Everglades Agricultural Area Regional Feasibility Study

Deliverable 4.2 – Final Operating Strategy for Optimizing STA Performance with Existing EAA Goals

(Work Order No. CN040912-WO04 Phase 2)

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EVERGLADES AGRICULTURAL AREA
REGIONAL FEASIBILITY STUDY

DELIVERABLE 4.2 – FINAL OPERATING STRATEGY FOR OPTIMIZING STA PERFORMANCE WITH EXISTING EAA GOALS

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1.0 INTRODUCTION

The EAA Regional Feasibility Study (RFS) is being conducted by A.D.A. Engineering, Inc. for SFWMD through Work Order Numbers CN040912-WO03 and WO04. Under the Everglades Construction Project (ECP), SFWMD has constructed several Stormwater Treatment Areas (STAs) to help improve the quality of water released to the Everglades Protection Area (EPA). In addition to the existing STAs, SFWMD is planning certain STA expansions and enhancements, EAA canal improvements, construction of the EAA Storage Reservoir Project, and other EAA improvements. With recognition of these planned improvements, the EAA RFS will evaluate alternatives for redistributing inflow volumes and phosphorus loads to the various STAs to optimize phosphorus removal performance. This study is not intended to define the final arrangement, location, or character of these proposed projects but is a fact-finding exercise to develop the information necessary for the subsequent planning, design, and construction of these future projects.

2.0 SCOPE OF WORK

This document is an interim deliverable for Phase 1 Task 3 – Operating Strategy for Optimizing STA Performance with Existing EAA Canals. This task will define an operating strategy for redistributing the inflows to the STAs to optimize phosphorus reduction prior to the completion of EAA Canal Improvements, the A-1 Reservoir, and the Build-outs of Compartments B and C (these improvements are anticipated to be completed by 2010). This interim deliverable will define the hydraulic constraints to redistributing inflows to the STAs. The draft deliverable that will follow this interim deliverable will define the optimum redistribution of inflows to achieve optimum operation of the STAs between 2006 and 2010. The scope-of-work for Phase 1 Task 3 was limited to the Miami, North New River, Bolles, Cross, Hillsboro, West Palm Beach, Ocean, and STA 3/4 Supply Canals. However, this assessment also includes canals, flow-ways, and hydraulic control structure for the Rotenberger Tract, the Holeyland Wildlife Management Area, all STAs and the L-canals.

3.0 AVAILABLE DATA

SFWMD measures flows, stages, gate levels, and rainfall at numerous stations in the EAA. These data are available from DBHYDRO. Documents from SFWMD were used for dimensions of various EAA structures and STAs. **Table 3.1** presents a summary of available data used for this task. Detailed references are presented in the References section of this report.

Table 3.1 – Data Used in This Assessment

Source	Title	Data Used	Data Type
SFWMD	STA Operation Plans for STA 1E, STA 1W, STA 2, STA 3/4, STA 5, and STA 6	Pump and gate operations, pump sizes	Reports
SFWMD	EAA Farm Runoff daily flows	EAAWQDWN.dat	Data
SFWMD	S-6, STA 2 gates, G-335, G-370, STA 3/4 gates	2004 Hourly gate level, stage, and flow data. STA 2 data from DBHYDRO, STA 3/4 data from spreadsheets	Data
SFWMD	S-5A Diversion Structure G-341 Design Drawings	Gate dimensions	Plans
Burns & McDonnell	Addendum to the Design Documentation Report, STA 1E	Gate dimensions, cell bottom elevations, pump capacities, target water levels	Report
Brown and Caldwell	Final BODR for STA 2 Cell 4	Gate, canal, and cell dimensions	Reports
URS	Draft BODR for STA 5 Flow-way 3 and STA 6 Section 2	Gate, canal, and cell dimensions	Reports
Stanley Consultants	EAA Permitted Farm Area and pump station GIS data	Fstruct and dsub shape files	Shape files
US ACE /DHI	MIKE 11 Model and database of daily flows and stages – selected stations	Hydraulic model, measured stage and flow data (122 and 59 stations)	MIKE 11 files

3.1 Measured Hourly Data Used to Verify STA Operations

3.1.1 STA 2

Hourly data were obtained for the STA 2 inflow pump stations S-6, the outflow pump station G-335, and selected gates. These data were used to confirm predicted water levels at the headwater of S-6, predicted water levels within STA 2, and the operation protocols for STA 2 gates and outflow pump station G-335. **Figure 3.1** presents flows and headwater stages for pump station S-6. **Figure 3.2** presents gate elevations for the cell 3 inflow (G-333) and outflow (G-334) gates. **Figure 3.3** presents overall flows from STA 2 at pump station G-335. Key aspects of STA 2 operation are summarized below:

- Water levels at S-6_H drop from above 10 ft-NGVD to 9 ft-NGVD within approximately 5 hours after S-6 begins operation.
- S-6 operates during the day and not at night. Although not presented in this document, S-6 operates 24-hours per day if headwater elevations remain closer to elevation 10 than elevation 9.
- Inflow gate operation for STA 2 cells closely follows S-6 pump station operation.
- Outflow gate operation for STA 2 cells is not related to the inflow pump station operation.
- Significant variation over periods of a number of hours are experienced in the vicinity of STA 2 due to operational issues. Oscillations in water levels upstream of the STA inflow pump stations can be expected due to the relatively small number of large pumps (S-6 has three 975 cfs pumps).

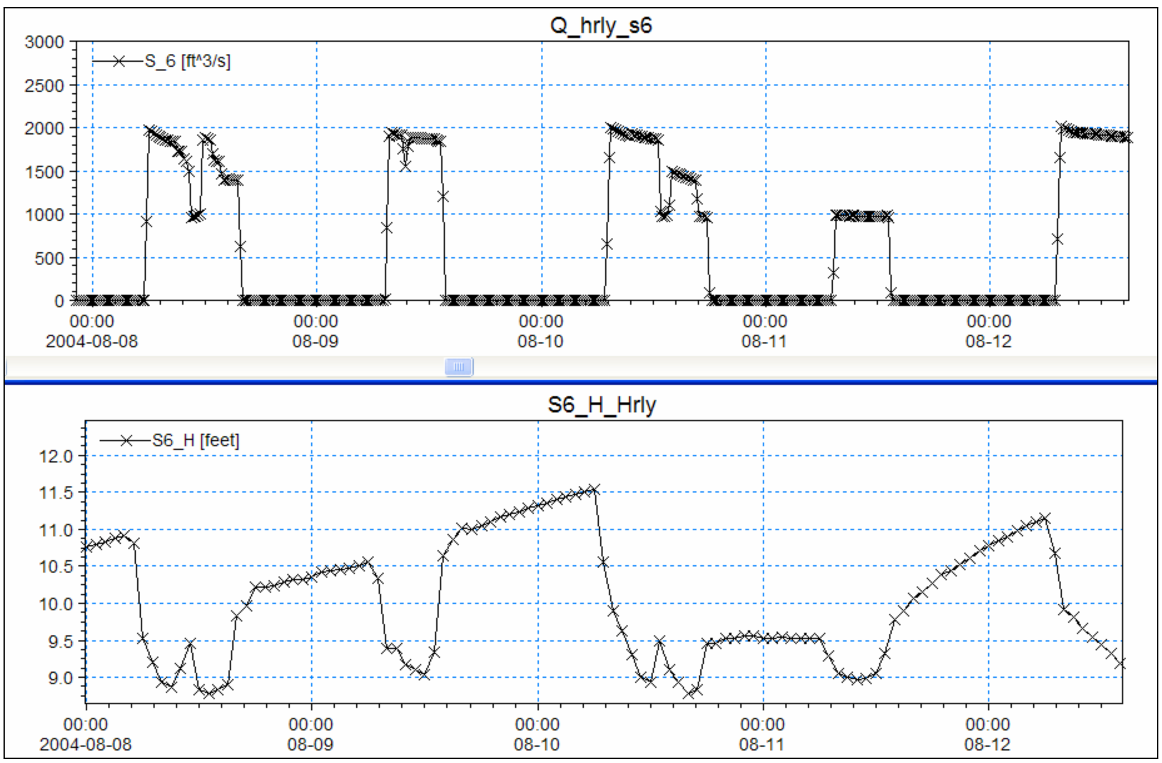

Figure 3.1 – Measured Flows and Headwater Stages at S-6

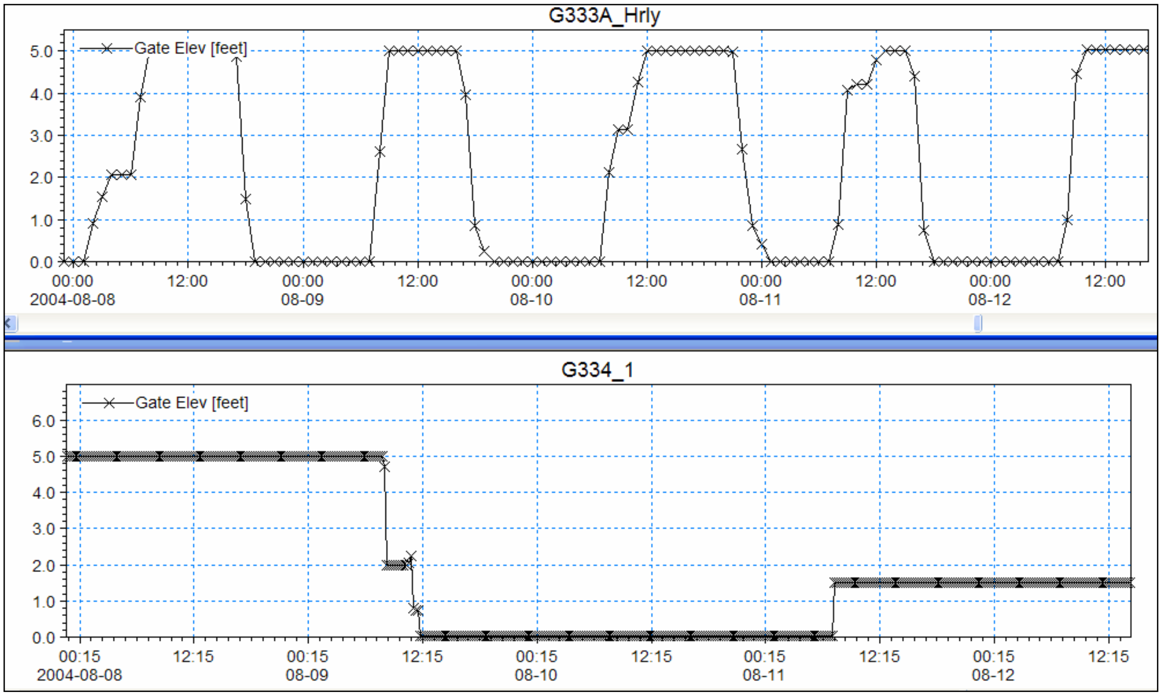

Figure 3.2 – Measured Gate Elevations for Cell 3 of STA 2 (Level 0.0 is closed)

