South Lee County Watershed Plan Update
Work Order C-4600000791 WO01

Final Report

South Florida Water Management District in Partnership with Lee County

Client Representative — Steve Sentes, SFWMD Project Manager
Roland Ottolini, Lee County Project Manager

Boyle Engineering Corporation

Project Manager — Karen Brandon
Project Engineer — Pradeep Nagarajan
GIS Analyst — Roosevelt Wiggins

A.D.A. Engineering, Inc.

Project Manager — Roger Copp
Lead Modeler — Michael Walters
Modeler — James Greco, III

Project 17312.01 and 17312.02

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2090 Palm Beach Lakes Blvd., Suite 600 West Palm Beach, FL 33409 BOYLE | AECOM

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EXECUTIVE SUMMARY

In 1992 and 1995 a series of large rainfall events led to significant flooding in the Bonita Springs area, resulting in the evacuation and prolonged displacement of hundreds of citizens as well as associated flood damages to homes, businesses and public infrastructure. As a result of flooding within the Imperial and Cocohatchee watersheds during these events, a study (South Lee County Watershed Plan or SLCWP) was conducted to identify causes of the flooding, recommend improvements to the region, restore flow ways, and prevent future flooding. The SLCWP was completed in July 1999 and identified a number of causes that contributed to the flooding. Most notably was the loss of historical flows within the Estero River and Halfway Creek watersheds.

The SLCWP identified the construction of I-75 as one of the causes of the loss of historical flows. The SLCWP also identified a number of improvements to be completed geared towards restoring natural flowways, removal of constrictions and enhancing conveyance capacities within Estero River, Imperial River, Cocohatchee River, Belle Meade and Camp Keais Strand. Numerous recommendations from the 1999 SLCWP were implemented to enhance conveyance, including clearing and snagging of the Imperial River, adding gates to the Kehl Canal Weir, replacement of the IBE bridge on the Imperial River, widening of Halfway Creek from I-75 to the west end of the Brooks development, construction of an emergency by-pass gate from Halfway Creek at Three Oaks Parkway to divert flows to the South Branch Estero River, additional Halfway Creek culverts under the railroad west of the Brooks, clearing exotic vegetation in Halfway Creek between the railroad and U.S. 41, removal of the FPL bridge and bridge approaches in Halfway Creek west of U.S. 41, and additional culverts for the South Branch Estero River at Three Oaks Parkway and Corkscrew Road. A number of 1999 recommendations were not implemented as of 2008, including additional culverts for Halfway Creek under I-75.

On February 14, 2008, the Governing Board of the South Florida Water Management District (District) approved permit number 36-03802-P for a project known as "I-75 Collier/Lee County Line North to Corkscrew Road/Segment B." This permit authorized the widening of I-75 from four lanes to six lanes for this segment. As part of this permit, five 60-inch diameter culverts are proposed to be installed adjacent to two existing 9' by 8' box culverts located 1.9 miles south of Corkscrew Road to convey additional surface water flows from east of I-75 to the west. The additional culverts are proposed to accommodate a component of the SLCWP. During the review of the permit application several concerns were expressed by adjacent property owners and other stakeholders in regard to the additional culverts proposed under I-75. As a result of these concerns, a Special Condition was added to the permit that requires an update to the SLCWP.

The objective of this update is to verify and validate the findings and material assumptions of the SLCWP for the Halfway Creek, Spring Creek, and the South Branch of the Estero River region.

The MIKE SHE/MIKE 11 integrated surface/groundwater model developed for Lee County's Density Reduction Groundwater Resource (DRGR) Study was used as the modeling tool for the SLCWP Update. The data collection process included acquisition of information from previous studies and models, permit files, and construction plans. A significant amount of detailed information on bridges, culverts, weirs, and gates west of I-75 were added to the model, in addition to newly surveyed cross sections of several channels/flow-ways. A lengthy calibration process was conducted using both available surface water and groundwater data. Overall, the calibration results were considered good.

A hydroecological assessment of the SLCWP area was conducted to characterize the health and hydroecology of the natural and disturbed wetland communities and to provide estimated seasonal high water (SHW) elevations and flooding depths for various locations within the study area. A comparison of the field-estimated hydroecological data with hydrologic model outputs was made and an evaluation of whether the proposed alternatives were likely to have an adverse effect upon on-site wetlands was conducted.

As part of the study process, four Stakeholder Meetings were held by the project team to present the project status, model results and findings to date, and to solicit public input on the study. Throughout the study, SFWMD's project manager received and distributed numerous e-mailed comments to the project team from the stakeholders. The study was a very interactive process between the project team, including SFWMD and Lee County, and the stakeholders.

A series of design storm model runs using the calibrated model were analyzed as part of the problem identification process. Stakeholder input from a February 2009 public meeting was used to refine those runs. In addition, model results for this study were compared to the 1999 SLCWP study. In general, there was less flow for the South Branch of the Estero River at I-75 and for the emergency bypass from Halfway Creek to the South Branch of the Estero River than in the recommended plan from the 1999 SLCWP. Peak stages were generally higher than for the 1999 SLCWP. Differences in flow and stage are attributed to the use of a more comprehensive model, updated data, changes in channels, land use, and other information, as well as different assumed antecedent conditions. Estimated pre-development peak flows for the South Branch Estero River and Halfway Creek were in the range of 1,800 cfs, while the combined existing 100-year peak flow for the two systems is 460 cfs.

Fourteen components that individually addressed one or more of the problems identified in the Problem Identification task were posted to the SFWMD's external website for stakeholder review, and comments on those alternatives were received and considered during the development of four initial alternatives. These alternatives are based on combinations of the fourteen components, and their objectives were as follows:.

- Alternative 1: Increase flow through Halfway Creek Watershed

- Alternative 2: Increase flows to the South Branch Estero River and improve conveyance downstream in Halfway Creek to lower peak stages while maintaining existing flow capacities.
- Alternative 3: Improve conveyance to Spring Creek and improve conveyance in downstream Halfway Creek to lower peak stages while maintaining existing Halfway Creek flow capacities.
- Alternative 4: Increase detention east of I-75 to reduce peak discharges to the Imperial River and reduce flooding in the Estero, Halfway Creek and Spring Creek without increasing peak flows.

The four alternatives were evaluated with the objective of reducing flooding, improving peak flow distribution, and not adversely impacting wetland hydration. Alternative 1 is most effective at reducing stages in Halfway Creek. Alternative 2 is most effective in increasing flow in the South Branch of the Estero River. Alternative 3 does not meet flood reduction objectives. Alternative 4 is the most effective alternative in reducing flood elevations in the Imperial River. Because existing 100-year peak flows to the South Branch Estero River and Halfway Creek are approximately 25% of pre-development peak flows, one of the objectives of this study was to review increasing flood flows under I-75 via the Estero River, Halfway Creek and/or Spring Creek as long as that flow increase did not harm wetlands upstream of I-75. Therefore, portions of Alternative 1 and 2 were combined into Alternative 2v5. This alternative was further refined for hydroecological considerations and iterations run for optimization of the number of culverts under I-75.

As a result of the Alternatives Analysis twelve plan components are recommended for implementation in Section 6 of this document. A brief summary of the recommendations is presented below. See Section 6 for additional details.

- Construction of a conveyance system under I-75 at Halfway Creek at invert elevation 9.0 ft-NAVD that will convey up to 900 cfs of total future flows. Since the South Branch Estero River 100-year peak flow with the recommended plan will not exceed 200 cfs, the combined peak flow for Halfway Creek and the South Branch Estero River will still be significantly below pre-development peak flows. See section 6.0 for additional details.
- Construction of a conveyance system under I-75 to Bonita Bill Canal in the Spring Creek watershed that could convey up to 160 cfs of total future flows, subject to the constraints given in Section 6.0.
- Consideration of construction of a connector channel just east of I-75 from Halfway Creek to the South Branch Estero River
- Consideration of construction of weirs upstream of I-75 and downstream of the proposed connector channel for Halfway Creek and the South Branch Estero River to maintain adequate water depths for wetlands east of I-75
- Connection of Halfway Creek to the Rapallo Lake west of Via Coconut Point Rd.
- Improve vegetation maintenance in Halfway Creek east and west of U.S 41.

- Improve conveyance through the emergency by-pass gate and channel from Halfway Creek in the Brooks to the South Branch Estero River
- Increase conveyance in the South Branch Estero River at County Creek Drive
- Increase conveyance in the North Branch Estero River at Rivers Ford Road
- Enlargement of culverts in the Spring Creek watershed west of Old U.S. 41
- Further evaluation of restoration of flood flows deliveries from the Kehl Canal watershed to wetlands south of Bonita Beach Road and east of I-75 for ultimate conveyance to Cocohatchee Canal. This evaluation should be coordinated with Collier County and the Naples Service Center of SFWMD.

1 DATA COLLECTION

This section describes the data collection effort conducted for the update of the South Lee County Watershed Plan. This task was originally completed in September, 2008, however additional data collection needs were identified during the subsequent phases of the project. In some cases, due to excellent cooperation by key study participants (SFWMD, Lee County, the City of Bonita Springs, Bonita Springs Utilities, Agnoli, Barber & Brundage, Johnson Engineering, Ned Duhurst, Exceptional Engineering, Hole Montes, Morris Depew & Associates, Resource Conservation Systems, LLC, and Banks Engineering), additional information was obtained and used in the course of the analysis. This section was updated to reflect the understanding of the study area as of May, 2009.

1.1 Introduction

This section provides a summary of the data collection activities as part of the South Lee County Watershed Plan (SLCWP) Update. The SLCWP Update is being conducted for SFWMD and Lee County to evaluate the impacts of possible additional culverts under I-75 on:

- environmental conditions in wetlands east of I-75, and
- flooding conditions west of I-75.

1.2 Data Collection Requirements from the Statement of Work

This study was being conducted in accordance with Work Order C-4600000791 WO01 issued to Boyle Engineering Corporation on May 8, 2008 and received by Boyle on June 25, 2008. **Table 1-1** provides a listing of the data collection task requirements per the scope of work.

Table 1-1: Data Collection Activities

No.	Task
1	Identify, review, and compile data such as past studies (See **Table 1-2**)
	Identify, review, and compile GIS data
	Identify, review, and compile data from outside agencies, NRCS, NWI
	Identify, review, and compile data from recent Density Reduction/Groundwater Recharge (DRGR) Study
2	Review array of sub-basin studies (See **Table 1-3**)
3	Compile and review historical flow data for Halfway Creek, South Branch of the Estero, Spring Creek, and the Imperial River
4	Verify, through review of as-built drawings and permit records, the installed conveyance capacity from I-75 to tidal waters
5	Identify the available format of data
6	Identify SFWMD and Lee County GIS data for topography, current land use/land cover, meteorological, surface, and groundwater monitoring stations
7	Identify prominent data gaps
8	Provide clear maps showing the location of data reference points with respect to roads, and key hydraulic conveyance features

1.3 Prior Studies Conducted in the Study Area

Table 1-2 provides a listing of known data sources, some of which are from hydrologic studies that have been conducted or are in progress within the study area. **Figure 1-1** presents a map of the study area for this project.

Table 1-2: Data Sources

No	Study
1	Link to SLCWP on Lee County's web site
2	Copy of staff report with addendum for Permit No. 36-03802-P
3	Map of project region with SFWMD permit boundaries, permit numbers, and pending permit application numbers
4	Copy of cost share agreement between SFWMD and Lee County
5	Information supporting the Southwest Florida Feasibility Study (Partially provided)
6	Electronic copy of SLCWP
7	Electronic copies of stormwater mgt models (See **Table 1-3** below)
8	Scope of Work for DRGR
9	Topographic information for DRGR
10	Any other DRGR Study data
11	Lee County water table monitoring network

The model files from the DRGR study and an initial calibration report for the DRGR model were obtained. The DRGR model covers all of Lee County, however the focus of the model calibration was the DRGR area, which is east of I-75, south of SR 82 (Immokalee Road), and north of Bonita Beach Road. The DRGR model calibration focused on surficial aquifer conditions rather than flooding issues west of I-75. There are several existing culverts and bridges in the Estero River and Halfway Creek watersheds, which are not included in the DRGR Model. Therefore, additional information was necessary to include the structures in the model to evaluate flooding impacts west of I-75. A majority of the missing structure information has been obtained, as discussed below in **Section 1.4**. The source of the additional information is provided below in **Table 1-3**, which lists prior studies or project information west of I-75.

Figure 1-1: Map of Study Area

Table 1-3: Sub-basin Studies and Project Information West of I-75

No.	Structure / Study	Consultant	Status
1	Halfway Creek FPL Crossing	Hole Montes	Obtained. Cross sections available
2	Water Quality Weirs, Brooks Ditch to South Branch Estero	Barraco & Associates	Obtained
3	Villages at Country Creek	Wilson Miller	Obtained
	Via Villagio Parkway Halfway Creek Culverts	Hole Montes	Obtained
5	Halfway Creek RR Culverts		Obtained
6	Via Coconut Point Road Culverts	David Plummer & Assoc., Inc.	Obtained
7	Rookery Pointe Development, North Branch Estero River at Rookery Drive	Community Engineering Services, Inc.	Field measured, Invert elevation, approximate
8	Brooks Development	Wilson Miller and Johnson Engineering	Obtained
9	Brooks North Emergency Structure	Brooks of Bonita Springs II Community Dev. Dist.	Obtained
10	SWFFS Estero River Basin Modification of Hydrologic Model, July 2006	DHI, Inc.	Report and model files Obtained
11	SWFFS Integrated Hydrologic Model – Model Documentation Report, January, 2008	SDI Inc., DHI, Inc., and BPC Group, Inc.	Report and model files obtained
12	SWMM Model of Halfway Creek, 1999 SLCWP	JEI, AB&B	Model files obtained

1.4 Structures in the Estero River, Halfway Creek, Spring Creek, and Imperial River Watersheds

Figure 1-2 and **Figure 1-3** present locations of the structures and the stream network along Estero River, Halfway Creek and Spring Creek, west of I-75. **Figure 1-4** presents locations of structures and the stream network for the Imperial River. **Table 1-4** provides a detailed listing of stream crossings in the study area and summarizes structure details and dimensions. The following **sub-sections 1.4.1** through **1.4.4** describe structures in the Estero River, Halfway Creek, Spring Creek, and Imperial River watersheds. Structures from **Table 1.4-1** are shown in ***bold italics*** when discussed within the body of this report. A complete GIS geodatabase was developed for all structures within the project limits and was provided to SFWMD as part of this Data Collection effort. **Table 1-4** is taken from the geodatabase.

Table 1-4: Recent Structure Information for the Estero River, Halfway Creek, Spring Creek and Imperial River

Location	Structure Type	Structure Size	Length (Feet)	No. of Structures	Upstream Invert (Ft. NGVD)	Downstream Invert (Ft NGVD)	Permit No
3 Oaks Bonita Bill	BOX CULVERT	12' x 6'	190	1	9	9	36-04007-P
BonBeach Culv	CULVERTS	3x6' + 1x5.5' dia.	100	4	9	9	
Bonita Grande	BOX CULVERT	49' x 14'	45	1	4.1	4.1	1999 SLCWP
Brooks	BOX CULVERT	10' x 6'	150'	4	9	0	36-00288-S-02
Brooks 3 Oaks	BOX CULVERT	10' x 6'	100'	4	9	0	Barraco & Assoc plans
Brooks Ditch to ER	WEIR	36' Weir Crest Length, 3' deep V-Notch	1'	1	14	14	Barraco & Assoc plans
Brooks Div to SB Es	GATES	4.5' Wide x 6' High	1'	2	12	0	36-04007-P
Brooks East	BOX CULVERT	10' x 6'	100'	4	8	0	36-00288-S-02
Brooks M	BOX CULVERT	10' x 6'	100'	4	9	0	36-00288-S-02
Brooks N	BOX CULVERT	10' x 6'	100'	4	9	0	36-00288-S-02
Brooks Outfall North	BROAD CRESTED WEIR	200' Weir Crest Length	15.4	1	13.6	0	36-00288-S
Brooks Outfall South	BROAD CRESTED WEIR	14.1' weir	2	1	13.6	0	36-00288-S
Curve	BOX CULVERT	10' x 5'		1	7.7	7.7	
Estero NB 3OaksN	BOX CULVERT	9' x 4'	130'	3	11.4		85-00149-S
Estero NB 3OaksS	BOX CULVERT	10' x 5'	130'	4	10.72		85-00149-S
Estero NB I-75M	BRIDGE	Bridge Opening 134' W		1			36-03802-P
Estero NB I-75N	BOX CULVERT	8' x 8'	220'	1	11		36-03802-P
Estero NB I-75S	BOX CULVERT	10' x 6'	220'	2	9.67		36-03802-P
Estero NB I-75S2	BOX CULVERT	10' x 7'	220'	2	9		36-03802-P
Estero NB Rivers Fd	BRIDGE	Bridge Opening 40' W		1	5.66	5.66	36-00735-S
Estero NB Rookery	BOX CULVERT	27' x 8'	45'	3		0	36-03903-P
Estero RR		Bridge Opening 65' W				0	

Location	Structure Type	Structure Size	Length (Feet)	No. of Structures	Upstream Invert (Ft. NGVD)	Downstream Invert (Ft NGVD)	Permit No
Estero Sandy Lane	BRIDGE	Bridge Opening 54' W	137'	1	8	8	
Estero SB 3Oaks	BOX CULVERT	10' x 8'	125'	4	5	0	36-04007-P
Estero SB 40-inch dia.	BOX CULVERT	40" dia RCP	300	1	13	13	36-030802-P
Estero SB CC DrN	BRIDGE	Bridge Opening 60' W		1	0.35	0	36-00735-S
Estero SB CC DrS	BRIDGE	Bridge Opening 38' W		1	0.51	0.51	36-00735-S
Estero SB Cork Rd	BOX CULVERT	10.5' x 5.5' (2) & 10' x 8' (1)	80'	3	3.2	0	36-03277-P
Estero SB I-75 Bridge	BRIDGE	Bridge Opening 119' W		2	9.7	9.7	
Estero SB I-75N	BOX CULVERT	10' x 6'	300'	1	7		36-030802-P
Estero SB I-75S	BOX CULVERT	8' x 8'	300'	3	8.6	8.6	36-030802-P
Estero SB Sanctuary	BRIDGE	7' x 4.5'	30'	10	7.3	0	Field survey, Boyle
Estero US 41							80-00044-S
FPL Crossing					5	0	36-00681-S
Halfway Ck Weir	WEIR	200' Weir at 12', 460' at 16'	3'	1	12	12	
Halfway I-75	BOX CULVERT	9' x 8'	300'	2	8.4	8.4	36-030802-P
Halfway RR North	BOX CULVERT	10' x 4'		4	10	13.6	36-00288-S
Halfway RR South	BOX CULVERT	7' x 4'		2	10.5	13.6	36-00288-S
Halfway US 41	BOX CULVERT	10' x 7'	200'	3	7.1	7.1	36-00288-S
I-75	BRIDGE	New			0	0	
Imp Bourbonnierre Drive	BRIDGE	New			0	0	
Imp Matheson Ave	BRIDGE				0	0	
Imp_Trib_75	BRIDGE	300' Wide bridge		3	5.2	5.2	
Imperial Old 41	BRIDGE				0	0	
Imperial River	I-75 Bridge	288 ft wide	200	1	1.6	1.6	FDOT HEC-RAS

Location	Structure Type	Structure Size	Length (Feet)	No. of Structures	Upstream Invert (Ft. NGVD)	Downstream Invert (Ft NGVD)	Permit No
Imperial RR	BOX CULVERT	90' wide, LC to WL 7'	30	1	0	0	
Knollview Blvd	BOX CULVERT	9' x 6'	100'	4	9	0	36-00288-S-02
Leitner Creek	I-75 BOX CULV	12' x 8'	200	2	5.8	5.8	
Leitner Terry St							
N Rosemary Old 41	BOX CULVERT	10' x 7'		3	4	4	
N San Carlos	Never installed	N/A		0			
Orr Road	BRIDGE				1	0	Removed in 2007
Pinecrest Lane	CULVERT	4' dia.	30	1	unk	unk	
Road culvert	BOX CULVERT	6' x 4'		1	8.6	8.6	Terry St at I-75
Rosemary 3 Oaks	BOX CULVERT	12' x 7'		2	4	4	
Rosemary Creek	BOX CULVERT	7' x 6'		1	7.6	7.6	
Rosemary Old 41	BOX CULVERT	10' x 7'		2	0	0	
RR	BRIDGE	Timber	25	1	unk	unk	
S portion of Brooks	CULVERTS	30" dia.		2	13	13	From DOT
San Carlos Weir 1	WEIR	29.3' Wide x 2.24' High	2	1	10	10	
San Carlos Weir 2	WEIR	28.8' Wide x 2.21' High	2	1	10	10	
Southern Pines Drive	BOX CULVERT	15' x 5.5'		1	0	0	Field Measurements Sep 24, 2008
Spring Ck Countess	CMP	42" dia (3) & 36" dia (1)	20	4	0	0	
Spring Ck FPL	BRIDGE	No dimensions available	30	1	0	0	
Spring Ck Old 41	BOX CULVERT			2	6.6	6.6	
Spring Ck RR	BRIDGE	Bridge Opening		0	0	0	
Spring Ck Trib Cedar	RCP	24" & 54" dia, Cedar Ck Drive	80	1	1.6	1.6	
Spring Ck Trib FPL	RCP	36" dia., silted in	40	2	2.9	2.9	

Location	Structure Type	Structure Size	Length (Feet)	No. of Structures	Upstream Invert (Ft. NGVD)	Downstream Invert (Ft NGVD)	Permit No
Spring Ck US 41	BRIDGE			0	0	0	
Spring Trib Old 41	BOX CULVERT	8' x 4'		2	8.5	8.5	
Spring Trib RR	RCP	48-inch dia.	60'	1			
Via Coconut Point N	BOX CULVERT	10' x 6'	60'	4	8		36-00288-S
Via Coconut Point S	BOX CULVERT	10' x 6'	60'	2	8		36-00288-S
Via Villagio North	BOX CULVERT	10' x 6'	100'	3	7		36-00288-S
Via Villagio South	BOX CULVERT	10' x 6'	100'	3	7		36-00288-S

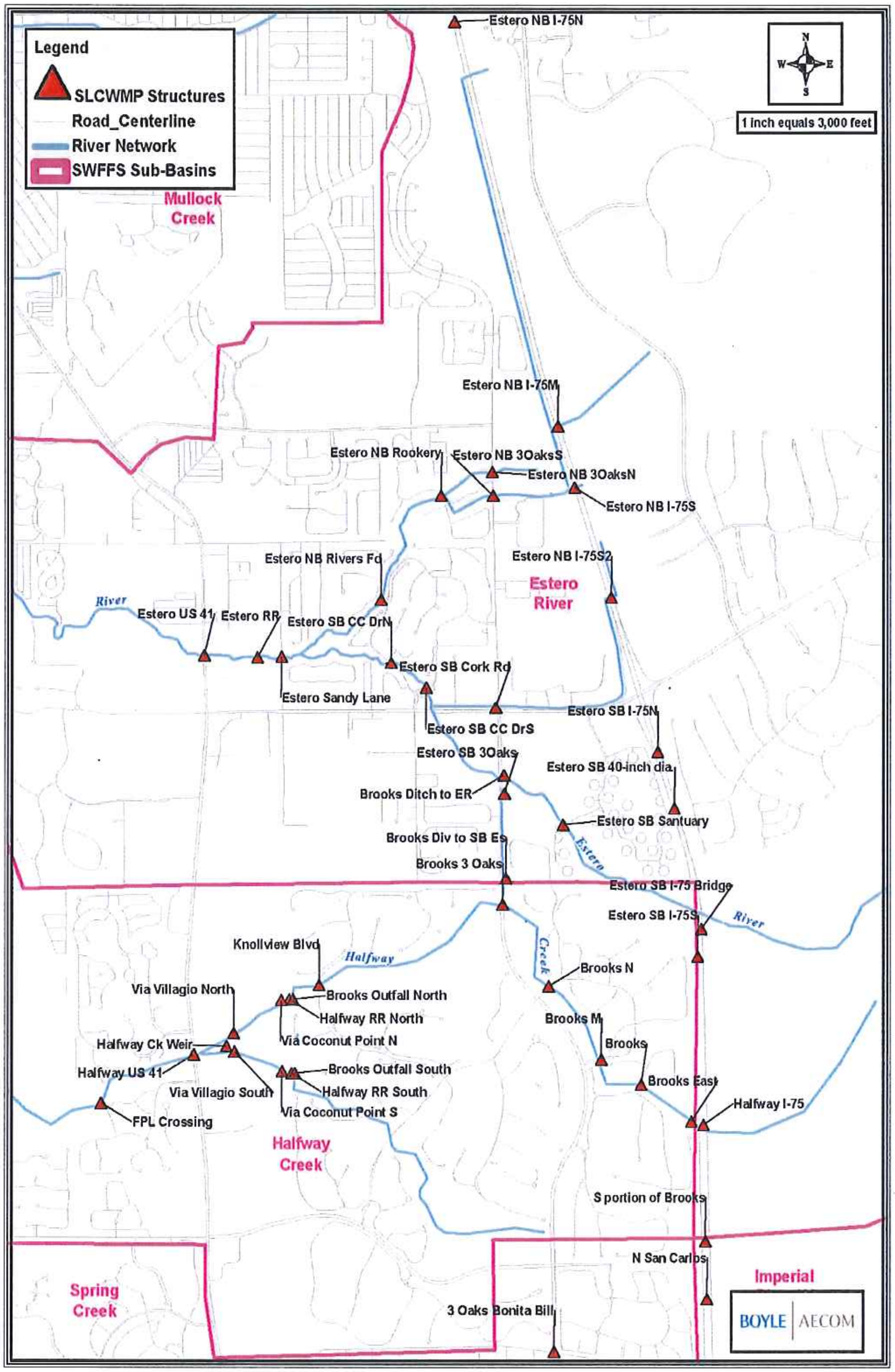

Figure 1-2: Structures in Estero River and Portions of Halfway Creek

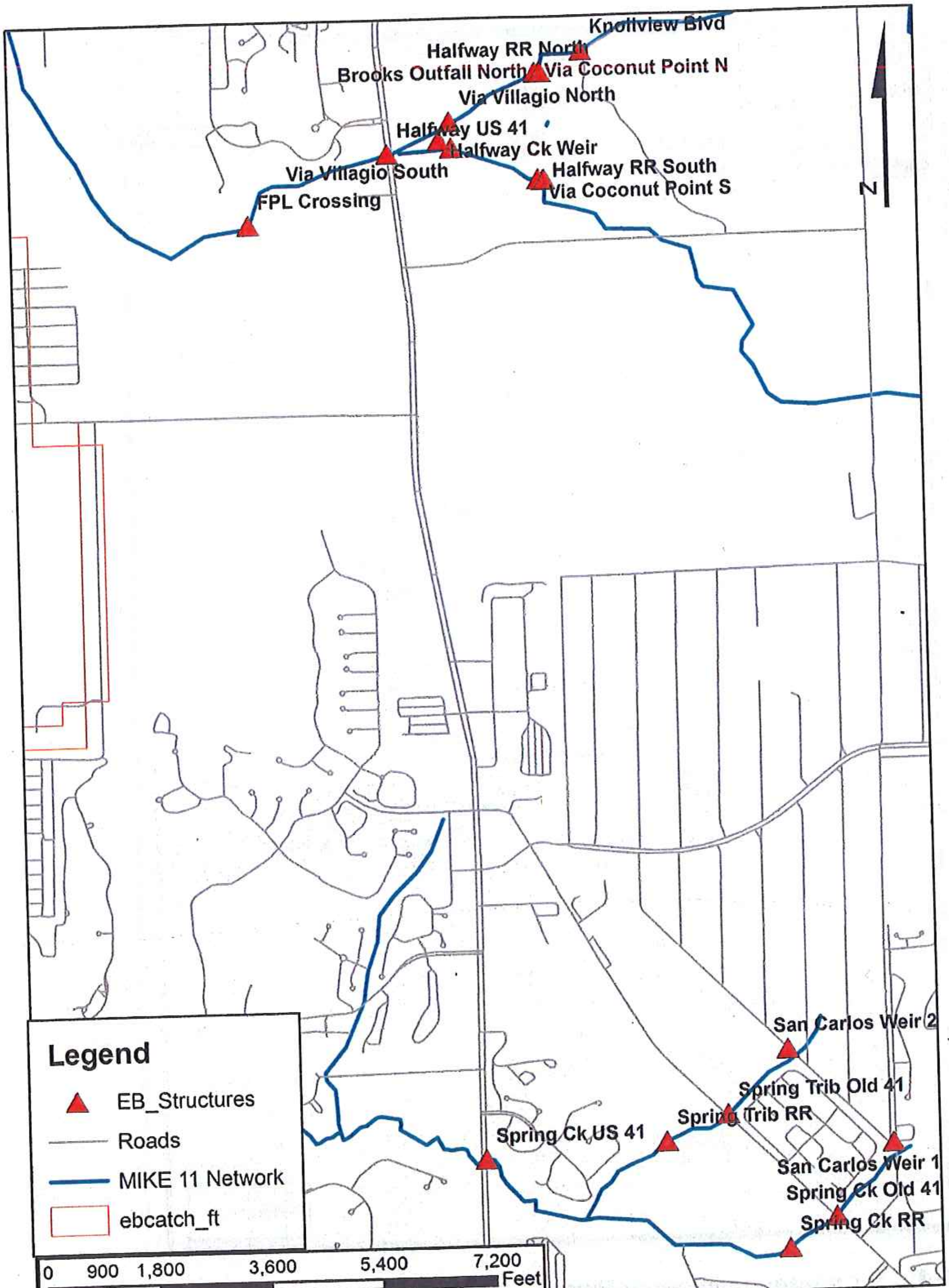

Figure 1-3: Structures in Halfway Creek and Spring Creek

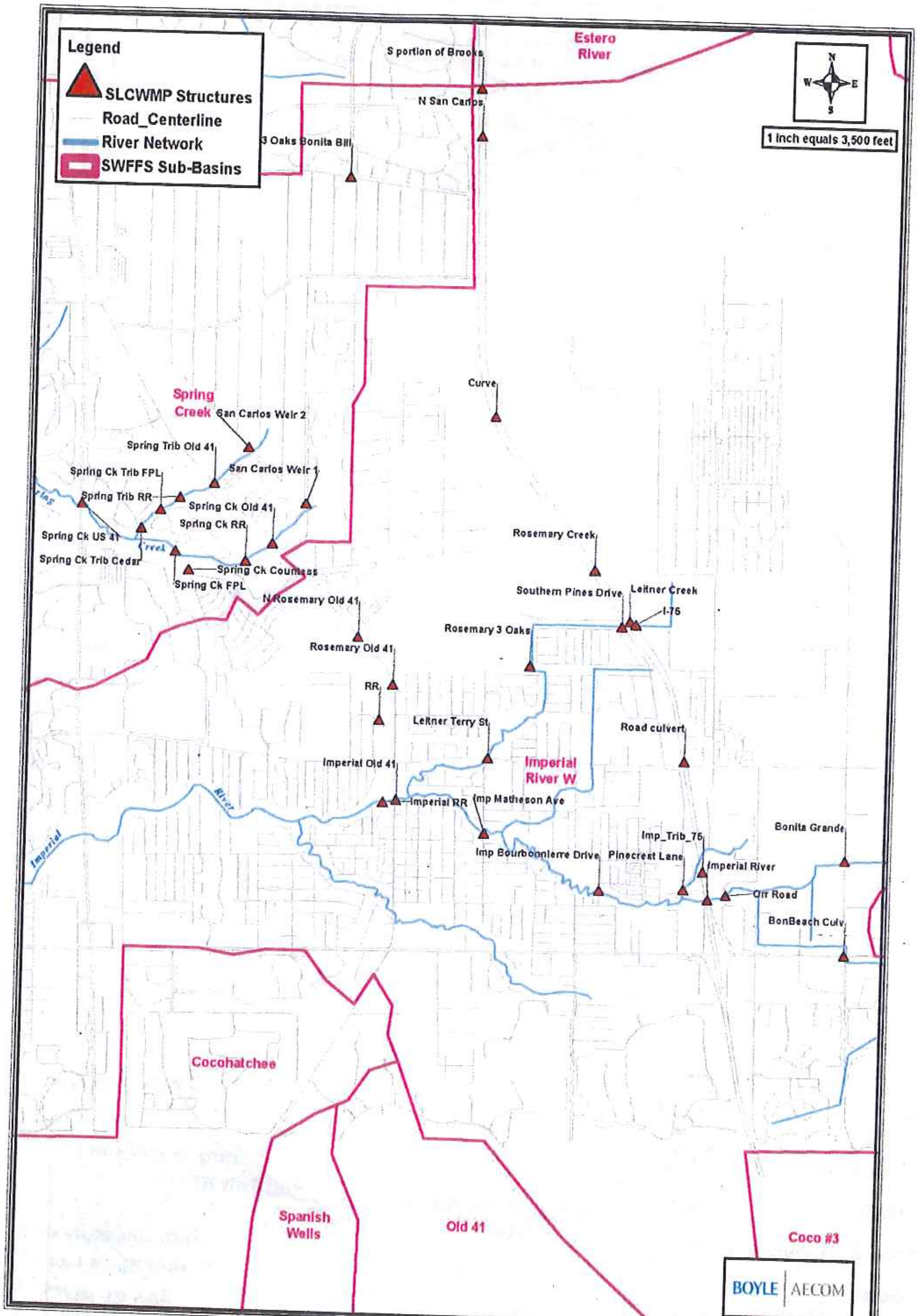

Figure 1-4: Structures in Imperial River

1.4.1 . Estero River

The Estero River headwaters are located east of I-75 in a broad system of wetlands. Flows from this area pass under I-75 north of Corkscrew Road to the North Branch of the Estero River, and south of Corkscrew Road to the South Branch of the Estero River. The North Branch of the Estero River crosses I-75 at three locations referred to as ***Estero NB I-75M, Estero NB I-75S***, and ***Estero NB I-75S2***. These conveyances consist of a bridge, two 10' x 6' culverts, and two 10' x 7' culverts, respectively. ***Estero NB I-75M*** and ***Estero NB I-75S*** enter two flow-ways to the North Branch of the Estero that flow under Three Oaks Parkway and then flow through a bridge in the Rookery Pointe development and then through a bridge in the Villages at Country Creek development. ***Estero NB I-75S2*** flows either to the Rookery Pointe flowway or enters a ditch on the north side of Corkscrew Road that enters the South Branch of the Estero River.

The South Branch of the Estero River receives flows from three I-75 conveyances that are referred to as ***Estero SB I-75 Bridge*** (a bridge), ***Estero SB I-75S*** (three 8' x 8' box culverts), and ***Estero SB I-75N*** (one 10' x 6' box culvert). A small channel through dense vegetation restricts flows downstream of the 8' x 8' box culverts. The South Branch then flows under a bridge at Sanctuary Road, under Three Oaks Parkway, and under Corkscrew Road (USGS gaging station), under two bridges in the Villages at Country Creek development, and then merges with the North Branch in the Villages at Country Creek development. There is a tributary ditch to the South Branch of the Estero River from the Brooks development that enters from the south just east of Three Oaks Parkway. A double gate controls this diversion and is referred to as ***Brooks Div to SB Es***. See **Section 1.4.2** for additional details on this diversion. The Three Oaks Ditch is constrained by a weir north of the **Brooks Div to SB Es**. The weir is 35 feet wide, has an invert elevation of 14 ft-NGVD, and a 1.2 foot wide V-notch weir that is 3 feet high. The Estero River then flows under Sandy Lane, the railroad, and U.S. 41 bridges.

1.4.2 Halfway Creek

Halfway Creek originates in a broad marsh system east of I-75. Flows pass under I-75 through two 9' x 8' box culverts (***Halfway I-75***) and then flow through the Brooks development. Field measurements indicated that the I-75 culverts are half-filled with sediment. The sediment for the I-75 culverts was cleaned out in the fall of 2008. There are six sets of box culverts within the Brooks. Each set consists of four submerged 10' x 6' box culverts.

Brooks Diversion Gate to the South Branch of the Estero River. As mentioned above, the Brooks development has an emergency gate to divert flood flows from the Brooks development north to the South Branch of the Estero River just east of Three Oaks Parkway (***Brooks Ditch to ER***). **Figure 1-5** presents a diagram of this structure. The gate operations were modified in 2006. There are two gate openings in the concrete box structure with vertical lift gates that can operate either as overflow or underflow gates. In a fully open position, the opening is 4.5' wide x 6' high with an invert elevation of 12 ft-NGVD. The east gate is now left open as an overflow gate with the weir crest set at 14 ft-NGVD. The west underflow gate opens fully if the headwater elevation exceeds 15 ft-NGVD and the Estero River at Corkscrew Road is less than elevation 12 ft-NGVD. Under these same high water level conditions, the west gate opens fully so that the bottom elevation of the vertical lift gate is 18 ft-NGVD (SFWMD Permit No. 36-00288-S-02, Brooks North Outfall OS-1, April 3, 2006).

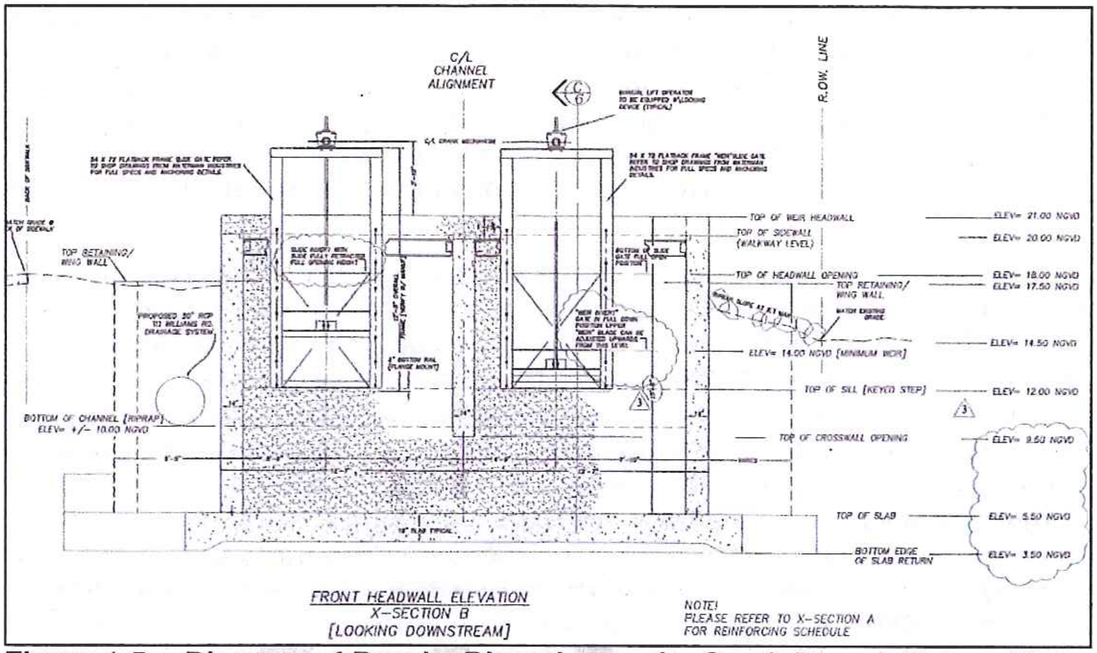

Figure 1-5: Diagram of Brooks Diversion to the South Branch Estero River

A south branch of Halfway Creek originates within the Brooks. Flows out of the Brooks are controlled by two weirs with invert elevations at 13.6 ft-NGVD (***Brooks Outfall North*** and ***Brooks Outfall South***). The crest length of the south weir is 11.4 ft and the width of the weir (parallel to the axis of flow) is 24 inches. The north weir crest length is 200 feet and the width of the weir is 16 feet. The top of the embankment on either side of the north weir is 16.2 ft-NGVD, and the distance from the top elevation of the two ends of the weirs is 210.4 ft (perpendicular to the flow-line). The south weir has vertical endwalls with a top elevation of 16.2 ft-NGVD.

Halfway Creek then flows under railroad culverts (four 10' x 4' box culverts for the main branch and two 7' x 4' culverts for the south branch) and Via Coconut Point. The existing railroad culverts were installed in the late 1990s and replaced a set of variously sized culverts that restricted flows during the 1995 floods.

The Via Coconut Point culverts consist of two 10' x 6' box culverts for the south Branch and four 10' x 6' box culverts for the main branch of Halfway Creek. Just west of Via Coconut Point, there is a ditch (referred to herein as the Via Coco Ditch) that connects the north and south branches of Halfway Creek. Flows then pass through two wetland flow-ways and pass under Via Villagio. There are three 10' x 6' culverts at two separate locations that convey Halfway Creek under Via Villagio. The invert elevation is 7.0 ft-NGVD.. The two branches of Halfway Creek merge downstream of Via Villagio and then through a weir (***Halfway Ck Weir***) with a 200-foot section with an invert of 12 ft-NGVD and a 460-foot section with an invert of 16 ft-NGVD. This weir was installed in the late 1980's as part of the initial Brooks development (which was called Sweetwater Ranch). Halfway Creek then flows under U.S. 41 through a double set of 10' x 7' box culverts with an invert elevation of 7 ft-NGVD (***Halfway US 41***). The final constriction is the ***FPL Crossing***, which has an invert elevation of 5 ft-NGVD. Hole Montes designed a new pipeline crossing that will not constrict flows, and this crossing construction work was completed in the spring of 2009. Cross sections from this design work were incorporated into the model.

1.4.3 Spring Creek

Spring Creek is located south of the Brooks and west of I-75. Runoff from San Carlos Estates is the primary source of Spring Creek, and there are two 29-foot weirs (invert at 10 ft-NGVD) just east of Old U.S. 41 which control runoff from San Carlos Estates. The Moriah Canal weir (Weir #2) is 2,300 feet north of the San Carlos Weir #1, which is on Stillwell Canal. Moriah Canal flows into the North Branch of Spring Creek. The right bank of the channel leading south to the Moriah weir is parallel to a cypress swamp west of the Moriah Canal. The levee is breached at approximately elevation 8.8 ft-NAVD (10.1 ft-NGVD), which is 0.1 feet higher than the spillway elevation for this weir (see **Figure 1-6**).

Figure 1-6: San Carlos Estates Moriah Weir with Failed Right Bank Levee

The North Branch of Spring Creek passes under Old U.S. 41 through two 8'x4' box culverts at the Brentwood Business Park and then under a railroad bridge via a single 48" RCP. The velocity in the 48" diameter culvert exceeded 2 feet per second on September 24, 2008. Note that the cross sectional area at Old 41 is 64 square feet, and the 48" diameter culvert has a cross sectional area of 12.6 square feet. Culvert conveyance normally increases in a downstream direction. There is extensive vegetation growth upstream of the railroad culvert. The North Branch of Spring Creek then flows under an FPL easement through two 36" diameter culverts that have silt accumulations. No flow was discernable at these culverts on September 24, 2008. The North Branch of Spring Creek then flows under Cedar Creek Drive via a 24" diameter RCP and a 54" diameter RCP culvert, however no flow was observed. It is likely that the North Branch has found another conveyance to Spring Creek.

The main Branch of Spring Creek flows under Old U.S. 41 north of Cockleshell Drive via two 8' x 4' box culverts. The depth from the culvert crown to the channel invert was 3.5 feet, therefore some silt accumulation must have occurred at these culverts. There is a USGS gaging station at this location. Spring Creek then flows under a railroad wooden bridge, under a new set of triple 12'x5' box culverts (inv. 3.5 ft-NGVD) under Milagro Lane, and then under a set of corrugated metal pipes at Countess Lane (one 36" and three 42" diameter culverts). As with the North Branch, the cross sectional area at Old U.S. 41 is 64 square feet and decreases to approximately 40 square feet at Countess Lane. Spring Creek then flows under a bridge at the FPL easement. There is dense vegetation upstream and downstream of the FPL easement. The tributaries merge before flowing under U.S. 41. Significant cleaning of both branches of Spring Creek is needed, and it appears that flows through the North Branch are much less than the main stem due to the decreasing culvert conveyance area and dense riparian vegetation consisting of Brazilian pepper and other invasive species.

1.4.4 Imperial River

Kehl Canal is the source of flow to the Imperial River upstream of I-75, along with flows from a drainage canal south of Bonita Beach Road. There are two sets of culverts in the upper reaches of Kehl Canal that are located at Poorman's Pass Road (3 X 42" CMPs, Inv 12.5 ft-NGVD) and Vincent Road (30", 32", and 42" CMPs, unknown invert). Kehl Canal water levels are controlled by a gate and weir at the downstream end of Kehl Canal just east of Bonita Grande Drive. The Kehl Canal gate consists of two steel plates that have an elevation of 12 ft-NGVD when closed. The invert elevation is 3 ft-NGVD, and the gates open during the wet season. Opening criteria vary depending upon a variety of factors, and gate operations are therefore based on gate operation records. There is a 100-foot weir at the Kehl Canal gate with an invert elevation equal to 10 ft-NGVD. Bonita Grande Drive consists of a box opening that is 49 feet wide, 12 feet high, with the invert elevation equal to 4 ft-NGVD.

Imperial River road crossings are all bridges from I-75 to U.S. 41, and all bridges except the railroad bridge and the Bourbonnierre Street bridge appear to be new. These older bridges do not appear to be a significant constraint, however no detailed cross sections of these bridges were found. Dimensions were obtained from existing HEC-RAS files.

Rosemary and Leitner Creeks enter Imperial River from the north, and the drainage areas for these two creeks have been substantially modified since construction of Three Oaks Parkway (called Imperial Boulevard within Bonita Springs). Permit information was reviewed to improve the representation of these two creeks.

1.5 Calibration Data Available for the Study Area

Flow and stage data is available from the SFWMD DBHYDRO data base from February, 1987 through December, 1999 for the Imperial River at Orr Road, Spring Creek at Old U.S. 41, South Branch of the Estero River at Corkscrew Road, and the North Branch of the Estero River just east of the end of Broadway Avenue. Stage and flow data are still being measured and are available from USGS at these same four stations. Lee County also has measured flows at the Kehl Canal gate in the Imperial River continuously since 2003. **Figure 1-7** presents a map of stream gaging stations in the study area. **Figure 1-8** and **Figure 1-9** present USGS measured stage and flow data for study area gages. **Figure 1-10** presents water level measurements in Halfway Creek that were taken by the Brooks of Bonita Springs & Brooks II Community Drainage District.

1.6 Historical Flows and Stages

A review of historical flows and stages was conducted as the first step in determining how flood flows will be re-distributed from the Imperial River to either Spring Creek, Halfway Creek, and/or the Estero River. Where possible, peak flows should be limited in each creek to flows that were present during pre-development conditions and the flow conveyance should also maintain acceptable hydroperiods upstream of I-75. This section lists available historical peak flows for South Lee County streams and uses drainage basin information to estimate peak flows for streams that do not have measured flows for the largest floods. Subsequent sections will present flow comparisons between undeveloped and existing conditions and hydroperiod information.

Historic Peak Flows. The United States Geological Survey (USGS) has been measuring stages during major floods since 1936 and began flow measurements in the Imperial River since 1940. Flow measurements began in Spring Creek and the Estero River (North and South Branches) since 1987. In each watershed, spot measurements were taken starting in 1936 by USGS, and are presented below. Another source of information is USGS gaging data from the Orange River in Lee County. The largest floods on record in the Imperial River, South Branch Estero River, and Orange River are listed below in **Table 1-5**. Historic Orange River flows are being used because the Orange River watershed was once very similar to the Imperial River watershed as the headwaters were predominantly wetlands prior to the channelization of Lehigh Acres. No flow data were obtained for Spring Creek, Halfway Creek, or the Estero River for the period preceding construction of I-75 in the late 1960's.

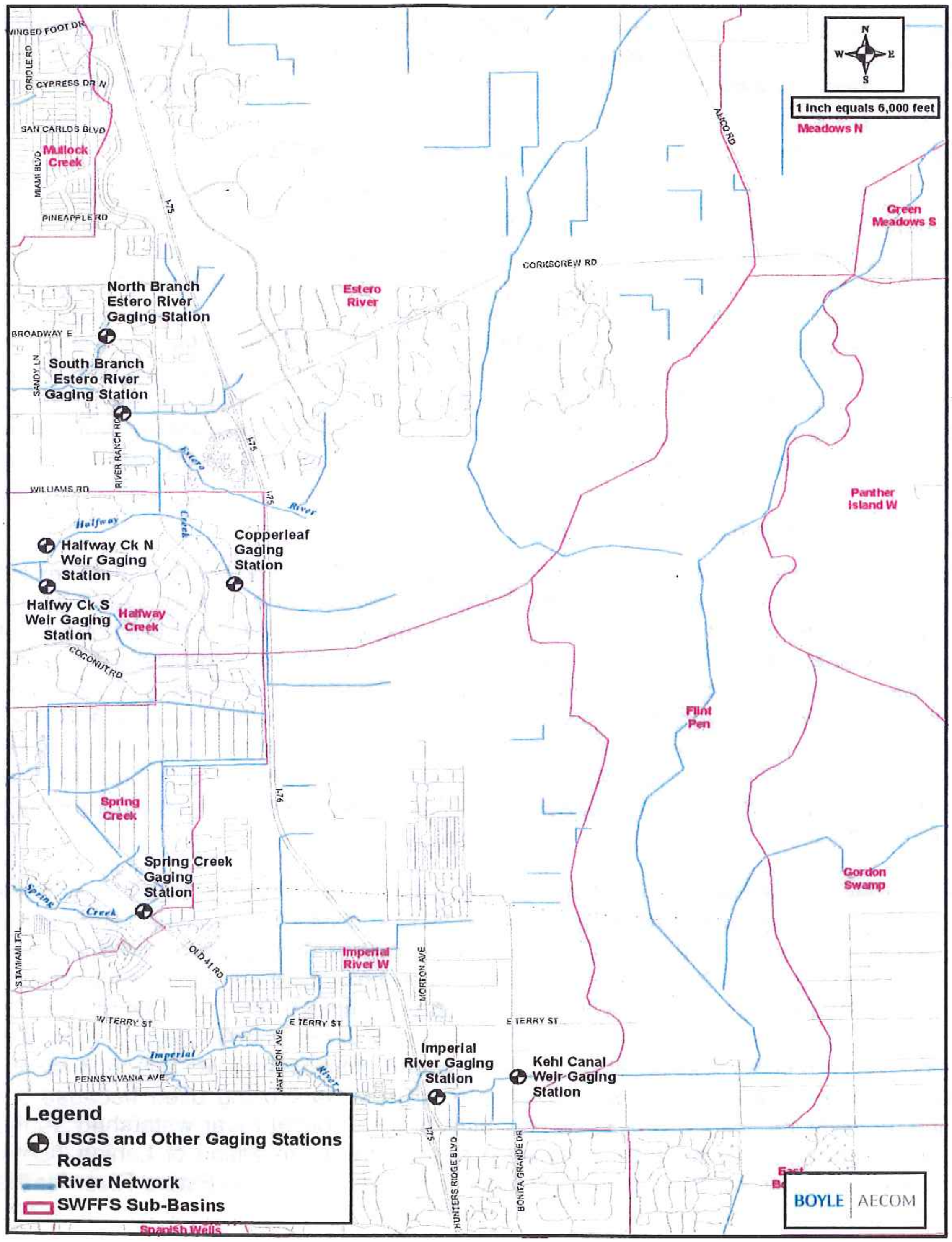

Figure 1-7: Map of Stream Gaging Stations

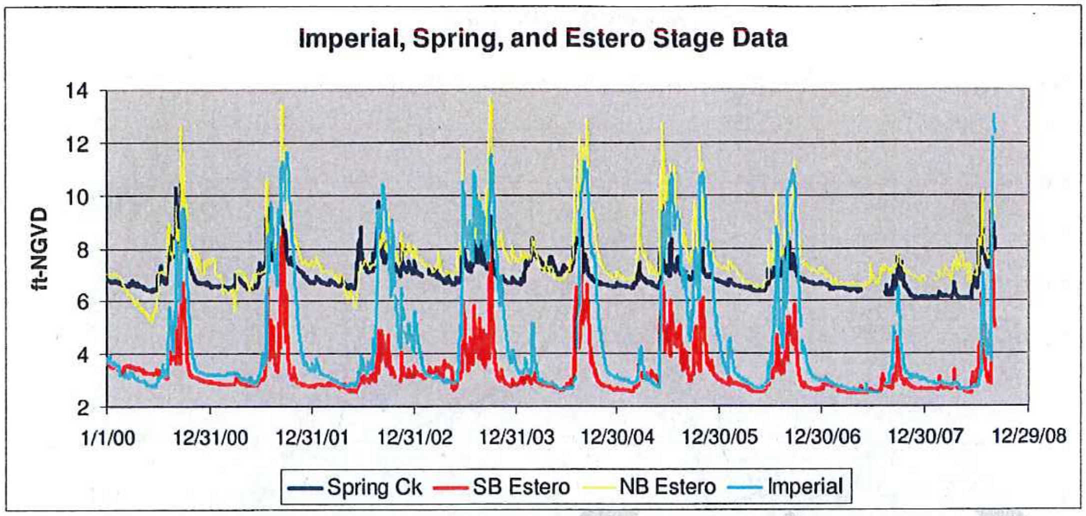

Figure 1-8: USGS Water Level Measurements for the Imperial River, Spring Creek, South Branch Estero River, and North Branch Estero River

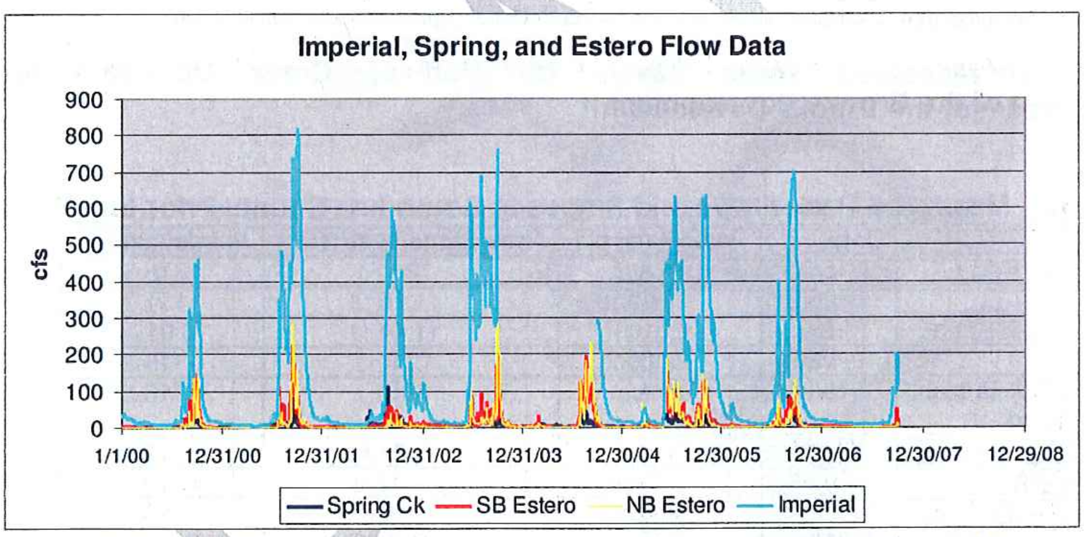

Figure 1-9: USGS Flow Measurements for the Imperial River, Spring Creek, South Branch Estero River, and North Branch Estero River

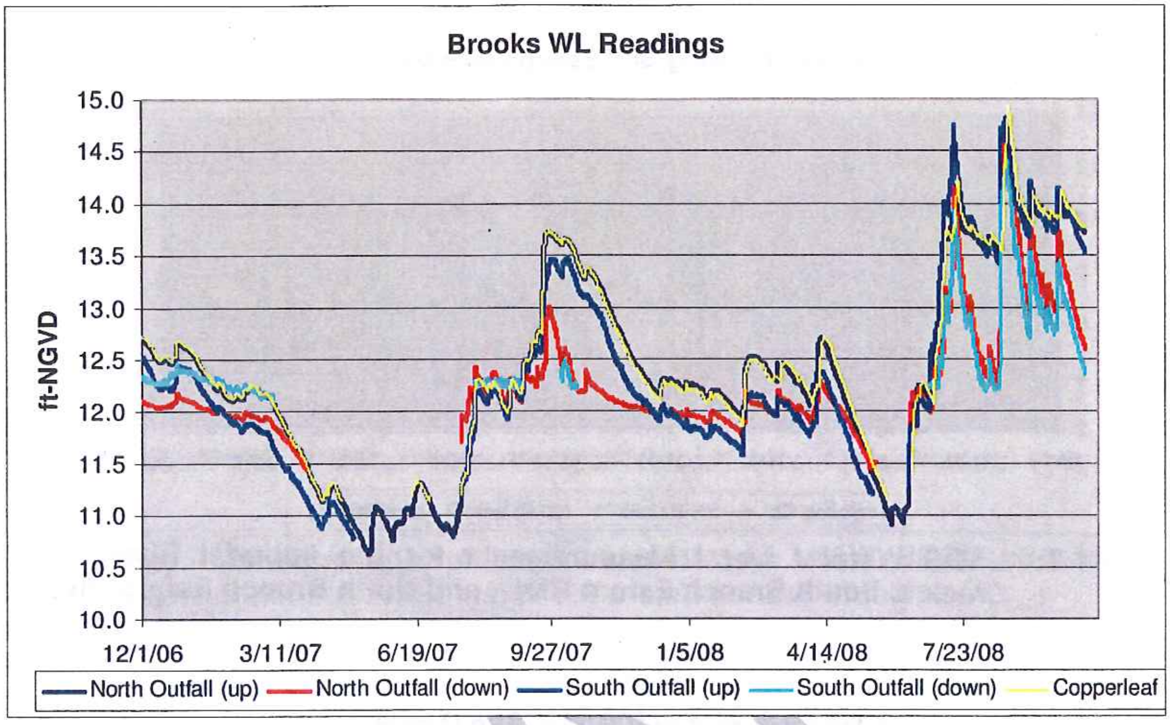

Figure 1-10: Measured Water Levels for Halfway Creek Upstream and Downstream of the Brooks Development

Table 1-5: Measured Peak Flows and Stages in South Lee County Prior to I-75

Station	Date	Peak Flow, cfs	Peak Stage, ft-NAVD	Rainfall, in.
Imperial R. Orr Rd.	6/15/36	N/A	12.1	13.5
	9/12/40	2,890	11.15	11.7
	10/2/51	2,810	11.44	10.94
	9/4/95	2,000	12.3	13.2
Estero R, South Branch, Corkscrew Road	6/15/36	N/A	12.7	13.5
Estero R. SB (estimated)	8/26/95	410	N/A	13.2
Estero R. NB	8/26/95	366	13.0	13.2
Spring Ck. Old US 41	10/19/95	269	8.5	13.2
	9/21/99	465	9.0	6.4*
Orange R. Buckingham Rd	6/15/36	5,300	13.8	13.5
	6/26/92	2,040	N/A	12.86

Note: Rainfall data taken from the Fort Myer Page Field Station, which was the closest station with a long record of rainfall data. Data for 1999 is from Flint Pen rain gage FPWX.

Table 1-5 identifies that the Imperial River 1940 peak flow was almost 44% larger than the 1995 peak flow, while the 1940 peak stage was more than one foot less than the 1995 peak stage. This is due partly to the extremely wet conditions preceding the 1995 flood which consumed available floodplain storage east of I-75 and south of the Imperial

River. Downstream flow constrictions in the Imperial River during 1995 also likely contributed to the higher peak stage of the 1995 event. Estero River maximum measured flows occurred in 1995, after construction of I-75. Spring Creek maximum measured flows occurred in 1999, after construction of I-75. There are no measured Estero River or Spring Creek flows available during major floods for the period that precedes construction of I-75.

The drainage areas for all of these creeks are poorly defined and prior studies have determined that historic watershed divides may become inundated, which then result in re-direction of flows to the direction with the greatest hydraulic gradient (slope of the water surface). In the 1995 flood, the SLCWP states that flows which historically flowed south into the Cocohatchee Canal and the Corkscrew Slough could not flow in that direction due to high stages resulting from high rainfall amounts in the Big Cypress Basin (south of the Imperial River in Collier County). This resulted in a re-direction of flows to the Imperial River. However, for the purposes of this analysis, we will rely on the commonly accepted drainage areas to estimate peak flows for Spring Creek, Halfway Creek, and the Estero River.

Peak flows were estimated for the Estero River, Halfway Creek, and Spring Creek prior to construction of I-75, as shown in **Table 1-6**. The peak flows were estimated using the Imperial River unit peak flow rate from the 1940 flood. The Orange River unit peak flow is much larger, and was not used as it is uncertain if South Lee County rivers and creeks ever had the conveyance capacity to deliver 55.2 cfs/mi^2. Wetlands comprised less than 50% of the Orange River watershed, while historic wetlands were likely to cover more than 75% of the South Lee County watersheds.

Table 1-6: Listing of Measured Flows for the Imperial and Orange Rivers and Estimated Peak Flows for the Estero River, Spring Creek, and Halfway Creek

Watershed	Measured Peak Flow, cfs	Drainage Area, mi^2	Unit flow, cfs/mi^2	Est. Peak Flow, cfs*
Imperial River, Orr Rd., measured	2,890	86	33.6	
Orange R, Buckingham Rd, measured	5,300	96	55.2	
Estero R., North Branch, I-75	N/A	29		975
Estero R., South Branch, I-75	N/A	48		1,613
Halfway Creek, I-75	N/A	5		168
Halfway Creek, U.S. 41	N/A	9		302
Spring Creek, U.S. 41	N/A	10		336

Source of drainage areas: SLCWP, 1999
* Estimated peak flows were generated using 33.6 cfs/mi^2

1.7 Ecological Assessment

Although final work products are not yet available from the Southwest Florida Feasibility Study (SWFFS), a technical memorandum titled the "Ecological Memorandum of the Density Reduction/Groundwater Resource Area" (July, 2008) prepared by Kevin L. Erwin Consulting Engineers, Inc. has been completed and was reviewed as part of this data collection task.

The technical memorandum presents the results of a detailed ecological mapping of current and historic land uses and evaluation of the 82,880 acre DRGR area. The historic and existing land use maps will be used to calibrate the MIKE SHE model being created for the DRGR Study.

1.8 Data Gaps

In the course of this data collection effort, a number of data gaps were identified and they are presented in **Table 1-7**. Note that some of these data gaps were identified after the completion of the data collection effort during calibration and modeling during the problem identification phase.

Table 1-7: Known Data Gaps

Data Gap	Addressed During Study?
Bridge elevations for North Branch Estero River in Rookery Pointe	No
South and North Branch Estero River I-75 Bridge Drawings	Yes
South Branch Estero River Sanctuary Road Bridge Survey	Yes
Inspection of the Halfway Creek Railroad for obstructions	No
Halfway Creek cross sections between Via Coconut Point and the Halfway Creek Weir	Yes
S. Branch Estero River cross sections between I-75 and Sanctuary Rd	Yes
Spring Creek cross sections downstream of Old U.S. 41	Yes
First floor elevations, Manna Christian Trailer Park	Yes
First floor elevations, Quinn Street area, Bonita Springs	Yes
Identified after completion of Data Collection Phase	
Survey of first floor elevations, N Branch Estero, Rivers Ford Road bridge	No
Cross sections within San Carlos Estates	No
Measured canal stage and flow data for the Stillwell and Moriah weirs, and Strike Lane Canal at Stillwell Road, San Carlos Estates	No

New surveyed cross sections were obtained for Halfway Creek between Via Coconut Point and the Halfway Creek weir upstream of U.S. 41, the Three Oaks Parkway Ditch that conveys overflows from Halfway Creek to the South Branch Estero River, and South Branch Estero River between I-75 to downstream of Sanctuary Road bridge. Cross sections were also obtained in Spring Creek downstream from Old U.S. 41, and spot elevations were shot in the Manna Christian Trailer Park south of Kehl Canal and the Quinn Street area of Bonita Springs west of I-75 and north of Bonita Beach Road.

1.9 Survey Cross Sections

Cross sections were surveyed by Boyle|AECOM so that the modeling effort could be representative of existing conditions in the study area. Cross sections were surveyed in locations where significant changes had occurred due to urban development. In addition, cross sections were surveyed in the South Branch of the Estero River at Sanctuary Road (upstream of Three Oaks Parkway) because existing information on this river crossing was not available from prior studies.

During the course of the study, additional cross sections were deemed necessary for the South Branch Estero River from just west of I-75 to Sanctuary Road. Lee County conducted this surveying and provided the survey data. Additional cross sections were also needed for Spring Creek just west of the USGS gaging station at Old U.S. 41. The City of Bonita Springs sent out a surveying team to obtain these cross sections and provided their data.

Figures 1-11a and Figure 1-11b show the locations where cross sections were surveyed by Boyle|AECOM. There were some adjustments to cross section locations based on a field survey conducted immediately prior to the surveying. A key concern of this study is the peak stages in Halfway Creek within and downstream of the Brooks. As a result, cross sections were surveyed west of Via Coconut Point. A cross section was surveyed along a weir in Halfway Creek just upstream of U.S. 41 (referred to the Halfway Creek Cypress Weir), and three cross sections were surveyed west of U.S. 41. A wooden walkway was constructed just west of U.S. 41, and local engineers reported that Halfway Creek channel bottom elevations appeared to be higher than previously surveyed. Accordingly, a cross section was surveyed at the walkway. Halfway Creek west of this walkway is a dense cypress swamp. An additional cross section was surveyed halfway between the wooden walkway and the FPL crossing and a cross section was surveyed at the Williams Road bridge within the West Bay Club.

Stakeholders expressed another concern regarding Brooks outflows north to the South Branch of the Estero River. It has been observed that outflows are restricted due to sediment deposits in the channel north of the Brooks diversion gate just east of the Three Oaks Parkway north of the intersection with Williams Road. A cross section was also surveyed at this location.

Figure 1-12 provides a map of the surveyed cross sections provided by Lee County, and **Figure 1-13** provides a map of the surveyed cross sections provided by the City of Bonita Springs.

Appendix 1 presents detailed maps of cross section locations and drawings of these cross sections.

Figure 1-11a: Map of Cross Sections Surveyed by Boyle Engineering

Figure 1-11b: Map of Cross Sections Surveyed by Boyle Engineering

Figure 1-12: Map of Cross Sections Surveyed by Lee County

Figure 1-13: Location of Cross Sections Surveyed by City of Bonita Springs

1.10 Comparison of Actual SLCWP Recommendations with Actual Implementation

Many of the recommendations from the 1999 SLCWP were implemented, however some were not. **Table 1-8** presents this information.

Table 1-8: List of 1999 SLCWP Recommendations and Status of Implementation

Recommendation	Status in 2009
1. Estero River: clean and snag from US 41 to confluence of N and S Branches. Completed. N & S Branch: clean and snag from confluence of branches to I-75	Partially completed by not maintained
2. Estero – N Branch: connect I-75 outfall to headwaters of N Branch, acquire flow-way	Not completed
3. Estero – N Brach: Enlarge existing 2 – 10'x5' box culverts in Three Oaks Parkway	Completed
4. Estero – S Branch: construct Corkscrew Road structure	Completed
5. Channels east of I-75 between Halfway Creek and SB Estero River	Not completed
6. Construct a by-pass channel to divert 160 cfs from Halfway Creek to the South Branch Estero River	Completed, however subsequent permitting of Three Oaks Blvd. compromised flow conveyance
7. Halfway Creek – Seminole Gulf RR to I-75: channel and structure construction	Completed
8. Halfway Creek – periodic clean and snag vegetation upstream and downstream of US 41	Completed upstream of US 41. Not completed downstream
9. Halfway Creek – FP&L Bridge: replace existing bridge	Completed – removed culverts and approach berms
10. Halfway Creek – RR: replace undersized culverts	Completed
11. Halfway Creek – Divert 160 cfs to Spring Ck.	Not completed
12. Spring Creek – replace Old 41 and FPL and Imperial Harbor crossings	Partially done
13. Imperial River: clean and snag from Matheson Street to Bonita Grand Drive	Completed but not maintained
14. Imperial River: reconstruct IBE Bridge	Completed
15. Imperial River – Matheson Street to Bonita Grande Drive: purchase floodway right of way from willing sellers	Not completed
16. Reconstruct Kehl Canal weir	Completed
17. Corkscrew Swamp Sanctuary South Dike: replace 5 - 30" CMPs with 5 - 72" CMPs in east to west dike located approximately 2 miles north of the north end of Corkscrew Canal.	Completed. Included modification of Corkscrew Canal, construction of 6 bridges and 2 gated weirs.
18. Partially restore Camp Keais flow way between Lake Tafford and SR 846	Some vegetation control was implemented. CR 858 improvements are underway.
19. Activate integrated gage system to monitor Corkscrew Swamp area pool levels and the Imperial River basin	Completed
20. Purchase storage lands to the east of I-75	In progress and substantially complete by CREW and SFWMD. Some land S of Kehl Canal and N of Bonita Beach Rd is in private ownership.

2 CALIBRATION

The section describes the simulation algorithms and input data processing, calibration of the model, sensitivity analyses of the simulation, problems encountered, and trouble-shooting process during the calibration and verification process. Both an analytical and graphical summary of calibration results is provided.

2.1 Model Update

MIKE SHE/MIKE 11 is an integrated surface/ground water modeling software package that is being used for a number of hydrologic/hydraulic modeling projects in southwest Florida. This modeling tool allows for a simultaneous assessment of stream flow and groundwater dynamics. The model also has the capability to simulate overland flow outside of river networks, such as in the wetlands east of I-75 between Corkscrew Road and the Imperial River. Lee County is conducting an assessment of water resource impacts of a number of mining proposals within an area east of I-75 and south of State Route 82 called the Density Reduction Groundwater Resource (DRGR) area, and MIKE SHE/MIKE 11 Version 2008 SP2 is being used for this assessment (DHI, Inc., 2008). The MIKE SHE/MIKE 11 model developed by DHI, Inc. covers all of Lee County, but the focus of the model was lands east of I-75, therefore a number of bridges, culverts and weirs in the Estero River, Halfway Creek, Spring Creek, and Imperial River basins were not included in the initial model. In order to maintain consistency, it was decided to use the MIKE SHE/MIKE 11 Lee County model for the South Lee County Watershed Plan Update, to add more detailed information on bridges, culverts, weirs, and gates west of I-75 and to utilize more recent information to modify the cross section database in the model. This section summarizes the changes made to the model as part of the Update.

2.2 Calibration Data

Additional calibration data for 2008 was obtained from Lee County for groundwater wells, USGS for calibration wells and surface water stations (stage and flow data), SFWMD for wells in DBHYDRO, and Lee County DOT for gate level measurements and headwater and tailwater stage data for the Kehl Canal gate. Johnson Engineering provided measured stage data for Halfway Creek, and the District Manager for the Brooks Community Development Districts confirmed that the Brooks emergency gate remained closed in 2008.

Measured ground elevations and horizontal coordinates were obtained for each groundwater well used in the calibration, and these elevations were compared to the elevation in the MIKE SHE digital elevation model (DEM) at that location. There were significant differences for some calibration wells, and these differences can affect the calibration accuracy because all simulated groundwater elevations are relative to the DEM ground elevation. **Table 2-1** lists the elevation differences for the groundwater calibration wells. Surficial well L-5844 has a surveyed ground elevation that is 6.6 feet lower than the DEM elevation. The DEM elevation is an average elevation for a 750x750 foot grid cell, and that elevation is calculated from a LIDAR-generated topographic map. The LIDAR-based DEM may not be representative of actual ground elevations, particularly in forested areas that have rapidly changing elevations. The area surrounding L-5844 is one such well that is located in a ravine north of the Estero River just west of U.S. 41, and the DEM elevation for that cell is clearly incorrect. As will be discussed later in **Section 2.8.3**, calibration accuracy for that well is not good.

Table 2-1: Comparison of Surveyed and DEM Elevations (ft-NAVD) for Groundwater Calibration Wells

Well ID	DEM Elevation (ft NAVD)	Surveyed Elevation (ft NAVD)	Elevation Difference (ft)
Imperial 49-GW3	27.09	26.80	-0.29
Imperial 49-GW6	17.29	18.00	0.71
Imperial 49-GW7	16.73	17.10	0.37
Imperial 49-GW8	16.25	15.62	-0.63
Imperial 49-GW9	15.93	14.90	-1.03
Imperial 49-GW10	12.51	12.90	0.39
Imperial 49-GW11	13.36	12.40	-0.96
Imperial 49-GW12	11.10	11.50	0.40
Imperial 49-GW14	12.29	12.10	-0.19
Imperial 49-GW15	10.30	8.60	-1.70
Leitner 49L-GW1	13.42	12.50	-0.92
FP2_GW1	17.37	16.30	-1.07
FP3_GW1	16.85	13.70	-3.15
FP4_GW1	16.92	13.95	-2.97
FP5_GW1	16.57	13.50	-3.07
FP6_GW1	16.82	13.45	-3.37
FP7_GW1	16.74	15.60	-1.14
FP8_GW1	16.59	13.30	-3.29
FP9_G	16.51	15.20	-1.31
L-5667	16.33	N/A	N/A
FP10_G	16.71	15.00	-1.71
HF1_G	21.02	17.48	-3.54
HF2_G	21.11	17.80	-3.31
HF3_G	22.09	19.44	-2.65
HF4_G	22.28	18.46	-3.82
HF7_G	20.69	17.48	-3.21
ST1_G	28.12	25.39	-2.73
ST2_G	28.39	25.39	-3.00
ST3_G	27.77	25.06	-2.71
WF3_G	28.35	27.70	-0.65
WF4_G	27.89	27.70	-0.19
WF5_G	28.36	27.70	-0.66
WF6_G	27.76	27.70	-0.06

Well ID	DEM Elevation (ft NAVD)	Surveyed Elevation (ft NAVD)	Elevation Difference (ft)
WF7_G	27.55	27.32	-0.23
L-5844	12.20	5.60	-6.60

Certain wells used in the DRGR calibration do not have measured data for 2006 – 2008. These wells are Imperial 49-GW3, Imperial 49-GW8, FP4_GW1, L-5667, WF1_G, and L-5649.

2.3 Model Input Data

OneRain grid rainfall data for 2006-2008 was obtained from Lee County, and SFWMD provided evapotranspiration data for 2008. **Figure 2-1** presents cumulative rainfall for 2006 from the OneRain grid rainfall file. The MIKE SHE model domain and the MIKE 11 river network is also shown on **Figure 2-1** Lee County Utilities provided groundwater pumpage information for the Green Meadows and Corkscrew well fields and SFWMD provided data for the Pinewoods well field. Florida Governmental Utilities Authority provided Lehigh Acres well field pumpage data for 2008. Bonita Springs Utilities provided pumpage data for 2008. Boundary time series data was obtained from the SFWMD DBHYDRO data base.

