Submittal to:
South Florida Water Management District

Reevaluation of the C-51 Basin Rule

Number: C-13412

Technical Memorandum # 4: Rule Development

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September 2004

CERTIFICATION

Project Name: Reevaluation of the C-51 Basin Rule
Technical Memorandum #4: Rule Development
SFWMD Contract No. C-13412

The following key professionals were responsible for completion of the work products contained in this document.

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I hereby certify that the work products contained in this document have been prepared in accordance with generally accepted engineering practices under the supervision and direction of the undersigned, whose Seal as a Licensed Professional Engineer in the State of Florida is affixed below.

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1.0 INTRODUCTION

1.1 STUDY AREA DESCRIPTION

The C-51 basin has a drainage area of approximately 177 square miles and is located in east central Palm Beach County, Florida. The basin is comprised of two major sub-basins: C-51 West (104 square miles) and C-51 East (73 square miles). State Road 7 (SR-7) is generally the boundary between these two major sub-basins. The C-51 canal is the portion of the West Palm Beach Canal that is east of the intersection of the L-8 and the L-40 levees (S-5AE) and is the only Central and Southern Florida Project canal in the basin. The area is bounded on the north by Northlake Boulevard and the Grassy Waters Preserve; to the south by Lake Worth Road; to the west by L-8 and L-40; and to the east by U. S. Highway 1 (US-1). The size of the contributing area has increased as a result of interagency agreements to alleviate pressure on the L-8 basin. The general site location map is shown on Figure 1-1, which was prepared by superimposing the sub-basin boundary on 7.5-minute U.S. Geological Survey quadrangle maps of West Palm Beach 2 SE, Delta, Rivera Beach, Loxahatchee, Palm Beach Farms, Palm Beach, Loxahatchee SE, Greenacres City, and Lake Worth in Palm Beach County, Florida.

The study area is located within the resource management jurisdiction of the South Florida Water Management District (SFWMD). However, multiple local water control districts are involved in the operation and management of water control facilities within the basin.

1.2 PROJECT OBJECTIVE

In order to better manage unplanned growth and to provide flood protection to residents within the C-51 drainage basin, SFWMD adopted a non-structural approach by implementing a set of basin-specific development regulations in 1984. This rule, at the time, represented the most stringent set of criteria for permits in regards to both discharge limits and water quality treatment standards. The primary intent of the basin rule was to provide "hold the line" standards, which prevented any increased flood damages until a structural solution could be implemented. This is known as the C-51 Basin Rule (Part III, Ch. 40E-41, Rules 40E-41.220 through 40E-41.265, FAC).

Recently, a structural solution has been designed and is in the process of being implemented under the leadership of the Jacksonville District of the U.S. Army Corps of Engineers (USACE). The structural solution includes a stormwater treatment area (STA-1E), a pump station (S-319), and a control structure (S-155A) along the C-51 canal. With the potential for completion of the structural solution in the immediate future, the District intends to revisit the rule making process to provide better protection to the current and future residents in the C-51 drainage basin.

The project objective is therefore to reevaluate the C-51 Basin Rule. This involves hydrologic and hydraulic modeling and then assisting the District during rule development and the rule making process. In order to achieve this objective, the project has been divided into several technical and deliverable tasks as given below.

Task 1 – Data Acquisition

This included data collection, field reconnaissance, initial evaluation and verification, digital terrain model development, basin and sub-basin delineation, and storage of data for future usage during the modeling phase.

Task 2 – Basin Modeling System

This involved development of the hydrologic and hydraulic models for the existing conditions of the C-51 basin that included development of design storm, generation of sub-basin runoff hydrographs, and evaluation of the performance of the C-51 canal system.

Task 3 – Model Application

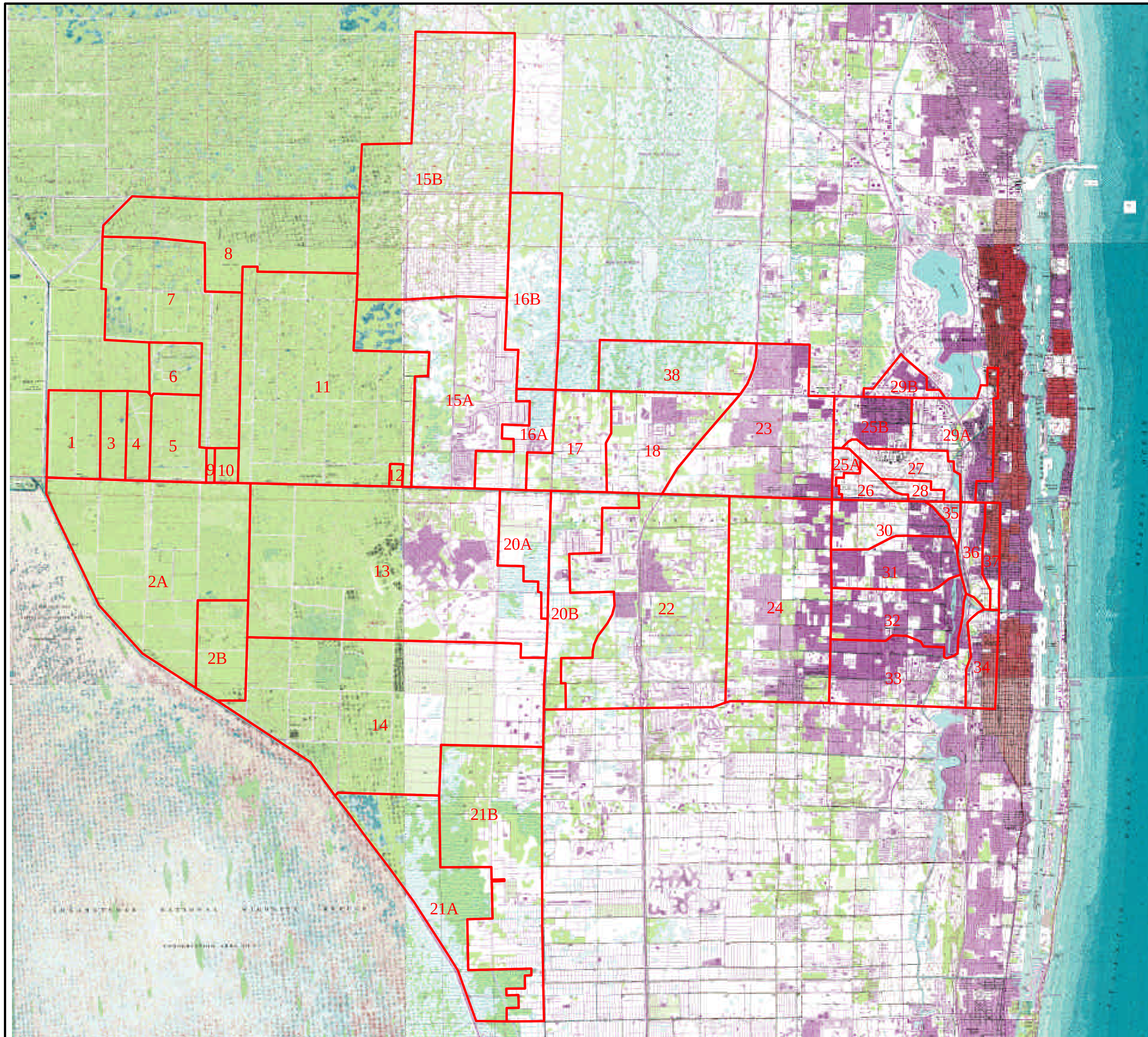
This involves application of the models developed in Task 2 and modified for Federal Improvements for specific design storms to evaluate and support the basin rule modifications. This includes baseline simulations (with existing basin rule criteria) and modified simulations (with modified allowable discharges) for design storm events (10-year and 100-year, 72-hour storms). The scope also includes preparation of revised figures for the rule 40E-41.263 (similar to Figures 41-8 and 41-9) and recommendation of revised rule language.

Task 4 – Assistance During Rule Development and Rule Making

This includes participation on an as-needed basis in the rule development process, attending public meetings, and participating in public outreach programs.

1.3 SCOPE OF WORK

The scope of work for Task 1 was completed in December 2002. The findings of data acquisition, including production of a digital terrain model and basin/sub-basin delineation, were presented in the Task 1 Draft Report, which was reviewed by members of the review committee and the District technical staff. The review comments were addressed, and a final report was prepared as Technical Memorandum #1 dated December 30, 2002, which was then accepted by the District.



Sub-Basin	Area (acres)
1	1164.3
2A	6715.8
2B	1226.4
3	579.4
4	540.0
5	1142.4
6	673.5
7	4126.9
8	3966.8
9	72.8
10	208.0
11	8138.4
12	74.1
13	10537.9
14	9270.3
15A	5116.6
15B	8640.6
16A	1065.1
16B	2448.8
17	1650.5
18	2294.9
20A	1138.6

Sub-Basin	Area (acres)
20B	2341.8
21A	3540.4
21B	5056.2
22	7375.2
23	4206.9
24	5282.0
25A	205.8
25B	972.1
26	376.1
27	830.7
28	223.4
29A	1578.1
29B	440.3
30	1153.0
31	1467.7
32	1812.7
33	2323.8
34	711.3
35	172.9
36	603.3
37	390.2
38	1955.2

Legend:

15B Sub-Basin Boundary with Name

N

Scale 1:144,000

0 10000 20000 30000 40000 Feet

Source:
Land Boundary Information System (www.labins.org)
Scanned in 1997 from 7.5 Minute Series,
USGS Quadrangle Maps: West Palm Beach 2 SE, Delta, Rivera Beach, Loxahatchee,
Palm Beach Farms, Palm Beach, Loxahatchee SE, Greenacres City, Lake Worth, Florida

	NAME	DATE
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CHECKED BY		
APPROVED BY		08/13/04
FILE NAME: FL02006-TM4-FIGURE 1-1.APR		

I hereby certify that this document was prepared by me or under my direct supervision and that I am a duly registered Professional Engineer under the laws of the State of Florida.

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NAME
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SITE LOCATION MAP

Reevaluation of the C-51 Basin Rule
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South Florida Water Management District, Contract No. C-13412

FIGURE 1-1

FILE NUMBER FL02006 SHEET ____ OF ____

The scope of work for Task 2 was completed in August 2003. The results of the Basin Modeling System, including HEC-HMS and HEC-RAS models and calibration results, were presented in the Task 2 Draft Report, which was reviewed by members of the review committee and the District technical staff. The review comments were addressed, and a final report was prepared as Technical Memorandum #2 dated August 25, 2003, which was then accepted by the District.

The scope of work for Task 3 was finalized in July 2004. The results for the Model Applications, including the Alternatives A0 through A3, were reviewed by members of the review committee and the District Technical staff. The initial TM #3 was prepared and accepted by the District in November 2003. However, there were some revisions to the model geometric input parameters that impacted a couple of sub-basins. Therefore, the initial TM #3 was revised and replaced in entirety by the revised report in July 2004 (TM #3). TM #3 also presented the results for evaluation of Alternatives B1 through B3 for the ACME Basin B CERP Project, which were included through a contract amendment for Task 3.

The scope of work for this task, Task 4, includes assisting the District in developing the basin rule and attending the public meeting to support the District staff during the basin rule development process. This Technical Memorandum (TM #4) primarily presents the final basin rule, and documents the amendments and/or response to comments that were received after the TM #1 through TM #3 were accepted by the District and were not already documented in the corresponding technical memorandum reports.

1.4 SOURCES OF INFORMATION

The listing of materials and the sources used in the development of this report are presented below.

- Technical Memorandum #1
- Technical Memorandum #2
- Technical Memorandum #3
- Written Comments from Alan Wertepny, Mark Wilsnack, and Juan Carrizo
- Public Workshop on April 29, 2004
- Meetings and discussions with Tony Waterhouse, Suelynn Dignard, Damon Meiers, Mark Wilsnack, Bob Howard, Jay Foy, Patrick Martin, Ken Todd

1.5 RESPONSE TO COMMENTS

Several comments related to specific deliverables were received after TM #1 through TM #3 were accepted by the District. Responses to all such comments are presented here in Appendix A. Appendix A also includes supplemental information describing the process for construction of the DTM using LIDAR data.

2.0 BASIN CHARACTERISTICS

2.1 BASIN DESCRIPTION

The basin and sub-basin boundaries are excerpted from TM #2, shown on Figures 1-1 and 2-1, and further details are given below.

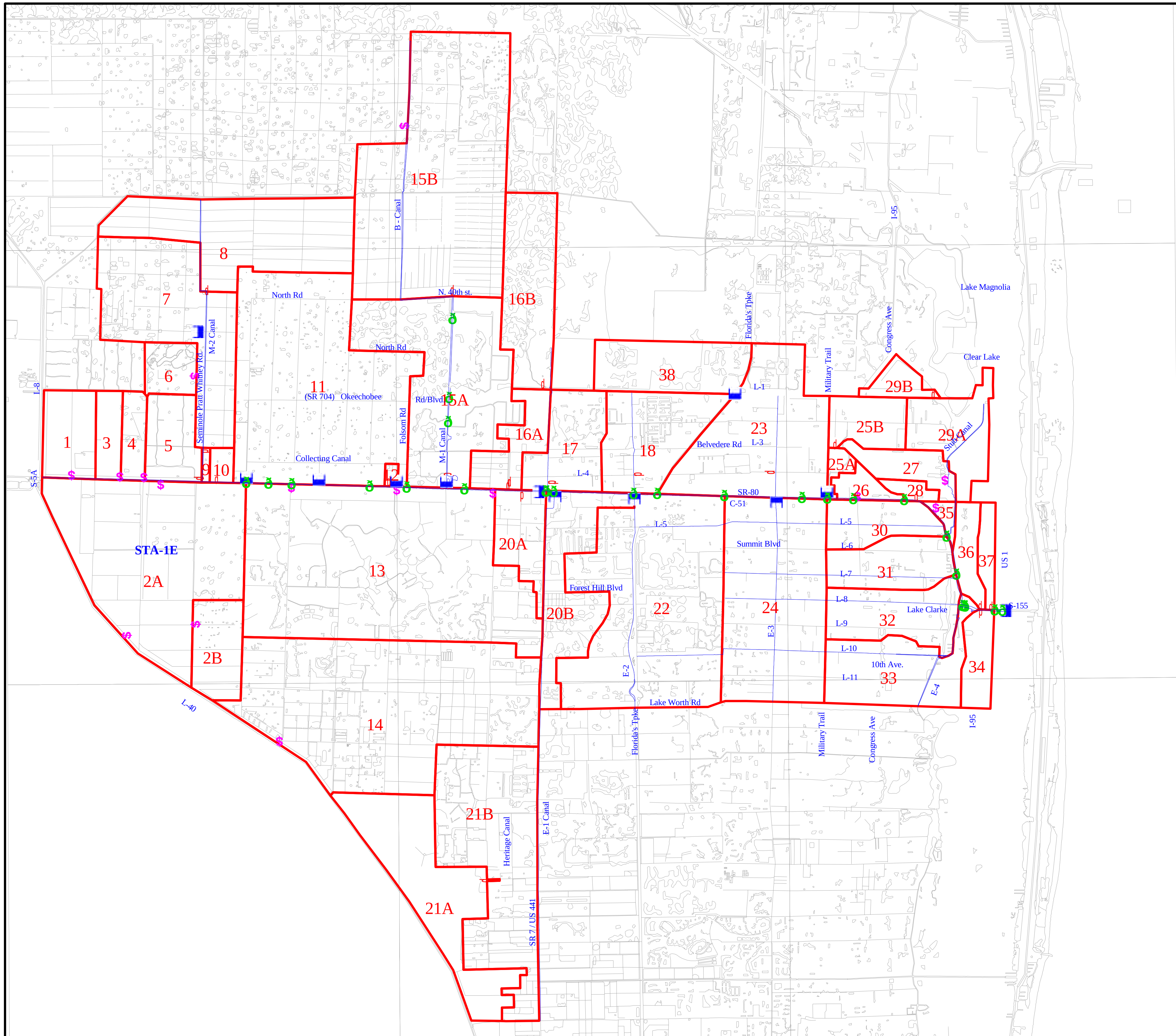
As shown on Figure 2-1, the C-51 basin encompasses a drainage area of approximately 113,810 acres (177.8 square miles). The basin extends from Northlake Boulevard and Grassy Waters Preserve on the north to Lake Worth Road on the south, and from L-8 and L-40 on the west to US-1 on the east.

The runoff from various sub-basins within the study area discharges to the C-51 canal through a number of lateral and equalizer canals. The tidal gate S-155 located east of US-1 ultimately controls the outfall from the C-51 canal. Section 2.2 presents a complete description of the primary drainage pattern and features within the project area. The project area is divided into 44 sub-basins designated as 1 through 38 (alternately, designated as B1 through B38) as shown on Figure 2-1. The basin information is summarized in Tables 2-1a and 2-1b.

In addition, the study area includes three federal projects. They are a) S-155A, which is an in-line control structure located on the C-51 canal dividing the basins into the C-51 West and C-51 East basins; b) STA-1E, which is a storage and treatment reservoir built with approximately the same footprint as Basin 2A; and c) Pump Station 319, which is located along the C-51 canal, that pumps from the C-51 canal to STA-1E as per pre-defined operational criteria. All of these federal projects are located within the C-51 West drainage basin. These features are also shown on Figure 2-1 and summarized in Table 2-2a.

