Proposed Minimum Flows and Levels for Little Manatee River Appendices

Photo by: Richard Gant

Southwest Florida
Water Management District

Table of Contents

PHABSIM Appendix……...2

Wetted Perimeter Appendix……...19

Water Quality Appendix……55

Vegetation Appendix……...65

HEC-RAS Appendix……155

Monthly Flows Appendix A……214

Moving Flows Appendix B..……216

Yearly Flows Appendix C……218

PHABSIM Appendix

IFIM/PHABSIM PROTOCOL – Little Manatee

Started with IFG4 deck/file containing all transects and all calibration sets. These were entered from downstream to upstream with a dummy transect.

Two sets of transects were examined:

- ELAPP with data from low flow measurement of 24.46 cfs, a medium flow of 68.42 cfs, and a high flow of 84.65 cfs. The range of simulated flows ranged from 9.78 cfs to 169.3 cfs.
- Toscana with low flow (40.94 cfs), medium flow (72.53 cfs) and high flow (263.45 cfs). The range of simulated flows ranged from 16.37 cfs to 526 cfs.

The simulated flow ranges used in two time-series analyses were from gaging records between 1940 and 1969 and between 1970 and 1999.

The following codes were entered on the N/S lines:

CODE	DESCRIPTION
0	**Delimiter**
1	No cover and silt **or** terrestrial vegetation
2	No cover and sand
3	No cover and gravel
4	No cover and cobble
5	No cover and small boulder
6	No cover and boulder, angled bedrock, or woody debris
7	No cover and mud or flat bedrock
8	Overhead vegetation and terrestrial vegetation
9	Overhead vegetation and gravel
10	Overhead vegetation and cobble
11	Overhead vegetation and small boulder, boulder, angled bedrock, or woody debris

12	Instream cover and cobble
13	Instream cover and small boulder, boulder, angled bedrock, or woody debris
14	Proximal instream cover and cobble
15	Proximal instream cover and small boulder, boulder, angled bedrock, or woody debris
16	Instream cover or proximal instream cover and gravel
17	Overhead vegetation or instream cover or proximal instream cover and silt or sand
18	Aquatic Vegetation – macrophytes
100	**Delimiter**

The IFG4 predicted WSL's were placed in a (hand-made) table to be compared with observed WSL's for the given discharges on the CAL lines. The predicted WSL's were all within 0.2 ft of the observed values [accepted surveying error for the "touch" technique] and IFG4 was considered to be an adequate predictor.

A second discharge is added to each CAL line (see A.51 from the PHABSIM user's manual). This second discharge is the calculated flow for that transect using the velocities measured. This is used as a secondary adjustment factor when predicting velocities and roughness coefficients.

The IFG4 input decks/files were then converted to several IFG4 input decks/files, each with a single velocity set, corresponding to measured calibration sets. The simulated discharges overlap but encompass the measured discharge for that calibration set.

	TosA. in4	TosB.in4
Simulated Discharge Range	16 – 74 cfs	66 – 525 cfs
	ELAPPA.in4	ELAPPB.in4
Simulated Discharge Range	9.8 – 76 cfs	60 – 176 cfs

For each *.IN4 model, an IFG4 run was made. VAF (Velocity Adjustment Factor) values are checked. The slope of the VAF values must be positive. The VAF value at the

discharge for which the velocity set is given should be between 0.85 and 1.15. Ideally, such a tight fit allows expansion of the simulation beyond .4 x the lowest discharge and 2 x the highest discharge. If the VAF values are low, no such expansion is recommended.

- Where VAF slope was a problem for a particular transect, WSL's are adjusted up or down [usually lowering WSL increases VAF value and increasing WSL decreases VAF value for given discharge] (based upon the range of WSL's [right bank, center, and left bank] measured in the field).

In all cases, VAF values were found to be acceptable, but low, since all slopes were positive (ranging from 0.714 to 1.172 in each case).

[Note: the table of VAF values is presented after adjustment of Manning's "n" values for some data points]

Discharge	Tosa	Tosb
40.9		
Tr 1	1.027	.960
Tr 2	1.033	.930
Tr 3	1.164	.99
72.5		
Tr 1	.915	.89
Tr 2	1.00	.935
Tr3	.983	.891
263		
Tr 1	.875	.9
Tr 2	1.09	1.069
Tr 3	.844	.861
Discharge	ELAPPa	ELAPPb
24.46		

Tr 1	1.007	.843
Tr 2	.991	.928
Tr 3	.949	.944
68.42		
Tr 1	.921	.843
Tr 2	1.428	.944
Tr 3	.654	.871
84.65		
Tr 1	.913	.853
Tr 2	1.623	.943
Tr 3	.622	.872

Both Toscana and ELAPP were considered to be unreliable simulation at high flows for transect 3; may not be critical to MFL evaluation

After each *.IN4 file/model was calibrated to produce the best VAF's possible, the roughness values ("n") **calculated by IFG4** for each transect was checked. Those with values greater than 0.2 are chosen for adjustment. For each transect with some "n" values greater than 0.2, the mean value for "n" is calculated. Those "n" values above the median value are replaced with the mean value on the NS lines of the *.IN4 deck/file. This approach tries to adjust the worst problems without making drastic changes in WSL predictions and it is transect-specific [as compared to creating an NMAX line]. Professional judgment was also used, in some cases, to adjust other "n" values, where appropriate.

After "n" adjustments, IFG4 was run, again, with the adjusted roughness values and particular attention was placed on the predictions of velocities at the highest discharges. Each IFG4 output was checked for velocity "hot spots" at the high discharge simulations. Where predicted velocities exceeded 4.5 fps in a single cell **and** adjacent cells had low velocities, higher "n" values for that vertical/cell were added to the NS lines in the *.IN4 deck/file. This inserted "n" value was usually derived from the "n" values predicted by IFG4 for adjacent cells. When several contiguous cells had velocities that ranged from 3

to 6 fps (especially at high discharges), they were considered to be acceptable (i.e., **not** hot spots).

HABTAV was run with the appropriate HSI models for the "A", "B", "C", etc., models and the ZHAQF output files were examined. These contained habitat (WUA) versus discharge relationships for overlapping discharge ranges.

The overlapping ZHAQF values were combined on a spreadsheet (XCEL or SigmaPlot) into a single habitat versus discharge relationship. Weighted averages were used to combine the overlapping WUA values (these were different since different VAF values to adjust predicted velocities were not the same for comparable discharges in different runs). When an abrupt "jump" in the relationship occured, a plot of WUA/Q values is created and a curve smoothing routine (usually a third or fourth-order polynomial regression in SigmaPlot) was used for those values.

The WAU / Discharge results were prepared for the final report of WUA and Discharge and were the values used for time-series analysis.

Time-Series Analysis

Two sets of discharge data were assessed, from 1940-1969 [roughly equivalent to wet AMO years] and 1970-1999 [roughly equivalent to dry AMO years].

The TSLIB (time-series library) from the USGS Mid-Continent Research Laboratories was used to conduct the analysis.

Monthly discharge files were created for existing conditions, 10% monthly flow reductions, 20% monthly flow reductions, 30% monthly flow reductions, and 40% monthly flow reductions. For each set of discharge conditions, a monthly time-series was created as the amount of habitat (WUA) available for each discharge for each month. HAQ files (habitat availability) were created for the high discharge events by linear (first-order regression) or curvilinear (second-order polynomial regression) fits. Duration analysis was then accomplished through the percentage of time that the average and median habitat values were met or exceeded for each month over the period of record. Comparisons to existing conditions were made to evaluate the amount of habitat gain or loss under conditions of reduced flow.

During this analysis, habitat suitability curves for both “catalog” (USGS Blue Books of habitat suitability) and locally derived HIS’s were compared. Although the catalog and locally derived curves were quite similar, there was sufficient difference in at least one

category of local preference (usually in substrate/cover preference, more often than not) that the predicted amount of available habitat was an order of magnitude less for Florida curves as opposed to catalog curves. This result supports conclusions by Gore and Nestler (1988) and Gore et al. (2001) who have indicated that habitat-specific derivations of suitability curves are the most appropriate application for this type of analysis.

The following habitat suitability criteria were used:

Habitat Guilds:

1. Shallow-Slow
2. Shallow-Fast
3. Deep-Slow
4. Deep-Fast

Largemouth Bass

1. Adult
2. Juvenile
3. Spawning
4. Fry

Bluegill

1. Adult
2. Juvenile
3. Spawning
4. Fry

Spotted Sunfish

1. Adult
2. Juvenile
3. Spawning
4. Fry

Benthic Macroinvertebrates

1. Total Community Diversity

Cyprinidae (minnows)

2. Combined all life stages

Since predictions of less initial habitat availability are predicted in the PHABSIM runs for Florida curves, losses in smaller amounts of habitat result in larger incremental gains or losses in habitat. [For example if the catalog curves predict 2350 square feet of habitat under existing conditions (per 1000 linear feet of river) and the time series predicts a loss of 50 square feet of habitat, this results in a 3% habitat loss; however, if Florida curves for the same species predict only 235 square feet of habitat under existing conditions and the time series predicts only a loss of 20 square feet of habitat, the result is a 9% loss]. It should not be surprising, then, that some habitat gain / loss analyses are dramatically different using locally derived habitat information where a much lower initial habitat availability is predicted.

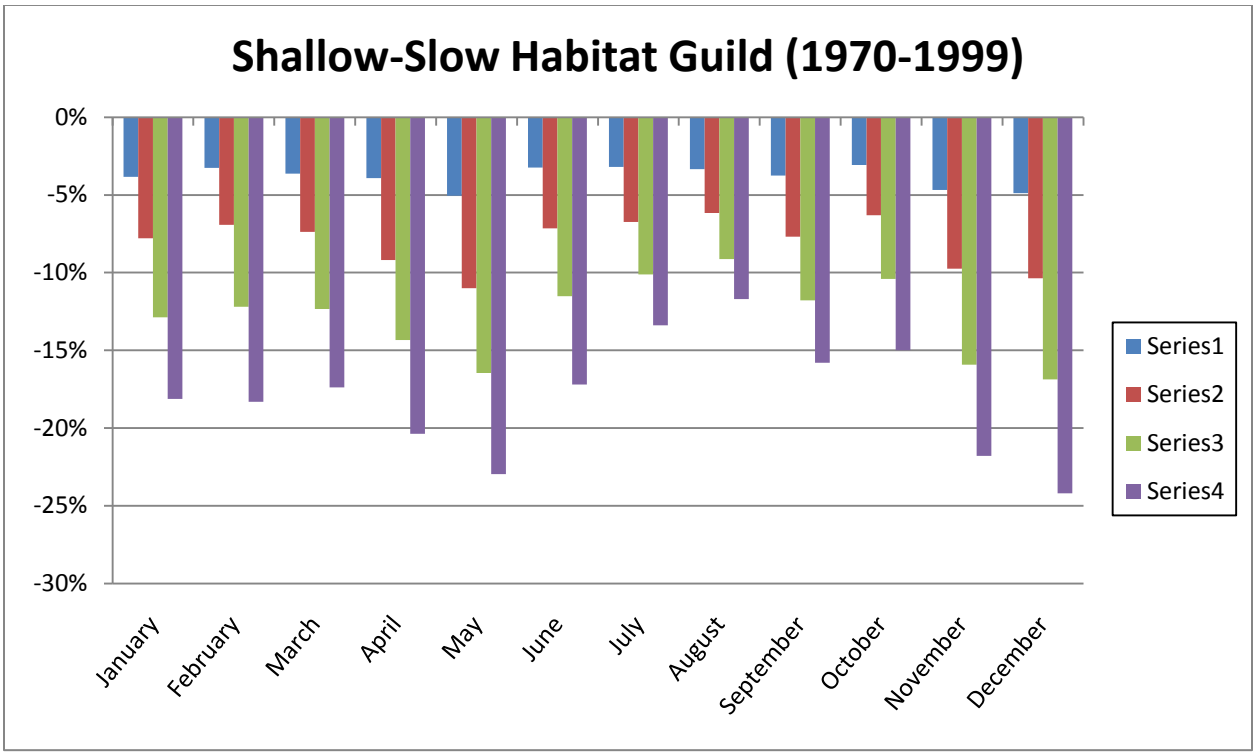
References:

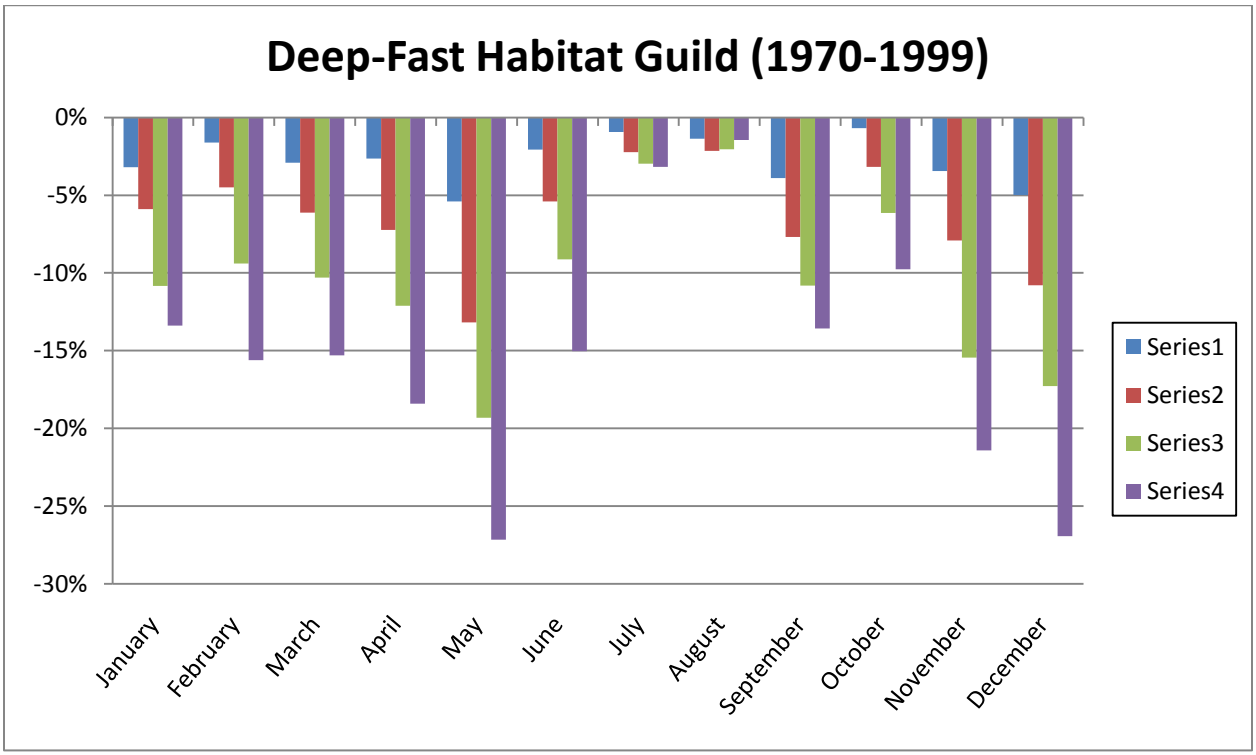
Gore, J.A., and J.M. Nestler. 1988. Instream flow studies in perspective. ***Regulated Rivers*** **2: 93-101.**

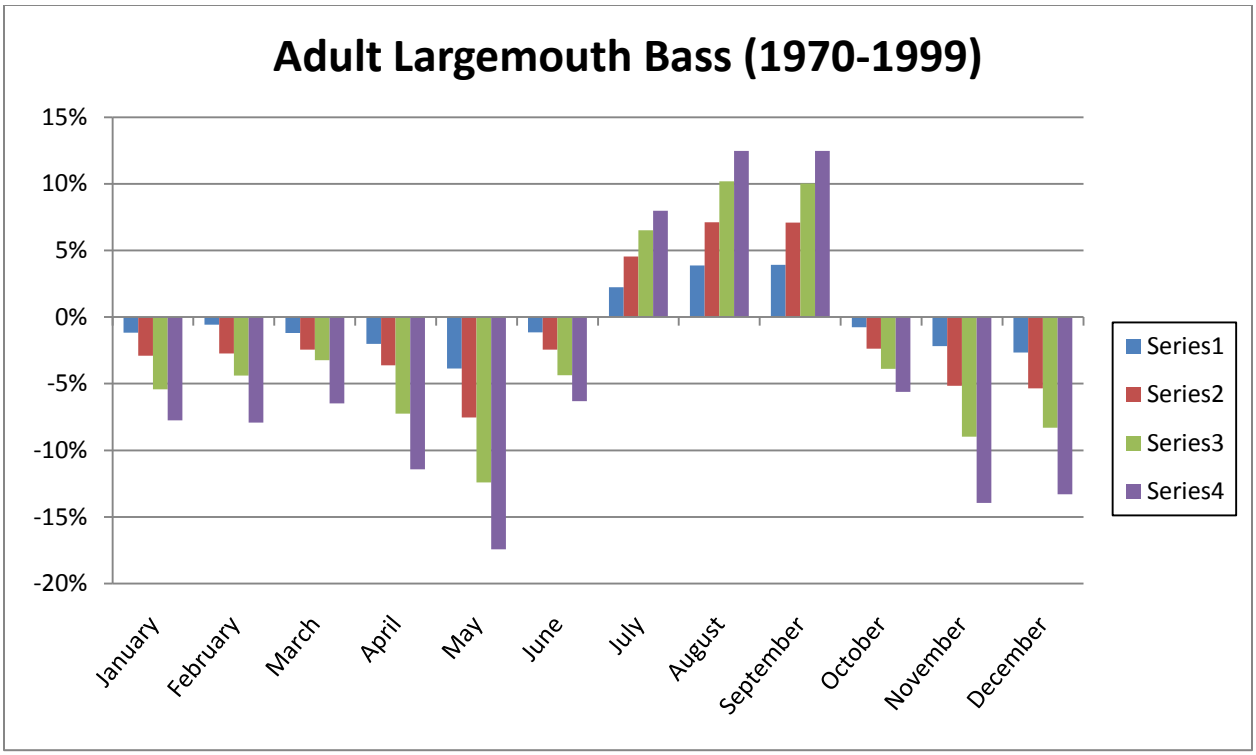
Gore, J.A., J.B. Layzer, and J. Mead. 2001. Macroinvertebrate instream flow studies after 20 years: a role in stream and river restoration. ***Regulated Rivers*** **17: 527-542.**

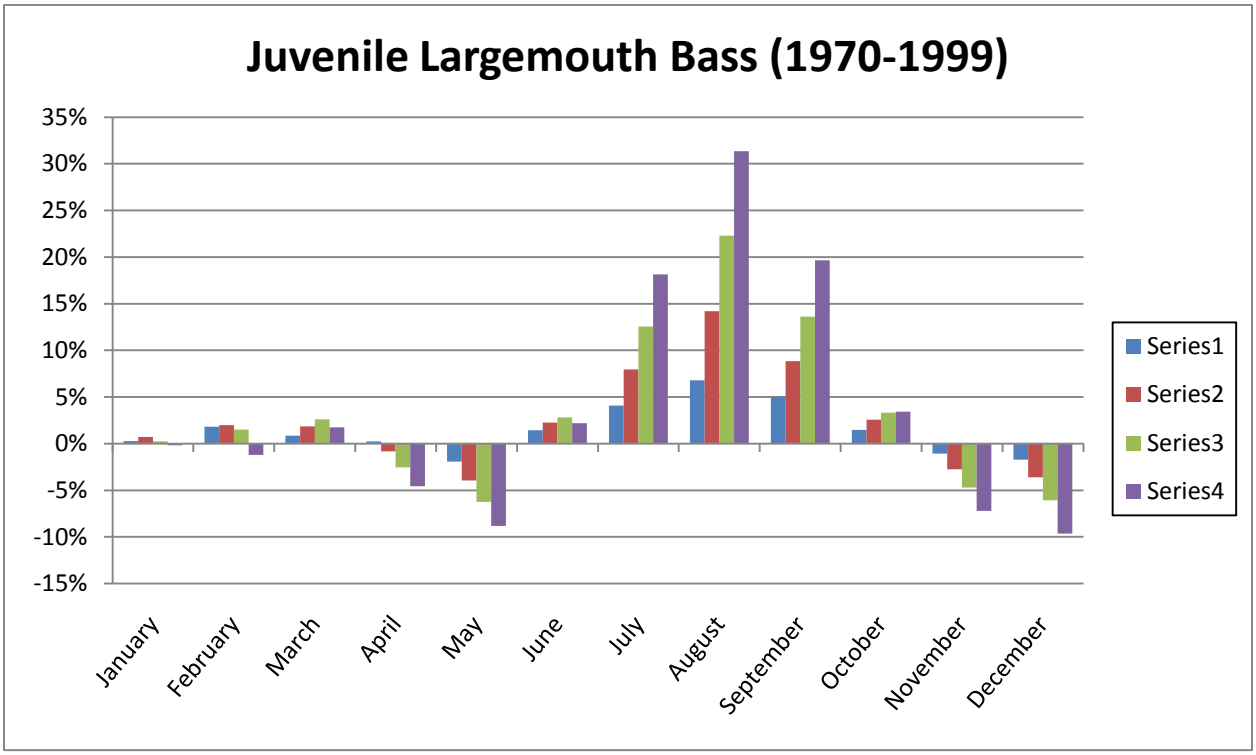
PHABSIM analysis, when given hydrologic data and habitat preferences, establishes a relationship between hydrology and WUA which allows examination of habitat availability in terms of the historic and altered flow regimes. Determining from these data the amount of loss, or deviation from the optimum, that a system is capable of withstanding is based on professional judgment. For the purpose of minimum flows and levels development, we have defined percent-of-flow reductions that result in 15% reduction in habitat from historic conditions as limiting factors. This representation was determined by combining the WUA for all PHABSIM sites for each species, life stage, or guild. The inference is made that the entire study reach is represented equally by the selected PHABSIM sites, which was also the intention when establishing sites. In addition, PHABSIM is typically utilized by the District to determine allowable flow reductions for Block 1 and Block 2 period of the year, utilizing inundation of floodplain features for Block 3 analyses.

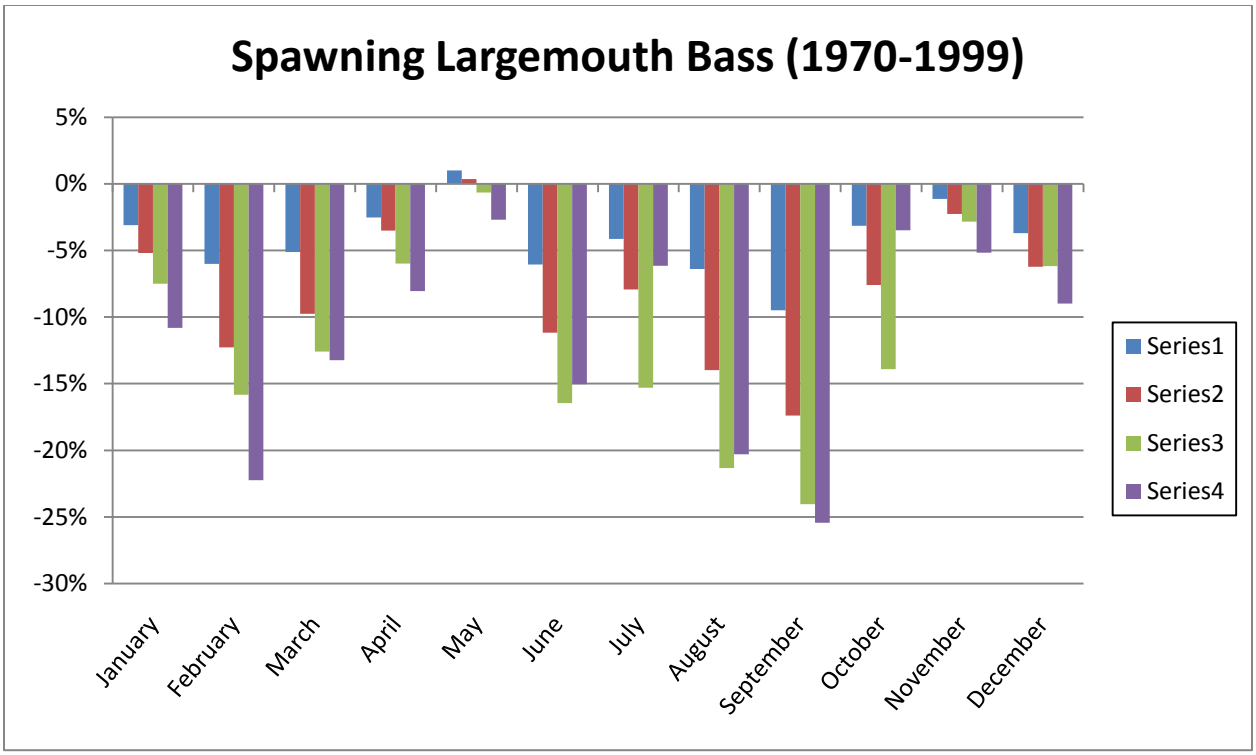
Below are graphics generated for visual inspection of PHABSIM output. They are arranged by species and depict total weighted usable area for the entire reach of the study (all sites combined).

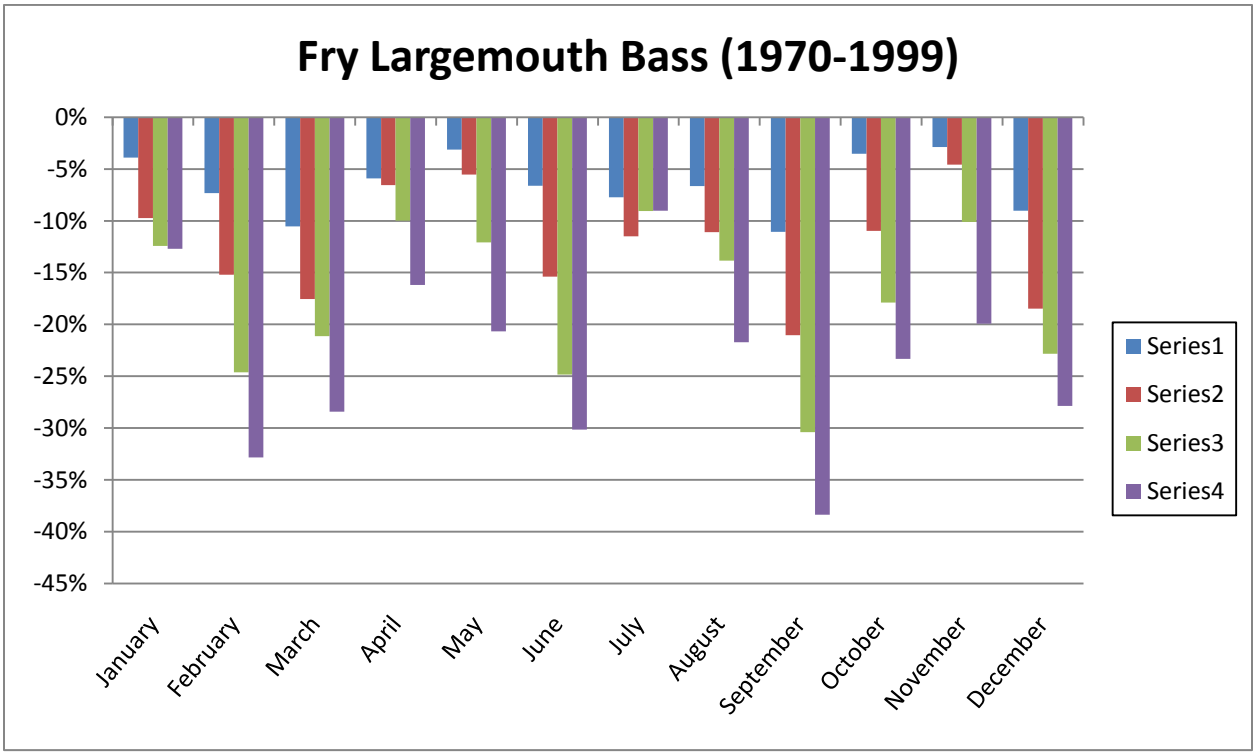


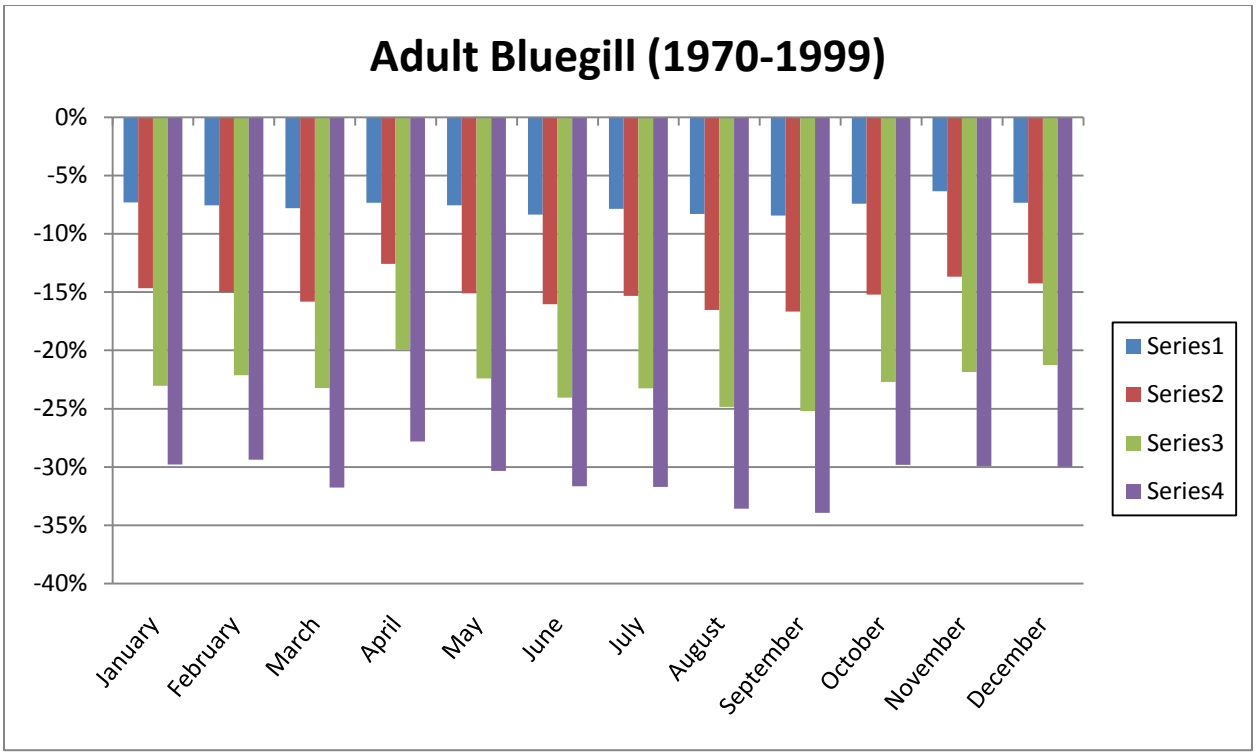


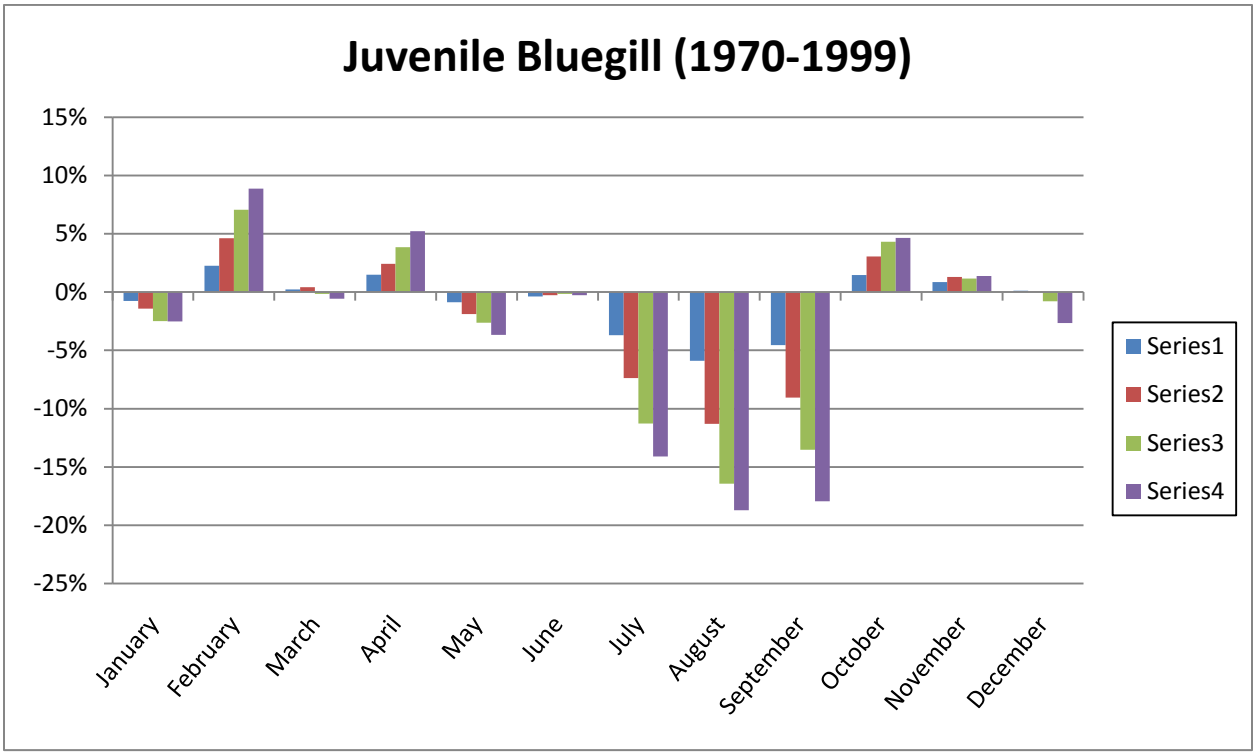

Adult Largemouth Bass (1970-1999)
15%
10%
5%
0%
-5%
-10%
-15%
-20%
January
February
March
April
May
June
July
August
September
October
November
December
Series1
Series2
Series3
Series4

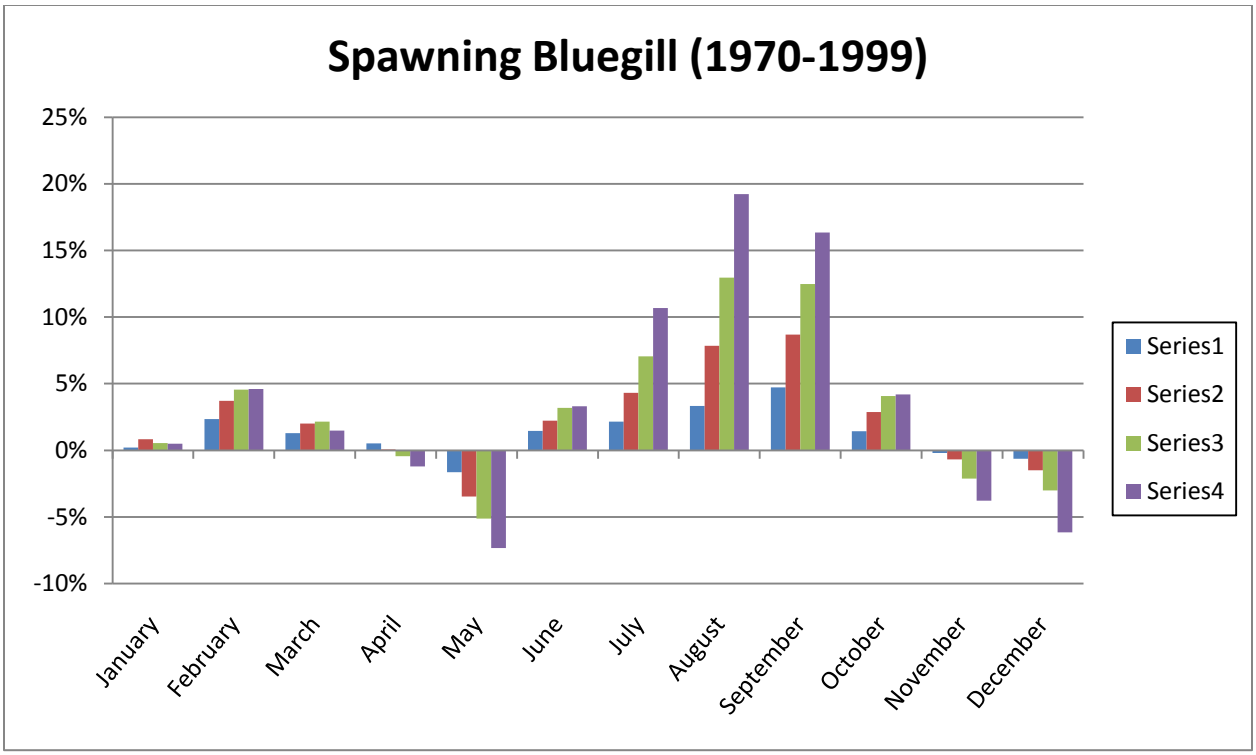

Juvenile Largemouth Bass (1970-1999)
35%
30%
25%
20%
15%
10%
5%
0%
-5%
-10%
-15%
January
February
March
April
May
June
July
August
September
October
November
December
Series1
Series2
Series3
Series4

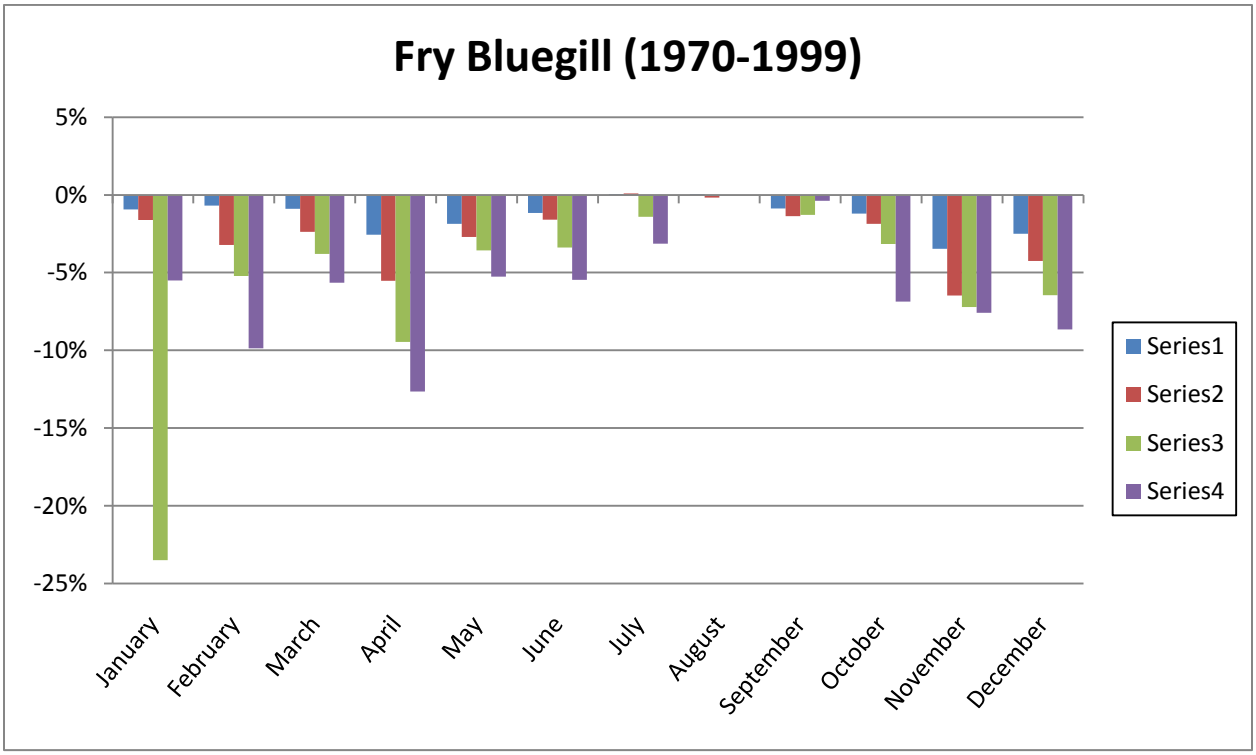

Spawning Largemouth Bass (1970-1999)
5%
0%
-5%
-10%
-15%
-20%
-25%
-30%
January
February
March
April
May
June
July
August
September
October
November
December
Series1
Series2
Series3
Series4

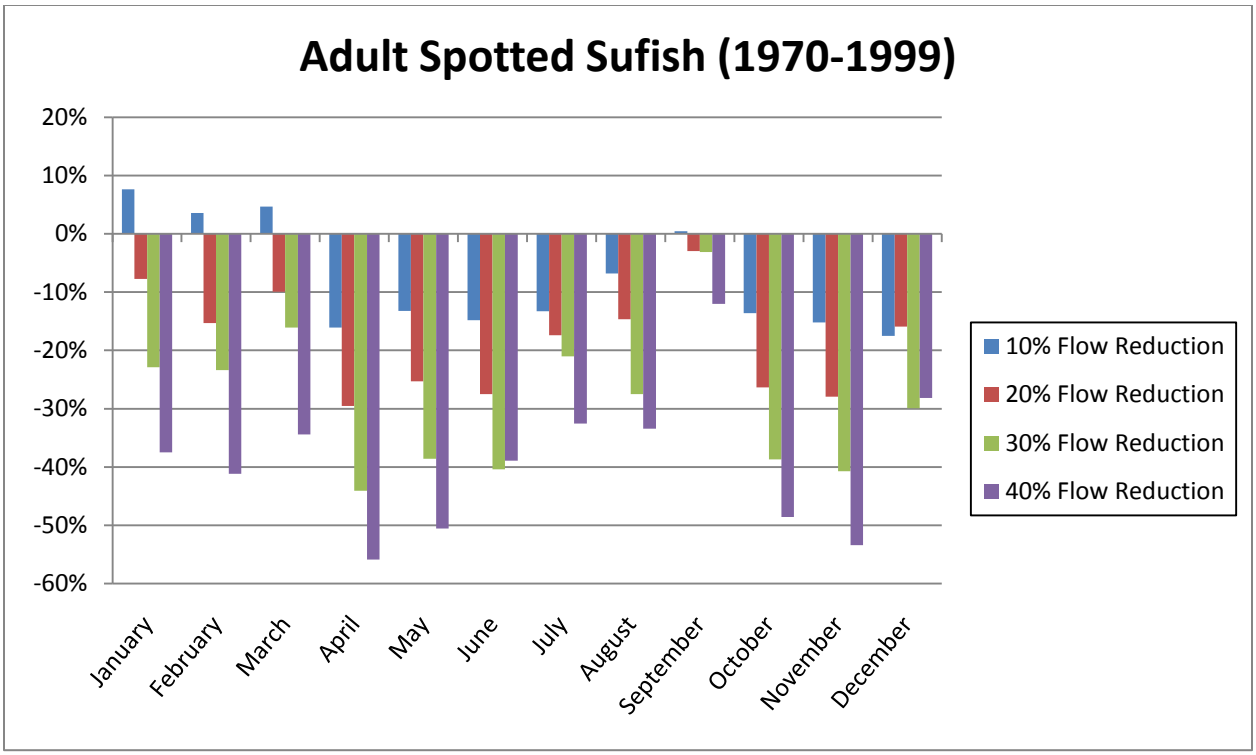

Fry Largemouth Bass (1970-1999)
0%
-5%
-10%
-15%
-20%
-25%
-30%
-35%
-40%
-45%
January
February
March
April
May
June
July
August
September
October
November
December
Series1
Series2
Series3
Series4

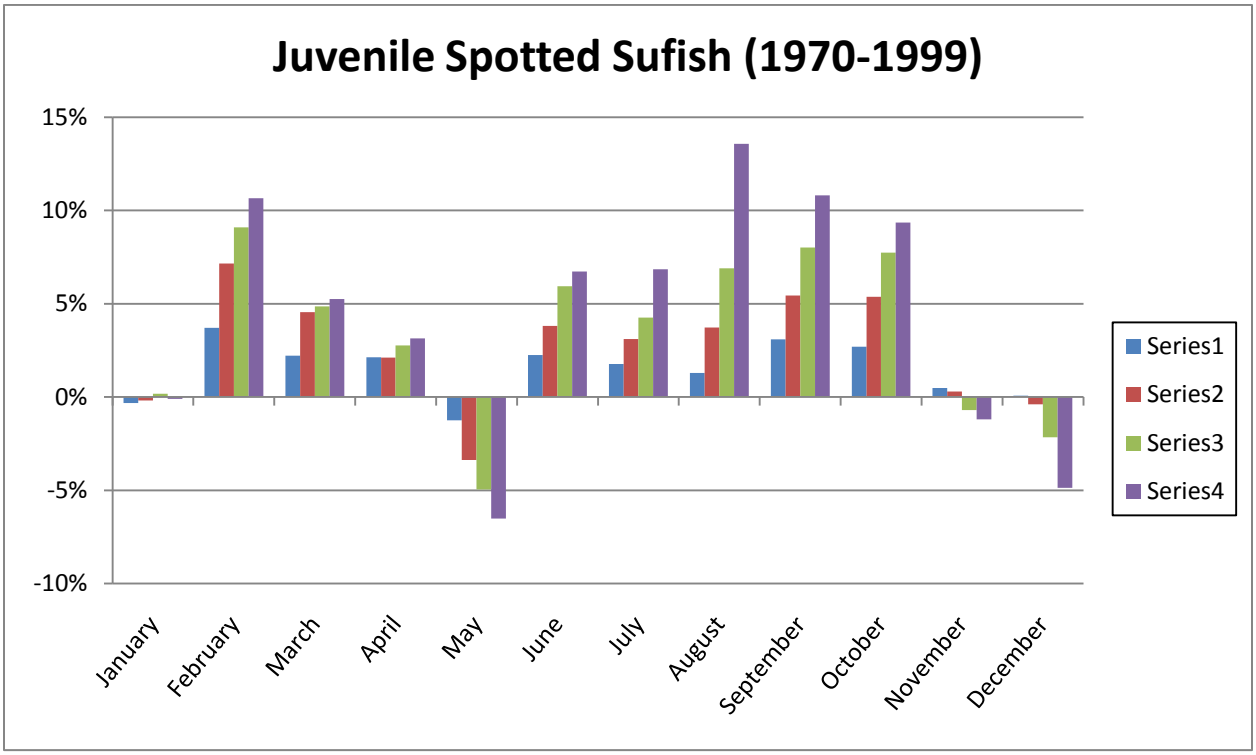

Adult Bluegill (1970-1999)
0%
-5%
-10%
-15%
-20%
-25%
-30%
-35%
-40%
January
February
March
April
May
June
July
August
September
October
November
December
Series1
Series2
Series3
Series4

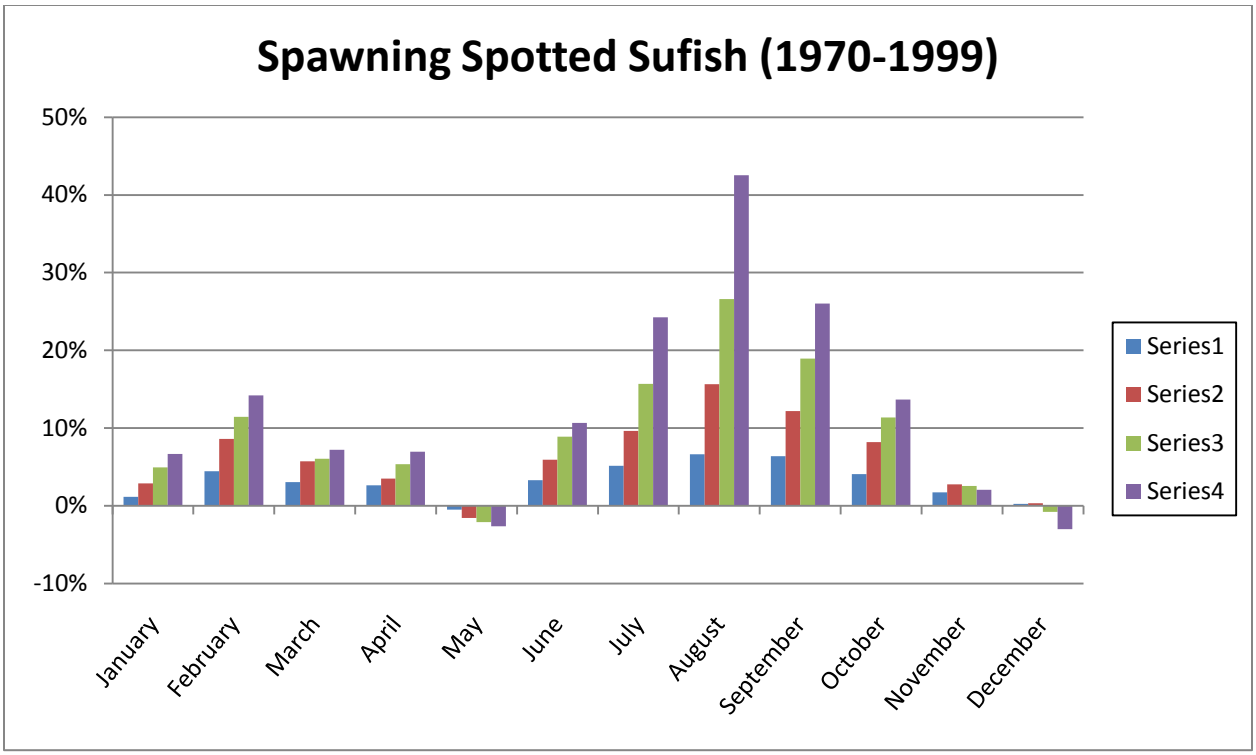

Juvenile Bluegill (1970-1999)
15%
10%
5%
0%
-5%
-10%
-15%
-20%
-25%
January
February
March
April
May
June
July
August
September
October
November
December
Series1
Series2
Series3
Series4

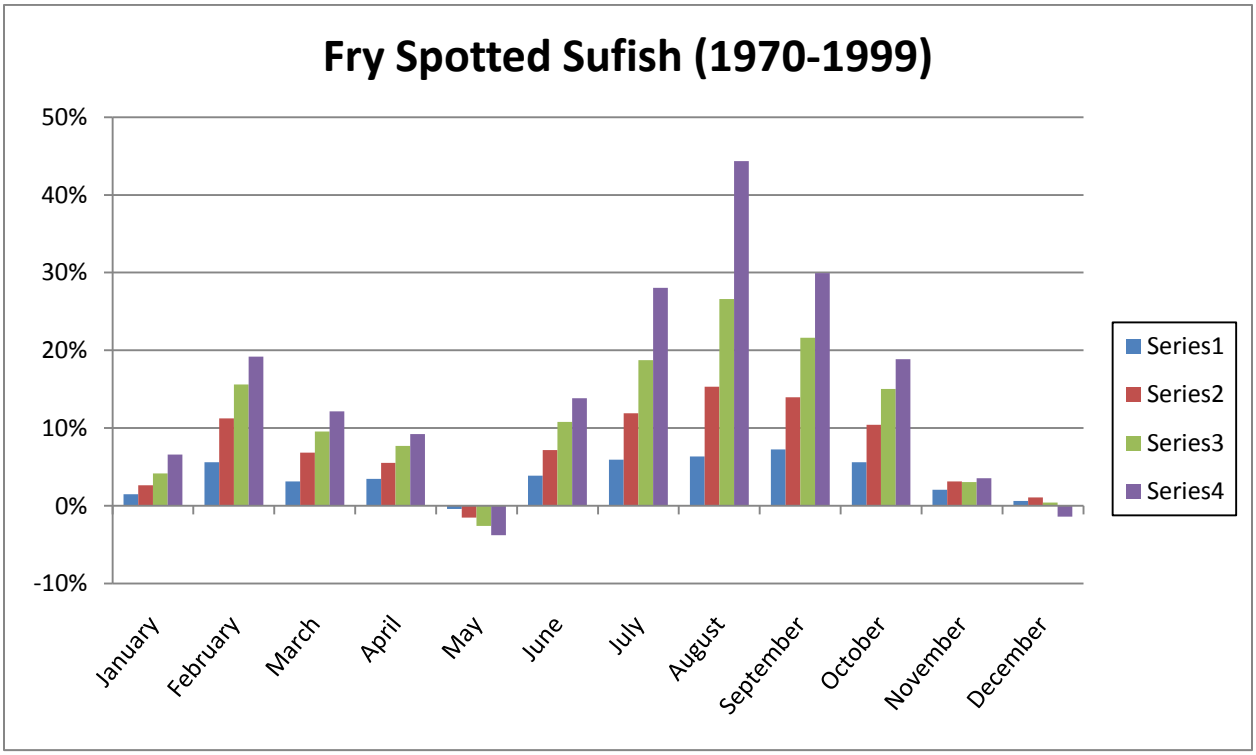

Spawning Bluegill (1970-1999)
25%
20%
15%
10%
5%
0%
-5%
-10%
January
February
March
April
May
June
July
August
September
October
November
December
Series1
Series2
Series3
Series4

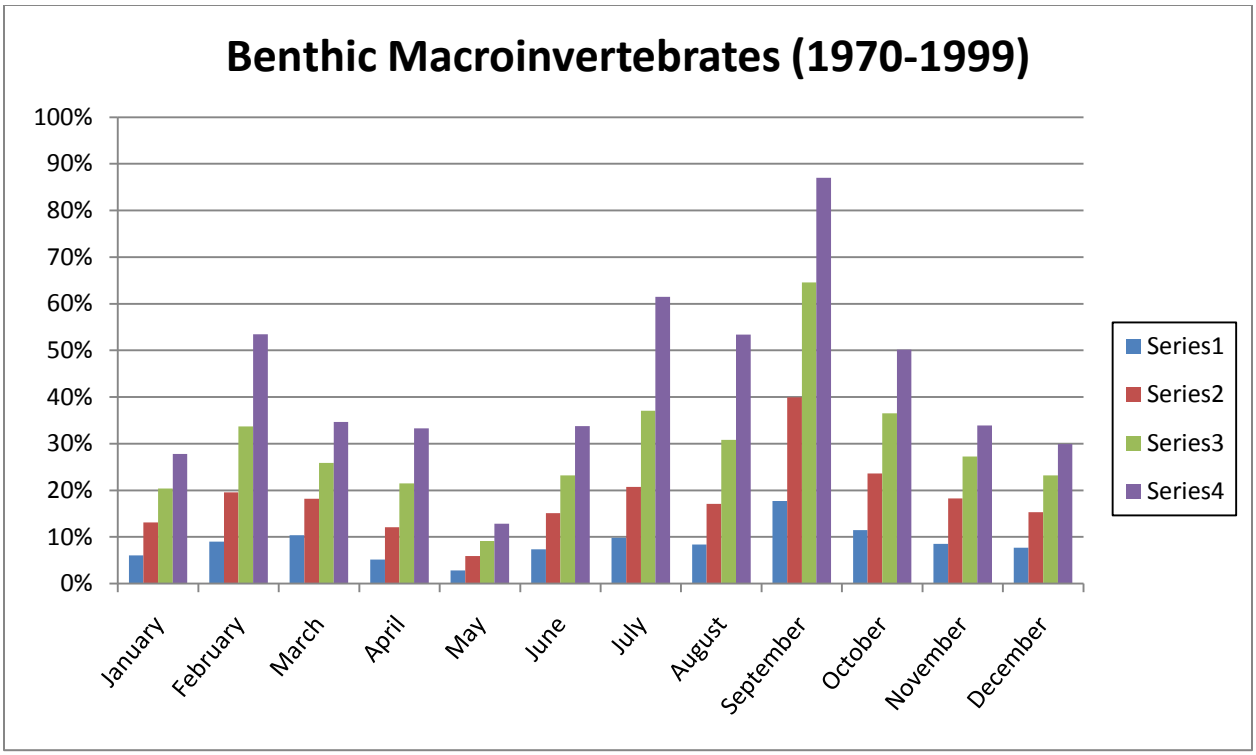

Fry Bluegill (1970-1999)
5%
0%
-5%
-10%
-15%
-20%
-25%
January
February
March
April
May
June
July
August
September
October
November
December
Series1
Series2
Series3
Series4

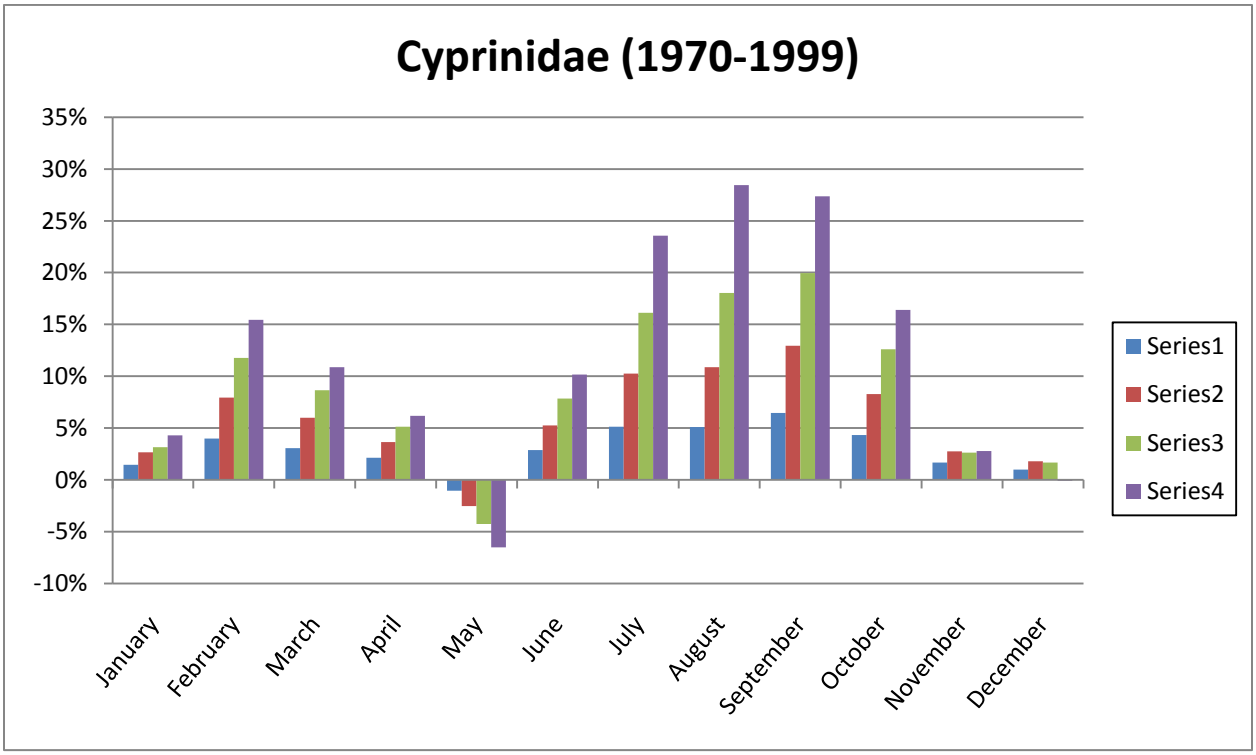

Adult Spotted Sufish (1970-1999)
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-60%
January
February
March
April
May
June
July
August
September
October
November
December
10% Flow Reduction
20% Flow Reduction
30% Flow Reduction
40% Flow Reduction


Juvenile Spotted Sufish (1970-1999)
15%
10%
5%
0%
-5%
-10%
January
February
March
April
May
June
July
August
September
October
November
December
Series1
Series2
Series3
Series4


Spawning Spotted Sufish (1970-1999)
50%
40%
30%
20%
10%
0%
-10%
January
February
March
April
May
June
July
August
September
October
November
December
Series1
Series2
Series3
Series4

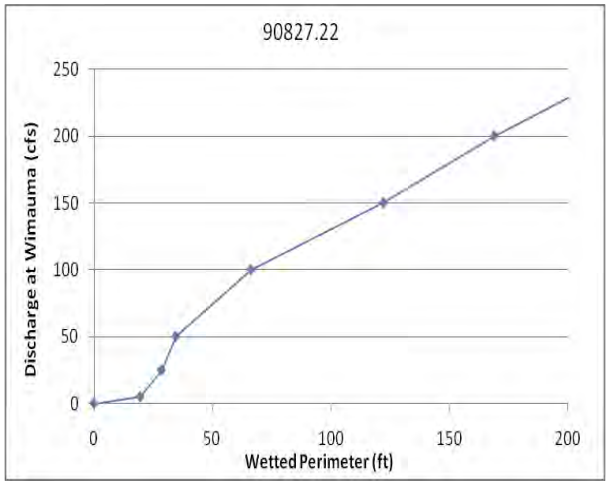

Fry Spotted Sufish (1970-1999)
50%
40%
30%
20%
10%
0%
-10%
January
February
March
April
May
June
July
August
September
October
November
December
Series1
Series2
Series3
Series4

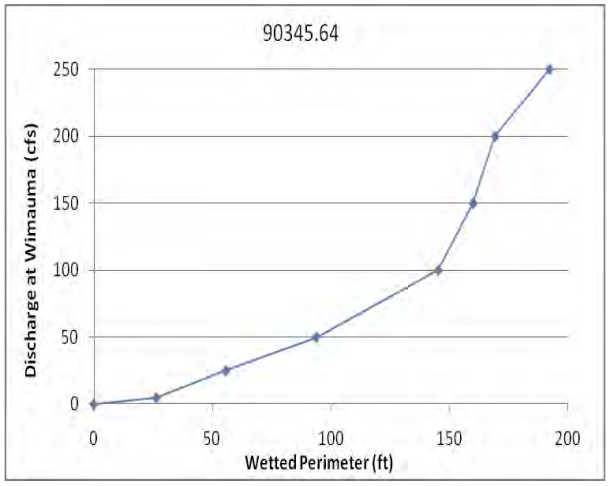

Benthic Macroinvertebrates (1970-1999)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
January
February
March
April
May
June
July
August
September
October
November
December
Series1
Series2
Series3
Series4

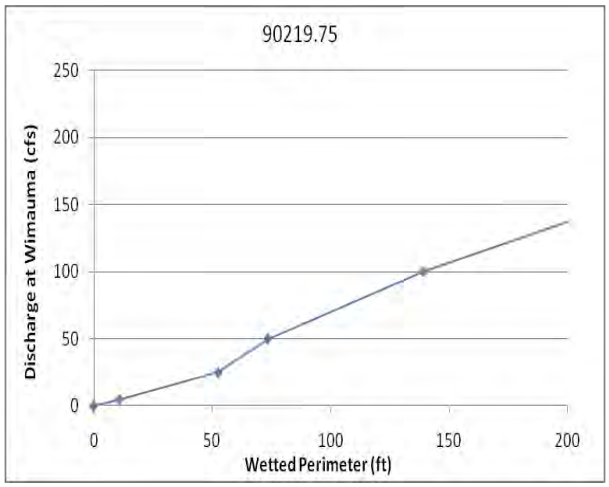

Cyprinidae (1970-1999)
35%
30%
25%
20%
15%
10%
5%
0%
-5%
-10%
January
February
March
April
May
June
July
August
September
October
November
December
Series1
Series2
Series3
Series4

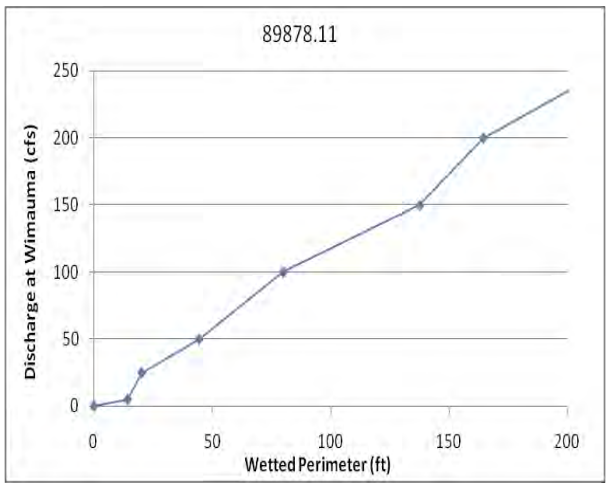
Wetted Perimeter Appendix

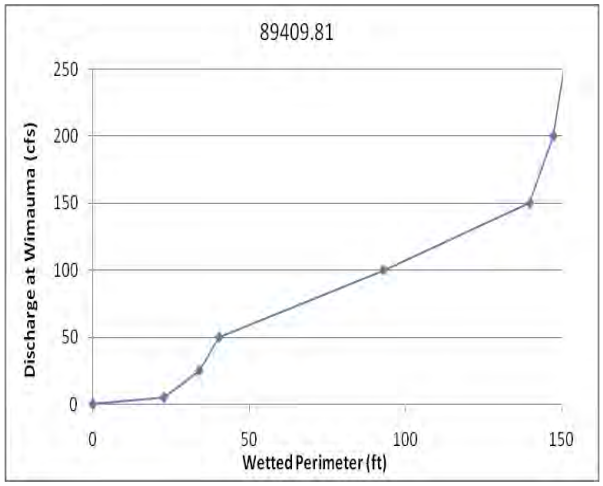
The graphs below represent wetted perimeter versus discharge at HEC-RAS stations based on the feet upstream of USGS Little Manatee River near Wimauma gage.

