Appendix J

Prepared for

South West Florida Water Management District

HEC-RAS MODELING OF LITTLE MANATEE RIVER
10POSOW0468

Final Report

Prepared by

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Client		
SOUTH WEST FLORIDA WATER MANAGEMENT DISTRICT		
Project		
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SECTION 1 **Introduction**

1.1 Project Background

ZFI Engineering and Construction Inc. (ZFI), is undertaking the HEC-RAS Modeling of Little Manatee River Project (10POSOW0468) provided by the Southwest Florida Water Management District. The District is committed to developing scientifically defensible methodologies to be used in the establishment of minimum flows on priority watercourses within its boundaries as required by Sections 373.042 and 373.0421 of the Florida Statutes.

This project pertains to technical assistance in the determination of minimum flows for Little Manatee River. One methodology, Hydrologic Engineering Centers River Analysis System (HEC-RAS), has been used throughout the United States. HEC-RAS has been utilized by the District for the Alafia, Upper Myakka, Hillsborough, Braden and Middle Peace Rivers. This approach is based on determining the river stages along the study reach under various flow conditions, which is the major objective of this project. The data can then be used to determine fish passage and wetted perimeter requirements, inundation of snag habitat, and inundation frequency/duration of riverine vegetation and floodplains.

1.2 Project Location and General Description

The Little Manatee River (LMR) watershed lies primarily in southern Hillsborough County and northern Manatee County, Florida. The study area in the project does not cover the entire LMR watershed which is bordered by the Alafia River and Bullfrog Creek watersheds on the north, the Manatee River watershed on the South, the Peace River watershed on the east and Tampa Bay on the west. Instead, only part of river, which is from USGS02300100 near Ft. Lonesome, FL to USGS02300500 near Wimauma, FL is studied in this project.

The main channel of the river in the study area flows from east to west for approximately 15 miles, providing surface drainage for approximately 200 square miles. It contains several major named tributaries, including Howard Prairie Branch, Pierce Branch, Carlton Branch, Gully Branch, Lake Wimauma Plain, Dug Creek, and South Fork, etc..

Ecosystems observed along the River included Oak Hammocks, Scrubby High Pines, and Temperate Hardwood Forests (possibly in some areas of the river). Flora observed included various Oak species (i.e. Chapman Oak, Live Oak), Saw Palmetto, Rosemary, and Sand Pines. The topography is mainly low-lying hilly areas and the substrate was mostly sandy. The River banks were primarily steep and sandy. Water flow along the River is generally regulated by natural controls, including both rocky and sandy shoals.

The LMR watershed contains only two natural lakes, Carlton Lake and Lake Wimauma, and a 4,000 acre cooling water reservoir located south of the river where it dips into Manatee County. Water from the reservoir is withdrawn from the Little Manatee River and is used to cool the existing Florida Power and Light (FP&L) electric generating facility.

SECTION 2 Description of the Study Area

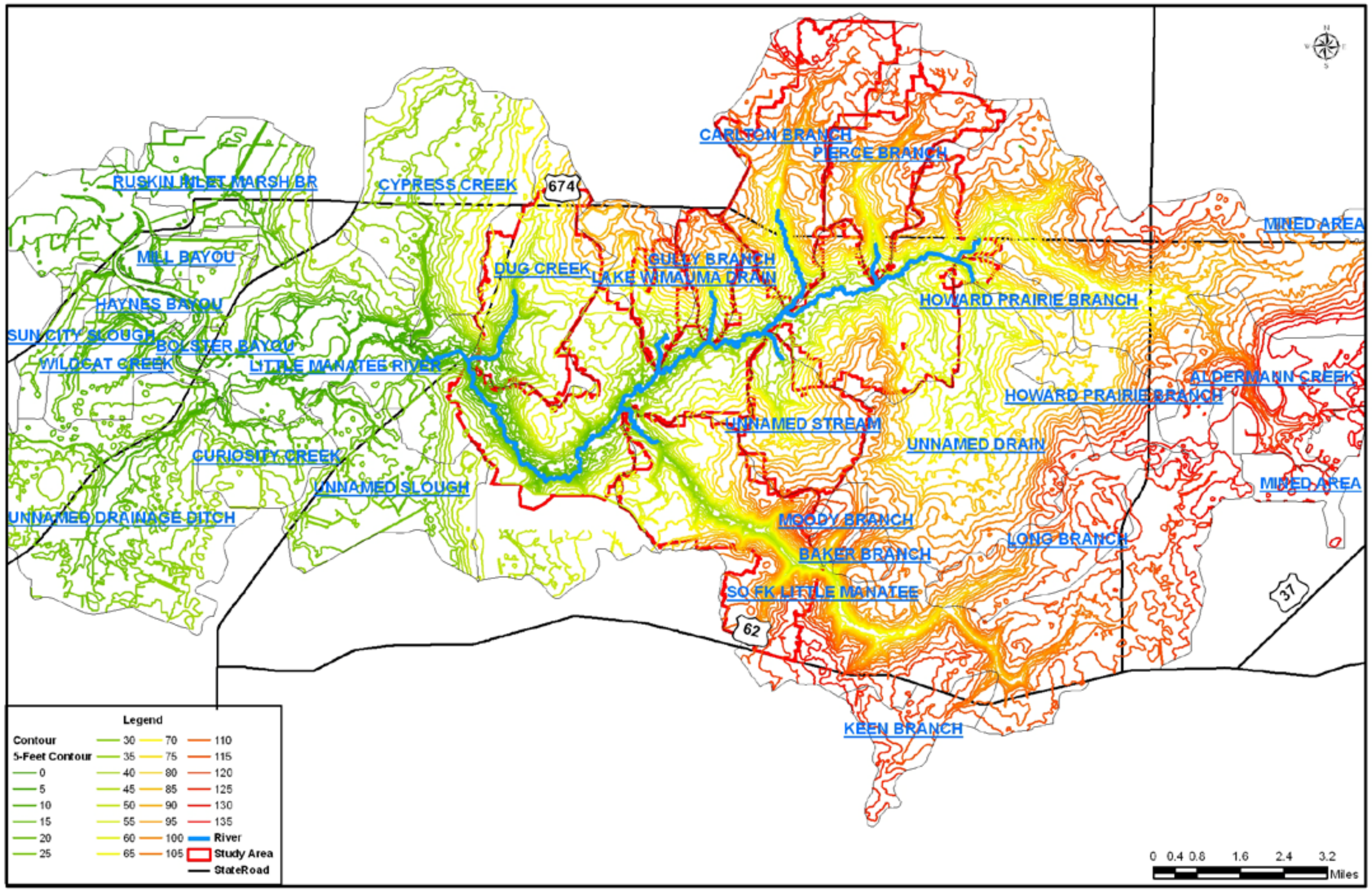
2.1 Local Climate

The climate in the study area can be characterized as subtropical, typified by warm, humid summers, mild winters, and dry spring and fall seasons. The annual mean temperature is about 72 degree F (Fahrenheit). The mean monthly temperature ranges from a low of approximately 60 degree F in January to a high of approximately 82 degree F in August. Summer daytime temperatures commonly exceed 90 degrees F. Typical winter low temperatures generally range above freezing into the 40's; only occasionally dropping into the low 20's and teens.

Average annual precipitation for the NWS Parrish Station (1958-2009) is approximately 53.8 inches. More than half of the annual rainfall typically falls during the four-month rainy season that extends from June through September. This time frame coincides with the occurrence of most tropical storms and hurricanes and the conditions are ripe for regular, convective afternoon and evening thunderstorms. Winter rainfall is historically relatively light and is generally associated with the weak cold fronts that descend from the northern part of the country and travel south through the region.

2.2 Topography

The LMR watershed rises from sea level at Tampa Bay to about 50 feet NAVD88 at USGS02300100 near Ft. Lonesome, FL. Slopes are relatively mild in the basin, with more pronounced slopes east of US 301 and Wimauma. Areas with the steepest topographic slopes include the Lake Wimauma Drain and Gully Branch tributaries in Hillsborough County and portions of the South Fork tributary located primarily in Manatee County. Figure 2-1 shows the contour lines for the LMR watershed. Red color indicates areas of high elevation and green lines indicate topographically lower areas.



Five-Feet Contour Lines (Topography)

HEC-RAS MODELING OF LITTLE MANATEE RIVER

10POSOW0468

Figure 2-1 Five-feet Contour Lines (Topography)

