C-139 REGIONAL FEASIBILITY STUDY SUMMARY REPORT AND PROJECT WORK PLAN (FINAL)

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

APPENDIX A **(Section 2 - Existing Data Collection Review)**

A1 C-139 Cross-Sections
A2 C-139 Additional Cross-Sections
A3 Compartment C Topographic Survey
A4 Feeder and L-28 Basins Cross-Sections
A5 L-3 Canal & STA 5 Spreader Canals – As Built Survey
A6 Farm Scale Permit Information

APPENDIX B **(Section 3 - Field Data)**

B1 Specific Purpose Survey
B2 Electronic Files of Existing Topographic Information
B3 Soil Boring Logs
B4 Groundwater and Surface Water level Monitoring Wells Photographs
B5 As-Built Groundwater and Surface Water level Monitoring Wells
B6 Generalized Lithological Cross Section
B7 Slough Test Calculation Files
B8 Electronic Files of Groundwater and Surface Water Level Data

APPENDIX C **(Section 4.2 - Calibration and Validation)**

C1 Procedure for Adding Farm-Level Above-Ground Impoundments to the Model
C2 Operational protocols for C-139 Region Structures
C3 Maximum Permitted Irrigation Information from Hope Radin, SFWMD
C4 Daily Surface Water Calibration Plots
C5 Daily Groundwater Calibration Plots
C6 Daily Surface Water Validation Plots
C7 Daily Groundwater Validation Plots
C8 50 Percent Model Calibration Status Brief Memorandum
C9 MIKE SHE Model Input Files
C10 Calibration Model Run Results
C11 Validation Model Run Results

APPENDIX D **(Section 4.3 - Modeling)**

D1 Long Term Run Model
D2 Water Quality Data
D3 Additional Information per SFWMD Review Team Comments to Calibration and Validation Report
D4 Water Budget Tables

APPENDIX E **District Review Team (DRT) Comments and Responses**

E1 DRT Comments and Responses for Data Collection Review
E2 DRT Comments and Responses for Field Data
E3 DRT Comments and Responses for Model Set-up
E4 DRT Comments and Responses for Calibration and Validation
E5 DRT Comments and Responses for Modeling

EXECUTIVE SUMMARY

Introduction

For the purpose of this Study, the "C-139 Region" is defined to consist of the "C-139", the "Feeder Canal" and the "L-28" drainage basins. The region is located west of the Everglades Agriculture Area (EAA), south of the S-4/Industrial Canal drainage basin and northwest of the Everglades Protection Area (EPA). The region comprises approximately 266,000 acres with the primary land use classified as agriculture.

Two major water resource challenges for this region are: 1) water quality of discharges to downstream waters and 2) balancing annual climate patterns with flood, natural resources (wetlands) protection and water availability. Increases in phosphorus load from the subject basins have been identified and are of primary concern due to the potential downstream environmental impacts and related legislative mandates of the Everglades Forever Act (EFA). Recent and projected changes in the regional water resource management infrastructure have contributed to the need for a regional assessment of how existing or supplemental projects, operations, or alternative efforts could be implemented to optimize the overall effectiveness of the system with respect to water quality, flood control and water supply.

The Scope of Work for the "C-139 Regional Feasibility Study of Water Resource and Protection Project" (C-139 RFS) is divided into two Phases.

Phase I consisted of data collection, development of a modeling framework to evaluate hydrology, hydraulics, and water quality for the study area, definition of alternatives to improvement management of the region, and recommendations for additional data collection and modeling activities. A project work plan for Phase II is also included in this Final Summary report.

Phase II will include additional data collection, refinement of the modeling tools, and use of the model to evaluate alternative efforts to improve basin management.

The purpose of this Final Summary Report is to provide the results of the different tasks conducted in Phase I are presented in this report. This Executive Summary provides a brief overview of the tasks conducted as part of Phase I.

Data Review and Atlas of Available Information

There is a significant amount of available hydrologic, hydraulic, and water quality data within the Study region. Several of the infrastructure improvements recommended in the reviewed documents are likely to not be operational in the next 5 years, and accordingly it will be important to coordinate with stakeholders to determine how these proposed improvements affect the assumptions of the existing and proposed conditions for the simulations of Phase II.

The data review supports that there is sufficient historical and operational data to develop and calibrate the surface water components of the selected model. The stage and flow monitoring network is mostly limited to primary drainage features and includes limited records of secondary and tertiary drainage networks; however, considering the regional focus of the Study, this concern should not be considered a constraint. The data review of surface water quality records demonstrates that the monitoring sites include secondary and tertiary drainage locations; however, in many of these locations, the sampling protocol is weekly grab sampling. Therefore, the water quality effort was focused on the primary drainage features such as the basin outfall structures.

The atlas section illustrates the information available at the time that the data collection effort was completed. There are components of the hydrologic and hydraulic characteristics that will be mapped or refined as the study progresses. An example of this additional refinement are the surface water flow and stage recording stations that were installed recently by the District as part of the C-139 Basin management initiatives and continued to provide excellent data that will be valuable for calibration during the Phase II effort. At the close of the overall project the atlas documentation will be re-visited and re-created based on new and modified data.

Data Gap Work Plan

Since there is some data available for topography, canal cross-sections, surface water and ground water, it is possible to provide a coarsely calibrated model without any additional data. However, in order to minimize potential errors introduced by known parameters, data collection efforts were recommended at the beginning of the Phase I effort. The table below presents a summary of the proposed data collection plan for Phase I including the timeline describing at what Phase of the proposed work the data would be most useful.

Data Collection Plan Summary for Phase I

ITEM	DATA TO BE COLLECTED	QUANTITY	PHASE OF WORK (when most useful)
1	Topography: Spot surveys to Validate the DEM	One (1) Set of Spot Measurements at Each Basin	Model Development and Calibration
2	Surveys of Canal Cross-Sections	Eleven (11) Canal Cross Sections.	Model Development and Calibration
3	Groundwater Monitoring (Well Installation)	Nine (9) Nested Wells (Lower Tamiami and Surficial Wells).	Model Development and Calibration
	Groundwater Monitoring (Well Data Recording)		Proposed Selected Project Design
4	Surface Water Monitoring	Flow entering Seminole Reservation (Six (6) Surveys at Canal connecting G409 & CR833)	Model Development and Calibration
		Installation & Monitoring of One (1) Staff Gauge per Basin (at Wetlands)	Proposed Selected Project Design

Model Selection

The primary objective of the model selection was to select a model or combination of models capable of incorporating the basin-scale hydrologic, hydraulic, groundwater, permitted farm-scale surface water, consumptive use practices of individual land-owners and water quality components of the Region.

Previous modeling experience for the basin indicates that interactions between the surface water system and groundwater systems are important. Therefore, the selected models should employ an interactive surface water/groundwater analysis to represent the hydrology and hydraulics of the region.

In order to provide perspective for the qualification of selected modeling tools, it was important to identify categories of potential alternatives for evaluation. Based on previous efforts in the Region and throughout the District, there are several conceptual categories of potential alternatives that were identified, such as:

1. Storage in above-ground impoundments
2. Storage and treatment in above-ground impoundments
3. Evaluation of S-4 diversion alternatives
4. Diversion of runoff through infrastructure changes
5. Diversion of runoff through operational changes
6. Reduction in withdrawals from the Lower Tamiami Aquifer
7. Re-use of stormwater from internal surface water management systems for irrigation
8. Use of surface water from the regional canal system for irrigation
9. Alternative water storage
10. Alternative treatment technologies

Based on the analysis performed during this model selection exercise, it was decided that the MIKE SHE/MIKE 11 model would provide the most comprehensive detailing of a fully integrated surface water and ground water interaction analysis for the C-139 Region. The model will be open-ended such that it can continue to be refined as additional data is received during later phases of the project. Due to concerns over the quality of existing water quality data, a limited water quality model was proposed for the basin study. The recommended option proposes a post-processing spreadsheet analysis of available water quality data. The post processing spreadsheet analysis can be used to provide conceptual level evaluations of Basin-scale water supply and nutrient retention alternatives at an annual resolution. This post-processing analysis would not provide enough detail to evaluate proposed alternatives on an inter-annual or farm-level scale.

Field Data

The objective of the field data collection was to gather the information necessary to fill the gaps identified in the Data Gap Work Plan. The data collection exercise for ground water elevations will be conducted over a sufficient period of time to accurately reflect the area's conditions throughout at least one wet/dry season cycle. Data will continue to be collected in subsequent design phases. Other types of data might also be defined and collected based on alternatives/scenarios selected if necessary. The data collected will help to further refine the open-ended baseline regional model during the evaluation of project alternatives.

Model Set-Up

The purpose of the model set-up section was to present the parameterization that was established for the selected MIKE SHE/MIKE 11 model and its boundary conditions prior to calibration. This includes the definition of the model domain, model input (topography, precipitation and potential evapotranspiration (PET)), land use (vegetation, soils), overland-groundwater leakage, separated flow areas, saturated zone, surface water, irrigation command areas, and calibration and validation period.

Calibration and Validation

The purpose of calibration and validation was to present the updates to the parameterization for the selected model and its boundary conditions, and the calibration and validation results. The model was calibrated for calendar years 2004-2006 and was validated for calendar years 2007-2008. The calibration period was generally wet and the validation period included a major drought followed by significant rainfall at the end of 2008.

There were numerous challenges that were overcome during the calibration, however some challenges remain. A summary of the main successes and challenges are presented as follows:

Calibration

The model was able to represent both peak wet season stages and dry season low stages for 2004 and 2006 in the L-1 Canal at G-136 HW, L-2 Canal at G-150 HW, G155, and PC-17A HW. The simulated stages at the headwater side of STA-5 (G342AB HW) were generally good, however simulated stages were less than measured stages during the early part of 2005. All of the surface water stage stations have a satisfactory level of model performance.

The flow calibration was very good. Six out of seven of the flow stations have a high level of calibration performance for correlation coefficient. Nash-Sutcliff performance is either high or good for all seven flow stations. However, gate operations for G-135 and G-136 were a particular challenge. More information will be required to improve calibration in the L-1 Basin, such as a better definition of the decision-making process for opening and closing gates, the degree of leakage at the gates, and more accurate records of gate levels. In spite of these challenges, the predicted flow for G-136 is reasonably similar to measured flows.

Cumulative flow statistics were calculated for the major discharge locations in the study area. The cumulative flow error for the C-139 Basin is 11%. Cumulative flow error is highest for G-135, G-136, and S-140. In addition to the challenges in the L-1 Basin discussed above, there are information gaps for the Seminole Tribe of Florida Big Cypress Reservation. The data gaps include a lack of surveyed cross sections for many canals, unknown operational protocols of hydraulic control structures for canals east of the North Feeder Canal, and unknown culvert dimensions for Snake Road culverts. Additionally, one of the canals east of Snake Road was cleaned during the calibration/validation period, which changed the drainage efficiency for lands east of the North Feeder Canal. These information gaps limited the ability of the modeling team to completely understand the hydrology and hydraulics of the L-28 and Feeder Canal Basins.

The groundwater model performance is either medium or high for most stations and is either medium or high for all metrics for wells HE-854, 856, 855 and 861.

A comparison of the model performance of the MIKE SHE/MIKE 11 model to the West Coast MODFLOW model was conducted. The MIKE SHE model performs better than the MODFLOW model for 9 of 11 stations for Mean Error. Only one of 11 stations for the MIKE SHE model has a lower Standard Deviation than the MODFLOW model.

Validation

The validation surface water flow statistics are equal to or superior to the calibration statistics. Stage statistics are not as good. Per District request, the pasture irrigation was removed from the input files after completion of calibration and validation activities. Because irrigation rates were generally higher in recent years due to the conversion of pasture lands to crop lands, it is believed that the impact of removing irrigation from pasture lands had a greater effect on the validation period than for the calibration period. It is interesting to note that simulated stages for the validation model generally match measured stages with an offset. Therefore, correlation statistical performance for surface water stage is actually better for the validation model, however stage validation metrics show poorer performance than calibration metrics. This substantiates the hypothesis that the change in irrigation affected simulated stages. This issue will be explored further in Phase II. The model does an excellent job of predicting C-139 Basin flow to the STA-5 complex during both the calibration and validation period.

The statistical performance of groundwater stations for the validation model is slightly worse for most performance metrics, and slightly better for correlation coefficient r than the calibration statistics. As with the surface water calibration, the late change in the irrigation routine is believed to be a factor in the decreased level of performance for the validation period.

Modeling

A baseline simulation was conducted utilizing existing land-uses for a 41-year period of record (1965 to 2005) or "Long Term Baseline". Based on the Model Selection exercise, a parallel task provided a simple spreadsheet water quality assessment tool to evaluate water quality responses for the water management alternatives. Twenty one (21) watershed management alternatives were formulated.

Long Term Baseline

The long-term baseline model represents the response of the watershed for existing conditions (2010) to a rainfall time series from 1965 to 2005. Because the existing conditions hydraulic control structures and land use conditions were assumed to be constant or operating for the entire simulation period, this baseline model does not represent measured actual conditions. It provides an estimate of the range of flows and stages that might be observed if the existing system was constant for a 41-year period.

An analysis was conducted of subsets of the 1965-2005 period determined that shorter simulation period can yield results that are similar to the 1965-2005 simulation. Using a shorter simulation period (11 years) rather than the 41 year period would save 132 hours of computer run time.

Water Quality

The Total Phosphorus (TP) load post-processing spreadsheet analysis was performed by establishing Event Mean Concentrations (EMCs) for the MIKE SHE/MIKE 11 land uses. The results of the post-processing spreadsheet analysis for the C-139 RFS are in agreement with the measured data in a basin level. When comparing alternatives the flows used will be the same for the four alternatives. This will eliminate the TP concentration variability associated with the different flows. This method will also be able to differentiate between the alternative formulations based on land use changes due to each of the alternatives and water quality treatment method. Possible attenuation factors can be included for each of the specific alternatives.

Potential Alternatives

Twenty one (21) watershed management alternatives were formulated based on:

- a review of measured water level, flow, and water quality data,
- a review of results from the initial calibrated/validated model, and
- discussions with both SFWMD staff and farming consultants.

A screening tool will be developed as part of a separate task to streamline the twenty one (21) alternatives to four (4) alternatives. The four (4) preferred alternatives can be any one of the twenty one (21) alternatives or a combination or two or more, any one of which may be modified based on further discussions.

Conclusions

The findings of the model selection task recommend the development of a comprehensive interactive surface water/groundwater model. Data gaps in the topography needed for conceptual level modeling were overcome as part of the model development portion of Phase I by collecting additional cross sections and spot elevations as indicated in the Data Gap Plan. Groundwater data was collected throughout the project and will continue during Phase II. Land-use management and consumptive use due to irrigation demand was represented in the model using modifications to the built-in parameterization schemes based on land-use type, permit documentation, and field research.

The primary objective of the Phase II modeling effort will be to evaluate potential strategies for resolving the water resources challenges in the Region. In order to identify suitable model candidates, the Model Selection technical memorandum also reviewed a conceptual list of potential project alternatives. By developing baseline and alternative scenario simulations of the final calibrated model, comparative analyses of the benefits of each proposed alternative in Phase II can be provided. This will allow for decision support to stakeholders and policymakers.

The final calibrated model developed under Phase I is expected to be reasonably capable of representing the hydrology of the region despite the known limitations described above. Under Phase II, the model is expected to be sufficient for providing comparative evaluations of several proposed alternatives, Additional data from the field, and continued refinement of the base models further during Phase II will help improve the performance of the model.

1 INTRODUCTION AND PURPOSE

1.1 INTRODUCTION

For the purpose of this Study, the "C-139 Region" will be defined to consist of the "C-139" drainage basin, the "Feeder Canal" drainage basin, and the "L-28" drainage basin. This region is located west of the Everglades Agriculture Area (EAA), south of the S4/Industrial Canal drainage basin, and northwest of the Everglades Protection Area (EPA) (see ***Figure 1.1.1***). The region comprises approximately 266,000 acres with the primary land use classified as agriculture. It is readily conceivable that this agricultural activity will continue at current levels or increase over time.

Two major water resource challenges facing this region relate to: 1) Water quality of discharges to downstream waters and 2) Balancing annual climate patterns with flood, natural resources (wetlands) protection and water availability. Notable increases in phosphorus load from the subject basins have been identified and are of primary concern due to the potential downstream environmental impacts and related legislative mandates of the Everglades Forever Act (EFA). The 2010 South Florida Environmental Report indicated that the C-139 Basin Total Phosphorous (TP) average observed load from 2003 through 2009 was 54 metric tons, 31 metric tons higher than the average target TP load. The observed load exceeded the measured load from 2003 through 2007 and 2009, but was less than the target TP load in 2008. The Feeder Canal Basin loads are also higher than desired loads to the EPA.

In general, the phosphorus leaving the basin results from rainfall generated runoff. Much of the annual flow coming out of the region occurs in a relatively short period of time – approximately four consecutive months of every year (typically, July through October). In addition, some quantity of water is brought into the region from below ground via water supply wells. There appears to be a significant opportunity for this groundwater to interact with the regional soils, become phosphorus laden, and to flow out of the basin, thus contributing to the phosphorus load leaving the basin. These aspects of water utilization within the region may afford significant opportunities for "tailwater recovery" conservation projects, water reuse and the development of regional storage.

The potential for the development of local retention/storage has the double benefit of treating runoff water and also capturing and reusing runoff water, thereby reducing phosphorus loads leaving the study area. Preliminary data suggests that increasing the "Best Management Practices (BMP) effort", required of the regional landowners, may not be sufficient by itself, to improve the water quality enough for the region to meet water quality goals and/or mandates.

Recent and projected changes in the regional water resource management infra-structure (e.g. construction of STAs 5 and 6, implementation of on-farm BMPs, planned re-routing of the C-139 Annex runoff from WCA 3A into STA-6, construction of stormwater treatment facilities in the Feeder Canal Basin, the Big Cypress Seminole Indian Western

Water Conservation Restoration Project currently under construction, etc.) have contributed to the need for a regional assessment of the C-139 Region. The assessment will evaluate how existing or supplemental projects, operations, or alternative efforts could be implemented to optimize the overall effectiveness of the system with respect to water quality, flood control and water supply.

In addition to the above aspects of the region, The S-4 Basin Feasibility Study prepared by Burns & McDonnell, 2008 describes six different possible S-4 flow diversion alternatives to offset C-139 Region water availability challenges. One alternative is to re-route a portion of the water from the adjacent S-4 Basin/Industrial Canal Basin, which is located immediately north of the three subject basins. Re-routing of a portion of the S-4 Basin/Industrial Canal Basin runoff towards the south and the three subject basins, is anticipated to provide a benefit to both Lake Okeechobee and the Caloosahatchee River Tributary. The re-routing of water south may help alleviate potential water supply issues for the region; however, the impact of adding additional inflow phosphorus load to the region must be evaluated and considered. Depending on a number of related planning activities, it is likely that one of the alternatives to be modeled in Phase II evaluates the potential of the possible inflows from the S-4 Basin.

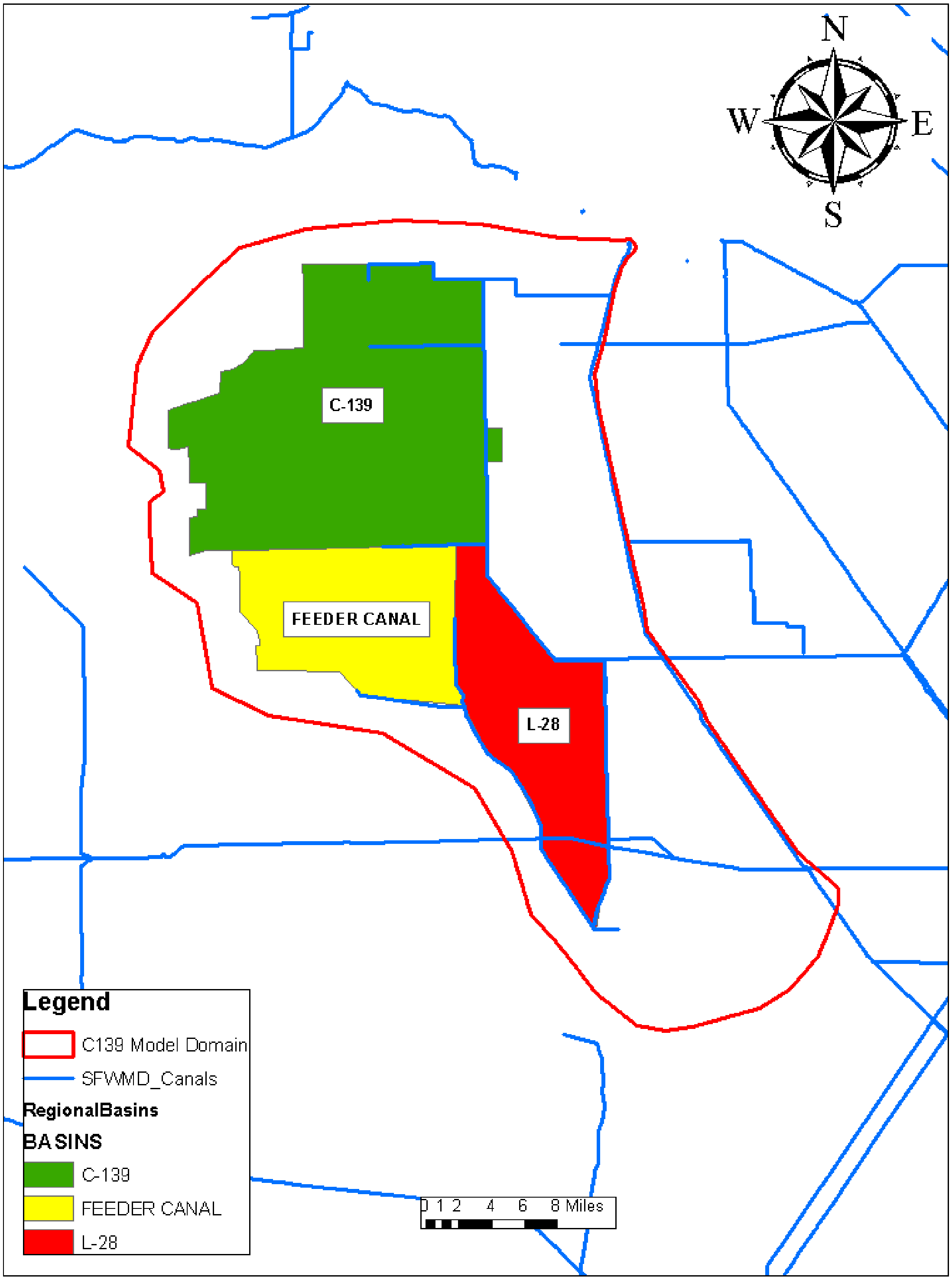


Figure 1.1.1 - Regional Study Location Map

There are two phases to the C-139 Regional Feasibility Study:

- Phase I: Data Collection, development of a modeling framework to evaluate hydrology, hydraulics, and water quality for the study area, definition of alternative efforts to improvement management of the region, and recommendations for additional data collection and modeling activities.

- Phase II: Additional data collection, refinement of the modeling tools, and use of the model to evaluate alternative efforts to improve basin management.

Tasks of Phase I completed in 2008 include:
- Desktop data collection
- Atlas of existing information
- Model selection memorandum
- Data collection plan.

Tasks of Phase I conducted in 2009-2010 include:
- Field data collection including:
    - Surveying of new cross sections and spot elevations
    - New well installation
- Model set-up
- Model calibration and validation
- Simulation of baseline conditions using rainfall from 1965-2000
- Water quality post-processing spreadsheet analysis
- Description of 21 potential alternatives for potential evaluation in Phase II

This Final Summary Report and Project Work Plan compiles the documents generated in Phase I of the C-139 Regional Feasibility Study. The project work plan for Phase II is also be included in this Final Summary Report and Project Work Plan. This Project Work Plan includes recommendations as to the activities to be conducted in Phase II for the continued use of the open-ended baseline model, and field data monitoring activities.

The District Review Team (DRT) comments and responses for all documents generated in Phase I Tasks 2, 3 and 4 are included in ***Appendix E***.

1.2 PURPOSE

The goal of this project is to develop a baseline model that characterizes the study area hydrology, water supply, and water quality. Based on analysis performed during the Model Selection exercise in Task 2 it was decided that the MIKE SHE/MIKE 11 model would provide the most comprehensive detailing of a fully integrated surface water and groundwater interaction analysis for the C-139 Region. The model will be open-ended such that it can continue to be refined as additional data is received during later phases of the project. The specific objectives of the model are listed below:

- Provide a better understanding of interactions between the surficial aquifer and the Lower Tamiami aquifer, which is a major source of irrigation water to agricultural operations.
- Provide a better understanding of hydrologic interactions between the C-139 Region and lands to the west.
- Provide a model that can simulate the flows and water levels in the C-139 Basin with greater accuracy than prior modeling efforts using WAM and HEC-HMS/MIKE 11 (ADA 2007, URS/ADA 2008).
- Provide a model with sufficient hydraulic capability to evaluate both dry and wet season responses to a range of alternative projects and/or water resource optimization strategies, including but not limited to:
    - Importing water from the S-4 basin and delivery of that water to any of the watersheds within the C-139 Region.
    - Detention of stormwater runoff in either regional or multiple agricultural reservoirs.
    - Incorporating some form of irrigation withdrawals from surface water sources to reduce groundwater abstractions and to reduce nutrient loads to STA-5 and STA-6.
- Determine the influence of groundwater withdrawals on surface water hydrology in adjacent basins.

The baseline model will be utilized in Phase II to evaluate various regional operational and infrastructural alternatives such that the region's water supply and quality goals are met. A parallel task provided a simple water quality spreadsheet assessment tool to evaluate the water quality for the baseline condition once the water flows were established for the baseline condition. Reduction of nutrient discharges to the Everglades Protection Area is a key objective of both this hydrologic/hydraulic modeling study and the related water quality modeling effort.

1.3 WORK AUTHORIZATIONS

Authorization for preparation of this Final Summary Report and Project Work Plan was provided as Work Order No. 4600000895-WO02 Revision 1, **Task 5.1.3 – Final Summary Report and Project Work Plan**, from the District General Engineering Services – Full Services, to URS Corporation with Notice to Proceed (NTP) dated May 21, 2009.

2 EXISTING DATA COLLECTION REVIEW

2.1 EXISTING REPORTS AND DATA

2.1.1 INTRODUCTION

The purpose of this existing reports and data reviews is to compile and summarize all pertinent data and previous project information available for this region. Identified herein are available documents or other published information which may serve future Phases of the Regional Feasibility Study. In addition to a review of available documents, this section includes a review of available hydrologic, hydraulic and water quality data for the region as well as a field data collection plan to identify surface water and ground water wells/structures, current drainage configuration, measure flow volumes, document canal characteristics, and other relevant information needed to complete future tasks.

2.1.2 DOCUMENT REVIEW

An extensive review of available studies and technical reports has been conducted throughout the Study region as part of this document review. The content of these reports has been summarized in ***Table 2.1.1*** with a description of the scope, recommendations and application to the C-139 Regional Feasibility Study of each technical report reviewed.

Table 2.1.1 - Summary of Reviewed Documents

Item	Document	Document Scope	Recommendations	Application to Study
1	Western Basins Environmental Assessment (Mock-Roos, 1991-1992)	Study of drainage, land-use, water quality, pollutant assimilation capacity and wetland quality for the entire western basins (C-139, the Feeder Canal and L-28 Interceptor Canal).	-SFWMD should continue monitoring rainfall, canal stages and flows at the existing monitoring locations on a daily basis and consider adding more monitoring stations (in the Feeder Canal Basin). The L-28 Canal and Deer Fence Canal should be surveyed for cross-sections.	The Western Basin Environmental Assessment Project provided the first complete drainage analysis of the C-139, L-28 and Feeder Canal Basins combining basin hydrology and channel hydraulics into models and comparing results with recorded information.
2	Water Quality Assessment for the C-139, L-28 Interceptor, Feeder Canal and L-28 Gap Basins (E&E, 1992)	Results of quarterly and synoptic water quality sampling performed from 1990 until 1992.	-In situ and laboratory analysis methodology should be well documented. -Sampling and analysis programs should benefit from Quality Assurance Plans developed in accordance with Chapter 17-160, F.A.C. -Locations of sample sites should be periodically reviewed. Control of flows, particularly during dry season months, by the District and private land owners should be documented and referenced to all water quality data and modeling. -The spraying of canals to control macrophytes should be documented.	-Provides reference water quality measurements for use in model development and calibration. -Provides procedural recommendations for any potential additional water quality monitoring performed as part of this project.
3	Everglades Protection Project Conceptual Design (Burns & McDonnell, 1994)	Technical plan for the Everglades Construction Project Stormwater Treatment Areas.	-Basic configurations of STA 5 and STA 6 were defined and peak design flow capacities were recommended. -An inflow pump station to STA 5 in L-2/L-3 at Deer Fence Canal was recommended.	-Relevant information from this study was used in developing hydraulic models for the final design of STA 5 and STA 6. -Provides a reference for the conditions of the L-2, L-3 and Deer Fence Canals at the time of publication.

Item	Document	Document Scope	Recommendations	Application to Study
4	Big Cypress Seminole Indian Western Water Conservation Restoration Project (Burns & McDonnell, 1995)	Report outlining two phases of water resources projects in the Big Cypress Seminole Indian Reservation. Phase I includes canal improvements to provide conveyance of water supply entitlement, and Phase II includes both internal impoundments (Water Resource Areas (WRAs), Stormwater Cells (SCs), and Irrigation Cells (ICs)) and conveyance to the south (Siphons under the West Feeder Canal).	-Phase I construction nearing completion at the time of report publication. -Divides the Reservation into 4 Basins. -Recommends construction of 2 WRAs, 6 ICs, and 1 siphon in Basin 1. -Recommends construction of 2 WRAs, 3 ICs, and 1 siphon in Basin 2. -Recommends construction of 1 WRA, 1 IC, and 1 siphon in Basin 3. -Recommends construction of 1 WRA and 1 SC in Basin 4.	-Provides detailed information about existing and proposed internal hydraulics of the Big Cypress Seminole Indian Reservation.
5	ECP General Design Memo for STA 5/6 (Burns & McDonnell, 1996)	Preliminary designs for STA-5, STA-6, and hydroperiod restoration work within the Rotenberger Tract and WCA 3A	-Provides detailed information on the inflow and outflow structures for STA 5/6 and flow deliveries to the Rotenberger Tract and WCA-3A. -STA 5 inflow pump station was eliminated from the Conceptual design and G-406 was added along with inflow gates G-342A-D.	-Findings of this study were used in the EAA Regional Feasibility Study and the Compartment C design.
6	General Design Memorandum (GDM) for STA-5, STA-6, Rotenberger Tract Restoration, and West WCA Hydropattern Restoration (Burns & McDonnell, 1996)	Preliminary designs for STA-5, STA-6, and hydroperiod restoration work within the Rotenberger Tract and WCA 3A	-Aspects of the Conceptual Design were modified based on multi-agency coordination. -Design was modified to accommodate higher flows and loads from the C-139 Basin. -Design was modified to accommodate diversion of USSC Ranch 1 to the current location of Compartment C. -Design was modified to account for reduction in the treatment efficiency of the western 25% of STA5 (to account for the use of gravity inflow structures instead of pumps).	-Provides insight into the downstream boundaries of the Study Region (STA5, STA6, Rotenberger Tract, and West WCA). -Describes the multi-agency coordination and comments in deriving the final general design memorandum.

Item	Document	Document Scope	Recommendations	Application to Study
7	Final Design Report for STA-5, STA-5 Discharge Canal and STA-5 Outlet Canal (Burns & McDonnell, 1997)	Refinement of the original General Design Report and the subsequent Detailed Design Report	-Based on the topography of the site and budgetary considerations at the time, the final design was modified from the GDM. -Recommended an intermediate N-S levee dividing both Cell 1 and Cell 2 to fully utilize the available treatment area. - Recommended more C-139 runoff would be diverted to STA5, due to a delay in the construction of STA6 and increased capacity in STA5.	-Provides insight into the downstream boundaries of the Study Region (STA5, STA6, Rotenberger Tract, and West WCA). -Describes the modifications to the original GDM.
8	Determination of the Seminole Big Cypress Reservation Entitlement Amount (SFWMD, 1998)	Memorandum providing statistical analysis, water budget analysis and modeling simulations of historic flows to determine water supply entitlement.	-Entitlement for the Big Cypress Reservation is 47,000 acre-feet per year distributed as twelve equal monthly amounts of 3,917 acre-feet.	-Provides an example of estimating and quantifying the "water availability" for the Big Cypress Seminole Reservation using C-139 hydrologic data. -Serves as the technical basis for the legal entitlement of the Seminole Big Cypress Reservation. -None of the water quality improvement alternatives evaluated will be viable if they negatively impact the availability or delivery of the specified entitlement amount.
9	STA-5 Assessment of Operational Impacts (Burns & McDonnell, 1999)	Description of potential flooding impacts, gage validation, and evaluation of operations for STA-5.	-Identified two operational conditions of the L-2/L-3 Canal System (G-406): Temporary and Long-Term. -Under Temporary operational conditions there were potential impacts to flood protection along the western bank of the L-2/L-3 Canals. -Under Temporary operational conditions there were potential impacts to flood protection west of CR 846. -Recommended close monitoring of stage-discharge relationship of the STA. -Recommended a slightly lower "trigger" elevation for G-406. -Recommended a flowage easement on parcel west of STA5.	-Provides an example of analysis of impacts to flood protection in the C-139 Basin. -Illustrates the logic behind current regional operations.

Item	Document	Document Scope	Recommendations	Application to Study
10	Western Boundary Flows at the L-1 and L-3 Canals for the Simulation of the ECP Base, ECP Future Base and CERP Update (SFWMD, 2002)	Description of methodologies used to determine the Western Boundary flows at the L-1 and L-3 canals for the SFWMM.	-Updated boundary flows from the SFWMM at the G-136 location and the L-3 canal, to be used for regional model simulations related to the ECP. -Utilized the most up to date runoff data from the C-139 Basin rulemaking process.	-Provides a reference for discharges from the north and south outfall locations of the C-139 Basin.
11	Final Report Basin Specific Feasibility Studies Everglades Stormwater Program Basins (SFWMD, 2002)	As an important step towards development of the Long-Term Compliance Permit application that was required under the Everglades Forever Act, the District completed the Basin-Specific Feasibility Studies for the Everglades Protection Area Tributary Basins. These studies formed the basis for the *Long-Term Plan.*	-The two alternatives presented were to 1) implement source control and complete STA construction by 2006 and 2) implement source control by 2006.	-A basin-wide overview of the Feeder Canal projects and is presented along with illustrations of sub-catchment delineation.
12	Lower West Coast Surficial Aquifer System Model (Marco Water, 2003)	Report documenting a calibrated groundwater flow model (MODFLOW) for the entire Lower West Coast region of Florida, covering a total area of 5,129 square miles. The transient model calibration was conducted for a 15-year period from January 1986 through December 2000.	-Model results are sensitive to canal water level, therefore, efforts to verify the existing canal stages and unknown stages for lower level canals. -A continuation of the calibration process addressing water budgets and structure flow in the LWC area is critical. -Further boundary condition study is needed for the saltwater-freshwater interface (outside of Study region).	The results of the modeling effort and the parameters used to define the hydrogeology represented can be used as a reference in any future groundwater simulations of the region.

Item	Document	Document Scope	Recommendations	Application to Study
13	Everglades Protection Area Tributary Basins Long-Term Plan for Achieving Water Quality Goals (Burns & McDonnell, 2003)	The Long-Term Plan was developed in response to an EFA requirement, and is a comprehensive set of water quality improvement measures designed to ensure that all waters entering the Everglades Protection Area (EPA) achieve compliance with water quality standards.	-Long Term Plan provides framework for meeting water quality goals through expanded source controls, STA enhancements, and integration with CERP. -Three primary components were identified: Pre-2006 Projects, Process Development and Engineering, and Post-2006 Strategy. -Each component is designed to achieve and maintain the water quality goals established.	-Identifies the ECP (C-139) and Non-ECP Basins (Feeder and L-28 Basins). -Describes the coordination of efforts of EFA and CERP projects with respect to the Study region and affected areas.
14	Hydrologic and Hydraulic Design Analysis for the Big Cypress Seminole Indian Reservation Water Conservation Plan Critical Restoration Project (Ardaman & Assoc, 2003)	Hydrologic and hydraulic analysis (CHAN model) of the design parameters for the proposed siphons, irrigation cells, stormwater cells and conveyance structures.	-Lack of recorded storm event data precluded model calibration. -Lack of downstream topographic and hydraulic data limited the conclusiveness of the allowable peak discharge of the siphons under the West Feeder Canal. -Recommended emergency overflow structures for WRAs 1, 2 and 3.	-Provides simulation parameters and results of the proposed internal hydrology and hydraulics of the Big Cypress Seminole Indian Reservation.
15	EAA Regional Feasibility Study (EAARFS) for Period 2010 – 2014 (ADA Engineering, 2005)	The EAARFS evaluated alternatives for optimizing the performance of the STAs, including the STA expansions on Compartments B and C, by re-distributing flows and loads to further assist the existing STAs in improving water quality in the Everglades Protection Area.	-Identified uncertainty in the TP removal effectiveness of STA 5. -Redirection of flows to the A-1 Reservoir and compartments B and C will change the magnitude of discharges to the WCAs. -Overall impacts appear to be minor and are currently being evaluated further.	-Identifies that additional stormwater treatment areas are needed to handle the C-139 Basin. -Uncertainties in the STA 5 assimilative capacity need to be addressed to determine if STA 5 / Compartment C could handle additional EAA runoff.

Item	Document	Document Scope	Recommendations	Application to Study
16	C-139 Basin Phosphorus Water Quality and Hydrology Analysis, Phase I and Phase II (ADA Engineering, 2006-2007)	Report provides data review, model development and alternatives analysis for farm and regional scale water quality improvement projects in the C-139 Basin.	-Phase I includes basin delineations that provide the basis for recommendation of surface water monitoring sites. -Phase II includes the evaluation of 5 regional water quality improvement projects (including variations on adding storage, changing land-use, and diverting runoff). -The WAM simulations were best suited for use at the basin-scale. -Further investigation into the hydrogeologic conditions is recommended. -Additional information pertaining to the operation of un-documented structures or to irrigation demand and water table elevations could improve the calibration of the C-139 WAM simulation.	The basin delineation, data gathering efforts and WAM simulations can be used as a starting point for model parameterization efforts.
17	Everglades Agricultural Area Stormwater Treatment Compartment C Watershed Hydraulic Study (ADA Engineering, 2006)	The report provides a description of the development, calibration and verification of a hydrologic/hydraulic model of the contributing watersheds to Compartment C (C-139 and C-139 Annex).	-Provided analysis of the interim operational condition along with 3 alternative operations. -Alt 2: Modification of G-407A gate opening criteria -Alt 3: Construction of a pump to remove flows from L-3 during periods when peak stages for a given design event exceed existing flood levels -Alt 4: Expansion of L-1, L-2, and L-3 upstream of G-406 -Recommends the implementation of Alternative 3.	-Includes a detailed HEC HMS model of the C-139 Basin. -Includes a detailed hydraulic model (MIKE 11) of the primary drainage system for the C-139 Basin that could be used in future model development efforts. -Provides production simulation hydrographs for selected storm events.

Item	Document	Document Scope	Recommendations	Application to Study
18	WY06 Analysis of C-139 Basin Phosphorus Sources, Transport, Cycling and Export (Community Watershed Fund, 2007)	This report describes CWF's evaluation of WY06 C-139B, C-139D, and C-139 Compliance Points data to assess C-139 Basin phosphorus sources, transport, cycling, and export.	-Monitoring should attempt to all stations within a single day and measure TSS and chlorophyll *a* with phosphorus sampling and should measure flow coincident with sampling of TP, TDP, and SRP. -Monitoring should sample TP, TDP, SRP, TSS, chlorophyll *a*, and Floating Aquatic Vegetation (FAV) during quiescent periods. -Dye tests could be used to evaluate the relative contribution to G342A-D and G406. -L2-01 phosphorus and flow might be simplified by a structure on the L-2 Canal. -Discharge from the canal downstream of the SM05.0TW station and upstream of SM02.2TW02 should be investigated. -Investigate removal or dilution of P upstream of SM02.1TW and SMWeir -Investigate removal or dilution of P upstream of L206.0TW01 . -The sediments should be investigated at L209.1TW01.	-Provides review of available nutrient monitoring in the C-139 Basin. -Provides analysis at the primary, secondary and tertiary drainage scale of nutrient loads in the C-139 Basin.
19	Compartment C Final Design Report (URS, 2008)	Design Report outlining the build-out of additional flow-ways for STA 5 and STA 6, into the remaining 6,395 acres of the Compartment C area. The Compartment C is part of the Long Term Plan (LTP). The purpose of the project is to provide additional EMG and SAV water treatment cells. The Project is located in the southwest corner of Hendry County at the intersection of Palm Beach, Broward, and Hendry County lines.	Final Design documents and drawings for the construction of the Compartment C buildout. The major components for the project are: -Approx. 4,850 ac. of added treatment area in the form of EMG and SAV treatment cells -One 100 cfs Hydration PS (G-509) -New Canals and Levees. -20 New Concrete Box Culverts Control Structures with telemetric controls Other STA 5/6 system components which are not part of this STA Final Design but the IPS design currently in progress are: -One 1,630 cfs Inflow PS (G-508) and Seepage pumps (50 cfs) -Hydraulic connectivity to STAs 5-1 & 5-2 -Inflow Canal Bridge Crossing	-Provides a proposed design for the Compartment C which is the last part of the STA 5/6 system. -Provides the hydrographs for storms including the 5-, 10-, 25-year, and Standard Project Flood (SPF) events. -Presents the maximum flows accepted for each of the flow-ways. -Presents the DMSTA modeling results for the STA 5/6 system.

Item	Document	Document Scope	Recommendations	Application to Study
20	Crook's and Golden Ox Ranches Hydro-geologic Assessment (SFWMD, 2008)	Draft report documenting the findings of a local-scale hydrogeologic study within the C-139 Basin.	-Monitor on-site water levels at least a year after the new reservoirs are completed. -Conduct post-reservoir wetland assessments and compare to pre-reservoir conditions. -Install a rain gauge and surface water staff gauge(s) at each of the seven well locations. -Conduct sieve analyses on cores (site 2 and 7) of the semi-confining unit to quantify vertical hydraulic conductivity between the two aquifers. -Require ground water withdrawals be metered, or specific irrigation schedules from the various farm managers. -Correlation analyses should be performed using daily mean values. -Integrate the hydrograph analyses into the hydrogeologic data and surface water management scheme to determine site specific cause and affect relationships.	-Provides farm scale assessment of impacts to wetlands from ground water withdrawals. -Provides indication of leakance rate between the surficial and the Lower Tamiami Aquifer.
21	S-4 Basin Feasibility Study (Burns & McDonnell, 2008)	Alternatives analysis of diversion of runoff from the S-4 Basin to either the C-139 Basin and STA5 or the S-3/S-8 Basins. Includes XPSWMM modeling and Opinion of Probable Construction Cost (OPCC).	-Detention storage will likely be required to improve the average diversion percentage of the C-139 alternatives to 80 percent or more, however the addition of a storage reservoir would increase the initial capital cost significantly. -Notes that to overcome adverse head conditions, diversions to the C-139 Canal will require a pump station at the G-150 structure. -Additional treatment and/or storage areas would need to be developed within the S-3/S-8 Basin to accommodate these S-4 Basin diversions.	-Quantifies potential flows and loads for diversion from the S-4 Basin to the C-139 Basin. -Identifies conveyance issues in the L-1, L-2 and L-3 Canals.

Item	Document	Document Scope	Recommendations	Application to Study
22	Feeder Canal Basin - Watershed Data Evaluation (BPC Group, 2008)	Compilation of available field collection data and related document review; Statistical analysis of rainfall and flow; and investigation of factors contributing to TP load for the Feeder Canal Basin.	-Developing and implementing a monitoring plan for the entire Basin. -Development of rainfall-runoff computational relationships. -Continuation and expansion of the nutrient monitoring program to establish a longer record of distribution of P speciation / partition. -Study mass balance at smaller than sub-basin level to better define variation of TP.	-Provides most current available analysis of the hydrologic, hydraulic and nutrient runoff conditions of the Feeder Canal Basin.
23	2008 Report on the Long-Term Plan for Achieving Water Quality Goals for the Everglades Protection Area Tributary Basins (CH2M HILL and Gary Goforth, Inc., 2008)	The document provides the first 5-year report on the October 27, 2003 *Everglades Protection Area Tributary Basins, Long-Term Plan for Achieving Water Quality Goals.*	-Provides description of the conditions and the performance of the STAs, the ECP Basins and the Non-ECP Basins. -Summarizes progress achieved in execution of the many activities included in the 2003 Long-Term Plan. -Documents that major increases in STA system footprint have occurred well in advance of original targets. -Documents the conversion of significant portions of the macrophyte-based STAs to SAV systems has been achieved.	-Provides overview of the conditions of the C-139, Feeder Canal and L-28 Basins along with descriptions of potential changes in the future. -Provides description of STA5 and STA6 conditions. -Describes the effects of the major disturbances of the hurricane seasons of 2004 and 2005 followed by the severe drought conditions that have prevailed in the region in 2006, 2007, and much of 2008.

Item	Document	Document Scope	Recommendations	Application to Study
24	Influence of STA-5 Operation on C-139 Basin Load Compliance (Malcolm Pirnie, Gary Goforth Inc., 2008)	This document was prepared to assist the District better understand the influence of STA-5 operations on the hydrology and TP conditions in the C-139 Basin.	-Wet season rainfall has increased by 15% and dry season rainfall has decreased by 27%, compared to WY1980-1989. -A trend of increasing monthly runoff-to-rainfall values began prior to STA-5 operation, and has continued. -C-139 Basin has a trend of increasing agricultural land use that began prior to STA-5 operation. -Water Use permit information indicate a trend of increasing irrigation withdrawal allocations that began prior to STA-5 operation. -A trend of increasing basin-wide TP concentrations began prior to STA-5 operation. -Dry season stages have been held higher since STA-5 began operation. -Flood control level of service has improved since STA-5 has been in operation.	-Provides statistical analyses of hydrologic, hydraulic and water quality metrics of the C-139 Basin prior to and after the construction and operation of STA-5.
25	Regional Everglades Works of the District Permits and Post-Permit Compliance Files (SFWMD)	WOD permits that outline on-farm management practices are available only for the C-139 Basin.	-WOD permits require the selection of BMPs from a weighted menu of: Nutrient Control, Sediment Control, Water Management and Pasture Management practices.	-Provides best available documentation of how individual farms are managed in the C-139 Basin.
26	Regional Environmental Resource Permit and Surface Water Permits (SFWMD)	All pertinent ERP and SW permits that have been approved in the S-4, C-139, Feeder Canal and L-28 Basin.	-ERP permits require documentation on behalf of the land-owner to assure that water supply, flood protection, water quality and wetlands are protected as part of any proposed improvements.	-Provide best available documentation of the water management systems for individual farms throughout the Study region.

2.1.3 DATA REVIEW

In addition to the review of the reports described above an additional review of available environmental data was performed based on various data collection efforts in the region of interest. The environmental monitoring network installed and maintained by the District is supplemented by efforts on behalf of the Florida Department of Environmental Protection (FDEP), United States Geological Survey (USGS) and other stakeholders.

2.1.3.1 Surface Water Stages and Flows

As part of the surface water management infrastructure utilized by the District to maintain levels of service of flood protection and provide water supply to stakeholders, there is a network of surface water monitoring stations in the region that provide data streams that will be used as part of this study. ***Table 2.1.2*** describes the available surface water data from DBHYDRO for the region.

Table 2.1.2 - Summary of Available Surface Water Data

Structure	Flow		US Stage		DS Stage		Gate	
	Start	End	Start	End	Start	End	Start	End
G-88	10/1/1978	Present	9/24/1974	4/10/1996	6/10/1976	4/5/2004	6/25/1974	2/12/2007
G-89	6/20/1975	6/24/2006	6/20/1975	Present	6/20/1975	Present	6/20/1975	Present
G-108	6/29/1999	Present	6/29/1999	Present	6/29/1999	Present	N/A	N/A
G-134	12/31/1986	Present	7/1/1986	Present	12/31/1986	Present	12/31/1986	Present
G-135	12/31/1986	Present	7/1/1986	Present	12/31/1986	Present	12/31/1986	Present
G-136	10/1/1978	Present	4/20/1983	Present	4/20/1983	Present	4/21/1983	Present
G-150	5/31/1997	Present	5/2/1989	Present	5/2/1989	Present	5/2/1989	Present
G-151	5/2/1989	Present	5/2/1989	Present	5/2/1989	Present	5/2/1989	Present
G-152	7/31/1989	Present	7/6/1989	Present	12/31/1989	Present	7/31/1989	Present
G-155	1/1/1978	Present	7/3/1989	4/5/2004	7/3/1989	4/5/2004	7/31/1989	7/31/2007
G-342A	10/1/1999	Present	6/23/1999	Present	6/23/1999	Present	6/23/1999	Present
G-342B	10/1/1999	Present	4/27/1999	Present	4/27/1999	Present	4/27/1999	Present
G-342C	10/1/1999	Present	4/27/1999	Present	4/27/1999	Present	5/19/1999	Present
G-342D	10/1/1999	Present	5/18/1999	Present	5/18/1999	Present	5/19/1999	Present
G-342E	4/24/2008	Present	5/10/2008	Present	5/10/2008	Present	4/24/2008	Present
G-342F	4/24/2008	Present	4/24/2008	Present	4/24/2008	Present	4/24/2008	Present
G-353A	4/17/2008	Present	4/17/2008	Present	4/17/2008	Present	4/17/2008	Present
G-353B	4/17/2008	Present	4/17/2008	Present	4/17/2008	Present	4/17/2008	Present
G-353C	4/17/2008	Present	4/17/2008	Present	4/17/2008	Present	4/17/2008	Present
G-396A	4/17/2008	Present	4/17/2008	Present	4/17/2008	Present	4/17/2008	Present
G-396B	4/17/2008	Present	4/17/2008	Present	4/17/2008	Present	4/17/2008	Present
G-396C	4/17/2008	Present	4/17/2008	Present	4/17/2008	Present	4/17/2008	Present
G-406	6/26/2000	Present	6/3/1999	Present	6/3/1999	Present	6/15/1999	Present

Structure	Flow		US Stage		DS Stage		Gate	
	Start	End	Start	End	Start	End	Start	End
G-407	4/17/2008	Present	4/17/2008	Present	4/17/2008	Present	4/17/2008	Present
G-601	11/30/2008	Present	11/30/2008	Present	11/30/2008	Present	N/A	N/A
G-602	11/30/2008	Present	11/30/2008	Present	11/30/2008	Present	N/A	N/A
G-603	11/30/2008	Present	11/30/2008	Present	11/30/2008	Present	N/A	N/A
L-28U	2/3/1997	Present	N/A	N/A	N/A	N/A	N/A	N/A
PC-17A	6/29/1999	Present	6/29/1999	Present	6/29/1999	Present	N/A	N/A
S-140	10/1/1969	Present	1/1/1984	Present	1/1/1969	Present	N/A	N/A
S-190	9/1/1969	Present	1/1/1978	Present	1/1/1978	Present	4/1/1968	Present
USSO	12/2/1995	Present	12/2/1995	Present	12/2/1995	Present	N/A	N/A
WEST WEIR	1/31/1996	Present	1/31/1996	Present	1/31/1996	Present	N/A	N/A

2.1.3.2 Surface Water Quality

Also pertinent to the review of available data for the study region is any available water quality monitoring information. There has been several water quality monitoring efforts performed within the area including regular scheduled grab sampling by District contractors and surface water quality auto-samplers. ***Table 2.1.3*** describes the availability of recorded P concentrations from DBHYDRO for the Study area.

Table 2.1.3 - Summary of Available Surface Water Quality Data

Site	Description	Auto (A)/ Grab (G) Samples	TP Measurement Period	
			Start	End
C139S1	Deer Fence Canal at Duck Curve	G/A	9/2006	Present
C139S2	L-2 Canal in STA5	G/A	9/2006	Present
C139S3	L-2 Canal South of G-150	G/A	09/06	Present
C139S4	L-2 Canal East of G-151	G/A	09/06	Present
C139S6	S&M Canal	G/A	09/06	Present
DF12.3TS	Crow's Nest-Discharge north to Deer Fence Canal	G	03/03	Present
DF12.2TS	Duck Curve Pasture-Discharge north to Deer Fence Canal	G	08/06 (only)	
DF11.3TW01	Duck Curve A-Discharge E to L3 Canal	G	06/04	10/06
DF02.0TW	Hilliard Deer Fence Structure-Discharge to Deer Fence Canal at road	G	08/05	10/06
DF02.1TW	On McDaniel Property, approx. 650 feet west of the Hilliard Bridge	G	02/06	Present
DF11.1TN01	Crook's-Discharge south to Deer Fence Canal	G	08/05	Present
DF08.1TN01	South Bay-Discharge south to Deer Fence Canal	G	03/03	Present
L212.1TW13	Devil's Garden-Discharge E to L2 Canal	G	03/03	Present
L209.1TW01	Midway Canal-Discharge E to L2 Canal	G	03/03	Present

Site	Description	Auto (A)/ Grab (G) Samples	TP Measurement Period	
			Start	End
L209.6TW02	Alico Structure 1-Discharge E to L2 Canal	G	06/06	Present
L207.6TW02	Alico Gator, Discharge E to L2 Canal	G	08/03	Present
L206.0TW02	Alico Southwest, Discharge E to L2 Canal	G	09/03	Present
L206.0TW01	Alico South, Discharge E to L2/L3 Canal	G	03/03	Present
L-28U	Seminole station at southern boundary Big Cypress	G/A	09/97	06/98
G-108	Agricultural discharge location at structure north of Seminole Reservation	G/A	06/96	Present
G-136	Structure on the L-1 Levee, approx. 3 miles W of CR835	G	05/94	Present
G-150	G150 Gated Culvert Structure	G	04/05	Present
G-151	Culvert at SR846-1 mile S of SR832	G	09/06	10/07
G-342A	STA5, cell 1A inflow	G/A	06/99	Present
G-342B	STA5, cell 1A inflow	G/A	11/98	Present
G-342C	STA5, cell 2A inflow	G/A	06/99	Present
G-342D	STA5, cell 2A inflow	G/A	11/98	Present
G-342E	STA5 flow way 3 inflow structure	G/A	07/08	Present
G-342F	STA5 flow way 3 inflow structure	G/A	06/08	Present
G-353A	Gated culvert structure in STA 6	G	07/07	Present
G-353B	Gated culvert structure in STA 6	G	07/07	Present
G-353C	Gated culvert structure in STA 6	G	07/07	Present
G-396A	Gated culvert structure in STA 6	G	07/07	Present
G-396B	Gated culvert structure in STA 6	G	07/07	Present
G-396C	Gated culvert structure in STA 6	G	07/07	Present
G-406	L3 Canal at STA 5 inflow location	G/A	06/00	Present
G-407	STA 6 diversion structure	G/A	09/07	Present
G-602	STA 6 Section 1, Cell 5 Inflow Weir 2	G/A	10/02	Present
G-603	STA 6 Section 1, Cell 3 Inflow Weir 3	G/A	10/02	Present
PC-17A	Seminole Reservation, ag. Discharge from McDaniels' property to N Feeder Canal	G	06/96	Present
S-140	Western Broward on SR84,N or I-75, intersection of L-28 and C-60	G/A	11/74	Present
S-190	On L28I, 2.5 miles S of SR833	G/A	04/87	Present
SM00.2TW	On Obern Property-approx. 800 feet west of SMWEIR, on the S&M Canal	G	02/06	Present
SM02.2TW02	Zipperer culvert-Discharge to S&M Canal	G	08/05	Present
SM02.1TN01	Zipperer A-Discharge south to S&M Canal	G	08/05	Present
SM02.1TW	Zipperer Discharge E to L3 Canal	G	03/03	Present
SM05.0TN	Zipperer western-most culvert (E of bridge)	G	08/05	Present
SMWEIR	Upstream of the S&M Canal	G	10/03	09/06
USSO	North end of BIA HWY 1296, approximately 2.2 miles North of Snake Rd	G/A	10/95	Present
WWEIR	In Seminole Reservation, at weir, WFEED, 150 ft downstream from WFEED	G/A	10/97	Present

Although this document is intended only to provide a summary of available data and does not incorporate any independent analyses of the surface water quality records presented above, ***Table 2.1.4*** below describes the annual TP loads from WY1998 to WY2009 for each of the Study basins as reported in the SFWMD South Florida Environmental Report (2008 DRAFT).

Table 2.1.4 - Summary of Annual TP Loading for Study Basins

Year	C-139 Basin			Feeder Canal Basin			L-28 Basin		
	Flow (kac-ft)	TP (Mton)	FWMC (ppb)	Flow (kac-ft)	TP (Mton)	FWMC (ppb)	Flow (kac-ft)	TP (Mton)	FWMC (ppb)
C-139 Basin									
1998	169.9	35.6	170	70.3	7.0	81	155.8	6.9	36
1999	135.8	35.6	213	47.5	4.5	76	94.5	6.4	55
2000	201.7	52.4	211	97.6	13.2	110	180.0	15.5	70
2001	56.5	17.1	245	37.3	8.1	177	63.0	11.2	144
2002	199.7	65.9	267	85.0	9.3	89	110.0	6.5	48
2003	224.4	77.3	279	88.0	9.4	86	136.4	10.4	62
2004	203.9	69.0	274	117.7	14.4	99	136.1	7.0	42
2005	167.5	40.3	195	94.6	11.3	97	138.0	7.2	42
2006	333.2	106.9	260	150.4	28.7	155	203.6	12.5	50
2007	77.3	29.1	306	70.7	18.8	215	88.5	5.1	47
2008	38.7	5.4	113	25.3	3.2	101	90.3	4.0	36
2009	165.0	52.3	255	87.8	14.9	137	138.3	6.6	40

2.1.3.3 Precipitation Monitoring

There are two types of resources for recorded precipitation data: point-based (gauging station) and grid-based (RADAR product). The point-based data provides data with reliable accuracy for finite locations but with no representation of spatial variability between stations. ***Figure 2.1.1*** illustrates the locations of active regional precipitation gauging stations, and ***Table 2.1.5*** describes the period of record available for data at these locations.

The grid-based data provides the best available representation of spatial variability within a rainfall event, but does not provide reliable accuracy with respect to precipitation magnitude. One method for deriving a precipitation input that provides both accuracy and representation of spatial variability is by statistically adjusting the RADAR data based on measurements from gauging stations. One such product utilized by the District is Next Generation RADAR (NEXRAD). NEXRAD data is a U.S. National Weather Service product that provides 2-km by 2-km resolution data at 15-minute intervals from January 1, 2002 until the present.

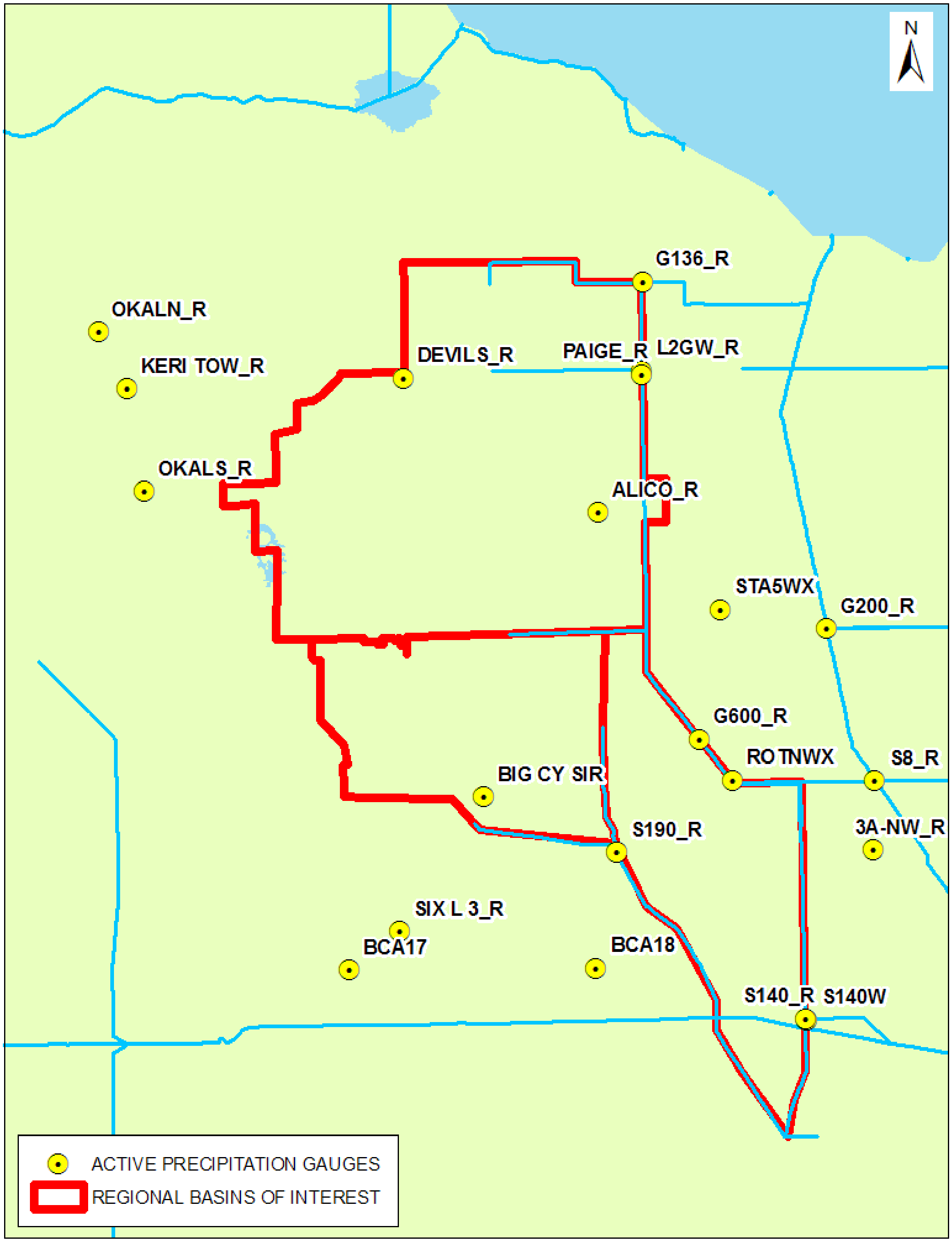


Figure 2.1.1 - Active Precipitation Gauging Stations

Table 2.1.5 - Period of Record for Active Regional Precipitation Gauging Stations

GAUGE	START DATE	END DATE
G3ANW	05/24/2000	Present
ALICO	01/01/1973	Present
BCA17	06/11/2002	Present
BCA18	06/11/2002	Present
BCSI	10/21/1992	Present
DEVILS	10/01/1978	Present
G136	10/21/1993	Present
G200A	03/18/1997	Present
G600	10/20/1997	Present
KERI TOW	10/31/1969	Present
L2GW	06/24/2004	Present
OKALN	12/18/2003	Present
OKALS	12/19/2003	Present
PAIGE	09/01/1982	Present
ROTNWX	12/23/1997	Present
S140	03/18/1997	Present
S140W	10/21/1992	Present
S190	03/18/1997	Present
S8	01/01/1973	Present
SIXL3	03/20/1995	Present
STA5WX	09/17/2002	Present

2.1.3.4 Evapotranspiration

With respect to available evapotranspiration data in the Region, four (4) of the precipitation gauging stations described above incorporate the meteorological measurements required to estimate reference evapotranspiration (BCSI, ROTNWX, S140W and STA5WX). The estimates produced at these locations are synthesized into a grid-based dataset that can be used in model development. For representation of actual evapotranspiration predictive models can be used that incorporate land-use, vegetation and antecedent soil moisture to adjust the reference evapotranspiration appropriately.

2.1.3.5 Ground Water Levels and Quality

There are multiple available data sources describing the groundwater conditions of the region. With regard to the piezometric surfaces of regional aquifers, DBHYDRO lists the locations of monitored locations including components of the Hendry Observation Well Data Inventory (HOWDI) dataset, which provides manual monthly measurements at locations within the C-139 and L-28 Basins and surrounding areas. The USGS maintains continuous water level recorders on several wells in the area, including some nested well pairs. Additionally, as part of the FDEP's Watershed Monitoring program (www.dep.state.fl.us/water/monitoring) there is a select dataset of ambient ground water quality data. ***Figure 2.1.2*** below illustrates the locations and formations for each of the regional monitoring well locations.

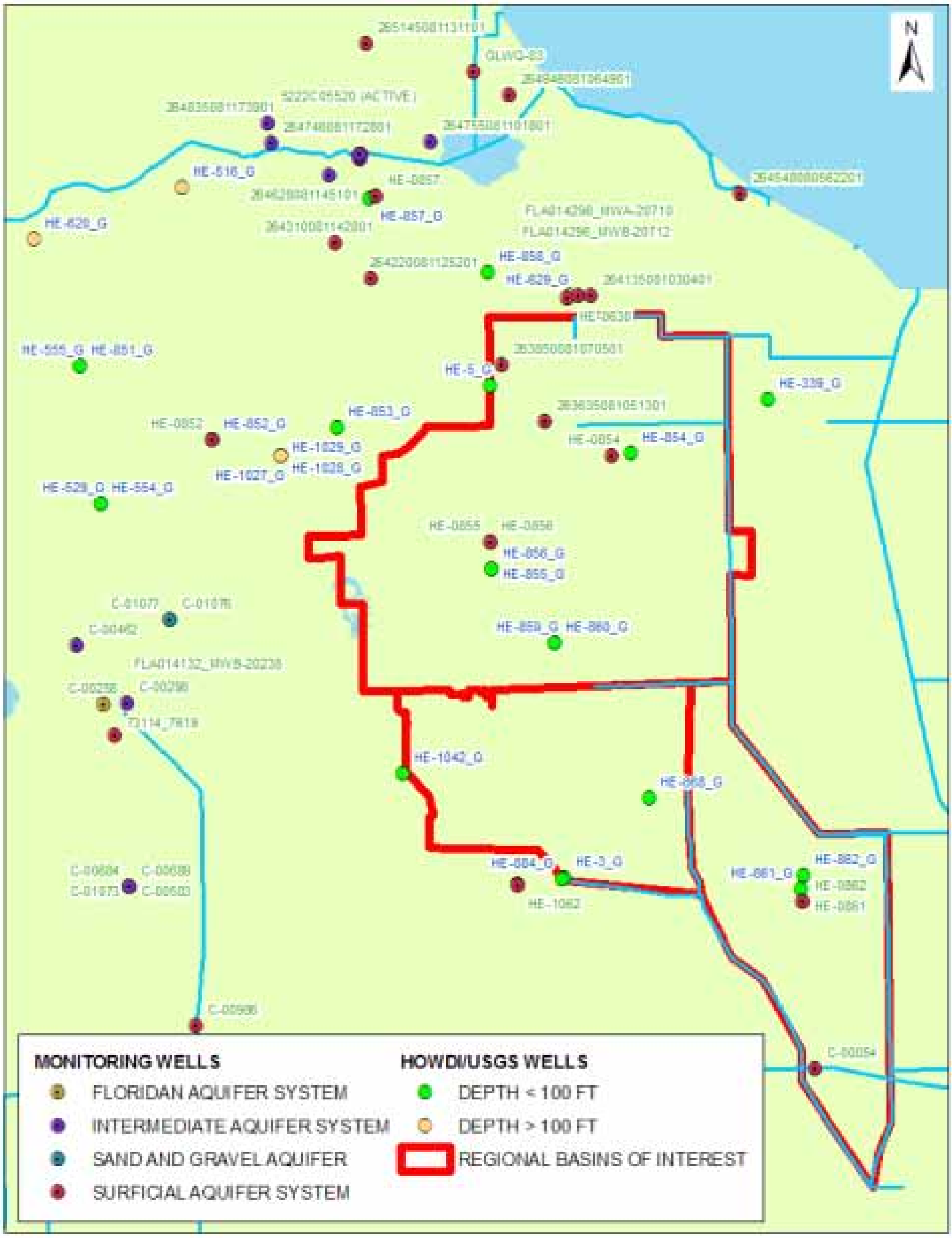


Figure 2.1.2 - Groundwater Monitoring Locations

There are five monitoring wells in the L-28 and Feeder Canal Basins. One is a surficial aquifer monitoring well and the remaining four are Lower Tamiami monitoring wells. There is a Lower Tamiami monitoring well in the S-4 Basin and there are two Lower Tamiami monitoring wells in the East Caloosahatchee Basin. More Lower Tamiami monitoring wells are needed in the C-139 Basin, and more surficial aquifer monitoring wells are needed in the L-28/Feeder Canal area. ***Table 2.1.6*** describes the monitoring wells applicable to the Study region, with nested well locations indicated using highlighted rows.

Table 2.1.6 - Regional Monitoring Well Network

SITE NAME	AGENCY	WELL DEPTH [FT]	NOTES
HE-1042	USGS	80	NWIS available from 2004 - Present
HE-1062	USGS	10	NWIS available from 2003 - Present
HE-1063	USGS	123	NWIS available from 2003 - Present
HE-3	HOWDI	80	DBHYDRO available from 1956 – 1988 (Well destroyed)
HE-5	HOWDI	13	DBHYDRO available from 1956 - 1988
HE-629	HOWDI	144	DBHYDRO available from 1985 - 1988 (Well inaccessible since 2005)
HE-853	HOWDI	61	DBHYDRO available from 1986 - 1988
HE-854	HOWDI	14	DBHYDRO available from 1986 - 1988
HE-855	USGS	90	DBHYDRO available from 1900 - 1988
HE-856	USGS	11	DBHYDRO available from 1977 - 1988
HE-858	HOWDI	11	DBHYDRO available from 1977 - 1988
HE-859	USGS	60	DBHYDRO available from 1985 - 1988
HE-860	USGS	16	DBHYDRO available from 1985 - 1988
HE-861	USGS	70	DBHYDRO available from 1978 - Present
HE-862	USGS	7	DBHYDRO available from 1977 - 2002
HE-868	HOWDI	97	DBHYDRO available from 1977 - 1988 (Well destroyed)
HE-884	HOWDI	67	DBHYDRO available from 1986 - 1988

2.1.3.6 Ground Water Quality

The FDEP's Watershed monitoring program provides a limited spatial and temporal perspective on the Total Phosphorus concentrations in the Lower Tamiami Aquifer. For the 13 monitoring sites nearest to the Study area, there has been only one measurement taken at each location since 2000. The average Total P concentration measured is 0.05 mg/L. No other publicly recorded water quality data is available to correlate assertions that the ambient water quality of the groundwater is contributing to the nutrient loading measured in the surface waters of the region.

2.1.3.7 Ground Water Allocations

As part of the Consumptive Use Permitting efforts of the District in the region, there is a comprehensive database of water use allocation and primary irrigation well locations and parameters available. Although this data is not necessarily a reflection of actual agricultural water use in the region, it does give some indication of the importance of groundwater pumping on regional hydrology. Within the database there are 2,449 wells permitted in Hendry County listed with one of the following qualifiers:

- Abandoned
- Inactived by RegGSS
- Monitor
- Primary
- Proposed but never constructed
- Recharge
- Secondary
- Standby
- To be plugged/abandoned

Of these permitted Hendry County wells, there are 1,562 that are classified as Primary for irrigation purposes. From the subset of primary wells in Hendry County there are 962 that are located within the boundaries of the C-139, Feeder Canal and L-28 Basins. Of that number only 147 primary wells within the Study region include information concerning the date of installation and those dates listed range from 1960 to 1994. The amount of information available for the existing database is limited with respect to the date of installation. For the purposes of establishing an increasing trend in wells installed with time, this database is not currently capable of providing the necessary information. For reference purposes, ***Figure 2.1.3*** below illustrates the location of all permitted primary irrigation wells in the Hendry County.

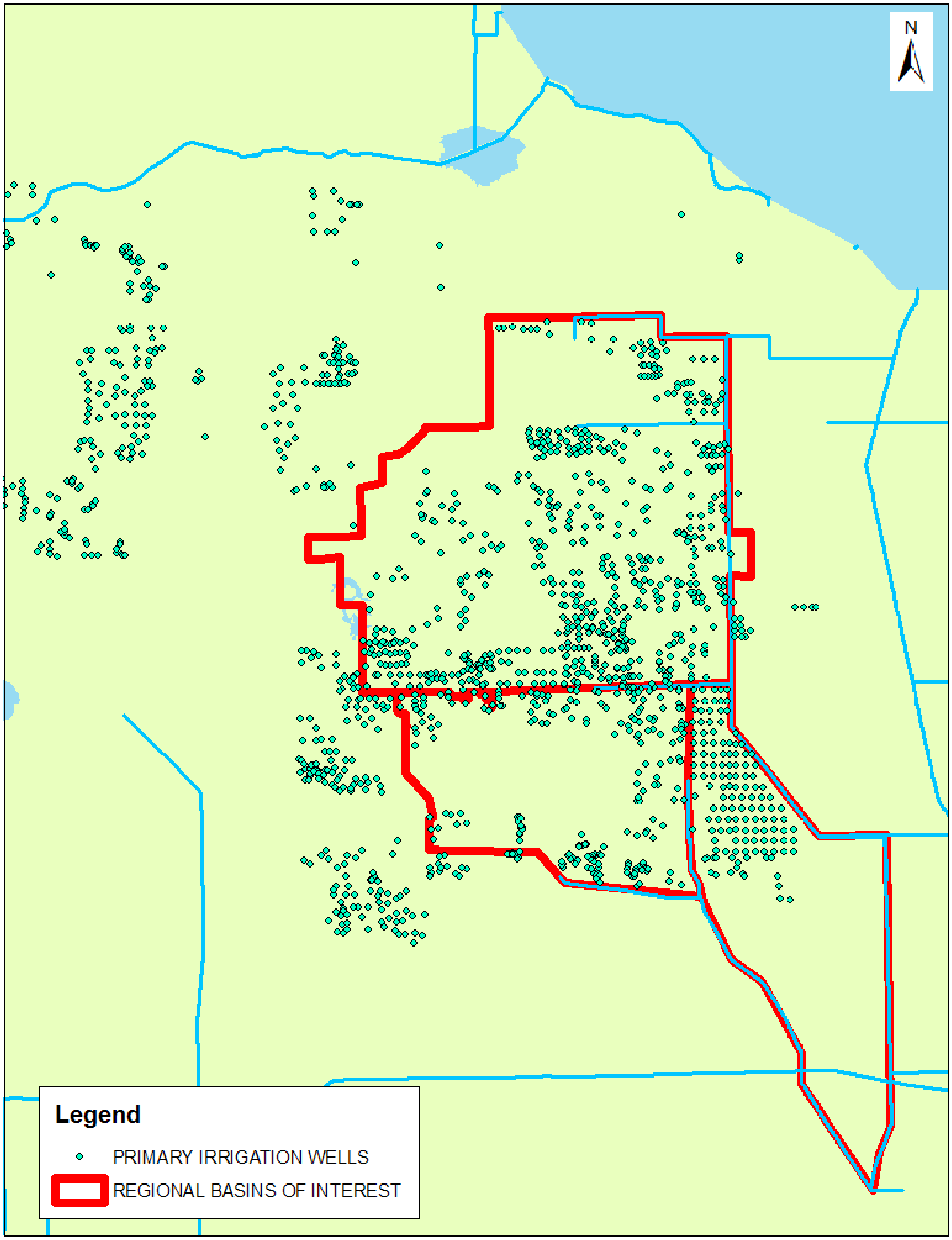


Figure 2.1.3 - Primary Irrigation Well Locations

2.1.3.8 Available Topography and Survey Information

In order to develop a representation of the Study region, topography of the land surface is necessary for hydrologic assumptions (basin delineation). Surveyed cross-sections of regional canals are needed for hydraulic assumption (conveyance capacity). With regard to topographic information, previous regional studies have utilized the Southwest Florida Feasibility Study (SWFFS) Digital Elevation Model (DEM) available from the Fort Myers Service Center of the SFWMD. The DEM is a composite from several sources. In the north and west portions of Hendry County, Light Detection and Ranging (LIDAR) data was used. For the remainder of the county, the best available information was a surface derived from USGS 5-foot contours and spot elevations. The cell-size of the DEM is 100-ft. The projection of the DEM is state plane, Florida East, US Feet, NAD83-90. All elevations are relative to NAVD 1988. There is also LiDAR topography data available from the Florida Division of Emergency Management (FDEM). Although this data set does not include the entire Study Region it could be used to supplement the commonly used DEM. ***Figure 2.1.4*** illustrates the spatial extent of both the Hendry County and the FDEM datasets. Although there is some accuracy concerns associated with both dataset's development methodology there are very few other resources for such a large Study Region.

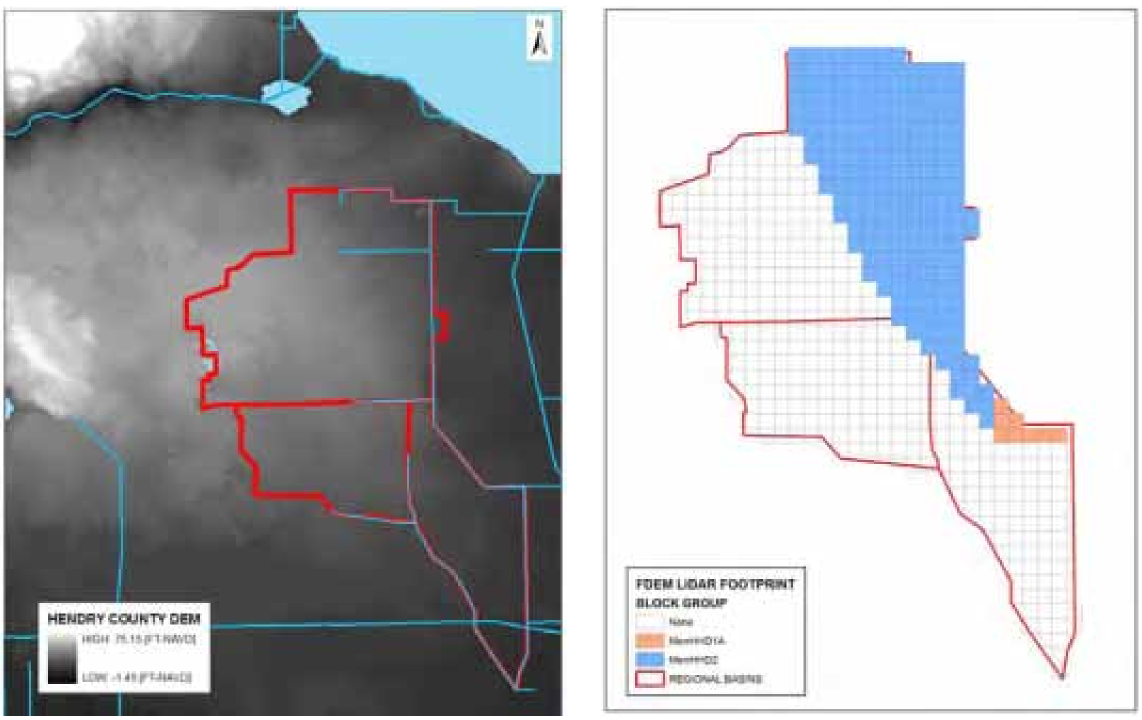


Figure 2.1.4 - Hendry County and FDEM Datasets

There is some available data describing the canal cross-sections within the Study region. The C-139 Basin Phosphorus Water Quality and Hydrology Analysis (ADA 2006), included 24 bathymetric canal cross-sections for major and minor canals collected within the C-139 Basin, see ***Appendix A1 - C-139 Cross-Sections***. As part of the Everglades

Agricultural Area Stormwater Treatment Compartment C Watershed Hydraulic Study (ADA Engineering, 2006) data collection effort, 20 additional cross-sections along primary drainage canals were collected**.** In addition field surveys of the south and west banks of the L-1, L-2 and L-3 Canals, and both the north and south banks of the L-2W Canal were also performed, see ***Appendix A2 - C-139 Additional Cross-Sections.*** These field surveys were used to identify low spots in the adjacent berms, where out-of-bank flows and negative impacts to flood protection are most likely. ***Figures 2.1.5*** and ***2.1.6*** illustrate the location of the all the cross-sections and top of bank elevations surveyed, within the north and south ends of the C-139 Basin, respectively. All canal bank low points are shown on the figures with the exception of survey performed for the L-2W Canal between G-150 and G-152. A continuous profile of both the north and south top of bank was developed, but is not shown in the figures below.

Figure 2.1.5 - Cross-Section and Bank Survey Locations (C-139 North)

Figure 2.1.6 - Cross-Section and Bank Survey Locations (C-139 South)

For the L-3 Canal there is also as-built survey data available from a hydraulic dredging operation performed by the District in September, 2008. For the Feeder Canal and L-28 Basins, there are several sources available for cross-section data. For the L-3 Canal, south of STA 5-1 and between Compartment C and the C-139 Annex, there is surveyed cross-section data collected approximately every 1,000 feet as part of the Compartment C Basis of Design Review (URS, 2008), see ***Appendix A3 - Compartment C Topographic Survey***. For the Feeder Canal and L-28 Basins there is a combination of cross-section data available from the original Central & South Florida (C&SF) Design Report (1963) and the Big Cypress Seminole Indian Western Water Conservation Restoration Project (Burns & McDonnell, 1995). ***Figure 2.1.7*** illustrates the C&SF design documentation; also refer to ***Appendix A4 - Feeder and L-28 Basins Cross-Sections.***

Another resource with regard to the C-139 Basin is the results of a recent dredging effort of the L-3 Canal and STA-5. This hydraulic, environmental dredging operation was done as part under the Long-Term Plan effort. See ***Appendix A5 - L-3 Canal & STA 5 Spreader Canals – As Built Survey***

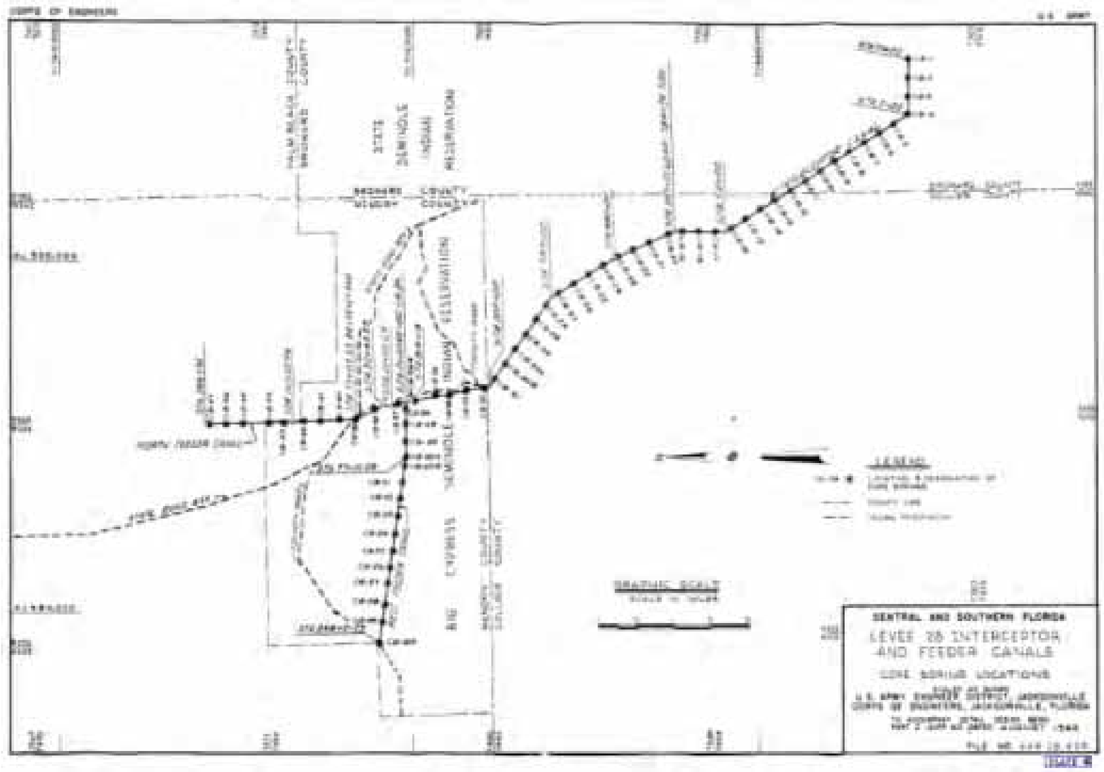


Figure 2.1.7 - Design Documents for the Feeder Canal and L-28 Basins

2.1.4 SUMMARY AND RECOMMENDATIONS

As shown in the sections above, there is a significant amount of available hydrologic, hydraulic, and water quality data within the Study region. The document review illustrates the various studies that have analyzed the water resources issues in the region and the recommendations that have been made, as part of each study. Although all of the documents reviewed provide insight into the existing and potential future conditions, it will be important to identify which of the recommended or permitted features are now, or are anticipated to become, operational. Several of the infrastructure improvements recommended in the reviewed documents are likely to not be operational in the next 5 years, and accordingly it will be important to coordinate with stakeholders to determine how these proposed improvements affect the assumptions of the existing and proposed conditions simulations of Phase II.

The data review supports that there is sufficient historical and operational data to develop and calibrate the surface water components of the selected model. The stage and flow monitoring network is mostly limited to primary drainage features and includes limited records of secondary and tertiary drainage networks, however considering the regional focus of the Study this concern should not be considered a constraint. The data review of surface water quality records demonstrates that the monitoring sites include secondary and tertiary drainage locations; however, in many of these locations, the sampling protocol is weekly grab sampling. For the purposes of calibrating a water quality model, the available data may provide corroboration with simulated results at upstream locations; however, whether or not the grab samples captured high runoff event concentrations is yet to be determined. Therefore, the detailed calibration of the selected model will be focused on the primary drainage features such as the basin outfall structures.

With regard to ground water data there are two significant constraints: limited spatial resolution of piezometric surface monitoring (Surficial and Lower Tamiami Aquifers) and the lack of available records of consumptive-use pumpage rates. Improving the spatial resolution of monitoring wells can be achieved with the installation of additional monitoring equipment at existing wells; however the data collected will not be available at the time of groundwater model development. The lack of information concerning consumptive use pumping will be a significant constraint in the development of a calibrated groundwater model. Utilizing either permitted allocations or simulated agricultural demand are the most commonly utilized techniques for dealing with this constraint. Further investigation into the appropriate methodology may be required during model development.

With respect to topography, it is difficult to find high-resolution detailed survey data for large areas. Although the quality and resolution of the Hendry County DEM would not be recommended for use in design engineering, it is the best available information and is considered sufficient for the planning level purposes of this Study. With respect to the available cross-section data, there appears to be sufficient survey information to construct a working hydraulic model of the region. For locations where canal cross-section survey data is greater than 10 years old it may be advisable to perform some verification surveys.

2.2 ATLAS OF AVAILABLE INFORMATION

2.2.1 INTRODUCTION

This atlas summarizes available spatial data in the format of a series of regional scale maps and an attached farm-scale review of permits and surface water management systems in the study area.

2.2.2 REGIONAL MAPS

There are 11 regional maps in the attached documents. These maps illustrate only information available at the time of the Existing Data Collection effort. There were no additional analyses performed to develop original content. Updated figures are presented in subsequent sections. A description of each included map is as follows:

Figure 2.2.1: Regional Hydrologic Basin Map

Describes the primary drainage system for the overall Study area including SFWMD canals and structures. Notably, the C-139 Basin boundary is defined differently than is shown in District GIS databases (hyhdbwtr.shp). For the purposes of this study the C-139 Basin boundary is defined based on the aggregation of the Everglades Works of the District permit boundaries as illustrated in the C-139 Basin Phosphorus Water Quality and Hydrology Analysis, Phase I (ADA Engineering, 2006).

Figures 2.2.2 to 2.2.4: C-139, Feeder Canal and L-28 Canal Basins Hydrologic Maps

Describes the secondary and tertiary drainage infrastructure of the C-139 Basin, and Feeder Canal, respectively, based on a compilation of site visits, staff interviews, permit reviews, field survey, and additional analysis. For the L-28 Interceptor Basin it describes the secondary and tertiary drainage infrastructure based on permit reviews, available reports and aerial photography

Figure 2.2.5: Regional Well Location Map

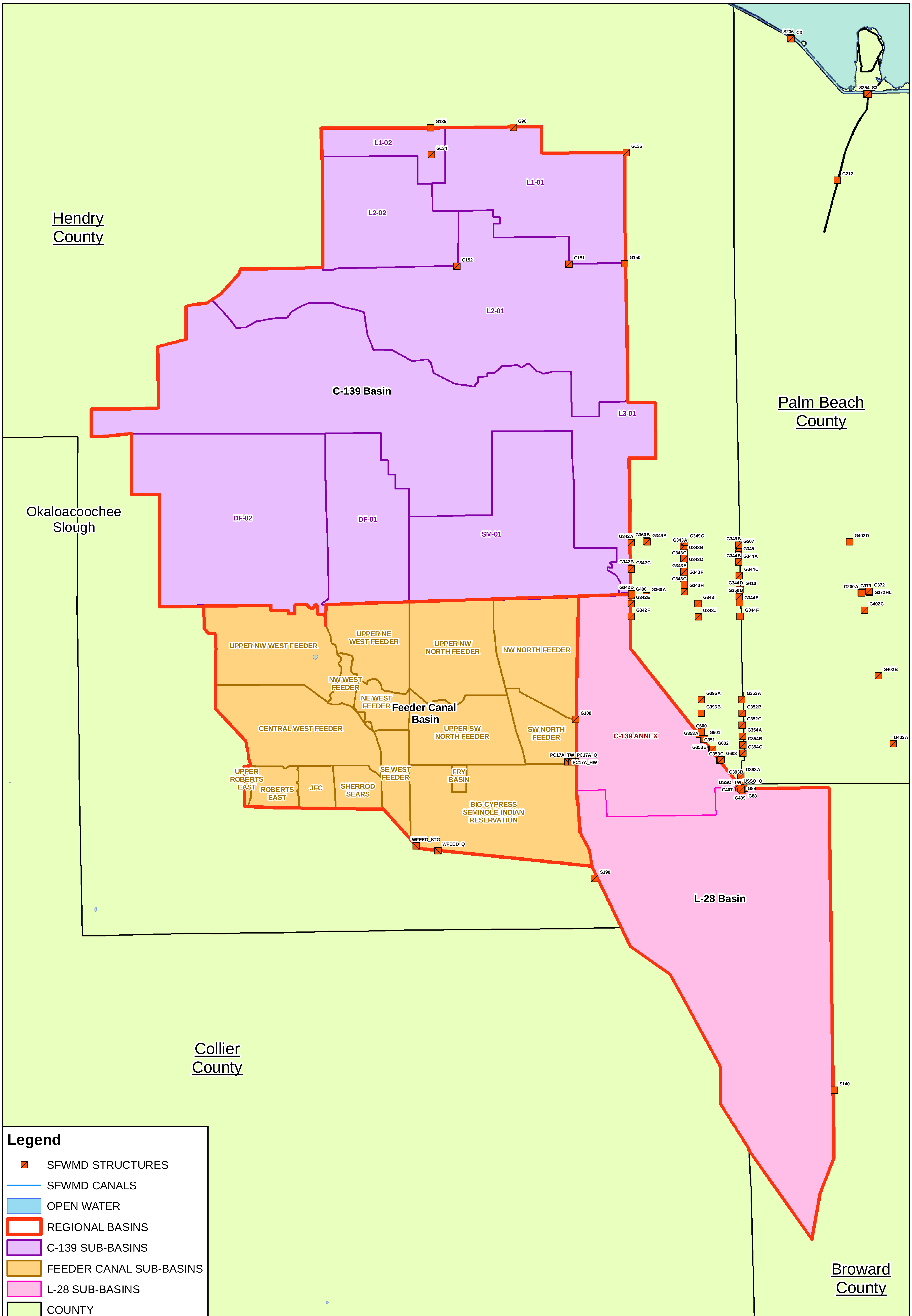
Illustrates the monitoring wells and primary consumptive-use wells for the overall study region based on District databases.

Figures 2.2.6 to 2.2.8: C-139, Feeder Canal and L-28 Canal Basin Land-Use Map

Illustrates the spatial extent of land-uses in the C-139, Feeder Canal and L-28 Interceptor Basins, respectively, based on 2005 coverage from SFWMD.

Figures 2.2.9 to 2.2.11: C-139, Feeder Canal and L-28 Canal Basin Soils Map

Illustrates the spatial extent of soil types in the C-139 Basin, based on coverage from SFWMD (sossrunt.shp). The SFWMD dataset does not contain soils data for Collier or Broward County. For the purposes of future model development, these soil types will be discerned from other available National Resource Conservation Service (NRCS) documentation as shown in ***Section 4.1.4.2 Soils***.



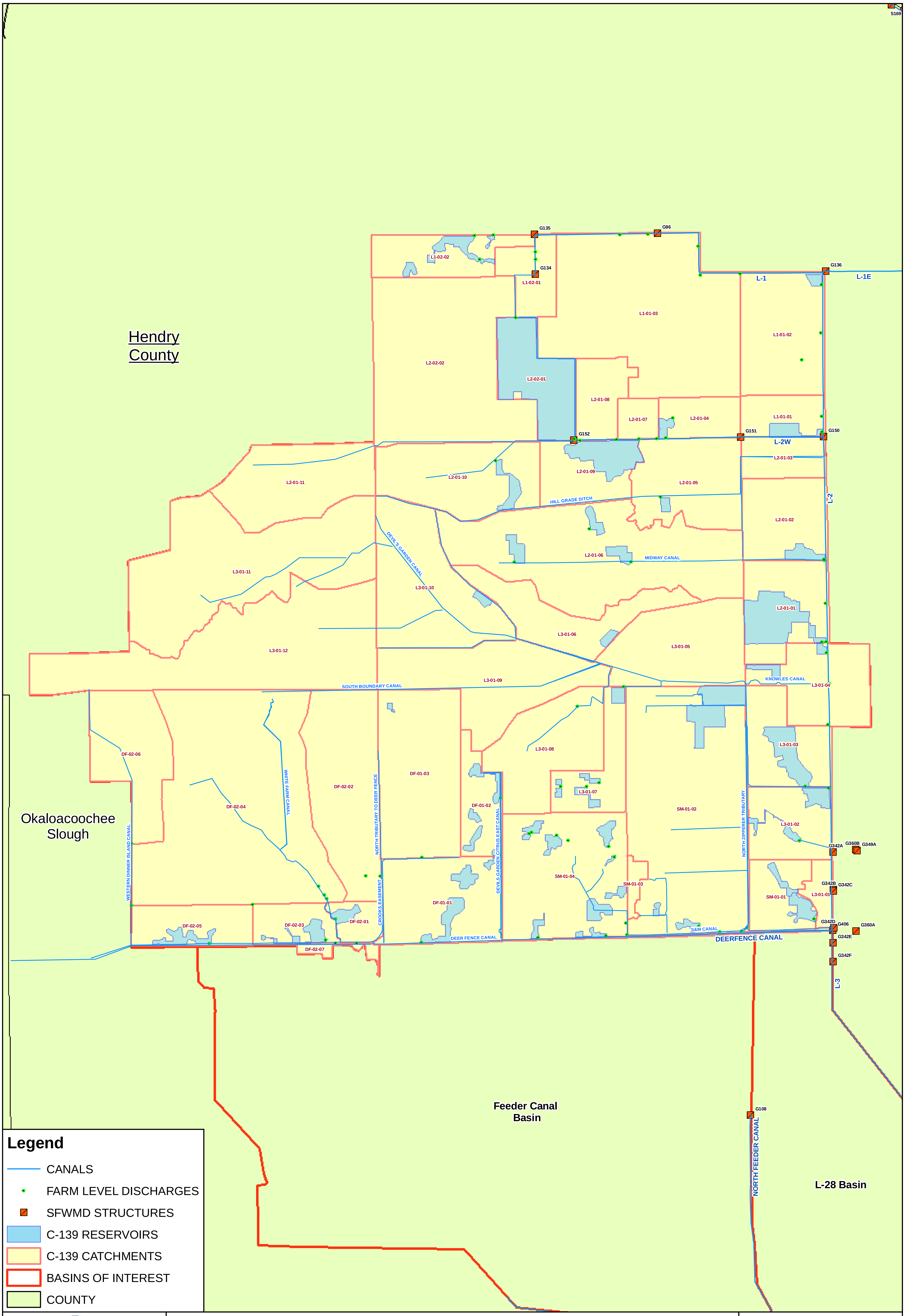
URS

Regional Hydrology Map

1 inch = 1.5 miles

2 1 0 2 4 6 8 Miles

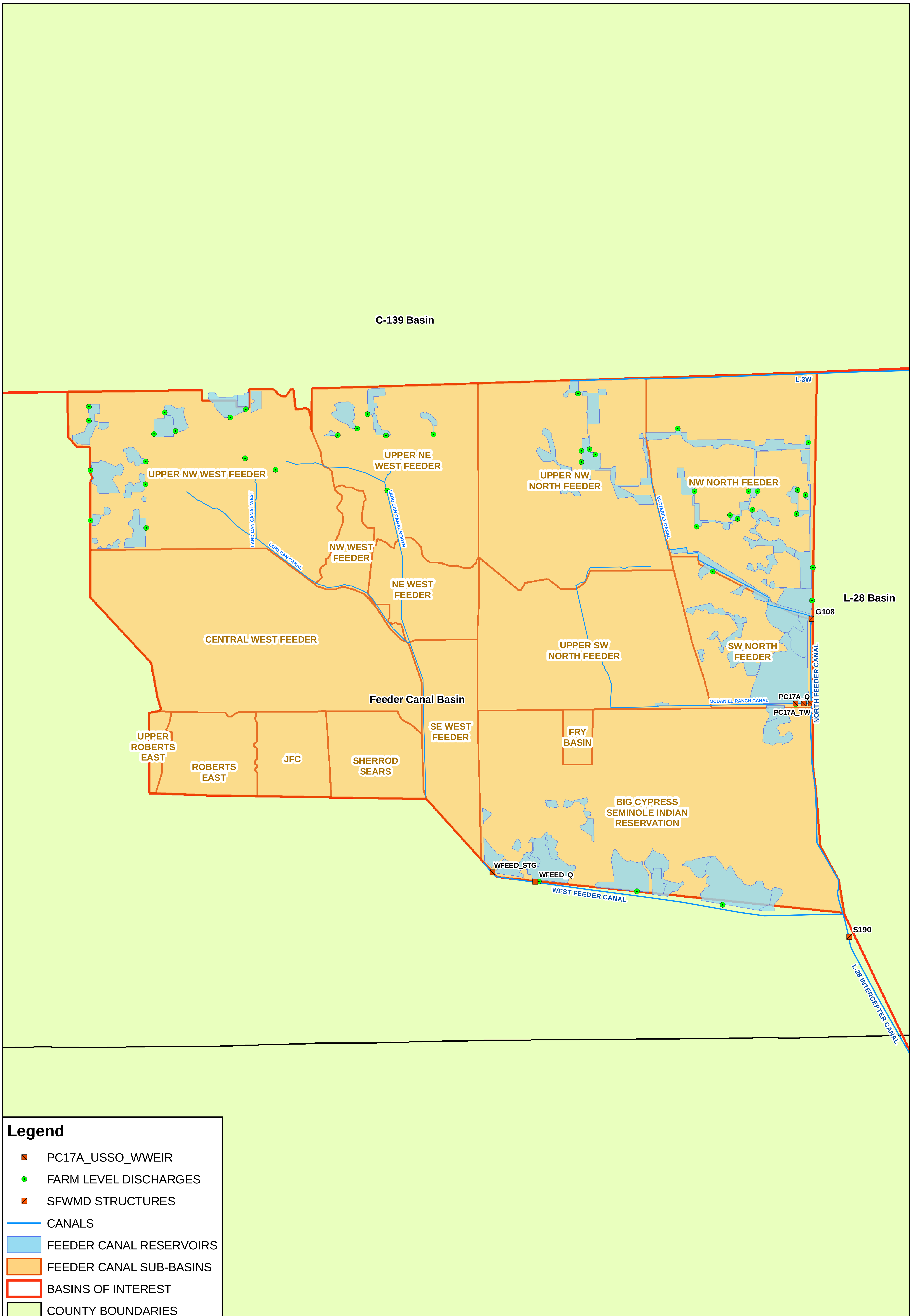
Figure 2.2.1



C-139 Hydrology Map

1 inch equals 1 miles

Figure 2.2.2

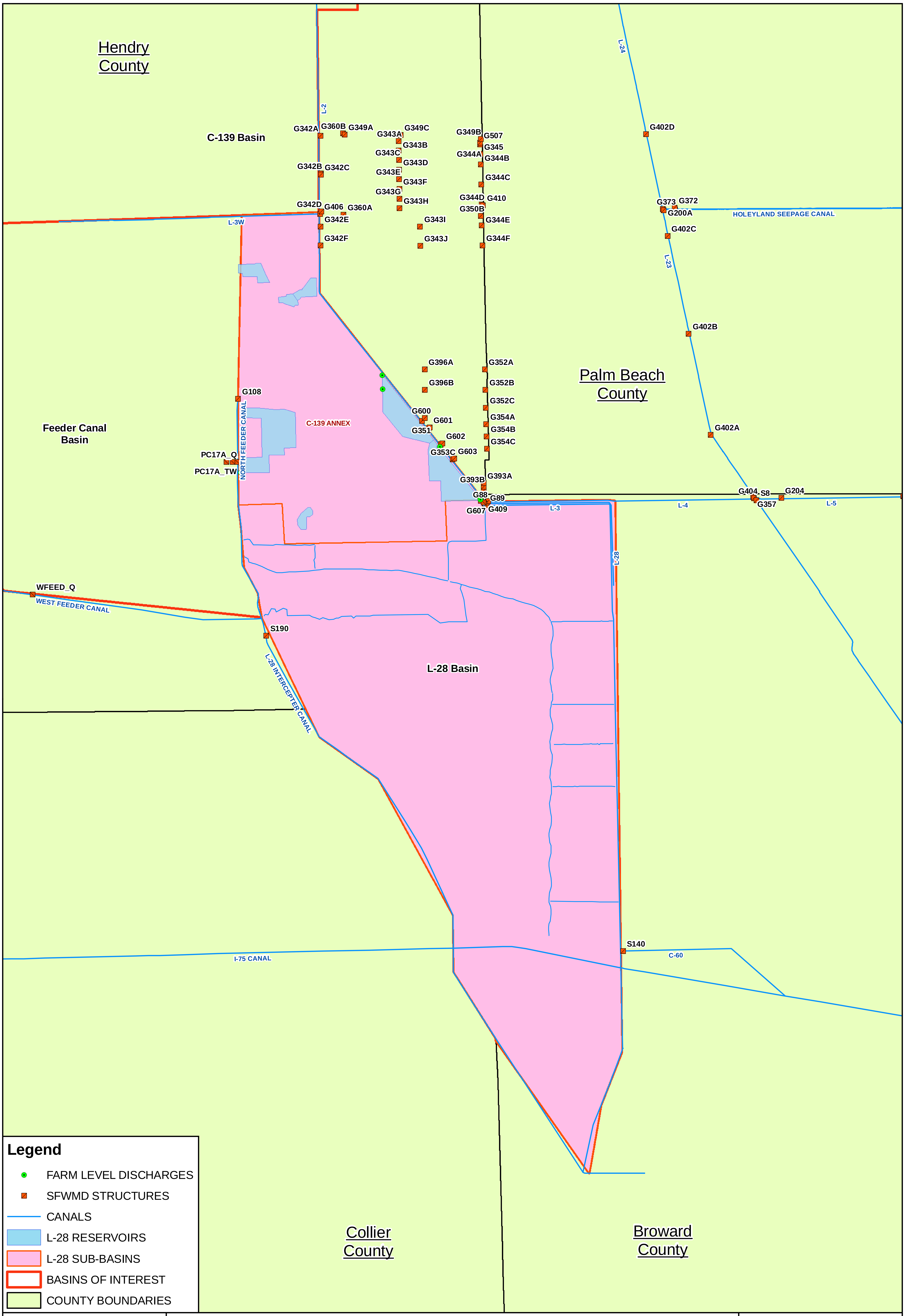


Feeder Canal Basin Hydrology Map

1 inch = 0.75 miles

1 0.5 0 1 2 3 4 Miles

Figure 2.2.3



URS

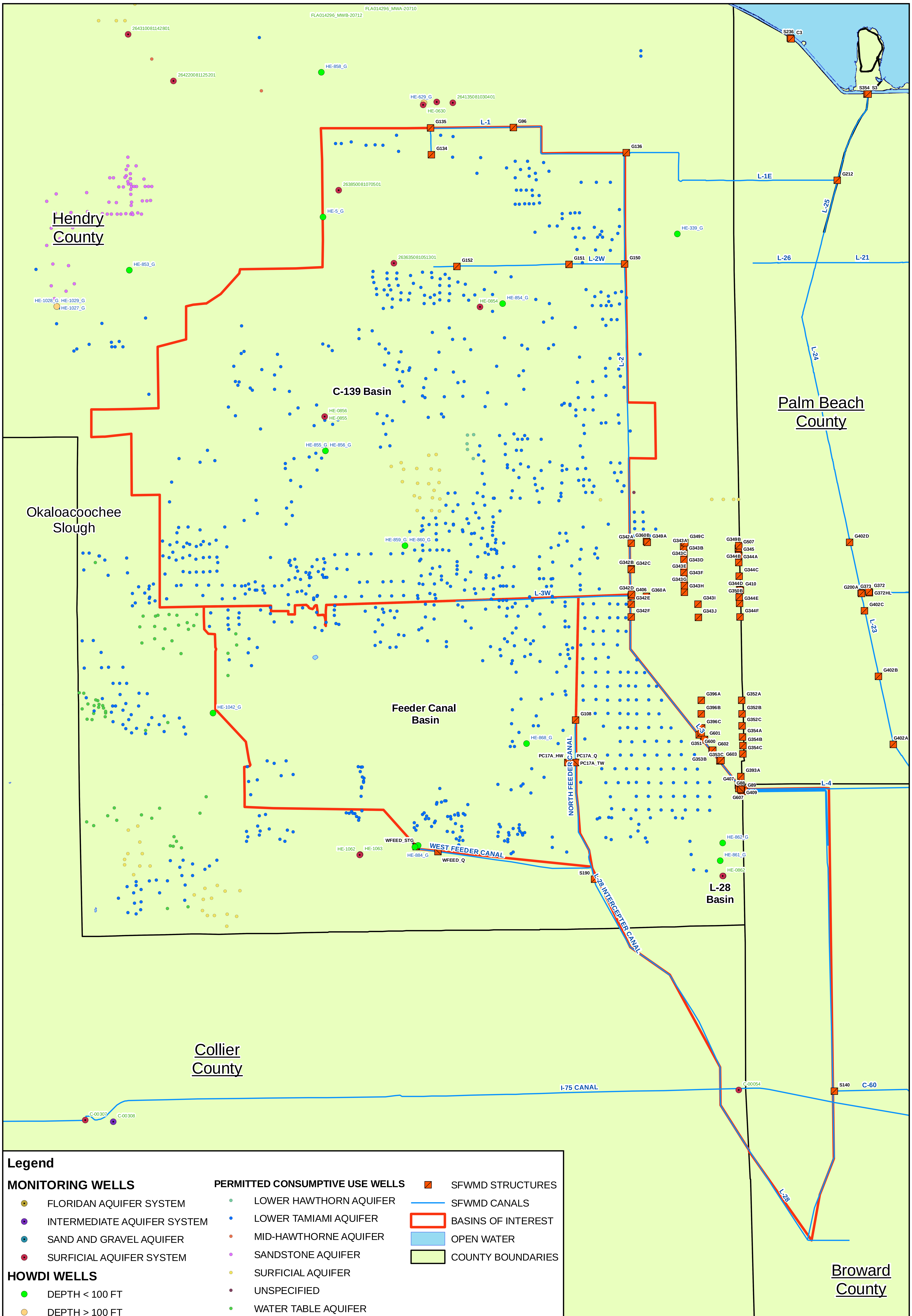
L-28 Basin Hydrology Map

1 inch = 1 miles

1 0.5 0 1 2 3 4 Miles

A·D·A ENGINEERING

Figure 2.2.4

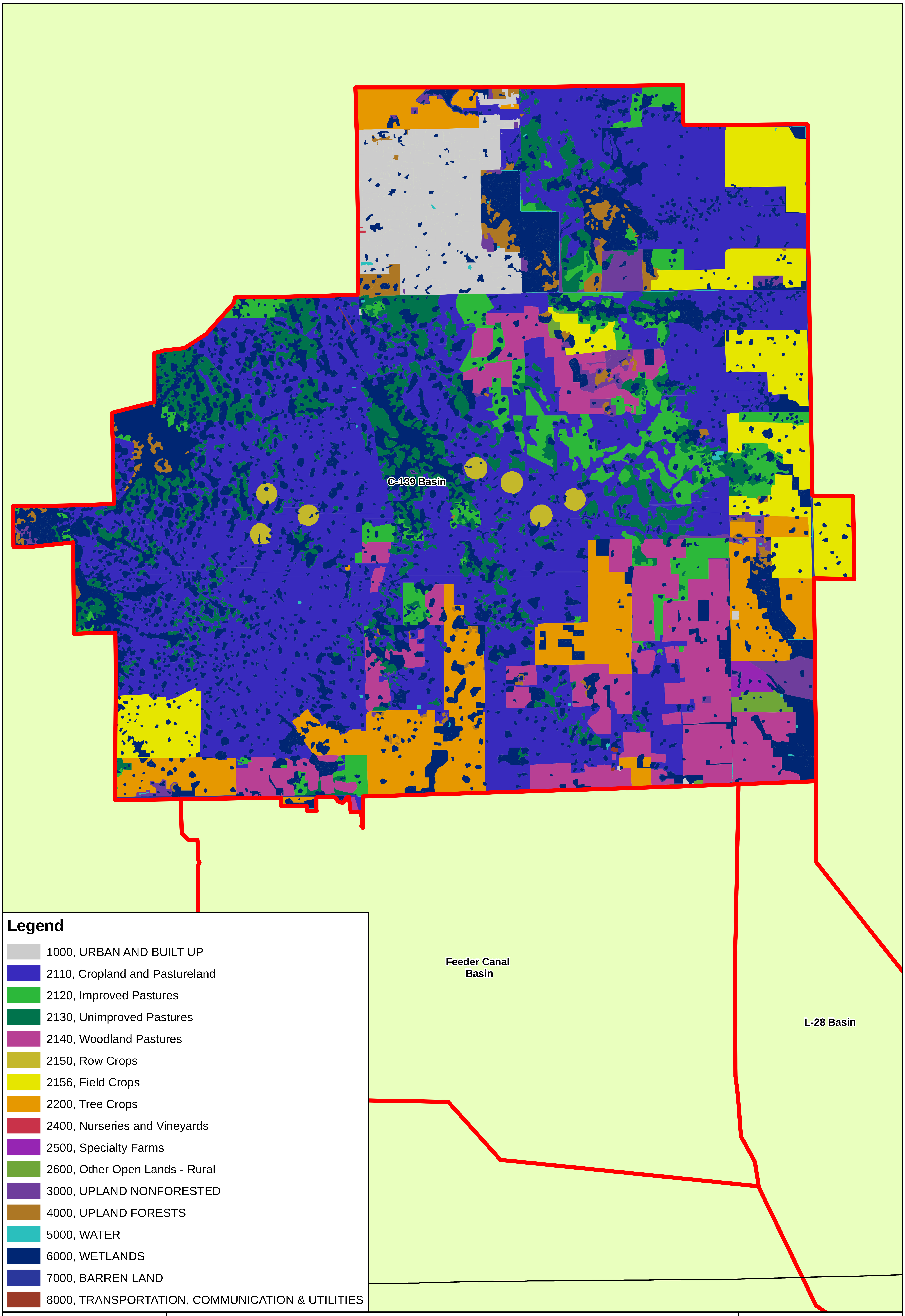


Regional Well Location Map

1 inch = 1.5 miles

2 1 0 2 4 6 8 Miles

Figure 2.2.5

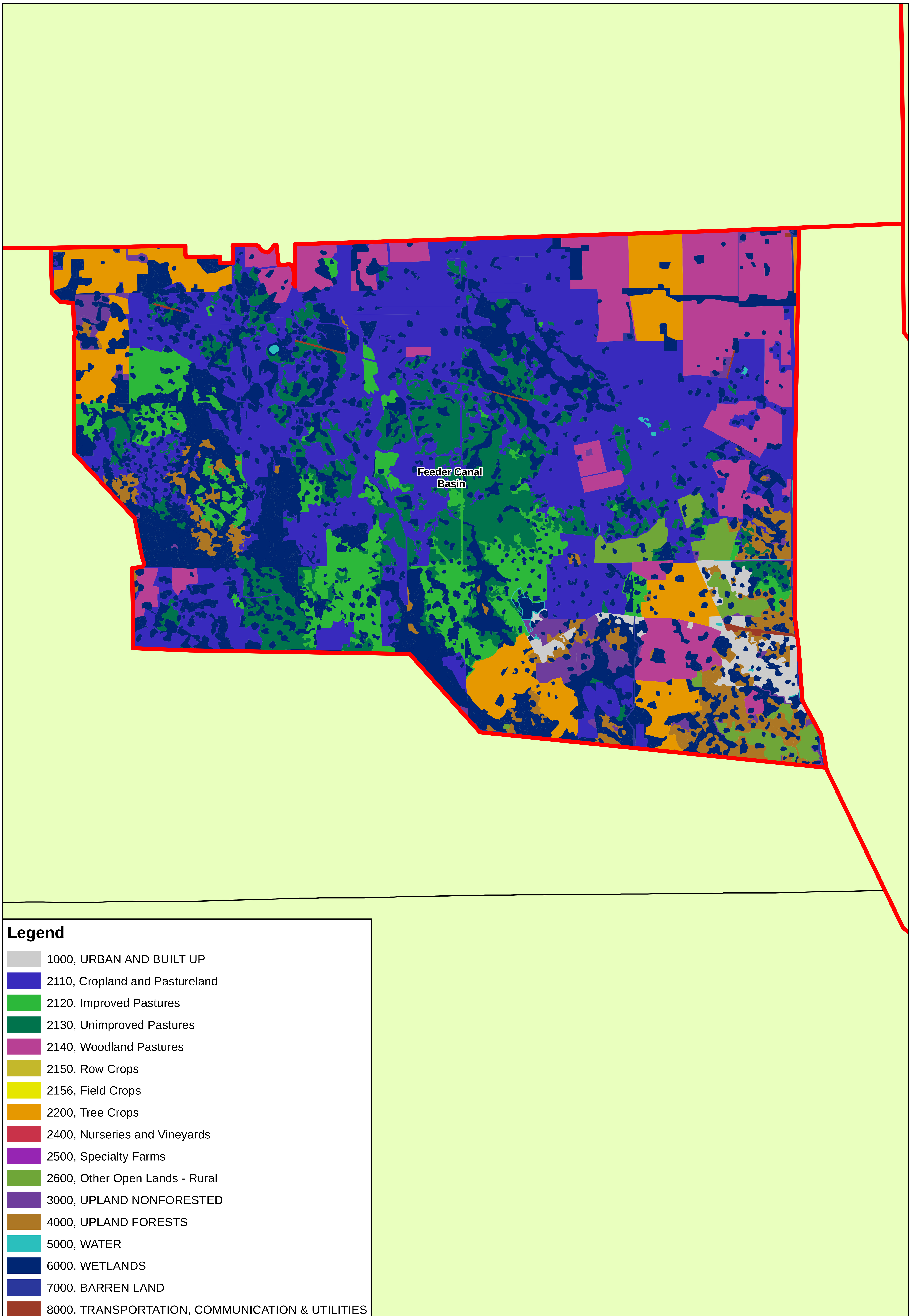


C-139 Basin Land Use Map

1 inch equals 1 mile

1 0.5 0 1 2 3 4 Miles

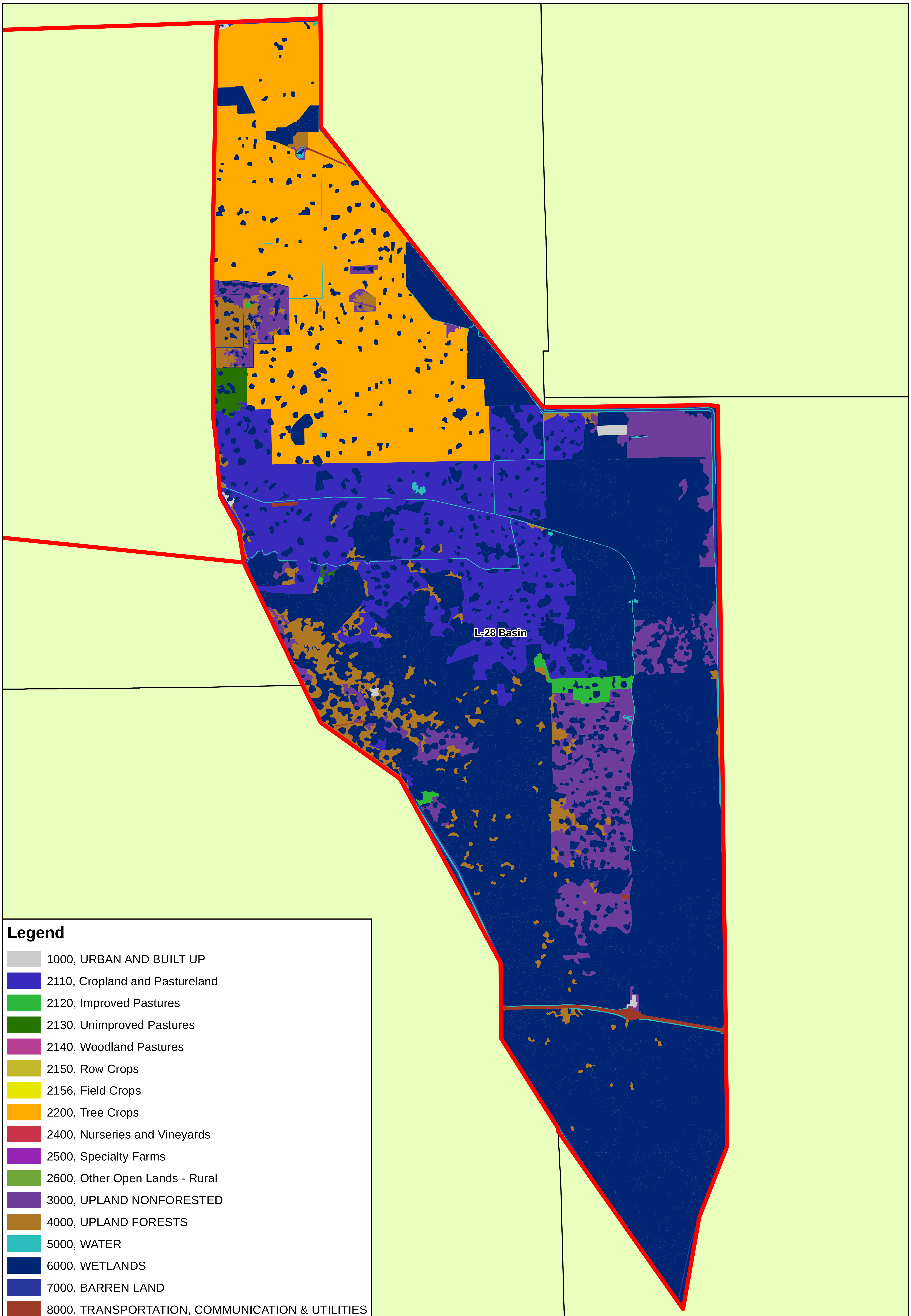
Figure 2.2.6



Feeder Canal Basin Land Use Map

1 inch equals 0.75 mile

Figure 2.2.7

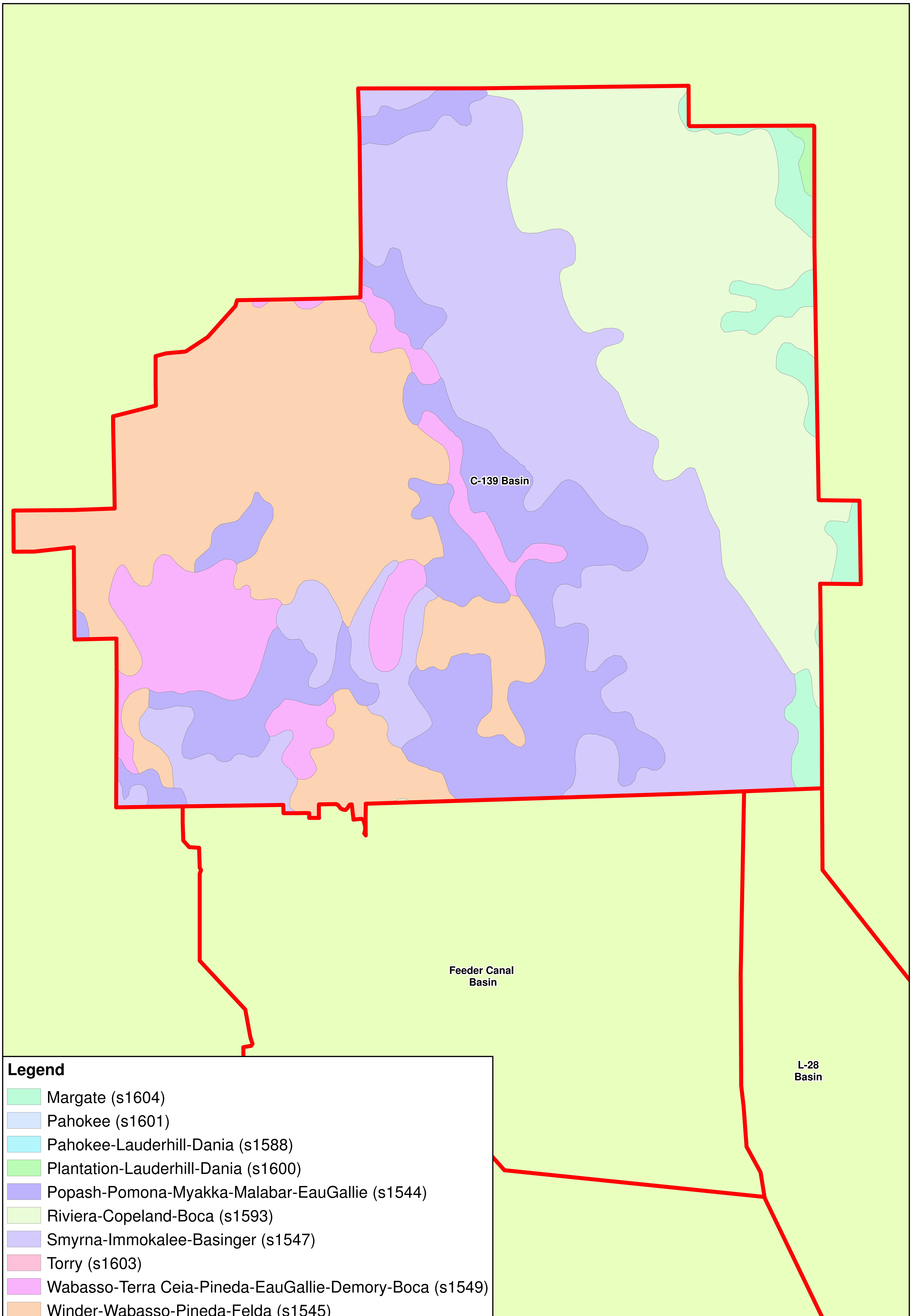


L-28 Basin Land Use Map

1 inch equals 0.75 mile

1 0.5 0 1 2 3 4 Miles

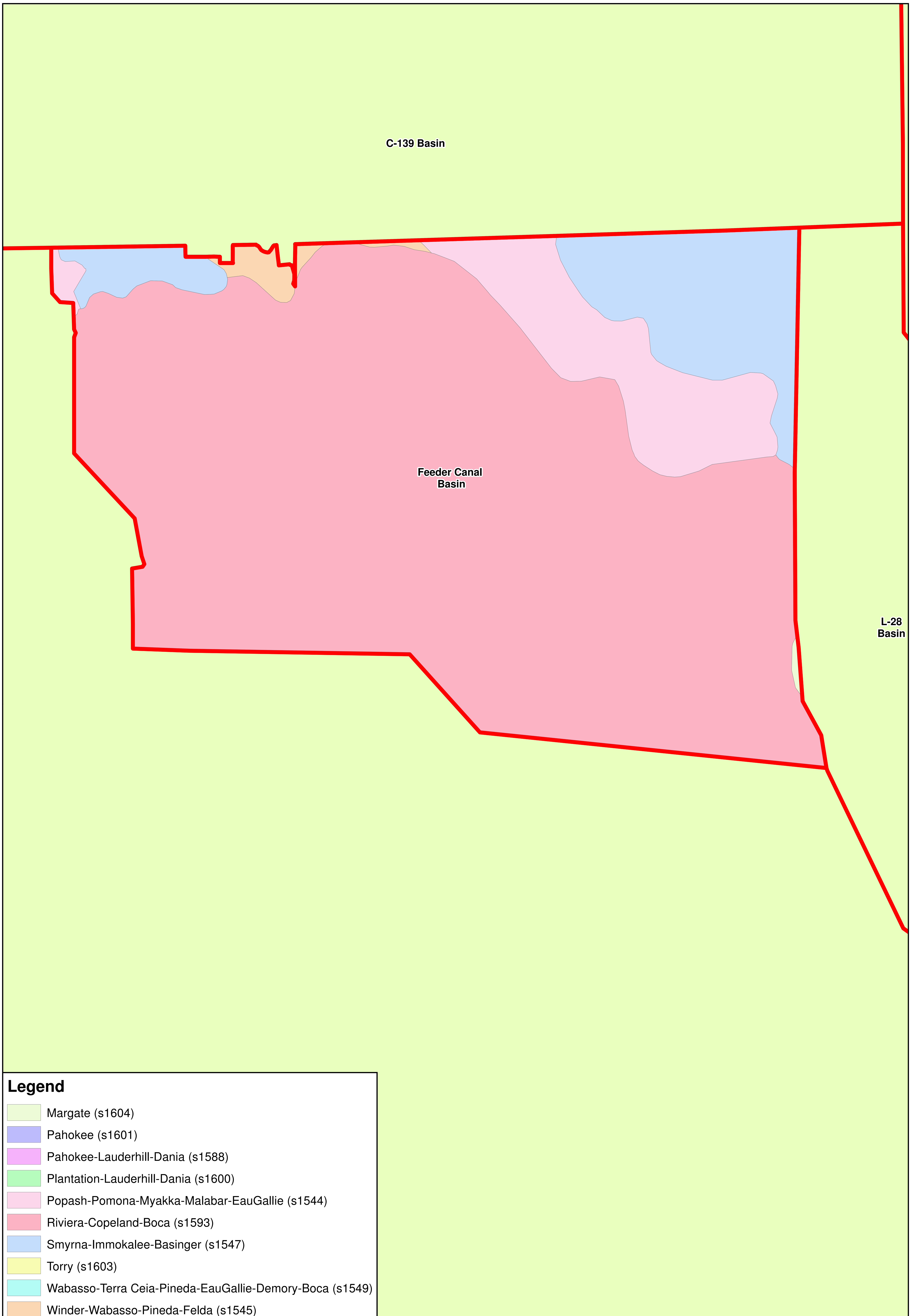
Figure 2.2.8



C-139 Basin Soils Map

1 inch = 1 mile

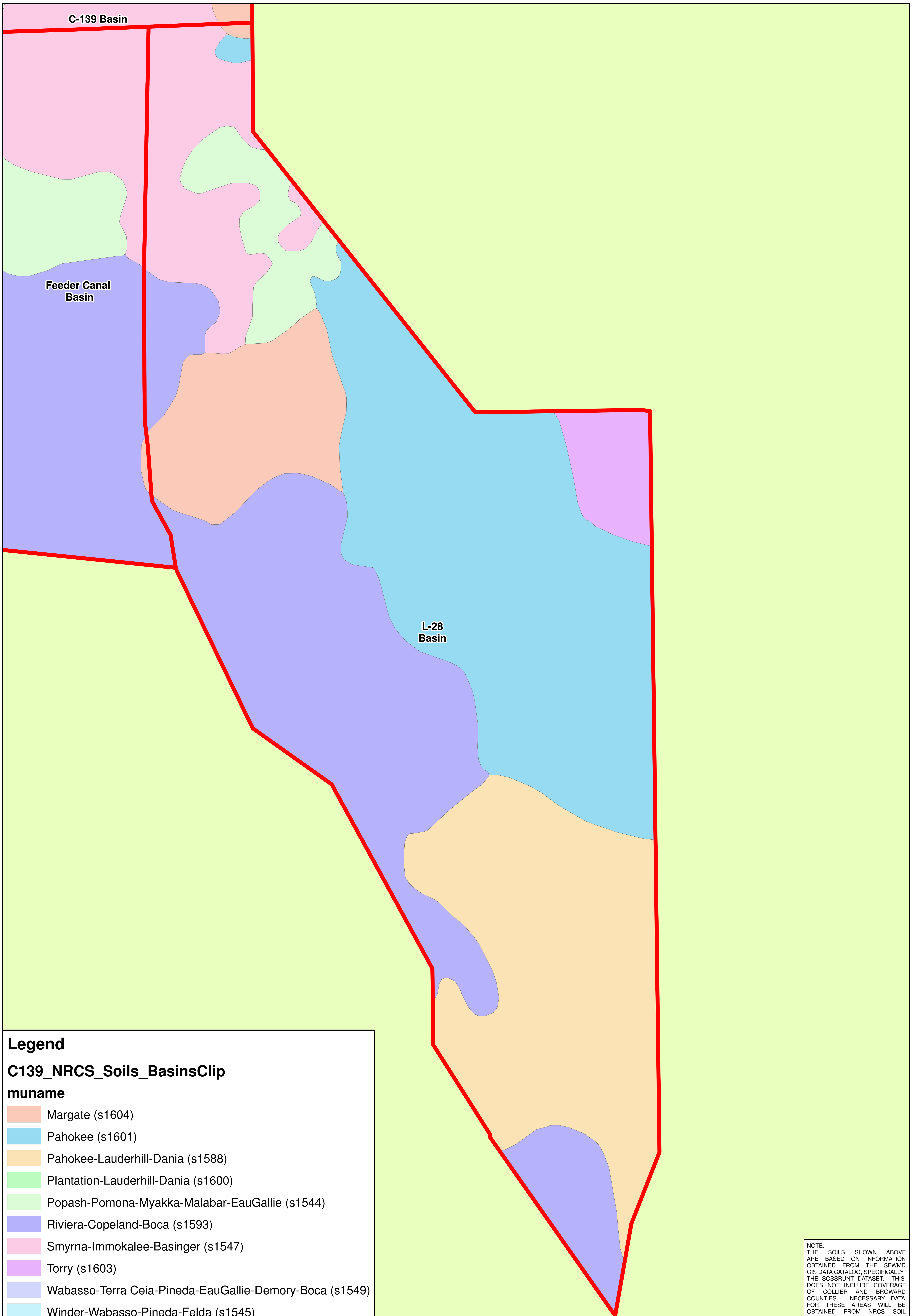
FIGURE 2.2.9



Feeder Canal Basin Soils Map

1 inch = 0.75 mile

FIGURE 2.2.10



L-28 Basin Soils Map

1 inch = 0.75 mile

1 0.5 0 1 2 3 4 Miles

FIGURE 2.2.11

2.2.3 SOURCE DATA

The figures described above were developed using a compilation of available datasets and reports. The following describes each dataset and the data source:

SFWMD STRUCTURES	District GIS (ehchasta.shp)
SFWMD CANALS	District GIS (hysurcrc.shp)
OPEN WATER	District GIS (hysurlak.shp)
C-139 BASIN	C-139 Basin Phosphorus Water Quality and Hydrology Analysis, Phase I (ADA Engineering, 2006)
FEEDER CANAL BASIN	District GIS (hyhdbwtr.shp)
L-28 BASIN	District GIS (hyhdbwtr.shp)
C-139 CANALS	C-139 Basin Phosphorus Water Quality and Hydrology Analysis, Phase I (ADA Engineering, 2006)
FEEDER CANAL BASIN CANALS	Digitized based on Final Report Basin Specific Feasibility Studies Everglades Stormwater Program Basins (SFWMD, 2002)
L-28 CANALS	Developed for current study based on available information
C-139 SUB-BASINS	C-139 Basin Phosphorus Water Quality and Hydrology Analysis, Phase I (ADA Engineering, 2006)
FEEDER CANAL SUB-BASINS	Digitized based on Final Report Basin Specific Feasibility Studies Everglades Stormwater Program Basins (SFWMD, 2002)
L-28 SUB-BASINS	Developed for current study based on available ERP information
COUNTY	Florida Geographic Data Library (www.fgdl.org)

C-139 FARM LEVEL DISCHARGES	C-139 Basin Phosphorus Water Quality and Hydrology Analysis, Phase I (ADA Engineering, 2006)
C-139 RESERVOIRS	C-139 Basin Phosphorus Water Quality and Hydrology Analysis, Phase I (ADA Engineering, 2006)
C-139 CATCHMENTS	C-139 Basin Phosphorus Water Quality and Hydrology Analysis, Phase I (ADA Engineering, 2006)
FEEDER FARM LEVEL DISCHARGES	Developed for current study based on available ERP information
FEEDER RESERVOIRS	Developed for current study based on available ERP information
L-28 FARM LEVEL DISCHARGES	Developed for current study based on available ERP information
L-28 RESERVOIRS	Developed for current study based on available ERP information
MONITORING WELLS	District GIS (ehchasta.shp)
HOWDI WELLS	USGS National Water Information System
PERMITTED CONSUMPTIVE WELLS	Provided by District Water Supply Group based on internal District database query
LAND-USE (ALL BASINS)	District GIS (2004_05_LCLU_SFWMD_Geodatabase.mdb)
SOILS (ALL BASINS)	District GIS (sossrunt.shp)

2.2.4 FARM SCALE PERMIT INFORMATION

Appendix A6 Farm Scale Permit Information, provides a farm-by-farm description of the permitted surface water management systems for each study basin. The farms within the C-139 Basin include the most extensive summaries since this data is more readily available from prior documents. ***Illustration 2.2.1*** illustrates which farms are included in ***Appendix A6***. Locations that are not included have either not been subject to the Environmental Resource Permitting process or have not been the subject of any of the documents reviewed. These locations are primarily undeveloped and will be modeled as such unless additional information is made available.

