Floodplain Forest and Instream Woody Habitat Data Analysis to Support MFL Development for Wakulla, Sally Ward, and the St. Marks River Rise Springs Systems

Submitted to the Northwest Florida Water Management District

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Executive Summary

The Northwest Florida Water Management District (District) is developing minimum flows and levels (MFLs) for the St. Marks River Rise, Wakulla Springs, and Sally Ward Spring to address protection of these water resources under Florida's Water Resources Act, enacted in 1972. The purpose of this study was to characterize the floodplain and instream woody habitats along the Wakulla and St. Marks rivers below the three springs and provide potential floodplain and instream metrics (e.g., elevations) on which MFLs may be established. Vegetation and soils were sampled along 19 forested floodplain transects and woody instream habitat features were sampled along six instream transects in the river corridors. Vegetation in the estuarine/tidal marsh portion of the river was characterized using aerial photography and four field verification transects. Elevations of floodplain and instream transects were surveyed. Results of this study indicate elevations can be a good predictor of vegetation classes on these rivers and that vegetation, elevations, and soils differ significantly both within and between rivers. Consequently, metrics used to establish MFLs may also be different for these two systems. Previous studies have characterized plant communities at specific locations along these rivers or described riverine forests in general for northwest Florida; this study may be the first quantitative analysis of vegetation and soils in these river corridors.

Elevations and Soils. Soils and elevations varied considerably between the Wakulla and St. Marks rivers. Average elevations (NAVD) reflect upstream-downstream gradients more than river channel to upland elevation gradients.

- Wetland soils sampled along Wakulla River transects were almost exclusively mucky mineral (90 percent) and seasonal high saturation (SHS) in soils was typically at the land surface. The river channel bottom declined a total of 6.35 feet from the most upstream to the most downstream transect. Average change in elevation along Wakulla River transects, from river channel to upland, was 1.76 feet. Mean elevations (feet NAVD) of vegetation classes ranged from 1.70 (tupelo hardwood swamp) to 5.07 (tupelo cypress hardwood mix).
- The St. Marks River wetland soils were characterized by a substantial proportion of sandy or clayey/ loamy hydric soils (35 percent of samples) rather than mucky mineral soils. The decline in elevations (upstream to downstream) along the channel was 23.08 feet. Changes in elevation along transects averaged 4.20 feet. Mean elevations (feet NAVD) of vegetation classes ranged from 1.95 (tupelo hardwood) to 10.04 (ironwood hammock).

Vegetation Classes. Importance Values (IVs) were calculated for wetland tree species and provided an estimate of the relative dominance of plant species within a vegetation class (or plant community) as well as a means of comparing vegetation classes. Trees were selected as indicator species of floodplain habitats because they are long-lived and integrate long-term hydrologic conditions better than shrubs or herbaceous plants. Differences between vegetation classes corresponded to a transition from swamp vegetation classes with greater depth and duration of inundation (i.e., "wetter") at the river channel to hammock vegetation classes characterized by shorter depth and duration of inundation (i.e., "drier") nearer the upland extent of the floodplain. These differences between vegetation classes can be related to elevations, which in turn can be used as metrics to establish MFLs that are protective of floodplain vegetation along the rivers.

- Five vegetation classes were identified along the Wakulla River: tupelo cypress swamp, tupelo hardwood swamp, bay hardwood hammock, tupelo cypress hardwood mix, and hardwood hammock. Obligate wetland species accounted for more than 70 percent of the relative importance (based on IV) in four of the five vegetation classes. Swamp tupelo (*Nyssa sylvatica* var. *biflora*) was the single most dominant (IV=83) tree species on the Wakulla River, followed by several obligate wetland species of lesser dominance, such as pumpkin ash (*Fraxinus profundus*, IV=44), swamp bay (*Persea palustris*, IV=43), and bald cypress (*Taxodium distichum*, IV=31).
- Six vegetation classes were identified along the St. Marks River: tupelo bay swamp, cypress hardwood mix, tupelo hardwood mix, ash swamp, hardwood hammock, ironwood hammock. Only two of six vegetation classes included more than 70 percent obligate wetland species and no single species had conspicuously greater dominance than other species. Instead, relative importance was shared among several co-dominants with similar IVs, including both bald (IV=45) and pond (IV=53) cypress, swamp bay (IV=43*)*, swamp tupelo (IV=54), and both pumpkin (IV=24) and pop (F. *caroliniana*, IV=23) ash. The single most common tree in sample plots on the St. Marks River was ironwood (*Carpinus caroliniana*), a facultative wetland species.

Relationships among Vegetation, Soils, and Elevations. Discriminant function analysis (DFA) was used to develop statistical models of vegetation classes as a function of the following environmental variables: land surface elevation (ft. NAVD), elevation (feet) relative to channel bottom, elevation (feet) relative to edge of water (EOW), distance to river channel, depth to SHS, soil condition (hydric/nonhydric, mineral/organic). The models were evaluated by assessing their ability to correctly predict vegetation classes. Although vegetation classes were distinct in terms of IVs, DFA results suggest relationships between vegetation classes and soil and elevation parameters were stronger for the St. Marks River than for the Wakulla River, likely due to larger elevation differences along transects and from upstream to downstream on the St. Marks River.

- Elevations (NAVD) and distance to river were significant ($p<0.001$) in distinguishing between vegetation classes along the Wakulla River and elevation relative to channel bottom was significant at a $p=0.10$ value. In other words, vegetation classes were successfully identified based only environmental variables. The number of correct vegetation classifications was greatest for tupelo cypress swamp (75 percent), followed by tupelo cypress hardwood mix (71 percent), bay hardwood hammock (63 percent), tupelo hardwood swamp (33 percent), and hardwood hammock (29 percent).
- Elevation (NAVD) relative to channel bottom and EOW, and soil type were significant ($p<0.05$) in predicting vegetation classes along the St. Marks River. Vegetation classes were correctly classified 50 percent of the time for ash swamp and tupelo hardwood mix, 60 percent for hardwood hammock, 75 percent for cypress hardwood mix and ironwood hammock, 79 percent for tupelo hardwood mix, and 100 percent for the tupelo bay swamp, with the greatest overlap with other classes occurring in the hardwood hammock class.

Instream Woody Habitats. Elevations relative to channel bottom were measured for dead woody debris (DWD) and live roots as a metric for instream woody habitat. Average elevations for woody debris and root snags were 0.50 feet and 1.10 feet below water surface, respectively, in the Wakulla

River, and 0.11 feet above and 0.45 feet below water surface, respectively, in the St. Marks River. Variability in elevations among these features was small, suggesting DWD and root snags may provide a habitat for aquatic invertebrates and fishes in both rivers.

Estuarine Vegetation. Estuarine vegetation along the lower St. Marks River was characterized using aerial photography and field verification. About halfway between the confluence of the St. Marks and Wakulla rivers and the mouth of the river, vegetation shifted from freshwater and low salinity (typically no more than 5 ppt) sawgrass (*Cladium jamaicense*) marsh with interspersed black needle rush *(Juncus roemerianus*) to black needle rush marsh. Salt marsh cordgrass (*Spartina alterniflora*) became prevalent along the river bank farther downstream, approximately three-quarters of the way between the rivers' confluence and the river mouth. Tracking the upstream and downstream extent of these species can provide a metric for shifts in locations of marsh types (e.g., saltmarsh, freshwater marsh) under altered flow regimes.

Conclusions

Results of floodplain and instream data analysis indicated significant differences in vegetation, soils, and elevations, both within and between the Wakulla and St. Marks rivers. Along the St. Marks River, elevation changes from upstream to downstream and river channel to upland were greater, differences in vegetation classes were more strongly correlated with elevations, and overlap among vegetation classes was less, when compared with the Wakulla River. The Wakulla River had greater similarity in vegetation classes and less variability in soils and elevations among vegetation classes. Results also suggest that the tupelo cypress and tupelo hardwood swamps along the Wakulla River and the tupelo bay swamps along the St. Marks River have greater depth and duration of inundation (i.e., are "wetter") than other vegetation classes examined, and, elevations for these forest classes may serve as metrics on which to establish minimum flows protective of floodplain habitats for each river and commensurate changes in wildlife value. Instream woody habitat features also corresponded to specific elevation ranges in both river channels and provide another potential resource on which to establish MFLs.

Vegetation and instream woody habitat may change under altered flow regimes. For example, reducing inundation in swamp (e.g., tupelo swamp) vegetation classes to less than six to eight months per year may result in a shift from obligate to facultative wetland species and cause potential invasion by nonnative and/or invasive species. Similarly, reduced freshwater flows can result in increased salinities farther upstream and increased upstream distribution of saltmarsh species. Future efforts will include development of surface and groundwater flow models, a hydrodynamic analysis of the estuarine portion of the system, and an analysis of the baseline flows in the rivers that will be used in establishing MFLs for St. Marks River Rise, Wakulla Springs, and Sally Ward Spring.

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1 PURPOSE

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

The purpose of this study was to characterize relationships among vegetation, soils, and elevation in wetlands and instream woody habitats along the St. Marks and Wakulla rivers in support of establishment of MFLs for Wakulla and Sally Ward springs and the St. Marks River Rise (Figure 1). Given the assumption that vegetation is the best and most easily measured "integrator of environmental and landscape conditions" (Light et al. 1993, Bedford 1996), vegetation, soils, and elevations will be used to provide information the Northwest Florida Water Management District (District) to establish MFLs and protect the ecology and natural systems of these waterbodies.

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

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

Data were collected along forested floodplain and instream woody habitat transects along the St. Marks and Wakulla river corridors to support modeling and/or analysis to be used in development of MFLs for the St. Marks River Rise, Wakulla Springs, and Sally Ward Spring system, consistent with the conceptual approach developed in the District's Work Plan (Figure 1). The conceptual model illustrates the approach for MFLs and provides context for floodplain and instream woody habitat evaluations. In this approach, fish passage requirements are shown as a likely "water resource value" (per Chapter 62-40.473, F.A.C.), or metric, for determining acceptable reductions in low springs flows that typically during the dry season. Floodplain inundation of vegetation communities may provide a metric for determining allowable reductions in high spring flows that typically occur during the wet season. The frequency of inundation of instream woody (snag) habitat may provide a metric between the dry season and wet season conditions.

Data were analyzed to characterize the vegetation, soils, and/or elevations associated with dominant forested floodplain communities and instream woody habitat in both river corridors and used to define metrics for selected water resource values (i.e., fish and wildlife habitat).

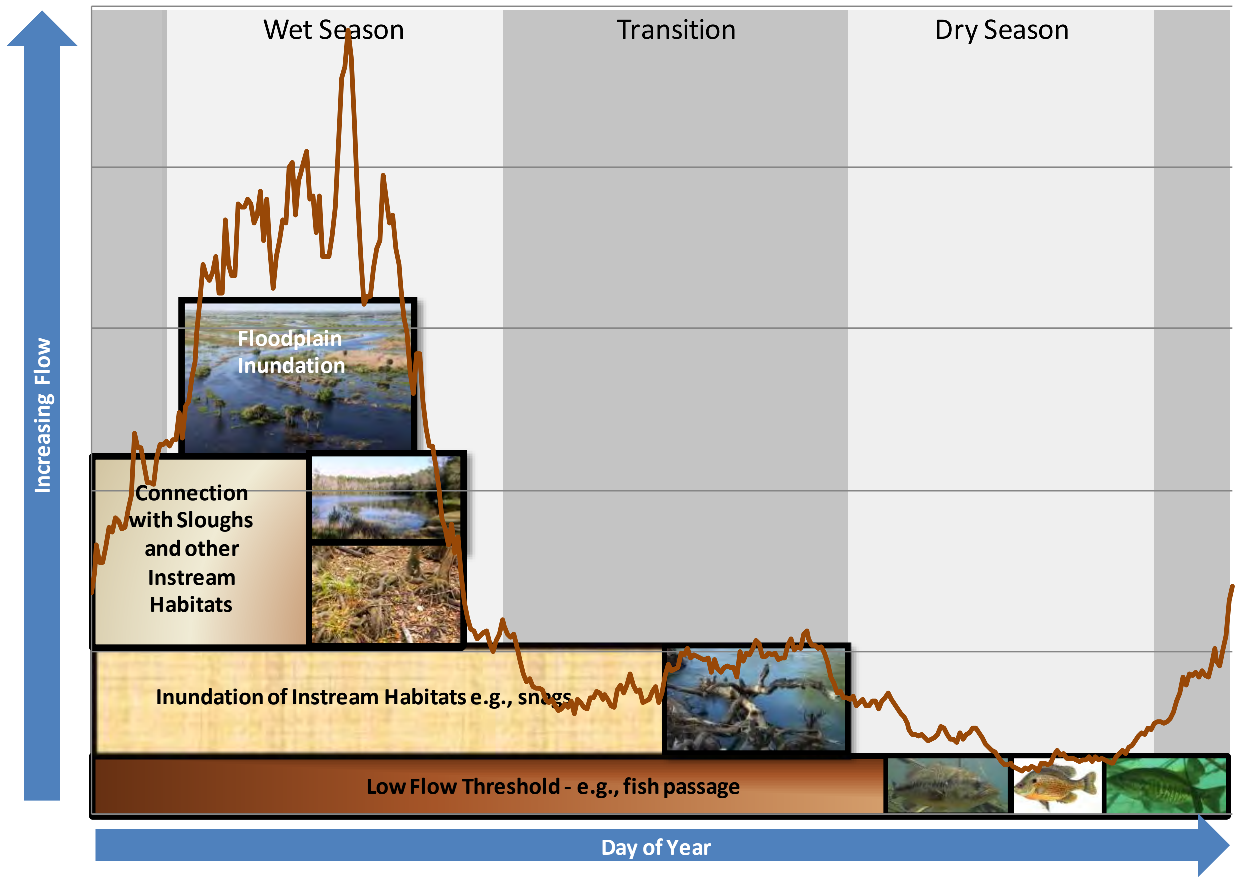

Figure 1. Conceptual approach to developing minimum flows for seasonal blocks illustrating the use of different resource targets for different times (e.g. wet and dry season) of the year.

The analyses presented here correspond to tasks 5.3 and 5.4 in the District's MFL Work Plan (June 2014). The tasks accomplished under this work order are summarized below.

- Task 1. Develop relationships among elevation and floodplain habitat for each of the two river corridors
- Task 2. Develop relationships among elevation and instream woody habitat for each of two river corridors

2 Study Area

The St. Marks River Rise, Wakulla, and Sally Ward springs are within the St. Marks River watershed, which includes about 1,170 square miles in Georgia and Florida, from about Thomasville, Georgia, south to Apalachee Bay (Lewis et al. 2009). The St. Marks River begins in eastern Leon County and flows 36 miles south through Leon and Wakulla counties into Apalachee Bay in the Gulf of Mexico (Figure 2). Wakulla and Sally Ward springs flow into the Wakulla River, which flows into the St. Marks River about three miles upstream of the Gulf of Mexico.

Approximately 93 percent of the St. Marks River watershed is above Natural Bridge Rise where the river drops below land surface into a swallet. The river re-emerges approximately a half mile south at the St. Marks River Rise, a first magnitude spring with average discharge above 100 cubic feet/second (cfs). While the river continues to receive additional flow in the lower reaches, most of the flow to the river above the confluence with the Wakulla River is due to ground and surface water input from above the Rise. The estimated baseflow contribution to the St. Marks River below the rise is about 77 percent of the river flow (Lewis et al. 2009). Flows from Wakulla Springs and the St. Marks River Rise accounted for a combined mean daily discharge of 1,097 cfs for the period of record (May 1997 to June 2009).

The Wakulla River is the main tributary to the St. Marks River and originates in northern Wakulla County at Wakulla Springs, flowing south approximately 10 miles before joining the St. Marks River at the City of St. Marks. In addition to the main spring vent that discharges an average 623 cfs (about 291 mgd), 28 additional springs proximate to the river discharge directly or through spring runs into the river (Barrios 2006). The combined discharge of these smaller springs represents a small percentage of the Wakulla River flow. Sally Ward Spring has a short spring run that enters the Wakulla River just downstream of Wakulla Spring in the Wakulla Springs State Park and has a median flow of approximately 17 cfs. In addition to being a popular recreation spot, Wakulla Springs was the location for much of the underwater filming in the Johnny Weissmuller movies Tarzan's Secret Treasure (1941), Tarzan's New York Adventure (1942), and Airport 77 (Florida Department of State 2014).

The District's Lower St. Marks River/Wakulla River/Apalachee Bay Characterization (Lewis et al. 2009) and a technical memorandum prepared for the District by Interflow Engineering LLC (2015), provide descriptions of the ecology and hydrogeological characteristics of the study area and are the basis of the description presented here. The groundwater contribution zone of the Wakulla and St. Marks rivers is more than twice as large as the surface watershed, totaling 2,400 square miles, and demonstrating the large contribution of groundwater to regional surface water flows. The Cody Scarp, referred to as "the most persistent topographic break in the state", marks the transition from the Tallahassee Hills to the coastal regions of the Gulf Coastal Lowlands (Torak et al. 2010). Karst features become more numerous in southern Leon County and Wakulla County as the confining unit over the Upper Floridan aquifer shifts from semi-confined in the Tallahassee Hills to unconfined (100 feet or absent confining unit) south of the Cody Scarp and onto the Woodville Karst Plain. The District reports "Approximately 42 sinkholes north of the Cody Scarp … identified and mapped by state and local agencies with about 232 sinkholes and 66 springs mapped below the scarp" (Lewis et al. 2009), emphasizing the importance of groundwater to these systems.