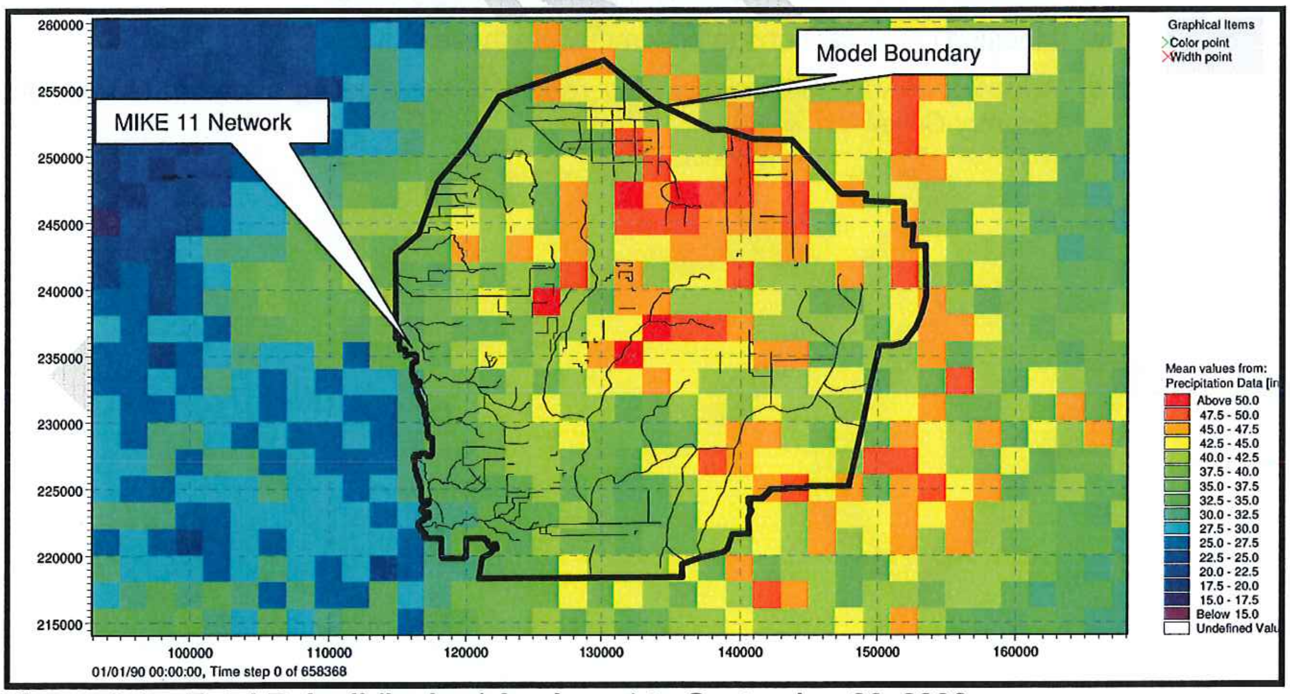

Figure 2-1: Total Rainall (inches) for June 1 to September 30, 2006

2.4 MIKE 11 Changes

The following list documents the additions made to the surface water channels and flow-ways. There is some MIKE 11 modeling terminology used, as explained below. A river or channel reach is referred to as a Branch. Branches are lines representing the centerline of a river, channel, or flow-way. Position along the branch is shown as chainage (abbreviated as ch.), and typically chainage is 0 feet at the upstream end and increases in a downstream direction. Cross sections (abbreviated as XS) are required upstream and downstream of any culvert, weir, or gate. **Figure 2-2** and **Figure 2-3** provide maps of the study area with structure names, roads, and general features. The changes to the MIKE 11 files are summarized below:

1. North Branch of the Estero River, Branch EsteroI75
    a. Modified culvert dimensions to be consistent with bridge conveyance, ch. 450 ft
2. North Branch of the Estero River, Branch EsteroRiv
    a. Added another set of culverts under Three Oaks since there are two sets of culverts, ch. 1600
    b. Added culverts inside Rookery Development, ch. 2006
    c. Modified cross sections to accommodate these culverts
    d. Added a culvert with capacity equivalent to the existing bridge in Village of Country Creek, ch. 4980

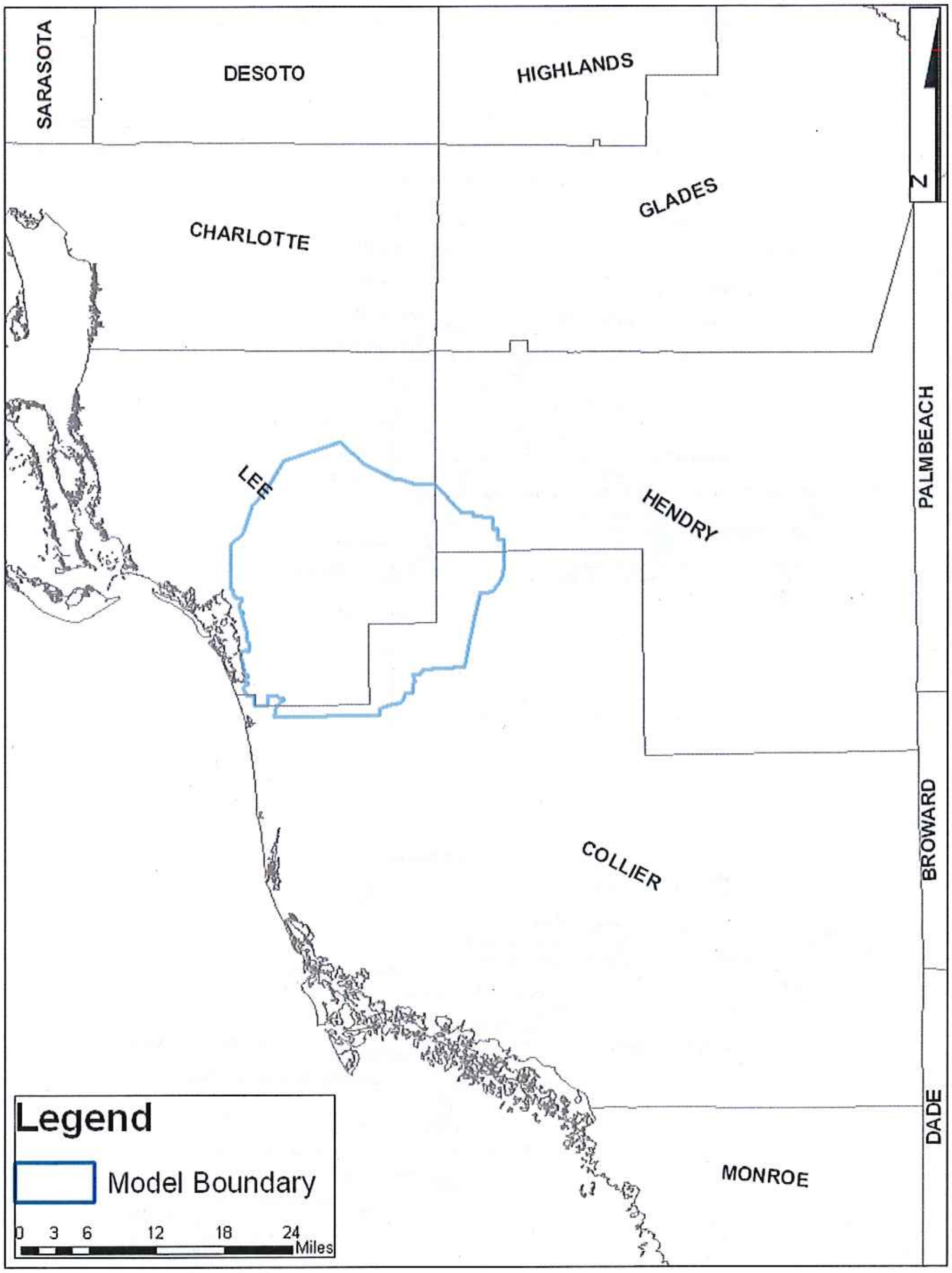

Figure 2-2: General Map of SLCWP Study Area and Model Domain

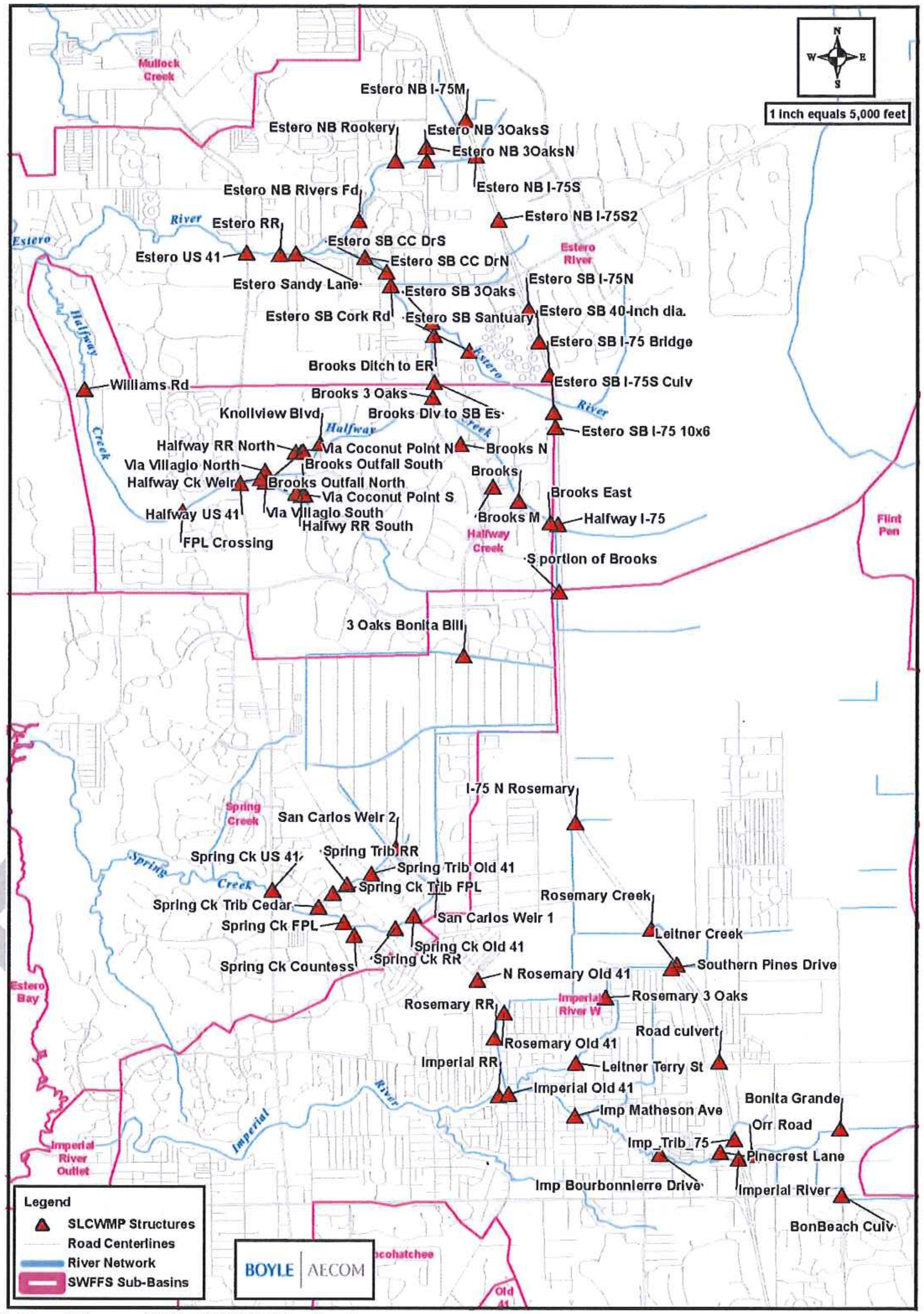

Figure 2-3: Map of SLCWP Study Area

3. South Branch of the Estero River, Branch ESTERORIVS
    a. Added a culvert with the capacity equivalent to the existing Monty Run bridge at I-75, ch. 252.6.
    b. A branch was added to represent runoff from the Stonybrook development.
    c. Moved Sanctuary Road culverts to the correct location (ch. 4200) and put in correct dimensions from Boyle survey. Added Boyle surveyed cross sections upstream and downstream.
    d. Put in Village of Country Creek bridges 1 and 2 from permit drawings and deleted culverts (ch. 9,680 and 11,250).
4. Three Oaks Branch - ThreeOaks
    a. Deleted existing cross sections and replaced them with Boyle surveyed cross sections plus more detailed information from Three Oaks permit.
    b. Modified weir at north end of branch.
5. Estero River – Branch EsteroRiv
    a. Put in Sandy Lane bridge (ch. 10,056 ft).
    b. Modified cross sections to accommodate bridge.
6. Halfway Creek Upstream of I-75 – Branch HalfwayUp
    a. Modified cross sections downstream of I-75 culvert and added culverts at the east end of the Brooks (ch. 6,300 and 7,700). Note that the culverts under I-75 have a reduced capacity to reflect sediment accumulations observed in the summer of 2008. This will be modified for the alternatives analysis.
    b. Cross sections in the Brooks taken (with modifications) from HEC-RAS files.
7. Halfway Creek from east of Three Oaks to Outfall Weir – Branch HalfwayCr
    a. Culverts at Three Oaks not added
    b. Added 3 sets of culverts within the Brooks (ch. 800, 2,600, and 8486.53).
    c. Weir at outfall of Brooks modified to be consistent with permit drawings (ch. 10,400 ft).
8. Spring Creek Headwaters Tributary – Branch SpringHW
    a. This branch was added to allow flows to pass under I-75 from areas near the southern end of the Brooks. This branch may be used to evaluate alternatives intended to direct additional flows to Spring Creek.
    b. This branch looks as if it should enter Spring Creek, but it is directed north to Halfway Creek upstream of the Brooks based on input from Johnson Engineering.
    c. Cross sections estimated using best engineering judgment. Added box culvert (4.36 ft wide x 2.25 ft high) which is equivalent to two 30" dia. culverts.

Culvert information from I-75 design drawings (ch. 5218.15 ft). Note that the I-75 design drawings show a 72" diameter culvert, however this culvert does not exist (confirmed by Richard Dun, ACCI/API Joint Venture, 11/12/08 e-mail).

9. Halfway Creek South Branch – Branch HalfwayS to South Weir
    a. This is a new branch added to MIKE 11 starting west of Three Oaks.
    b. Cross sections within Brooks are best engineering estimates.
    c. No culverts added.
    d. South Brooks weir added (ch. 7555).
    e. Railroad culverts added to model (ch. 7700), but Via Coconut Point culverts not added as conveyance in these culverts is larger than the railroad culverts.
10. Via Coconut Point Ditch
    a. This is a new branch that connects HalfwayCr with HalfwayS.
    b. Cross sections from Boyle survey
11. Halfway Creek and South Tributary from Brooks outfall to Williams Rd (HalfwayCrDS and HalfwayS)
    a. Location of main branch moved using aerial survey information.
    b. Cross sections west of Via Coconut Point are from Boyle survey.
    c. Added in a parallel branch to HalfwayCRDS to represent Rapallo Lake and added inflow and outflow weirs with elevation equal to boardwalk surveyed elevation
    d. Culverts at Via Villagio for Halfway CrDS (ch 12,000 on HalfwayCrDS) and South Branch (ch. 9,410 on HalfwayS) are from permit drawings.
    e. Halfway Creek Cypress weir east of U.S. 41 added from Boyle survey (ch. 12,400).
    f. U.S. 41 culverts moved to correct location (ch. 12,870 ft).
    g. Halfway Creek cross section west of U.S. 41 at wooden walkway is from Boyle survey (ch. 13,500 in SWMM XS folder). The effect of the walkway is also included as the walkway is modeled as a bridge.
    h. Another newly surveyed cross section by Boyle was added west of the walkway cross section.
    i. Halfway Creek cross section at FPL crossing was obtained from Hole Montes FPL pipeline crossing design drawings (ch. 15,338.7 ft)
    j. Williams Road bridge added using information from Boyle survey (ch. 23,447.8 ft).
12. Spring Creek – Branch SpringCr

a. Added culverts at railroad (ch. 3,253 ft), FPL crossing (ch. 3,900), and Cedar Creek Road (ch. 4,400 ft) (source: Exceptional Engineering, 2008).

b. Cross sections modified to accommodate culverts.

13. Spring Creek – Branch SpringCRSS

    a. Added new cross sections provided by City of Bonita Springs for the reach just west of Old U.S. 41

    b. Added Milagro Lane culverts

    c. Put in correct dimensions for Countess Lane culverts

14. Rosemary Creek Tributary (Branch RosemaryTrib)

    a. The I-75 culvert was added at ch. 1,700 ft).

15. Imperial River – Branch Imperial

    a. Culverts were added for Poor Man's Pass Road, a farm ford between Poor Man's Pass Road and Vincent Road, and Vincent Road culverts were added. Invert elevations for the farm ford and Vincent road culverts and road elevation were estimated using best engineering judgment.

    b. Culverts at I-75 (ch. 4,888 ft) were replaced by bridges using information from the I-75 design.

    c. Matheson Road bridge (ch. 14,291) was simulated as a culvert. The conveyance of the culvert is consistent with the bridge conveyance. This approach is sometimes used to overcome model instabilities and is valid as long as the culvert dimensions are the same as the part of the bridge that conveys water.

    d. Bonita Grande Drive and Orr Road were simulated as culverts in the DRGR model, however dimensions were incorrect. The correct dimensions were entered into the model files.

    e. The old Imperial Bonita Estates bridge or Bourbonnibiere bridge from the MIKE 11 DRGR model was updated to reflect new bridge dimensions.

    f. Bridges at Old 41 and the railroad were already in the MIKE 11 network.

Note: While MIKE 11 is a proprietary computer program, all input and output model files can be viewed without a user license. The software can be downloaded from www.dhisoftware.com, however it is easier to request a DVD from DHI (contact Janice Kutsmeda at jak@dhi.us).

2.5 MIKE SHE Changes

The MIKE SHE changes include modifications to flood codes (which define exchanges between branches and overland flow), land use information, and rainfall data. Changes were implemented to improve the calibration, reduce model instability, and in general to update information where available. For example flood codes were added to allow the channels to spill over on the flood plains where appropriate. Flood codes were removed where it was evident that a barrier (e.g. a berm prevented water from spilling over. In some instances flood codes were replaced by the spillage option (an alternative to flood codes) to reduce model instabilities. These changes are summarized below.

1. Estero River North Branch – Branches EsteroRivN, Esterol75, and EsteroTrib
    a. Removed flood codes on the east side of EsteroTrib.
    b. Added flood codes just west of Esterol75 to allow overland flow from wetlands east of I-75 to reach the branch.
    c. Added flood codes to EsteroRivN.
2. Halfway Creek – Branch HalfwayUp
    a. Modified flood codes so that lands east of I-75 have a different flood code than lands west of I-75.
3. Spring Creek Headwaters – Branch SpringHW
    a. Added flood code cells for lands east of I-75.
4. Halfway Creek South Tributary – Branch HalfwayS
    a. Added a flood code for lands east of the south weir.
5. Halfway Creek Main Stem – Branch HalfwayCrDS
    a. Flood codes were not used downstream of the Brooks outfall weir, but the spillage option is used for exchanges between the overland flow plane to the river network. This approach was used because the spacing of roads that restrict overland flow is closer than can be simulated using flood codes.
6. Spring Creek tributary Bonita Bill Canal – Branch SpringCkNE
    a. Added a flood code for a section of Bonita Bill Canal east of Old U.S. 41 that flows to and from a large wetland area north of Strike Lane in the vicinity of Amarillo Street.
7. Rosemary Creek – Branches Rosemary and RosemaryTrib
    a. Reduced the extent of flood code 77 (lands west of I-75) and added flood codes 110 (Rosemary) and 109 (RosemaryTrib).
8. Imperial River
    a. Reduced extent of flood code 30 so that only lands west of I-75 are covered, and added flood code 108 for lands east of I-75 and west of Boca Grande Drive.
    b. At Kehl Canal weir, the flood codes were modified to separate flood code 30 from 36, and additional flood code cells (code 36) north of Kehl Canal were added.

2.5.1 Land Use Changes

Land use files from the Lee County DRGR were checked against known 2008 land use information. The MIKE SHE land use files were found to be accurate in most areas, as evidenced by the land use details within the Brooks development. In the MIKE SHE land use file, the areas with lakes, hardwood forest, and wetlands are indicated by appropriate land use codes, and the developed areas with roads and houses are shown as medium density urban land use. It was noted that the land use file for some areas west of the Brooks and east of U.S. 41 were shown as undeveloped land, while the current land use is the Coconut Point Mall (see **Figure 2-4**). The land use file used in the Lee County DRGR MIKE SHE/MIKE 11 model was calibrated using stream flows and water levels from 2001 through 2006, therefore the land use file was determined to be representative for the period of interest for the DRGR study. However, for the South Lee County Watershed Plan Update, the calibration focuses on conditions from 2006 through 2008, therefore these undeveloped areas were converted to high density urban.

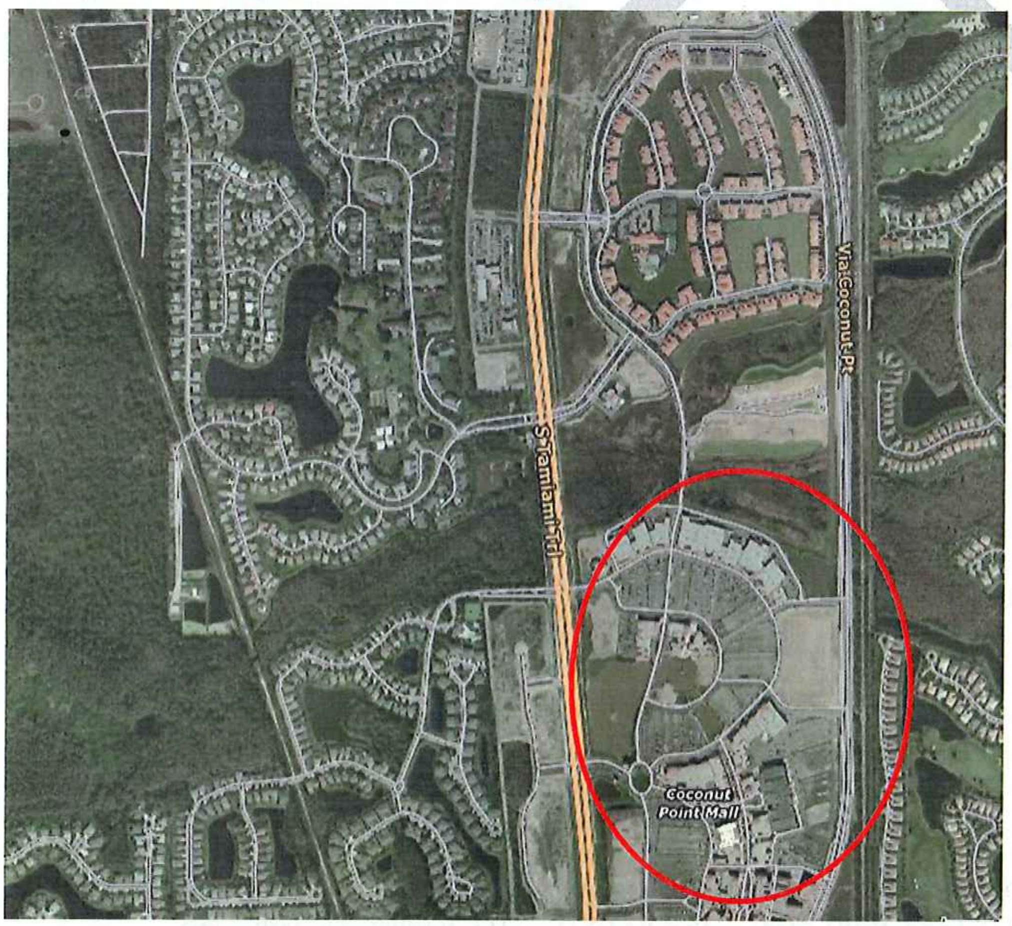

Figure 2-4: Current Land Use in Lower Halfway Creek Watershed Highlighting the Coconut Point Mall (source: www.mapquest.com)

2.5.2 Rainfall Data

The Lee County DRGR study uses daily rainfall data, and the focus of the South Lee County Watershed Plan Update is peak flow conditions, therefore OneRain grid rainfall files from Lee County were used. The information was provided in 15-minute intervals that was then grouped into an hourly time interval. The rainfall period used is 2006 through October, 2008.

2.6 Modeling Results

The model was run for 2002 through 2006 using daily rainfall data to evaluate the impact of the changes described above on the calibration. The next step was to document the calibration using hourly rainfall data from 2006 through October, 2008. This report describes initial calibration results, steps taken to improve the calibration, and the calibration results following adjustment of model parameters.

2.7 Initial Model Calibration

The model development and calibration process for this project involves the following steps:

1. Verification of the physical information.
2. Use of daily rainfall data to make sure the model runs smoothly.
3. Checking of calibration results to determine where improvements are necessary.
4. Adjustment of model parameters that influence the rainfall runoff process such as detention storage, drainage depth, and vegetation evapotranspiration parameters.
5. Review and check physical data if necessary.
6. Utilize hourly rainfall and refine the calibration.

When daily rainfall data is used and the groundwater time step is less than 24 hours, MIKE SHE divides the daily rainfall by the groundwater time step to calculate the rainfall amount. This under-estimates the rainfall amount for summer tropical thunderstorms. In general, hourly rainfall is needed for MIKE SHE/MIKE 11 models of urban watersheds.

The initial calibration using daily rainfall data was generally good for flow at the North Branch of the Estero River, and simulated stage follows the pattern of the measured stage. An updated cross section was obtained from the USGS which improved the stage calibration. Calibration is generally good for both stage and flow for the South Branch of the Estero River, however both simulated peak stages and flows were higher than measured values for most events. Improving the flow calibration for the North and South Branch of the Estero River was a focus during the calibration process.

Spring Creek initial simulated stages were generally good, however simulated flows were much less than measured flows. Increasing runoff was a focus during the calibration process. It was found that the initial conceptualization of the canal network was incorrect and that the north and south branches of Spring Creek needed to be connected within San Carlos Estates to correct this problem. Additionally, it was discovered during calibration that certain cross sections in Spring Creek downstream of the Old U.S. 41 USGS gaging station were necessary, and additional cross sections were obtained from the City of Bonita Springs who conducted a rapid-response surveying effort.

Initial simulated stages were good for the Imperial River at Orr Road, however simulated flows were less than measured flows. Increasing runoff in the Imperial River was a focus during the calibration process. The steps taken to address these calibration challenges are discussed below in the next section.

2.8 Final Calibration Results

This section describes the calibration process without providing results files for each of over 50 calibration runs conducted. Rather, a summary of the changes is provided with some comparison of performance for key parameter changes. This section also provides calibration plots, statistics, and water balance information. Note that the calibration effort addressed most of the challenges discussed above in Section 2.7.

2.8.1 Calibration Process

A broad range of calibration parameters were reviewed during the calibration process. In many cases, the original parameters were maintained, however certain parameters were modified. Parameters that were modified temporarily or permanently are described below.

Overland flow and channel Manning's n values were modified for MIKE 11 and for overland flow in portions of the model to increase flow from the Green Meadows Branch to the Kehl Canal and also to calibrate stages in the Estero River, Halfway Creek, Spring Creek, and the Imperial River. **Table 2-2** provides a summary of the changes made to overland flow Manning's n values and **Figure 2-5** through **Figure 2-8** provide maps of MIKE 11 Manning's n values used in this model. The MIKE 11 and overland flow Manning's n values were modified in certain locations during calibration to further attenuate peak flows determined to be too high when compared to measured data. One such location is the South Branch of the Estero River (**see Figure 2-5**) just upstream of I-75 that has a high river Manning's n value to account for a dense stand of Melaleuca just east of I-75. **Figure 2-7** shows areas of higher Manning's n values in Halfway Creek where resistance is high due to dense stands of cypress (downstream of U.S. 41) and willow (upstream of Via Villagio). **Figure 2-9** and **Figure 2-10** provide photographs of vegetation at these two locations that have high Manning's n values.

In the overland flow Manning's n file, the urban categories including areas around Estero River and Halfway Creek were modified by multiplying the original values by 4.0. These values were modified to account for the large number of ponds that have restrictive features such as culverts and weirs, and bleed down systems that were not included explicitly in the model. In addition, the detention storage value for urban areas was set at 2.5 inches to account for the storage of urban runoff. An inspection of the development plans for the Brooks indicated that there are over 100 lakes that provide detention for various sub-basins of Halfway Creek.

Table 2-2: Summary of Changes to Overland Flow Manning's n Values

Land Use Category	DRGR Mannings n	SLCWP Update 2009 Mannings n
Urban High Density	0.11	0.44
Urban Medium Density	0.12	0.48
Urban Low Density	0.14	0.56

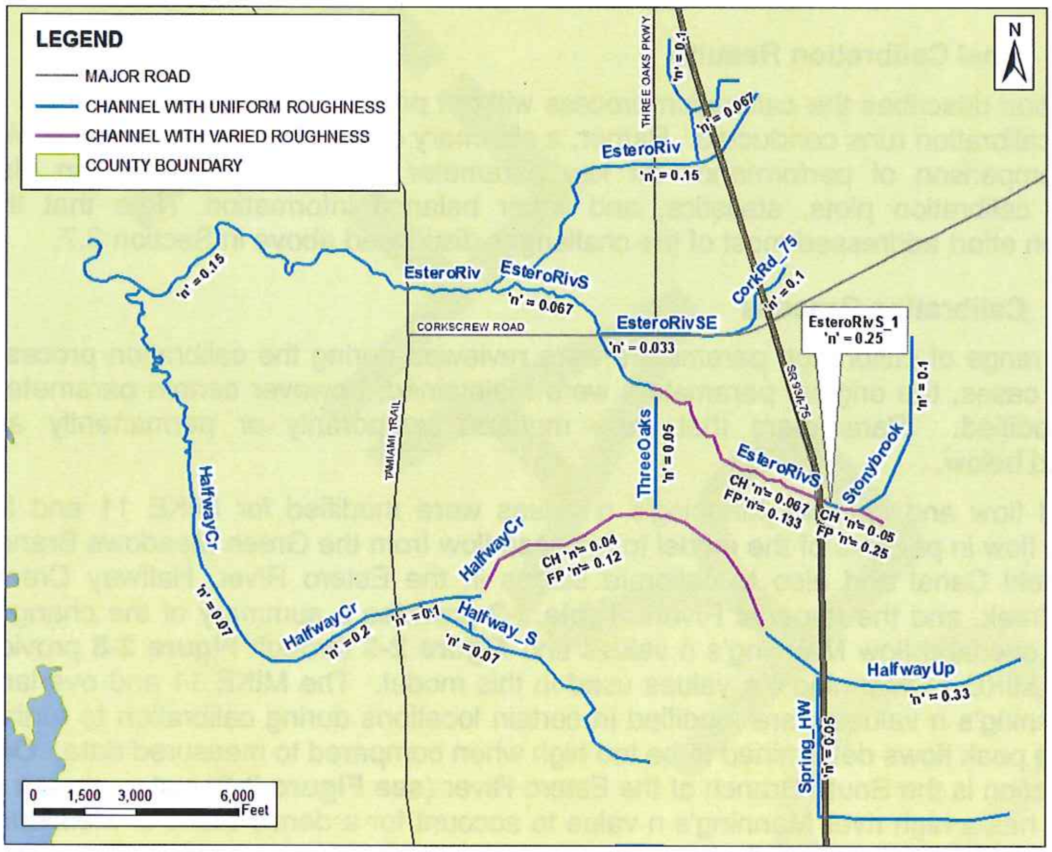

Figure 2-5: Estero River and Halfway Creek Manning's n Values

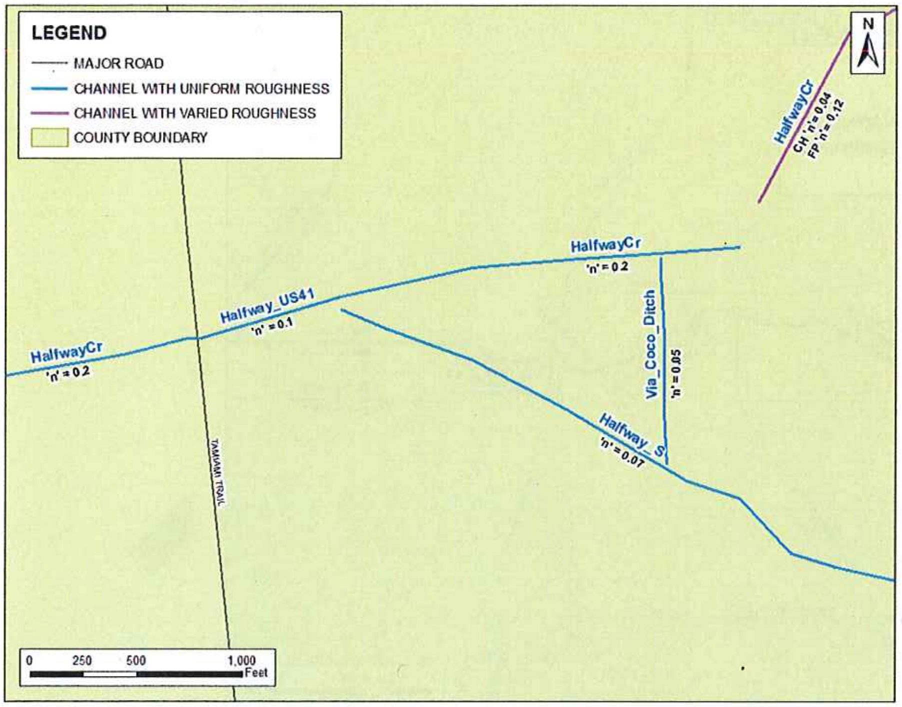

Figure 2-6: Detailed View of Selected Halfway Creek Manning's n Values (Upstream of U.S. 41 and west of the Brooks Weirs)

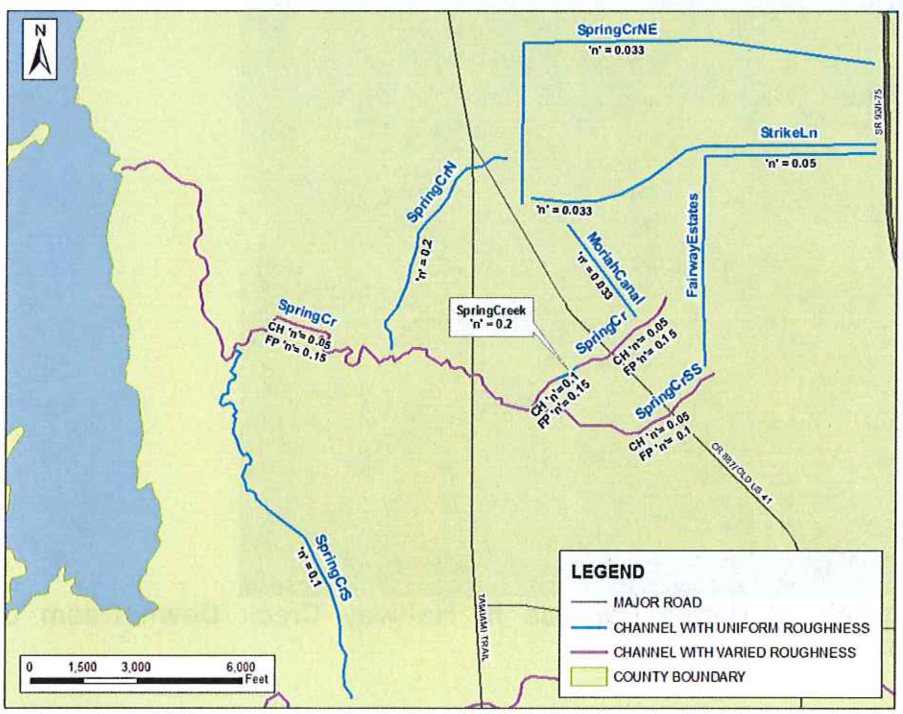

Figure 2-7: Spring Creek Manning's n Values

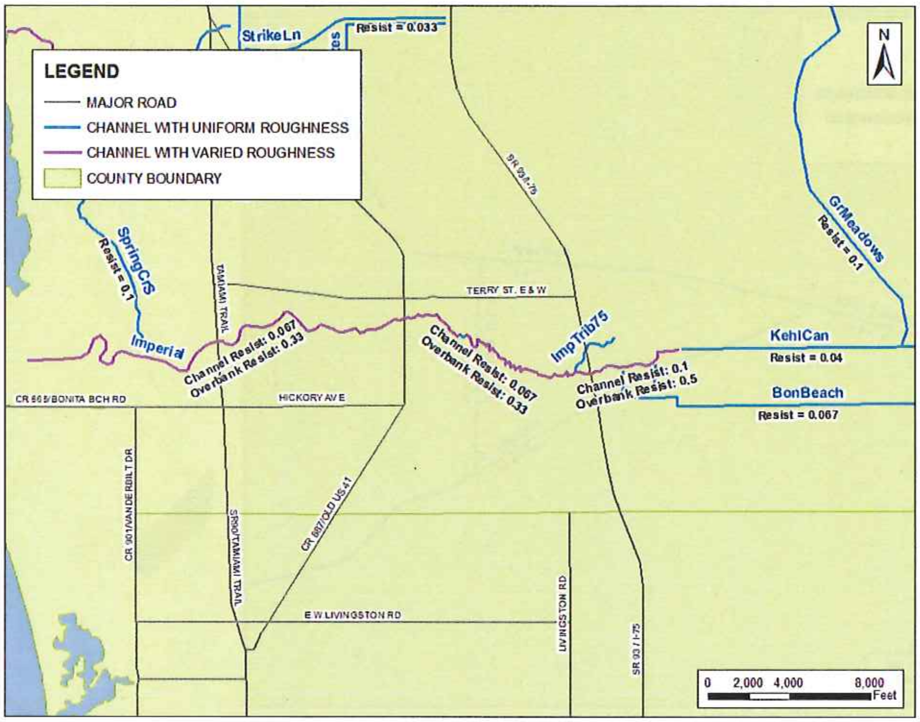

Figure 2-8: Imperial River Manning's n Values

Figure 2-9: Photograph of Dense Cypress in Halfway Creek Downstream of U.S. 41

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Figure 2-10: Photograph of Willow and Sedges in Halfway Creek Upstream of Via Villagio

A range of parameters were modified to decrease flows in the South Branch of the Estero River including overland flow and channel Manning's n values, and I-75 bridge and culvert entrance loss coefficients, vegetation evaporation coefficients were increased, and hydraulic conductivity values were changed for the surficial and Sandstone aquifers. Detention storage coefficient, drainage level and time constants, and paved area coefficient were modified up and down to test the sensitivity of the calibration to those parameters.

Changes were made to the Paved Runoff coefficient for urban categories. Initial model runs indicate that the runoff rates for urban areas were too high. Consequently, the paved runoff coefficient was reduced from 70 to 35 percent. This reduction was justified because a large percentage of paved area runoff is routed to detention ponds that are not a part of the Mike 11 network. The assumption here is that 35 percent will runoff directly and only a portion of the remaining 65 percent will contribute to runoff depending on infiltration rates, etc.

On examining the evapotranspiration parameters in the DHI model, it was noted that the crop coefficients (kc) were all set at unity. The crop coefficient sets the maximum rate of evapotranspiration (potential evapotranspiration) for each crop or land use as a function of the Reference evapotranspiration (RET). Typically, open water bodies or wetlands may be equal to or approach RET which is the evapotranspiration rate for a wet prairie/marsh system, so that a value of unity may be appropriate. However, some other categories (e.g., pasture) normally have a lower value to account for the fact that evapotranspiration would be less than that of an open water body. Under the same climatological conditions, potential evapotranspiration from wetlands is larger than potential evapotranspiration from vegetated unsaturated soil areas primarily because of water availability with direct exposure to the atmosphere. The vegetated unsaturated soil areas are typically defined by adjusting the RET to a lower value by the application of a multiplier coefficient. The values of unity for all categories was then not considered to be appropriate and was modified to initially use lower values as used in the Camp Keias (HGL, DHI, 2006) and Kissimmee (Earth Tech, DHI, 2007) models. Final calibrated values used in this model are shown below in **Table 2-3**.

Table 2-3: Crop Coefficients Used in the SLCWP MIKE SHE Model

Land Use	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Citrus	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.754
Pasture	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Sugar Cane	0.73	0.73	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.76	0.91
Truck Crops	0.62	0.62	0.63	1.00	1.00	1.00	1.00	0.68	0.68	0.76	0.71	0.84
Golf Course	0.67	0.67	0.61	0.65	0.66	0.68	0.68	0.76	0.85	0.85	0.83	0.73
Bare Ground	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Mesic Flatwood	0.64	0.64	0.64	0.64	0.81	0.90	0.90	0.81	0.72	0.63	0.63	0.63
Mesic Hammock	0.64	0.64	0.64	0.64	0.81	0.90	0.90	0.81	0.72	0.63	0.63	0.63
Hydric Flatwood	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Hydric Hammock	0.50	0.50	0.50	0.61	0.78	0.87	0.87	0.78	0.70	0.61	0.52	0.50
Wet Prairie	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Marsh	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Cypress	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Swamp Forest	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Mangrove	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Water	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Urban Low Density	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Urban Median Density	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Urban High Density	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

The values for an urban category were relatively large compared to a value of 0.70 in the Camp Keias model. These relatively high values were determined during calibration and justified because of the numerous ponds as shown on **Figure 2-11** which are open water bodies with high rates of evapotranspiration.

Saturated flow components were modified during calibration. Specifically, the Holocene-Pliocene layer horizontal and vertical hydraulic conductivities were increased by a factor of 10, and the specific yield changed from 0.15 to 0.05 to conform to information provided by SFWMD. For the Lower Tamiami layer, the horizontal and vertical hydraulic conductivities were increased by a factor of 5, and the specific yield changed from 0.20 to 0.10. For the Sandstone layer, the horizontal and vertical hydraulic conductivities were decreased by a factor of 10.

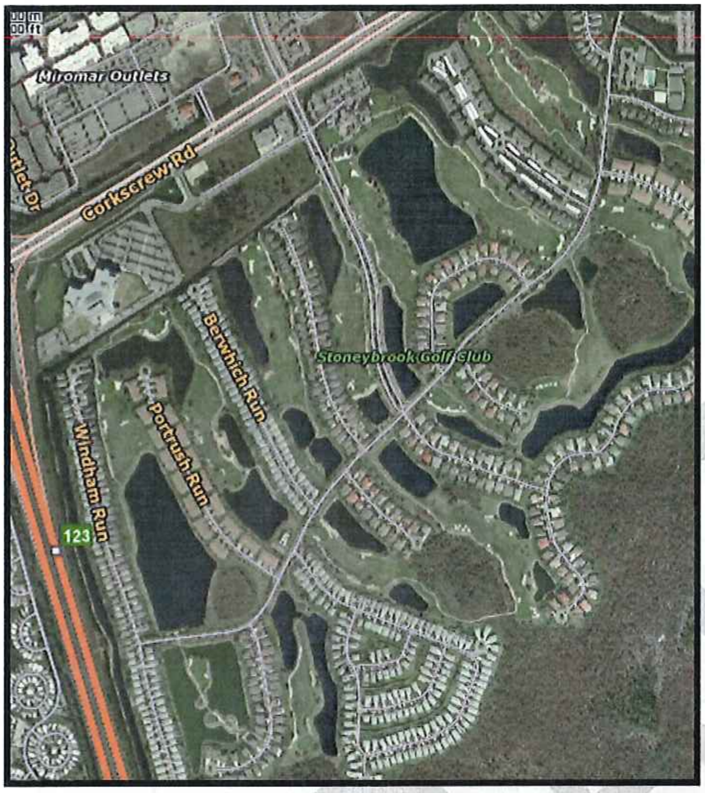

Figure 2-11: Urban Detention Ponds

Irrigation files were modified for lands west of I-75 to increase irrigation rates. DRGR irrigation rates were less than 5 inches/year for most urban lands west of I-75, and measured irrigation flow data obtained from Resource Conservation Systems, LLC were reviewed to determine if irrigation rates should be adjusted. Measured average irrigation from Brooks lakes and the surficial aquifer was 13 inches/year for 2006-2008. As a result, irrigation rates were increased for the Brooks and a number of other areas west of I-75. **Table 2-4** provides a summary of irrigation values used in the model for the Brooks area, and **Figure 2-12 and Figure 2-13** show the DRGR and revised irrigation command areas, respectively.

Table 2-4: Old and New Flow Rates for Model Irrigation Command Areas

Irrigation Command Area	Old Flow Rate, cfs	New Flow Rate, cfs
214 (golf course reuse water)	0.57	9.0
579	0.57	0.57
626	0.57	5.0
1180	N/A	4.0
1181	N/A	3.0

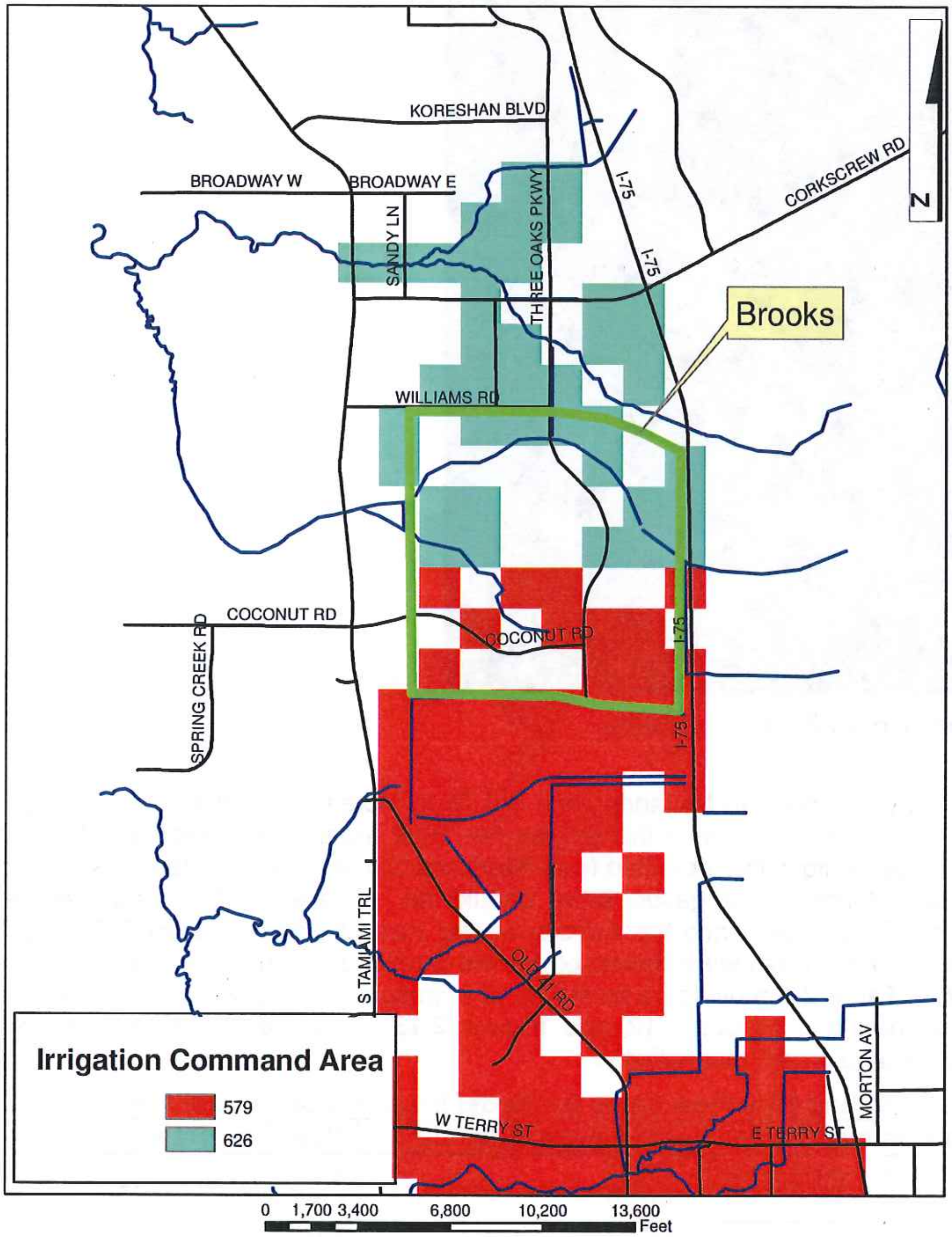

Figure 2-12: Irrigation Command Areas used in the DRGR Model that were modified as part of this study (see next Figure)

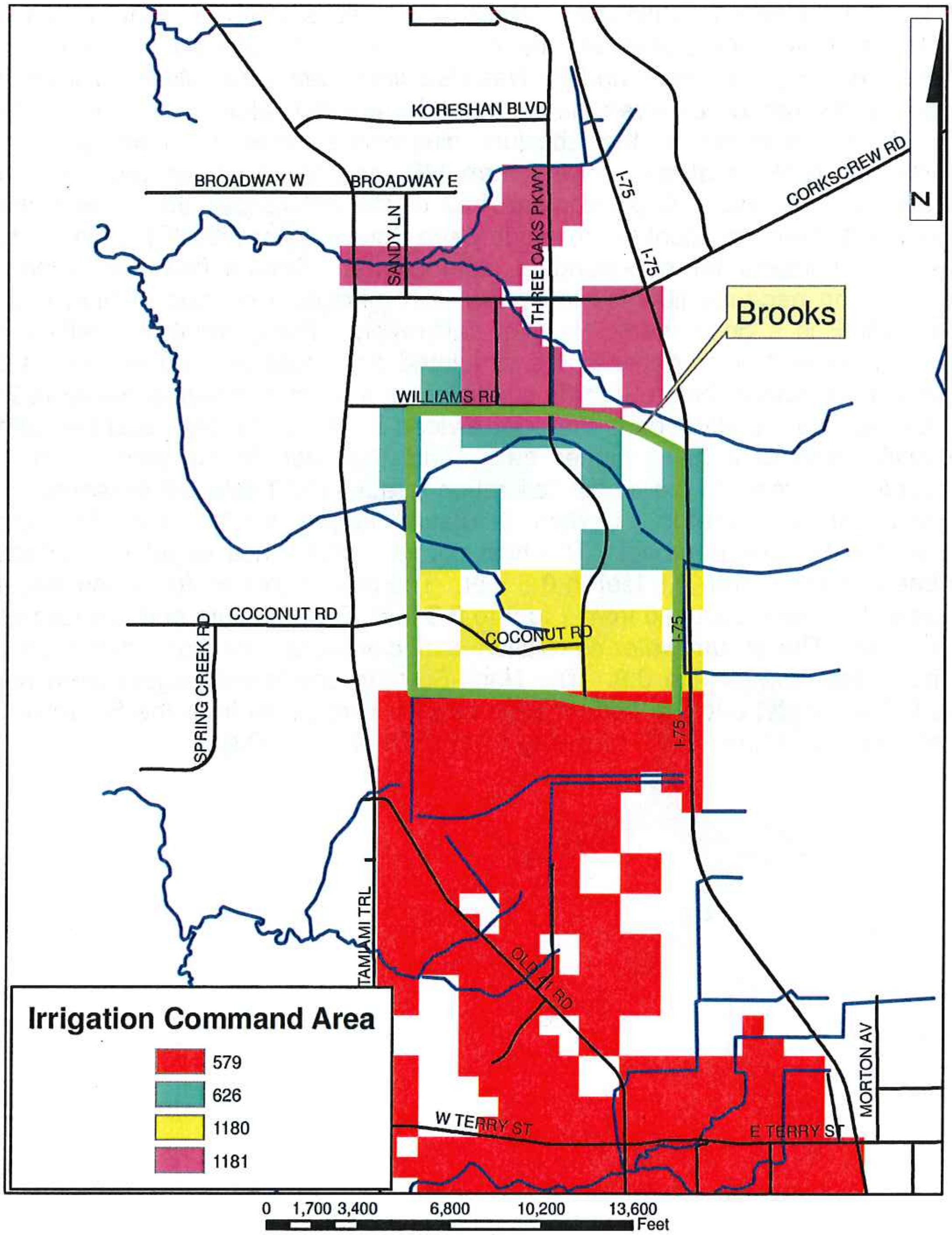

Figure 2-13: Revised Irrigation Command Areas for the Estero River, Halfway Creek, Spring Creek, and Imperial River Watersheds

2.8.2 Calibration Statistics

MIKE SHE/MIKE 11 generates calibration statistics for stations where measured data is available. The statistics 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 good metric for river calibration. The correlation coefficient measures the closeness of fit between the simulated and measured values, and 1.0 indicates perfect correlation. Nash Sutcliffe coefficient is a difficult statistical measure to describe, however it generally means the error divided by the variability. Stations with higher variability generally have higher error, and this statistic corrects for high variability. **Table 2-5** presents the model calibration targets and **Table 2-6** presents the equations used for each metric. Certain calibration targets for ME and MAE are narrower than for the DRGR model. The high model performance target for surface water has been reduced from 0.8 feet to 0.5 feet. The high model performance target for groundwater has been reduced from 1 foot to 0.5 feet. The medium and low targets were also revised. The groundwater correlation coefficient target for high performance has been increased from 0.7 to 0.8. The Nash-Sutcliffe coefficient targets were not used in the DRGR study, and the performance targets were taken from the Southwest Florida Feasibility Study MIKE SHE modeling study (SDI et. al., 2008).

Table 2-5: Performance Metrics

	Level of Model Performance		
Statistical parameter	High	Medium	Low
Surface Water Flow Targets			
R	0.8 <= R < 1.0	0.6 <= R < 0.8	R < 0.6
Surface Water Stage			
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 <= 1.0	1.0< RMSE<= 2.0	RMSE > 2.0
R	0.8 <= R < 1.0	0.6 <= R < 0.8	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	0.8 <= R < 1.0	0.5 <= R < 0.8	R < 0.5
Nash Sutcliffe, R2	0.7 <=R2<=1.0	-1.0<=R2<=0.7	NS<= -1.0

Table 2-6: 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	$\sqrt{\frac{\sum_{i=1}^{n}(Obs_i - Calc_i)^2}{\sum_{i=1}^{n}(Obs_i - \langle Obs_i \rangle)^2}}$
R2	Nash Sutcliffe	$R2 = \frac{\sum_t (Obs_{i,t} - Calc_{i,t})}{\sum_t (Obs_{i,t} - \overline{Obs_i})}$

2.8.3 Calibration Results

Calibration statistics are presented in **Table 2-7** and **Table 2-8**. Cells highlighted in green meet the calibration criteria, yellow cells are just outside the calibration criteria, and orange cells indicate poor calibration.

Table 2-7: Surface Water Calibration Statistics

Surface Water Stage Statistics					
Name	ME (ft)	MAE (ft)	RMSE (ft)	R_Correlat	R2_Nash_Su
Estero R NB 3943.57 (EsteroRiv, 1202.000	-0.53	0.62	0.73	0.83	0.31
Estero R SB 8628 (EsteroRivS, 2630.000)	-0.06	0.41	0.59	0.88	0.39
Copperleaf (Halfwayup, 2133.600)	-0.17	0.33	0.40	0.92	0.75
Halfway Creek S HW (Halfway_S, 2270.76	-0.76	0.83	0.99	0.75	-0.20
Halfway Creek S TW (Halfway_S, 2316.48	-0.23	0.45	0.58	0.81	-0.06
HalfwayCrDS HW (HalfwayCrDS, 3127.000	-0.18	0.32	0.39	0.93	0.82
HalfwayCrDS TW (HalfwayCrDS, 3200.400	0.10	0.36	0.50	0.81	0.29
Imperial_Orr (Imperial, 1230.000)	-0.99	1.16	1.55	0.89	0.63
KehlCan_9358 (KehlCan, 9358.000)	0.57	1.19	1.50	0.89	0.76
KehlCan_9479 (KehlCan, 9479.000)	-0.61	1.09	1.49	0.88	0.72
Spring Ck 1574.8 (SpringCRSS, 480.0000)	-0.14	0.36	0.48	0.77	0.38

Surface Water Flow Statistics		
Name	R_Correlat	R2_Nash_Su
Estero R NB Q 4443 (EsteroRiv, 1354.500)	0.84	0.70
Estero R SB 8697 (EsteroRivS, 2651.000)	0.85	0.61
Spring Ck 1637 (SpringCRSS, 499.0000)	0.80	0.56
Imperial_Orr (Imperial, 1245.000)	0.90	0.78

Table 2-8: Groundwater Calibration Statistics

Name	Layer	ME (ft)	MAE (ft)	RMSE (ft)	R_Correlat	R2_Nash_Su
Corkscrew Swamp	1	-1.54	1.54	1.61	0.89	-1.90
FP10_G	1	-0.23	0.52	0.65	0.91	0.80
FP2_GW1	1	-1.37	1.46	1.63	0.82	-0.12
FP3_GW1	1	-0.31	0.51	0.61	0.92	0.77
FP5_GW1	1	-0.46	0.62	0.73	0.92	0.74
FP6_GW1	1	-0.43	0.68	0.78	0.91	0.72
FP7_GW1	1	-0.33	0.66	0.81	0.91	0.70
FP8_GW1	1	-0.45	0.67	0.78	0.92	0.75
FP9_G	1	-0.34	0.70	0.86	0.87	0.52
Imperial 49-GW10	1	-1.78	2.03	2.27	0.85	0.01
Imperial 49-GW11	1	-1.60	2.17	2.51	0.91	0.18
Imperial 49-GW12	1	-0.57	1.30	1.47	0.84	0.44
Imperial 49-GW14	1	0.11	0.51	0.63	0.96	0.86
Imperial 49-GW15	1	1.26	1.26	1.33	0.74	-4.01
Imperial 49-GW6	1	0.19	0.75	0.95	0.86	0.63
Imperial 49-GW7	1	0.01	0.64	0.69	0.87	0.75
Imperial 49-GW9	1	0.71	0.76	0.94	0.95	0.75
L-1138	1	-0.08	0.37	0.52	0.78	0.53
L-5667	1	0.69	0.78	1.09	0.89	0.47
L-5669R	1	-0.36	0.38	0.45	0.96	0.75
Leitner 49L-GW1	1	-0.99	1.32	1.50	0.76	0.00
USGS L-2195	1	-2.68	2.83	3.08	0.87	-0.76
USGS L-5730	1	1.70	1.70	1.79	0.91	-1.30
Average Values:		-0.38	1.05	1.20	0.88	0.10

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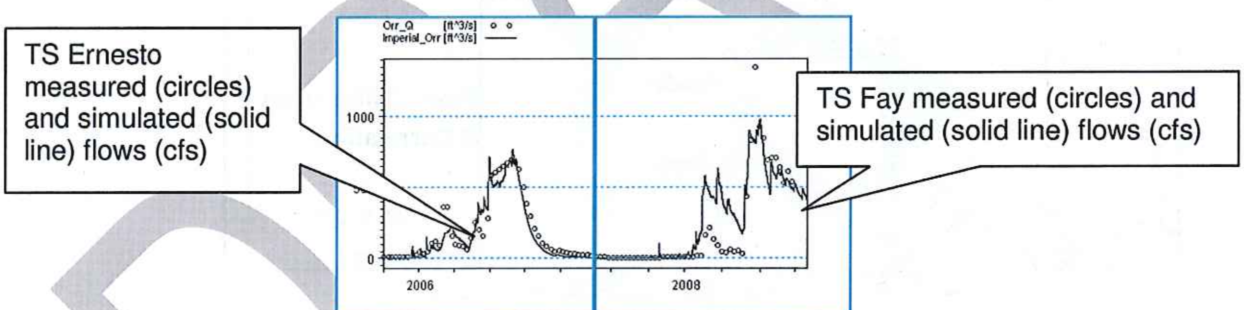
The information presented in **Table 2-1** was compared with **Table 2-8** above. In general, if the elevation in the topography file in the model is higher than that surveyed and used in computing measured water level data used in the calibration, then the model may simulate a higher groundwater elevation than measured. Wells presented in **Table 2-1** and **Table 2-8** were compared. The wells FP2-GW1, FP3-GW1, FP5-GW1, FP6-GW1,FP7-GW1, FP8-GW1, FP9-GW1, and FP10-G all had negative differences in **Table 2-1** meaning that the information in the model was higher than that surveyed. This is consistent with **Table 2-8** which shows negative MEs for these wells indicating the model is simulating higher values than that measured.

Figure 2-14 provides a map of calibration performance for river stations, and **Figure 2-15** provides a map of calibration performance for surficial aquifer stations. Green points represent stations that meet the calibration criteria, yellow points represent stations that are just outside of the calibration criteria, and red points indicate poor calibration. Plots of measured and simulated values are presented in **Figure 2-16** through **Figure 2-24.**

The calibration results for the surface water stations show generally excellent agreement during the wet seasons between 2006 and 2008 for the Estero River and Halfway Creek. The 2006 wet season calibration is also excellent for the Imperial River and good for 2008, however the 2008 simulated Imperial River peak stages and flows were less than measured values as shown below.



Investigations reveal that 2008 grid rainfall values were less than measured rainfall totals at the Flint Pen Strand rain gage FPWX, thus the Imperial River calibration was deemed to be good. The flow calibration for Spring Creek was good for 2008 and acceptable for 2006, however the stage calibration was less than desired. Simulated peak stages for both 2006 and 2008 were less than measured values.

Surface Water Calibration

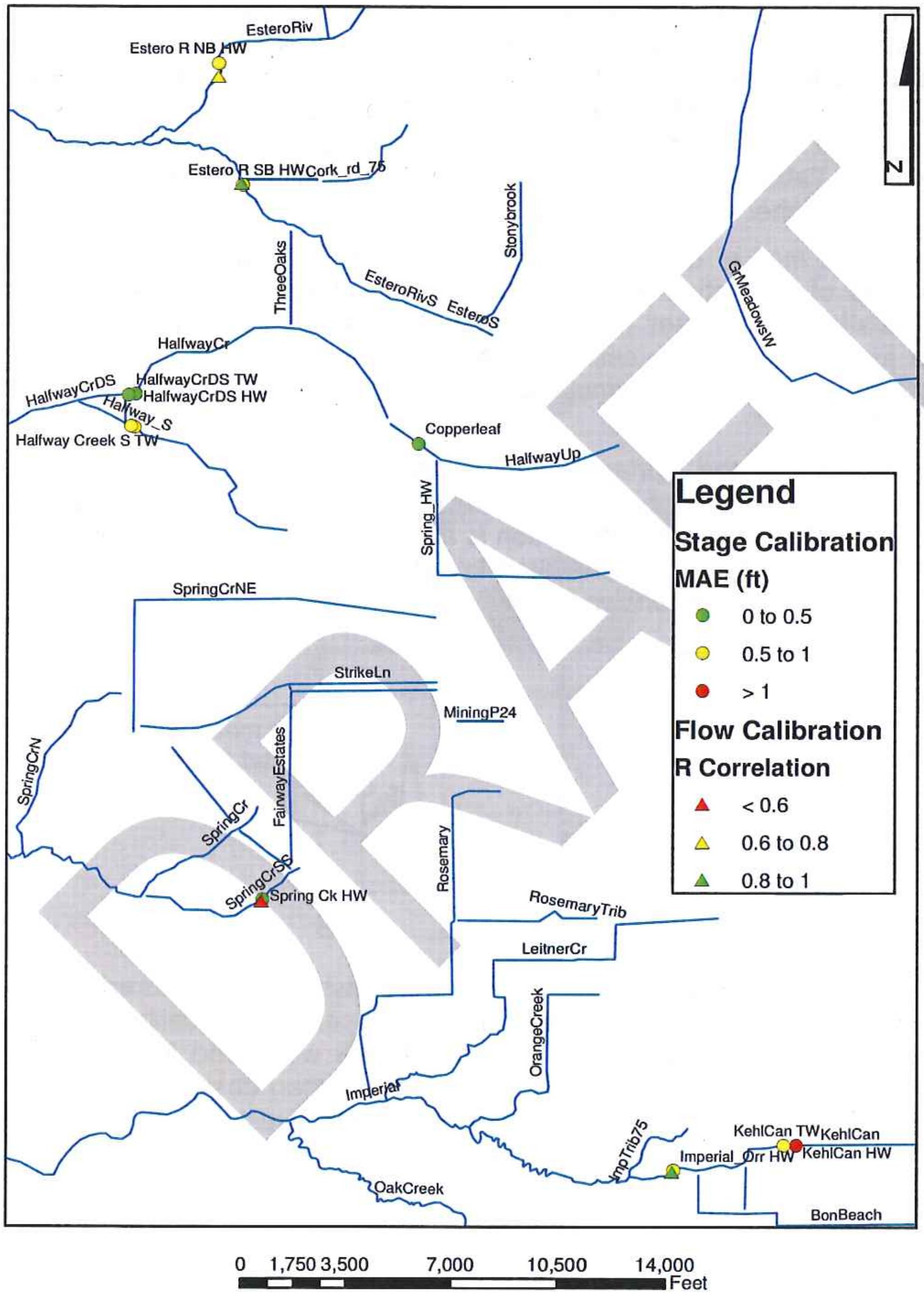


Figure 2-14: Map of Surface Water Calibration Performance

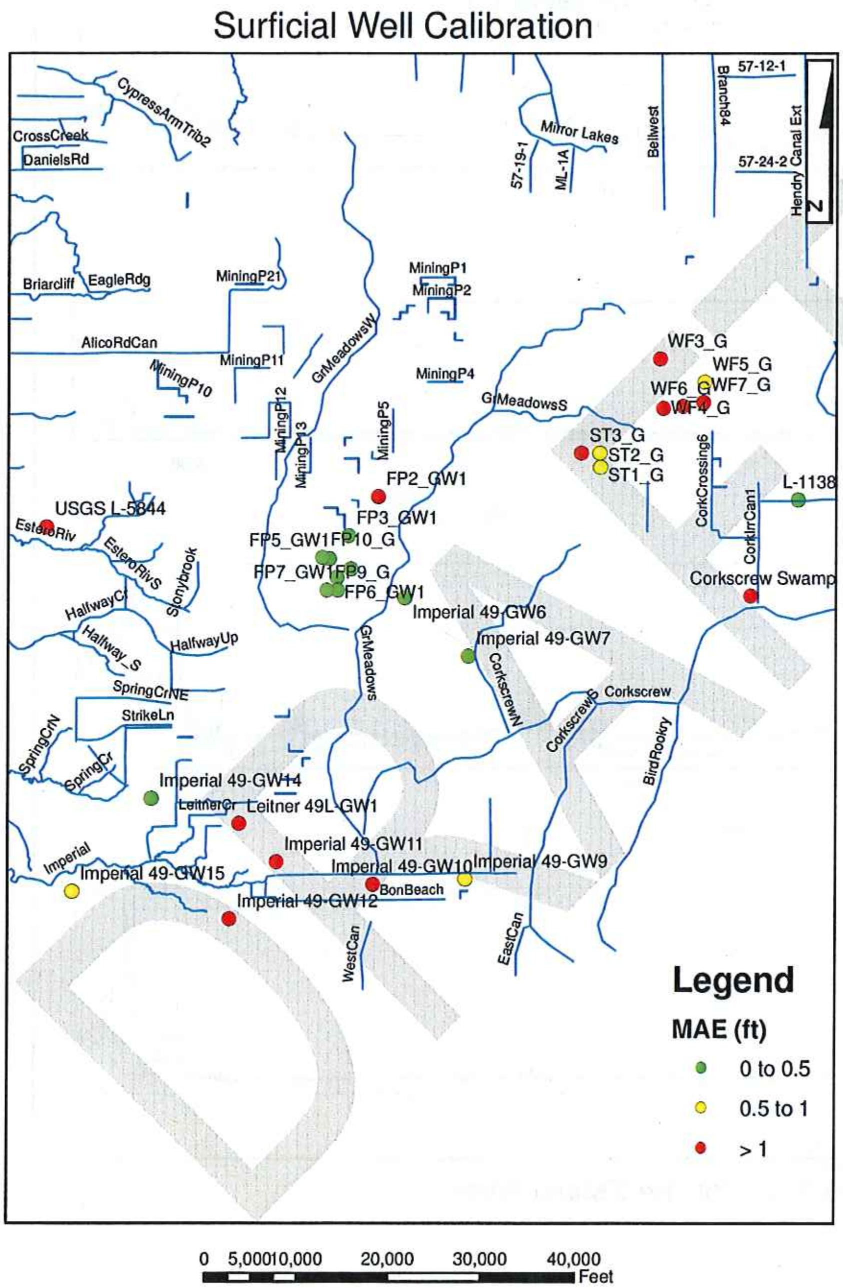


Figure 2-15: Map of Surficial Aquifer Calibration Performance

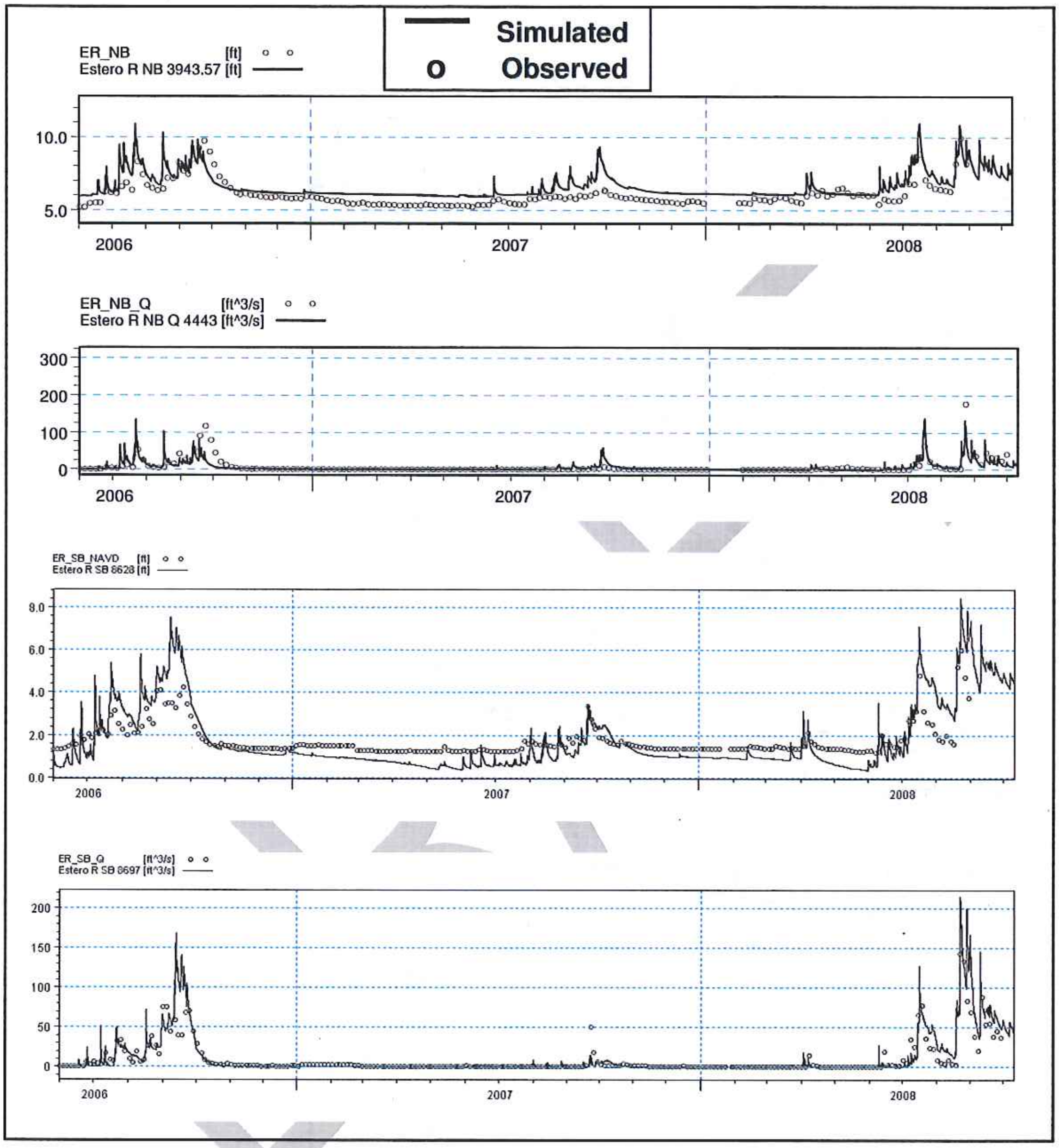


Figure 2-16: Calibration Plots for the Estero River

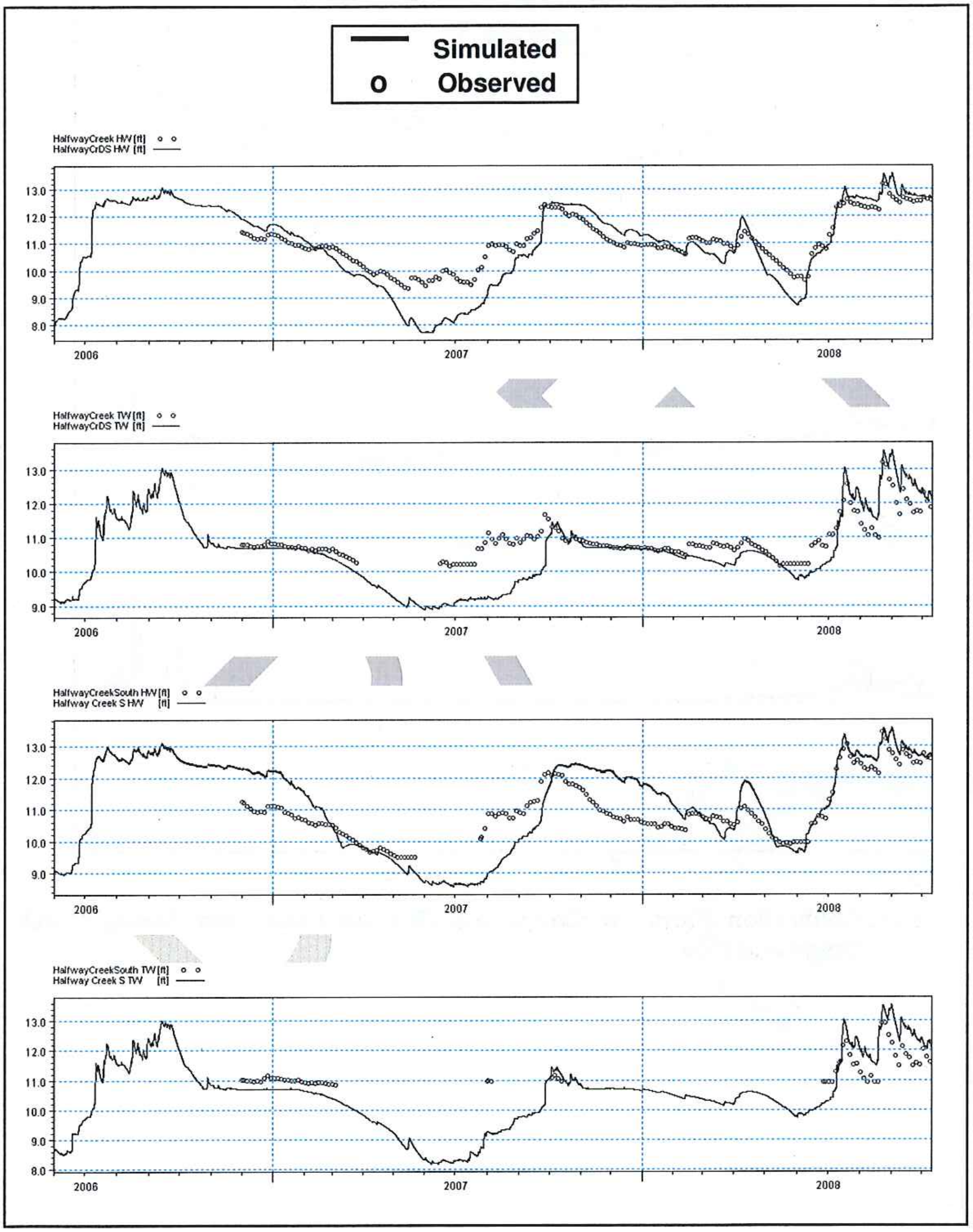


Figure 2-17: Calibration Plots for Halfway Creek

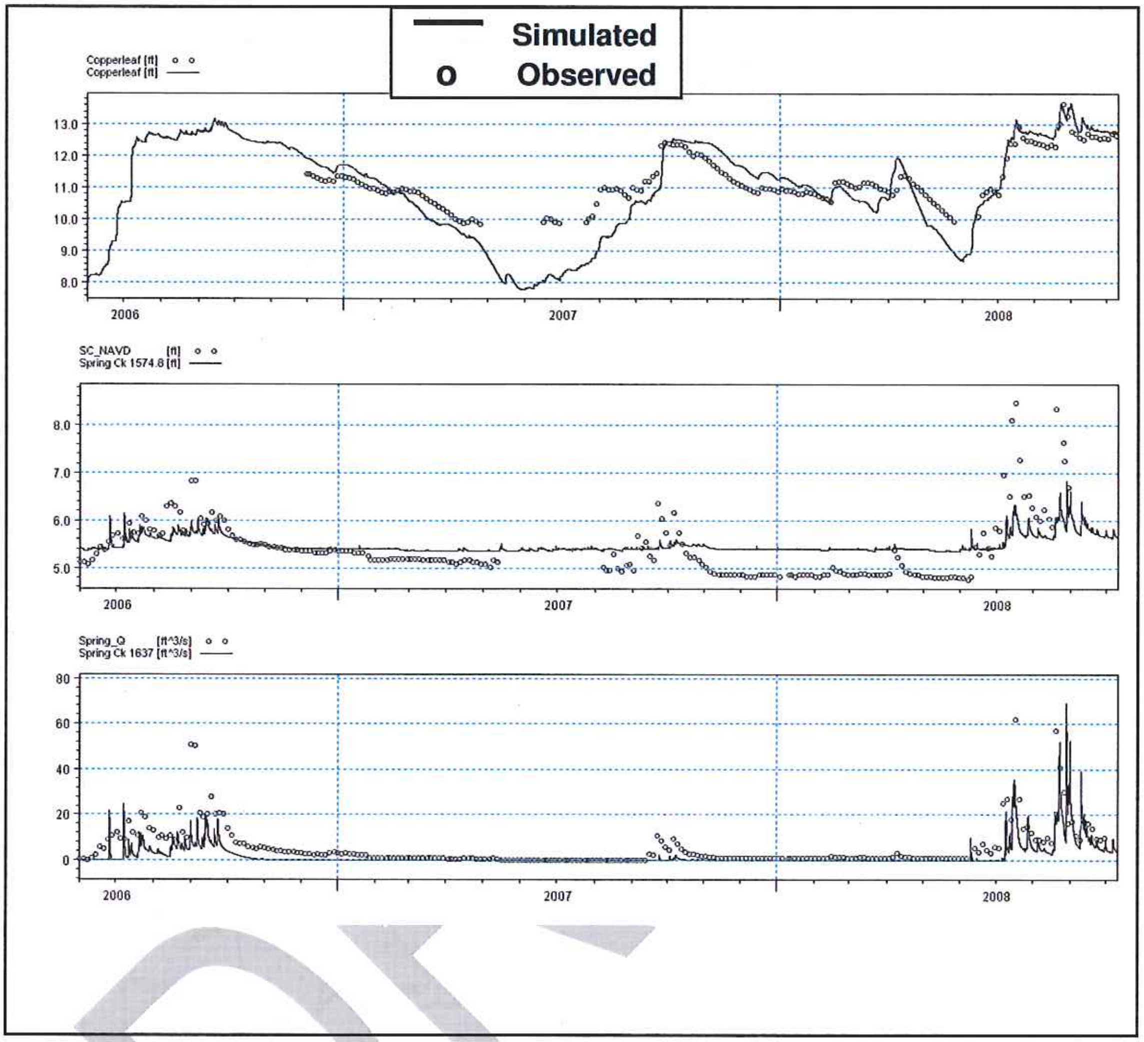


Figure 2-18: Calibration Plots for Copperleaf (Brooks Lake) and Spring Creek Stage and Flow