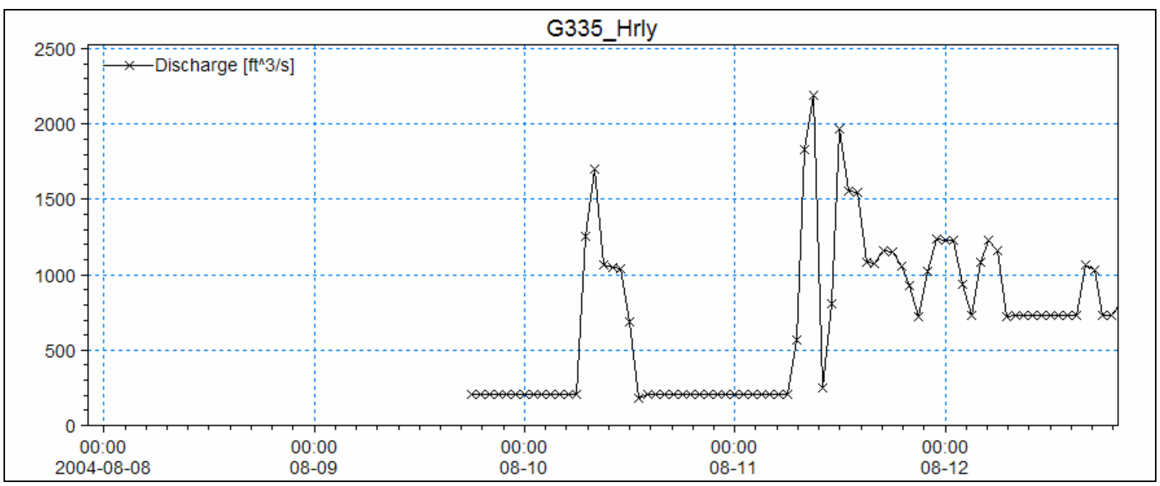

Figure 3.3– STA 2 Outflows at Pump Station G-335

3.1.2 STA ¾

Hourly data was obtained for STA 3/4 inflow pump station G-370 and gate elevations at the inflow and outflow of selected cells. These data were obtained from spreadsheets that are used to pre-process data prior to entry into DBHYDRO. STA 3/4 was in a start-up mode in 2004 and therefore, less data is available which must be processed prior to analysis. **Figure 3.4** presents hourly stage and flow data for G-370. Pump station G-370 flows in October, 2004 (a time of significant runoff due to prior hurricanes) ranged from 925 cfs to 2,775 cfs. Flows at G-370 in fall 2004 did not follow the S-6 pattern of operation during daylight hours. As with

S-6, depressed water levels are observed at the G-370 headwater during pumping. S-6 and G-370 have the same pump station capacity (2,775 cfs), however a runoff to the North New River will be less between 2006 and 2010 because Compartment C (9,590 acres) and STA 3/4 (16,543 acres) do not contribute runoff. The expansion of the Cross and Bolles Canals by 2010 will restore additional runoff to the North New River.

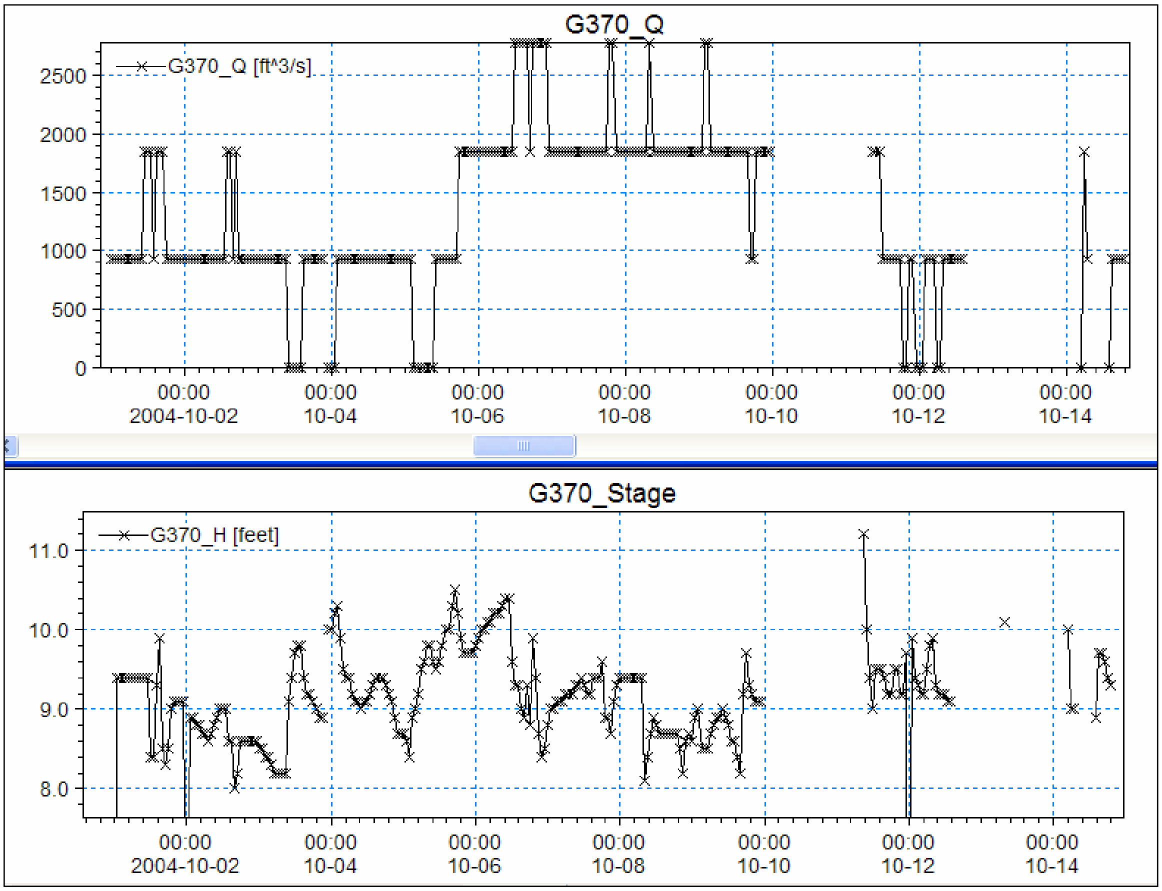

Figure 3.4 – Hourly Flow and Headwater Stage Data for STA 3/4 Inflow Pump Station G-370

4.0 MODEL DEVELOPMENT

The initial scope-of-work for this contract stated that an existing conditions HEC-RAS hydraulic analysis model would be developed for the Miami, North New River, Bolles, Cross, Hillsboro, West Palm Beach, Ocean, and STA 3/4 Supply Canals. The Phase 1 Task 2 Report (Evaluation Methodology and Evaluation Criteria, ADA, 2005) described the recommended hydraulic analysis approach. The hydraulic analysis will not use HEC-RAS but will use an existing MIKE 11 model of the EAA canals that includes the L canals and five of the six STAs.

4.1 Model Provided by U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers is conducting the Project Implementation Report (PIR) for the EAA Storage Reservoirs, and a MIKE SHE/MIKE 11 model was developed to assist in the development of the PIR. This integrated surface/ground water continuous simulation model describes the full hydrologic cycle of the EAA including rainfall, evapo-transpiration, infiltration, groundwater, runoff, canal hydraulics, and canal/aquifer exchanges. Structure details and operations of over 150 hydraulic control structures are handled by the surface water hydraulics model MIKE 11. The model represents 2004 conditions, and included STA 3/4 with structures G-371 and G-373 on the North New River and Miami Canals, respectively. G-371 and G-373 are gated structures that are closed for headwater elevations less than 12.5 feet and are intended to direct all EAA runoff from these canals into STA 3/4. The MIKE 11 portion of the MIKE SHE/MIKE 11 model was provided by US ACE to SFWMD for use in the EAA RFS. The EAA RFS Phase 1 Task 3 hydraulic analysis of existing EAA canals will use MIKE 11 with boundary inflows that represent the rainfall/runoff process for EAA farms, as described below. The MIKE SHE portion of the model (rainfall, overland flow, groundwater) was decoupled from the MIKE 11 model and not used. Rainfall and evapo-transpiration can be modeled in either MIKE SHE or MIKE 11, and was used in this study for the canals, STAs, and reservoirs. A number of refinements were made to the network to represent 2006 conditions (see section 4.4) and to improve hydraulic control structure operations to remove model instabilities (see section 5). The MIKE 11 hydraulic network is shown in **Figure 4.1**.

