Submittal to:
South Florida Water Management District

# Reevaluation of the C-51 Basin Rule

## Number: C-13412

## Technical Memorandum # 2: Basin Modeling System

*Prepared By:*

TBE GROUP

BPC GROUP
BP Consulting Group, Inc.
Engineers • Scientists • Planners • Surveyors

*380 Park Place Boulevard, Suite 300*
*Clearwater, Florida 33759*
*727-531-3505*

*6220 S. Orange Blossom Trail, Suite 110*
*Orlando, Florida 32809*
*407-851-5020*

**August 2003**

# CERTIFICATION

**Project Name:** Reevaluation of the C-51 Basin Rule
Technical Memorandum #2: Basin Modeling System
SFWMD Contract No. C-13412

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

Charles Alan Hall, P.E., Director, TBE Group
Maricela Torres Reyes, P.E., Project Engineer, BPC Group
Bijay K. Panigrahi, Ph.D., P.E., P.G., Principal, BPC Group

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.

**Name (Please Print):** Bijay K. Panigrahi, Ph.D., P.E., P.G.
**Title:** Principal
**Company Name:** BP Consulting Group, Inc.
**Address:** 6220 S. Orange Blossom Trail, Suite 110
Orlando, Florida 32809
**Telephone Number:** 407-851-5020

(Affix Seal Below)

**Signature of Professional:** ____________________
**Date Signed:** August 25, 2003
**License Number:** 46959

# TABLE OF CONTENTS

APPENDICES

# LIST OF FIGURES



# LIST OF TABLES

# 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. The basin is comprised of two major sub-basins: C-51 West (92 square miles) and C-51 East (85 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-41.200 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 storage reservoir (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 includes 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 modeling phase.

Task 2 – Basin Modeling System

This involves development of the hydrologic and hydraulic models for the existing conditions of the C-51 basin that includes 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).

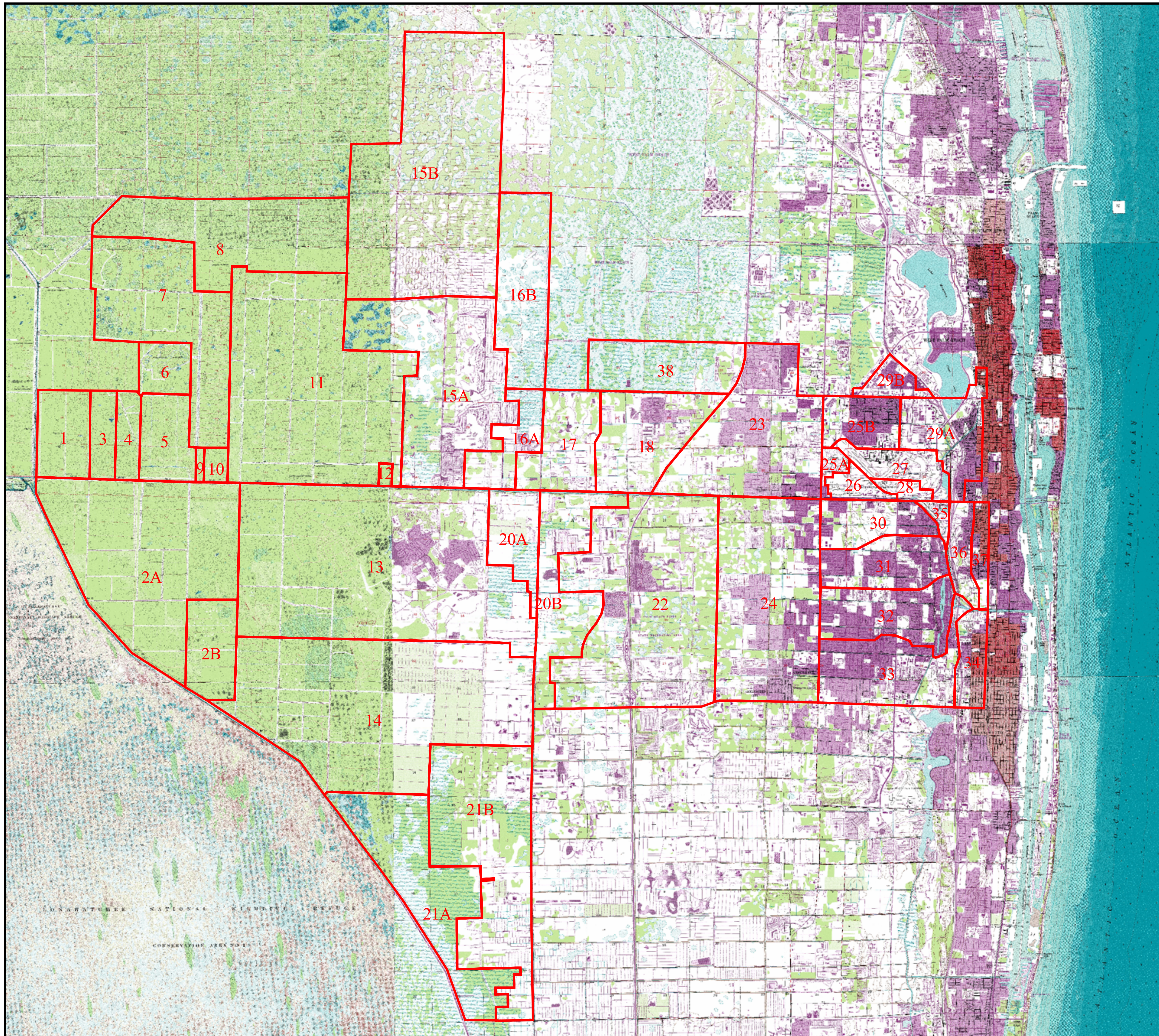
Task 4 – Assistance During Rule Development and Rule Making

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

This report (Technical Memorandum #2) includes the scope of work outlined for Task 2. The technical activities in Task 2 are based on the findings presented in Technical Memorandum #1. In accordance with the contractual agreement with the District (Contract Number: C-13412 and amendments), the following scope of work was completed as part of this task (Task 2).




| Sub-Basin | Area (acres) | Sub-Basin | Area (acres) |
|---|---|---|---|
| 1 | 1164.3 | 20B | 2341.8 |
| 2A | 6715.8 | 21A | 3540.4 |
| 2B | 1226.4 | 21B | 5056.2 |
| 3 | 579.4 | 22 | 7375.2 |
| 4 | 540.0 | 23 | 4206.9 |
| 5 | 1142.4 | 24 | 5282.0 |
| 6 | 673.5 | 25A | 205.8 |
| 7 | 4126.9 | 25B | 972.1 |
| 8 | 3966.8 | 26 | 376.1 |
| 9 | 72.8 | 27 | 830.7 |
| 10 | 208.0 | 28 | 223.4 |
| 11 | 8138.4 | 29A | 1578.1 |
| 12 | 74.1 | 29B | 440.3 |
| 13 | 10537.9 | 30 | 1153.0 |
| 14 | 9270.3 | 31 | 1467.7 |
| 15A | 5116.6 | 32 | 1812.7 |
| 15B | 8640.6 | 33 | 2323.8 |
| 16A | 1065.1 | 34 | 711.3 |
| 16B | 2448.8 | 35 | 172.9 |
| 17 | 1650.5 | 36 | 603.3 |
| 18 | 2294.9 | 37 | 390.2 |
| 20A | 1138.6 | 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

BPC Group
BP Consulting Group, Inc.
Engineers • Scientists • Planners • Surveyors

TBE GROUP

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

| REV | DATE | REMARKS | ENG | BY | CKD |
|---|---|---|---|---|---|
| | | NA | | | |

| | NAME | DATE |
|---|---|---|
| DESIGNED BY | AZM / BKP | 05/30/03 |
| DRAWN BY | AZM | 05/30/03 |
| CHECKED BY | BKP | 05/30/03 |
| APPROVED BY | BKP | 05/30/03 |
| FILE NAME: FL02006-FIG 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.

SIGNED NA
NAME
DATE REG. NO.

## SITE LOCATION MAP

Reevaluation of the C-51 Basin Rule
Technical Memorandum #2: Basin Modeling System
South Florida Water Management District, Contract No. C-13412

## FIGURE 1-1

FILE NUMBER FL02006 SHEET ___ OF ___

- Sub-Task 2.1: Design Storm Development
- Sub-Task 2.2: Generation of Sub-Basin Runoff Hydrographs (includes ACME Basin B)
- Sub-Task 2.3: Development of the Hydraulic Model (includes ACME Basin B)
- Sub-Task 2.4: Documentation of C-51 Basin Modeling System Development (Technical Memorandum #2)

The next report (Technical Memorandum #3) will include the scope of the work outlined in Task 3, which is listed below.

- Sub-Task 3.1: Baseline Simulations (includes ACME Basin B)
- Sub-Task 3.2: 10-Year Design Storm Simulation (includes ACME Basin B)
- Sub-Task 3.3: 100-Year Design Storm Simulation (includes ACME Basin B)
- Sub-Task 3.4: Documentation of 10-Year and 100-Year Storm Events (Technical Memorandum #3)

The contract amendment for Task 3 includes evaluation of the following three (3) alternatives for the ACME Basin B.

- Include ACME Basin B as additional inflow to C-51 through ACME Basin A
- Include ACME Basin B as a new inflow to C-51 along the west side of ACME Basin A
- Include ACME Basin B as a new inflow to STA-1 East

## 1.4 LEVEL OF SERVICE

A level of service designation is a relative assessment of overall performance of a stormwater management system based upon the hydraulic performance of the individual stormwater management system elements (e.g., culverts, channels, storm sewers, ponds, etc.) contained throughout the basin. Prioritization of facility improvement funding, operations and maintenance, and regulatory enforcement of development programs can be properly and efficiently addressed once a level of service standard is established.

The minimum level of service standard for this project is two-fold. They are different for Tasks 2 and 3 corresponding to Technical Memoranda #2 and #3. The level of service for this technical memorandum (TM #2) is not based on storm frequency; rather it is based on the available information for a specific storm that can be used for calibration. Based on the available rainfall and flow measurements from the District, the 72-hour storm selected for Task 2 is from October 14 to October 16, 1999 that corresponds to the Hurricane Irene. However, for better representation of the basin hydrology and hydraulics, the calibration period is extended to one-week duration from October 12 to October 18, 1999. The largest 24-hour and 72-hour storm in 1999 occurred during the month of October.

The minimum level of service standard for Task 3 (Model Application) is specified as the 10-year, 72-hour and 100-year, 72-hour storm events, which will be further discussed in TM #3.

## 1.5 SOURCES OF DATA

Available drainage data from local, state, and federal sources have been researched and compiled during preparation of this report. Especially important and useful data and information was provided by Patrick Martin, Lake Worth Drainage District, Jay G. Foy, StormwaterJ Engineering, Alan Wertepny, Mock-Roos & Associates, Clete J. Saunier, Loxahatchee Groves Water Control District, and Ken Todd, Palm Beach County. The listing of materials and the sources used in the development of this report are presented below.

**Maps, Plans, and Drawings**:

- Topographic Quadrangle Maps (U.S. Geological Survey, USGS)
- Land Use Map (South Florida Water Management District, SFWMD)
- Soil Series Map (Natural Resources Conservation Service, NRCS)
- Digital Terrain Model, constructed from LIDAR data (SFWMD)
- Cross-section Drawings from Lake Worth Drainage District
- Structure Drawings from Palm Beach County and Indian Trail Improvement District
- Data collected and summarized in Technical Memorandum #1

**Reports and Information**:

- Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55), Soil Conservation Service, 2nd Edition, June 1986
- Hydrologic Modeling System (HEC-HMS) User's Manual, Version 2.1, January 2001
- Hydrologic Modeling System (HEC-HMS) Release Notes, Version 2.2.1, October 2002
- River Analysis System (HEC-RAS) User's Manual, Version 3.1.1, May 2003
- Cross-sectional data used in UNET model for FEMA study, EMA Engineering
- Storm operations logs from Lake Worth Drainage District
- DBHYDRO hydrometeorological data from SFWMD

**Meetings, Discussions, and/or Communications**:

- Ken Konyha, South Florida Water Management District
- Tony Waterhouse, South Florida Water Management District
- Sharon Trost, South Florida Water Management District
- Kathy Collins, South Florida Water Management District
- Michael Voich, South Florida Water Management District
- Ron Mierau, South Florida Water Management District
- Mark Wilsnack, South Florida Water Management District
- Tom Conboy, South Florida Water Management District

- Tommy Strowd, South Florida Water Management District
- Arlan Pankow, South Florida Water Management District
- Cal Neidrauer, South Florida Water Management District
- Bob Howard, South Florida Water Management District
- Andre Cadogan, Jacobs-Montgomery Watson Joint Venture
- Chris Smith, U. S. Army Corps of Engineers, Jacksonville District
- Paul Moczynski, U. S. Army Corps of Engineers, Jacksonville District
- Jerry Grubb, U. S. Army Corps of Engineers, Jacksonville District
- Jay Foy, Indian Trail Improvement District
- Patrick Martin, Lake Worth Drainage District
- Clete J. Saunier, Loxahatchee Grove Water Control District
- Alan Wertepny, Mock Roos & Associates
- Ken Todd, Palm Beach County

# 2.0 EXISTING BASIN CONDITIONS

## 2.1 BASIN DESCRIPTION

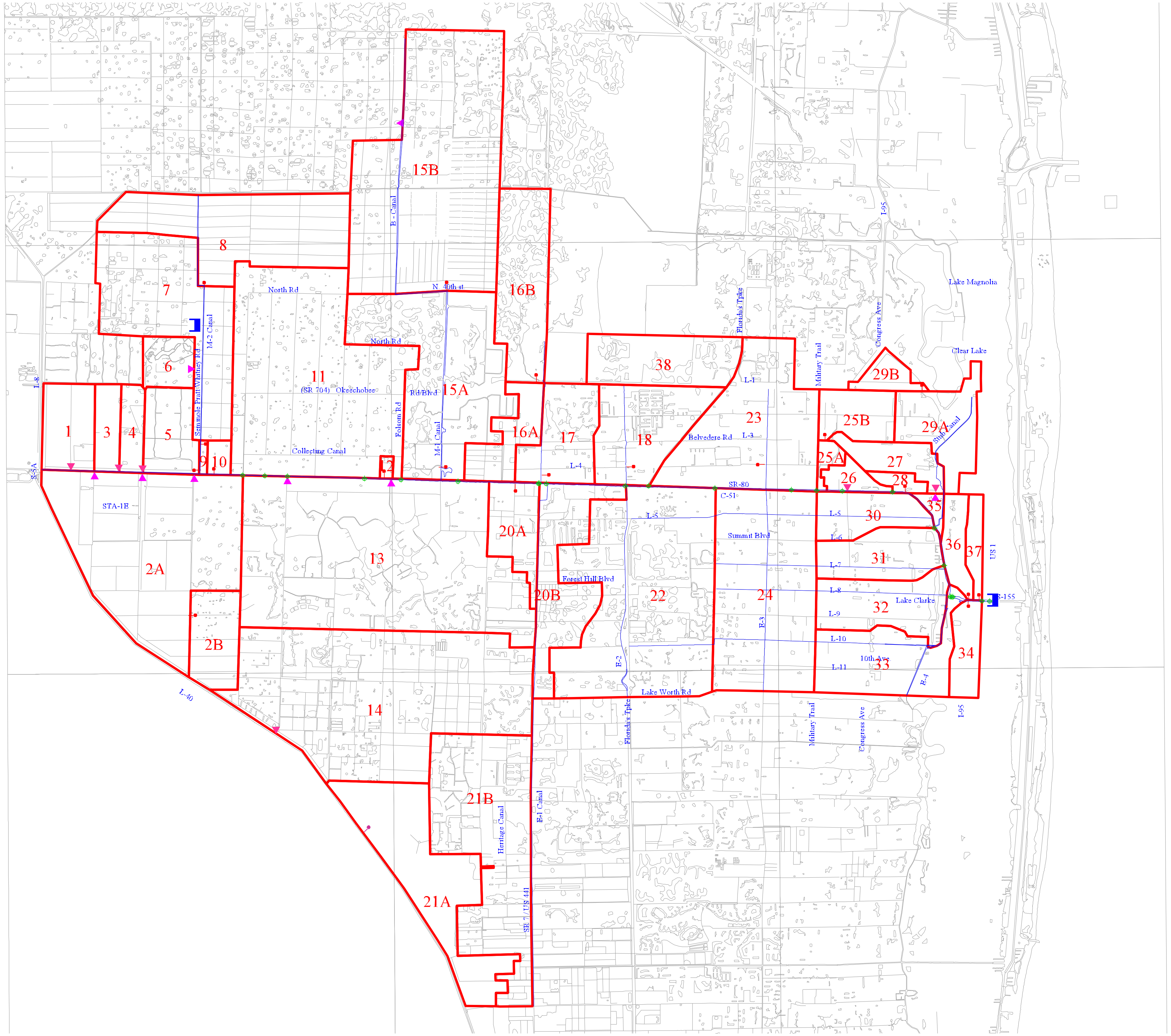
A number of site visits were conducted to confirm the basin information collected during this study. The summary of the information collected was presented in the Technical Memorandum #1 in December 2002. The scope of this study was limited to the primary structures along C-51 canal or contributing to the conveyance through C-51 canal. The pipe sizes and approximate horizontal locations along with inverts and hydraulic operation information of all relevant structures were obtained from the sources listed in Section 1.5 and TM #1, and were used for all subsequent analyses. Visual inspection of the site topography, existing drainage patterns, and stormwater control structures was performed during this study. The procedure of delineating the basins and sub-basins along with the basin and sub-basin boundaries were presented in TM #1. At the request of the project review team members, some of the sub-basins and stormwater control structures were adjusted to reflect the actual field conditions and structure operations. The revised basin and sub-basin boundaries are shown on Figures 1-1 and 2-1, and further details are given below.