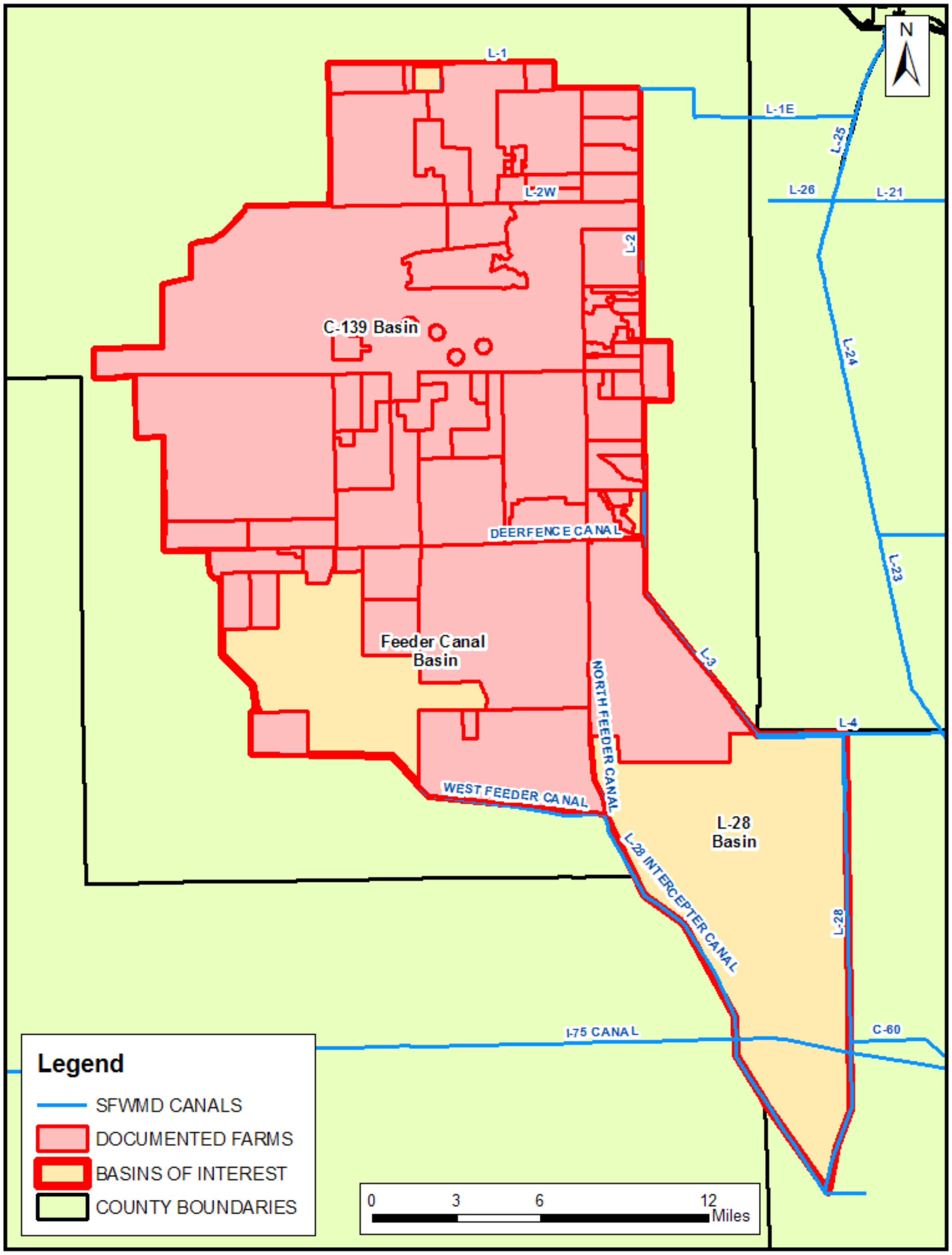


Illustration 2.2.1 Included Farms in Appendix A6

2.2.5 SUMMARY AND RECOMMENDATION

The atlas documentation illustrates the information available at the time the Atlas was prepared. There are components of the hydrologic and hydraulic characteristics that will be mapped or refined as the study progresses. An example of this additional refinement is the sub-basin and catchment delineation for the Basins. At the close of the overall project the atlas documentation will be re-visited and re-created based on new and modified data.

2.3 DATA GAP WORK PLAN

2.3.1 INTRODUCTION

This section summarizes the existing data gaps and recommends an approach to fill the identified data gaps. The data gaps discussed in this section are an outgrowth of the data collection effort described in the previous section.

Where filling the data gap is either too timely or expensive, a methodology is recommended to minimize the impact of those gaps. The Data Gap Work Plan will describe a field data collection plan to collect information that is not readily available in existing reports or databases to identify surface water and groundwater wells/structures, current drainage configuration, measure flow rates and TP concentrations, document canal characteristics and other relevant information.

2.3.2 KNOWN DATA GAPS

There are a number of data gaps in the study area. Data gaps exist for topographic data, ground water information, flow measurements at key SFWMD structures, and cross-sections in key canals.

2.3.2.1 Topography

The first data gap is a lack of reliable topographic information. As described in the Data Review, there are topographic maps which have been developed for the Southwest Florida Feasibility Study (SWFFS) and the Florida Division of Emergency Management (FDEM). These maps are available as a Digital Elevation Model (DEM), however the accuracy of the topographic information is low.

2.3.2.2 Groundwater

As described in ***Section 2.1***, there are a number of monitoring wells, however the frequency of measurement for existing monitoring wells in the C-139 Basin is insufficient to describe the range of water levels in the Lower Tamiami aquifer and surficial aquifer. Currently there are two Lower Tamiami and four surficial aquifer monitoring wells in the C-139 Basin. The two Lower Tamiami monitoring wells are USGS nested wells with monitoring of the surficial aquifer. The two remaining surficial aquifer wells are monitored monthly as part of the HOWDI well database. There are seven pairs of nested surficial and Lower Tamiami private wells in the C-139 Basin that were monitored as part of the Crooks Golden Ox Hydrogeologic Assessment that was conducted as part of a permit application. Five of these monitoring wells have a second surficial aquifer well placed in a wetland adjacent to the well pair. Data are available for these wells since March 2005. In addition to the available monitoring well data, the Lower West Coast Water Supply Plan includes a calibrated MODFLOW simulation that can be used to estimate the potentiometric surface of the surficial and Lower Tamiami aquifers.

This level of detail is sufficient for conceptual modeling and planning evaluations, however, additional monitoring wells are recommended to support the recommendations of this Study and to supplement available information when the selected alternative is designed and constructed.

2.3.2.3 Surface Water Quantity and Quality

The C-139 Basin has an adequate surface water monitoring network with regard to drainage infrastructure. The L-28 and Feeder Canal Basins have surface stage and flow data measured at N-Feed, W-Weir, S-190 and S-140. C-139 Annex outflows are measured, as are pumped flows into the canal system of the Seminole Big Cypress Reservation from the L-3 Borrow Canal via pump station G-409. This flow monitoring data should be sufficient for calibration of the selected hydrologic and hydraulic model.

One aspect of surface water monitoring that is not represented in the region is the monitoring of wetland water levels. The Study area has extensive wetland coverage; however, there are little recorded data with regard to stages and hydroperiods. With regard to surface water quality, it is believed that the ongoing monitoring efforts described in ***Section 2.1*** are sufficient to meet the model development and calibration needs of subsequent phases of this project.

2.3.2.4 Canal Cross-Sections

More current cross-sections are recommended for the North Feeder, West Feeder and L-28 Borrow Canals. As mentioned in ***Section 2.1***, the only available information is from the 1963 Central and South Florida (C&SF) design reports, which may not be representative of existing conditions. A rough comparison of information from the 1963 design reports to canal top widths (using GIS) indicates that the top widths are generally correct. However, bottom widths and bottom invert elevations are not known and may have changed in the last 45 years.

2.3.2.5 Irrigation

As described in the Data Review, there are 962 primary irrigation wells located within the boundaries of the C-139, Feeder Canal and L-28 Basins. However of that number only 147 primary wells within the Study region include information concerning the date of installation and those dates listed range from 1960 to 1994. In order to establish if there is an increasing trend in wells installed, additional research of individual consumptive use permits is required. In addition to identifying when and if permitted wells are installed, determining the relationship between water use allocation and irrigation pumpage would provide a useful indicator of model validity. Irrigation pumpage appears to be a significant component of the water budget for the study area. If SFWMD could make arrangements with a number of farmers to record their irrigation flows and provide that information to SFWMD, that information would be valuable for model calibration. If this is not possible, the modeling will need to evaluate alternative pumping scenarios for calibration purposes.

2.3.3 DATA COLLECTION PLAN

The known data gaps described above provide an indication of what types of field data should be collected as a part of subsequent phases of this project. The following sub-sections describe the recommended collection plan.

2.3.3.1 Topography

As described in ***Section 2.3.2.1***, the only available datasets are the SWFFS and FDEM DEMs. Although the proposed analysis efforts are planning-level in nature, there is some question with regard to the accuracy of this topographic data. The use of spot measurements is recommended where available to check the accuracy of the topographic data. If the spot measurements indicate a systematic problem with the DEM, adjustments may be required in consultation with Tim Lieberman of SFWMD and staff of the FDEM.

2.3.3.2 Groundwater Monitoring

As illustrated in ***Section 2.1***, there is limited recorded groundwater data for the Study region. Additional nested wells (Lower Tamiami and Surficial Wells) are recommended, as shown in ***Figure 2.3.1***, in the following locations:

1. L-1 near G-96. This well nest is needed to understand changes in soil storage in the L-1 Basin.
2. L-2 West on CR 833 south of Keri Road. This well nest is needed to understand the aquifer levels in the west portion of the L-2 West Basin.
3. Ocaloacoochee Slough. This well nest is needed to better understand fluxes between the OK Slough and the C-139 Basin.
4. CR 835 near Catchment L3-01-02. A well nest is recommended along a north-south gradient. There are questions regarding C-139 Annex pumping on water level in the vicinity of G-406.
5. CR 835 near the Deer Fence Canal. This well is a part of the proposed north-south well alignment. These wells will address this issue in combination with a well in the C-139 Annex watershed (see below).
6. C-139 Annex. One well nest is recommended south of Deer Fence Canal in the C-139 Annex. This nest is located in an area with extensive groundwater pumping.
7. West Feeder Canal Basin. One well nest is recommended in an area without extensive groundwater pumping.
8. Southern L-28 Basin. This well nest will also evaluate an area without extensive groundwater pumping.
9. L-28 Canal Basin near the S-140 pump station. This well nest will also evaluate an area without extensive groundwater pumping.

Automated data-loggers are recommended for the Feeder Canal wells HE-868 and HE-3 and the S-4 well HE-629. If sufficient funds are available, it is recommended that all the functional HOWDI listed in ***Table 2.1.6 Regional Monitoring Well Network*** have hourly data recorders.

2.3.3.3 Surface Water Monitoring

As discussed in earlier sections, there should be sufficient surface water data, both stages and flows, to calibrate the selected model. It is possible that an additional flow station would be useful to measure the flows entering the Seminole Reservation at the south end of the canal that connects the G-409 pump station to the east-west portion of the Seminole Canal at CR 833. This monitoring could be performed by field crews on an event basis for calibration purposes, or could be achieved using a side-looking Doppler installation.

With regard to wetland monitoring, there are three relatively undeveloped areas, one in each Study basin, where wetland monitoring may provide additional insight into model development and calibration. The first is in northwestern C-139 in the ALICO property near the watershed divide (approximately 4 miles west of Proposed Well 2 in ***Figure 2.3.1***), the second is in the central western Feeder Canal Basin (approximately 2 miles southwest of Proposed Well 7) and the third is in central L-28 Basin west of Snake Road (approximately 1 mile east of Proposed Well 8). By positioning these locations near the proposed groundwater well clusters, the correlation of wetland level monitoring data and regional groundwater conditions could be analyzed.

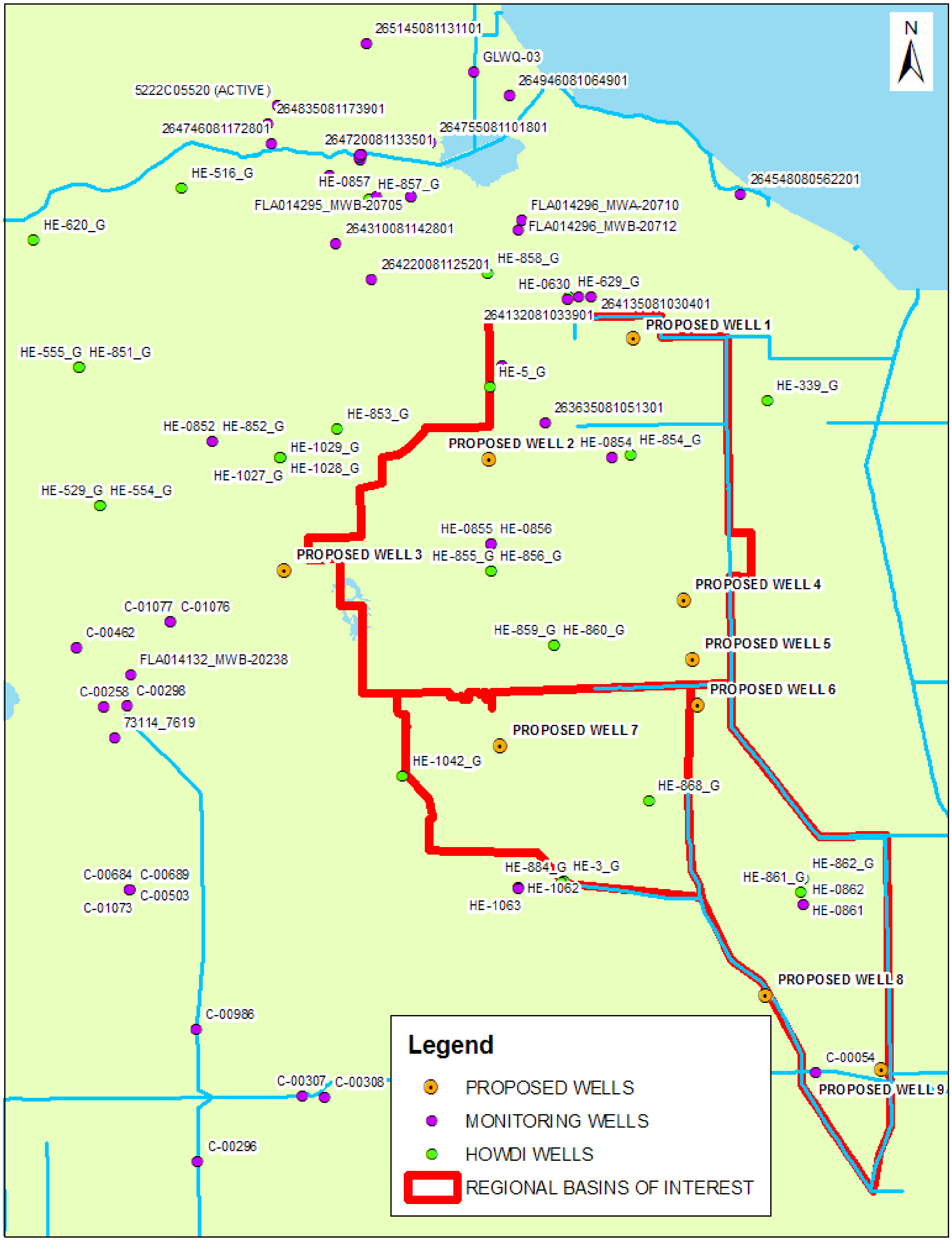
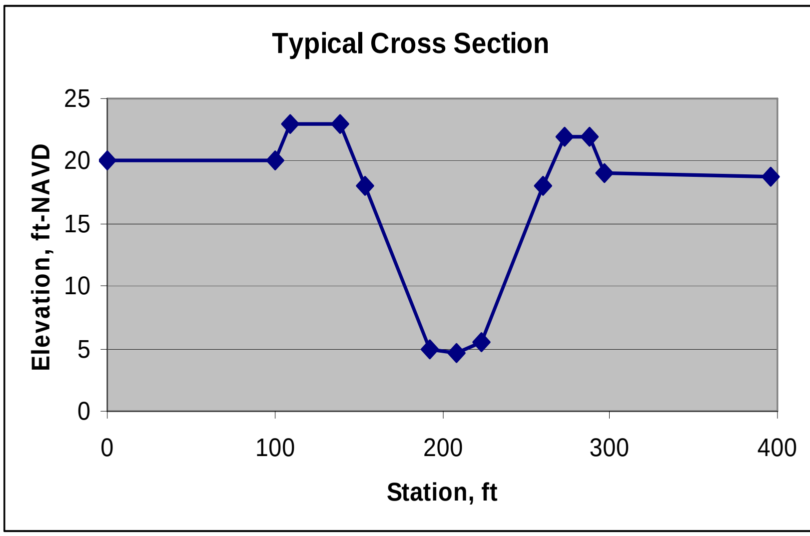


Figure 2.3.1 - Locations of Proposed Monitoring Well Nests

2.3.3.4 Canal Cross-Sections

It is assumed that for the Feeder and L-28 Canal Basins, the focus of the modeling will be limited to gaining a general understanding of the flows and stages in the Region and not providing a complete flood control analysis. Therefore only a verification of the cross-section data presented in the 1963 C&SF design documentation is needed. Eleven cross-sections are recommended and should include two natural ground shots on the left and right canal banks beyond the outside edge of the canal levee banks. If a complete flood control analysis of the Feeder Canal and L-28 Basins is required, then a minimum of thirty cross-sections would be recommended. ***Figure 2.3.2*** presents desired survey points for a typical cross-section. Horizontal information would be desired for the centerline point and the two end points.



Station, ft	Elevation, ft-NAVD
0	20
100	20
109	23
139	23
154	18
193	5
208	4.7
223	5.5
260.5	18
272.5	22
287.5	22
296.5	19
396.5	18.7

Figure 2.3.2 - Typical Cross-Section Information Desired from Survey

2.3.3.5 Data Gap Work Plan Summary

This Data Gap Work Plan describes the recommended data collection efforts needed to provide an accurate representation of the Study region within the selected model. The available data is sufficient to begin the development and calibration of the selected model. Since there is some data available for topography, canal cross-sections, surface water and ground water, it is possible to provide a coarsely calibrated model without any additional data. However, in order to minimize potential errors introduced by knowable parameters, the above data collection efforts are recommended. The discrepancy between when the collection efforts yield usable data and when the data is needed for the alternative evaluation and design effort is a potential concern. ***Table 2.3.1*** presents a summary of the proposed data collection plan including a conceptual timeline describing at what Phase of the proposed work the data will be most useful.

Notably, most of the data gathered would be incorporated into the model development and calibration. There would not be any stop/go timelines required since the data could be incorporated during the process. With regard to monitoring well installation there are some aquifer parameters that can be discerned from the installation of the monitoring well that could be useful during development and calibration. With regard to monitoring well data recording, it is assumed that a significant period of record will not be available until at least some seasonal data has been gathered. Accordingly, this data will likely be used when the selected conceptual alternatives go into the design for construction phase.

The data gaps and data collection methodologies described above are based on a review of publicly available data. Since this technical memorandum is intended to be used as a planning tool, there are no prescriptions of the proposed methodologies or cost estimates included.

Table 2.3.1 - Data Collection Plan Summary

ITEM	DATA TO BE COLLECTED	QUANTITY	PHASE OF WORK (when most useful)
1	Spot Surveys to Validate LiDAR DEMs	One (1) Set of Spot Measurements at Each Basin	Model Development and Calibration
2	Groundwater Monitoring (Well Installation)	Nine (9) Nested Wells (Lower Tamiami and Surficial Wells). See ***Figure 2.3.1*** for Locations.	Model Development and Calibration
	Groundwater Monitoring (Well Data Recording)		Proposed Project Design
3	Surface Water Monitoring	Flow Entering Seminole Reservation (Six (6) Surveys at Canal Connecting G409 & CR833)	Model Development and Calibration
		Installation & Monitoring of One (1) Staff gGauge per Basin (at Wetlands)	
4	Surveys of Canal Cross-Sections	Eleven (11) to Thirty (Max) Canal Cross sections as shown in ***Figure 2.3.2***.	Model Development and Calibration

2.4 MODEL SELECTION

2.4.1 INTRODUCTION

As described in ***Section 2.1 - Existing Reports and Data***, the two major water resource challenges facing the Study region relate to:

1. Water quality of discharges to downstream waters, and
2. Balancing annual climate patterns with flood, natural resources (wetlands) protection and water availability.

Notable increases in total phosphorus (TP) load from the subject basins have been identified and are of primary concern due to the potential downstream environmental impacts, legislative mandates of the Everglades Forever Act (EFA), and environmental regulatory programs. Recent and projected changes in the regional water resource management infrastructure have contributed to the need for a regional assessment of how existing or supplemental projects, operations, or alternative efforts could be implemented to improve the overall effectiveness of the system with respect to water quality, flood control and water supply.

Section 4 - Modeling of this report includes the development and calibration of models representing the hydrology, hydrogeology, and water quality of the region. The purpose of this model selection section was to identify the most appropriate models for this regional study.

2.4.2 REGIONAL CONCERNS AND OBJECTIVES OF THE STUDY

There are several land ownership interests in the Study region including individual private landowners, corporate-owned agricultural lands, Seminole- and Miccosukee Tribe-owned lands and state managed preservation lands. The stakeholder interests have a variety of water resource concerns including water quality, flood protection and water supply.

2.4.2.1 Water Quality

The primary focus of the water quality concern in the Study region is increased nutrient discharge in the form of TP. Consistent with the EFA and the Long-Term Plan, the District has been implementing a source control program to reduce TP loads within surface water discharges. The source control program requires mandatory utilization of Best Management Practices (BMP) in the C-139 Basin and encourages voluntary utilization of BMPs in the Feeder Canal and L-28 Basins. Unfortunately, the measured annual TP loads from each basin have exceeded the target values. Based on recorded monitoring data and discussions with District staff, oftentimes the compliance targets are exceeded over the course of a small number of high runoff events. Accordingly, proposed control alternatives should address both peak and average discharge conditions.

The primary objective of this study is to develop and analyze local and regional alternatives for reducing annual TP loads in basin discharges. Therefore, it is recommended that the models considered for providing analysis of the regional system and the proposed alternatives should be capable of representing the land management and natural processes that determine TP loads in runoff. For similar purposes, it is recommended that the models considered should be capable of event-based, short-term simulations for high runoff conditions and capable of forecasting long-term annual average annual TP loads in basin discharges. Although these characteristics may not preclude the selection of models with weaknesses in simulating water quality, these processes are important to consider.

2.4.2.2 Flood Protection

Although flood protection is not the primary focus of this Study, degradation of flood protection cannot occur as part of the implementation of any proposed alternatives. The L-1, L-2 and L-3 Canals were not constructed primarily for conveyance purposes, but instead were focused on providing borrow materials to construct the L-1, L-2 and L-3 Levees.

The limited conveyance of the drainage infrastructure results in out-of-bank flows for high runoff events. Therefore, the models considered must provide a methodology for representing flooding within fields adjacent to the canals. Although out of bank flow could be handled in a one-dimensional hydraulic model by assuming wide cross-sections, the low relief topography common in the Region does not lend itself to the definition of standard floodplains with easily defined boundaries. A two-dimensional model with linkage between the channel and adjacent overland areas allows for the most accurate representation of the Study Region. The preference would be for a model that has an overland flow routine for areas outside of the main canal system and full-linkage between canals and adjacent overland areas.

2.4.2.3 Water Supply

The typical semiannual dry season for the region poses an additional stress on the operation of Stormwater Treatment Areas (STAs) that treat discharges from this basin. Inadequate dry weather water supply increases the likelihood that phosphorus sequestered within the STAs will be remobilized and released to downstream areas. Maintaining the water supply to these STAs during the dry season may improve the overall phosphorus treatment provided by those systems. Along with the water supply needs for the STAs, other consumptive uses increase during the dry season.

Similar to flood protection, water supply needs are not the primary focus of this Study. However, no negative impacts to the availability of water for consumptive use are allowed as part of the implementation of any proposed alternatives. Since the C-139, Feeder Canal and L-28 Canal Basins are all rain-driven systems and currently receive no external source of water, the majority of the permitted consumptive use allocations within the region are for groundwater withdrawals from the Lower Tamiami Aquifer. The Lower Tamiami Aquifer is found at depths of approximately 80 – 100 feet, separated from the surficial aquifer by a semi-confining unit.

Intensification of land utilization over the past 20 years has lead to an increase in irrigation withdrawals and there have been recent studies that suggest that the increased withdrawals may impact regional hydrology by depressing the surficial aquifer and increasing surface water losses during dry periods and increasing the quantity of surface water runoff in wet periods. In addition, consumptive use permitting requirements include minimizing impacts to wetlands, therefore impacts to wetlands in the Region are generally reflective of impacts to the surficial aquifer. As documented in Deliverable 10.4 of the C-139 Basin Phosphorus Water Quality and Hydrology Analysis (ADA, 2007), the limited representation of regional hydrogeology reduced the accuracy of past analyses. Therefore, future model simulations should incorporate a sound methodology for representing the multi-layer groundwater system and its interconnection with the surface water system.

2.4.2.4 Additional Considerations

One consideration dealing with the water quality, flood protection and water supply concerns of the stakeholders is a potential diversion of a portion of the S-4 Basin runoff south to the C-139 Basin, instead of north to Lake Okeechobee. As discussed in Deliverable 2.1.1, the S-4 Basin Feasibility Study (Burns & McDonnell, 2008) discusses a potential diversion to the C-139 Basin of 64 percent of the water historically discharged north to Lake Okeechobee. Based on average annual discharges from WY1993 to WY2007, the average diverted quantity would amount to 28,800 ac-ft/year.

In order to utilize this additional inflow as a source for water supply, compensating treatment and or storage projects may need to be implemented to prevent any adverse impacts to water quality or flood protection. The models considered must provide a methodology for representing the treatment and/or storage required of a potential diversion of a portion of S-4 Basin runoff.

2.4.3 EXISTING MODELS IN THE REGION

As part of various projects, a number of models have been developed previously for the Study region, However, the scope of those projects were different and accordingly the models developed for the basins of interest have different strengths and weaknesses.

There was an ICPR simulation developed for the Western Basins Environmental Assessment (Mock-Roos, 1992) that includes the entire area of interest. However this simulation does not include any water quality components and it was developed prior to the significant changes to the regional land-use and drainage infrastructure that have occurred within the basins. There was an XP-SWMM model developed for the S-4 Basin Feasibility Study (Burns & McDonnell, 2008) to evaluate conveyance of diverted runoff through the C-139 Basin. However, that model did not include significant detail with respect to hydrologic components of the C-139 Basin.

The three recent simulations developed for the Study region with a scope of work more in accordance with the current proposed modeling effort are discussed as follows:

2.4.3.1 C-139 Basin Phosphorus Water Quality and Hydrology Analysis

As part of the C-139 Basin Phosphorus Water Quality and Hydrology Analysis (ADA, 2007) WAM was used to simulate hydrology and TP dynamics for the C-139 Basin only. The strengths of the WAM simulation were in representation of field-scale water management and nutrient BMPs. The WAM simulation also provided long-term simulations of the seasonal variability in management practices and structure operations. The weakness of the WAM modeling effort was an inability to resolve the interactions between surface water and groundwater.

2.4.3.2 C-139 Watershed Study

As part of the C-139 Watershed Study developed for the Compartment C BODR, HEC-HMS and MIKE 11 was used for flood event simulations. The strength of the modeling approach was in simulating short-term high runoff events. The weakness of the modeling approach was in representing a number of sequential runoff events where the ground water elevations increased throughout the wet season, and in a lack of representation of groundwater flow into the canals. In addition, the de-coupled hydrology and hydraulic models did not properly simulate over bank storage and flow on the floodplain during high runoff events. Additionally, the modeling did not include the effect of evapotranspiration and the modification of antecedent soil conditions.

2.4.3.3 Lower West Coast Water Supply Planning Model

In 2003, Marco Water prepared a report documenting a calibrated groundwater flow model (MODFLOW) for the entire Lower West Coast region of Florida, covering a total area of 5,129 square miles. Included in the model domain were the C-139, Feeder Canal and L-28 Basins. The transient model calibration was conducted for a 15-year period from January 1986 through December 2000. The MODFLOW simulation included the WETLANDS package and utilized a 700-ft resolution. The model includes existing irrigation features up to December 2000. However for use in future efforts, minor recalibration is recommended to include consumptive users added after December 2000.

2.4.4 POTENTIAL ALTERNATIVES

In order to provide perspective for the qualification of selected modeling tools, it is important to identify categories of potential alternatives for evaluation. Based on previous efforts in the Region and throughout the District, there are several conceptual categories of potential alternatives that may be identified for evaluation as part of Phase II, such as:

1. Storage in above ground impoundments
2. Storage and treatment in above ground impoundments
3. Evaluation of S-4 diversion alternatives
4. Diversion of runoff through infrastructure changes
5. Diversion of runoff through operational changes
6. Reduction in withdrawals from the Lower Tamiami Aquifer
7. Re-use of stormwater from internal surface water management systems for irrigation
8. Use of surface water from the regional canal system for irrigation
9. Alternative water storage
10. Alternative treatment technologies

These conceptual categories are not intended to limit the types of alternatives simulated as part of the Phase II evaluation; however the selected model should provide the capabilities to represent at least these types of potential alternatives. Some of the mechanisms required to implement these alternatives would be:

- simulation of conditionally operated gates and pumps based on stage or flow conditions within the hydraulic network,
- simulation of evaporation from open water surfaces,
- simulation of surface water seepage to groundwater,
- evaluation of the impact on the Lower Tamiami Aquifer by irrigation withdrawals,
- characterization of irrigation demands, and
- parameterization of the irrigation source.

2.4.5 DATA LIMITATIONS

As described in Existing Reports and Data Reviews Section, there are limitations to the data available to develop and calibrate a model of the Study Region. The two most significant limitations are with regard to consumptive water use and measured water quality.

2.4.5.1 Consumptive Water Use

As described in the review of available data, the only available information describing withdrawals from the Surficial and Lower Tamiami aquifers for irrigation purposes is found in consumptive use permits. Although this does give an indication to the permitted allocation, it is not reflective of irrigation demand which is largely a function of land-use, management practices and meteorological conditions. Since representing the Lower Tamiami aquifer has been identified as a primary objective of this modeling effort, the selected model should be capable of either inputting pumpage data that becomes available or inferring irrigation demand based on known parameters such as land-use and rainfall.

2.4.5.2 Water Quality

Within the Study Region the availability of water quality data is limited both spatially and temporally. The best temporal records are provided by both manual and automatic water quality sampling efforts at major structure locations, however these sites do not provide the spatial distribution required to evaluate the performance of a water quality model at any smaller scale than total Basin loads. There are some locations where grab sampling has been performed at the sub-basin scale, however there is no temporally continuous record at these locations. With regard to farm scale water quality parameters, the only available information is land-use and management practices. Because of this data limitation, the development and calibration of models that utilize complex water quality parameterization schemes may be limited and a simplistic water quality model may be as appropriate.

2.4.6 MODEL EVALUATION CRITERIA

Based on the Study objectives described above, the following components of the existing system should be properly represented in the selected models. These evaluation criteria may require that more than one model be used to represent these components.

1. Field-scale water management BMPs (above ground impoundments, multiple irrigation techniques, water table management, etc.),
2. Field scale nutrient BMPs (varying application rates, slow release fertilizer, reduced cattle density, etc.),
3. The fate and transport of TP within runoff,
4. Backwater conditions during the wet season resulting from canal conveyance limitations and hydraulic control structures,
5. Variable hydraulic control structure operations,
6. Bank overflow and storage of water in farm areas adjacent to the canal in portions of the watershed,
7. Simulation of regional and local wetlands,
8. Interactions between the surficial and Lower Tamiami aquifers,
9. Two-way exchange between surface waters and the surficial aquifer,
10. Impacts of varying irrigation demands (pumpage rates) on surface water and the surficial and Lower Tamiami aquifers,
11. The fate and transport of TP within groundwater,

12. Temporal variation of runoff, storage of runoff in off-line basins, and surface-ground water interactions with existing and proposed reservoirs (continuous, long-term simulation),
13. Peak discharge events with high TP loads (design event, short-term simulation),
14. Reasonable model set-up time and run time,
15. Availability of model pre-processing and post-processing tools or modules,
16. Capability to simulate expected basin operations,
17. Capability to simulate water storage facilities as proposed alternatives,
18. Prior use in the Study Region in prior modeling efforts,
19. Capability to be used without model code modification,
20. Capability to use readily available irrigation demand and water quality data in development and calibration, and
21. Wide scale acceptability by the technical community in South Florida.

2.4.7 PRACTICAL APPLICATION

There are additional concerns with respect to development cost, schedule and run-time that should also be considered. In general, models that provide physically-based representations of the natural system also require significant effort to develop. Oftentimes the effort required to develop and calibrate complex parameterization schemes increase the schedule and budget for the project. To an even greater degree, the effort required to couple two individual models or to add new capabilities to an existing model can be very difficult to define. Each of these additional levels of complexity leads to increased simulation run-times which can cause difficult to manage project schedules. In a modeling project, increased model complexity, the development of multiple models and extended run-times may lead to cost and schedule overruns.

Because of the realistic constraints of cost and schedule, it is valuable to consider the model capabilities from the perspective of effort required to develop, calibrate and simulate the Study region and the eventually selected alternatives. A valuable consideration in reducing development effort is to make use of previously developed models such as HEC-HMS, MIKE 11, MODFLOW or WAM. Other practical considerations should be to reduce the level of model complexity, reduce the use of multiple stand-alone models and reduce the development of additional model features where it is not warranted by the project objectives.

2.4.8 EVALUATION OF AVAILABLE MODELS

A variety of hydrologic, hydraulic, groundwater, and water quality models were vetted in relation to the model requirements above. The modeling requirements were assembled into a matrix to allow comparison with the capabilities of the various model candidates. ***Table 2.4.1*** presents a matrix presenting the capabilities of 10 models and some combinations of models as they apply to the requirements presented above. Due to the wide range of requirements, a single model is not expected to meet all the requirements.

Table 2.4.1 - Evaluation Matrix of Available Models

REQUIREMENTS	2x2	HEC-HMS / HEC-RAS	MIKE SHE / MIKE 11	MIKE SHE/ MIKE 11 / ECOLAB	GSFLOW	MODBRANCH	MODFLOW	RSM	SWMM	SWMM / MODFLOW	WAM	WAM / MODFLOW	WaSh
Field-scale water management BMPs		W	S	S		W		S	S	S	S	S	S
Field scale nutrient BMPs				S					W	W	S	S	S
Nutrient Fate and Transport in Surface Water				S					W	W	S	S	S
Backwater conditions		S	S	S		S		S	S	S			W
Variable Hydraulic Control Structure Operations	S	S	S	S		S		W	S	S	S	S	S
Bank overflow and floodplain storage	S	W	S	S	W			S	W	W			S
Simulation of regional and local wetlands	S		S	S	S	S		S			S	S	S
Interactions between the surficial and Lower Tamiami aquifers			S	S	S	S	S			S		S	W
Two-way exchange between surface waters and the surficial aquifer	W	W	S	S	S	S	S	S		W		W	S
Impacts of Lower Tamiami pumpage rates	W		S	S	S	S	S	W		S		S	W
Groundwater fate and transport of TP											S	S	S
Long-term simulation	S		S	S	S		S	S	S	S	S	S	S

REQUIREMENTS	2x2	HEC-HMS / HEC-RAS	MIKE SHE / MIKE 11	MIKE SHE/ MIKE 11 / ECOLAB	GSFLOW	MODBRANCH	MODFLOW	RSM	SWMM	SWMM / MODFLOW	WAM	WAM / MODFLOW	WaSh
Design-event simulation		S	S	S		S			S	S	W	W	W
Set-up and Run-time	W	S	S	S	W	W	S	W	S	W	W	W	S
Pre-processing and post-processing tools	W	S	S	W	S	S	W	W	S	W	W	W	S
Capability to simulate expected basin operations	W	S	S	S	W	S	W	W	S	W	W	S	S
Capability to simulate water storage facilities	S	W	S	S		S		S			W	W	S
Previously used in the Study Region		W	W	W			S		W		S		
Model code requires no additional modification	W	S	S	S	S	S	S	W	S	W	S	W	W
Data for water quality parameterization and calibration readily available				W					W	W	S	S	S
Widely accepted	S	S	S	W	W	W	S	W	S	W	S	W	S

S – STRONG CAPABILITY
W –WEAK CAPABILITY
BLANK – LITTLE OR NO CAPABILITY

2.4.9 SUMMARY AND RECOMMENDATIONS

As demonstrated in ***Table 2.4.1***, each model provides a unique set of strengths and weaknesses. Some of the models that appear to demonstrate a poor fit with the selection criteria, do so based on either a lack of strength in simulating groundwater or surface water or both. Below is a description of the strengths and lack of for the models considered:

- The **2x2** and **HEC-HMS / HEC-RAS** do not have water quality and Lower Tamiami representation methodology. **RSM** is designed with a water quality module, however, the water quality feature will not be available in time to meet the projected schedule. Although the lack of a water quality or Lower Tamiami component does not preclude a model from consideration, since these models currently do not have either capability they are not suitable for use with this Study.

- The **MODFLOW, MODBRANCH** and **GSFLOW** lack the capabilities to provide accurate representation of hydraulic control structures in combination with short run times. Since the hydraulics of the Study Region are largely impacted by water control structures, and one of the primary concerns is high-runoff events, it is important that the selected model has the capability to represent control structure operations during design event conditions.

- With regard to **SWMM** and **WAM** the poor representation of surface water interaction with groundwater prevents their use as stand-alone models. Therefore if **WAM** or **SWMM** was selected, a **MODFLOW** model should be developed in parallel to be used as a lower boundary condition along with a linkage mechanism to connect the two models.

- The **WaSh** software includes hydrologic and hydraulic modeling of surface water. The **WaSh** simulation also includes a one-layer groundwater model, providing an improvement with respect to groundwater surface water interactions. However, the development of a time-varying potentiometric map of the Lower Tamiami aquifer is also recommended to provide a lower boundary condition for the single groundwater layer. **WaSh** also provides water quality modeling capabilities based on the Event Mean Concentration (EMC) values associated with each land-use and includes phosphorus sequestration and mobilization modeling, and land use changes needed to effectively predict future phosphorus performance. The EMC methodology used by **WaSh** is less complex than the physically-based processes of **WAM** and could allow for a shorter model development time. In the case of **WaSh** or **WAM**, the water quality methodologies would have to be calibrated to the observed water quality data.

- **MIKE SHE / MIKE 11** offers the capability of representing a fully-integrated surface water and multi-layer groundwater simulation, which could better depict the impact of Lower Tamiami consumptive use and out-of-bank flows during peak stage conditions. However, for **MIKE 11**, water quality modeling is performed by a separate software package (**EcoLab**) which has been used in the C-43 Basin and the City of Plantation. However it has not been generally accepted as a primary water quality modeling tool in South Florida.

There are no models that individually provide strong capabilities with respect to all the requirements of the Study objectives. In the case where none of the available models provide the necessary capabilities, there are two approaches for meeting the project goals: either select more than one model or prioritize the requirements for model capabilities such that a single model can best meet those requirements.

2.4.9.1 Multiple Model Approach

The first approach is to select more than one model. Representing the system using multiple models could be done by either using the results of one model as input for the other, or developing them independently and utilizing them separately to answer separate questions.

An example of using one model's results as input for another would be coupling WAM or WaSh with a time varying grid of potientiometric heads for the Lower Tamiami aquifer. This allows for the water quality strengths of either WAM or WaSh to be enhanced with a representation of the groundwater system such that their independent weaknesses are minimized.

An example of utilizing two models separately or independently would be to utilize the MIKE SHE / MIKE 11 model to simulate groundwater and surface water to clearly describe flood protection and water supply issues, but a separate WAM or WaSh simulation could be developed and used to simulate the water quality conditions in the region separately. The selection of either WAM or WaSH is based on the fact that they are the most capable nutrient models available to simulate water quality concerns separate from the MIKE SHE / MIKE 11 simulation. The benefits of WAM are in its physically-based representation of farm-scale nutrient fate and transport. The benefits of WaSh are in the way groundwater hydrology and nutrient transport are handled.

2.4.9.2 Single Model Approach

The second approach is to prioritize the requirements for model capabilities. As described in ***Section 2.4.2 – Regional Concerns and Objectives of the Study***, there are significant water quantity related issues in the Study region: Flood protection, water supply, storage of storm water for re-use, irrigation water supply and the potential S-4 diversion through C-139 to STA 5 and STA 6. With respect to the water quality concerns of the region there is evidence that the high loads are closely related to excess runoff. Therefore, the requirement of simulating the fate and transport of TP may be a lower priority than representing water quantity processes. In this case, a model such as MIKE SHE / MIKE 11 could be utilized to simulate all of the water quantity processes, while the water quality analyses could be provided using statistical post-processing.

The statistical post-processing analysis of flow and TP concentration data would rely on measured flows and TP concentrations to apportion nutrient discharges from the C-139 Regional sub-basins. The data used in the post-processing analysis would include nutrient and flow data collected as part of the expanded monitoring network that was implemented in 2007 along with other historical data. These data would hopefully provide an understanding of the distribution of nutrient discharges from the sub-basins.

The post-processing analysis would include development of a spreadsheet model that would include a definition of nutrient assimilation in existing on-farm reservoirs as well as nutrient delivery ratios from L-2 and L-3 tributaries. This spreadsheet model will be a coarse model using simple assumptions which could be used to provide conceptual level evaluations of Basin-scale water supply and nutrient retention alternatives at an annual resolution. This post-processing analysis would not provide enough detail to evaluate proposed alternatives on an inter-annual or farm-level scale.

Another option for the single model approach is to use the WaSh model to perform all hydrology, hydraulics, geohydrology, and water quality modeling. WaSh has been used in several large basin-specific studies for both the District and FDEP. A minor deficiency of the WaSh model is that it is not as fully capable as MIKE SHE/MIKE 11 in modeling the backwater-controlled hydraulics of the region. The WaSh model's groundwater model is a single-layer representation, similar to the RSM software. Since the region is expected to be affected by pumping from the underlying Lower Tamiami Aquifer, the WaSh model may require code modification to better represent seepage loss from the Surficial to the Lower Tamiami Aquifer. These losses can be modeled in the current WaSh version, but the losses are not related to head differences between the aquifers. The current version may still be suitable to model the region.

2.4.9.3 Model Recommendation

There are several components to the successful execution of a modeling analysis. The primary concerns with regard to model selection are technical capabilities and practical application with respect to project budget and schedule. Based on the above discussion of the capabilities of available models and the practical constraints of application, there are two initial separate recommendations.

2.4.9.3.1 Alternative 1: Multiple Model Approach

If technical capabilities are of primary importance, then developing two separate models is recommended including:

- MIKE SHE / MIKE 11 model of the groundwater and surface water hydrology and hydraulics,

- WaSh model to simulate the fate and transport of TP in the Study region.

It is our opinion that the former recommendation of a Multiple Model Approach including MIKE SHE/MIKE 11 Model combined with a WaSh model has the advantages of developing tools that can comprehensively address the management of source control programs. Also the ground water interaction capability of WaSh can provide more complete evaluation of TP fate and transport in the C-139 Region. Another advantage of utilizing WaSh (or WAM) for the water quality would be the ability to provide a useful tool for evaluating future management and operation revisions to the basins, to simulate dynamic nutrient processes such as re-suspension, and the flexibility to model different alternatives during Phase II of the project.

2.4.9.3.2 Alternative 2: Single Model Approach

If there are constraints with regard to budget and schedule, then developing only a MIKE SHE / MIKE 11 model is recommended. If this is the selected model alternative, a statistical post-processing of simulated water quantity results and measured water quality data would be used to represent long-term average annual TP loads in the Study region.

This spreadsheet model would be a coarse model using simple assumptions, This method would be able to provide the tools necessary to address the impacts of notable increases in consumptive withdrawals and the management of increased runoff volume; however it would not be able to provide a useful tool for evaluating future management and operation revisions to the basins nor to simulate dynamic nutrient processes such as re-suspension.

As additional information becomes available, more detailed assessments could be conducted as part of subsequent modeling efforts using either a more complex spreadsheet model or an established watershed water quality model such as WAM or WaSh.

The spreadsheet model may also be able to represent the off-line storage and nutrient assimilation of future reservoir alternatives. However, the complexity and cost of this method may become similar to or greater than that of using WaSh. In addition the spreadsheet model may lack several of the WaSh capabilities such as sediment re-suspension, surface water/groundwater interaction and water budget accounting.

Past modeling efforts on similarly sized regions indicate that the WaSh modeling is less costly than the spreadsheet modeling performed for the EAA study. Also the ground water interaction capability of WaSh can provide more complete evaluation of TP fate and transport in the C-139 Region. Recent improvements to the WaSh model software have further improved the accuracy and ability to develop water quality models of basins with lower effort and cost.

2.4.9.3.3 Final Recommendation

Based on comments received from the District during the review of the Draft Modeling Selection Memo, URS has the following recommendation:

Due to the limited reliable water quality data in the Feeder canal basin and the L-28 basin and cost constraints the District should pursue the former recommendation of a MIKE SHE/MIKE 11 Model combined with a statistical post-processing of available water quality data from the region. Although this option could be used to provide conceptual level evaluations of Basin-scale water supply and nutrient retention alternatives at an annual resolution, this post-processing analysis would not provide enough detail to evaluate proposed alternatives on an inter-annual or farm-level scale.

The final calibrated model developed under Phase I is expected to be capable of representing the hydrology of the region despite the known limitations described in related memoranda. Under Phase II the model is expected to be sufficient for providing comparative evaluations of several proposed alternatives. Additional data from the field, and continuing refinement of the base models further during Phase II will help improve the performance of the model. As additional information becomes available, more detailed assessments could be conducted using either a more complex spreadsheet model or an established watershed water quality model such as WAM or WaSh.

2.4.10 MODEL REFERENCES

SFWMM (2x2): South Florida Water Management District (SFWMD) – Documentation of the South Florida Water Management Model, Version 5.5, November 2005.

HEC-HMS: U.S. Army Corps of Engineers (USACE) – Hydrologic Modeling System User's Manual, Version 3.3, September 2008. (http://www.hec.usace.army.mil/software/hec-hms/index.html)

HEC-RAS: U.S. Army Corps of Engineers (USACE) – River Analysis System User's Manual, Version 4.0, March 2008. (http://www.hec.usace.army.mil/software/hec-ras/)

MIKE SHE / MIKE 11 / ECOLAB: Danish Hydrologic Institute (DHI) - Graham, D.N. and M. B. Butts (2005) Flexible, integrated watershed modeling with MIKE SHE. In Watershed Models, Eds. V.P. Singh & D.K. Frevert Pages 245-272, CRC Press. ISBN: 0849336090. (http://www.dhigroup.com/)

GSFLOW: U.S. Geological Survey (USGS) - Coupled Ground-water and Surface-water FLOW model based on the USGS Precipitation-Runoff Modeling System (PRMS) and Modular Ground-Water Flow Model (MODFLOW-2005). (http://water.usgs.gov/nrp/gwsoftware/gsflow/gsflow.html)

MODFLOW: U.S. Geological Survey (USGS) - Harbaugh, A.W., and McDonald, M.G., 1996, User's documentation for MODFLOW-96, an update to the U.S. Geological Survey modular finite-difference ground-water flow model: U.S. Geological Survey Open-File Report 96-485, 56 p. (http://water.usgs.gov/nrp/gwsoftware/modflow.html)

MODBRNCH: U.S. Geological Survey (USGS) - Swain, E.D., and Wexler, E.J., 1996, A coupled surface-water and ground-water flow model (MODBRNCH) for simulation of stream-aquifer interaction: U.S. Geological Survey Techniques of Water-Resources Investigations, book 6, chap. A6, 125 p. (http://water.usgs.gov/cgi-bin/man_wrdapp?modbrnch)

RSM: South Florida Water Management District – Theory Manual for the Regional Simulation Model, May 2005.

SWMM: U.S. Environmental Protection Agency – Storm Water Management Model User's Manual, Version 5.0. Lewis A. Rossman, Water Supply and Water Resources Division, National Risk Management Laboratory. (http://www.epa.gov/ednnrmrl/models/swmm/)

WAM: Soil & Water Engineering Technology, Inc. (SWET) – Watershed Assessment Model Training Manual, Southeastern Climate Consortium: Gainesville, FL, June 2006.
(http://www.swet.com/index.html)

WaSh: South Florida Water Management District – WaSh Model Theory Documentation, URS Corporation, October 2008.

3 FIELD DATA

3.1 INTRODUCTION

The objective of the field data collection is to gather the information necessary to fill the gaps identified in the Data Gap Work Plan presented in ***Section 2.3***. The data collection exercise for ground water elevations will be conducted over a sufficient period of time to accurately reflect the area's conditions throughout a wet/dry season cycle. Due to delays in acquiring the access agreements from the different farmers, the Big Cypress Seminole Reservation (BCSR), and the Miccosukee Indian Reservation (MIR), a complete wet/dry season cycle of ground water elevation has not been completed. Therefore, the data collection will continue in Phase II.

Data will continue to be collected in subsequent design phases. Other types of data might also be defined and collected based on alternatives/scenarios selected if necessary. The data collected will help to further refine the open-ended baseline regional model during the evaluation of project alternatives.

3.2 DATA GAP WORK PLAN

The Data Gap Work Plan presented in ***Section 2.3***, which describes the recommended data collection efforts needed to provide an accurate representation of the study region within the selected model. Since there was some data available for topography, canal cross-sections, surface water and ground water, it was possible to provide a coarsely calibrated model without any additional data. Therefore, the available data was sufficient to begin the development and calibration of the selected model. However, in order to minimize potential errors introduced by knowable parameters, the data collection efforts presented below were recommended. ***Table 3.1*** presents a summary of the proposed data collection plan including a conceptual timeline delineating the proposed work phase at which the data will be most useful. The following sections present the different data collection efforts including data collection plan modifications made in accordance with access availability.

Some of the data gathered was incorporated into the model development and calibration. The data used for the calibration and validation of the model is described in ***Section 4.2 - Calibration and Validation.*** There will not be any stop/go timelines required since any additional data can be incorporated during the process. Some aquifer parameters can be discerned from the installation of the monitoring wells. Due to the timing of the well drilling and the calibration and validation efforts, some of the parameters were used and some will be integrated in Phase II. With regard to monitoring well data recording, it is assumed that a significant period of record will not be available until at least some seasonal data has been gathered. Accordingly, this data will likely be used in when the selected conceptual alternatives go into the design for construction phase.

Table 3.1 - Data Collection Plan Summary

ITEM	DATA TO BE COLLECTED	QUANTITY	PHASE OF WORK (when most useful)
1	Topography: Spot surveys to Validate the DEM	One (1) Set of Spot Measurements at Each Basin	Model Development and Calibration
2	Surveys of Canal Cross-Sections	Eleven (11) Canal Cross Sections. See ***Figure 3.2*** for Locations.	Model Development and Calibration
3	Groundwater Monitoring (Well Installation)	Nine (9) Nested Wells (Lower Tamiami and Surficial Wells). See ***Figure 3.1*** for Locations.	Model Development and Calibration
	Groundwater Monitoring (Well Data Recording)		Proposed Selected Project Design
4	Surface Water Monitoring	Flow Entering Seminole Reservation (Six (6) Surveys at Canal Connecting G409 & CR833)	Model Development and Calibration
		Installation & Monitoring of One (1) Staff Gauge per Basin (at Wetlands)	Proposed Selected Project Design

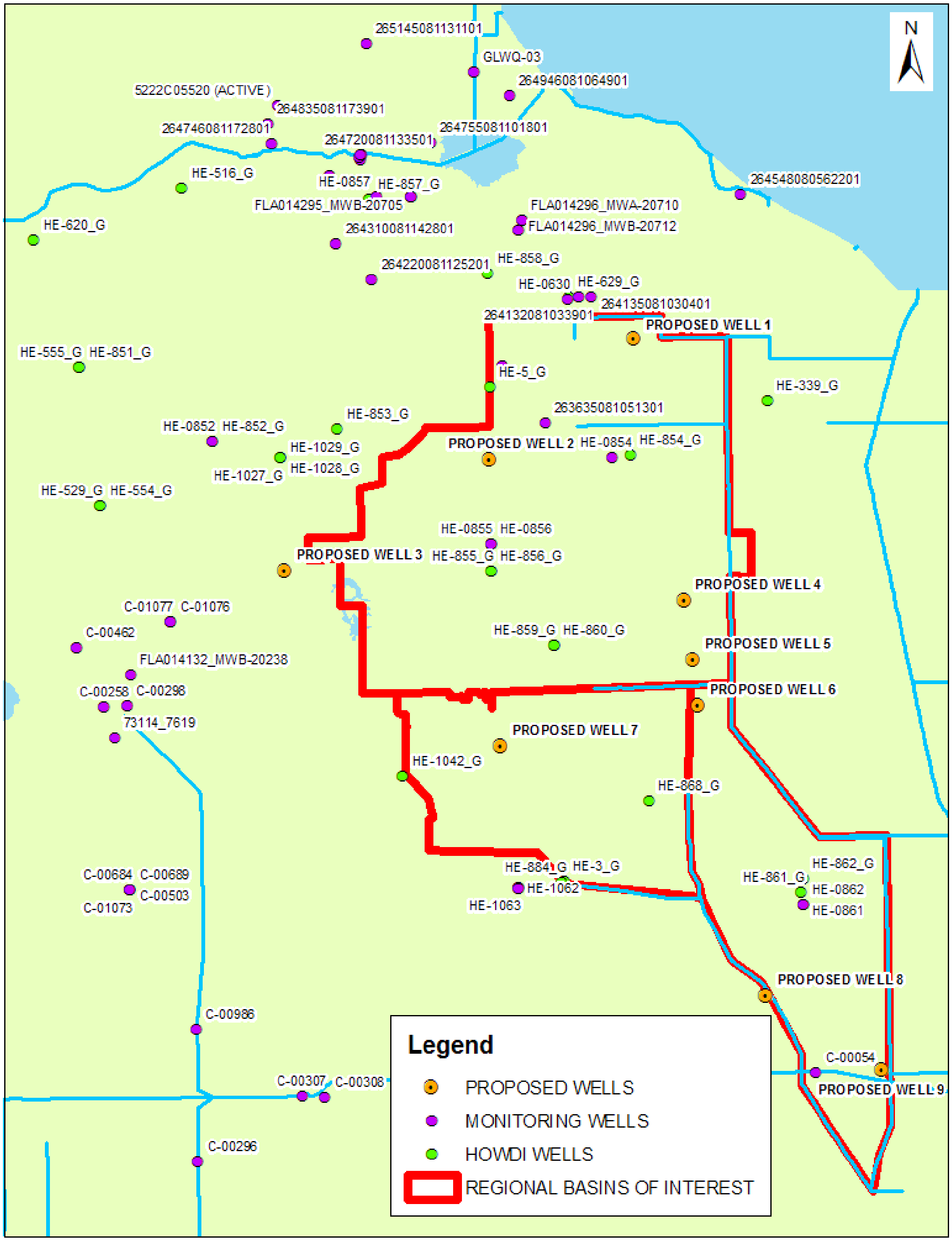


Figure 3.1 - Work Plan Locations of Proposed Monitoring Well Nests

3.3 TOPOGRAPHY

3.3.1 TOPOGRAPHIC SURVEY

Betsy Lindsay Inc. was sub-contracted to obtain spot elevations to support the surface water and groundwater interaction model. These measurements utilized GPS RTK and fast static GPS sections in reference to the control points listed in the survey drawing included in ***Appendix B1 - Specific Purpose Survey***. The GPS values have an accuracy of ± 0.15feet. Vertical control was surveyed in the North American Vertical Datum of 1988 (NAVD 1988) datum. Elevations were also converted to National Geodetic Vertical Datum of 1929 (NGVD1929) by adding 1.36 ft to the NAVD 1988 value.

The initial steps of the field data collection efforts included requesting and collecting topographic information from multiple sources including Florida Division of Emergency Management (FDEM) and Light Detection and Ranging (LIDAR) data from the United States Army Corps of Engineers (USACE). Based on the Southwest Florida Feasibility Study (SWFFS), Digital Elevation Model (DEM) and the footprint of the LIDAR data, the location of 40 spot elevations was selected as shown in pink letters and numbers in ***Figure 3.2***. Based on these locations, URS worked with the South Florida Water Management District (SFWMD) to obtain access to the different locations for the spot elevations, cross sections, and ground water wells.

Due to the lack of a timely access agreement for the locations in the Miccosukee Indian Reservation (MIR), the spot elevations at the MIR where relocated to the positions shown in red letters and numbers in ***Figure 3.3***. Due to additional time delays to obtain access to two of the farms identified for relocation of the MIR spot elevation locations, one spot elevation was eliminated. ***Table 3.2*** presents the final spot elevation locations and identifies the ones that were relocated or cancelled.

Access to the BCSR had to be authorized by the tribal counsel. Due to the lengthy process associated with the access approval, the survey was divided into two separate phases, leaving all the locations in the BCSR for Phase II. Phase I of the topographic survey was conducted on July 20 and 24, 2009 and September 8-10, 2009.

Due to time constrains related to the access authorization, the locations for F8 (Wingate Farms) and F9 (Little Ranch) were adjusted during Phase I of the survey to open fields just off existing roads to the southeast of the original locations. Location F6 (Jokis Ranch) was eliminated due to lack of timely access to alternate locations. Additionally some of the spot elevation final locations for Phase I were adjusted according to field conditions. The final surveyed location of these spot elevations is shown in ***Figure 3.4*** and in the survey drawings presented in ***Appendix B1 - Specific Purpose Survey***.

Access to conduct Phase II of the topographic survey was authorized by the Seminole Tribe of Florida with resolution C-110-10 dated December 21, 2009. However, the resolution was received on January 11, 2010. The survey was conducted on January 19, 2010. The results of the Phase II survey are also presented in ***Appendix B1 - Specific Purpose Survey***.

Table 3.2 - Spot Elevation Locations

Point	Farm/Owner	Status/Comment
C-139 Basin		
C1	Montura Ranch Estates	Measured
C2	Jackman Cane and Cattle Cia	Measured
C3	ABC Ranch (Flaghole)	Measured
C4	Alico Inc (Pasture)	Measured
C5	Alico Inc (Pasture)	Measured
C6	Alico Inc (Pasture)	Measured
C7	Alico Inc (Pasture)	Measured
C8	Alico Inc (Pasture)	Measured
C9	Alico Inc (Pasture)	Measured
C10	Alico Inc (Pasture)	Measured
C11	US Sugar Corporation	Measured
C12	Hilliard Brothers (Dinner Island)	Measured
C13	Hilliard Brothers (Dinner Island)	Measured
C14	Alico Inc (Pasture)	Measured
C15	Collier Nursery L	Relocated from Sunshine Agriculture Inc. (Sugar tree Grove)
C16	Collier Groves LTD (Crown's Nest Grove North)	Measured
C17	Collier Enterprises LTD (Joiner & Sons Farm)	Measured
C18	Zipperer Farms LLC (Devil's Garden Farm South)	Measured
C19	Montura Ranch Estates	Relocated from Miccosukee
C20	ABC Ranch (Flaghole)	Relocated from Miccosukee
Feeder Canal Basin		
F1	Crown's Nest Groves	Measured
F2	Point of Cypress	Measured
F3	McDaniel Ranch JW SR Inc	Measured
F4	McDaniel Ranch JW SR Inc	Measured
F5	Cow Bone Slough, LLP	Measured
F6		Cancelled (Flying Ranch (Smith, C Perry) and Yokis Ranch)
F7	McDaniel Reserve realty, Hold	Measured
F8	Open field by roadway	Relocated from Wingate Farms
F9	Open field by roadway	Relocated from Little Ranch
F10	Big Cypress Seminole Reservation	Measured
L-28 Interceptor Basin		
L1	US Sugar Corp C-139 Annex	Measured
L2	US Sugar Corp C-139 Annex	Measured
L3	Big Cypress Seminole Reservation	Measured
L4	Big Cypress Seminole Reservation	Measured
L5	Big Cypress Seminole Reservation	Measured
L6	Big Cypress Seminole Reservation	Measured
L7R	Big Cypress Preserve	Relocated from Miccosukee
L8R	Big Cypress Seminole Reservation	Relocated from Miccosukee
L9R	Big Cypress Preserve	Relocated from Miccosukee
L10	Relocated to Montura Ranch States	See C19
L11	Relocated to ABC Ranch (Flaghole)	See C20
L12		Cancelled (Miccosukee)

Note: Some measured locations were adjusted within the same farm or general area.

3.3.2 EXISTING TOPOGRAPHIC INFORMATION COLLECTION

The existing topographic survey information collected from multiple sources during the field data collection included the following data:

- Spot elevations obtained as part of this project (URS 2010)
- Spot elevations from wells in Crooks and Golden Ox ranches, SFWMD. (2009)
- Stream gauging reports for the Deer Fence Canal, Advanced Hydro Technologies. (8-31-08 & 9-30-09)
- L-3 Canal & STA 5 Spreader Canals – As Built Survey, BLS. (2008)
- WCA3A 2X2 model topography, SFWMD. (2009)
- Obern Property topo for relocation of cultural resources, Betsy Lindsay Inc. (1-10-08)
- Spot elevations of natural ground from cross sections surveyed as part of the Compartment C Hydrologic and Hydraulic Design (URS-ADA, 2007)
- As-built drawings of levees within the McDaniel Ranch in the Feeder Canal Basin, BSE Consultants (09-04-07)
- L-3 West Levee topography, Betsy Lindsay Inc. (1-10-07)
- Compartment C topography, Betsy Lindsay Inc. (1-10-07)
- Index Velocity Site Cross Sections Project Site DF11, L202 and L207, Nick Miller, Inc. (05-10-06)
- S&M Topography Survey, Mc Kim and Creed. (4-19-05)
- Topographic maps of U.S. Sugar lands within the C-139 and C-139 Annex basins. (1994)
- Jackman’s Ranch (TWP 44, RGE 31E, Sections: 17, 18, 19, 20, 31 & 32) Central and Southern Florida Flood Control District, (2-27-75)
- Topography from the Central & South Florida (C&SF) Design Report (1963)

All the information collected is included in ***Appendix B2 – Electronic Files of Existing Topographic Information***. The topographic information listed above and the spot elevations obtained in this section were used to check the accuracy of the SWFFS-DEM and the LIDAR data. The result of this comparison is presented in ***Section 4.2 - Calibration and Validation***.

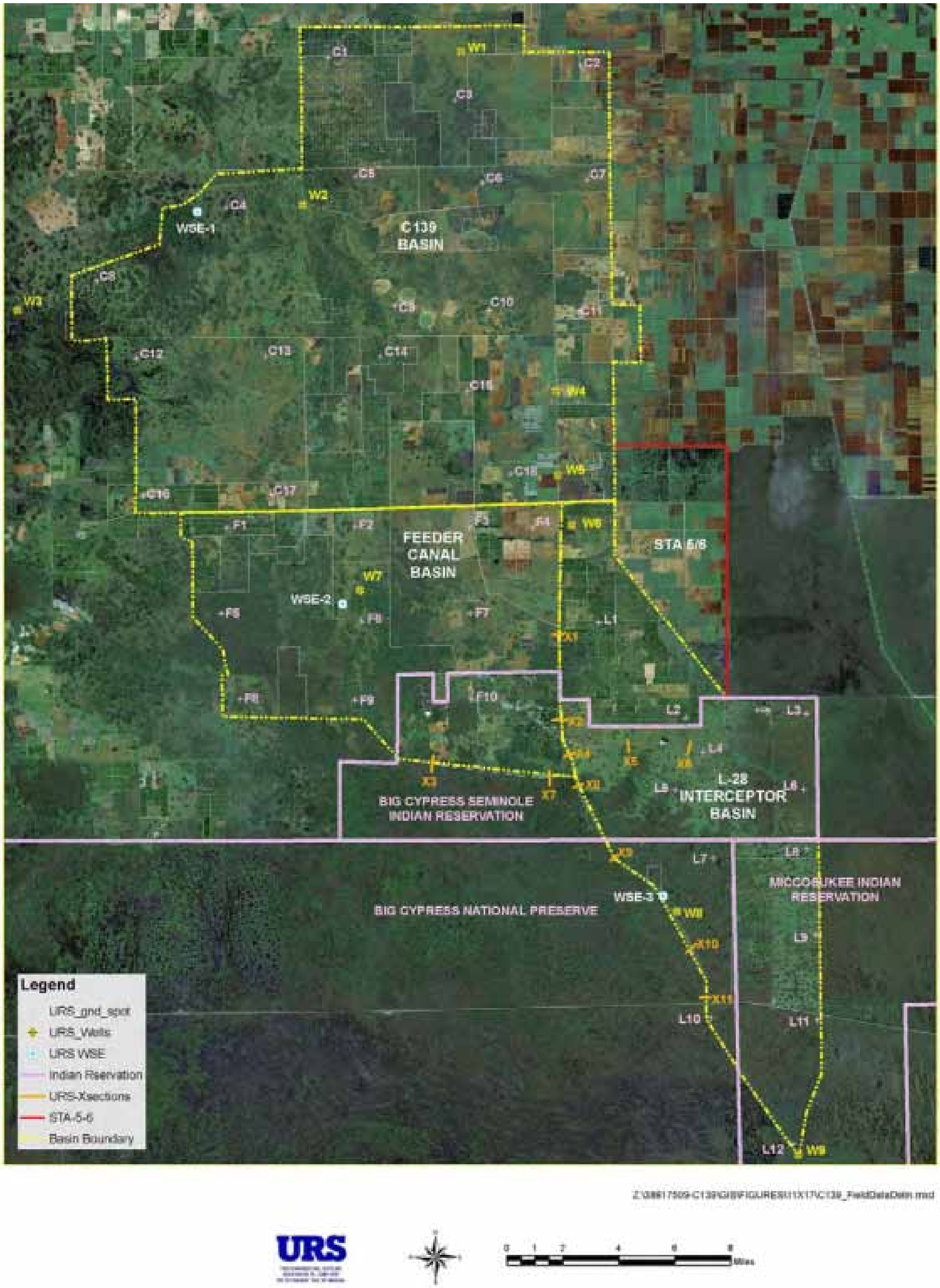


Figure 3.2 - Initial Field Data Delineation

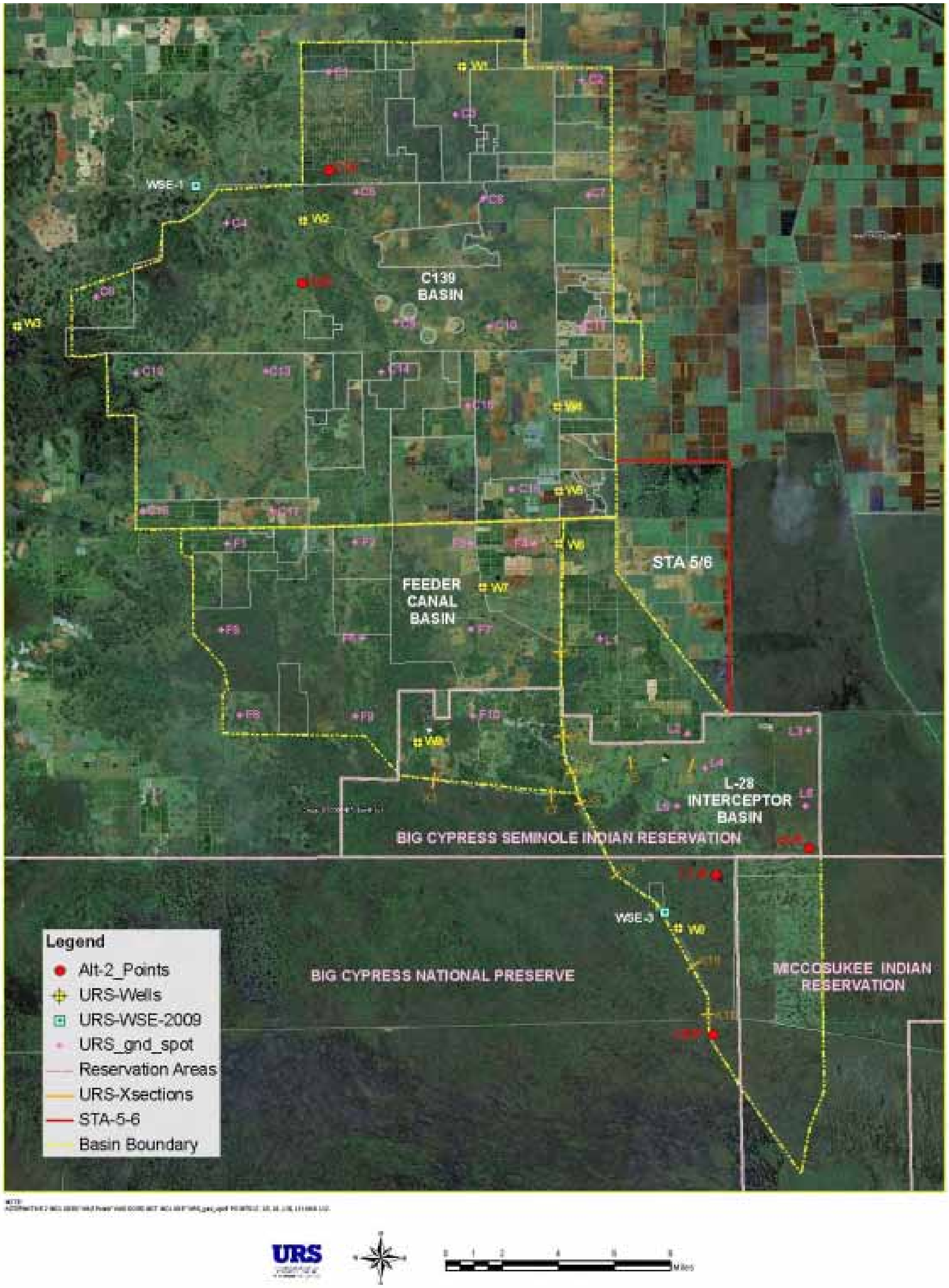


Figure 3.3 - Final Field Data Delineation

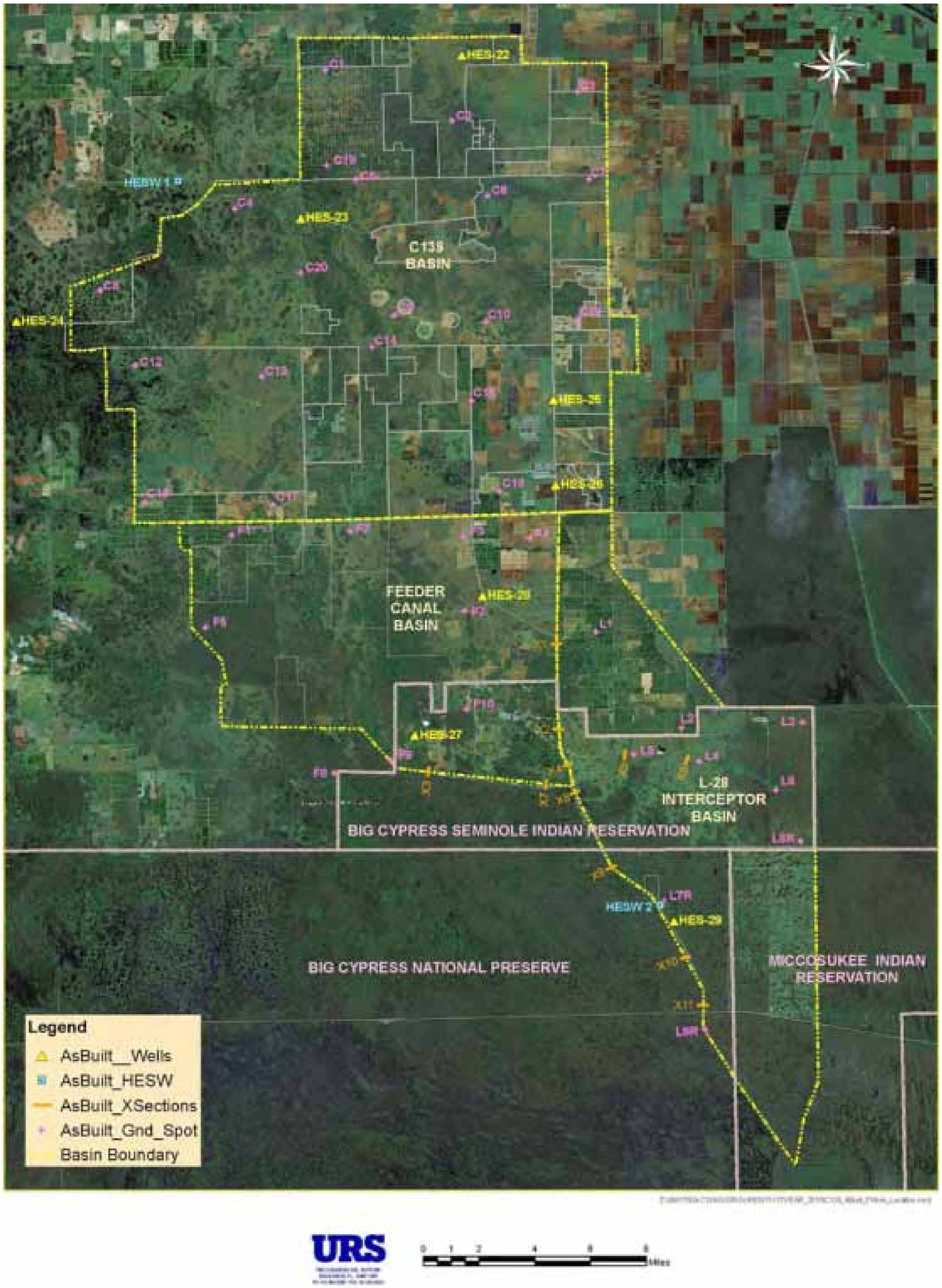


Figure 3.4 - As-Built Field Data Delineation

3.4 CANAL CROSS SECTIONS

Betsy Lindsay, Inc. was sub-contracted to obtain the canal cross sections to support the surface water and groundwater interaction model. These measurements utilized GPS RTK and fast static GPS sections reference to the control points listed in the survey drawing included in ***Appendix B1 - Specific Purpose Survey***. The GPS values have an accuracy of ± 0.15feet. Vertical control was surveyed in the North American Vertical Datum of 1988 (NAVD 1988) datum. Elevations were also converted to NGVD1929 by adding 1.36 ft to the NAVD 1988 value.

As mentioned in ***Section 2.3 – Data Gap***, the only canal cross section information available is from the 1963 Central and South Florida (C&SF) design reports, which may not be representative of existing conditions. A rough comparison of information from the 1963 design reports to canal top widths (using GIS) indicates that the top widths are generally correct. However, bottom widths and bottom invert elevations are not known and may have changed in the last 45 years. It is assumed that for the Feeder and L-28 Canal Basins, the focus of the modeling will be limited to gaining a general understanding of the flows and stages in the Region and will not provide a complete flood control analysis. Therefore, the data gap analysis determined that a minimum of eleven cross sections were needed to verify the cross section data presented in the 1963 C&SF design documentation to have a more current cross section information.

The cross sections were located to confirm the cross section of the North Feeder, West Feeder, and L-28 Interceptor canals and to have cross section data from the East-West Canal along State Road 833 in the BCSR which connects the canal going south from the G-409 and the North Feeder Canal. The canal cross sections included at least the points shown in ***Figure 3.5***.

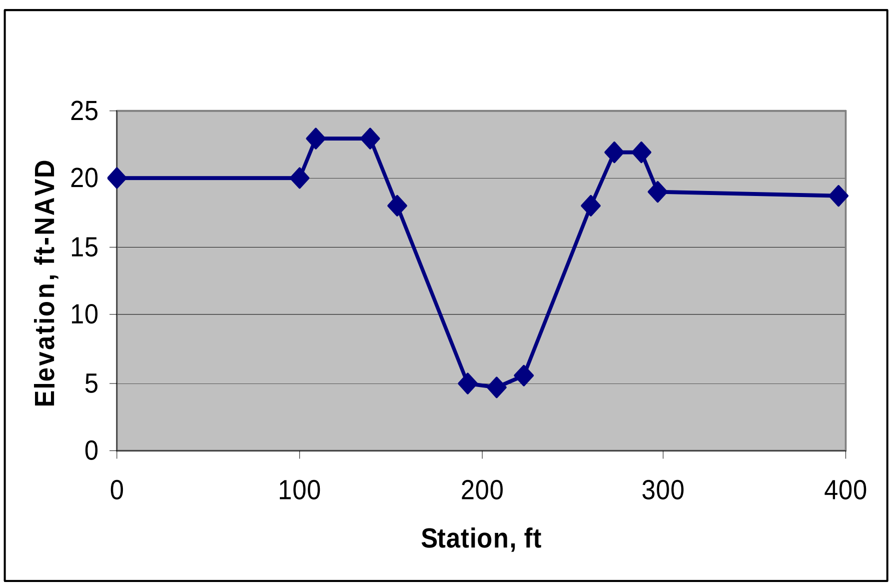


Figure 3.5 - Typical Cross-Section

The locations for the cross sections were defined at the beginning of the field data collection and were maintained throughout the process to obtain access approvals. The final locations of the cross sections are shown in ***Figure 3.4***. The Seminole Tribe of Florida granted access authorization to survey the cross sections within the canals right-of-ways in September 2009. All the canal cross sections were surveyed from October 20 to October 22, 2009.

Photo 3.1 shows the surveying crew collecting bathymetric data along the L-28 Interceptor Canal. The results of the cross section survey are presented in the survey drawings included in ***Appendix B1 - Specific Purpose Survey***. The canal cross sections obtained as part of this section were integrated to the MIKE SHE/MIKE 11 model during the calibration and validation.

Photo 3.1 - Surveying Crew Collecting Cross Section Data in L-28 Interceptor Canal

3.5 GROUNDWATER WELLS

3.5.1 INTRODUCTION

The data gap plan identified the need for the 9 nested groundwater level monitoring wells shown in ***Figure 3.1***. The proposed nested wells consisted of a shallow and a deep well to cover the Water Table Aquifer (WTA) and the Lower Tamiami Aquifer (LTA) respectively. In both cases the location of the well screen was determined by a site geologists based on field information collected during drilling (cuttings, drilling characteristics, logs, etc.). The final depth of the well screens varied in between 7 to 23 ft for the deep wells and between 65 ft to 100 ft for the LTA.

In addition to the 9 nested groundwater level monitoring wells, automated data-loggers were recommended for the Feeder Canal wells HE-868 and HE-3 and HE-629. Personnel from the SFWMD Hydrogeology group confirmed that groundwater monitoring well HE-3 was destroyed and well HE-868 was not available for instrumentation. Existing groundwater well HE-629 was field verified on December 16, 2009. The well is abandoned but was found to be in apparently good condition. The bottom of the well was measured to be 77 feet below the top of casing. The condition of the well will be further verified with a well camera, and the well will be pumped to make sure it is in good working condition before installing a data transducer and initiating data collection.

The naming convention for the groundwater level monitoring wells was modified in consultation with the SFWMD Hydrogeology group. The naming convention adopted follows the naming protocol of the groundwater monitoring wells in the region. Groundwater level monitoring well W-1 was given the official name HES-22 following the last groundwater level monitoring well in the region (HES-21). An “S” or a “D” is added at the end of the name to differentiate between Shallow (WTA) and Deep wells (LTA). The original and official names are presented below in ***Table 3.3.***

3.5.2 WELL LOCATIONS

The original locations defined in the data gap analysis were verified with aerial photographs from Global explorer service and were confirmed with an initial site visit on May 18, 2009. During this process the SFWMD confirmed that the Miccosukee Indian Reservation (MIR) would not grant access to their reservation for any survey or well installation. Therefore, the location of ground water well W-9 was moved from the original location in the MIR to the Big Cypress Seminole Reservation (BCSR). The well locations resulting from the initial location exercise are shown in ***Figure 3.2***.

With the locations defined, the SFWMD Project Manager conducted an internal search for information for the different farms in which wells were to be located. The search was conducted with help from the SFMWD Global Information System (GIS) and Real Estate groups. The different land owners were subsequently contacted to obtain access agreements to their farms for groundwater monitoring well installation.

Table 3.3 - Groundwater Level Monitoring Wells Original and Official Names

Original Name	Official Name
W1	HES-22S HES-22D
W2	HES-23S HES-23D
W3	HES-24S HES-24D
W4	HES-25S HES-25D
W5	HES-26S HES-26D
W6	Eliminated
W7	HES-28S HES-28D
W8	HES-29S HES-29D
W9	HES-27S HES-27D

Due to delays for the authorization to install groundwater level monitoring wells at some of the farms, the wells that had to be relocated or eliminated were as follows:

- W2 (HES-23): Originally located in Alico Inc. was moved to the right of way of County Road (CR) 833 Right of Way (ROW) East side, about 300' south of Hill Grade road. See ***Table 3.4*** for the as built location of the ground water wells.

- W4 (HES-25): This well was originally located in Alico's property as well. This well was moved to CR 835 ROW East side, about 1.4 miles south of CR 832 road, just south of Hill Grade road.

- W6: This well was initially located in the Southern Groves Corporation's C-139 Annex. New locations for the well were explored; however, due to additional requirements from property owners and time limitations, this well was finally eliminated.

- W7 (HES-28): This well was to be located initially on Dr. Smith's property. As access to his property could not be agreed on in a timely manner, access to Little Ranch and Jokis Ranch were explored. However, due to additional delays to obtain access at the alternative locations, W7 was moved to CR 833 ROW East side.

- W9 (HES-27): As mentioned above, due to the lack of a timely access agreement for the locations in the MIR, this well was removed from the MIR. Groundwater well W9 was re-located to the BCSR at the W. Boundary Road ROW, as shown in

Figure 3.3. The Seminole Tribe of Florida granted access to the reservation for the installation of well W9 (HES-27) with resolution C-110-10 dated December 21, 2009. The resolution was received on January 11, 2010.

The As-built information for the Groundwater wells is presented in ***Table 3.4***. The As-built locations for the groundwater wells are presented in ***Figure 3.6***

Table 3.4 - As-Built Groundwater Well Construction Information

Official Name	Total Depth (NGVD)	TOC Elevation (NGVD)	Latitude	Longitude	Northing	Easting	Location/ Farm Name
HES-22S HES-22D	12' 70'	22.35' 22.42'	26º 40' 17.8"	81º 02' 00.8"	849804.2	645208.8	ABC Ranch (Solon Crews Mills Property)
HES-23S HES-23D	9.5' 65'	27.56' 27.46'	26º 35' 11.5"	81º 07' 37.2"	818896.6	614662.8	CR 833 ROW East side
HES-24S HES-24D	10' 90'	32.82' 32.44'	26º 31' 57.0"	81º 17' 30.5"	799346.3	560759	Okaloacoochee Slough State Forest
HES-25S HES-25D	20' 92'	23.30' 23.28'	26º 29' 30.0"	80º 58' 49.5"	784396.1	662571.8	CR 835 ROW East side
HES-26S HES-26D	23' 90'	25.50' 25.45'	26º26' 50.9"	80º 58' 45.5"	768332.4	662937.8	C&B Vegetables (Charles W. Obern)
HES-27S HES-27D	18' 78'	19.28 19.3	26°19' 01"	81° 03' 39"	720893	636240	W Boundry Road ROW, South Side
HES-28S HES-28D	22' 66'	23.37 23.34	26º 23' 22.7"	81º 01' 17.1"	747311.4	649155.7	CR 833 ROW East side
HES-29S HES-29D	9' 100'	16.19' 15.84'	26º 13' 12.9"	80º 54' 38.4"	685752.93	685453.3	Big Cypress National Preserve

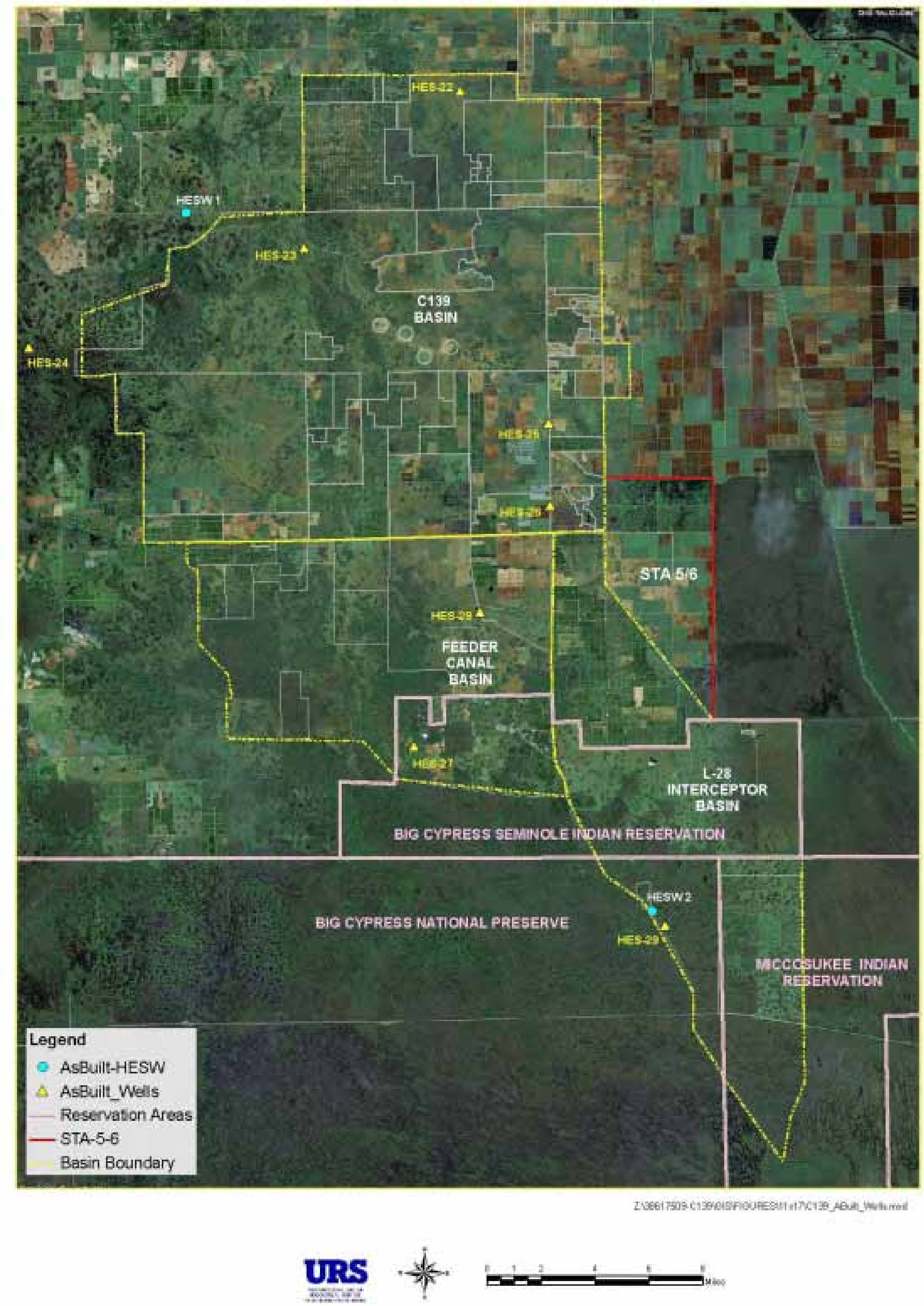


Figure 3.6 - As-Built Groundwater Well and WSE Locations

3.5.3 WELL CONSTRUCTION.

Ground Water Protection Inc. of Orlando, Florida, was sub-contracted by URS to complete well drilling, coring, and construction of the wells. A URS site geologist and the field data work manager were present during construction and testing of all wells and made decisions on casing and screen depths based on field information collected during drilling (cuttings, drilling characteristics, logs, etc.). ***Photo 3.2*** shows drill cuttings collected during well drilling.

Sonic well drilling was commenced on October 13, 2009 and was completed on October 22, 2009 for wells W1 (HES-22), W2 (HES-23), W3 (HES-24), W4 (HES-25), W5 (HES-26), W7 (HES-28) and W8 (HES-29). Drilling for well W9 (HES-27) was commenced on January 25, 2010, and was completed on January 26, 2010. ***Photo 3.3*** shows the drilling of well HES-29. Soil borings were completed for each of the wells and are presented in ***Appendix B3 – Soil Boring Logs***.

Photo 3.2 - Drill Cuttings for Soil Samples

The data gap called for nested wells consisting of one WTA monitor well and one LTA monitor well. During initial discussions with the SFWMD, the installation of paired wells was chosen instead, to avoid possible interaction and installation issues. Paired groundwater level monitoring wells were installed at eight locations for a total of sixteen wells. The paired wells were constructed using a 2-inch diameter, Schedule 40, polyvinyl chloride (PVC) well casing, and 2-inch diameter, 0.020-inch slot, PVC well screen. Ground Water Protection Inc. completed each well with a concrete pad.

Photo 3.3 - Well Drilling at HES-29 Location

Two different types of wells were installed. The first type was a stand-up well with about 3 feet of 6” diameter casing above ground and bollards as shown in ***Figure 3.7***. This type of well was installed mainly in remote locations where vegetation overgrowth could cover the wells. The second type was a flush well as shown in ***Figure 3.8***. This type of well was installed in the right of way locations where wells could be damaged by vehicular traffic or mowing equipment. Photographs of the paired wells are provided in ***Appendix B4 - Groundwater and Surface Water Level Monitoring Wells Photographs***. As-built well construction diagrams of the paired groundwater level monitoring wells are included in ***Appendix B5 - As-built Groundwater and Surface Water Level Monitoring Wells.***

All wells were developed by over pumping methods until visible particulate matter was removed from the produced formation water during the day of drilling. Well development was done again several days after installation to clear any sediments deposited. ***Table 3.4*** above summarizes the final as-built well construction information for all the wells.

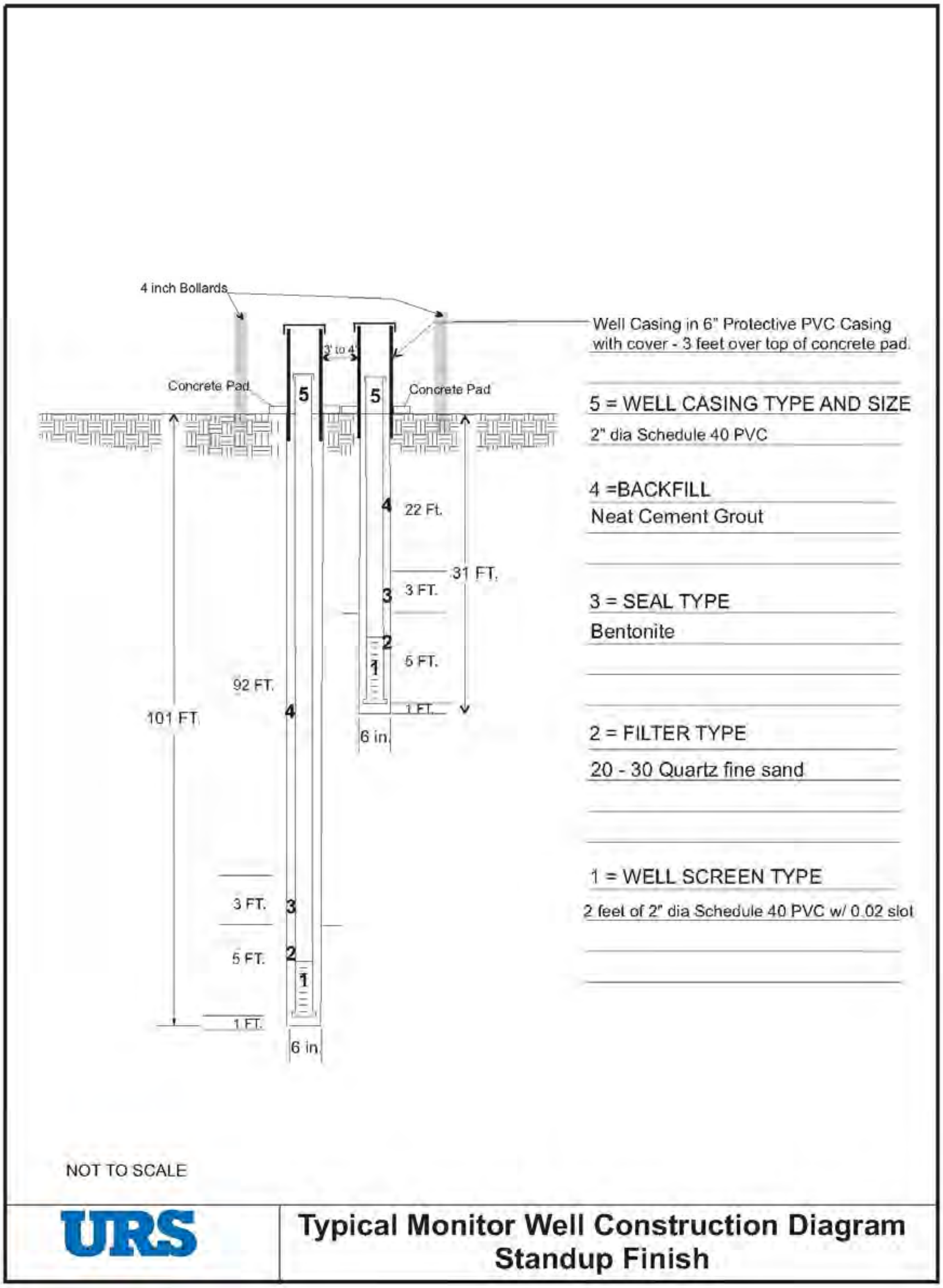


Figure 3.7 - Typical Standup Well Diagram

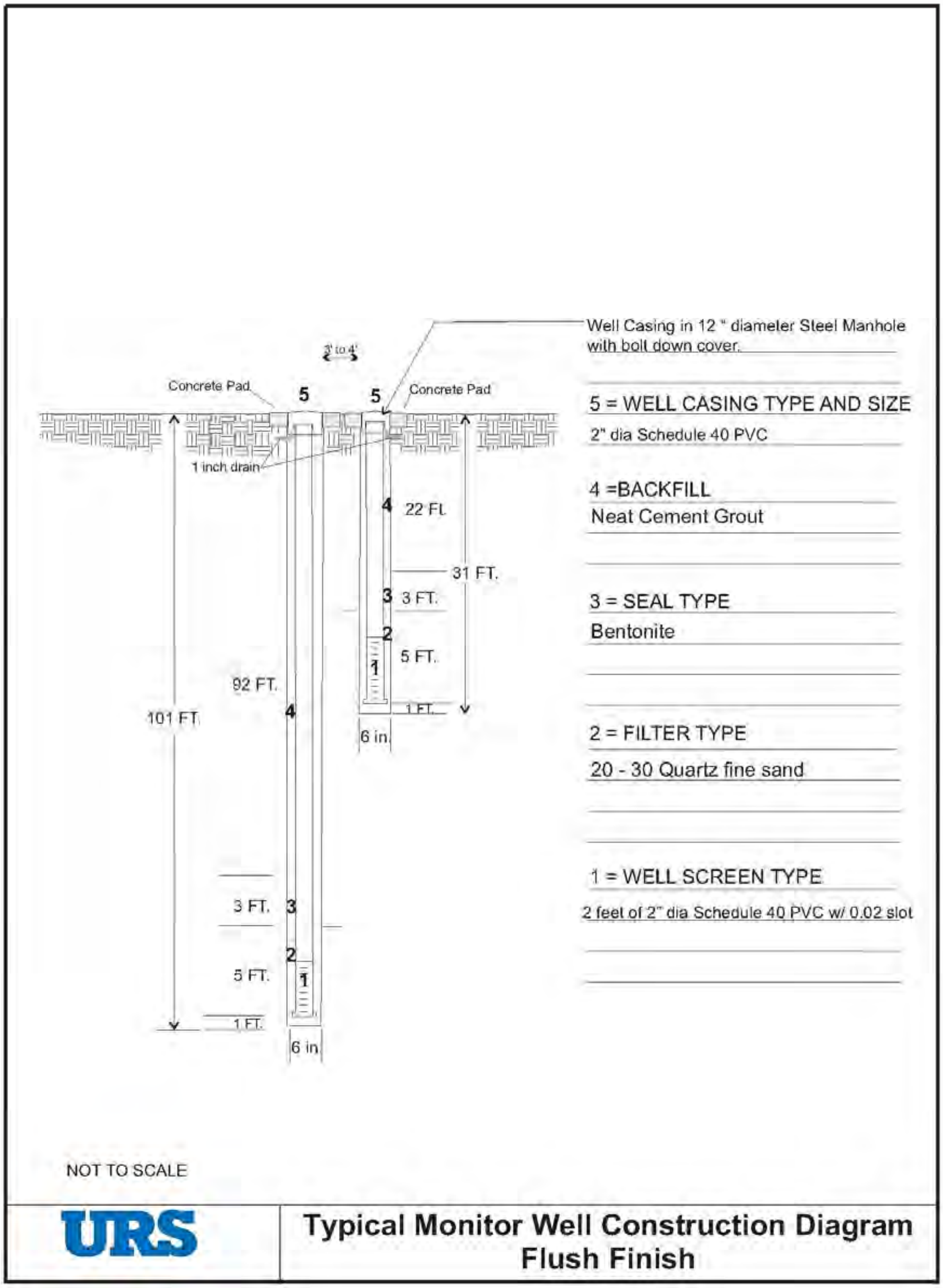


Figure 3.8 - Typical Flush Well Diagram

The well elevations were surveyed by Betsy Lindsay Inc. Due to the delays in obtaining access agreements from the different land owners for the installation of the wells the surveyor flagged the location and placed a rod to mark the elevation at the different well locations. These measurements utilized GPS RTK and fast static GPS section reference to the control points listed in the survey drawing included in ***Appendix B1 - Specific Purpose Survey***. The GPS values have an accuracy of ± 0.15feet. Vertical control was surveyed in the North American Vertical Datum of 1988 (NAVD 1988) datum. Elevations were also converted to NGVD 1929 by adding 1.36 ft to the NAVD 1988 value.

Once the wells were installed, the elevations surveyed by Betsy Lindsay Inc. were transported to the different wells during the equipment installation. ***Photos 3.4, 3.5, and 3.6*** show the equipment used to transport the elevation to the top of the casing during the instrumentation of the shallow and deep wells for locations HES-22, HES-28 and HES-29.

Photo 3.4 - Instrumentation of Wells HES-22 S and D

Photo 3.5 - Instrumentation of Wells HES-28 S and D

Photo 3.6 - Instrumentation of Wells HES-29 S and D

3.5.4 SUMMARY OF LITHOLOGY

Prior to commencing drilling activities, URS reviewed lithological well logs as provided in the *Ground Water Resource Assessment of Hendry County (GWRAHC), Florida, SFWMD Technical Publication 88-12* dated September 1988 for wells located nearest to the current new well locations. According to the lithological descriptions for the nearest reported wells, the bottom of the Water Table Aquifer (WTA) ranged from 5 feet (HES-24) to 30 feet (HES-26).

Water Table Aquifer (WTA)

Based on examination of the sediment samples obtained from the sonic drill installations during the current field work, the general lithology encountered during the well installation varied greatly from north to south. The primary findings were the absence of a shallow limestone layer in the central area monitoring wells HES-25, HES-26, and HES-28 and the absence of a significant thickness of marl/clay confining sediments between the Water Table Aquifer (WTA) and the Lower Tamiami Aquifer (LTA) at the HES-25 and HES-28 monitoring well locations. See ***Table 3.5*** for a summary of the lithology for the shallow WTA wells.

Table 3.5 - Summary of Lithology Shallow WTA Wells

Shallow (WTA) Wells			
Well ID	**Description**		
	Surficial sand overlying soft limestone with marl confining layer @10'-12'	**Unconsolidated quartz sands/No shallow limestone layer**	**No marl/clay confining sediments**
HES-22	X		
HES-23		X	
HES-24	X		
HES-25		X	X
HES-26		X (confining layer 22' - 40')	
HES-27	X (Very leaky confining layer)		
HES-28		X	X
HES-29	X		

Based on the samples examined, a solid clay/marl confining layer which consisted of a dense firm clay layer from 22 feet to 40 feet in depth between the WTA and LTA was identified at well location HES-26. The difference in the static water table level between the shallow (1.3 feet) and deep well (12.7 feet) at the HES-26 well location implies that the lower Tamiami Formation in this area is at least partially confined with respect to the vertical lithology.

For well locations HES-22, HES-23, HES-24, and HES-29, the bottom of the WTA appeared to be very shallow (10 to 12 feet). The bottom of the WTA at these locations consisted

primarily of surficial sand overlying soft limestone and marl layers. These findings were consistent with the *Ground Water Resource Assessment of Hendry County*.
For wells HES-25, HES-26, and HES-28, the WTA appeared to consist primarily of unconsolidated quartz sands, due to the absence of the limestone layers. The elevation of the bottom of the WTA was also consistent with the existing information except at the HES-28 well location. The surficial lithology encountered at well HES-28 was similar to that of well locations HES-25 and HES-26, where a shallow limestone layer was not encountered. A marl/clay confining layer of sediments between the WTA and lower Tamiami Formation members was also missing at the HES-28 well location, which was not previously described. Therefore, the lithology of well HES-28 appeared very similar to that of well HES-25, where a marl/clay confining layer of sediments between the WTA and lower Tamiami Formation members is missing. For well HES-27 the confining layer between the WAT and LTA consists of soft marly quartz sand with shells which appear to be a very leaky confining layer.

Lower Tamiami Aquifer (LTA)

At well locations HES-25, HES-26, HES-27 and HES-28, the upper unconsolidated layers of quartz sand with varying amounts of silt, clay, shell fragments, and phosphatic sand were encountered at the top of the LTA at approximately 60 to 68 feet in depth and 85 feet in depth at well location HES-29. See ***Table 3.6*** for a summary of the lithology for the deep LTA wells. For each of the deep wells at locations HES-25, HES-26, HES-27, HES-28, and HES-29, the screen interval was placed in a hard fossiliferous limestone.

At well locations HES-22, HES-23 and HES-24, the LTA consisted primarily of unconsolidated sand with varying amounts of silt, shell fragments, and phosphatic sand. A lithologic cross section is presented in ***Appendix B6 - Generalized Lithological Cross Section.***

Table 3.6 - Summary of Lithology Deep LTA Wells

Deep (LTA) Wells		
Well ID	Description	
	LTA consisted of unconsolidated layers of quartz sand with varying amounts of silt, clay, shell fragments, & phosphatic sand overlying hard fossiliferous limestone	LTA consisted of unconsolidated sand with varying amounts of silt, shell fragments, and phosphatic sand
HES-22		X
HES-23		X
HES-24		X
HES-25	X	
HES-26	X	
HES-27	X	
HES-28	X	
HES-29	X	

3.5.5 HYDRAULIC CONDUCTIVITY

URS conducted slug tests to estimate horizontal hydraulic conductivity at each well location. A solid slug or a slug of water was rapidly deployed into each well in the presence of a pressure transducer attached to a data logger. The changes in water levels were imported into the Super Slug software in order to estimate the horizontal hydraulic conductivity. The Super Slug software appeared to provide reasonable estimates for hydraulic conductivity in the shallow wells.

However, since the changes in water levels in the deep wells showed a “bouncing” effect, the Super Slug software could not provide reasonable estimates of hydraulic conductivity due to inconsistent data. Consequently, URS used an Excel spreadsheet for analyzing slug tests in formations with high hydraulic conductivity. This spreadsheet was published by the Kansas Geological Survey as “Simple Procedures for Analysis of Slug Tests in Formations of High Hydraulic Conductivity using Spreadsheet and Scientific Graphics Software”, dated December 2000 (KGS Open File Report 2000-20). Because slug tests in formations of high hydraulic conductivity (K) are often affected by mechanisms that are ignored in models developed for tests in less permeable formations, this analysis provided solutions where the changes in water levels showed “bouncing” or wavy graphical plots of the data. The Super Slug software and the High K spreadsheets both provided estimates of K using the Bower and Rice Model for calculating K.

The K value estimates from the shallow wells ranged from 0.95 feet/day to 78.8 feet/day. The K values from the shallow wells appear to be lower than the values from the MODFLOW model except at wells HES-22 and HES-26. Since shallow wells HES-23, HES-24, HES-29 are not pumping wells, the calculated K values appear to be representative of the lithology observed during the well installation.

For the deep wells, the K values estimated with the High K spreadsheet appear to be higher than values from MODFLOW except at well HES-22, for which the K value is at the upper level of the MODFLOW K value of 1,500 feet/day. The K values for the deep wells ranged from 1,540 feet/day to 2,900 feet/day except at well HES-28, where the K value was estimated at 13,400 feet/day. In general, the K values obtained seem to agree with the well yield observed during the well development, with the exception of well HES-23. Deep well HES-23 should have a low yield, since drawdown during the well development for the well was greater than 25 feet, which exceeded the pumping lift of the centrifugal pump. However, the initial test gave high yield results. URS re-tested well HES-23D at the same time that well HES-27 was tested. Wells HES-27S and HES-23D were tested with a short duration pump test to evaluate drawdown and recovery in the wells. A small 1¼ inch centrifuge pump was used to create the drawdown.

A slug test was also performed for HES-27S and for HES-27D. The data for well HES-27D was too thin to get a good value. A summary of the calculated K values is presented in ***Tables 3.7*** and ***3.8.*** The files for the slug test calculations are included in ***Appendix B7 - Slough Test Calculation Files***.

Table 3.7 - Summary of Conductivity Test Results for the WTA

Well ID	DTW (ft)	Screen Interval	B&R-GM (ft/day)	B&R-ACM (ft/day)	Pumping Rate gpm[1]
Water Table Aquifer Wells					
HES-22S	3.16	10-12	78.8	73.3	1.5
HES-23S	2.10	7.5-9.5	0.9479	1.032	Well Pumped Dry
HES-24S	4.92	8-10	0.1055	0.2654	Well Pumped Dry
HES-25S	5.87	18-20	2.468	2.393	1
HES-26S	1.3	21-23	9.979	7.58	1.5
HES-27S	2.75	16-18	3.92	3.16	2
HES-27S[2]	2.75	16-18	4.47	4.52	2
HES-28S	1.83	20-22	4.015	2.263	1
HES-29S	1.74	7-9	1.999	1.791	Well Pumped Dry

DTW = Depth to water from ground at time of test
B&R-GM = Bouwer & Rice Graphical Method
B&R-ACM = Bouwer & Rice Automatic Calculation Method
[1] Pumping rate during development
[2] Short pump test results

Table 3.8 - Summary of Conductivity Test Results for the LTA

Well ID	DTW (ft)	Screen Interval	HKES (ft/day)	B&R-GM (ft/day)	Pumping Rate gpm[1]
Lower Tamiami Wells					
HES-22D	3.02	68-70	1,510		1.5
HES-23D	1.48	63-65		0.308	DD Below 25 ft
HES-24D	2.14	88-90	2,900		1.5
HES-25D	5.71	90-92	1,540		2
HES-26D	12.7	88-90	2,550		1.5
HES-27D	2.42	76-78	9,200		2
HES-28D	4.08	64-66	13,400		2
HES-29D	1.97	98-100	1,560		1.5

DTW = Depth to water from ground at time of test
DD = Draw Down
HKES = High K Estimator Spreadsheet
B&R-GM = Bouwer & Rice Graphical Method
[1] Pumping rate during development

3.5.6 WELL INSTRUMENTATION

The wells were instrumented by the SFWMD Hydrogeology group and URS utilizing Level Trolls and Mini Trolls to record water levels. Water temperatures are also being recorded for all the LTA wells and most of the WTA wells. ***Photo 3.7*** below shows two Level Trolls and the one Mini Troll data logger. The data loggers were installed in wells HES-22 to HES-26 and wells HES-28 and HES-29 on November 9 and 10, 2009. The first set of readings was collected on December 16 and 17, 2009. The data loggers for HES-27 were installed on February 18, 2010. The Data collected up to November, 2010 is presented in ***Appendix B8 – Electronic Files of Groundwater and Surface Water Level Data.*** Since monitoring well HES-28 was located after the Phase I survey had been completed, water surface elevations for this well were adjusted using the top of casing elevation obtained during Phase II of the surveys. The adjusted water level readings are be presented in the ***Appendix B8 – Electronic Files of Groundwater and Surface Water Level Data.***

Photo 3.7 - Level Troll and Mini Troll Data Loggers

3.6 SURFACE WATER MONITORING

3.6.1 FLOW MEASUREMENTS

As discussed in earlier sections, the existing surface data both for stages and flows should be sufficient to calibrate the selected model. The data gap plan suggested measuring the flows entering the Seminole Reservation at the south end of the canal, which connects the G-409 pump station to the east-west portion of the Seminole Canal at CR 833. This monitoring could be performed by field crews on an event basis for calibration purposes or could be achieved using a side-looking Doppler installation. However, the BCSR did not authorize the measurement of such flows.

3.6.2 WATER SURFACE ELEVATION (WSE) MONITORING

With regard to wetland monitoring, there are three relatively undeveloped areas, one in each study basin, where wetland monitoring may provide additional insight into model development and calibration. The first is in the northwestern C-139 in the ALICO property near the watershed divide (approximately 4 miles west of Proposed Well 2), the second is in the central western Feeder Canal Basin (approximately 2 miles southwest of Proposed Well 7), and the third is in central L-28 Basin west of Snake Road (approximately 1 mile east of Proposed Well 8). By positioning these locations near the proposed groundwater well clusters, the correlation of wetland level monitoring data and regional groundwater conditions could be analyzed.

3.6.2.1 WSE Monitoring Locations

The proposed location of the wetland monitoring Water Surface Elevation (WSE) sites is shown in ***Figure 3.9***. However, as shown in ***Figure 3.3***, WSE-2 was eliminated. This was the result of lack of timely access agreements in the area.

