Caloosahatchee River Groundwater / Surface Water Interaction Monitoring Study

I. Introduction

This study was designed to help define the operation of the groundwater/ surface water system in the Caloosahatchee Watershed (298 District). Specifically, data provided by the monitoring study will help determine the importance of groundwater seepage to the Caloosahatchee watershed irrigation system. To achieve maximum value, data should be correlated with groundwater and surface water levels provided by adjacent well nests and stage height recorders, respectively, at the seepage monitoring sites. The range of hydrologic scenarios (e.g. groundwater levels, surface water levels, rainfall, etc.) encountered during the study period is not known at this time. Knowledge of agriculture pumping schedules during field studies would also be helpful in interpreting data. This report presents only seepage meter and *in situ* monitoring data.

II. Methods

Seepage Meter Installation and Sampling

Twenty-two (22) seepage meters were installed in canal and Caloosahatchee benthic sediment to measure groundwater seepage. Three (3) meters were installed at CRS01; five (5) at CRS02; three (3) at CRS03; four (4) at CRS04; three (3) at CRS05; and four (4) at CRS06 (Table 1). These meters were placed at varying distances from the shore in transects. In general, the meters were equally spaced on the slope out to the flat central area of the canal or river. Seepage meter distance from shore and sediment type data are shown in Table 1.

The seepage meters were constructed of steel 55-gallon drums that were cut and inserted into canal sediments (Fig. 1). The design of these meters is similar to that described by Belanger and Kirkner (1994) for measurement of groundwater seepage into water bodies. A plastic bag and tubing were attached to each meter through a rubber stopper inserted into the bung of the drum. The rate of seepage was calculated by measuring the change in volume of water in the bag over time. The change in water volume was converted to units of Liters per m^2-day. Details of meter construction and proper techniques for meter installation and sampling are discussed by Belanger and Montgomery (1992).

In Situ Piezometers

Shallow (3.0-5.0ft.) and deep (7.5-11.1ft.) 3/4 in. *in situ* piezometers were installed in the benthic sediment at nearshore and farshore transect sites. Exact locations and other site data are specified in Table 1. Both shallow and deep piezometers have 1 ft. screened intervals. The piezometers were installed by jetting in a 11/4 inch temporary casing outside the piezometer pipe with a 11/2 h.p. Honda water pump connected to a 11/4 inch hose line. After the 3/4 inch piezometer pipe (5ft. sections) was positioned inside the temporary casing, the outside casing was pulled back, allowing sediment to collapse against the pipe and firmly establish the piezometer pipe at the desired depth. After the piezometers were allowed to settle and equilibrate for several days, the head difference between the surface level (outside piezometer water level) and the groundwater (inside piezometer level) was routinely measured. The piezometers were very difficult to install because of the limestone outcropping occurring at most sites. Unfortunately, many of the installed piezometers were later destroyed due to high flow rates and pressure from moving water hyacinth mats (Table 1).

III. Results and Discussion

Several reconnaissance trips were made to establish exact sites and all piezometers and seepage meters were installed on October 2, 1998, with measurements beginning on October 23, 1998. The field trip dates were October 23-24, 1998; December 4-5, 1998 and January 8-9, 1999. Piezometer (water level and head difference) and seepage meter (rate) data are presented in Table 2. Missing data were the result of destroyed piezometers or seepage meter leaks (bag and meter).

In general, the limited head difference data from piezometers correlate well with seepage rate transect trends. Usually, the distribution of amount of groundwater seepage across the benthic sediment surface is primarily influenced by the groundwater configuration and the "leakance" of the benthic sediments (hydraulic conductivity/ thickness). In this study, the limestone (karst) geology, with its intricate and circuitous groundwater flow paths, result in large variations in seepage for sites in very close proximity to each other. Limestone was present inches below the ground surface at many sites. Seepage meters fairly close to each other may exhibit greatly different seepage rates in this type of terrain, and this was seen at several sites in this study. Generally, temporal variability is much less than site to

site variability, as was the case in this study, but the temporal variations should be correlated with watershed hydrologic conditions for better understanding.