As shown on Figure 2-1, C-51 basin encompasses a drainage area of approximately 113,810 acres (177.83 square miles). The basin extends from Northlake Boulevard and Grassy Waters Preserve on the north to Lake Worth Road on the south, and 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 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 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.

## 2.2 STORMWATER CONVEYANCE FEATURES

Figure 2-1 presents the drainage or stormwater conveyance features within the basin boundary, which shows primary and secondary canal systems. The present study is limited to only the primary canal system. As shown on Figure 2-1, the primary conveyance features include the C-51 canal, M-1 canal, M-2 canal, Homeland canal, equalizer canals E-1 through E-4, and Stub canal. Some of the 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 are given below, and also summarized in Table 2-2 for existing conditions (calibration conditions). The proposed conditions (Task 3 scope) will be presented in the next report (Technical Memorandum #3).




**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

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
BP Consulting Group, Inc.
Engineers • Scientists • Planners • Surveyors

TBE GROUP

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

| | NAME | DATE |
|---|---|---|
| DESIGNED BY | AZM/BKP | 06-02-03 |
| DRAWN BY | AZM | 06-02-03 |
| CHECKED BY | BKP | 06-02-03 |
| APPROVED BY | BKP | 06-02-03 |

FILE NAME: FL02006-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.

SIGNED NA
NAME
DATE REG. NO.

**STORMWATER CONVEYANCE SYSTEM**
Reevaluation of the C-51 Basin Rule
Technical Memorandum #2: Basin Modeling System
South Florida Water Management District, Contract No. C-13412

**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 | |
| 2A | B2A | 6715.7 | 10.49 | Proposed STA-1E | 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** | | **38368.1** | **73.35** | | |

**Table 2-2**
**Summary of Stormwater Conveyance Features (Existing Conditions)**

| 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 |
| 2A | B2A | Pump | 25,000 gpm, 20,000 gpm, and 18,000 gpm Discharge Pumps. Pump Station 319 with 2-550 cfs and 3-960 cfs Pumps non-existent at this time. | C-51 Canal |
| 2B | B2B | Culvert | 1-36” x 40’ CMP | Sub-Basin 2A |
| 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 at A (4’ opening, open @16’, close @15.5’, sill @10.0’); 2-12’ Sluice Gates (2’ opening, open @16.5’, close @15.5’, sill @9.0’) and 2-12’ Weirs (crest @18.5’) at D; 1-6’ Side Gate at G (4’ opening, open @16’, close @15.5’, sill @10.0’). | 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) non-existent at this time. | 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. | 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 |

**Table 2-2 (continued)**
**Summary of Stormwater Conveyance Features (Existing Conditions)**

| 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. | C-51 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 |

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 consider the secondary and tertiary conveyance systems.

The general information related to stormwater conveyance control structures directly connected to primary conveyance features are summarized in Table 2-2. The topographic variation over the site was obtained from the DTM information presented in TM #1, and the topographic data was transformed to stage-area-storage relationships for the sub-basins. Further details on the canals, control structures, and stage-area-storage relationships for each sub-basin are presented later in Section 3 of this report.

## 2.3 LAND USE DESCRIPTION

The existing land use map for the project area was included in TM #1. Table 2-3 presents a summary of the existing land use for the study area. The land use within the drainage basin includes 30 different categories of Florida Land Use, Cover and Forms classification system (FDOT Handbook, January 1999). These land use categories were grouped into 15 classes of similar kind, and are summarized in Table 2-3. For the purpose of calculating curve numbers, however, all 30 categories were utilized. Further details on the existing land use distribution are given in Appendix B-1.

## 2.4 HYDROLOGIC SOIL GROUPS

Natural Resources Conservation Service (NRCS), (formerly, Soil Conservation Service or SCS), defines the hydrologic soil group for each soil type as described in TR-55 (2nd Edition, June 1986). The hydrologic soil groups are important due to their direct use in the computation of runoff curve number, which is described later in Section 3.0 of this report. For the present study, the hydrologic soil groups defined by the NRCS are used, and the details of each group and contributing areas are presented in Appendix B-1.

The SFWMD also maintains a hydrologic soil group database. The SFWMD database was downloaded and randomly compared with the NRCS database for several sub-basins within the project area. There are some significant discrepancies between the two databases. After a careful evaluation of the two databases, the NRCS database was used for the present study. The reasoning behind not using the SFWMD database for hydrologic soil groups is better explained with the following example for sub-basin 15B.

Figure 2-2 presents two images representing the distribution of hydrologic soil groups for sub-basin 15B. The Image A represents the hydrologic soil groups as classified by the SCS or NRCS, and the Image B represents the hydrologic soil groups as downloaded from the SFWMD soil file website. The soil delineations are identical. The difference is in the database. The SFWMD database is coded as Group D for sub-basin 15B, as well as most of the study area, while the SCS (NRCS) database is coded Group B/D, C/D or D for the same sub-basin. It seems unusual that most of the soil types in sub-basin 15B and other sub-basins are Group D, because the soil series and land use delineated for the project area are not uniform. Therefore, the NRCS classifications were used for this project.

**Table 2-3**
**Summary of Existing Land Use**

| Land Use Code | Land Use Description | Sub-Basin Area (acres) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2A | 2B | 3 | 4 | 5 | 6 | 7 | 8 |
| 110 120 130 | Residential (Low, Medium, High Density) | - | 0.7 | 638.7 | 0.3 | 4.8 | 650.8 | 12.3 | 3430.4 | 23.4 |
| 140 | Commercial and Services | - | - | - | - | - | - | - | - | - |
| 150 | Industrial | - | - | - | - | - | - | - | - | - |
| 170 | Institutional | - | - | - | - | - | - | - | - | - |
| 180 | Recreational | - | 0.2 | - | - | - | - | 304.9 | 6.9 | - |
| 190 260 | Open Land | 43.9 | 16.5 | 107.8 | 1.6 | - | - | - | - | - |
| 210 | Cropland and Pastureland | 1036.2 | 3902.5 | 422.8 | 490.2 | 461.8 | 6.8 | 0.4 | 2.6 | - |
| 220 440 | Tree Crops; Tree Plantations | - | 2185.9 | 0.01 | - | 2.8 | 0.1 | - | - | 3924.6 |
| 240 250 | Nurseries & Vineyards; Specialty Farms | - | - | 35.9 | - | 0.6 | 34.0 | - | 3.8 | 0.2 |
| 310 320 | Herbaceous; Shrub & Brushland | - | - | - | - | - | - | - | - | - |
| 410 420 430 | Upland Coniferous / Hardwood Forests | - | 135.6 | 0.5 | 0.004 | - | 384.5 | 300.5 | 334.9 | 0.2 |
| 510 520 530 | Streams and Waterways, Lakes, Reservoirs | 15.5 | 45.7 | - | 14.6 | 15.4 | 30.7 | - | 191.0 | 18.4 |
| 610 620 630 640 | Wetland (Hardwood / Coniferous / Forested / Non-Forested) | 0.1 | 297.0 | 12.0 | 0.7 | 43.5 | 8.3 | 55.5 | 99.2 | - |
| 740 | Disturbed Lands | 30.6 | - | 8.7 | - | - | - | - | 58.0 | - |
| 810 820 830 | Transportation, Communication, Utilities | 37.9 | 131.6 | - | 72.0 | 11.2 | 27.2 | - | - | - |
| **Total** | | **1164.3** | **6715.7** | **1226.3** | **579.4** | **540.0** | **1142.4** | **673.5** | **4126.9** | **3966.7** |

**Table 2-3 (continued)**
**Summary of Existing Land Use**

| Land Use Code | Land Use Description | Sub-Basin Area (acres) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 9 | 10 | 11 | 12 | 13 | 14 | 15A | 15B | 16A |
| 110 120 130 | Residential (Low, Medium, High Density) | 1.7 | 159.7 | 5925.6 | 9.6 | 6550.7 | 1799.0 | 2015.2 | 7376.6 | 276.3 |
| 140 | Commercial and Services | - | - | 9.9 | - | 123.4 | 22.0 | 130.0 | - | 7.1 |
| 150 | Industrial | - | - | - | - | - | - | - | - | 51.4 |
| 170 | Institutional | - | - | - | 30.4 | 154.0 | - | 83.4 | - | - |
| 180 | Recreational | - | - | - | - | 974.3 | 553.2 | 357.1 | 121.9 | - |
| 190 260 | Open Land | - | - | 125.1 | - | 580.1 | 990.3 | 348.5 | 228.5 | - |
| 210 | Cropland and Pastureland | 37.2 | 12.4 | 551.9 | - | 477.0 | 645.8 | - | - | 277.0 |
| 220 440 | Tree Crops; Tree Plantations | - | - | 82.8 | - | - | 2010.0 | - | 5.2 | 22.1 |
| 240 250 | Nurseries & Vineyards; Specialty Farms | - | - | 298.0 | - | 221.5 | 1657.2 | 0.4 | - | 14.0 |
| 310 320 | Herbaceous; Shrub & Brushland | - | - | 80.2 | - | 13.7 | 512.0 | - | - | - |
| 410 420 430 | Upland Coniferous / Hardwood Forests | - | 13.6 | 879.4 | 17.2 | 355.4 | 393.7 | 1229.5 | 104.6 | 222.4 |
| 510 520 530 | Streams and Waterways, Lakes, Reservoirs | 30.2 | 11.3 | 34.3 | 11.6 | 537.4 | 200.3 | 291.4 | 261.0 | 69.9 |
| 610 620 630 640 | Wetland (Hardwood / Coniferous / Forested / Non-Forested) | - | - | 82.9 | - | 150.4 | 325.5 | 465.6 | 425.1 | 45.0 |
| 740 | Disturbed Lands | - | - | - | - | 16.2 | 6.1 | - | - | - |
| 810 820 830 | Transportation, Communication, Utilities | 3.8 | 11.1 | 68.2 | 5.3 | 383.7 | 154.9 | 195.4 | 117.8 | 79.3 |
| **Total** | | **72.8** | **208.0** | **8138.3** | **74.1** | **10537.9** | **9270.2** | **5116.6** | **8640.6** | **1064.4** |

**Table 2-3 (continued)**
**Summary of Existing Land Use**

| Land Use Code | Land Use Description | Sub-Basin Area (acres) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 16B | 17 | 18 | 20A | 20B | 21A | 21B | 22 | 23 |
| 110 120 130 | Residential (Low, Medium, High Density) | 1.3 | 356.9 | 696.4 | 183.3 | 482.8 | 0.6 | 1769.3 | 2938.2 | 2675.0 |
| 140 | Commercial and Services | - | 56.2 | 37.6 | 25.4 | 59.9 | - | - | 171.9 | 267.5 |
| 150 | Industrial | - | 436.8 | 573.5 | 0.1 | 0.9 | - | - | 0.7 | 202.8 |
| 170 | Institutional | - | - | 43.7 | - | - | - | - | 41.0 | 29.8 |
| 180 | Recreational | - | 313.4 | 13.8 | - | - | - | 104.4 | 950.7 | 128.2 |
| 190 260 | Open Land | - | 44.4 | 168.8 | 108.7 | 7.3 | 0.7 | 198.2 | 312.4 | 225.2 |
| 210 | Cropland and Pastureland | - | - | - | 196.6 | 989.5 | 7.8 | 737.3 | 395.4 | 106.6 |
| 220 440 | Tree Crops; Tree Plantations | - | - | - | 203.9 | - | 1.7 | 78.0 | - | - |
| 240 250 | Nurseries & Vineyards; Specialty Farms | - | 2.9 | 59.4 | 7.2 | 18.9 | 0.7 | 419.7 | 89.3 | - |
| 310 320 | Herbaceous; Shrub & Brushland | - | 9.8 | 7.2 | 12.4 | 17.2 | 0.1 | 77.8 | 7.4 | 10.8 |
| 410 420 430 | Upland Coniferous / Hardwood Forests | 1089.0 | 305.5 | 458.6 | 188.1 | 137.5 | 343.3 | 811.6 | 1310.9 | 287.2 |
| 510 520 530 | Streams and Waterways, Lakes, Reservoirs | 59.2 | 78.8 | 144.8 | 36.7 | 87.5 | 50.0 | 182.7 | 545.2 | 116.0 |
| 610 620 630 640 | Wetland (Hardwood / Coniferous / Forested / Non-Forested) | 1272.4 | - | - | 91.2 | 208.9 | 3017.0 | 359.8 | 170.5 | - |
| 740 | Disturbed Lands | - | 15.4 | 23.1 | 25.0 | 199.8 | 46.6 | 156.9 | 52.5 | - |
| 810 820 830 | Transportation, Communication, Utilities | 27.0 | 30.4 | 67.9 | 60.0 | 131.4 | 71.8 | 160.5 | 389.1 | 157.7 |
| **Total** | | **2448.8** | **1650.5** | **2294.9** | **1138.6** | **2341.8** | **3540.3** | **5056.2** | **7375.2** | **4206.9** |

**Table 2-3 (continued)**
**Summary of Existing Land Use**

| Land Use Code | Land Use Description | Sub-Basin Area (acres) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 24 | 25A | 25B | 26 | 27 | 28 | 29A | 29B | 30 |
| 110<br>120<br>130 | Residential (Low, Medium, High Density) | 4210.9 | 99.7 | 648.3 | 0.1 | 0.9 | 2.8 | 414.6 | 155.0 | 483.4 |
| 140 | Commercial and Services | 424.2 | 21.7 | 193.8 | 0.03 | 40.4 | - | 772.7 | 200.1 | 56.1 |
| 150 | Industrial | 10.6 | - | - | 0.2 | - | - | - | - | 89.8 |
| 170 | Institutional | 82.0 | - | - | - | - | - | 32.7 | 37.8 | - |
| 180 | Recreational | 13.7 | - | 50.8 | 0.2 | - | - | 43.1 | - | 69.6 |
| 190<br>260 | Open Land | 106.0 | - | - | - | - | 12.0 | 82.2 | - | 40.5 |
| 210 | Cropland and Pastureland | - | - | - | - | - | - | - | - | - |
| 220<br>440 | Tree Crops;<br>Tree Plantations | - | - | - | - | - | - | - | - | - |
| 240<br>250 | Nurseries & Vineyards;<br>Specialty Farms | 4.3 | - | - | - | - | - | - | - | - |
| 310<br>320 | Herbaceous;<br>Shrub & Brushland | - | - | - | 0.2 | - | - | - | - | 209.4 |
| 410<br>420<br>430 | Upland Coniferous / Hardwood Forests | 215.9 | - | 4.8 | 0.03 | - | - | - | - | 156.2 |
| 510<br>520<br>530 | Streams and Waterways, Lakes, Reservoirs | 70.3 | 21.1 | 3.1 | 8.0 | 66.2 | - | 85.1 | - | 10.2 |
| 610<br>620<br>630<br>640 | Wetland (Hardwood / Coniferous / Forested / Non-Forested) | 1.5 | - | - | - | 1.6 | - | 11.3 | - | 7.3 |
| 740 | Disturbed Lands | - | - | - | - | - | - | - | - | - |
| 810<br>820<br>830 | Transportation, Communication, Utilities | 142.6 | 63.3 | 71.3 | 367.4 | 721.7 | 208.6 | 136.3 | 47.4 | 30.4 |
| **Total** | | **5282.0** | **205.8** | **972.1** | **376.1** | **830.7** | **223.4** | **1578.1** | **440.3** | **1153.0** |

