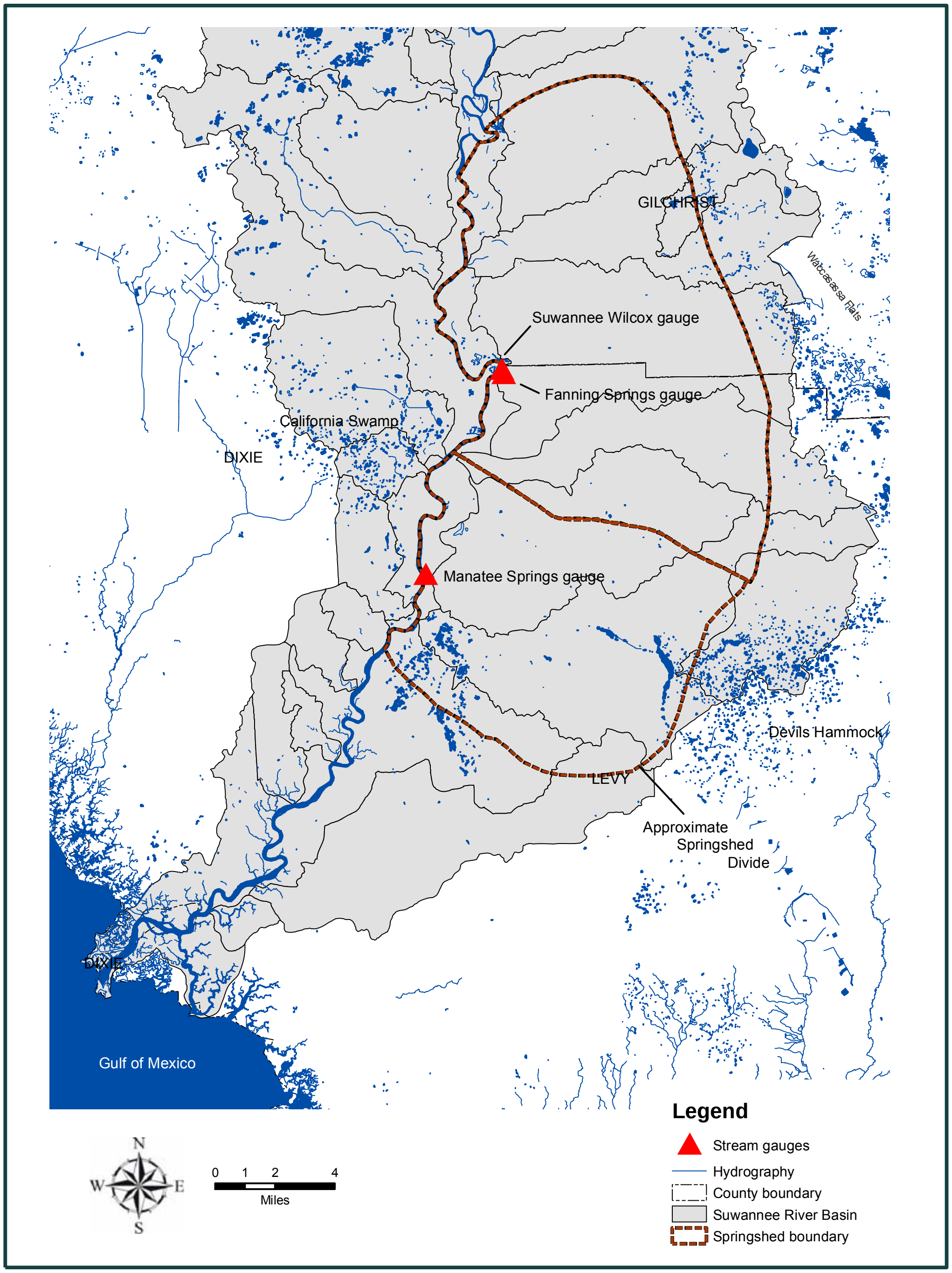

Figure 3-12. Location of stream gages within the Fanning and Manatee Springs springshed.

Stream Gaging Station			Period of Record	# of Daily Gage Values		# of Direct Measurements	
USGS Ref. #	SRWMD Site ID	Description		Stage	Discharge	Stage	Discharge
02323500	-101429002	Suwannee River near Wilcox	10/01/1941 – 05/31/2005	20801	23254	326*	293*
02323556	-111326002	Manatee Springs	01/19/2001 – 05/31/2005	1469	1486	54	66
02323502	-101429001	Fanning Springs	05/27/2001 – 05/31/2005	1455	1466	39	47

Table 3-10. Stage and discharge data available within the study area (data after 9/30/2004 are provisional).
*Measurements not available in digital format prior to 1983.

The most complete and extensive dataset is for the gage located on the Suwannee River near Wilcox. This gage is discussed in Section 3.1.

Temporary and then permanent staff gages have been located at Manatee and Fanning springs for many years. Early discharge measurements were based on temporary rating curves developed at the time of measurement. Historical discharge data (measurements made prior to 2001) for Fanning and Manatee Springs are summarized in Table 3-11. Note that these data were described as historic, “sporadic” discharge data in Section 2.3.5.1. The AVM gages at Fanning and Manatee Springs were installed in 2001, so a fairly short, though continuous, set of daily stage and discharge data has been collected there.

Manatee Spring		Fanning Spring		Little Fanning Spring	
Date	Discharge (cfs)	Date	Discharge (cfs)	Date	Discharge (cfs)
03/14/1932	149	10/25/1930	109	1/18/1985	6.38
12/17/1942	218	03/14/1932	79.2	05/8/2003	26.5
07/24/1946	137	12/17/1942	137	05/28/2003	20.4
04/27/1956	110	05/01/1956	64	06/25/2003	18.3
11/18/1960	238	11/18/1960	111	09/10/2003	23.8
05/28/1963	145	03/27/1963	83.4	04/07/2004	7.94
04/19/1972	220	04/25/1972	98.7	07/01/2004	0.89
04/25/1972	210	07/31/1973	139		
07/31/1973	203	01/18/1985	188		
01/18/1985	209	08/14/1990	116		
08/14/1990	125	06/16/1997	76.1		
06/25/1997	141.7	07/24/1997	77.3		
05/11/1998	228	05/11/1998	62		
05/18/1998	204	05/18/1998	69		
06/01/1998	251	06/01/1998	116		
06/08/1998	268	06/08/1998	104		
06/15/1998	246	06/15/1998	109		

Table 3-11. Historical discharge measurements, in cubic feet per second, for Fanning, Little Fanning, and Manatee Springs.

Little Fanning Springs has never been monitored on a regular basis. Discharge has been measured at Little Fanning Spring a total of seven times to date (Table 3-11). While one of these measurements might be considered “historical”, the remaining six measurements were all completed within a relatively short time frame in 2003 and 2004.

3.2.2.2 Spring Bathymetry Data

3.2.2.2.1 Manatee Spring Bathymetric Survey

In April of 2005, the Florida Geological Survey completed a bathymetric survey of the Manatee Spring run and the Suwannee River in the vicinity of the spring. The survey utilized a precision depth recorder and GPS navigation system. Depths were converted to elevations (NGVD) by correlating with stage observations at Manatee Springs State Park. The results of this survey are shown in Figure 3-13. Using these data, a series of cross-sectional profiles were constructed over the shoals within the spring run. The locations of these profiles are shown on the inset in Figure 3-13. Plots of these cross-sectional profiles are included in Appendix B.

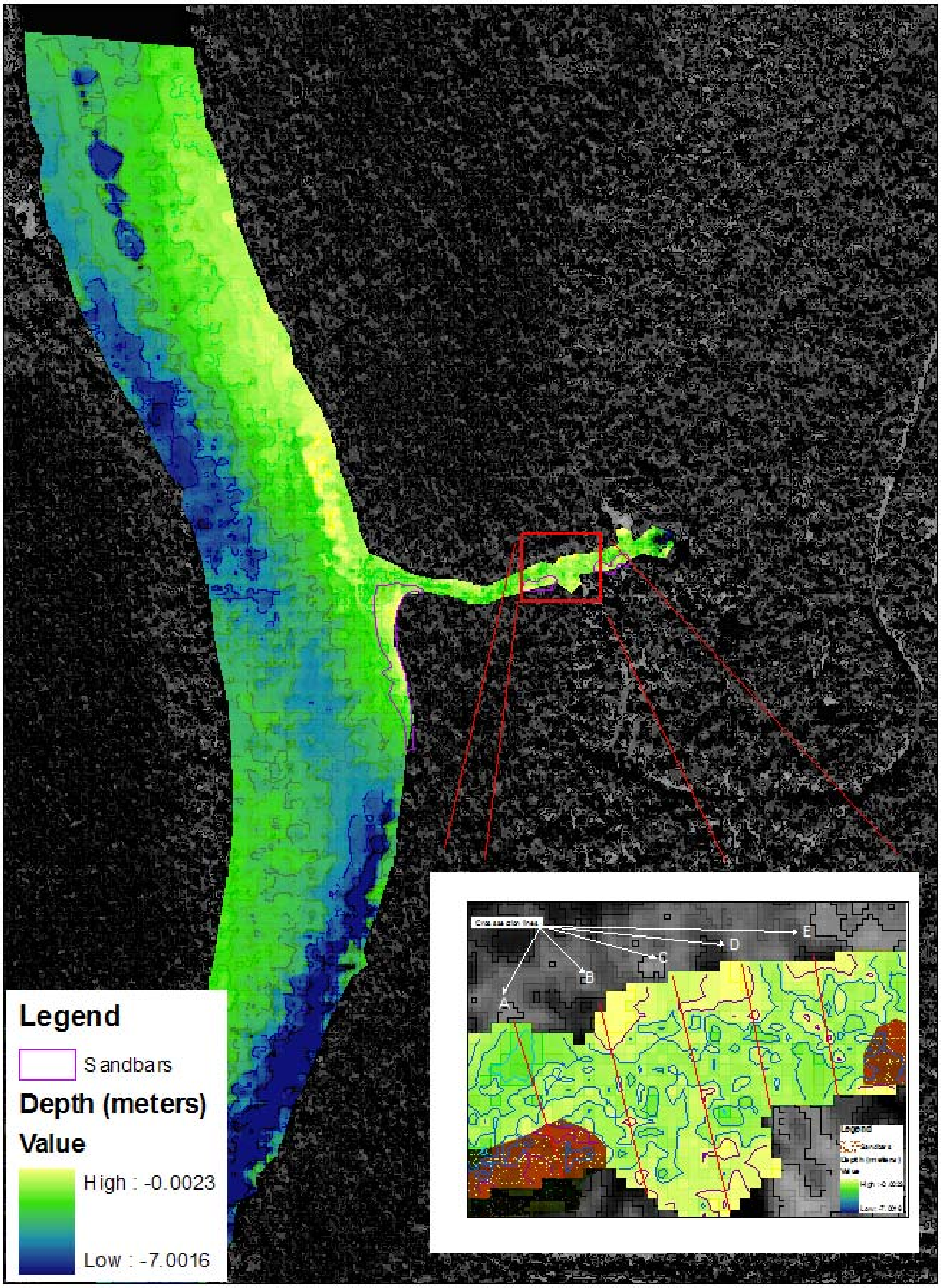

Figure 3-13. Bathymetry surface of Manatee Spring and the adjacent Suwannee River. Inset: Locations of cross-sectional profiles across the shoals in the Manatee Spring run. Data source: Florida Geological Survey, 2005.

These profiles were utilized to identify the highest elevation within the thalweg (the line defining the lowest points along the length of a channel). This “sill” within the spring run is important because it limits the passage of manatees up the spring run into the area of the spring pool. As shown in Figure 3-13, the shoals are located approximately two-thirds of the way up the run from the river. Manatees have relatively free access down stream from the shoal. Within the profiles shown on Figure 3-13, the elevation of the thalweg ranges from greater than 4 feet (Profile A) to just under 2 feet (Profile C) below the water surface.

3.2.2.2.2 Fanning Spring Bathymetric Profiles

On June 20, 2005, a land surveying company retained by Water Resource Associates collected five cross-sectional profiles across the shallowest part of the Fanning Spring run. The location of these profiles is shown in Figure 3-14. Plots of these cross-sectional profiles are included in Appendix C.

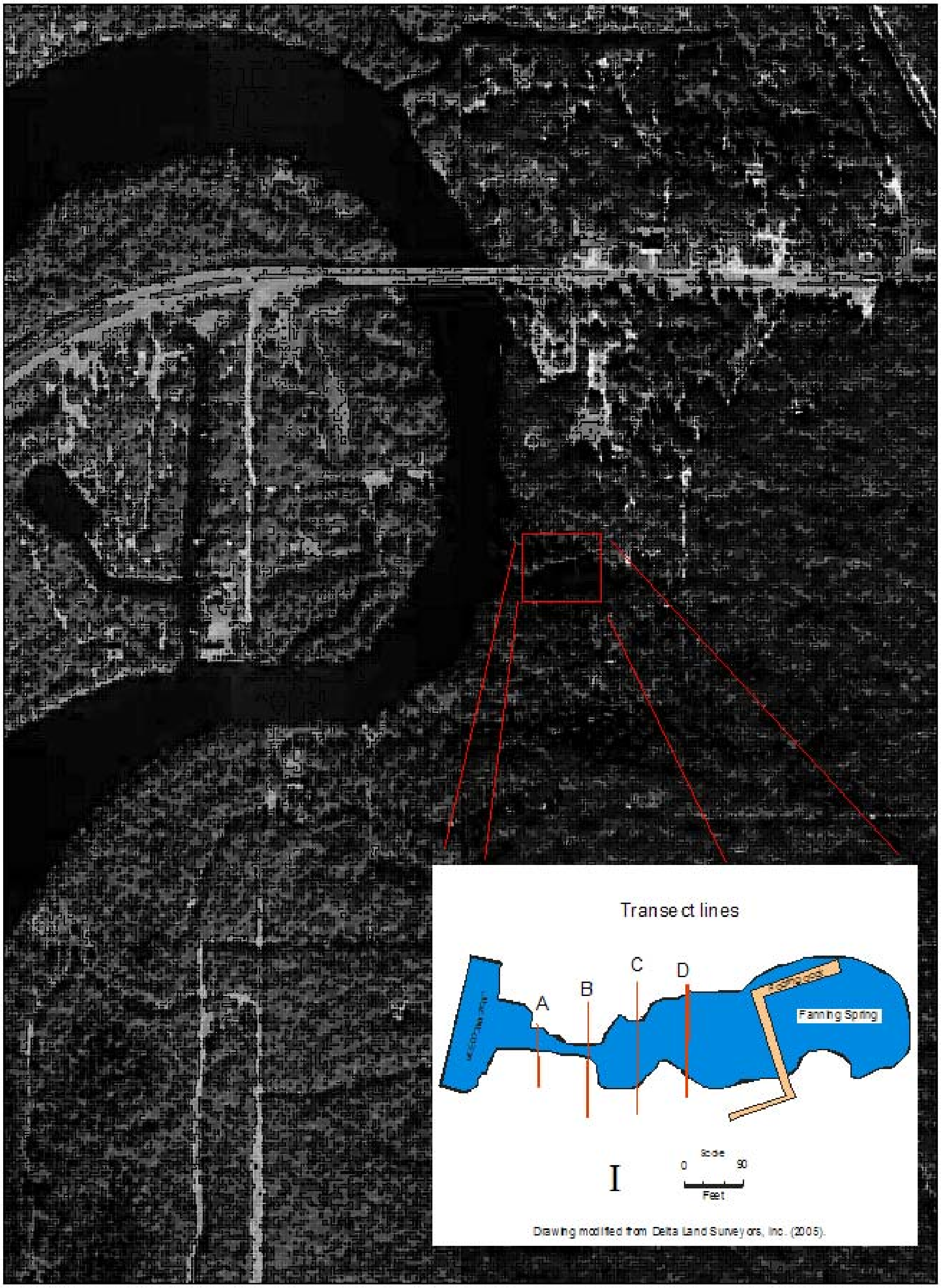

Figure 3-14. Locations of cross-sectional profiles across the Fanning Spring run.

As with the Manatee Spring profiles, this survey was utilized to identify the “sill” within the thalweg of the spring run in order to address manatee passage issues. The elevation of the thalweg within these profiles ranged from a low of –3.81 feet NGVD (Profile C) to as high as –2.29 feet NGVD (Profile B).

3.2.2.3 Groundwater Data

3.2.2.3.1 Groundwater Levels

The District has collected groundwater level data in Levy and Gilchrist County at 183 wells located within the Suwannee River drainage basin. Of these, a total of 109 wells are located within the Manatee and Fanning Springs springshed (Figure 3-15). Table 3-12 contains information on water-level data available for these wells, including the date first and last measured, the frequency measured, total number of measurements, and minimum and maximum groundwater levels within each well. Appendix E contains the complete data set for each of the wells in the study area. Only those wells with 10 or more measurements are depicted graphically in Appendix D; the data from the remaining wells (74% of the total wells) are presented in a table in the Appendix.

Of these 109 wells, only 12 have been monitored on a daily basis for some period, and only two have been continuously monitored on a daily basis for an extended period of time (e.g. longer than ten years). The remaining wells have been monitored on a monthly, quarterly, or yearly basis. Some wells have significant gaps within their monitoring records.

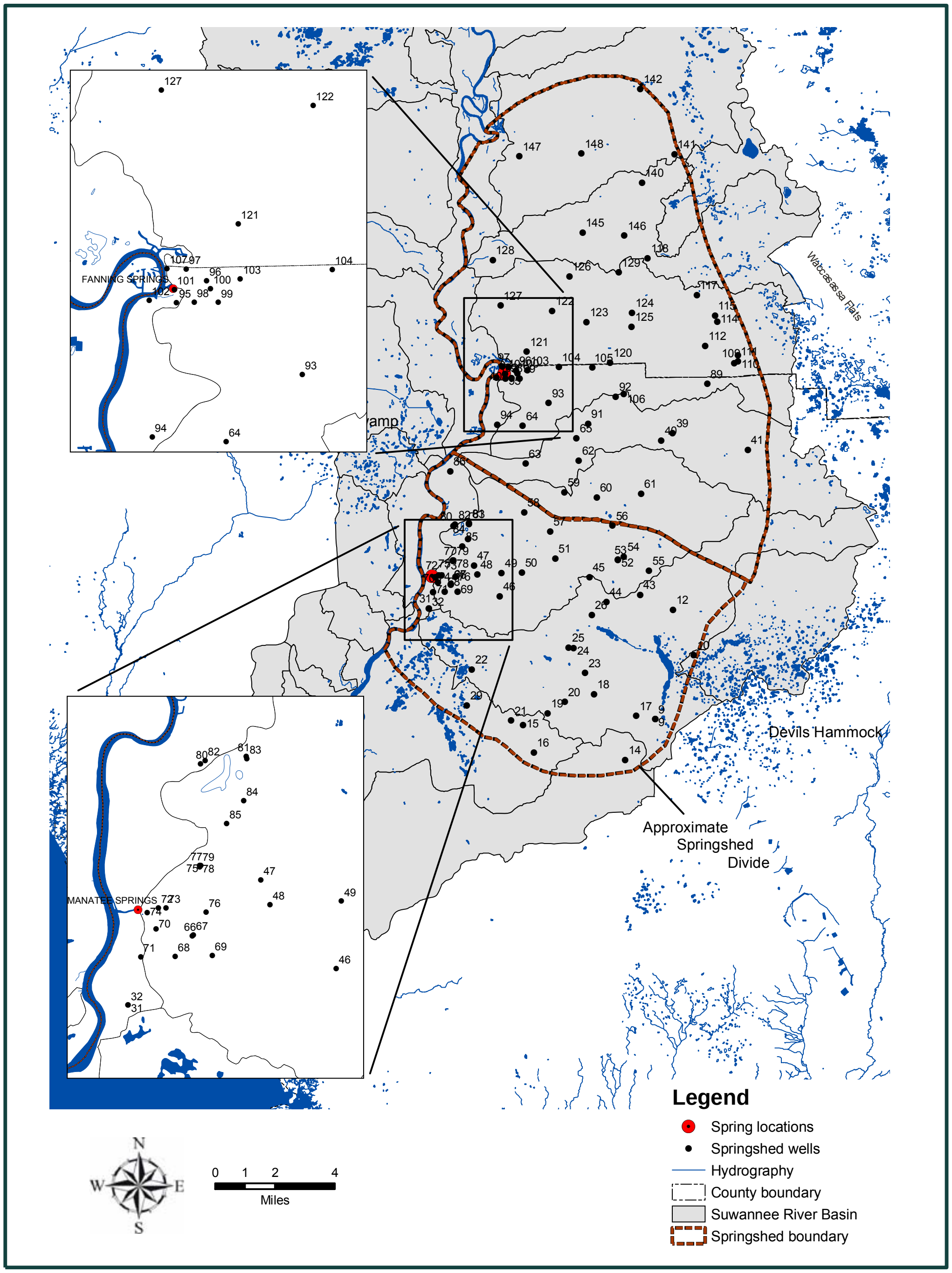

Figure 3-15. Location of water-level monitoring wells within the Fanning and Manatee Springs springshed.

Well	Site ID	First Measured	Last Measured	Frequency Measured	Number of Measurements	Min (ft msl)	Max (ft msl)
9	-121519001	05/21/2002	01/28/2004	Quarterly	3	8.40	12.94
10	-121508005	09/07/2000	09/24/2004	Daily	1439	15.31	30.50
12	-121506002	12/12/2001	01/28/2004	Yearly	4	8.66	15.28
14	-121436002	09/30/2003	01/28/2004	Quarterly	2	9.94	13.65
15	-121429005	06/13/1989	09/09/2004	Monthly*	38	5.86	20.11
16	-121428004	12/17/2003	01/28/2004	Monthly	2	11.25	12.34
17	-121424006	03/05/2002	01/28/2004	Quarterly*	4	5.23	9.89
18	-121423007	03/05/2002	01/28/2004	Quarterly*	4	4.30	9.17
19	-121422002	03/06/2002	01/28/2004	Quarterly*	4	4.50	8.80
20	-121422001	03/06/2002	09/29/2004	Daily	808	5.03	20.03
21	-121420001	11/01/1976	01/28/2004	Monthly*	58	6.04	22.70
22	-121418002	06/22/1982	12/06/1982	Quarterly	3	9.89	12.23
23	-121415003	03/06/2002	01/28/2004	Quarterly*	4	5.72	10.56
24	-121410003	05/28/2002	01/28/2004	Yearly	4	5.17	11.09
25	-121410001	06/22/1982	03/27/2003	Quarterly*	6	4.88	13.47
26	-121402003	02/28/2002	01/28/2004	Quarterly*	4	6.32	11.45
29	-121324001	03/07/2002	01/28/2004	Quarterly*	4	7.85	12.01
31	-121302011	02/21/2003	03/11/2004	Yearly	3	3.49	6.23
32	-121302010	02/21/2003	03/11/2004	Yearly	3	4.49	6.23
39	-111506010	03/08/2002	01/29/2004	Quarterly*	4	5.20	11.44
40	-111506001	06/23/1981	12/08/1982	Quarterly	5	9.45	14.49
41	-111503011	03/06/2002	01/29/2004	Quarterly*	4	10.90	18.23
43	-111436001	01/06/1966	05/13/1998	Monthly*	65	12.17	27.17
44	-111435007	12/19/2001	01/29/2004	Quarterly*	5	7.03	12.59
45	-111434010	02/22/2002	01/29/2004	Quarterly*	4	6.90	12.67
46	-111431006	03/05/2002	10/03/2002	Quarterly	3	2.89	4.08
47	-111430015	05/31/2002	01/29/2004	Yearly	3	1.56	4.72
48	-111430014	01/19/2001	01/29/2004	Quarterly*	5	2.20	4.29
49	-111429006	12/19/2001	01/29/2004	Quarterly*	5	2.94	5.21
50	-111429005	02/21/2002	01/29/2004	Quarterly*	4	3.81	7.71

Table 3-12. Wells located within the Fanning and Manatee springshed. (* large gaps in data collection)

Well	Site ID	First Measured	Last Measured	Frequency Measured	Number of Measurements	Min (ft msl)	Max (ft msl)
51	-111428007	02/21/2002	01/29/2004	Quarterly*	4	5.37	10.13
52	-111426010	12/11/2001	01/28/2004	Quarterly*	5	7.37	12.80
53	-111426001	07/24/1979	12/06/1982	Monthly	38	12.50	19.31
54	-111425012	04/25/2001	01/28/2004	Quarterly*	7	7.48	15.69
55	-111425001	07/24/1979	01/28/2004	Monthly*	44	7.31	19.76
56	-111423013	04/27/2001	04/07/2004	Quarterly*	8	5.51	14.04
57	-111421001	03/11/2002	01/29/2004	Quarterly*	4	5.05	9.93
58	-111417003	03/05/2002	01/29/2004	Quarterly*	4	4.91	9.62
59	-111415002	03/11/2002	01/29/2004	Quarterly*	4	5.60	10.27
60	-111414008	02/22/2002	01/29/2004	Quarterly*	4	5.65	11.32
61	-111413007	02/27/2002	01/29/2004	Quarterly*	4	5.76	12.84
62	-111410024	02/22/2002	01/29/2004	Quarterly*	4	3.17	9.49
63	-111408002	03/11/2002	01/29/2004	Quarterly*	4	4.77	8.56
64	-111405001	06/13/1989	1/29/2004	Monthly*	27	3.47	9.19
65	-111403008	03/06/2002	01/29/2004	Quarterly*	4	5.08	9.34
66	-111336005	01/28/2004	03/11/2004	Monthly	2	2.32	4.76
67	-111336004	01/28/2004	04/30/2004	Monthly	3	2.35	4.81
68	-111336003	04/29/2002	01/28/2004	Quarterly*	6	1.71	3.09
69	-111336002	04/29/2002	01/28/2004	Quarterly*	6	1.21	3.14
70	-111335006	01/28/2004	01/28/2004	----------	1	1.73	1.73
71	-111335005	04/29/2002	09/14/2004	Daily	756	1.14	8.42
72	-111335002	09/09/1981	05/06/1987	Bimonthly	30	-0.75	8.23
73	-111326008	02/15/2000	10/03/2002	Quarterly*	4	1.23	1.85
74	-111326004	10/01/1981	08/27/2004	Daily	7930	0.34	12.91
75	-111325018	04/29/2002	01/28/2004	Quarterly*	6	2.47	4.52
76	-111325017	04/29/2002	09/14/2004	Daily	755	2.08	9.45
77	-111325016	02/15/2001	05/29/2002	Quarterly*	4	2.61	3.29
78	-111325008	12/13/2000	01/28/2004	Yearly	5	2.52	4.48
79	-111325001	07/24/1979	12/11/2001	Monthly*	41	2.96	10.68
80	-111324033	05/15/2002	05/15/2002	----------	1	1.91	1.91