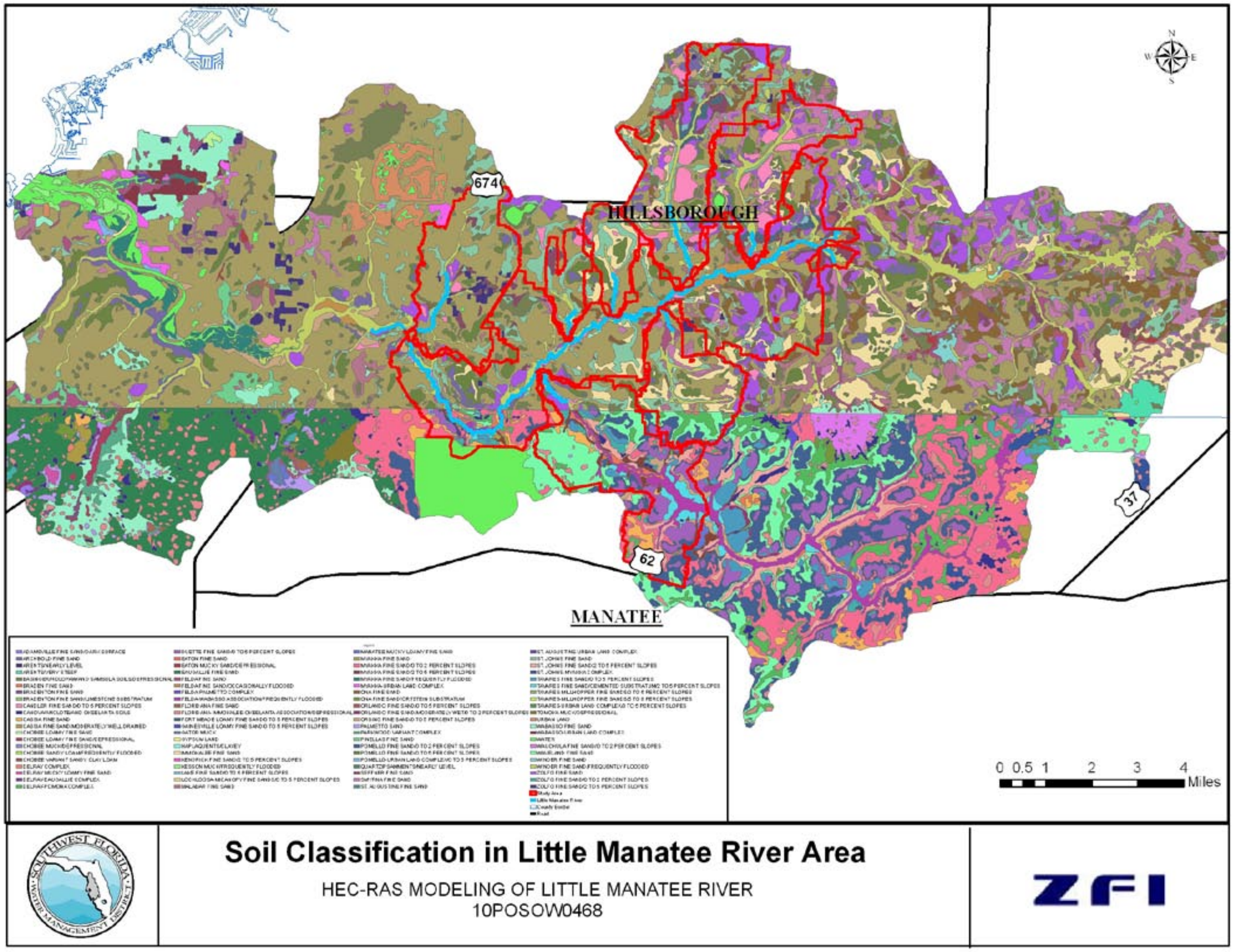
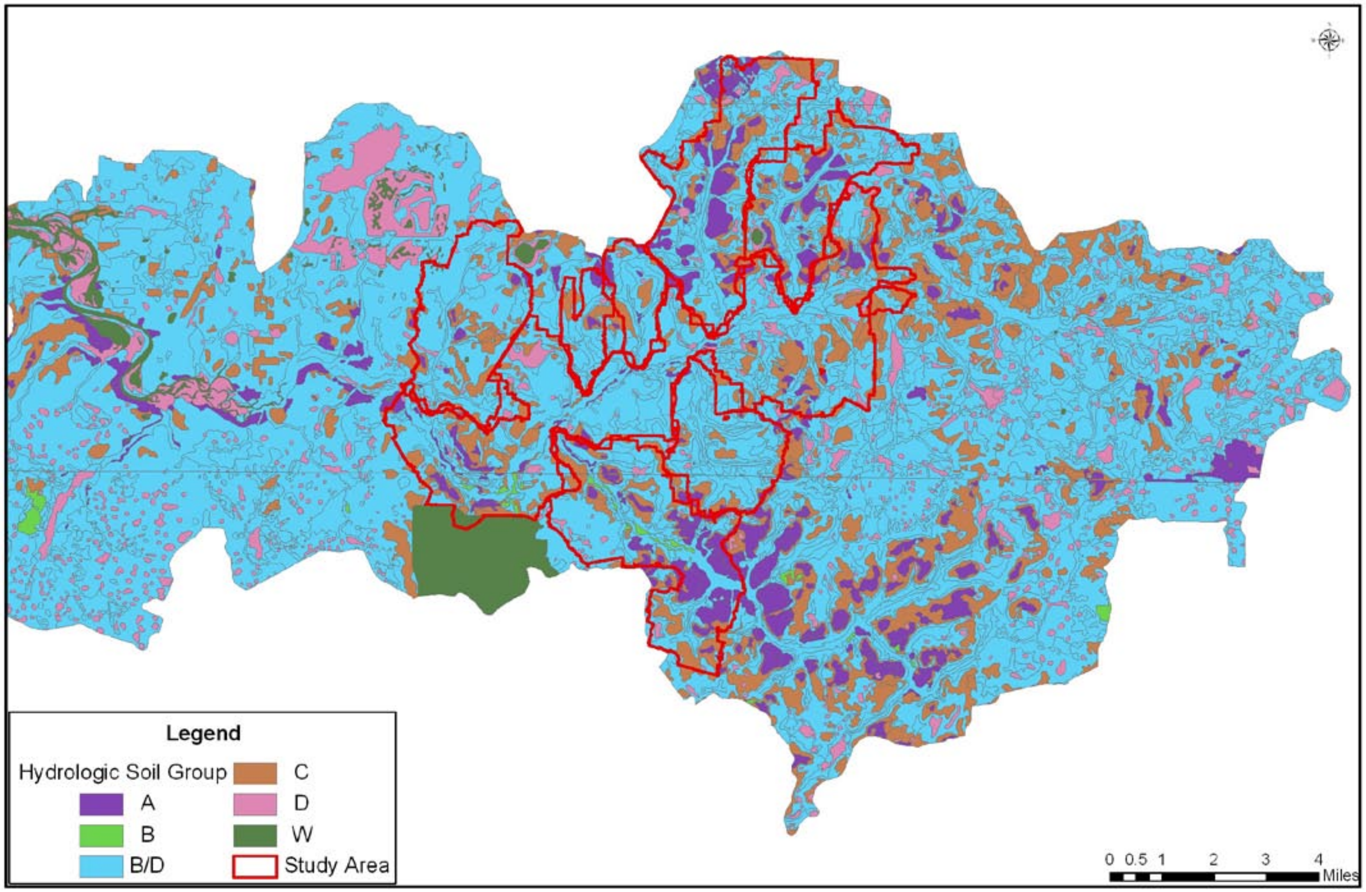


Figure 2-2 Soil Classification



Hydrologic Soil Group

HEC-RAS MODELING OF LITTLE MANATEE RIVER
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Figure 2-3 Hydrologic Soil Group

2.3 Soils

Primary soil group in the LMR watershed is the Myakka Fine Sand which is characterized by wet, sandy soils with an organic-stained subsoil layer. Figure 2-2 shows the location of soil classifications in the LMR watershed. This information was developed based on SCS Soil Survey with GIS coverages developed by SWFWMD.

Soils are also classified by their hydrologic characteristics. The Hydrologic Soil Groups (HSG) designation for soils is used to estimate infiltration rates, moisture capacity and runoff from precipitation. Hydrologic soil polygons were developed from the SCS Soil Survey of Hillsborough County, Florida, 1989 (USDA SCS, 1989). Each soil with identification numbers contained in the Soil Survey can be associated with its corresponding Hydrologic Soil Group. Hydrologic Soil Groups in the LMR watershed consist of the following designations as shown in Figure 2-3.

- Group A (low runoff potential) soils have high infiltration rates and a high rate of water transmission even when thoroughly wetted. They have typical infiltration rates of 10 in/hr when dry and 0.50 in/hr when saturated.

- Group B (moderate runoff potential) soils have moderate infiltration rates when thoroughly wetted and a moderate rate of water transmission. They typically have infiltration rates of 8 in/hr when dry and 0.40 in/hr when saturated.

- Group C (moderately high runoff potential) soils have low infiltration rates when thoroughly wetted and a low rate of water transmission. They typically have infiltration rates of 5 in/hr when dry and 0.25 in/hr when saturated.

- Group D (high runoff potential) soils have very slow infiltration rates when thoroughly wetted and a very low rate of water transmission. They typically have infiltration rates of 3 in/hr when dry and 0. 10 in/hr when saturated.

- Dual classifications (e.g. A/D or B/D) can be assigned to soils that exhibit substantially different hydrologic characteristics during the wet and dry seasons. Soils that have a seasonal high water table but can be drained are assigned first to a hydrologic soil group that represents the drained conditions of the soil and then to a hydrologic group that denotes the undrained condition. Many soils in the LMR watershed have dual HSG designations. The predominate Hydrologic Soil Group within the LMR watershed is B/D comprising almost 70% of the watershed.

2.4 Land Use / Land Cover

The SWFWMD has developed GIS coverages for the 2008 land use/land cover for the entire LMR watershed. The GIS coverage was developed using the Florida Land Use/Cover Classification System (FLUCCS) to define land use/land cover in one of about 50 categories. Each polygon in the coverage has been assigned a FLUCCS code corresponding to the existing land use for that area. As shown in Figure 2-4, existing land use/land cover in the Little Manatee River basin is dominated by agriculture which encompasses more than 40 percent of the total basin area. The primary agricultural uses include pastureland, citrus and row crops. Table 2-1 contains the distribution of existing land use/land cover (2008) for the watershed.

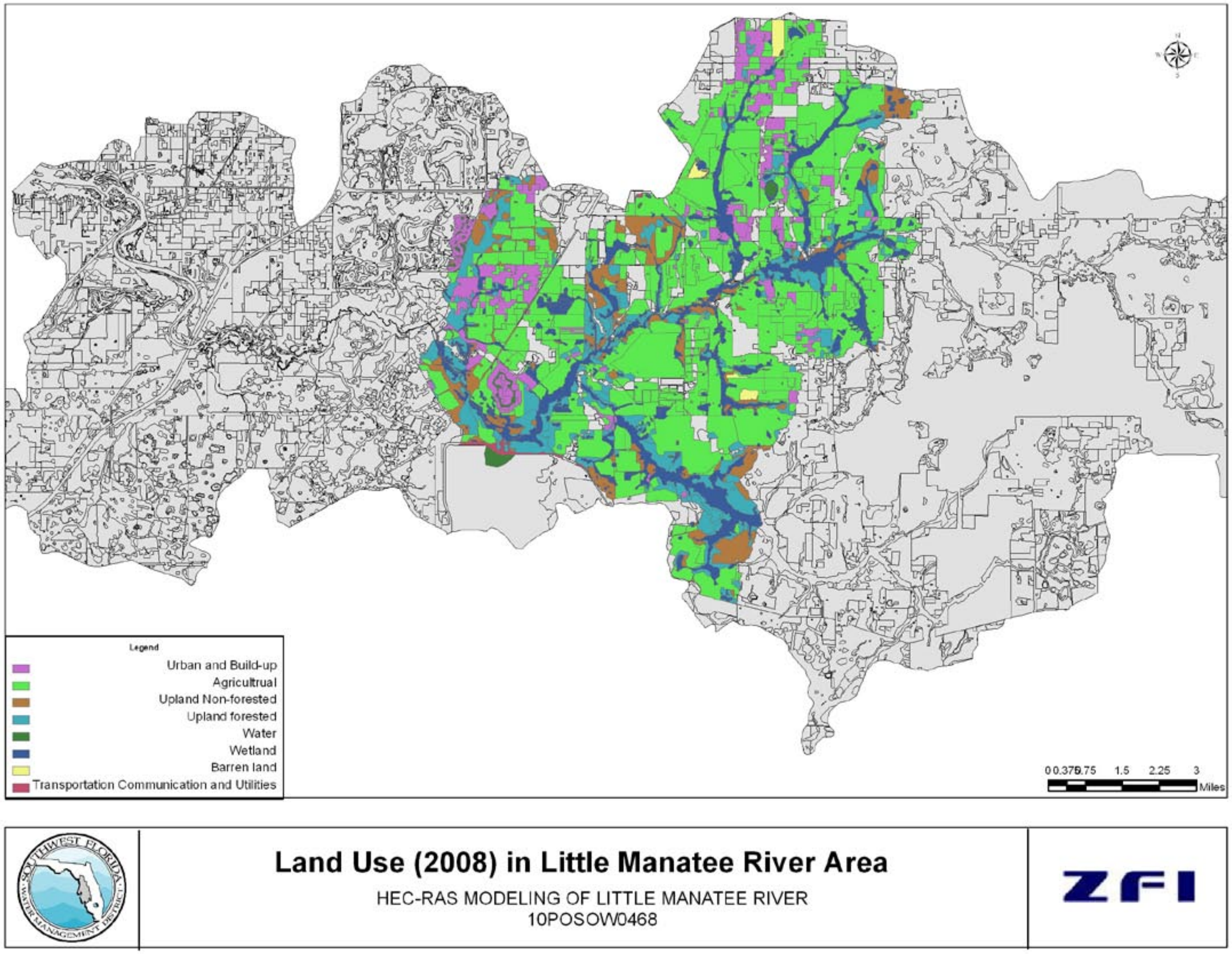

Figure 2-4 Land Use (2008)

Table 2-1 Existing Land Use / Land Cover (2008) Distribution

FLUCCS Codes	Land	Percentage	Area (sq mles)
1100	Residential Low Density < 2 Dwelling Units	5.64%	3.07
1300	Residential High Density	0.27%	0.15
1300	Residential High Density	0.18%	0.10
1400	Commercial And Services	0.29%	0.16
1500	Industrial	0.07%	0.04
1600	Extractive	0.35%	0.19
1700	Institutional	0.07%	0.04
1900	Open Land	1.31%	0.71
2100	Cropland And Pastureland	20.53%	11.17
2140	Row Crops	10.83%	5.89
2200	Tree Crops	9.21%	5.01
2400	Nurseries And Vineyards	3.02%	1.64
2550	Tropical Fish Farms	1.02%	0.55
2600	Other Open Lands <Rural>	11.03%	6.00
3100	Herbaceous	0.19%	0.10
3200	Shrub And Brushland	6.83%	3.72
3300	Mixed Rangeland	0.42%	0.23
4110	Pine Flatwoods	6.31%	3.44
4200	Upland Hardwood Forests - Part 1	0.33%	0.18
4340	Hardwood Conifer Mixed	5.72%	3.11
4400	Tree Plantations	0.14%	0.08
5200	Lakes	0.15%	0.08
5300	Reservoirs	0.70%	0.38
6150	Stream And Lake Swamps (Bottomland)	12.30%	6.70
6210	Cypress	0.40%	0.22
6410	Freshwater Marshes	0.97%	0.53
6430	Wet Prairies	0.64%	0.35
6530	Intermittent Ponds	0.06%	0.03
8100	Transportation	0.67%	0.37
8200	Communications	0.04%	0.02
8300	Utilities	0.29%	0.16

2.5 Major Tributaries

Major tributaries contained in the study area include Howard Prairie Branch, Pierce Branch, Carlton Branch, Gully Branch, Lake Wimauma Plain, Dug Creek, and South Fork. There are also several smaller unnamed tributaries that drain into the main channel of the little manatee river.