2.2 STORMWATER CONVEYANCE FEATURES

Figure 2-1 presents the drainage or stormwater conveyance features within the basin boundary and shows both primary and secondary canal systems. The present study is limited to the performance of the primary canal system. As shown on Figure 2-1, the primary conveyance features include the primary canal (C-51 canal) and some of the secondary canals (M-1 canal, M-2 canal, Homeland canal, equalizer canals E-1 through E-4, and Stub canal). Some of the other secondary canals, such as the lateral canals L-4 through L-11 are also shown on this figure. The detailed descriptions of the above listed stormwater conveyance features for the baseline condition are given below, and also summarized in Table 2-2a for the C-51 West basin, and in Table 2-2b for the C-51 East basin.



Legend:

- Primary and Some Secondary Stormwater Conveyance System
- Secondary and Tertiary Stormwater Conveyance System
- 15B Sub-Basin Boundary with Name
- $ Pump Station
- Gate
- Culvert / Weir
- Bridge

N

Scale 1:144,000

0 10000 20000 30000 40000 Feet

Source:
Land Boundary Information System (www.labins.org)
The most up-to-date or based on the 1994 DOQQs
State Plane Projection; NAD 83 Datum; In Shape File FORMAT for:
West Palm Beach 2 SE, Delta, Rivera Beach, Loxahatchee, Palm Beach Farms,
Palm Beach, Loxahatchee SE, Greenacres City, Lake Worth, Florida

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CHECKED BY		
APPROVED BY		08/13/04
FILE NAME: FL02006-TM4-FIGURE 2-1.APR		

I hereby certify that this document was prepared by me or under my direct supervision and that I am a duly registered Professional Engineer under the laws of the State of Florida.

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STORMWATER CONVEYANCE SYSTEM

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FIGURE 2-1

FILE NUMBER FL02006 SHEET____ OF____

Table 2-1a
Summary of Information for C-51 West Basin

Sub-Basin		Area		Locality	Other Information
ID	Other ID	(acre)	(sq mi)		
1	B1	1164.3	1.82	Palm Beach Aggregate	
STA-1E	B2A	6715.7	10.49	Same as Basin 2A	SFWMD
2B	B2B	1226.3	1.92		SFWMD
3	B3	579.4	0.91		Fleming Property
4	B4	540.0	0.84		Leonard Property
5	B5	1142.4	1.78		Fox Trail
6	B6	673.5	1.05		Lion Country Safari
7	B7	4126.9	6.45	Indian Trail Improvement District	M-2 Basin
8	B8	3966.7	6.20	Seminole Improvement District	Callery-Judge Groves
9	B9	72.8	0.11		
10	B10	208.0	0.32	Entrada Acres	Developed by Henry Schieffer
11	B11	8138.3	12.71	Loxahatchee Groves	LGWCD
12	B12	74.1	0.12	HCA Health Services	Palms West Hospital
13	B13	10537.9	16.46	ACME Improvement District	ACME Basin A
14	B14	9270.2	14.48	ACME Improvement District	ACME Basin B
15A	B15A	5116.6	7.99	Village of Royal Palm	M-1 Canal, Gates and Structures: Indian Trail Improvement District
15B	B15B	8640.6	13.50	Indian Trail Improvement District	M-1 Acreage Area Lower Basin
16A	B16A	1064.4	1.66		
16B	B16B	2448.8	3.83		
20A	B20A	1138.6	1.78	Lake Worth Drainage District	
TOTAL		**66845.5**	**104.42**		

Table 2-1b
Summary of Information for C-51 East Basin

Sub-Basin		Area		Locality	Other Information
ID	**Other ID**	**(acre)**	**(sq mi)**		
17	B17	1650.5	2.58	Lake Worth Drainage District	
18	B18	2294.9	3.58	Lake Worth Drainage District	FDOT Structure
20B	B20B	2341.8	3.66	Lake Worth Drainage District	
21A	B21A	3540.3	5.53	Strazulla Wetlands	SFWMD
21B	B21B	5056.2	7.90		
22	B22	7375.2	11.52	Lake Worth Drainage District	
23	B23	4206.9	6.57	Lake Worth Drainage District	
24	B24	5282.0	8.25	Lake Worth Drainage District	
25A	B25A	205.8	0.32	Palm Beach County	PBIA
25B	B25B	972.1	1.52	Palm Beach County	
26	B26	376.1	0.59	Palm Beach International Airport	
27	B27	830.7	1.30	Palm Beach International Airport	
28	B28	223.4	0.35	Palm Beach International Airport	
29A	B29A	1578.1	2.46		
29B	B29B	440.3	0.69		
30	B30	1153.0	1.80	Palm Beach County	
31	B31	1467.7	2.29	Lake Worth Drainage District	
32	B32	1812.7	2.83	Lake Worth Drainage District	
33	B33	2323.8	3.63	Lake Worth Drainage District	
34	B34	711.3	1.11	City of Lake Worth	
35	B35	172.9	0.27	City of Cloud Lake	Palm Beach County
36	B36	603.3	0.94	Dreher Park	
37	B37	390.2	0.61	City of West Palm Beach	
38	B38	1955.2	3.05		Vista Centre
TOTAL		**46964.4**	**73.35**		

Table 2-2a
Summary of Stormwater Conveyance Features (Baseline: C-51 West)

Sub-Basin ID	Sub-Basin Other ID	Control Structure	Structure Description and Operations	Conveyance System
1	B1	Pump	1-20,000 gpm Pump and 1-25,000 gpm Pump; Only one pump at a time. Allowable discharge=47.6 cfs	C-51 Canal
STA-1E	B2A	Pump	Pump Station 319; 2-550 cfs and 3-960 cfs Pumps; on @12’ to 12.4’ (at 0.1’ increment) and off @11’ to 11.4’ (at 0.1’ increment) at S-155A HW on C-51 canal.	C-51 Canal to STA-1E
2B	B2B	Pump	Pump Station 361; 3-25 cfs pumps; on @11’, off @10’; Initial Stage @10’.	STA-1E
3	B3	Pump	11,830 gpm Pump	C-51 Canal
4	B4	Pump	13,170 gpm Pump	C-51 Canal
5	B5	Weir	1-54” x 40’ CMP; Allowable discharge=47 cfs	M-2 Canal
6	B6	Pump	30,000 gpm Pump	M-2 Canal
7	B7	Slide Gate	2-36” x 75’ Culverts controlled by Sluice Gates (6’ wide, sill @8’).	M-2 Canal
8	B8	Weir	4-72” Sharp Crested Weirs (crest @17.5’)	M-2 Canal
9	B9	Weir	2 ft Flash Board Riser	M-2 Canal
		Channel M-2 Canal	M-2 discharges to C-51 via 3-84” CMP with Risers with control elevation @ 12 ft-NGVD.	C-51 Canal
10	B10	Riser Weir	36” Riser with Control Elevation at 17.5 ft.	C-51 Canal
11	B11	Gate & Weir	1-6’ Slide Gate (4’ opening, open @16’, close @15’, sill @10’) at A and at G; 2-12’ Radial Gates (2’ opening, open @16.5’, close @15’, sill @9’) and 2-12’ Weirs (crest @18.5’) at D.	C-51 Canal
12	B12	Riser Weir	24” x 250’ RCP Riser (Palms West Hospital), crest @14’.	C-51 Canal
13	B13	Pump	1-60,000 gpm Discharge Pump (PS#4); 1-60,000 gpm Discharge Pump (PS#3); 1-62,000 gpm Discharge Pump (PS#6); on @13’, off @12’ (same as Existing).	C-51 Canal
14	B14	Pump	1-100,000 gpm and 1-120,000 gpm Discharge Pumps; on @13’, off @12’.	WCA 1
15A	B15A	Channel	Open Channel flow to M-1, weir crest @13’.	M-1 Canal
		Culvert	2-72” RCP to C-51 from Lake Challenger	C-51 Canal
		Amil Gate & Slide Gate	1-Automatic D-710 Amil Gate (12’ wide, sill @5’) and 4 Slide Gates (5.9’ wide each, sill @2.7’) on M-1 controlling the discharge to C-51	C-51 Canal
15B	B15B	Culvert	Roach Structure: 2-84” x 80’ RCP with Slide Gates. 40th Structure: 4-large & 2-small Gates. Outflow controlled by 1-60” x 76’ RCP. No Flow to M-1 in 72 hrs.	M-1 Canal
16A	B16A	Weir	30’ wide Weir; Control Elevation @ 13 ft-NGVD.	C-51 Canal
16B	B16B	Weir	2-72” RCP controlled by 3-48” control structures with weir elevation @ 17.5 ft.	Sub-Basin 16A
20A	B20A	Culvert	2-60” CMP upstream of STA 4+94 on S-4 Canal, Invert @10’.	C-51 Canal
--	S-155A	Gate	Control Structure, divides C-51 West from C-51 East, remains closed, designed discharge capacity 1,000 cfs.	C-51 Canal

Table 2-2b
Summary of Stormwater Conveyance Features (Baseline: C-51 East)

Sub-Basin		Control Structure	Structure Description and Operations	Conveyance System
ID	Other ID			
17	B17	Channel	L-1, L-2, L-3, L-4 Lateral Canals to E-1 Canal ; weir with crest @8.5’	C-51 Canal
18	B18	Culvert	E-2 Canal discharging through 10’ wide x 11’ high FDOT Box Culvert, crest @8.5’.	C-51 Canal
20B	B20B	Radial Gate	Control Structure #2: 2-12’ Radial Gates on E-1, sill @8.5’.	C-51 Canal
21A	B21A	Overflow	Land Locked Basin controlled by Stage-Storage relationship. Overflows to Basin 21B when stage reaches 18.5 ft-NGVD.	Sub-Basin 21B
21B	B21B	Channel	Homeland Canal discharging to E-1 Canal.	E-1 Canal
22	B22	Radial Gate	Control Structure #4: 2-12’ Radial Gates on E-2, sill @8.5’.	C-51 Canal
23	B23	Channel	L-1, L-2, L-3, L-4 Lateral Canals to E-3 Canal.	C-51 Canal
24	B24	Radial Gate	Control Structure #6: 3-12’ Radial Gates on E-3, sill @6.5’.	C-51 Canal
25A	B25A	Slide gate	2-10’ wide x 8’ high Box Culverts with Slide Gate, sill @8.5’.	C-51 Canal
25B	B25B	Culvert	2-8’ high x 10’ wide Box Culverts under Belvedere Road.	Sub-Basin 25A
26	B26	Pump	Southern PBIA Pump Station: 4-106.6 cfs Pumps; Pump 4 only operates when one of the other 3 fails.	C-51 Canal
27	B27	Pump	Eastern PBIA Pump Station: 4-106.6 cfs Pumps; Pump 4 only operates when one of the other 3 fails.	Stub Canal
28	B28	Culvert	40’ wide x 8’ high FDOT Box Culvert: Structure S-199, invert @7’.	C-51 Canal
29A	B29A	Channel	Discharge to C-51 through Stub Canal, weir crest @9’	Stub Canal
29B	B29B	Weir	6-6’ wide Weirs with Gates	Sub-Basin 29A
30	B30	Channel	L-5 Canal Open Channel flow to C-51, weir crest @9’.	C-51 Canal
31	B31	Channel	L-6, L-7 Canals Open Channel flow to C-51, weir crest @9’.	C-51 Canal
32	B32	Channel	L-8, L-9 Canals Open Channel flow to C-51, weir crest @9’.	C-51 Canal
33	B33	Channel	L-10, L-11 Open Channel flow to C-51, weir crest @9’.	E-4 Canal
34	B34	Culvert	1-48”x1800’ RCP; 1-36”x1000’ RCP, invert @7.5’	C-51 Canal
35	B35	Pump	Pump Station: 45 cfs pump	C-51 Canal
36	B36	Culvert	Dreher Zoo control structure: 30’ wide Weir (crest @10’); 60”x2500’ RCP at Municipal Golf Course (invert @7.5’); 36”x3000’ RCP at Georgia Ave (invert @7.5’).	C-51 Canal
37	B37	Culvert	1-36” x 2000’ RCP; 1-36” x 2500’ RCP, invert @7.5’.	C-51 Canal
38	B38	Slide Gate	2-66” RCP; One is plugged and the other is controlled by a 5.5 ft wide Gate (sill @8.5’, opening 2’).	C-51 Canal
--	S-155	Gate	Outfall Structure, remains operational, designed discharge capacity approximately 4,800 cfs.	C-51 Canal

As can be seen from the background hydrologic feature map shown on Figure 2-1, the secondary and tertiary stormwater conveyance system within the project basin consists of a myriad of interconnected canals and water bodies. These secondary and tertiary canals are generally evaluated on a local scale. This study presents the hydrologic and hydraulic evaluations on a basin wide scale, and therefore, did not include detailed evaluations of the secondary and tertiary conveyance systems.

The general information related to stormwater conveyance control structures directly connected to primary conveyance features are summarized in Tables 2-2a and 2-2b. The topographic variation over the site along with the stage-area-storage relationships for the sub-basins was obtained from TM #2. Further details on the canals, control structures, and stage-area-storage relationships for each sub-basin are presented in TM #3.

2.3 DESIGN STORM EVENTS

The design storms for the basin rule evaluations are identified as 10-year, 72-hour and 100-year, 72-hour storm events. The 24-hour (1-day) and 72-hour (3-day) duration maximum rainfalls are the most commonly considered storm events by the District's Regulation Department in the permit review process described in "Management and Storage of Surface Waters, Permit Information Manual, Volume IV". The District is committed to maintaining the most accurate and updated rainfall frequency data for use in evaluating the permit applications within its jurisdiction. In order to maintain such commitment, the District initially developed rainfall frequency curves for 24-hour through 120-hour durations in 1981 (MacVicar). Based on the increased number of stations and rainfall measurement records, Trimble (1990) published revised rainfall frequency curves in the "Technical Memorandum, Frequency Analysis of One and Three-Day Rainfall Maxima for Central and Southern Florida", SFWMD in October 1990. Since then the Regulation Department of the SFWMD has been using these new rainfall frequency curves as the basis of review for permit applications.

A more comprehensive discussion on the development of the design storm events was presented in TM #2. For consistency of the permitting review process for the entire jurisdiction, we recommended in TM #2 to continue the use of the SFWMD rainfall frequency curves of 1990. Based on this publication, Table 2-3 presents the estimated storm event rainfall quantities for the C-51 basin, which were used for the present study during Task 3 (TM #3). A single storm depth is used over the entire C-51 basin. The 15-minute interval rainfall distribution consisting of unit hydrograph and cumulative percentage of 24-hour peak rainfall for a 72-hour storm event is presented in Appendix B.

Table 2-3
Storm Event Rainfall Quantities for Basin Rule Development

Storm Frequency (year)	Storm Duration (hour)	Storm Depth (inch)
10	24	7.4
	72	10.1
100	24	12.0
	72	16.3

Note: the 100-year, 24-hour storm depth is same as in the FEMA study, and 72-hour storm depths were calculated by multiplying the 24-hour depth by 1.359.

2.4 BASIN MODEL

The hydrologic computation was performed using the Hydrologic Modeling System (HEC-HMS) software. The hydraulic computation was performed using the River Analysis System (HEC-RAS) software. Both HEC-HMS (HMS) and HEC-RAS (RAS) have been developed by the Hydrologic Engineering Center, USACE. The latest versions of the HMS (Version 2.2.1 with release date of October 2002) and RAS (Version 3.1.1 with release date of May 2003) models were used for this project. Further discussion on the principles of these models applicable to this study was presented in TM #2.

The calibration of the basin models was completed during Task 2 (Report TM #2). The model calibration was performed for the storm event of Hurricane Irene that occurred from 14th October to 16th October, 1999. For better performance and integrity of the model calibration, a longer duration was selected as the calibration period, which started two days prior to the calibration storm and continued two days after the designated storm. Based on the available records and types of measurements, C51WEL and C51SR7 were designated as key locations for peak stage calibration, and S155 was designated as key location for peak discharge calibration. The River Stations (RS) for the calibration locations are C51WEL at RS 65500, C51SR7 at RS 56807, and S155 at RS 720 or RS 750 (upstream of the gated structure).

The major basin characteristics that were adjusted during the model calibration in Task 2 included curve numbers and time lags for the sub-basins, and Manning's n coefficients for the channel sections and overbanks. The relevant calibrated basin characteristics are summarized in Table 2-4. Complete details on the model calibration process, including the initial and boundary conditions and the transient hydraulic computational parameters are presented in TM #2.

