Appendix H

Characterization of Woody Wetland Vegetation Communities along the Little Manatee River

DRAFT

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Executive Summary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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1.0 Purpose

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

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

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

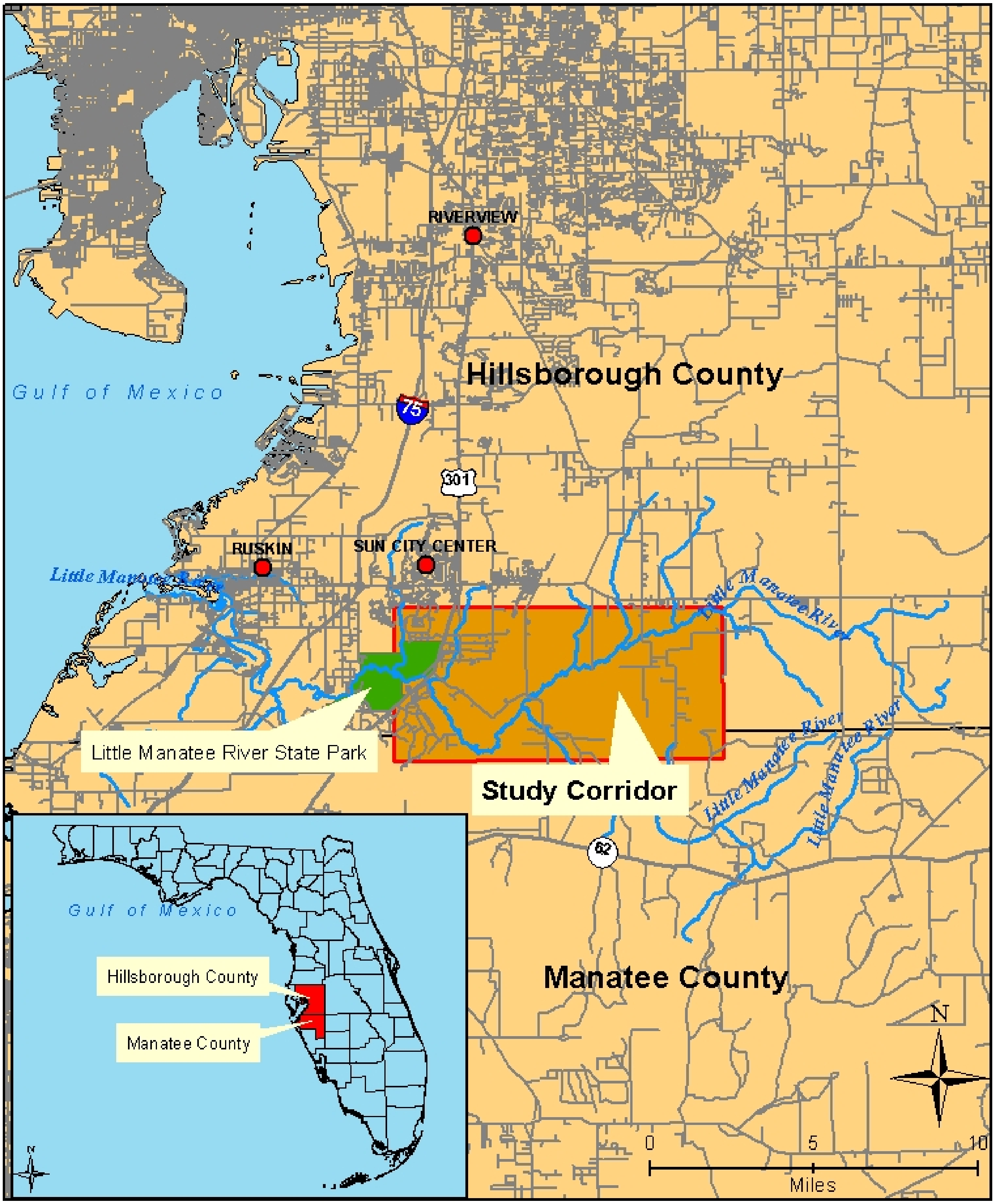
- Address Florida Statute 373.042(1)(a)&(b)
- Protect water resources and ecology
- Determine water availability