River sites (CRS01, CRS02) and sites adjacent to the river (CRS03) consistently exhibited the lowest seepage rates. Canal sites farther away from the river showed higher seepage rates. The exception to this trend was CRS05, the farthest site from the river, where significant negative rates were often recorded and the lowest mean seepage was measured. Mean site seepage values for CRS01, CRS02, CRS03 and CRS05 were 66, 43, 121 and 15 mL/m^2-hr., respectively. These represent low rates compared to many other Florida water bodies. CRS05, however, was significantly positive on December 5, 1998 when the head difference in the nearshore deep piezometer was 0.13 ft. Again, data should be compared to GW/SW data in the area to explain temporal variations. This site (CRS05), in particular, is strongly influenced by agricultural operations, and pump schedule data may help explain seepage data. However, all canal sites south of Highway 80 (CRS04; CRS05; CRS06) are probably all significantly impacted by agricultural activities.

Individual site data (Table 2) showed that Caloosahatchee River sites (CRS01 and CRS02) exhibited minimal GW/SW interaction, with very low or negative seepage rates. Although data are somewhat erratic, river shore areas appear to exhibit more interaction than deeper areas, as shore seepage oscillated between positive (seepage input) and negative (recharge or river outflow) directions in response to the watershed hydrology. Generally, with a few exceptions, head difference data indicated the direction of seepage. Depth to hardpan and sediment type data alone did not predict seepage rate trends well, however.

At site CRS03, head difference data were either zero or positive, except for the deep piezometer on October 23, 1998. This site, located less than two hundred meters from the river, exhibited low seepage rates with occasional negative values. Meters 1 and 3 exhibited similar rates, while meter 2 seepage rates were very low. High seepage rates recorded at meters 1 and 3 on October 23, 1998 may be in error, however, as they don't correlate with head difference data and they are much higher than all other values. Reasons for this are unclear at this time.

The CRS04 site represents the highest seepage site in the study, with an incredibly high mean rate of >7768 mL/m2-hr. Data from duplicates 2 and 2A (separate meters) were fairly similar, considering the extremely high rates encountered and indicates the validity of the method. Although rates were similar, the high percentage difference between 2 and 2A (up to 36%),

indicates the extremely site specific nature of seepage in this area. Three measurements run consecutively on December 5, 1998 were very similar in most cases (Table 2), also, indicating the data can be viewed with confidence. Extremely high head difference data were recorded at this site, and seepage rates seem to correlate with that data. Highest rates were found on December 5, 1998, when a nearshore deep head difference of 0.57 ft. was measured. On the two dates when shallow and deep piezometers were both intact and measurable at seepage meter 2, values were nearly identical, indicating little variation in head difference with depth. Lowest seepage rates occurred at seepage meter 1, where the greatest thickness of organic muck occurred (90cm), and this low permeability sediment probably contributed to the lower seepage at that location.

At CRS05, discussed previously, very low but variable seepage rates were measured. Head differences varied from -0.05ft. on October 24, 1998 to 0.13 ft. on December 5, 1998. As stated previously, agricultural operations (pumpage) probably have a great impact at this site. Groundwater surface water interaction variations occurred largely at the shore, while offshore rates remained relatively constant.

Seepage meter 2 at site CRS06 exhibited the highest seepage rate measured during the study, higher than those found at site CRS04. At this site, the high rates were not indicated by the nearshore head difference data. The head difference data were relatively constant at seepage meter 1 and 3, varying from 0.07 to 0.12. Seepage rates at meters 1 and 3 were low and did not approach the magnitude of seepage encountered at seepage meter 2, while seepage at meter 4 was moderately high and consistent. The extremely high seepage at meter 2 indicates the extremely variable nature of seepage in this watershed. Apparently, the *in situ* piezometer at seepage meter 2 was not located in the same groundwater flow path as the adjacent seepage meter.