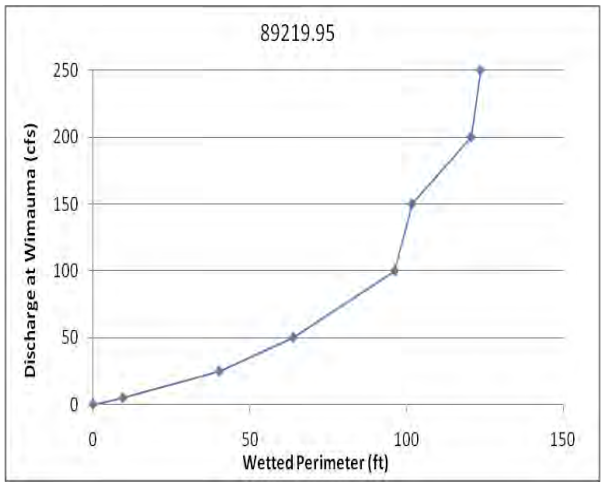


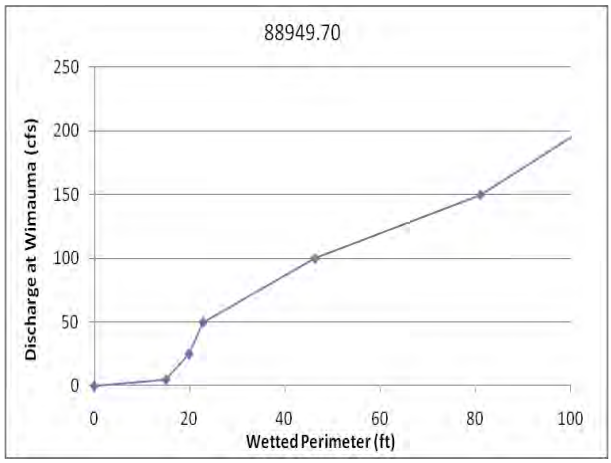


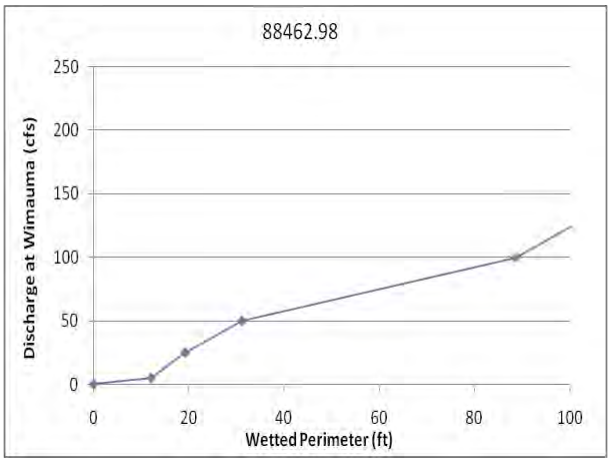

90219.75
Discharge at Wimauma (cfs)
250
200
150
100
50
0
0
50
100
150
200
Wetted Perimeter (ft)

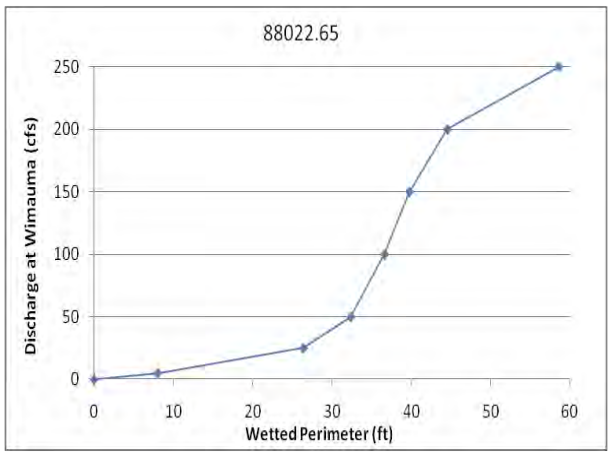

89878.11
Discharge at Wimauma (cfs)
250
200
150
100
50
0
0
50
100
150
200
Wetted Perimeter (ft)

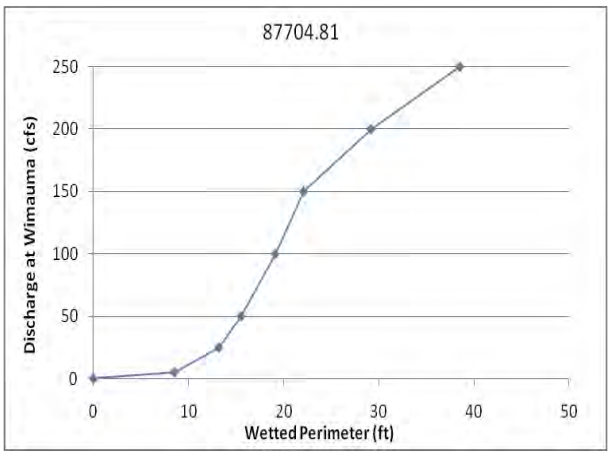

89409.81
Discharge at Wimauma (cfs)
250
200
150
100
50
0
0
50
100
150
Wetted Perimeter (ft)

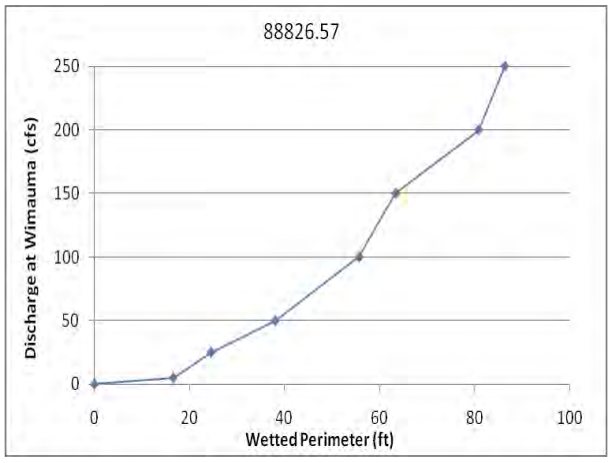

89219.95
Discharge at Wimauma (cfs)
250
200
150
100
50
0
0
50
100
150
Wetted Perimeter (ft)

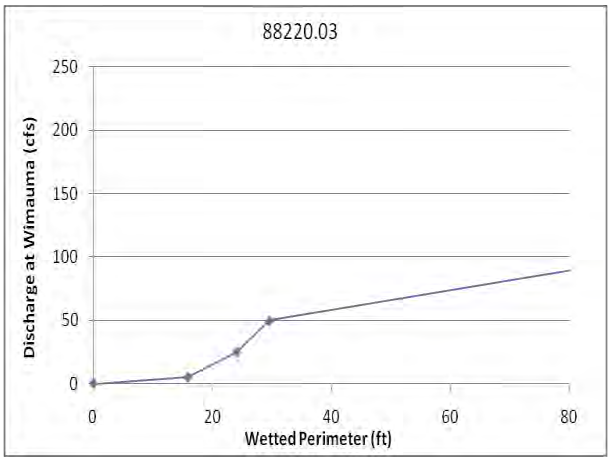

88949.70
Discharge at Wimauma (cfs)
250
200
150
100
50
0
0
20
40
60
80
100
Wetted Perimeter (ft)

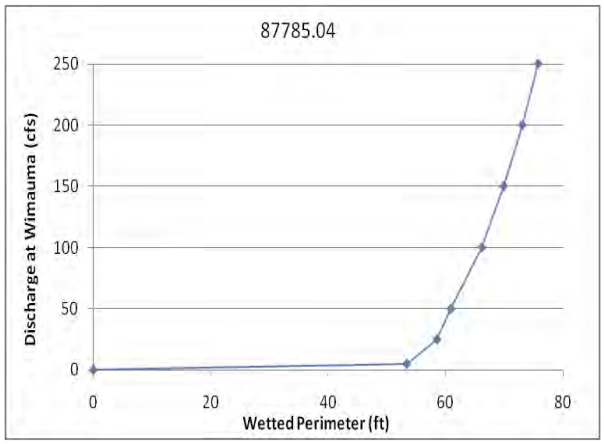

88462.98
Discharge at Wimauma (cfs)
250
200
150
100
50
0
0
20
40
60
80
100
Wetted Perimeter (ft)

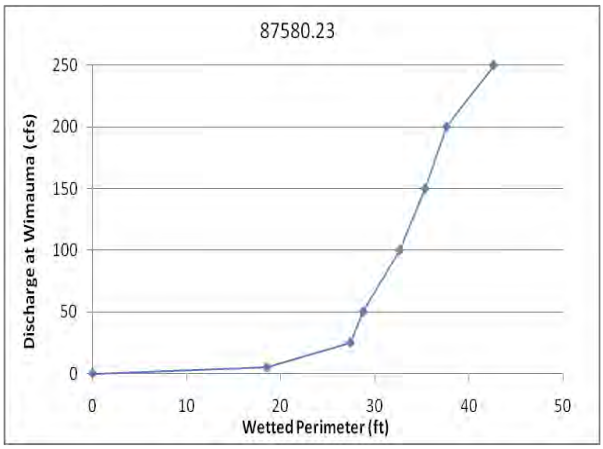

88022.65
Discharge at Wimauma (cfs)
250
200
150
100
50
0
0
10
20
30
40
50
60
Wetted Perimeter (ft)

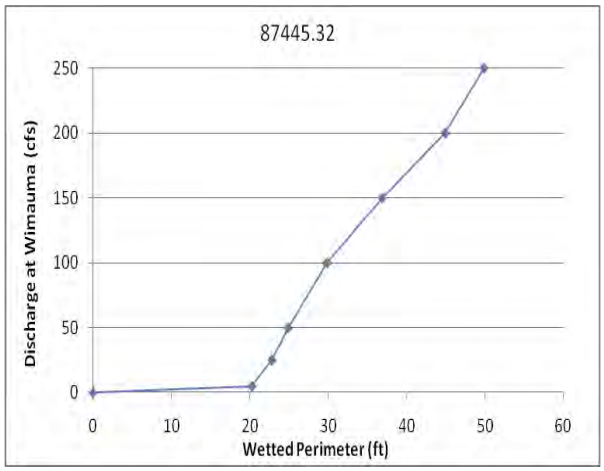

87704.81
Discharge at Wimauma (cfs)
250
200
150
100
50
0
0
10
20
30
40
50
Wetted Perimeter (ft)

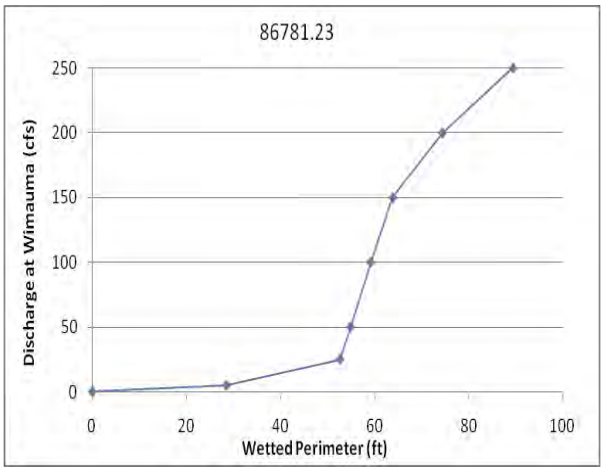

88826.57
Discharge at Wimauma (cfs)
250
200
150
100
50
0
0
20
40
60
80
100
Wetted Perimeter (ft)

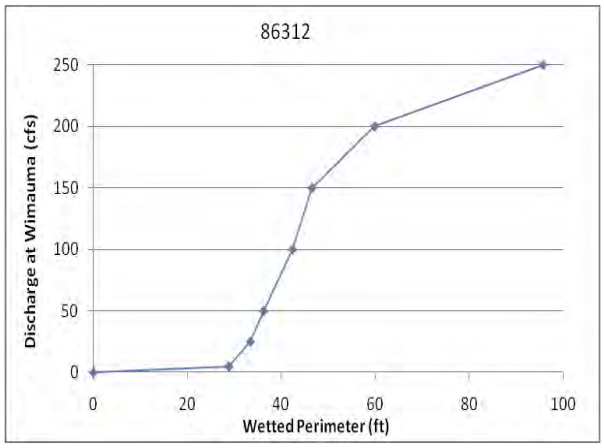

88220.03
Discharge at Wimauma (cfs)
250
200
150
100
50
0
0
20
40
60
80
Wetted Perimeter (ft)

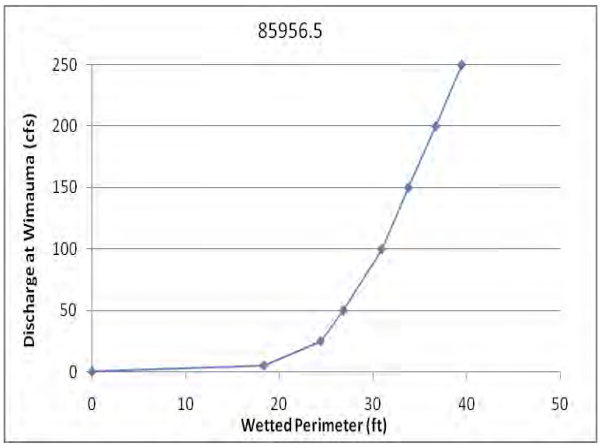

87785.04
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80

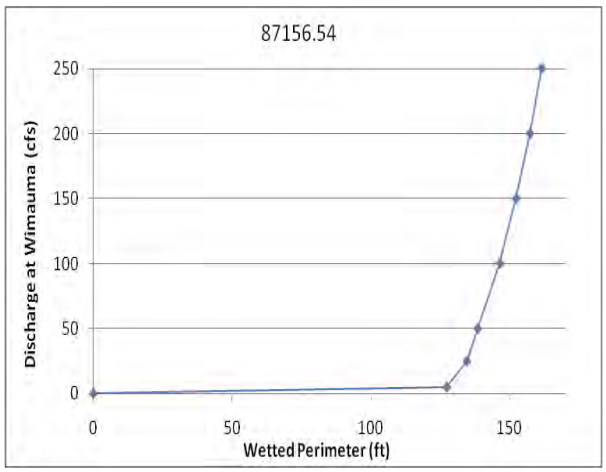

87580.23
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50

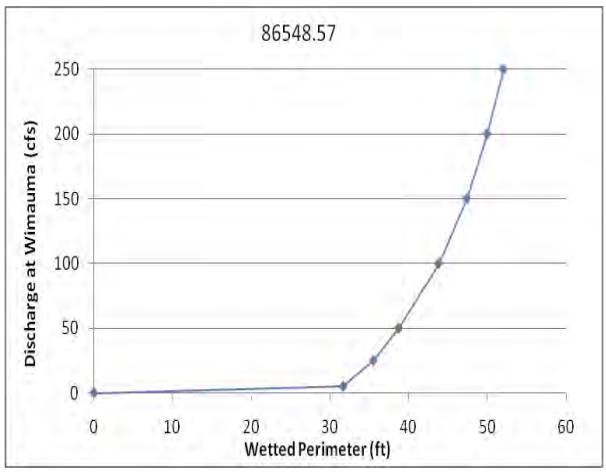

87445.32
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60

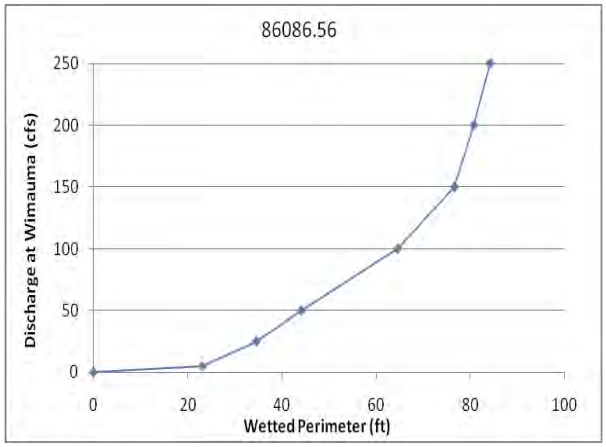

86781.23
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100

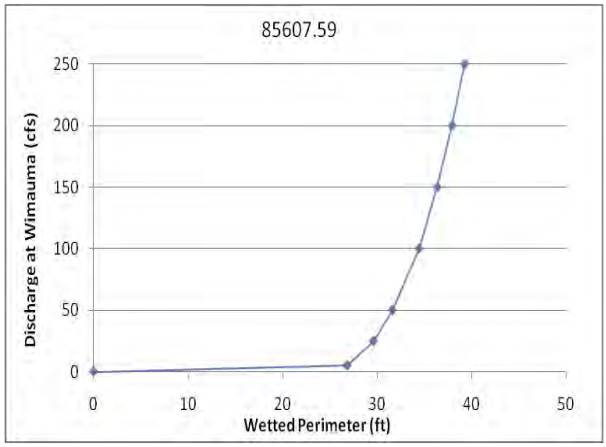

86312
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100

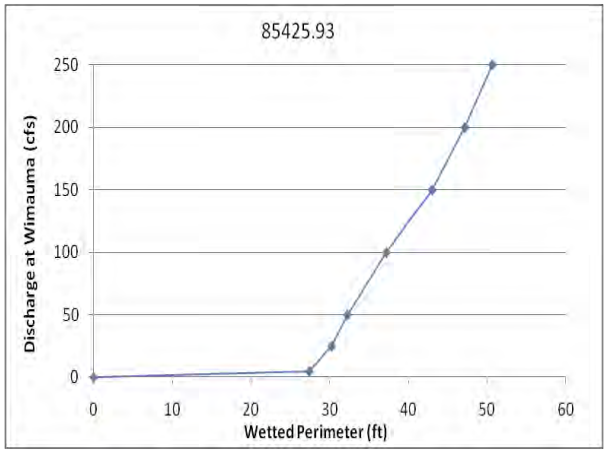

85956.5
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50

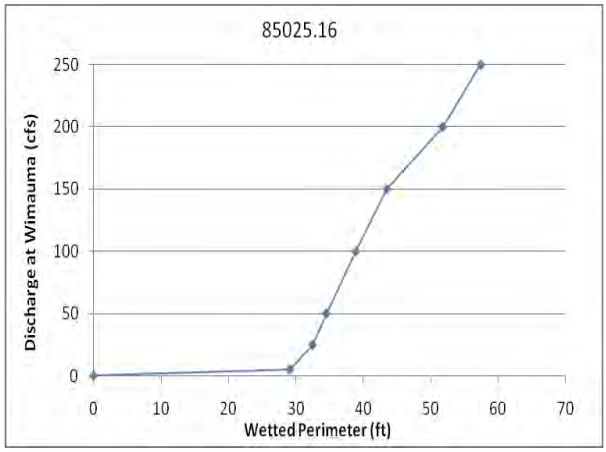

87156.54
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
50
100
150

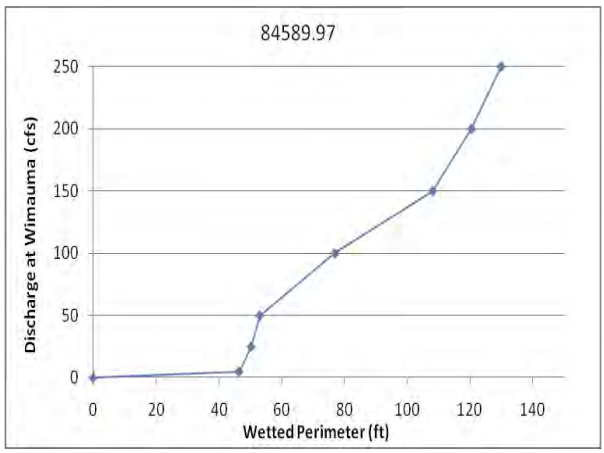

86548.57
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60

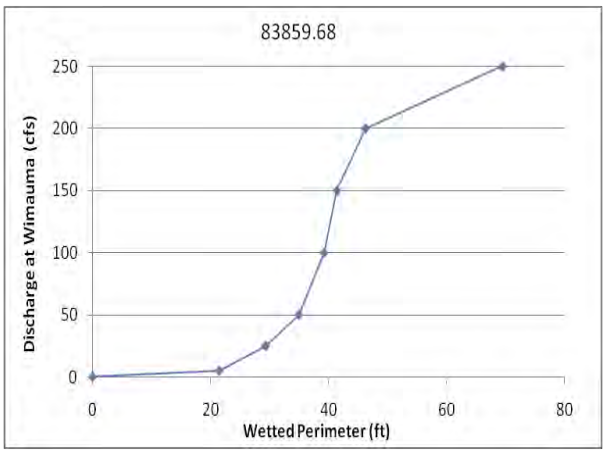

86086.56
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100

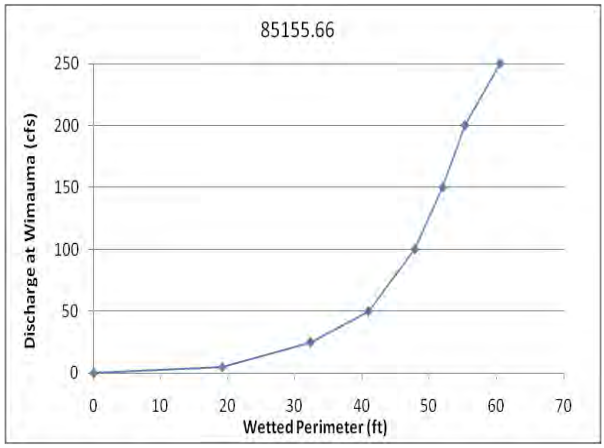

85607.59
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50

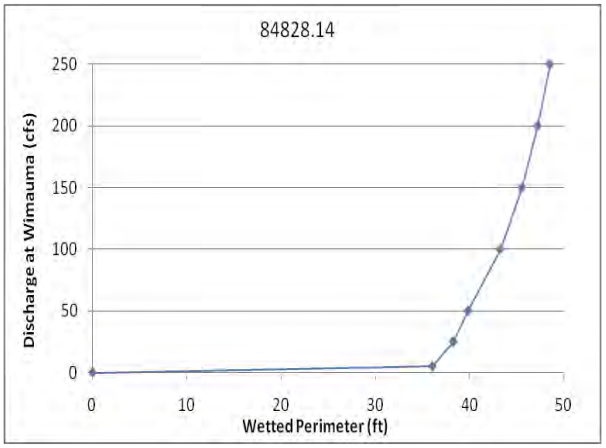

85425.93
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60

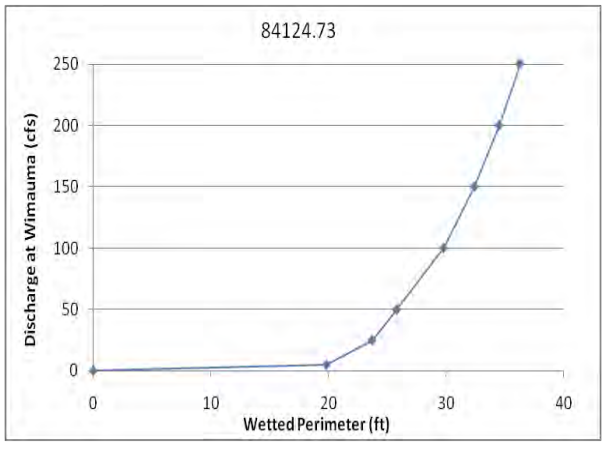

85025.16
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70

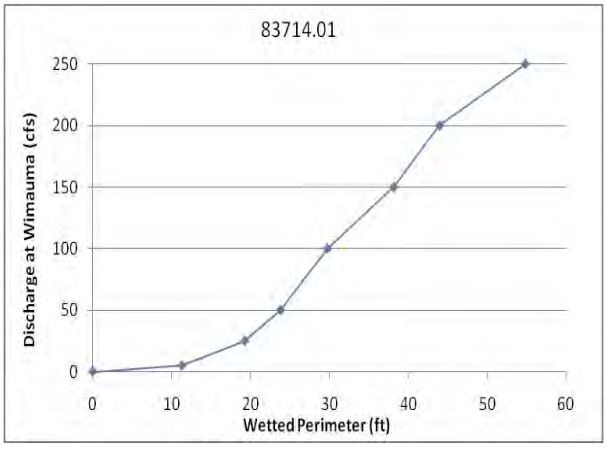

84589.97
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140

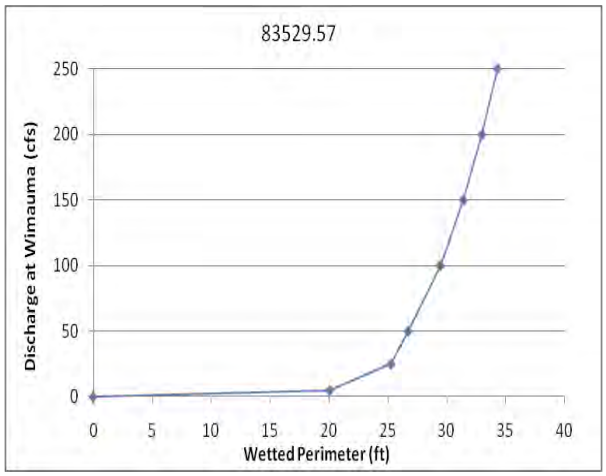

83859.68
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80

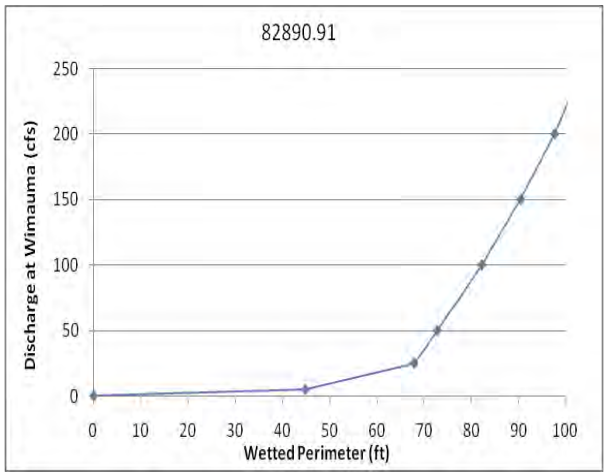

85155.66
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70

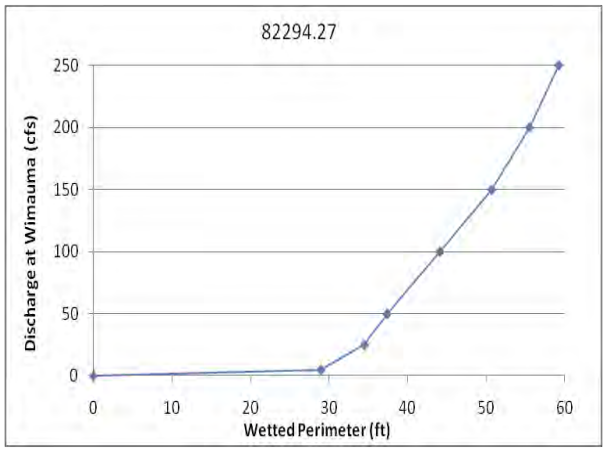

84828.14
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50

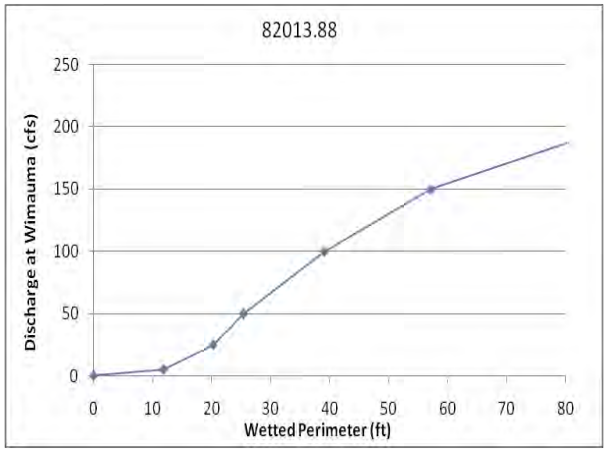

84124.73
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40

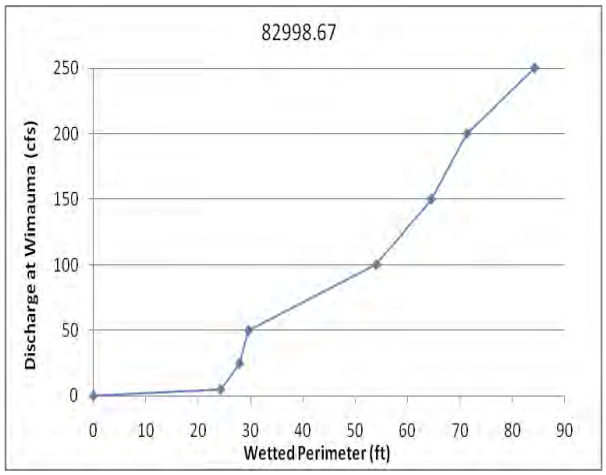

83714.01
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60

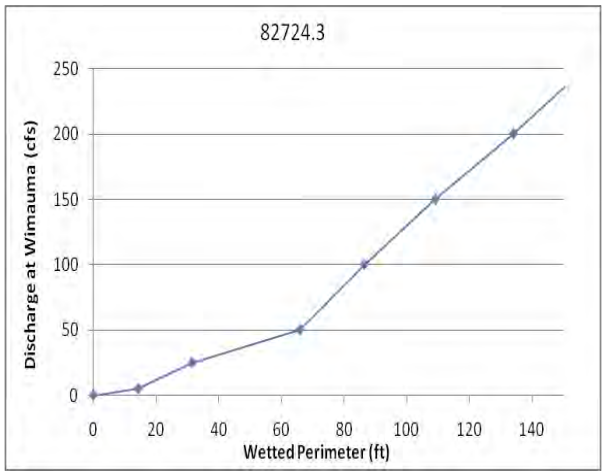

83529.57
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 5 10 15 20 25 30 35 40

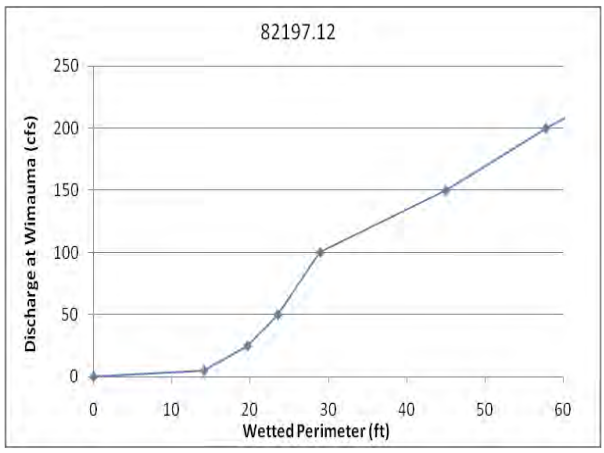

82890.91
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100

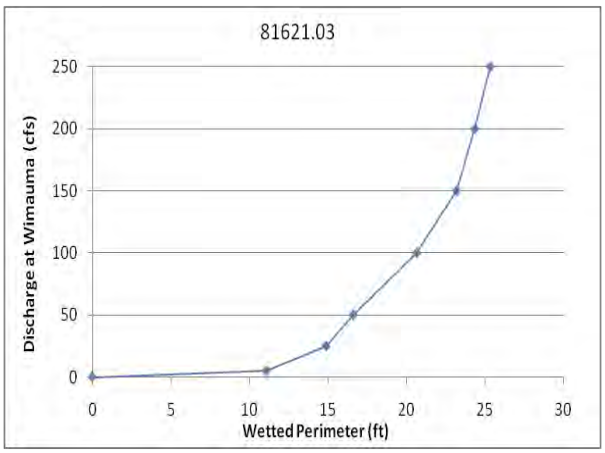

82294.27
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60

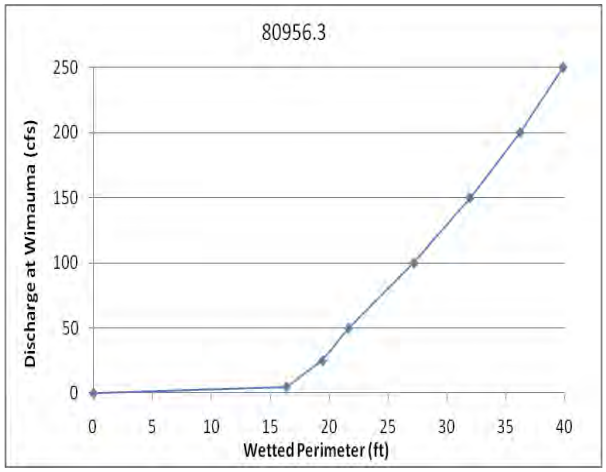

82013.88
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80

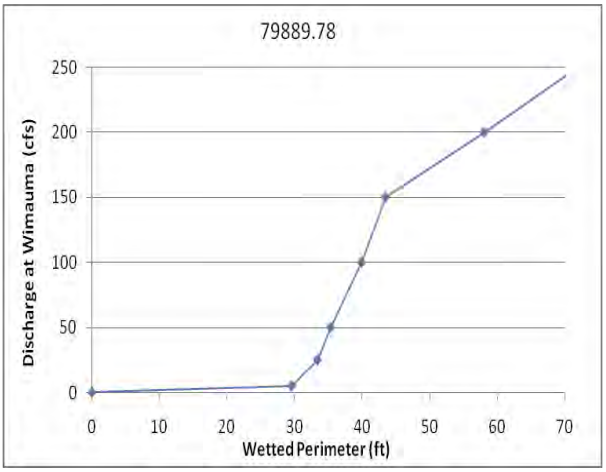

82998.67
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90

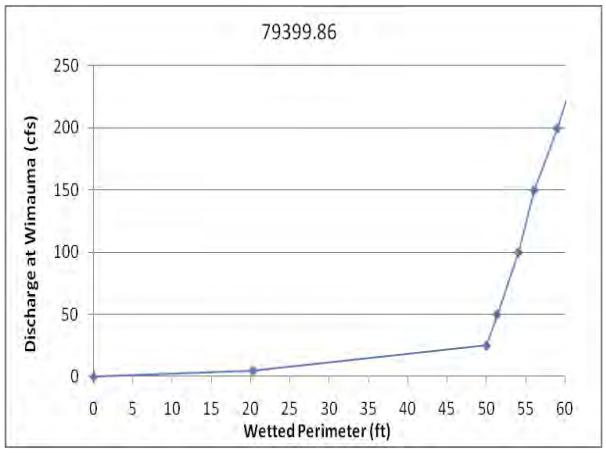

82724.3
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 20 40 60 80 100 120 140

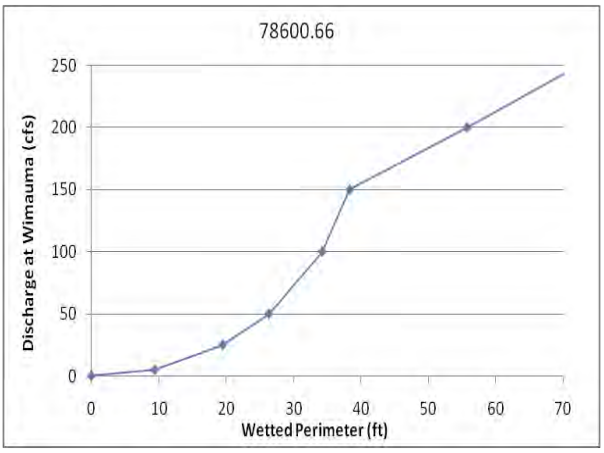

82197.12
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60

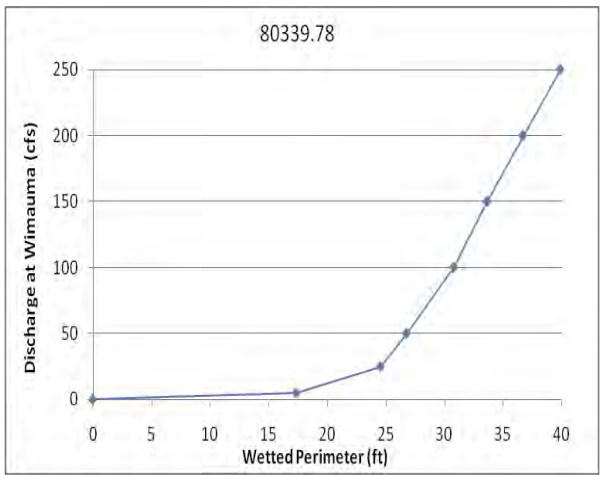

81621.03
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
5
10
15
20
25
30

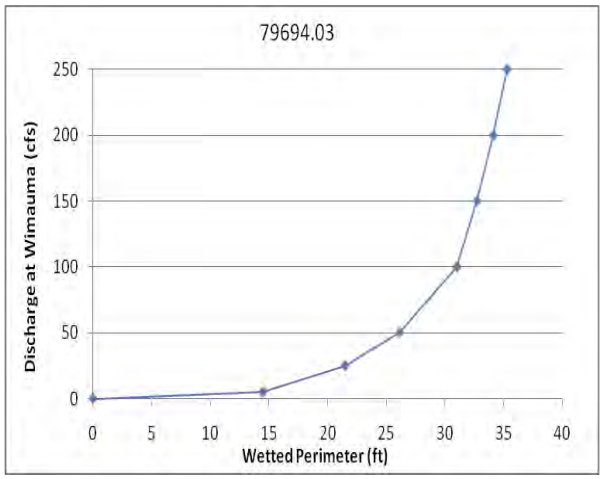

80956.3
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
5
10
15
20
25
30
35
40

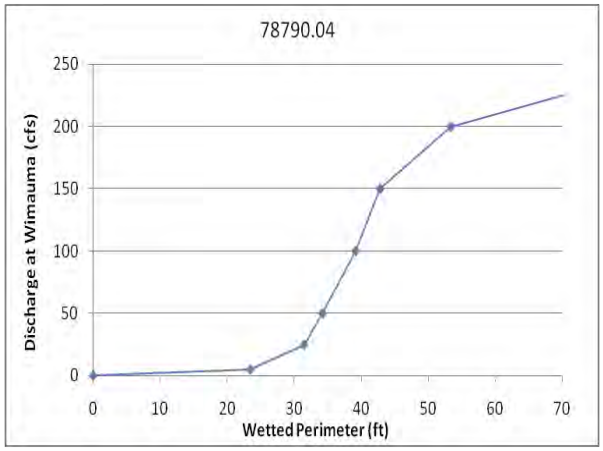

79889.78
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70

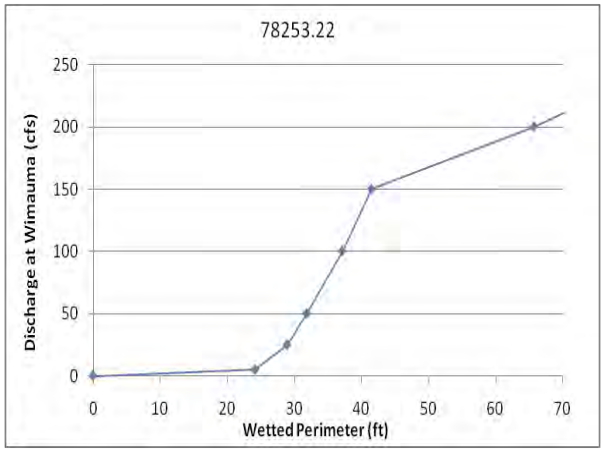

79399.86
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
5
10
15
20
25
30
35
40
45
50
55
60

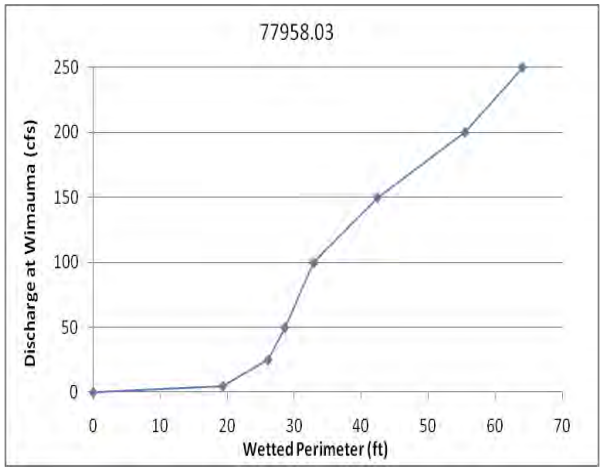

78600.66
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70

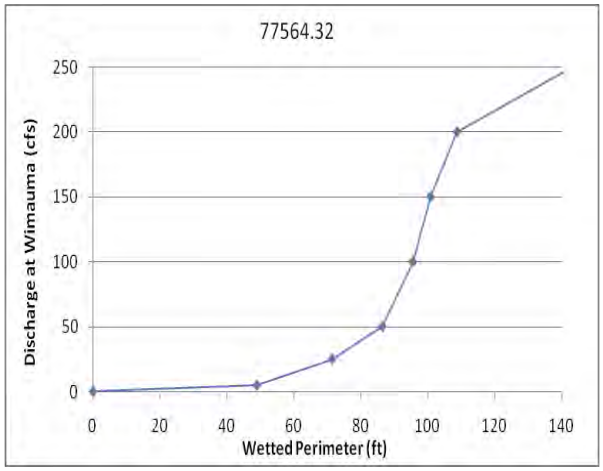

80339.78
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 5 10 15 20 25 30 35 40

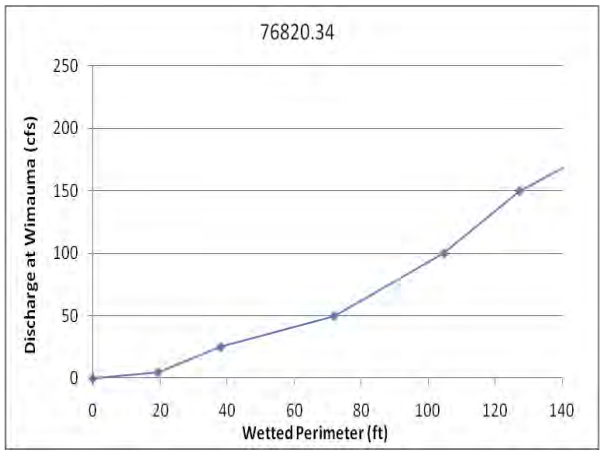

79694.03
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 5 10 15 20 25 30 35 40

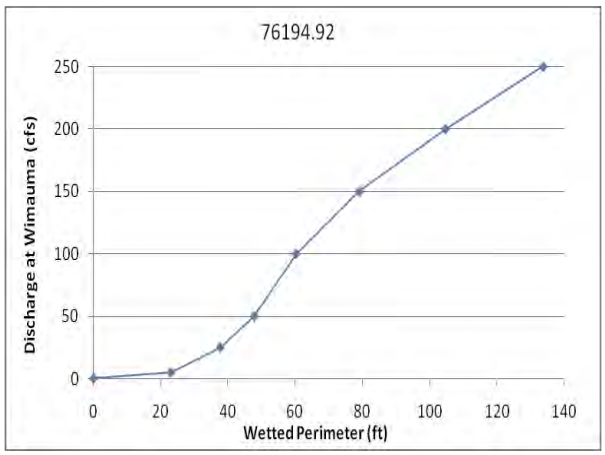

78790.04
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60 70

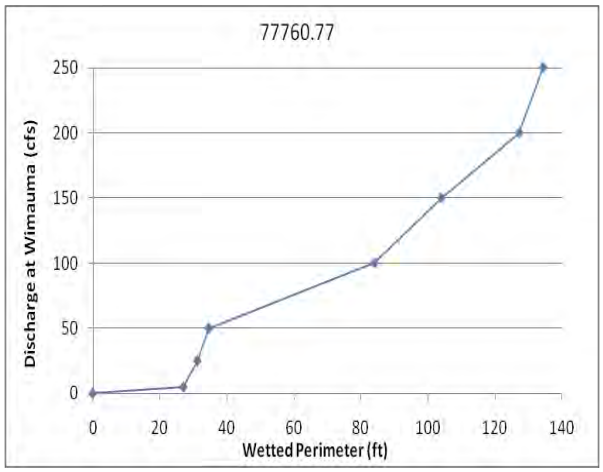

78253.22
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60 70

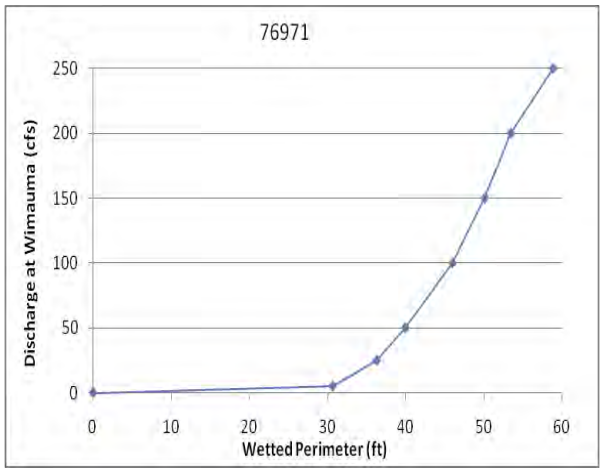

77958.03
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60 70

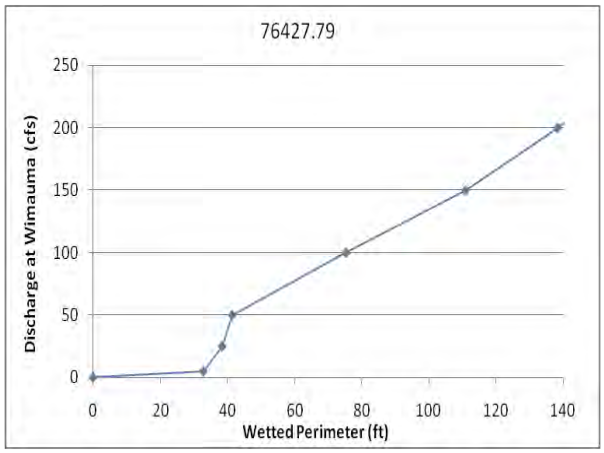

77564.32
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 20 40 60 80 100 120 140

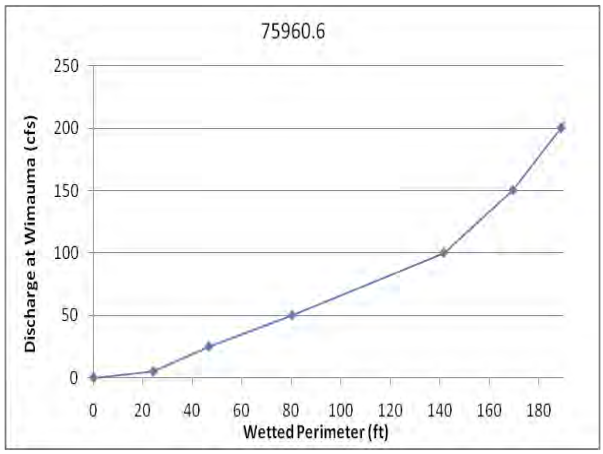

76820.34
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140

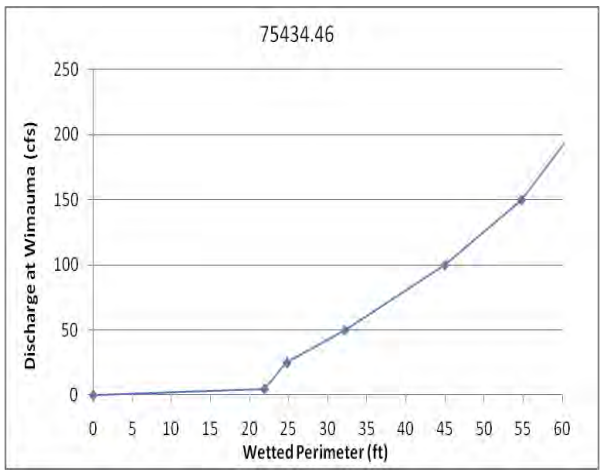

76194.92
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140

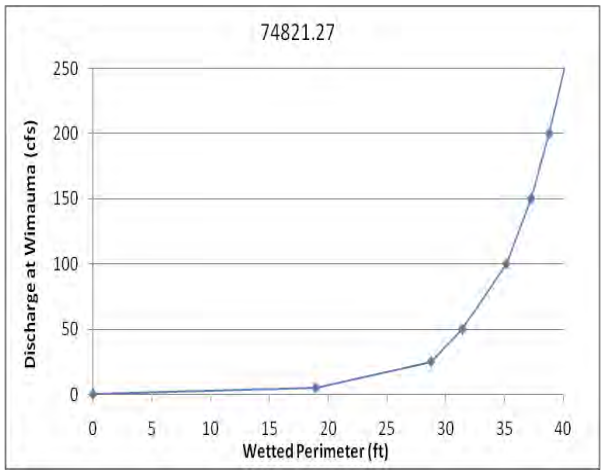

77760.77
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140

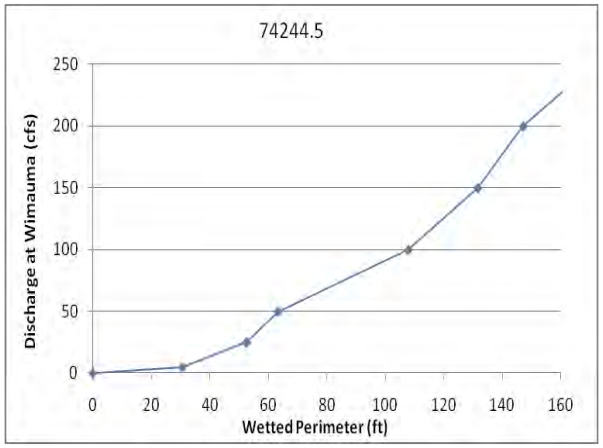

76971
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60

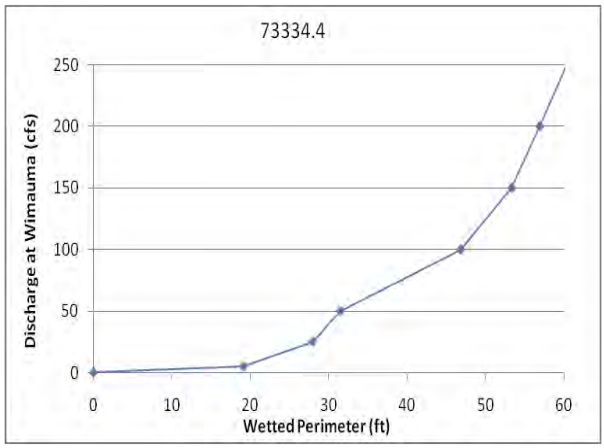

76427.79
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140

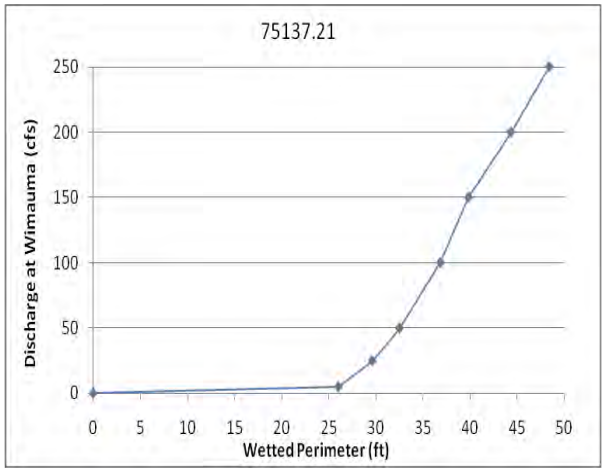

75960.6
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160
180

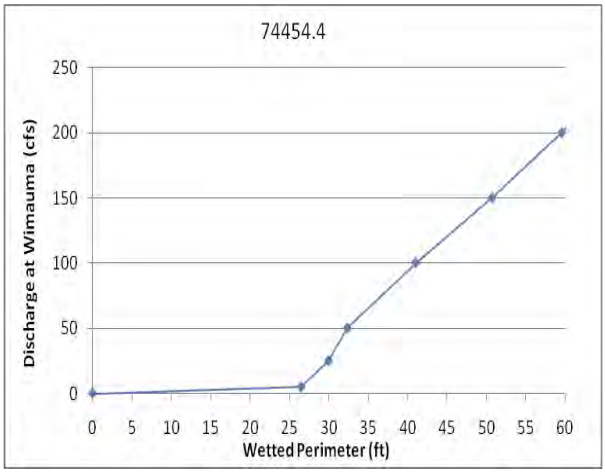

75434.46
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 5 10 15 20 25 30 35 40 45 50 55 60

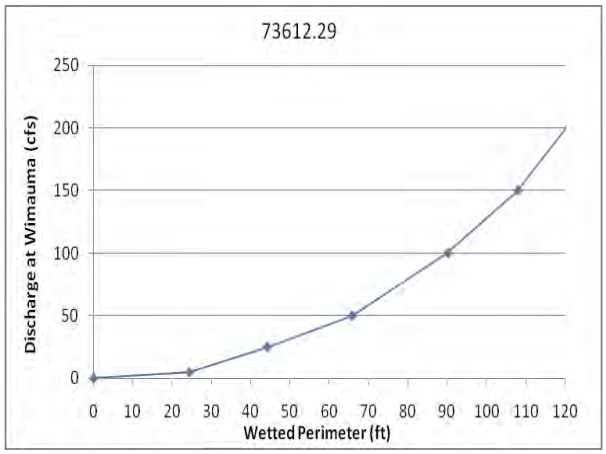

74821.27
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 5 10 15 20 25 30 35 40

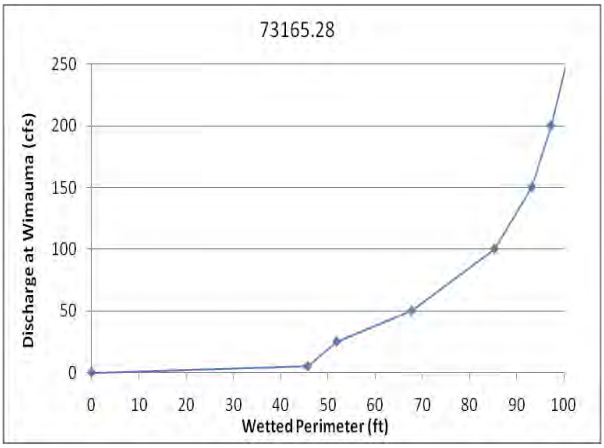

74244.5
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160

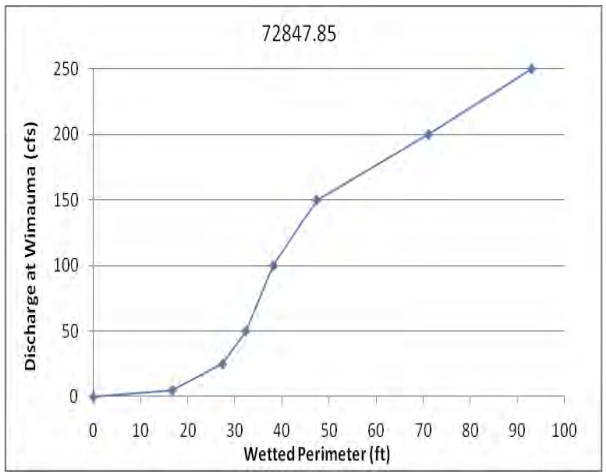

73334.4
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60

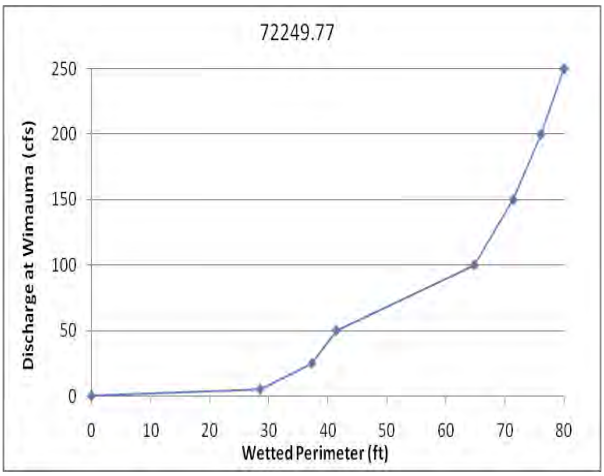

75137.21
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 5 10 15 20 25 30 35 40 45 50

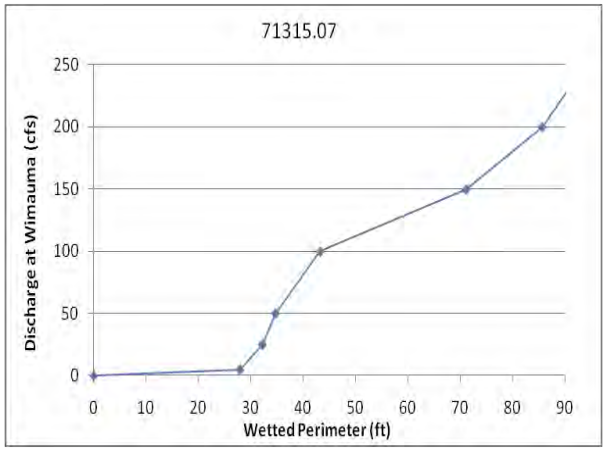

74454.4
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 5 10 15 20 25 30 35 40 45 50 55 60

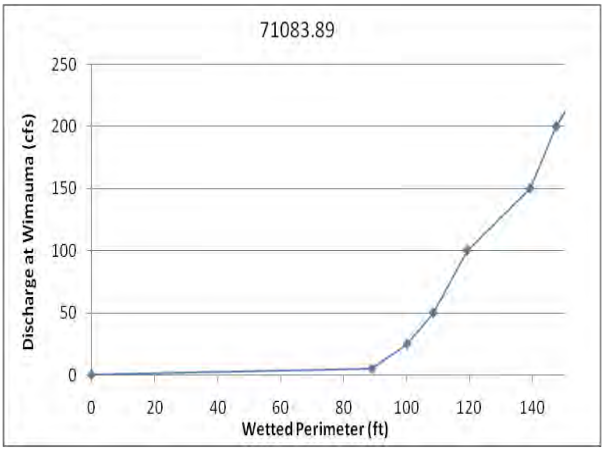

73612.29
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100 110 120
Wetted Perimeter (ft)

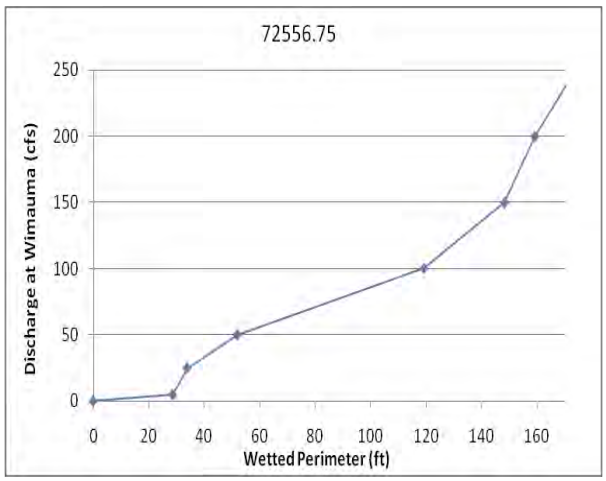

73165.28
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100
Wetted Perimeter (ft)

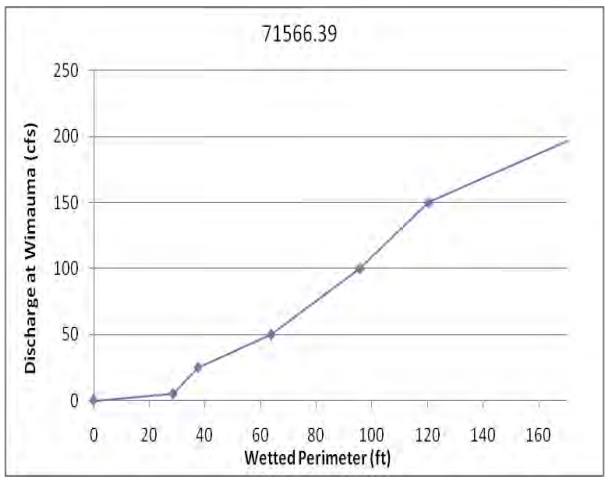

72847.85
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100
Wetted Perimeter (ft)

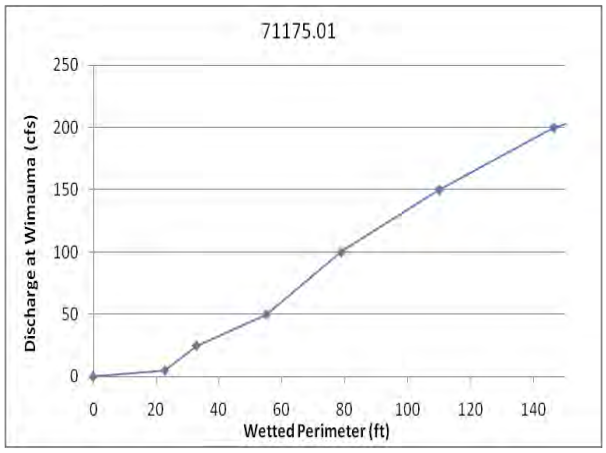

72249.77
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80
Wetted Perimeter (ft)

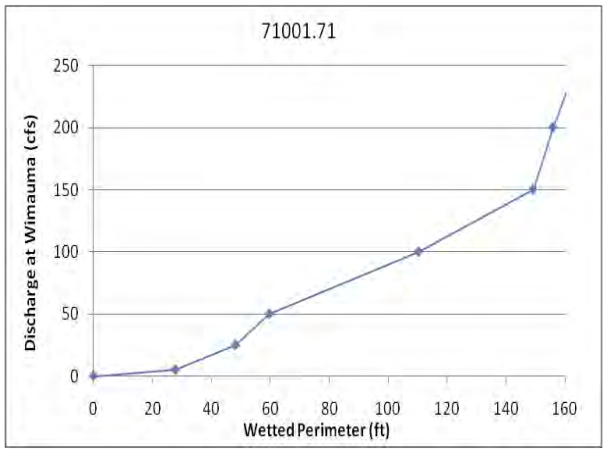

71315.07
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90
Wetted Perimeter (ft)

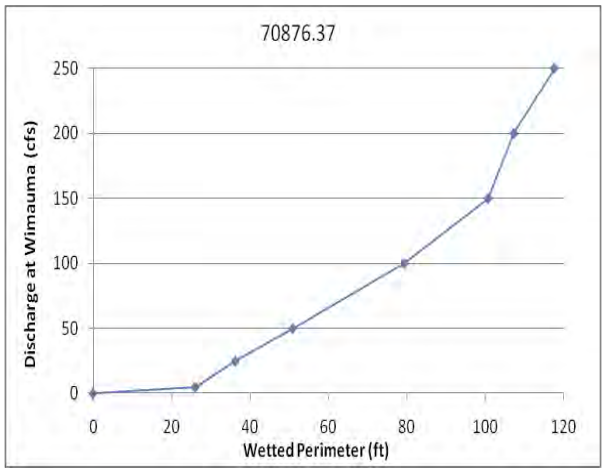

71083.89
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140
Wetted Perimeter (ft)

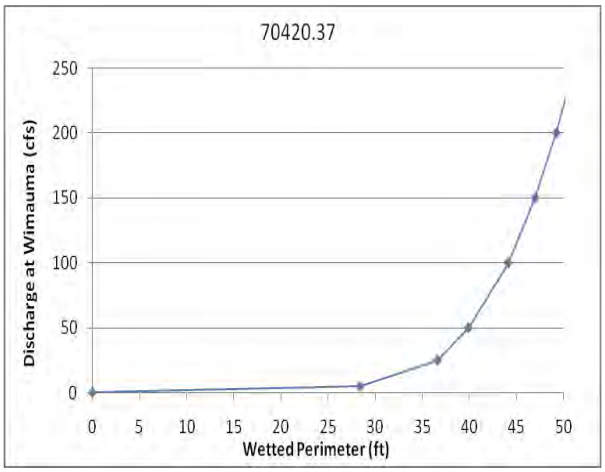

72556.75
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160

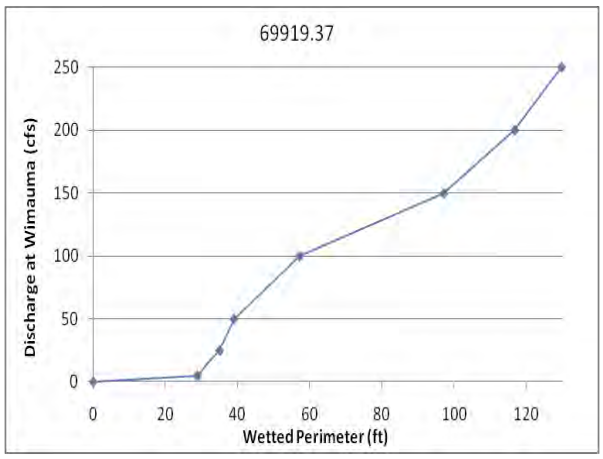

71566.39
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160

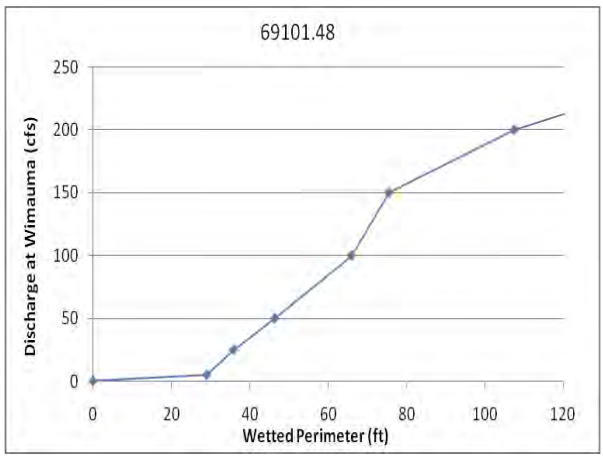

71175.01
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140

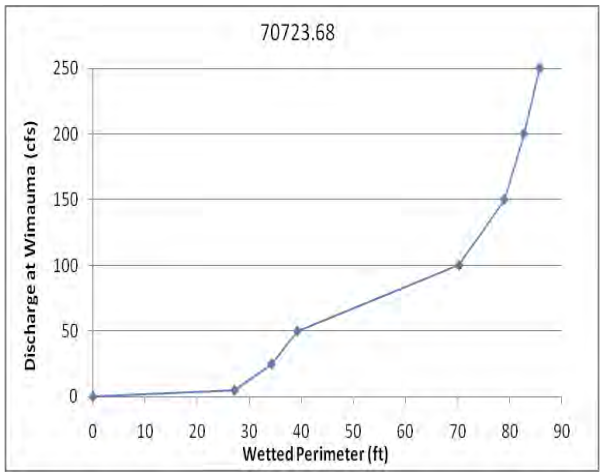

71001.71
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160

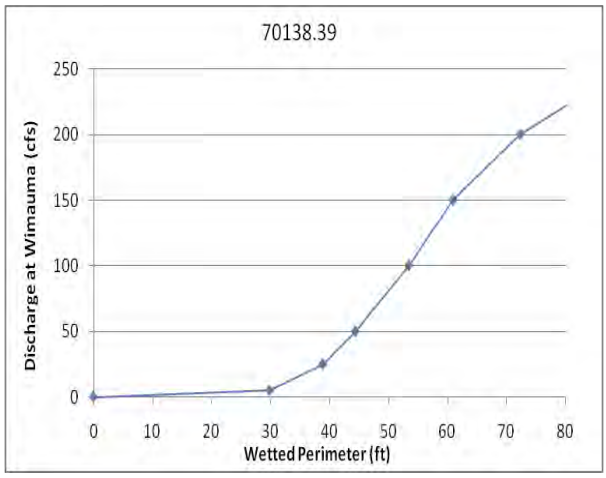

70876.37
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120

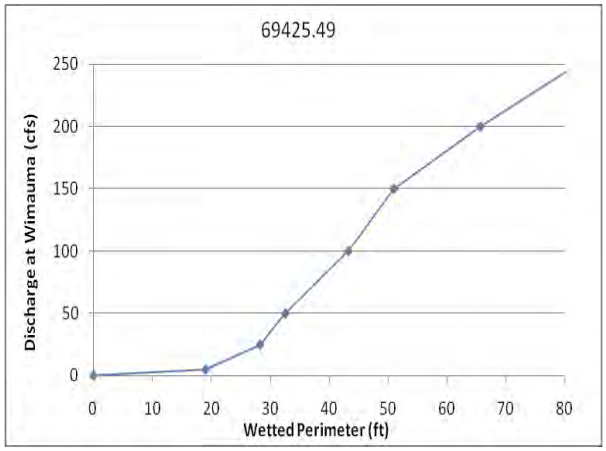

70420.37
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
5
10
15
20
25
30
35
40
45
50

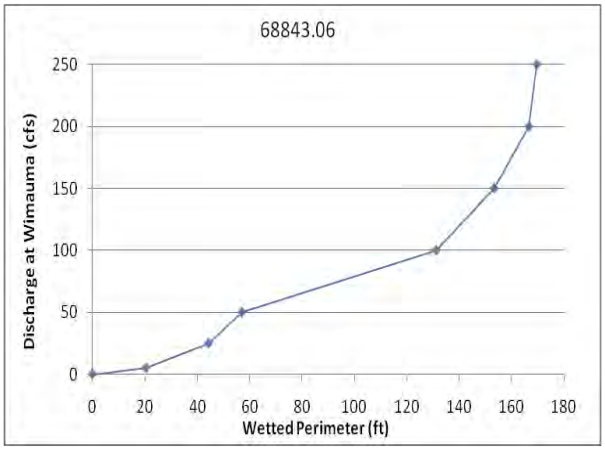

69919.37
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120

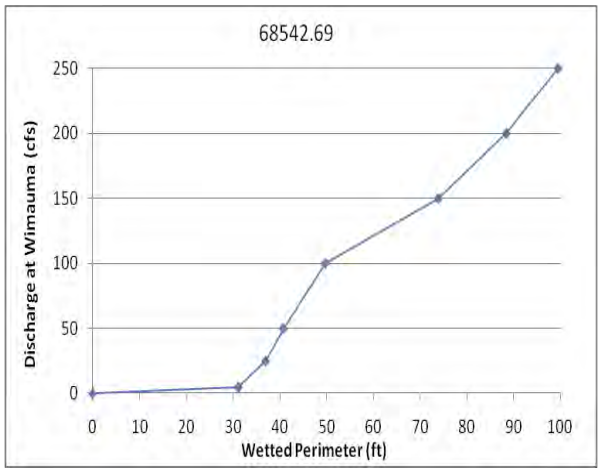

69101.48
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120

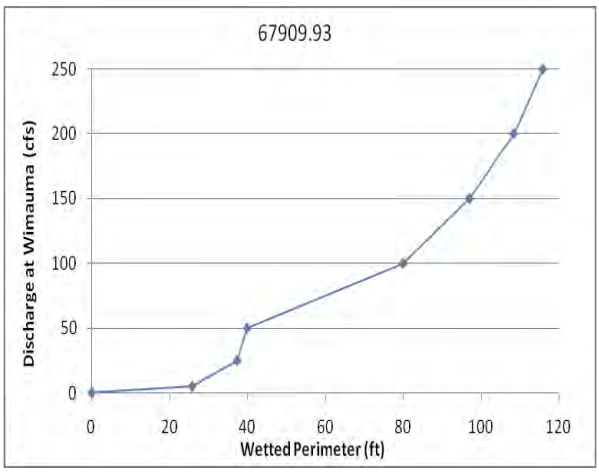

70723.68
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80
90

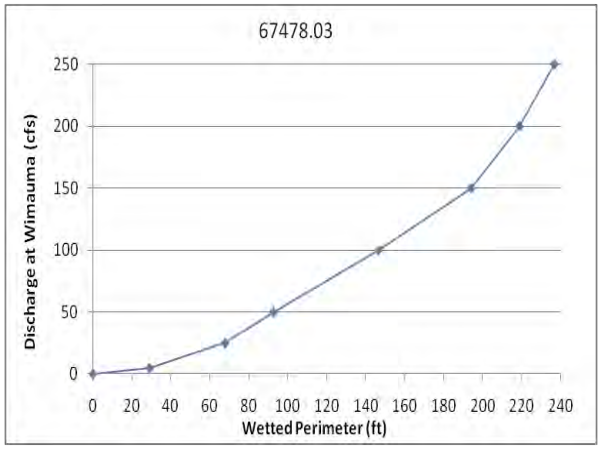

70138.39
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

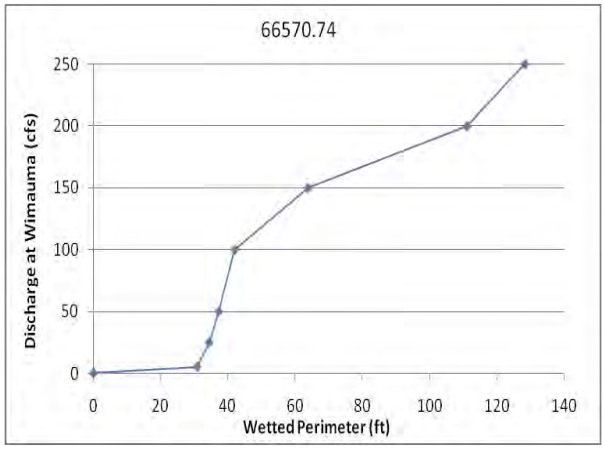

69425.49
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

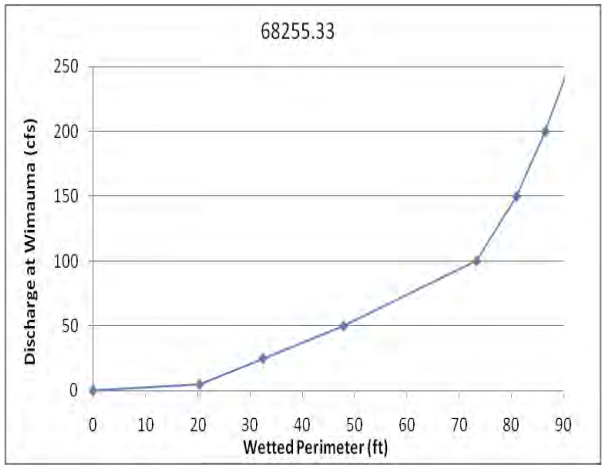

68843.06
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160
180

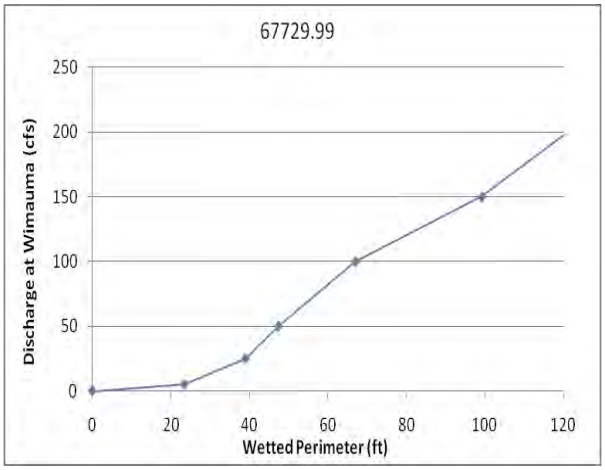

68542.69
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100

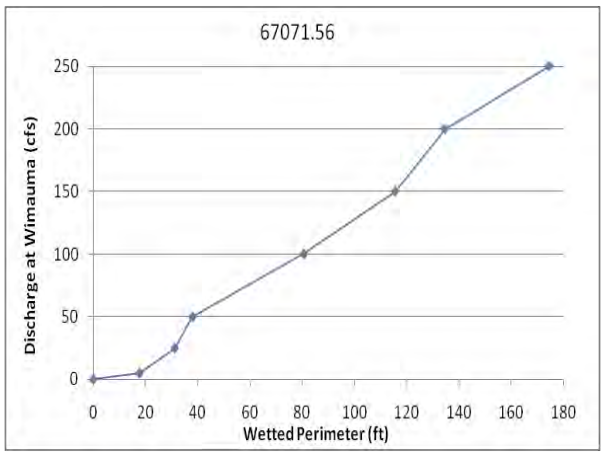

67909.93
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 20 40 60 80 100 120

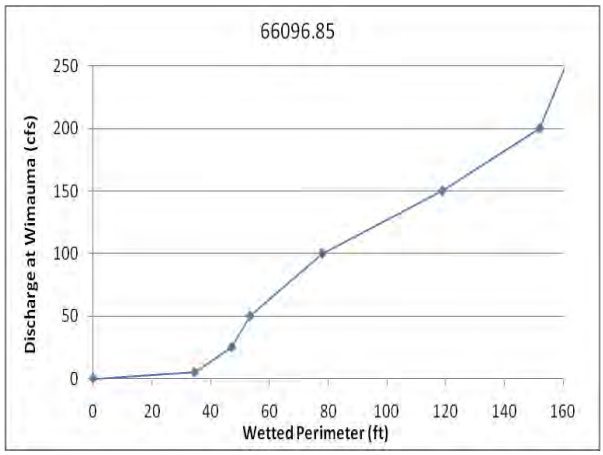

67478.03
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160 180 200 220 240

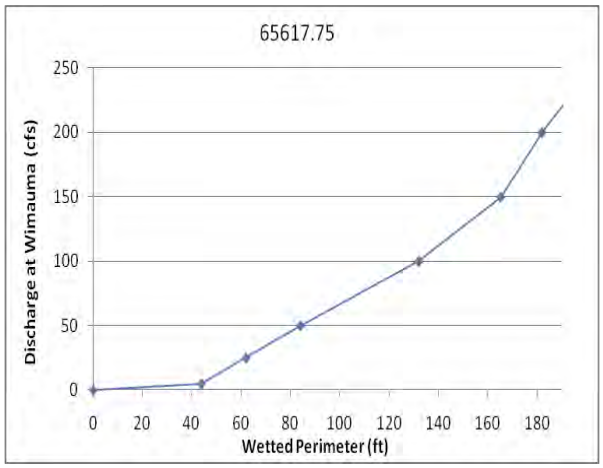

66570.74
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 20 40 60 80 100 120 140

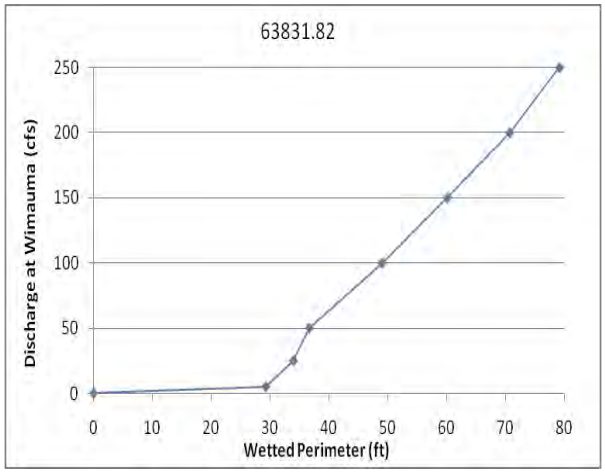

68255.33
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90

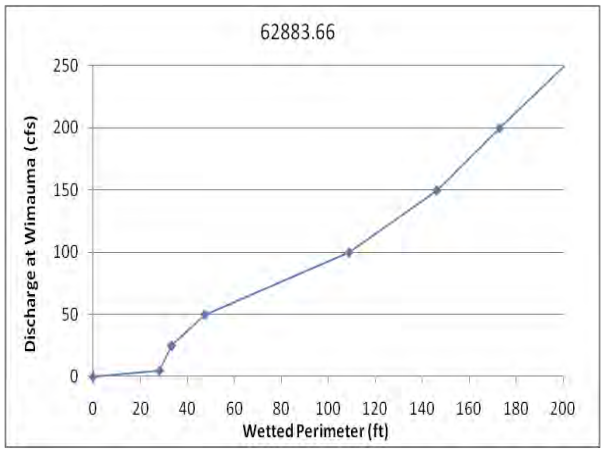

67729.99
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 20 40 60 80 100 120

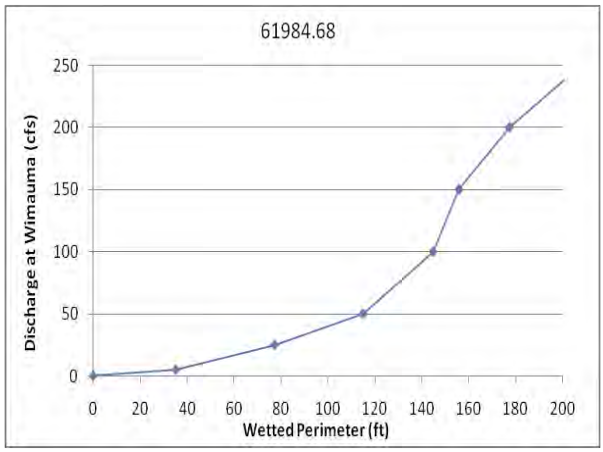

67071.56
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)

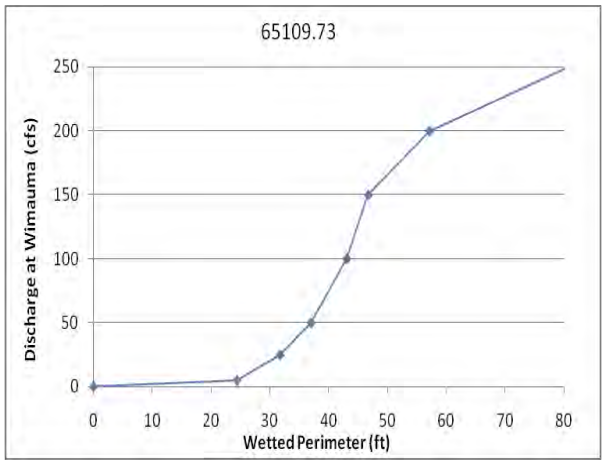

66096.85
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)

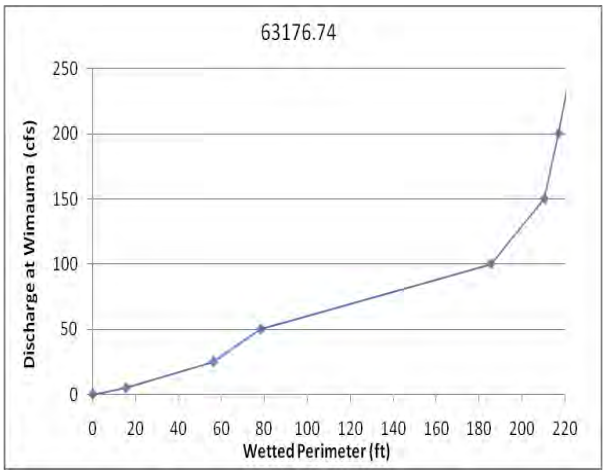

65617.75
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)

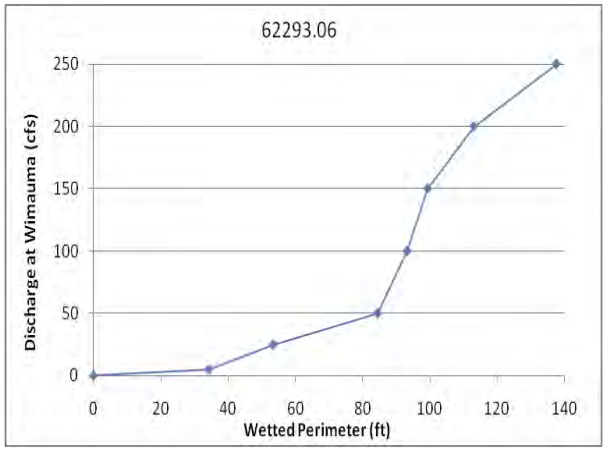

63831.82
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)

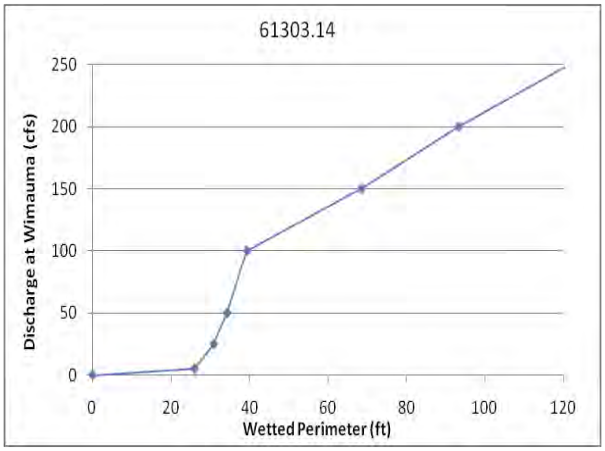

62883.66
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)

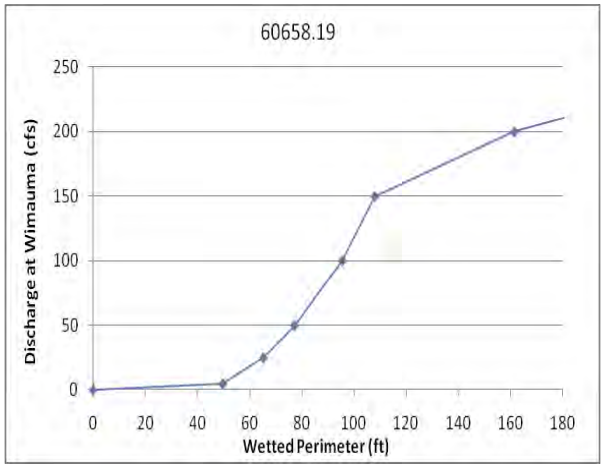

61984.68
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)

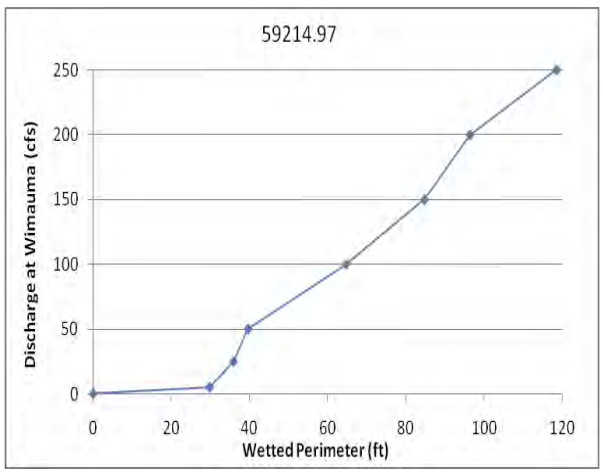

65109.73
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80
Wetted Perimeter (ft)

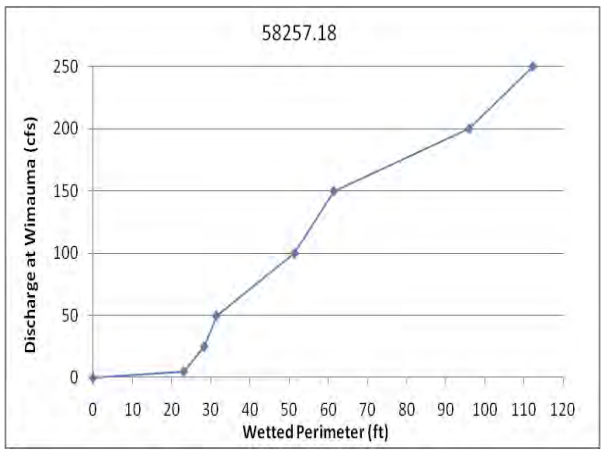

63176.74
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160 180 200 220
Wetted Perimeter (ft)

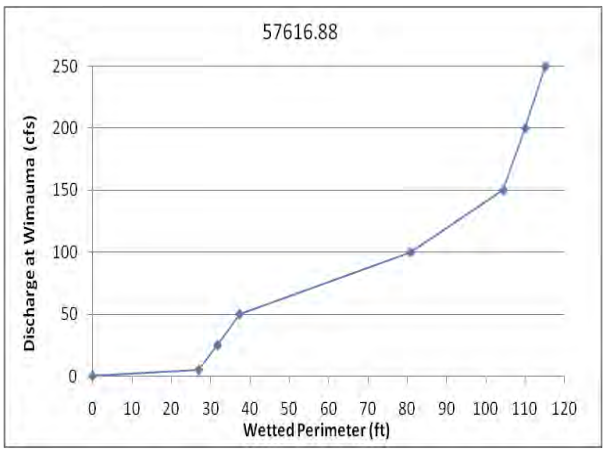

62293.06
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140
Wetted Perimeter (ft)

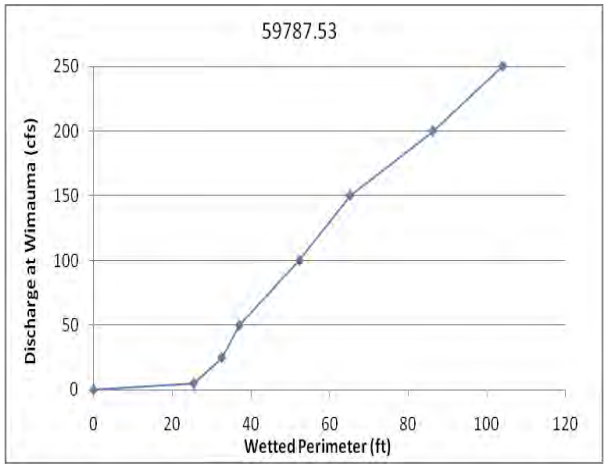

61303.14
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120
Wetted Perimeter (ft)