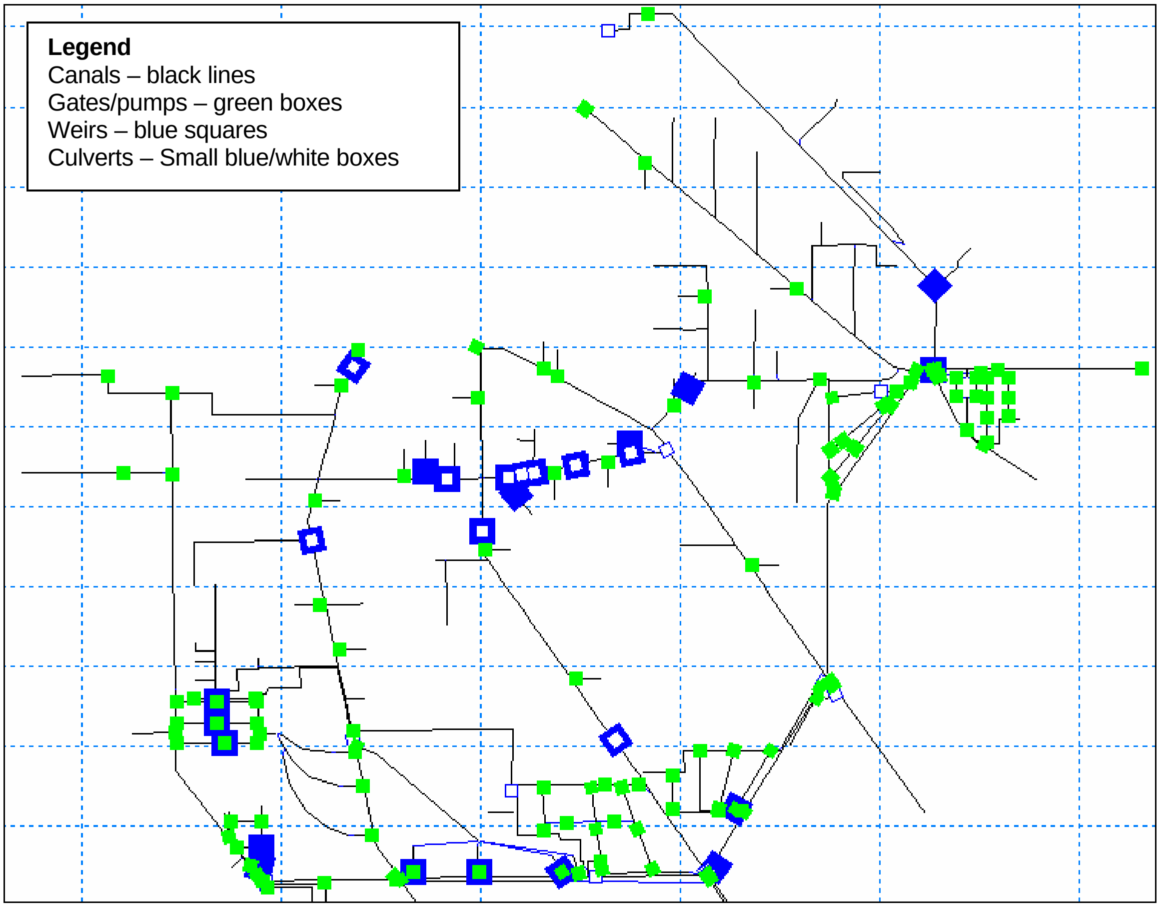

Figure 4.1 – MIKE 11 Hydraulic Network

4.2 Hydrology

There are 226 farms in the EAA that have SFWMD permits to discharge to the main EAA canals. These permits are for specific farm areas and specific intake and discharge locations. The discharges are pumped outflows from the EAA farms, and the maximum flow for each pump is defined in the permit (there are 292 permitted pumps). Typically, the maximum pump discharge is equal to 1.5" per day, and the average permitted discharge is ¾"-NGVD/day. The irrigation inflows are either pumped or are regulated by gated structures. The permit stipulates that farm runoff volume and Total Phosphorus (TP) concentration shall be measured using approved methods and reported to SFWMD. SFWMD maintains a data base of daily average discharge flows and discharge TP concentrations. EAA farms utilize best management practices (BMPs) to control the runoff with the intent of retaining at least 25% of the TP load on the farm. This is achieved by a variety of methods including in-canal retention upstream of the farm outflow pump station. When possible, EAA farms will not discharge any runoff for small storms and will use the runoff stored in internal canals for irrigation during periods following the runoff event. Some EAA farms are over 10,000 acres in size, and often experience heavy rainfall in one part of the farm while crop stresses are experienced in other fields due to low groundwater elevations. The net effect of the BMP program is that farm runoff is very difficult to predict.

The analysis conducted during this assessment assumes that runoff from EAA farms will range from 3/8"-NGVD to 3/4"-NGVD. The runoff rate can be varied by major EAA drainage basins (STA 1E, STA 1W STA 2, STA 3/4 East, STA 3/4 West, STA 5 and STA 6, and others). The initial assessment analyzed a uniform rate of runoff in each basin equal to 3/8". Then, 3/4" of runoff was used is a portion of the EAA to test if inter-basin transfers would be possible with the existing canal network.

The 292 EAA farm pumps have been grouped by ADA into 148 discharge locations, and the area for a "grouped pump" is equal to the combined area for the pumps included in that one "grouped pump". Pumps were grouped when the distance between pumps was less than 0.5 miles and there were no bridges or culverts between the pumps. **Figure 4.2** presents the farm pumps and the grouped farm pumps. The runoff rate for the 148 discharge locations is presented in **Table 4.1**.