Table 3-12. (cont.). Wells located within the Fanning and Manatee springshed. (* large gaps in data collection)

Well	Site ID	First Measured	Last Measured	Frequency Measured	Number of Measurements	Min (ft msl)	Max (ft msl)
81	-111324030	05/23/2002	06/26/2002	Monthly	2	2.74	3.00
82	-111324029	04/29/2002	01/28/2004	Quarterly*	8	3.94	6.70
83	-111324028	04/29/2002	09/26/2004	Daily	767	4.00	14.73
84	-111324027	04/29/2002	03/16/2004	Quarterly*	6	3.87	8.98
85	-111324026	04/29/2002	08/05/2004	Daily	716	3.65	12.05
86	-111312001	04/01/2003	04/07/2004	Quarterly*	3	6.70	10.25
89	-101528013	03/06/2002	01/29/2004	Quarterly*	4	6.04	12.11
91	-101435008	12/18/2001	01/29/2004	Quarterly*	5	5.02	9.54
92	-101435007	12/18/2001	01/29/2004	Quarterly*	5	5.41	9.90
93	-101433012	12/18/2001	01/29/2004	Quarterly*	4	2.77	5.35
94	-101432001	03/22/2002	04/30/2004	Quarterly*	6	3.13	6.53
95	-101429025	04/26/2002	09/14/2004	Daily	754	2.10	12.05
96	-101429024	04/26/2002	01/29/2004	Quarterly*	6	2.46	4.50
97	-101429023	04/29/2002	09/14/2004	Daily	754	1.97	11.81
98	-101429022	04/26/2002	01/29/2004	Quarterly*	6	2.15	4.43
99	-101429021	04/26/2002	01/29/2004	Quarterly*	6	2.01	4.48
100	-101429020	04/26/2002	09/14/2004	Daily	753	2.33	8.37
101	-101429016	11/03/2000	08/27/2004	Daily	1211	1.62	11.84
102	-101429011	10/14/1997	09/10/2004	Monthly	91	1.01	14.70
103	-101428001	09/09/1981	09/09/2004	Monthly*	129	2.40	16.03
104	-101427005	12/18/2001	01/29/2004	Quarterly*	5	3.13	5.94
105	-101426007	12/18/2001	10/04/2002	Quarterly*	4	3.87	4.76
106	-101425008	01/31/2001	04/01/2004	Quarterly*	7	3.35	10.63
107	-101420026	12/06/2001	01/29/2004	Quarterly*	4	3.57	4.19
109	-101528003	07/24/1979	10/21/1981	Monthly	22	12.60	19.67
110	-101522006	10/01/1981	01/28/2004	Quarterly*	8	39.71	55.21
111	-101522001	02/12/1982	12/07/1982	Monthly	10	17.00	24.37
112	-101520004	03/14/2002	01/28/2004	Quarterly*	4	7.09	13.15
114	-101516017	01/12/1993	09/29/2004	Daily	3421	5.66	25.15
115	-101516001	11/01/1976	10/04/1994	Monthly*	151	7.49	24.84

Table 3-12. (cont.). Wells located within the Fanning and Manatee springshed. (* large gaps in data collection)

Well	Site ID	First Measured	Last Measured	Frequency Measured	Number of Measurements	Min (ft msl)	Max (ft msl)
117	-101508002	03/29/1982	01/28/2004	Quarterly*	8	6.00	24.56
118	-101506003	05/08/1998	09/29/2004	Daily	2075	3.80	21.41
120	-101423001	08/29/1979	12/06/1982	Monthly	39	9.59	16.37
121	-101421003	03/12/2002	01/28/2004	Quarterly*	4	2.83	4.35
122	-101416006	03/13/2002	01/28/2004	Quarterly*	4	3.28	7.04
123	-101414001	03/21/2002	01/28/2004	Quarterly*	4	3.76	7.84
124	-101413010	03/21/2002	01/28/2004	Quarterly*	4	4.78	10.07
125	-101413001	11/01/1976	05/15/1979	Quarterly	10	8.37	13.73
126	-101410005	03/13/2002	01/28/204	Quarterly*	4	3.61	7.68
127	-101408003	03/12/2002	01/28/2004	Quarterly*	4	2.89	5.21
128	-101406001	03/21/1982	01/29/2004	Quarterly*	7	3.58	6.06
129	-101401002	03/13/2002	01/28/2004	Quarterly*	4	4.31	9.19
140	-91530005	06/14/1989	07/01/2004	Monthly*	75	4.75	17.80
141	-91520001	09/08/1981	10/04/2002	Quarterly*	8	11.96	22.99
142	-91506002	09/21/1981	01/28/2004	Quarterly*	6	9.38	21.85
145	-91436008	03/25/2002	01/28/2004	Quarterly*	4	4.21	8.78
146	-91436002	03/22/1982	12/06/1982	Quarterly	4	15.41	19.32
147	-91420001	11/01/1976	09/09/2004	Monthly	299	3.71	19.77
148	-91415002	10/01/1981	10/04/2002	Quarterly*	8	4.58	18.22

Table 3-12. (cont.). Wells located within the Fanning and Manatee springshed. (* large gaps in data collection)

3.2.2.5 Precipitation Data

Precipitation data exist for several stations in the vicinity of Fanning and Manatee Springs. The first and last date measured, along with the largest rainfall total for a single month at that gage, are presented in Table 3-13 and locations of the gages are shown in Figure 3-16. The data are presented graphically in Appendix F. Only monthly rainfall totals are available for the three rainfall stations located within the Fanning and Manatee Springs basin. The total period of record for these gages ranges from about 7 to 30 years.

Station	First Measured	Last Measured	Maximum Event (Date)
Trenton Tower (71)	January 1976	Present	16.87 in. (Aug. 1985)
Fanning Spring (72)	May 1998	Present	11.6 in. (July 2001)
Manatee Spring (93)	March 1989	Present	17.66 in. (July 1994)

Table 3-13. Available precipitation data in the Fanning and Manatee Spring basins.

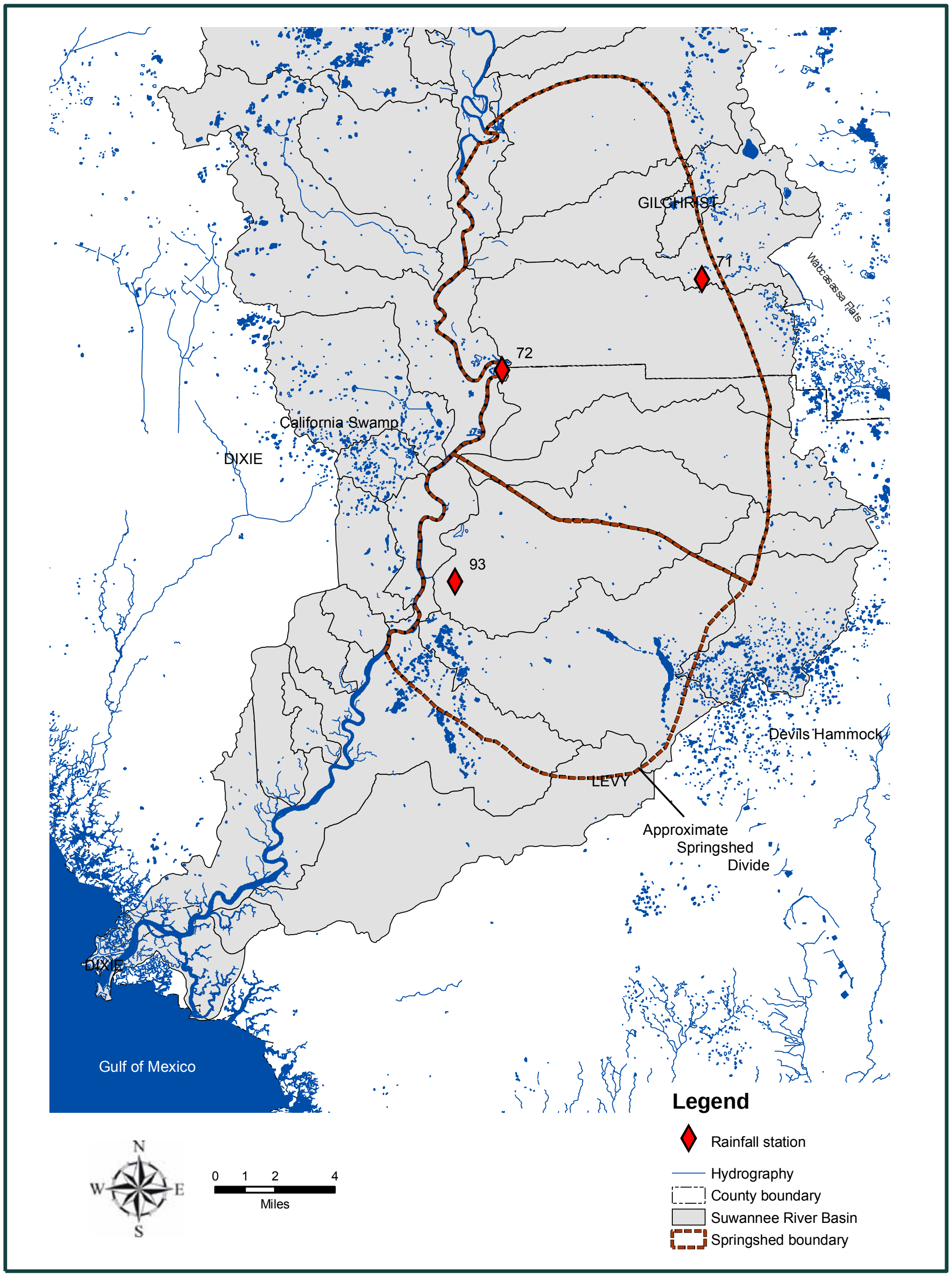

Figure 3-16. Location of rainfall gages within the Fanning and Manatee Springs springshed.

3.2.2.6 Summary

The hydrologic and geologic data available for the determination of minimum flows and levels for Manatee and Fanning Springs are:

- An excellent period of record for stage and discharge at the Suwannee River near Wilcox;
- Fairly short periods of record for the gages at Fanning and Manatee Springs;
- Monthly to yearly groundwater level data from 96 wells;
- A short daily record of groundwater levels from 11 wells;
- Significantly long daily records of groundwater levels from 2 wells;
- Groundwater permit information by county;
- Monthly rainfall data from three stations in the vicinity of study area;
- Bathymetric survey data for the Fanning and Manatee Spring runs; and
- Thermal data from the Suwannee River at Manatee Springs for approximately two months in March and April 2004.

3.2.3 Data Synthesis and Analyses

3.2.3.1 Introduction

As noted above, Fanning and Manatee Springs are part of a complex, interdependent hydrologic system. Discharge from the springs depends on both water levels within the springshed (groundwater potentials) and within the river. Water levels and discharge in the river are affected by the flux of water from the upstream portion of the Suwannee Basin as well as by tidal flux in the Suwannee River Estuary.

Unfortunately, the data available for use in characterizing the inter-relationships within this system are not extensive. Gages have only been present within the springs for a few years. Furthermore, due to the problems inherent in installing and calibrating these gages, there is uncertainty regarding the quality of the short dataset available. The Fanning Spring discharge record appears to be representative of actual discharge from this spring, while significant portions of the Manatee Spring discharge record appear to be flawed.

Although there are over 100 wells located within the Fanning and Manatee springsheds, groundwater elevations have not been measured in most of these wells with regularity. In addition, due to the hydraulic interactions between the Floridan aquifer and the Suwannee River, wells in close proximity to the river appear to better represent conditions within the river. One well (Well #114) with a fairly long period of daily measurements is located a sufficient distance from the river to reduce influences of the river. This dataset, combined with the data from the gage on the Suwannee River near Wilcox, was sufficient to characterize the driving forces behind discharge from Fanning and Manatee springs.

The results from the data synthesis presented below indicate that, while daily stage values in the springs can be simulated from river stage with a high degree of confidence, working with average monthly values to simulate discharge significantly increases confidence in the results. Equations for simulation of daily discharge have been developed and could be used; however, a MFL for either water body is likely to be based on longer-term average or median flows (i.e. monthly average) due to the significant short-term variability in discharge at both springs and in the river. Therefore, the simulated monthly discharge represents the statistically best values, as well as likely being the most useful.

The regression equations developed for simulating monthly discharge from Fanning and Manatee springs represent statistically significant relationships. However, these equations are only based on a period of record for Fanning Spring of approximately 40 months. In the case of Manatee Spring, this period of record is much shorter (about 16 months); much of the remaining data from this gage appear to be flawed and were not used. While the simulated monthly discharge for these two springs (Figure 3-17) appear to be reasonable, the numerous limitations in the available data result in a certain level of uncertainty. As such, hydrologic conditions not experienced during the period of record for the springs may result in spring conditions different from those predicted by the regression equations. Even though this analysis makes use of the "best available" data, the inherent limitations should be considered when applying these data to management decisions.

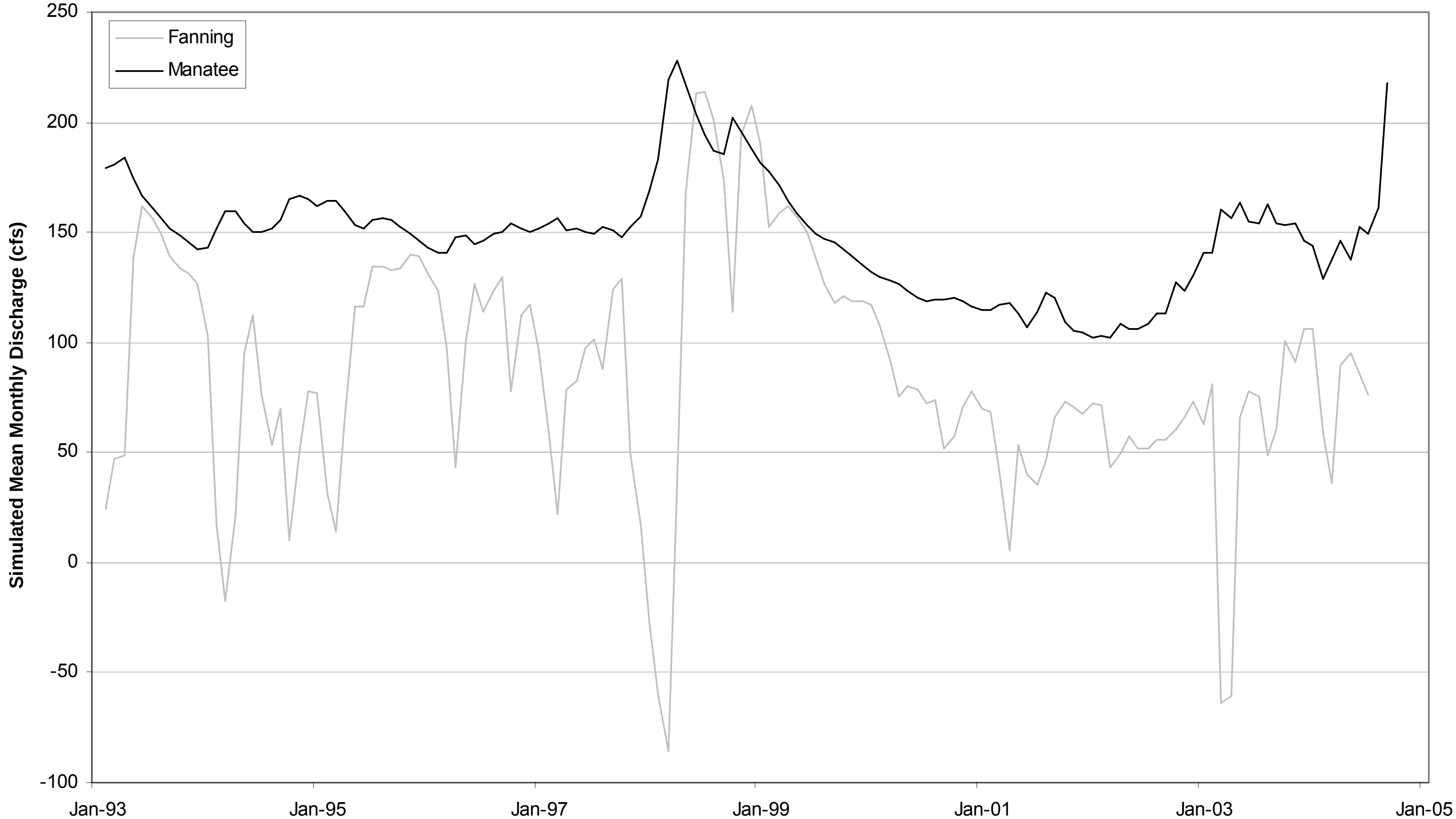

Figure 3-17. Simulated average monthly discharge for Manatee and Fanning Springs.

3.2.3.2 Methods

3.2.3.2.1 Simulating Stage Data

The spring runs for Fanning and Manatee springs are relatively short and do not contain significant sills that restrict interaction with the Suwannee River, such as holding the elevation of the spring pool above that of the adjacent Suwannee River. Therefore, spring stage is generally dependent on the stage within the river adjacent to the spring. In order to develop relationships between measured spring and river stage, cross-plots of the data were created. Generating trendlines for the data and evaluating various types of trends (e.g. linear, polynomial) and the quality of their fit produced simplified relationships between spring stage and river stage as measured at a nearby gage. This relationship, or equation, relating spring stage to river stage was used to generate more complete periods of record for spring stages at Fanning and Manatee springs.

3.2.3.2.2 Simulating Discharge Data

Discharge from Fanning and Manatee springs is dependent on several variables, as will be discussed further below. Due to this complexity, multiple linear regressions are necessary to define the relationships between spring discharge and the environmental factors that drive it. Stepwise multiple linear regressions performed to develop equations using the statistical software package SYSTAT®. The regression analysis was begun with all potentially important independent variables included. A backward, stepwise regression systematically removed each variable that exceeded the designated alpha value of 0.05. The result of each step-wise regression is a set of variables and associated coefficients for a equation that relates the statistically significant independent variables to the dependent one (spring discharge). The equation can then be applied for the entire period of record of the independent variables to generate a simulated period of record data set for the dependent variable.

3.2.3.2.3 Uncertainty Associated With Data Simulation

Fanning and Manatee Springs, the Suwannee River, and related portions of the Floridan aquifer form a complex, interactive hydrologic system. Due to this level of complexity, there is a level of uncertainty that goes along with simulating data for Fanning and Manatee springs. This uncertainty is additive at each step in the data simulation process. Even if the uncertainty associated with each step in the process of data simulation is kept to a minimum, the uncertainty can compound as simulated data are used to simulate additional data sets. Uncertainty is kept reasonably low during each phase of data simulation, but the inherent complexities of the system result in some uncertainty, particularly with the peak stage and discharge values. Primary control on uncertainty is through calibration or confirmation comparisons of calculated and observed stage or discharge.

3.2.3.3 Fanning Spring

The water level in Fanning Spring generally reflects the stage of the adjacent Suwannee River due to the lack of any significant sill within the spring run. Therefore, discharge from the spring is impeded or enhanced based upon the river stage. Figure 2-36 shows the Wilcox stage for corresponding measured discharge at Fanning Spring. As can be seen, spring discharge fluctuates on a daily basis due to the tidal nature of the Suwannee River in the vicinity of the spring. Flood events significantly reduce spring discharge, and extreme floods actually reverse the flow of the spring. Discharge from the spring reverses at a river stage of approximately 9 ft.

NGVD. These patterns are superimposed on the long-term discharge trends, which are primarily due to variability of water levels within the Floridan aquifer.

3.2.3.3.1 Simulating Spring Stage

Average daily stage measurements for Fanning Spring were compared to the average daily stage for the Suwannee River gage near Wilcox, located just upstream from Fanning Spring. As Figure 3-18 shows, the two data sets are highly correlated. This relationship was used to simulate a time series of average daily stage for Fanning Springs. Figure 3-19 shows the simulated historical time-series data, along with the measured stage for comparison.

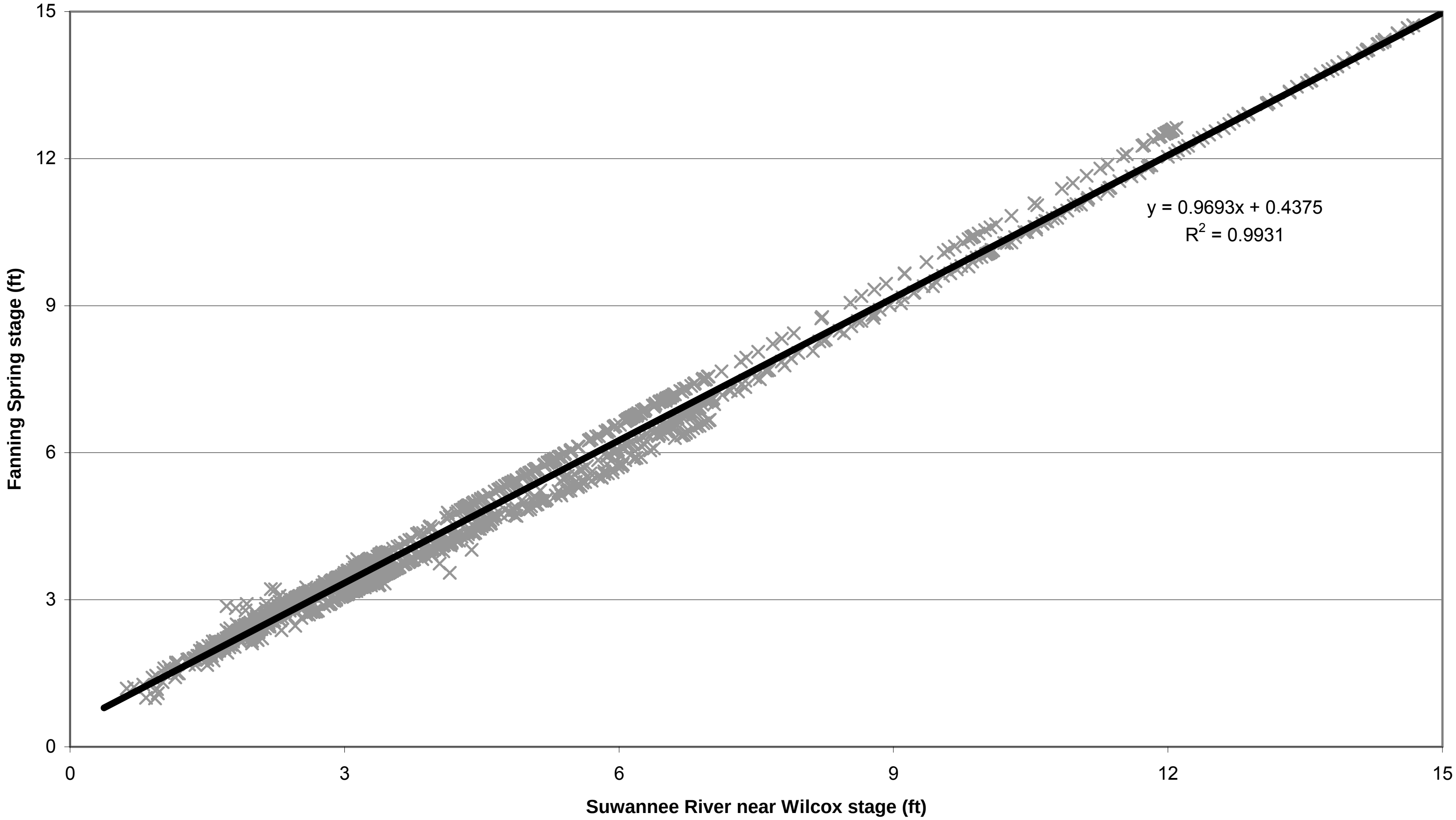

Figure 3-18. Cross-plot of stage data from the Suwannee River near Wilcox and the Fanning Spring gages.