Table 2-4
Summary of Basin Parameters for Basin Rule Development

Sub-Basin		Area		Calibrated * Curve Number (CN)	Calibrated Time of Concentration (Minute)	Calibrated Time Lag (Minute)
ID	Other ID	(acre)	(sq mi)			
1	B1	1164.3	1.82	71.5	252	151
2A	B2A	6715.8	10.49	99.0	651	390
2B	B2B	1226.4	1.92	74.3	138	83
3	B3	579.4	0.91	73.9	231	139
4	B4	540.0	0.84	75.2	260	156
5	B5	1142.5	1.78	77.4	232	139
6	B6	673.5	1.05	81.5	146	88
7	B7	4126.9	6.45	76.0	501	300
8	B8	3966.8	6.20	76.0	401	241
9	B9	72.8	0.11	76.1	93	56
10	B10	208.0	0.32	81.9	226	136
11	B11	8138.3	12.71	77.0	518	310
12	B12	74.1	0.12	86.0	94	56
13	B13	10537.9	16.46	82.0	521	313
14	B14	9270.3	14.48	75.0	429	258
15A	B15A	5116.7	7.99	86.0	551	330
15B	B15B	8640.6	13.50	78.0	592	355
16A	B16A	1064.4	1.66	83.4	308	185
16B	B16B	2448.8	3.83	89.0	752	450
20A	B20A	1138.6	1.78	80.0	255	153
17	B17	1650.5	2.58	84.8	303	182
18	B18	2294.9	3.58	83.5	287	172
20B	B20B	2341.8	3.66	80.7	364	218
21A	B21A	3540.4	5.53	96.9	534	320
21B	B21B	5056.2	7.90	76.4	493	296
22	B22	7375.2	11.52	80.0	518	310
23	B23	4206.9	6.57	81.0	364	218
24	B24	5282.0	8.25	81.5	440	264
25A	B25A	205.8	0.32	77.0	104	63
25B	B25B	972.1	1.52	79.0	131	79
26	B26	376.1	0.59	80.1	162	97
27	B27	830.7	1.30	84.5	274	164
28	B28	223.4	0.35	83.0	92	55
29A	B29A	1578.1	2.46	80.5	130	78
29B	B29B	440.3	0.69	85.9	144	86
30	B30	1153.0	1.80	78.3	159	95
31	B31	1467.8	2.29	80.0	157	94
32	B32	1812.7	2.83	81.0	271	162
33	B33	2323.9	3.63	80.0	228	137
34	B34	711.3	1.11	75.0	262	157
35	B35	172.9	0.27	82.7	74	45
36	B36	603.3	0.94	72.1	187	112
37	B37	390.2	0.61	69.0	184	111
38	B38	1955.2	3.05	86.0	225	135

* Basin 2A or STA-1E is the only exception, where the CN value was changed from 75 to 99

3.0 SUMMARY OF BASIN RULE EVALUATION

For the basin rule development, the allowable flows are determined from model results for the 10-year, 72-hour design storm, and the allowable stages are determined from model results for the 100-year, 72-hour design storm. As indicated earlier, the hydrologic and hydraulic computations were performed using the HEC-HMS and HEC-RAS models calibrated in Task 2 (TM #2).

3.1 DESCRIPTION OF ALTERNATIVES

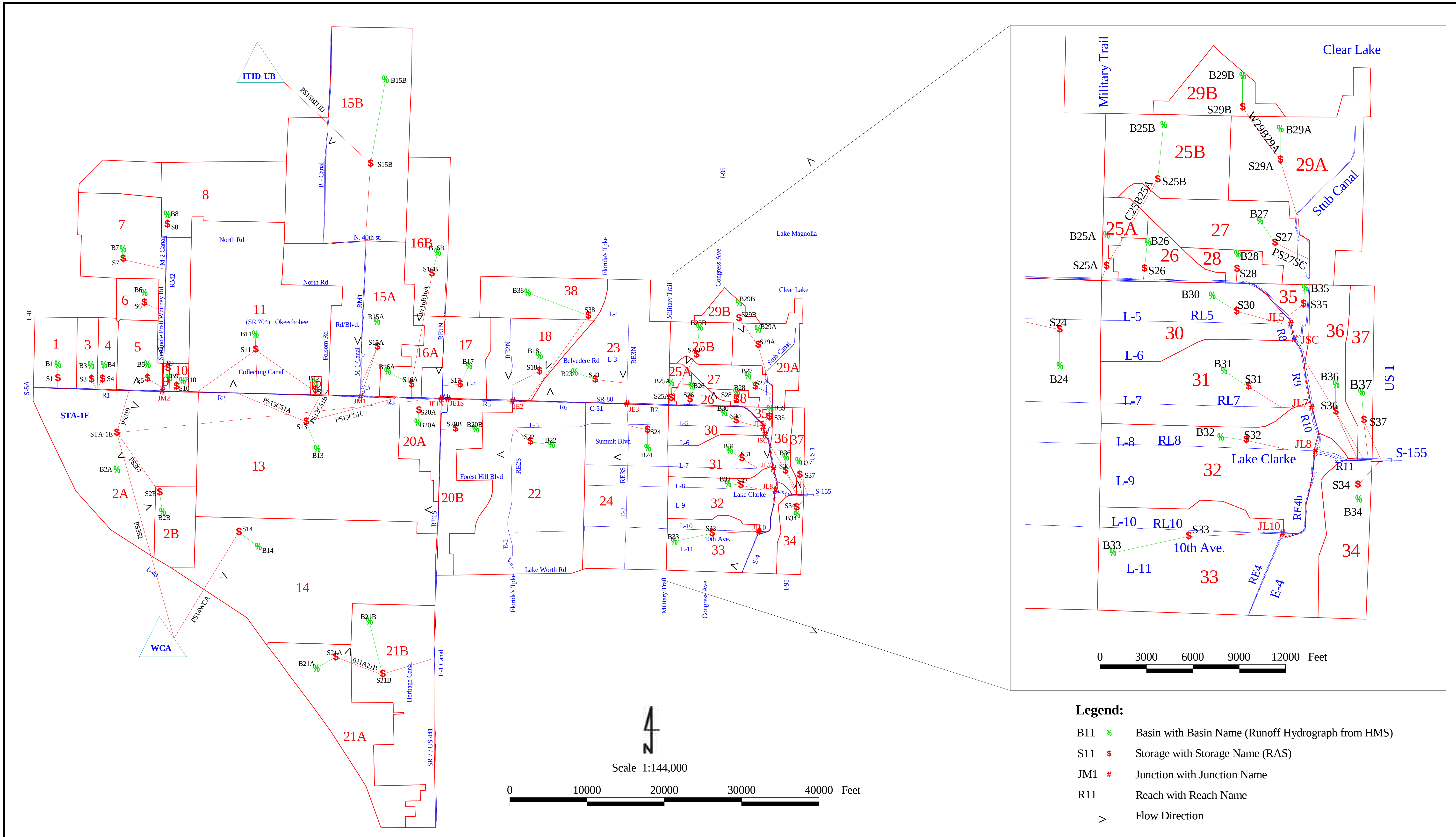
The following alternatives were simulated as part of the model application for the basin rule evaluation in Task 3. Complete results and discussion are presented in TM #3 (July 2004).

- Alternative A0: Baseline (Existing Rule) Simulation
- Alternative A1: Unrestricted Flow Simulation
- Alternative A2: USACE Design Manning's n Simulation
- Alternative A3: USACE Design Flow Simulation

Figure 3-1 presents the link-node diagram for the C-51 basin for all alternatives evaluated during Task 3. Figure 3-1 also represents a geographically based nodal diagram for these alternatives. Complete details on the model simulation for the C-51 basin were presented in TM #3.

Alternative A0: Baseline (Existing Rule) Simulation

The primary purpose of this alternative was to establish the baseline conditions for each sub-basin under the existing rule with the federal projects in operational condition. The federal projects for this alternative included: STA-1E, S-319, S-361, S-362, and S-155A. These structures are all located in the C-51 west, and no physical change was considered for the C-51 East basin. The existing rule includes the peak discharge coefficients and peak stages for each sub-basin that are currently used for permitting purposes. The peak flow or discharge coefficients were based on the 10-year, 72-hour design storm event, while the peak stages were based on the 100-year, 72-hour design storm event.



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CHECKED BY		
APPROVED BY		08/13/04
FILE NAME: FL02006-TM4-FIGURE 3-1.APR		

I hereby certify that this document was prepared by me or under my direct supervision and that I am a duly registered Professional Engineer under the laws of the State of Florida.

SIGNED NA
NAME
DATE REG. NO.

NODAL DIAGRAM FOR BASIN RULE ALTERNATIVES (AO THROUGH A3)

Reevaluation of the C-51 Basin Rule
Technical Memorandum #4: Rule Development
South Florida Water Management District, Contract No. C-13412

FIGURE 3-1

FILE NUMBER FL02006 SHEET ___ OF ___

Alternative A1: Unrestricted Flow Simulation

This alternative simulated the 10-year, 72-hour and 100-year, 72-hour design storm events that involved generating the hydrologic conditions for each sub-basin under the unrestricted discharge condition with the federal projects in operational condition. The peak discharges and the peak stages were computed for the 10-year, 72-hour and the 100-year, 72-hour design storm events. The federal projects for this alternative included: STA-1E, S-319, S-361, S-362, and S-155A. These structures are all located in the C-51 west, and no change was considered to the C-51 east. This alternative considered unrestricted flow through the control structures for each sub-basin except for sub-basin 15B. In addition, sub-basin 14 (ACME Basin B) is not considered as a part of the C-51 West, and is modeled to discharge to the WCA as described in TM #2.

Alternative A2: USACE Design Manning's n Simulation

This alternative is identical to Alternative A1 with the only exception being the use of different Manning's n coefficients along the C-51 canal in the C-51 West basin. A Manning's n coefficient of 0.03 was used for the segment of the C-51 canal in the C-51 West basin. This was the design value used by the USACE for design of the C-51 canal improvements. The primary purpose of this alternative was to generate comparative information on the head difference between the headwater at S-155A and the pump station S-319 along the C-51 canal resulting from a change in Manning's n.

Alternative A3: USACE Design Flow Simulation

The purpose of this alternative was to simulate the design scenario that USACE used to design the STA-1E. USACE assumed that most of the sub-basins in the C-51 West will have one inch of allowable peak discharge resulting from a 10-year, 72-hour storm event, except for sub-basins 8, 11, and 15A. The sub-basins in the C-51 East were not considered a part of the design process for the 10-year, 72-hour design storm event as they do not contribute flows to the S-319 pump station. This scenario assumed that there would be unrestricted flow from the sub-basins to the primary conveyance system in the C-51 East basin. Further details on this alternative were presented in TM #3. The peak stage simulation corresponding to the 100-year, 72-hour storm event is identical to the conditions of Alternative 1.

3.2 SUMMARY OF EVALUATION RESULTS

This section presents a direct comparison of all the alternatives simulated in Task 3 for the basin rule evaluation. Complete results were documented in TM #3. The following section only presents a summary of discussions and conclusions from TM #3.

Basin Rule Peak Discharges

Table 3-1 summarizes the simulated peak discharge for the design storm event (10-year, 72-hour) for all the basin rule alternatives. This table also presents the improvement on allowable discharge for various alternatives over the existing rule conditions. It was concluded that Alternatives A1 through A3 produced significant improvement on peak discharge for each sub-basin over the baseline (Alternative A0) and the existing rule conditions. Intuitively, the peak discharge values for Alternatives A1 and A2 are similar since there was no difference in sub-basin conditions between the two alternatives. The difference between the two alternatives is the Manning's n coefficient along the western segment of the C-51 canal, which does not significantly impact the sub-basin discharge characteristics. Since, the flow was restricted for Alternative 3 (according to the USACE design conditions) for the sub-basins in the C-51 West, the peak discharge values in C-51 in the restricted sub-basins are obviously lower than the other two alternatives representing unrestricted flow condition, except for sub-basins where the allowable discharges for Alternative A3 are greater than those for Alternatives A1 and A2. This exception is for sub-basins 1, 2B, 7, 8, 10, 13, 16B and 36 (TM #3).

Basin Rule Peak Stages

Table 3-2 summarizes the simulated peak stage for this design storm event (100-year, 72-hour) for all of the alternatives. This table also presents the improvement on allowable stage for various alternatives over the existing rule conditions (TM #3). As can be seen from this table, there is insignificant difference in peak stage for each sub-basin amongst the Alternatives A1 through A3. However, in most cases, there is a significant improvement on peak stage for the sub-basins resulting from these alternatives over the existing rule condition (TM #3).

3.3 RECOMMENDED ALLOWABLE DISCHARGES AND STAGES

In accordance with the contractual scope of services, the model application was completed in Task 3. In order to begin the basin rule, based on the results presented in TM #3, we concluded that higher allowable discharges than the existing rule can be allocated for most of the sub-basins. In addition, the allowable 100-year peak stages can be lower than the existing rule conditions for all sub-basins.

Based on the model applications presented in TM #3, the recommended allowable discharge coefficients and peak stages are summarized in Table 3-3. These recommended discharge values are the same as the USACE Design discharge values for the C-51 West sub-basins. The recommended discharge values for the C-51 East sub-basins are equivalent to the USACE design capacity of the S-155 Spillway of 4,800 cfs divided by its service area of 73.4 square miles (equals to 65 CSM).

Table 3-1
Comparison of Alternatives for Allowable Peak Discharge (10-year, 72-hr Storm)

Sub-Basin		Area (sq mi)	Existing Rule Flow (cfs)	Flow for Various Alternatives (cfs)				Improvement Over Existing Rule (cfs)			
ID	Other ID			A0	A1	A2	A3	A0	A1	A2	A3
1	B1	1.82	49	48	48	48	49	-1	-1	-1	0
2A	STA1E	10.49	--	--	--	--	--	--	--	--	--
2B	B2B	1.92	52	50	50	50	52	-2	-2	-2	0
3	B3	0.91	24	24	26	26	24	0	2	2	0
4	B4	0.84	23	23	29	29	23	0	6	6	0
5	B5	1.78	48	53	53	52	49	5	5	4	1
6	B6	1.05	25	25	67	67	28	0	42	42	3
7	B7	6.45	155	152	151	151	166	-3	-4	-4	11
8	B8	6.20	335	260	260	260	333	-75	-75	-75	-2
9	B9	0.11	3	5	9	9	7	2	6	6	4
10	B10	0.32	0	0	3	3	9	0	3	3	9
11	B11	12.71	343	357	1360	1357	1027	14	1017	1014	684
12	B12	0.12	3	5	35	35	3	2	32	32	0
13	B13	16.46	296	296	406	406	445	0	110	110	149
14	B14	14.48	--	--	--	--	--	--	--	--	--
15A	B15A	7.99	560	559	826	827	579	-1	266	267	19
15B	B15B	13.50	--	--	--	--	--	--	--	--	--
16A	B16A	1.66	0	0	384	384	45	0	384	384	45
16B	B16B	3.83	0	0	26	26	103	0	26	26	103
20A	B20A	1.78	0	0	131	126	50	0	131	126	50
17	B17	2.58	70	63	384	384	384	-7	314	314	314
18	B18	3.58	97	100	322	322	323	3	225	225	225
20B	B20B	3.66	59	62	535	535	535	3	476	476	476
21A	B21A	5.53	0	0	0	0	0	0	0	0	0
21B	B21B	7.90	0	0	111	111	111	0	111	111	111
22	B22	11.52	403	371	371	371	371	-32	-32	-32	-32
23	B23	6.57	230	230	675	675	675	0	445	445	445
24	B24	8.25	289	292	452	452	452	3	163	163	163
25A	B25A	0.32	11	13	370	370	369	2	359	359	358
25B	B25B	1.52	53	40	344	344	330	-13	291	291	277
26	B26	0.59	21	21	107	107	107	0	86	86	86
27	B27	1.30	45	45	320	320	320	0	275	275	275
28	B28	0.35	12	11	270	270	267	-1	258	258	255
29A	B29A	2.46	86	89	309	309	309	3	223	223	223
29B	B29B	0.69	24	26	628	626	628	2	604	602	604
30	B30	1.80	63	61	123	123	123	-2	60	60	60
31	B31	2.29	80	75	333	333	333	-5	253	253	253
32	B32	2.83	99	99	278	279	278	0	179	180	179
33	B33	3.63	127	128	272	272	272	1	145	145	145
34	B34	1.11	39	35	137	136	128	-4	98	97	89
35	B35	0.27	9	9	45	45	45	0	36	36	36
36	B36	0.94	33	36	79	79	94	3	46	46	61
37	B37	0.61	21	18	93	94	85	-3	72	73	64
38	B38	3.05	0	0	145	145	145	0	145	145	145

-- did not contribute to the Basin Rule evaluation or not applicable

Table 3-2
Comparison of Alternatives for Allowable Peak Stage (100-year, 72-hr Storm)