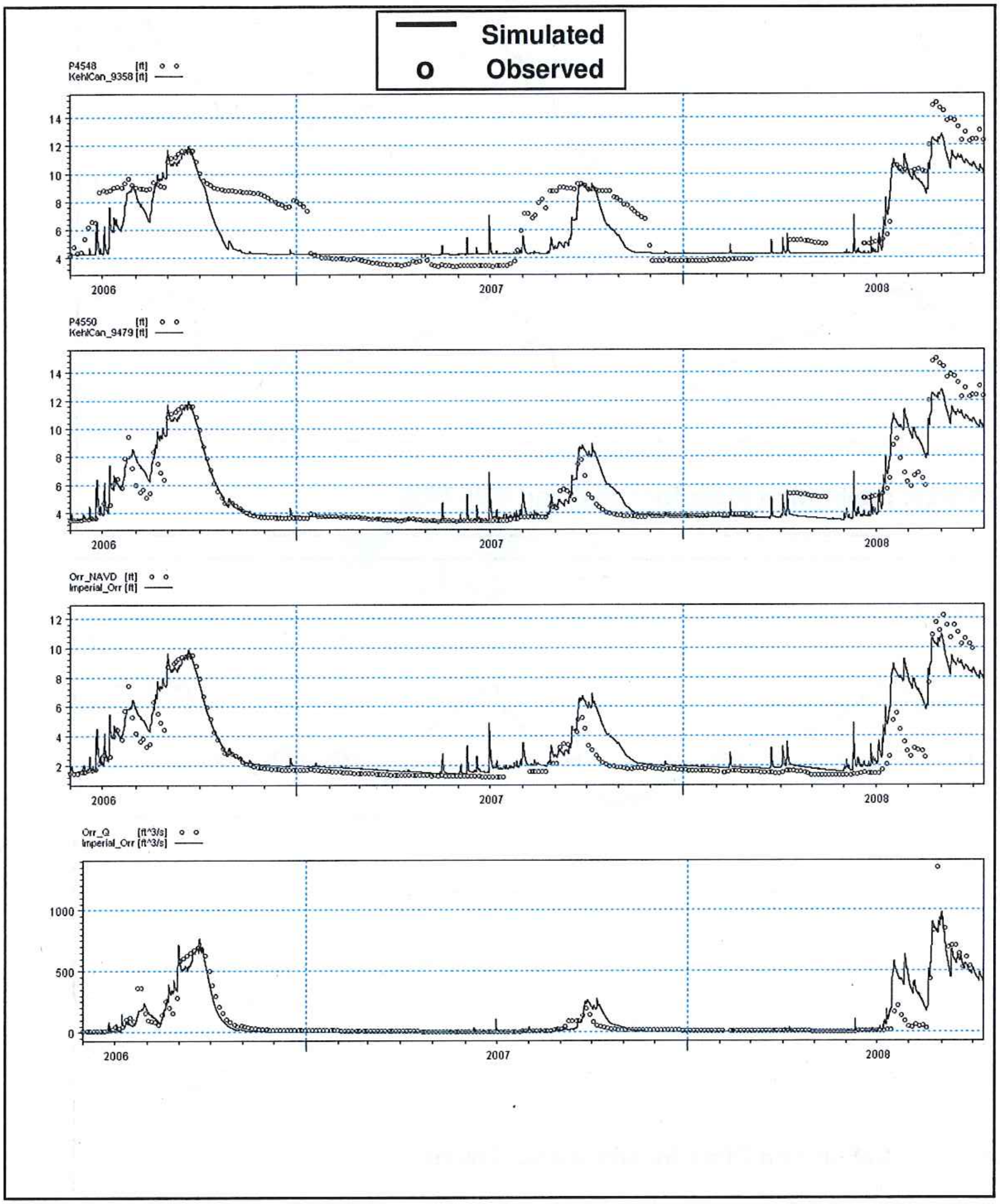


Figure 2-19: Calibration Plots for the Imperial River

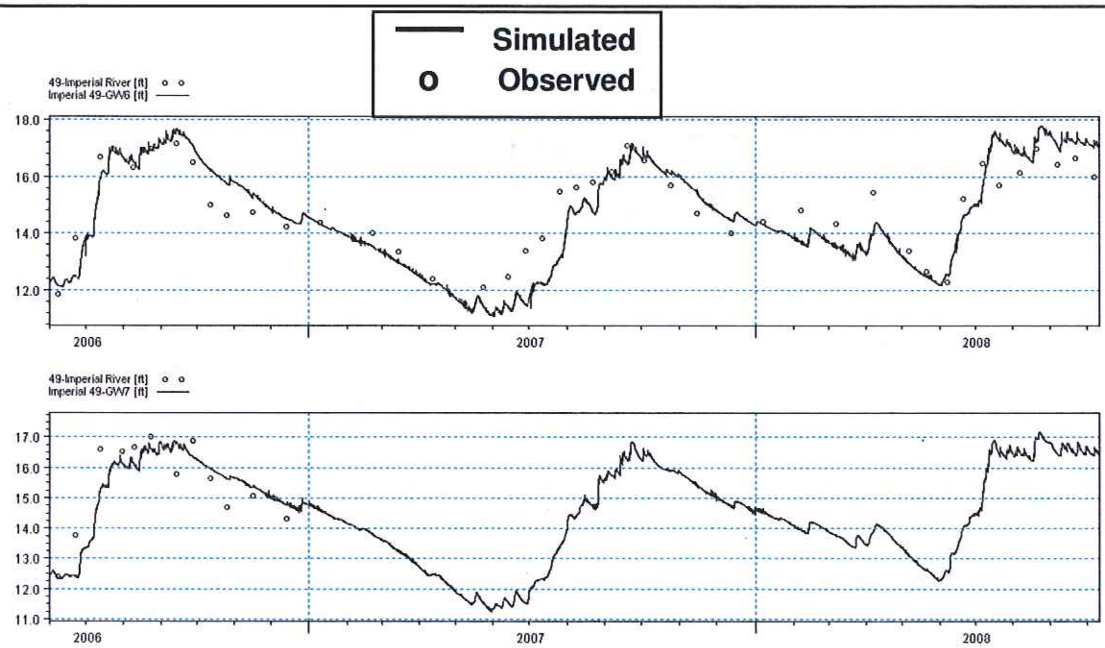


Figure 2-20: Calibration Plots for GW-6 and GW-7

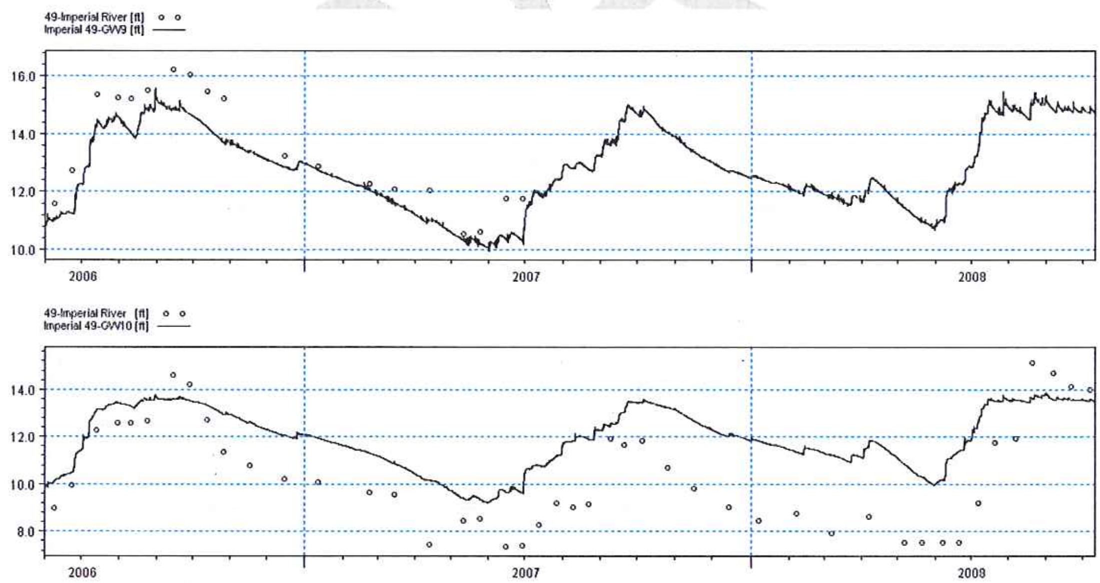


Figure 2-21: Calibration Plots for GW-9 and GW-10

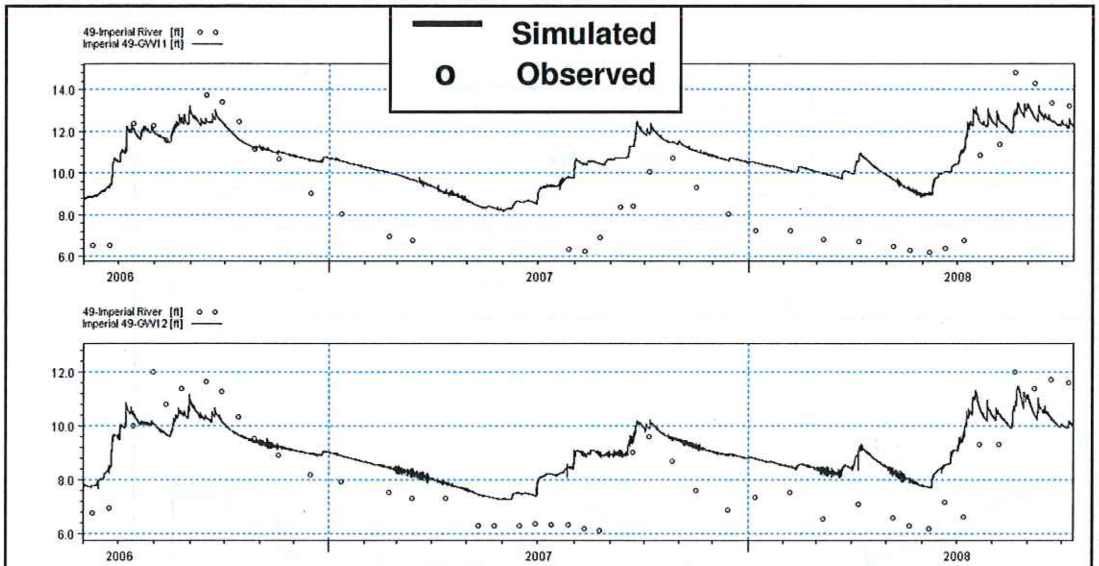


Figure 2-22: Calibration Plots for GW-11 and GW-12

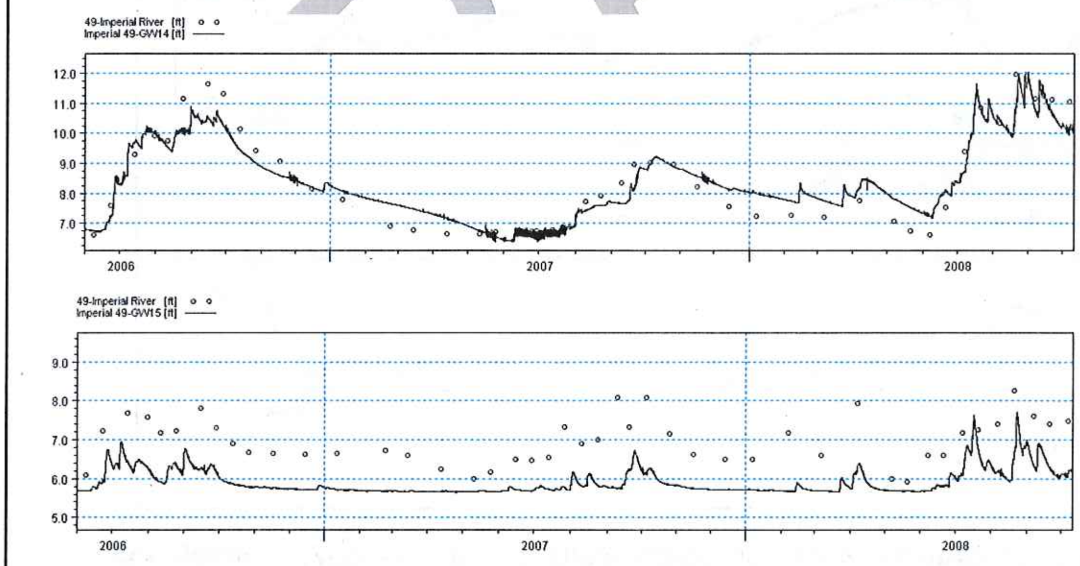


Figure 2-23: Calibration Plots for GW-14 and GW-15

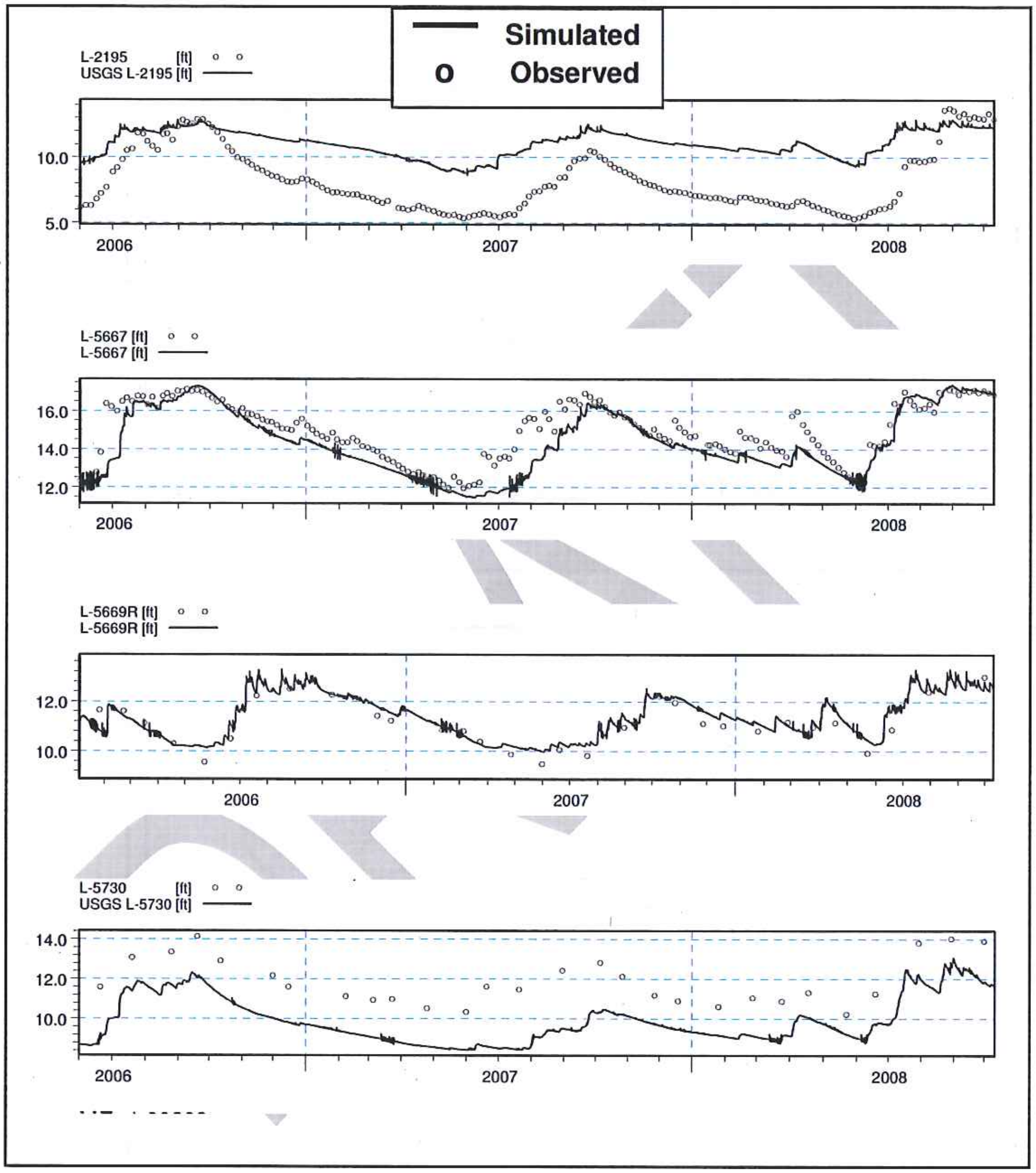


Figure 2-24: Calibration Plots for USGS Wells L-2195, L-5667, L-5669R and L-5730

2.9 Mass Balance Information for the Calibrated MIKE SHE/MIKE 11 Model of the Estero River, Halfway Creek, and Imperial River

A mass balance plot for the entire model domain is presented in **Table 2-9** for June 1, 2006 through October 11, 2008. The annual average precipitation during that period was 48 inches, and the evapotranspiration was 31 inches/year, or 64% of rainfall. The Total Error term in Table 2-9 is used as a check to determine if the inflows and outflows to the model are balanced. Error is quite low, less than 0.5% for all years.

Table 2-9: Water Balance for Entire Model Domain (values in inches)

Period of Record (Number of Months used in Water Balance)	Rain *(Rai)*	Actual ET *(AET)*	Canopy-OL Storage Change *ΔOL*	Runoff +Drainage to River *(Ro)*	OL Boundary Flows *(OL_{BC})*	Baseflow *(BF)*	Irrigation *(Irr)*	Pumpage *(GW_P)*	SZ Boundary Flow *(SZ_{BC})*	SubSurface Storage Change *(ΔSUB)*	Total Error *(Err)*
6/1/06 to 12/31/06	45.17	22.06	0.39	14.11	0.000	2.32	1.02	1.60	0.24	5.99	-0.040
1/1/07 to 12/31/07	40.91	35.37	-0.17	5.09	0.000	1.93	4.79	5.81	0.81	-1.35	-0.184
1/1/08 to 10/11/08	58.74	30.53	2.09	17.87	0.000	2.49	3.42	4.19	0.04	5.19	-0.166

Irrigation in the Brooks for the DRGR model was less than 1 inch/year, which seemed low, therefore measured irrigation pumpage rates were obtained to assist in the calibration. Measured irrigation was equal to 11.3 inches/year from surface water and the surficial aquifer between June 1, 2006 and September, 2008. Measured irrigation from external sources was 6.3 inches/year during the same period.

2.9.1 Overland Flow Depths during the Wet Season

The model simulates flooding in areas without river channels and in areas where the water depth exceeds the maximum channel elevation within the river cross section. **Figure 2.25** presents the overland flow depth map for Tropical Storm Ernesto in the fall of 2006. The areas of red and orange are mining pits where water depths are greater than 5 feet deep. In general, overland flow depths are in the range of 0-1 foot deep with some areas in Flint Pen Strand that have water depths in the range of 2 feet. The overland flow vectors illustrate that a portion of the water in DRGR wetlands flows toward the Estero River and Halfway Creek during the wet season.

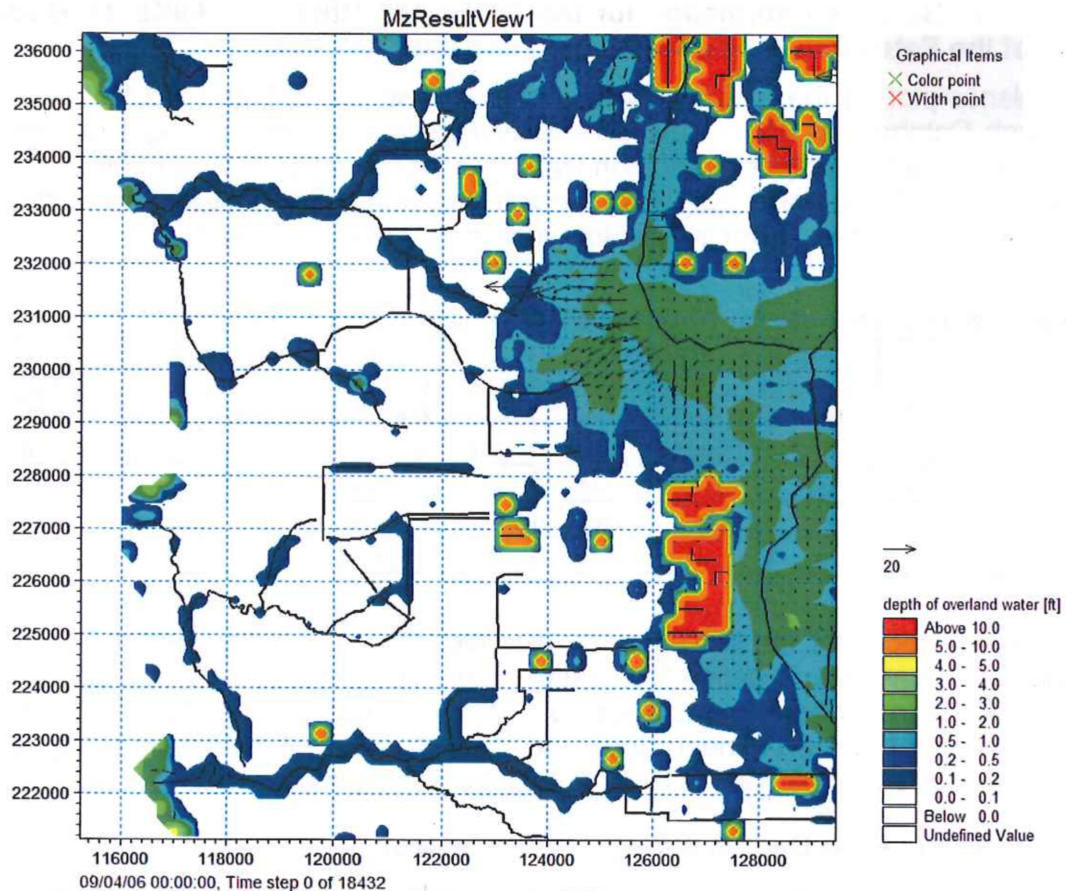


Figure 2-25: Overland Flow Depth Map for September 4, 2006

3 HYDROECOLOGICAL ASSESSMENT

One of the alternatives being considered as part of the South Lee County Watershed Plan (SLCWP) update is the installation of additional culverts under I-75 in the two-mile stretch south of the Estero River. Although there are existing culverts beneath this section of I-75, management of regional surface flows may be facilitated by increasing the capacity of the existing culvert system. Although site hydrology will be a primary determinant of whether this alternative is feasible and desirable, the potential for adverse ecological effects also requires evaluation, particularly with regard to the potential for altering wetland hydrologic regimes on the upstream (i.e., eastern) side of I-75.

As part of this evaluation process, Winchester Environmental Associates, Inc. (WEA) was requested to conduct a hydroecological assessment of the SLCWP study area **(Figure 3-1)**. The study area is bounded by the Estero River to the north and I-75 to the west, and extends roughly two miles south and one mile east from the northern and western boundaries, respectively.

The primary objectives of the WEA assessment were to: 1) characterize the health and hydroecology of the natural and disturbed wetland communities within the study area, 2) provide estimated seasonal high water (SHW) elevations and flooding depths for various locations within the study area, 3) compare the field-estimated hydroecological data with hydrologic model outputs, and 4) evaluate whether the proposed expansion of culvert capacity is likely to have an adverse effect upon on-site wetlands.

3.1 Methodology

WEA carried out field evaluations of the SLCWP study area during the December 5-8, 2008 period. During that period WEA examined field hydroecological indicators at 60 locations distributed throughout the study area. Using various hydrobiological indicators (e.g., stain lines, lichen lines, melaleuca bark rot lines, fence rust lines, moss collars, drift lines), estimated normal SHW elevations were identified for each of these locations. A laser level was used to establish the relative elevations of these estimated SHWs relative to a field benchmark. Using the NAVD 1988 datum, elevations of the field benchmarks were subsequently provided by a professional land surveyor, allowing WEA to calculate the actual NAVD elevations of each SHW point.

Ideally, the hydroecologic evaluation of a site should be based on both field hydrobiological indicators as well as stage/piezometer data, which provides for site-specific referencing of hydrobiological indicators. Hydroecologic evaluations can still be performed on sites where hydrologic monitoring data are not available, but there is invariably some loss in precision in the estimates developed from the various field hydrobiologic indicators. In the case of the SLCWP study area, the occurrence of a major storm event in 2008 added complexity because it established field indicators reflecting this high-high water event in addition to the normal SHW indicators. Nonetheless, on-site field indicators were still considered adequate to develop reasonable field estimates of normal SHW elevations across much of the study area.

Figure 3-1: SLCWP study area location map

3.2 Existing Hydroecological Conditions

3.2.1 Site Ecological Characteristics

The SLCWP study area supports three major native plant communities: cypress-pine-palm forest, cypress swamp, and pine flatwoods. Of these three communities, only pine flatwoods is considered an upland community that does not typically inundate for extended periods during the wet season. Depending on the location within the study area, all three of these native plant communities have been invaded to varying degrees by melaleuca (Melaleuca quinquenervia), an aggressive exotic species that often displaces native plant species and sometimes forms dense monotypic stands in which virtually no other plant species are present.

Melaleuca tend to be particularly invasive where natural hydrologic regimes have been altered by surface drainage and/or lowered water tables, and also where the soil surface has been physically disturbed. They are slower to invade the deeper native wetlands that still retain their natural hydrologic regimes. On the SLCWP study area, melaleuca-dominated communities are more prevalent along the western and northern portion of the study area, presumably due to the presence of the I-75 corridor (and its historic soil disturbance) and the altered hydrologic regimes in this same area.

The aerial photograph in **Figure 3-1** shows that the cypress-pine-cabbage community (gray photographic signature) is the most common community within the SLCWP study area, with scattered pine flatwoods uplands (green photographic signature) usually occurring as "islands" within the wetland landscape. A secondary green signature occurs in the northwestern and west-central portions of the study area where melaleuca has become the dominant tree species. An excerpt from a recent vegetation map prepared by Agnoli, Barber and Brundage (2008) shows the distribution of native plant communities on the study area along with an overlay indicating the degree of melaleuca infestation **(Figure 3-2)**. This figure is in good agreement with WEA's on-site field observations in December 2008.

A melaleuca removal/control program has recently been carried out on the tract of land immediately north of the study area. This control program has drastically altered the vegetation composition of this area, and has been effective in restoring a much more natural assemblage of plant species. **Figure 3-3** through **Figure 3-5** provide a series of photographs comparing the melaleuca dominated communities on the SLCWP study area with the adjacent restored lands to the north. These photos are useful both in showing the extent to which some areas within the study area have been adversely affected by melaleuca, and in showing what a successful melaleuca elimination program can achieve.

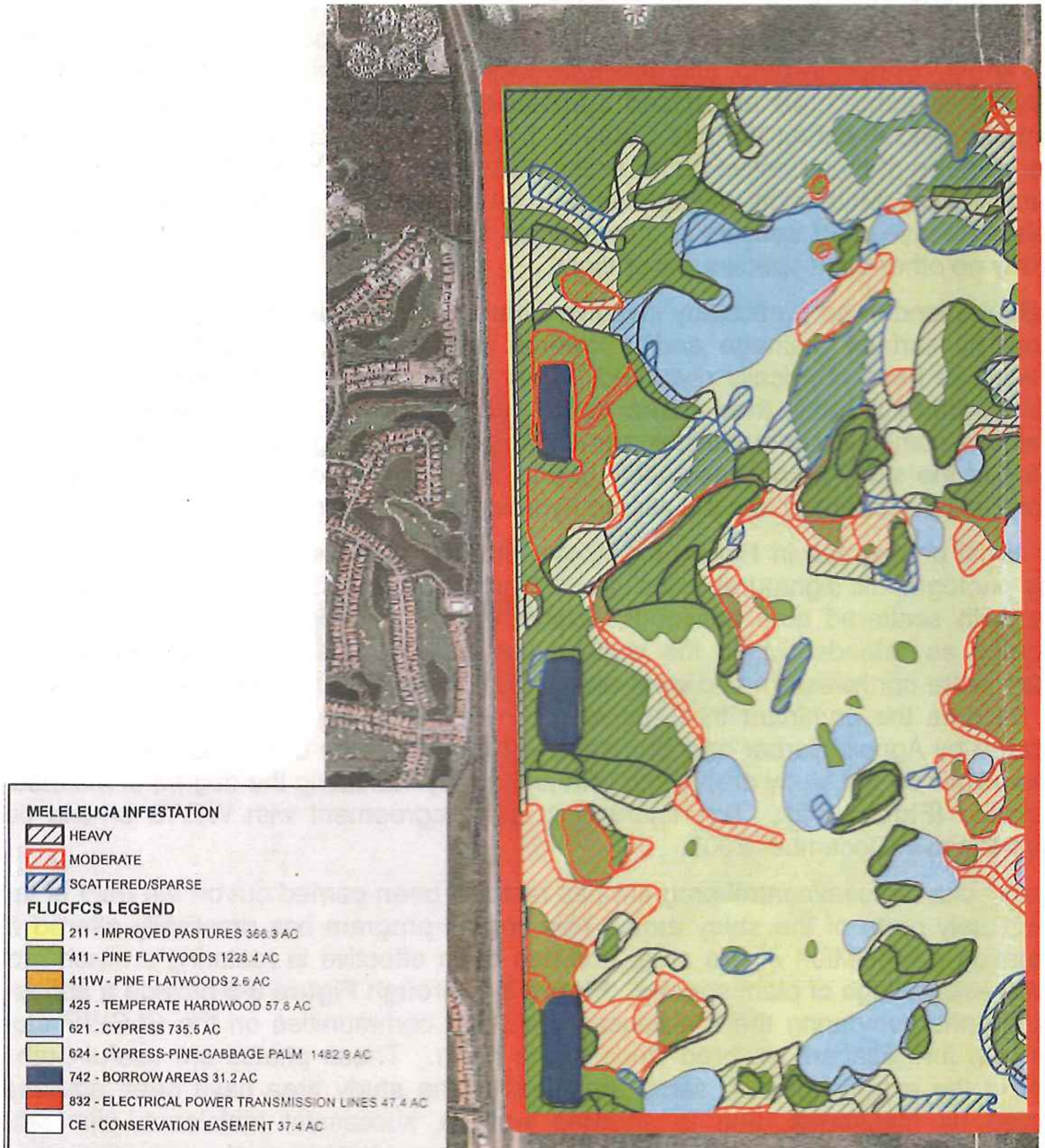


Figure 3-2: SLCWP study area vegetation map
(adapted from map prepared by Agnoli, Barber and Brundage, 2008)

Figure 3-3: Ground photographs at WEA Field Site 7-1
(Top photograph looking north at restored area with dead melaleuca trunks still standing; bottom photograph looking south at unrestored area)

Figure 3-4: Ground photographs at WEA Field Site 7-2
(Top photograph looking north at restored area with dead melaleuca trunks still standing; bottom photograph looking south at unrestored area)

Figure 3-5: Ground photographs east of WEA Field Site 7-2
(Top photograph looking north at restored area with dead melaleuca trunks still standing; bottom photograph looking south at unrestored area)

3.2.2 Site Hydroecological Conditions

From a qualitative standpoint, WEA's field studies on the SLCWP study area found that the degree of vegetation disturbance and modification of natural hydrologic regimes generally decreased on west-to-east and north-to-south gradients. There were many areas in the eastern half of the study area that supported very natural wetland plant communities with either minimal or no melaleuca invasion. Representative photos of these wetland areas are provided in **Figures 3-6** and **Figure 3-7**.

Hydroecological indicator data collected by WEA in December 2008 are presented in Error! Reference source not found.; field data collection points are shown in **Figure 3-8**. Because these data were collected from the study area over a three-day period rather than over an annual or multi-year period with water level monitoring data, they are not sufficient to develop precise estimates of hydroecological conditions within the study area. However, when evaluated in concert with the review of historic and recent aerial photography, the data do support the development of preliminary conclusions regarding the general hydroecological characteristics of the site. WEA's hydroecological evaluation also included the comparison of modeled average SHW elevations and site topography provided by A.D.A. Engineering Inc. (ADA). **Figure 3-9** compares WEA's field-estimated average SHW elevations with available topographic data for the site. **Figure 3-10** compares WEA's field-estimated average SHW elevations with ADA's modeled average SHW elevations for 2008.

A summary of the preliminary findings from WEA's hydroecological evaluation are provided below:

<u>*Normal SHW Elevations*</u>

- Normal SHW elevation is defined as the high water level elevation normally encountered at a particular location during the wet season of a normal water year. It is distinct from the episodic high-high water levels that are typically associated with major storm events occurring on an average frequency of once every 10 years or more.
- WEA's estimated normal SHW elevations across the SLCWP study area ranged from 14.3 to 15.5 feet NAVD. Normal SHW elevations were generally higher in the southern third of the study area (15.0 to 15.4 feet NAVD) than in the northern two-thirds of the study area (14.5 to 15.0 feet NAVD)
- The lowest normal SHW elevations were generally found in the west-central portion of the study area in the vicinity of Halfway Creek, and just to the north between Halfway Creek and the Estero River. Although these lower SHW elevations may be attributable in part to lower ground surface elevations in this area, WEA's hydroecological field observations suggest that this area currently has an altered hydrologic regime compared to natural, historic conditions. This altered hydrologic regime is likely expressed in both lower average SHW elevations as well as reduced average hydroperiods, though no direct data are available to support this later supposition. The existing drainage system under I-

75 in the vicinity of Halfway Creek is the most likely causative factor for these observed indicators of a reduced hydrologic regime.

- It should be noted that the currently-available topographic data for the study area are not completely reliable. Available topographic data indicate an elevationally higher area in the south-central portion of the site (shown in dark green in **Figure 3-9)**. While small elevationally-higher areas occur throughout the study area in association with pine flatwoods "islands," the presence of the large south-central rise shown in **Figure 3-9** is not supported by WEA's field observations and elevation measurements, or by available aerial photography. **Figure 3-9** indicates that ground surface elevations in this area are in the range of 15.5 to 16.0 feet NAVD. WEA's referenced spot elevations in this same area are consistently below 14.0 feet NAVD. The elevationally-lower nature of this area is also clearly seen in color infrared aerial photography of the study area, which shows large areas of seasonal inundation and with greater flooding depths (**Figure 3-11**).
- A comparison was made of WEA's estimated normal SHW elevations with those produced by the ADA modeling effort (**Figure 3-10**). There was close agreement between the WEA estimates and the model estimates for the southern and northernmost portions of the study area. In the central portion of the study area WEA's estimated normal SHW elevations were somewhat lower, indicating that field observations are showing more of a drainage effect in this area than the model results are.

Figure 3-6: Ground photographs of the cypress-pine community within the SLCWP study area

Figure 3-7: Ground photographs of the cypress swamp community within the SLCWP study area

Table 3-1: Estimated Normal SHW and High Pool Elevations in the SLCWP Study Area

Station No.	GPS Latitude	GPS Longitude	Typical Ground Elevation (NAVD-ft)	Estimated Normal SHW Elevation (NAVD-ft)	Estimated High-High Pool Elevation (NAVD-ft)	Spot Water Surface Elevation (NAVD-ft)	Comments
1-1	26.3934677	-81.7718587	14.11		15.53	-	Wire rust line
1-2	26.3934033	-81.7704608	13.88	15.09		-	Moss line, stain line
1-3	26.3939027	-81.7698398	14.02	15.06	15.37	-	Moss line/lichen line
1-4	26.3933353	-81.7678023	13.81		15.38	-	Lichen line
1-5	26.3935633	-81.7665786	13.67	14.97		13.71	Stain lines
1-6	26.3926891	-81.7648391	13.45	14.62	15.26	13.71	Stain line/high lichen line
1-7	26.3927242	-81.7629875	13.54		15.23	13.71	High lichen line
1-8	26.3918613	-81.761379	13.50		15.28	13.71	High lichen line
1-9	26.392707	-81.760337	13.60			13.71	
1-10	26.3942213	-81.7609004	13.51			13.71	
1-11	26.3963507	-81.7616123	13.47			13.71	
1-12	26.3975393	-81.761779	13.56		15.02	13.71	Lichen line
2-1	26.3988819	-81.7615868	13.29	14.70	15.21	13.71	Moss and stain line/high stain line
2-2	26.3981113	-81.764141	13.57		15.10	13.71	Stain line
2-3	26.398871	-81.7659417	13.49		15.12	13.71	Stain line
2-4	26.3988667	-81.7666861	13.71			13.72	
2-5	26.3995667	-81.7710167	13.73		15.23	13.72	Stain line
2-7	26.3995827	-81.7720173	13.98	14.98		-	Moss line, stain line
DOT BM 412	26.3997167	-81.7722087	14.28		15.30	-	Wire rust line
3-1	26.4024257	-81.7721883	14.28		15.19	-	Wire rust line
4-1	26.405429	-81.772175	13.85		15.17	-	Stain line
4-2	26.4051267	-81.7710157	13.70	14.28		-	Wire rust line
4-3	26.4052003	-81.769879	13.98	14.78		-	Wire rust line
4-4	26.4056536	-81.7692917	13.84	14.53		-	Wire rust line
4-5	26.4054674	-81.7682343	15.20	-		-	Upland
WEA BM 3	26.405796	-81.7656557	14.09	14.72		13.89	Wire rust line
4-6	26.405947	-81.7653837	13.90	14.96		13.89	Stain line
4-7	26.406326	-81.7617333	13.83	14.71		13.89	Wire rust line
4-7B	26.4062783	-81.7611333	13.63	14.65		13.89	Lichen line
4-8	26.4058863	-81.7591983	14.69	-		-	Upland break between 4-7B and 4-9
4-9	26.4057673	-81.7585377	13.84	14.90		14.25	Wire rust line
5-1	26.409654	-81.7648003	13.67	14.90		13.87	Lichen line
5-2	26.4109062	-81.7658583	13.37			13.87	
5-3	26.4114067	-81.766023	13.87			13.87	
5-4	26.4113063	-81.766323	<11.8			13.87	Edge of pop ash depression
5-5	26.411733	-81.7660797	13.62	14.82		13.87	Lichen line
5-6	26.4119995	-81.767356	14.12	14.82		-	Moss line

Table 3-1: Estimated Normal Pool and High Pool Elevations in the SLCWP Study Area (cont.)

Station No.	GPS Latitude	GPS Longitude	Typical Ground Elevation (NAVD-ft)	Estimated Normal SHW Elevation (NAVD-ft)	Estimated High-High Pool Elevation (NAVD-ft)	Spot Water Surface Elevation (NAVD-ft)	Comments
6-1	26.415475	-81.7726153	14.23	14.66			Next to wood road @ 13.01 NAVD
6-2	26.4153122	-81.7718675					SHW 0.5 - 0.6 ft abg
6-3	26.4147329	-81.7706783					SHW 0.2 - 0.5 ft abg
6-4	26.4144993	-81.769658					SHW 0.2 - 0.4 ft abg
6-5	26.415658	-81.7691067					SHW 0.7 - 0.8 ft abg
6-6	26.4160797	-81.7694547					SHW 0.5 ft abg
6-7	26.416021	-81.7703997					SHW 0.6 ft abg
6-8	26.4155840	-81.7716293	14.12	14.42			MQ rot line
6-9	26.4155540	-81.770893	14.51	14.87			Lichen line, MQ rot line
WEA BM 6	26.4134253	-81.7687057		15.04		14.14	Moss line
FDOT BM 482	26.4190457	-81.7728377	14.73	14.78			Stain line
7-1	26.4204685	-81.7721129					
WEA BM 7	26.4205056	-81.7707708	14.66	14.84		13.84	Wire rust line
7-2	26.4203097	-81.768885	14.20	14.73			Wire rust line
7-3B	26.4203027	-81.7642824					
7-4	26.4203363	-81.76231					
WEA BM 8	26.42021	-81.7603843	14.17		15.12	14.18	Wire rust line
7-5	26.420356	-81.7572819	14.47		15.33		Lichen line
7-6	26.4205965	-81.7586891					Flow to north
7-7	26.4205423	-81.760121					Flow to north
8-1	26.4215353	-81.772768	14.41	15.28			Hummock stain line
WEA BM 9	26.4214421	-81.7733536	14.51	15.30			Wire rust line

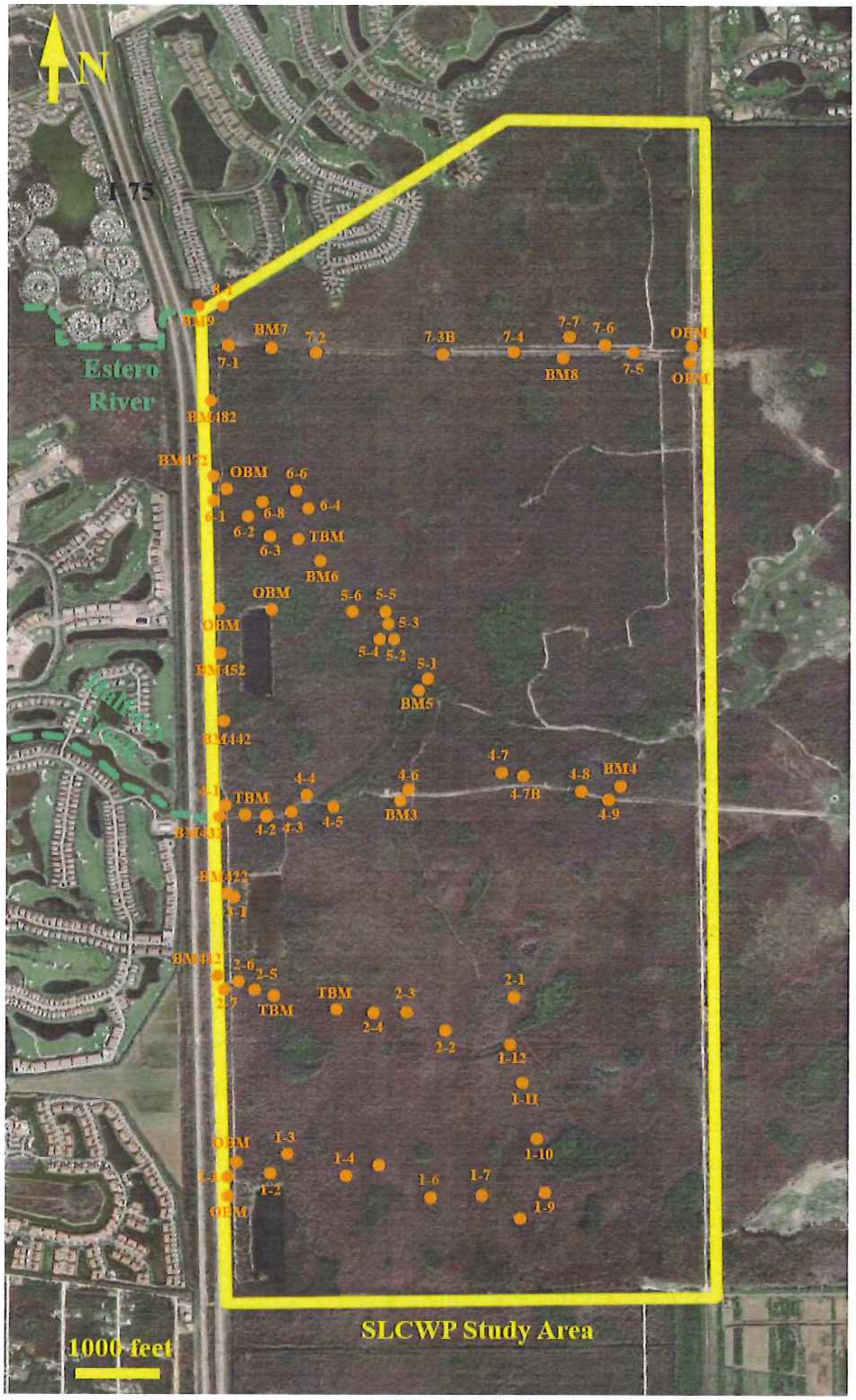


Figure 3-8: WEA hydroecological field sites within the SLCWP study area

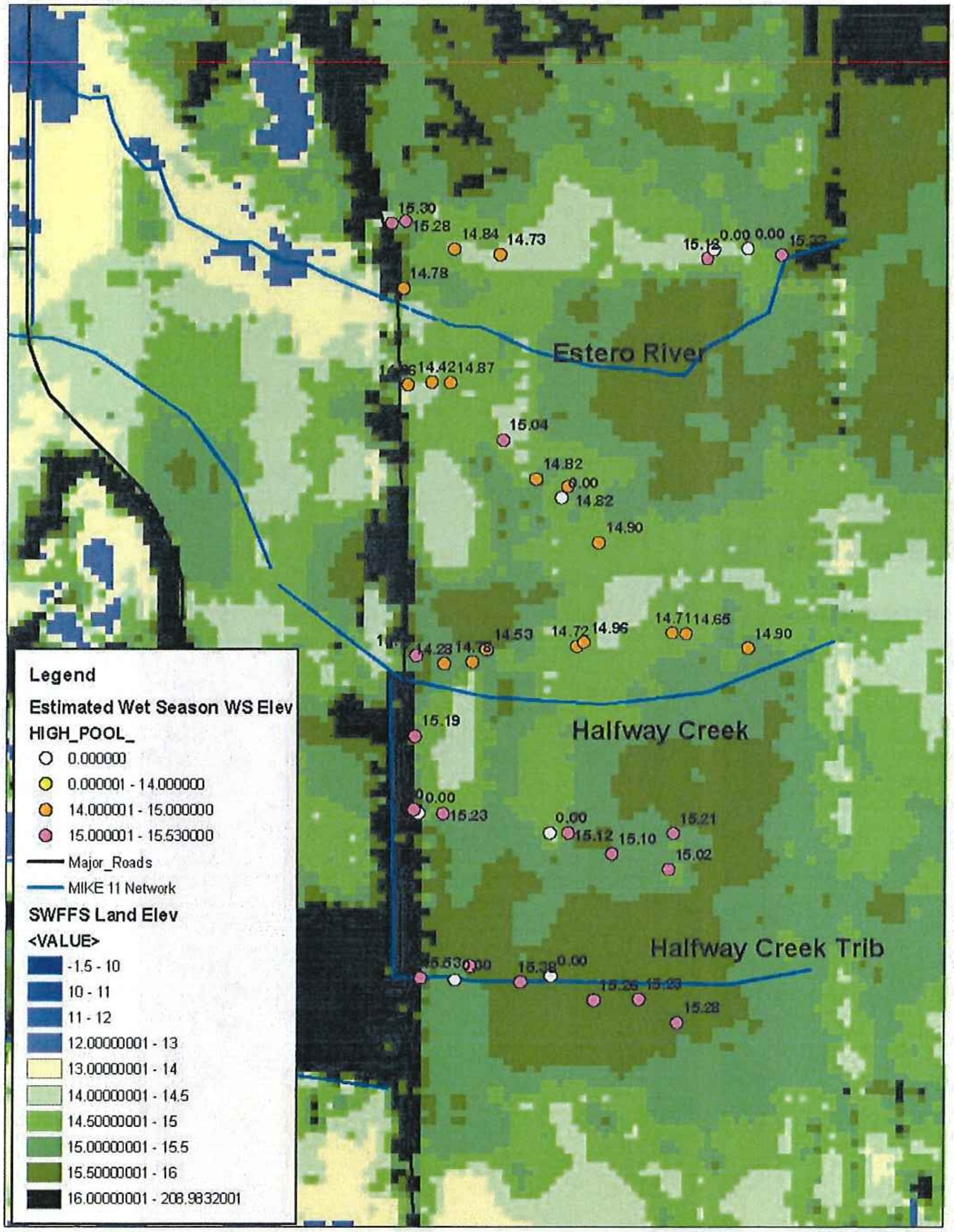


Figure 3-9: Estimated normal SHW elevations versus topography within the SLCWP study area
(topographic information provided by A.D.A. Engineering, Inc.)

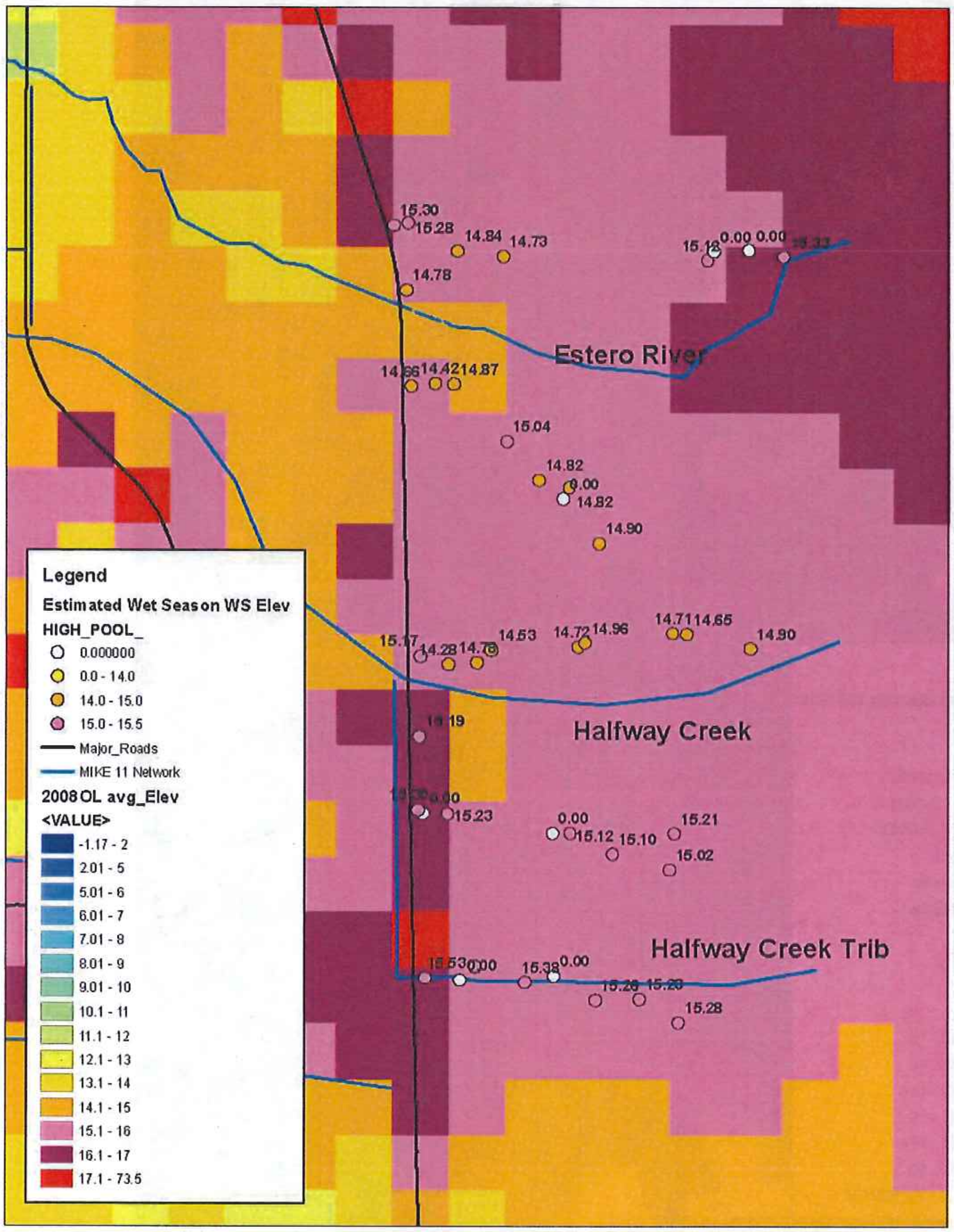


Figure 3-10: Estimated normal SHW elevations versus modeled SHW elevations within the SLCWP study area
(modeled elevations provided by A.D.A. Engineering, Inc.)

Figure 3-11: 1999 color infrared aerial photograph of the SLCWP study area

Normal Flooding Depths

- Normal flooding depth is defined as the depth of water above the ground surface when a site is exhibiting normal SHW levels. Normal flooding depths within the SLCWP study area can be derived by comparing WEA's field-estimated normal SHW elevations with the measured ground surface elevations at the same location. The discussion below concerning normal flooding depths is all in relation to the cypress-pine-palm community (with or without melaleuca). Cypress swamps tend to occur in elevationally-lower depression and basins within the study area, and would therefore be expected to have greater flooding depths than the cypress-pine-palm community. Consequently, it would not be appropriate to compare normal flooding depths across these two community types.
- Normal flooding depths were generally greater than 1.0 feet in the southern portion of the study area but less than 0.5 feet in the west-central portion of the study area. The existing culvert drainage system beneath I-75 has likely caused these reduced normal flooding depths in the west-central portion of the study area. In the southwestern portion of the study area where greater normal flooding depths occur, it is possible that the historic construction of I-75 altered sheet flow patterns and that there is now a minor impoundment effect east of I-75. Regardless of the cause, the net result is that the wetlands in the southwestern portion of the study area appear to be less drained than their counterparts in the west-central and northwestern portion of the study area.
- Normal flooding depths appear to consistently increase on a gradient from west to east across the study area. Normal flooding depths are often in the 1.0-1.3 foot range in the eastern half of the study area, and in the 0.4-0.8 foot range in the westernmost portion of the study area (excepting the southernmost area, as discussed above). This suggests that the existing drainageways under I-75 are having a substantial drainage effect on the westernmost portion of the study area. This drainage effect is most pronounced in the westerly portion of Halfway Creek and in the area immediately to the north, where normal flooding depths are generally below 0.5 feet.

Site Hydrology and the Distribution/Density of Melaleuca

- Field observations indicate that the thickest melaleuca stands occur in the northwestern and west-central portions of the study area. These general observations are supported by the observations of Agnoli, Barber & Brundage (2008), as shown in **Figure 3-2**. There appears to be a general correlation between melaleuca density on the site and the degree of drainage as indicated by normal flooding depths, with the areas more affected by drainage supporting older, denser melaleuca stands. However, the areas of greater melaleuca invasion within the study area may also be related simply to their proximity to the I-75 corridor, where historic melaleuca colonization was presumably facilitated by soil disturbance and importation of seeds on construction equipment. Even in the absence of any effect from altered hydrologic regimes, the direction of melaleuca invasion would be expected to be west to east for this particular site.

- Model predictions have not yet been developed for normal SHW levels and hydroperiods after installation of the proposed culvert improvements. To the extent that the additional culverts lower normal SHW elevations, normal flooding depths, and average hydroperiods in those portions of study area where melaleuca is not dominant, the encroachment of melaleuca will likely be facilitated. If the additional culverts have no significant effect upon the hydrologic regimes of the eastern half of the study area due to the distances involved, then no change in the rate of melaleuca invasion would be expected for these areas.
- In the westernmost portion of the study area where melaleuca is well-established as a dominant or co-dominant species, further reduction of hydrologic regimes is not likely to have much incremental effect. In these areas historic drainage has already allowed/facilitated melaleuca establishment, and even restoring the former natural hydrologic regimes would not eliminate these melaleuca stands.

3.3 Target Pool Elevations

After review of the field information, model results and information from Mike Deuver, target average wet season pool elevations and target high pool elevations were developed as shown in **Table 3-2**. These are based on surveyed ground elevations and observed seasonal high water marks. During the measurement of the field indicators and adjacent ground surfaces, it became apparent that there were discrepancies between actual measured ground elevations and the topographic data used in the modeling analysis. This likely accounts for many of the differences in specified control elevations. Additional analysis of the field data will be necessary once more accurate topographic data are available for modeling analysis. This updated information will then be used to translate these targets to hydraulic conveyance improvements to be discussed further in **Section 5**.

Table 3-2: Target Pool Elevations

Target normal SHW and high pool elevations in the SLCWP study area							
Station No.	GPS Latitude	GPS Longitude	WEA Measured Ground Elevation (NAVD-ft)	SFWMD Median Topo Elevation (NAVD-ft)	SFWMD - WEA Topo Variance (ft)	Target High Pool/SHW Elevation (NAVD-ft)	Target Average Wet Season Pool Elevation
1-1	26.3934677	-81.7718587	14.11	15.75	1.64	15.3	14.3
1-2	26.3934033	-81.7704608	13.88	15.25	1.37	15.3	14.3
1-3	26.3939027	-81.7698398	14.02	15.75	1.73	15.3	14.3
1-4	26.3933363	-81.7678023	13.81	15.75	1.94	15.0	14.3
1-5	26.3935633	-81.7665786	13.67	15.75	2.08	15.0	14.3
1-6	26.3926891	-81.7648391	13.45	15.75	2.30	15.0	14.1
1-7	26.3927242	-81.7629875	13.54	15.75	2.21	14.8	14.1
1-8	26.3918613	-81.761379	13.50	15.75	2.25	14.8	14.1
1-9	26.392707	-81.760337	13.60	15.75	2.15	14.8	14.1
1-10	26.3942213	-81.7609004	13.51	15.75	2.24	14.8	14.1
1-11	26.3963507	-81.7616123	13.47	15.75	2.28	14.8	14.1
1-12	26.3975393	-81.761779	13.56	14.75	1.19	14.8	14.1
2-1	26.3988819	-81.7615968	13.29	15.25	1.96	14.7	14.1
2-2	26.3981113	-81.764141	13.57	15.25	1.68	14.7	14.1
2-3	26.398871	-81.7659417	13.49	15.25	1.76	15.0	14.1
2-4	26.3988667	-81.7666961	13.71	14.50	0.79	15.0	14.1
2-5	26.3995667	-81.7710167	13.73	15.00	1.27	15.2	14.1
2-7	26.3995827	-81.7720173	13.98	14.75	0.77	15.2	14.3
DOT BM 412	26.3997167	-81.7722087	14.28	-	-	15.2	
3-1	26.4024257	-81.7721883	14.28	14.75	0.47	-	
4-1	26.405429	-81.772175	13.85	15.25	1.40	15.0	14.2
4-2	26.4051267	-81.7710157	13.70	15.25	1.55	15.0	14.2
4-3	26.4052003	-81.769879	13.98	15.25	1.27	15.0	14.2
4-4	26.4056536	-81.7692917	13.84	15.75	1.91	15.0	14.2
4-5	26.4054674	-81.7682343	15.20	15.25	0.05	15.0	
WEA BM 3	26.405796	-81.7656557	14.09	14.75	0.66	15.0	
4-6	26.405947	-81.7653837	13.90	14.75	0.85	15.0	14.4
4-7	26.406326	-81.7617333	13.83	14.75	0.92	14.8	14.4
4-7B	26.4062783	-81.7611333	13.63	14.75	1.12	14.8	14.4
4-8	26.4058863	-81.7591983	14.69	15.25	0.56	14.8	
4-9	26.4057673	-81.7585377	13.84	15.25	1.41	14.8	14.4
5-1	26.409654	-81.7648003	13.67	14.75	1.08	14.9	14.4
5-2	26.4109062	-81.7658583	13.37	15.25	1.88	14.9	14.4
5-3	26.4114067	-81.766023	13.87	15.25	1.38	14.9	14.4
5-4	26.4113063	-81.766323	<11.8	14.75	>2.95	14.9	14.4
5-5	26.411733	-81.7660797	13.62	15.25	1.63	14.9	14.4
5-6	26.4119995	-81.767356	14.12	15.50	1.38	14.9	14.4

Table 3-2: Target Pool Elevations (cont.)

Target normal SHW and high pool elevations in the SLCWP study area							
Station No.	GPS Latitude	GPS Longitude	WEA Measured Ground Elevation (NAVD-ft)	SFWMD Median Topo Elevation (NAVD-ft)	SFWMD - WEA Topo Variance (ft)	Target High Pool/SHW Elevation (NAVD-ft)	Target Normal Pool Elevation
6-1	26.416475	-81.7726153	14.23	14.50	0.27	15.3	14.6
6-2	26.4153122	-81.7718675					
6-3	26.4147329	-81.7706783					
6-4	26.4144993	-81.769658					
6-5	26.415658	-81.7691067					
6-6	26.4160797	-81.7694547					
6-7	26.416021	-81.7703997					
6-8	26.4155840	-81.7716293	14.12	14.25	0.13	15.3	14.6
6-9	26.4155540	-81.770893	14.51	14.75	0.24	15.3	14.6
WEA BM 6	26.4134253	-81.7687057					
FDOT BM 482	26.4190457	-81.7728377	14.73	-		-	
7-1	26.4204685	-81.7721129					
WEA BM 7	26.4205066	-81.7707708	14.66	14.50	-0.16	15.3	14.9
7-2	26.4203097	-81.768885	14.20	14.25	0.05	15.3	14.9
7-3B	26.4203027	-81.7642824					14.9
7-4	26.4203363	-81.76231					
WEA BM 8	26.42021	-81.7603843	14.17	14.25	0.08	15.2	14.8
7-5	26.420356	-81.7572819	14.47	15.25	0.78	15.2	14.8
7-6	26.4205965	-81.7586891					14.8
7-7	26.4205423	-81.760121					
8-1	26.4215353	-81.772768	14.41	15.00	0.59	15.3	14.9
WEA BM 9	26.4214421	-81.7733536	14.51	14.25	-0.26	15.3	14.9

4 PROBLEM IDENTIFICATION

This section of the report describes the simulations conducted to identify problems, assumptions made for the simulations, and the initial findings. It should be noted that additional information was obtained from stakeholders during a February 10, 2009 public meeting. This additional information was added to the model, the design storms were run again, and this document presents revised peak stages and flows that reflect the additional information.

4.1 Design Storm Analysis Methodology

The calibrated model has been used as the basis for the design storm analysis. After calibration was almost complete, a number of design storm test runs were conducted to make sure that the model was suitable for design storm analysis. In addition, changes were necessary to account for changes in actual field conditions that have taken place after the end of the calibration period. The model was modified slightly after these initial design storm tests. The modifications are summarized below:

- A revised cross section was used at the FPL crossing in Halfway Creek downstream of U.S. 41 since the construction work for that project will be completed prior to the 2009 wet season.
- The Orr Road bridge was removed from the model because this bridge was demolished recently.
- New surveyed cross section information was added to the model. The new cross sections were provided by the City of Bonita Beach in Spring Creek downstream of Old U.S. 41 and by Lee County for the South Branch of the Estero River downstream of I-75 and upstream of Sanctuary Road.
- Flood codes were added in Spring Creek tributaries in San Carlos Estates to better represent flows for the larger rainfall events.
- An existing lake was added in Halfway Creek downstream of Via Coconut Point so that the base condition model results could be compared to an alternative with an improved connection to the lake.
- The following structures were added in Kehl Canal: culverts and a weir representing Poorman's Pass Road, a weir representing a farm ford downstream of Poorman's Pass Road, and a culvert and a weir representing Vincent Road.
- Flows were prevented from moving south of the south boundary of new residential developments south of Bonita Beach Road east of I-75.
- The North Branch Estero River configuration at I-75 was modified to be consistent with aerial photographs and to simulate more realistic flows under the I-75 bridge.

- Other minor changes were made to the model to reduce instabilities.
- Modifications were made in San Carlos Estates to better represent conditions when water levels exceed top-of-bank elevations.

The calibration was checked after completion of these modifications, and the calibration was improved by the modifications.

4.1.1 1995 Wet Season

A simulation was conducted to evaluate the potential consequences of experiencing rainfall equivalent to the rainfall that fell on the model domain in 1995. Daily rainfall values from 1995 were copied into the 2006 rainfall database, and the simulation utilized the surface water features (weirs, bridges, culverts, by-pass structures, gates, cross sections) representing current conditions. The full county-wide DRGR model was run with measured 1995 water levels and flows were used as boundary conditions along the edges of the county-wide model. One example of this is C-43 flow from Hendry County, which is a boundary for the county-wide model. The local-scale model was used for this study (see Section 2 Calibration for the model domain and a more complete discussion of local-scale model boundaries) with water level boundaries from the county-wide model with 1995 rainfall spliced into the 2006 rainfall file. Results are presented below in **Section 4.2.5**.

4.1.2 5-, 10-, 25-, and 100-Year Design Storms

The design storms were started using initial conditions representing water levels that would be experienced on July 5 for a rainfall condition equivalent to the summer wet season of 1995. The July 5 water levels from that model run were used for initial conditions for all design storms. Hourly rainfall values were then used for the design storm runs. The rainfall file used for each design storm included 1995 rainfall for the month of July (with an hourly distribution) with the peak of the design storm rainfall occurring on August 3. The total rainfall values for each design event are presented below in **Table 4-1**. The 5- and 10-year design events have a one-day duration, and the 25- and 100-year events have a three day distribution. **Figure 4-1** presents the distribution of rainfall throughout the events.

Table 4-1: Rainfall Totals for Design Storms

Return Period and Duration	Rainfall (inches)
5-year 1-day	5.0
10-year 1-day	6.3
25-year 72-hour	11.5
100-year 72-hour	15.0

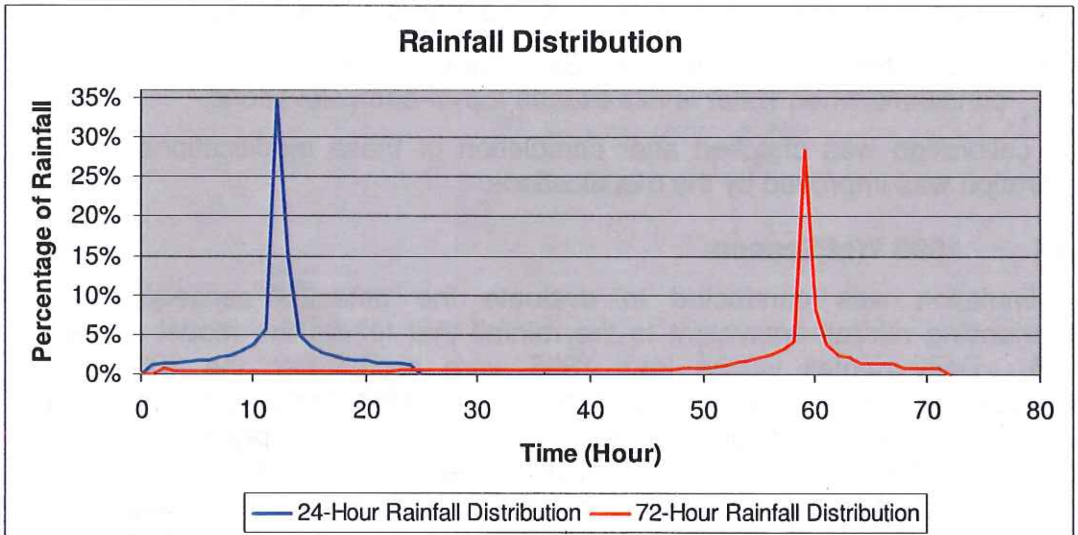


Figure 4-1: Rainfall Distributions

4.2 Design Storm Results

This section provides information on peak stages and flows for the 5-, 10-, 25-, and 100-year design storms.

4.2.1 5-Year Design Storm

Table 4-2 presents peak stages and flows for the design storms at key stations. Yellow highlighting indicates where water levels exceed the bridge deck elevation or a minimum road elevation within a development. **Table 4-3** presents a simulated design storm stages for a wider range of locations within the study area. Water levels are generally high, however overtopping of road surfaces is rare. Overtopped roads are restricted to San Carlos Estates in the Spring Creek watershed and include:

- Strike Lane ditch at the junction with Stillwell Parkway,
- Strike Lane at the junction with Tuck Drive (near Moriah Canal)

Note that there is no level of service established for San Carlos Estates, and therefore un-obstructed passage along roads within San Carlos Estates is not guaranteed for periods of high rainfall. According to surveying of selected houses in San Carlos Estates by Morris Depew & Associates, there is a single house on Strike Lane with a finished floor elevation (FFE) of 13 ft-NAVD, which is lower than the predicted peak stage for Strike Lane at Stillwell Road. Flooding of this residence is anticipated for the 5-year design storm. **The degree of flooding in San Carlos Estates is unexpected since reports of house flooding are relatively rare for this community. The simulation results are based on a model that uses information from a 1970 Plan of Reclamation for San Carlos Estates channel cross sections. Additional simulations are**

recommended for this area using surveyed cross sections within San Carlos Estates.

Water surface profiles are presented in **Appendix 2**.

Table 4-2: Design Storm Peak Stages and Flows for Key Study Area Locations

	Basev2b042309	5yr DS		10yr DS		25yr DS		100yr DS	
Location	Branch H & Q Chainages	Water Level	Discharge	Water Level	Discharge	Water Level	Discharge	Water Level	Discharge
Kehl Canal Gate	KehlCan 30702, 30767	13.4	1,177	13.8	1,350	14.2	1,683	14.7	2,048
Imperial R. I-75	Imperial 4588, 4888	10.8	1,233	11.2	1,400	11.8	1,744	12.2	2,070
Imperial R. Bourbonniere	Imperial 8430, 8488	8.1	1,319	8.8	1,469	10.0	1,853	10.6	2,267
Halfway Ck., I-75	Halfwayup 5889, 6049	14.1	157	14.6	187	15.2	253	16.0	329
By-pass Gate to SB Estero	HW 3939, ThreeOaks 25	14.0	10	14.4	20	14.9	35	15.5	41
Brooks North Weir	HalfwayCRDS 10259, 10400	13.9	352	14.3	424	14.9	593	15.5	646
Brooks South Weir	HalfwayCrS 7450, 7555	14.0	70	14.3	86	14.9	110	15.6	138
Halfway Ck., U.S. 41	HalfwayCRDS 12800, 12870	13.6	413	13.9	488	14.4	624	14.9	759
SB Estero I-75	EsteroRivS 99, 252	16.6	58	16.8	68	17.2	88	17.6	130
SB Estero, Sanctuary Rd	EsteroRivS 4100, 4200	11.9	113	12.4	136	13.6	213	14.3	340
SB Estero, Three Oaks	EsteroRivS 6299,	10.1	168	11.4	220	12.9	326	13.9	475
SB Estero, Corkscrew Rd	EsteroRivS 8628	9.7	227	11.0	302	12.7	430	13.8	482
SB Estero County Ck Dr	EsteroRivS 11155, 11250	7.3	395	8.2	555	9.8	787	10.8	936
NB Estero, I-75	Esterol75 328, 450	16.1	121	16.2	167	16.6	289	17.2	530
NB Estero, Rivers Ford Rd	EsteroRiv 4944, 4980	10.9	240	12.3	447	12.8	605	14.1	896
Strike Ln at Stillwell Rd	StrikeLn 4921	13.9	#N/A	14.0	#N/A	14.1	#N/A	14.5	#N/A
Stillwell Weir	FairwayEstates 10750, 10800	10.2	130	10.6	171	11.4	280	13.1	373
Moriah Weir	MoriahCanal 2952, 3116	10.4	127	11.1	157	12.1	248	13.6	420
Countess Lane	SpringCRSS 4000, 4245	6.6	223	6.7	234	7.1	262	8.4	398
Spring Ck Trib RR	SpringCR 3200, 3253	10.0	74	10.7	93	11.7	114	12.7	126
Spring Ck Trib Cedar Ln	SpringCR 4079, 4400	4.6	788	5.3	1,008	6.2	1,307	7.3	1,868

Table 4-3: Peak Stages (NAVD) for Design Storms at Key Locations (NGVD = NAVD+1.3 ft)

Location Upstream of Description	5yrDS	10yrDS	25yrDS	100yrDS				
Branch	Max WL	Max WL	Max WL	Max WL	Polygon Name	Road el	Min bldg	Description
ESTERORIV 9996.00	6.5	7.4	8.5	9.3	ER-1	16		Sandy Lane Bridge
ESTERORIV 11439.01	2.4	3.3	4.8	6.1	ER-2			U.S. 41
ESTEROI75 328.08	16.1	16.2	16.6	17.2	ERNB-1	24.7		Culvert @ I-75
ESTERORIV -330.00	15.6	16.3	16.5	17.1	ERNB-2	23		I-75 Bridge
ESTEROTRIB 8600.00	16.1	16.3	16.7	17.2	ERNB-3	NA		Detention storage weir
ESTERORIV 1562.01	14.4	15.1	15.9	16.4	ERNB-4	16.7		Estero Three Oaks Road
ESTERORIV 1952.10	14.4	15.0	15.9	16.3	ERNB-5	15.7	17.2	Rookery Road
ESTERORIV 4944.23	10.9	12.3	12.8	14.1	ERNB-7	12.7	11.2	Rivers Ford Road
STONYBROOK 1710.71	16.7	16.9	17.5	18.2	ERSB-1	17.5	19	Stonybrook Outfall
ESTERORIVS 99.00	16.6	16.8	17.2	17.6	ERSB-2	20.7		I-75 Bridge and Culverts
ESTERORIVS 4100.00	11.9	12.4	13.6	14.3	ERSB-3	14.6		Sanctuary Road
ESTERORIVS 6299.21	10.1	11.4	12.9	13.9	ERSB-4	15		Three Oaks Bridge
THREEOAKS 2900.00	13.7	14.2	14.9	17.3	ERSB-5	NA		Weir in ditch from Brooks to SB ER
ESTERORIVS 8628.61	9.7	11.0	12.7	13.7	ERSB-6	16		Corkscrew Road
ESTERORIVS 9744.09	9.0	10.2	11.9	13.0	ERSB-7	13.2		Country Creek Dr at Old Oak Pl.
ESTERORIVS 11155.51	7.3	8.2	9.8	10.8	ERSB-8	10.7		Country Ck Dr near Split Oak Way
CORK_RD_75 950.00	14.1	15.5	16.9	18.1	ERSB-C1	22		I-75 culverts
CORK_RD_75 3000.00	13.9	15.3	16.8	18.0	ERSB-C2			driveway culverts
ESTERORIVSE 918.64	13.5	14.8	16.2	17.6	ERSB-C3			Three Oaks Culvert
HALFWAYUP 5889.11	14.1	14.6	15.2	16.0	HC-1	22		I-75 Culverts
SPRING_HW 5000.00	16.0	16.1	16.4	16.7	HC-2	22		I-75 Culvert
HALFWAYUP 6200.00	14.1	14.5	15.2	15.9	HC-3	14.5	15.8	Halfway Cr downstream of I-75 Culverts
HALFWAYCRDS 10259.19	13.9	14.3	14.9	15.5	HC-4	14.3	15.8	Brooks Outfall North weir
HALFWAYCRDS 11900.00	13.7	14.0	14.5	15.0	HC-5	16.8	15.2	Villagio North Road

Location Upstream of Description	5yrDS	10yrDS	25yrDS	100yrDS				
HALFWAYCRDS 12800.00	13.6	13.9	14.4	14.9	HC-6	16.5	15.2	U.S. 41
HALFWAYCRDS 14100.00	12.7	13.1	13.6	14.0	HC-7	NA		Boyle 2nd Survey XS
HALFWAY_S 7450.00	14.0	14.3	14.9	15.6	HC-S1	NA		Brooks South Weir
IMPERIAL 4588.00	10.8	11.2	11.8	12.2	IR-1	22.8		I-75 Bridge
IMPTRIB75 1591.21	9.4	10.0	10.9	12.1	IR-2	18.8		I-75
IMPTRIB75 2739.50	9.4	10.0	10.8	11.3	IR-3	10.5		Pinecrest Lane
IMPERIAL 8430.00	8.1	8.8	10.0	10.6	IR-4	10	9.3	Bourbonierre Bridge
IMPERIAL 14107.61	6.6	7.4	8.5	9.7	IR-5	13.3		Matheson Road
KEHLCAN 10141.40	15.5	15.7	16.0	16.4	KC-1			Poormans Road
KEHLCAN 15981.27	15.1	15.3	15.7	16.0	KC-2	16		Vincent Road
KEHLCAN 20377.30	14.4	14.6	15.0	15.4	KC-3	16		Kehl Canal at GreenMeadows
KEHLCAN 30702.10	13.4	13.8	14.2	14.7	KC-4	12.7	13.7 Club	Kehl-1-Gate
STRIKELN 4921.26	13.9	14.0	14.1	14.5	SC-1	13.2	13	Strike Lane at Stillwell Rd
SPRINGCRSS 1574.80	9.7	10.3	11.0	12.6	SC-10	13		Old 41
SPRINGCRSS 2500.00	9.4	9.9	9.2	10.4	SC-11	14		RR crossing
SPRINGCRSS 2900.00	7.3	7.4	8.4	9.8	SC-12	10.7		New road to Pueblo Bonito Ph III
SPRINGCRSS 4000.00	6.6	6.7	7.1	8.4	SC-13	8		Countess Lane
SPRINGCRSS 4700.00	3.2	3.5	4.2	5.6	SC-14	10		Just upstream of FPL Crossing
SPRINGCR 4944.23	2.6	3.2	3.9	5.1	SC-15	8.3		SpringCrSS Confluence with SpringCr
STRIKELN 10232.94	13.7	13.8	13.9	14.2	SC-2	14.2	13	Strike Lane at Moriah Lane
FAIRWAYESTATES 10750.00	10.2	10.6	11.4	13.1	SC-3	13.7	12.5	Stillwell Weir
MORIAHCANAL 2952.76	10.4	11.1	12.1	13.6	SC-5	10.6	13	Moriah Weir
SPRINGCR 1139.99	10.3	11.0	11.8	12.8	SC-6	16		Spring Ck N trib at Old U.S. 41
SPRINGCR 2362.20	10.3	10.9	11.8	12.7	SC-7	15		Bernwood Dr
SPRINGCR 3707.35	8.4	9.0	9.8	10.2	SC-8	13		FPL crossing
SPRINGCR 4079.99	4.6	5.3	6.2	7.3	SC-9	7		Cedar Culvert

4.2.2 10-Year Design Storm

Conditions for the 10-year design storm are similar to the 5-year design storm. There is one additional flooded road in San Carlos Estates, which is Moriah Lane next to the Moriah Canal upstream of the Moriah Weir. The peak stage is 11.1 ft-NAVD (12.5 ft-NGVD). It is likely that there are additional streets that connect to this road that will also experience flooding, such as Papillon, Ponson, and Busy Bee Drives. As mentioned above, there is no level of service defined by Lee County for San Carlos Estates. Flooding of private residences is also anticipated for houses upstream of the Moriah weir in San Carlos Estates. This information is consistent with field observations of a by-pass of the Moriah weir that was observed in the fall of 2008. The right bank of the channel leading south to the Moriah weir is parallel to a cypress swamp west of the Moriah Canal. The levee is breached at approximately elevation 8.8 ft-NAVD (10.1 ft-NGVD), which is 0.1 feet higher than the spillway elevation for this weir.