Although many sites in this watershed show only average seepage rates, occasional "spring-like" conditions can occur where discontinuities and cracks in the limestone bedrock occur, contributing to high average seepage in the area. Due to the complexity of groundwater/ surface water interactions and variations in the direction and magnitude of seepage rates recorded in water bodies located in geological areas such as this watershed, special concern must be placed on extrapolation of seepage data for entire systems based on a limited number of seepage meters. The 22 meters employed in this study should give an indication of the groundwater surface water interaction occurring in the area, however, more meters under greater hydrologic variations would be desirable.

IV. Conclusions

Mean transect seepage at most transect sites were not high compared to other systems in Florida and ranged from 15 to 121 mL/m^2-hr. at four of the six transect sites. Average seepage rates for these transect sites were similar to those measured in Pools A (126 mL/m^2-hr.) and B (70 mL/m^2-hr.) of the Kissimmee River (Belanger, 1999), but were significantly lower than those recorded in Pool B in 1993. Mean seepage rates at all transect sites in Pool B ranged from -540 to > 1326 mL/m^2-hr. during seven field trips. A great variation in head difference and stage level data was recorded for Pool B, and seepage rates in that study correlated very well with those data. This is generally the case for most systems.

At this time, we are unaware of the range of hydrologic conditions encountered during the Caloosahatchee Watershed Study. Data indicate groundwater seepage in not a major input to the Caloosahatchee River, but the extremely high rates encountered at sites CRS04 (>7768 mL/m^2-hr.) and CRS06 (>2182 mL/m^2-hr,) indicate the high potential for groundwater to contribute significant quantities of water to the extensive agricultural canal network. This is particularly true under optimum conditions (e.g. low stage, high groundwater). These data also show the extremely site specific nature of groundwater seepage in the area and the difficulty in estimating mean rates for large areas.

V. References

Belanger, T.V. 1999. Unpublished data. Kissimmee River Groundwater Seepage Study funded by SFWMD.

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Belanger, T.V. and M.E. Montgomery. 1992. Seepage Meter Errors. Limnology and Oceanography 37(8): 1787-1795.

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Table 1. *In Situ* Piezometer and Seepage Meter Construction and Location Data

Site	Installed (y/n)	Seepage Meter location	S.M. distance from shore(ft.)	Piez. distance from shore(ft.)	Piez. depth BLS (ft.)	destroyed? (y/n)	Sediment type	Depth to hardpan (cm)
CRS01								
nsh. shal. piez.	y	sm #1		1.5	5	y (10/23/98)		
nsh. deep piez.	y	sm #1		1.5	10	n		
offsh shal. piez	n							
offsh. deep piez	n							
seepage meter								
1	y		12				sand	15
2	y		22				shell, sand	15
2A	n							
3	y		44				thin layer sand	125
4	n						on silty muck	
5	n							
CRS02								
nsh. shal. piez.	n							
nsh. deep piez.	y	sm #2		16	7.5	n		
offsh shal. piez	y	sm #1		44	5	y (10/23/98)		
offsh. deep piez	n							
seepage meter								
1	y		16				sand/limestone	15
2	y		44				shellsand/lmst	30
2A	n							
3	y		60				shellsand/lmst	18
4	y		69				siltsand/limst	50
5	y		102				siltsand/limst	60

Key: nsh. = nearshore, offsh= offshore, bet.= between, piez.= piezometer, BLS= below land surface

Note: Screened Interval= 1ft. for all piezometers

Table 1. contd.								
Site	Installed (y/n)	Seepage Meter location	S.M. distance from shore(ft.)	Piez. distance from shore(ft.)	Piez. depth BLS (ft.)	destroyed? (y/n)	Sediment type	Depth to hardpan (cm)
CRS03								
nsh. shal. piez.	y	sm#1		7.7	5	n		
nsh. deep piez.	y	sm#1		7.7	10	n		
offsh shal. piez	n							
offsh. deep piez	y	sm#3		25.7	11.1	y(10/23/98)		
seepage meter								
1	y		7.7				shelly sand	50
2	y		17				organic muck	75
2A	n							
3	y		25.7				organic muck	110
4	n							
5	n							
CRS04								
nsh. shal. piez.	y	bet.#1 and #2		6.5	4.1	y (12/5/98)		
nsh. deep piez.	y	bet.#1 and #2		6.5	7.6	n		
offsh shal. piez	y	sm. #3		19.5	5	y (12/5/98)		
offsh. deep piez	n							
seepage meter								
1	y		1.5				org.muck/sand	90
2	y		11				org.muck/sand	60
2A	y		11				org.muck/sand	60
3	y		18				org.muck/sand	70
4	n							
5	n							
Key:	nsh. = nearshore, offsh= offshore, bet.= between, piez.= piezometer, BLS= below land surface							
Note:	Screened Interval= 1ft. for all piezometers							