Sub-Basin		Area (sq mi)	Existing Rule Stage (ft-NGVD)	Stage for Various Alternatives (ft-NGVD)				Improvement Over Existing Rule (ft)			
ID	Other ID			A0	A1	A2	A3	A0	A1	A2	A3
1	B1	1.82	18.2	14.2	14.2	14.2	14.2	-4	-4	-4	-4
2A	STA1E	10.49	--	--	--	--	--	--	--	--	--
2B	B2B	1.92	17.2	13.8	13.8	13.8	13.8	-3.4	-3.4	-3.4	-3.4
3	B3	0.91	18.3	15.8	15.8	15.8	15.8	-2.5	-2.5	-2.5	-2.5
4	B4	0.84	18.3	16.6	16.6	16.6	16.6	-1.7	-1.7	-1.7	-1.7
5	B5	1.78	18.7	17.4	17.4	17.4	17.4	-1.3	-1.3	-1.3	-1.3
6	B6	1.05	21.0	19.2	19.2	19.2	19.2	-1.8	-1.8	-1.8	-1.8
7	B7	6.45	21.0	19.9	19.9	19.9	19.9	-1.1	-1.1	-1.1	-1.1
8	B8	6.20	22.0	20.6	20.6	20.6	20.6	-1.4	-1.4	-1.4	-1.4
9	B9	0.11	21.0	17.6	17.6	17.6	17.6	-3.4	-3.4	-3.4	-3.4
10	B10	0.32	20.1	18.3	18.3	18.3	18.3	-1.8	-1.8	-1.8	-1.8
11	B11	12.71	20.2 – 21.0	18.9	18.9	18.9	18.9	-2.1	-2.1	-2.1	-2.1
12	B12	0.12	20.2	17.5	17.5	17.5	17.5	-2.7	-2.7	-2.7	-2.7
13	B13	16.46	17.5	16.6	16.6	16.6	16.6	-0.9	-0.9	-0.9	-0.9
14	B14	14.48	--	--	--	--	--	--	--	--	--
15A	B15A	7.99	19.0	18.2	18.2	18.2	18.2	-0.8	-0.8	-0.8	-0.8
15B	B15B	13.50	--	--	--	--	--	--	--	--	--
16A	B16A	1.66	18.1	16.8	16.8	16.8	16.8	-1.3	-1.3	-1.3	-1.3
16B	B16B	3.83	19.1	19.0	19.0	19.0	19.0	-0.1	-0.1	-0.1	-0.1
20A	B20A	1.78	18.1	16.1	16.1	16.1	16.1	-2	-2	-2	-2
17	B17	2.58	18.0	16.6	16.6	16.6	16.6	-1.4	-1.4	-1.4	-1.4
18	B18	3.58	17.9	15.7	15.7	15.7	15.7	-2.2	-2.2	-2.2	-2.2
20B	B20B	3.66	18.3	16.8	16.8	16.8	16.8	-1.5	-1.5	-1.5	-1.5
21A	B21A	5.53	19.8	17.3	17.3	17.3	17.3	-2.5	-2.5	-2.5	-2.5
21B	B21B	7.90	19.8	17.7	17.7	17.7	17.7	-2.1	-2.1	-2.1	-2.1
22	B22	11.52	19.0	17.5	17.5	17.5	17.5	-1.5	-1.5	-1.5	-1.5
23	B23	6.57	19.1	17.1	17.1	17.1	17.1	-2	-2	-2	-2
24	B24	8.25	19.3	17.9	17.9	17.9	17.9	-1.4	-1.4	-1.4	-1.4
25A	B25A	0.32	16.6	14.6	14.6	14.6	14.6	-2	-2	-2	-2
25B	B25B	1.52	16.6	14.7	14.7	14.7	14.7	-1.9	-1.9	-1.9	-1.9
26	B26	0.59	15.9	13.8	13.8	13.8	13.8	-2.1	-2.1	-2.1	-2.1
27	B27	1.30	15.6	13.2	13.2	13.2	13.2	-2.4	-2.4	-2.4	-2.4
28	B28	0.35	15.6	12.3	12.3	12.3	12.3	-3.3	-3.3	-3.3	-3.3
29A	B29A	2.46	15.6	14.8	14.8	14.8	14.8	-0.8	-0.8	-0.8	-0.8
29B	B29B	0.69	15.6	15.2	15.2	15.2	15.2	-0.4	-0.4	-0.4	-0.4
30	B30	1.80	16.4	14.1	14.1	14.1	14.1	-2.3	-2.3	-2.3	-2.3
31	B31	2.29	15.2	13.1	13.1	13.1	13.1	-2.1	-2.1	-2.1	-2.1
32	B32	2.83	15.3	13.0	13.0	13.0	13.0	-2.3	-2.3	-2.3	-2.3
33	B33	3.63	15.3	13.6	13.6	13.6	13.6	-1.7	-1.7	-1.7	-1.7
34	B34	1.11	20.0	17.0	17.0	17.0	17.0	-3	-3	-3	-3
35	B35	0.27	15.6	11.3	11.3	11.3	11.3	-4.3	-4.3	-4.3	-4.3
36	B36	0.94	15.7	14.0	14.0	14.0	14.0	-1.7	-1.7	-1.7	-1.7
37	B37	0.61	20.0	16.4	16.4	16.3	16.4	-3.6	-3.6	-3.7	-3.6
38	B38	3.05	18.8	17.2	17.2	17.2	17.2	-1.6	-1.6	-1.6	-1.6

-- did not contribute to the Basin Rule evaluation or not applicable

Table 3-3
Recommended Allowable Discharges and Stages

Sub-Basin		Area		10-yr, 72-hr Allowable Discharge			100-yr, 72-hr Stage
ID	Other ID	(acre)	(sq mi)	Flow (CSM)	Flow (cfs)	Flow (in/day)	(ft-NGVD)
1	B1	1164.3	1.82	27	49	1.0	14.2
2A	STA1E	6715.8	10.49	--	--	--	--
2B	B2B	1226.4	1.92	27	52	1.0	13.8
3	B3	579.4	0.91	27	25	1.0	15.8
4	B4	540.0	0.84	27	23	1.0	16.6
5	B5	1142.5	1.78	27	48	1.0	17.4
6	B6	673.5	1.05	27	28	1.0	19.2
7	B7	4126.9	6.45	27	174	1.0	19.9
8	B8	3966.8	6.20	54	335	2.0	20.6
9	B9	72.8	0.11	27	3	1.0	17.6
10	B10	208.0	0.32	27	9	1.0	18.3
11	B11	8138.3	12.71	81	1,030	3.0	18.9
12	B12	74.1	0.12	27	3	1.0	17.5
13	B13	10537.9	16.46	27	444	1.0	16.6
14	B14	9270.3	14.48	--	--	--	--
15A	B15A	5116.7	7.99	70	559	2.6	18.2
15B	B15B	8640.6	13.50	--	--	--	--
16A	B16A	1064.4	1.66	27	45	1.0	16.8
16B	B16B	2448.8	3.83	27	103	1.0	19.0
20A	B20A	1138.6	1.78	27	48	1.0	16.1
17	B17	1650.5	2.58	65	168	2.4	16.6
18	B18	2294.9	3.58	65	233	2.4	15.7
20B	B20B	2341.8	3.66	65	238	2.4	16.8
21A	B21A	3540.4	5.53	65	360	2.4	17.3
21B	B21B	5056.2	7.90	65	514	2.4	17.7
22	B22	7375.2	11.52	65	749	2.4	17.5
23	B23	4206.9	6.57	65	427	2.4	17.1
24	B24	5282.0	8.25	65	536	2.4	17.9
25A	B25A	205.8	0.32	65	21	2.4	14.6
25B	B25B	972.1	1.52	65	99	2.4	14.7
26	B26	376.1	0.59	65	38	2.4	13.8
27	B27	830.7	1.30	65	85	2.4	13.2
28	B28	223.4	0.35	65	23	2.4	12.3
29A	B29A	1578.1	2.46	65	160	2.4	14.8
29B	B29B	440.3	0.69	65	45	2.4	15.2
30	B30	1153.0	1.80	65	117	2.4	14.1
31	B31	1467.8	2.29	65	149	2.4	13.1
32	B32	1812.7	2.83	65	184	2.4	13.0
33	B33	2323.9	3.63	65	236	2.4	13.6
34	B34	711.3	1.11	65	72	2.4	17.0
35	B35	172.9	0.27	65	18	2.4	11.3
36	B36	603.3	0.94	65	61	2.4	14.0
37	B37	390.2	0.61	65	40	2.4	16.4
38	B38	1955.2	3.05	65	198	2.4	17.2

-- did not contribute to the Basin Rule evaluation or not applicable

4.0 PROPOSED BASIN RULE

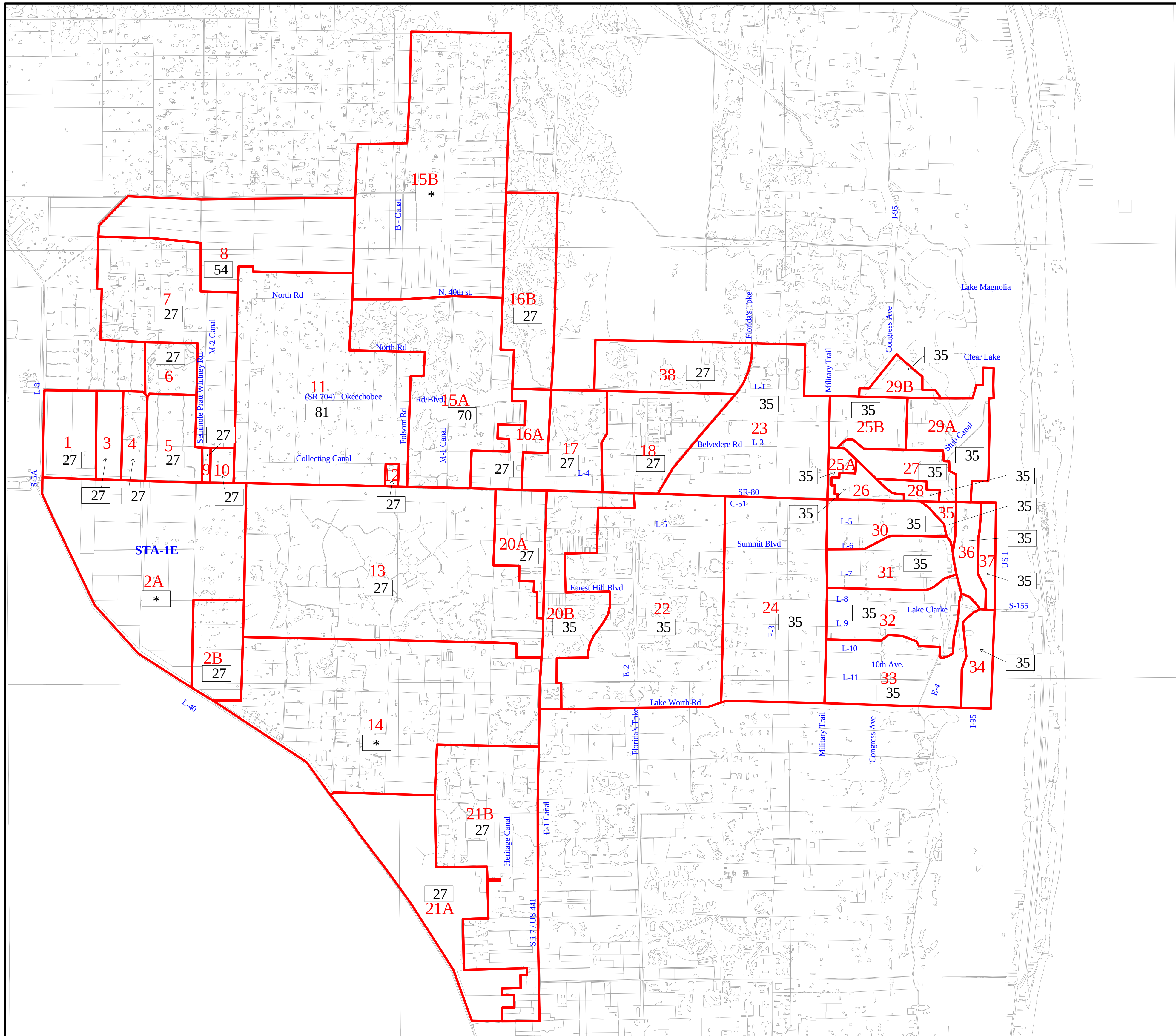
4.1 BASIN RULE CRITERIA

Based on the model applications presented in TM #3, the recommended allowable discharge coefficients and peak stages were summarized in Table 3-3. After regulatory review meetings and considering the overall impact on the ecosystem within the C-51 basin, the recommended allowable discharges were slightly modified, and the final proposed basin rule criteria are presented in Table 4-1. The final allowable discharge coefficients for all sub-basins are shown on Figure 4-1. The final allowable 100-year peak stages for all sub-basins are shown on Figure 4-2. The basin rule criteria for discharge values are the same as the USACE Design discharge values for the C-51 West sub-basins. The basin rule criteria for discharge values for the C-51 East sub-basins are the same as with the current rule. It was determined that this was appropriate in that it provided additional protection for the Lake Worth Lagoon ecosystem.

Table 4-1
Proposed Basin Rule Criteria: Allowable Discharges and Stages

Sub-Basin		Area		10-yr, 72-hr Allowable Discharge			100-yr, 72-hr Stage
ID	Other ID	(acre)	(sq mi)	Flow (CSM)	Flow (cfs)	Flow (in/day)	(ft-NGVD)
1	B1	1164.3	1.82	27	49	1.0	14.2
2A	STA1E	6715.8	10.49	--	--	--	--
2B	B2B	1226.4	1.92	27	52	1.0	13.8
3	B3	579.4	0.91	27	25	1.0	15.8
4	B4	540.0	0.84	27	23	1.0	16.6
5	B5	1142.5	1.78	27	48	1.0	17.4
6	B6	673.5	1.05	27	28	1.0	19.2
7	B7	4126.9	6.45	27	174	1.0	19.9
8	B8	3966.8	6.20	54	335	2.0	20.6
9	B9	72.8	0.11	27	3	1.0	17.6
10	B10	208.0	0.32	27	9	1.0	18.3
11	B11	8138.3	12.71	81	1,030	3.0	18.9
12	B12	74.1	0.12	27	3	1.0	17.5
13	B13	10537.9	16.46	27	444	1.0	16.6
14	B14	9270.3	14.48	--	--	--	--
15A	B15A	5116.7	7.99	70	559	2.6	18.2
15B	B15B	8640.6	13.50	--	--	--	--
16A	B16A	1064.4	1.66	27	45	1.0	16.8
16B	B16B	2448.8	3.83	27	103	1.0	19.0
20A	B20A	1138.6	1.78	27	48	1.0	16.1
17	B17	1650.5	2.58	27	70	1.0	16.6
18	B18	2294.9	3.58	27	97	1.0	15.7
20B	B20B	2341.8	3.66	35	128	1.3	16.8
21A	B21A	3540.4	5.53	27	149	1.0	17.3
21B	B21B	5056.2	7.90	27	213	1.0	17.7
22	B22	7375.2	11.52	35	403	1.3	17.5
23	B23	4206.9	6.57	35	230	1.3	17.1
24	B24	5282.0	8.25	35	289	1.3	17.9
25A	B25A	205.8	0.32	35	11	1.3	14.6
25B	B25B	972.1	1.52	35	53	1.3	14.7
26	B26	376.1	0.59	35	21	1.3	13.8
27	B27	830.7	1.30	35	46	1.3	13.2
28	B28	223.4	0.35	35	12	1.3	12.4
29A	B29A	1578.1	2.46	35	86	1.3	14.8
29B	B29B	440.3	0.69	35	24	1.3	15.2
30	B30	1153.0	1.80	35	63	1.3	14.1
31	B31	1467.8	2.29	35	80	1.3	13.1
32	B32	1812.7	2.83	35	99	1.3	13.0
33	B33	2323.9	3.63	35	127	1.3	13.6
34	B34	711.3	1.11	35	39	1.3	17.0
35	B35	172.9	0.27	35	10	1.3	13.0
36	B36	603.3	0.94	35	33	1.3	14.0
37	B37	390.2	0.61	35	21	1.3	16.4
38	B38	1955.2	3.05	27	82	1.0	17.2

-- did not contribute to the Basin Rule evaluation or not applicable



Legend:

35	Csub = Allowable Discharge Coefficient in CSM
CSM	Cubic Feet per Second per Square Mile
*	Sub-basin NOT included in Rule

N

Scale 1:144,000

0 10000 20000 30000 40000 Feet

Source:
Land Boundary Information System (www.labins.org)
The most up-to-date or based on the 1994 DOQQs
State Plane Projection; NAD 83 Datum; In Shape File FORMAT for:
West Palm Beach 2 SE, Delta, Rivera Beach, Loxahatchee, Palm Beach Farms,
Palm Beach, Loxahatchee SE, Greenacres City, Lake Worth, Florida

bpc GROUP

TBE GROUP

	NAME	DATE
DESIGNED BY		
DRAWN BY		
CHECKED BY		
APPROVED BY		08/13/04
FILE NAME: FL02006-TM4-FIGURE 4-1.APR		

I hereby certify that this document was prepared by me or under my direct supervision and that I am a duly registered Professional Engineer under the laws of the State of Florida.