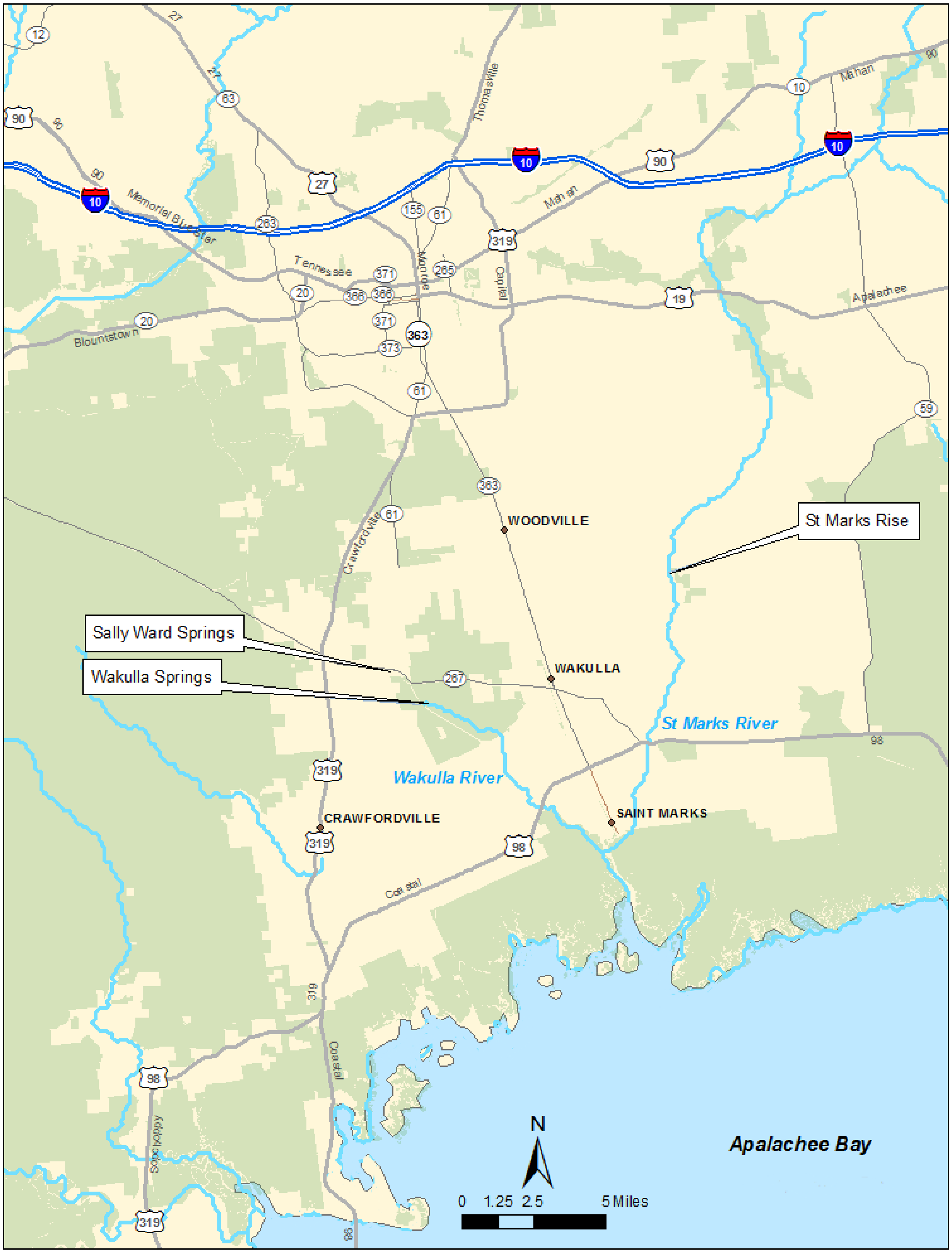

Figure 2. Location of St. Marks River Rise, Sally Ward Spring, and Wakulla Springs.

3 METHODS

Sampling methods for this study were designed to provide data needed to characterize the floodplain wetlands and instream woody habitat along the upper Wakulla and St. Marks rivers and the estuarine portion of the lower St. Marks River. The methods used in transect selection and vegetation and soil data collection are summarized here and detailed in the Technical Memorandum: Floodplain and Instream Sampling (RPI 2015) document provided to the District (hereafter referred to as the 2015 Technical Memorandum). Twenty-three transects, including four estuarine transects, were selected along the St. Marks and Wakulla rivers (Figure 3). Six instream transects were also sampled. Statistical analysis was performed to determine if environmental variables, such as elevation, could be used as predictors of vegetation classes along floodplain transects.

3.1 FLOODPLAIN VEGETATION AND SOILS

Vegetation classes, plant species metrics, soil characteristics, and elevations were sampled along eight transects along the Wakulla River (W1-W8, Figure 4), 11 transect along the St. Marks River upstream of its confluence with the Wakulla River (SM1-SM11, Figure 5). Four transects along the lower St. Marks River, below the confluence of the Wakulla and St. Marks rivers (E1-E4, Figure 6) were established and characterized via aerial photography and field verification

Transect Selection

Transect selection was based on mapping and evaluation of relevant data and selection of representative vegetation communities/classes for floodplain sampling. Several data layers were acquired from the NWFWMD (Karen Kebart), the Florida Geographic Data Library (FGDL), Natural Resource Conservation Service (NRCS), FEMA, and ESRI. Data layers included vegetation classifications and cover (NWI 2014, FDEP 2009), roads (Tiger Roads 2011), hydric soils (NRCS 2004), LiDAR elevations data from the District's website (http://www.nwfwmdlidar.com/), 100-year floodplain boundaries (FEMA 2014), and aerial photography (ESRI 2015). Data were mapped and reviewed for consistency with floodplain extent, e.g. FEMA 100-year floodplain boundaries layered with NWI wetlands and NRCS (2004) hydric soils, to develop a study corridor for sampling. Shoal locations and FEMA map data were provided by the District.

Vegetation classes were first mapped using NWI classification codes that include national wetland classification system map units and codes (Cowardin *et al*. 1979) corresponding to habitat types (Table 1 and Table 2). For example, PFO6C is a palustrine forested system with deciduous tree species (6) and is seasonally flooded (C). Initial transects included:

- Wakulla River. Transects were selected that included NWI classes covering 95 percent of wetlands cover in the floodplain. The remaining five percent included 14 vegetation classes.
- Upper St. Marks River. Transects were selected that included NWI classes covering 95 percent of the wetlands classes. The remaining five percent included 15 other vegetation classes. An emergent vegetation class was omitted from further consideration due to small area (less than 16 acres in the floodplain), and scattered distribution of polygons.
- Lower St. Marks River. Nearly exclusively (77 percent) estuarine intertidal emergent marsh.

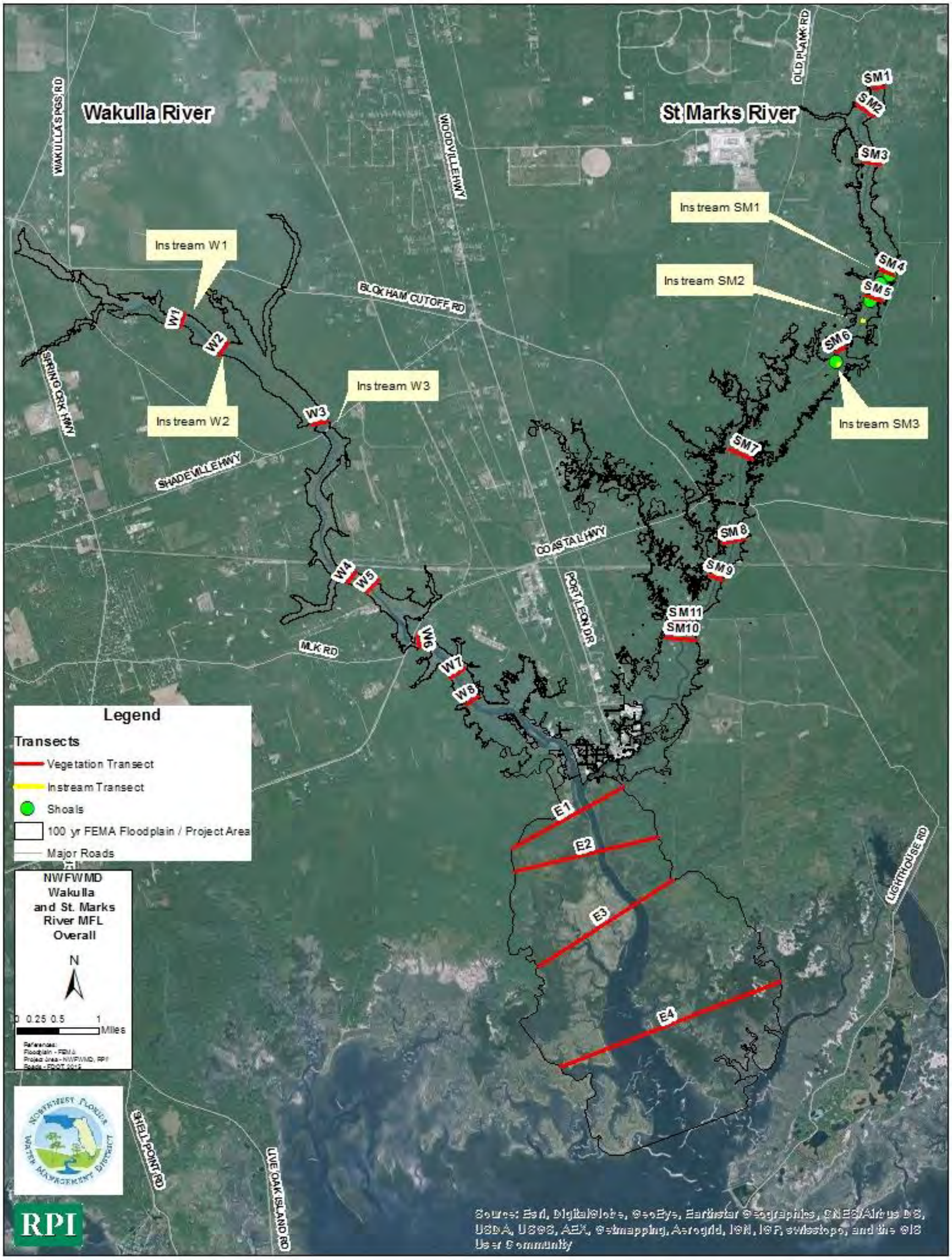

Figure 3. Sampling transect locations along the St. Marks and Wakulla rivers.

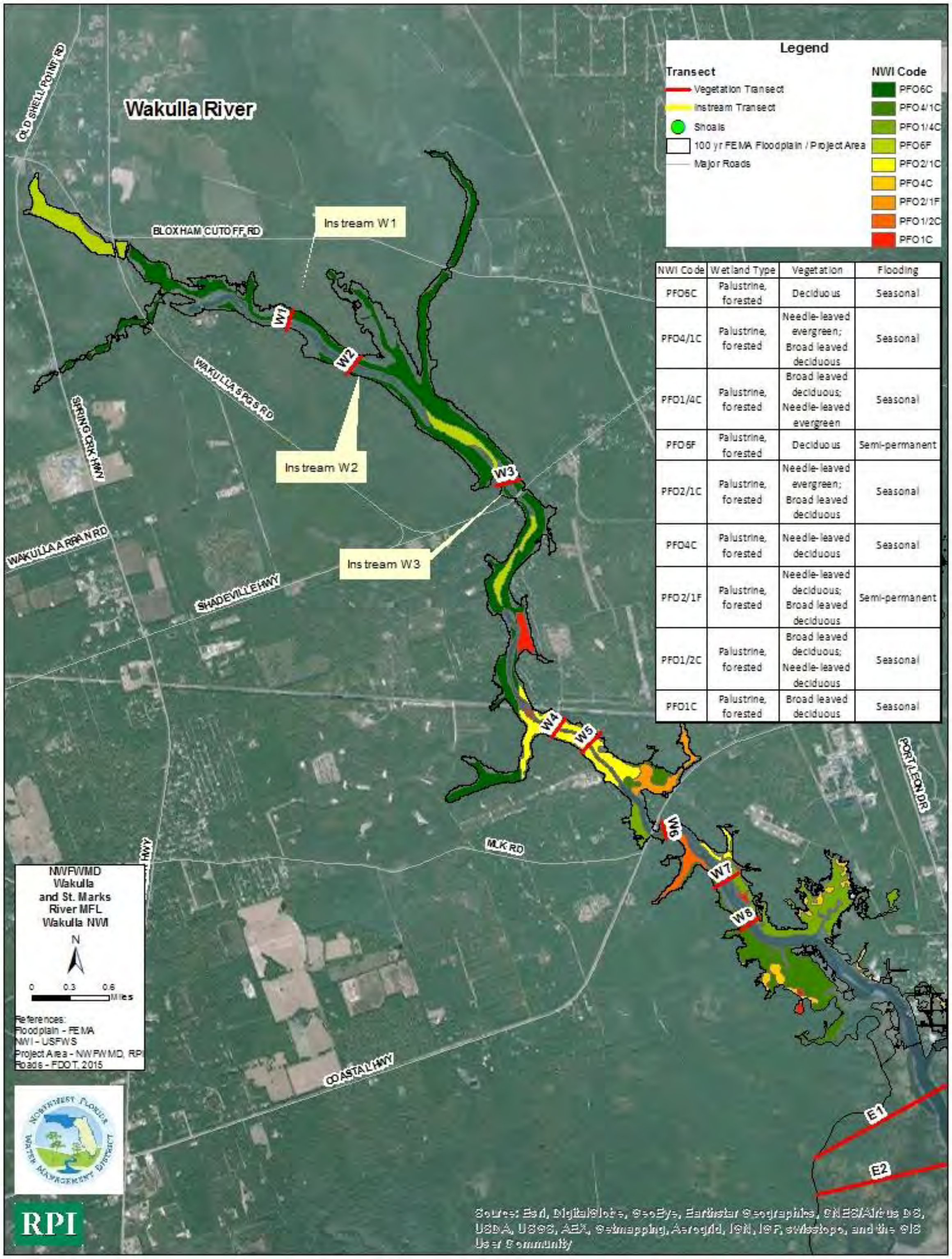

Figure 4. **Sampling transect locations along the Wakulla River.**

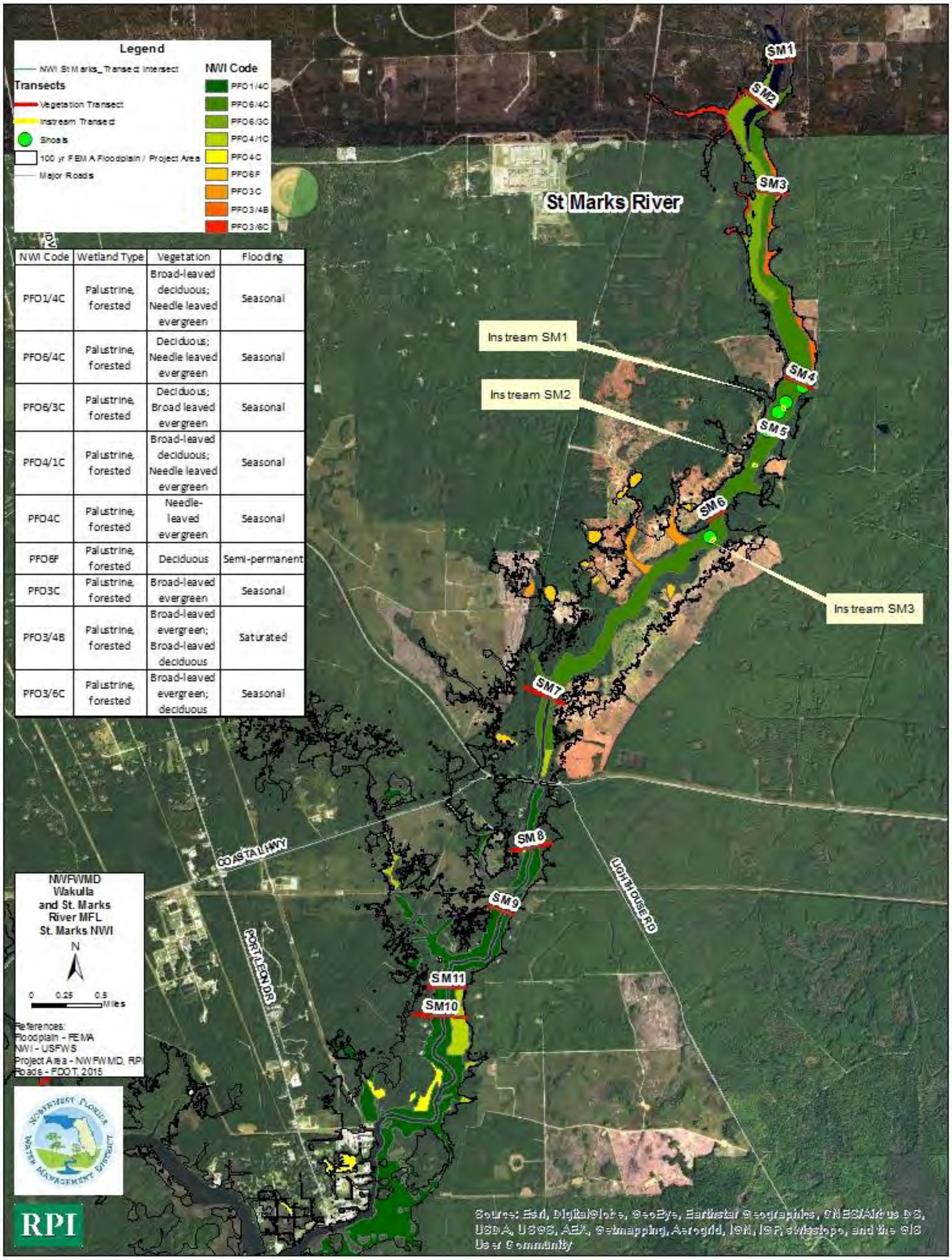

Figure 5. Sampling transect locations along the upper St. Marks River.