2.5.1 **Howard Prairie**

The Howard Prairie Branch lies in upstream portion of the study area. The tributary has two major branches. Both tributaries have a relatively mild slope. The headwaters of the western branch fall in Manatee County. Flow for this branch is in a northerly direction where it crosses Stanland Road approximately one mile upstream of its confluence with the eastern branch. A potential connection exists between the west branch of Howard Prairie and Moody Branch of the South Fork tributary under high flow conditions. Flow for the eastern branch is in a northwesterly direction toward the main channel of the river. Grange Hall Loop crosses both branches just upstream of their confluence. Downstream portions of both branches of the system contain a series of wetlands connected by channels with wide floodplains.

2.5.2 **Pierce Branch**

The Pierce Branch tributary lies north of the main channel of the river. Headwaters for the tributary lie north of SR 672. Since the watershed boundary crosses Hurrah Bay, flow transfer between Pierce Branch of the LMR and Lewis Branch of the Alafia River is possible at high flows. In addition to the above mentioned crossing, this six mile tributary intersects the major road crossings of Sweat Loop Road, Owens Road and SR 674. Several unnamed tributaries discharge to Pierce Branch north of the SR 674 crossing. One of the two natural lakes in the watershed, Carlton Lake outfalls to Pierce Branch. This is a 34 acre natural feature surrounded primarily by agricultural lands. Although there is no man-made control structures on the lake, once the lake reaches flood stage, flows can pass to Pierce Branch through an open channel.

2.5.3 **Carlton Branch**

Carlton Branch is located north of the main channel of the river between Pierce Branch and Gully Branch. The headwaters of the tributary are in the vicinity of SR 672. Flow from the headwaters travels in a southwesterly direction and crosses under Carlton Lake Road, Sweat Loop Road and Colding Loop. Downstream of these crossings, several smaller unnamed tributaries confluence with Carlton Branch. Flow then follows a southerly direction for approximately two miles and then crosses SR 674. A historic USGS discharge/stage gage is located on the downstream side of this road crossing. The tributary continues to flow south for about another two miles where it converges with the main channel of the river.

2.5.4 **Gully Branch**

Gully Branch lies north of the main channel of the river between Pierce Branch and Lake Wimauma Drain. This tributary has one branch located west of the main tributary channel. Flow is in a north to south direction. The headwaters for the main channel of Gully Branch lie south of SR 674. The main tributary is approximately two miles long and has a relatively steep bottom profile.

2.5.5 **Lake Wimauma Drain**

The Lake Wimauma drain tributary lies north of the main channel of the river between Gully Branch and the C.S.X. railroad. As the name would indicate, this channel provided a historical outfall for Lake Wimauma. However, this historical surficial connection no longer exists. The main channel of this tributary, as well as the connecting branches, flow from north to south and discharge into the main channel of the river. The channel bottom slope for Lake Wimauma Drain is slightly milder than that for Gully Branch.

2.5.6 **Dug Creek**

Dug Creek is located in the downstream portion of the study area west of US 301 and east of Cypress Creek. Headwaters for the tributary lie in a small wetland adjacent to US 301, north of SR 674. Land use surrounding the creek is primarily agriculture. Tropical fish farms are located in the downstream reaches of the creek. The creek flows in a southerly direction, crossing an unnamed dirt road and SR 674 to a large wetland. Flow continues to the south where several tributaries join the main channel of the creek before it crosses Bishop Road. A discontinued USGS discharge/stage gage is located at the downstream side of this road crossing. The creek continues in a southwesterly direction and crosses Saffold Road before discharging to the main channel of the river.

2.5.7 **South Fork**

The South Fork basin is almost entirely contained in Manatee County. The basin is roughly bounded by the IMC mine on the east, SR 579 on the west, Manatee County on the north and SR 62 on the south. South Fork is the largest tributary to the Little Manatee River, providing surface drainage for approximately 38.5 square miles. This tributary consists of five named tributaries including: Long Branch, Baker Branch, Moody Branch, Keen Branch, and Graveyard Creek. There are also a number of unnamed contributing tributaries. The headwaters for the main channel of South Fork lie near the IMC Mine. From the headwaters, flow is in a southwesterly then northwesterly direction until the tributary discharges into the main channel of the river downstream of SR 579. Other major road crossings include: County Road 39, Bunker Hill Road, Taylor Grade Road, Trail Arch Road, Trail Road.

SECTION 3 Hydrology Model Development

3.1 Introduction

This section summarizes the methodology used to develop the hydrologic model for the Little Manatee Watershed Study. The modeling was performed using USACE's Hydrologic Engineering Center's Hydrologic Modeling System program (HEC-HMS) Version 3.4. The HEC-HMS model is designed to simulate the precipitation-runoff processes of dendritic watershed systems. It is designed to be applicable in a wide range of geographic areas for solving the widest possible range of problems. This includes large river basin water supply and flood hydrology, and small urban or natural watershed runoff. Hydrographs produced by the program are used directly or in conjunction with other software for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems operation. The program is a generalized modeling system capable of representing many different watersheds. A model of the watershed is constructed by separating the hydrologic cycle into manageable pieces and constructing boundaries around the watershed of interest.

3.2 Hydrology Methodology

The HEC-HMS model was used to simulate runoff volumes and hydrographs resulting from design storms for 5, 10, 25, 50 and 100 year return periods using the design storms outlined in the Hillsborough County Storm Water Management Technical Manual and SWFWMD Watershed Management Program Guidelines and Specifications. The hydrology methodology contains five primary components: subarea delineation, rainfall, runoff volume, runoff hydrographs and routing.

3.2.1 <u>Subarea Delineation</u>

The study area in the Little Manatee Watershed was divided into 8 sub-basins based on the GIS coverage provided by the District. All the sub-basins were further delineated into 151 sub-areas. A map showing the sub-area boundaries are shown on Figure 3-1. The delineation was performed using ArcGIS, HEC-GeoHMS, and the digital elevation model (DEM) developed from the

LiDAR data provided by the District. The HEC-GeoHMS tool runs within ArcGIS and uses the DEM to delineate subareas and to determine the overland flow path for each subarea.

Using the HEC-GeoHMS tool, the approximate locations for subarea outlets, such as stream crossings and tributaries were identified using ArcGIS and available GIS data. The HEC-GeoHMS tool used these points to automatically delineate the subarea boundaries based on DEM. The preliminary HEC-HMS model was then created based on the automated subarea delineations. The auto-delineated subareas were manually checked against contours and drainage structure locations to accurately define the boundaries. The preliminary HEC-HMS model was manually modified to reflect updated subarea boundaries. All subareas were given a unique alphanumeric name with the format “AAA-Wxxx”. “AAA” is the two or three letter code showing the sub-basin name. “xxx” is a three digit code to identify the subarea. The sub-area identification table is shown in Table 3-1.