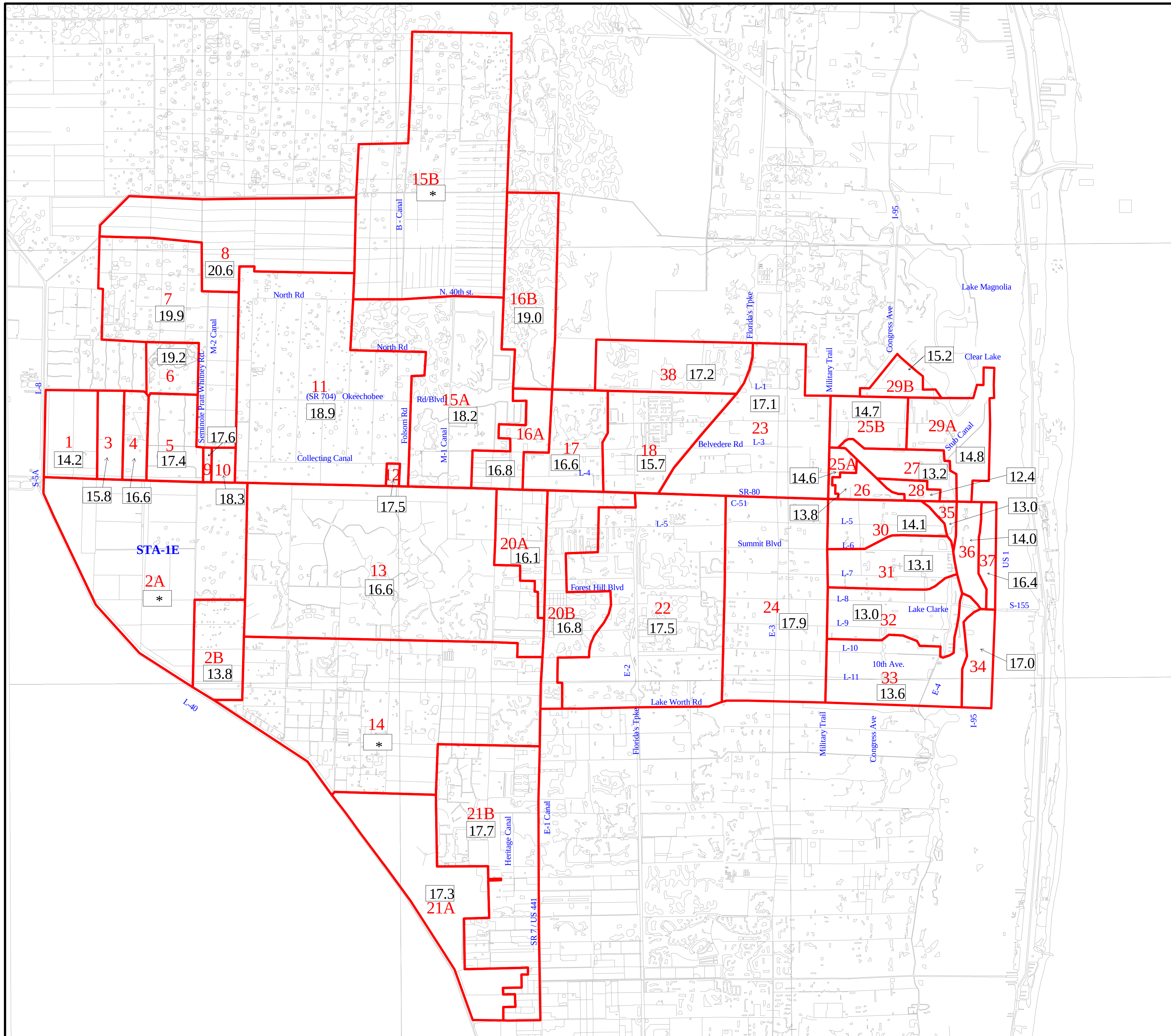
SIGNED NA
NAME
DATE REG. NO.

DISCHARGE COEFFICIENTS FOR THE SUB-BASINS OF THE C-51 BASIN IN PALM BEACH COUNTY, FLORIDA [FIGURE 41-8 (REVISED 2004)]

Reevaluation of the C-51 Basin Rule
Technical Memorandum #4: Rule Development
South Florida Water Management District, Contract No. C-13412

FIGURE 4-1

FILE NUMBER FL02006 SHEET___ OF___



Legend:

13.1	Peak Flood Stage in ft-NGVD during a 1-in-100 year Storm Event (Minimum Floor Elevation)
*	Sub-basin NOT included in Rule

N

Scale 1:144,000

0 10000 20000 30000 40000 Feet

Source:
Land Boundary Information System (www.labins.org)
The most up-to-date or based on the 1994 DOQQs
State Plane Projection; NAD 83 Datum; In Shape File FORMAT for:
West Palm Beach 2 SE, Delta, Rivera Beach, Loxahatchee, Palm Beach Farms, Palm Beach, Loxahatchee SE, Greenacres City, Lake Worth, Florida

bpc GROUP

TBE GROUP

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

	NAME	DATE
DESIGNED BY		
DRAWN BY		
CHECKED BY		
APPROVED BY		08/13/04
FILE NAME: FL02006-TM4-FIGURE 4-2.APR		

I hereby certify that this document was prepared by me or under my direct supervision and that I am a duly registered Professional Engineer under the laws of the State of Florida.

SIGNED NA
NAME
DATE REG. NO.

PEAK FLOOD STAGE (ft-NGVD) DURING A 1-IN-100 YEAR STORM EVENT AND MINIMUM FLOOR ELEVATION [FIGURE 41-9 (REVISED 2004)]

Reevaluation of the C-51 Basin Rule
Technical Memorandum #4: Rule Development
South Florida Water Management District, Contract No. C-13412

FIGURE 4-2

FILE NUMBER FL02006 SHEET ___ OF ___

4.2 BASIN RULE LANGUAGE

In accordance with the scope of work for this task (Task 4), we attended the public meeting with the District staff. Based on the outcome of the public meeting, the proposed new Basin Rule language at the time of this publication (September 2004) includes the following. Figures 41-8 and 41-9, referenced in the rule language below, correspond to figures presenting the same information as Figures 4-1 and 4-2 in this report.

> 40E-41.263 – Conditions for Issuance of Environmental Resource and Surface Water Management Permits in the C-51 Basin.
>
> The following criteria shall apply:
>
> (1)(a) The allowable discharge shall be based upon the post development discharge rate not exceeding the rate as depicted on Figure 41-8 during a design storm of a 10-year, 3-day duration. The allowable discharge rate shall be calculated by the formula:
>
> $$Q = (C_e)(A/640)$$
>
> Where,
>
> Q = allowable flow in cubic feet per second (cfs);
> A = project size in acres;
> C_e = discharge coefficient under design conditions
>
> (b) This criteria is not intended to limit inflows to the C-51 canal to the rates specified in subsection (a) above during non-flood conditions. Discharge capacity during non-flood conditions shall be considered on a case-by-case basis pursuant to the "Basis of Review for Environmental Resource Permit Applications Within the South Florida Water Management District" (Basis of Review), incorporated by reference and Rule 40E-4.301, Florida Administrative Code, (Conditions for Issuance).
>
> (2) Finished building floor elevations shall be above the most restrictive of the following:
>
> (a) the 1-in 100-year, 3-day storm elevations as determined by peak flood stages in the C-51 Basin as depicted in Figure 41-9, or
> (b) the Federal Flood Insurance Rate Map, or
> (c) the on-site stage created by a 100-year, 3-day storm event assuming no off-site discharge.
>
> (3) No net encroachment into the floodplain shall be allowed. Any water storage volume removed from the floodplain must be accommodated by an equal volume of open storage compensation. Water Storage volume shall be computed by utilizing Figure 41-9. For the purposes of this part, the minimum volume of water

which must be accommodated shall be that quantity equal to the volume of water stored below the level shown in Figure 41-9 and above the existing grades. Compensation for any reduction in soil storage shall also be accommodated.

(4) All criteria in the Basis of Review which is incorporated by reference in Rule 40E-4.091, F.A.C., (Environmental Resource Permits, Publications, Rules and Interagency Agreements Incorporated by Reference).

(5) Projects within the C-51 Basin shall provide one-half inch of dry retention/detention pretreatment as part of the required retention/detention.

Specific Authority 373.044, 373.113 FS. Law Implemented 373.085, 373.413, 373.416 FS. History – New 5-15-87, Revised __-__-2004.

This proposed language includes consideration of additional Best Management Practices for the entire C-51 Basin for water quality improvement. The original Basin Rule in 1987 included this for the western basin because of the concerns for the quality of water entering the Water Conservation Area 1. During this rule reevaluation process concerns were expressed by local representatives over the potential impacts of new development on the Lake Worth Lagoon. The federal improvement project will greatly improve the quantity, timing and delivery of runoff to the Lagoon. By extending the extra pretreatment criteria to new projects in the eastern basin, the Lake Worth Lagoon can also benefit from improved water quality over time.

Note: The proposed Basin Rule language described above was in the rule development process at the time of this report preparation in September 2004. Please refer to SFWMD's Environmental Resource Permit Information Manual Volume IV for the final adopted and official C-51 Basin Rule. For specific sub-basin or guidance information, contact District regulatory staff.

APPENDICES

APPENDIX A
Supplemental Information and Response to Comments

Appendix A-1
Supplemental Information Relevant to TM #1
Process for Construction of DTM Using LIDAR Data

A Digital Terrain Model (DTM) of the C-51 basin was developed using the data provided by the South Florida Water Management District (SFWMD). The SFWMD provided TBE with spot elevations from multiple agencies in various formats, such as:

- Lidar elevation points – United States Army Corps of Engineers (USACE)
- Lattice w/elevation in pixel – Palm Beach County
- Interpolated elevation points – SFWMD

There were some significant differences between the USACE and Palm Beach County LIDAR data sets. The Palm Beach County data set was generally much higher than the USACE data set. The District and consultants discussed options for marrying the two sets into one cohesive DTM for the basin: adjustment of one set to match the other, additional survey work, build separate DTMs, etc.

Since the USACE data set covered approximately 80% of the basin and the County data set only covered 20% it was felt that the most technically appropriate action would be to adjust the smaller data set to mesh with the larger set. An additional reason to do this is that the USACE data set was used for detailed design of the federal facilities that will be modeled. The procedure for adjustment, after SFWMD concurrence, would be to compare the data from the overlapping boundaries and compute an appropriate adjustment factor to apply to the County data set.

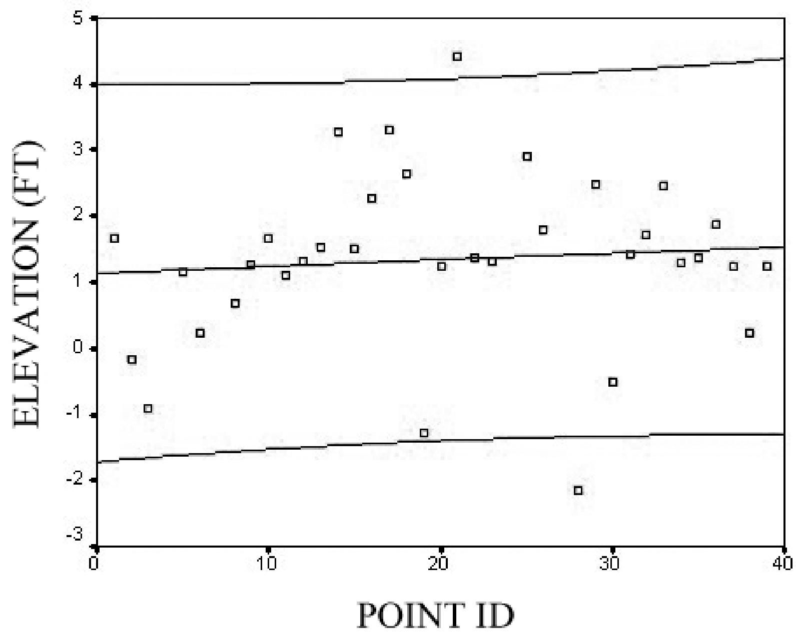
The other area of concern was a data gap in the USACE set in the Loxahatchee Groves area on the north side of C-51. One advantage is that this area is relatively homogeneous and flat such that a straight interpolation across the gap will probably only be off by a few tenths of a foot.

These two recommended adjustments to the data for construction of the DTM were reviewed and given concurrence by the District.

The original data and final deliverables are in Stateplane Florida East (NAD83). The data was processed using Environmental Systems Research Institutes (ESRI) ArcINFO software. The SFWMD noted at the kick-off meeting that the Palm Beach County elevations appeared to be approximately 1 to 2 feet higher than the USACE elevations. The SFWMD requested that TBE examine the differences between the two data sets and perform a comparative statistical analysis to determine the necessary adjustment to combine the two datasets together. The process is described below.

A sample of forty points was taken documenting the spot elevation differences between the USACE and Palm Beach County spot elevation dataset overlap in the southeast quadrant of basin C-51. A linear regression statistical analysis was performed using the statistical program SPSS by creating a scatter plot of these elevation differences, as shown below, to see which data points fell outside of 2 standard deviations from the best-fit line of the data points. This approach minimizes bias when performing a statistical analysis. The mean difference between the USACE and Palm Beach County spot elevations was estimated to be 1.25, meaning the Palm Beach County elevations were on average higher than the USACE elevations by 1.25 feet.

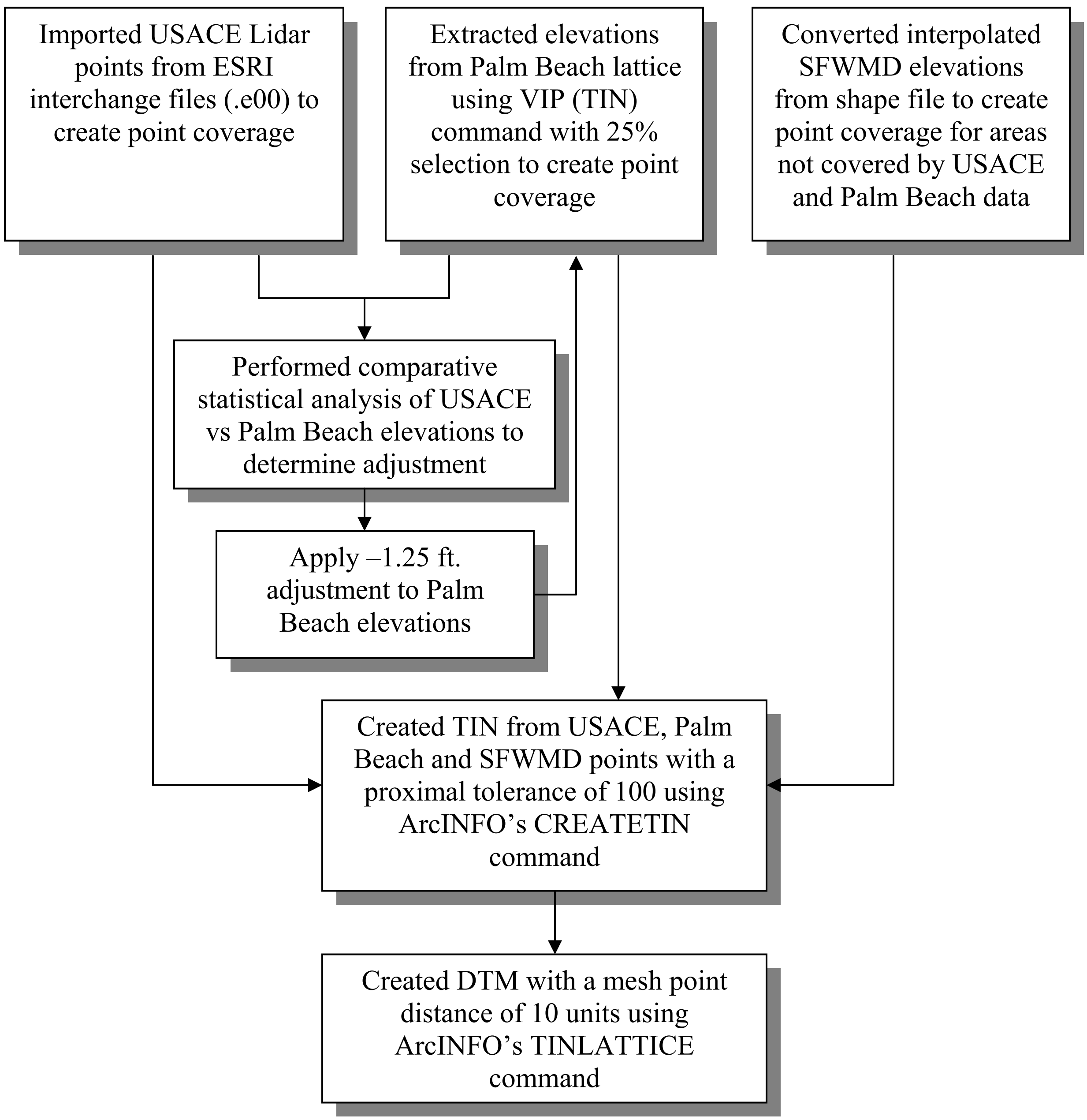
Figure 1 - SPSS Scatter Plot and Linear Regression Output



Note: The line near elevation 1 represents the best-fit line through the data points, while the curves above and below it represent 2 standard deviations from the best-fit line. The data points falling outside of 2 standard deviations were considered as outliers and omitted from the statistical analysis.

The general procedure used to create the DTM was to first import the various data sources into a compatible format, which could be used to create a Triangulated Irregular Network (TIN). The chosen format was ESRI point coverages. The next step was to perform a comparative statistical analysis to determine the most suitable adjustment required for the Palm Beach points. An adjustment of –1.25 feet was estimated and applied to the Palm Beach elevations, as discussed above. Once the data was in a compatible format and the necessary adjustments were made, a TIN was created using ArcINFO's CREATETIN command from the USACE, Palm Beach, and SFWMD data. From the TIN, a DTM was created using ArcINFO's TINLATTICE command. The following flowchart illustrates the DTM creation process.