The permit records for the Village of Country Creek indicate that the minimum finished floor elevation for Basin 2 is below the 10-year elevation for the Estero River at chainage 4944 feet. This is the location of the Rivers Ford Road bridge (the bridge is actually on Halfhitch Lane that connects Rivers Ford Road to Country Creek Drive). This bridge is located in the Village of Country Creek Estates that is north of Corkscrew Road and west of Three Oaks Parkway. Further investigations are needed to determine if structural flooding is anticipated upstream of this bridge.

The Manna Christian Trailer Park in the Kehl Canal watershed east of I-75 and north of Bonita Beach Road also experienced flooding during Tropical Storm Fay. All of the trailers that experienced flooding have been raised, however the clubhouse is a permanent structure with a finish floor elevation = 13.7 ft-NAVD, 0.1 feet less than the 10-year peak stage for the upstream side of the Kehl Canal gate (located just downstream of Manna Christian Trailer Park).

Water surface profiles are presented in **Appendix 2**.

4.2.3 25-Year Design Storm

There are two additional street bridges that will experience flooding during the 25-year design storm. These bridges are located in the North Branch of the Estero River. The bridges are:

- Rookery Circle (just west of Three Oaks Parkway and south of Estero Parkway),
- Rivers Ford Road (the bridge is actually located on Halfhitch Lane that connects Rivers Ford Road to County Creek Drive).

The Quinn Street area of Bonita Springs has seven houses with finished floor elevation less than 10 ft-NAVD, and the minimum finished floor elevation in this neighborhood is 9.3 ft-NAVD. The 25-year peak stage for the Imperial River at the Bourbonniere bridge is 10 ft-NAVD. This neighborhood experienced flooding in 1995 and during Tropical Storm Fay in 2008, therefore these findings are not unexpected. The Lee County 2007 Lee Plan has established a goal that major arterial roads in the Imperial River watershed will be passable during a 25-year storm. Major arterial roads in the Imperial River watershed include Bonita Beach Road, Old U.S. 41, Imperial Road, and West Terry Street from Old U.S. 41 to U.S. 41. Based on the information available to AECOM, it does not appear that these roads will experience flooding during the 25-year design storm. There is no level of service established by Lee County for the Estero and Halfway Creek watersheds.

Flooding of private residences is also anticipated for houses upstream of the Moriah weir in San Carlos Estates and as mentioned above, for the Manna Christian Trailer Park.

Water surface profiles are presented in **Appendix 2.**

4.2.4 100-Year Design Storm

Road flooding is expected throughout the study area a for the 100-year design storm The only roads designed to provide safe passage for the 100-year design are major evacuation routes established by FDOT, such as I-75. Flooding of some roads is predicted during the 100-year storm for many residential developments such as the Stonybrook development, which is located east of I-75 and south of Corkscrew Road. This information is consistent with information presented in the permit for that development (Permit No. 36-01685-S). Minor road flooding is also possible for the Estero River at chainage 11,115 (U.S. 41). The peak stage at the corner of Strike Lane and Stillwell Parkway in San Carlos Estates is 14.5 ft-NGVD, and flooding of multiple structures is expected for the 100-year design storm. Flooding of private residences is also anticipated for houses upstream of the Stillwell and Moriah weirs in San Carlos Estates.

Water surface profiles are presented in **Appendix 2.**

4.2.5 1995 Design Storm

The summer rainfall from 1995 was spliced into the 2006 rainfall file to create a synthetic rainfall time series to evaluate possible consequences of a repeat of 1995 rainfall conditions. Rainfall during the summer of 1995 was frequent, and there were four events during the summer that gradually increased the groundwater conditions such that the last event in late September fell on a saturated watershed. Peak stages were very high and there was an extended duration of high water levels. The 1995 floods were the stimulus for the 1999 South Lee County Watershed Plan, and numerous measures were instituted to reduce the flooding conditions experienced during that summer. The analysis conducted for this study uses the existing system of channels, bridges, culverts, and water control structures and then predicts the response of the existing system to 1995 rainfall conditions. Because the existing hydraulic conveyance system is different from what was present in 1995, one should not expect that the predicted stages for today's conditions will be the same as they were in 1995. The simulation results (Table 4-4) indicate flooding in the Manna Christian Trailer Park north of Bonita Beach Road and east of Bonita Grande Drive. Flooding of one or two homes in the Quinn Street area are indicated, and flooding of San Carlos Estates is indicated.

Table 4-4: Peak Stage and Flow Data for 1995 Event Simulation

LC_LS_ECM_95Precip_Event_ADA_Base_v2b_042309.RES11		1995 Rainfall	
Location	Branch H & Q Chainages	Water Level	Discharge
Kehl Canal Gate	KehlCan 30702, 30767	14.3	1,725
Imperial R. I-75	Imperial 4588, 4888	11.8	1,832
Imperial R. Bourbonniere	Imperial 8430, 8488	9.5	1,876
Halfway Ck., I-75	Halfwayup 5889, 6049	14.1	225
By-pass Gate to SB Estero	HW 3939, ThreeOaks 25	13.9	9
Brooks North Weir	HalfwayCRDS 10259, 10400	13.8	374
Brooks South Weir	HalfwayCrS 7450, 7555	13.9	68
Halfway Ck., U.S. 41	HalfwayCRDS 12800, 12870	13.6	400
SB Estero I-75	EsteroRivS 99, 252	16.8	68
SB Estero, Sanctuary Rd	EsteroRivS 4100, 4200	11.6	98
SB Estero, Three Oaks	EsteroRivS 6299,	9.6	144
SB Estero, Corkscrew Rd	EsteroRivS 8628	9.1	184
SB Estero County Ck Dr	EsteroRivS 11155, 11250	6.9	321
NB Estero, I-75	EsteroI75 328, 450	16.0	102
NB Estero, Rivers Ford Rd	EsteroRiv 4944, 4980	10.5	231
Strike Ln at Stillwell Rd	StrikeLn 4921	13.8	#N/A
Stillwell Weir	FairwayEstates 10750, 10800	10.0	97
Moriah Weir	MoriahCanal 2952, 3116	10.0	100
Countess Lane	SpringCRSS 4000, 4245	6.3	204
Spring Ck Trib RR	SpringCR 3200, 3253	9.6	63
Spring Ck Trib Cedar Ln	SpringCR 4079, 4400	4.2	69

Table 4-5 provides a comparison of the measured 1995 flows and stages at key locations to simulated flows from this study. The measured data from 1995 came from page 2-6 of Deliverable 1-B, Data Collection Report, Johnson Engineering, 1999. The measured flows are only spot measurements, and the simulation results indicate that September 7, 1995 was during a period of decreasing flows following the peak. Therefore, the comparisons can only be general in nature.

The comparison indicates a number of trends that appear to be consistent with the existing understanding of the situation. Flows in the Imperial River are generally in agreement for the Imperial River. Measured 1995 stages are slightly higher at the Kehl Canal structure and the IBE Bridge than the 2009 simulated values. Lower stages are not unexpected since there were changes made to the Kehl Canal gate (it was only a weir in 1995, and there are now two gates in addition to the weir) and the IBE Bridge (the Bourbonniere bridge replaced the IBE bridge, and it has twice the width of the old IBE bridge). Spring Creek flows are low for both measured 1995 conditions and the 2009 simulation of 1995 conditions with upgrades to the Old U.S. 41 culverts. Since there are major flow obstructions downstream of Old U.S. 41, it is not surprising that the

2009 simulation does not show a flow increase. Simulated flow using the 2009 model is greater than measured 1995 conditions for Halfway Creek. This also is not surprising since there were flow conveyance improvements made in the Spring Creek watershed. Measured 1995 flows and stages are higher than 2009 simulation results. Again, this is not unexpected since there are more flow obstructions today than are believed to have been present in 1995.

Table 4-5: Comparison of Measured 1995 Stage and Flow Data to Simulated Values from the 2009 Model

Location	Meas. H 9/7/95, ft-NAVD	Meas. Flow, cfs	2009 sim. H, ft-NAVD	2009 sim Q, cfs
S Branch Estero, Corkscrew Rd	8.1	249	5.4	67
Halfway Ck, US 41	11.2	36	12.9	246
Spring Ck, N Branch, Old US 41		4	7.0	15
Spring Ck, S Branch, Old US 41	7.2	44	5.0	20
Imperial R., Old US 41	3.3	1794	5.2	1600
Kehl Canal Weir	14.2		13.8	1340
IBE Bridge	9.2		8.0	1450

4.3 Differences between this analysis and the 1999 SLCWP

The section presents a comparison of stages and flows between this 2009 South Lee County Watershed Plan Update and the 1999 SLCWP study. Overlapping information was available for the following locations.

- Estero River South Branch at I-75
- Estero River South Branch Corkscrew Road,
- Halfway Creek at US 41,
- Spring Creek at Strike Lane
- Spring Creek South at Old US 41
- Spring Creek @ FPL crossing
- Spring Creek at US 41
- Kehl Canal at Bonita Grande Drive
- Imperial River at Matheson Street Bridge

Differences in flows are shown in **Table 4-6** below.

Table 4-6: Comparison of Simulated Flows (cfs) for the 5-, 10-, 25-, and 100-Year Design Storms

River	Chainage	1999 SLC Flood Study				2009 SLC Update			
		5	10	25	100	5	10	25	100
Estero River South Branch at I-75	252.6	196	248	343	380	58	68	88	130
ER SB Corkscrew Rd,	8697.5	196	243	340	378	228	303	432	482
Halfway Ck at US 41,	12870	85	87	84	129	407	480	612	744
Spring Ck at Strike Lane,	14107.6	32	43	78	103	30	64	97	128
Spring Ck South at Old US 41	1637.1	59	79	145	189	70	85	107	108
Spring Ck @ FPL crossing	3900	160	217	400	520	78	97	120	132
Spring Ck at US 41.	7358.9	160	217	400	520	410	500	715	1,110
Kehl Canal at Bonita Grande Drive	98.4	782	830	1,205	1,641	1,177	1,349	1,680	2,054
Imperial R at Matheson Street Br	14291	939	940	1,312	1,736	1,078	1,526	1,927	2,389

River	Difference, cfs				Difference, %			
	5	10	25	100	5	10	25	100
Estero River South Branch at I-75	-138	-180	-255	-250	-70%	-73%	-74%	-66%
ER SB Corkscrew Road,	32	60	92	104	16%	25%	27%	28%
Halfway Ck at US 41,	322	393	528	615	379%	452%	629%	476%
Spring Ck at Strike Lane,	-2	21	19	25	-6%	49%	24%	25%
Spring Ck South at Old US 41	11	6	-38	-81	-59	-79	-145	-43%
Spring Ck @ FPL crossing	-82	-120	-280	-388	-51%	-55%	-70%	-75%
Spring Ck at US 41.	250	283	315	590	156%	130%	79%	114%
Kehl Canal at Bonita Grande Drive	395	519	475	413	50%	63%	39%	25%
Imperial R. at Matheson Street Bridge	139	586	615	653	15%	62%	47%	38%

Flow differences were attributed to:

- the use of a more comprehensive model
- updated data
- change in channel, land use, and other information
- different antecedent conditions

This study indicates that there is less flow for the South Branch of the Estero River at I-75. The low flows are likely a result of constrictions in the channel downstream of I-75. The invert elevation at the I-75 bridge is 12 ft-NGVD, and the surveyed elevation at the channel bottom just downstream of the bridge is 14.6 ft-NGVD. There is also fill in the floodplain associated with a parking lot for recreational vehicles of residents in Corkscrew Woodlands. Extensive infestation of Melaleuca is present on the left bank of the South Branch of the Estero River downstream of I-75. The flow in Halfway Creek at U.S. 41 is predicted to be 738 cfs for the 100 year design storm. The flow is less than 400 cfs with the FPL cross section that was present prior to implementation of this restoration project. Peak flows are generally higher in the Imperial River. This is believed to be due to snagging and clearing of the Imperial River after the 1995 event and elimination of a bridge west of I-75.

Flows are also significantly less than the 1999 SLCWP for the Emergency by-pass from Halfway Creek to the South Branch of the Estero River. The design flow from the 1999 plan was 160 cfs, and the 5-, 10-, 25-, and 100-year peak flows from this assessment are 11, 16, 30, and 9 cfs, respectively.

Differences in stages (NAVD) are shown in **Table 4-7** below.

Table 4-7: Comparison of Simulated Stages (NAVD) for the 5-, 10-, 25-, and 100-Year Design Storms

River	Chainage	1999 SLC Flood Study				2009 SLC Update			
		5	10	25	100	5	10	25	100
Estero River South Branch at I-75	252.6	16.7	17.7	18.2	18.3	16.6	16.8	17.2	17.6
ER SB Corkscrew Road,	8697.5					9.7	11.0	12.7	13.8
Halfway Ck at US 41,	12870	12.8	12.8	12.8	13.0	7.5	8.3	14.4	14.9
Spring Ck at Strike Lane,	14107.6	13.0	14.3	15.5	15.6	13.7	13.8	13.9	14.2
Spring Ck South at Old US 41	2200	10.1	10.6	11.4	11.7	10.3	11.0	11.8	12.8
Spring Ck @ FPL crossing	3900	5.9	6.2	6.8	7.2	8.4	9.0	9.8	10.2
Spring Ck at US 41.	7358.9	2.7	2.8	3.3	3.7	2.5	3.0	3.7	4.9
Kehl Canal at Bonita Grande Drive	98.4					13.4	13.8	14.1	14.5
Imperial R at Matheson Street Bridge	14291					6.6	7.4	8.5	9.7

River	Difference			
	5	10	25	100
Estero River South Branch at I-75	-0.1	-0.8	-1.0	-0.7
ER SB Corkscrew Road,				
Halfway Ck at US 41,	-5.3	-4.6	1.7	1.9
Spring Ck at Strike Lane,	0.7	-0.5	-1.5	-1.4
Spring Ck South at Old US 41	-0.3	-0.4	-0.4	0.9
Spring Ck @ FPL crossing	2.5	2.8	3.0	3.0
Spring Ck at US 41.	-0.2	0.3	0.4	1.2
Kehl Canal at Bonita Grande Drive				
Imperial R at Matheson Street Bridge				

Stage differences were attributed to:

- the use of a more comprehensive model
- updated data include cross sectional survey
- change in channel, land use, and other information

Peak stages are generally higher than for the SLCWP, and the locations with the largest increases in stage are

- Spring Creek at the FPL crossing (due to exotic vegetation and clogged culverts),
- Imperial River at Matheson Street Bridge
- Spring Creek at Strike Lane in San Carlos Estates
- Halfway Creek at U.S. 41 (due to a number of factors)

4.4 Comparison of Simulations to Historical Flows and Stages

In seeking to re-distribute peak flows in the South Lee County streams, the flows listed in **Table 1-6** will be used as general guides when evaluating alternatives, except for Halfway Creek. Due to improvements made in the Halfway Creek basin since 1999, this study will not recommend flow reductions for Halfway Creek. Halfway Creek conveyance improvements **may be considered** that reduce peak stages in areas where permitted developments were constructed on the presumption of maintaining regulatory peak stages. Halfway Creek conveyance improvements will consider wetland and scour impacts.

In addition to evaluating Halfway Creek peak flow conveyance (required by the Statement of Work), this study will identify other routes for re-direction of flows away from the Imperial River as long as flooding problems are not created by the diversions. This is a particular concern for the South Branch of the Estero River, where the current 100-year peak flow estimate of 128 cfs is less than 10% of the estimated historic peak flow. South Branch Estero River flows are constricted by fill and exotic tree infestation in the natural floodplain of the South Branch Estero River. Impacts to the Corkscrew Woodlands neighborhood (just west of I-75 and adjacent to the South Branch) will have to be evaluated carefully for alternatives involving re-direction of flows to the South Branch of the Estero River. Additional survey information of the Corkscrew Woodlands Estero levee will be required for any detailed consideration of this recommendation. In all cases, this effort seeks to increase conveyance where it is appropriate while protecting hydroperiods of wetlands systems of the watershed.

Range of Flows – Existing vs Pre-Development Conditions. The DRGR study has conducted simulations that predict flows and stages that might occur if all existing urban developments (including road culverts and bridges) were removed. For the purposes of this discussion, the simulated pre-development flows are referred to as Natural System Model (NSM) flows. The NSM flows presented herein are only approximations of what might have occurred during pre-development conditions as the topography and stream channel dimensions of pre-development conditions are unknown. Flows from this natural system model were compared to the final calibration flows for the 2006 year (see **Figures 4-2 – 4-5**). The results are very interesting:

- The simulated base condition Imperial River flows are much higher than simulated historic flows
- The simulated base condition South Branch Estero River flows are much less than simulated historic flows

- Halfway Creek base condition simulated flows are similar to historic flows

Maintenance of Halfway Creek flows were based on the design analysis of the SLCWP, which partially explains the small difference between existing and prior flows. The difference between base condition and natural system flows for the Imperial River and South Branch of the Estero River provide a basis for formulating an appropriate flow-balancing strategy.

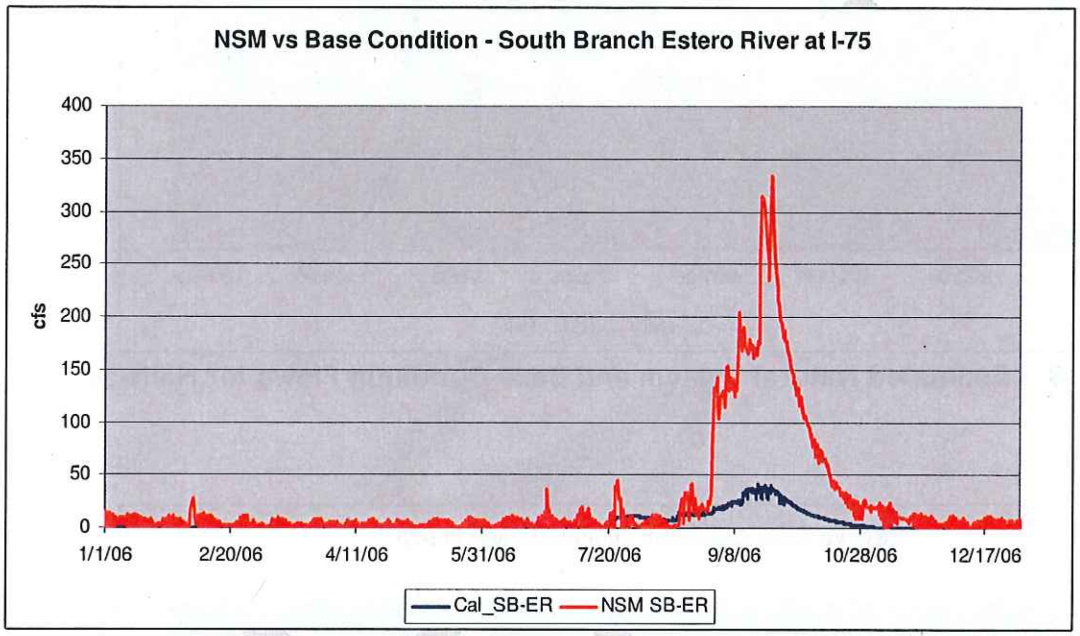


Figure 4-2: Estimated Natural System and Base Condition Flows for the South Branch of the Estero River

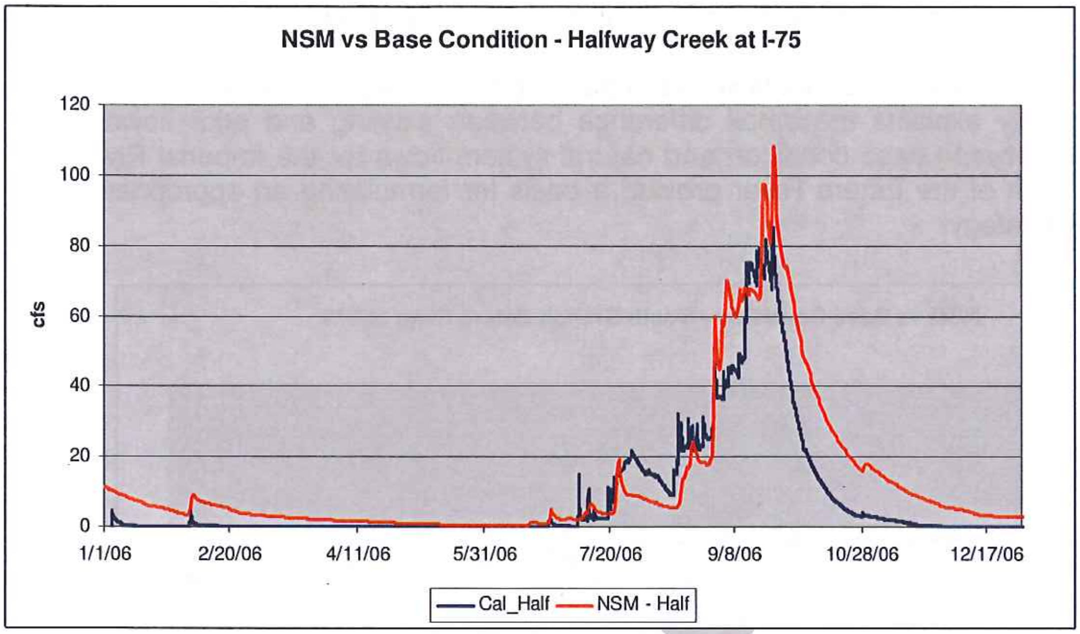


Figure 4-3: Estimated Natural System and Base Condition Flows for Halfway Creek

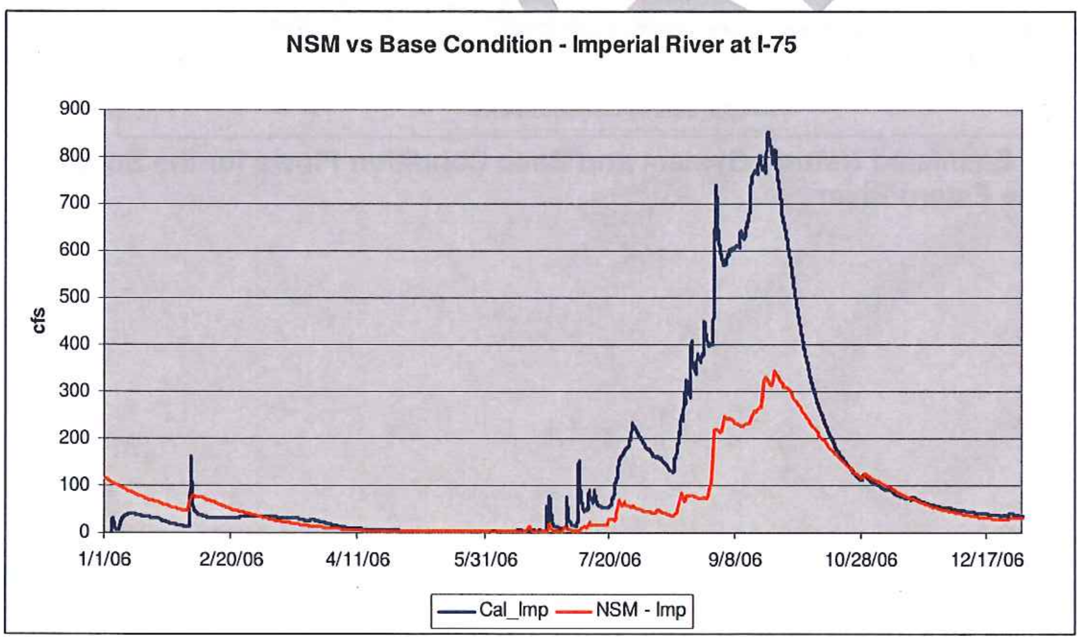


Figure 4-4: Estimated Natural System and Base Condition Flows for the Imperial River

Hydroperiod Requirements for Wetlands East of I-75. The ecologic assessment measured seasonal and maximum high water marks for a number of locations east of I-75 for the headwaters of Halfway Creek and the South Branch of the Estero River. Seasonal high water depths were in the range of 0.5 feet for pine flatwoods and 1.0 - 1.5 feet for cypress wetlands, which is consistent with best available information on water depth ranges of cypress wetlands from Michael Duever of SFWMD presented in **Table 4-8**. The information in **Table 4-8** was compared to model results for the four alternatives, and alternatives that have simulated wetland water depths and hydroperiods close to optimum conditions will rank higher from an ecosystem perspective. The analysis was conducted for all major wetlands within the study area east of I-75. The focus area of the ecologic field work (just east of I-75 from south of Corkscrew Road to the south end of the Brooks) was used to verify the validity of the results for the alternatives analysis since direct field measurements were conducted in that area.

Table 4-8: Water Depth and Hydroperiod Ranges for Undisturbed Southwest Florida Wetland Communities (source: M. Duever, SFWMD)

High Water Level (inches)	Hydroperiod (months)	Plant Communities
≤ 2	≤ 1	Mesic Pine Flatwoods, Mesic Hammock
2 – 6	1 – 2	Hydric Pine Flatwoods, Hydric Hammock
6 – 12	2 – 6	Wet Prairie, Dwarf Cypress
12 – 24	6 – 10	Marsh
12 – 18	6 – 8	Cypress Forest
18 – 24	8 – 10	Mixed Swamp Forest
> 24	> 10	Open Water

The evaluation also assessed normal pool elevations in wetlands east of I-75. As discussed in Chapter 6, further modeling work needs to be done to refine recommended normal pool elevations.

Summary of Approach for Determining Target Flows and Stages

The general approach for flow re-distribution is to reduce flows in the Imperial River and to increase flows in the South Branch of the Estero River. Final target stages are presented below and were based on a number of factors including ecologic, hydrologic, and economic factors.

Design Storms. Where possible, peak 100-year design storm water levels need to be reduced to the following ***target*** elevations (organized by drainage area):

Imperial River

- 10.0 ft-NAVD at the Bourbonniere bridge near the Quinn Street area of Bonita Springs, which experiences frequent flooding. There are seven houses in the

Quinn Street area that have first-floor elevations below 10 feet NAVD (Source: City of Bonita Springs).

- 14 ft-NAVD at the upstream side of the Kehl Canal gate. There are approximately 10 housing units in the Manna-Christian trailer park with first floor elevations that range from 12.7 to 13.8 feet-NAVD (Source: Lee County).

Spring Creek

- 13 ft-NAVD in San Carlos Estates upstream of the Moriah and Stillwell Weirs. There are three houses in San Carlos Estates with elevations less than 13 ft-NAVD (Source: Morris Depew).
- 14 ft-NAVD in San Carlos Estates at the intersection of Strike Lane and Stillwell Parkway. There is one house in San Carlos Estates with elevations less than 14 ft-NAVD (Source: Morris Depew).
- 9.7 ft-NAVD for Pueblo Bonito Phase III (first culvert downstream of wooden RR, source: SFWMD Permit #36-03295-P).

Halfway Creek

- 16.2 ft-NAVD at Three Oaks Parkway (minimum Brooks FFE)
- 15.2 ft-NAVD at Via Villagio and U/S of U.S. 41. (minimum Rapallo FFE)

South Branch of the Estero River (based on surveying conducted by AECOM and Lee County)

- 14.7 ft-NAVD at the Sanctuary Road bridge in Corkscrew Woodlands
- 14.1 ft at Lee County cross section #2 (3,400 ft U/S of Sanct Rd Br)
- 14.6 ft-NAVD at Lee County cross section #3 (2300 ft U/S of Sanct Rd Br)
- 16.0 ft-NAVD at Lee County cross section #4 (740 ft U/S of Sanct Rd Br)

North Branch of the Estero River

- 11.2 ft-NAVD at Rivers Ford Bridge (minimum Country Creek FFE, Source: SFWMD Permit #36-00735-S)

Wetland Water Levels. In addition to the design storm analysis, water depth ranges for a three-year continuous 2006-2008 simulation was checked in a number of wetland systems east of I-75. Spot checks were made in a range of wetland communities using information from **Table 4-8** to determine impact to wetland hydrology.

5 ALTERNATIVES ANALYSIS

This section provides a description of the alternatives evaluated to improve the flow distribution to the Estero River, Halfway Creek, Spring Creek, and Imperial River. The first step in developing the alternatives was to describe 14 components that individually address one or more problems identified in the Problem Identification task. The 14 components were posted to the SFWMD external web site for stakeholder review, and comments on those alternatives were received and considered during the initial development phase of the four alternatives, which consisted of options from the 14 components. Section 5.2 describes the alternatives in greater detail and provides simulation results. Section 5.3 compares the alternatives and provides an ecological assessment of the alternatives performance. Section 5.4 provides a description of refined alternatives and summarizes the results.

5.1 Potential Measures to Improve the Distribution of Flows in South Lee County

The problem identification task listed areas of flooding in the South Lee County area. The ecologic assessment identified wetland impacts east of I-75, and the southern Corkscrew Regional Ecosystem Watershed (CREW) Team has ecologic restoration goals for lands east of I-75 both north and south of Bonita Beach Road. Water supply planning efforts are also underway to identify additional sources of water to meet the future needs of South Lee County. These challenges are sometimes conflicting and sometimes complimentary. For example, storage of water upstream of I-75 can reduce flooding problems and, within constraints, also provide water for both wetland rehydration and public consumption. These constraints include:

- If water is frequently stored at depths greater than normal inundation depth ranges, then ecosystem damage will occur.
- High aquifer permeability limits the depth of storage if residential communities are nearby the storage area. Water level rise in an isolated mining pit north of Bonita Beach Road and east of Vincent Road was two feet during Tropical Storm Fay (fall, 2008). The water level was at similar elevations with Kehl Canal (which is adjacent to the mining pit). Direct rainfall on the mining pit was only five inches, which indicates that seepage through the ground (two feet minus five inches)is high in the vicinity of Kehl Canal.
- Improving conveyance will be feasible as long as that improved conveyance does not drain nearby wetlands and minimizes direct impact to wetland ecosystems. This will be a constraint in Halfway Creek west of U.S. 41 where improving conveyance cannot lower dry season water levels in the cypress wetlands.

Four alternatives will be evaluated with the objectives of reducing flooding, improving peak flow distribution, and improving wetland hydration. These alternatives will consist of multiple components that together will address the multiple challenges in the Estero River, Halfway Creek, Spring Creek, and the Imperial River watershed.

This section presents a range of ideas that address one or more water resource challenges of the study area. Each idea originated from a problem identified during the Task III Problem Identification phase. For example, high stages and low flows were identified as problems in the Halfway Creek watershed. Ideas 1, 2, 3, and 5 address that problem. Flooding in Bonita Springs was identified as a problem, and ideas 10, 11, and 14 were identified to address that problem. These ideas were circulated within SFWMD and Lee County for comment, and then the ideas were distributed to all stakeholders who attended any of the public meetings or asked to be on the mailing list. All comments were reviewed prior to finalizing the four alternatives identified below in **Section 5.2**.

The next section will combine a number (but not necessarily all) of these ideas into four alternatives that will be evaluated using the hydrologic/hydraulic model and the ecologic constraints.

Idea 1: Johnson Engineering, Inc. provided a figure showing some lakes deeded to Lee County downstream of Via Coconut Point Road and upstream of Via Villagio Rd. that are disconnected from the Halfway Creek flow-way by a wooden boardwalk. They suggested raising the boardwalk at the upstream and downstream ends of the lake (shown by the red lines in **Figure 5-1**) to increase conveyance in Halfway Creek. The lakes were created during construction of the Rapallo Development, but are outside the property lines of Rapallo.

Figure 5-1: Connection to the Rapallo Lake North of Halfway Creek and West of Via Coconut Point

Idea 2: Similar to Idea 1, but downstream of U.S. 41. The concept is to dredge out a connection from the wooden walkway to an existing channel on the north side of Halfway Creek that runs along the Fountain Lakes Development. The location of the improvements and key Halfway Creek features are presented in **Figure 5-2**. The wooden walkway may have to be raised to increase conveyance under the walkway. Additional upstream culverts may be needed at either U.S. 41 and/or Via Villagio. Any removal of vegetation would require an environmental site assessment and could not proceed without an environmental resource permit.

Idea 3: Similar to **Idea 2**, however, increase conveyance in Halfway Creek by removing accumulated sediments, fallen trees, dead brush vegetation, and weedy brush vegetation west of U.S. 41. The material would be removed along the centerline of Halfway Creek west of U.S. 41 (the hatched polygon in **Figure 5-2**) rather than along the north side of the flow-way. Along with this activity, modify current vegetation management strategies east of U.S. 41. The current vegetation management strategy east of U.S. 41 allows for piling of cleared vegetation in stacks (tee-pee style). This practice complicates downstream maintenance, and the management approach should be modified to remove any cleared vegetation and debris. This vegetation maintenance program would have to be implemented frequently to maintain adequate flow conveyance. Any removal of vegetation would require an environmental site assessment and could not proceed without an environmental resource permit.

Idea 4: Yearly maintenance needs to be coordinated for critical flow-ways. Private entities should conduct the clearing where required by permit conditions, and government maintenance programs need to be modified to clear those remaining sections of critical flow-ways.

Figure 5-2: Connection to the Fountain Lakes Channel North of Halfway Creek and West of U.S. 41

Idea 5: Dredge out the emergency bypass channel just east of Three Oaks Parkway from Halfway Creek to the South Branch of the Estero River. Remove the water quality weir from the bypass channel that is 450 feet south of the South Branch of the Estero River at the Three Oaks Parkway culverts. The water quality weir has the 1.1 foot V-notch opening with the top of the weir at 14.0 ft-NGVD. The 100-year design storm model shows that flow from the Brooks to this branch is less than 50 cfs (the original design flow was 160 cfs). Replacement of water quality treatment facilities will be needed to off-set the loss in storage. This study does not include the design of the replacement water quality facilities.

Idea 6: Install one or more new I-75 culverts to Spring Creek that flows across the north end of San Carlos Estates (Bonita Bill Canal). This canal would have to be expanded, which would require buying parcels in San Carlos Estates. Most of these parcels are undeveloped, and one house would need a new driveway. The location of this idea is shown in **Figure 5-3**.

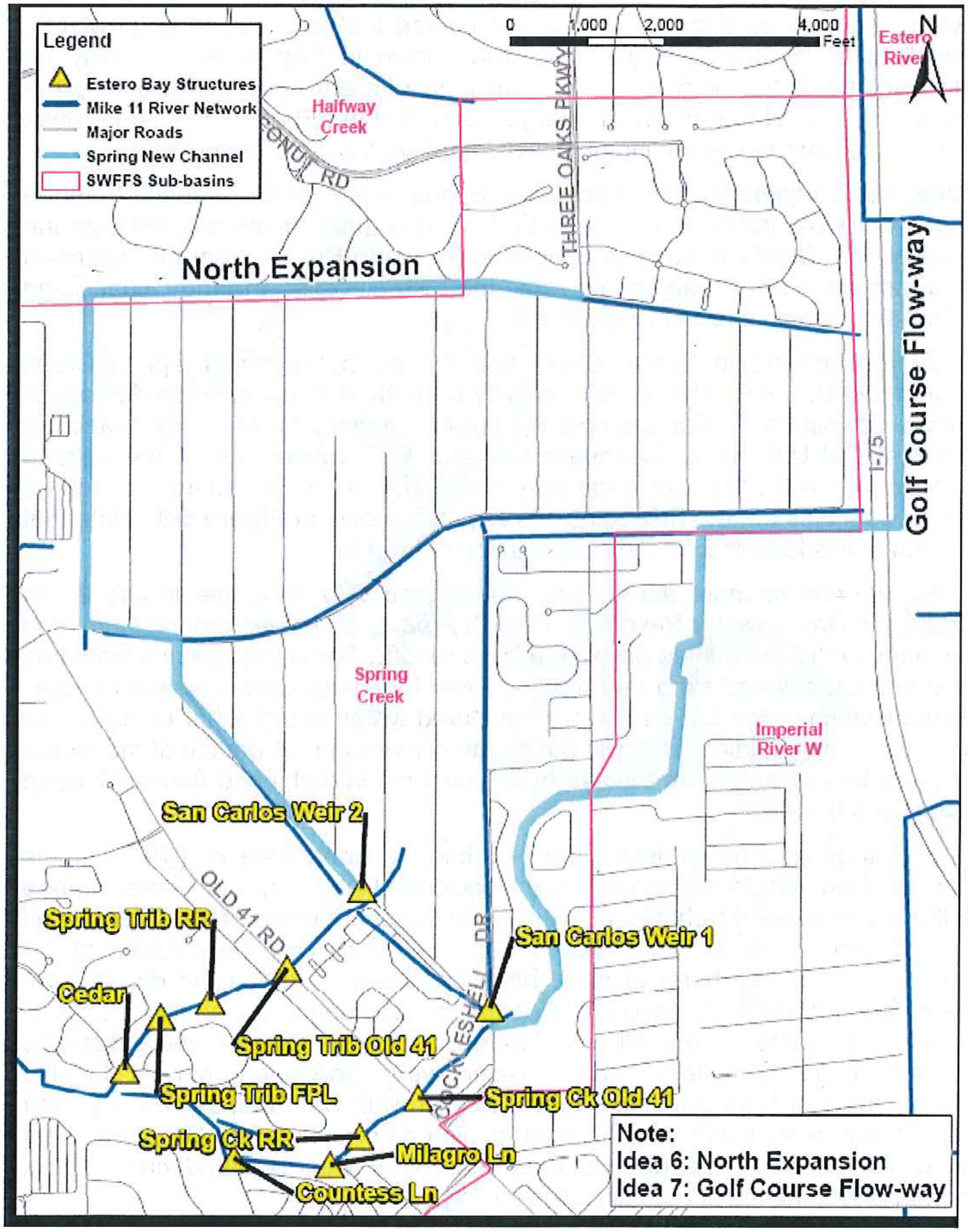


Figure 5-3: Increase Conveyance from I-75 to Spring Creek at U.S. 41

Idea 7: Similar to **Idea 5**, but route the water under I-75 and then south of San Carlos Estates toward Spring Creek south of the San Carlos Estates Stillwell Canal weir. This location is at the intersection of Fairway Estates Road south of the Stillwell weir. Property would have to be acquired from a golf course that was closed as of March, 2009. The location of this conveyance is also shown in **Figure 5-3**. It may be appropriate to combine this with Idea 6 if there is insufficient land available in either route to construct a canal that conveys a target peak flow of 160 cfs. The target peak flow may not be achievable depending on downstream conveyance restrictions.

Idea 8: Clear exotic vegetation from portions of Spring Creek (receives runoff from the Stillwell Canal weir) and the north branch of Spring Creek (that receives runoff from the Moriah Canal weir). Debris removal is needed in the north Branch from the upstream and downstream sides of the railroad culverts, the FPL culverts, and the Cedar Road culverts. This area is also shown in **Figure 5-3**.

Idea 9: Enlarge culverts in Spring Creek and the north branch of Spring Creek downstream of Old U.S. 41. The culvert capacity for both of these streams decreases as flows move downstream. For example the culvert capacity for the north branch of Spring Creek at Old U.S. 41 is 64 square feet and 12.6 square feet at the railroad culverts. In Spring Creek, the culvert capacity at Old U.S. 41 is 64 square feet and 39 square feet at Countess Lane. These culverts are also shown in **Figure 5-3**. Note that implementation of this idea requires implementation of **Idea 8**.

Idea 10: Acquire one or more mining pits (**see Figure 5-4**) no longer in use in the Density Reduction Groundwater Resource (DRGR) Area, build levees around them, and then utilize pumps to fill the mining pits with excess runoff. The pumpage rate would be equal to the amount diverted from the Imperial River to Spring Creek, Halfway Creek, and the South Branch of the Estero River. The stored water would either recharge the aquifer or be used to maintain baseflows during the dry season. A portion of the stored water could also be removed from the facility and pumped into planned Aquifer Storage and Recovery (ASR) wells.

Idea 11: Construct a berm or levee from Corkscrew Road east of I-75 from the intersection with Ben Hill Griffin Parkway and Corkscrew Road south to Bonita Grande Drive and the south levee of Kehl Canal, west along the south levee of Kehl Canal, and south along Vincent Road to Bonita Beach Road. Gates would be installed at the upstream (east) side of the berm to allow baseflow releases during the dry season, higher releases during the wet season, and peak flow attenuation during major storms. The gates would be opened at the tail end of a major storm to decrease wetland stages east of the gates to optimum late wet season water levels. Seepage from Kehl Canal to low-lying lands south of Kehl Canal is a major concern with this idea, as SFWMD staff have observed that water levels in an isolated mining pit south of Kehl Canal and east of Vincent Road increased 2 feet (the same as Kehl Canal water levels) during Tropical Storm Fay with only 5 inches of rainfall on the mining pit.

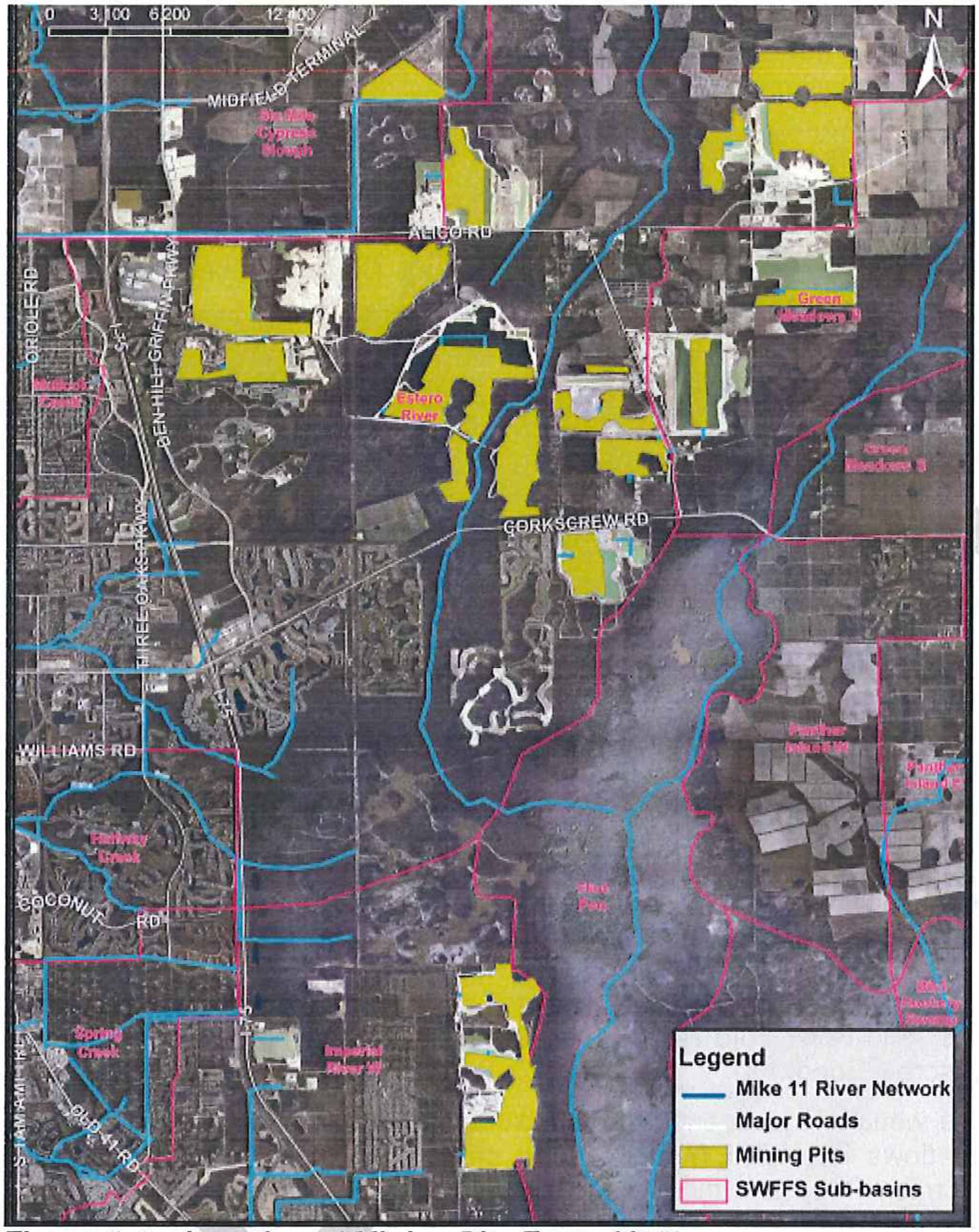


Figure 5-4: Location of Mining Pits East of I-75

Idea 12: Increase conveyance in the South Branch of the Estero River between I-75 and Corkscrew Road. Flow is restricted due to sediment accumulations, filling of the floodplain, and melaleuca just west of I-75. Removal of the sediments, fill material and vegetation would increase velocities under I-75, which were very low during Tropical Storm Fay. Melaleuca and other invasive vegetation are present just down to Three Oaks Blvd, and there is illegal fill in the floodplain upstream and downstream of Three

Oaks Blvd. **Figure 5-5** illustrates the improvements in the South Branch just west of I-75.

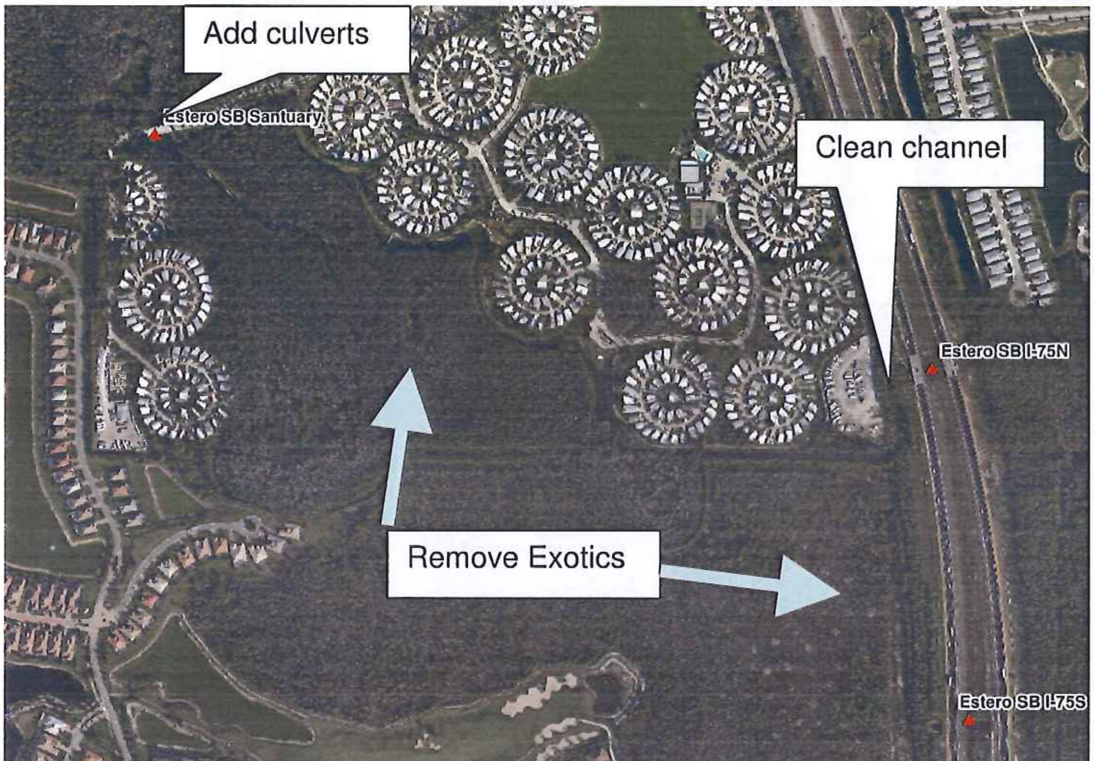


Figure 5-5: Improvements to the S. Branch Estero R. Just West of I-75

Idea 13: Increase conveyance in the North Branch of the Estero River between Alico Road (east of I-75) and River Ford Road in the Village of Country Creek (west of I-75 and north of Corkscrew Road).

Idea 14: Improve wetland hydroperiods in CREW lands north of Kehl Canal (east of I-75) and restore flows from CREW lands north of Bonita Beach Road to wetlands between Bonita Beach Road and the Cocohatchee Canal in Collier County. Possible components of this idea are:

- Construction of canal blocks in Kehl Canal upstream of Poorman's Pass Road.
- Delivery of flows to wetlands south of Bonita Beach Road
- Modification of Kehl Canal gate
- Either removal or raising the elevation of north-south roads upstream of the Kehl Canal gate.

As with **Idea 11**, implementation of this idea is constrained by flood protection needs for residential lands between Bonita Beach Road and Kehl Canal.

Rejected Ideas. The alternatives described below did not incorporate all of these 14 ideas for a number of reasons. **Table 5-1** lists those reasons for not evaluating an idea in greater detail:

Table 5-1: Ideas Not Considered Further and Why

Idea	Why Not Used
7. Route water from east of I-75 to Spring Creek via golf course east of San Carlos Estates	Assumed to be more expensive than Idea 6 and results deemed similar to Idea 6. Although this idea was not used, components were used in some alternatives
11. Water resources berm east of I-75 from Corkscrew Road to Bonita Grande Drive to raise water levels east of berm	Seepage from upstream of the berm would impact existing residential lands that are south of Kehl Canal and east of Bonita Grande Drive
13. Increase conveyance of the North Branch of Estero River between Alico Road and River Ford Road	Would require significant wetland impacts. Although this idea was not used, components were used in some alternatives
14. Improve wetland hydroperiods in CREW lands north of Kehl Canal	This concept was partially evaluated. A more detailed model is needed for further evaluation

5.2 Alternatives Evaluated In Greater Detail

The following four alternatives were evaluated further. These alternatives are based on a combination of ideas listed above in **Section 5.1** and are intended to address the range of challenges in South Lee County. During initial testing of each of these alternatives, components of ideas were modified to improve performance, and portions of one or more Alternatives were incorporated into one alternative as deemed appropriate. Note that one of the objectives of the study was to determine "the required flow and conveyance capacity to restore flows to Halfway Creek, the South Branch of the Estero River and Spring Creek" (page 2 of the Scope of Work). To that end, pre-development peak flood flows to the South Branch Estero River and Halfway Creek in Table 1-6, and the combined flow is 1,800 cfs. Section 5 indicates that the base condition peak flow for these two systems is 459 cfs, therefore it is reasonable to increase flood flows to these two systems as long as the structural improvements do not drain wetlands upstream of the structural improvements.

5.2.1 Alternative 1 – Detailed Description

This alternative is intended to increase the flow through the Halfway Creek watershed. This alternative includes up to five new culverts under I-75 to Halfway Creek, improvements in Halfway Creek conveyance and bridge/culvert replacements for areas with existing flooding, as shown in **Figure 5-6.** This alternative is a combination of the following ideas described in **Table 5-2.**:

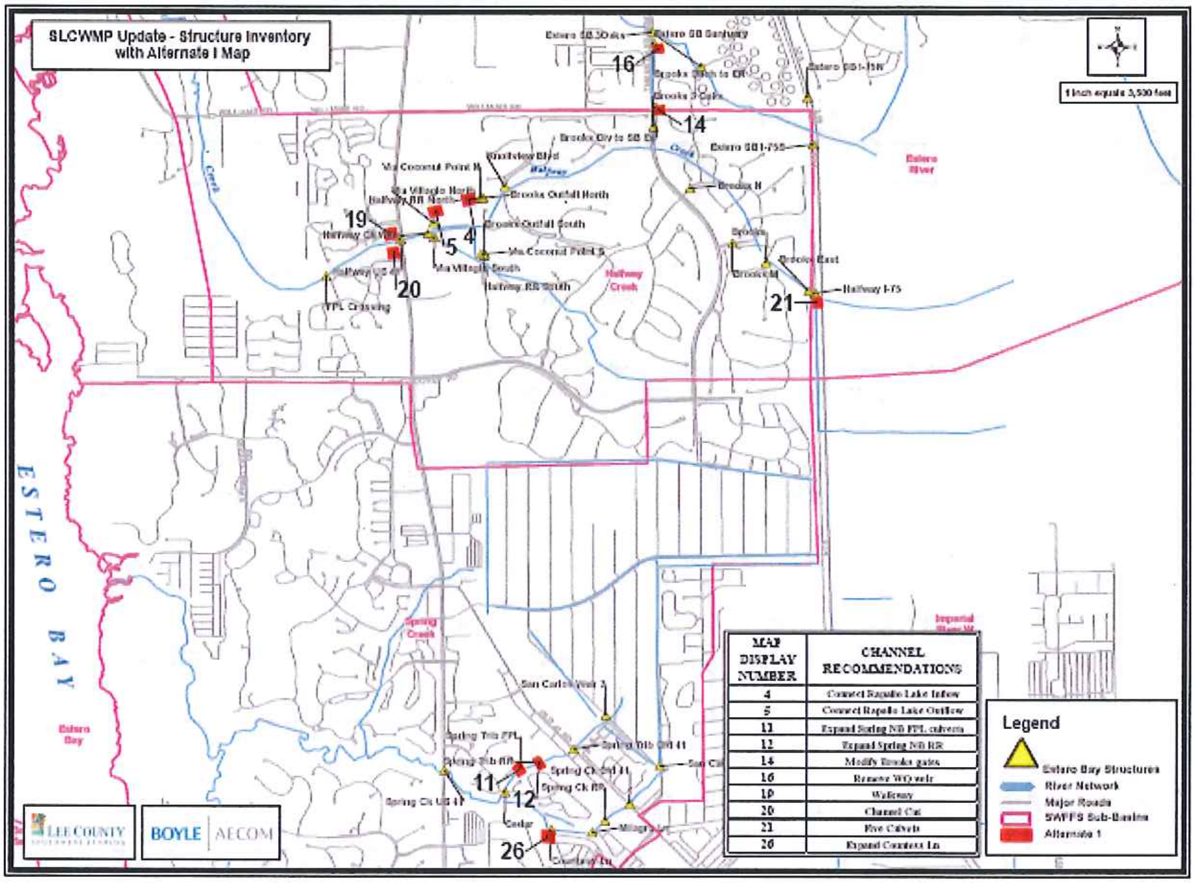


Figure 5-6: Alternative 1 Map

Table 5-2: Alternative 1 Components

Idea	Description
	Addition of up to five 60-inch diameter culverts under I-75 to Halfway Creek with an invert elevation of 9 ft-NAVD.
1	Connection of Halfway Creek to Rapallo Lake (100 ft wide weir, invert elevation 10 ft-NAVD). Raise wooden walkway above weir, with low chord raised to 15.5 ft-NAVD
2	Halfway Creek channel west of U.S. 41 (100-ft wide, invert elevation 8 ft-NAVD,)
4	Yearly maintenance of exotic and dead vegetation, Halfway Creek west of U.S. 41
5	Increase the Three Oaks by-pass channel from the Brooks to S. Br. Estero R. to have a 40-ft bottom width, lower invert elevations, remove the water quality weir, by-pass gates fully open during floods, and gate invert lowered 2 ft to 8.8 ft-NAVD
8	Clear exotic vegetation in Spring Creek
9	Enlarge Spring Creek culverts: doubled Countess Lane, add a 3'x4' culvert at

	North Branch Spring Creek for the railroad, FPL easement and Cedar Lane
13	Enlarge the Rivers Ford bridge of the North Branch Estero River (vertical side walls without widening the bridge

Note: Diagrams of the ideas are presented in Section 5.1

It is intended to achieve the target Halfway Creek flows listed in Amendment 1 of the 1999 SLCWP. This alternative includes installation of up to five new 60-inch culverts under I-75 in the Halfway Creek watershed. This alternative is also intended to provide adequate 100-year capacity for River Ford Road bridge in the North Branch of the Estero River and to improve a number of bridges/culverts in the Spring Creek watershed to be identified in the Alternatives Analysis. The permit conditions for the expansion of I-75 stipulate that of the five culverts, only three culverts are authorized that increase flows by 225 cfs. An additional two culverts could only be installed if this study indicates the need for those two additional culverts. A permit modification would be required for the two additional culverts. Note that the dimensions of the connection from Halfway Creek to Rapallo Lake may need to be refined during design phase to reduce the impact of the Rapallo Lake modifications on the adjacent residential complex.

5.2.2 Alternative 1 – Results

Table 5-3 presents a comparison of the hydraulic performance of Alternative 1 to the base condition. This alternative increases the flow from Halfway Creek to the South Branch of the Estero River by dropping the invert elevation of the by-pass gate, increasing the channel dimensions of the Three Oaks Ditch north of Williams Road, and removing the Three Oaks water quality weir. 100-year flows through the by-pass gate increase from 11 to 259 cfs. As a result, this alternative reduces stages in Halfway Creek west of the Brooks. Halfway Creek flows under I-75 with 5 additional culverts were only slightly higher (350 cfs) than base condition flows (317 cfs). There are only minor decreases in stages (0.04 ft) in the Imperial River west of I-75 at the Bourbonniere Road bridge, which is just downstream of the Quinn Street. Stages in Halfway Creek wetlands east of I-75 are lower than the base condition. Because this alternative did not have a significant increase in Halfway Creek I-75 flows and it decreased water levels in wetlands east of I-75, it was not considered as a suitable candidate for the recommended plan. However, components of this alternative were retained for inclusion in a refined alternative described below in **Section 5.4**.

Table 5-3: Predicted 100-yr Stages (ft-NAVD) and Flows (cfs) for Alt 1 Green Indicates Improvement

Station	Branch H & Q Chainages	Target Stage/Flow		Base_v2a		Alt1_v7	
				Stage	Flow	Stage	Flow
Kehl Canal Gate HW	KehlCan 30702, 30767	13		14.53	1946	14.62	1970
Imperial R I-75	Imperial 4588, 4888	22.8		12.09	1962	12.15	2020
Imperial R Bourbonniere	Imperial 8430, 8488	9.3		10.56	N/A	10.52	2062
Halfway I-75	Halfwayup 5889, 6049	22		16.16	317	15.7	350
Brooks By-pass	HalfwayCR 3937, ThreeOaks 25		160	15.48	10.5	15	259
Halfway Brooks N Weir	HalfwayCRDS 10259, 10400	15.8		15.47	560	14.95	664
Halfway Brooks S Weir	HalfwayCrS 7450, 7555	15.8		15.58	140	15.33	173
Halfway U.S. 41	HalfwayCRDS 12800, 12870	15.2		14.89	752	14.31	657
SB Estero R. I-75	EsteroRivS 99, 252	20.7		17.57	130	16.67	130
SB Estero R. Sanctuary	EsteroRivS 4100, 4200	14.6		14.19	320	14.13	206
SB Estero R. 3 Oaks Pkwy	EsteroRivS 6299, 6364	<15.0		13.91	372	14.05	529
SB Estero R. Corkscrew Rd	EsteroRivS 8628, 8697	<16.0		13.7	479	13.83	615
SB Estero R. County Ck Dr	EsteroRivS 11155, 11250	10.7		10.8	929	10.49	1002
NB Estero R I-75	Esterol75 328, 450	24.7		17.21	530	17.18	531
NB Estero R Rivers Ford	EsteroRiv 4944, 4980	11.2		14.11	892	14.15	892
Strike Lane at Fairway	StrikeLn 4921	13		14.43	N/A	14.46	N/A

5.2.3 Alternative 2 – Detailed Description

Alternative 2 is intended to increase flows to the South Branch Estero River, and improve conveyance in downstream Halfway Creek to lower peak stages while maintaining existing flow capacities. **Figure 5-7** illustrates this alternative. This alternative assumes implementation of ideas 1, 2, 4, 5, 8, 9, 12, and 13 described below in **Table 5-4**.

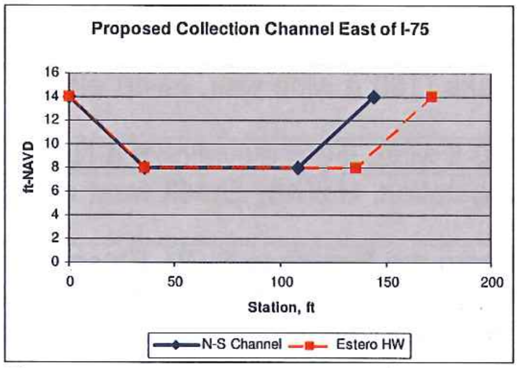
Figure 5-7: Alternative 2 Map

Table 5-4: Alternative 2 Components

Idea	Description
1	Connection of Halfway Creek to Rapallo Lake (100 ft wide weir, invert elevation 10 ft-NAVD)
2	Halfway Creek channel west of U.S. 41 (100-ft wide, invert elevation 8 ft-NAVD)
4	Yearly maintenance of exotic and dead vegetation, Halfway Creek west of U.S. 41
5	Increase the Three Oak by-pass channel from the Brooks to S. Br. Estero R. to have a 40-ft bottom width, lower invert elevations, remove the water quality weir, by-pass gates fully open during floods, and gate invert lowered 2 ft to 8.8 ft-NAVD
8	Clear exotic vegetation in Spring Creek
9	Enlarge Spring Creek culverts: doubled Countess Lane, add a 3'x4' culvert at North Branch Spring Creek for the railroad, FPL easement and Cedar Lane
12	Remove exotic vegetation in the South Branch Estero River west of I-75, add two culverts to the Sanctuary Road bridge, and expand the County Creek Drive bridge over the South Branch Estero River
13	Enlarge the Rivers Ford bridge of the North Branch Estero River

This alternative initially did not include installation of the five 60-inch culverts under I-75 in the Halfway Creek watershed. During iterations of this alternative, five 60-inch culverts were added to Alternative 2v5.

During analysis of this alternative, iteration Alt 2v5 also includes a north-south channel east of I-75 from the headwaters of South Branch Estero River to Halfway Creek. It also includes a 700-foot channel in the South Branch Estero River east of I-75. The proposed invert elevation is 8 ft-NAVD, and the side slopes are 6:1. These channels were recommended as part of the 1999 SLCWP, however they were never constructed. Alternative 2v5 also assumes construction of two weirs downstream of the channels so that the channels do not drain wetlands east of I-75. The bottom width of the weirs is 100 feet with an invert elevation of 14 ft-NAVD. The weir width gradually increases and reaches a top width of 1000 feet at elevation 15 ft-NAVD. **Figure 5-8** presents a diagram of the proposed channels and weirs. **Figure 5-9** shows the location of the proposed channels and weirs. Note: a sensitivity analysis was conducted for the channel dimensions and weir elevations east of I-75, as discussed below in **Section 5.4.2**.



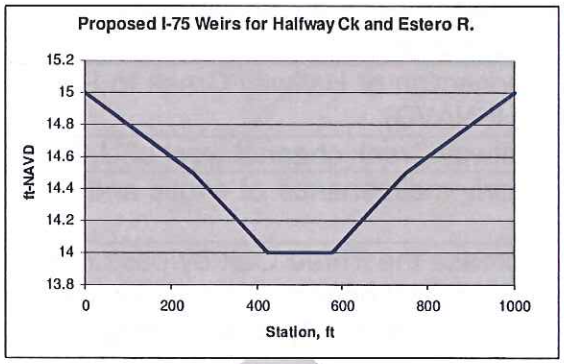


Figure 5-8: Proposed Collection Channels and Weirs for Halfway Creek and the South Branch Estero River East of I-75

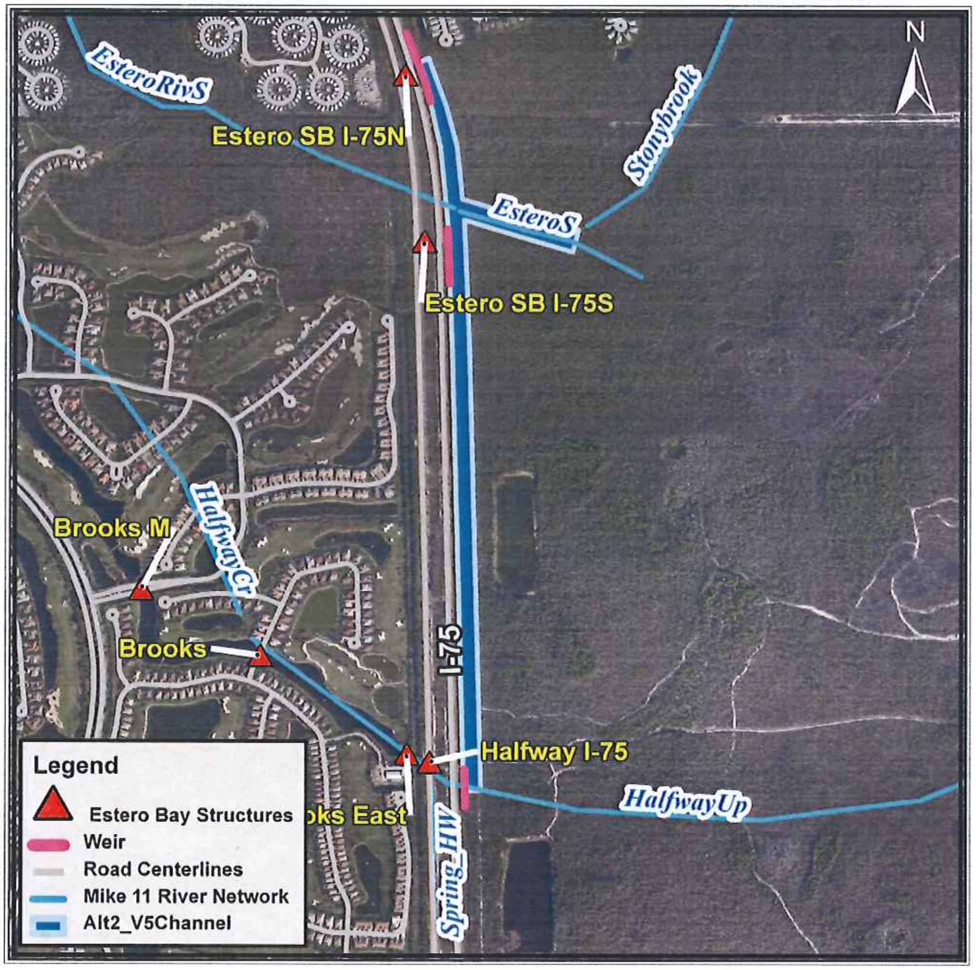


Figure 5-9: Location of Proposed Collection Channels and Weirs for Halfway Creek and the South Branch Estero River East of I-75

5.2.4 Alternative 2 – Results

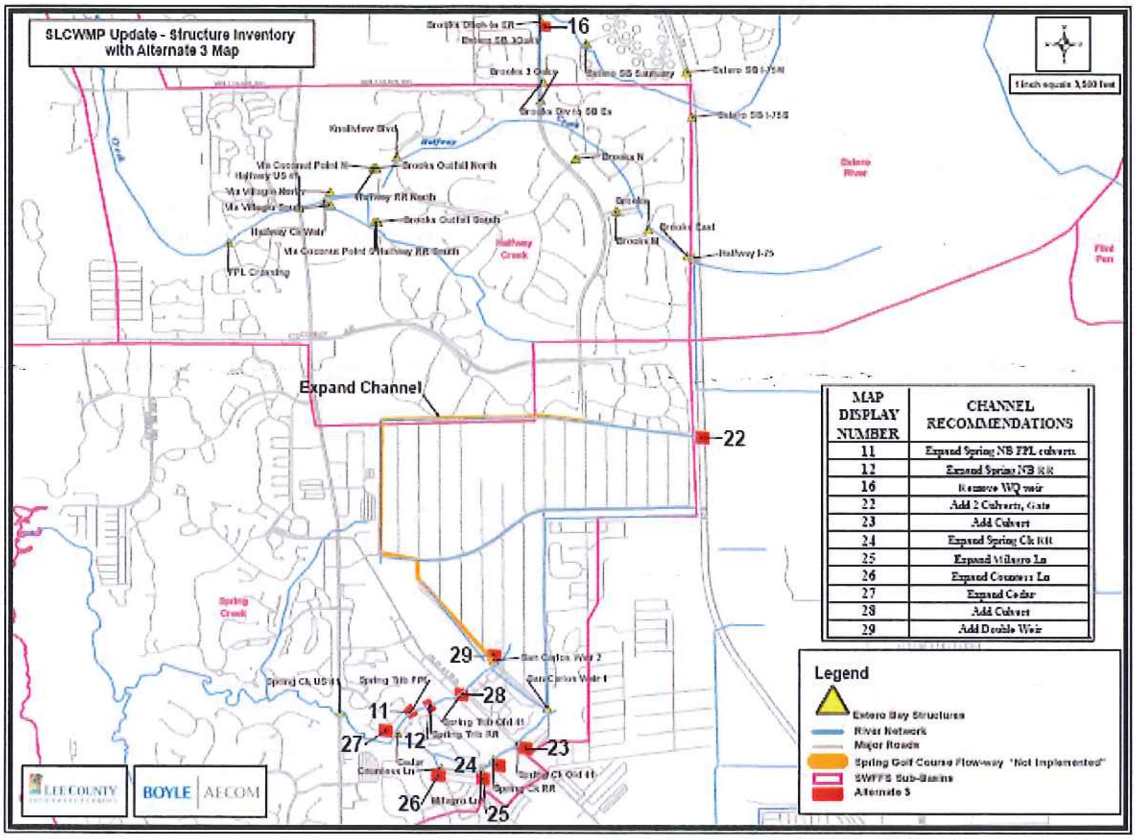
All runs of this alternative showed significant increases for flow in the South Branch Estero River at I-75, as shown in **Table 5-5**. Drainage effects to wetlands east of I-75 were noted, which led to Alternative 2v5 with the excavated channels east of I-75. This variation of alternative 2 was the most effective alternative for increasing Halfway Creek flows under I-75 (317 to 630 cfs),. However drainage effects were still noted for wetlands east of I-75. Components of this alternative were retained for inclusion in a refined alternative described below in **Section 5.4**.

Table 5-5: Predicted 100-yr Stage (ft-NAVD) and Flow (cfs) for Alt 2 Green Indicates Improvement

Station	Branch H & Q Chainages	Target Stage/Flow		Base_v2a		Alt 2_v4		Alt 2_v5	
				Stage	Flow	Stage	Flow	Stage	Flow
Kehl Canal Gate HW	KehlCan 30702, 30767	13		14.53	1946	14.56	1922	14.57	1920
Imperial R I-75	Imperial 4588, 4888	22.8		12.09	1962	12.13	2000	12.15	2001
Imperial R Bourbonniere	Imperial 8430, 8488	9.3		10.56	N/A	10.52	2199	10.53	2193
Halfway I-75	Halfwayup 5889, 6049	22		16.16	317	15.89	558	15.82	630
Brooks By-pass	HalfwayCR 3937, ThreeOaks 25		160	15.48	10.5	15.25	50	15.06	245
Halfway Brooks N Weir	HalfwayCRDS 10259, 10400	15.8		15.47	560	15.23	640	15.00	629
Halfway Brooks S Weir	HalfwayCrS 7450, 7555	15.8		15.58	140	15.43	160	15.34	166
Halfway U.S. 41	HalfwayCRDS 12800, 12870	15.2		14.89	752	14.55	843	14.43	788
SB Estero R. I-75	EsteroRivS 99, 252	20.7		17.57	130	15.89	490	15.82	475
SB Estero R. Sanctuary	EsteroRivS 4100, 4200	14.6		14.19	320	14.75	528	14.76	515
SB Estero R. 3 Oaks Pkwy	EsteroRivS 6299, 6364	<15.0		13.91	372	14.61	678	14.64	784
SB Estero R. Corkscrew Rd	EsteroRivS 8628, 8697	<16.0		13.7	479	14.42	712	14.39	816
SB Estero R. County Ck Dr	EsteroRivS 11155, 11250	10.7		10.8	929	11.26	1047	11.24	1166
NB Estero R I-75	EsteroI75 328, 450	24.7		17.21	530	17.2	530	17.17	530
NB Estero R Rivers Ford	EsteroRiv 4944, 4980	11.2		14.11	892	14.14	896	14.13	896
Strike Lane at Fairway	StrikeLn 4921	13		14.43	N/A	14.47		14.5	N/A

5.2.5 Alternative 3 – Detailed Description

Alternative 3 is intended to improve conveyance to Spring Creek, improve conveyance in the downstream part of Halfway Creek to lower peak stages while maintaining existing Halfway Creek flow capacities (**Figure 5-10**). This alternative maintains existing flows in Halfway Creek from I-75 to Three Oaks Parkway, and reduces peak flood stages in Halfway Creek, and improves conveyance in the Spring Creek watershed from east of I-75 to U.S. 41. This alternative assumes implementation of ideas 1, 2, 4, 5, 6 and/or 7, 8, 9, and 13 (partial). This alternative included installation of the three 60-inch culverts under I-75 in the Halfway Creek watershed. In addition, this alternative included two 60-inch culverts under I-75 to convey flows to Spring Creek. Improvements in the North Branch of the Estero River are restricted to providing safe conveyance of existing peak flows. The components of this alternative are shown below in **Table 5-6**:



MAP DISPLAY NUMBER	CHANNEL RECOMMENDATIONS
11	Expand Spring NB FPL culverts
12	Expand Spring NB RR
16	Remove WQ weir
22	Add 2 Culverts, Gate
23	Add Culvert
24	Expand Spring Ck RR
25	Expand Milagro Ln
26	Expand Countess Ln
27	Expand Cedar
28	Add Culvert
29	Add Double Weir

Figure 5-10: Alternative 3 Map

Table 5-6: Alternative 3 Components

Idea	Description
1	Connection of Halfway Creek to Rapallo Lake (100 ft wide weir, invert elevation 10 ft-NAVD). Raise wooden walkway above weir.
2	Halfway Creek channel west of U.S. 41 (100-ft wide, invert elevation 8 ft-NAVD,)
4	Yearly maintenance of exotic and dead vegetation, Halfway Creek west of U.S. 41
5	Increase the Three Oak by-pass channel from the Brooks to S. Br. Estero R. to have a 40-ft bottom width, lower invert elevations, remove the water quality weir, by-pass gates fully open during floods, and two 4.5' wide gate inverts lowered 2 ft to 8.8 ft-NAVD
6	Two new culverts under I-75, expand Bonita Bill Canal (currently 20 ft wide,. 4-ft deep, make it 40 ft wide, 6 ft deep, 2:1 side slopes), double width of Moriah Weir
8	Clear exotic vegetation in Spring Creek
9	Enlarge Spring Creek culverts: add another 8' x 4' culvert for both branches of Spring Creek under U.S. 41, tripled Countess Lane culvert capacity, add two 3'x4' culverts at North Branch Spring Creek for the railroad, FPL easement and Cedar Lane

The expansion of the Bonita Bill Canal involves the following activities:

- Widening 16,000 ft of canal. Assume that a 30 ft easement is required from 94 properties along the 16,000 ft canal length. There are houses on 24 of the lots, and the lot length for most of the houses is 300 ft
- Area without houses = 6 acres and area with houses = 5 acres
- The maintenance road is paved, therefore 7,300 square yards of pavement will have to be replaced.
- Culverts will be needed under Strike Lane: Assume two 50' long x 8'x 4'

5.2.6 Alternative 3 – Results

This alternative was intended to reduce or eliminate flooding in San Carlos Estates while also providing additional flow conveyance for wetlands east of I-75. Initially, this alternative was run without any additional culverts under I-75, however initial tests were unsuccessful with a doubling of culvert capacity west of Old U.S. 41. The next iteration of this alternative included:

a. Tripling of culvert capacity west of Old U.S. 41
b. Adding another 8' x 4' box culvert at Old U.S. 41 for the two Spring Creek branches discharging from San Carlos Estates
c. Doubling the width of Bonita Bill and Moriah Canals and doubling the width of the Moriah Weir.

d. Addition of gate-controlled culverts under I-75 with the gates closing if the Moriah weir headwater elevation exceeded 10.8 ft-NAVD (12 ft-NGVD, the top elevation of the current weirs, see photo in **Figure 1-6**).