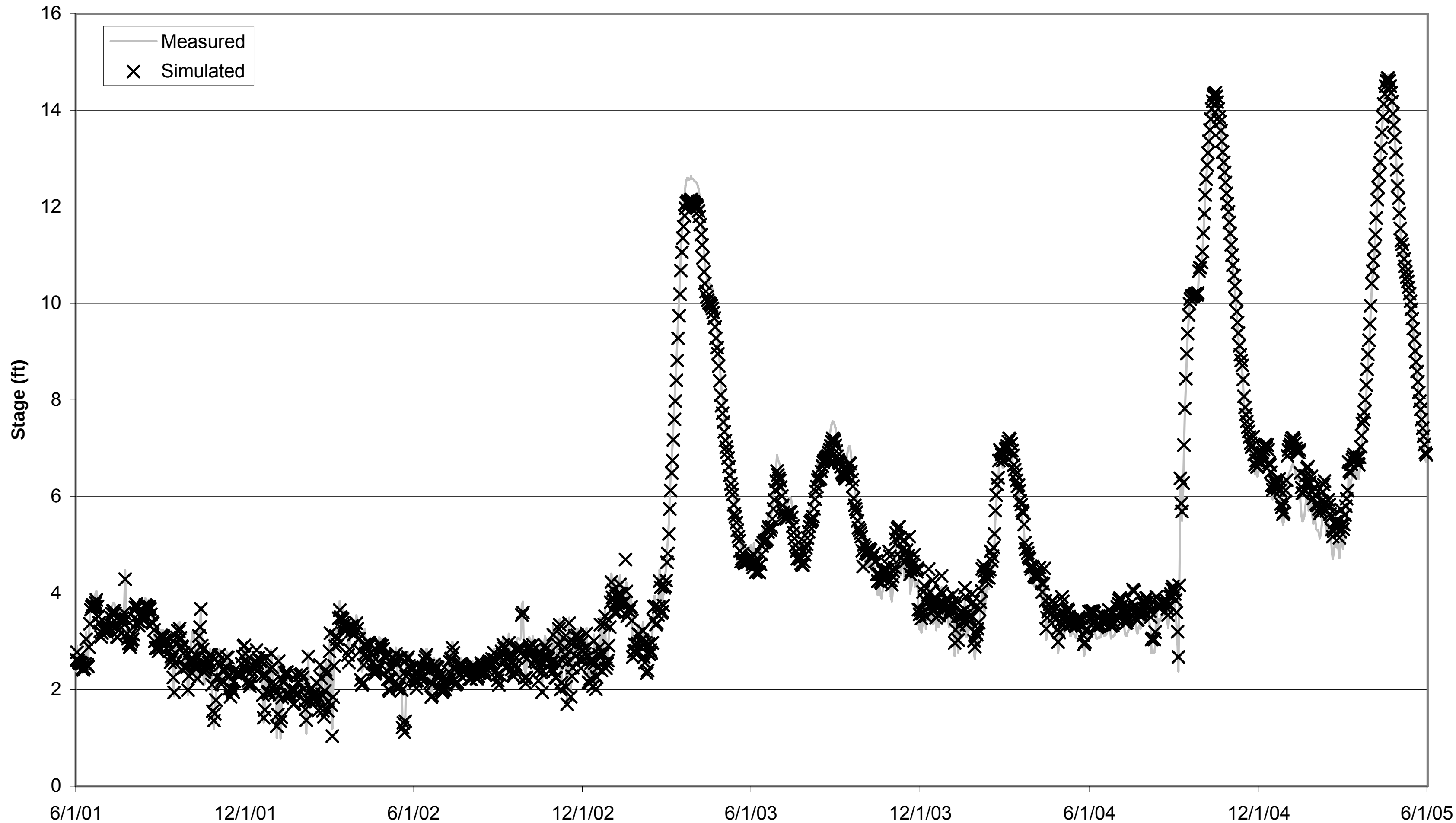

Figure 3-19. Comparison of measured and simulated stage at Fanning Spring.

3.2.3.3.2 Simulation of Fanning Spring Discharge

As discussed above, discharge from Fanning Spring is dependent on water levels in both the aquifer and the adjacent Suwannee River. A step-wise multiple linear regression was developed using average monthly well, rainfall, and river data from sources with the longest period of record. Average monthly values were utilized in an attempt to smooth the short-term, tidally induced variability in the data (also, the rainfall data were only available in monthly format).

Of the 109 wells located within the springshed, only two (#74 and #114) have been continuously monitored for some substantial period of time. Well #74 actually has a longer period of record, and this well is located within close proximity to Fanning Spring and the Suwannee River. Well #114 is located some distance from the river; and measured water levels in this well reflect only the long-term fluctuations in the aquifer, as opposed to the short-term fluctuations seen in Well #74 which result primarily from changes in river stage (Figure 3-20).

The rainfall gage located at Manatee Spring (#93) was used as a basis of simulation because it has a much longer period of record (i.e., it was installed in 1989) than the gage located at Fanning Spring (installed in 1998). The monthly average stage for the Wilcox gage was used; this data set extends back to the 1940's. The monthly average water level data for well #114 is most limiting; this dataset begins in 1993.

The stepwise multiple linear regression proceeded to remove the gage #93 rainfall data and retain the data for Well #114 (h_{114}) and the Wilcox gage (h_{Wilcox}). The resulting polynomial for the average monthly discharge at Fanning Spring is:

$$Q_{Fanning} = 28.825 - 24.994(h_{Wilcox}) + 12.511(h_{114}).$$

This equation reproduces the discharge at Fanning Spring with an R^2 of 0.78, a statistically significant fit. The maximum residual is approximately 40 cfs. As expected, higher water levels in the aquifer yield higher spring discharge, and greater water levels in the river reduce the spring discharge.

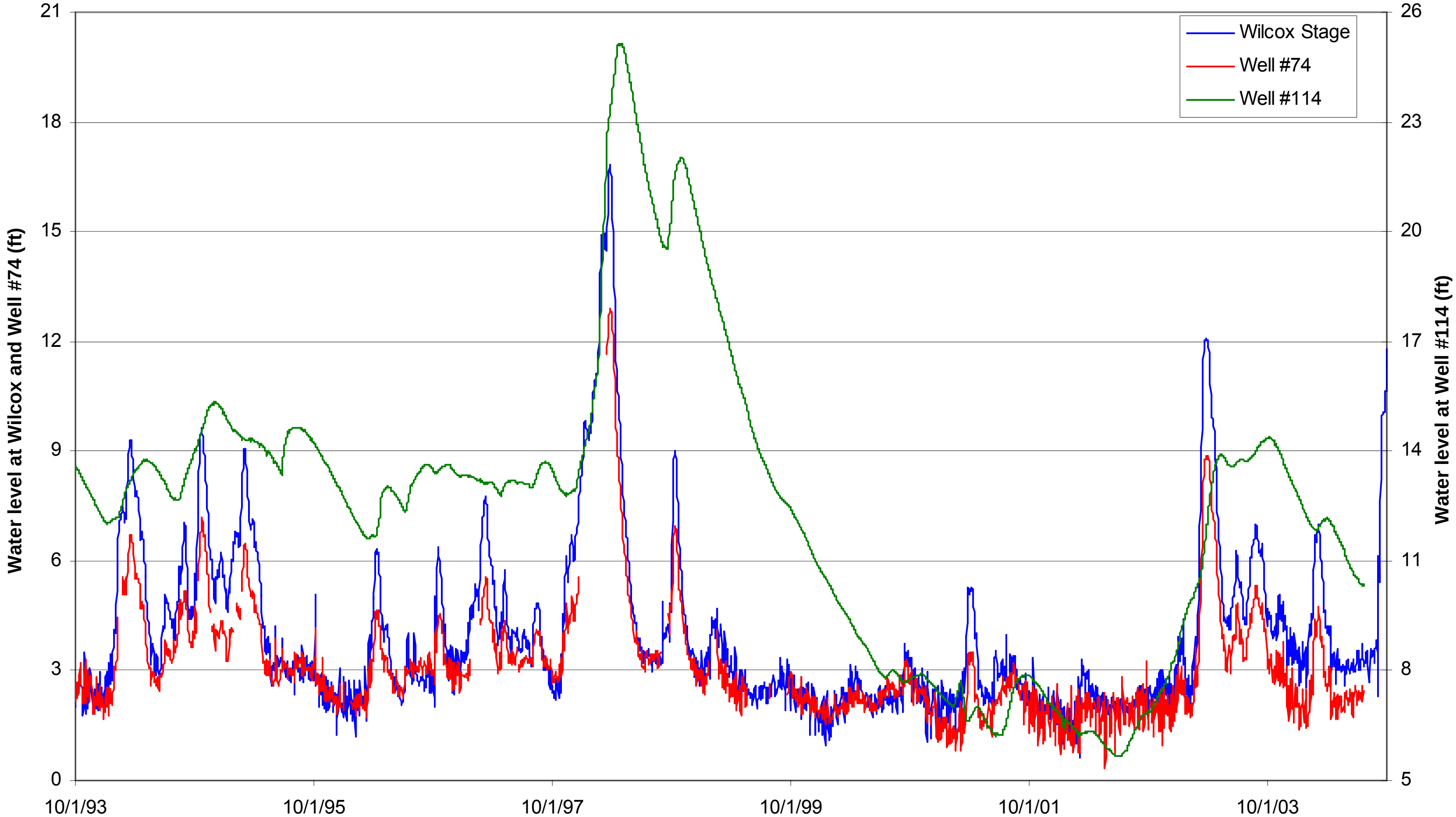

Figure 3-20. Comparison of Wilcox stage and water levels in nearby wells.

Figure 3-21 compares the predicted and measured mean monthly discharge for Fanning Spring. The magnitude of spring discharge is generally well reproduced, and the pattern of change in spring discharge with time is also well simulated.

A similar analysis was completed using the daily water level values, instead of monthly averages. The rainfall data are only available as a monthly total and could not be included. A similar result (the coefficients are nearly the same) was obtained using the daily river and aquifer water levels, though the uncertainty is greater. The resulting polynomial for daily discharge simulation at Fanning Spring is:

$Q_{Fanning} = 26.468 – 25.043(h_{Wilcox}) + 12.724(h_{114})$.

The equation reproduces the daily values with an R^2 of 0.71, and the maximum residual is approximately 100 cfs. Therefore, the error inherent in the synthesized monthly discharge is significantly less than that associated with simulated daily values.

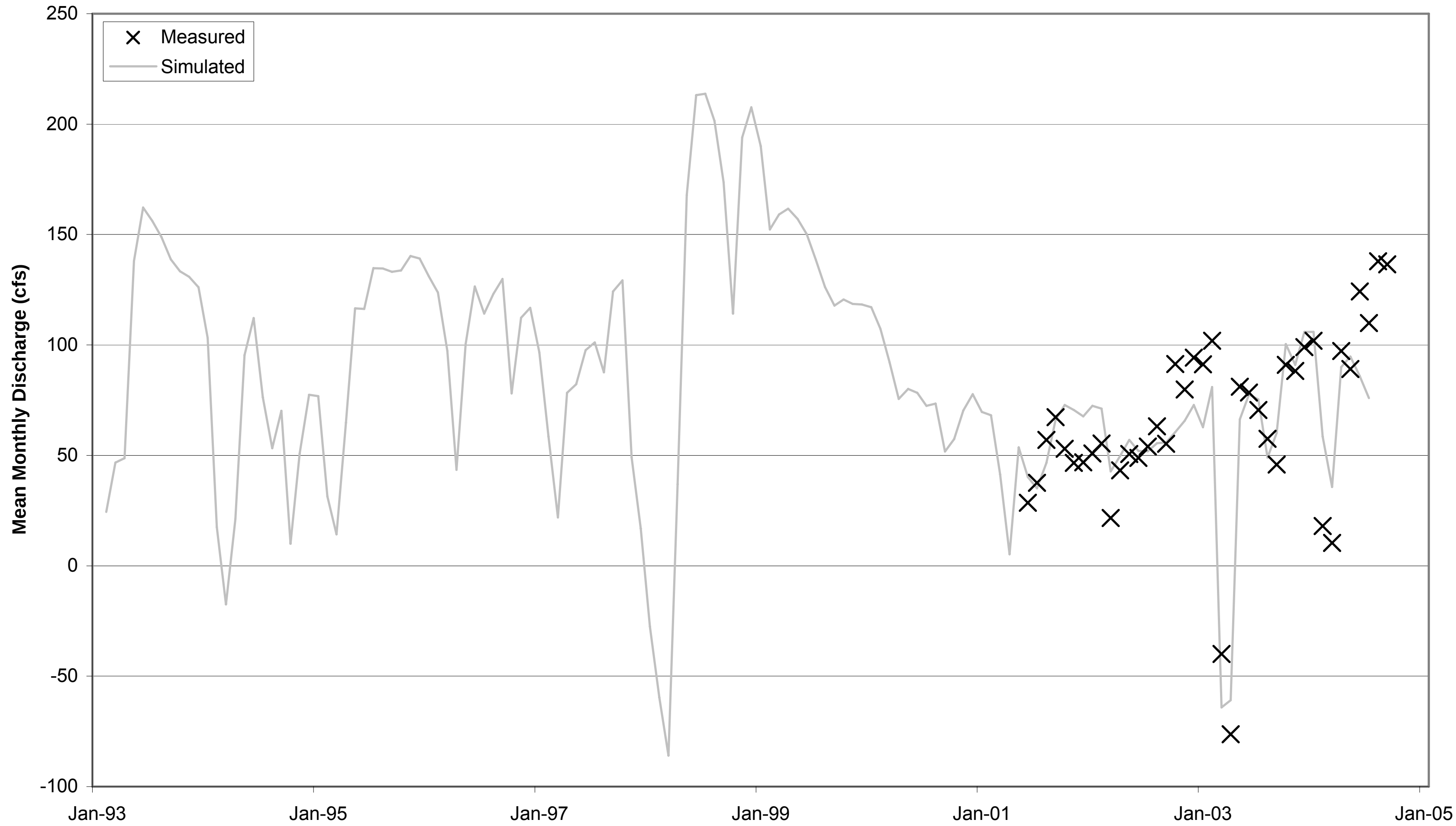

Figure 3-21. Comparison of measured and simulated average monthly discharge for Fanning Spring.

3.2.3.3.3 Data Characteristics

3.2.3.3.3.1 Population Descriptors

Summaries of the daily AVM data collected at Fanning Spring are presented in Tables 2-11 and 2-12. The simulated data, however, represent a longer period of record, resulting in a better data sample for descriptive statistics. Average daily stage data were synthesized for Fanning Spring based on the relationship between spring stage and stage at the Wilcox gage. The Wilcox gage has been in operation since 1941; however, the available stage data prior to 1951 do not contain values for times when stage was below approximately 5 feet. As these censored data tend to skew the simulated dataset, the period of record for the synthesized stage data at Fanning Spring begins in 1951.

Because of tidal and other transient discharge variability, the best results for synthesizing discharge data were obtained for the average monthly discharge at Fanning Spring (Section 3.2.3.2.2). The period of record for the simulated discharge data is limited by the sampling period for Well #114. Therefore, the simulated discharge data only extend back to 1993. Figures 3-22 and 3-23 present box-whisker graphs of the simulated daily stage data and the simulated monthly discharge data, respectively.

3.2.3.3.3.2 Flow and Stage Duration Curves

Flow- and stage-duration curves were constructed from the synthesized data for Fanning Spring. The flow-duration curve (Figure 3-24) represents the exceedance probabilities for average monthly spring discharges. Over the period of record for this dataset (February 1993 – July 2004) the median average monthly discharge was approximately 78 cfs. The resulting stage duration curve for this dataset is shown in Figure 3-25. The median average daily stage at Fanning Spring was approximately 4 feet.

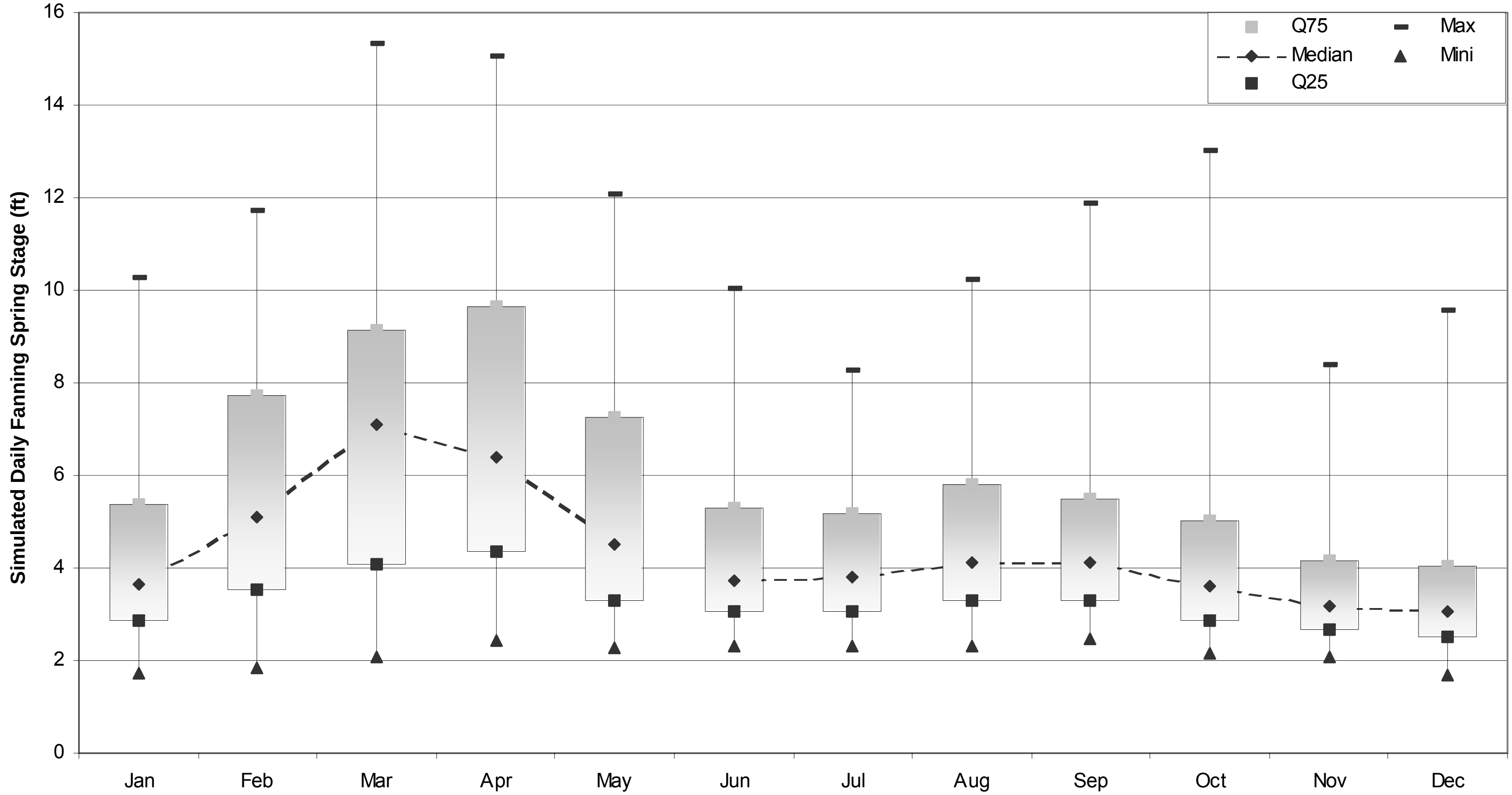

Figure 3-22. Box-whisker plot of simulated daily stage for Fanning Spring, by month.

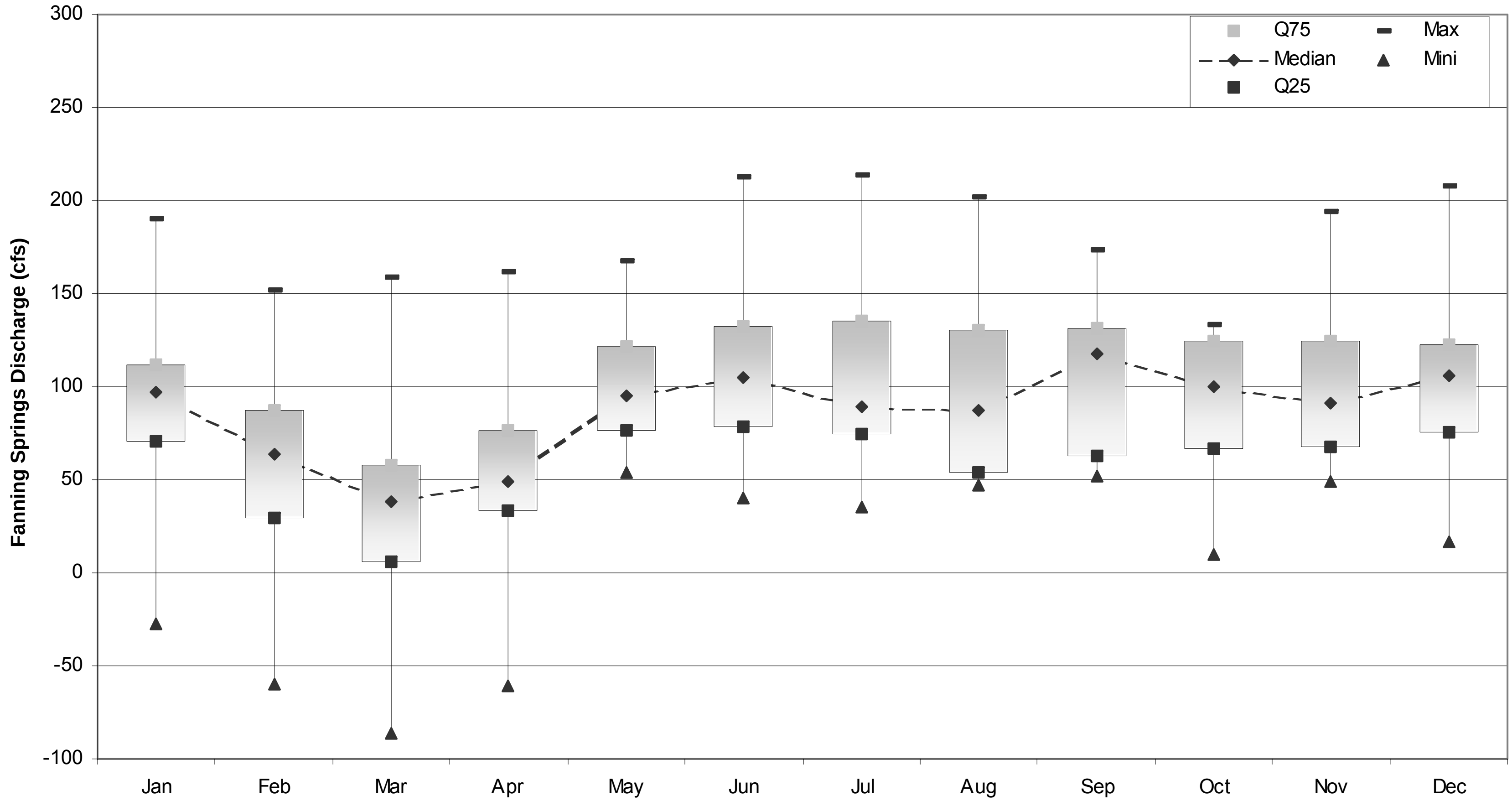

Figure 3-23. Box-whisker plot of simulated monthly discharge for Fanning Spring, by month.

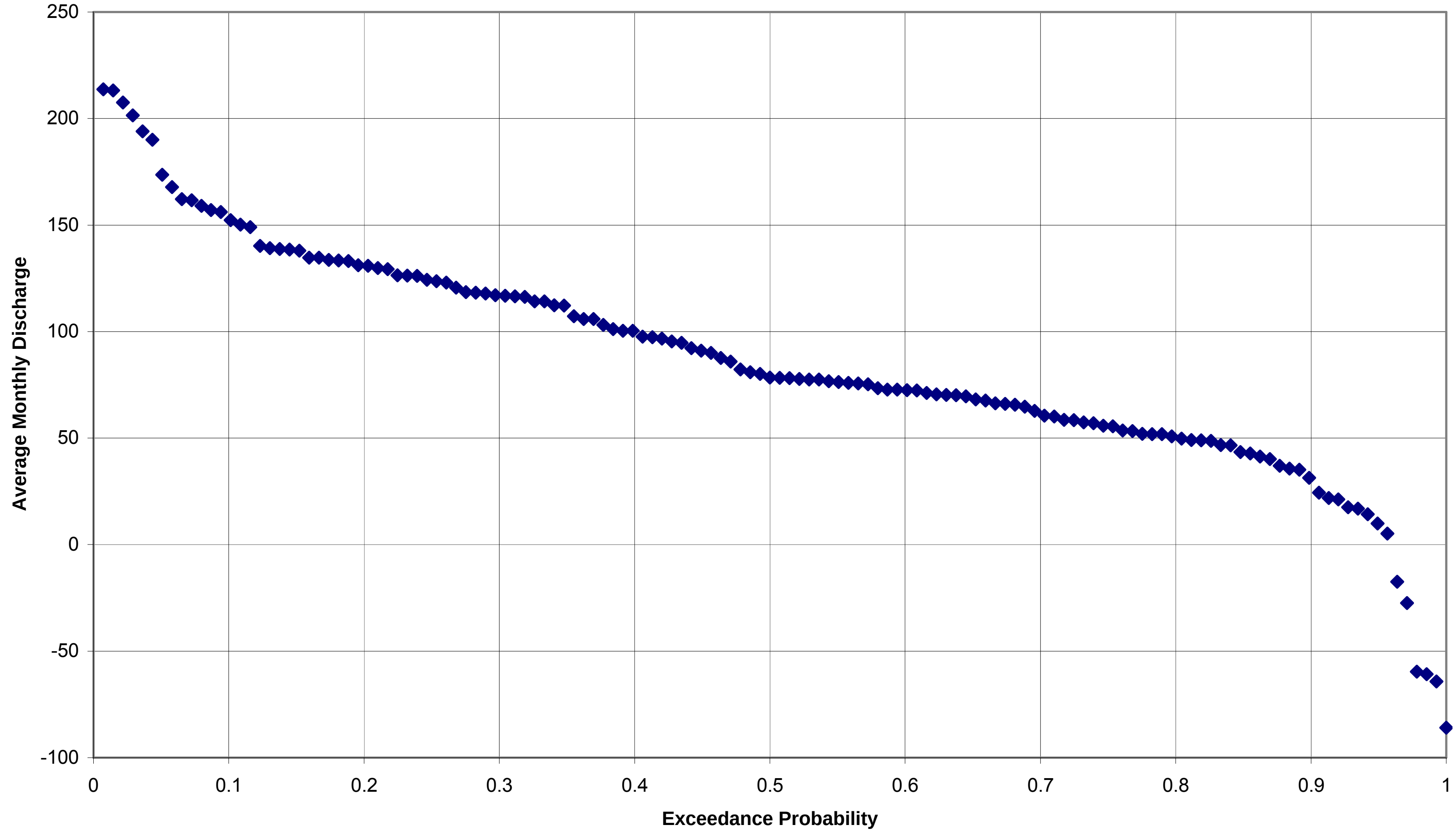

Figure 3-24. Flow-duration curve for simulated average monthly discharge at Fanning Spring.