DTM Creation Flowchart



Appendix A-2
Response to Comments Relevant to TM #2
(Comments Dated November 6, 2003)

General Comments

In regards to the storage areas that connect to the canal network via pumping stations, it appears that the pump performance curves entered into the model are not really pump performance curves but, rather, appear to be fictitious curves that enable the pumped outlets to discharge at their permitted rates or capacities. This may or may not lead to acceptable estimates of the actual pumping rates, depending on the nature of the pumping station as well as the TDH the station is pumping against. In contrast, it is understood that pump performance curves may not be attainable for a number of the pumps in the model. For which pumping stations are performance curves available? How sensitive are computed stages and flows at calibration sites to the pumping rates assigned to these outlets?
Response: No pumping curves were available. Insignificantly sensitive; the pumping rates are so small in capacities compared to runoff volume and discharge along C-51 canal; discharge is only 1" in 24-hr, where the total runoff is in the range of 7" to 8" in 24-hr.

How were storage areas assigned to channel locations along the various tributaries of C-51 (excluding M-2)? In many instances the storage area representing a given subbasin was connected to the main channel near its downstream end (e.g. the connection of S 20B to E-1S). Ideally, this location should represent some sort of "hydraulic centroid" of the basin. Incorrect placement of these connections could lead to errors in the outflow hydrographs of the subbasins.
Response: Hydraulic centroids are appropriate for undeveloped/unimproved land, and for local scale modeling. However, this basin is full of engineered channels on a grid pattern, and it was not the intent of this study to have a detailed sub-basin scale modeling.

It is not clear what the sources of canal cross sectional data were for many of the modeled reaches. In particular, Part V, Suppl 54 only mentions data for the C-51 canal itself. What were the cross sectional data sources for the other canals? When were these surveys conducted? Where do the data now reside, and in what format (apart from the model data sets)? Apart from Part V, Suppl 54 and the previous FEMA model, no specific field surveys were cited. What QA/QC process did these surveys go through?
Response: Page 32, 1st paragraph provides some details and the sources of all the lateral and equalizer canal cross-sections used in the model. The primary source is LWDD as indicated in the report. The field survey details and QA/QC process of the surveys were beyond the scope of this study.

Similarly, the specific data source for each culvert and bridge should be documented. In each subbasin, it would be useful to know the elevations at which discharges to the surrounding basins could occur.

Response: The specific data sources for each culvert/bridge are documented on Page 32 under the section “Bridges”. A CD containing the DTM results was delivered as part of TM #1, which can provide elevation related information for the basin.

Some of the subbasins lacking a primary outlet structure were connected to their outfall channels with large fictitious weirs. While it is understood that some mechanism for connecting the subbasins to the channels is needed, please explain how the properties of these weirs were determined.
Response: The fictitious weir widths were based on equivalent canal widths.

In cases where a culvert or bridge was not included in the model, some desktop calculations should be included in the report to demonstrate that head losses within the expected range of flows will be negligible.
Response: We are not aware of any culverts or bridges along C-51 that were not included in the model.

Sub-Basin / Sub-Area (SA) Specific Comments

SA #1: The basis for the pump performance curve needs to be documented.
Response: None of the pumps has performance curve; in its absence, all pumps are specified to pump at 100% of its capacity for head of 1’ to 10’.

SA #2A: 3 pump stations were input to the model while the schematic drawing provided with the report only shows 1.
Response: Figure 2-1 (Storm Water Conveyance System) and Figure 3-2 (Nodal Diagram) show all 3 pump stations correctly as modeled and as they existed during the calibration period.

SA #3: The basis for the pump performance curve needs to be documented.
Response: Please refer to Response for SA #1.

SA #4: The basis for the pump performance curve needs to be documented.
Response: Please refer to Response for SA #1.

SA #5: Please explain how the culvert entrance and exit loss coefficients were determined. Based on the weir coefficient of 2.6, it appears that the weir included with the culvert pertains to the embankment in which the culvert was installed. The top elevation of 19' seems too high since it is about 1.5 feet above the surrounding grade. According to the permit file, an 84" riser with flash boards installed up to elevation 15.0 exists just upstream from the culvert. This weir is not included in the model. Additionally, the culvert invert was input as 13.5 feet; this is much higher than the permitted elevation of 8.0. Please explain.
Response: The loss coefficients were determined on the basis of our practical experience at other locations throughout the State of Florida. The discharge at this location is weir controlled, not culverts. Therefore, the culvert invert is not a controlling factor.

M-2 Canal: The cross sections input to the model depict the channel as being much shallower than expected; namely, 3 - 5 feet within the main channel. Is this correct? At certain cross section locations (e.g. river sta 2287) the top of bank stations appear to be located well within the main channel. Please clarify. Why was a 70 ft weir placed at the downstream end instead of the existing embankment with 3 FDOT (8' x 8' box) culverts?
Response: Yes, the channels are shallower and correctly input to the model. The culverts with risers located upstream are the boundary control, which totals to an equivalent width of 70 ft.

SA #7: The primary outfall structure entered into the model is comprised of 1 6' x 6' gated weir with a crest elevation of 13. This does not agree with the 2 gates described in TM #2. Moreover, neither the model input nor TM #2 appear to agree with the outfall structure data contained in the permit file. Please clarify.
Response: Please refer to Table 2-2 on Page 11 of TM #2, which shows 2 culverts (not gates) controlled by 1-6' wide sluice gate; the modeled information agrees with the physical condition at the site.

SA #8: The culverts located downstream of the outfall weir are missing. In addition, the water control plan for SWCD indicates that a pump station is located at the outfall as well. How was this pump station operated during Irene?
Response: This is not a discharge pump station; it's an irrigation pump, and is not relevant to the present study.

SA #9: The discharge culverts located immediately downstream of the outfall weir are missing.
Response: Please refer to Table 2-2 of TM #2; discharge is weir controlled – not culvert.

SA #10: The permit file indicates that the outfall structure for this subbasin is a 36" riser and pipe that discharges into a 100' long 52 " culvert under U.S. 98. The model input only includes a 9' weir at this location. Please clarify. Also, Tables 2-2 and 3-7 of TM #2 provide conflicting information on the attributes of this structure.
Response: Both the Tables (2-2 and 3-7) say the structure is weir. The width of the weir was estimated at 9 ft by considering a riser diameter of 3 ft.

SA #11: Based on the permit file, gate 'A' consists of a aft wide sluice gate installed in a 72" diameter culvert. This culvert apparently discharges into three 66" DOT culverts that pass underneath U.S. 98 to C-51. The structure 'A' input to the model does not resemble this. Similar statements can be made regarding structure 'G'. Why is 2.7 used as a coefficient for a sharp crested weir? I'm assuming that the 50' wide, broad crested weir was included to handle overtopping of the structure. If so, the crest elevation of 18.0 may be too low. Also, this weir should discharge to somewhere outside of the model domain, not into C-51. The 'D' structure is entered into the model as a sluice gate mounted on a broad crested weir while, in

reality, it is an ogee spillway with radial gates. Please explain why a different structure is used here. Also, why is the gate opening assumed to be only 2 feet high?
Response: The model input is based on the practical and correct information received from and verified correct by the Loxahatchee Grove. This is summarized in Table 2-2.

SA #12: The discharge structure should be a 2 ft wide sharp crested weir while the mode depicts it as a 3 ft wide broad crested weir. Also, the 250 ft outfall culvert located immediately downstream of the weir was not included in the model.
Response: Width was weir equivalent of the riser = π. R = 3 ft.

SA #13: It is my understanding that the two Acme pump stations discharging into C-51 commence pumping when their headwater elevations reach 12.1 feet and turn off when they drop to 12.0 feet. Also, there are gravity driven components to these structures that lower the headwater stage from 12.0 to 11.0. In contrast, model input depicts these pump stations turning on at 12.0 and turning off at 11.0. Please clarify. There are two open channel connections between the eastern portion of Acme basin A and C-51. Both of these were omitted from the model. Please explain.
Response: The model input is based on the practical and correct information received from and verified correct by the ACME A representing Wellington.

SA #15A: What is the basis for the 22 ft weir used to connect this basin to the M-1 channel? In reality, there are a number of open-channel connections between developments in this subbasin and the M-1 canal.
Response: Based on the main segment of Challenger connecting to M-1; the grid of channels connecting to M-1 may be included in detailed local scale modeling that is beyond the scope of this Basin Rule study.

It appears that all inflow to M-1 was directed to somewhere near the downstream end of the channel. This could distort the shape and timing of the resultant outflow hydrograph from M-1 into C-51 since channel routing only occurs over a small length of M-1. I don't believe that the hydrologic techniques used by HEC-HMS to compute the subbasin runoff hydrograph are accurate enough to account for this. At a minimum, subbasin 15A should be connected to M-1 at some hydraulically based midpoint of M-1 so that the effects of channel routing through M-1 can be better simulated in the model. Alternatively, and better yet, this subbasin could be further divided (if possible) into a few smaller storage areas each with an appropriate connection to M-1. I would suggest treating Lake Challenger as an in-line storage area with 2 outlet reaches connecting to C-51. One of these reaches would depict the rest of M-1 with the Amil gate as an in-line structure while the other would contain the two 72" culverts (with weirs) located under U.S. 98. The invert elevation of the 2 culverts located downstream of Lake Challenger may be incorrect. It was specified in the model as 13.42' while the permit file indicates 10.78'. Which is correct? If the former is used in the model, the upstream weir elevation would then be 16.42' since the bottom 3 feet of each culvert is blocked. This elevation seems much too high. The latter would imply 13.78', which is much closer to the target control elevation of 13.5'. Furthermore, blocking off the bottom half of each culvert in

the model implies that only half of the cross sectional area can convey water while, in reality, the entire (or nearly so) culvert can convey water downstream of the weir. How much error will this introduce for higher flows? The broad crested weir used to depict overtopping of the culverts will not discharge water into C-51, as implied in the model input. With a crest elevation of 21.5, however, this is most likely inconsequential.
Response: HEC-HMS does not do hydraulic routing (canal or river simulation) as indicated in TM #2 (please refer to Section 3.1 and Figure 3-1). The culverts connecting Lake Challenger to C-51 (refer to Nodal Diagram, Figure 3-2) are correctly modeled as given in Table 2-2.

SA #16A: The three 190' culverts are missing from the outfall structure.
Response: Weir is the discharging control, not the culvert.

SA #17: The junction of E-1N with C-51 appears to be at the wrong location - it should be located just downstream of the mall entrance bridge.
Response: Please refer to Figure 3-2, which represents the correct location as verified by the LWDD. Figure 3-2 is the correct representation of the model used for the calibration.

SA #18: Does this whole subbasin drain into E-2 via the FDOT culvert mentioned?
Response: Yes.

SA #20A: According to TM #2, this subbasin should be connected to LWDD S-4. Instead, it is connected directly to C-51. Please clarify.
Response: It is connected and modeled correctly; the culverts are on S-4, a feeder canal directly connected to C-51.

SA #20B: The manner in which this subbasin is connected to E-1 is unclear. The junction of E-1S with C-51 is incorrectly located - it should be just downstream of the Mall Entrance bridge, assuming its location is correct.
Response: This sub-basin is connected to E-1 as an open channel connection through a fictitious weir as specified in Table 3-7. The junction is correctly located (verified by the District and LWWD), and is connected and modeled correctly as shown.

SA #21A: The permit file indicates an overflow elevation of 18.5' while 19' is used in the model. Also, how were the dimensions and discharge coefficient for the weir determined?
Response: Model used stage and dimension from DTM.

SA #22 – 24: The basis for this subbasin's connection to E-2 is unclear.
Response: Please refer to Table 3-7; scope does not include detailed simulation of all laterals and tertiary channels.

SA #25A: The two 8 x 10 box culverts under U.S. 98 were omitted from the outfall structure, although head losses through these should be negligible. In the model, the outfall appears to be on the wrong side of Military Trail.

Response: It is on east side of Military Trail, which is the correct location.

SA #26: The culverts located downstream of the pump station were omitted. The outfall appears to be on the wrong side of Kirk Road. The actual pump performance curves should be used in the model, if available. What is the basis for the performance curves used?
Response: Pump controls over the culverts. The outfall is correctly placed. Pump performance curves are not available; in the absence of performance curves, all pumps are specified to pump at 100% of its capacity for head of 1' to 10'.

SA #27: Is subbasin 27 supposed to discharge directly into the C-51 canal? According to the permit files, it historically discharged into the stub canal and was later (or maybe will in the future) rerouted to a detention basin within subbasin 28. Please verify the correct location of this pump station's discharges during the calibration POR.
Response: This is correctly modeled as documented in TM #2; please refer to the PBIA plan (delivered to the District in the Appendices of TM #1).

SA #28: Is this subbasin directly connected to C-51 (via the box culvert) in reality? Is the FDOT structure S-199 located within this subbasin? If so, was it present during the calibration POR? Our experience suggests that the rating curves computed by UNET for large culverts such as the 40 x 8 FDOT culvert may contain significant errors. This can be verified by computing the rating curves manually and then entering them into the model. Alternatively, this culvert should be included in the model as a tunnel (if possible).
Response: Yes, the sub-basin is directly connected to C-51. There is no Tunnel Option in the latest version of HEC-RAS (used for this study).

SA #29A: TM #2 says the weir crest elevation for this subbasin's outfall is 9' while 11' was used in the model. How were emergency inflows from Clear Lake, if any, accounted for?
Response: The model uses the verified information. The model does not have special treatment for emergency inflows, if any.

SA #30: What is the basis for the weir located near the end of L-5?
Response: Open channel connection, through a fictitious weir as specified in Table 3-7. The controlling location of discharge from a lateral/tertiary canal to C-51 is near the confluence (upstream of the junction).

SA #31: What is the basis for the weir located near the end of L-7 and the weir connecting this subbasin to L-7?
Response: Please refer to Response for SA #30.

SA #36: The outfall weir is only 3 feet instead of the 30 feet specified in TM #2. The long outfall culverts should be modeled as tunnels.
Response: It was initially modeled as 30'wide weir with crest @10'. However, the discharge was significantly higher than experienced in the past by the County. Therefore, the

weir width was reduced instead of raising the crest elevation to control the flow within the high range that the County had historically experienced. There is no Tunnel Option in HEC-RAS. Instead, they have been modeled as long culverts.

SA #38: The discharges from this subbasin should be routed through the outfall gate and culverts, down the turnpike canal and through the connecting culvert to C-51.
Response: A detailed sub-basin scale simulation and calibration was beyond the scope of this study.

C-51 Channel: The bridge located at station 1057+40 is missing. Does the U.S. 441 bridge have only 1 of its piers located in the main channel? Why is S-155 spillway classified as a broad crested weir rather than an ogee spillway?
Response: We have incorporated all the bridge-sections that were made available to us. All pier and section information for the US 441 bridge were correctly represented in the model as they were obtained from USACE/FEMA data sets. The S-155 was classified as such for convenience only; it could be simulated using ogee spillway but with a higher discharge coefficient; it is insignificantly critical as the calibration was performed to measured discharge values.

Appendix A-3
Response to Comments Relevant to TM #2
(Comments Dated September 24, 2003 addressed to SFWMD)

As we discussed in phone conversations earlier today, I have a question about the 'Peak Factor" used in the C-51 Basin hydrologic model. As you know, the C-51 Basin is being modeled with the HEC-HMS for the hydrology and HEC-RAS for the routing of the drainage system. The SCS Curve Number (CN) method is being used to generate the basins' runoff hydrographs. The SCS CN method in HEC-HMS has a peak factor of 484. The HEC-HMS Technical Reference Manual Ch. 6 page 58 explains the use of equations (6-8), (6-9), and (6-10). The Consultant used Equation (6-10) to relate the basin's time of concentration to the lag time that is required by HEC-HMS. The Technical Reference Manual also explains the method to calculate the time of concentration which the Consultant followed accurately as indicated in the C-51 Basin Modeling Report.

SFWMD, in the ERP manual, recognizes that the peak factor of 484 may not be appropriate for the South Florida Water Management District as it is indicated in page C-II-2, which indicates the following:

- For slopes less than 5 feet/mile, a value of 100 for a peak factor is recommended;
- And for slopes greater than 5 feet/mile, a value of 286 is recommended.

Perhaps you can get an explanation for this discrepancy from the Consultant and relay back to me. Thanks.