This last iteration did not solve flooding problems and flows through the new culverts under I-75 were in the range of 20-35 cfs. The flow under I-75 was limited by high stages in San Carlos Estates in spite of doubling the canal widths for Bonita Bill Canal, Moriah Canal, and Stillwell Canal, doubling the width of both San Carlos weirs, and extensive capacity increases downstream of San Carlos Estates. It is possible that I-75 culverts can provide beneficial base flows to Spring Creek, however these culverts will not be able to deliver flood flows to the Spring Creek watershed without even more extensive drainage improvements than assumed in this assessment.

5.2.7 Alternative 4 – Detailed Description

Alternative 4 is intended to increase detention east of I-75 to reduce peak discharges to the Imperial River. This alternative is should also reduce flooding problems in the Estero River, Halfway Creek, and Spring Creek without increasing peak flows.

Alternative 4 assumes the construction of a detention facility in one or more mining pits east of I-75 (Idea 10). The location of the reservoir is not given since a pump station would be installed west of I-75 in the vicinity of the Quinn Street area. This pump station location was selected after initial tests demonstrated that a pump station in the Green Meadows wetlands (northeast of the intersection of Terry Street and Bonita Grande Drive) was not effective in reducing stages in the Imperial River west of I-75. Improvements will be made in the North Branch of the Estero River, Halfway Creek, and Spring Creek to provide safe conveyance of existing peak flows. This alternative did not include any of the components described in earlier alternatives (including additional Halfway Creek I-75 culverts) since this alternative is directed specifically at reducing stages in the Imperial River west of I-75.

5.2.8 Alternative 4 – Results

Initial tests were conducted with a reservoir intake pump station located in the Green Meadows wetlands northeast of the intersection of Terry Street and Bonita Grande Drive. A reservoir intake at this location did not decrease stages in the Imperial River west of I-75. Accordingly, a pump station intake location was selected west of I-75 and it was assumed that a pipeline would be used to convey the water to the reservoir location (no specific location was assumed for the reservoir). The pump station capacity was varied to determine a relationship between river stage at the Bourbonniere Bridge and pump rate. **Figure 5-11** demonstrates that pump flow needs to be larger than 1,000 cfs to reduce stages in the Imperial River near the Quinn Street area. As shown in **Table 5-7**, reservoir storage capacity would need to be in the range of 10,000 acre-feet to reduce peak stages to 9.3 ft-NAVD. The pump station would only operate during periods of high flow.

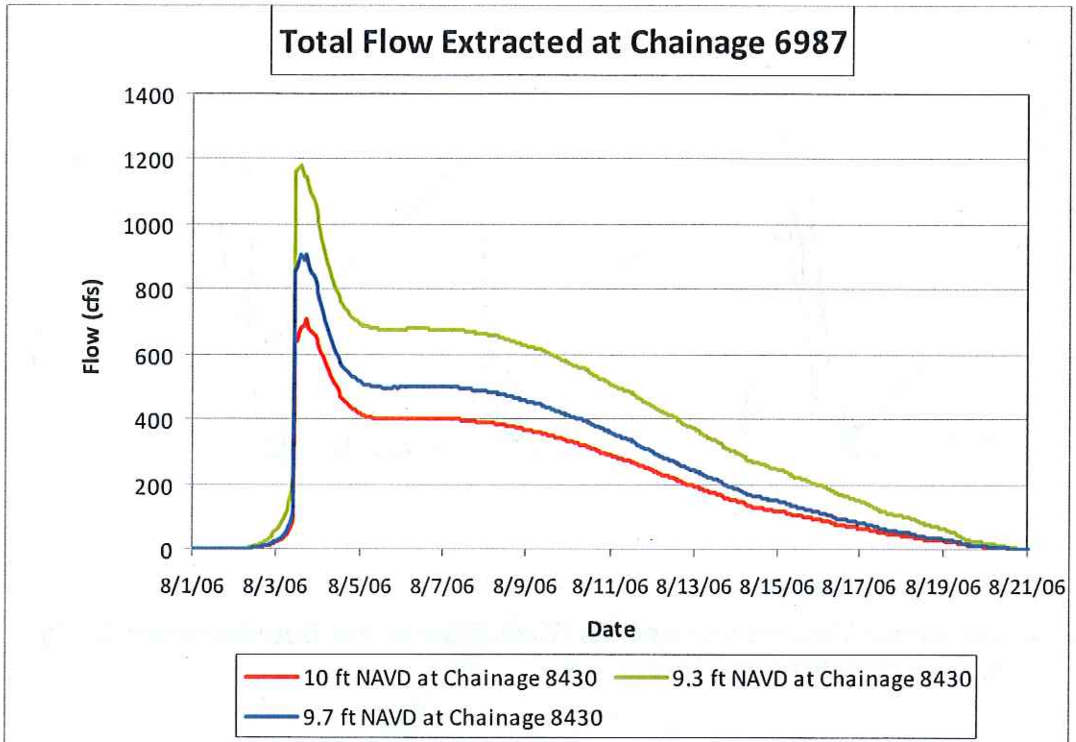


Figure 5-11: Reservoir Pump Station Capacity vs Imperial River Stage at the Bourbonniere Bridge

Table 5-7: Reservoir Pump Station Capacity vs Reservoir Storage Volume

Maximum Stage (feet) at Chainage 8430	Volume (ac-ft) of water to be Pumped at Chainage 6987
10	6,258
9.7	7,806
9.3	10,585

A simulation was conducted for 2006 – 2008, and the pump was set to turn off when flows dropped below 150 cfs at the Bourbonniere bridge. In this simulation, the pump flow gradually decreased from 250 to 50 cfs as the river flow decreased. **Figure 5-12** presents water storage, and river flow with and without the reservoir. Analysis of the simulation indicated the following:

- Base flow is unaffected by the reservoir pumpage
- peak pump flow was 250 cfs
- water storage was a maximum of 10,000 acre-feet, which translates to a depth of 10 feet for a 1,000-acre reservoir

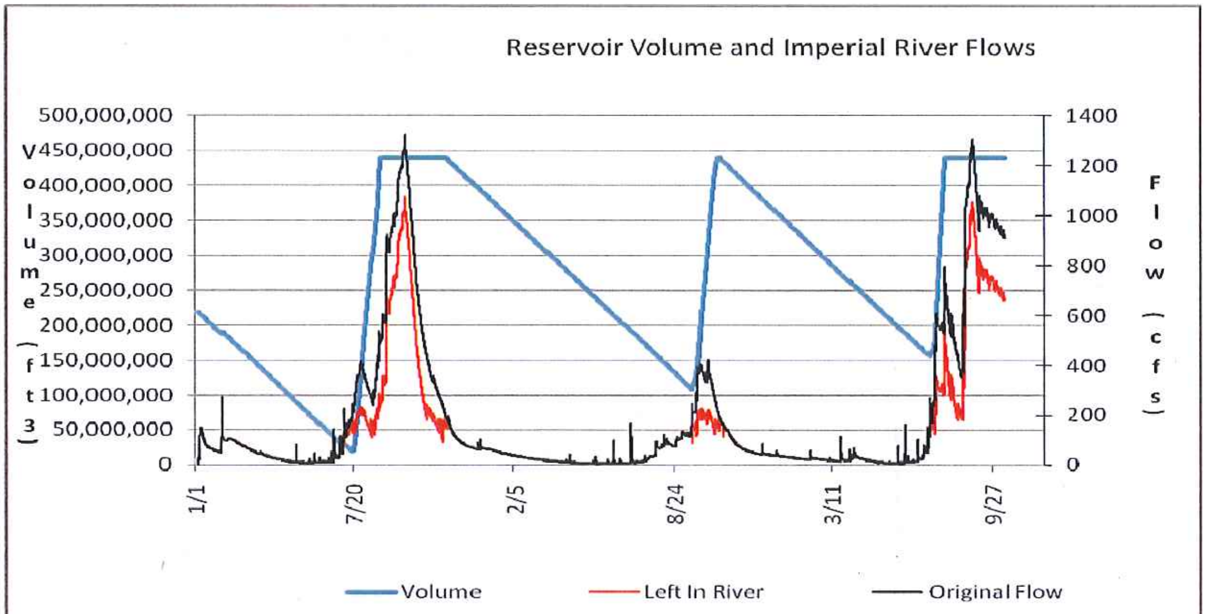


Figure 5-12: Reservoir Volume vs Imperial River Flow at the Bourbonniere Bridge with and without the Reservoir

Including evaporative losses and assuming full lining of the reservoir to minimize seepage, the reservoir was able to release a constant outflow of 9 cfs (6 MGD) for some beneficial use, such as public water supply or baseflow augmentation.

5.3 Comparison of Alternatives

5.3.1 Hydraulics

Table 5-8 summarizes simulated stages and flows for the base run and 5 alternatives. Alternative 1 is most effective in reducing stages in lower Halfway Creek. Alternative 2 is most effective in increasing flow in the South Branch Estero River. Adding a north-south channel and weirs east of I-75 to Alternative 2 (Alt 2 v5) almost doubled the Halfway Creek flow under I-75. Furthermore, the combined flow under I-75 for Halfway Creek and the South Branch Estero River was highest for Alt 2 v5. Alternative 3 does not meet flood reduction objectives and is only marginally effective in conveying storm flows from wetlands east of I-75 to the lower reaches of Spring Creek. Alternative 4 is the most effective alternative in reducing flood elevations in the Imperial River. Since one of the main objectives of this study was to restore flood flows through I-75 via the Estero River, Halfway Creek, and/or Spring Creek, portions of Alternatives 1 and 2 were combined into a refined alternative that is discussed below in **Section 5.4**. Alternative 4 remains as a potential component of an overall solution depending on the cost and the level of interest in the stored water by public water utilities or other water resources management entities.

Table 5-8: 100-Year Base Run vs. Alternatives Simulated Stage (ft-NAVD) and Flow (cfs) (Green Indicates Improvement)

Station	Target Stage/Flow		Base_v2b		Alt_1v8a- 4-20		Alt1_v8b		Alt 2_v5		Alt 3_v3		Alt 4	
	Stage	Flow	Stage	Flow	Stage	Flow	Stage	Flow	Stage	Flow	Stage	Flow	Stage	Flow
Kehl Canal Gate HW	13		14.6	1,975	14.4	1,768	14.3	1,745	14.6	1,920	14.6	1975	14.5	1,947
Imperial R I-75	22.8		12.2	2,019	12.1	1,930	12.0	1,872	12.2	2,001	12.2	2018	11.9	1,965
Imperial R Bourbonniere	9.3		10.6	2,208	10.5	2,169	10.5	2,156	10.5	2,193	10.6	2201	9.7	1,531
Halfway I-75	22		16.0	328	15.8	530	15.5	311	15.8	630	15.7	333	16.3	305
Brooks By-pass		160	15.5	41	15.0	244	15.0	230	15.1	245	15.1	90	15.7	19
Halfway Brooks N Weir	15.8		15.5	646	15.0	636	14.9	690	15.0	629	15.1	611	15.7	618
Halfway Brooks S Weir	15.8		15.6	138	15.3	166	15.3	173	15.3	166	15.4	167	15.8	128
Halfway U.S. 41	15.2		14.9	759	14.4	784	14.4	765	14.4	788	14.5	803	15.2	663
SB Estero R. I-75	20.7		17.6	130	15.8	452	16.0	526	15.8	475	17.6	129	17.6	129
SB Estero R. Sanctuary	14.6		14.3	340	14.7	514	14.8	571	14.8	515	no change From base		no change from base	
SB Estero R. 3 Oaks Pkwy	<15.0		13.9	472	14.6	768	14.6	782	14.6	784				
SB Estero R. Corkscrew Rd	<16.0		13.8	481	14.4	805	14.4	816	14.4	816				
SB Estero R. County Ck Dr	10.7		10.8	940	11.3	1154	11.3	1160	11.2	1166				
NB Estero R I-75	24.7		17.2	530	17.2	530	17.2	530	17.2	530	17.2	530	17.2	532
NB Estero R Rivers Ford	11.2		14.1	896	14.1	896	14.1	896	14.1	896			14.1	893
Strike Lane at Fairway	13		15.6	#N/A	14.5	#N/A	14.5	#N/A	14.5	N/A		N/A	14.5	#N/A
Combined I-75 Flow Halfway + South Br. Estero R.				458		982		837		1105		462		435
Volume Stored, Ac-ft														7,806

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5.3.2 Ecologic Assessment

Summer average wet season water depths were calculated for Alternatives 1, 2, and the base condition. **Figures 5-13** and **5-14** present the difference between the alternative and the base condition summer average wet season water depths in wetlands east of I-75 for Alternatives 1 and 2v5.

5.4 Refined Alternatives

5.4.1 Merged Alternatives 1 and 2 – Detailed Description

Alternative 2v5 was carried forward as the best alternative for restoring flood flows under I-75 to Halfway Creek and South Branch Estero River and is essentially a merging of the original forms of Alternatives 1 and 2 see **Figure 5-15**. This alternative was further modified with the objective of limiting drainage of wetlands east of I-75. Additional iterations focused on optimizing the number of new culverts under I-75, and minimizing environmental and cost impacts while improving Halfway Creek conveyance. The common features of this refined alternative are:

- Expanding the North Branch Estero River bridge at Rivers Ford Road
- Expanding the South Branch Estero River bridge at County Creek Drive
- Thinning of nuisance vegetation in the SB ER west of I-75
- Addition of two additional culverts under Sanctuary Road
- Construction of weirs just upstream of I-75 for Halfway Creek and the South Branch Estero River to minimize draining of wetlands east of I-75
- Dropping the invert elevation of the Brooks emergency by-pass structure from Halfway Creek to the South Branch Estero River
- Widening and deepening the Three Oaks channel downstream of the by-pass structure
- Raising the Rapallo wooden boardwalk on the east and west ends between Via Coconut Point Rd. and Via Villagio Rd. and installation of inflow and outflow weirs (elevation 11 ft-NAVD, 100 ft wide)
- Improved vegetation maintenance in Halfway Creek west of U.S. 41
- Diversion of 200 cfs from Kehl Canal to wetlands south of Bonita Beach Road

Note that as mentioned above, the modifications to the Rapallo wooden boardwalk may be adjusted during the design-phase. There are two versions of this alternative. Alternative 1v8a includes the north south channel east of I-75 for Halfway Creek and the South Branch Estero River. Alternative 1v8b does not have the north-south channel.

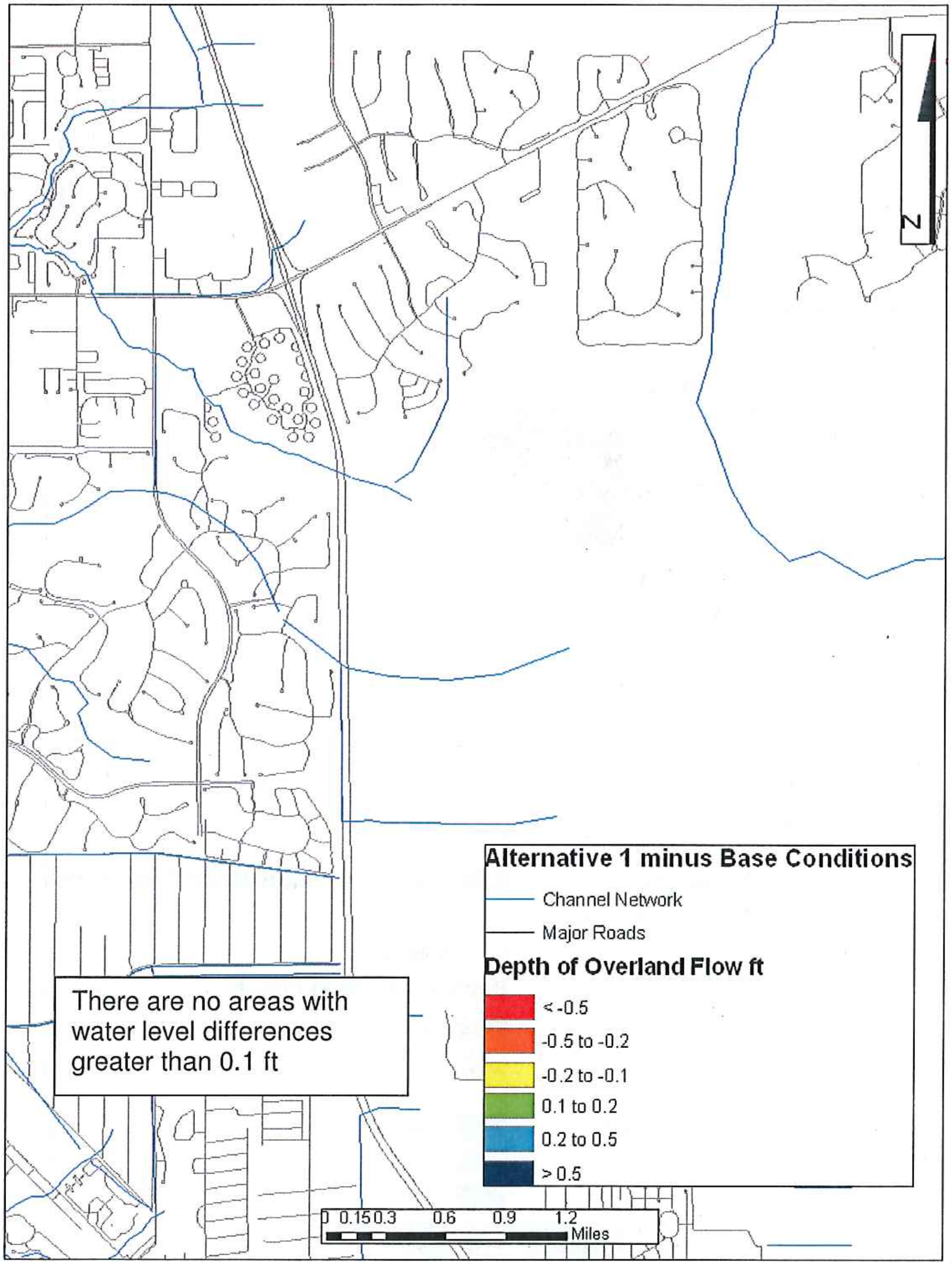


Figure 5-13: Depth of Overland Flow - Alternative 1 Minus Base Conditions

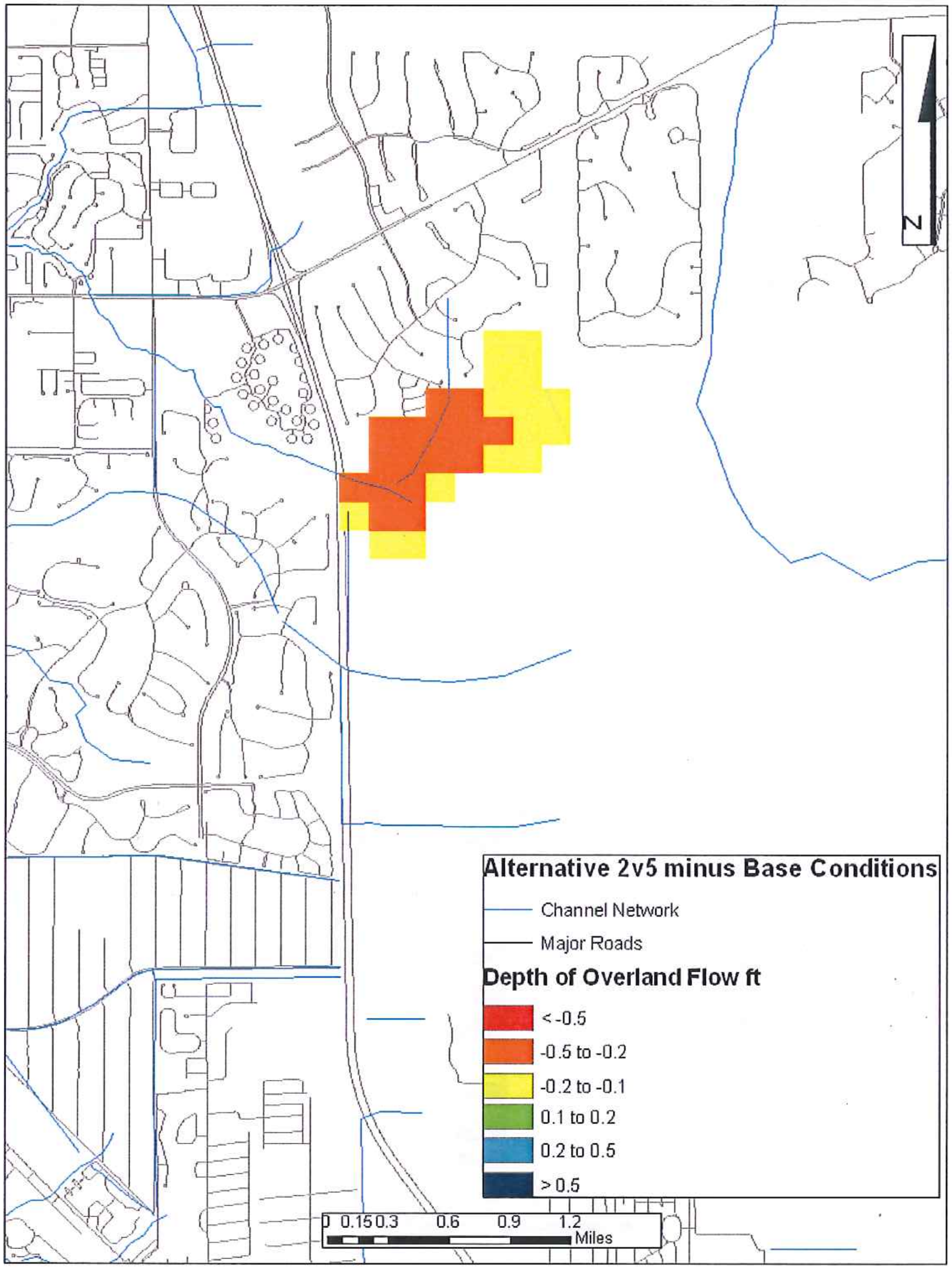


Figure 5-14: Depth of Overland Flow - Alternative 2v5 Minus Base Conditions

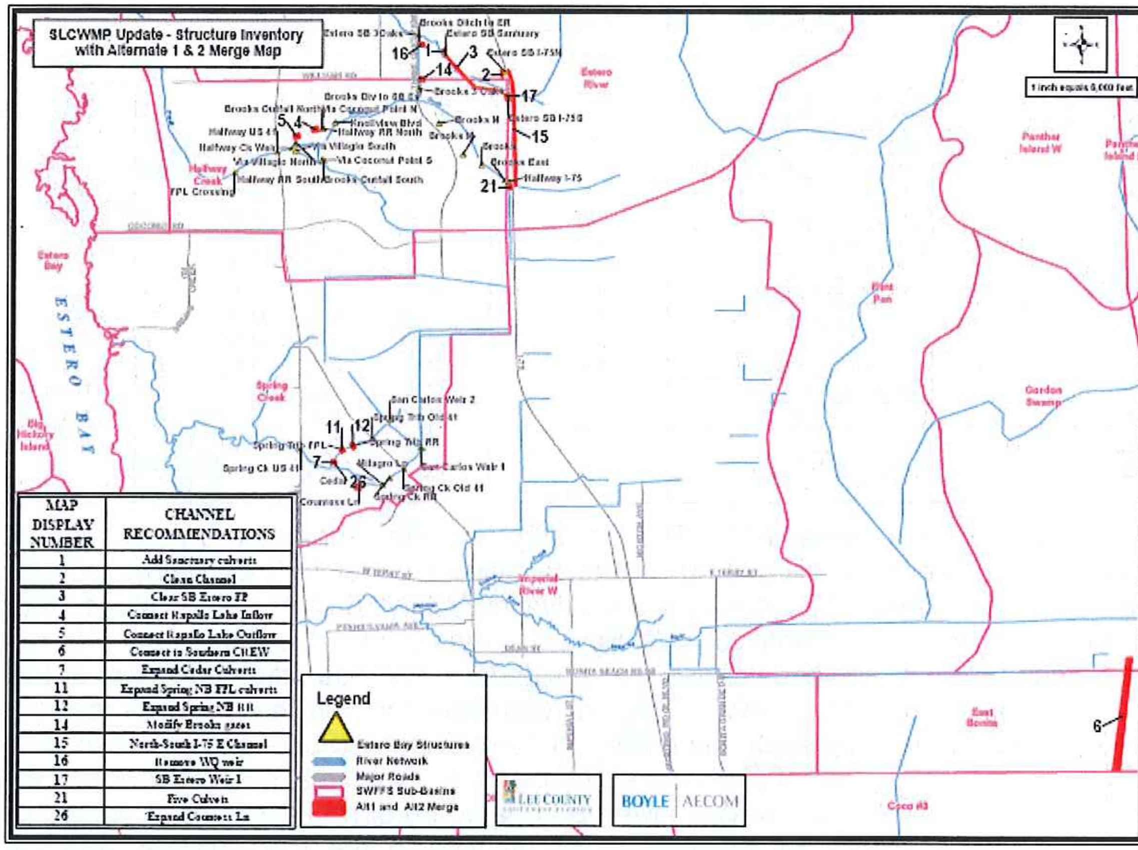


Figure 5-15: Alternatives 1 and 2 Map

5.4.2 Merged Alternatives 1 and 2 – Results

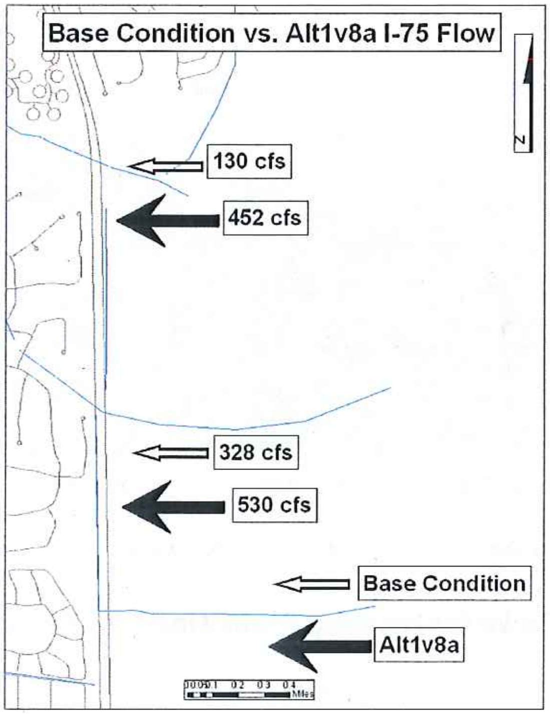
Hydraulics. Table 5-9 presents 100-year design storm results of this alternative with and without the North-South channel east of I-75. Alt 1 v8a has more flow under I-75 for Halfway Creek than Alt 1 v8b, and the combined flow for Halfway Creek and South Branch Estero River is greatest for Alt 1 v8a. Based on this analysis, Alt 1 v8a was subjected to further refinement, as discussed below. **Figure 5-15a** provides a graphical depiction of the difference in flow under I-75 for these options

Table 5-9: Simulated Stage (ft-NAVD) and Flow (cfs) for Merged Alt 1 & 2 (Green Indicates Improvement)

Station	Branch H & Q Chainages	Target Stage/Flow		Base_v2b		Alt_1v8a- 4-20		Alt1_v8b	
		Stage	Flow	Stage	Flow	Stage	Flow	Stage	Flow
Kehl Canal Gate HW	KehlCan 30702, 30767	13		14.61	1,975	14.36	1,768	14.30	1,745
Imperial R I-75	Imperial 4588, 4888	22.8		12.15	2,019	12.08	1,930	12.03	1,872
Imperial R Bourbonniere	Imperial 8430, 8488	9.3		10.55	2,208	10.53	2,169	10.53	2,156
Halfway I-75	Halfwayup 5889, 6049	22		16.01	328	15.75	530	15.56	311
Brooks By-pass	HalfwayCR 3937, ThreeOaks 25		160	15.52	41	15.04	244	14.98	230
Halfway Brooks N Weir	HalfwayCRDS 10259, 10400	15.8		15.50	646	14.98	636	14.92	690
Halfway Brooks S Weir	HalfwayCrS 7450, 7555	15.8		15.59	138	15.34	166	15.32	173
Halfway U.S. 41	HalfwayCRDS 12800, 12870	15.2		14.91	759	14.43	784	14.39	765
SB Estero R. I-75	EsteroRivS 99, 252	20.7		17.57	130	15.75	452	16.02	526
SB Estero R. Sanctuary	EsteroRivS 4100, 4200	14.6		14.25	340	14.73	514	14.78	571
SB Estero R. 3 Oaks Pkwy	EsteroRivS 6299, 6364	<15.0		13.90	472	14.61	768	14.64	782
SB Estero R. Corkscrew Rd	EsteroRivS 8628, 8697	<16.0		13.76	481	14.36	805	14.39	816
SB Estero R. County Ck Dr	EsteroRivS 11155, 11250	10.7		10.83	940	11.25	1154	11.26	1160
NB Estero R I-75	Esterol75 328, 450	24.7		17.19	530	17.19	530	17.19	530
NB Estero R Rivers Ford	EsteroRiv 4944, 4980	11.2		14.13	896	14.13	896	14.11	896
Strike Lane at Fairway	StrikeLn 4921	13		15.62	#N/A	14.52	#N/A	14.48	#N/A
Combined I-75 Flow Halfway + South Br. Estero R.					458		982		837
Volume Stored, Ac-ft									

Number of Culverts Under I-75. The first step for refinement was to determine the appropriate number of additional 60" diameter culverts under I-75 for Halfway Creek. **Figure 5-16** and **Figure 5-17** presents Halfway Creek flows under I-75 and stages east of I-75 for 5, 1, and 0 additional culverts. Reducing the number of culverts from 5 to 1 or 5 to 0 does not significantly decrease the flow under I-75. The stage upstream of I-75 increases from 15.8 to 16 ft-NAVD. This analysis indicates that the additional culverts are not necessary for conveying the additional flows under I-75, as long as the existing 9 x 8 ft culverts remain free of sediment accumulations. Since the invert elevation of the existing 9 x 8 ft culverts is four feet lower than natural ground elevations, it should be expected that sediments will continue to accumulate in the I-75 culverts, and this accumulation could occur during a flood due to sediment transport. Therefore, additional culverts provide the following benefits:

- provide a safety factor to protect against maintenance issues and any unforeseen conditions
- provide capacity to account for potential additional flows resulting from using more accurate topography which is now available
- provide reserve conveyance capacity should future downstream conveyance improvements or restoration projects exceed the improvements evaluated by this study.


Base Condition vs. Alt1v8a I-75 Flow
N
130 cfs
452 cfs
328 cfs
530 cfs
Base Condition
Alt1v8a

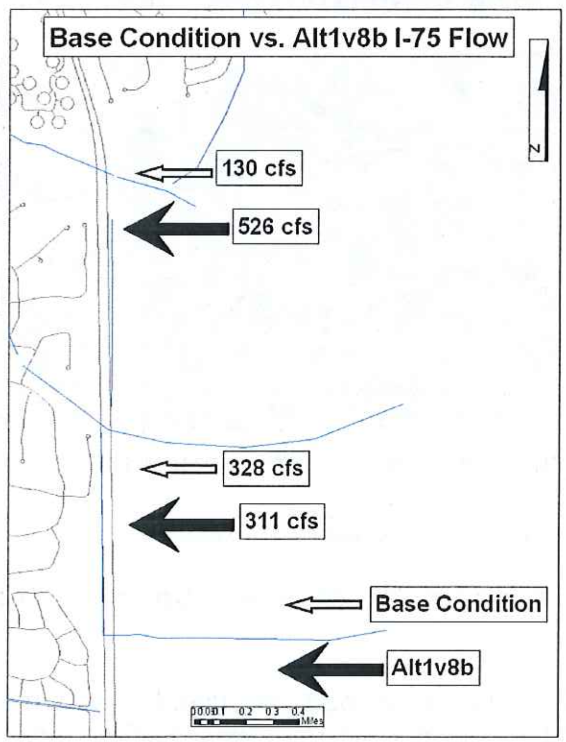

Base Condition vs. Alt1v8b I-75 Flow
N
130 cfs
526 cfs
328 cfs
311 cfs
Base Condition
Alt1v8b

Figure 5-15a.

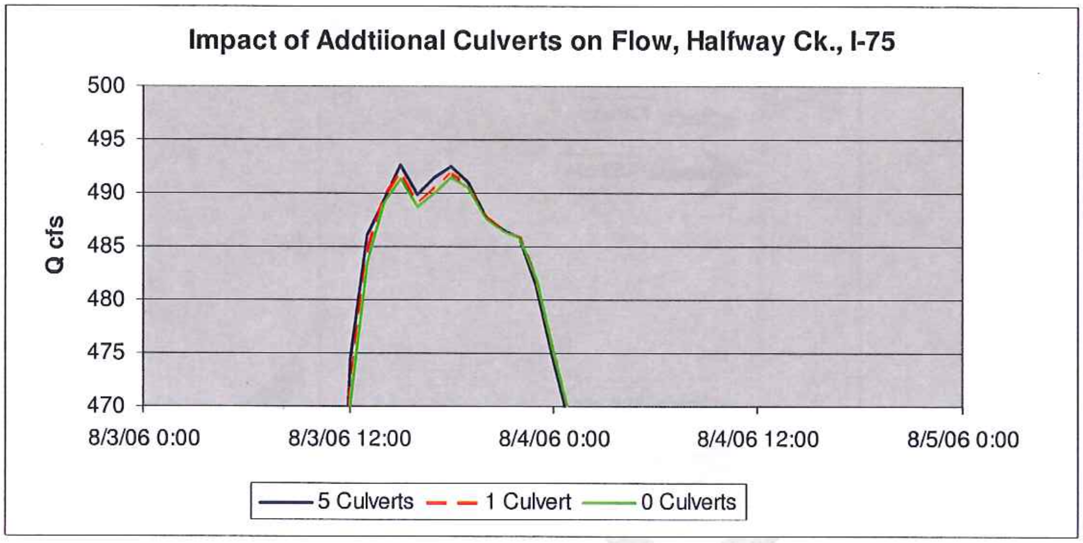


Figure 5-16: 100-Year Flows for Halfway Creek Under I-75 with 5, 1, and 0 Additional Culverts

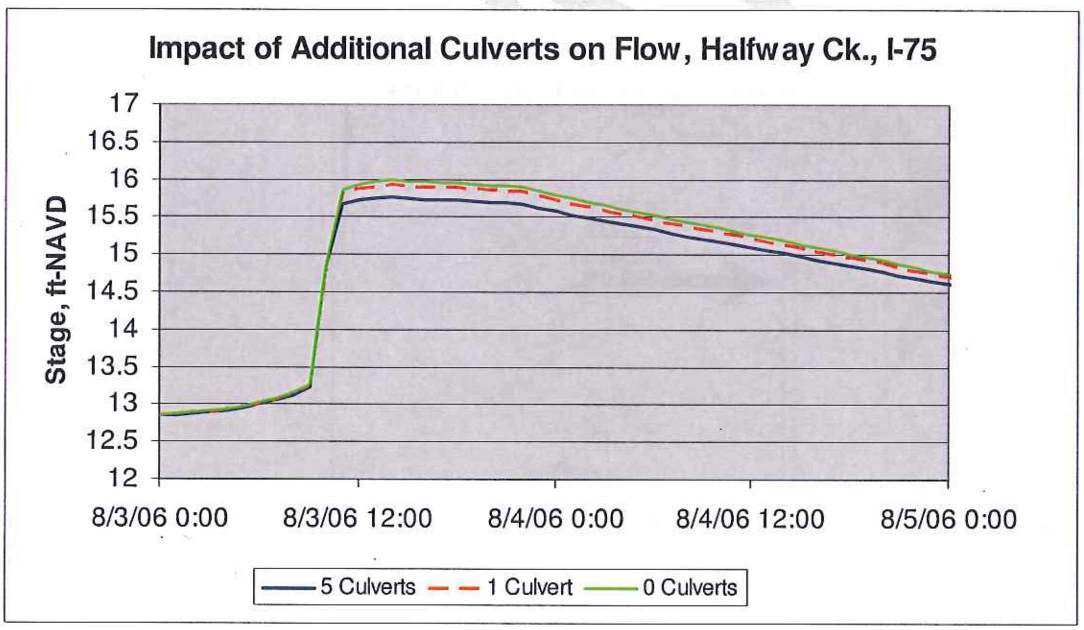


Figure 5-17: 100-Year Stages for Halfway Creek Upstream of I-75 with 5, 1, and 0 Additional Culverts

Weirs Upstream of I-75. An analysis was conducted to determine the impact of weir dimensions upstream of I-75. Three different weir configurations were simulated and are shown in **Figure 5-18:**

1) Weir elevation = 14 ft-NAVD, length = 150 ft
2) Weir elevation = 15 ft-NAVD, length = 150 ft
3) 10-ft notch at 15 ft-NAVD, remainder at 16 ft

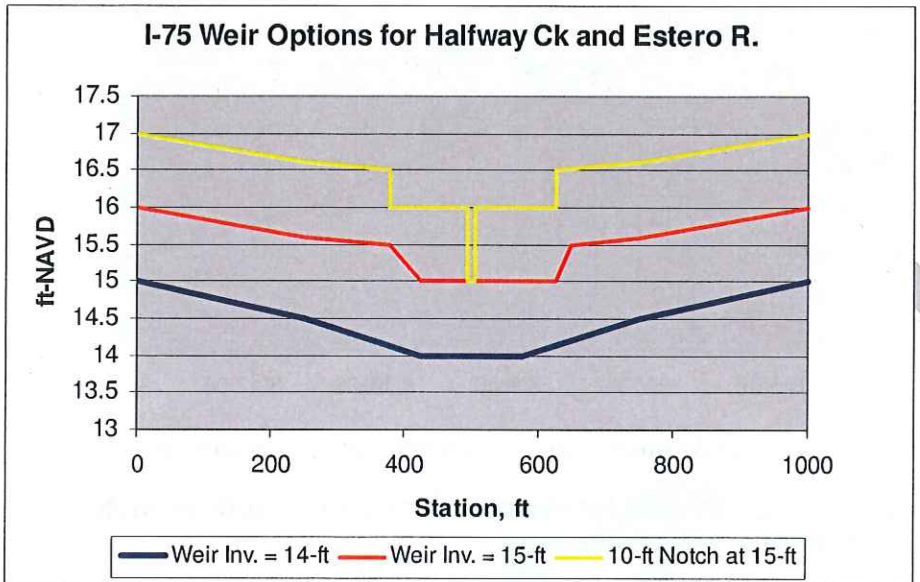


Figure 5-18: Three Weir Configuration Options for Halfway Creek and South Branch Estero River East of I-75

Figure 5-19 presents the results of this analysis, and the iterations with the weir with an invert elevation of 14 and 15 ft-NAVD have similar total 100-year flows for Halfway Creek and South Branch Estero River. The cumulative flow for the weir at 15 feet is less than for the iteration with the weir at 14 feet. A further iteration was conducted with a weir at elevation 15, but with the width reduced to 40 feet instead of 150 feet. This iteration yielded similar results to the original width of 150 feet. Additional iterations are recommended to refine the width of the proposed weir. At this point in time, it is anticipated that the control elevation should be 15 feet, subject to ecologic considerations, as discussed below.

Proposed Channel from Halfway Creek to South Branch Estero River Upstream of I-75. An iteration was conducted with a modified channel upstream of I-75. The original dimensions were reduced to a bottom width of 36 feet, a top width of 72 feet, and an invert elevation of 11 ft-NAVD. This iteration yielded similar results to the original proposed channel dimensions presented above in **Figure 5-8**. Additional iterations are recommended to refine the proposed dimensions of this channel.

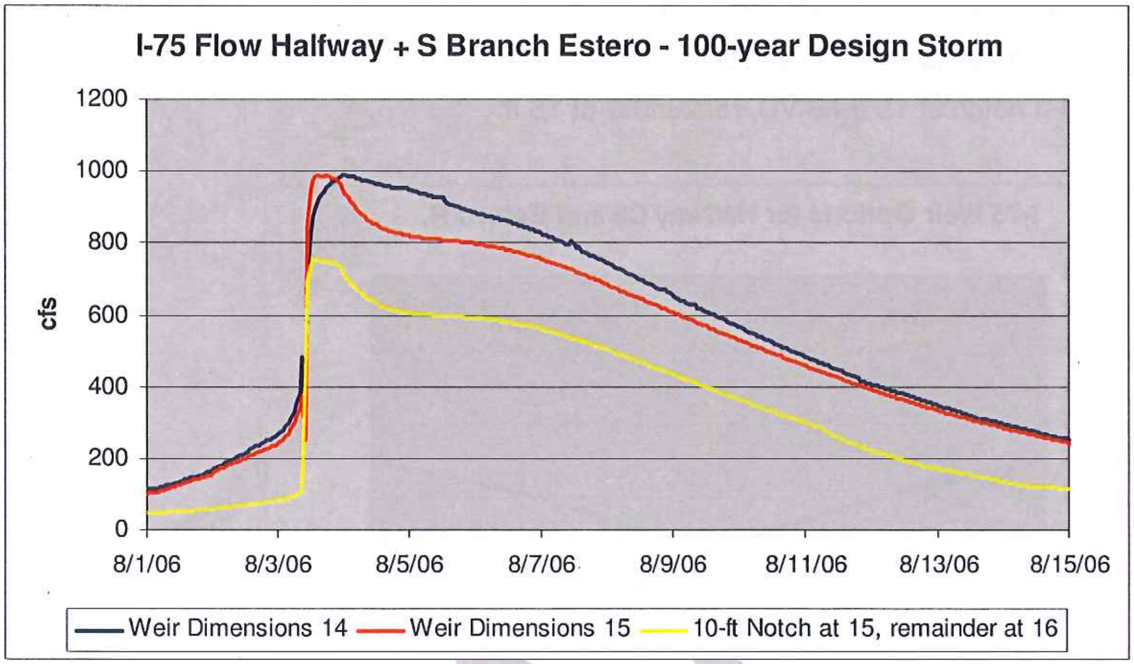


Figure 5-19: 100-Year Flows Under I-75 for Halfway Creek and South Branch Estero River for Three Different Weir Elevations

1995 Rainfall Evaluation. Table 5-10 presents the 1995 rainfall simulations for the base and merged alternatives. The base condition predicted water levels for Halfway Creek at I-75 are less than the observed 1995 water levels. This is due to increased conveyance capacity in the Halfway Creek watershed. The measured 1995 Halfway Creek flow under U.S. 41 was 36 cfs while the current simulated base condition peak flow at US. 41 is 400 cfs. Simulated water levels in the Imperial River are also less than measured 1995 levels, which is also due to downstream conveyance improvements, such as the replacement of the IBE bridge with the Bourbonniere bridge.

The results of these simulations indicate that either Alt 1v8a or Alt 1v8b have lower peak water levels within the Imperial River and Halfway Creek watersheds. Water levels in the Imperial River at the Bourbonniere bridge drop from 9.5 to 9.1 ft-NAVD. The Alt 1v8a and Alt 1v8b simulation flows through the Brooks emergency by-pass gate are in the range of 100 cfs, which is approximately 10 times the base condition flows. This is due to:

1. Opening the gate at elevation 12.8 ft-NAVD instead of 13.8 ft-NAVD
2. Lowering the gate invert elevation 2 feet, and
3. The proposed channel modifications downstream of the gate.

As expected, flows and stages increase in the South Branch Estero River due to conveyance improvements. However the increased water levels do not cause flooding of roads or structures.

Table 5-10: Simulation Results for Alt 1v8a and Alt 1 v8b Using 1995 Rainfall

Location	Branch H & Q Chainages	Base		Alt1v8a		Alt1v8b	
		Water Level	Discharge	Water Level	Discharge	Water Level	Discharge
		(ft NAVD)	(cfs)	(ft NAVD)	(cfs)	(ft NAVD)	(cfs)
Kehl Canal Gate HW	KehlCan 30702, 30767	14.3	1,725	14.1	1,526	14.1	1,526
Imperial R I-75	Imperial 4588, 4888	11.8	1,832	11.6	1,653	11.6	1,653
Imperial R Bourbonniere	Imperial 8430, 8488	9.5	1,876	9	1,702	9	1,701
Halfway I-75	Halfwayup 5889, 6049	14.1	225	13.7	205	13.5	161
Brooks By-pass	HW 3939, ThreeOaks 25	13.9	9	13.5	99	13.4	98
Halfway Brooks N Weir	HalfwayCRDS 10259, 10400	13.8	374	13.4	350	13.3	331
Halfway Brooks S Weir	HalfwayCrS 7450, 7555	13.9	68	13.8	66	13.8	66
Halfway U.S. 41	HalfwayCRDS 12800, 12870	13.6	400	13.1	422	13	402
SB Estero R. I-75	EsteroRivS 99, 252	16.8	68	14.3	204	14.5	221
SB Estero R. Sanctuary	EsteroRivS 4100, 4200	11.6	98	12.5	214	12.7	242
SB Estero R. 3 Oaks Pkwy	EsteroRivS 6299,	9.6	144	10.6	297	10.8	312
SB Estero R. Corkscrew Rd	EsteroRivS 8628	9.1	184	10	303	10.2	323
SB Estero R. County Ck Dr	EsteroRivS 11155, 11250	6.9	321	7.3	435	7.4	458
NB Estero R I-75	EsteroI75 328, 450	16	102	16	102	16	102
NB Estero R Rivers Ford	EsteroRiv 4944, 4980	10.5	231	10.5	235	10.5	234
Strike Lane at Fairway	StrikeLn 4921	13.9	#N/A	13.9	#N/A	13.9	#N/A
Stillwell Weir	FairwayEstates 10750, 10800	10	97	10	97	10	97
Moriah Weir	MoriahCanal 2952, 3116	10	100	10	100	10	100
Spring CkSS Countess	SpringCRSS 4000, 4245	6.3	204	4.3	110	4.3	110
Spring Ck Trib RR	SpringCR 3200, 3253	9.6	63	8	75	8	75
Spring Trib Cedar Lane	SpringCR 4079, 4400	4.2	69	2.7	81	2.7	81

Determining Maximum Flow for Halfway Creek from I-75 to Railroad Culverts. Because the predicted flows to Halfway Creek in this assessment are less than proposed in Amendment 1 of the 1999 SLCWP, simulations were conducted using higher flow similar to the 1999 Amendment 1 flows. Flows through the Halfway Creek I-75 culverts increase with increasing gradients across I-75, and localized heavy precipitation could generate flood elevations east of I-75 higher than 100-year predicted elevations. Flows at I-75 were set to equal 900 cfs, which is the flow in Halfway Creek recommended by the 1999 SLCWP (without 160 cfs to Spring Creek). **Table 5-11** below indicates that Halfway Creek between I-75 and U.S. 41 can convey 900 cfs under I-75. Flows and stages are essentially the same if the number of new culverts are dropped from 5 to 2. Culvert velocities were compared for this analysis, and the I-75 culvert velocity with five additional culverts is 3.7 ft/second (fps), 4.3 fps for three additional culverts, and 4.8 fps for two additional culverts.

Table 5-11: 100 Year Peak Stages and Flows for Halfway Creek between I-75 and U.S. 41

		Target Stage/Flow		Base_v2b		5 culverts	
Station	Branch H & Q Chainages	Stage	Flow	Stage	Flow	Stage	Flow
Kehl Canal Gate HW	KehlCan 30702, 30767	13.0		14.6	1,975	14.6	1,997
Imperial R I-75	Imperial 4588, 4888	22.8		12.1	2,019	12.2	2,033
Imperial R Bourbonniere	Imperial 8430, 8488	9.3		10.6	2,208	10.6	2,414
Halfway I-75	Halfwayup 5889, 6049	16.0		16.0	328	17.2	904
Brooks By-pass	HW 3939, ThreeOaks 25		160	15.5	41	15.3	300
Halfway Brooks N Weir	HalfwayCRDS 10259, 10400	15.8		15.5	646	15.3	752
Halfway Brooks S Weir	HalfwayCrS 7450, 7555	15.8		15.6	138	15.4	150
Halfway U.S. 41	HalfwayCRDS 12800, 12870	15.2		14.9	759	14.5	869
SB Estero R. I-75	EsteroRivS 99, 252	20.7		17.6	130	17.6	138
SB Estero R. Sanctuary	EsteroRivS 4100, 4200	14.6		14.3	340	14.5	281
SB Estero R. 3 Oaks Pkwy	EsteroRivS 6299,	<15.0		13.9	472	14.4	654
SB Estero R. Corkscrew Rd	EsteroRivS 8628	<16.0		13.8	481	14.2	722
SB Estero R. County Ck Dr	EsteroRivS 11155, 11250	10.7		10.8	940	11.2	1,011

Ecologic Assessment. A one-year continuous simulation of 2006 was conducted for Alternative 1v8a, and the results of this simulation were compared to a one-year simulation of the base condition. The difference in dry season groundwater elevations (Alt 1v8a minus base) is presented in **Figure 5-20**, and this analysis indicates that the ground water elevation for Alternative 1v8a is lower than the base condition in the vicinity of the by-pass channel along Three Oaks Parkway north of the Brooks. The excavated Three Oaks channel associated with this alternative is six feet lower than the existing channel, which exerts a drainage effect on the surficial aquifer. A simulation was conducted with the gate moved to the downstream (north) end of this channel to offset this negative impact, and the simulation results confirm that moving the gate downstream eliminates the groundwater impact. Another possible option is to reduce the depth of the channel and maximize channel width along with widening the gate opening of the by-pass structure.

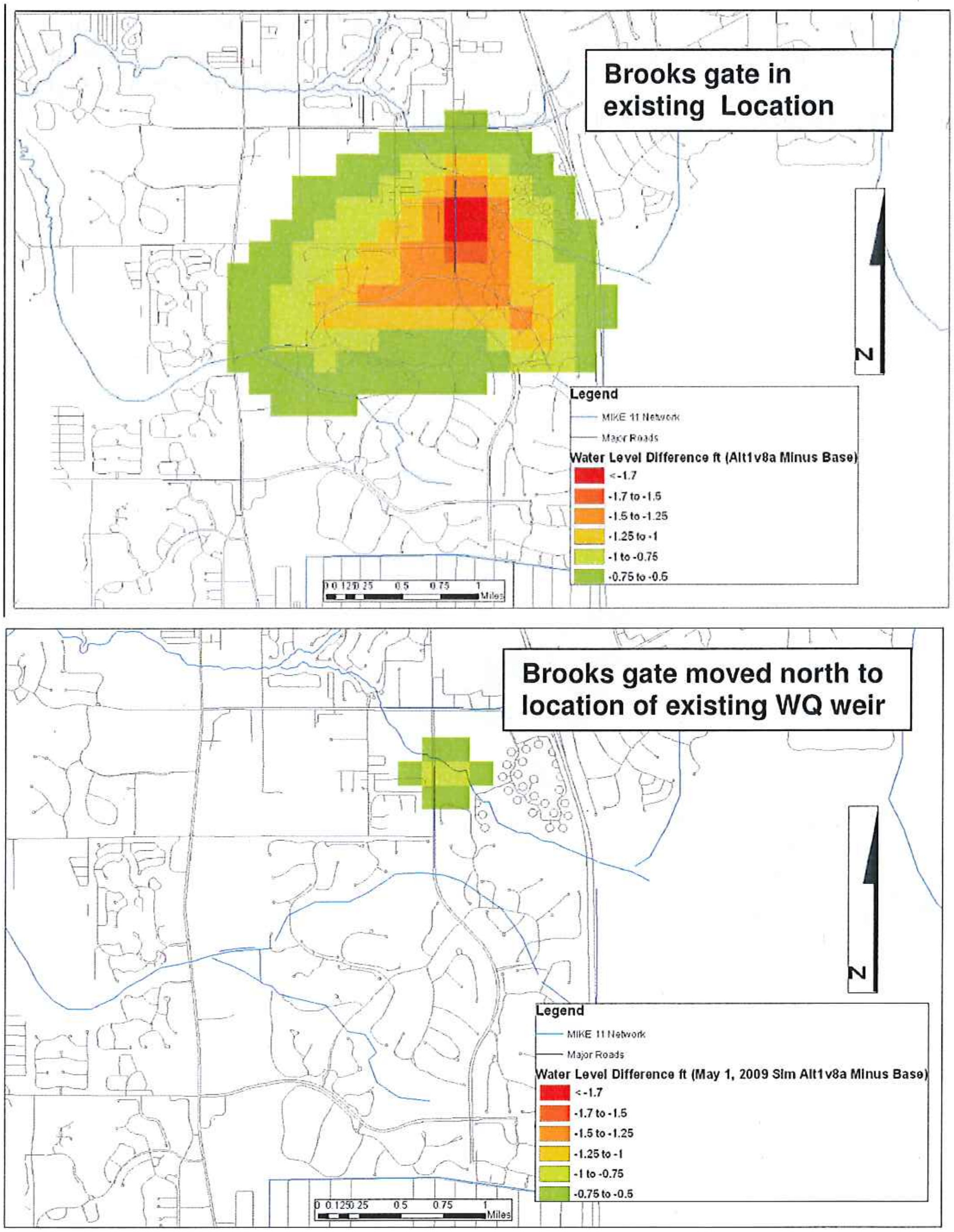


Figure 5-20: Average Dry Season (2/1 – 5/31, 2006) Groundwater Difference Map for Alternative 1v8a Minus Base for Existing Location and a Downstream Location

Figure 5-21 presents an overland depth difference map for Alternative 1v8a, and it is clear that the proposed improvements decrease average wet season water levels east of I-75. Decreased wet season water levels are expected since the purpose of this alternative is to increase conveyance under I-75. Because of limitations of elevation data from the model in the wetlands east of I-75, it is not possible to make a definitive conclusion if this change in water level is beneficial or harmful.

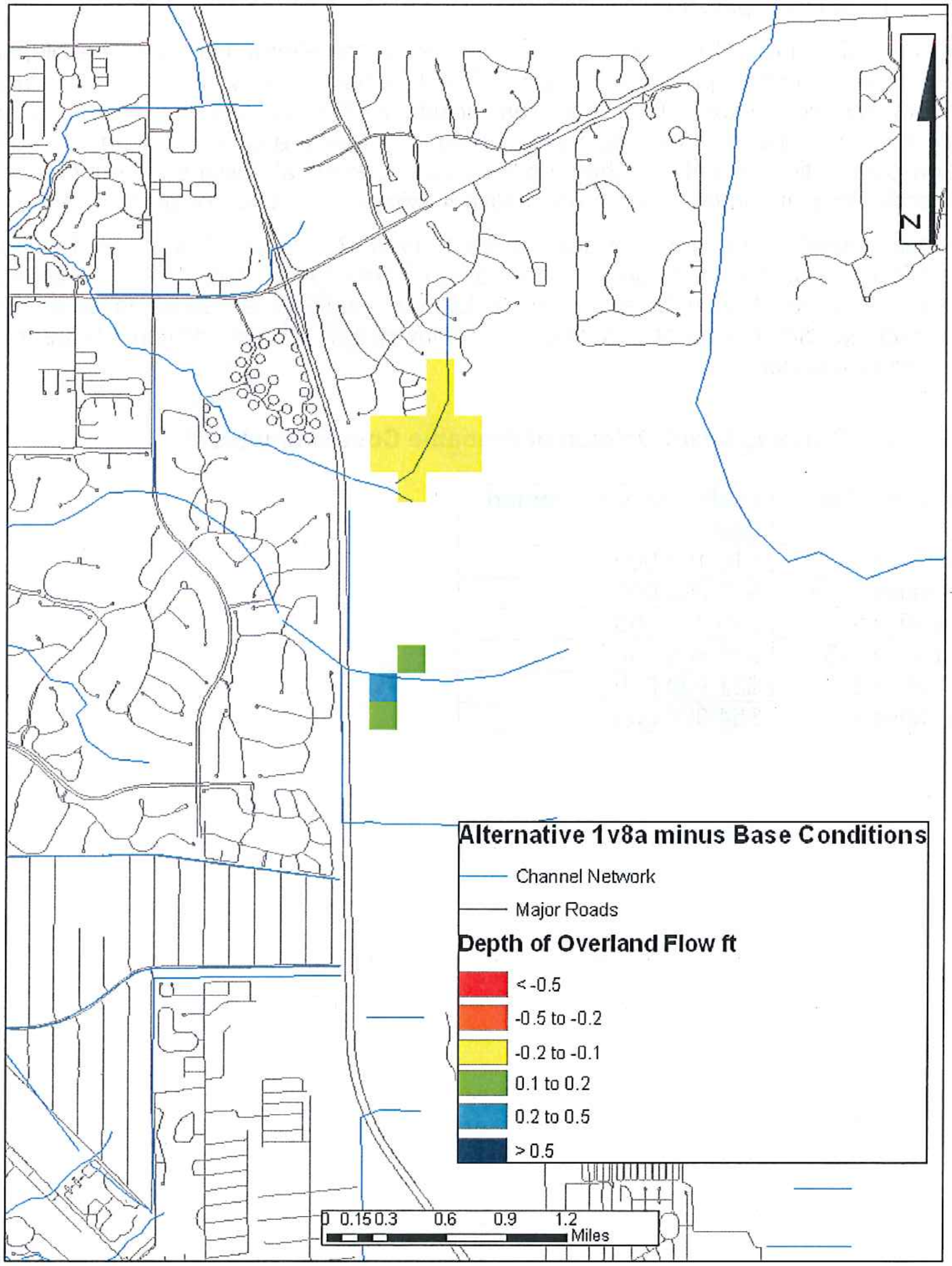


Figure 5-21: Average Wet Season (7/1 – 10/31, 2006) Overland Flow Difference Map for Alternative 1v8a Minus Base

5.5 Cost Considerations

Planning level opinion of probable cost estimates for the alternatives were developed utilizing sources such as published data, the FDOT website, Lee County staff, structural engineers and contractors. The estimates include a 30% contingency and 18% for survey, engineering and construction administration. These are to be relied on as "order of magnitude" estimates only, as they are based on conceptual designs without detailed site specific data, and in the case of Alternative 4, without a specific location.

The single largest cost element of alternatives 1, 1v8a, 2, 2v5 and 3 is the $5.4 million sheet pile walls of the excavated channel along Three Oaks Parkway from Halfway Creek to the South Branch Estero River. Additional studies are needed to determine the appropriate dimensions of this channel to convey the desired additional flows in a cost effective manner.

Table 5-12: Planning Level Opinion of Probable Cost Estimates

Alternative No.	Preliminary Estimated Costs
Alternative 1	$10,100,000
Alternative 1v8a	$10,300,000
Alternative 2	$10,300,000
Alternative 2v5	$11,600,000
Alternative 3	$21,900,000
Alternative 4	$54,000,000

6 RECOMMENDED PLAN

The original SLCWP identified the construction of I-75 as one of the causes of the loss, disruption, and alteration of historical flows. The SLCWP also identified a number of improvements to be completed geared towards restoring natural flow-ways, removal of constrictions and enhancing conveyance capacities within the Estero River, Imperial River, Cocohatchee River, Belle Meade, and Camp Keais Strand. The objective of the SLCWP Update is to verify and validate the findings and material assumptions of the original SLCWP for the Halfway Creek, Spring Creek, and the South Branch Estero River region. The SLCWP Update will serve as a useful tool to assist local and state agencies with current and future planning decisions in the South Lee County area.

On page 5-32 of the subject report is the segment "Determining Maximum Flow for Halfway Creek from 1-75 to Railroad Culverts". It states that because the predicted flows to Halfway Creek in this assessment are less than proposed in Amendment 1 of the 1999 SLCWP, simulations were conducted using higher flow similar to the 1999 Amendment 1 flows. Flow through the Halfway Creek I-75 culverts increase with increasing gradients across I-75, and localized heavy precipitation could generate flood elevations east of I-75 higher than 100-year predicted elevations. Flows at I-75 were set to equal 900 cfs, which is the flow in Halfway Creek recommended by the 1999 SLCWP (without 160 cfs to Spring Creek). Table 5-11 in the report indicates that Halfway Creek between I-75 and U.S. 41 can convey 900 cfs under I-75 with minimal impacts. Because the South Branch Estero River peak flow will not exceed 200 cfs with the recommended plan, the combined flow for these two systems will be 1,100 cfs, less than the combined pre-development peak flow of 1,800 cfs presented in Table 1-6.

A wide range of alternatives were evaluated to determine the optimum set of components that will meet the study objectives. These components were a product of the alternative analysis and the ecological assessment and assisted the project team with the final recommendations below.

6.1 Plan Components

The following actions are recommended for implementation, in order of decreasing priority:

1) Construction of a conveyance system under 1-75 to Halfway Creek at invert elevation 9.0 ft-NAVD that will convey up to 900 cfs of total future flows. Note that the control elevation upstream of I-75 is addressed in recommendation 4 discussed below. The model indicates that currently 330 cfs can pass through the system under existing conditions without major downstream impacts. The conveyance system will include a control system or temporary blockage to allow only 330 cfs flows until downstream restrictions and impediments are removed and improvements are completed. This includes recommendation 7).

Since the invert elevation of the existing 9 x 8 ft culverts is four feet lower than natural ground elevations, it should be expected that sediments will continue to accumulate in the existing system. Therefore any design should include:

i) providing a safety factor to protect against maintenance issues and any unforeseen conditions;

ii) a conveyance capacity not to exceed 900 cfs, which accounts for a worse-case scenario of potentially higher than designed storm and flooding scenarios within the model. I-75 is designated a major evacuation route and protection of this area under extreme conditions is critical for the public safety and health of the region.

iii) the not to exceed capacity also accounts for potential additional flows resulting from using the more accurate topography (LIDAR) that is now available; and

iv) the recommended capacity will reserve conveyance capacity should future downstream conveyance improvements or restoration projects exceed the improvements evaluated by this study

2) Construction of a conveyance system under I-75 to Bonita Bill Canal in the Spring Creek watershed that could convey up to 160 cfs of total future flows. The conveyance system will include a control system that will only allow a current base flow of 25 cfs under the following conditions:

   i) conveyance improvements downstream have been implemented to a sufficient degree to allow for delivery of additional storm flows to the Spring Creek, or

   ii) flows under I-75 are controlled by a gate to only allow flows when water levels at the upstream side of the Moriah weir are less than 10.8 ft-NAVD and water depths upstream of the gate are greater than 1.5 ft. Utilizing gates would provide improved wetland hydroperiods for lands east of I-75 that appear to be wetter than desired and would also provide much-needed flows to Spring Creek during non-flood conditions.

3) Consideration of construction of a connector collection system just east of I-75 from Halfway Creek to the South Branch Estero River Bridge to increase conveyance under I-75. Initial modeling results indicate that the collection system should have a bottom width of 100 feet with an invert elevation of 8 ft-NAVD. An iteration was conducted with a narrower channel with a bottom width of 36 feet, top width of 72 feet, and an invert elevation of 11 ft-NAVD; and initial results suggest that this smaller channel will provide similar conveyance. Geotechnical testing should be conducted if the 6 ft-NAVD invert elevation is maintained to determine depth to rock. Once more accurate elevation data is used in the modeling assessment, the sensitivity analysis should be continued to determine the optimum depth and width of this proposed channel.

4) Consideration of construction of weirs upstream of I-75 for Halfway Creek and South Branch Estero River to maintain adequate wet and dry season water levels consistent with wetland hydroperiod needs. Additional modeling is needed using more accurate topographic data east of I-75 to finalize the invert elevation and length of the weirs. Initial testing suggests that the weir length can be reduced to approximately 50 feet.
5) Connection of Halfway Creek to the Rapallo Lake west of Via Coconut Point Rd. and east of Via Villagio Road.
6) Improve vegetation maintenance in Halfway Creek east and west of U.S. 41. Vegetation removed east of U.S. 41 should be removed from the flood way and not stacked in "tee-pees". Fallen vegetation and dense brush west of U.S. 41 should be removed and any recently deposited sediment should be removed. Any exotic vegetation west of the FPL force-main should be identified and removed in accordance with an ecologic assessment.
7) Improve conveyance through the emergency by-pass gate and channel from the Brooks to the South Branch Estero River without decreasing groundwater elevations in the vicinity of Three Oaks Parkway and Williams Road.
8) Increasing conveyance in the South Branch Estero River at Country Creek Drive near Split Oak Way.
9) Increasing conveyance in the North Branch Estero River at Rivers Ford Road.
10) Enlargement of culverts downstream of the Old U.S. 41 culverts in the Spring Creek tributary that receive flows from the Moriah weir. The capacity of the downstream culverts at the railroad, FPL crossing, and Cedar Lane should be at least as large as the Old U.S. 41 culverts (two 8' x 4' box culverts).
11) Enlargement of the Countess Lane culverts to be at least as large as the Old U.S. 41 culverts in Spring Creek at the USGS gaging station (two 8' x 4' box culverts)
12) Further evaluation of restoration of flood flow deliveries from the Kehl Canal watershed to wetlands south of Bonita Beach Road and east of I-75 for ultimate conveyance to Cocohatchee Canal. The maximum flood flow deliveries are only necessary for the 25- and 100-year design storm events, and the peak flow is expected to be in the range of 200 cfs. Additional modeling and evaluation is needed to assure that the wetlands south of Bonita Beach Road (east of I-75) and the Cocohatchee Canal can safely receive these flows.

6.2 Ecologic Assessment

The field assessment conducted as a part of this study indicated that the wetlands east of I-75 are impacted by drainage effects from the Halfway Creek and South Branch Estero River culverts and bridges. Simulations indicate that implementation of the recommendations presented above in **Section 6.1** will decrease the average wet season water level of wetlands east of the I-75 South Branch Estero River bridge and culverts by approximately 0.15 feet for the 142-acre area of impact. There is a corresponding 40-acre area of increased average wet season water levels in the Halfway Creek watershed east of I-75. This change is likely beneficial since the South Branch Estero River flows under I-75 are much lower than historic flows due to channel constrictions downstream of I-75.

As mentioned above in **Section 6.1**, additional modeling is needed to establish the control elevation for proposed weirs east of I-75. If possible, it is recommended that the additional modeling utilize measured water levels in a number of wells east of I-75 in the Halfway Creek and South Branch Estero River, if these data can be obtained from private sources.

6.3 Costs

The cost of the recommended plan has been estimated at a preliminary planning level of detail. There are a number of further iterations recommended for a number of recommended features that will affect the final construction cost, plus there are a number of unknowns that could significantly affect the cost, such as depth to rock, availability of easements for channel enlargements, and surface/groundwater seepage rates (should a reservoir be considered further). There are many other unknown factors that will affect the cost. Therefore, the costs presented herein are preliminary in nature and will likely change in magnitude. With these qualifiers, the planning level opinion of probable cost for the recommended plan is $10,300,000. The single largest cost element of the recommended alternative is the sheet pile walls of the excavated channel along Three Oaks Parkway from Halfway Creek to the South Branch Estero River. Additional studies are needed to determine the appropriate dimensions of this channel to convey the desired additional flows in a cost effective manner.

6.4 Recommended Additional Studies

During the initial phases of this project, new topographic information was being developed for Lee County that was expected to be significantly more accurate than the existing topography. In addition, there have been numerous developments since the older topographic data was generated which changed land elevations significantly. There was consideration of using this new topographic data, however the fixed deadline of May 14, 2009 for this report prevented that topographic data from being utilized. During the initial phases of the Problem Identification task, elevation difference maps were generated for the old and new topography. These difference maps confirmed findings during the ecologic assessment which indicated that surveyed spot elevations east of I-75 were significantly different from the topographic data used in this modeling assessment. Because the new topography is more representative of existing conditions and is more accurate, it is recommended to revise the design storm simulations using the more accurate topography. The topographic data used for the modeling results presented in this report is believed to be sufficient to determine the flow splits between the Estero, Halfway, and Imperial River watersheds, however the existing simulations are not sufficient for determining the appropriate control elevations for wetlands east of I-75.

The degree of flooding in San Carlos Estates is unexpected since reports of house flooding are relatively rare for this community. The simulation results are based on a model that uses information from a 1970 Plan of Reclamation for San Carlos Estates channel cross sections. Additional simulations are recommended for this area using surveyed cross sections within San Carlos Estates. In addition, channel dimensions in the South Branch Estero River between Sanctuary Road and Corkscrew Road are different from the cross sections used in this modeling study. Therefore new cross sections are recommended for this reach as well.

Flooding of two bridges is predicted in Country Creek Estates for the North and South Branch Estero River, and bridge cross sections are recommended for these bridges.

It is understood that measured water level data is available for a number of locations in wetlands east of I-75 in the headwaters of the Estero River and Halfway Creek watersheds. These measured data have been requested but have not yet been obtained. These data would be useful in the revision of the design storm peak stages and flows and should be obtained if at all possible.

Further work is recommended to evaluate flow exchanges between the Kehl Canal area and the Cocohatchee Canal to confirm the study findings and to determine if it will be possible to divert flood flows south to the Cocohatchee Canal.

As discussed above in Sections 5.4.2 and 6.1, further iterations are recommended to determine the elevations and dimensions of proposed weirs and the north-south channel upstream of I-75.