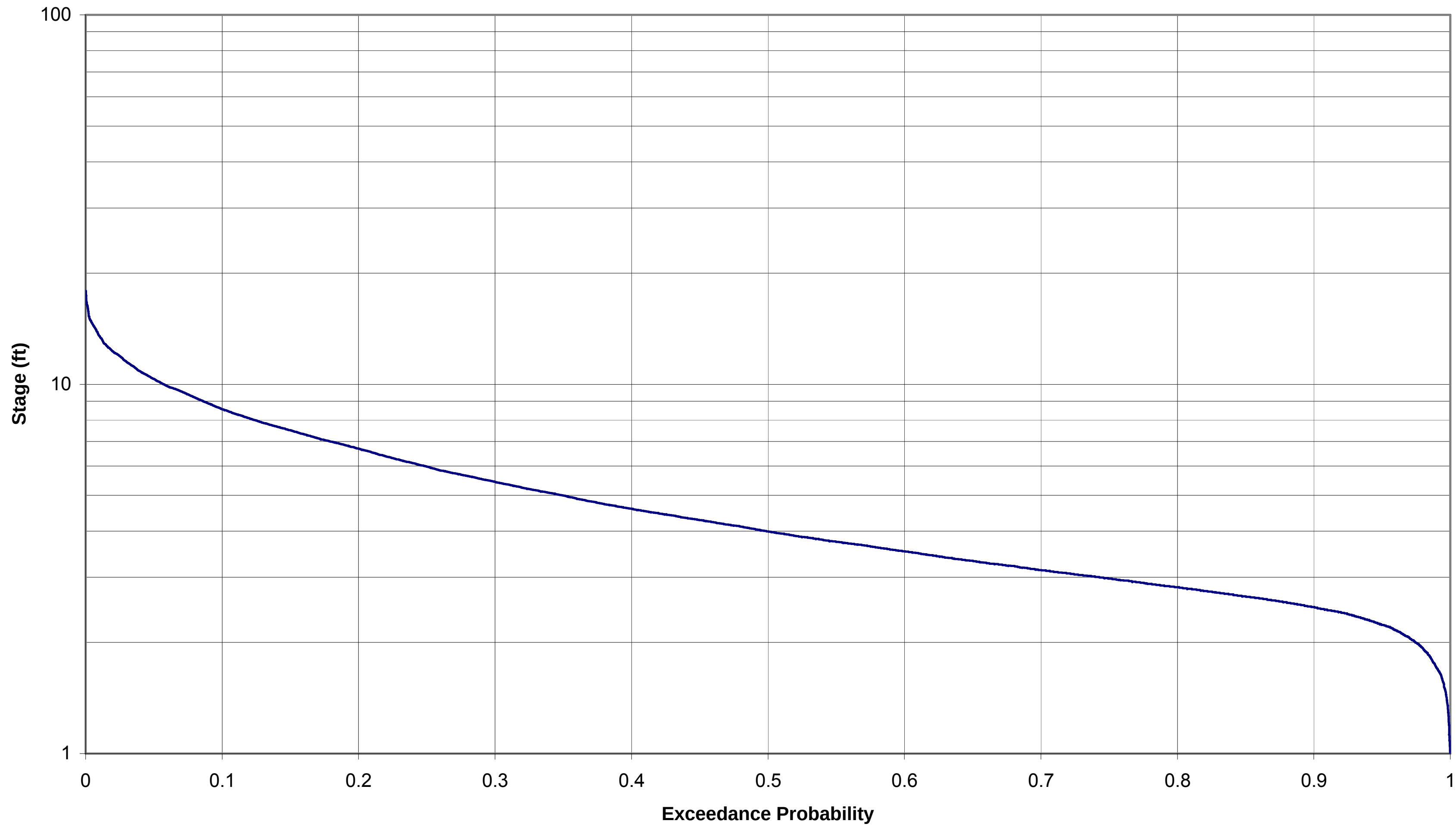

Figure 3-25. Stage-duration curve for synthesized average daily stage at Fanning Spring.

3.2.3.3.3.3 Relationship to Wilcox Stage and Flow

Over the simulated period of record, stage at Fanning Spring peaks in the spring (with a secondary peak in the late summer), and discharge is lowest in the spring (Figures 3-24 and 3-25). As seen in Section 3.2.3.3.1, stage at Fanning Spring is directly related to stage in the Suwannee River at Wilcox. So the pattern of stage at Wilcox through the year (Figure 3-26) is identical to that shown in Figure 3-24 for Fanning Spring. The pattern in discharge is also, but to a lesser extent, controlled by the stage at Wilcox. Times of peak stage in the river (February-April) correspond to times of lowest discharge from the spring. Moreover, aquifer levels within the springshed probably play a more significant role in determining spring discharge patterns the remainder of the year, when floods are infrequent.

Because there is significant tidal and other noise in the Wilcox stage and Fanning discharge data, the ability of the predictive equations to fit the daily Fanning Spring discharge data is weakened somewhat. Analysis of manatee passage issues and other factors discussed in subsequent sections of this report indicates that a seasonal MFL is appropriate. Therefore, it was determined that the equation to predict monthly discharge, which eliminated much of the high frequency noise and strengthened ability to estimate discharge, from Fanning Spring is the preferred approach. Because the MFLs to be proposed for Fanning Spring are seasonal and based on monthly stage estimates in the river, it was also reasoned that a predictive model using the same time frame was appropriate.

3.2.3.3.3.4 Discharge Trends

Trends in historic measurements of Fanning Spring discharge are discussed in Section 2.3.5.5. There are short- and mid-term, cyclic trends resulting from rainfall cycles. However, there is little evidence indicating the presence of long-term changes in discharge at Fanning Spring within the historic discharge measurements. The simulated discharge dataset is not of sufficient length (only about 12 years) to analyze for the presence of long-term trends.

3.2.3.3.4 Hydrologic Conditions During MFL Study

The majority of Fanning spring data for this study was collected within the last approximate four years. At the beginning of this period (May 2001), Florida was experiencing one of the worst droughts on record. As a consequence, even though conditions have since improved considerably, the MFL study period represents much drier conditions than normal.

As previously discussed, Fanning Spring discharge is dependent on conditions in the Suwannee River and the Floridan Aquifer within the springshed. Figure 3-27 depicts a flow-duration curve for the period of record at the Wilcox gauge, along with a curve representing the MFL study period. With the exception of peak flows (exceedance probability less than 10 %), flows in the Suwannee River were considerably less than for the period of record as a whole. Median discharge was approximately 5,600 cfs for the study period, compared to 8,040 cfs for the period of record.

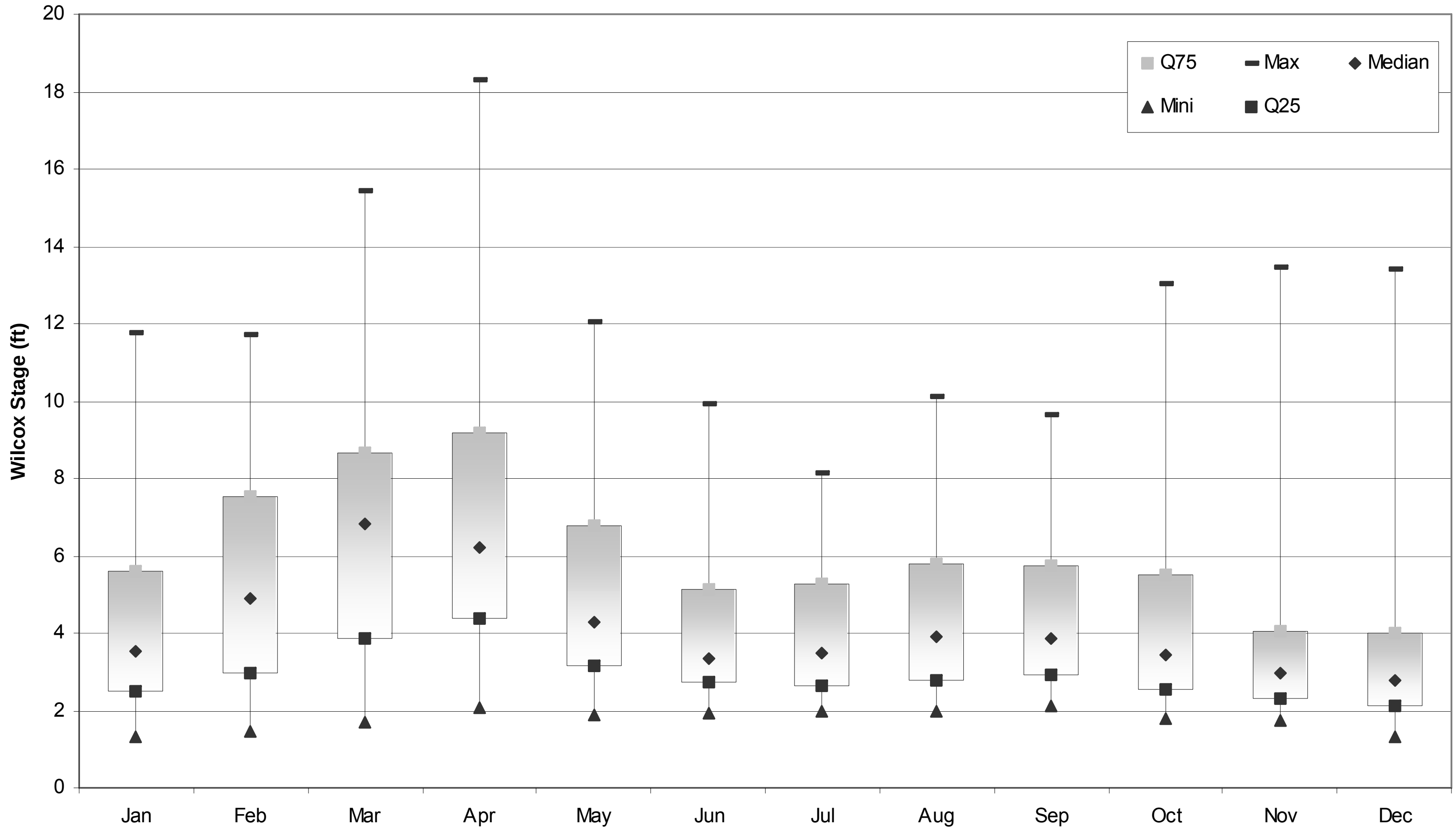

Figure 3-26. Box-whisker plot of measured stage at the Wilcox gauge, by month.

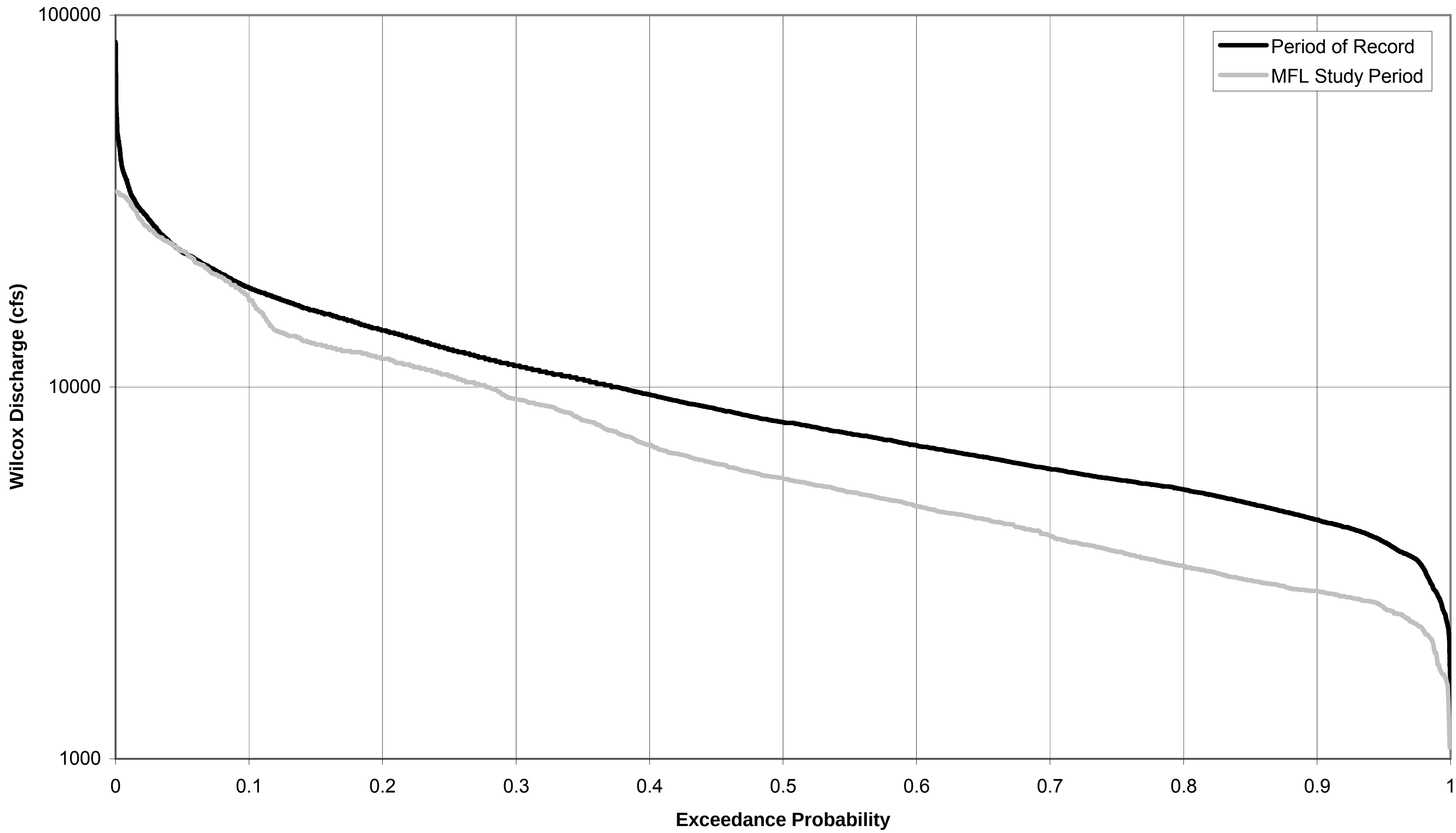

Figure 3-27. Comparison of Wilcox flow conditions during the MFL study period for the springs and the period of record.

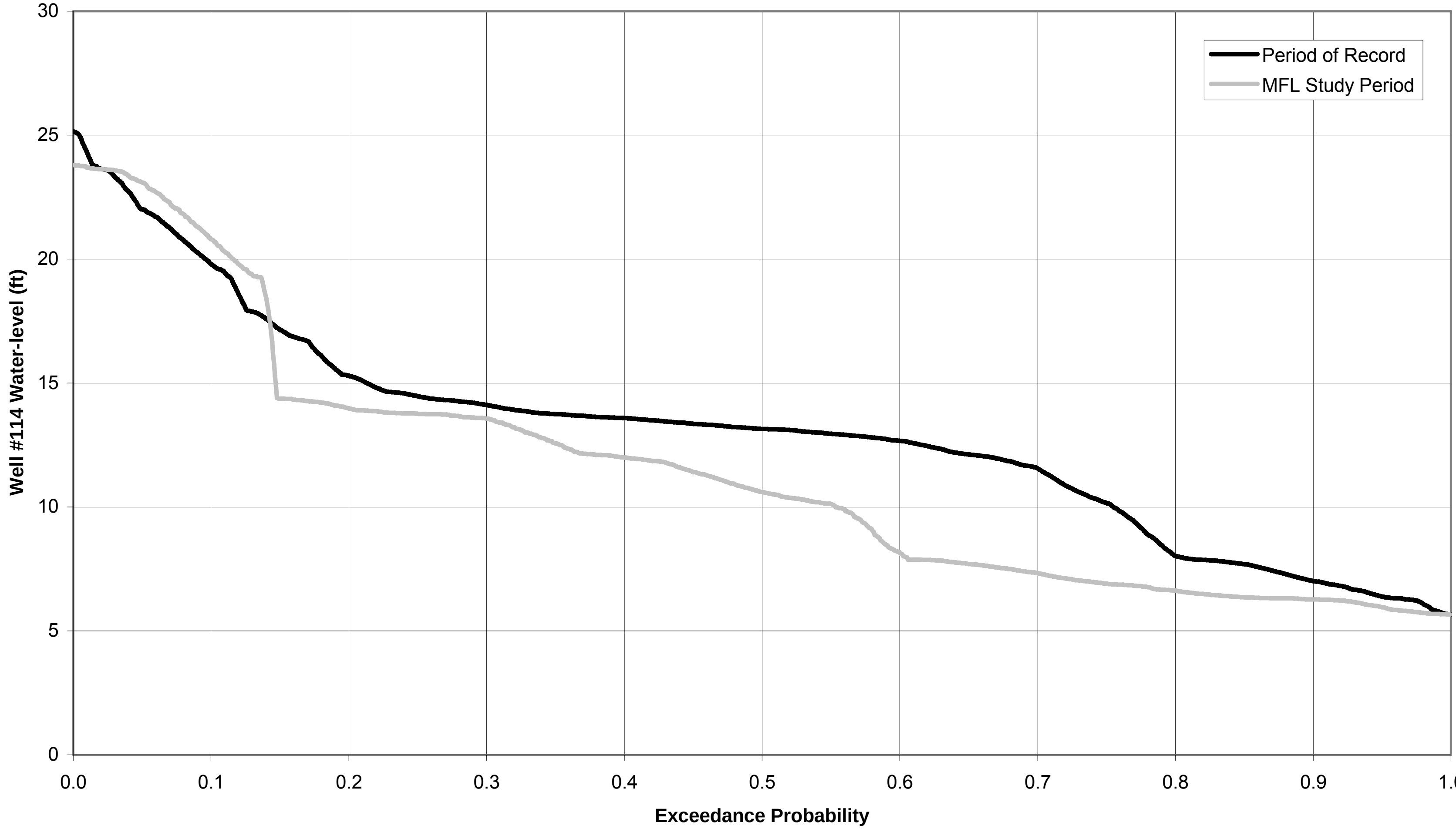

Figure 3-28. Analysis of aquifer levels during the MFL study period for the springs and the period of record.

Figure 3-28 contains duration curves for water levels in the Floridan Aquifer, as recorded at Well #114. The two curves compare the pattern of water levels during the study period (May 2001 – May 2005) to the entire period of record for this well (1993-2005). Water levels below an exceedance probability of about 15 % are actually greater during the study period than for the period of record as a whole. For the remainder of the time, water levels were much lower. The median water level during the study period is approximately 10.5 ft, compared with a median water level of about 13.1 for the period of record.

3.2.3.4 Manatee Spring

While Manatee Spring is an estavelle and the discharge pattern for all river events would show an inverse relationship between spring discharge and river stage, the historic data do not depict the rare events when flooding caused the spring to backflow. As will be shown below (see Figure 3-46), the majority of valid discharge data was collected during low to moderate flow conditions, which are of interest with respect to manatee refuge conditions. The monthly data, especially data taken during low flow to moderate flood in the river (the period of record for the spring), reflect fluctuations in rainfall and potentiometric head in the Fanning/Manatee spring system. Daily discharge data from Manatee Spring show an inverse relationship between river stage and spring discharge. When the river stage rises because of increased rainfall, discharge from the spring is inhibited. Conversely, when the river is low, Manatee Spring discharge is at a maximum. On a monthly time scale, the small scale variations in discharge, including tidally influenced variations, are masked and the diving forces for Manatee Spring discharge at low to moderate river stage are a result of regional groundwater flow and river stage.

The equation for predicting daily discharge indicates that there are short-term inverse relationships between river stage and discharge, which are discussed in Section 3.2.3.3. These data are affected by tidal variations as well as rainfall-discharge events, however.

Discharge at Fanning Spring was utilized as an independent variable in the Manatee discharge predictive equations because those data are of high quality and reflect the regional interplay between groundwater potentials in the Fanning/Manatee springshed and river. The springs essentially share a single springshed (Upchurch and Champion, 2003a), so discharge behavior in Fanning Spring reflects springshed interaction with the river and groundwater potential distributions in the springshed.

Only one well with a sufficiently long period of record is located in the vicinity of Manatee Spring. Water levels in this well are more representative of stage in the Suwannee River than the potentiometric head in the springshed (Figure 3-21). Therefore, it was decided that Fanning Spring discharge data provide a better variable for aquifer behavior prediction than the available well data. The monthly data provide ability to quantify seasonal conditions by use of monthly simulations while minimizing daily tidal interferences.

As with Fanning Spring, the water level in Manatee Spring generally reflects the stage of the adjacent Suwannee River due to the lack of any significant sill within the spring run. Therefore, discharge from the spring is impeded or enhanced based upon the river stage. Figure 3-29 shows the stage for corresponding measured discharge at Manatee Spring. While portions of the discharge data follow this expected pattern, a significant part of the discharge data do not.

Discharge from Fanning and Manatee springs is controlled by similar environmental conditions. The two springs essentially drain separate portions of a single springshed. The pattern and relative magnitude of river levels that impede springflow do not vary between the two springs. Therefore, while the magnitude of spring discharge from these springs may differ, the pattern of discharge variability through time should be similar.

Figure 3-30 shows smoothed (31-day running average) discharge data for both Fanning and Manatee springs. Shading of this figure indicates time intervals where the pattern of variability in spring discharge over time for the two springs are similar (not shaded), and where they are not (shaded). The discharge data from Fanning Spring follow a pattern that is expected from the variability of river stage (Figure 2-35). Therefore, it seems reasonable to "believe" the entire dataset for Fanning Spring, and to only "believe" those portions of the Manatee Spring discharge data that mirror the Fanning Spring data.

As a result, the available AVM-derived discharge data for Manatee Spring are much more limited than the Fanning Spring data. Similar to the Fanning Spring analysis, data simulation was carried out using average monthly values due to the significant short-term variability in spring stage and discharge. Only the average monthly discharge values for June 2001 through February 2002 and October 2003 through May 2004 were included in the analysis, as these data appear to reflect actual conditions at the spring while the remainder of the data does not.

The systematic offsets in discharge data from Manatee Springs (Figure 3-29) appear to have resulted from changes in calibration of the gage data

.

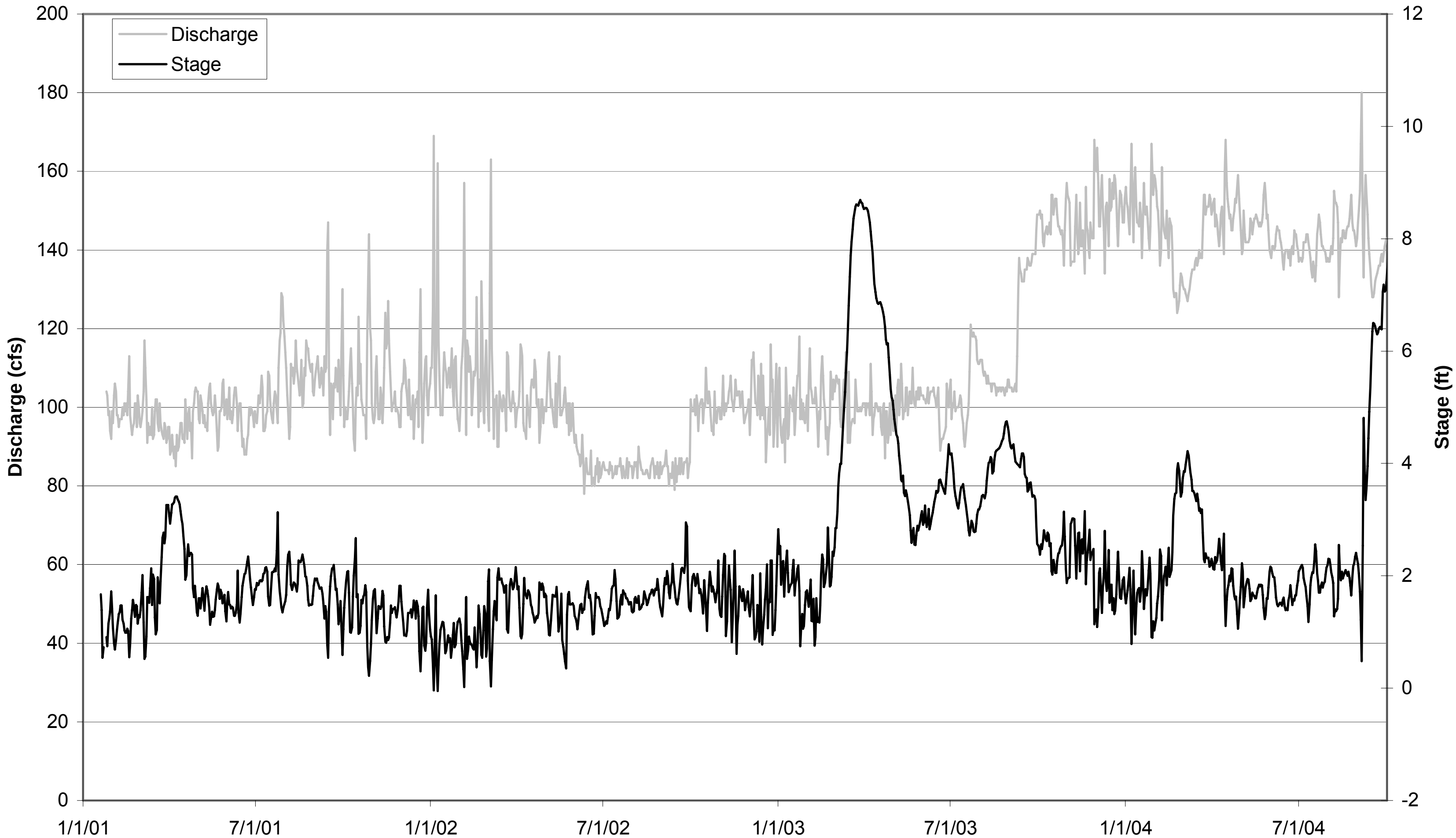

Figure 3-29. Average daily stage and discharge, Manatee Spring gage.