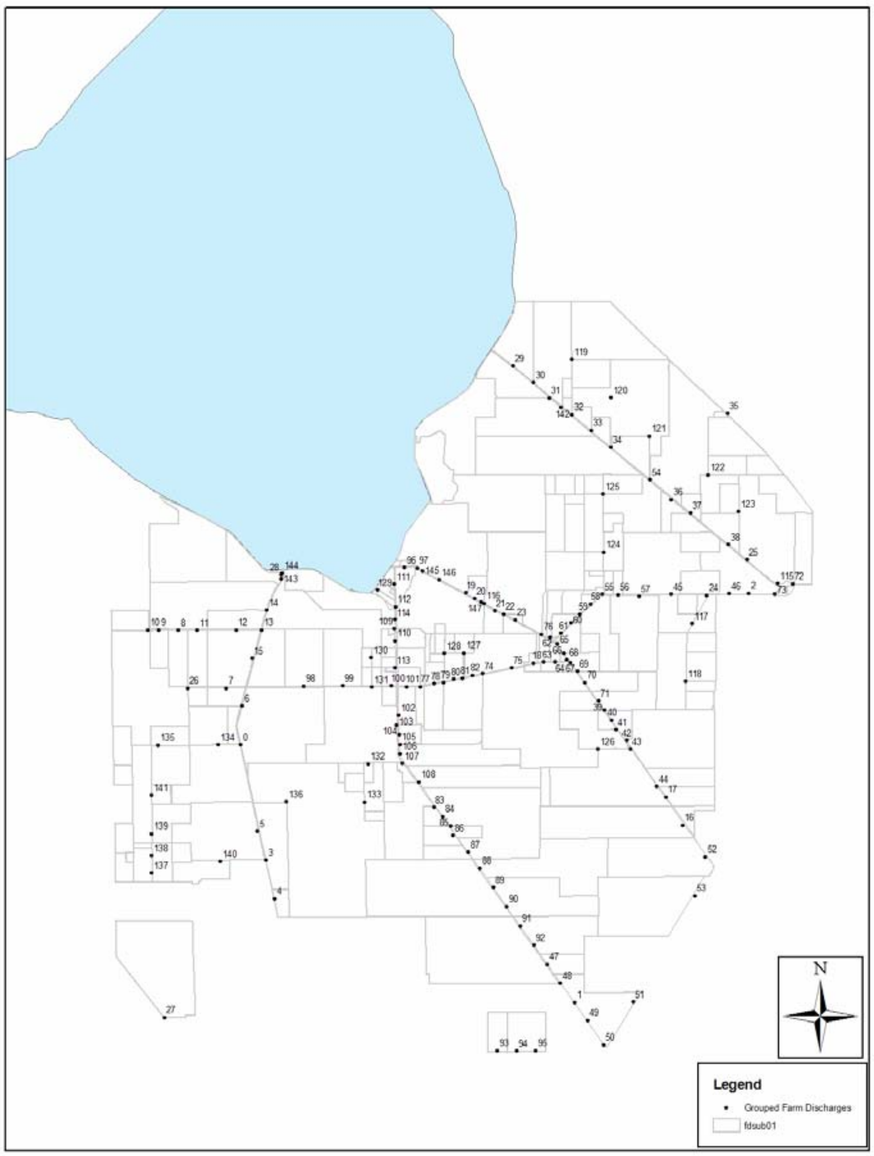

Figure 4.2 – Locations of Runoff Inputs

Table 4.1 – Lateral Inflows Runoff Rate

Structure	Flow (cfs)	Comments	Structure	Flow (cfs)	Comments	Structure	Flow (cfs)	Comments
BC00.1TS	18	Added BC00.1TN	HC23.1TS	30	Added HC23.5TN01	NR18.2TW04	116	Added NR18.2TW02,03,05,06
BC00.6TN	5	Added BC00.6TS	L101.1TS	0		NR18.2TW08	10	Added NR18.2TW07,09,10
BC01.2TN	7		L103.1TS	0		NR18.7TE	130	
BC01.8TN	15	Added BC01.8TS	L104.1TS	0		NR19.2TE	47	
BC02.9TN	58	Added BC02.4TS	L105.1TS	40		NR19.7TE	24	
BC04.5TN	0		L105.6TS	39		NR20.2TW	309	
BC05.0TN	0		L406.6TN01	33		NR20.7TE	0	
BC05.5TN01	20		L503.6TN	0		NR23.1TW	66	Added NR23.2TW, 22.7TE, 23.7TE
BC05.5TS	108		L504.6TN	0		NR24.6TW	47	Added NR24.7TE, NR24.2TW
BC06.0TN	28		L505.6TN	40		NR25.2TW	0	
BC06.5TN02	40	Added BC06.5TN01,03,04,05,06	L601.8TN	276		NR25.8TW	7	
BC06.5TS	48	Added BC06.6TN	L608.2TN	127		NR26.4TE	18	Added NR26.7TW, NR27.2TE
BC07.0TN	17	Added BC07.0TS	L811.0TW	0		NR26.7TW-A	1	
BC07.8TS	16	Added BC07.7TN	MC08.6TE	21	Added MC09.7TE01	NR27.6TW	9	Added NR27.7TE, NR28.2TW
BC08.5TS	37		MC10.7TE	120		OC00.5TS	6	
BC09.2TN	27	Added BC09.3TS	MC10.7TW01	59	Added MC10.7TW-E	OC02.0TN	116	
BC10.2TN03	30	Added BC10.2TN01,02	MC10.7TW02	9	Added MC10.7TW-I,07	OC03.0TN	0	Added OC02.5TS
BC10.3TS	10	Added BC10.5TN	MC10.7TW03	129	Added MC10.7TW06	OC04.1TS	259	Added OCT04-A, OCT04.5TN
BC11.7TN	120		MC10.7TW11	123	Added MC10.7TW09,10,12	OC04.1TS06	137	Added OCT04.05,09,I,K,L,M,N
BC13.7TN	120		MC10.7TW15	20	Added MC10.7TW04,05	OC04.1TS-E	204	Added OCT04.1TS-01,02,07,08,B,C,H
BC17.7TS	36		MC12.2TW	231		OC06.0TN	0	
BC19.7TS	46	Added BC19.2TS, 19.2TN, 19.7TS01	MC13.7TE03	0	Added MC13.7TE04	OC07.6TS	180	
HC00.7TS	204		MC13.SFCD	504	SFCD	OC08.7TN	13	
HC00.ESWD	439	ESWCD	MC16.8TE	34	Added MC16.9TW	OC09.5TN07	313	Added OCT09.5TN02-13,24
HC02.7TS	274	Added HC02.8TN	MC16.8TW03	239	Added MC16.8TW01,02,04,05	OC09.5TN19	162	Added OCT09.5TN14-23,25
HC04.5TN	51		MC16.8TW06	275	Added MC16.8TW07	OC09.6TN	18	Added OCT09.2TN
HC05.2TS	51	Added HC05.1TN01-03, HC05.2TS01	MC18.8TE	0	Added MC18.8TW	OC10.3TN	99	Added OCT10.3TS
HC07.6TS	0		MC21.5TW	141		OC11.1TN	25	
HC07.6TS-A	0	Added HC07.6TS-B	MC23.0TE	148	Added MC23.3TW	OC11.7TN	20	Added OCT11.8TS
HC08.1TN	240		MC24.1TE	42	Added MC24.1TE	OC12.5TN	0	
HC08.8TS	87		MC26.1TW	67		WP00.8TN	294	Added WP00.7TN, WP00.8TS
HC09.4TN	38	Added HC09.5TS	MC26.SSDD	178	SSDD	WP01.6TN	0	
HC10.0TN	81		NR00.3TE	0		WP03.6TN	0	
HC10.6TN	37	Added HC10.7TS	NR01.8TE	0		WP04.1TN01	93	Added WP04.TN03
HC11.8TN	55	Added HC11.8TS	NR03.0TE	222	Added NR03.0TW	WP04.8TN	91	Added WP04.1TS, WP04.5TS01,02
HC12.5TN	30		NR04.1TE	0	Added NR04.2TW	WP06.7TN03	201	Added WP06.7TN01-06
HC13.0TN	0		NR05.4TE	39		WP07.5TN	47	Added WP07.4TS
HC13.6TN	226	Added HC13.6TN-A,B HC13.8TS	NR06.6TE	42	Added NR06.6TW	WP08.7TS	312	Added WP09.1TN
HC14.2TN	32		NR07.8TE	0		WP10.1TN	51	Added WP10.6TS, 10.8TN, 09.9TS
HC14.7TN	34	Added HC14.7TS	NR09.0TE	165		WP10.1TN-C	0	Added WP10.1TN-A,D,E,F
HC15.2TN	184	Added HC15.4TS, 15.5TS, 15.5TS-E	NR10.3TE	39	Added NR10.3TW	WP12.8TN	293	Added WP12.1TS, WP12.0TN
HC16.8TN	5		NR11.4TE	241		WP12.8TN-C	60	Added WP12.8TN-A,B,D,E,F,I
HC17.4TN	260		NR12.5TE	37	Added NR12.5TW	WP14.1TN	22	Added WP13.7TN
HC17.9TS	25		NR13.6TW	33		WP15.4TN01	210	Added WP15.3TS, 15.4TN03, 16.0TN
HC18.5TN	36	Added HC18.5TN01	NR14.2TE	18		WP15.4TN02	208	
HC19.1TN	43		NR14.7TE	0		WP16.8TS	159	
HC19.7TN	226	Added HC19.6TS	NR15.4TW	164	Added NR15.5TW	WP16.EBWCD	169	50% EBWCD
HC19.EBWCD	169	50% of EBWCD	NR16.9TE	145		WP17.9TN	266	Added WP18.4TS
HC22.5TN	0		NR18.2TW01	10		WP19.3TN	103	
HC22.AG3420	100	Agricutlural Release 3420						

4.3 Boundary Conditions

MIKE 11 requires a boundary condition for the terminal end of each MIKE 11 branch. This boundary condition can be specified as zero flow, a specified constant head elevation, a specified constant flow, or a time series of head or flow. Inflows are specified for the L-8, C-51W, C-139, and C-139 Annex basins, as presented in **Table 4.2**.

Table 4.2 – Inflow Boundary Conditions

Basin	Boundary	Value	Source
L-8	L-8 North 1	750 cfs	Ph 2 Task 1.3
	L-8 North 2	750 cfs	Ph 2 Task 1.3
	L-8 Tieback	-150 cfs	CH2M Hill (2005)
C-51W	Local runoff	2,000 cfs	Ph 2 Task 1.3
C-139	L-1	400 cfs	Ph 2 Task 1.3
	L-2W	800 cfs	Ph 2 Task 1.3
	Deerfence	800 cfs	Ph 2 Task 1.3
C-139 Annex	Local runoff	452 cfs	URS, 2005
S-2, S-3, S-352, L-8 at Lake	Lake Okee	L006 stage	DBHYDRO
G-300, G-301, S-6, S-7, S-8, L-3Ext, L-28	WCAs	12 ft	Review of data from DBHYDRO, limit flow within WCAs
C-51W	G-155A	8 ft	G-155A design

The L-8 and C-51W inflows were estimated based on an inspection of measured daily flows as part of Phase 2 Task 1.3 of this project (Historic Inflow Volumes and Total Phosphorus Concentration by Source (Draft Report), May, 2005. **Figures 4.3 and 4.4** present graphs of the daily flows for L-8 and C-51W. **Figure 4.5** presents calculated C-139 runoff daily peak flows, and flows in the range of 1000 – 1700 cfs were observed eight times from 2000-2004. **Figures 4.3-4.5** were generated from files used to prepare the Phase 2 Task 1.3 draft report.

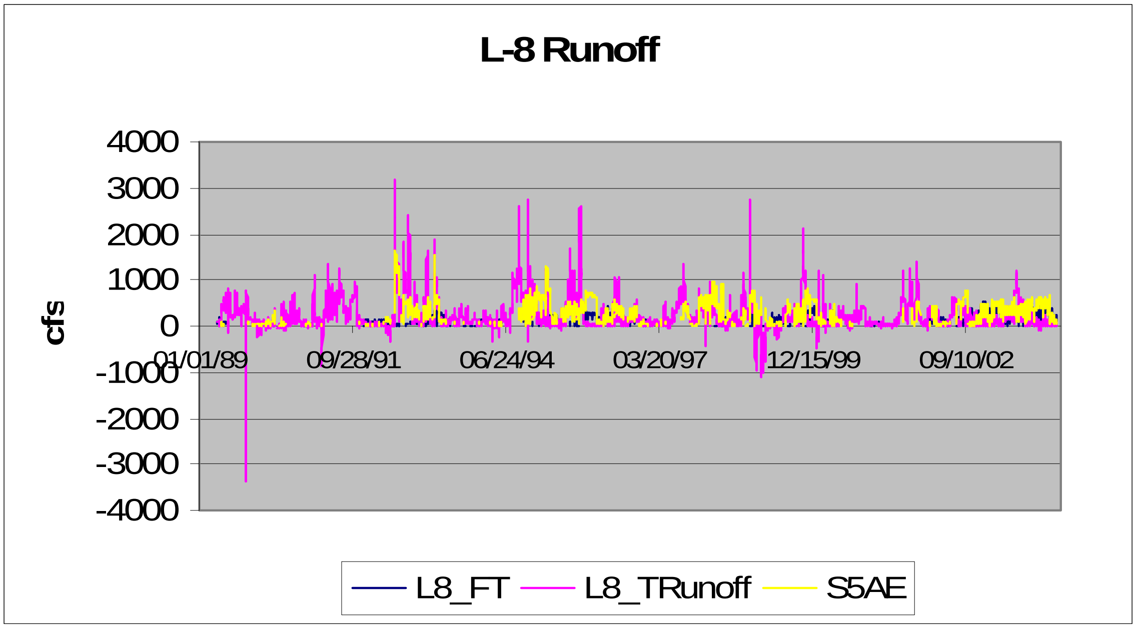

Figure 4.3 – Observed L-8 Flow Through (from Lake Okeechobee), L-8 Runoff, and S-5AE eastward flows