**Table 2-3 (continued)**
**Summary of Existing Land Use**

| Land Use Code | Land Use Description | Sub-Basin Area (acres) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 |
| 110<br>120<br>130 | Residential (Low, Medium, High Density) | 1091.2 | 1398.2 | 1437.8 | 472.4 | 117.7 | 173.7 | 256.0 | - |
| 140 | Commercial and Services | 120.4 | 189.3 | 429.1 | 17.8 | - | 37.3 | 58.5 | 12.5 |
| 150 | Industrial | 94.1 | - | 157.1 | 51.5 | - | - | 8.0 | 0.1 |
| 170 | Institutional | 13.1 | 20.9 | 38.5 | 26.1 | - | 24.4 | 0.01 | - |
| 180 | Recreational | - | 19.0 | 18.8 | 43.7 | - | 230.2 | 63.5 | 242.4 |
| 190<br>260 | Open Land | 33.4 | 30.9 | 3.3 | - | 20.1 | 26.4 | - | 571.2 |
| 210 | Cropland and Pastureland | - | - | - | - | - | - | - | - |
| 220<br>440 | Tree Crops;<br>Tree Plantations | - | - | - | - | - | - | - | 8.3 |
| 240<br>250 | Nurseries & Vineyards;<br>Specialty Farms | - | - | - | - | - | - | - | - |
| 310<br>320 | Herbaceous;<br>Shrub & Brushland | 0.1 | 14.3 | 12.6 | 0.8 | - | - | - | - |
| 410<br>420<br>430 | Upland Coniferous / Hardwood Forests | 8.5 | - | 65.5 | 30.0 | - | 4.2 | 2.4 | 223.2 |
| 510<br>520<br>530 | Streams and Waterways, Lakes, Reservoirs | 41.2 | 27.4 | 66.4 | - | 15.7 | 6.8 | - | 213.2 |
| 610<br>620<br>630<br>640 | Wetland (Hardwood / Coniferous / Forested / Non-Forested) | - | - | 7.6 | - | - | - | - | 576.0 |
| 740 | Disturbed Lands | - | - | - | - | - | - | - | 6.9 |
| 810<br>820<br>830 | Transportation, Communication, Utilities | 65.7 | 112.7 | 87.1 | 68.8 | 19.5 | 100.4 | 1.8 | 101.4 |
| **Total** | | **1467.7** | **1812.7** | **2323.8** | **711.3** | **172.9** | **603.3** | **390.2** | **1955.2** |

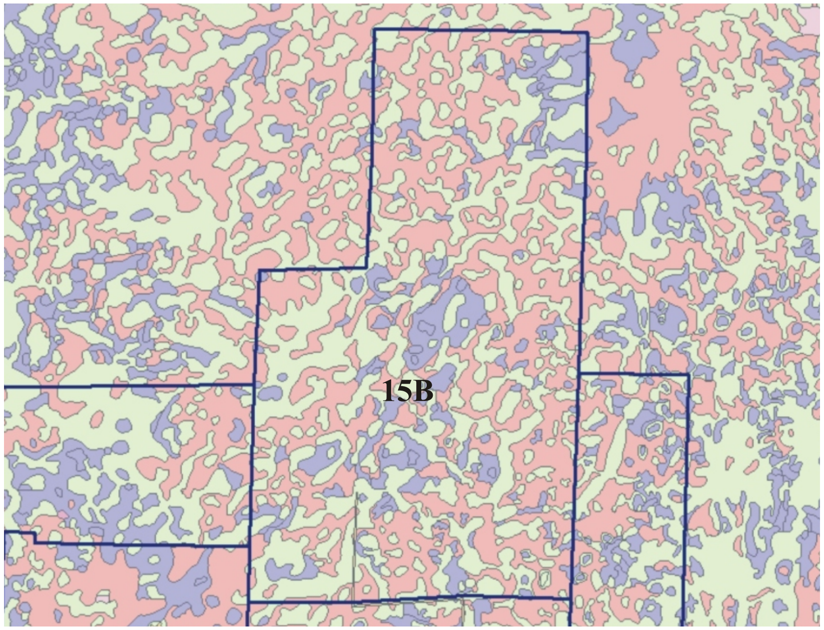



**Image A Hydrologic Soil Group Designation by NRCS for Sub-Basin 15B**

Legend:

- A
- B
- B/D
- C
- C/D
- D

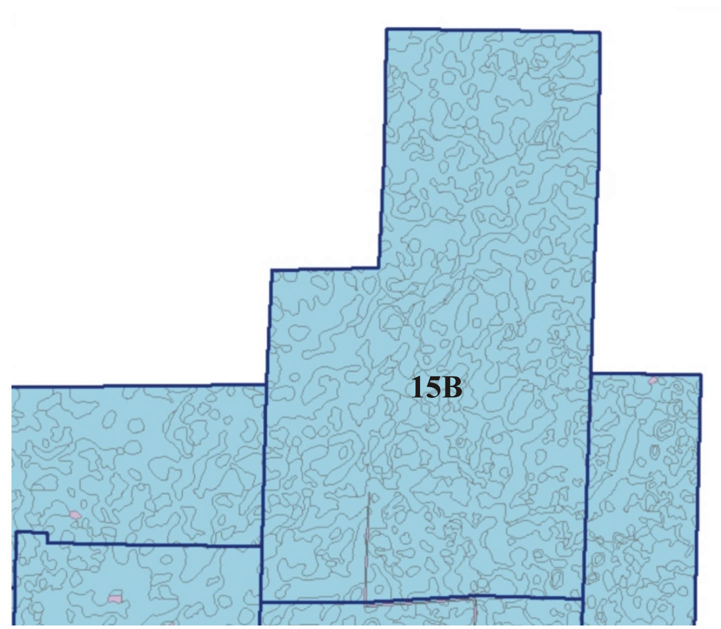



**Image B Hydrologic Soil Group Designation in SFWMD Soil Profile Database for Sub-Basin 15B**

Legend:

- C
- D
- NA

BPC Group
BP Consulting Group, Inc.
Engineers • Scientists • Planners • Surveyors

TBE GROUP

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

**HYDROLOGIC SOIL GROUP COMPARISON**
Reevaluation of the C-51 Basin Rule
Technical Memorandum #2: Basin Modeling System
South Florida Water Management District, Contract No. C-13412

**FIGURE 2-2**

FILE NUMBER FL02006 SHEET ___ OF ___

FL02006-Figure 2-2.cdr

# 3.0 BASIN MODEL DEVELOPMENT

## 3.1 METHODOLOGY

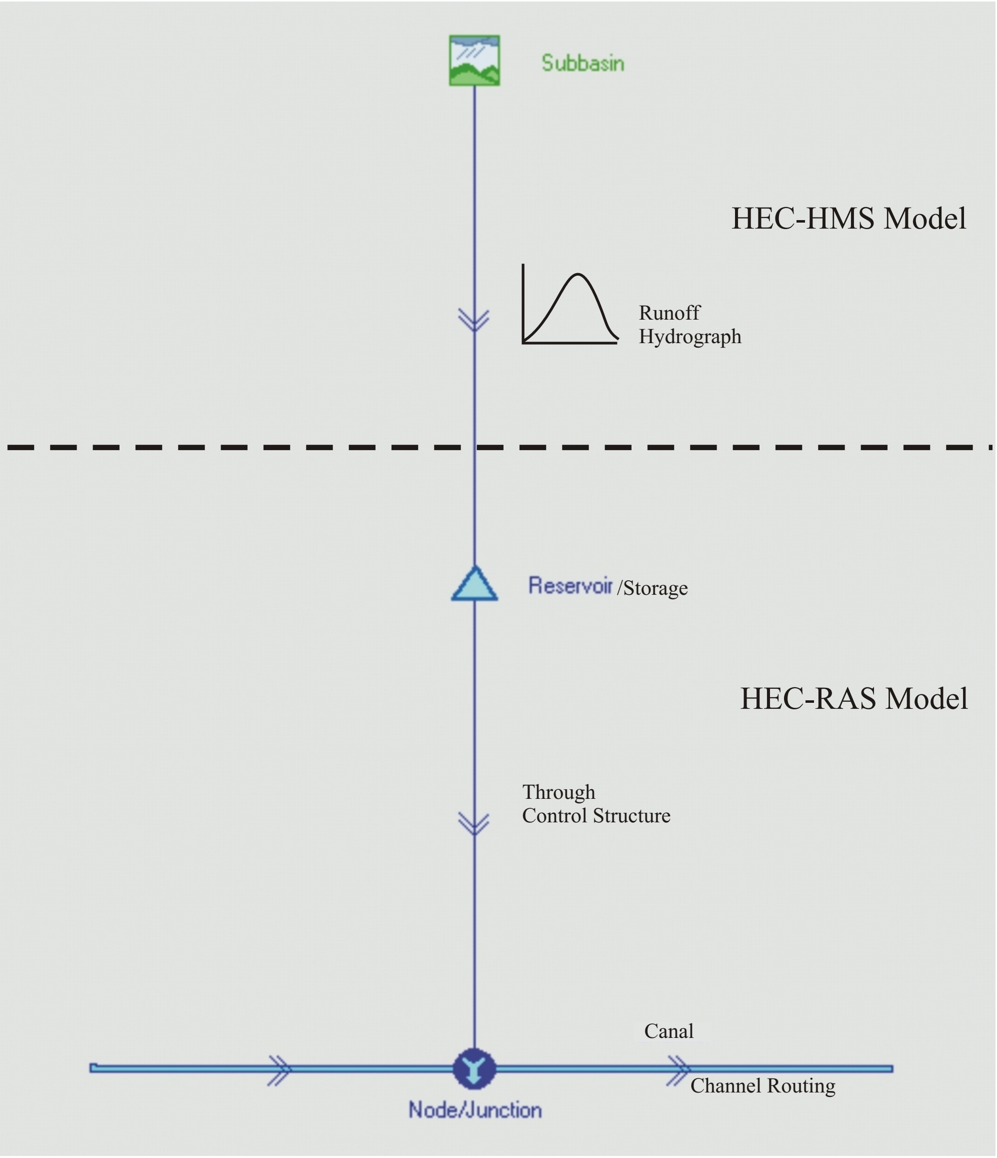
The major computational components of a basin model include hydrologic and hydraulic analyses. The basin hydrological computation begins with a storm event distributed over the basin that generates runoff (runoff hydrograph) after initial abstraction. The runoff fills the available storage through topographic depressions, and then overflows or outflows from the basin. The available storage for a specific basin behaves like a reservoir, which intakes the runoff hydrograph, stores the water in accordance with the available stage-storage relationship, and then outflows from the reservoir according to the control structure(s). The outflow from the basin or reservoir is then conveyed to discharge point through a stormwater conveyance system consisting of canal, stream, river, and flow control structures. In other words, the hydrologic computation includes runoff generation for each sub-basin, while the hydraulic computation constitutes the flow routing within the canal system including the hydraulically connected storage or reservoir system. Figure 3-1 presents a schematic representation of the hydrologic and hydraulic computation scheme for the basin and sub-basins for this study.

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 original intent was to use Geo-HMS and Geo-RAS, which are identical to HMS and RAS, respectively, except that the Geo-HMS and Geo-RAS have the capability to generate river sections using ArcGIS files. For the present study, the GIS files are in NAVD 88 system, while the monitoring (DBHYDRO), structural information, and information from other studies (USACE and FEMA) are in NGVD 29 system. Due to the two different coordinate systems and integrity and consistency of the historical measurements (as indicated above), the HMS and RAS models (instead of Geo-HMS and Geo-RAS) were implemented for this study. The latest versions of the HMS (Version 2.2.1) and RAS (Version 3.1.1) models are used for this project.

**Hydrologic Modeling**

For the present study, the hydrologic modeling process using the HMS model includes the following sequential steps.

- Develop a basin schematic including all sub-basins
- Provide input information
    - Select a method for hydrograph generation (SCS method was selected)
    - Provide basin parameters (sub-basin area, curve number, time lag, and initial abstraction)
- Generate runoff hydrograph




BPC Group
BP Consulting Group, Inc.
Engineers • Scientists • Planners • Surveyors

TBE GROUP

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

**SCHEMATIC OF MODELING PROCESS**
Reevaluation of the C-51 Basin Rule
Technical Memorandum #2: Basin Modeling System
South Florida Water Management District, Contract No. C-13412

**FIGURE 3-1**

FILE NUMBER FL02006 SHEET ___ OF ___

FL02006-Figure 3-1.cdr

**Hydraulic Modeling**

The hydraulic modeling process using the RAS model includes the following sequential steps for this study.

- Develop a basin schematic including all sub-basins and channel flow segments
- Provide input information
    - Define storage areas (stage-storage relationships) for each sub-basin
    - Input runoff hydrographs from HMS as input to the storage areas in RAS
    - Define control structures (bridges, gates, weirs, pumps)
    - Provide channel geometry and flow parameters (canal length, cross-sections, energy slope, roughness coefficient, initial stage)
- Define initial and boundary conditions
- Perform channel routing to generate hydrographs (flow and stage) along the flow reaches

The peak stage in storage areas for each sub-basin determines the flood stage and duration of flood for the corresponding sub-basin.

**Calibration Process**

The computed time-stage and time-discharge hydrographs from RAS may be compared with observed hydrographs at calibration locations, if available. According to the computed stages at various channel sections from the RAS model, the basin hydrologic parameters in HMS and the hydraulic parameters in RAS may be modified, and the model runs may be iterated until a reasonable agreement is achieved. According to the scope of services, this would complete the calibration process for this study.

## 3.2 NODAL DIAGRAM

The development of this model involved establishing a nodal network to represent the stormwater management system consisting of the basin hydrographs and the flow conveyance system (pipes, channels, lakes, etc) from basin outlet to the most downstream canal outfall. The model generates runoff hydrographs and conveys or "routes" the hydrographs through the flow conveyance canal and the hydraulic structures such as bridges, culverts, gates, weirs, etc. along the conveyance system. This model calculates flow rates, water depths, and elevations within the stormwater system. The conceptual representation of the stormwater management system is based on the "link-node" or "reach-junction" concept as shown on Figure 3-1. The links or reaches represent river or canal sections (segments of C-51, M-1, M-2, E-1 through E4, L-1 through L-11 canals for the present study) along the conveyance system. The nodes or junctions represent intersection of two or more reaches describing confluence or diversion of flow system at the junctions. They also provide a computation point that is used to determine water surface elevations within the primary storm system.

The link-node diagram for the present study (combined hydrologic and hydraulic model) is depicted on Figure 3-2 for the C-51 basin. Figure 3-2 also represents a geographically based nodal diagram showing the hydraulic structures (bridges, culverts, weirs, gates, pumps) and canal cross-sections considered for this task (Task 2). The details on the model calibration completed for the C-51 basin is further discussed later in this report.

## 3.3 BASIN PARAMETERS

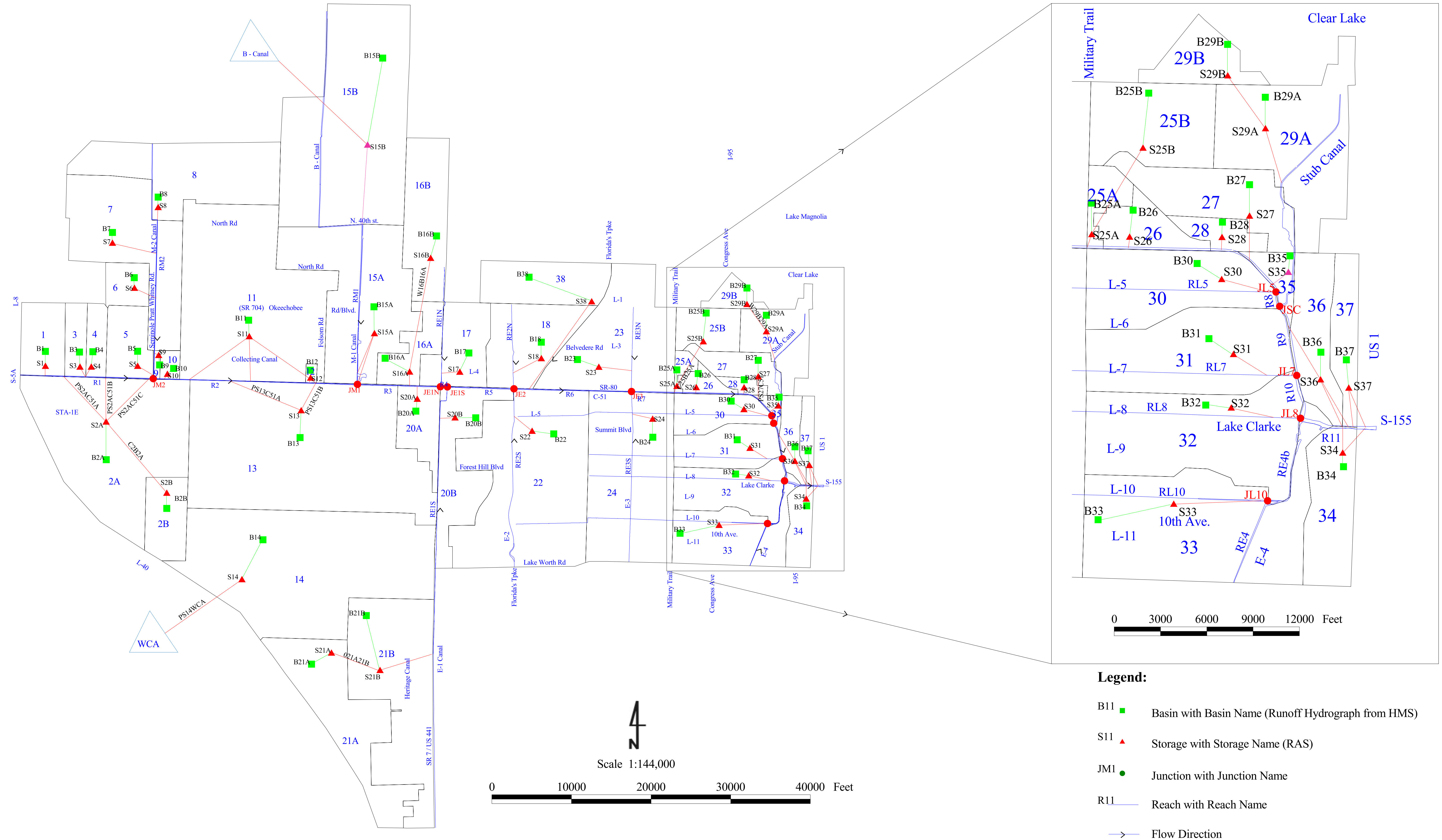
### Basin Area and Land Use

The C-51 basin and the sub-basins were delineated as described in TM #1. Based on the current operational conditions as identified by the project review team members, boundaries for some of the sub-basins (sub-basins 11, 12, 16A, and 17) were modified. In addition, sub-basin 29A was divided into two sub-basins: 29A and 29B. Figures 1-1 and 2-1 reflect these modifications, and all figures presented in this report reflect the new and final sub-basin boundary configurations. The sub-basin areas were then computed from the GIS database that was delivered to the District in TM #1. Section 2.3 presents the land use details that were used for this project. The computed sub-basin areas are presented in Table 3-1 and Appendix B-1, which are the same information presented earlier in Tables 2-1a through 2-3.