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

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

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

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



2.0 Background

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

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

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

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

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

2.1 Physiography

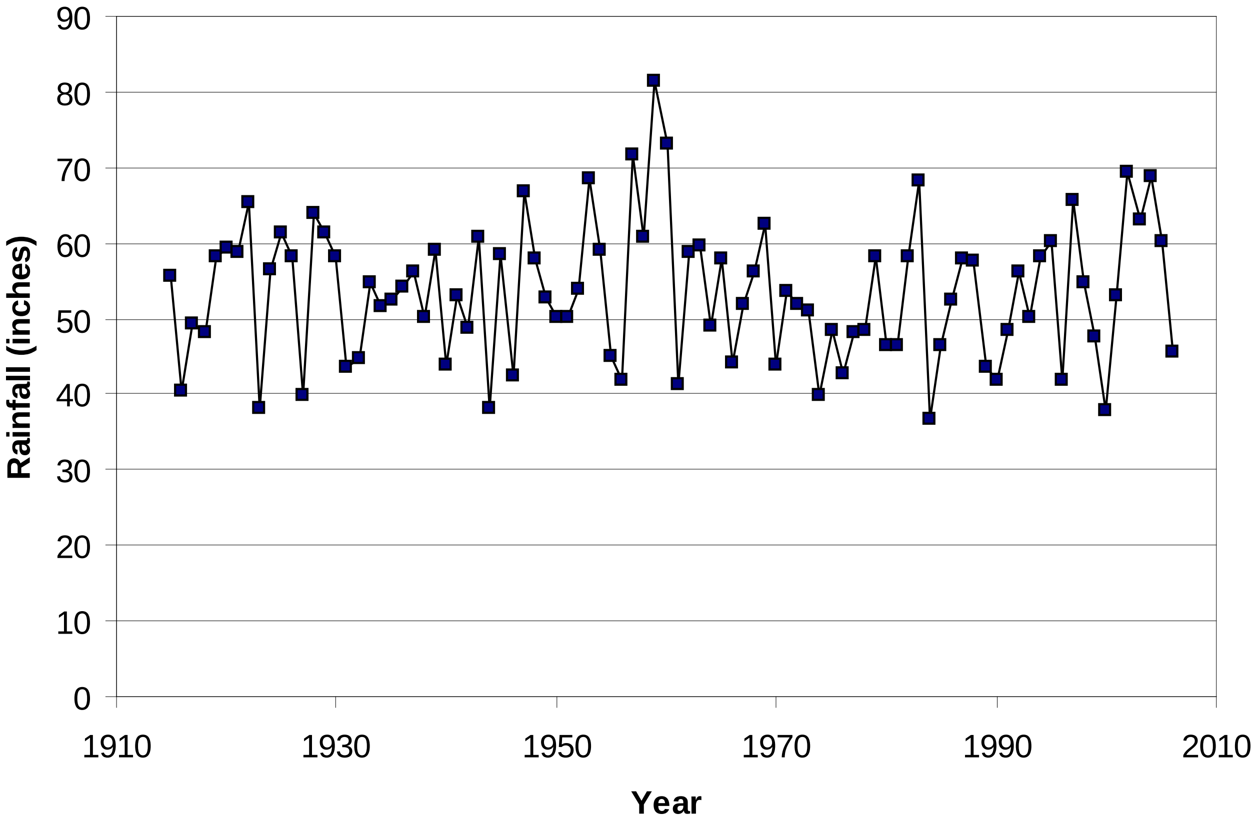
The Little Manatee River watershed occurs across three physiographic provinces: the Gulf Coastal Lowlands, DeSoto Plain, and the Polk Upland (White 1970). The lower portion of the watershed flows over the relatively flat plains of the Gulf Coastal Lowlands province and DeSoto Plain that extend eastward with a gentle slope upward to the border with the Polk Upland physiographic province. The western edge of the Polk Upland is defined by the presence of the first of several paleoshoreline scarps associated with the Pleistocene ice-age sea level fluctuations. This physiographic feature is known as the Pamlico Scarp or shoreline (Healy 1975). Elevations in the Gulf Coast lowlands and DeSoto Plain range from sea level to 50 feet.

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

2.2 Climate and Precipitation

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

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



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

2.3 Surface and Ground Water

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

2.4 Surface Water

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

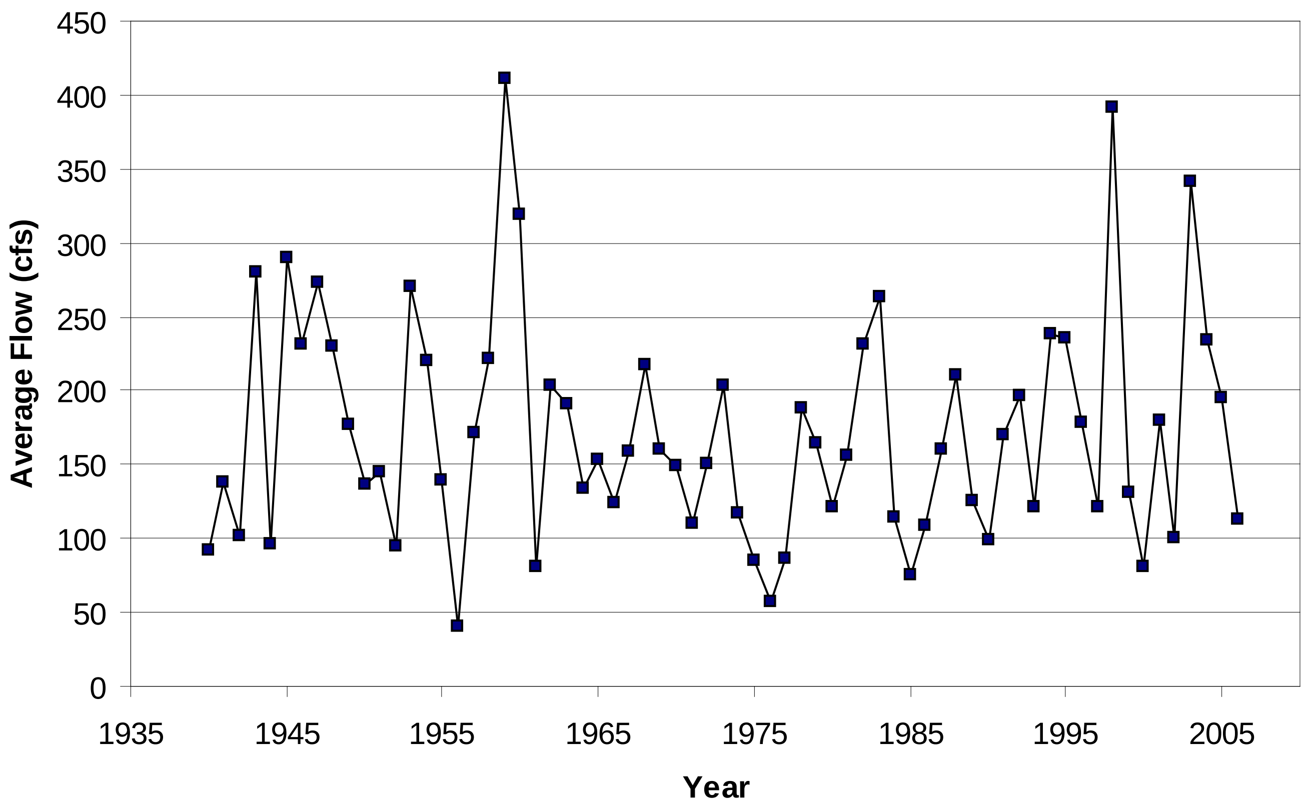
Mean annual flow in the Little Manatee River recorded at the United States Geological Survey (USGS) gage near Wimauma was 171.4 cfs for the period of record from 1940 to 2006 and ranged from about 100 cfs to 300 cfs. Mean annual flows were less than 100 cfs in only 11 of the 67 years measured and exceeded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

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

Low recharge to the aquifer in the Little Manatee River and watershed results in relatively large flows during short periods of time due and makes the system “flashy”. Stream flow records and associated land use influences suggest that agricultural practices have increased flows in the river due to excessive irrigation of row crops that subsequently flows off the land and into the river. In contrast, total annual discharge from the watershed decreased from the 1960s to 1990 and coincided with reduced rainfall in southwest Florida. Also as a result of the low recharge, there are few lakes and wetlands in the Little Manatee River watershed below the upper reaches.