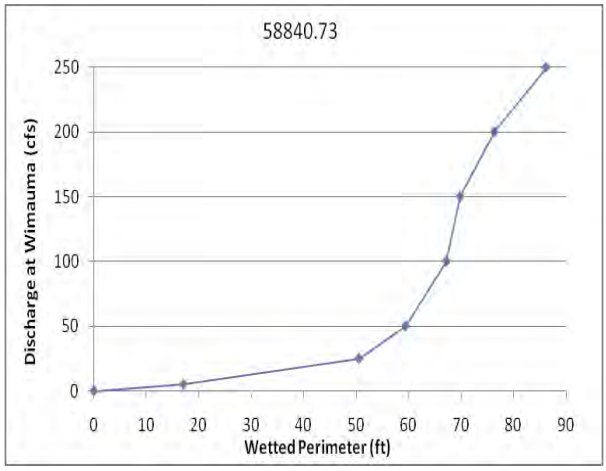

60658.19
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160 180
Wetted Perimeter (ft)

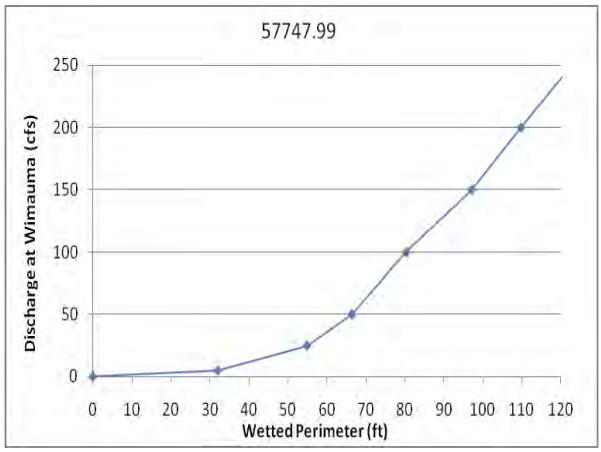

59214.97
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120
Wetted Perimeter (ft)

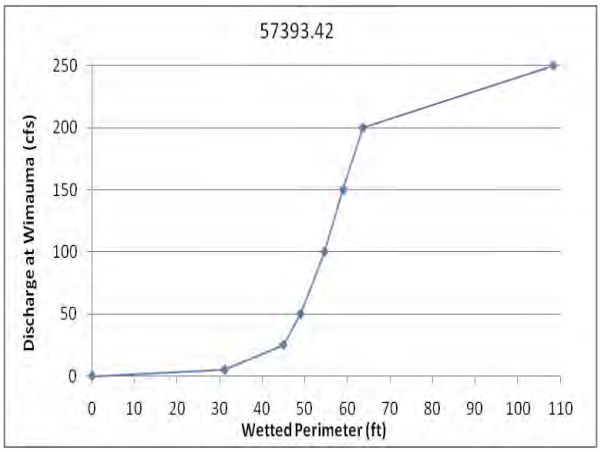

58257.18
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)

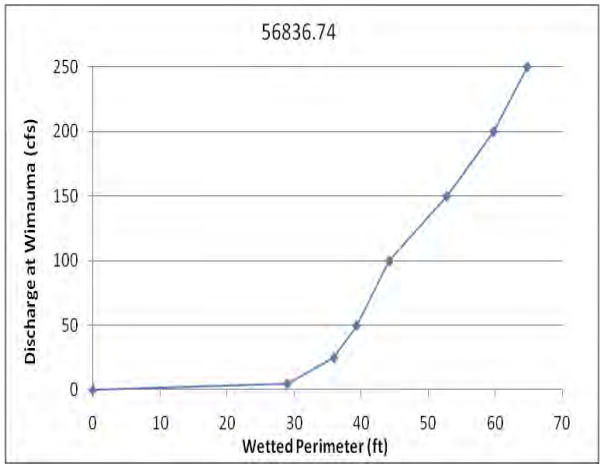

57616.88
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)

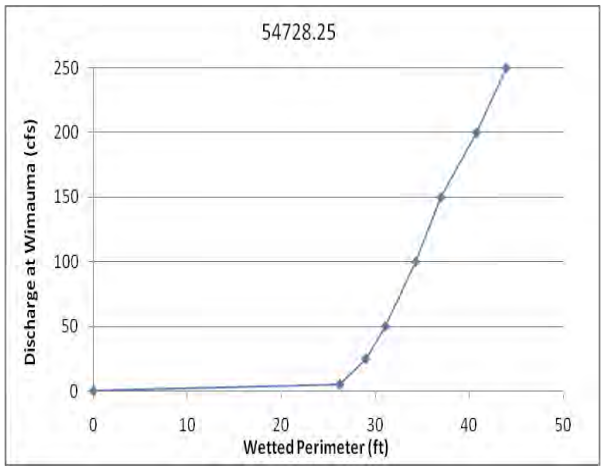

59787.53
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)

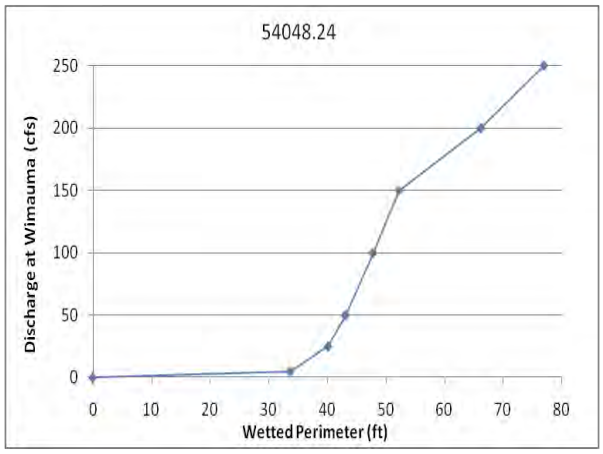

58840.73
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)

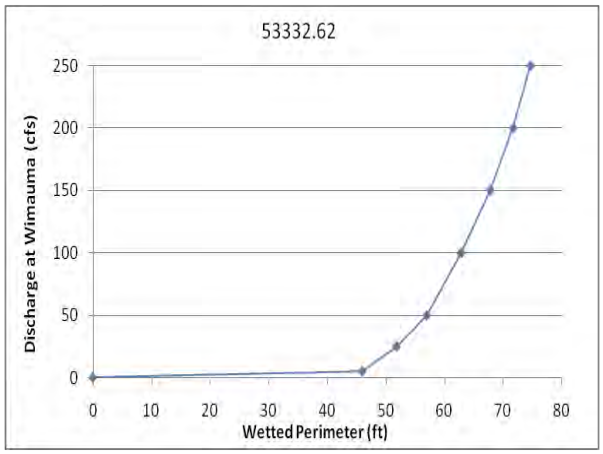

57747.99
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)

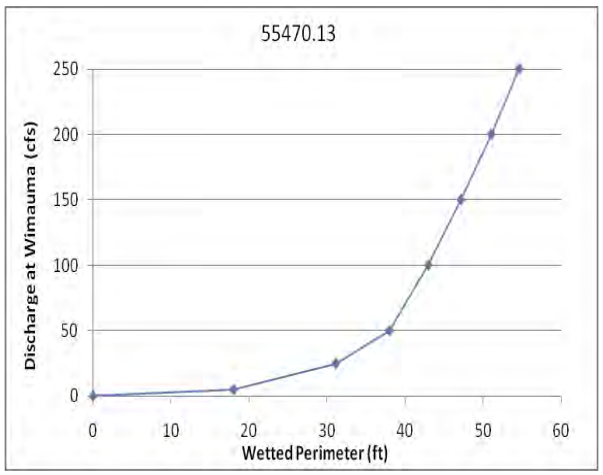

57393.42
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)

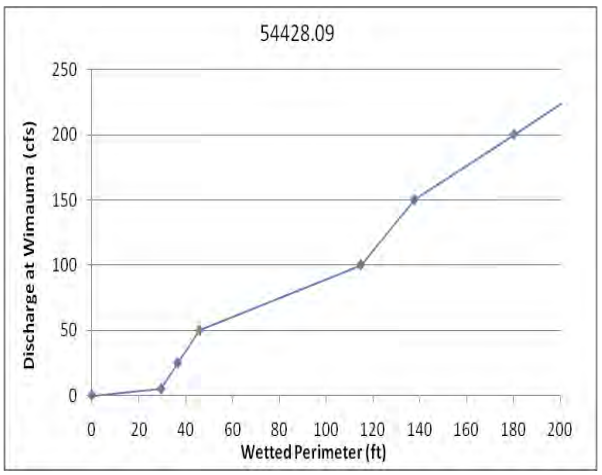

56836.74
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70

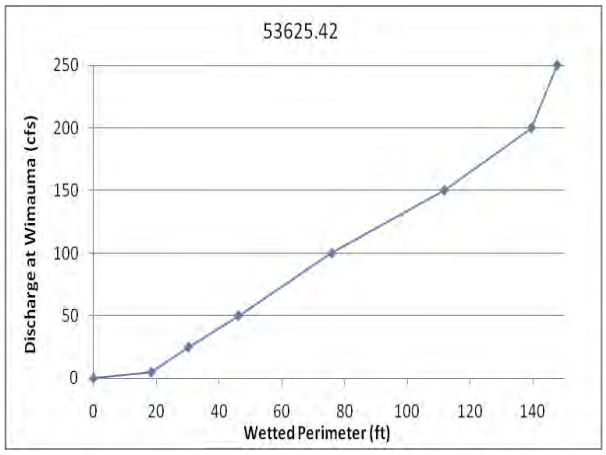

54728.25
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50

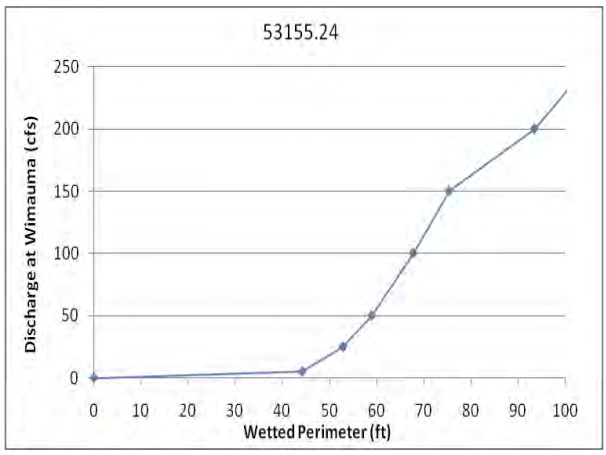

54048.24
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

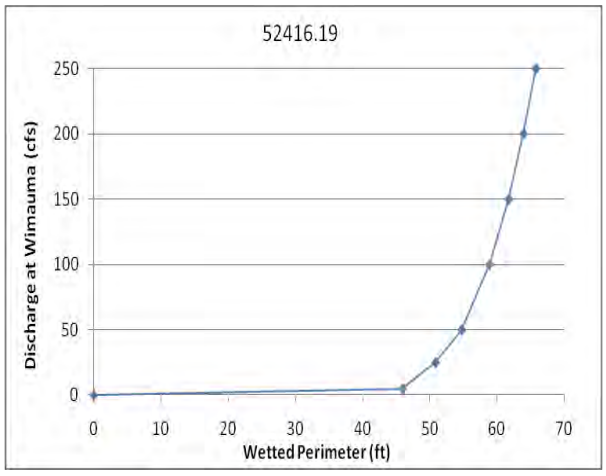

53332.62
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

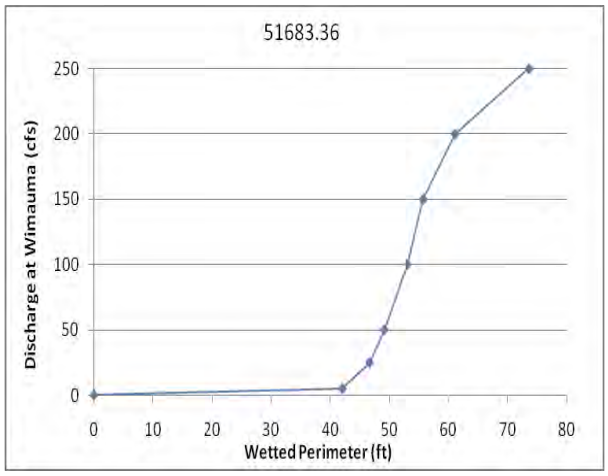

55470.13
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60

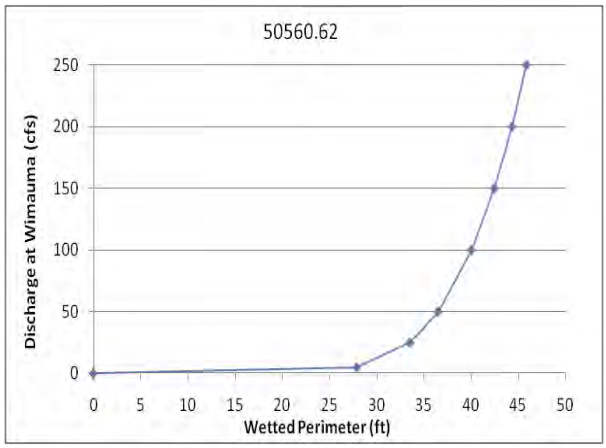

54428.09
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160
180
200

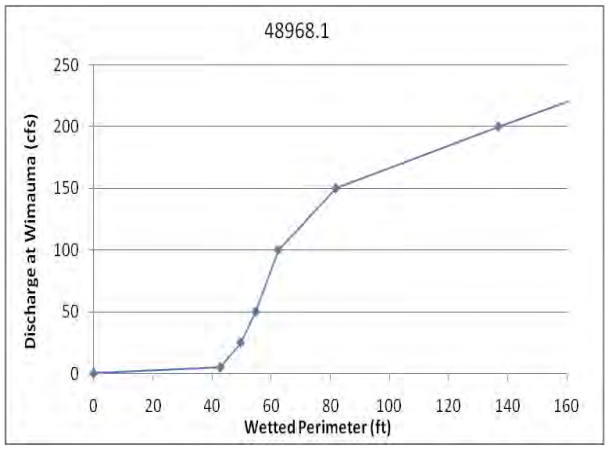

53625.42
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140

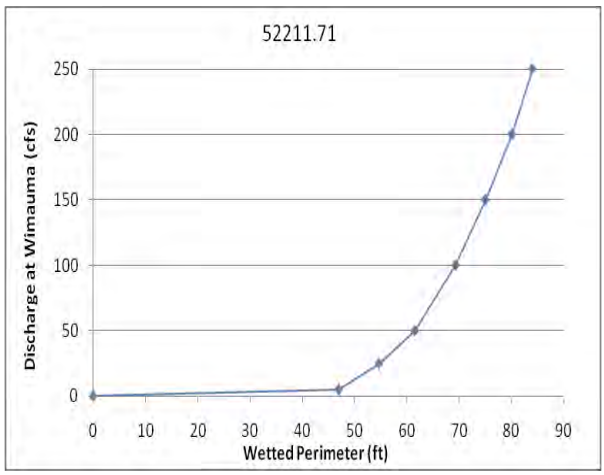

53155.24
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80
90
100

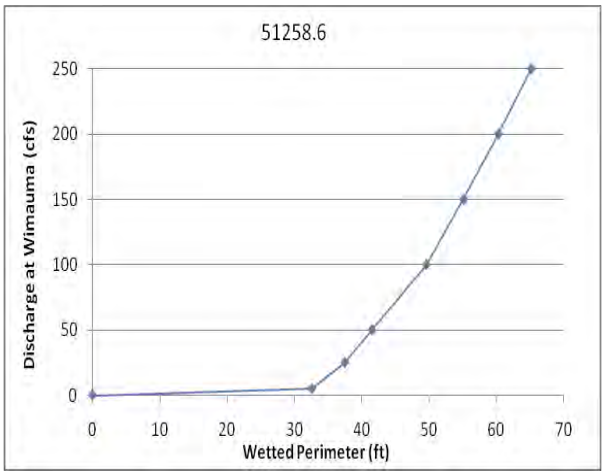

52416.19
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70

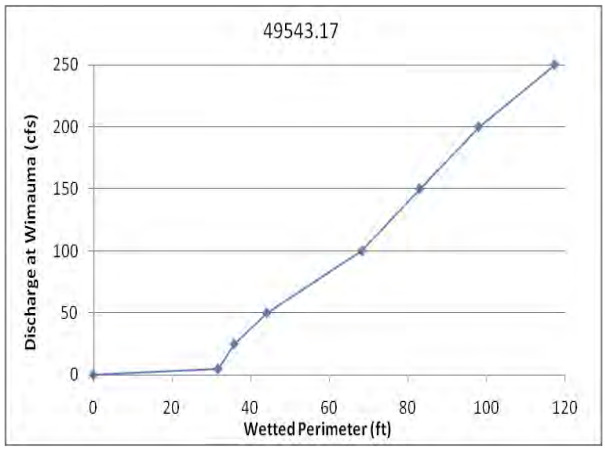

51683.36
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80

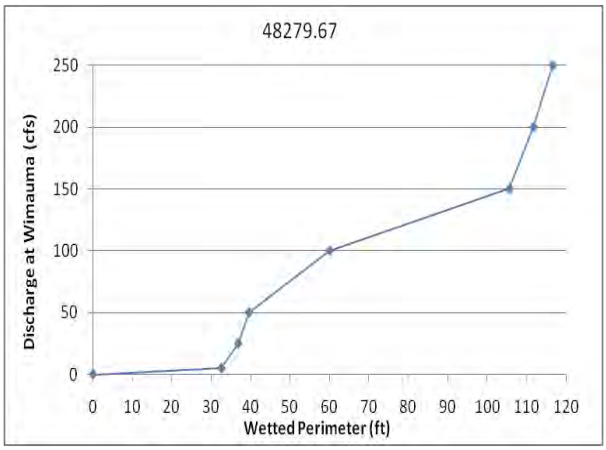

50560.62
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
5
10
15
20
25
30
35
40
45
50

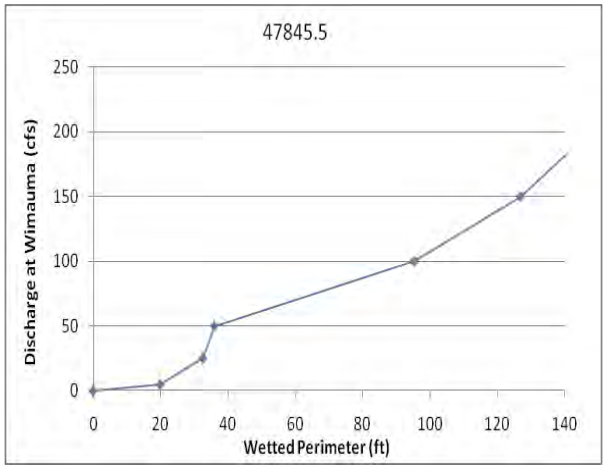

48968.1
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160

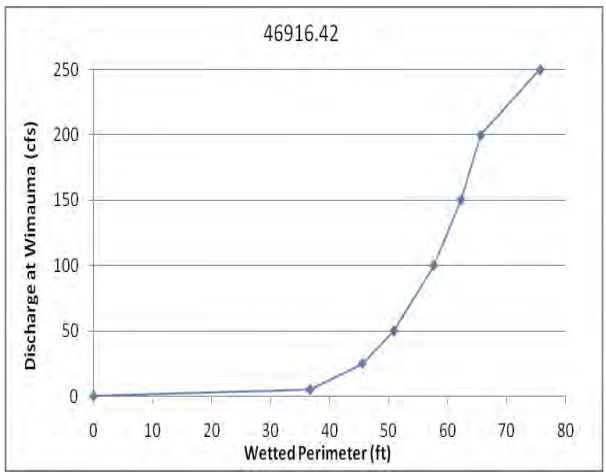

52211.71
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90

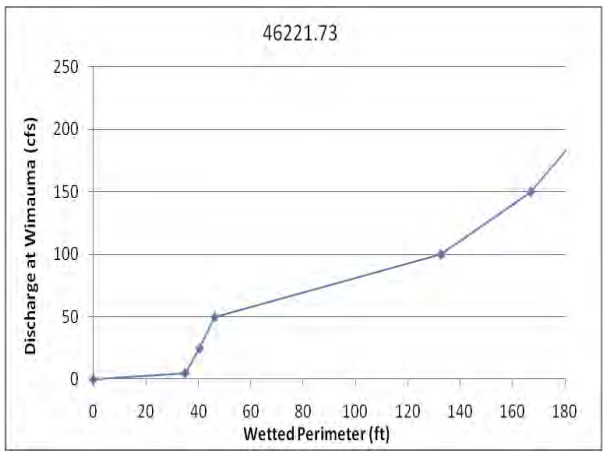

51258.6
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60 70

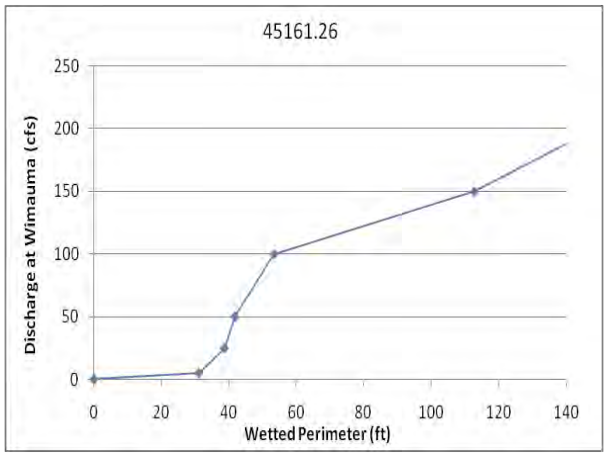

49543.17
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 20 40 60 80 100 120

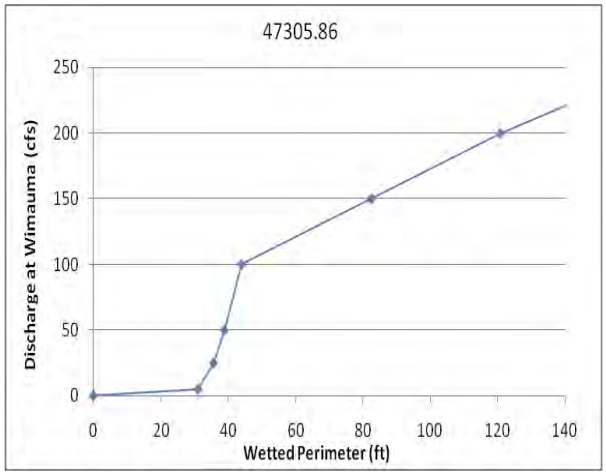

48279.67
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100 110 120

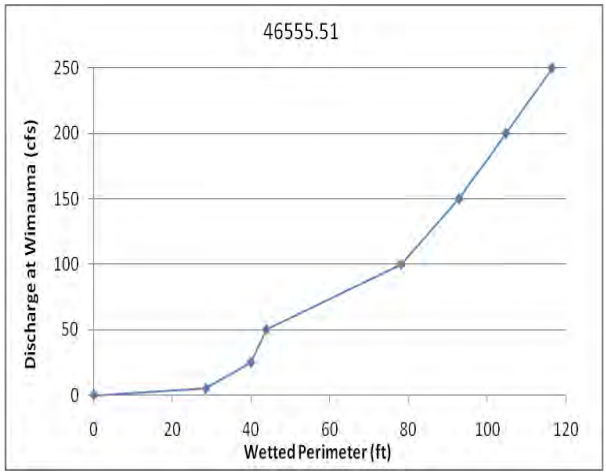

47845.5
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 20 40 60 80 100 120 140

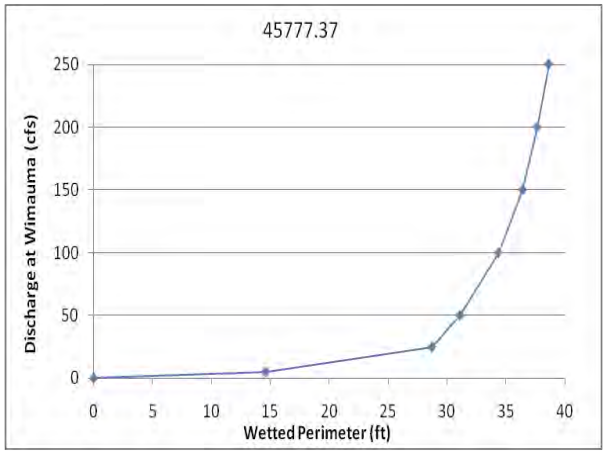

46916.42
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80

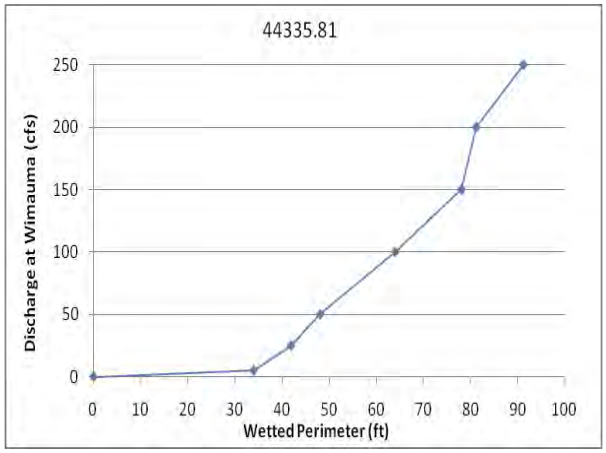

46221.73
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160
180

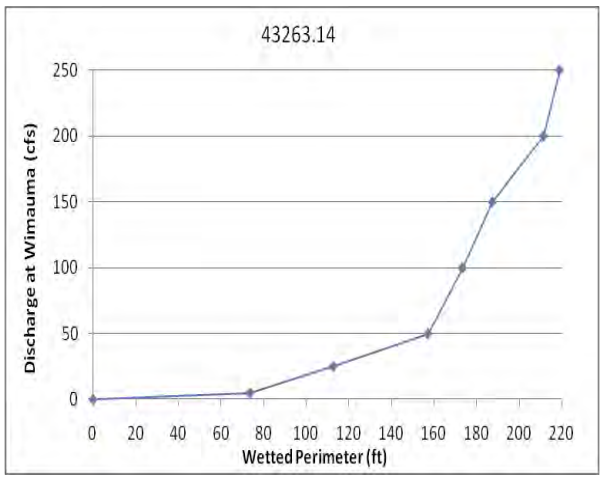

45161.26
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140

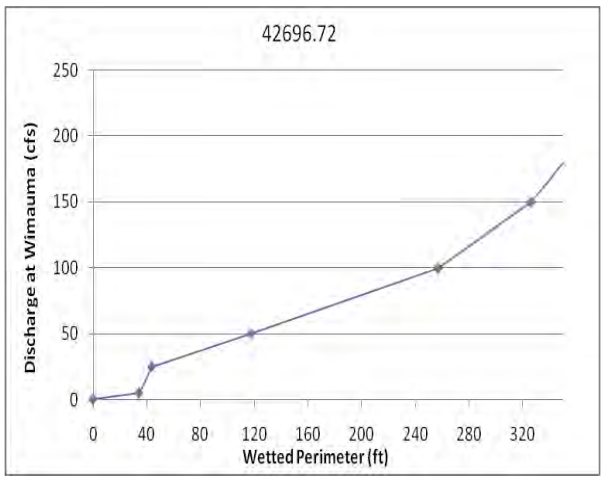

47305.86
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140

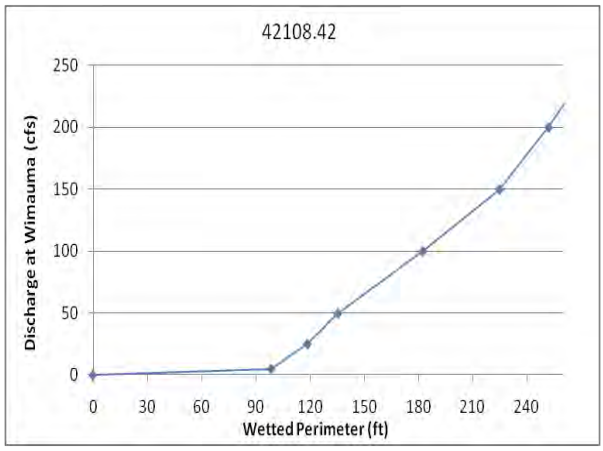

46555.51
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120

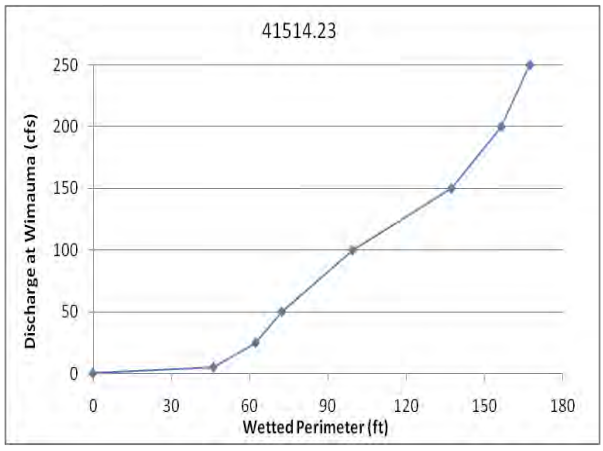

45777.37
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
5
10
15
20
25
30
35
40

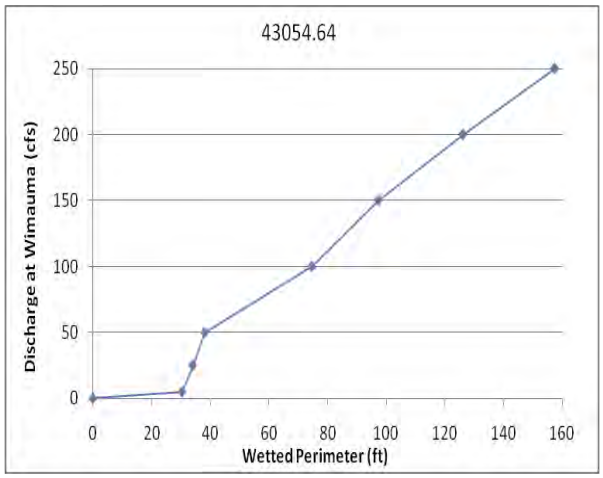

44335.81
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80
90
100

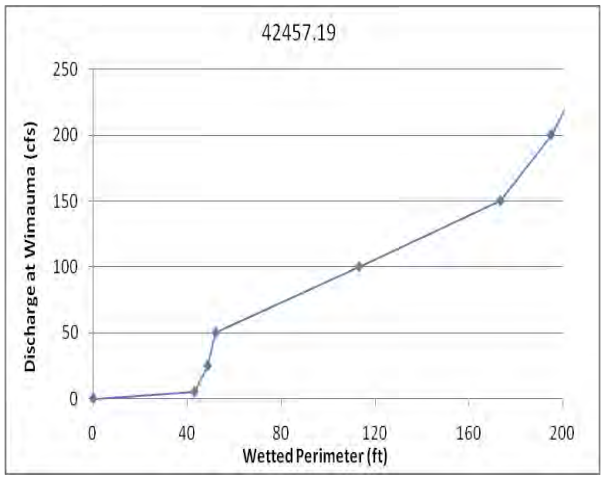

43263.14
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160 180 200 220
Wetted Perimeter (ft)

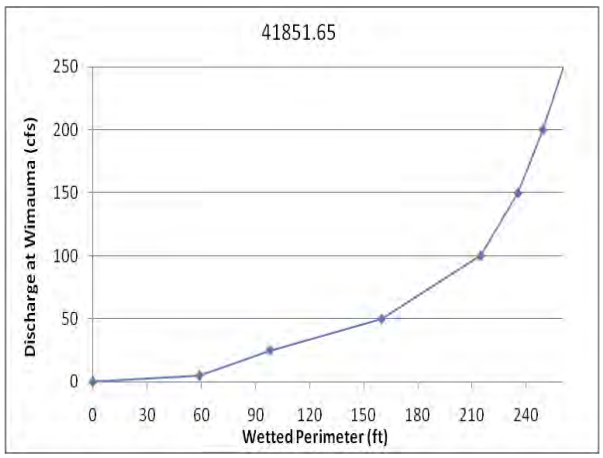

42696.72
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 40 80 120 160 200 240 280 320
Wetted Perimeter (ft)

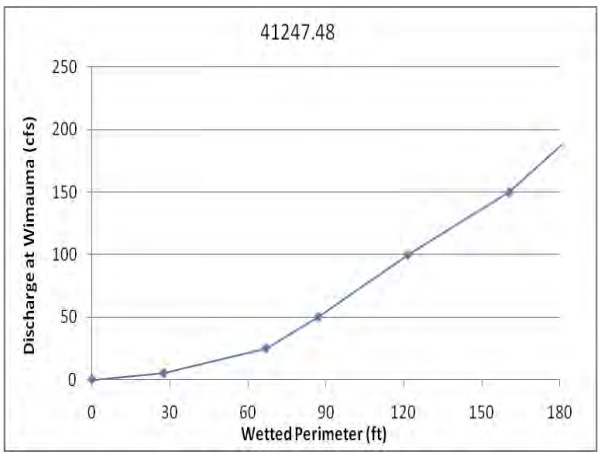

42108.42
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 30 60 90 120 150 180 210 240
Wetted Perimeter (ft)

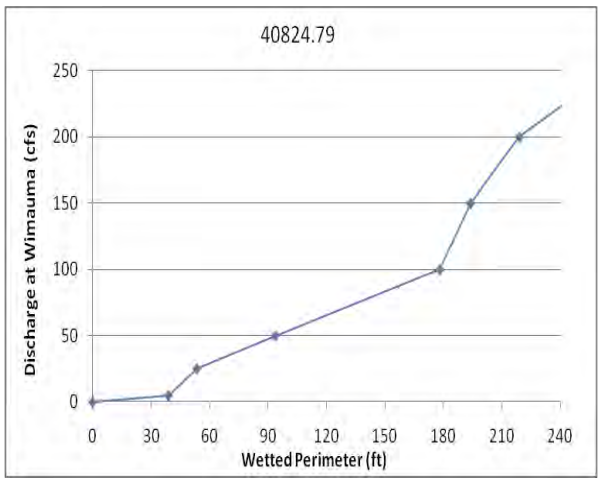

41514.23
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 30 60 90 120 150 180
Wetted Perimeter (ft)

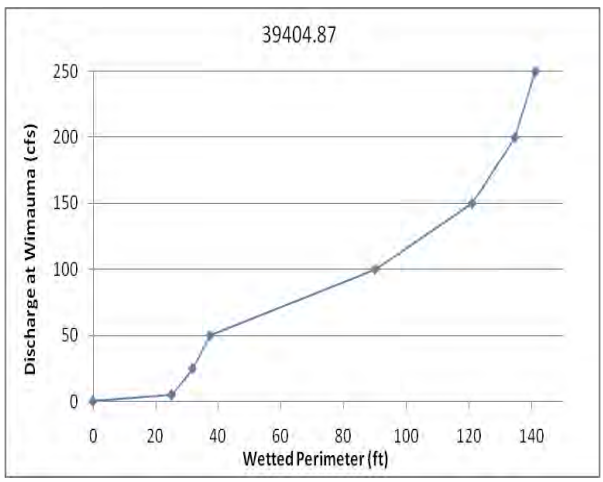

43054.64
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160
Wetted Perimeter (ft)

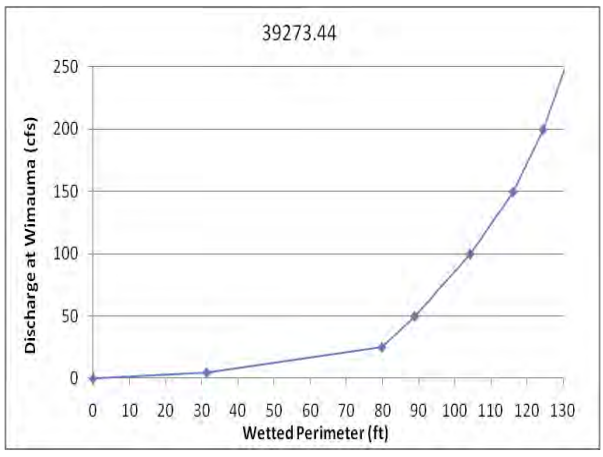

42457.19
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 40 80 120 160 200
Wetted Perimeter (ft)

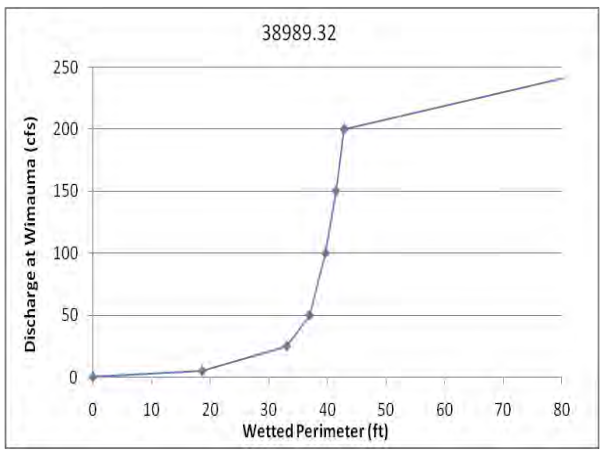

41851.65
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 30 60 90 120 150 180 210 240
Wetted Perimeter (ft)

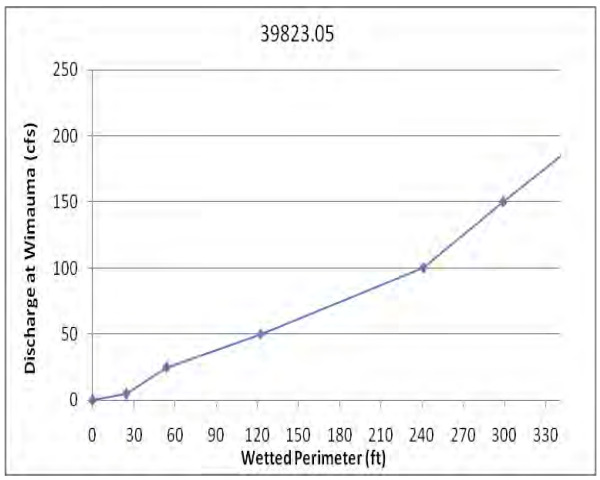

41247.48
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 30 60 90 120 150 180
Wetted Perimeter (ft)

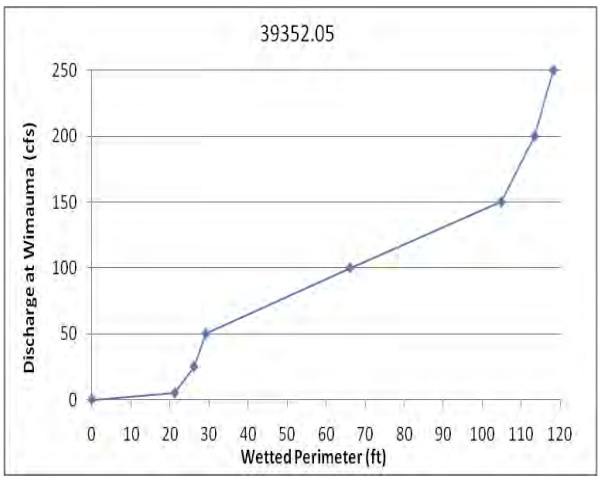

40824.79
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 30 60 90 120 150 180 210 240
Wetted Perimeter (ft)

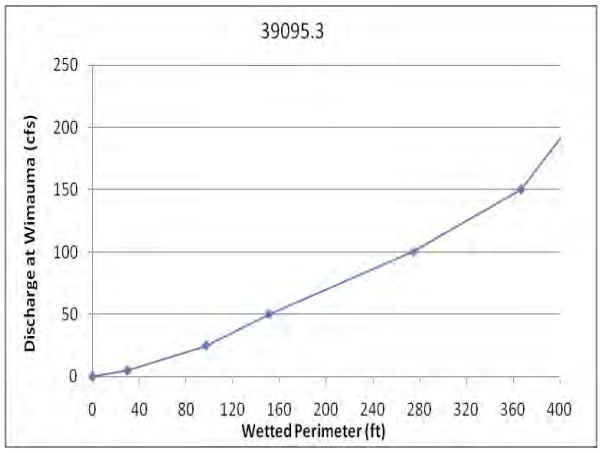

39404.87
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140
Wetted Perimeter (ft)

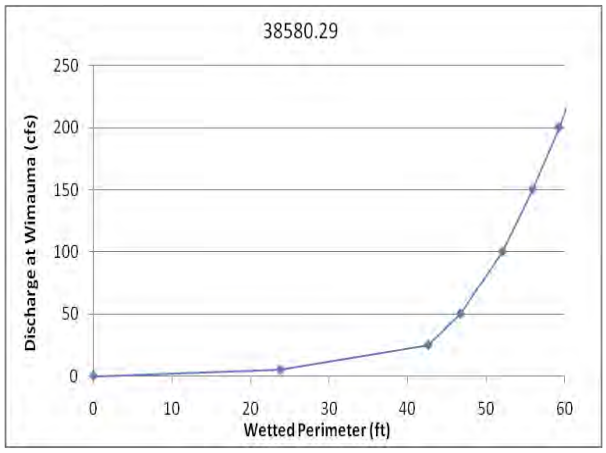

39273.44
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100 110 120 130
Wetted Perimeter (ft)

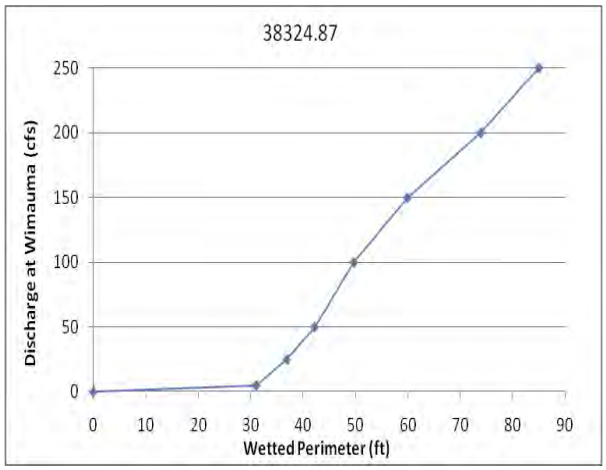

38989.32
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80
Wetted Perimeter (ft)

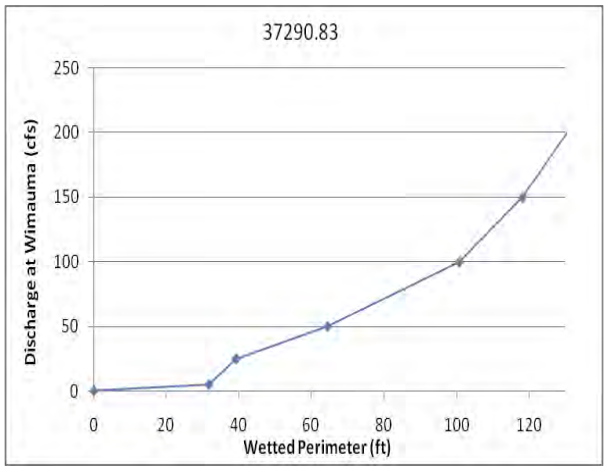

39823.05
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 30 60 90 120 150 180 210 240 270 300 330
Wetted Perimeter (ft)

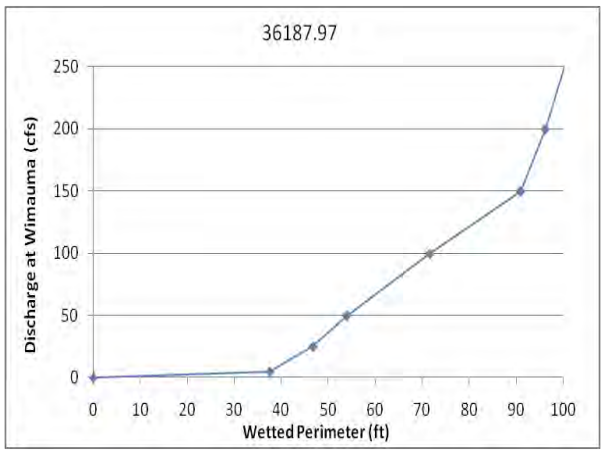

39352.05
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100 110 120
Wetted Perimeter (ft)

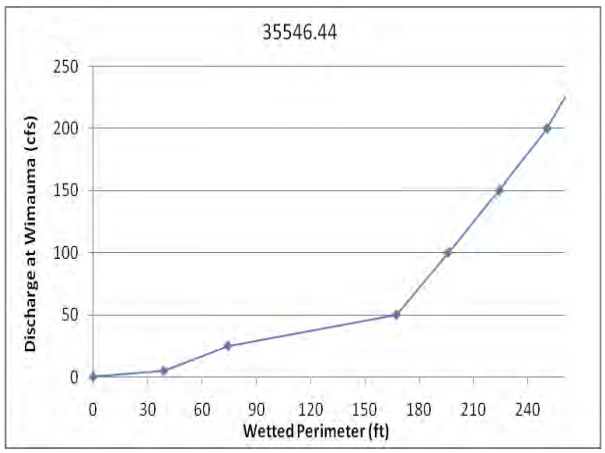

39095.3
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 40 80 120 160 200 240 280 320 360 400
Wetted Perimeter (ft)

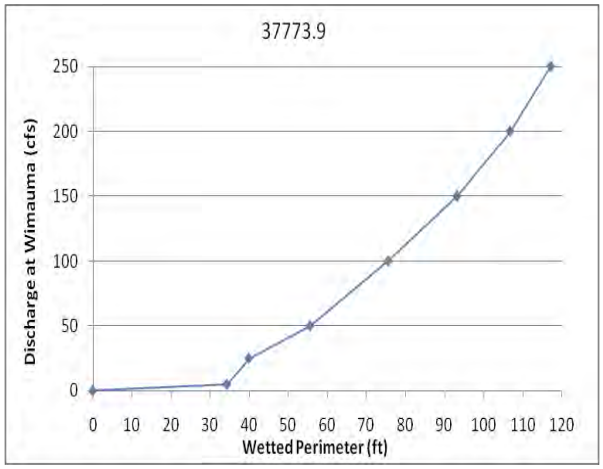

38580.29
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60
Wetted Perimeter (ft)

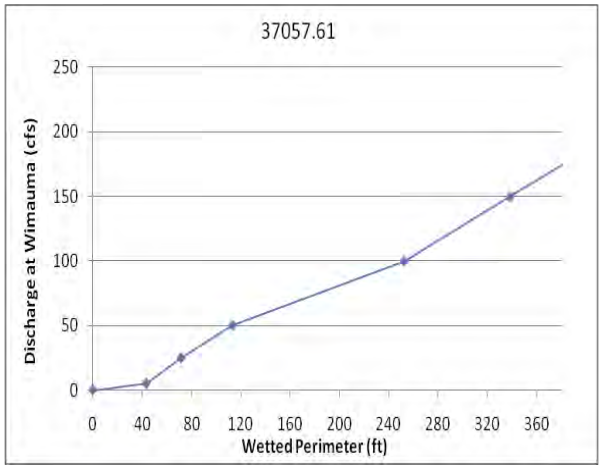

38324.87
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90
Wetted Perimeter (ft)

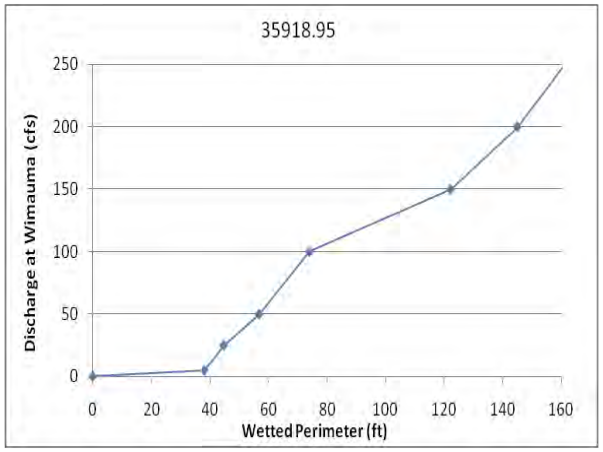

37290.83
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120
Wetted Perimeter (ft)

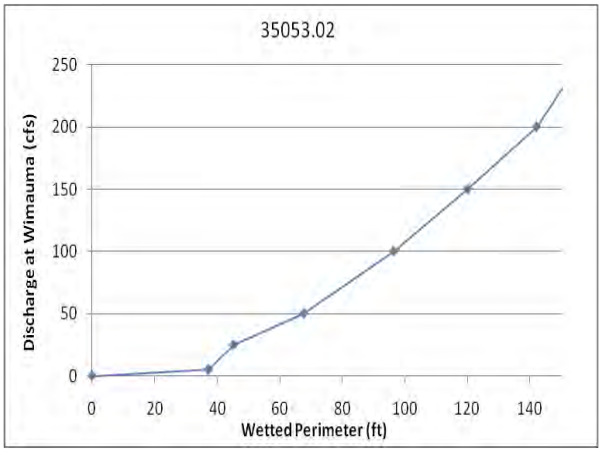

36187.97
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100

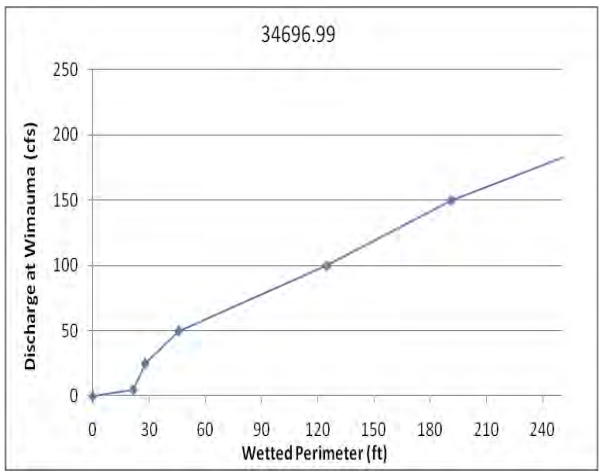

35546.44
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 30 60 90 120 150 180 210 240

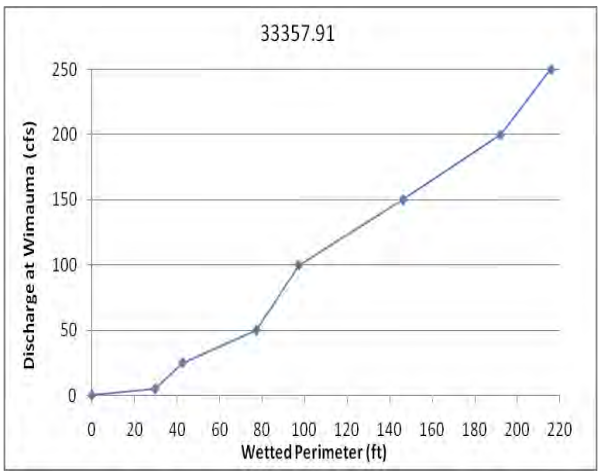

37773.9
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100 110 120

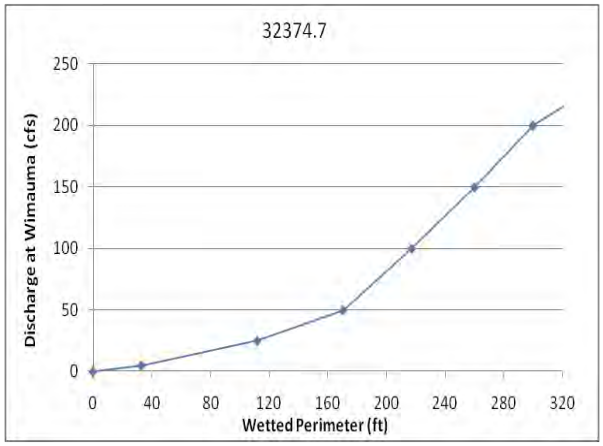

37057.61
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 40 80 120 160 200 240 280 320 360

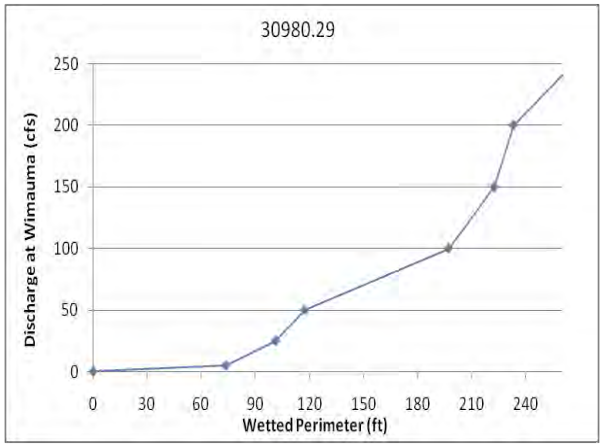

35918.95
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160

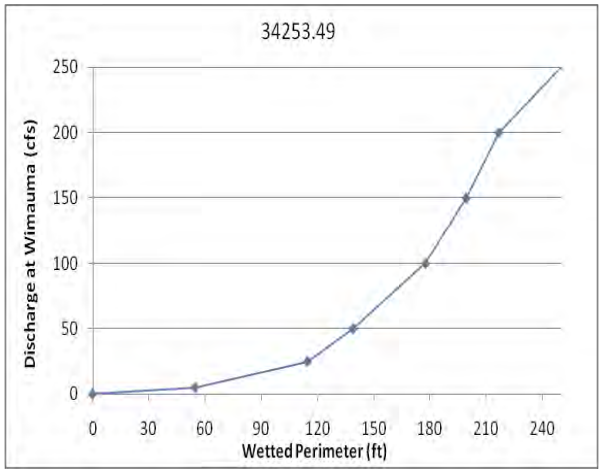

35053.02
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0 20 40 60 80 100 120 140

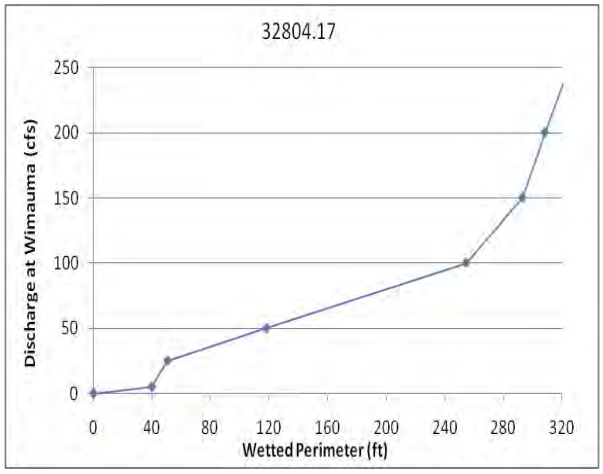

34696.99
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 30 60 90 120 150 180 210 240
Wetted Perimeter (ft)

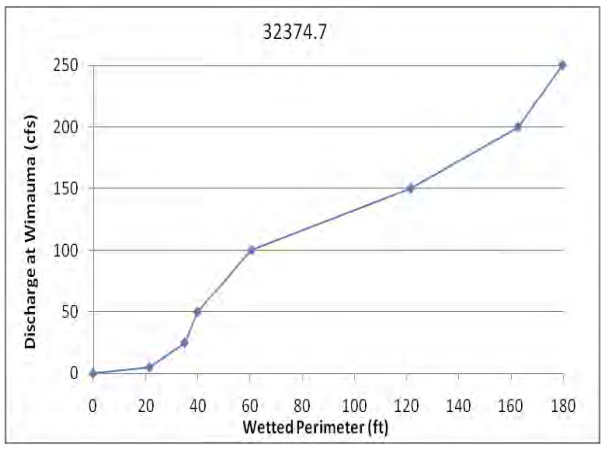

33357.91
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160 180 200 220
Wetted Perimeter (ft)

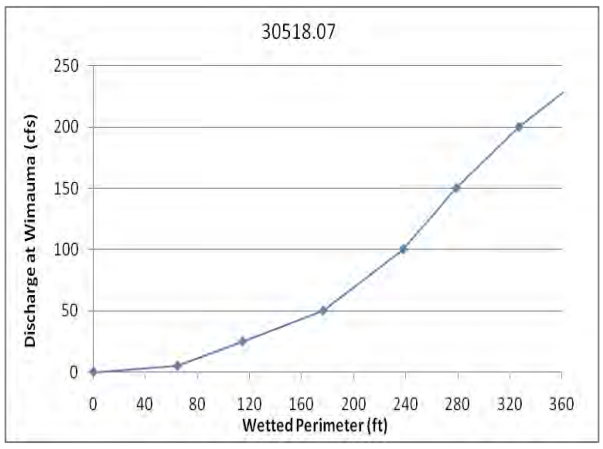

32374.7
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 40 80 120 160 200 240 280 320
Wetted Perimeter (ft)

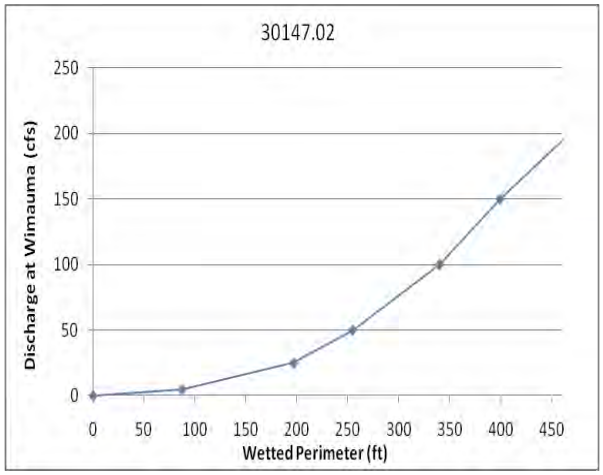

30980.29
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 30 60 90 120 150 180 210 240
Wetted Perimeter (ft)

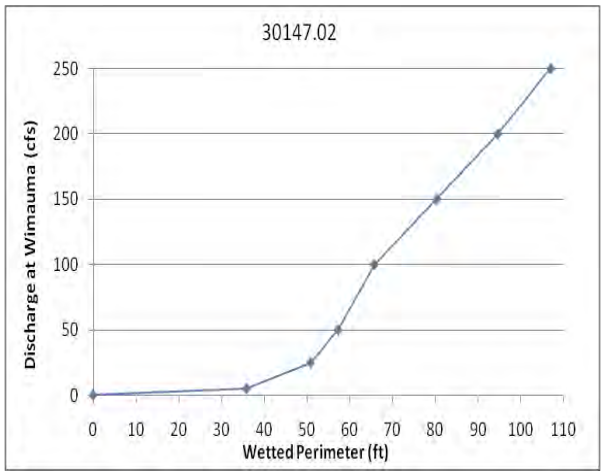

34253.49
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 30 60 90 120 150 180 210 240
Wetted Perimeter (ft)

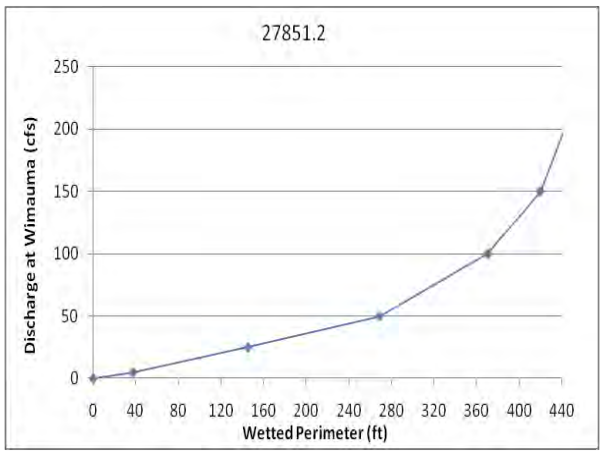

32804.17
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 40 80 120 160 200 240 280 320
Wetted Perimeter (ft)

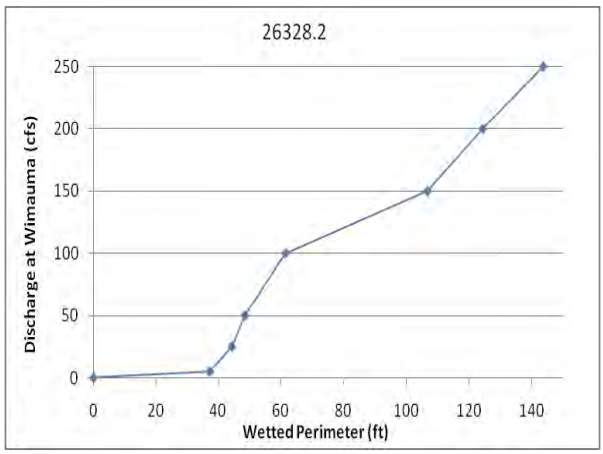

32374.7
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160 180
Wetted Perimeter (ft)

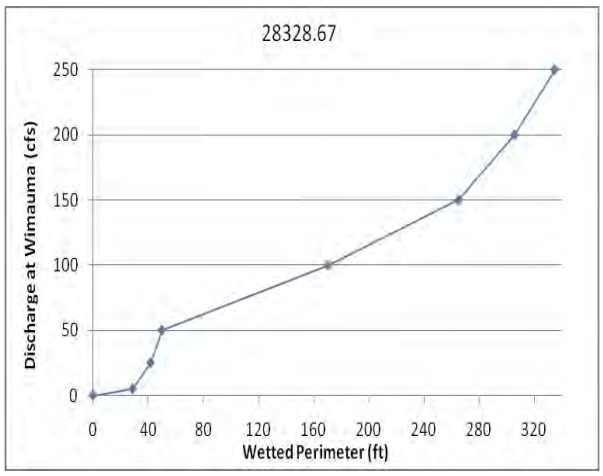

30518.07
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 40 80 120 160 200 240 280 320 360
Wetted Perimeter (ft)

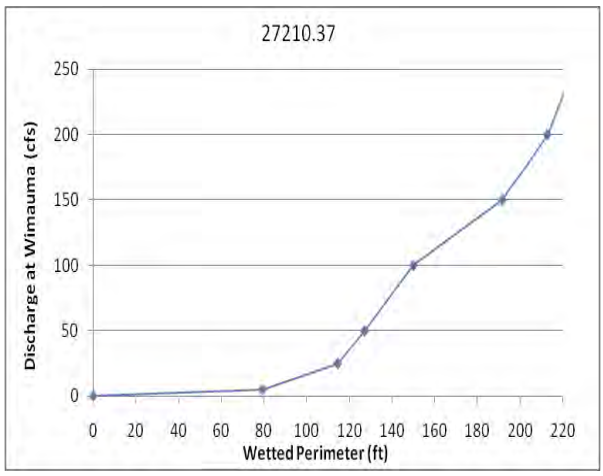

30147.02
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 50 100 150 200 250 300 350 400 450
Wetted Perimeter (ft)

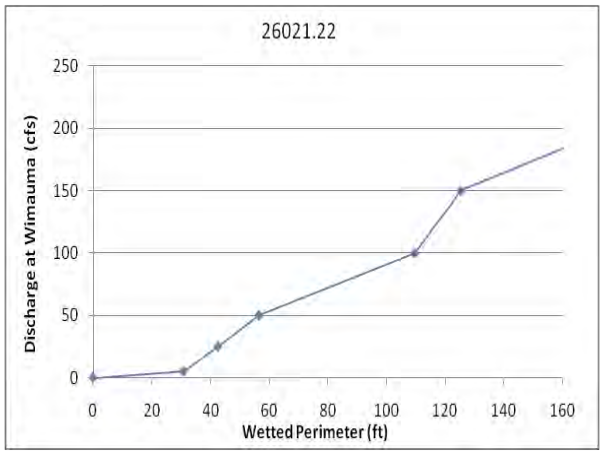

30147.02
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100 110
Wetted Perimeter (ft)

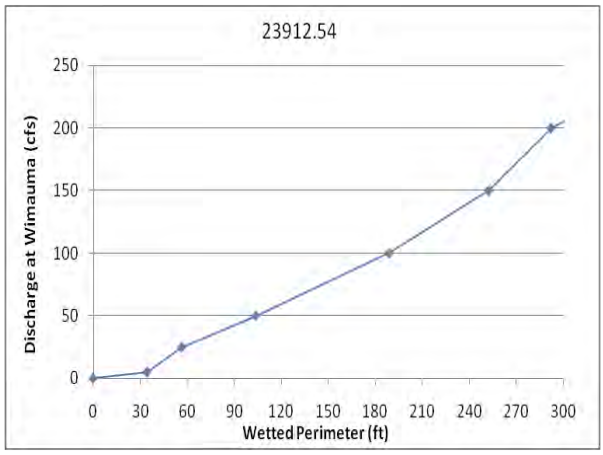

27851.2
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 40 80 120 160 200 240 280 320 360 400 440
Wetted Perimeter (ft)

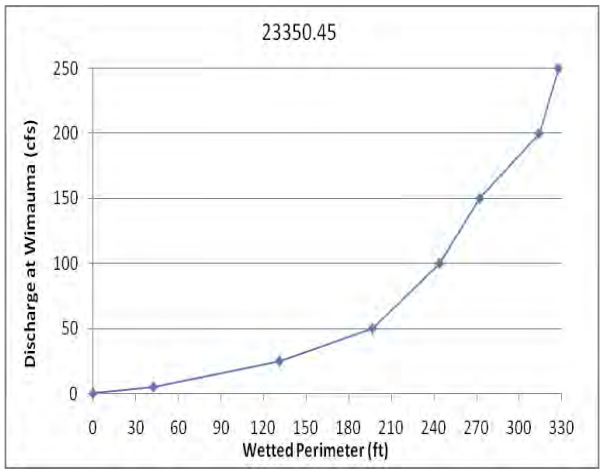

26328.2
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140
Wetted Perimeter (ft)

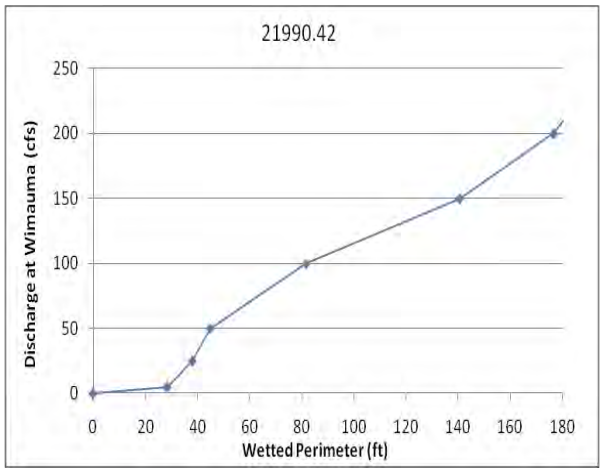

28328.67
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 40 80 120 160 200 240 280 320
Wetted Perimeter (ft)

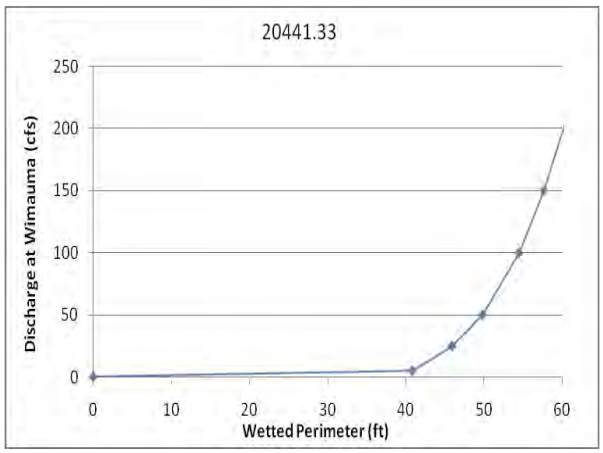

27210.37
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160 180 200 220
Wetted Perimeter (ft)

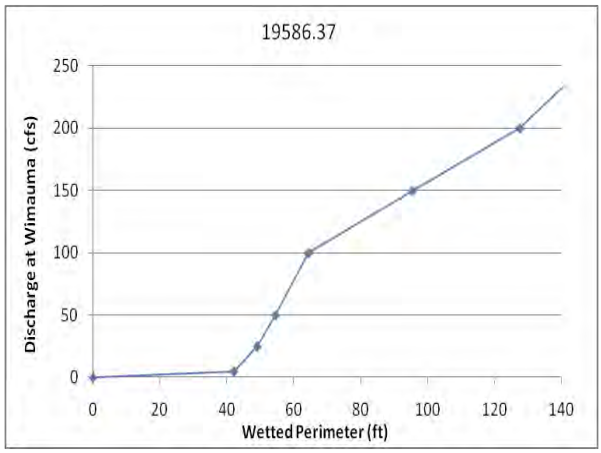

26021.22
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160
Wetted Perimeter (ft)

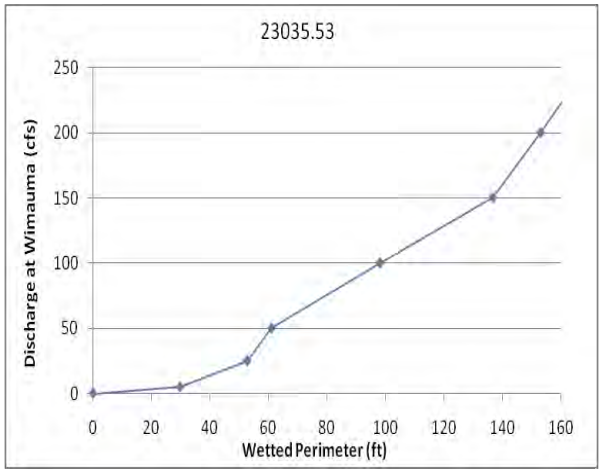

23912.54
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 30 60 90 120 150 180 210 240 270 300
Wetted Perimeter (ft)

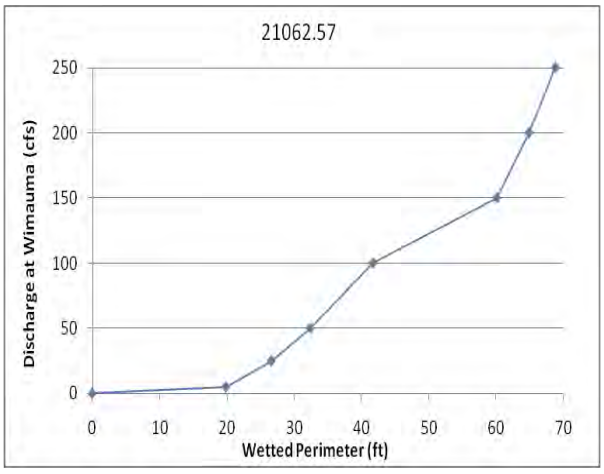

23350.45
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 30 60 90 120 150 180 210 240 270 300 330
Wetted Perimeter (ft)

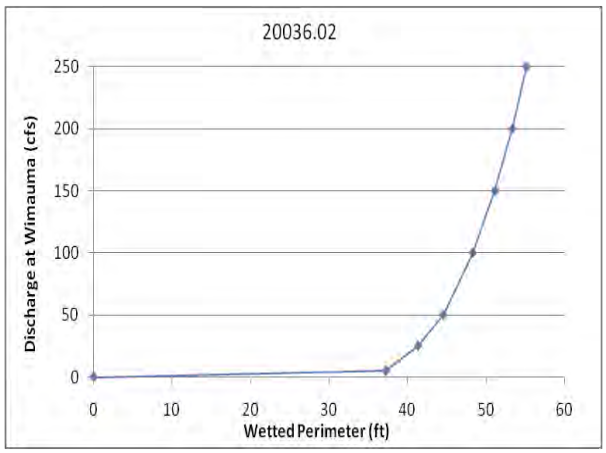

21990.42
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160 180
Wetted Perimeter (ft)

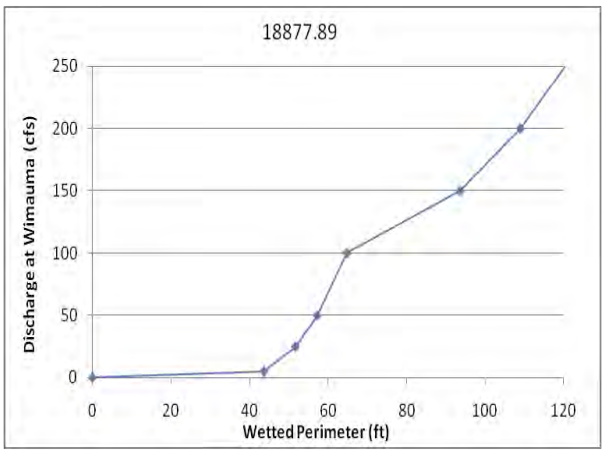

20441.33
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60

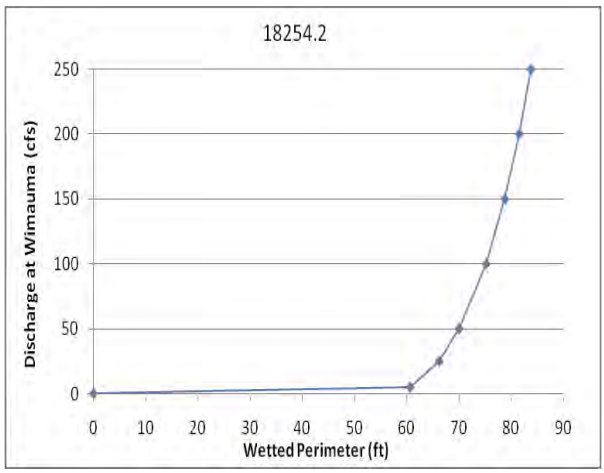

19586.37
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140

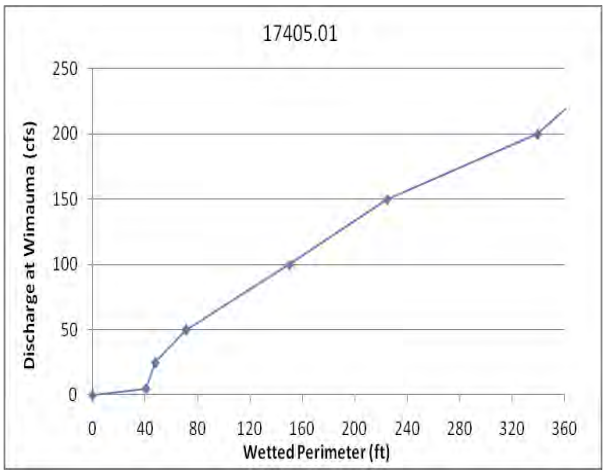

23035.53
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160

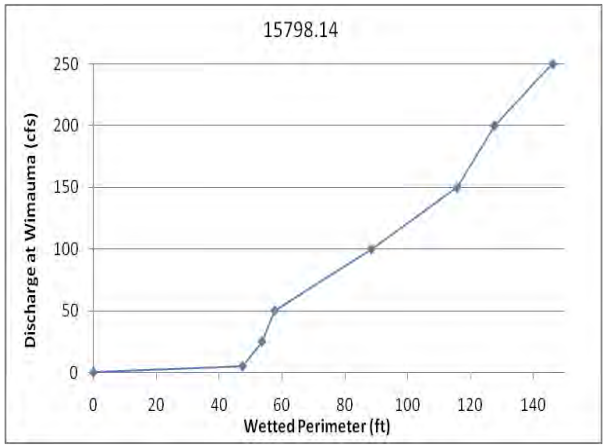

21062.57
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70

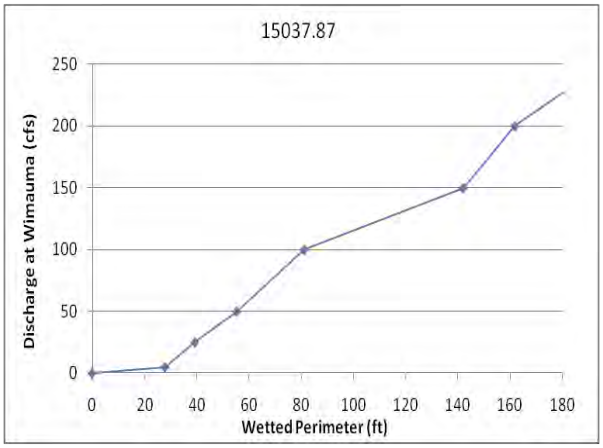

20036.02
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60

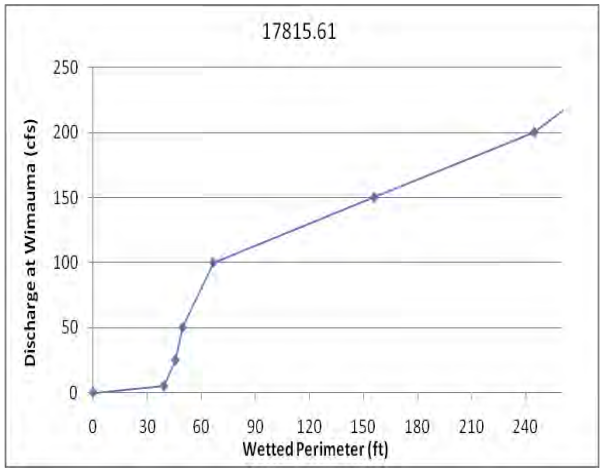

18877.89
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120

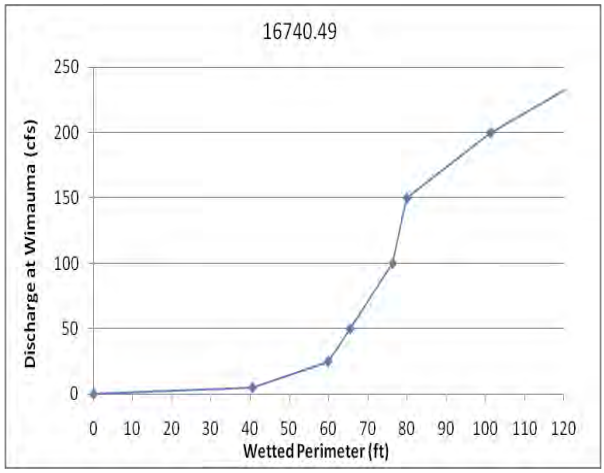

18254.2
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90
Wetted Perimeter (ft)

