

Final Report

Analysis of Soil Moisture and Salinity in the Floodplains of the Loxahatchee River Watershed

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INTRODUCTION

The overall goal of this project is to continue assessment of changes in soil water and salinity within the floodplains of the Loxahatchee River in order to understand the relationship between surface, groundwater, and soil interactions on floodplain vegetation; as well as to determine the duration of inundation, moisture, and salinity events in the area and their relation to river dynamics. Specific attention has been given to calibrating the dielectric probes for the organic soils and high water content in the study area. Field conditions have been very hard on the monitoring equipment, which resulted in data gaps in the previous study. In the FY07 study, monitoring equipment has been upgraded in an attempt to decrease down times and increase overall data capture. It is important to recognize that although the tasks presented here are self-contained and deliverable within the one-year project, the assessment of annual and multi-season variability that is critical to understanding the bald cypress floodplain environment and its response to environmental stressors will only be achieved by extensions of this project in subsequent years. Similarly, the integration and modeling of these responses will be greatly improved the longer the experimental record is available.

The specific objectives of this study are:

1. Continued collection of soil moisture and porewater electrical conductivity (EC) data at Transects 1 and 7
2. Collection and analysis of groundwater samples at the Transects 1 and 7 using groundwater piezometers

The most recent report (submitted August 2007) included detailed information on project background, rationales, and all experimental methodologies. This information not repeated in this report, however topographic maps showing the layout of instrumentation on Transects 1 and 7 are shown in Figures 1 and 2. Note that the naming convention for monitoring locations has been changed to be more straightforward; each location name consists of transect number, followed by distance from the river (in meters), followed by probe installation depth. Transect and water quality measurement locations are shown in Figure 3. A United States Geological Survey (USGS) sampling station located at RM 9.1 (adjacent to Transect 7) measures surface and bottom salinity and elevation every 15 minutes (Station ID: 265906080093500; data acquired from USGS staff). A SFWMD sampling station at Lainhart Dam (close to Transect 1) measures mean daily stage (LNHRT_H) and flow (LNHRT_W), both of which are available on the DBHYDRO browser. The Loxahatchee River District (LID) maintains a sampling station (Datasonde Station 69) on the Northwest Fork of the Loxahatchee River at the intersection of Indiantown Road that measures electrical conductivity (EC) (and other water quality parameters) hourly.

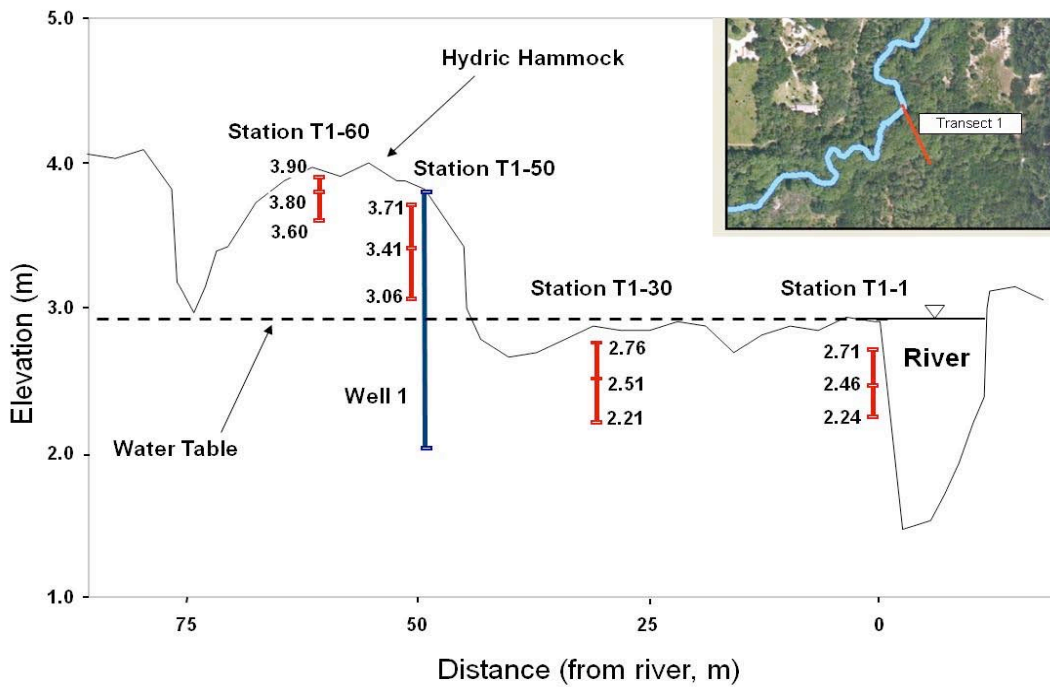


Figure 1. Topography and instrumentation layout/elevations at Transect 1.

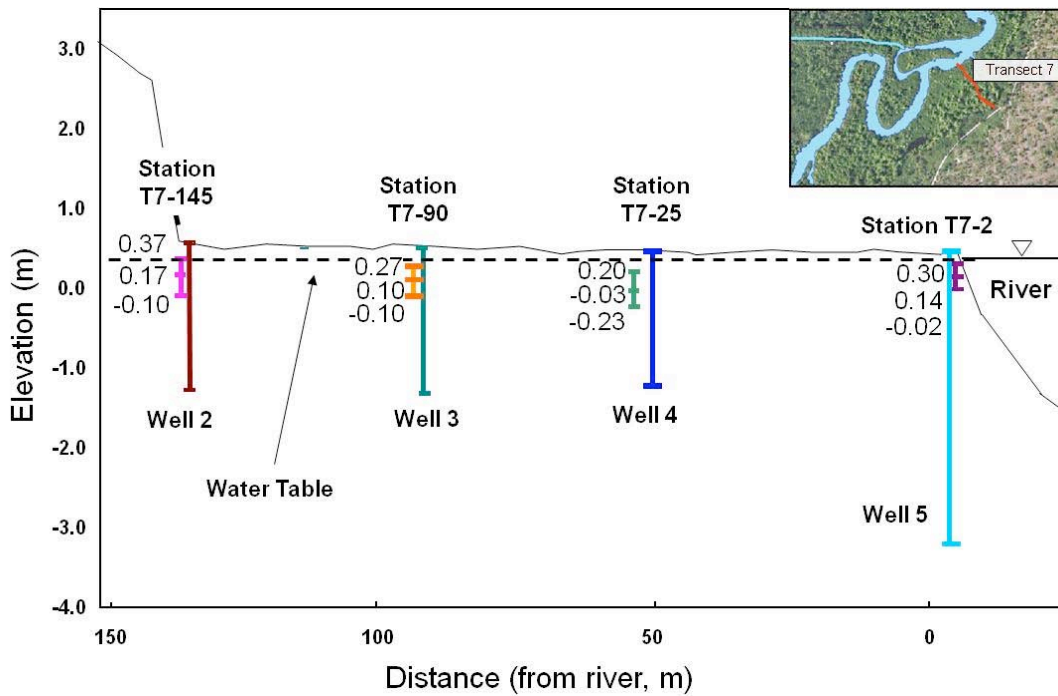


Figure 2. Topography and instrumentation layout/elevations at Transect 7.

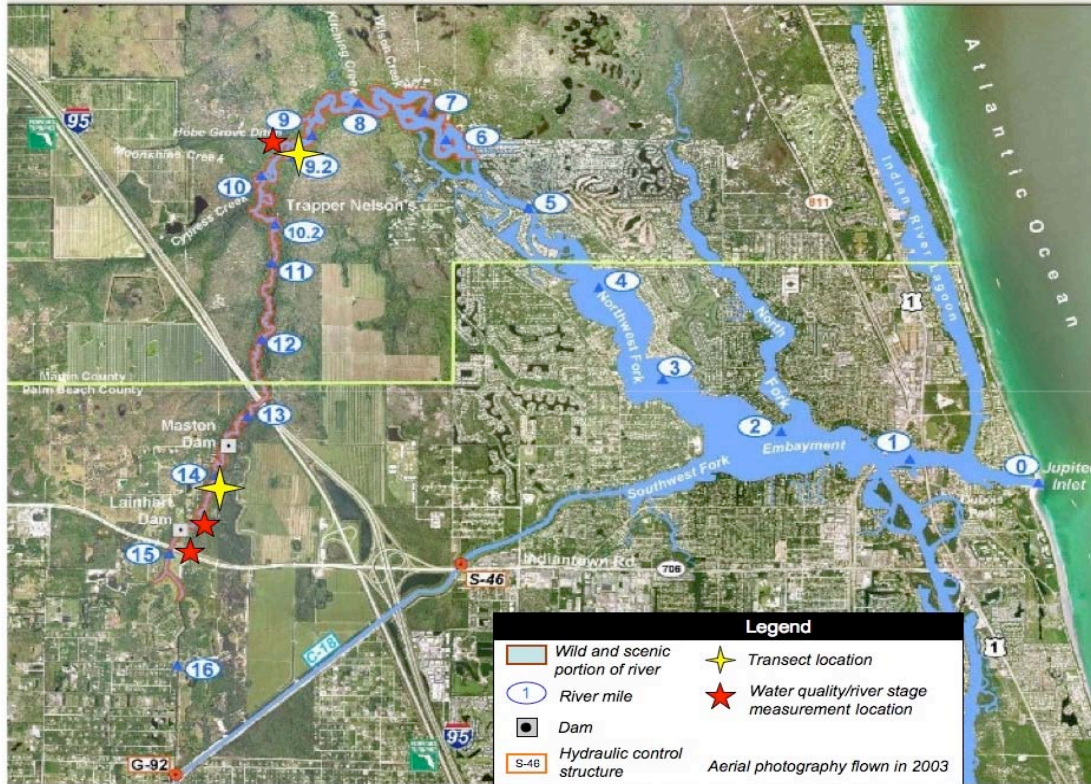


Figure 3. Transect and water quality sampling locations. River stage and salinity are measures at USGS Station at RM 9.1, adjacent to T-7, at Lainhart Dam, and at the Indiantown Bridge

RESULTS

Task 1.0 Soil Moisture and Salinity Monitoring

Soil Moisture Time Series

Figures 4 through 76 show time series of soil moisture data collected from Hydra probes at each of the four monitoring stations located on Transect 1. For the sensors installed in the sandy soils of the hydric hammock (Figs. 4 and 5), changes in soil moisture were observed throughout the soil's entire range, from residual to saturation soil moistures. Furthermore, for the sensors closest to the surface (25 and 35 centimeters below ground surface [bgs]), the effects of climate and river stage (as shown below) are apparent. For example, the three large peaks in soil moisture in 2005 correspond to peaks in river stage due to intense rainfall events associated with tropical storms and a hurricane in 2005. For the middle probe (35 cm bgs), the effects of changing environmental conditions are still apparent, but this sensor registers saturated conditions more often and its responses appear damped as compared to the superficial sensors. Finally, for the deepest probes (55, 60, and 95 cm), there are long periods of saturation. However, even at these depths the sensors measure values close to the residual soil moisture level during the dry seasons of 2005, 2006, and 2007.