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

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



2.5 Ground Water

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

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

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

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

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

2.6 Topography and Soils

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

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

2.7 Vegetation

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

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

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

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

2.8 Issues

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

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

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

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

3.0 Sampling Methods

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

3.1 Transect Selection

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

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

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

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

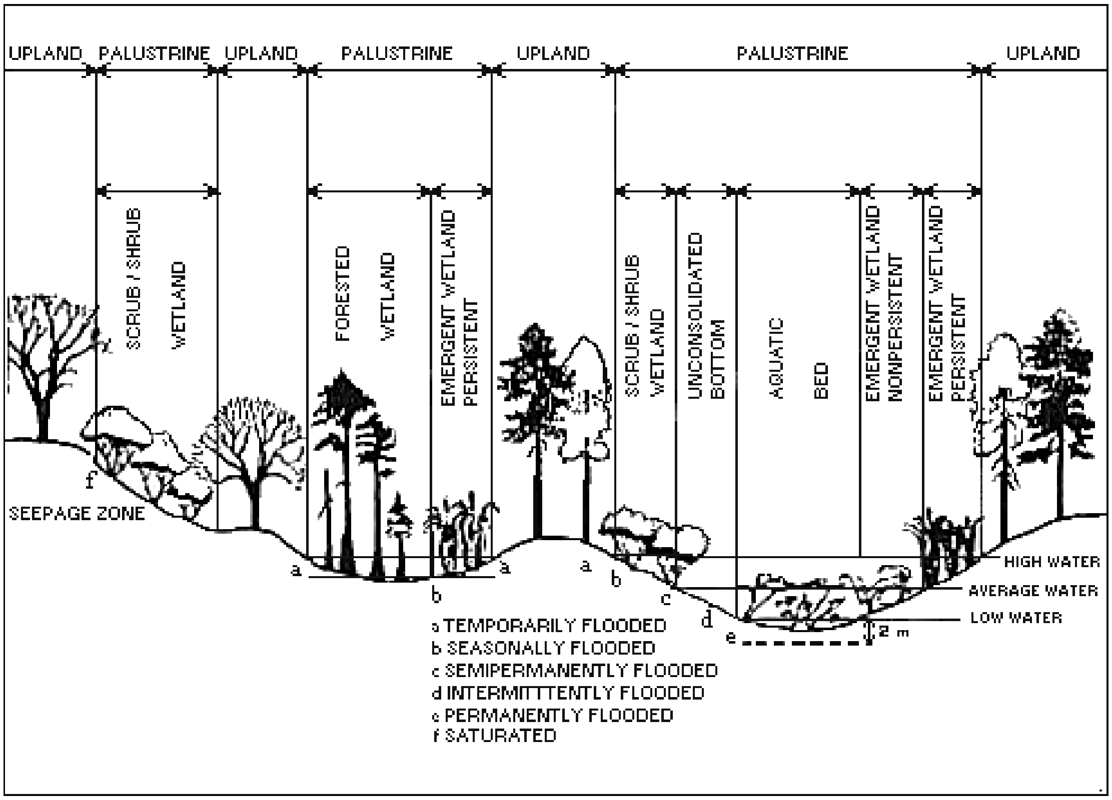
An analysis of the NWI vegetation classes was used as the basis on which to allocate transects among vegetation communities along the river channel. Corridors 500 feet wide were used to quantify the vegetation classes along each transect and identify the dominant vegetation classes along transects. The percent of each NWI vegetation class present along the 10 sampling transects are listed in Table 3-3. Potential transects were assigned in areas characterized by native vegetation, while residential and commercial development were omitted. The vegetation classes identified for this study were based on woody species dominance and generally corresponded with NWI vegetation classes.