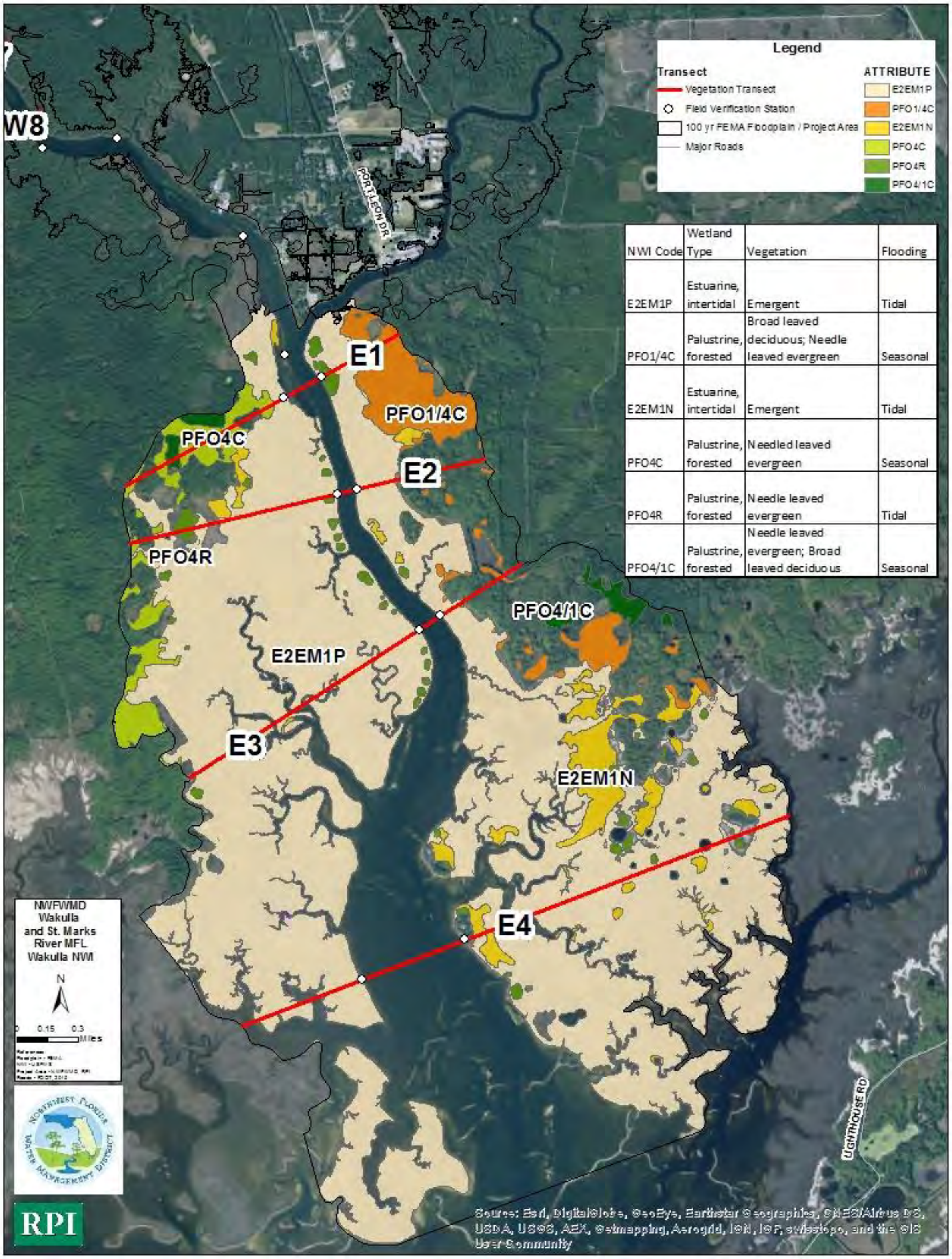

Figure 6. **Sampling transect locations along the estuarine portion/lower St. Marks River.**

Original transects were allocated among the nine representative NWI vegetation classes along the river corridors above their confluence. Below the confluence, transects were assigned to the single marsh vegetation class referred to as estuarine, intertidal, emergent (vegetation), persistent, irregularly flooded (i.e. marsh) by NWI (E2EM1P).

Names for vegetation classes were refined (from NWI names) in the field, based on woody species most prevalent along the sampling transect. The extent of NWI wetlands corresponded well with the FEMA 100-year floodplain along the Wakulla River. The same was true for the St. Marks River except for a portion of the river just above the confluence of the St. Marks and Wakulla rivers where the FEMA floodplain was noticeably wider than the NWI wetlands cover. Above the confluence of the two rivers, NRCS soils maps indicated a wider band of wetland forest along the Wakulla River (when compared with the St. Marks River), which can be seen in Figure 3.

Potential transect locations were designated in areas characterized by native vegetation, little or no disturbance, and riverine wetlands. Locations were mapped and meetings were held in person with District staff to confirm selections. During field reconnaissance, potential transects were evaluated with respect to vegetation, hydrology, and access. Transects were selected to avoid stream crossings, disturbed areas, or access issues, if possible. Transects were placed so that two or more transects crossed through a vegetation class and ensure that the vegetation classes most representative of the river corridors were sampled. Not all NWI wetland subclasses were sampled due to the scattered nature of the polygons and the inability to access all areas. The final 23 transects SM1 – SM11, W1-W8, and four estuarine transects (E1-E4) were approved by the District. Vegetation sampling was completed during September, October, and November of 2015. Final transects are listed with corresponding NWI classes in Table 1 and Table 2.

Vegetation classes along both rivers are classified as palustrine forested (NWI code PFO) upstream of the confluence of the two rivers, while estuarine marshes (E2EM1P) characterized the lower St. Marks River downstream of the confluence. NWI data include a separate class for needle leaved deciduous (PFO2) tree species (bald cypress) along the Wakulla River, but not the St. Marks River. The St. Marks River NWI data include a separate class for broad leaved evergreen (PFO3) tree species (e.g. bays, American holly, sabal palm) that was not included in the NWI mapping for the Wakulla River.

Table 1. NWI vegetation classes and corresponding numbers of acres selected for reconnaissance along the Wakulla and St. Marks river corridors (mapped in Figures 3 and 4). The last column gives the number of transects that intersect each vegetation class.

NWI Code	Description	Total acres	Percent of total	Cumulative percent	Original number of transects	Final Transects
Wakulla River - palustrine only						
PFO6C	Deciduous (e.g. maple, ash, tupelo, oak, cypress), seasonally flooded	517.4	41	41	5	W1, W2, W3
PFO4/1C	Needle leaved evergreen (NLE) (e.g. cedar and pine) and broad leaved deciduous (BLD), (e.g. tupelo, maple, elm), seasonally flooded	183.6	15	56	3	W6, W7, W8
PFO1/4C	BLD and NLE, seasonally flooded	136.0	11	67	-	W7, W8
PFO6F	Deciduous, semi-permanently flooded	117.3	9	76	-	-
PFO2/1C	NLD (e.g. bald cypress) and BLD, seasonally flooded	107.9	9	85	2	W4, W5
PFO4C	Needle leaved evergreen (NLE), seasonally flooded	43.8	4	88	-	-
PFO2/1F	NLD (e.g. bald cypress) and BLD, semi-permanently flooded	34.6	3	91	-	-
PFO1/2C	BLD and NLD, seasonally flooded	26.7	2	93	-	-
PFO1C	BLD, seasonally flooded	25.1	2	95	-	-
St. Marks River - palustrine only						
PFO1/4C	BLD and NLE, seasonally flooded	420.4	36	36	4	SM8, SM9, SM10, SM11
PFO6/4C	Deciduous (e.g. maple, ash, oak, tupelo, cypress), and NLE, seasonally flooded	367.9	31	67	5	SM1, SM2, SM3, SM4, SM5, SM6, SM7
PFO6/3C	Deciduous and broad leaved evergreen (BLE) (e.g. holly, bay, sabal palm), seasonally flooded	101.2	9	76	-	SM1, SM2, SM3
PFO4/1C	BLD and NLE, seasonally flooded	49.8	4	80	-	SM10, SM11
PFO4C	Needle leaved evergreen (NLE), seasonally flooded	37.1	3	83	-	SM8
PFO6F	Deciduous, semi-permanently flooded	31.2	3	86	-	-
PFO3C	BLE, seasonally flooded	29.6	3	89	1	SM1, SM2, SM3
PFO3/4B	BLE and BLD, saturated	28.8	2	91	-	SM3
PFO3/6C	BLE and deciduous, seasonally flooded	25.4	2	93	-	-
PFO6/3F	Deciduous/BLE, semi-permanently flooded	13	1	96		SM1

Table 2. NWI vegetation classes and corresponding numbers of acres along the river corridor in the estuarine portion of the Wakulla and St. Marks rivers (see Figure 5). The last column gives the number of transects (out of four) that intersect each vegetation class.

NWI Code	Description	Acres	Percent of total acres	Cumulative Percent	Original number of transects	Final Transects
E2EM1P	Estuarine, intertidal, emergent (vegetation), persistent, irregularly flooded (i.e. marsh)	3,396.3	77.2	77.2	4	E1, E2, E3, E4
PFO1/4C	BLD and NLE, seasonally flooded	204.3	4.6	81.8	2	E1, E3
E2EM1N	Estuarine, intertidal, emergent (vegetation), persistent, regularly flooded (i.e. marsh)	191.5	4.4	86.2	1	E4
PFO4C	NLE, seasonally flooded	130.3	3	92.3	2	E1, E2
PFO4R	Needle leaved evergreen (NLE), seasonal - tidal	58.7	1.3	95.7	3	E1, E2, E4
PF04/1C	BLD and NLE, seasonally flooded	41.8	1.0	97.5	1	E1

Floodplain Vegetation Sampling

Floodplain sampling followed protocols to ensure data were accurate to support the establishment of MFLs and included data collection protocols and verification, as described in the 2015 Technical Memorandum (RPI 2015). Trees were selected as indicator species of floodplain habitats because they are long-lived and integrate long-term hydrologic conditions better than shrubs or herbaceous plants. Sampling protocols are summarized below.

- Vegetation classes (plant community names) were assigned and recorded based on dominant tree species and soil characteristics.
- Vegetation sampling plots were located along transects at random distances within each vegetation class. The point-centered-quarter (PCQ) sampling method (Mueller-Dombois and Ellenberg 1974), a standard plotless tree sampling method, was used: at each sampling point in each community type (minimum = 3 sample points / community), trees were identified, measured, and recorded for each of four quarters/sampling points.
- Transect number, sample point, distance from center point of sample, diameter breast height (DBH) for trees with DBH≥ 1.0 inches, canopy cover (percent), and ground cover (percent) were recorded (these data were used to calculate density, frequency, basal area, and importance value (IV) for each tree species, by transect and vegetation class, as described in the analysis section). Raw data were provided in the 2015 Technical Memorandum.

Soils sampling

Soil cores were extracted with a soil probe and examined at each vegetation sampling point along each transect. The soil profile was examined to a minimum depth of 25 cm (10 inches). Hydric soil indicators described in the *Field Indicators of Hydric Soils in the U.S.: a Guide for Identifying and Delineating Hydric Soils, Version 7.0* (NRCS 2010) were recorded as appropriate. For example, a sandy soil with stripping and sandy redox were recorded as S5/S6, while a mucky mineral soil was recorded as A7, and a loamey /clayey soil with redox features within a dark surface was recorded as F6, consistent with the Guide. In addition, SHS was recorded. SHS is defined as the shallowest depth below the surface where water is expected to remain for approximately 30 or more days during the wettest part of years, under normal annual and wet season precipitation, with possible flooding (Hurt, G.W. and F.C. Watts 2007). Soil indicators were recorded as outlined below.

- hydric (1)/non-hydric (0)
- mucky mineral soil (1) or not mucky mineral (i.e., sandy or clayey/loamy) (0)
- hydric indicator (e.g., A7, S6, F6)
- depth to SHS (in inches)

3.2 Vegetation Sampling in the Estuarine Portion of the Lower St. Marks

Vegetation classes on the lower St. Marks River are predominately classified as emergent vegetation, persistent, irregularly flooded marsh (NWI code E2EM1P) (refer to Table 12). Higher elevation areas to the east and west (landward) of the river include palustrine forested mixes of deciduous and evergreen, broad and needled leaved, tree species. Four transects (E1 – E4) were selected on the lower St. Marks River floodplain based on initial field reconnaissance and subsequent review of aerial photography, NWI, FLUCFCS, NRCS soils survey, and FEMA 100-year floodplain layers (sources listed below and included in literature citations). The FEMA 100-year floodplain and LiDAR (elevation) map data were provided by the District.

- ESRI. 2015. Aerial Imagery: 2015. ESRI Basemaps, ArcGIS.
- Florida Land Use Cover and Forms Classification System (FLUCFCS). 2009. LU_NWFWMD_2004. Florida Department of Environmental Protection (FDEP). http://www.fgdl.org/metadataexplorer/explorer.jsp.
- NRCS (Natural Resource Conservation Service). 2004. http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
- NWI (National Wetlands Inventory). 2014. "NWIP_OCT14." United States Fish and Wildlife Service. http://www.fws.gov/wetlands/Data/State-Downloads.html.

The four estuarine transects were located perpendicular to the St. Marks River channel and extended to the landward edge of the marsh (and landward palustrine forest if present). Field verification of aerial photography included recording GPS coordinates at locations 50 feet landward of the marsh edge on the west side of the river to 50 feet landward of the marsh edge on the east side (transect endpoints). Transect endpoints of the on each side of the river were used as field verification locations from which observations of dominant vegetation were made and recorded. Observations made during the field sampling, November 10, 2015, corroborated NWI vegetation classes along the lower St. Marks. Notes on dominant vegetation were made on aerial photographs and GPS coordinates were recorded (reported in the 2015 Technical Memorandum). Soils were not sampled along marsh transects.

Vegetation (NWI) classes making up more than one percent of the total cover in the estuarine portion of the river are mapped in Figure 6. As indicated in Table 2, 77 percent of the estuarine vegetation (below the confluence of the two rivers) is regularly flooded emergent marsh and another 4.4 percent is irregularly flooded emergent marsh. None of the remaining vegetation classes below the confluence of the two rivers make up more than 4.6 percent of the vegetation classes. Forested palustrine classes described in Table 2 occur landward of the marshes.

3.3 Instream woody habitat Data Sampling and Collection

Naturally occurring snags, characterized as DWD and live roots, are an important habitat component of streams and rivers (Fischenich and Morrow 2000). Snags buffer the effects of strong currents, provide spawning habitat and refugia for fish, and are important cover for invertebrates and substrate for their larvae. Snags also influence channel morphology by enhancing scouring and resulting pools of deeper water available to fish (HSW 2016). Characterizing these features will provide data that can be related to flow and the associated river stage and inundation and, subsequently, used to model the relative amount of time (or area) they are inundated. For this study, DWD and live roots were located and elevations of these features were measured.

Potential locations for instream woody habitat and sampling were identified during reconnaissance surveys along the Wakulla and St. Marks rivers were completed in July and August 2015. Six instream sample transects were selected to characterize elevations and types of instream woody habitat.

Instream woody habitats were characterized along a total of six transects during September, October, and November 2015. Instream features were measured along three belt transect along each of the rivers (Figure 7).

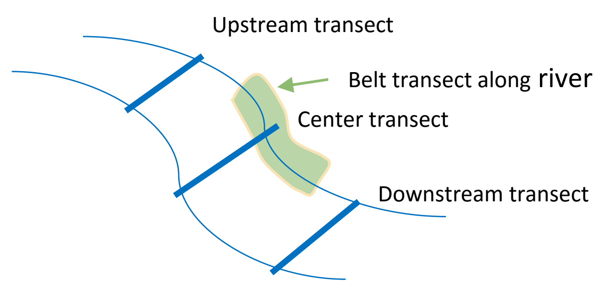

Figure 7. Instream sampling transect schematic

Transects were established across the river channel, perpendicular to the flow, and continuous with floodplain vegetation transects. Transects were located at shallow (on the St. Marks River) or “pinched” areas (on the Wakulla River) along the rivers where flows may be constricted and instream woody habitat features, i.e. snag habitat, would be expected to be more sensitive to changes in flows and associated changes in inundation of instream habitat structures.

- St. Marks River transects were located across shoals.
- Wakulla River transects were co-located with vegetation transects.

Elevations of instream features were surveyed relative to temporary benchmarks that were subsequently referenced to permanent benchmarks. Belt transects were bounded by the top of bank on either side of the river channel. Within each belt transect, locations of DWD and live roots were located and surveyed along 25 feet of the river channel and elevations of a minimum of 15 exposed root and snag habitat features were measured from within the transect.

3.4 Elevation Surveys

Elevation data for floodplain and instream transects and river channels were measured and recorded by surveyors under a separate contract with the District. Surveys included elevations measured and recorded at 10-foot intervals along sample transects, from the EOW to the upland edge, channel profiles, temporary and permanent benchmarks, and times at which EOW elevations were recorded. These data were combined with the vegetation and soils data for further analysis.

3.5 Analysis

Elevation, soils, and vegetation data were compared among and between vegetation classes identified in the river corridor. Statistical analyses were performed using R statistical software (from R Project for Statistical Computing, available free of charge, R Core Team 2016). As described previously, analyses will be performed by the District and used to characterize inundation conditions based on elevations of vegetation classes and other environmental parameters of interest and were not part of the present study. Coordinates of transect locations, vegetation types along transects, general soil series, and other data identified by the District, are included in the 2015 Technical Memorandum (RPI 2015).

3.5.1 Elevations and Wetted Perimeter

Ground elevation data (feet NAVD88) were combined with vegetation, soils, and distance data collected along transects. Normalized (relative) elevations were calculated as the difference between the transect elevations and the river channel bottom to account for variation due to the elevation decrease from upstream to downstream.

Wetted perimeter (WP) is the total linear distance of habitat inundated along a transect at a particular elevation or water level (river stage). Wetted perimeter can provide a metric for the amount of variation in wetted perimeter (habitat) with discharge and typically increases with flow (Jowett 1997). For example, a small increase in water level in a wetland results in inundation of a relatively large extent of habitat, compared with the same increase in water level that inundates a smaller extent of habitat across a river bank or upland characterized by a steeper elevation change. Wetted perimeter was calculated (total linear extent of transect/net change in elevation along transect) for vegetation classes in the study corridor to evaluate the potential change in inundated habitat that may be anticipated due to changes in river stage.