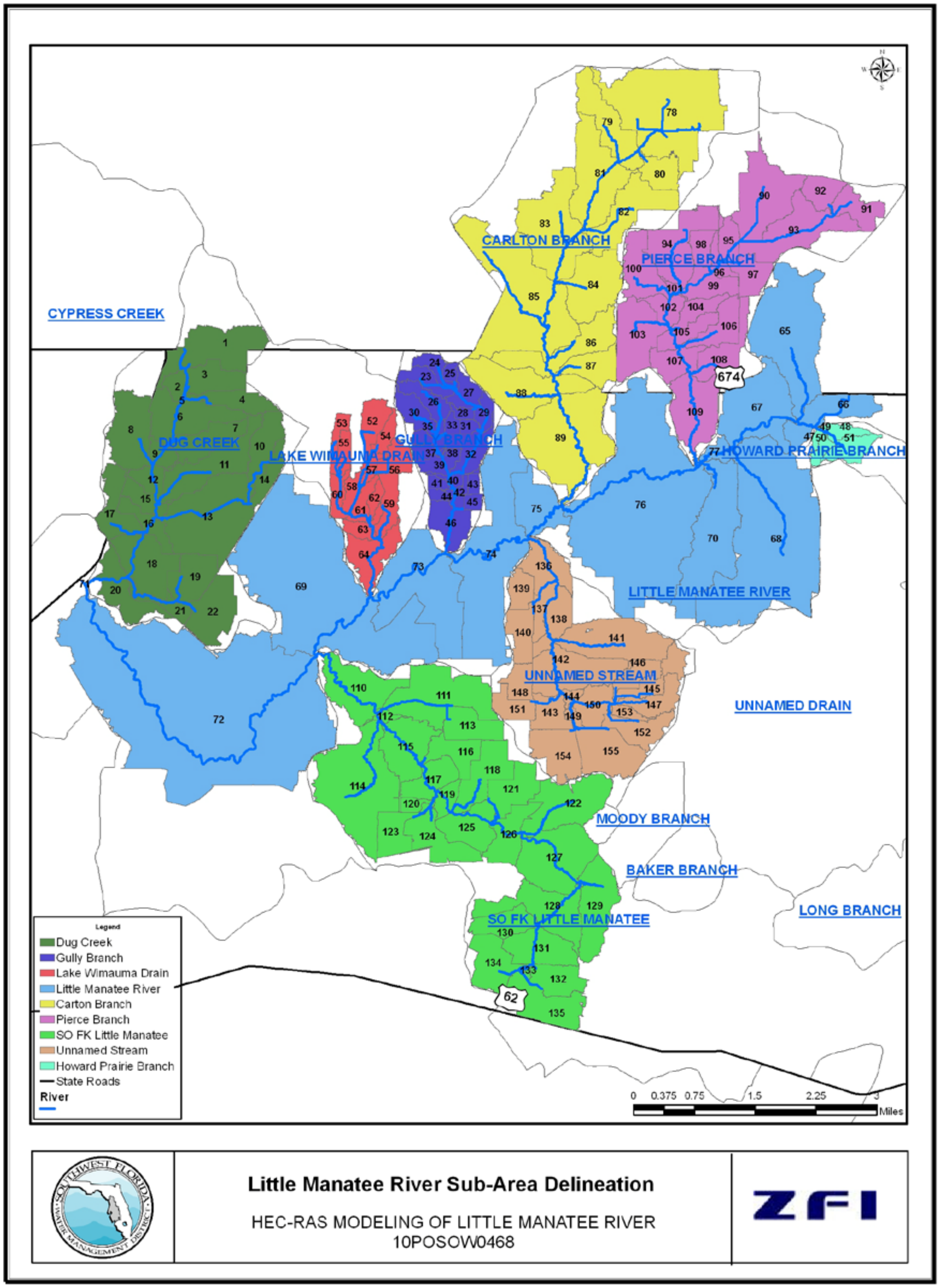

Figure 3-1 Little Manatee River Sub-Area Delineation

Table 3-1 Sub-Area Identification Table

NO.	Sub-Basin Name	Sub-Area ID	NO.	Sub-Basin Name	Sub-Area ID
1	Dug Creek	DC-W260	79	Carton Branch	CB-W370
2	Dug Creek	DC-W270	80	Carton Branch	CB-W380
3	Dug Creek	DC-W280	81	Carton Branch	CB-W390
4	Dug Creek	DC-W290	82	Carton Branch	CB-W400
5	Dug Creek	DC-W300	83	Carton Branch	CB-W430
6	Dug Creek	DC-W310	84	Carton Branch	CB-W480
7	Dug Creek	DC-W320	85	Carton Branch	CB-W490
8	Dug Creek	DC-W330	86	Carton Branch	CB-W510
9	Dug Creek	DC-W340	87	Carton Branch	CB-W520
10	Dug Creek	DC-W350	88	Carton Branch	CB-W540
11	Dug Creek	DC-W360	89	Carton Branch	CB-W550
12	Dug Creek	DC-W370	90	Pierce Branch	PB-W230
13	Dug Creek	DC-W380	91	Pierce Branch	PB-W240
14	Dug Creek	DC-W390	92	Pierce Branch	PB-W250
15	Dug Creek	DC-W400	93	Pierce Branch	PB-W260
16	Dug Creek	DC-W410	94	Pierce Branch	PB-W270
17	Dug Creek	DC-W420	95	Pierce Branch	PB-W280
18	Dug Creek	DC-W430	96	Pierce Branch	PB-W290
19	Dug Creek	DC-W440	97	Pierce Branch	PB-W300
20	Dug Creek	DC-W450	98	Pierce Branch	PB-W310
21	Dug Creek	DC-W460	99	Pierce Branch	PB-W320
22	Dug Creek	DC-W470	100	Pierce Branch	PB-W330
23	Gully Branch	GB-W270	101	Pierce Branch	PB-W340
24	Gully Branch	GB-W290	102	Pierce Branch	PB-W350
25	Gully Branch	GB-W300	103	Pierce Branch	PB-W370
26	Gully Branch	GB-W310	104	Pierce Branch	PB-W380
27	Gully Branch	GB-W320	105	Pierce Branch	PB-W390
28	Gully Branch	GB-W330	106	Pierce Branch	PB-W400
29	Gully Branch	GB-W340	107	Pierce Branch	PB-W410
30	Gully Branch	GB-W350	108	Pierce Branch	PB-W420
31	Gully Branch	GB-W360	109	Pierce Branch	PB-W430
32	Gully Branch	GB-W370	110	SO FK Little Manatee	SF-W290
33	Gully Branch	GB-W380	111	SO FK Little Manatee	SF-W310
34	Gully Branch	GB-W390	112	SO FK Little Manatee	SF-W320

NO.	Sub-Basin Name	Sub-Area ID	NO.	Sub-Basin Name	Sub-Area ID
35	Gully Branch	GB-W400	113	SO FK Little Manatee	SF-W330
36	Gully Branch	GB-W410	114	SO FK Little Manatee	SF-W340
37	Gully Branch	GB-W420	115	SO FK Little Manatee	SF-W350
38	Gully Branch	GB-W430	116	SO FK Little Manatee	SF-W360
39	Gully Branch	GB-W440	117	SO FK Little Manatee	SF-W370
40	Gully Branch	GB-W450	118	SO FK Little Manatee	SF-W380
41	Gully Branch	GB-W460	119	SO FK Little Manatee	SF-W390
42	Gully Branch	GB-W470	120	SO FK Little Manatee	SF-W400
43	Gully Branch	GB-W480	121	SO FK Little Manatee	SF-W410
44	Gully Branch	GB-W490	122	SO FK Little Manatee	SF-W420
45	Gully Branch	GB-W500	123	SO FK Little Manatee	SF-W430
46	Gully Branch	GB-W510	124	SO FK Little Manatee	SF-W440
47	Howard Prairie Branch	HPB-W120	125	SO FK Little Manatee	SF-W450
48	Howard Prairie Branch	HPB-W130	126	SO FK Little Manatee	SF-W460
49	Howard Prairie Branch	HPB-W140	127	SO FK Little Manatee	SF-W470
50	Howard Prairie Branch	HPB-W150	128	SO FK Little Manatee	SF-W480
51	Howard Prairie Branch	HPB-W160	129	SO FK Little Manatee	SF-W490
52	Lake Wimauma Drain	LWD-W360	130	SO FK Little Manatee	SF-W500
53	Lake Wimauma Drain	LWD-W370	131	SO FK Little Manatee	SF-W510
54	Lake Wimauma Drain	LWD-W380	132	SO FK Little Manatee	SF-W520
55	Lake Wimauma Drain	LWD-W410	133	SO FK Little Manatee	SF-W530
56	Lake Wimauma Drain	LWD-W420	134	SO FK Little Manatee	SF-W540
57	Lake Wimauma Drain	LWD-W440	135	SO FK Little Manatee	SF-W550
58	Lake Wimauma Drain	LWD-W480	136	Unnamed Stream	US-W270
59	Lake Wimauma Drain	LWD-W510	137	Unnamed Stream	US-W280
60	Lake Wimauma Drain	LWD-W520	138	Unnamed Stream	US-W290
61	Lake Wimauma Drain	LWD-W540	139	Unnamed Stream	US-W340
62	Lake Wimauma Drain	LWD-W550	140	Unnamed Stream	US-W350
63	Lake Wimauma Drain	LWD-W610	141	Unnamed Stream	US-W360
64	Lake Wimauma Drain	LWD-W630	142	Unnamed Stream	US-W370
65	Little Manatee River	LMR-W160	143	Unnamed Stream	US-W390
66	Little Manatee River	LMR-W280	144	Unnamed Stream	US-W400
67	Little Manatee River	LMR-W190	145	Unnamed Stream	US-W410
68	Little Manatee River	LMR-W200	146	Unnamed Stream	US-W420
69	Little Manatee River	LMR-W430	147	Unnamed Stream	US-W430
70	Little Manatee River	LMR-W230	148	Unnamed Stream	US-W440

NO.	Sub-Basin Name	Sub-Area ID	NO.	Sub-Basin Name	Sub-Area ID
71	Little Manatee River	LMR-W330	149	Unnamed Stream	US-W450
72	Little Manatee River	LMR-W380	150	Unnamed Stream	US-W460
73	Little Manatee River	LMR-W480	151	Unnamed Stream	US-W470
74	Little Manatee River	LMR-W530	152	Unnamed Stream	US-W480
75	Little Manatee River	LMR-W580	153	Unnamed Stream	US-W490
76	Little Manatee River	LMR-W630	154	Unnamed Stream	US-W500
77	Little Manatee River	LMR-W640	155	Unnamed Stream	US-W510
78	Carton Branch	CB-W360			

3.2.2 **Rainfall**

As recommended by the Hillsborough County Storm Water Management Technical Manual, SCS (the Soil Conservation Service, now called the Natural Resources Conservation Service - NRCS) design storm with a 24-hour SCS Type II Florida modified distribution was used to simulate rainfall events for each return interval. This rainfall distribution is also required by SWFWMD.

The Technical Manual also indicates that a value of 256 with a corresponding dimensionless unit hydrograph is appropriate for simulating hydrologic processes in the study area. Therefore, the shape factor (or peaking factor) was modified to 256 to account for the relatively flat terrain of the watershed.

Rainfall depths were estimated from isohyetal maps and procedures contained in the SWFWMD's Environmental Resource Permitting (ERP) Information Manual. Where the LMR watershed was located between two isohyets, the rainfall amount was estimated using a straight line interpolation between two isohyets. The rainfall depths used for the 24-hour design events are as follows:

Table 3-2 Rainfall Depths for the 24-hour Design Events

Storm Event Precipitation	24-hour Depth (inches)
Mean Annual	4.5
5-Yr	5.6
10-Yr	6.75
25-Yr	8.0
50-Yr	9.5
100-Yr	10.2

3.2.3 Runoff Volume (SCS CN)

The Natural Resource Conservation Service (NRCS) Curve Number (CN) method was used to predict rainfall excess for each sub-basin. The SCS Curve Number option in the HEC-HMS model uses an initial abstraction value and composite curve number (CN) to estimate runoff volumes from each subarea for a particular design rainfall event.

Initial abstraction is defined as losses from rainfall before runoff begins. Initial abstraction is a function of the composite CN and is calculated using the following equation.

$$Ia = 0.2(1000/CN - 10) \quad \text{Equation 1}$$

The CN is a function of the land use condition and hydrologic soil group (HSG). For each subarea, a composite CN was developed using the GIS by overlaying the soils and land use coverages and spatially analyzing the percent of each land use and soil condition in each sub-area.

Hydrologic soils groups are used to classify soils based on runoff potential. Soils are grouped into four hydrologic soil groups (A through D), which reflect varying levels of infiltration rates and soil moisture capacities. In Florida, certain soils can also have dual hydrologic soil group classifications (B/D). The first hydrologic soil group designates the drained condition and the second hydrologic soil group designates the undrained condition of the soil.

The latest SWFWMD Land Use GIS coverage was used to represent existing conditions land use in the watershed. Each land use polygon in the GIS coverage is associated with an attribute that designates a classification from the Florida Land Use Classification System (FLUCS).

Runoff CN tables were used to assign a CN to each soil and land use combination. The runoff CN lookup table is provided below. The CNs listed represent average Antecedent Moisture Conditions (AMC II conditions).

Table 3-3 Runoff CN Lookup Table

LUValue	Description	A	B	C	D
1100	Residential Low Density < 2 Dwelling Units	50	68	79	84
1200	Residential Low Density 2->5 Dwelling Units	57	72	81	86
1300	Residential High Density	77	85	90	92
1400	Commercial and Service	89	92	94	95
1500	Industrial	81	88	91	93
1600	Extractive	77	86	91	94
1700	Institutional	89	81	87	90
1800	Recreational	49	69	79	84
1900	Open Land	39	61	74	80
2100	Cropland and Pastureland	49	69	79	84
2140	Row Crops	49	69	79	84
2200	Tree Crops	44	65	77	82
2300	Feeding Operation	73	83	89	92
2400	Nurseries and Vineyards	57	73	82	86
2420	Sod Farms	57	73	82	86
2440	Vineyards	57	73	82	86
2500	Special Farms	59	74	82	86
2550	Tropical Fish Farms	0	0	0	0
2600	Other Open Lands (Rural)	30	58	71	78
3100	Herbaceous	63	71	81	89
3200	Shrub and Brushland	35	56	70	77
3300	Mixed Rangeland	49	69	79	84
4100	Upland Coniferous Forest	45	66	77	83
4110	Pine Flatwoods	57	73	82	86
4120	Longleaf Pine – Xeric Oak	43	65	76	82
4200	Upland Hardwood Forest – Part 1	36	60	73	79
4300	Hardwood Forest	36	60	73	79
4340	Hardwood Conifer Mixed	36	60	73	79
4400	Tree Plantations	36	60	73	79

5100	Streams and Waterways	100	100	100	100
5200	Lakes	100	100	100	100
5230	Lakes < 100 Acres, > 10 Acres	100	100	100	100
5240	Lakes < 10 Acres	100	100	100	100
5300	Reservoirs	100	100	100	100
5310	Reservoirs > 500 Acres	100	100	100	100
5320	Reservoirs > 100 Acres, <500 Acres	100	100	100	100
5330	Reservoirs > 10 Acres, <100 Acres	100	100	100	100
5340	Reservoirs < 10 Acres	100	100	100	100
5400	Bays and Estuaries	100	100	100	100
6100	Wetland Hardwood Forests	98	98	98	98
6110	Bay Swamps	98	98	98	98
6120	Mangrove Swamps	98	98	98	98
6150	Stream and Lake Swamps (Bottomland)	98	98	98	98
6200	Wetland Coniferous Forests	98	98	98	98
6210	Cypress	98	98	98	98
6300	Wetland Forests Mixed	98	98	98	98
6400	Vegetated Non-Forested Wetland	98	98	98	98
6410	Freshwater Marshes	98	98	98	98
6420	Saltwater Marshes	98	98	98	98
6430	Wet Prairies	98	98	98	98
6440	Emergent Aquatic Vegetation	98	98	98	98
6500	Non-Vegetated	98	98	98	98
6510	Tidal Flats/Submerged Shallow Platform	98	98	98	98
6520	Shorelines	98	98	98	98
6530	Intermittent Ponds	98	98	98	98
7100	Beaches Other Than Swimming Beaches	77	86	91	94
7400	Disturbed Land	77	86	91	94
8100	Transportation	81	88	91	93
8200	Communications	81	88	91	93
8300	Utilities	81	88	91	93
9113/9116	Seagrass	100	100	100	100

The AMC of the soil is unknown at the time of the event, but is often estimated by the accumulated rainfall depth in the five-day period prior to the event. The moisture condition can also be determined according to the runoff volume. During model calibration, additional simulations of the hydrologic model were performed with the same rainfall depth but higher or lower AMC to bracket the observed runoff volume at some gages. The selected AMC was determined by the closest volumetric match found during the hydrologic calibration. The following table was used as a guide to convert between the average AMC II to wet (AMCIII) and dry (AMCI) SCS runoff curve numbers (Wanielista, Yousef, 1993).