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

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

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

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



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

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

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

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

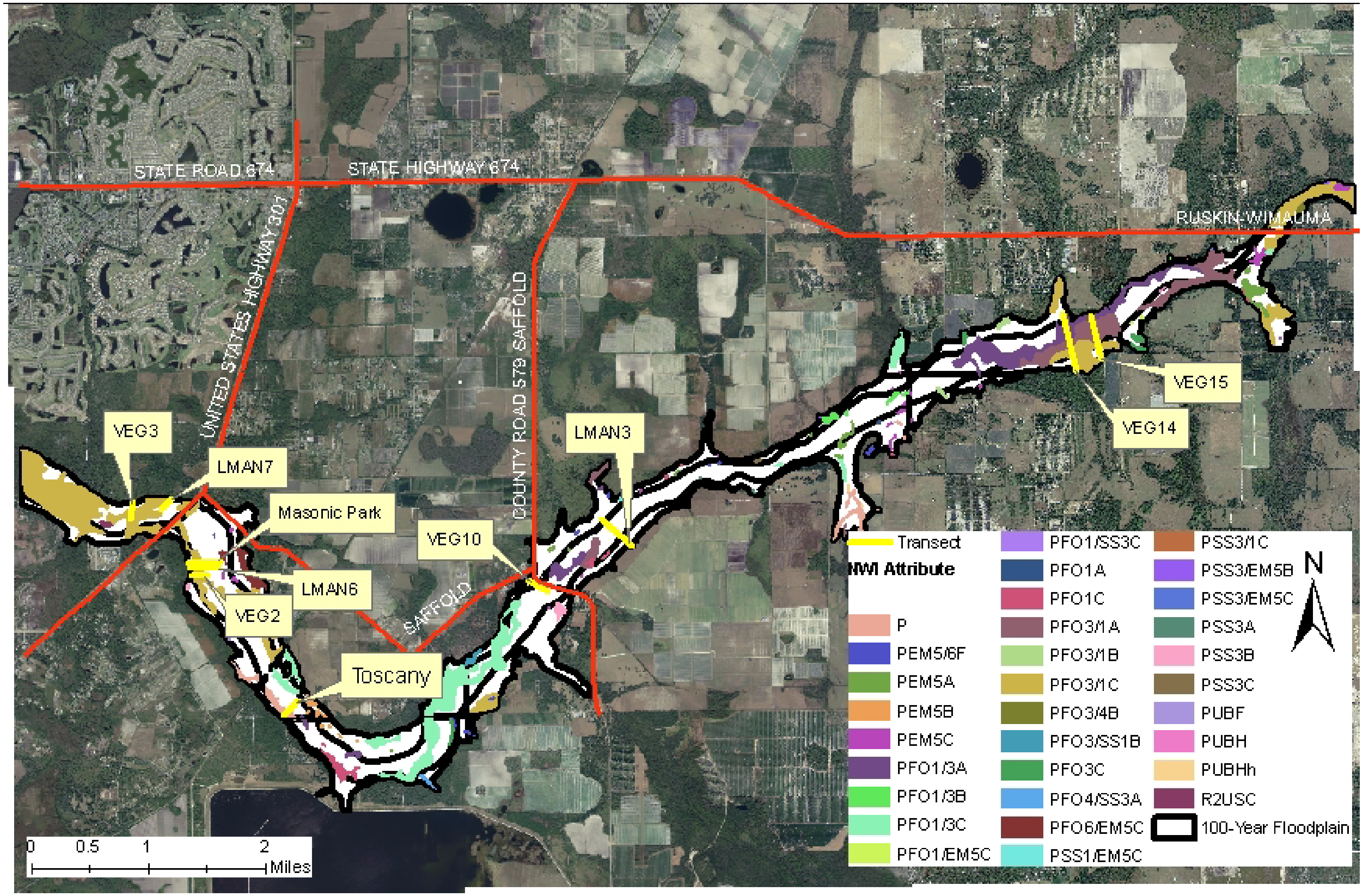


Table 3-3
Percent Cover by NWI Class and Transect in the
Little Manatee River Study Corridor

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

3.2 Elevation Surveys and Distance to Channel

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

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

3.3 Vegetation Characterization

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

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

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

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

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

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

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

- Density/ 100 square meters = 100/(average measured distance, in meters)^2
- Basal area = basal area of individual trees (cm^2)
- Dominance = (relative density) (basal area, in cm^2)

3.4 Soils Characterization

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

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

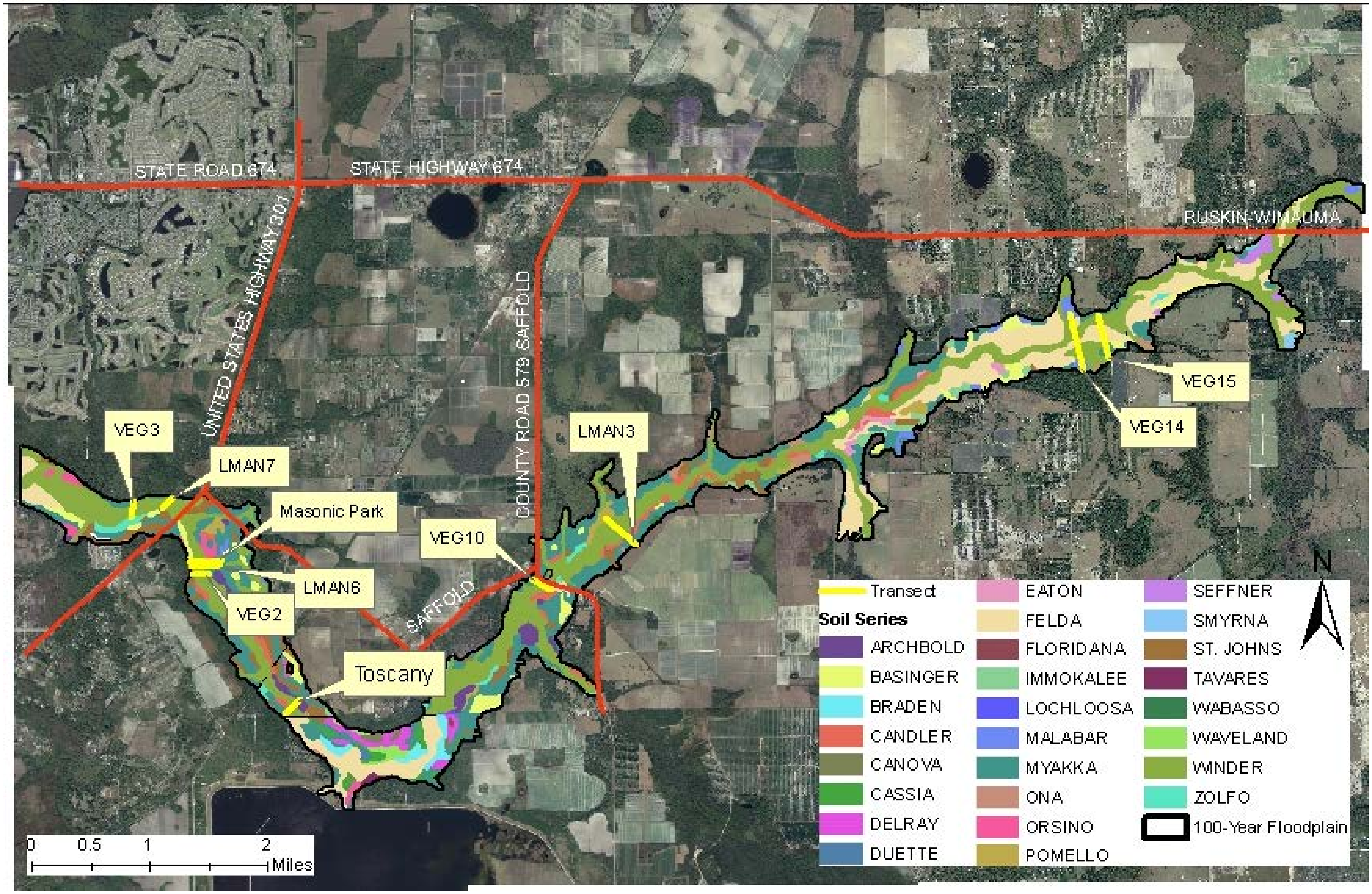
Soils data along the Little Manatee River study corridor (USDA/NRCS 1996) are mapped in Figure 3-3. Soils along the Little Manatee River are typically poorly drained sandy soils characteristic of flatwoods and primary soil associations in the Little Manatee River watershed were described earlier (Section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

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

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

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

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



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

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

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

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

3.5 Data Analysis

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

3.5.1 Elevations and Wetted Perimeter

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

Wetted perimeter was calculated for vegetation classes in the study corridor to evaluate the potential change in inundated habitat that may be anticipated due to changes in river stage. The wetted perimeter for a vegetation class is the linear distance inundated along a transect below a particular elevation or water level (river stage). Consequently, as distance from the river channel increases, the total wetted perimeter also increases, but can vary among vegetation classes.