Table 1. contd.

Site	Installed (y/n)	Seepage Meter location	S.M. distance from shore(ft.)	Piez. distance from shore(ft.)	Piez. depth BLS (ft.)	destroyed? (y/n)	Sediment type	Depth to hardpan (cm)
CRS05								
sh. shal. piez.	y	sm#1		8.1	5			
sh. deep piez.	y	sm#1		8.1	9.7			
offsh shal. piez	y	sm#3		21.1	5	y(10/23/98)		
offsh. deep piez	n							
seepage meter							sand	170
1	y		8.1				org. muck	120
2	y		16.2					
2A	n						shelly sand	128
3	y		21.1					
4	n							
5	n							
CRS06								
sh. shal. piez.	y	sm#2		17	3	n		
sh. deep piez.	n							
offsh shal. piez	y	sm#3		36	4	n		
offsh. deep piez	n							
seepage meter								
1	y		7				silty sand	3
2	y		17				silty sand	2.5
2A	n							
3	y		32				org. muck	15
4	y		46				org. muck	15
5	n							
Key:	nsh. = nearshore, offsh= offshore, bet.= between, piez.= piezometer, BLS= below land surface							
Note:	Screened Interval= 1ft. for all piezometers							

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Table 2. Piezometer and Seepage meter data

Site	Date:	23-Oct	24-Oct	4-Dec.	5-Dec	8-Jan	9-Jan	
CRS01								
I. Nearshore Deep Piez. sm#1								
water level inside		1.83		2.05		2.04		
water level outside		1.9		2.05		2.04		
water level change		0.07		0		0		
II. sm#1 seepage rate		499		0; 57		-145	21*	
III. sm#2 seepage rate		163		-74;-65		84	32*	
IV. sm#3 seepage rate		111		236; 143		-103	38*	
V. seepage transect mean		258		54; 45		-55	30*	
VI. overall seepage site mean								**66**
CRS02								
I. Nearshore Deep Piez. sm#1								
water level inside		0.95; 1.27	0.75		1.13	1		
water level outside		1; 1.27	0.8		1.18	0.96		
water level change		0.05	0.05		0.05	-0.04		
II. sm#1 seepage rate			96		39; 108	-51;-16		
III. sm#2 seepage rate		158	93		137; 153	-110;-8		
IV. sm#3 seepage rate		46	15		29; 35	11;12		
V. sm#4 seepage rate		36	-15		153;-28	21;15		
VI. sm#5 seepage rate		106	103		28; 101	32;102		
VII. seepage transect mean		87	58		77; 74	-19;-21		
VIII. overall seepage site mean								**43**

Note: **1.** seepage rate reported in mL/m2/hr., **2.** * denotes bags left on overnight, **3.** sm= seepage meter#
4. water levels recorded in feet., **5.** [ ] represents possible error or outlying pt.,
6. > = seepage rate could only be estimated due to fullness of bag after incubation