Table 3-4 AMC Curve Number Conversion Guide

AMC2	AMCI	AMC3
100	100	100
95	87	98
90	78	96
85	70	94
80	63	91
75	57	88
70	51	85
65	45	82
60	40	78
55	35	74
50	31	70
45	26	65
40	22	60
35	18	55
30	15	50

The rainfall depth estimated AMC and volumetric match determined AMC are different for some gages. This could be due to a number of factors including depth to water table, availability of soil storage and amount of depression storage among others. Where a discrepancy exists, the AMC determined by the volumetric calibration was used for hydrologic and hydraulic calibration.

3.2.4 Runoff Hydrographs

The SCS Dimensionless Unit Hydrograph was used to distribute the runoff volume to a unit hydrograph. The determination of an SCS lag time was required for this method. Consistent with the methodology of the SCS's Technical Release-55 Urban Hydrology for Small Watersheds published June 1986, the lag time for a subarea was assumed to equal 0.6 times the time of concentration. The time of concentration, in turn, was defined as the time required for water to travel to the subarea outlet from the most hydraulically distant point in the subarea.

The time of concentration for each subarea was calculated using the methodology outlined in TR-55 (SCS 1986). For each subarea, the longest flow path to the subarea outlet was determined using the DEM and ArcGIS tools that divided the flow path into four elements:

- Sheet flow
- Secondary channel
- Shallow concentrated flow
- Primary channel

The travel times associated with each of the four elements were added to calculate the time of concentration for each subarea.

a. Sheet Flow

Sheet flow is assumed to occur at the most hydraulically distant portion of the flow path. The sheet flow length was calculated using GIS. Physical data are required to calculate the travel time associated with sheet flow using the TR-55 methodology, including flow length, slope, and overland flow roughness coefficient. The surface condition was determined from the aerial photos.

b. Shallow Concentrated Flow

Shallow concentrated flow occurs between the areas of sheet flow and open channel flow. Shallow concentrated flow for urban areas may include gutters, swales, and sometimes small ditches. Open channels are assumed to begin where channels are visible on aerial photographs and include major conveyances, including creeks and rivers. To calculate the travel time associated with shallow concentrated flow by the TR-55 methodology, physical data including the shallow concentrated flow length, slope, and surface conditions along the path are required.

c. Secondary Channel Flow and Primary Channel Flow

Secondary channel flow occurs between the end of shallow concentrated flow and the flow path intersection with the primary stream network, while primary channel flow occurs along the primary stream network to the subarea outlet. The primary stream network is the main channel of Little Manatee River and its tributaries. For both types of channel flow, travel time was calculated based on channel length and velocity. The velocity, in turn, was estimated based on channel slope and assumed flow depth and cross-sectional geometry. All of these data were developed from GIS. Slope data were calculated by using the upstream and downstream elevations and the stream length in GIS. Cross-section geometries were assigned based on review of stream geometry data developed by using GIS tools and DEM.

3.2.5 Routing (Muskingum-Cunge)

The Muskingum-Cunge Routing method was used to route runoff through the watershed. A channel cross section was developed for each routed reach using ArcGIS. The channel length, slope and other parameters were also determined using DEM data, digital aerial photos and field photographs.

SECTION 4 Hydraulic Model Development

4.1 Introduction

This section provides a description of the methodology used to develop the hydraulic model for the Little Manatee River Watershed study. The hydraulic model was used to simulate the watershed's primary stream network based on existing land use conditions and estimate water surface elevations and to determine the river stages along the study reach under various flow conditions. The hydraulic modeling was performed using USACE's HEC-RAS Version 4.0 steady state option.

4.2 HEC-RAS Model Development

HEC-RAS model data requirements can be summarized into the following model parameters.

- Stream network
- Cross sections (river station and geometry data)
- Downstream reach lengths (channel and overbanks)
- Channel bank stations
- Manning's n-values
- Roadway crossings
- Expansion and contraction coefficients
- Boundary conditions
- Ineffective flow areas

Table 4-1 lists these parameters, the data and the methods used to develop the data requirements. All the model parameters were developed using a combination of manual procedures and automation tools using ArcGIS and HEC-GeoRAS in conjunction with GIS data.

Table 4-1 HEC-RAS Parameter Development

HEC-RAS Model Parameter	Data Requirements	Data Used	Development Method
Stream network	Stream centerline coverage with unique stream reach names	DEM, Contours	ArcGIS and HEC-GeoRAS
Cross sections (river station and geometry data)	Cross section cut line coverage	DEM, TIN, Contour	ArcGIS and HEC-GeoRAS
Downstream reach lengths (channel and overbanks)	Stream centerline and overbank (left and right) flow path coverage	DEM, Contours	ArcGIS and HEC-GeoRAS
Channel bank stations	Cross section geometries (station and elevation data)	DEM, Contours	Manual input using standard procedures and engineering judgment
Manning's n-values	Mannings n-value assigned	land use data, digital aerial, field survey photos, field observations	Manual input using standard values and engineering judgment
Roadway crossings	Roadway profile and bridge or culvert geometry information	Field survey data, as-built information	Manual input
Expansion and contraction coefficients	Cross section cut line coverage	DEM, Contours	Manual input using standard values and engineering judgment
Boundary conditions	Normal depth boundary conditions	DEM, Contours, stream centerline, cross section cut line coverage	ArcGIS
Ineffective flow areas	Cross section cut line coverage	DEM, Contours	Manual input using standard procedures and engineering judgment

The HEC-RAS model development procedures are described in the subsequent sections.

4.2.1 <u>Stream Network, Cross Sections, and Reach Lengths</u>

The first step in developing the HEC-RAS model was to create a HEC-RAS geometry file containing the stream network, cross section river stations & geometries and channel & overbank downstream reach lengths. The stream network defines the extent of the model. Cross section river stations define the location of the cross section along the stream. Downstream reach lengths define the distance to the next downstream cross section along the stream reach and along the left and right overbanks.

HEC-GeoRAS and ArcGIS were used to prepare a model input file that can be directly imported into HEC-RAS, creating a geospatially referenced HEC-RAS geometry file.

HEC-GeoRAS uses the following data to create the model import file:

a. Triangular Irregular Network

The TIN was created from the LiDAR/DEM data using ArcGIS. The TIN is a surface representing the ground topography and is used in conjunction with the cross section cut line coverage to develop station and elevation information for cross section geometry data. A ground surface elevation was recorded at each station along the cross section cut line that crosses the TIN edge.

b. Stream Centerline Coverage

The stream centerline coverage was manually digitized in ArcGIS to represent the center line of the main channel. HEC-GeoRAS requires a river name and reach name be assigned to each line segment. For the purpose of this study, the river name was assigned "Little Manatee River" and the reach name was assigned to "Reach 1" – "Reach 8".

c. Cross Section Cut Line Coverage

The cross section cut line coverage is a GIS line coverage that identifies the location and extent of each cross section. The cross section cut line coverage was generated in ArcGIS. Additional cut lines were located along the stream centerline at points that represent the average geometry of the stream reach and at changes in geometry, slope, channel, overbank roughness, and discharge. Available aerial photographs and contour information were used to lay out the cross section cut lines. The FEMA 100-year floodplain boundary was used as a guide in determining the extent of the cross sections. The average distance between cross sections was approximately

400 feet, with less distance between cross sections in the vicinity of structures and abrupt changes in channel geometry. There are more than 400 cross sections created for the entire watershed. All the cross sections plots are provided in Appendix A.

The cross section cut lines are oriented from left to right looking downstream. Each cross section was identified by the stream name, reach name, and river station. The river station for each cross section is the cumulative distance from the model outfall in feet.

d. Overbank Flow Path Coverage

The overbank flow path coverage is a GIS line coverage that represents the average left and right overbank flow paths between each cross section. The overbank flow path coverage was used to determine the downstream reach lengths for the left and right overbanks. The FEMA 100-year flood plain boundary and the contour information were used as a guide to locate the overbank flow paths.

The developed stream network and cross section river stations were imported into HEC-RAS and are presented in Figure 4-1.

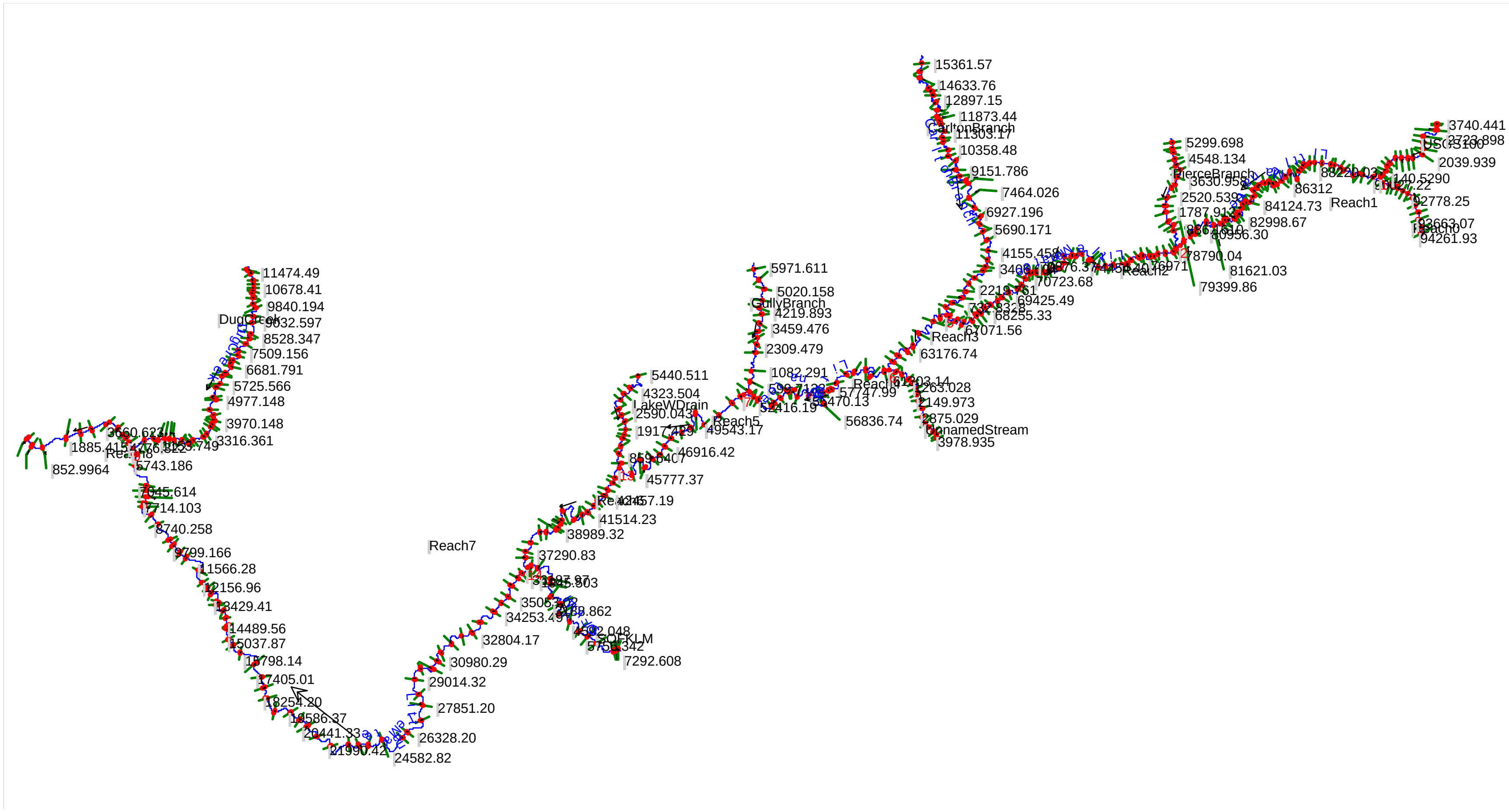

Figure 4-1 Steam Network and Cross Section River Stations

4.2.2 **Manning's n-Values**

The Manning's n-values at each cross section were estimated using land use data, digital aerial and field photographs. Manning's n-values are assigned with the purpose to represent land surface characteristics identified in Table 4-2. The initial n-values were used as a model starting point and were adjusted within the provided ranges during calibration. Horizontally varied Manning's n-values were entered in the HEC-RAS model to capture changes in land use spanning the cross section.