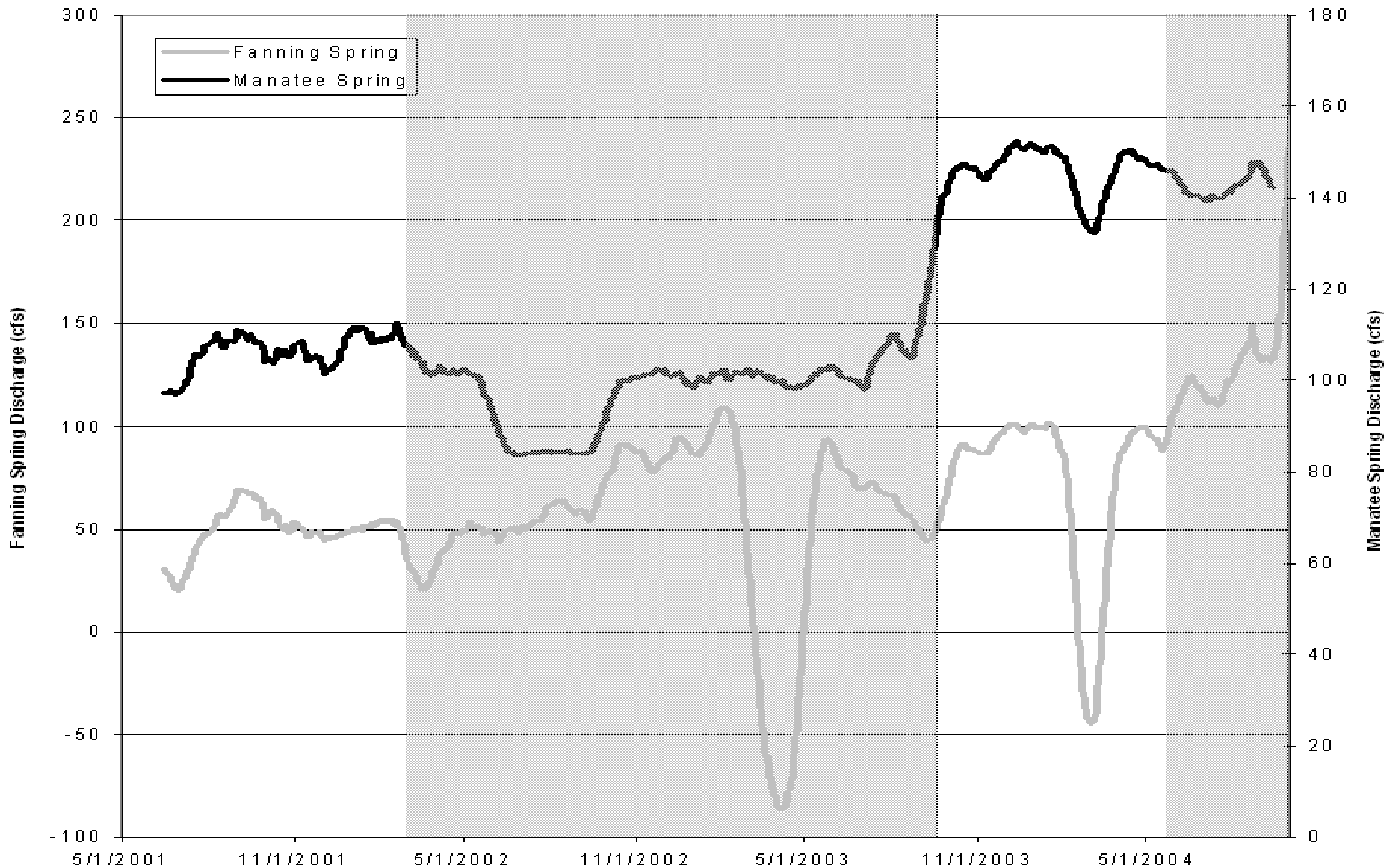

Figure 3-30. 31-day running average discharge for Manatee and Fanning Spring. Shading indicates time when discharge patterns do not agree.

3.2.3.4.1 Simulation of Manatee Spring Stage

Average daily stage measurements for Manatee Spring were compared to the average daily measured stage for the Suwannee River gage near Wilcox. As was the case for Fanning Spring, the stage at Manatee Spring is highly correlated to the Wilcox gage (Figure 3-31). In this case, an exponential trendline provided a better fit to the data than a linear one. This relationship was used to simulate a time series of average daily stage for Manatee Spring. Figure 3-32 shows the simulated data, along with the measured stage data for comparison.

3.2.3.4.2 Simulation of Manatee Spring Discharge

As discussed above, the pattern of discharge from Manatee Spring is similar to the pattern of discharge observed at Fanning Springs, though the magnitude of variability is not as great. According to the available data, flooding in the Suwannee River appears to easily reverse the flow at Fanning Springs, while discharge is only moderately impeded at Manatee Springs. For example, the flood event in March of 2004 reduced Fanning Spring discharge to –50 cfs from previous values of around 100 cfs, while Manatee Spring discharge was only reduced by approximately 20 cfs, from about 150 cfs to approximately 130 cfs (Figure 3-30). While the two datasets are clearly related, a simple linear regression between the two does not adequately reproduce Manatee Spring discharge.

A step-wise multiple linear regression was developed using monthly average values for Fanning Spring discharge, Wilcox stage, and rainfall at Manatee Spring (gage #93). The stepwise multiple linear regression proceeded to remove the gage #93 rainfall data and to retain the data for Fanning Spring discharge ($Q_{Fanning}$) and the Wilcox gage (h_{Wilcox}). The resulting polynomial for the discharge at Manatee Spring is:

$$Q_{Manatee} = 60.462 + 12.649(h_{Wilcox}) + 0.423(Q_{Fanning}).$$

This equation reproduces the discharge at Manatee Spring with a R^2 of 0.84, a statistically significant fit. The maximum residual is approximately 15 cfs.

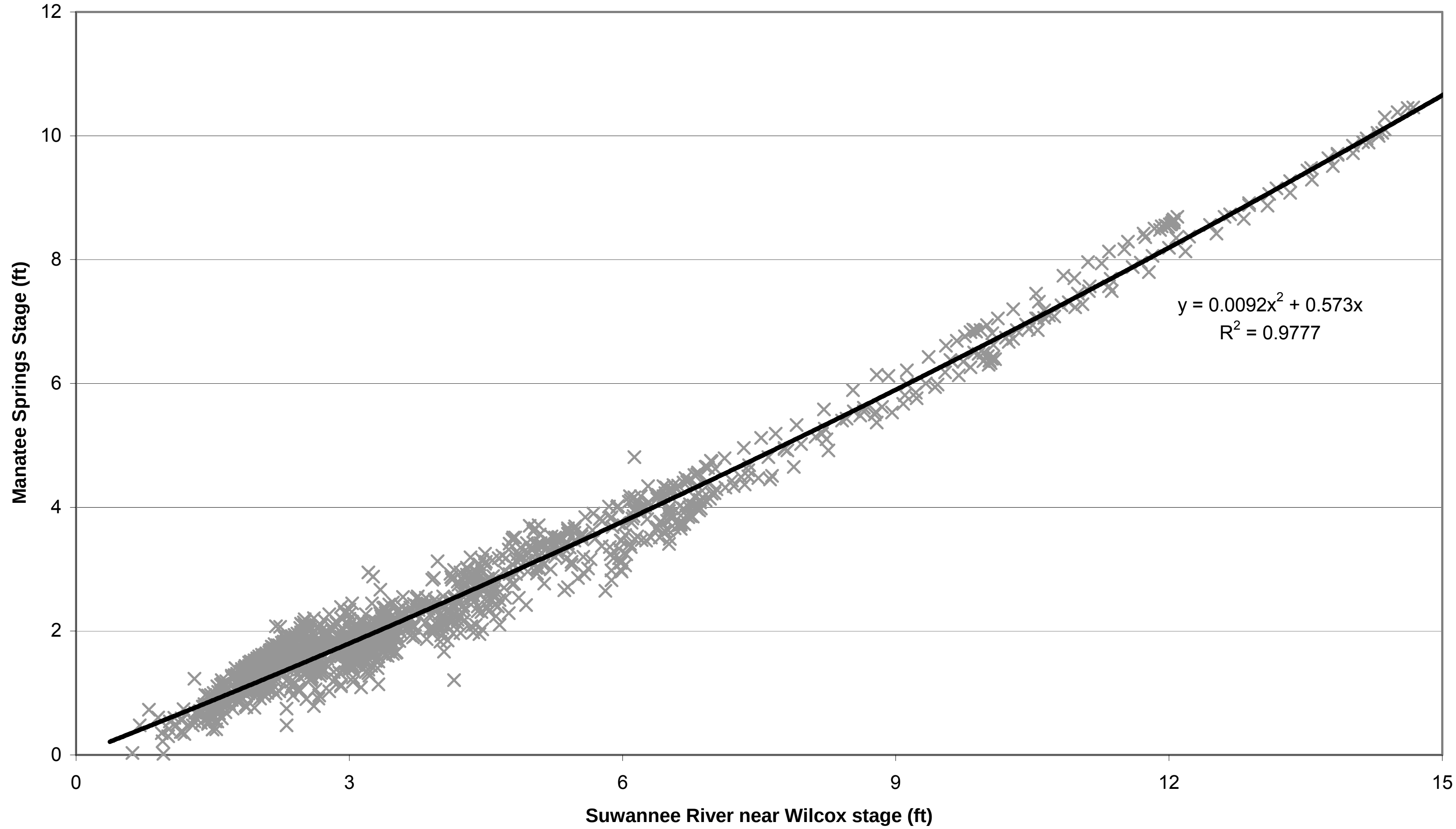

Figure 3-31. Cross-plot of Suwannee River near Wilcox stage and Manatee Springs stage.

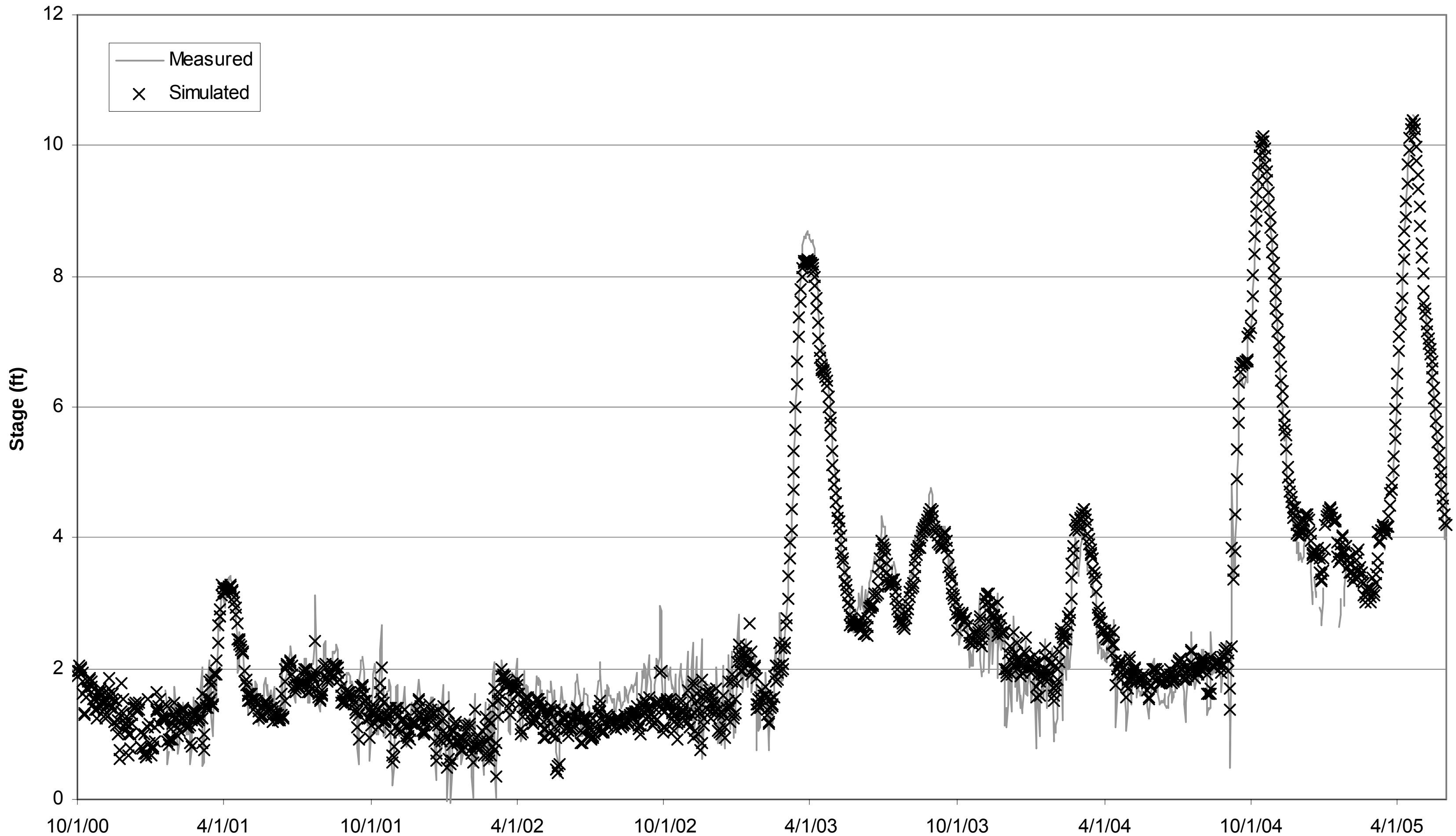

Figure 3-32. Comparison of measured and simulated Manatee Spring stage.

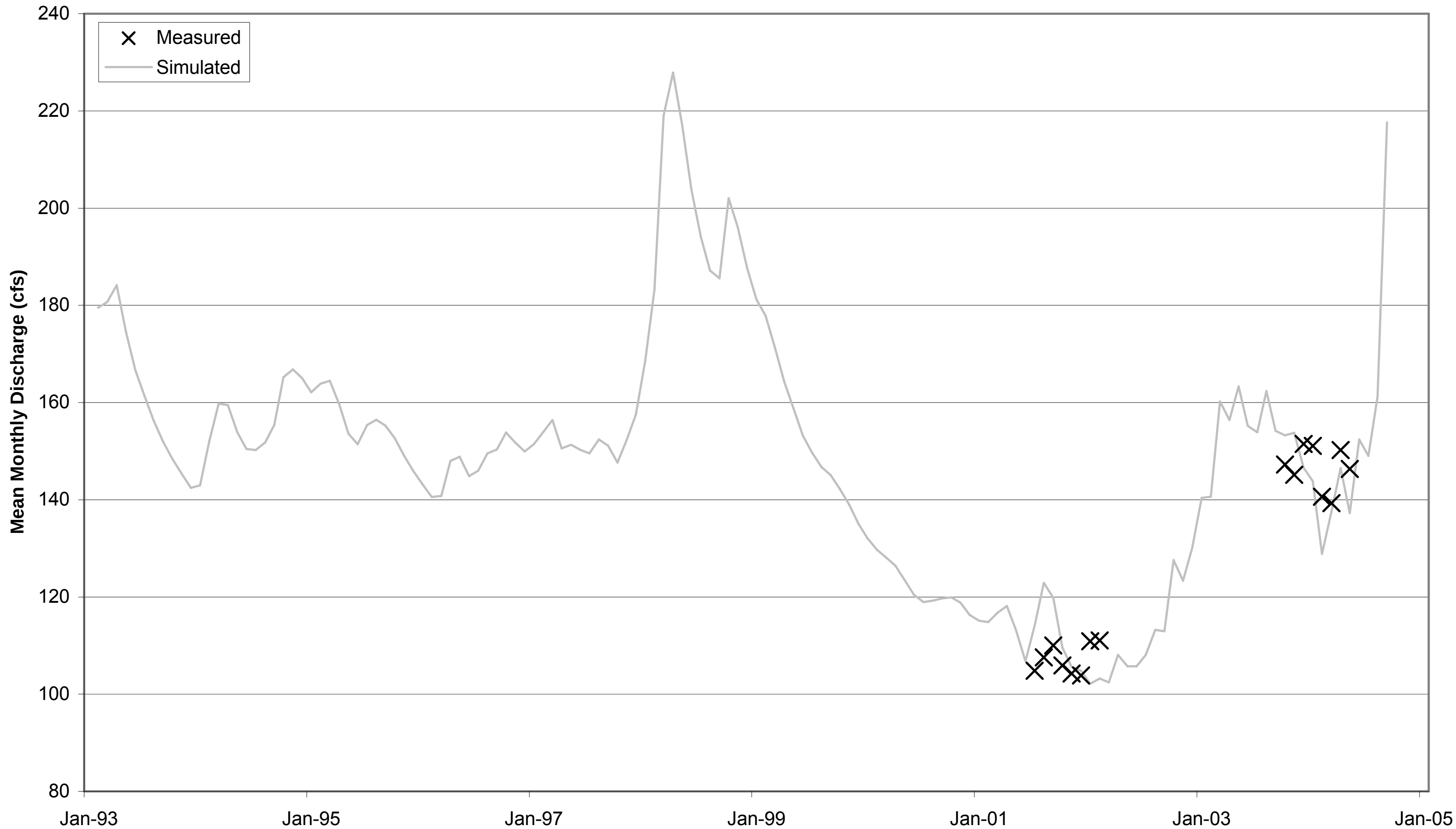

Figure 3-33. Comparison of measured and simulated average monthly discharge at Manatee Spring.

Figure 3-33 compares the predicted and measured mean monthly discharge for Manatee Spring. As shown in Figure 3-33, the magnitude of spring discharge is generally well reproduced. A similar analysis was completed using daily data, as opposed to monthly data. Similar to the results from Fanning Spring, the daily data yielded a poorer fit. The resulting polynomial for the daily discharge at Manatee Springs is:

$Q_{Manatee} = 43.619 – 11.057(h_{Wilcox}) + 0.659(Q_{Fanning})$.

The equation reproduces the daily values with a R^2 of 0.80, and the maximum residual is approximately 60 cfs. Therefore, the uncertainty inherent in the synthesized monthly discharge is significantly less than that associated with daily values.

3.2.3.4.3 Data Characteristics

3.2.3.4.3.1 Population Descriptors

Summaries of the daily AVM data collected at Manatee Spring are presented in Tables 2-11 and 2-13. The simulated data, however, represent a longer period of record, resulting in a better data sample for descriptive statistics. Furthermore, the simulated data attempt to correct data problems discussed in Section 3.2.3.4. As for Fanning Spring, average daily stage data were synthesized for Manatee Spring based on the relationship between spring stage and stage at the Wilcox gage. Therefore, simulated stage data for Manatee Spring extends back to 1951 (see Section 3.2.3.3.3.1)

The best results for synthesizing discharge data for Manatee Spring were obtained for the average monthly discharge (Section 3.2.3.4.2). The period of record for the simulated discharge data is limited by the simulated Fanning Spring dataset. Therefore, the simulated discharge data only extend back to 1993. Figures 3-34 and 3-35 are box-whisker plots of the simulated daily stage data and the simulated monthly discharge data, respectively.

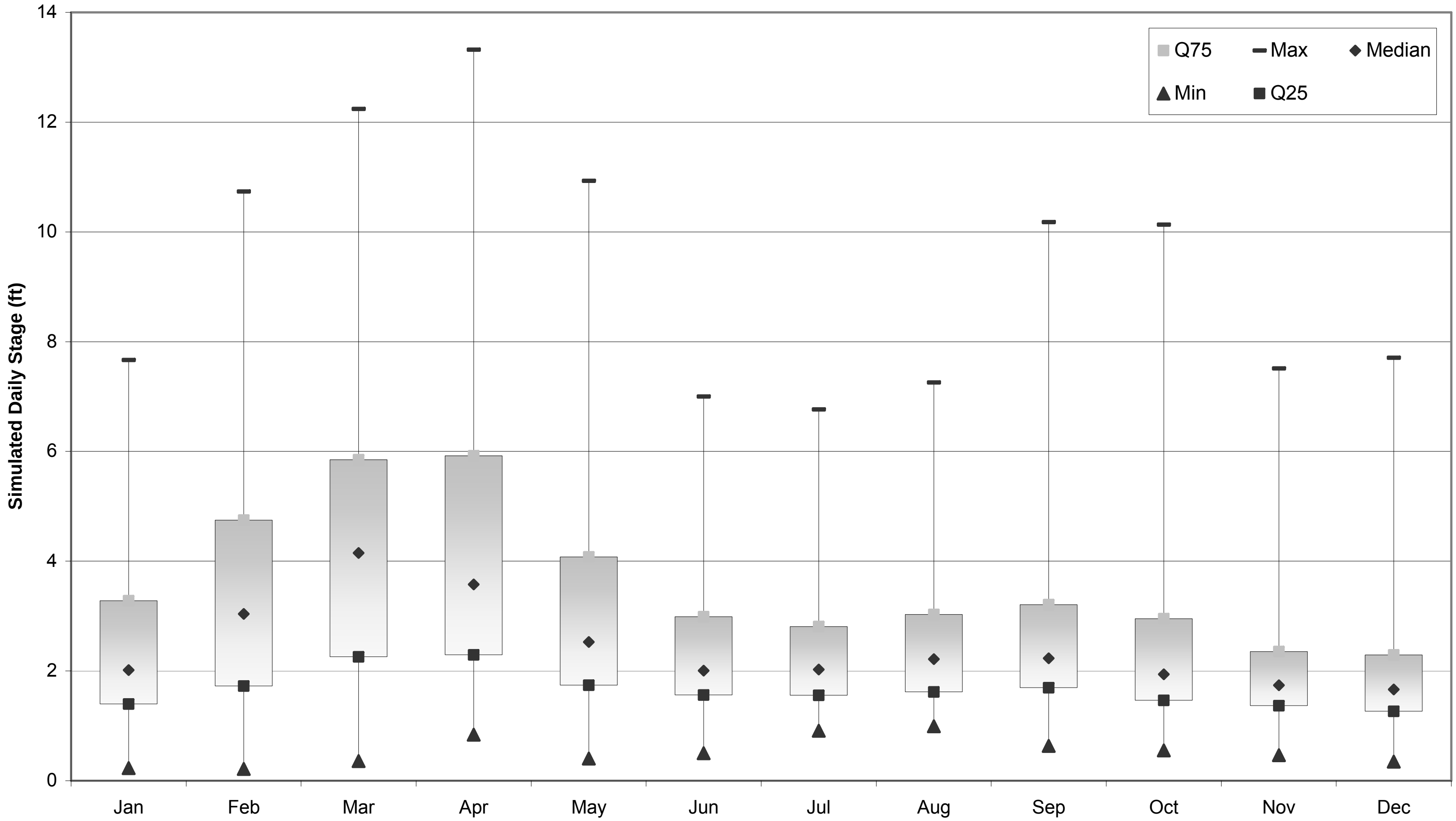

Figure 3-34. Box-whisker plot of simulated daily stage data for Manatee Spring, by month.

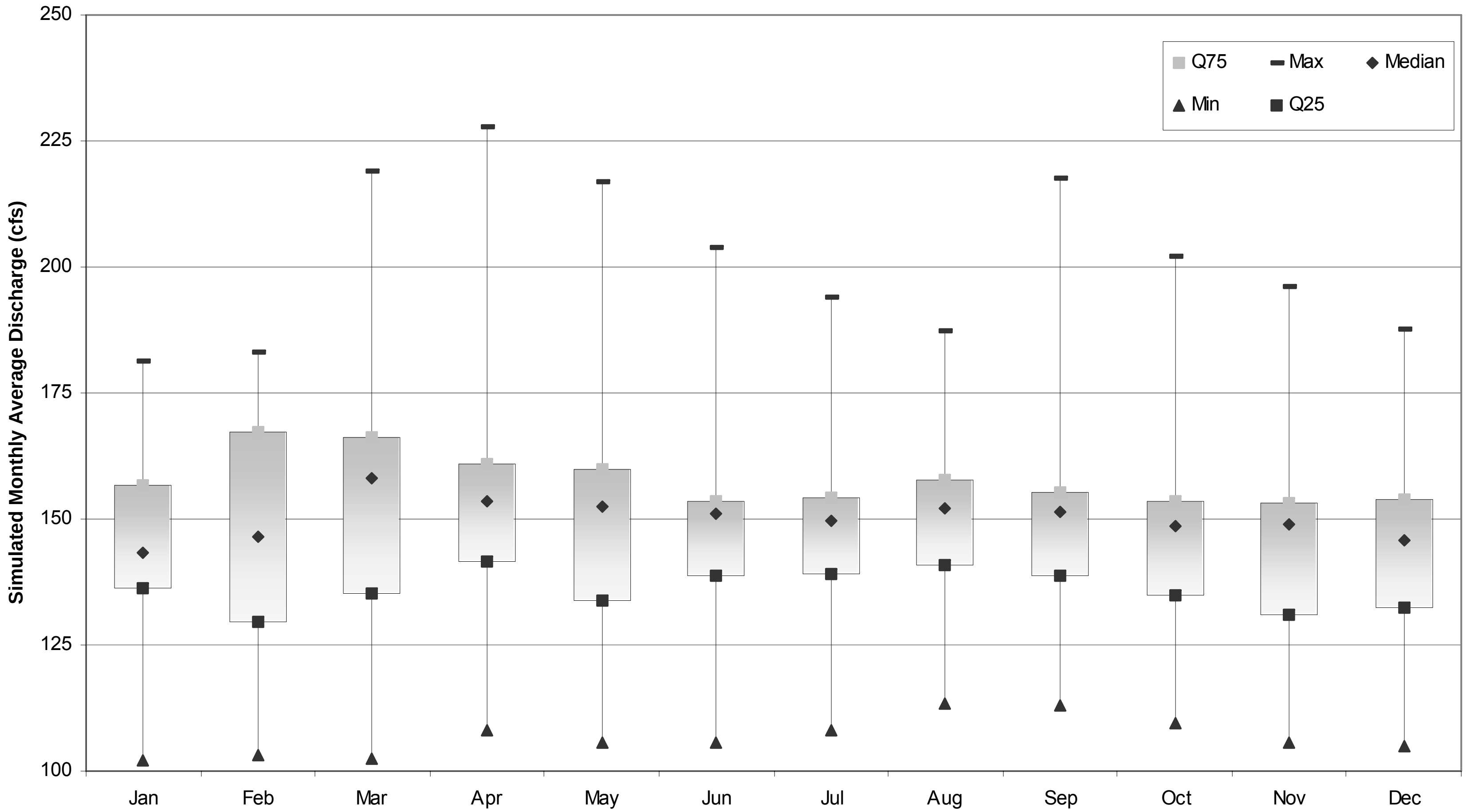

Figure 3-35. Box-whisker plot of simulated monthly average discharge for Manatee Spring, by month.