3.5.2 Vegetation

Density, frequency, basal area, and IV were calculated for each tree species, by transect and vegetation class to characterize and differentiate between vegetation classes. Because the PCQ method is a distance metric, the total density of all trees is required to calculate the relative and absolute values for density for a species (refer to Mueller-Dombois and Ellenberg 1974) for further detail).

- Density of all trees (per acre) = 43,560 feet/(average measured distance, in feet)^2, where 43,560 is the number of square feet in one acre
- Relative density = number of occurrences of a species/ total number of trees
- Absolute density = relative density of a species X density of all trees

- Absolute frequency = number of times a plant species is encountered along a transect out of total number of sample points
- Relative frequency = frequency of a plant species/ sum of all frequencies
- Absolute basal area = mean basal of a species X absolute density of that species (inches2)
- Relative basal area = absolute basal area of a species/ sum of basal area for all species
- Importance value (IV) = relative density + relative frequency + relative basal area

The IV is an index of species dominance in a vegetation class. The value of IVs may range from 0 to 3.00 (or 300 percent), therefore IVs in a vegetation class total 300 (percent). Dividing IV by 3 results in values ranging from 0 to 1.00 (or 100 percent). Relationships between vegetation classes and corresponding environmental parameters were examined in the present study to ascertain whether there were differences in:

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

3.5.3 Statistical Analyses

Due to small sample size and non-normal data distributions, nonparametric statistics were applied to comparisons of species importance between vegetation classes. The Wilcoxon Signed Rank test (a nonparametric analog to the paired-t test) was used to evaluate differences in species IV (or "dominance") between individual vegetation classes, for example differences in species dominance between willow marsh and hardwood swamp vegetation classes. This step indicated which classes were distinct in terms of species and IV and appropriate for use as vegetation classes in the DFA. Classes that are significantly different from one another were retained for the DFA classes. Classes that were not significantly different from one another could be combined into a single class.

The overall sample size for comparisons of elevation and soils among vegetation classes was large (a total of 788 trees) and a parametric DFA was used to develop models for each river that predicts vegetation class as a function of elevation and soils variables and distance from river channel. All field data were reviewed for the 2015 Technical Memorandum with respect to potential outliers and the final data were included in the DFA. The following candidate variables were included in the analysis: elevation relative to EOW, elevation relative to channel minimum along that transect, mean elevation of vegetation class, soil type (mineral or not), depth to SHS, and distance from river channel as a proxy for inundation, based on work performed in previous MFL studies, e.g., see MFL reports prepared by the Southwest Florida Water Management District. All parameters were included in the DFA output as a means of identifying which parameters were significant. P-values indicate the significance of a relationship, e.g. the ability to predict a vegetation class using elevation or another environmental parameter.

DFA is used to identify the variable(s) that best distinguish between two or more groups (in this case, vegetation classes) and are therefore the best predictors of vegetation class. The DFA is computationally similar to a multivariate analysis of variance (MANOVA) and relies on an F test to determine significance of variables in discriminating between classes. Here, the DFA identified the environmental parameters (e.g., elevation, soil characteristics) that best differentiated between the vegetation classes and then used environmental variables to "re-classify" all vegetation classes. For example, elevations and soils characteristics of each vegetation class sampled would be characterized and then used to re-classify all the vegetation classes based only on elevations and soils characteristics.

A misclassification would occur if, for example, a vegetation class that was identified in the field as a wetland was re-classified as an upland vegetation class because it occurred at elevations soils that corresponded better with an upland vegetation class rather than a wetland vegetation class. "Correct" classification in the DFA would be those that correctly pair vegetation classes with environmental parameters based only on the environmental parameters. If statistically significant relationships are observed that can be used to successfully assign vegetation classes, then these parameters can be used as metrics to establish MFLs that protect vegetation communities.

4 RESULTS

Biological and physical environmental parameters were analyzed to identify potential floodplain, instream, and estuarine habitat characteristics that may be used in establishing MFLs for St. Marks River Rise, Wakulla, and Sally Ward springs system.

4.1 ELEVATIONS

Elevations surveyed along the Wakulla and St. Marks river corridors were included in analyses of vegetation classes, soils, and WP, and will be used in the development of channel profiles for future hydrodynamic modelling in the rivers. Elevations of channel minimum (bottom), floodplain transect minimum, and floodplain transect maximum (beginning of upland) are listed in Table 3 and graphed in Figure 8 for the Wakulla River transects. Corresponding elevations for the St. Marks River transects are presented in Table 4 and Figure 9.

Upstream-downstream changes in elevation along the channel bottoms were more than six feet in the Wakulla River and more than 23 feet for the St. Marks River. Minimum transect elevations (at river channel) declined by 5.21 feet from upstream to downstream along the Wakulla River and by 6.57 feet along the St. Marks River. However, tidal influence reaches to Wakulla Spring on the Wakulla River and at least as high as the shoals (above SM6) on the upper portion of the St. Marks River. Reconciliation of elevations with tidal influence was beyond the scope of this study.

Channel bottom elevations along the Wakulla River ranged from -15.58 (W4) to 0.63 (W2) feet NAVD (Table 3 and Figure 8), with the deepest measured point in the channel occurring in the thalweg of the river below the Shadeville Highway bridge. The net decline in elevation in the channel from the most upstream transect (W1) to the most downstream transect (W8) was 6.35 feet. Average decline along Wakulla River transects, from river channel to upland, was 1.76 feet (compared with 4.2 feet along St. Marks River transects). Channel bottom elevations along the St. Marks River ranged from -20.22 (SM11), just above its confluence with the Wakulla River, to 2.86 (SM1) (Table 4 and Figure 9).

Average elevations associated with vegetation classes reflect a strong upstream to downstream elevation gradient and, consequently, average elevations (NAVD) of classes are not always reflected of the relative elevation of vegetation classes to each other. For example, tupelo cypress swamp had the highest *average* elevation among the five vegetation classes sampled on the Wakulla River, but occurred at both the most upstream transect (W1, minimum transect elevation = 4.95 feet NAVD, and the second most downstream transect (W7, minimum transect elevation 1.09 feet NAVD). Consequently, tupelo cypress class of vegetation had the lowest elevation at an individual transect (as anticipated), but the highest average elevation.

Table 3. Summary of Elevations along Wakulla River Transects

Transect		Transect Length (feet)	Elevation (feet NAVD)				(feet)
			Transect Maximum	Transect Minimum	River Channel Minimum	Edge of Water	Elevation Change on Transect
Upstream ↓ Downstream	W1	866	7.29	4.95	-3.65	4.96	2.34
	W2	927	7.71	5.03	0.63	5.03	2.68
	W3	1046	6.48	3.40	-4.22	3.22	3.08
	W4	969	2.54	0.96	-15.58	0.96	1.58
	W5	1171	2.58	1.82	-12.18	1.82	0.76
	W6	697	3.13	1.51	-8.67	1.78	1.62
	W7	1137	2.91	1.09	-7.53	-0.92	1.82
	W8	950	2.43	2.23	-10.00	-0.25	0.2
Change*		970	-4.86	-2.72	-6.35	-5.21	1.76

*Change is net from upstream to downstream except for transect length and change along transects, which is the average of the increase along each transect.

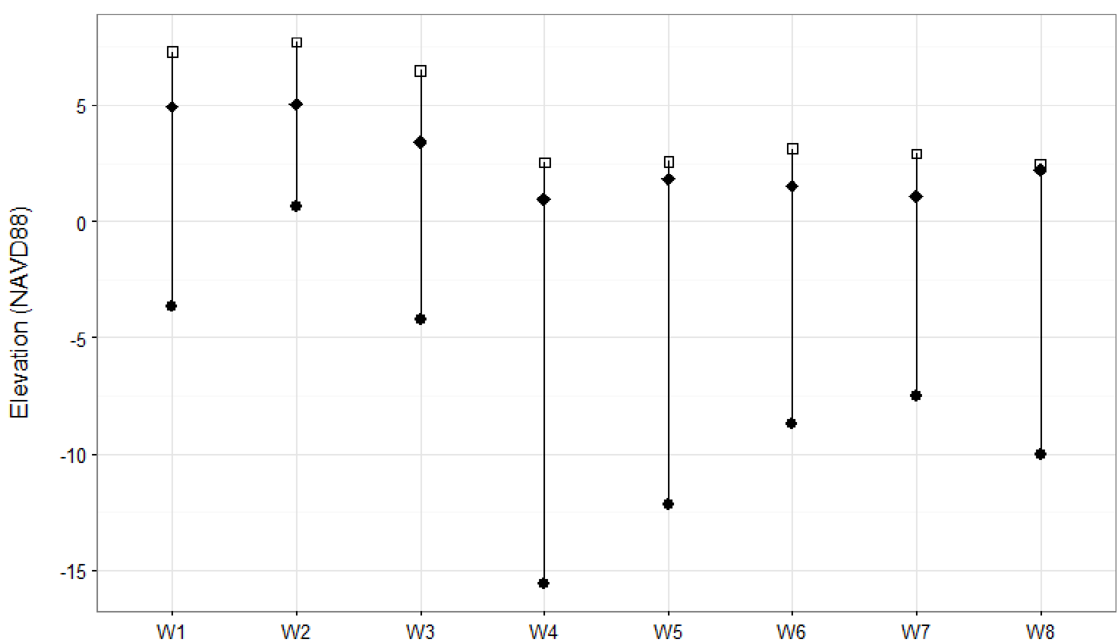

Figure 8. Channel Bottom (filled circles), Transect Minimum (filled diamonds), and Transect Maximum (open square) Elevations along the Wakulla River Transects

Table 4. Summary of Elevations along the St. Marks River

Transect		Transect Length (feet)	Elevation (feet NAVD)				(feet)
			Transect Maximum	Transect Minimum	Channel Minimum	Edge of Water	Elevation Change on Transect
Upstream ↓ Downstream	**SM1**	807	15.80	8.91	2.86	8.93	6.89
	SM2	1142	10.54	8.50	2.80	8.50	2.04
	SM3	1221	7.86	6.08	-0.55	4.98	1.78
	SM4	677	7.31	2.57	-3.01	2.57	4.74
	SM5	457	7.74	4.50	-5.59	2.31	3.24
	SM6	340	7.21	0.92	-9.33	0.92	6.29
	SM7	678	5.26	1.41	-9.31	1.41	3.85
	SM8	568	2.82	-0.71	-18.41	-0.71	3.53
	SM9	451	6.90	-0.45	-14.70	0.61	7.35
	SM10	1900	3.20	-0.30	-17.92	-0.30	3.50
	SM11	1442	3.53	0.91	-20.22	2.36	2.62
Change*		635	-12.27	-8.00	-23.08	-6.57	4.2

*Change is net from upstream to downstream except for transect length and change along transects, which is the average of the increase along each transect.

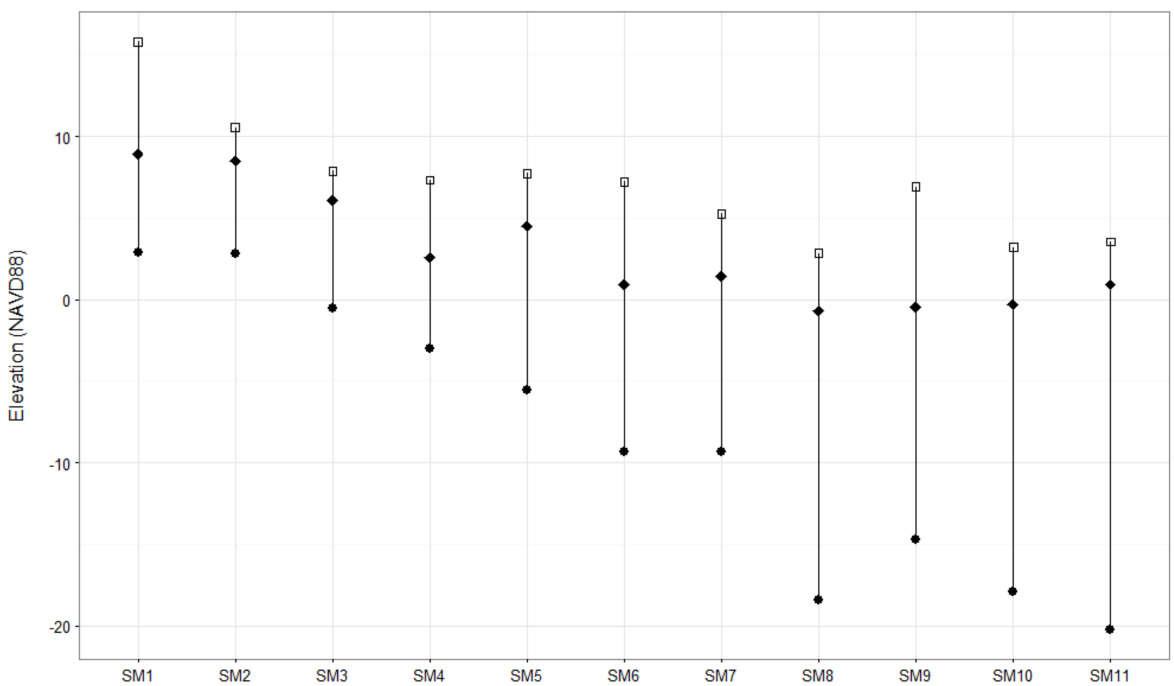

Figure 9. Channel Bottom (filled circles), Transect Minimum (filled diamonds), and Transect Maximum (open square) Elevations along the St. Marks River Transects

The net decline in elevation in the channel (from SM1 to SM11) was 23.08 feet over about 11 miles (2.02 feet/mile), more than three times the decline in the Wakulla River. The channel deepens to elevations of 18.41 to 20.22 feet before (upstream of) its confluence with the Wakulla River below the US 98 bridge. For illustrative purposes, the elevation profile and associated vegetation along Transect W1 are graphed in Figure 10. Graphs of the 19 transects for which elevation surveys were completed are presented in Appendix A.

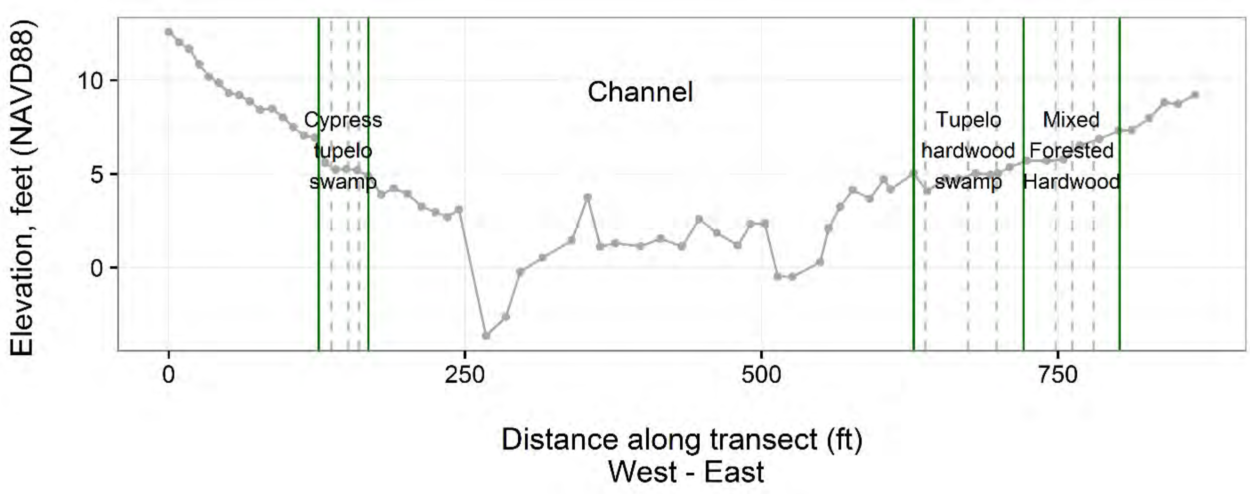

Figure 10. Elevation and Vegetation Profile along Transect W1 on the Wakulla River

4.2 Soils

The Wakulla County soil survey (NRCS 1991) classifies the soils along the lower St. Marks River (below its confluence with the Wakulla River) as Bayvi, Isles, and Estero soils. This group of soils is described as nearly level, very poorly drained soils of tidal marshes on marine sands along the Gulf coast that are flooded daily by high tides. Above the confluence, Tooles Nutall fine sands, typical of floodplains on marine terraces, characterize both river corridors and are described as being flooded for six to eight months during the year with a depth to water table of 0 inches for Tooles, 0-12 inches for Nutall, and a seasonal high water table within a depth of 12 inches for most of the remainder of the year. Soils maps also indicate a wider corridor associated with these soils along the Wakulla River (vs. St. Marks River), consistent with elevation differences between the two rivers.

Soils along the Wakulla River transects were almost exclusively mucky mineral soils, while more than a third of the wetlands soils sample along the St. Marks River corridor were sandy or loamy. Average elevations (at land surface) of wetland soils along transects are presented in Table 5 (Wakulla River) and Table 6 (St. Marks River). Depth to SHS was 6.0 inches or less in wetlands along all transects on both rivers and described with respect to vegetation in the following section (Section 4.4). Sandy soils were encountered only once on Transects W2 and W8.

Table 5. Average Elevations of Soils within each Transect along the Wakulla River

Transect	Hydric, Sandy	Number of Soil Samples	Hydric Mineral with Muck	Number of Soil Samples
W1			5.44	9
W2	5.46	1	5.64	7
W3	4.99	2	3.96	12
W4			1.86	13
W5			2.08	14
W6	2.01	3	1.73	14
W7	2.07	4	1.52	18
W8	2.35	1	1.64	14

Shading indicates absence of soil type.