Table 4-2 Land Surface Characteristics and Associated Manning's n-Values

Land Surface Type	Initial n-Value	Range of n-Value
Grass, urban and maintained	0.030	0.025–0.035
Trees and brush	0.090	0.035–0.160
Brush	0.060	0.035–0.160
Residential areas2	0.150	0.035–0.2
ADF Plant - (developed area)2	0.100	0.035–0.2
Agricultural, Pasture	0.035	0.025–0.050
Pavement	0.020	0.013–0.025
Lake	0.025	0.0160–0.033

Channel n-values were manually adjusted using the HEC-RAS cross section data editor. A combination of digital aerial photos, field photographs, and site visits was used to select an appropriate n-value. Table 4-3 lists channel descriptions and associated ranges of n-values used for Little Manatee River.

Table 4-3 Channel Descriptions and Associated Manning's n-Values

Channel Description	Initial n-Value	Range of n-Value
Clean, straight	0.030	0.025 - 0.033
Straight channels, weeds	0.035	0.030 - 0.040
Clean, meandering	0.040	0.033 - 0.045
Meandering, weedy	0.045	0.045 - 0.050
Sluggish, weedy	0.070	0.050 - 0.080
Very weedy, floodways with heavy timber and underbrush	0.13	0.075 - 0.150

4.2.3 **Roadway crossings**

Roadway profile and bridge or culvert geometry information were determined according to field surveys and as-built information provided by FDOT and Hillsborough County. These data were manual entered into HEC-RAS and were summarized in the following table.

Table 4-4 Summary of Bridges in the Study Area

No.	Structure Name	ID	County	River/Tributary	Stationing	Lat.	Long.
1	US 301/ LMR	100003	Hillsborough	LMR/Reach 8	4501.3555	27°40'16.953"N	82°21'9.545"W
2	CR579/ LMR	100260	Hillsborough	LMR/Reach 6	39313.551	27°39'46.264"N	82°18'4.25"W
3	SR 674 / CARLTON BRANCH	100501	Hillsborough	Carton Branch	11779.413	27°42'18"N	82°15'22.37"W
4	CR579 OVER SOUTH FORK	100259	Hillsborough	SO FK Little Manatee	7225.6328	27°38'58.888"N	82°17'39.532"W
5	GRANGE HALL LOOP/ LMR	104332	Hillsborough	LMR/Reach 2	71052.453	27°41'20.961"N	82°14'41.501"W
6	Dug Creek	10346	Hillsborough	Dug creek	2509.4968	27°40'16.241"N	82°20'41.108"W
7	Leonaldo Lee Road/ LMR	104307	Hillsborough	Reach 4	57683.965	27°40'37.347"N	82°16'9.42"W

4.2.4 **Expansion and contraction coefficients**

The expansion and contraction coefficients were estimated based on the ratio of expansion and contraction of the effective flow area in the floodplain occurring at cross sections and at roadway crossings. An expansion coefficient of 0.3 and a contraction coefficient of 0.1 are used in the analysis. These coefficients can be manually adjusted using HEC-RAS cross section data editor.

4.2.5 **Boundary Conditions**

Normal depth was used as the downstream boundary condition. This is explained in detail in Section 5.

4.2.6 **Ineffective Flow Areas**

Ineffective flow areas were determined using the cross section plots and contour information. Ineffective flow areas were entered manually using the HEC-RAS cross section data editor.

SECTION 5 Model Calibration and Verification

The approach, methodology and results of the hydrologic and hydraulic model calibration and verification efforts are described in this section. The primary purpose of performing model calibration and verification is to ensure that the developed models reflect observed conditions in the watershed. A model is considered well-calibrated when model results of stage, flow, and volume are in reasonable agreement with the recorded data at the gage stations. Once this agreement is achieved, the model can then be verified by comparing model results of a different storm event to the observed values without making adjustments to the model. This ensures the reliability of the results.

5.1 Hydraulic and Hydrologic Data Collection

The HEC-RAS model will perform one dimensional hydraulic calculations for the full network on natural streams that encompass the Little Manatee River study area. To model the study area in HEC-RAS, hydrological data was required for the approximately 15.6 mile reach. Hydraulic data input required by the model includes flow data and stage data for the boundary conditions. The SWFWMD provided data pertaining to flow and stage which was collected by the USGS. The daily data provided include flow in cfs and stage in ft for three locations which bounded the study area: USGS near Wimauma 02300500, USGS south fork near Wimauma 02300300, and USGS at Ft. Lonesome 02300100. However, additional branches/creeks feed the Little Manatee River within the boundary conditions. These branches/creeks include: Howard Prairie Branch, Pierce Branch, Carlton Branch, Gully Branch, Lake Wimauma Plain, Dug Creek, South and several unnamed streams

Data of the three USGS stations were not enough on their own to run the HEC-RAS model for the Little Manatee River. The data points are too spatially large and there are multiple tributaries entering the river branch between the stations. Flow/stage data for the above listed tributaries is needed to input in the HEC-RAS model of Little Manatee River. A search for flow/stage data in the seven locations revealed no useful information/data. Therefore, daily runoff figures along with flow depths for each sub-basin were created using the HEC-HMS model.

Precipitation data is required to run the HEC-HMS model. Precipitation data would have to encompass a period which SWFWMD would analyze in model runs of the HEC-RAS model. A review of existing data prepared by the USGS on locations 02300500, 02300300, and 02300100 showed best period of record to perform a search. The Period of Record (POR) was decided by the best available data string which was 1/1/1988 thru 12/31/2009.

A data search on the USGS site, SWFWMD site and GIS data for records available in the POR or encompassing those dates was performed. A series of precipitation recording stations were located and a review of the recording station data yielded 13 useful locations. The 3 USGS sites and 13 rainfall stations are summarized in the following table.

Table 5-1 Rainfall, Stage and Discharge Gages

Site Number	Data Type	Site Name	Site Location (State Plan)	
			SPFN	SPFE
USGS02300100	Stage and discharge	Little Manatee River Near Ft. Lonesome FL	1225308.419	592083.7205
USGS02300300	Stage and discharge	South Fork Little Manatee River Near Wimauma FL	1205274.767	560847.3491
USGS02300500	Stage, discharge and rainfall	Little Manatee River Near Wimauma FL	1213201.083	541985.4626
17958	Rainfall	WIMAUMA	1225182.244	555383.16
17960	Rainfall	HURRAH TOWER	1238614.741	609086.7717
17961	Rainfall	BROWN TOWER	1246106.588	547739.2717
17964	Rainfall	HERRING	1223572.867	605114.1076
18133	Rainfall	ROMP 123 STARLING	1214837.106	574985.1509
18135	Rainfall	WIMAUMA AIRPORT	1227585.853	563686.7618
18145	Rainfall	RUSKIN	1225771.972	526112.5164
18151	Rainfall	ROMP 48 THATCHER	1238613.898	609805.5709
18153	Rainfall	ROMP 49 BALM PARK	1246649.281	574151.6043
25610	Rainfall	FOUR CORNERS MINE	1203857.792	628650.0525
25611	Rainfall	ROMP 39 OAK KNOLL	1183531.722	575101.5354
26073	Rainfall	FP & L	1188047.329	544972.4475

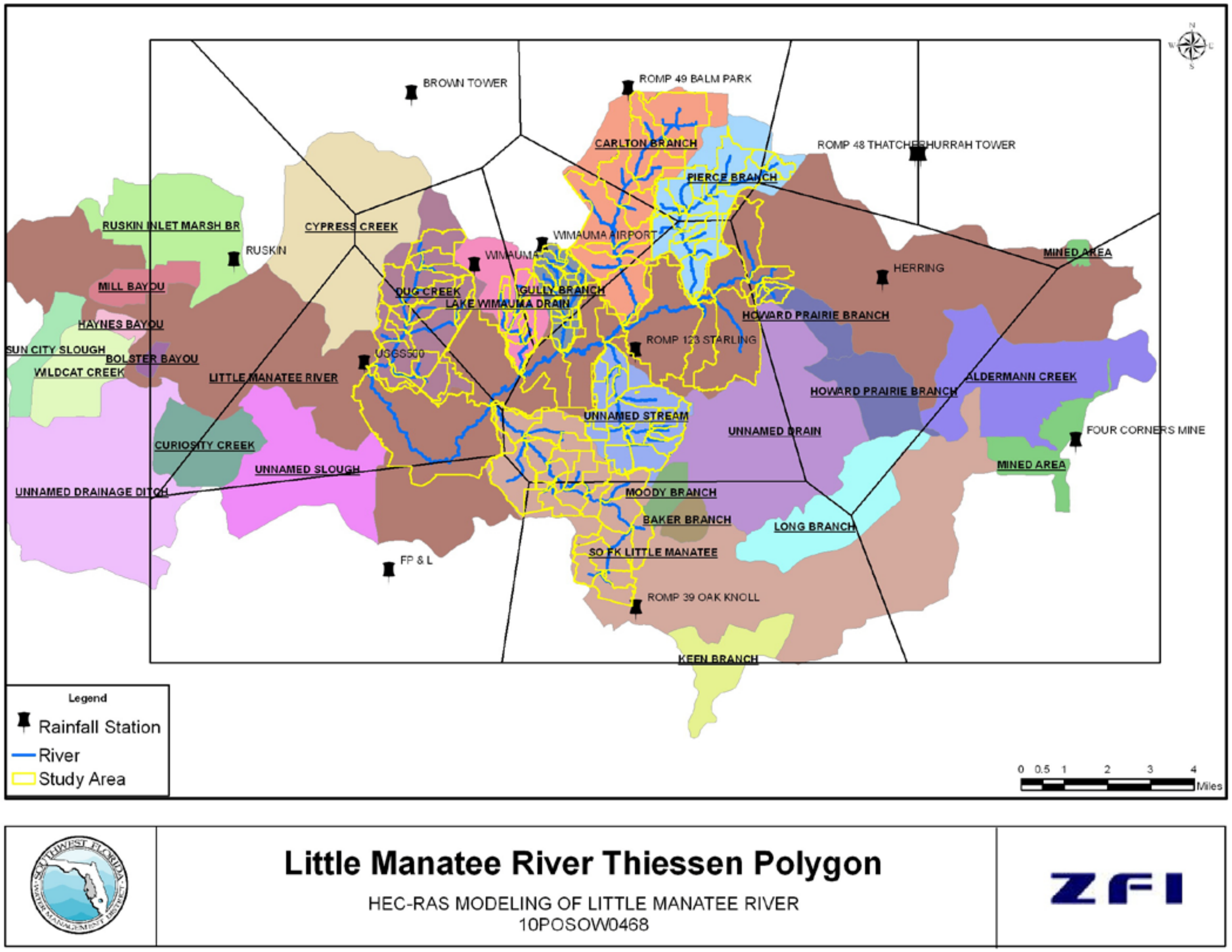

Figure 5-1 Thiessen Polygon Network for Rainfall and USGS Station

Figure 5-1 shows the Little Manatee study area and the previously discussed sub-basins, stream reaches, rainfall recording stations, and a rainfall delineation grid know as the Thiessen Polygons. Thiessen polygons define individual areas of influence around each of a set of points. The weights of the rainfall gages for each sub-area are calculated using the Thiessen Polygon Method. Thiessen polygons are polygons whose boundaries define the area that is closest to each point relative to all other points. They are mathematically defined by the perpendicular bisectors of the lines between all points. A TIN structure is used to create Thiessen polygons. This TIN structure can be created by GIS and be directly imported to HEC-HMS model. The model can use this precipitation or hydrological information to route the overland runoff and provide output data to be used in the HEC-RAS model.