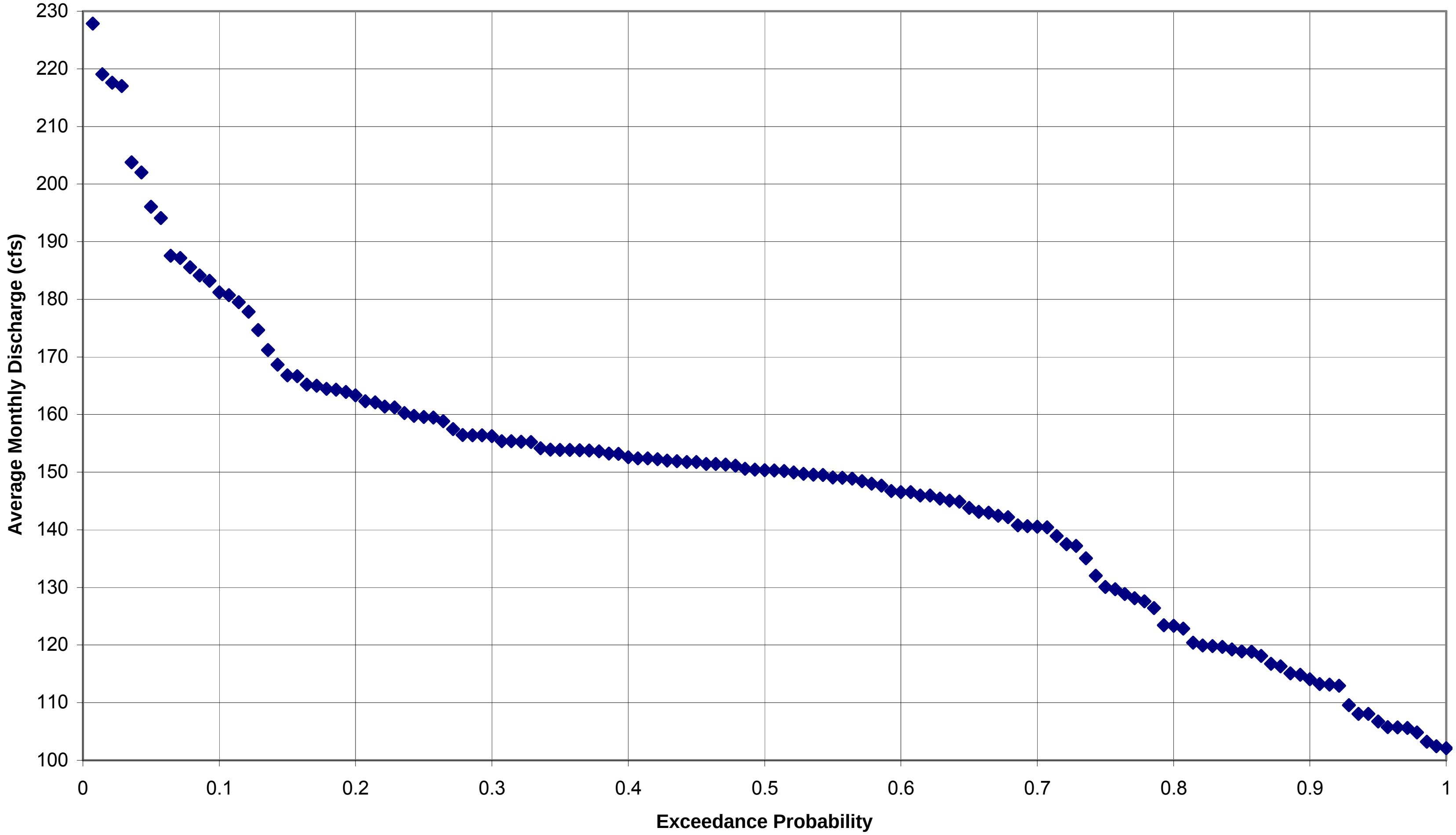

Figure 3-36. Flow-duration curve for simulated average monthly discharge at Manatee Spring.

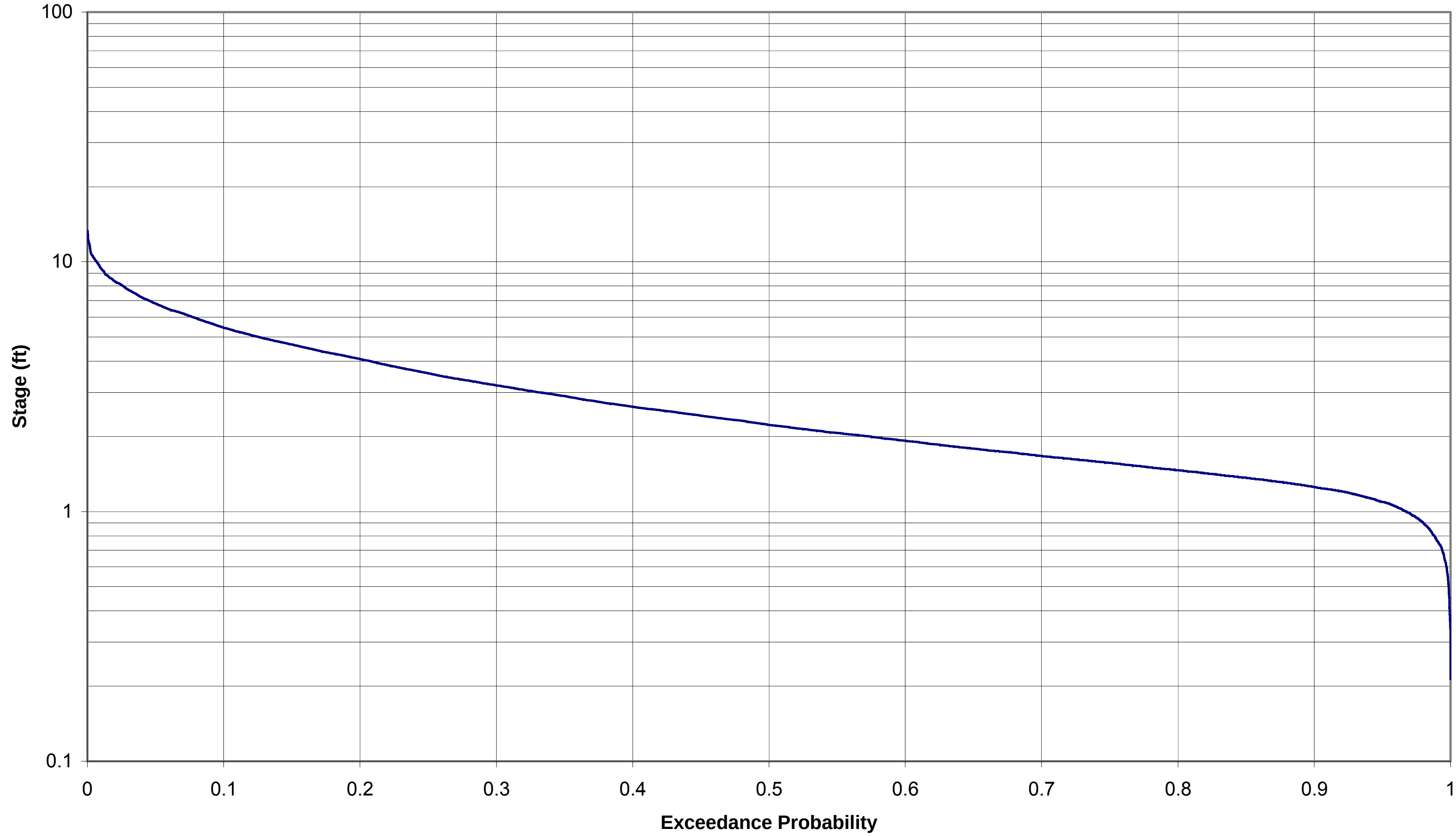

Figure 3-37. Stage-duration curve for synthesized average daily stage at Manatee Spring.

3.2.3.4.3.2 Flow and Stage Duration Curves

Flow- and stage-duration curves were constructed from the synthesized data for Manatee Spring. The flow-duration curve (Figure 3-36) represents the exceedance probabilities for average monthly spring discharges. Over the period of record for this dataset (February 1993 – July 2004), the median average monthly discharge was approximately 150 cfs. The resulting stage duration curve for this dataset is shown in Figure 3-37. The median average daily stage at Manatee Spring was approximately 2.2 feet.

3.2.3.4.3.3 Relationship to Wilcox Stage and Flow

Over the simulated period of record, stage at Manatee Spring peaks in the spring, with a secondary peak in the late summer (Figure 3-34). As seen in Section 3.2.3.3.1, stage at Manatee Spring is directly related to stage in the Suwannee River at Wilcox. So the pattern of stage at Wilcox through the year (Figure 3-26) is identical to that shown in Figure 3-34 for Fanning Spring.

Contrary to Fanning Spring discharge, the simulated discharge at Manatee Spring does not exhibit a low coinciding the peak in stage (Figure 3-35). Median monthly stage only varies by about 2 feet throughout the year at Manatee Spring, versus a range of about 4 feet in median stage at Fanning Spring. Apparently, the smaller range of stages experienced at Manatee Spring results in less variability in spring discharge.

None of the historic or AVM data indicate reversals in flow when the river is in flood. This appears to be a sampling problem, and at extreme high river stage, the spring should show an inverse relationship in discharge with river stage.

3.2.3.4.3.4 Discharge Trends

Trends in historic measurements of Manatee Spring discharge are discussed in Section 2.3.5.5. There are short- and mid-term, cyclic trends resulting from rainfall cycles. However, there is little evidence indicating the presence of long-term changes in discharge at Manatee Spring within the historic discharge measurements. The simulated discharge dataset is not of sufficient length (only about 12 years) to better analyze for the presence of long-term trends.

3.2.3.4.4 Hydrologic Conditions During MFL Study

The MFL study period for Manatee Spring was similar to Fanning Spring (the Manatee Spring's AVM gauge was installed several months before the gauge at Fanning Spring). Therefore the hydrologic conditions during the Manatee Spring study period were similar to conditions experienced during the Fanning Spring study period (Section 3.2.3.3.4).

3.2.3.5 Contribution of Springs to River Flow

While the combined discharge of Manatee and Fanning Springs constitutes a large flux to the river, the overall contribution from these springs to Suwannee River discharge is minimal. Average monthly combined discharge for the springs ranges from about 100 cfs to about 400 cfs, while average monthly discharge at the Wilcox gauge ranges from about 2,000 cfs to 40,000 cfs (Figure 3-38).

Figure 3-39 shows a graph of the combined Wilcox and spring discharge and percent of this combined discharge that comes from Fanning and Manatee springs. The percent contribution from the springs ranges from less than one to almost eight percent. The percent contribution is inversely proportional to the total combined discharge. This is attributed to two factors. First, the range in spring discharge is much less than that for river discharge. Therefore, as river discharge increases, spring discharge becomes a smaller proportion of the river discharge. Second, during very high river stage and discharge, spring discharge becomes impeded, and eventually reverses (particularly at Fanning Spring). So the proportion of total river discharge derived from the springs is largest when river discharge is low, and it becomes very small at high river discharge.

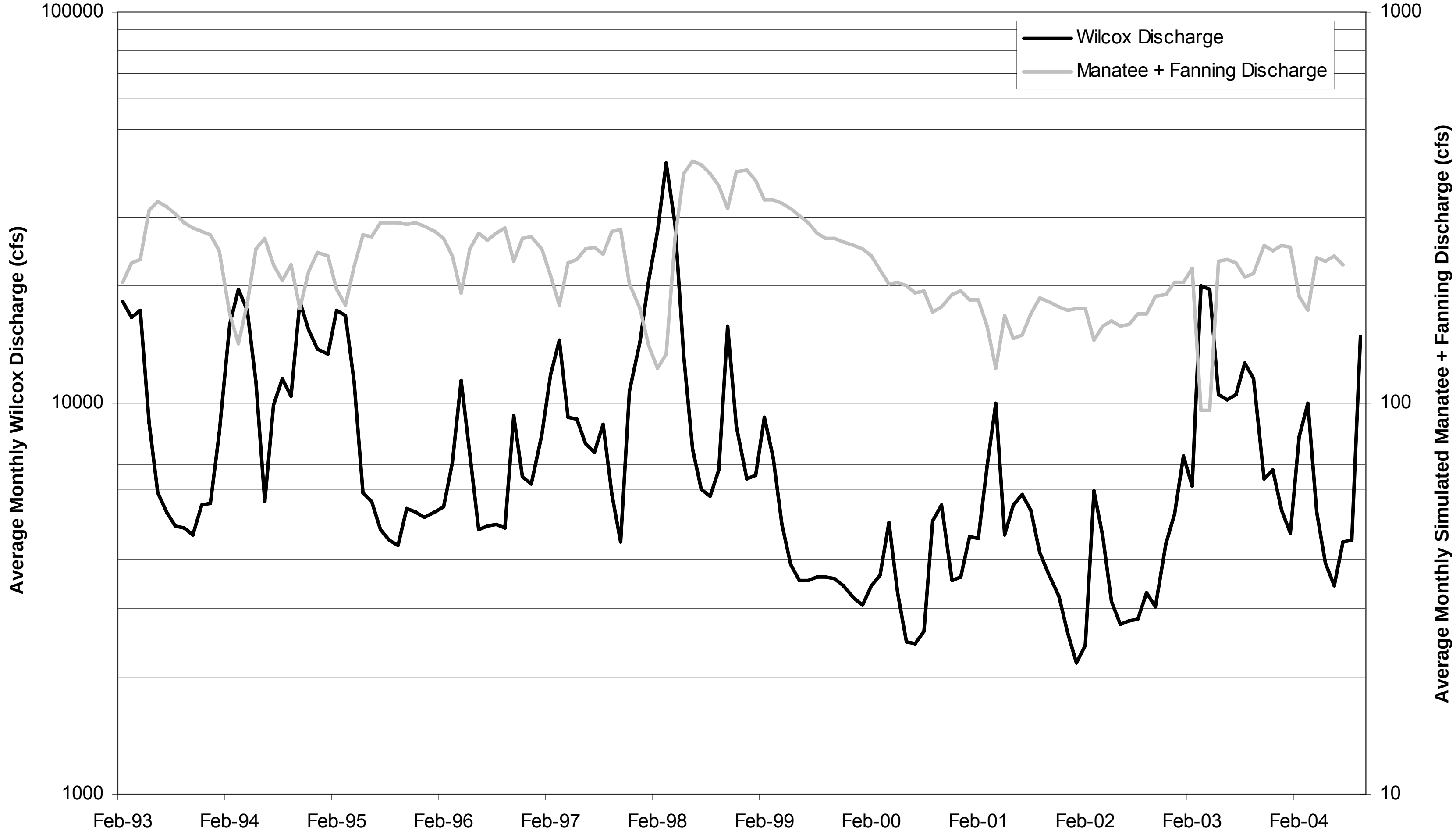

Figure 3-38. Comparison of average monthly Wilcox discharge and average monthly Fanning + Manatee discharge.

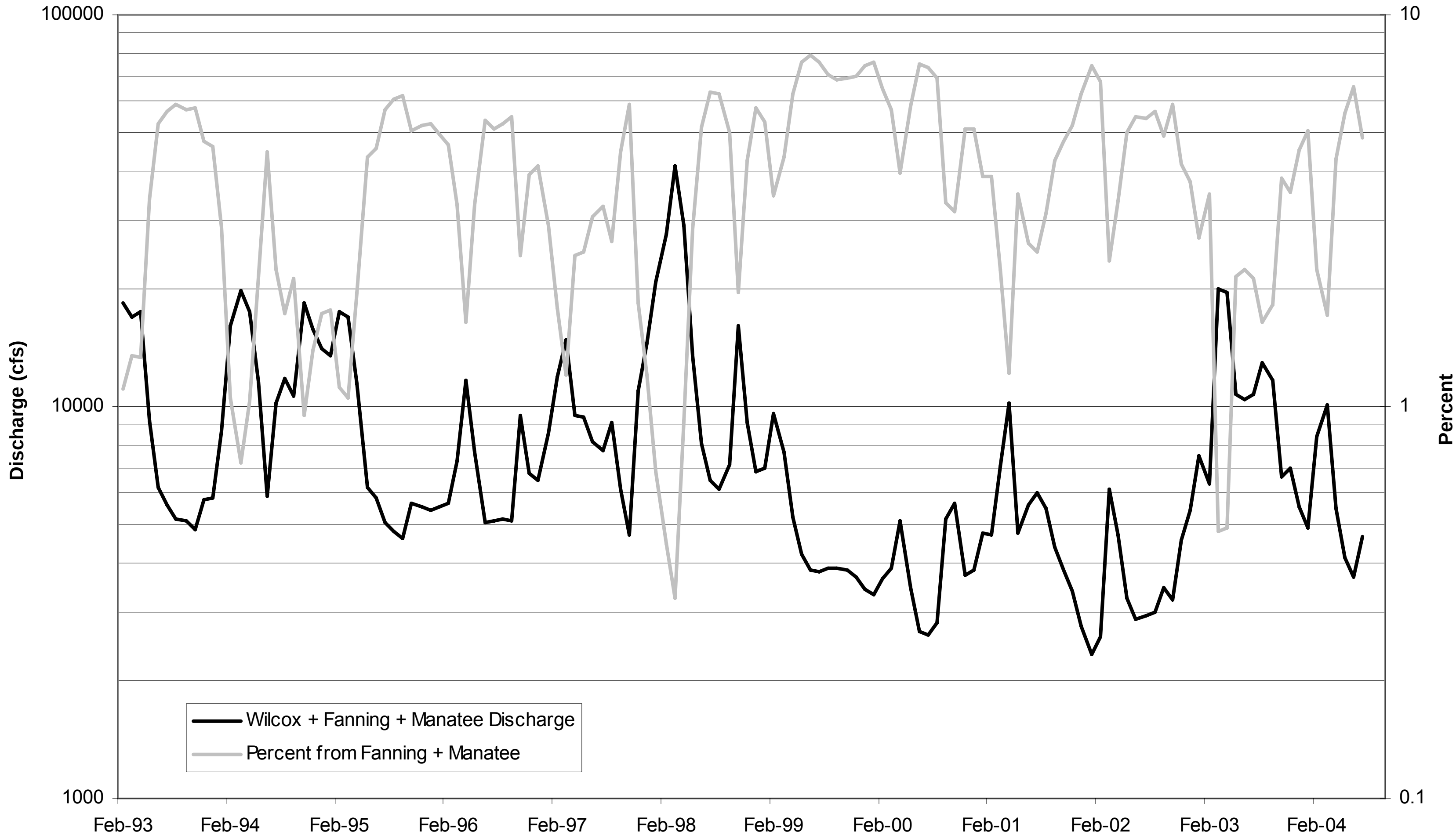

Figure 3-39. Comparison of Wilcox + Fanning + Manatee discharge with the percent of discharge from Fanning + Manatee.

3.2.3.6 Relationship of Spring Discharge and Stage to Discharge at Wilcox Gage

MFLs are developed in this report for the Suwannee River based in part on discharge in the Suwannee River at the Wilcox gage. The Lower Suwannee River and its springs constitute a linked system with discharge from the springs controlled by river stage and discharge. It is anticipated that river and correlated spring behavior will control the MFL regime for the Lower Suwannee. Therefore, this section of the Lower Suwannee River MFL report presents some additional details on the relationships between the river and its springs.

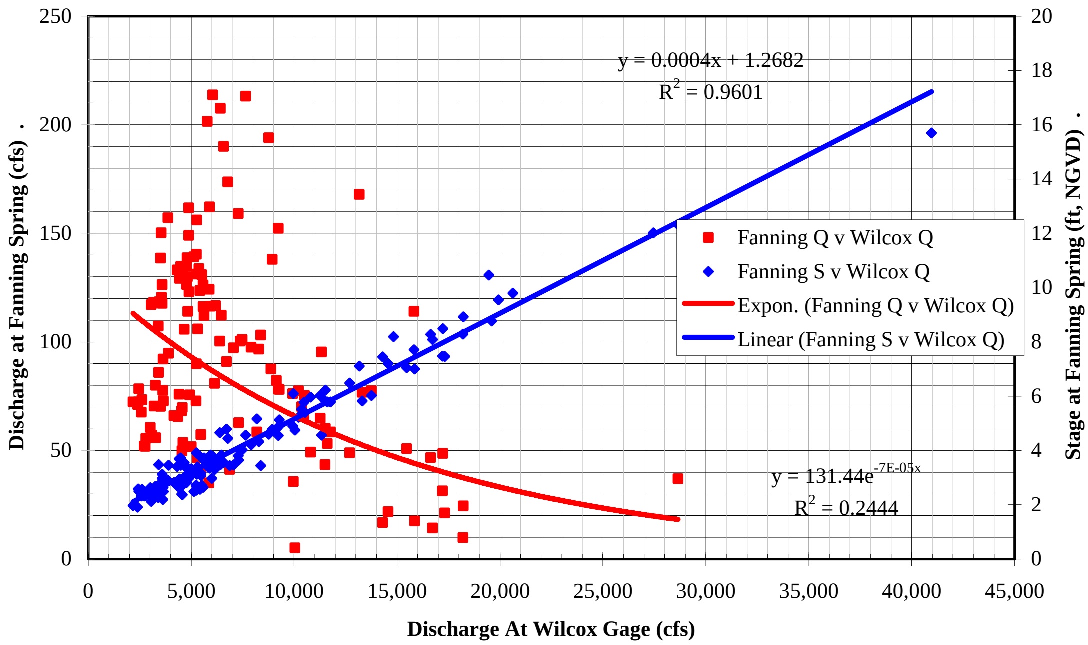

Figure 3-40. Relationships of discharge and stage at Fanning Spring to discharge at the Wilcox gage on the Suwannee River. Note that these are monthly averages in order to minimize tidal and other noise sources. Also, negative discharge as a result of backflow of river water has been eliminated from the Fanning discharge data.

Figures 3-40 and 3-41 depict the relationships of discharge and stage at Fanning and Manatee springs, respectively. The values plotted are monthly averages and negative discharge values at Fanning Spring have been removed to enhance data fitting. Note that there is a very nearly perfect linear relationship between discharge at the Wilcox gage and stage at both springs. The higher the discharge and therefore the higher the river stage, the higher the stage in the spring runs and springs. Notice also that discharge relationships are opposite with high discharge (and stage) in the river inhibiting discharge from the springs.

These relationships clearly demonstrate that the behavior of the springs can have an affect on MFL development in the river and vice versa. To assist in quantifying these relationships and understanding the consequences of MFL development in the river, best-fit equations were developed for each of the data sets shown in Figures 3-40 and 3-41. The equations are shown in the figures. These relationships and the contributions by the springs of water to the river at low flow are utilized in Section 6 of this report to develop MFLs for the rivers and springs.

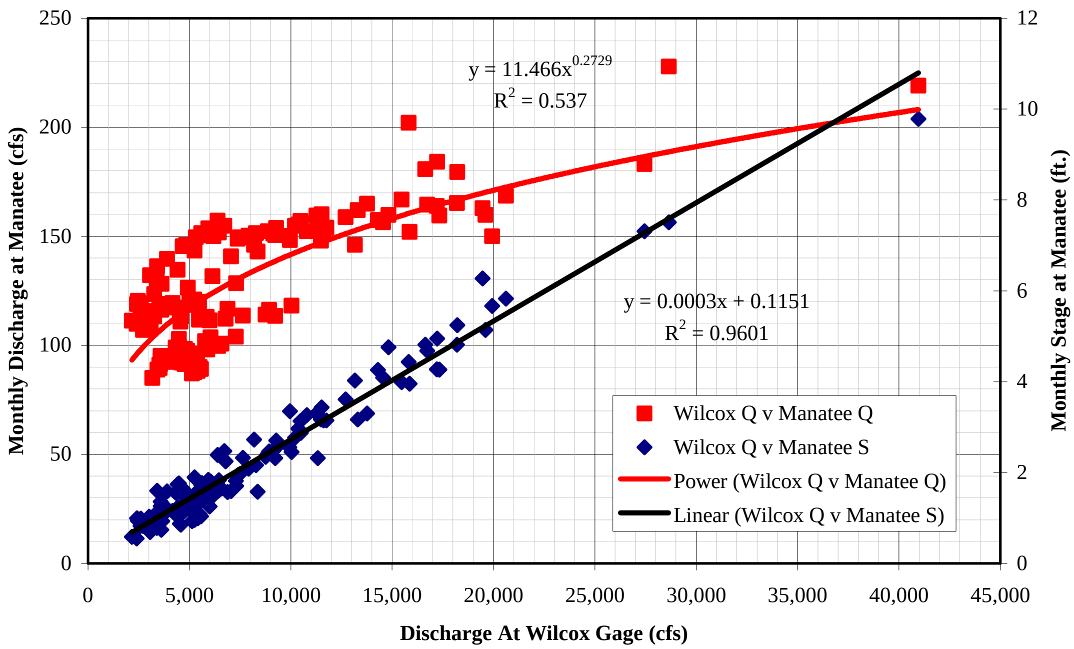

Figure 3-41. Relationships of discharge and stage at Manatee Springs to discharge at the Wilcox gage on the Suwannee River. Note that these are monthly averages in order to minimize tidal and other noise sources.

SECTION 4

4.0 Ecological Foundations

4.1 Hydrology-Habitat Linkages

Hydrologic conditions include the principal physical forces, which influence the structure and function of stream ecosystems (Poff et al., 1997; Poff and Ward, 1989). Flow influences ecological integrity directly (Poff and Allan, 1995), or indirectly via other factors such as water quality, physical habitats, etc. (Schlosser, 1991; Poff et al., 1997). The MFLs proposed in this document are initially oriented toward protection of estuarine habitats of the Lower Suwannee and thermal refuge for manatee in Fanning and Manatee springs. Furthermore, subsequent MFL criteria further upstream will focus on other portions of the flow regime in order to protect other target riverine habitats.

Priority Habitat Targets and Significant Harm Considerations

The approach for developing MFLs for the Lower Suwannee River is a resource-based approach, focusing on meeting the water needs of priority or target habitats in order to protect the resource values of the Lower Suwannee River ecosystem. USEPA (United States Environmental Protection Agency), National Marine Fisheries Service and others note that the primary emphasis for maintaining wildlife biodiversity in Florida (including protection of listed species) should be the conservation of the important habitats upon which indigenous wildlife depend. Thus, basing the development of MFLs for the lower Suwannee on sustaining target habitats is consistent with a variety of other conservation approaches at national, regional, and state levels.