### Curve Number (CN)

The curve numbers for the existing condition were developed using hydrologic soil groups, soil conditions and existing land uses. The computation of weighted curve number (CN) for each sub-basin for this study was accomplished, for the most part, utilizing a special GIS utility that applies SCS curve numbers based upon a FLUCCS code in combination with the site specific soils data from the NRCS database. However, because this utility program applies a generalized land use assumption, for low-density (less than 2 dwelling units per acre) urban FLUCCS codes, the computed curve numbers were observed to be significantly higher for some sub-basins than either the local norms or the mass-accounting procedures of the SFWMD Volume IV which considers the maximum soil moisture storage capabilities of the region.

The GIS utility assumed a residential density of less than two dwelling units per acre with a requisite 38% impervious coverage assumption. Since the actual lot sizes in several sub-basins are greater than or equal to 1.25 acres, it was felt that a more appropriate curve number should be applied to the low-density FLUCCS codes for these basins that considers the large lot sizes and percentage impervious coverage is more in the 12% range. Therefore, the curve numbers used for low-density FLUCCS designated land uses for soil types with Hydrologic Soil Groups of A, B, C and D were 46, 65, 77 and 82, respectively (ref: NRCS TR-55, Urban Hydrology For Small Watersheds, June 1986, Page 2-5).




BPC Group
BP Consulting Group, Inc.
Engineers • Scientists • Planners • Surveyors

TBE GROUP

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

| REV | DATE | REMARKS | ENG | BY | CKD |
|---|---|---|---|---|---|
| | | NA | | | |

| | NAME | DATE |
|---|---|---|
| DESIGNED BY | AZM / BKP | 07/29/03 |
| DRAWN BY | AZM | 07/29/03 |
| CHECKED BY | BKP | 07/29/03 |
| APPROVED BY | BKP | 07/29/03 |
| FILE NAME: FL02006-FIG 3-2.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.

**NODAL DIAGRAM**
Reevaluation of the C-51 Basin Rule
Technical Memorandum #2: Basin Modeling System
South Florida Water Management District, Contract No. C-13412

**FIGURE 3-2**

FILE NUMBER FL02006
SHEET ___ OF ___

**Table 3-1**
**Summary of Computed Basin Parameters**

| Sub-Basin | | Area | | Weighted Curve Number (CN) | Time of Concentration (Minute) | Time Lag (Minute) |
|---|---|---|---|---|---|---|
| ID | Other ID | (acre) | (sq mi) | | | |
| 1 | B1 | 1164.3 | 1.82 | 72.0 | 252 | 151 |
| 2A | B2A | 6715.8 | 10.49 | 74.7 | 692 | 415 |
| 2B | B2B | 1226.4 | 1.92 | 74.2 | 138 | 83 |
| 3 | B3 | 579.4 | 0.91 | 74.8 | 231 | 139 |
| 4 | B4 | 540.0 | 0.84 | 76.3 | 260 | 156 |
| 5 | B5 | 1142.5 | 1.78 | 78.0 | 232 | 139 |
| 6 | B6 | 673.5 | 1.05 | 82.2 | 146 | 88 |
| 7 | B7 | 4126.9 | 6.45 | 77.6 | 574 | 344 |
| 8 | B8 | 3966.8 | 6.20 | 78.0 | 401 | 241 |
| 9 | B9 | 72.8 | 0.11 | 77.0 | 93 | 56 |
| 10 | B10 | 208.0 | 0.32 | 82.0 | 226 | 136 |
| 11 | B11 | 8138.3 | 12.71 | 77.1 | 567 | 340 |
| 12 | B12 | 74.1 | 0.12 | 86.0 | 94 | 56 |
| 13 | B13 | 10537.9 | 16.46 | 82.2 | 521 | 313 |
| 14 | B14 | 9270.3 | 14.48 | 74.8 | 429 | 258 |
| 15A | B15A | 5116.7 | 7.99 | 88.1 | 603 | 362 |
| 15B | B15B | 8640.6 | 13.50 | 79.6 | 592 | 355 |
| 16A | B16A | 1064.4 | 1.66 | 83.2 | 308 | 185 |
| 16B | B16B | 2448.8 | 3.83 | 89.5 | 848 | 509 |
| 20A | B20A | 1138.6 | 1.78 | 81.7 | 255 | 153 |
| 17 | B17 | 1650.5 | 2.58 | 84.8 | 303 | 182 |
| 18 | B18 | 2294.9 | 3.58 | 83.4 | 287 | 172 |
| 20B | B20B | 2341.8 | 3.66 | 80.8 | 364 | 218 |
| 21A | B21A | 3540.4 | 5.53 | 97.0 | 573 | 344 |
| 21B | B21B | 5056.2 | 7.90 | 76.8 | 493 | 296 |
| 22 | B22 | 7375.2 | 11.52 | 80.9 | 597 | 358 |
| 23 | B23 | 4206.9 | 6.57 | 83.0 | 364 | 218 |
| 24 | B24 | 5282.0 | 8.25 | 82.3 | 440 | 264 |
| 25A | B25A | 205.8 | 0.32 | 77.8 | 104 | 63 |
| 25B | B25B | 972.1 | 1.52 | 79.8 | 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 | 80.4 | 130 | 78 |
| 29B | B29B | 440.3 | 0.69 | 85.9 | 144 | 86 |
| 30 | B30 | 1153.0 | 1.80 | 78.0 | 159 | 95 |
| 31 | B31 | 1467.8 | 2.29 | 81.5 | 157 | 94 |
| 32 | B32 | 1812.7 | 2.83 | 82.4 | 271 | 162 |
| 33 | B33 | 2323.9 | 3.63 | 81.2 | 228 | 137 |
| 34 | B34 | 711.3 | 1.11 | 76.8 | 262 | 157 |
| 35 | B35 | 172.9 | 0.27 | 82.7 | 74 | 45 |
| 36 | B36 | 603.3 | 0.94 | 72.2 | 187 | 112 |
| 37 | B37 | 390.2 | 0.61 | 66.5 | 184 | 111 |
| 38 | B38 | 1955.2 | 3.05 | 91.8 | 225 | 135 |

Based on the above considerations, the weighted curve numbers were recomputed, and are summarized in Table 3-1 for each sub-basin. The details on CN computations are presented in Appendix B-1. The calibrated CN values are presented later in this report.

**Time of Concentration ($T_c$) and Time Lag ($T_l$)**

The time of concentration ($T_c$) is the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed (TR-55, 2nd Edition, June 1986). This parameter controls at what point in the storm event the entire basin is contributing runoff. The time of concentration computations were performed based on the general topography and field observations. The computed values of the time of concentration for the sub-basins are summarized in Table 3-1. The engineering calculations, including the computational procedures and assumptions, are presented in Appendix B-2. The time of concentration values were calculated based on the equations and procedures outlined in TR-55 (2nd Edition, June 1986).

The HMS model requires time lag ($T_l$) instead of time of concentration. The time lag value for each sub-basin is presented in Table 3-1. As described in TR-55 and in the HMS User's Manual, the time lag for a basin is estimated from the time of concentration by the following relationship, and given in Table 3-1 and Appendix B-2.

$$T_c = 1.67\ T_l \qquad \text{or} \qquad T_l = 0.6\ T_c$$

The calibrated time lag for each sub-basin is presented later in this report.

## 3.4 STAGE-AREA-STORAGE COMPUTATION

The stage-area and stage-storage relations were computed from the DTM that was developed using recent LIDAR provided by the SFWMD. The DTM was delivered in TM #1. The stage-area-storage values for each sub-basin are presented in Appendix B-3. The DTM was developed using the North American Vertical Datum 1988 (NAVD 88). The geometric, hydrologic, hydraulic, and control structures operational data collected from various sources for the model exist in National Geodetic Vertical Datum 1929 (NGVD 29). In order to avoid further confusion, the vertical datum for modeling of the C-51 basin is performed in NGVD 29. Therefore, the stage-area-storage data computed for the present study are presented in both the NAVD 88 and NGVD 29 formats. The following procedure was performed to convert the stage data from NAVD 88 to NGVD 29.

All datum conversion was performed using CORPSCON software developed by the USACE. At each end (north, south, east, west) of the basin boundaries and along the C-51 canal, values of a range of stages in NAVD 88 were transformed to values in NGVD 29. The difference between the NAVD 88 and NGVD 29 values for a particular stage was estimated to range between 1.42 to 1.54 feet with an average value of 1.48 feet (rounded to 1.5 feet). Therefore, NGVD 29 values were obtained by adding 1.5 feet to the NAVD 88 stage values computed from the DTM. For convenience of the users, both formats of stage values are included in the stage-area-storage tables presented in Appendix B-3.

## 3.5 DESIGN STORM DEVELOPMENT

### 3.5.1 Design Storm Event

As indicated in Section 1.4 describing the level of service, 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 for review of permit applications.

In the mid-1990's, EMA completed a hydrologic modeling study in support of the Federal Emergency Management Authority (FEMA) flood plain mapping project for the area. During this project, the FEMA contractor evaluated the rainfall records provided by the District. The 100-year, 24-hour storm event rainfall quantity generated during the FEMA study was not significantly different from the District published values of 1990. However, there is a significant difference in the rainfall quantity for the 100-year, 72-hour storm event. The FEMA study did not include the 10-year storm events. Table 3-2 presents the comparative rainfall quantities estimated from both studies.

**Table 3-2**
**Comparison of Rainfall Quantity Estimates**

| Storm Event | Storm Duration | Estimated Rainfall Quantity for C-51 Basin | |
|---|---|---|---|
| | | FEMA study (mid-90s) | SFWMD (1990) |
| 10-year | 24-hour | -- | 7.4 |
| | 72-hour | -- | 10.1 |
| 100-year | 24-hour | 12.0 | 12.0 |
| | 72-hour | 13.1 | 16.3 |

The discrepancy is probably based on the extent of database used in each study. In addition, the SFWMD (1990) publication provided a range of values for the C-51 basin due to its large aerial extent, while the FEMA study gave a single value for the entire basin. The historical records for the C-51 basin indicate that the western area of C-51 basin (west of SR 7) generally has smaller storm than the eastern area for the same storm event. This is reflected in the SFWMD (1990) publication. In addition, for consistency of the permitting review process for the entire jurisdiction, we recommend to continue the use of the SFWMD rainfall frequency curves of 1990. Based on this publication, Table 3-3 presents the estimated storm event rainfall quantities for the C-51 basin, which will be used for the present study in Task 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-4.

**Table 3-3**
**Storm Event Rainfall Quantities**

| 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. | | |

The storm depth values in Table 3-3 are not used for this report during Task 2, but will be used as design storms for further analysis during Task 3 in TM #3. Task 2 (this report) is based on the actual storm event that is described in Section 3.5.2.

### 3.5.2 Rainfall Event

The primary modeling objective of this task is calibration against a known storm event. The District database was used to select a storm event for the model calibration. Initially, the total rainfall amounts for the years 1996 through 2000 were examined to determine the wettest year for the project area. The year 1999 was the wettest year with a total rainfall of 9.1 inches above normal. Then the monthly rainfall values at the selected monitoring stations (Stations S5A_R and WPBFS+R) were analyzed to determine the two wettest months of the year. June and October were determined to be the two wettest months with total rainfall of 6.9 inches and 9.2 inches above normal for the year 1999. The daily records of the two wettest months were then evaluated to determine the two largest 72-hour storm events. The two largest 72-hour storm events in 1999 occurred from 14$^{th}$ through 16$^{th}$ October and 7$^{th}$ through 9$^{th}$ June with a total 72-hour rainfall amount of 5.01 and 7.223 inches respectively at Station S5A_R, and 14.31 and 4.28 inches respectively at Station WPBFS+R. Table 3-4 summarizes the results of the storm event selection process.

The 72-hour storm event from 14$^{th}$ through 16$^{th}$ October corresponds to Hurricane Irene that struck the C-51 basin area in 1999. The rainfall measurements at Station WPBFS+R had recorded the maximum storm depth during the hurricane. Therefore, the rainfall measurements at WPBFS+R during Hurricane Irene were used for calibration purpose. For the October 1999 storm event, the 72-hour rainfall depth of 14.31 inches at WPBFS+R was used for all the sub-basins. The rainfall distributions used in the model calibration is presented in Appendix B-5.

**Table 3-4**
**Selection of Rainfall Events for Calibration**

| Year | Annual Rainfall Above Normal (in) | Two Wettest Monthly Rainfall Above Normal (in) | | Two Largest 72-hour Rainfall (in) | | | |
|---|---|---|---|---|---|---|---|
| | | June 1999 | October 1999 | June 1999 | | October 1999 | |
| | | | | S5A_R | WPBFS+R | S5A_R | WPBFS+R |
| 1996 | -6.8 | -- | -- | -- | -- | -- | -- |
| 1997 | +8.3 | -- | -- | -- | -- | -- | -- |
| 1998 | +3.2 | -- | -- | -- | -- | -- | -- |
| 1999 | +9.1 | +6.9 | +9.2 | 7.223 | 4.28 | 5.01 | 14.31 |
| 2000 | -11.2 | -- | -- | -- | -- | -- | -- |
| **Dates of Largest Storm Events** | | | | **June 7 to 9, 1999** | | **October 14 to 16, 1999** | |

The model calibration also needs the stage and flow data for the corresponding storm event(s). The stage and flow data for the selected storm events were available at the SFWMD Stations S5A_E, C51WEL, and C51SR7. The measured stage and flow hydrograph data for these stations are presented in Appendices B-6 and B-7, respectively. In addition, the stage, gate opening, and flow data at Station S155 (S155_H for stage measurements and S155_G for gate opening) were available for the storm event. The measured stage and gate opening values at this station are included in Appendix B-6, and the flow information is included in Appendix B-7.