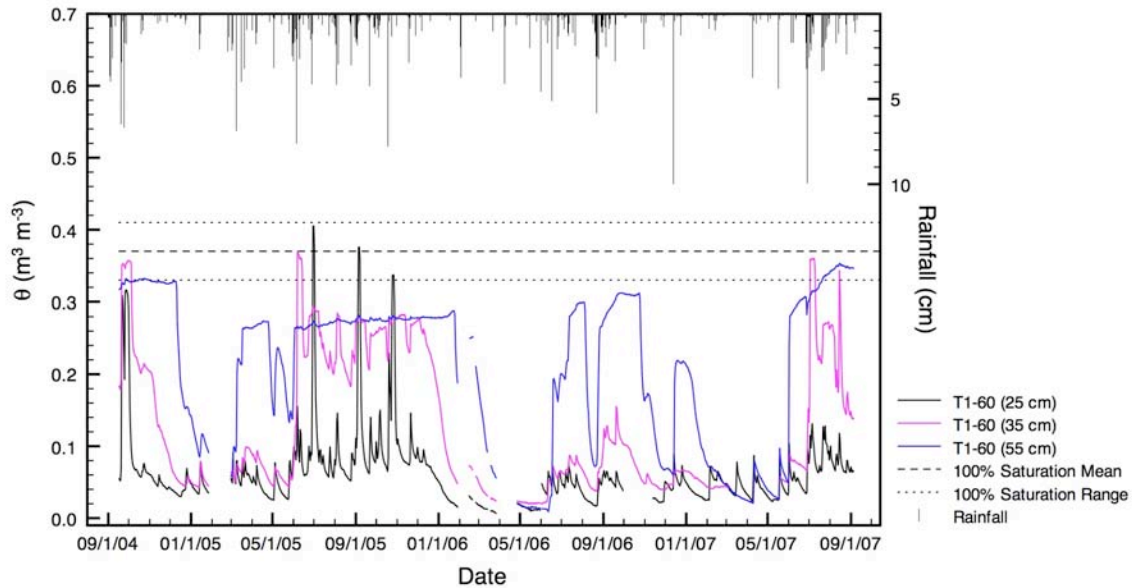


Figure 4. Average daily soil moisture recorded by Hydra probes at station T1-60 from 9/14/04 – 9/6/07.

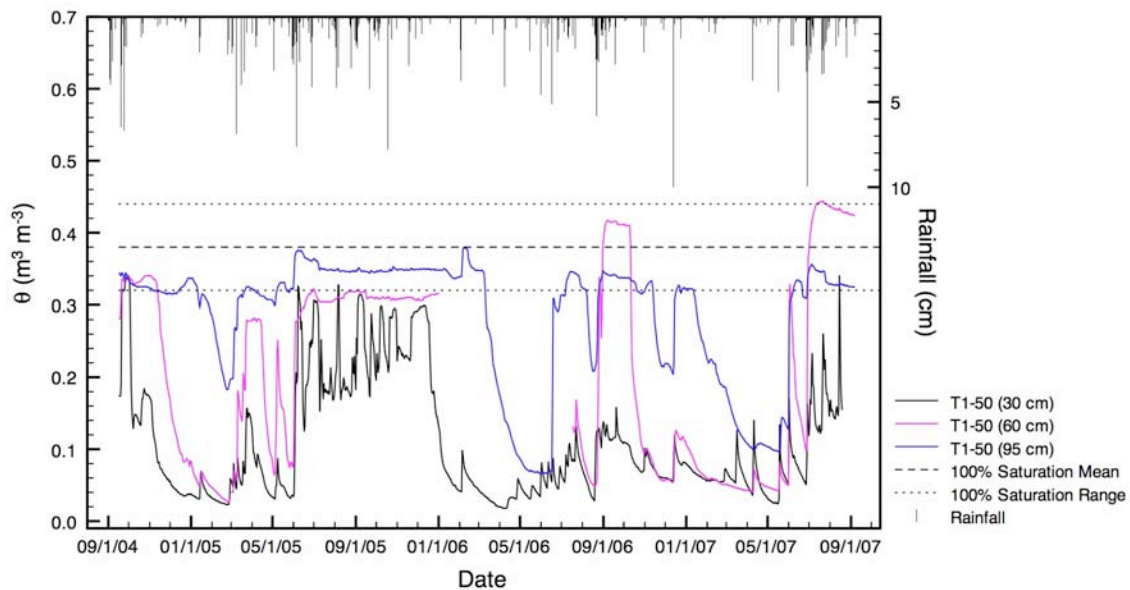


Figure 5. Average daily soil moisture recorded by Hydra probes at Station T1-50 from 9/14/04 – 9/6/07.

For the stations in the lower floodplain (Figs. 6 and 7), the values of soil moisture fall below saturation only in the dry seasons of 2006 and 2007, and only for the most superficial probes (both at 25 cm). The probes at 50, 72, and 80 cm bgs remained saturated (with minor variations) during the entire three-year study period. This part of the floodplain was inundated throughout much of 2005 and the spring of 2006; dried

down during the summer and early fall of 2006; briefly re-flooded in late 2006; and was again dry until the arrival of significant rains in summer 2007. Also of note is that for Station T1-1 (closest to the river, Fig. 7) there appears to be a relationship between soil moisture at saturation and depth. Here, the soil becomes more sandy with depth and thus has a greater bulk density and lower soil moisture (by volume) at saturation.

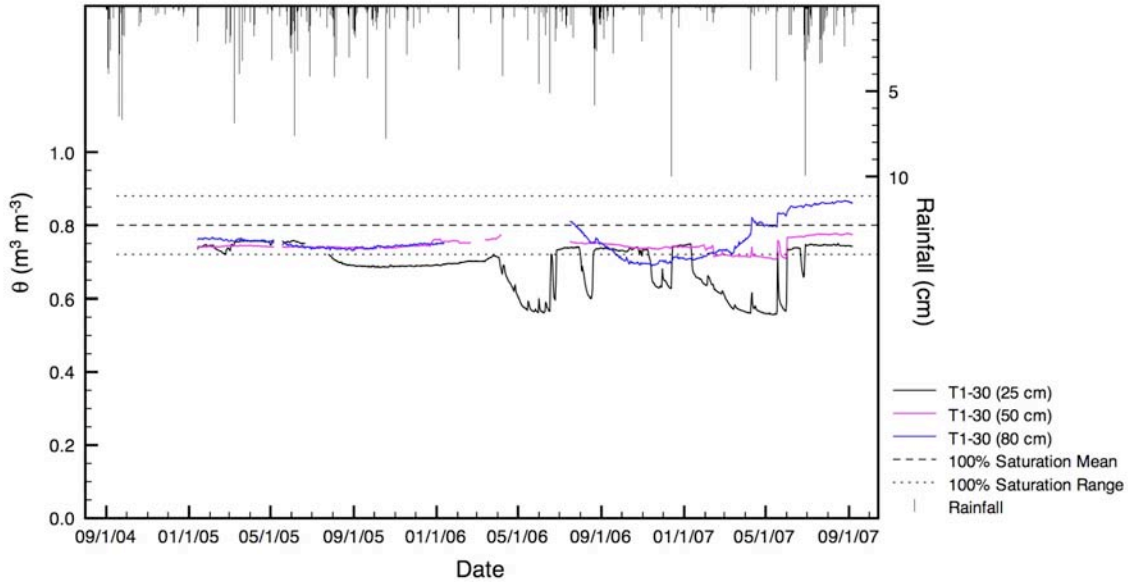


Figure 6. Average daily soil moisture recorded by Hydra probes at Station T1-30 from 1/14/05 – 9/6/07.

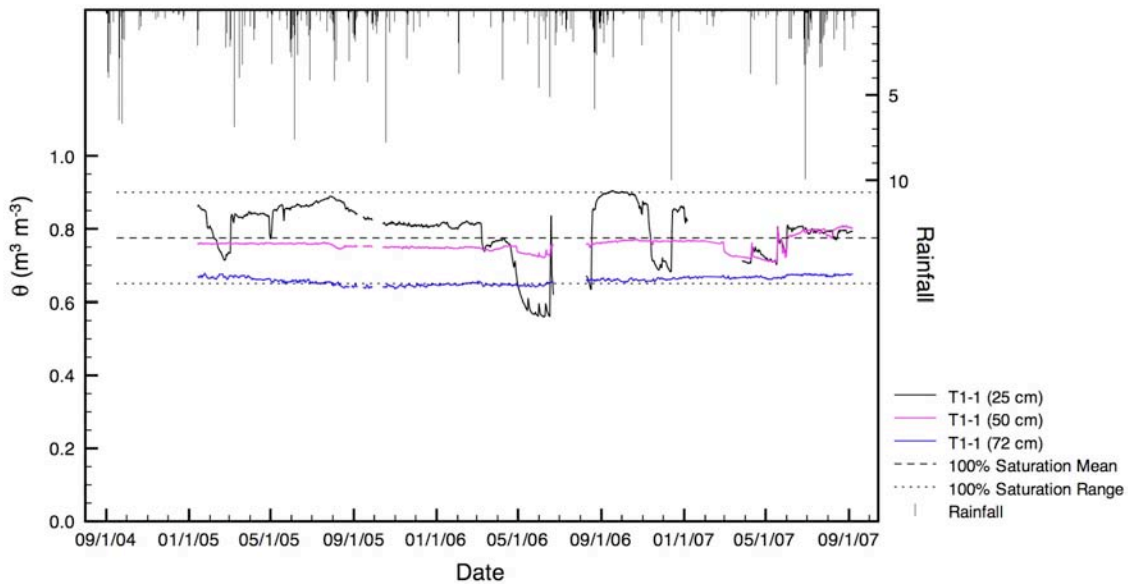


Figure 7. Average daily soil moisture recorded by Hydra probes at Station T1-1 from 1/14/05 –9/6/07.

