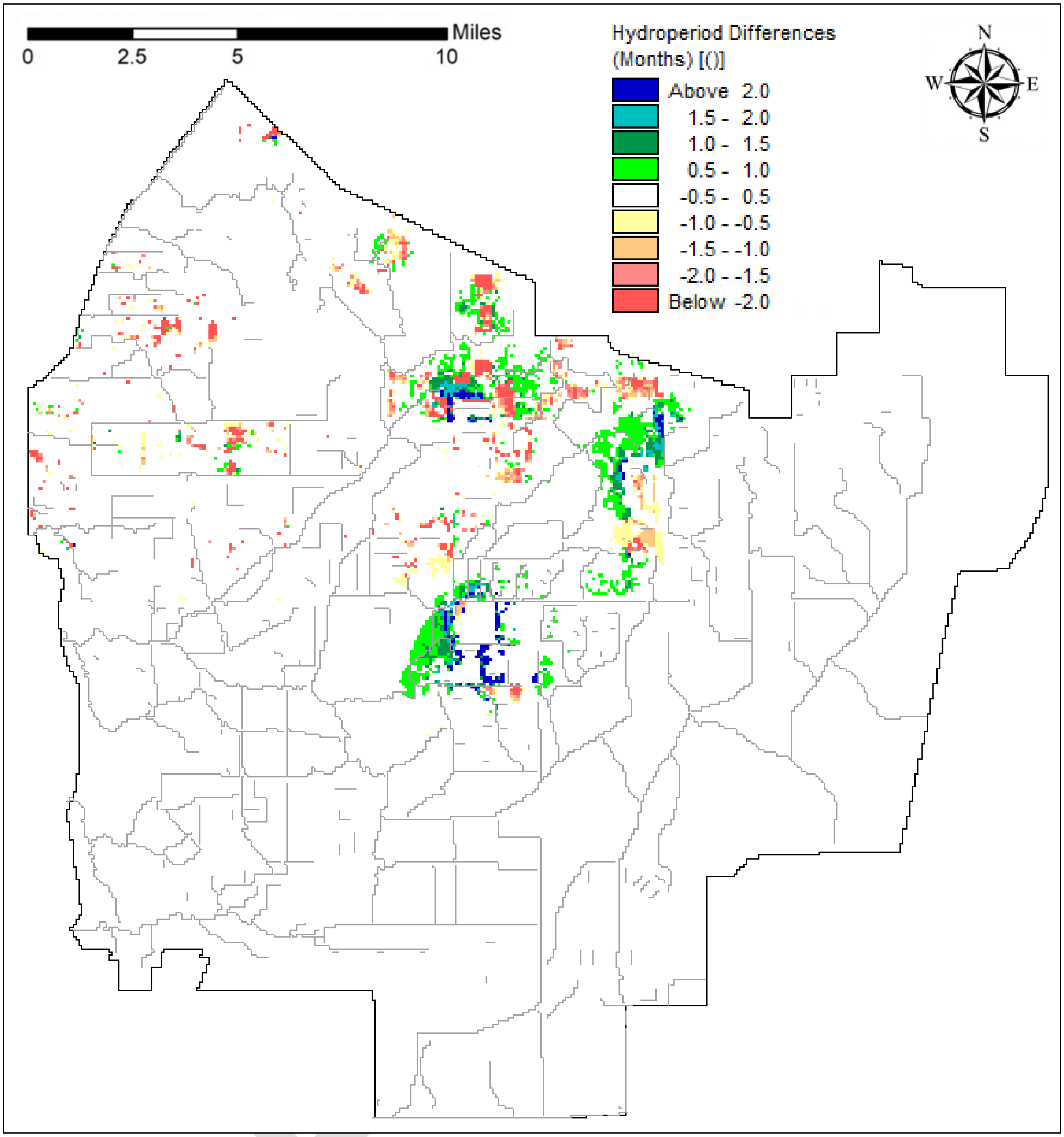


Figure 13. Future condition hydroperiod differences after the landuse changes in the scenarios: Intermediate Restoration/Development (FCM3) – Future Condition Baseline (FCM0)

Results

Hydrological Model Development and Calibration

The integrated surface/ground water tool developed for this project is a robust modeling tool that is appropriate for evaluation of a range of alternative water management strategies to address existing and future water management challenges. The model is based on the best available information and is suitable for both wet and dry season conditions.