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APPENDIX 1

Survey Cross Section Location Maps and Drawings

Location Maps:


XS_ER_SB_N
XS_ER_SB_S
XS 3_Oaks

Section-Boyle2

0.0	10.72	Halfway Creek South Branch
3.8	11.46	200 ft west of Via Coconut Point
13.9	15.11	
18.9	14.94	
35.4	13.09	
52.0	12.27	
80.3	12.14	
92.4	12.22	
95.0	10.57	
114.6	10.49	
119.6	11.77	
124.5	11.94	
129.2	11.93	
134.8	10.34	
153.3	10.13	
159.2	12.10	
180.0	10.58	
187.1	10.66	
195.1	10.31	
203.3	10.40	
214.6	10.37	
221.5	10.29	
229.5	10.68	
237.4	11.03	
247.7	11.82	
258.4	12.15	
272.2	12.08	

Section-Boyle2a

0.0	16.11	Via Coconut Point Ditch
1.6	15.93	Just north of Halfway Creek South Branch
11.2	13.53	
18.6	11.80	
26.0	8.12	
34.4	7.41	
43.3	6.36	
50.6	6.72	
56.9	7.60	
60.9	8.93	
72.7	11.45	
82.5	12.27	
94.1	12.38	

Section-Boyle2b

0.0	15.67	Via Coconut Point Ditch
2.3	15.49	Just south of Halfway Creek Middle Branch
12.6	13.21	
19.5	11.71	
26.1	8.37	
33.1	6.93	
40.3	6.48	
47.3	6.44	
55.3	6.69	
61.0	8.65	
72.7	10.81	
77.1	11.59	
84.3	12.31	
98.3	12.57	

Section-Boyle2c

12.45	0	Halfway Creek Middle Flowway
12.381	17.521045	200 ft West of Via Coconut Point
11.155	30.992853	
10.213	45.73835	
10.38	57.643924	
11.212	64.579988	
11.29	76.470469	
10.087	85.317637	
10.007	95.995044	
8.783	101.35446	
8.788	103.7599	
8.599	110.50102	
8.48	114.78402	
8.548	118.81167	
10.007	124.32619	
12.124	129.25958	
12.245	141.60742	

Section-Boyle2d

0.0	15.39	Via Coconut Point Ditch
2.5	15.07	Just south of Halfway Creek Main Branch
10.1	13.50	
18.0	11.46	
27.2	8.53	
33.9	7.16	
44.4	6.90	
49.7	6.87	
56.9	7.03	
63.1	7.39	
69.2	8.95	
76.5	10.59	
83.2	13.02	
94.2	13.25	

Section-Boyle3

Halfway Creek Main Branch
270 ft West of Via Coconut Point

0.0	12.45
10.7	11.42
23.6	10.87
32.1	9.65
38.1	9.80
42.6	10.42
67.3	10.55
78.4	11.29
80.4	11.79
100.7	11.53
112.3	10.63
121.9	10.88
133.6	11.50
150.3	11.44
179.6	12.61
191.7	13.62
199.5	14.04

Section-Boyle3a

Halfway Creek Main Branch
430 ft West of Via Coconut Point

	Adj Sta	Elev	Orig Sta
reversed	0.0	9.69	388.8
elevations	9.6	10.88	384.9
so that we	15.7	12.40	378.7
have LB	26.9	12.09	372.9
facing D/S	37.2	11.35	366.1
	44.4	10.60	361.8
	53.2	8.60	357.4
	59.5	7.66	347.9
	66.6	11.07	339.9
	77.5	11.50	337.0
	88.3	11.32	321.0
	97.9	11.13	305.8
	105.5	11.33	280.0
	115.7	11.47	263.5
	124.9	11.42	243.3
	132.8	11.66	218.3
	140.1	11.61	193.5
	151.7	11.59	174.0
	174.0	11.73	151.7
	193.5	11.97	140.1
	218.3	11.66	132.8
	243.3	11.11	124.9
	263.5	10.21	115.7
	280.0	8.20	105.5
	305.8	6.09	97.9
	321.0	4.57	88.3
	337.0	1.86	77.5
	339.9	2.11	66.6
	347.9	3.28	59.5
	357.4	4.51	53.2
	361.8	6.35	44.4
	366.1	8.12	37.2
	372.9	11.19	26.9
	378.7	13.70	15.7
	384.9	14.54	9.6
	388.8	15.20	0.0

Section-Boyle3b

	Adj Sta	Elev	Orig Sta	390 ft west of 3A
reversed	0.0	9.74	358.1	
elevations	9.3	10.74	352.5	Halfway Creek Main Branch
so that we	19.6	12.64	348.9	800 ft West of Via Coconut Point
have LB	30.6	12.20	342.1	
facing D/S	35.7	10.45	332.2	
	43.2	8.75	328.1	
	54.0	8.59	318.5	
	64.0	8.95	316.0	
	73.7	10.88	304.2	
	81.1	11.21	289.3	
	86.6	10.96	274.0	
	99.6	11.10	259.8	
	110.2	11.18	241.5	
	125.6	11.30	222.1	
	147.1	11.68	201.2	
	167.4	11.62	183.5	
	183.5	11.74	167.4	
	201.2	11.74	147.1	
	222.1	12.00	125.6	
	241.5	11.63	110.2	
	259.8	10.84	99.6	
	274.0	9.29	86.6	
	289.3	7.69	81.1	
	304.2	6.35	73.7	
	316.0	3.77	64.0	
	318.5	4.52	54.0	
	328.1	4.96	43.2	
	332.2	7.64	35.7	
	342.1	8.42	30.6	
	348.9	11.19	19.6	
	352.5	13.25	9.3	
	358.1	15.23	0.0	

Section-Boyle4

0.0	16.34
6.2	14.95
14.2	12.62
18.9	12.24
24.5	12.25
32.4	12.55
39.7	14.18
57.0	18.91
71.9	23.99

Section-North Box Culverts - Via Villagio

9.184	0
5.933	15.65364
5.919	26.965643
6.012	37.407519
7.251	51.042907
7.702	123.30133
5.973	137.07152
6.165	149.01058
5.85	160.59149
6.911	172.74248

Section-South Box Culverts - Via Villagio

9.461	0
5.606	16.759106
5.791	29.902706
5.904	40.663984
7.695	55.428583
6.555	144.90091
5.88	159.61001
5.381	171.46827
5.659	183.08286
7.437	198.67436

Section-North Corkscrew

	0	10
0.0	500.0	9.06
8.1	508.1	8.99
17.3	517.3	9.05
24.6	524.6	8.77
31.5	531.5	8.41
40.5	540.5	10.14
75.9	575.9	11.63
88.8	588.8	13.41
96.6	596.6	10.61
164.8	664.8	9.88
	1164.8	10

Section-South Corkscrew

	0	14.8
0.0	500.0	14.71
15.9	515.9	14.95
21.9	521.9	12.25
23.5	523.5	11.20
28.0	528.0	9.92
33.2	533.2	9.59
39.8	539.8	9.22
42.4	542.4	9.00
48.9	548.9	9.70
51.7	551.7	11.18
56.8	556.8	13.29
74.7	574.7	13.08
	1074.7	13.5

Section-Bay Club - Halfway Ck at Williams Rd

0.0	12.16
17.2	11.12
37.3	8.40
60.5	6.13
80.7	3.64
88.0	1.55
96.2	1.56
109.4	-0.52
113.9	-0.89
117.6	-1.57
126.7	-0.65
134.1	-0.63
139.8	-0.84
149.1	-0.91
157.4	-0.62
160.9	0.98
169.6	1.66
177.9	1.47
189.7	2.66
203.7	3.42

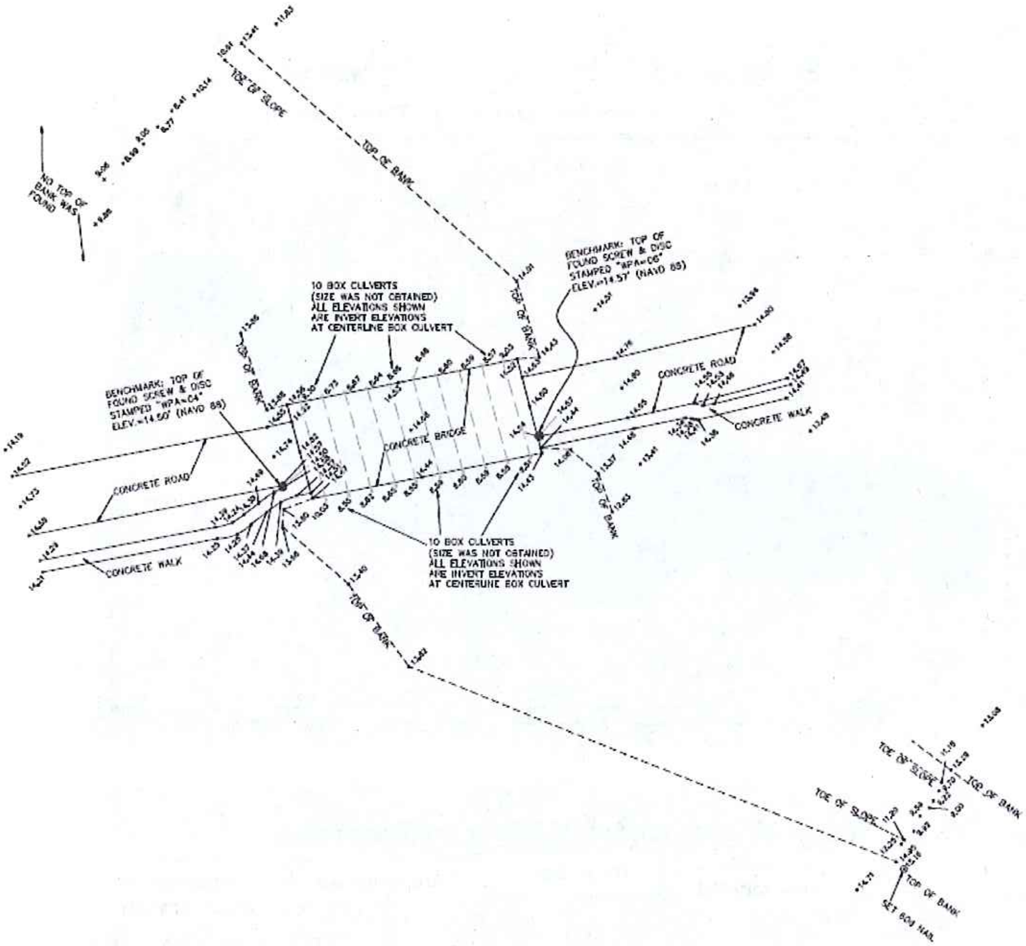
Section-west-of-wood-bridge

12.10	0.0
11.84	43.5
11.54	86.3
10.88	115.4
10.58	126.9
9.73	151.4
9.20	173.6
8.82	192.7
9.80	213.1
10.25	228.7
10.64	244.6
11.25	264.6
11.55	283.8
11.58	303.4
11.59	323.6
11.82	343.2
11.88	363.1
11.82	383.4
11.64	402.8
11.58	422.7
11.94	438.3
12.63	452.9

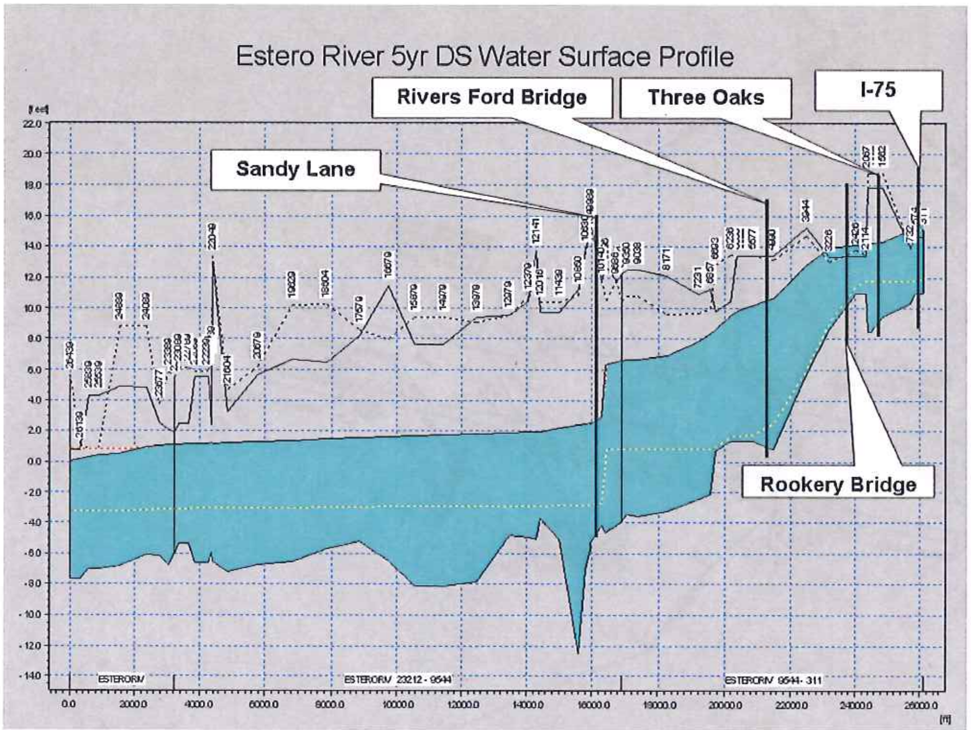
Section Halfway Creek 800 ft West of U.S. 41

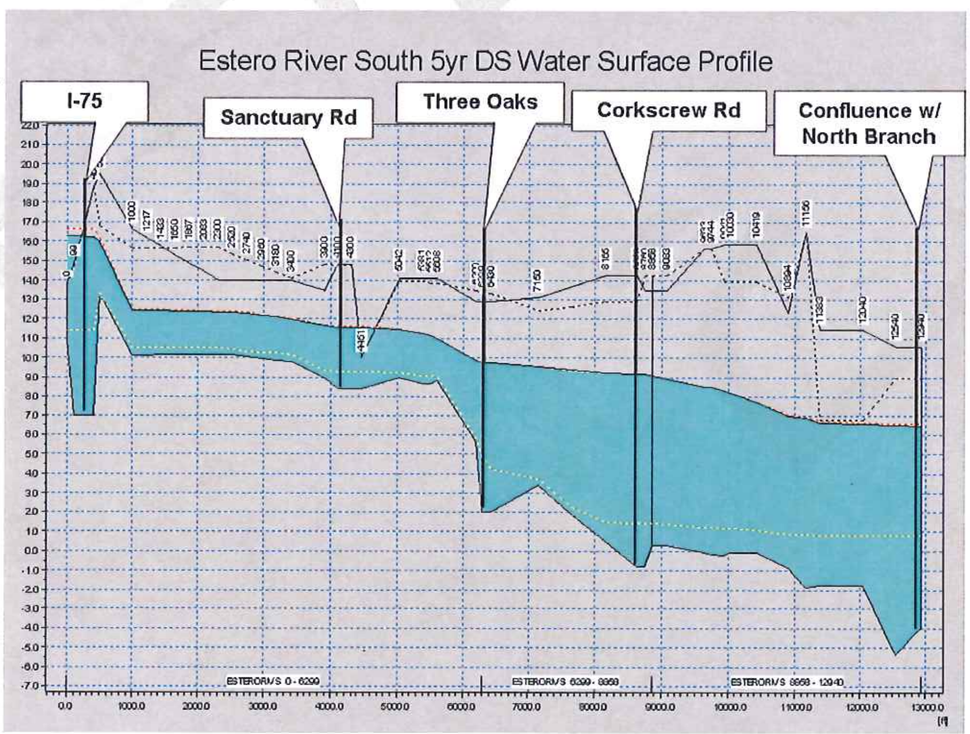
stationing	Z - ft-NAVD
0.0	13.5
15.3	12.8
29.3	9.3
32.3	5.6
523.7	12.4
561.1	11.2
625.0	11.1
698.4	10.0
749.5	9.6
889.3	9.9
951.0	9.4
1,019.4	9.9
1,025.1	9.1
1,028.5	6.5
1,241.3	9.4

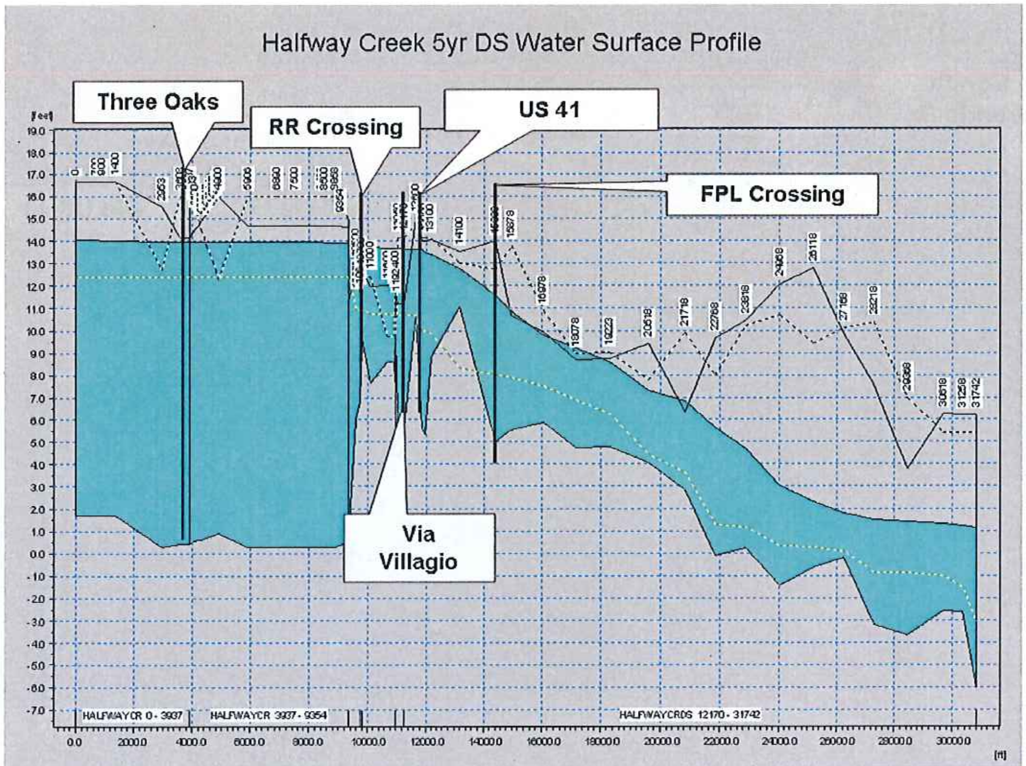
Sanctuary Road Bridge Surveying

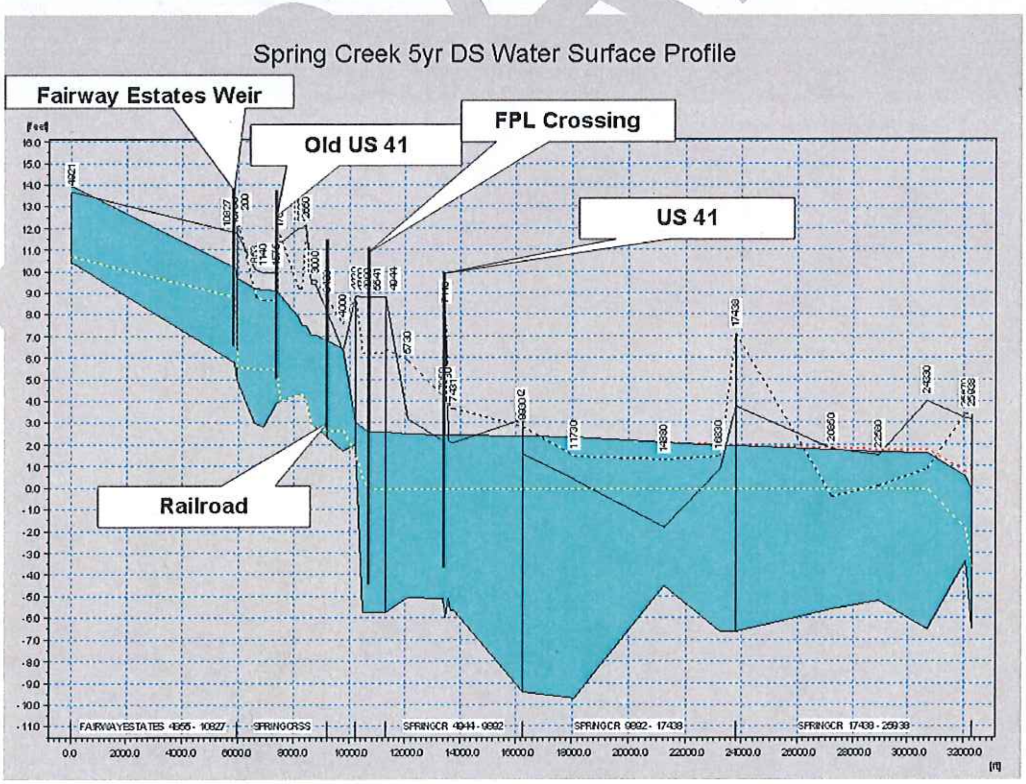


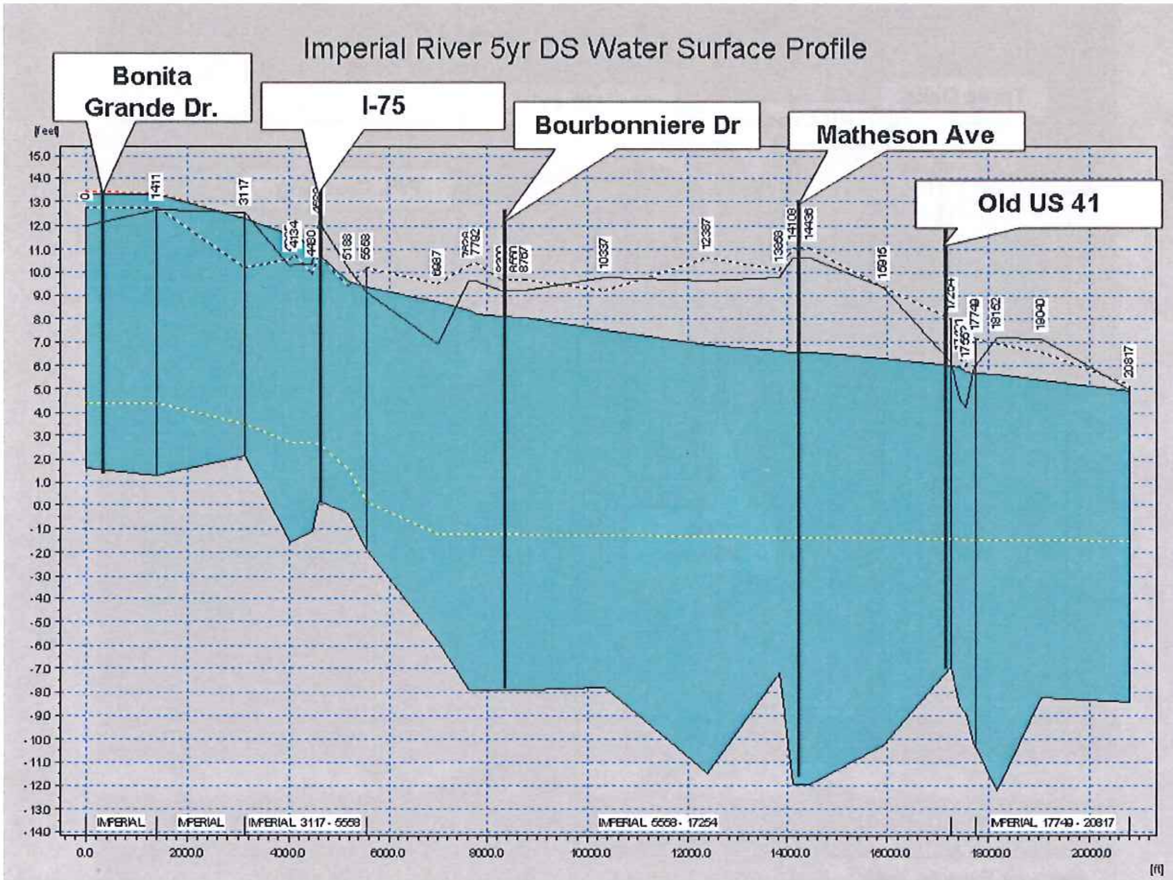
APPENDIX 2
Flood Profiles for Base Condition – All Results are ft-NAVD

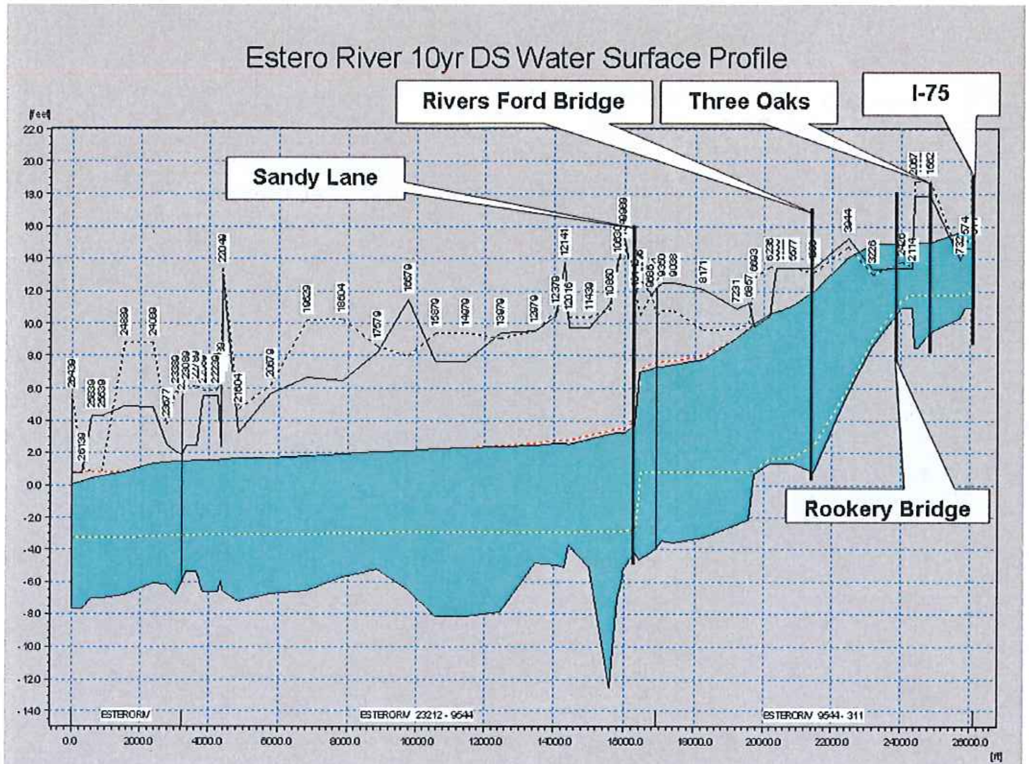


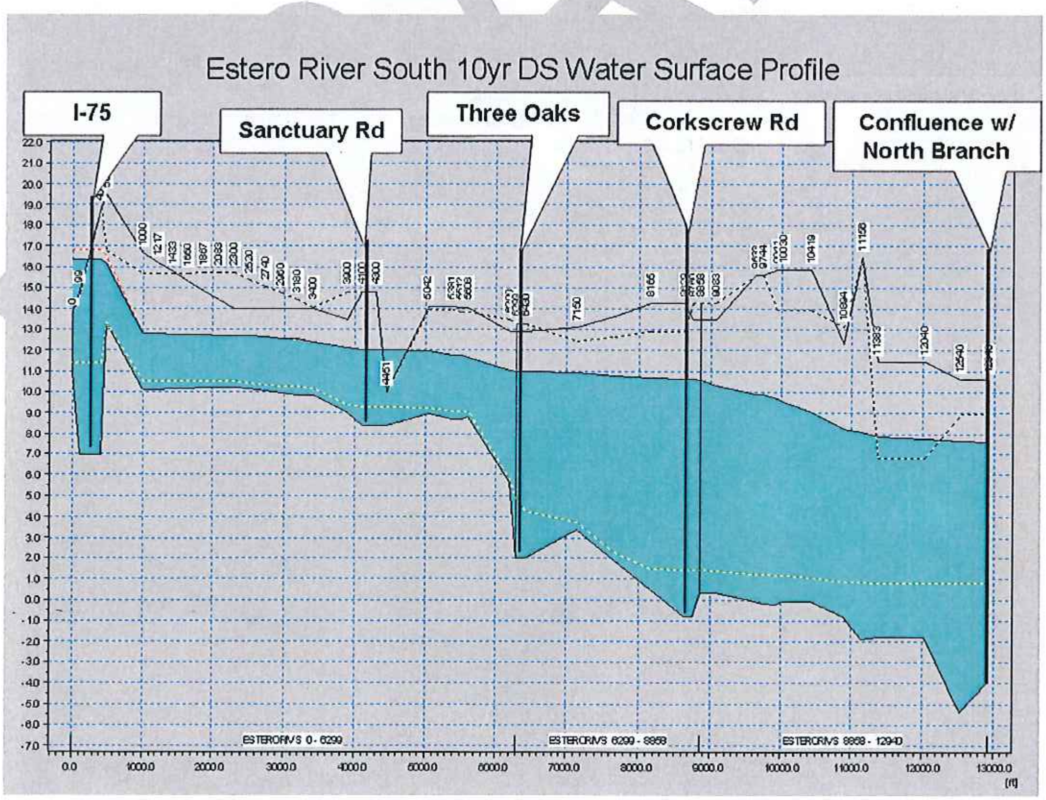



Halfway Creek 5yr DS Water Surface Profile
Three Oaks
RR Crossing
US 41
FPL Crossing
Via Villagio
[feet]
[ft]


Spring Creek 5yr DS Water Surface Profile
Fairway Estates Weir
Old US 41
FPL Crossing
US 41
Railroad
[feet]
[ft]


Imperial River 5yr DS Water Surface Profile
Bonita Grande Dr.
I-75
Bourbonniere Dr
Matheson Ave
Old US 41
[feet]
IMPERIAL
IMPERIAL
IMPERIAL 3117 - 5558
IMPERIAL 5558 - 17254
IMPERIAL 17749 - 20817
[ft]


Estero River 10yr DS Water Surface Profile
Rivers Ford Bridge
Three Oaks
I-75
Sandy Lane
Rookery Bridge
Feet
ESTERORV
ESTERORV 23212 - 9544
ESTERORV 9544 - 311
(ft)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North Branch
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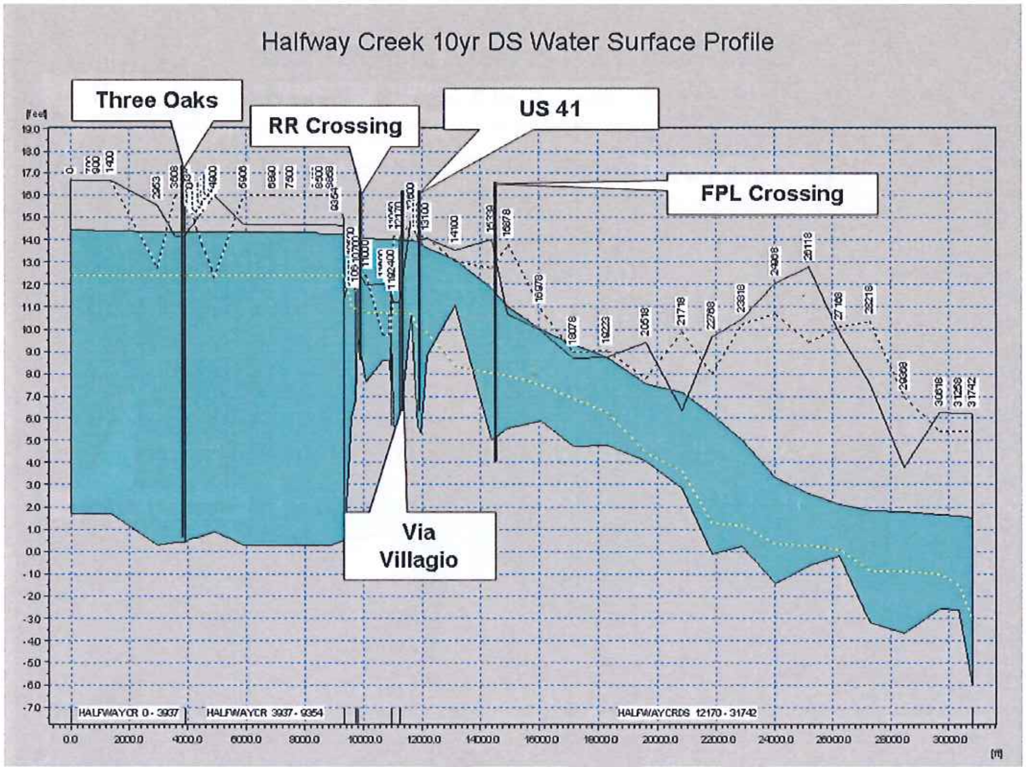
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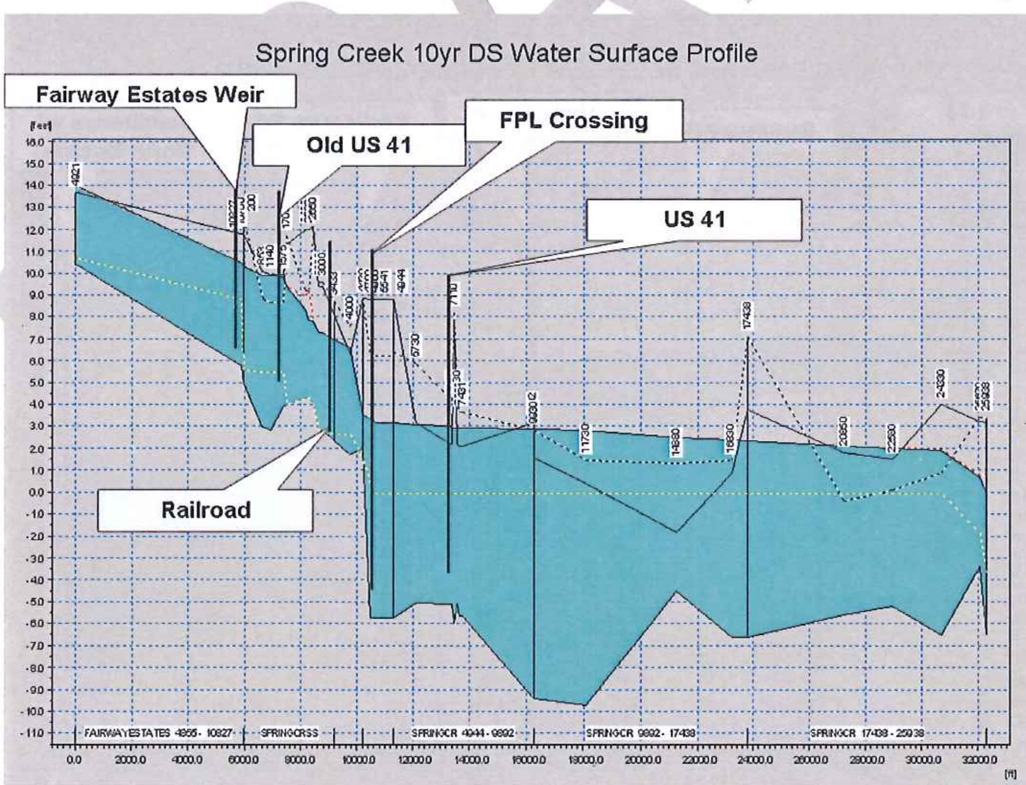
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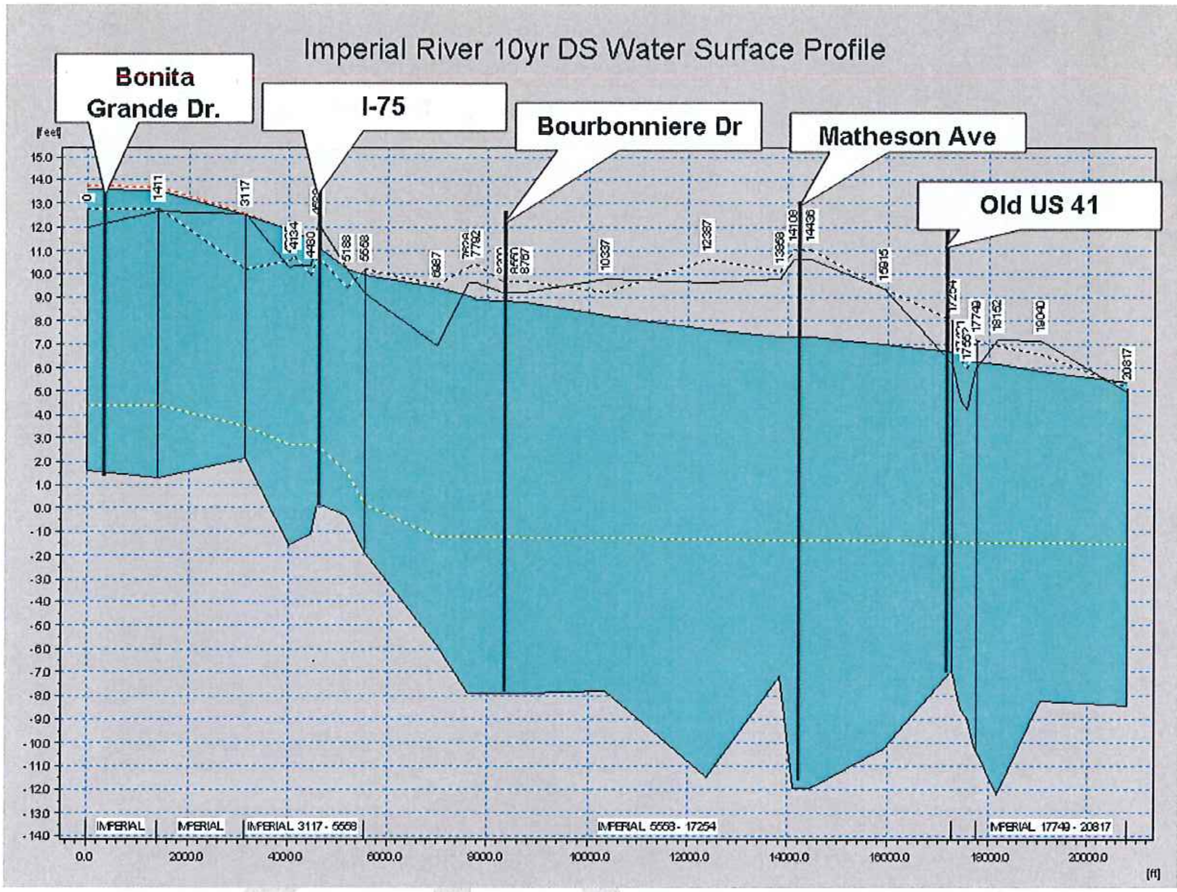
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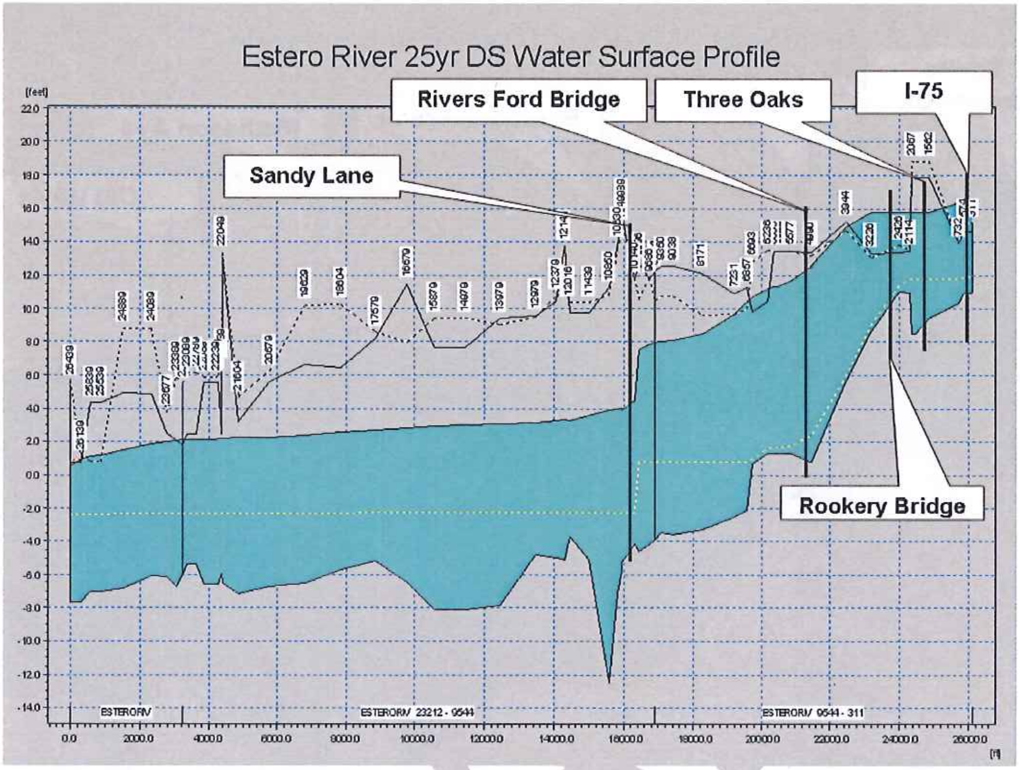
IMPERIAL 17749 - 20817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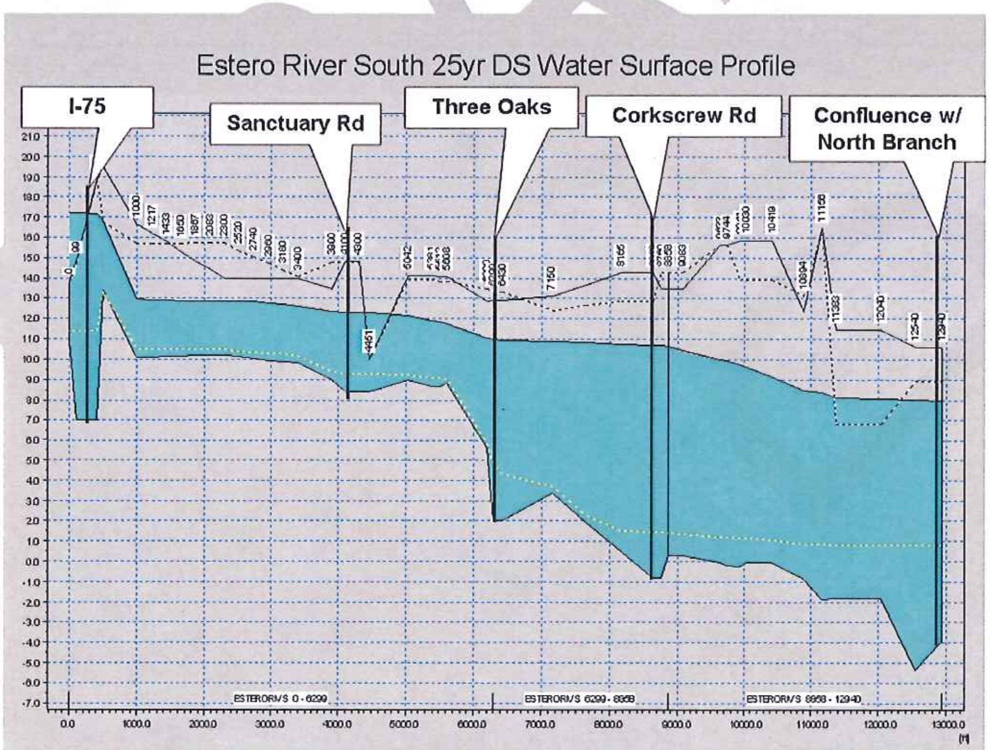
I-75
Sandy Lane
Rookery Bridge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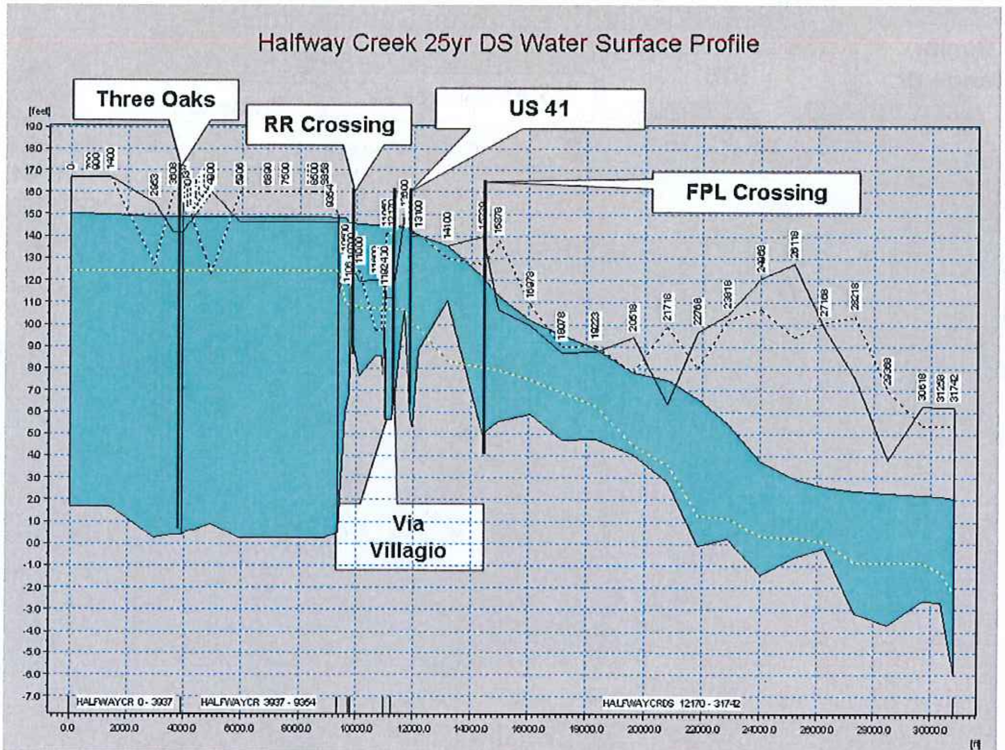
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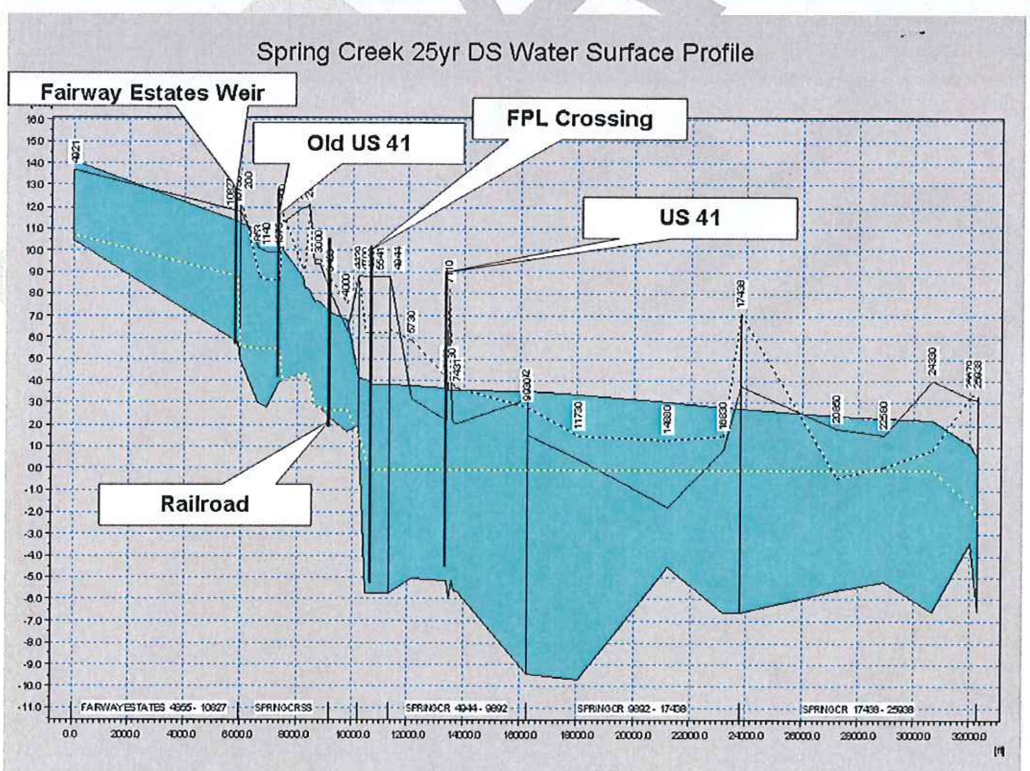
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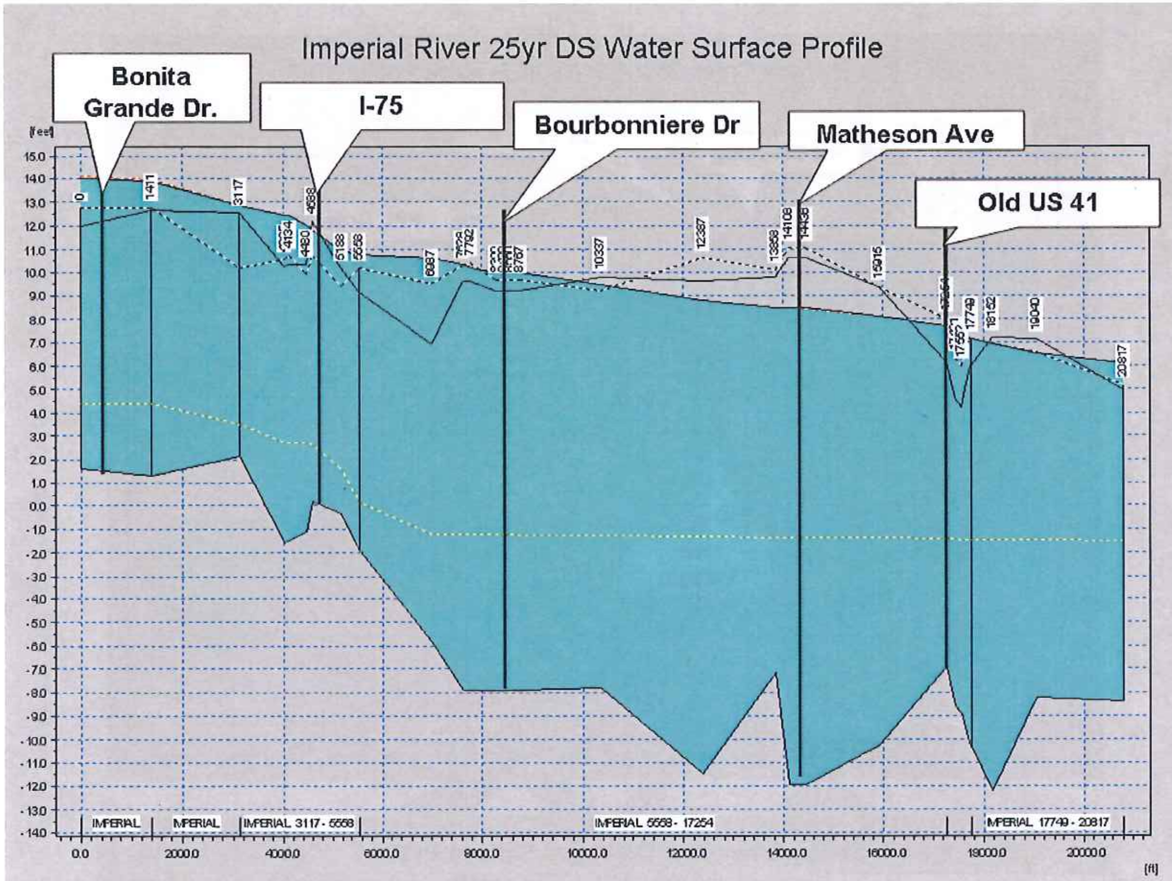
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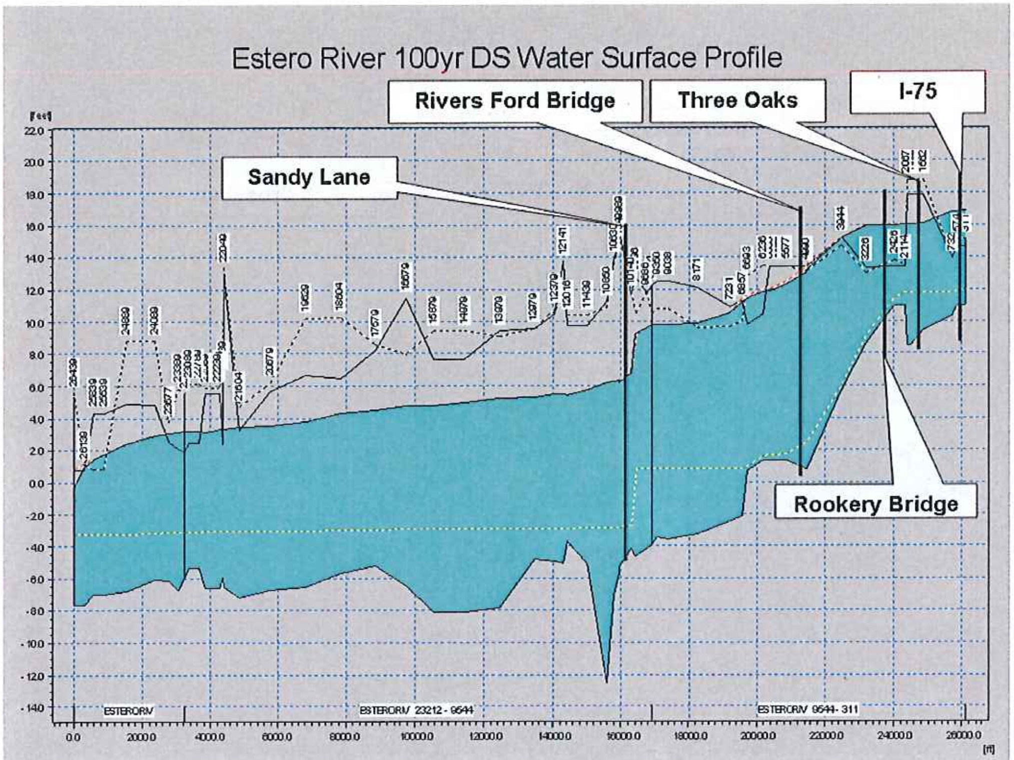
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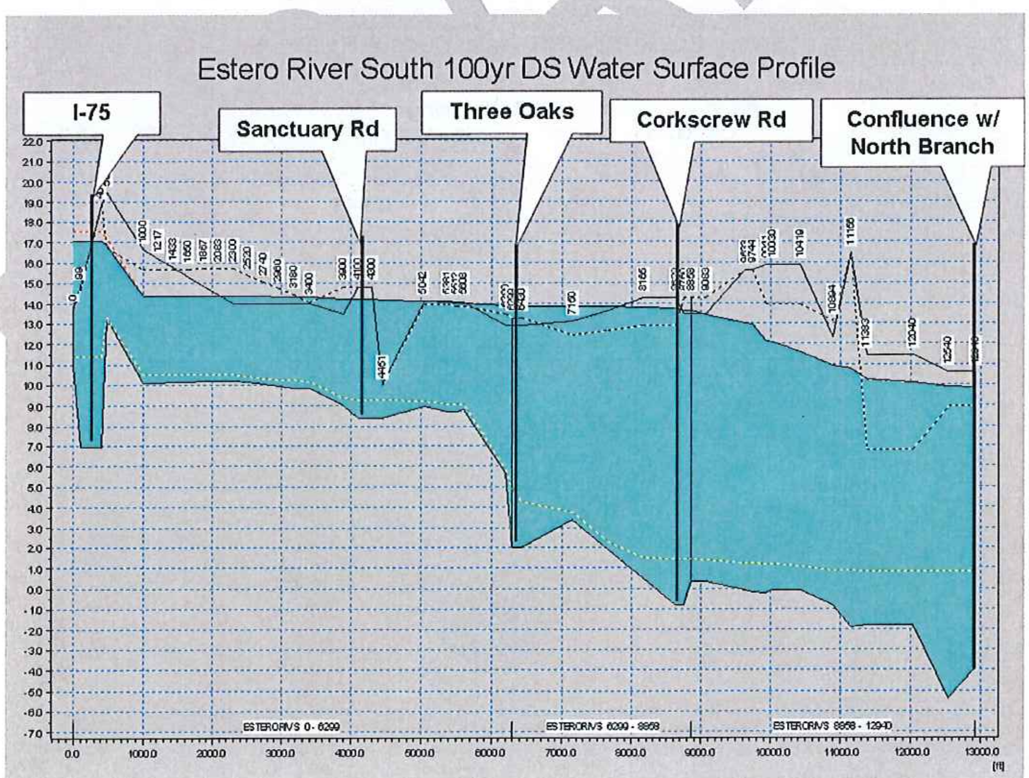
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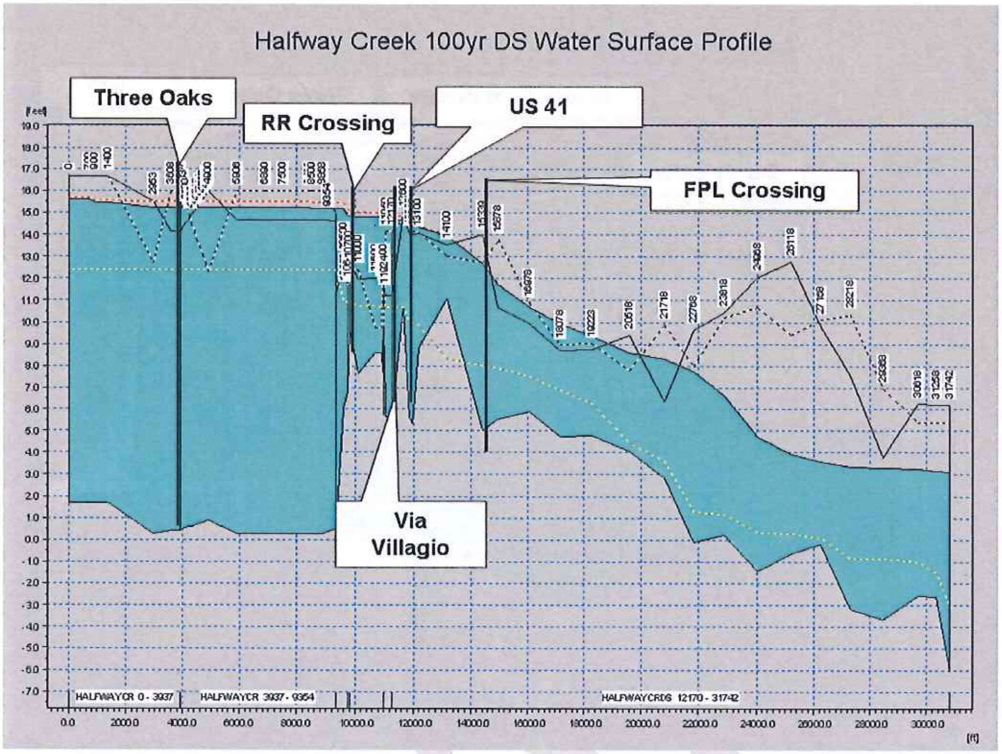
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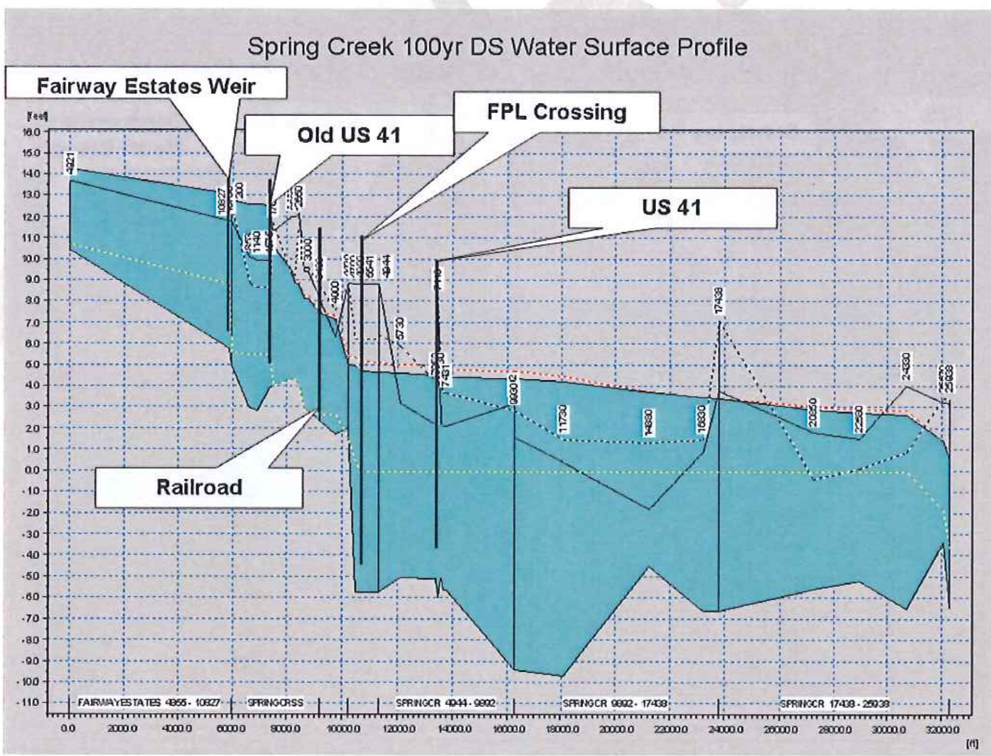
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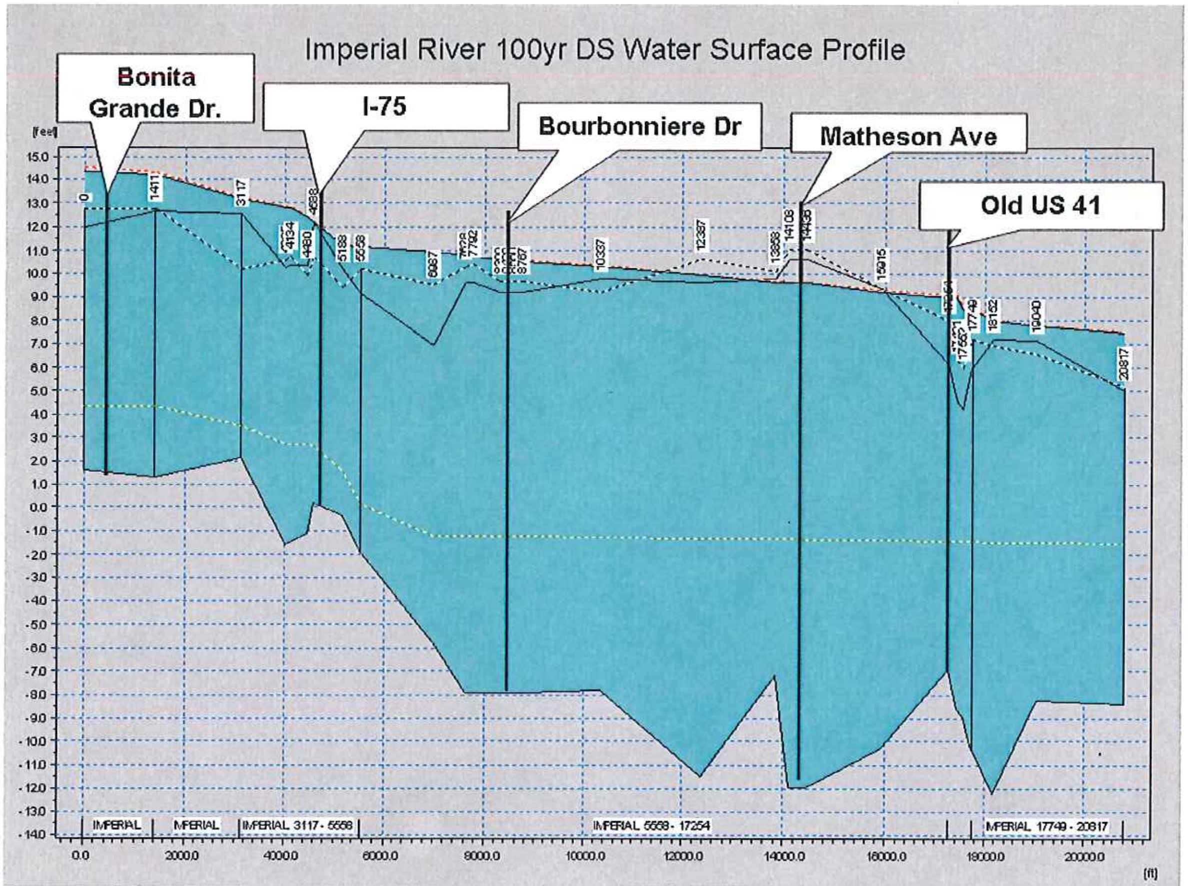
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Bonita Grande Dr.
I-75
Bourbonniere Dr
Matheson Ave
Old US 41

South Lee County Watershed Plan Update
Work Order C-4600000791 WO01-R1
100% Deliverable 1C
Task 1 – Survey Cross Sections and Model Update

South Florida Water Management District

Client Representative	Steve Sentes

Boyle | AECOM

Project Manager	Karen Brandon
Project Engineer	Pradeep Nagarajan
Boyle Staff	Roosevelt Wiggins

A.D.A. Engineering, Inc.

Project Manager	Roger Copp
Lead Modeler	Michael O. Walters

April 2, 2009

BOYLE | AECOM

2090 Palm Beach Lakes Blvd., Suite 600	West Palm Beach, FL 33409

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INTRODUCTION

This report is being submitted as the 100% Deliverable 1C for the Survey Cross Sections and Model Update task of the South Lee County Watershed Plan Update in accordance with Work Order C-4600000791 WO01-R1 issued to Boyle Engineering Corporation on October 17, 2008. The report describes the simulation algorithms and input data processing, calibration of the model, sensitivity analyses of the simulation, problems encountered, and trouble-shooting process during the calibration and verification process. Both an analytical and graphical summary of calibration results is provided.

1.0 SURVEY CROSS SECTIONS

Cross sections were surveyed by Boyle Engineering so that the modeling effort could be representative of existing conditions in the study area. Cross sections were surveyed in locations where significant changes had occurred due to urban development. In addition, cross sections were surveyed in the South Branch of the Estero River at Sanctuary Road (upstream of Three Oaks Parkway) because existing information on this river crossing was not available from prior studies.

Figure 1-1 shows the locations where cross sections were surveyed. There were some adjustments to cross section locations based on a field survey conducted immediately prior to the surveying. A key concern of this study is the peak stages in Halfway Creek within and downstream of the Brooks. As a result, cross sections were surveyed west of Via Coconut Point. A cross section was surveyed along a weir in Halfway Creek just upstream of U.S. 41 (referred to the Halfway Creek Cypress Weir), and three cross sections were surveyed west of U.S. 41. A wooden walkway was constructed just west of U.S. 41, and local engineers reported that Halfway Creek channel bottom elevations appeared to be higher than previously surveyed. Accordingly, a cross section was surveyed at the walkway. Halfway Creek west of this walkway is a dense cypress swamp. An additional cross section was surveyed halfway between the wooden walkway and the FPL crossing (see **Figure 1-1** for location), and a cross section was surveyed at the Williams Road bridge within the West Bay Club.

Stakeholders expressed another concern regarding Brooks outflows north to the South Branch of the Estero River. It has been observed that outflows are restricted due to sediment deposits in the channel north of the Brooks diversion gate just east of the Three Oaks Parkway north of the intersection with Williams Road. A cross section was also surveyed at this location.

Appendix 1 presents detailed maps of cross section locations and drawings of these cross sections.

Figure 1-1 – Map of Cross Sections Surveyed by Boyle Engineering

2.0 MODEL UPDATE

MIKE SHE/MIKE 11 is an integrated surface/ground water modeling software package that is being used for a number of hydrologic/hydraulic modeling projects in southwest Florida. This modeling tool allows for a simultaneous assessment of stream flow and groundwater dynamics. The model also has the capability to simulate overland flow outside of river networks, such as in the wetlands east of I-75 between Corkscrew Road and the Imperial River. Lee County is conducting an assessment of water resource impacts of a number of mining proposals within an area east of I-75 and south of State Route 82 called the Density Reduction Groundwater Resource (DRGR) area, and MIKE SHE/MIKE 11 Version 2008 SP2 is being used for this assessment (DHI, Inc., 2008). The MIKE SHE/MIKE 11 model developed by DHI, Inc. covers all of Lee County, but the focus of the model was lands east of I-75, therefore a number of bridges, culverts and weirs in the Estero River, Halfway Creek, Spring Creek, and Imperial River basins were not included in the initial model. In order to maintain consistency, it was decided to use the MIKE SHE/MIKE 11 Lee County model for the South Lee County Watershed Plan Update, to add more detailed information on bridges, culverts, weirs, and gates west of I-75 and to utilize more recent information to modify the cross section database in the model. This memorandum summarizes the changes made to the model as part of the Update.

2.1 Calibration Data

Additional calibration data for 2008 was obtained from Lee County for groundwater wells, USGS for calibration wells and surface water stations (stage and flow data), SFWMD for wells in DBHYDRO, and Lee County DOT for gate level measurements and headwater and tailwater stage data for the Kehl Canal gate. Johnson Engineering provided measured stage data for Halfway Creek, and the District Manager for the Brooks Community Development Districts confirmed that the Brooks emergency gate remained closed in 2008.

Measured ground elevations and horizontal coordinates were obtained for each groundwater well used in the calibration, and these elevations were compared to the elevation in the MIKE SHE digital elevation model (DEM) at that location. There were significant differences for some calibration wells, and these differences can affect the calibration accuracy because all simulated groundwater elevations are relative to the DEM ground elevation. **Table 2-1** lists the elevation differences for the groundwater calibration wells. Surficial well L-5844 has a surveyed ground elevation that is 6.6 feet lower than the DEM elevation. The DEM elevation is an average elevation for a 750x750 foot grid cell, and that elevation is calculated from a LIDAR-generated topographic map. The LIDAR-based DEM may not be representative of actual ground elevations, particularly in forested areas that have rapidly changing elevations. The area surrounding L-5844 is one such well that is located in a ravine north of the Estero River just west of U.S. 41, and the DEM elevation for that cell is clearly incorrect. As will be discussed later in section 3.2, calibration accuracy for that well is not good.

Well ID	DEM Elevation (ft NAVD)	Surveyed Elevation (ft NAVD)	Elevation Difference (ft)
Imperial 49-GW3	27.09	26.80	-0.29
Imperial 49-GW6	17.29	18.00	0.71
Imperial 49-GW7	16.73	17.10	0.37
Imperial 49-GW8	16.25	15.62	-0.63
Imperial 49-GW9	15.93	14.90	-1.03
Imperial 49-GW10	12.51	12.90	0.39
Imperial 49-GW11	13.36	12.40	-0.96
Imperial 49-GW12	11.10	11.50	0.40
Imperial 49-GW14	12.29	12.10	-0.19
Imperial 49-GW15	10.30	8.60	-1.70
Leitner 49L-GW1	13.42	12.50	-0.92
FP2_GW1	17.37	16.30	-1.07
FP3_GW1	16.85	13.70	-3.15

FP4_GW1	16.92	13.95	-2.97
FP5_GW1	16.57	13.50	-3.07
FP6_GW1	16.82	13.45	-3.37
FP7_GW1	16.74	15.60	-1.14
FP8_GW1	16.59	13.30	-3.29
FP9_G	16.51	15.20	-1.31
L-5667	16.33	N/A	N/A
FP10_G	16.71	15.00	-1.71
HF1_G	21.02	17.48	-3.54
HF2_G	21.11	17.80	-3.31
HF3_G	22.09	19.44	-2.65
HF4_G	22.28	18.46	-3.82
HF7_G	20.69	17.48	-3.21
ST1_G	28.12	25.39	-2.73
ST2_G	28.39	25.39	-3.00
ST3_G	27.77	25.06	-2.71
WF3_G	28.35	27.70	-0.65
WF4_G	27.89	27.70	-0.19
WF5_G	28.36	27.70	-0.66
WF6_G	27.76	27.70	-0.06
WF7_G	27.55	27.32	-0.23
L-5844	12.20	5.60	-6.60

Table 2-1 – Comparison of Surveyed and DEM Elevations (ft-NAVD) for Groundwater Calibration Wells

Certain wells used in the DRGR calibration do not have measured data for 2006 – 2008. These wells are Imperial 49-GW3, Imperial 49-GW8, FP4_GW1, L-5667, WF1_G, and L-5649.

2.2 Model Input Data

OneRain grid rainfall data for 2006-2008 was obtained from Lee County, and SFWMD provided evapotranspiration data for 2008. **Figure 2-1** presents cumulative rainfall for 2006 from the OneRain grid rainfall file. The MIKE SHE model domain and the MIKE 11 river network is also shown on **Figure 2-1**. Lee County Utilities provided groundwater pumpage information for the Green Meadows, Corkscrew, and SFWMD provided data for the Pinewoods well field. Florida Governmental Utilities Authority provided Lehigh Acres well field pumpage data for 2008. Bonita Springs Utilities provided pumpage data for 2008. Boundary time series data was obtained from the SFWMD DBHYDRO data base.

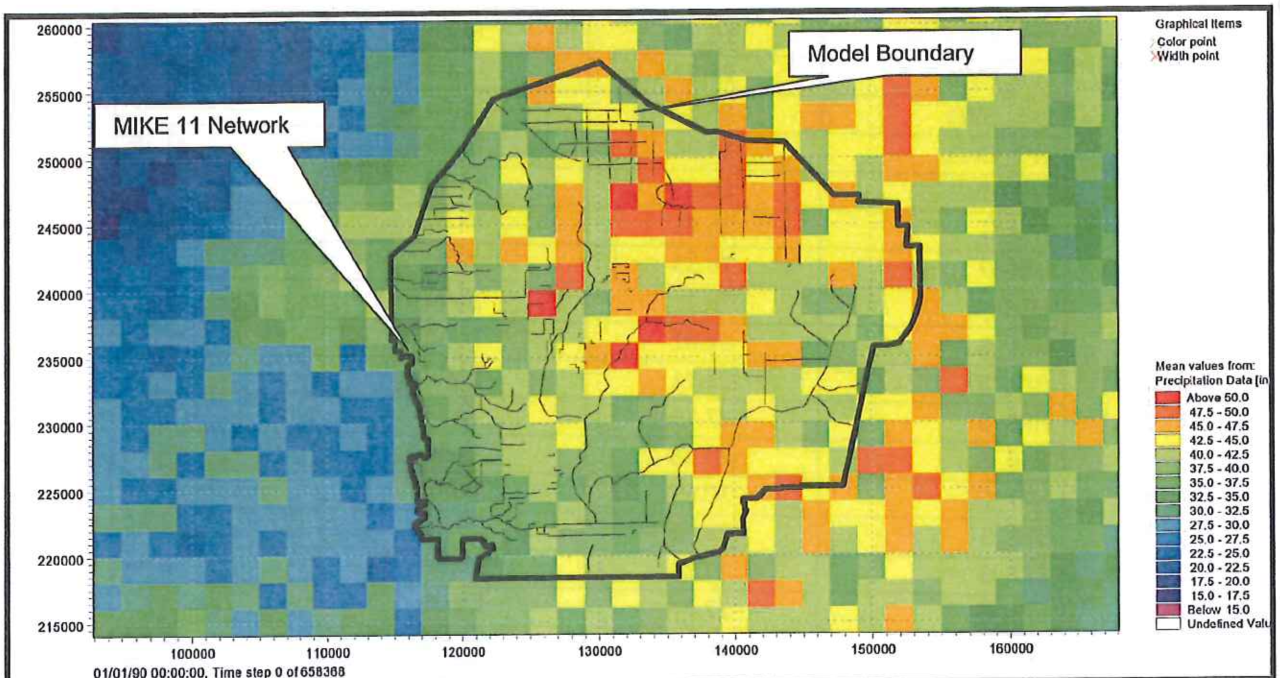


Figure 2-1 – Total Rainall (inches) for June 1 to September 30, 2006

2.3 MIKE 11 Changes

The following list documents the additions made to the surface water channels and flow-ways. There is some MIKE 11 modeling terminology used, as explained below. A river or channel reach is referred to as a Branch. Branches are lines representing the centerline of a river, channel, or flow-way. Position along the branch is shown as chainage (abbreviated as ch.), and typically chainage is 0 feet at the upstream end and increases in a downstream direction. Cross sections (abbreviated as XS) are required upstream and downstream of any culvert, weir, or gate. **Figures 2-2a and 2-2b** provide maps of the study area with structure names, roads, and general features. The changes to the MIKE 11 files are summarized below:

1. North Branch of the Estero River, Branch Esterol75
   a. Modified culvert dimensions to be consistent with bridge conveyance, ch. 450 ft
2. North Branch of the Estero River, Branch EsteroRiv
   a. Added another set of culverts under Three Oaks since there are two sets of culverts, ch. 1600
   b. Added culverts inside Rookery Development, ch. 2006
   c. Modified cross sections to accommodate these culverts
   d. Added a culvert with capacity equivalent to the existing bridge in Village of Country Creek, ch. 4980

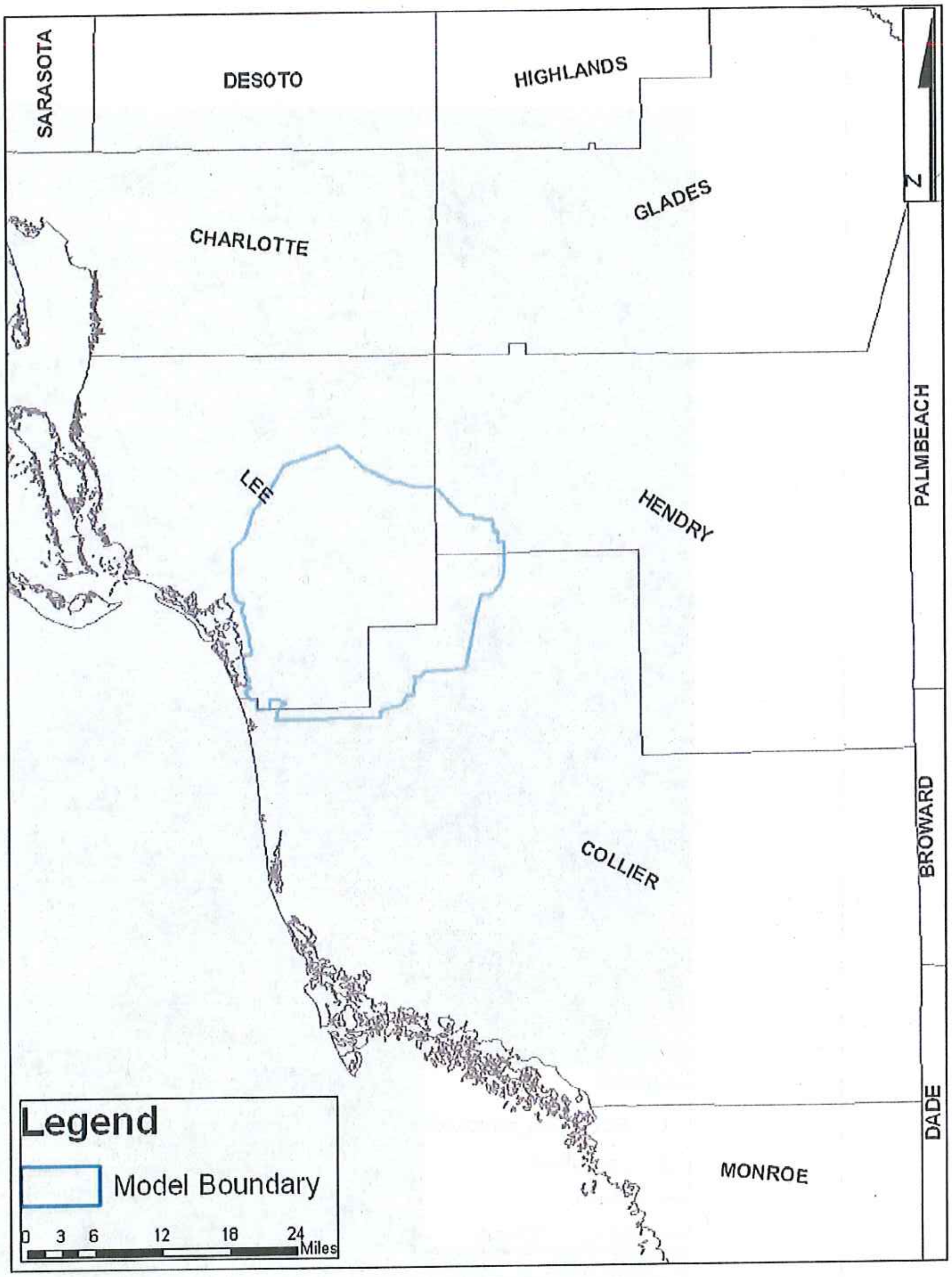


Figure 2-2a – General Map of SLCWP Study Area and Model Domain

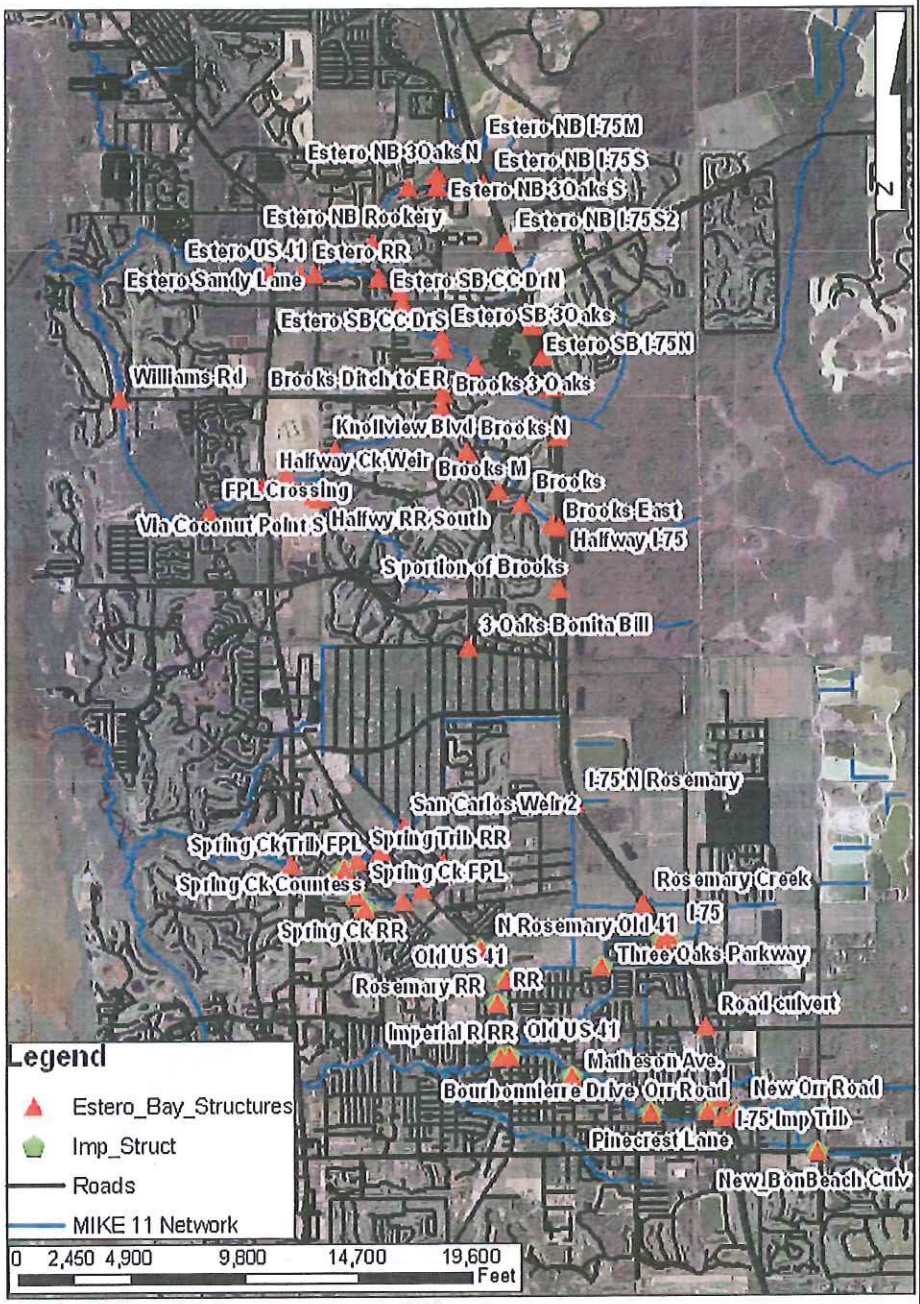


Figure 2-2b – Map of SLCWP Study Area

3. South Branch of the Estero River, Branch ESTERORIVS
    a. Added a culvert with the capacity equivalent to the existing Monty Run bridge at I-75, ch. 252.6.
    b. A branch was added to represent runoff from the Stonybrook development.
    c. Moved Sanctuary Road culverts to the correct location (ch. 4200) and put in correct dimensions from Boyle survey. Added Boyle surveyed cross sections upstream and downstream.
    d. Put in Village of Country Creek bridges 1 and 2 from permit drawings and deleted culverts (ch. 9,680 and 11,250).
4. Three Oaks Branch - ThreeOaks
    a. Deleted existing cross sections and replaced them with Boyle surveyed cross sections plus more detailed information from Three Oaks permit.
    b. Modified weir at north end of branch.
5. Estero River – Branch EsteroRiv
    a. Put in Sandy Lane bridge (ch. 10,056 ft).
    b. Modified cross sections to accommodate bridge.
6. Halfway Creek Upstream of I-75 – Branch HalfwayUp
    a. Modified cross sections downstream of I-75 culvert and added culverts at the east end of the Brooks (ch. 6,300 and 7,700). Note that the culverts under I-75 have a reduced capacity to reflect sediment accumulations observed in the summer of 2008. This will be modified for the alternatives analysis.
    b. Cross sections in the Brooks taken (with modifications) from HEC-RAS files.
7. Halfway Creek from east of Three Oaks to Outfall Weir – Branch HalfwayCr
    a. Culverts at Three Oaks not added yet
    b. Added 3 sets of culverts within the Brooks (ch. 800, 2,600, and 8486.53).
    c. Weir at outfall of Brooks modified to be consistent with permit drawings (ch. 10,400 ft).
8. Spring Creek Headwaters Tributary – Branch SpringHW
    a. This branch was added to allow flows to pass under I-75 from areas near the southern end of the Brooks. This branch may be used to evaluate alternatives intended to direct additional flows to Spring Creek.
    b. This branch looks as if it should enter Spring Creek, but it is directed north to Halfway Creek upstream of the Brooks based on input from Johnson Engineering.
    c. Cross sections estimated using best engineering judgment. Added box culvert (4.36 ft wide x 2.25 ft high) which is equivalent to two 30" dia. culverts. Culvert information from I-75 design drawings (ch. 5218.15 ft). Note that the I-75 design drawings show a 72" diameter culvert, however this culvert does not exist (confirmed by Richard Dun, ACCI/API Joint Venture, 11/12/08 e-mail).