5.2 QA/QC of Hydraulic and Hydrologic Data

Hydraulic and Hydrologic data delivered to, and extracted by ZFI was reviewed, scrutinized, and patched prior to use in the HEC-RAS model for the Little Manatee River. First, the data important to the model and what data could be finalized as model quality data was identified. The water stream data of the USGS which would be used for the HEC-RAS model was reviewed. Three data locations were provided and two data sets were included in each of the locations. Data locations ID's are 02300100, 02300300, and 02300500 and each included stage and flow data. These hydraulic data are crucial inputs to the HEC-RAS model, therefore the Period of Record (POR) was determined with this data source. Data of ID location 02300100 spans from 1/1/1964 to 12/31/2009, ID location 02300300 spans from 1/1/1988 to 12/31/2009 (large gap of missing data spans from 2/1/1989 to 9/30/2000), and ID location 02300500 spans from 1/1/1940 to 12/31/2009. Of these the POR of significant quality data was determined to be 1/1/1988 thru 12/31/2009 and a large patch was performed on Station ID 02300300 to fill in missing data points.

All ID locations had small and some large gaps in daily data throughout the POR. Data patching came about through methods such as matching similar string of daily conditions in the ID locations (based on flow, stage, and/or precipitation) while other statistical methods were incorporated by means of linear regression and trend prediction. Small gaps of stage data (where flow data was known) were filled by matching other similar stage/flow relationship (of the ID location in close range of missing date), this was feasible in free-flowing river systems. Small gaps of flow data were patched with the comparison of flow data of the other ID locations of the same date and logical linear trend. In addition, to support these flow patches, local precipitation data was analyzed to verify the patches. This was useful to verify if flows were increasing, steady, or decreasing but mainly useful for steady or decreasing flows since the river's increasing rate can be considerable.

In larger periods of missing data Linear Regression or Trend functions were used to patch the portions of missing data. Linear Regressions were preformed with Excel - LINEST function. This function calculates the statistics for a line by using the least squares method to calculate a straight line that best fits the data, then returns an array that describes the line. The data in the array provides one with details on how data of missing series relates to other similar data (e.g. local precipitation data & USGS data sets which are intact and in close proximity have a correlation). An R^2 value is returned in the array, this provides a measure of how well future outcomes are likely to be predicted (calculated R^2 values averaged at 90% indicating strong correlation). In addition to LINEST, the Excel - Trend function was used. The Trend function returns values along a linear trend, which also fits a straight line to the array known and returns a new value y for a specified value of x. The Trend is very useful for filling large stage gaps.

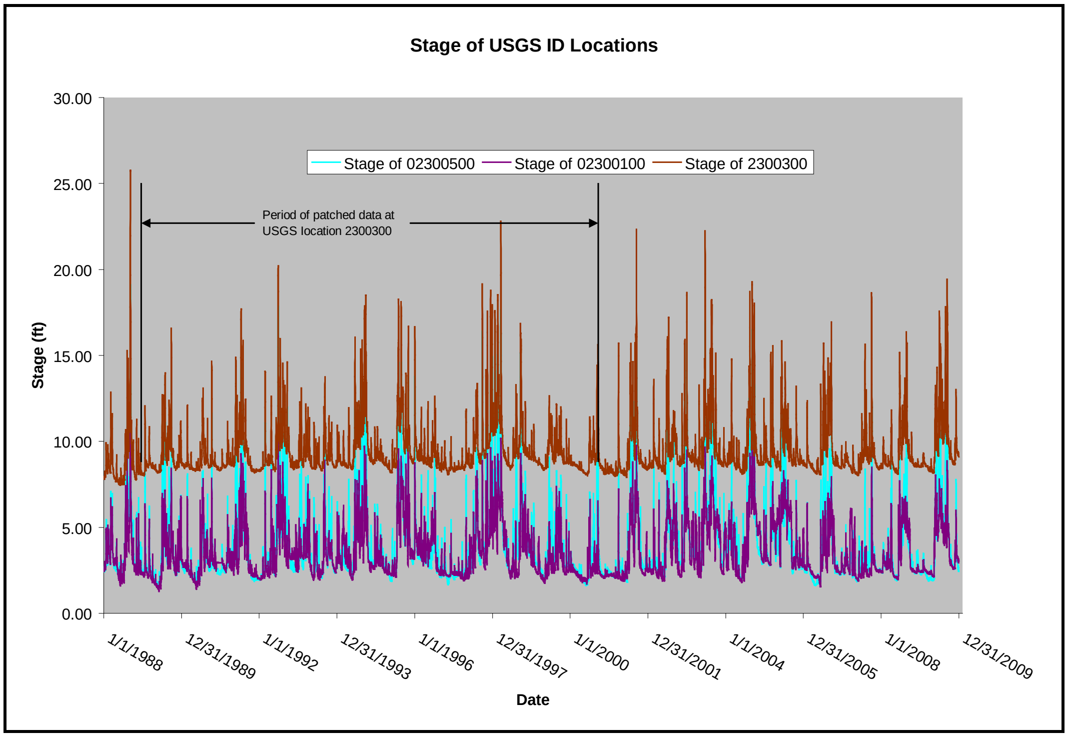

Figure 5-2 USGS Stage Data Patched thru POR

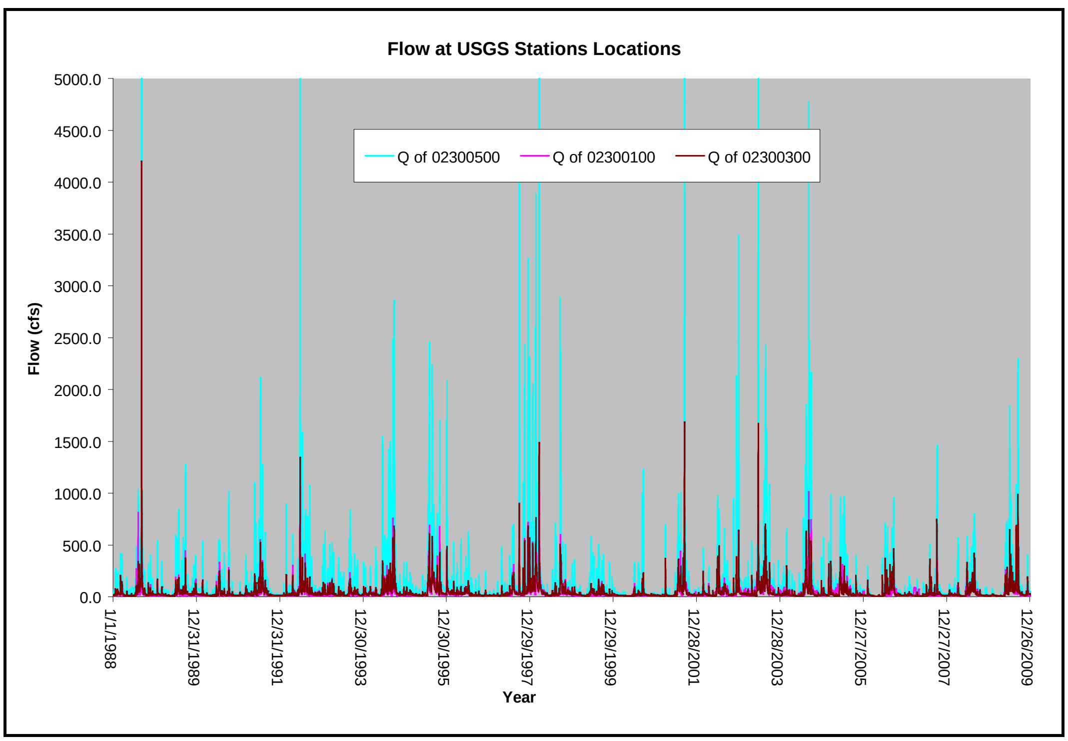

Figure 5-3 USGS Flow Data Patched thru POR

The trend function was used exclusively in providing the adjusted stage value to the adjusted flow at station 02300500. These adjusted values were requested by the District. The adjustment removed runoff volumes known to discharge to the river from agricultural sources (15 cfs daily) and reincorporated pumping volumes removed from the FP&L's consumptive use records. Some outliers were created using the TREND function and were reviewed and rejected. These outliers amounted to less than 0.6% of the stage data or 48 out 8036 data sets. These outliers were manually adjusted to match existing measured stage data.

Precipitation data from many of the rainfall stations, required data patching. Data was patched in the same methods as listed above but spatial consideration was taken. There were 13 rainfall station locations and the approach to patching missing data strings was done with the Nearest Neighbor method. Most of the precipitation data adjustments were performed with a linear match or linear regression.

5.3 Event Selection

Important factors considered in selecting storm events for calibration and verification include the magnitude of the storm event, spatial distribution of observed data locations and the measurement interval of the data.

The Oct 2-8, 2007 storm event was picked up for calibration purposes after reviewing all the measured data. This large event produced extreme measurements for the water year for most gages and provided observed data at all 13 rainfall gages in the watershed. Approximately 7 inches of rainfall fell during this period. The Sep10-20, 2009 storm event was selected for model verification due to its magnitude and relatively recent occurrence. Approximately 5 inches of rainfall occurred during this period, producing large peak stages and discharges within the LMR watershed.

5.4 Boundary Condition

Normal depth was used as the downstream boundary condition for all modeled reaches. This boundary condition requires the input of the energy grade line (EGL) slope at the downstream boundary of each reach. The downstream EGL slope can be approximated as the channel invert slope from the contour data. Therefore, the slope between the two most downstream cross sections was used to calculate the normal depth boundary condition. This slope was calculated in ArcGIS using the DEM data, cross section cut line coverage, and stream centerline coverage. The calculated normal depth at the downstream of the river in the study area is 0.0001.

5.5 Hydrologic Model Calibration and Verification

Because of insufficient stream flow and stage data for most of the tributaries, the HEC-HMS model was not calibrated using historical data. The model results were compared to the Federal Emergency Management Agency (FEMA) Hillsborough County Flood Insurance Study (FIS) (2008) (Flood Insurance Study Number 12057CV001A). Table 5-2 through Table 5-5 provide comparisons of the HEC-HMS results compared to effective FIS flow information at downstream of the major tributaries.