## 3.6 GEOMETRIC AND STRUCTURAL FEATURES

### Reaches and Junctions

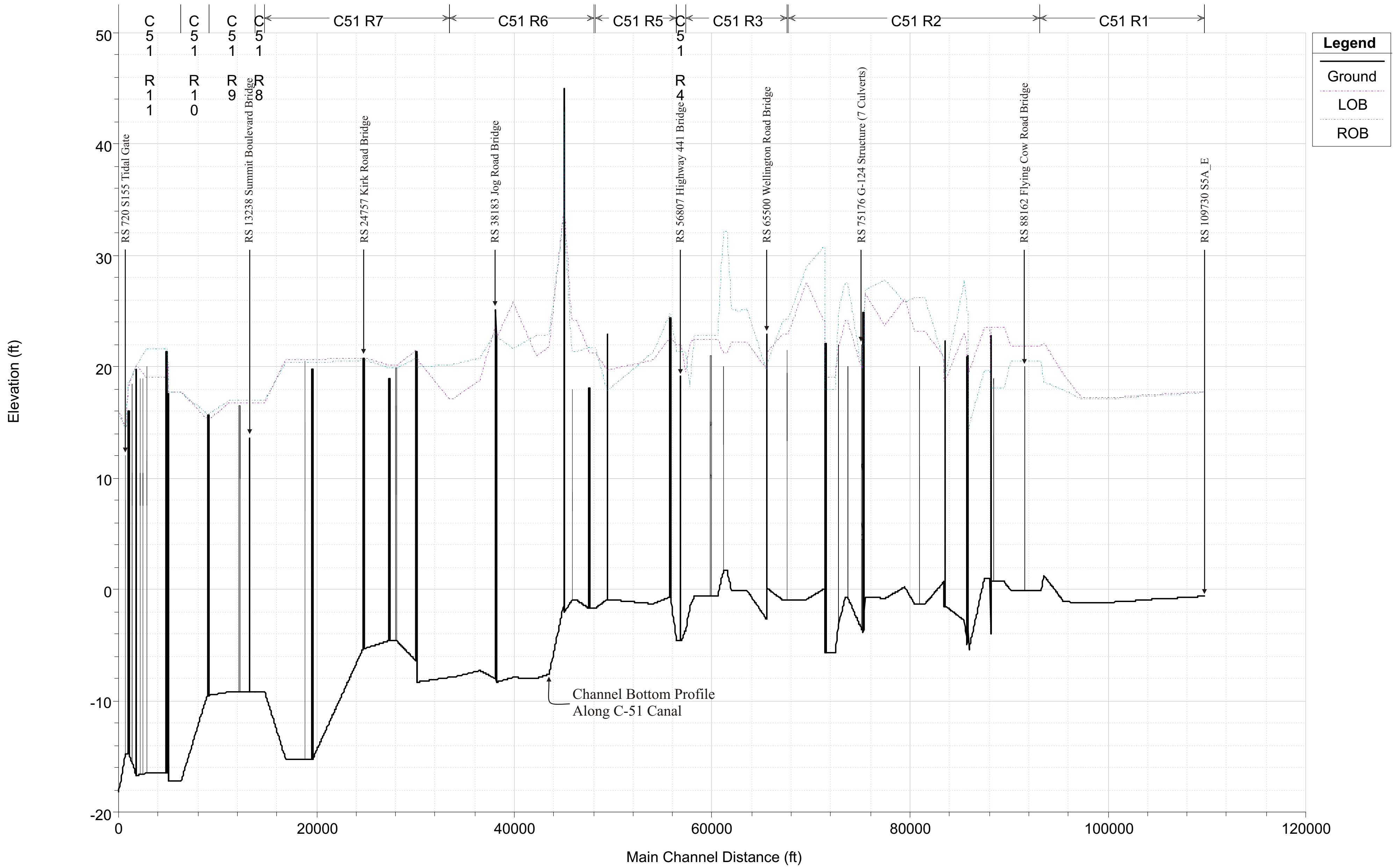
The C-51 canal and the major tributary canals (equalizer canals) are included in the model as shown on Figure 3-2. The equalizer canals include E-1 through E-4 canals. In addition, the Stub canal and some of the lateral canals (L-5 through L-11) are also included in the model. Each equalizer canal, one lateral canal for each sub-basin where applicable, and the Stub canal are represented as separate reaches in the model. Eleven reaches represent the C-51 canal, which are separated by junctions where one or more of the tributary canals intersect with each other or with the C-51 canal. The reaches and junctions are shown on Figure 3-2, and are summarized in Table 3-5.

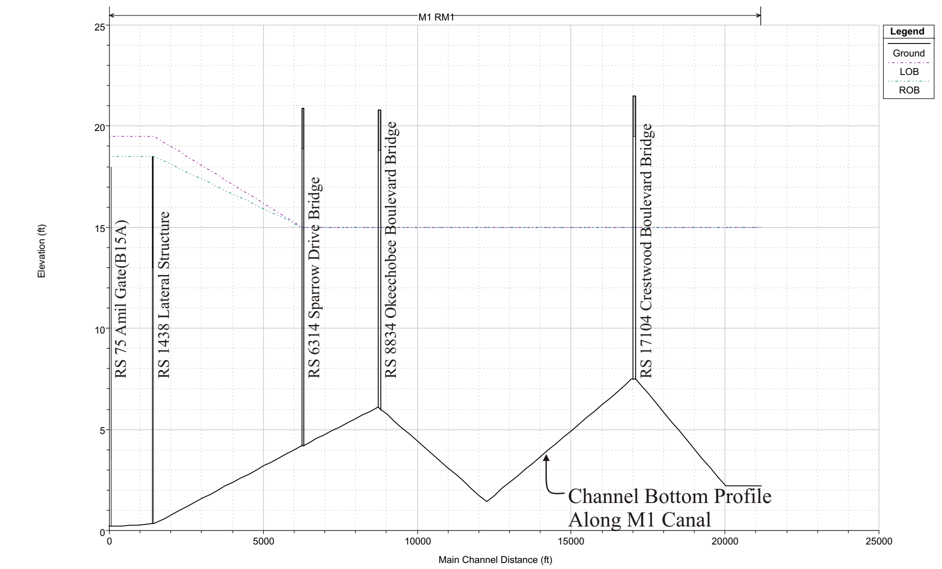
### Canal Cross-Sections

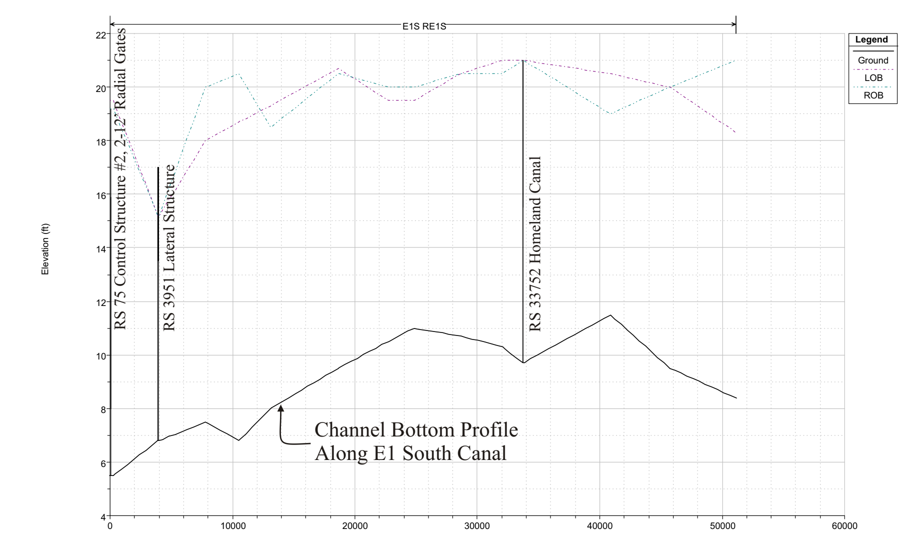
Channel cross-sections are necessary to accurately simulate the stage in the conveyance system. The cross-sections used in the previous studies by USACE and FEMA were utilized for the present modeling effort. USACE developed certain cross-sections for the C-51 west, and FEMA generated a number of cross-sections for the C-51 east. These cross-sections were believed to have been field surveyed. The cross-sections from the USACE study are used in the present model to define the channel geometry for the C-51 canal west of SR-7, and those from the FEMA study are used to define the channel geometry for the C-51 canal east of SR-7. The remaining cross-sections along the C-51 canal were generated from interpolation at 50-foot interval. Figure 3-3 presents the channel bottom profile along C-51 canal that was developed from the cross-sectional information.

**Table 3-5**
**Summary of Information on Reaches and Junctions**

| Canal Name | Reach Name | Reach Length (ft) | Junction Name |
|---|---|---|---|
| C51 | R1 | 16681 | -- |
| M2 | RM2 | 20065 | JM2 |
| C51 | R2 | 25442 | -- |
| M1 | RM1 | 21163 | JM1 |
| C51 | R3 | 10305 | -- |
| E1N | RE1N | 5175 | JE1N |
| C51 | R4 | 918 | -- |
| E1S | RE1S | 51118 | JE1S |
| C51 | R5 | 8276 | -- |
| E2N | RE2N | 10449 | JE2 |
| E2S | RE2S | 20290 | -- |
| C51 | R6 | 14667 | -- |
| E3N | RE3N | 8039.06 | JE3 |
| E3S | RE3S | 19990 | -- |
| C51 | R7 | 18718 | -- |
| L5 | RL5 | 8890 | JL5 |
| C51 | R8 | 939 | -- |
| Stub Canal | RSC | 16716 | JSC |
| C51 | R9 | 4646 | -- |
| L7 | RL7 | 10020 | JL7 |
| C51 | R10 | 2857 | -- |
| L8 | RL8 | 11961 | JL8 |
| E4 | RE4b | 6653 | -- |
| L10 | RL10 | 11643 | JE4 |
| E4 | RE4 | 5349 | -- |
| C51 | R11 | 6281 | -- |




**Legend/Notes:**

- LOB Left Over Bank
- ROB Right Over Bank
- Vertical lines represent locations of hydraulic structures (such as bridges, culverts, etc.)
- Main Channel Distance is measured from downstream end (same as River Station)
- C51 R7 Reach 7 of C51 Canal

BPC Group
BP Consulting Group, Inc.
Engineers • Scientists • Planners • Surveyors

TBE GROUP

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

| | NAME | DATE |
|---|---|---|
| DESIGNED BY | NA | |
| DRAWN BY | | |
| CHECKED BY | | |
| APPROVED BY | | |
| FILE NAME: FL02006-Figure 3-3.cdr | | |

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.

# CHANNEL BOTTOM PROFILES ALONG SELECTED CANALS

Reevaluation of the C-51 Basin Rule
Technical Memorandum #2: Basin Modeling System
South Florida Water Management District, Contract No. C-13412

## FIGURE 3-3

FILE NUMBER FL02006

SHEET ___ OF ___

A number of cross-sections along E-1 canal and limited representative cross-sections along other equalizer and lateral canals were available from the Lake Worth Drainage District. These cross-sections were utilized to describe the channel hydraulics along the tributary canals. The cross-sections along M-1 and M-2 canals at selected locations were obtained from the DTM map generated during TM #1. The bottom elevations of the cross-sections along M-1 canal were adjusted to reflect the information presented in the ITID M-1 Basin Report dated February 7, 1997. The remaining cross-sections along the lateral and equalizer canals were generated from interpolation at 100-foot to 500-foot interval. Figure 3-3 presents the channel bottom profile along selected canals that were developed from the cross-sectional information.

**Bridges**

A total of 28 bridges were included in the model calibration. Figure 2-1 shows the bridge locations along the C-51 canal. The bridge profiles and the station-elevation data for bridge sections were field surveyed during the USACE and FEMA studies, and therefore, these sections were utilized for the current model. At least one upstream and one down stream cross-sections bound each bridge. For the sake of simplicity and model stability, the upstream cross-sections were duplicated to form the down stream sections for the bridges. In addition, some of the bridge sections along M-1 canal were obtained from the ITID M-1 Basin Report dated February 7, 1997. The bridge location information is summarized in Table 3-6.

**Inline Structures**

The inline structures include culverts, weirs, and gates that are located along the canal and directly control the flow along the conveyance system. For calibration of the existing condition, one culvert (Structure G-124) is considered along the C-51 canal. The only gate present is the outfall structure S155 located at the downstream section of the canal. S155 gate structure contains three gates that may be operated individually. The sill elevation of each gate is 1.8 ft-NGVD, and the maximum gate opening for each gate is set at 10.2 feet. The gates were modeled as slide gates.

The other inline structures that are incorporated into the model include radial gates along E-1, E-2, and E-3 canals, Amil gate and slide gates along M-1 canal, and discharge weirs at the confluence of the lateral canals. Table 3-6 presents a summary of information for the inline structures.

## 3.7 STORAGE ROUTING

The runoff hydrographs were generated for each sub-basin using HMS model. These hydrographs were then routed in RAS model using the storage area and lateral structure / pump station options. A storage area containing the stage-storage relationship was defined for each sub-basin. A lateral structure and/or pump station options were used to connect the storage area with the channel flow. The storage routing and channel routing are thus interconnected and interdependent based on the operating criteria and the stages on the channel and the storage areas. This process eliminates the manual generation of rating curves by the user. The lateral structures were weir, culvert, or gate, and were connected to appropriate reaches at corresponding river stations as shown on Figure 3-2. The information related to lateral structure and pump station connections used in the RAS model is summarized in Table 3-7.

The discharge from sub-basin 15B to the M-1 canal is a special condition, and was modeled using the lateral inflow hydrograph option in RAS. The lateral inflow hydrograph to the M-1 canal as suggested by the project review team, is presented in Table 3-8.

**Table 3-6**
**Summary of Information on Bridges and Inline Structures**

| Canal Name | Reach Name | River Station | Structure Width* | Structure Description |
|---|---|---|---|---|
| M1 | RM1 | 17104 | 88 | Bridge: Crestwood Blvd |
| M1 | RM1 | 8834 | 98 | Bridge: Okeechobee Blvd |
| M1 | RM1 | 6314 | 38 | Bridge: Sparrow Drive |
| M1 | RM1 | 75 | 10 | Inline Structure: Amil Gate (B15A) |
| E1S | RE1S | 75 | 10 | Inline Structure: CS# 2 2-12' Radial Gates (B20B) |
| E2N | RE2N | 150 | 90 | Culvert: FDOT Culvert - from E2N to C51 (B18) |
| E2S | RE2S | 170 | 10 | Inline Structure: CS# 4 2-12' Radial Gates (B22) |
| E3S | RE3S | 75 | 10 | Inline Structure: CS# 6 3-12' Radial Gates (B24) |
| L5 | RL5 | 160 | 5 | Inline Structure: Weir (B30) |
| Stub Canal | RSC | 160 | 5 | Inline Structure: Weir (B35) |
| L7 | RL7 | 160 | 5 | Inline Structure: Weir (B31) |
| L8 | RL8 | 160 | 5 | Inline Structure: Weir (B32) |
| E4 | RE4b | 160 | 5 | Inline Structure: Weir (B33) |
| M2 | RM2 | 18 | 3 | Inline Structure: 65.9' wide weir on M-2 |
| C51 | R2 | 88162 | 30 | Bridge: Flying Cow |
| C51 | R2 | 85845 | 89.08 | Bridge: Binks Forest |
| C51 | R2 | 83528 | 30 | Bridge: Ozzly Sod Farm |
| C51 | R2 | 75318 | 30 | Bridge: Big Blue Trace Rd |
| C51 | R2 | 75176 | 51 | Culvert: G-124 Structure (7 Culverts) |
| C51 | R2 | 71496 | 30 | Bridge: Forest Hill Blvd |
| C51 | R3 | 65500 | 30 | Bridge: Wellington Rd |
| C51 | R4 | 56807 | 40 | Bridge: Highway 441 |
| C51 | R5 | 55775 | 40 | Bridge: Mall Entrance |
| C51 | R5 | 49412.5 | 0.8 | Bridge: Pipe Crossing |
| C51 | R6 | 47587 | 30 | Bridge: Benoist Farms Rd |
| C51 | R6 | 45052 | 31 | Bridge: Florida's Turnpike Southbound |
| C51 | R6 | 45010 | 31 | Bridge: Florida's Turnpike Northbound |
| C51 | R6 | 38183 | 149 | Bridge: Jog Road |
| C51 | R7 | 30177 | 1 | Bridge: Pipeline West of Haverhill Road |
| C51 | R7 | 30088 | 85 | Bridge: Haverhill Road |
| C51 | R7 | 27392 | 95 | Bridge: Military Trail |
| C51 | R7 | 24757 | 49 | Bridge: Kirk Road |
| C51 | R7 | 19589 | 76 | Bridge: Congress Ave |
| C51 | R9 | 13238 | 60 | Bridge: Summit Blvd |
| C51 | R10 | 9093 | 70 | Bridge: Forest Hill Blvd |
| C51 | R11 | 5112 | 10 | Bridge: Seaboard Coastline Railroad |
| C51 | R11 | 4956 | 51 | Bridge: I-95 Southbound |
| C51 | R11 | 4853 | 51 | Bridge: I-95 Northbound |
| C51 | R11 | 1801 | 19 | Bridge: Florida East Coast Railroad |
| C51 | R11 | 999 | 77 | Bridge: US Highway 1 |
| C51 | R11 | 720 | 15 | Inline Structure: S-155 Tidal Gate |

* Width is measured along the direction of flow.