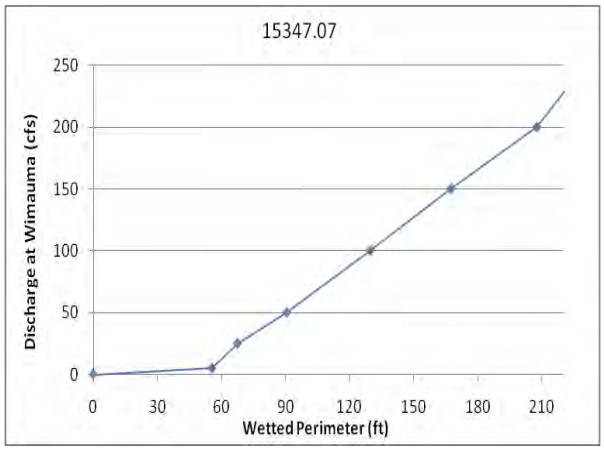

17405.01
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 40 80 120 160 200 240 280 320 360
Wetted Perimeter (ft)

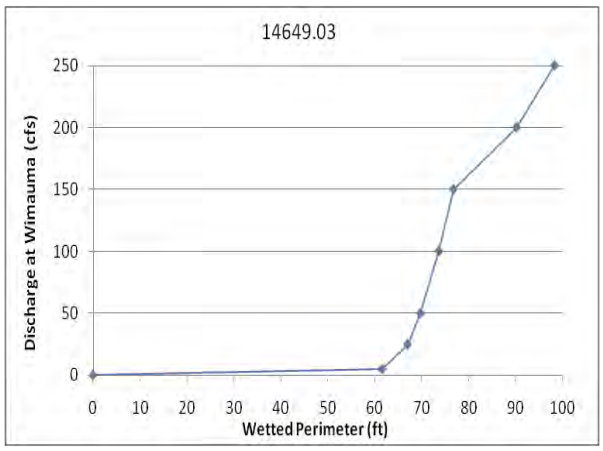

15798.14
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140
Wetted Perimeter (ft)

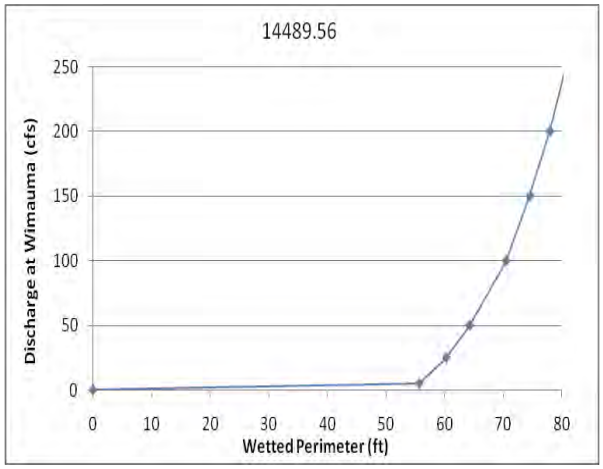

15037.87
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160 180
Wetted Perimeter (ft)

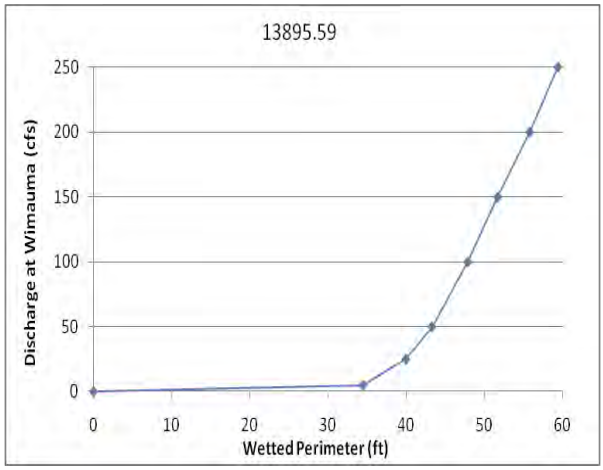

17815.61
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 30 60 90 120 150 180 210 240
Wetted Perimeter (ft)

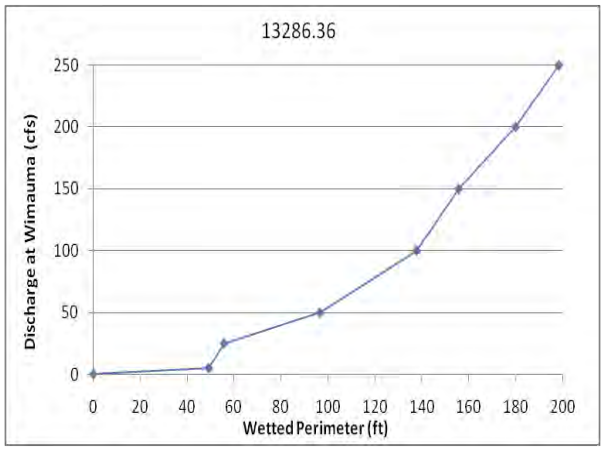

16740.49
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100 110 120
Wetted Perimeter (ft)

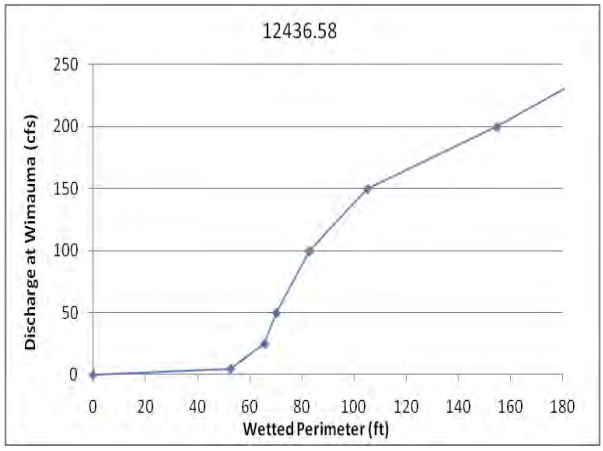

15347.07
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0
30
60
90
120
150
180
210
Wetted Perimeter (ft)

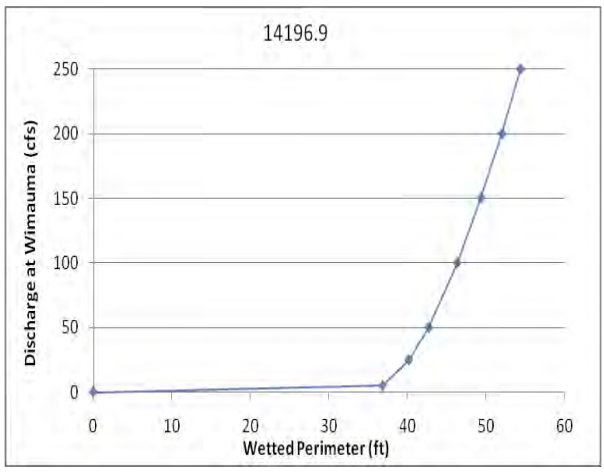

14649.03
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80
90
100
Wetted Perimeter (ft)

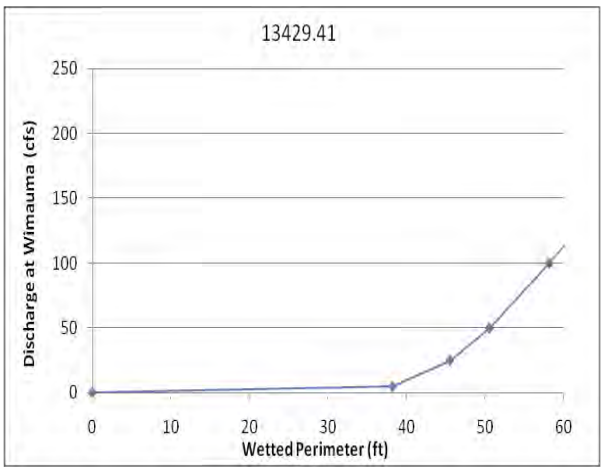

14489.56
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80
Wetted Perimeter (ft)

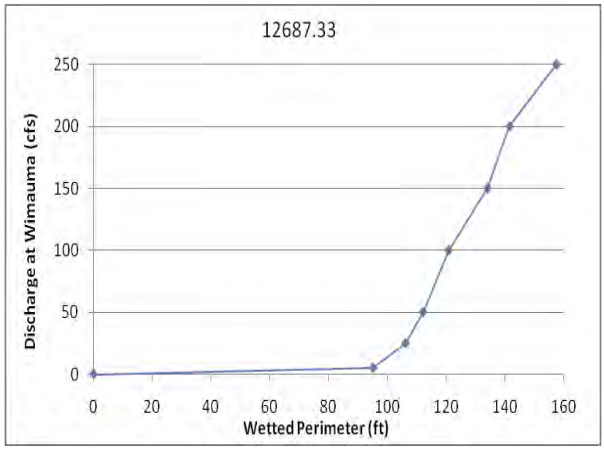

13895.59
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0
10
20
30
40
50
60
Wetted Perimeter (ft)

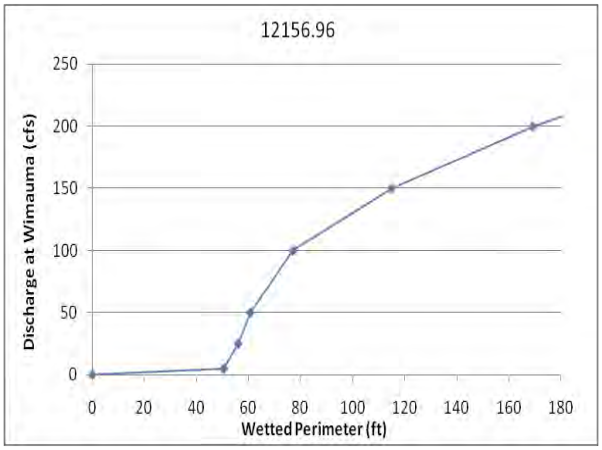

13286.36
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160
180
200
Wetted Perimeter (ft)

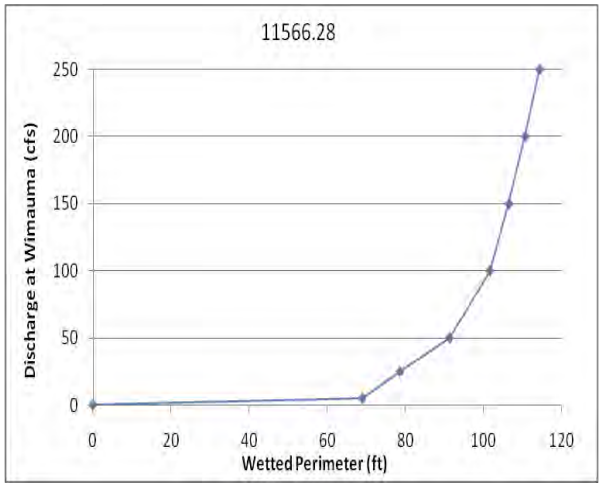

12436.58
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160
180
Wetted Perimeter (ft)

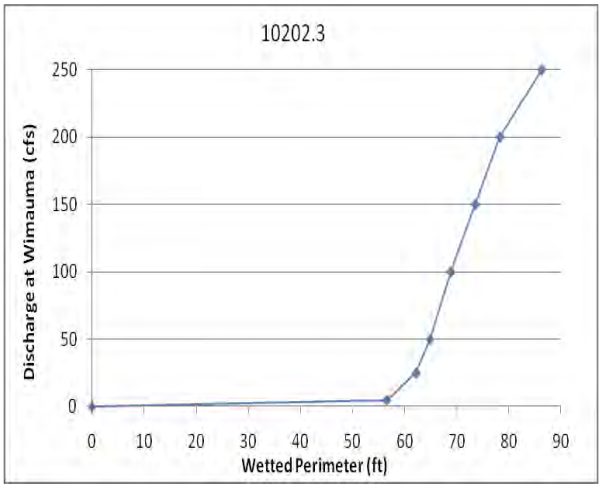

14196.9
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60

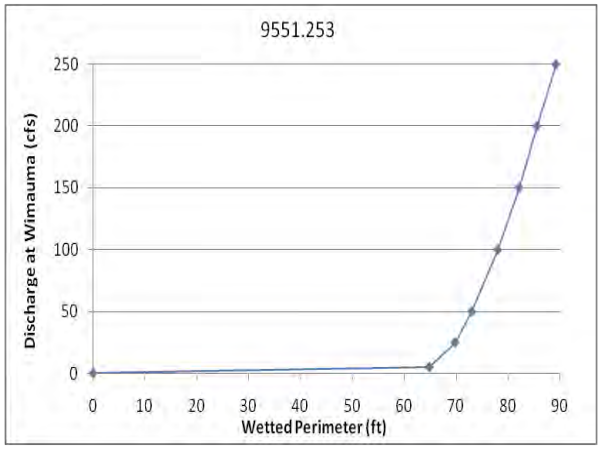

13429.41
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60

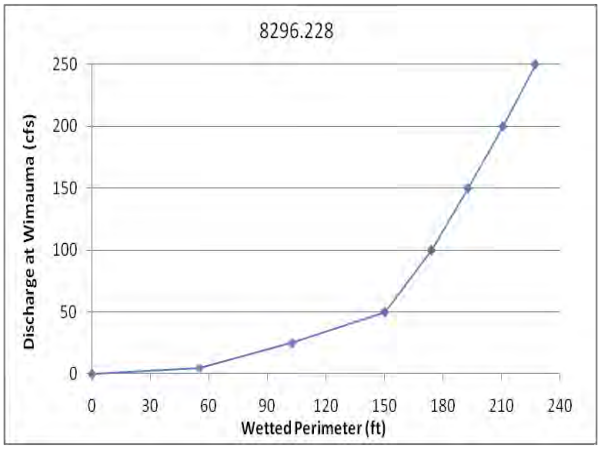

12687.33
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160

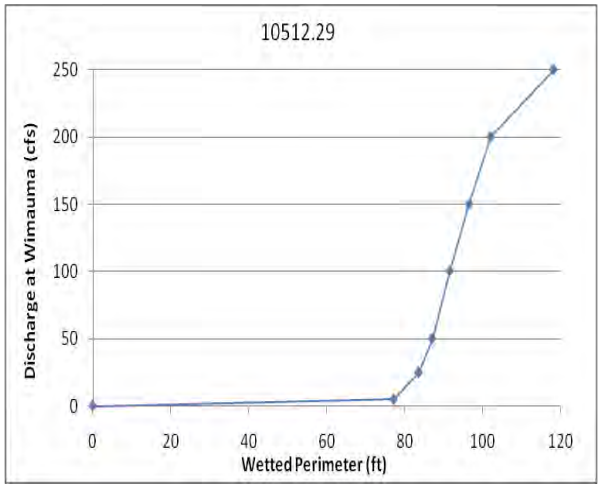

12156.96
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160
180

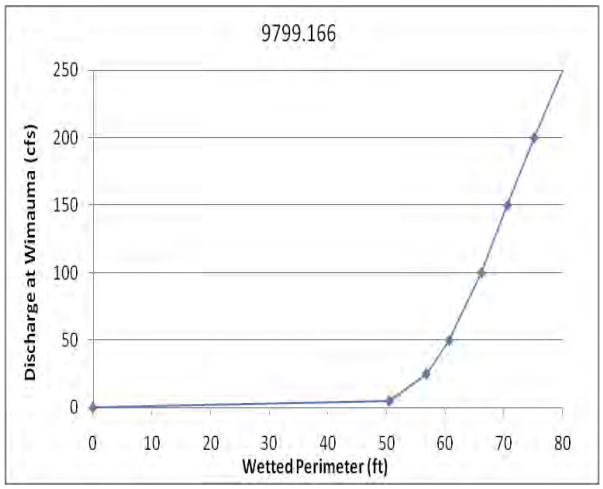

11566.28
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120

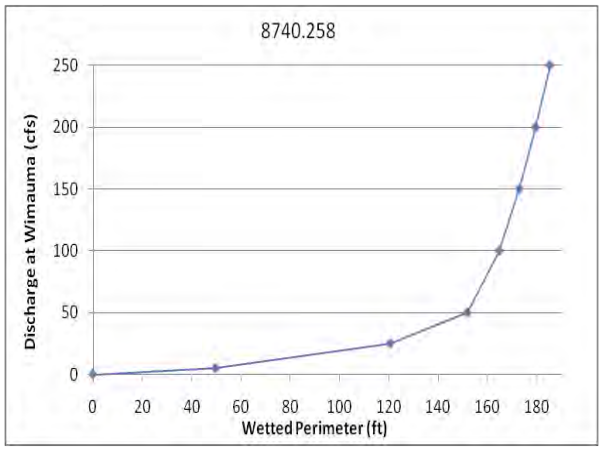

10202.3
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80
90

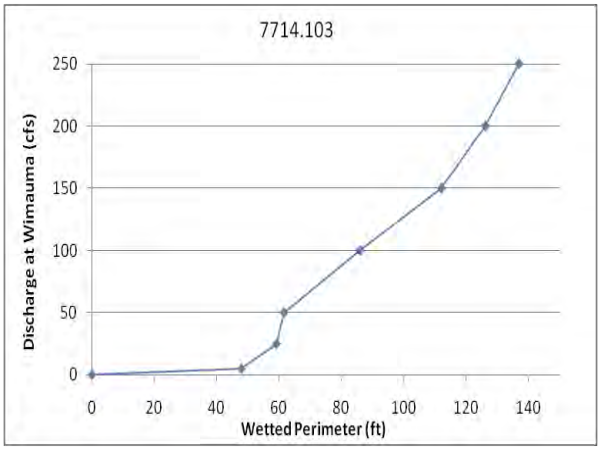

9551.253
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90
Wetted Perimeter (ft)

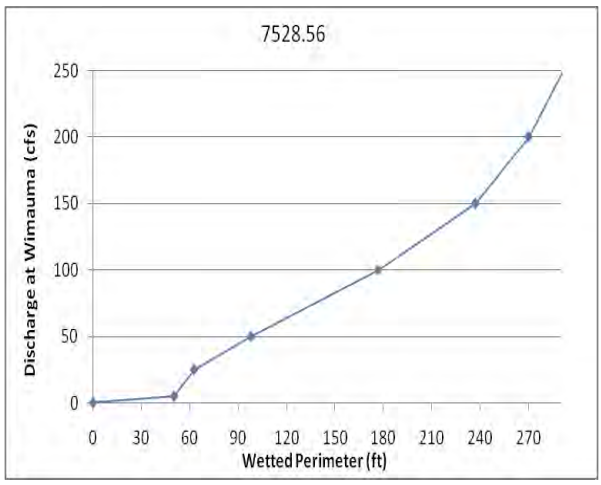

8296.228
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 30 60 90 120 150 180 210 240
Wetted Perimeter (ft)

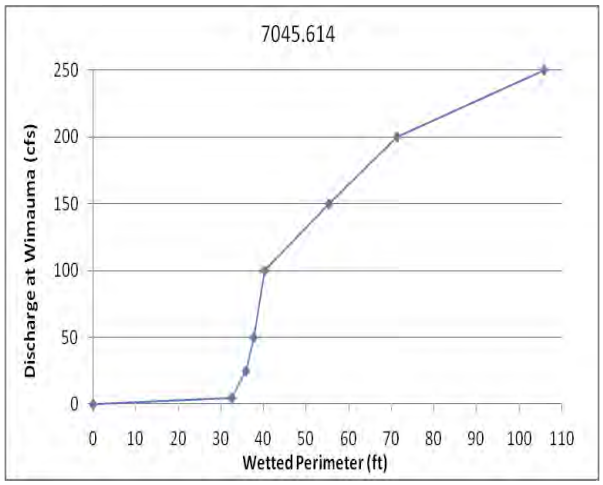

10512.29
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120
Wetted Perimeter (ft)

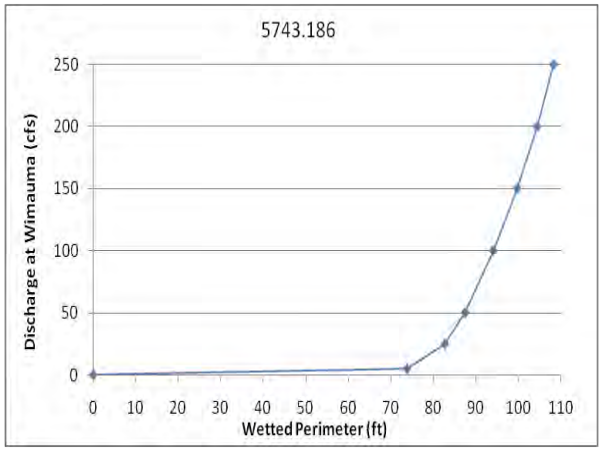

9799.166
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80
Wetted Perimeter (ft)

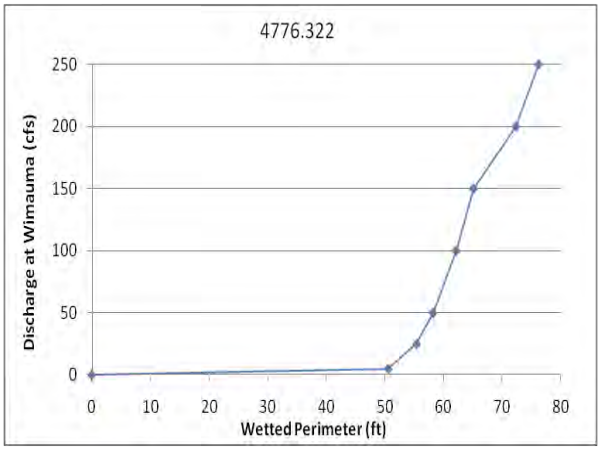

8740.258
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160 180
Wetted Perimeter (ft)

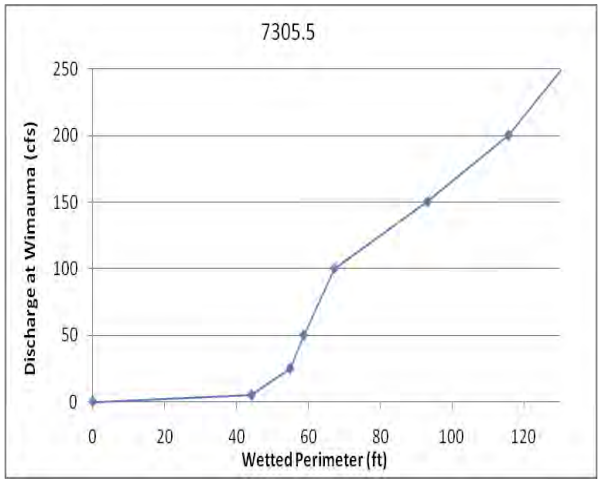

7714.103
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140
Wetted Perimeter (ft)

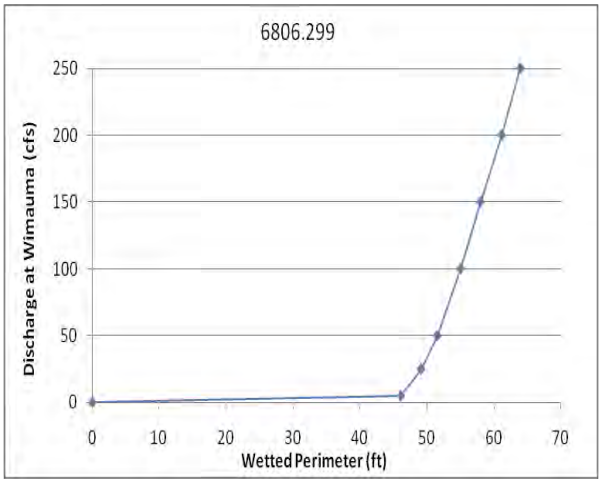

7528.56
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 30 60 90 120 150 180 210 240 270
Wetted Perimeter (ft)

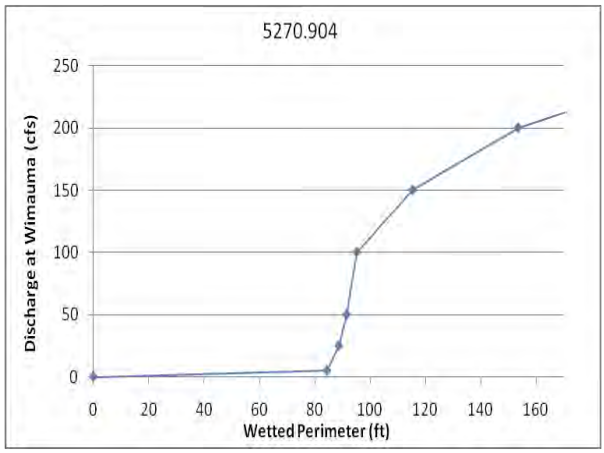

7045.614
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100 110
Wetted Perimeter (ft)

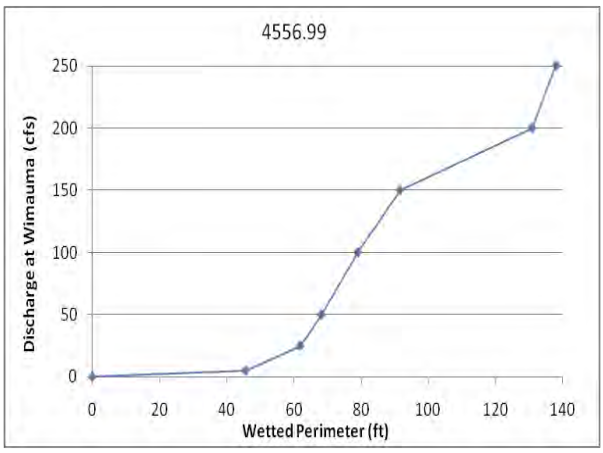

5743.186
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80 90 100 110
Wetted Perimeter (ft)

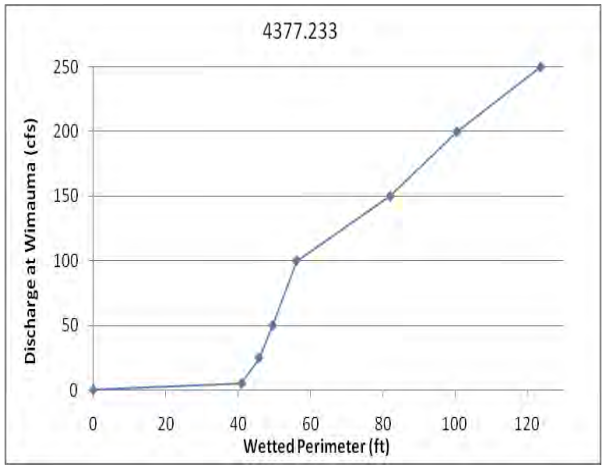

4776.322
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70 80
Wetted Perimeter (ft)

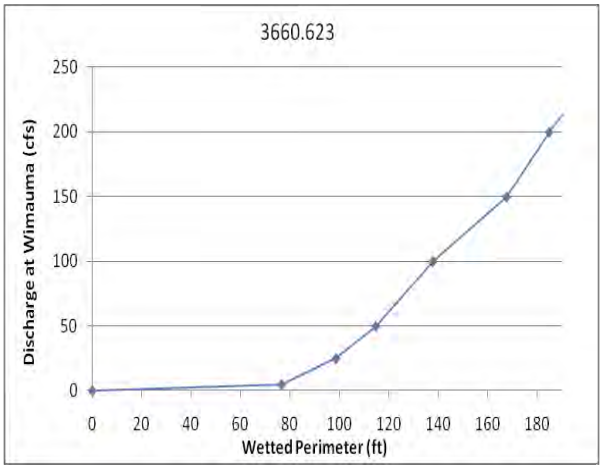

7305.5
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120
Wetted Perimeter (ft)

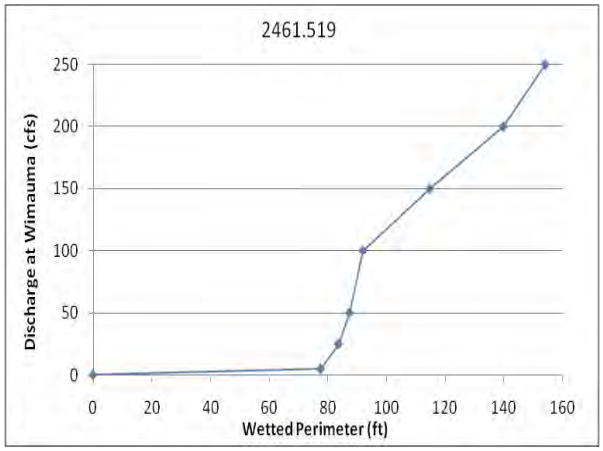

6806.299
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 10 20 30 40 50 60 70
Wetted Perimeter (ft)

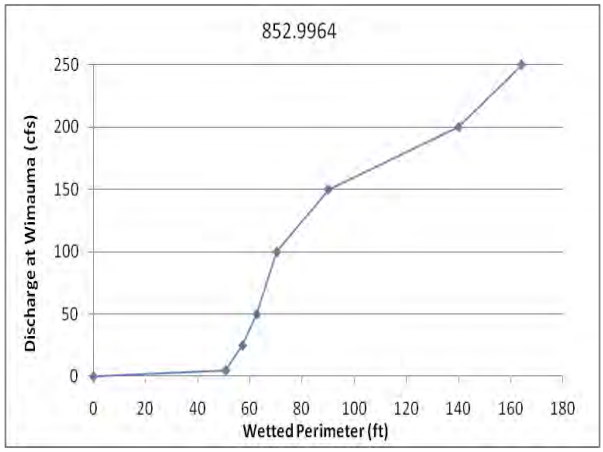

5270.904
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160

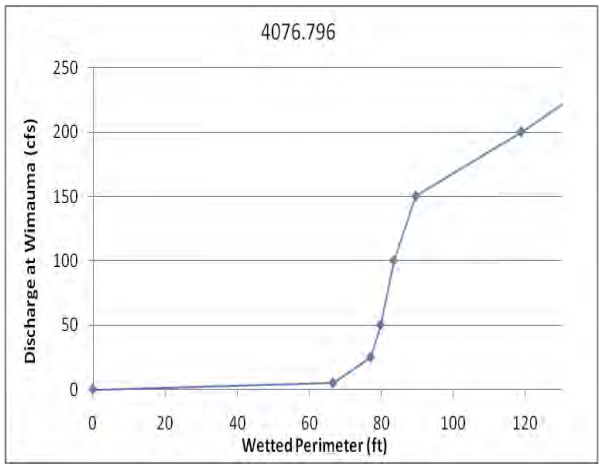

4556.99
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140

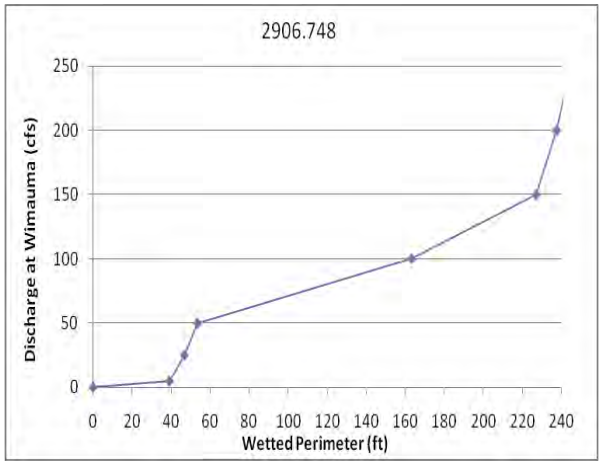

4377.233
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120

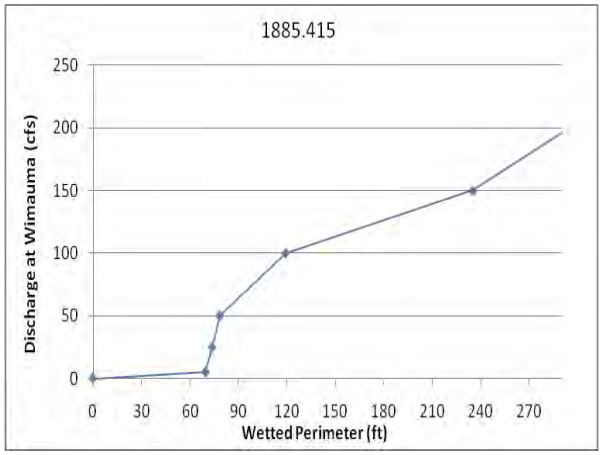

3660.623
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160
180

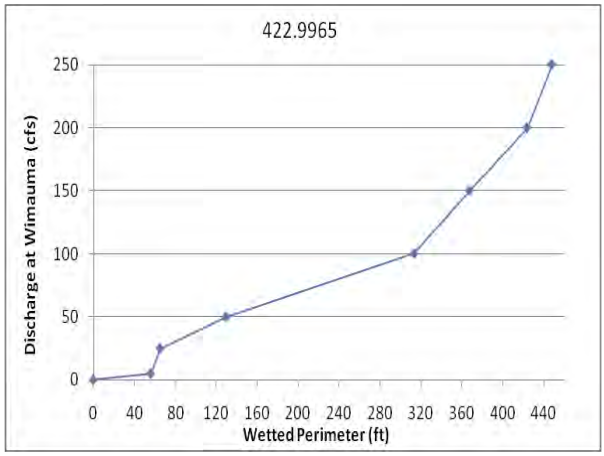

2461.519
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160

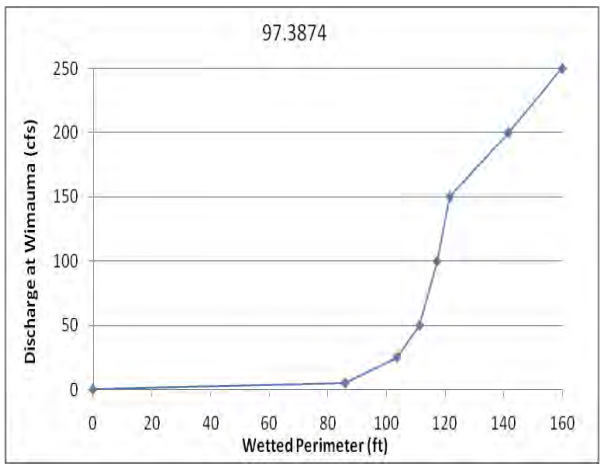

852.9964
Discharge at Wimauma (cfs)
Wetted Perimeter (ft)
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160
180


4076.796
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120
Wetted Perimeter (ft)

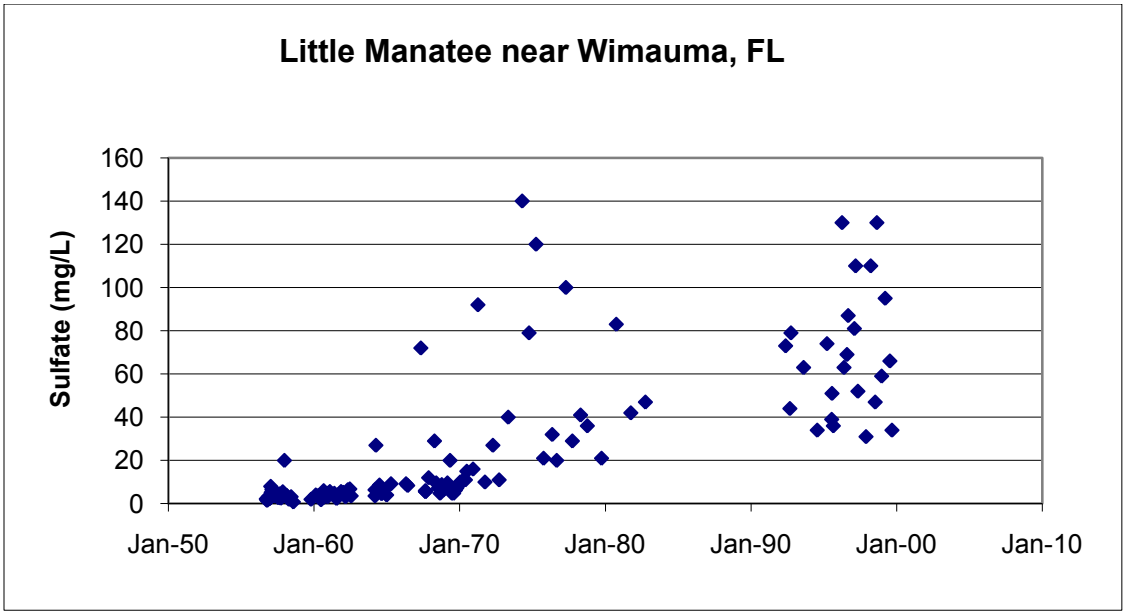

2906.748
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160 180 200 220 240
Wetted Perimeter (ft)

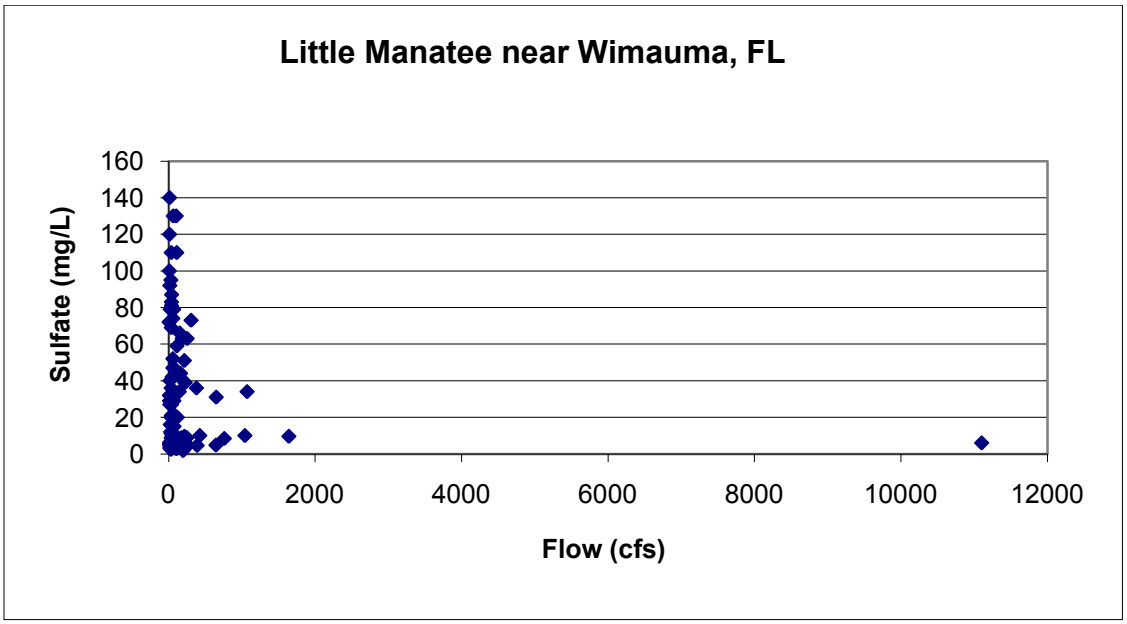

1885.415
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 30 60 90 120 150 180 210 240 270
Wetted Perimeter (ft)

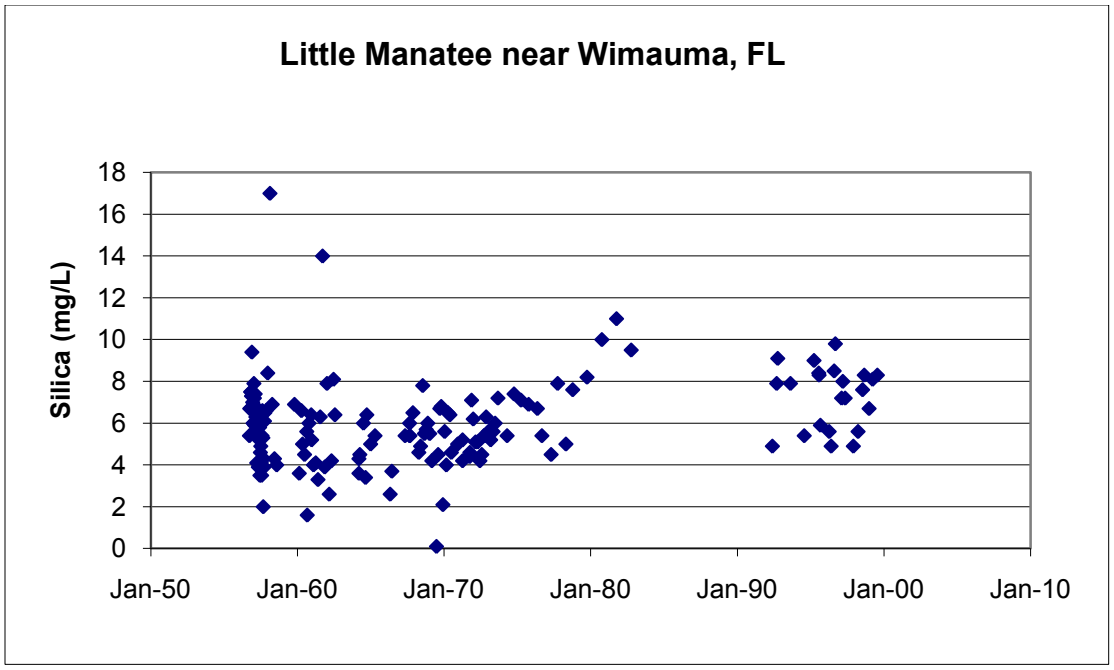

422.9965
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 40 80 120 160 200 240 280 320 360 400 440
Wetted Perimeter (ft)

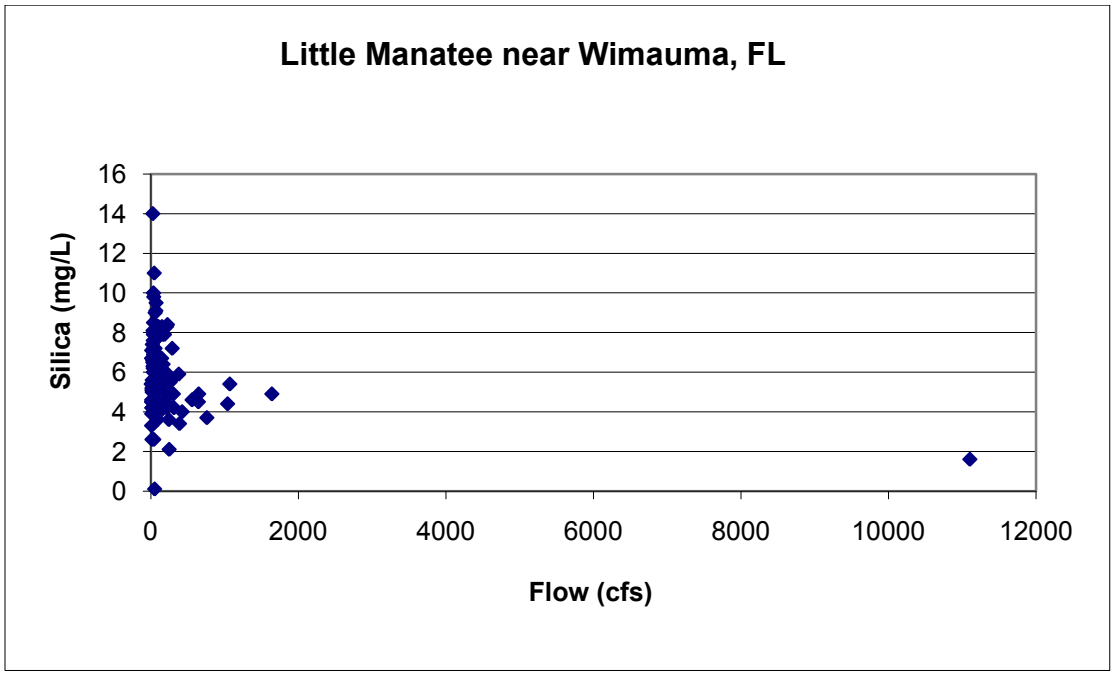

97.3874
Discharge at Wimauma (cfs)
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160
Wetted Perimeter (ft)

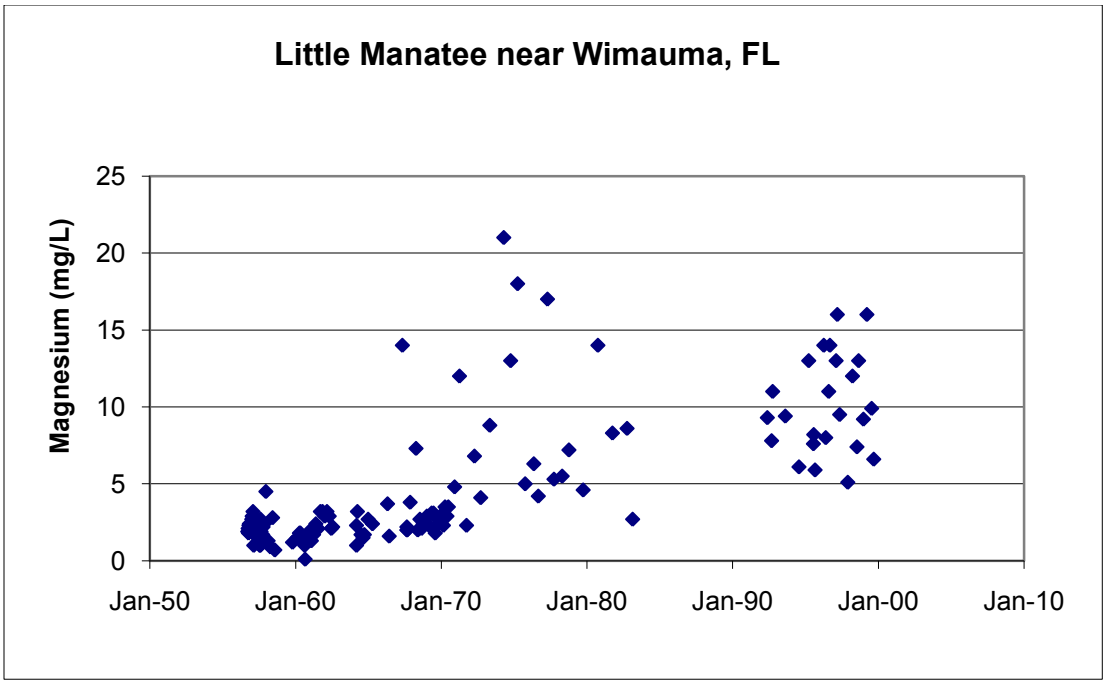
Water Quality Analyses for Little Manatee River near Wimauma

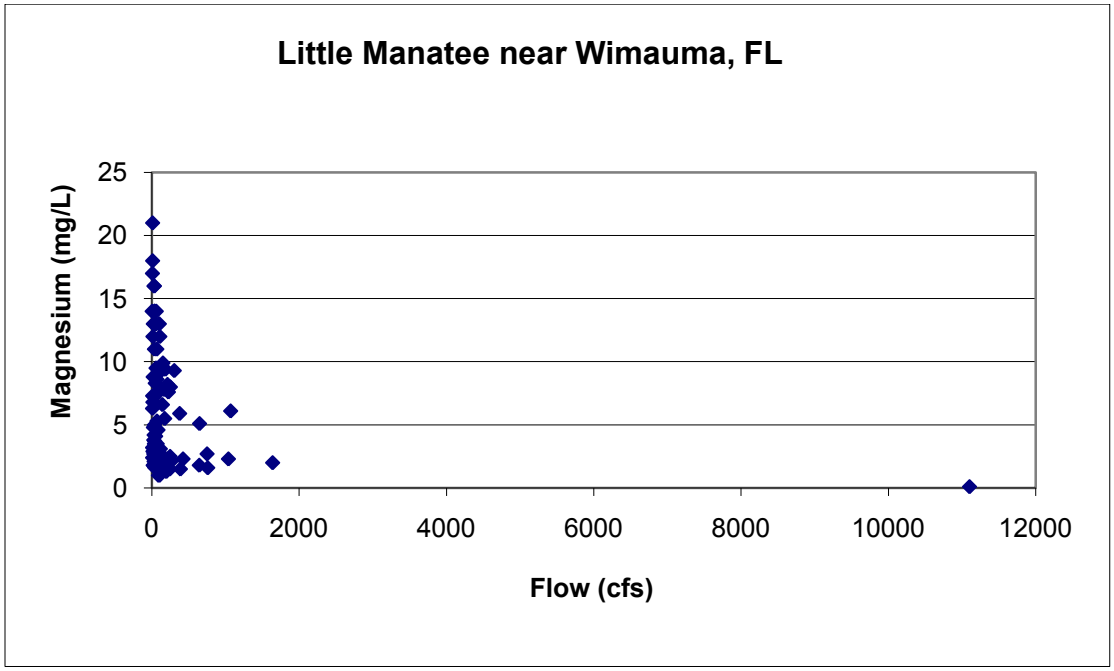


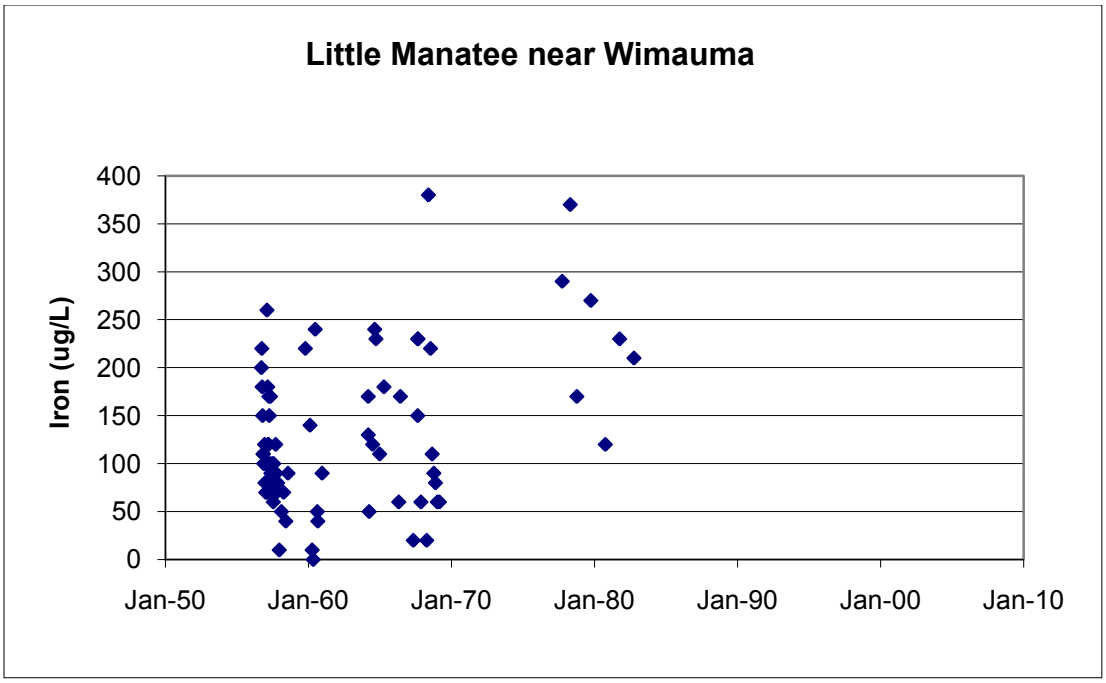


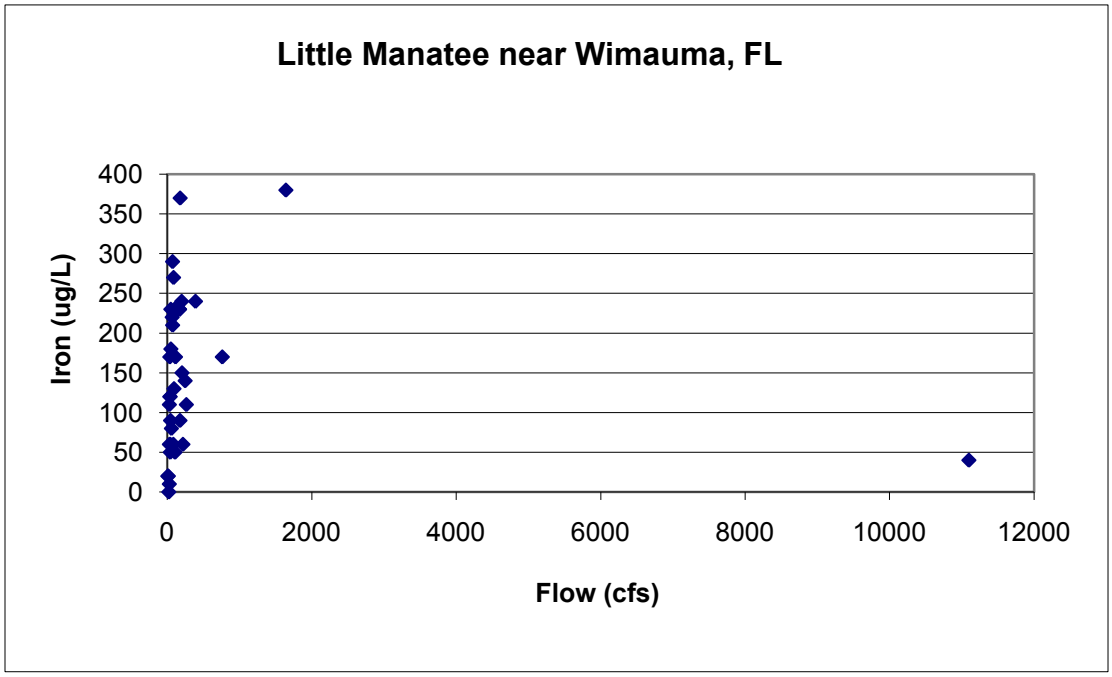

Little Manatee near Wimauma, FL
Silica (mg/L)
18
16
14
12
10
8
6
4
2
0
Jan-50
Jan-60
Jan-70
Jan-80
Jan-90
Jan-00
Jan-10

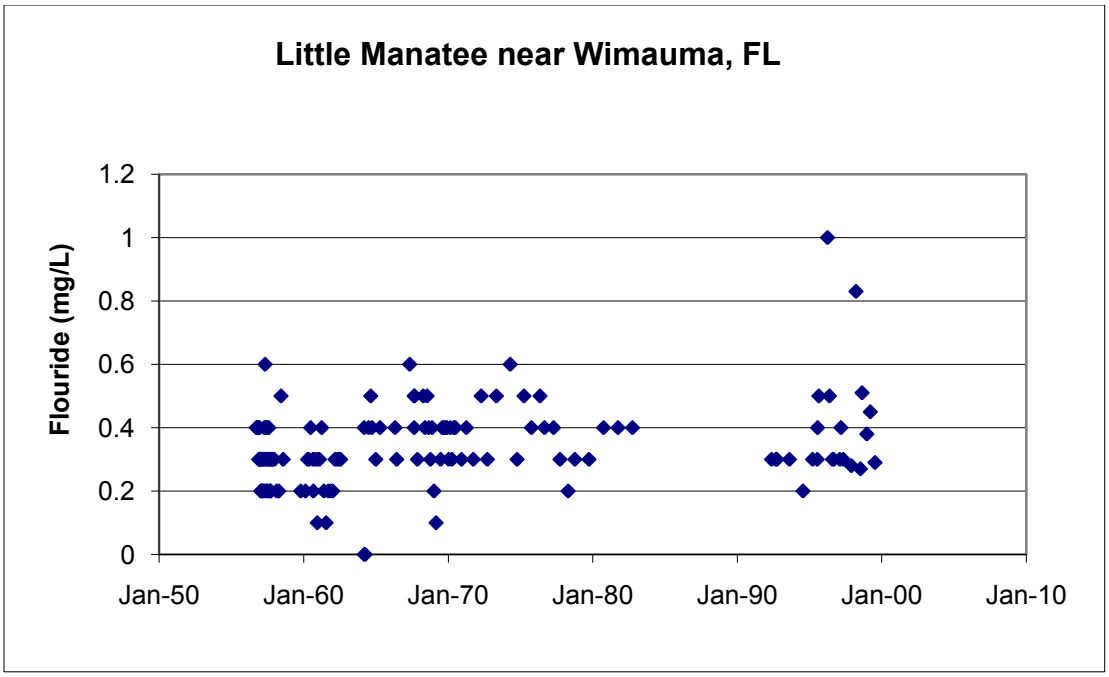

Little Manatee near Wimauma, FL
Silica (mg/L)
16
14
12
10
8
6
4
2
0
0
2000
4000
6000
8000
10000
12000
Flow (cfs)

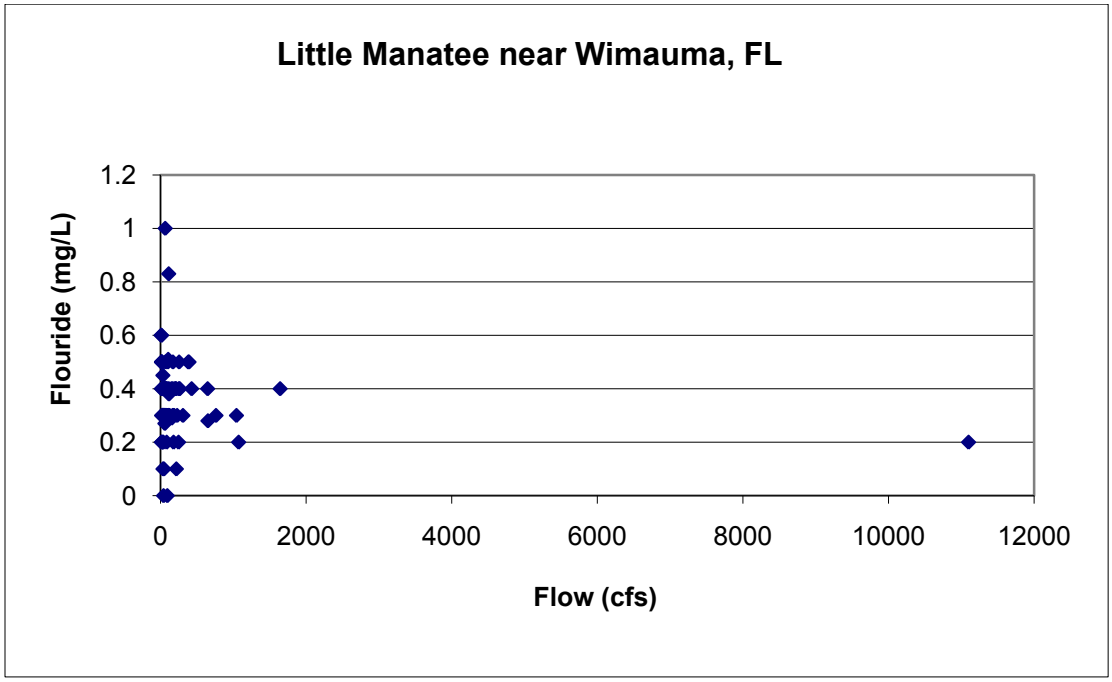

Little Manatee near Wimauma, FL
Magnesium (mg/L)
25
20
15
10
5
0
Jan-50
Jan-60
Jan-70
Jan-80
Jan-90
Jan-00
Jan-10

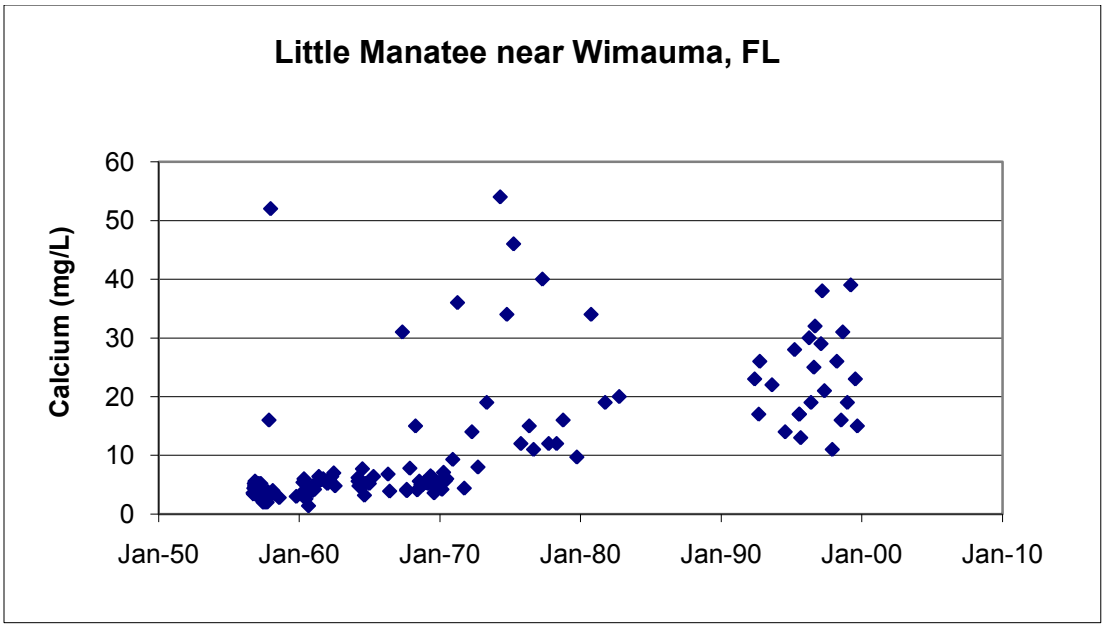

Little Manatee near Wimauma, FL
Magnesium (mg/L)
25
20
15
10
5
0
0
2000
4000
6000
8000
10000
12000
Flow (cfs)

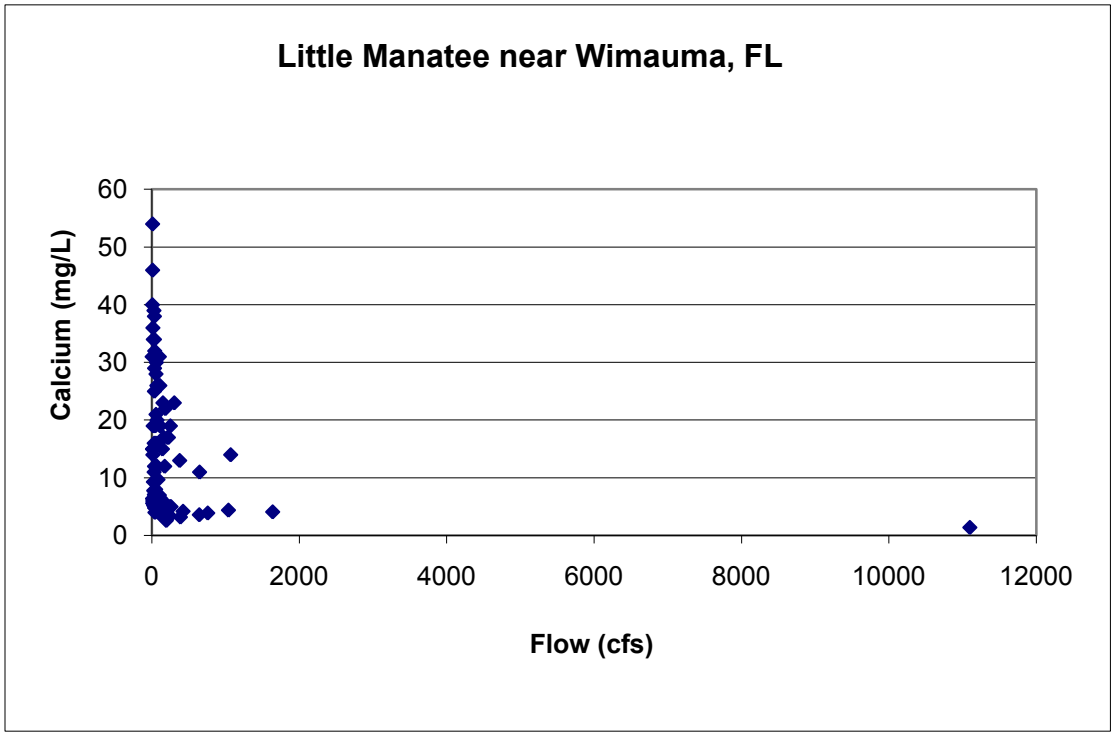

Little Manatee near Wimauma
Iron (ug/L)
400
350
300
250
200
150
100
50
0
Jan-50
Jan-60
Jan-70
Jan-80
Jan-90
Jan-00
Jan-10

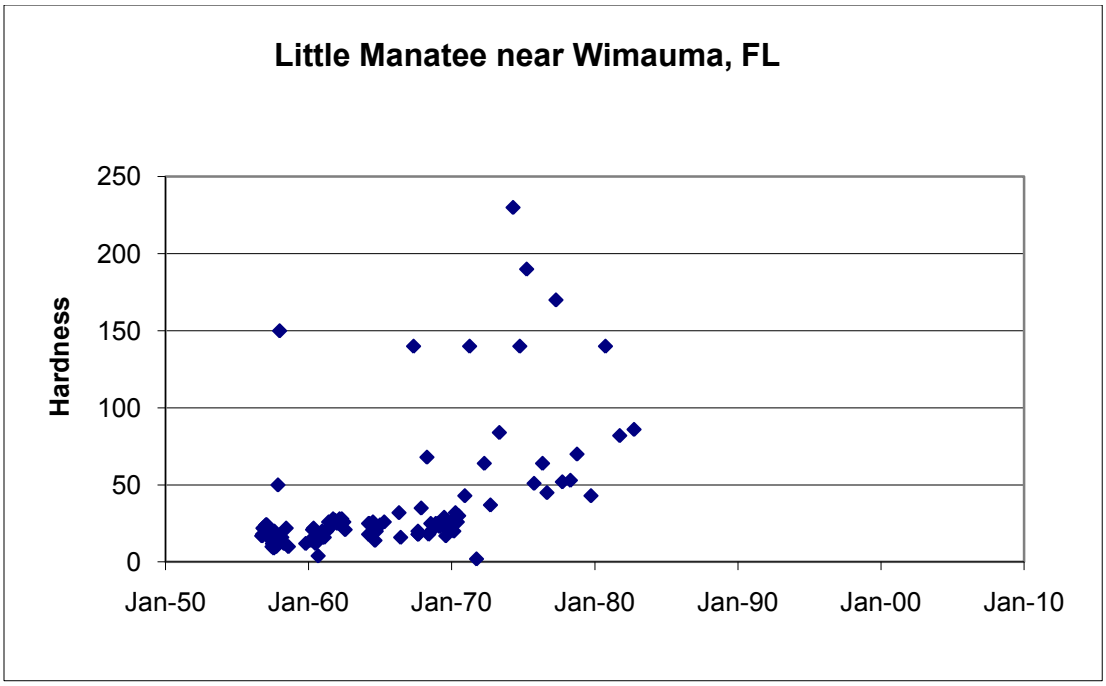

Little Manatee near Wimauma, FL
Iron (ug/L)
400
350
300
250
200
150
100
50
0
0
2000
4000
6000
8000
10000
12000
Flow (cfs)

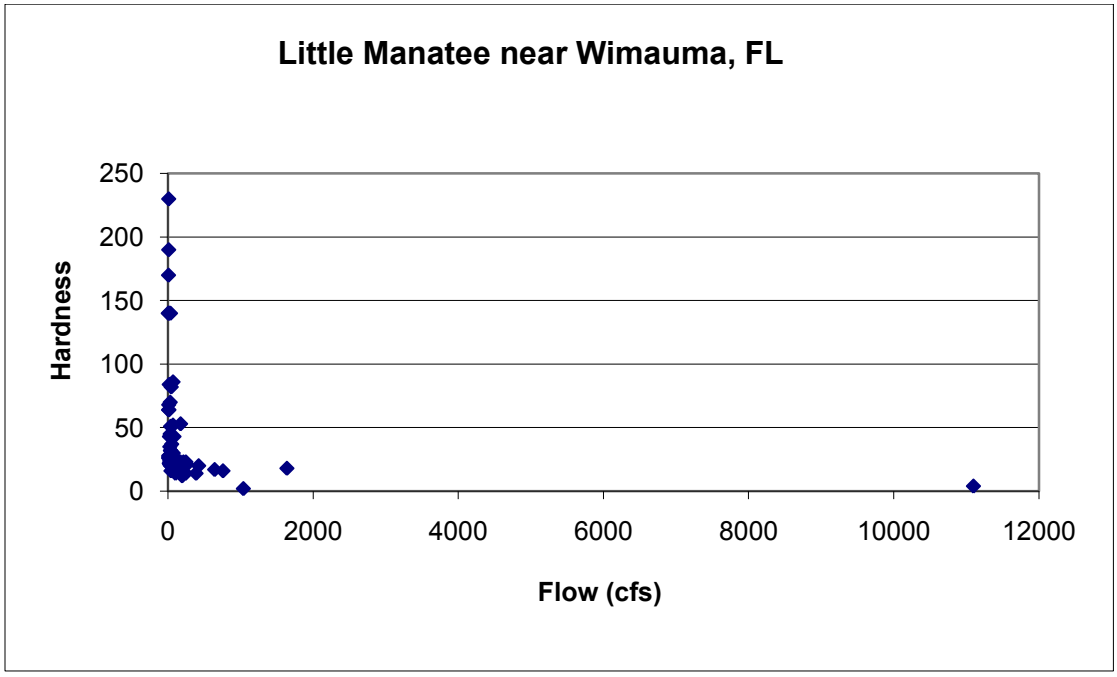

Little Manatee near Wimauma, FL
Flouride (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
Jan-50
Jan-60
Jan-70
Jan-80
Jan-90
Jan-00
Jan-10

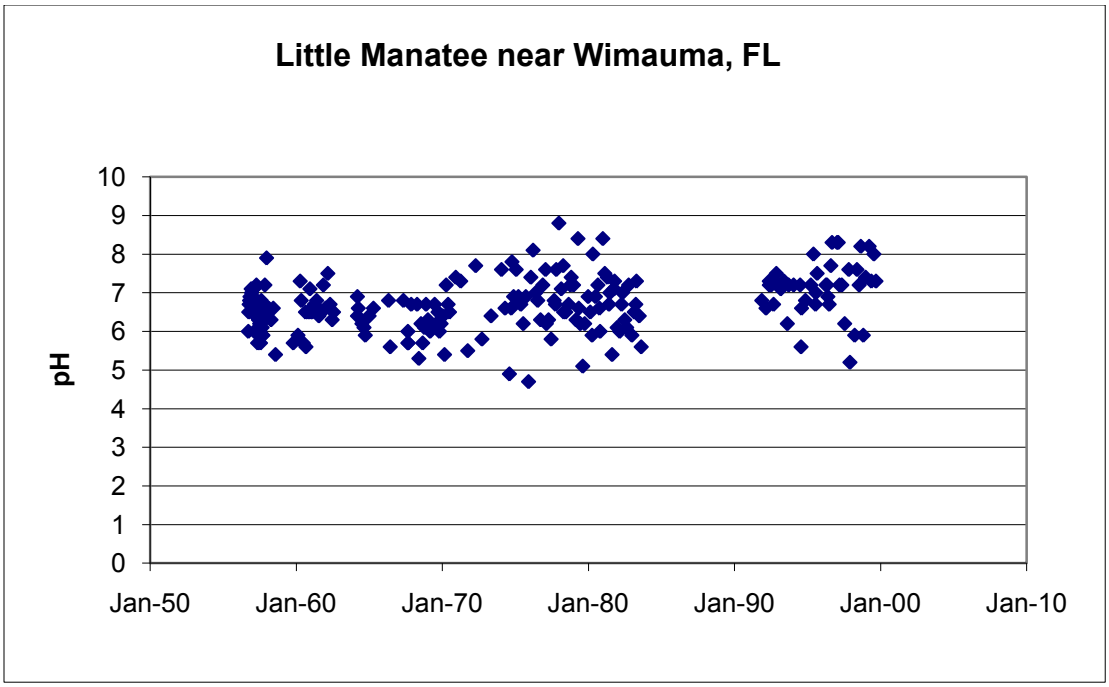

Little Manatee near Wimauma, FL
Flouride (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
0
2000
4000
6000
8000
10000
12000
Flow (cfs)

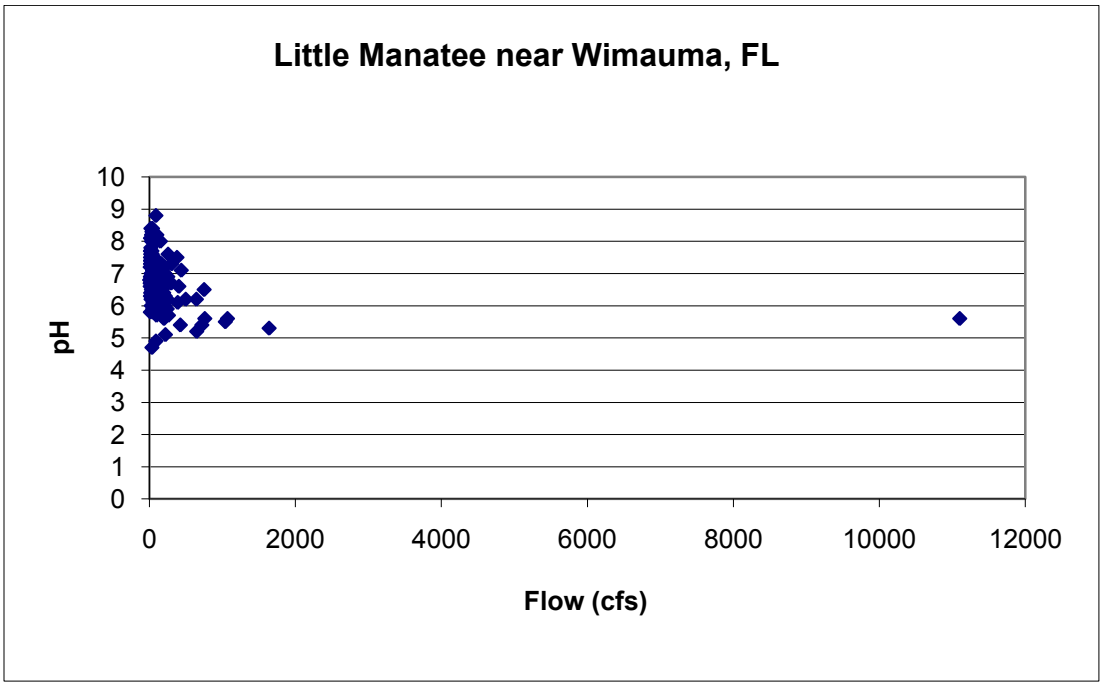

Little Manatee near Wimauma, FL
Calcium (mg/L)
60
50
40
30
20
10
0
Jan-50
Jan-60
Jan-70
Jan-80
Jan-90
Jan-00
Jan-10

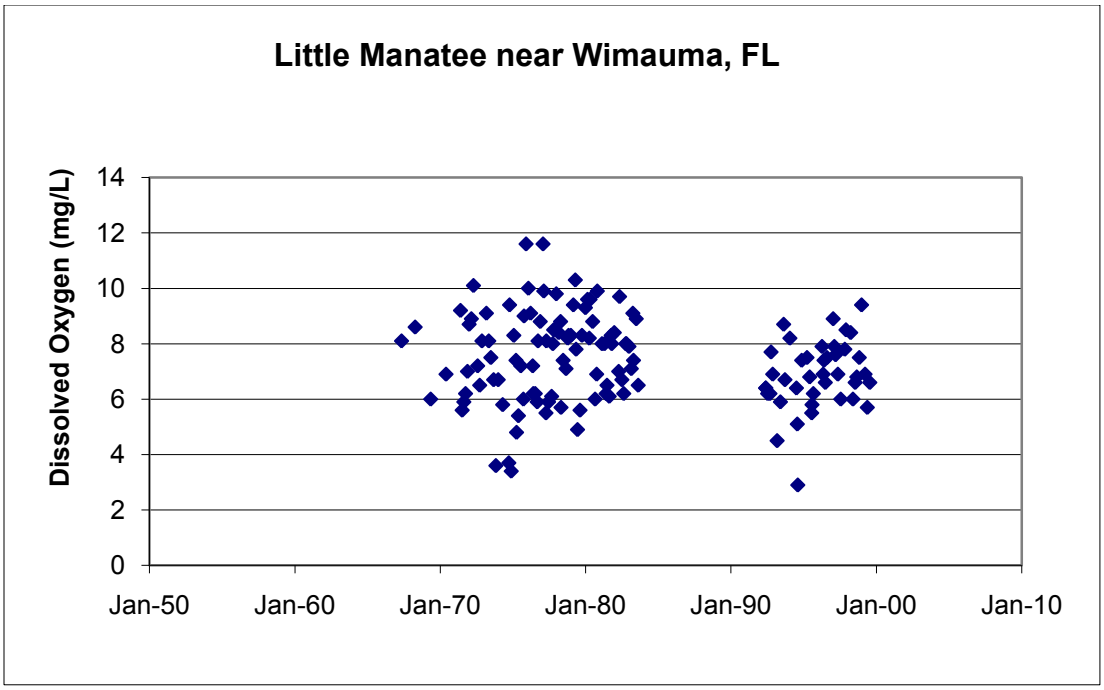

Little Manatee near Wimauma, FL
Calcium (mg/L)
60
50
40
30
20
10
0
0
2000
4000
6000
8000
10000
12000
Flow (cfs)

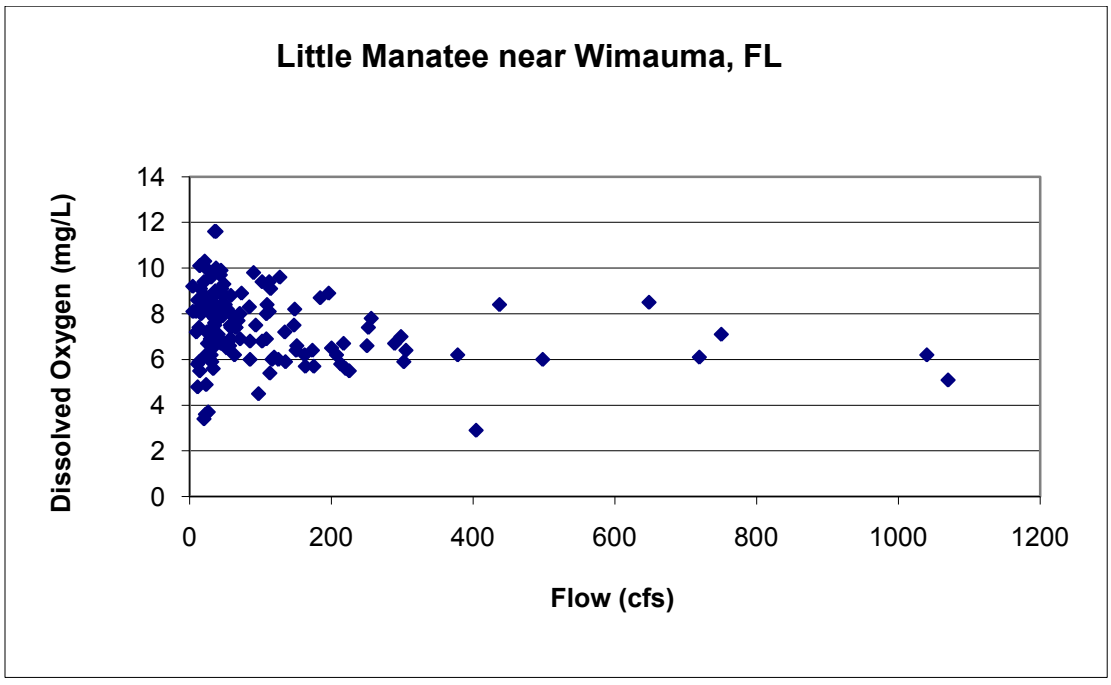

Little Manatee near Wimauma, FL
Hardness
250
200
150
100
50
0
Jan-50
Jan-60
Jan-70
Jan-80
Jan-90
Jan-00
Jan-10

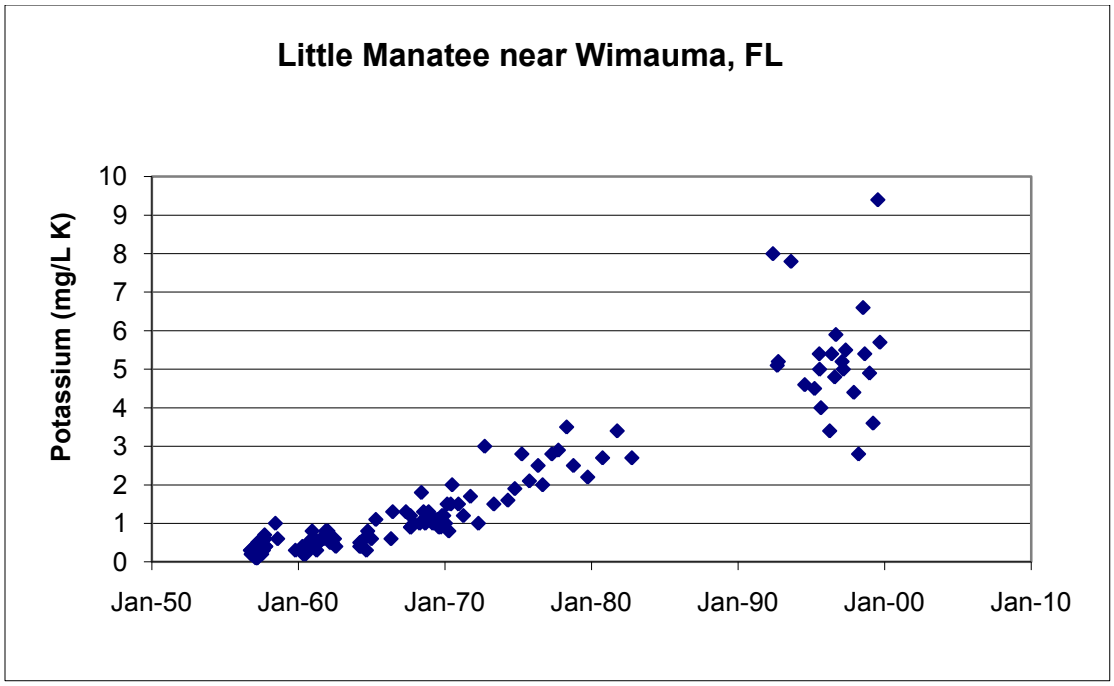

Little Manatee near Wimauma, FL
Hardness
250
200
150
100
50
0
0
2000
4000
6000
8000
10000
12000
Flow (cfs)

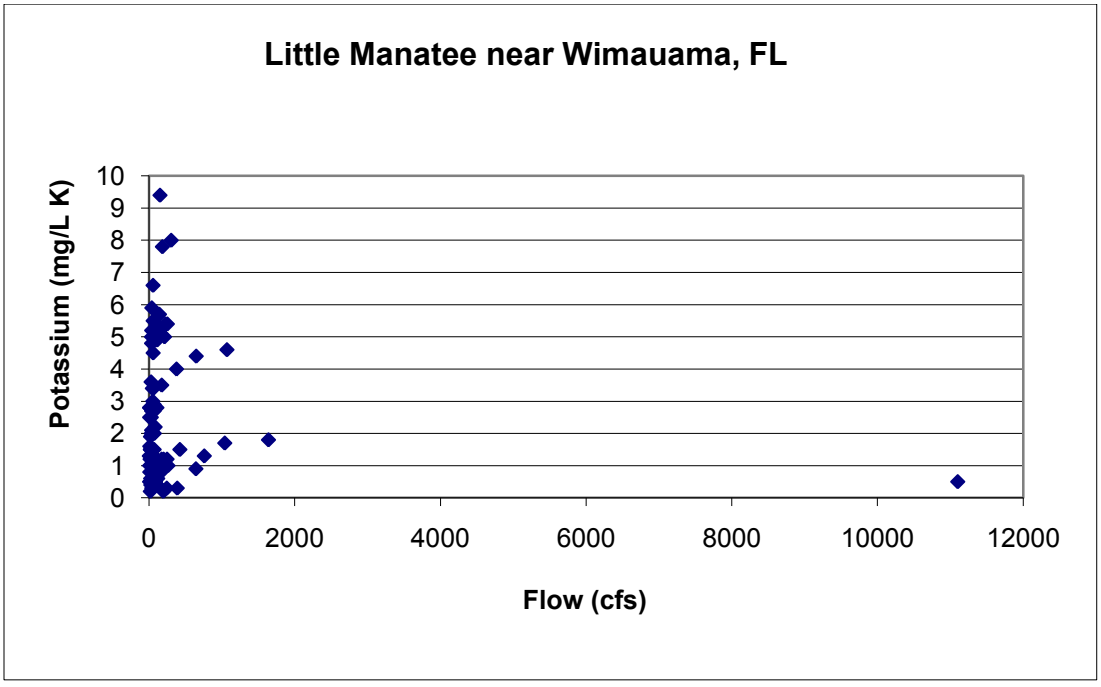

Little Manatee near Wimauma, FL
pH
10
9
8
7
6
5
4
3
2
1
0
Jan-50
Jan-60
Jan-70
Jan-80
Jan-90
Jan-00
Jan-10


Little Manatee near Wimauma, FL
pH
10
9
8
7
6
5
4
3
2
1
0
0
2000
4000
6000
8000
10000
12000
Flow (cfs)


Little Manatee near Wimauma, FL
Dissolved Oxygen (mg/L)
14
12
10
8
6
4
2
0
Jan-50
Jan-60
Jan-70
Jan-80
Jan-90
Jan-00
Jan-10


Little Manatee near Wimauma, FL
Dissolved Oxygen (mg/L)
14
12
10
8
6
4
2
0
0
200
400
600
800
1000
1200
Flow (cfs)


Little Manatee near Wimauma, FL
Potassium (mg/L K)
10
9
8
7
6
5
4
3
2
1
0
Jan-50
Jan-60
Jan-70
Jan-80
Jan-90
Jan-00
Jan-10


Little Manatee near Wimauama, FL
Potassium (mg/L K)
10
9
8
7
6
5
4
3
2
1
0
0
2000
4000
6000
8000
10000
12000
Flow (cfs)

Vegetation Appendix

Characterization of Woody Wetland Vegetation Communities along the Little Manatee River

DRAFT

February 2008

Submitted to

Southwest Florida Water Management District

Submitted by

PBS&J

5300 West Cypress Street

Tampa, Florida 33607

Executive Summary

The purpose of this study was to characterize relationships among vegetation, soils, and elevation in wetlands along the Little Manatee River and assist the Southwest Florida Water Management District (District) in establishing MFLs for the river. Vegetation classes, plant species importance, soil characteristics, and elevations were evaluated for 10 transects along the Little Manatee River study corridor. The study corridor extended approximately 12 miles downstream of State Road (S.R.) 64 to just downstream of U.S. Highway 301.