While the floodplain is inundated for long periods of time, the soil moisture in all probes is expected to remain at a constant value equal to the soil moisture saturation

value. However, because the environment in which the soil moisture sensors are installed is not static, we do observe some changes in probe response, even under inundated conditions. These variations in measured soil moisture are due to any changes in the dielectric properties of the soil being monitored. In a natural system like the floodplain of the Loxahatchee River, these changes may include changes in soil properties (porosity, bulk density, etc.) due to flood-induced soil compaction and de-compaction, root growth and decay, and burrowing by soil macroinvertebrates. For example, any soil compaction increases the bulk density of the soil, leaving less room for water and decreasing the dielectric constant of the soil/water/air matrix. This leads to a lower reading of soil moisture by the sensor.

Soil moisture measurements at Transect 7 over the three-year study period showed very little variation in soil moisture with time, regardless of depth or distance from the river (Figures 8 – 11). Here the soil is a highly organic muck (classified as Terra Ceia Variant Muck) with depths of over 1 meter, underlain by sand. Like the soils in the floodplain of Transect 1, this soil has a low bulk density and high soil moisture at saturation. Due to daily tidal inundation, the 12 sensors on Transect 7 measured values at, or very close to, saturation (close to 0.90) during the entire three-year study period. Again, with the floodplain experiencing daily tidal inundation, soil moisture in all probes is expected to remain at or close to a constant value equal to the soil moisture saturation value. However, as mentioned above, some variations in measured soil moisture are expected in this ilnvg soil. At T-7, there is some apparent soil moisture variation at the end of the soil moisture time series at T-7 (soil moisture “bumps” above saturation values), which we believe are due to a lightning strike affecting sensor readings. These data will likely be removed in the next data clean up.

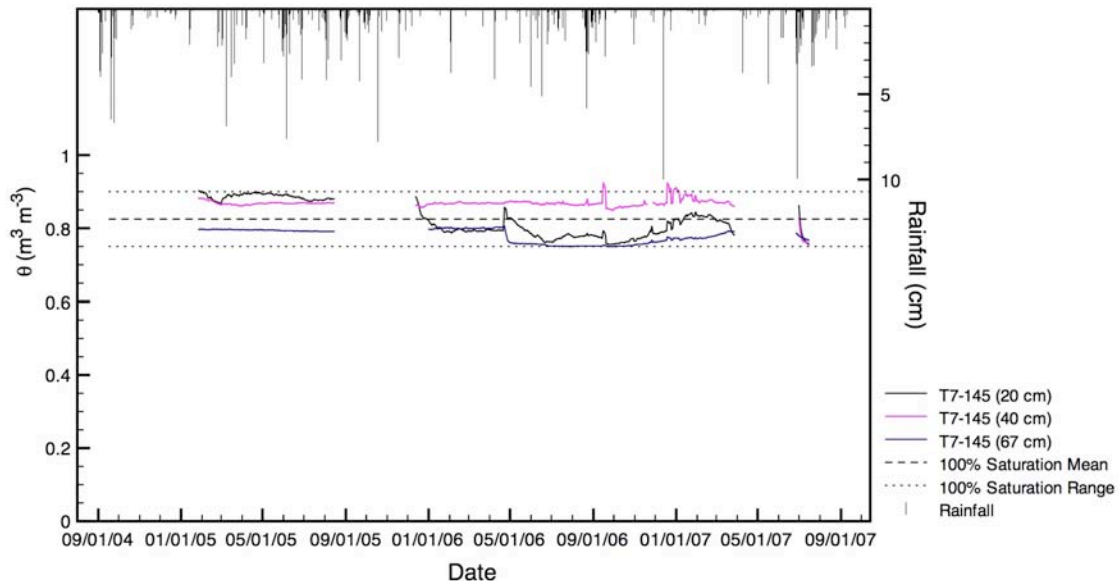


Figure 8. Average daily soil moisture recorded by Hydra probes at Station T7-145.

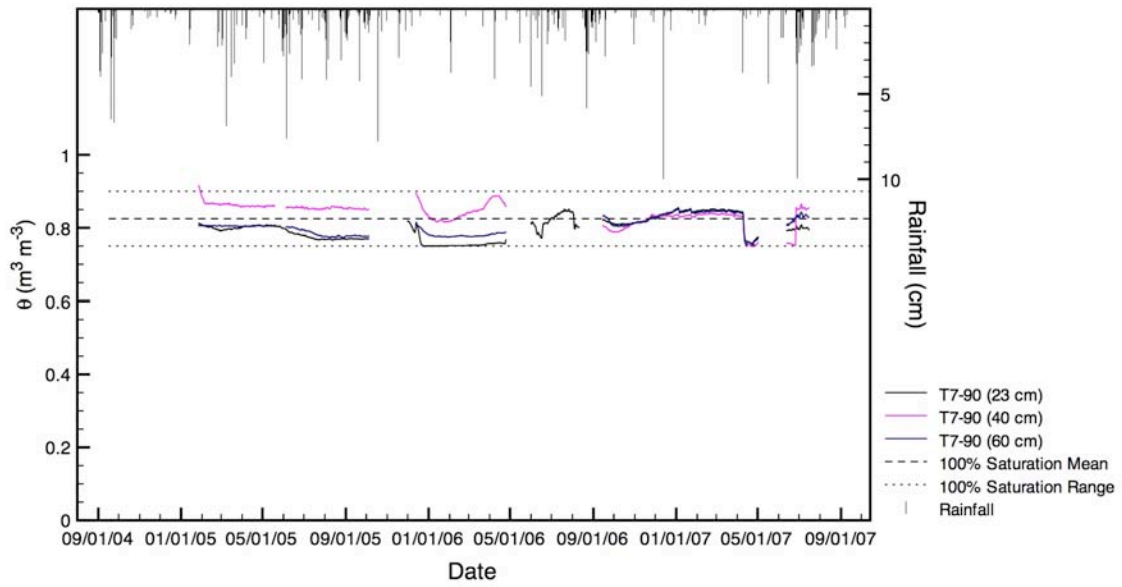


Figure 9. Average daily soil moisture recorded by Hydra probes at Station T7-90.

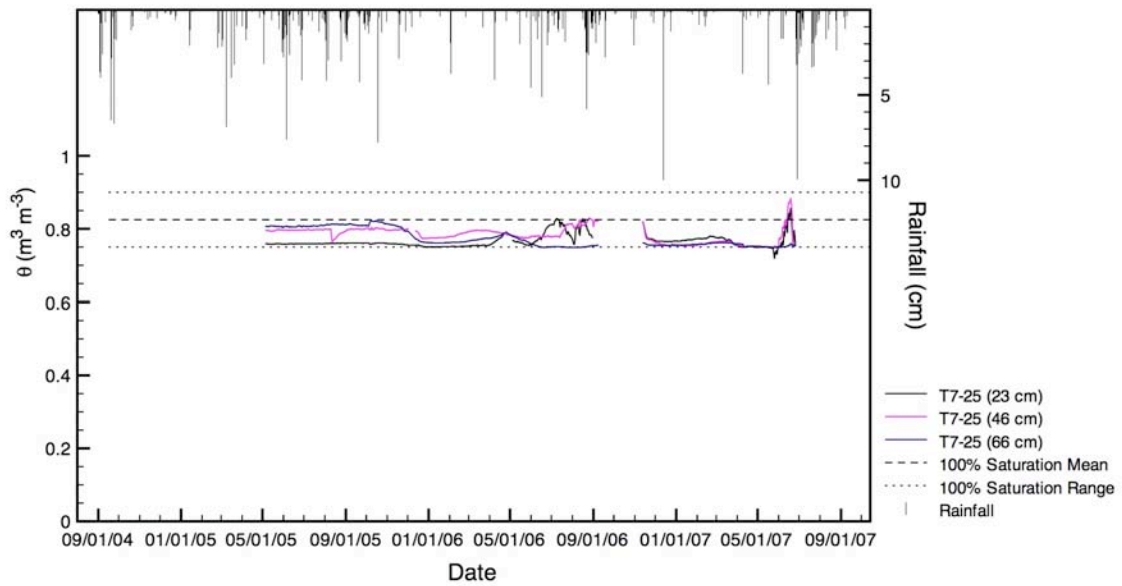


Figure 10. Average daily soil moisture recorded by Hydra probes at Station T7-25.

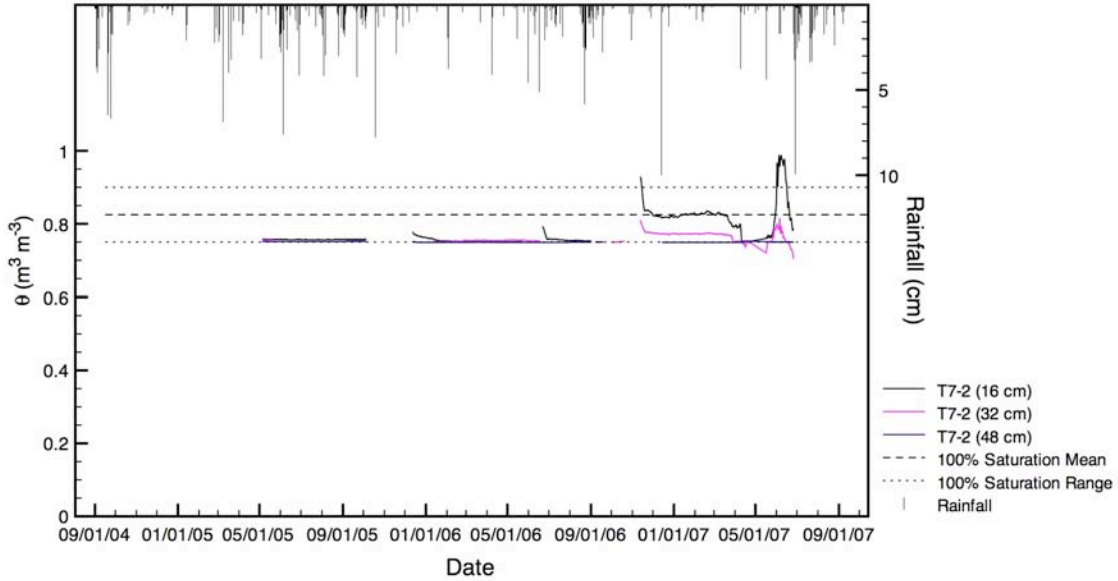


Figure 11. Average daily soil moisture recorded by Hydra probes at Station T7-2.