Table 6. Average Elevations of Soils within each Transect along the St. Marks River

Transect	Hydric Sandy	N	Hydric Sandy with muck	N	Hydric Mineral	N	Hydric Mineral with muck	N
SM1	11.00	4					9.59	3
SM2	9.35	3					9.38	9
SM3	5.95	1			6.31	2	6.07	5
SM4	4.24	4					4.32	2
SM5	7.00	2	6.98	1				
SM6							4.92	3
SM7	3.76	5					3.81	1
SM8	2.54	1					2.13	4
SM9	4.71	3					2.49	3
SM10	1.11	2					1.41	12
SM11	0.59	2					1.54	11
Total		27						53
Percent		0.34		ND		ND		0.66

Shading indicates absence of soil type.

4.3 Vegetation Relationships

Differences between vegetation classes along the Wakulla (Table 7) and St. Marks (Table 8) rivers study corridor, as measured by average IV, were significant. Species IVs for vegetation classes total 300 and IVs in graphs are presented on a scale of 100 percent. Pairwise comparison of IV values were made among all vegetation community classes using the Wilcoxon Signed Rank tests. For example, along the Wakulla River, average species IVs (for classes in which a species occurred) were consistently different between the tupelo cypress swamp (second row heading) and the tupelo hardwood swamp (first column heading) regardless of transect ($p < 0.01$ level), as well as between these two classes and any of the remaining three vegetation classes. The results of all pairwise comparisons are provided in Appendix C. Graphs of vegetation classes are presented in Figure 11 (Wakulla River) and Figure 12 (St. Marks River) and illustrate conspicuous differences between the two rivers.

Vegetation Classes

A total of 13 obligate (OBL) wetland species (identified per FDEP 1986) were recorded from sample plots along both rivers, with 12 species on each river. Only one of the Wakulla River vegetation classes included more than 75 percent facultative wetland (FACW), facultative (FAC), and/or upland (UPL) species, while all but one of the vegetation classes sampled along the St. Marks River included more than 75 percent FACW, FAC, and/or UPL tree species. There were 13 FACW species recorded for the two rivers and each river included nine of the 13 species. The single vegetation class common to both rivers is the hardwood hammock, characterized by the OBL species swamp bay (*Persea palustris*) and swamp tupelo (*Nyssa sylvatica* var. *biflora*) and the FACW species ironwood, sweetgum (*Liquidambar styraciflua*), water or American elm (*Ulmus americana*), and FAC cabbage palm (*Sabal palmetto*), as well as various UPL species. Five vegetation classes were characterized along the Wakulla River transects and are are described below (in order of most to least relative importance of obligate wetland species).

- Tupelo cypress swamp. Swamp tupelo was the most dominant species in this vegetation class, followed by bald cypress, with the most bald cypress of any other Wakulla River vegetation class. Dahoon holly and sugar maple were smaller components in this community, as well as a single FACW species, red maple. This class corresponds with NWI codes for semi-permanently flooded (F) wetlands and broad leaved deciduous (BLD) (e.g., tupelo) and NLD (needle-leaved deciduous, e.g., cypress), i.e. codes PFO6F and PFO2/1F (refer to Table 1 for more detail on NWI codes).
- Tupelo hardwood swamp. Swamp tupelo was the dominant species in this community, making up nearly half of the IVs, followed by pumpkin ash, swamp bay, sugar maple, and four other OBL species. This class corresponds to NWI codes for semi-permanently flooded wetlands with broad-leaved deciduous species (PFO6F).
- Bay hardwood hammock. Swamp bay and pumpkin ash dominated this vegetation class, with smaller components of button bush and swamp tupelo, although several FAC and UPL species were also represented, This class corresponds with NWI codes for seasonally inundated wetlands with BLD and needle-leaved evergreen (NLE) tree species (PFO1/4C and possibly PFO4/1C).
- Tupelo cypress hardwood mix. Dominated by swamp tupelo with smaller representation by bald cypress and pumpkin ash, along with several other species including two upland species. This class had the largest number of species (20) in any one class on the Wakulla River. The class corresponds with NWI wetlands classified as seasonally inundated with both broad and needle leaved deciduous tree species (PFO1/2C, PFO2/1C, and possibly PFO2/1F).
- Hardwood hammock. This vegetation class included several OBL species and was dominated by swamp bay, ironwood, and sweetgum. This vegetation class included 16 different species and was the only class that was also represented on the St. Marks River. This class best corresponds to seasonally inundated wetlands with both deciduous and evergreen broad and needle leaved tree species. This class corresponds best with NWI code PFO6C, which is the broadest grouping mapped for the Wakulla River, although none of the NWI codes mapped for this study refer specifically to broad-leaved evergreen species, such as swamp bay.

RPI

Table 7. IVs for Tree Species, by Vegetation Class, along the Wakulla River* (shading indicates absence of species)

Species	DEP Status	Tupelo cypress swamp	Tupelo hardwood swamp	Bay hardwood hammock	Tupelo cypress hardwood mix	Hardwood hammock	Average across classes
Acer saccharum	OBL	27.08	22.43		1.40		16.97
Carya aquatica	OBL			3.29			3.29
Cephalanthus occidentalis	OBL		8.45	30.97	2.73		14.05
Fraxinus caroliniana	OBL		3.23	2.57	2.85		2.88
Fraxinus profunda	OBL		67.01	65.80	38.77	5.20	44.19
Ilex cassine	OBL	27.53		2.65	2.74	4.44	9.34
Magnolia virginiana	OBL	13.46	7.35			14.77	11.86
Nyssa aquatica	OBL	13.76					13.76
Nyssa sylvatica var. biflora	OBL	111.84	138.58	23.32	121.76	20.84	83.27
Persea palustris	OBL	14.65	27.41	98.77	17.36	57.81	43.20
Taxodium ascendens	OBL			7.99			7.99
Taxodium distichum	OBL	62.24	14.47	9.12	39.39		31.31
Acer rubrum	FACW	29.44		2.81	3.35	4.17	9.94
Carpinus caroliniana	FACW			5.25	10.23	36.75	17.41
Celtis laevigata	FACW					4.84	4.84
Cornus foemina	FACW				6.75	4.09	5.42
Crataegus sp.	FACW			2.56			2.56
Ilex decidua	FACW				7.31		7.31
Liquidambar styraciflua	FACW				2.01		2.01
Quercus nigra	FACW				10.16	31.73	20.94
Ulmus americana	FACW				2.96	26.89	14.93
Ilex opaca	FAC		2.78	5.26	3.42	12.23	5.92
Ilex vomitoria	FAC			2.59			2.59
Morella cerifera	FAC		8.31	7.31	13.16	31.58	15.09
Sabal palmetto	FAC			4.61	4.64	29.34	12.87
Carya glabra	UPL					9.41	9.41
Ostrya virginiana	UPL			14.47	7.02	5.94	9.14
Pinus taeda	UPL			6.65			6.65
Prunus caroliniana	UPL			4.01	1.98		2.99

Total for each vegetation class (column) = 300

Table 8. IVs for Tree Species, by Vegetation Class, along the St. Marks River (shading indicates absence of species).

Species	DEP Status	Tupelo bay swamp	Cypress hardwood mix	Tupelo hardwood mix	Ash swamp	Hardwood hammock	Ironwood hammock	Average across classes
Acer saccharum	OBL	10.70		4.11				7.40
Carya aquatica	OBL				21.44	4.08		12.76
Carya spp.	OBL		7.84					7.84
Cephalanthus occidentalis	OBL			2.99		2.51		2.75
Fraxinus caroliniana	OBL		5.06		61.82	2.38		23.08
Fraxinus profunda	OBL		15.64	12.33	59.19	10.34		24.38
Ilex cassine	OBL		4.74	3.22				3.98
Magnolia virginiana	OBL			4.74				4.74
Nyssa sylvatica var biflora	OBL	150.42	32.92	91.31	22.38	9.54	19.27	54.31
Persea palustris	OBL	75.46	5.16	47.92		41.94		42.62
Taxodium ascendens	OBL		53.11					53.11
Taxodium distichum	OBL		84.20			5.96		45.08
Acer rubrum	FACW	24.48	13.78			15.36		17.88
Carpinus caroliniana	FACW		38.11	3.25	23.65	59.29	157.02	56.26
Celtis laevigata	FACW			6.07		6.69	20.36	11.04
Liquidambar styraciflua	FACW		10.22			44.04	17.83	24.03
Morella heterophylla	FACW			2.98				2.98
Quercus laurifolia	FACW			10.53		5.36		7.94
Quercus nigra	FACW			8.14	23.84	1.75	17.45	12.79
Quercus phellos	FACW			4.07				4.07
Tilia americana	FACW					3.94		3.94
Ulmus americana	FACW		4.82		50.52	13.04		22.79
Ilex opaca	FAC					1.73		1.73
Ilex vomitoria	FAC			3.04	10.52	1.74		5.10
Morella cerifera	FAC	28.35	9.57	30.58	26.64	16.30	18.64	21.68
Sabal palmetto	FAC		14.82	21.10		13.28		16.40
Fagus grandifolia	UPL	10.60		3.41				7.01
Juniperus virginiana	UPL					5.48		5.48
Magnolia grandiflora	UPL			12.56		4.68		8.62
Ostrya virginiana	UPL			15.76		5.22		10.49
Pinus elliottii	UPL					9.92	49.44	29.68
Pinus taeda	UPL			11.88				11.88
Prunus caroliniana	UPL					3.70		3.70
Quercus virginiana	UPL					11.72		11.72

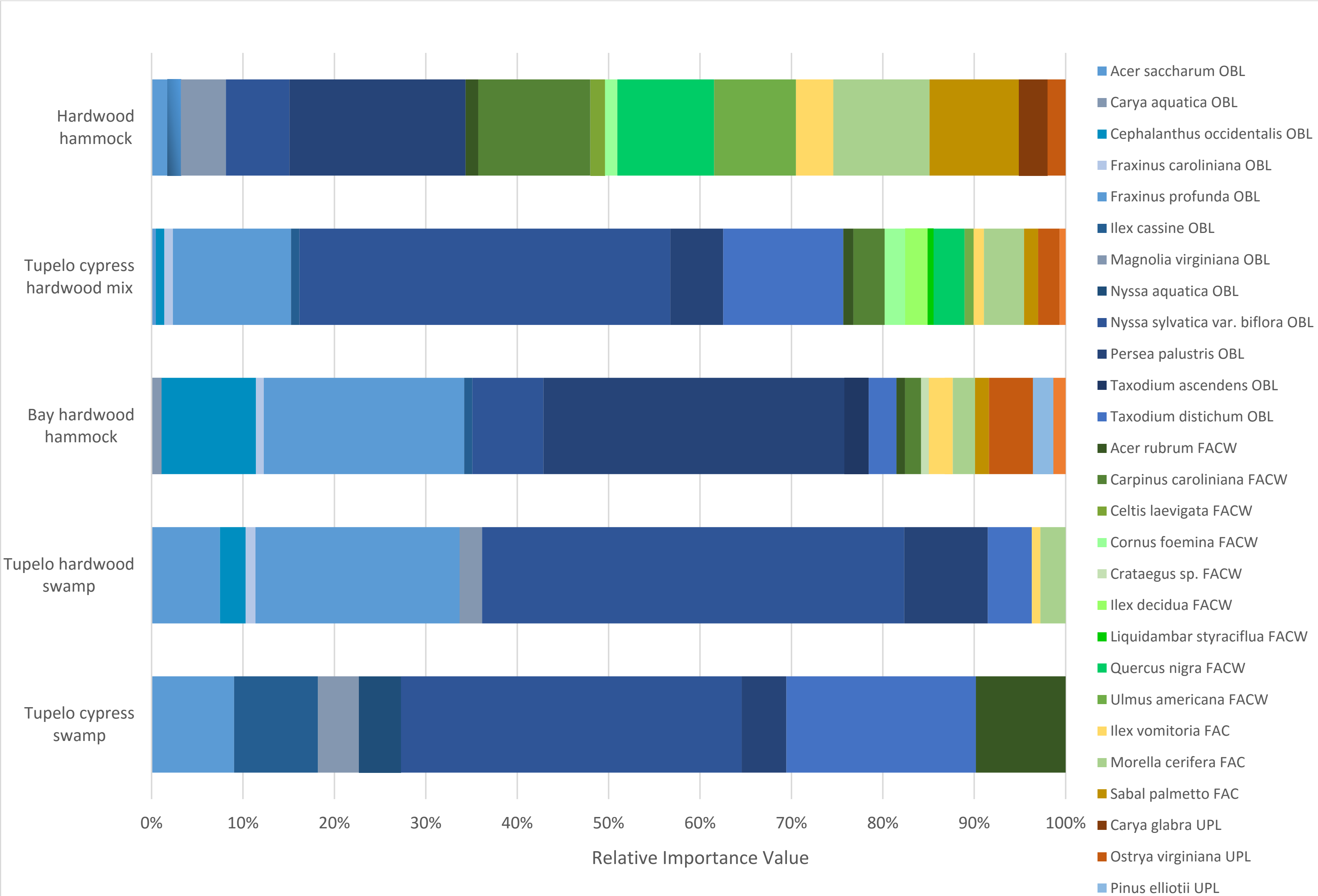

Figure 11. Importance Values for Tree Species in Vegetation Classes along the Wakulla River Study Corridor

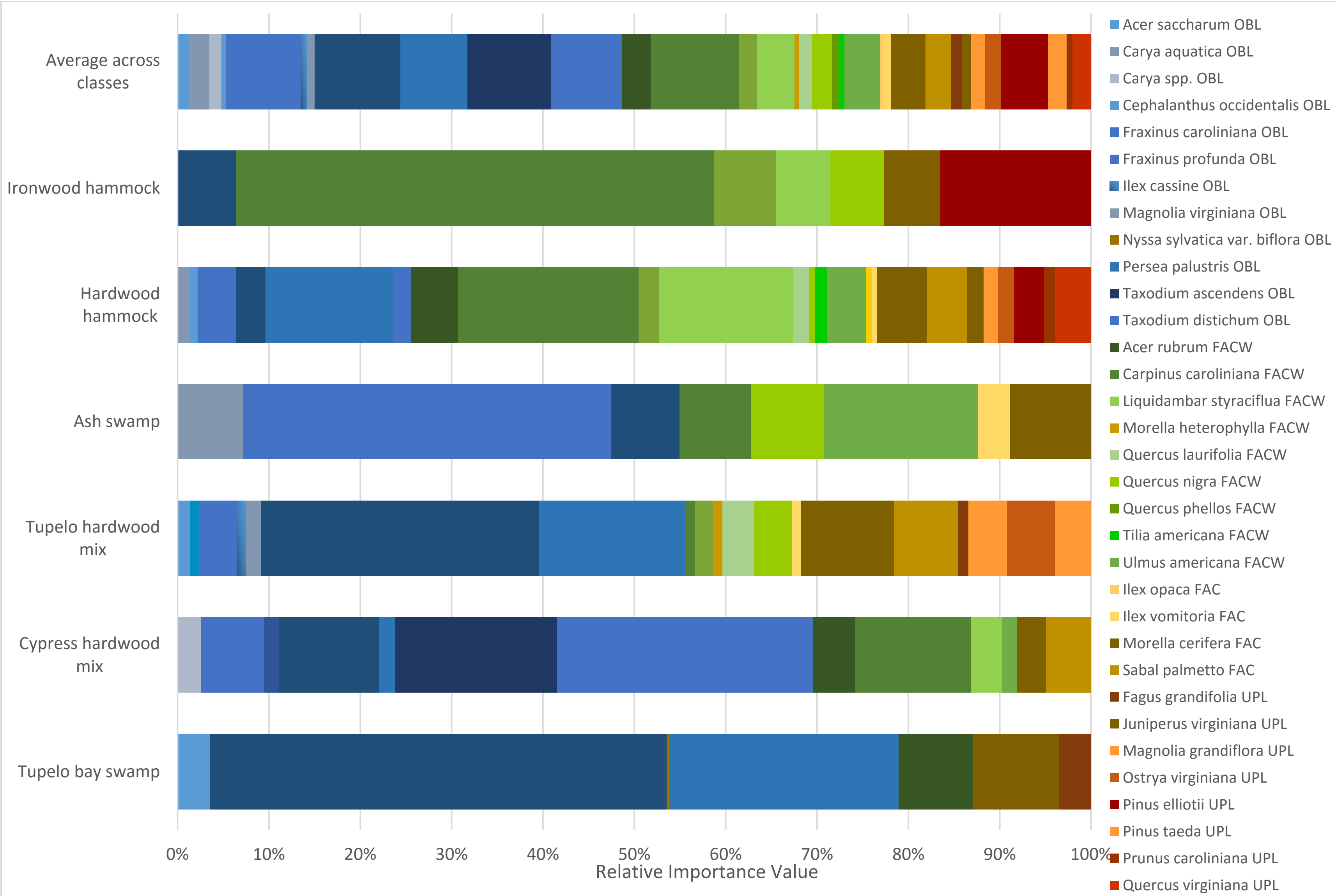

Figure 12. Importance Values for Tree Species in Vegetation Classes along the St. Marks River Study Corridor

Six vegetation classes were designated along the St. Marks River and demonstrated a gradual change in species dominance from classes dominated by OBL to FAC or UPL species: from approximately 80 percent OBL species to less than 10 percent dominance by these same species and approximately 70 percent dominance by FACW species (ironwood hammock).