During the location and access authorization process, the naming convention for the WSE monitoring locations was modified in consultation with the SFWMD Hydrogeology group. The original and official names are presented below in ***Table 3.10.***

Table 3.9 - WSE Monitoring Locations Original and Official Names

Original Name	Official Name
WSE-1	HESW-01
WSE-3	HESW-02

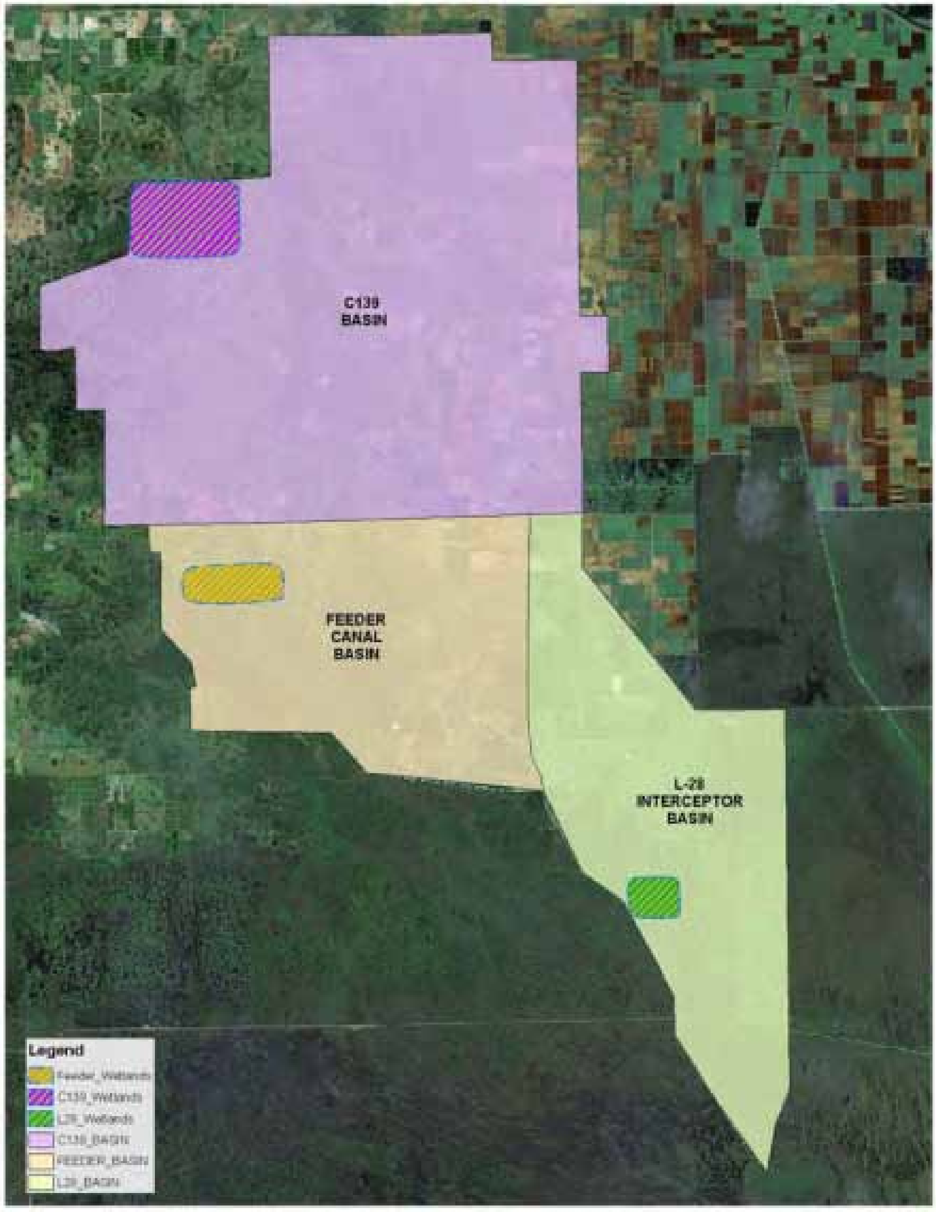


Figure 3.9 - Location of Wetland for Proposed WSE Measurements

3.6.2.2 WSE Monitoring Construction

Wetland water surface elevation monitoring is being conducted with a stilling well consisting of a 4" PVC screened pipe. A 5" diameter 5 ft hole was excavated with a hand auger and the PVC pipe placed into the hole. The space between the soil and the PVC pipe was filled with coarse graded sand. The As-built information for the WSE locations is presented in ***Table 3.10***. The As-built locations for the WSE locations are presented in ***Figure 3.6***.

Photographs of HESW-1 and HESW-2 are provided in ***Appendix B4 - Groundwater and Surface Water Level Monitoring Wells Photographs***. As-built construction diagrams of

HESW-1 and HESW-2 are included in ***Appendix B5 - As-built Groundwater and Surface Water Level Monitoring Wells***.

WSE Instrumentation

The instrumentation at HESW-1 and HESW-2 was installed by the SFWMD Hydrogeology group and URS utilizing Mini Trolls to record water levels. ***Photo 3.7*** shows two Level Trolls and the one Mini Troll data logger. The data loggers were installed on November 9 and 10, 2009. The first set of readings was collected on December 16 and 17, 2009 and is presented in ***Appendix B8 – Electronic Files of Groundwater and Surface Water Level Data.***

Table 3.10 - As-Built WSE Construction Information

Official Name	Total Depth (NGVD)	Ground Elevation (NGVD)	TOC Elevation (NGVD)	Latitude	Longitude	Northing	Easting	Location/ Farm Name
HESW-01	5'	28.5	30.0'	26º 36' 20.4"	81º 11' 53.3"	825882.9	591425.2	CR 832 ROW South side.
HESW-02	4'	14	15.05'	26º 13' 42.2"	80º 55' 08.1"	688709.4	682746.8	Big Cypress National Preserve

3.7 REFERENCES

Kansas Geological Survey. 2000. Simple Procedures for Analysis of Slug Tests in Formations of High Hydraulic Conductivity using Spreadsheet and Scientific Graphics Software, Open File Report 2000-20.

Marco Water Engineering, Inc. 2005. Lower West Coast Surficial Aquifer System Model. Prepared for SFWMD by Marco Water Engineering and Ecology and Environment, Inc.

SFWMD b. 2009. BDhydro data base. Hydrogeology Data.

SFWMD b. 2009. South Florida Environmental Report, Chapter 4 – Phosphorus Source Controls for the South Florida Environment.

SFWMD. 1988. Ground Water Resource Assessment of Hendry County (GWRAHC), Florida, Technical Publication 88-12.

United States Army Corps of Engineers (USACE), 2009. Light Detection and Ranging (LIDAR) data.

URS-ADA. 2009. Deliverable 2.3.2 – Final Data Gap Technical Memorandum. Prepared for SFWMD.

URS. 2008. Compartment C Stormwater Treatment Area Final Design Report. Prepared for SFWMD.

4 MODELING

4.1 Model Set-Up

4.1.1 INTRODUCTION

The goal of this project model is to develop a baseline model that characterizes the study area hydrology, water supply, and water quality. Based on analysis performed during the Model Selection exercise in ***Section 2.4*** it was decided that the MIKE SHE/MIKE 11 model would provide the most comprehensive detailing of a fully integrated surface water and groundwater interaction analysis for the C-139 Region. The model will be open-ended such that it can continue to be refined as additional data is received during later phases of the project. The specific objectives of the model are listed below:

- Provide a better understanding of interactions between the surficial aquifer and the Lower Tamiami aquifer, which is a major source of irrigation water to agricultural operations.
- Provide a better understanding of hydrologic interactions between the C-139 Region and lands to the west.
- Provide a model that can simulate the flows and water levels in the C-139 Basin with greater accuracy than prior modeling efforts using WAM and HEC-HMS/MIKE 11 (ADA 2007, URS/ADA 2008).
- Provide a model with sufficient hydraulic capability to evaluate both dry and wet season responses to a range of alternative projects and/or water resource optimization strategies, including but not limited to:
    - importing water from the S-4 basin and delivery of that water to any of the watersheds within the C-139 Region
    - detention of stormwater runoff in either regional or multiple agricultural reservoirs
    - incorporating some form of irrigation withdrawals from surface water sources to reduce groundwater abstractions and to reduce nutrient loads to STA-5 and STA-6
- Determine the influence of groundwater withdrawals on surface water hydrology in adjacent basins.

The baseline model will be utilized in Phase II to evaluate various regional operational and infrastructural alternatives such that the region's water supply and quality goals are met. The purpose of this section is to present the parameterization that was established for the selected model and its boundary conditions prior to calibration. Updates to the model parameterization are presented in ***Section 4.2 Calibration*** and ***Validation*** and in ***Section 4.3 Modeling Report***.

4.1.2 MIKE SHE MODEL

4.1.2.1 Overview

MIKE SHE is a grid based dynamic continuous simulation modeling system developed by DHI Water and Environment (DHI) that can be used to simulate integrated surface water and groundwater systems. It can simulate all the major land phase hydrological processes and is comprised of several independent modules that represent each hydrological process. A number of numerical approaches and/or conceptualizations are available within each module and allow users to tailor the model to meet the objectives and data constraints of a given project. The basic hydrologic flow processes incorporated into MIKE SHE are shown in ***Figure 4.1.1*** (DHI Manual).

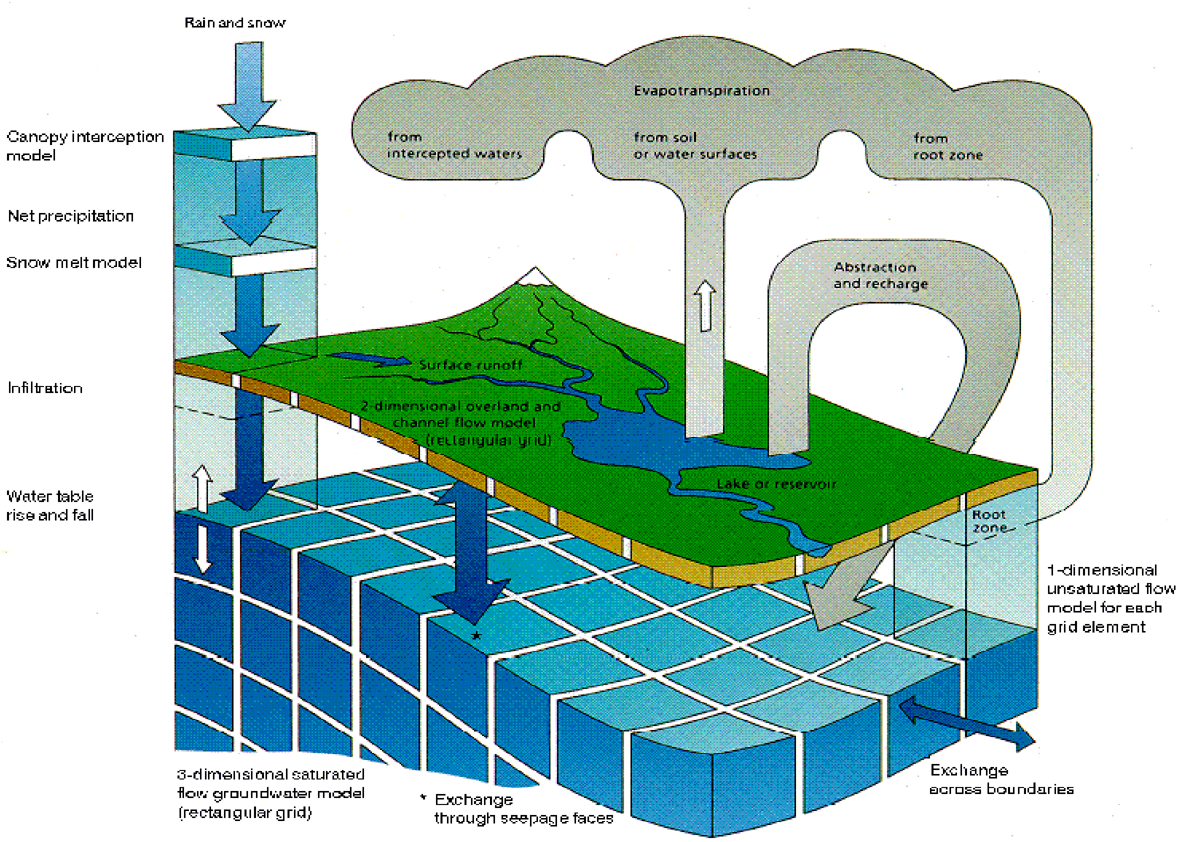


Figure 4.1.1 - MIKE SHE Hydrologic Processes (Image from DHI Manual)

4.1.2.2 Model Domain

Figure 4.1.2 shows the model domain in relation to the existing Regional Basins and SFWMD Canal network. The model domain includes the Miami canal as a model boundary on the east. Boundaries to the north, west, and south are outside the boundaries of the C-139, Feeder Canal, and L-28 watersheds (source: SFWMD Subwatershed GIS file). Data from ground water wells shown in ***Figure 4.1.2*** were used to establish boundary conditions. The model boundary was defined as a time-varying constant head boundary. If water levels within the model domain are higher than the boundary water levels, water will leave the model, and conversely, water will enter the model if the boundary water levels are higher than the water levels within the model.

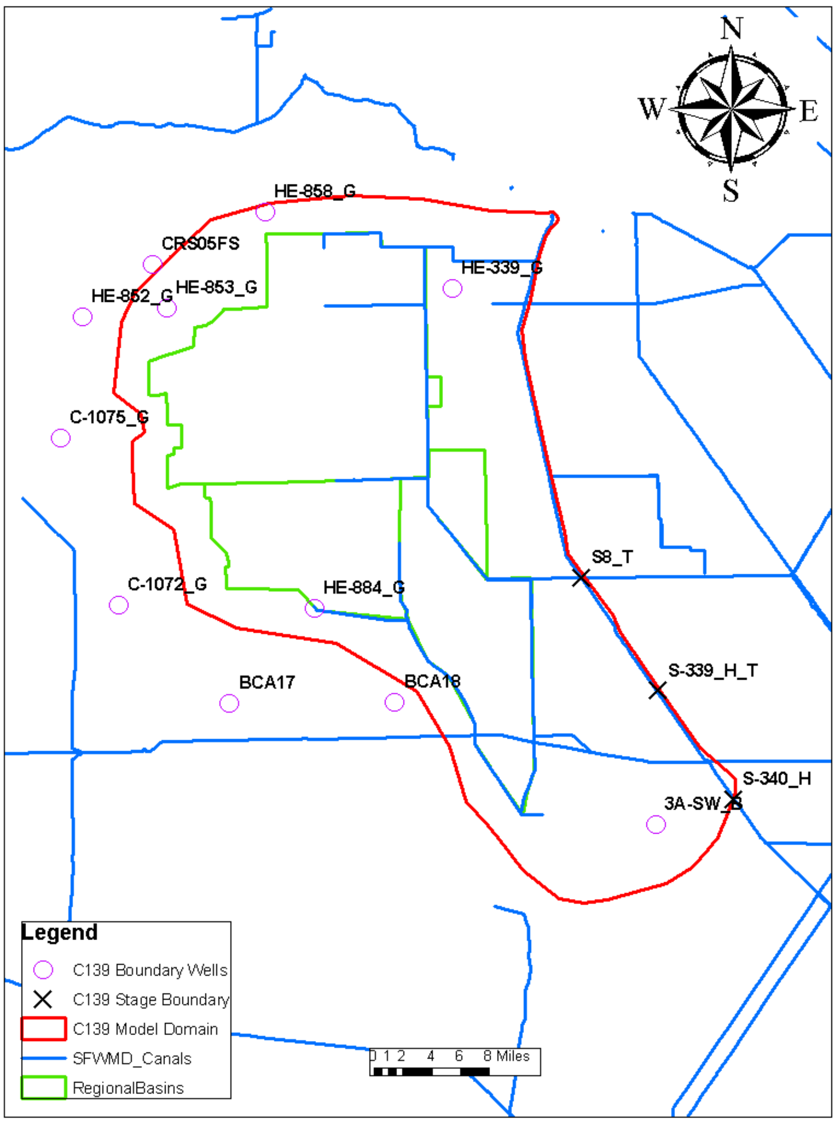


Figure 4.1.2 - Model Domain

Figure 4.1.3 is a graphic of the MIKE SHE model input to illustrate the requirements for the model to run and also provide a framework for this memo as to what has been done to this point with regards to model input. The proposed grid size is 1000 x 1000 ft, resulting in 31,000 grid cells per model layer within the 1,113 square-mile model domain. A smaller grid size would make model run-times excessively long. If possible, the model run-times should be less than 4-5 hours/year.

Figure 4.1.3 - MIKE SHE Model Input Schematic

4.1.3 MODEL INPUT

4.1.3.1 Topography

MIKE SHE (surface and groundwater hydrologic processes) relies heavily on the topographic file used for the simulation, thus model accuracy and simulation output is highly dependent on the accuracy of the topography file used in the model. SFWMD has a 100ft-grid topographic data set from the Southwest Florida Feasibility Study, Digital Elevation Model (SWFFS DEM) shown in ***Figure 4.1.4***; however, this data set has a data gap in the southeast portion of the model. Elevation data from the SFWMD 2x2 model was used for this area (Source: personal communication, Danielle Morancy, SFWMD). In addition, Light Detection and Ranging (LiDAR) from the Florida Division of Emergency Management (FDEM) data is available for a portion of the model domain from the State of Florida as shown in ***Figure 4.1.5***. Additional topographic data were obtained from:

- as-built drawings of levees within the McDaniel Ranch in the L-28 Basin
- spot elevation of Jackman's Ranch in the C-139 basin (Levee 1 and 2 topographic map, area west of levee, Hendry County Engineering Division, 1975)
- spot elevations from wells in Crooks and Golden Ox ranches (SFWMD, 2009)
- topographic maps of U.S. Sugar lands within the C-139 and C-139 Annex basins
- spot elevations of natural ground from cross sections surveyed as part of the Compartment C Hydrologic and Hydraulic Design (URS and ADA, 2007)
- spot elevations obtained as part of this project (task in progress as of August, 2009)

These data sources were used to check the accuracy of the SFWMD topo. It was anticipated that some adjustment of the SWFFS DEM may be needed after the SWFFS DEM was compared to the sources listed above. The results of the comparison are presented in ***Section 4.2. Calibration and Validation.***

Figure 4.1.4 - SFWMD SWFFS DEM

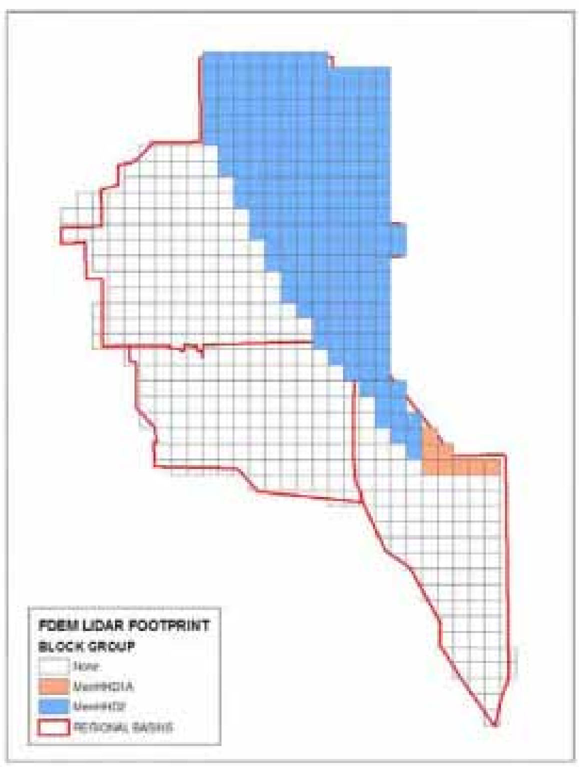


Figure 4.1.5 - Extent of LiDAR Data Available from FDEM

4.1.3.2 Precipitation and PET

Precipitation data are available from rain gages within the model domain and from NEXRAIN grid rainfall files. Both sources of data are described below. This section describes an analysis of both types of rainfall data to determine the type of data to be used in initial model calibration efforts for this project.

Rain Gage Data. Precipitation break point data and Potential Evapotranspiration (PET) daily data, and XY gage locations near and within the model domain were obtained from SFWMD's DBHYDRO browser as show in ***Figures 4.1.6*** and ***4.1.7***, and ***Tables 4.1.1*** and ***4.1.3***. From the gage locations, Thiessen polygons were developed in ArcMap to distribute precipitation and PET over the model domain (***Figures 4.1.8*** and ***4.1.9***).

Several stations (Precip and PET) were missing data for the proposed simulation period (1/1/2003 to 12/31/2008); the stations with missing data were updated with the stations listed in ***Tables 4.1.2*** and ***4.1.4***.

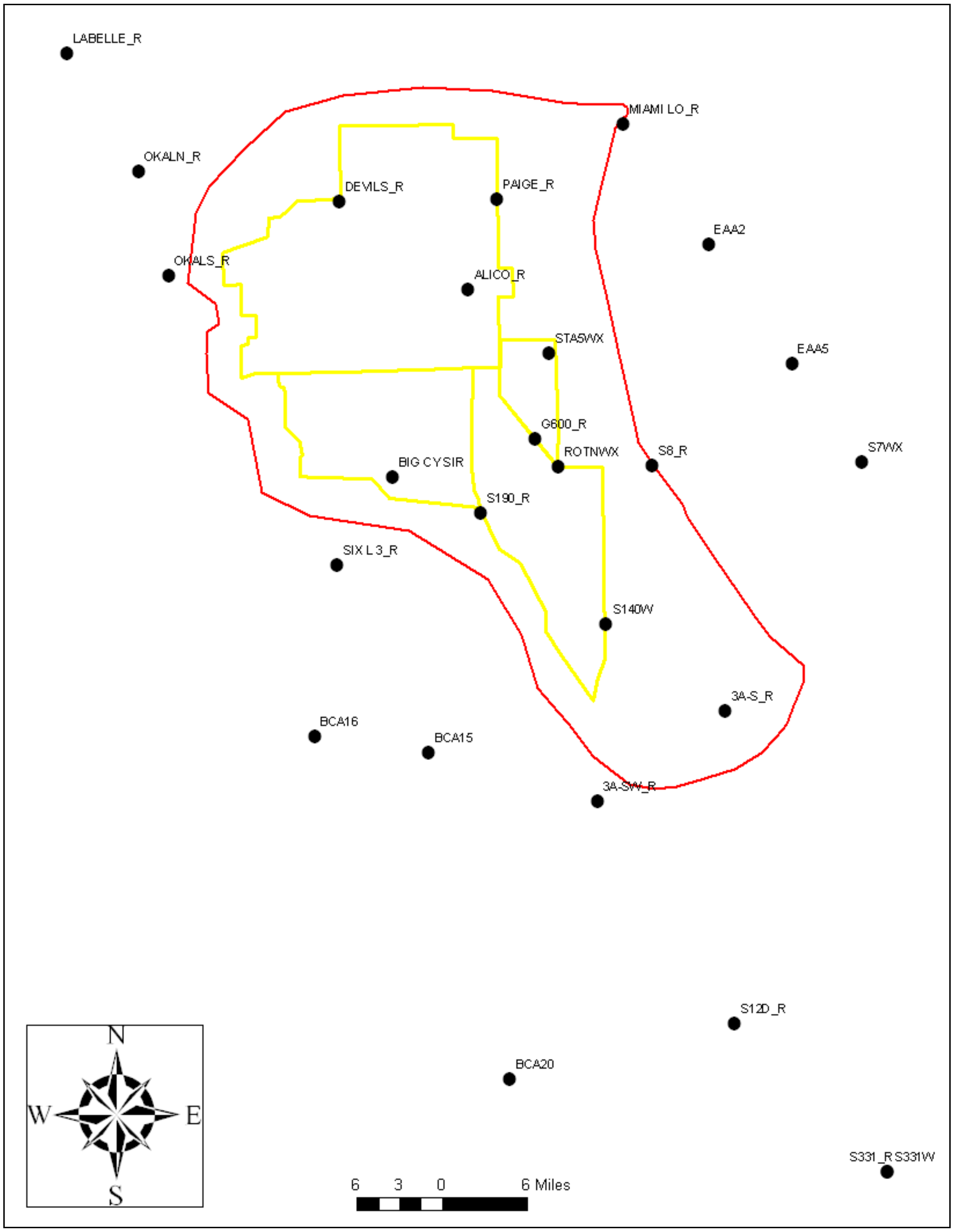


Figure 4.1.6 - DBHYDRO Precipitation Gage Locations

Table 4.1.1 - DBHYDRO Precipitation Locations

X	Y	Station Name	DBKEY
662050.191	792096.255	ALICO_R	IW781
633944.208	722538.985	BIG CY SIR	IW864
614211.264	824829.382	DEVILS_R	IX083
513011.352	879677.744	LABELLE_R	IX895
539617.227	836134.119	OKALN_R	RS693
550799.272	797258.648	OKALS_R	RS697
672665.109	825820.991	PAIGE_R	IY197
692094.773	768364.864	STA5WX	OO373
757409.486	635647.544	3A-S_R	IW752
709980.134	602022.486	3A-SW_R	JA345
647262.815	620082.531	BCA15	PT537
604969.376	626283.728	BCA16	PT540
677568.774	498882.424	BCA20	PT552
817707.71	464586.936	S331W	IY618
817707.71	464586.936	S331_R	P6931
760851.75	519299.406	S12D_R	LS270
807896.812	728054.542	S7WX	IY945
751216.546	808761.194	EAA2	IX113
782131.763	764518.932	EAA5	IX116
730112.505	726534.776	S8_R	RQ469
695472.56	726381.876	ROTNWX	IY274
713237.513	667986.813	S140W	IY400
719458.18	853630.902	MIAMI LO_R	IY090
666738.25	708953.75	S190_R	RQ459
687056.212	736766.359	G600_R	IX542
613438.525	689641.771	SIX L 3_R	IZ044

Table 4.1.2 - Locations Used to Gap-Fill Precipitation Time Series

Precipitation		
Station Name	Station Used To Update	Dates Updated
STA5WX	EAA2	06/27/05 to 06/29/05
ROTNWX	S8_R	10/24/05 to 02/01/07
PAIGE_R	DEVILS_R	05/07/08 to 04/30/09
OKALS_R	SIX L 3_R	03/20/95 to 12/19/03
OKALN_N	DEVILS_R	04/01/1980 to 12/18/03
G600_R	S8_R	09/18/04 to 08/31/05

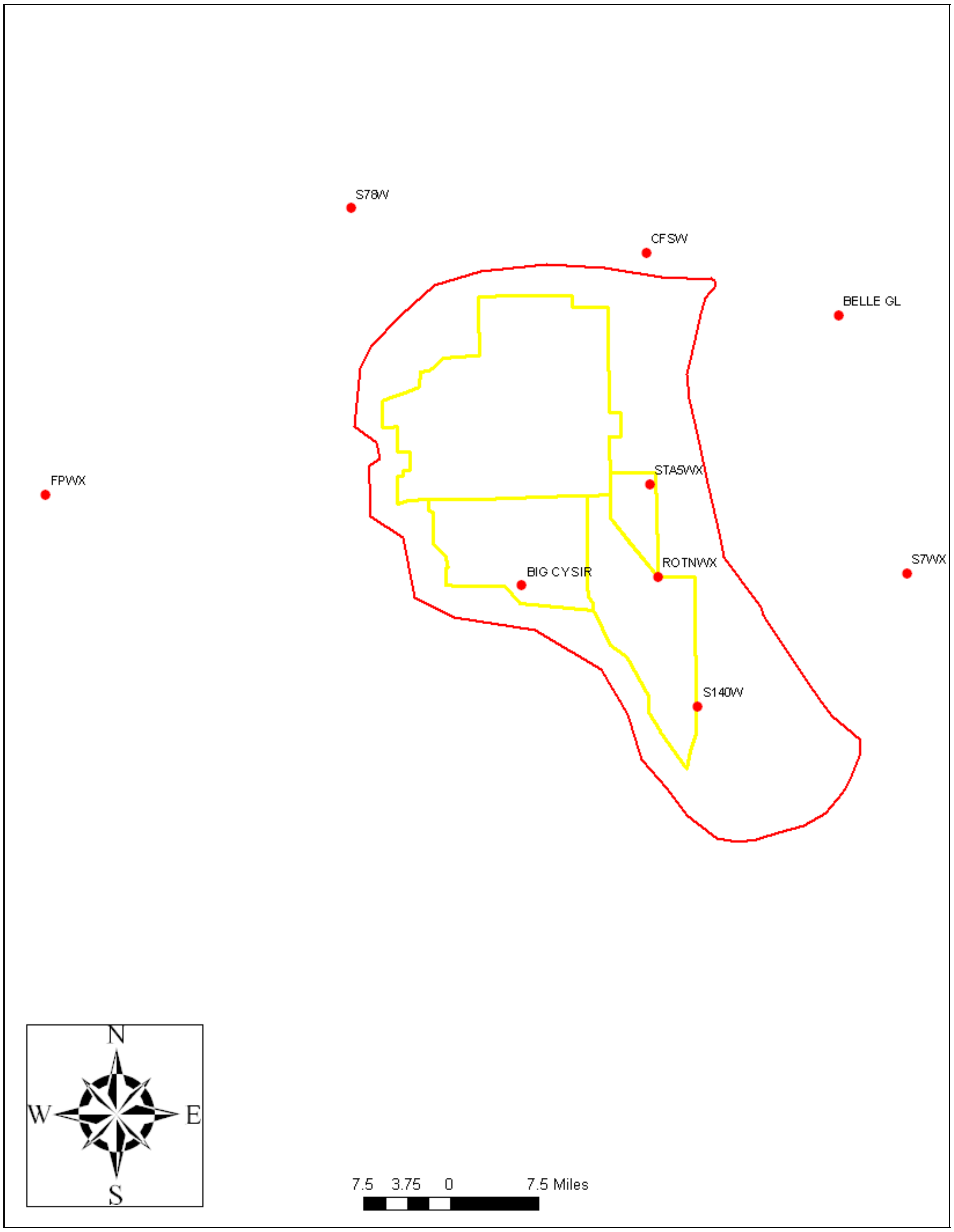


Figure 4.1.7 - DBHYDRO PET Gage Locations

Table 4.1.3 - DBHYDRO PET Locations

X	Y	Station Name	DBKEY
633944.208	722538.985	BIG CY SIR	OU850
690325.941	872881.572	CFSW	OU851
692094.773	768364.864	STA5WX	UK534
713237.513	667986.813	S140W	OH516
695472.56	726381.876	ROTNWX	RW486
777001.906	844609.153	BELLE GL	OH518
419436.348	763584.203	FPWX	OH520
557370.739	892876.155	S78W	RW483
807896.812	728054.542	S7WX	RW484

Table 4.1.4 - Locations Used to Gap-Fill Evapotranspiration Time Series

Evapotranspiration		
Station Name	Station Used To Update	Dates Updated
BIG_CY_SIR	FPWX	07/01/03 to 03/31/05
BIG_CY_SIR	ROTNWX	11/24/03 to 11/29/03
S140W	S7WX	07/17/04 to 07/24/04 09/04/03 to 09/06/03 09/09/03 to 09/16/03 11/21/03 to 11/22/03 11/24/03 to 12/06/03 12/08/03 12/13/03 to 12/15/03 07/19/03 to 08/16/03 04/14/03 to 04/22/03
STA5WX	CFSW	01/01/01 to 07/01/06
ROTNWX	S7WX	01/27/03 to 02/23/03 02/26/03 to 03/24/03 06/02/03 to 06/06/03 08/28/03 to 08/30/03 09/03/03 to 09/06/03 09/08/03 to 09/11/03 09/15/03 10/22/02 to 10/24/03 12/25/03 to 12/27/03 01/04/04 to 01/06/04

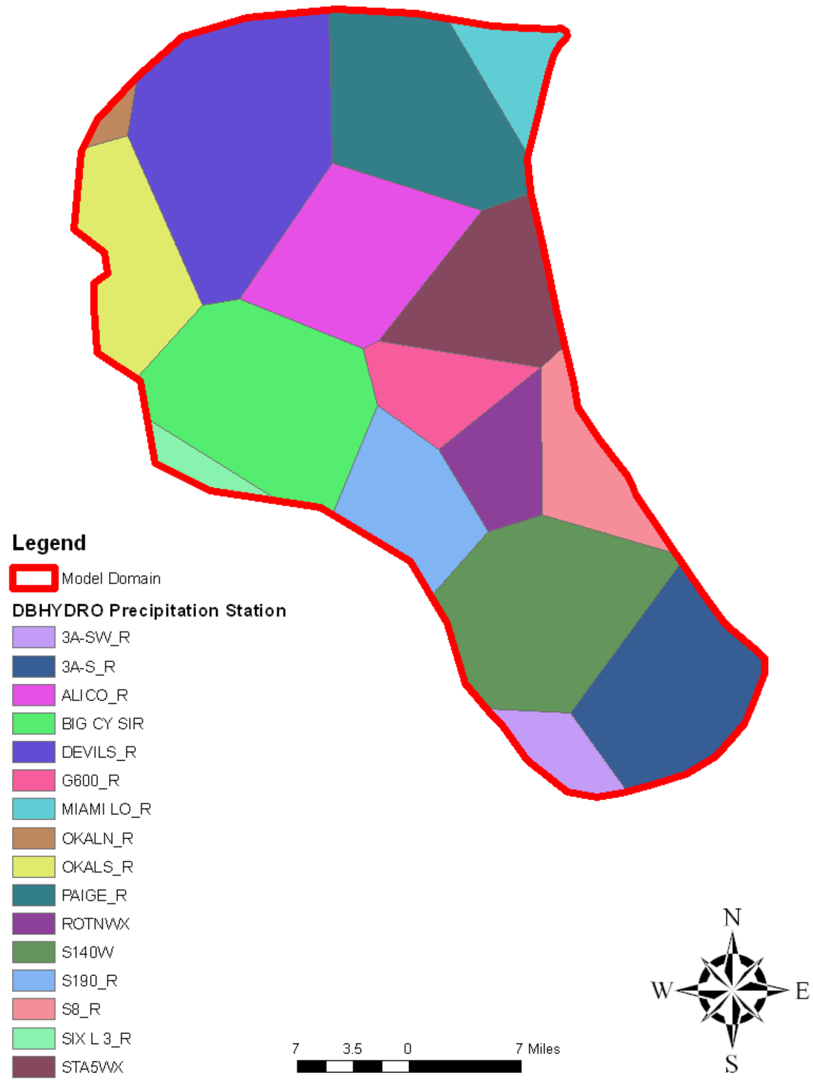


Figure 4.1.8 - MIKE SHE Precipitation Thiessen Polygons

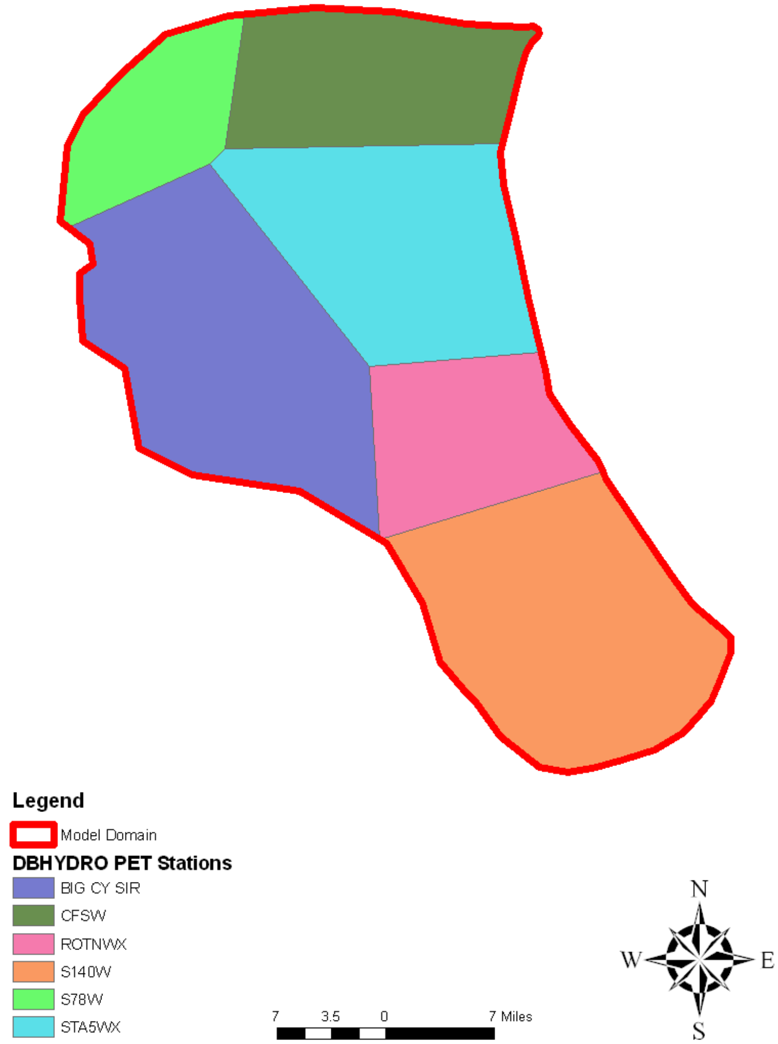


Figure 4.1.9 - PET Thiessen Polygons

NEXRAIN Grid Rainfall Data. Grid rainfall data was compared to rain gage data using both monthly and hourly rainfall totals. The monthly comparisons were conducted by Chandra Pathak of SFWMD, and the results of that analysis were provided to the project team. Pathak's analysis indicates that the grid rainfall data is generally similar to point rain gage data. As shown in ***Figure 4.1.10***, differences are noted for a number of storms.

The URS/ADA modeling team obtained hourly grid rainfall files for selected cells directly on top of point rain gage locations or next to point rain gage locations (if the rain gage was located on the edge of a rainfall grid cell). Comparisons were made of the measured rain gage hourly information and grid rainfall values for 2005-2008. ***Figures 4.1.11*** and ***4.1.12*** show the results for selected periods for the Alico rain gage station. It can be seen that grid rainfall over-predicts rainfall in relation to gage data at the Alico station. The Alico cumulative grid rainfall and gage rainfall do not fall under acceptable range. Grid rainfall data also over-predicts rainfall at the 3A_S, G600, ROTNWX and STA5WX gages by 6 to 27%. No stations were found to have grid rainfall cumulative totals less than rain gage rainfall totals. Differences are minor for the S-140 rain gage. Since the grid rainfall data will require extensive programming to translate the data into the correct format, the model was calibrated first using gage rainfall data. A switch to grid rainfall data is possible in future Phases of the project if considered necessary.

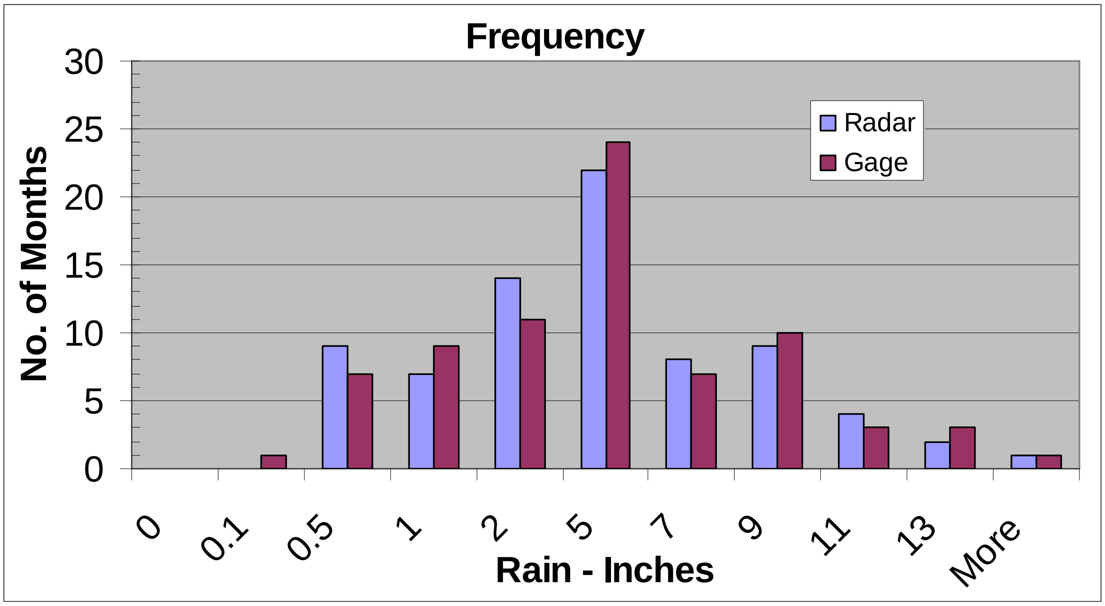


Figure 4.1.10 - Radar and Gage Monthly Totals for 2002 – 2008, Grouped by Monthly Totals

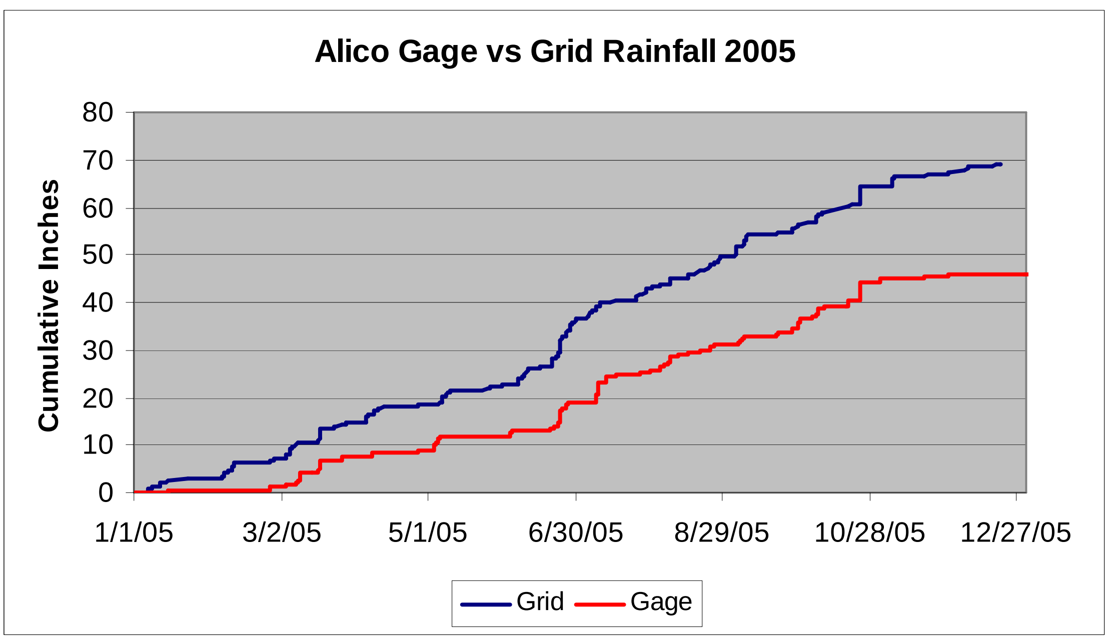


Figure 4.1.11 - 2005 Alico Rain Gage and NEXRAIN Cumulative Rainfall

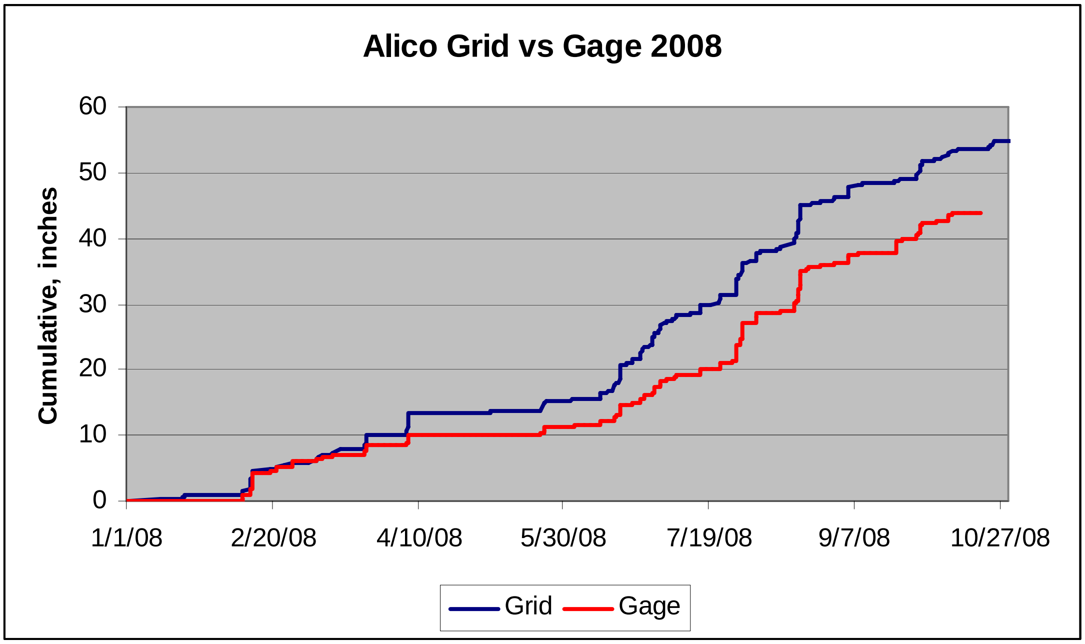


Figure 4.1.12 - 2008 Alico Rain Gage and NEXRAIN Cumulative Rainfall

4.1.4 LAND USE

4.1.4.1 Vegetation

MIKE SHE land use categories (***Table 4.1.5***) were derived from the SFWMD 2004-2005 land use spatial and tabular data. The tabular data or FLUCCS codes were then related to the MIKE SHE land use code and description within the model boundary. From this coverage a grid code file was developed to show the spatial distribution of the land use types within the model domain (***Figure 4.1.13***). A description of the MIKE SHE land use types is provided in ***Table 4.1.5***.

Other parameters related to the SFWMD 2004-2005 land use coverage include: Paved Runoff Coefficient, Manning Number, and Detention Storage. These parameters are shown in ***Table 4.1.5*** and were obtained from previous modeling efforts near the study area where the values of the parameter were considered appropriate. In the case of Manning's M overland flow values, the original reference documents used to select roughness values for the prior models included Chow (1959), SCS (1986), and Figure 3.1 of SFWMD (2004). Each of the land use parameters listed in ***Table 4.1.5*** was developed from a land use coverage point file, which was then imported into MIKE SHE. ***Figures 4.1.14*** through ***4.1.16*** present graphics of the aforementioned land use parameters and ***Tables 4.1.6*** through ***4.1.8*** present the accompanying statistics.

Table 4.1.5 - MIKE SHE Land use Grid Code and Description

Land Use Code	MIKESHE Description	Detention Storage (inch)	ManningsM	Paved Runoff Coefficient
1	Citrus	1.15	5.88	0
2	Cropland	1	7.14	0
3	Sugar Cane	1	5.88	0
5	Truck Crops	1.25	5.88	0
6	Rangeland - Upland Forests	1	6.14	0
7	Pasture	1	7.14	0
8	Mesic Flatwood	1.2	5	0
9	Mesic Hammock	1.2	3.33	0
10	Xeric Flatwood	1.2	5	0
11	Xeric Hammock	1.2	3.33	0
12	Hydric Flatwood	1.2	5	0
13	Hydric Hammock	1.2	2.5	0
14	Wet Prairie	1.25	3.33	0
15	Cypress	1.25	2.5	0
16	Marsh	1.25	1.67	0
18	Swamp Forest	1.25	2.5	0
20	Water	0	0	0
41	Urban - Low Density	2.5	7.14	0.07
42	Urban - Medium Density	2.5	8.33	0.22
43	Urban - High Density	2.5	9.01	0.62
50	Commercial	2.5	9.01	0.35
60	Levee	0	6.67	0

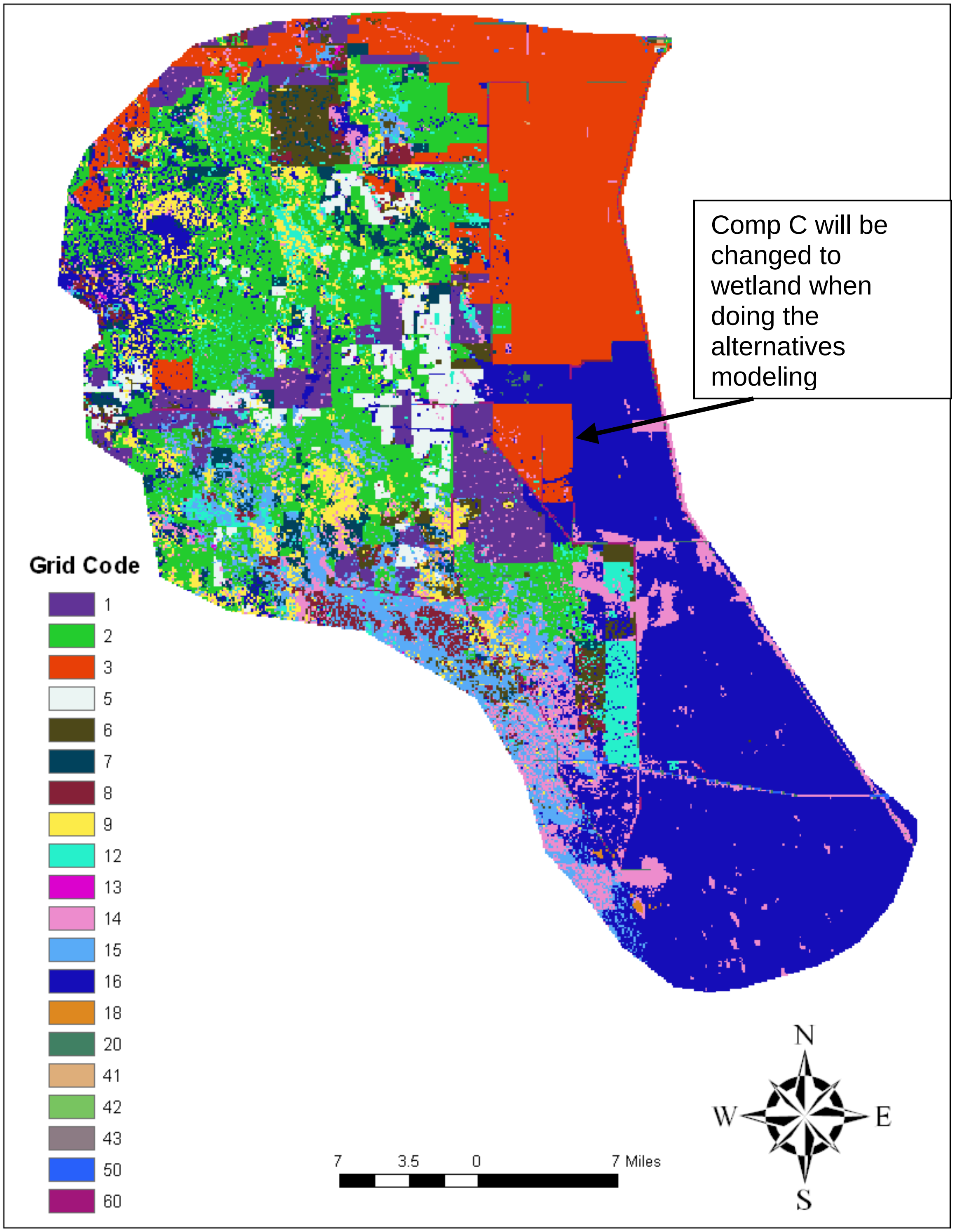


Figure 4.1.13 - MIKE SHE Land Use Grid Codes

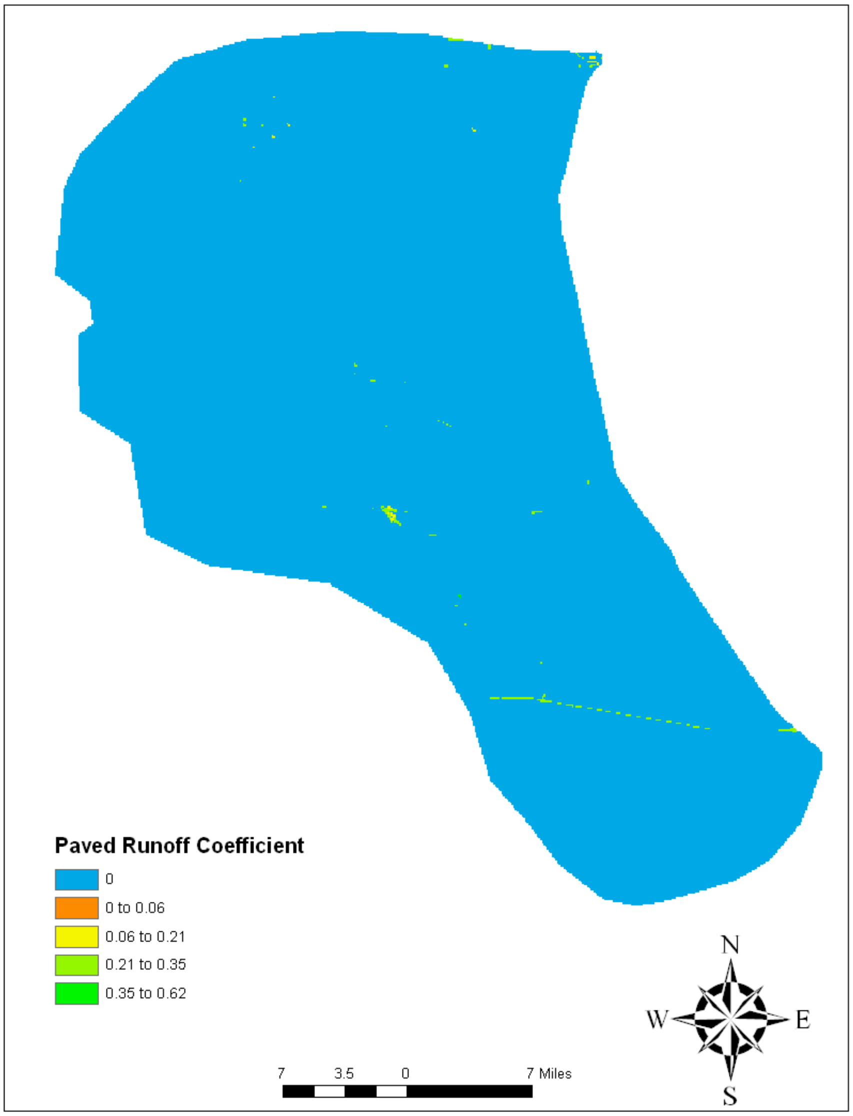


Figure 4.1.14 - MIKE SHE Paved Runoff Coefficient

Table 4.1.6 - Paved Runoff Coefficient Statistics

- [Paved_RunoffCoefficient]

Statistics

Statistics | Sub-Set

Selection Statistics

Max. Value:	0.517870	Min. Value:	0.000000
Mean Value:	0.000793	Standard Deviation:	0.013449

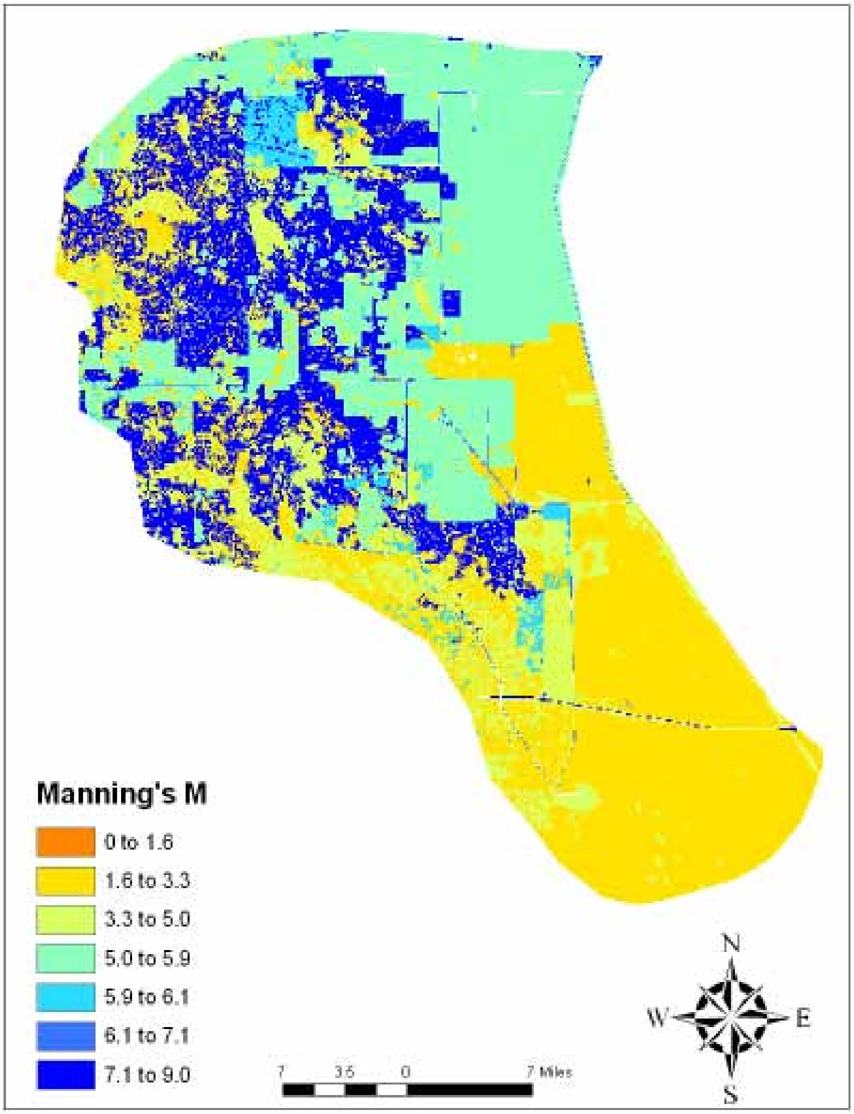


Figure 4.1.15 - MIKE SHE Manning's M Roughness Coefficient

Table 4.1.7 - Manning's M Roughness Coefficient Statistics

- [Mannings_M]

Statistics

Statistics | Sub-Set

Selection Statistics

Max. Value:	9.010000	Min. Value:	0.000000
Mean Value:	4.350331	Standard Deviation:	2.036062

Distribution

URS

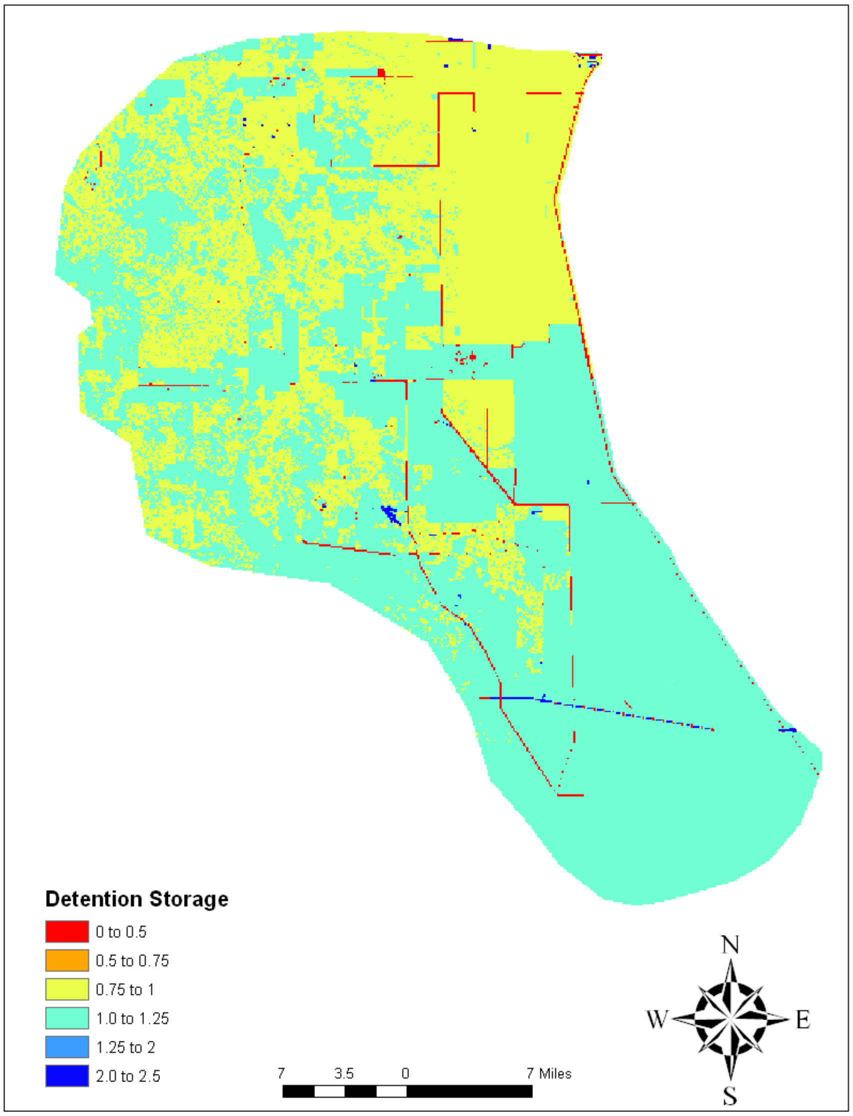


Figure 4.1.16 - MIKE SHE Detention Storage

Table 4.1.8 - Detention Storage Statistics

[DetentionStorage]

Statistics

Statistics | Sub-Set

Selection Statistics

Max. Value:	0.098425	Min. Value:	0.000000
Mean Value:	0.044580	Standard Deviation:	0.006126

Distribution

4.1.4.2 Soils

Soils data was obtained from the National Resources and Conservation Services (NRCS) state of Florida soils coverage (***Table 4.1.9*** and ***Figure 4.1.17***). Another potential source of data that was considered was the SFWMD soil database. The SFWMD information was not used as it only covers a portion of the model domain and the level of detail is finer than needed for a regional simulation model. MIKE SHE will utilize the 2-D soil parameter calculation which has been commonplace for previous model studies in the area.

Table 4.1.9 - NRCS Soil Name Legend

FID	NRCS Soil Name
0	Urban land-Margate-Hallandale-Boca (s1599)
1	Smyrna-Immokalee-Basinger (s1547)
2	Wabasso-Terra Ceia-Pineda-EauGallie-Demory-Boca (s1549)
3	Smyrna-Immokalee-Basinger (s1547)
4	Winder-Wabasso-Pineda-Felda (s1545)
5	Margate (s1604)
6	Riviera-Copeland-Boca (s1593)
7	Popash-Pomona-Myakka-Malabar-EauGallie (s1544)
8	Winder-Wabasso-Pineda-Felda (s1545)
9	Plantation-Lauderhill-Dania (s1600)
10	Popash-Pomona-Myakka-Malabar-EauGallie (s1544)
11	Smyrna-Immokalee-Basinger (s1547)
12	Popash-Pomona-Myakka-Malabar-EauGallie (s1544)
13	Smyrna-Immokalee-Basinger (s1547)
14	Torry-Pahokee (s1591)
15	Popash-Pomona-Myakka-Malabar-EauGallie (s1544)
16	Wabasso-Terra Ceia-Pineda-EauGallie-Demory-Boca (s1549)
17	Popash-Pomona-Myakka-Malabar-EauGallie (s1544)
18	Popash-Pomona-Myakka-Malabar-EauGallie (s1544)
19	Wabasso-Terra Ceia-Pineda-EauGallie-Demory-Boca (s1549)
20	Wabasso-Terra Ceia-Pineda-EauGallie-Demory-Boca (s1549)
21	Smyrna-Immokalee-Basinger (s1547)
22	Smyrna-Immokalee-Basinger (s1547)
23	Popash-Pomona-Myakka-Malabar-EauGallie (s1544)
24	Winder-Wabasso-Pineda-Felda (s1545)
25	Popash-Pomona-Myakka-Malabar-EauGallie (s1544)
26	Winder-Wabasso-Pineda-Felda (s1545)
27	Winder-Wabasso-Pineda-Felda (s1545)
28	Wabasso-Terra Ceia-Pineda-EauGallie-Demory-Boca (s1549)
29	Smyrna-Immokalee-Basinger (s1547)
30	Smyrna-Immokalee-Basinger (s1547)
31	Wabasso-Terra Ceia-Pineda-EauGallie-Demory-Boca (s1549)
32	Popash-Pomona-Myakka-Malabar-EauGallie (s1544)
33	Popash-Pomona-Myakka-Malabar-EauGallie (s1544)
34	Wabasso-Terra Ceia-Pineda-EauGallie-Demory-Boca (s1549)
35	Margate (s1604)
36	Water (s8369)
37	Torry-Pahokee (s1591)
38	Terra Ceia-Pahokee (s1590)
39	Pahokee (s1589)
40	Torry-Pahokee (s1591)
41	Terra Ceia-Pahokee (s1590)
42	Terra Ceia-Pahokee (s1590)
43	Pahokee (s1601)
44	Torry (s1603)
45	Riviera-Copeland-Boca (s1593)
46	Terra Ceia (s1602)
47	Pennsuco-Ochopee (s1592)
48	Pahokee-Lauderhill-Dania (s1588)

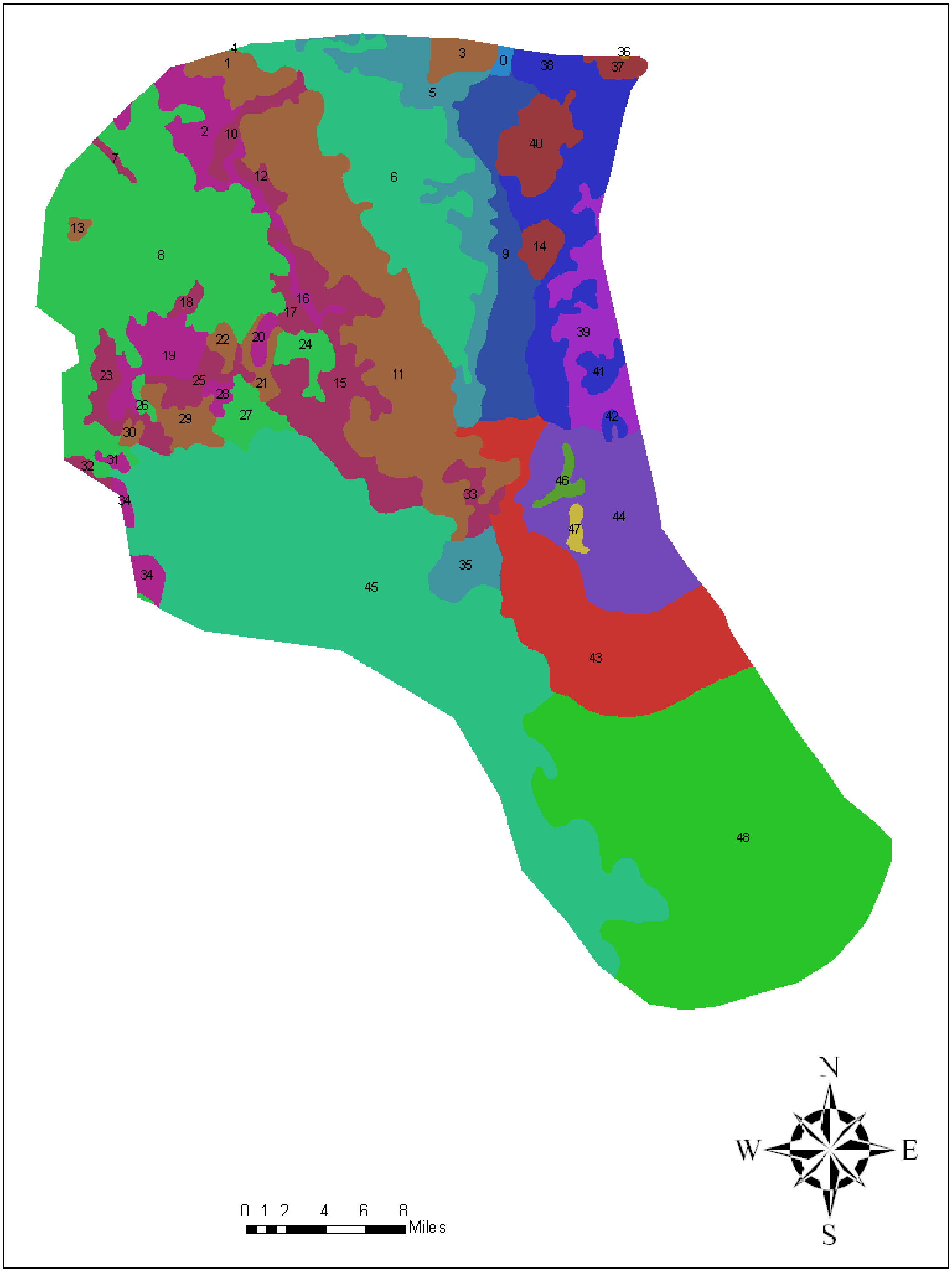


Figure 4.1.17 - NRCS Soils Map

4.1.5 OVERLAND-GROUNDWATER LEAKAGE

MIKE SHE has the capability to limit leakage from the overland flow plane to the groundwater system using a user-specified coefficient. This coefficient is added as a constant value across the model domain or as a spatially-varied grid file. This is normally used in wetland areas where an organic layer is known to be present on the land surface that is not part of the normal soils coverage. Another area where overland-groundwater leakage coefficients are defined is for soils that are known to have caprock, a fragipan, or a thin area of clay near the land surface. An overland-groundwater leakage coefficient file was defined during the early phases of calibration. This parameter is often used if there is a wetland that has low permeability soils which result in a perched water table above the surficial aquifer. If monitoring data or empirical observations indicate that the wetland water levels are higher than the surficial aquifer, then the overland-groundwater leakage coefficient will be necessary. In these situations, an empirically derived value will be inputted and adjusted until the wetland hydroperiod is deemed sufficient. The calibration and validation section documents the areas where this coefficient is being used and provide a summary of the considerations made during calibration.

4.1.6 SEPARATED FLOW AREAS

MIKE SHE has the capability to prevent overland flow from moving across user-specified boundaries. Separated flow areas are added as using a shape file. This is normally used where there are known barriers to overland flow. MIKE 11 branches are needed to transport waters from one overland flow area to another. Because flows are limited by MIKE 11 conveyance features, separated flow areas should not be used in areas without MIKE 11 branches unless the modeler is sure that there are no outflows from the separated flow area. The separated flow area file was not been finalized during the model set-up, however I-75, levees L-1, L-2, and L-3, and farm perimeters are likely separated flow areas. This information was used to generate a separated flow area file prior to the start of calibration. ***Figure 4.1.18*** a map of the separated flow areas being used in the model set-up.

Often there are small berms to limit flooding and/or discharges to and from farm fields during most periods, except when they become over-topped during major floods. If this is the case, a short branch with a user-defined weir is added to the MIKE 11 network with the weir elevation equal to the top elevation of the small berm.

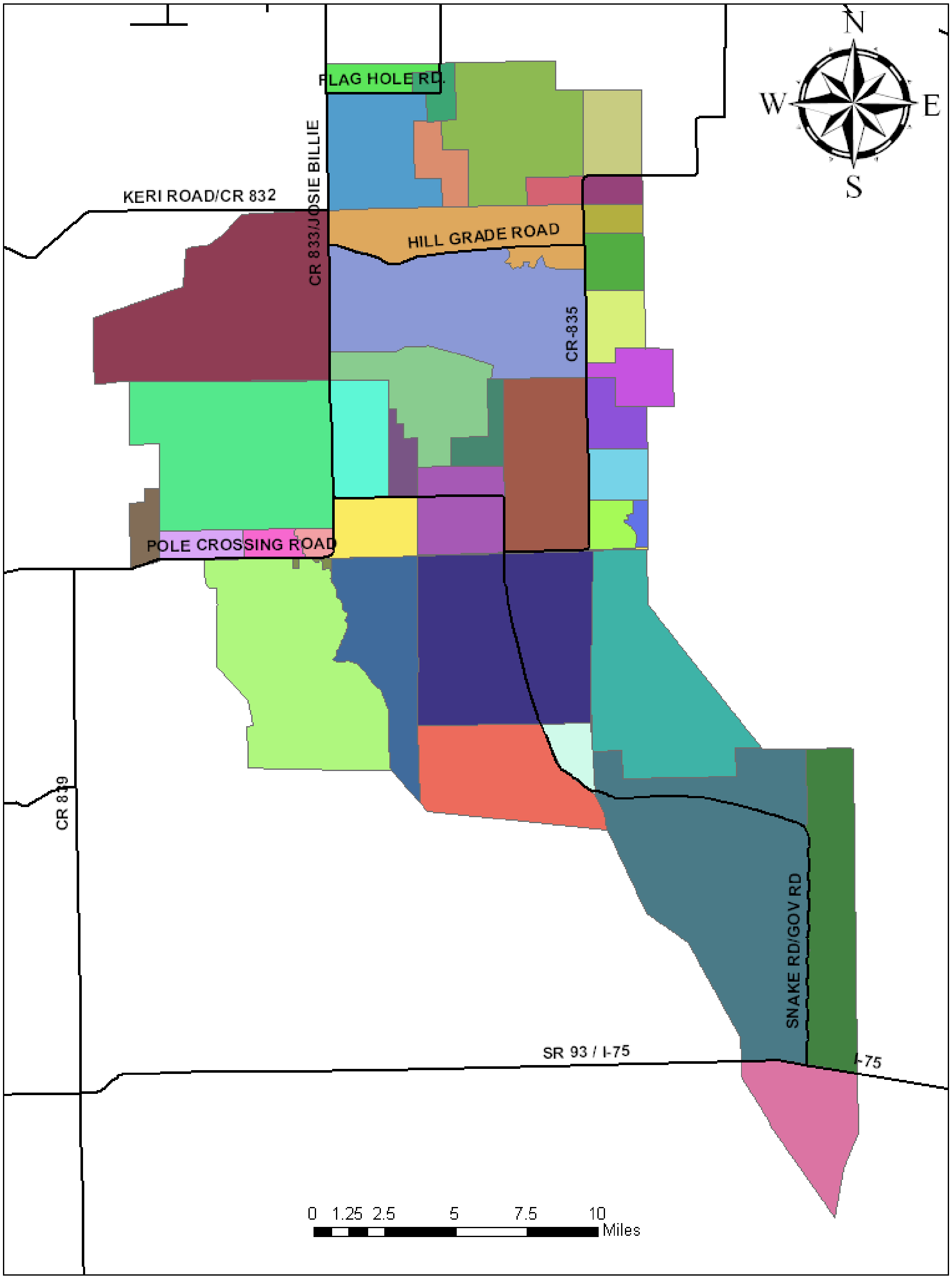


Figure 4.1.18 - Separated Flow Area Map

4.1.7 SATURATED ZONE

4.1.7.1 Hydrogeology

The hydrogeologic investigation commenced with a review of available literature and model files that contained pertinent data. Documents and models that cover the study area were obtained and are listed below:

1. Radin, H., Rodberg, K., 2009, C-139 Model Runs, South Florida Water Management District, Executive Summary.
2. Radin, H., Rodberg, K., 2009, C-139 Model Runs, South Florida Water Management District, Model files.
3. Marco Water Engineering, 2005, Lower West Coast Surficial Aquifer System Model, Report.
4. Marco Water Engineering, 2005, Lower West Coast Surficial Aquifer System Model, MODFLOW Model files.
5. Reese, S., Cunningham, K., 2000, Hydrogeology of the Gray Limestone Aquifer in Sothern Florida, US Geological Survey, Water Resources Investigation Report 99-4213, Prepared in cooperation with the South Florida Water management District.
6. Southwest Florida Feasibility Study (SWFFS) GIS hydrostratiographic files.
7. SFWMD Water Supply Staff, 2009, Hydrogeologic Assessment of Crook's and Golden Ox Ranches, Hendry County, SFWMD.
8. Hendry County Aquifer Performance Test Results (no date). The file HendryCo-APT-AquiferTests.pdf contains data that was provided to us by Steve Krupa. The document was found in a SFWMD library and is undated. It is believed that the information from this file was used to develop the first MODFLOW model of the C-139 Watershed, which was subsequently modified by Marco Water Engineering, 2005.

A synopsis on each of the above is provided in the following subsections.

4.1.7.1.1 Reports Synopsis

Lower West Coast Surficial Aquifer System (LWCSAS) Model
This model covered a large area including most of the C-139 model domain as shown in ***Figure 4.1.19***.

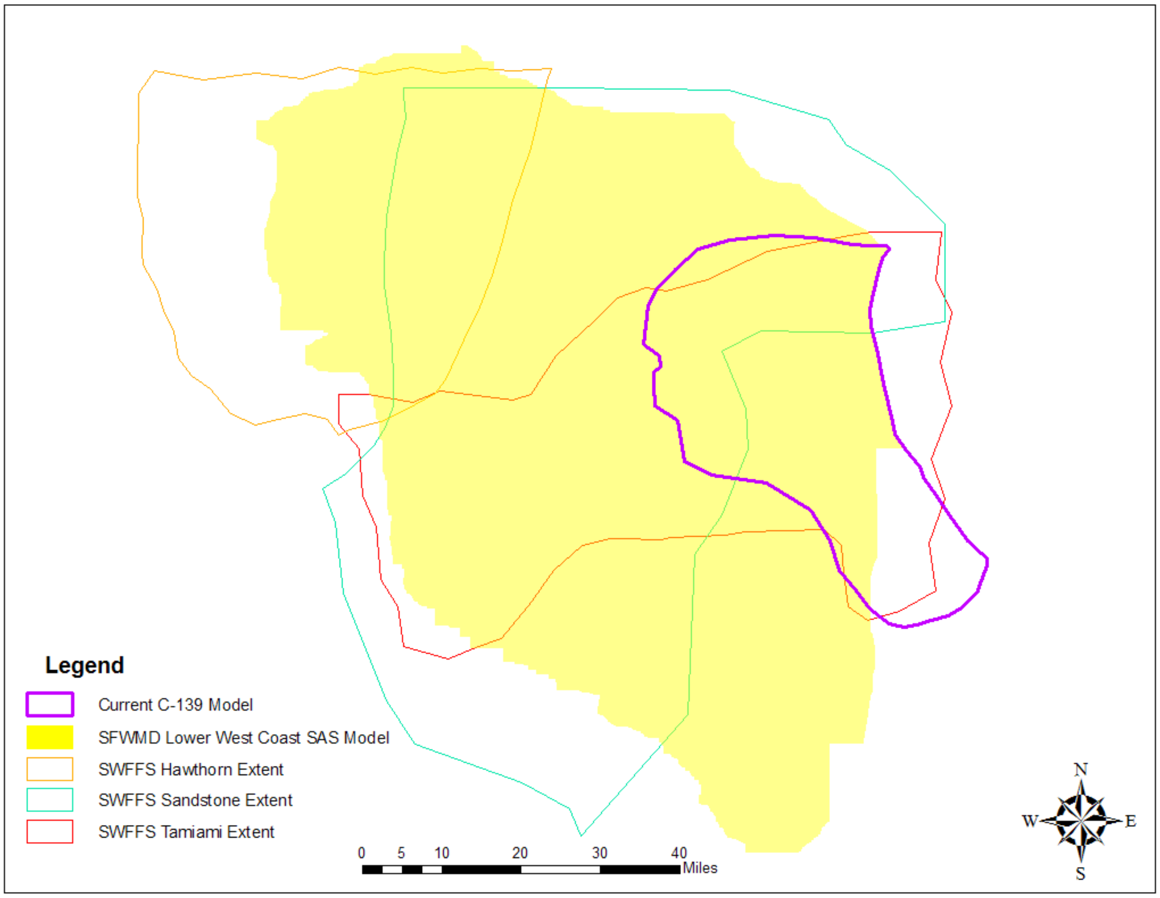


Figure 4.1.19 - Map of Groundwater Models to be Used in C-139 Feasibility Study MIKE SHE Model

This work provided the basis for the model framework used and described in this memorandum. The following in italics is a direct extract from the LWCSAS report:

> *The Lower West Coast is underlain by three aquifer systems: The Surficial Aquifer System, the Intermediate Aquifer System, and the Floridan Aquifer System. In this study, three layers of aquifers - Water Table Aquifer (Layer 1), Lower Tamiami Aquifer (Layer 2), and Sandstone Aquifer (Layer 3) - were simulated in the model.*
>
> *In southwest Florida, the Surficial Aquifer System consists of the Surficial and the Lower Tamiami Aquifers. These aquifers are the predominant sources of water for both urban and agricultural demands. The Intermediate Aquifer System consists of the Sandstone and Mid-Hawthorn Aquifers. It separates the Surficial Aquifer System and the Floridan Aquifer System. The Floridan Aquifer System consists of the Upper Floridan, Middle Floridan, and Lower Floridan Aquifers.*

The MODFLOW model files provided with this report include values of hydraulic conductivities, storativities, and top and bottom elevation for each layer. However, it does not provide vertical hydraulic conductivities since MODFLOW 96 was used and these are not required. Leakances between the layers were simulated as leakance coefficients in MODFLOW. However, MIKE SHE requires vertical hydraulic conductivities.

The MODFLOW model files were loaded within the GWVistas Version 4 software and shape files of horizontal hydraulic conductivity, storativity, and layer elevations exported for importation into MIKE SHE.

C-139 Model Runs

An executive summary and MODFLOW model files were provided by SFWMD. The focus of this modeling effort was to use the LWCSAS model to obtain a more accurate C-139 basin simulation. This was accomplished by updating the model with permit information in the C-139 basin. According to the executive summary, the original LWCSAS model documentation emphasized that only the Lee County Permits had previously been checked for quality control. This means that Hendry County was not checked and there are potential errors. Furthermore, permits needed to be updated to current conditions. The focus though, is on C-139 and not the entire Hendry County. Consequently, this model provided pertinent information of current 2009 permitted water allocations within C-139. Other information in the model appeared to be the same, including the model domain shown in ***Figure 4.1.19***, as the LWCSAS model as described under LWCSAS Model above.

Hydrogeology of the Gray Limestone Aquifer in Sothern Florida

This report provided an overall description of the hydrostratiography in a large area including the C-139 basin. The Gray Limestone aquifer extends over most of central-south Florida including eastern and central Collier County and southern Hendry County. It includes the Lower Tamiami and water table aquifer in some locations. This report is comprehensive and provides information on hydrostratiography in the study area showing that the thickness of the aquifer is 30 to 100 feet. Results of pumping test data are also provided. Hydraulic conductivities ranged from 200 to 12, 000 feet per day.

GIS Hydrostratiographic Files

This information was available from the Southwest Florida Feasibility study which included a GIS database of spatial extent of aquifers and semi-confining lens, hydraulic conductivities, storativity, and top and bottom elevations of aquifers. Model extents for various hydrogeologic layers are shown in ***Figure 4.1.19***.

Crook's and Golden Ox Ranches Hydrogeologic Assessment

This report was for a small area within the C-139 basin shown in ***Figure 4.1.20*** below. The hydrogeologic assessment included aquifer performance tests for two sites within the ranches are shown below in ***Table 4.1.10***.

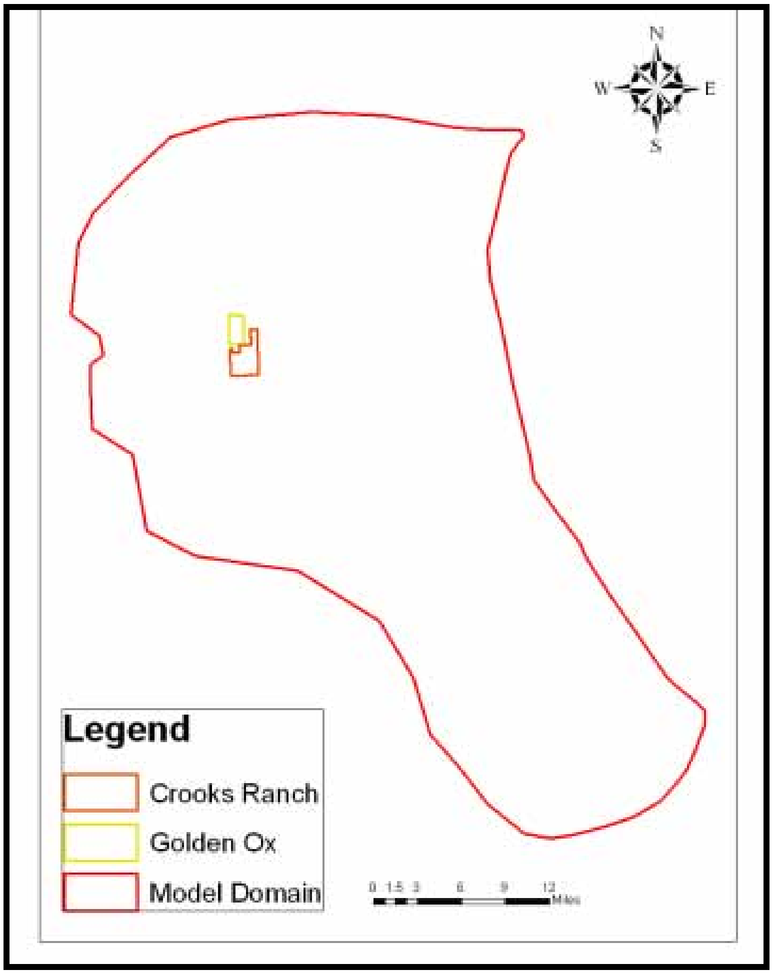


Figure 4.1.20 - Location of Crook's and Golden Ox Ranches

Table 4.1.10 - Information from Aquifer Performance Tests

	Site 4	Site 6
Vertical hydraulic conductivity (ft/day)	0.15	0.044
leakance coefficient (/day)	0.0026	0.0015
Transmissivity (ft2/day)	21,734	18,834
Storativity	2.46E-04	1.85E-04
Aquifer thickness (ft)	58	30
Calculated hydraulic conductivity	375	628

Also shown in the report is a figure showing the North-South hydrogeologic cross section across the site (***Figure 4.1.21***).

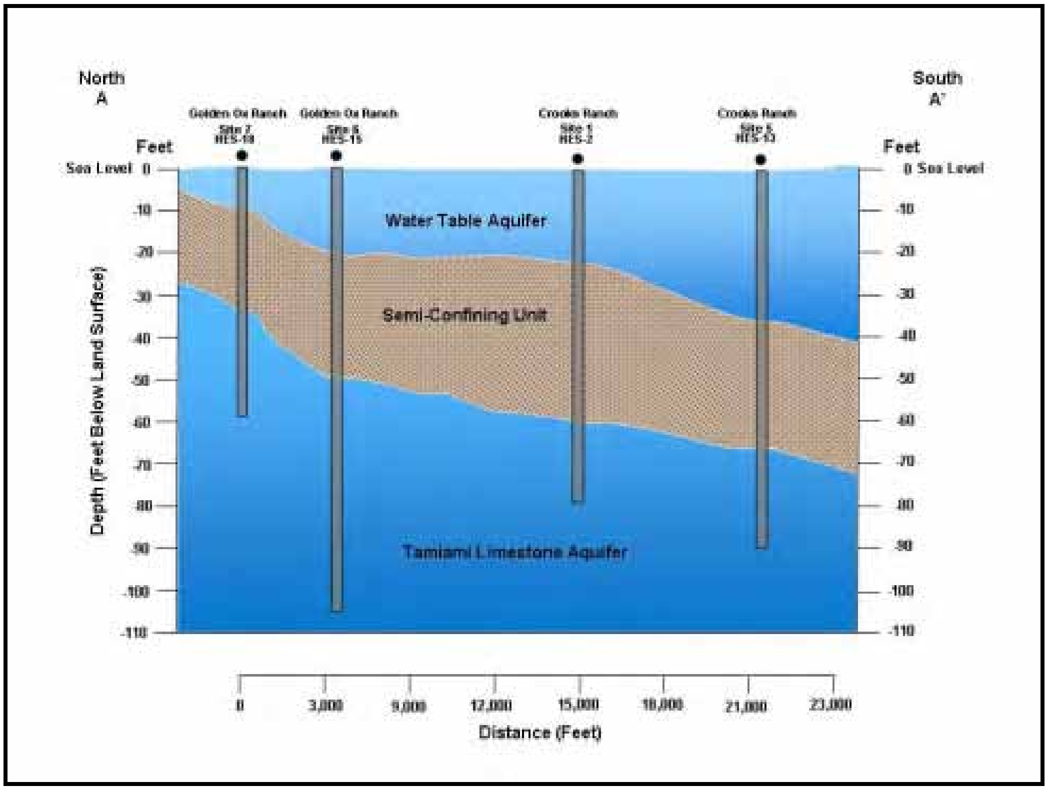


Figure 4.1.21 - North-South Hydrogeologic Cross Section (Source SFWMD, 2009)

HendryCo-APT-AquiferTests.pdf

This undated file was found in the SFWMD library and contains aquifer performance test (APT) results for a number of wells in Hendry County. ***Figure 4.1.22*** illustrates the location of APTs that were used during calibration. Information from tables in the pdf was copied into an attribute table of an APT shape file created by ADA and was used during the calibration to check aquifer hydrogeologic parameters.

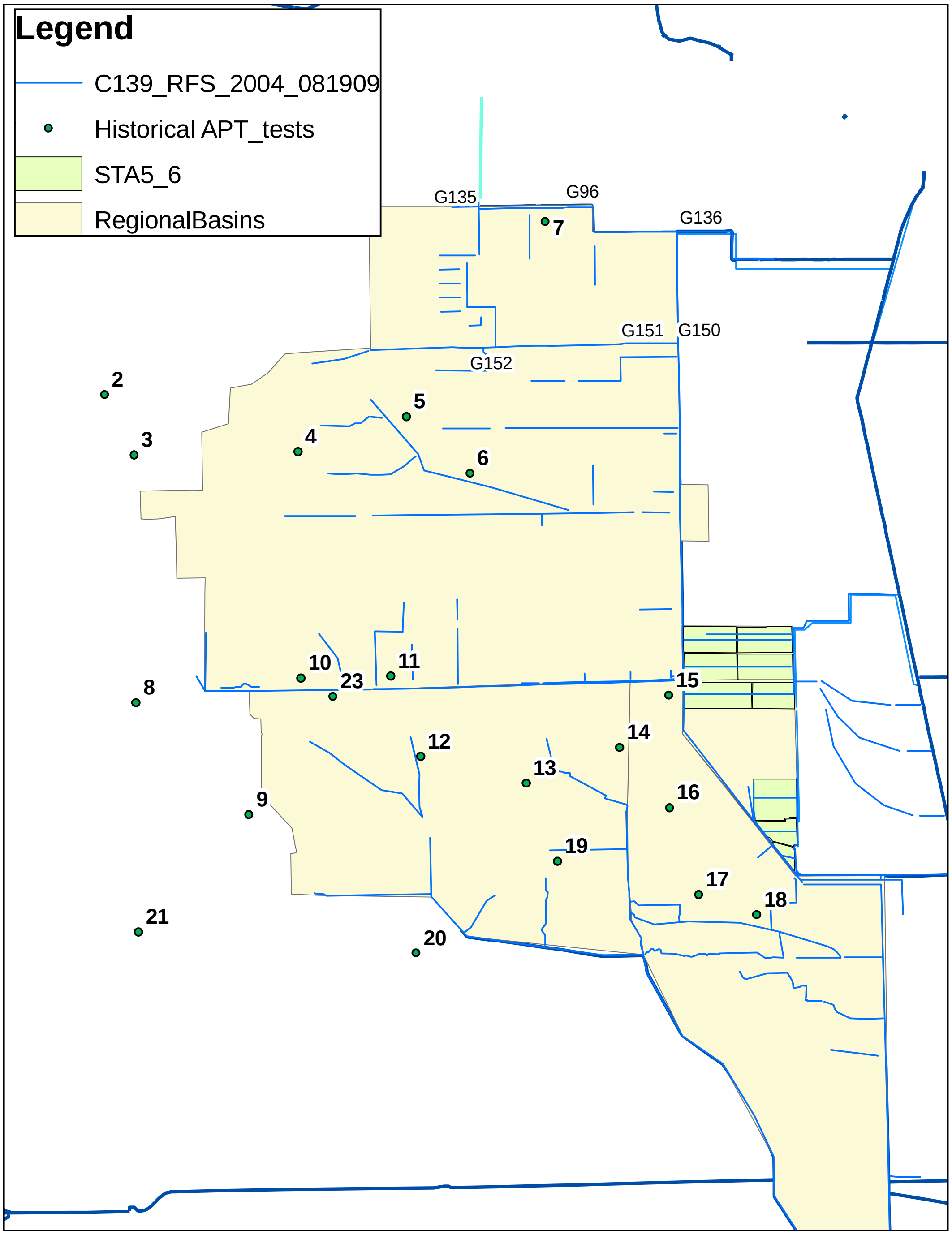


Figure 4.1.22 - Aquifer Performance Test Locations from Undated SFWMD files

4.1.7.2 MIKE SHE Hydrogeology Model Setup

Based on the above review, and review of other information and models such as the SFWMD Hendry County Model, the MIKE SHE model saturated zone was set up as a three-layer model with lens representing the semi-confining units as shown in ***Figure 4.1.23***.

MODEL LAYER 1	WATER TABLE AQUIFER
MODEL LENS	LENS REPRESENTING SEMI-CONFINING UNIT **(BONITA SPRINGS LENS)**
MODEL LAYER 2	LOWER TAMIAMI AQUIFER
MODEL LENS	LENS REPRESENTING SEMI-CONFINING UNIT **(UPPER PEACE RIVER LENS)**
MODEL LAYER 3	SANDSTONE AQUIFER
MODEL BASE	**NO FLOW BONDARY**

Figure 4.1.23 - Model Layers (Not to scale)

Initial parameters used in model for each layer and lens are described in the following sub-sections.

4.1.7.2.1 Water Table Aquifer

The water table aquifer is the uppermost layer of the model from land surface (***Figure 4.1.24***) and the bottom elevations of the water table aquifer are shown in ***Figure 4.1.25***. The data for the top elevation were the same data as the topography described in ***Section 3.1***. Data for the bottom elevation of the water table aquifer were extracted from the C-139 MODFLOW by Radin and Rodberg. The bottom elevation data were compared with that in the model files of Marco Engineering and found to be similar if not identical.

Figure 4.1.24 shows that the elevation of the top of the water table aquifer varies from just over 30 feet NGVD to less than 9 feet NGVD. The bottom of the aquifer varies in elevation from 16 to -100 feet as shown in ***Figure 4.1.25***. The difference between the top and the bottom of the aquifer is the aquifer thickness and is shown in ***Figure 4.1.26***. This thickness map shows thicknesses varying from almost 100 feet to approximately 10 feet. Top and bottom elevations, as well as aquifer thickness were directly extracted for the C-139 MODFLOW model. The information though was consistent with the other models and reports.

Hydraulic conductivities were extracted from the MODFLOW model files and extrapolated to the eastern end of the model domain which was not covered in MODFLOW. The horizontal hydraulic conductivity of the Water Table Aquifer (presented in ***Figure 4.1.27***) ranges from 20 to over 500 (ft/day). Vertical hydraulic conductivity (***Figure 4.1.28***) in the water table aquifer was initially estimated as approximately 10 percent of the horizontal hydraulic conductivity.

Specific yield of the water table aquifer was also obtained from the C-39 MODFLOW model. The values within this current model domain was primarily 0.20, but there were two pockets of 0.25 and 0.10 as shown in ***Figure 4.1.29***.

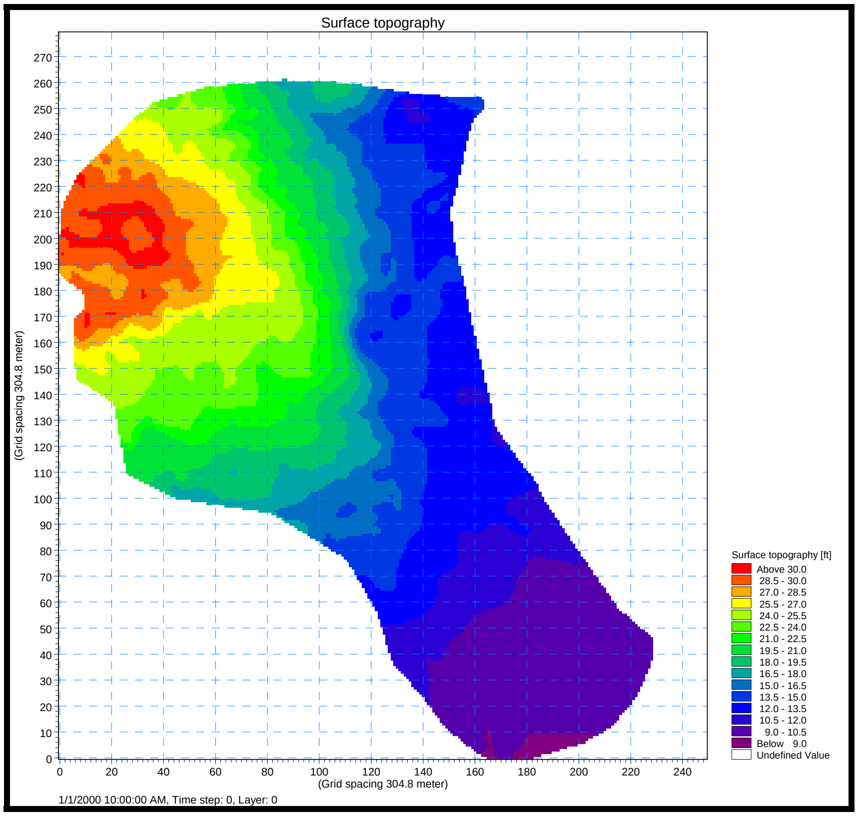


Figure 4.1.24 - Water Table Aquifer Top Elevation (ft-NGVD)

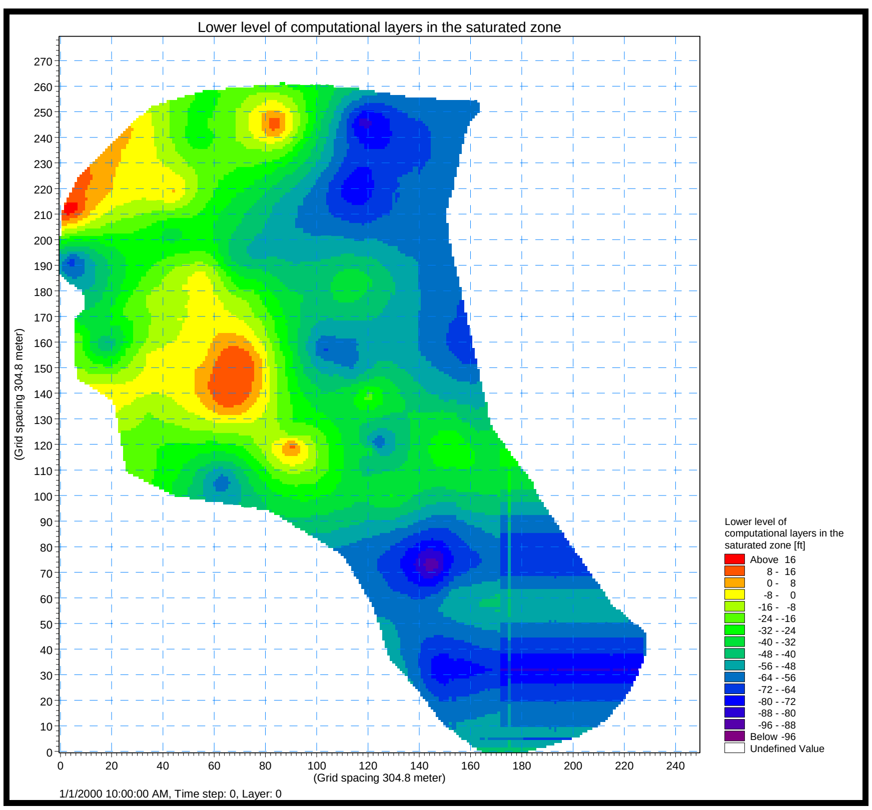


Figure 4.1.25 - Water Table Aquifer Bottom Elevation (ft-NGVD)

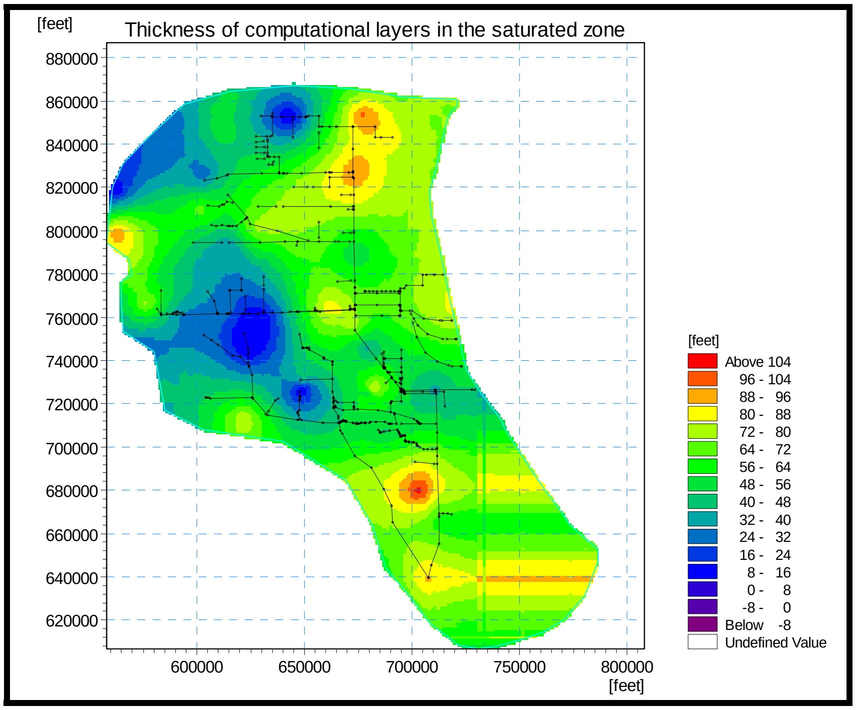


Figure 4.1.26 - Water Table Aquifer – Thickness

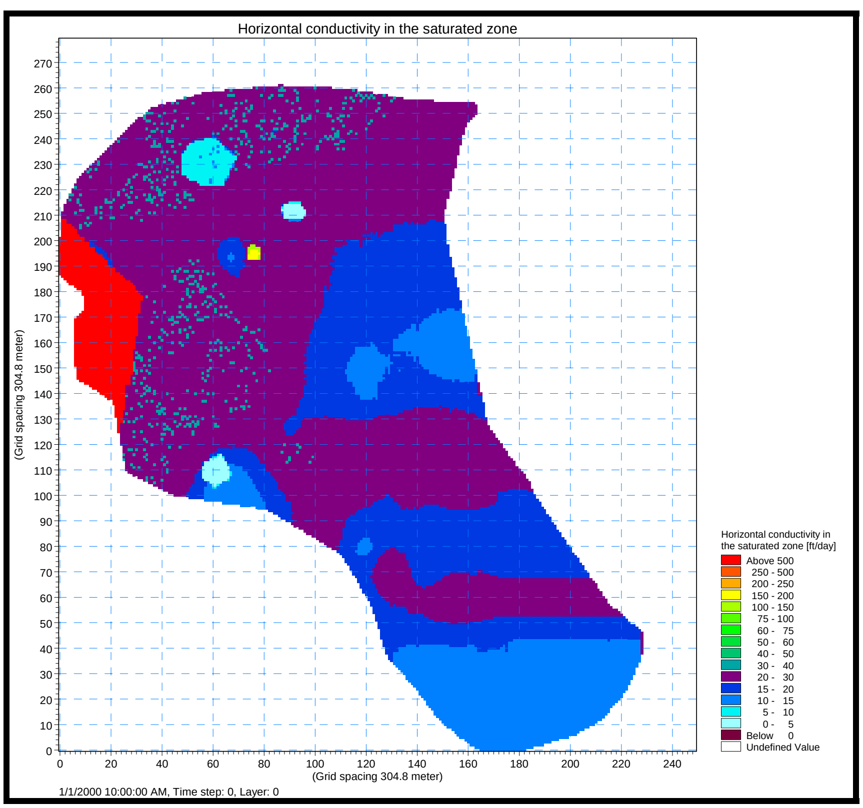


Figure 4.1.27 - Water Table Aquifer Horizontal Hydraulic Conductivity (ft/day)

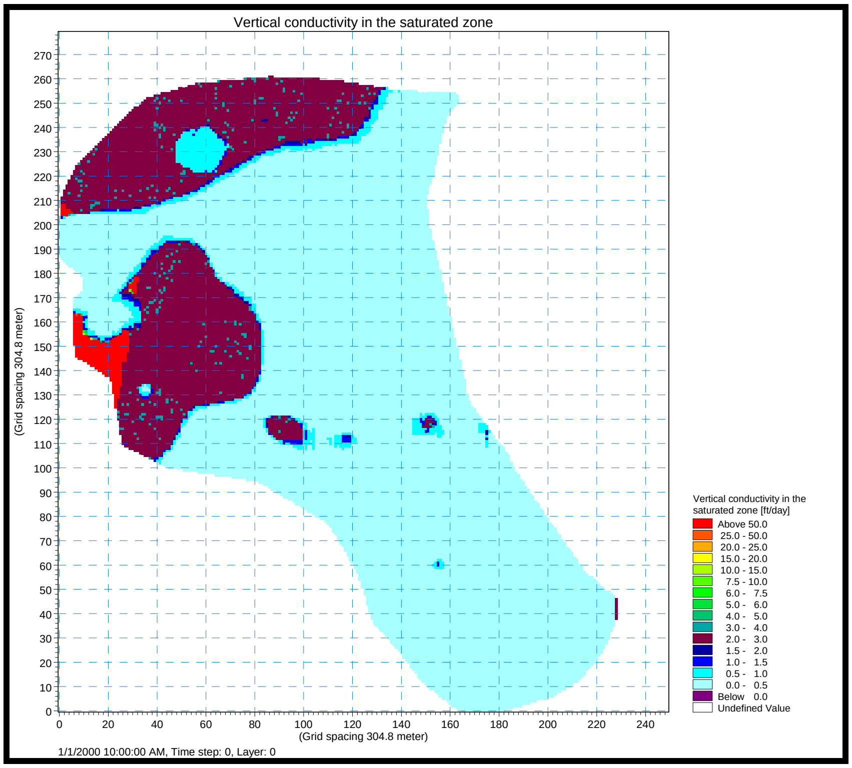


Figure 4.1.28 - Water Table Aquifer Vertical Hydraulic Conductivity (ft/day)

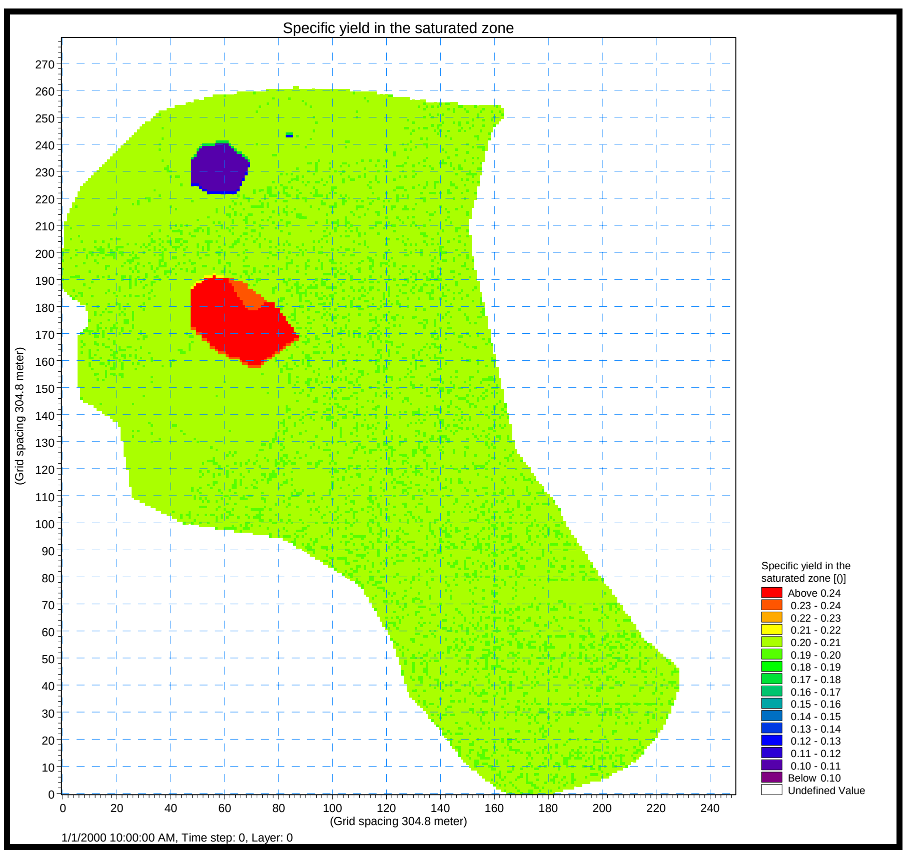


Figure 4.1.29 - Water Table Aquifer Specific Yield

4.1.7.2.2 Bonita Springs Lens

Although this is termed the Bonita Springs lens in the model, it comprises not just Bonita Springs but other material that forms the semi-confining unit below the water table aquifer. Information on this semi-confining unit was obtained from the SWFFS GIS files. Horizontal and Vertical Hydraulic Conductivity of the Bonita Springs Lens in the project area is a constant value of 0.004 (ft/day), as such are not presented in a figure for this report. The specific storage of the Bonita Springs Lens is also a constant value 3.048e-05.

4.1.7.2.3 Lower Tamiami Aquifer

The elevation of the top of the Lower Tamiami Aquifer is equal to the elevation of the bottom of the water table aquifer as shown in ***Figure 4.1.27***. The elevation of the bottom of the Lower Tamiami Aquifer is shown in ***Figure 4.1.30***. The thickness is shown in ***Figure 4.1.31***. This aquifer has a thickness to over 100 feet which is consistent with information in other studies.

Horizontal hydraulic conductivity (***Figure 4.1.32***) for the Lower Tamiami aquifer was also extracted from the C-139 MODFLOW model. Values varied from 15 feet per day to over 180 feet per day. These values were consistent with other studies but may be modified during calibration. Vertical hydraulic conductivity (***Figure 4.1.33***) was estimated as approximately 10 percent of the horizontal hydraulic conductivity but may also be modified during calibration.

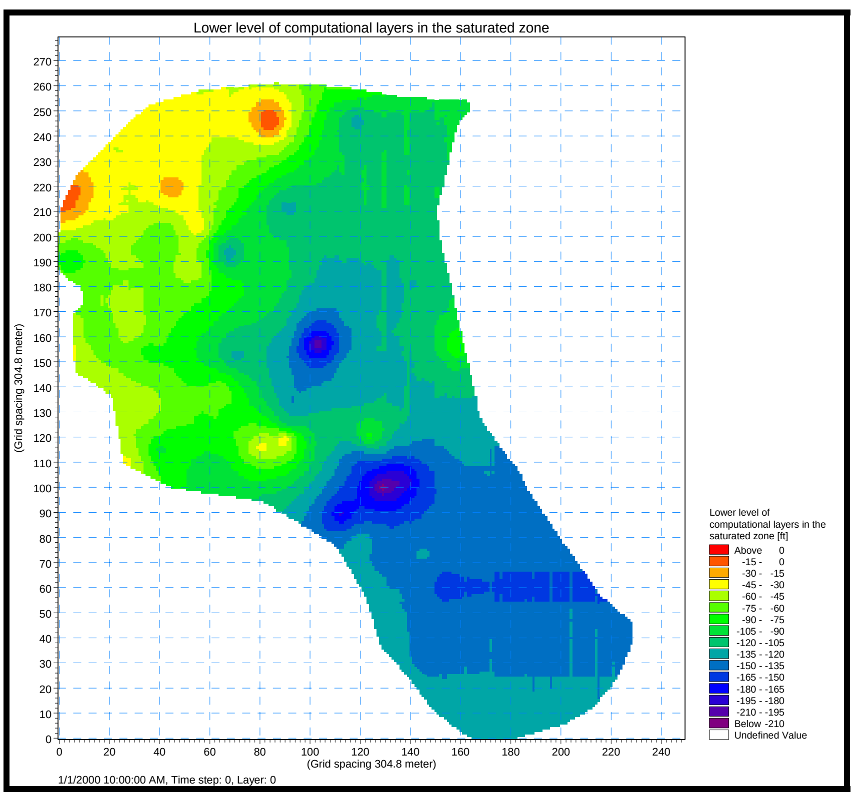


Figure 4.1.30 - Lower Tamiami Aquifer Bottom Elevation (ft-NGVD)

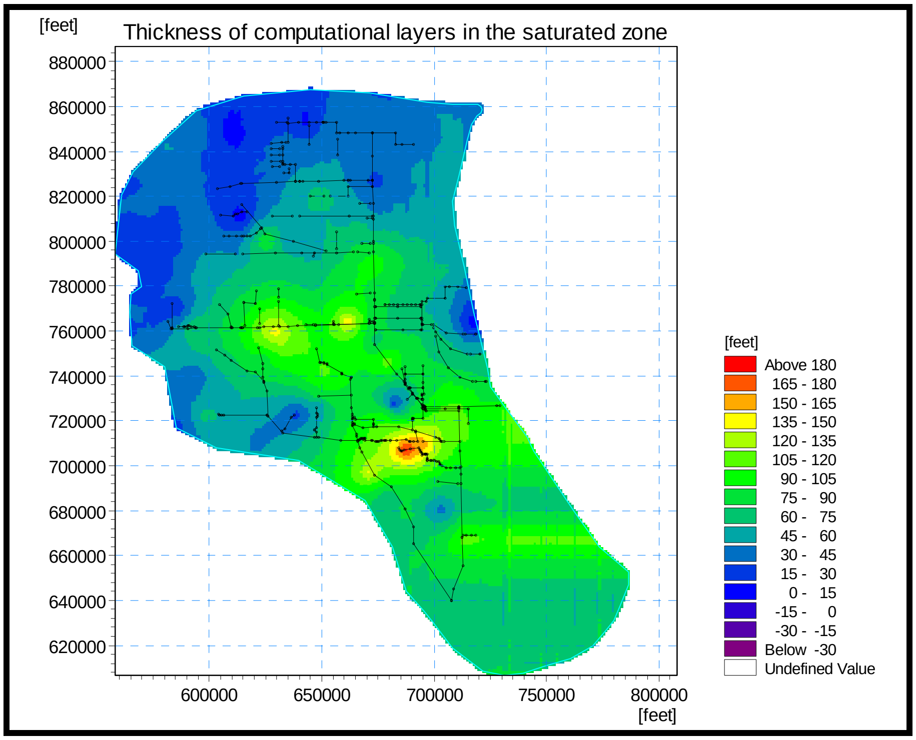


Figure 4.1.31 - Lower Tamiami Aquifer Thickness

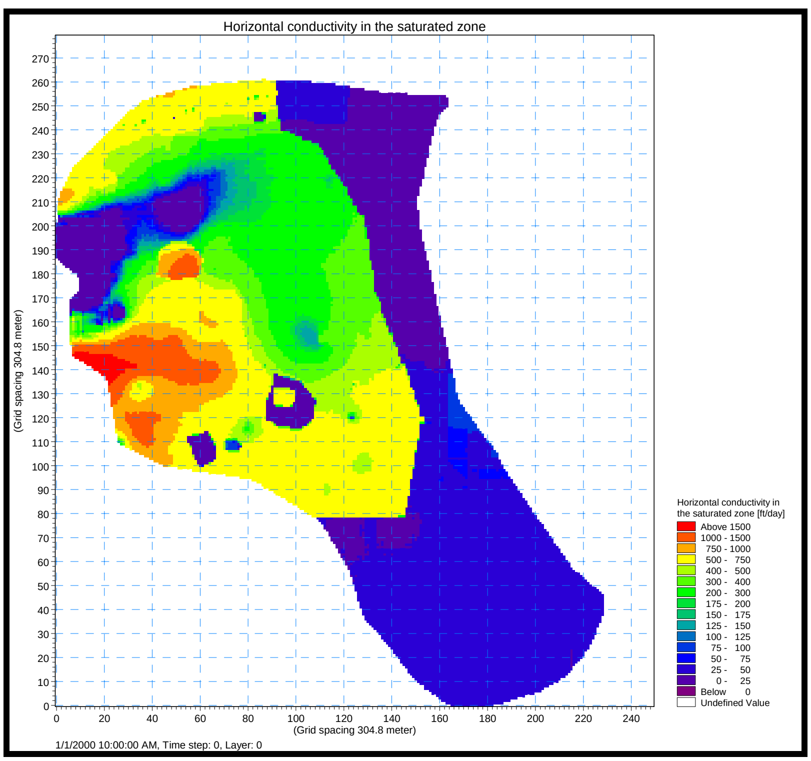


Figure 4.1.32 - Lower Tamiami Aquifer Horizontal Hydraulic Conductivity (ft/day)

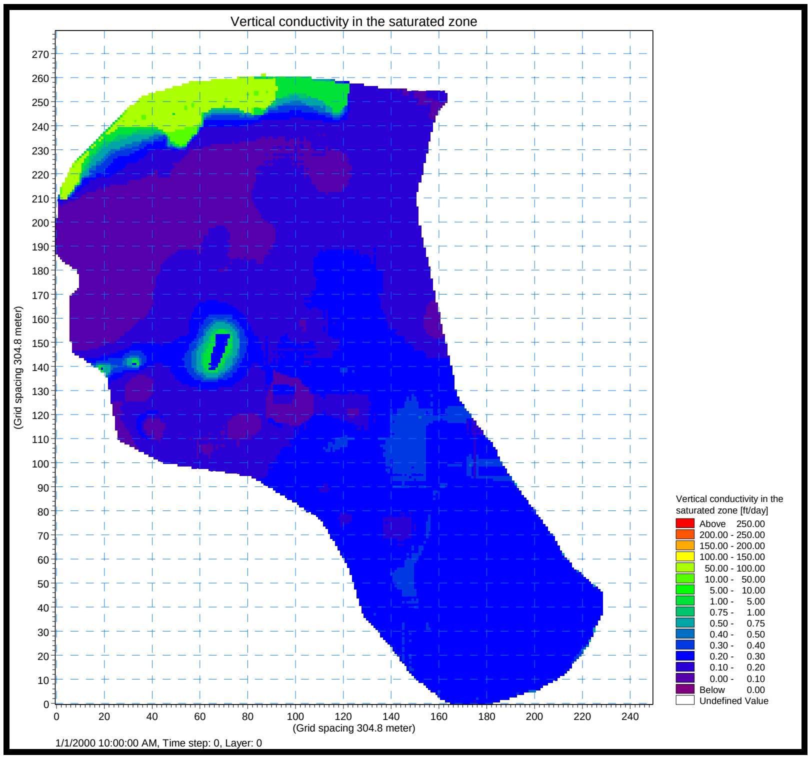


Figure 4.1.33 - Lower Tamiami Aquifer Vertical Hydraulic Conductivity (ft/day)

Storage coefficient for the Lower Tamiami was also extracted from the C-139 MODFLOW model. Values are shown in ***Figure 4.1.34***.

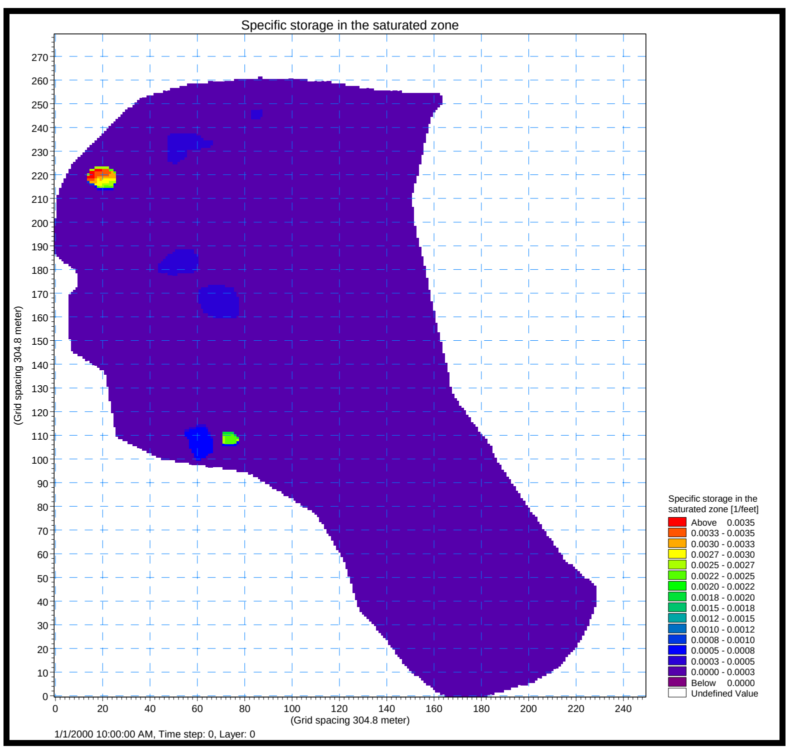


Figure 4.1.34 – Lower Tamiami Aquifer Storage Coefficient (1/ft)

4.1.7.2.4 Upper Peace River Lens

This semi-confining unit referred to as the Peace River lens represents separates the Lower Tamiami from the Sandstone aquifer. Although referred to as a semi-confining unit it includes pockets of relatively high hydraulic conductivity as shown in ***Figure 4.1.35***. This data was obtained from the SWFFS GIS database.

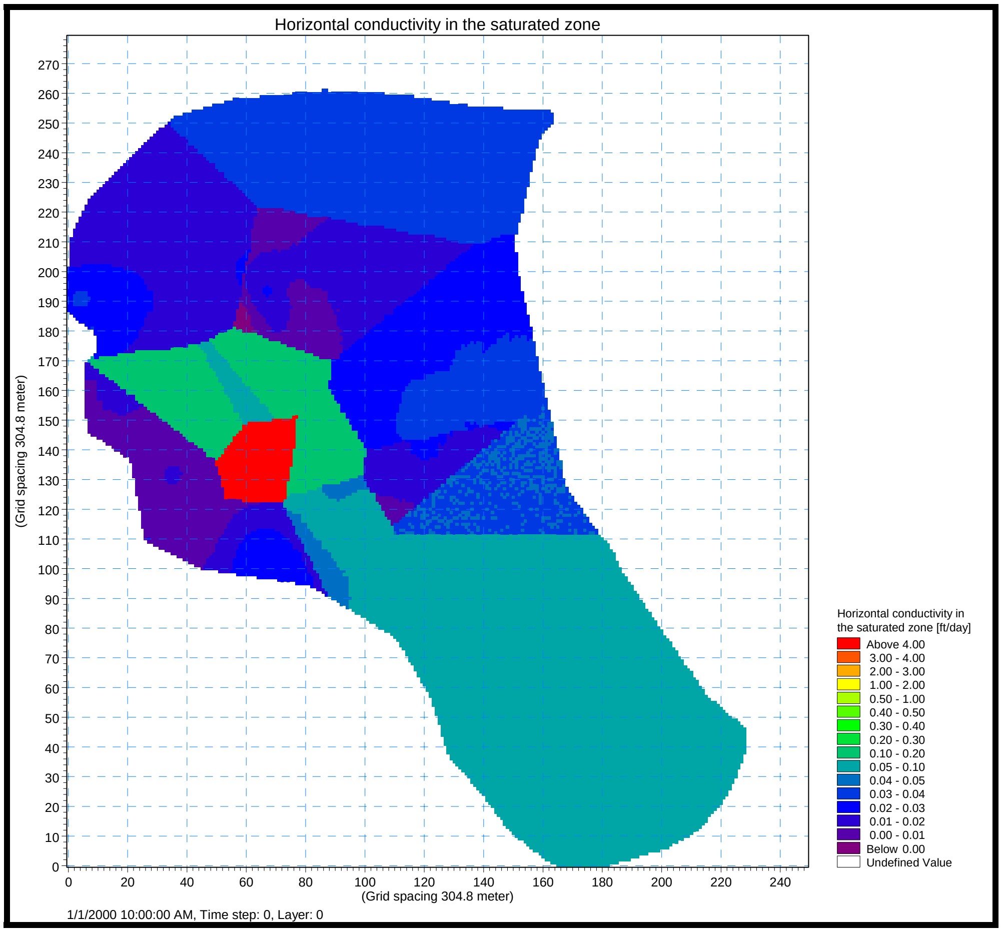


Figure 4.1.35 – Upper Peace River Lens Horizontal and Vertical Hydraulic Conductivity (ft/day)

The specific storage of the Upper Peace River lens is a constant value 3.048e-05.

4.1.7.2.5 Sandstone Aquifer

The elevation of the top of the sandstone aquifer is the same as the bottom of the Lower Tamiami Aquifer, which is shown above in ***Figure 4.1.30***. Bottom elevations of the Sandstone Aquifer are shown in ***Figure 4.1.36***. Aquifer thickness is shown in ***Figure 4.1.37***. These values were obtained from the C-139 MODFLOW model.