Table 5-2 Carlton Branch Flow (cfs) Comparisons

	10 Year	50 Year	100 Year
FEMA FIS	1,210	2,270	2,650
Model	1273.8	2205.9	2467.2
Percent Difference	5.0%	-2.9%	-7.4%

Table 5-3 Dug Creek Flow (cfs) Comparisons

	10 Year	50 Year	100 Year
FEMA FIS	1,240	2,010	2,230
Model	1243	2223.1	2474.4
Percent Difference	0.2%	9.6%	9.9%

Table 5-4 Gully Branch Flow (cfs) Comparisons

	10 Year	50 Year	100 Year
FEMA FIS	577	1,130	1,130
Model	574	1007.4	1122.9
Percent Difference	-0.5%	-12.2%	-0.6%

Table 5-5 Pierce Branch Flow (cfs) Comparisons

	10 Year	50 Year	100 Year
FEMA FIS	1,270	2,410	3,040
Model	1351.2	2361.2	2675.4
Percent Difference	6.0%	-2.1%	-13.6%

On average, the peak runoff rates estimated by the HEC-HMS model under existing land use conditions are within 5-10 percent of the FEMA published flows.

5.6 Hydraulic Model Calibration and Verification

5.6.1 <u>Model Calibration</u>

A calibration effort was undertaken after a fundamental hydraulic model check, to compare the observed and simulated values and to make adjustments to the calibration parameters in order to produce a model that would yield reasonable results. The hydraulic model for the October 2-8, 2007 event was simulated using the calibrated hydrologic parameters. Simulated stage and discharge values were compared and adjustments to the Manning roughness coefficients and other parameters were made where appropriate. Figure 5-4 and Figure 5-5 show graphical comparisons of simulated and observed discharge and stage values for the USGS 02300500 used for calibration. As shown in the two figures, though the simulated peak discharge is somewhat higher than the observed peak value, generally, the simulated discharge and stage values and observed values appear to follow the same pattern.

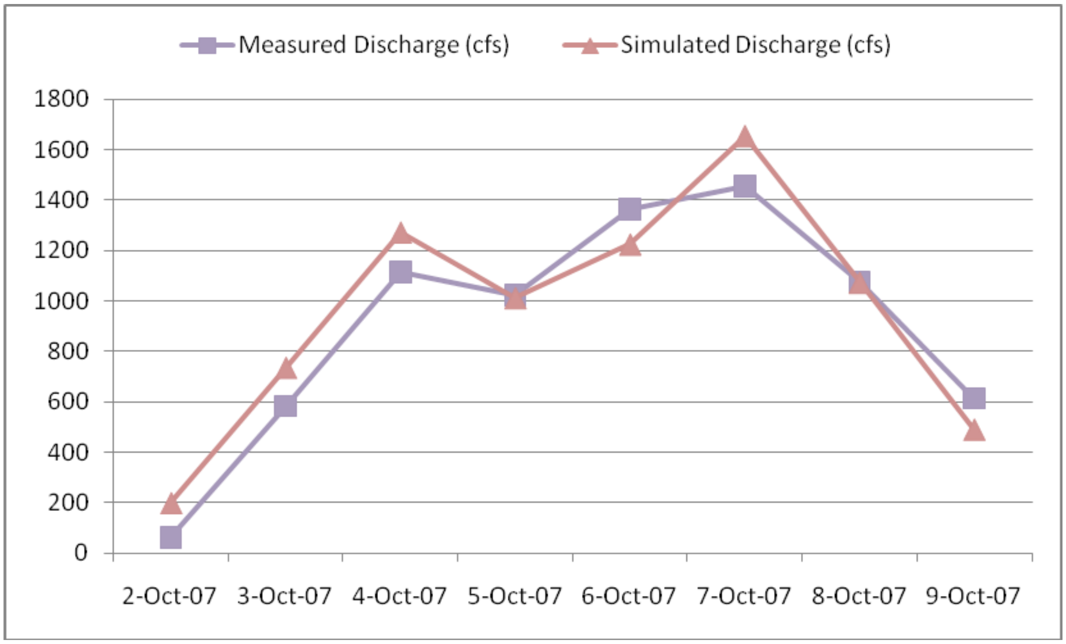

Figure 5-4 Comparison of Observed and Simulated Discharge (cfs)
USGS 02300500 October 2 - 9, 2007

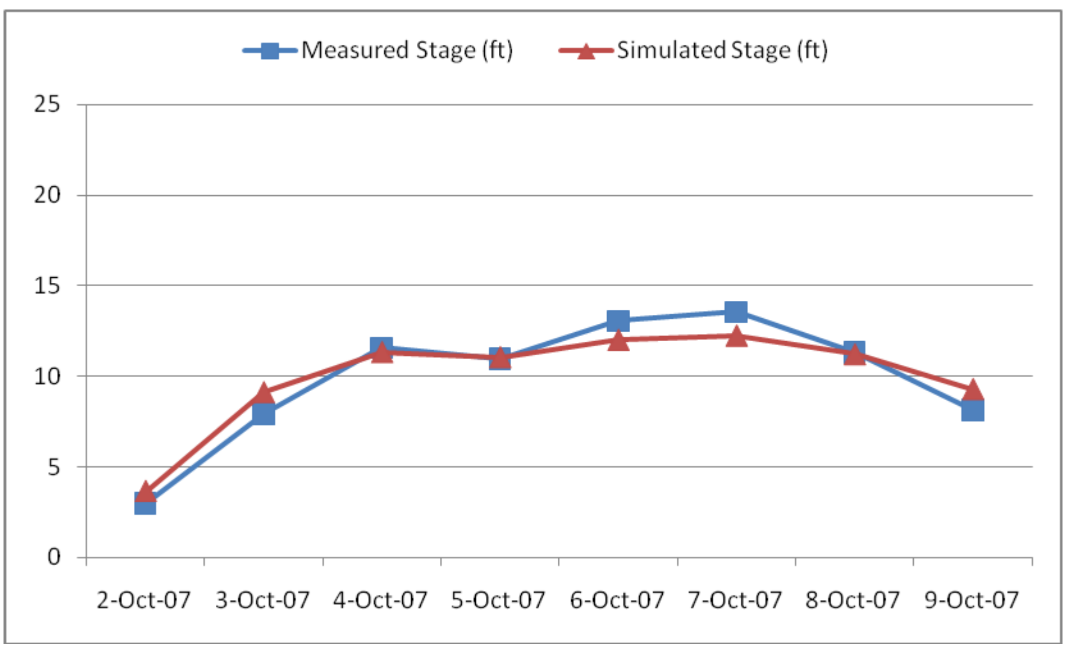

Figure 5-5 Comparison of Observed and Simulated Stage (ft)
USGS 02300500 October 2 - 9, 2007

5.6.2 **Model Verification**

Hydraulic model verification is conducted to ensure adjustments made to the model during calibration are appropriate and to ensure that the model will produce reliable results. Using the same method described for model calibration, observed and simulated runoff volumes were compared for the selected verification event, September 10 – 20, 2009. With the exception of initial conditions, no changes were made to the hydraulic model during the model verification process. The comparison results are presented in Figure 5-6 and Figure 5-7.

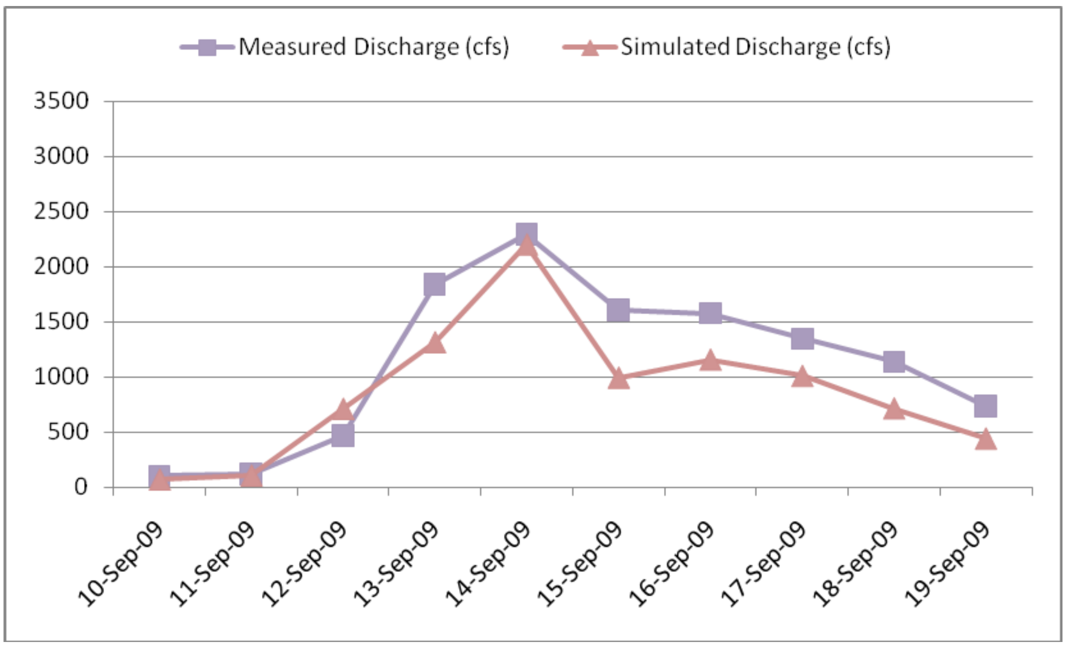

Figure 5-6 Comparison of Observed and Simulated Discharge (cfs)
USGS 02300500 September 10 - 20, 2009

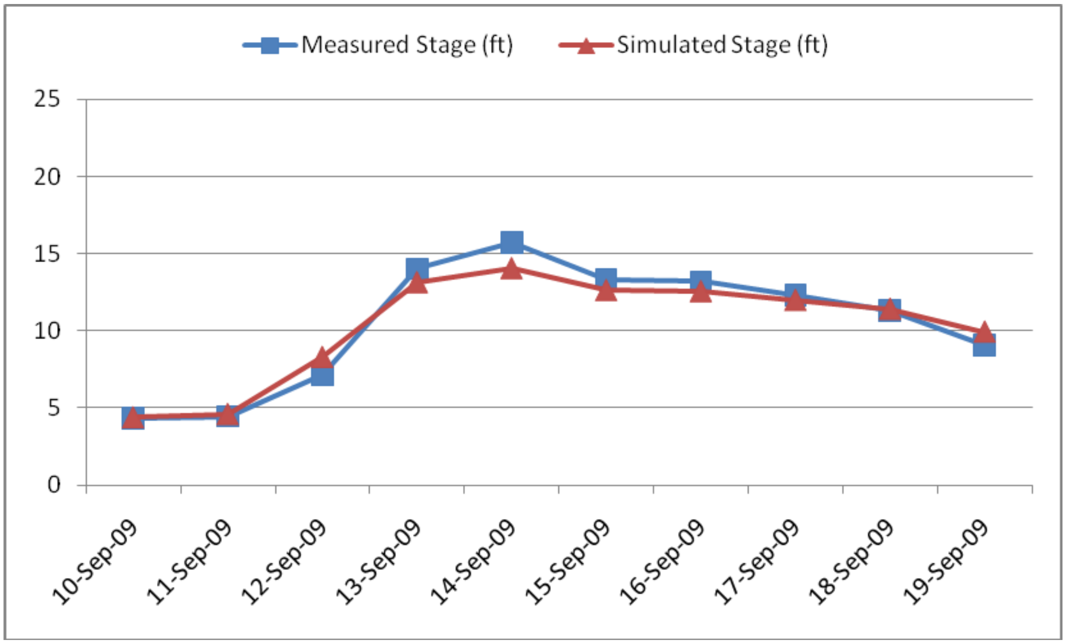

Figure 5-7 Comparison of Observed and Simulated Stage (ft)
USGS 02300500 September 10 - 20, 2009

As shown in Figure 5-6, a good match is observed for the discharge patterns and peak values for the simulated model. Observed discharge is slightly higher than simulated values. The difference may be explained by use of a constant shape factor in the hydrologic model. Discrepancies between observed and simulated values may also be attributed to limitations of the SCS methodology and the limited spatial and temporal rainfall data. The simulated and observed stage values evaluated for the verification events yielded a similar trend as shown in Figure 5-7.

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