Another justification for the habitat-based approach is that it is generally acknowledged that impacts to and changes in habitat are relatively straightforward to measure and quantify (Stalnaker, et al., 1995). This is in contrast to documenting impacts to or changes in fish and wildlife populations. Quantitative, repeatable measurement of many fish and wildlife populations remains subject to wide error. Thus, by focusing on target habitats, ecological changes due to hydrologic alteration may be detected or predicted at an earlier stage more reliably, and MFL criteria can be modified accordingly. This section identifies the priority target habitats used to develop MFLs for the lower Suwannee, the rationale for selecting those habitat targets, and criteria considered in developing an MFL for the Lower Suwannee system.

4.1.1 Manatee Thermal Refuge

Two major springs are found in the Lower Suwannee MFL study area: Fanning Springs and Manatee Springs. Many springs in Florida are known to provide important warm-water refuge during the winter for populations of Florida manatee (*Trichechus manatus latirostris*), when water temperatures drop below 68 °F (20 °C; Warm-Water Task Force, 2004). The manatees need these warm-water refuges, as they are unable to tolerate cold temperatures for an extended period of time.

Langtimm et al. (2003) discussed manatee population characteristics in the Big Bend region and the role of Manatee Springs for the manatee population in the region. Manatees in this region are recognized by the U.S. Fish and Wildlife Service as the “Northwest Region” manatee population. The primary winter warm-water refuges for this manatee population are the headspring areas of the Crystal River and Homosassa River (Langtimm et al., 2003).

Manatee Springs appears to provide important secondary warm-water refuge, most often during the late fall and late winter when manatees are more dispersed from the main wintering refuge areas (Langtimm et al., 2003). Tidal fluctuation and river stage combined with the shallow depths of the spring run at Manatee Springs limit the extent to which manatees can swim up the run. Thus, the main thermal refuge at Manatee Springs is the "plume" of spring outflow at the confluence of the spring run and the Suwannee River (Langtimm et al., 2003).

The role of Fanning Spring in providing warm-water refuge is less-established, but manatee use of this spring is commonly observed in the winter (FDEP, 2005). The Warm Water Task Force has classified Fanning Spring as a secondary refuge. Depths in the spring run, which depend on river stage, are often adequate to allow manatees to swim up the run and congregate about the main spring.

Evaluation of the potential for adverse environmental impacts to manatee thermal refuge includes considerations of maintaining spring flows and/or stages necessary to preserve adequate volumes of warm-water at the critical temperature of $\geq$68 °F (20 °C). Maintaining spring stage for manatee passage should allow for depths $\geq$5 feet (1.5 m) to allow for manatee passage. These recommendations were made by Langtimm et al. (2003) and are consistent with criteria used to develop proposed MFLs for Blue Spring in Volusia County (Newfields Inc., 2004).

4.1.2 Upper Estuary Submerged Aquatic Vegetation

Beds of fresh-water submerged aquatic vegetation (SAV), which are tolerant of modest levels of salinity (Figure 4-3) represent one of the major aquatic habitats in the upper Suwannee estuary. In their study of conservation priorities in the northern Gulf of Mexico, Beck et al. (2000) identified these tidal, fresh-water grasses as one of their highest-ranked "Priority Habitat Targets." They are often under-represented in assessments of coastal habitats in the Gulf (M. Beck, pers. comm.), and few estimates of SAV acreage are available. Estevez and Sprinkel (1999) reported 19 species of SAV in these beds and found they were dominated by fresh-water eelgrass (*Vallisneria americana*), springtape (*Sagittaria kurziana*), and Eurasian watermilfoil (*Myriophyllum spicatum*). A later study (Golder Associates, 2000) delineated 27.1 acres (0.11 km^2) in the study area. The Golder study was made during a period of record low river flows. During this time, salinity in the upper estuary was much higher than normal, which considerably reduced SAV coverage. An additional 4.4 acres of "potential SAV acreage" were conservatively identified in by Golder. This acreage encompassed areas known to previously support SAV stands prior to the reduced flows of 1999-2000. Note that this spatial estimate includes only SAV beds present in the main channel of the Suwannee River and East and West passes. It does not include SAV, which may be found in the small tidal creeks branching off the main passes. SAV coverage in these creeks is substantial and could account for much of the total acreage of this community type in the upper estuary.

The habitat value of these low-salinity SAV beds for small fishes and benthic invertebrates has been documented (Rozas and Odum, 1987a; 1987b; Thorp et al., 1997). In conjunction with their location in the upper, lower salinity reaches, they are a major nursery habitat for early larval and juvenile fishery species, and important forage species such as shrimps of the genus *Palaemonetes*. Electro-shocking surveys conducted in East Pass by the FWCC in 1993-95 documented use of these beds by juvenile spotted seatrout and other recreational fishery species (Mattson and Krummrich, 1995). The abundance of SAV in tidal creeks in the estuary, which are also important fish and wildlife habitats (Montague and Wiegert, 1990), is another facet of their overall importance in the ecology of the Suwannee estuary.

Figure 4-1. A bed of *V. americana* (center and foreground) in upper West Pass in the Suwannee estuary. These beds are known to be important nursery habitat for the juveniles of spotted seatrout, an important recreational fishery species. Map shows generalized location of upper estuary SAV habitat in the lower Suwannee MFL study area.

The potential for significantly adverse environmental impacts to low salinity SAV beds can be assessed by evaluating changes in salinity, which might cause the following significant alterations in plant community diversity or composition in the beds,

- unacceptable changes in natural populations of benthic invertebrates characteristically found in low salinity SAV beds (including considering taxa richness, diversity, abundance, productivity, or species composition);
- unacceptable upstream movement of the downstream limit of SAV distribution in the estuary; or
- the potential for unacceptable overall loss of acreage of low salinity SAV habitat.

4.1.3 Tidal, Fresh-water Swamps

The intertidal areas of the uppermost Suwannee estuary are vegetated with tidal fresh-water swamps (Wharton et al., 1982; Clewell et al., 1999; Light et al., 2002). Tidal fresh-water swamps have been characterized as the least understood (in terms of quantitative study) coastal wetland ecosystems in the southeastern U.S. (Tiner, 1993; Clewell et al., 1999). Because of this lack of study, these forested wetlands are rarely identified as a distinct wetland community type in west-coast Florida rivers, so no data are available to compare the Suwannee to other river systems. However, it is probable that the lower Suwannee River supports the most extensive acreage of this wetland type on the Florida Gulf coast. Likewise, the habitat values of these swamps have not been studied or quantified. It is known that they provide important nesting habitat for Swallow-tailed kites in the Lower Suwannee Wildlife Refuge (Sykes et al., 1999). The abundance of fiddler and shore crabs in these swamps suggests that they may provide important forage habitat for crab-feeding birds, such as Yellow-crowned night heron and Little green heron, and mammals such as raccoon and mink. The leaf detritus produced in these swamps is likely an important allochthonous food base for the downstream estuarine aquatic communities.

Light et al. (2002) and Darst et al. (2003) mapped 6,652 acres (2,692 ha) of tidal, fresh-water swamps in the upper estuary. These areas correspond to their “Lower Tidal Swamp 1 and Swamp 2” forest types (Figure 4-2). Most of these are flooded daily by high tides. An additional 2,572 ac (1,041 ha) of Lower Tidal Mixed forest were also mapped. These are flooded during the higher spring tides each month. The “Lower Tidal” reach identified by Light et al. is regarded as the tidal, fresh-water portion of the Suwannee estuary (after Odum et al., 1984). In the estuary dominant trees include bald and/or pond cypress, pumpkin ash, swamp tupelo, cabbage palm, sweet and swamp bay, and red maple (Light et al., 2002; Clewell et al., 1999; Wharton et al., 1982).

Figure 4-2. Tidal, fresh-water swamp forest in the upper Suwannee estuary. Map shows generalized location of upper estuary tidal forest habitat in the lower Suwannee MFL study area.

The potential for significant harm to tidal, fresh-water swamps can be estimated by considering changes in salinity, which might cause undesirable shifts in species composition of canopy, subcanopy, or groundcover plant communities to those of a more saline community type;. In fact, the change can be responsible for not only the loss of canopy species from the swamps; encroachment of plants or animals indicative of higher salinity conditions into upstream areas where they have not previously been observed or recorded. Furthermore, the change can also lead to the following:

- the potential for unacceptable upstream movement of the tree line denoting the demarcation between tidal marsh and tidal freshwater swamp; or
- the loss of acreage of tidal swamps or changes in acreage of swamp forest types.

4.1.4 Tidal Creeks

Tidal Creeks fringing the East and West Passes and on the adjacent delta areas (Figure 4-3) represent the most important animal habitat in the tidal marshes (Montague and Odum, 1997). They note that "Tidal creeks are perhaps the key to some of the greatest values of intertidal marshland to estuarine animal life." (Montague and Odum, 1997; p. 19). The creeks provide access to the marshes for fish and natant invertebrates (e.g., shrimp, blue crabs), they include shallow water bank habitat and SAV which provides important nursery refuge for small fishes and invertebrates, and they are important feeding habitat for wading birds and waterfowl (Montague and Weigert, 1990).

Figure 4-3. Portion of the Suwannee estuary delta. Note the dense network of tidal creeks penetrating the delta area and branching off the two major passes. Map shows generalized location of tidal creek habitat in the lower Suwannee MFL study area.

Tsou and Matheson (2002) analyzed four years of juvenile fish data collected in the Florida Marine Research Institute's Fisheries Independent Monitoring Program in the Suwannee estuary and found that tidal creeks were an important explanatory variable accounting for the distribution and abundance of several important "FWRI selected taxa" (Table 2-7). These included important forage species such as spot (*Leiostomus xanthurus*), pinfish (*Lagodon rhomboides*), silversides (*Menidia* spp.) and mojarras (*Eucinostomus* spp.); juvenile sportfish including redfish (*Sciaenops ocellatus*) and spotted seatrout (*Cynoscion nebulosus*); and commercial taxa including blue crab (*Callinectes sapidus*), pink shrimp (*Farfantepenaeus duorarum*), and mullet (*Mugil cephalus*). They attributed one of the main habitat values of tidal creeks to be the associated areas of reduced salinity. Thus, a suitable regime of fresh-water inflows to the Suwannee estuary is necessary to maintain the fishery habitat values of tidal creeks.

In assessing the potential for significantly adverse environmental impacts to tidal creek habitat, consideration was given to alterations in natural populations of fauna or flora of tidal creeks (including consideration of taxa richness, diversity, abundance, productivity or species composition); and alterations in fisheries habitat value due to loss of critical habitat (e.g., SAV or oyster) or other changes due to exposure to unacceptably high salinities.

4.1.5 Oyster Bars and Reefs

In Suwannee Sound, the bay into which the river drains, and in adjacent tidal creek areas north and south of the river, the principal habitat that provides "structure" is oyster reefs and bars (Figure 4-4). These are composed primarily of the eastern oyster (*Crassostrea virginica*), with two species of mussels (*Brachidontes* spp. and/or *Ischadium recurvum*) being secondary members of the reefs. The oysters themselves are a harvestable economic resource. Oyster landings from Dixie and Levy counties (which primarily reflect harvest in the Suwannee estuary) in 2001 were 78,000 lbs, and average 50,000-100,000 lbs annually (FWCC website; www.florida conservation.org), making the Suwannee estuary the second largest oyster-producing area in the state, after Apalachicola Bay.

In addition to their economic importance, perhaps even more important, is the value of oyster habitats for estuarine invertebrates and fishes (Bahr and Lanier, 1981). A recent study by Glancy (2000) found that oyster habitats in the Crystal River area supported significantly higher biomass and density of decapod crustaceans (primarily various crabs) than seagrass or marsh-edge habitats. He interpreted this result to indicate that ". . .oyster makes a potentially important contribution to estuarine systems by supporting large abundances of a distinct assemblage of decapod crustaceans." (Glancy, 2000 - p. xi). This contribution constitutes an important food base for highly sought recreational species such as red drum, black drum, and sheepshead (Pattillo et al., 1997). Biodiversity of oyster-associated fauna is relatively high. Mote Marine Laboratory (1986) collected a total of 248 taxa of oyster reef-associated benthic invertebrates in estuaries in the southern Big Bend region of Florida (Levy to Pasco counties). Bass and Guillory (1979) documented a distinct assemblage of oyster reef-associated fish in the Withlacoochee River estuary. This assemblage is dominated by benthic species, such as gobies, toadfish and blennies.

Figure 4-4 . Lone Cabbage Reef; an oyster reef habitat in Suwannee Sound. Map shows generalized location of oyster reef and bar habitat in the lower Suwannee MFL study area.

Baymont (2002) mapped oyster habitats in the Suwannee estuary using natural color, 1:24,000 scale aerial photography taken in November, 2001. They identified 680 acres of oyster habitat in Suwannee Sound and the adjacent tidal creek areas north and south of the river mouth. Beck et al. (2000) designated oyster reefs a Primary Habitat Target for estuarine conservation in the northern Gulf of Mexico, and they specifically designated this habitat as being of direct importance in the Suwannee estuary.

Evaluation of the potential for significant harm to oyster habitats involved consideration of changes in salinity that would cause unacceptable alterations in natural populations of oyster-associated benthic invertebrates (including consideration of taxa richness, diversity, abundance, productivity or species composition); alterations in oyster reef characteristics (juvenile, subadult, or adult oyster density or cover) due to exposure to unacceptably high salinities; or the potential for loss of acreage of oyster habitat due to increases in salinity caused by fresh-water inflow reductions.

4.1.6 Other Important Habitats

Three other habitats, two riverine and one estuarine, were identified as being target habitats, which, while not "priority" habitats, were given consideration in setting of MFLs. The two river habitats were riverine upper tidal bottomland hardwood forests ('UTblh' forests of Light et al., 2002) and riverine woody snag habitat on the lower river below Wilcox. The estuarine habitat is tidal marsh.

Upper Tidal Bottomland Hardwood Forests. In their study of floodplain forests of the lower Suwannee River, Light et al. (2002) identified 13 distinct wetland forest community types in three major reaches in their lower Suwannee study area. Five of these forest types are associated with their 'Riverine Reach', which mostly occurs upstream of Wilcox, and development of MFLs to protect these forests will be considered as part of the middle

Suwannee MFL effort. The four forest types associated with their 'Lower Tidal' reach are considered part of the estuary, and were discussed above in Section 4.2.3. The remaining four forest types are found in the current MFL study area below Wilcox, in the 'Upper Tidal Reach' of Light et al. and consist of Upper Tidal Swamps 1 and 2 (Utsw1 and Utsw2), Upper Tidal Mixed forest (Utmix), and Upper Tidal Bottomland Hardwood forest (UTblh - Light et al., 2002). The Swamps are typically inundated a few days each month by the spring tides, which occur at spring high tides and during river floods. The Mixed and Bottomland Hardwood forests are inundated by river flooding.

Floodplain wetlands are known to be an integral part of the river ecosystem, with important roles in nutrient, organic matter, and sediment dynamics, fish and wildlife habitat, and flood-water storage (Wharton, et al., 1982; Mitsch and Gosselink, 1986; Schlosser, 1991; Kleiss, et al., 1989; Light, et al., 1998). Some of the organic production in these wetlands is transported to the adjacent river and downstream to the estuary, where it is used in aquatic food webs (Mattraw and Elder, 1984). Hynes (1975) elucidated the need to consider this important "lateral connectivity" in understanding and managing stream ecosystems. Subsequent conceptual paradigms in stream ecology have incorporated the importance of river-floodplain linkages (Ward, 1989; Schlosser, 1991).

Noss et al. (1995) designated riparian forests nationwide, including floodplain wetlands, as "threatened ecosystems", meaning they experienced a 70-84% decline in the occurrence of high quality, intact examples. In the southeastern U.S., the acreage of intact bottomland hardwood wetlands has declined by 78% since pre-European settlement times (Harris, 1984). Within the MFL study area, floodplain wetland habitats remain largely intact and in good ecological condition, the only major impact being historical logging. Several large tracts of floodplain in the Lower Suwannee River study area were identified as being of exceptionally high ecological quality by Lynch (1984) in a survey of the river. These included forests located in the MFL study area near Yellow Jacket and Fowler's Bluff. Many of these areas have been acquired by the District or by the Lower Suwannee National Wildlife Refuge for conservation, in part because of their high quality.

Of the Upper Tidal forest types identified by Light et al. (2002), three of the four forest types had >30 canopy and subcanopy taxa (Upper Tidal Swamp 2 - 33, Mixed - 31, and Bottomland Hardwood forests – 35). This species richness was among the highest compared to tree diversity in other southeastern U.S. floodplain forests (Light, et al., 2002). These results indicate that plant community diversity is exceptional in many of the Upper Tidal forests of the lower Suwannee floodplain. The Upper Tidal forests should be taken into account because some of this forest type may convert to upland if flood flows are changed too much. Light et al. (2002) identified flood depth as an important hydrologic variable influencing the canopy composition of these floodplain forests, as well as the location of the transition zone between the Riverine and Upper Tidal reaches.

In assessing the potential for significantly adverse environmental impacts, ecological considerations for floodplain wetlands should include preventing unacceptable shifts in canopy, subcanopy, and/or groundcover plant species composition in a particular wetland forest type to that of a "drier" forest type; potential alterations to natural populations of floodplain wetland-dependent fauna (which might include changes in biodiversity, productivity, species richness or composition); unacceptable upstream movement of the boundary between upper tidal and riverine forest types; unacceptable loss of acreage of floodplain wetlands; or the potential for unacceptable changes in acreage of forest types.

Riverine Woody Snag Habitat. Some of the most ecologically important aquatic habitats in the Lower Suwannee River, channel are associated with the river bank zone (Bass and Cox, 1985; Dolloff, 1994). In particular, areas of submerged, large woody debris bordering river channels have been shown to support high biological diversity and production (Dolloff, 1994; Maser and Sedell, 1994), especially in southeastern coastal plain streams (Benke et al., 1984; Benke et al., 1985). These have been referred to as “snag” habitats (Maser and Sedell, 1994; Benke et al., 1984). Although the distribution of this habitat may change following flood events (e.g., wood moved downstream by the current) or wood may degrade over time, the constant input of wood to the river from tree fall means that this is a “persistent” habitat which is always available in the river. Estevez and Sprinkel (2000) cite a South Carolina study, which indicated that the amount and distribution of wood at a river site was comparable among years over a 6 year period.

Much of the fish production in southeastern coastal plain streams is associated with snag habitat (Benke et al., 1985; Smock and Gilinsky, 1992). Benke et al. (1985) showed that 82% of the diet of redbreast sunfish in the Ogeeche River was composed of snag-associated invertebrates. They indicated that the snag invertebrate community was part of a “snag habitat – invertebrates – sunfish” food chain in the river. Redbreast are the dominant fish, by abundance, in the Lower Suwannee system (FDER, 1985; Bass, 1991), and snags are likely a key habitat supporting production of this important sportfish. For these reasons, riparian aquatic wood, such as snags, planters, etc., was identified as an important habitat in the river channel portion of the lower Suwannee.

Considerations for riverine snag habitat in assessing the potential for significantly adverse environmental impacts include evaluation of whether hydrologic changes would cause unacceptable alterations in natural populations of benthic invertebrates on snags (including possible changes in taxa richness, diversity, abundance, composition, or productivity); unacceptable reductions in frequency or duration of availability of aquatic snag habitat during the year (particularly at low flow conditions); or unacceptable losses of the surface area or volume of aquatic snag habitat at a given flow condition.

Tidal Marsh Habitat. The major intertidal wetland community in the Suwannee estuary is tidal marsh. Three broad types of tidal marsh communities occur in the estuary (Clewell et al., 1999). Tidal fresh-water marshes are found in the upstream, lowest salinity reaches of the upper estuary. Dominant plants include sawgrass, bulrushes, wild rice, cattail, arrowhead, water parsnip, pickerelweed, spatterdock, and other freshwater emergent marsh plants (Clewell et al., 1999). Overall they have the highest plant diversity of the various tidal marsh community types in the Suwannee estuary. The general structure and function of tidal fresh-water marsh communities were described by Odum et al. (1984). Their fisheries habitat value is likely equivalent to those of downstream, higher salinity marshes (Odum et al., 1984). Beck et al. (2000) identified “tidal fresh marshes” as a high priority habitat target for conservation in the northern Gulf of Mexico.

Intertidal marsh areas adjacent to the lower 4-5 miles (5-7 km) of the river passes are oligohaline or brackish tidal marsh. Dominant plants in these marshes include sawgrass, black rush, giant reed, bulrushes, cordgrasses, and lance- leaved arrowhead (Clewell et al., 1999). These low-salinity marshes, in association with their complex of tidal creeks, are known to provide critical nursery habitat for many fishes of commercial or recreational importance (Rozas and Hackney, 1983; Comp and Seaman, 1985), particularly during the earliest larval stages. “Oligohaline saltmarsh” was identified as a priority Habitat Target for conservation in the northern Gulf of Mexico by Beck et al. (2000).

Salt marshes are found in the intertidal wetland areas north and south of the river delta. Dominant plants include black rush, cordgrasses, sea lavender and seashore saltgrass. These higher-salinity tidal marsh communities have been well-studied in estuaries throughout the southeastern U.S. and Florida (Montague and Wiegert, 1990; Coultas and Hsieh, 1997). Concurrently, their ecological value as fishery and wildlife habitat has been well documented (Weinstein, 1979; Boesch and Turner, 1984; Durako et al., 1985). Beck et al. (2000) designated these higher-salinity intertidal marshes (which they termed "mesohaline saltmarsh" and "polyhaline saltmarsh") as Priority Habitat Targets for conservation in the northern Gulf of Mexico.

In assessing the potential for significantly adverse environmental impacts to tidal marshes, consideration was given to changes in salinity that might cause the following:

- changes in the species composition of marsh plant communities to those of a more saline marsh type; cause unacceptable encroachment of tidal marsh plants or animals indicative of higher salinity conditions into upstream areas where they have not previously been observed or recorded;
- cause or increase the potential for unacceptable losses of acreage of low salinity tidal marsh habitat (those in the areas of <10 ppt average annual salinity); or
- cause unacceptable alterations in natural plant or animal populations in low salinity oligohaline and tidal freshwater marshes.

4.2 Target Species

Although the District's approach to MFLs includes consideration of the water needs of target habitats, incorporation of the water requirements of certain key species within each of those habitats can provide additional information to set and evaluate the proposed MFL criteria. Working with PBS&J (2003), the District identified a suite of "target taxa" associated with each of the priority habitats (Table 4.1). Some are officially listed taxa, others are important because of commercial or recreational value, and others are sensitive environmental indicators. All are dominant (by abundance or occurrence) or characteristic taxa associated with each of the habitats. Some are characteristic of more than one habitat type. A literature search was conducted (PBS&J, 2003) to compile and evaluate the best available data to determine the water needs of these target taxa.

Additional taxa were examined by Janicki Environmental (2005a) and McMichael and Tsou (2003) using fish and salinity data from the FWCC Fisheries Independent Monitoring Program in the Suwannee estuary. McMichael and Tsou examined several taxa from the FWCC's "Selected Taxa" list (Table 4.2) and their responses to salinity and river flow. Janicki Environmental also analyzed the species-specific responses of a number of fish taxa to salinity/flow, most of which were either FWCC Selected Taxa or ELMR taxa (Table 4.2). Janicki

Taxonomic grouping	**Habitat**			
	Low Salinity SAV	**Tidal Creeks**	**Tidal Swamps**	**Oyster reefs/bars**
Invertebrates	Pink shrimp, Grass shrimp, Blue crab, Olive nerite	Grass shrimp, Blue crab, Fiddler crab	Grass shrimp, Blue crab, Fiddler crab	Stone crab, Blue crab, Oysters
Fish	Bay anchovy, Red drum, Silversides, Mullet, Silver perch, Mojarras, Spotted seatrout	Bay anchovy, Silversides, Mullet, Red drum, Silver perch, Mojarras, Spotted seatrout		Spotted and Sand seatrout, Red drum, Mojarras, Black drum, Spot, Pinfish
Reptiles		Diamondback terrapin, *American alligator*		
Birds		*Limpkin*	Swallow-tailed kite, *Yellow-crowned night heron,* Little green heron	*American oystercatcher*
Mammals	*Florida manatee*	*Florida manatee*		
Plants	Tapegrass, Strapleaf Sagittaria		Cabbage palm, Tupelo, Ash, Cypress	

Table 4-1. List of targeted taxonomic groups/priority taxa and commensurate habitats for development of minimum flows and levels for the Suwannee River (taxa in italics are listed species). Filled cells were not assigned species. Table adapted from PBS&J (2003).

INVERTEBRATES	FWCC Selected Taxon	ELMR Taxon
Blue crab (*Callinectes sapidus*)[1,2]	√	√
Pink shrimp (*Farfantepenaeus duorarum*)[1,2]	√	√
Penaid shrimp (*Farfantepenaeus* spp.)[2]	√*	√ *
FISHES		
Diamond killifish (*Adinia xenica*)[2]		
Striped anchovy (*Anchoa hepsetus*)[1,2]		
Bay anchovy (*Anchoa mitchilli*)[1,2]		√
Menhaden (*Brevoortia* spp.)[1,2]		√ *
Spotted seatrout (*Cynoscion arenarius*)[2]	√	√
Sand seatrout (*Cynoscion nebulosus*)[1,2]	√*	√ *
Spotfin mojarra (*Eucinostomus harengulus*)[2]		
Mojarra (*Eucinostomus* spp.)[1,2]		
Gulf killifish (*Fundulus grandis*)[2]		√ *
Striped killifish (*Fundulus majalis*)[2]		
Scaled sardine (*Harengula jaguana*)[2]		
Pinfish (*Lagodon rhomboides*)[1,2]		√
Spot (*Leiostomus xanthurus*)[1,2]	√*	√ *
Redbreast sunfish (*Lepomis auritus*)[2]		
Spotted sunfish (*Lepomis punctatus*)[2]		
Rainwater killifish (*Lucania parva*)[2]		
Rough silverside (*Membras martinica*)[1,2]		
Silversides (*Menidia* spp.)[1,2]		
Gulf whiting (*Menticirrhus americanus*)[1,2]	√	
Clown goby (*Microgobius gulosus*)[2]		
Largemouth bass (*Micropterus salmoides*)[2]		
Striped mullet (*Mugil cephalus*)[1,2]	√	√
Gulf flounder (*Paralichthys albigutta*)[2]	√*	√ *
Red drum (*Sciaenops ocellatus*)[1,2]	√*	√ *

Table 4-2. Estuarine fish and invertebrate taxa examined by McMichael and Tsou (2003) and/or Janicki Environmental (2005a). * - listed as "moderate to high sensitivity" to salinity change by Christensen et al. (1997) for the Suwannee estuary.