Hydrological Restoration and Flood Mitigation

This modeling study affirms that flood mitigation can be achieved while preserving water resources and wetland hydroperiods, with enhanced water management that optimizes projects to achieve multiple objectives. Flooding events occur typically during the wet season when the water table levels are higher and there is less storage inside and above the ground. The project proposed in the Lee County Stormwater Management Master Plan are intended to mitigate flooding by increasing conveyance and storage. During Hurricane Irma, it was also apparent that there is a need to improve channel maintenance to remove debris and other unnatural flow restrictions.

The berm proposed in the Lee County stormwater project east of the I-75 and north from Kehl Canal (projects 1.3.11 and 1.3.13 described above) is a good example of surface water management features that can be used for both purposes: flood control and water resources preservation. During the wet season, the controlling gates can be operated to minimize water levels upstream of the berm for flood control. In the case of a heavy forecasted storm, water levels could be lowered even more in advance. However, by the end of the wet season, the gates can be operated differently to keep the upstream water level higher to increase water stored within the watershed. This approach of using seasonal rules and emergency operation protocols is not new and has been used by the SFWMD at gated structures for many years. This type of water level control could become more important in the future to reduce the impact of climate change.

Future Scenarios that meet Project Goals

Maximum Restoration (FCM1) and Intermediate Restoration (FCM3) future conditions scenarios both provide opportunities to increase wetland hydroperiods in existing conservation lands and increase water storage for aquifer recharge, which the Maximum Development scenario would not provide. Therefore, pursuing Intermediate to Maximum Restoration is advisable to support natural system needs and public water supplies.

Climate Change

This modeling study evaluated the impact of climate change on watershed hydrology. This study suggests that reduced wetland hydroperiods, reduced water depths, reduced stream flows, and higher tidal water levels may be experienced by 2050. This study assumed higher rates of evapotranspiration resulting from a warming climate. A range of rainfall forecasts were reviewed during the development of the climate change scenario. Because forecasts of future rainfall range from +/- 10% of existing rainfall, no changes were made to the rainfall input data set. This surface and ground water integrated modeling study has shown that the predicted increase in temperatures and the sea level rise due to climate change could have adverse impacts to freshwater resources in areas of South Lee County and Corkscrew Swamp by year 2050. The uncertainty of rainfall emphasizes the need of hydrological preservation and restoration.

Recommendations

As a result of this project and the modeling results, a number of proposed projects and additional modeling activities are recommended that would advance the work of the South Lee County Watershed Initiative.

Recommended Future Projects

1. Grey Infrastructure - Mining Pit Additional Storage

The predicted changes in wetland hydroperiods across the model domain suggest that future water management planning should consider additional storage within disturbed or developed areas. Water can be routed to storage areas during the wet season with subsequent release during the latter part of the wet season to offset the predicted hydroperiod changes. The proposed water storage area in the Lee County Master Plan may help to offset flooding impacts since extreme wet weather events are predicted to be more frequent resulting from climate change. Should additional storage beyond the levels described in the Lee County Masterplan be considered, the impact of the additional storage will need to be evaluated to assure that wetlands are not adversely affected either in terms of hydroperiods or average wet season depths.

Existing mining pits are also feasible locations for the suggested additional storage areas. Possible locations include the Bonita Springs mine, mining pits north and east of Alico Road, and the mining pits that are currently being mined north of Corkscrew Road such as the Troyer Brothers property. Since these mining pits are privately owned, it is expected that this recommendation will depend greatly on having sufficient funds to purchase those mining pits.

Another potential water management solution is to work collaboratively with private developers to create storage beyond the volumes currently required to meet regulatory water management requirements. These private-public partnerships have the potential to achieve restoration goals at significant savings.