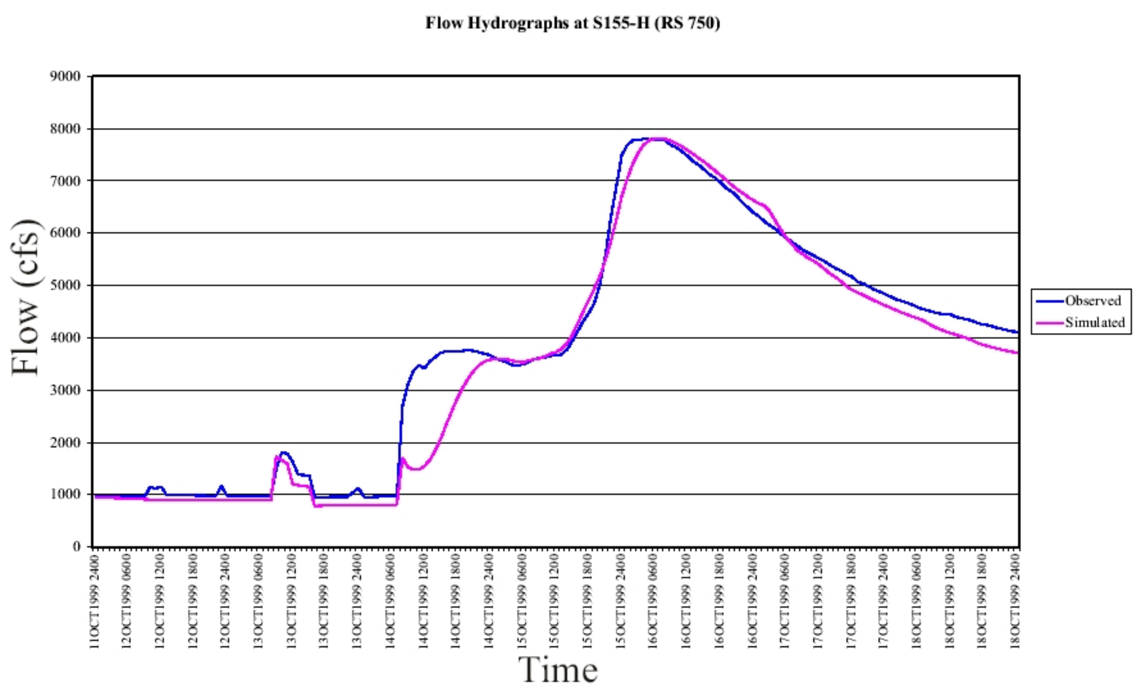
Response: Concern was expressed by reviewers as to the appropriate utilization of Unit Hydrograph Peak Rate Factors in the model calibration phase of this study. The calibration for the hydrologic modeling was accomplished with the HEC-HMS hydrologic model.

Key calibration factors in this model was the Runoff Curve Number and Time of Concentration/Lag Time values for each sub-basin, and of course for the watershed model as a whole. Within the HEC-HMS computer model there is no option for inputting any other value for the peak rate factor than the SCS standard value of 484. There have been extensive studies in Florida over the past twenty years to develop a better understanding of the improved use of the SCS Unit Hydrograph Method for predicting peak rates from unimproved and "ungaged" watersheds. Some studies have even suggested values as low as 100 for extremely flat watersheds in the central portion of the state.

The C-51 watershed as modeled in this study is neither extremely flat nor an ungaged watershed. The sub-basins are predominately fully connected with lateral canals and other stormwater collection systems that increase, well above natural background, the rates at which water can arrive at the discharge points. The net effect is that the runoff hydrographs for these developed tributaries will appear more like the standard hydrograph assumed in the SCS methods.

During the calibration process an iterative process was applied to the sub-basin hydrologic parameters that attempted to identify the best fit values for both the runoff curve numbers, in matching the volumes of runoff generated, and the time of concentration/lag times, in matching the peak rates of runoff observed during the calibration event. It is important to note that in the key equation for the SCS Unit Hydrograph method there are only two variables that can be changed, the peak rate factor or the time to peak. In matching the observed peak runoff rates during the calibration process the peak rate factor in the HEC-HMS model is kept constant at 484 and the time to peak is allowed to vary until an acceptable match is achieved. For the calibration event the observed peak discharge at the outlet was 7805 cfs versus the model predicted peak discharge of 7815 cfs, less than a 0.2% error! See the attached measured versus modeled hydrograph for excellent correlation that we were able to produce using the inherent limitations of the HEC-HMS program.

Based upon this information and the combined experience of our modeling team we feel that manipulating the peak rate factor within the HEC-HMS model would have influenced the only other variable, the time of concentration/lag time, but would not have produced a better watershed simulation model. The negative effect is that we would have undermined the national credibility of the public-domain HEC-HMS program itself by violating its internal coding, thus making void the use of its manuals and standards.



Appendix A-4
Response to Comments Relevant to TM #3
(Comments Dated January 5, 2004 and February 25, 2004 addressed to SFWMD)

See following pages.

MOCK • ROOS
ENGINEERS • SURVEYORS • PLANNERS

January 5, 2004

Sue Lynn Dignard
South Florida Water Management District
3301 Gun Club Road
West Palm Beach, FL 33406

Ref. No. W3100.01
Subject: C-51 Basin Rule Re-Evaluation Study
Sub-basin 29B

Dear Sue Lynn:

Pursuant to our telephone conversation regarding sub-basin 29B of the C-51 Basin, I have been in contact with the City of West Palm Beach on the details of the control structure for this sub-basin. On December 31, 2003, I received plans for the structure. The plans are dated May 1993 and indicate that the structure has six six-foot wide gates with a crest elevation of 11.0' that discharge into a double 8'x 10' box culvert. A copy of the pertinent details from these plans is attached. On January 2, 2004, I inspected the control structure and took the attached photos. The existing structure plans is consistent with the existing structure. During the inspection water was flowing over the top of the six gates.

In South Florida Water Management District's (SFWMD's) Re-Evaluation of the C-51 Basin Rule, Technical Memorandum No. 3 provides information on the structure for sub-basin 29B. The structure is noted as six six-foot wide weirs with gates with no crest elevation identified. Computer model may have used a crest elevation of approximately 17.0' NGVD since the discharges from the structure range from 12.0 to 20.0 cfs for the 10-year and 100-year rainfall events, respectively. The stages for the sub-basin are represented as 16.6' for the 10-year and 17.2' for the 100-year storm event. Incorporating the correct weir crest elevation of 11.0' and the box culverts into the analysis will provide increased discharges from this sub-basin and lower stages for the 100-year storm event. This modification could be incorporated in SFWMD's proposed revised rule for C-51 Basin.

It is recommended that SFWMD coordinate with the consultant (Tampa Bay Engineering) to re-evaluate sub-basin 29B only. Once SFWMD has the new information, it is advisable that a meeting be set up between SFWMD and the City of West Palm Beach to discuss the results and any appropriate modifications to the 100-year peak flood stage for this sub-basin in a revised C-51 Basin Rule.

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Mock, Roos & Associates, Inc.
5720 Corporate Way, West Palm Beach, Florida 33407-2066, (561) 683-3113, fax 478-7248

If you have any questions or would like to discuss this information further, please call me at 683-3113, extension 231.

Sincerely,

MOCK, ROOS & ASSOCIATES, INC.

Alan D. Wertepny, P.E.
Senior Project Manager

ADW:jeh
Enclosure
Copies: Charles Langley (w/encl.)
Ken Rearden (w/encl.)
Alan Hall (w/encl.)
Thomas A. Biggs
Anne Capelli

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February 25, 2004

Sue Lynn Dignard
South Florida Water Management District
3301 Gun Club Road
West Palm Beach, FL 33406

Ref. No.: W3100.01
Subject: South Florida Water Management District C-51 Basin Rule Re-Evaluation Study – Subbasin 29B

Dear Sue Lynn:

Pursuant to my telephone conversation with your consultant for the above referenced Project, I have researched the computer modeling Mock•Roos conducted for the City of West Palm Beach on the Stub Canal. Latest model used the Chan program for both hydrology and hydraulics. Our analysis of discharges and stages at the City's Control No. 4 which is the discharge structure for Subbasin 29B in your study for the C-51 Basin Rule. The results are as follows:

Frequency (year)	Stage (feet ngvd)	Peak Flow (cfs)
5-1 day	14.4	758
10-3 day	14.6	766
25-3 day	14.9	751

Please note that this analysis used weir flow for the control structure and took in account for tailwater conditions. Analysis did not include the double 8x10 box culvert associated with the weir structure. If considered, the impact of the box culverts would tend to decrease the discharge rate and increase the stage. However, the stage increase could only be slightly above the top of the structure which is at an elevation of 15.1'.

It is unrealistic that the discharge and stage in Subbasin 29B for the 100-year/3-day event to be on the order of 27 cfs and a stage of 17.2' ngvd as contained in the re-evaluation of the C-51 Basin Rule Technical Memorandum #3.

As noted in our January 6, 2004 letter to you, we recommend that Subbasin 29B be re-evaluated, that a meeting be set up between SFWMD and the City to discuss the results prior to finalizing the 100-year peak flood stage for the revised C-51 Basin Rule. My understanding is there will be a public workshop in April regarding the C-51 Basin Rule. Hopefully we can have this meeting in early March.

If you have any questions please contact me at 561-683-3113 extension 231.

Sincerely,

MOCK, ROOS & ASSOCIATES, INC;

Alan D. Wertepny, P.E.
Senior Project Manager

ADW:cbm
Copies: Ken Rearden
Charles Langley
Bijay K. Panigrahi

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Response: After a discussion on March 9, 2004 with the District personnel (Suelynn Dignard, Tony Waterhouse, and Damon Meiers), Personnel from Mock Roos & Associates (Alan Wertepny and Ann Capelli), Steven Sarley from City of West Palm Beach, and Alan Hall from CSA Group representing TBE Group, we decided to revisit the model to determine the cause for low discharge (and hence high stage) from sub-basin 29B. The results of the re-investigation are summarized below, and the results have already been incorporated into the revised TM #3 (July 2004).

The outfall structures for the sub-basin 29B consists of six six-foot wide weirs with gates, thus a total width of 36 feet. In the model, this is represented by one 36-foot wide weir (since flow through the structure is always over the top of the gates) with crest elevation at 11.0 ft-NGVD and bank elevation of 15.5 ft-NGVD. This is consistent with the information provided in the referenced letter. The weir coefficient is specified at 2.7.

Initially, the maximum stage was specified at the top of the gate since the flow was expected to occur through the gate. However, the later information indicated that the flow is always over the top of the gate, and therefore acts like a weir with crest at 11.0 ft-NGVD. After several test runs for flow through structures, it was concluded that the oversight was on re-specification of the maximum headwater stage in the TM #3 model. The maximum headwater stage was set to 18 ft-NGVD. After such correction, all alternatives were re-simulated, and the results were documented in the revised TM #3. As a direct response to the comment, the simulation of 100-year, 72-hour storm event for Alternative A3 resulted in a discharge of 830 cfs through the structures from sub-basin 29B to sub-basin 29A. The corresponding simulated 100-year stages in sub-basin 29A and sub-basin 29B are 14.8 ft-NGVD and 15.2 ft-NGVD, respectively. As a measure of QA/QC, we have also compared the stages and discharges from these model runs at several sections (primarily at bridge sections) along the stub canal and C-51 canal downstream of stub canal with those from the previous model runs. The difference between the model results away from these two sub-basins is negligible.

Appendix A-5
C-51 Basin Rule Reevaluation Contract (C-13412)

Comments on Draft Deliverable #4

The comments listed below are compiled based on review of the draft deliverable #4 by the internal SFWMD Team (Part A) and the external Technical Review Team (Part B) for the C-51 study.

Part A: SFWMD Internal Review Team Comments

The following comments on the draft Deliverable #4 are provided by SFWMD's Internal Review Team for the C-51 study.

Comment A-1: Table of Contents, List of Figures:
- Figure 4-2: The "A" in the title of this figure listed in the List of Figures should be lower case "a".

Response: Revised as suggested.

Comment A-2: Page 4, Section 1.5:
- This paragraph reads awkwardly. Suggest rewording, similar to the following: "Several comments related to specific deliverables were received after TM #1 through TM #3 were accepted by the District. Responses to all such comments are presented here in Appendix A. Appendix A also includes supplemental information describing the process for construction of the DTM using LIDAR data."

Response: Revised as suggested.

Comment A-3: Page 22, Table 4-1:
- Sub-basin 28: 100-yr elevation for Sub-basin 28 should be 12.4 to be consistent with rule as currently being proposed.
- Sub-basin 35: 100-yr elevation for Sub-basin 35 should be increased to 13.0. Local knowledge and more detailed local studies suggest that until improvements are made within this sub-basin, 13.0 ft is a more appropriate 100-yr elevation.

Response: Revised as suggested. Figure 4-2 has also been revised accordingly.

Comment A-4: Page 25, Section 4.2:
- First Paragraph, Second Sentence: Please modify as follows: "Based on the outcome of the public meeting, the proposed new Basin Rule language at the time of this publication (September 2004) includes the following."

- Also please add the following sentence to this paragraph: “Figures 41-8 and 41-9, referenced in the rule language below, correspond to figures presenting the same information as Figures 4-1 and 4-2 in this report.

Response: Revised as suggested.

Comment A-5: Page 26, Section 4.2:

- Add a paragraph at the very end of this section: “Note: The proposed Basin Rule language described above was in the rule development process at the time of this report preparation in September 2004. Please refer to SFWMD’s Environmental Resource Permit Information Manual Volume IV for the final adopted and official C-51 Basin Rule. For specific sub-basin or guidance information contact District regulatory staff.”

Response: Revised as suggested.

Comment A-6: Appendix A:

- Title would be more appropriate as “Supplemental Information and Response to Comments”

Response: Revised as suggested.

Comment A-7: Appendix A.1:

- First sentence: Revise to “A Digital Terrain Model (DTM) of the C-51 basin was developed….”
- To be consistent with the report all references to the United States Army Corps of Engineers should be USACE. This appendix uses both COE and ACOE – all should be USACE. This applies to the text of the full appendix as well as the flow chart. Where Army Corps of Engineers is spelled out for the first time in the first bullet, add United States Army Corps of Engineers.
- Second Page: What is SPSS? Please spell out in the text.
- Third Page, flow chart: Some of the text in the boxes is cut off. Please adjust appropriately.

Response: Revised as suggested. SPSS is the name of a statistical software, which has been restated with better clarity.

Comment A-8: Appendix A.2:

- Second Page of Comments/Responses: Please change the “Specific Comments” heading in the middle of this page to “Sub-Basin / Sub-Area (SA) Specific Comments”.

Response: Revised as suggested.

Comment A-9: Appendix A.4:

- Appendix A.4 cover page: Change “Insert the PDF files (3 pages)” to “See following pages”
- Last page of this Appendix, Response, First Paragraph, Last Sentence: add “revised” before TM #3 (July 2004).

- Last page of this Appendix, Response, Middle of Last Paragraph: add "revised" as follows: "After such correction, all alternatives were re-simulated, and the results were documented in the revised TM #3".

Response: Revised as suggested.

Part B: External Technical Review Team Comments

The following comments are compiled based on review of the draft deliverable #4 by the external Technical Review Team for the C-51 study.

Comment B-1: Table 2-2a, Page 9, Sub-Basin 11:

- Please revise Table 2-2a (page 9) under Sub-Basin 11's Structure Description and Operations. Change "2-12' sluice gates" to "2-12' radial gates." Reviewer thought this had already been addressed, is it just a type-o?

Response: Revised as suggested.

Comment B-2: Rule Development:

- I continue to question having this rule, especially now that the C-51 Basin will have protection that is similar to other SFWMD Basins. My belief is based on equal protection under the law. In my opinion, a better position is to have similar rules for all SFWMD Basins.
- The study is flat pool. As such the intrabasin losses and differences are not included. We understood this from the start, however I do not believe finished floors should be set at the minimum as calculated unless the engineer is certain it applies. I know the rule says "minimum", but some engineers, regulators, or home owners may not understand the analyses. I do believe this is the appropriate stage and for the most part (see bullet 4 below) methodology to calculate equal compensation storage. I suggest a warning statement be added regarding intrabasin variations.
- In addition to bullet "2" above and because local criteria typically includes it, I recommend the following be added on page 25:

  "(c) … no off-site discharge, or

  (d) at least 12 inches above adjacent road crown."
- On small projects with high existing ground it is difficult to meet the rule as stated. I suggest an alternate calculation methodology be added to state the volume of runoff from a site after development must be equal to or less than the existing (data base is the year 2000) volume of runoff for the 100 year 3 day storm for the duration of the storm. The citation of the year 2000 is important because of the data base. The calculation being limited to the duration of the storm is needed because the calculated total volume of runoff is always increased for detention systems when impervious areas are added. Also, once the peak of the storm is passed, the bleed off volume does not affect flood elevations.