Site	Date:	23-Oct	24-Oct	4-Dec.	5-Dec	8-Jan	9-Jan	
CRS03								
I. Nearshore Shal. Piez. sm#1								
water level inside		1.15	0.89	1.75				
water level outside		1.2	0.089	1.78				
water level change		0.05	0	0.03				
II. Nearshore Deep Piez. sm#1								
water level inside		1.6	1.22	1.39				
water level outside		1.59	1.29	1.48				
water level change		-0.01	0.07	0.08				
III. sm#1 seepage rate		[1421]	283	296; 336	227; -176			
IV. sm#2 seepage rate		135	34	0; 43	10; 0			
V. sm#3 seepage rate		[1489]	212	434; 42				
VI. seepage transect mean		[1015]	176	243; 140	119; -88			
VII. overall seepage site mean								**121 [268]**
CRS04								
I. Nearshore Shal. Piez. sm#2								
water level inside		1.13	1.38					
water level outside		1.38	1.64					
water level change		0.25	0.26					
II. Nearshore Deep Piez. sm#2								
water level inside		1.75	2.03	4.38	2.14	2.05		
water level outside		2.02	2.29	4.95	2.31	2.3		
water level change		0.27	0.26	0.57	0.17	0.25		
III. Farshore Shal. Piez. sm#3								
water level inside		0.25	0.53					
water level outside		0.41	0.65					
water level change		0.16	0.12					
Note:	**1.** seepage rate reported in mL/m2/hr., **2.** * denotes bags left on overnight, **3.** sm= seepage meter#							
	4. water levels recorded in feet., **5.** [ ] represents possible error or outlying pt.,							
	6. > = seepage rate could only be estimated due to fullness of bag after incubation							

table 2. (contd.)

Site	Date:	23-Oct	24-Oct	4-Dec.	5-Dec	8-Jan	9-Jan	
IV. sm#1 seepage rate		1200	312	206;929;1170	0	42		
V. sm#2 seepage rate		>3500	6600	12100;13040;13500	3375	3040		
VI sm#2A seepage rate		>3500	>10,000	16900;21900;21429	6360	5960		
VII. sm#3 seepage rate		>3500	7200	14640;18480	5207	4446		
VIII. seepage transect mean		>3800	>6028	10962;13587;11643	4981	3372		
IX. overall seepage site mean								**>7768**
CRS05								
I. Nearshore Shal. Piez. sm#1								
water level inside			0.15		2.67			
water level outside			0.13		2.77			
water level change			-0.02		0.1			
II. Nearshore Deep Piez. sm#1								
water level inside			0.65		3.05			
water level outside			0.6		3.18			
water level change			-0.05		0.13			
III. sm#1 seepage rate			-710		828	-300	-30*	
IV. sm#2 seepage rate			94	46; -66	62	32	19*	
V. sm#3 seepage rate			45	23; -81	21	43	19*	
VI. seepage transect mean			-190	35	304	-75	3*	
VII. overall seepage site mean								**15**

Note: **1.** seepage rate reported in mL/m2/hr., **2.** * denotes bags left on overnight, **3.** sm= seepage meter#
4. water levels recorded in feet., **5.** [ ] represents possible error or outlying pt.,
6. > = seepage rate could only be estimated due to fullness of bag after incubation

table 2. (contd.)

Site	Date:	23-Oct	24-Oct	4-Dec.	5-Dec	8-Jan	9-Jan	
CRS06								
I. Nearshore Shal. Piez. sm#2								
water level inside (ft.)			1.44	2.12			1.52	
water level outside			1.51	2.2			1.62	
water level change			0.07	0.08			0.01	
II. Nearshore Deep Piez. sm#3								
water level inside (ft.)			0.99	1.65			2.1	
water level outside			1.08	1.75			2.22	
water level change			0.09	0.11			0.12	
III. sm#1 seepage rate			169; 159	240; 155	218		82; 107	
IV. sm#2 seepage rate			>4000; >7500	14000;8950	8625		5972; 6071	
V. sm#3 seepage rate			0; 192	0; 0	97		39; 71	
VI. sm#4 seepage rate			857; 844	800; 600	554		388; 400	
VII. seepage transect mean			>1257;>2174	3750; 2426	2374		1620; 1662	
VIII. overall seepage site mean								**>2182**

Note: **1.** seepage rate reported in mL/m2/hr., **2.** * denotes bags left on overnight, **3.** sm= seepage meter#
4. water levels recorded in feet., **5.** [ ] represents possible error or outlying pt.,
6. > = seepage rate could only be estimated due to fullness of bag after incubation