River Stage - Soil Moisture Relationships

Soil moisture time series developed for each probe are reported as actual (measured) soil moisture (with soil-specific calibrations). However, Mortl et al. (2006) found the three soil categories in the Loxahatchee River floodplain to have widely varying hydraulic characteristics, including wide ranges of bulk density (ρ_b), saturated hydraulic conductivity (K_s), and residual and saturated soil moistures (θ_r and θ_s). Thus, when comparing moisture values across soil categories it is helpful to scale the measured values using effective soil moisture (Θ_e), which ranges from a value of zero at θ_r to 1 at θ_s . Effective soil moisture is calculated by:

$$\Theta_e = \frac{\theta - \theta_r}{\theta_s - \theta_r} \quad (\text{equation 1})$$

where Θ_e is the effective soil moisture content [-], θ is the actual (measured) soil moisture content [m^3/m^3], θ_r is the residual soil moisture content [m^3/m^3], and θ_s is the saturated soil moisture content [m^3/m^3].

Effective soil moisture values were then compared with river stage to create soil moisture versus stage relationships at each transect. Soil moisture in the floodplain versus stage at Lainhart Dam for Transect 1 was fitted to a common model (sigmoid curve, 3 parameters) of the form:

$$\Theta_e = \frac{A}{1 + e^{-\frac{h-b}{c}}} \quad (\text{equation 2})$$

where h is the river stage at Lainhart Dam (m), and A , b , and c are curve parameters (Fig. 12). The A term indicates the maximum effective soil moisture value (equal to 1 in this case, since Θ_e is scaled from 0 to 1); b is indicative of how soon the curve begins increasing; and c is indicative of the slope of the curve. It is important to note that this relationship is in reality a representation of the non-linear variation of water content with matric potential (characteristic curve), expressed for the relative distance between the water table and an observation point. This is valid for short distances and relatively hydrostatic conditions.

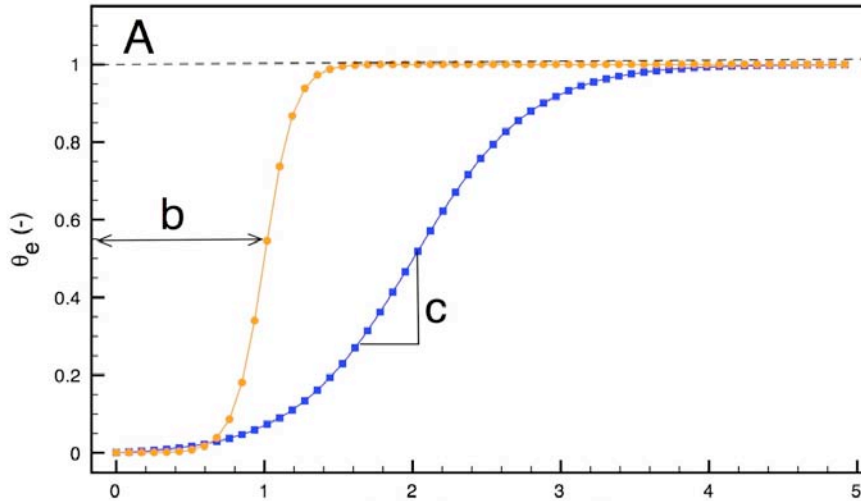


Figure 12. Conceptual model relating river stage and soil moisture.

Relationships between river stage and Θ_e at different depths and distances from the river at Transect 1 are shown in Figure 13. The Nash-Sutcliffe Coefficient of Efficiency (C_{eff}) was used as a measure of goodness of fit for the model. Model parameters (A , b , and c) and NS values are summarized in Table 1. For soils which exhibited a wide range of θ values (shallow and middle-depth sandy soils), the sigmoidal model does a good job of predicting soil moisture based on river stage ($0.72 < c_{eff} < 0.89$). For deeper sandy soils which are below the water table for long periods and for the surface soils of the lower floodplain, which only rarely dry out, the sigmoid model performed fairly ($0.32 < c_{eff} < 0.66$). For soils that were saturated for the entire study period, the three-parameter model is simplified to the equation $y = 1$, independent of river stage (with a corresponding $c_{eff} = 1.0$).

Sigmoid relationships between Θ_e and river stage developed for each location and depth are shown in Figure 14. In general, this figure shows increasingly dry soil moisture profiles as distance from the river and elevation increase, with the widest range of response to river stage occurring in the soils closest to the surface and farthest from the river. At Transect 7, daily tidal flooding resulted in near-constant soil saturation for all probes, however responses to brief periods of drawdown in the shallowest (i.e., highest elevation) probes were evaluated using a Fourier smoothing technique. When mean tide elevation is above probe elevation, smoothing collected data from 15- and 30-minute

readings to a 6-hour time series revealed a close correlation between measured soil moisture and tidal stage data. This relationship ceases to hold as mean tide falls below probe elevation, and measured changes in soil moisture on very small scale (approximately 1-2% between saturation and “drawdown” moisture contents). This phenomenon is demonstrated for the surface probe at Station T7-145 (installed 20 cm bgs at an elevation of 0.37 meters, NGVD) in Figure 15.

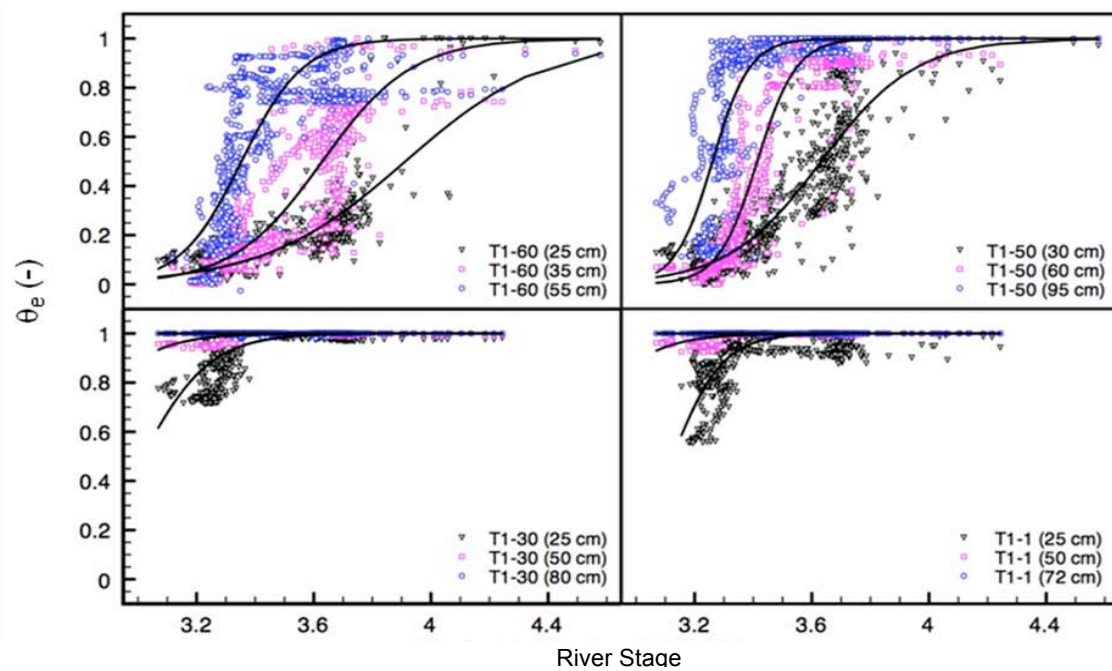


Figure 13. Soil moisture versus river stage for the 12 locations on Transect 1 with sigmoidal curves.

Sensor	A	b	c	NS
T1-60 (25 cm)	1	3.913	0.243	0.72
T1-60 (35 cm)	1	3.629	0.153	0.78
T1-60 (55 cm)	1	3.326	0.055	0.66
T1-50 (30 cm)	1	3.633	0.161	0.84
T1-50 (60 cm)	1	3.414	0.067	0.89
T1-50 (95 cm)	1	3.261	0.063	0.63
T1-30 (25 cm)	1	3.014	0.116	0.42
T1-30 (50 cm)	1	2.749	0.121	0.32
T1-30 (80 cm)	1	--	0.000	1.00
T1-1 (25 cm)	1	3.125	0.086	0.60
T1-1 (50 cm)	1	2.759	0.120	0.42
T1-1 (72 cm)	1	--	0.000	1.00

NS = Nash and Sutcliffe coefficient of efficiency (1970)

Table 1. 1 Model fit parameters and NS coefficients for Transect 1.

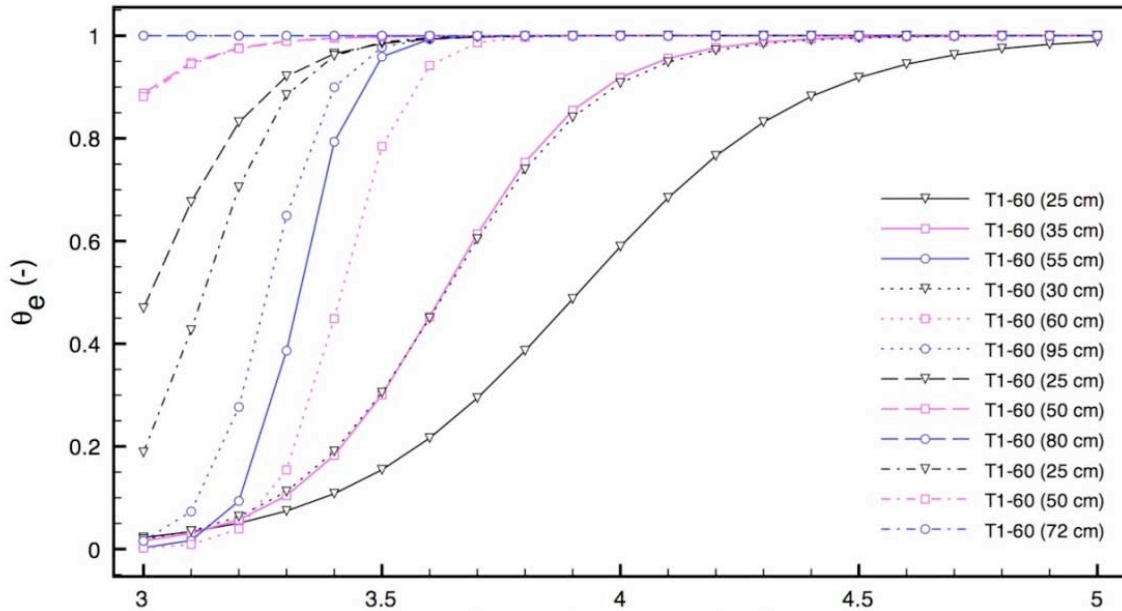


Figure 14. Sigmoidal relationships for all 12 measurement locations on Transect 1.