Wetted perimeter changes, relative to changes in elevation, were compared using the Kruskal Wallis test, a nonparametric analog to a one-way analysis of variance (ANOVA).

3.5.2 Vegetation and Soils

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

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

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

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

4.0 Results and Discussion

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

4.1 Elevations

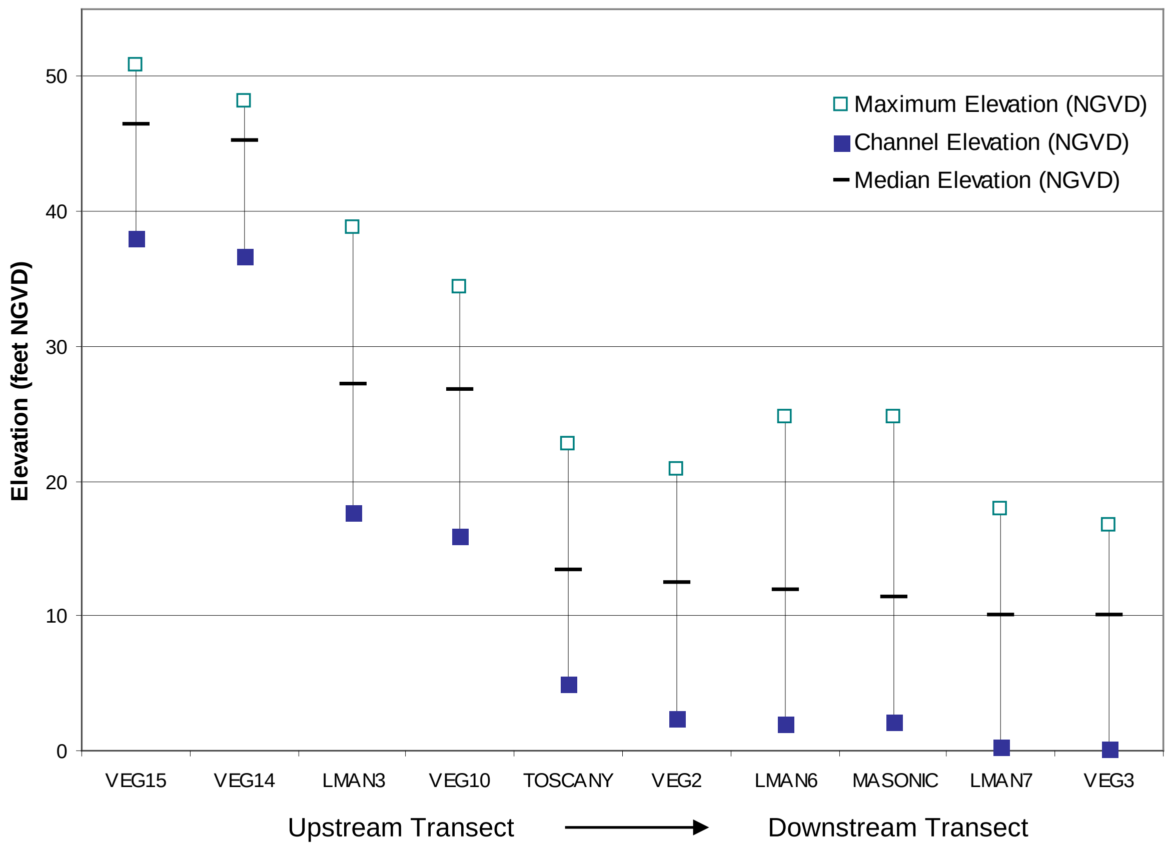
River channel elevations declined dramatically downstream along the Little Manatee River, from 38.0 feet NGVD (Toscany) to 0.1 feet NGVD at the VEG3 transect farthest downstream (just east of U.S. Highway 301), a change in elevation of approximately 38 feet over about 12 miles (0.3 feet/mile) (Table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