## Table 3-7
## Summary of Information on Lateral Structures and Pump Stations

| Basin Name | Storage Name | Canal Name | Reach Name | Structure River Station | Structure Type | Basin Storage | Description |
|---|---|---|---|---|---|---|---|
| B1 | S1 | C51 | R1 | 106604 | Pump | S1 | PS1C51: 47.6 cfs pump |
| B2A | S2A | C51 | R1 | 104304 | Pump | S2A | PS2AC51A: 55.7 cfs pump |
| B2A | S2A | C51 | R1 | 99068 | Pump | S2A | PS2AC51B: 44.6 cfs pump |
| B2A | S2A | C51 | R1 | 93530 | Pump | S2A | PS2AC51C: 40.1 cfs pump |
| B3 | S3 | C51 | R1 | 101600 | Pump | S3 | PS3C51: 26.3 cfs pump |
| B4 | S4 | C51 | R1 | 101600 | Pump | S4 | PS4C51: 29.3 cfs pump |
| B5 | S5 | M2 | RM2 | 436 | Culvert | S5 | 54" CMP |
| B6 | S6 | M2 | RM2 | 10124 | Pump | S6 | PS6M2: 66.8 cfs pump |
| B7 | S7 | M2 | RM2 | 15788 | Gate | S7 | 6' wide Slide Gate |
| B8 | S8 | M2 | RM2 | 19975 | Weir | S8 | 4-72" wide weir |
| B9 | S9 | M2 | RM2 | 3262 | Weir | S9 | 2' Flash Board Riser (Weir) |
| B10 | S10 | C51 | R2 | 91618 | Weir | S10 | 9' wide Weir |
| B11 | S11 | C51 | R2 | 88526 | Gate | S11 | Gate A: 1-6' Slide Gate |
| B11 | S11 | C51 | R2 | 80973 | Weir | S11 | Gate D: 2-12' Sluice Gates & 2-12' Weir |
| B11 | S11 | C51 | R2 | 72778 | Gate | S11 | Gate G: 1-6' Slide Gate |
| B12 | S12 | C51 | R2 | 73679 | Weir | S12 | 2' wide Weir |
| B13 | S13 | C51 | R2 | 83455 | Pump | S13 | PS13C51A: 133.7 cfs pump |
| B13 | S13 | C51 | R2 | 72838 | Pump | S13 | PS13C51B: 133.7 cfs pump |
| B14 | S14 | -- | -- | -- | Pump | S14 | PS14WCA: 222.8 cfs pump |
| B15A | S15A | C51 | R3 | 67560 | Culvert | S15A | 2-72" RCP |
| B15A | S15A | M1 | RM1 | 1438 | Weir | S15A | Open Channel |
| B16A | S16A | C51 | R3 | 61174 | Weir | S16A | 30' Wide Weir |
| B17 | S17 | E1N | RE1N | 1712 | Weir | S17 | S17 to E1N |
| B18 | S18 | E2N | RE2N | 1979 | Weir | S18 | S18 to E2N |
| B20A | S20A | C51 | R3 | 59869 | Culvert | S20A | 2-60" CMP |
| B21B | S21B | E1S | RE1S | 33752 | Canal | S21B | Homeland Canal |
| B20B | S20B | E1S | RE1S | 3951 | Weir | S20B | S20B to E1S |
| B38 | S38 | C51 | R6 | 45825 | Gate | S38 | 1-5.5' Wide Slide Gate |
| B22 | S22 | E2S | RE2S | 3423 | Weir | S22 | S22 to E2S Canal |
| B23 | S23 | E3N | RE3N | 2641 | Weir | S23 | S23 to E3N Canal |
| B24 | S24 | E3S | RE3S | 2713 | Weir | S24 | S24 to E3S Canal |
| B25A | S25A | C51 | R7 | 28070 | Gate | S25A | 2 Slide Gates |
| B26 | S26 | C51 | R7 | 24880 | Pump | S26 | PS26C51: 3-106.6 cfs pumps |
| B28 | S28 | C51 | R7 | 18858 | Culvert | S28 | 8' x 40' Box Culvert |
| B27 | S27 | C51 | R7 | 16882 | Pump | S27 | PS27C51: 3-106.6 cfs pumps |
| B29A | S29A | Stub | RSC | 8615 | Weir | S29A | S29A to Stub Canal |
| B30 | S30 | L5 | RL5 | 450 | Weir | S30 | S30 to L5 Canal |
| B31 | S31 | L7 | RL7 | 1930 | Weir | S31 | S31 to L7 Canal |
| B32 | S32 | L8 | RL8 | 1771 | Weir | S32 | S32 to L8 Canal |
| B33 | S33 | L10 | RL10 | 1453 | Weir | S33 | S33 to L10 Canal |
| B35 | S35 | C51 | R8 | 14700 | Pump | S35 | PS35C51: 45 cfs pump |
| B36 | S36 | C51 | R9 | 12243 | Weir | S36 | 30' wide weir at Dreher Zoo |
| B36 | S36 | C51 | R11 | 2853 | Culvert | S36 | 2500' of 60" RCP |
| B34 | S34 | C51 | R11 | 2843 | Culvert | S34 | 1800' of 48" RCP |
| B36 | S36 | C51 | R11 | 2467 | Culvert | S36 | 3000' of 36" RCP |
| B37 | S37 | C51 | R11 | 2167 | Culvert | S37 | 2000' of 36" RCP |
| B34 | S34 | C51 | R11 | 1400 | Culvert | S34 | 1000' of 36" RCP |
| B37 | S37 | C51 | R11 | 1335 | Culvert | S37 | 2500' of 36" RCP |

**Table 3-8**
**Discharge Hydrograph from Sub-basin 15B to M-1 Canal**

| Date | Clock Time | Flow to M-1 Canal (cfs) | Comments |
|---|---|---|---|
| 10-12-99 | 00:00 hr | 0 | Both 40th and Roach Structures closed |
| 10-14-99 | 00:00 hr | 0 | Beginning of Hurricane Irene |
| 10-17-99 | 00:00 hr | 125 | Open 40th structure half way to allow about 125 cfs after 72 hours of the storm (assumed past peak) |
| 10-17-99 | 12:00 hr | 250 | Fully open 40th structure to allow about 250 cfs |
| 10-18-99 | 08:00 hr | 1000 | Fully open 40th structure, and open Roach structure to allow approximately additional 750 cfs |

Note: This hydrograph was adopted for calibration purpose at the recommendation of the project review team members

# 4.0 MODEL CALIBRATION

The hydrologic modeling of the existing system was performed using the HEC-HMS model Version 2.2.1 with release date of October 2002. The hydraulic modeling of the existing system was performed using the HEC-RAS model Version 3.1.1 with release date of May 2003.

## 4.1 CALIBRATION LOCATIONS

The break point data for the stage measurements and flow values were available from DBHYDRO at Stations S5A-E, C51WEL, C51SR7, and S155. The gate openings at uneven, discrete times were also available at Station S155. Therefore, these four locations were designated as the calibration locations. For all calibration purpose, one-hour stage (time-stage hydrograph) and flow (time-discharge) measurement values were used, where appropriate.

Based on the available records and types of measurements, S5A-E, C51WEL, and C51SR7 are designated as key locations for peak stage calibration, and S155 is designated as key location for peak discharge calibration.

The river stations for the calibration locations are S5A-E at RS 109730, C51WEL at RS 65500, C51SR7 at RS 56807, and S155 at RS 720 or RS 750 (upstream of the gated structure).

## 4.2 CALIBRATION PERIOD

As indicated earlier in this report, Hurricane Irene was the selected storm event that continued from 14$^{th}$ October to 16$^{th}$ 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. Therefore, the calibration period started at 00:00 hour on October 12, 1999 and continued until 24:00 hour on October 18, 1999.

## 4.3 CALIBRATION PARAMETERS

### Curve Number

The initial curve numbers were estimated using the procedure outlined in Section 3.3, and were summarized in Table 3-1. The HMS model simulation began with these CN values. The runoff hydrographs were computed from the HMS model, and then the hydrographs were routed through the RAS model. The peak stages and flows were computed in RAS, and compared with the measurements at the observed stations. The CN values for the sub-basins were then adjusted within the range of ±20% of the estimated CN values, and the HMS and

RAS simulations were repeated until the observed peak stages and/or flows were approximately reproduced by the model. The CN values for the basins were adjusted based on the land use conditions and professional judgment on the basin hydrology. This resulted in calibrated CN values that varied differently from the estimated CN values. The calibrated results are presented later in this report.

**Time Lag**

As described earlier in Section 3, the HMS model uses time lag instead of time of concentration. The time lag generally shapes the runoff hydrograph, which in turn controls the simulated time to peak stage and flow within each sub-basin and at the observed stations. The time to peak may eventually change the magnitude of peak stage and/or flow at the observation locations. The calibration started with the estimated time lag values (Table 3-1), and then adjusted within the range of ±30% of the estimated time lag values. The time lag values for the basins were adjusted based on the topographic conditions and professional judgment on the basin hydrology and hydraulics. This resulted in calibrated time lag values that varied differently from the estimated time lag values. The calibrated time lag and the time of concentration values are presented later in this report.

**Manning's n Coefficient**

Manning's n values were assigned for each segment of the main channel and overbanks. The n values were varied during the model calibration from 0.025 to 0.06 for the main channel and from 0.1 to 0.5 for the overbanks. The primary factors that influenced the variation of n values during the model calibration included professional judgment on the channel hydraulics, available knowledge on the operation and maintenance of the canal systems in the basin, and the geometry of the channels and the overbanks. The calibrated n values for the main channel and overbanks for all the reaches are presented later in this report.

**Transient Condition Parameters**

Successful completion of an unsteady state model calibration also depends on the transient condition parameters related to numerical stability of the executed model. The two most significant factors of interest include the time step and the implicit weighting factor used for the model execution. The incremental time step was varied from 5 seconds to 5 minutes. The implicit weighting factor was varied from 0.6 to 1.0. After a sequence of model runs and based on the professional judgment, the values of time step and implicit weighting factor for this model were maintained at one minute and 1.0, respectively.

**Initial Abstraction**

The initial abstraction value for SCS method is normally 0.2. This value has not been changed during the model calibration.

## 4.4 BOUNDARY AND INITIAL CONDITIONS

### Boundary Conditions

The river station 0+00 is considered the downstream end of the C-51 canal reach for the model, which is located approximately 720 feet downstream of structure S155. The boundary condition at the downstream end is specified by the stage hydrograph measured at downstream / tailwater of the structure S155. The upstream boundary condition is also specified by the measured stage hydrograph for the calibration period. The upstream boundary is at river station 109730 that coincides with the location of structure S-5A. The stage hydrograph data for these stations for the period of October 12 through 18, 1999 were obtained from the DBHYDRO database.

In addition, the model requires for specification of boundary conditions at upstream end of each canal. Since, the stage or flow measurements at the upstream ends of the canals are not available, an assumed constant minimum flow equal to the initial condition was assumed for each canal. The assumed flow ranged from 10 to 30 cfs for the equalizer and lateral canals.

### Initial Conditions

It is necessary to provide initial conditions at the upstream and downstream ends of each reach. The initial conditions for the present study refers to the conditions at 00:00 hour on October 12, 1999. The break point data on stage measurements were available at structures S5A-E, C51WEL, S155-H, and S155-T. Therefore, the initial stages were specified at these locations. The initial conditions for the remaining reaches were specified by assumed flows. An initial flow in the range of 10 to 30 cfs was specified for the equalizer and lateral canals. The initial conditions for the reaches along the C-51 canal were approximated from the measured discharge values at upstream and downstream structures S5A-E and S155.

## 4.5 CALIBRATION RESULTS

### Peak Stage and Flow Comparison

As indicated earlier, the primary goal during the calibration process was to minimize the error between measurements and simulated results at the calibration locations. Table 4-1 presents a comparison of the peak stages between simulated and measured values at the calibration locations (S5A-E, C51WEL, C51SR7, and S155). A comparison of the time to peak stage is also presented in this table. As can be seen from Table 4-1, the simulated peak stages are within 1.4% of the measured values along the C-51 canal except at S155 where the peak stage is approximately 11.3% below the measured record. The simulated times to peak stage at the calibration locations (C51WEL, C51SR7, S155) occur approximately 2 to 4 hours later than the measured times to peak that occur in early hours on October 16, 1999. Figure 4-1 presents the calibrated maximum water surface profile along the C-51 and other selected canals.

**Table 4-1**
**Calibration Results for Peak Stage**

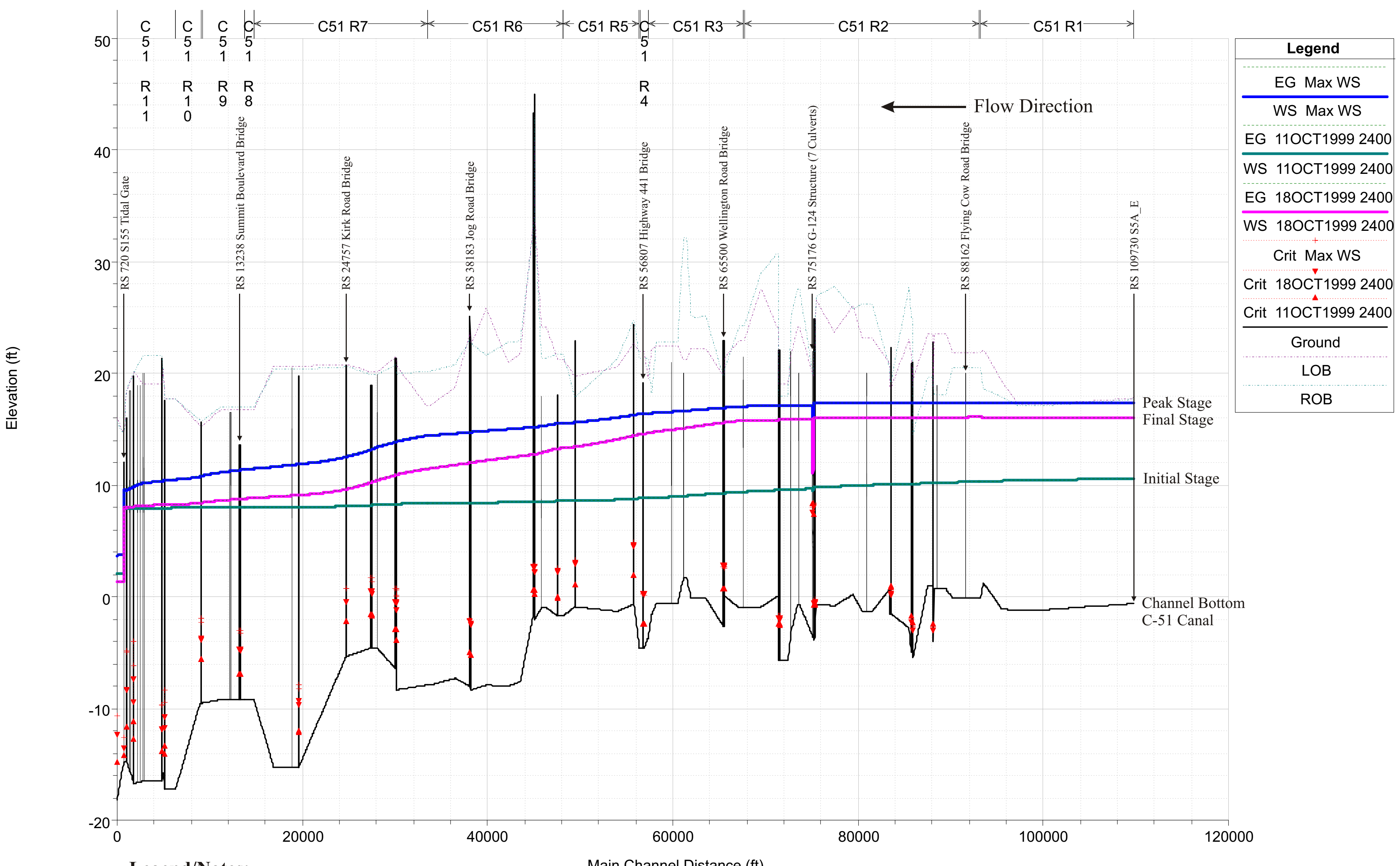
| Location | Canal Name | Reach Name | River Station | Peak Stage (ft-NGVD) | | | Time to Peak | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Measured | Simulated | Difference (%) | Measured | Simulated | Difference (hr) |
| S5A-E | C-51 | R1 | 109730 | 17.37 | 17.37 | + 0.0 | 16:00 hr 10-16-99 | 14:00 hr 10-16-99 | - 2 |
| C51WEL | C-51 | R3 | 65500 | 16.92 | 16.94 | - 0.1 | 03:00 hr 10-16-99 | 07:00 hr 10-16-99 | + 4 |
| C51SR7 | C-51 | R4 | 56807 | 16.17 | 16.40 | - 1.4 | 03:00 hr 10-16-99 | 06:00 hr 10-16-99 | + 3 |
| S155-H | C-51 | R11 | 750 | 10.85 | 9.62 | + 11.3 | 04:00 hr 10-16-99 | 06:00 hr 10-16-99 | + 2 |

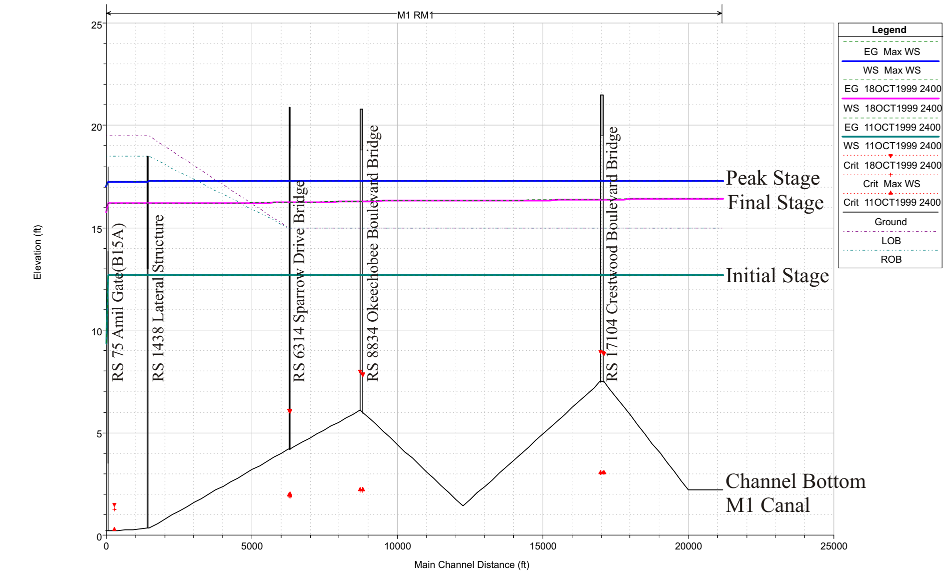
Table 4-2 presents a comparison of the peak flows between simulated and measured values at the calibration locations. A comparison of the time to peak flow is also presented in this table. As can be seen from Table 4-2, the simulated peak flow at the outfall structure (S155) is 7,815 cfs, which is within 1% of the measured value of 7,805 cfs. The simulated time to peak discharge (07:00 hour on October 16, 1999) at this location occurs approximately 3 hours later than the measured time (04:00 hour on October 16, 1999). The peak discharge at this outfall structure occurs approximately one hour later than the peak stage.