Maximizing storage within the purview of hydroperiod and depth ranges that are protective of natural areas can be achieved with future proposed projects such as those in the Lee County Master Plan by incorporating operable gates and other surface water management control features.

2. Green Infrastructure – Restoring Wetland Hydroperiods in Existing Wetlands

Where existing natural areas have wetland hydroperiods less than optimum, infrastructure could be added to enhance wetland hydroperiods that would have added benefits to holding more water on land while reducing downstream flooding. There are already examples of this such as the Corkscrew Mitigation Bank north of Corkscrew Road (4 miles east of Alico Road intersection with Corkscrew Road). The outflow gates at this location shown in Figure 14 could be modified to have automatic gate operations and additional outflow structures could be added to increase conveyance to lower water levels in advance of major flooding events and then operate the gates to maximize attenuation of peak flows during the flood. Gate operation of this type is common in Lehigh Acres by LA-MSID and could be implemented within the South Lee County area.

Figure 14. Corkscrew Mitigation Bank Outfall, August 8, 2019

Figure 15 presents possible locations of cross berms that could be constructed across natural wetlands within the South Lee County area that could be used to restore wetland hydroperiods and attenuate peak flows. The proposed cross berms would have gated weir structures to manage water levels upstream of the berms to achieve both flood mitigation and hydroperiod restoration. Cross berms in locations where wetland hydroperiods are most severely impacted would have the highest priority, and the details associated with the design should be closely coordinated between wetlands scientists, hydrologists, and design engineers. Potential alignments for these berms could be along existing ATV trails that have lower elevations than surrounding lands. These berms could also be used to enhance recreational access to these existing natural public lands that currently have poor access.

There are existing roads that currently cross large wetland systems where flows are routed under the roads via open culverts. Gated culverts with upstream risers should be considered for those roads where the upstream wetlands are below optimum hydroperiod. The road along the Green Meadows wellfield alignment is one example of where this approach might be feasible. Another location is the north section of the Bird Rookery hiking trail that is adjacent to the southern end of Corkscrew Swamp Sanctuary (CSS). Prior studies have documented reduced wetland hydroperiods in CSS, and improvements to these structures has already been recommended and studies are underway to further evaluate the benefits of hydrological improvements at the south end of CSS.