- Tupelo bay swamp. Swamp tupelo, swamp bay, and red maple (*Acer rubrum*) were the dominant species in this community, which includes no cypress and very few facultative or upland species. Tupelo bay swamp corresponds best with NWI codes pertaining to semi-permanently flooded wetlands with broad leaved deciduous tree species such as PFO6F and PFO1/2C.
- Cypress hardwood mix. Bald and pond cypress made up the largest component of this vegetation class, followed by swamp tupelo and the facultative wetland species ironwood. Cypress hardwood mix corresponded best with NWI codes pertaining to seasonally flooded wetlands with predominantly needle-leaved deciduous species, such as PFO2/1F and PFO6F.
- Tupelo hardwood mix. Another swamp tupelo vegetation class, this class differed from tupelo bay swamp in that is had a greater number of species (seven OBL species vs. three for tupelo bay swamp) and lower dominance by both swamp tupelo and swamp bay. This vegetation class corresponded with seasonally flooded wetlands with broad-leaved deciduous and broad-leaved evergreen tree species (PFO6C, PFO1C, and possibly PFO1/4C).
- Ash swamp. Pop and pumpkin ash made up the largest components and are two of the nine species making up this class. Water elm, followed by nearly equal relative importance by water hickory, ironwood, water oak, and wax myrtle were secondary dominants. Ash swamp corresponded with NWI codes pertaining to semi-permanent flooding and primarily broad-leaved deciduous species (PFO6F and possibly PFO2/1F).
- Hardwood hammock. This vegetation class included small components of several OBL species, although ironwood and sweetgum have the largest IVs. It also included a greater number of species (22) than any other St. Marks River vegetation class and was the only class that was also represented on the Wakulla River, as described above. Just as for the Wakulla River, this class best corresponded to NWI code PFO6C, which is the broadest grouping mapped for the Wakulla River.
- Ironwood hammock. The FACE species ironwood mades up more than half of the total IV of this vegetation class and the second largest component was slash pine (*Pinus elliottii*). The class included only seven species and OBL species making up less than 10 percent of the relative importance in the class. This vegetation class corresponded to seasonally flooded wetlands with broad-leaved deciduous and needle-leaved evergreen tree species in NWI (PFO6C and PFO1/4C).

Vegetation classes identified for this study were consistent with, although more specific than, the NWI vegetation classes initially used to map vegetation along transects. The species-specific designations used in this study were retained so they could be easily combined into a more general context or class if appropriate. Species composition in vegetation classes assigned in the field were also consistent with communities previously described for the Wakulla and St. Marks rivers, as referenced or described in FNAI(2010), Lewis et al. (2009), Messina and Conner (1998), Light et al. (1983), and Clewell (1985). Distinct differences noted by Clewell 1985, and found in this study, included the near absence of pond cypress along the Wakulla River and the presence of water tupelo on the Wakulla River but not the St. Marks River.

Five distinct vegetation classes were identified along the Wakulla River and six along the St. Marks River, with some conspicuous differences in vegetation between the rivers (Figures 11 and 12), including a greater number (34) of tree species along the St. Marks River, compared with the Wakulla River (29 species). Other comparisons are summarized below.

- Only one of five woody vegetation classes sampled along the Wakulla River floodplain was characterized by less than 70 percent dominance by OBL species (as measured by relative importance values), while five of seven woody vegetation classes sampled for the St. Marks River floodplain had less than 60 percent dominance by OBL species.
- Differences in overall relative importance in vegetation classes were apparent both within and between rivers. For example, swamp tupelo (*Nyssa sylvatica var. biflora*) was a larger component of vegetation classes along the Wakulla River, while the St. Marks had larger components of bald (*Taxodium distichum*) and pond (*T. asendens*) cypress.
- Along the Wakulla River, average IV across classes for swamp tupelo was 83.27, followed by several species of lesser but similar IVs, such as pumpkin ash (*Fraxinus profundus*, IV=44.19), swamp bay (*Persea palustris*, IV=43.20), and bald cypress (*Taxodium distichum*, IV=31.31). In contrast, average IVs across vegetation classes for the St. Marks River included several co-dominants with similar IVs, including larger components of both bald (IV=45.08) and pond (*T. asendens*, IV=53.11) cypress, swamp bay (IV=42.62), and both pumpkin (IV=24.38) and pop (*F. caroliniana*, IV=23.08) ash.
- Facultative wetland species were typically much smaller components of vegetation classes than obligate wetland species. A notable exception was ironwood (*Carpinus caroliniana*), which had an overall relative importance of 56.26 on the St. Marks River, compared with 17.41 on the Wakulla River.

Basal Area and Density of Trees

Comparisons of basal area and density of species (used in calculation of IVs) can indicate whether a community or species population is more mature (smaller numbers of larger trees) or in transition in response to a disturbance or change of some sort (increased numbers of smaller trees). A developed tree canopy will shade out new seedlings and inhibit invasion by other species or individuals, which may have an opportunity only when a gap creates an opening in the canopy following the loss of an older tree. Changes in stream flows due to rainfall patterns or local ground water withdrawals, or other factors, can also alter vegetation growth and distribution patterns.

Among the vegetation classes, the vegetation classes that included cypress had greater basal areas. For example, the tupelo cypress swamp in the Wakulla River and the cypress hardwood mix in the St. Marks river corridor had the greatest basal areas/tree (greater than 80 in^2/tree) (Table 9) when compared with other vegetation classes on the same rivers. Basal areas/tree ranged from 35.61 to 51.91 in^2/tree for the remaining classes on the Wakulla River and from 15.73 to 47.39 in^2/tree for the remaining classes on the St. Marks River. While average DBH values for these vegetation classes appear relatively small (all are less than 10.0 inches), the means reflect a small number of species with large DBHs combined with a larger number of species with small DBHs along transects on both rivers (Table 10 and Table 11).

On the Wakulla River, the maximum DBH for swamp tupelo was 31.1 inches, followed by bald cypress (29.9 inches) and sugar maple (24.9 inches) (excluding species for which only a single individual was measured), while 11 of the remaining 26 species had DBH values less than 5.0 inches. On the St. Marks River, species with the greatest maximum DBHs (excluding species with only one individual measured) were pond cypress (39.8 inches), bald cypress (27.6 inches), swamp bay (23.3 inches), and slash pine (26.0 inches).

Both basal area per tree and tree density were generally higher for the Wakulla River and may suggest less disturbance or less recent disturbance. Larger and fewer trees in the cypress wetlands on both rivers, i.e. tupelo cypress swamp on the Wakulla River and cypress hardwood mix on the St. Marks River, may also be indicators of historic (e.g., tree harvest), rather than more recent, disturbance. A single study of 37 of the largest bald cypress trees on a tree plantation found the average DBH was 14.2 inches at 31 years of age. Based on this information, the largest cypress trees measured in this study could range from 60 to 65 years old (bald cypress are typically harvested at about 100 years old).

Table 9. Average Basal Area/Tree for Vegetation Communities Sampled along the Wakulla and St. Marks River Corridors

Wakulla River					
Measure	**Tupelo cypress swamp**	**Tupelo swamp**	**Tupelo hardwood swamp**	**Bay hardwood hammock**	**Hardwood hammock**
BA (in^2)/tree	82.87	51.91	45.89	43.25	35.61
Mean DBH (in)/tree	7.91	6.22	4.83	5.55	5.26
Density (trees/acre)	467.2	1172.3	561.3	748.4	771.8

St. Marks River						
Measure	**Tupelo bay swamp**	**Cypress hardwood mix**	**Tupelo hardwood mix**	**Ash swamp**	**Hardwood hammock**	**Ironwood hammock**
BA (in^2)/tree	44.75	84.50	37.94	15.73	46.19	47.39
Mean DBH (in)/tree	5.80	7.19	5.31	3.81	5.59	6.64
Density (trees/acre)	816.6	615.8	718.6	412.6	710.1	475.1

Table 10. Summary of Floodplain Wetland Tree Canopy Composition over all Vegetation Classes along the Wakulla River

Species	DEP Status	N	Total Basal Area	Mean Basal Area per Tree	Maximum Diameter (DBH, inches)	Relative Basal Area	Relative Density
Acer saccharum	OBL	7	718.44	102.63	24.8	0.03	0.02
Carya aquatica	OBL	1	33.18	33.18	6.5	0.00	0.00
Cephalanthus occidentalis	OBL	20	111.24	5.56	4.2	0.01	0.04
Fraxinus caroliniana	OBL	4	45.47	11.37	5.9	0.00	0.01
Fraxinus profunda	OBL	94	1,607.05	17.10	13.5	0.08	0.21
Ilex cassine	OBL	6	30.47	5.08	3.3	0.00	0.01
Magnolia virginiana	OBL	6	182.61	30.43	12.7	0.01	0.01
Nyssa aquatica	OBL	1	4.91	4.91	2.5	0.00	0.00
Nyssa sylvatica var. biflora	OBL	131	8,660.75	66.11	31.1	0.41	0.29
Persea palustris	OBL	55	3,257.21	59.22	14.5	0.16	0.12
Taxodium ascendens	OBL	1	240.53	240.53	17.5	0.01	0.00
Taxodium distichum	OBL	19	2,997.63	157.77	29.9	0.14	0.04
Acer rubrum	FACW	6	107.81	17.97	7.4	0.01	0.01
Carpinus caroliniana	FACW	20	176.27	8.81	6.3	0.01	0.04
Celtis laevigata	FACW	1	16.62	16.62	4.6	0.00	0.00
Cornus foemina	FACW	6	11.04	1.84	2.1	0.00	0.01
Crataegus sp.	FACW	1	1.13	1.13	1.2	0.00	0.00
Ilex decidua	FACW	6	13.05	2.17	1.9	0.00	0.01
Ilex opaca	FACW	2	13.70	6.85	4.0	0.00	0.00
Liquidambar styraciflua	FACW	9	680.35	75.59	16.6	0.03	0.02
Quercus nigra	FACW	5	321.93	64.39	17.0	0.02	0.01
Sabal palmetto	FACW	5	681.86	136.37	11.2	0.03	0.01
Ulmus americana	FACW	7	161.17	23.02	8.7	0.01	0.02
Ilex vomitoria	FAC	1	2.27	2.27	1.7	0.00	0.00
Morella cerifera	FAC	29	124.99	4.31	5.3	0.01	0.06
Carya glabra	UPL	2	27.72	13.86	4.3	0.00	0.00
Ostrya virginiana	UPL	8	482.83	60.35	18.5	0.02	0.02
Pinus taeda	UPL	1	181.46	181.46	15.2	0.01	0.00
Prunus caroliniana	UPL	2	119.14	59.57	9.1	0.01	0.00

N is the number of trees measured.

Table 11. Summary of Floodplain Wetland Tree Canopy Composition over all Vegetation Classes along the St. Marks River

Species	DEP Status	N	Total Basal Area	Mean Basal Area per Tree	Maximum Diameter (DBH, inches)	Relative Dominance Based on Basal Area	Relative Dominance Based on Density
Acer saccharum	OBL	2	38.91	19.45	6.5	0.00	0.01
Carya aquatica	OBL	3	85.29	28.43	7.4	0.01	0.01
Carya spp.	OBL	1	126.68	126.68	12.7	0.01	0.00
Cephalanthus occidentalis	OBL	3	6.61	2.20	2.4	0.00	0.01
Fraxinus caroliniana	OBL	8	151.46	18.93	10	0.01	0.02
Fraxinus profunda	OBL	18	221.84	12.32	8.5	0.01	0.05
Ilex cassine	OBL	2	8.68	4.34	3.1	0.00	0.01
Magnolia virginiana	OBL	1	51.53	51.53	8.1	0.00	0.00
Nyssa sylvatica var biflora	OBL	47	2,693.97	57.32	21.1	0.17	0.14
Persea palustris	OBL	37	2,082.57	56.29	23.3	0.13	0.11
Taxodium ascendens	OBL	3	1,580.23	526.74	39.8	0.10	0.01
Taxodium distichum	OBL	16	1,461.47	91.34	27.6	0.09	0.05
Acer rubrum	FACW	11	444.10	40.37	10.8	0.03	0.03
Carpinus caroliniana	FACW	62	1,208.70	19.50	13.1	0.08	0.19
Celtis laevigata	FACW	7	89.98	12.85	6.3	0.01	0.02
Liquidambar styraciflua	FACW	18	1,487.86	82.66	20	0.09	0.05
Morella heterophylla	FACW	1	0.79	0.79	1	0.00	0.00
Quercus laurifolia	FACW	4	258.27	64.57	10.7	0.02	0.01
Quercus nigra	FACW	7	51.66	7.38	4.8	0.00	0.02
Quercus phellos	FACW	1	32.17	32.17	6.4	0.00	0.00
Tilia americana	FACW	2	33.30	16.65	4.8	0.00	0.01
Ulmus americana	FACW	12	197.19	16.43	9.1	0.01	0.04
Ilex opaca	FAC	1	1.33	1.33	1.3	0.00	0.00
Ilex vomitoria	FAC	3	5.85	1.95	1.8	0.00	0.01
Morella cerifera	FAC	31	125.29	4.04	5.5	0.01	0.09
Sabal palmetto	FAC	8	1,072.19	134.02	16.9	0.07	0.02
Fagus grandifolia	UPL	2	17.73	8.86	4.1	0.00	0.01
Juniperus virginiana	UPL	1	243.28	243.28	17.6	0.02	0.00
Magnolia grandiflora	UPL	7	103.12	14.73	6.1	0.01	0.02
Ostrya virginiana	UPL	8	97.82	12.23	9.1	0.01	0.02
Pinus elliottii	UPL	2	782.58	391.29	26.0	0.05	0.01
Pinus taeda	UPL	1	257.30	257.30	18.1	0.02	0.00
Prunus caroliniana	UPL	1	128.68	128.68	12.8	0.01	0.00
Quercus virginiana	UPL	1	646.92	646.92	28.7	0.04	0.00

N is the number of trees measured.

Percent Occurrence along Transects

Transects (based on NWI data) typically included broad leaved deciduous and mixed deciduous trees. Individual transects along the Wakulla River included two to five of the five designated classes and the tupelo cypress hardwood mix occurred on seven of the eight transects (Table 12). Average transect lengths were 970 feet from upland on one side of the river to upland on the other side of the river for the Wakulla River. Six (transects 5-9) of 11 transects along the St. Marks River were limited to one side of the river due to lack of access. Consequently, the average transect length sampled along the St. Marks River was 880 feet, although the average length of the transects that include both sides of the river was 1,198 feet. The average distance to the most landward wetland class (from the edge of the river channel) was about 217 feet for the Wakulla River and 246 feet for the St. Marks River.

None of the St. Marks River transects included more than two vegetation classes (Table 13) and differences in vegetation classes appeared to correspond more closely to the upstream-downstream gradient on this river, compared with a more homogenous mix of species on the Wakulla River. Hardwood hammock, a broad leaved deciduous plant community, occurred along six of eight transects on the Wakulla River and six of 11 transects on the St. Marks River, and was the only vegetation class common to both rivers.

Table 12. Occurrence of the Dominant Vegetation Classes by Transect along the Wakulla River

Transect	Total Length	Tupelo cypress swamp	Tupelo hardwood swamp	Bay hardwood hammock	Tupelo cypress hardwood mix	Hardwood hammock
W1	866	37%			63%	
W2	927			50%	25%	25%
W3	1046			24%	76%	
W4	969				83%	17%
W5	1,171		37%		20%	43%
W6	697		19%	72%		9%
W7	1,137	10%	32%	12%	33%	13%
W8	950		17%	19%	54%	10%
Total Sampling Points		4	24	24	48	14
Occurrence across all Transects		4%	17%	17%	44%	18%

Shading indicates absence of vegetation class.

Table 13. Occurrence of the Dominant Vegetation Classes by Transect along the St. Marks River

Transect	Total Length	Tupelo bay swamp	Cypress hardwood mix	Tupelo hardwood mix	Ash swamp	Hardwood hammock	Ironwood hammock
SM1	807		66%				34%
SM2	1,142					100%	
SM3	1,221		100%				
SM4	677					82%	18%
SM5	457				100%		
SM6	340					100%	
SM7	678					100%	
SM8	568			100%			
SM9	451			21%		79%	
SM10	1,900			82%	18%		
SM11	1,442	50%				50%	
Total Sampling Points		7	12	19	6	35	4
Occurrence across all Transects		17%	18%	30%	10%	17%	8%

Shading indicates absence of vegetation class.

4.4 ESTUARINE VEGETATION

Aerial photography was successfully used to characterize estuarine vegetation and provides a means of tracking changes in marsh extent along the lower St. Marks River in response to potential changes in freshwater flows.

Just above the confluence of the Wakulla and St. Marks rivers, swamp vegetation classes are replaced by sawgrass (*Cladium jamaicense*) marsh along the river, indicating low salinities (probably no more than 5 ppt average), interspersed with black needle rush (*Juncus roemerianus*). Landward and at higher elevations, marsh is replaced by hardwood forests, including oaks, cedar, cabbage palms, and swamp bay that are tolerant of some inundation and very low salinities. About halfway between the confluence of the two rivers and the river mouth, marsh vegetation shifts from sawgrass to black needle rush along the river. Approximately three-quarters of the way downstream, between the rivers' confluence and the river mouth, saltmarsh cordgrass (*Spartina alterniflora*) becomes prevalent along the river edge and black needle rush makes up the marshes landward of the saltmarsh cordgrass, where elevations are higher and average salinities are lower.

The marsh vegetation in the estuarine portion of the St. Marks River is summarized below, by transect.

- Transect E1. East side of transect was characterized by hardwood forest including oaks, cedar, cabbage palms, and swamp bay. On the west side, sawgrass marsh was the dominant cover along the river, with black needle rush interspersed, ending at mixed hardwood forest.
- Transect E2. Sawgrass marsh with black needle rush at water's edge on both east and west side, extending landward to upland ridges on the west side.

- Transect E3. East side is dominated by black needle rush marsh, extending to upland hardwood mix of cabbage palm, pine, and red cedar. Black needle rush marsh on the west side extends approximately 50 feet and then transitions to sawgrass. Periwinkles present.
- Transect E4. Saltmarsh cordgrass occurs along the river edge at the most downstream transect, then transitions to black needle rush marsh to the east, which then shifts to a cedar-dominated ridge at the upland ridge. The west side includes a narrow band of cordgrass, black needle rush marsh extending west along entire transect, with no sawgrass present. Periwinkles present.

4.5 Discriminant Function Analysis (DFA)

As described previously, vegetation is probably the best and most easily measured "integrator of environmental and landscape conditions" (Light et al. 1993, Bedford 1996). Consequently, a DFA is appropriate for modeling the relationship among vegetation and parameters that are strongly related to vegetation, i.e. elevation (as a proxy for inundation) and soils. Transects in the present study were designed for sampling vegetation and corresponding environmental parameters across gradients of elevation and soils. DFA was used to model relationships among vegetation classes and environmental variables and identify environmental variables that best predict vegetation classes. Results of the DFA indicated that elevations, soils, distance to river, and/or depth to SHS accounted for a significant amount of variation among vegetation classes in both rivers. "Successful" DFA classifications indicate a vegetation class that is relatively distinct in terms of both species composition and IV and is also relatively distinct in terms of soils and elevation parameters.