Environmental (2005a) also examined species-specific and community-level responses to river flow and salinity using benthic invertebrate data collected in the FWCC Inshore Monitoring and Assessment Program (IMAP) in the Suwannee estuary (2000 and 2003 sampling) and invertebrate data collected with Hester-Dendy samplers by the SRWMD in their ambient river monitoring program from the river sites SUW150C1 and SUW240C1 (1989-2003 sampling period).

4.3 Habitat-Based Hydrologic Analyses

4.3.1 Riverine Studies and Data

Wetland communities

Data used to develop MFLs to protect floodplain wetlands and aquatic habitats came mostly from a study by Light et al. (2002). They collected data on topography, soils, and plant communities at 5 intensive study transects, located along the river from the Santa Fe confluence down to near Fowler's Bluff (Figure 4-5). They also conducted forest type mapping (Darst et al., 2003), and surveys at a number of sites to verify the classification accuracy of the maps (locations shown in Light et al., 2002 and Darst et al., 2003). A summary of groundcover data at transects and verification sites was presented in Darst et al. (2002). Other information on floodplain wetland and aquatic communities was derived from the scientific literature in a review by PBS&J (2003), which is cited. Other than the work reported above, there exist no detailed, quantitative studies of floodplain wetlands (or other floodplain habitats or biological communities) in the lower Suwannee.

Study	Investigator(s)	Description	Period of Record
Floodplain wetlands and aquatic habitats	U.S. Geological Survey	Specific study for lower Suwannee MFL effort	October 1996-September 1999
Riverine snag habitat	Mote Marine Laboratory	Specific study for lower Suwannee MFL effort	February 1998-November 1998
Riverine benthic invertebrates	Janicki Environmental	Analysis of SRWMD monitoring data	February 1989-December 2003
Tidal Marshes	A.F. Clewell, Inc.	Specific study for lower Suwannee MFL effort and follow-up study	July 1997- September 1998 and June 2000
	SRWMD	Follow-up study during drought	July 2002
Tidal Freshwater Swamps	U.S. Geological Survey	Specific study for lower Suwannee MFL effort	October 199 - September 1999
Low-salinity SAV – field studies	Mote Marine Laboratory	Specific study for lower Suwannee MFL effort and follow-up studies	January 1998-January 1999; June 2000 and July 2002
Low-salinity SAV - mapping	Golder Associates	Specific study for lower Suwannee MFL effort	May - October 2000
Oyster reefs – field studies	University of Florida	Specific study for lower Suwannee MFL effort	October 2002- March 2003
Oyster reefs - mapping	Agra-Baymont	Specific study for lower Suwannee MFL effort	Based on Nov. 2001 photography
Estuarine fisheries	FWCC Fish and Wildlife Research Institute	Analysis of Fisheries Independent Monitoring Program data	January 1997 - December 2000
	Janicki Environmental	Analysis of Fisheries Independent Monitoring Program data	January 1997 – December 2003
	FWCC Freshwater Fish Division	Fish populations in East Pass	February 1993-1995

Table 4-3. Summary of ecological studies and data networks conducted on the lower Suwannee, which provided data used in MFL development.

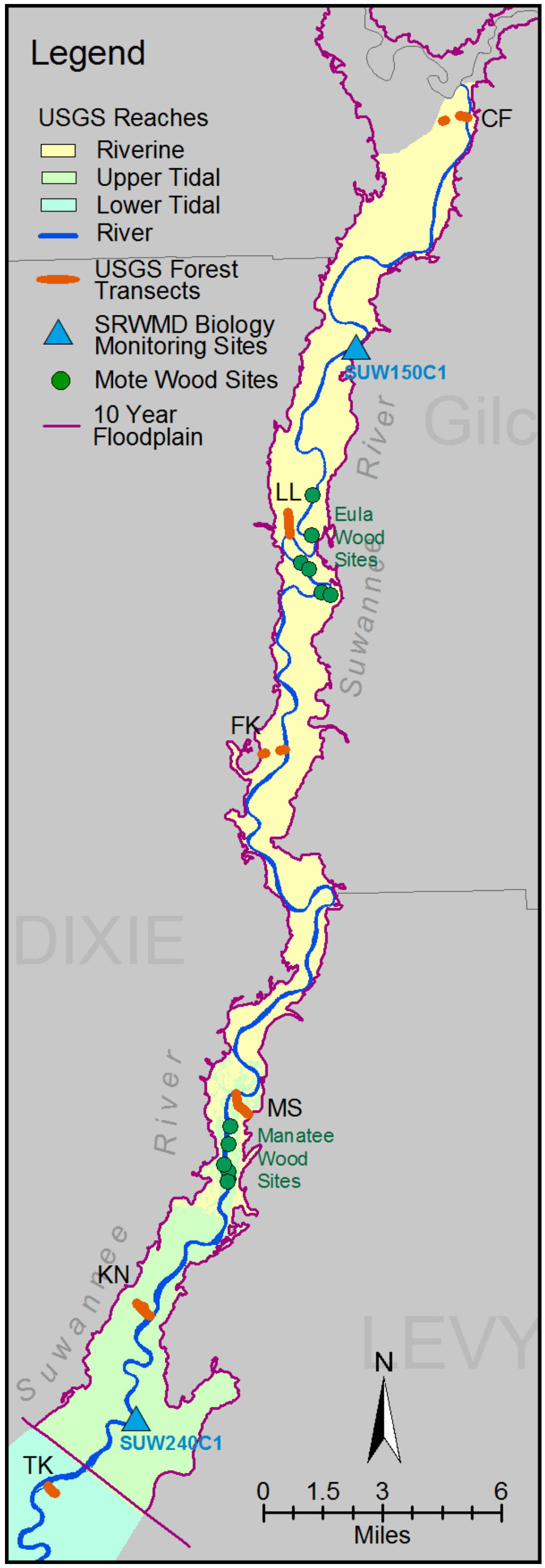

Figure 4-5. Map of the riverine portion of the Lower Suwannee River MFL study area and reaches upstream to the confluence with the Santa Fe. Locations of USGS floodplain transects, Mote wood study sites, and SRWMD long-term surfacewater quality/ biology sites are shown.

Wharton et al. (1982) and Lynch (1984) presented qualitative, descriptive summaries of floodplain plant communities and tree canopy species composition in the Suwannee River. Their data are useful as background information but could not be used directly for establishing MFLs. In like manner, Howell (1999) conducted detailed studies of soils and geomorphology in the Lower Suwannee River floodplain. Some of his data were reported and used in Light et al. (2002) and are incorporated into the Lower Suwannee study area MFLs via use of their work.

Aquatic communities. Studies on riparian snag habitat were conducted by Mote Marine Laboratory at six river bank sites located in each of two regions of the river: near Eula Landing and near Manatee Springs (Figure 4-5). Their methodology and results are reported in Estevez and Sprinkel (2000). Characteristics of benthic invertebrate communities existing on snags were estimated using Hester-Dendy sampler data collected in the SRWMD long-term river monitoring network at the sites SUW150C1 and SUW240C1 (Figure 4-5). These invertebrate analyses are reported in Janicki Environmental (2005a). Information from the scientific literature was also employed in evaluating snags and riverine SAV, summarized in PBS&J (2003).

Some historical studies of riverine aquatic habitats and their fauna have been conducted in the lower Suwannee. Bass and Cox (1985) and Bass and Hitt (1973) report on studies of fish populations and benthic invertebrates associated with different habitats in the lower Suwannee River. FDER (1985), Mason (1991), Mason et al. (1994) and Mattson et al. (1995) presented data on riverine benthic macroinvertebrate and periphytic algal communities in the Suwannee River, but all of these studies are primarily descriptive. They serve as useful background information but were not specifically incorporated into the Lower Suwannee MFLs. Fish population data at several locations in the Lower Suwannee have been collected for the past 25 years by the FWCC, in the form of electroshocking surveys conducted annually or for special investigations (Bass and Hitt, 1973; Bass, 1990; 1991). These data were collected to characterize the status and condition of fish populations in this reach of the river and were evaluated for use in MFL development but were found to be unusable for that purpose. The FWCC is currently collecting fish data more amenable to use in MFLs, but the data have not been collected over a long enough period of time yet. A number of studies of Gulf sturgeon in the Suwannee River have been conducted (summarized in Sulak et al., 2001). Their data either were focused more on the upper river, where the spawning locations are, or were too qualitative to use for MFL development. Langtimm et al. (2003) provided an overview of Florida manatee population dynamics in the lower river. Their study primarily focused on evaluating the importance of Manatee Spring as temporary warm-water refuge in the winter. This study is useful for development of MFLs for that spring, but is not as useful for the Lower Suwannee system as a whole.

4.3.2 Estuarine studies and data

Wetland communities. Data on tidal-marsh communities were collected by Clewell, et al. (1999). They collected topographic, soils, and plant community data at 7 intensive study transects located in the estuary (Figure 4-6). Supplemental qualitative observations were made at numerous other sites located throughout the estuary (Clewell et al., 1999). Marsh plant community data were also collected during this time by Clewell et al. (1999) along both river banks at the locations of 15 salinity sites sampled for two years by the FWCC in 1993-95 (Mattson and Krummrich, 1995) and by the USGS from 1997-1999 (Tillis, 2000). Follow-up plant community surveys at most of the intensive tidal marsh transects were conducted in 2000 (Clewell, 2000) and 2002 (Mattson, 2002b), Data used to develop MFLs to protect tidal freshwater swamps came from the floodplain wetland study by Light et al. (2002). The data they collected in this plant community came from 6 intensive study transects stretching from Turkey Island to near the treeline (Figure 4-6), and consisted of topography, soils, and plant communities. Maps of tidal freshwater swamp forest types were presented in Darst et al. (2003) and groundcover data from the tidal swamp study transects were summarized in Darst et al. (2002).

A few general studies have been conducted in tidal marshes of the Suwannee estuary. Coultas (1997) summarized marsh soils studies he conducted in tidal marshes in Dixie and Levy counties (including the Suwannee estuary). Wright (1995) studied the geologic history and sedimentation characteristics of the delta area at the mouth of the Suwannee. Additional data from Suwannee estuary marshes were reported in several presentations and posters at a Symposium held in 1997 (Lindberg, 1997). All of these studies provided descriptive data useful for generally characterizing the marshes and tidal creeks of the estuary, but they were determined to be not directly useful for MFL development.

Aquatic communities. Studies in low salinity SAV beds in the upper estuary were conducted by Mote Marine Laboratory at 16 sites (Figure 4-6). Non-destructive sampling of SAV was conducted at all of these, consisting of Braun-Blanquet measurement of vegetation. A subset of these sites was sampled more intensively for above- and below-ground vegetation standing crop and epiphytic invertebrate communities, as described in Estevez and Sprinkel (1999). Revisits of the Mote sites were conducted in 2000 and 2002 (Estevez, 2000b; 2002). Low salinity SAV was mapped in 2000 by Golder Associates (2000). Studies in oyster reef habitats were conducted by the University of Florida (Baker et al., 2003) at 36 sites, along with selected elements of the oyster-associated benthic invertebrate fauna (Figure 4-7). Salinity data collected by the FDACS shellfish monitoring program (SEAS) were employed in this oyster study (Figure 4-7) to characterize salinity conditions for comparison with the oyster data (as described in Baker et al., 2003). The SEAS data were also used to develop salinity/flow regression models (Janicki Environmental, 2005b) used in evaluating salinity dynamics for other estuarine target habitats. Other salinity data networks used were described in Section 3.1.9. Oyster reefs and bars were mapped in 2002 by Baymont (2002) using natural color, 1:24,000 scale natural color aerial photography flown by a contractor for SRWMD in 2001. Data on benthic invertebrate communities in the upper estuary were analyzed by Janicki Environmental (2005a) from the site SUW275C1 (Figure 4-6).

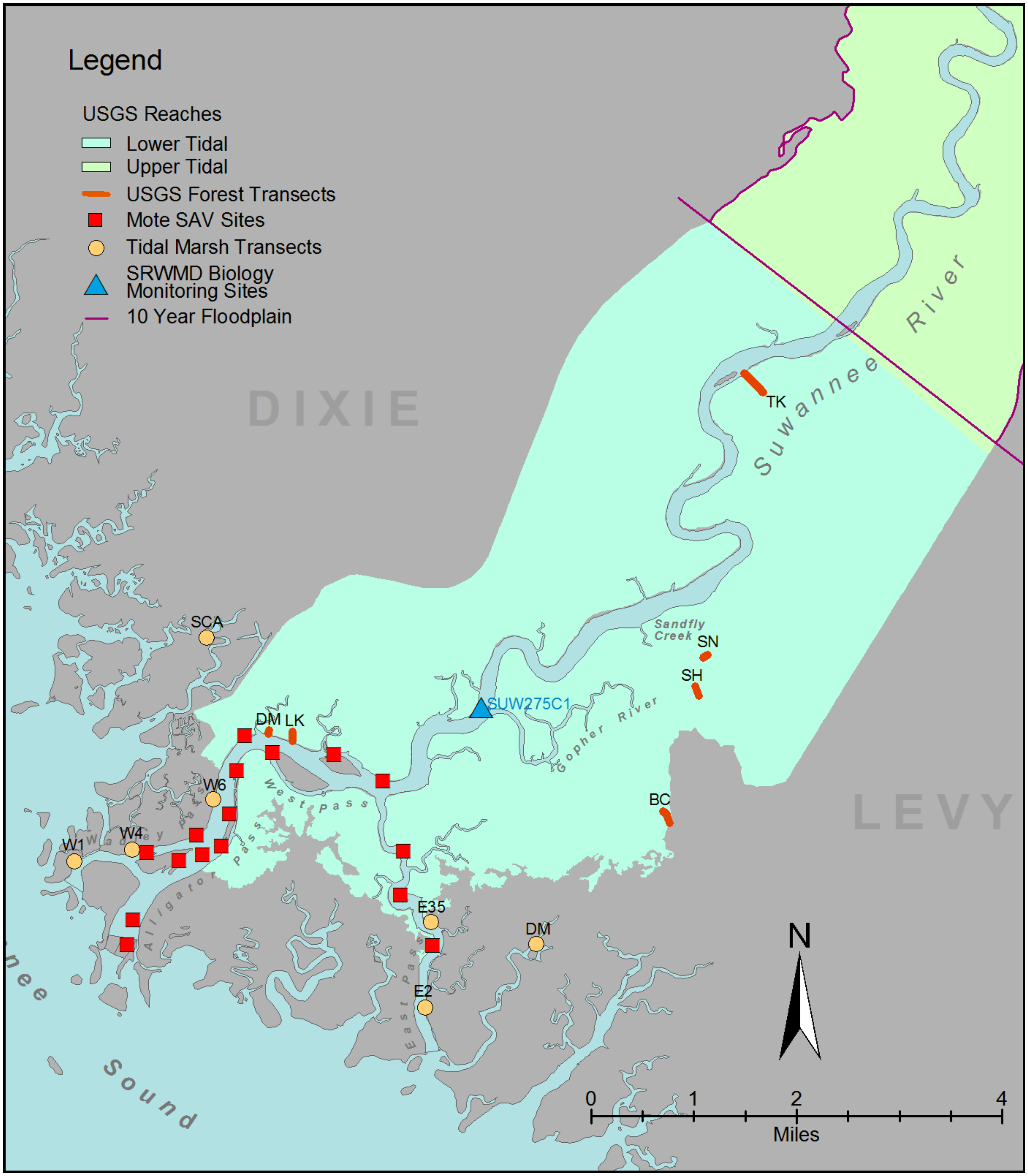

Figure 4-6. Map of the upper Suwannee estuary, showing locations of Clewell tidal marsh transects, USGS tidal freshwater swamp transects, Mote SAV study sites, and SRWMD long-term surfacewater/biology site.

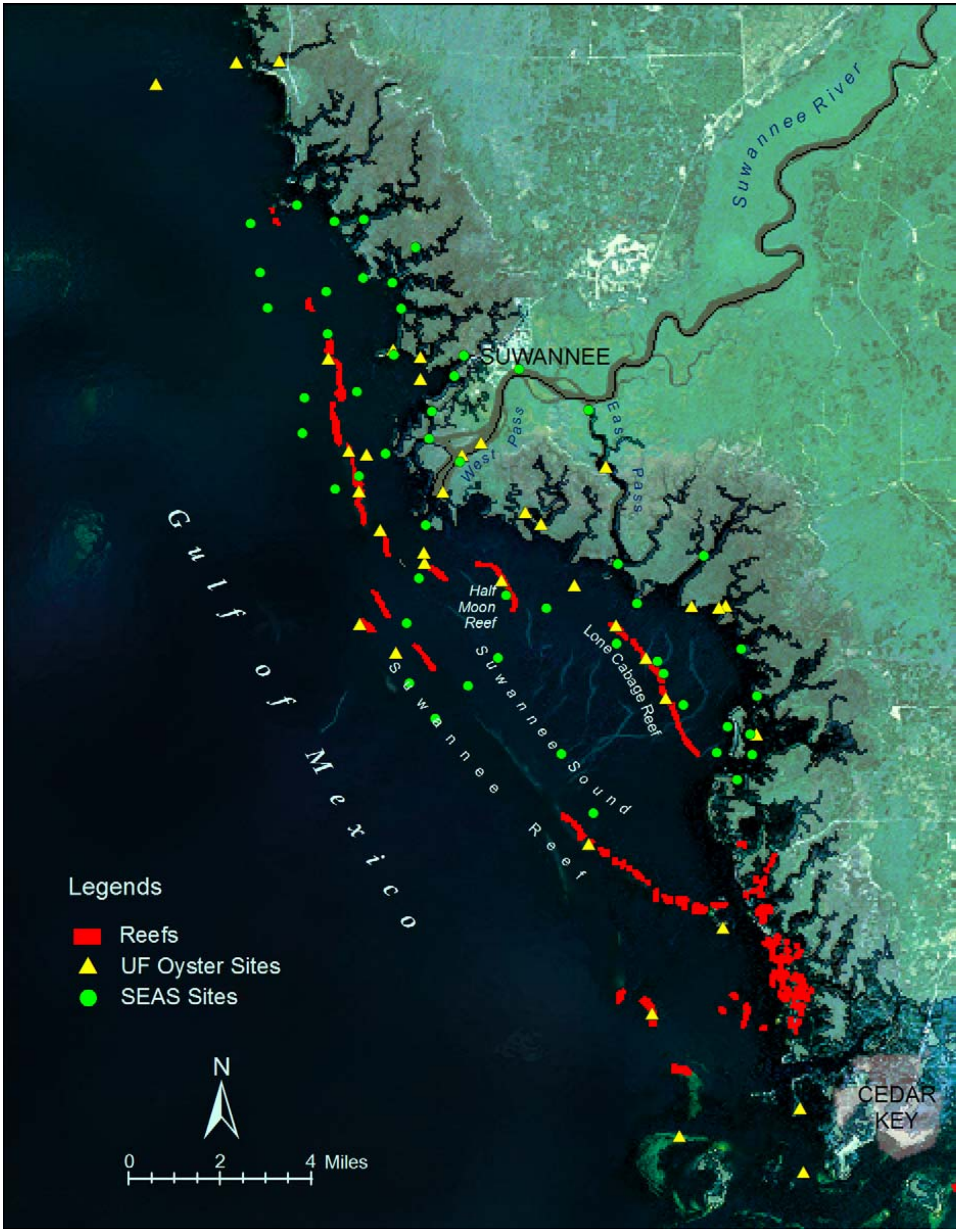

Figure 4-7. Satellite image of the Suwannee estuary showing locations of UF oyster study sites and SEAS salinity sites.

Information on tidal creeks and related fisheries data came from several sources. SRWMD developed a GIS coverage of tidal creeks on the Suwannee delta area. This was used in conjunction with a GIS coverage, created by SRWMD, segmenting the major passes (East, West, Alligator and Wadley) into 0.25 km sections to evaluate cumulative geographic characteristics of tidal creeks in the estuary. Additional data came from the FWRI Fisheries Independent Monitoring program. This program samples juvenile fishes and related physical and habitat characteristics in the Suwannee estuary using a stratified random sampling grid. Station locations used in analyses in this report are indicated in Figure 4-8. Data from the FIM program collected 1997-2000 were analyzed by McMichael and Tsou (2003) and Tsou and Matheson (2002). Janicki Environmental (2005a) conducted additional analyses using FIM data collected from 1997-2003. Some analysis of benthic invertebrate data from the FWRI Inshore Marine Monitoring and Assessment Program (IMAP) was also conducted by Janicki Environmental (2005a). Fish population data collected by electroshocking at six sites in East Pass were used to evaluate upper estuary fish populations (Mattson and Krummrich, 1995). Additional information on estuarine wetland and aquatic communities in the scientific literature was consulted to develop MFLs for the lower Suwannee. This is summarized in PBS&J (2003).

Bledsoe (1998; 2003), Bledsoe and Phlips (2000) and Bledsoe et al. (2004) studied phytoplankton communities and water quality in the Suwannee estuary. Their focus was on determination of water quality and physical factors most responsible for influencing the composition and standing crop of phytoplankton in the estuary. Even though their data are extensive, because their study design was not oriented towards examining specifically how freshwater inflow affects phytoplankton populations, the data are not entirely applicable towards developing MFLs for the lower Suwannee. Wolfe and Wolfe (1985) presented some phytoplankton community data from the estuary, but they were critical of the sampling design, and thus those data were not used in the lower Suwannee MFL effort. Information on estuarine benthic macroinvertebrates were reported in Wolfe and Wolfe (1985) and Mason, et al. (1994). These data are primarily descriptive and provide useful background information but were not suitable for use in MFL development. Data collected by Brooks and Sulak (2004) were more quantitative, but were not collected over a wide enough range of salinities or a long enough period of time to be useful for MFLs. Grinnel (1971) conducted surveys of the structure and development of oyster reefs in the Suwannee estuary, but again, his data are largely descriptive and cannot be used in MFL development. Adicks (1998) evaluated juvenile and small fish populations in Alligator Pass and tried to relate fish community characteristics to salinity variation but did not find clear relationships. Additional data from the Suwannee estuary were reported in several presentations and posters at a Symposium held in 1997 (Lindberg, 1997), but these are mostly descriptive.

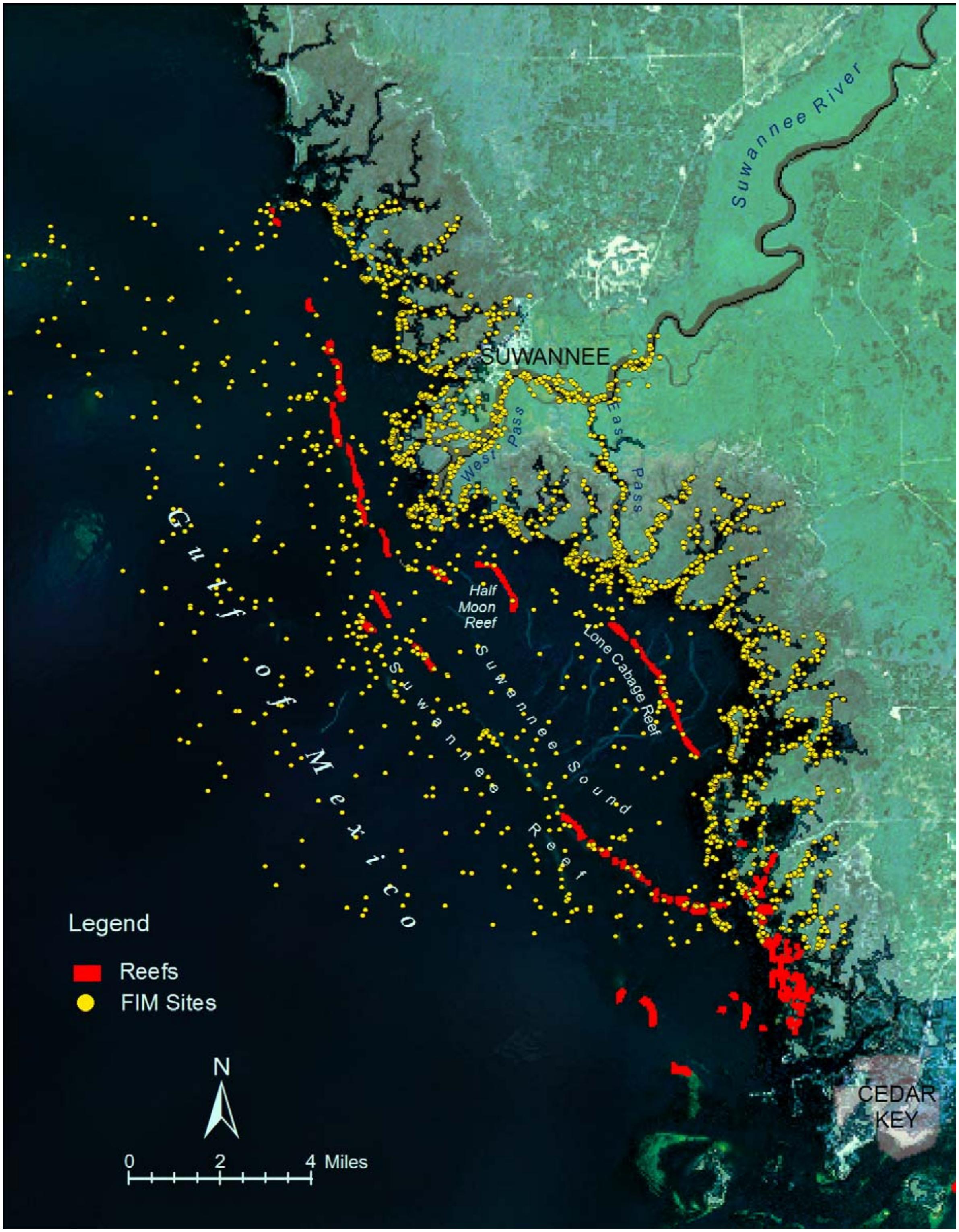

Figure 4-8. Satellite image of the Suwannee estuary showing locations of the FWCC Fisheries Independent Monitoring (FIM) sites used in analyses in this report.