Vegetation. Differences in vegetation classes along the Little Manatee River study corridor were significant based on importance values (IVs) that were calculated using tree species density, basal area, and frequency, and provided a relative measure of species dominance (no units). Three wetland vegetation classes were identified in the study corridor. The classes included only obligate and facultative wetland tree species, including Carolina willow (*Salix carolinana*), tupelo (*Nyssa sylvatica*), sweet bay or swamp bay (*Magnolia virginiana*), water oak (*Quercus nigra*), and popash (*Fraxinus caroliniana*). These classes (below) included six or fewer species.

- Willow marsh: comprised exclusively of the obligate wetland species Carolina willow, with smaller components of popash and holly (*Ilex cassine)*.

- Tupelo swamp: characterized by only two tree species, primarily swamp tupelo (obligate wetland species), in addition to a small component of slash pine (*Pinus elliottii*) (facultative wetland species).

- Hardwood swamp: included six species and characterized by predominantly swamp bay (obligate) and water oak (facultative wetland).

Transition vegetation classes (between wetlands and uplands) were characterized by predominantly facultative wetland species such as laurel oak (*Q. laurifolia*) and slash pine in combination with other facultative species. The transition classes included laurel oak/ pine hammock, pine/ laurel oak hammock, pine/ maple hammock, and laurel oak hammock vegetation classes. These classes were composed of six to 23 different species. Species in the two upland classes included primarily the facultative cabbage palm (*Sabal palmetto*) and the upland scrub hickory (*Carya glabra*). Total numbers of species in the upland classes ranged from six to 11. The upland classes were palm hammock and oak scrub.

Species IVs for the 29 tree species in the nine vegetation classes indicated a shift in importance from willows, tupelo, and sweet bay to laurel oak and slash pine to scrub oak and sand pine coincided with a gradual transition from wetland to upland vegetation classes. Overall trends in species dominance and diversity are summarized below.

- Laurel oak, slash pine, tupelo, and Carolina willow made up approximately 56 percent of the total IVs (by species) among all classes. Cabbage palm, water oak, popash, live oak, and scrub hickory made up approximately 29 percent of the total IVs by species. The remaining 20 species made up approximately 28 percent of the total IVs.

- Laurel oak occurred in seven of the nine vegetation classes. Slash pine and live oak (*Q. virginiana*) were in five classes. The remaining 26 species occurred in five or fewer vegetation classes.

- The oak hammock class had the largest number of tree species (23). The total number of tree species in other classes ranged from two to 15. The laurel oak hammock class also had the largest total basal area (35,718 in^2/acre) and lowest density (approximately 12 trees/acre), indicating older stands of larger trees.

- The willow marsh and tupelo swamp had the highest tree densities (90 and 135 trees/acre, respectively), and relatively low total basal areas (3,743 and 19,215 in^2/acre, respectively), indicating younger trees.

- Laurel oak (21,099 in^2/acre) in the laurel oak hammock class and tupelo (19,010 in^2/acre) in the tupelo swamp class had the highest basal areas of any other tree species in any other vegetation class. The remaining seven vegetation classes had 50 trees/acre or less.

Elevations and Soils. River channel elevations declined from 38.0 feet NGVD at the most upstream transect to 0.1 feet NGVD at the transect farthest downstream, a decline of just over 38 feet over about 12 miles (0.3 feet/mile). In contrast, elevation changes along transects ranged from 11.6 to 22.8 feet over a half mile or less (22.4 feet/mile). The median elevation along the most upstream transect was 46.5 feet NGVD, about 36.5 feet higher than the median elevation at the most downstream transect (10.0 feet NGVD). Changes in elevation along the two most upstream transects were only 11.6 to 12.8 feet, while elevation changes along the more downstream transects ranged from to 16.6 feet to 22.8 feet.

Changes in vegetation were more conspicuous along transects than along the upstream – downstream river channel gradient and may reflect the steeper elevation change along transects when compared with the upstream to downstream elevation gradient. Wetland vegetation communities occurred along the three upstream and three downstream transects and were absent along the four mid-reach transects.

Median elevations among wetland vegetation classes ranged from 10.1 to 7.3 feet NGVD and ranged from 7.6 to 11.9 feet NGVD in transition vegetation classes. Elevations ranged from 7.4 to 17.7 feet NGVD in the two upland classes. Median relative elevations of vegetation classes were often, but not always, lower for the willow marsh, tupelo swamp, and hardwood swamp when compared with other communities along a transect.

Hydric soils were found along nine of the 10 study transects and in all vegetation classes except the scrub oak class. Muck soils were found at all transects. The tupelo swamp and hardwood swamp classes were the only classes with exclusively hydric soils. Median elevations of hydric soils were lower when compared with nonhydric soils and elevation differences between hydric and nonhydric soils ranged from 0.3 to 0.9 feet at the two most upstream transects to a difference of about seven feet at mid-reach transects (VEG10, VEG2, LMAN6) to a difference of about three feet at the two most downstream

transects. Both hydric and nonhydric conditions occurred in many vegetation classes, although hydric soils consistently occurred at lower elevations when compared with nonhydric soils in all but one instance (laurel oak hammock class).

Discriminant Function Analysis (DFA). DFA was used to measure the contribution of elevation, distance from river channel, and soil parameters in characterizing vegetation classes along the Little Manatee River study corridor. Vegetation classes were classified correctly 40 percent of the time for willow marsh and 100 percent of the time for tupelo and hardwood swamp classes (willow marsh was classified incorrectly more frequently than correctly). Transition vegetation classes were correctly classified in 13.5 to 80 percent of the cases. The two upland classes were classified correctly in 88.9 and 66.7 percent of the cases. Overlap among classes was greatest among classes that were sampled less frequently, had greater variability in species, and occurred along more transects.

Vegetation classes were distinct in terms of species composition and IV, and environmental variables were significant in accounting for differences between vegetation classes. Elevations, relative elevations along transects, distance from channel, and hydric soil index were significant in separating vegetation classes from each other, although overlap in environmental parameters between vegetation classes was frequent. Correlations between environmental variables and vegetation class were not strong. However, relative elevation was more strongly correlated with vegetation class ($r^2 = 0.32$) when compared with soils ($r^2 = 0.29$), and distance to channel ($r^2 = 0.28$), and elevation ($r^2 = 0.23$), respectively.

Wetted Perimeter. There was no consistent steep increase in cumulative wetted perimeter (inundated habitat) coincident with a particular shift in vegetation classes along the Little Manatee River transects. The sigmoid-shaped curve generally associated with corresponding changes in habitat and elevation was apparent along six of the 10 study transects, but wetland classes did not consistently align with a particular portion of the curve. These characteristics reflect the variation in habitat, from an incised channel through uplands to broader floodplain areas that occur along the Little Manatee River.

Conclusions. Nine distinct vegetation classes were identified along the Little Manatee River study corridor based on woody species composition and IV. Soils, elevations, and distances from river channel were significantly related to vegetation classes, but not highly correlated. Willow marsh, tupelo swamp, and hardwood swamp vegetation classes generally occurred at lower elevations on hydric and/or saturated soils in contrast with the upland palm hammock and oak scrub vegetation class. However, wetland vegetation classes were encountered along only four of the ten transects, while each of the remaining six vegetation classes occurred along three or more transects. Based on the results of this study, only the tupelo swamp and hardwood swamp vegetation classes may provide a criterion on which to establish MFLs for vegetation communities along the Little Manatee River.

Wetland systems are not well developed along the Little Manatee River and minimum flows that rely on fish passage will likely include a small extent of wetlands in the river corridor. No cypress wetlands were encountered along the river channel during the vegetation studies, and the three wetland classes sampled are characterized by species less tolerant of flooding than cypress.

Table of Contents

Section *Page Number*

Executive Summary Error! Bookmark not defined.

Table of Contents Error! Bookmark not defined.

1.0 Purpose ..... Error! Bookmark not defined.

2.0 Background ..... Error! Bookmark not defined.

2.1 Physiography ..... **Error! Bookmark not defined.**

2.2 Climate and Precipitation ..... **Error! Bookmark not defined.**

2.3 Surface and Ground Water ..... **Error! Bookmark not defined.**

2.4 Surface Water ..... **Error! Bookmark not defined.**

2.5 Ground Water ..... **Error! Bookmark not defined.**

2.6 Topography and Soils ..... **Error! Bookmark not defined.**

2.7 Vegetation ..... **Error! Bookmark not defined.**

2.8 Issues ..... **Error! Bookmark not defined.**

3.0 Sampling Methods ..... Error! Bookmark not defined.

3.1 Transect Selection ..... **Error! Bookmark not defined.**

3.2 Elevation Surveys and Distance to Channel ..... **Error! Bookmark not defined.**

Vegetation Characterization ..... **Error! Bookmark not defined.**

3.3 Soils Characterization ..... **Error! Bookmark not defined.**

3.4 Data Analysis ..... **Error! Bookmark not defined.**

3.4.1 Elevations and Wetted Perimeter ..... **Error! Bookmark not defined.**

3.4.2 Vegetation and Soils ..... **Error! Bookmark not defined.**

4.0 Results and Discussion ..... Error! Bookmark not defined.

4.1 Elevations ..... **Error! Bookmark not defined.**

4.2 Soils ..... **Error! Bookmark not defined.**

4.3 Vegetation Relationships ..... **Error! Bookmark not defined.**

4.4 Vegetation Classes ..... **Error! Bookmark not defined.**

4.4.1 Elevations and Vegetation Classes ..... **Error! Bookmark not defined.**

4.4.2 Soils, Distance to Channel, and Vegetation Classes **Error! Bookmark not defined.**
4.4.3 Discriminant Function Analysis (DFA)..... **Error! Bookmark not defined.**
4.4.4 Wetted Perimeter ..... **Error! Bookmark not defined.**
4.5 Relationship of Vegetation with Environmental Variables **Error! Bookmark not defined.**

5.0 Conclusions ..... Error! Bookmark not defined.

6.0 Relevant Literature ..... Error! Bookmark not defined.

Appendix A Elevation and Vegetation Profiles for the Anclote River Study Corridor Error! Bookmark not de

Appendix B Wetted Perimeter Graphs for the Little Manatee River Study Corridor Error! Bookmark not def

Appendix C Photographs from the Little Manatee River Study Corridor Error! Bookmark not defined.

List of Tables

Table 3-1 Percent Cover of NWI Classes in the Little Manatee River Study Corridor**Error! Bookmark not defined.**

Table 3-2 Descriptions of Florida NWI Classifications in the Little Manatee River Study Corridor..... **Error! Bookmark not defined.**

Table 3-3 Percent Cover by NWI Class and Transect in the Little Manatee River Study Corridor..... **Error! Bookmark not defined.**

Table 4-1 Elevation and Distance along the Little Manatee River Transects**Error! Bookmark not defined.**

Table 4-2 Median Elevations (feet NGVD) of Hydric, Muck, and Saturated Soils along Transects in the Little Manatee River Study Corridor * ..... **Error! Bookmark not defined.**

Table 4-2 Median Elevations (feet NGVD) of Hydric, Muck, and Saturated Soils along Transects in the Little Manatee River Study Corridor * ..... **Error! Bookmark not defined.**

Table 4-3 Wilcoxon Signed Rank Test (S Values) for Comparisons between Vegetation Classes along the Little Manatee River Study Transects..... **Error! Bookmark not defined.**

Table 4-4 Importance Values for Tree Species in Vegetation Classes along the Little Manatee River Study Corridor* ..... **Error! Bookmark not defined.**

Table 4-5 Basal Area and Density* in Vegetation Classes along the Little Manatee River Study Corridor..... **Error! Bookmark not defined.**

Table 4-6 Basal Area and Density of Tree Species in Vegetation Classes along the Little Manatee River Study Corridor..... **Error! Bookmark not defined.**

Table 4-7 Percent Composition of Vegetation Class along the Little Manatee River Transects***Error! Bookmark n**

Table 4-8 Median Elevation (NGVD) of Vegetation Classes along the Little Manatee River Transects* ..... **Error! Bookmark not defined.**

Table 4-9 Median Relative Elevation (feet above channel bottom), of Vegetation Classes along the Little Manatee River Transects* ..... **Error! Bookmark not defined.**

Table 4-10 Median Elevations (feet NGVD) of Hydric Soils by Vegetation Class along the Little Manatee River Study Corridor*..... **Error! Bookmark not defined.**

Table 4-11 Median Values of Parameters Used in DFA for Vegetation Classes along the Little Manatee River Study Corridor..... **Error! Bookmark not defined.**

Table 4-12 DFA Results for Vegetation Classifications* ..... **Error! Bookmark not defined.**

Table 4-13 Wetted Perimeter (linear feet), by Vegetation Class and Transect, along the Little Manatee River Study Corridor..... **Error! Bookmark not defined.**

Table 4-14 Typical Hydrology, Soils, and Species Composition in Floodplain Communities in the Southeastern U.S..... **Error! Bookmark not defined.**

List of Figures

Figure 1-1 Location of the Little Manatee River Study Corridor in Hillsborough County, Florida**Error! Bookmark n**

Figure 2-1 Total Annual Rainfall for the Little Manatee River (Wimauma Gage)**Error! Bookmark not defined.**
Figure 2-2 Annual Mean Daily Stream Flows for the Little Manatee River (Wimauma Gage)**Error! Bookmark not defin**
Figure 2-3 Transect Locations and Soils along the Little Manatee River Study Corridor**Error! Bookmark not define**

Figure 3-1 Distinguishing Features and Examples of Habitats in the Palustrine System**Error! Bookmark not defined**
Figure 3-2 Transect Locations and Vegetation along the Little Manatee River Study Corridor (based on data from the NWI) ..... **Error! Bookmark not defined.**

Figure 4-1 Channel Bottom, Maximum, and Median Elevations along Transects in the Little Manatee River Study Corridor..... **Error! Bookmark not defined.**
Figure 4-2 Elevation and Vegetation Profile along the Masonic Transect in the Little Manatee River Study Corridor ..... **Error! Bookmark not defined.**
Figure 4-3 Median Elevations of Hydric and Nonhydric Soils along the Little Manatee River Study Corridor ..... **Error! Bookmark not defined.**
Figure 4-5 Basal Area and Density for Vegetation Classes along the Little Manatee River Study Corridor..... **Error! Bookmark not defined.**
Figure 4-6 Median Elevations of Vegetation Classes along Transects in the Little Manatee River Study Corridor ..... **Error! Bookmark not defined.**
Figure 4-7 Median Relative Elevations of Vegetation Classes along Transects in the Little Manatee River Study Corridor..... **Error! Bookmark not defined.**
Figure 4-8 Percent Correct Classifications of Vegetation Classes along the Little Manatee River Study Corridor ..... **Error! Bookmark not defined.**
Figure 4-9 Wetted Perimeter and Associated Median Elevations along the Masonic Transect in the Little Manatee River Study Corridor ..... **Error! Bookmark not defined.**
Figure 4-9 Wetted Perimeter and Associated Median Elevations along the Masonic Transect in the Little Manatee River Study Corridor ..... **Error! Bookmark not defined.**

Purpose

The statutory directive for minimum flows and levels (MFLs) included in the Water Resources Act was enacted by the Florida Legislature in 1972. Section 373.042 F.S. of the Act directs each water management district to establish MFLs for surface water bodies, watercourses, and aquifers within their respective jurisdictions. Under the statute, the minimum flow for a given watercourse is defined as the limit at which further withdrawals would be "significantly harmful" to the water resources or ecology of the area. In addition, the determination of MFLs must be based on the "best available" information.

The purpose of this study was to characterize relationships among vegetation, soils, and elevation in wetlands along a portion of the Little Manatee River (Figure 1-1). Given the assumption that vegetation is a good and easily measured integrator of environmental and historical site conditions, vegetation, soils, and elevation will be used to support the Southwest Florida Water Management District (District) in establishing MFLs for the Little Manatee River.

Instream flows are important to maintaining a functional river or stream system, fish and wildlife habitat, recreation, navigation, and consumptive uses such as irrigation and domestic water supply. MFLs are intended to guide water resource and water supply development to ensure water resource sustainability for people and the natural environment. They will also be used to assist in making water use and other permitting decisions. In summary, MFLs are being established to:

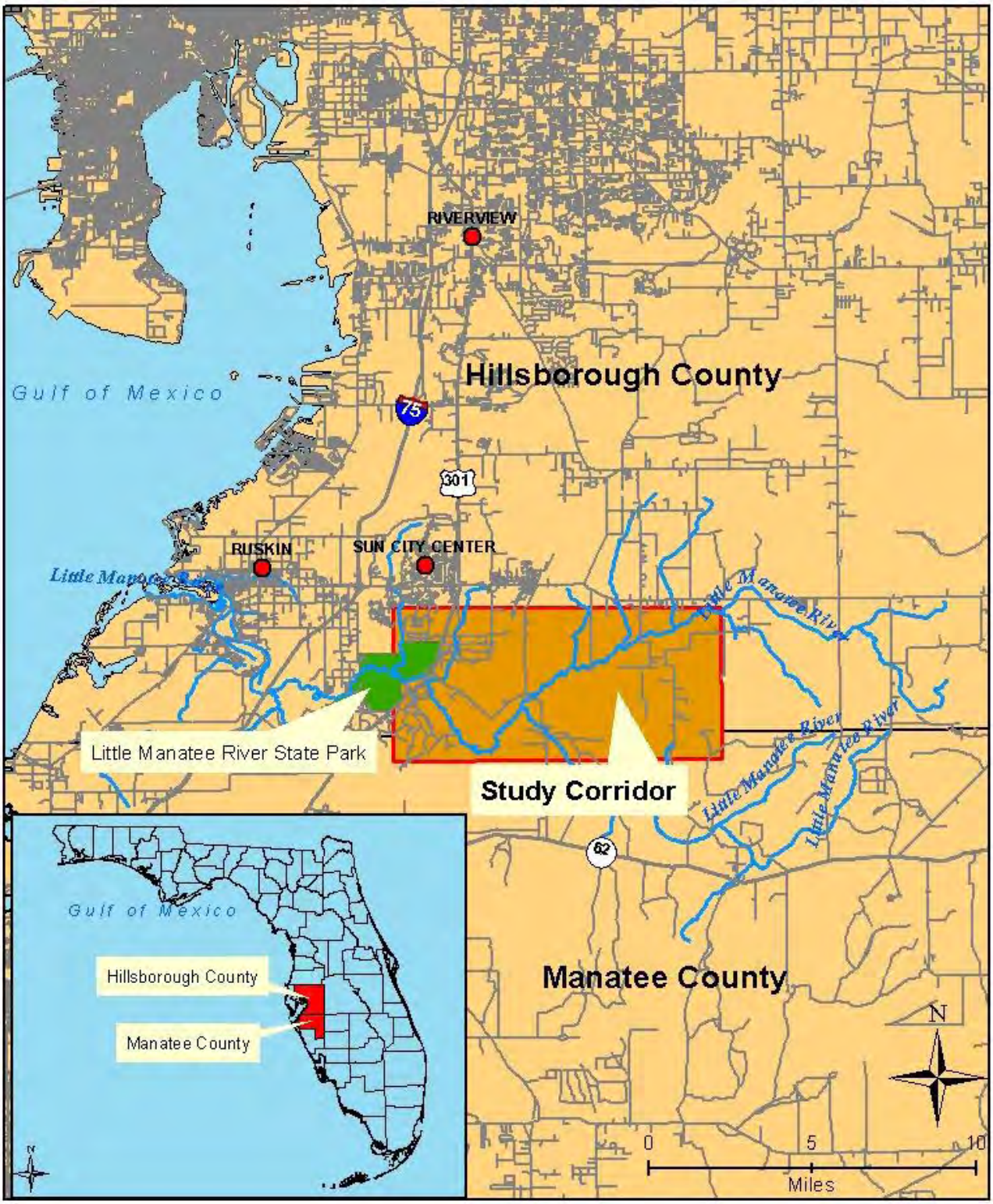
- Address Florida Statute 373.042(1)(a)&(b)
- Protect water resources and ecology
- Determine water availability

The District Governing Board has the final authority to set MFLs within its jurisdiction, using several guidelines provided by the state (and listed below).

- Using the best information available
- When appropriate, setting MFLs to reflect seasonal variations
- Considering the protection of non-consumptive uses of water (e.g. recreation)

This report presents the relationships among vegetation and physical factors, such as elevation and soils that characterize the Little Manatee River study corridor and may be used in establishing MFLs for vegetation communities.

Figure 1-1
Location of the Little Manatee River Study Corridor
in Hillsborough County, Florida



• Background

The Little Manatee River flows west about 40 miles from its headwaters east of Fort Lonesome in southeastern Hillsborough County before emptying into Tampa Bay near Ruskin. The main channel of the Little Manatee River begins at the confluence of the North and South Fork tributaries about 22 miles upstream of the river mouth. The North Fork, however, is often referred to and considered an extension of, the Little Manatee River, while the South Fork is considered a separate tributary. Several smaller tributaries also flow into the Little Manatee River, including Dug, Cypress, and Carlton Branch creeks.

The tidal reach of the Little Manatee River extends approximately 15 miles upstream from the river mouth (SWFWMD 1988a) to approximately one mile upstream of U.S. 301 (Fernandez 1985). The channel ranges in width from approximately 4,000 feet at Shell Point at the mouth of the river to 400 feet at U.S. 41, and narrows to 40 to 150 feet at U.S. 301.

The Little Manatee River watershed includes 222 square miles in southern Hillsborough County and northern portion of Manatee County and includes the City of Palmetto and the communities of Parrish, Ruskin, Sun City, Wimauma, and Terra Ceia. Port Manatee is a port/industrial facility on Manatee County's northern coastline. In terms of port activity, the facility is the fifth largest in the state of Florida (Bureau of Economic and Business Research (BEBR 2001).

The Little Manatee River State Park is located just downstream (east) of U.S. 301 and the Cockroach Bay Aquatic Preserve is located at the mouth of the river. Lake Wimauma, in the central portion of the watershed, and Carlton Lake, in the eastern portion of the watershed, are the only naturally occurring lakes in the Little Manatee River watershed. Lake Parrish is a 3,500 acre cooling reservoir for the Florida Power and Light (FPL) facility and is located about 1.5 miles downstream of the confluence of the South Fork of the Little Manatee River.

Land uses along the downstream reaches of the Little Manatee River are predominantly row crops and residential land uses and smaller areas of commercial and industrial land uses. Farther upstream, urban development includes high density residential associated with Sun City and Lake Wimauma. The upper reaches of the Little Manatee River include primarily agricultural uses such as pasture and crop lands, while phosphate mining dominates the far eastern portion of the watershed.

○ Physiography

The Little Manatee River watershed occurs across three physiographic provinces: the Gulf Coastal Lowlands, DeSoto Plain, and the Polk Upland (White 1970). The lower portion of the watershed flows over the relatively flat plains of the Gulf Coastal Lowlands province and DeSoto Plain that extend eastward with a gentle slope upward to the border with the Polk Upland physiographic province. The western edge of the Polk Upland is defined by the presence of the first of several paleoshoreline scarps associated with the Pleistocene ice-age sea level fluctuations. This physiographic feature is known as the

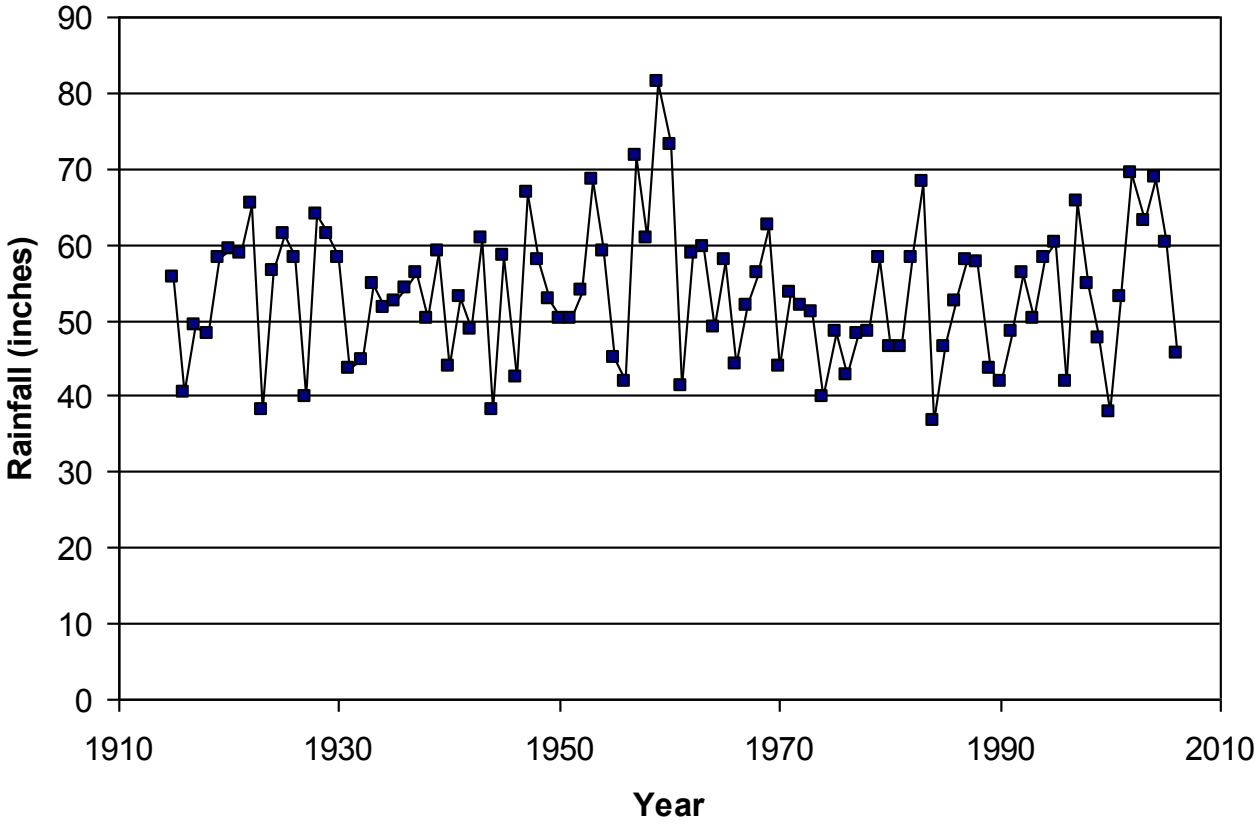
Pamlico Scarp or shoreline (Healy 1975). Elevations in the Gulf Coast lowlands and DeSoto Plain range from sea level to 50 feet.

Elevations in the Little Manatee River watershed are lower and range between 25 and 75 feet. In the vicinity of Wimauma, sand bluffs along the river may reach 75 feet in elevation. Near the town of Fort Lonesome, the river flows over the Bone Valley Member of the Peace River formation. This is the lithologic unit mined for phosphate minerals in the eastern part of the Little Manatee River watershed. The floodplain here has less topographic relief when compared with the mid-reaches of the river and is characterized by scattered wetlands.

○ Climate and Precipitation

The annual average precipitation in the Little Manatee River near Wimauma for the period 1915-2006 was 53.24 inches. The lowest rainfall was 36.70 inches for the year 1984 and 81.45 in 1959 (SWFWMD Water Management Database) (Figure 2-1). Evapotranspiration the Little Manatee River watershed and surrounding areas is approximately 39 inches per year (SWFWMD 1994) and is highest in May and June and nearly 60 percent of the total yearly evapotranspiration occurs between May and October.

Figure 2-1
Total Annual Rainfall for the Little Manatee River (Wimauma Gage)



Climate conditions in west-central Florida are humid subtropical climate. The mean normal yearly temperature for Hillsborough County is 72.2 ^{o}F, generally ranging from a normal maximum temperature of 91 ^{o}F in July and August, to a normal minimum temperature of 49 ^{0}F in January. In a typical year, approximately 60 percent of the annual precipitation comes from convective thunderstorms during the four-month period between June through September. Heavy precipitation periods associated with the passage of tropical low pressure systems occur during summer and early fall.

○ Surface and Ground Water

Water supply issues in the Little Manatee watershed include ground water use, surface water use, development of alternative water supplies, and establishment of minimum flows and levels. Alternative water supply sources are being developed in the Tampa Bay region as part of an approach to reduce/supplement existing ground water supplies and alleviate pressure on the aquifers. Water projects currently being developed in the Tampa Bay region to address future water supply include diverting flows from the Alafia and Hillsborough rivers and the Tampa Bypass Canal, as well as the construction of a reservoir in the Alafia River watershed. The desalination facility adjacent to the Tampa Electric Company (TECO) Big Bend facility in southern Hillsborough County began operation in March 2007.

○ Surface Water

The Little Manatee River is considered the least impacted of the rivers flowing into Tampa Bay. Among the rivers in west central Florida, the Alafia and Little Manatee Rivers have the highest rates of surface water runoff because of soil characteristics and topographic gradients in the respective watersheds (Estevez et al. 1991). There are no records of springs in the Little Manatee River watershed and stream flow and water quality data indicate that dry season flows are significantly supplemented by farm irrigation that is pumped from deep aquifers.

Mean annual flow in the Little Manatee River recorded at the United States Geological Survey (USGS) gage near Wimauma was 171.4 cfs for the period of record from 1940 to 2006 and ranged from about 100 cfs to 300 cfs. Mean annual flows were less than 100 cfs in only 11 of the 67 years measured and exceeded 300 cfs except in 1959, 1960, 1998, and 2003. The highest recorded mean annual flow was 410 cfs (in 1959) and the lowest mean annual flow was 40.2 cfs (1956). Average annual flows measured at the Wimauma gage are graphed in Figure 2-2.

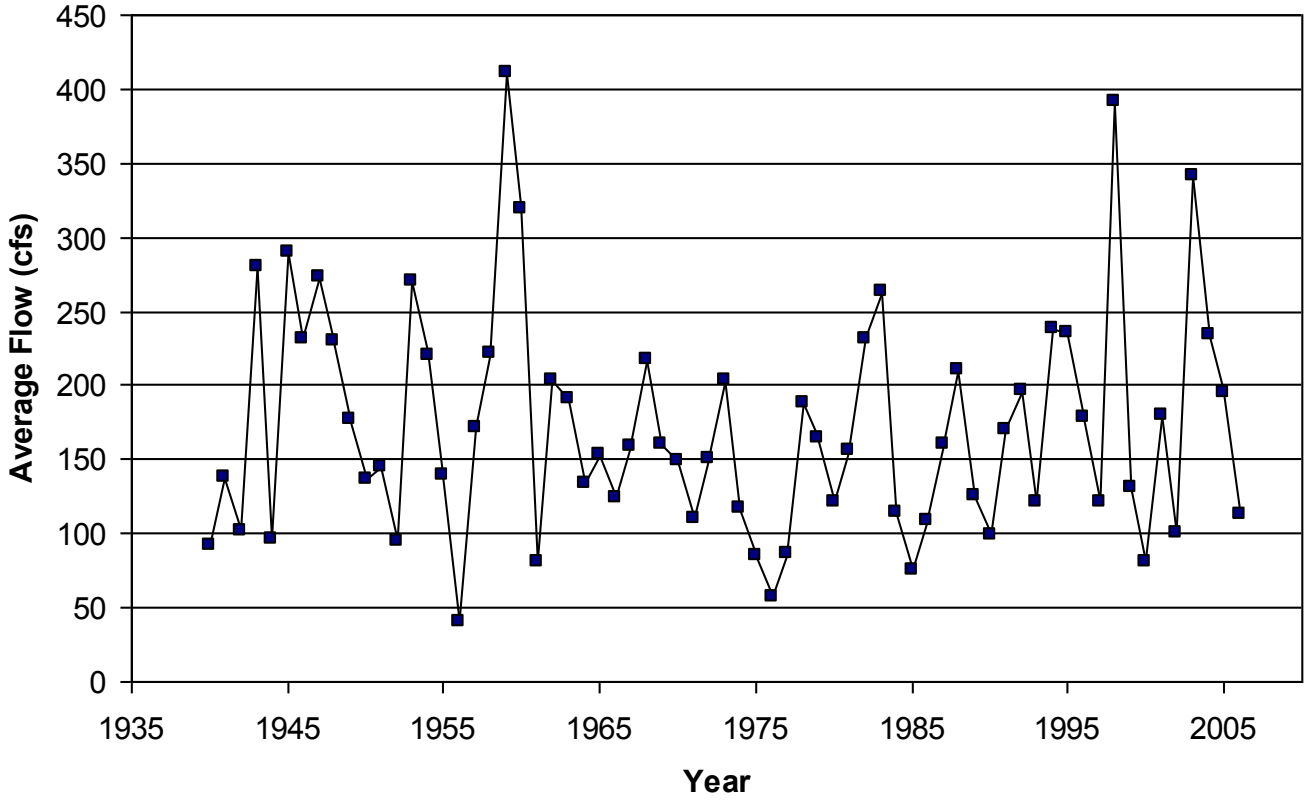
Except for the most upstream portions of the Little Manatee River, the river channel is well-defined, becoming narrow and well-incised along the North and South forks. At the U.S. 301 gage, 15 miles upstream of the river mouth, the river bottom is less than two feet NGVD. About 22 miles upstream, elevations reach 100 feet NGVD. The hydraulic gradients along the tributaries and upstream of U.S. 301 are much steeper when compared with the gradual slope and tidal influence in the river that occur downstream of U.S. 301.

Low recharge to the aquifer in the Little Manatee River and watershed results in relatively large flows during short periods of time due and makes the system “flashy”. Stream flow records and associated land use influences suggest that agricultural practices have increased flows in the river due to excessive

irrigation of row crops that subsequently flows off the land and into the river. In contrast, total annual discharge from the watershed decreased from the 1960s to 1990 and coincided with reduced rainfall in southwest Florida. Also as a result of the low recharge, there are few lakes and wetlands in the Little Manatee River watershed below the upper reaches.

The Little Manatee River below State Road 674 has been designated as an Outstanding Florida Water. As such, special permitting criteria are used by the Florida Department of Environmental Protection for activities that might impact the water quality of the river. This section of the river below U.S. Highway 301 is also designated as an aquatic preserve, which has implications for various types of activities on and along the river.

Figure 2-2
Annual Mean Daily Stream Flows for the Little Manatee River (Wimauma Gage)



- **Ground Water**

The Little Manatee watershed is underlain by water-bearing limestones and dolomites of Eocene to Miocene age and covered by a 200-300 foot layer of unconsolidated sands and sandy clays of Pliocene, Pleistocene and Recent origin. The watershed is in the southern ground water basin, and includes the surficial, intermediate and Floridan aquifers. The surficial aquifer is unconfined and varies in composition from clean quartz to clayey sand (Upchurch 1985). The underlying intermediate aquifer is made up of permeable lithologies in the Hawthorne Group, including the lowermost limestone unit (Tampa Member). The intermediate aquifer is a locally important potable water source for domestic wells.

The average thickness of the Floridan aquifer system is approximately 1,100 feet in the Little Manatee River watershed area (Wolansky and Thompson 1987) and is the potable water source for most of the watershed. In the coastal areas, the Floridan aquifer contains high total dissolved solids and is less desirable for potable water and for some agricultural purposes. The surficial aquifer is usually unconfined. Depth to the water table ranges from near land surface along the coast and in flat poorly drained areas to as many as ten feet below land surface on higher sand ridges (SWFWMD 1992). Seasonal fluctuations in the water table are generally less than five feet and are lower in the spring and higher in the summer.

The Upper Floridan aquifer is the principal water bearing unit in the region and ranges from 1,200 to 1,300 feet thick along the Little Manatee River. The Hawthorn Formation forms a clay confining unit approximately 75 to 150 feet thick that restricts the downward movement of water from the surficial layer to the Upper Floridan aquifer and limits recharge to the Upper Floridan aquifer. Karst activity is also limited and few sinkholes and no springs have been identified in the watershed, although artesian flow in coastal wells was apparently common in the past (CBAPMP 1999).

The Little Manatee River is included in the Southern Water Use Caution Area (SWUCA) designated by the SWFWMD based on declines in ground water. Declines in ground water potentiometric surfaces in southern Hillsborough County and northern Manatee County over the past decades have been attributed to a combination of rainfall deficit, low natural recharge, and increased consumptive use.

Agriculture has the largest number of ground water withdrawal permits in the watershed and ground water withdrawals in the southeastern portion of the watershed are primarily used for phosphate mining and associated activities.

○ Topography and Soils

Land surface elevations near the headwaters of the Little Manatee River reach about 125 feet NGVD. Immediately to the west, much of the drainage system crosses a small northern lobe of the DeSoto Plain, and the lower third of the watershed lies in the Gulf Coast Lowlands, where elevations range from sea level to 50 feet NGVD. The two principal tributaries of the river are narrow and well incised, as described previously. The average channel slope for the northern tributary is 0.13 percent in the Fort Lonesome area. Near the USGS stream gauge at U.S. 301, the channel slope of the river becomes gentler and minor tidal fluctuations are observed at the gauge during low flow periods. Along the lower 10 miles, the river channel and floodplain are much wider. Tidal creeks, bayous, and mangrove-dominated islands become prevalent in this river section. Western portions of the watershed are characterized by

floodplains that are nearly level to level and gently sloping, while higher, gently rolling areas characterize the central and eastern portions.

Soils in the watershed are typically poorly drained sandy soils with an organic pan that impedes vertical water infiltration and account for the high runoff potential in the Little Manatee River watershed. About 90 percent of the soils have a B/D, C, or D hydrologic soils group (HSG) classification, indicating runoff rather than infiltration. Primary soil associations in the Little Manatee River watershed include the Myakka-Urban land-St. Augustine and Estero-Wulfer-Kesson associations in the coastal areas. These are nearly level, poorly drained black soils commonly found in swamps, tidal marshes and river floodplains. Inland, the prevalent soil types are the EauGallie-Floridana, Myakka-Basinger-Holopaw, Malabar-Wabasso-Bassinger, Myakka Immokalee-Pomello, Myakka Waveland and Waveland-Pomello-Myakka associations. These associations include nearly level and poorly to moderately drained soils characteristic of flatwood areas (USDA/SCS 1983 and 1959).

○ Vegetation

Natural vegetation along the freshwater portion of the Little Manatee River is often characterized by forested swamps along the banks and floodplain transition to hydric and mesic forests of mixed hardwoods and pine. Landward of these, pine flatwoods and scrub and brushlands are common (SWFWMD 1992).

The study area for the District's Resource Evaluation of the Little Manatee River Project for the Save our Rivers (SOR) Program (SWFWMD 1992) begins just down stream of U.S. 301 and extends upstream almost to S.R. 674 and includes the South Fork of the Little Manatee River. Coincidentally, the study corridor for the present area falls within the SOR study area. The SOR report describes the river corridor as predominantly uplands (about 74 percent). Uplands include primarily cropland and pastureland (about 16 percent) and relatively unaltered uplands (16 percent). Uplands include pine flats, shrub and brush lands, and mixed hardwoods and pines.

Forested wetlands and open water and non-forested wetlands make up about 27 percent of the Little Manatee River corridor. Forested wetlands along the river itself include water oaks (*Quercus nigra*), red maple (*Acer rubrum*), sweet gum (*Liquidambar styraciflua*), willows (*Salix* spp.), bays (*Magnolia virginiana* and *Persea palustris*), pop ash (*Fraxinus caroliniana*), and hickories (*Carya* spp.). The understory is usually sparse due to low light penetration. Wet prairies are infrequent to absent in the watershed.

Several agencies have land-acquisition programs in the Little Manatee River watershed, including the Department of Environmental Protection's Conservation and Recreational Lands program, the District's Save Our Rivers and Florida Forever (formerly Preservation 2000 (P2000)) program, and Hillsborough County's Environmental Lands Acquisition and Preservation Program. Some areas along the river corridors have been purchased for flood control, water quality, and habitat protection. Typically, these programs emphasize preservation of natural systems and enhancement/ preservation of water quality. These areas are often flood prone and acquisition serves to prevent development in these natural flood storage areas.

○ Issues

Water supplies for primarily agricultural uses, but also for industrial and municipal uses, have been an issue in recent decades due to increased populations and declining water supplies. Consequently, the watershed is an area of induced recharge due to intense agricultural pumping demands. Ground water withdrawals from the upper Floridan aquifer have lowered the potentiometric surface and intermediate aquifer, creating an induced recharge area. Consequently, special regulatory measures have been developed for the Southern Water Use Caution Area (SWUCA), including the Little Manatee River watershed. Parts of the Little Manatee River watershed are also within the Most Impacted Area (MIA), an area in the SWUCA where no new Floridan aquifer withdrawals are allowed. The SWUCA Information Report provides a concise summary of the history, current conditions and future plans for the SWUCA within the District.

The shift to induced recharge also increases the potential for ground water contamination. The degree of ground water contamination potential in areas of induced recharge depends on both hydrogeologic properties and the rate of ground water withdrawal. Potential pollutant sources in the Little Manatee River watershed include landfills, borrow pits, mining activities, stormwater ponds, septic systems, and urban and agricultural runoff. A detailed discussion of the potential for ground water contamination from man-made byproducts in the Tampa Bay area is presented by SWFWMD (1995).

Surface water use in the watershed, in contrast to ground water, is limited primarily to a permitted withdrawal from the river by FPL. The principal studies related to surface water supplies from the Little Manatee River pertain to the FPL facility. Studies to assess the feasibility of withdrawing cooling water from the Little Manatee River were conducted in the early and mid- 1970s (Brown and Root 1973, FPL 1979) and focused on the impacts of the proposed conversion to orimulsion fuel. The use of orimulsion was not approved by the Florida Cabinet, however, and the findings of the studies were not considered relevant to the existing permit. Consequently, the FPL withdrawal schedule remains as it was initially permitted in 1973.

A hydrobiological study of the Little Manatee River conducted in the late 1980s identified increasing base flow in the main river channel and some tributaries and attributed the increase to excess irrigation water not used by crops (Flannery *et al*. 1991). These findings suggest that there is a considerable amount of water savings that can be accomplished in the watershed through the use of more efficient agricultural water use practices.

• Sampling Methods

An underlying assumption of vegetation classification is that vegetation is the best and most easily measured integrator of environmental and historic site conditions. Sampling methods for this study were designed to provide data needed to characterize the wetlands and associated vegetation and soils along the Little Manatee River. The methods used in transect selection, data collection, and data analyses are described in the following sections.

○ Transect Selection

Ten sampling transects were established along the Little Manatee River study corridor, perpendicular to the river channel, as requested by the District. The first step in assigning transect locations was a thorough review of potential criteria on which to base the selections. The data used to examine potential criteria for selecting transects are listed below.

- Vegetation communities based on NWI and Florida GAP vegetation classification
- U.S. Department of Agriculture/ Soil Conservation Service (SCS) soils classifications and Hydric Soils Groups
- USGS elevation/topography
- USGS water level gage locations
- Aerial photography
- Land use, e.g. historical alterations

NWI and GAP classifications were compared with available aerial photography, soils maps, and field observations. NWI classes were more consistent with aerial photography than GAP classifications in the study corridor, and priority communities were identified in which sampling efforts would be focused. NWI data were subsequently used for mapping and selecting transects. Numbers of acres and corresponding percent of NWI classes in the Little Manatee River study corridor are listed in Table 3-1. A diagram of the distinguishing features of the NWI palustrine vegetation classes are presented in Figure 3-1 for illustrative purposes and are further described in Table 3-2.

Transects and associated NWI vegetation classes for river reaches are mapped in Figure 3-2. Transects were initially numbered in order from upstream to downstream and designated with a prefix of PHABSIM or VEG to identify the transect consistent with the District's instream transects or PBS&J's wetland transects. However, several transects were omitted, added, and/or replaced due to access issues, disturbance, or other issues. Added transects were subsequently assigned the prefix LMAN (Little Manatee transect) or VEG (vegetation transect) and two were named for nearby features (for example, the transect "Masonic" is in the vicinity of Masonic Park).

An analysis of the NWI vegetation classes was used as the basis on which to allocate transects among vegetation communities along the river channel. Corridors 500 feet wide were used to quantify the vegetation classes along each transect and identify the dominant vegetation classes along transects. The

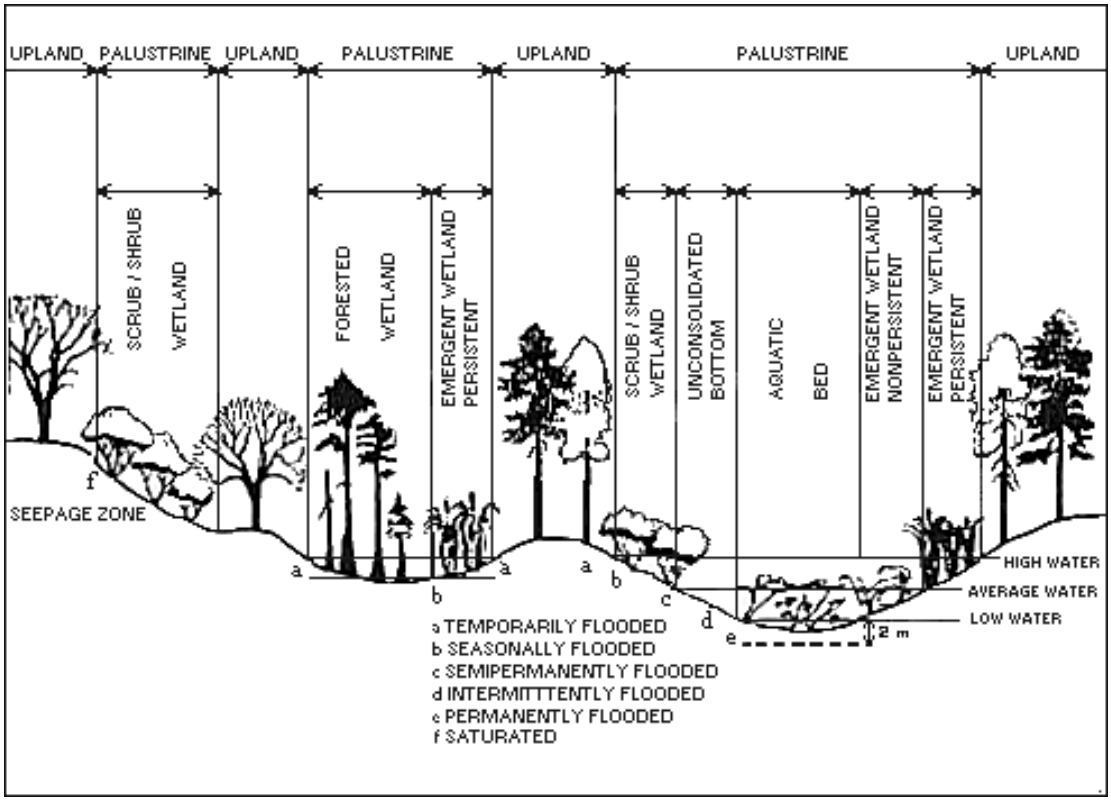
percent of each NWI vegetation class present along the 10 sampling transects are listed in Table 3-3. Potential transects were assigned in areas characterized by native vegetation, while residential and commercial development were omitted. The vegetation classes identified for this study were based on woody species dominance and generally corresponded with NWI vegetation classes.

NWI mapping indicated broad-leaved deciduous and evergreen tree (P_FO3 or P_FO1) species along all transects and a single transect (in the mid-reach of the study corridor) included an emergent (herbaceous) component. No needle-leaved (e.g. cypress) forested classes were identified in the NWI data. Upstream transects included only temporarily flooded wetlands, while downstream transects included seasonally flooded wetlands.

Table 3-1
Percent Cover of NWI Classes in the Little Manatee River Study Corridor

NWI Classification	Description	Acres	Percent of Total	
			Including Uplands	Excluding Uplands
U	Uplands	2,529	68	-
P_FO3/FO1_C	Palustrine Forested Broad-leaved Evergreen / Broad-leaved Deciduous Seasonally Flooded	456	12	38
P_FO1/FO3_C	Palustrine Forested Broad-leaved Deciduous / Broad-leaved Evergreen Seasonally Flooded	202	5	17
P_FO1/FO3_A	Palustrine Forested Broad-leaved Deciduous / Broad-leaved Evergreen Temporarily Flooded	150	4	12
P_FO3/FO1_A	Palustrine Forested Broad-leaved Evergreen / Broad-leaved Deciduous Temporarily Flooded	143	4	12
Additional classes and subclasses	Additional Palustrine Forested, Emergent, and Scrub-shrub classes and subclasses and combinations; each no more than 1 percent.	255	7	21
Total		3,735	100	100

Figure 3-1
Distinguishing Features and Examples of Habitats in the Palustrine System



*After Cowardin, L. M., V. Carter, F. C. Golet, E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U. S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/ resource/ 1998/ classwet/classwet.htm (Version 04DEC98).

Table 3-2
Descriptions of Florida NWI Classifications in the Little Manatee River Study Corridor

NWI Class	Class Description	
P_ **Palustrine** (no further classification)	Nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and same wetlands in tidal areas with ocean-derived salinity < 0.5 ‰. Includes wetlands lacking such vegetation, but with (1) area < 20 acres; (2) no active wave-formed or bedrock shoreline features; (3) deepest water depth < 2 m at low water; and (4) salinity less than 0.5 ppt.	
P_EM **Palustrine Emergent**	These wetlands are usually dominated by perennial plants. Characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens that are present for most of the growing season in most years. Vegetation types may include: grasses, bulrushes, spikerushes and various other marsh plants such as cattails, arrowheads, pickerelweed and smartweeds. Subclasses: persistent and nonpersistent	
P_FO **Palustrine** **Forested**	Woody vegetation greater than 6 meters (20 feet) tall. Species include both broad and needle leaved deciduous and evergreen categories, e.g. red maple, ash, willows, dogwoods, cypress.	
	_4 ***Needle-leaved Evergreen***	Species dominating this class may include slash (*Pinus elliottii*) and long leaf (*P. palustris*) dominate this palustrine forested class. Spruce, pond pine, red cedar (*Juniperus virginiana*), and more rarely, Atlantic white cedar (*Chamaecyparis thyoides*) are other needle-leaved evergreens in Florida.
	_6 ***Indeterminate Deciduous***	This class may include a mix of broad-leaved and needle-leaved deciduous trees such as slash pine, oak, popash, maple, and others. This general description may be due to the difficulty in identifying species as broad-leaved or needle-leaved in aerial photography taken when leaves are absent.
	_7 ***Indeterminate Evergreen***	This class may include a mix of broad-leaved and needle-leaved evergreen trees such as slash pine, cabbage palm, oak, and others. This general terminology may be due to the difficulty in identifying species in aerial photography or timing of photography.
Hydrologic Modifiers For Classes and Subclasses (see Figure 3-1 for further detail)		
A	Temporarily Flooded	
F	Saturated	
C	Seasonally Flooded	
D	Seasonally Flooded/Well Drained	
E	Seasonally Flooded/Saturated	
F	Semi-permanently Flooded	

NWI Class	Class Description
H	Permanently Flooded

Figure 3-2
Transect Locations and Vegetation along the Little Manatee River Study Corridor (based on data from the NWI)

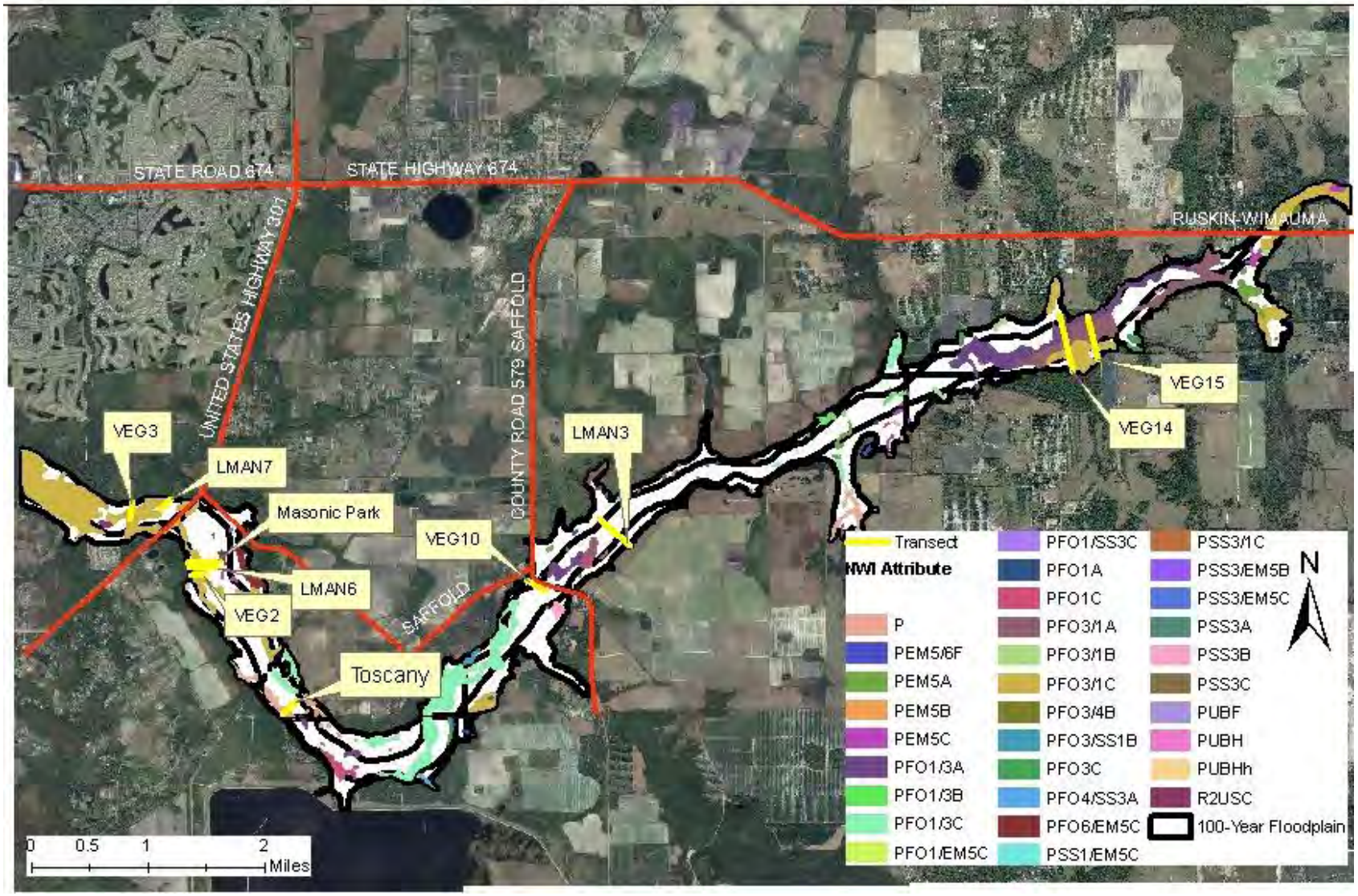


Table 3-3
Percent Cover by NWI Class and Transect in the Little Manatee River Study Corridor

Transect		Upland	Wetlands				
			Palustrine Forested (P_FO)			Palustrine Emergent (P_EM)	Palustrine, not classified further (P)
			Broad-leaved deciduous (1) or evergreen (3)				
			Temporarily Flooded (A)		Seasonally Flooded (C)		
	NWI Class	U	P_FO3/1A	P_FO1/3A	P_FO3/1C	P_EM_C	P
Upstream	VEG15	22.5	53.9	10.9	12.8		
	VEG14	27.0	16.2	22.2	34.6		
	LMAN3	100.0					
	VEG10	65.3				34.7	
	Toscany	60.0					40.0
	VEG2	29.6			70.4		
	LMAN6	51.9			48.1		
	Masonic	64.3			35.7		
	LMAN7	62.2			37.8		
Downstream	VEG3	43.2			56.8		

○ Elevation Surveys and Distance to Channel

The landward extent of wetlands along sampling transects generally coincided with the FEMA-designated 100 year floodplain. Transects were subsequently located to include the area between 100 year floodplain elevations on the north and south sides of the river channel. Elevations were surveyed at 50-foot intervals along transects and more frequently where changes in elevation were conspicuous. Distances from the center of the river channel were recorded as reference points for pairing with vegetation and soils data. Beginning and ending points for each change in plant community were recorded to evaluate the potential influence of distance from channel on vegetation communities. Elevation data were plotted against distances along transects.

Hydrologic indicators of ordinary high water, buttressing, lichen lines, moss lines, and stain lines on trees were also recorded if found along transects. Height of the indicator from the ground surface was measured and included in the elevation surveys.

○ Vegetation Characterization

Vegetation class (plant community) identification, nomenclature, and characterization in the study corridor were based on plant species importance. Based on NWI-designated wetlands (Table 3-1), upstream transects were drier (temporarily flooded), compared with seasonally flooded wetlands farther downstream. Upstream transects VEG15 and VEG14 included both evergreen and deciduous broad leaved, forested wetlands and a mix of the evergreen and deciduous species.

The five downstream transects (VEG2, LMAN6, Masonic, LMAN7, and VEG3) included only the mix of evergreen and deciduous broad leaved forested wetlands. The seasonally flooded emergent vegetation class was included in NWI data only along Transect VEG10 at the mid-reach of the river. Also in the mid-reaches of the river, NWI data indicated palustrine wetlands along the Toscany transect, but did not further differentiate any of the vegetation. A single transect, LMAN3, had no wetlands along the transect (based on NWI data). Vegetation classes were further differentiated by dominant species identified during sampling along individual transects. Individual subclasses that made up no more than one percent of the study corridor comprised 255 acres and included palustrine forested, emergent, and scrub-shrub subclasses. None of these classes occurred along sampling transects.

While these NWI classes were adequate for identifying general vegetation classes for sampling purposes, they were considered too broad for the level of community characterizations in this study. Boundaries between communities were identified in the field using a combination of indicators, including, but not limited to the following:

- General community type (e.g. wetland to upland)
- Species cover (e.g. popash to oak, obligate wetlands to facultative wetlands)
- Elevation (e.g. scarp presence)
- Soils (e.g. hydric or nonhydric)

Subsequently, a general method of vegetation class nomenclature was developed based on species dominance (below).

- Vegetation classes with greater than 40 percent tree cover were designated based on dominant tree species (Cowardin *et al*. 1979)
- Species dominance was used to further refine classes using importance values (IVs) of tree species, an index that combines relative density, frequency, and basal area of tree species

Sampling plots were located randomly along transects in each vegetation class and the point-centered-quarter (PCQ) sampling method (Mueller-Dombois and Ellenberg 1974) was used to characterize the vegetation. A minimum of three plots from each vegetation class was sampled at each change in dominant species. Density, basal area, and IV were calculated for each tree species, by transect and vegetation class. Density, basal area, and relative dominance values were calculated for each tree species, by transect and vegetation class:

- Density/ 100 square meters = 100/(average measured distance, in meters)^2

- Basal area = basal area of individual trees (cm^2)
- Dominance = (relative density) (basal area, in cm^2)

Soils Characterization

The U.S. Army Corps of Engineers (USACE) Wetlands Delineation Manual defines a hydric soil as one that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part. These definitions were used in evaluating soils.

Under saturated or flooded conditions that are anaerobic for part of the growing season, soil profiles usually acquire unique characteristics that can be relied upon as positive indicators of hydric conditions. Most organic soils (histosols) are hydric, and the extent of decomposition of organic plant materials can be used to classify these soils as muck (highly decomposed remains of plants and other organisms), peaty muck, mucky peat, and peat (partially decomposed remains of plants and other organisms).

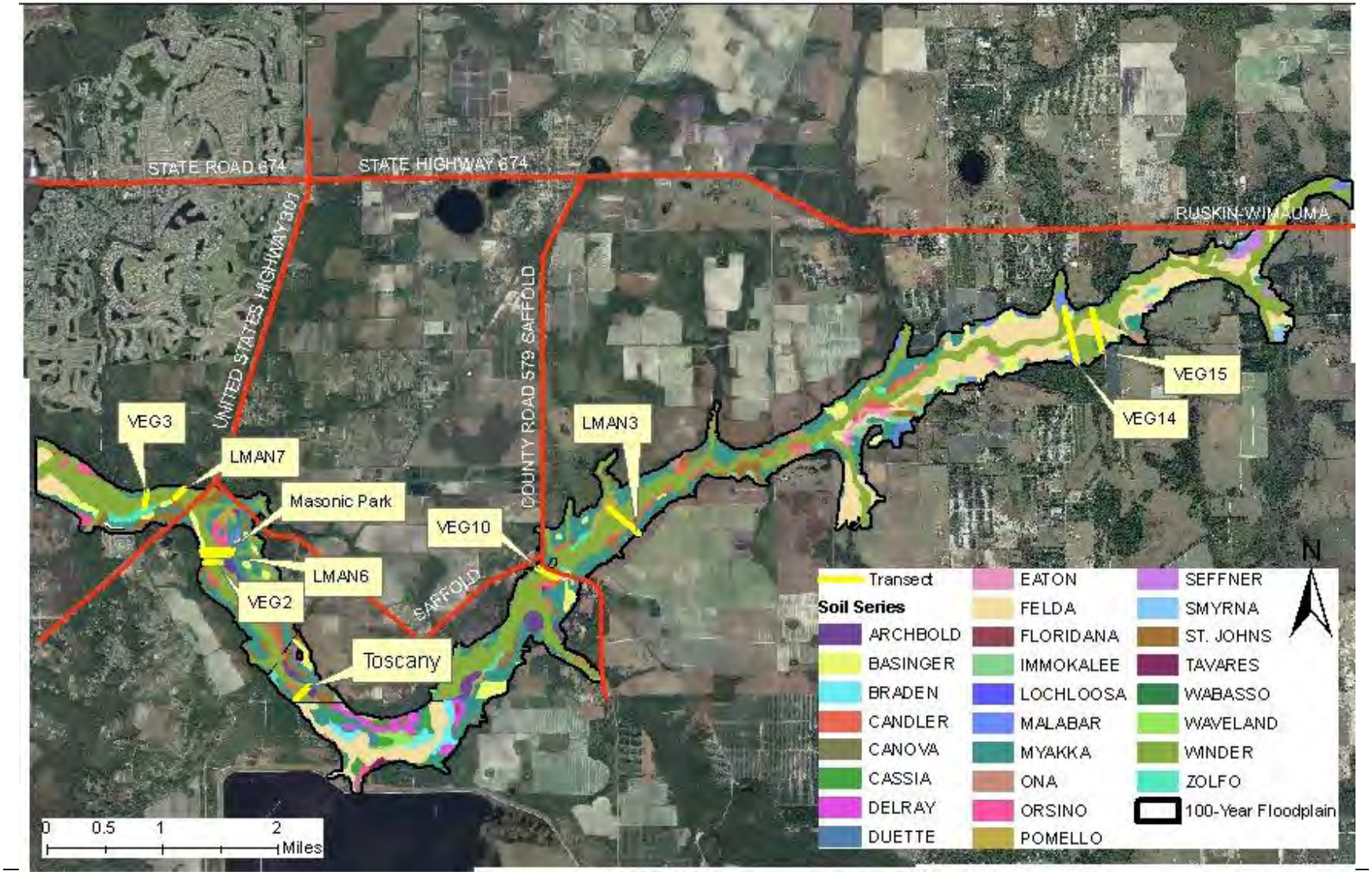
Soils data along the Little Manatee River study corridor (USDA/NRCS 1996) are mapped in Figure 3-3. Soils along the Little Manatee River are typically poorly drained sandy soils characteristic of flatwoods and primary soil associations in the Little Manatee River watershed were described earlier (Section 2). The Winder soils series is the dominant soil type along the river and are very deep, poorly drained, slowly to very slowly permeable soils on broad, low flats and depressional areas that formed in loamy marine sediments on the Lower Coastal Plain. The two upstream transects (VEG14 and VEG15) occur in an area of Felda soils in addition to the Winder soils. Felda soils are very deep, poorly drained and very poorly drained, moderately permeable soils in drainageways, sloughs and depressions, and on flood plains and low flats. These soils formed in stratified, unconsolidated marine sands and clays

Flatwoods soils, like those along the study corridor, generally have an organic pan that impedes vertical water infiltration. About 90 percent of the soils in the Little Manatee watershed have a B/D, C, or D hydrologic soils group (HSG) classification, indicating high runoff potential rather than infiltration of water into the soils. These soils are mineral, rather than organic, and consist primarily of sand, silt, and/or clay sized particles of minerals or rock fragments rather than being dominated by organic materials. Wetland conditions associated with mineral soils typically have:

- Histic epipedon (organic surface horizon)
- Hydrogen sulfide odor and other sulfidic material
- Aquic conditions (oxygen-deficient soil saturation)
- Soil series on hydric soil lists
- Redoximorphic features such as gleyed soil matrix color, low chroma matrix color with or without bright mottling and segregated iron and manganese concretions

Evidence in soil profiles can also be used as an indication of flooding in soils that may not be hydric. Importantly, hydric soils are used in characterizing wetlands, not river channels in which organics are washed downstream. For example, flooded river banks that have a high sand content

Figure 3-3
Transect Locations and Soils along the
Little Manatee River Study Corridor



and occur at elevations high enough that flooding is infrequent generally have nonhydric soils, but show signs of flooding such as thin strata of gravel, sand, silt, or clay deposited by flood waters. Other evidence of flooding includes cypress buttressing, moss collars, lichen lines, and water stains.

Soil cores were examined for each sampling point along each transect. Soil cores were exhumed with a shovel. The presence of hydric or flooding indicators, as well as saturation and/or inundation conditions were evaluated and recorded. The soil profile was examined to a minimum depth of 50 cm (20 inches). In addition, several indicators described in the *Hydric Soil Delineation Indicators* (A5-A9, S5-S6) were evaluated and recorded: a numeric code of "0" was recorded if a characteristic was absent, and a "1" was recorded if the characteristic was present. Soils data were subsequently paired with vegetation and elevation data for analysis.

Once soils data were compiled, hydric indicators were assigned a composite soil index for each core sampled. As noted previously, some soils have evidence of flooding, e.g. sandy and steep river banks, although the soils may not show indications of hydric conditions. Consequently, soils with no evidence of wetland indicators (uplands) were given a soils index of zero. In contrast, saturated hydric soils received a maximum value of three. Soils indices were assigned as described below.

0 = soil showed no evidence of flooding or hydric conditions
1 = hydric soils
2 = soil was hydric with muck
3 = soil was hydric and saturated

○ Data Analysis

Elevation, soils, and vegetation data were compared among and between vegetation classes identified in the river corridor. Statistical analyses were performed using SAS statistical software (Cary NC 1998). Hydrologic flow analyses were performed by the District and used to characterize inundation conditions based on median elevations of vegetation classes and were not part of the present study.

▪ Elevations and Wetted Perimeter

Ground elevation data (feet NGVD) were used to compare vegetation, soils, and distance from channel among transects. Normalized (relative) elevations were calculated as the difference between the transect elevations and the river bottom to account for variation due to downstream-upstream elevation gradients.

Wetted perimeter was calculated for vegetation classes in the study corridor to evaluate the potential change in inundated habitat that may be anticipated due to changes in river stage. The wetted perimeter for a vegetation class is the linear distance inundated along a transect below a particular elevation or water level (river stage). Consequently, as distance from the river channel increases, the total wetted perimeter also increases, but can vary among vegetation classes. Wetted perimeter changes, relative to changes in elevation, were compared using the Kruskal Wallis test, a nonparametric analog to a one-way analysis of variance (ANOVA).

Vegetation and Soils

Relationships between vegetation classes and corresponding environmental parameters were examined for this study to ascertain whether there were differences in:

- Species composition and dominance between or among vegetation classes
- Elevation, soils, and distance from channel between or among vegetation classes

Plant species IVs were calculated for woody species in vegetation classes along sampling transects. Due to small sample size (N = 10 transects, N = 9 vegetation classes) and non-normal data distributions, nonparametric statistics were applied to comparisons of species dominance between vegetation classes. The Kruskal Wallis test was used to measure the difference (or lack of difference) in species dominance among vegetation classes. The Wilcoxon Signed Rank test (a nonparametric analog to the paired-t test) was used to evaluate differences in species importance (or "dominance") between individual communities, for example differences in species dominance between willow marsh and hardwood swamp vegetation classes.