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

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

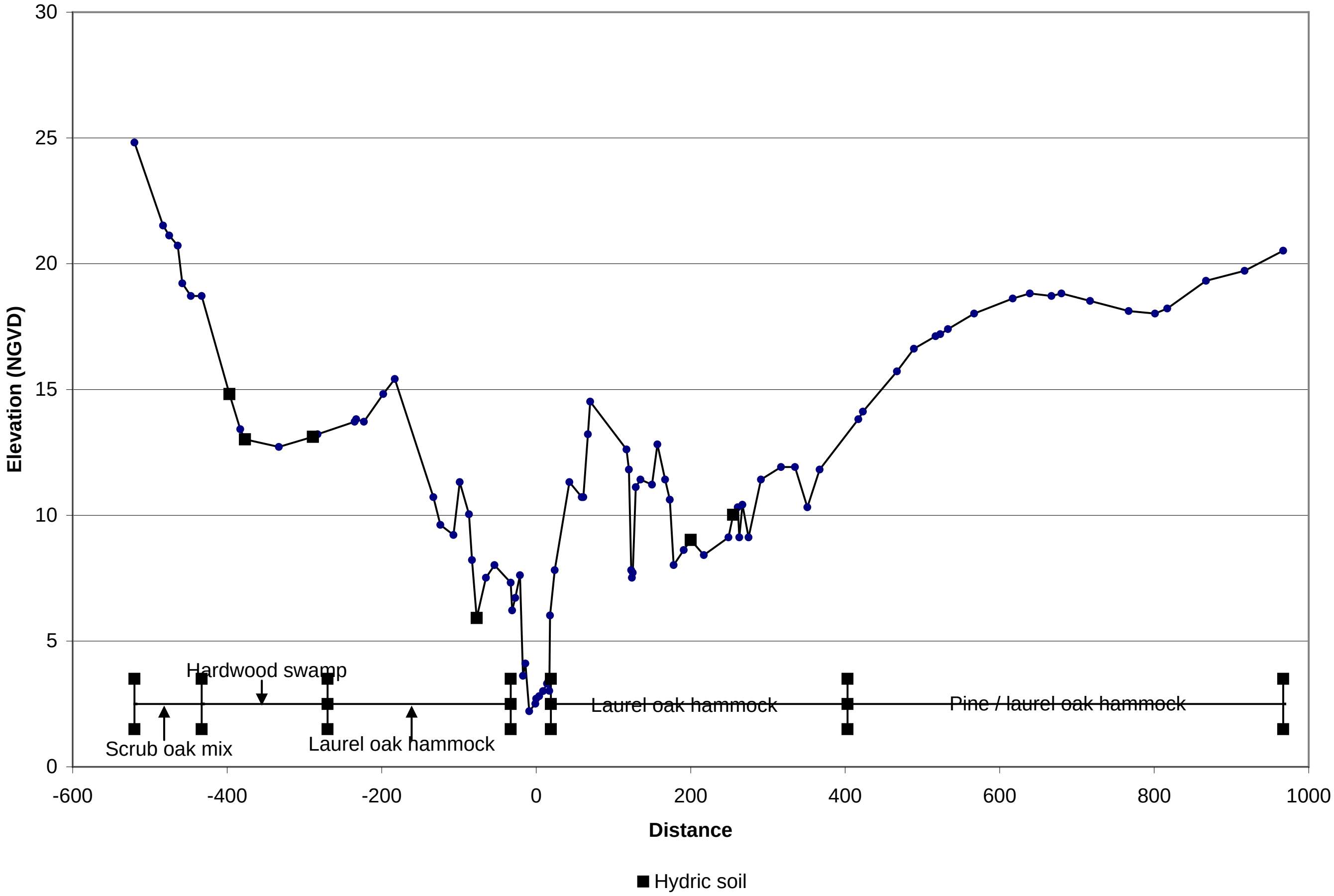
	Transect	Transect Distance (feet)	Maximum Elevation (NGVD)	Channel Elevation (NGVD)	Maximum Elevation Change	Median Elevation (NGVD)	Median Relative Elevation	N
Downstream ← → Upstream	VEG15	2025	50.8	38.0	12.8	46.5	8.5	98
	VEG14	2665	48.2	36.6	11.6	45.2	8.6	109
	LMAN3	1857	38.8	17.7	21.1	27.1	9.4	108
	VEG10	994	34.4	15.9	18.5	26.8	10.9	58
	TOSCANY	950	22.8	5.0	17.8	13.4	8.4	82
	VEG2	749	20.9	2.4	18.5	12.4	10	66
	LMAN6	1350	24.8	2.0	22.8	11.9	9.9	93
	MASONIC	1487	24.8	2.2	22.6	11.4	9.2	93
	LMAN7	720	17.9	.3	17.6	10.0	9.7	51
	VEG3	771	16.7	.1	16.6	10.0	9.9	47

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



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

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



4.2 Soils

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

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

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

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

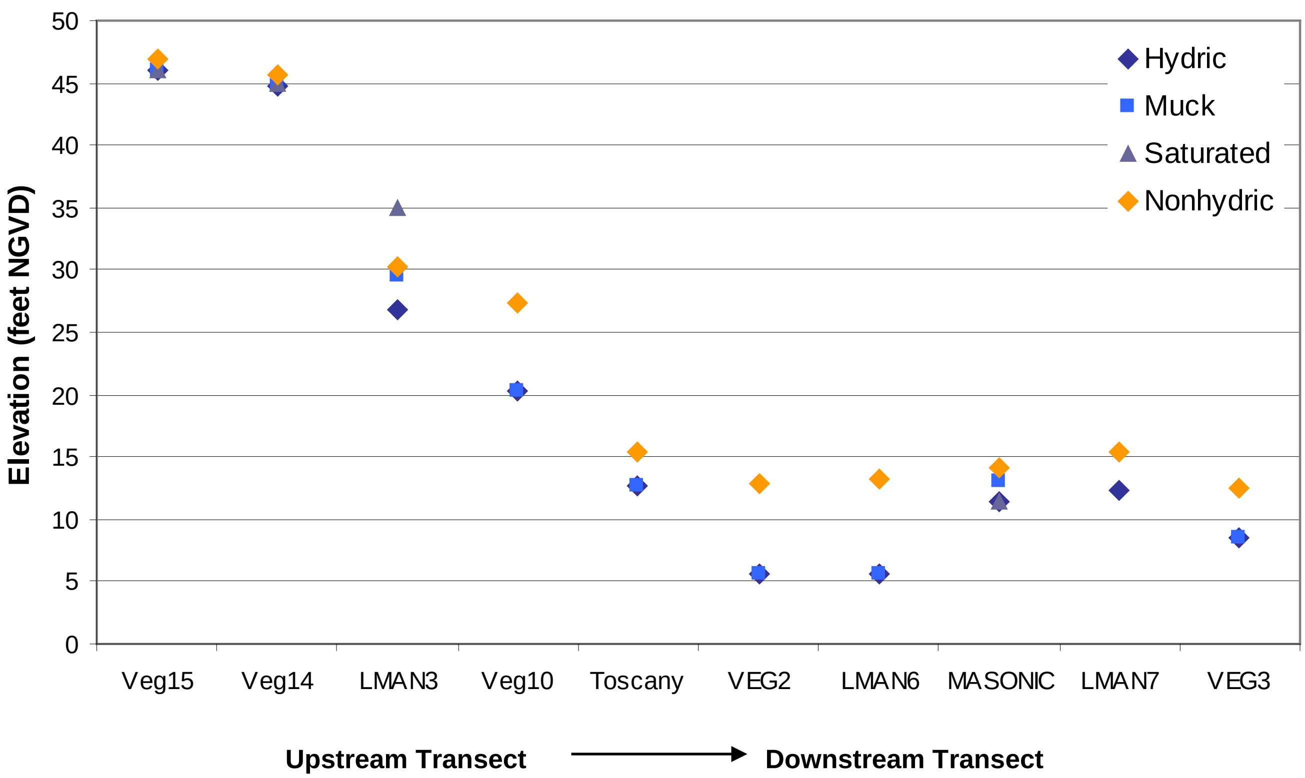


Table 4-2
Median Elevations (feet NGVD) of Hydric, Muck, and Saturated Soils along Transects in the Little Manatee River Study Corridor *