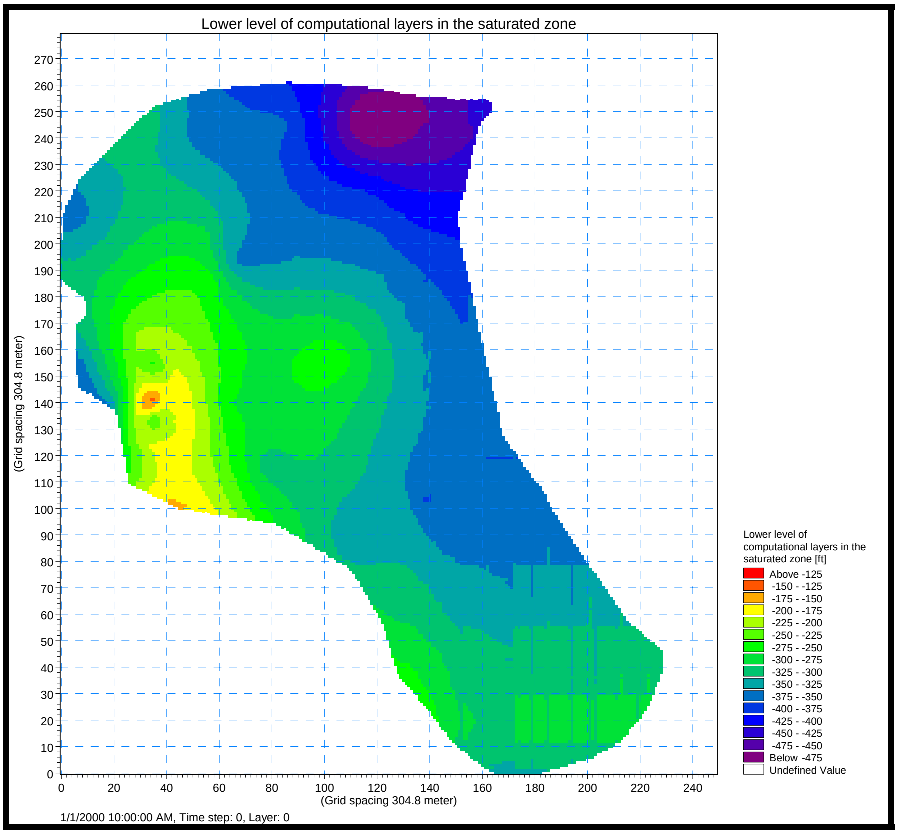


Figure 4.1.36 - Sandstone Aquifer Bottom Elevation (ft-NGVD)

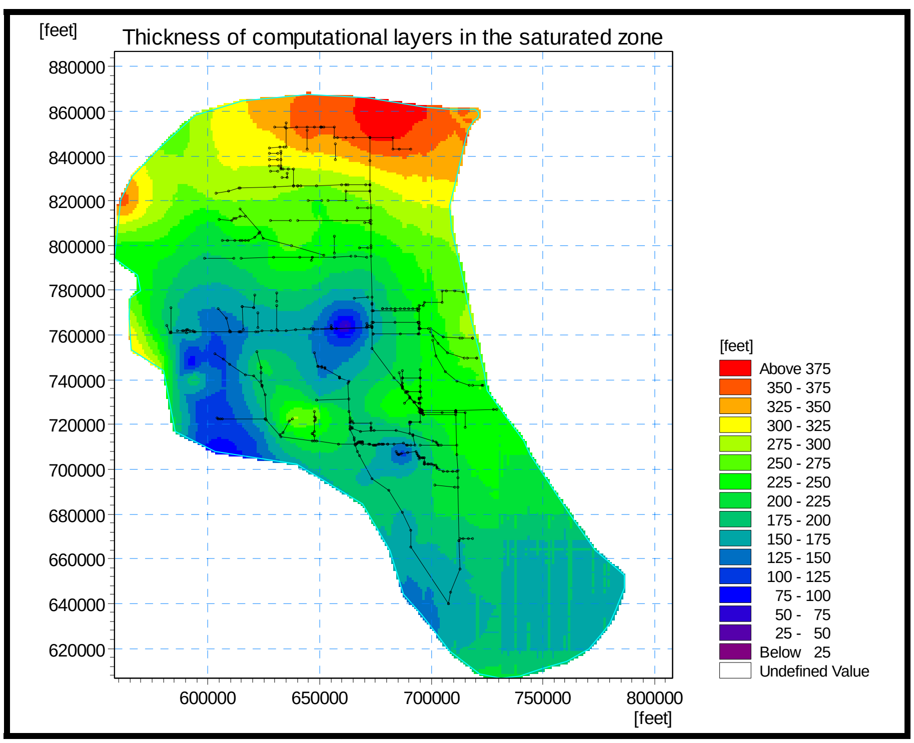


Figure 4.1.37 - Sandstone Aquifer Thickness

Horizontal hydraulic conductivity (***Figure 4.1.38***) for the Sandstone Aquifer varied from 500 to just under 40 feet per day. Vertical hydraulic conductivity (***Figure 4.1.39***) was calculated as approximately 10 percent of the horizontal hydraulic conductivity. Storage coefficient is shown in ***Figure 4.1.40***.

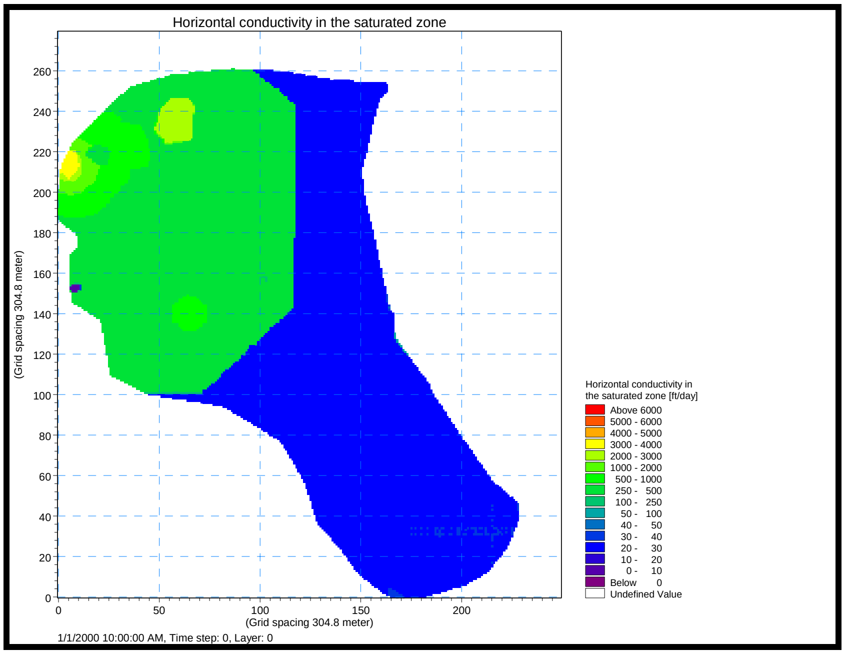


Figure 4.1.38 - Sandstone Aquifer Horizontal Hydraulic Conductivity (ft/day)

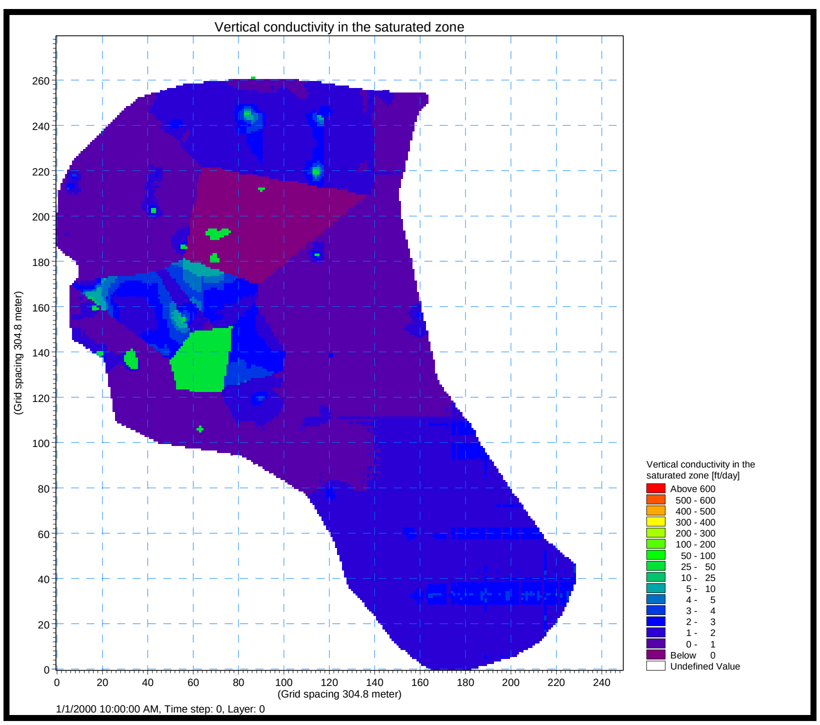


Figure 4.1.39 - Sandstone Aquifer Vertical Hydraulic Conductivity (ft/day)

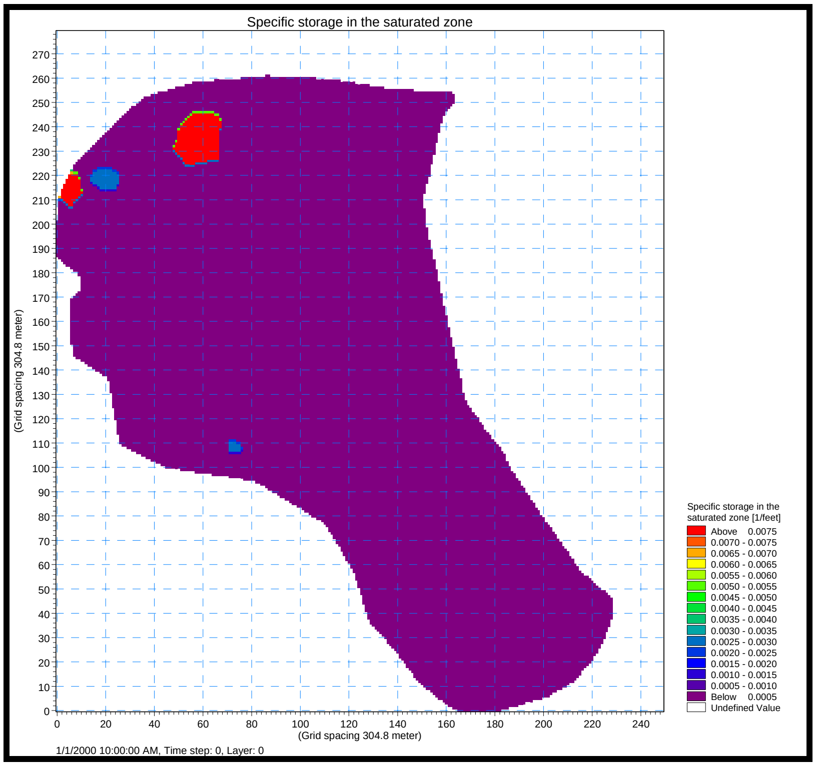


Figure 4.1.40 - Sandstone Aquifer Storage Coefficient (1/ft)

4.1.7.3 Calibration Stations

The groundwater calibration will utilize measured data for monitoring wells within the study area. ***Table 4.1.11*** presents well data that has been obtained to assist in the calibration, and ***Figure 4.1.41*** shows the locations of groundwater monitoring sites within the model domain.

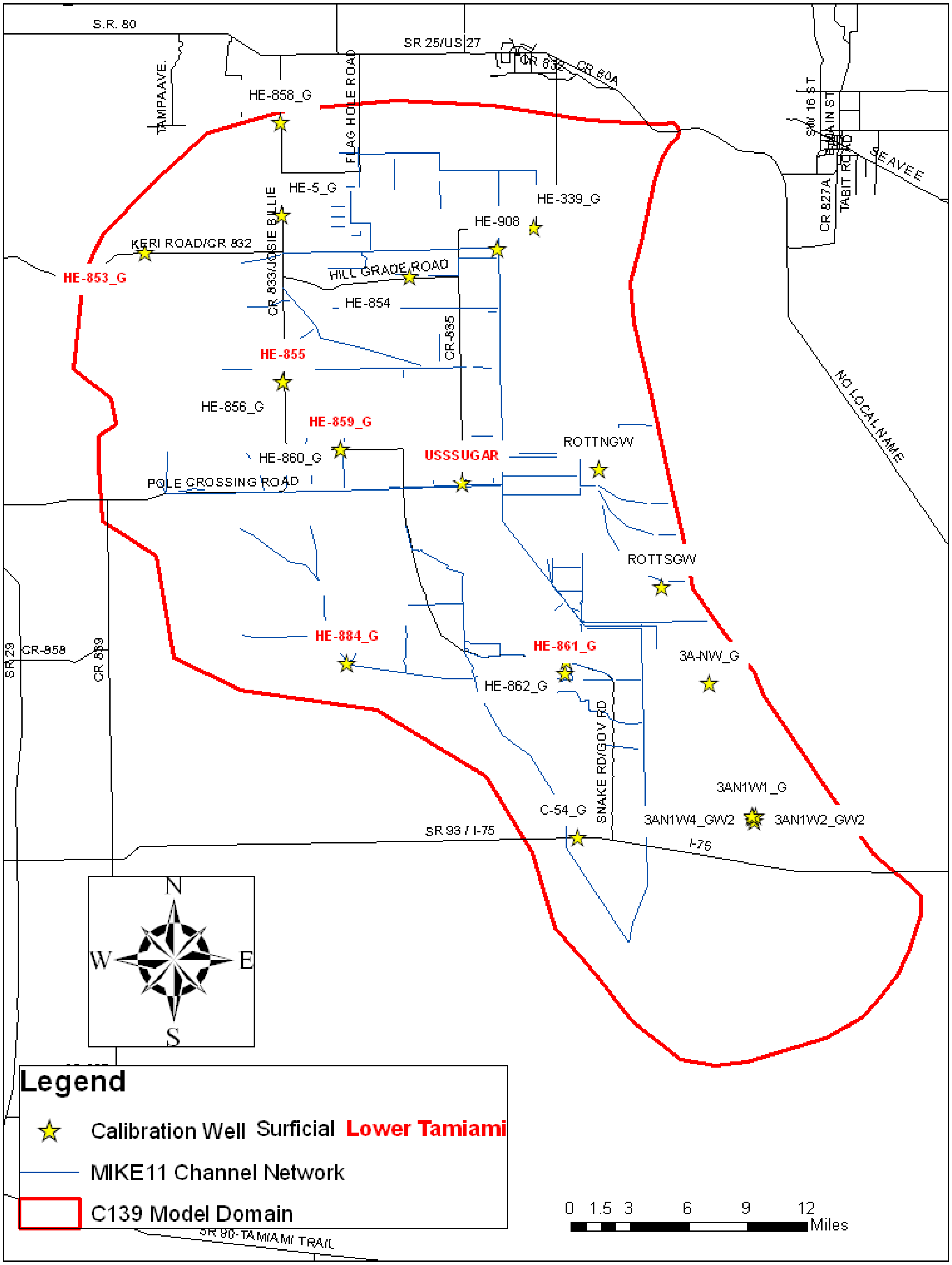


Figure 4.1.41 - Groundwater Monitoring Sites

Table 4.1.11 - Groundwater Calibration Data

Well Name	Dbhydro Elevation (ft NGVD)	Model Topo Elevation (ft NGVD) estimates	Elevation difference (model-dbhyro)	100 ft Grid Elevation (ft NGVD)	Dbhydro ft BLS	Bottom of well (ft NGVD)	Lower Level of Surficial (ft NGVD)	Lower Level of Tamiami (ft NGVD)	Middle of Surficial Aquifer (Topo+SAS)/2	Middle of Tamiami Aquifer (Surficial+Tam)/2	Depth for Model ft	Aquifer in Model
3AN1W1_G	10.22	10.3	0.08	10.13	38	-27.78	-62	-148.9	-25.85		36.15	Surficial
3AN1W2_GW2	10.05	10.3	0.25	10.13	15	-4.95	-62	-148.9	-25.85		36.15	Surficial
3AN1W3_GW2	10.5	10.3	-0.2	10.1	36.6	-26.1	-60	-151.35	-24.85		35.15	Surficial
3AN1W4_GW2	10.61	10.3	-0.31	10.1	7.09	3.52	-60	-150.09	-24.85		35.15	Surficial
3A-NW_G	N/A	11.7		12.1	N/A		-40.5	-135.75	-14.4		26.1	Surficial
C-54_G	12.86	12.7	-0.16	12.75	8.5	4.36	-64	-136.5	-25.65		38.35	Surficial
HE-339_G	14.38	14.34	-0.04	14.4	13	1.38	-70	-107.21	-27.83		42.17	Surficial
HE-5_G	29.77	26.36	-3.41	25.7	13	16.77	-20	-44.15	3.18		23.18	Surficial
HE-853_G	N/A	30		30	61	-31	0.18	-37.7		-18.76	48.76	Lower Tamiami
HE-854	N/A	20.9		20.8	14	6.8	-55.6	-122.88	-17.35		38.25	Surficial
HE-855	27.6	26.9	-0.7	27.87	90	-62.4	-6.03	-60.26		-33.145	60.045	Lower Tamiami
HE-856_G	27.56	26.9	-0.66	27.87	11	16.56	-6.03	-60.26	10.435		16.465	Surficial
HE-858_G	22.57	23	0.43	23.32	17	5.57	-27.3	-43.35	-2.15		25.15	Surficial
HE-859_G	26.3	25	-1.3	25	59	-32.7	-4.58	-102.65		-53.615	78.615	Lower Tamiami
HE-860_G	26.3	25	-1.3	25	16	10.3	-4.58	-102.65	10.21		14.79	Surficial
HE-861_G	14.42	14.75	0.33	14.9	70	-55.58	-35.93	-186.64		-111.285	126.035	Lower Tamiami
HE-862_G	14.42	14.57	0.15	14.6	11	3.42	-38	-164.35	-11.715		26.285	Surficial
HE-884_G	19.96	18.56	-1.4	18.65	67	-47.04	-37.82	-82.57		-60.195	78.755	Lower Tamiami
HE-908	17.5	16.4	-1.1	16.3	165	-147.5	-79	-105.86	-31.3		47.7	Surficial
ROTTNGW	N/A	13.34		13.18	N/A		-57.16	-114.84	-21.91		35.25	Surficial
ROTTSGW	N/A	13		13.1	N/A		-40.7	-124.48	-13.85		26.85	Surficial
USSSUGAR	0	22.7	22.7	20.9	100	-100	-62	-192.77		-127.385	100	Lower Tamiami

It is the objective of the calibration process to obtain as close a match as possible to both surface water stages and flows, along with surficial aquifer and lower confined aquifer water levels. The calibration process involves simultaneously adjusting surface and ground water information. In some cases, calibration is dependent on properly defining canal gate and pump protocols and obtaining correct dimensions of culverts and weirs. In most cases, irrigation rates are checked against known data (where available) or against permitted maximum or average pump rates. Groundwater aquifer thicknesses, hydraulic conductivity, storativity, and specific yield are reviewed, compared to aquifer performance test data (where available), and adjustments are made. In this project, aquifer performance data are available for the Crooks and Golden Ox ranches (SFWMD, 2009b), and these data will be utilized during calibration. SFWMD (2009b) reports communication between the surficial and the Lower Tamiami aquifers, however the locations of leakage are unknown. There are no known methods to fill these data gaps. The calibration process will therefore, explore a number of potential solutions to this problem which are documented in the Model Calibration and Validation section.

4.1.8 SURFACE WATER

4.1.8.1 Surface Water System to be Added to the Model

The surface water system of the C-139 Region is comprised of wetlands, SFWMD canals, STAs, canals maintained by water control districts, and interior farm canals. The MIKE 11 files used in the Compartment C Hydrologic and Hydraulic Design Study will be used as a starting point, and additional canals will be added as described below. MIKE 11 is set up differently when it is run together with MIKE SHE. When MIKE 11 is run with MIKE SHE, it is not necessary to define all storage elements within the MIKE 11 network because MIKE SHE includes overland flow routines and detention storage (for small reservoirs and depressional areas), and drainage (for representing effects of small canals not in the MIKE 11 network). When MIKE SHE is run with MIKE 11, the MIKE 11 surface water network can be limited to canals and streams that have a major effect on watershed hydrology. Canals to be added to the MIKE 11 canal network of the C-139 Basin used in the Compartment C Hydrologic and Hydraulic Design include:

1. Other main canals. These consist of SFWMD canals not included in the Compartment C model, such as the L-28 Interceptor Canal and the North Feeder Canal (NFEED). A number of other major canals maintained by other entities will be included such as the canal from G-409 (at confusion corner) to the Seminole Lands.
2. Minor Canals. These canals handle runoff from multiple farms and may or may not be maintained by a water control district.
3. Interior Farm Canals. These canals are usually part of one farm and are normally used to convey farm runoff to and from interior water supply reservoirs and water quality treatment reservoirs. This network will include the farm reservoirs and control structures that control flow out of the farm.
4. Wetlands. A number of wetlands in the study area have a dug canal through the center of the wetland, and some of these drained wetlands are represented in the MIKE 11 network. Other wetlands are handled as part of the MIKE SHE overland flow module.

The MIKE 11 model used in the Compartment C Design had wide cross sections for a number of smaller canals where it was known that there was significant storage within that canal sub-basin that attenuated peak flows. The storage was either farm reservoirs or large wetland areas. These wide cross sections were generated from a DEM of the watershed and most of the cross section was set to be approximately 1-2 feet lower than the DEM. Since the current model setup includes MIKE SHE, the cross sections used in the Compartment C MIKE 11 model were modified as part of this modeling effort so that the cross sections are similar to elevations found in the DEM.

Information was added to the model for a number of road culverts within the C-139 Basin. This information was obtained from a variety of sources including permit drawings, the Devil's Garden Water Control District Facilities Map (Johnson – Prewitt & Associates, Inc. (2001), and field measurements made by Mitch Murphy of the SFWMD Clewiston Field Station. Feeder Canal and L-28 structures were obtained from McDaniels Ranch agricultural farm reservoir as-built levee drawings, The Seminole Tribe of Florida GIS files, and the SFWMD Structure Book. STA-5 and STA-6 information was obtained from Goforth (2008).

Figure 4.1.42 presents the proposed MIKE 11 network. ***Figures 4.1.43*** to ***4.1.47*** and ***Tables 4.1.12*** to ***4.1.15*** present the structures that are currently in the model. There are a number of structures that have either been removed or constructed between 2003 and 2008. The model will either simulate the structures to operate for only a portion of the simulation period or multiple network files will be used for different portions of the calibration/verification period. The information presented at this time for STA-6 is for the period prior to construction of STA-6 Section 2 and prior to Confusion Corner modifications. The modeling team is aware that some STA-6 inflow and outflow structures have changed, that there are some recent changes including installation of G-407, removal of G-155. A detailed timeline of improvements is provided in ***Section 4.3 - Modeling***.

The interior farm canals will be added after the model has been developed with the main and minor canals. The interior canals are being added step-wise so that the modeling team can understand the computational load associated with the interior canals. If the computation time increases to unacceptable levels, (greater than 4-6 hours/year), it may be necessary to minimize the number of interior canals that are added to the network.

There is no intention of adding all of the farm canals to the model as the model execution time would be too long. MIKE SHE has a “drainage” feature that approximates the effect of small canals on surficial aquifer water levels, and this feature will be used to represent most of the interior farm canals. The modeler inputs a drainage depth (below ground) and a drainage time constant (which represents the time it takes for water to reach a MIKE 11 canal from interior farm canals not in the model).

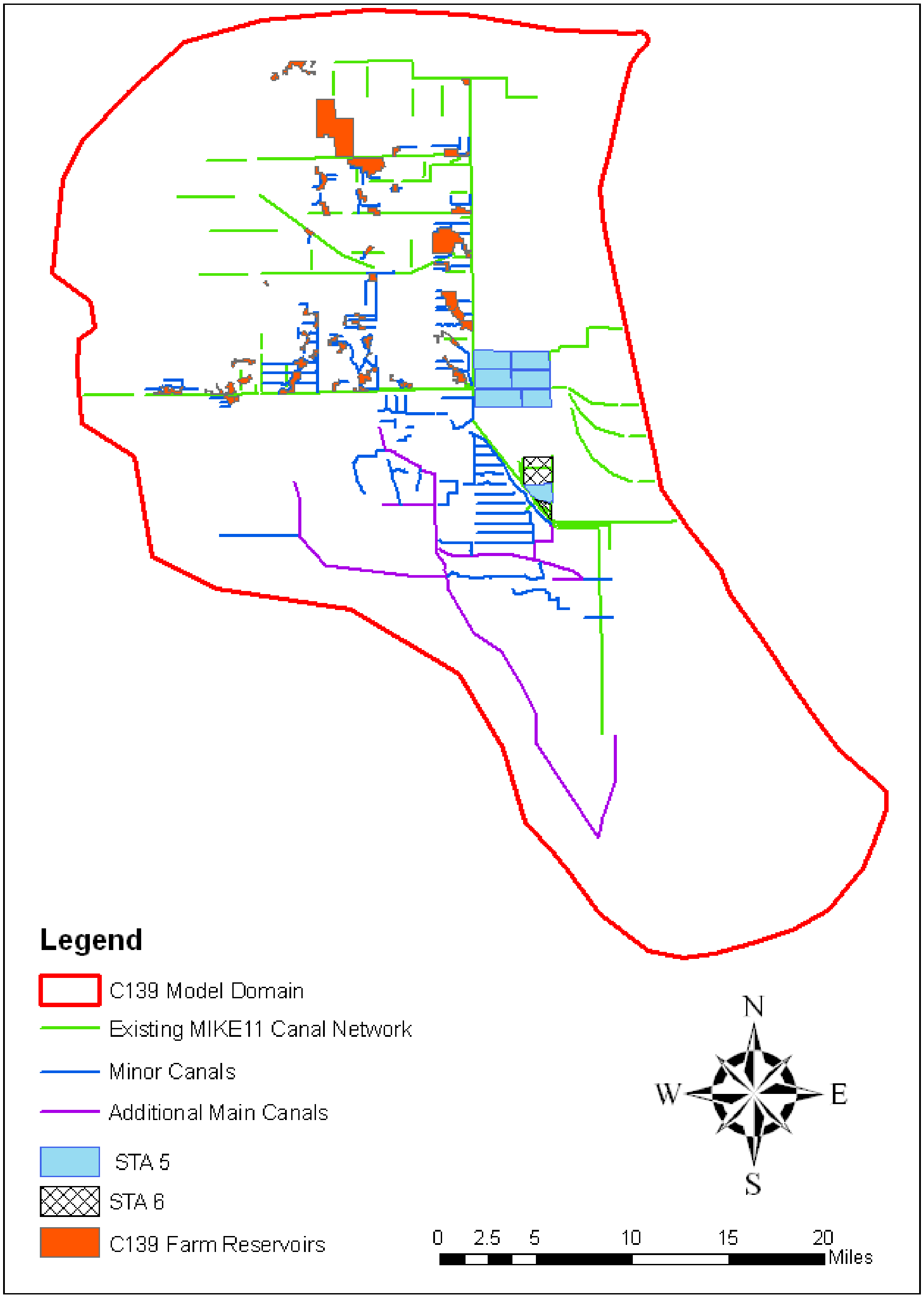


Figure 4.1.42 - Canal and Reservoir Network

Table 4.1.12 - Structures in the Model Shown in Figures 4.1.43 – 4.1.47

ID	Structure	ID	Structure
152	G-135	184	G-342EF
153	G406 Weir	185	G-344AB
154	S and M Weir	186	G-344CD
155	G-343AB	187	G-344EF
156	G-343CD	188	G-352ABC
157	G-343EF	189	G-396ABC
158	G-393ABC	190	G-402A
159	G-603	191	G-402B
160	G354ABC	192	G-402C
161	G-353AB	193	G-406
162	G-406 Weir	194	G-410
163	Pond Weir	195	G-604
164	Farm Weir 2	196	G-88abcd
165	Farm Weir	197	G-89abc
166	Zipperer Gates	198	G349A
167	G-152	199	G349B
168	G-607	200	G96 Gate
169	Snake Road Culvert 3	201	S-140 PS
170	Snake Road Culvert 2	202	G409
171	CR 833 Culvert 3	203	Pump_E1
172	CR 833 Culvert 2	204	S190
173	CR 846	205	G-134
174	CR 833 Culvert	206	CCDD_riser
175	BC17	207	PS-2
176	BC19	208	PS-4
177	G-135	209	PS-3
178	G-136abc	210	PS-1
179	G-150abc	211	Hilliard Gate
180	G-151	212	PC17A Gate
181	G-155	213	BC07
182	G-342AB	214	BC13
183	G-342CD	215	USS_pump

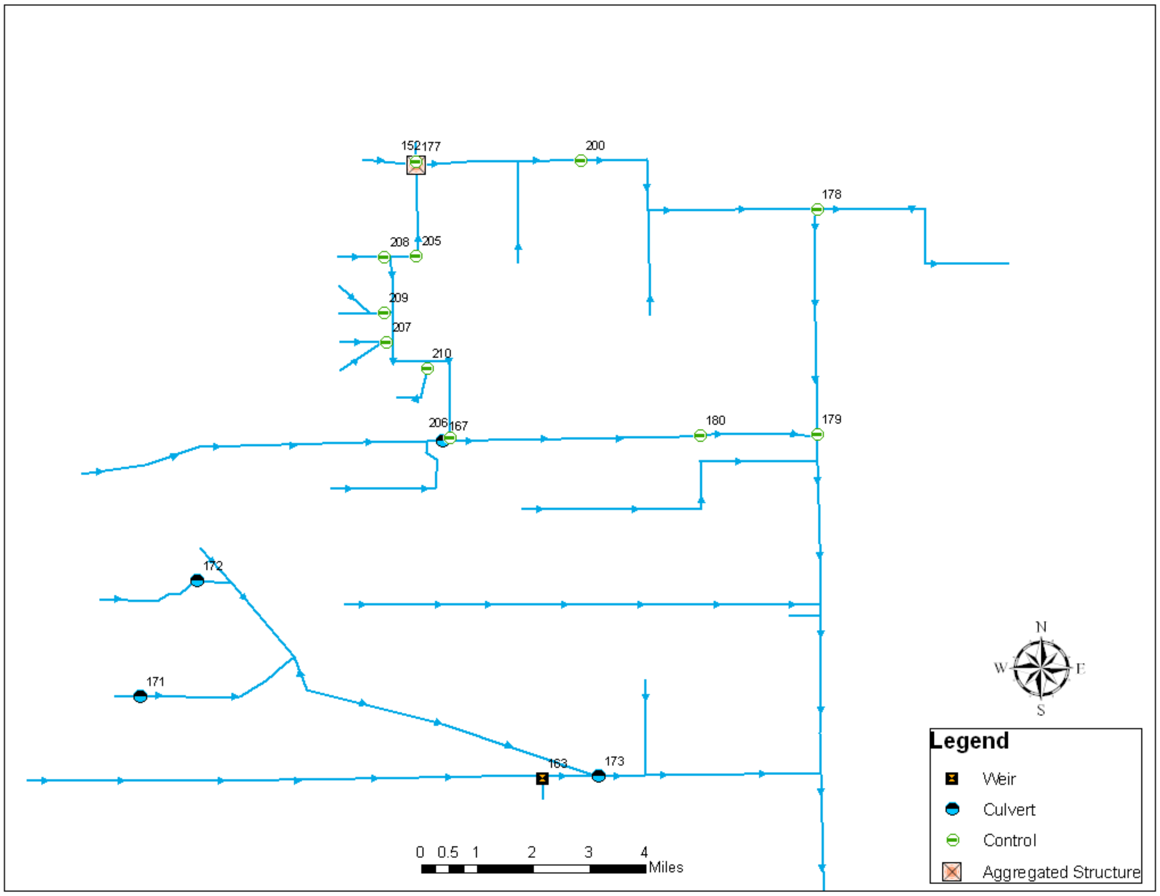


Figure 4.1.43 - Structures in the MIKE 11 Network – North Portion

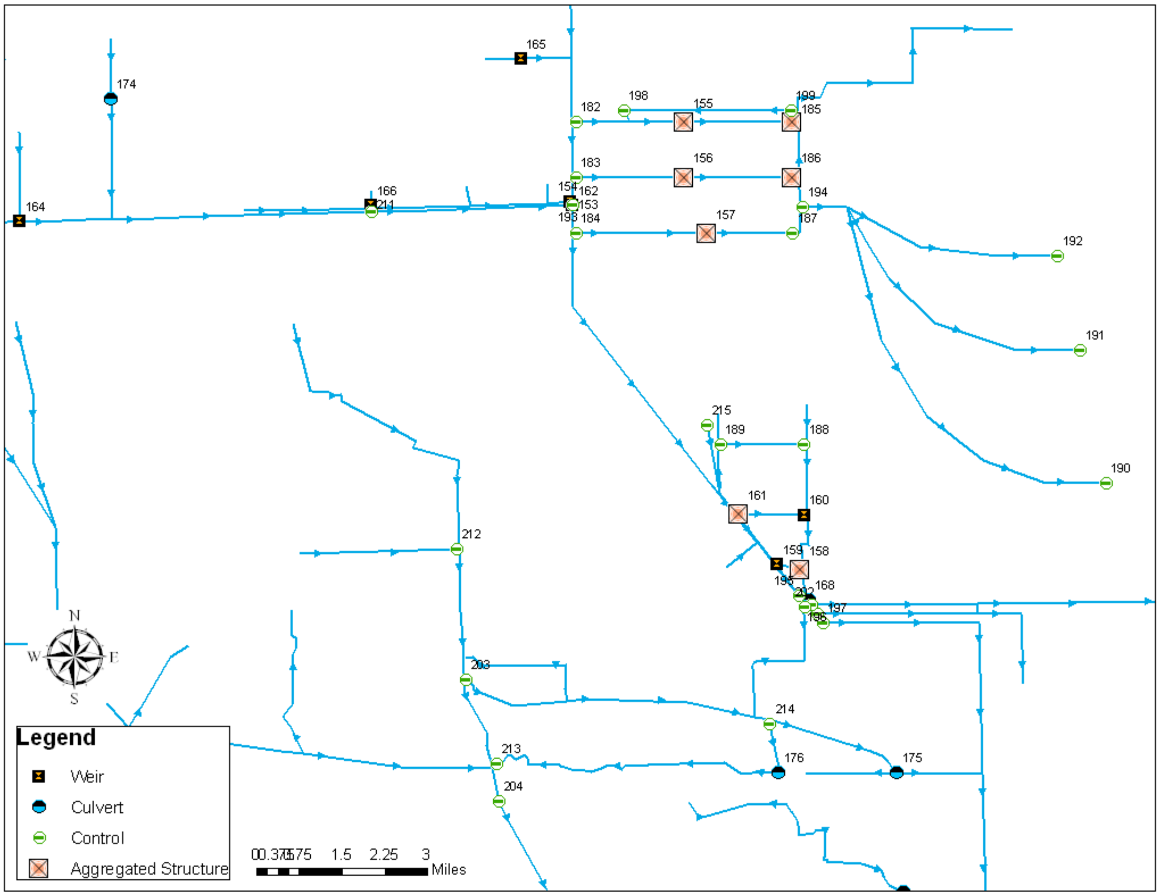


Figure 4.1.44 - Structures in the MIKE 11 Network – Middle Portion

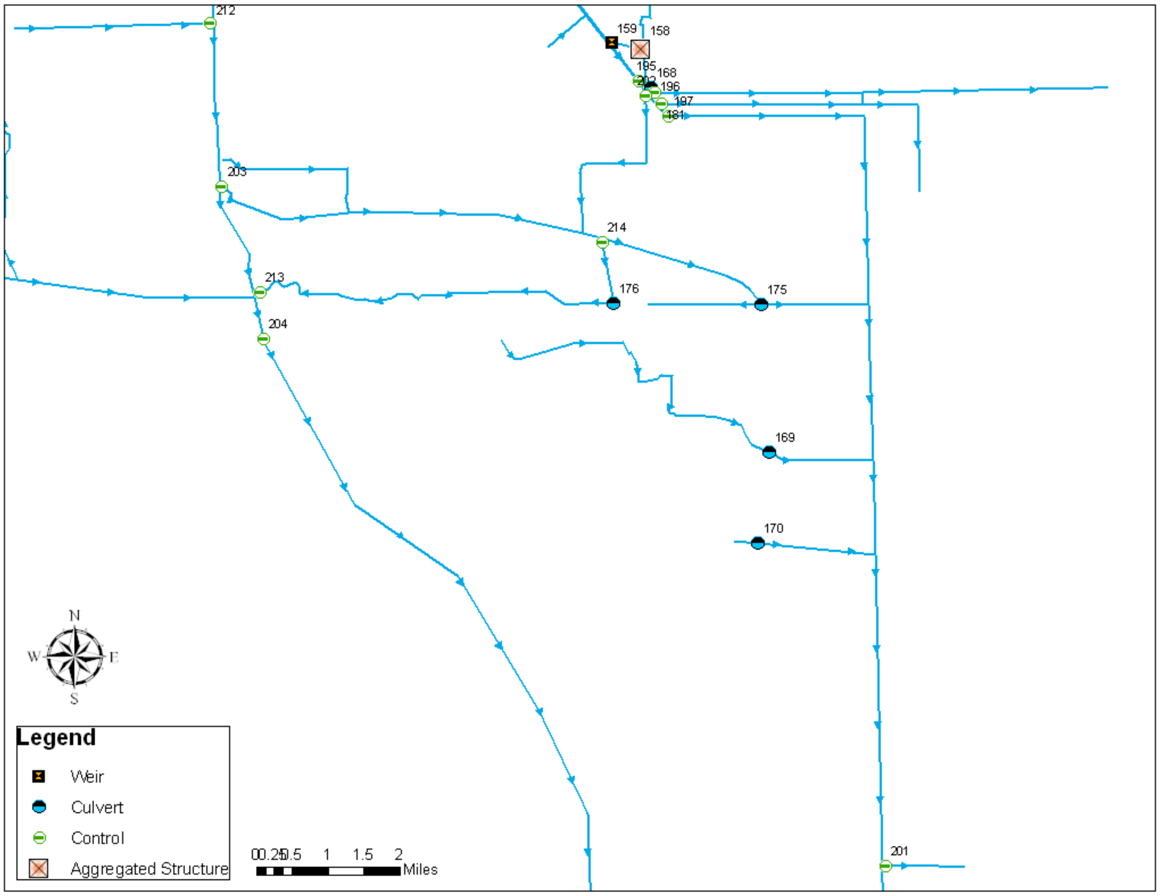


Figure 4.1.45 - Structures in the MIKE 11 Network – South Portion

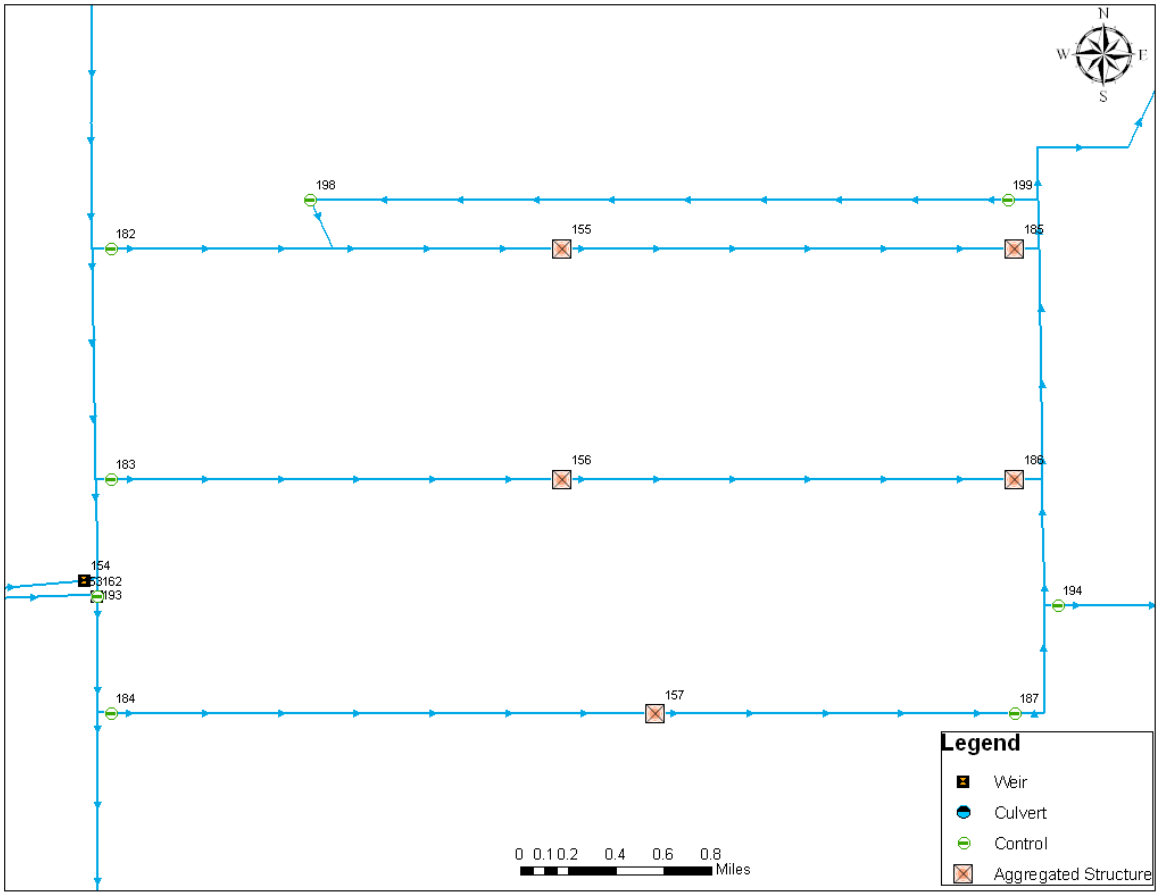


Figure 4.1.46 - Structures in the MIKE 11 Network – STA-5

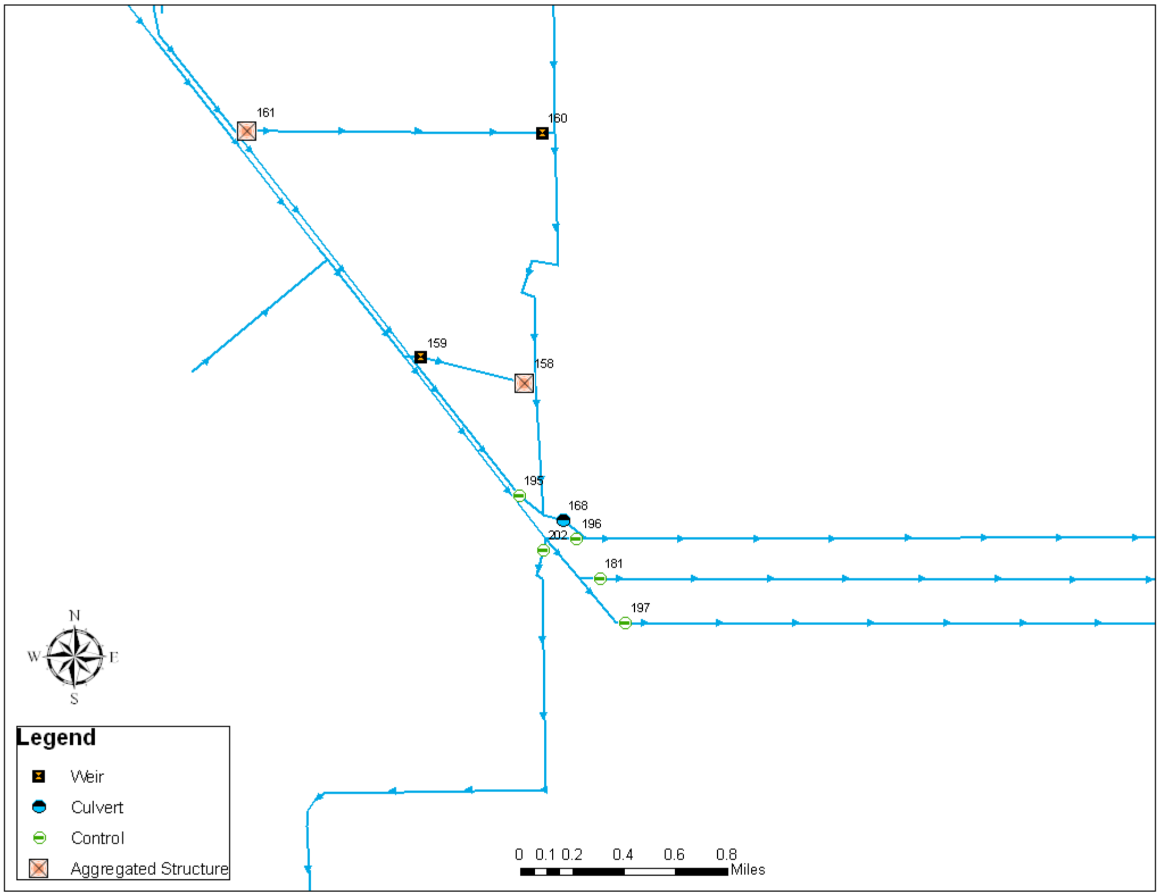


Figure 4.1.47 - Structures in the MIKE 11 Network – Confusion Corner

Table 4.1.13 - Gates and Pumps in the MIKE 11 Network

Station	Type	Width, ft	Invert, ft	Max Q, cfs	Ref.
BC07	Pump	0	0	165	Sem
BC13	Pump	0	0	188	Sem
CCDD_riser	Overflow	5.5	22		N/A
G-134	Overflow	6	12.24		SB
G-135	Overflow	9.3	13		SB
G-136abc	Overflow	7	8		SB
G-150abc	Underflow	7	8.5		SB
G-151	Overflow	6	9		SB
G-155	Overflow	80.2	9.92		SB
G-342AB	Underflow	10	7.25		OP
G-342CD	Underflow	10	7.25		OP
G-342EF	Underflow	10	6		OP
G-343ABC	Overflow	5	11		OP
G-343EFG	Overflow	5	11		OP
G-343IK	Underflow	10	4		OP
G-344A	Underflow	10	0		OP
G-344B	Underflow	10	0		OP
G-344C	Underflow	10	0		OP
G-344D	Underflow	10	0		OP
G-344EF	Underflow	10	4		OP
G349A	Pump	0	0	36-54	OP
G349B	Pump	0	0	39	OP
G-352ABC	Underflow	10	4		OP
G-393AC	Overflow	20	14		OP
G-396ABC	Underflow	8	4		OP
G-402A	Underflow	4.5	7.13		N/A
G-402B	Underflow	4.5	7.23		N/A
G-402C	Underflow	4.5	7.57		N/A
G-406	Underflow	10	6		OP
G409	Pump	0	0		OP
G-410	Pump	0	0		N/A
G-604	Overflow	11	11		SB
G-88abcd	Overflow	6	5.5		SB
G-89abc	Overflow	6	7.85		SB
G96 Gate	Overflow	5.5	7.57		SB
Hilliard Gate	Underflow	5.5	14.7		N/A
PC17A Gate	Overflow	5	8		N/A
PS-1	Pump	0	0	167	Permit
PS-2	Pump	0	0	167	Permit
PS-3	Pump	0	0	167	Permit
PS-4	Pump	0	0	167	Permit
Pump_E1	Pump	0	0		OP
S-140 PS	Pump	0	0	1300	SB
S190	Underflow	25	3.5		SB

SB	SFWMD Structure book	N/A	Could not locate info in SB or OP
OP	STA 5 6 August 2007 Operation Plan	Sem	From Seminole Tribe of Florida

Table 4.1.14 - Weirs in the MIKE 11 Network

Station	Height (ft)	Width (ft)	Height (ft)	Width (ft)	Height (ft)	Width (ft)	Height (ft)	Width (ft)
Flaghole Rd Weir	22	500	22.5	510				
G406 Weir	21.25	250	24	250				
	13	65	16	66				
G343ABCD	14	120	19	120				
G343EFGH	14	120	19	120				
G343 Cell3 weir	14	105	19	105				
G393B	14	20	19	20				
G-603	14.2	15	18	15				
G354ABC	14.1	60	19	60				
G-601	14	11	18	11				
G-601 & G-602	14	50	14.2	1000				
G-406 Weir	17.5	50	17.6	90	20	120		
Pond Weir	23	2	24.5	5	25	100		
Ag Pond Weir	23.75	4	24	15	24.75	35	24.85	400
Ag Pond 2 Weir	18	2	18.7	10	19.3	500		
Ag Pond 3 Weir	22.3	5	23	20	23.5	1000		

Note: A number of these weirs represent roads over culverts. The G-406 elevation was lowered in 2008 and a different elevation will be used for the validation model.

Table 4.1.15 - Culverts in the MIKE 11 Network

Station	# culverts	Type	Dia., ft	Mann. N	Length, ft	Inv., ft
G-152	4	Circular	6	0.013	40	14.5
G-607	6	Circular	7	0.013	70	4
Snake Road Culvert 3	3	Circular	2	0.013	70	10.7
Snake Road Culvert 2	3	Circular	2	0.013	120	10.7
CR 833 Culvert 3	3	Circular	3	0.013	145	22.46
CR 833 Culvert 2	3	Circular	4	0.013	120	22.02
Flaghole Rd	2	Circular	5	0.026	50	16.51
CR 846_guess	5	Box	6x6	0.013	50	12
CR 833 Culvert	1	Circular	3	0.012	100	10
BC17	1	Box	7x3	0.026	70	7.6
BC19	1	Box	3x7	0.026	90	7.6

Cross sections are not available for all of the canals to be added in the model. Most of the main canals already have surveyed cross sections, and surveying to be done as part of this study will fill in the gaps for the major canals (See Data Collection Plan for details). Minor and interior farm canal dimensions will be estimated using GIS and best engineering estimates. Cross sections for minor canals in the Compartment C model included wide approximate cross sections that accounted for on-farm storage of water in either un-modified wetlands or man-made reservoirs. As mentioned above this assessment may not include those wide cross sections depending on the level of detail that is added for the interior of C-139 Study Area farms.

There is a number of hydraulic control structures used in the study area, including both SFWMD and privately-operated structures. All SFWMD structures and major privately-operated structures were added to the model. As with the interior farm canals, the level of detail for smaller hydraulic control structures was determined as the structures were added to the network.

4.1.8.2 Surface Water Calibration Stations

There are measured headwater stage, tailwater stage, and flow data available from the SFWMD DBHYDRO database for many of the hydraulic control structures. Stations with measured data include G-134, G-135, G-136, G-96, G-150, G-151, G-152, G-342A-G, G343A-J, G-344A-F, G-349A-C, G-350B, G-410, G-406, STA-6 inflow and outflow structures G-353A-C, G354A-C, G-393A-C, G-396A-C, G-352A-C, G-407, L3BRN, L3BRS, USSO, G-88, G-89, G-155, G-409, G-108, PC17A, NFEED, WFEED, S-190, and S-140 shown in ***Table 4.1.16*** and ***Figure 4.1.48***. Some of these stations have measured headwater elevation, tailwater elevation, and flow data, and some of the stations only have stage data. The quality of the data varies depending on the frequency of collection and the entities responsible for measuring the information.

Table 4.1.16 - Surface Water Calibration Stations

Structure	ID	Structure	ID
Gate	G-135	Gate	G96
Gate	G-150	Pump	G349A
Gate	G-151	Pump	G349B
Gate	G342A	Gate	G152
Gate	G-342C	Gate	G406
Gate	G342F	Gate	G155
Gate	G343B	Gate	G88
Gate	G343A	Gate	G89
Gate	G342B	Pump	S140
Gate	G342D	Gate	G393A
Gate	G342E	Gate	S190
Gate	G343C	Gate	PC17A
Gate	G343E	Staff Gage	NFEED
Gate	G343F	Staff Gage	L3BRS
Gate	G343I	Gate	G393B
Gate	G343J	Gate	G393A
Gate	G344A	Gate	G393C
Gate	G344B	Gate	G136
Gate	G344C	Gate	G134
Gate	G344D	Staff Gage	WFEED
Gate	G344E	Gate	Hilliard Gate
Gate	G344F		

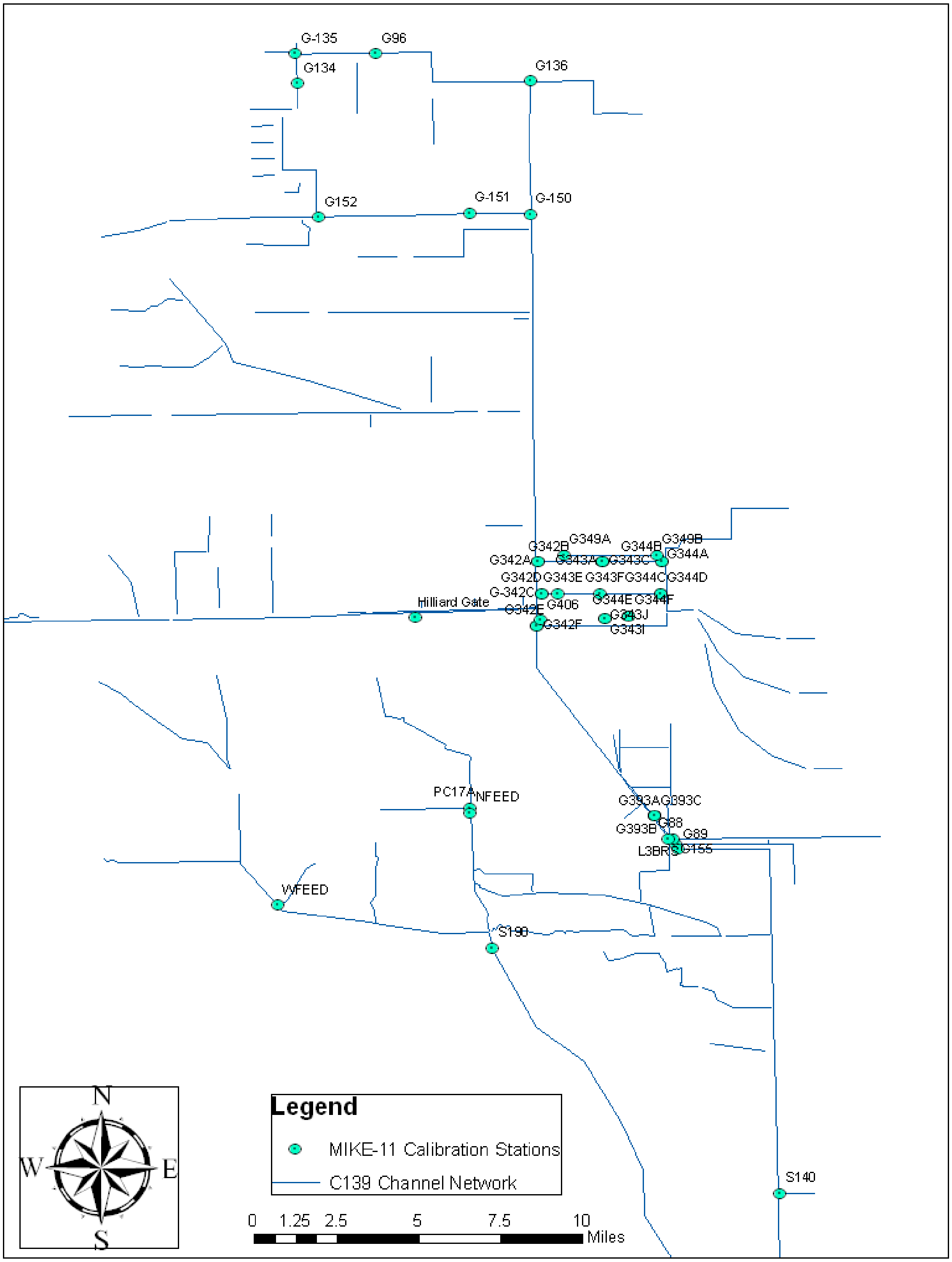


Figure 4.1.48 - SFWMD Flow and Stage Monitoring Locations

There are operation protocols for a number of structures that are documented in either the SFWMD Structure Book or the STA 5 and 6 Operation Plan (SFWMD, undated; and Goforth, 2008). However, there are periods where the gate operation appears to deviate from the operation plans. For instance, it appears that STA-5 was drained in 2005 for maintenance. In the case of gates that are operated by farmers or flashboards are manually removed and replace, there may not be records of those operations. The modeling team was able to obtain measured gate levels for a number of structures, and those structures are listed in ***Table 4.1.17***. For details of further development regarding the operation protocols see ***Section 4.2.2.6. Surface Water***.

Additionally, a number of water quality stations were established in 2006-2007, and spot measurements of flow and stage area are available at a number of these sites as show in ***Table 4.1.18*** and ***Figure 4.1.49***.

Table 4.1.17 - Structures with Available Measured Gate Operation Data

Structures	Period of Available Data
G-342 A-D	1/1/06 - 12/31/08
G-342 E-F	4/8/08 – 12/31/08
G-343 A-C	11/16/07 - 12/31/08
G-343 E, F, & G	3/19/08 – 12/31/08
G-343 I 1&2 & J1&2	3/25/08 – 12/31/08
G-344 A-D	1/1/03 - 12/31/08
G-344 E-F	4/4/08 – 12/31/08
G352 A-C	4/9/08 – 12/31/08
G-396 A-B	4/17/08 – 12/31/08
G-402 A-C	1/1/03 – 12/31/08
G-600+1 and G-600+2	7/7/04 – 12/31/08

Note: Utilization of these data is complicated by file size. The gate operation file for G-342 has 157,824 rows of data

Table 4.1.18 - Water Quality Monitoring Site Location Descriptions and Coordinates

Station	Description	Latitude	Longitude
L212.1TW13	Devil's Garden	263619.128	810738.306
L209.6TW02	Alico Structure 1 Discharge east to L2 Canal	263452.967	810737.676
L209.5TW01	Alico Structure II Discharge east to L2 Canal	263415.432	810737.093
L207.6TW02	Alico Gator Discharge east to L2 Canal	263227.120	810735.880
L206.0TW02	Alico Southwest Discharge east to L2 Canal	263108.970	810734.832
DF12.3TS	Crow's Nest Discharge north to Deer Fence	262543.679	810833.356
DF12.2TS	Duck Curve Pasture Discharge north to Deer Fence	262543.815	810808.380
DF11.4TN01	Dinner Island Discharge south to Deer Fence Canal	262635.403	810728.071
DF11.1TN01	Crook's Discharge south to Deer Fence	262733.792	810630.653
DF08.1TN01	South Bay Discharge south to Deer Fence	262735.920	810438.139
SM05.0TW	J7 S/M Discharge east to SM at SR833 bridge	262554.478	810139.954
SM05.0TN	J7 S/M Culvert Discharge south to SM	262555.025	810139.444
DF05.0TW	Deer Fence Creek Discharge east to Deer Fence Canal at SR833 bridge	262552.197	810139.877
SM02.2TW02	Zipperer Culvert Discharge to SM	262559.348	805856.912
SM02.1TW01	Zipperer Culvert Discharge to SM	262604.040	805848.950
SM02.1TN01	Zipperer A Discharge south to S/M	262659.369	805848.219
L209.1TW01	Midway Canal Discharge east to L2 Canal	263354.283	805855.004

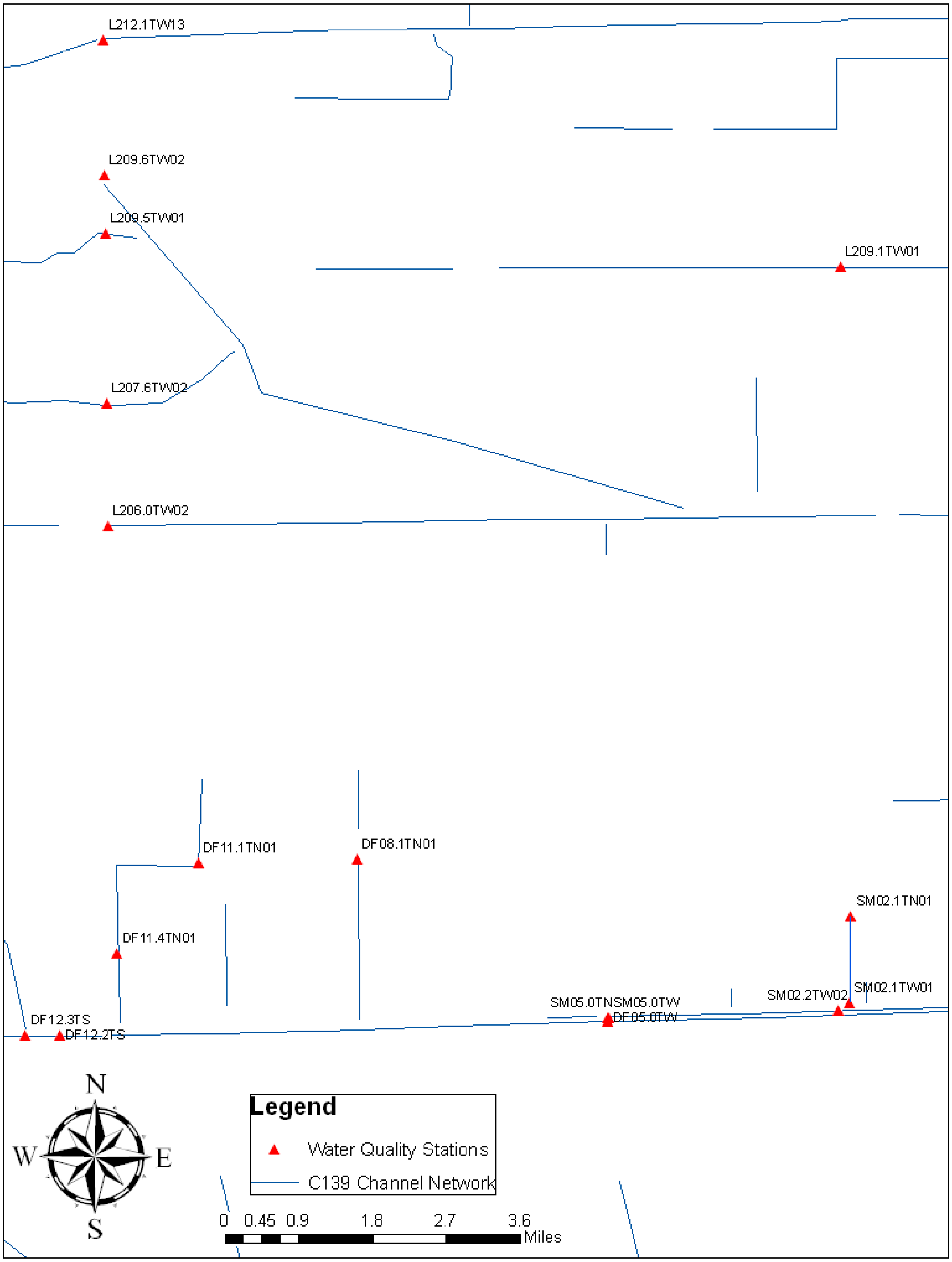


Figure 4.1.49 - SFWMD Water Quality Monitoring Locations

4.1.9 IRRIGATION COMMAND AREAS

Irrigation command areas were completed through the use of District permit coverage and withdrawal allocations. The procedure to be followed during the model set-up is described below:

1. Subtract the wetlands and agricultural reservoir shape files from the farm permit polygons. The net polygons will be only farmed lands grouped by farm permit.
2. Subdivide the permitted farm areas by crop, if appropriate.
3. Merge the farm permit polygon with the maximum permitted irrigation pumpage files created by Hope Radin of SFWMD (see ***Table 4.1.19***) to obtain farm-specific maximum irrigation pumpage rates and depth interval of groundwater pumpage.
4. The irrigation type will be specified, and the turn-on, turn-off elevations will be established, and the type of soil moisture accounting will be specified.

Figure 4.1.50 presents the irrigation command areas. The irrigation command area calibration were compare permitted maximum flows from SFWMD permit information to simulated irrigation amounts obtained from water balance tables and plots and adjust the irrigation set up as necessary during the calibration process. Irrigation pump records for the Crooks and Golden Ox ranches have been requested and these data will also be used in the calibration. Updated irrigation information is presented in **Section 4.2 - Calibration and Validation**.

4.1.10 CALIBRATION PERIOD

The model will be calibrated for calendar years 2004-2006 and will be validated for calendar years 2007-2008. The calibration period was generally wet and the validation period included a major drought followed by significant rainfall at the end of 2008 (Tropical Storm Fay occurred in September, 2008, and the rainfall total for this event was approximately 6 inches.

Table 4.1.19 - Permits in C-139 basin, Radin and Rodberg, 2009

Map Designation	Permit Number	Current Allocation (MGY)	Renewal Allocation (MGY)		Comment
	11-00147-W	2301.00	2301.00		
3	26-00002-W	1214.98	1487.80	*	
	26-00004-W	1469.28	1469.28		
16	26-00012-W	2963.47	4272.23	*	
4	26-00013-W	6285.27	4.38	*	Cattle Watering only
	26-00020-W	13936.56	13936.56		
	26-00024-W	1564.00	1564.00		
	26-00029-W	119.48	119.48		
	26-00068-W	2546.36	2546.36		
1	26-00070-W	0.00	0.00		
	26-00073-W	2788.42	2788.42		
	26-00074-W	3792.07	3792.07		
5	26-00083-W	572.21	1224.96	*	
6	26-00087-W	6020.43	5854.90	*	
	26-00094-W	15684.45	15684.45		
	26-00095-W	36.25	36.25		
2	26-00098-W	0.00	0.00		
7	26-00108-W	13618.80	48420.9	*	
8	26-00115-W	6516.14	3414.00	*	
	26-00143-W	7168.53	7168.46		
	26-00282-W	1135.65	1135.65		
	26-00300-W	1893.56	1893.56		
9	26-00303-W	2005.35	6405.80	*	
	26-00318-W	1214.23	1214.23		
11	26-00368-W	210.20	756.00	*	
10	26-00373-W	957.60	2798.00	*	
	26-00383-W	174.00	174.18		
	26-00385-W	678.43	678.43		
Too small to show	26-00389-W	0.00	0.00		
	26-00419-W	6048.73	6048.73		
12	26-00453-W	6003.60	6480.10	*	
	26-00455-W	1816.34	1816.34		
13	26-00456-W	1580.40	5026.00	*	
	26-00483-W	783.97	783.97		
	26-00533-W	433.70	433.70		
	26-00630-W	2616.05	2616.05		
	26-00639-W	451.77	451.77		
	26-00655-W	1727.94	1727.94		
	26-00694-W	22.15	22.15		
15	26-00949-W		432.79	*	
14	app 990208-9		422	*	
	MGY	Million Gallons per year			
	*	Permit changed			
	(purple shading)	Permit under review			
	(yellow shading)	EXPIRED			

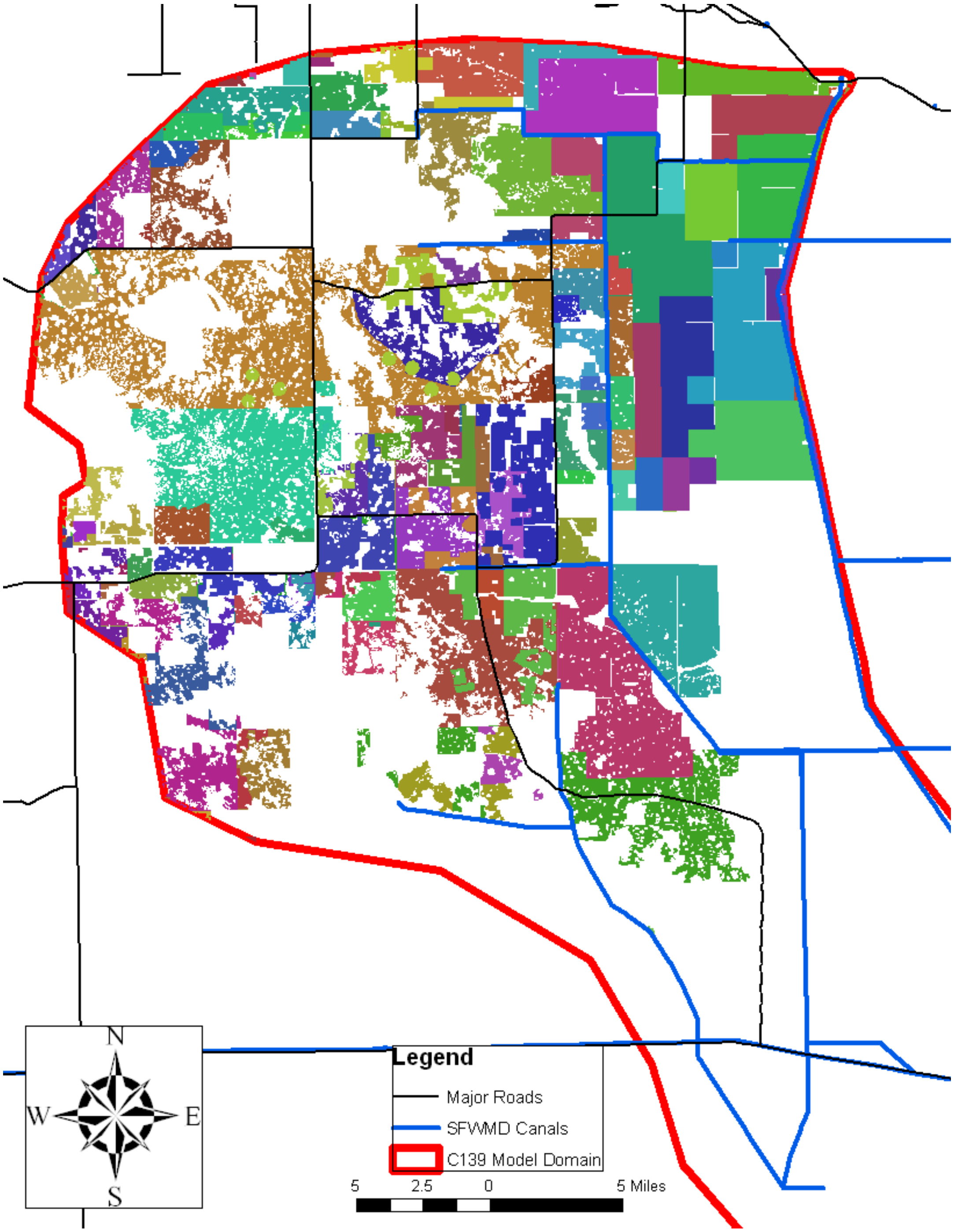


Figure 4.1.50 - Irrigation Command Areas

4.1.11 REFERENCES

ADA Engineering, Inc. 2007. C-139 Basin Phosphors Water Quality and Hydrology Analysis Deliverable 10.4 – Final Water Quality Improvement Projects Report. Prepared for SFWMD.

Burns & McDonnell. 2008. S-4 Basin Feasibility Study. Prepared for the Everglades Agricultural Area Environmental Protection District and South Florida Water Management District. September, 2008.

Chow, Ven Te. 1959. Open Channel Hydraulics. McGraw Hill.

Goforth, G. 2008. Operation Plan – Integrated Stormwater Treatment Areas 5 & 6. Prepared for SFWMD by Gary Goforth, Inc., October, 2008

Johnson – Prewitt & Associates, Inc. 2001. Devil's Garden Water Control District – District Facilities Map, Plate B.

Marco Water Engineering, Inc. 2005. Lower West Coast Surficial Aquifer System Model. Prepared for SFWMD by Marco Water Engineering and Ecology and Environment, Inc.

Radin, H. Rodberg, K. 2009. C-139 Model Runs, SFWMD, Executive Summary and Model Files.

Reese, R.S., and K.J. Cunningham. 2000. Hydrogeology of the Gray Limestone Aquifer in Southern Florida, Water Resources Investigations Report 99-4213, USGS. Prepared in coordination with the SFWMD.

SCS. 1986. Urban Hydrology for Small Watersheds, Technical Release 55.

SFWMD. Undated. Hendry County Aquifer Performance Test Results. From SFWMD library. (Contains data use in the first MODFLOW model of the C-139 watershed).

SFWMD. Undated. SFWMD Structure Books. Operations Control Center.

SFWMD. 2004. Operation Plan, Stormwater Treatment Area-3/4.

SFWMD a. 2009. Hydrogeologic Assessment of the Crooks and Golden Ox Ranches, Hendry County, FL, Technical Publication WS-28. SFWMD Water Supply Department Staff.

SFWMD b. 2009. South Florida Environmental Report, Chapter 4 – Phosphorus Source Controls for the South Florida Environment.

URS. 2008. Compartment C Stormwater Treatment Area Final Design Report.

4.2 Calibration and Validation

4.2.1 INTRODUCTION

As mentioned in ***Section 4.1 - Model Set-Up***, the goal of this project is to develop a baseline model that characterizes the study area hydrology, water supply, and water quality. The baseline model will be utilized in Phase II to evaluate various regional operational and infrastructural alternatives such that the region's water supply and quality goals are met. The purpose of this section is to present the following: a) Parameterization for the selected model and its boundary conditions, b) calibration plots and statistics, c) irrigation amounts for the irrigated portions of the model, d) a water balance for the model domain, e) a summary of calibration activities (what parameters were modified during initial calibration), f) changes made to the validation model, and g) summary of validation metrics and plots. The model inputs presented in this section are only the ones that are different to those presented in ***Section 4.1 - Model Set-Up***. Preliminary results of the calibration at approximately a 50 percent level are presented in ***Appendix C8 - 50 Percent Model Calibration Status Brief Memorandum***, which was not required as an official submittal of the Work Order but was presented as a courtesy copy to review progress.

4.2.2 MODEL INPUT

This section provides a summary of model input files that were used in the calibration model. Certain input files are not described in this document because they were described in the Model Setup Section (URS and ADA, Sept. 8, 2009) and there were no changes to those input files during the calibration process. The input files not changed include rainfall, land use and saturated zone.

Additionally, the proposed grid size was changed from the Model Set-Up to the Calibration and Validation. The proposed grid size is 1000 x 1000 ft, resulting in 31,000 grid cells per model layer within the 1,113 square-mile model domain. A smaller grid size would make model run-times excessively long. The calibration and validation model run times are approximately 5.5 hours/year. The MIKE SHE model input files are included in ***Appendix C9***.

4.2.2.1 Topography

MIKE SHE (surface and groundwater hydrologic processes) relies heavily on the topographic file used for the simulation, thus model accuracy and simulation output is highly dependent on the accuracy of the topography file used in the model. The SFWMD has a 100 ft-grid topographic data set from the Southwest Florida Feasibility Study, Digital Elevation Model (SWFFS DEM) shown in ***Figure 4.2.1***; however, this data set has a data gap in the southeast portion of the model (SDI et al, 2008). Elevation data from the SFWMD 2x2 model was used for this area (Source: Personal Communication, Danielle Morancy, SFWMD).

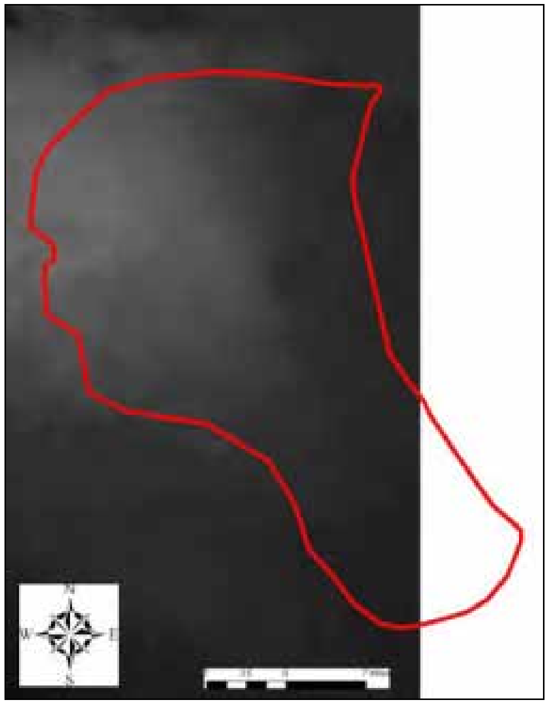


Figure 4.2.1 – SFWMD SWFFS DEM

In addition, Light Detection and Ranging (LiDAR) from the United States Army Corps or Engineers (USACE), Florida Division of Emergency Management (FDEM) data is available for a portion of the model domain from the State of Florida as shown in ***Figure 4.2.2***. Additional surveyed topographic data were obtained from:

- As-built drawings of levees within the McDaniel Ranch in the Feeder Canal Basin
- Spot elevations from wells in Crooks and Golden Ox ranches (SFWMD, 2009a)
- Obern Property, L-3 West Levee topography
- Compartment C topography
- Stream gauging reports for the Deer Fence Canal
- S&M Topography Survey Mc Kim and Creed (4-19-05)
- Deer Fence Canal cross sections, March 31, 2005
- Index Velocity Site Cross Sections Project (05/10/06) Site DF11, L202 and L207
- Jackman's Ranch (TWP 44, RGE 31E, Sections: 17, 18, 19, 20, 31 & 32)
- WCA3A 2X2 model topography
- Topographic maps of U.S. Sugar lands within the C-139 and C-139 Annex basins
- Spot elevations of natural ground from cross sections surveyed as part of the Compartment C Hydrologic and Hydraulic Design (URS and ADA, 2007)
- Spot elevations obtained as part of this project

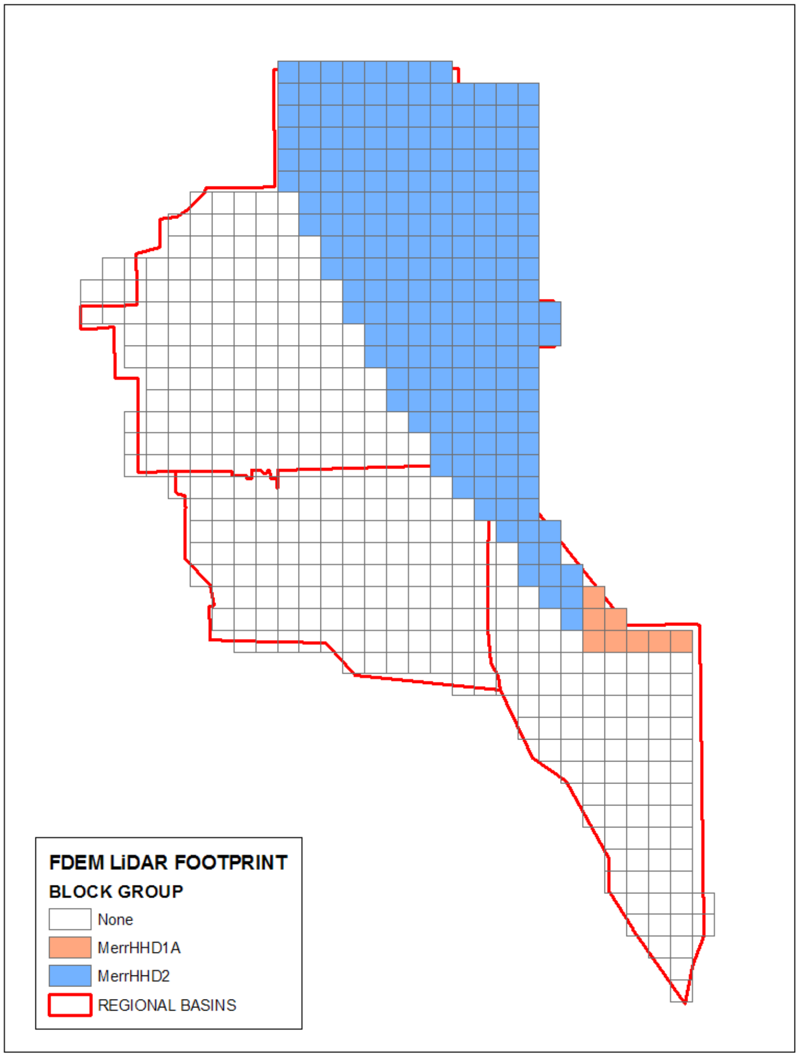


Figure 4.2.2 – Extent of LiDAR Data Available from USACE, FDEM

Topography Analysis

As-built McDaniel Ranch Ground Elevations. Cross sections of proposed new impoundment levees were obtained from permit files (SFWMD, 2009b), and the outer and inner toe elevations of the cross sections represented natural ground elevations within and outside of the proposed impoundments. Elevations (at the +/- 0.5 feet accuracy) were coded into GIS, and were then compared to the DEM. The average difference was 0.24 feet for 48 comparison points (a positive difference indicates that the SWFFS DEM is higher than the surveyed elevation). The 10^{th} and 90^{th} percentile differences were -0.85 and 1.3 feet, respectively. Differences less than +/- 0.5 and +/- 1.0 feet were 44% and 75%, respectively. The differences were deemed to be sufficiently minor and no adjustments were recommended for the McDaniel Ranch.

Crooks and Golden Ox Ranch Well Ground Elevations. Natural ground elevations were available for seven sites within the two ranches. Five of the sites also have wells located in adjacent wetlands, which provided two elevations for these five sites. These elevations were compared to the DEM, and the average difference between the surveyed elevations of the wetland sites and the DEM was 1.3 feet, with the DEM having a lower elevation. The average difference between the nested wells in upland areas and the DEM was 2.6 feet (for 6 of 7 sites) with the DEM being lower than the ground elevation shots. For one site (Site 6 on the Golden Ox Ranch), the DEM is 1.7 feet higher. There are two potential explanations for these elevation differences:

1) the wells are located on high spots that are not representative of overall ground elevations, or
2) the DEM for this area of the model domain could be inaccurate.

Additional investigations of the topography are needed for this area.

C-139 Annex US Sugar Topographic Maps. The US Sugar spot elevations were similar to the DEM for much of the Annex as shown in ***Figure 4.2.3***. The contour lines in ***Figure 4.2.3*** are based on a US Sugar topographic map provided by Pepe Lopez of US Sugar. Yellow and green contour lines differ by less than +/- 1.0 feet, and red and blue lines differ by more than +/- 1.0 feet. There is a small area on the north end of the Annex where US Sugar topography is greater than the SWFFS DEM, and there is east-west path on the south end of the Annex where the SWFFS DEM is higher than US Sugar topography. No adjustment was made to the current DEM, however it is recommended that the DEM in this area be revised for any subsequent revisions to this MIKE SHE/MIKE 11 model.

Spot Elevations Surveyed as Part of This Project. URS contracted with Betsy Lindsay, Inc. to provide spot elevations at 29 locations. The survey had to be divided in Phase I and II due to the lengthy process to obtain access to the Big Cypress Seminole Reservation (BCSR). At the time of the calibration and validation only Phase I of the topographic survey was completed (includes all locations except for the ones in Seminole Reservation). Phase I was completed in September, 2009 and Phase II in January, 2010. The results of the surveys are presented in ***Section 3 - Field Data***. Difference maps were created to compare to the SWFFS DEM and for the LiDAR data provided by FDEP. The average difference was -0.17 feet (DEM is higher) for the SWFFS DEM. Sixty-two percent of the values were less than +/- 0.5 feet difference, and the 10th and 90th percentile values were -0.8 and +0.5 feet. ***Figure 4.2.4*** presents the difference map between the SWFFS DEM and the spot survey elevations.

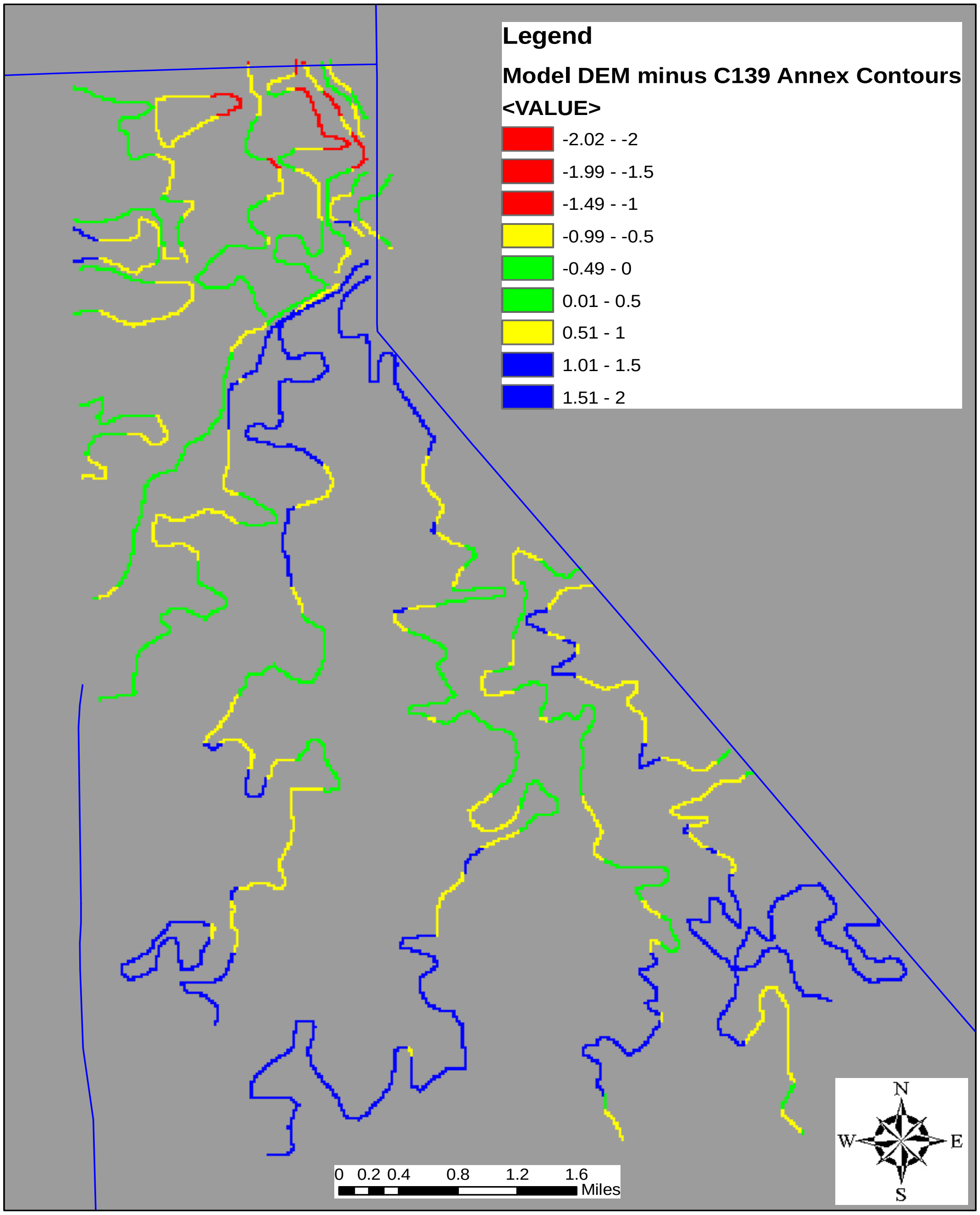


Figure 4.2.3 – US Sugar Topographic Differences

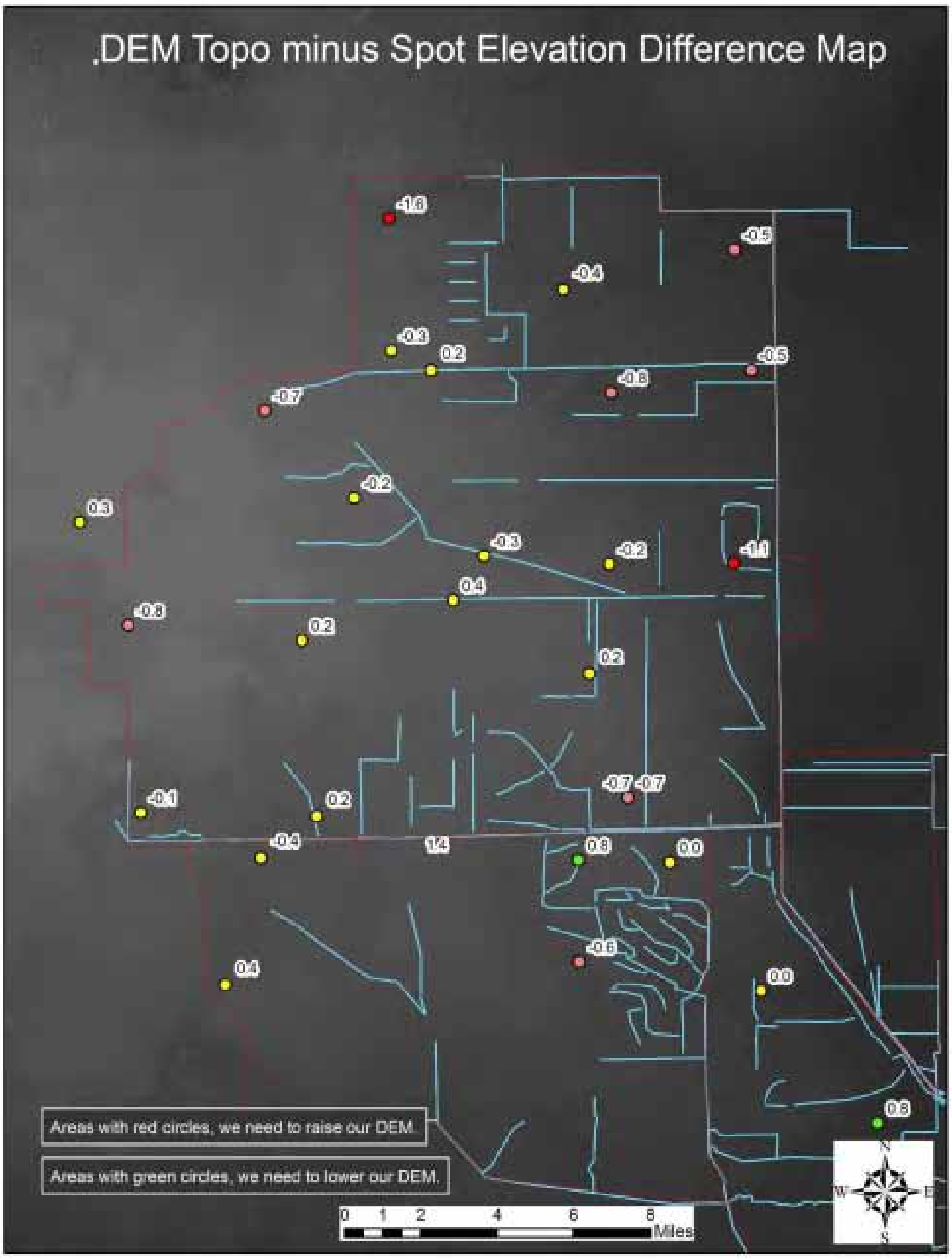


Figure 4.2.4 – Comparison between the SWFFS DEM and C-139 RFS Spot Survey Elevations

The LiDAR file was compared to 16 surveyed spot elevations (see ***Figure 4.2.5***), and the average difference was -0.56 ft (DEM is lower than LiDAR elevation). Sixty-three percent of the values were less than +/- 0.5 feet difference, and the 10^{th} and 90^{th} percentile values were 0.2 and -1.2 feet. Because the LiDAR data was not more accurate than the SWFFS DEM, it was decided to not incorporate the LiDAR data into the DEM used in the model. In general, there were no systematic differences between the SWFFS DEM and the spot elevations (the DEM was lower than spot elevations in certain areas and higher in other areas). One trend noted was than the SWFFS DEM was higher than spot elevations in the eastern portion of the model domain near the L-1 and L-2 Canals.

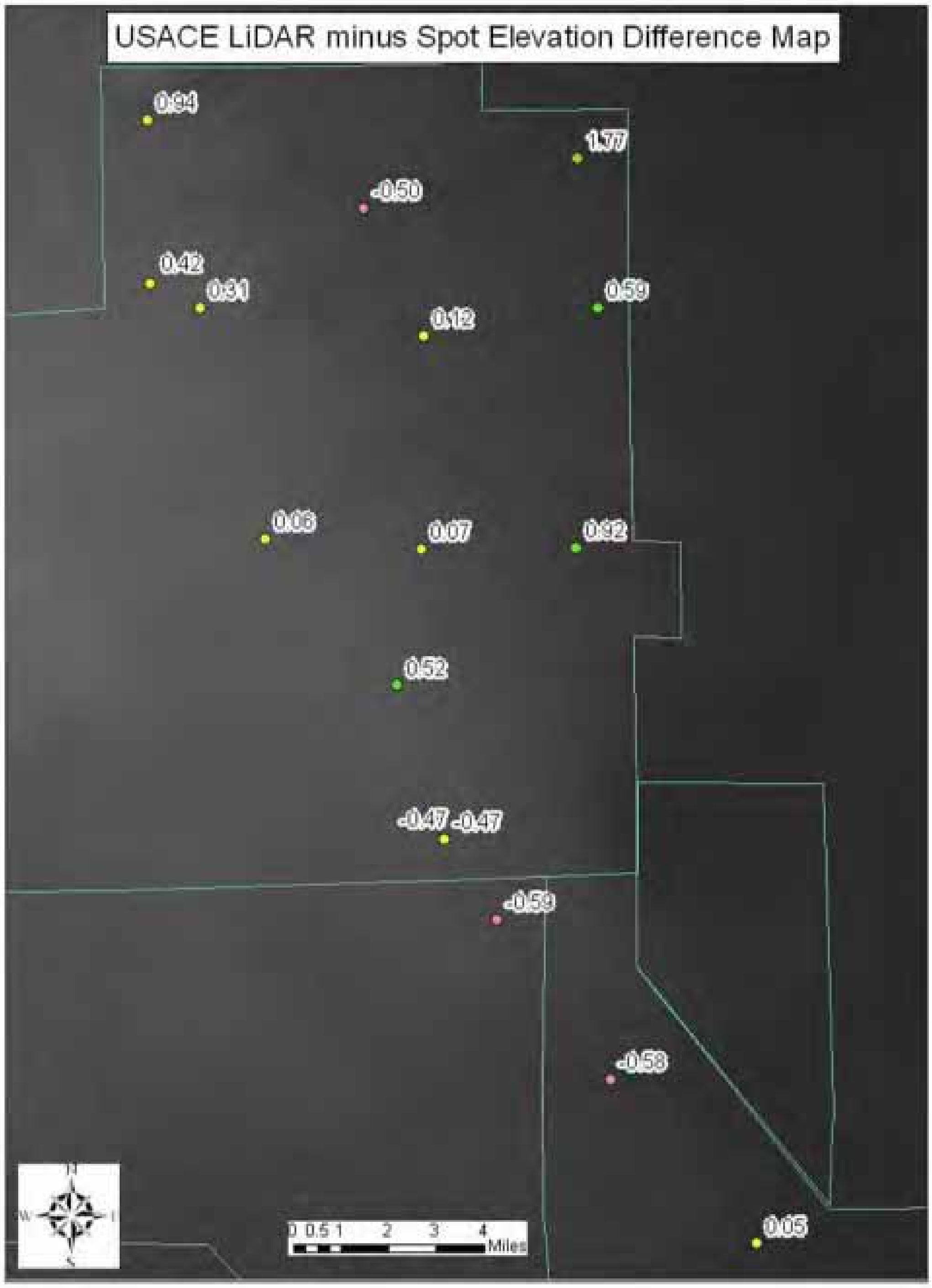


Figure 4.2.5 – Comparison between USACE, FDEM LIDAR and C-139 RFS Spot Survey Elevations

Conclusions of the Topographic Analysis. The topographic analysis indicated that differences exist for certain areas of the model domain, such as portions of the C-139 Annex, and lands along the L-1 and L-2 Canals on the eastern portion of the C-139 Basin. The DEM used in the model was not revised to incorporate these new data because the full data set was not available until late in the calibration process. The SWFFS DEM was made by generating a digital elevation model of all reliable spot elevation data that was available to SFWMD GIS specialists as of September, 2005. It is recommended that all spot elevation data obtained from this effort be added to the spot elevation data used to generate the SWFFS DEM and then used to generate a new DEM. Based on a review of permit files, it appears that a number of farms have a significant amount of topographic data. An effort should be made to request these data as better data will lead to a better model, which will allow better decision-making. Digital files of spot elevations should be requested from the McDaniel Ranch and US Sugar and a number of other ranches, if available.

4.2.2.2 Overland-Groundwater Leakage

MIKE SHE has the capability to limit leakage from the overland flow plane to the groundwater system using a user-specified coefficient. This coefficient is added either as a constant value across the model domain or as a spatially-varied grid file. This is normally used in wetland areas where an organic layer is known to be present on the land surface that is not part of the normal soils coverage. Another area where overland-groundwater leakage coefficients are defined is for soils that are known to have caprock, a fragipan, or a thin area of clay near the land surface. A constant overland-groundwater leakage coefficient value of 1×10^{-5}/second was used in the model.

4.2.2.3 Separated Flow Areas

MIKE SHE has the capability to prevent overland flow from moving across user-specified boundaries. Separated flow areas are added using a shape file. This is normally used where there are known barriers to overland flow. MIKE 11 branches are needed to transport waters from one overland flow area to another. Because flows are limited by MIKE 11 conveyance features, separated flow areas should not be used in areas without MIKE 11 branches unless the modeler is sure that there are no outflows from the separated flow area. Separated flow areas have been used for each permitted Environmental Resource Permit (ERP) within the study area since water typically does not flow across ERP boundaries. ***Figure 4.2.6*** presents the separated flow area map that was used for the model.

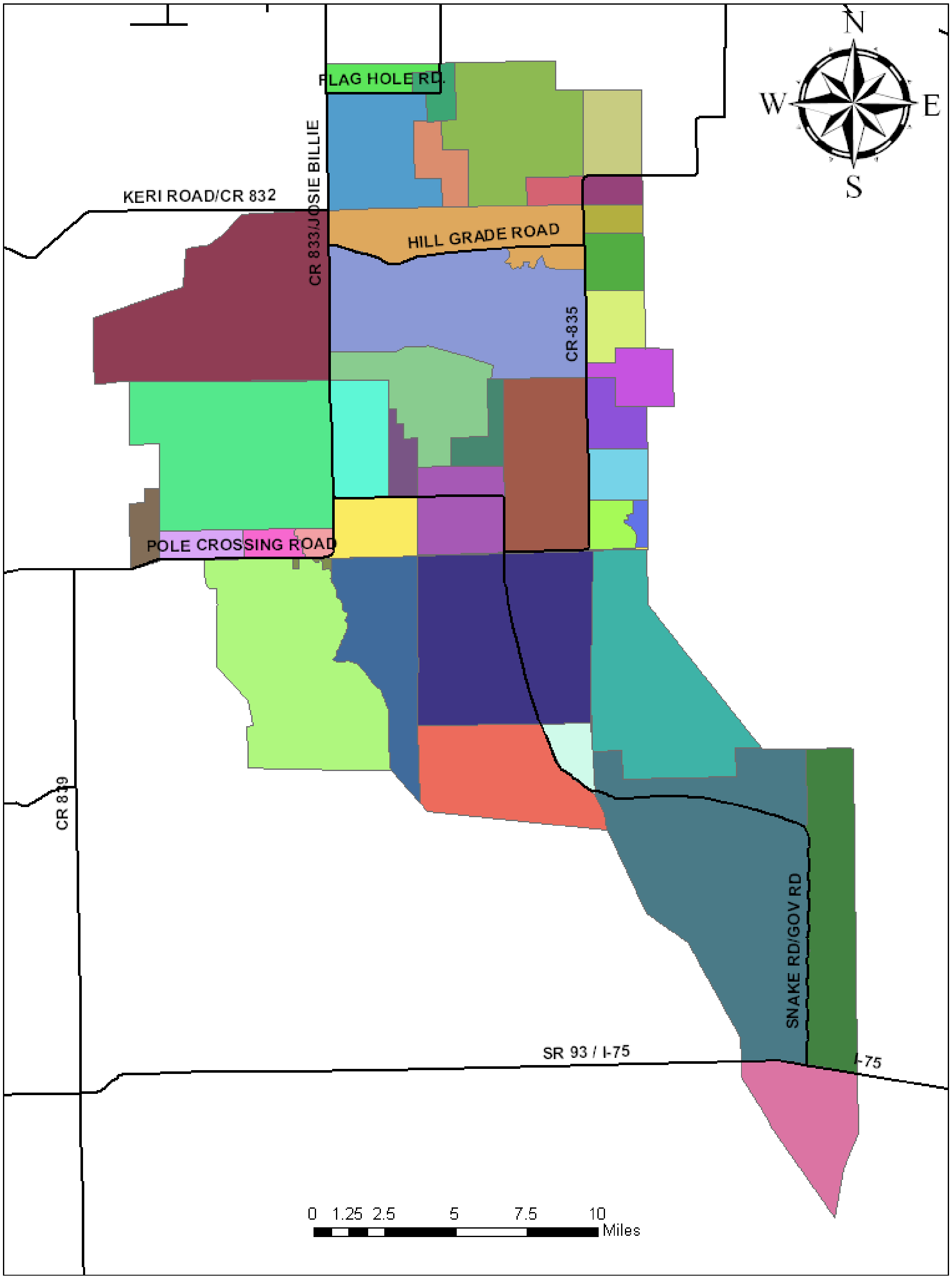


Figure 4.2.6 – Separated Flow Area Map

4.2.2.4 MIKE SHE Hydrogeology Model Setup

Based on the above review and review of other information and models, such as the SFWMD Hendry County Model, the MIKE SHE model saturated zone was set up as a three-layer model with lens representing the semi-confining units as shown below in ***Figure 4.2.7***.

MODEL LAYER 1	WATER TABLE AQUIFER
MODEL LENS	LENS REPRESENTING SEMI-CONFINING UNIT **(BONITA SPRINGS LENS)**
MODEL LAYER 2	LOWER TAMIAMI AQUIFER
MODEL LENS	LENS REPRESENTING SEMI-CONFINING UNIT **(UPPER PEACE RIVER LENS)**
MODEL LAYER 3	SANDSTONE AQUIFER
MODEL BASE	**NO FLOW BOUNDARY**

Figure 4.2.7 – Model Layers (Not to scale)

Initial parameters used in model for each layer and lens are described in the following sub-sections.

4.2.2.4.1 Water Table Aquifer

The water table aquifer is the uppermost layer of the model from land surface (***Figure 4.2.8***) and the bottom elevations of the water table aquifer are shown in ***Figure 4.2.9***. The data for the top elevation were the same data as the topography described in ***Section 4.2.2.1 - Topography***. Data for the bottom elevation of the water table aquifer were extracted from the C-139 MODFLOW by Radin and Rodberg, 2009. The bottom elevation data were compared with that in the model files of Marco Engineering and found to be similar, if not identical.

Figure 4.2.8 shows that the elevation of the top of the water table aquifer varies from just over 30 feet NGVD to less than 9 feet NGVD. The bottom of the aquifer varies in elevation from 16 to -100 feet as shown in ***Figure 4.2.9***. The difference between the top and the bottom of the aquifer is the aquifer thickness and is shown in ***Figure 4.2.10***. This thickness map shows thicknesses varying from almost 100 feet to approximately 10 feet. Top and bottom elevations, as well as aquifer thickness were directly extracted for the C-139 MODFLOW model. The information though was consistent with the other models and reports.

Hydraulic conductivities were extracted from the MODFLOW model files and extrapolated to the eastern end of the model domain which was not covered in MODFLOW. The horizontal hydraulic conductivity of the Water Table Aquifer (presented in ***Figure 4.2.11***) ranges from 1 to over 250 (ft/day). Vertical hydraulic conductivity in the water table aquifer was initially estimated as 10 percent of the horizontal hydraulic conductivity, but was then modified during calibration to the values shown in ***Figure 4.2.12***.

Specific yield of the water table aquifer was also obtained from the C-139 MODFLOW model. The values within this current model domain was primarily 0.20, but there were two pockets of 0.25 and 0.10 as shown in ***Figure 4.2.13***.

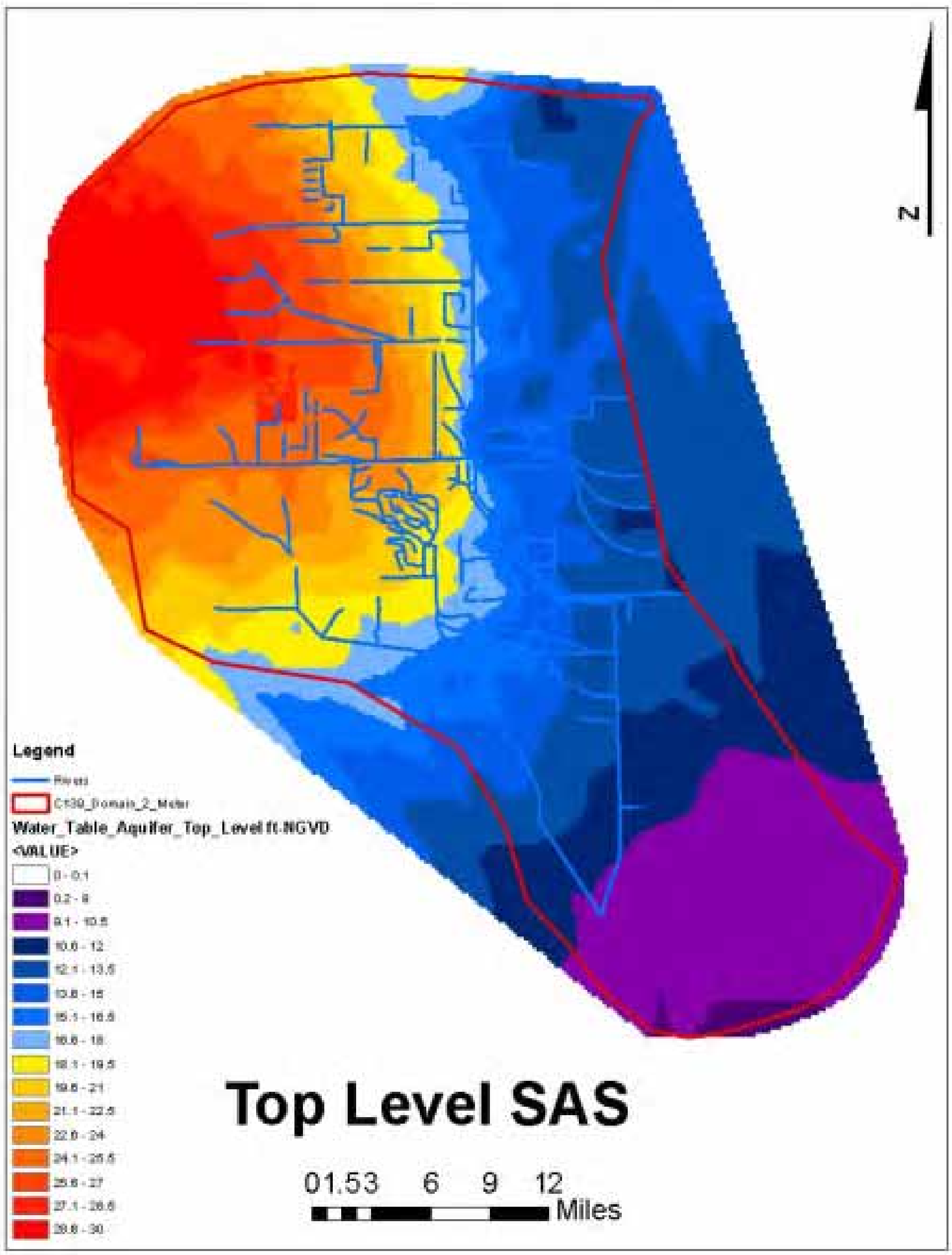


Figure 4.2.8 –Water Table Aquifer Top Elevation (ft-NGVD)

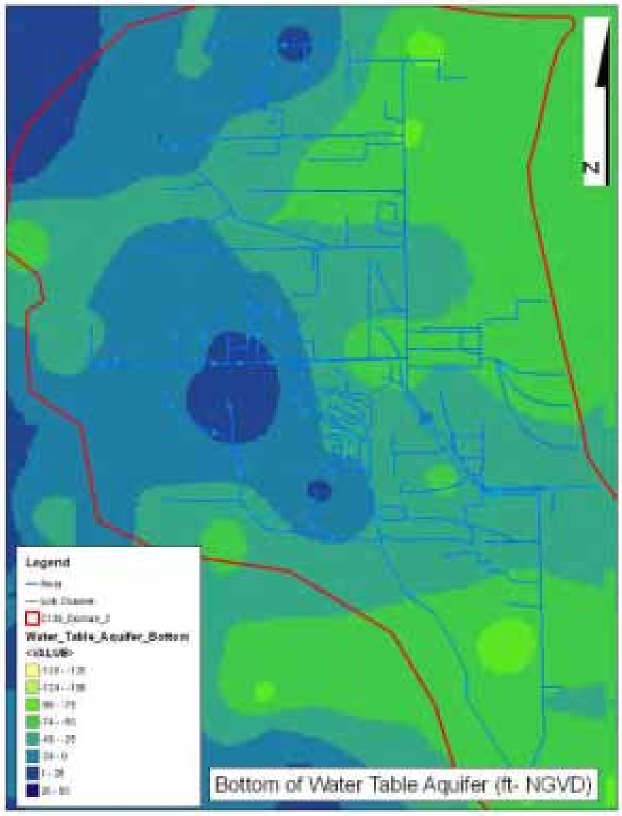


Figure 4.2.9 –Water Table Aquifer Bottom Elevation (ft-NGVD)

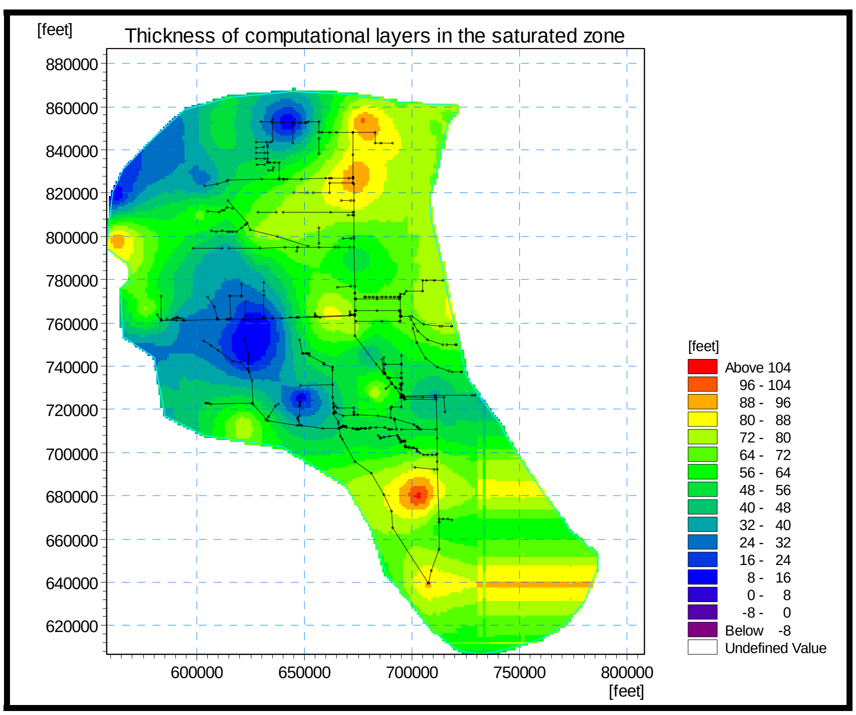


Figure 4.2.10 – Water Table Aquifer– Thickness

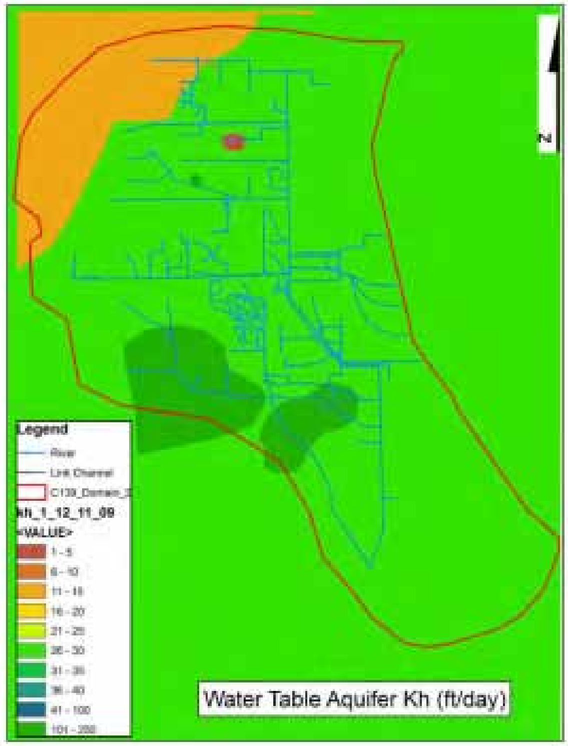


Figure 4.2.11 – Water Table Aquifer Horizontal Hydraulic Conductivity (ft/day)

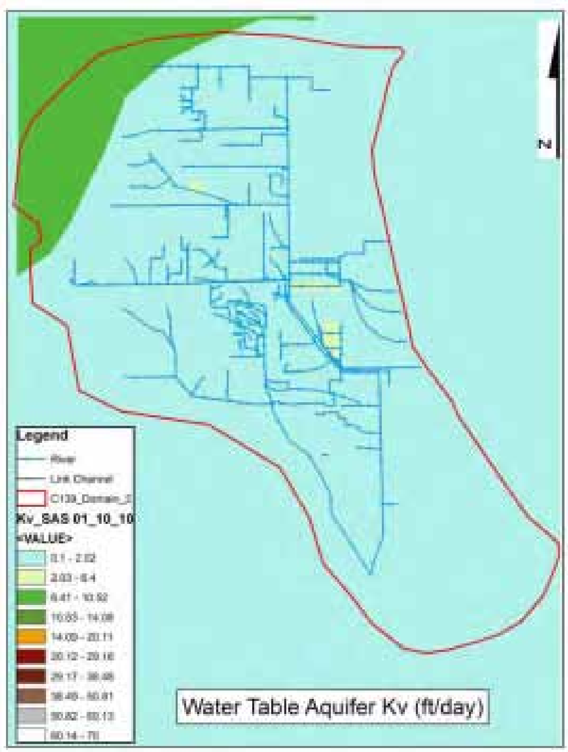


Figure 4.2.12 – Water Table Aquifer Vertical Hydraulic Conductivity (ft/day)

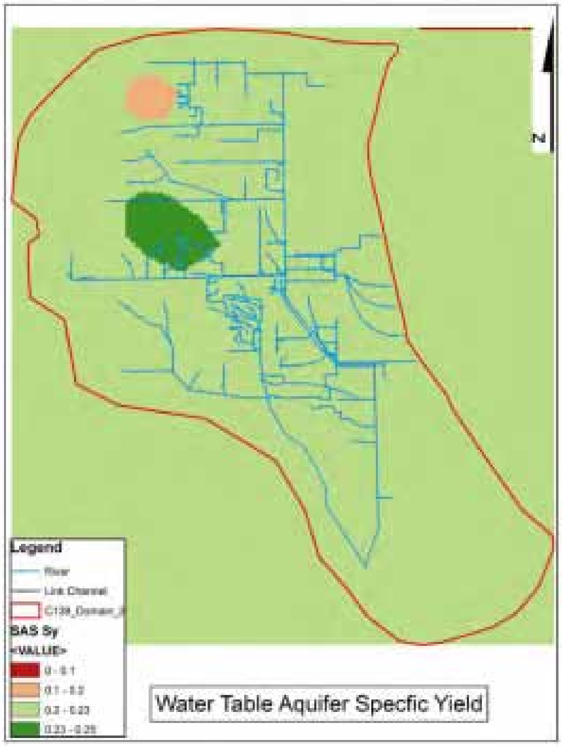


Figure 4.2.13 – Water Table Aquifer Specific Yield

4.2.2.4.2 Bonita Springs Lens

Although this is termed the Bonita Springs Lens in the model, it comprises not just Bonita Springs Lens but other low-permeability material that forms the semi-confining unit below the water table aquifer. Information on this semi-confining unit was obtained from the SWFFS GIS files. Horizontal Hydraulic Conductivity of the Bonita Springs Lens in the project area is a constant value of 0.004 (ft/day), however the Vertical Hydraulic Conductivity varies and is presented in ***Figure 4.2.14*** below. The specific storage of the Bonita Springs Lens is also a constant value 3.048e-05.

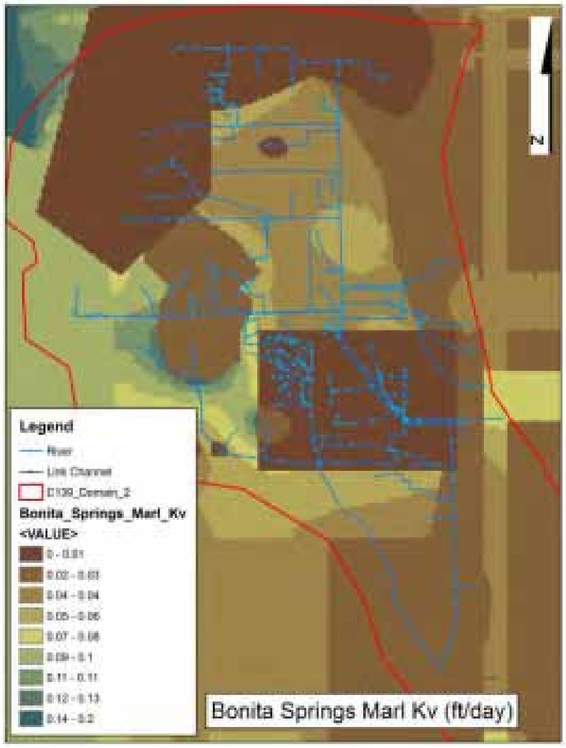


Figure 4.2.14 – Vertical Hydraulic Conductivity of the Bonita Springs Lens

4.2.2.4.3 Lower Tamiami Aquifer

The elevation of the top of the Lower Tamiami Aquifer is equal to the elevation of the bottom of the water table aquifer, as shown in ***Figure 4.2.9***. The elevation of the bottom of the Lower Tamiami Aquifer is shown in ***Figure 4.2.15***. The thickness is shown in ***Figure 4.2.16***. This aquifer has a thickness to over 100 feet which is consistent with information in other studies.

Horizontal hydraulic conductivity (***Figure 4.2.17***) for the Lower Tamiami Aquifer was also extracted from the C-139 MODFLOW model. Values varied from one foot per day to over 1,000 feet per day. These values were consistent with other studies but were modified during calibration. Vertical hydraulic conductivity was initially estimated as 10 percent of the horizontal hydraulic conductivity but was modified during calibration to the values, as shown in ***Figure 4.2.18***.

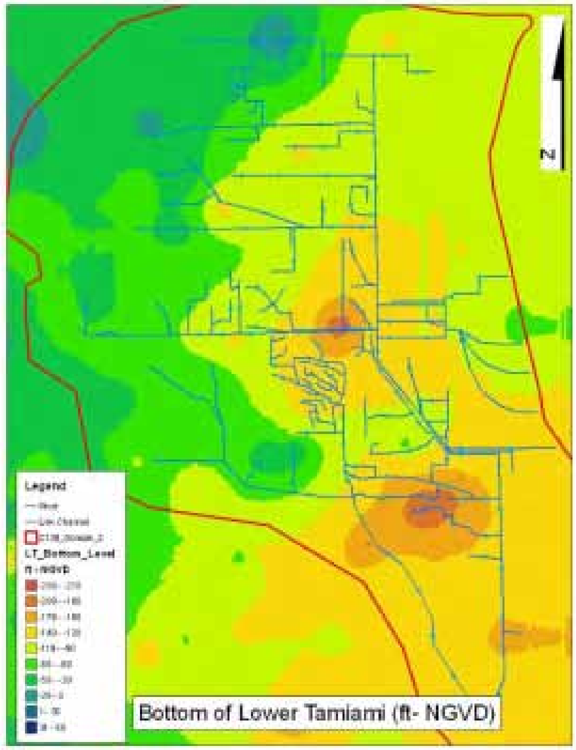


Figure 4.2.15 – Lower Tamiami Aquifer Bottom Elevation (ft-NGVD)

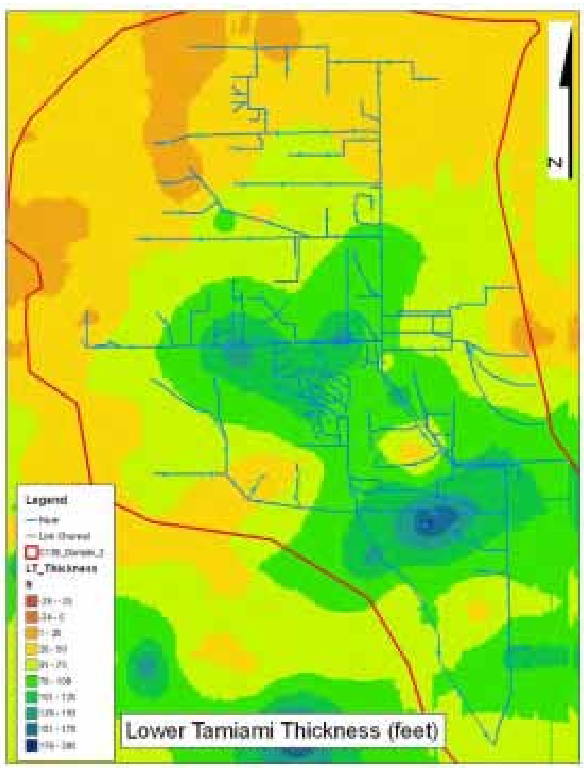


Figure 4.2.16 – Lower Tamiami Aquifer Thickness

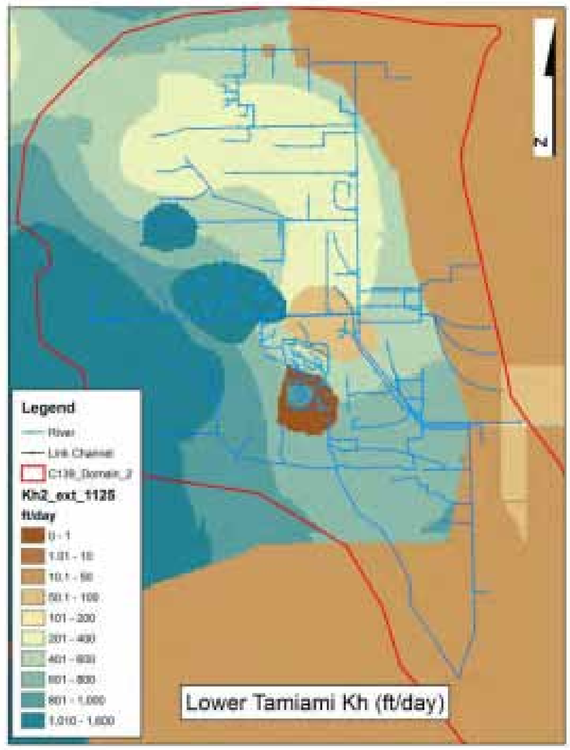


Figure 4.2.17 – Lower Tamiami Aquifer Horizontal Hydraulic Conductivity (ft/day)

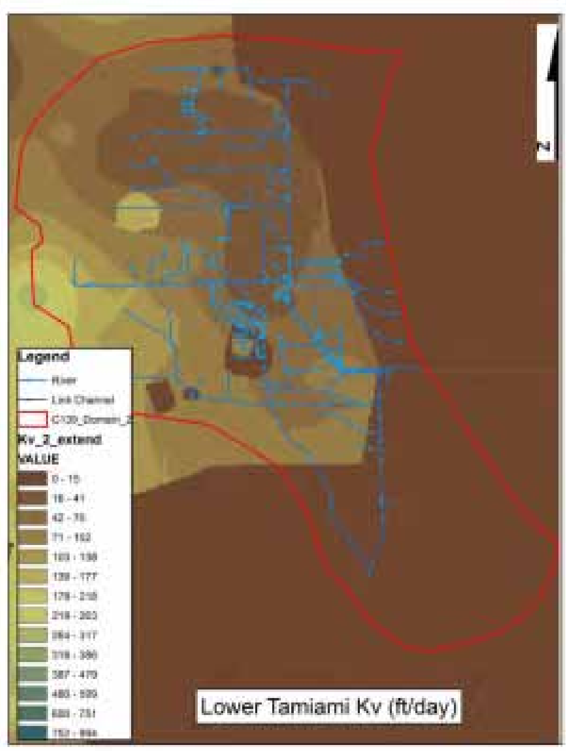


Figure 4.2.18 – Lower Tamiami Aquifer Vertical Hydraulic Conductivity (ft/day)

Storage coefficient for the Lower Tamiami was also extracted from the C-139 MODFLOW model. Values are shown in ***Figure 4.2.19***.