The sample size for comparisons of elevation and soils among vegetation classes was relatively large and a parametric discriminant function analysis (DFA) was used to quantify the contribution of elevation, soils, and distance from river channel in defining vegetation classes, based on relationships between environmental variables and species composition and dominance along sampling transects. A "successful" DFA is one that results in correct pairing of vegetation types and environmental parameters into vegetation classes. P-values indicate the significance of a relationship, e.g. the ability to predict a vegetation class using elevation, while r^2 values indicate the amount of variation in vegetation classes accounted for by each variable.

• Results and Discussion

The relationships among vegetation classes and environmental variables along the Little Manatee River study corridor were evaluating using DFA. Elevations, soils, and distance to channel were significant in characterizing environmental conditions of vegetation classes along the river, although there was overlap among vegetation classes that was associated with similar measures of elevation, soils, and/or distance to river channel.

○ Elevations

River channel elevations declined dramatically downstream along the Little Manatee River, from 38.0 feet NGVD (Toscany) to 0.1 feet NGVD at the VEG3 transect farthest downstream (just east of U.S. Highway 301), a change in elevation of approximately 38 feet over about 12 miles (0.3 feet/mile) (Table 4-1 and Figure 4-1). In contrast, elevation changes along transects ranged from 11.6 to 22.8 feet over a half mile or less (22.4 feet/mile). For illustrative purposes, the elevation profile and associated vegetation along the Masonic transect are graphed in Figure 4-2 and all 11 transects are graphed individually in Appendix A.

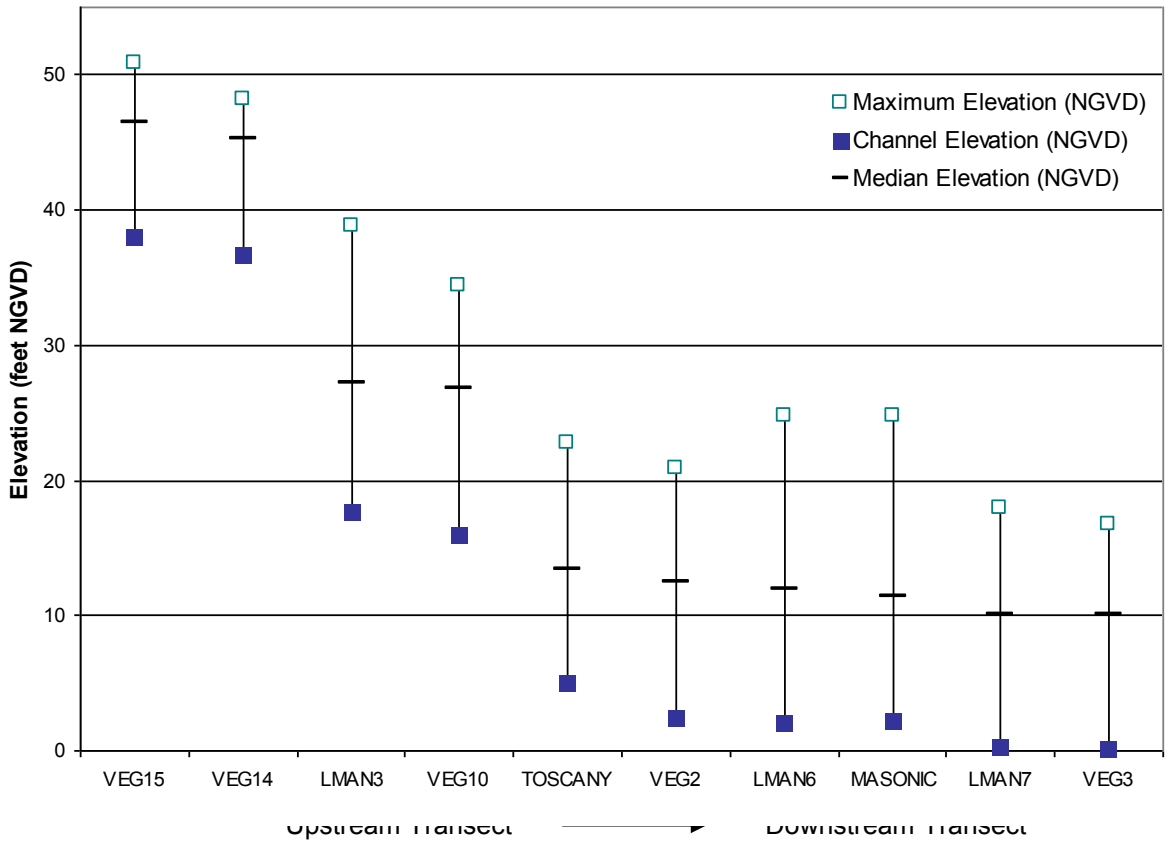
Channel elevations decreased from 38.0 and 36.6 feet NGVD at upstream transects VEG15 and VEG14 to 17.7 and 15.9 feet NGVD at the next two downstream (LMAN3 and VEG10). Median relative elevations (elevation relative to channel bottom) ranged from 8.5 to 10.9 feet. Changes in elevation along the two most upstream transects were only 11.6 to 12.8 feet, while elevation changes along the more downstream transects ranged from to 16.6 feet to 22.8 feet.

Table 4-1
Elevation and Distance along the Little Manatee River Transects

Transect		Transect Distance (feet)	Maximum Elevation (NGVD)	Channel Elevation (NGVD)	Maximum Elevation Change	Median Elevation (NGVD)	Median Relative Elevation	N
Downstream ↓ Upstream	VEG15	2025	50.8	38.0	12.8	46.5	8.5	98
	VEG14	2665	48.2	36.6	11.6	45.2	8.6	109
	LMAN3	1857	38.8	17.7	21.1	27.1	9.4	108
	VEG10	994	34.4	15.9	18.5	26.8	10.9	58
	TOSCANY	950	22.8	5.0	17.8	13.4	8.4	82
	VEG2	749	20.9	2.4	18.5	12.4	10	66

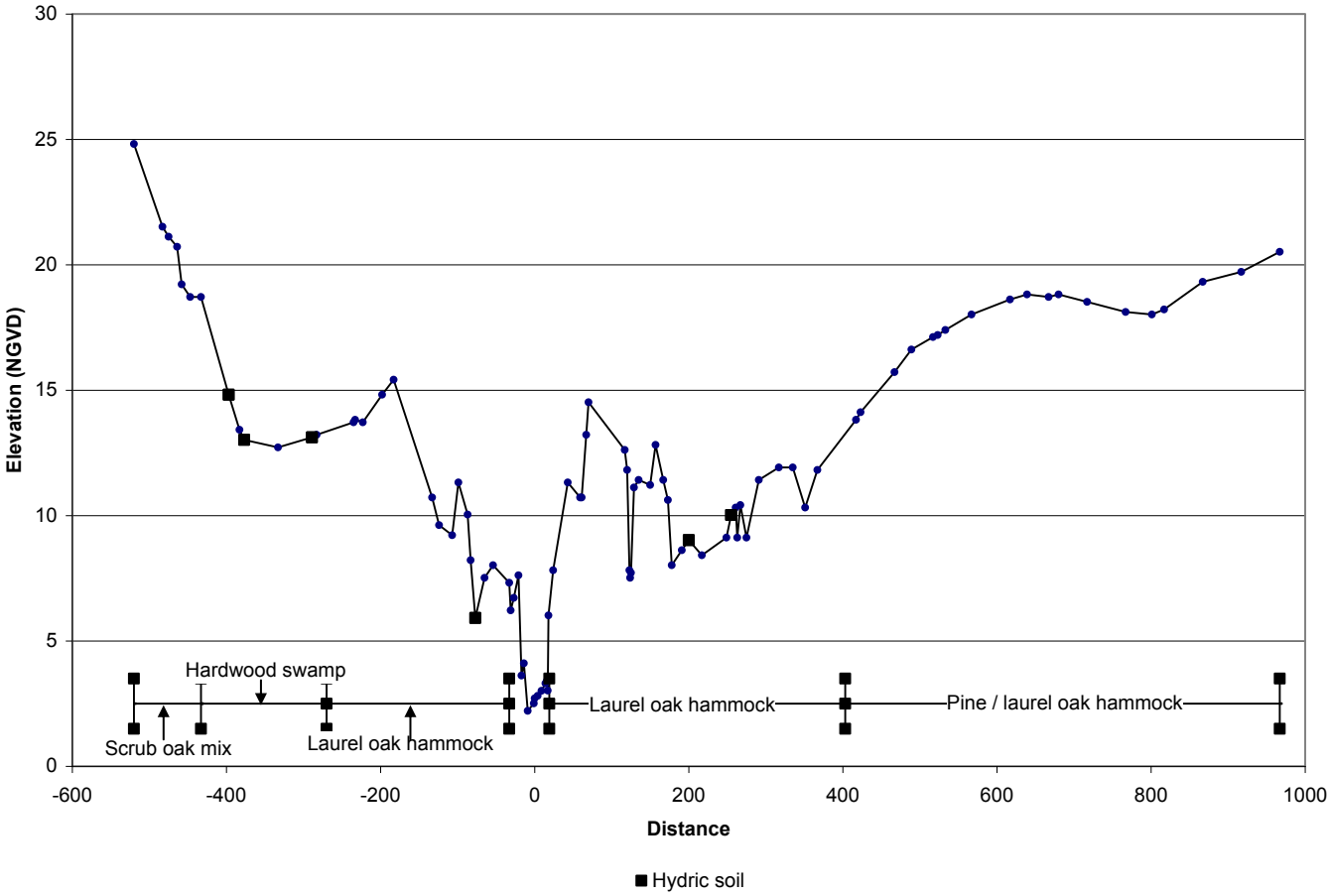
	LMAN6	1350	24.8	2.0	22.8	11.9	9.9	93
	MASONIC	1487	24.8	2.2	22.6	11.4	9.2	93
	LMAN7	720	17.9	.3	17.6	10.0	9.7	51
	VEG3	771	16.7	.1	16.6	10.0	9.9	47

Figure 4-1
Channel Bottom, Maximum, and Median Elevations along Transects in the Little Manatee River Study Corridor



Changes in vegetation were more conspicuous along study transects than along the upstream – downstream river channel gradient and may reflect the steeper elevation change along transects when compared with the upstream to downstream elevation gradient. Wetland vegetation communities occurred along the upstream (VEG15, VEG14, and LMAN3) and downstream (Masonic, LMAN7, VEG3) transects, and were absent along the mid-reach (VEG10, Toscany, VEG2, and LMAN6) study transects. No upland classes occurred along the five most upstream transects.

Figure 4-2
Elevation and Vegetation Profile along the Masonic Transect in the Little Manatee River Study Corridor



○ Soils

The soils along the Little Manatee River (refer back to Figure 3-3), like other rivers in southwest Florida, are part of the southwestern flatwoods physiographic district developed on rocks and sediments primarily from the Miocene to Pleistocene age (Myers and Ewel 1990). These soils are dominated by sand, limestone, and clay (USDA/ SCS 198) rather than organic materials. These contrast with soils along the St. Johns and Wekiva rivers in the eastern flatwoods physiographic district which originated along a series of barrier islands. Soils of the eastern flatwoods district are primarily sandy with significant peaty deposits that indicate extreme anaerobic conditions, saturation for at least 30 consecutive days in most years.

FDEP, under FAC Chapter 62-340.550 (Delineation of the Landward Extent of Wetlands and Surface Waters), indicates that inundation for at least seven consecutive days or saturation for at least twenty consecutive days annually constitutes long term hydrologic conditions necessary for the maintenance of hydric soils. Thus, the minimum period of inundation to maintain hydric soil conditions is shorter than that required to exclude upland vegetation, which may be as little as two weeks.

Hydric soils were found along nine of the 10 study transects and in all vegetation classes except the scrub oak class. Muck soils were found at all transects (Figures 4-3 and Table 4-2). The tupelo swamp and hardwood swamp classes were the only classes with exclusively hydric soils. Median elevations of hydric soils were lower when compared with nonhydric soils (Wilcoxon Signed Rank; $S = 52.5$, $p < 0.0001$). Elevation differences between hydric and nonhydric soils ranged from 0.3 to 0.9 feet at the two most upstream transects to a difference of about seven feet at mid-reach transects (VEG10, VEG2, LMAN6) to a difference of about three feet at the two most downstream transects. Both hydric and nonhydric conditions occurred in many vegetation classes, although hydric soils still occurred at lower elevations when compared with nonhydric soils in all but one instance (laurel oak hammock class).

Figure 4-3
Median Elevations of Hydric and Nonhydric Soils along the Little Manatee River Study Corridor

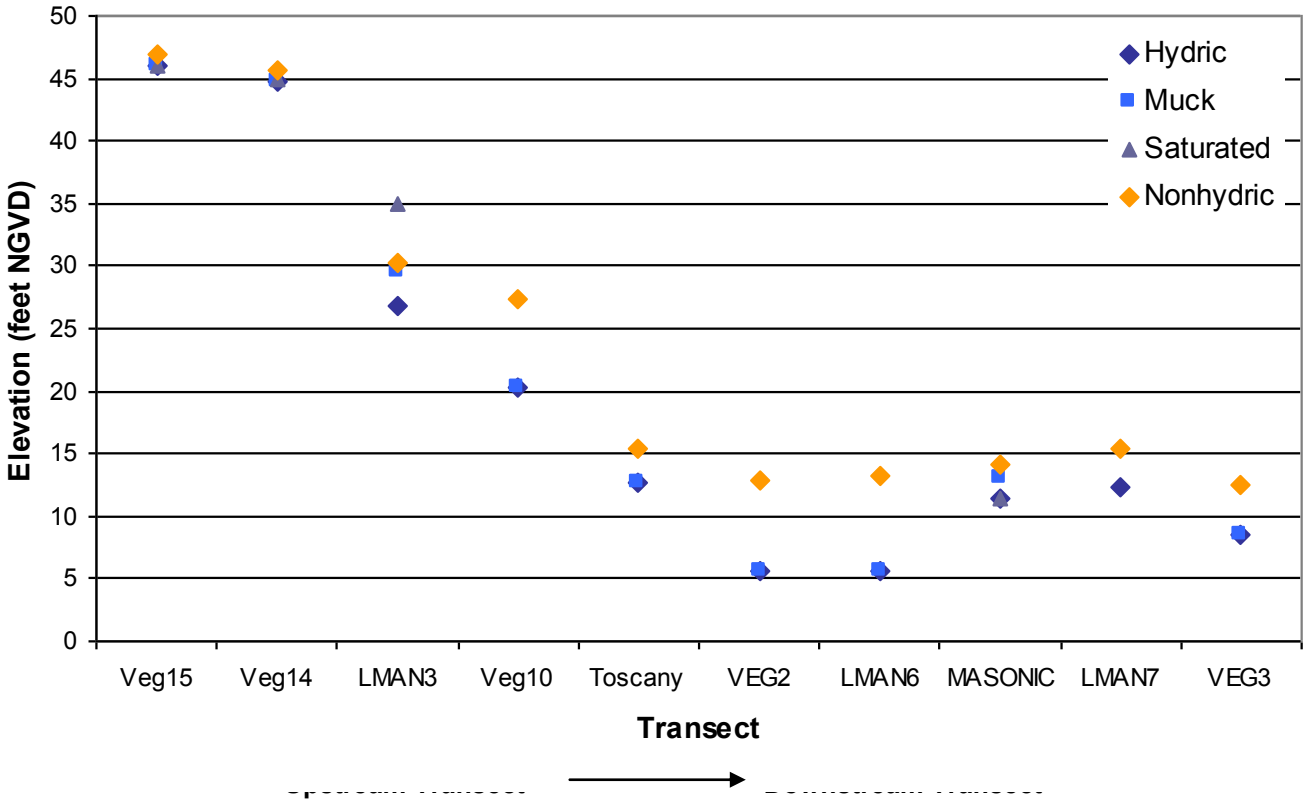


Table 4-2
Median Elevations (feet NGVD) of Hydric, Muck, and Saturated Soils along Transects in the Little Manatee River Study Corridor *

	Transect	Hydric	Not Hydric	Muck	Not Muck	Saturated	Not Saturated
Downstream ← Upstream	VEG15	46.3 (10)	46.9 (19)	46.3 (10)	46.9 (19)	46.3 (7)	46.6 (22)
	VEG14	44.8 (7)	45.7 (26)	44.8 (6)	45.6 (27)	44.9 (3)	45.5 (30)
	LMAN3	26.8 (9)	30.2 (10)	30.2 (4)	28 (15)	34.9 (1)	28.1 (18)
	VEG10	20.3 (6)	27.3 (11)	20.3 (6)	27.3 (11)		26.8 (17)
	Toscany	12.6 (3)	15.4 (12)	12.6 (3)	15.4 (12)		14.6 (15)
	VEG2	5.6 (1)	12.9 (9)	5.6 (1)	12.9 (9)		12.8 (10)
	LMAN6	5.6 (1)	13.2 (21)	5.6 (1)	13.2 (21)		13.2 (22)
	MASONIC	11.5 (6)	14.1 (15)	13.0 (5)	13.9 (16)	11.5 (2)	13.7 (19)
	LMAN7	12.3 (1)	15.4 (6)		15 (7)		15 (7)
	VEG3	8.6 (3)	12.5 (6)	8.6 (3)	12.5 (6)		11.2 (9)

* Shaded cells indicate absence of conditions. Numbers in parentheses are N.

○ Vegetation Relationships

Differences in vegetation classes along the Little Manatee River study corridor were significant based on importance values (IVs) that were calculated using tree species density, basal area, and frequency and provide a relative measure of species dominance (no units).

○ Vegetation Classes

Nomenclature. Vegetation classes identified for this study were consistent with, although more specific than, the NWI vegetation classes initially used to map vegetation along transects. The NWI classification system does specifically address cabbage palm, while authors such as Myers and Ewel (1990) recognize its importance in Florida systems. In addition, the presence of popash is better addressed by NWI than by the SCS.

The species-specific designations used in this study were retained so that they could be easily combined into a more general context or class. While the NWI classes were too general for use in this study, the

NWI flooding component may be useful in addressing MFLs. Forested wetlands along the river are seasonally or temporarily flooded, rather than permanently or semi-permanently flooded, consistent with NWI and SCS mapping.

Class Comparisons. Comparisons between vegetation classes based on IV indicated significant differences between vegetation classes for all comparisons (Table 4-3). For example, when species IVs were compared between the willow marsh (first row heading) and the hardwood swamp (second column heading), the S-value (22.5) is significant at the $p < 0.01$ level, which means that the probability that two vegetation classes are the same is less than one percent.

Table 4-3
Wilcoxon Signed Rank Test (S Values) for Comparisons between Vegetation Classes along the Little Manatee River Study Transects

Vegetation Class	Vegetation Class								
	Permanent – Semi-permanent Wetlands			Transition to Uplands			Uplands		
	Willow Marsh	Tupelo Swamp	Hardwood Swamp	Pine / Laurel Oak Hammock	Laurel Oak / Pine Hammock	Pine / Maple Hammock	Laurel Oak Hammock	Palm Hammock	Oak Scrub
Willow Marsh		7.5*	22.5***	18.0***	27.5***	85.5***	138.0***	18.0***	60.0***
Tupelo Swamp			18.0***	14.0**	18.0***	68.0***	150.0***	27.5***	52.5***
Hardwood Swamp				27.5***	33.0***	85.5***	150.0***	27.5***	52.5***
Pine/ Laurel Oak Hammock					27.5***	95.0***	150.0***	27.5***	60.0***
Laurel Oak/ Pine Hammock						76.5***	138.0***	33.0***	60.0***
Pine Maple Hammock							175.5***	85.5***	105.0***
Oak Hammock								150.0***	175.5***
Palm Hammock									52.5***
Oak Scrub									

***p < 0.01; **p < 0.05; *p < 0.1

Comparisons of vegetation classes with themselves (such as willow marsh with willow marsh) were unnecessary and consequently, these cells were left empty. Likewise, repeated comparisons (willow marsh row with tupelo swamp column v. tupelo swamp row with willow marsh column) were also left empty.

IVs of individual species for each of these vegetation classes are summarized in Table 4-4 and illustraged in Figure 4-4. The IVs provide a relative measure of species dominance (no units) and were calculated using tree species density, basal area, and frequency, as described previously.

Based on vegetation classes and species composition and IVs, three wetland vegetation classes were identified in the study corridor. The classes included only obligate and facultative wetland tree species, including Carolina willow (*Salix carolinana*), tupelo (*Nyssa sylvatica*), sweet bay or swamp bay (*Magnolia virginiana*), water oak (*Quercus nigra*), and popash (*Fraxinus caroliniana*). These classes (below) included six or fewer species.

- Willow marsh: comprised exclusively of the obligate wetland species Carolina willow, with smaller components of popash and holly (Ilex cassine).

- Tupelo swamp: characterized by only two tree species, primarily swamp tupelo (obligate wetland species), in addition to a small component of slash pine (facultative wetland).

- Hardwood swamp: included six species and characterized by predominantly swamp bay (obligate) and water oak (facultative wetland).

Transition vegetation classes (between wetlands and uplands) were characterized by predominantly facultative wetland species such as laurel oak (*Q. laurifolia*) and slash pine (*Pinus elliottii*) in combination with other facultative species. The transition classes (below) included six to 23 different species.

- Laurel oak/ pine hammock: characterized by primarily laurel oak with a smaller component of slash pine, but also included the obligate wetland species American snowbell (*Styrax americanus*) and two upland species.

- Pine/ laurel oak hammock: dominated by slash pine, but otherwise similar in composition to the laurel oak/pine hammock.

- Pine/ maple hammock: differed from the laurel oak/pine and pine/ laurel oak classes due to a large red maple and water oak components that were small to absent in the other transition classes. This class also includes eight upland species, compared with less than three in the pine/ laurel oak and laurel oak/pine classes.

- Oak hammock: primarily laurel oak, but also a relatively large component of live oak (*Q. virginiana*). This class had the largest number of different tree species (23) when compared with the other classes, although like the other transition classes, it included primarily obligate and facultative wetland species.

Table 4-4
Importance Values for Tree Species in Vegetation Classes along the Little Manatee River Study Corridor*

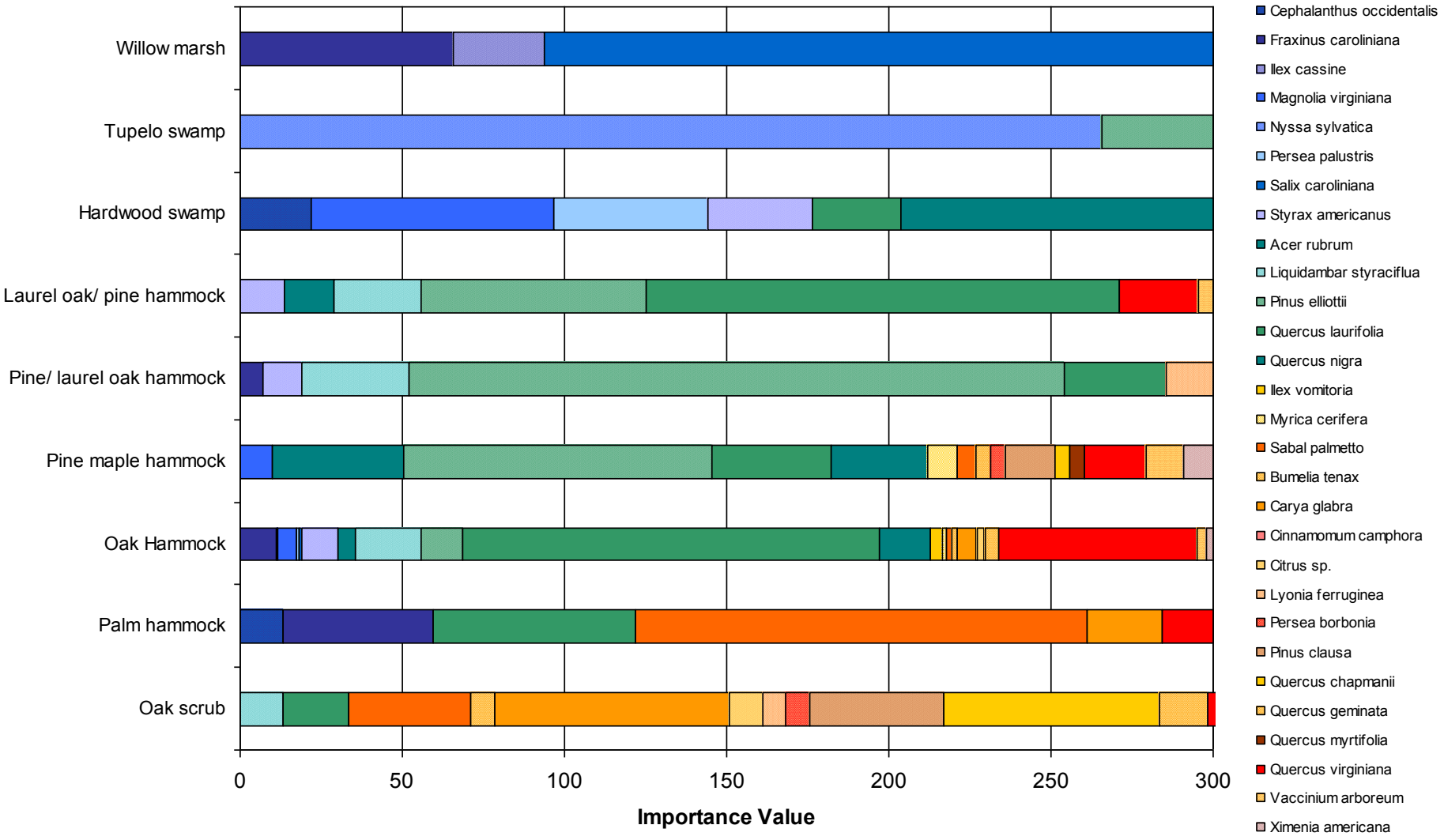
Status	Species	Willow Marsh	Tupelo Swamp	Hardwood Swamp	Pine / Laurel Oak Hammock	Laurel Oak / Pine Hammock	Pine / Maple Hammock	Laurel Oak Hammock	Palm Hammock	Oak Scrub
OBL	*Cephalanthus occidentalis*			22.0					13.4	
OBL	*Fraxinus caroliniana*	65.8			7.0			11.0	46.2	
OBL	*Ilex cassine*	28.0						0.7		
OBL	*Magnolia virginiana*			74.5			9.9	5.6		
OBL	*Nyssa sylvatica*		265.6							
OBL	*Persea palustris*			47.8				0.8		
OBL	*Salix caroliniana*	206.2						0.7		
OBL	*Styrax americanus*			32.1	12.0	13.7		11.2		
FACW	*Acer rubrum*					15.4	40.5	5.4		
FACW	*Liquidambar styraciflua*				32.8	26.5		20.5		13.1
FACW	*Pinus elliottii*		34.4		202.1	69.6	95.0	12.5		
FACW	*Quercus laurifolia*			27.2	31.7	145.8	36.7	128.6	62.5	20.5
FACW	*Quercus nigra*			96.4			3.0	15.8		
FAC	*Ilex vomitoria*							3.7		

FAC	*Myrica cerifera*						9.1	1.3		
FAC	*Sabal palmetto*						5.5	1.8	139.0	37.4
UPL	*Bumelia tenax*						4.5	1.5		7.4
UPL	*Carya glabra*							5.7	23.1	72.4
UPL	*Cinnamomum camphora*							0.7		
UPL	*Citrus sp.*							1.8		10.2
UPL	*Lyonia ferruginea*				14.3					7.1
UPL	*Persea borbonia*						4.6			7.4
UPL	*Pinus clausa*						15.5			41.6
UPL	*Quercus chapmanii*						4.6	0.7		66.2
UPL	*Quercus geminata*							3.9		15.1
UPL	*Quercus myrtifolia*						4.6			
UPL	*Quercus virginiana*					24.4	18.9	61.3	15.9	9.0
UPL	*Vaccinium arboreum*					4.5	11.3	2.7		
UPL	*Ximenia americana*						9.3	2.2		

*Shaded cell indicates absence of species

Figure 4-4

Importance Values for Tree Species in Vegetation Classes along the Little Manatee River Study Corridor



Species in the two upland classes included primarily the facultative cabbage palm (*Sabal palmetto*) and the upland scrub hickory (*Carya glabra*). Species numbers ranged from six to 11.

- Palm hammock: cabbage palm dominated this vegetation class, followed by laurel oak and popash, and smaller components of both upland and wetland species.

- Oak scrub was the only vegetation class dominated by upland species, including primarily scrub hickory (Carya glabra), scrub oak (Q. chapmanii), and sand pine (Pinus clausa). This was also the only class that included no obligate wetland species.

Species Composition in Vegetation Classes. Differences in species IVs for the 29 species in the nine vegetation classes represent a shift in importance from obligate wetland species such as willows, tupelo, and sweet bay to laurel oak and slash pine to upland scrub oak and sand pine coincided with a gradual transition from wetland to upland vegetation classes.

- Laurel oak occurred in seven of the nine vegetation classes, and was the largest component in two classes (laurel oak/ pine and laurel oak hammock). Slash pine and live occurred in five classes, while four species occurred in four classes, and the remaining species occurred in fewer than four of the vegetation classes.

- The largest number of tree species (23) occurred in the laurel oak hammock class, followed by the pine/ maple hammock (15 species) and the oak scrub (12 species). The total number of tree species in other classes ranged from two to seven.

Species Importance. Species IVs comparisons (Table 4-4) indicate that the overall dominant species were the facultative wetland species laurel oak and slash pine. A shift in importance from willows, tupelo, and sweet bay to laurel oak and slash pine to scrub oak and sand pine coincided with a gradual transition from wetland to upland vegetation classes. Overall trends in species dominance and diversity are summarized below.

- Five species had IVs that exceeded 100 in a single class: cabbage palm (139), tupelo (IV=265.6), slash pine (IV=202.1), willow (IV=206.2) laurel oak (IV=145.8 in the laurel oak/pine hammock and IV=128.6 in the laurel oak hammock) had IVs that exceeded 100.

- Four species made up approximately 56 percent of the total IVs (by species) among all classes: laurel oak (453), slash pine (414) had the largest IVs, followed by tupelo (266) and Carolina willow (207).

- Five species made up approximately 29 percent of the total IVs by species: cabbage palm, water oak, popash, live oak, and scrub hickory ranged from 101 to 184.

- The remaining 20 species had IVs less than 100 and made up approximately 28 percent of the total IVs.

These vegetation classes were used in further analyses and, for organizational purposes, are presented in general order from those nearest the river channel (willow marsh) to those farthest from the channel (scrub oak).

Density and Basal Area. Species IVs for each vegetation class totaled 300, as described in Section 3.0, and provide a means of comparison among species. However, total basal area and density were also calculated for each vegetation class (Table 4-5) and species (Table 4-6) to provide a means of comparison between vegetation classes (Figure 4-5) and among species.

Comparisons of tree basal areas and densities can indicate whether a population is more mature (smaller numbers of larger trees) or in transition in response to a disturbance or change of some sort (increased numbers of smaller trees). A developed tree canopy will shade out new seedlings and inhibit invasion by other species or individuals, which may have an opportunity only when a gap is created by the loss of an older tree and an opening in the canopy. A disturbance that produces a gap in the canopy provides the light necessary for the expansion of new species and individuals. Reduced or loss of stream flows due to rainfall patterns or local ground water withdrawals can also alter vegetation growth and distribution patterns.

Table 4-5
Basal Area and Density* in Vegetation Classes along the Little Manatee River Study Corridor

Parameter	Vegetation Class								
	Willow Marsh	Tupelo Swamp	Hardwood Swamp	Pine/ Laurel Oak Hammock	Laurel Oak Pine Hammock	Pine / Maple Hammock	Laurel Oak Hammock	Palm Hammock	Oak Scrub
Density (trees/acre)	90	135	45	18	39	45	12	45	25
Basal Area (in^2)	3,743	19,215	8,274	9,297	25,194	17,479	35,718	20,637	8,728
Basal Area/tree/acre	42	142	183	515	652	388	3,036	458	355

*Rounded to the nearest whole number.

Differences in basal area and densities varied among vegetation classes along the river. The oak classes had the lowest density and the greatest basal area/tree, indicating an older aged stand, while the wetland classes had higher densities and lower basal areas, indicating a younger age class. In general:

- The laurel oak hammock class had the largest total basal area (35,718 in^2/acre) and lowest density (approximately 12 trees/acre), indicating older stands of larger trees.

- The willow marsh and tupelo swamp had the highest densities (90 and 135 trees/acre, respectively), and relatively low total basal areas (3,743 and 19,215 in^2/acre, respectively), indicating younger trees.

- Laurel oaks (21,099 in^2/acre) in the laurel oak hammock class and tupelos (19,010 in^2/acre) in the tupelo swamp class had substantially higher basal areas than any other tree species in any other vegetation class. There were less than 50 trees/acre in the remaining seven vegetation classes.

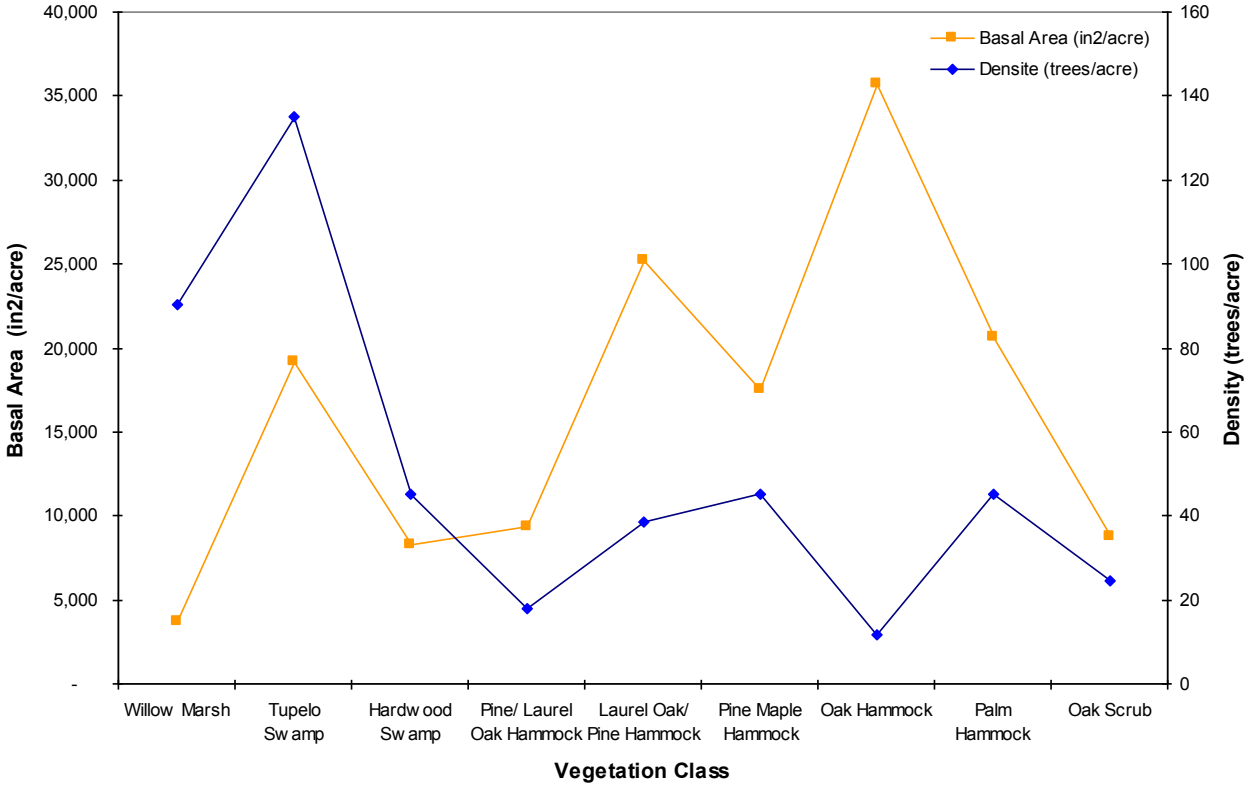
Table 4-6
Basal Area and Density of Tree Species in Vegetation Classes along the Little Manatee River Study Corridor

Wetland Status	Species	Total Basal Area (in^2)	Density (trees/acre)
OBL	*Cephalanthus occidentalis*	39.1	16.9
OBL	*Fraxinus caroliniana*	1,701.9	99.9
OBL	*Magnolia virginiana*	1,098.2	22.4
OBL	*Nyssa sylvatica*	1,241.5	16.2
OBL	*Persea palustris*	487.3	8.9
OBL	*Salix caroliniana*	190.9	1.0
OBL	*Styrax americanus*	186.1	71.1
FACW	*Acer rubrum*	670.1	37.8
FACW	*Liquidambar styraciflua*	2,196.7	123.9
FACW	*Pinus elliottii*	13,045.6	135.7
FACW	*Quercus laurifolia*	70,656.2	427.7
FACW	*Quercus myrtifolia*	5.0	2.5
FACW	*Quercus nigra*	3,834.7	94.4
FAC	*Ilex cassine*	4.3	1.2
FAC	*Ilex vomitoria*	19.1	7.8
FAC	*Myrica cerifera*	67.3	13.9

FAC	*Sabal palmetto*	7,163.2	72.0
UPL	*Carya glabra*	1,591.3	44.5
UPL	*Lyonia ferruginea*	21.7	3.7
UPL	*Persea borbonia*	8.6	2.5
UPL	*Persea humilis*	7.7	1.2
UPL	*Pinus clausa*	295.4	17.3
UPL	*Quercus chapmanii*	73.0	23.7
UPL	*Quercus geminata*	518.8	36.5
UPL	*Quercus virginiana*	41,983.5	184.1
UPL	*Vaccinium arboreum*	62.6	18.3
UPL	*Ximenia americana*	53.2	17.4

Figure 4-5
Basal Area and Density for Vegetation Classes along the Little Manatee River Study Corridor

Cabbage palms, like all palms, have no “bark” (secondary phloem) and consequently do not grow in diameter as they grow in height. All the cabbage palms measured were approximately 11 inches in diameter. Therefore, basal area can be considered a constant among cabbage palms and differences in IV among cabbage palms in vegetation classes can be attributed to density alone. Cabbage palm had its highest IV and was the dominant species in the palm hammock class.



Percent Occurrence along Transects. Based on NWI data, vegetation along most transects is broad leaved deciduous and evergreen in temporarily and seasonally flooded conditions (Table 4-7). Based on NWI data, upstream transects (VEG15 and VEG14) are only temporarily flooded, compared with seasonally flooded at the five transects farthest downstream (VEG2, LMAN6, Masonic, LMAN7, and VEG3) and therefore, downstream transects would be expected to have better developed wetlands. Transect VEG10 was classified in NWI as emergent (or herbaceous) and the transect LMAN3 was classified as all uplands. While two of the three transects farthest downstream did have wetlands, two of the three wetlands farthest upstream also had wetlands. The remaining transects were characterized by transition and upland classes. One-hundred percent of the transect length at transects Toscany and VEG10 (mid-reaches of the river) were laurel oak hammock. The two upland classes (palm hammock and oak scrub occurred along the six most downstream transects, and were absent at the six most upstream transects. No needle-leaved vegetation was identified in the NWI data and no cypress or cedar were found along the study transects.

Table 4-7
Percent Composition of Vegetation Class along the Little Manatee River Transects*

Transect	Willow Marsh	Tupelo Swamp	Hardwood Swamp	Pine/ Laurel Oak Hammock	Laurel Oak/ Pine Hammock	Pine / Maple Hammock	Laurel Oak Hammock	Palm Hammock	Oak Scrub
VEG15				5.3	7.0	8.4	79.2		

	VEG14		14.6			3.4	24.9	57.1		
	LMAN3	15.5						84.5		
	VEG10							100.0		
	TOSCANY							100.0		
	VEG2				21.5			24.5	54.0	
	LMAN6				36.5		8.4	13.3	3.6	38.2
	MASONIC			11.3		39.3		43.3		6.1
	LMAN7	19.2		5.0	30.5			8.6		36.7
	VEG3				26.2	35.4		30.6	7.8	

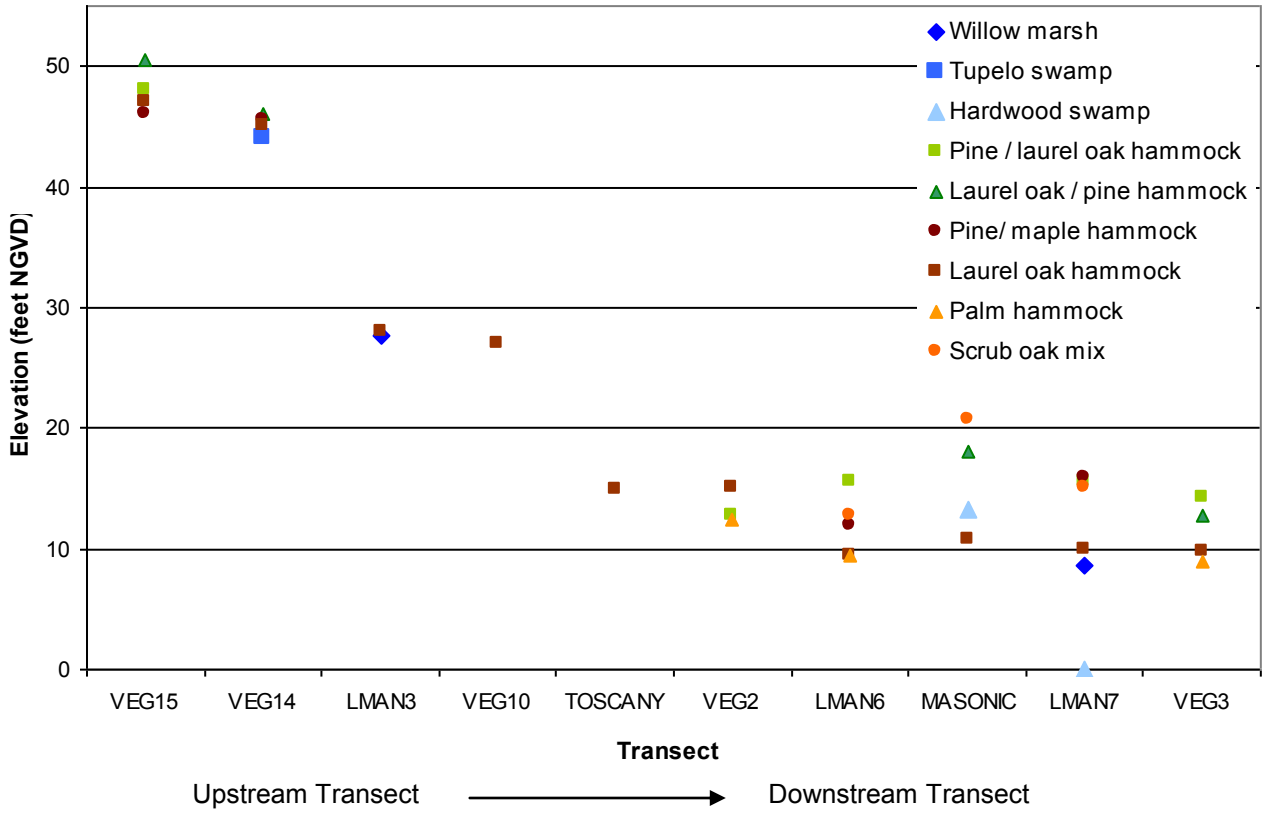
*Shaded cells indicate absence of vegetation class.

▪ Elevations and Vegetation Classes

Wetland vegetation classes generally had lower elevations when compared with transition and upland classes, although because of the relatively small number of wetlands, variability was high. Median elevations of vegetation classes along the river corridor and for each transect are graphed in Figure 4-6. Median elevations were generally lower in willow marsh, tupelo swamp, and hardwood swamp vegetation classes when compared with the remaining transition and upland classes (Table 4-8 and Table 4-9). Median elevations were highest at the most upstream transect (VEG15) and ranged from 46.0 feet NGVD to 50.5 feet NGVD, and the relative elevations of vegetation classes along VEG15 were consistently lower when compared with other transects, i.e. upstream transects had less elevation relief than downstream transects.

Wetland classes occurred along only four of the 10 transects. Median relative elevations in the wetland classes (Figure 4-7) ranged from 7.0 feet NGVD (willow marsh) to 10.2 feet NGVD (hardwood swamp), while elevations ranged from 6.2 (laurel oak hammock) to 15.7 (laurel oak/pine hammock) feet NGVD in the remaining classes. Median relative elevations in willow marsh were 7.0 and 8.4, compared with 7.3 in the tupelo swamp and 10.2 in the hardwood swamp.

Figure 4-6
Median Elevations of Vegetation Classes along Transects in the Little Manatee River Study Corridor



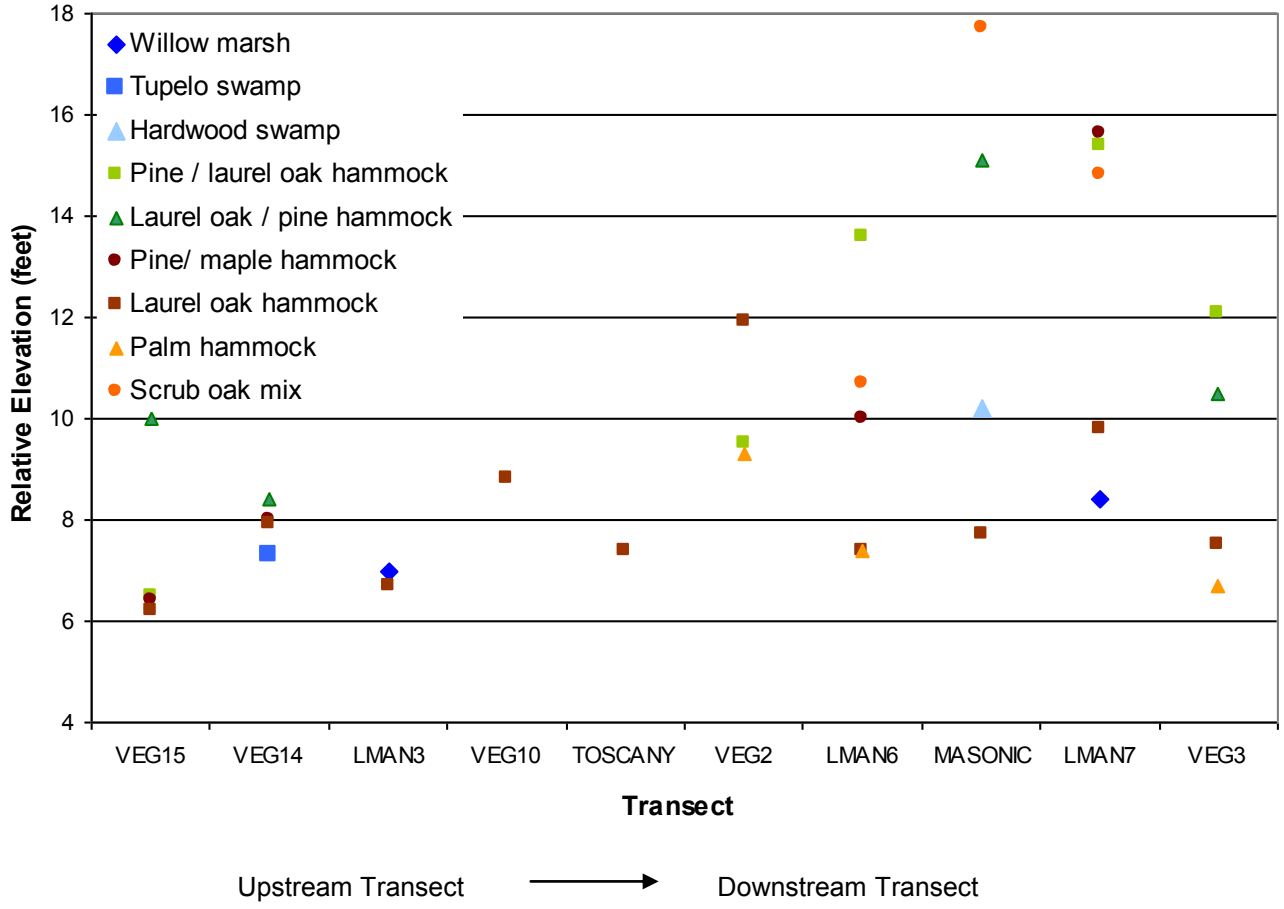
- **Soils, Distance to Channel, and Vegetation Classes**

Changes in elevation associated with vegetation classes were not as consistent as the elevation gradients associated with soils. While hydric soils consistently occurred at lower elevations when compared with nonhydric soils, wetland vegetation classes did not consistently occur at lower elevations when compared with transition or upland vegetation classes. Within vegetation classes that had both hydric and nonhydric soils, hydric soils consistently occurred at lower elevations and illustrate the broad overlap among vegetation classes.

Results indicate that soils were a more consistent indicator of wetlands along the Little Manatee River than elevation changes. Median relative elevations of hydric soils by vegetation class indicated that in vegetation classes with both hydric and nonhydric soils, hydric soils occurred at lower elevations. Also, median elevations (feet NGVD) of hydric soils in wetland classes were the same as the elevations of the wetland class (Table 4-10), i.e. wetlands had almost exclusively hydric soils, while hydric soils were not limited to wetlands (consequently, the cells filled in Table 4-10 do not always coincide with Tables 4-8

and 4-9). Muck soils were found along several transects (Figure 4-3), but did not occur at elevations that were any lower than hydric (but not muck) soils.

Figure 4-7
Median Relative Elevations of Vegetation Classes along Transects in the Little Manatee River Study Corridor



Inconsistencies in vegetation-elevation relationships are likely due to the broad environmental tolerance of wetland species and the small number of study transects (four) that included wetlands. The broad environmental range of wetland and transition vegetation when compared with upland species results in greater overlap of wetland and transition species across elevation and soils gradients. For example, overlap was most conspicuous for the laurel oak hammock class, which was the only vegetation class present along all transects and the variation in elevation along this transect was therefore higher when compared with other vegetation classes.

Distance to river channel may provide a proxy for combinations of elevation, wave energy, soils, and vegetation if distance coincides with these other variables. Such a pattern was not apparent along the Little Manatee River transects and may also be a result of the small number of wetlands sampled. Mean distances of vegetation classes from the river channel were not correlated strongly with vegetation class. The willow marsh vegetation class occurred along or close to the river channel (mean distance =

76.9 feet from the channel). The tupelo swamp class occurred at a mean distance of 739.4 feet from the river channel, followed by hardwood swamp at a mean distance of 321.2 feet. The remaining vegetation classes ranged from 160.6 to 1,073.0 feet from the river channel.

Table 4-8
Median Elevation (NGVD) of Vegetation Classes along the Little Manatee River Transects*

	Transect	Willow Marsh	Tupelo Swamp	Hardwood Swamp	Pine / Maple Hammock	Pine / Laurel Oak Hammock	Laurel Oak / Pine Hammock	Laurel Oak Hammock	Palm Hammock	Oak Scrub
Upstream	VEG15				46.8	50.5	46.0	46.5		
	VEG14		44.9			46	45.6	45.5		
	LMAN3	27.6						27.3		
	VEG10							27		
	TOSCANY							14.9		
	VEG2				12.8			15.1	12.5	
	LMAN6				15.6		12	9.4	9.4	12.7
Downstream	MASONIC			13.2		18.1		10.7		20.7
	LMAN7	7.4		5.3	15.6		15.9	10		15
	VEG3				14.3	12.7		9.7	8.9	

*Shaded cells indicate absence of vegetation class.

Table 4-9
Median Relative Elevation (feet above channel bottom), of Vegetation Classes along the Little Manatee River Transects*

	Transect	Willow Marsh	Tupelo Swamp	Hardwood Swamp	Pine / Maple Hammock	Pine / Laurel Oak Hammock	Laurel Oak / Pine Hammock	Laurel Oak Hammock	Palm Hammock	Oak Scrub
m Up str	VEG15				6.5	10.0	6.4	6.2		

	VEG14		7.3			8.4	8.0	7.9		
	LMAN3	7.0						6.7		
	VEG10							8.8		
	TOSCANY							7.4		
	VEG2				9.5			11.9	9.3	
	LMAN6				13.6		10.0	7.4	7.4	10.7
	MASONIC			10.2		15.1		7.7		17.7
	LMAN7	8.4		2.3	15.4		15.7	9.8		14.8
	VEG3				12.1	10.5		7.5	6.7	

*Shaded cells indicate absence of vegetation class.

Table 4-10
Median Elevations (feet NGVD) of Hydric Soils by Vegetation Class along the Little Manatee River Study Corridor*

	Transect	Willow marsh	Tupelo swamp	Hardwood swamp	Pine/ laurel oak hammock	Laurel oak/ pine hammock	Pine / maple hammock	Laurel oak hammock	Palm hammock	Oak scrub
Upstream	VEG15				48.3			46.2		
	VEG14		44.9			44.8				
	LMAN3	27.4						33.6		
	VEG10							20.3		
	TOSCANY							13.05		
Downstream	VEG2								5.6	
	LMAN6								5.6	
	MASONIC			13.1				5.9		
	LMAN7									
	VEG3							9.3	7.1	

*Shaded cells indicate absence of hydric soils.

▪ Discriminant Function Analysis (DFA)

DFA was used to examine relationships among vegetation classes and environmental variables along the Little Manatee River study corridor. Elevations, soils, and distance to channel accounted for a significant amount of variation in among vegetation classes.

Correlation Results. DFA results indicated that the contributions of elevation, distance from river channel, and hydric soils index were significant in separating vegetation classes (Wilks' Lambda = 0.48; $p < 0.001$) (Table 4-11). Elevation and relative elevation had the strongest correlations with vegetation class ($r^2 = 0.23$ and 0.32, respectively), while correlations with soils ($r^2 = 0.29$) and distance from river channel ($r^2 = 0.28$) were lower.

Vegetation classes were distinct in terms of species composition and IV, and environmental variables were significant in accounting for these differences. The wetland vegetation classes (willow marsh,

tupelo swamp, and hardwood swamp) generally, but not always, had lower mean elevations and more hydric soils characteristics. Only the willow marsh occurred closer to the river channel when compared with the other vegetation classes. The tupelo swamp was a depressional swamp rather than connected to the river as the willow marsh and hardwood swamp often were. The hydric soils conditions were the best predictors of wetland vegetation.

Elevation (NGVD), relative elevations along transects, distance from channel, and hydric soil index were significant in separating vegetation classes from each other, although overlap in environmental parameters between vegetation classes occurred.

Classifications and Misclassifications. DFA was used to measure the contribution of elevation, distance from river channel, and soil parameters in characterizing vegetation classes along the Little Manatee River study corridor. Vegetation classes were classified correctly 40 percent of the time for willow marsh and 100 percent of the time for tupelo and hardwood swamp classes (willow marsh was classified incorrectly more frequently than correctly). Transition vegetation classes were correctly classified in 13.5 to 80 percent of the cases. The two upland classes were classified correctly in 88.9 and 66.7 percent of the cases. Overlap among classes was greatest among classes that were sampled less frequently, had greater variability in species, and occurred along more transects.

Row totals (the “to” classes) in Table 4-11 indicate the percent of the time (and number of times) a vegetation class was classified correctly and incorrectly. For example, willow marsh was identified in the field on five occasions (100 percent), but was classified as willow marsh using environmental measures on only two (40 percent) of those occasions. Willow marsh was incorrectly classified as hardwood swamp once, laurel oak/pine hammock once, and palm hammock once. In contrast, tupelo swamp was correctly classified as tupelo swamp all three times it was encountered (100 percent of the time.

Column totals in Table 4-11 (the “from” classes) represent the total number of times a group of measurements recorded in the field was classified as a target community (column heading) in the DFA analysis. Using the tupelo swamp example again, the number of observations classified as tupelo swamp was 10 (five percent) based on field measurements. While tupelo swamp was correctly classified 100 percent of the time (3 times), laurel oak hammock (row heading) was also classified as tupelo swamp (column heading) 6.4 percent of the time (in seven of the 110 times it was encountered).

Tupelo swamp and hardwood swamp were classified correctly 100 percent of the time. Laurel oak/pine hammock, pine/maple hammock, palm hammock, and oak scrub were classified correctly between 66.7 and 88.9 percent of the time. Pine/ laurel oak and laurel oak hammock were classified correctly 54.5 and 13.5 percent of the time and laurel oak hammock was classified as every other vegetation class. Willow marsh was correctly classified as willow marsh 40 percent of the time (2 cases), while it was incorrectly classified as hardwood swamp, laurel oak/ pine hammock, and palm hammock the remaining 60 percent of the time. Of the total 179 field samples, only six samples (3.4 percent) were classified as hardwood swamp, in contrast with 38 samples (21.2 percent) classified as palm hammock.

Vegetation classes were distinct in terms of species composition and IV, and environmental variables were significant in accounting for differences between vegetation classes. Elevations, relative elevations

along transects, distance from channel, and hydric soil index were significant in separating vegetation classes from each other, although overlap in environmental parameters between vegetation classes was frequent. Correlations between environmental variables and vegetation class were not strong.

Table 4-11

DFA Results for Vegetation Classifications*

Vegetation Class	Willow Marsh	Tupelo Swamp	Hardwood Swamp	Pine / Laurel Oak Hammock	Laurel Oak / Pine Hammock	Pine / Maple Hammock	Laurel Oak Hammock	Palm Hammock	Oak Scrub	Total
Willow marsh	40 (2)		20 (1)		20 (1)			20 (1)		100 (5)
Tupelo swamp		100 (3)								100 (3)
Hardwood swamp			100 (3)							100 (3)
Pine / laurel oak hammock				54.5 (6)		36.4 (4)		9.1 (1)		100 (11)
Laurel oak / pine hammock					80 (12)	20 (3)				100 (15)
Pine / maple hammock					14.3 (2)	71.4 (10)			14.29 (2)	100 (14)
Laurel oak hammock	5.5 (6)	6.4 (7)	1.8 (2)	6.4 (7)	26.4 (29)	7.3 (8)	13.5 (15)	23.6 (26)	9.1 (10)	100 (110)
Palm hammock						11.1 (1)		88.9 (8)		100 (9)
Oak scrub						11.1 (1)		22.2 (2)	66.7 (6)	100 (9)
Total	4.5 (8)	5. (10)	3.4 (6)	7.3 (13)	24.6 (44)	15.1 (27)	8.4 (15)	21.2 (38)	10.1 (18)	100 (179)

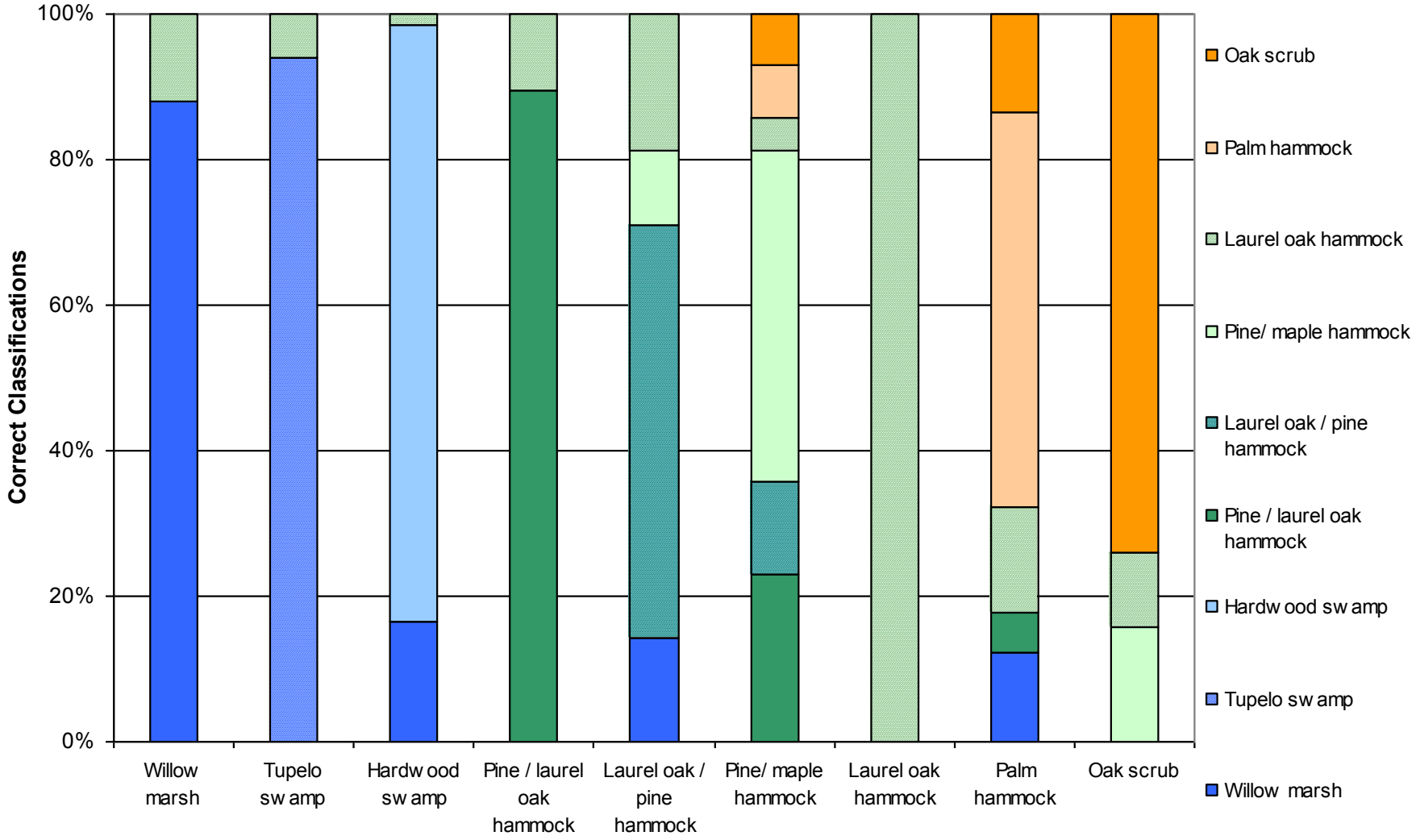
Wilks' Lambda=0.47624; F=19.35; DF=12

Variable	R-Square	F Value	Pr>F

Elevation	0.2262	6.21	<.0001
Relative elevation	0.3232	10.15	<.0001
Soils	0.2936	8.83	<.0001
Distance	0.2756	8.08	<.0001

*Shaded cells indicate zero classes and zero percent. Numbers in parentheses are N.

Figure 4-8
Percent Correct Classifications of Vegetation Classes along the Little Manatee River Study Corridor



However, relative elevation was more strongly correlated with vegetation class ($r^2 = 0.32$) when compared with soils ($r^2 = 0.29$), and distance to channel ($r^2 = 0.28$), and elevation ($r^2 = 0.23$), respectively. Environmental parameters accounted for a significant amount of variation among vegetation classes and correct classifications ranged from 53.6 percent to 100 percent in three other classes. The percent correct for each classification (outlined in bold in Table 4-11) is graphed in Figure 4-8 and are briefly summarized below.

- Tupelo swamp and hardwood swamp were classified correctly 100 percent of the time, followed by palm hammock (88.9 percent) and laurel oak / pine hammock (80 percent).
- The laurel oak hammock class was classified incorrectly 85 percent of the time, predominantly as laurel oak/ pine hammock (26.4 percent) and palm hammock (23.6 percent), overlapped with all the remaining vegetation classes, and was the most common vegetation class sampled.
- Vegetation classes were significantly correlated with measured environmental variables, although no correlation accounted for more than 32 percent of the variability.

Misclassifications in the DFA occur when a vegetation class is not successfully paired with corresponding environmental parameters and subsequently overlaps with other vegetation classes in regards to soil index, relative elevation, and distance from channel. Overlapping vegetation classes can indicate shared, or similar, habitat based on measured parameters (McNeely 1987). The overlap itself gives no indication of the resource preferences of overlapping species, although it does indicate the habitat being used (Colwell and Futuyama 1971), as well as the similar resource requirements of most plants (Goldberg and Werner 1983).

The mean values for elevation (NGVD), relative elevation, soils index, and distance from channel associated with each vegetation class through the DFA are listed in Table 4-12. The three wetland vegetation classes frequently corresponded to lower relative elevations, higher soils index values, and shorter distances to the river channel than the transition and upland vegetation classes.

Table 4-12

Mean Values of Parameters Used in DFA for Vegetation Classes along the Little Manatee River Study Corridor

	Willow marsh	Tupelo swamp	Hardwood swamp	Pine/ laurel oak hammock	Laurel oak/ pine hammock	Pine / maple hammock	Laurel oak hammock	Palm hammock	Oak scrub
Elevation (NGVD)	20.3	44.9	13.6	32.5	38.8	19.4	28.8	9.3	17.0
Relative Elevation (feet)	7.9	7.3	10.6	10.0	7.8	11.9	7.6	6.7	15.3

Soil Index	0.6	3.0	1.3	0.2	0.2		0.3	0.3	
Distance (feet)	76.9	739.4	321.2	1,073.0	421.8	563.9	376.8	160.6	238.7

▪ Wetted Perimeter

The wetted perimeters of vegetation classes in the study corridor are listed in Table 4-13 and indicate the linear distance inundated along a transect at a particular elevation or water level (river stage) in the Little Manatee river channel. The total wetted perimeter increases as elevation increases and does not vary significantly among vegetation classes. For example, if river stage was level with the median elevation for at the swamp vegetation class at the Masonic transect, 699 linear feet of habitat would be inundated below the median elevation of the hardwood swamp class (Table 4-13). Similarly, at a river stage equal to the median elevation of the oak scrub class along the same transect, 1,482 linear feet of habitat would be inundated.

The wetted perimeter along the Masonic transect is graphed in Figure 4-9 (all 10 transects are graphed in Appendix B). The graph is a standard x-y graph: the independent variable, elevation, is plotted along the x-axis, and the dependent variable, wetted perimeter, is plotted along the y-axis (elevation changes along transects were presented earlier in Section 4.1).

Typically, a sigmoid-shaped wetted perimeter curve coincides with a large increase in habitat across a small elevation gradient in floodplains (e.g. VEG15 and VEG14, Appendix B). Changes in wetted perimeter are also typically greater over more gradual changes in elevation than across steeper gradients (e.g. Masonic and LMAN7, Appendix B).

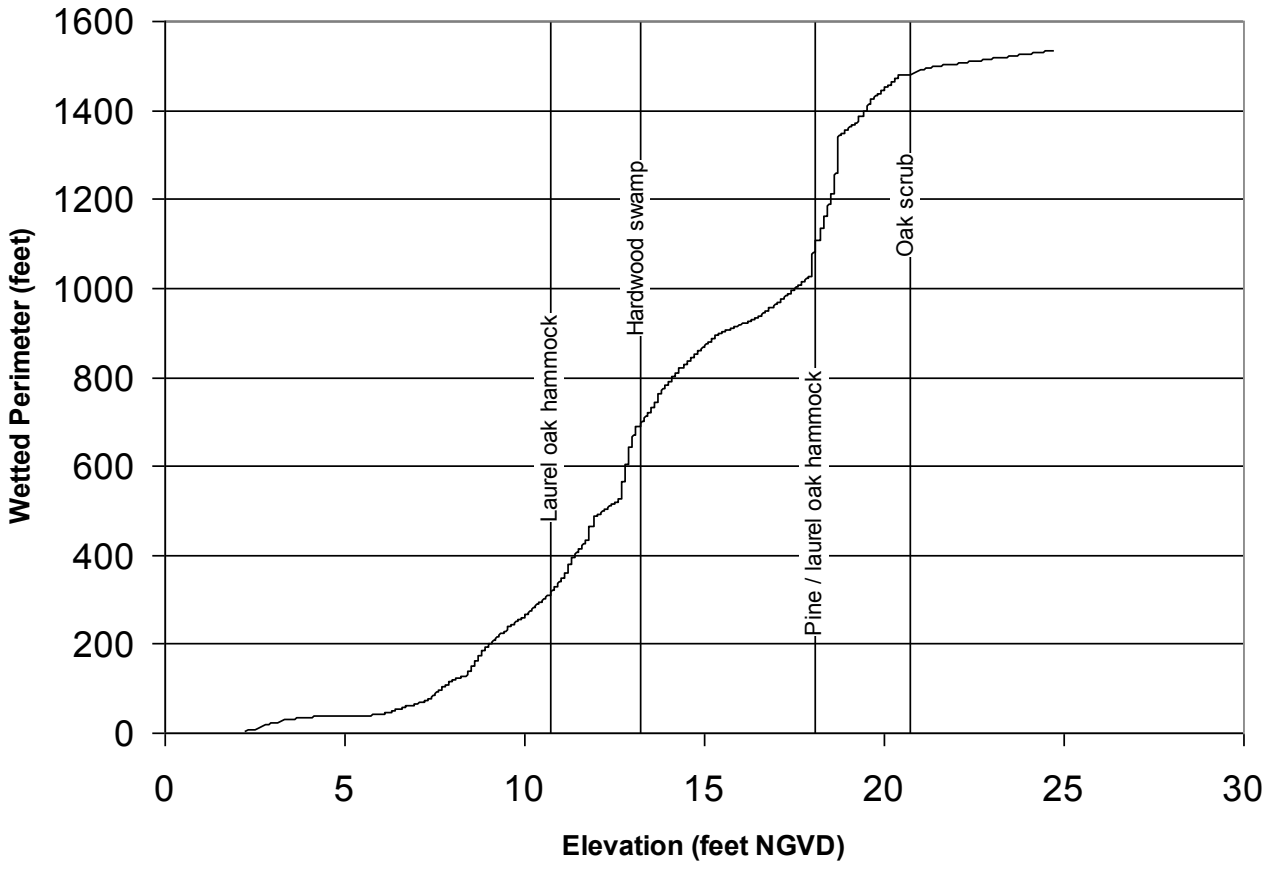
Table 4-13
Wetted Perimeter (linear feet), by Vegetation Class and Transect, along the Little Manatee River Study Corridor

Transect		Willow marsh	Tupelo swamp	Hardwood swamp	Pine / maple hammock	Pine / laurel oak hammock	Laurel oak / pine hammock	Laurel oak hammock	Palm hammock	Oak scrub
Downstream ↓ Upstream	**VEG 15**				1383	2,235	351	1,132		
	VEG 14		867			2,204	1,786	1,634		
	LMAN3	729						678		

	VEG 10							485		
	TOSCANY							482		
	VEG 2				431			671	318	
	LMAN6				944		461	205	205	600
	MASONIC			699		1,108		319		1,482
	LMAN7	246		186	419		436	284		388
	VEG 3				689	550		268	153	

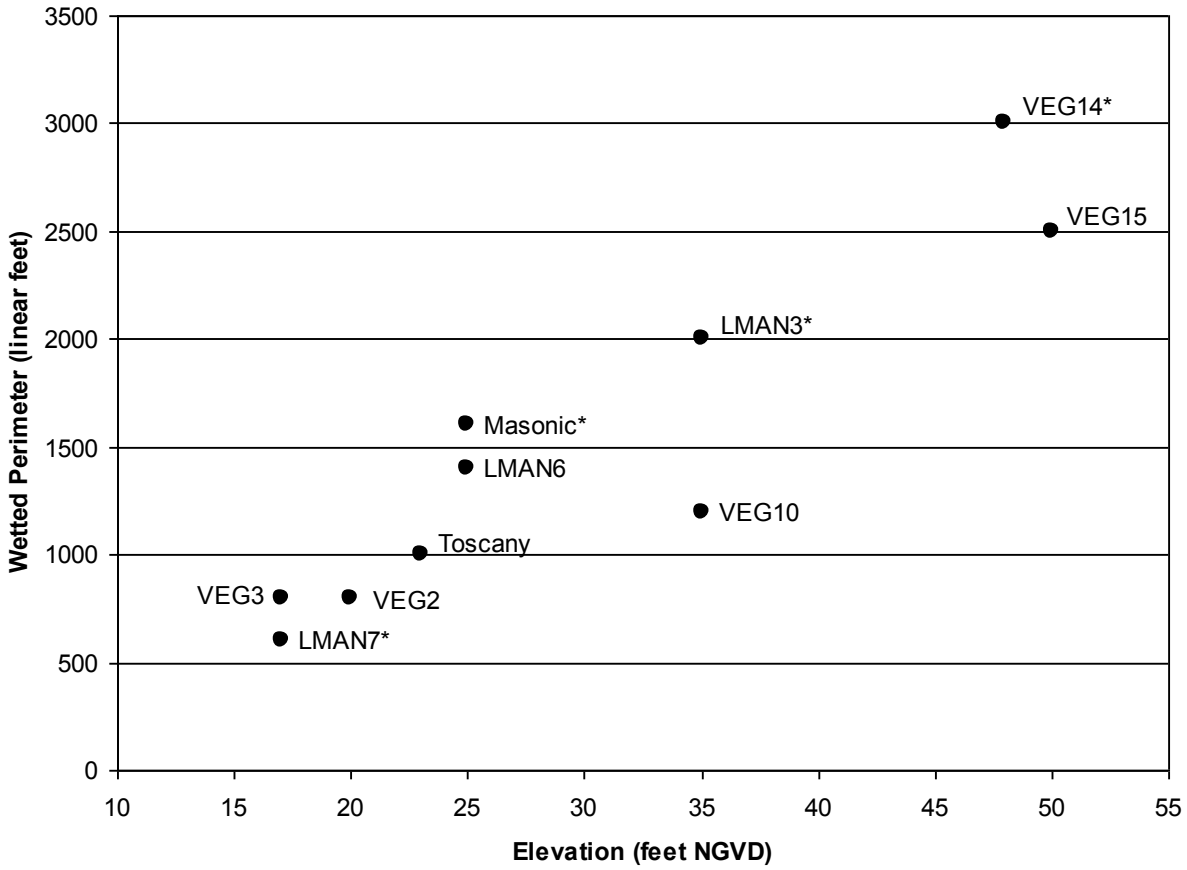
*Shaded cells indicate absence of vegetation class.

Figure 4-9
Wetted Perimeter and Associated Median Elevations along the Masonic Transect in the Little Manatee River Study Corridor



Wetted perimeters along the Little Manatee River transects corresponded with the upstream-downstream elevation gradient and were significantly ($p < 0.01$) and highly ($r^2 = 0.84$) correlated with elevation (feet NGVD) along the river (Figure 4-10). Wetted perimeter in the floodplain of the upper reaches of the river (transects VEG15, VEG14, and LMAN3) was greater than along the downstream reaches (VEG3, LMAN7, VEG2, and Toscany, etc.). Wetted perimeter did not correspond well with vegetation classes along the river and when wetlands were present along a transect (identified with asterisks in Figure 4-10), wetted perimeter differences were not apparent between wetlands and other vegetation classes that could not be accounted for by elevation differences. In other words, the upstream-downstream elevation differences were greater than the differences between vegetation classes. In addition, the small number of wetland classes may have obscured any elevation trends among wetland, transition, and upland vegetation classes, as described previously.

Figure 4-10
Wetted Perimeter and Associated Median Elevations along the Masonic Transect in the Little Manatee River Study Corridor



○ Relationship of Vegetation with Environmental Variables

Relationships among river stage, flow, and elevations were developed by the District for the Little Manatee River and are not presented here. However, it is appropriate to address hydrologic conditions such as saturation and inundation that are critical to the development of hydric soils and associated wetland vegetation.

Hydrology. Saturation and/or inundation are critical to the maintenance of wetlands vegetation in floodplains, although overbank flooding is not necessary (Cowardin *et al*. 1979, Reid and Wood 1976), and ground water can strongly influence the extent of wetlands (Light *et al.* 2002). Wetland trees are relatively fast-growing and in five years can generally grow to a height at which inundation will not kill it. For example, cypress trees can exceed one meter tall in one to two years (Harms 1973). Cabbage palms are unusual in that they require an initial establishment phase of 30 to 60 years during which they have no above-ground trunk (McPherson and Williams 1996) and flood events at 25 year intervals or more probably restrict the regeneration of cabbage palm. Once established, they are susceptible to only rising sea level, hurricanes, and fires. Therefore, under existing conditions, the tree communities along the Little Manatee River are not anticipated to change in composition or structure.

Competition. Wetland species occur in wetlands because they are tolerant of saturated and anoxic conditions that preclude upland species. Several studies have indicated that environmental gradients are more important in determining species distributions under physiological stressful conditions such as flooding, while competition may be more important under relatively benign environmental conditions (Latham *et al.* 1994, Grace and Wetzel 1981, others). Species such as laurel oak, which is relatively intolerant of persistent inundation when compared with a species such as cypress or tupelo, can be at a competitive advantage in the absence of persistent flooding and subsequently expand into areas previously dominated a wetland species such as popash or tupelo. The basal area and densities of oaks in the laurel oak vegetation class suggest that this is a well-established stand of vegetation. There was no indication of recent invasion of wetlands by upland species along the study corridor.

Disturbance. Invasive and nonnative species such as Brazilian pepper (*Schinus terebinthifolius*) and paragrass have a competitive advantage under disturbed conditions. Disturbances can occur as fire, flooding, animal activity, etc. and provide an opening into which a species that may not otherwise survive can become established due to the absence of other species. Mature native trees can continue to shade out many invasive species until the native trees die and create openings into which invasive species expand. No exotic species such as Brazilian pepper, punk trees (*Melaleuca quinquenervia),* Chinese tallow *(Sapium sebiferum),* or camphor tree *(Cinnamomum camphora),* were observed along any of the transects. Nor were any signs of serious invasion by nonnative and invasive species observed.