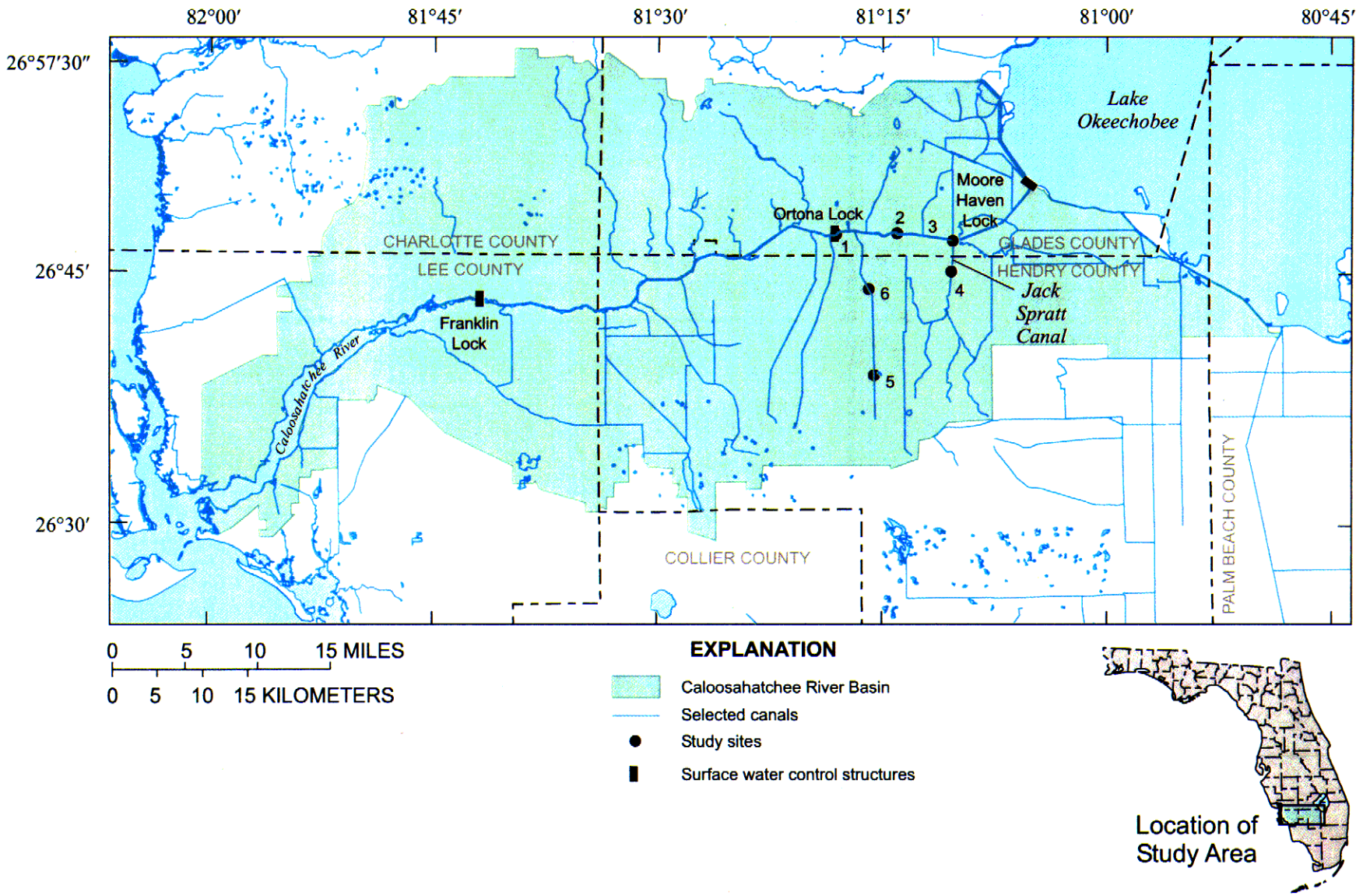

Figure 1. Location of study sites in the Caloosahatchee River Basin.