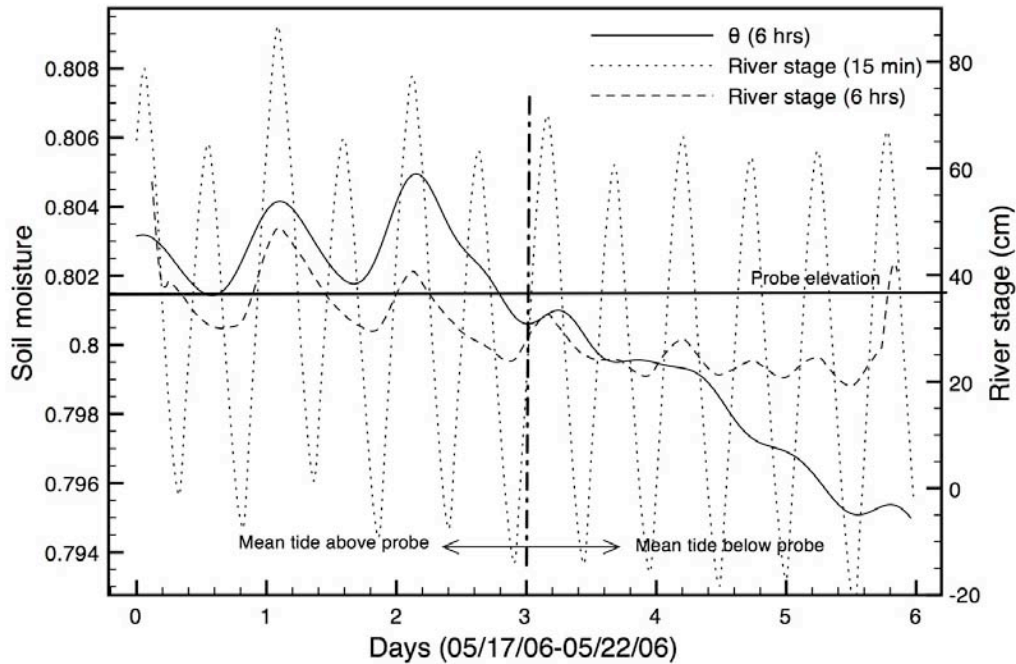


Figure 15. Relationship between river stage and soil moisture at Transect 7.

Salinity (EC) Results

Figure 16 shows the 15-minute and average daily electrical conductivity measured in the Loxahatchee River at River Mile (RM) 9.1 (from USGS Data Station

265906080093500). Peaks in EC occur during periods of low flow and low rainfall, and also vary enormously during the tidal cycle. The dashed line in this figure represents the maximum salinity for maintenance of the health of bald cypress seedlings, 2 parts per thousand (ppt), or approximately 0.3125 Siemens per meter (S/m) (Liu et al., 2007). This value was exceeded for 6, 16, and 51 days, respectively in 2005, 2006, and 2007. Figure 17 shows the relationship between stage measured upstream at Lainhart Dam and average daily salinity measured at RM 9.1 during the entire three-year study period. This figure mirrors figure 6-18 from the Restoration Plan for the Northwest Fork of the Loxahatchee River (SFWMD, 2006), and shows a similar relationship. However, the longer period of record covered in Figure 17 shows a slightly greater range of variability between upstream freshwater flow and downstream average daily salinity.

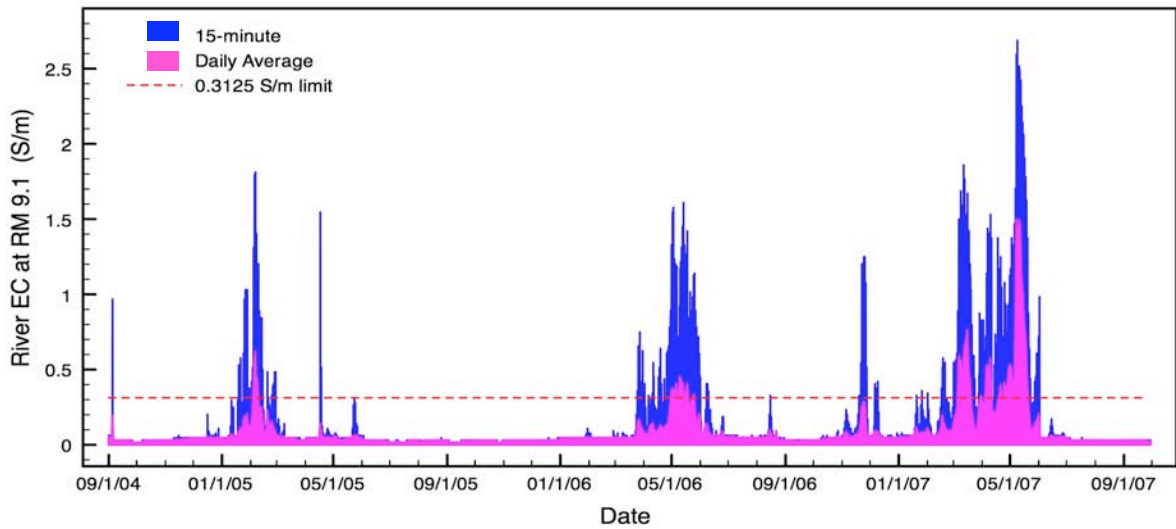


Figure 16. 15-minute and daily average river EC measured at RM 9.1.

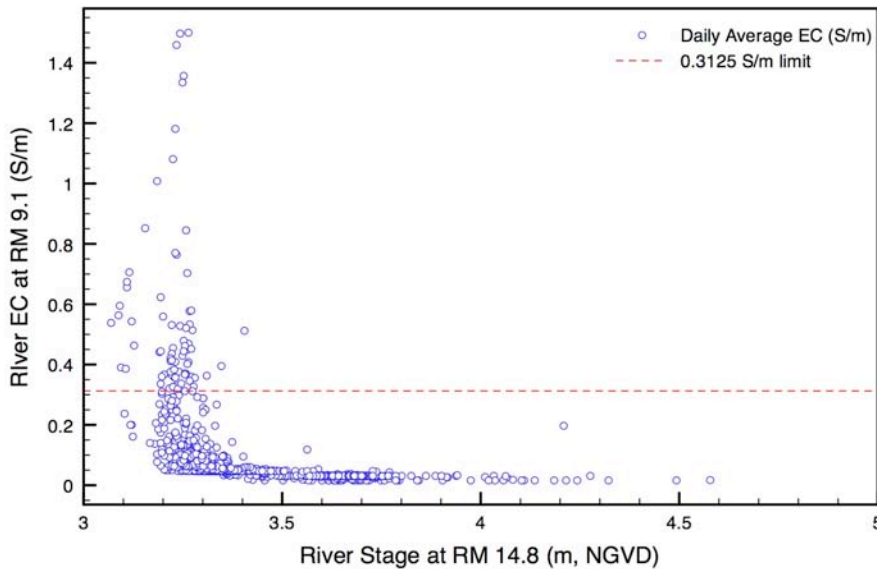


Figure 17. River stage measured at Lainhart Dam versus average daily river EC at RM 9.1.

Figures 18 through 21 show time series of soil porewater EC data collected from Hydra probes at the four stations on Transect 7. Data gaps are due to malfunctions in equipment due to lightning and other environmental conditions in the area. The addition of shallow groundwater sampling wells (data with dotted lines) adjacent to sensor installation locations at Station T7-145 and T7-2 helped to complete the time series for these stations during equipment malfunction and confirm sensor values. The complete chemical analysis from these piezometers is included in a subsequent section of this report.

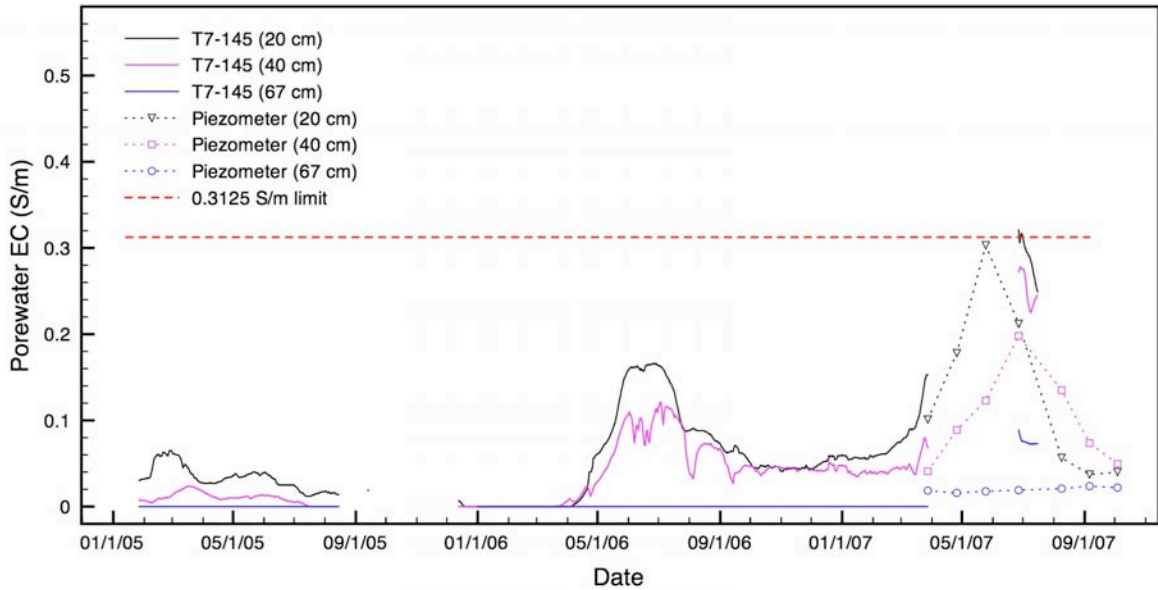


Figure 18. Average daily porewater EC recorded by Hydra probes at Station T7-145 from 1/27/05 - 9/6/07.