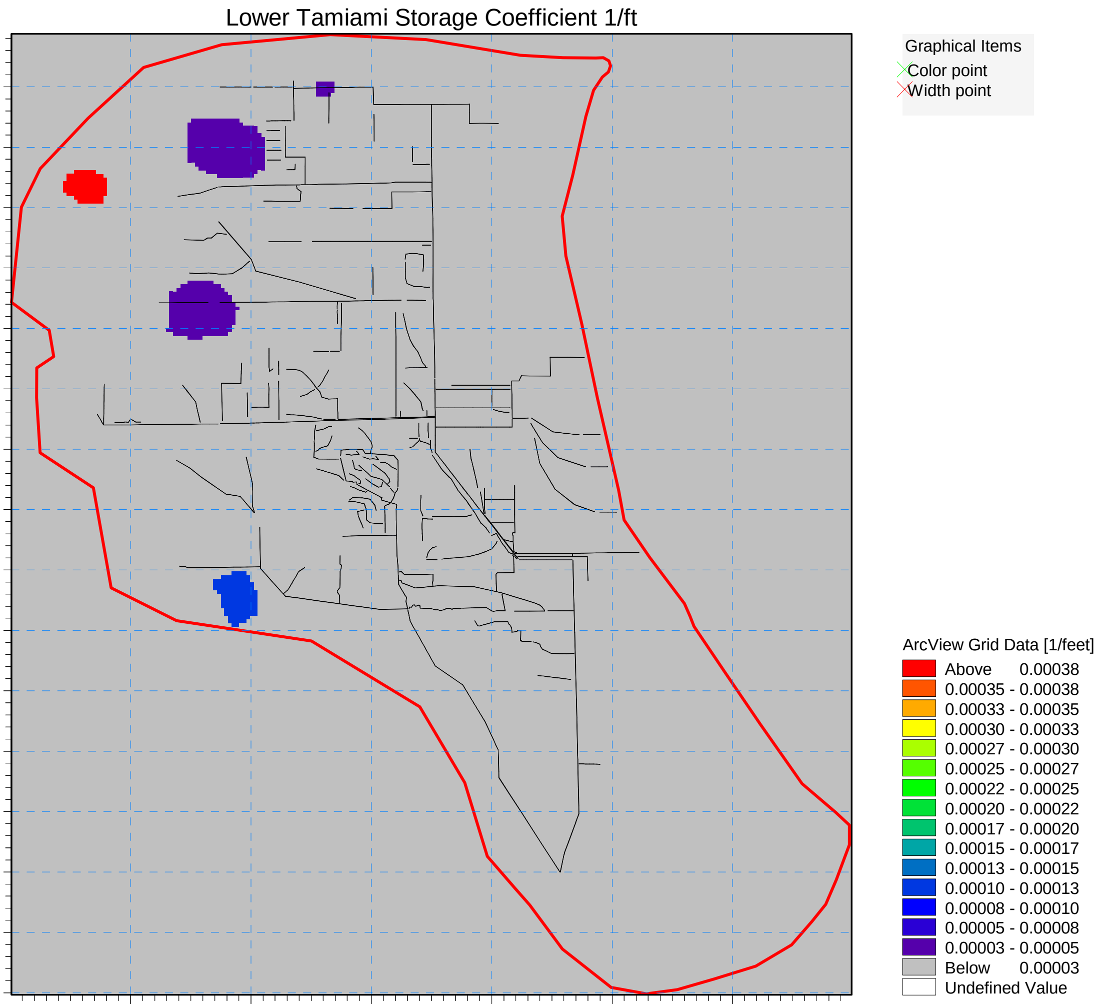


Figure 4.2.19 – Lower Tamiami Aquifer Storage Coefficient (1/ft)

4.2.2.4.4 Upper Peace River Lens

This semi-confining unit referred to as the Peace River Lens separates the Lower Tamiami from the Sandstone Aquifer. Although referred to as a semi-confining unit it includes pockets of relatively high horizontal and vertical hydraulic conductivities, as shown in ***Figure 4.2.20***. This data was obtained from the SWFFS GIS database.

The specific storage of the Upper Peace River Lens is a constant value 3.048e-05.

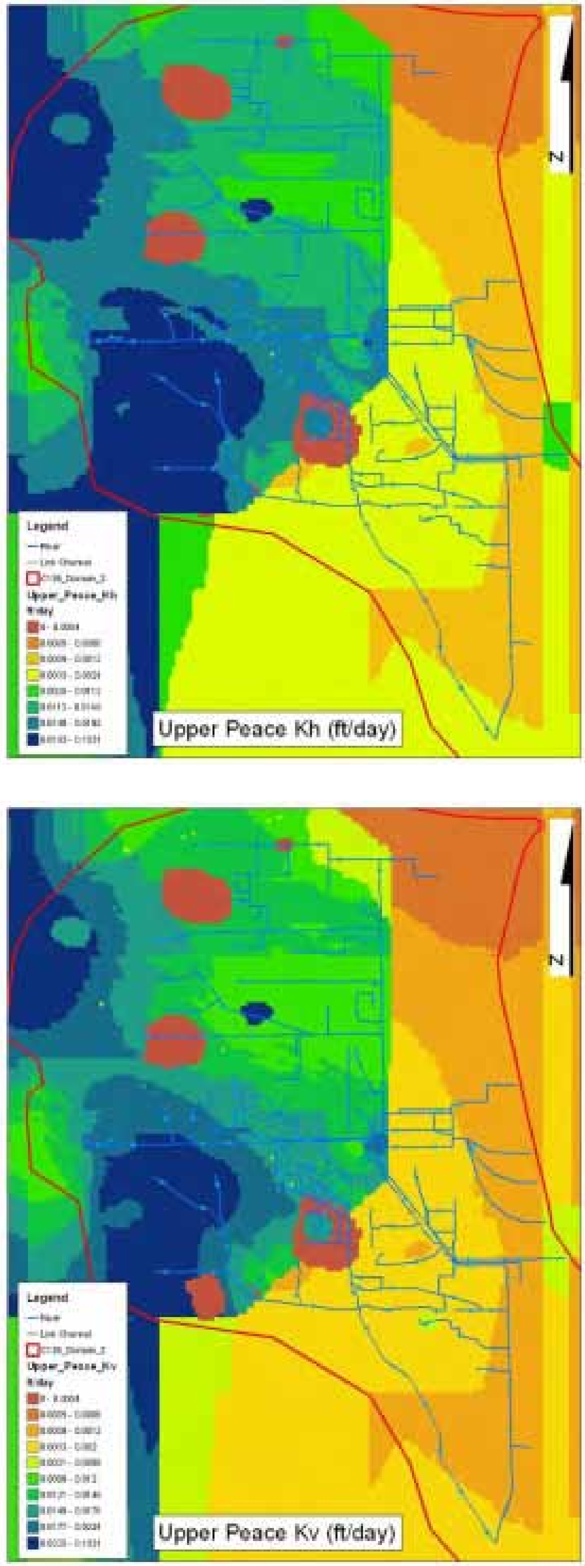


Figure 4.2.20 – Upper Peace River Lens Horizontal and Vertical Hydraulic Conductivity (ft/day)

4.2.2.4.5 Sandstone Aquifer

The elevation of the top of the Sandstone Aquifer is the same as the bottom of the Lower Tamiami Aquifer, which is shown above in ***Figure 4.2.15***. Bottom elevations of the Sandstone Aquifer are shown in ***Figure 4.2.21***. Aquifer thickness is shown in ***Figure 4.2.22***. These values were obtained from the C-139 MODFLOW model.

Horizontal hydraulic conductivity (***Figure 4.2.23***) for the Sandstone Aquifer varied from 500 to just under 40 feet per day. Vertical hydraulic conductivity (***Figure 4.2.24***) was calculated as 10 percent of the horizontal hydraulic conductivity. Storage coefficient is shown in ***Figure 4.2.25***.

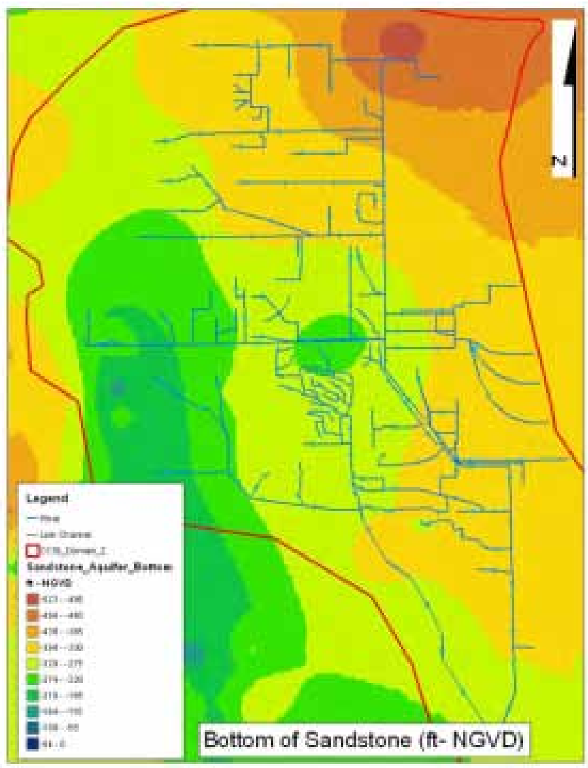


Figure 4.2.21 – Sandstone Aquifer Bottom Elevation (ft-NGVD)

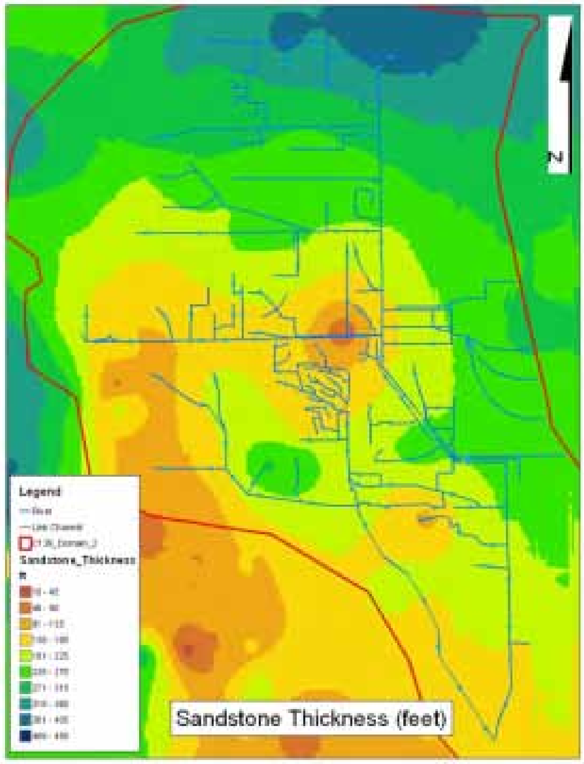


Figure 4.2.22 – Sandstone Aquifer Thickness

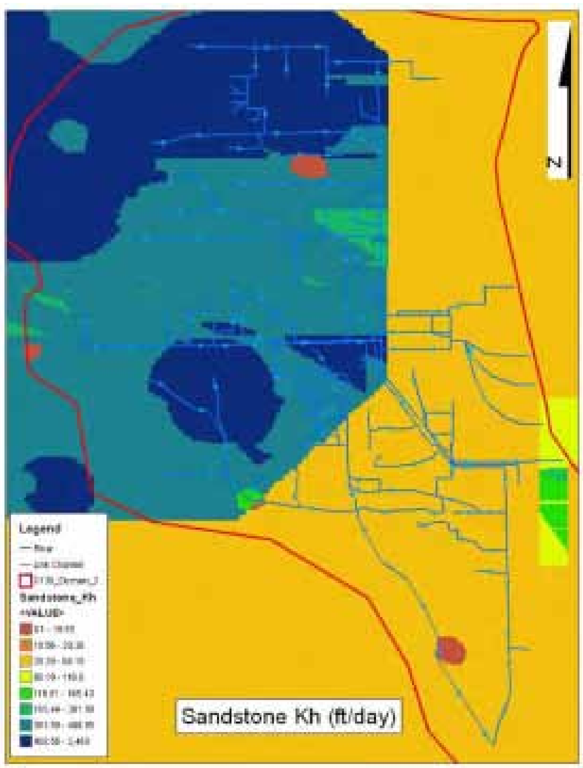


Figure 4.2.23 – Sandstone Aquifer Horizontal Hydraulic Conductivity (ft/day)

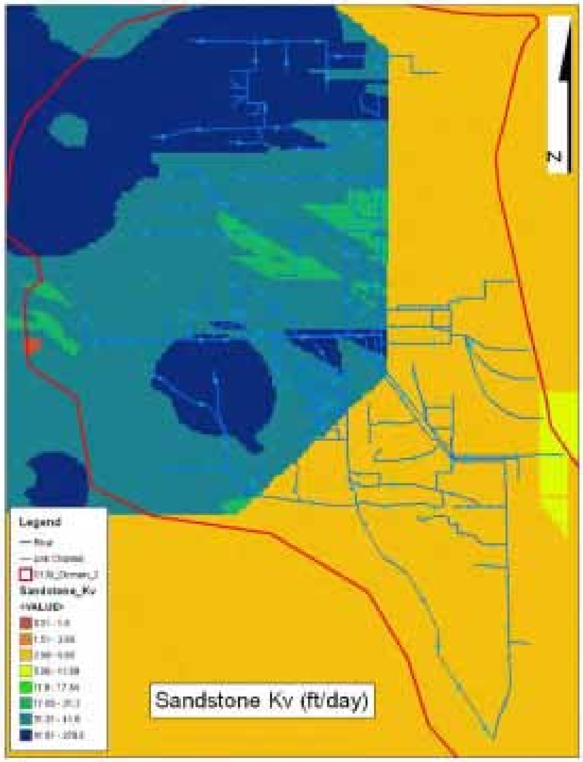


Figure 4.2.24 – Sandstone Aquifer Vertical Hydraulic Conductivity (ft/day)

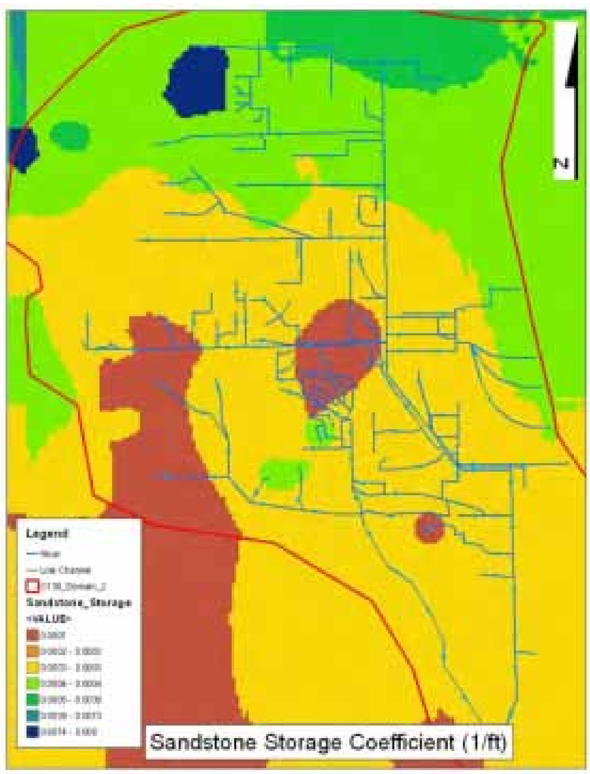


Figure 4.2.25 – Sandstone Aquifer Storage Coefficient (1/ft)

4.2.2.5 Calibration Stations

The groundwater calibration utilized measured data for monitoring wells within the study area. ***Table 4.2.1*** presents well data that has been obtained to assist in the calibration, and ***Figure 4.2.26*** shows the locations of groundwater monitoring sites within the model domain.

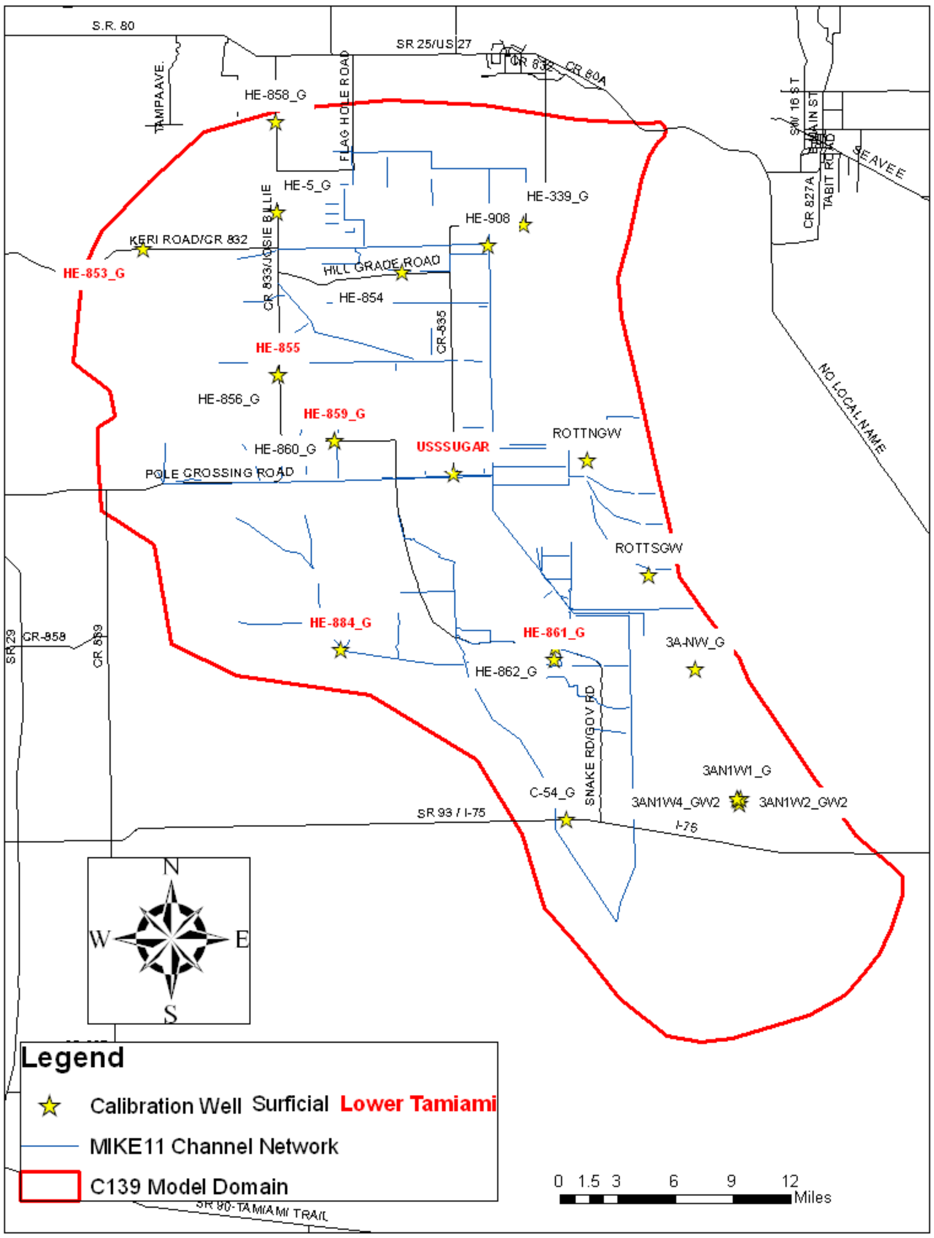


Figure 4.2.26 – Groundwater Monitoring Sites

Table 4.2.1 – Groundwater Calibration Data

Well Name	Dbhydro Elevation (ft NGVD)	Model Topo Elevation (ft NGVD) estimates	Elevation difference (model-dbhyro)	100 ft Grid Elevation (ft NGVD)	Dbhydro ft BLS	Bottom of well (ft NGVD)	Lower Level of Surficial (ft NGVD)	Lower Level of Tamiami (ft NGVD)	Middle of Surficial Aquifer (Topo+SAS)/2	Middle of Tamiami Aquifer (Surficial+Tam)/2	Depth for Model ft	Aquifer in Model
3AN1W1_G	10.22	10.3	0.08	10.13	38	-27.78	-62	-148.9	-25.85		36.15	Surficial
3AN1W2_GW2	10.05	10.3	0.25	10.13	15	-4.95	-62	-148.9	-25.85		36.15	Surficial
3AN1W3_GW2	10.5	10.3	-0.2	10.1	36.6	-26.1	-60	-151.35	-24.85		35.15	Surficial
3AN1W4_GW2	10.61	10.3	-0.31	10.1	7.09	3.52	-60	-150.09	-24.85		35.15	Surficial
3A-NW_G	N/A	11.7		12.1	N/A		-40.5	-135.75	-14.4		26.1	Surficial
C-54_G	12.86	12.7	-0.16	12.75	8.5	4.36	-64	-136.5	-25.65		38.35	Surficial
HE-339_G	14.38	14.34	-0.04	14.4	13	1.38	-70	-107.21	-27.83		42.17	Surficial
HE-5_G	29.77	26.36	-3.41	25.7	13	16.77	-20	-44.15	3.18		23.18	Surficial
HE-853_G	N/A	30		30	61	-31	0.18	-37.7		-18.76	48.76	Lower Tamiami
HE-854	N/A	20.9		20.8	14	6.8	-55.6	-122.88	-17.35		38.25	Surficial
HE-855	27.6	26.9	-0.7	27.87	90	-62.4	-6.03	-60.26		-33.145	60.045	Lower Tamiami
HE-856_G	27.56	26.9	-0.66	27.87	11	16.56	-6.03	-60.26	10.435		16.465	Surficial
HE-858_G	22.57	23	0.43	23.32	17	5.57	-27.3	-43.35	-2.15		25.15	Surficial
HE-859_G	26.3	25	-1.3	25	59	-32.7	-4.58	-102.65		-53.615	78.615	Lower Tamiami
HE-860_G	26.3	25	-1.3	25	16	10.3	-4.58	-102.65	10.21		14.79	Surficial
HE-861_G	14.42	14.75	0.33	14.9	70	-55.58	-35.93	-186.64		-111.285	126.035	Lower Tamiami
HE-862_G	14.42	14.57	0.15	14.6	11	3.42	-38	-164.35	-11.715		26.285	Surficial
HE-884_G	19.96	18.56	-1.4	18.65	67	-47.04	-37.82	-82.57		-60.195	78.755	Lower Tamiami
HE-908	17.5	16.4	-1.1	16.3	165	-147.5	-79	-105.86	-31.3		47.7	Surficial
ROTTNGW	N/A	13.34		13.18	N/A		-57.16	-114.84	-21.91		35.25	Surficial
ROTTSGW	N/A	13		13.1	N/A		-40.7	-124.48	-13.85		26.85	Surficial
USSSUGAR	0	22.7	22.7	20.9	100	-100	-62	-192.77		-127.385	100	Lower Tamiami

During the calibration process, a wide range of model parameters were modified to obtain as close a match as possible to both surface water stages and flows, along with surficial aquifer and lower confined aquifer water levels. The calibration process involved simultaneously adjusting surface and ground water information. In some cases, calibration was dependent on properly defining canal gate and pump protocols and obtaining correct dimensions of culverts and weirs. In most cases, irrigation rates were checked against known data (where available) or against permitted maximum or average pump rates. Groundwater aquifer thicknesses, hydraulic conductivity, storability, and specific yield were reviewed, compared to aquifer performance test data (where available), and adjustments were made. In this project, aquifer performance data were available for the Crooks and Golden Ox ranches (SFWMD, 2009c), and these data were reviewed during calibration.

The SFWMD (2009c) reports communication between the surficial and the Lower Tamiami Aquifers (across the Bonita Springs Lens), however the locations of leakage are unknown. There are no known methods to fill these data gaps. Therefore the calibration process explored a number of potential solutions to this problem, such as:

- Varying the hydraulic conductivity of the entire Bonita Springs Lens semi-confining unit. Tests were conducted at +/- 10X the values initially obtained from the Lower West Coast MODFLOW model files.
- Varying the hydraulic conductivity of portions of the Bonita Springs Lens. These changes were made based on a review of aquifer pump tests, Lower Tamiami well calibration results, and best professional judgment.

This basic approach of varying hydraulic conductivity both globally and locally was also used for the surficial aquifer and the Lower Tamiami Aquifer.

4.2.2.6 Surface Water

4.2.2.6.1 Surface Water System Added to the Model

The surface water system of the C-139 Region is comprised of wetlands, SFWMD canals, STAs, canals maintained by water control districts, and interior farm canals. The MIKE 11 files used in the Compartment C Hydrologic and Hydraulic Design Study was used as a starting point, and additional canals were added as described below. Since MIKE 11 was coupled with MIKE SHE for this project, there were a few significant differences in the MIKE 11 surface water network used in the 2006 Compartment C Hydrologic and Hydraulic Design Study (URS, 2008). When MIKE 11 is run with MIKE SHE, it is not necessary to define all storage elements within the MIKE 11 network because MIKE SHE includes overland flow routines and detention storage (for small reservoirs and depressional areas), and drainage (for representing effects of small canals not in the MIKE 11 network). When MIKE SHE is run with MIKE 11, the MIKE 11 surface water network can be limited to canals and streams that have a major effect on watershed hydrology. Canals that were added to the MIKE 11 canal network of the C-139 Basin used in the Compartment C Hydrologic and Hydraulic Design include:

1. Other Main Canals. These consist of SFWMD canals not included in the Compartment C model, such as the North Feeder Canal (NFEED), West Feeder Canal (WFEED) and L-28 Interceptor Canal. A number of other major canals maintained by other entities were included such as the canal from G-409 (at "Confusion Corner") to the Seminole Lands.
2. Minor Canals. These canals handle runoff from multiple farms and may or may not be maintained by a water control district.
3. Interior Farm Canals. These canals are usually part of one farm and are normally used to convey farm runoff to and from interior water supply reservoirs and water quality treatment reservoirs. This network includes the farm reservoirs and control structures that control flow out of the farm.
4. Wetlands. A number of wetlands in the study area have a dug canal through the center of the wetland, and some of these drained wetlands are represented in the MIKE 11 network. Other wetlands are handled as part of the MIKE SHE overland flow module.

The MIKE 11 model used in the Compartment C Design had wide cross sections for a number of smaller canals where it was known that there was significant storage within that canal sub-basin that attenuated peak flows. The storage was either farm reservoirs or large wetland areas. These wide cross sections were generated from a DEM of the watershed and most of the cross section was set to be approximately 1-2 feet lower than the DEM. Since the current model setup includes MIKE SHE, the cross sections used in the Compartment C MIKE 11 model were modified as part of this modeling effort so that the cross sections are similar to elevations found in the DEM.

Information was added to the model for a number of road culverts within the C-139 Basin. This information was obtained from a variety of sources including permit drawings, the

Devil's Garden Water Control District Facilities Map (Johnson – Prewitt & Associates, Inc. (2001), and field measurements made by Mitch Murphy of the SFWMD Clewiston Field Station. Feeder Canal and L-28 structures were obtained from McDaniels Ranch agricultural farm reservoir as-built levee drawings, The Seminole Tribe of Florida GIS files, and the SFWMD Structure Book. STA-5 and STA-6 information was obtained from (Goforth 2008).

Figure 4.2.27 presents the MIKE 11 network used in the initial phases of calibration. Once the model was stable and providing reasonable calibration, additional details were added to represent main interior farm canals and above-ground impoundments (AGIs) that are part of agricultural ERPs or Chapter 298 District facilities. This network and the AGIs added to the model are also presented in ***Figure 4.2.27***. ***Figures 4.2.28 - 4.2.33*** provide additional details for the network that show gates, pumps, weirs, AGI naming, etc.

The typical farm in the study area has a dense network of farm canals that both serve as an irrigation flow distribution network and as a drainage network. Pumps are commonly used to lift the farm runoff into an above-ground impoundment (AGI) that is constructed by the farmer with man-made levees. The AGI levees are often constructed around an existing wetland or group of wetlands. AGIs are often linked together and drain downstream with the inflow pump station of the most downstream AGI lifting outflows from to?? the upstream AGIs. Operation of the farm pumps is controlled by the farmer, and typically, no farm discharges occur without operation of farm pumps. It is the personal experience of ADA staff that farmers can wait quite a while to begin farm discharges if they feel it is in their benefit. Thus, the rainfall runoff response of the C-139 watershed is affected by farm operators.

The first step for adding farm level AGIs to the model was to inspect 1-meter resolution 2005 aerial photographs (source:Labins) using GIS to identify the locations of the reservoirs. Permit files were then reviewed to confirm that the features observed in the aerial photographs were indeed AGIs. In some cases, additional AGIs were noted in the permit files, and the aerial photographs were reviewed again to determine if AGIs were "in the ground". In some cases, a permit listed or showed an AGI that was not yet installed for the calibration and validation periods. Inflow pump station capacities and locations, operation protocols, and outflow control structures dimensions and locations were also determined from the permit files. The permit files provide pump locations, pump capacities, on and off elevations, and outflow structure dimensions.

AGIs were sometimes grouped in MIKE 11 where an individual Environmental Resource Permit (ERP) listed information for multiple AGIs on a single farm. One example of this is the J-7 Ranch, which has nine reservoirs totaling 867 acres within a 5,811-acre permitted farm. These reservoirs were grouped into two reservoirs since seven AGIs discharge to the S&M Canal, while two AGIs discharge to the Deerfence Canal.

Interior farm canal dimensions were not normally given in the permit files. Interior farm canal coverage is generally quite dense with lateral farm canals as close as 1,200 feet apart. In many cases, an AGI will have multiple inflow pump stations located on multiple inflow canals. It would be impractical for the MIKE 11 model to have all of these farm canals, therefore the inflow canal (s) used in the model were a very rough approximation of the inflow canal capacity. The inflow canals to the AGIs used in the MIKE 11 model were generally assumed to have a top width of 20 – 50 feet with a canal depth of 5 – 10 feet. Larger farms with large inflow pump stations had larger inflow canals.

Surface area for a grouped AGI was typically the sum area of the group of AGIs. Outflow weir dimensions were exactly as listed in the ERP for the following cases:

- AGIs were not grouped (e.g. C-139 Annex)
- Multiple AGIs were connected in series where the most downstream AGI outlet weir controlled overall outflow capacity

Where there were multiple AGIs with multiple discharge weirs, a single outflow location was assumed by the modeling team and a "composite" weir was utilized that had similar discharge characteristics to the group of individual weirs. Because this is a regional model covering 266,000 acres, it should not be assumed that detailed hydraulic analysis was conducted to assure that grouped outlet structures used in the model have the exact hydraulic conveyance of the overall set of individual outflow structures.

After the AGIs were added to the model, the result files were reviewed to determine the "reasonableness" of the farm discharges. If the inflow pumps operated too frequently with extended periods of inundation within the reservoirs, the on/off control elevations for the inflow pumps were modified. In the C-139 Annex, the simplified canal network had a higher gradient than is believed to exist, plus the farm permit files indicate that there are numerous interior gates that control different canals at different control elevations. The first attempt at representing interior farm canals generated too much runoff from the C-139 Annex. Accordingly, some weirs were added to the longer farm canals to maintain higher canal water surface elevations in upstream portions of the MIKE 11 canal, which reduced overall C-139 discharge rates to more reasonable levels.

Appendix C1 – Procedure for Adding Farm Level AGIs provides additional details on how farm-level AGIs were added to the model. ***Figures 4.2.28*** to ***4.2.33*** and ***Tables 4.2.2*** to ***4.2.4*** present the structures that are represented in the model. ***Figure 4.2.34*** presents a detailed diagram of one farm with an AGI. There are a number of structures that have either been removed or constructed between 2003 and 2008, such as the addition of STA-5 Cell 3, STA-6 Section 2, G-407, and the removal of G-155. The model was set up to simulate the structures to operate for only a portion of the simulation period. In the case of G-407, this structure was not present prior to 2007. Since the structure conveyance area is much less than the canal conveyance area, a hypothetical structure was added to be fully open prior to 2007, and the conveyance area of this hypothetical structure was equal to the difference in conveyance between the L-3 Canal and G-407.

A detailed timeline of improvements provided by SFWMD and was used to guide the development of the network files so that the appropriate hydraulic controls are used for the validation model, which is for the period 2007-2008 (see ***Table 4.2.5***). During calibration, it was noted that G-344 headwater stages (downstream end of STA-5 Cell 1) in the spring of 2005 dropped rapidly to very low elevations, yet there were no flow increases through G-344 during this period. SFWMD staff was consulted for clarification, and it was discovered that this STA cell was drained with pumps that transferred the water from Cell 1B to Cell 2B as part of an effort to improve nutrient retention in STA-5. The network was modified to represent this.

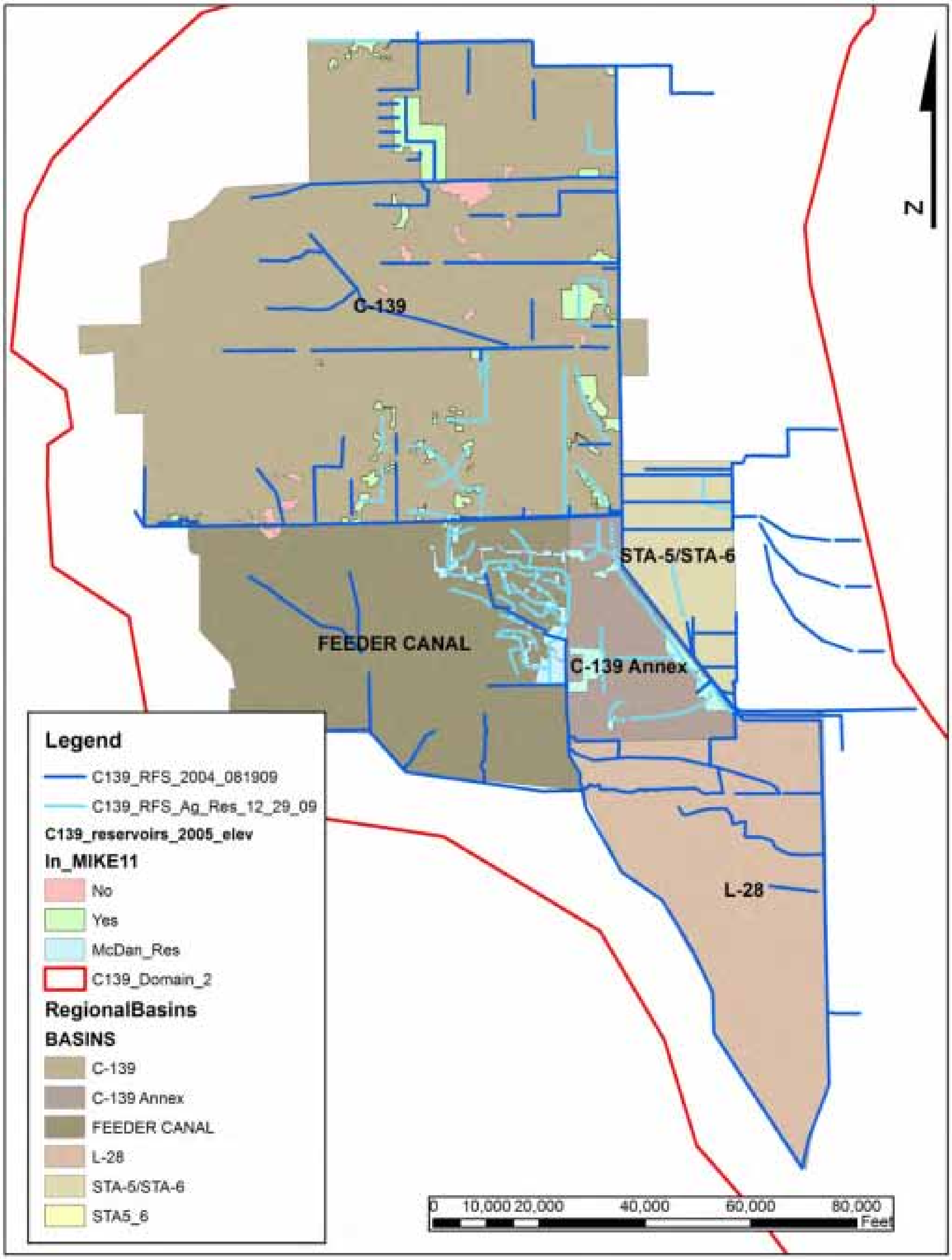


Figure 4.2.27 – Canal and Reservoir Network

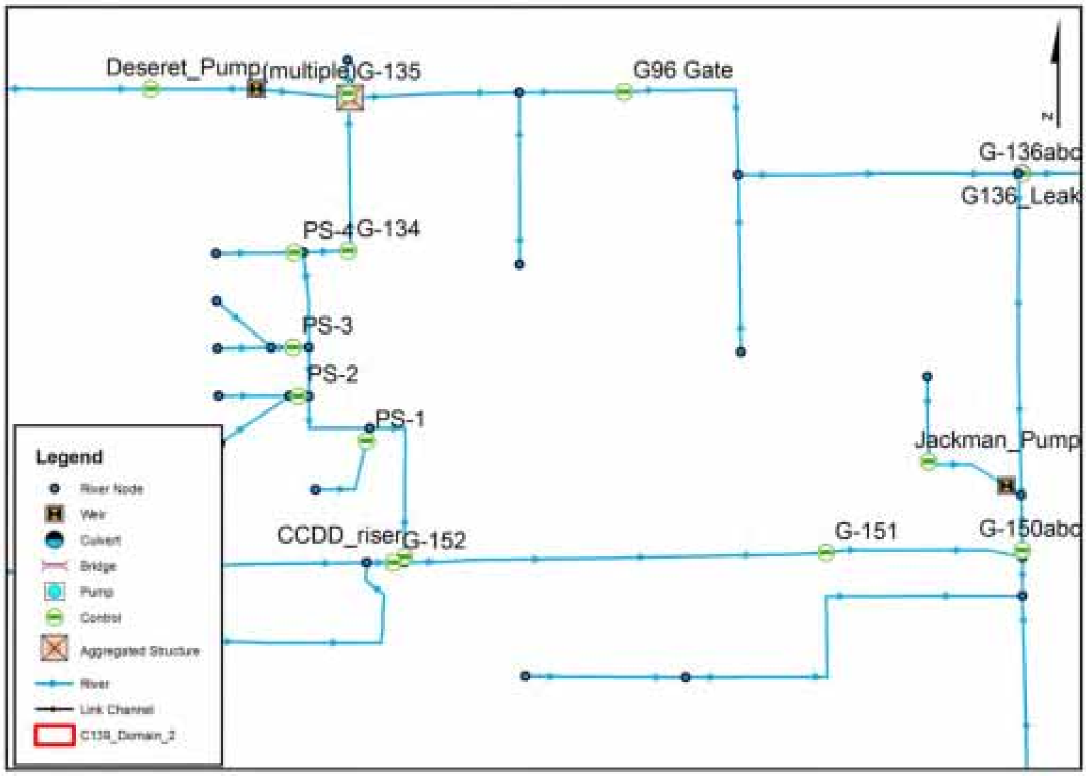


Figure 4.2.28 – Structures in the MIKE 11 Network – North Portion

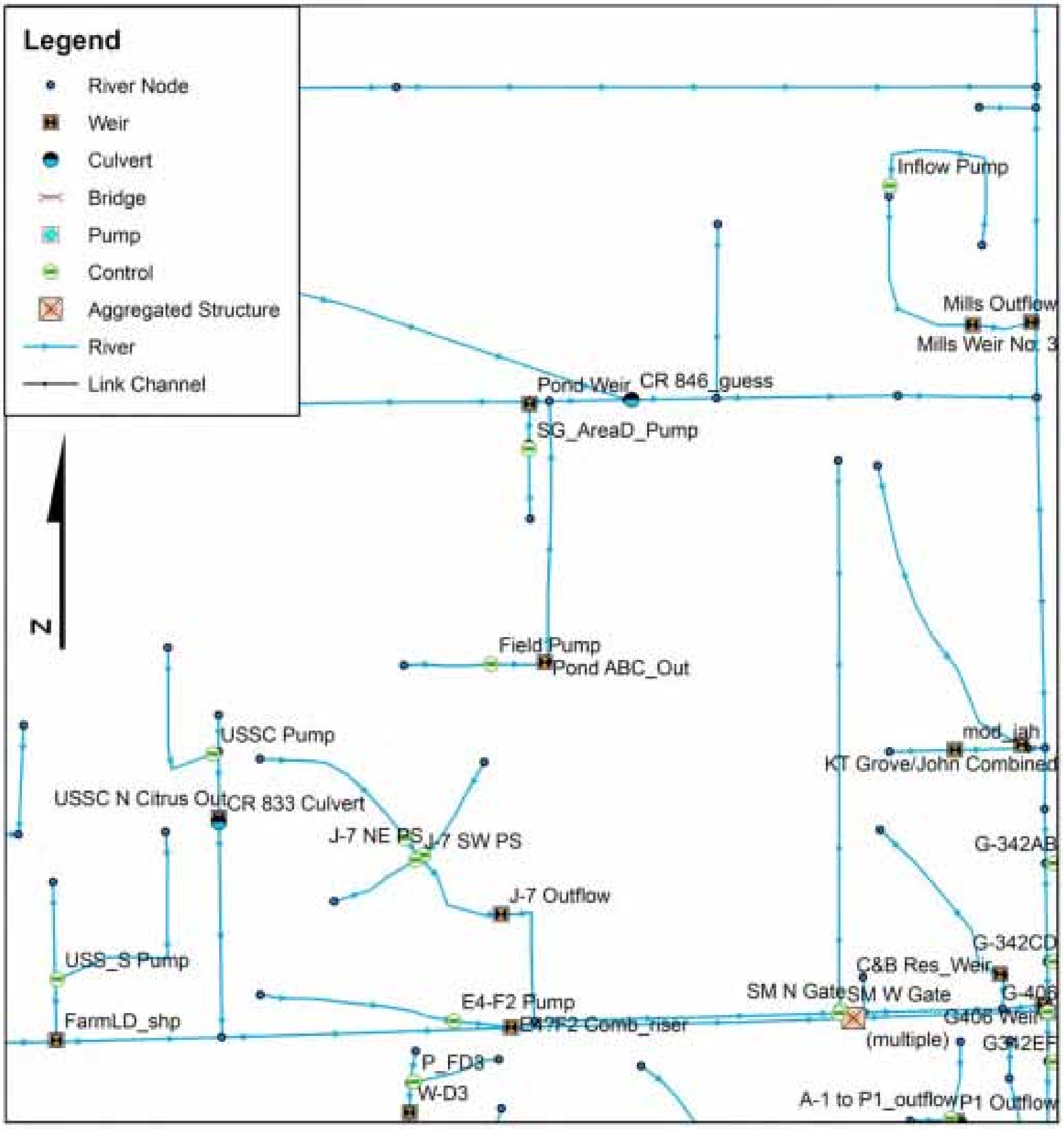


Figure 4.2.29 – Structures in the MIKE 11 Network – Middle Portion

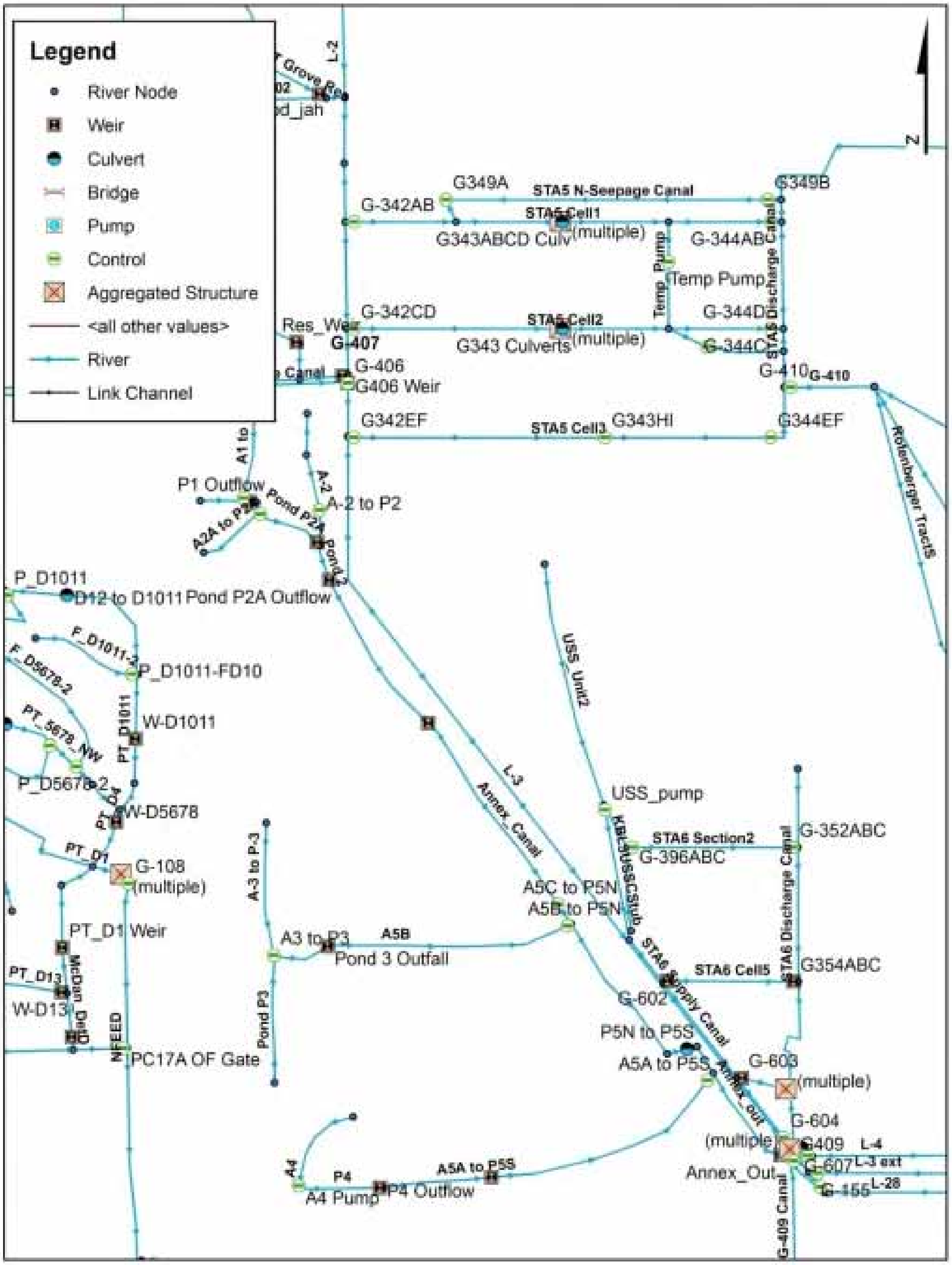


Figure 4.2.30 – Structures in the MIKE 11 Network – STA Region

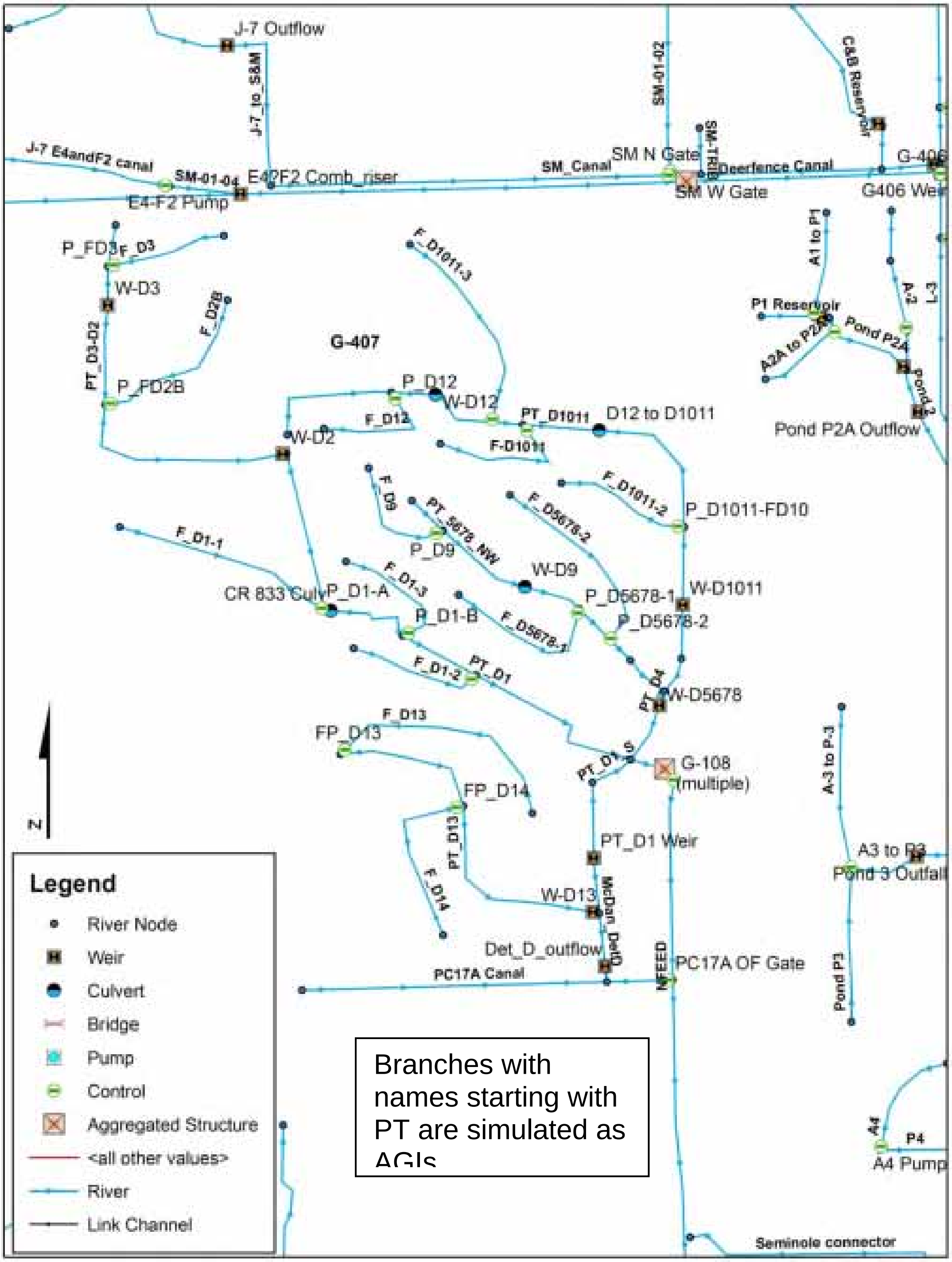


Figure 4.2.31 – Structures in the MIKE 11 Network – McDaniel Ranch

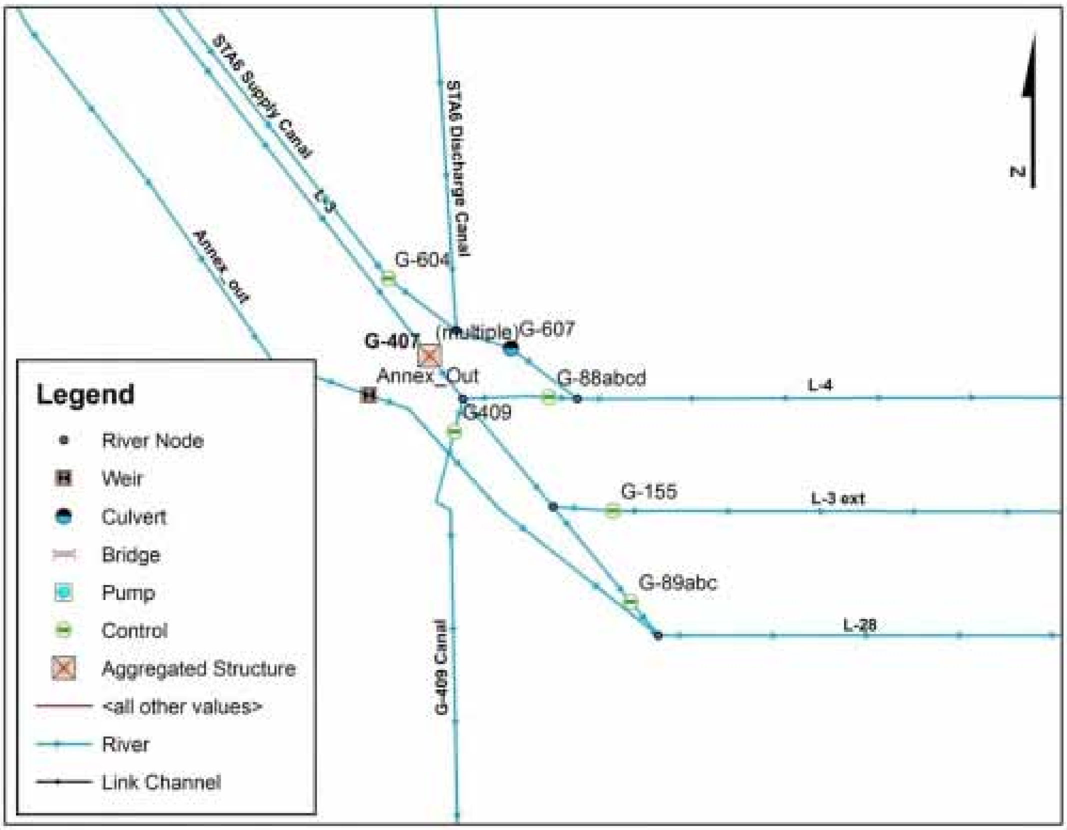


Figure 4.2.32 – Structures in the MIKE 11 Network – Confusion Corner

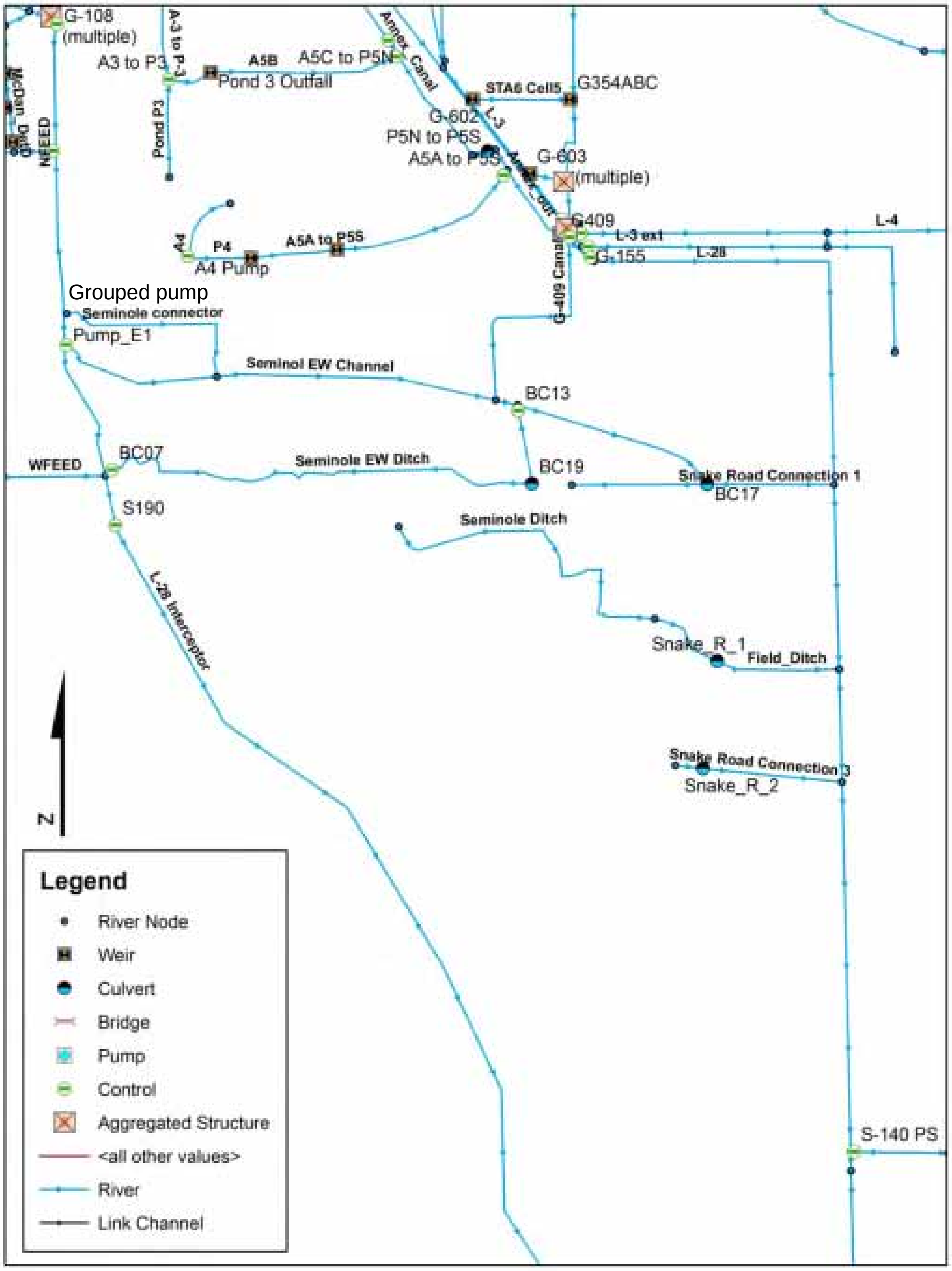
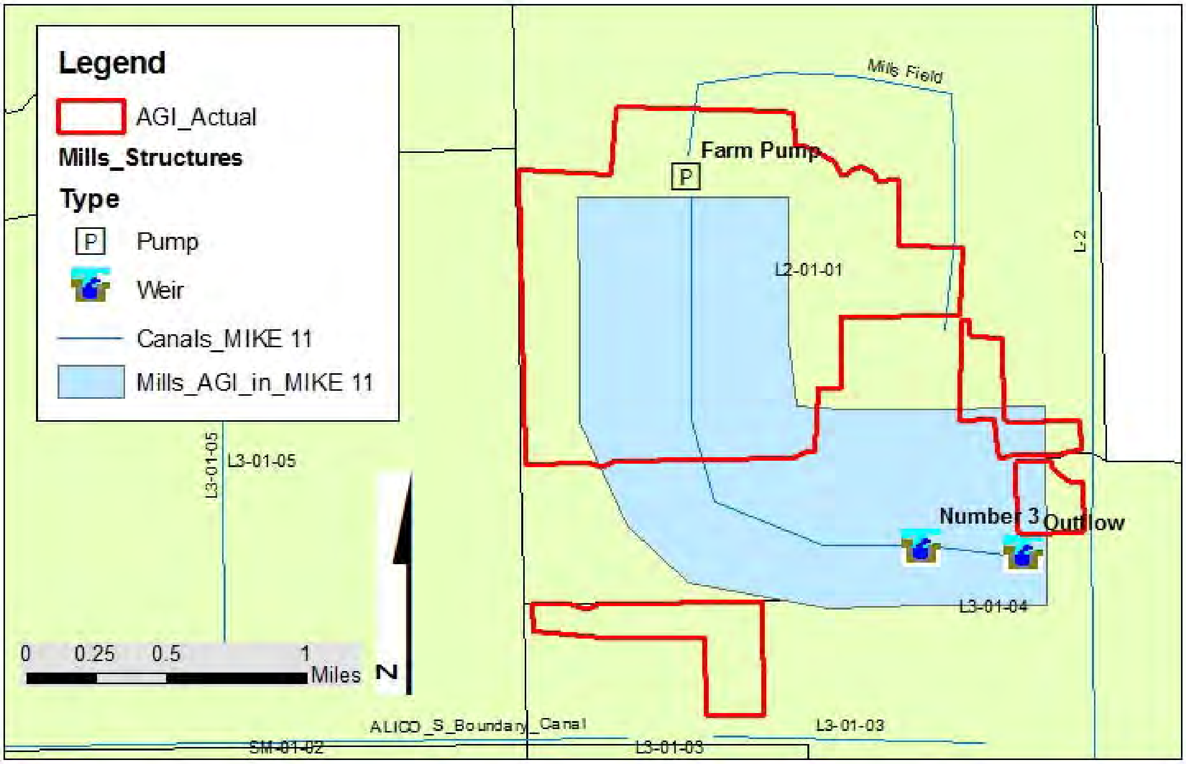


Figure 4.2.33 – MIKE 11 Network in the L-28 Basin



Notes:

1. The Mills Field branch is pumped into the AGI via the Farm Pump, and outflows are controlled by two weirs at the downstream end.
2. Farm Pump Operations:
   a. Off if the AGI is >20 or if the field ditch is < 17 ft-NGVD.
   b. Maximum pump flow is 40 cfs if Ditch water level is > 17.5 ft-NGVD.
3. No. 3 weir is: 3.5 ft wide at invert elevation 18 ft.
4. The outflow weir is:
   a. 1.8 ft wide at 17.75 ft,
   b. 3.5 ft wide at 19 ft, and
   c. 5.3 ft wide at 20 ft.

Figure 4.2.34 – Representation of an AGI on a Typical Farm

Table 4.2.2 – Gates and Pumps in the MIKE 11 Network

Station	Type	Width, ft	Invert, ft	Max Q, cfs	Ref.
BC07	Pump	0	0	165	Sem
BC13	Pump	0	0	188	Sem
CCDD_riser	Overflow	5.5	22		N/A
G-134	Overflow	6	12.24		SB
G-135	Overflow	9.3	13		SB
G-136abc	Overflow	7	8		SB
G-150abc	Underflow	7	8.5		SB
G-151	Overflow	6	9		SB
G-155	Overflow	80.2	9.92		SB
G-342AB	Underflow	10	7.25		OP
G-342CD	Underflow	10	7.25		OP
G-342EF	Underflow	10	6		OP
G-343ABC	Overflow	5	11		OP
G-343EFG	Overflow	5	11		OP
G-343IK	Underflow	10	4		OP
G-344A	Underflow	10	0		OP
G-344B	Underflow	10	0		OP
G-344C	Underflow	10	0		OP
G-344D	Underflow	10	0		OP
G-344EF	Underflow	10	4		OP
G349A	Pump	0	0	36-54	OP
G349B	Pump	0	0	39	OP
G-352ABC	Underflow	10	4		OP
G-393AC	Overflow	20	14		OP
G-396ABC	Underflow	8	4		OP
G-402A	Underflow	4.5	7.13		SB
G-402B	Underflow	4.5	7.23		SB
G-402C	Underflow	4.5	7.57		SB
G-406	Underflow	10	6		OP
G409	Pump	0	0	190	OP
G-410	Pump	0	0		N/A
G-604	Overflow	11	11		SB
G-88abcd	Overflow	6	5.5		SB
G-89abc	Overflow	6	7.85		SB
G96 Gate	Overflow	5.5	7.57		SB
Hilliard Gate	Underflow	5.5	14.7		N/A
PC17A Gate	Overflow	3.65x4	15.1-18.1		N/A
PS-1	Pump	0	0	167	Permit
PS-2	Pump	0	0	167	Permit

Station	Type	Width, ft	Invert, ft	Max Q, cfs	Ref.
PS-3	Pump	0	0	167	Permit
PS-4	Pump	0	0	167	Permit
Pump_E1 (grouped)	Pump	0	0	-190	Sem
S-140 PS	Pump	0	0	1300	SB
S190	Underflow	25	3.5		SB

SB	SFWMD Structure book	N/A	Could not locate info in SB or OP
OP	STA 5 6 August 2007 Operation Plan	Sem	From Seminole Tribe of Florida

Table 4.2.3 – Weirs in the MIKE 11 Network

Station	Height (ft)	Width (ft)	Height (ft)	Width (ft)	Height (ft)	Width (ft)	Height (ft)	Width (ft)
Flaghole Rd Weir	22	500	22.5	510				
G406 Weir	21.25	250	24	250				
	13	65	16	66				
G393B	14	9.6	19	9.6				
G-603	14.2	15	18	15	18.2	95		
G354ABC	14.1	60	19	60				
G-601	14	11	18	35				
Pond Weir	23	0	24	0.5	24.1	6.3		
Ag Pond Weir	25	3.5	27	3.5	27.1	12.8		
Ag Pond 2 Weir	16.5	6	18.7	6	18.8	24		
Annex_Out	11.5	12.8	17.9	12.8	18	69		
G-602	14	11	18	35				
Det_D_out W-D	19	47.1	25.9	47.1	26	200		
PT_D1 Weir	20.6	5.4	24.1	8	24.9	8	25	300
W-D1AB_1 val	24.16	0	24.45	4.45	27.15	4.45	27.16	6
W-D1AB-2 val	24.16	0	24.45	4.45	27.15	4.45	27.16	6
W-D5678	20.3	5.3	24.7	5.3	24.75	6	28	6
W-D1011	21	5	25.4	5	25.6	6	27	6
W-D3	23.46	0.5	27.42	0.5	27.45	2.5		
W-D2	23.3	1	27	1	27.1	2		
W-D13	20	1.5	23.9	1.5	24.1	3	27	3
Ag Pond 3 Weir	23	18.8	24.3	18.8	24.31	7.8	26	7.8
J-7 Outflow	23.4	3	26	3	26.1	36		
P1 Outflow	21	0	21.5	0.27	23.75	0.27	23.8	12

Station	Height (ft)	Width (ft)	Height (ft)	Width (ft)	Height (ft)	Width (ft)	Height (ft)	Width (ft)
Pond P2A Outflow	16	0	17.25	2.5	17.26	20.74		
Pond P2A Outflow	18	0	19	2	19.1	12		
Pond 3 Outfall	18	0	18.55	1.1	18.6	7	21.6	7
P4 Outflow	17	3.5	20.9	3.5	21	15		
Pond ABC_Out	23	0	24	0.75	24.1	3.14		
USSC N Citrus Out	26	2	29.5	2	29.6	12		
C&B Res_Weir	18	3.8	19.5	3.8	20	25		
KT Grove/John Combined	16.5	3	20.9	3	21	6	22	6
Mills Outflow	17	0	17.75	1.8	18.9	1.8	19	3.5
Mills Weir No. 3	18	3.5	20	3.5				
Deseret Outflow	21.8	0	22.3	1	22.35	2		
Jackman Outflow	16.5	1.5	21	1.5	21.2	12		
Annex_Canal_Hyp	15	40	16	100				
Annex_P5S	15	20	17	100				
W_weir_01_08_10	17	136	21	136	21.5	200		
G343abcdW_2_06	14	120	20	120				
G343efgh_W_2_06	14	120	20	120				

Note: A number of these weirs represent roads over culverts. The G-406 elevation was lowered in 2008 and a different elevation will be used for the validation model.

Table 4.2.4 – Culverts in the MIKE 11 Network

Station	# culverts	Type	Dia./Wx H, ft	Mann. N	Length, ft	Inv., ft
G-607	6	Circular	7	0.013	70	4
Snake Road Culvert 3	3	Circular	2	0.013	70	10.7
Snake Road Culvert 2	3	Circular	2	0.013	120	10.7
CR 833 Culvert 3	3	Circular	3	0.013	145	22.46
CR 833 Culvert 2	3	Circular	4	0.013	120	22.02
Flaghole Rd	2	Circular	5	0.026	50	16.51
CR 846_guess	5	Rectangular	6x6	0.013	50	12
CR 833 Culvert	1	Circular	4	0.012	100	10
Station	**# culverts**	**Type**	**Dia./Wx H, ft**	**Mann. N**	**Length, ft**	**Inv., ft**
BC17	1	Rectangular	7x3	0.026	70	7.6
BC19	1	Rectangular	3x7	0.026	90	7.6

D12 to D1011	3	Circular	4	0.026	35	20
W-D12	1	Rectangular	4x9.4	0.013	10	21.5
W-D9	1	Rectangular	2x3.8	0.013	10	21.3
W-D Culvert D/S of risers	1	Circular	4	0.026	60	8
CR 833 Culv	1	Rectangular	10x7.2	0.013	60	14.5
P5N to P5S	1	Circular	4	0.013	66	12
G343 Culverts	4	Rectangular	10x8	0.013	60	5
G343ABCD Culv	4	Rectangular	10x8	0.013	60	5
Corrosion_on_G136	1	Circular	1.43	0.013	70	9

Table 4.2.5 - Timeline of Surface Water Modifications in the C-139 RFS Area

Structure	Date	Modification
G-343A-H	12/2006	Overflow weirs converted to underflow gates
G-406	12/2006	Operation Modified, Weir lowered to 17.5 ft-NGVD
G-342E-F, Cell 3A	12/2006	Construction Complete
G-343IJ, Cell 3A-B	12/2006	Construction Complete
G-344EF, Cell 3B	12/2006	Construction Complete
G-600	12/2006	Flow substantially reduced
G-396A-C, STA-6-2	12/2006	Construction Complete
G-352A-C	12/2006	Construction Complete
G-352A-C	12/2006	Construction Complete, L-3 to STA-6 inflow canal
G-407	12/2006	Construction Complete
STA-6 Outfall	12/2006	Discharge changed from G-607 to L-3 south of G-407
G-155	3/2007	Structure Removed
McDaniel W-D1AB	12/2006	Structure installed, reduces flows to G-108
PC-17A	12/2006	Gate operation of lower plates modified for wet season 07-08

Minor and interior farm canal dimensions were estimated using permit file information, high-resolution aerial photographs, and best engineering estimates. Cross sections for minor canals in the Compartment C model included wide approximate cross sections that accounted for on-farm storage of water in either un-modified wetlands or man-made reservoirs. As mentioned above, this assessment eliminated those wide cross sections.

There is no intention of adding all of the interior farm canals to the model as the model execution time would be too long. MIKE SHE has a "drainage" feature that approximates the effect of small canals on surficial aquifer water levels, and this feature was used to represent most of the interior farm canals. A drainage depth (below ground) and a drainage time constant were included in the model (which represents the time it takes for water to reach a depression or MIKE 11 branch from interior farm canals not in the model). Drainage depths were in the range of 1-2 feet for cultivated agricultural lands, and 0.45 feet for pasture and range lands. Wetlands had a drainage depth of 0 feet. The drainage time constant was set at 4 days for truck crops, row crops, pasture, and citrus. The drainage time constant was set at 7 days for sugar cane. Drainage time constants were set at 0 days for all natural lands, which means that drainage is turned off for those land use types.

Cross sections are not available for all of the canals to be added in the model. Most of the main canals already have surveyed cross sections, A variety of sources were used for the cross sections used in the model, plus surveyed cross sections from earlier modeling studies of the C-139 Basin (ADA 2007, URS/ADA 2008). Additional cross sections were surveyed as part of this effort. The locations of the cross sections surveyed as part of this project as well as surveyed cross sections from other studies are presented in ***Figures 4.2.35 and 4.2.36***. The cross section shown are the following:

- ***XY_SC_XS:*** The C-139 Basin Phosphorus Water Quality and Hydrology Analysis (ADA 2006), included bathymetric 24 canal cross-sections for major and minor canals collected within the C-139 Basin,

- ***G&O_XS:*** As part of the Everglades Agricultural Area Stormwater Treatment Compartment C Watershed Hydraulic Study (ADA Engineering, 2006) data collection effort, 20 additional cross-sections along primary drainage canals were collected***.*** In addition field surveys of the south and west banks of the L-1, L-2 and L-3 Canals, and both the north and south banks of the L-2W Canal were also performed.

- ***URS_XS:*** Cross sections collected as part of the C-139 regional Feasibility Study, Task 3 in October, 2009.

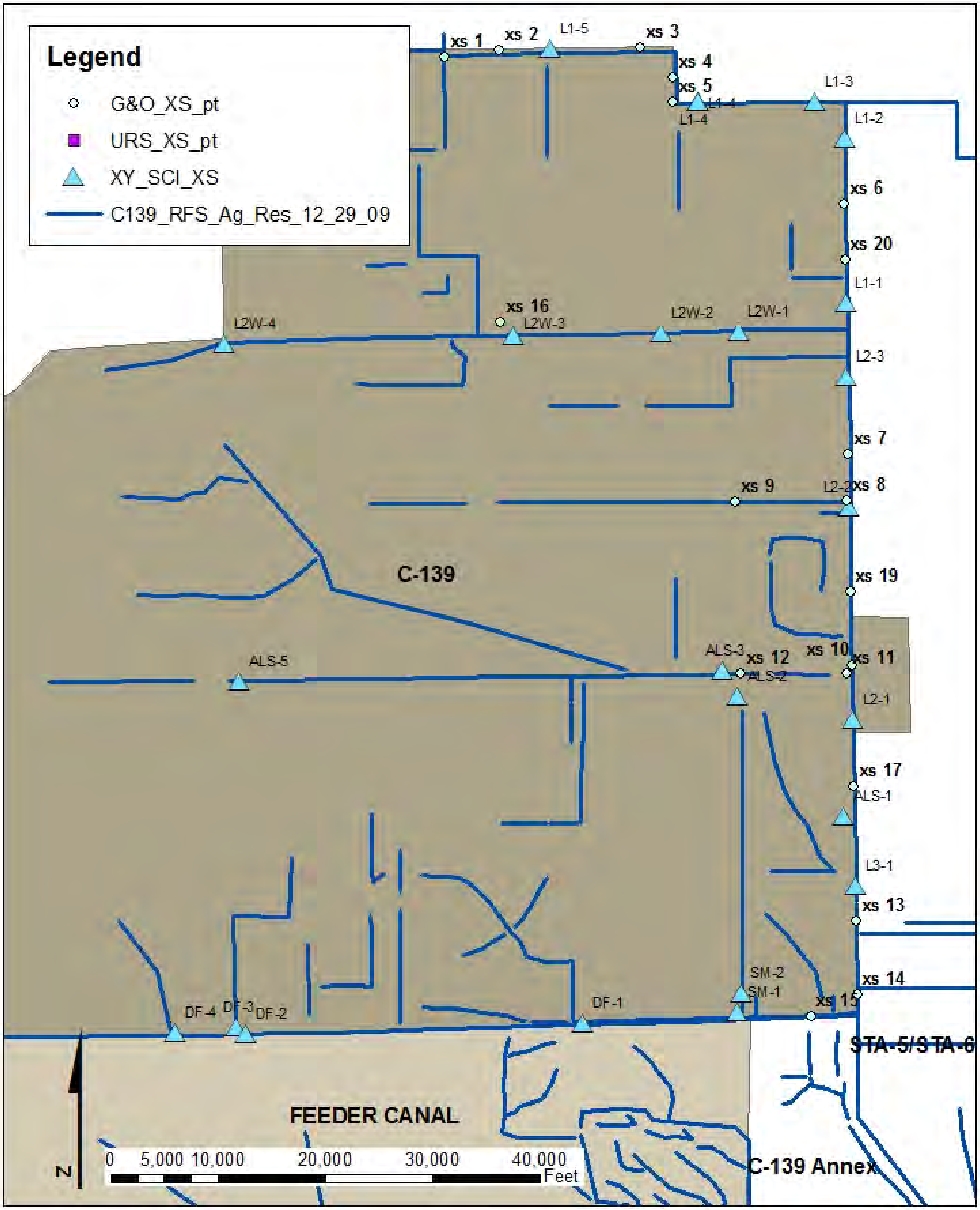


Figure 4.2.35 - Surveyed Cross Sections in the C-139 Basin

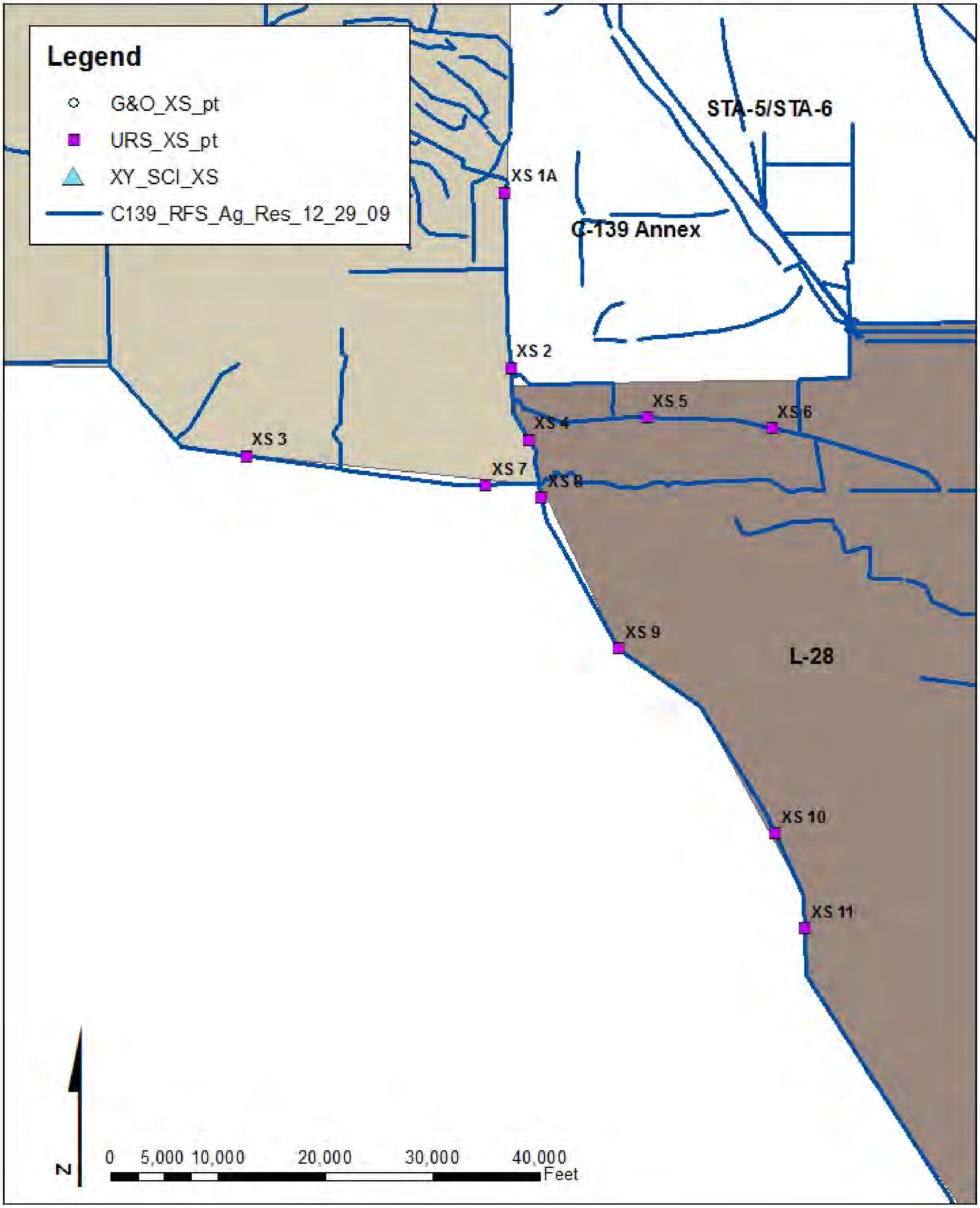


Figure 4.2.36 - Surveyed Cross Sections in the L-28 and Feeder Canal Basins

4.2.2.6.2 Surface Water Calibration Stations

There are measured headwater stage, tailwater stage, and flow data available from the SFWMD DBHYDRO database for many of the hydraulic control structures (SFWMD, 2010). Stations with measured data include G-134, G-135, G-136, G-96, G-150, G-151, G-152, G-342A-G, G343A-J (partial records), G-344A-F, G-349A-C, G-350B, G-406, STA-6 inflow and outflow structures G-353A-C, G354A-C, G-393A-C, G-396A-C, G-352A-C, G-407, L3BRN, L3BRS, USSO, G-88, G-89, G-155, G-108, PC17A, NFEED, WFEED, S-190, and S-140 shown in ***Table 4.2.6*** and ***Figure 4.2.37***. Certain structures with measured data were not used for calibration because these structures were operated with measured data since no operational protocols were available. Some of these stations have measured headwater elevation, tailwater elevation, and flow data, and some of the stations only have stage data. The quality of the data varies depending on the frequency of collection and the entities responsible for measuring the information.

Table 4.2.6 – Structures in the Model with Flow and Stage Monitoring

Structure	Structure	Structure
G-134	G-600	S-140 PS
G-135	G-396ABC	PC-17A
G-96	G-353ABC	NFEED
G-136	G-352ABC	WWEIR
G-150	G-354AB	S-190
G-151	G-393ABC	C139 S1
G-152	G-601	C139 S2
G-342AB	G-602	C139 S3
G-342CD	G-603	C139 S4
G-342EF	G-407	C139 S5
G-344AB	G-155	C139 S6
G-344CD	USSO	DFNBV
G-344EF	G-88	SMSBV
G-406	G-89	

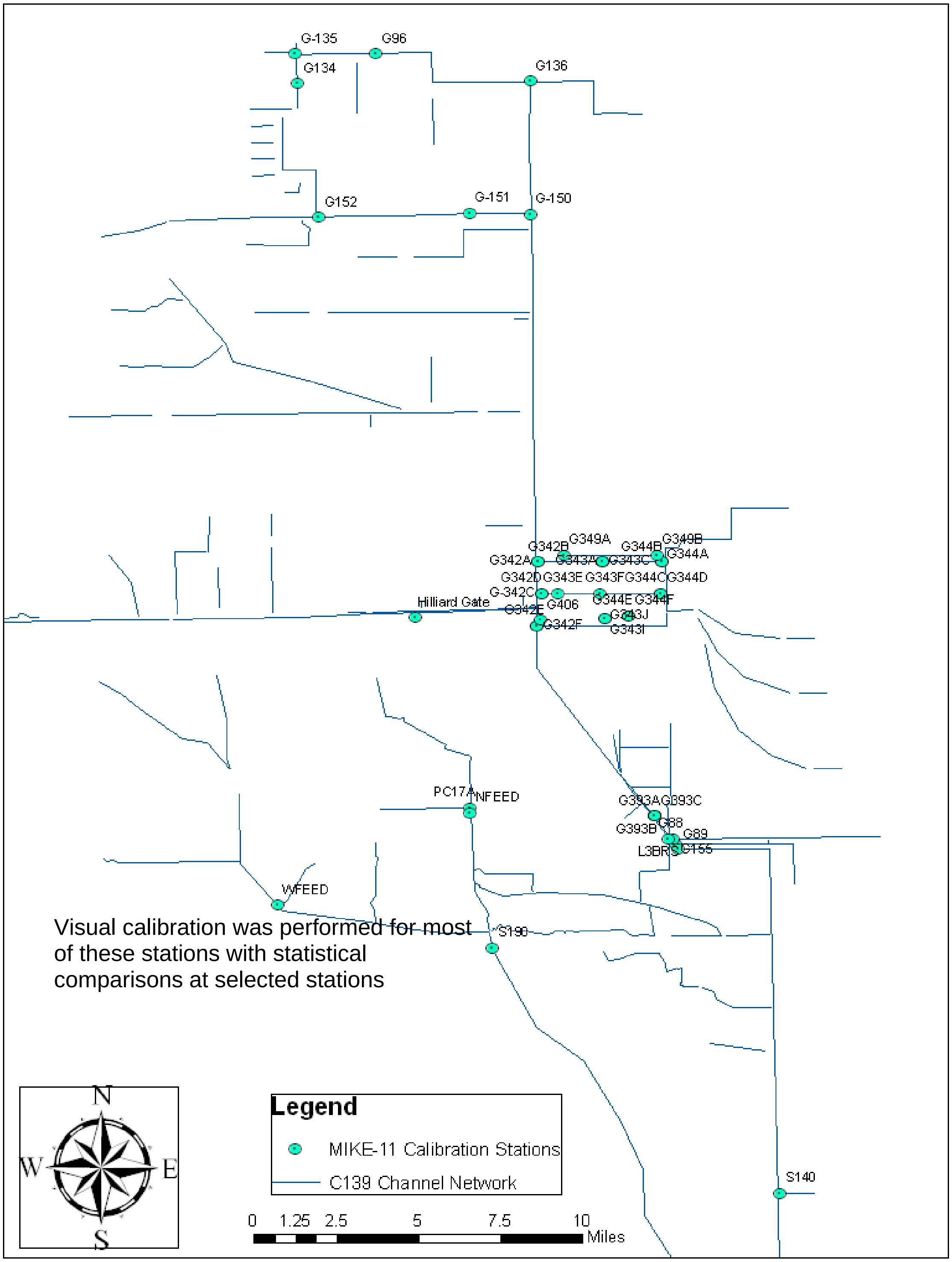


Figure 4.2.37 – SFWMD Flow and Stage Monitoring Locations

There are operation protocols for a number of structures that are documented in either the SFWMD Structure Book or the STAs 5 and 6 Operation Plan (SFWMD, undated; and

Goforth, 2008). However, there are periods where gate operations may deviate from Normal operations described in the operation plans. For instance, in order to implement major enhancements in STA-5 pursuant to the Long-Term Plan for Achieving Water Quality Goals (Long-Term Plan), in 2005 and 2006 structures were operated to dry out portions of the treatment cells. In the case of gates that are not operated by SFWMD staff or flashboards are manually removed and replaced (G-135, G-96, G-136, G-151, G-152), the records of those operations may be incomplete or inaccurate. The modeling team was able to obtain measured gate levels for a number of structures, and those structures are listed in ***Table 4.2.7***. During the initial calibration, gate operations were based on operational logic (e.g. open gate if the headwater elevation exceeds 16 feet, close the gate when the headwater elevation drops to 15 feet). DBHYDRO now has actual recorded gate operations for many structures in the C-139, Feeder Canal, and L-28 Basins. At approximately 35% through the calibration process, gate operations were modified to open the gates according to the reported gate levels. Operational protocols will be used for the baseline model (Task 4.2.2 of this Task Order). The baseline model will use the existing network (circa 2008) and rainfall values from 1965-2000. The operational protocols **that will be used in the baseline model** are presented in ***Appendix C2 – Structure Operation Protocols for C-139 Region Structures***. Calibration challenges for G-136 (which conveys L-1 Canal runoff to the EAA via L-1-E) prompted a detailed investigation of that structure. SFWMD reported that this corrugated metal riser structure had visible corrosion with leakage through corroded holes below the normal control elevations of 14 or 15 feet-NGVD. ***Figure 4.2.38*** presents a photograph of these corrosion holes. An orifice was added to the network to represent the drainage effect of these corrosion holes.

Table 4.2.7 – Structures with Available Measured Gate Operation Data

Structure	Data Gaps	Challenges
G-135		Values reported once/2 weeks
G-96		Values reported once/2 weeks
G-136		Significant un-measured flow
G-150		
G-151		Values reported once/2 weeks
G-342A-F, G-342I		
G-343A-C, E-G, H-J	No data 3/15/05 – 3/18/08	
G-344A-F		
G352A, B, C		
G-396-A and B		
G-402A-C		
G-600		
PC17A	2007-2008	HW stage <15 ft not recorded
S-190		

Figure 4.2.38 – Photograph of Corrosion at G-136

Additionally, a number of water quality stations were established in 2006-2007, and spot measurements of flow and stage area are available at a number of these sites (***Figure 4.2.39)***. Station C139S1 has flow and stage data for March, 2007 through 2008, C139S2 and C139S3 flow and stage data began in September, 2006, C139S4 flow and stage data started in October, 2007, C139S5 and C139S6 have only stage data which starts in January and March, 2008, respectively. Additional data are available for stations DFNBV and SMSBV (labeled as DFNB and SMSB on Figure 41). DFNBV is located on Deerfence Canal and have flow and stage data available from December, 2005. SMSBV is on the S&M Canal, and flow and stage data began in January, 2006. ***Figure 4.2.40*** presents stage and flow data for station C139S2 (on L-2 just north of STA-5). The April 2007 average flow is -4 cfs, which may be due to irrigation demands for a number of farms that have permits to withdraw irrigation flows from the L-2 Canal. This information was helpful during the calibration process when negative flows were observed in the surface water simulation result file.

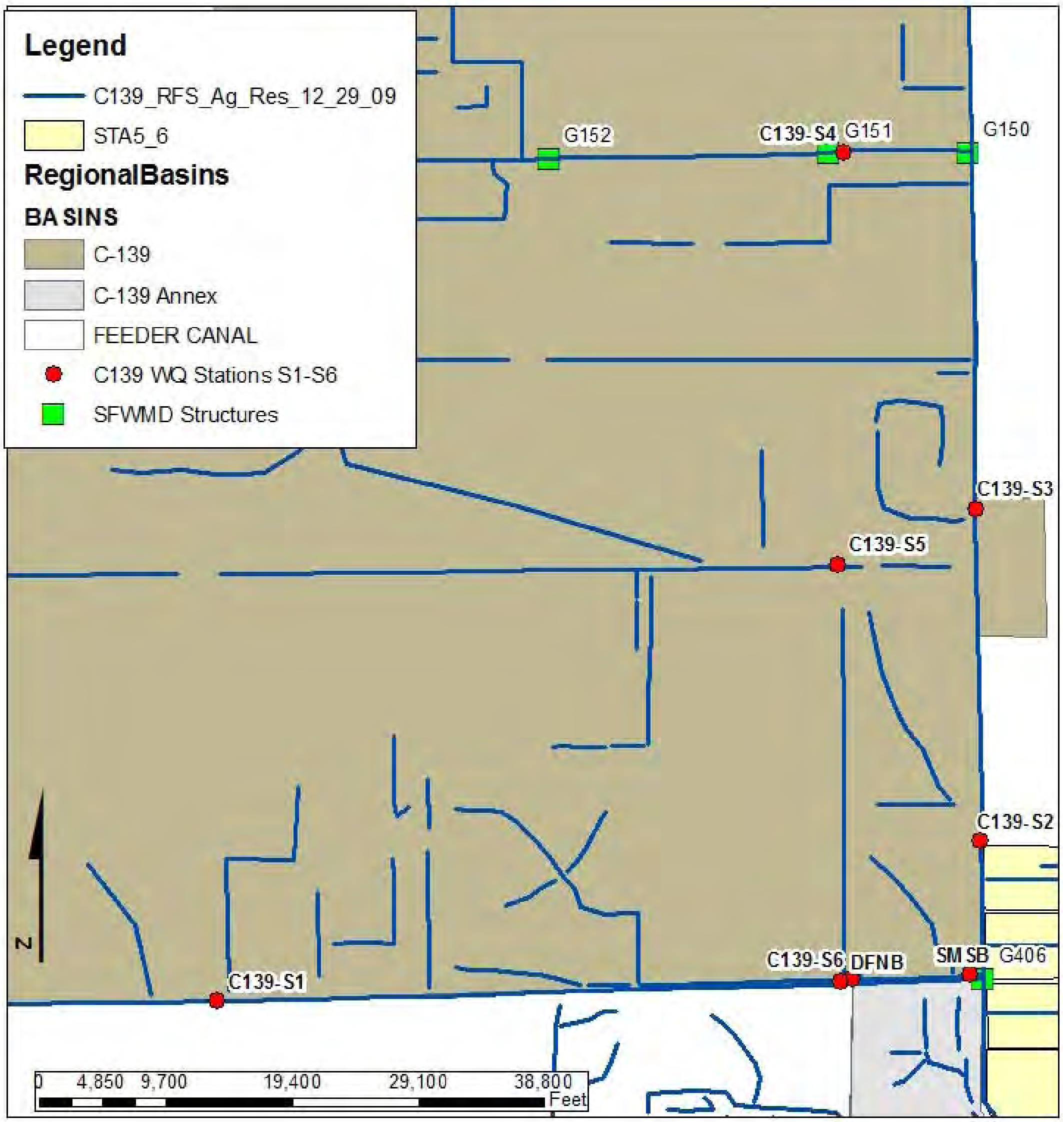


Figure 4.2.39 – SFWMD Water Quality Monitoring Locations

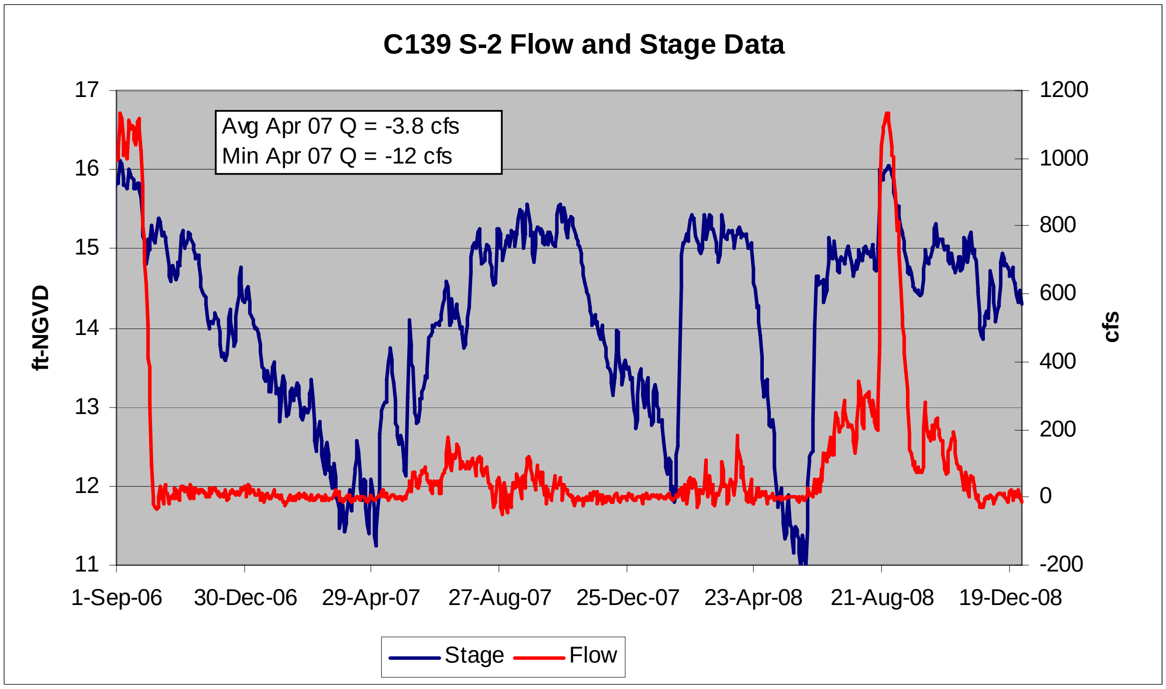


Figure 4.2.40 – C-139 S-2 Measured Flow and Stage Data

4.2.2.7 Water Level Boundaries

Water level boundaries are needed for all surface water features that are at the upstream and downstream boundaries of the model domain. As shown in ***Table 4.2.8***, SFWMD measured water levels are used for most of the boundaries, except for the east end of the L-4 Canal. Because there are significant inflows to the L-4 Canal from the Miami Canal, a flow boundary is used for this branch.

Table 4.2.8 – MIKE 11 Boundary Type

Branch	Boundary Type	Boundary Station	DBKey
L-4	Inflow	G-357 & G-404 Combined Flows	G357 LX263 G404 M9916
G-402A	Water Level	S8_H	6697
G-402B	Water Level	S8_H	6697
G-402C	Water Level	S8_H	6697
L-1 East	Water Level	S8_H	6697
L-28 Interceptor	Water Level	L28-1_H	JA338
L1-02-01	Water Level	G135_TW	6931
S140 Discharge Canal	Water Level	S140_TW	OU383
STA5 Discharge Canal	Water Level	S8_H	6697
L-3 Ext	Water Level	3A-NW & 3A-10B	3A-NW LA369 3A-10B KS831

Note: L-3 Ext Boundary used Surficial groundwater stage at 3A-NW and a gap from March 8-19, 2007 was filled in with Station 3A-10B

4.2.2.8 Irrigation Command Areas

The starting point for representing irrigation is to create an ET Vegetation Properties file. This file defines the monthly changes in leaf area index, root depth, crop coefficients, moisture deficit start, moisture deficit stop, for each vegetation type. The method for calculating the reference moisture content is also specified (either field capacity or saturation) at this time.

Irrigation command areas were developed based on District permit files and withdrawal allocations. The procedure that was followed is described below:

1. Subtract the wetlands and agricultural reservoir shape files from the farm permit polygons. The net polygons will be only farmed lands grouped by farm permit.
2. Subdivide the permitted farm areas by crop.
3. Merge the farm permit polygon with the maximum permitted irrigation pumpage files created by Hope Radin of SFWMD (see ***Appendix C3***) to obtain farm-specific maximum irrigation pumpage rates and depth interval of groundwater pumpage.
4. Confirm irrigation sources through a review of permit files
5. The irrigation type was specified, the turn-on, turn-off elevations were established, and the type of soil moisture accounting was specified.

The irrigation command area menu allows the user the start with river irrigation until the river level or flow drops below the user-specified minimum level, then switch to groundwater irrigation until the groundwater level drops below the user-specified minimum groundwater elevation. ***Figure 4.2.41*** presents the irrigation command areas. The irrigation command area calibration compared permitted maximum flows to simulated irrigation amounts. Irrigation command area definitions were adjusted during the calibration process to improve calibration. Irrigation pump records for a number of farms within the study area have been obtained (***Table 4.2.9***) and these data were also used in the calibration (see ***Section 4.2.3 – Calibration*** for further information). Numerous permits report pasture irrigation, however no pasture lands were irrigated as part of this modeling effort. The procedure described above in Items 1 and 2 defined pasture lands as part of the irrigation command areas. As a result, the first versions of the model included irrigation of pasture lands. During calibration, irrigation command areas for pasture were set to have no irrigation.

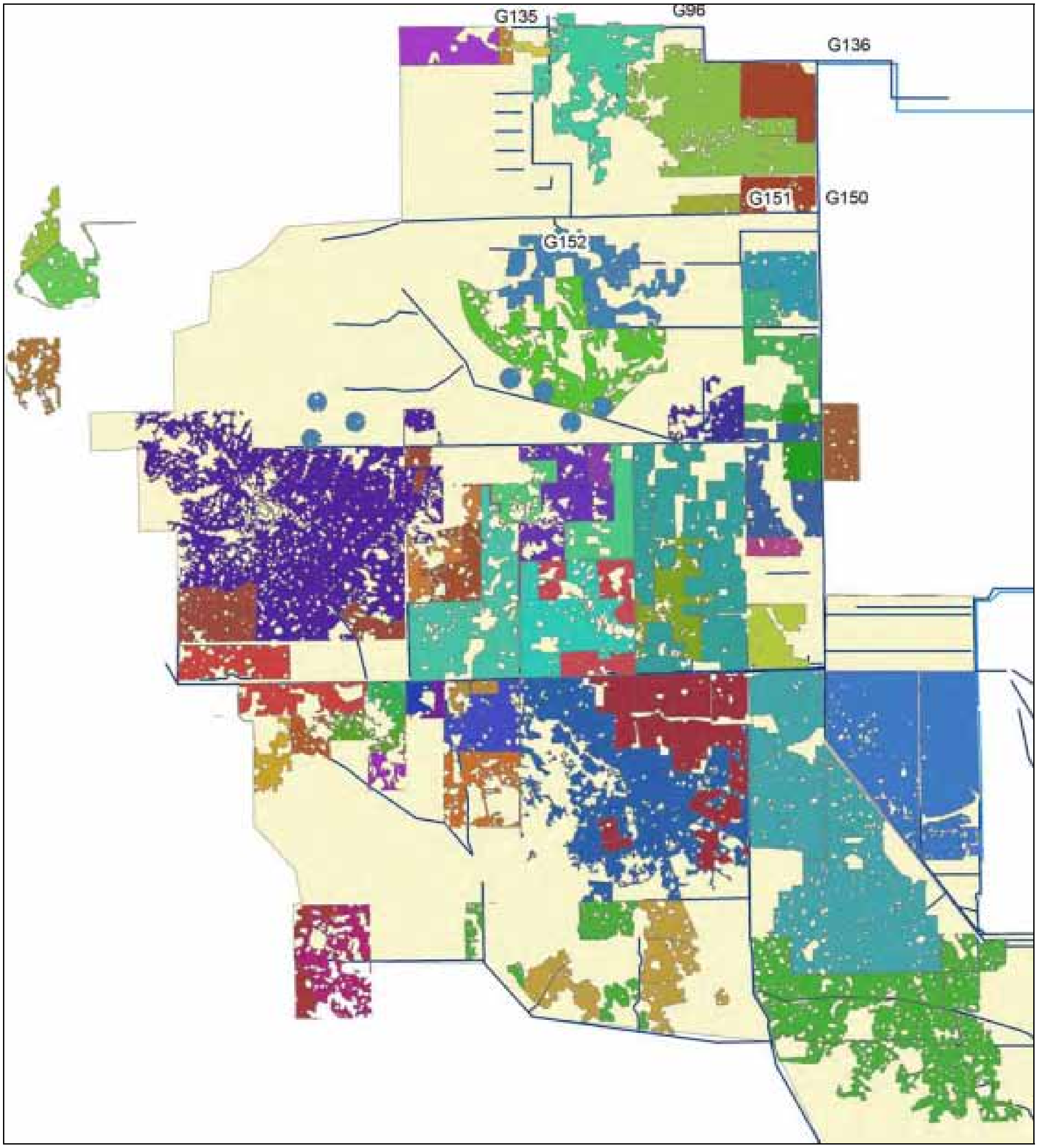


Figure 4.2.41 – Irrigation Command Areas

Table 4.2.9 – Reported Irrigation Rates for Selected Farms (Inches/Year)

Farm	Reported	
	2004-2005	2006-2008
Alico West Ranch	0.6	3
Collins Slough E	29.2	14.9
Crows Nest Grove	6.3	17.2
Zipperer	ND	8.7
Devil's Garden S	6.3	12.8
Dinner Island 0030	6.7	21.3
Half Circle L	5	5.8
Jackman B	0.9	4.3
McDaniel	26.6	28.2
Mills ABC	10	28.4
Oak Hammock	ND	5.9
So Div Unit 1	14.2	15.8
Crooks	33.6	47.6 for 2006

4.2.3 CALIBRATION

4.2.3.1 Introduction

The model was calibrated for calendar years 2004-2006 and was validated for calendar years 2007-2008. The calibration period was generally wet and the validation period included a major drought followed by significant rainfall at the end of 2008 (Tropical Storm Fay occurred in September, 2008, and the rainfall total for this event was approximately 6 inches).

This section provides the calibration plots, calibration statistics, irrigation amounts for the irrigated portions of the model, and a water balance for the model domain. To assist the reader in interpretation of the calibration plots, the reader should refer to the maps of surface and groundwater calibration stations presented above in ***Section 4.2.2.6.2 – Surface Water Calibration Stations***.

Section 4.2.3.2 – Summary of Calibration Metrics of this document provides a summary of calibration statistics that are being used in evaluating model performance, ***Section 4.2.3.3 – Calibration Plots and Statistics*** provides the calibration plots, ***Section 4.2.3.4 – Water Balance Information*** summarizes water balance information for the C-139 region and for irrigated areas, and ***Section 4.2.3.5 – Summary of Calibration Activities*** summarizes calibration activities (what parameters were modified during initial calibration). Calibration model run results are included in ***Appendix C10***.

4.2.3.2 Summary of Calibration Metrics

MIKE SHE/MIKE 11 generates calibration statistics for stations where measured data is available. The statistical metrics being used are: Mean error, mean absolute error, root mean square error, correlation coefficient, and the Nash-Sutcliffe coefficient. Mean error (ME) is the average of differences between measured and predicted values. Mean absolute error (MAE) is the average of the absolute differences between measured and simulated values. MAE is always greater than ME, and ME tends to under-report calibration accuracy as ME = 0 could mean half of the differences are -5 with the remainder of the differences equal to +5. Root Mean Square Error (RMSE) is similar to MAE, however it corrects for non-standard distributions. Stream flow has a non-standard distribution because flow is mostly low with infrequent periods of high flow. Accordingly, RMSE is a useful metric for river calibration. The correlation coefficient measures the closeness of fit between the simulated and measured values, and 1.0 indicates perfect correlation. The Nash-Sutcliffe coefficient in general terms is the error divided by the variability. Stations with higher variability generally have higher error, and this statistic corrects for high variability. The Nash-Sutcliffe coefficient is not used for groundwater because it was originally intended for use in highly variable river systems (Krause et al, 2005, Jan & Sudheer, 2008, McCuen et al, 2006, and Schaefli & Gupta, 2007). ***Table 4.2.10*** presents the model calibration targets and ***Table 4.2.11*** presents the equations used for each performance metric (DHI, 2009). The performance targets were taken from a number of prior integrated surface/ground water modeling studies including the South Lee

County Watershed Plan Update (AECOM/ADA, 2009), and the Southwest Florida Feasibility Study MIKE SHE modeling study (SDI et. al., 2008). Depending on challenges encountered in understanding gate and pump operations (which are very poorly understood for some structures in the C-139 Region), these performance metrics may be modified.

Table 4.2.10 – Model Performance Metrics

Statistical parameter	Level of Model Performance		
	High	Medium	Low
Surface Water Flow Targets			
R	0.75 <= R < 1.0	0.6 <= R < 0.75	R < 0.6
Nash Sutcliffe, R2	0.7 <=R2<=1.0	-1.0<=R2<=0.7	NS<= -1.0
Surface Water Stage Targets			
ME (ft)	|ME| <= 0.75	0.75 < |ME| <= 1.25	|ME| > 1.25
MAE (ft)	MAE <= 0.75	0.75 < MAE <= 1.25	MAE > 1.25
RMSE (ft)	RMSE <= 1.0	1.0< RMSE<= 2.0	RMSE > 2.0
R	0.75 <= R < 1.0	0.6 <= R < 0.75	R < 0.6
Nash Sutcliffe, R2	0.7 <=R2<=1.0	-1.0<=R2<=0.7	NS<= -1.0
Groundwater Level Targets			
ME (ft)	|ME| <= 0.5	0.5 < |ME| <= 1.0	|ME| > 1.0
MAE (ft)	MAE <= 0.5	0.5< MAE <= 1.0	MAE > 1.0
RMSE (ft)	RMSE <= 1.25	1.25 < RMSE<= 2.5	RMSE > 2.5
R	0.75 <= R < 1.0	0.6 <= R < 0.75	R < 0.6

Table 4.2.11 – Equations Used to Define Performance Metrics

Symbol	Name	Formula
ME	Mean error	$\langle Obs_i - Calc_i \rangle = \frac{1}{n}\sum_{i=1}^{n}(Obs_i - Calc_i)$
MAE	Mean Absolute Error	$\frac{1}{n}\sum_{i=1}^{n}\lvert Obs_i - Calc_i \rvert$
RMSE	Root Mean Square Error	$\sqrt{\frac{1}{n}\sum_{i=1}^{n}(Obs_i - Calc_i)^2}$
R	Correlation Coefficient	$r_i = \frac{\sum_t (Calc_{i,t} - \overline{Calc_{i,t}}) \cdot (Obs_{i,t} - \overline{Obs_{i,t}})}{\sqrt{\sum_t (Calc_{i,t} - \overline{Calc_{i,t}})^2 \cdot \sum_t (Obs_{i,t} - \overline{Obs_{i,t}})^2}}$
R2	Nash Sutcliffe	$R2 = 1 - \frac{\sum_t (Obs_{i,t} - Calc_{i,t})^2}{\sum_t (Obs_{i,t} - \overline{Obs_i})^2}$

4.2.3.3 Calibration Plots and Statistics

The calibration model was run for 2004 through 2006, and the run time is over 5 hours/year. This section summarizes the calibration of the model as of June, 2010.

4.2.3.3.1 Surface Water

Table 4.2.11 provides a summary table of surface water flow calibration statistics. ***Table 4.2.12*** provides a summary table of surface water stage calibration statistics. This section also provides plots of surface water and water flow calibration. There were numerous challenges that were overcome during the calibration, however a number of challenges remain. Successes and challenges are discussed below:

- Gate operations for G-135 and G-136 were a particular challenge. The gate operations for both structures that are described in the SFWMD Structure Book appear to differ from measured values. For example, the SFWMD Structure Book states that G-135 remains closed if the downstream elevation is greater than 16 ft-NGVD, yet there are numerous instances where there are discharges through G-135 when the tailwater elevation exceeds 16 ft. ***Figure 4.2.42*** shows that G-135 flow was frequent during periods when tailwater stages exceeded 16 ft.

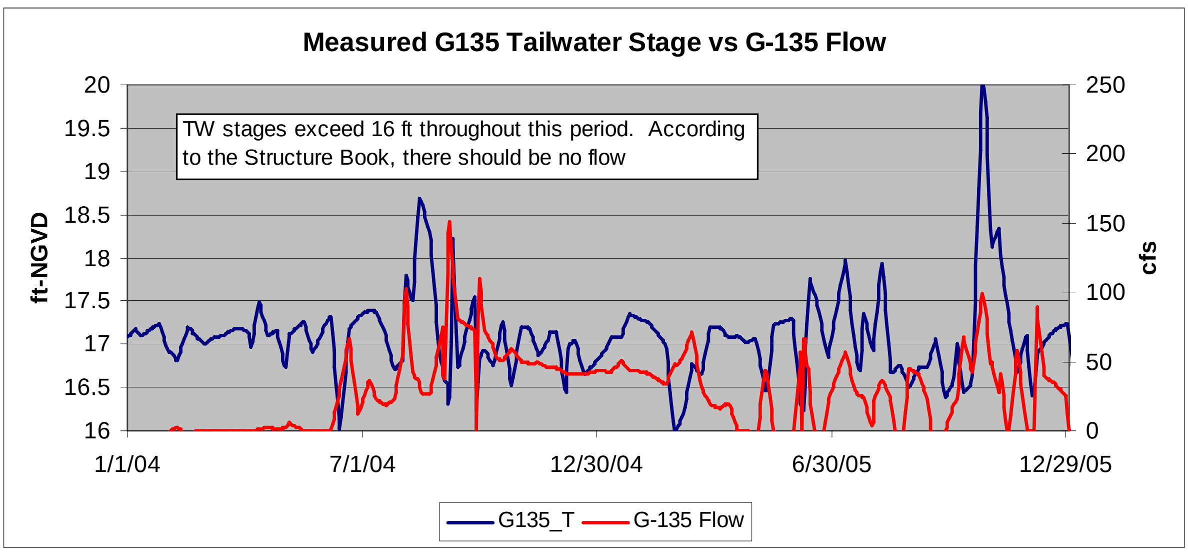


Figure 4.2.42 – Illustration of G-135 Flow When Tailwater Stages Exceed 16 ft-NGVD

The SFWMD Structure Book states that the G-136 overflow log crest is set at 13 ft-NGVD and will be raised to 14 when the tailwater stage exceed 15.5 ft. ***Figure 4.2.43*** clearly illustrates that the gate level was 14 ft from January through May of 2005 when tailwater stages were less than 11.5 ft.

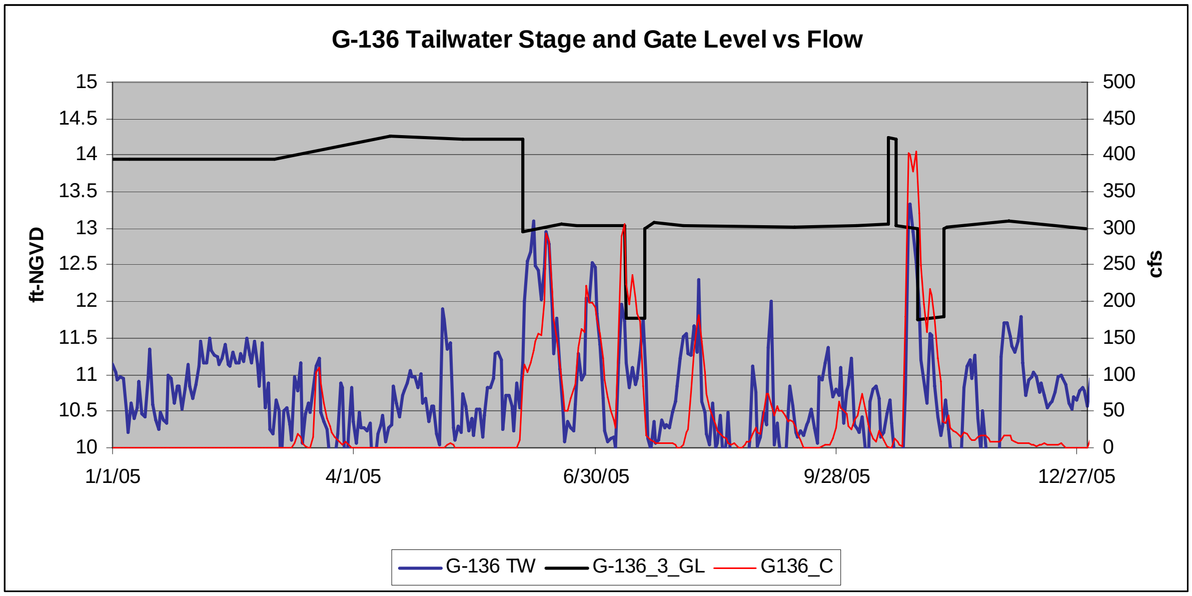


Figure 4.2.43 – Measured G-136 Gate Levels, Tailwater Stages, and Flows for 2005

More information will be required to improve calibration in the L-1 Basin, such as a better definition of the decision-making process for opening and closing gates, the degree of leakage at the gates, and more accurate records of gate levels.

- In spite of these challenges, the predicted flow for G-136 is reasonably similar to measured flows.
- The model was able to represent both peak wet season stages and dry season low stages for 2004 and 2006 in the L-1 Canal at G-136 HW, L-2 Canal at G-150 HW, G155, and PC-17A HW. The simulated stages at the headwater side of STA-5 (G342AB HW) were generally good, however simulated stages were less than measured stages during the early part of 2005.
- Flow calibration was very good (>0.8) for G-136, G-150, G342ABCD, G-406, S-190, and S-140.
- Simulated flows in the Feeder Canal upstream of S-190 were less than measured flows for the 2004 and 2005 wet seasons. Simulated flows for the L-28 Basin at S-140 were also less than measured for the 2004, 2005, and 2006 wet seasons. There were a number of significant unknowns for these two basins that limited the calibration.
- Measured gate levels were used for G-135, G-96 G-136, G-151, the STAs, G-406, confusion corner structures, and S-140.

4.2.3.3.2 Surface Water Calibration Statistics

Table 4.2.12 presents the Surface Water Flow Calibration Statistics. As shown six out of seven of the flow stations have a high level of calibration performance for correlation coefficient. Nash-Sutcliff performance is either high or good for all seven flow stations.

Table 4.2.12 – Surface Water Flow Calibration Statistics

Station	R	R2
G-135 Q	0.27	-0.84
G-136 Q	0.81	0.40
G-342ABCD Q	0.90	0.78
G-406 Q	0.98	0.93
S-190 Q	0.89	0.75
S-140 Q	0.91	0.77
G-150 Q	0.87	0.58

Notes: Green: high level of performance
Yellow: medium level of performance
White: low level of performance

As shown in ***Table 4.2.13,*** all of the surface water stage stations have a high level of model performance for ME. The model performance level is high for 3 of 5 stations for MAE and four of five for RMSE. Correlation coefficient performance is above 0.7 for four of the five stations.

Table 4.2.13 – Surface Water Stage Calibration Statistics

Station	ME (ft)	MAE (ft)	RMSE (ft)	R_Corr Coeff	R2_Nash Sut
G-136 HW	-0.56	0.71	0.93	0.70	0.12
G-150 HW	-0.52	0.69	0.91	0.71	0.18
G-342AB HW	0.26	0.87	1.07	0.54	-0.20
G-155 HW	0.70	0.76	0.90	0.88	0.17
PC17A HW	-0.08	0.31	0.40	0.84	0.64

Notes: Green: high level of performance
Yellow: medium level of performance
White: low level of performance

Cumulative flow statistics were calculated for the major discharge locations in the study area as shown in ***Table 4.2.14***. It can be seen that the cumulative flow error for the C-139 Basin is 11%. ***Figure 4.2.44***, which presents a plot of measured versus simulated flows for STA-5 plus G-406, confirms the high level of model performance for the C-139 Basin. Cumulative flow error is highest for G-135, G-136, and S-140. The challenges in the L-1 Basin (G-135 and G-136) have already been discussed. There are significant information gaps for the Seminole Tribe of Florida Big Cypress Reservation, such as:

- a lack of surveyed cross sections for many canals,
- unknown operational protocols of hydraulic control structures for canals east of the North Feeder Canal, and
- unknown culvert dimensions for Snake Road culverts.

One of the canals east of Snake Road was cleaned during the calibration/validation period, which changes the drainage efficiency for lands east of the North Feeder Canal. These information gaps limited the ability of the modeling team to understand the hydrology and hydraulics of the L-28 and Feeder Canal Basins. Monthly flow and stage calibration plots are present in ***Figures 4.2.45 to 4.2.51*** and ***Figures 4.2.52 to 4.2.56*** *respectively*. The plots are presented for selected stations defined in coordination with the District during the review of the Calibration and Validation TM. Daily surface water calibration plots are included in ***Appendix C4***.