9. Halfway Creek South Branch – Branch HalfwayS to South Weir
    a. This is a new branch added to MIKE 11 starting west of Three Oaks.
    b. Cross sections within Brooks are best engineering estimates.
    c. No culverts added.
    d. South Brooks weir added (ch. 7555).
    e. Railroad culverts added to model (ch. 7700), but Via Coconut Point culverts not added as conveyance in these culverts is larger than the railroad culverts.
10. Via Coconut Point Ditch
    a. This is a new branch that connects HalfwayCr with HalfwayS.
    b. Cross sections from Boyle survey
11. Halfway Creek and South Tributary from Brooks outfall to Williams Rd
    a. Location of main branch moved using aerial survey information.
    b. Cross sections west of Via Coconut Point are from Boyle survey.
    c. Culverts at Via Villagio for Halfway Ck (ch 12,000 on HalfwayCr) and South Branch (ch. 9,410 on HalfwayS) are from permit drawings.
    d. Halfway Creek Cypress weir east of U.S. 41 added from Boyle survey (ch. 12,400).
    e. U.S. 41 culverts moved to correct location (ch. 12,870 ft).
    f. Halfway Creek cross section west of U.S. 41 at wooden walkway is from Boyle survey (ch. 13,500 in SWMM XS folder). The effect of the walkway is also included as the walkway is modeled as a bridge.
    g. Another newly surveyed cross section by Boyle was added west of the walkway cross section.
    h. Halfway Creek cross section at FPL crossing was obtained from Hole Montes FPL pipeline crossing design drawings (ch. 15,338.7 ft)
    i. Williams Road bridge added using information from Boyle survey (ch. 23,447.8 ft).
12. Spring Creek – Branch SpringCr
    a. Added culverts at railroad (ch. 3,253 ft), FPL crossing (ch. 3,900), and Cedar Creek Road (ch. 4,400 ft) (source: Exceptional Engineering, 2008).
    b. Cross sections modified to accommodate culverts.
13. Rosemary Creek Tributary (Branch RosemaryTrib)
    a. The I-75 culvert was added at ch. 1,700 ft).
14. Imperial River – Branch Imperial
    a. Culverts were added for Poor Man's Pass Road, a farm ford between Poor Man's Pass Road and Vincent Road, and Vincent Road culverts were added. Invert elevations for the farm ford and Vincent road culverts and road elevation were estimated using best engineering judgment.
    b. Culverts at I-75 (ch. 4,888 ft) were replaced by bridges using information from the I-75 design.
    c. Matheson Road bridge (ch. 14,291) was simulated as a culvert. The conveyance of the culvert is consistent with the bridge conveyance.

This approach is sometimes used to overcome model instabilities and is valid as long as the culvert dimensions are the same as the part of the bridge that conveys water.

d. Bonita Grande Drive and Orr Road were simulated as culverts in the DRGR model, however dimensions were incorrect. The correct dimensions were entered into the model files.
e. The old Imperial Bonita Estates bridge or Bourbonnibiere bridge from the MIKE 11 DRGR model was updated to reflect new bridge dimensions.
f. Bridges at Old 41 and the railroad were not added to the model.

Note: While MIKE 11 is a proprietary computer program, all input and output model files can be viewed without a user license. The software can be downloaded from www.dhisoftware.com, however it is easier to request a DVD from DHI (contact Janice Kutsmeda at jak@dhi.us).

2.4 MIKE SHE Changes

The MIKE SHE changes include modifications to flood codes (which define exchanges between branches and overland flow), land use information, and rainfall data. Changes were implemented to improve the calibration, reduce model instability, and in general to update information where available. For example flood codes were added to allow the channels to spill over on the flood plains where appropriate. Flood codes were removed where it was evident that a barrier (e.g. a berm prevented water from spilling over. In some instances flood codes were replaced by the spillage option (an alternative to flood codes) to reduce model instabilities. These changes are summarized below.

Flood Code Changes

1. Estero River North Branch – Branches EsteroRivN, Esterol75, and EsteroTrib
   a. Removed flood codes on the east side of EsteroTrib.
   b. Added flood codes just west of Esterol75 to allow overland flow from wetlands east of I-75 to reach the branch.
   c. Added flood codes to EsteroRivN.
2. Halfway Creek – Branch HalfwayUp
   a. Modified flood codes so that lands east of I-75 have a different flood code than lands west of I-75.
3. Spring Creek Headwaters – Branch SpringHW
   a. Added flood code cells for lands east of I-75.
4. Halfway Creek South Tributary – Branch HalfwayS
   a. Added a flood code for lands east of the south weir.
5. Halfway Creek Main Stem – Branch HalfwayCrDS
   a. Flood codes were not used downstream of the Brooks outfall weir, but the spillage option is used for exchanges between the overland

flow plane to the river network. This approach was used because the spacing of roads that restrict overland flow is closer than can be simulated using flood codes.

6. Spring Creek tributary Bonita Bill Canal – Branch SpringCkNE
   a. Added a flood code for a section of Bonita Bill Canal east of Old U.S. 41 that flows to and from a large wetland area north of Strike Lane in the vicinity of Amarillo Street.
7. Rosemary Creek – Branches Rosemary and RosemaryTrib
   a. Reduced the extent of flood code 77 (lands west of I-75) and added flood codes 110 (Rosemary) and 109 (RosemaryTrib).
8. Imperial River
   a. Reduced extent of flood code 30 so that only lands west of I-75 are covered, and added flood code 108 for lands east of I-75 and west of Boca Grande Drive.
   b. At Kehl Canal weir, the flood codes were modified to separate flood code 30 from 36, and additional flood code cells (code 36) north of Kehl Canal were added.

2.4.1 Land Use Changes

Land use files from the Lee County DRGR were checked against known 2008 land use information. The MIKE SHE land use files were found to be accurate in most areas, as evidenced by the land use details within the Brooks development. In the MIKE SHE land use file, the areas with lakes, hardwood forest, and wetlands are indicated by appropriate land use codes, and the developed areas with roads and houses are shown as medium density urban land use. It was noted that the land use file for some areas west of the Brooks and east of U.S. 41 were shown as undeveloped land, while the current land use is the Coconut Point Mall (see **Figure 2-3**). The land use file used in the Lee County DRGR MIKE SHE/MIKE 11 model was calibrated using stream flows and water levels from 2001 through 2006, therefore the land use file was determined to be representative for the period of interest for the DRGR study. However, for the South Lee County Watershed Plan Update, the calibration focuses on conditions from 2006 through 2008, therefore these undeveloped areas were converted to high density urban.

Figure 2-3 – Current Land Use in Lower Halfway Creek Watershed Highlighting the Coconut Point Mall (source: www.mapquest.com)

2.4.2 Rainfall Data

The Lee County DRGR study uses daily rainfall data, and the focus of the South Lee County Watershed Plan Update is peak flow conditions, therefore OneRain grid rainfall files from Lee County were used. The information was provided in 15-minute intervals that was then grouped into an hourly time interval. The rainfall period used is 2006 through October, 2008.

3.0 MODELING RESULTS

The model was run for 2002 through 2006 using daily rainfall data to evaluate the impact of the changes described above on the calibration. The next step was to document the calibration using hourly rainfall data from 2006 through October,

2008. This report describes initial calibration results, steps taken to improve the calibration, and the calibration results following adjustment of model parameters.

3.1 Initial Model Calibration

The model development and calibration process for this project involves the following steps:

1. Verification of the physical information.
2. Use of daily rainfall data to make sure the model runs smoothly.
3. Checking of calibration results to determine where improvements are necessary.
4. Adjustment of model parameters that influence the rainfall runoff process such as detention storage, drainage depth, and vegetation evapotranspiration parameters.
5. Review and check physical data if necessary.
6. Utilize hourly rainfall and refine the calibration.

When daily rainfall data is used and the groundwater time step is less than 24 hours, MIKE SHE divides the daily rainfall by the groundwater time step to calculate the rainfall amount. This under-estimates the rainfall amount for summer tropical thunderstorms. In general, hourly rainfall is needed for MIKE SHE/MIKE 11 models of urban watersheds.

The initial calibration using daily rainfall data was generally good for flow at the North Branch of the Estero River, and simulated stage follows the pattern of the measured stage. An updated cross section was obtained from the USGS which improved the stage calibration. Calibration is generally good for both stage and flow for the South Branch of the Estero River, however both simulated peak stages and flows were higher than measured values for most events. Improving the flow calibration for the North and South Branch of the Estero River was a focus during the calibration process.

Spring Creek initial simulated stages were generally good, however simulated flows were much less than measured flows. Increasing runoff was a focus during the calibration process. It was found that the initial conceptualization of the canal network was incorrect and that the north and south branches of Spring Creek needed to be connected within San Carlos Estates to correct this problem. Additionally, it was discovered during calibration that certain cross sections in Spring Creek downstream of the Old U.S. 41 USGS gaging station were necessary, and additional cross sections were obtained from the City of Bonita Springs who conducted a rapid-response surveying effort.

Initial simulated stages were good for the Imperial River at Orr Road, however simulated flows were less than measured flows. Increasing runoff in the Imperial

River was a focus during the calibration process. The steps taken to address these calibration challenges are discussed below in the next section.

3.2 Final Calibration Results

This section describes the calibration process without providing results files for each of over 50 calibration runs conducted. Rather, a summary of the changes is provided with some comparison of performance for key parameter changes. This section also provides calibration plots, statistics, and water balance information. Note that the calibration effort addressed most of the challenges discussed above in Section 3.1.

3.2.1 Calibration Process

A broad range of calibration parameters were reviewed during the calibration process. In many cases, the original parameters were maintained, however certain parameters were modified. Parameters that were modified temporarily or permanently are described below.

Overland flow and channel Manning's n values were modified for MIKE 11 and for overland flow in portions of the model to increase flow from the Green Meadows Branch to the Kehl Canal and also to calibrate stages in the Estero River, Halfway Creek, Spring Creek, and the Imperial River. **Table 3-1** provides a summary of the changes made to overland flow Manning's n values and **Figures 3-1 through 3-4** provide maps of MIKE 11 Manning's n values used in this model. The MIKE 11 and overland flow Manning's n values were modified in certain locations during calibration to further attenuate peak flows determined to be too high when compared to measured data. One such location is the South Branch of the Estero River (**see Figure 3-1**) just upstream of I-75 that has a high river Manning's n value to account for a dense stand of Melaleuca just east of I-75. **Figure 3-3** shows areas of higher Manning's n values in Halfway Creek where resistance is high due to dense stands of cypress (downstream of U.S. 41) and willow (upstream of Via Villagio). **Figures 3-5 and 3-6** provide photographs of vegetation at these two locations that have high Manning's n values.

In the overland flow Manning's n file, the urban categories including areas around Estero River and Halfway Creek were modified by multiplying the original values by 4.0. These values were modified to account for the large number of ponds that have restrictive features such as culverts and weirs, and bleed down systems that were not included explicitly in the model.

Land Use Category	DRGR Mannings n	SLCWP Update 2009 Mannings n
Urban High Density	0.11	0.44
Urban Medium Density	0.12	0.48
Urban Low Density	0.14	0.56

Table 3-1 – Summary of Changes to Overland Flow Manning's n Values

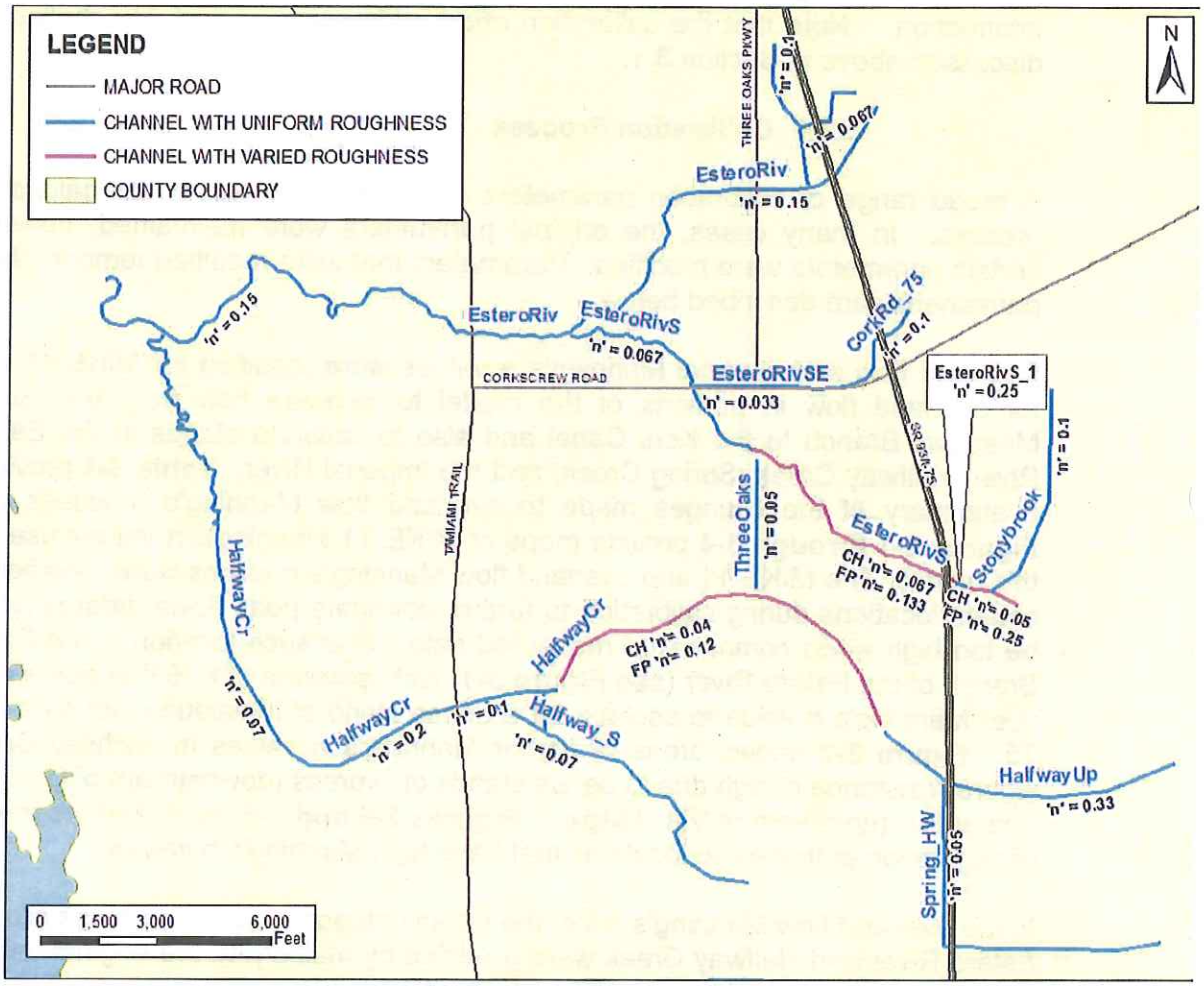


Figure 3-1 – Estero River and Halfway Creek Manning's n Values

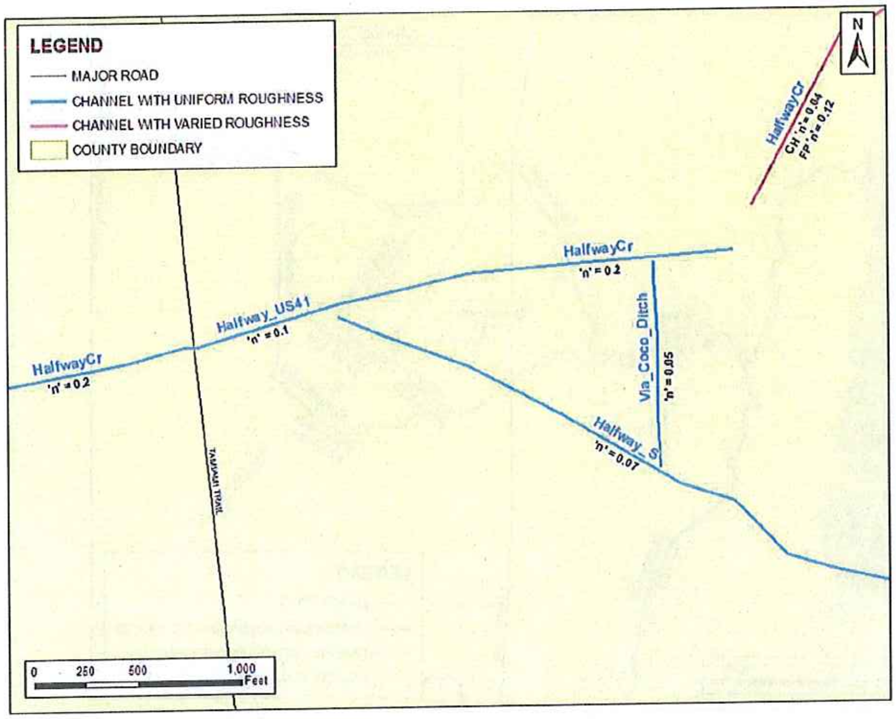


Figure 3-2 – Detailed View of Selected Halfway Creek Manning's n Values (Upstream of U.S. 41 and west of the Brooks Weirs)

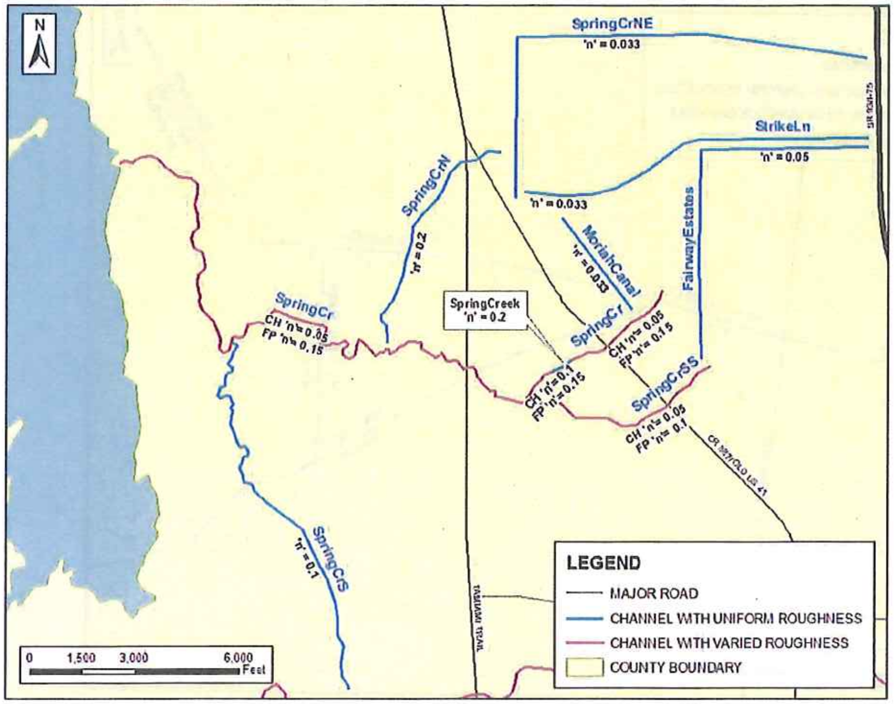


Figure 3-3 – Spring Creek Manning's n Values

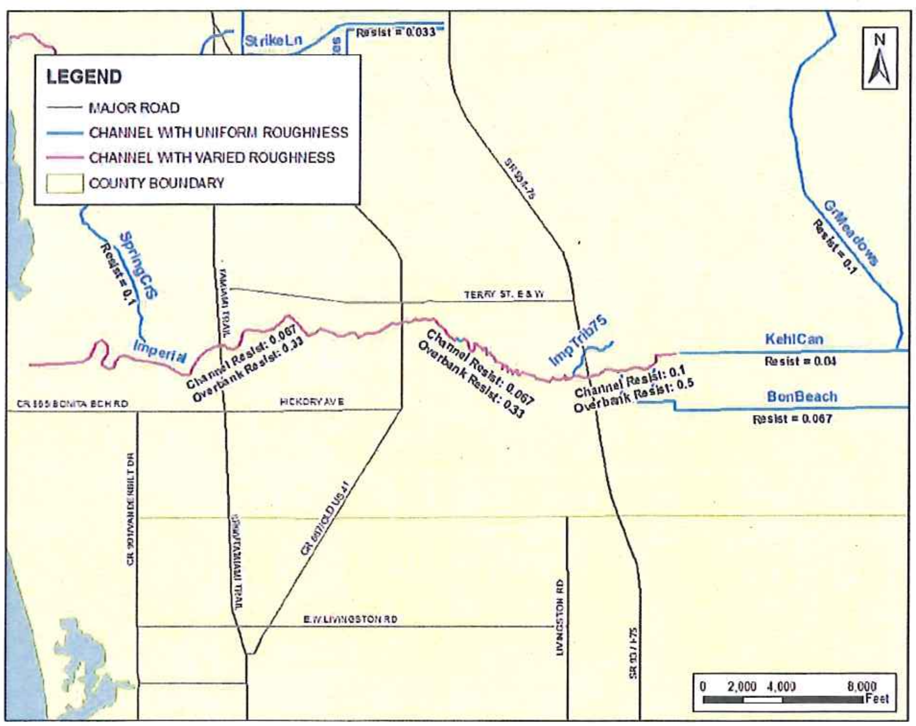


Figure 3-4 – Imperial River Manning's n Values

Figure 3-5 – Photograph of Dense Cypress in Halfway Creek Downstream of U.S. 41

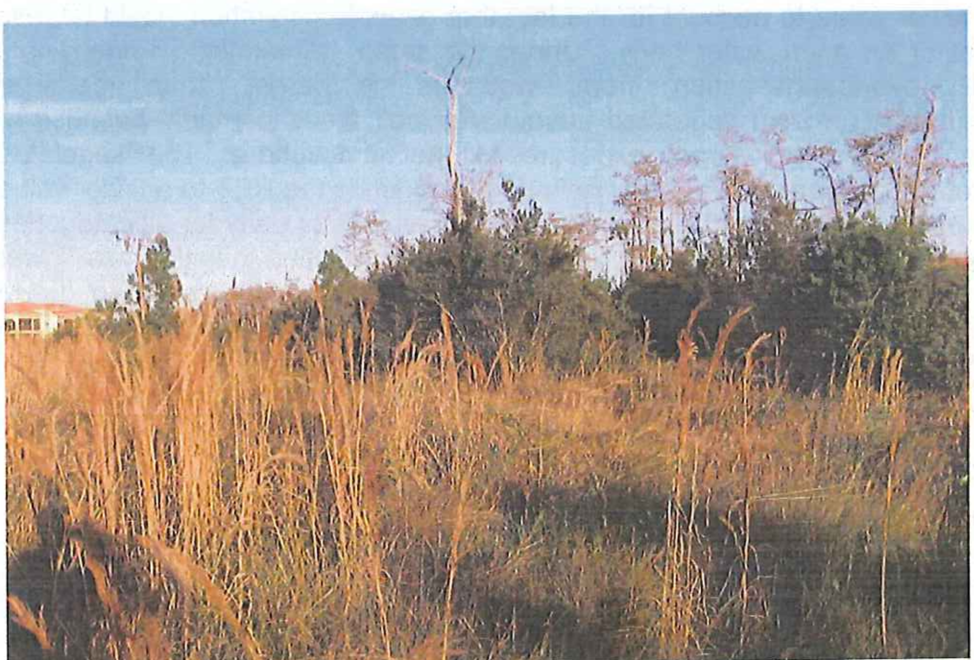


Figure 3-6 – Photograph of Willow and Sedges in Halfway Creek Upstream of Via Villagio

A range of parameters were modified to decrease flows in the South Branch of the Estero River including overland flow and channel Manning's n values, and I-

75 bridge and culvert entrance loss coefficients, vegetation evaporation coefficients were increased, and hydraulic conductivity values were changed for the surficial and Sandstone aquifers. Detention storage coefficient, drainage level and time constants, and paved area coefficient were modified up and down to test the sensitivity of the calibration to those parameters.

Changes were made to the Paved Runoff coefficient for urban categories. Initial model runs indicate that the runoff rates for urban areas were too high. Consequently, the paved runoff coefficient was reduced from 70 to 35 percent. This reduction was justified because a large percentage of paved area runoff is routed to detention ponds that are not a part of the Mike 11 network. The assumption here is that 35 percent will runoff directly and only a portion of the remaining 65 percent will contribute to runoff depending on infiltration rates, etc.

On examining the evapotranspiration parameters in the DHI model, it was noted that the crop coefficients (kc) were all set at unity. The crop coefficient sets the maximum rate of evapotranspiration (potential evapotranspiration) for each crop or land use as a function of the Reference evapotranspiration (RET). Typically, open water bodies or wetlands may be equal to or approach RET which is the evapotranspiration rate for a wet prairie/marsh system, so that a value of unity may be appropriate. However, some other categories (e.g., pasture) normally have a lower value to account for the fact that evapotranspiration would be less than that of an open water body. Under the same climatological conditions, potential evapotranspiration from wetlands is larger than potential evapotranspiration from vegetated unsaturated soil areas primarily because of water availability with direct exposure to the atmosphere. The vegetated unsaturated soil areas are typically defined by adjusting the RET to a lower value by the application of a multiplier coefficient. The values of unity for all categories was then not considered to be appropriate and was modified to initially use lower values as used in the Camp Keias (HGL, DHI, 2006) and Kissimmee (Earth Tech, DHI, 2007) models. Final calibrated values used in this model are shown below in **Table 3-2**.

Land Use	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Citrus	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.754
Pasture	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Sugar Cane	0.73	0.73	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.76	0.91
Truck Crops	0.62	0.62	0.63	1.00	1.00	1.00	1.00	0.68	0.68	0.76	0.71	0.84
Golf Course	0.67	0.67	0.61	0.65	0.66	0.68	0.68	0.76	0.85	0.85	0.83	0.73
Bare Ground	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Mesic Flatwood	0.64	0.64	0.64	0.64	0.81	0.90	0.90	0.81	0.72	0.63	0.63	0.63
Mesic Hammock	0.64	0.64	0.64	0.64	0.81	0.90	0.90	0.81	0.72	0.63	0.63	0.63
Hydric Flatwood	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Hydric Hammock	0.50	0.50	0.50	0.61	0.78	0.87	0.87	0.78	0.70	0.61	0.52	0.50
Wet Prairie	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Marsh	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Cypress	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Swamp Forest	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Mangrove	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Water	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Urban Low Density	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Urban Median Density	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Urban High Density	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

Table 3-2 – Crop Coefficients Used in the SLCWP MIKE SHE Model

Figure 3-7 – Urban Detention Ponds

The values for an urban category were relatively large compared to a value of 0.70 in the Camp Keias model. These relatively high values were determined during calibration and justified because of the numerous ponds as shown on **Figure 3-7** which are open water bodies with high rates of evapotranspiration.

Saturated flow components were modified during calibration. Specifically, the Holocene-Pliocene layer horizontal and vertical hydraulic conductivities were increased by a factor of 10, and the specific yield changed from 0.15 to 0.05 to conform to information provided by SFWMD. For the Lower Tamiami layer, the horizontal and vertical hydraulic conductivities were increased by a factor of 5, and the specific yield changed from 0.20 to 0.10. For the Sandstone layer, the horizontal and vertical hydraulic conductivities were decreased by a factor of 10.

Irrigation files were modified for lands west of I-75 to increase irrigation rates. DRGR irrigation rates were less than 5 inches/year for most urban lands west of I-75, and measured irrigation flow data obtained from Resource Conservation Systems, LLC were reviewed to determine if irrigation rates should be adjusted. Measured average irrigation from Brooks lakes and the surficial aquifer was 13 inches/year for 2006-2008. As a result, irrigation rates were increased for the Brooks and a number of other areas west of I-75. **Table 3-3** provides a summary of irrigation values used in the model for the Brooks area, and **Figures 3-8 and 3-9** show the DRGR and revised irrigation command areas, respectively.

Irrigation Command Area	Old Flow Rate, cfs	New Flow Rate, cfs
214 (golf course reuse water)	0.57	9.0
579	0.57	0.57
626	0.57	5.0
1180	N/A	4.0
1181	N/A	3.0

Table 3-3 – Old and New Flow Rates for Model Irrigation Command Areas

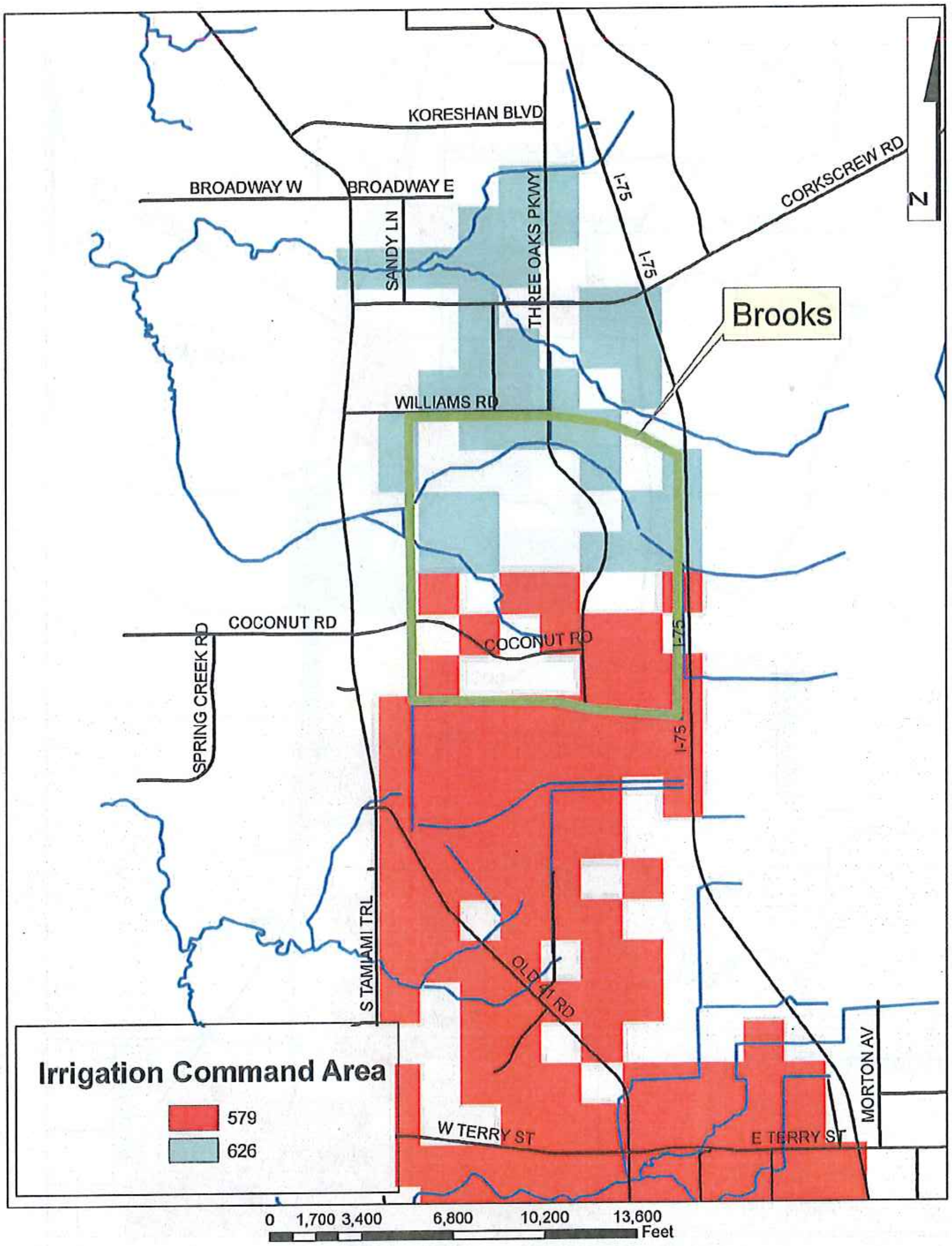


Figure 3-8 – Irrigation Command Areas used in the DRGR Model that were modified as part of this study (see next Figure)

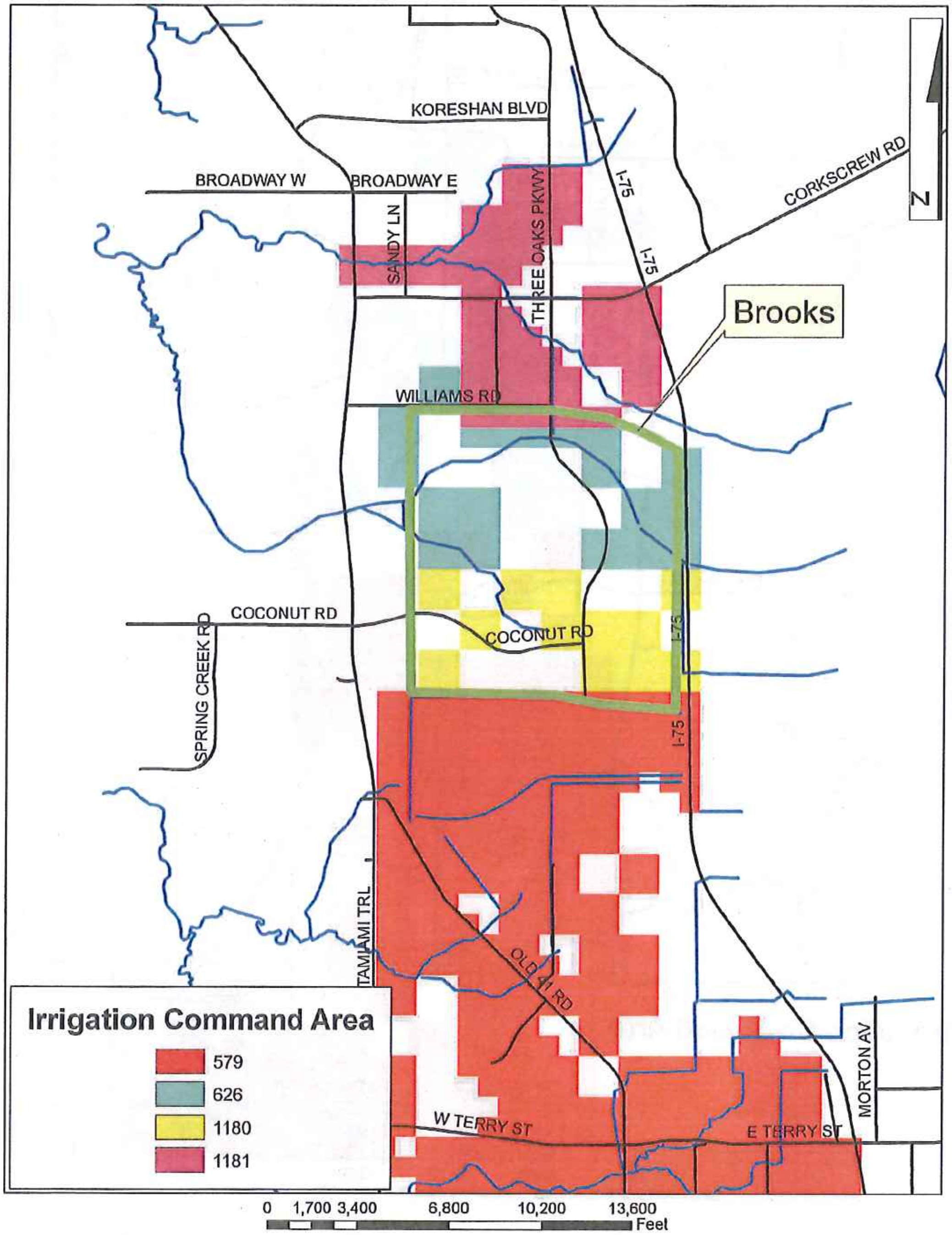


Figure 3-9 – Revised Irrigation Command Areas for the Estero River, Halfway Creek, Spring Creek, and Imperial River Watersheds

3.2.2 Calibration Statistics

MIKE SHE/MIKE 11 generates calibration statistics for stations where measured data is available. The statistics 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 good metric for river calibration. The correlation coefficient measures the closeness of fit between the simulated and measured values, and 1.0 indicates perfect correlation. Nash Sutcliffe coefficient is a difficult statistical measure to describe, however it generally means the error divided by the variability. Stations with higher variability generally have higher error, and this statistic corrects for high variability. **Table 3-4** presents the model calibration targets and **Table 3-5** presents the equations used for each metric. Certain calibration targets for ME and MAE are narrower than for the DRGR model. The high model performance target for surface water has been reduced from 0.8 feet to 0.5 feet. The high model performance target for groundwater has been reduced from 1 foot to 0.5 feet. The medium and low targets were also revised. The groundwater correlation coefficient target for high performance has been increased from 0.7 to 0.8. The Nash-Sutcliffe coefficient targets were not used in the DRGR study, and the performance targets were taken from the Southwest Florida Feasibility Study MIKE SHE modeling study (SDI et. al., 2008).

	Level of Model Performance		
Statistical parameter	High	Medium	Low
Surface Water Flow Targets			
R	0.8 <= R < 1.0	0.6 <= R < 0.8	R < 0.6
Surface Water Stage			
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 <= 1.0	1.0< RMSE<= 2.0	RMSE > 2.0
R	0.8 <= R < 1.0	0.6 <= R < 0.8	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	0.8 <= R < 1.0	0.5 <= R < 0.8	R < 0.5
Nash Sutcliffe, R2	0.7 <=R2<=1.0	-1.0<=R2<=0.7	NS<= -1.0

Table 3-4 - 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	$\sqrt{\frac{\sum_{i=1}^{n}(Obs_i - Calc_i)^2}{\sum_{i=1}^{n}(Obs_i - \langle Obs_i \rangle)^2}}$
R2	Nash Sutcliffe	$R2 = \frac{\sum_t (Obs_{i,t} - Calc_{i,t})}{\sum_t (Obs_{i,t} - \overline{Obs_i})}$

Table 3-5 - Equations used to define Performance Metrics

3.2.3 Calibration Results

Calibration statistics are presented in **Tables 3-6 and 3-7**. Cells highlighted in green meet the calibration criteria, yellow cells are just outside the calibration criteria, and orange cells indicate poor calibration.

Surface Water Stage Statistics					
Name	ME (ft)	MAE (ft)	RMSE (ft)	R_Correlat	R2_Nash_Su
Estero R NB 3943.57 (EsteroRiv, 1202.000	-0.53	0.62	0.73	0.83	0.31
Estero R SB 8628 (EsteroRivS, 2630.000)	-0.06	0.41	0.59	0.88	0.39
Copperleaf (Halfwayup, 2133.600)	-0.17	0.33	0.40	0.92	0.75
Halfway Creek S HW (Halfway_S, 2270.76	-0.76	0.83	0.99	0.75	-0.20
Halfway Creek S TW (Halfway_S, 2316.48	-0.23	0.45	0.58	0.81	-0.06
HalfwayCrDS HW (HalfwayCrDS, 3127.000	-0.18	0.32	0.39	0.93	0.82
HalfwayCrDS TW (HalfwayCrDS, 3200.400	0.10	0.36	0.50	0.81	0.29
Imperial_Orr (Imperial, 1230.000)	-0.99	1.16	1.55	0.89	0.63
KehlCan_9358 (KehlCan, 9358.000)	0.57	1.19	1.50	0.89	0.76
KehlCan_9479 (KehlCan, 9479.000)	-0.61	1.09	1.49	0.88	0.72
Spring Ck 1574.8 (SpringCRSS, 480.0000)	-0.14	0.36	0.48	0.77	0.38

Surface Water Flow Statistics		
Name	R_Correlat	R2_Nash_Su
Estero R NB Q 4443 (EsteroRiv, 1354.500)	0.84	0.70
Estero R SB 8697 (EsteroRivS, 2651.000)	0.85	0.61
Spring Ck 1637 (SpringCRSS, 499.0000)	0.80	0.56
Imperial_Orr (Imperial, 1245.000)	0.90	0.78

Table 3-6 – Surface Water Calibration Statistics

Name	Layer	ME (ft)	MAE (ft)	RMSE (ft)	R_Correlat	R2_Nash_Su
Corkscrew Swamp	1	-1.54	1.54	1.61	0.89	-1.90
FP10_G	1	-0.23	0.52	0.65	0.91	0.80
FP2_GW1	1	-1.37	1.46	1.63	0.82	-0.12
FP3_GW1	1	-0.31	0.51	0.61	0.92	0.77
FP5_GW1	1	-0.46	0.62	0.73	0.92	0.74
FP6_GW1	1	-0.43	0.68	0.78	0.91	0.72
FP7_GW1	1	-0.33	0.66	0.81	0.91	0.70
FP8_GW1	1	-0.45	0.67	0.78	0.92	0.75
FP9_G	1	-0.34	0.70	0.86	0.87	0.52
Imperial 49-GW10	1	-1.78	2.03	2.27	0.85	0.01
Imperial 49-GW11	1	-1.60	2.17	2.51	0.91	0.18
Imperial 49-GW12	1	-0.57	1.30	1.47	0.84	0.44
Imperial 49-GW14	1	0.11	0.51	0.63	0.96	0.86
Imperial 49-GW15	1	1.26	1.26	1.33	0.74	-4.01
Imperial 49-GW6	1	0.19	0.75	0.95	0.86	0.63
Imperial 49-GW7	1	0.01	0.64	0.69	0.87	0.75
Imperial 49-GW9	1	0.71	0.76	0.94	0.95	0.75
L-1138	1	-0.08	0.37	0.52	0.78	0.53
L-5667	1	0.69	0.78	1.09	0.89	0.47
L-5669R	1	-0.36	0.38	0.45	0.96	0.75
Leitner 49L-GW1	1	-0.99	1.32	1.50	0.76	0.00
USGS L-2195	1	-2.68	2.83	3.08	0.87	-0.76
USGS L-5730	1	1.70	1.70	1.79	0.91	-1.30
Average Values:		-0.38	1.05	1.20	0.88	0.10

Table 3-7 – Groundwater Calibration Statistics

The information presented in Table 2-1 was compared with Table 3-7 above. In general, if the elevation in the topography file in the model is higher than that surveyed and used in computing measured water level data used in the calibration, then the model may simulate a higher groundwater elevation than measured. Wells presented in Table 2-1, and Table 3-7 were compared. The wells FP2-GW1, FP3-GW1, FP5-GW1, FP6-GW1,FP7-GW1, FP8-GW1, FP9-GW1, and FP10-G all had negative differences in Table 2-1 meaning that the information in the model was higher than that surveyed. This is consistent with Table 3-7 which shows negative MEs for these wells indicating the model is simulating higher vales than that measured.

Figure 3-10 provides a map of calibration performance for river stations, and **Figure 3-11** provides a map of calibration performance for surficial aquifer stations. Green points represent stations that meet the calibration criteria, yellow points represent stations that are just outside of the calibration criteria, and red points indicate poor calibration. Plots of measured and simulated values are presented in **Figures 3-12** through **3-20.**

Surface Water Calibration

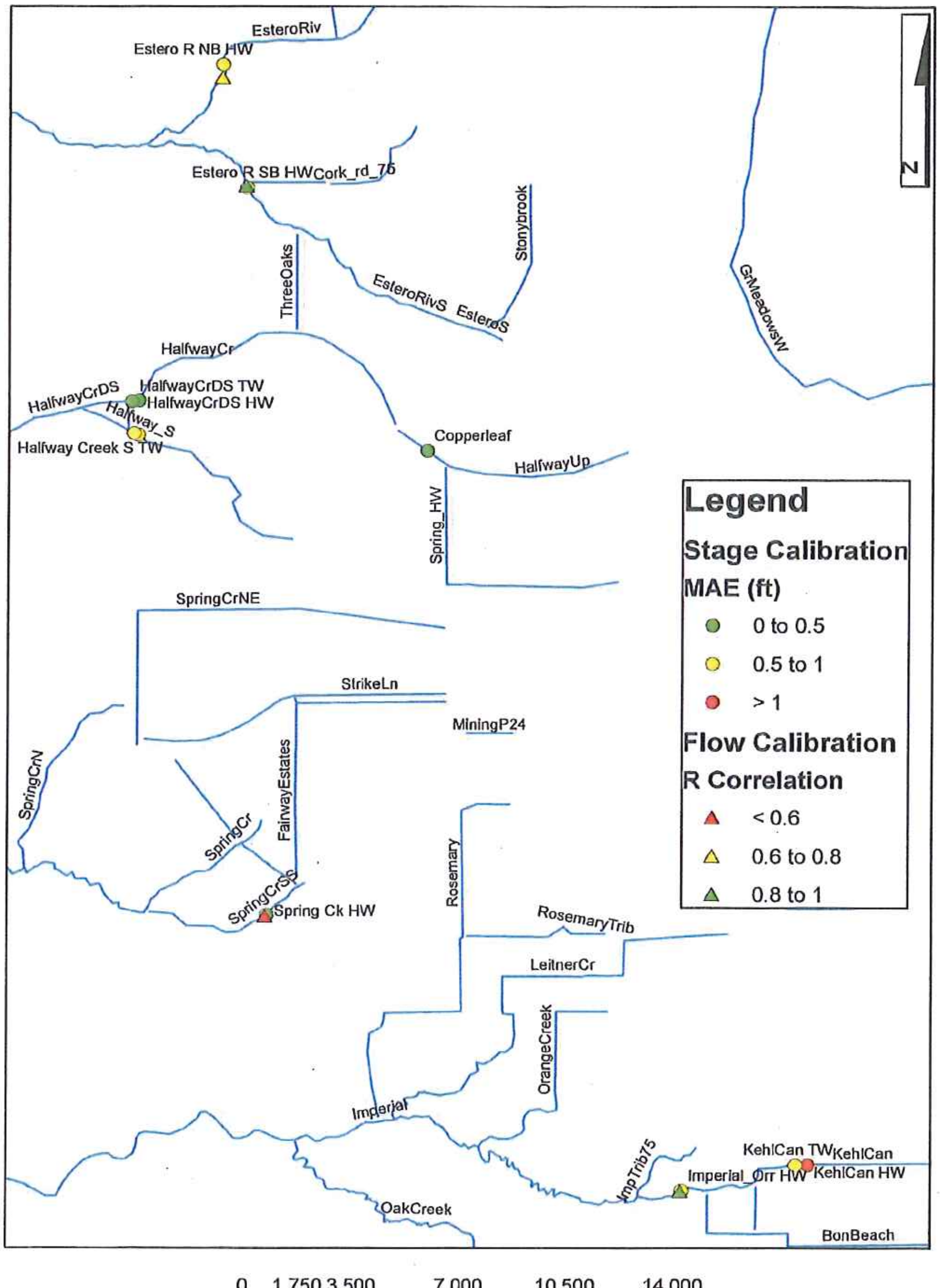


Figure 3-10 – Map of Surface Water Calibration Performance

Surficial Well Calibration

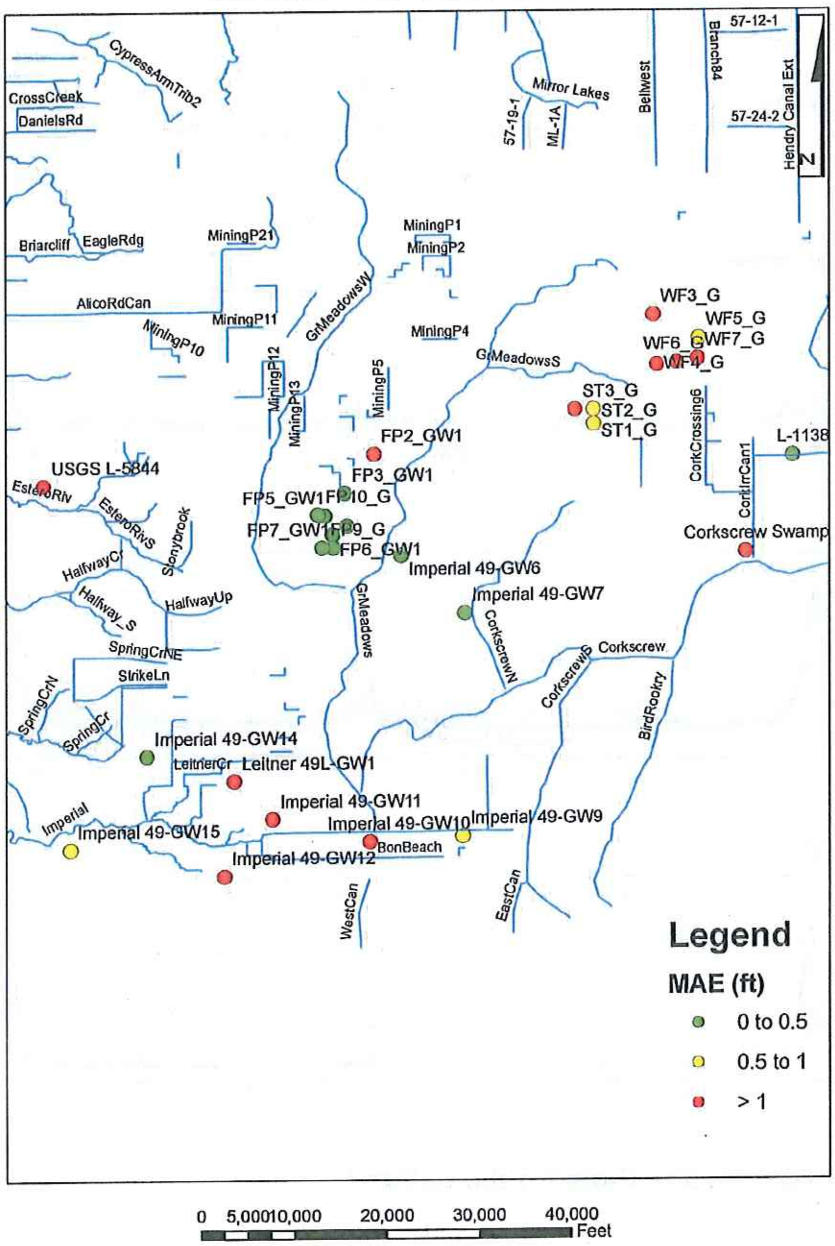


Figure 3-11 – Map of Surficial Aquifer Calibration Performance

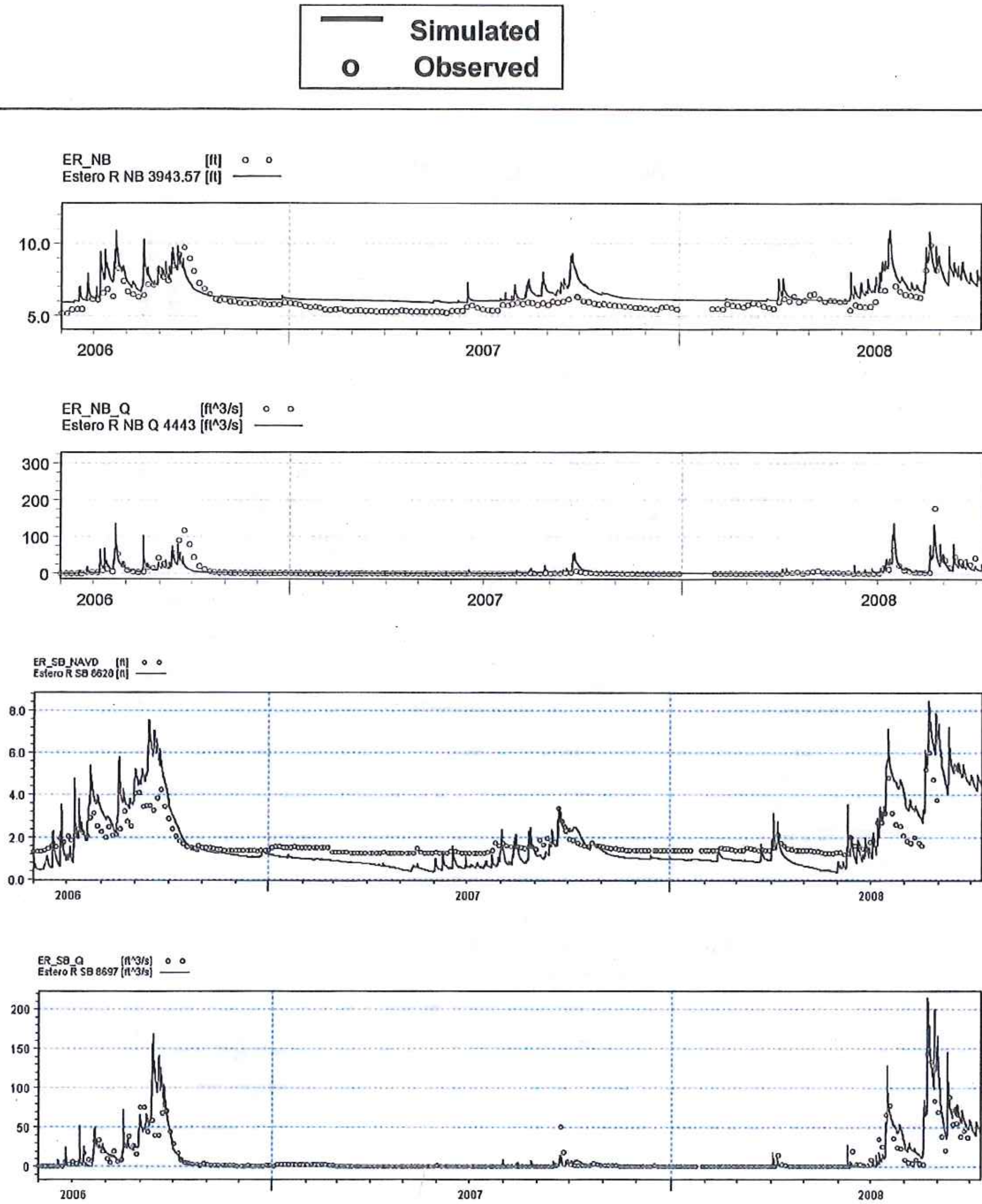


Figure 3-12 – Calibration Plots for the Estero River

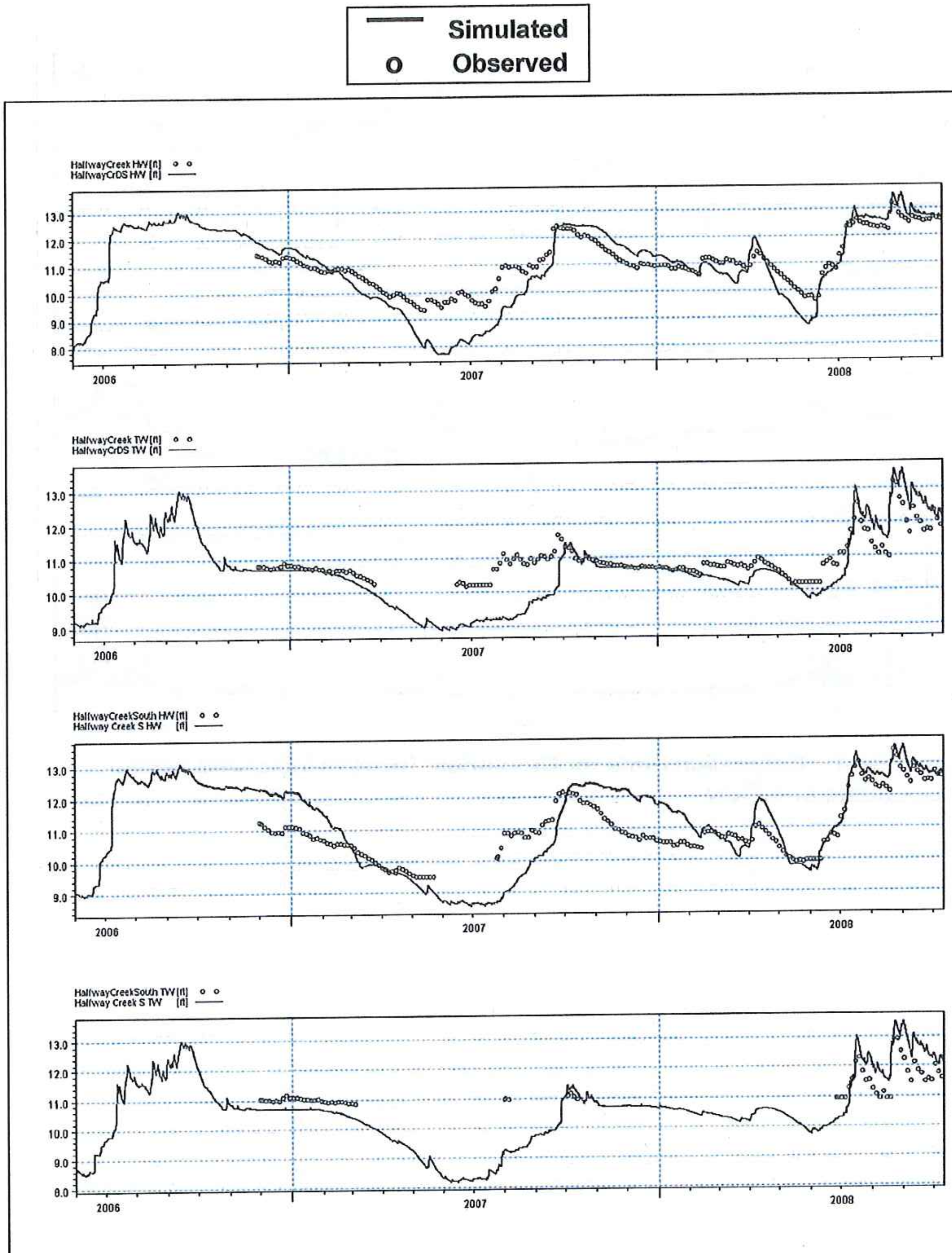


Figure 3-13 – Calibration Plots for Halfway Creek

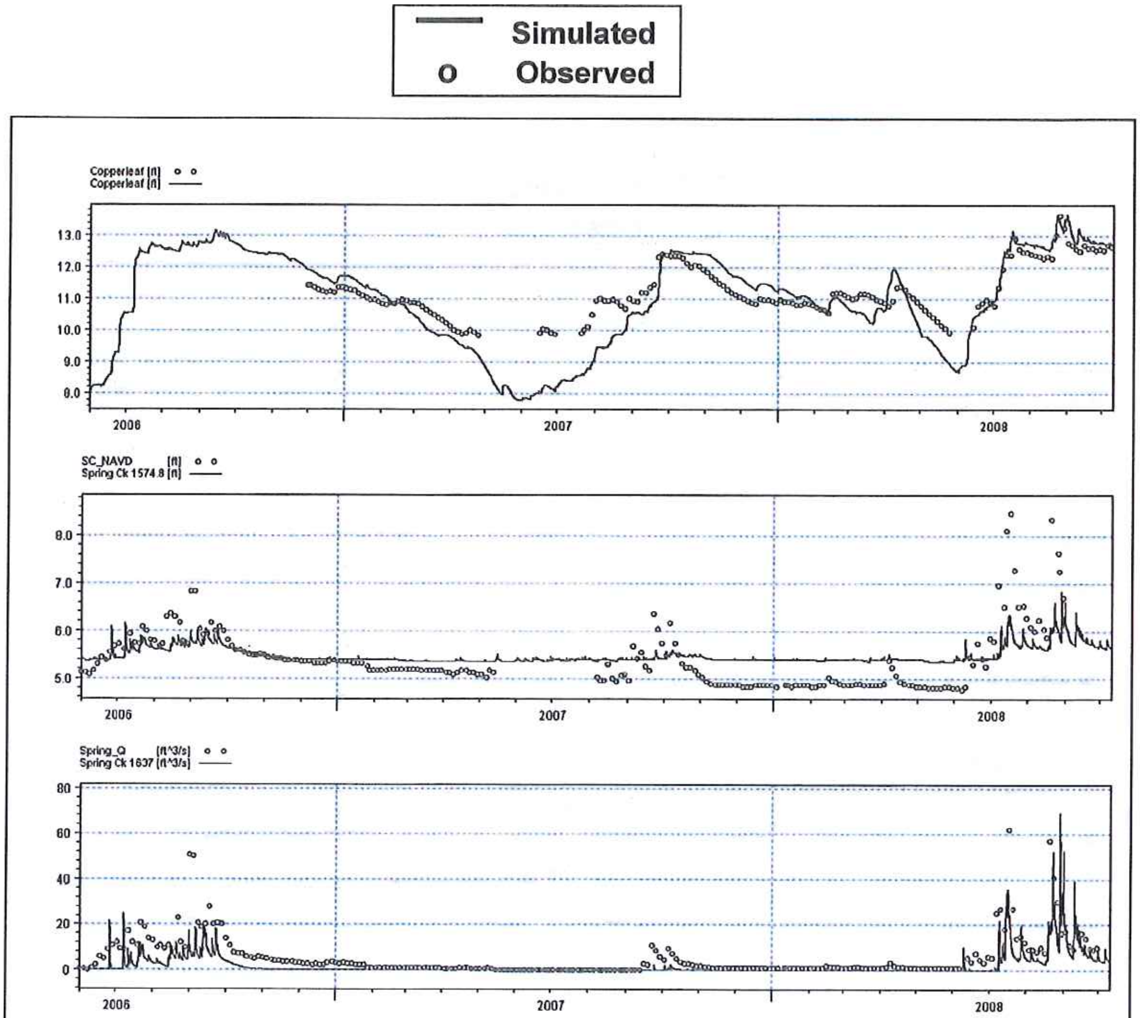


Figure 3-14 – Calibration Plots for Copperleaf (Brooks Lake) and Spring Creek Stage and Flow

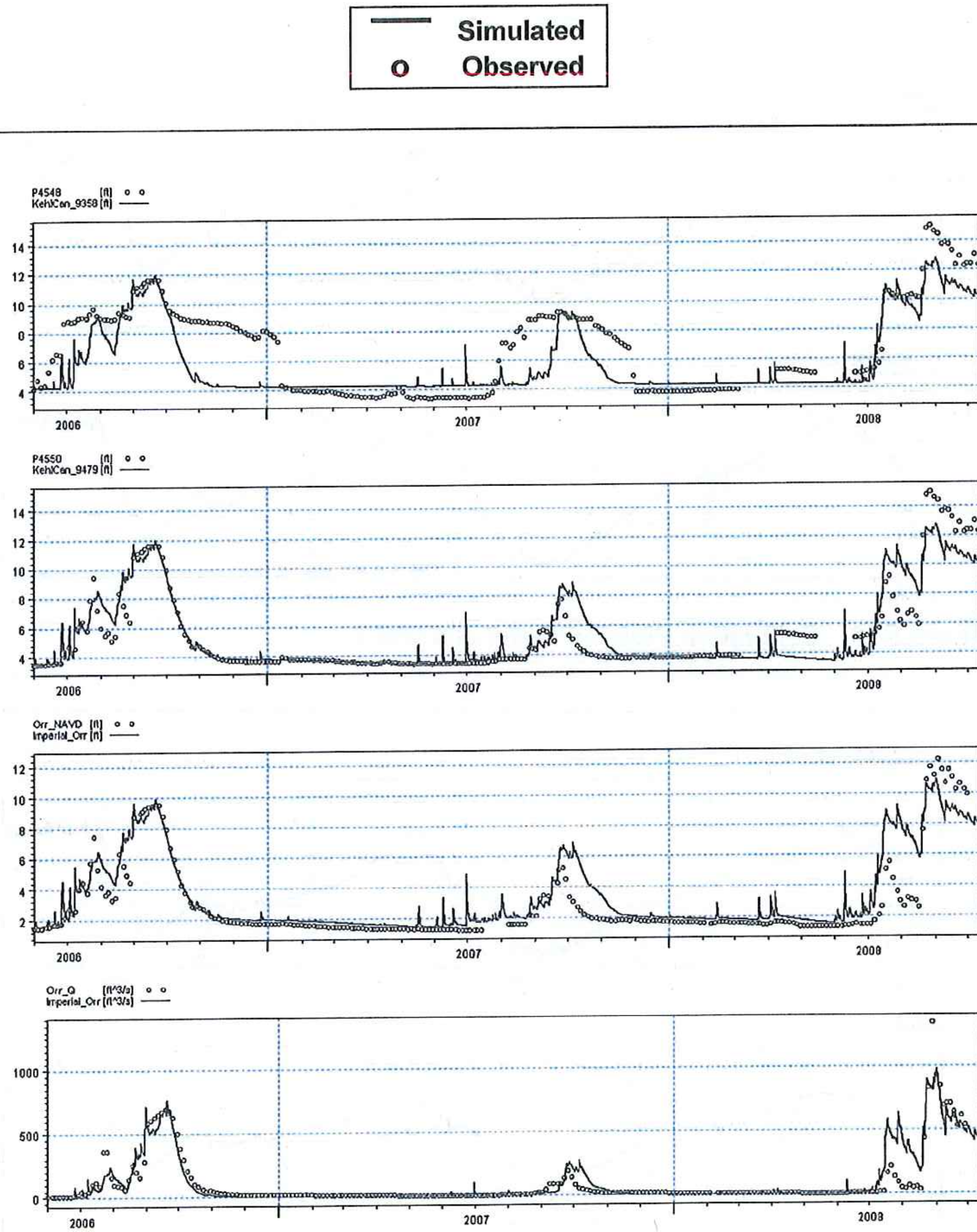
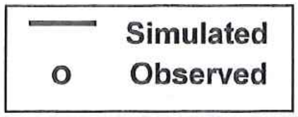


Figure 3-15 – Calibration Plots for the Imperial River



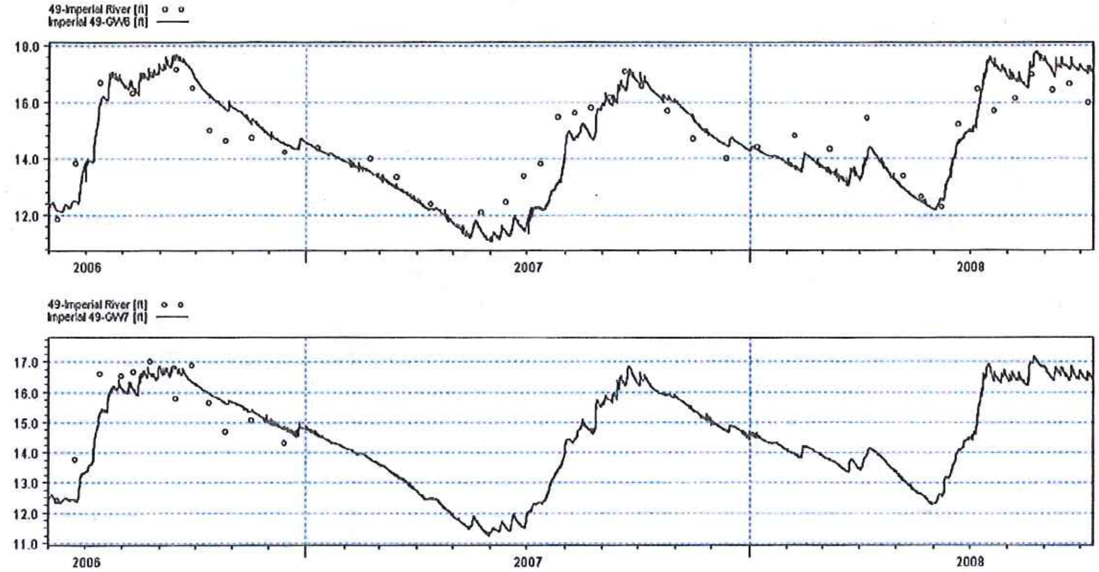


Figure 3-16 – Calibration Plots for GW-6 and GW-7

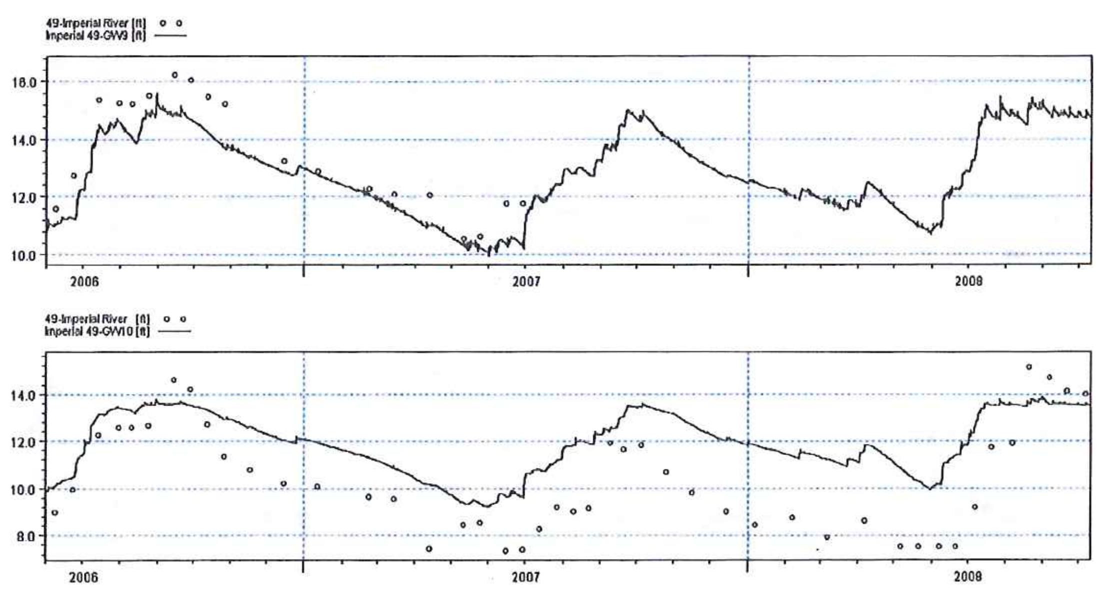
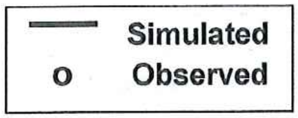


Figure 3-17 – Calibration Plots for GW-9 and GW-10



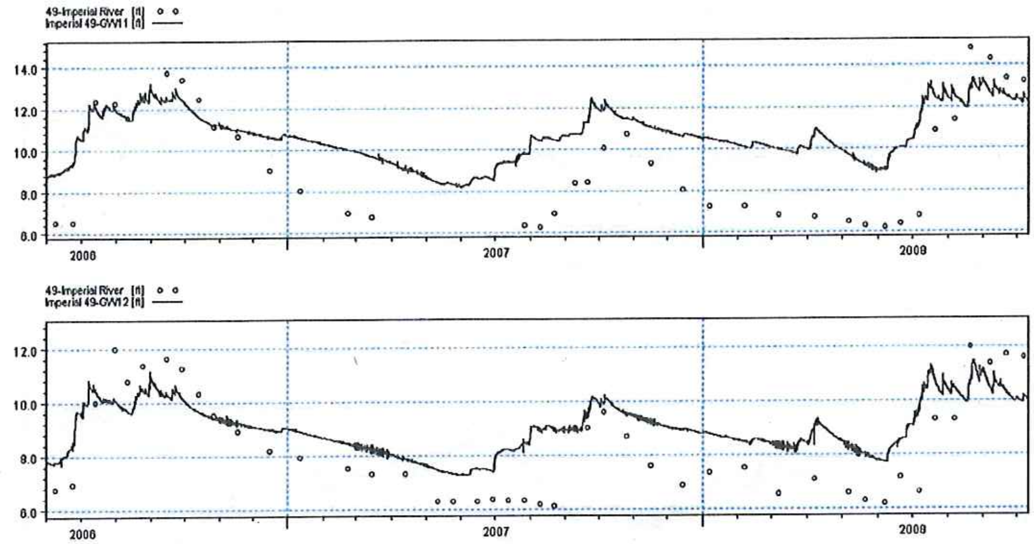


Figure 3-18 – Calibration Plots for GW-11 and GW-12

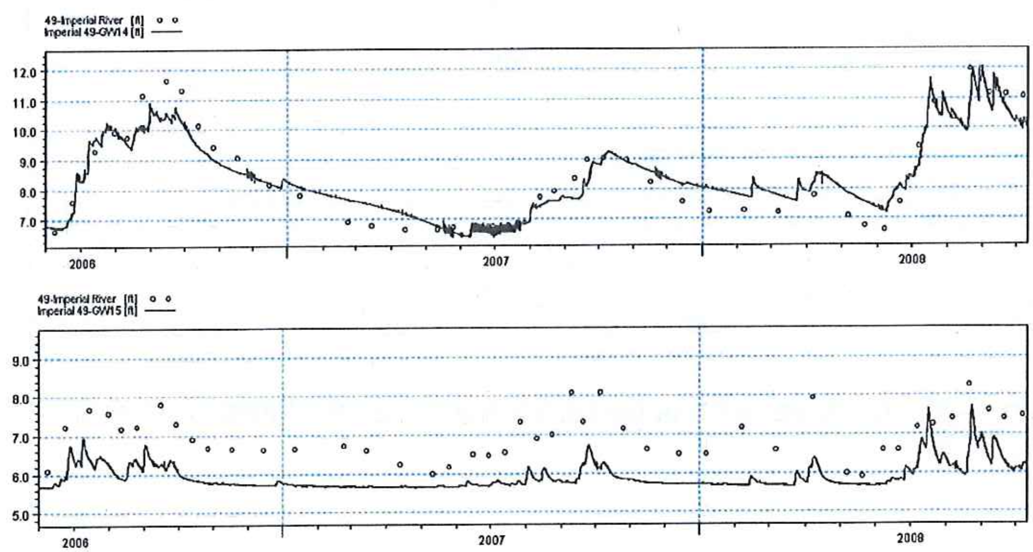


Figure 3-19 – Calibration Plots for GW-14 and GW-15

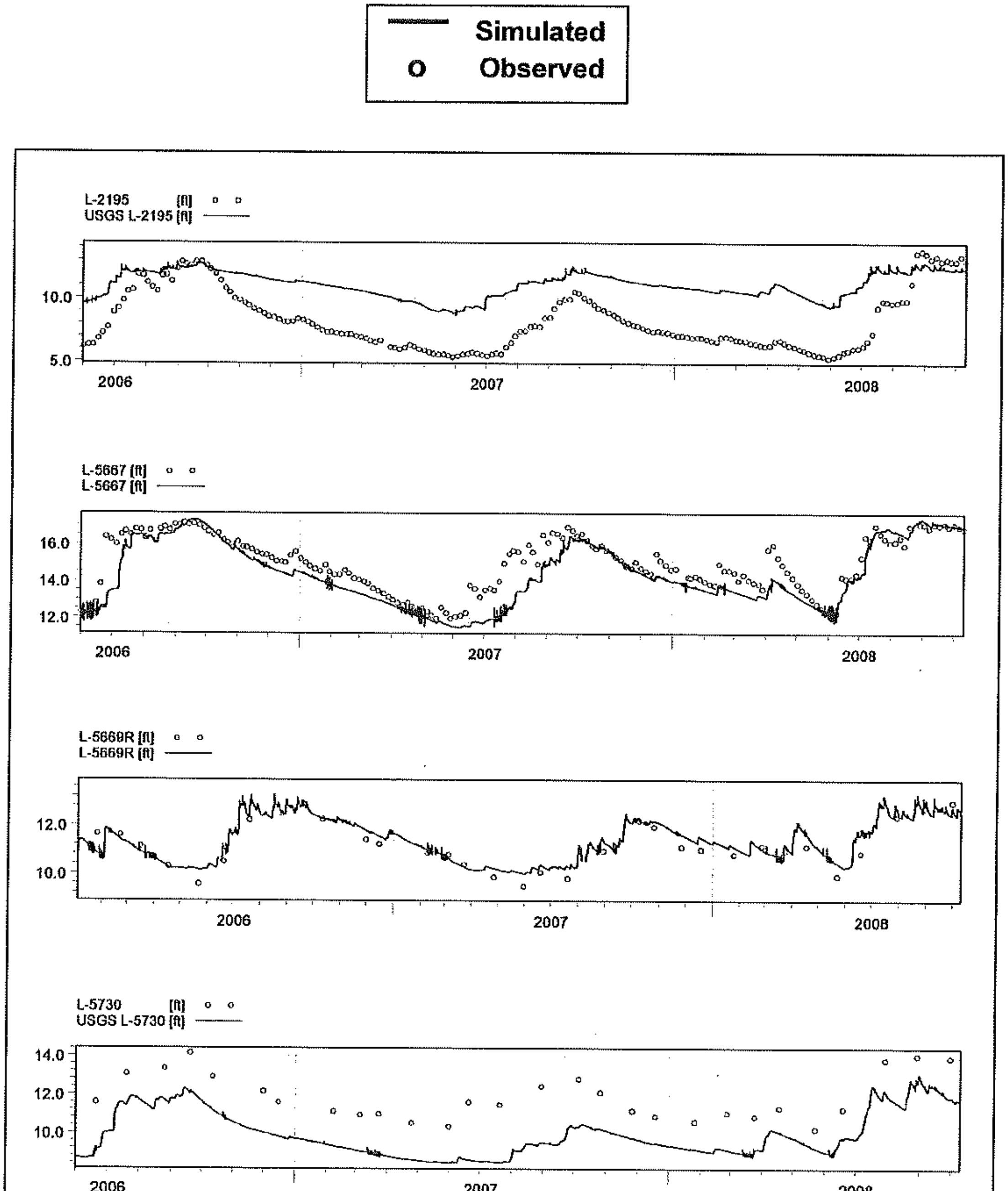


Figure 3-20 – Calibration Plots for USGS Wells L-2195, L-5667, L-5669R and L-5730

3.3 Mass Balance Information for the Calibrated MIKE SHE/MIKE 11 Model of the Estero River, Halfway Creek, and Imperial River

A mass balance plot for the entire model domain is presented in **Table 3-8** for June 1, 2006 through October 11, 2008. The annual average precipitation during that period was 48 inches, and the evapotranspiration was 31 inches/year, or 64% of rainfall.