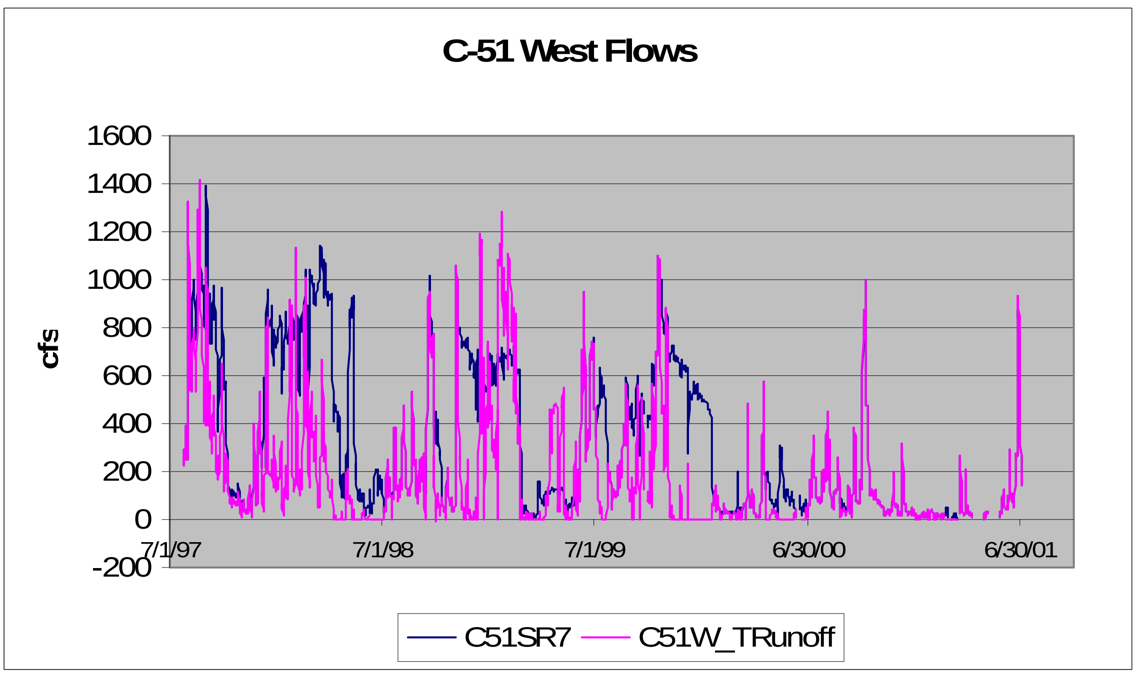

Figure 4.4 – Observed C-51W Runoff and Flows in C-51W at SR 7

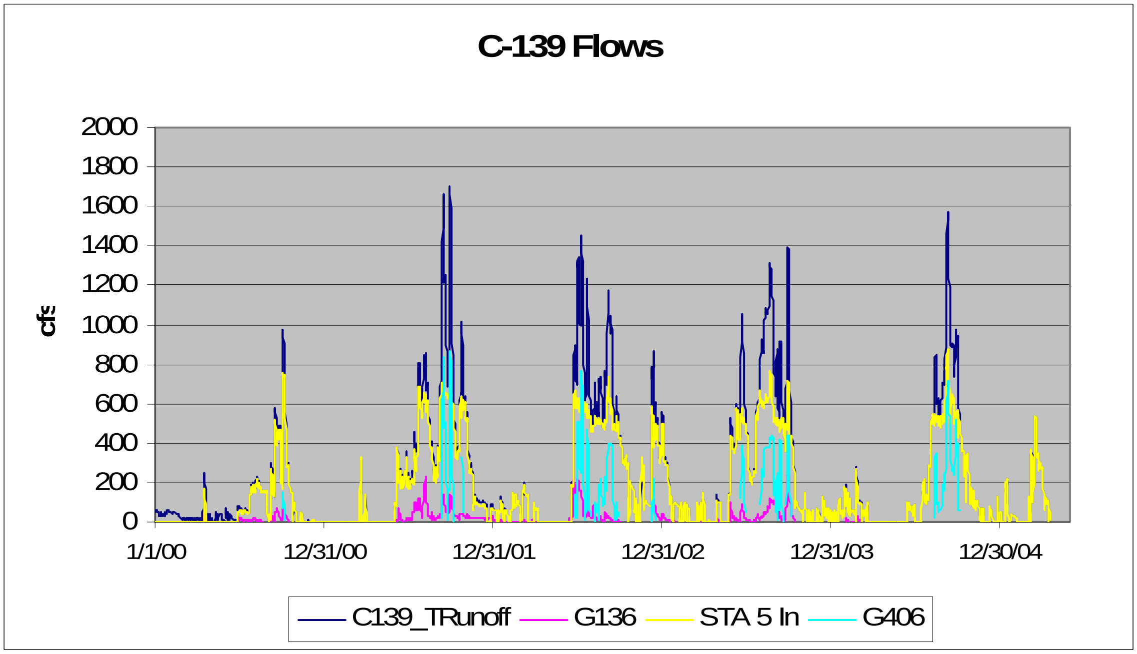

Figure 4.5 – Observed C-139 Flows

Precipitation and evaporation are included in the reservoir mass balance. The time series of reservoir precipitation and evaporation are presented in **Figure 4.6**. ET values were taken from an ET station in WCA 1, and the rainfall values were taken from an October 2000 event at station ROTNWX. The daily values for this event were adjusted down by 33% so that the total rainfall was equal to the average rainfall observed at Stations S-6, EAA5, NNRC, ROTNWX, and G-343.

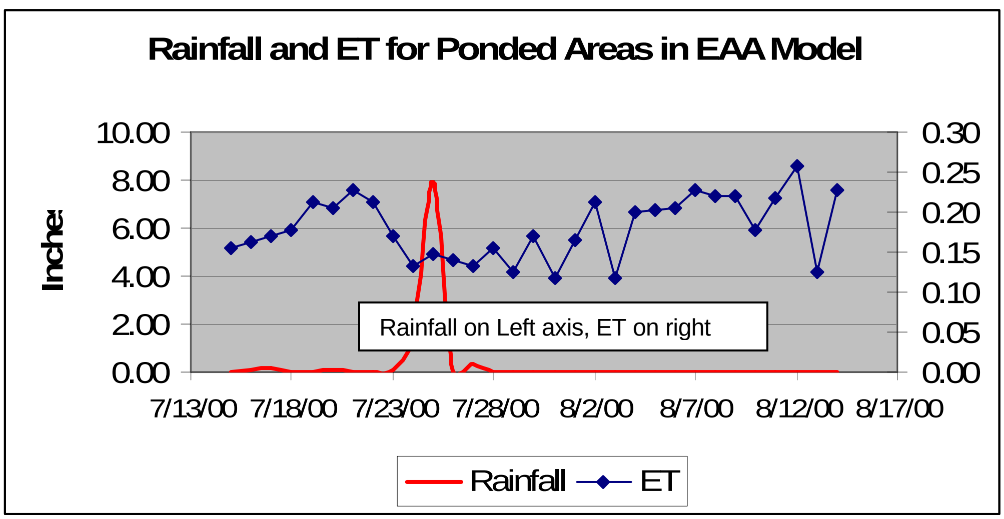

Figure 4.6 – Rainfall and ET values used for Ponded Areas within the EAA

4.4 MIKE 11 Model Refinements

4.4.1 STA 1E

STA 1E was added to the MIKE 11 model so that the distribution of flows between STA 1E and 1W could be described at high flow conditions. It was not part of the original MIKE 11 network but was added so that the distribution of flows between STA 1E and 1W could be addressed. It was decided to add a somewhat simplified representation of STA 1E as shown in **Figure 4.7**. Pump station S-361 is not included, and approximate ground elevations were used for the STA cells.

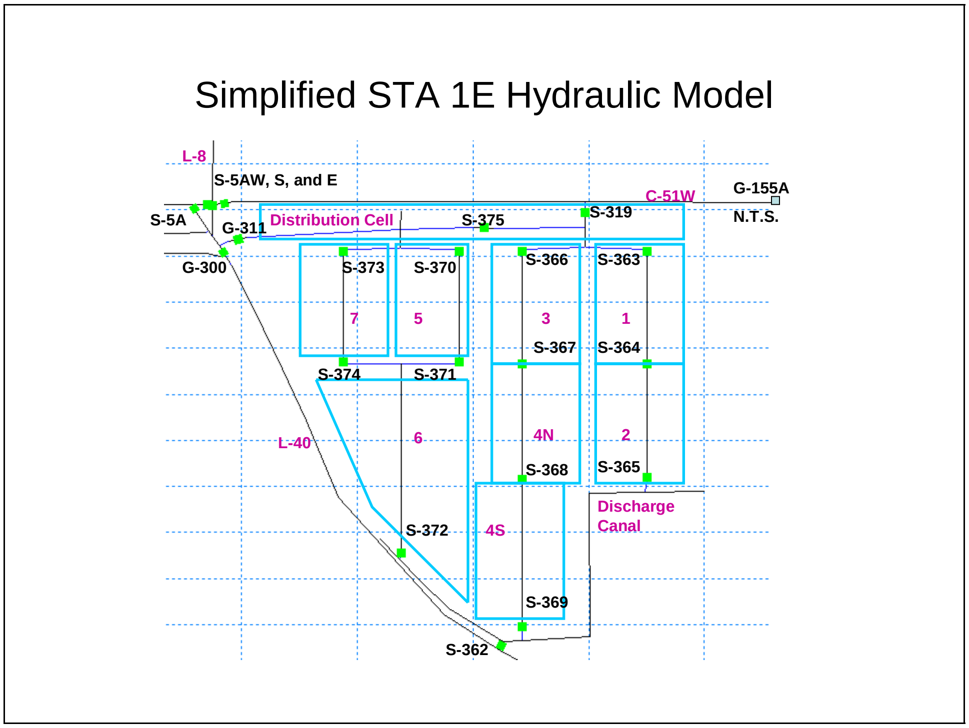

Figure 4.7 – Representation of STA 1E

4.4.2 C-51W

Approximate cross sections were used for C-51W from S-5A E to S-155W. Detailed cross sections have been obtained from US ACE and were added to the model. The as-built cross sections differ somewhat from the design, however conveyance is similar. The S-155W tailwater elevation has been assumed to be constant at 8 feet.

4.4.3 G-341

G-341 is currently under construction and will be completed in 2005. This structure is located on the Ocean Canal 1,900 feet east of the Gladeview Canal. There are two 25-ft wide x 15-ft high underflow gates that have an invert elevation of 0.0 ft NGVD when closed. This structure was added to the model using design drawings, and has been programmed to open if water levels west of the structure exceed

12.5 ft NGVD, which is consistent with the design of G-341 (Burns & McDonnell, 1995, SFWMD, 2004).

4.4.4 STA 2 Cell 4

STA 2 Cell 4 cross sections were obtained from Brown and Caldwell (2005). The outflow structure discharges to the west end of the existing STA 2 discharge canal and consists of two 8'x8' gated box culverts. The gates are programmed to open if the water level upstream of the structure is greater than 11.5 ft NGVD. The gate will be fully open when water level upstream of the structure reaches 12.5 ft NGVD. Additionally, gate operations are limited to once every three hours. Based on discussions with SFWMD Operations staff, the sequence of filling STA 2 was changed to be consistent with actual operation of this STA. The current practice is to fill cell 3, then cell 2, and finally cell 1. It was assumed that cell 4 would be filled at the same time as cell 3.

4.4.5 STA 3/4 Enhancements

Structure operations for G-370 and G-372 were modified to reduce pump oscillations. The following operation logic was employed:

Pump A:	If H in NNR > 10 ft NGVD, pump on using pump curve
	If H in NNR < 9 ft and pumps B&C off, pump off
Pump B	If H in NNR > 10 ft and pump A on, pump on
	If H in NNR < 9 ft and pump C off, pump off
Pump C	If H in NNR > 10 ft, and pumps A&B on, pump on
	If H in NNR < 9 ft, pump off

Pump operations are limited to once/hour. The same basic strategy is used to control G-372 on the Miami Canal.

4.4.6 G-136

G-136 is a stop-log overflow structure that is used to control flows between the L-1 canal south to STA 5 and L-1 E canal to the Miami Canal. The SFWMD Structure Book states that the stop logs are maintained at elevation 13 ft NGVD, and raised to 14 ft NGVD when the tailwater (east side of structure in L-1 E canal) reaches 15.5 ft. Model results indicate that the water levels in the tailwater never go above elevation 12, so the weir elevation is always 13. Water levels in L-1 at the upstream end of this structure are commonly above elevation 13, and significant flow enters L-1 E Canal. Measured flows are relatively rare through G-136 and are never above 200 cfs. Accordingly, the overflow invert elevation of this structure was changed to 16 ft NGVD unless the L-1E elevation reached 15.5 ft, at which point the invert elevation drops to 14 ft.