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

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

4.3 Vegetation Relationships

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

4.4 Vegetation Classes

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

The species-specific designations used in this study were retained so that they could be easily combined into a more general context or class. While the NWI classes were too general for use in this study, the NWI flooding component may be useful in addressing MFLs. Forested wetlands along the river are seasonally or temporarily flooded, rather than permanently or semi-permanently flooded, consistent with NWI and SCS mapping.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

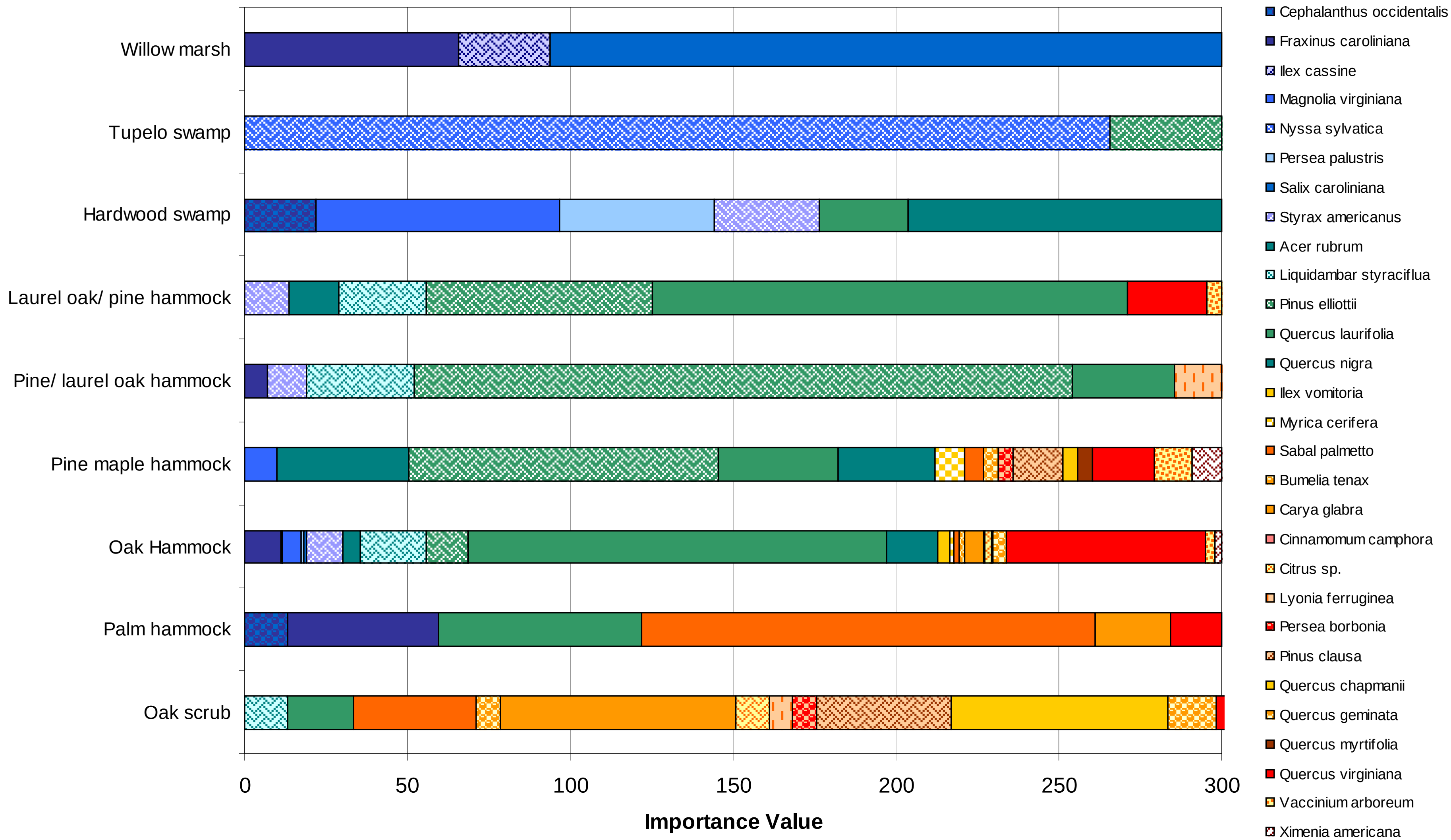
- Oak hammock: primarily laurel oak, but also a relatively large component of live oak (*Q. virginiana*). This class had the largest number of different tree species (23) when compared with the other classes, although like the other transition classes, it included primarily obligate and facultative wetland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