Classifications and Misclassifications

Wetland vegetation classifications (e.g., tupelo cypress swamp) were developed based on species composition and relative importance. The DFA re-classified vegetation class samples "from" the original 114 samples "to" a vegetation class based solely on environmental parameters. For example, in Table 14, 75 percent (three of four times) of tupelo cypress swamps were re-classified as tupelo cypress swamps when only environmental parameters were used to identify vegetation classes. Although vegetation classes were distinct in terms of IV, the contributions of measured environmental variables to distinguishing between vegetation classes varied between rivers. Results for each river are summarized below.

- Wakulla River. The number of vegetation classes correctly re-classified based on environmental parameters was greatest for tupelo cypress swamp (75 percent), followed by tupelo cypress hardwood mix (71 percent), bay hardwood hammock (63 percent), and least for tupelo hardwood swamp (33 percent), and hardwood hammock (29 percent) (Table 14). Calculated p-values for mean elevation (NAVD), distance to river ($p<0.001$), and elevation relative to channel bottom ($p=.10$) suggest these measurable parameters can be used to predict locations of wetland vegetation classes along the Wakulla River. Remaining variables were not statistically significant predictors in the DFA. The stronger relationship of mean elevation (NAVD) to vegetation class (vs. elevation relative to channel bottom) also suggests an upstream-downstream vegetation gradient.

- St. Marks River. Correct classifications were greatest for tupelo bay swamp (100 percent), followed by tupelo hardwood mix (79 percent), cypress hardwood mix and ironwood hammock (75 percent), hardwood hammock (60 percent), and ash swamp and tupelo hardwood mix (50 percent), with the greatest overlap between classes occurring in the hardwood hammock class. Elevation relative to channel bottom and to EOW, elevation (NAVD), and soil type were all significant ($p<0.01$) in distinguishing among vegetation classes, while the remaining variables were not (Table 15). Upstream-downstream elevation changes on the St. Marks River (Figure 9), although steeper, were less variable when compared among adjacent transects and can explain why elevation relative to channel bottom was a significant predictor of vegetation class on the St. Marks (but not on the Wakulla) River. Interestingly, distance to river was not a significant predictor of vegetation class on the St. Marks River, possibly because sloughs and streams that introduced even more variation into a steeper (compared to the Wakulla River) floodplain.

Soil (mineral or not) was a significant factor for the St. Marks River because of the greater number of times sandy hydric soils were encountered, compared with the Wakulla River. Relationships characterizing vegetation classes and soil and elevations parameters were stronger for the St. Marks River as a result of larger differences in elevation and soils along St. Marks River transects when compared with the Wakulla River transects. Depth to SHS did not contribute to distinguishing between vegetation classes for either river, although depth to SHS was significantly greater for St. Marks River transects. Field observations indicated water typically at or above land surface on Wakulla River transects, and more frequently below land surface for the St. Marks. While differences were significant ($p<.001$), the difference was small (less than one inch) and likely reflects within-river variation between vegetation classes.

Misclassifications in the DFA occurred when a vegetation class was misidentified, resulting in overlap between classes. For example, 25 percent of the tupelo cypress swamp samples were misclassified as tupelo hardwood swamp due to overlapping elevation, soil type, and/or distance from channel. For tupelo hardwood swamp, 67 percent of the samples were misclassified, compared with 37 percent misclassifications of bay hardwood hammock, 28 percent of tupelo cypress hardwood mix, and 71 percent of hardwood hammock samples. Overlapping vegetation classes can indicate shared, or similar, habitat based on measured parameters (McNeely 1987). Overlap itself gives no indication of resource preferences of overlapping species, but does indicate the habitat being used (Colwell and Futuyama 1971), as well as the similar resource requirements of most plants (Goldberg and Werner 1983). Swamp vegetation classes were distinct in terms of species composition and IV and environmental variables were significant in differentiating these particular vegetation classes from the remaining hardwood and hammock vegetation classes.

Overlap among vegetation classes (in the DFA) for the Wakulla and St. Marks rivers indicated that vegetation classes generally corresponded to elevation changes from upstream to downstream and from river channel to upland. Future hydrodynamic modeling of both rivers will quantify the influence of tides on river levels and be used in establishing flows to protect estuarine habitats.

Table 14. DFA Results for Vegetation Classifications: Wakulla River

	"To" class					
"From" class	Tupelo cypress swamp	Tupelo hardwood swamp	Bay hardwood hammock	Tupelo cypress hardwood mix	Hardwood hammock	Total Classifications
Tupelo cypress swamp	75(3)	25(1)				100 (4)
Tupelo hardwood swamp		33(8)	8(2)	54(13)	4(1)	100 (24)
Bay hardwood hammock		13(3)	63(15)	25(6)		100 (24)
Tupelo cypress hardwood mix	2(1)	15(7)	6(3)	71(34)	6(3)	100 (48)
Hardwood hammock	14(2)		7(1)	50(7)	29(4)	100 (14)
						100 (114)

Wilks' Lambda= 0.40635; F=3.7775; DF=28; p<0.0001

Variable	F Value	Pr>F
Elevation relative to channel minimum (feet)	**2.0133**	**0.10**
Elevation relative to EOW (feet)	1.9495	0.11
Depth to SHS (inches)	0.6764	0.61
Elevation NAVD88 (feet)	**6.6209**	**<0.001**
Soils(mineral or not)	1.2128	0.31
Soils (hydric or not)	0.3855	0.82
Distance to River (feet)	**8.231**	**<0.001**

Table 15. DFA Results for Vegetation Classifications: St. Marks River

	"To" class						
"From" Class	Tupelo bay swamp	Cypress hardwood mix	Tupelo hardwood mix	Ash swamp	Hardwood hammock	Ironwood hammock	Total classifications
Tupelo bay swamp	100 (7)						100 (7)
Cypress hardwood mix		75 (9)			17 (2)	8 (1)	100 (12)
Tupelo hardwood mix			79 (15)	16 (3)	5 (1)		100 (19)
Ash swamp			50 (3)	50 (3)			100 (6)
Hardwood hammock	6 (2)	14 (5)	17 (3)		60 (21)	3 (1)	100 (35)
Ironwood hammock					25 (1)	75 (3)	100 (4)
Total Classifications							100 (114)

Wilks' Lambda= 0.1369; F=3.1454; DF=30; p<0.0001

Variable	F Value	Pr>F
Elevation relative to channel minimum (feet)	**24.929**	**<0.001**
Elevation relative to EOW (feet)	**7.97**	**< 0.001**
Depth to SHS (inches)	0.9989	0.4242
Elevation NAVD88 (feet)	**12.215**	**<0.001**
Soils(mineral or not)	3.1021	0.0133
Soils (hydric or not)	3.083	0.1377

Table 16. Mean Values for Environmental Parameters: Wakulla River Vegetation Classifications

Vegetation Class	Elevation relative to channel bottom	Elevation relative to EOW	Hydric soils (present or not)	Depth to SHS	Elevation NAVD88	Distance to river	Mineral soils (present or not)
Tupelo cypress swamp (N=4)	9.69	1.58	1.00	0.00	5.07	101.50	1.00
Tupelo hardwood swamp (N=24)	11.59	1.05	1.00	0.25	1.70	89.71	1.00
Bay hardwood hammock (N=24)	9.30	0.61	0.96	0.79	2.33	64.71	0.83
Tupelo cypress hardwood mix (N=48)	10.99	1.18	0.98	0.48	3.06	111.63	0.85
Hardwood hammock (N= 14)	11.73	1.48	1.00	0.36	2.97	216.79	0.86

Table 17. Mean Values for Environmental Parameters: St. Marks River Vegetation Classification

Vegetation Class	Elevation relative to channel bottom	Elevation relative to EOW	Hydric soils (present or not)	Depth to SHS	Elevation NAVD88	Distance to river	Mineral soils (present or not)
Tupelo bay swamp (N=7)	22.00	-0.49	1.00	0.00	1.78	110.71	1.00
Cypress hardwood mix (N=12)	6.64	0.94	1.00	0.58	7.23	75.75	0.83
Tupelo hardwood mix (N=19)	19.48	2.30	1.00	0.79	1.95	155.47	0.68
Ash swamp (N=6)	16.53	3.77	1.00	0.83	4.78	81.50	0.50
Hardwood hammock (N= 35)	11.86	1.05	1.00	1.29	5.27	200.97	0.63
Ironwood hammock (N=4)	8.65	2.66	1.00	1.25	10.04	245.75	0.00

4.6 Wetted Perimeter (WP)

Average WP (linear distance of community/change in elevation) was greatest for the swamp vegetation classes along both the Wakulla and St. Marks river transects. Swamp vegetation classes would be expected to have higher WP values, compared with lower values in hammocks, because they have less elevation change, i.e., are "flatter", and are also, therefore, more sensitive to smaller changes in water level elevations. Uplands had the lowest WP values, given the steeper increase in elevation. Elevations in channels can also have steep sides and subsequently lower WP values. This may help explain the low WP value for the tupelo cypress swamp on the Wakulla River.

Results (Table 18, Figure 13) are not inconsistent with this expectation. Tupelo hardwood swamp on the Wakulla River and tupelo bay swamp on the St. Marks River had the greatest average WP values, indicating that small changes in water level elevations can result in large changes in the amount of wetland habitat inundated, particularly for these two classes. For example, in the Wakulla River, the same one foot change in water level (and commensurate flow) would affect 624 linear feet of tupelo hardwood swamp compared with 183 linear feet of hardwood hammock. Wetted perimeter can provide a metric for habitat changes with changes in discharge and can be used to ensure that habitats that may be disproportionately impacted by small incremental changes in flows are addressed under an MFL.

Table 18. Average Change in Wetted Perimeter (WP, in linear feet of habitat/ elevation change, in feet) for Vegetation Communities Sampled along the Wakulla and St. Marks River Corridors

Wakulla River		St. Marks River	
Vegetation Class	**WP**	**Vegetation Class**	**WP**
Tupelo cypress swamp	89	Tupelo bay swamp	4,567
Tupelo hardwood swamp	624	Cypress hardwood mix	154
Bay hardwood hammock	233	Tupelo hardwood mix	56
Tupelo cypress hardwood mix	149	Ash swamp	623
Hardwood hammock	183	Hardwood hammock	152
Upland	29	Ironwood hammock	41
		Upland	79

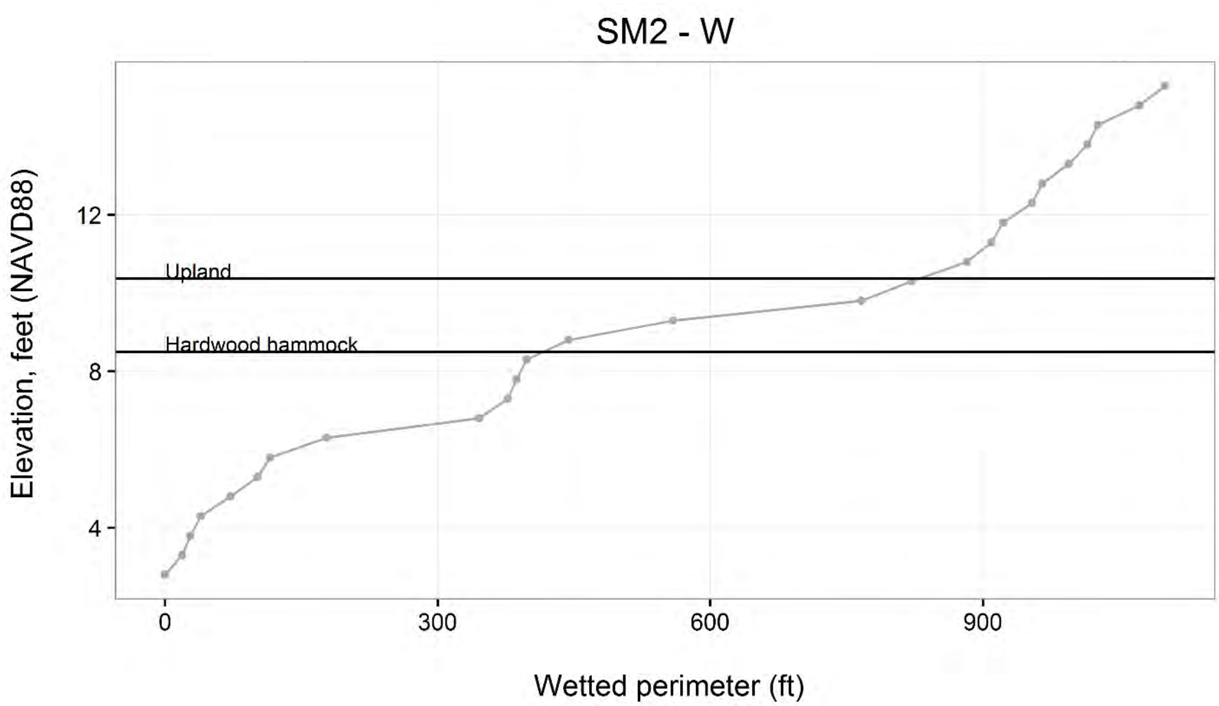

Figure 13. Wetted Perimeter and Associated Vegetation Classes on Transect SM-2, St. Marks River

4.7 INSTREAM WOODY HABITATS

Median and mean elevations (relative to water surface), associated lower and upper quartiles (25 percent and 75 percent), and minimum and maximum elevations, for DWD and live root features are graphed as box and whisker plots in Figure 14 for the Wakulla River and Figure 15 for the St. Marks River. Instream transects on the Wakulla River coincided with locations of floodplain transects W1, W2, and W3. Instream transects on the St. Marks River were located at the shoals near SM4 (instream transect SM1), adjacent to SM5 (instream transect SM2), and on the south side of SM6 (instream transect SM3). Elevations of instream habitats are relative to water surface elevations and indicate similar elevations at a transect, but variation among transect along river channels, coincident with channel bottom elevations (presented previously in Figures 8 and 9). For the Wakulla River, the lower elevations of both DWD and live roots are lowest at transect W2, where channel bottom elevation was higher (about five feet) than either transect W1 or W2. Median DWD elevations were consistently lower than live root elevations and overlap in elevations was minimal except at transects W3 and SM2. Standard errors ranged from 0.12 to 0.19 for five of six transects on the Wakulla River (Table 19) and from 0.09 to 0.18 feet at St. Marks River transects.

Table 19. Mean and standard error for elevations of DWD and live root instream woody habitats on the Wakulla and St. Marks rivers.

Instream Transect	Wakulla River			St. Marks River		
	Mean	Standard Error	N	Mean	Standard Error	N
DWD						
1	0.23	0.19	4	0.66	0.17	14
2	-0.12	0.16	14	0.23	0.2	9
3	-0.45	0.31	13	0.60	0.2	14
Live root						
1	0.72	0.12	11	1.37	0.16	16
2	0.65	0.13	3	0.49	0.09	21
3	-0.01	0.18	7	1.45	0.18	16

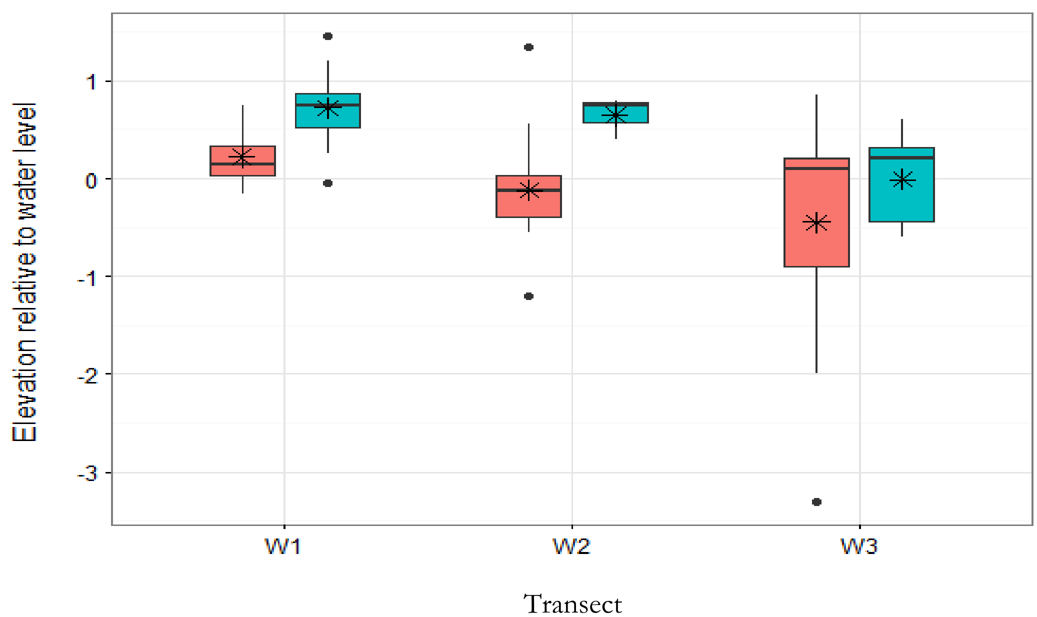

Figure 14. **Mean (asterisk) and median (horizontal line) elevations and 25th, 75th, and 95th percentiles (relative to water level) for DWD and root snags (live root) along the Wakulla River**

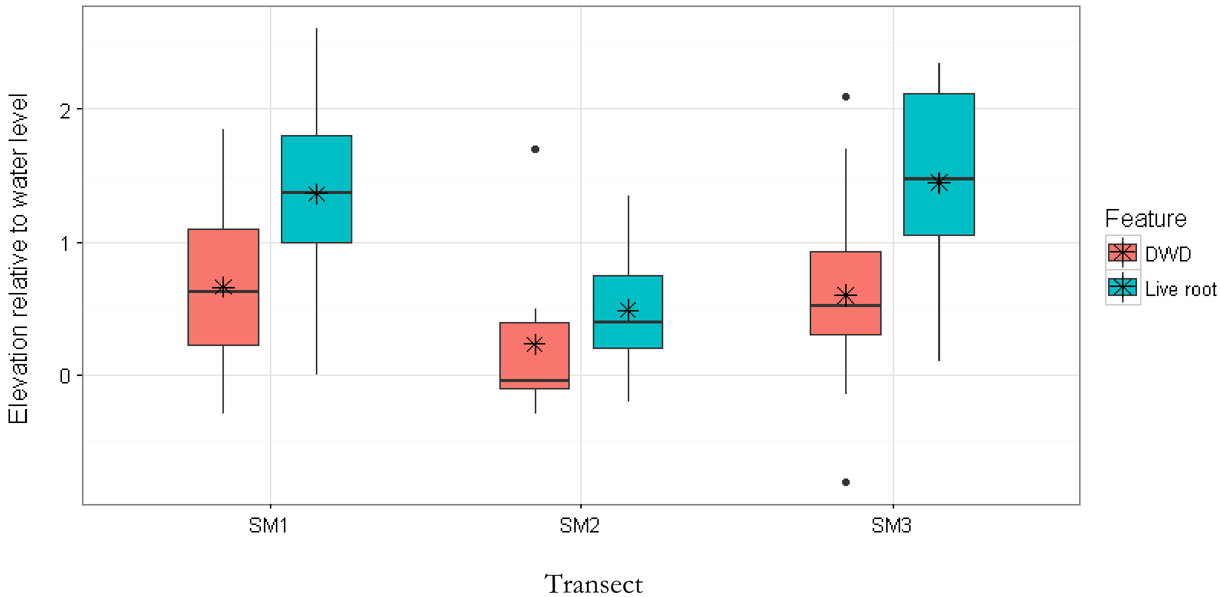

Figure 15. Mean (asterisk) and median (horizontal line) elevations and 25th, 75th, and 95th percentiles (relative to channel bottom) for DWD and root snags (live root) along the St. Marks River

4.8 Considerations for Relationships of Vegetation with Environmental Variables

Relationships among river stage, flow, and elevations for the St. Marks and Wakulla rivers are being developed by the District (e.g., Hydrologic Engineering Center's River Analysis System, or HEC-RAS, model) and are not presented here. However, it is appropriate to address hydrologic conditions such as saturation and inundation that are critical to the development and maintenance of hydric soils and associated wetland vegetation.