4.4.7 STA 5 Flow-way 3, STA Discharge Canal, and G-406

Draft BODR documents for STA 5 Flow-way 3 were reviewed to obtain design information for Flow-way 3 (URS, 2005a). **Figure 4.8** provides details of how this flow-way was added to the model. Flow-way 3 receives water from L-2 just north of G-406. The MIKE 11 network includes inflow gates G-342E&F, Flow-way 3a outflow gates G-343 I-K, and Flow-way 3b gates G-344E-F. Dimensions and invert elevations were obtained from URS (2005).

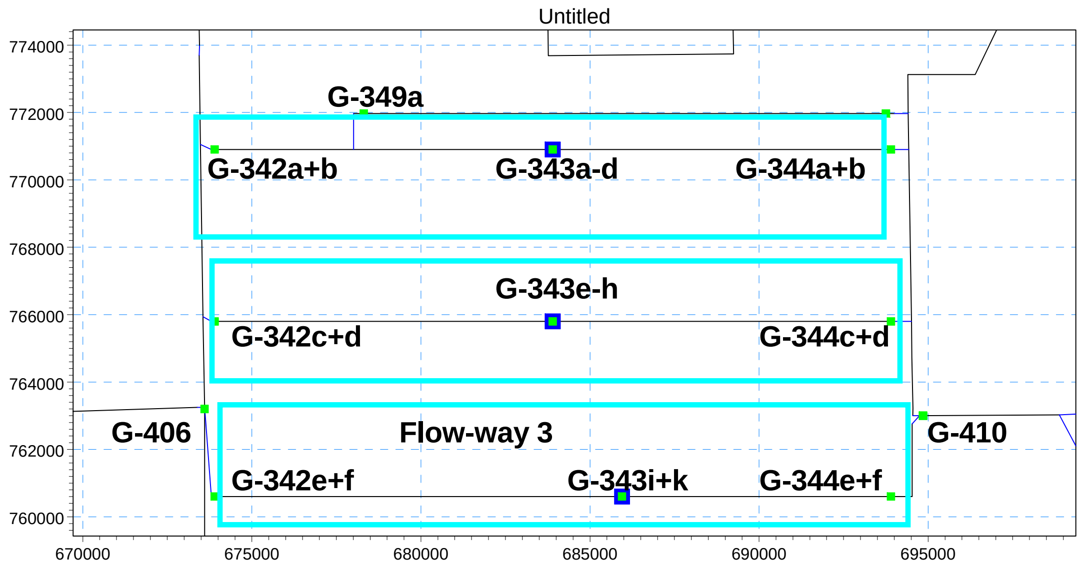

Figure 4.8 – Representation of STA 5 in MIKE 11 Network

Gate operations are:

G-342: Closed at upstream head elevation 16 ft NGVD, fully open at 17 ft
G-343: Always open
G-344: Closed at upstream head elevation 13 ft NGVD, fully open at 17 ft
G-410: Pumps when there is a positive outflow from STA 5 and the water level in the Rotenberger Tract is below regulation schedule
G-349a: Pump on if seepage canal head elevation exceeds 10.5 ft NGVD, full flow at 17.8 ft

The STA 6 Operations Manual states that Gate G-406 is closed until the headwater (north of the structure) elevation reaches elevation 16 ft NGVD. The purpose of this gate operation was to prevent hydraulic overloading of STA 5. G-406 operation will be modified after construction of STA 5 Flow-way 3 and STA 6 Section 2. G-406 will remain open most of the time unless inflows to STA 6 exceed the design capacity of that STA (personal communication, M. Brungard, URS, June, 2005). The STA 5 discharge canal to the Miami Canal has been modified to reflect the design of the STA 5 Outlet Canal to transport water from the STA Discharge Canal around STA 3/4 inflow pump station G-372 to the Miami Canal downstream of gate G-373. This discharge canal will eliminate STA 3/4 treatment of STA 5 outflows (SFWMD, 2005). The construction of this bypass is over 90% complete and will commence operation in 2005. Cross sections for this outlet canal were obtained from the Outlet Canal design plans.

4.4.8 STA 6 Section 2

STA 6 Section 2 is currently under design and is anticipated to be flow-ready in 2006. Draft BODR documents for STA 6 Section 2 were reviewed to obtain design information for the new treatment cell (URS, 2005b). **Figure 4.9** provides details of how this treatment cell was added to the model.

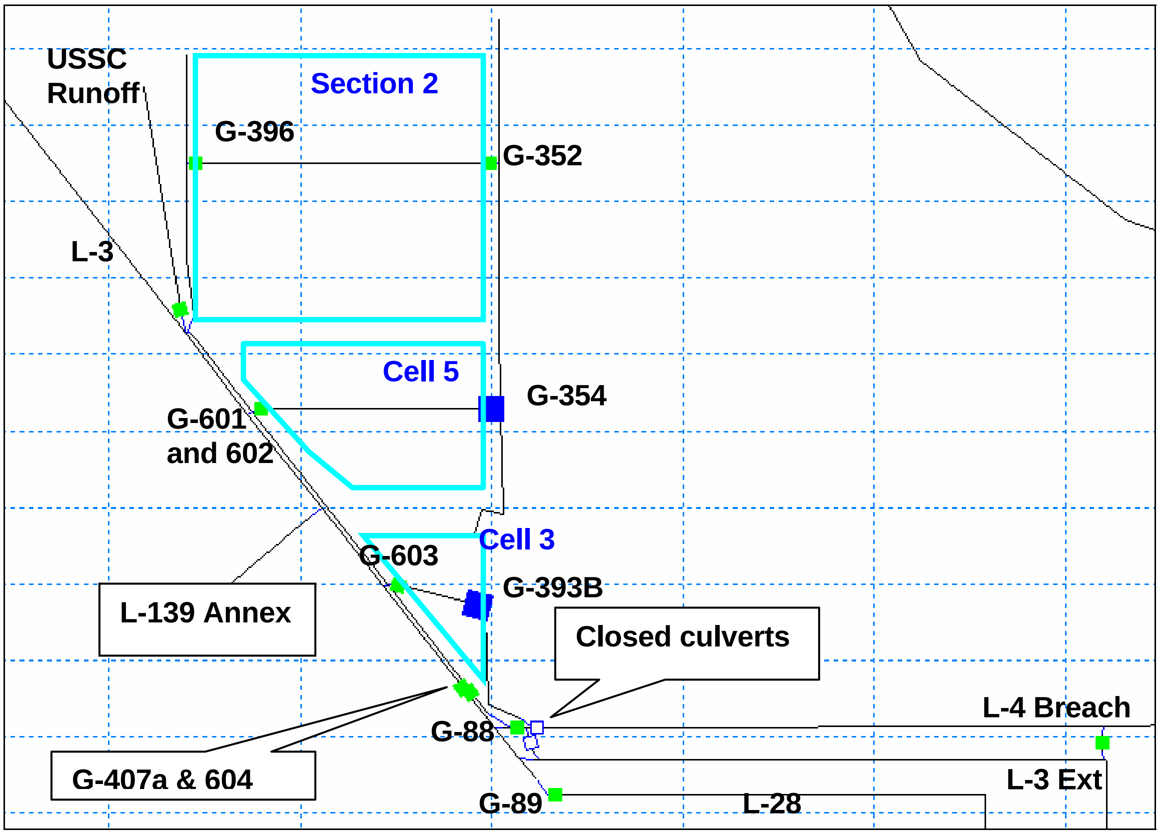

Figure 4.9 – MIKE 11 Representation of STA 6 and Confusion Corner

The design of this new section of STA 6 includes significant changes in the operation of Canal L-3. The plans call for a new structure (G-407a) presented in Figure 13 that will isolate L-3 from the rest of the L-canals during normal operation. G-407a will normally be closed but will open if stages in the L-3 Canal exceed 19.5 ft NGVD. L-3 will be an inflow distribution canal for STA 6, and gates G-353 A-C control the inflow to STA 6. The MIKE 11 network includes inflow gates G-601, 602, and 603 to existing cells 3 and 5, Section 2 inflow gates G-396 A-C, Section 2 outflow gates G-352 A-C, Cell 5 outflow gates G-354 A-C, cell 3 outflow gates G-393 A-C, the STA 6 Discharge Canal, and G-607. Dimensions and invert elevations were obtained from URS (2005). Gate operations are:

G-396: Closed at upstream head elevation 16 ft NGVD, fully open at 18 ft
G-353: (now G-601 and 602): same as above
G-353c: (now G-603): same as above
G-352: Closed at upstream head elevation 15.5 ft NGVD, fully open at 16.5 ft

4.4.9 Confusion Corner

G-155 was removed from the US ACE MIKE 11 model, and a branch was added from L-4 to L-3 Extension at G-607 (see **Figure 4.9**). A closed gated structure was added to L-4 just east of this new branch, and G-88 operations were modified so that it is normally closed.

4.4.10 Rotenberger Tract and Holeyland Wildlife Management Area

The Rotenberger Tract and the Holeyland Wildlife Management Area were not explicitly modeled by US ACE in MIKE 11 as MIKE SHE was able to effectively handle the rainfall/runoff process. Branches were added to this MIKE 11 project because MIKE SHE is not being run. Cross sections were added to represent the expected flow paths through these natural wetland systems. Rainfall and ET time series are part of the hydraulic balance for these systems.

5.0 CHANGES MADE TO IMPROVE MODEL STABILITY

5.1 Operation of Pumps and Gates for STA 2

The headwater is maintained at elevation 11.5 ft NGVD in the dry season and 10.5 ft NGVD during the wet season. The pump-off level is 9.75 ft NGVD. Manning's n values in cells 1 and 2 were increased to a value of 1.0. The Manning's n value for SAV cells 3 and 4 remained at 0.25.

The control operation of STA2 inflow structures was modified according to "Meeting Minutes" (meeting with George Hwa, SFWMD Operations). The details are summarized below:

- Cell 1 opens @ 14.5' and closes @ 14',
- Cell 2 opens @ 15' and closes @ 14.5', and
- Cell 3 opens @ 14' and closes @ 13.5'.
- Gates open fully and remain unchanged for at least 3 hrs.
- The proposed inlet structure for Cell 4 opens @ 13.2' and closes 10.5'.