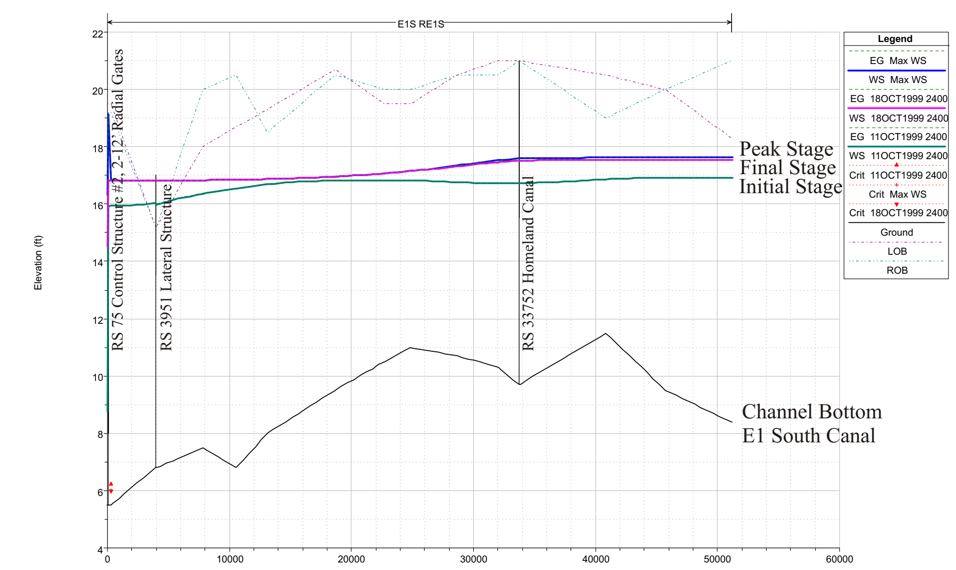
**Table 4-2**
**Calibration Results for Peak Flow**

| Location | Canal Name | Reach Name | River Station | Peak Flow (cfs) | | | Time to Peak | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Measured | Simulated | Difference (%) | Measured | Simulated | Difference (hr) |
| S5A-E | C-51 | R1 | 109730 | -- | -- | -- | -- | -- | -- |
| C51WEL | C-51 | R3 | 65500 | NA | 2074 | -- | NA | 15:00 hr 10-18-99 | -- |
| C51SR7 | C-51 | R4 | 56807 | NA | 2479 | -- | NA | 06:00 hr 10-17-99 | -- |
| S155-H | C-51 | R11 | 750 | 7805 | 7815 | + 0.13 | 04:00 hr 10-16-99 | 07:00 hr 10-16-99 | + 3 |

Considering the scale of the model considered during this study for the C-51 basin, the accuracy of the calibrated results is acceptable.




**Legend/Notes:**

- EG Energy Grade
- WS Water Surface
- Crit Critical Depth
- LOB Left Over Bank
- ROB Right Over Bank
- Vertical lines represent locations of hydraulic structures (such as bridges, culverts, etc.)
- Main Channel Distance is measured from downstream end (same as River Station)
- C51 R7 Reach 7 of C51 Canal

BPC Group
BP Consulting Group, Inc.
Engineers • Scientists • Planners • Surveyors

TBE GROUP

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

| | NAME | DATE |
|---|---|---|
| DESIGNED BY | NA | |
| DRAWN BY | | |
| CHECKED BY | | |
| APPROVED BY | | |
| FILE NAME: FL02006-Figure 4-1.cdr | | |

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.

**WATER SURFACE PROFILES ALONG SELECTED CANALS**
Reevaluation of the C-51 Basin Rule
Technical Memorandum #2: Basin Modeling System
South Florida Water Management District, Contract No. C-13412

**FIGURE 4-1**

FILE NUMBER FL02006 SHEET ___ OF ___

### Other Stage and Flow Comparison

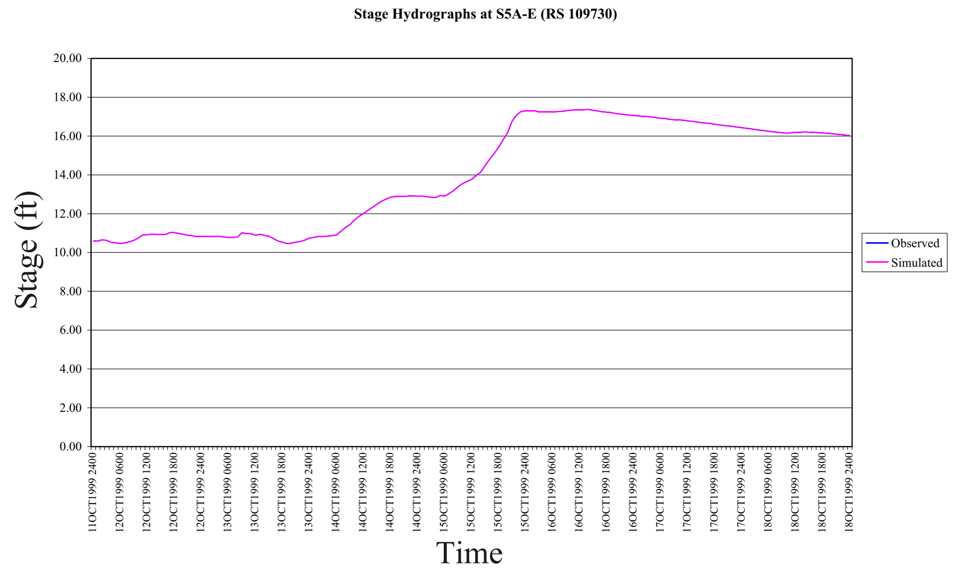
A comparison of the measured and simulated stage hydrographs (time-stage plots) at S5A-E, C51WEL, C51R7, and S155-H for the entire calibration period is shown on Figure 4-2. The calibrated stages for stations S155, C51SR7 and C51WEL at selected time intervals (at 24-hour interval starting at 00:00 hour on October 12, 1999) during the calibration period are summarized in Table 4-3. As can be seen from Figure 4-2, the simulated stages have close agreement with the observed stages throughout the calibration period. In general, the simulated stages are slightly lower than the measured stages during pre-hurricane period (prior to Hurricane Irene on October 14, 1999), while the simulated stages are slightly higher than the measured stages during the post-hurricane period (after October 16, 1999). The higher stages after the hurricane is partially attributed to the 1000 cfs discharge from M-1 canal to the C-51 canal.

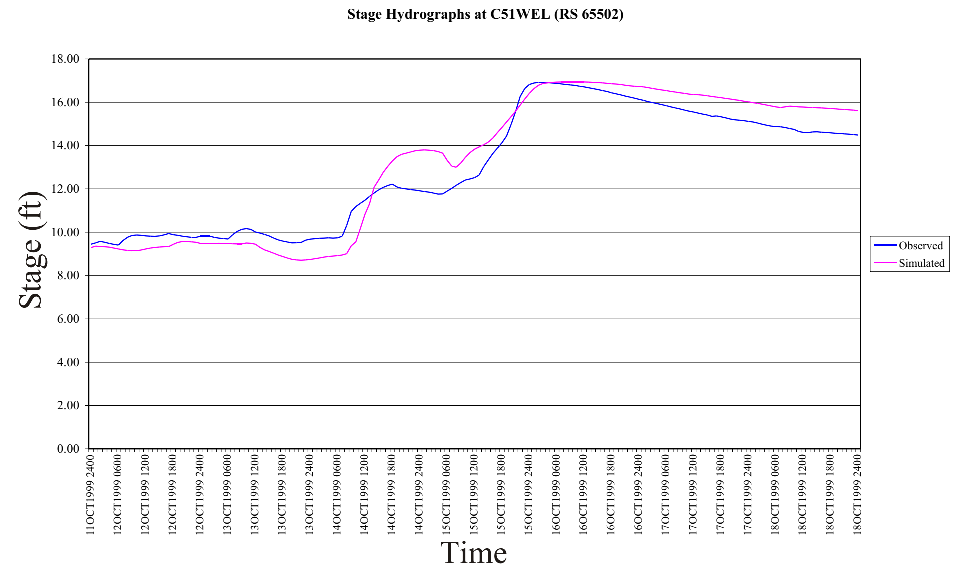
**Table 4-3**
**Calibrated Stage Hydrographs**

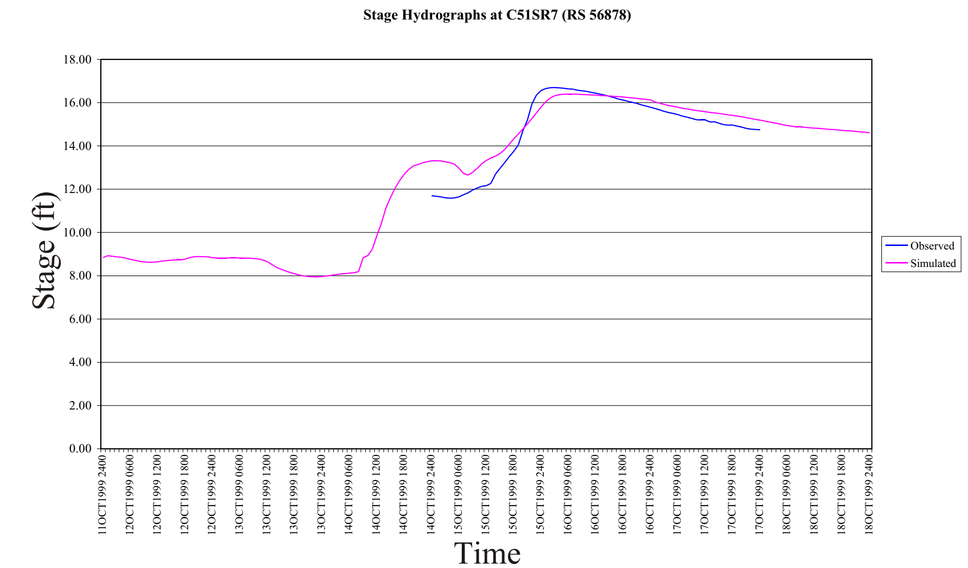
| Date | Clock Time | S155-H (RS 750) | | C51SR7 (RS 56807 or 56878) | | C51WEL (RS 65500) | |
|---|---|---|---|---|---|---|---|
| | | Measured Stage (ft) | Simulated Stage (ft) | Measured Stage (ft) | Simulated Stage (ft) | Measured Stage (ft) | Simulated Stage (ft) |
| 10-12-99 | 00:00 | 7.93 | 7.94 | NA | 8.83 | 9.45 | 9.29 |
| 10-13-99 | 00:00 | 8.12 | 7.27 | NA | 8.83 | 9.82 | 9.48 |
| 10-14-99 | 00:00 | 7.62 | 6.03 | NA | 7.96 | 9.68 | 8.74 |
| 10-15-99 | 00:00 | 7.27 | 7.86 | 11.70 | 13.31 | 11.91 | 13.79 |
| 10-16-99 | 00:00 | 10.63 | 9.29 | 16.56 | 15.80 | 16.82 | 16.41 |
| 10-17-99 | 00:00 | 9.72 | 9.27 | 15.79 | 16.13 | 16.14 | 16.73 |
| 10-18-99 | 00:00 | 8.38 | 8.53 | 14.75 | 15.19 | 15.12 | 16.02 |
| 10-19-99 | 00:00 | 7.71 | 8.00 | NA | 14.61 | 14.49 | 15.62 |

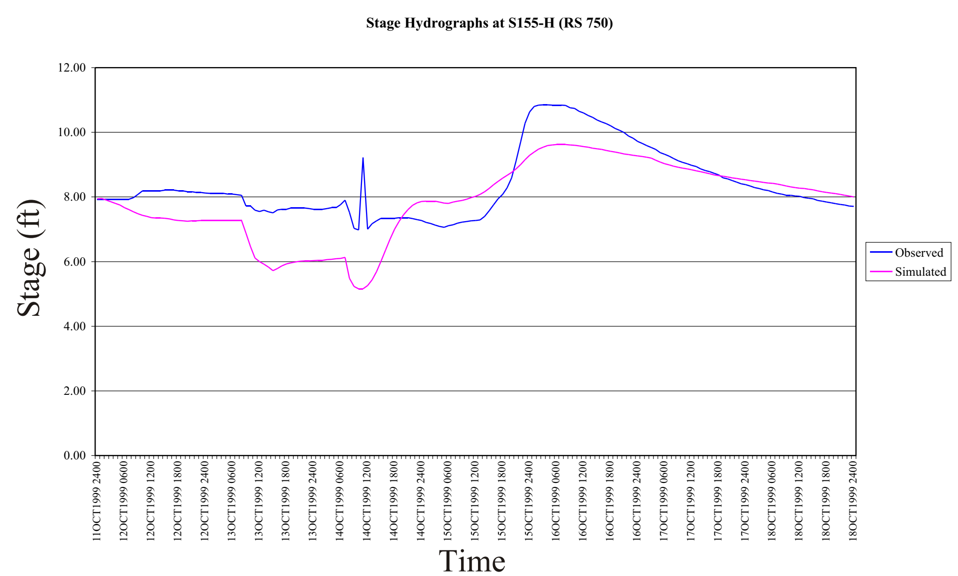
A comparison plot of the measured and simulated flow hydrograph (time-flow plot) at S155-H is also shown on Figure 4-2. The simulated stage and flow hydrographs at other selected locations in the C-51 basin are shown on Figure 4-3. Considering the scale of the model considered during this study for the C-51 basin, the accuracy of the calibrated results is acceptable.

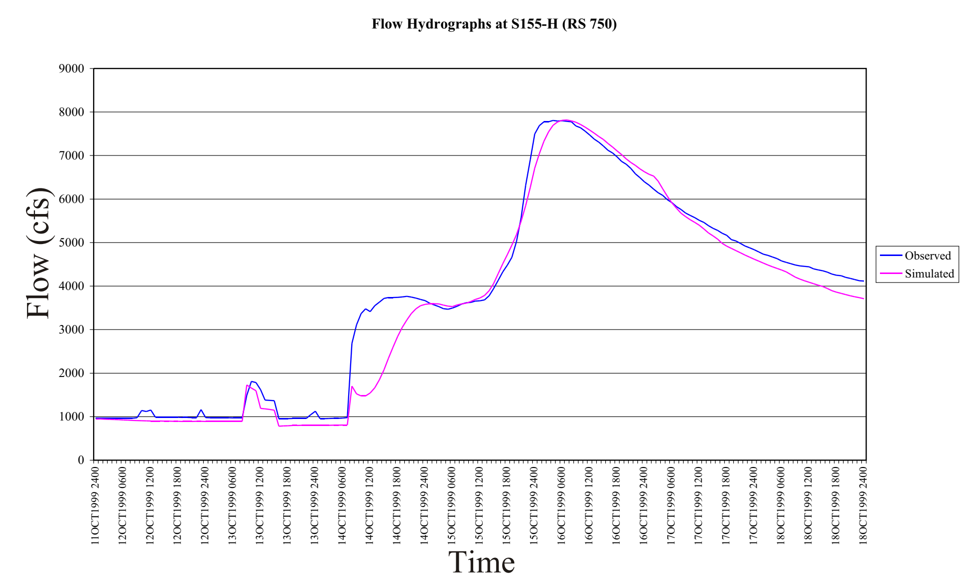
Figure 4-1 also presents the water surface profiles at the initial (at 00:00 hour on October 12, 1999) and the end (at 24:00 hour on October 18, 199) of the calibration period. The calibration locations are identified on the figure. Due to extensive size, hard copy of the model input and output is not provided. The model output in DSS format (standard output format for HMS and RAS models), including the inflow hydrographs, is provided in electronic format in Appendix C-3. A printout of the HMS and RAS model result summary is provided in Appendices C-1 and C-2, respectively.