Inundation Periods in Southeastern Wetlands. The vegetation classes along the Little Manatee River are not typical of forested southeastern flood plains (described by Light *et al*. 2002 and Wharton *et al*. 1982), but are more consistent with seasonally and temporarily flooded river systems that are characterized by a wider range of environmental conditions and extremes, similar to the Braden River in Manatee County. Seasonal and temporarily flooded wetlands may be more sensitive to changes in

natural flow regimes and hydrological variability (quantity, timing and duration of flows and floods, and periods of low flows) and subsequent effects on biodiversity and fisheries (Poff *et al.* 1997).

Alterations in the historical inundation patterns in the upper reaches of the Little Manatee River have not been documented. The vegetation along the study corridor appears consistent with species of temporarily flooded dry hardwood hammocks and in some cases the wet hardwood hammocks described for the southeastern U.S. (Table 4-14). Only the hardwood and tupelo swamps encountered along VEG14 and the Masonic transect appeared to be seasonally or possibly permanently flooded. Wetland vegetation in the study corridor indicates that the river channel itself is deep enough for more than three weeks during the wet season to preclude the expansion of upland species into the river itself and along the river banks. Cypress trees occur infrequently along the Little Manatee River and none were encountered along sampling transects in the study corridor. Cypress is an obligate wetland species, tolerant of up to three meters of inundation for more than 10 years, and more tolerant of wetland conditions than the species documented as part of this study. Tupelo trees are also very tolerant of flooding, although like the cypress, they occur in depressional areas that intercept the water table and have fluctuating water levels. Cypress cannot germinate under flooded conditions and do not grow quickly enough to successfully compete with other wetland tolerant species. Fire following logging or drainage can destroy both seeds and roots in the soil and favor replacement by willows and then mixed hardwoods (Myers and Ewel 1990). The paucity of cypress in south Hillsborough and Manatee counties in general has been attributed to logging, fire, declines in ground water levels, and differences in geomorphology. Unfortunately, no documentation of the actual cause(s) is available.

Climate. Large-scale climatic events may also influence long term stream flows and should be considered when establishing MFLs for the Little Manatee River. For example, seasonal and long term flow pattern differences between north Florida rivers (Suwannee River, Apalachicola River, Withlacoochee River) and south Florida rivers (Alafia River, Peace River, Myakka River) appear to coincide with the Atlantic multi-decadal oscillation (AMO) events (Basso and Schultz 2003). These events affect ocean temperature and rainfall patterns that ultimately influence regional stream flows, floodplain inundation, and vegetation patterns. In the Peace River watershed, wet periods correspond to higher wet season flows, but not dry season flows. Stream flow and rainfall data recorded since the 1900s indicate flow declines in the Peace River even when these rainfall patterns are accounted for. The conditions in the Little Manatee River watershed appear similar and at low flows in the river have been attributed at least in part to agricultural withdrawals.

Table 4-14
Typical Hydrology, Soils, and Species Composition in Floodplain Communities in the Southeastern U.S.

Vegetation Community[1]	Hydrology [2,3,4]	Soils[1,2]	Dominant Trees[1]
Cypress, palm/ cypress, and hardwood swamps, semi-permanently flooded	Inundated avg. 7 mo./yr. [2] Flooded 4-7 mo./yr. Saturated 9 mo.[3,4] Min. 14-day flood/2 yr. at 1m. Range of 5-10 mo./yr. [5]	Hydric-clay, muck, loam	Cypress dominant in lower swamp, mixed in higher swamp.
Wet hardwood hammock, seasonally flooded	Flooded avg. of 2 mo./year. Saturated 3 mo. [2,3,4] Min. 14-day flood/2 yr.	Hydric-loam, sand, clay	Cypress, hickory, ash, water oak, maple
Dry hardwood hammock, temporarily flooded	Flooded up to 1 month of growing season [3,4] Minimum 14-day flood/5 yr.	Hydric/ nonhydric	Maple, elm, ash, gum, oak.

[1]Peace and Myakka Rivers (PBS&J 2002). [2]Light *et al.* 2002). [3]Wharton *et al.* 1982. [4]Cowardin *et al.* 1979. [5]Coultas and Deuver 1984.

• Conclusions

Forested systems within the 100 year floodplain of the Little Manatee River study corridor were comprised of nine distinct vegetation classes based on tree species diversity and IV. Wetland, transitional, and upland vegetation classes generally coincided with commensurate changes in elevations, soils, and distance to channel, although soils corresponded better with elevation than vegetation and overlap among vegetation classes was frequent. The small number of wetlands along the sampling transects contributed to the high variability in elevation within vegetation classes, and consequently, to the overlap among vegetation classes.

Vegetation. Differences in vegetation classes along the Little Manatee River study corridor were significant based on importance values (IVs) that were calculated based on tree species density, basal area, and frequency and provide a relative measure of species dominance (no units). Three wetland vegetation classes were identified in the study corridor. The classes included only obligate and facultative wetland tree species, including Carolina willow (*Salix carolinana*), tupelo (*Nyssa sylvatica*), sweet bay or swamp bay (*Magnolia virginiana*), water oak (*Quercus nigra*), and popash (*Fraxinus caroliniana*). Transition vegetation classes (between wetlands and uplands) were characterized by predominantly facultative wetland species such as laurel oak (*Q. laurifolia*) and slash pine (*Pinus elliottii*) in combination with other facultative species and up to 23 different species. Species in the two upland classes included primarily the facultative cabbage palm and the upland scrub hickory and included from six to 11 different species.

Species IVs indicated a shift in importance from willows, tupelo, and sweet bay to laurel oak and slash pine to scrub oak and sand pine coincided with a gradual transition from wetland to upland vegetation classes. Laurel oak, slash pine, tupelo, and willow made up approximately 56 percent of the total IVs (by species) among all classes. Five species made up approximately 29 percent of the total IVs by species: cabbage palm, water oak, popash, live oak, and scrub hickory. The laurel oak hammock class had the largest total basal area (35,718 in^2/acre) and lowest density (approximately 12 trees/acre), indicating older stands of larger trees. The willow marsh and tupelo swamp had the highest densities (90 and 135 trees/acre, respectively), and relatively low total basal areas (3,743 and 19,215 in^2/acre, respectively), indicating younger trees.

Elevations and Soils. River channel elevations declined appreciably downstream, from 5.0 feet to 0.1 feet NGVD at the transect farthest downstream (just east of U.S. Highway 301), a change in elevation of approximately 38 feet over about 12 miles (0.3 feet/mile). In contrast, elevation changes along transects ranged from 11.6 to 22.8 feet over a half mile or less (22.4 feet/mile).

Changes in vegetation were more conspicuous along study transects than along the upstream – downstream river channel gradient and may reflect the steeper elevation change along transects when compared with the upstream to downstream elevation gradient. Wetland vegetation communities were absent along the mid-reach study transects and no upland classes occurred along the five most upstream transects.

Hydric soils were found along nine of the 10 study transects and in all vegetation classes except the scrub oak class. Muck soils were found at all transects. The tupelo swamp and hardwood swamp classes were the only classes with exclusively hydric soils. Median elevations of hydric soils were lower when compared with nonhydric soils in all but the laurel oak hammock class.

Discriminant Function Analysis (DFA). Vegetation classes were distinct in terms of species composition and IV, and environmental variables were significant in accounting for differences between vegetation classes. Elevations, relative elevations along transects, distance from channel, and hydric soil index were significant in separating vegetation classes from each other, although overlap in environmental parameters between vegetation classes was frequent. Correlations between environmental variables and vegetation class were not strong. Relative elevation was more strongly correlated with vegetation class ($r^2 = 0.32$) when compared with soils ($r^2 = 0.29$), and distance to channel ($r^2 = 0.28$), and elevation ($r^2 = 0.23$), respectively.

Vegetation classes were classified correctly 100 percent of the time for tupelo and hardwood swamp classes. Willow marsh and laurel oak hammock were classified incorrectly more frequently than correctly. Overlap was greatest among vegetation classes with the fewest samples, greatest variation in species, and those that occurred along more transects. The laurel oak hammock vegetation class overlapped with all other vegetation classes, but predominantly with the palm hammock and the pine/ maple hammock.

Wetted Perimeter. Wetted perimeters along the Little Manatee River transects corresponded with the upstream-downstream elevation gradient and were significantly ($p < 0.01$) and highly ($r^2 = 0.84$) correlated with elevation (feet NGVD) along the river In contrast, wetted perimeter did not correspond well with vegetation classes and when wetlands were present along a transect, wetted perimeter differences were not apparent between wetlands and other vegetation classes that could not be accounted for by elevation differences. The small number of wetland classes may have contributed to the absence of any identifiable trends in wetted perimeter and vegetation class.

Conclusions. Nine distinct vegetation classes were identified along the Little Manatee River study corridor based on woody species composition and IV. Soils, elevations, and distances from river channel were significantly related to vegetation classes, but not highly correlated. Willow marsh, tupelo swamp, and hardwood swamp vegetation classes generally occurred at lower elevations on hydric and/or saturated soils in contrast with the upland palm hammock and oak scrub vegetation class. However, wetland vegetation classes were encountered along only four of the ten transects, while each of the remaining six vegetation classes occurred along three or more transects.

Based on the results of this study, only the tupelo swamp and hardwood swamp vegetation classes may provide a criterion on which to establish MFLs for vegetation communities along the Little Manatee River. Hydric soils appeared to be better indicators of wetland conditions than most vegetation classes. No cypress wetlands were encountered along the river channel during the vegetation studies, and the three wetland classes sampled are characterized by species less tolerant of flooding than cypress.

• Relevant Literature

Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. U.S. Geologic Survey. Professional Paper 964. 28 pp.

Austin, M.P., and P.C. Heyligers. 1989. Vegetation survey design for conservation: gradsect sampling of forests in northeastern New South Wales. Biological Conservation 50:(3 32).

Baker, J.A., K.J. Kiligore, and R.L. Kasul. 1991. Aquatic habitats and fish communities in the lower Mississippi River. Reviews in Aquatic Sciences 3(4):313-356.

Bass, D.B. Jr. 1991. Riverine fishes of Florida. Pp 65-84 *In* Livingston, R.J. (ed.) The Rivers of Florida. Springer-Verlag. New York. 289 pp.

Brown, C.A. 1984. Morphology and biology of cypress trees. Pp. 16-24 *In* Ewel, K.C. and Odum, H.T. (eds.) Cypress Swamps: Gainesville, University Presses of Florida.

Brown, M.T., Schaefer, J.M. and Brandt, K.H. 1990. Buffer zones for water, wetlands and wildlife in east central Florida. CFW Publication #89-07. Florida Agricultural Exp. Stations Journal Series No. T-00061. East Central Florida Regional Planning Council.

Burns, R. and B. Honkala. 1990. Silvics of North America, Volume 1. Conifers. Agricultural Handbook No. 654. United States Department of Agriculture, Forest. Service. 675 pp.

Collins, M.E. 1985. Key to soil orders in Florida. Soil Science Fact Sheet SL-43. Florida Cooperative Extension Service, IFAS. University of Florida, Gainesville, Florida.

Conner, W.H., and G.R. Askew. 1993, Impact of saltwater flooding on red maple, redbay, and Chinese tallow seedlings. Castanea 58(3): 214-219.

Coultas, C.L. and M.J. Deuver. 1984. Soils of Cypress Swamps. Pp. 51-59. *In* K.C. Ewel and H.T. Odum (eds.) *Cypress Swamps*. University Presses of Florida. Gainesville, Florida. 492 pp.

Cowardin, L.M., Virginia Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS-79/31. 103 pp.

Cox, J., R. Kautz, M. MacLaughlin, and T. Gilbert. 1994. Closing the GAPs in Florida's Wildlife Habitat Conservation System. Prepared for Florida Game and Fresh Water Fish Commission, Tallahassee, Florida. 39 pp.

Demaree, D. 1932. Submerging experiments with *Taxodium*. Ecology 13(3):258-262.

DeSteven, D. and M. Toner. 2004. Vegetation of upper coastal plain depression wetlands: environmental templates and wetland dynamics within a landscape framework. Wetlands 24(1):23-42.

DuBarry, A.P., Jr. 1963. Germination of bottomland tree seed while immersed in water. Journal of Forestry 61: 225-226.

Duever, M.J., J.E. Carlson, L.A. Riopelle, and L.C. Duever. 1978. Ecosystem analysis at Corkscrew Swamp. *In* Cypress Wetlands for Water Management, Recycling, and Conservation. Pp 534-570. 4th Annual Report to the National Science Foundation and Rockefeller Foundation, Center for Wetlands. University of Florida, Gainesville, Florida.

Enfield, D.B., A.M. Mestas-Nunez, and P.J. Trimble. 2001. The Atlantic Multidecadal Oscillation and its relation to rainfall and river flows in the continental U.S. Geophysical Research Letters 28(10):2077-2080.

Ernst, K.A. and J.R. Brooks. 2001. The influence of increased flooding on stand structure and community composition in a central Florida hardwood swamp. Forest Ecology and Management.

Estevez, E.D., L. K. Dixon, and M.S. Flannery. Pp 187-222 *In* Livingston, R.J. (ed.) The Rivers of Florida. Springer-Verlag. New York. 289 pp.

FDEP. 2007. Peace River Cumulative Impact Study. Prepared by PBS&J, Tampa, FL. 1,800p.

FDEP (formerly Department of Natural Resources Division of Recreation and Parks). 1987. Little Manatee River State Recreation Area Unit Management Plan. 80 pp. and appendices.

Fernandez, M., Jr. 1990. Surface-Water Hydrology and Salinity of the Anclote River Estuary, Florida. U.S. Geological Survey Water-Resources Investigations Report 89-4046, prepared in cooperation with the Southwest Florida Water Management District.

Fernandez, Mario, Jr. 1985, Salinity characteristics and distribution and effects of alternative plans for fresh-water withdrawal, Little Manatee River estuary and adjacent areas of Tampa Bay, Florida: U.S. Geological Survey Water-Resources Investigations Report 84-4301, 45 p.

Fowells, H.A. 1965. Silvics of forest trees of the United States (revised): Washington, D.C., U.S. Department of Agriculture, Forest Service, Agriculture Handbook No. 271. 762 pp.

Gilbert, K.M., J.D. Tobe, R.W. Cantrell, M.E. Sweeley, and J.R. Cooper. 1995. The Florida Wetlands Delineation Manual. Florida Department of Environmental Protection, South Florida Water Management District, St. Johns River Water Management District, Southwest Florida Water Management District, and Northwest Florida Water Management District. 1997 pp.

Gillison, A.N. and K.R.W. Brewer. 1985. The use of gradient directed transects or gradsects in natural resource survey. Journal of Environmental Management 20:103 127.

Goldberg, D.E., and P.A. Werner. 1983. Equivalence of competitors in plant communities: a null hypothesis and a field experimental approach. American Journal of Botany 70:1098-1104.

Grace, J. B. and R. Wetzel. 1981. Habitat positioning and competitive displacement in cattails (Typha): experimental field studies. American Naturalist 113:463-474.

Hammett, K.M. 1985. Low-flow frequency distributions for streams in west-central Florida: U.S. Geological Survey Water-Resources Investigations Report 84-4299. 166p.

Harms, W.R. 1973, Some effects of soil type and water regime on growth of tupelo seedlings. Ecology 54(1):188-193.

Harms, W.R., H.T. Schreuder, D.D. Hook, C.L. Brown, F.W. Shropshire. 1980. The effects of flooding on the swamp forest in Lake Ocklawaha, Florida. Ecology 61(6):1412-1421.

Hill, J., and GD Grossman. 1987. Home range estimates for three North American stream fishes. Copeia 1987 (2):376-380.

Hosner, J.F. 1960. Relative tolerance to complete inundation of fourteen bottomland tree species. Forest Science 6(3): 246-251.

Kroes, D.E. and M.M. Brinson. 2004. Occurrence of riverine wetlands on floodplains along a climatic gradient. Wetlands 24(1):167-177.

Latham, P. J., W. M. Kitchens, L.G. Pearlstine. 1994. Species associations changes across a gradient of freshwater, oligohaline, and mesohaline tidal marshes along the Savannah River. Wetlands 14: 174-83.

Light, H.M., M.R. Darst, and J.W. Grubbs. 1998, Aquatic habitats in relation to river flow in the Apalachicola River floodplain, Florida: U.S. Geological Survey Professional Paper 1594, 77 pp., 3 plates.

Light, H.M., M.R. Darst, L.J. Lewis, and D.A. Howell. 2002. Hydrology, vegetation, and soils of riverine and tidal floodplain forests of the Lower Suwannee River, Florida, and potential impacts of flow reduction, U.S. Geological Survey Professional Paper.

Lopez, M.A., J.D. Fretwell. 1992. Relation of Change in Water Levels in Surficial and Upper Floridan Aquifers and Lake Stage to Climatic Conditions and Well-Field Pumpage in Northwest Hillsborough, Northeast Pinellas, and South Pasco Counties, Florida. U.S. Geological Survey Water-Resources Investigations Report 91-4158 prepared in cooperation with the Southwest Florida Water Management District and Pinellas County, Florida.

Loucks, W.L. and R.A. Keen. 1973. Submergence tolerance of selected seedling trees. Journal of Forestry 71. 496-497.

McCarron, J.K., K.W. McLeod, W.H. Conner. 1998. Flood and salinity stress of wetland woody species, buttonbush (*Cephalanthus occidentalis*) and swamp tupelo (*Nyssa sylvatica* var. *biflora*). Wetlands 18(2).

McPherson, K. and K. Williams. 1996. Establishment growth of cabbage palm, *Sabal palmetto* (Arecaceae). American Journal of Botany (83)12:1566-1570.

Metz, P.A. 1995. Hydrogeology and simulated effects of ground-water withdrawals for citrus irrigation, Hardee and De Soto Counties, Florida U.S. Geological Survey Water-Resources Investigations Report 93-4158. 83 pp.

Mueller-Dombois, D., and Ellenberg, H. 1974. Aims and Methods of Vegetation Ecology. New York, John Wiley. 547 pp.

Peek, H.M. 1958. Ground water resources of Manatee County, Florida: Florida Geologic survey Report Investigation 15. 99 pp.

Perry, L., and K. Williams. 1996. Effects of salinity and flooding on seedlings of cabbage palm (*Sabal palmetto*). Oecologia (105): 428-434.

Poff, N.L., D. Allen, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks and J.C. Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. BioScience 47(11): 769-784.

Randazzo, A.F. and D.S. Jones, eds. 1997. *The Geology of Florida.* Gainesville, FL University Press of Florida.

Reid, G. K., and R. D. Wood. 1976. Ecology of Inland Waters and Estuaries. D. Van Nostrand and Co., New York. 485 pp.

Richter, B.D, J.V. Baumgartner, R. Wigington, and D.P. Braun. 2001. How much water does a river need? Freshwater Biology 37:231-249.

Rosenau, J.C., Faulkner, G.L., Hendry, C.W., and Hull, R.W. 1977. Springs of Florida (2d ed.): Florida Bureau of Geology Bulletin no. 31, 461 p.

SAS Statistical Software. SAS Institute Inc. 100 SAS Campus Drive Cary, NC 27513-2414 USA

Soil Conservation Service. 1983. *Soil Survey of Manatee County, Florida*. United States Department of Agriculture, Soil Conservation Service. 1991. *Soil Survey of Sarasota County, Florida*. United States Department of Agriculture.

Soil Conservation Service. 1958. So*il Survey of Hillsborough County, Florida*. United States Department of Agriculture, Soil Conservation Service. *Soil Survey of Sarasota County, Florida*. United States Department of Agriculture.

Clewell, A., M. Flannery, S. Janicki, R. Elsenwerth, and R. Montgomery. 2002. An Analysis of vegetation-salinity relationships in seven tidal rivers on the coast of west-central Florida (DRAFT). Technical Report of the Southwest Florida Water Management District, Brooksville, FL.

Souther, R.F. and G.P. Shaffer. 2000. The effects of submergence and light on two age classes of baldcypress (*Taxodium distichum* (L.) Richard) seedlings. Wetlands 20(4).

Southwest Florida Water Management District. 2002. Little Manatee River Comprehensive Watershed Management Plan. Southwest Florida Water Management District. 2379 Broad Street Brooksville, Florida 34604.

Southwest Florida Water Management District. 2001. Regional Water Supply Plan. Southwest Florida Water Management District. 2379 Broad Street Brooksville, Florida 34604.

Southwest Florida Water Management District. 1975. Hydrobiological Assessment of the Alafia and Little Manatee Rivers. Prepared by Dames and Moore. Document number 00444 (microfilmed). Southwest Florida Water Management District. 2379 Broad Street Brooksville, Florida 34604.

Southwest Florida Water Management District. 1992. Resource Evaluation of the Little Manatee River Progect (Save Our Rivers Program/ Preservation 2000). 2379 Broad Street Brooksville, Florida 34604.

Tolliver, K.S., D.W. Martin, and D.R. Young. 1997. Freshwater and saltwater flooding response for woody species common to barrier island swales. Wetlands 17(1).

U.S. Department of Agriculture, Soil Conservation Service (SCS) 1982. Soil Survey of Pasco County, Florida. Published by the USDA Soil Conservation Service in cooperation with the University of Florida, Institute of Food and Agricultural Sciences, Agricultrual Experiment Stations, Soil Science Department, and Florida Department of Agriculture and Consumer Services. 39 p, 52p.

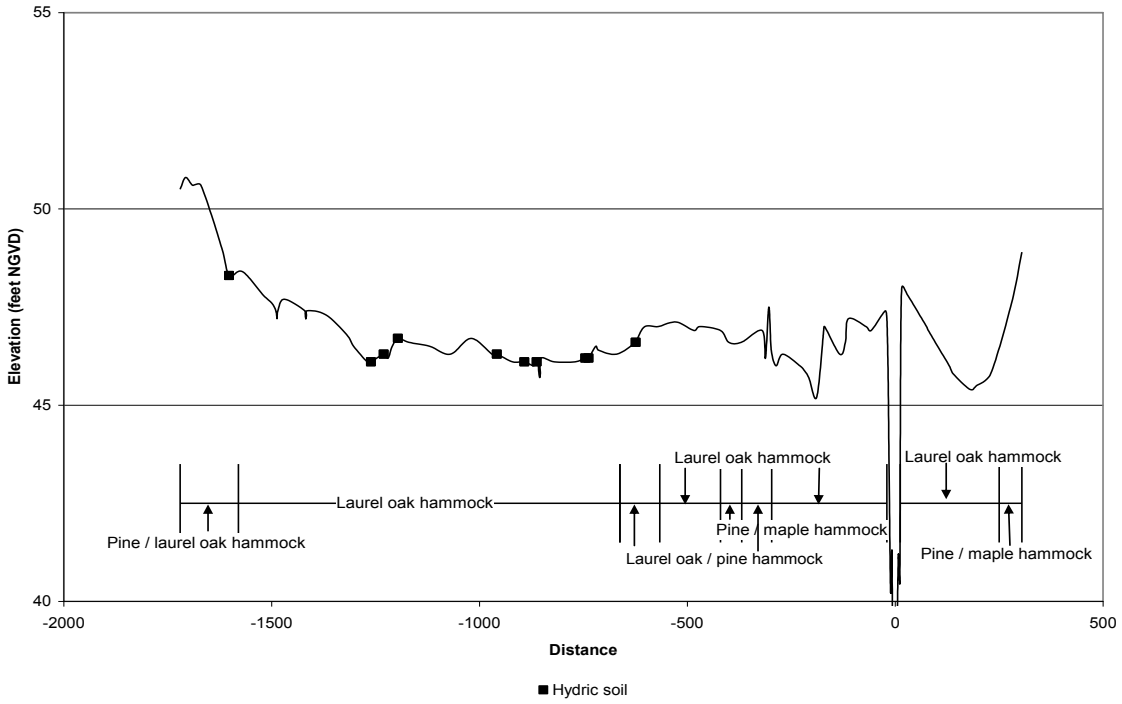
U.S. Department of Agriculture, Soil Conservation Service. 1996. Field Indicators of Hydric soils in the United States. G.W. Hurt, P.M. Whited, and R.F. Pringle R.F. (eds). USDA, NRCS, Fort Worth, TX.

Wharton, C.H., Kitchens, W.M., Pendleton, E.C., and Sipe, T.W. 1982. The ecology of bottomland hardwood swamps of the southeast: A community profile: U.S. Fish and Wildlife Service FWS/OBS- 81/37, 133 pp.

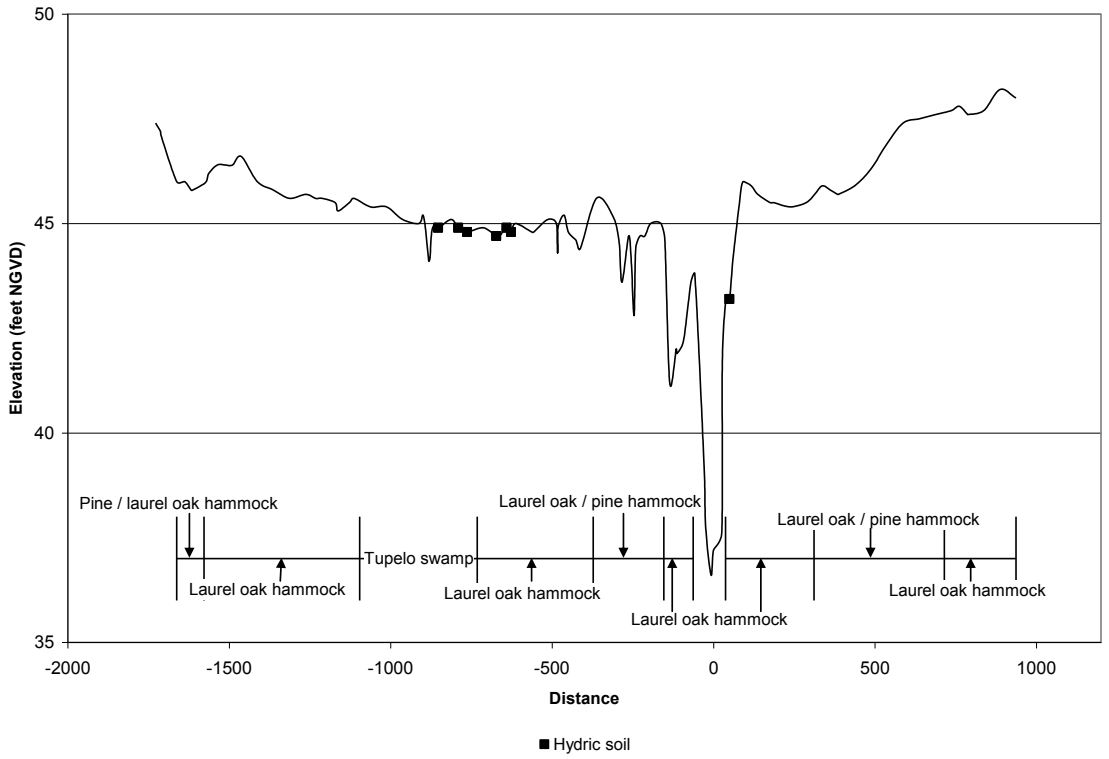
Appendix A

Elevation and Vegetation Profiles for the Little Manatee River Study Corridor

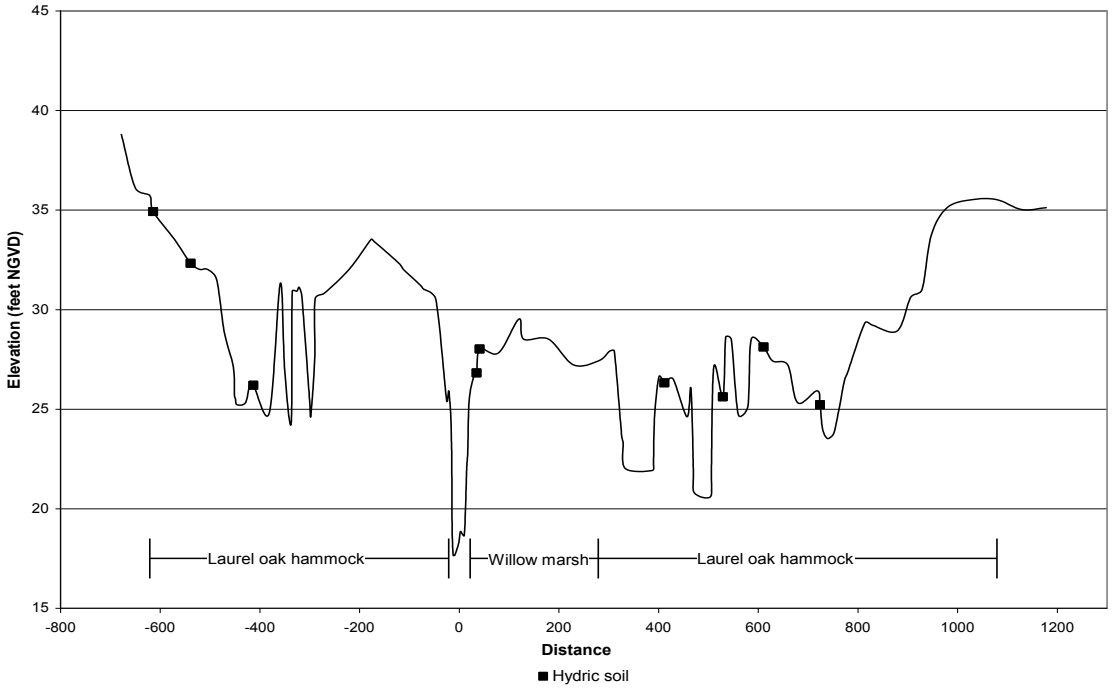
VEG15


55
50
45
40
Elevation (feet NGVD)
-2000
-1500
-1000
-500
0
500
Distance
Laurel oak hammock
Laurel oak hammock
Laurel oak hammock
Pine / laurel oak hammock
Pine / maple hammock
Laurel oak / pine hammock
Pine / maple hammock
Hydric soil

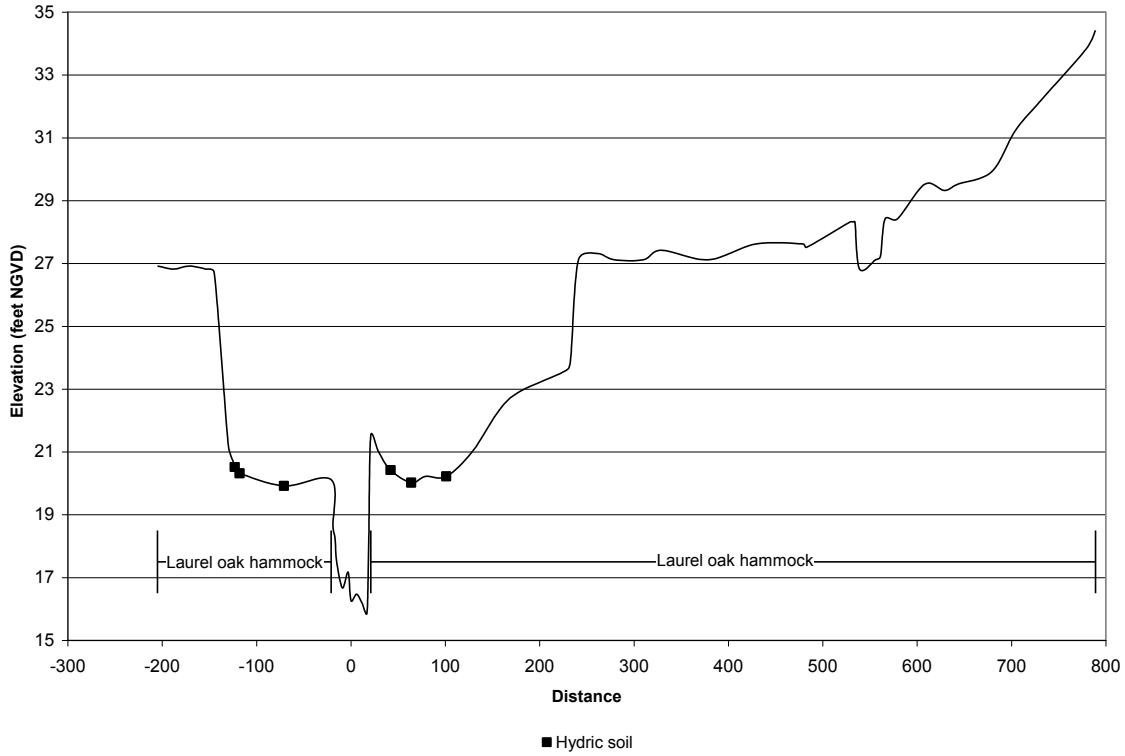
VEG14


50
45
40
35
Elevation (feet NGVD)
-2000
-1500
-1000
-500
0
500
1000
Distance
Pine / laurel oak hammock
Laurel oak / pine hammock
Laurel oak / pine hammock
Tupelo swamp
Laurel oak hammock
Laurel oak hammock
Laurel oak hammock
Laurel oak hammock
Hydric soil

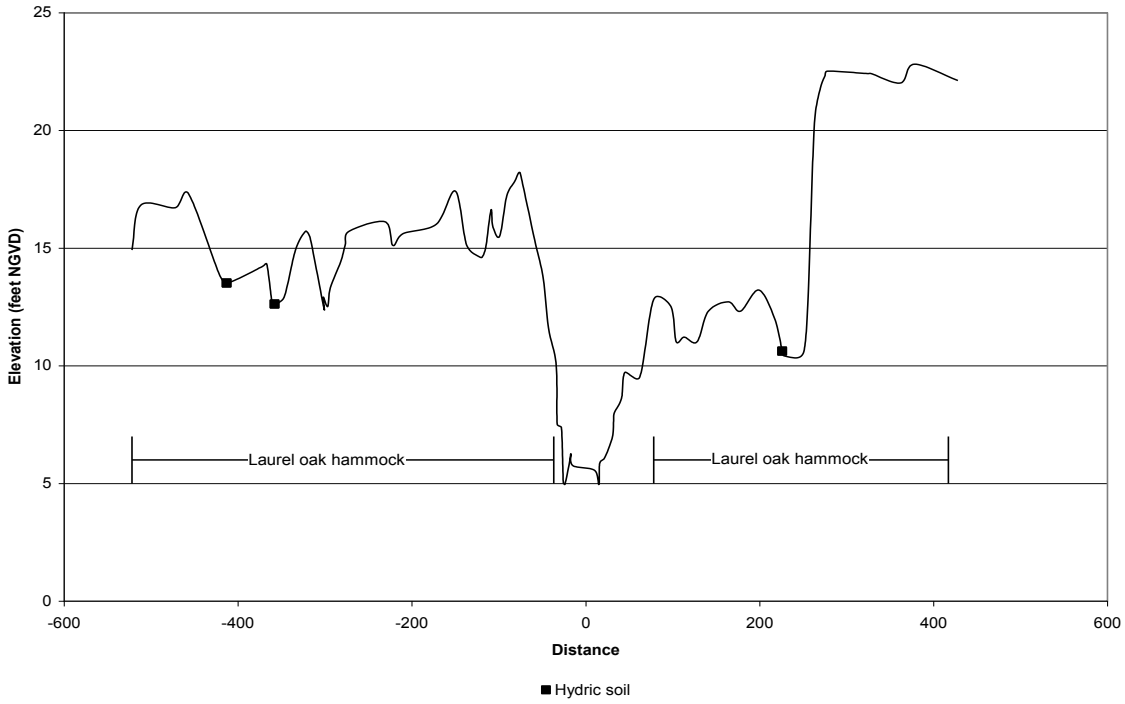
LMAN3


45
40
35
30
25
20
15
Elevation (feet NGVD)
-800
-600
-400
-200
0
200
400
600
800
1000
1200
Distance
Laurel oak hammock
Willow marsh
Laurel oak hammock
Hydric soil

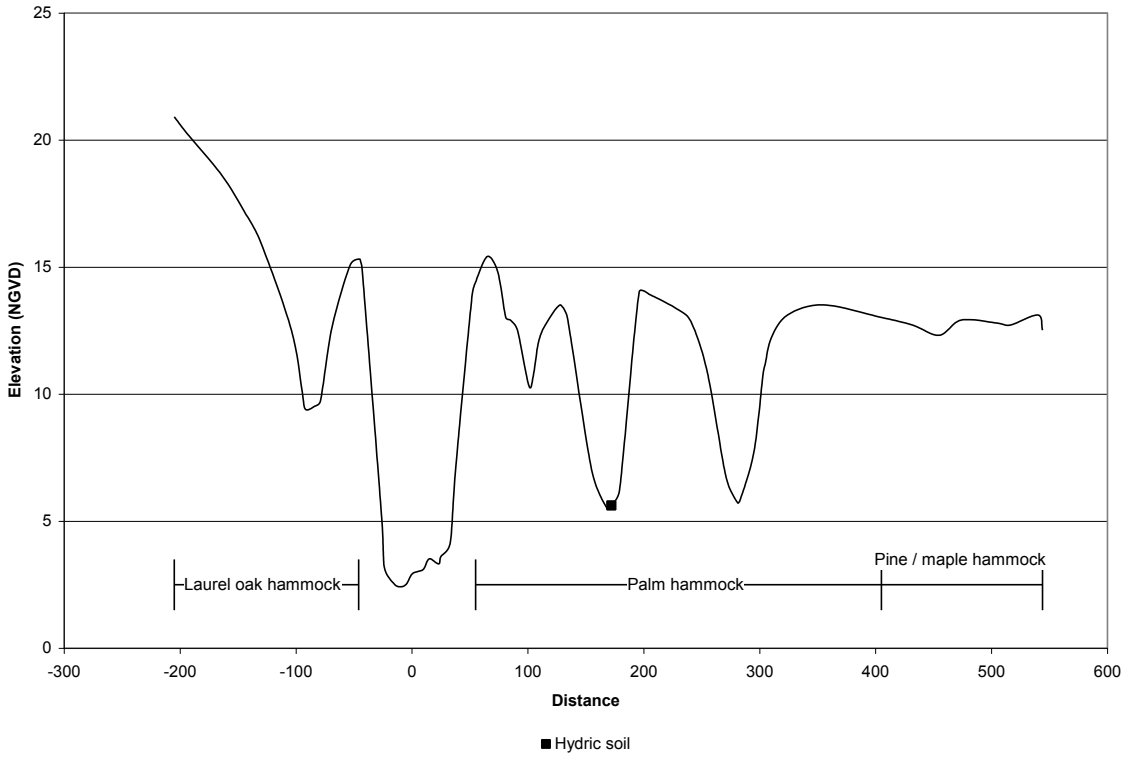
VEG10


35
33
31
29
27
25
23
21
19
17
15
Elevation (feet NGVD)
-300
-200
-100
0
100
200
300
400
500
600
700
800
Distance
Laurel oak hammock
Laurel oak hammock
Hydric soil

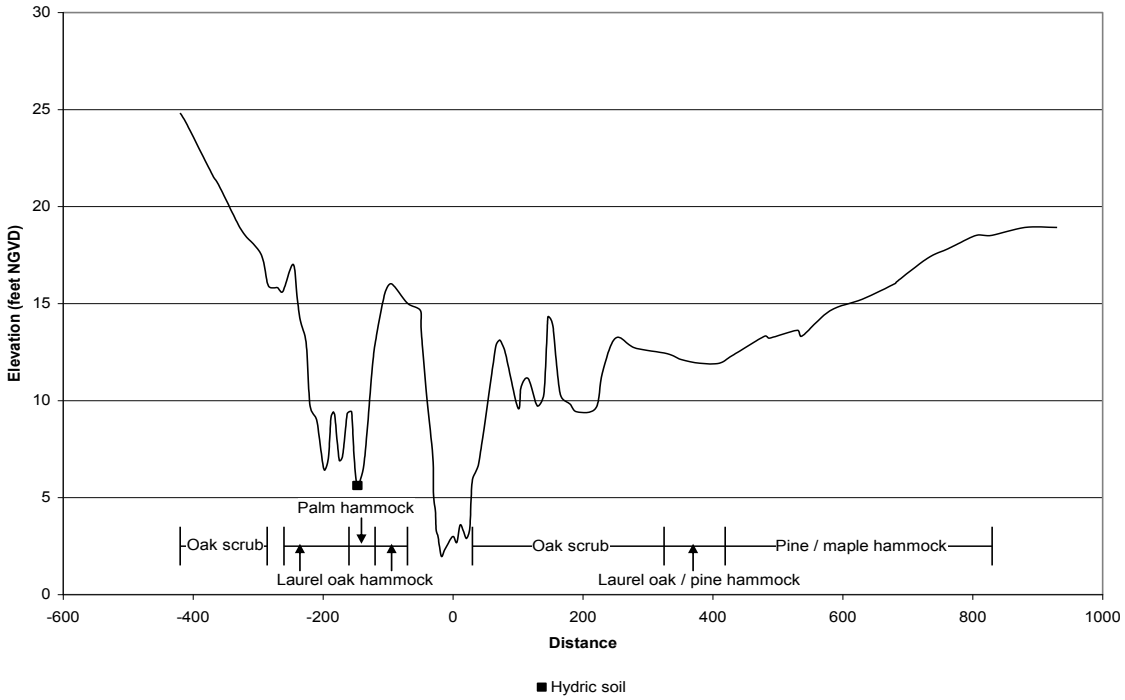
TOSCANY



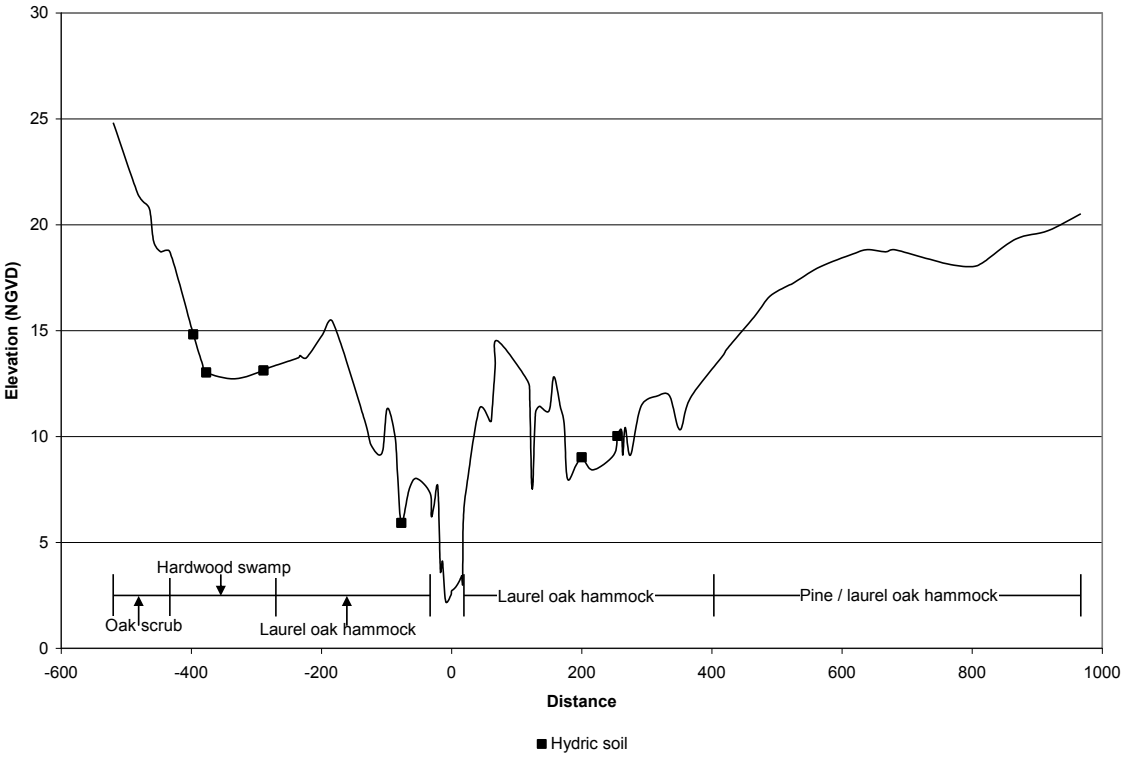
VEG2



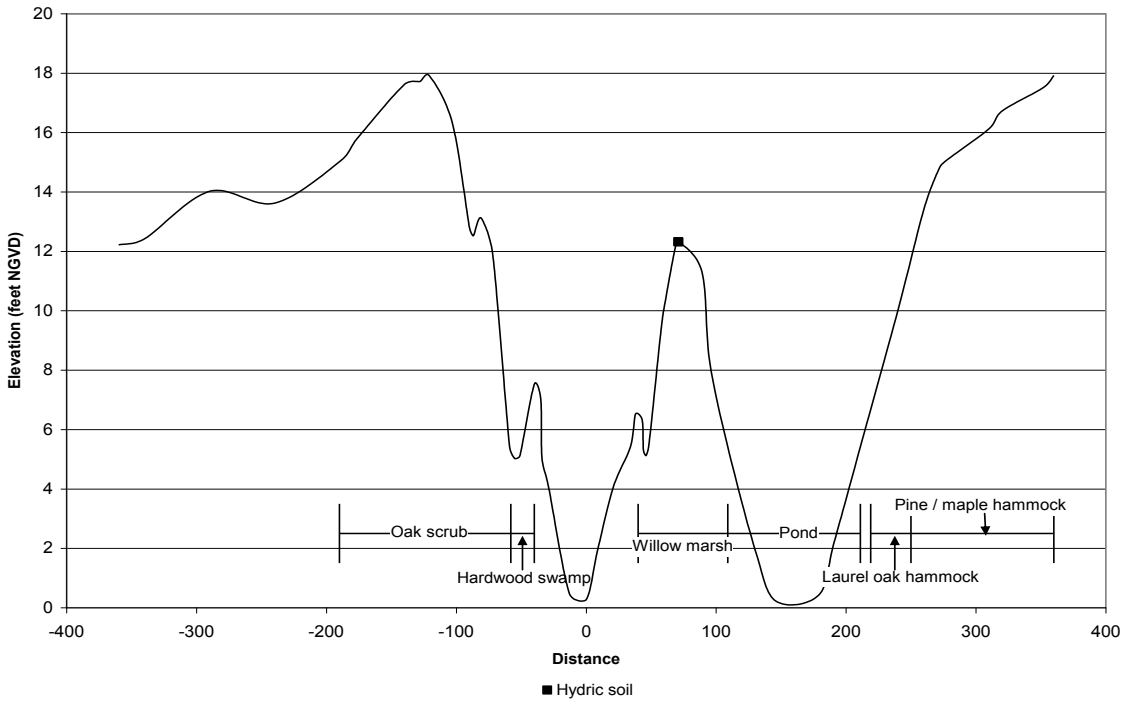
LMAN6



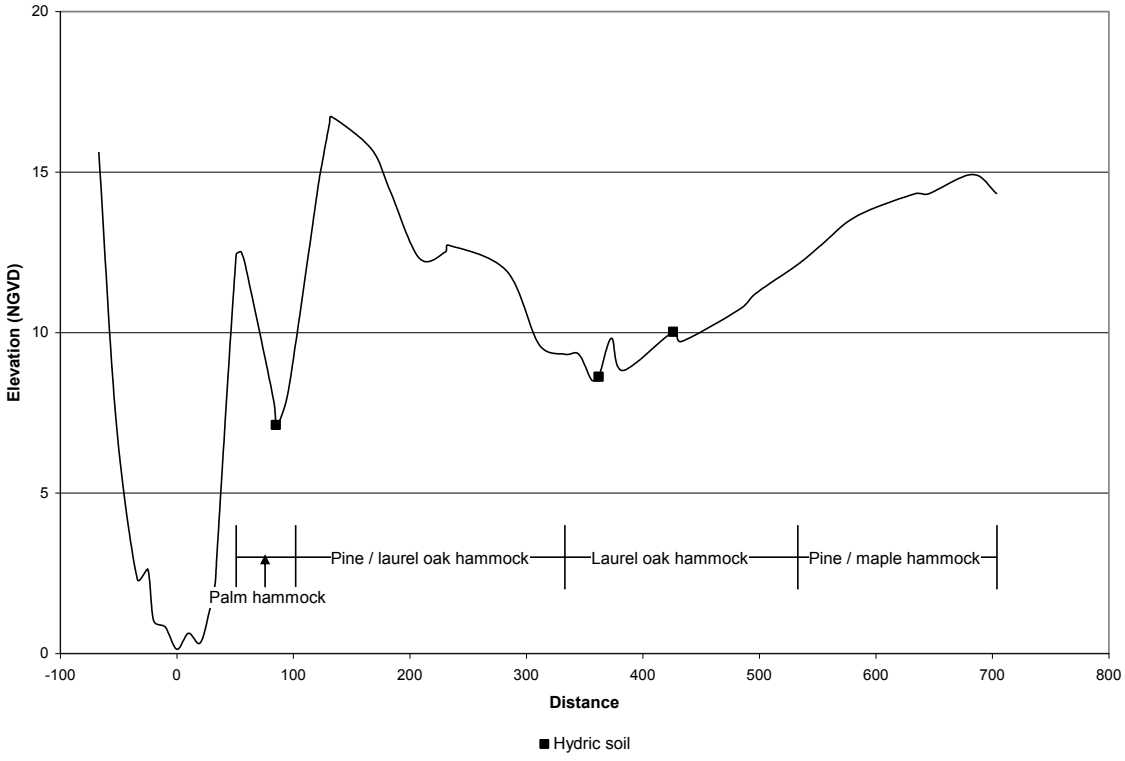
MASONIC PARK



LMAN7


Elevation (feet NGVD)
Distance
Oak scrub
Hardwood swamp
Willow marsh
Pond
Laurel oak hammock
Pine / maple hammock
Hydric soil

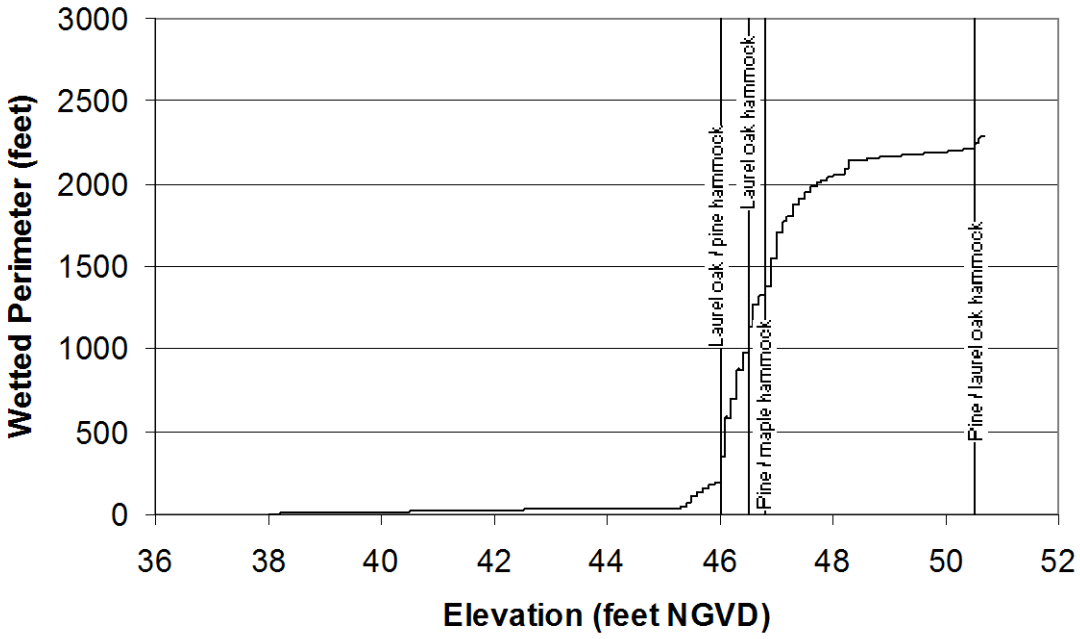
VEG3


Elevation (NGVD)
Distance
Palm hammock
Pine / laurel oak hammock
Laurel oak hammock
Pine / maple hammock
Hydric soil

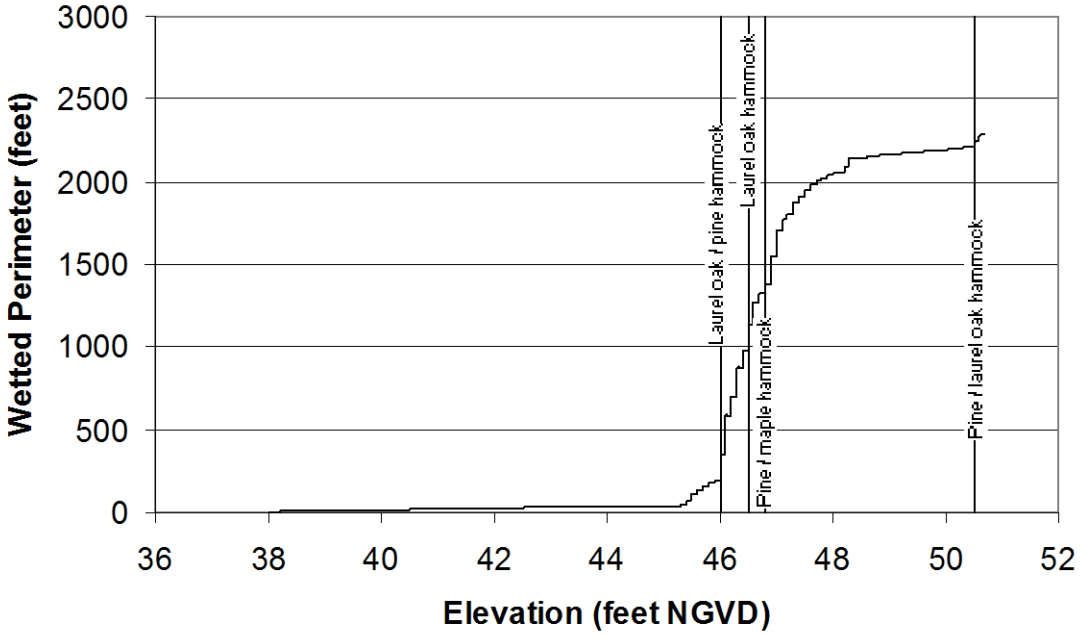
Appendix B

Wetted Perimeter Graphs for the Little Manatee River Study Corridor (In upstream-to-downstream order)

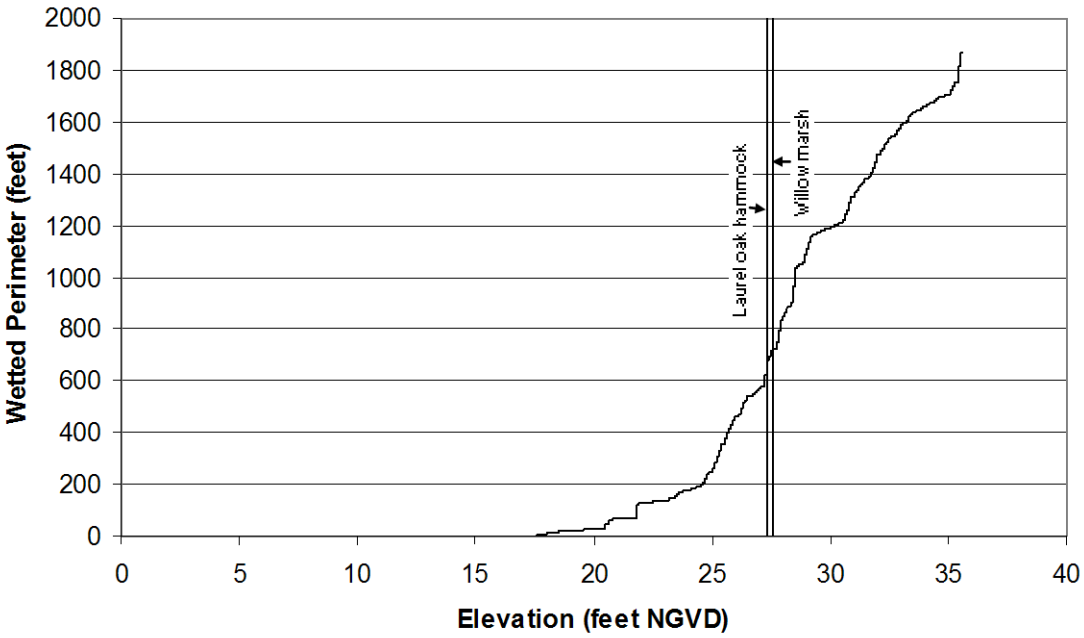
Transect VEG 15



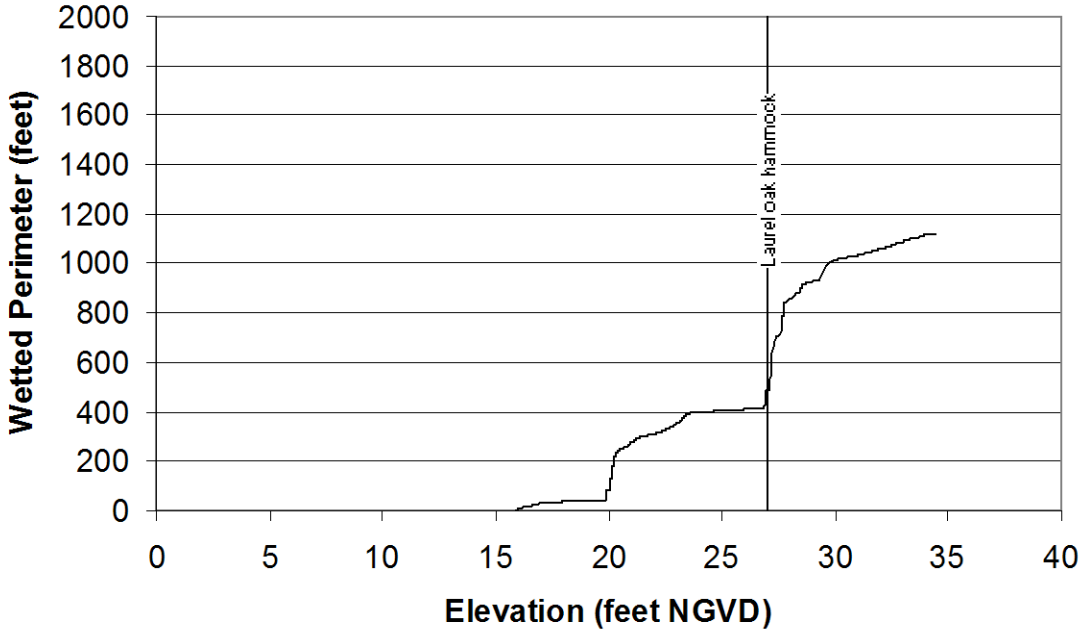
Transect VEG 14



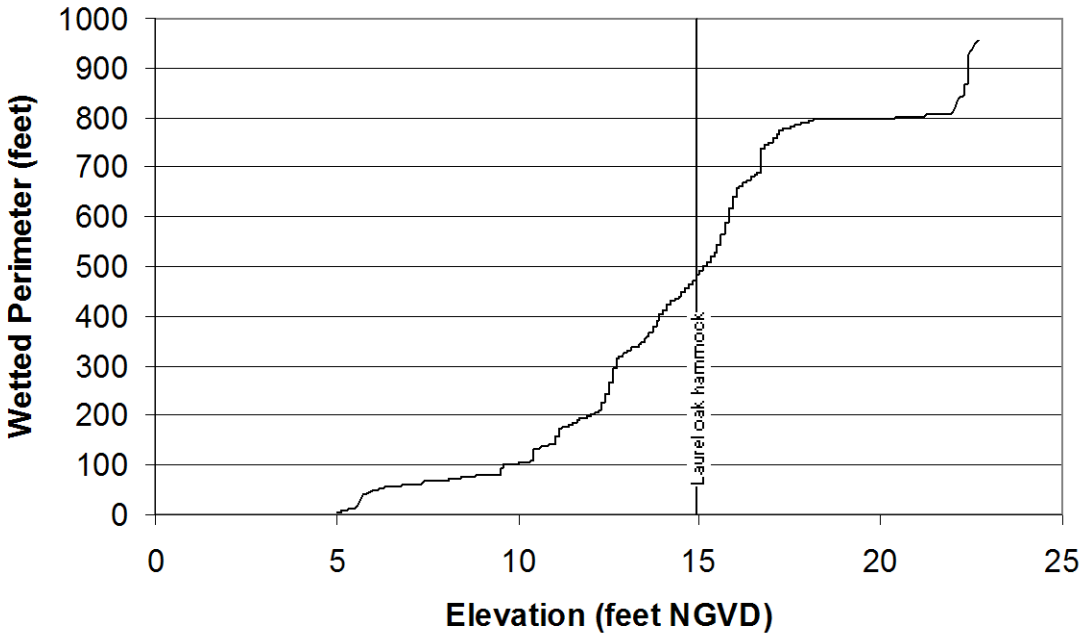
Transect LMAN3



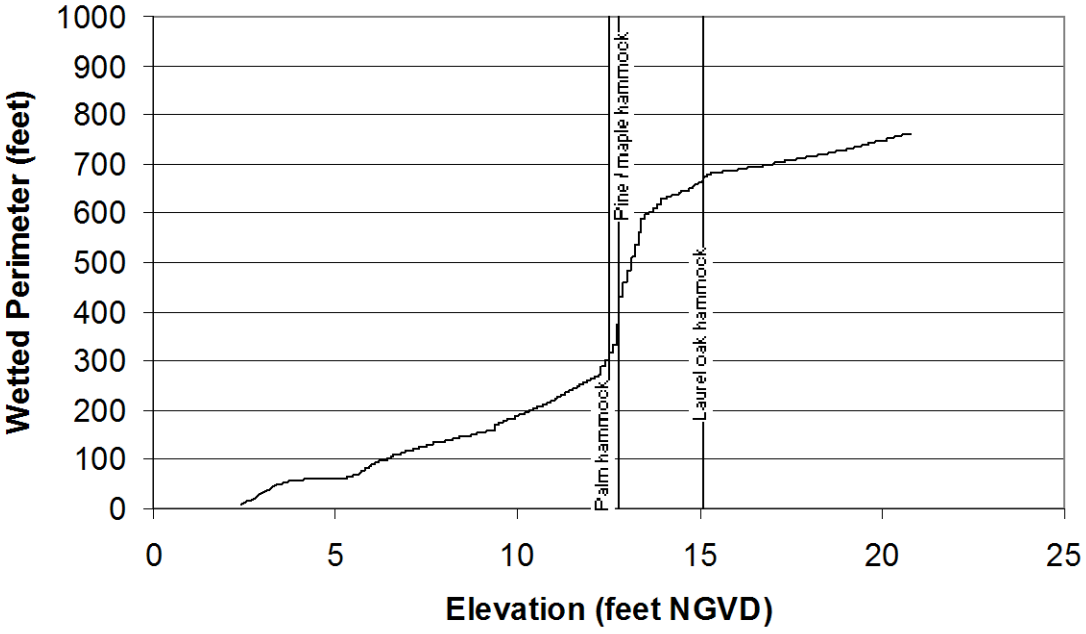
Transect VEG 10



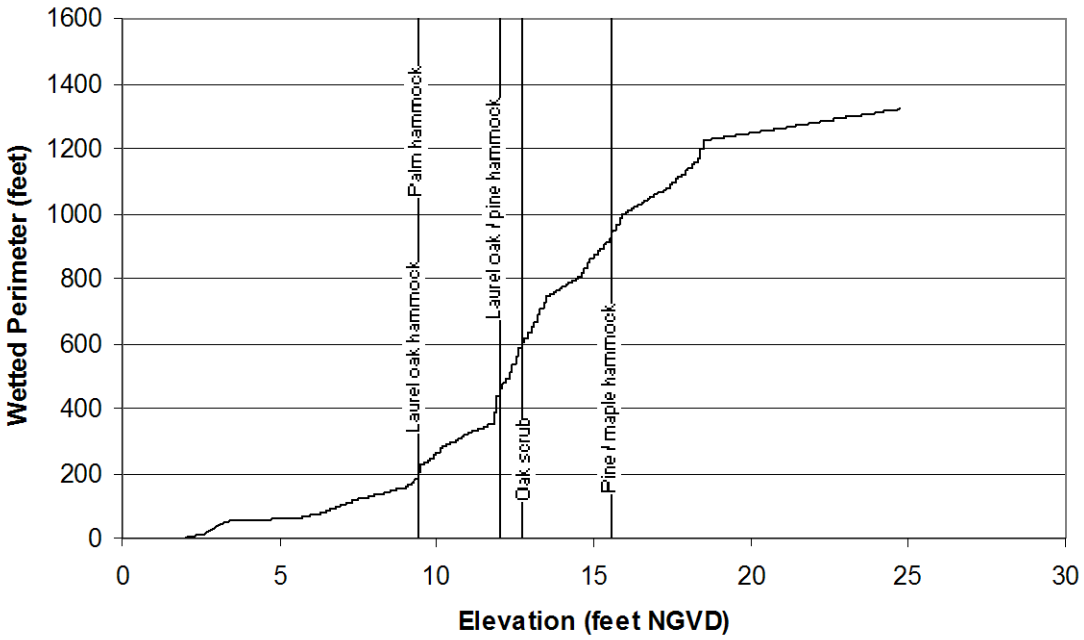
Transect Toscany



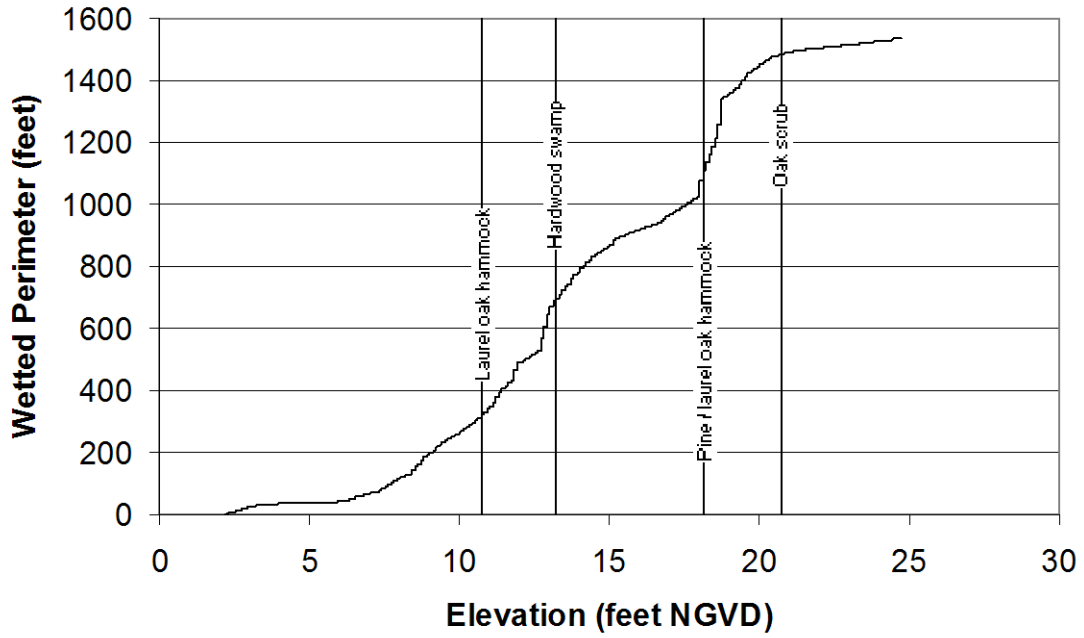
Transect VEG 2



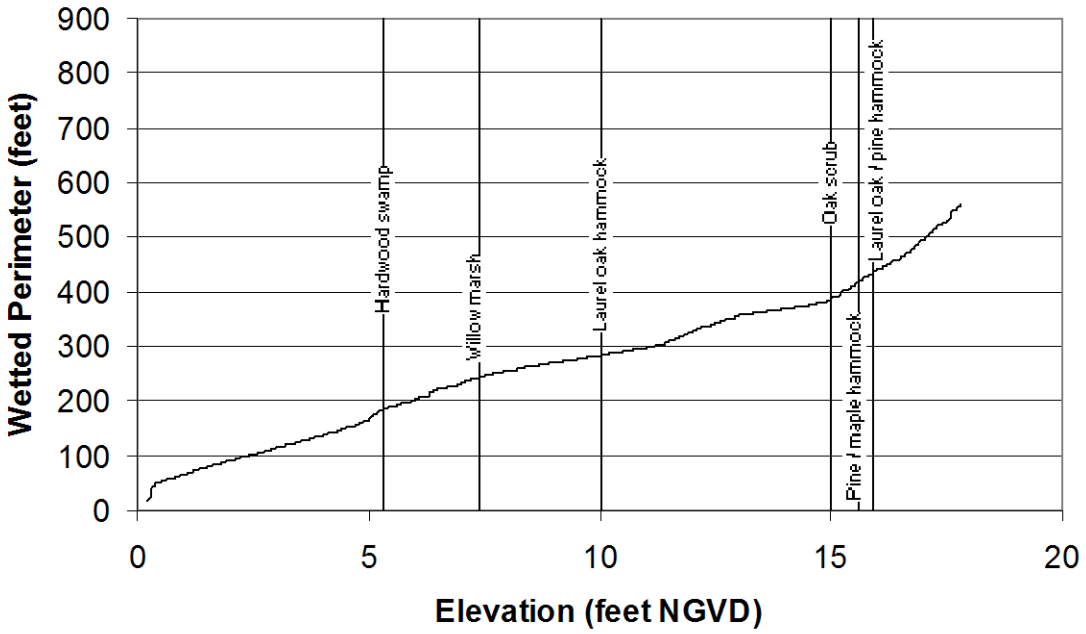
Transect LMAN 6



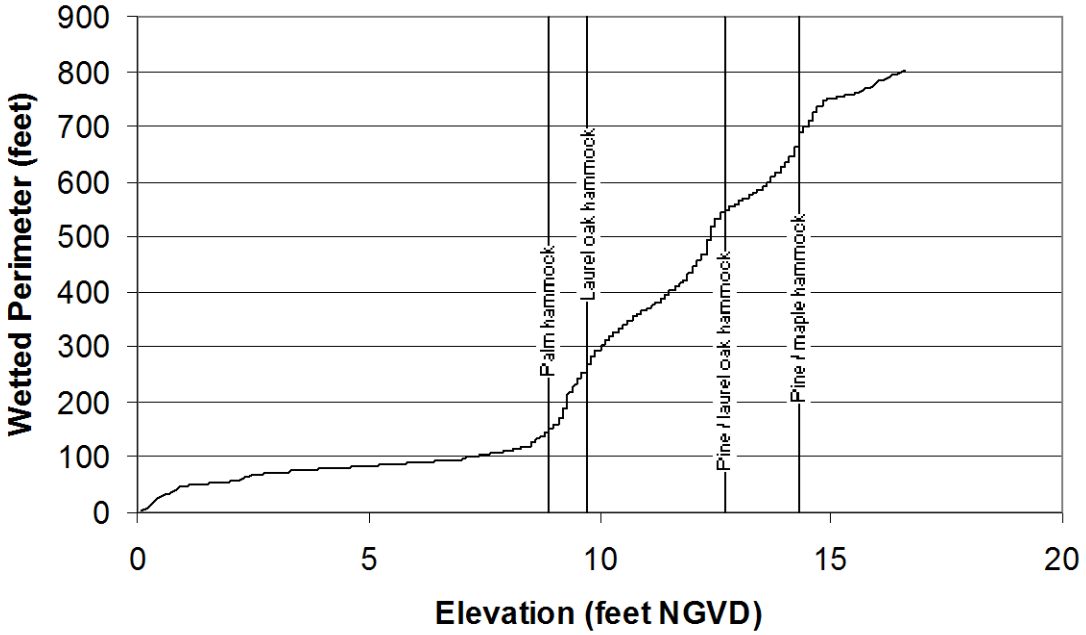
Transect Masonic Park



Transect LMAN 7



Transect VEG 3



Appendix C

Photographs from the Little Manatee River Study Corridor

Willow Marsh

Tupelo Swamp

Hardwood Swamp

Pine / Laurel Oak Hammock

Laurel Oak / Pine Hammock

Laurel Oak Hammock

Palm Hammock

Oak Scrub

HEC-RAS Appendix – HEC-RAS Modeling of Little Manatee River

Prepared for

South West Florida Water Management District

HEC-RAS MODELING OF LITTLE MANATEE RIVER

10POSOW0468

Final Report

Prepared by

Engineering & Construction, Inc.

651 Danville Drive, Suite 100

Orlando, FL 32825

Phone: (407)281-1100

Fax: (407)281-1108

July, 2010

Client

SOUTH WEST FLORIDA WATER MANAGEMENT DISTRICT

Project

HEC-RAS MODELING OF LITTLE MANATEE RIVER

10POSOW0468

PJE0654a

Report No.	*Copy No.*

Date of Issue

July, 2010

Report Title

Final Report

		Date
Prepared by	***Tony Guan (ZFI)***	***6/29/2010***

Reviewed by	***Antonio De Corral (ZFI)***	***7/1/2010***
Submitted to	***Jason Hood (SWFWMD)***	***7/2/2009***

Distribution

Copy No	*Issued to*

TABLE OF CONTENTS

TABLE OF CONTENTS lxxxvi

TABLE OF TABLES lxxxviii

TABLE OF FIGURES lxxxix

SECTION 1 Introduction 90

1.1 Project Background 90

1.2 Project Location and General Description 90

SECTION 2 Description of the Study Area 92

2.1 Local Climate 92

2.2 Topography 92

2.3 Soils 97

2.4 Land Use / Land Cover 98

2.5 Major Tributaries 102

2.5.1 Howard Prairie 102

2.5.2 Pierce Branch 103

2.5.3 Carlton Branch 103

2.5.4 Gully Branch 103

2.5.5 Lake Wimauma Drain 104

2.5.6 Dug Creek 104

2.5.7 South Fork 104

SECTION 3 Hydrology Model Development 105

3.1 Introduction 105

3.2 Hydrology Methodology 105

3.2.1 Subarea Delineation 105

3.2.2 Rainfall 111

3.2.3 Runoff Volume (SCS CN) 112

3.2.4 Runoff Hydrographs 117

3.2.5 Routing (Muskingum-Cunge) 119

SECTION 4 Hydraulic Model Development 120

4.1 Introduction 120
4.2 HEC-RAS Model Development 120
4.2.1 Stream Network, Cross Sections, and Reach Lengths 122
4.2.2 Manning's n-Values 125
4.2.3 Roadway crossings 126
4.2.4 Expansion and contraction coefficients 127
4.2.5 Boundary Conditions 127
4.2.6 Ineffective Flow Areas 127

SECTION 5 Model Calibration and Verification 128
5.1 Hydraulic and Hydrologic Data Collection 128
5.2 QA/QC of Hydraulic and Hydrologic Data 132
5.3 Event Selection 135
5.4 Boundary Condition 135
5.5 Hydrologic Model Calibration and Verification 135
5.6 Hydraulic Model Calibration and Verification 137
5.6.1 Model Calibration 137
5.6.2 Model Verification 139

References 142

TABLE OF TABLES

Table 2-1 Existing Land Use / Land Cover (2008) Distribution 101
Table 3-1 Sub-Area Identification Table 108
Table 3-2 Rainfall Depths for the 24-hour Design Events 112
Table 3-3 Runoff CN Lookup Table 113
Table 3-4 AMC Curve Number Conversion Guide 116
Table 4-1 HEC-RAS Parameter Development 121
Table 4-2 Land Surface Characteristics and Associated Manning's n-Values 125
Table 4-3 Channel Descriptions and Associated Manning's n-Values 125
Table 4-4 Summary of Bridges in the Study Area 126
Table 5-1 Rainfall, Stage and Discharge Gages 129
Table 5-2 Carlton Branch Flow (cfs) Comparisons 135
Table 5-3 Dug Creek Flow (cfs) Comparisons 136
Table 5-4 Gully Branch Flow (cfs) Comparisons 137
Table 5-5 Pierce Branch Flow (cfs) Comparisons 137

TABLE OF FIGURES

Figure 2-1 Five-feet Contour Lines (Topography) 94
Figure 2-2 Soil Classification 95
Figure 2-3 Hydrologic Soil Group 96
Figure 2-4 Land Use (2008) 100
Figure 3-1 Little Manatee River Sub-Area Delineation 108
Figure 4-1 Steam Network and Cross Section River Stations 124
Figure 5-1 Thiessen Polygon Network for Rainfall and USGS Station 131
Figure 5-2 USGS Stage Data Patched thru POR 133
Figure 5-3 USGS Flow Data Patched thru POR 134
Figure 5-4 Comparison of Observed and Simulated Discharge (cfs) 138
Figure 5-5 Comparison of Observed and Simulated Stage (ft) 139
Figure 5-6 Comparison of Observed and Simulated Discharge (cfs) 140
Figure 5-7 Comparison of Observed and Simulated Stage (ft) 141

Introduction

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.

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.