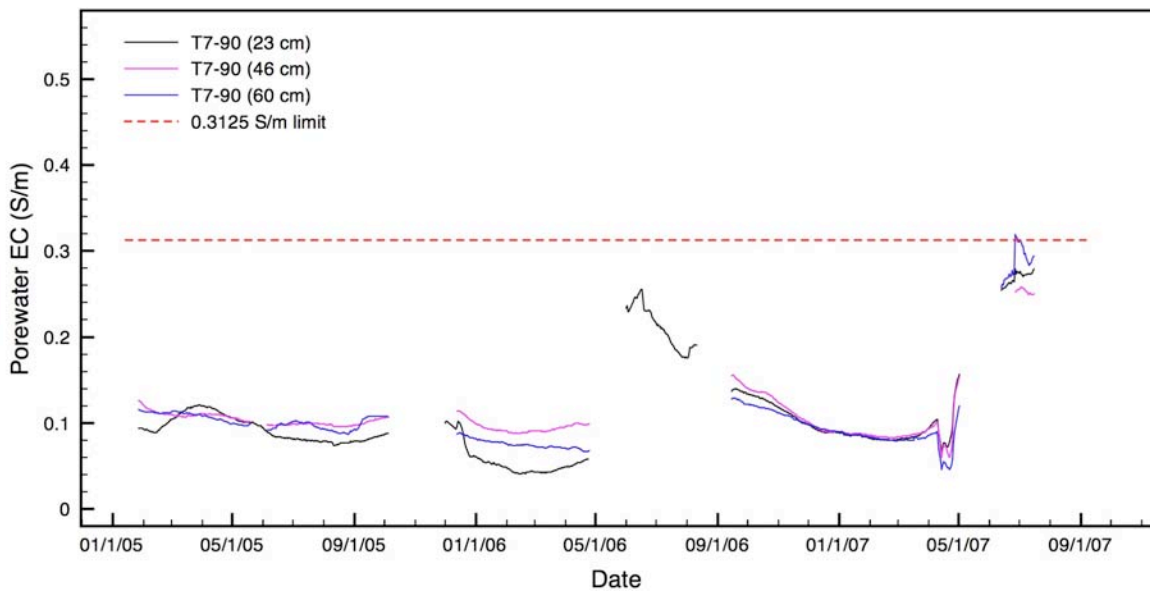


Figure 19. Average daily porewater EC recorded by Hydra probes at Station T7-90 from 1/27/05 - 9/6/07.

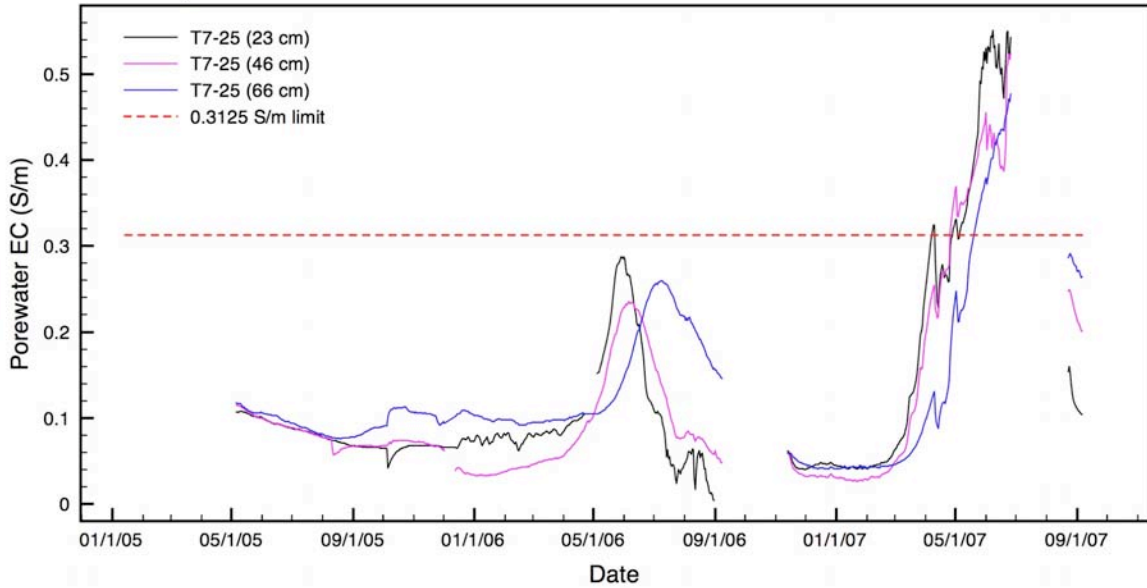


Figure 20. Average daily porewater EC recorded by Hydra probes at Station T7-25 from 5/14/05 - 9/6/07.

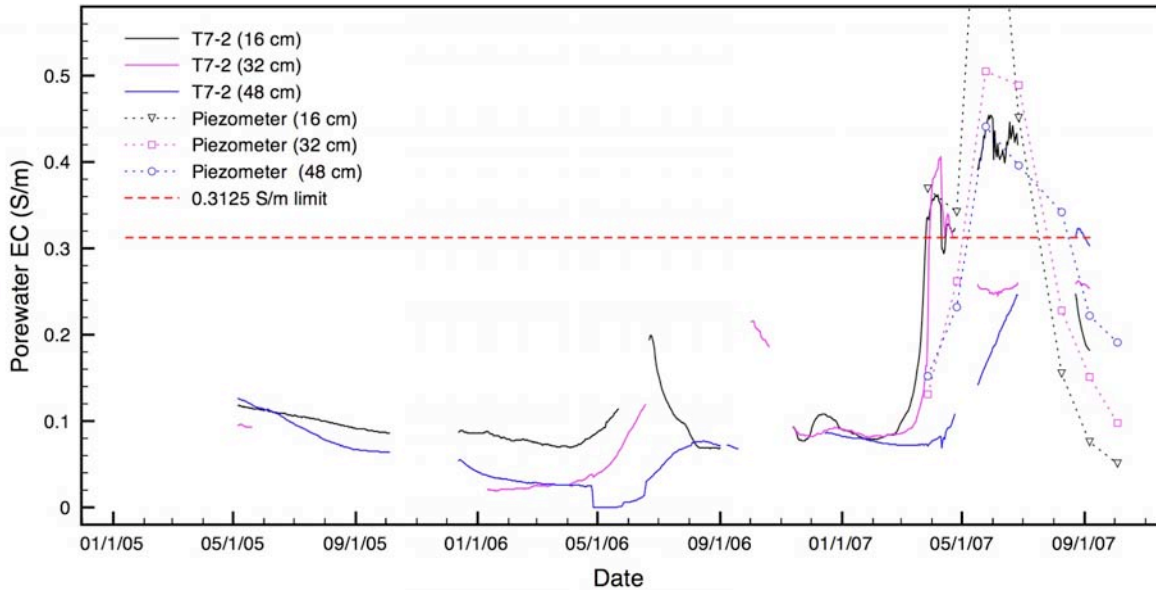


Figure 21. Average daily porewater EC recorded by Hydra probes at Station T7-2 from 5/14/05 - 9/6/07.

In each of the time series, peaks in soil porewater EC can be observed, which mirror the peaks in river EC at RM 9.1 observed during each year's dry season. For Station T7-145 (furthest from the river), these peaks in soil porewater EC have increased in magnitude in each of the study years, but reached the critical limit only in 2007, and only in the most superficial probe (20 cm bgs). For this station, the probe installed 67 cm bgs registered porewater EC values at or very close to zero throughout the measurement period. The time series for Station T7-90 is less complete, but these data resemble those from Station T7-145, with EC values approaching the critical value only in 2007.

Station T7-25 is closer to the river, where the floodplain vegetation begins to change to mangroves. Here the measured porewater EC is higher, exceeding the critical value for a significant time in 2007. From the data recorded at this station, this threshold was exceeded for 53, 55, and 34 days for the three measurement depths (not including any days during gaps due to equipment malfunction). However, from the shape of the existing data, it is likely that missing data from July 2007 would be above this limit at each depth, resulting in an estimate of 83, 85, and 64 days of EC values above the critical threshold in 2007 for the three measurement depths, respectively. Again, data from Station T7-2 is less complete, though piezometer grab samples at this location help to fill data gaps. At this station right on the river, it appears that EC peaks closely mirror those seen at station T7-25, with the threshold salinity exceeded for a significant time between April and late August of 2007. Soil porewater EC may have been above the critical threshold slightly longer here (the available data points to an estimate of approximately 100 – 140 days above the 2 ppt limit), and may have peaked higher than at Station T7-25, as indicated by the piezometer data.

Salinity Relationships – Timing and Magnitude

Beyond the magnitude and duration of salinity peaks observed in the soil porewater, of additional note is the time lag between peaks in river EC and those seen in the soil. These delays range between 22 and 64 days, as summarized in Figure 22 and Table 2. It is also interesting to note that, in 2005, the deepest soils at Station T7-25 show a higher peak in EC than soils at the intermediate depth, and remain at a higher salinity than either the intermediate or superficial soils for an extended period of time. It also appears that these time delays increase with depth and distance from the river. In-depth analysis of this trend (deeper soils, longer delays) is certainly needed, but will require additional observation, hypothesis, and testing. Our current assessment is that as higher salinity water inundates the floodplain during the dry season, movement of salts is dominated by diffusion, rather than advection because the soils are saturated (at Transect 7). Thus, the surface soils see peaks in EC sooner, while these peaks are delayed in middle and lower depth soils as the higher EC front diffuses downward. Reductions in salinity during the wet season proceed in the same manner, with decreases in EC moving from surface soils downward.

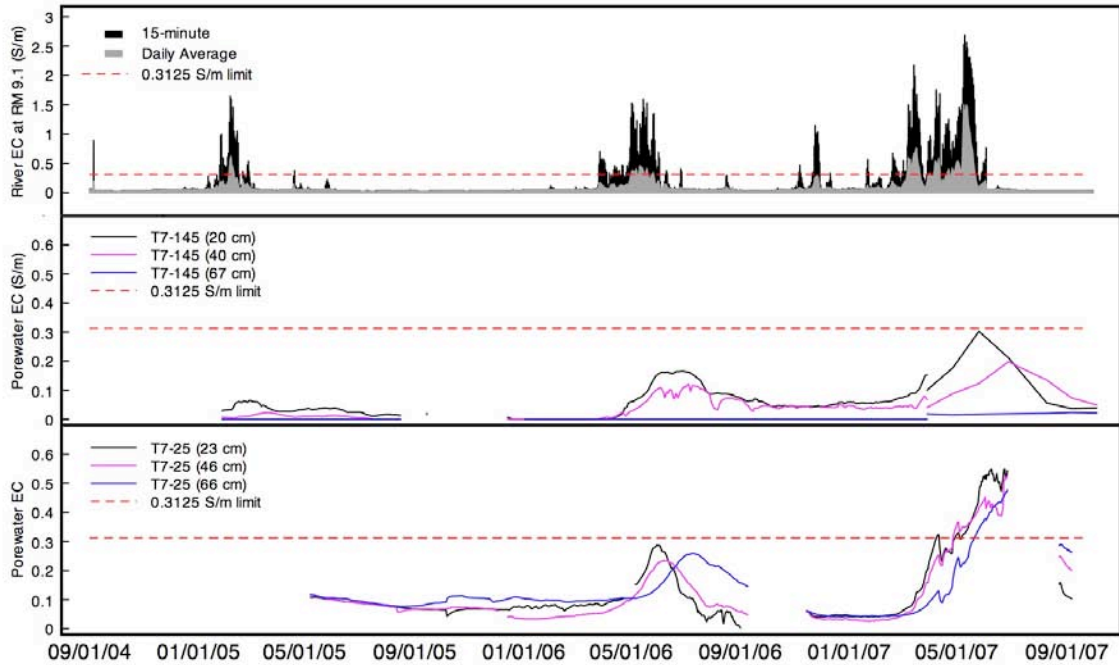


Figure 22. Time series of river EC measured at RM 9.1 and two stations near (25 m) and far (145 m) from the river.