Response: *Comments will be considered by SFWMD during rule making.*

APPENDIX B
Design Storm Events for Basin Rule Development

Design Storm Events for Basin Rule Development

Time (hr)	72-hour Distribution			
	Cumulative percentage of peak one day rainfall (%)	Ordinate for Unit Hydrograph (in)	Ordinate for 10-yr Storm (in) (10.1 in)	Ordinate for 100-yr Storm (in) (16.3 in)
0	0.0	0.0000	0.0000	0.0000
0.25	0.2	0.0011	0.0113	0.0182
0.5	0.3	0.0022	0.0226	0.0365
0.75	0.5	0.0034	0.0339	0.0547
1	0.6	0.0045	0.0452	0.0729
1.25	0.8	0.0056	0.0565	0.0912
1.5	0.9	0.0067	0.0678	0.1094
1.75	1.1	0.0078	0.0791	0.1276
2	1.2	0.0089	0.0904	0.1459
2.25	1.4	0.0101	0.1017	0.1641
2.5	1.5	0.0112	0.1130	0.1823
2.75	1.7	0.0123	0.1243	0.2006
3	1.8	0.0134	0.1356	0.2188
3.25	2.0	0.0145	0.1469	0.2370
3.5	2.1	0.0157	0.1582	0.2552
3.75	2.3	0.0168	0.1695	0.2735
4	2.4	0.0179	0.1808	0.2917
4.25	2.6	0.0190	0.1920	0.3099
4.5	2.7	0.0201	0.2033	0.3282
4.75	2.9	0.0213	0.2146	0.3464
5	3.0	0.0224	0.2259	0.3646
5.25	3.2	0.0235	0.2372	0.3829
5.5	3.3	0.0246	0.2485	0.4011
5.75	3.5	0.0257	0.2598	0.4193
6	3.6	0.0268	0.2711	0.4376
6.25	3.8	0.0280	0.2824	0.4558
6.5	4.0	0.0291	0.2937	0.4740
6.75	4.1	0.0302	0.3050	0.4922
7	4.3	0.0313	0.3163	0.5105
7.25	4.4	0.0324	0.3276	0.5287
7.5	4.6	0.0336	0.3389	0.5469
7.75	4.7	0.0347	0.3502	0.5652
8	4.9	0.0358	0.3615	0.5834
8.25	5.0	0.0369	0.3728	0.6016
8.5	5.2	0.0380	0.3841	0.6199
8.75	5.3	0.0391	0.3954	0.6381
9	5.5	0.0403	0.4067	0.6563
9.25	5.6	0.0414	0.4180	0.6746
9.5	5.8	0.0425	0.4293	0.6928
9.75	5.9	0.0436	0.4406	0.7110
10	6.1	0.0447	0.4519	0.7293
10.25	6.2	0.0459	0.4632	0.7475
10.5	6.4	0.0470	0.4745	0.7657
10.75	6.5	0.0481	0.4858	0.7839
11	6.7	0.0492	0.4971	0.8022
11.25	6.8	0.0503	0.5084	0.8204
11.5	7.0	0.0515	0.5196	0.8386
11.75	7.1	0.0526	0.5309	0.8569
12	7.3	0.0537	0.5422	0.8751
12.25	7.4	0.0548	0.5535	0.8933
12.5	7.6	0.0559	0.5648	0.9116
12.75	7.8	0.0570	0.5761	0.9298
13	7.9	0.0582	0.5874	0.9480
13.25	8.1	0.0593	0.5987	0.9663
13.5	8.2	0.0604	0.6100	0.9845
13.75	8.4	0.0615	0.6213	1.0027
14	8.5	0.0626	0.6326	1.0209
14.25	8.7	0.0638	0.6439	1.0392
14.5	8.8	0.0649	0.6552	1.0574

Design Storm Events for Basin Rule Development

Time (hr)	72-hour Distribution			
	Cumulative percentage of peak one day rainfall (%)	Ordinate for Unit Hydrograph (in)	Ordinate for 10-yr Storm (in) (10.1 in)	Ordinate for 100-yr Storm (in) (16.3 in)
14.75	9.0	0.0660	0.6665	1.0756
15	9.1	0.0671	0.6778	1.0939
15.25	9.3	0.0682	0.6891	1.1121
15.5	9.4	0.0693	0.7004	1.1303
15.75	9.6	0.0705	0.7117	1.1486
16	9.7	0.0716	0.7230	1.1668
16.25	9.9	0.0727	0.7343	1.1850
16.5	10.0	0.0738	0.7456	1.2033
16.75	10.2	0.0749	0.7569	1.2215
17	10.3	0.0761	0.7682	1.2397
17.25	10.5	0.0772	0.7795	1.2580
17.5	10.6	0.0783	0.7908	1.2762
17.75	10.8	0.0794	0.8021	1.2944
18	10.9	0.0805	0.8134	1.3126
18.25	11.1	0.0816	0.8247	1.3309
18.5	11.2	0.0828	0.8360	1.3491
18.75	11.4	0.0839	0.8472	1.3673
19	11.6	0.0850	0.8585	1.3856
19.25	11.7	0.0861	0.8698	1.4038
19.5	11.9	0.0872	0.8811	1.4220
19.75	12.0	0.0884	0.8924	1.4403
20	12.2	0.0895	0.9037	1.4585
20.25	12.3	0.0906	0.9150	1.4767
20.5	12.5	0.0917	0.9263	1.4950
20.75	12.6	0.0928	0.9376	1.5132
21	12.8	0.0940	0.9489	1.5314
21.25	12.9	0.0951	0.9602	1.5496
21.5	13.1	0.0962	0.9715	1.5679
21.75	13.2	0.0973	0.9828	1.5861
22	13.4	0.0984	0.9941	1.6043
22.25	13.5	0.0995	1.0054	1.6226
22.5	13.7	0.1007	1.0167	1.6408
22.75	13.8	0.1018	1.0280	1.6590
23	14.0	0.1029	1.0393	1.6773
23.25	14.1	0.1040	1.0506	1.6955
23.5	14.3	0.1051	1.0619	1.7137
23.75	14.4	0.1063	1.0732	1.7320
24	14.6	0.1074	1.0847	1.7506
24.25	14.8	0.1091	1.1014	1.7775
24.5	15.0	0.1107	1.1178	1.8039
24.75	15.3	0.1123	1.1341	1.8303
25	15.5	0.1139	1.1505	1.8567
25.25	15.7	0.1155	1.1668	1.8831
25.5	15.9	0.1171	1.1832	1.9095
25.75	16.1	0.1188	1.1995	1.9358
26	16.4	0.1204	1.2159	1.9622
26.25	16.6	0.1220	1.2322	1.9886
26.5	16.8	0.1236	1.2486	2.0150
26.75	17.0	0.1252	1.2649	2.0414
27	17.2	0.1269	1.2813	2.0678
27.25	17.5	0.1285	1.2976	2.0942
27.5	17.7	0.1301	1.3140	2.1206
27.75	17.9	0.1317	1.3303	2.1469
28	18.1	0.1333	1.3467	2.1733
28.25	18.3	0.1350	1.3630	2.1997
28.5	18.6	0.1366	1.3794	2.2261
28.75	18.8	0.1382	1.3957	2.2525
29	19.0	0.1398	1.4121	2.2789
29.25	19.2	0.1414	1.4284	2.3053

Design Storm Events for Basin Rule Development

Time (hr)	72-hour Distribution			
	Cumulative percentage of peak one day rainfall (%)	Ordinate for Unit Hydrograph (in)	Ordinate for 10-yr Storm (in) (10.1 in)	Ordinate for 100-yr Storm (in) (16.3 in)
29.5	19.4	0.1430	1.4448	2.3317
29.75	19.7	0.1447	1.4611	2.3580
30	19.9	0.1463	1.4775	2.3844
30.25	20.1	0.1479	1.4938	2.4108
30.5	20.3	0.1495	1.5102	2.4372
30.75	20.5	0.1511	1.5265	2.4636
31	20.8	0.1528	1.5429	2.4900
31.25	21.0	0.1544	1.5592	2.5164
31.5	21.2	0.1560	1.5756	2.5428
31.75	21.4	0.1576	1.5919	2.5691
32	21.6	0.1592	1.6083	2.5955
32.25	21.9	0.1609	1.6246	2.6219
32.5	22.1	0.1625	1.6410	2.6483
32.75	22.3	0.1641	1.6573	2.6747
33	22.5	0.1657	1.6737	2.7011
33.25	22.7	0.1673	1.6900	2.7275
33.5	23.0	0.1689	1.7064	2.7538
33.75	23.2	0.1706	1.7227	2.7802
34	23.4	0.1722	1.7391	2.8066
34.25	23.6	0.1738	1.7554	2.8330
34.5	23.8	0.1754	1.7718	2.8594
34.75	24.1	0.1770	1.7881	2.8858
35	24.3	0.1787	1.8045	2.9122
35.25	24.5	0.1803	1.8208	2.9386
35.5	24.7	0.1819	1.8372	2.9649
35.75	24.9	0.1835	1.8535	2.9913
36	25.2	0.1854	1.8725	3.0220
36.25	25.4	0.1870	1.8892	3.0489
36.5	25.6	0.1887	1.9055	3.0753
36.75	25.9	0.1903	1.9219	3.1017
37	26.1	0.1919	1.9382	3.1281
37.25	26.3	0.1935	1.9546	3.1545
37.5	26.5	0.1951	1.9709	3.1808
37.75	26.7	0.1968	1.9873	3.2072
38	27.0	0.1984	2.0036	3.2336
38.25	27.2	0.2000	2.0200	3.2600
38.5	27.4	0.2016	2.0364	3.2864
38.75	27.6	0.2032	2.0527	3.3128
39	27.8	0.2049	2.0691	3.3392
39.25	28.1	0.2065	2.0854	3.3655
39.5	28.3	0.2081	2.1018	3.3919
39.75	28.5	0.2097	2.1181	3.4183
40	28.7	0.2113	2.1345	3.4447
40.25	28.9	0.2130	2.1508	3.4711
40.5	29.2	0.2146	2.1672	3.4975
40.75	29.4	0.2162	2.1835	3.5239
41	29.6	0.2178	2.1999	3.5503
41.25	29.8	0.2194	2.2162	3.5766
41.5	30.0	0.2210	2.2326	3.6030
41.75	30.3	0.2227	2.2489	3.6294
42	30.5	0.2243	2.2653	3.6558
42.25	30.7	0.2259	2.2816	3.6822
42.5	30.9	0.2275	2.2980	3.7086
42.75	31.1	0.2291	2.3143	3.7350
43	31.4	0.2308	2.3307	3.7614
43.25	31.6	0.2324	2.3470	3.7877
43.5	31.8	0.2340	2.3634	3.8141
43.75	32.0	0.2356	2.3797	3.8405
44	32.2	0.2372	2.3961	3.8669

Design Storm Events for Basin Rule Development

Time (hr)	72-hour Distribution			
	Cumulative percentage of peak one day rainfall (%)	Ordinate for Unit Hydrograph (in)	Ordinate for 10-yr Storm (in) (10.1 in)	Ordinate for 100-yr Storm (in) (16.3 in)
44.25	32.5	0.2389	2.4124	3.8933
44.5	32.7	0.2405	2.4288	3.9197
44.75	32.9	0.2421	2.4451	3.9461
45	33.1	0.2437	2.4615	3.9725
45.25	33.3	0.2453	2.4778	3.9988
45.5	33.6	0.2469	2.4942	4.0252
45.75	33.8	0.2486	2.5105	4.0516
46	34.0	0.2502	2.5269	4.0780
46.25	34.2	0.2518	2.5432	4.1044
46.5	34.4	0.2534	2.5596	4.1308
46.75	34.7	0.2550	2.5759	4.1572
47	34.9	0.2567	2.5923	4.1835
47.25	35.1	0.2583	2.6086	4.2099
47.5	35.3	0.2599	2.6250	4.2363
47.75	35.5	0.2615	2.6413	4.2627
48	35.9	0.2642	2.6684	4.3065
48.25	36.2	0.2660	2.6866	4.3359
48.5	36.4	0.2678	2.7052	4.3659
48.75	36.7	0.2697	2.7238	4.3958
49	36.9	0.2715	2.7422	4.4255
49.25	37.2	0.2734	2.7610	4.4558
49.5	37.4	0.2752	2.7795	4.4858
49.75	37.7	0.2770	2.7981	4.5158
50	37.9	0.2789	2.8169	4.5461
50.25	38.2	0.2811	2.8390	4.5818
50.5	38.5	0.2833	2.8613	4.6177
50.75	38.8	0.2855	2.8836	4.6537
51	39.1	0.2877	2.9058	4.6895
51.25	39.4	0.2901	2.9300	4.7287
51.5	39.8	0.2925	2.9542	4.7677
51.75	40.1	0.2949	2.9783	4.8066
52	40.4	0.2973	3.0027	4.8460
52.25	40.8	0.3004	3.0341	4.8966
52.5	41.3	0.3035	3.0657	4.9476
52.75	41.7	0.3067	3.0973	4.9985
53	42.1	0.3098	3.1290	5.0497
53.25	42.6	0.3136	3.1679	5.1125
53.5	43.2	0.3175	3.2069	5.1755
53.75	43.7	0.3214	3.2459	5.2384
54	44.2	0.3252	3.2845	5.3008
54.25	44.8	0.3298	3.3314	5.3764
54.5	45.5	0.3344	3.3778	5.4513
54.75	46.1	0.3390	3.4243	5.5263
55	46.7	0.3436	3.4704	5.6007
55.25	47.4	0.3490	3.5246	5.6882
55.5	48.2	0.3543	3.5785	5.7752
55.75	48.9	0.3596	3.6324	5.8621
56	49.6	0.3650	3.6865	5.9495
56.25	50.5	0.3712	3.7494	6.0510
56.5	51.3	0.3775	3.8126	6.1530
56.75	52.2	0.3837	3.8758	6.2549
57	53.0	0.3900	3.9390	6.3570
57.25	54.0	0.3974	4.0132	6.4768
57.5	55.0	0.4047	4.0875	6.5966
57.75	56.1	0.4128	4.1693	6.7287
58	57.2	0.4209	4.2511	6.8607
58.25	58.4	0.4297	4.3403	7.0046
58.5	59.6	0.4386	4.4299	7.1492
58.75	61.2	0.4503	4.5483	7.3404

Design Storm Events for Basin Rule Development

Time (hr)	72-hour Distribution			
	Cumulative percentage of peak one day rainfall (%)	Ordinate for Unit Hydrograph (in)	Ordinate for 10-yr Storm (in) (10.1 in)	Ordinate for 100-yr Storm (in) (16.3 in)
59	62.8	0.4621	4.6672	7.5322
59.25	65.3	0.4805	4.8531	7.8322
59.5	67.8	0.4989	5.0389	8.1321
59.75	82.8	0.6093	6.1539	9.9316
60	101.5	0.7469	7.5437	12.1745
60.25	105.2	0.7737	7.8147	12.6118
60.5	108.8	0.8006	8.0861	13.0498
60.75	110.7	0.8146	8.2272	13.2775
61	112.6	0.8286	8.3689	13.5062
61.25	114.0	0.8389	8.4724	13.6733
61.5	115.4	0.8492	8.5769	13.8420
61.75	116.6	0.8576	8.6619	13.9791
62	117.7	0.8661	8.7476	14.1174
62.25	118.6	0.8723	8.8106	14.2190
62.5	119.4	0.8786	8.8739	14.3212
62.75	120.2	0.8841	8.9295	14.4109
63	120.9	0.8896	8.9850	14.5005
63.25	121.7	0.8951	9.0409	14.5908
63.5	122.4	0.9007	9.0967	14.6808
63.75	123.2	0.9062	9.1524	14.7708
64	123.9	0.9117	9.2082	14.8607
64.25	124.4	0.9150	9.2416	14.9147
64.5	124.8	0.9183	9.2751	14.9687
64.75	125.3	0.9216	9.3085	15.0226
65	125.7	0.9249	9.3415	15.0759
65.25	126.2	0.9283	9.3754	15.1306
65.5	126.6	0.9316	9.4088	15.1845
65.75	127.1	0.9349	9.4423	15.2385
66	127.5	0.9382	9.4758	15.2927
66.25	128.0	0.9415	9.5092	15.3465
66.5	128.4	0.9448	9.5426	15.4004
66.75	128.9	0.9481	9.5760	15.4544
67	129.3	0.9514	9.6095	15.5084
67.25	129.8	0.9547	9.6429	15.5624
67.5	130.2	0.9581	9.6764	15.6163
67.75	130.7	0.9614	9.7098	15.6703
68	131.1	0.9647	9.7435	15.7246
68.25	131.4	0.9669	9.7656	15.7603
68.5	131.7	0.9691	9.7879	15.7962
68.75	132.0	0.9713	9.8102	15.8322
69	132.3	0.9735	9.8325	15.8682
69.25	132.6	0.9757	9.8547	15.9042
69.5	132.9	0.9779	9.8770	15.9402
69.75	133.2	0.9801	9.8993	15.9762
70	133.5	0.9823	9.9212	16.0115
70.25	133.8	0.9845	9.9439	16.0481
70.5	134.1	0.9868	9.9662	16.0841
70.75	134.4	0.9890	9.9885	16.1201
71	134.7	0.9912	10.0108	16.1561
71.25	135.0	0.9934	10.0331	16.1921
71.5	135.3	0.9956	10.0554	16.2280
71.75	135.6	0.9978	10.0777	16.2640
72	135.9	1.0000	10.1000	16.3000

Note:

Design Storm Events for Basin Rule Development

Time (hr)	72-hour Distribution			
	Cumulative percentage of peak one day rainfall (%)	Ordinate for Unit Hydrograph (in)	Ordinate for 10-yr Storm (in) (10.1 in)	Ordinate for 100-yr Storm (in) (16.3 in)

Data obtained from the table included in section 8.2 (a) of the *Basis of Review for Environmental Resource Permit Applications* (01/2001). The values in column "Cumulative Percentage of Peak One Day Rainfall" were interpolated in order to obtain the respective values for each 15 minute interval, and later were divided by 135.9 to get an unitary distribution for 72-hour period.

APPENDIX C
Electronic Format of Deliverables