Table 4.2.14 – 2004-2006 Cumulative Flow Statistics for the C-139 Basin Study Area

Location	Average cfs		(Meas-Sim)/Meas
	Measured	Simulated	
G-135	25.3	18.5	36%
G-136	24.5	29.7	-18%
STA5/406	244.2	217.1	13%
C-139 Sum	293.9	265.3	11%
S-140	197.8	167.6	18%
S-190	147.3	132.1	12%

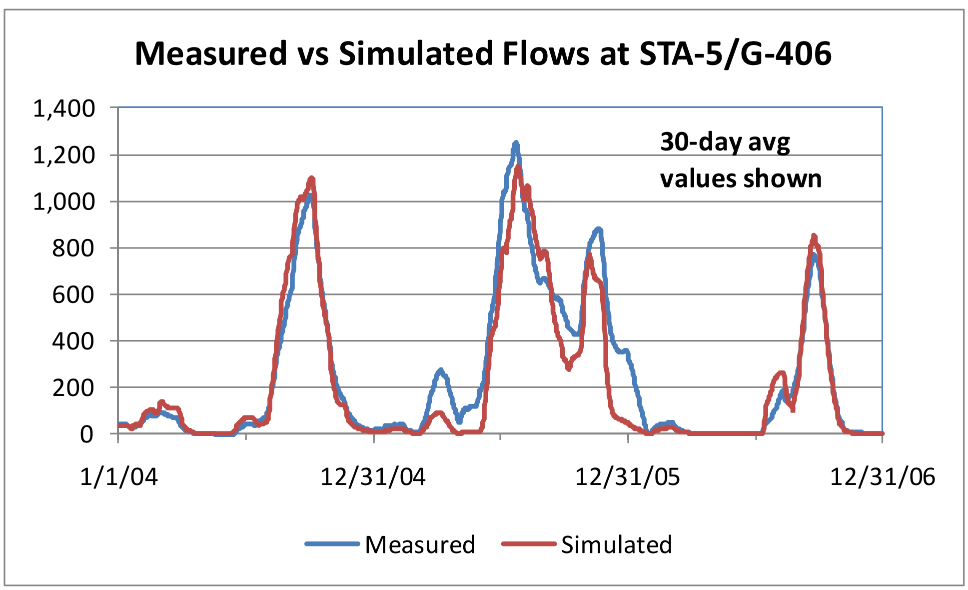


Figure 4.2.44 – Measured versus Simulated Flow for STA-5 plus G-406

Flow Calibration Plots

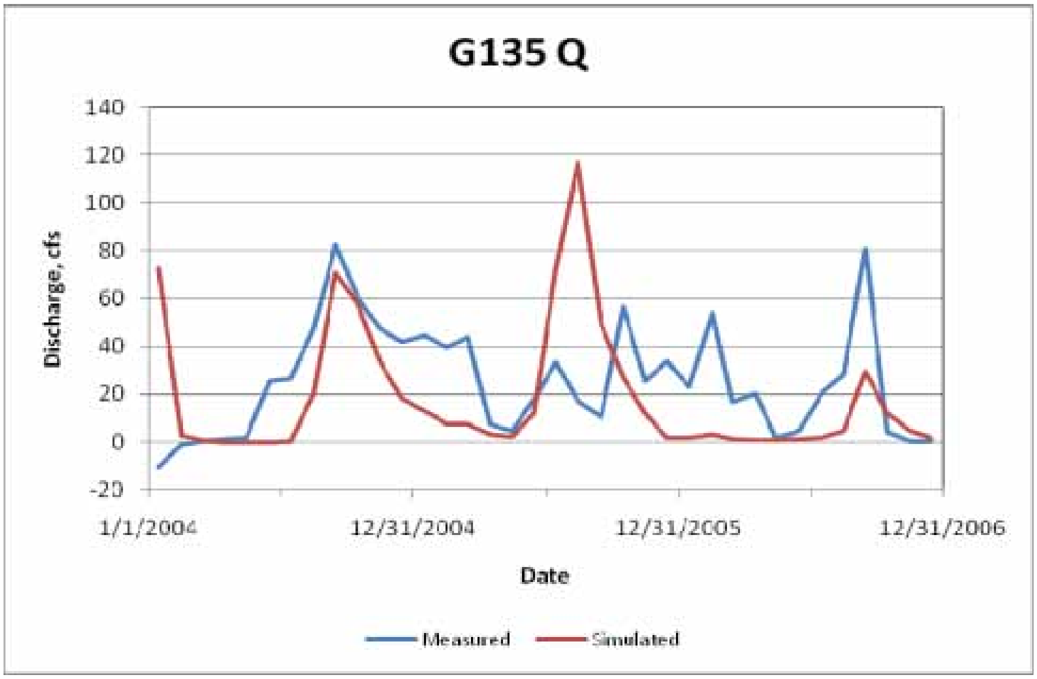


Figure 4.2.45 – G-135 Monthly Flow Calibration Plot

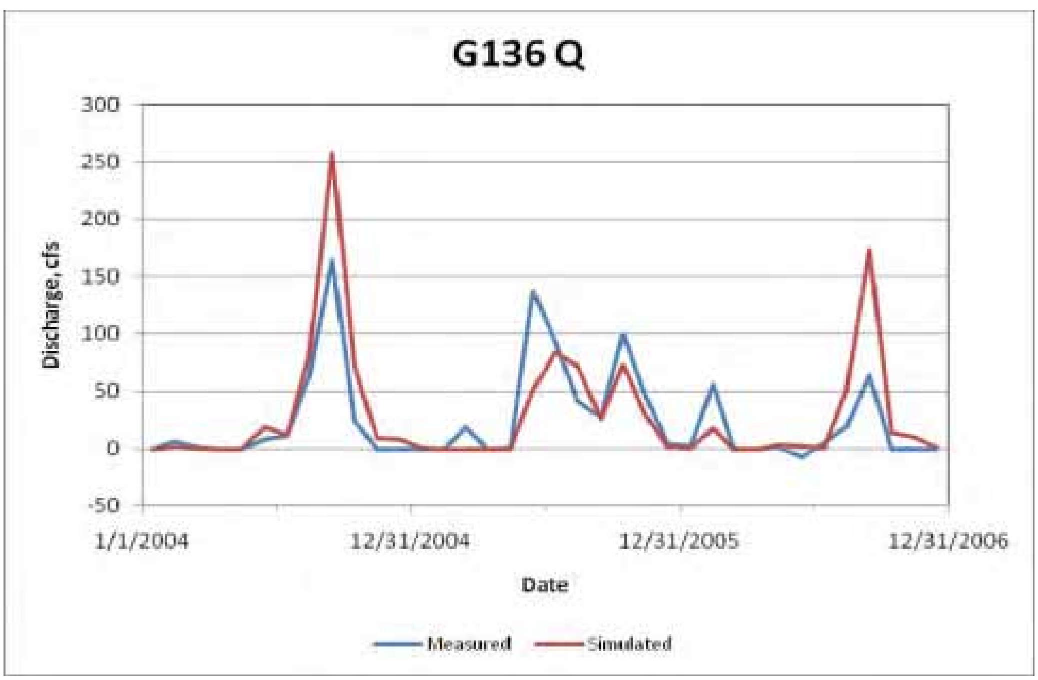


Figure 4.2.46 – G-136 Monthly Flow Calibration Plot

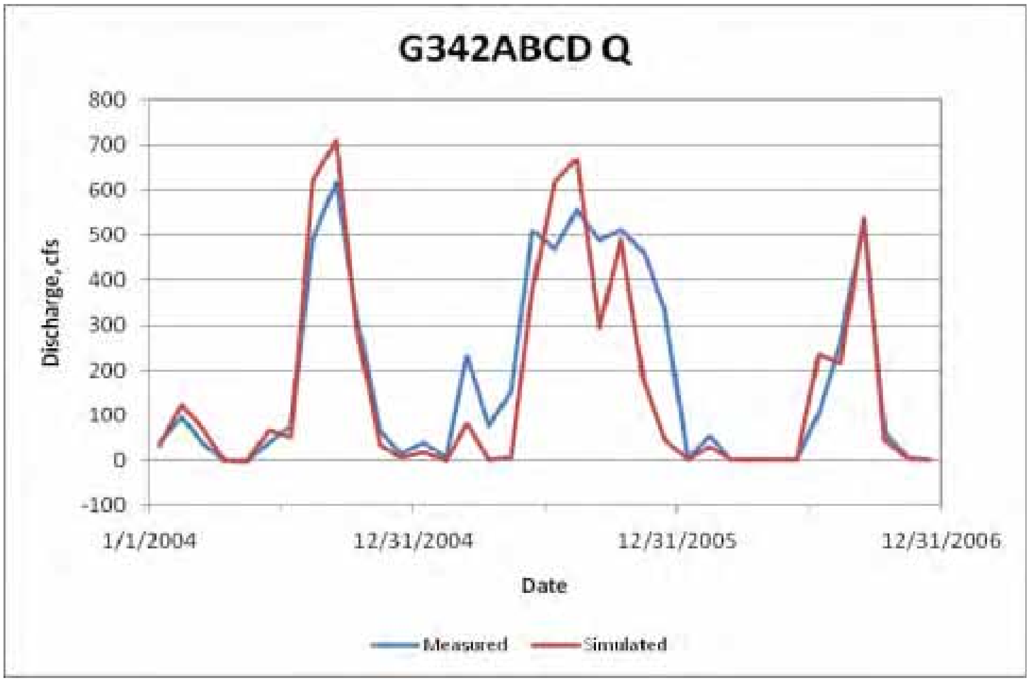


Figure 4.2.47 – G-342ABCD Monthly Flow Calibration Plot

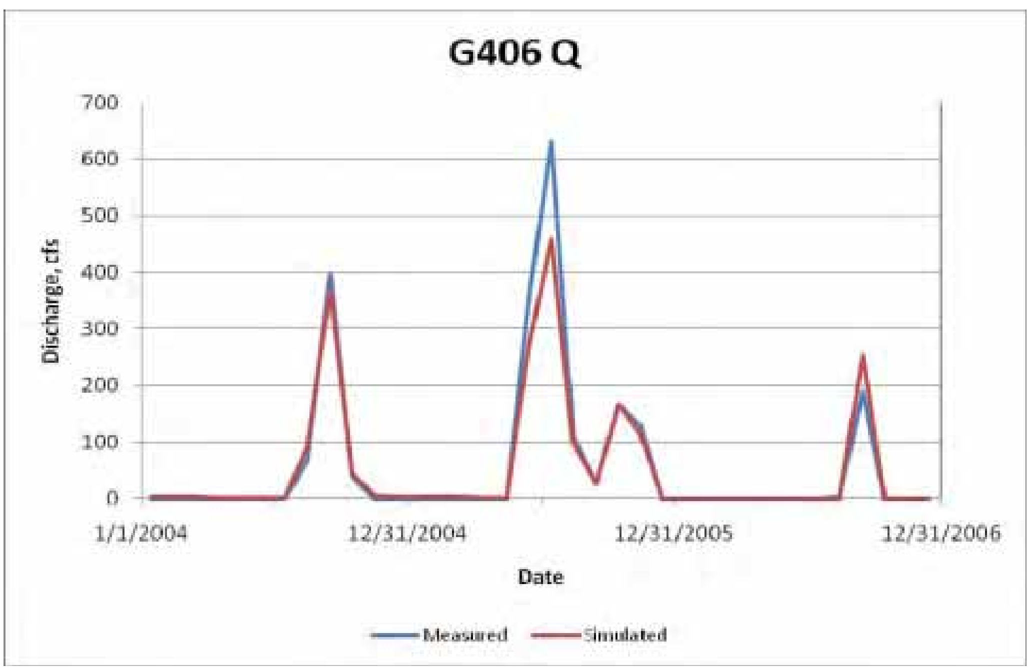


Figure 4.2.48 – G-406 Monthly Flow Calibration Plot

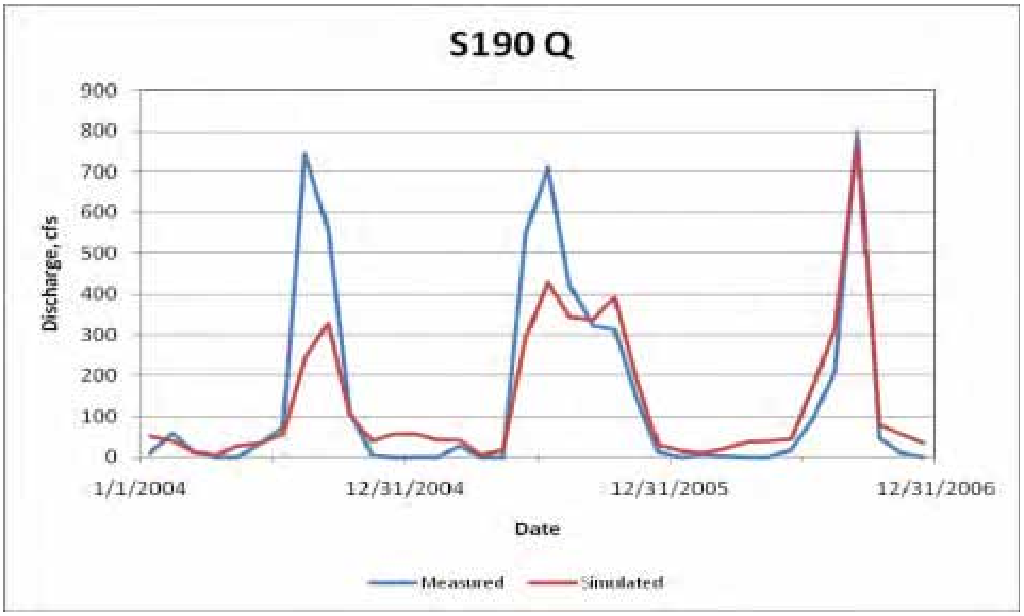


Figure 4.2.49 – S-190 Monthly Flow Calibration Plot

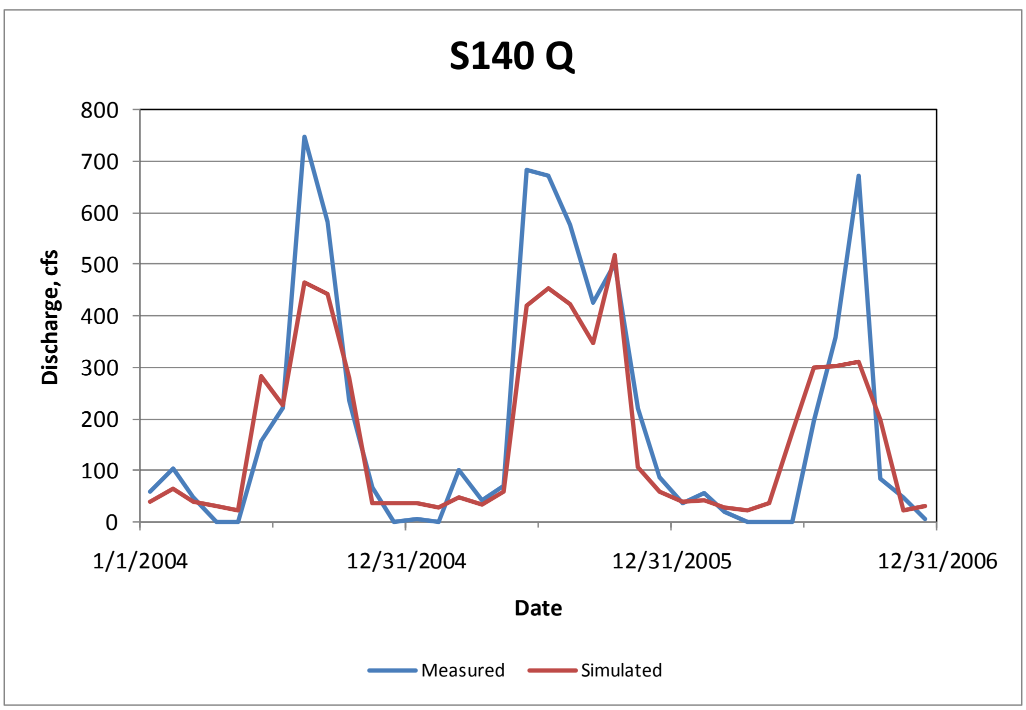


Figure 4.2.50 – S-140 Monthly Flow Calibration Plot

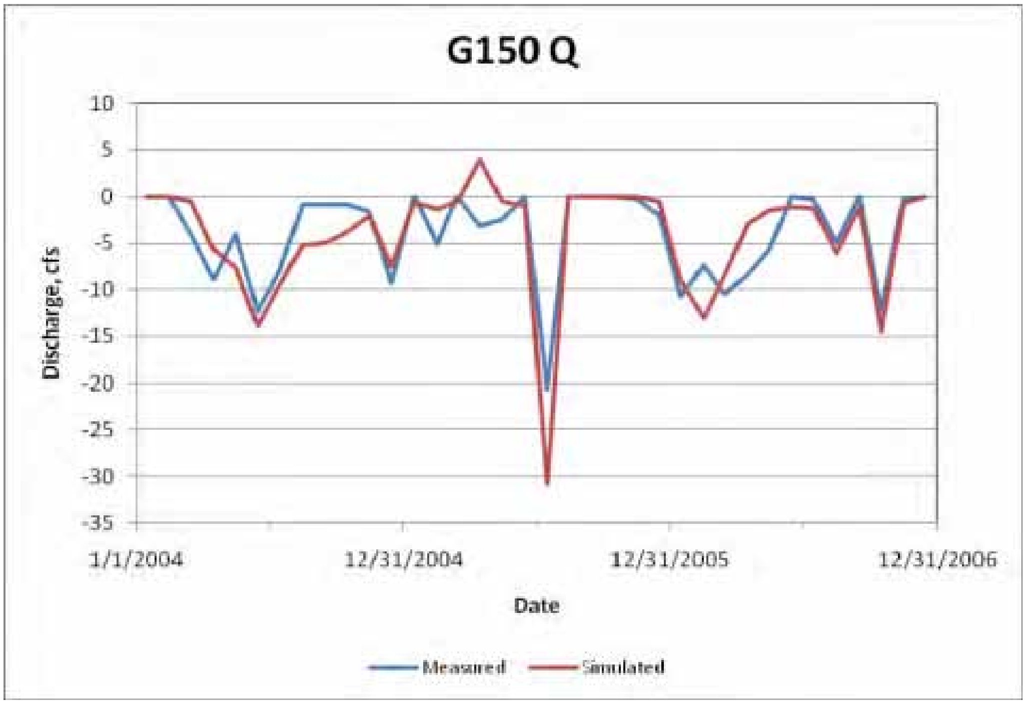


Figure 4.2.51 – G-150 Monthly Flow Calibration Plot

Stage Calibration Plots

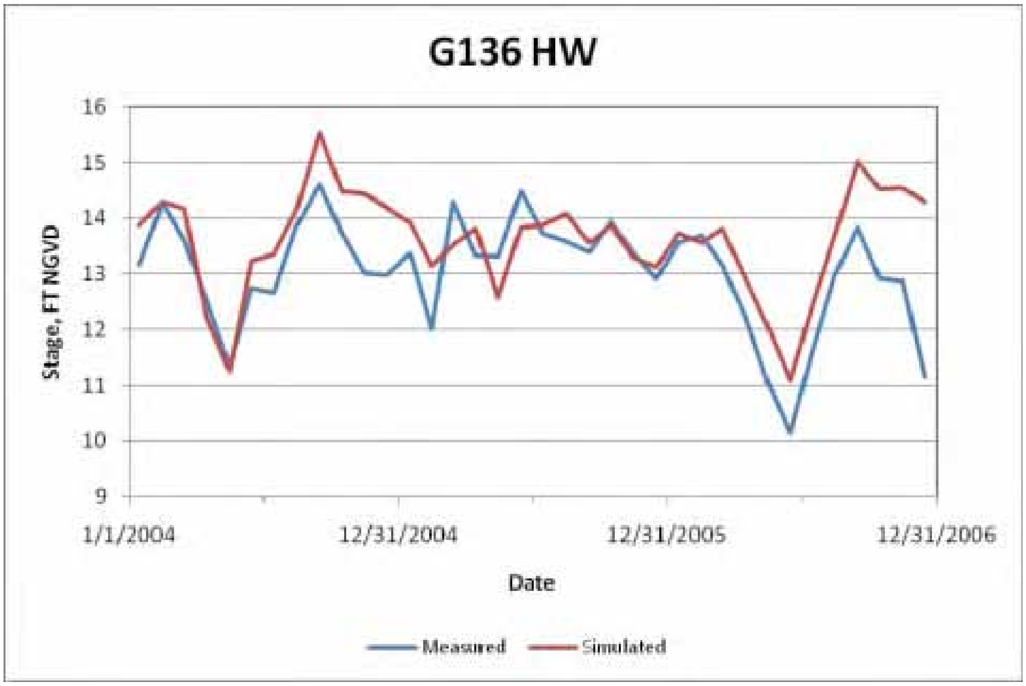


Figure 4.2.52 – G-136 Monthly Stage Calibration Plot

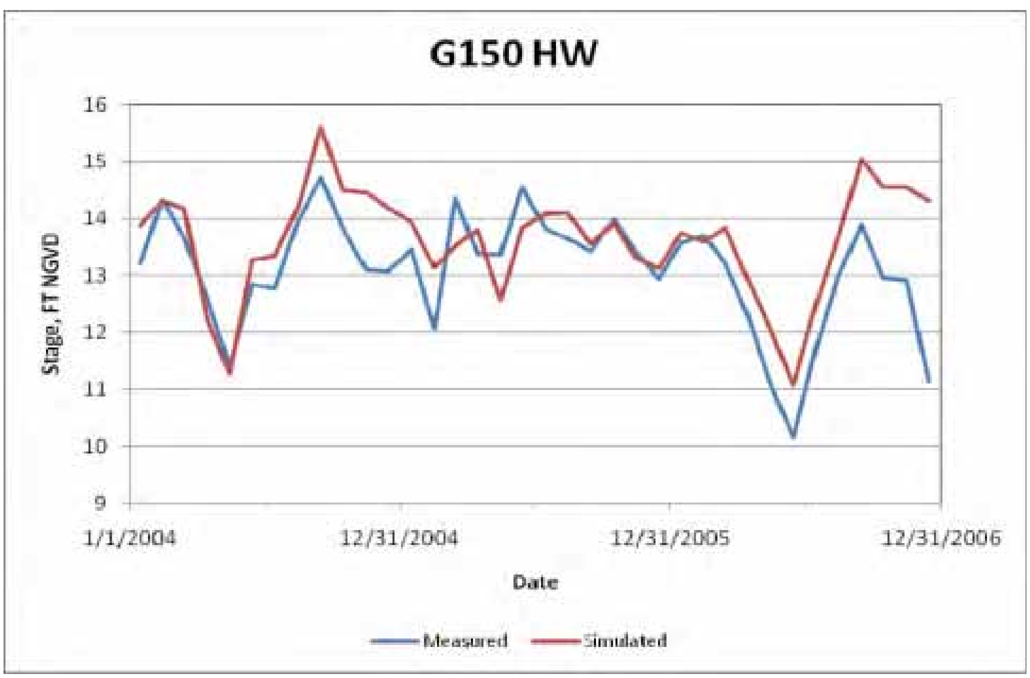


Figure 4.2.53 – G-150 Monthly Flow Calibration Plot

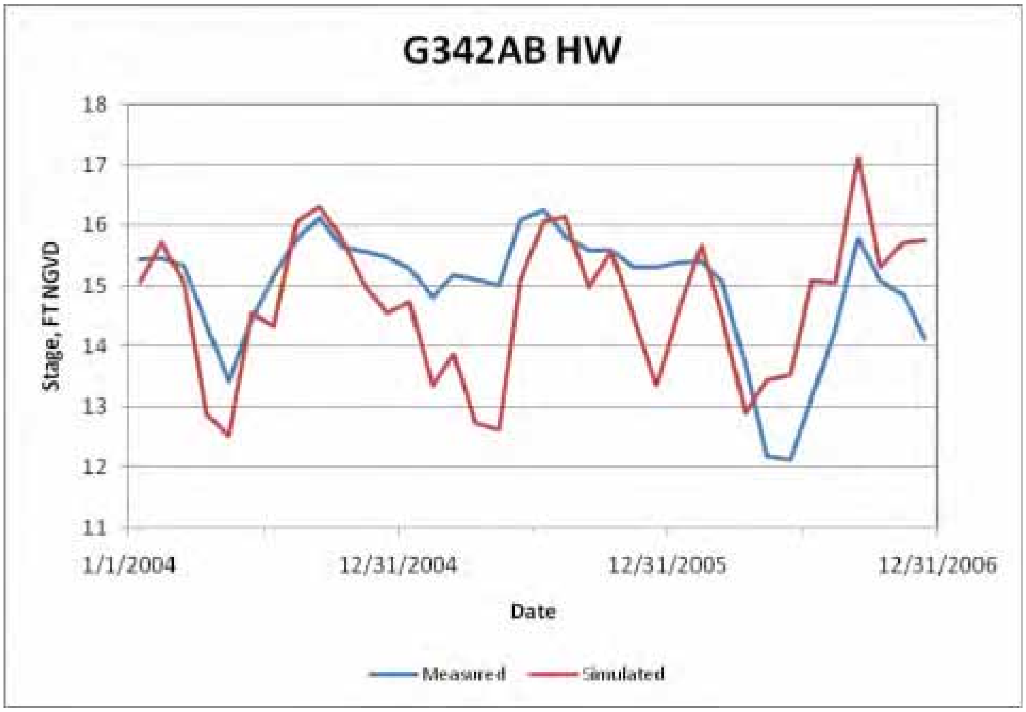


Figure 4.2.54 – G-342AB Monthly Stage Calibration Plot

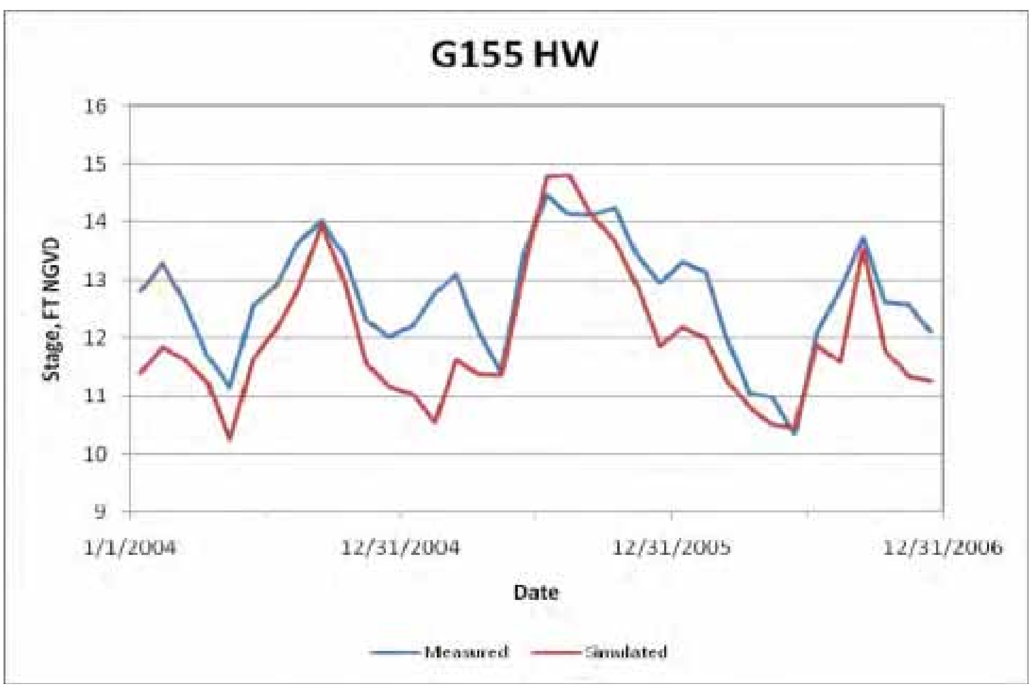


Figure 4.2.55 – G-155 Monthly Stage Calibration Plot

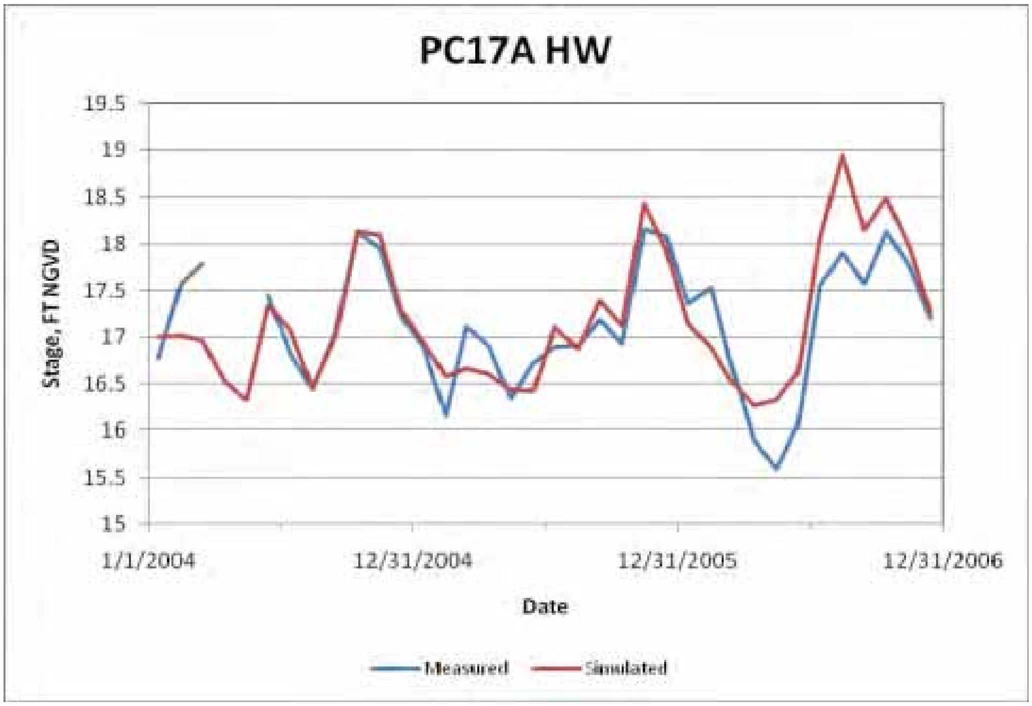


Figure 4.2.56 – POC-17A Monthly Stage Calibration Plot

Simulated vs Measured Cumulative Flow Comparison Plots

Plots comparing the simulated and measured cumulative flows for selected stations are presented in ***Figures 4.2.57 to 4.2.61***.

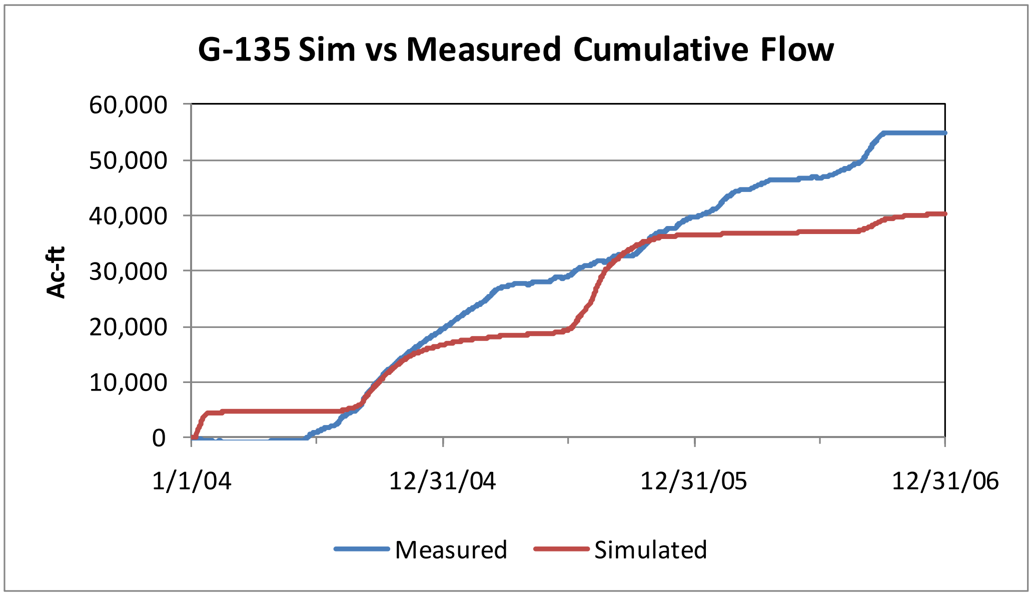


Figure 4.2.57 – S-135 Simulated vs Measured Cumulatve Flow Comparison Plot

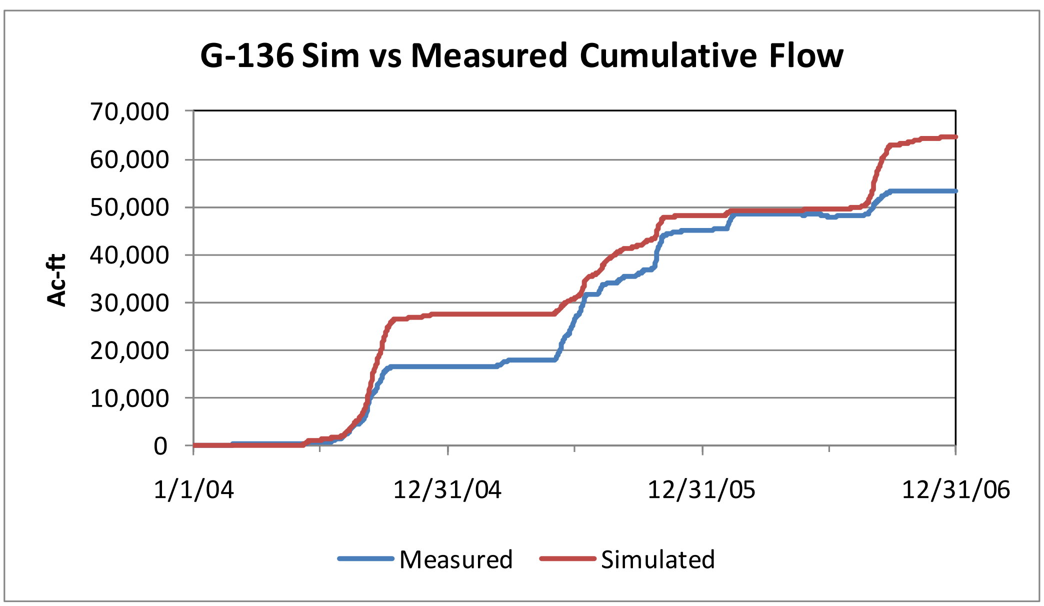


Figure 4.2.58 – G-136 Simulated vs Measured Cumulatve Flow Comparison Plot

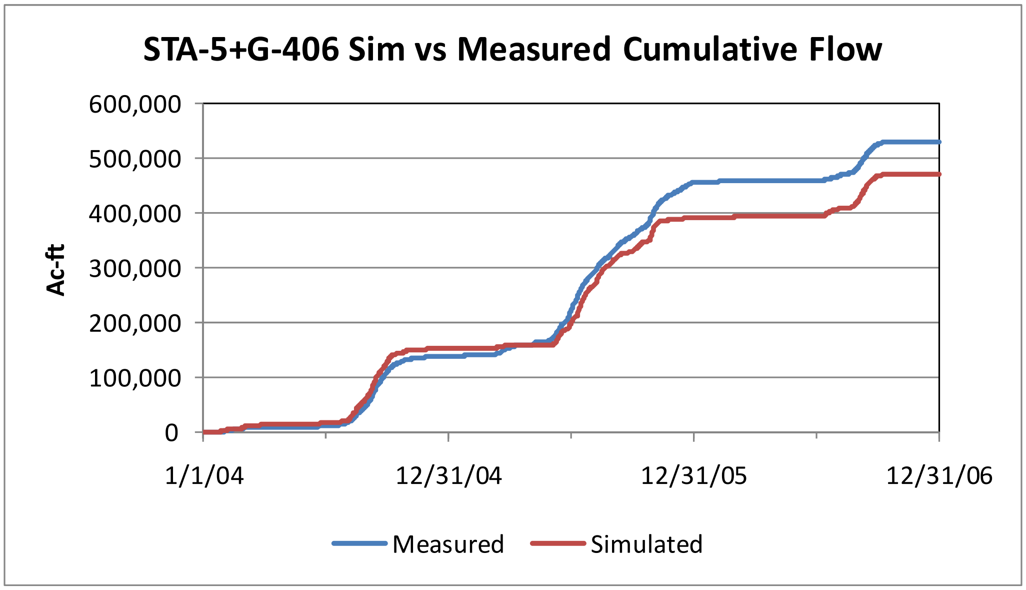


Figure 4.2.59 – STA-5 & G-406 Simulated vs Measured Cumulatve Flow Comparison Plot

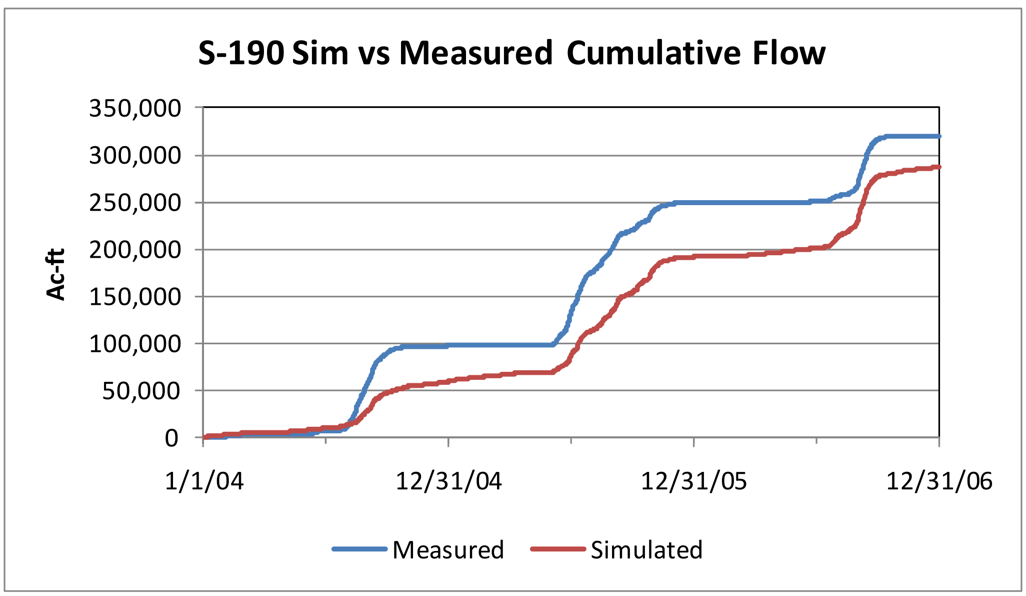


Figure 4.2.60 – S-190 Simulated vs Measured Cumulatve Flow Comparison Plot

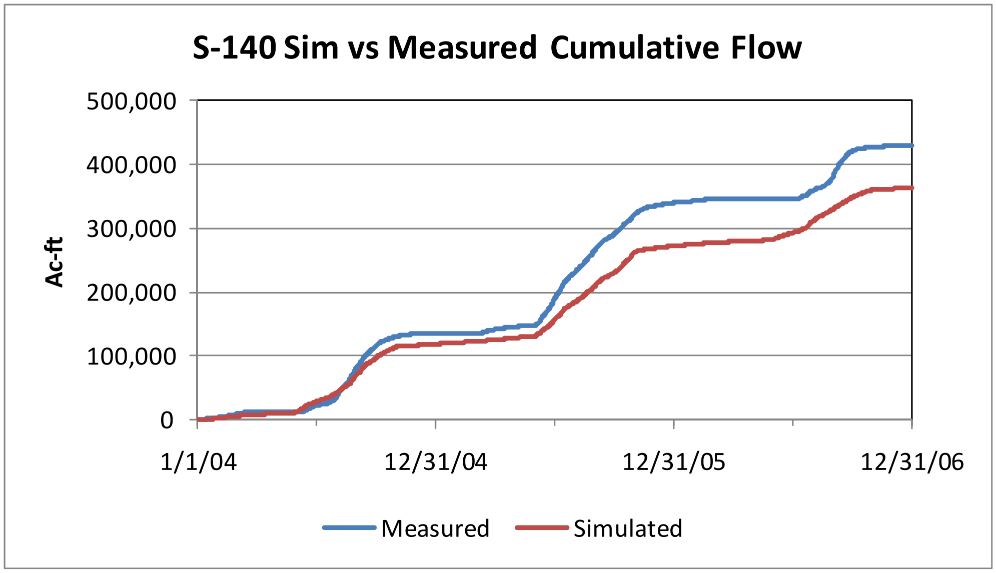


Figure 4.2.61– S-140 Simulated vs Measured Cumulatve Flow Comparison Plot

4.2.3.3.3 Groundwater Calibration Statistics

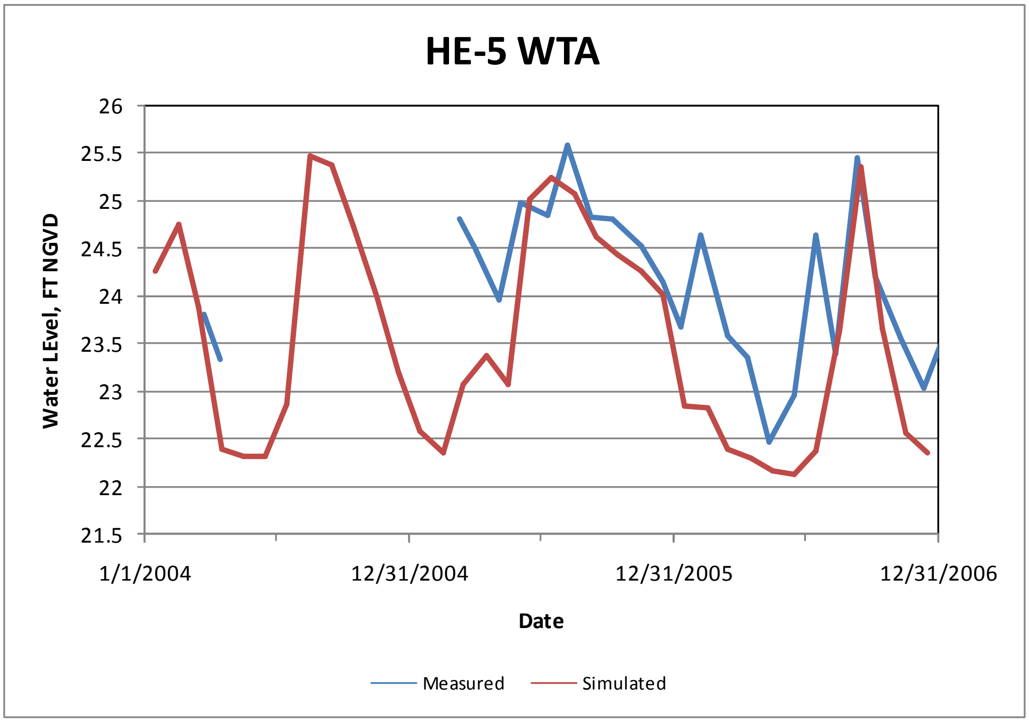
Table 4.2.15 provides a summary of groundwater calibration statistics. Model performance is either medium or high at 6 of 8 stations for ME, and at 4 of 8 stations for MAE. Model performance is high at 6 of 8 stations for RMSE, and 4 of 8 stations for correlation coefficient. Model performance is either medium or high for all metrics for wells HE-854, 856, 855, and 861. Monthly groundwater level calibration plots for the selected stations are presented in ***Figures 4.2.62 to 4.6.70***. Daily groundwater calibration plots are included in ***Appendix C5***.

Table 4.2.15 – Groundwater Calibration Statistics

Station	ME	MAE	RMSE	R
Water Table Aquifer				
HE-854	0.69	0.94	1.13	0.66
HE-856	-0.37	0.61	0.71	0.86
HE-860	1.08	1.08	1.24	0.87
HE-862	0.95	1.03	1.20	-0.19
Lower Tamiami Aquifer				
HE-855	0.77	0.87	1.10	0.87
HE-859	0.94	1.44	1.77	0.74
HE-884	-1.13	1.13	1.28	0.61
HE-861	0.77	0.78	0.95	0.86

Notes: Green: high level of performance
Yellow: medium level of performance
White: low level of performance

Water Table Aquifer Calibration Plots



Note: HE-5 data is breakpoint at irregular intervals. Plots are presented, however data for statistical analysis is inadequate.

Figure 4.2.62 – HE-5 Monthly Groundwater Level Calibration Plot

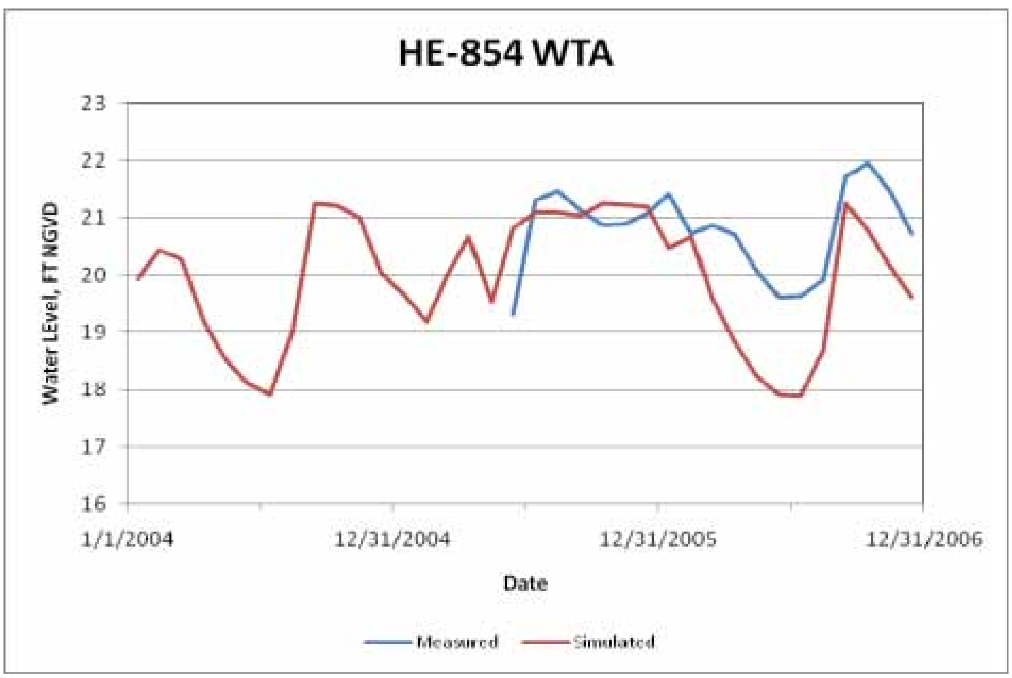


Figure 4.2.63 – HE-854 Monthly Groundwater Level Calibration Plot

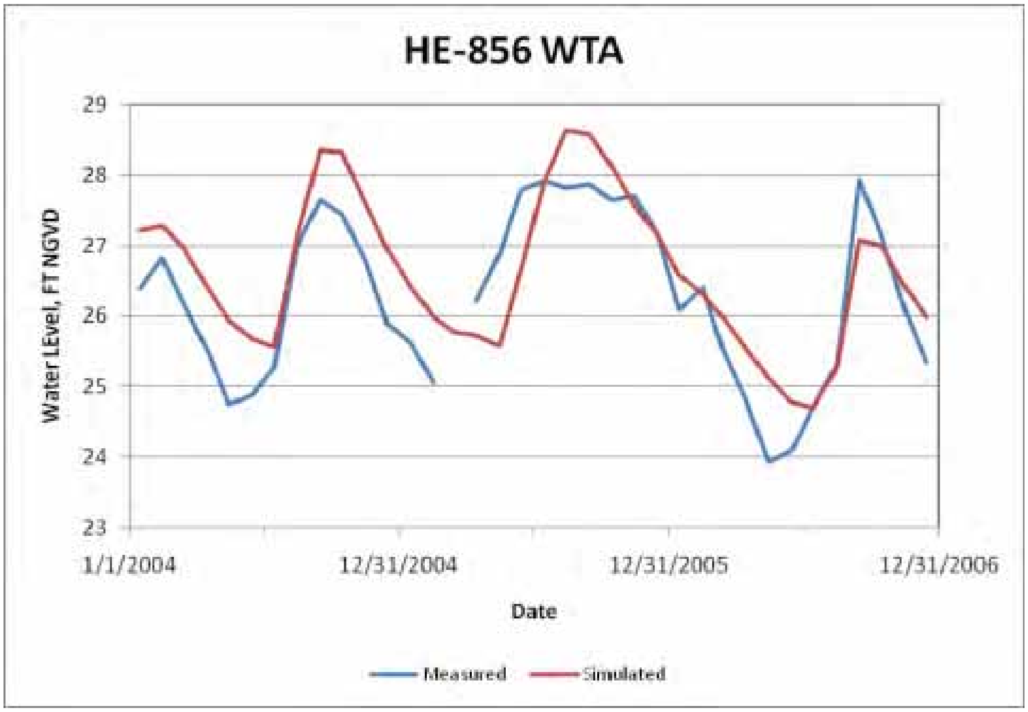


Figure 4.2.64 – HE-856 Monthly Groundwater Level Calibration Plot

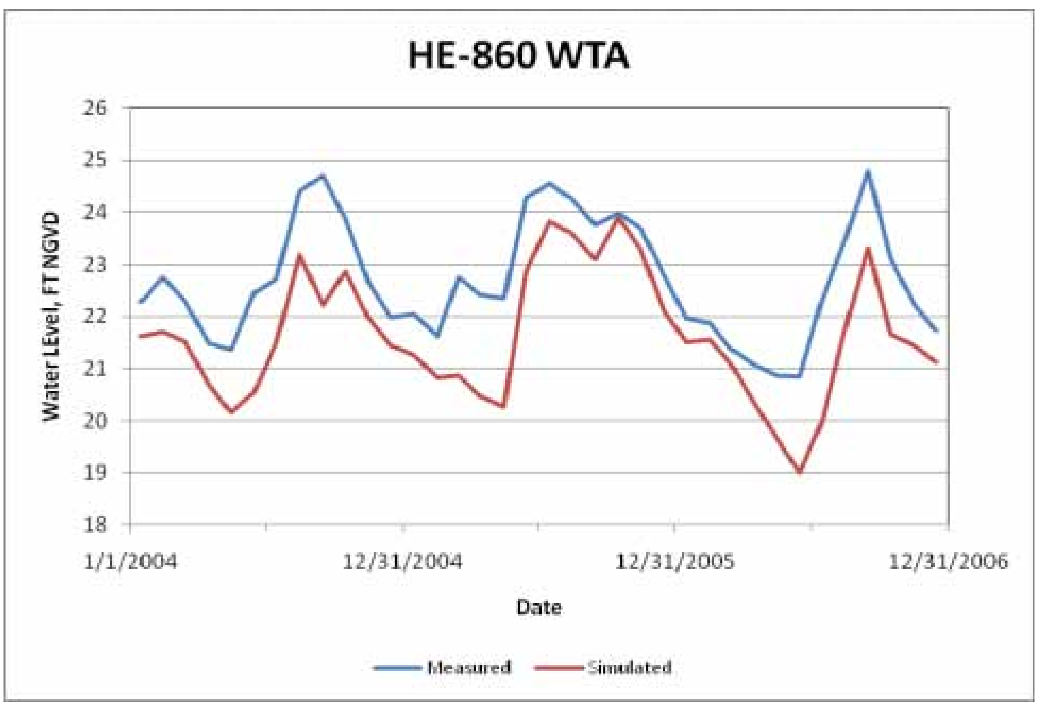


Figure 4.2.65 – HE-860 Monthly Groundwater Level Calibration Plot

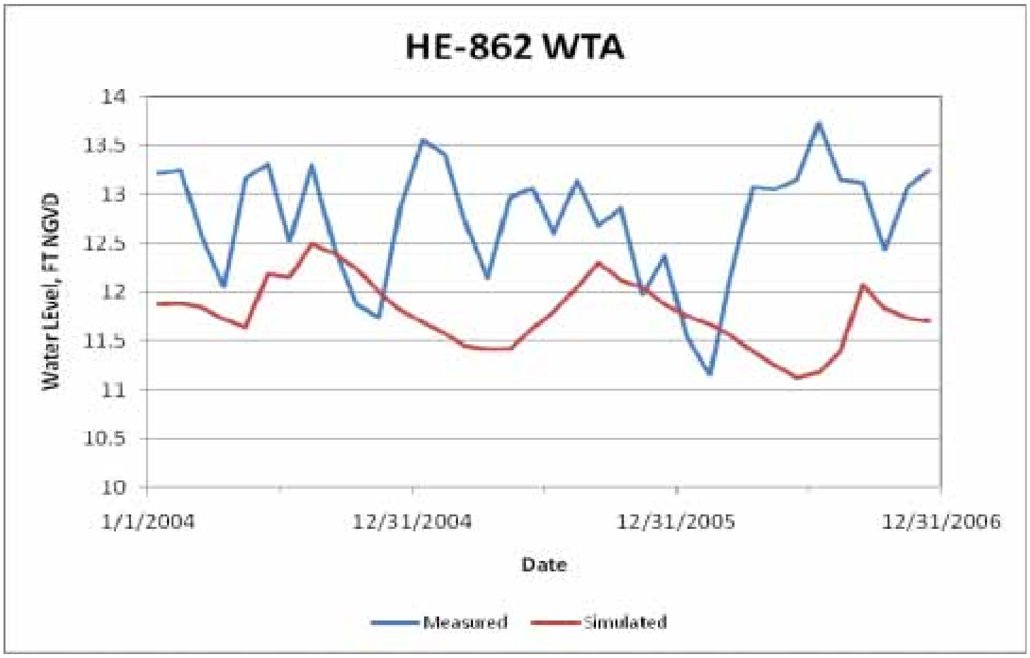


Figure 4.2.66 – HE-862 Monthly Groundwater Level Calibration Plot

Lower Tamiami Aquifer Calibration Plots

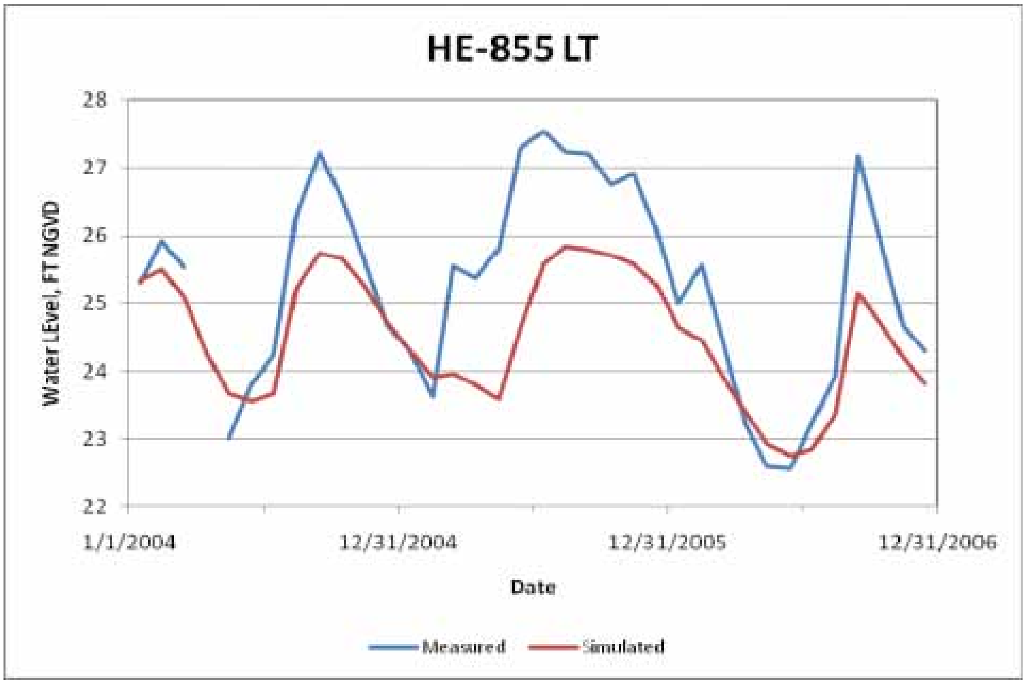


Figure 4.2.67 – HE-855 Monthly Groundwater Level Calibration Plot

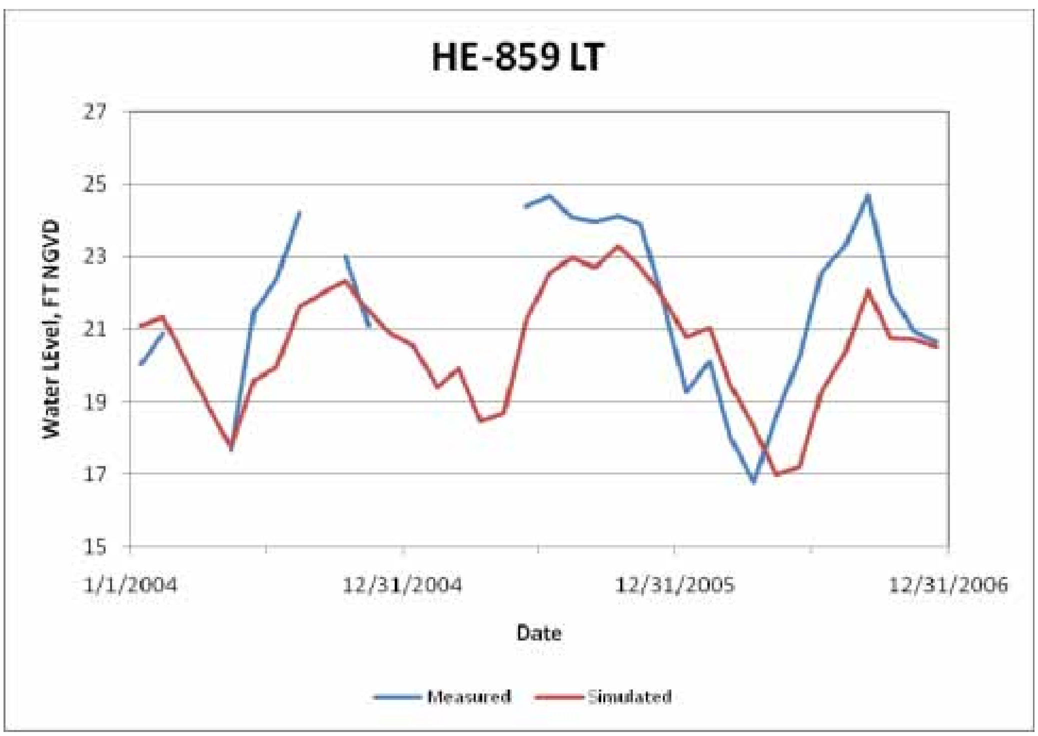


Figure 4.2.68 – HE-859 Monthly Groundwater Level Calibration Plot

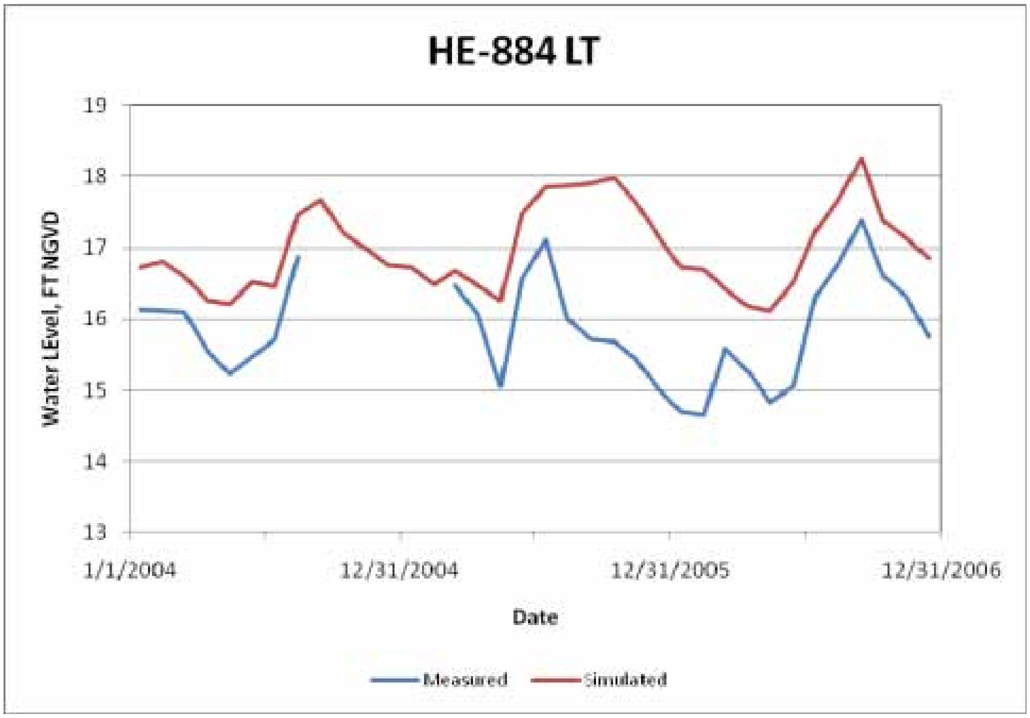


Figure 4.2.69 – HE-884 Monthly Groundwater Level Calibration Plot

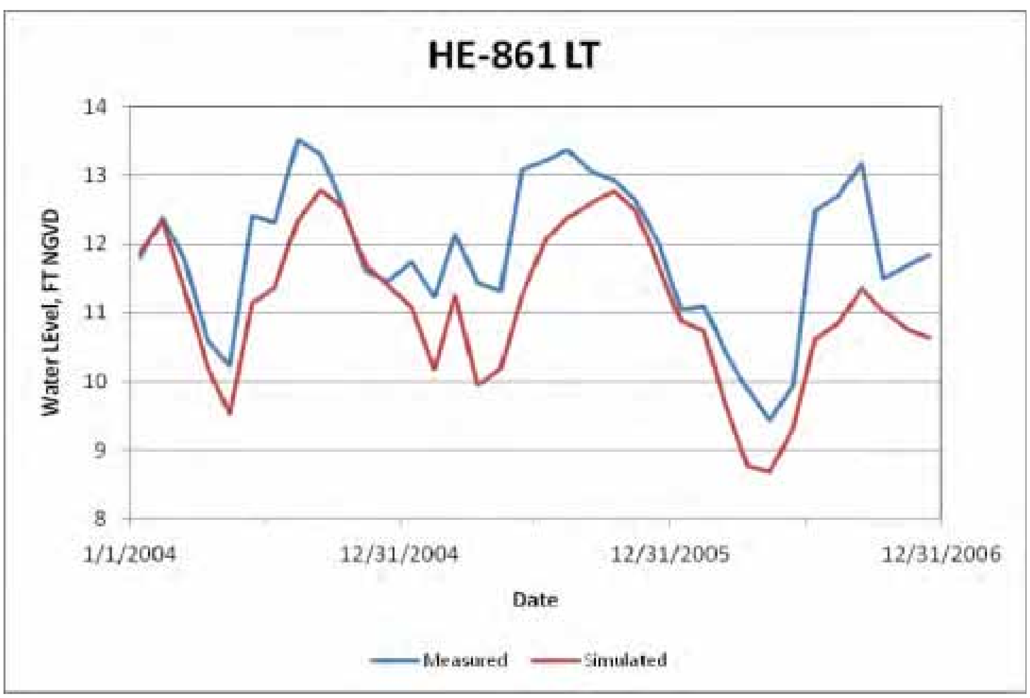


Figure 4.2.70 – HE-861 Monthly Groundwater Level Calibration Plot

4.2.3.3.4 MIKE SHE/MIKE 11 Results Comparison with MODFLOW

Table 4.2.16 presents a comparison of the model performance of the MIKE SHE/MIKE 11 model to the West Coast MODFLOW model. It can be seen that the MIKE SHE model performs better than the MODFLOW model for 9 of 11 stations for Mean Error. Only 1 of 11 stations for the MIKE SHE model has a lower Standard Deviation than the MODFLOW model.

Table 4.2.16 – Comparison of the Model Performance of the MIKE SHE/MIKE 11 Model to the West Coast MODFLOW Model

Well Name	Modflow		MIKE SHE		ME Diff abs(mike)-modflow	Std Dev Diff abs(mike)-modflow
	ME (avg Diff)	Std Dev	ME	Std Dev		
C-54	0.93	0.87	0.40	0.87	-0.53	0.00
HE-339	1.09	1.33	0.01	1.23	-1.08	-0.10
HE-5	0.75	1.76	-0.52	0.65	-0.22	-1.11
HE-853	0.90	1.98	-0.11	1.07	-0.78	-0.92
HE-854	1.10	1.61	0.84	0.82	-0.26	-0.78
HE-855	1.26	1.82	0.76	0.87	-0.50	-0.95
HE-856	0.98	1.87	-0.35	0.68	-0.63	-1.19
HE-859	1.60	1.61	0.88	1.88	-0.72	0.27
HE-860	0.97	1.78	1.08	0.74	0.11	-1.05
HE-862	0.68	0.96	0.95	0.85	0.27	-0.11
HE-884	1.34	1.29	-1.02	0.76	-0.32	-0.53
				Averages:	-0.42	-0.59

Mike SHE calibration statistics are better
Modflow calibration statistics are better
Minor Differences
No Differences

4.2.3.4 Water Balance Information

The C-139 Basin water budget is presented in ***Table 4.2.17***. ***Table 4.2.18*** provides a description of the terms for the water budget equation. Evapotranspiration (ET) rates are close to simulated rates because MIKE SHE counts irrigation as an additional input to the land surface, and is thus equivalent to rainfall. Rainfall in 2004 was 46.15 inches, and total irrigation was 4.44 inches, with the total water input equal to 51 inches. ET is 39 inches, or 76% of rainfall plus total irrigation. Pumping is irrigation from groundwater, and the difference between total irrigation and pumping is river irrigation. Therefore, river irrigation for 2004 was 0.71 inches. The total model domain for the C-139 Basin is 171,945 acres.

Table 4.2.17 – Water Budget for the C-139 Basin

Year	Precip	Evapotrans	OL Stor.Change	OL Bou.Inflow	OL Bou.Outflow	OL->River	Irrigation	SubSurf.Stor.Change	SubSurf.Bou.Inflow	SubSurf.Bou.Outflow	Pumping	Drain->River	Drain->Ext.River	Baseflow to river	Baseflow from river	Error
2004	46.15	-38.86	0.12	0.07	-1.32	3.79	4.44	2.64	0.38	-3.91	-3.73	-9.59	-0.01	-0.36	0.18	-0.01
2005	56.23	-39.17	0.00	0.12	-1.28	5.77	3.24	-2.14	0.36	-3.79	-2.79	-16.26	-0.01	-0.41	0.15	0.00
2006	36.23	-34.69	0.04	0.06	-2.02	3.04	5.75	4.69	0.47	-3.81	-4.94	-4.73	0.00	-0.30	0.21	0.00

Source: C_139_waterbal_yearly_incrementa_auto_subtotall_rc.xls

Precip = ET + OL->Stor.Change + OL->Boun.Inflow + OL->Boun.Outflow + OL->River + Irrigation+
Drain->Ext.River + Baseflow to River + Baseflow from River

Table 4.2.18 – Water Balance Terms

WBAL Term	Definition
Precip	Precipitation water added to model
Canopy Stor. Change	Net water added or removed from storage on canopy
Evapotrans	Water lost to evapotranspiration
OL Stor.Change	Net water added or removed from overland flow plain
OL Bou.Inflow	Water added at overland boundaries
OL Bou.Outflow	Water removed at overland boundaries
OL>River	Overland added to river
Irrigation	Water added for irrigation
SubSurf.Stor.Change	Net water added or removed from saturated zone
SubSurf.Bou.Inflow	Water added to saturated zone
SubSurf.Bou.Outflow	Water removed from saturated zone
Pumping	Water pumped from saturated zone
Drain>River	SZ water drained to river inside the subcatchment
Drain>Ext.River	SZ water drained to river outside the subcatchment
Drain Inflow	SZ water drained into subcatchment
Drain Outflow	SZ water drained out of subcatchment
Baseflow to river	SZ baseflow to river
Baseflow from river	SZ baseflow from river
Error	sum of all variables after conventional signage applied

Table 4.2.19 presents irrigation rates for each crop type and for the combined acreage of all irrigated lands. The 2006 irrigation rate of 22 inches/year translates to 103 cfs. This model does not include any irrigation of pasture. **A prior version of the model irrigated 64,968 acres of pasture, and pasture irrigation was 54 of 139 cfs, or 39% of total C-139 Basin irrigation.** ***Table 4.2.20*** presents a comparison of reported and simulated irrigation rates for selected farms that report irrigation pump rates to SFWMD. Irrigation rates are presented as cfs since some of the farms use canal water for irrigation. The overall simulated irrigation rate for these selected farms is 162 cfs, which is higher than reported irrigation rates. The reported totals include some periods where no irrigation is reported either because the permitted fields were not farmed that year or due to malfunctioning recorders.

Table 4.2.19 – C-139 Basin Irrigation Rates by Crop Type (No Pasture Irrigation)

Year	C-139 Basin Irrigation Rates, inches/year				
	Citrus	Cropland	Sugar Cane	Truck Crops	Overall
2004	12.8	2.1	19.8	18.2	16.7
2005	9.8	1.6	13.4	13.6	12.2
2006	17.8	2.9	23.4	23.8	21.6
Acres irrigated	13,292	344	11,272	15,794	40,702

Table 4.2.20 – Comparison of Measured and Simulated Irrigation Rates

Irrigation Analysis for Model: 5_21_10_Aonly_Run_Cal						
Farm	Permit	Grid Codes	Reported cfs		Simulated flow, cfs	
			2004-2006	2007-2008	GW	River
Alico West Ranch	26-00108-W	161	3.7	5.2	11.7	
Collins Slough E	26-00174-W	118	10.4	11.8	0.0	
Crows Nest Grove	26-00630-W	30	3.3	4.5	6.5	
Zipperer	26-00143-W	163	6.4	13.3	25.4	
Devils Garden S	26-00073-W	5	4	5.2	9.8	
Dinner Island 0030	26-00020-W	4, 99	0.9	2.4	8.4	
Half Circle L	11-00147-W	155	1.4	1	4.6	
Jackman B	26-00419-W	128	0.5	3.6	4.2	2.2
Jackman B - L-1 Irr			1.4	6.4		
McDaniel	26-00087-W	6, 160	23.4	24.8	15.6	
Mills ABC	26-00012-W	98	10	28.4	2.2	2.0
Mills ABC L-2 Irr			3.3	3.7		
Oak Hammock	26-00112-W	9, 162	NR	1.9	0.8	
So Div Unit 1	26-00094-W	7	21.8	24.2	40.0	15.5
Crooks	26-00083-W	159	2.3	NR	3.1	
Hilliard SE L-2 irr	26-00004-W	97	0	2.7	1.26	3.5
Hilliard West L-2 irr	26-00002-W	96	4.7	5.9	1.6	3.8
Totals:			**97.5**	**145**	**135.2**	**27**

Note: Yellow-highlighted rows are for farms with irrigation from the L-1 and L-2 Canals. Southern Division Unit 1 river irrigation is from impoundments inside the C-139 Annex.

4.2.3.5 Summary of Calibration Activities

After the initial model set up, calibration activities included adjustments of model parameters or in some cases changing input data as further information became available. The following are examples of some of the major calibration changes to the MIKE SHE/MIKE 11 Model:

- MIKE 11 boundaries were changed since model inception and with the addition of a time series boundary at L-4 to account for westerly flows from the Miami Canal.
- Vertical hydraulic conductivities were increased in the northwest portion of the model domain and in the vicinity of STA-5 cell 3 and STA-6.
- Many iterations were conducted to evaluate groundwater communication between the surficial and Lower Tamiami aquifers. Leakance rates between these two aquifers were modified. However, there is a significant degree of variability in leakance rates, and a number of challenges remain, such as wells HE-859 and HE-860 along CR 833/846 just east of Crooks Bend, the Crooks wells, and the US SUGAR well near the Deerfence Gate.
- Detention storage was increased to approximately 2 inches in the Alico farm west of CR 846, south of L-2W and north of the Alico South Boundary Canal to account for significant storage of rainfall on pasture lands that was observed during the summer of 2006.
- STA-5 headwater stage calibration improved with the incorporation of measured gate levels for gates G-342 A-D. A number of farms along the L-2 Canal utilize canal water for irrigation as evidenced by negative flows during the dry season at station C139 S2 (on L-2 Canal just upstream of STA-5). Adjusting river irrigation rates for these farms improved dry season stage calibration for 2004 and 2006, however the dry season stage recession was not observed in measured G-342 headwater water levels in 2005. Either a number of farms did not irrigate from L-2 in the 2005 dry season or rainfall rates in this portion of the C-139 Basin were higher than indicated by the Alico and STA-5 rain gages.
- A leakage structure was added to G-136 to account for rust holes at that structure.
- Pumps were added to STA-5 to account for maintenance lowering of the STA cells.
- As mentioned above, recorded gate operations were used for most structures in the model. This approach allowed the modeling team to focus on runoff processes during calibration rather than both runoff and gate operations. However, S-190 and S-140 were challenging. Gate logic was ultimately utilized at both of these structures. Simulated stages in the Feeder Canal upstream of S-190 were more than five feet higher than measured stages when using reported gate levels. S-190 flow calibration statistics are good using gate logic (correlation r = 0.89 for the calibration period), however S-190 headwater calibration is poor. Additional information will be needed to improve calibration of the Feeder Canal Basin.
- As mentioned above in ***Section 3.8***, which discusses the irrigation routine, removal of pasture irrigation had a negative impact on calibration.

4.2.4 VALIDATION

4.2.4.1 Changes Made to Validation Model

A number of changes were made to the validation model to account for expansion of STA-5 and STA-6. Construction of the following facilities was completed at the end of 2006. These features were flow-capable at the end of 2006, however gate control instrumentation and installation of monitoring equipment was not complete until sometime in 2007:

- Weirs for the middle of STA-5 (G-343A-G) were removed and replaced with underflow gates
- Cell 3 of STA-5 was completed in 2006
- Section 2 of STA-6 was completed in 2006
- The G-406 overflow weir was lowered from 21 to 17.5 feet-NGVD
- Connection of L-3 to the inflow canal to Section 2 of STA-6
- Construction of G-407 at the southern limit of the L-3 Canal just upstream of Confusion Corner was completed in 2007
- Removal of G-155 structural elements (concrete sill and flashboard I-beams)
- Re-routing of the STA-6 discharge to L-3 just upstream of Confusion Corner and plugging of the old STA-6 discharge to the L-4 Canal east of G-88

Hand-written paper notes of the gate operation for G343A-G, G-342EF, G-343IJ, G-344 EF, G-396ABC, and G-407 are available from the Operations Center of SFWMD. There were insufficient resources to obtain and digitize these records, therefore operation of these gates was estimated based on observed gate operation records for G-406 and G-342ABCD in STA-5 Cells 1 and 2. Starting in 2007, Gate G-406 was opened more frequently to deliver flows to STA-5 Cell 3. G-407 was opened less frequently, and only when flows to Confusion Corner were greater than the design capacity of Cells 1-3 of STA-5 and STA-6 Cells 3, 4, and Section 1. The validation results might improve if additional information becomes available for operation of these new gates during 2007.

After completion of the initial validation runs, it was noted that pump station G-600 which removes farm runoff from the sugar cane lands between STA-5 and STA-6 did not operate during most of 2007-2008 because this area was under construction for Compartment C. Accordingly, for both the final validation runs, G-600 was changed to operate using reported pump flows. Validation model run results are included in ***Appendix C11***.

4.2.4.2 Summary of Validation Metrics

The validation metrics are the same as the calibration metrics, see **Section 4.2.3.2**.

4.2.4.3 Validation Plots and Statistics

4.2.4.3.1 Surface Water Validation Statistics

Tables 4.2.21 and 4.2.22 present the summary of statistical performance for surface water flow, and surface water stage, respectively. The validation surface water flow statistics are equal to or superior to the calibration statistics. Stage statistics are not as good. The plot for G-135 Q shows a spike in the measured data for December 2007 that was not simulated. Investigation of the data on DBHYDRO shows that the gate was opened from an elevation of 19.68 to 7.23 between the period of December 3 to December 10, 2007. This gate opening was outside of the normal operations and was not included in MIKE 11. As mentioned in the discussion of the irrigation command areas, pasture irrigation was removed from the input files after completion of calibration and validation activities. Because irrigation rates were generally higher in recent years due to the conversion of pasture lands to crop lands, it is believed that the impact of removing irrigation from pasture lands had a greater effect on the validation period than for the calibration period. It is interesting to note that simulated stages for the validation model generally match measured stages with an offset. Therefore, correlation statistical performance for surface water stage is actually better for the validation model, however stage validation metrics show poorer performance than calibration metrics. This substantiates the hypothesis that the change in irrigation affected simulated stages. This issue can be explored further in the next phase of this project. As shown in ***Table 4.2.21*** six out of seven of the flow stations have a high level of calibration performance for correlation coefficient. Nash-Sutcliff performance is either high or good for all seven flow stations.

Table 4.2.21 - Statistical Performance for Surface Water Flow Stations

Station	R	R2
G-135 Q	0.47	-0.51
G-136 Q	0.99	0.81
G-342ABCD Q	0.99	0.90
G-406 Q	0.99	0.97
S-190 Q	0.98	0.79
S-140 Q	0.87	0.73
G-150 Q	0.68	0.30

Notes: Green: high level of performance
Yellow: medium level of performance
White: low level of performance

As shown in ***Table 4.2.22,*** five of the six surface water stage stations have either a high or medium level of model performance for ME. The model performance level is high or medium for five of six stations for MAE and three of six for RMSE. Correlation coefficient performance is above 0.68 for all the stations.

Table 4.2.22 - Statistical Performance for Surface Water Stage Stations

Station	ME	MAE	RMSE	R	R2
G-150	0.12	0.70	1.75	0.68	0.30
G-136 HW	-1.86	1.92	2.27	0.80	-0.33
G-150 HW	-1.08	1.19	1.40	0.74	-0.41
G-342AB	-0.95	1.06	1.26	0.69	-0.39
G-155	-0.03	0.54	0.65	0.89	0.74
PC17A HW	-0.78	1.19	1.36	0.68	-0.73

Notes: Green: high level of performance
Yellow: medium level of performance
White: low level of performance

Table 4.2.23 provides the statistics of cumulative flow for the study area. The validation model performance is superior to the calibration run for the C-139 Basin draining to STA-5 and for S-140. Validation model performance is worse for the L-1 Basin and the Feeder Canal Basin. One possible explanation for this improved performance is that gate records for C-139 Basin may be more accurate than in the past, which enabled better calibration. ***Figures 4.2.71*** and ***4.2.72*** present cumulative flow plots for STA-5 and G-406 for the calibration and validation runs, and it can be seen that the model does an excellent job of predicting C-139 Basin flow to the STA-5 complex during both the calibration and validation period.

Table 4.2.23 – Cumulative Flow Statistics

Location	Average cfs		(Meas-Sim)/Sim
	Meas	Sim	
G-135	4.1	8.8	-53%
G-136	12.3	21.5	-43%
STA5/406	119.7	128.5	-7%
C-139 Sum	136.1	158.7	-14%
S-140	23.6	24.5	-4%
S-190	78.0	98.6	-21%

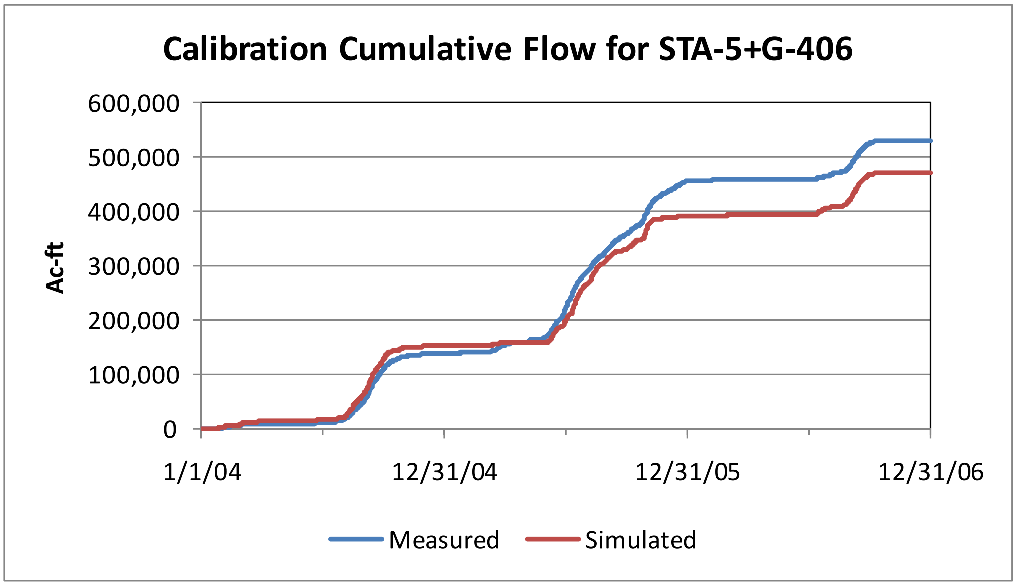


Figure 4.2.71 – Cumulative Flow for STA-5 and G-406 for the Calibration Run

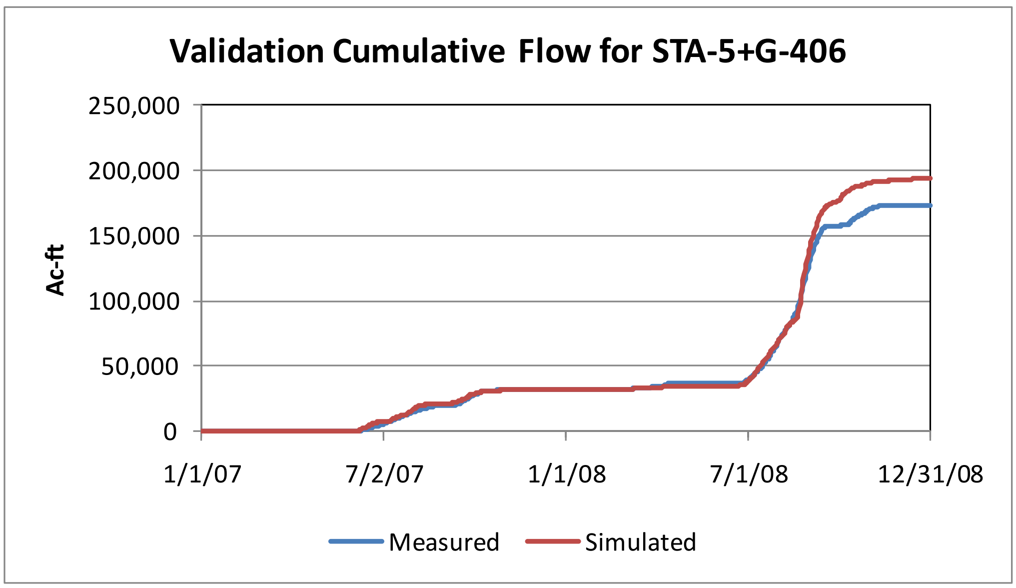


Figure 4.2.72 – Cumulative Flow for STA-5 and G-406 for the Validation Run

Monthly flow and stage validation plots are presented in ***Figures 4.2.73 to 4.2.79 and Figures 4.2.80 to 4.2.84*** *respectively*. The plots are presented for selected stations defined in coordination with the District during the review of the Calibration and Validation TM. Plots comparing the measured and simulated cumulative flows are also included. Daily surface water validation plots are included in ***Appendix C6***.

<u>Flow Validation Plots</u>

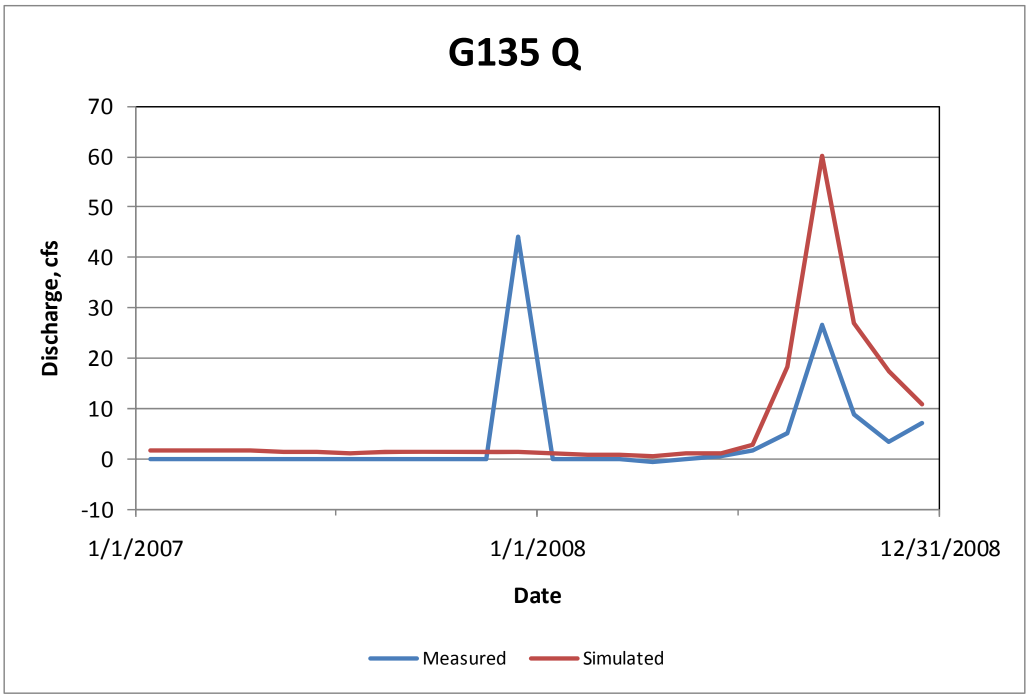


Figure 4.2.73 – G-135 Monthly Flow Validation Plot

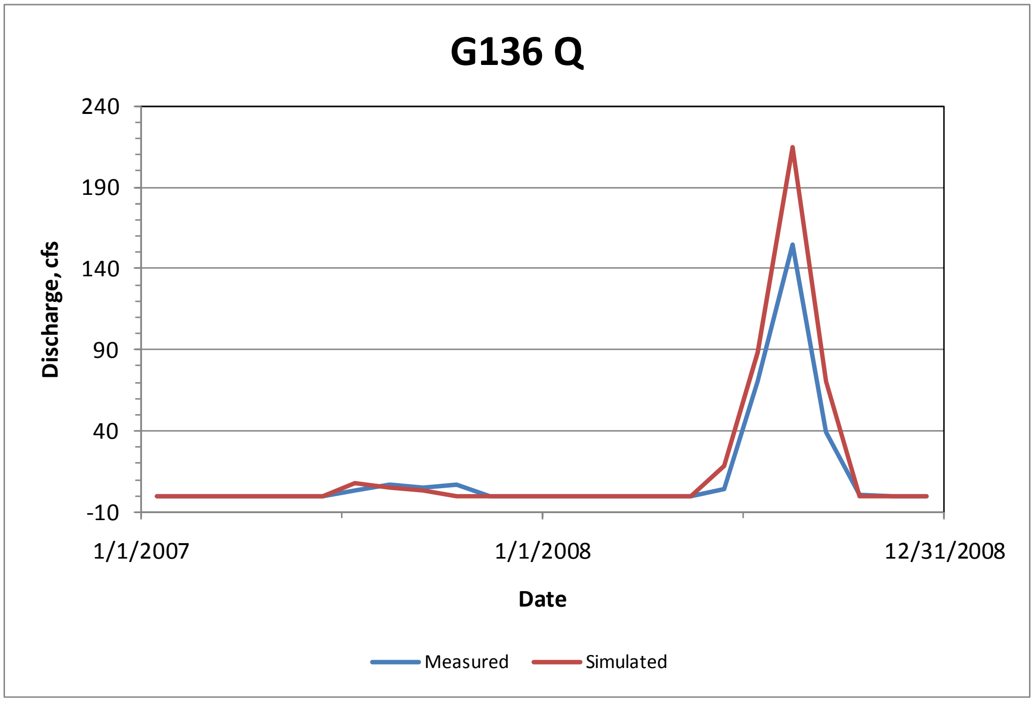


Figure 4.2.74 – G-136 Monthly Flow Validation Plot

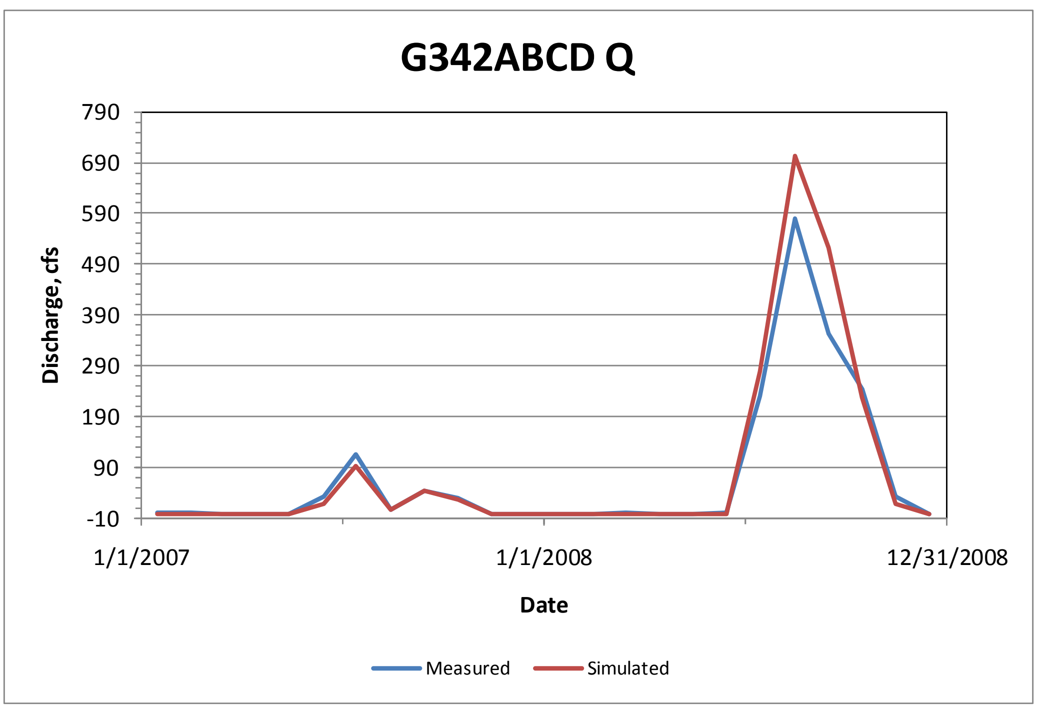


Figure 4.2.75 – G-342ABCD Monthly Flow Validation Plot

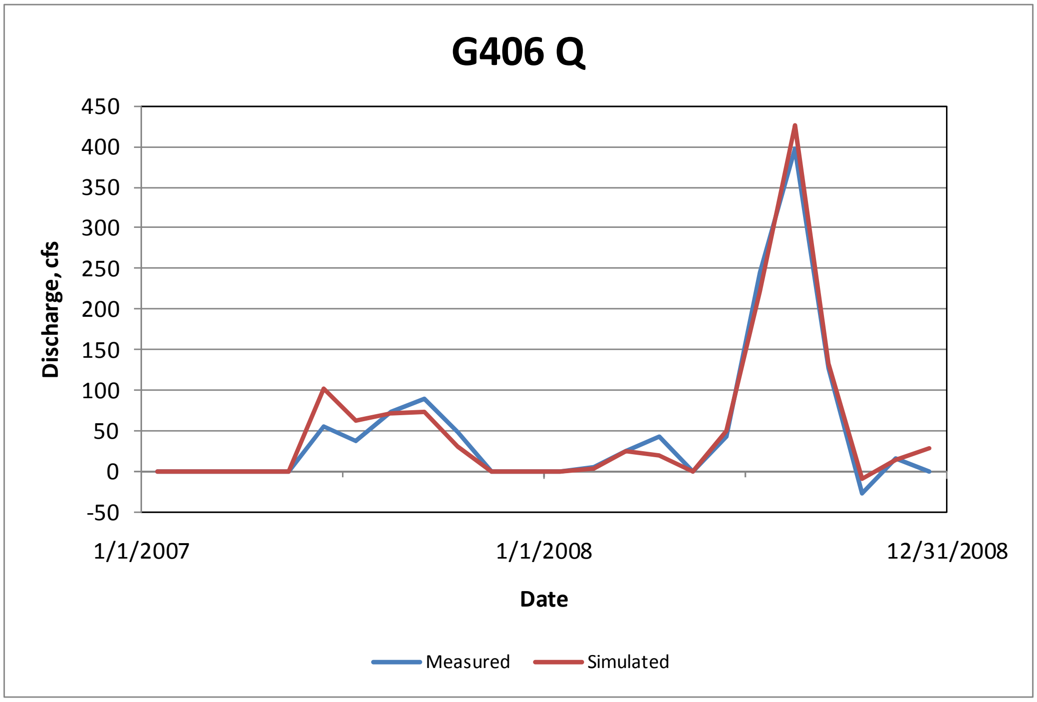


Figure 4.2.76 – G-406 Monthly Flow Validation Plot

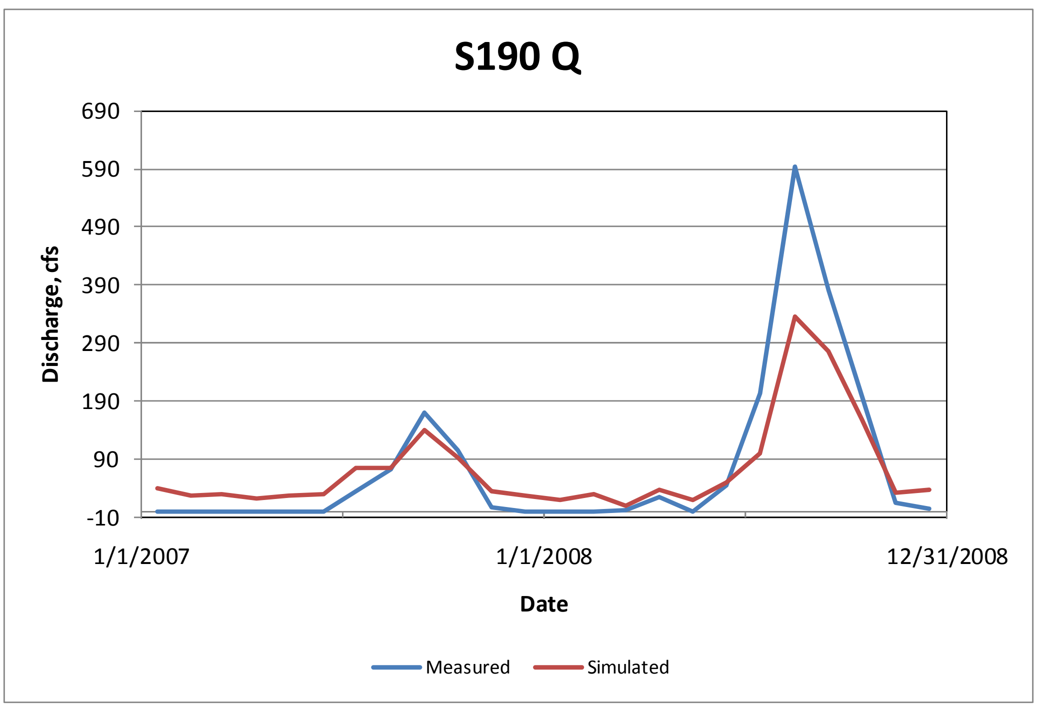


Figure 4.2.77 – S-190 Monthly Flow Validation Plot

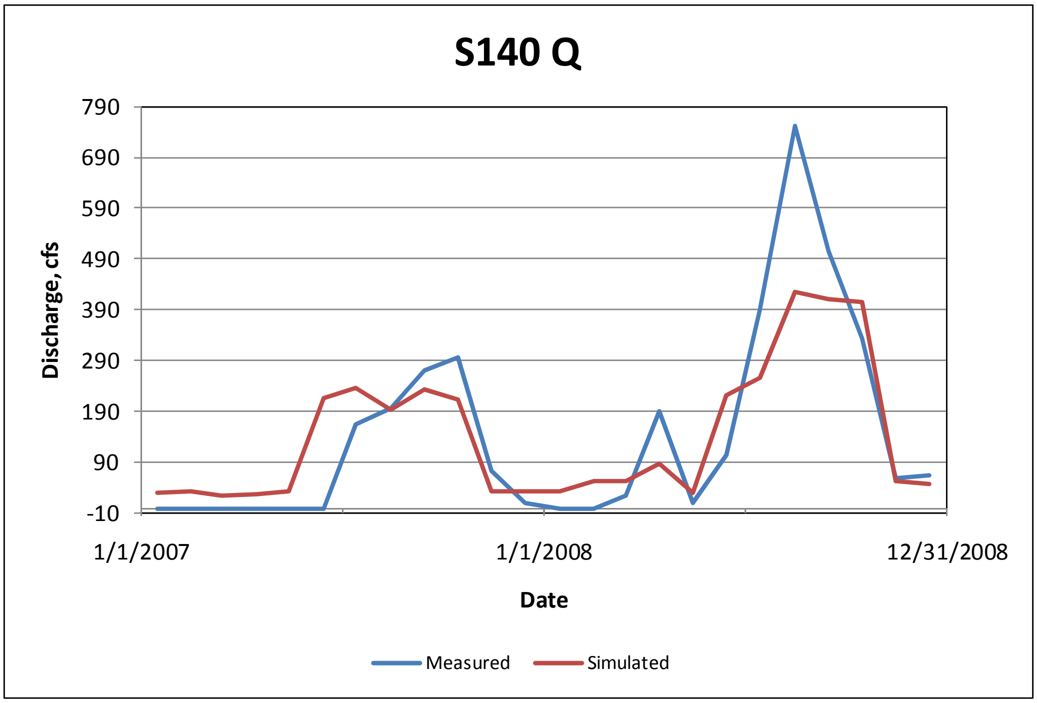


Figure 4.2.78 – S-140 Monthly Flow Validation Plot

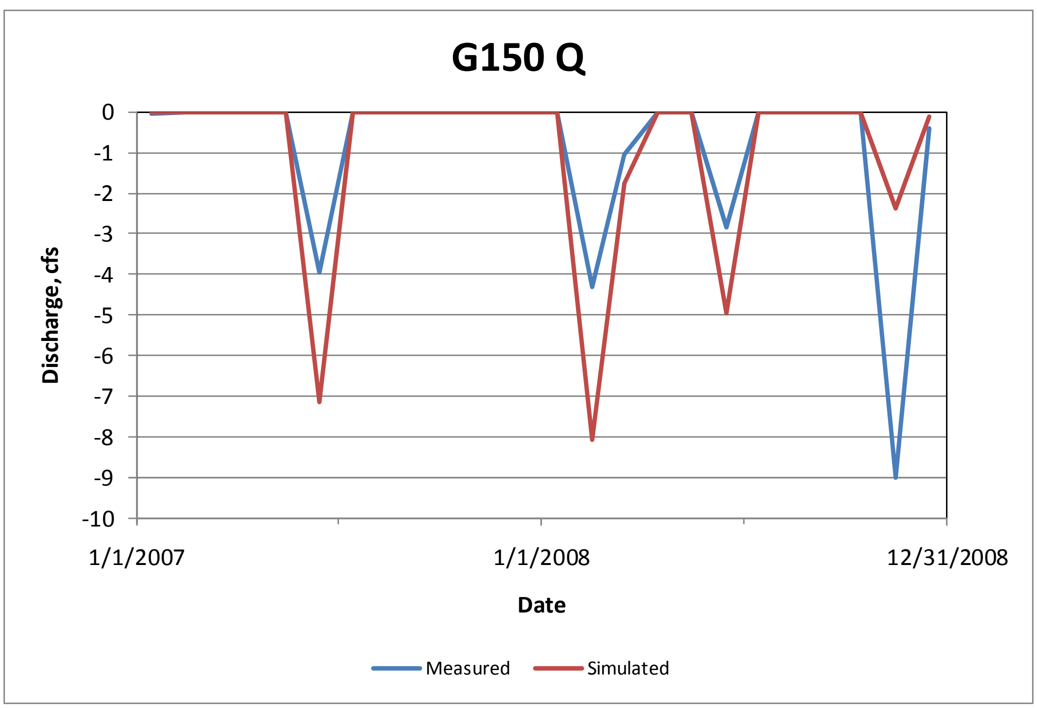


Figure 4.2.79 – G-150 Monthly Flow Validation Plot

Stage Validation Plots

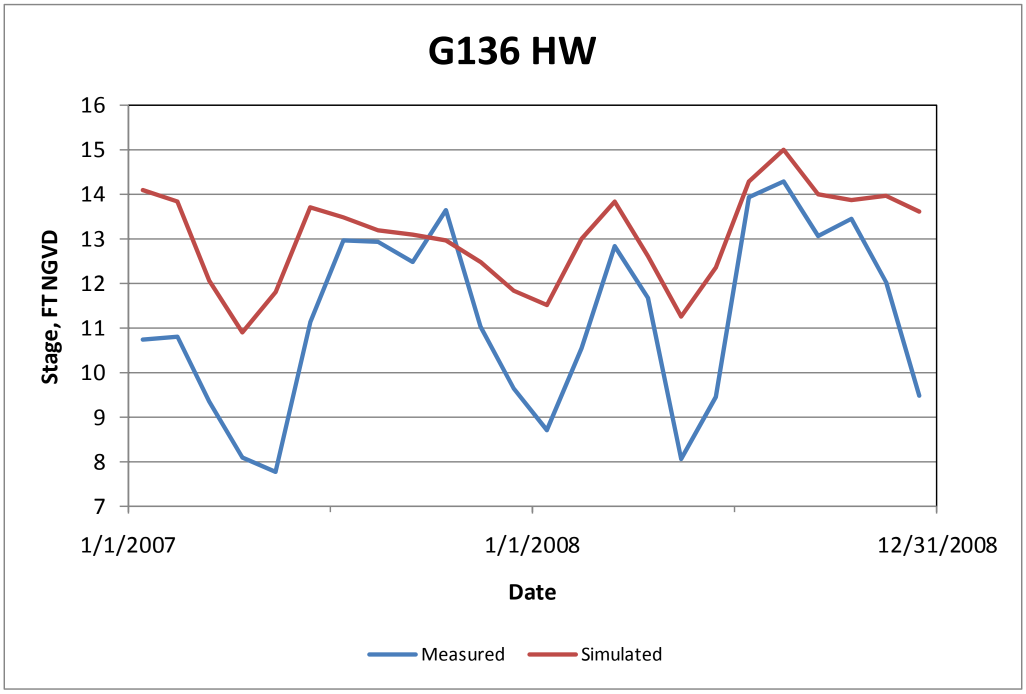


Figure 4.2.80 – G-136 Monthly Stage Validation Plot

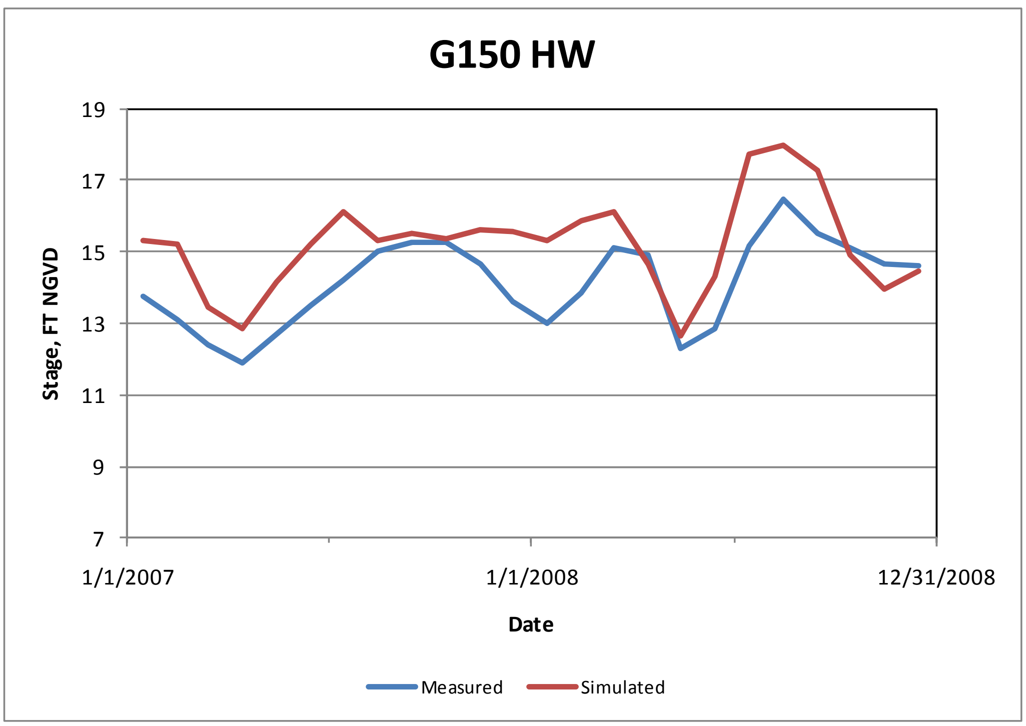


Figure 4.2.81 – G-150 Monthly Stage Validation Plot

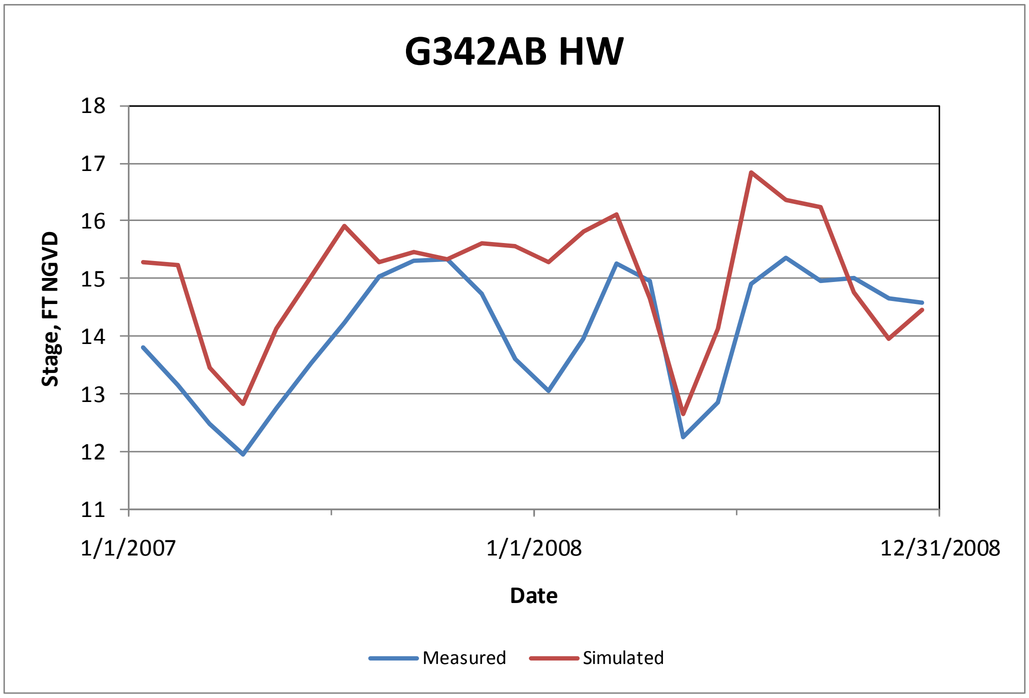


Figure 4.2.82 – G-342AB Monthly Stage Validation Plot

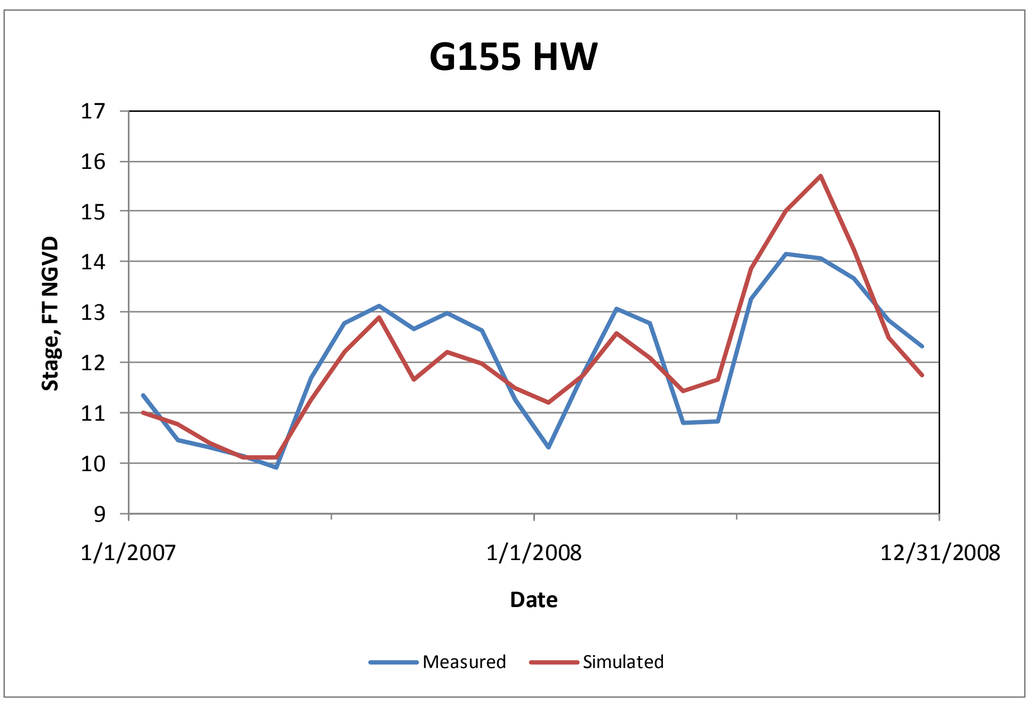


Figure 4.2.83 – G-155 Monthly Stage Validation Plot

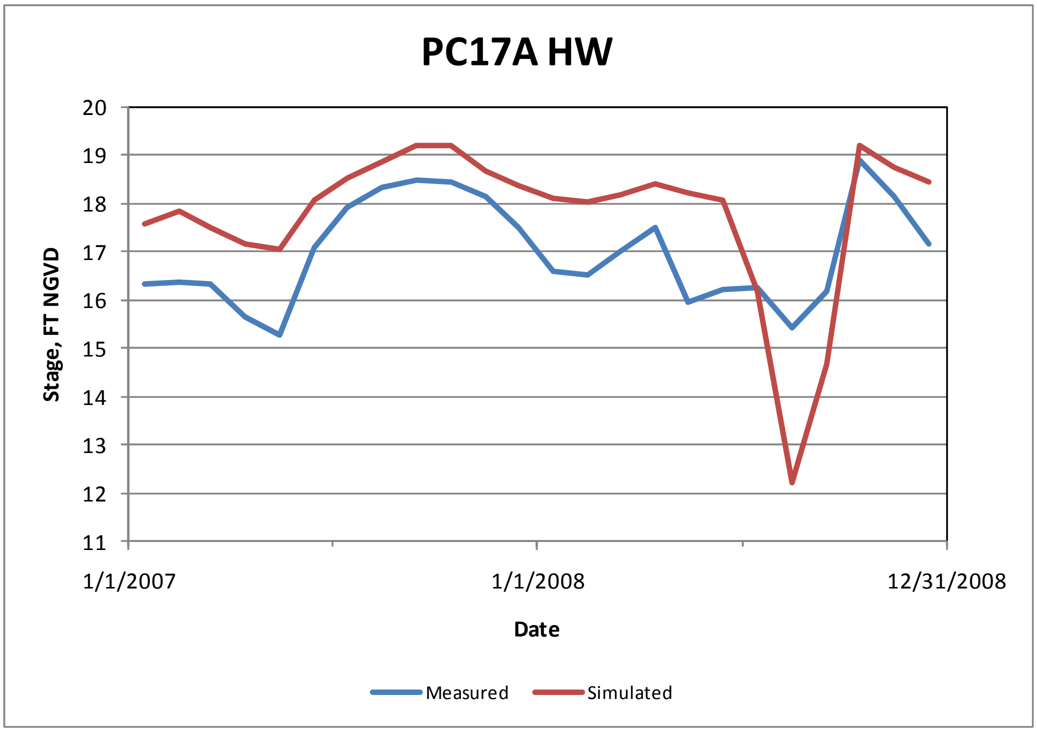


Figure 4.2.84 – PC17A Monthly Stage Validation Plot

Simulated vs Measured Cumulative Flow Comparison Plots

Plots comparing the simulated and measured cumulative flows for selected stations are presented in ***Figures 4.2.85 to 4.2.89***.

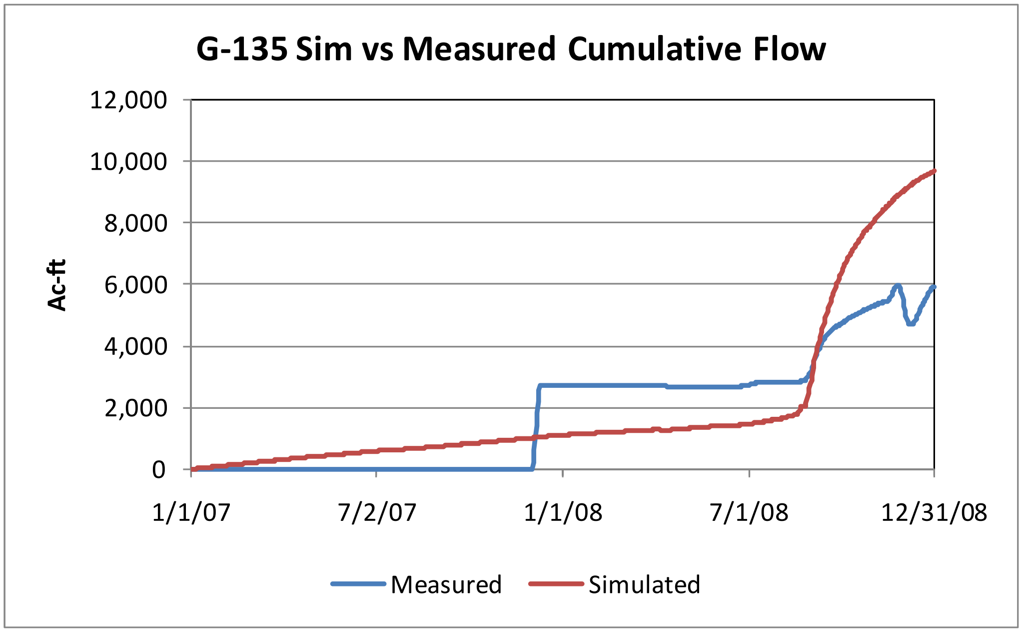


Figure 4.2.85 – S-135 Simulated vs Measured Cumulative Flow Comparison Plot

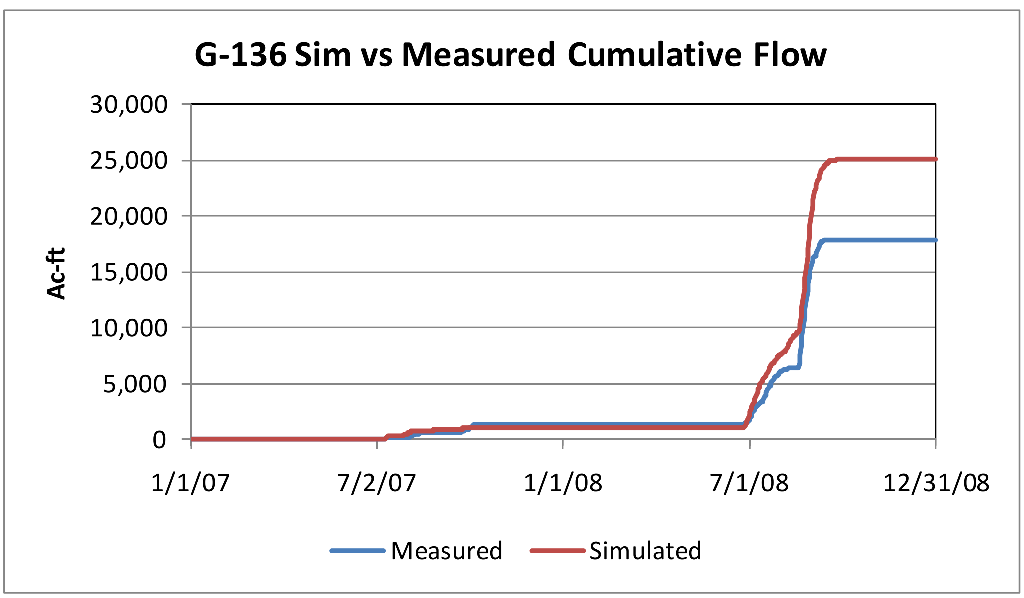


Figure 4.2.86 – G-136 Simulated vs Measured Cumulative Flow Comparison Plot

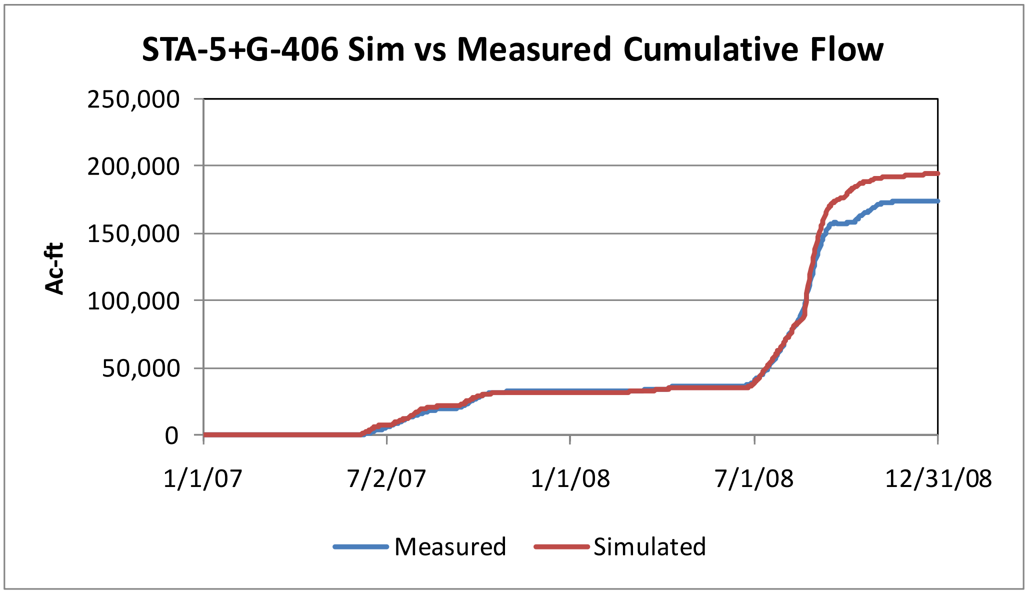


Figure 4.2.87 – STA 5 & G-406 Simulated vs Measured Cumulative Flow Comparison Plot

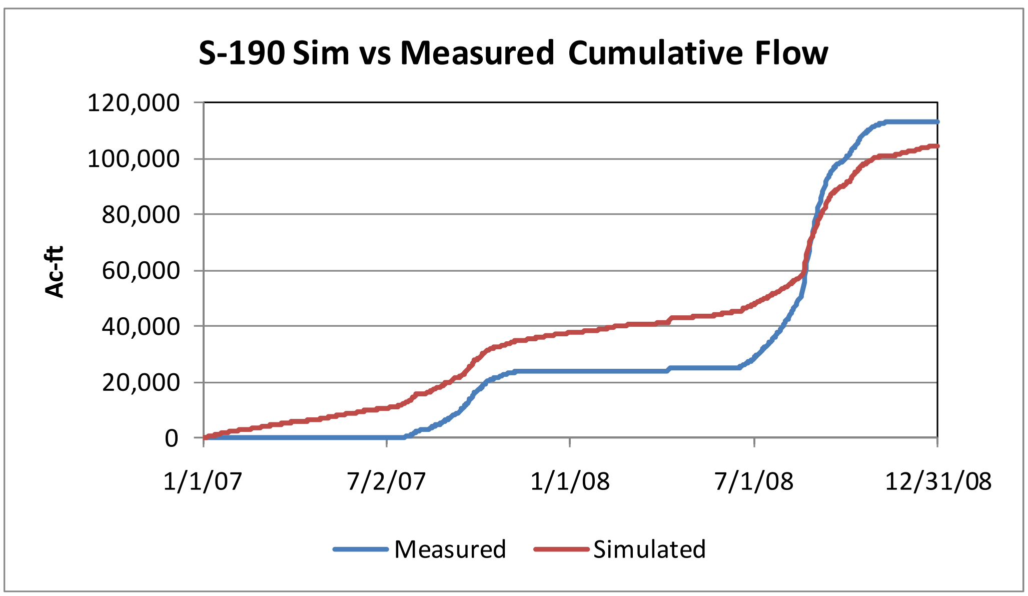


Figure 4.2.88 – S-190 Simulated vs Measured Cumulative Flow Comparison Plot

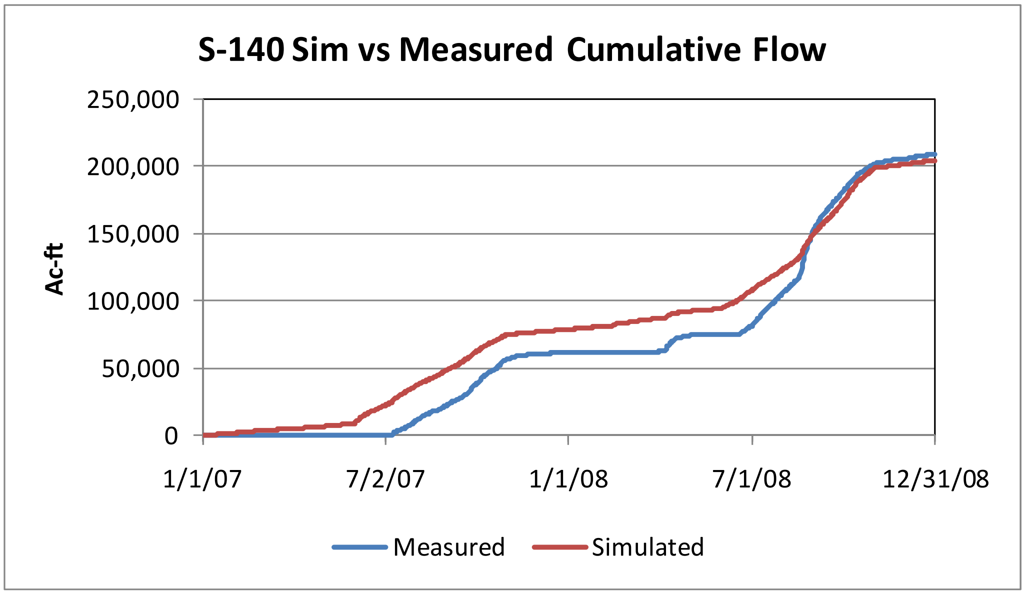


Figure 4.2.89 – S-140 Simulated vs Measured Cumulative Flow Comparison Plot

4.2.4.3.2 Ground Water Validation Statistics

Table 4.2.24 presents a summary of the statistical performance of groundwater stations. The statistical performance of groundwater stations for the validation is slightly worse for ME, MAE, RMSE, and slightly better for correlation coefficient r than the calibration statistics. As with the surface water calibration, the late change in the irrigation routine is believed to be a factor in the decreased level of performance for the validation period. Monthly groundwater level plots for selected stations are presented in ***Figures 4.2.90 to 4.2.98***. Daily groundwater validation Plots are included in ***Appendix C7***.