Tidal influence extends upstream of the US 98 bridge on both the Wakulla and St. Marks rivers. At Wakulla Springs, water level changes associated with tide can be six to 12 inches daily, depending on seasonal influence. Water level fluctuations at the confluence of the two rivers, at the City of St. Marks, average 3.64 feet. Consequently, EOW locations change with tide on both rivers and these differences will be addressed by the District's hydrodynamic modeling. These differences are not relevant for the vegetation relationships developed by the DFA because, for example, the swamp vegetation class is lower than the hammock vegetation class relative to EOW (or channel bottom or other metric) regardless of the actual EOW elevation. The present study identified vegetation classes with greater (or lesser) depth and duration of water as potential resources that can be examined with respect to the effects of inundation scenarios (with HEC-RAS). In addition, all elevations were measured in NAVD so that all elevations can be transformed relative to any selected benchmark if needed.

Hydrology. The wetland communities along the Wakulla and St. Marks rivers are influenced by groundwater conditions as well as surface water flows. Swamps along these rivers include tupelo, cypress, and swamp bay that are tolerant of permanent and semi-permanent flooding. Saturation and/or inundation are critical to the maintenance of wetlands vegetation in floodplains, although overbank flooding is not specifically necessary (Cowardin *et al*. 1979, Reid and Wood 1976), and ground water conditions can strongly influence the extent of wetlands (Light *et al.* 2002).

Wetland trees are relatively fast-growing and, in five years, can generally grow to a height at which they are tolerant of inundation. Cypress trees, for example, can exceed 39 inches in one to two years (Harms 1973). Cypress is an obligate wetland species, tolerant of up to nearly 10 feet of inundation for more than 10 years, and more tolerant of wetland conditions than the other species documented as part of this study. However, cypress cannot germinate under flooded conditions and do not grow quickly enough to successfully compete with other wetland tolerant species where inundation may be less persistent. Species that are less flood tolerant, such as cabbage palm and maple occur landward of the cypress, but may occur on the banks of the river where the transition to open water is steep. Cabbage palms are unusual in that they require an initial establishment phase of 30 to 60 years during which they have no above-ground trunk (McPherson and Williams 1996) and flood events at 25 year intervals or more probably restrict the regeneration of cabbage palm. Once established, they are susceptible to only rising sea level, hurricanes, and fires rather than changes in inundation depth and frequency.

Competition. Wetland species occur in wetlands because they are tolerant of saturated and anoxic conditions that preclude upland species. Similarly, saltmarsh plant species are tolerant of saline conditions while freshwater marsh species are excluded from saltmarshes due to salt intolerance. However, saltmarsh species are out-competed by freshwater species under freshwater conditions. Several studies have indicated that environmental gradients are more important in determining species distributions under physiological stressful conditions such as flooding and salinity, while competition may be more important under relatively benign environmental conditions (Grace and Wetzel 1981, others). Species such as laurel oak (*Quercus laurifolia)*, which is relatively intolerant of persistent inundation when compared with a species such as cypress or tupelo, as well as red maple, can be at a competitive advantage in the absence of persistent flooding and subsequently expand into areas previously dominated by a species such as cypress. There was no indication of recent invasion of wetlands on either river by upland species along the study corridor.

Disturbance. Invasive and non-native species can have a competitive advantage under disturbed conditions. Disturbances such as fire, flooding, and animal activity, can result in a gap into which a species that may not otherwise survive can become established due to the absence of other species. Mature native trees can continue to shade out many invasive species until the native trees die and create openings into which invasive species expand. No exotic species such as Chinese tallow *(Sapium sebiferum),* or camphor tree *(Cinnamomum camphora),* were observed along any of the study transects. Nor were any other terrestrial invasive or exotic species observed in sample plots or along transects during field visits, suggesting that there have been no changes or disturbances serious enough for these invasive/ exotic species to become established and affect the distribution of native species. Finally, no instances of expansion of red maple into wetlands typically characterized by obligate wetland species were observed during field visits, suggesting that water levels in these wetlands have been adequate to preclude invasion by colonizing red maple.

Comparisons with other Vegetation Studies. Lewis et al. (2009) state "Few investigators have focused on the wetland forests of the Wakulla and lower St. Marks basins". Clewell (1981) described cypress swamps along the bank of the Wakulla River, replaced by a bottomland hardwood terrace farther landward, and mixed hardwoods along the slope into the adjacent uplands. His description of the general composition of these communities included cypress swamps (bald cypress, ash, and maple), a shift to a bottomland terrace with swamp bay, planer tree (*Planera aquatic*), and other species, with very little cypress, and then a hardwood forest slope with sweet bay, laurel oak, ironwood, and no cypress.

Along the St. Marks River, Clewell (1981) described bottomland hardwood forest (also referred to as a hammock by Clewell) south of the St. Marks River Rise. The community was represented primarily by ironwood, green ash, sweetgum and sugarberry, with less than six percent of the basal area accounted for by bald cypress and tupelo. Light et al. (1993) provide a similar description of a site about a half mile below Natural Bridge: ironwood and sweet gum prevalence in all vegetation zones, with sweetbay, swamp dogwood, and bald cypress common in the lower zones, and loblolly pine the most abundant tree on the upper slope.

Forest community studies in the Ochlockonee, Wakulla/St. Marks and Suwannee rivers (Clewell 1986; Leitman et al. 1991; Light et al. 1993; Light et al. 2002) also describe palustrine forests of at least three major vegetation types: bottomland hardwoods, cypress swamps, and coastal tidal swamps. The distribution of these forests types are attributed to elevation, the degree and type of inundation, and proximity to the coast (i.e., salt water). Bottomland hardwood forests (Clewell 1986) are generally inundated, sometimes briefly but occasionally for prolonged periods annually. During the dry season, the root zone is aerated. Cypress-tupelo swamps dominate areas characterized by prolonged hydroperiods in which the soils are inundated at least several weeks every year and often for as long as six months (Clewell 1986).

Lewis et al. (2009) also expect that plant communities along the Wakulla and St. Marks rivers would be similar to those along the Suwannee River, described by Light et al. (2002), who defined three major forest types along the lower Suwannee River, from the mouth to the nontidal (riverine) portion of the river. Dominant trees included live oak (*Quercus virginiana*), sweet gum, laurel oak, river birch (*Betula nigra*), bald cypress, overcup oak (*Quercus lyrata*) and planer trees. Downstream of the riverine portions, upper tidal river habitats were dominated by swamp laurel oak, cabbage palm, bald cypress, pumpkin ash and water tupelo. Flooding in upper tidal habitats ranged from once every two years, with rapid soil drying after flood recession, to monthly by high tides or high river flow with continuously saturated soils. Inundation in lower tidal hammocks and swamps ranged from every one to two years to daily or several times monthly. In most cases, soils were saturated continuously, at least in the lowest areas. Lower tidal forests consist of cabbage palm and loblolly pine on the higher sites and pumpkin ash, swamp tupelo, sweetbay and bald cypress in the wetter sites.

These descriptions are generally consistent with the findings in the present study. The Wakulla River and St. Marks River above their confluence can be most readily described as upper tidal (after Light et al. 2002) and, within that broader classification, characterized by lower cypress tupelo swamps that shift to bottomland hardwoods and hammocks, where hydroperiods are shorter than in swamp communities, and finally to uplands (after Clewell 1981 and 1986, and Light et al. 2009). While the Wakulla River floodplain appears to fit rather neatly into this framework, the upper St.

Marks vegetation classes include predominantly hammocks. However, the vegetation classes at the two most downstream transects on the St. Marks River (SM10 and SM11), are characterized by tupelo hardwood mix and tupelo bay swamp, respectively, both represented by swamp tupelo and swamp bay as the most dominant (greatest single IV) species.

5 CONCLUSIONS

Results of the present study demonstrated significant differences in vegetation, soils, and elevations both within and between the Wakulla and St. Marks rivers floodplains. Environmental gradients from upstream to downstream and river channel to upland were greater, and differences in vegetation classes were more strongly correlated with elevations, for the St. Marks River when compared with the Wakulla River. In contrast, the Wakulla River was characterized by greater similarity among vegetation classes (e.g., characterized by many of the same species with more similar IVs), soils, and elevations than the St. Marks River.

Differences in vegetation in forested wetlands along the river corridors were significant based on importance values (IVs) and provided a relative measure of species dominance. Five distinct vegetation classes were identified on the Wakulla River and six on the St. Marks River. A single class, hardwood hammock, was common to both rivers. Differences between vegetation classes correspond to a transition from swamp vegetation classes (greater depth and duration of inundation) at the river to "drier" hammock vegetation classes (shorter depth and duration of inundation) at the upland extent of the floodplain.

- Wakulla River transects were represented by more than 70 percent obligate wetland species (as measured by IV). Swamp tupelo (IV=83) was the dominant species along the Wakulla River and the single most common species found in sample plots. Several obligate wetland species of lesser IVs comprised most of the remaining relative importance: pumpkin ash (IV=44), swamp bay (IV=43), and bald cypress (IV=31). Relative importance of upland species made up less than 25 percent of four of the five classes. Tupelo cypress and tupelo hardwood swamp appeared to have the greatest depth and duration of inundation among the vegetation classes sampled, while hardwood hammock appeared to be the vegetation community with the shortest hydroperiod based on species composition.
- On the St. Marks River, four of the six vegetation classes included less than half obligate wetland species and no single species had conspicuously greater dominance. Relative importance was shared among several co-dominants with similar IVs: bald (IV=45) and pond (IV=53) cypress, swamp bay (IV=43*)*, swamp tupelo (IV=54), and both pumpkin (IV=24) and pop (IV=23) ash. Ironwood was the single most common tree in sample plots. The tupelo bay swamp was the vegetation class with the greatest depth and duration of inundation, while hardwood hammock is likely to have the least depth and duration.

Within rivers, tupelo cypress and tupelo hardwood swamps (Wakulla River) and tupelo bay swamps (St. Marks River) appear to be the vegetation classes with the greatest depth and duration of inundation in these palustrine forested systems and may provide vegetation communities on which to establish MFLs for higher ranges of flows (refer to Figure 1). Hardwood hammocks were common to both rivers, had the greatest average distance from the river, included the greatest number of upland species, and appeared to be the "driest" vegetation class on both rivers. Instream woody habitat features also generally corresponded to elevations and provide another potential resource on which to establish MFLs, although the elevations of these features varied among transect locations.

Results of our analysis suggest that elevations of specific vegetation classes along the St. Marks and Wakulla rivers may provide metrics for establishing MFLs. However, greater overlap among vegetation classes and environmental parameters along the Wakulla River suggests that much more of the Wakulla River floodplain is inundated for longer when compared with the St. Marks River floodplain, likely a result of greater groundwater influence.

The floodplain along the upper St. Marks River appears to be characterized by shorter, more seasonal inundation by surface water flows, while downstream vegetation is influenced by tidal freshwater inundation. The District is currently performing hydrologic modeling that will be used to better evaluate the timing and extent of ground water and surface water on these river floodplains and the potential effects of changes in surface and/or ground water flows. Results of the District's hydrodynamic modeling will better clarify the influence of ground and surface water on these systems.

Elevations and Soils. Soils and associated elevations varied considerably between the Wakulla and St. Marks rivers. Channel bottom elevations declined much more dramatically along the St. Marks River than in the Wakulla River. Average depth to SHS was less than an inch at locations sampled along both rivers and no difference in depth to SHS between vegetation classes was found. However, field observations noted water at the surface much more frequently on the Wakulla River than the St. Marks River and the difference in mean depth to SHS between rivers, albeit small (less than a half inch), was significant.

- Wetland soils sampled along Wakulla River transects were almost exclusively mucky mineral (90 percent) and seasonal high soil saturation was typically at the land surface. Channel bottom elevations along the Wakulla River declined a total of 6.35 feet from the most upstream to the most downstream transect. Mean elevations (feet NAVD) of vegetation classes ranged from 1.70 (tupelo hardwood swamp) to 5.07 (tupelo cypress hardwood mix). Seasonal high water was closer to land surface than for the St. Marks River.
- The St. Marks River wetland soils were characterized by a substantial proportion of sandy or clayey/ loamy hydric soils (35 percent of samples) rather than mucky mineral soils. The decline in channel elevations (upstream to downstream) was 23.08 feet. Mean elevations (feet NAVD) of vegetation classes ranged from 1.95 (tupelo hardwood) to 10.04 (ironwood hammock).

Relationships among Vegetation, Soils, and Elevations

Although vegetation classes were distinct in terms of IV, results of DFA indicated relationships with soil and elevations parameters were stronger for the St. Marks River when compared to the Wakulla River, likely due to larger elevation differences along transects and from upstream to downstream on the St. Marks River. Average elevations associated with vegetation classes reflect a strong upstream to downstream elevation gradient and, consequently, average elevations (NAVD) of classes were not always reflected of the relative elevation of vegetation classes to each other.

- Wakulla River. Elevations (NAVD), and distance to river were significant ($p<0.001$) parameters in distinguishing between vegetation classes and elevation relative to channel bottom was significant at a $p=0.10$ value. Based on environmental parameters alone, the tupelo cypress swamp vegetation class was correctly classified 75 percent of the time, followed by tupelo cypress hardwood mix (71 percent), bay hardwood hammock (63 percent), tupelo hardwood swamp (33 percent), and hardwood hammock (29 percent).
- St. Marks River. Elevation (NAVD), elevation relative to channel bottom and to EOW, and soil type were significant ($p<0.001$) parameters in distinguishing among vegetation classes. Based on environmental parameters alone, ash swamp and tupelo hardwood mix were correctly classified 50 percent of the time, followed by hardwood hammock (60 percent), cypress hardwood mix and ironwood hammock (75 percent), tupelo hardwood mix (79 percent), and tupelo bay swamp (100 percent), with the greatest overlap with other classes occurring in the hardwood hammock class.

Both vegetation classes and instream woody habitats may change under flow scenarios that reduce (or increase) depth and duration of inundation of the vegetation. For example, reducing inundation in forested swamp vegetation classes to less than six to eight months per year may result in a shift from obligate wetland species to facultative wetland species, with potential invasion by noxious and/or invasive species and commensurate changes in wildlife value. In the estuarine portion of the system, location of the upstream extent of the salt marshes can provide an indicator of potential upstream expansion of saltmarsh due to reduced freshwater flows and resulting higher salinities. Tree species do not extend south of the confluence of the two riversdue to salinity intolerance as well as increased depth and duration of inundation, and sawgrass typically senesces at salinities greater than 5 ppt. In contrast, saltmarsh cordgrass and black needle rush are tolerant of a wide range of salinities (0 to >33 ppt).

Future Efforts

Tidal influence, flows associated with the mean elevations of different vegetation classes, and the frequency of inundation cannot be evaluated without hydrologic analyses, which were not part of the present study. However, surface water modeling and a hydrodynamic analysis of the St. Marks and Wakulla rivers system will be completed as part of future efforts to establish MFLs protective of the water resources of the St. Marks River Rise, Wakulla Springs, and Sally Ward Spring system.

Results of the present study indicate that floodplain vegetation classes and instream woody habitats can be predicted using elevation measures and therefore may be used as targets for MFLs. For example, elevations of swamp vegetation classes and/or instream woody habitats (DWD and live roots) can be used to estimate semi-permanently inundated vegetation and/or instream habit area as a function of river stage. The District's future efforts will include models of stage-discharge ratings that will be used to translate the habitat-river stage into habitat-discharge relationships for establishing MFLs.

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7 APPENDICES