Period of Record (Number of Months used in Water Balance)	Rain *(Rai)*	Actual ET *(AET)*	Canopy-OL Storage Change *ΔOL*	Runoff +Drainage to River *(Ro)*	OL Boundary Flows *(OL_{BC})*	Baseflow *(BF)*	Irrigation *(Irr)*	Pumpage *(GW_P)*	SZ Boundary Flow *(SZ_{BC})*	SubSurface Storage Change *(ΔSUB)*	Total Error *(Err)*
6/1/06 to 12/31/06	45.17	22.06	0.39	14.11	0.000	2.32	1.02	1.60	0.24	5.99	-0.040
1/1/07 to 12/31/07	40.91	35.37	-0.17	5.09	0.000	1.93	4.79	5.81	0.81	-1.35	-0.184
1/1/08 to 10/11/08	58.74	30.53	2.09	17.87	0.000	2.49	3.42	4.19	0.04	5.19	-0.166

Table 3-8 – Water Balance for Entire Model Domain (values in inches)

Irrigation in the Brooks for the DRGR model was less than 1 inch/year, which seemed low, therefore measured irrigation pumpage rates were obtained to assist in the calibration. Measured irrigation was equal to 11.3 inches/year from surface water and the surficial aquifer between June 1, 2006 and September, 2008. Measured irrigation from external sources was 6.3 inches/year during the same period.

3.4 Overland Flow Depths During the Wet Season

The model simulates flooding in areas without river channels and in areas where the water depth exceeds the maximum channel elevation within the river cross section. **Figure 3-21** presents the overland flow depth map for Tropical Storm Ernesto in the fall of 2006. The areas of red and orange are mining pits where water depths are greater than 5 feet deep. In general, overland flow depths are in the range of 0-1 foot deep with some areas in Flint Pen Strand that have water depths in the range of 2 feet. The overland flow vectors illustrate that a portion of the water in DRGR wetlands flows toward the Estero River and Halfway Creek during the wet season.

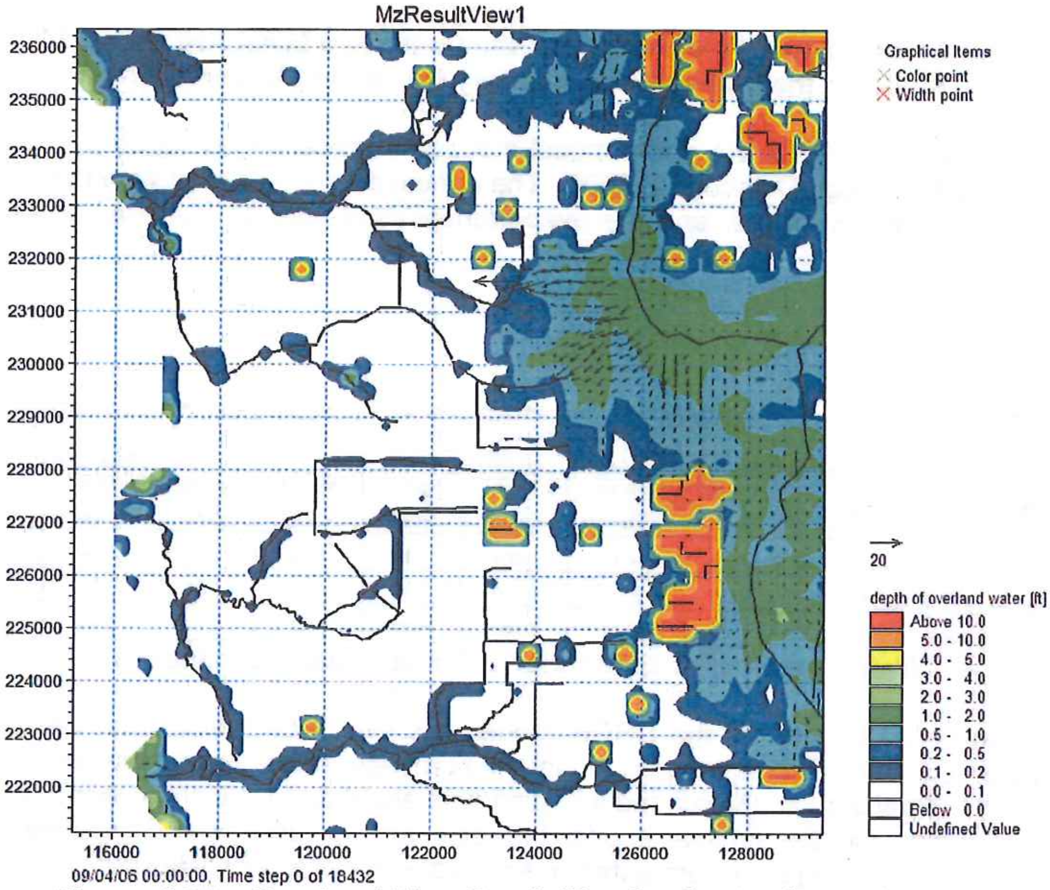


Figure 3-21 – Overland Flow Depth Map for September 4, 2006

REFERENCES

DHI, Inc. 2008. Lee County DRGR Mining Model Study. Tasks 1 & 2. Development of the Lee County Existing Condition Models. Prepared for Lee County, Draft Report.

Exceptional Engineering, Inc. 2008. Spring Creek Permitting History. Prepared for SFWMD, Draft Report.

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

Earth Tech, DHI, 2007, Kissimmee Basin Modeling and Operations Study KBMOS AFET Model Documentation / Calibration Report. Prepared for South Florida Water Management District.

HGL, DHI, 2006, Hydrologic-Hydraulic and Environmental Assessment for the Camp Keais Strand Flowway. Prepared for South Florida Water Management District.

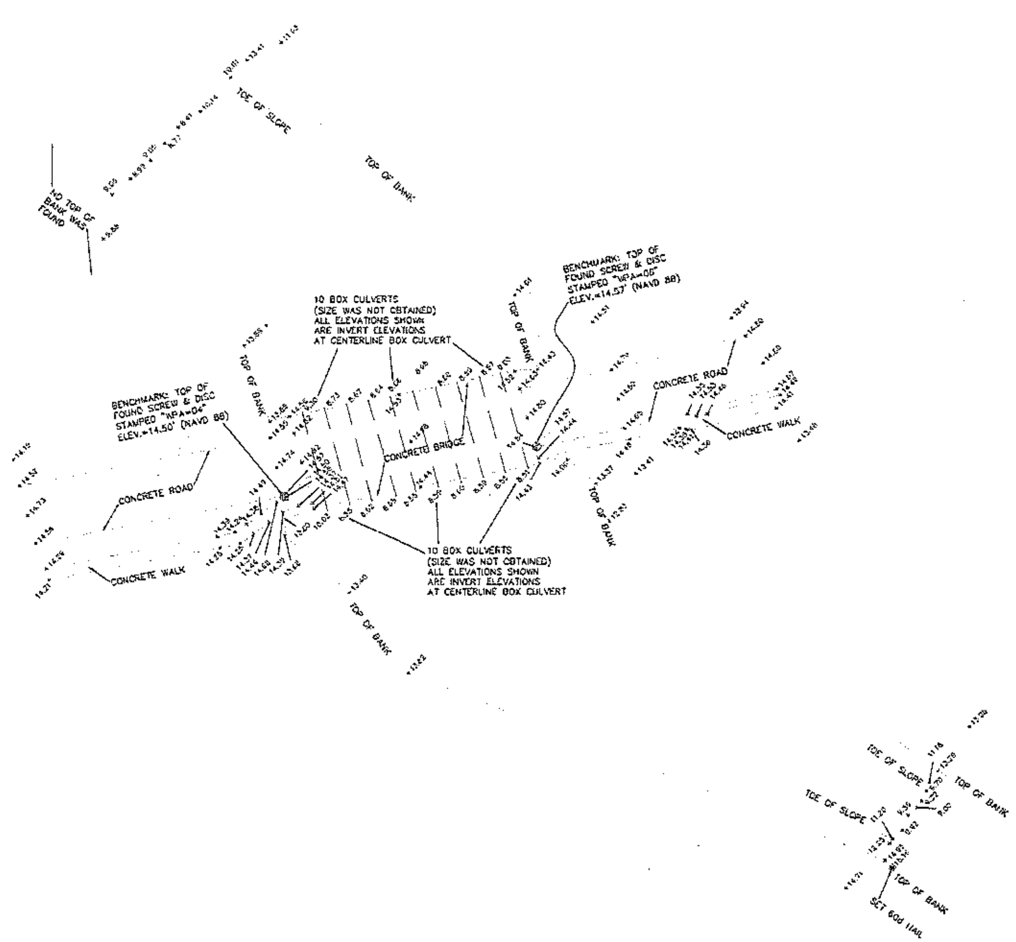
Appendix 1

Survey Cross Section Location Maps and Drawings

Location Maps


XS_ER_SB_N
XS_ER_SB_S
XS 3_Oaks


Williams



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SOUTH FLORIDA WATER MANAGEMENT DISTRICT	BEC PROJECT NO.	FIGURE
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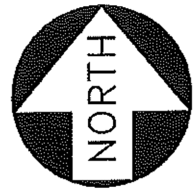

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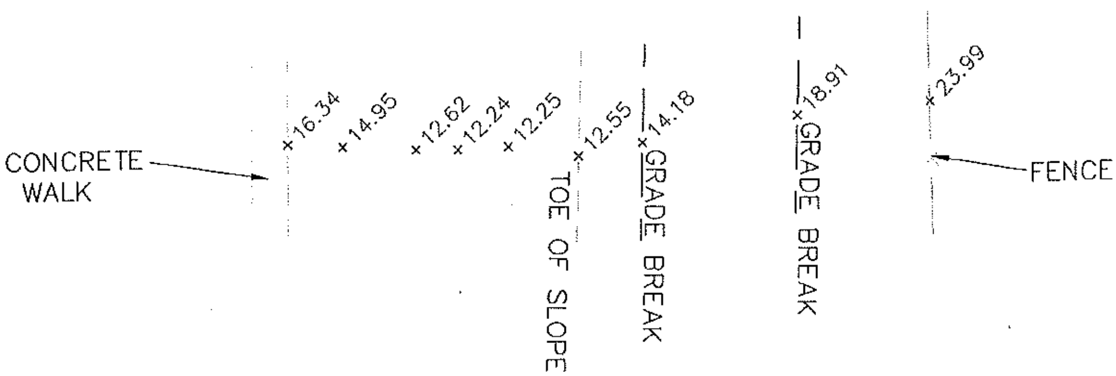

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SOUTH FLORIDA WATER MANAGEMENT DISTRICT	BEC PROJECT NO.	FIGURE
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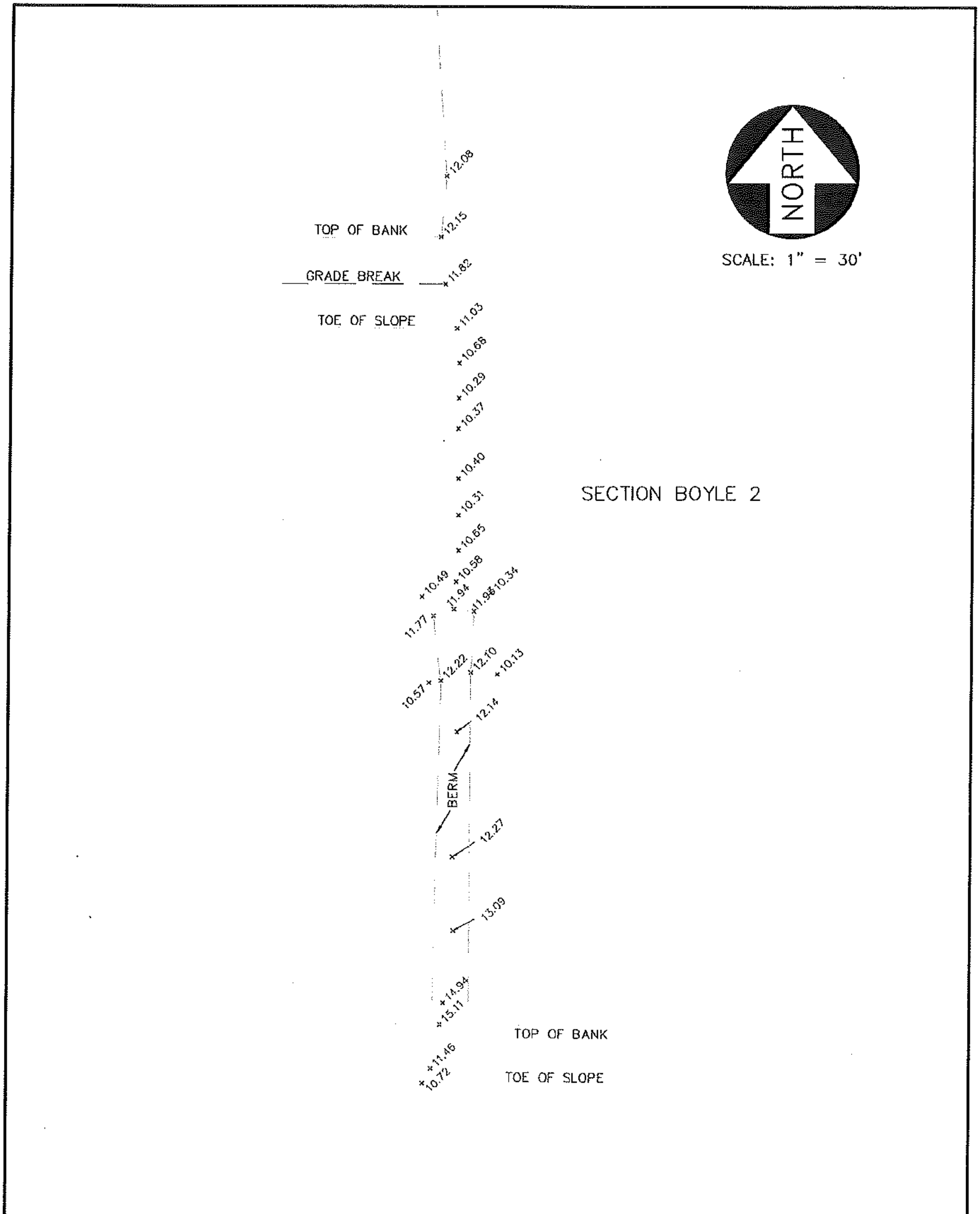

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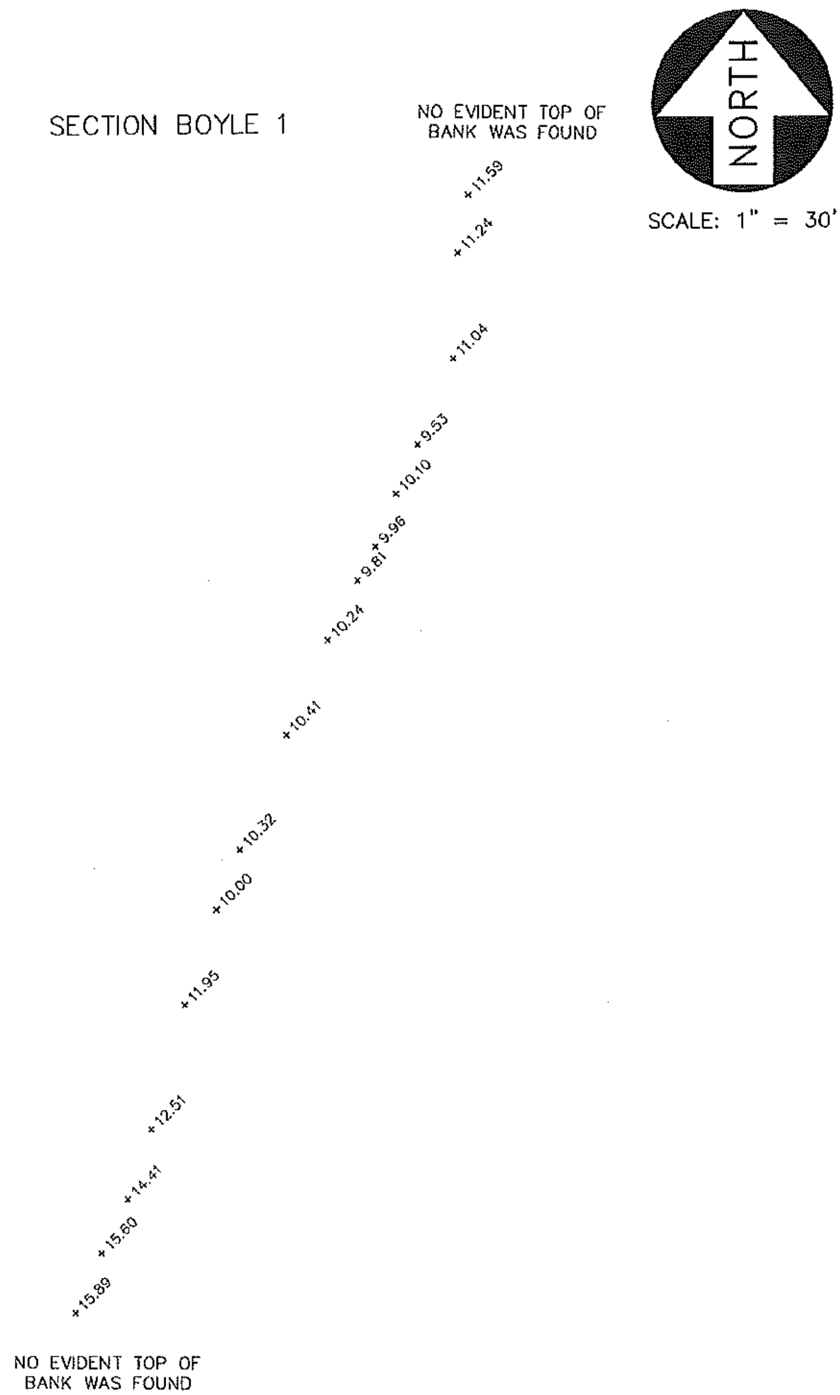

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SOUTH LEE COUNTY WATERSHED PLAN UPDATE

S BRANCH HALFWAY CREEK FLOWWAY

BEC PROJECT NO. 17312.02

FIGURE 4

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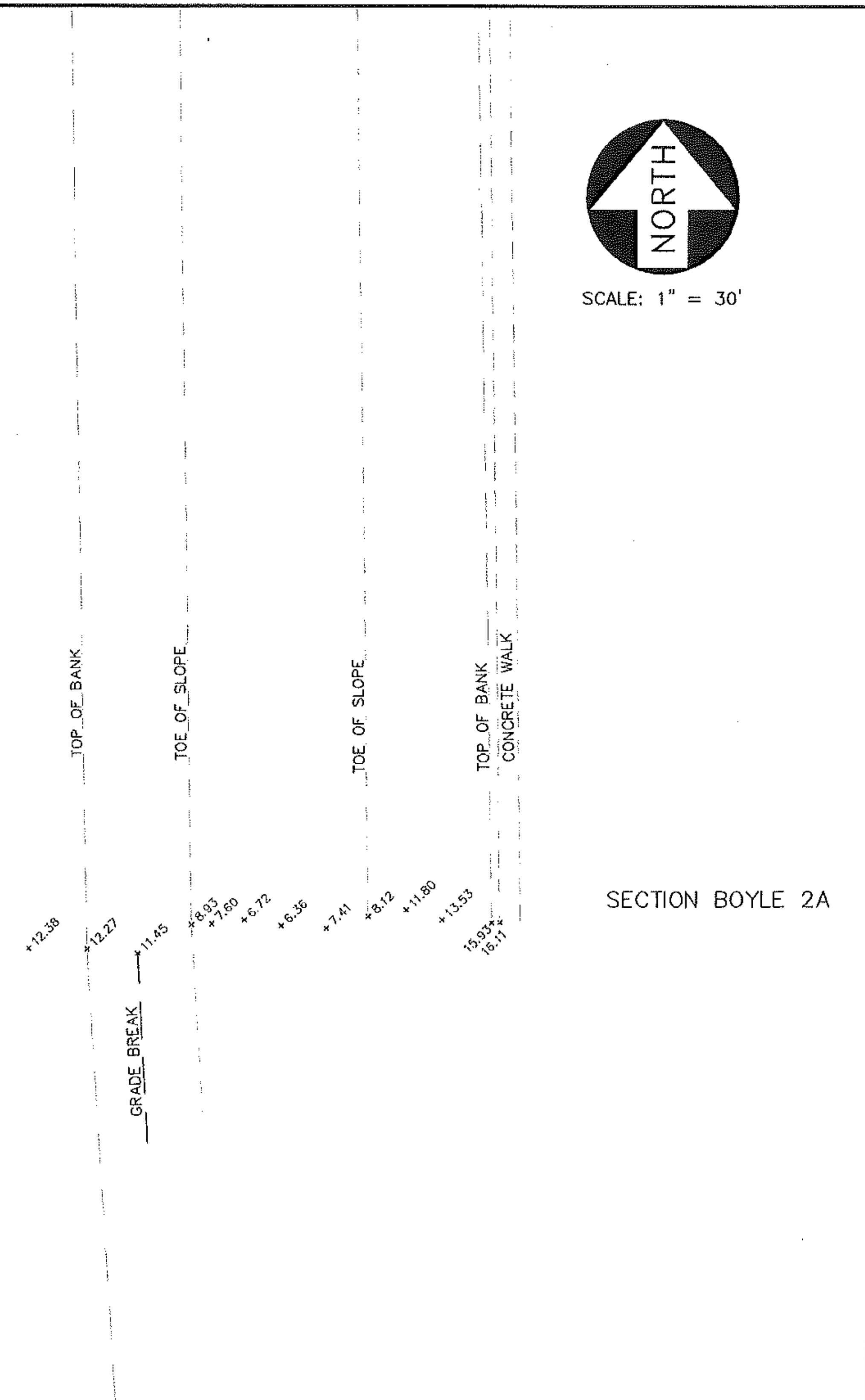

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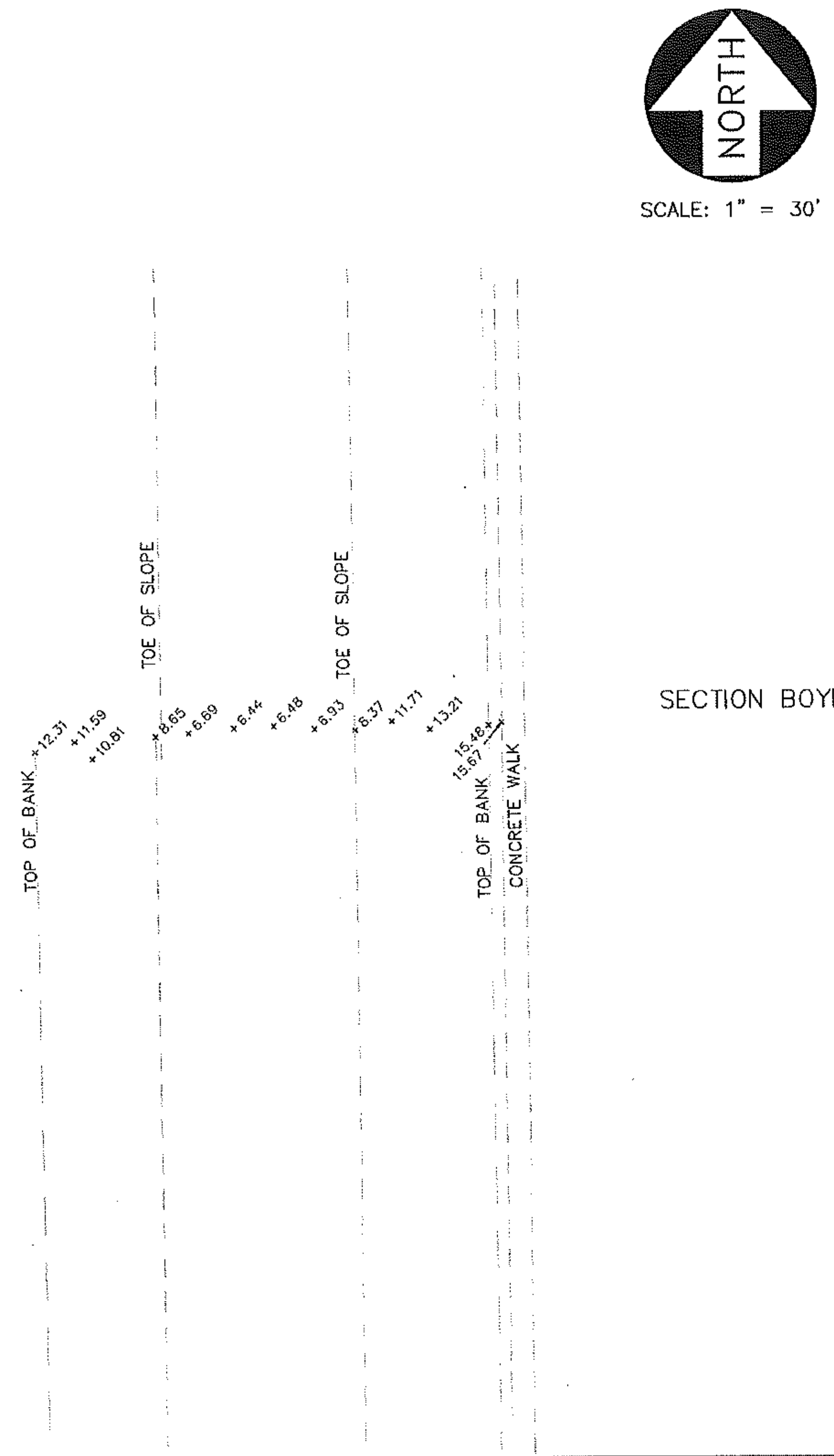

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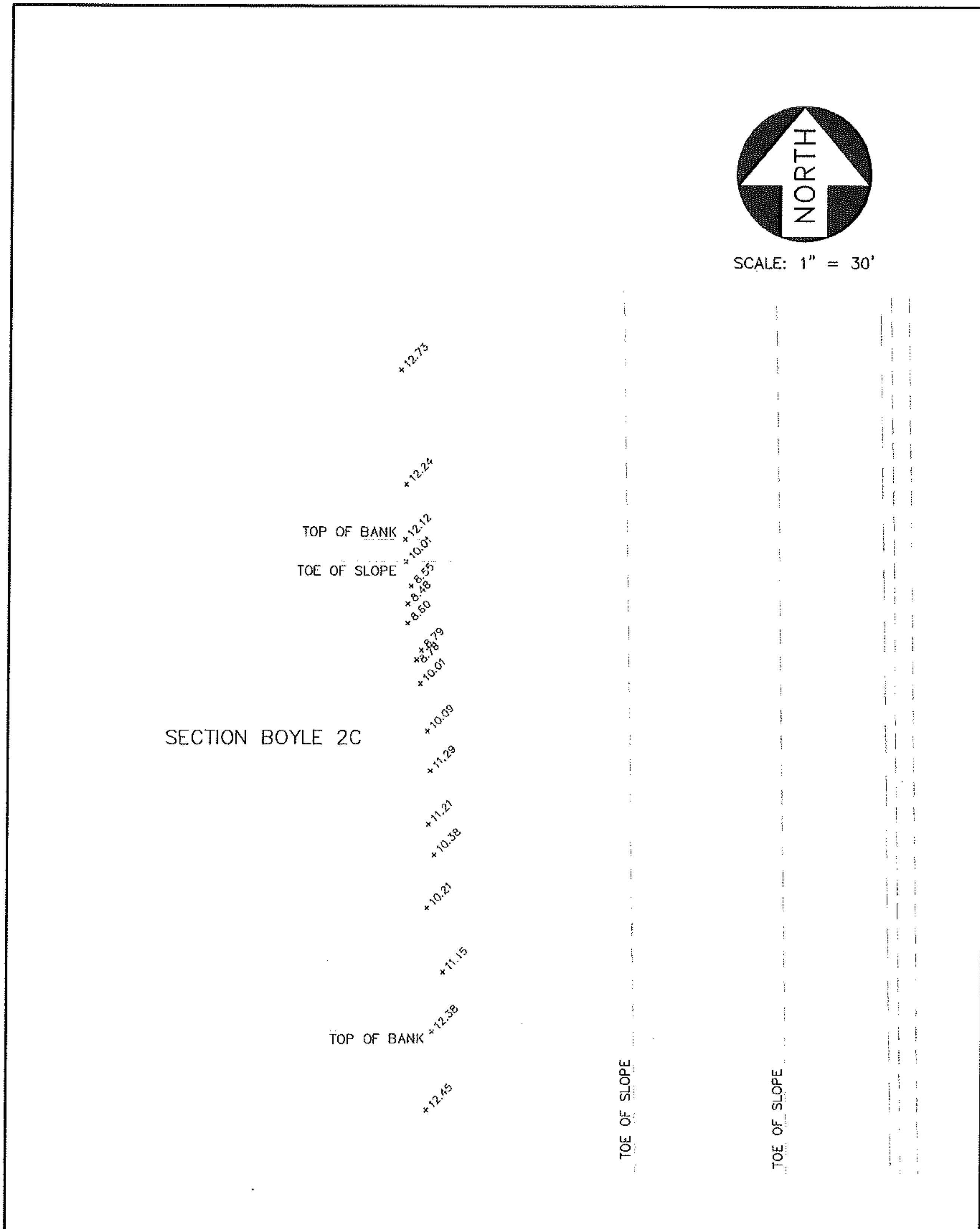

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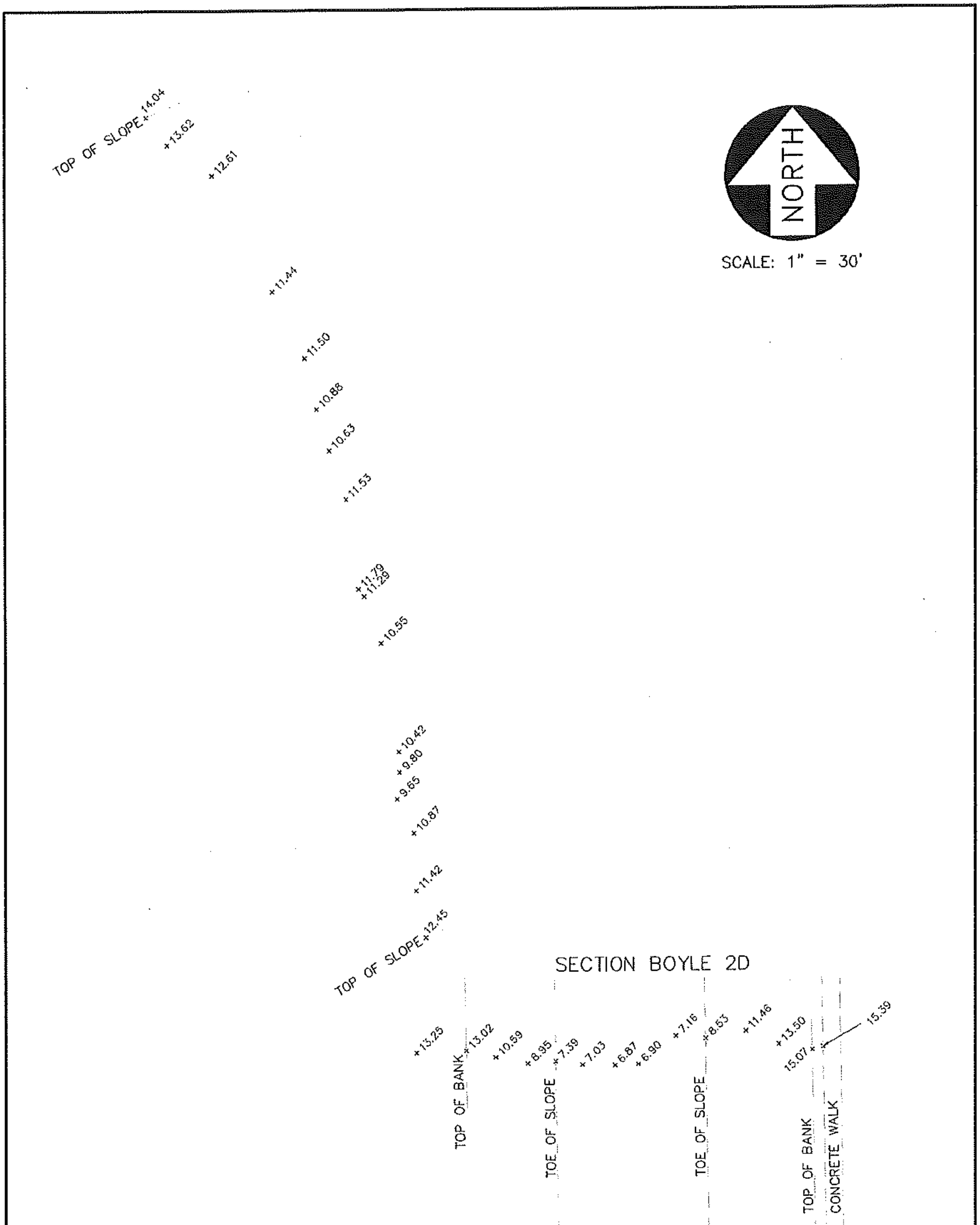

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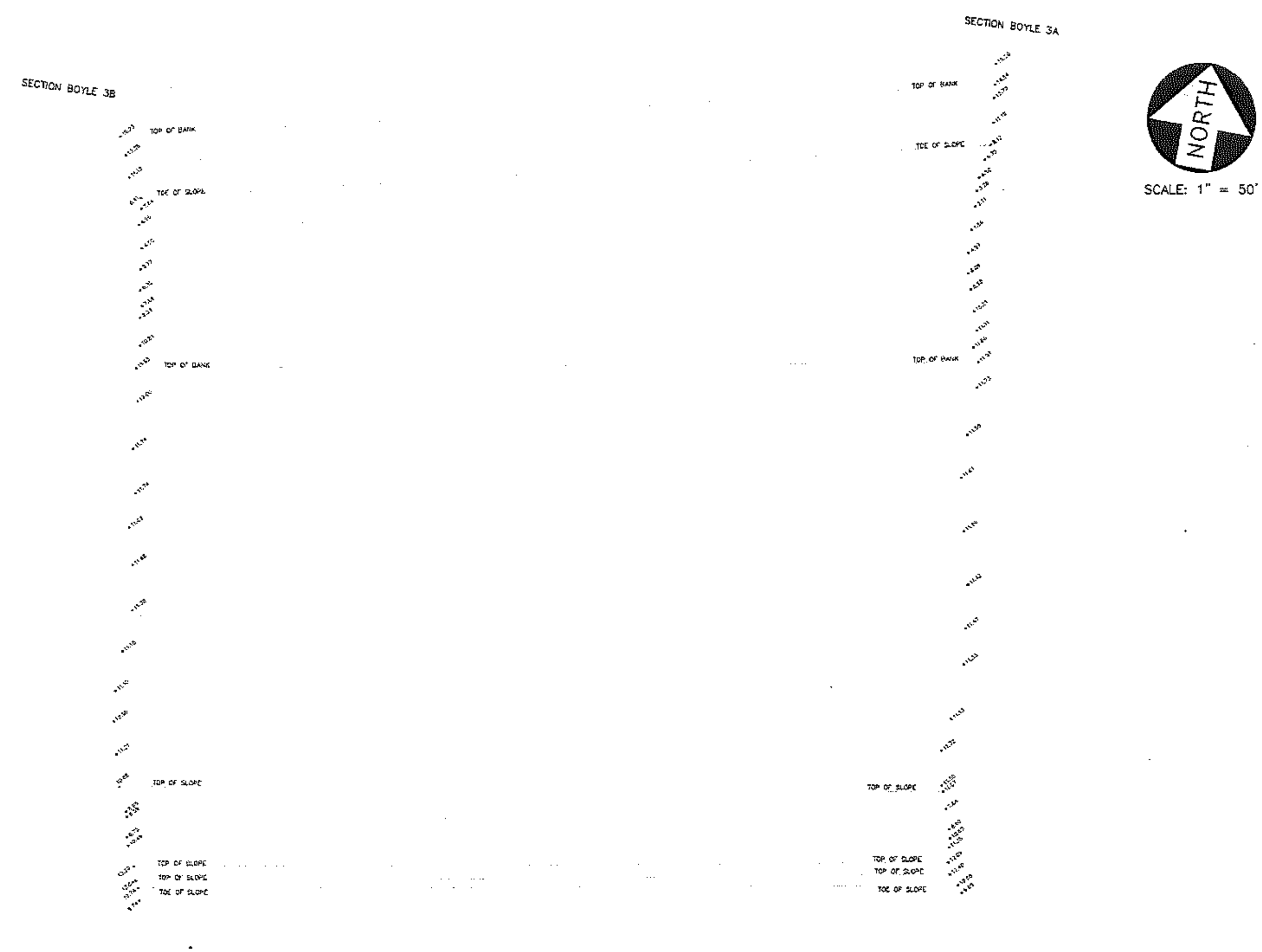

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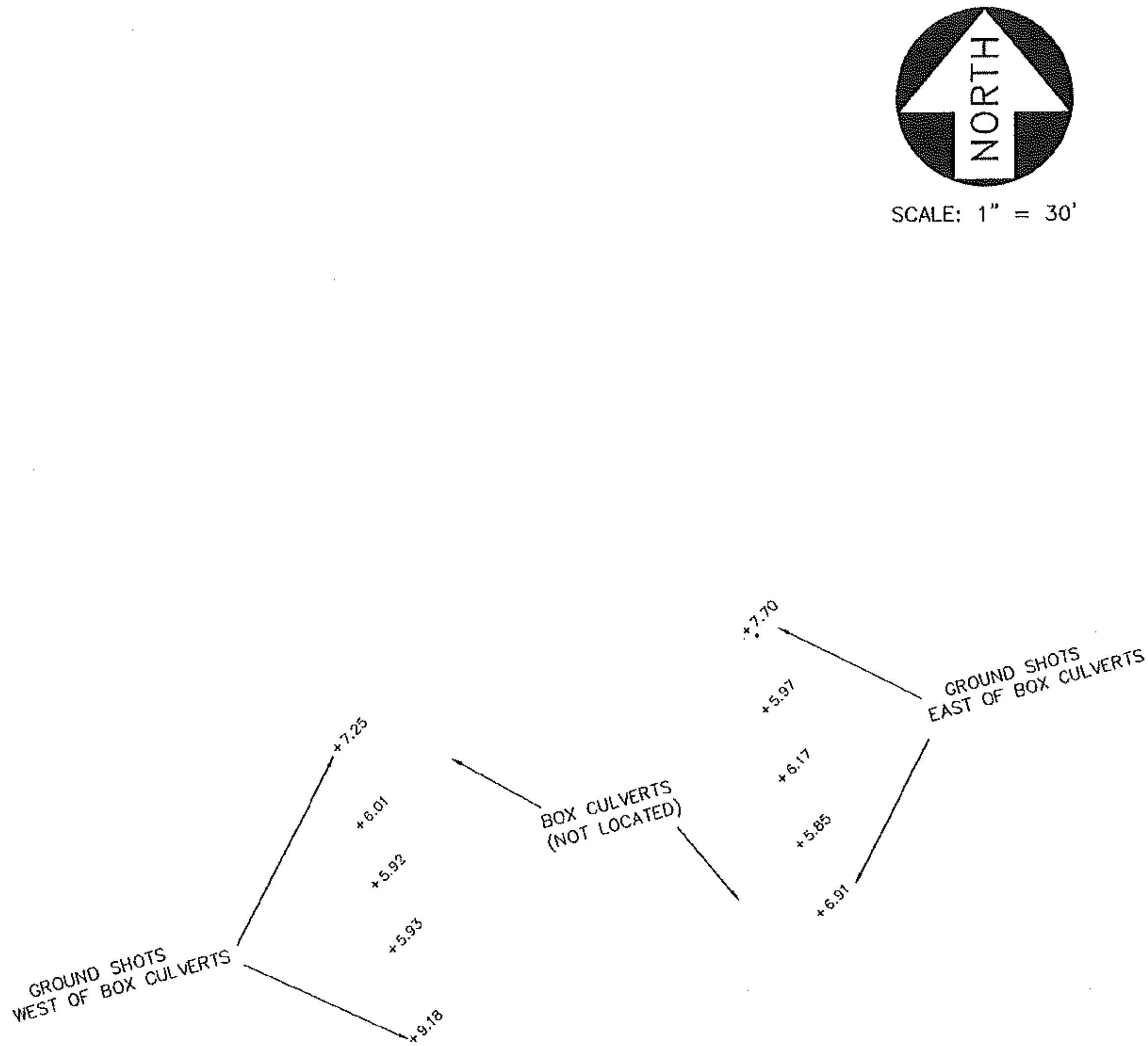
SOUTH LEE COUNTY WATERSHED PLAN UPDATE
XS-3A AND 3B
N BRANCH HALFWAY CREEK W OF 3 OAKS

BEC PROJECT NO.	FIGURE
17312.02	9



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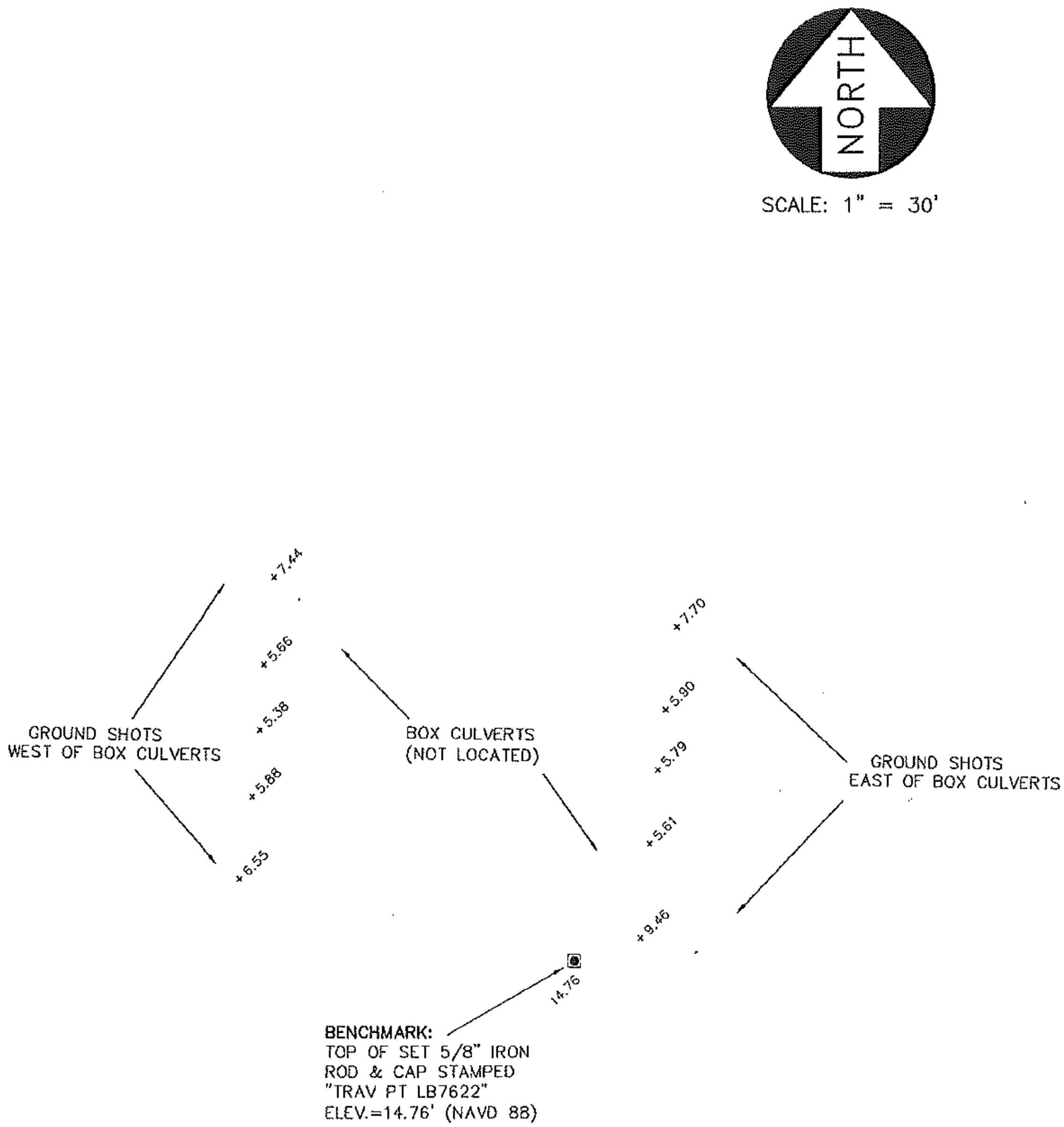

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VIA VILLAGIO S (W AND E)

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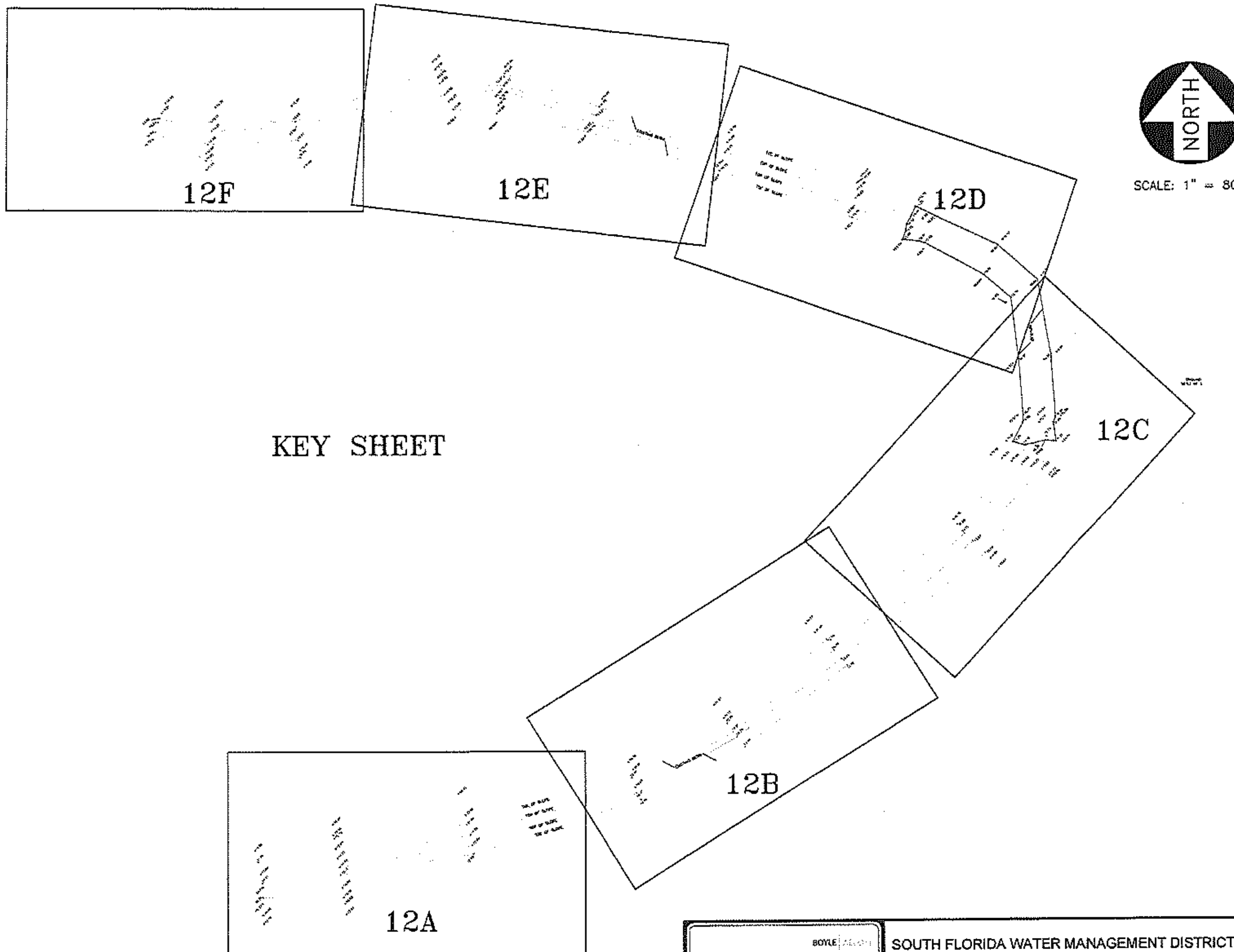

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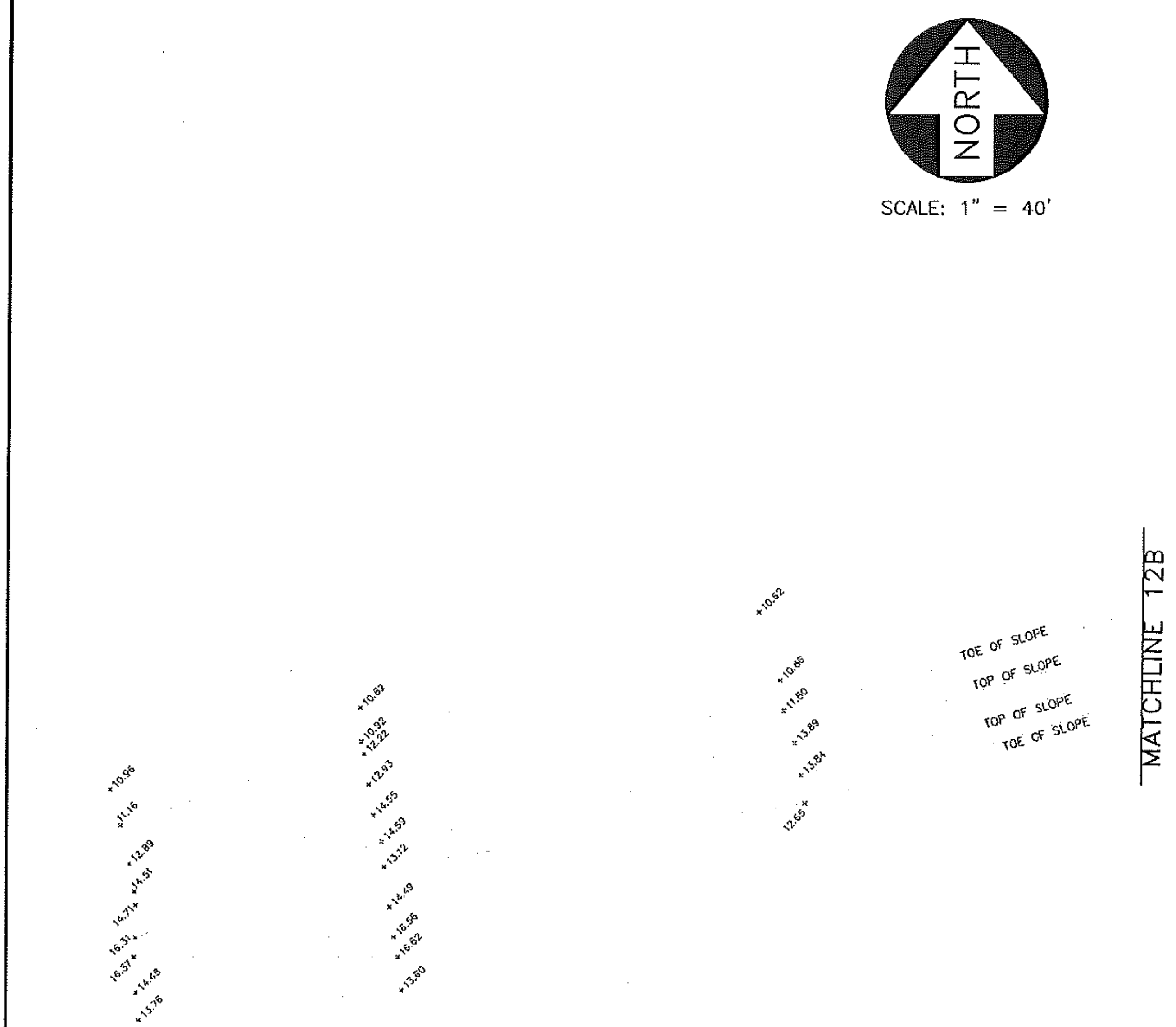
HALFWAY CREEK WEIR
CROSS SECTION

BEC PROJECT NO. 17312.02

FIGURE 12



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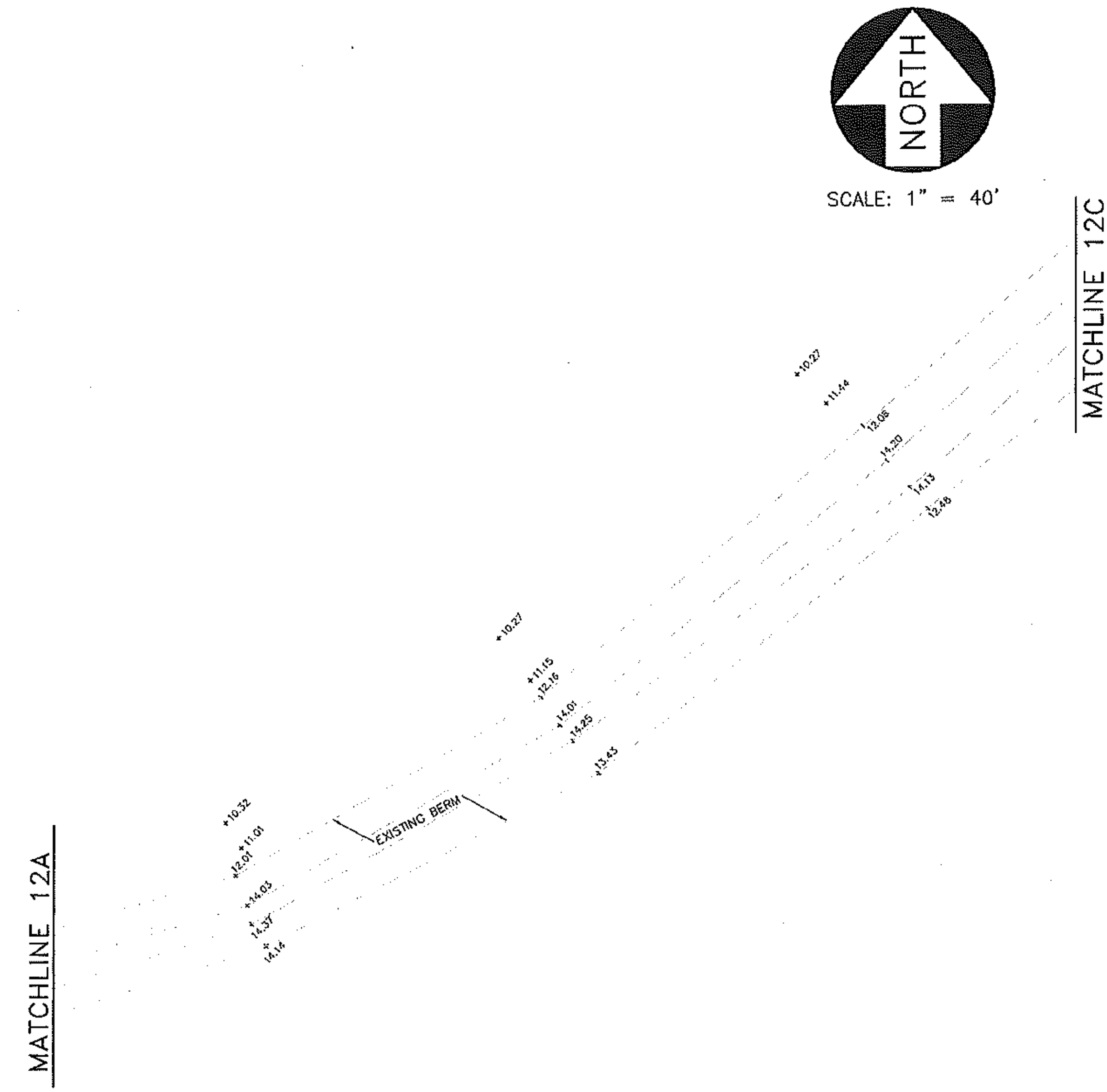

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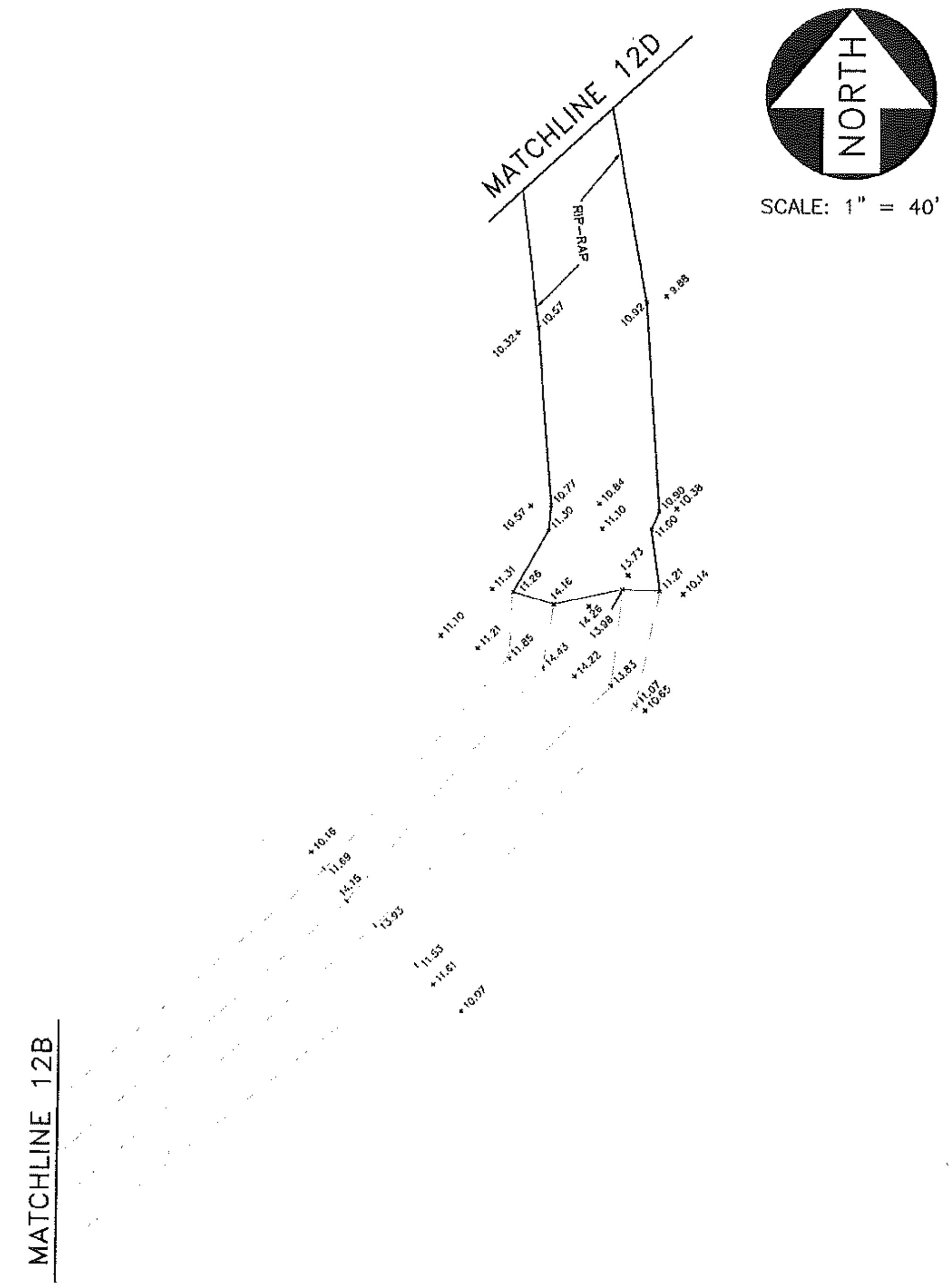

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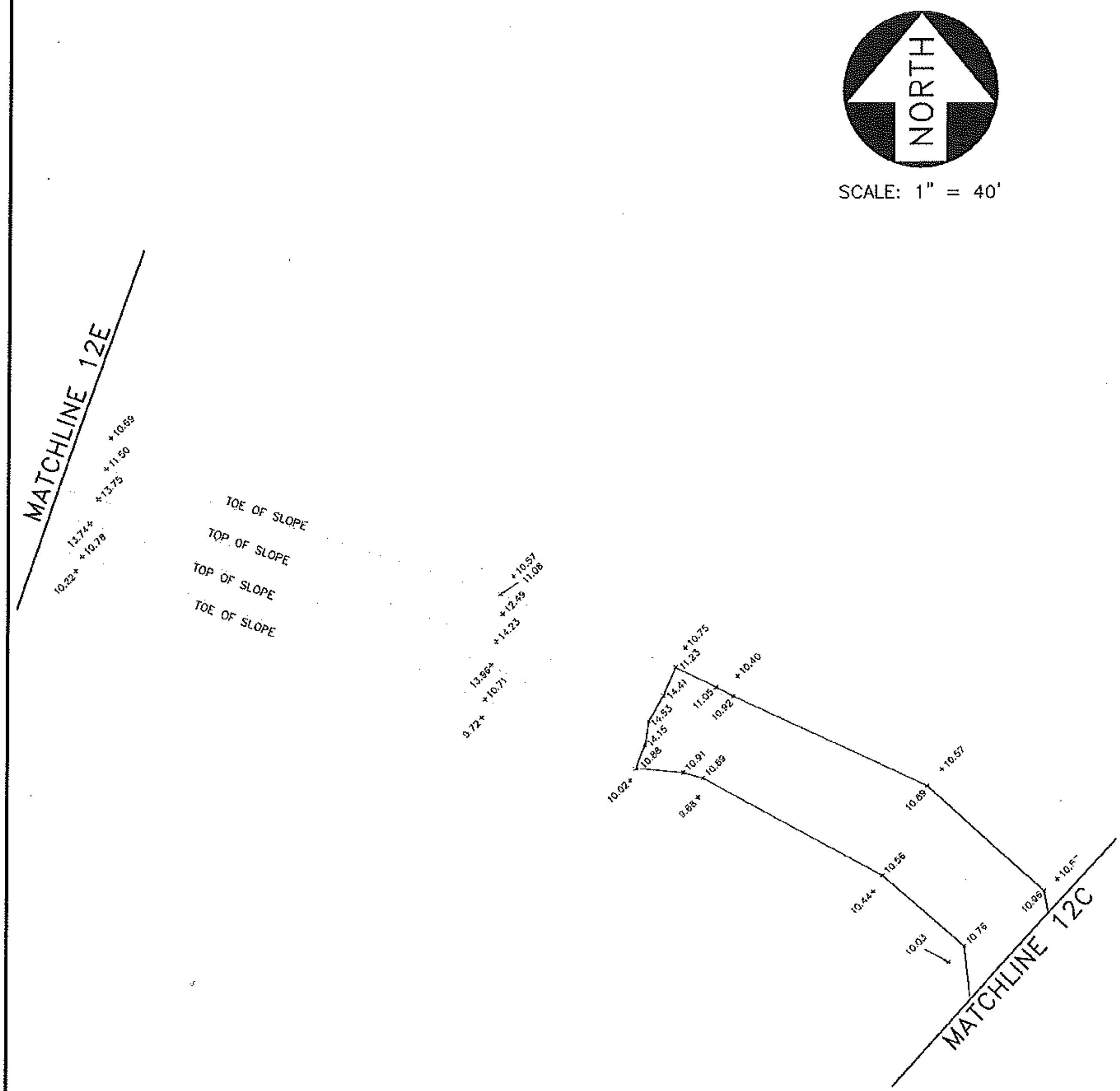
HALFWAY CREEK WEIR
CROSS SECTION

BEC PROJECT NO.	FIGURE
17312.02	12C
	3 OF 6



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HALFWAY CREEK WEIR
CROSS SECTION

BEC PROJECT NO. 17312.02

FIGURE 12D

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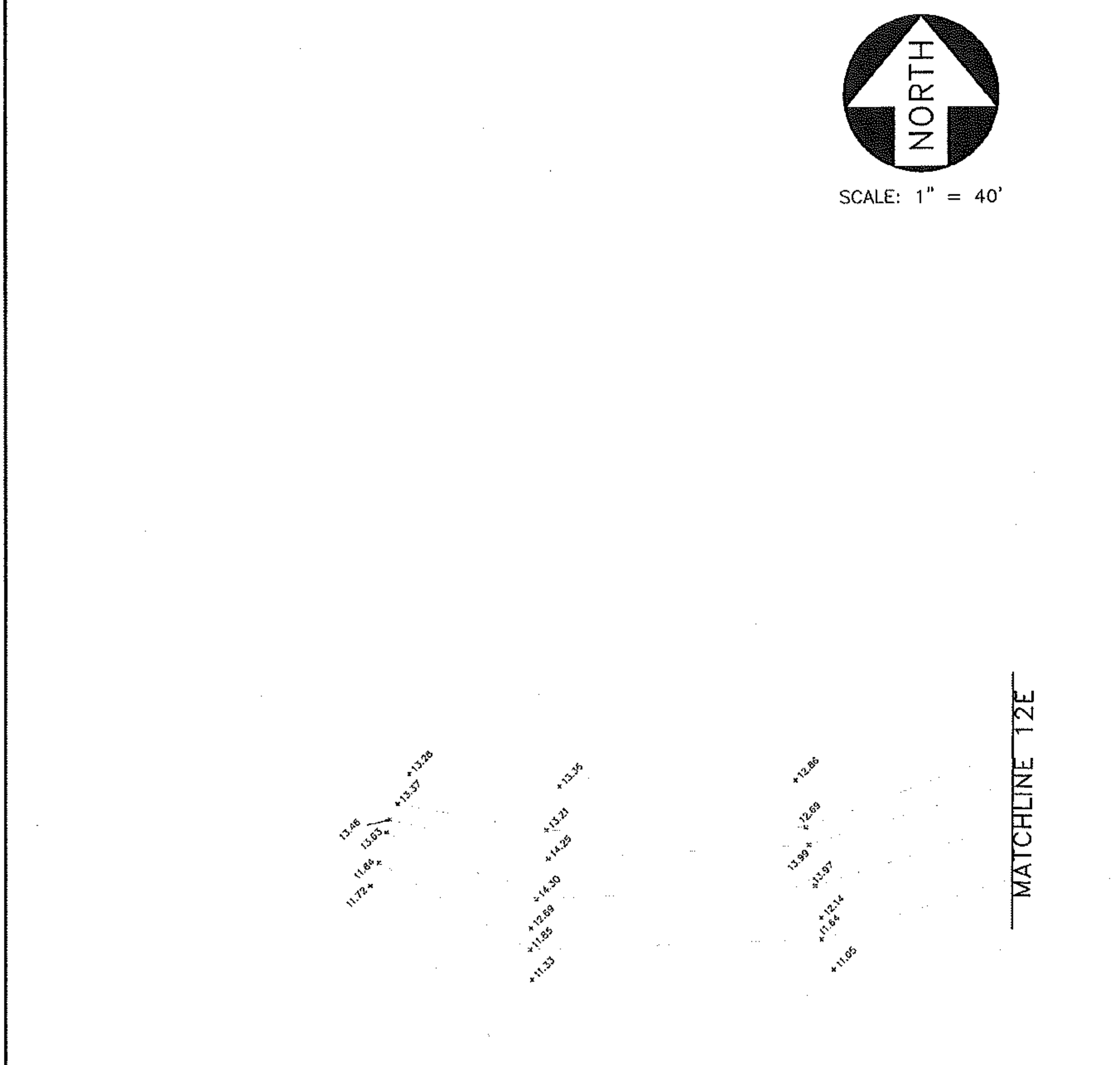

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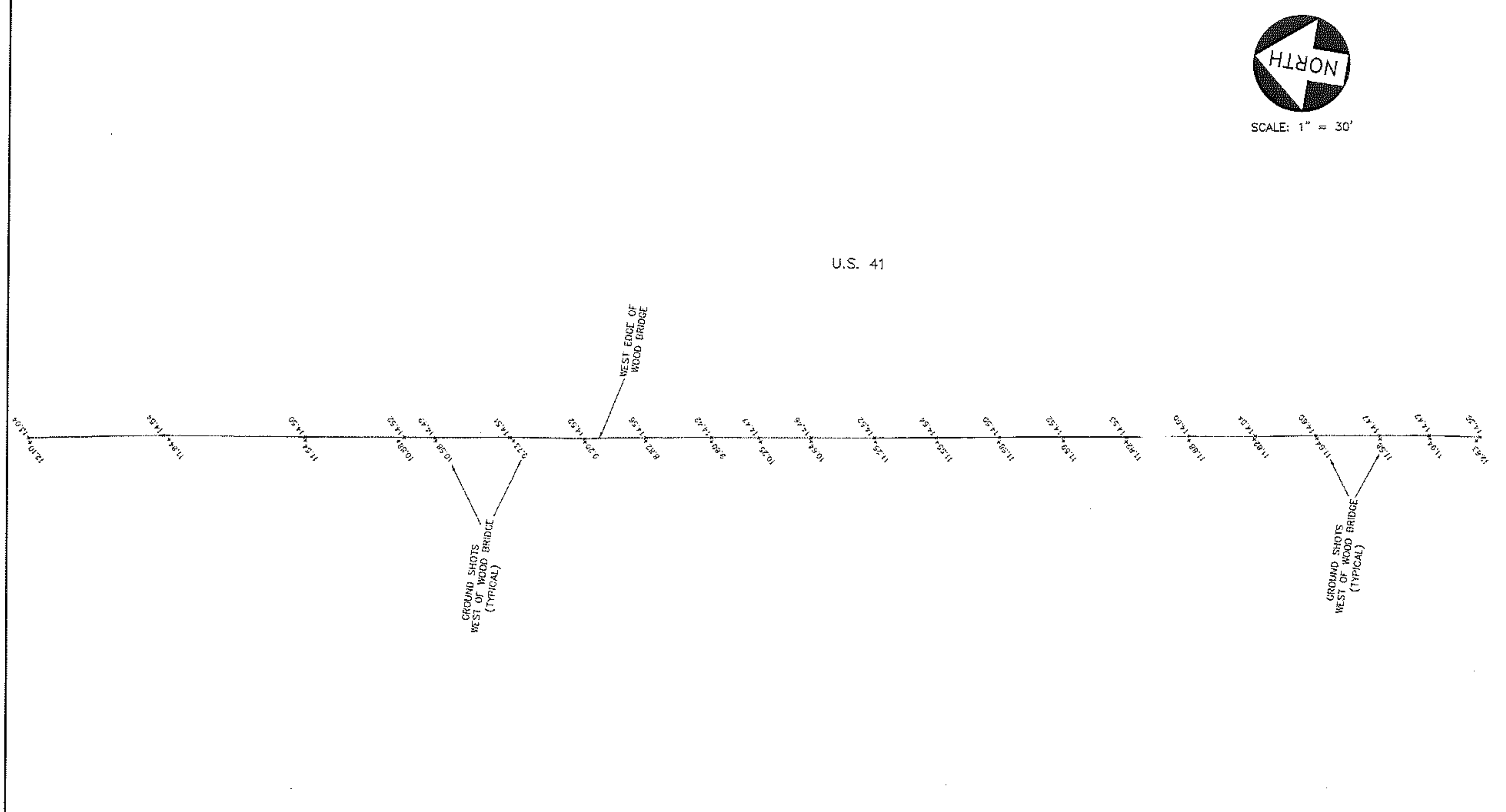
SOUTH LEE COUNTY WATERSHED PLAN UPDATE
HALFWAY CREEK WEIR
CROSS SECTION

BEC PROJECT NO. 17312.02

FIGURE 12F

6 OF 6



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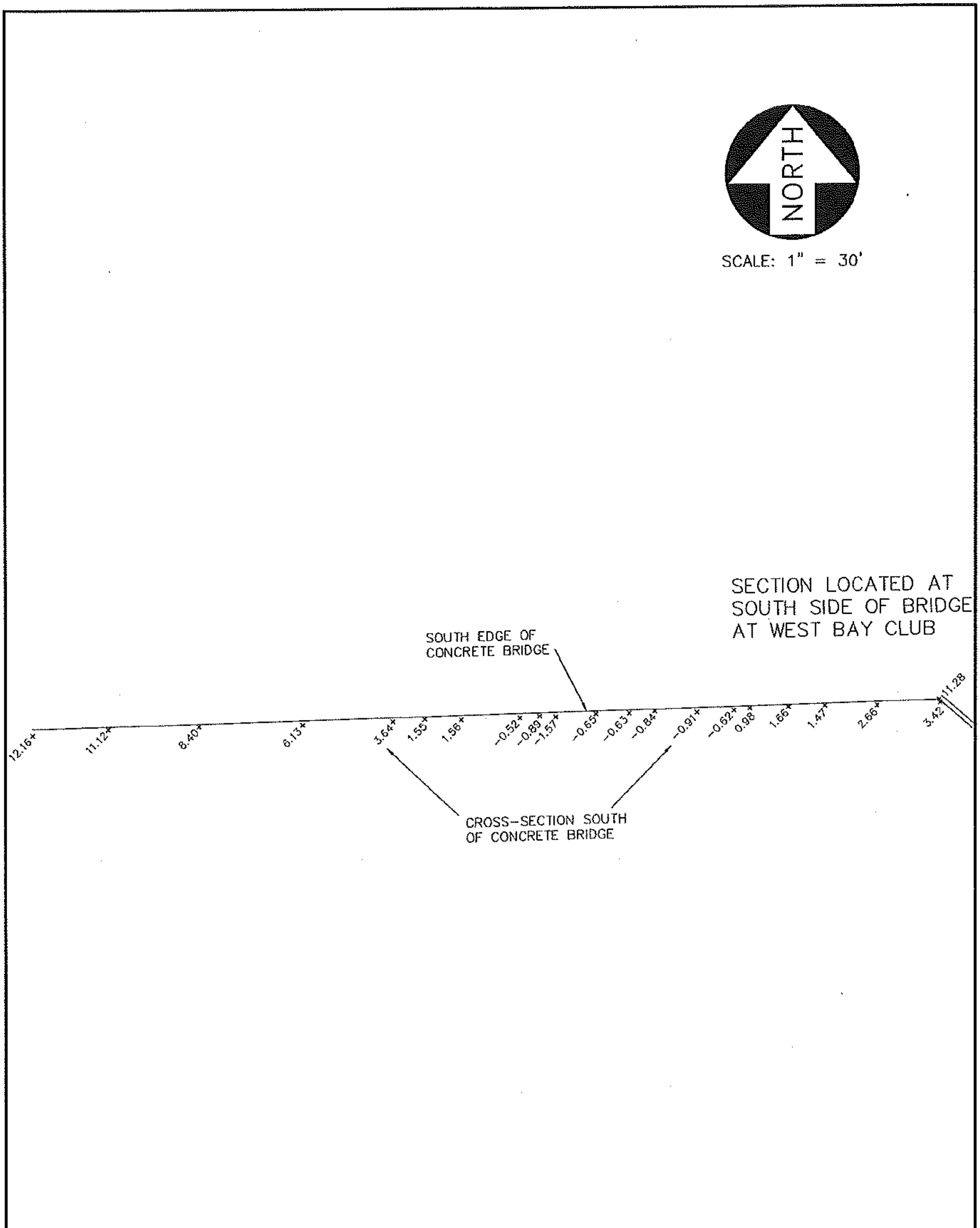

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