Table 4.2.24 - Statistical Performance for Groundwater Stations

Station	ME	MAE	RMSE	R
Water Table Aquifer				
HE-854	1.56	1.62	1.77	0.47
HE-856	0.08	0.52	0.63	0.87
HE-860	1.06	1.06	1.25	0.85
HE-862	1.32	1.37	1.45	-0.62
Lower Tamiami Aquifer				
HE-855	0.91	1.04	1.29	0.93
HE-859	1.25	1.86	2.13	0.72
HE-884	-0.77	1.13	1.32	0.68
HE-861	1.13	1.13	1.25	0.85

Notes: Green: high level of performance
Yellow: medium level of performance
White: low level of performance

Water Table Aquifer Validation Plots

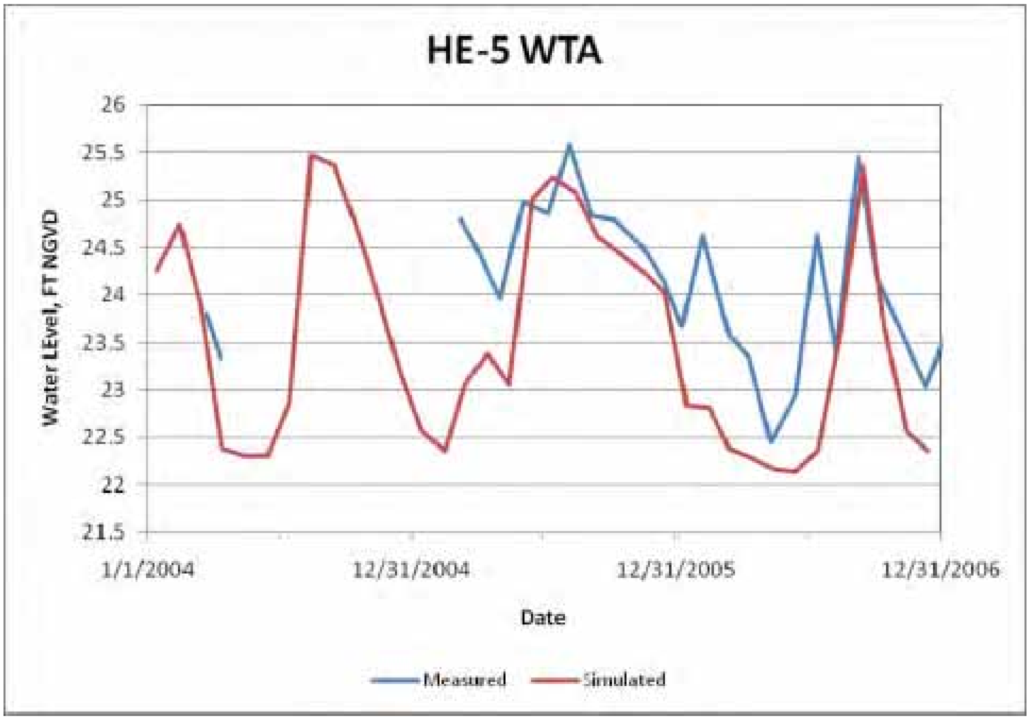


Figure 4.2.90 – HE-5 Monthly Groundwater Level Validation Plot

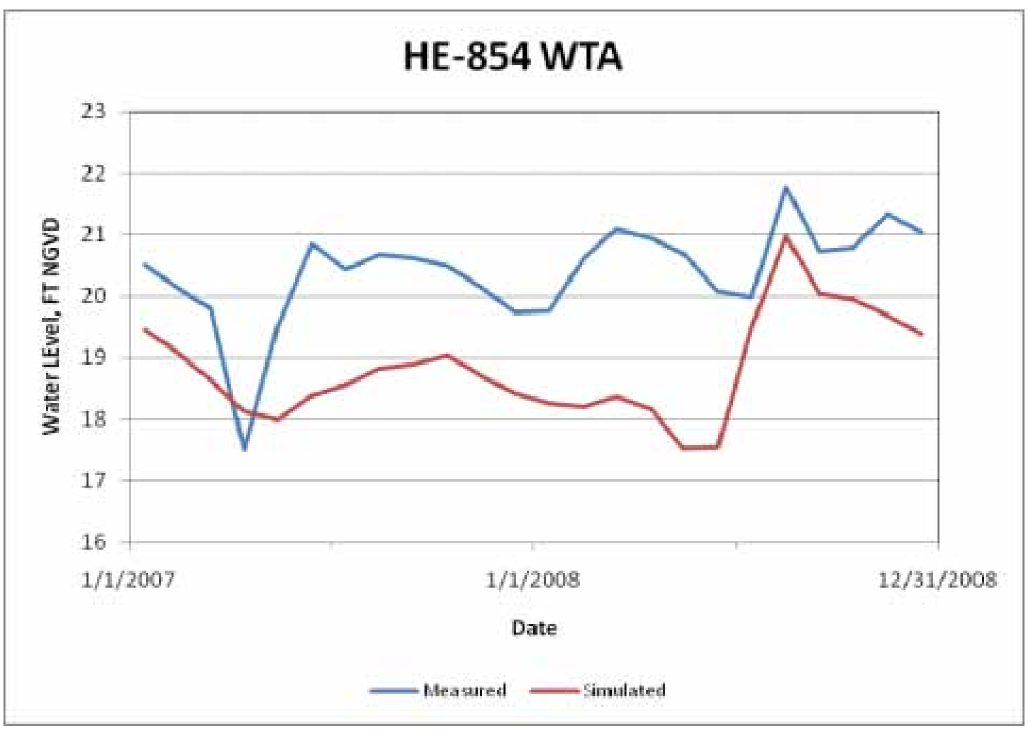


Figure 4.2.91 – HE-854 Monthly Groundwater Level Validation Plot

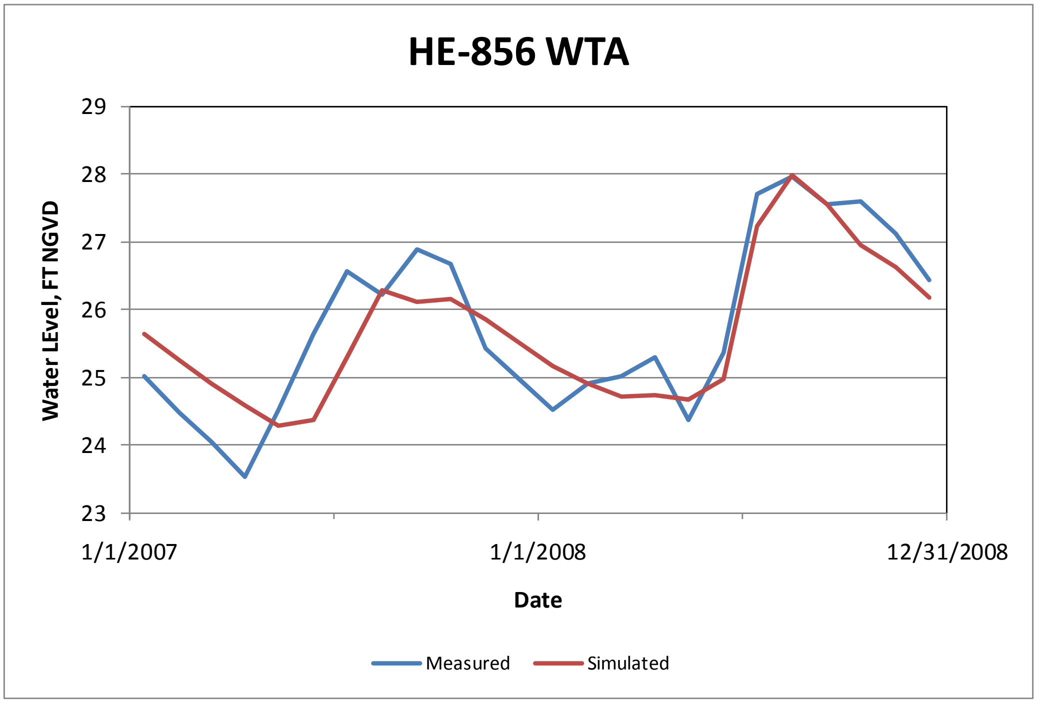


Figure 4.2.92 – HE-856 Monthly Groundwater Level Validation Plot

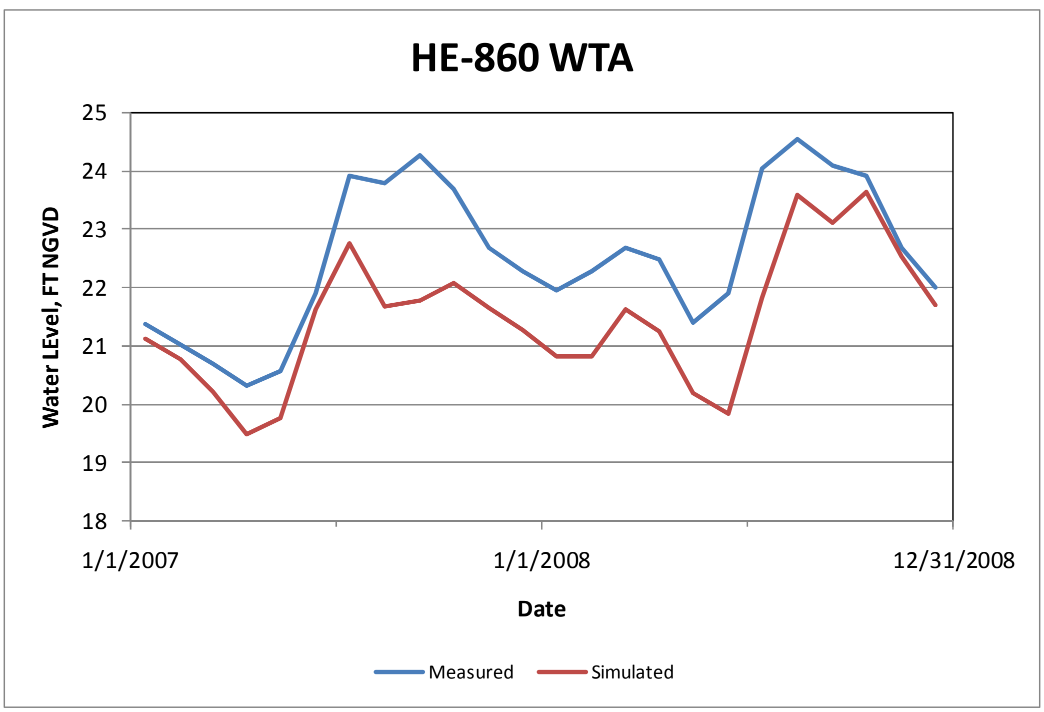


Figure 4.2.93 – HE-860 Monthly Groundwater Level Validation Plot

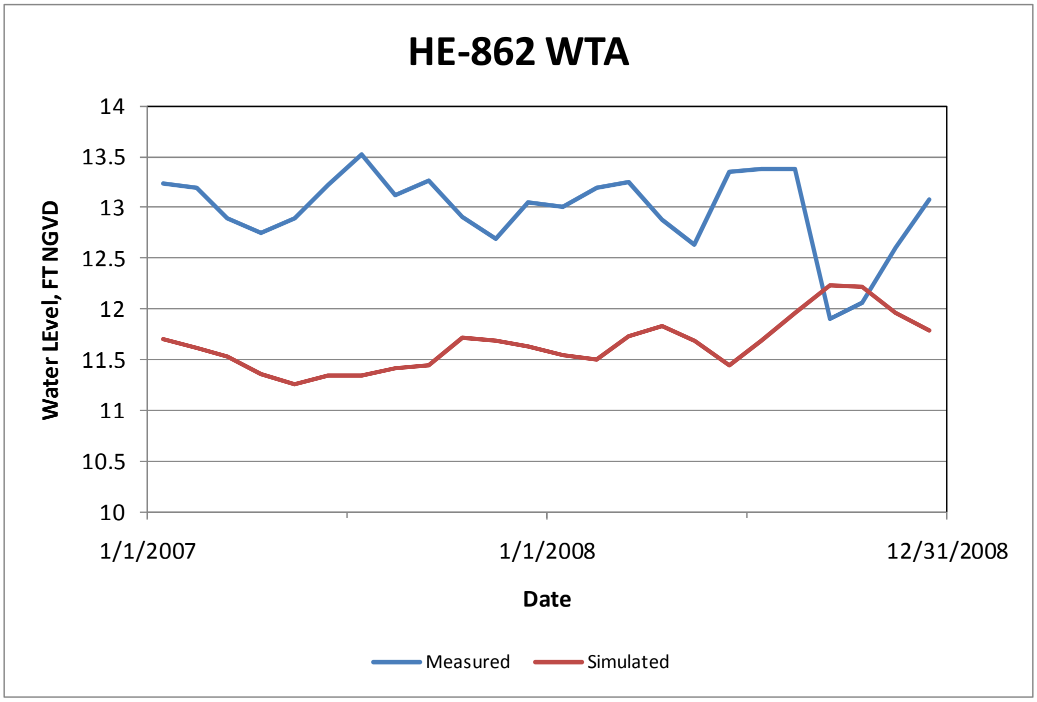


Figure 4.2.94 – HE-862 Monthly Groundwater Level Validation Plot

Lower Tamiami Aquifer Validation Plots

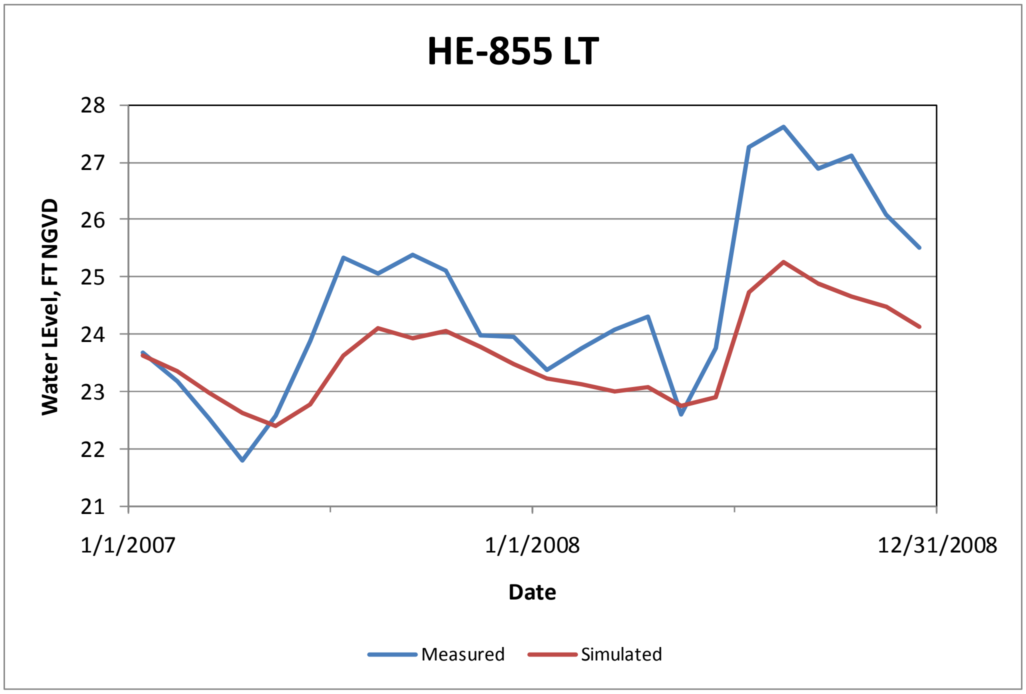


Figure 4.2.95 – HE-855 Monthly Groundwater Level Validation Plot

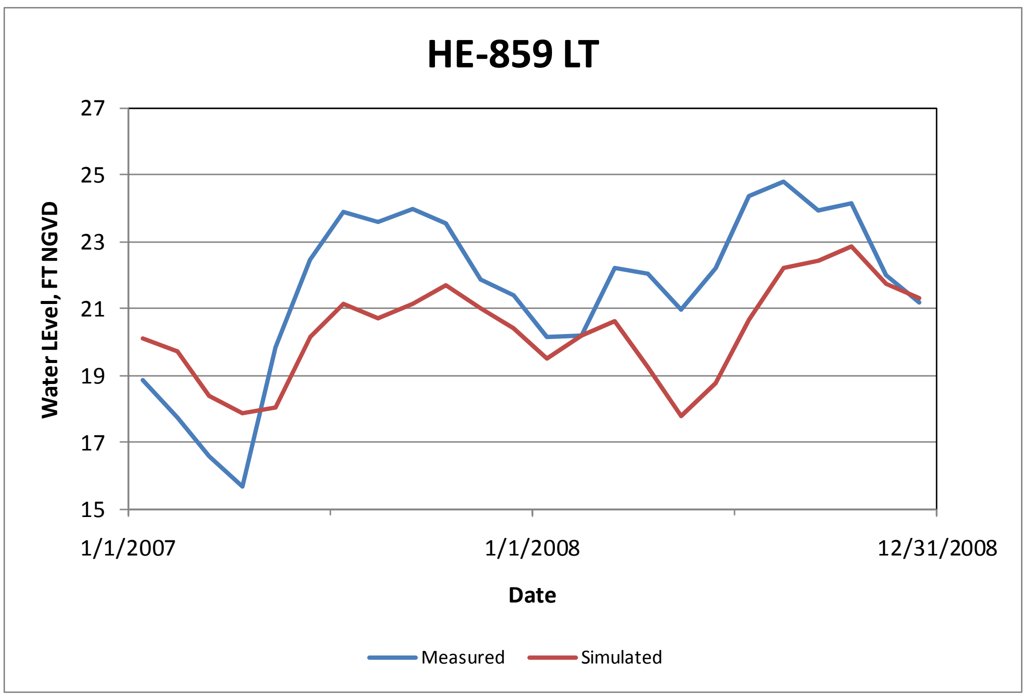


Figure 4.2.96 – HE-859 Monthly Groundwater Level Validation Plot

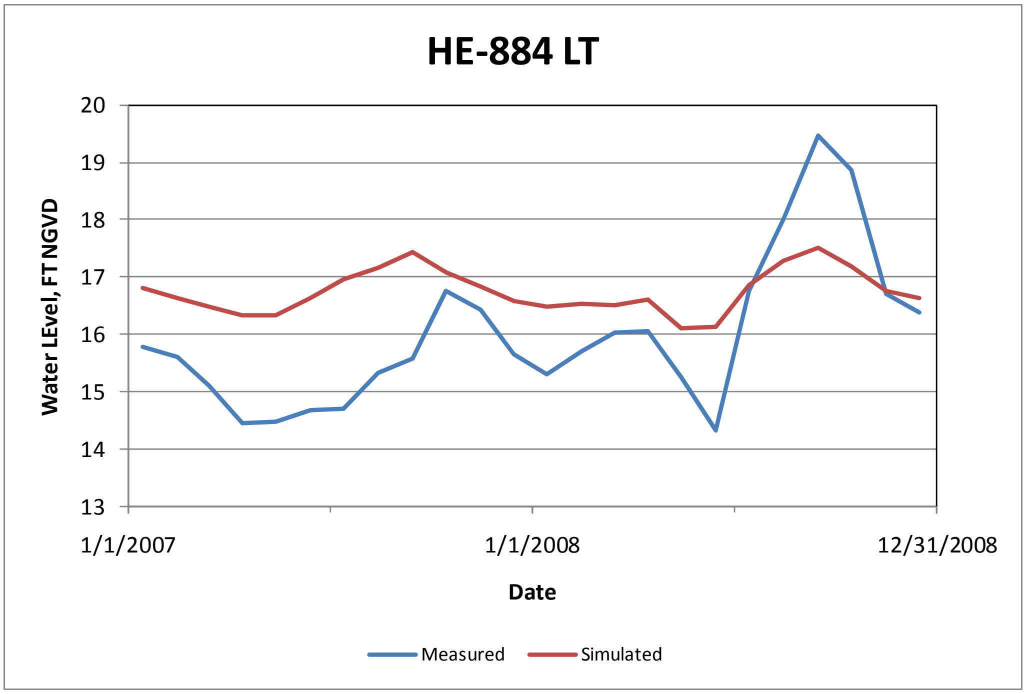


Figure 4.2.97 – HE-884 Monthly Groundwater Level Validation Plot

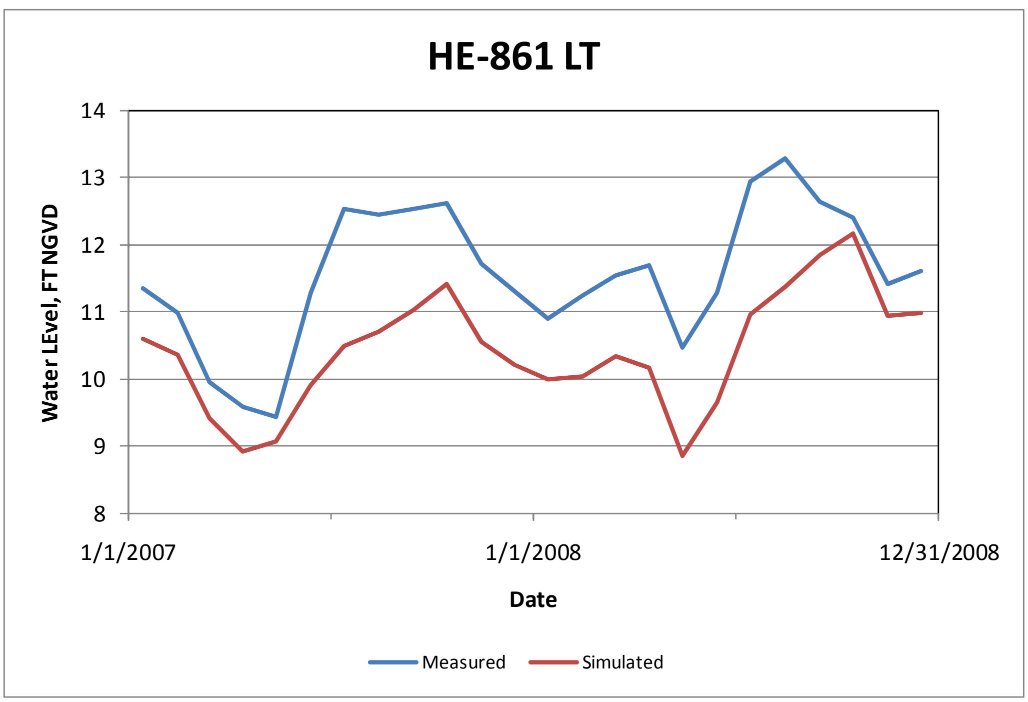


Figure 4.2.98 – HE-861 Monthly Groundwater Level Validation Plot

4.2.5 REFERENCES

ADA Engineering, Inc. 2007. C-139 Basin Phosphorus Water Quality and Hydrology Analysis Deliverable 10.4 – Final Water Quality Improvement Projects Report. Prepared for SFWMD.

AECOM/A.D.A. Engineering, Inc. 2009. South Lee County Watershed Plan Update, Final Report, Prepared for South Florida Water Management District and Lee County.

Burns & McDonnell. 2008. S-4 Basin Feasibility Study. Prepared for the Everglades Agricultural Area Environmental Protection District and South Florida Water Management District. September, 2008.

Chow, Ven Te. 1959. Open Channel Hydraulics. McGraw Hill.

DHI Water and Environment. 2009. MIKE SHE User Manual, Volume 2: Reference Guide. DHI Water and Environment, www.dhigroup.com.

Goforth, G. (2008). Operation Plan – Integrated Stormwater Treatment Areas 5 & 6. Prepared for SFWMD by Gary Goforth, Inc., October, 2008

Jain, S. K., K.P, Sudheer, 2008, Fitting of Hydrologic Models: A Close Look at the Nash-Sutcliffe. American Society of Civil Engineers Journal of Hydrologic Engineering
Johnson – Prewitt & Associates, Inc. 2001. Devil's Garden Water Control District – District Facilities Map, Plate B.

Krause, P., D.P. Boyle, F. Base, 2005, Comparison of Different Efficiency Criteria for Hydrological Model Assessment, Advances in Geosciences, European Geosciences Union.

Marco Water Engineering, Inc. 2005. Lower West Coast Surficial Aquifer System Model. Prepared for SFWMD by Marco Water Engineering and Ecology and Environment, Inc.

McCuen R. H., Knight Z., and Cutter A. G., 2006, Evaluation of the Nash-Sutcliffe Efficiency Index. American Society of Civil Engineers Journal of Hydrologic Engineering

Radin, H. Rodberg, K. 2009. C-139 Model Runs, SFWMD, Executive Summary and Model Files.

Jeff Giddings, personal Information, , SFWMD. Files e-mailed by Tom Kosier, Nov. 12, 2008.

Reese, R.S., and K.J. Cunningham. 2000. Hydrogeology of the Gray Limestone Aquifer in Southern Florida, Water Resources Investigations Report 99-4213, USGS.

Schaefli B. and Gupta H. V., 2007, Do Nash Values Have Value? Hydrological Processes, John Wiley & Sons, Ltd.

SCS. 1986. Urban Hydrology for Small Watersheds, Technical Release 55.

SDI Environmental Services, Inc., BPC Group, Inc, and DHI, Inc. 2008. Southwest Florida Feasibility Study Integrated Hydrologic Model – Model Documentation Report. Prepared for SFWMD.

SFWMD. Undated. SFWMD Structure Books. Operations Control Center.

SFWMD. 2004. Operation Plan, Stormwater Treatment Area-3/4.

SFWMD a. 2009. Hydrogeologic Assessment of the Crooks and Golden Ox Ranches, Hendry County, FL, Technical Publication WS-28. SFWMD Water Supply Department Staff.

SFWMD b. 2009. McDaniels Ranch Permit 26-00623-P, SFWMD e-permitting web site, http://my.sfwmd.gov/ePermitting/MainPage.do.

SFWMD c. 2009. South Florida Environmental Report, Chapter 4 – Phosphorus Source Controls for the South Florida Environment.

SFWMD. 2010. DBHYDRO Data Retrieval System. http://www.sfwmd.gov/dbhydroplsql/show_dbkey_info.main_menu.

SFWMD e-permitting web site, http://www.sfwmd.gov/portal/page/portal/levelthree/permits

Southwest Florida Feasibility Study (SWFFS) GIS Hydrostratiographic files
EarthFX and BEM Systems. 2003. Hydrostratigraphy Review Report. Letter Report to Clyde Dabbs, SFWMD, from Maged Hussein, BEM 11785 Saint Andrews Place, #101, West Palm Beach, FL 33414.

URS. 2008. Compartment C Stormwater Treatment Area Final Design Report.

4.3 Modeling

4.3.1 INTRODUCTION

Section 4.2 - Calibration and Validation described the integrated MIKE SHE/MIKE 11 surface/ground water model that was developed to evaluate the hydrology and hydraulics of the study area. The model has the ability to evaluate surface water hydrology, canal and Stormwater Treatment Area (STA) hydraulics, wetland water levels and hydroperiods, interior farm detention, and groundwater and surface water responses to agricultural irrigation. The model was constructed and calibrated to enable the study team to evaluate a range of alternative watershed management improvement scenarios specifically to address hydrologic, hydraulic, and groundwater responses resulting from implementation of those alternatives.

This section includes a baseline simulation utilizing existing land-uses and ran for a 41-year period of record (1965 to 2005) or "Long Term Baseline", as presented in ***Section 4.3.2***. A parallel task provided a simple spreadsheet water quality assessment tool to evaluate water quality responses for the water management alternatives; see ***Section 4.3.3***. ***Section 4.3.4*** presents twenty one (21) watershed management alternatives from which four (4) alternatives will be selected. The selected alternatives will be evaluated with the MIKE SHE/MIKE 11 model and the water quality spreadsheet analysis in Phase II. ***Appendix D3*** presents the additional information requested by the District's review team for the Calibration & Validation Technical Memorandum. This includes removing pasture irrigation and re-running the model calibration; annual and monthly water budget for the C-139 and selected farms; and an explanation of the procedure to add farms and Above Ground Impoundments (AGI)s to the model.

The goal of this project is to develop a baseline model that characterizes the study area hydrology, water supply, and water quality. Based on analysis performed during the Model Selection exercise in ***Section 2.4***, it was decided that the MIKE SHE/MIKE 11 model would provide the most comprehensive detailing of a fully integrated surface water and groundwater interaction analysis for the C-139 Region. The model will be open-ended so that it can continue to be refined as additional data is received during later phases of the project. Based on the Model Selection exercise and the scope of work, a simple spreadsheet water quality assessment tool will be utilized to evaluate water quality responses for the water management alternatives.

4.3.2 C-139 LONG TERM BASELINE MODEL

The long-term baseline model represents the response of the watershed for existing conditions (2010) to a rainfall time series from 1965 to 2005. Because the existing conditions hydraulic control structures and land use conditions were assumed to be constant or operating for the entire simulation period, this baseline model does not represent measured actual conditions. It provides an estimate of the range of flows and stages that might be observed if the existing system was constant for a 41-year period.

4.3.2.1 Model Input

Model files were essentially the same as the files presented in ***Section 4.1 – Model Set-Up*** and/or ***Section 4.2 – Calibration and Validation***, unless calibration files could not be used. This section presents only the model inputs that are different to those presented in the Calibration and Validation TM.

The precipitation and potential evapotranspiration files had to be changed as described below. Surface water hydraulic control structures for the calibration and validation models were initially set to operate exactly as reported in the SFWMD Structure Manual. However, this was an area where changes were also required for the long term model.

4.3.2.1.1 Precipitation and PET.

Precipitation from gages DEVILS_R and ALICO_R were used for all the stations. This was based upon a long term analysis of all gages used during the calibration and validation model time period as described below.

For the long term precipitation the modeling team originally used the following six rain gages for the entire model domain.

- Townsite (DBKEYS 5819, 5820, 6882, and 16205),
- Devils (DBKEY 06079),
- Alico (DBKEYS 5869 and 16224),
- Immokalee (DBKEYS 6195 and DU523),
- S-8 (DBKEYS 6327 and 15205), and
- 3A-S used four DBKEYS 5865, 5882, JA334, and 5959.

Many of the gages had gaps in data which were initially filled with data from the Devils rain gage. The Devils gage was chosen to fill the other stations because that rain gage had the most complete set of data out of all the rain gages chosen. After closer examination of the long term rainfall, a data quality check indicated that the annual sums were inconsistent. Further analysis indicated that some rain gages had weekly rainfall totals instead of daily totals. Accordingly, the most reliable gages for the run were Devils and Alico; therefore only these two rain gages were used for long term analysis of all rain gage locations used for the calibration and validation Thiessen Polygons shown in ***Figure 4.3.1***.

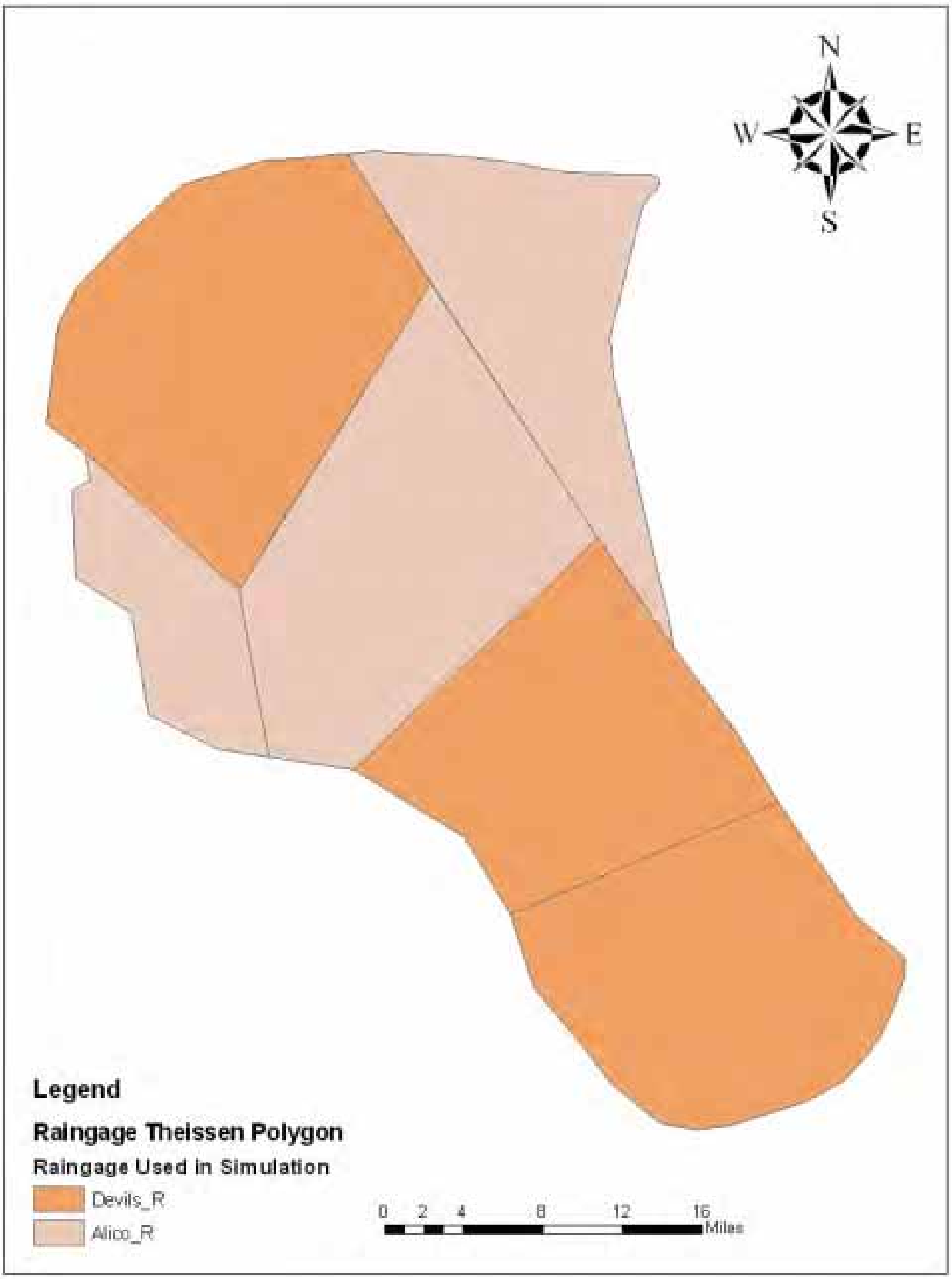


Figure 4.3.1 – MIKE SHE Precipitation Thiessen Polygons

Long term PET data was not available for the 65 years period; therefore, 2008 values were looped for each PET gage for the long term simulation. The PET gages chosen were the same ones used for the Thiessen Polygons in the calibration and validation models shown in ***Figure 4.3.2***.

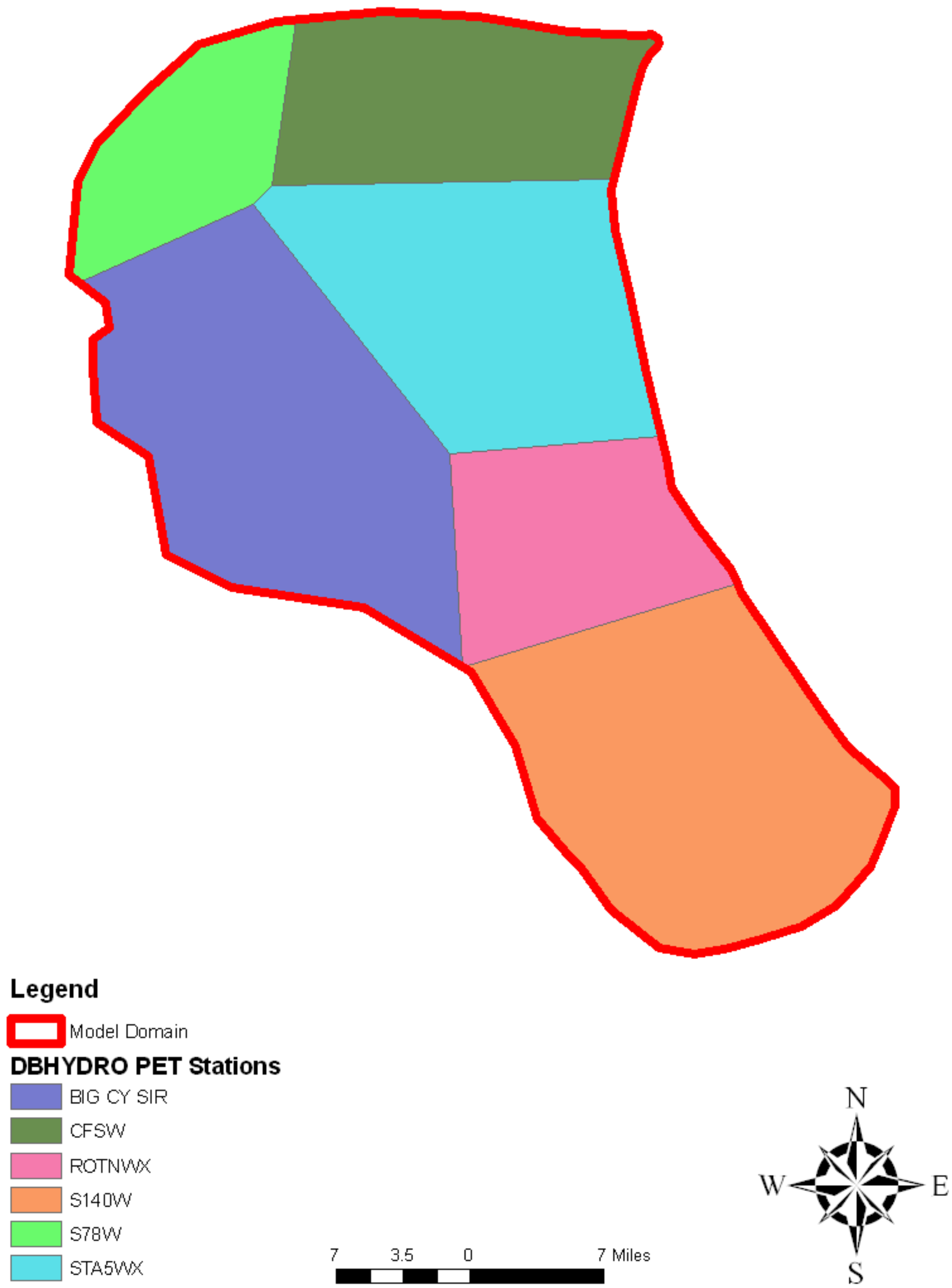


Figure 4.3.2 – MIKE SHE PET Thiessen Polygons

4.3.2.1.2 Saturated Zone

Very few groundwater wells were available starting in 1965; therefore groundwater boundary time series utilized 2008 data looped for the entire model period for the stations used in the calibration validation model shown in ***Figure 4.3.3***.

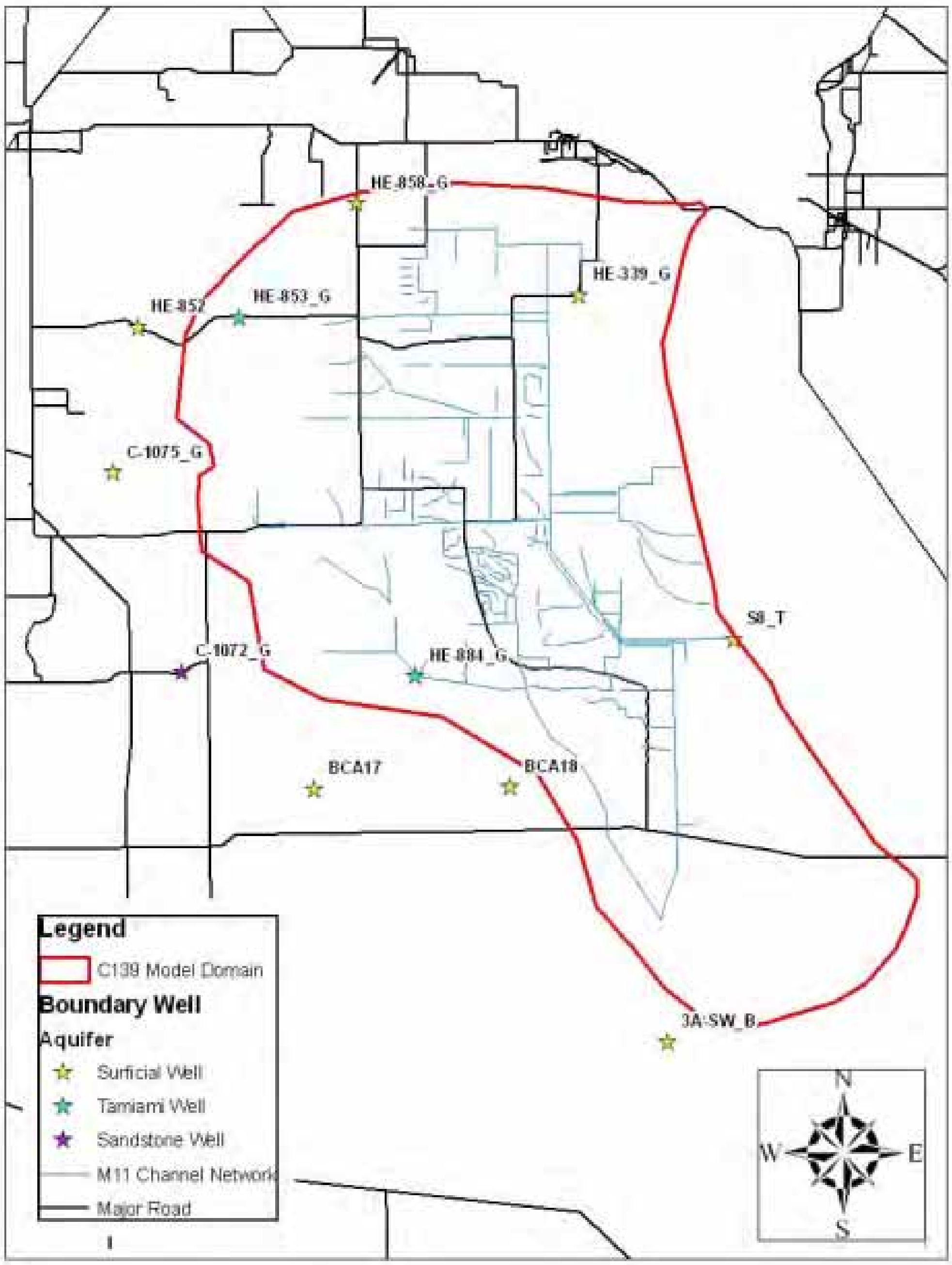


Figure 4.3.3 – Groundwater Monitoring Stations

4.3.2.1.3 Surface Water

The surface water system used in the Long Term Baseline model represents conditions existing in 2010. STA-5 flow-way 3, STA-6 Section 2, and G-407 are operational. G-406 is open during most times so that STA-5 Cell 3 receives runoff during all events. The C-139 Annex pump station is not operational.

The surface water boundary file has looped 2008 data for all time-varying boundaries. Hydraulic control structures were changed to run off logical operands for the long term model. These structures were: G-135, G-96, G-136, G-150, G-151, STA-5 structures, G-406, STA-6 structures, G-407, G-409, Seminole Pump E1, and S-140. S-190 was already operating using logical operands, and was therefore not changed. These structures logical operands were acquired from the SFWMD Structures Book or the STA 5/6 Integrated Operation Plan. If the structure was in the structure book we tried to represent the gate operations stated in the book. G-135 operation is as defined in the SFWMD Structure Book although it is known that actual operation rarely follows the Structure Book operation schedule. On average, baseline flows for the 1965 – 2005 period were significantly less than measured flows.

If the structure operation was not provided in the Structure Book, measured data were interpreted to develop gate operations for the structure. G-409 does not have a defined pump operation schedule, therefore it was assumed that G-409 would only operate when there was positive flow in the L-3 Canal at Confusion Corner, and that the G-409 flow would be up to a maximum of 130 cfs. The maximum G-409 flow used in the model was reduced from the known capacity of 190 cfs to 130 cfs based on a comparison of measured and simulated flows of a test run when measured data were available. Actual deliveries from confusion corner via G-409 are typically during the dry season, however decision factors for pump operation do not fit any known protocol, therefore the operation of this structure was set to replicate the average annual pump rates rather than the average monthly pump rates.

4.3.2.2 Model Results

Model results are presented in graphical format for the compliance discharge points of the study area. ***Figures 4.3.4 to 4.3.35*** present the results of the Long-Term Baseline. The model files are included in the model data DVDs enclosed in ***Appendix D1 Long Term Run***. ***Figures 4.3.36 to 4.3.39*** presents the flows for G-409. These results are presented because the operation of the G-409 structure was developed based on best professional judgment.

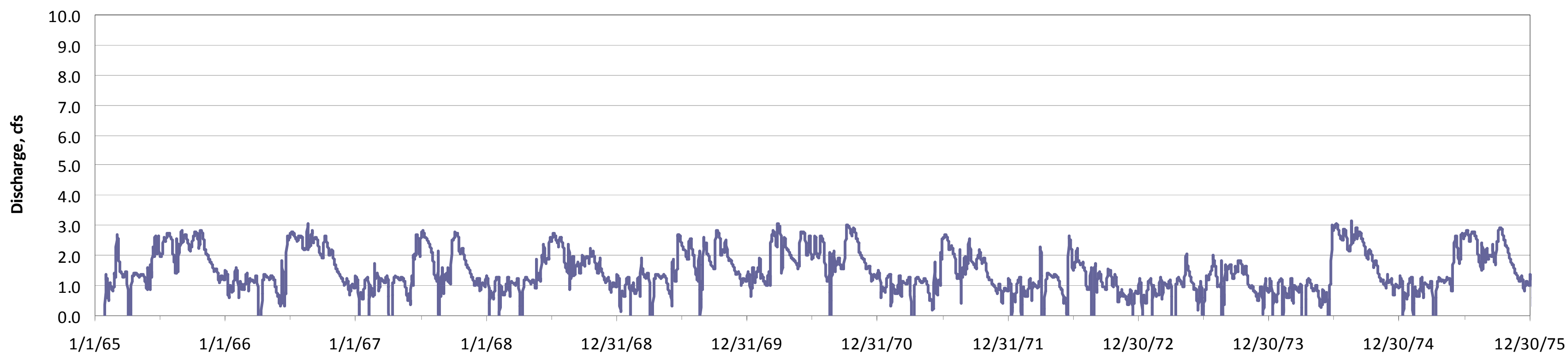


Figure 4.3.4 – G-135 Flows, 1965-1975

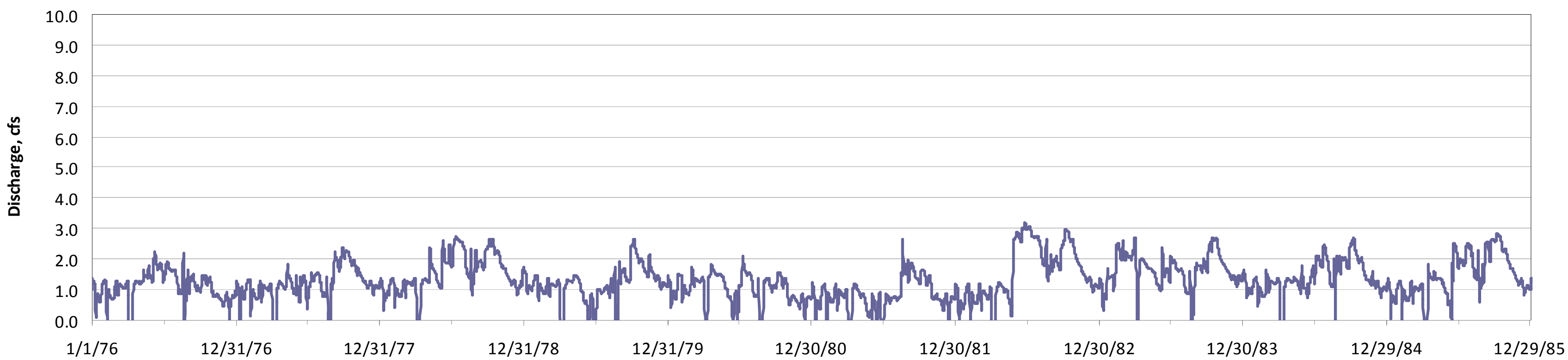


Figure 4.3.5 – G-135 Flows, 1976-1985

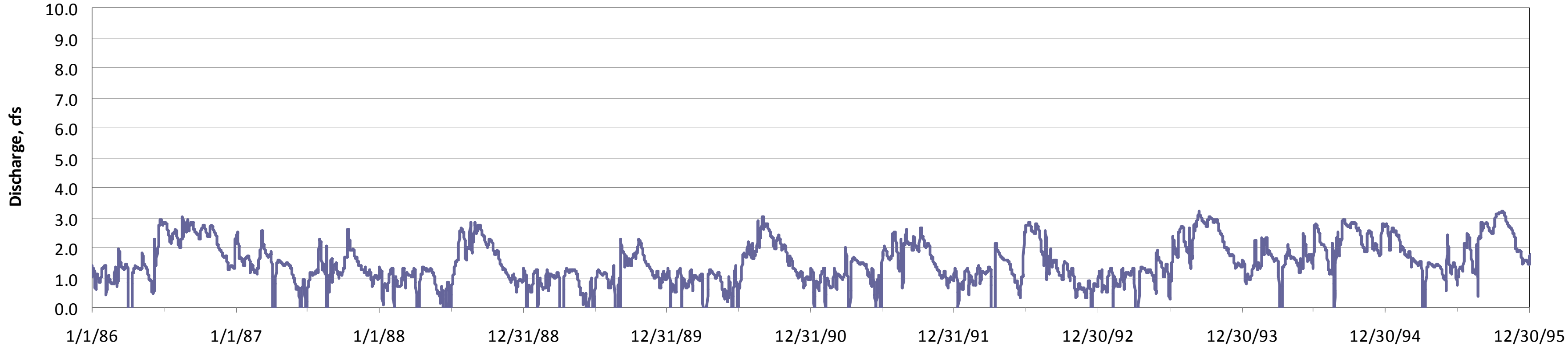


Figure 4.3.6 – G-135 Flows, 1986-1995

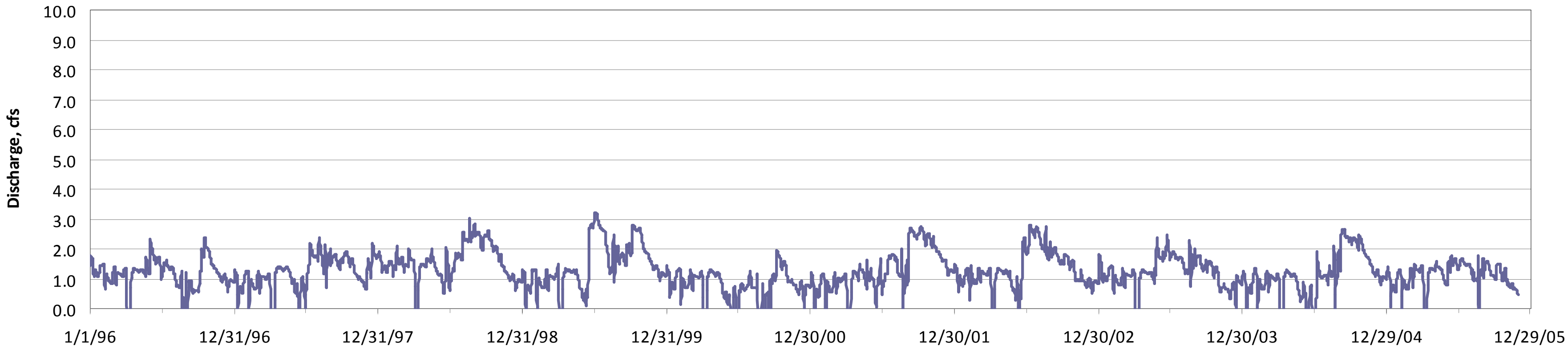


Figure 4.3.7 – G-135 Flows, 1996-2005

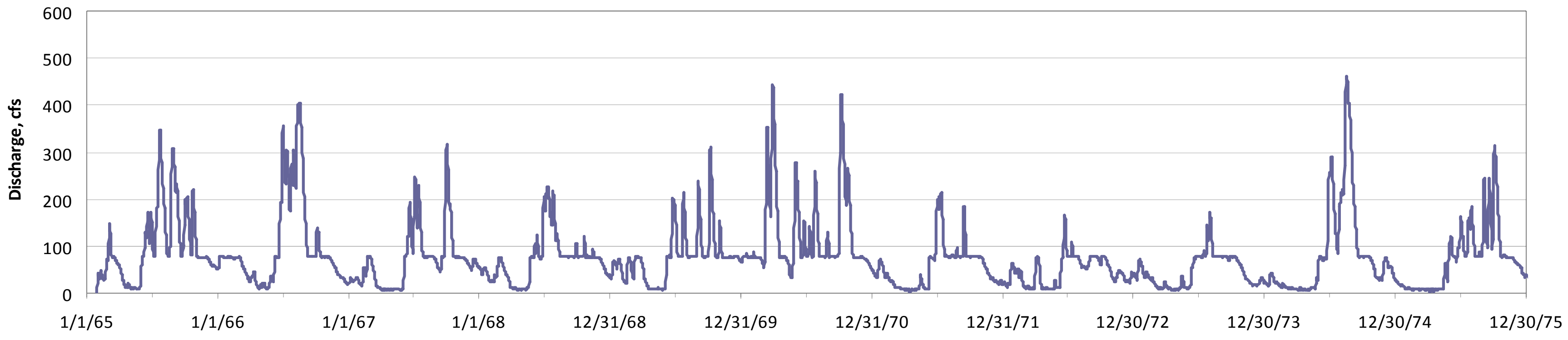


Figure 4.3.8 – G-136 Flows, 1965-1975

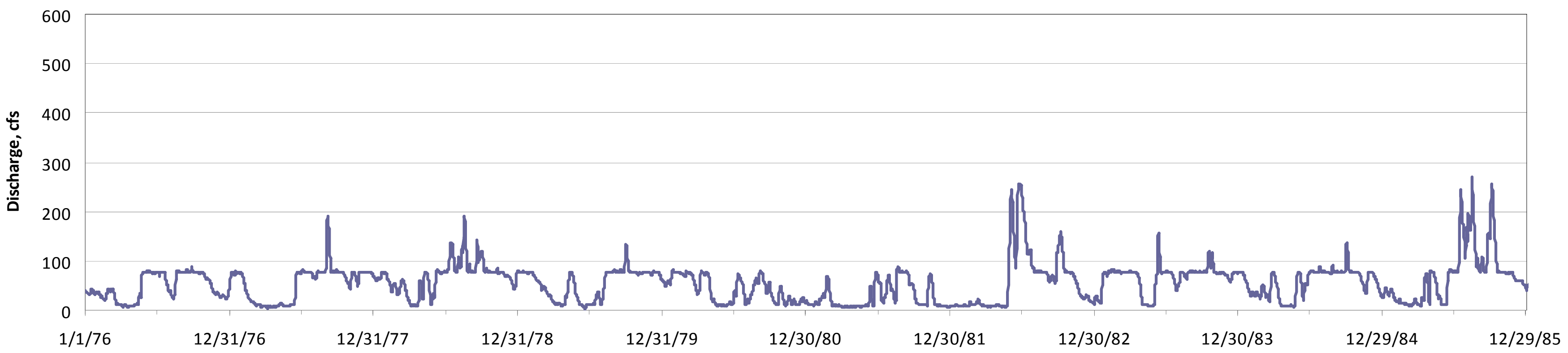


Figure 4.3.9 – G-136 Flows, 1976-1985

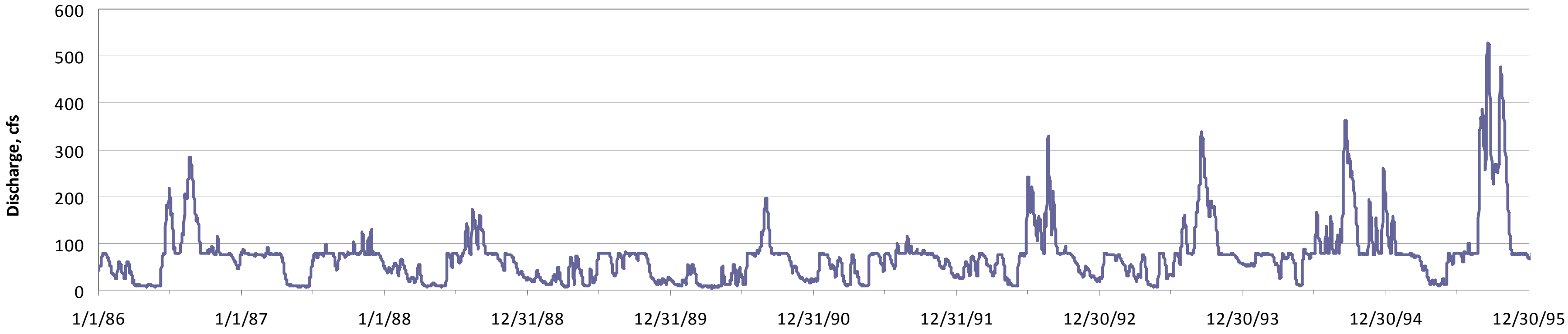


Figure 4.3.10 – G-136 Flows, 1986-1995

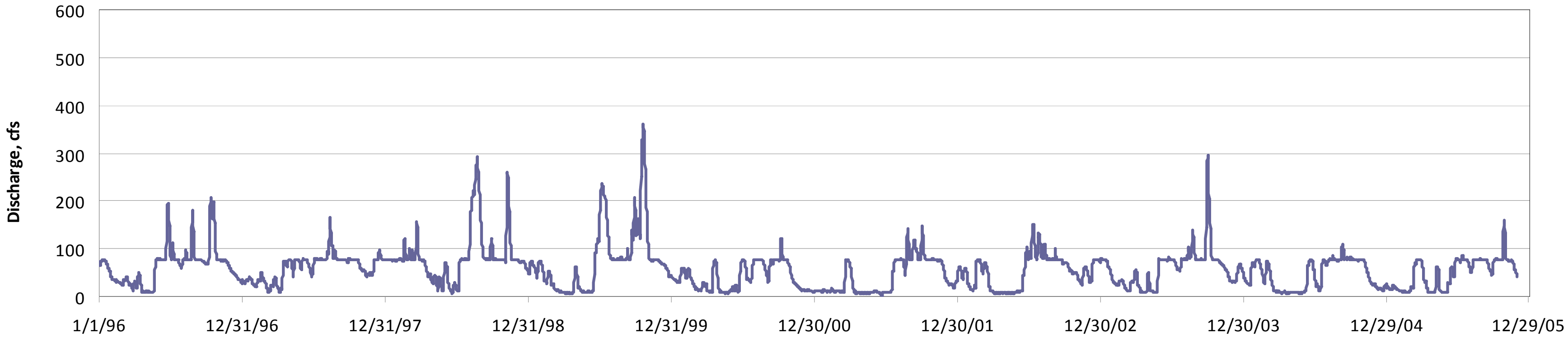


Figure 4.3.11 – G-136 Flows, 1996-2005

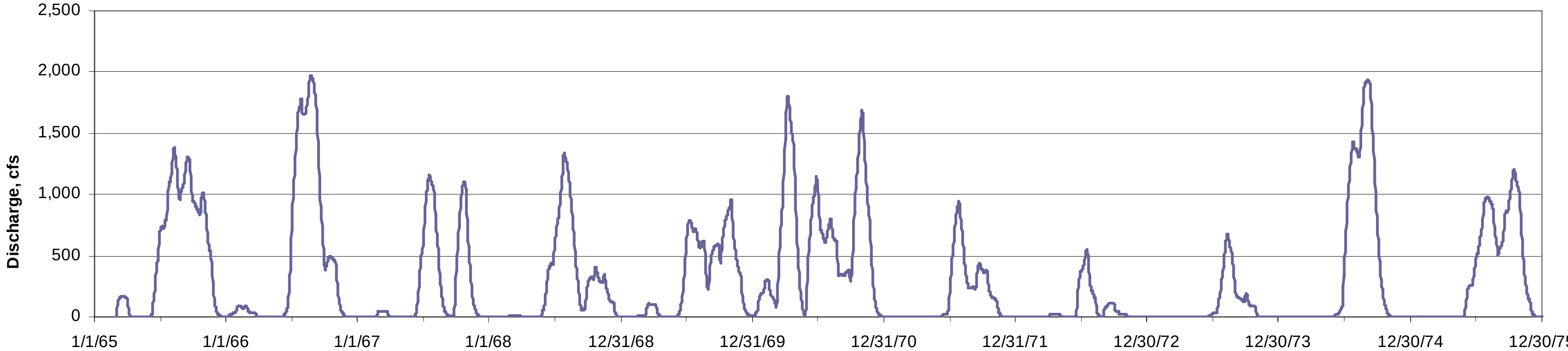


Figure 4.3.12 – STA 5 (G-342 A–D) & G-406 30-Day Rolling Avg. Flows, 1965-1975

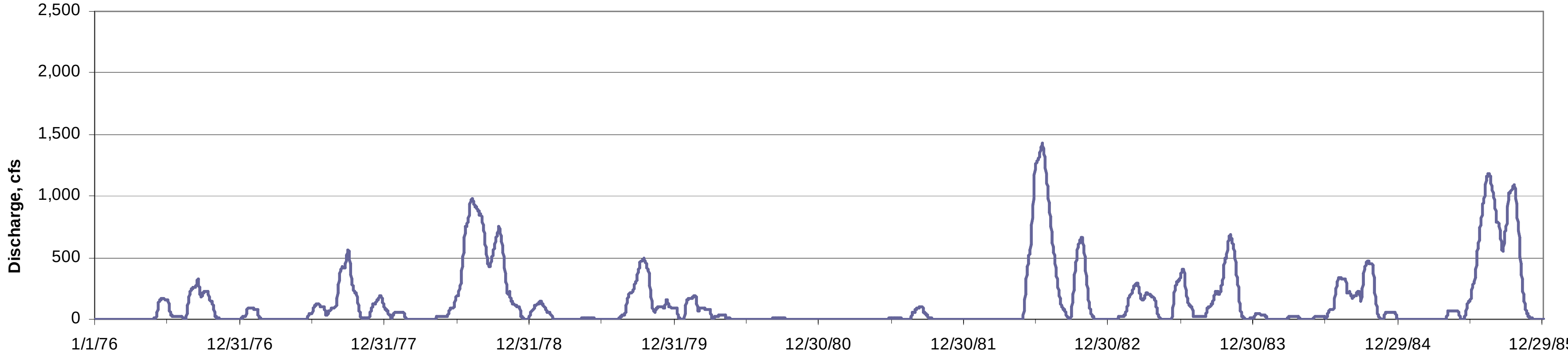


Figure 4.3.13 – STA 5 (G-342 A–D) & G-406 30-Day Rolling Avg. Flows, 1976-1985

URS

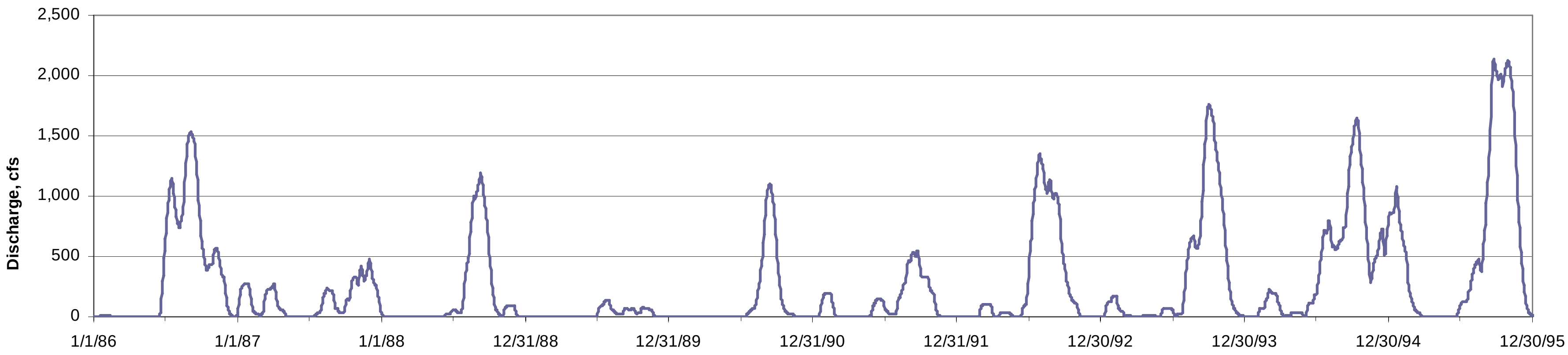


Figure 4.3.14 – STA 5 (G-342 A–D) & G-406 30-Day Rolling Avg. Flows, 1986-1995

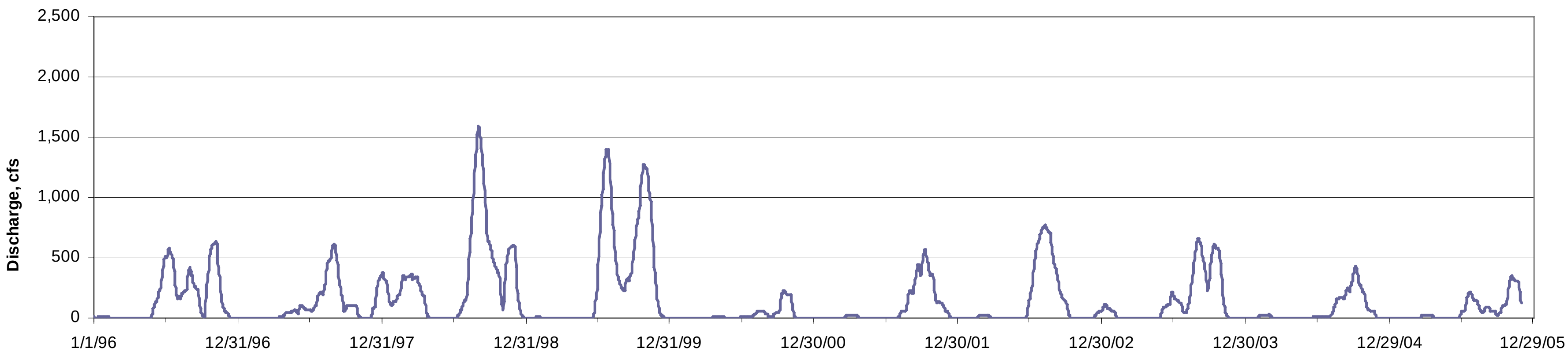


Figure 4.3.15 – STA 5 (G-342 A–D) & G-406 30-Day Rolling Avg. Flows, 1996-2005

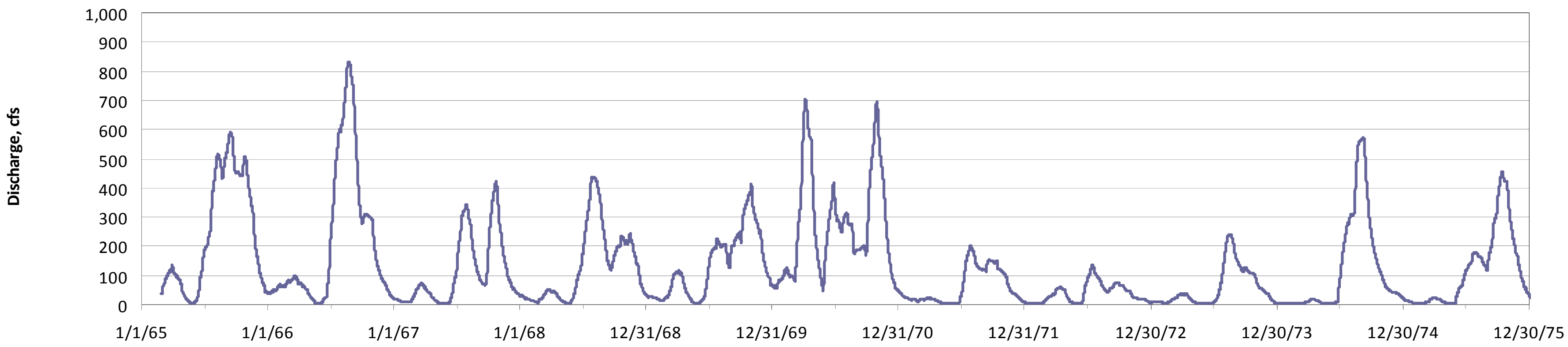


Figure 4.3.16 – S-190 30-Day Rolling Avg. Flows, 1965-1975

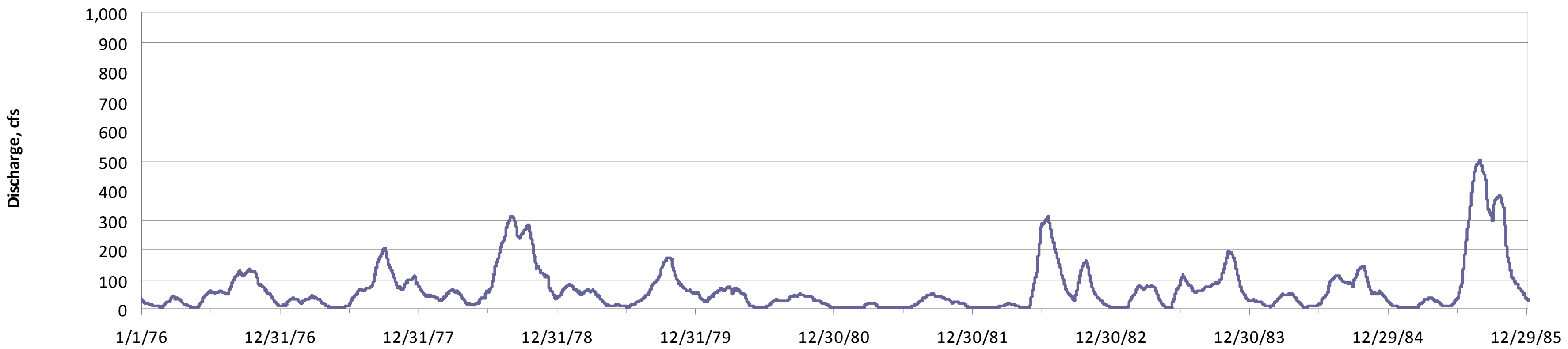


Figure 4.3.17 – S-190 30-Day Rolling Avg. Flows, 1976-1985

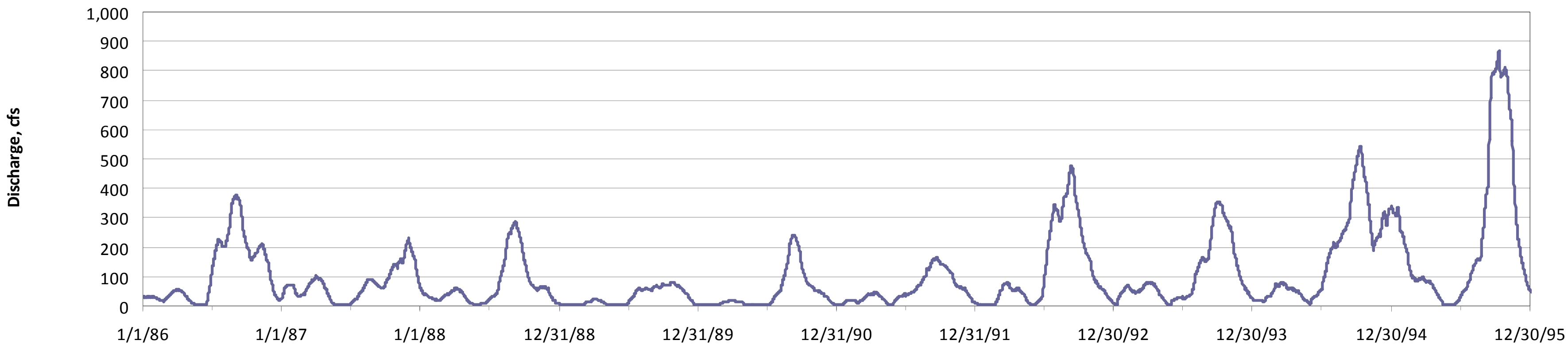


Figure 4.3.18 – S-190 30-Day Rolling Avg. Flows, 1986-1995

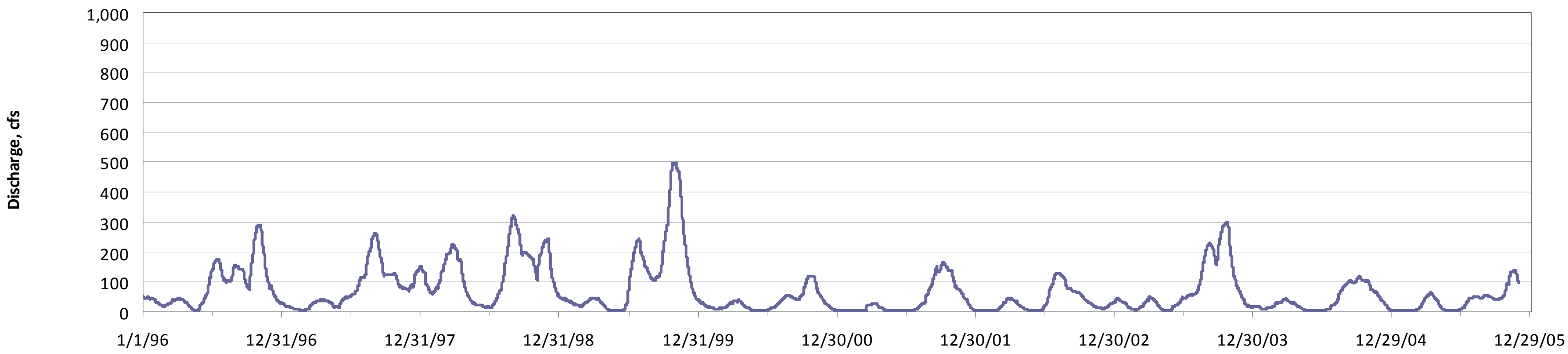


Figure 4.3.19 – S-190 30-Day Rolling Avg. Flows, 1996-2005

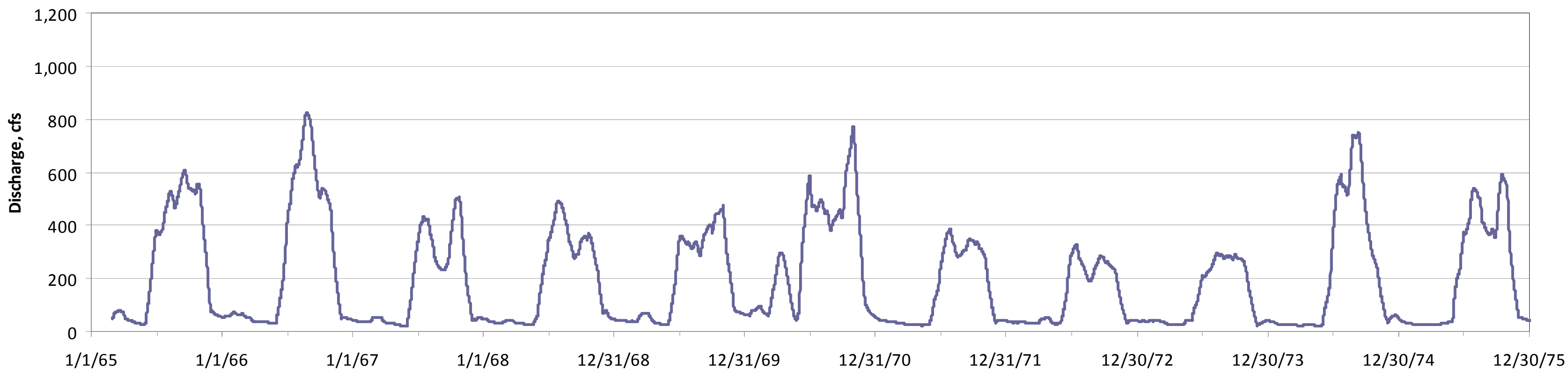


Figure 4.3.20 – S-140 30-Day Rolling Avg. Flows, 1965-1975

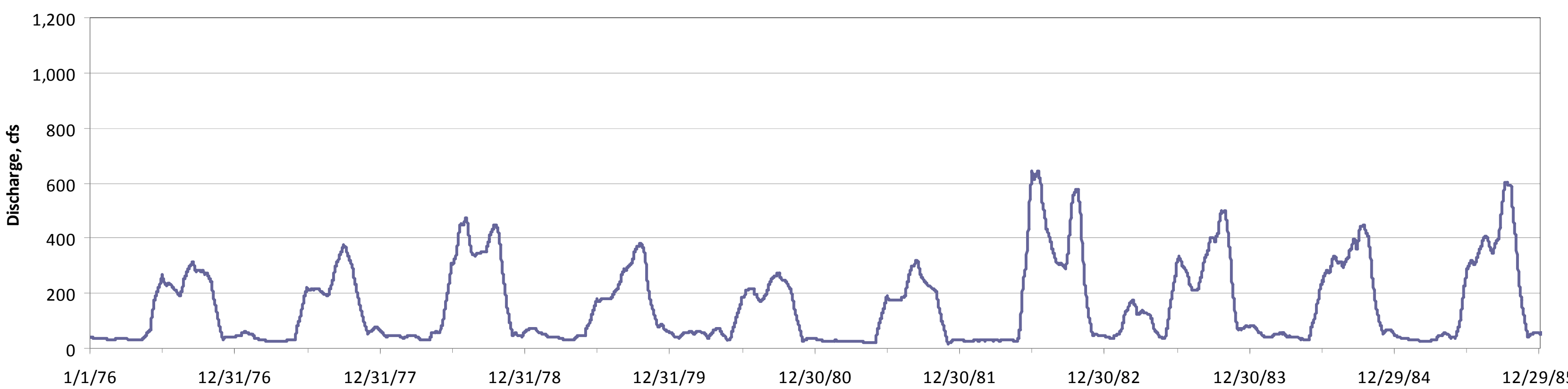


Figure 4.3.21 – S-140 30-Day Rolling Avg. Flows, 1976-1985

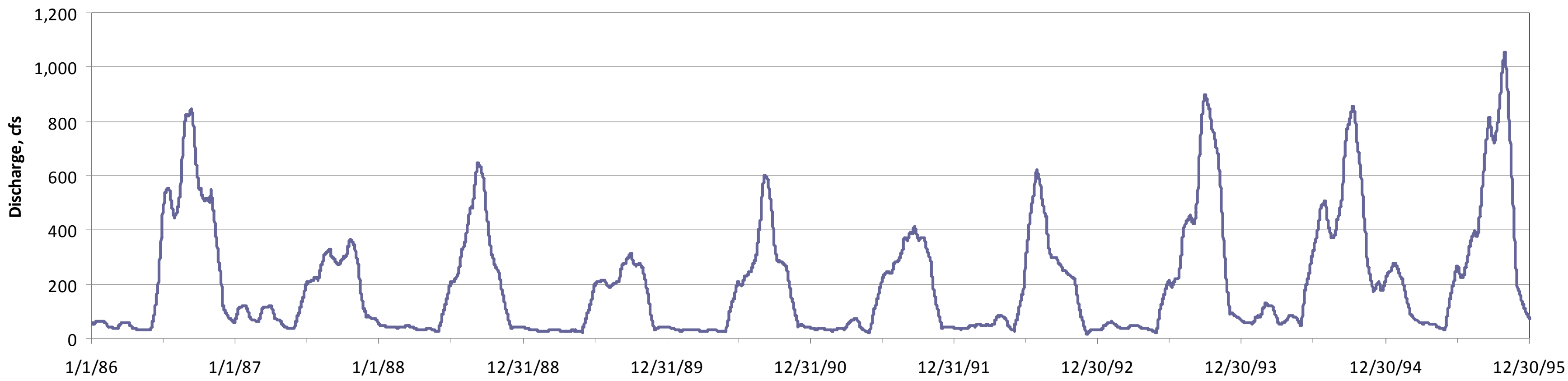


Figure 4.3.22 – S-140 30-Day Rolling Avg. Flows, 1986-1995

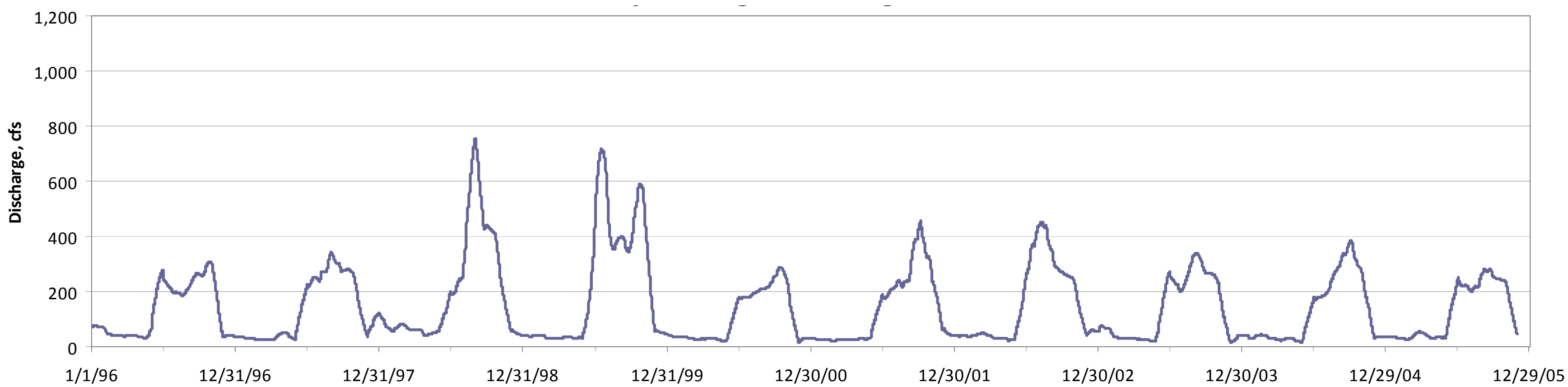


Figure 4.3.23 – S-140 30-Day Rolling Avg. Flows, 1996-2005

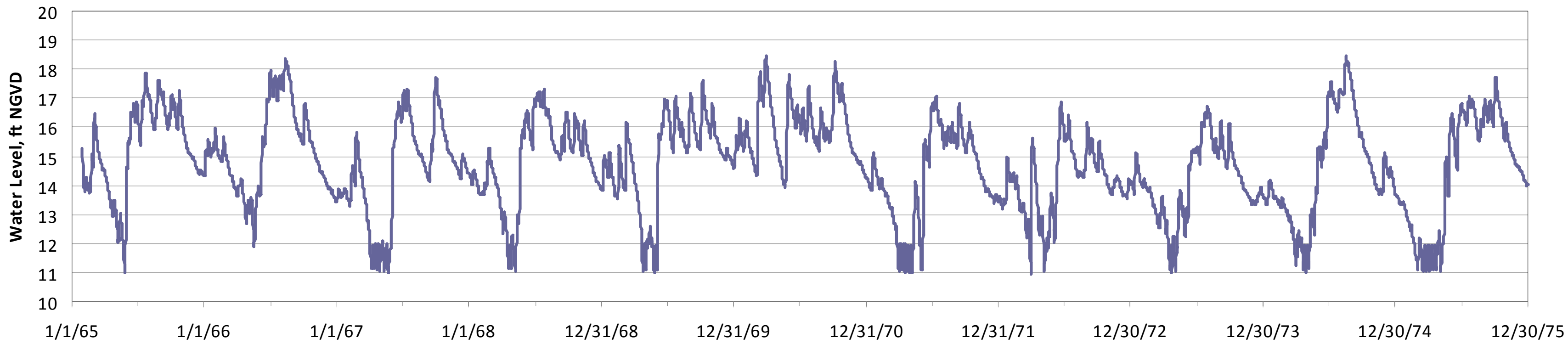


Figure 4.3.24 – G-342C & G-342D Headwater, 1965-1975

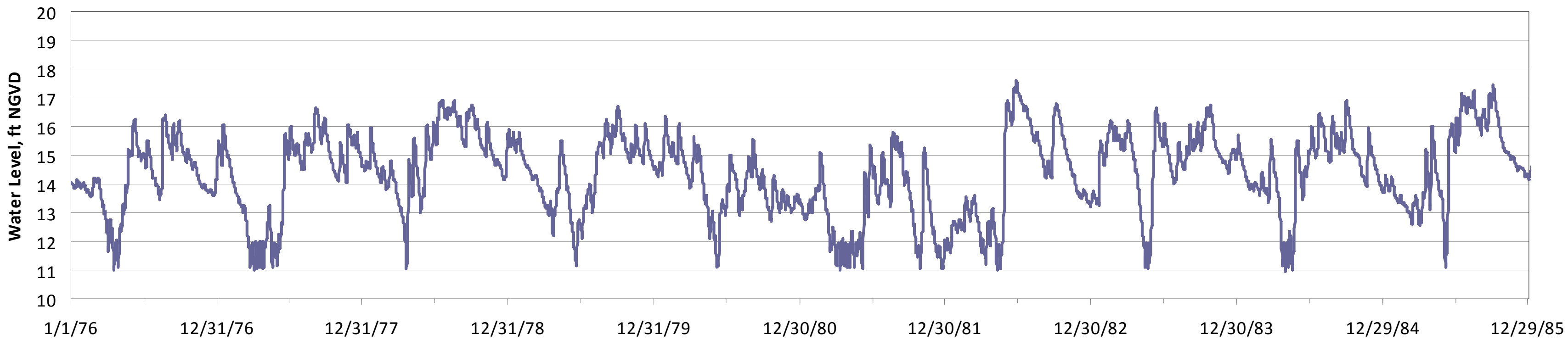


Figure 4.3.25 – G-342C & G-342D Headwater, 1976-1985

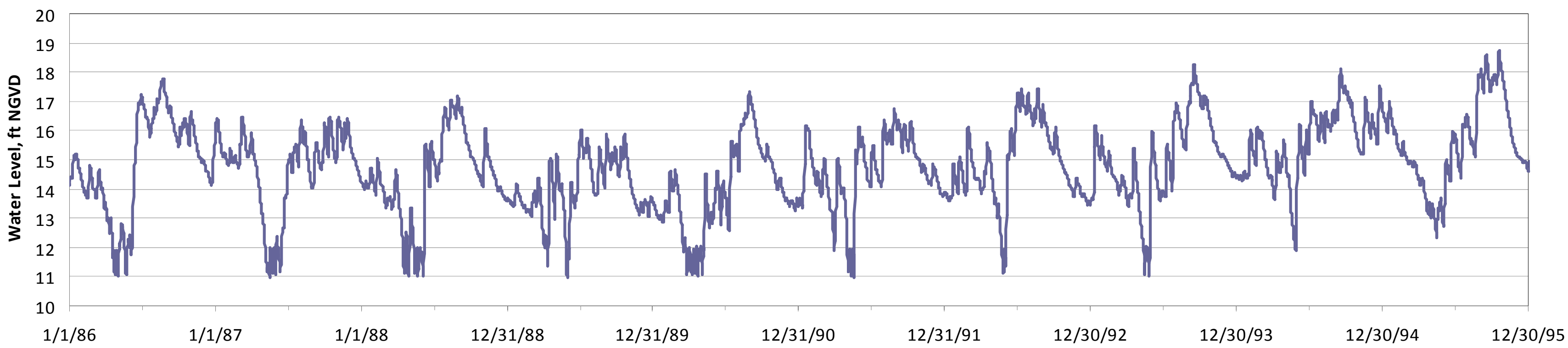


Figure 4.3.26 – G-342C & G-342D Headwater, 1986-1995

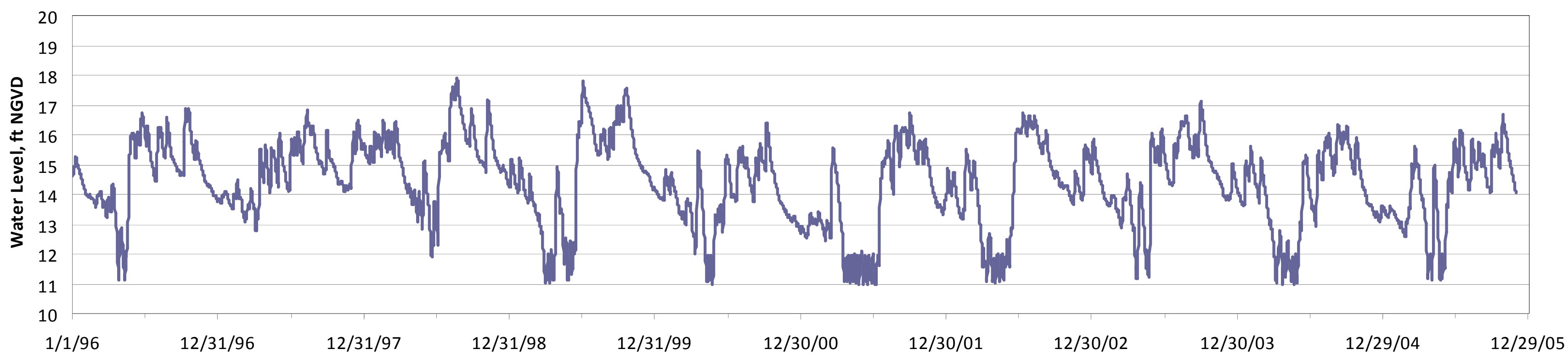


Figure 4.3.27 – G-342C & G-342D Headwater, 1996-2005

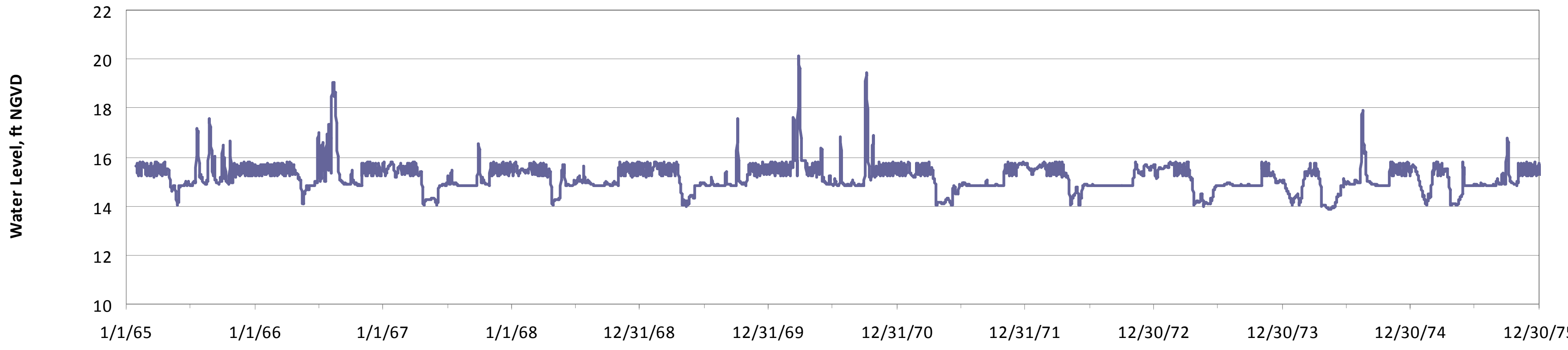


Figure 4.3.28 – S-190 Headwater, 1965-1975

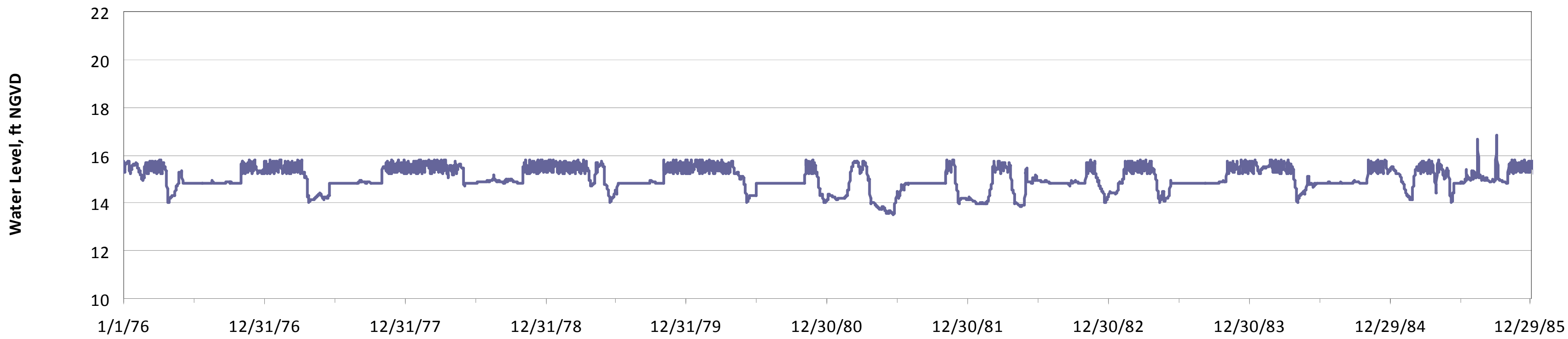


Figure 4.3.29 – S-190 Headwater, 1976-1985

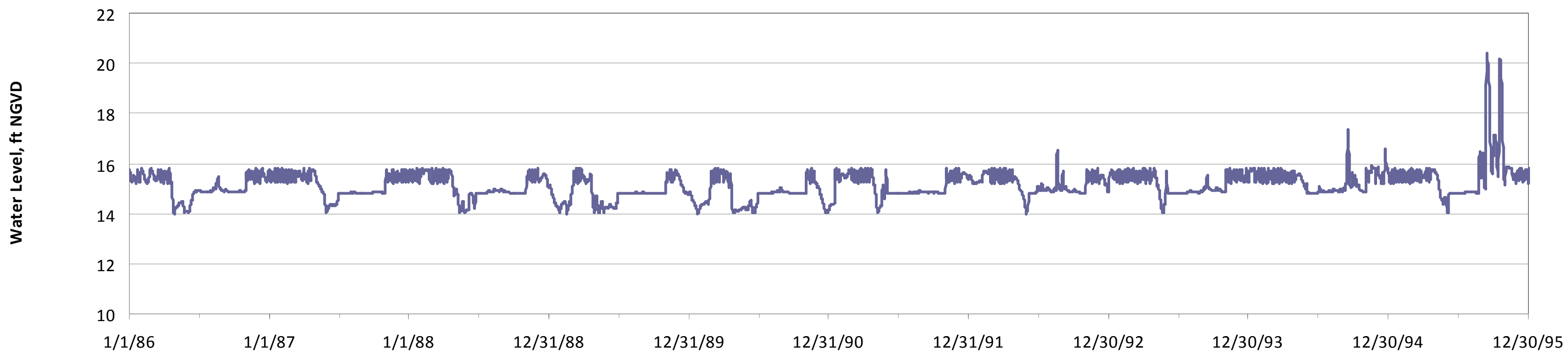


Figure 4.3.30 – S-190 Headwater, 1986-1995

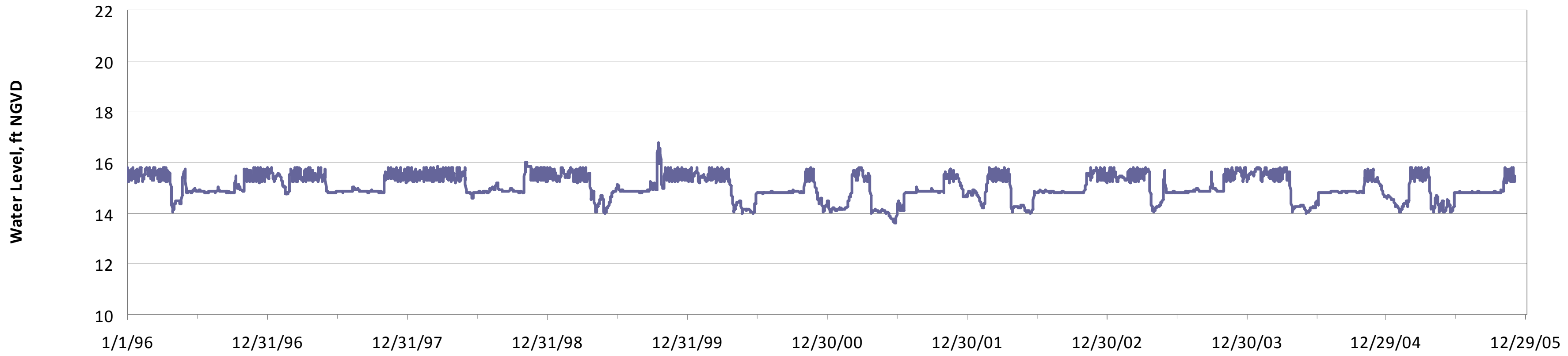


Figure 4.3.31 – S-190 Headwater, 1996-2005

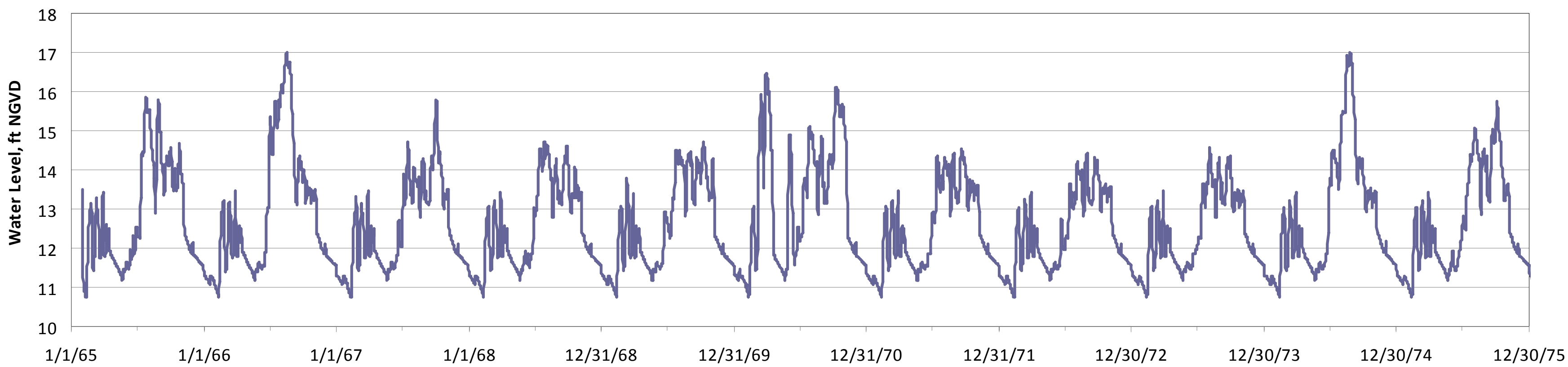


Figure 4.3.32 – Confusion Corner Water Levels, 1965-1975

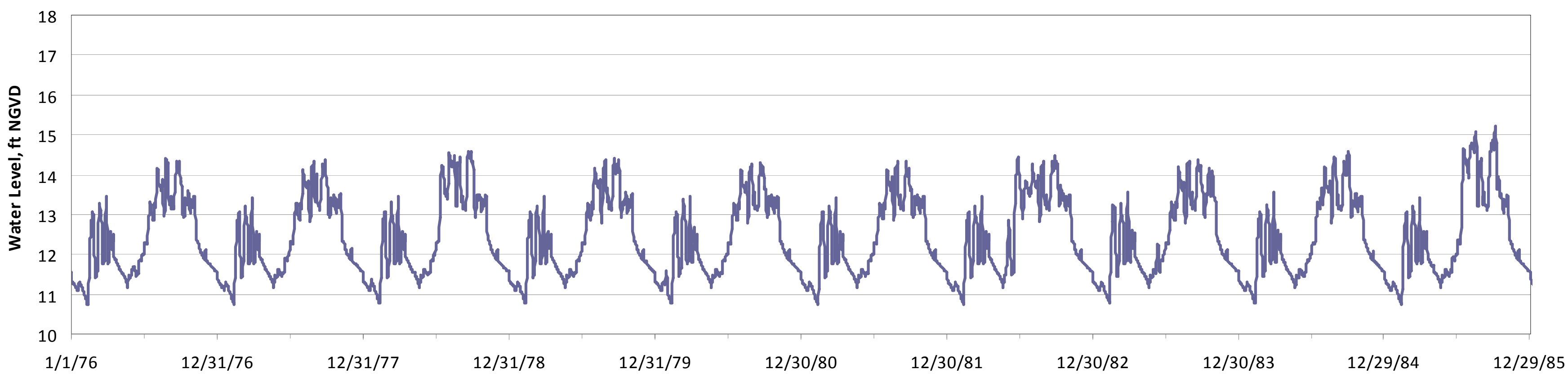


Figure 4.3.33 – Confusion Corner Water Levels, 1976-1985

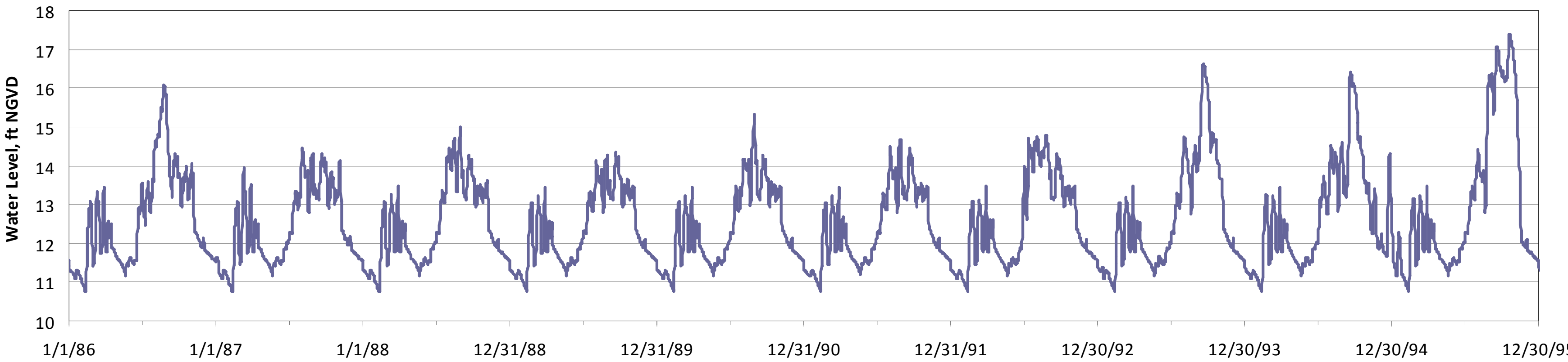


Figure 4.3.34 – Confusion Corner Water Levels, 1986-1995

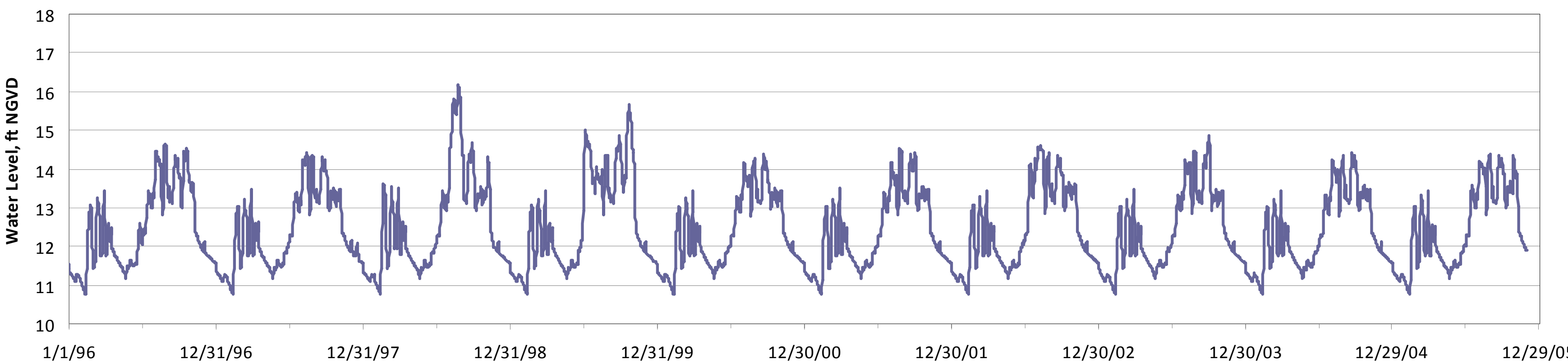


Figure 4.3.35 – Confusion Corner Water Levels, 1996-2005

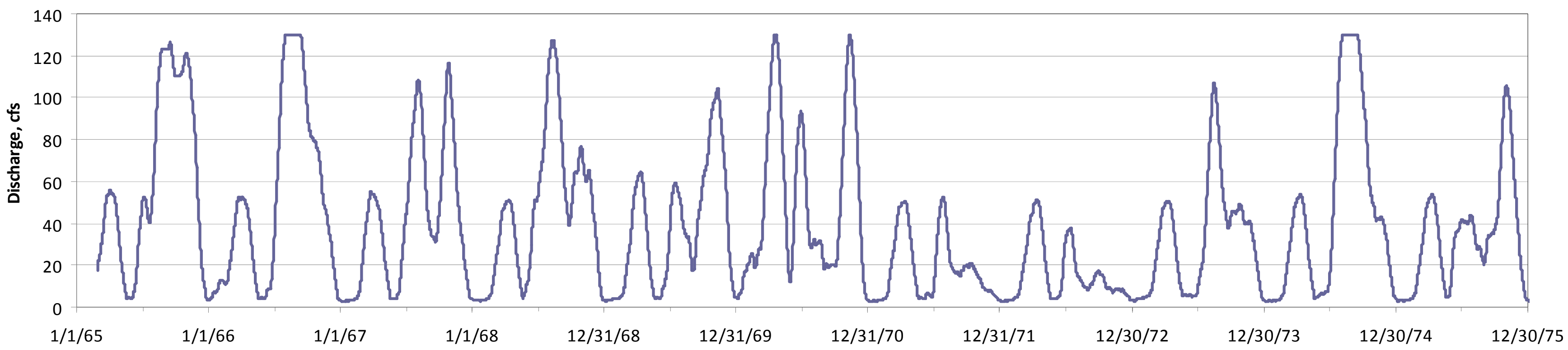


Figure 4.3.36 – G-409 30-Days Rolling Avg. Flows, 1965-1975

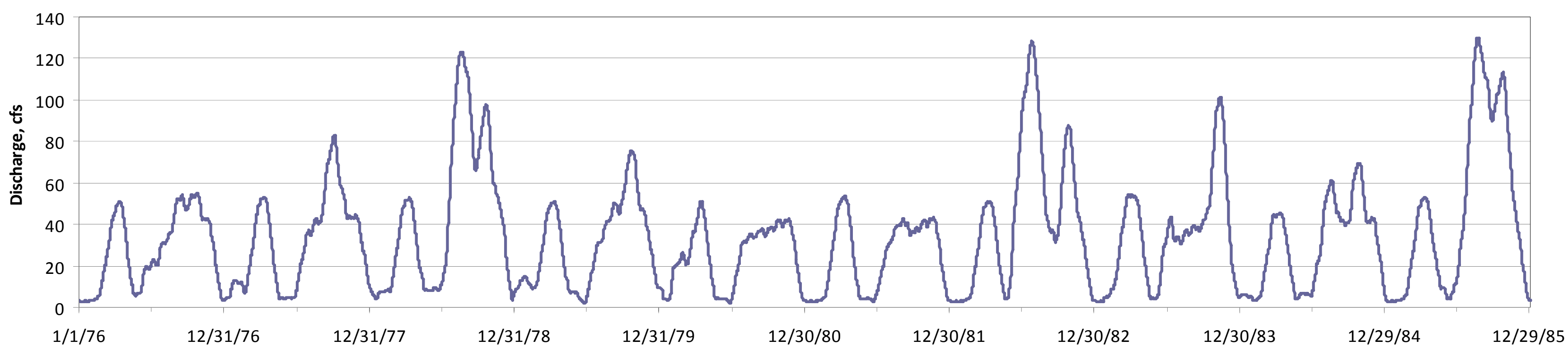


Figure 4.3.37 – G-409 30-Days Rolling Avg. Flows, 1976-1985

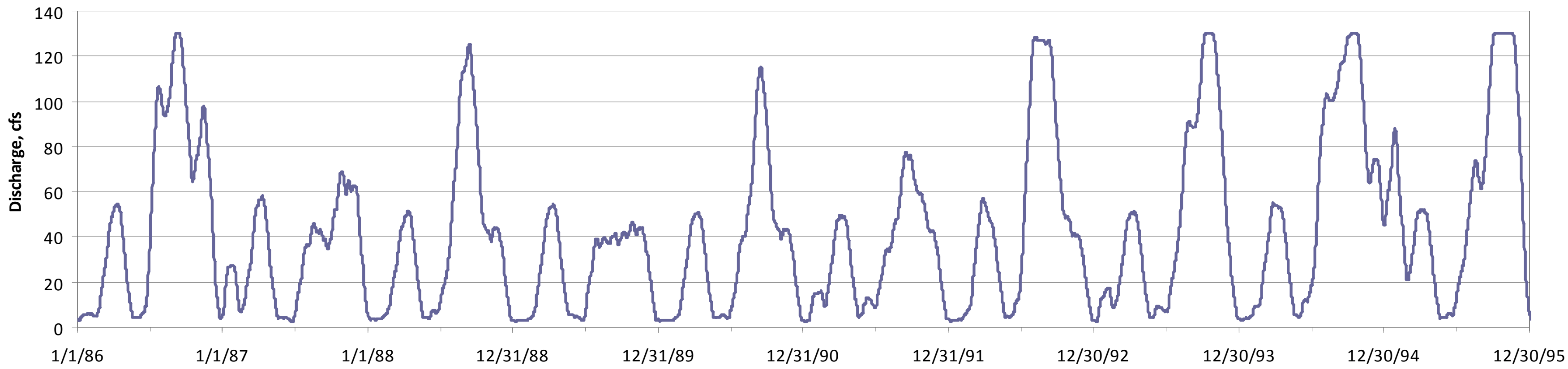


Figure 4.3.38 – G-409 30-Days Rolling Avg. Flows, 1986-1995

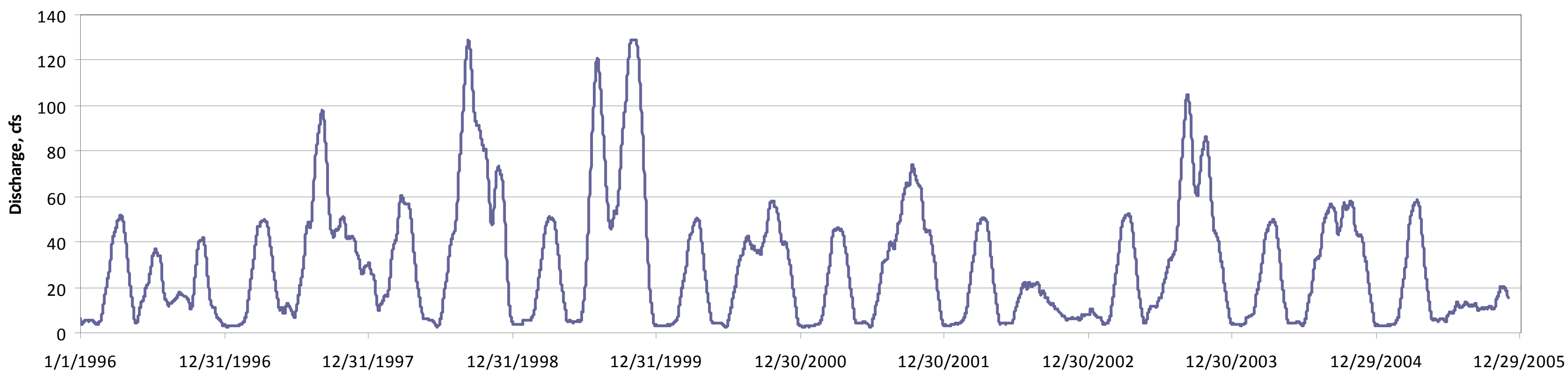


Figure 4.3.39 – G-409 30-Days Rolling Avg. Flows, 1996-2005

4.3.2.2.1 Analysis of Flows

An analysis was conducted for discharges from the C-139 basin to STA-5 and G-406. The results of the analysis are shown in ***Table 4.3.1*** below:

Table 4.3.1 STA-5 & G-406 Results Summary (1965-2005)

STA-5 & G-406	Amount
Average Flows	211 cfs
Median Flows	0 cfs
Positive Flows into STA-5 and G-406	154 days per year
90th percentile flow	818 cfs
98th percentile flow	1,631 cfs

The average flows for G-135 and G-136 were 1.3 and 65.8 cfs, respectively. As mentioned earlier, the simulated long-term discharge flows for G-135 are less than the measured discharges due to a lack of understanding of G-135 gate operations. The average G-409 flow was 36 cfs, which is higher than the measured average flow of 15 cfs between 2003 and 2008. This difference was also due to a lack of understanding of G-409 operation. Simulation of G-409 flows could be improved if additional information were available on the decision-making process that is used to operate this pump station.

Additionally, simulated flows were compared to measured flows for STA-5/G-406 for the period 1996 through 2005 when measured flows were available. The stations used were L3DF or the STA-5 and G-406. ***Figure 4.3.40*** presents a comparison plot of measured versus simulated flows. The average measured flow was 206 cfs, and the average simulated flow was 143 cfs. Simulated flows generally exceeded measured flows prior to 2000 and generally were less than measured flows after 2000.

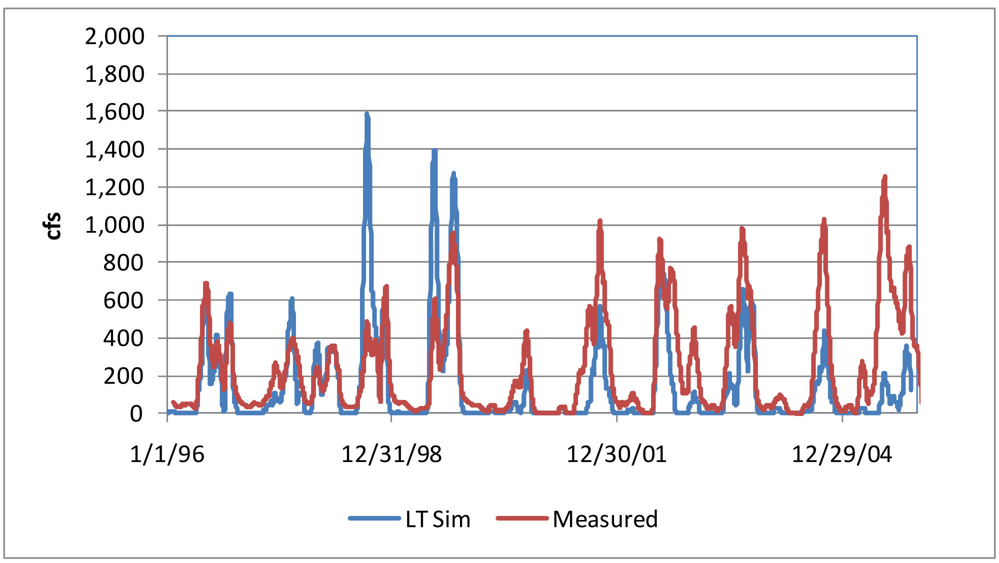


Figure 4.3.40 – Simulated and Measured Flows for L-3 Canal at the Intersection with Deerfence Canal

4.3.2.2.2 Duration of Simulation

Due to result file size limitations, the baseline simulation was run for two periods, 1965 – mid 1985, and mid 1985 – 2005. The simulation duration was 88 hours for the 1965 – 1985 simulation or 4.4 hours/year. The MIKE 11 result files were merged for selected stations to generate the statistics presented above. Additional analyses of subsets of the 1965 – 2005 results were conducted to calculate the average flow, and 98th percentile flow values for STA-5/G-406 combined flow.

The purpose of long-term model runs is to incorporate the range of expected high and low flow conditions, which is a worthy objective. However, starting the simulation in 1965 creates some inherent problems. Many stations around the perimeter of the C-139 Basin study area did not exist in 1965, which makes it difficult to establish water level boundary conditions for the entire period. If a shorter simulation period could be adopted using more recent conditions, more reasonable boundary conditions could be used. Accordingly, an analysis was conducted of subsets of the 1965-2005 period to determine if a shorter simulation period could yield results that are similar to the 1965-2005 simulation. The results of this analysis are summarized below:

- The period of 1995 through 2005 (11 year duration) had a mean flow of 205 cfs, 97% of the 1965 – 2005 average flow.
- The 98th percentile flow for the 1995 – 2005 period was equal to 1,397 cfs, 86% of the 98th percentile flow for the 1965 – 2005 period.

Using a shorter simulation period (11 years) rather than the 41 year period would save 132 hours of computer run time. In addition, more reasonable boundary conditions could be utilized, which would make the long-term runs more representative of expected variations in watershed response to meteorological conditions.

4.3.2.2.3 Water Budgets

This section provides a summary of water budget information for the C-139 Basin RFS Study area (C-139, Annex, L-28, and Feeder Canal Basins) and for the C-139 Basin that drains to STA-5 and G-406. The water budget is an output for the MIKE SHE model and does not include MIKE 11. It is easiest to think of the MIKE SHE model domain as a big box (comprised of all the MIKE SHE cells) that includes rainfall, overland flow, and ground water. This big box exchanges water with MIKE 11, and key terms are described below and are shown in ***Figure 4.3.41***:

- Irrigation is applied to the land surface as rainfall, therefore irrigation is added to precipitation when calculating ET as a percentage of rainfall. The difference between irrigation and pumping is equal to irrigation from rivers.
- Irrigation is applied to the entire MIKE SHE cell (1000x1000 ft), and land use of a MIKE SHE cell is based on the dominant land use for a given cell. If a cell is 50% citrus and 49% mesic flatwoods, the mesic flatwoods will receive irrigation.

- Overland Flow (OL>River): When rainfall exceeds infiltration, there is an exchange from MIKE SHE to MIKE 11 via the model term OL>River, which means Overland Flow to River.

- Drainage (Drain>River). MIKE SHE sends water to a river when the water level in the cells exceeds the drainage depth. The truck crop drainage depth is 1.5 feet, which means that there is flow from MIKE SHE to MIKE 11 with the surficial aquifer water level is closer than 1.5 feet to the surface.

- Baseflow to River. MIKE SHE sends water to a canal or river when the groundwater level in a MIKE SHE cell next to a river exceeds the river elevation. The river sends water back to MIKE SHE (Baseflow from River) if the river elevation exceeds the ground water elevation. This exchange occurs at a MIKE 11 cross section and the MIKE SHE cell that is closest to that cross section. This value is negative when the water flows out of the MIKE SHE box.

- The overall flow from MIKE SHE to River is: OL>R – Drain>R – BF>R + BF<R

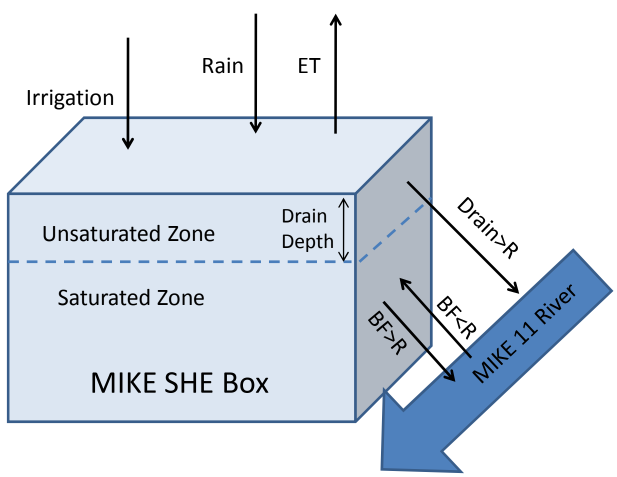


Figure 4.3.41 – Simplified Diagram of MIKE SHE – MIKE 11 Exchanges

Table 4.3.2 presents the definition of the different terms for the water budget in Mike SHE. ***Equation 4.3.1*** includes the main terms used in the water budget tables presented herein. ***Tables 4.3.3*** present water budgets for the entire model domain and ***Table 4.3.4*** for the C-139 Basin flows that drain to STA-5/G-406. ***Table 4.3.5*** presents water budgets for mesic flatwoods and citrus, which represent typical non-irrigated and irrigated lands. Note that the terms shown on the water budget tables do not add up to zero due to round-off and some minor terms that are not shown for clarity. The water budget tables generated from MIKE SHE discussed in this section are included in electronic format in ***Appendix D4***.

Evapotranspiration is 73% of precipitation plus irrigation. The difference between irrigation and pumping is 0.5 inches per year, which is equal to the river irrigation from the L-2 Canal to C-139 Basin farms. That irrigation from the L-2 Canal is an average flow of 7 cfs over the 1965-2005 simulation period. MIKE SHE contributions to river equal 15.5 and 16.2 inches/year for the 1965-1985 and 1985-2005 periods, respectively.

Irrigation of citrus was 14.5 inches/year for the 1965 – 1985 period. Irrigation of mesic flatwoods was 0.3 inches/year, which results from cells that are mostly croplands but include some non-crop land uses. MIKE SHE contributions to river equal 15.3 and 0.4 inches/year for citrus and mesic flatwoods, respectively. ET is also slightly higher for citrus than for flatwoods. It appears that a significant portion of the irrigation flows end up in surface runoff for citrus.

Table 4.3.2 – Water Budget Terms Definitions

Acronym	WBAL Term	Definition
P	Precipitation	Precipitation water added to model
CS.Ch	Canopy Stor. Change	Net water added or removed from storage on canopy
ET	Evapotranspiration	Water lost to evapotranspiration
OLS>CH	OL Stor.Change	Net water added or removed from overland flow plain
OLB.In	OL Bou.Inflow	Water added at overland boundaries
OLB.Out	OL Bou.Outflow	Water removed at overland boundaries
OL>R	OL>River	Overland added to river
I	Irrigation	Water added for irrigation
SSS.C	SubSurf.Stor.Change	Net water added or removed from saturated zone
SSB.In	SubSurf.Bou.Inflow	Water added to saturated zone
SSB.Out	SubSurf.Bou.Outflow	Water removed from saturated zone
Ppg	Pumping	Water pumped from saturated zone
Drain>R	Drain>River	SZ water drained to river inside the subcatchment
Drain>ER	Drain>Ext.River	SZ water drained to river outside the subcatchment
Drain In	Drain Inflow	SZ water drained into subcatchment
Drain Out	Drain Outflow	SZ water drained out of subcatchment
BF>R	Baseflow to river	SZ baseflow to river
BF<R	Baseflow from river	SZ baseflow from river
Error	Error	Sum of all variables with conventional signage

Equation 4.3.1:
Error = ET + P + OLB.In + OLB.Out + OL>R + I +SSS.C + SSB.In + SSB.Out + Ppg + Drain>R + Drain>ER + BF>R + BF<R

Table 4.3.3 – Water Budget, C-139 RFS Study Area (C-139, Annex, L-28, Feeder Canal Basins) for 1965-2005 Period, Inches/year

Simulation Period	P	ET	OLB.In	OLB.Out	OL>R	I	SSS.C	SSB.In	SSB.Out	Ppg	Drain>R	Drain>ER	BF>R	BF<R	Error
1/1/65 - 6/30/85	50.8	-41.6	0.0	-0.4	4.0	6.5	0.2	0.4	-2.5	-6.0	-11.4	0.0	-0.5	0.3	0.0
7/2/85 - 12/29/05	53.1	-43.7	0.0	-0.4	4.2	7.1	0.3	0.5	-2.6	-6.5	-11.9	0.0	-0.5	0.4	0.0

Table 4.3.4 – Water Budget, C-139 to STA-5 for 1965-2005 Period, Inches/year

Simulation Period	P	ET	OLB.In	OLB>out	OL>R	I	SSS.C	SSB.In	SSB.Out	Ppg	Drain>R	Drain>ER	BF>R	BF<R	Error
1965 - 6/30/85	51.1	-40.7	0.0	-0.2	7.5	8.1	0.2	0.4	-3.2	-7.6	-15.4	0.0	-0.4	0.2	0.0
7/2/85 - 12/29/05	50.7	-40.6	0.0	-0.2	7.5	8.6	0.3	0.5	-3.2	-8.1	-15.4	0.0	-0.4	0.2	0.0

Table 4.3.5 – Water Budget for Selected Irrigated and Non-Irrigated Land Uses for 1965-2005 Period, Inches/year

Land Use Type	P	ET	OLB.In	OLB.Out	OL>R	I	SSS.C	SSB.In	SSB.Out	Ppg	Drain>R	Drain>ER	BF>R	BF<R	Error
Mesic Flatwoods	51.7	-39.3	11.4	-11.2	-0.4	0.3	0.3	74.8	-85.8	-0.3	-0.3	-0.6	-0.6	0.2	0.0
Citrus	50.2	-39.8	2.9	-0.8	1.5	14.5	0.1	45.7	-48.0	-10.7	-14.1	-1.9	-0.1	0.4	0.0

Simulated 1965-2005 flows and stages in Canal L-2 just north of STA-5 are consistent with the analysis of the river irrigation water balance results as explained below. ***Figure 4.3.42*** illustrates that dry season low flows are negative during very dry periods, with canal stages dropping to almost 11 feet during high pumping rates. A number of farms along L-2 north of STA-5 are allowed to irrigate from the L-2 Canal. Therefore, the irrigation routine was set up in the model to withdraw irrigation water from Canal L-2 and terminate when Canal L-2 stages dropped below critical low elevations ranging from 11 to 13 ft-NGVD (the farms further north along L-2 had higher cut-off elevations). ***Figure 4.3.42*** shows that L-2 flows are more negative when L-2 water levels are higher, and the L-2 flow is zero just after low canal stages are at low levels. These results clearly illustrate that river irrigation pumps turned on and off in response to fluctuating Canal L-2 elevations.

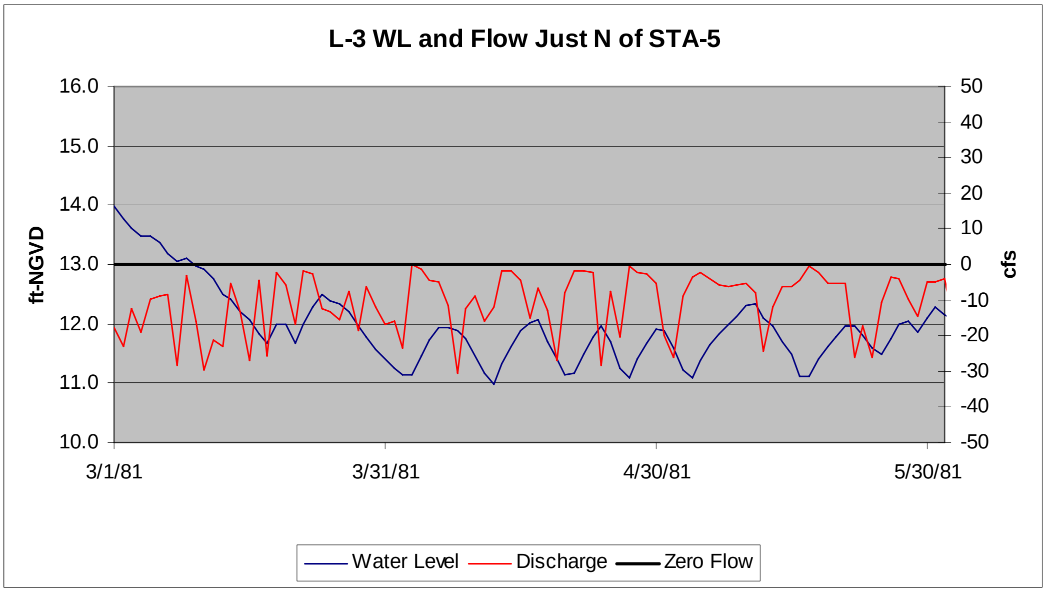


Figure 4.3.42 – L-3 Water Level and Flow Just North of STA-5

4.3.3 WATER QUALITY ANALYSIS

Based on the Model Selection exercise and the revised scope of work**,** a simple spreadsheet water quality assessment tool will be utilized to evaluate water quality responses for the water management alternatives.