Only positive flow through the inlet and outlet structures is allowed (the structures close if the gradient becomes negative). G-335 operation is a function of upstream water levels, as described below:

- No change less than hourly.
- If the flow upstream is <1000 and Hups>13 ft, outflow is 1000.
- Close if the Hups<12.5 ft and Qups<1000.
- If the Qups<2000 and Hups>11.5, Q = 2000.
- If the Qups<2000 and Hups<11, Q = 1000.
- Otherwise, flow is according to the following H/Q table:

Upstream Stage, ft	G-335 Q, cfs
-99	2000
8.9	2000
9.4	3370
99	3370

5.2 Operation of Pumps and Gates for STA 3/4

The inflow gates are programmed to be fully open at all times. This is not correct for low flow conditions but is acceptable for modeling of high flow conditions. Modifications would be necessary if this model were used for long-term simulations.

The outflow gates are programmed as follows:

Cell 1: Open if upstream elevation > 12.8 ft NGVD, full open at 13 ft NGVD
Cell 2: Open if upstream elevation > 12.9 ft NGVD, full open at 13 ft NGVD
Cell 3: Open if upstream elevation > 13.8 ft NGVD, full open at 14 ft NGVD

6.0 SUMMARY OF MODELING RESULTS

6.1 Hydrologic Scenarios

Hydraulic modeling was conducted to define the capacity of existing EAA canals and to determine if operational changes could be employed to direct runoff from the S-5A and S-6 basins to the S-7 basin. A number of alternatives were simulated as described below in **Table 6.1**.

Table 6.1 Specific Result Files Used In Simulations

Alt.#	Model Run	Output File Name
1	Existing Conditions, 3/8" runoff for entire EAA	EAA_2006EXISTINGCONDITIONS.res11
2	Existing Conditions, higher runoff for S-5A and S-6 Basins	EAA_2006EXCOND_2XS5A_6.res11
3	Ex. Conditions, higher runoff for S-5A and S-6 Basins, No Cross bridges & culverts	EAA_2006EXCOND_2XS5A_6_NOCRBR.res11
4	As run 3, with S-6 Pump 3 at 500 cfs	EAA_2006EX_2XS5A_6NOCRBR_S6_3_500.res11

Flow and water elevations are summarized at selected locations in this section. MIKE 11 result files include flows, elevations, depths, and velocities at numerous locations. Flow results are available at over 800 locations, and stage results are available at over 1100 locations. The MIKE 11 additional result file includes information at 231 structures:

- Structure flows
- Structure velocities
- Structure flow areas
- Structure gate levels

Boundary inflows and outflows are also available. These data are viewed through a non-proprietary graphical user interface called MIKE VIEW (see www.dhisoftware.com). This program allows the user to select results as plots or water surface profile animations, cross section animations, and plan view animations with flow directions indicated as arrows.

Model results at key station locations are summarized below in a tabular format. The key station locations listed in **Table 6.1** are shown below in **Figures 6.1, 6.1a, 6.1b, and 6.1c**.