Description of the Study Area

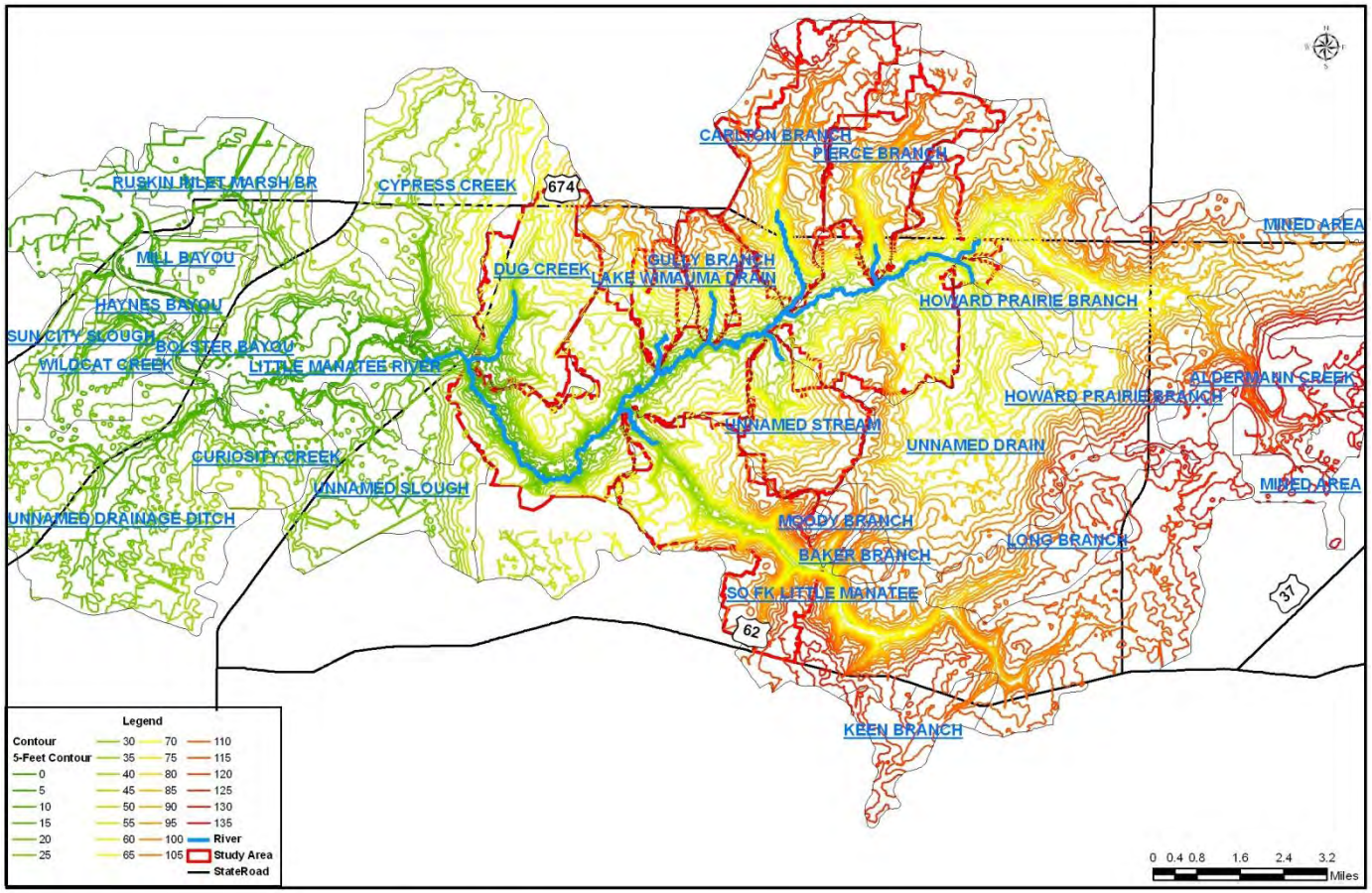
Local Climate

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.

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 0-1 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 0-1 Five-feet Contour Lines (Topography)

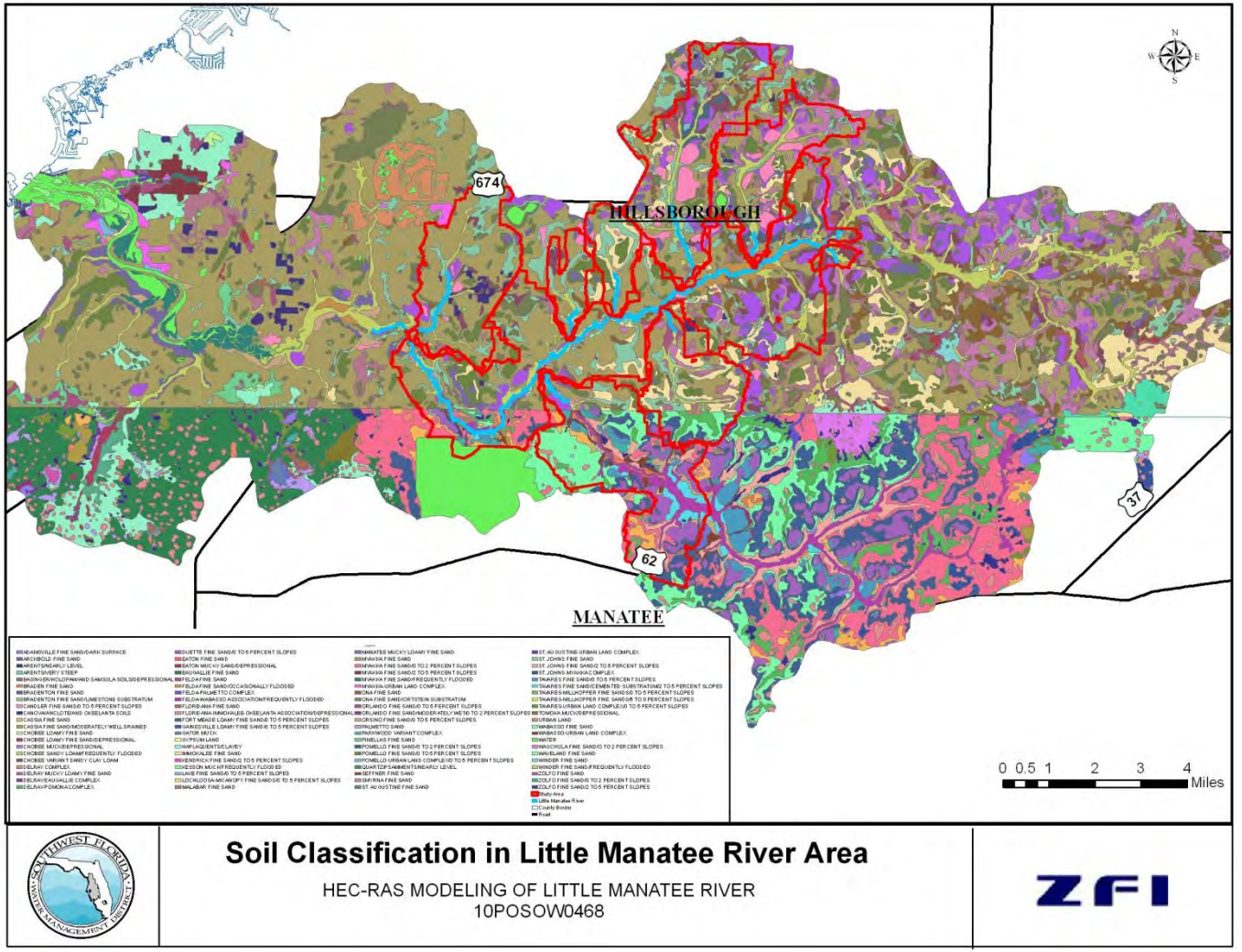
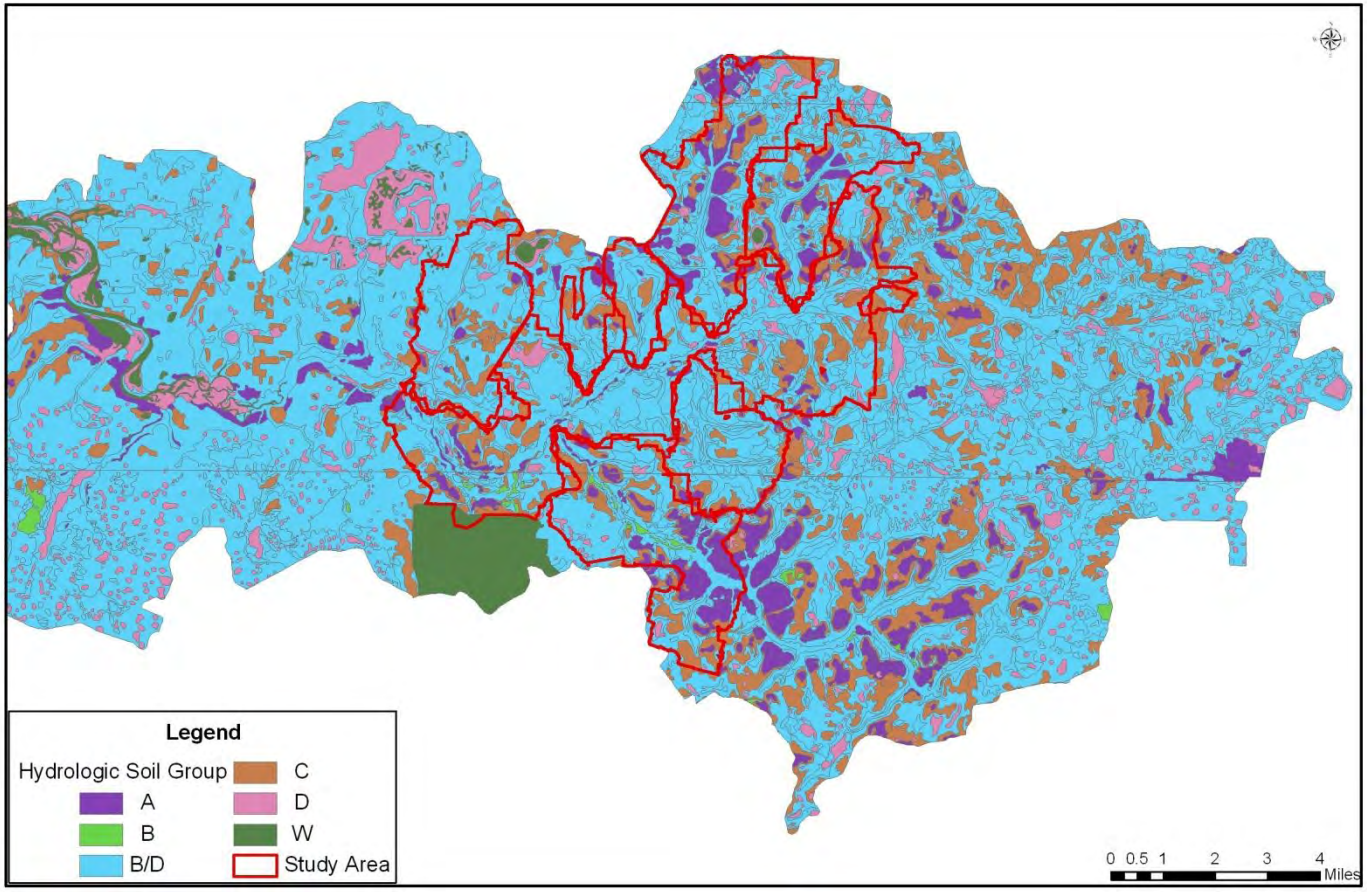


Figure 0-2 Soil Classification



Hydrologic Soil Group

HEC-RAS MODELING OF LITTLE MANATEE RIVER
10POSOW0468

Figure 0-3 Hydrologic Soil Group

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 0-2 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 0-3.

- 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.

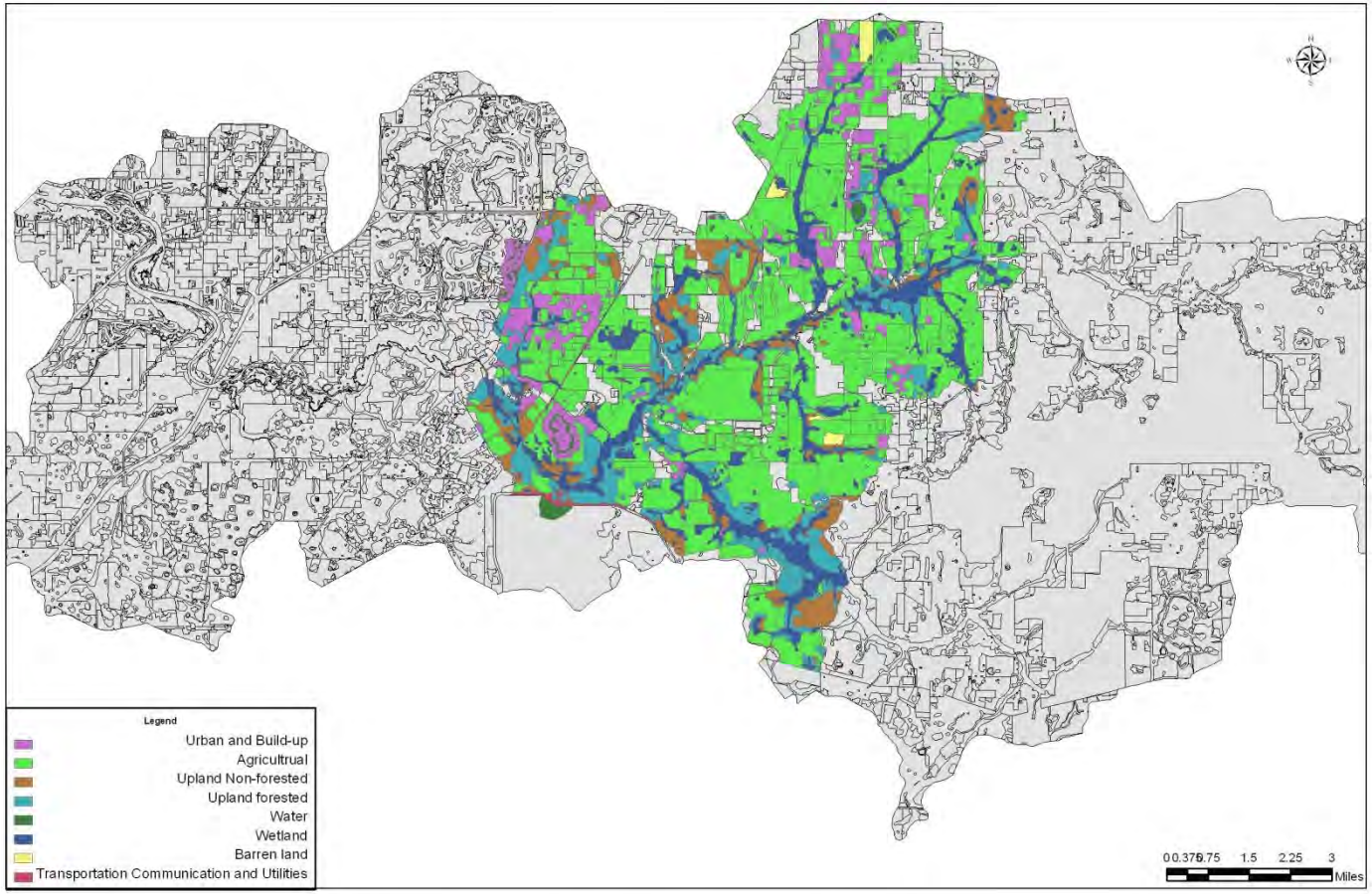
- Group D (high runoff potential) soils have very slow infiltration rates when thoroughly wetted and a very low rate of water transmission. They typically have infiltration rates of 3 in/hr when dry and 0. 10 in/hr when saturated.

- 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.

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 0-4, 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 0-1 contains the distribution of existing land use/land cover (2008) for the watershed.



Land Use (2008) in Little Manatee River Area

HEC-RAS MODELING OF LITTLE MANATEE RIVER
10POSOW0468

Figure 0-4 Land Use (2008)

Table 0-1 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

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.

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.

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.

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.

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.

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.

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.

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.

Hydrology Model Development

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.

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.

Subarea Delineation

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 0-1. 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 0-1.

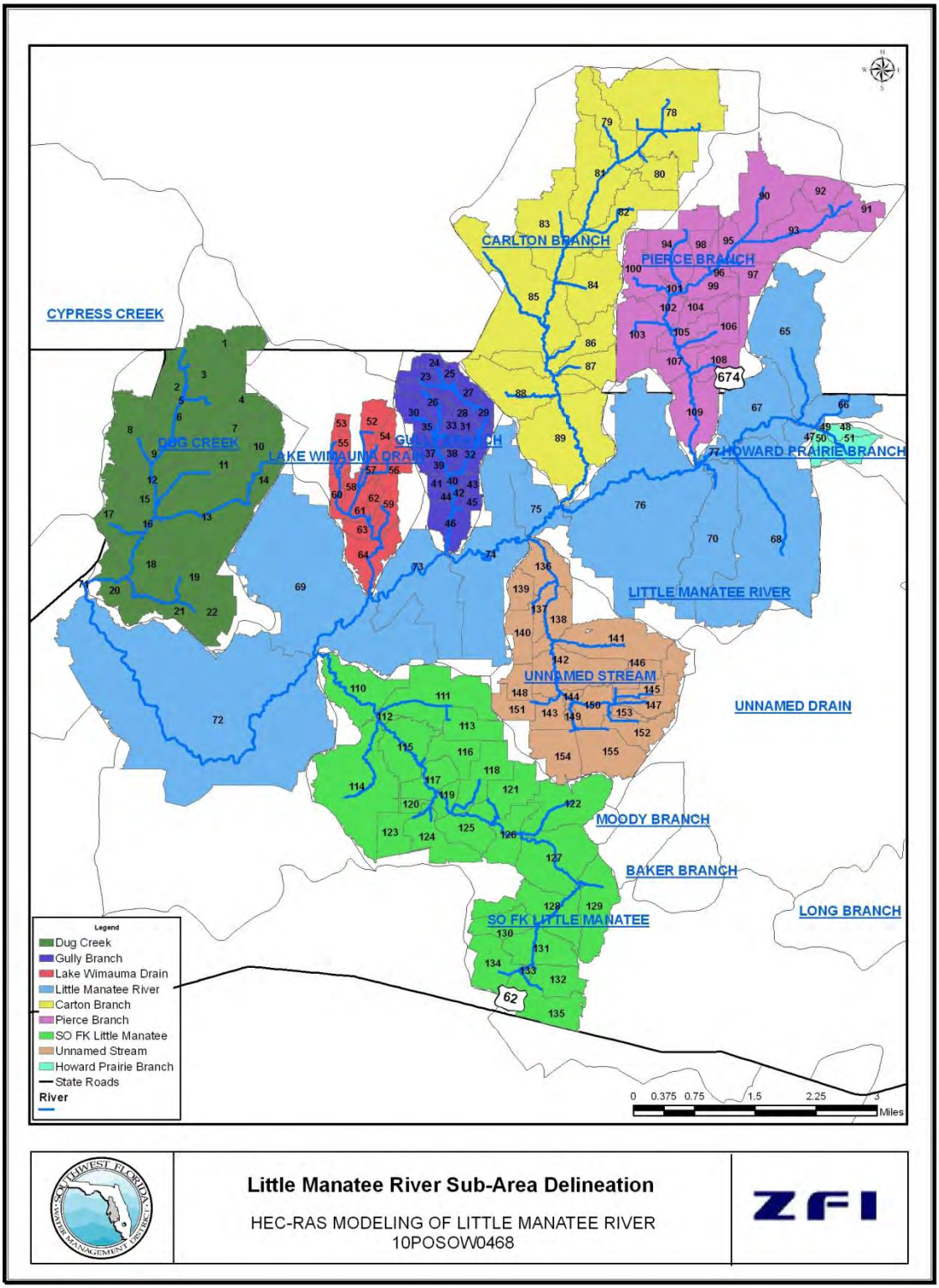

CYPRESS CREEK
CARLTON BRANCH
PIERCE BRANCH
DUG CREEK
LAKE WIMAUMA DRAIN
GULLY BRANCH
HOWARD PRAIRIE BRANCH
LITTLE MANATEE RIVER
UNNAMED STREAM
UNNAMED DRAIN
MOODY BRANCH
BAKER BRANCH
LONG BRANCH
SO FK LITTLE MANATEE
674
62
Legend
Dug Creek
Gully Branch
Lake Wimauma Drain
Little Manatee River
Carton Branch
Pierce Branch
SO FK Little Manatee
Unnamed Stream
Howard Prairie Branch
State Roads
River
0 0.375 0.75 1.5 2.25 3
Miles
Little Manatee River Sub-Area Delineation
HEC-RAS MODELING OF LITTLE MANATEE RIVER
10POSOW0468

Figure 0-1 Little Manatee River Sub-Area Delineation
Table 0-1 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

NO.	Sub-Basin Name	Sub-Area ID	NO.	Sub-Basin Name	Sub-Area ID
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
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

NO.	Sub-Basin Name	Sub-Area ID	NO.	Sub-Basin Name	Sub-Area ID
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

NO.	Sub-Basin Name	Sub-Area ID	NO.	Sub-Basin Name	Sub-Area ID
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
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			

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 0-2 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

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 0-3 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 0-4 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.

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.

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.

Hydraulic Model Development

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.

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 0-1 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 0-1 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.

Stream Network, Cross Sections, and Reach Lengths

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 0-1.

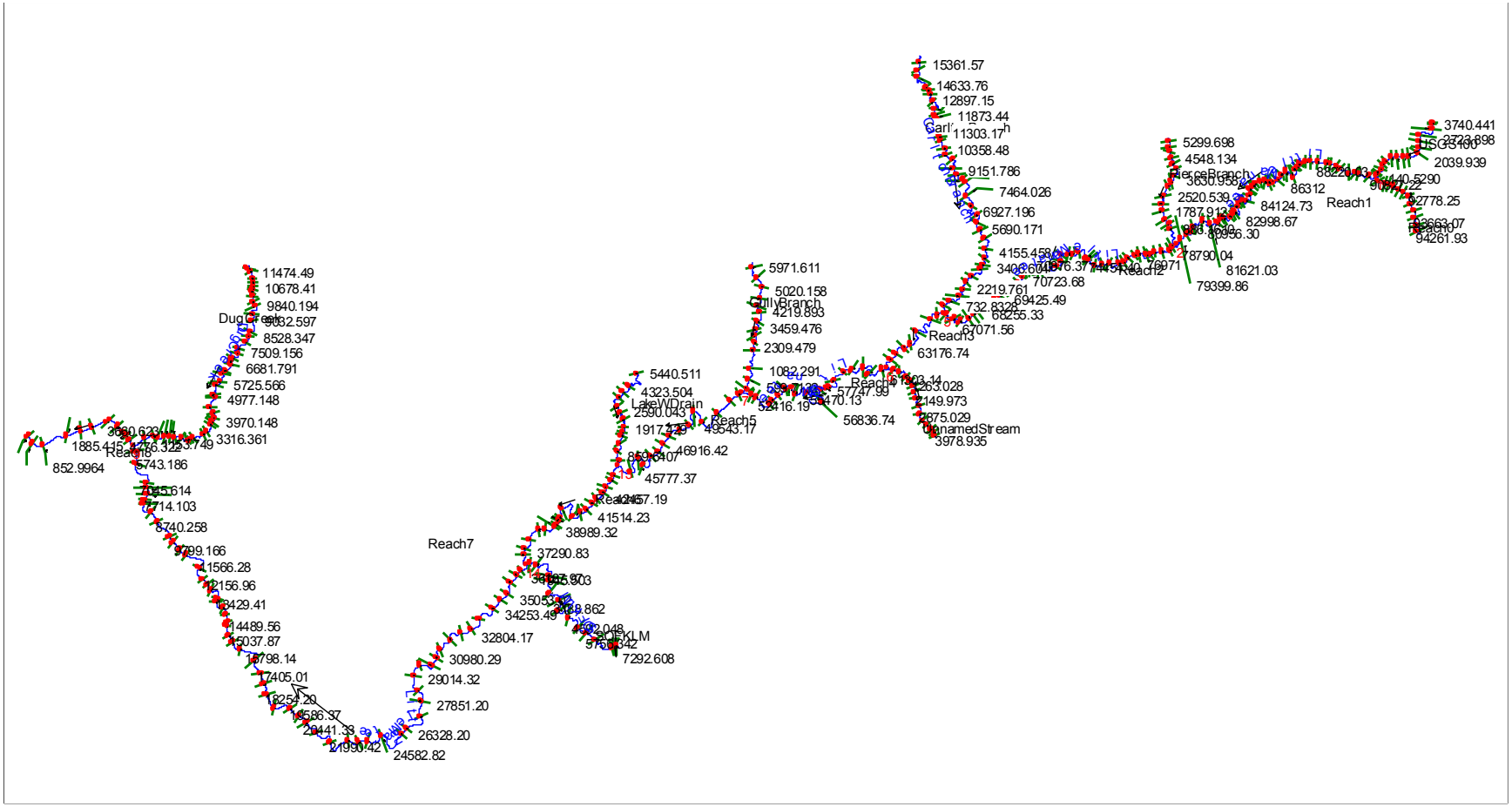


Figure 0-1 Steam Network and Cross Section River Stations

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 0-2. 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 0-2 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 0-3 lists channel descriptions and associated ranges of n-values used for Little Manatee River.

Table 0-3 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

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 0-4 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°15'2 2.37"W
4	CR579 OVER SOUTH FORK	100259	Hillsborough	SO FK Little Manatee	7225.6328	27°38'58.888"N	82°17'3 9.532"W
5	GRANGE HALL LOOP/ LMR	104332	Hillsborough	LMR/Reach 2	71052.453	27°41'20.961"N	82°14'4 1.501"W
6	Dug Creek	10346	Hillsborough	Dug creek	2509.4968	27°40'16.241"N	82°20'4 1.108"W

7	Leonaldo Lee Road/ LMR	104307	Hillsborough	Reach 4	57683.965	27°40'37.347"N	82°16'9.42"W

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.

Boundary Conditions

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

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.

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.

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

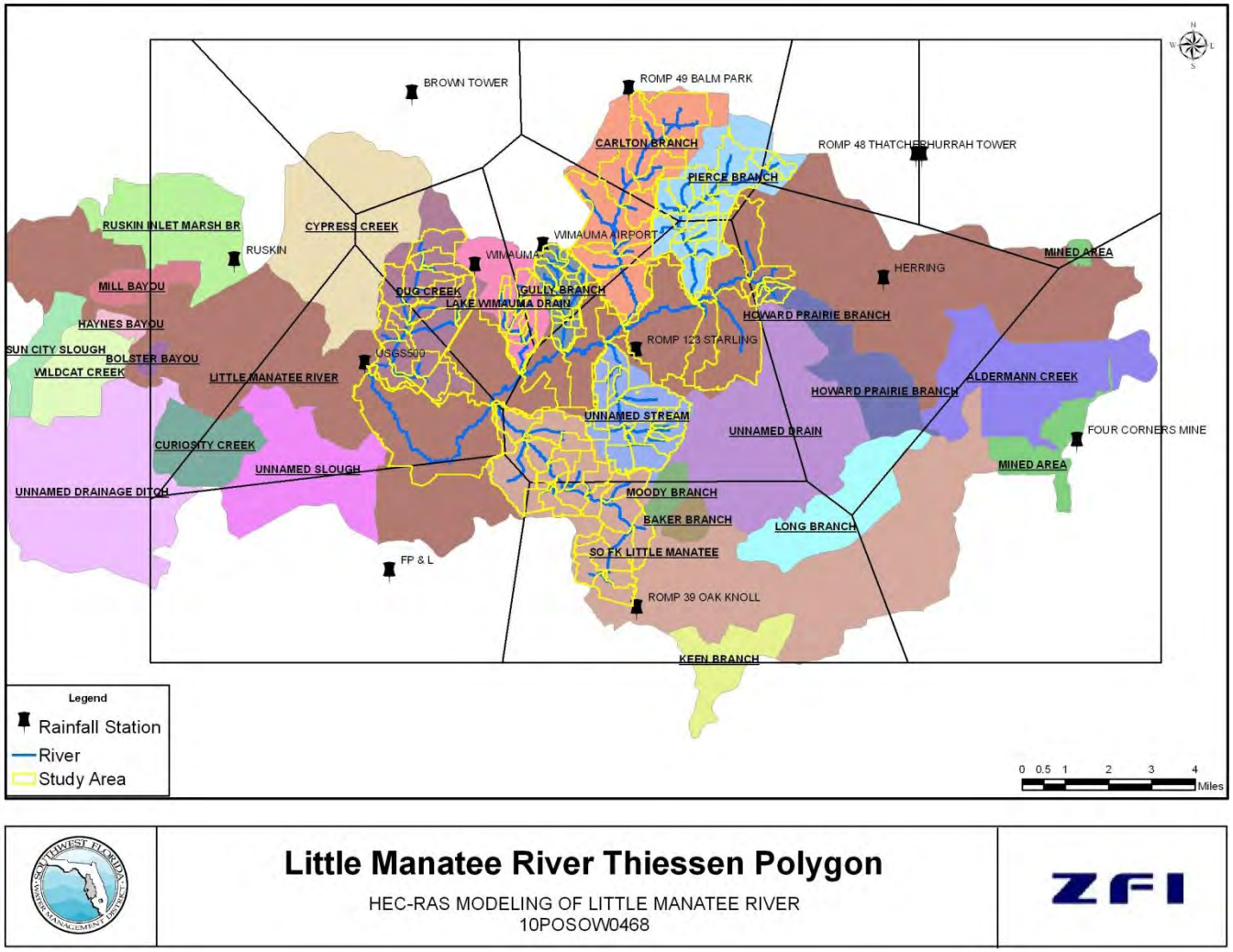
prepared by the USGS on locations 02300500, 02300300, and 02300100 showed best period of record to perform a search. The Period of Record (POR) was decided by the best available data string which was 1/1/1988 thru 12/31/2009.

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 0-1 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



Little Manatee River Thiessen Polygon

HEC-RAS MODELING OF LITTLE MANATEE RIVER
10POSOW0468

Figure 0-1 Thiessen Polygon Network for Rainfall and USGS Station

Figure 0-1 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.

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.

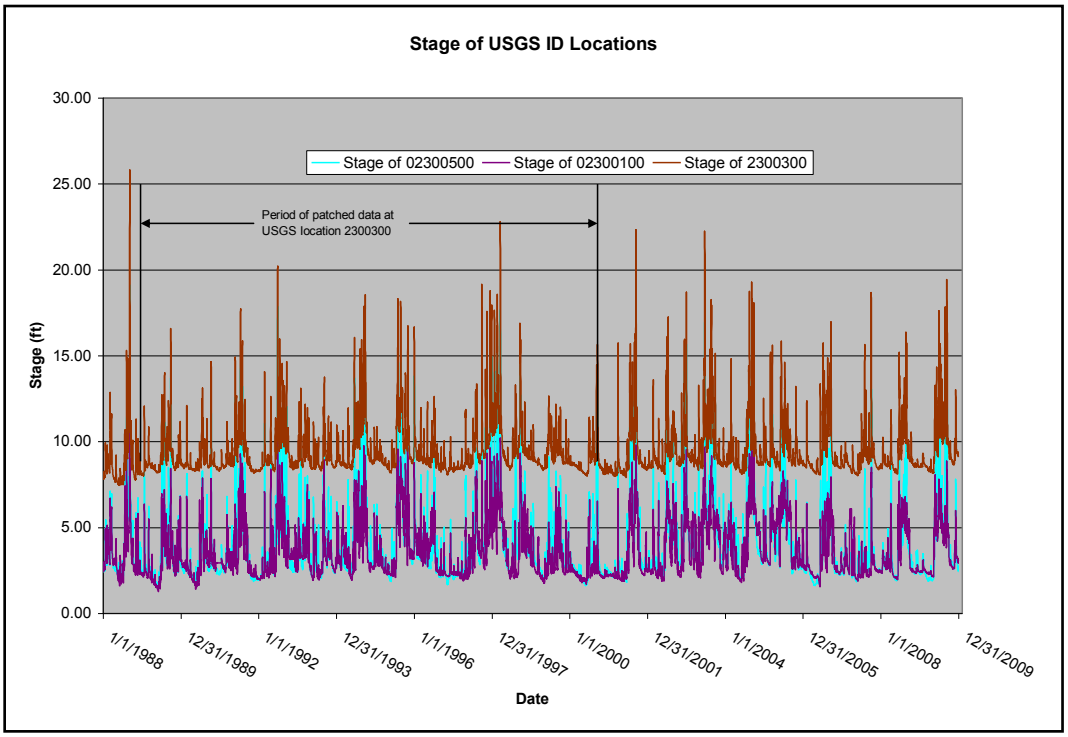


Figure 0-2 USGS Stage Data Patched thru POR

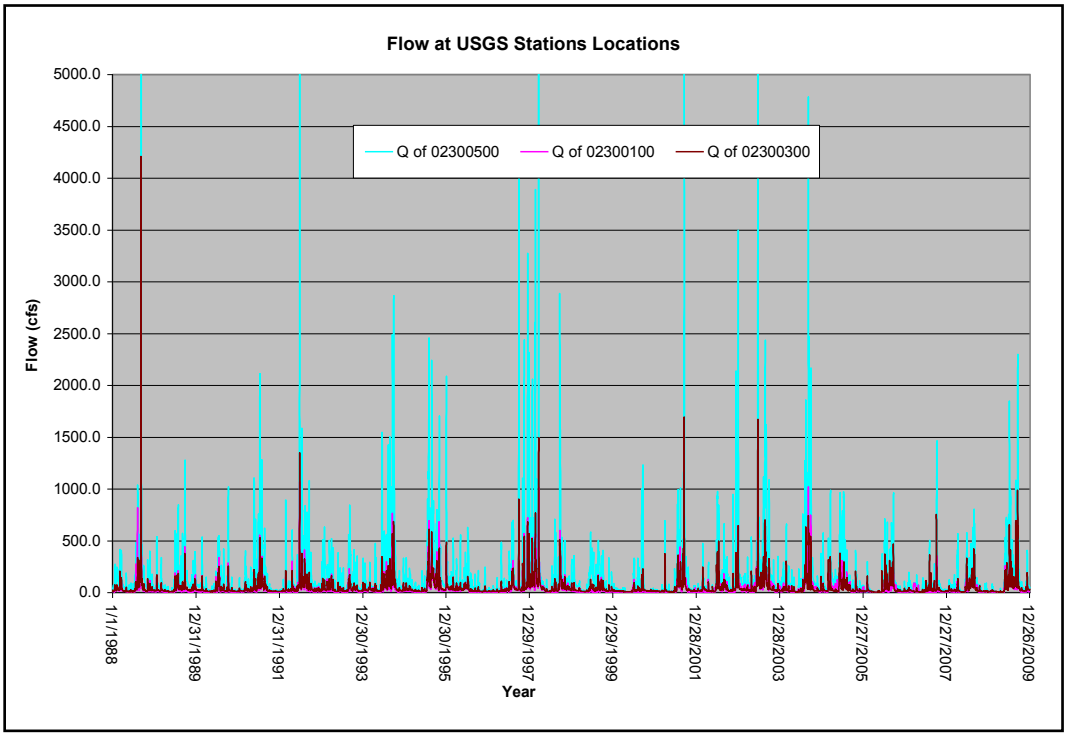


Figure 0-3 USGS Flow Data Patched thru POR

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.

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.

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.

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 0-2 through Table 0-5 provide comparisons of the HEC-HMS results compared to effective FIS flow information at downstream of the major tributaries.

Table 0-2 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 0-3 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 0-4 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 0-5 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.

Hydraulic Model Calibration and Verification

Model Calibration

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 0-4 and Figure 0-5 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.

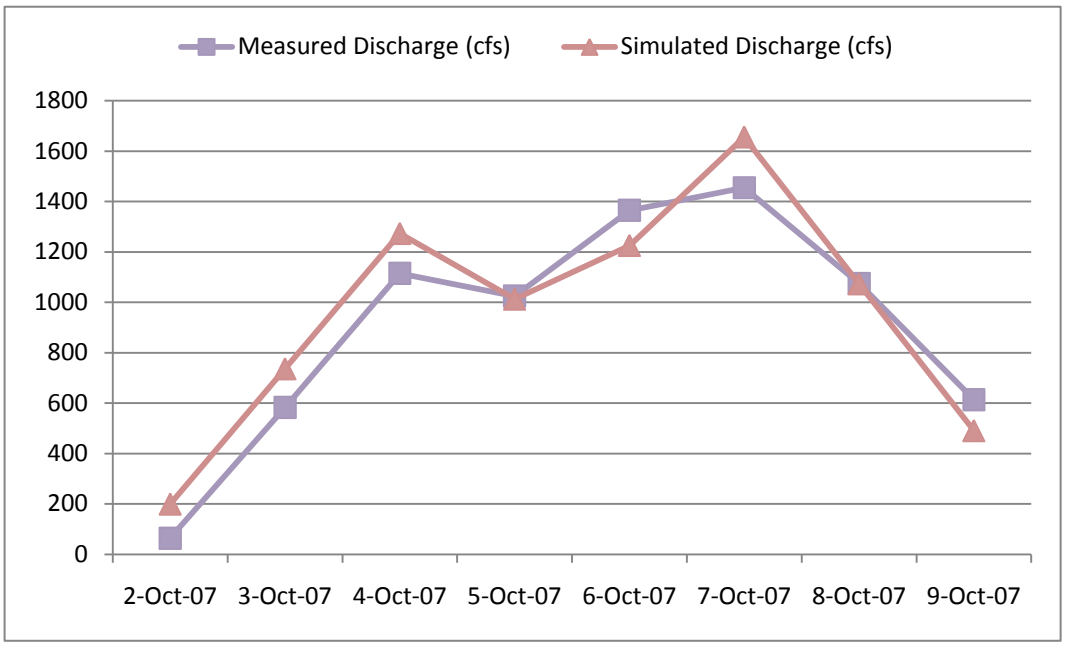


Figure 0-4 Comparison of Observed and Simulated Discharge (cfs)
USGS 02300500 October 2 - 9, 2007

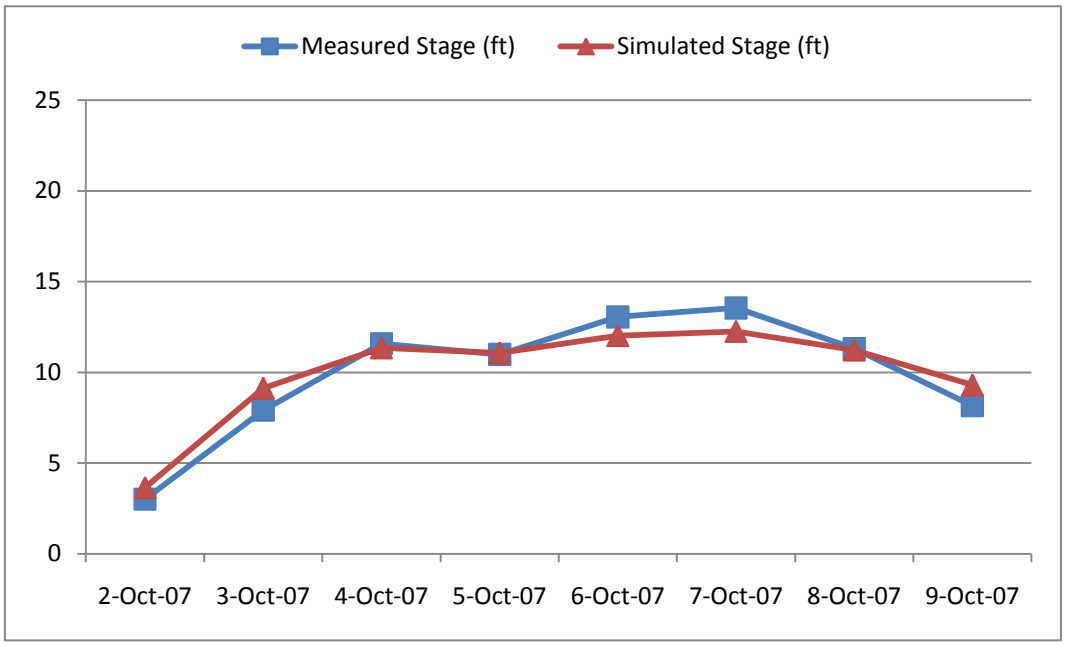


Figure 0-5 Comparison of Observed and Simulated Stage (ft)
USGS 02300500 October 2 - 9, 2007

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 0-6 and Figure 0-7.

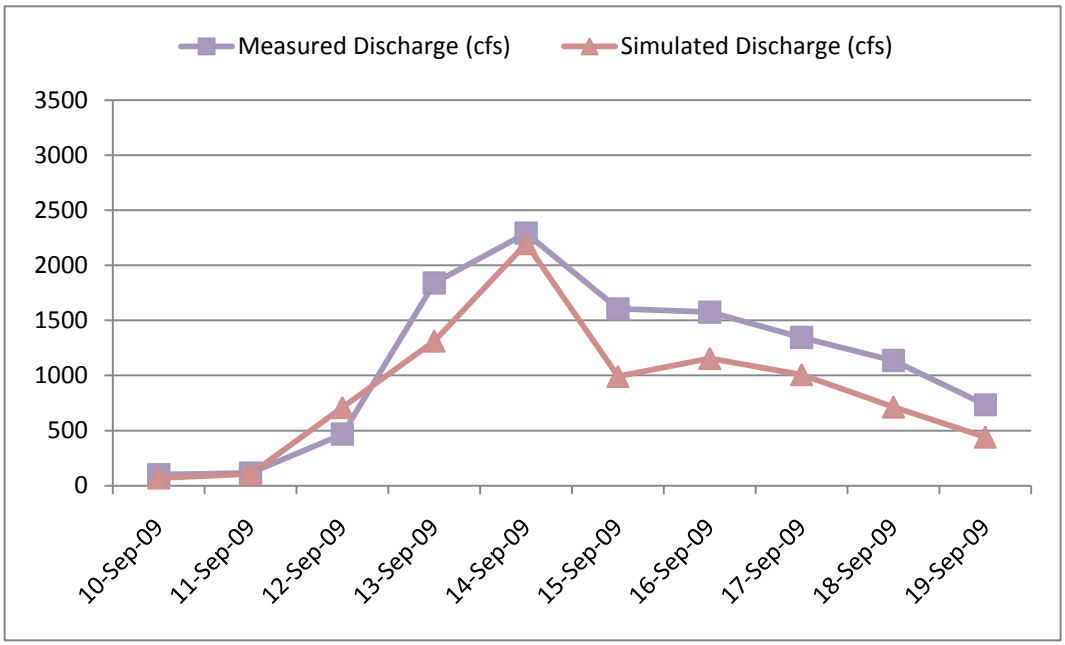


Figure 0-6 Comparison of Observed and Simulated Discharge (cfs)
USGS 02300500 September 10 - 20, 2009

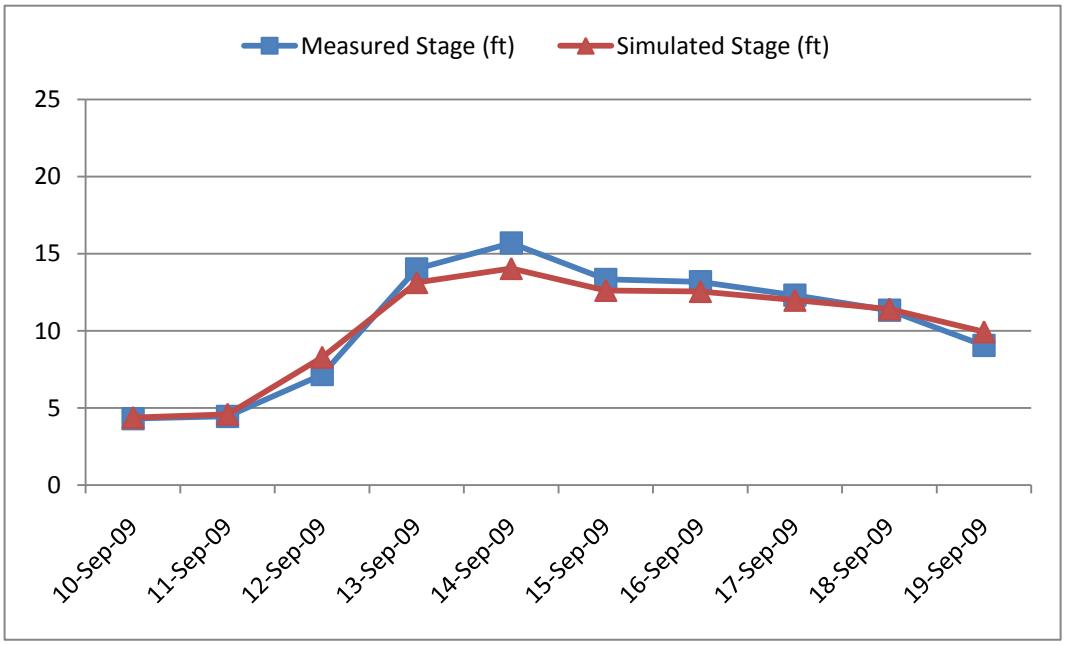


**Figure 0-7 Comparison of Observed and Simulated Stage (ft)
USGS 02300500 September 10 - 20, 2009**

As shown in Figure 0-6, 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 0-7.

References

FEMA 2008, *Flood Insurance Study (Hillsborough County, Florida and Incorporated Areas)*, Federal Emergency Management Agency

Hillsborough County 2008, *Hillsborough County Stormwater Management Technical Manual* Hillsborough County

PBS&J & Hillsborough County 2002, *Little Manatee River Watershed Management Plan*, Hillsborough County

SWFWMD 2002, *Southwest Florida Water Management District's Watershed Management Program Guidelines and Specifications*, Southwest Florida Water Management District

SWFWMD 2002, *Little Manatee River Comprehensive Watershed Management Plan,* Southwest Florida Water Management District

SWFWMD 2009, *Environmental Resource Permitting (ERP) Information Manual*, Southwest Florida Water Management District

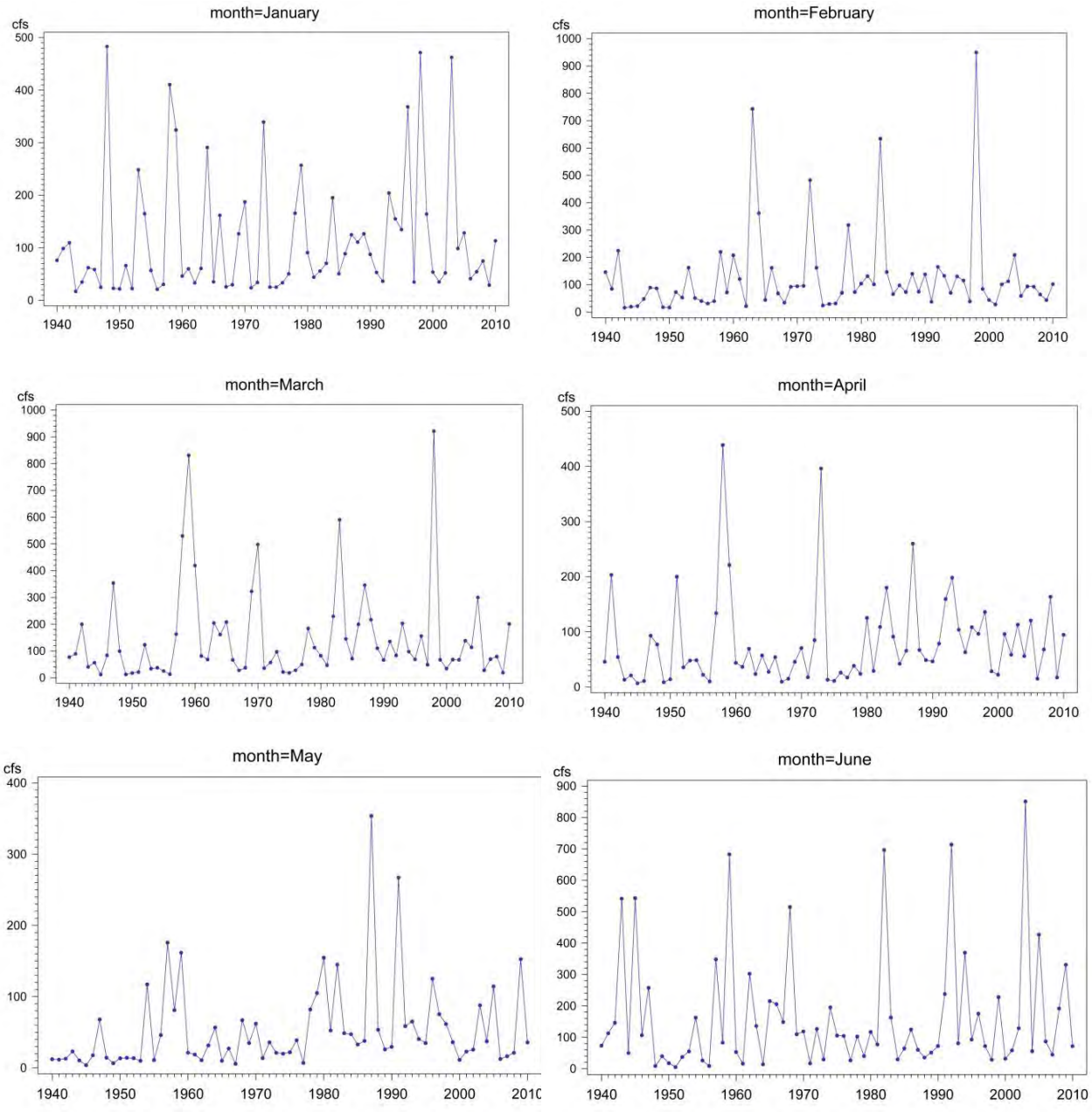
USDA NRCS 1986, *Technical Release-55 Urban Hydrology for Small Watersheds*, United States Department of Agriculture

USDA NRCS 1989, *Soil Survey of Hillsborough County, Florida*, United States Department of Agriculture

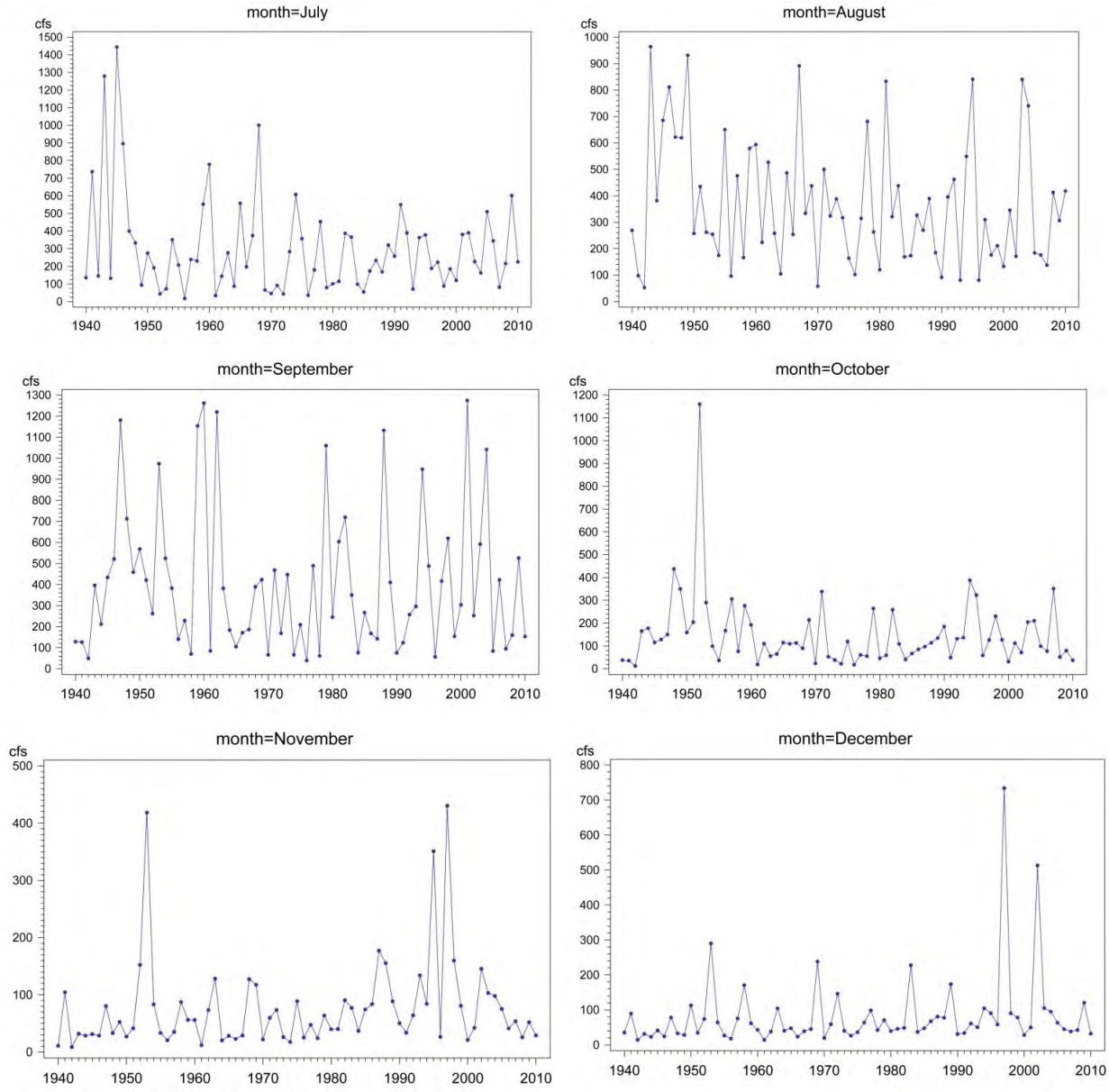
Wanielista, M.P. and Yousef, Y.A. 1993, *Stormwater Management*, John Wiley and Sons, Inc.

Appendix 2A

Hydrographs of Mean Monthly Flows for the Little Manatee River near Wimauma gage for 1940-2010.



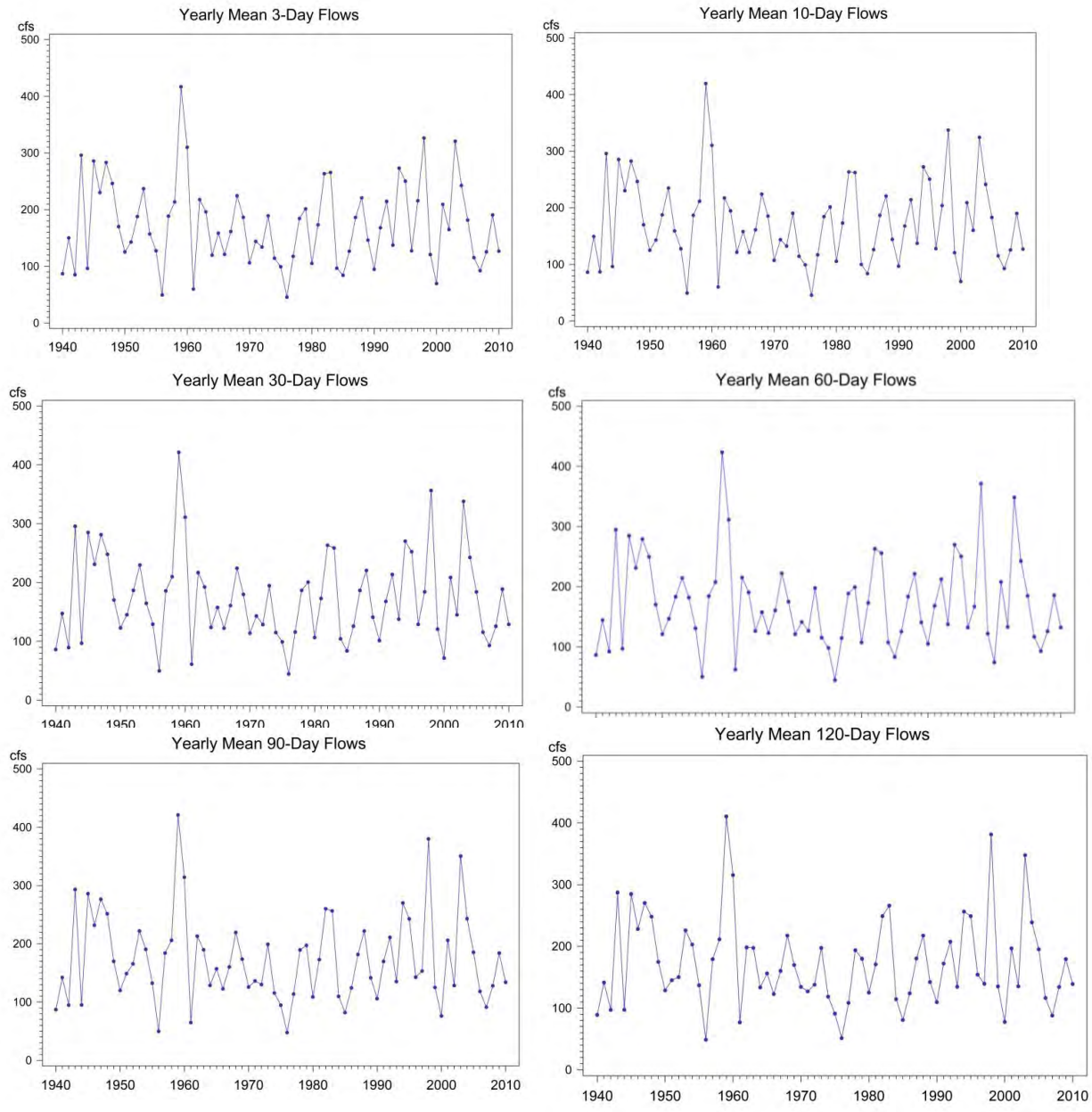
Hydrographs of mean monthly flows for the Little Manatee River near Wimauma, January – June, 1940-2010



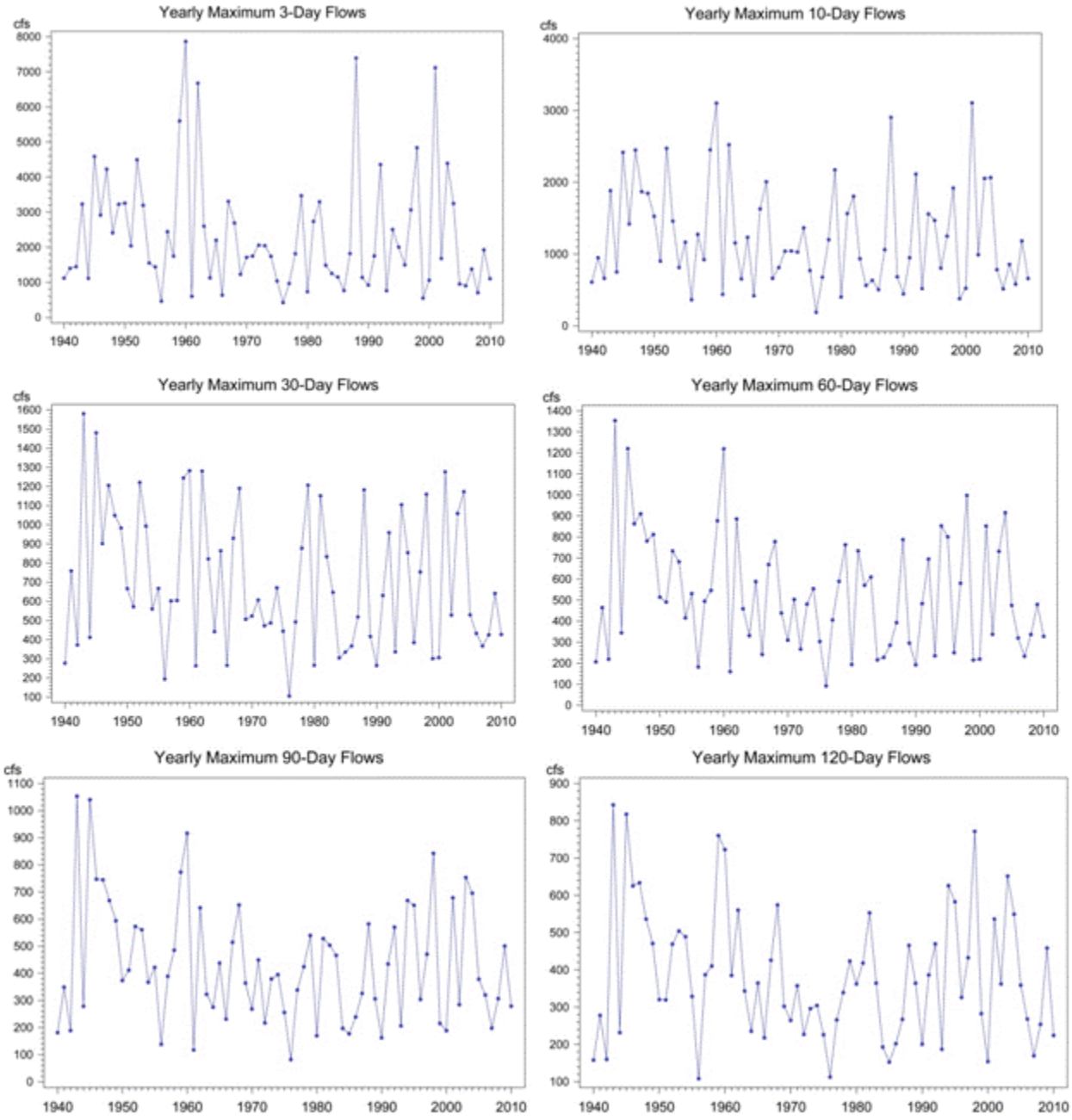
Hydrographs of mean monthly flows for the Little Manatee River near Wimauma: July – December, 1940-2010

Appendix 2B

Hydrographs of Mean and Maximum Values of Moving Average Flows within each year for the Little Manatee River near Wimauma gage:
1940-2010.



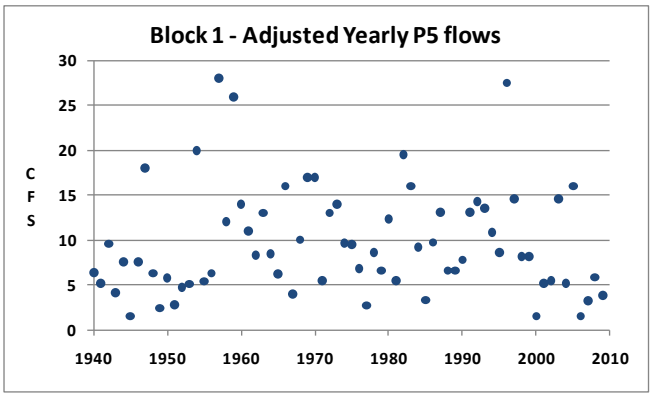
Hydrographs of mean values for moving average flows of different durations within each year for the Little Manatee River near Wimauma, 1940-2010

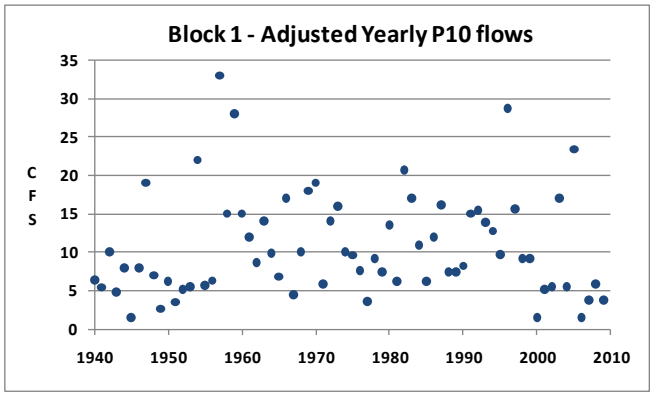


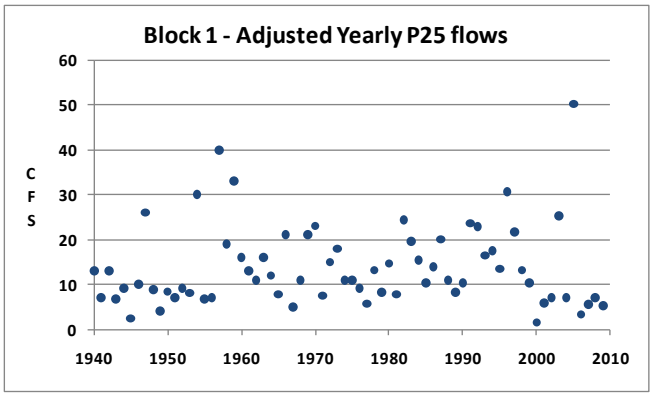
Hydrographs of maximum values for moving average flows of different durations within each year for the Little Manatee River near Wimauma, 1940-2010

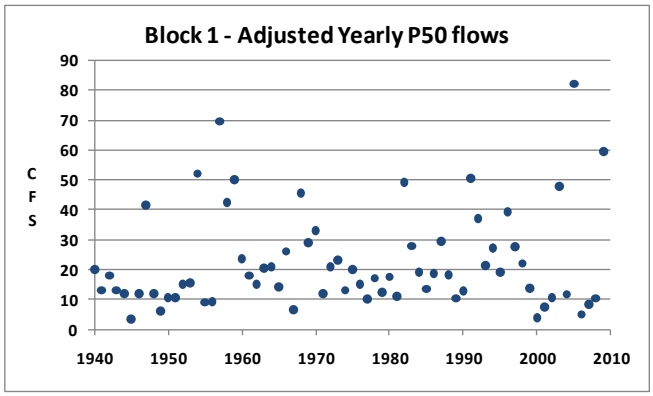
Appendix 2C

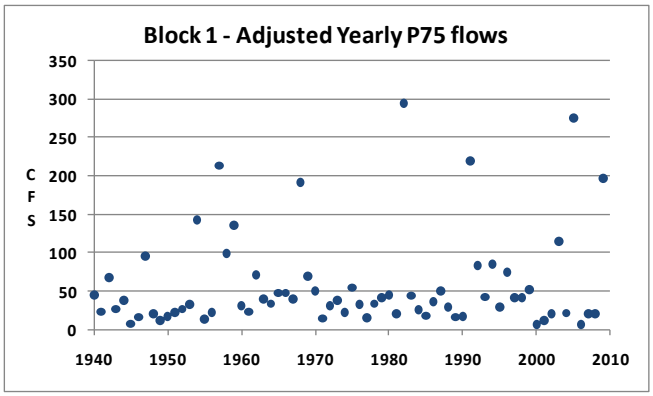
Hydrographs for selected yearly percentile flows for the adjusted flow record for the Little Manatee River near Wimauma gagefor three seasonal blocks: 1940-2009

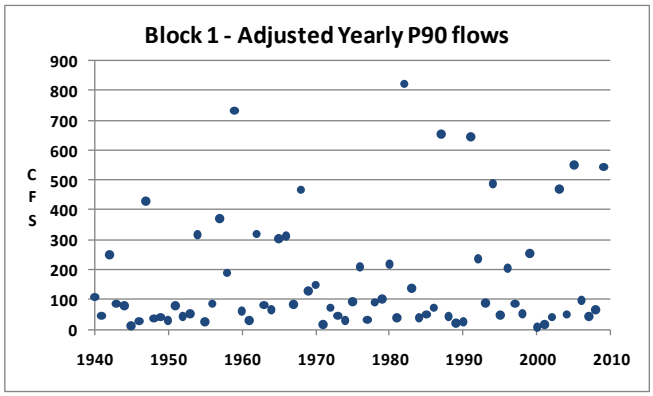




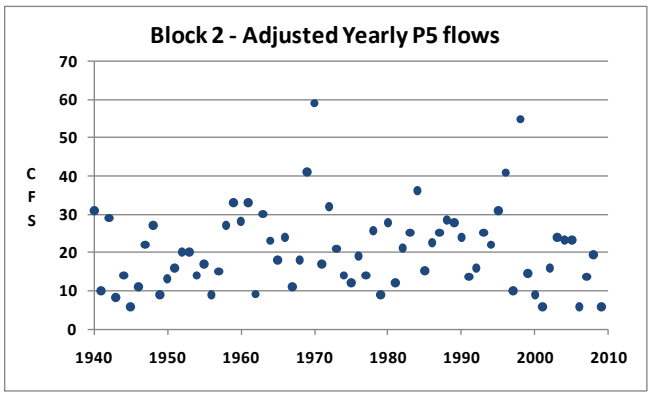


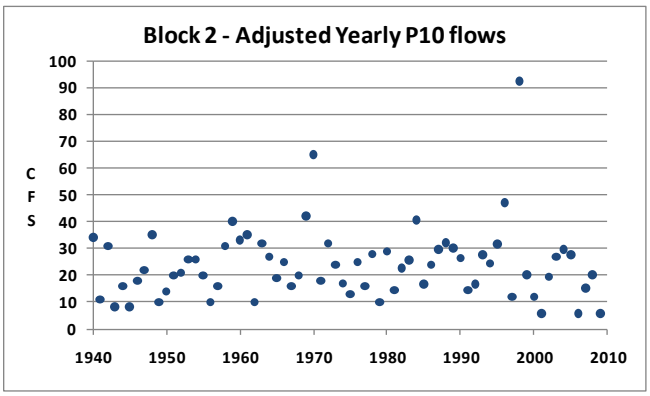


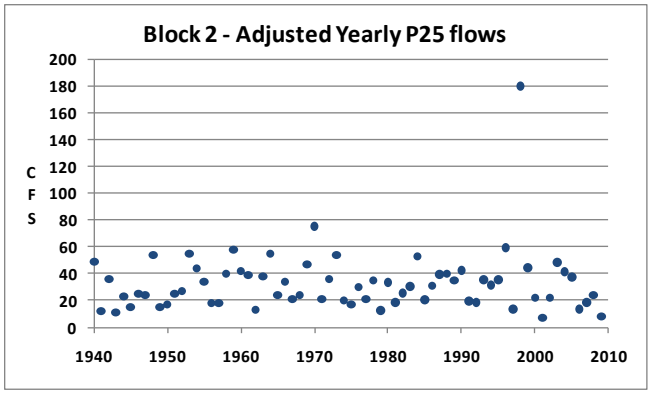


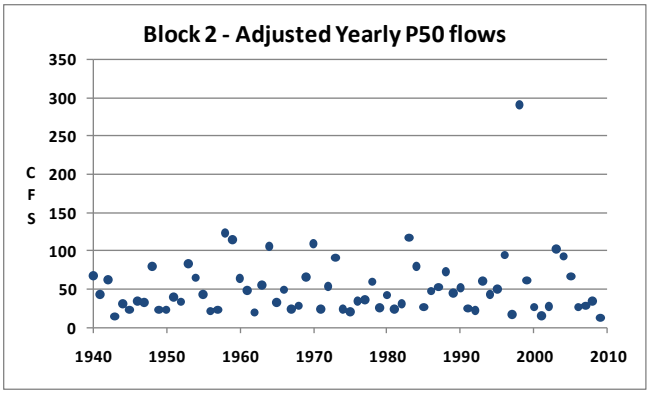


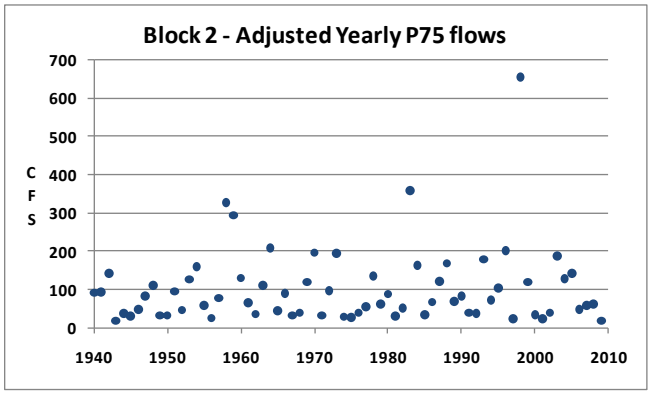
Hydrographs of selected yearly percentile flows for the adjusted flow record for the Little Manatee River near Wimauma gage: Block 1, 1940-2009

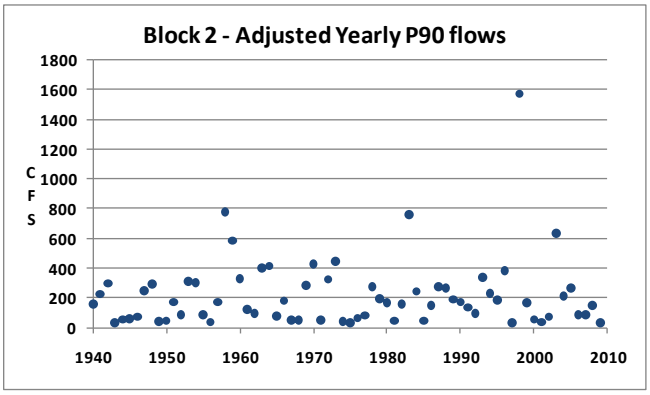




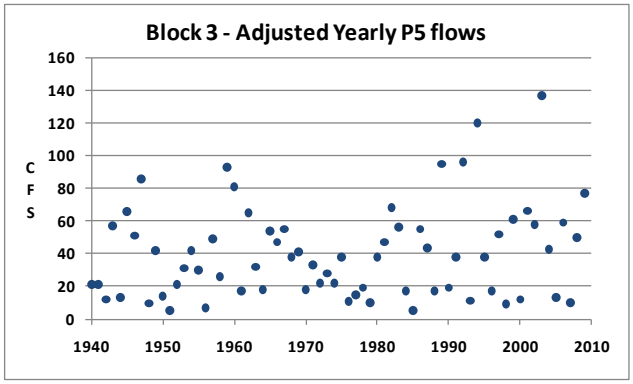


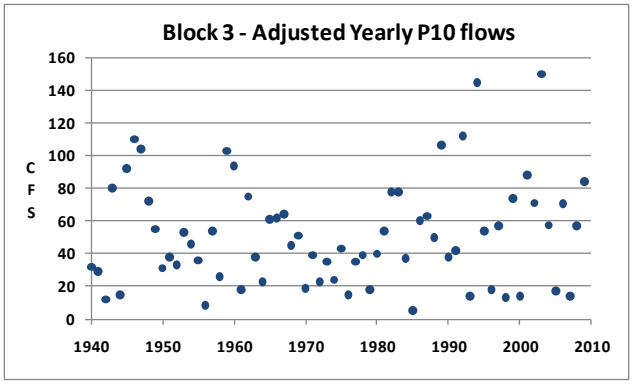


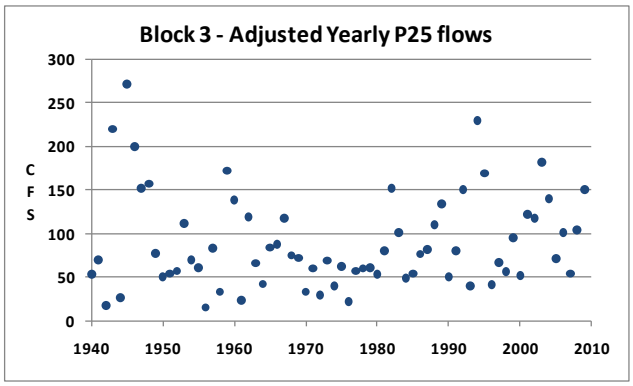


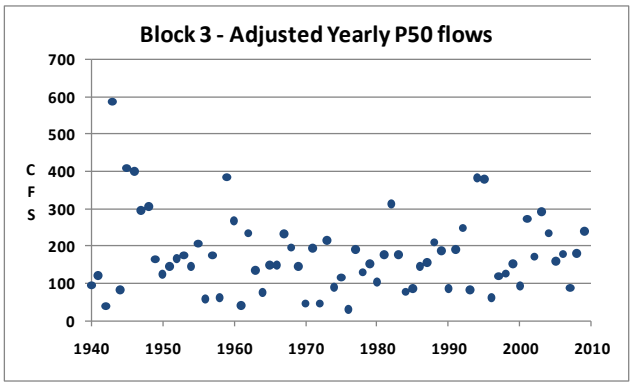


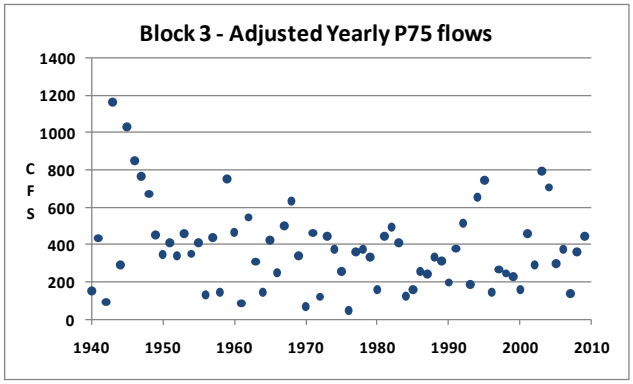
Hydrographs of selected yearly percentile flows for the adjusted flow record for the Little Manatee River near Wimauma: Block 2, 1940-2009

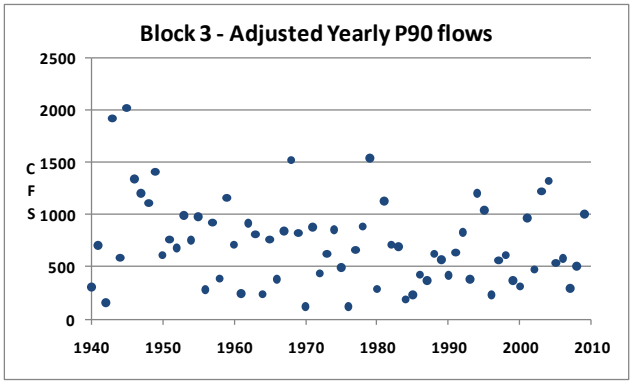












Hydrographs of selected yearly percentile flows for the adjusted flow record for the Little Manatee river near Wimauma: Block 3, 1940-2009