The Total Phosphorus (TP) load post-processing spreadsheet analysis was performed by establishing Event Mean Concentrations (EMCs) for the MIKE SHE/MIKE 11 land uses. This water quality analysis included the division of the C-139 Region into a total of fifteen sub-basins as described in **Section 4.3.3.1**. The analysis was conducted per the scope of work using GIS, Excel and database tools to calculate the potential TP loads for each sub-basin. Spatial distributions of land-use event mean concentration (EMC) for each sub-basin and the flows from the MIKE SHE/MIKE 11 model at the exit point of each of the sub-basins were utilized for the water quality analysis.

4.3.3.1 Water Quality Sub-basins

MIKE SHE has the capability to prevent overland flow from moving across user-specified boundaries. Separated flow-areas are normally used where there are known barriers to overland flow. MIKE 11 branches are needed to transport waters from one overland flow area to another. Separated flow areas were used for each permitted Environmental Resource Permit (ERP) within the study area since water typically does not flow across ERP boundaries. Roads and other existing boundaries were also considered. Often there are small berms to limit flooding and/or discharges to and from farm fields during most periods, except when these berms become over-topped during major floods. If this is the case, a short branch with a user-defined weir was added to the MIKE 11 network with the weir elevation equal to the top elevation of the small berm. ***Figure 4.3.43*** shows the separated flow areas.

For the purpose of this analysis, water quality sub-basins were defined based on the MIKE SHE separated flow areas. The sub-basins include one or more separated flow areas which were grouped based on the point of discharge, flow connections, and geographical characteristic. ***Figure 4.3.44*** shows the fifteen sub-basins defined for the water quality spreadsheet analysis and the original MIKE SHE separated flow areas.

The sub-basins defined herein will allow assignment of flow, TP concentration and/or TP load for each of the sub-basins. This will help determine the areas of high TP loads for evaluation of maximum benefits based on applied alternative. The separated flow areas included in each of the fifteen sub-basins are shown on ***Figure 4.3.44*** and ***Tables 4.3.6 to 4.3.8***.

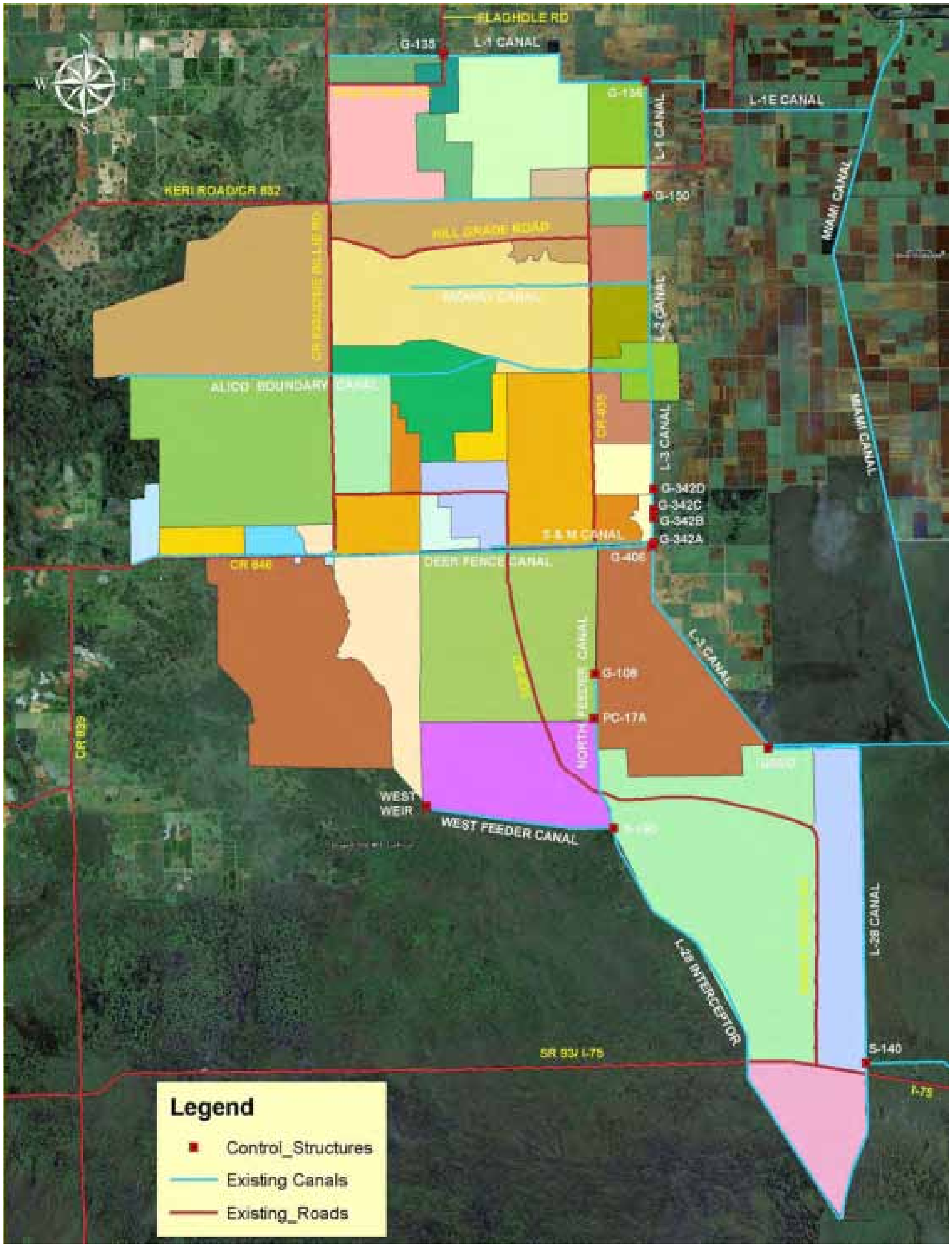


Figure 4.3.43 – Separated Flow Area Map

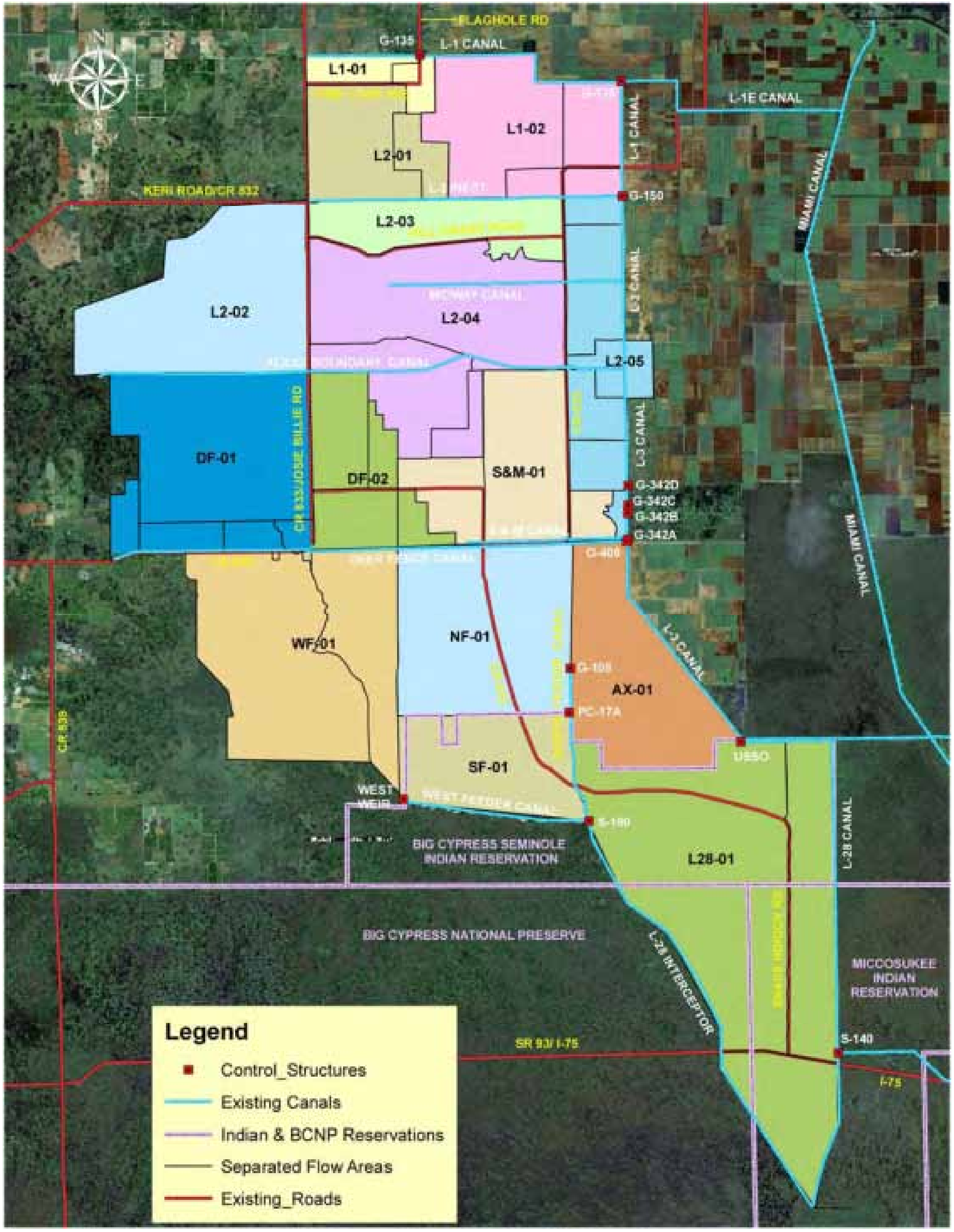


Figure 4.3.44 – C-139 RFS Sub-basins

Table 4.3.6 – C-139 Basin (10 Sub-basins)

Sub-basin	Flow Areas	Location/(Discharge Canal/Structure)	Modeled Structure
L1-01	2	• West of G-135 • South of L-1 canal • North of Pine Cove Ave. • (L-1 canal)	G-135
L1-02	4	• East of G-135 • South of the L-1 canal • North of L-2 West canal • (L-1 canal)	G-136
L2-01	2	• East of CR 833 • South of Pine Cove Ave. • North of L-2 West canal • (L-2 West canal)	G-342 A to D or G-406
L2-02	1	• West of County Road CR-833 • South of Keri Road/CR-832 • North of the Alico Boundary canal. • (L-2 West, and Alico Boundary canals)	G-342 A to D or G-406
L2-03	1	• East of CR 833 • West of CR 835 • South of the L-2 West canal • North of Hill Grade Road • (L-2 West canal and Hill Grade Ditch)	G-342 A to D or G-406
L2-04	2	• East of CR 833 • West of CR 835 • South of Hill Grade Road • North of Alico Boundary Canal and two separated flow areas south of it • (Alico Midway canal and Alico Boundary Canal)	G-342 A to D or G-406
L2-05	7	• East of CR-835 • South of the L-2 West canal • North of Deer Fence canal (except for separated flow area just east of CR-835 & just north of S&M Canal) • (L-2 and L-3 canals)	G-342 A to D or G-406
DF-01	5	• West of CR-833, • South of the Alico Boundary Canal • North of CR-846. • (Deer Fence Canal)	G-342 A to D or G-406
DF-02	3	• East of CR-833 • South of the Alico Boundary Canal • North of the Deer Fence Canal. • (Deer Fence Canal)	G-342 A to D or G-406
S&M-01	3	• West of CR-835 (including separated flow area just east of CR-835 and north of the S&M Canal) • South of the Alico Boundary Canal • North of the S&M Canal. • (S&M Canal)	G-342 A to D or G-406

Table 4.3.7 – Feeder Canal Basin (3 Sub-basins)

Sub-basin	Flow Areas	Location/(Discharge Canal)	Modeled Structure
WF-01	2	• West of the Big Cypress Seminole Reservation and West Weir • South of the Deer Fence canal • (West Feeder canal)	S-190
NF-01	1	• East of sub-basin WF-01 • South of the Deer Fence canal • North of the Big Cypress Seminole Reservation • (North Feeder Canal)	S-190
SF-01	1	• East of West Weir (Includes the Big Cypress Seminole Reservation) • South of sub-basin NF-01 and PC-17A • North of West Feeder canal.	S-190

Table 4.3.8 – L-28 Basin (2 Sub-basins)

Sub-basin	Flow Areas	Location/(Discharge Canal)	Modeled Structure
AX-01	1	• East of NF-01, includes the USSC C-139 Annex • South of Deer Fence canal • (USSO structure)	S-140
L28-01	1	• East of L-28 Interceptor • West of L-18 Canal • (L-28 Interceptor, L-28 canal, North Feeder)	S-140

The area for each of the sub-basins was calculated with GIS and is presented in ***Table 4.3.9*** below.

Table 4.3.9 – MIKE SHE Sub-basins Areas

Basins	Sub-Basins	Area	
		ft^2	Acres
C-139 Basin	L1-01	157,121,319	3,607
	L1-02	822,506,267	18,882.1
	L2-01	491,902,042	11,292.5
	L2-02	1,038,567,865	23,842.2
	L2-03	441,240,879	10,129.5
	L2-04	1,371,194,239	31,478.3
	L2-05	679,390,034	15,596.6
	DF-01	1,183,180,070	27,162.1
	DF-02	535,223,109	12,287.0
	S&M-01	771,305,015	17,706.7
	Total	**7,491,630,839**	**171,984.2**
Feeder Canal Basin	WF-01	1,395,804,711	32,043.3
	NF-01	1,028,444,396	23,609.8
	SF-01	578,326,071	13,276.5
	Total	**3,002,575,178**	**68,929.6**
L-28 Basin	AX-01	783,575,953	17,988.4
	L28-01	2,362,691,966	54,239.9
	Total	**3,146,267,919**	**72,228.4**
TOTAL			**313,142.2**

4.3.3.2 Land Uses

The land use categories that were used for MIKE SHE and this water quality analysis were derived from the SFWMD 2004-2005 land use spatial and tabular data. A description of the MIKE SHE land use types is provided in ***Table 4.3.10*** and ***Figure 4.3.45***.

Table 4.3.10 – MIKE SHE Land use Grid Code and Description

Land Use Code	MIKE SHE Description
1	Citrus
2	Cropland
3	Sugar Cane
5	Truck Crops
6	Rangeland - Upland Forests
7	Pasture
8	Mesic Flatwood
9	Mesic Hammock
10	Xeric Flatwood
11	Xeric Hammock
12	Hydric Flatwood
13	Hydric Hammock
14	Wet Prairie
15	Cypress
16	Marsh
18	Swamp Forest
20	Water
41	Urban - Low Density
42	Urban - Medium Density
43	Urban - High Density
50	Commercial
60	Levee

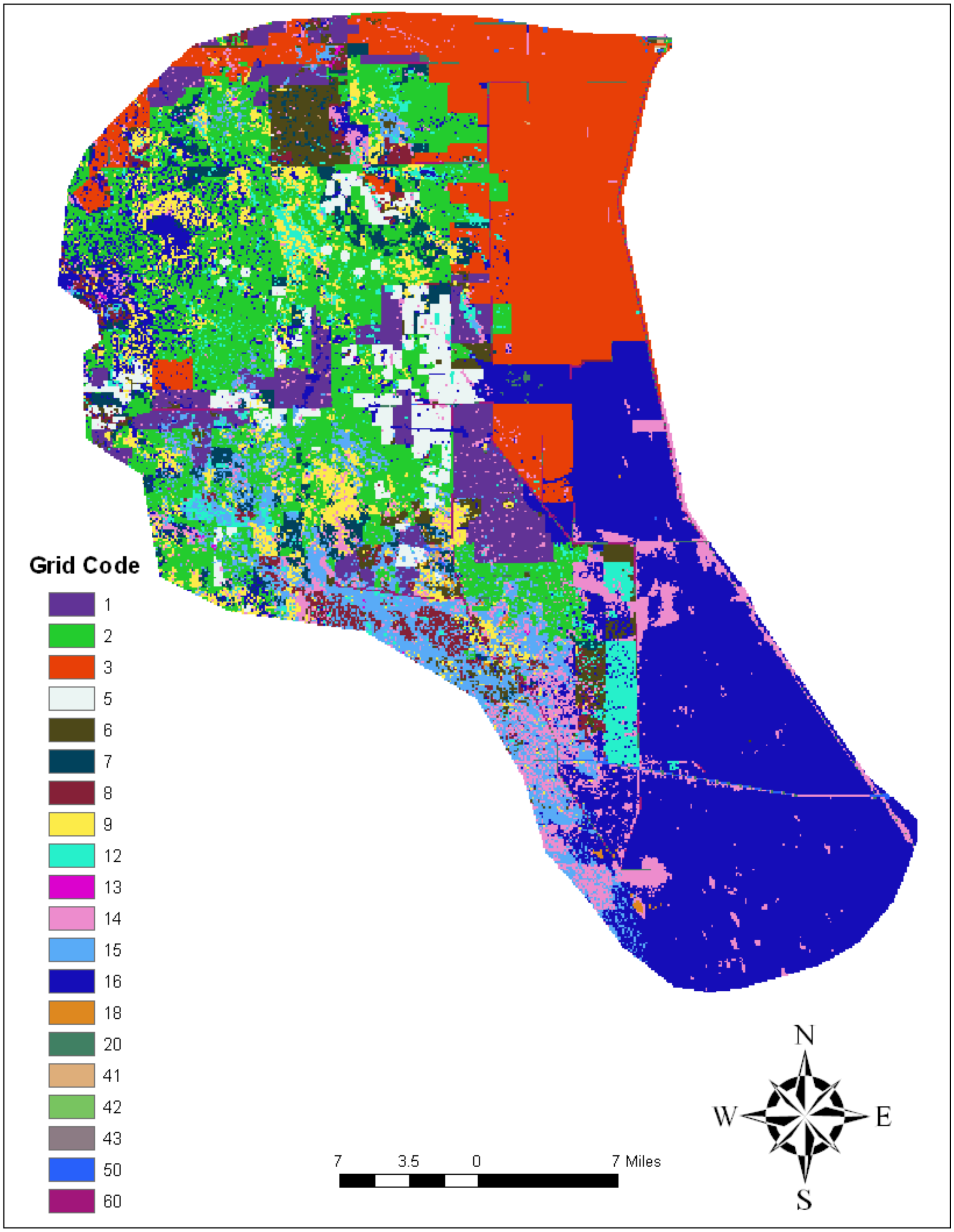


Figure 4.3.45 – MIKE SHE Land Use Grid Codes

4.3.3.3 Literature Based Event Mean Concentrations (EMCs)

In order to approximate TP loads for each sub-basin, EMCs were defined for the different land-uses from peer-reviewed literature in the C-139 Basin Phosphorus Water Quality and Hydrology Analysis (ADA, 2006). The article entitled "Water Quality Characteristics of Storm Water from Major Land-uses in South Florida" (Graves, Wan and Fike, 2004) presents results from a 30 month runoff sampling project for the watersheds tributary to the Indian River Lagoon. The results include the calculation of TP EMCs for the six land-uses shown in ***Table 4.3.11***. As it can be seen, this study did not include EMCs for forested land-uses.

Table 4.3.11 – TP Concentrations from Graves, Wan and Fike (2004)

LANDUSE	MEAN TP (mg/L)	MEDIAN TP (mg/L)
Citrus	0.29	0.16
Pasture	0.29	0.22
Urban	0.22	0.09
Golf	0.24	0.19
Wetland	0.02	0.01
Row	0.63	0.45
Residual	0.26	0.2
Dairy	12.54	8.86

Another source of information for EMCs is the report "Evaluation of Alternative Stormwater Regulations for Southwest Florida (ERD, 2003). This report includes a literature review of available EMC data for different land-uses. The EMCs described in this report include results from the 1994 Environmental Research & Design (ERD) study "Stormwater Loading Rate Parameters for Central and South Florida" (1994). The values shown in the 1994 ERD report often display a bias towards higher TP concentrations due to the high levels of phosphorus found in the soils of Central Florida. ***Table 4.3.12*** presents the average EMCs compiled by ERD. The one exception is the mean EMC for Citrus which is lower (0.183 mg/l) than the one presented by Graves, Wan and Fike (2004) (0.29 mg/l).

In 2005, ADA utilized the values presented in ***Tables 4.3.11*** and ***4.3.12*** to determine the 47 average EMCs shown in ***Table 4.3.13***. These EMC values were used to approximate TP loads within the C-139 Basin for the effort conducted in 2006 by ADA.

Table 4.3.12 – TP Concentrations from ERD (2003)

LANDUSE	TP (mg/L)
Low-Density Residential	0.19
Single-Family	0.335
Multi-Family	0.49
Low-Intensity Commercial	0.18
High-Intensity Commercial	0.43
Industrial	0.31
Highway	0.27
Pasture	0.476
Citrus	0.183
Row Crop	0.638
General Agriculture	0.344
Undeveloped Rangeland/Forest	0.046
Mining	0.15
Wetland	0.09
Open Water/Lake	0.067

Table 4.3.13 – TP EMCs for Land Uses within the C-139 Basin (ADA, 2006)

DESCRIPTION	EMC (mg/L)
Improved pastures	0.22
Unimproved pastures	0.22
Freshwater Marshes/Graminoid Prairie	0.02
Citrus groves	0.29
Row crops	0.63
Woodland pastures	0.29
Sugar Cane	0.63
Wet Prairies	0.02
Pine Flatwoods	0.05
Herbaceous (Dry Prairie)	0.29
Mixed Shrubs	0.02
Upland Shrub and Brush Land	0.63
Cypress	0.02
Cypress - Domes/Heads	0.02
Spoil areas	0.02
Low Density: Fixed Single Family Units	0.22
Palmetto Prairies	0.29
Upland Hardwood Forest	0.05
Mixed Rangeland	0.05
Channelized Waterways, Canals	0.05
Field crops	0.29
Hardwood/Confererous Mixed	0.05
Mixed wetland hardwoods	0.02
Emergent aquatic vegetation	0.02
Oak-Cabbage Palm Forest	0.05
Brazilian Pepper	0.05
Wet Pinelands Hydric Pine	0.02
Cypress - Mixed Hardwoods	0.29
Low Density: Mobile Home Units	0.22
Live Oak	0.05
Reservoirs	0.05
Wetland Forested Mixed	0.02
Commercial and Services	0.22
Grass airports	0.22
Medium Density: Mobile Home Units	0.22
Solid waste disposal	0.22
Cabbage Palm	0.05
Lakes	0.05
Educational Facilities	0.22
Borrow areas	0.02
Other Groves	0.63
Ornamentals	0.29
Low Density Mixed, Fixed & Mobile Home Units	0.22
Freshwater Marshes - Sawgrass	0.02
Communications	0.02
Disturbed land	0.02
Melaleuca	0.05

The EMCs for the current C-139 RFS were defined for the SFWMD 2004-2005 land use spatial and tabular data used for the MIKE SHE/MIKE 11 model. These EMC values were defined based mainly on values from ADA, 2006 and also on the other two sources of information cited above. ***Table 4.3.14*** present the EMC values defined for the C-139 RFS water quality post-processing analysis.

Once the EMCs were defined, a detailed review of the land uses and EMCs was conducted based on aerial photography and GIS tools. Based on this review and best professional judgment, the following adjustments were made: Revision of Montura Ranch from Rangeland-Upland Forests to Residential land use, change of some areas in the L-28 basin identified as Improved Pasture land use to Rangeland-Upland Forests land use and the change to Rangeland-Upland Forests of some isolated areas of natural vegetation that had not been identified in the SFWMD 2004-2005 land use file as such.

Additionally, once the TP loads were determined as described in the following sections, it was observed that the calculated TP loads for the L-28 basin were consistently higher than the measured TP loads from the 2009 South Florida Environmental Report (SFER). After further analysis, it was decided that the EMC value for the citrus crop of 0.29 mg/l defined by ADA, 2005, and Wan & Fike, 2004 appeared to be too high. As the EMC for Citrus presented in ERD, 1994 was determined to be 0.18 mg/l, and the median value for Wan & Fike, 2004 was 0.16 mg/l, it was decided to use an EMC value of 0.18 mg/l for citrus. The value of 0.18 considerably improved the results for the C-139 Annex as shown in the following sections.

Table 4.3.14 – EMCs Defined for the C-139 RFS

Land Use Code	MIKE SHE Description	EMC (mg/l)	EMC (ppb)
1	Citrus	0.18	180
2	Cropland	0.63	630
3	Sugar Cane	0.63	630
5	Truck Crops	0.63	630
6	Rangeland - Upland Forests	0.05	50
7	Pasture	0.22	220
8	Mesic Flatwood	0.05	50
9	Mesic Hammock	0.05	50
10	Xeric Flatwood	0.05	50
11	Xeric Hammock	0.05	50
12	Hydric Flatwood	0.02	20
13	Hydric Hammock	0.02	20
14	Wet Prairie	0.02	20
15	Cypress	0.02	20
16	Marsh	0.02	20
18	Swamp Forest	0.02	20
20	Water	0.05	50
41	Urban - Low Density	0.19	190
42	Urban - Medium Density	0.22	220
43	Urban - High Density	0.22	220
50	Commercial	0.22	220
60	Levee	0.05	50

4.3.3.4 TP Load Calculations with EMCs

The EMCs presented in ***Table 4.3.14***, in combination with the sub-basins areas defined in ***Figure 4.3.44*** were utilized to create a spatially weighted average EMC for each sub-basin. The EMC values for each sub-basin are shown in ***Table 4.3.15*** and ***Figure 4.3.46***.

Table 4.3.15 – C-139 Region Sub-basins EMCs

SUB-BASIN	EMC (mg/l)	EMC (ppb)
C-139 Basin		
L1-01	0.15	154
L1-02	0.24	237
L2-01	0.15	148
L2-02	0.13	130
L2-03	0.21	213
L2-04	0.17	168
L2-05	0.29	293
DF-01	0.21	211
DF-02	0.20	203
S&M-01	0.39	393
Feeder Canal Basin		
WF-01	0.13	127
NF-01	0.24	239
SF-01	0.13	129
L-28 Basin		
AX-01	0.14	143
L28-01	0.05	53

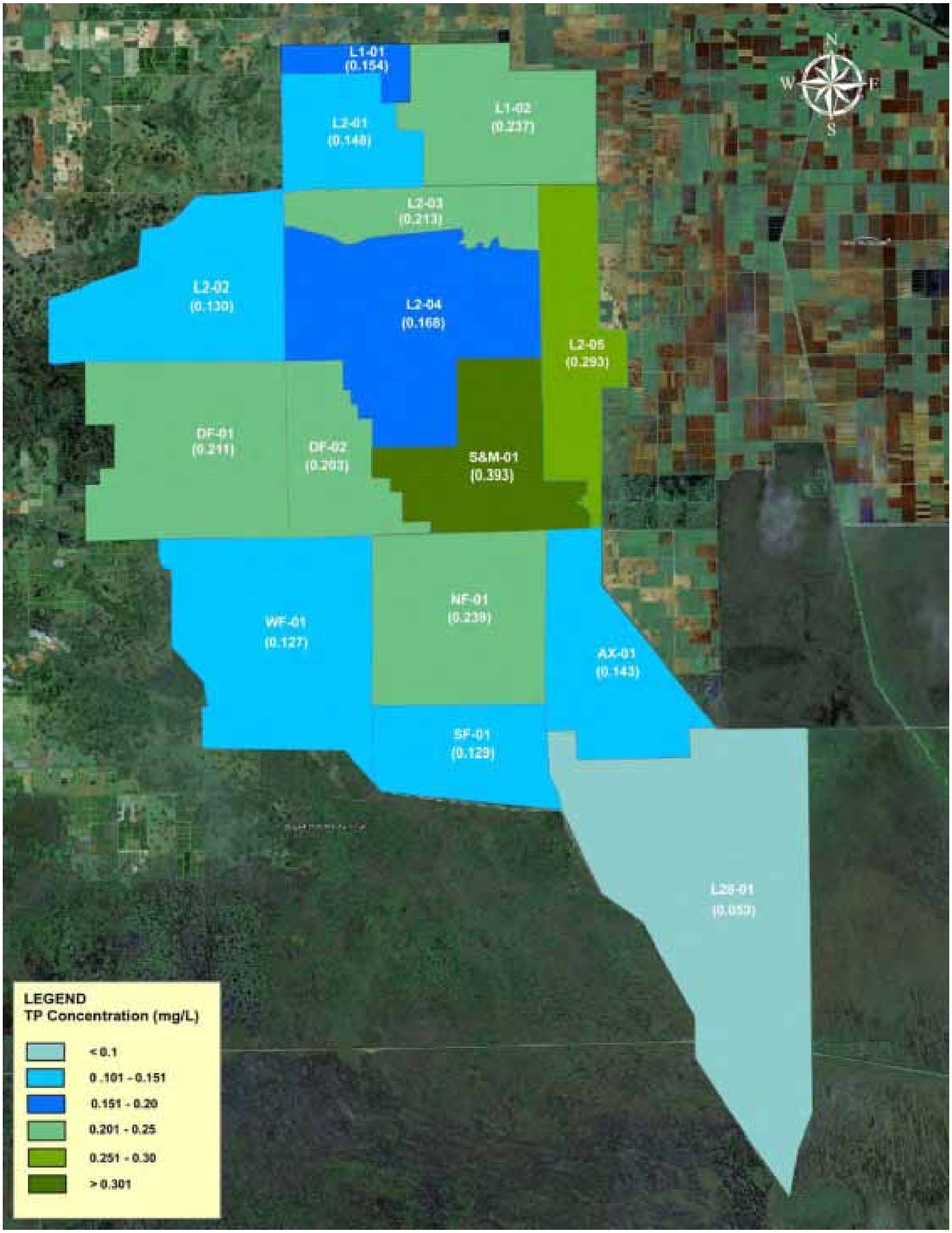


Figure 4.3.46 – C-139 Region Sub-basins EMCs

The EMC values calculated for the sub-basin are in accordance with the findings of the study entitled " C-139 Basin Deerfence and S&M Canals Phosphorus Transport and Cycling". (CWF & DB Env., 2005). One of the main findings of that study was greater measured TP concentrations in the S&M Canal than in the Deer Fence Canal. ***Table 4.3.15***. shows that the analysis conducted as part of the this post-processing spread sheet analysis predicts a higher EMC value for the S&M sub-basin discharging to the S&M Canal than the EMC values for two sub-basins that discharge into the Deer Fence Canal.

The TP loads for each sub-basin were obtained by multiplying the spatially averaged sub-basin EMCs with the MIKE 11 model runoff flows at the point of discharge for each sub-basin. The flows presented in ***Tables 4.3.16 to 4.3.19*** were obtained from the calibration (2004 to 2006), and the validation, (2007 and 2008). The loads were calculated in kilograms and metric tons for the SFWMD Water Years (WY) (May to April) of 2005 to 2008.

Table 4.3.16 – C-139 Region Sub-basins Modeled Flows and TP Loads WY-2005

Basins	Sub-Basins	Flow		TP	
		m^3	Ac-ft	kg	Mtons
C-139 Basin	L1-01	8,212,320	6,658	1,263	1.26
	L1-02	38,909,376	31,544	9,227	9.23
	L2-01	9,576,576	7,764	1,414	1.41
	L2-02	53,663,040	43,505	6,958	6.96
	L2-03	18,374,688	14,896	3,917	3.92
	L2-04	20,596,896	16,698	3,451	3.45
	L2-05	67,602,816	54,806	19,804	19.80
	DF-01	10,772,352	8,733	2,269	2.27
	DF-02	8,303,904	6,732	1,685	1.68
	S&M-01	5,704,992	4,625	2,244	2.24
	Total	**241,716,960**	**195,960**	**52,232**	**52.23**
Feeder Canal Basin	WF-01	20,309,184	16,465	2,579	2.58
	NF-01	25,067,232	20,322	6,003	6.00
	SF-01	22,525,344	18,261	2,911	2.91
	Total	**67,901,760**	**55,048**	**11,493**	**11.49**
L-28 Basin	AX-01	20,818,944	16,878	2,967	2.97
	L28-01	124,683,840	101,081	6,598	6.60
	Total	**145,502,784**	**117,959**	**9,565**	**9.57**

Table 4.3.17 – C-139 Region Sub-basins Modeled Flows and TP Loads WY-2006

Basins	Sub-Basins	Flow		TP	
		m^3	Ac-ft	kg	Mtons
C-139 Basin	L1-01	9,573,984	7,762	1,473	1.47
	L1-02	31,202,496	25,296	7,400	7.40
	L2-01	11,826,432	9,588	1,746	1.75
	L2-02	77,715,072	63,004	10,077	10.08
	L2-03	18,484,416	14,985	3,940	3.94
	L2-04	41,770,944	33,864	6,998	7.00
	L2-05	76,101,984	61,696	22,294	22.29
	DF-01	28,519,776	23,121	6,006	6.01
	DF-02	31,256,064	25,339	6,341	6.34
	S&M-01	16,267,392	13,188	6,399	6.40
	Total	**342,718,560**	**277,842**	**72,673**	**72.67**
Feeder Canal Basin	WF-01	53,741,664	43,568	6,825	6.83
	NF-01	53,860,032	43,664	12,898	12.90
	SF-01	41,953,248	34,012	5,422	5.42
	Total	**149,554,944**	**121,244**	**25,145**	**25.15**
L-28 Basin	AX-01	30,387,744	24,635	4,331	4.33
	L28-01	159,029,568	128,925	8,416	8.42
	Total	**189,417,312**	**153,561**	**12,746**	**12.75**

Table 4.3.18 – C-139 Region Sub-basins Modeled Flows and TP Loads WY-2007

Basins	Sub-Basins	Flow		TP	
		m^3	Ac-ft	kg	Mtons
C-139 Basin	L1-01	3,753,216	3,043	577	0.58
	L1-02	22,228,992	18,021	5,272	5.27
	L2-01	548,640	445	81	0.08
	L2-02	14,415,840	11,687	1,869	1.87
	L2-03	8,496,576	6,888	1,811	1.81
	L2-04	9,921,312	8,043	1,662	1.66
	L2-05	46,141,920	37,407	13,517	13.52
	DF-01	9,478,944	7,685	1,996	2.00
	DF-02	10,476,864	8,494	2,125	2.13
	S&M-01	10,508,832	8,520	4,134	4.13
	Total	**135,971,136**	**110,232**	**33,045**	**33.04**
Feeder Canal Basin	WF-01	37,798,272	30,643	4,800	4.80
	NF-01	41,526,432	33,666	9,944	9.94
	SF-01	27,458,784	22,261	3,549	3.55
	Total	**106,783,488**	**86,570**	**18,293**	**18.29**
L-28 Basin	AX-01	26,928,288	21,831	3,838	3.84
	L28-01	85,033,152	68,936	4,500	4.50
	Total	**111,961,440**	**90,767**	**8,338**	**8.34**

Table 4.3.19 – C-139 Region Sub-basins Modeled Flows and TP Loads WY-2008

Basins	Sub-Basins	Flow		TP	
		m^3	Ac-ft	kg	Mtons
C-139 Basin	L1-01	1,629,504	1,321	251	0.25
	L1-02	8,861,184	7,184	2,101	2.10
	L2-01	0	0	0	0.00
	L2-02	2,317,248	1,879	300	0.30
	L2-03	2,797,632	2,268	596	0.60
	L2-04	3,504,384	2,841	587	0.59
	L2-05	36,249,984	29,388	10,619	10.62
	DF-01	1,127,520	914	237	0.24
	DF-02	1,009,152	818	205	0.20
	S&M-01	8,576,064	6,953	3,373	3.37
	Total	**66,072,672**	**53,565**	**18,271**	**18.27**
Feeder Canal Basin	WF-01	8,133,696	6,594	1,033	1.03
	NF-01	16,231,104	13,159	3,887	3.89
	SF-01	9,146,304	7,415	1,182	1.18
	Total	**33,511,104**	**27,167**	**6,102**	**6.10**
L-28 Basin	AX-01	15,543,360	12,601	2,215	2.22
	L28-01	89,267,616	72,369	4,724	4.72
	Total	**104,810,976**	**84,970**	**6,939**	**6.94**

4.3.3.5 EMC TP Calculated Loads Comparison to SFER2009 TP Loads

A comparison was conducted between the results obtained from the post-processed water quality analysis using EMCs defined in the previous sections and loads reported in the 2009 South Florida Environmental Report (SFER2009). The comparison was done on a basin-scale per the scope of work and due to the limited water quality data for the sub-basins defined as part of this study.

The results presented in ***Table 4.3.20*** show general agreement between the reported loads and the calculated values. The exception is WY 2008 for the three basins but mainly for the C-139 basin. This discrepancy is attributed to the drought experienced during the wet season of WY 2008 (July-October, 2007). As reported in SFER2009, the maximum flows were significantly less than in previous years, and correspondingly, the annual TP concentrations were also less. It is presumed the drought conditions for the WY 2008 wet season, affected water operations especially within Agro Centric basins, which can be seen in the large differences of TP loads between the calculated and actual reported values as shown in ***Table 4.3.20*** below.

Table 4.3.20 – C-139 Region Basins TP Loads Comparison

Year	SFER-2009			Calculated			Error		
	Flow (kac-ft)	TP (Mton)	FWMC (ppb)	Flow (kac-ft)	TP (Mton)	FWMC (ppb)	Flow	TP	FWMC
C-139 Basin									
2005	167.5	40.3	195	196.0	52.2	216	-17%	-30%	-11%
2006	333.2	106.9	260	277.8	72.7	212	17%	32%	18%
2007	77.3	29.1	306	110.2	33.0	243	-43%	-13%	20%
2008	38.7	5.4	113	53.6	18.3	277	-38%	-237%	-144%
Feeder Canal Basin									
2005	94.6	11.3	97	55.0	11.5	169	42%	-2%	-75%
2006	150.4	28.7	155	121.2	25.1	168	19%	12%	-9%
2007	70.7	18.8	215	86.6	18.3	171	-22%	3%	20%
2008	25.3	3.2	101	27.2	6.1	182	-7%	-94%	-80%
L-28 Basin									
2005	138.0	7.2	42	118.0	9.6	66	15%	-33%	-55%
2006	203.6	12.5	50	153.6	12.7	67	25%	-2%	-35%
2007	88.5	5.1	47	90.8	8.3	74	-3%	-63%	-59%
2008	90.3	4.1	36	85.0	6.9	66	6%	-71%	-82%

Note: Negative values represent higher calculated values.

The results presented in ***Table 4.3.20*** show that the loads calculated for the C-139 and Feeder canal basins were in some cases higher and some lower than the loads reported in the SFER2009 report; however, the calculated loads for the L-28 basin were consistently higher. After further review it was observed that the C-139 Annex (AX-01) has five large reservoirs which add to over 10% of the sub-basin area. All the water in this sub-basin is routed through these 5 reservoirs prior to discharge out of the C-139 Annex. Furthermore, water stored in C-139 Annex reservoirs is available for irrigation, reducing the discharges from this sub-basin. Based on the measured SFWMD data, it appears that the large reservoirs in this sub-basin help reduce the TP loads discharged from the C-139 Annex, considerably. Therefore, a 25% reduction for the AX-01 sub-basin area weighted EMC value was implemented. ***Tables 3-11 to 3-14*** were revised based on the modified EMC of sub-basin AX-01 and are presented in

Tables 4.3.21 to 4.3.24. As seen in ***Table 4.3.25,*** the 25% reduction of the area weighted EMC value brings the calculated values closer to the SFER-2009 values for the L-28 sub-basin. The possible use of the reduced EMC based on the existence of reservoirs accounting for over 10% of the area of a farm will be reviewed and added based on the performance of the flow model when evaluating each of the selected four alternatives.

The reduction factor for TP loads due to the presence of potential new internal reservoirs will be applied during the comparison of alternatives. This factor will depend on the size of the reservoir and the amount of the sub-basin/basin flows that are routed through the reservoirs. This coefficient will represent the reduction of TP loads due to routing flows to new reservoirs. All the data and tables for the EMC water quality analysis are presented in the data CD enclosed in ***Appendix D2 Water Quality Data***.

Table 4.3.21 – C-139 Region Sub-basins Flows and TP Loads WY-2005 (Rev)

Basins	Sub-Basins	Flow		TP	
		m^3	Ac-ft	kg	Mtons
C-139 Basin	L1-01	8,212,320	6,658	1,263	1.26
	L1-02	38,909,376	31,544	9,227	9.23
	L2-01	9,576,576	7,764	1,414	1.41
	L2-02	53,663,040	43,505	6,958	6.96
	L2-03	18,374,688	14,896	3,917	3.92
	L2-04	20,596,896	16,698	3,451	3.45
	L2-05	67,602,816	54,806	19,804	19.80
	DF-01	10,772,352	8,733	2,269	2.27
	DF-02	8,303,904	6,732	1,685	1.68
	S&M-01	5,704,992	4,625	2,244	2.24
	Total	**241,716,960**	**195,960**	**52,232**	**52.23**
Feeder Canal Basin	WF-01	20,309,184	16,465	2,579	2.58
	NF-01	25,067,232	20,322	6,003	6.00
	SF-01	22,525,344	18,261	2,911	2.91
	Total	**67,901,760**	**55,048**	**11,493**	**11.49**
L-28 Basin	AX-01	20,818,944	16,878	2,374	2.37
	L28-01	124,683,840	101,081	6,598	6.60
	Total	**145,502,784**	**117,959**	**8,972**	**8.97**

Table 4.3.22 – C-139 Region Sub-basins Flows and TP Loads WY-2006 (Rev)

Basins	Sub-Basins	Flow		TP	
		m^3	Ac-ft	kg	Mtons
C-139 Basin	L1-01	9,573,984	7,762	1,473	1.47
	L1-02	31,202,496	25,296	7,400	7.40
	L2-01	11,826,432	9,588	1,746	1.75
	L2-02	77,715,072	63,004	10,077	10.08
	L2-03	18,484,416	14,985	3,940	3.94
	L2-04	41,770,944	33,864	6,998	7.00
	L2-05	76,101,984	61,696	22,294	22.29
	DF-01	28,519,776	23,121	6,006	6.01
	DF-02	31,256,064	25,339	6,341	6.34
	S&M-01	16,267,392	13,188	6,399	6.40
	Total	**342,718,560**	**277,842**	**72,673**	**72.67**
Feeder Canal Basin	WF-01	53,741,664	43,568	6,825	6.83
	NF-01	53,860,032	43,664	12,898	12.90
	SF-01	41,953,248	34,012	5,422	5.42
	Total	**149,554,944**	**121,244**	**25,145**	**25.15**
L-28 Basin	AX-01	30,387,744	24,635	3,464	3.46
	L28-01	159,029,568	128,925	8,416	8.42
	Total	**189,417,312**	**153,561**	**11,880**	**11.88**

Table 4.3.23 – C-139 Region Sub-basins Flows and TP Loads WY-2007 (Rev)

Basins	Sub-Basins	Flow		TP	
		m^3	Ac-ft	kg	Mtons
C-139 Basin	L1-01	3,753,216	3,043	577	0.58
	L1-02	22,228,992	18,021	5,272	5.27
	L2-01	548,640	445	81	0.08
	L2-02	14,415,840	11,687	1,869	1.87
	L2-03	8,496,576	6,888	1,811	1.81
	L2-04	9,921,312	8,043	1,662	1.66
	L2-05	46,141,920	37,407	13,517	13.52
	DF-01	9,478,944	7,685	1,996	2.00
	DF-02	10,476,864	8,494	2,125	2.13
	S&M-01	10,508,832	8,520	4,134	4.13
	Total	**135,971,136**	**110,232**	**33,045**	**33.04**
Feeder Canal Basin	WF-01	37,798,272	30,643	4,800	4.80
	NF-01	41,526,432	33,666	9,944	9.94
	SF-01	27,458,784	22,261	3,549	3.55
	Total	**106,783,488**	**86,570**	**18,293**	**18.29**
L-28 Basin	AX-01	26,928,288	21,831	3,070	3.07
	L28-01	85,033,152	68,936	4,500	4.50
	Total	**111,961,440**	**90,767**	**7,570**	**7.57**

Table 4.3.24 – C-139 Region Sub-basins Flows and TP Loads WY-2008 (Rev)

Basins	Sub-Basins	Flow		TP	
		m^3	Ac-ft	kg	Mtons
C-139 Basin	L1-01	1,629,504	1,321	251	0.25
	L1-02	8,861,184	7,184	2,101	2.10
	L2-01	0	0	0	0.00
	L2-02	2,317,248	1,879	300	0.30
	L2-03	2,797,632	2,268	596	0.60
	L2-04	3,504,384	2,841	587	0.59
	L2-05	36,249,984	29,388	10,619	10.62
	DF-01	1,127,520	914	237	0.24
	DF-02	1,009,152	818	205	0.20
	S&M-01	8,576,064	6,953	3,373	3.37
	Total	**66,072,672**	**53,565**	**18,271**	**18.27**
Feeder Canal Basin	WF-01	8,133,696	6,594	1,033	1.03
	NF-01	16,231,104	13,159	3,887	3.89
	SF-01	9,146,304	7,415	1,182	1.18
	Total	**33,511,104**	**27,167**	**6,102**	**6.10**
L-28 Basin	AX-01	15,543,360	12,601	1,772	1.77
	L28-01	89,267,616	72,369	4,724	4.72
	Total	**104,810,976**	**84,970**	**6,496**	**6.50**

Table 4.3.25 – C-139 Region Basins TP Loads Comparison (Rev)

Year	SFER-2009			Calculated			Error		
	Flow (kac-ft)	TP (Mton)	FWMC (ppb)	Flow (kac-ft)	TP (Mton)	FWMC (ppb)	Flow	TP	FWMC
C-139 Basin									
2005	167.5	40.3	195	196.0	52.2	216	-17%	-30%	-11%
2006	333.2	106.9	260	277.8	72.7	212	17%	32%	18%
2007	77.3	29.1	306	110.2	33.0	243	-43%	-13%	20%
2008	38.7	5.4	113	53.6	18.3	277	-38%	-237%	-144%
Feeder Canal Basin									
2005	94.6	11.3	97	55.0	11.5	169	42%	-2%	-75%
2006	150.4	28.7	155	121.2	25.1	168	19%	12%	-9%
2007	70.7	18.8	215	86.6	18.3	171	-22%	3%	20%
2008	25.3	3.2	101	27.2	6.1	182	-7%	-94%	-80%
L-28 Basin									
2005	138.0	7.2	42	118.0	9.0	62	15%	-25%	-46%
2006	203.6	12.5	50	153.6	11.9	63	25%	5%	-26%
2007	88.5	5.1	47	90.8	7.6	68	-3%	-48%	-45%
2008	90.3	4.1	36	85.0	6.5	62	6%	-60%	-71%

Note: Negative values represent higher calculated values.

4.3.3.6 Water Quality Analysis for Alternatives Comparison

The results of the post-processing spreadsheet analysis for the C-139 RFS using the EMCs and flows from the MIKE SHE/MIKE 11 model are in agreement with the measured data in a basin level. When comparing alternatives the flows used will be the same for the four alternatives. This will eliminate the TP concentration variability associated with the different flows. Also, during the comparative analysis of each of the alternatives all the EMC estimates for existing conditions will be equal. For the reason above the EMC approach procedure is deemed adequate for quantifying the water quality in a yearly basis, for the four selected alternatives to be analyzed during Phase II. This method will also be able to differentiate between the alternative formulations based on land use changes due to each of the alternatives and water quality treatment method.

Possible attenuation factors that may not be captured by the EMC based TP load calculations will be included for each of the specific alternatives. An example of these factors is the reduction factor used in **Section 4.3.3.5** to account for the reservoir in the AX-01 sub-basin. The reduction in TP loads due to the presence of internal reservoirs will depend on the size of the reservoir and the amount of the sub-basin/basin flows that are routed through the reservoirs.

4.3.4 POTENTIAL C-139 RFS ALTERNATIVES

4.3.4.1 Introduction

This section includes a formulation of twenty one (21) watershed management alternatives. A screening tool will be developed to streamline the 21 alternatives to (4) four alternatives. The four (4) preferred alternatives will be simulated with the MIKE SHE/MIKE 11 model and the Post Processing Water Quality spreadsheet analysis to show the hydrologic and water quality impacts. During Phase II, the alternatives will be represented in the model with sufficient detail, such that, it is possible to determine the basic sizes of new hydraulic conveyance features required to implement the alternative.

The twenty one (21) alternatives presented below were formulated based on:

- a review of measured water level, flow, and water quality data,
- a review of results from the initial calibrated/validated model, and
- discussions with both SFWMD staff and farming consultants.

The four (4) preferred alternatives can be any one of the twenty one (21) alternatives presented below, or a combination or two or more, any one of which may be modified based on further discussions.

4.3.4.2 Alternatives

The performance measures to be considered in Phase II of the Study will be the following:

1. Water Quality of regional Discharge Points
    a. G-136
    b. G342A-D
    c. G406
    d. S-140
    e. S-190
2. Effects on STA Performance

3. Stormwater Management/Flood Control
    a. Estimate effects of Alts on Flood Control

4. Water Supply
    a. Estimated effects of Alternatives on Water Supply

5. Costs Estimate
    a. Capital Costs
    b. Land Acquisition costs
    c. O&M costs
    d. Grant funds availability

6. Permitability
    a. Consistent with EFA, District Rules
    b. Wetlands impacts

7. Operational Flexibility of Regional Water Management system

8. Time to Implement

The alternatives are divided in the following three main subsets.

a) Regional scale alternatives
b) Sub-regional scale alternatives
c) Smaller Scale alternatives

4.3.4.2.1 Regional Scale Alternatives

1. S-4 Diversion South

Goal: Divert S-4 discharges away from Lake Okeechobee and store for use in meeting water supply demands in the C-139 Basin.

Rationale: S-4 discharges approximately 10 metric tons of TP to Lake Okeechobee through stormwater discharge via pump station S-4. Diverting this TP away from Lake O would benefit the Lake. Conveyance to, and capture of this water within the C-139 and Feeder Canal Basins, and subsequent use of this water during the dry season would benefit the C-139 and Feeder Canal basins. Some of the possible uses for this water are:

a. Hydroperiod maintenance flows for STAs,
b. C-139, Feeder and L-28 Basin farmers,
c. Seminole Tribe of Florida Big Cypress Reservation, and
d. Hydroperiod maintenance discharges (after treatment in the STAs) to WCA-3A.

Expected benefit: Water quality benefits to Lake Okeechobee; water supply benefits to C-139, Feeder Canal and L-28 Basins.

Required Infrastructure: Canal widening/improvement (up to about 50 miles); pump stations (3-4); increasing capacity of G-409 pump station; storage area. ***Figure 4.3.47*** shows a conceptual layout of this alternative.

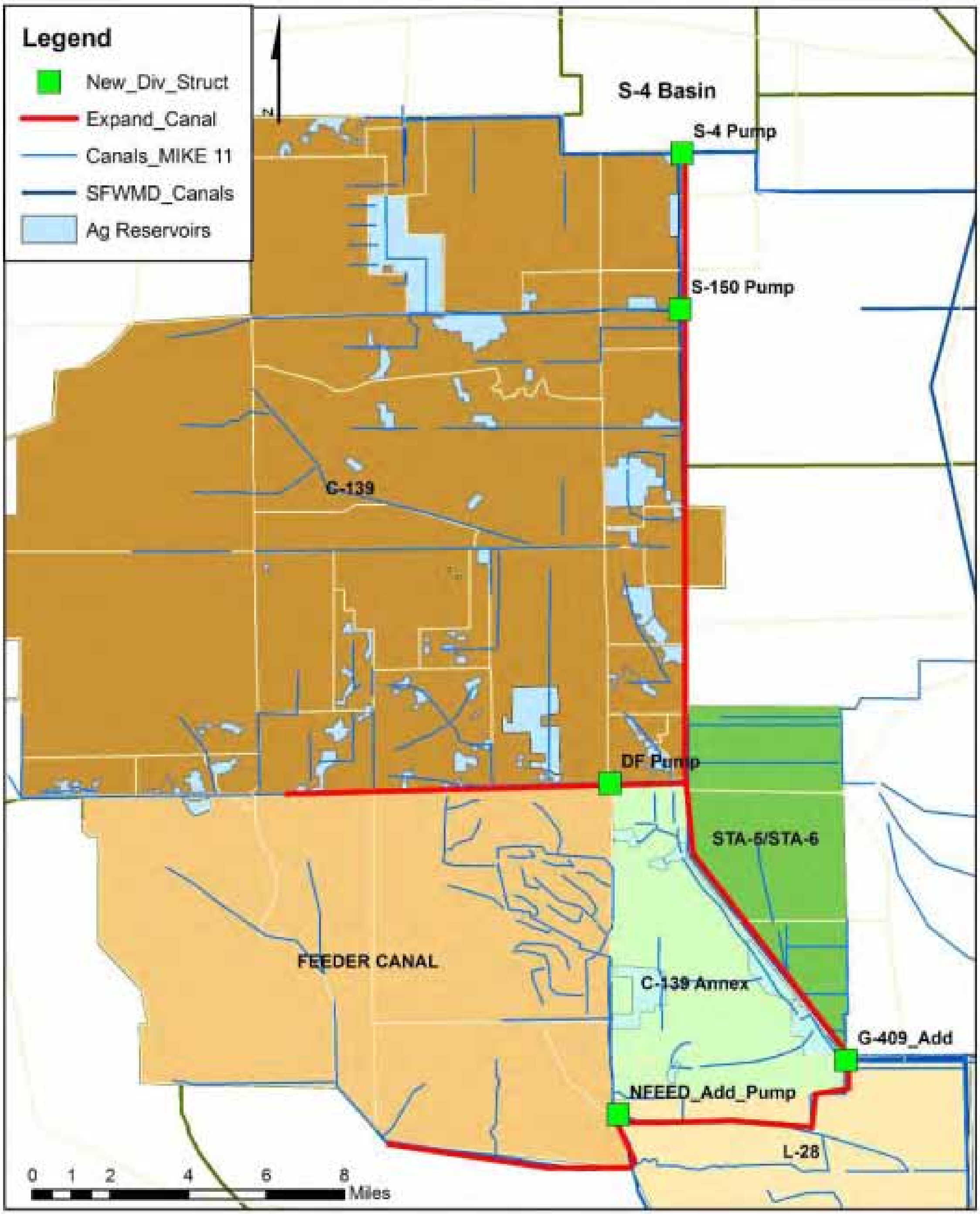


Figure 4.3.47 – Conceptual Layout for S-4 Diversion South

2. Caloosahatchee River Water Diversion South- East

Goal: Divert Lake Okeechobee Regulatory releases away from the Caloosahatchee River Estuary and store for use in meeting water supply demands in the C-139 Basin.

Rationale: At certain times of the year, Lake Okeechobee Regulatory releases to the Caloosahatchee River can be damaging to the lower river Estuary. Diverting some of this water away from the estuary would be of ecological benefit to the lower estuary. Capturing and storing this water (potentially in parcels of the land the District intends to purchase) for subsequent water supply use during the dry season would be of benefit to the C-139 and Feeder Canal Basins. Some of the possible uses for this water are:

a. Hydroperiod maintenance flows for STAs,
b. C-139, Feeder and L-28 Basin farmers,
c. Seminole Tribe of Florida Big Cypress Reservation, and
d. Hydroperiod maintenance discharges (after treatment in the STAs) to WCA-3A.

Expected benefit: Ecological benefit to the lower estuary of the Caloosahatchee River; water supply benefits to the C-139, Feeder Canal and L-28 Basins.

Required Infrastructure: Canal widening/improvements (up to about 50 miles); pump stations (3-4); increasing capacity of G-409 pump station; storage area. The conceptual layout for the most part will be similar to the one shown in ***Figure 4.3.47.***

3. Stormwater Management Improvements

Goal: Minimize flood damage in the western C-139 Basin and improve canal conveyance in order to minimize discharges from Above Ground Impoundments (AGI)s.

Rationale: West to East conveyance is currently limited and leads to significant, relatively long lasting flooding events within the basin. In addition, lack of good, predictable conveyance can lead to discharge from local AGIs when it would potentially be of benefit to hold water within the AGIs.

Expected Benefit: Less flooding; better AGI management leading to better water quality.

Required Infrastructure: Canal improvement (up to about 50 miles) and approximately ten gates. This alternative should be implemented with Alternative 6 (dredging of the L-2 and L-3 Canals), see ***Figure 4.3.48***.

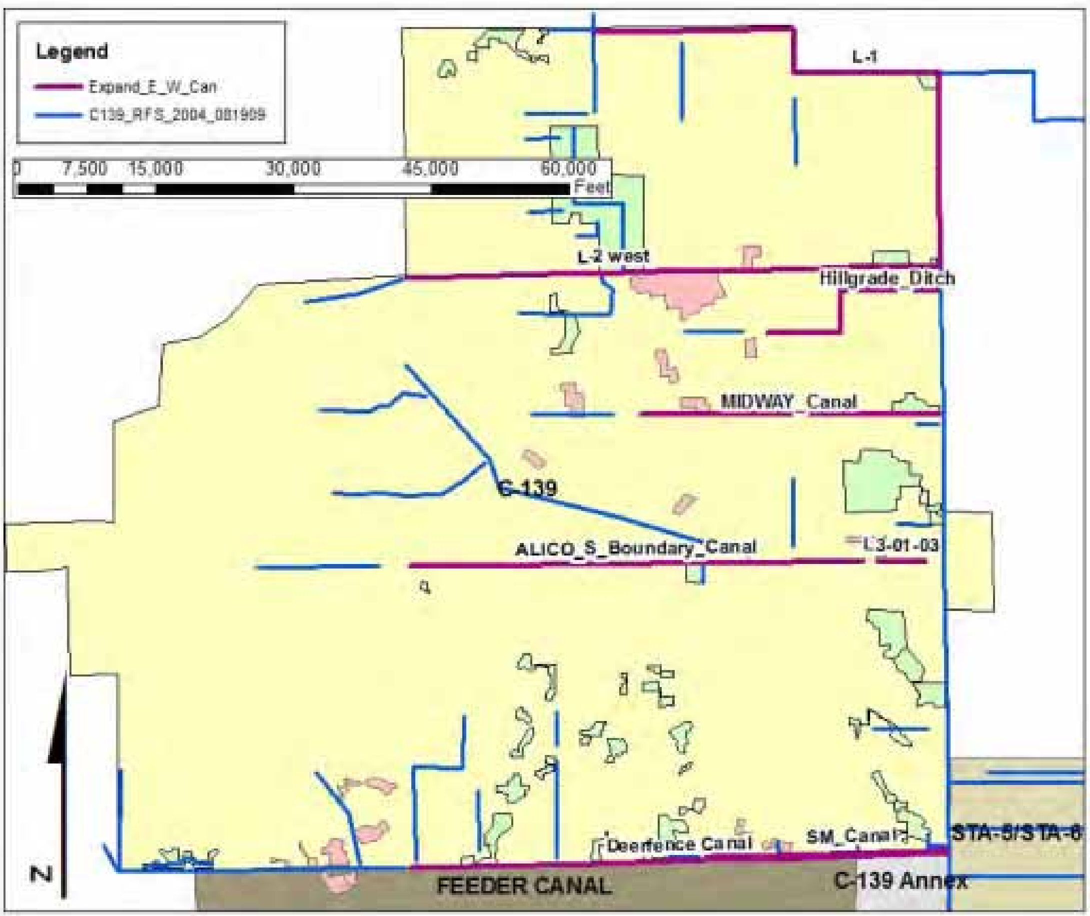


Figure 4.3.48 – Conceptual Layout of Canals to Have Conveyance Improvement

4. Regional Capture and Storage/Treatment of Stormwater in the C-139 Basin

Goal: Store excess runoff from C-139 Basin farms in a limited number of larger stormwater treatment areas and utilize the stored water for irrigation supply.

Rationale: Peak flow discharges are very high in this basin for large runoff events which occur late in the wet season. This is because existing on-farm AGIs are full. The purpose of the additional storage would be to store excess runoff during periods when those discharges carry high TP concentrations and allow that water to be used again for irrigation. ***Figure 4.3.49*** shows some conceptual locations for possible storage/treatment in the C-139 Basin.

Expected Benefit: Water quality benefit to basin discharges; benefit to District's STAs by lowering inflow loading rate; possible benefit to C-139 farms from additional water available for irrigation.

Required Infrastructure: Canal improvements; pump station(s); storage/treatment area(s).

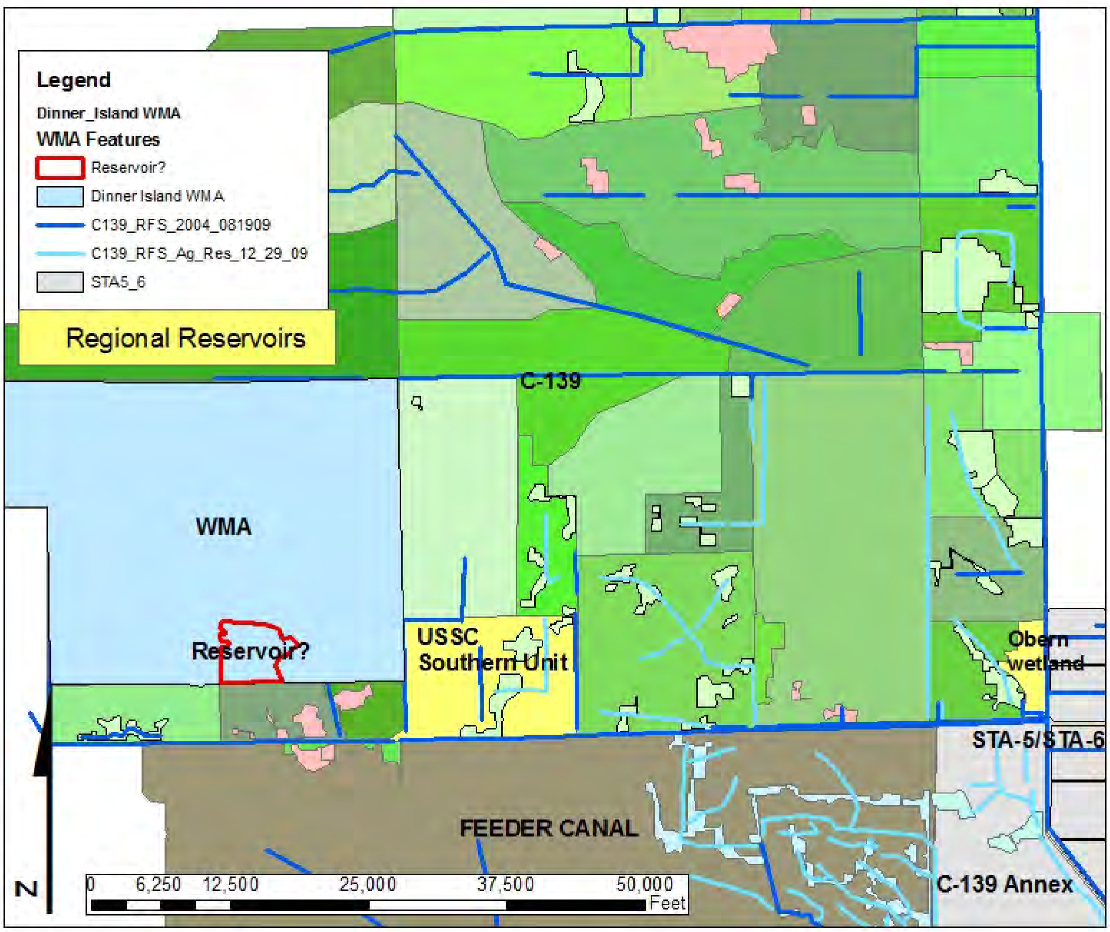


Figure 4.3.49 – Location of the Possible Regional Reservoirs in the C-139 Basin

5. Regional Capture and Storage of Stormwater in the Feeder Canal Basin

Goal: Store excess runoff from the C-139 and Feeder Canal Basins in a limited number of larger stormwater treatment areas and utilize the stored water for irrigation supply.

Rationale: The Seminole Tribe is engaged in an evaluation and preliminary design of water storage facilities within the Feeder Canal Basin to assist the Tribe in improving management of the Feeder Canal water resources. The G-409 pump station at Confusion Corner currently operates to supply water to the Seminole Tribe. This pump station typically only operates during the dry season. If there were wetlands within the Feeder Canal, or the L-28 Basins that were typically experiencing low water levels during the wet season, then the G-409 pump station could operate during the wet season to deliver excess flows from the C-139 Basin to improve Feeder Canal, and L-28 wetland hydroperiods. In addition, there is a potential that excess runoff could be stored in a number of reservoirs that are under design and/or construction in the Big Cypress Seminole Indian Reservation, depending on hydroperiods in those proposed facilities. ***Figure 4.3.50*** shows some conceptual locations for possible storage/treatment in the Feeder Canal and L-28 Basins.

Expected Benefit: Water quality benefit to basin discharges; reduction of peak flows and attenuation of the TP discharges; possible benefit to Feeder Canal and L-28 farmers from additional water available for irrigation.

Required Infrastructure: Canal improvement; pump station(s); storage/ treatment area(s).

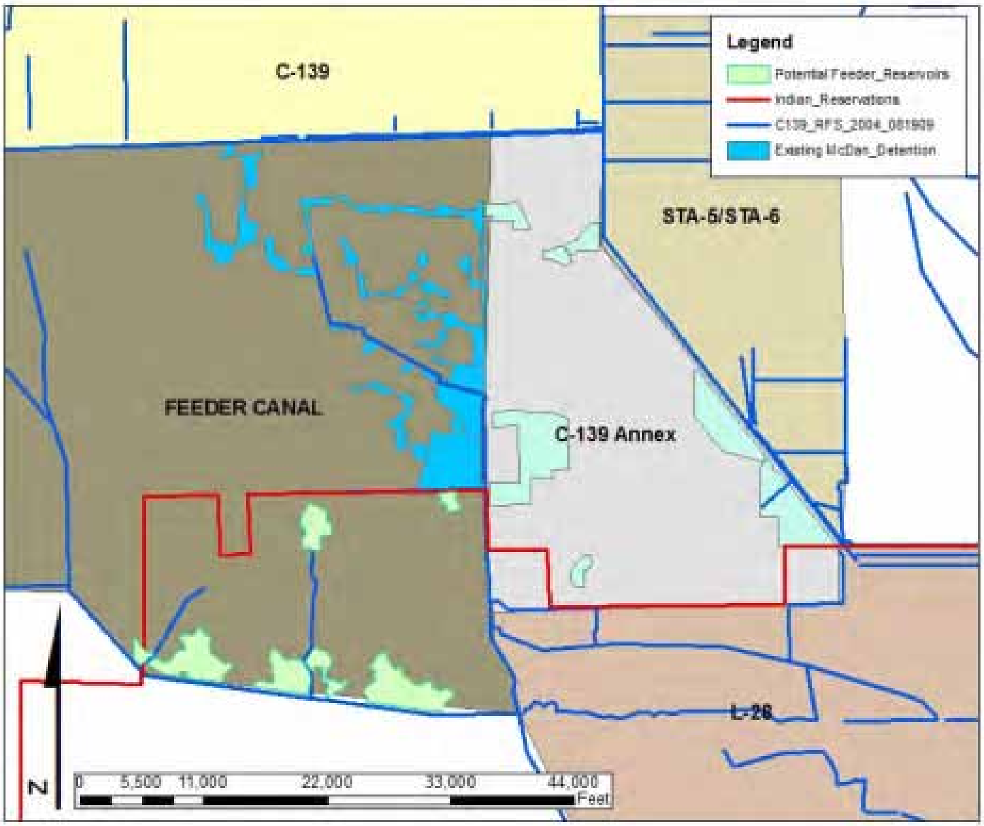


Figure 4.3.50 – Possible Regional Reservoirs Location in the Feeder Canal and L-28 Basins

6. Dredging of L-2/L-3 Canal and Enhancement of the Western L-2/L-3 Levee

Goal: Improved Regional scale storage and stormwater conveyance**.**

Rationale: Dredging of the L-2/L-3 canal and improving the L-2 levee on west side of canal so that stages within the canal can be higher, which will increase storage of flood waters within the canal to reduce peak flows into STA-5 and STA-6. If implemented, special care will have to be taken during design of this concept to prevent flooding in canals that discharge to L-2 and L-3 from the west.

Expected Benefit: Additional storage; improve water quality; improved stormwater conveyance**.**

Required Infrastructure: Canal dredging/improvement (up to 20 miles); levee improvements.

7. Switch to Surface Water Utilization when Excess Water is Available

Goal: Reduced pumping from ground water; reduce nutrient loads to STA 5.

Rationale: Flows to STA 5 are often above 100 cfs for a continued period of time, often in excess of four months. Farms in the C-139 Basin have continued irrigation needs during portions of the summer period, which they satisfy from ground water irrigation wells. This option would allow water from C-139 canals to be used for irrigation during the summer when STA-5 inflows are greater than 50 to 100 cfs and minimum elevations within the STAs have been achieved. Once the flow into STA-5 drops below 50 or 100 cfs, these newly permitted canal irrigation pumps would be turned off.

Expected Benefit: Cheaper source of irrigation water while reducing nutrient loads to STA 5.

Required infrastructure: Some farms may need to modify on-farm pump stations.

8. Construct Storage and/or Treatment Facilities on C-139 Annex.

Goal: Provide additional storage of flood waters to reduce peak flows, and extend the period of positive flows into STA-5 and STA-6 during the dry season. Treatment of runoff prior to entering STA-5 and STA-6, and provide additional water supply for both the Everglades Protection Area and agricultural lands.

Rationale: If the C-139 Annex is acquired by SFWMD, this large farm (17,845 acres) could be considered for some type of storage/wetland pre-treatment system or wetland flow-way. Additionally, the C-139 basin could be expanded to move the discharge compliance point further downstream after receiving treatment within the modified C-139 Annex. ***Figure 4.3.51*** presents a conceptual layout for this alternative. The pumps shown may or may not be necessary, depending on more detailed assessments of this alternative during the next phase of this project.

Expected Benefit: Additional storage; improve water quality; peak flow reduction, extension of positive flows to STA-5 and STA 6**.**

Required infrastructure: Canal widening/improvement (up to about 50 miles); pump station(s) (1 or 2); levees.

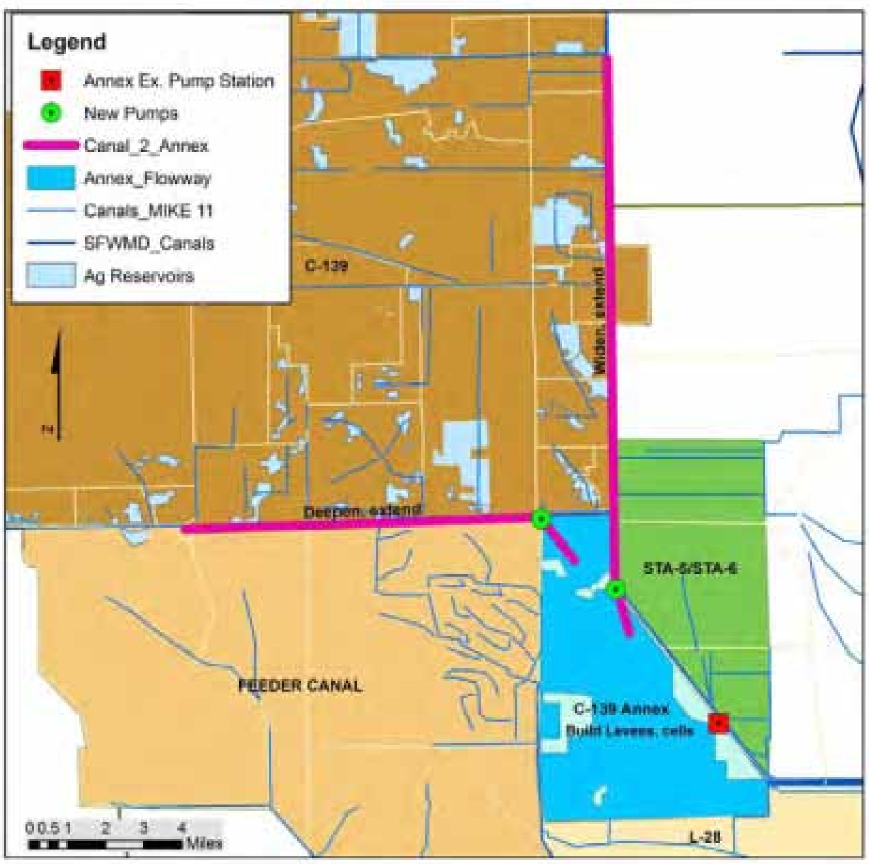


Figure 4.3.51 – Conceptual Layout to Construct Storage and/or Treatment Facilities on C-139 Annex

4.3.4.2.2 Sub-Regional Scale Alternatives

9. Sub-Regional Capture and Storage/Treatment of Stormwater, C-139 Basin

Goal: Select sub-basin with greatest need to focus efforts and minimize costs to entire region.

Rationale: Assess proposed Rule Amendment Sub-Basins for performance measures. Some sub-basin would meet performance measures while other sub-basins would exceed performance measures. Focusing the effort on the basins that exceed performance measures reduces negative financial impacts to farms that are already meeting regulatory requirements. ***Figure 4.3.52*** shows the Proposed Rule Amendment Sub-basins.

Expected Benefit: Water quality benefit to basin discharge and benefit to District's STAs by lowering inflow loading rate to STAs 5 and 6.

Required Infrastructure: Canal improvement; pump station(s); storage/ treatment area.

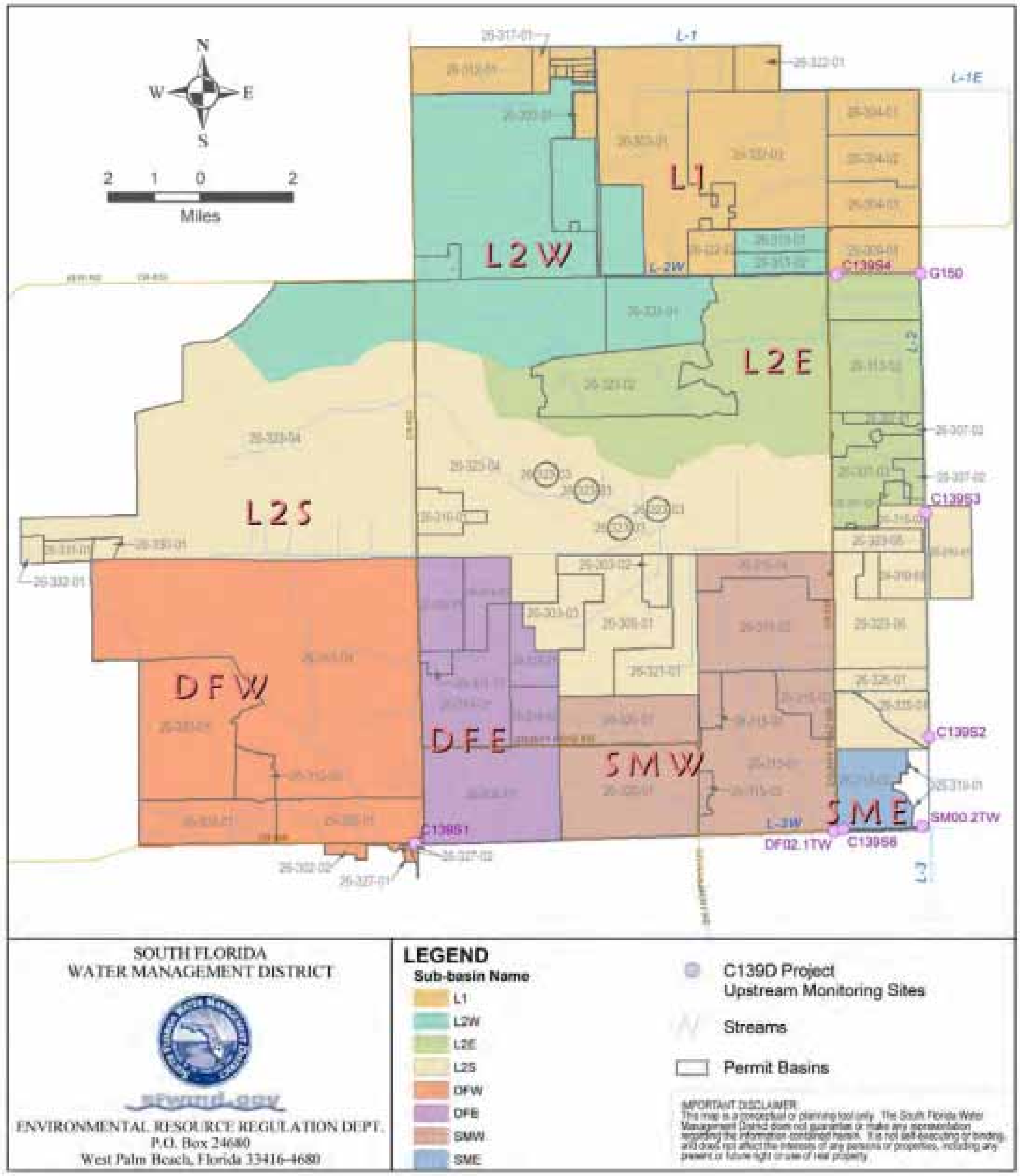


Figure 4.3.52 – C-139 Proposed Rule Amendment Sub-Basins

10. Sub- Regional Capture and Storage of Storm-water, Feeder Canal Basin

Goal: Select sub-regional basin with greatest need to focus efforts and minimize costs to entire region.

Rationale: Some sub-regional basins meet performance measures while other sub-basins exceed performance measures. Focusing the effort on the basins that exceed performance measures reduces negative financial impacts to farms that are already meeting regulatory requirements. Feeder Canal Basin sub-regional basins are shown in ***Figure 4.3.53***.

Expected Benefit: Water quality improvement for discharges to the Everglades Protection Area.

Required Infrastructure: Canal improvement; pump station(s); storage/treatment area.

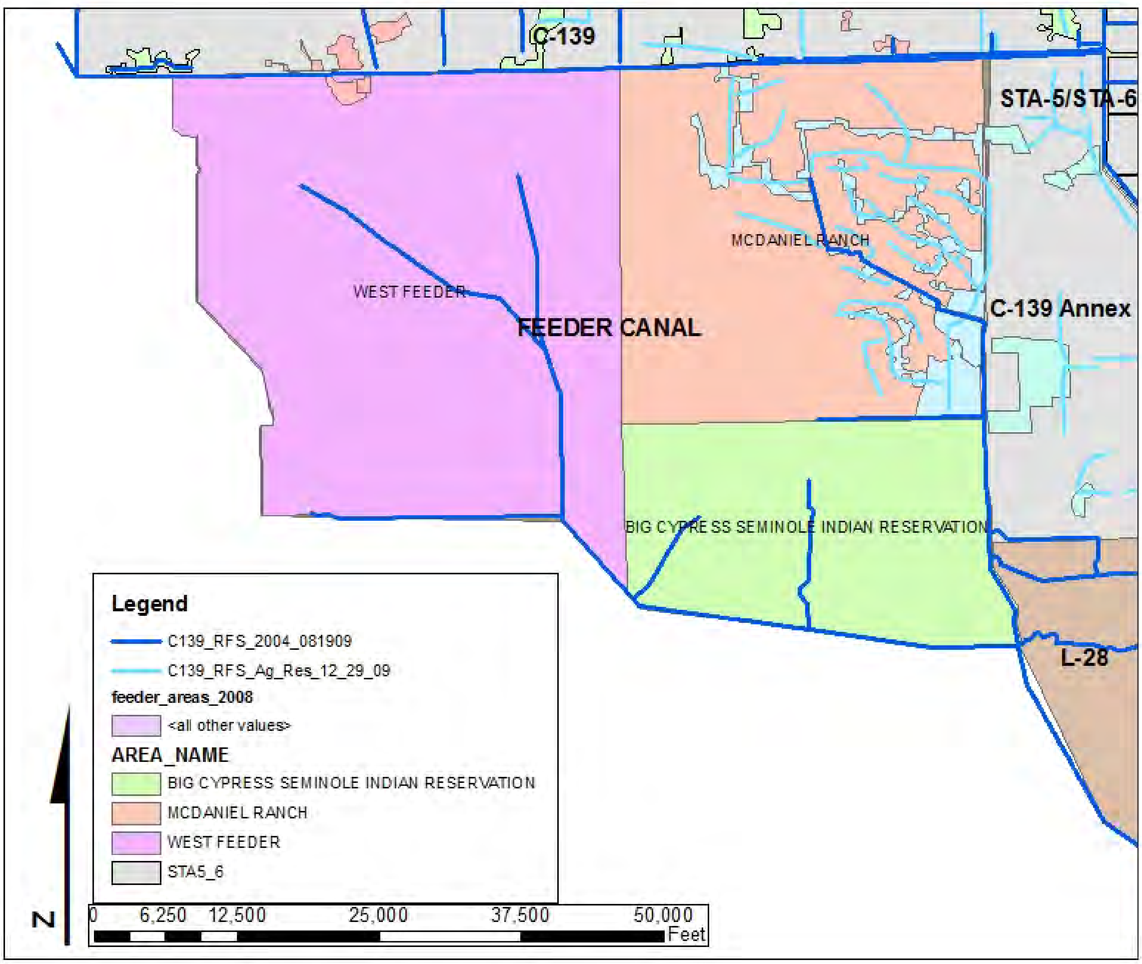


Figure 4.3.53 – Feeder Canal Sub-Basins

11. Disposal of Water on an AGI Adjacent to Compartment C STA

Goal: Reduce peak flows into the Comp C STA.

Rationale: District already owns approx 2,000 acres on the western edge of the new Compartment C that will not be used for treatment area. An AGI could be built in this area and could hold up 8,000 acre ft of water.

Expected Benefit Capability to store flows from the G-508 pump station which can then be used in Compartment C as a water supply dedicated to maintaining desirable water depths within the Compartment C cells. This will add retention time by storing excess runoff during periods when those discharges carry high TP concentrations, improving the water quality of discharges from STAs 5 and 6. ***Figure 4.3.54*** presents a conceptual layout for this alternative.

Required Infrastructure: New Connection from G-508 to new storage area; pump station increase capacity; storage area levees (about 15 miles).

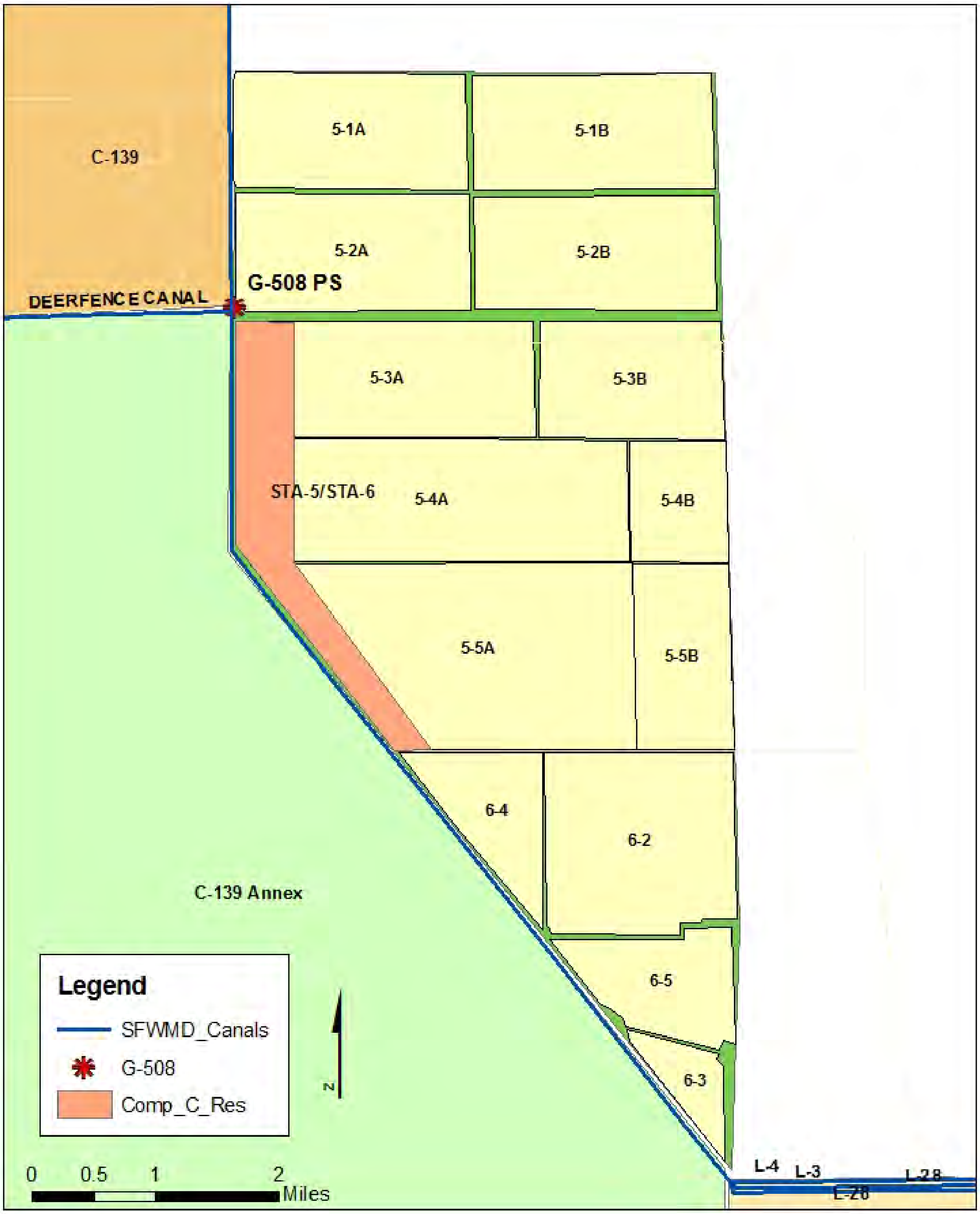


Figure 4.3.54 – Conceptual Layout for AGI in Compartment C

4.3.4.2.3 Smaller Scale Alternatives

12. Dispersed Storage - Leased Storage on Privately Owned Lands

Goal: Water disposal on private lands.

Rationale: The advantage of leasing storage from C-139 Basin farmers is that the design and construction of the reservoirs is performed by the farmers and their consultants rather than by SFWMD staff, and the operation of the reservoir is managed by the farmer. This generates revenue for Hendry County residents and keeps land on Hendry County tax rolls. It is possible that the overall cost and duration of implementation of the storage will be less than if SFWMD was responsible for land purchase, design, and construction.

Expected Benefit: Improved water quality.

Required Infrastructure: Canal improvement; pump station(s); small storage areas.

13. Advanced Treatment Technologies Coupled with Sub-basin or Farm Level Components.

Goal: Improve the quality of water entering STA 5 so that the C-139 Basin is in compliance with Long Term Plan goals.

Rationale: Example: District owns approx 500 acres just west of L-3 (Obern property), across from STA-5. Discharge from the S&M canal sub-basin could be easily routed to that area; chemical dosing accomplished; use the 500 acres as a settling pond; which would then discharge cleaner water back to the L-3 Canal. ***Figure 4.3.49*** above shows the location of the Obern property.

Expected Benefit: Improved water quality.

Required Infrastructure: New canal or existing canal improvement to connect to treatment area; small pump station(s); storage/treatment area; treatment plant operation.

14. Restoration of Deer Fence Canal Flows South to the Feeder Canal Basin.

Goal: Restore Historical flows south.

Rationale: Historically, flows from the western portion of the C-139 Basin flowed south through the Feeder Canal Basin into Big Cypress National Preserve. The construction of the L-2 and L-3 Canal system changed the direction of those flows from a southerly path to an easterly path. Detailed hydroperiod assessments of wetlands in the Feeder Canal Basin have not been conducted. However, if Feeder Canal wetland hydroperiods are less than optimal, restoration of the historic flows could improve Feeder Canal wetland hydroperiods while providing additional flood protection benefits to the C-139 Basin. ***Figure 4.3.55*** presents a conceptual layout for this alternative.

If this alternative is evaluated further, the assessment should also evaluate the impact of this alternative on existing levels of flood protection in the Feeder Canal Basin to assure that this alternative does not transfer flooding problems from one basin to another.

Expected Benefit: Reduce nutrient loads to STA 5 and improve the hydroperiod of Feeder Canal Basin wetlands without causing flooding problems in the Feeder Canal Basin.

Required Infrastructure: Canal improvement; pump station(s) and/or gates.

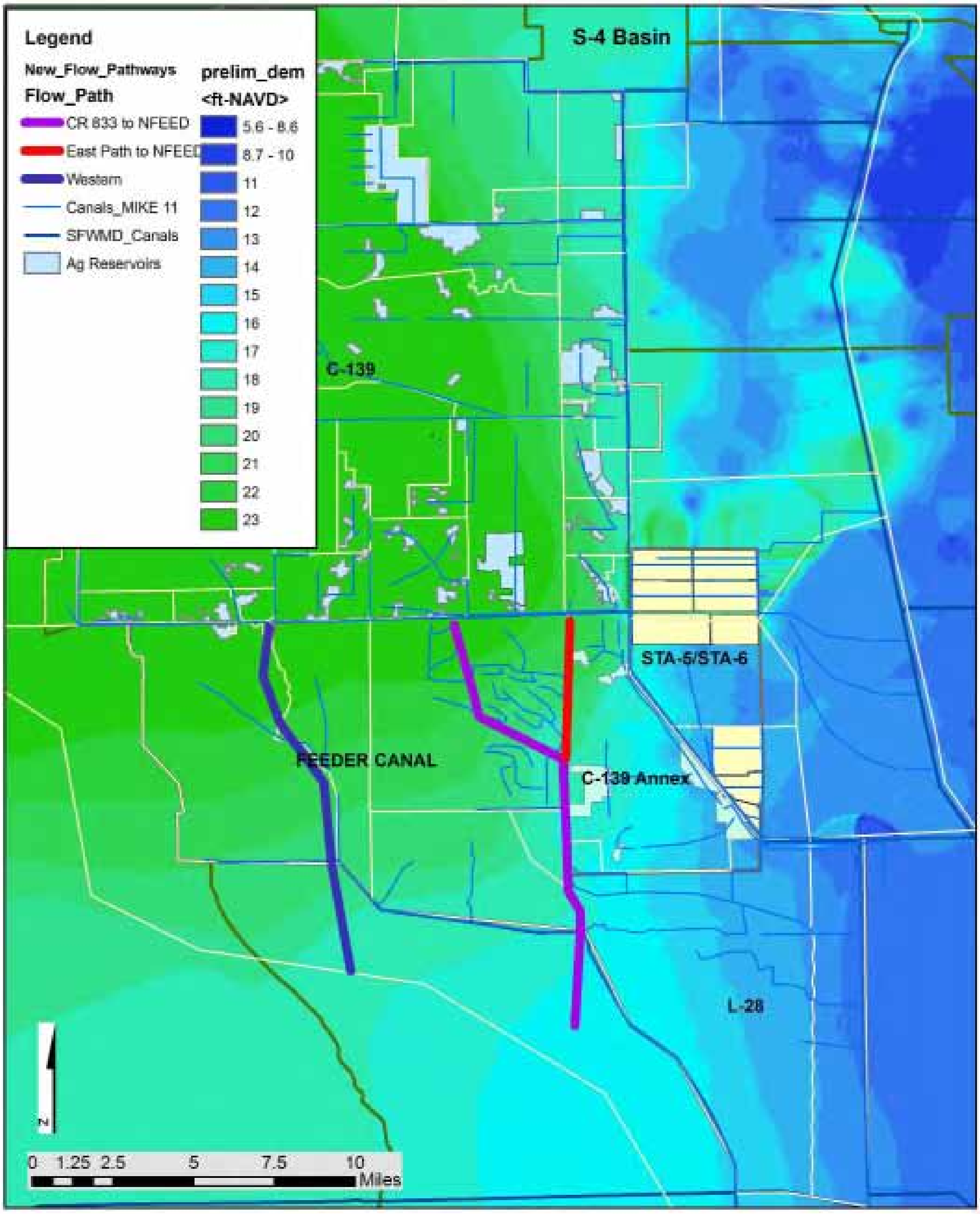


Figure 4.3.55 – Conceptual Layout for Restoration of Deer Fence Canal Flows South

15. Change District Structures from Bottom Opening to Overflow Type Structures

Goal: Improve water quality of discharges from District structures.

Rationale: Existing structures are underflow structures, and discharges from these structures are drawn from the bottom of canals. Due to settling of particulate pollutants, the water quality of bottom waters is worse than surface waters. Switching to overflow-type structures will improve water quality. There is a downside to this, which is that overflow structures require more maintenance due to floating vegetation and debris, which have to be removed from the canals if the anticipated water quality improvement is to be realized.

Expected Benefit: Improved water quality.

Required Infrastructure: New gates.

16. Construct Settling Basins Upstream of Major Structures

Goal: Lower mass of particulates flowing out of basin.

Rationale: Settling basins upstream of major structures will increase the cross section area upstream of the structure, which will lower the velocity upstream of the structure. This will lead to less re-suspension during periods of high flow, thereby improving water quality.

Expected Benefit: Improved water quality.

Required Infrastructure: Canal modifications.

17. Construct Step Down Weirs in Eastward Draining Canals

Goal: Reduce the annual discharge volume in areas where the land surface gradient is greater

Rationale: The eastward flowing canals in the C-139 Basin are relatively flat west of CR 846, however the gradient increases between CR 846 and the L-2 Canal. Constructing step-down weirs in the reaches between CR 846 and L-2 will maintain higher groundwater elevations in the area between CR846 and the L-2 Canal, which will reduce overall discharge volumes. That, in turn, will reduce annual nutrient discharge volumes.

Expected Benefit: Improved water quality.

Required Infrastructure: New weir and/or gate structures.

18. Increase Levee Height of AGIs by Eight Inches

Goal: Increase overall basin storage to improve the water quality of farm runoff

Rationale: AGI nutrient retention increases as the storage volume increases. Where the AGI is located in uplands or in wetlands that have low hydroperiods, increasing the levee and control structures height will result in improved water quality of AGI discharges.

Expected Benefit: Improved water quality by storing excess runoff during periods when those discharges carry high TP concentrations, and allowing that water to be used again for irrigation.

Required Infrastructure: Levee improvement/construction.

19. First Flush Retention Facilities

Goal: Lower mass of particulates flowing out of farm runoffs.

Rationale: First flush retention facilities will capture suspended particulates during periods of high flow, thereby improving water quality.

Expected Benefit: Improved water quality.

Required infrastructure: Retention facilities.

20. Incorporate Dinner Island

Goal: Utilize the Dinner Island Wildlife Management Area as part of a regional stormwater detention system.

Rationale: The C-139 Basin needs additional storage, and the Dinner Island property recently was acquired by the State of Florida. Upland areas of Dinner Island could be converted into a regional stormwater detention system that would decrease peak flow discharges and provide a source of irrigation water to a portion of the C-139 Basin. ***Figure 4.3.49*** above shows the location of Dinner Island.

Expected Benefit: Improved water quality; increased availability of water for irrigation supply.

Required Infrastructure: Levees; pump station(s); control structures.

21. Improved Storage within private farm AGIs

Goal: Improve the Performance of Existing AGIs
Rationale: A number of changes could be made to AGIs to improve storage of flood waters and increase the nutrient retention within the AGIs. These measures are:

a. Add interior levees with a series of cascading basins in the AGIs to increase the hydraulic retention time. ***Figure 4.3.56*** presents a hypothetical layout of interior levees within an existing AGI.
b. Identify where short-circuiting is occurring and reduce it to increase hydraulic retention time.
c. On-farm retention/recycling for example by transfer and storage of water between different crops and farm sections, and tailwater-recovery systems.
d. Evaluate the potential benefit of planting the interior of the AGIs with switch grass and harvest that grass for hay. This would increase nutrient harvesting of the nutrients trapped in the AGIs.

Expected Benefit: Water quality improvement by additional retention time and recycling of tailwater flows. Water can be used again for irrigation.

Required Infrastructure: Levee improvement/construction; control structures; vegetation planting; new gates.

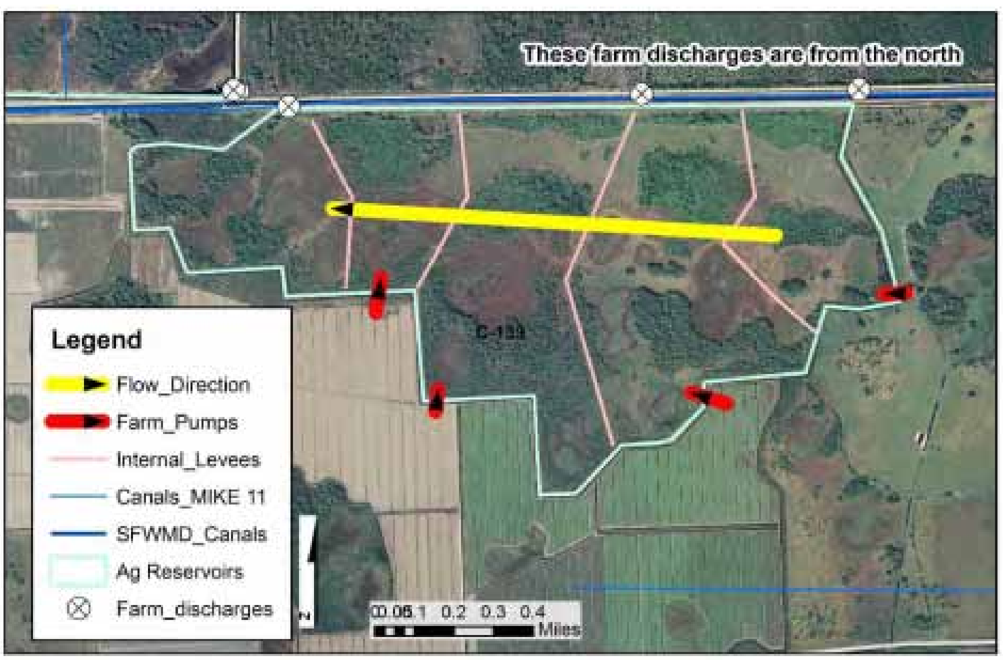


Figure 4.3.56 – Hypothetical Layout of Interior Levees within an AGI

4.3.5 REFERENCES

ADA Engineering Inc. C-139 Basin Phosphorus Water Quality and Hydrology Analysis. Deliverable 5.4 Phase I Report. February, 2006.

ADA Engineering Inc. C-139 Phosphorus Water Quality and Hydrological Analysis. Deliverable 9.2 Technical Memorandum on Proposed Regional Projects. March, 2007,

Burns & McDonnell. 2008. S-4 Basin Feasibility Study. Prepared for the Everglades Agricultural Area Environmental Protection District and South Florida Water Management District. September, 2008.

Chow, Ven Te. 1959. Open Channel Hydraulics. McGraw Hill.

Community Watershed Fund and DB Environmental, Inc. C-139 Basin Deerfence and S&M Canals Phosphorous Transport and Cycling. Prepared for SFWMD, November, 2005.

Environmental Research & Design, Inc. (ERD) Evaluation of Alternative Stormwater Regulations for Southwest Florida, September, 2003

Environmental Research & Design, Inc. (ERD) Stormwater Loading Rate Parameters for Central and South Florida, October, 1994.

Goforth, G. 2008. Operation Plan – Integrated Stormwater Treatment Areas 5 & 6. Prepared for SFWMD by Gary Goforth, Inc., October, 2008.

Gregory A. Graves, Yongshan Wan and Dana L. Fike, Water Quality Characteristics of Storm Water from Major Land Uses in South Florida, Journal of the American Water Resources Association, December 2004

Harper, Harvey. 2007. Current Research and Trends in the Treatment of Stormwater Runoff. 9th Biennial Stormwater Research and Watershed Management Conference, University of Central Florida, May, 2007.

HSA Engineers and Scientists, Inc. 2000. Chemical Treatment Followed by Solids Separation Advanced Technology Demonstration Project. Final Report to the South Florida Water Management District, West Palm Beach, Florida, USA.

Johnson – Prewitt & Associates, Inc. 2001. Devil's Garden Water Control District – District Facilities Map, Plate B.

Marco Water Engineering, Inc. 2005. Lower West Coast Surficial Aquifer System Model. Prepared for SFWMD by Marco Water Engineering and Ecology and Environment, Inc.

Radin, H. Rodberg, K. 2009. C-139 Model Runs, SFWMD, Executive Summary and Model Files.

Reese, R.S., and K.J. Cunningham. 2000. Hydrogeology of the Gray Limestone Aquifer in Southern Florida, Water Resources Investigations Report 99-4213, USGS.

SCS. 1986. Urban Hydrology for Small Watersheds, Technical Release 55.

SFWMD. Undated. SFWMD Structure Books. Operations Control Center.

SFWMD. 2004. Operation Plan, Stormwater Treatment Area-3/4.

SFWMD a. 2009. Hydrogeologic Assessment of the Crooks and Golden Ox Ranches, Hendry County, FL, Technical Publication WS-28. SFWMD Water Supply Department Staff.

SFWMD b. 2009. South Florida Environmental Report, Chapter 4 – Phosphorus Source Controls for the South Florida Environment.

SFWMD. 2010. Source Controls in Basins Tributary to the Everglades Protection Area. Presentation by Carmela Bedregal and Carlos Adorisio to the 7th Annual Public Meeting on the Long-Term Plan for Achieving Water Quality Goals for the Everglades Protection Area Tributary Basin, February 25, 2010.

SWET. 2008. Final Report – Task 4.1 Dairy Best Available Technologies in the Okeechobee Basin. SFWMD, West Palm Beach, FL.

URS. 2008. Compartment C Stormwater Treatment Area Final Design Report.

5 PROJECT WORK PLAN (SUBSEQUENT PHASES)

5.1 SCOPE OF WORK

Indicated below is a general description of the tasks that are anticipated to be required, at a minimum, for the Subsequent Phases of the C-139 Regional Feasibility Study (RFS) work.

- Schedule a kick-off, monthly and progress meetings with District staff (Task 1).
- Prepare and updated work plan (Task 2).
- Modify the field data collection plan according to Phase II Project Work Plan and continue with field data collection efforts established in Phase I (Task 3).
- Develop and refine performance measures such as (Task 4):
  - Water Quality Discharges (Total Phosphorus) at the appropriate, regional compliance points (C-136, C-342A-D, G-406, S-190, S-140),
  - Effects on Water Supply,
  - Effects on Flood Control,
  - Estimated Costs for implementation,
  - Constructability and Permit-ability.
- Prepare Technical Design Documents to Define Approach of recalibration task (Task 4).
- Refinement of Screening Level Tools for Narrowing the Number Alternatives (Task 5).
- Using the refined screening level tools, continue the evaluation of alternatives presented in Phase I to confirm the short list of four (4) alternatives (Task 5).
- Refine (re-calibrate, re-verify) the baseline model and water quality evaluation as further field data is collected and conduct Sensitivity and Uncertainty Analyses (Task 6).
- Using the modeling tool that has been re-calibrated, re-verified, and other information as necessary, evaluate the selected four alternatives using the performance measures described above in Task 4 (Task 7).
- Develop conceptual level cost estimates for each of the four alternatives (Task 8).
- Prepare a Preliminary Desktop Siting Analysis (Task 9).
- Prepare a Final, Summary Report of findings (Task 10).

All professional services will be performed under the direction of a Professional Engineer registered in the State of Florida and qualified in the appropriate discipline(s) with the appropriate expertise. Work products developed by the Consultant will be signed and sealed as required by the appropriate professional. Access to farms for purposes of field verifying H&H features is anticipated. The Consultant will inform the District when access to specific farm level locations is necessary for data gathering. The District will accompany the Consultant, as necessary. The District and the Consultant will agree on the alternative information or assumptions that will be utilized if farm level information can not be obtained in a timely manner. Assumptions and limitations should be clearly documented in the reports.

The Consultant will prepare a Project schedule for presentation to the District at the first Progress Review Meeting (see Task 1.2). The schedule will include all major Tasks included in this SOW.

STOP/GO EVALUATION: After each technical review meeting, the DISTRICT will make an assessment (Stop/Go Evaluation) as to whether the CONSULTANT should proceed with the subsequent tasks. The DISTRICT and the CONSULTANT will meet together to mutually agree upon the modified work plan and deliverables. At each juncture, the DISTRICT reserves the right to discontinue the project and cancel the remaining tasks; in which case, the CONSULTANT hereby agrees that the DISTRICT will have no further obligations regarding subsequent tasks described herein. In the event that a determination is made to proceed, the DISTRICT will provide the CONSULTANT with a written notice to proceed. No work will be performed by the CONSULTANT on a specific task unless written authorization is provided by the DISTRICT to the CONSULTANT. Estimated schedule will be adjusted according to the task NTP issued by the District.

5.2 WORK BREAKDOWN STRUCTURE

The following Scope of Work (SOW) describes the engineering services to be performed by the Consultant for this Work Order:

Task 1 – Meetings

Task 1.1 Kick Off Meeting

The Consultant will schedule, coordinate and attend a Project Kick-off Meeting with District staff. Key members of the Consultant Project team (including sub-consultants) will attend the kick-off meeting. The meeting will include a review of the Project objectives, scope of services, schedule and the QA/QC implementation plan. This meeting will also serve as a forum for introducing members of the Project team to District staff, establishing protocol for submittal of interim work products and deliverables, and establishing lines of communication. The summary notes of the Kick-off meeting will be prepared by the Consultant and distributed to the meeting attendees no later than three (3) business days after the meeting.

- **Deliverables:**
  1.1.1 Draft Meeting Summary
  1.1.2 Final Meeting Summary

Task 1.2 Monthly Progress Meetings

The Consultant will prepare for and attend monthly progress review meetings with the District. At the progress review meetings, the Consultant will update the District on work in progress, inform the District of problems or delays as they are encountered, and receive input from District staff on a continuing basis throughout the course of work on the Project. The CPM and one (1) key member of the Project team, as appropriate for the work to be discussed, will attend the progress review meetings.

At each monthly meeting, the Consultant will provide the District with a Monthly Project Status Report. This Report will include, but not necessarily be limited to, the following:

- Activities accomplished in the previous months,
- Problems and present concerns encountered in the Project,
- Planned actions for the next month, and
- Updated Work Order schedule.

The Consultant will prepare and submit a meeting summary for each progress review meeting to the District within seven (7) business days of the meeting.

- **Deliverables:**
  1.2.1 Progress Review Meeting / Summary
  1.2.2 Monthly Status Reports

Task 1.3 Technical Review Briefing Meetings

Within five (5) business days after completion of the Draft Report submittal in Tasks 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11 the Consultant will participate in a Technical Review Meeting with District staff to present the Draft Report. At each meeting, the Consultant will explain how the data or analyses results obtained during the task meet project objectives, discuss major findings and how results will be utilized in subsequent tasks, and discuss constraints and limitations in the process that may require change of the originally discussed/agreed methods, approach, timeline, etc. Each Technical Review Meeting will be held at the District's Headquarters in West Palm Beach and is estimated to last no more than three hours. Each meeting may be scheduled by the District to coincide with other District sponsored meetings to facilitate attendance by other interested parties.

Within five (5) business days of the Technical Review Meeting, the Consultant will submit meeting summary notes to the District for distribution. The District will communicate with the Consultant within three days to provide comments or confirm agreement with the summary.

- **Deliverables:**
  1.3.1 Draft Technical Review Briefing Meetings and Summary Notes
  1.3.2 Final Technical Review Briefing Meetings and Summary Notes

Task 2 – Updated Project Work Plan

The Consultant will update the Project Work Plan which will include the Project Work Plan/SOW developed at the end of Phase I. It shall build upon this scope of work to document dates, issues and methods to complete Phase II. The Work Plan will include the Project Schedule and Project conceptual plan that outlines the objectives and work methodology for the project.

The Consultant will submit three (3) copies of the Updated Project Work Plan.

- **Deliverables**:
  2.1.1 Draft Updated Project Work Plan
  2.1.2 Final Updated Project Work Plan

Task 3 – Continuing Field Data Collection and Reconnaissance

Task 3.1 Water Level Data Collection

The Consultant will continue with the field data acquisition implemented in Phase I. Groundwater and surface water elevation data collection began during Phase I in the month of November, 2009 for most wells, and in March 2010 for the well in the Big Cypress Seminole Indian Reservation. The data collection exercise will continue over a sufficient period of time to accurately reflect the area's condition throughout two wet/dry season cycles to minimize year to year seasonal variability. This data is to be used in the continued refinement of the open-ended baseline regional model and model scenario development for the selected alternatives. Data will continue to be collected in subsequent design phases.

Task 3.2 Water Level Data QA/QC and Data Analysis

The Consultant will continue the Monitoring Well data collection and data preparation for the eight "nested pair" monitoring wells installed previously. The consultant will also work closely with the District's Hydrogeology Group to analyze the groundwater data to determine general groundwater flow directions, and vertical and horizontal conductivities. Based on the selected four alternatives more detail analysis will be defined and performed in close coordination with the District's Hydrogeology Group. These analyses will help define the feasibility of alternatives, such as, the potential use of the C-139 basin for storage/wetland pre-treatment system or wetland flow-way.

Other types of data will be defined and collected based on the alternatives/scenarios selected, if necessary, to further refine the open-ended baseline models.

Task 3.3 Topographical Data Collection

Additional spot elevations will be obtained at the locations that will be identified based on an analysis of available topographic data that are available from permit files. All spot elevations obtained in Phase II via topographic survey and via permit files, and all the additional data obtained during Phase I, will be added to the SWFFS DEM in coordination with the District to generate a new DEM to be used in MIKE SHE/MIKE 11.

Task 3.4 Permeability Test

The Consultant will prepare a work plan for the performance of permeability test for lands that could be used as reservoirs, AGIs, or STAs. After review from the District Review Team (DRT) a final work plan will be presented and the test conducted. The test will be performed in identified locations using (4) four or more well clusters in standpipe piezometers using falling or constant head permeability test procedures. The Consultant will provide analysis of test results.

Following acquisition of the above listed field data; the Consultant will prepare an updated Field Data Technical Memorandum that includes:

- A description of the additional work performed
- Additional field data and permeability test results
- New digital elevation model (DEM) as well as a graphical comparison of the new DEM to the prior DEM

The Consultant will submit three (3) copies of the Updated Field Data Technical Memorandum to the District.

- **Deliverables**:
  3.1.1 Draft Updated Field Data Technical Memorandum
  3.1.2 Final Updated Field Data Technical Memorandum

Task 4 – Develop and Refine Performance Measures and Design Approach

Task 4.1 Develop and Refine Performance Measures

The Consultant will develop and refine performance measures by which to evaluate the (4) four preferred alternatives and conduct a failure analysis. The performance measures have been developed to some degree in the screening tool and this refinement will continue in Phase II. The performance measures are to include at least the following:

1. Water Quality Discharges (Total Phosphorus) at the appropriate, regional compliance points (C-136, C-342A-D, G 406, S-190, S-140)

2. Effects on Water Supply

3. Effects on Flood Control

4. Estimated Costs for implementation

5. Constructability and Permit-ability

The Consultant will submit three (3) copies of the Developed and Refined Performance Measures Letter Report to the District.

- **Deliverables**:
  4.1.1 Draft Developed and Refined Performance Measures Letter Report
  4.1.2 Final Developed and Refined Performance Measures Letter Report

Task 4.2 Design approach Technical Design Documents (TDDs)

The Consultant will develop the following TDDs that define the approach to be used in Task 7. The TDDs will describe the following:

4.2.1 General Methodology TDD

- Methodologies that will be used to revise the hydraulic/hydrologic and water quality models.
- New input data to be added to the model.
- New modeling approaches.
- Protocols for obtaining the information from SFWMD and processing of information into a format that can be read by MIKE SHE/MIKE 11.
- How will alternative features be modeled in MIKE SHE/MIKE11.
- Hydroperiods of wetlands in the basin.
- Information that will be shared with SFWMD staff and external stakeholders during the execution of the small-scale modeling task.
- The step-wise calibration procedure as well as calibration metrics to be used to evaluate model performance.
- Propose presentation of all data used in the development of model parameters as well as input data sets. (HESM to provide more detail recommendations for parameter presentation).
- The procedure for the sensitivity, and uncertainty analysis.

4.2.2 Rainfall Data TDD

- The type of rainfall to be used in the model, based on recommendations from HESM staff. The Phase I model utilized small incremental (e.g. 15 mins, hourly) rainfall. The HESM rainfall data is in daily increments. The small incremental rainfall provides much more accuracy and is desirable.

4.2.3 Farms Modeling TDD

- Methodologies for documenting how farm irrigation will be setup, including a description of how irrigation efficiency will be evaluated and documented.
- The procedure for defining farmed areas (e.g. what areas of a farm permit are farmed; what areas are for non-farming activities such as water management; habitat preservation; and the farm residence).

- The farms to be utilized for evaluation with the small-scale model, including the approach for obtaining more detailed information from the farmers. Close coordination with SFWMD EREG staff will be required for determining the appropriate farms and to work out communication protocols.

4.2.4 Water Quality Approach TDD

- Water quality modeling protocol, including the method for processing H/H model results, water quality concentration estimation (e.g. will the method utilize annual average measured values, EMCs, or varying concentrations as a function of time or flow?).
- Impact of modifying on-farm practices and/or implementation of watershed storage facilities.
- Possible use of the DMSTA2 from the Screening Tool for the water quality modeling. (Need to address concern on management of flows from reservoirs).
- Possibility of tricking DMSTA with the fixed flow from MIKE SHE/MIKE 11 model.

The Consultant will submit three (3) copies of the TDDs to the District.

- **Deliverables**:
  4.2.1.1 Draft General Methodology TDD
  4.2.2.1 Draft Rainfall Data TDD
  4.2.3.1 Draft Farms Modeling TDD
  4.2.4.1 Draft Water Quality Approach TDD

  4.2.1.2 Final General Methodology TDD
  4.2.2.2 Final Rainfall Data TDD
  4.2.3.2 Final Farms Modeling TDD
  4.2.4.2 Final Water Quality Approach TDD

Task 5 – Refine and Rerun Screening Level Tool for Confirmation of Alternatives

Task 5.1 Refine Screening Level Tool

The Consultant will conduct additional runs to look at the robustness of the screening-level selection process by looking at the sensitivity to phosphorus concentration and supplemental irrigation. The additional runs will use alternative values for phosphorous concentrations and alternative supplemental irrigation volumes. A detailed description of the comparative screening level tool, its parameterization, input, and simulation are to be provided in this Technical Memorandum for review by the District Modeling team.

The Consultant will submit three (3) copies of the Screening Level Tool Technical Memorandum to the District.

- **Deliverables:**
  5.1.1 Draft Refined Screening Level Tool Technical Memorandum
  5.1.2 Final Refined Screening Level Tool Technical Memorandum

Task 5.2 Rerun Screening Tool for Confirmation of Alternatives

The consultant will use the refined screening level tools developed in task 5.1 to continue the evaluation of the alternatives presented in Phase I to confirm the shortlist of alternatives. This screening exercise shall lead to the most viable alternatives selected for evaluations using the comprehensive baseline water resource model developed in Phase I and refined further in Phase II. The results of the findings will be presented in a Letter Report to be presented to the DRT.

The Consultant will submit three (3) copies of the Alternatives Screening Selection Letter Report to the District.

- **Deliverables:**
  5.2.1 Draft Alternatives Screening Selection Letter Report
  5.2.2 Final Alternatives Screening Selection Letter Report

Task 6 – Regional Model Re-Calibration and Re-Validation and Water Quality Post-processing Statistical Spreadsheet Refinement Technical Memorandum

Task 6.1 Model Re-Validation and Re-Calibration

The baseline model will continue to be refined and recalibrated during Phase II as additional field data is collected. It is understood that field data collection may continue until the period indicated in Task 2.1. Consultant will to the fullest extent possible incorporate the latest sets of field data so as to have the most accurate and current baseline model.

Task 6.1.1 Small Scale Model

A detailed model of at least one AGI (e.g. C & B Farms) where, pumpage data are available, will be constructed. The purpose is for the refinement of model parameters that can be applied to the large scale model described in Task 6.1.2. At least four other farms with AGIs will also be evaluated using model parameters, initially set using parameters developed from farm(s) with measured data. Sensitivity testing will be conducted of inflow canal dimensions, pump operations, and seepage. Results of the testing will be presented to the DRT for review and discussion.

Task 6.1.2 Large Scale Model

The model will be recalibrated to the two (2) selected periods that will have a duration of 1-2 years and the locations identified during Phase I. The validation will occur with one (1) additional selected period that will have a duration of 1-2 years. Calibration and validation will need to be conducted to simulate wet season/dry season effects to update the baseline condition from Phase I. This task will include:

- Review and definition of calibration metrics.
- Incorporating any improvements to input files resulting from the analysis of farm-scale models.
- Monthly and annual water budgets for selected farms, subbasins, and each basin, including simple diagrams.
- Irrigation Efficiency - The MIKE SHE irrigation routine used for Phase I applies irrigation water to crops depending on soil moisture conditions, plant requirements, and user input maximum irrigation rates. Whenever water is supplied, it is added to the rainfall and applied to the land surface. Consequently, some water may be lost depending on infiltration and irrigation rates, as well as percolation to groundwater. MIKE SHE does not have user-defined irrigation efficiency, however the model allows for irrigation losses due to over-application. The Consultant will have discussions with the District's Review Team (DRT) to make sure the District is in agreement with the irrigation routine used.
- Supplemental Irrigation Pumpage Volume - If monthly time series of irrigation pumpage volumes are available, they will be input to the model and used as maximum pumpage rates.
- Rainfall - If HESM can provide small incremental rainfall data in MIKE SHE format or a format that can be easily be converted to MIKE SHE format, this data will be used; data will be reviewed for accuracy when compared with measured point rainfall. Similarly refET data will be utilized if provided in an appropriate format.
- Irrigation land area will be refined within the constraints of the model grid cell size. The irrigation land areas should reflect the actual irrigated land for the period 2005-2008.
- The calibration process will be documented showing the selection of parameters that may be modified, and constraints of modification.
- Farm structure operations and main canal structure operations will be clearly described in reports.

Task 6.2 Sensitivity Analysis

A sensitivity analysis will be conducted to identify the most appropriate parameters to adjust to improve the model performance. The analysis will define parameters that impact the evaluation of alternatives for water supply, flood control and water quality. The insensitive parameters as well as the fixed parameters, defined by external data sets will also be presented. An objective function, based on the performance criteria, will be defined and optimized during calibration. The change in the objective function should be documented; to determine how much each step improved the model. The parameters will be adjusted systematically and the resulting changes documented.

Task 6.3 Uncertainty Analysis

Possible parameter and input uncertainty will be addressed during the calibration process with an uncertainty analysis. The analysis will be conducted by error propagation. The purpose will be to identify any possible uncertainty in the results due to known uncertainty in rainfall, PET and other parameters whose values are not known from local data.

Task 6.4 Water Quality Post-processing Statistical Spreadsheet Refinement

The water quality post processing methodology will be refined based on new field data collected during Task 2.1 Draft Field Data Letter Report and further discussion with District staff. The methodology should be sufficient to provide historical and simulated conditions to represent long-term average annual TP loads at the appropriate, regional compliance points (C-136, C-342A-D, G-406, S-190, S-140).

The Consultant will submit three (3) copies of the Model Re-Calibration and Re-Validation and Water Quality Post-processing Statistical Spreadsheet Refinement Technical Memorandum.

- **Deliverables:**
  6.1.1 Draft Model Re-Calibration and Re-Validation and Water Quality Post-processing Statistical Spreadsheet Refinement Technical Memorandum
  6.1.2 Final Model Re-Calibration and Re-Validation and Water Quality Post-processing Statistical Spreadsheet Refinement Technical Memorandum

Task 7 – Evaluation of the Selected Four Alternatives

The recalibrated baseline model performed as part of Task 7 will be applied to the four (4) preferred alternatives to develop a simulation of their hydrologic and hydrogeologic performance in the region. The Consultant will simulate past and future basin hydrologic, hydraulic and water quality conditions.

Representation of water quality for the four (4) preferred alternatives is to be evaluated using a statistical post processing methodology sufficient to provide historical and simulated conditions to represent long-term average annual TP loads for each of the alternatives at the appropriate, regional compliance points (C-136, C-342A-D, G-406, S-190, S-140). The results will be used to compare the effectiveness to reduce TP loads for each of the alternatives.

The consultant will prepare and present the findings of the modeling simulation and analysis of the four (4) selected alternatives in a Technical Memorandum in order of performance of each alternative.
The Consultant will submit three (3) copies of the draft C-139 Regional Model of selected Alternatives/Scenarios Technical Memorandum for review and comment by the District.

- **Deliverables:**
  7.1.1 Draft C-139 Regional Model of Selected Alternatives/Scenarios Technical Memorandum
  7.1.2 Final C-139 Regional Model of Selected Alternatives/Scenarios Technical Memorandum

Task 8 – Conceptual Level Cost Estimates for each of the Four Alternatives

The consultant will develop conceptual level cost estimates to provide a comparative reference on a cost basis for each of the four alternatives. The methodology and format for presentation of the cost estimate will be as agreed upon and approved by the District PM. The exercise is performed on an order-of-magnitude basis using up to date market cost information received from on-going District projects. Where sufficient detail is available, costs shall be broken down into unit costs, and all mark-ups applied. An appropriate contingency, developed in consultation with the District PM, shall be applied.

- **Deliverables:**
  8.1.1 Draft Cost Estimate Technical Memorandum
  8.1.2 Final Cost Estimate Technical Memorandum

Task 9 – Preliminary Desktop Siting Analysis

The Consultant will conduct a GIS basin-scale analysis for siting of the selected four (4) alternatives. The analysis shall be conducted based on exiting information on soils, geology and topography. Data obtained from the field data collection and well installation shall also be utilized. The information generated in Task 2.2 Water Level Data QA/QC and Data Analysis; and Task 2.3 Permeability Test, shall also be utilized for this study. The four alternatives will be evaluated and ranked in order of suitability based on the intended goals of this study.

The Consultant will submit three (3) draft copies of the Siting Analysis Report for review and comment by the District.

- **Deliverables**:
  9.1.1 Draft Siting Analysis Letter Report
  9.1.2 Final Siting Analysis Letter Report

Task 10 – Summary Report

The Consultant will compile the documents generated in the above tasks into a Phase II Summary Report and Project Work Plan (Report). The Report shall include:

- A description of the work performed.
- Maps and photo documentation to describe the basin hydraulics and hydrology, sub-basin segmentation and prioritization, including potential sources of phosphorus loading sites.
- Description of farm operations, if available.
- Description of structure operations.
- Conformance of all field and modeling activity results from Phase I/II into single summary report including recommendations and regional project/s conceptual implementation plan.
- A Project Work Plan suitable for use in conducting future phases in separate Work Orders, including a recommendation as to the continued use of the open-ended baseline model and field data monitoring activities, implementation of selected project/s (new storage, infrastructure modification, operational changes, etc.). The Work Plan should include a conceptual level development of the selected alternative to be implemented in the region.
- Final versions of all Technical Memoranda generated in the above tasks incorporating District comments.

The Consultant will submit three (3) draft copies of the Report for review and comment by the District.

- **Deliverables**:
  10.1.1 Draft Summary Report and Project Work Plan
  10.1.2 Final Summary Report and Project Work Plan