BPC Group
BP Consulting Group, Inc.
Engineers • Scientists • Planners • Surveyors

TBE GROUP

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

| | NAME | DATE |
|---|---|---|
| DESIGNED BY | NA | |
| DRAWN BY | | |
| CHECKED BY | | |
| APPROVED BY | | |
| FILE NAME: FL02006-Figure 4-2.cdr | | |

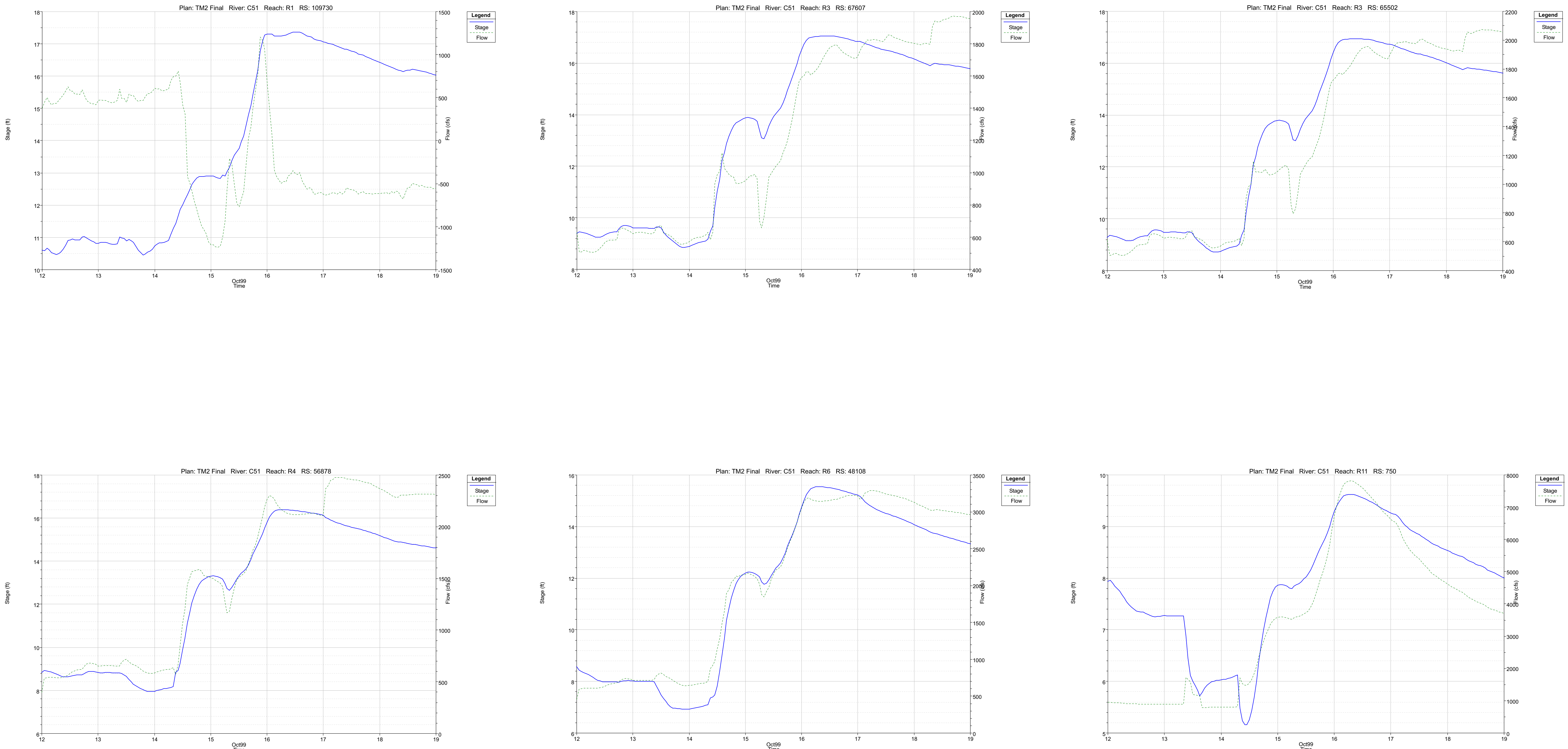
I hereby certify that this document was prepared by me or under my direct supervision and that I am a duly registered Professional Engineer under the laws of the State of Florida.

SIGNED NA
NAME
DATE REG. NO.

**STAGE AND FLOW HYDROGRAPHS AT CALIBRATION LOCATIONS**
Reevaluation of the C-51 Basin Rule
Technical Memorandum #2: Basin Modeling System
South Florida Water Management District, Contract No. C-13412

**FIGURE 4-2**

FILE NUMBER FL02006
SHEET ___ OF ___




| | NAME | DATE |
|---|---|---|
| DESIGNED BY | NA | |
| DRAWN BY | | |
| CHECKED BY | | |
| APPROVED BY | | |
| FILE NAME: FL02006-Figure 4-3.cdr | | |

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.

# STAGE AND FLOW HYDROGRAPHS AT SELECTED LOCATIONS

Reevaluation of the C-51 Basin Rule

Technical Memorandum #2: Basin Modeling System

South Florida Water Management District, Contract No. C-13412

## FIGURE 4-3

FILE NUMBER FL02006 SHEET __ OF __

### Basin Storage Results

Table 4-4 presents the basin summary results for each sub-basin that includes the runoff volume, peak runoff and time to peak runoff from the HMS model, and the peak stage and peak outflow information from the RAS model. Appendices C-1 and C-2 include a printout of the summary results from the HMS and RAS models, respectively. The complete model output is included in electronic format in Appendix C-3. The basin summary results in conjunction with the canal stages generally define the flooding level for each sub-basin. Similar results will be utilized in Task 3 (Model Application) to define the basin rule criteria. However, these results during the current task (Task 2) are presented here for informational purposes.

### Calibrated Parameters

The calibrated curve number and time lag for the sub-basins are presented in Table 4-5. The corresponding time of concentration values for the sub-basins are also presented in this table. The calibrated curve numbers are within 4% of the estimated (pre-calibration) values previously presented in Table 3-1 for all sub-basins except for sub-basin 38 where the difference is approximately 6.3%. Similarly, the calibrated time lags for the sub-basins are identical to the estimated time lags except for the sub-basins 2A, 7, 11, 15A, 16B, 21A, and 22. At these sub-basins, the calibrated time lags are approximately 6 to 14% lower than the estimated time lag values.

The calibrated values of Manning's n coefficient ranged from 0.03 to 0.05 along the main channel, and 0.5 along the overbanks. The calibrated coefficient was 0.03 along the main channel for the M-2, M-1, E-1 through E-4, and L-5 through L-11. The calibrated coefficients along the C-51 canal were 0.04 along the reaches R1 and a segment of R2, and 0.05 for remainder of the C-51 canal.

As indicated earlier in Section 4.3, the time step for RAS model implementation was set at one (1.0) minute interval, and the implicit weighting factor was maintained at 1.0.

**Table 4-4**
**Basin Summary Results**

| Sub-basin | Results from HEC-HMS Model | | | Results from HEC-RAS Model | | | |
|---|---|---|---|---|---|---|---|
| | Peak Runoff * (cfs) | Time of Peak Runoff | Total Runoff Volume ** (ac-ft) | Peak Stage (ft) | Time of Peak Stage | Peak Outflow * (cfs) | Time of Peak Outflow |
| 1 | 1417 | 15 Oct 99 2300 | 1162.4 | 14.02 | 10-16-99 0500 | 48 | 10-15-99 1100 |
| 2A | 5034 | 16 Oct 99 0230 | 6936.3 | 13.11 | 10-16-99 1600 | 225 | 10-16-99 0000 |
| 2B | 1947 | 15 Oct 99 2200 | 1261.0 | 13.95 | 10-16-99 0300 | 22 | 10-16-99 0400 |
| 3 | 742 | 15 Oct 99 2245 | 595.3 | 15.79 | 10-16-99 0500 | 22 | 10-15-99 2300 |
| 4 | 657 | 15 Oct 99 2300 | 556.5 | 16.67 | 10-16-99 0600 | 15 | 10-14-99 0900 |
| 5 | 1474 | 15 Oct 99 2245 | 1204.0 | 17.39 | 10-16-99 1700 | 82 | 10-18-99 2000 |
| 6 | 1060 | 15 Oct 99 2200 | 736.8 | 19.43 | 10-16-99 0200 | 33 | 10-12-99 1100 |
| 7 | 3642 | 16 Oct 99 0115 | 4306.0 | 19.79 | 10-16-99 1100 | 237 | 10-16-99 1000 |
| 8 | 3953 | 16 Oct 99 0015 | 4139.1 | 20.70 | 10-18-99 0900 | 1 | 10-16-99 1000 |
| 9 | 134 | 15 Oct 99 2145 | 73.5 | 17.88 | 10-16-99 0300 | 1 | 10-15-99 2200 |
| 10 | 271 | 15 Oct 99 2245 | 225.3 | 18.26 | 10-16-99 0400 | 16 | 10-16-99 0500 |
| 11 | 7074 | 16 Oct 99 0115 | 8565.1 | 18.85 | 10-16-99 1000 | 1276 | 10-14-99 2000 |
| 12 | 151 | 15 Oct 99 2145 | 87.4 | 17.21 | 10-16-99 0000 | 45 | 10-16-99 0000 |
| 13 | 9283 | 16 Oct 99 0115 | 11599.0 | 16.64 | 10-16-99 1400 | 255 | 10-16-99 0200 |
| 14 | 8860 | 16 Oct 99 0030 | 9574.9 | 15.67 | 10-16-99 1000 | 223 | 10-14-99 1400 |
| 15A | 4423 | 16 Oct 99 0130 | 5821.0 | 17.99 | 10-16-99 0800 | 888 | 10-16-99 0900 |
| 15B | 6961 | 16 Oct 99 0200 | 9181.7 | -- | -- | -- | -- |
| 16A | 1241 | 15 Oct 99 2330 | 1183.8 | 16.67 | 10-16-99 0400 | 408 | 10-16-99 0100 |
| 16B | 1764 | 16 Oct 99 0315 | 2857.0 | 18.88 | 10-16-99 1800 | 53 | 10-16-99 2200 |
| 20A | 1430 | 15 Oct 99 2300 | 1232.7 | 16.12 | 10-17-99 0300 | 123 | 10-14-99 1600 |
| 17 | 1949 | 15 Oct 99 2330 | 1861.4 | 16.51 | 10-16-99 0400 | 304 | 10-16-99 0000 |
| 18 | 2768 | 15 Oct 99 2315 | 2555.1 | 15.67 | 10-16-99 0600 | 276 | 10-17-99 0800 |
| 20B | 2506 | 15 Oct 99 2400 | 2550.3 | 16.80 | 10-18-99 2300 | 353 | 10-15-99 1900 |
| 21A | 3168 | 16 Oct 99 0130 | 4369.9 | 17.16 | 10-16-99 1800 | 0 | -- |
| 21B | 4502 | 16 Oct 99 0115 | 5293.9 | 17.63 | 10-16-99 1500 | 106 | 10-16-99 0200 |
| 22 | 6489 | 16 Oct 99 0115 | 7977.6 | 17.39 | 10-16-99 1100 | 497 | 10-16-99 1200 |
| 23 | 4502 | 15 Oct 99 2400 | 4589.9 | 16.86 | 10-16-99 0500 | 807 | 10-16-99 0600 |
| 24 | 5116 | 16 Oct 99 0045 | 5788.7 | 17.73 | 10-16-99 0800 | 565 | 10-16-99 0900 |
| 25A | 374 | 15 Oct 99 2145 | 215.7 | 14.37 | 10-16-99 0000 | 427 | 10-16-99 0000 |
| 25B | 1607 | 15 Oct 99 2200 | 1043.2 | 14.54 | 10-16-99 0100 | 389 | 10-16-99 0300 |
| 26 | 571 | 15 Oct 99 2215 | 408.9 | 13.95 | 10-16-99 0100 | 320 | 10-17-99 0200 |
| 27 | 1028 | 15 Oct 99 2300 | 935.6 | 13.20 | 10-16-99 0400 | 160 | 10-14-99 1300 |
| 28 | 439 | 15 Oct 99 2145 | 248.8 | 11.79 | 10-16-99 0600 | 304 | 10-15-99 2200 |
| 29A | 2628 | 15 Oct 99 2200 | 1711.1 | 14.21 | 10-16-99 0100 | 374 | 10-16-99 0100 |
| 29B | 714 | 15 Oct 99 2200 | 502.3 | 17.22 | 10-16-99 0300 | 9 | 10-16-99 0300 |
| 30 | 1745 | 15 Oct 99 2215 | 1227.6 | 14.02 | 10-16-99 0200 | 260 | 10-16-99 0200 |
| 31 | 2243 | 15 Oct 99 2215 | 1585.8 | 12.94 | 10-16-99 0100 | 612 | 10-16-99 0100 |
| 32 | 2229 | 15 Oct 99 2300 | 1977.1 | 12.94 | 10-16-99 0300 | 494 | 10-16-99 0300 |
| 33 | 3050 | 15 Oct 99 2245 | 2513.8 | 13.53 | 10-16-99 0300 | 522 | 10-16-99 0300 |
| 34 | 866 | 15 Oct 99 2300 | 734.0 | 16.71 | 10-16-99 0400 | 151 | 10-16-99 0400 |
| 35 | 376 | 15 Oct 99 2130 | 191.4 | 11.54 | 10-16-99 0100 | 23 | 10-16-99 0000 |
| 36 | 827 | 15 Oct 99 2230 | 604.0 | 13.85 | 10-16-99 0200 | 165 | 10-16-99 0200 |
| 37 | 530 | 15 Oct 99 2230 | 379.5 | 16.21 | 10-16-99 0200 | 103 | 10-16-99 1500 |
| 38 | 2620 | 15 Oct 99 2245 | 2222.1 | 17.03 | 10-16-99 0500 | 148 | 10-18-99 0500 |

* Rounded to the nearest whole number
** Rounded to the nearest one-tenth (one decimal)

**Table 4-5**
**Summary of Calibrated Basin Parameters**

| 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 | 75.0 | 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 |

# 5.0 MODEL APPLICATION

In accordance with the contractual scope of services, the model application will be completed in Task 3. In order to complete the project on schedule, the Task 3 activities have already been initiated. Following is a brief description of the activities that will be completed in Task 3, and the details of which will be reported in the Technical Memorandum #3.

The methodology described in Section 3.0 is applicable to the model application phase in Task 3 as given below.

- Use the 10-year, 72-hour and 100-year, 72-hour design storms presented in Appendix B-4 of this report.
- Maintain the calibrated curve number and time lag values, except for special circumstances. For example, basin 2A will be replaced by STA-1E, and therefore, the curve number will be changed to approximately 100.
- Generate runoff hydrograph using HMS model with the above described basin parameters and design storms.
- Add pump stations S319, Pump station for basin 2B, pump station for basin 14 (ACME Basin B), and PS #6 for basin B13 into RAS model.
- Add Inline Structure S155-A west of SR-7.
- Adjust for special conditions, such as upstream and downstream stage restrictions at structures S-155A and Amil Gate along M-1 Canal.
- Remove G-124 culvert structure, which was removed in the year 2000.
- Define the seepage from STA-1E as ground water recharge or lateral inflow hydrograph.
- Simulate the various alternatives in accordance with the scope of services and the amendment as described in Section 1.3.

# 6.0 REFERENCES

Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55), Soil Conservation Service, 2nd Edition, June 1986

Hydrologic Modeling System (HEC-HMS) User's Manual, Version 2.1, January 2001

Hydrologic Modeling System (HEC-HMS) Release Notes, Version 2.2.1, October 2002

River Analysis System (HEC-RAS) User's Manual, Version 3.1.1, May 2003

DBHYDRO hydrometeorological data from SFWMD, Daily and Breakpoint Data (1999)

# APPENDICES