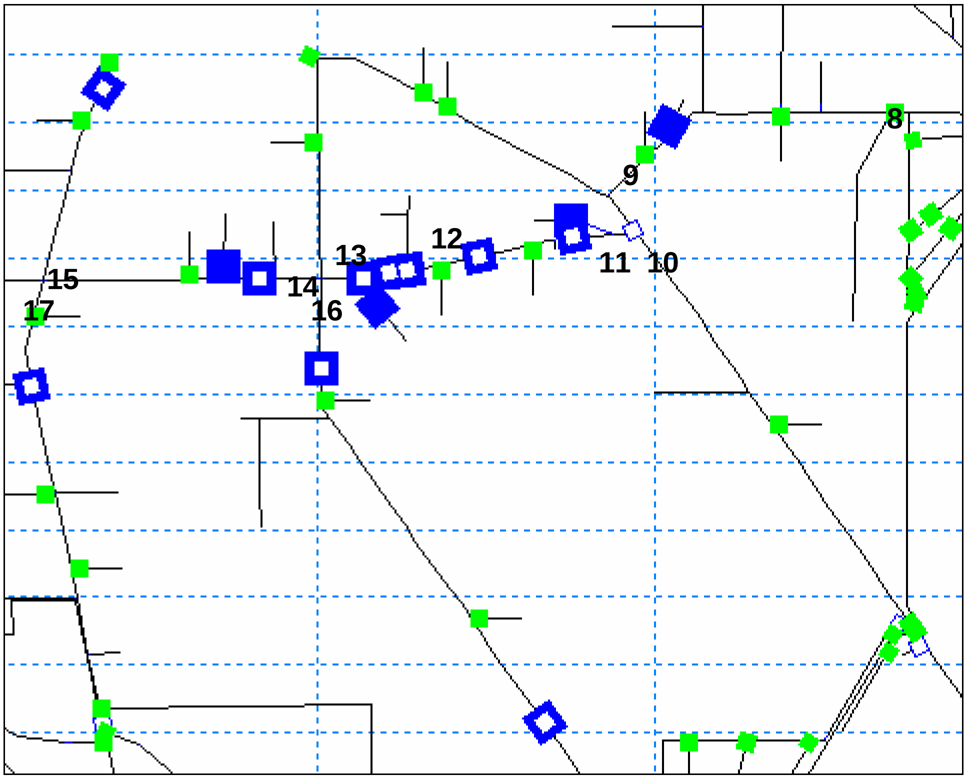

Figure 6.1 – Map of EAA Station Locations for MIKE 11 Results

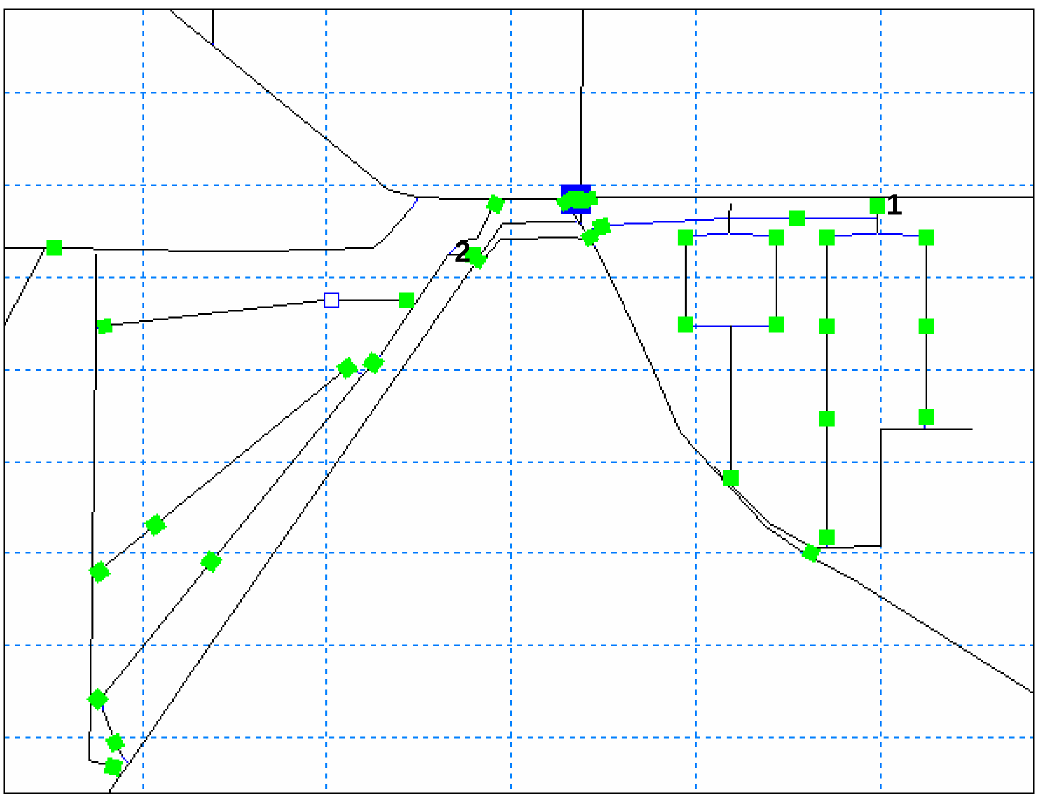

Figure 6.1a – Detail View of STA 1E and STA 1W

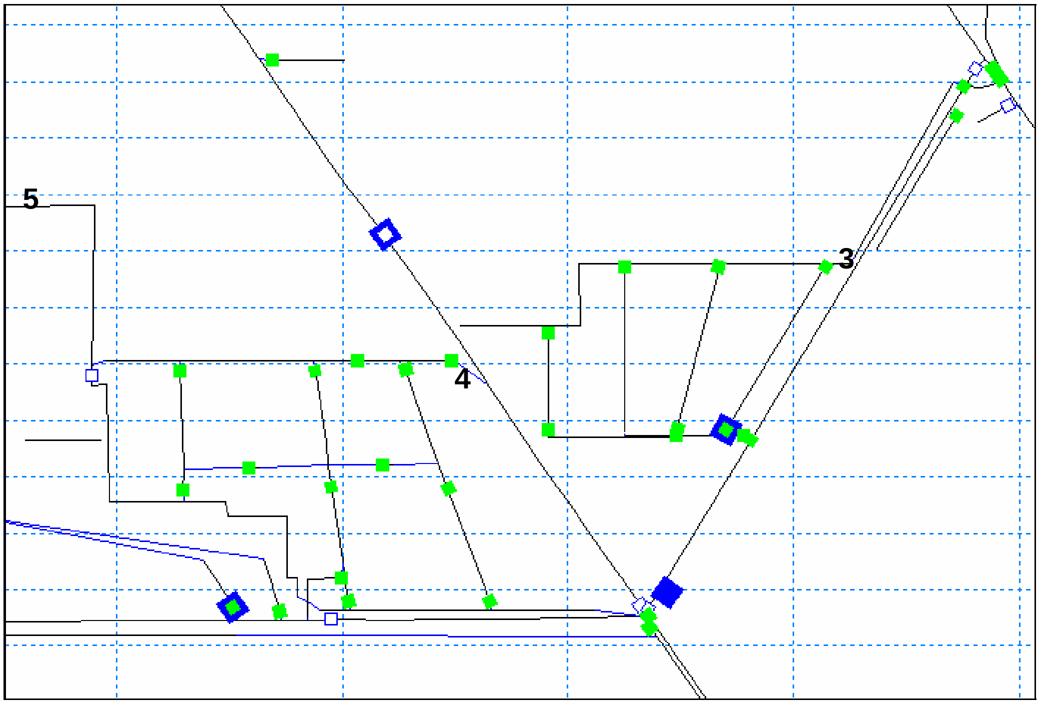

Figure 6.1b – Detail of STA 2 and STA 3/4

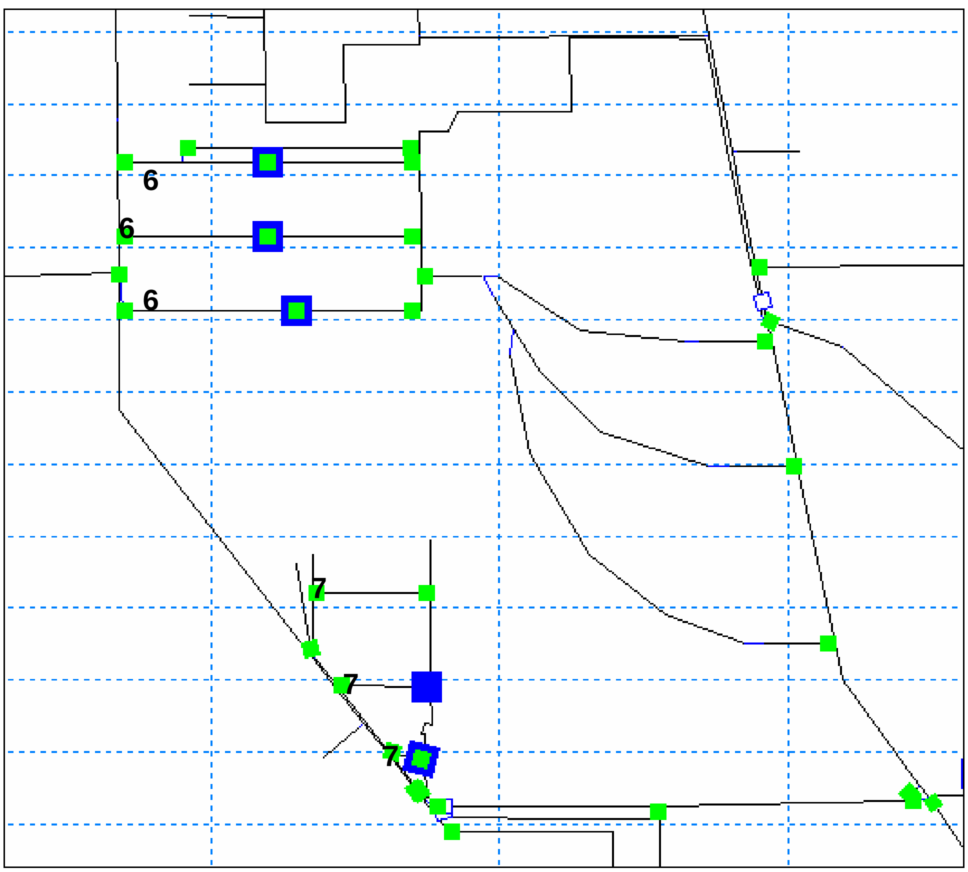

Figure 6.1c – Detailed View of STA 5 and STA 6

6.1.1 Flows and Water Levels for Uniform Runoff

The MIKE 11 model was run with a uniform rate of runoff equal to 3/8" for all farms. The results are summarized in **Table 5**. Peak stages in the Ocean Canal west of G-341 remain below 12.5 ft NGVD, therefore G-341 remains closed. There is no flow into Lake Okeechobee through S-2 and S-3. Flows in the southern portions of the Hillsboro, North New River, and Miami Canals oscillate because basin runoff is in between the flow levels of S-6 (975, 1,950, and 2,925 cfs), and G-370 and G-372 (925, 1,850, and 2,775 cfs). Water levels are higher in the center of the Cross Canal than at the east and west ends of the canal, which results in westerly flow (negative flow) on the west end and easterly flow on the east end (positive flow). Flow in the Bolles Canal is westerly (negative) at both ends because stages are lower in the Miami Canal than in the North New River Canals.

Table 6.2 - Flows and Stages at Key Locations in the EAA for 3/4" Runoff in S-5A and S-2/S-6 Basins

Location	Alternative 1 3/8" Runoff in Entire EAA		Alternative 2 High Runoff in S-5A/S-6	
	Flow, cfs	Stage, ft	Flow, cfs	Stage, ft
1. STA 1E Inflow	1,600	19.2	1,560	19.3
2. STA 1W Inflow	2,500	15.5	3,000	16.1
3. STA 2 Inflow	2,500	14.3	3,300	15.0
4. STA 3/4 Inflow G-370	2,250	13.6-14.6	1,814	13.0-13.6
5. STA 3/4 Inflow G-372	2,250	15.7	1,349	15.1
6. STA 5 Inflow	900	13.6-15.4	900	15.1 - 15.3
7. STA 6 Inflow	1,116	15.5-15.7	965	15.6 – 16.0
8. Ocean Canal, Gladeview 46400	0	11.8	457	12.7
9. Ocean Canal at Hillsboro Canal	-700	11.6	-975	12.4
10. Hillsboro Canal South of Cross	1,210	11.4	1,430	12.25
11. Cross Canal E	143	11.9	68	12.4
12. Cross Canal Mid-point 20579	-53	12.0	-16	12.4
13. Cross Canal W	-230	11.4	-225	11.79
14. Bolles Canal E	-80	11.3	-125	11.7
15. Bolles Canal W	-240	10.3	-278	9.6
16. NNR South of Cross	700 – 720	11.2-11.4	1,020	11.74
17. Miami Canal South of Bolles	1,220	10.0–10.2	725	9.6

6.1.2 Flows and Water Levels for High Runoff in the S-5A Basin

The MIKE 11 model was run with 3/4" of runoff in the S-5A and S-2/S-6 basin and 3/8" runoff elsewhere. The purpose of this simulation was to provide a base run to compare to simulations of minor canal improvements to the Cross Canal that are discussed in the next section of this document. Flows and stages at key locations are presented in **Table 5**. This model run did not change the directions of flow in the Cross Canal. As with uniform runoff from all EAA farms, flows in the Cross Canal were easterly at the east end and westerly on the west end. As expected, there were higher flows to STA 1W and STA 2 with this model run. Runoff from the Gladeview Drainage District flowed primarily to STA 2, however there was 457 cfs of easterly flow through G-341 to STA 1W.

6.2 Flows and Water Levels with Minor Changes to Cross Canal

Two simulations were conducted to determine if minor changes in the Cross Canal could enhance flows from the Hillsboro Canal to the North New River Canal. The first simulation tested the effect of removing flow constrictions along the Cross Canal assuming higher runoff in the S-5A and S-6 basins. The second simulation was an extension of the first simulation with higher stages in the Hillsboro Canal to generate a greater head differential between the east and west side of the Cross Canal. The greater head differential was generated by decreasing S-6 flow in the third pump station at S-6 from 975 cfs to 500 cfs. The results are presented in **Table 6**. Flow in the west side of the Cross Canal in the first scenario was -207 cfs, which is a discharge from the Cross Canal to the NNR. Flow from the Cross Canal to the Hillsboro Canal was 89 cfs, which is runoff from EAA farms discharging to the Cross Canal. Flow in the west side of the Cross Canal in the second scenario was -314 cfs, which is a discharge from the Cross Canal to the NNR. Flow in the east side of the Cross Canal was -26 cfs, which indicates flow from the Hillsboro Canal to the Cross Canal. The flow in the west side of the Cross Canal was higher because Cross Canal culvert constrictions were removed (two constrictions on the east end of the Cross Canal are significant restrictions).

The conclusion of this analysis is that it is possible to increase flows to the North New River by 107 cfs during a high runoff period where rainfall is higher in the S-5A and S-6 basins if total S-6 flows are reduced by 475 cfs. However, there are some negative impacts of this scenario:

- The peak stage in the Ocean Canal is 13.15 feet, which could result in flooding of some farms along portions of the Ocean and Hillsboro Canals.
- The peak stage in the Ocean Canal will open G-341 on the Ocean Canal, thereby delivering flow from the Gladeview Drainage District to STA 1W (G-341 opens if stages west of G-341 are higher than 12.5 ft NGVD).

Therefore, if it is decided to operate S-6 at a lower capacity during a large runoff event in the S-5A and S-6 basins, it will be necessary to modify the gate operations at G-341 and levee heightening will be necessary at a number of low spots along the Ocean and Hillsboro Canals.

Table 6.3 - Flows and Stages at Key Locations in the EAA Assuming Cross Canal Improvements and 3/4" Runoff in S-5A and S-2/S-6 Basins

Location	Alternative 3 High Runoff in S-5A/S-6 without Cross bridges		Alternative 4 High Runoff in S-5A/S-6, no Cross bridges, and decreased S-6 flows[1]	
	Flow, cfs	Stage, ft	Flow, cfs	Stage, ft
STA 1E Inflow	1630	19.9	1,500	19.8
STA 1W Inflow	2933	16.0	3,000	16.1
STA 2 Inflow	3260	14.8	2,800	14.7
STA 3/4 Inflow G-370	1835	13.0-13.6	2160	14.6-13.3
STA 3/4 Inflow G-372	1400	15	1400	15
STA 5 Inflow	900	15.1–15.3	900	15.1-15.3
STA 6 Inflow	968	15.6-16.0	968	15.6-16.0
Ocean Canal, Gladeview 46400	460	12.65	563	13.31
Ocean Canal at Hillsboro Canal	-966	12.36	-857	13.15
Hillsboro Canal South of Cross	1450	12.29	948	13.13
Cross Canal E 44844	89	12.31	-26	13.13
Cross Canal Mid-point 20579	4.8	12.34	-107	13.10
Cross Canal W 1402	-207	11.76	-314	12.10
Bolles Canal E	-120	11.74	-160	12.07
Bolles Canal W	-271	9.7	-307	9.7
NNR South of Cross	1020	11.73	1332	12.02
Miami Canal South of Bolles	725	9.7	759	9.65

1. S-6 pump station modified: 3rd pump capacity changed from 975 cfs to 500 cfs

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

This modeling study evaluated the existing capacity of EAA canals. The purpose of this assessment was to determine the maximum potential for re-directing flows from STA 1W to STA 3/4 since STA 1W outflow concentrations are above the target concentration of 50 ppb. The simulations included the following alternatives:

1. Runoff equal to 3/8” for all EAA farms
2. Runoff equal to 3/4” for farms in the S-5A and S-6 basins and 3/8” runoff in all other areas
3. Scenario 2 with bridges and culverts removed in the Cross Canal
4. Scenario 3 with the third pump at S-6 reduced from 975 to 500 cfs