Sensor	2005	2006	2007
T7-145 (20 cm)	22	50	51
T7-145 (40 cm)	41	64	52
T7-145 (67 cm)	---	---	50
T7-145 (23 cm)	---	22	31
T7-145 (46 cm)	---	27	49
T7-145 (66 cm)	---	60	49

Table 2. Time lag (in days) between peaks in river and soil porewater EC at different depths and distances from the river.

It is apparent from the collected data that the soil porewater salinity in the root zone of the floodplain vegetation does not reach the same level as that seen in the river. This trend is summarized in Table 3. While the time series data showed higher peaks in soil porewater EC in drier years (e.g., 2007 vs. 2005), comparison with river EC data suggests that in drier years, the maximum soil porewater EC values observed come closer to (i.e., reach a higher percentage of) the peak values recorded in the river. For example, in 2005 the average maximum porewater EC reached across the transect was only 5% of the maximum EC value recorded in the river (with a range of 0 – 7%). In 2007, this

value increased to 14%, with a range of 3 – 23%. Finally, graphing yearly maximum EC in the river versus yearly maximum EC in the porewater suggests a functional power relationship ($y=Ax^b$) between the two values (Fig. 23 and Table 4), though this relationship is, as of yet, very preliminary. These yearly maxima were used to avoid complications in shorter duration (i.e., month-to-month) comparisons caused by the time delay. To improve the analysis of the seasonal salinity trends clearly visible at Transect 7 it will be necessary to evaluate monthly data based on observed time lags between river and porewater salinity peaks. Relationships with monthly and seasonal maxima, as well as with average daily values to improve the relationships between river and soil porewater salinity are currently under study.

Sensor	Percentage of Max. River EC Reached in Porewater		
	2005	2006	2007
T7-145 (20 cm)	4%	7%	12%
T7-145 (40 cm)	1%	5%	10%
T7-145 (67 cm)	0%	0%	3%
T7-90 (23 cm)	7%	11%	10%
T7-90 (40 cm)	7%	7%	13%
T7-90 (60 cm)	6%	6%	12%
T7-25 (23 cm)	6%	12%	23%
T7-25 (46 cm)	6%	10%	20%
T7-25 (66 cm)	6%	11%	18%
T7-2 (16 cm)	6%	9%	18%
T7-2 (32 cm)	5%	9%	15%
T7-2 (48 cm)	7%	4%	12%
Average	5%	8%	14%

Table 3. Percentage of maximum river EC reached in soil porewater at each of the 12 measurement locations over the three year study period.

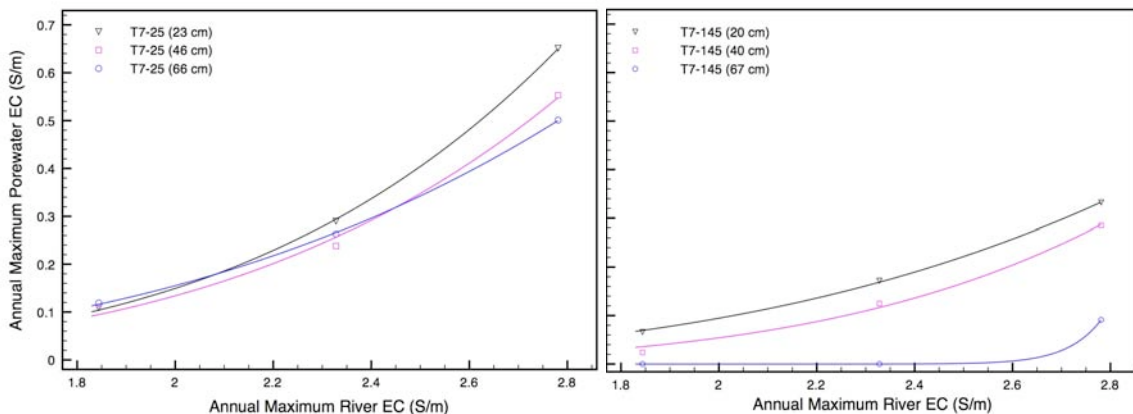


Figure 23. Relationship between maximum annual river EC and maximum annual porewater EC for two stations on Transect 7 located 25 meters (left) and 145 meters (right) from the river.

Sensor	A	b	r ²
T7-145 (20 cm)	0.007	3.819	0.999
T7-145 (40 cm)	0.002	5.064	0.987
T7-145 (67 cm)	1.000E-20	39.995	1.000
T7-90 (23 cm)	0.052	1.730	0.762
T7-90 (40 cm)	0.013	3.168	0.882
T7-90 (60 cm)	0.026	2.430	0.853
T7-25 (23 cm)	0.007	4.460	0.999
T7-25 (46 cm)	0.007	4.276	0.985
T7-25 (66 cm)	0.014	3.554	0.999
T7-2 (16 cm)	0.014	3.419	0.951
T7-2 (32 cm)	0.026	2.156	0.411
T7-2 (48 cm)	0.011	3.532	1.000

Table 4. Coefficients and r² values for functional power relationships (of the form $y=Ax^b$) relating maximum annual river and porewater salinities at each measurement location on Transect 7.

River EC measured at Indiantown Road (close to Transect1) is shown in Figure 24 and remains well below the 0.3125 S/m (2 ppt) threshold for maintenance of bald cypress health. Soil porewater EC in the floodplain at Transect 1 is slightly higher closer to the river (Station T1-1) and is relatively stable for most of the study period, with only the surface probes showing significant variation during the extended dry periods (Fig. 24). Interestingly, porewater salinity here appears to be inversely correlated with measured EC in the river, with increases in river EC coinciding with decreases in porewater salinity, although the relationship is not completely clear. Soil porewater is consistently higher than river EC (by a factor of 2-3), likely due to concentration of salts due to evapotranspiration. On the hydric hammock (Stations T1-60 and T1-50), bulk soil EC (σ_b) never exceeds 0.001 S/m and EC data for these boxes are not shown.

All data presented in this report can be accessed through our on-line database, UF-HydroBase. To access the database visit <http://carpena.ifas.ufl.edu> , select the UF-HydroBase tab and register to enter the system.

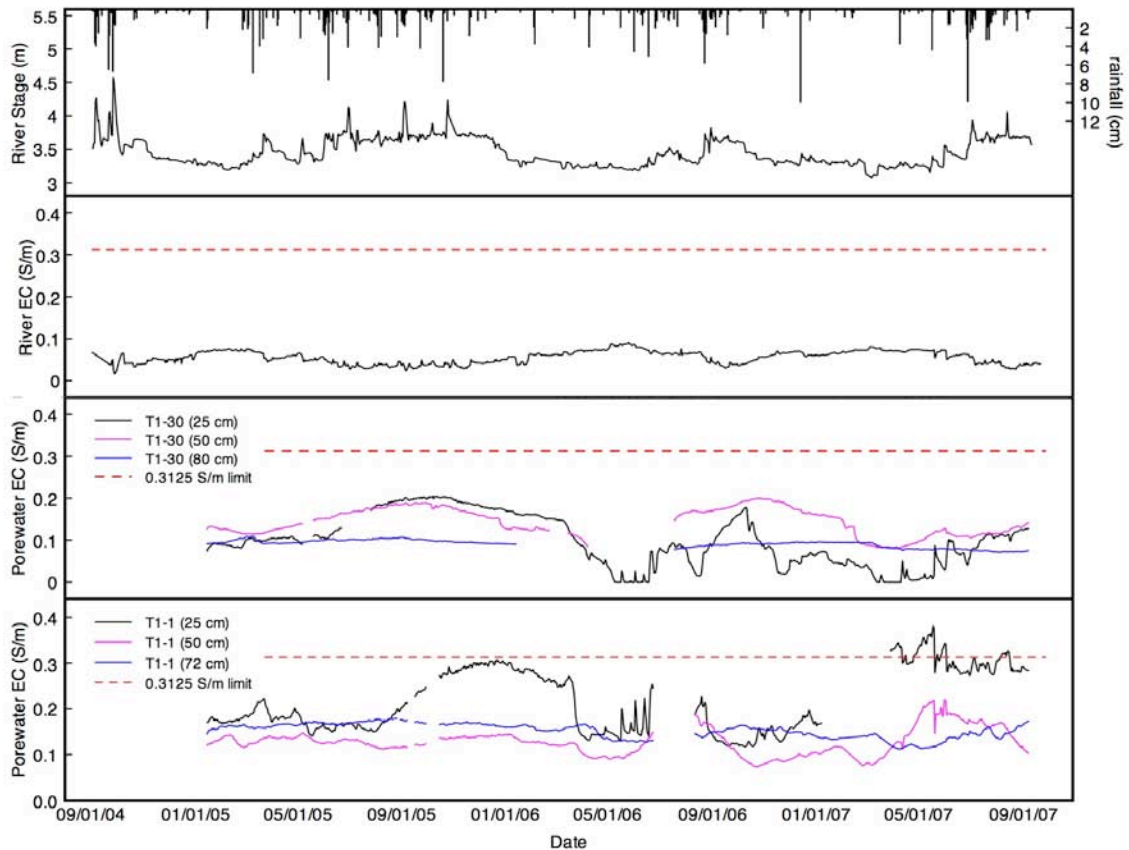


Figure 24. Rainfall, river stage, river EC, and soil porewater EC values recorded at Transect 1.