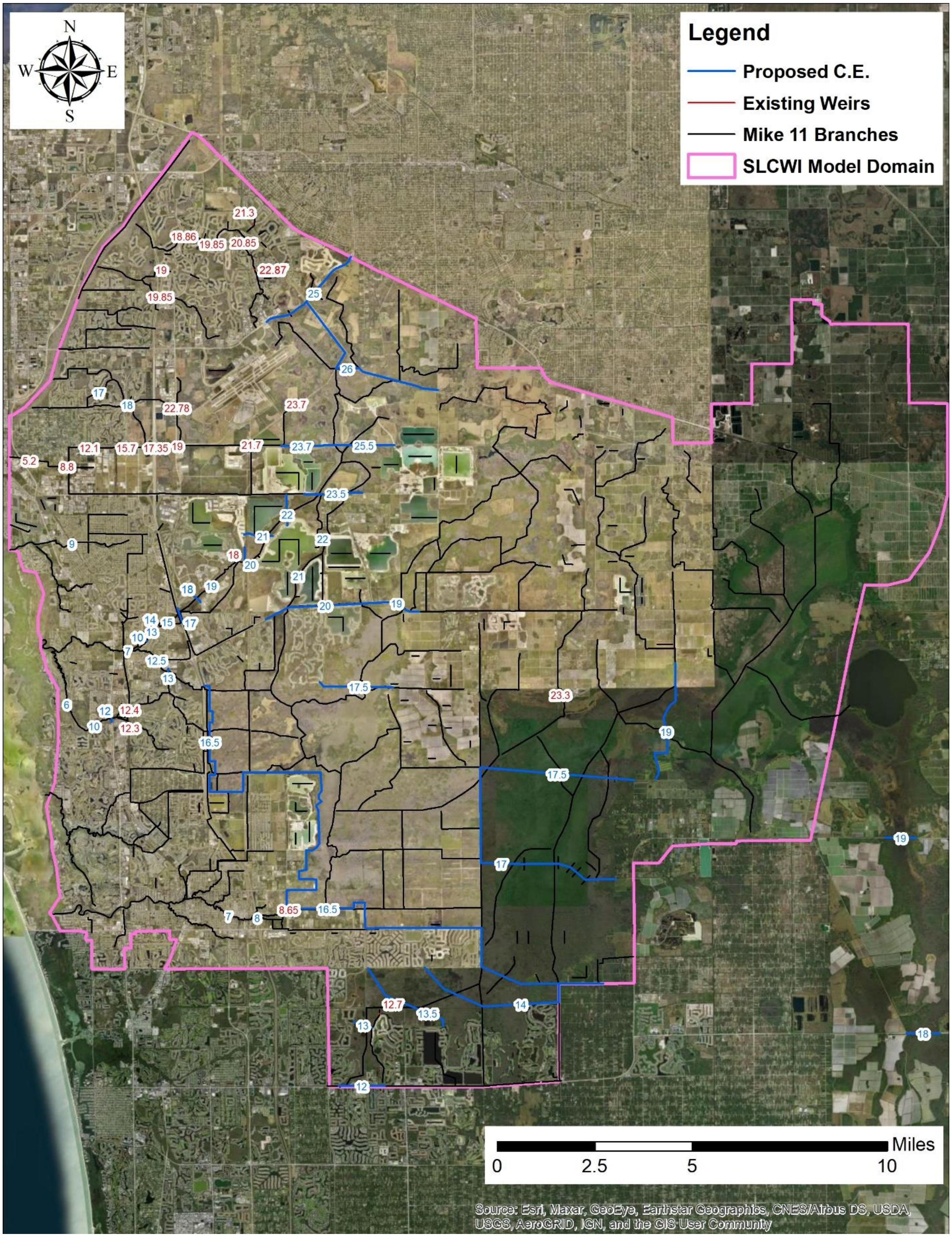


Figure 15. Potential Locations of Cross Berms to Restore Wetland Hydroperiods and Attenuate Peak Flood Flows

Recommended Future Modeling

1. MIKE SHE Modeling as a Living Tool

A very comprehensive surface and groundwater integrated model of the South Lee County Watershed has been developed in this study by incorporating updated available information with spatial resolution higher than the earlier models of the watershed formulated in 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 enhance flood protection and natural resource functions of the region. This developed model will need to be treated as a living model with frequent periodic updates and verifications to be consistent with changes in land and water use features of the watershed.

This model could be used in parallel with more detailed studies of the higher-priority projects recommended in the Lee County Flood Mitigation Plan. Evaluation of wetland hydroperiod impacts of proposed projects will aid in the final design of the proposed flood mitigation projects, and this type of evaluation can be used to facilitate the project review during the environmental permitting process.

Additional climate change simulations may be appropriate once there is greater certainty in predictions of how rainfall will change in the future due to climate change.

Conclusion

The outcomes of this modeling effort and report support objectives set forth by Coastal & Heartland National Estuary Partnership and members of the South Lee County Watershed Initiative to restore appropriate freshwater flow across the landscape to sustain healthy wetlands, rivers, and estuaries and to provide adequate aquifer recharge and freshwater volume and timing of flow to support healthy natural systems as well as to moderate flooding events. The modeling tool examined both dry and wet season water levels, flows, and needs in order to fill data gaps and bridge the various modeling efforts in the area to build a regional watershed-scaled picture.

Results will be useful to resource management agencies in the area to guide appropriate restoration and management of surface waters currently flowing from the South Lee County Watershed. Our strategy was to create a data-driven integrated surface/groundwater model and watershed planning tool to better understand the hydrology in the system help identify restoration projects that would protect and restore natural flow regimes and provide sufficient fresh surface water and groundwater to natural systems. This project also accounts for factors that would inform likely future conditions in the region such as infrastructure projects, additional development, and climate change.

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