Task 2.0 Groundwater Piezometer Monitoring

In March 2007, 12 piezometers were installed at sensor locations T1-30 (25 cm, 50, and 80 cm), T1-1 (25 cm, 50cm, and 72 cm), T7-145 (20 cm, 40 cm, and 67 cm), and T7-2 (16 cm, 32 cm, and 48 cm) to validate sensor data and analyze shallow groundwater samples selected constituents. Available results from the monthly groundwater chemical analysis are shown in Table 5. For analytes related to salinity (EC, Cl), similar trends are observed as those seen in sensor readings of porewater EC. Continued collection of these samples will help to clarify any seasonal or yearly trends or relationships.

		Sampling Date				
Parameter	Location	3/28/07	4/26/07	5/25/07	6/27/07	8/9/07
EC (μ S/cm)	KA	1010	1780	3030	2120	572
	KB	409	888	1230	1980	1230
	KC	185	158	177	191	214
	IA	3690	3420	8890	4510	1410
	IB	1310	2620	5050	4890	2120
	IC	1520	2320	4410	3960	3090

	T-7 RIV	957	1620	7910	6920	392
	CA	--	--	--	908	548
	CB	659	759	743	952	796
	CC	226	663	818	905	819
	EA	--	1170	1490	1740	433
	EB	1620	1360	1790	1800	881
	EC	1560	961	1410	1300	117
	T1 - RIV	919	644	692	577	327
pH	KA	6.53	6.44	6.98	6.06	6.98
	KB	6.66	5.89	7.7	5.48	7.11
	KC	6.86	5.9	5.88	4.85	7.36
	IA	7.78	7.04	7.92	6.74	7.65
	IB	8.13	6.91	7.11	6.27	7.25
	IC	7.91	7.17	7.06	6.37	7.55
	T-7 RIV	7.58	7.93	7.93	7.54	7.58
	CA				7.24	7.17
	CB	8.24	7.75	7.73	6.69	6.98
	CC	7.16	7.75	5.86	6.65	7.48
	EA		7.58	7.94	6.77	7.5
	EB	7.74	7.6	7.98	6.79	7.4
	EC	7.73	7.51	7.87	6.89	7.57
	T1 - RIV	8.13	7.51	7.72	7.28	7.52

Sampling Date

Parameter	Location	3/28/07	4/26/07	5/25/07	6/27/07	8/9/07
NH ₄ -N (mg/L)	KA	0.062	0.034	0.135	0.051	0.223
	KB	0.102	0.028	0.201	0.128	0.249
	KC	0.215	0.045	0.503	0.099	0.221
	IA	0.525	0.193	0.578	1.655	0.461
	IB	0.956	0.176	0.693	0.247	0.487
	IC	0.721	0.087	0.657	0.251	0.306
	T7 - RIV	0.023	0.028	0.102	0.047	0.141
	CA	--	--	--	0.625	0.687
	CB	0.724	0.02	0.668	0.269	0.556
	CC	0.65	0.017	0.286	0.118	0.254
	EA	--	0.029	0.488	0.196	0.203
	EB	0.612	0.053	0.42	0.23	0.297
	EC	0.92	0.448	0.387	0.47	0.553
	T-7 RIV	0.044	0.042	0.121	0.118	0.153
NO ₃ -N (mg/L)	KA	0	0.0119	0.1501	0	0.0623
	KB	0	0.0367	0.0966	0.1867	0.0738
	KC	0.0395	0.0361	0	0	0.0978
	IA	0.0869	0.0427	0	0.0172	0.0569
	IB	0.0369	0.0693	0	0	0.1215
	IC	0.1267	0.0548	0.2526	0	0.0747
	T-7 RIV	0.2386	0.0382	0.0254	0.1283	0.1837
	CA	--	--	--	0.3391	0.1695
	CB	0.7026	2.8921	0	0	0.055
	CC	0.0288	0.1412	0.2894	0	0.0774
	EA	--	2.383	0.3989	0.0123	0.1553
	EB	0.2969	1.8142	0.0996	0.085	0.2235
	EC	0.0725	0.2967	0.0254	0	0.0825
	T1 - RIV	0.2615	0.1663	0.1326	0.082	0.1574
PO ₄ -P (mg/L)	KA	0.0081	0.0098	0.0105	0.013	0.0177
	KB	0.0105	0.0095	0.0113	0.0083	0.0056
	KC	0.0122	0.0098	0.0006	0.0089	0.0054
	IA	0.1233	0.0386	0.1903	0.5528	0.4202
	IB	0.6221	0.2322	0.3092	0.194	0.52
	IC	0.0833	0.1184	0.1056	0.1256	0.1124
	T-7 RIV	0.0278	0.0162	0.0355	0.0309	0.0491
	CA	--	--	--	0.0063	0.0083
	CB	0.0089	0.0302	0.0125	0.0066	0.004
	CC	0.0089	0.0109	0.0133	0.0064	0.0047
	EA	--	0.0145	0.0124	0.0062	0.0156
	EB	0.0092	0.0099	0.0114	0.0081	0.0074
	EC	0.0094	0.0091	0.0111	0.0106	0.0055
	T1 - RIV	0.0176	0.0166	0.0107	0.0207	0.0251

Sampling Date

Parameter	Location	3/28/07	4/26/07	5/25/07	6/27/07	8/9/07
TP (mg/L)	KA	0.0096	0.0196	0.0244	0.0340	0.1115
	KB	0.0186	0.0101	0.0183	0.0404	0.1676
	KC	0.0222	0.012	0.0181	0.0289	0.1465
	IA	0.6715	0.1396	0.2493	0.7921	0.5695
	IB	0.6264	0.2429	0.4269	0.193	0.7705
	IC	0.1755	0.127	0.1444	0.1229	0.1895
	T-7 RIV	0.0342	0.0373	0.0393	0.0692	0.089
	CA	--	--	--	0.3586	0.2318
	CB	0.0947	0.0447	0.0247	0.088	0.348
	CC	0.0398	0.0453	0.0921	0.0551	0.1362
	EA	--	0.0608	0.1467	0.0436	0.191
	EB	0.0146	0.0205	0.0376	0.045	0.1554
	EC	0.0323	0.0141	0.0583	0.1606	0.3347
	T1 - RIV	0.0163	0.0260	0.0324	0.0391	0.0405
Br	KA	1.319	5.112	8.474	2.043	0.472
	KB	0.000	0.837	1.690	2.969	1.201
	KC	6.378	0.116	0.298	0.171	0.218
	IA	8.690	11.640	16.580	4.554	2.922
	IB	2.210	2.994	10.716	7.652	2.174
	IC	2.335	3.748	11.658	8.564	3.452
	T-7 RIV	2.493	5.999	3.055	1.459	0.267
	CA	--	--	--	1.026	1.413
	CB	0.000	0.000	0.000	0.425	0.155
	CC	1.047	2.047	3.392	0.105	0.452
	EA	--	0.000	0.000	5.844	0.991
	EB	3.551	3.324	0.000	2.453	0.561
	EC	0.245	3.747	7.842	1.933	0.729
	T1 - RIV	0.234	1.638	2.290	1.171	0.240
SO4	KA	85.22	118.61	199.46	39.89	2.93
	KB	10.64	52.05	44.12	23.28	5.18
	KC	0.00	2.62	0.65	1.05	1.27
	IA	140.02	155.99	89.87	26.42	10.70
	IB	13.35	78.43	29.58	104.18	14.59
	IC	27.30	58.11	26.58	66.49	22.26
	T-7 RIV	40.62	120.70	59.97	36.56	20.79
	CA	--	--	--	41.36	7.47
	CB	34.16	129.19	0.00	13.91	5.00
	CC	0.75	56.95	92.70	4.79	0.57
	EA	--	173.64	534.84	168.27	13.27
	EB	121.87	240.36	503.40	199.42	34.21
	EC	7.10	14.13	106.90	18.58	9.22
	T1 - RIV	26.44	34.69	39.25	20.72	11.28

Parameter	Location	Sampling Date				
		3/28/07	4/26/07	5/25/07	6/27/07	8/9/07
Cl	KA	327.0	632.8	1641.6	704.0	208.1
	KB	111.1	326.5	670.7	675.0	530.5
	KC	49.7	54.6	67.6	63.9	99.9
	IA	1193.9	1466.7	1250.7	1306.7	470.5
	IB	338.3	920.3	784.0	1484.6	780.5
	IC	397.6	851.6	634.8	1289.4	1212.6
	T-7 RIV	200.7	648.4	176.1	110.1	69.8
	CA	--	--	--	67.0	64.8
	CB	58.3	88.4	0.2	50.0	53.1
	CC	43.7	79.1	76.2	41.6	57.1
	EA	--	214.5	362.4	230.4	72.0
	EB	152.4	192.2	346.2	229.6	131.4
	EC	112.8	139.4	187.4	126.3	166.3
T1 - RIV	99.0	133.7	131.0	77.5	65.4	
F	KA	0	0.1539	0.0503	0	0.2577
	KB	0.0612	0.054	0	0	0.1774
	KC	0.1173	0.0713	0.0472	0	0.6244
	IA	0.3014	0.2394	0.2469	0.5624	0.828
	IB	0.6269	0.2551	0.2708	0.1557	0.365
	IC	0.7021	0.2795	0.2378	0.1723	0.4675
	T-7 RIV	0.2543	0.2665	0.2973	0.1914	0.1461
	CA	--	--	--	0.3735	0.4858
	CB	1.1195	0.1869	0	0.2172	0.2546
	CC	0.1255	0.2577	0.2606	0.208	0.2135
	EA	--	0.437	0.5033	0.2915	0.1637
	EB	0.5866	0.3475	0.544	0.3146	0.4736
	EC	0.46	0.4003	0.602	0.3999	0.3853
T1 - RIV	0.9507	0.1998	0.2346	0.1621	0.2034	

Table 5. Summary of groundwater piezometer data. '--' indicates a dry well (no sample taken).

FUTURE RESEARCH

Building on the work previously accomplished, a third phase of this work is needed to better characterize the full range of hydroecological conditions in the floodplains of the Loxahatchee River. To achieve this future work should focus in the following aspects:

- a. Continuing collection of soil moisture and soil porewater salinity data over a multi-season study period.
- b. Continuing collection of shallow groundwater samples for chemical analysis.
- c. Integrating University of Florida data collection with other available data (surface, groundwater, vegetation, etc.) for further analysis and modeling
- d. Re-evaluation on of the existing Loxahatchee management scenarios in view of the new response functions obtained in this study (floodplain hydroperiod and salinity vs. river and rainfall scenarios).

It is important to recognize that although the work presented here is self-contained, assessment of annual and multi-season variability that is critical to understand the bald cypress floodplain environment and response to environmental stressors will only be achieved by extensions of this project in subsequent years. Similarly, the integration and modeling of these responses will be greatly improved the longer the experimental record is available.

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