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

Status	Species	Willow Marsh	Tupelo Swamp	Hardwood Swamp	Pine / Laurel Oak Hammock	Laurel Oak / Pine Hammock	Pine / Maple Hammock	Laurel Oak Hammock	Palm Hammock	Oak Scrub
OBL	*Cephalanthus occidentalis*			22.0					13.4	
OBL	*Fraxinus caroliniana*	65.8			7.0			11.0	46.2	
OBL	*Ilex cassine*	28.0						0.7		
OBL	*Magnolia virginiana*			74.5			9.9	5.6		
OBL	*Nyssa sylvatica*		265.6							
OBL	*Persea palustris*			47.8				0.8		
OBL	*Salix caroliniana*	206.2						0.7		
OBL	*Styrax americanus*			32.1	12.0	13.7		11.2		
FACW	*Acer rubrum*					15.4	40.5	5.4		
FACW	*Liquidambar styraciflua*				32.8	26.5		20.5		13.1
FACW	*Pinus elliottii*		34.4		202.1	69.6	95.0	12.5		
FACW	*Quercus laurifolia*			27.2	31.7	145.8	36.7	128.6	62.5	20.5
FACW	*Quercus nigra*			96.4			3.0	15.8		
FAC	*Ilex vomitoria*							3.7		
FAC	*Myrica cerifera*						9.1	1.3		
FAC	*Sabal palmetto*						5.5	1.8	139.0	37.4
UPL	*Bumelia tenax*						4.5	1.5		7.4
UPL	*Carya glabra*							5.7	23.1	72.4
UPL	*Cinnamomum camphora*							0.7		
UPL	*Citrus sp.*							1.8		10.2
UPL	*Lyonia ferruginea*				14.3					7.1
UPL	*Persea borbonia*						4.6			7.4
UPL	*Pinus clausa*						15.5			41.6
UPL	*Quercus chapmanii*						4.6	0.7		66.2
UPL	*Quercus geminata*							3.9		15.1
UPL	*Quercus myrtifolia*						4.6			
UPL	*Quercus virginiana*					24.4	18.9	61.3	15.9	9.0
UPL	*Vaccinium arboreum*					4.5	11.3	2.7		
UPL	*Ximenia americana*						9.3	2.2		

*Shaded cell indicates absence of species

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



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

*Rounded to the nearest whole number.

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

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

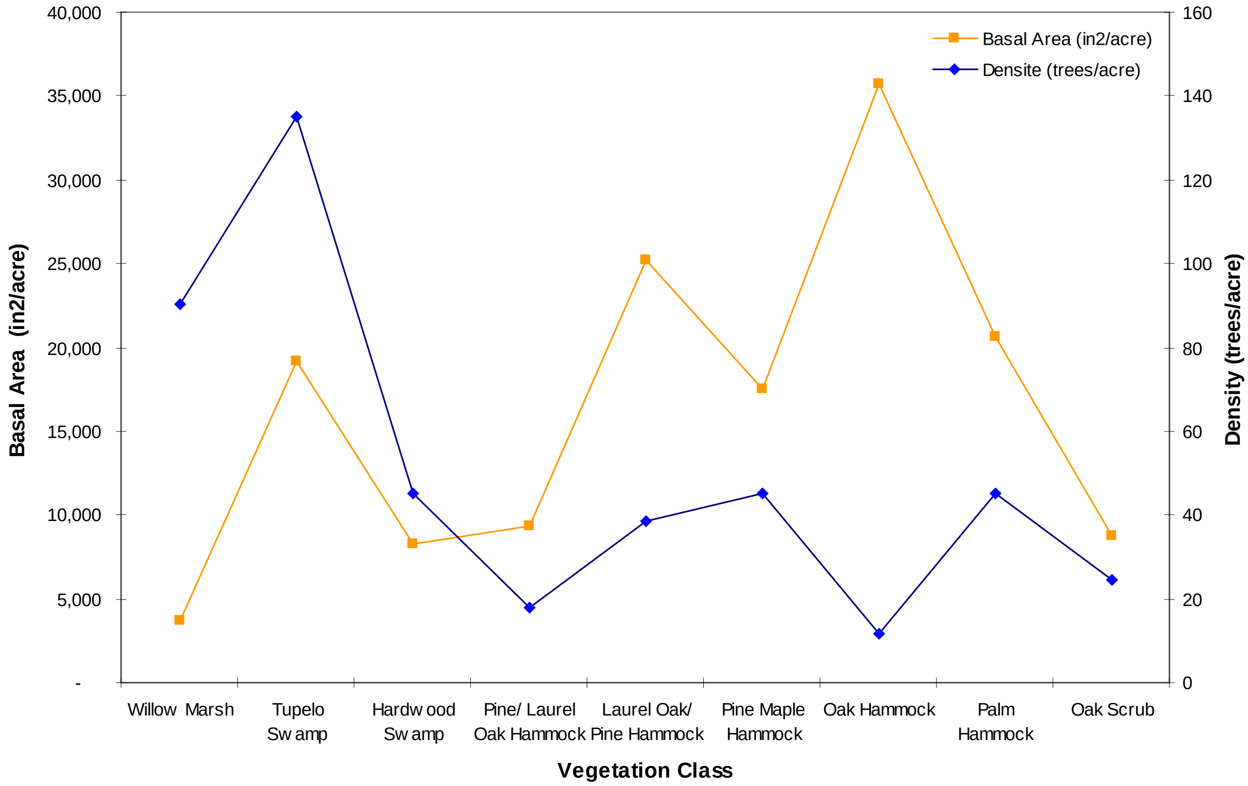
- The willow marsh and tupelo swamp had the highest densities (90 and 135 trees/acre, respectively), and relatively low total basal areas (3,743 and 19,215 in^2/acre, respectively), indicating younger trees.

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

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

Wetland Status	Species	Total Basal Area (in^2)	Density (trees/acre)
OBL	*Cephalanthus occidentalis*	39.1	16.9
OBL	*Fraxinus caroliniana*	1,701.9	99.9
OBL	*Magnolia virginiana*	1,098.2	22.4
OBL	*Nyssa sylvatica*	1,241.5	16.2
OBL	*Persea palustris*	487.3	8.9
OBL	*Salix caroliniana*	190.9	1.0
OBL	*Styrax americanus*	186.1	71.1
FACW	*Acer rubrum*	670.1	37.8
FACW	*Liquidambar styraciflua*	2,196.7	123.9
FACW	*Pinus elliottii*	13,045.6	135.7
FACW	*Quercus laurifolia*	70,656.2	427.7
FACW	*Quercus myrtifolia*	5.0	2.5
FACW	*Quercus nigra*	3,834.7	94.4
FAC	*Ilex cassine*	4.3	1.2
FAC	*Ilex vomitoria*	19.1	7.8
FAC	*Myrica cerifera*	67.3	13.9
FAC	*Sabal palmetto*	7,163.2	72.0
UPL	*Carya glabra*	1,591.3	44.5
UPL	*Lyonia ferruginea*	21.7	3.7
UPL	*Persea borbonia*	8.6	2.5
UPL	*Persea humilis*	7.7	1.2
UPL	*Pinus clausa*	295.4	17.3
UPL	*Quercus chapmanii*	73.0	23.7
UPL	*Quercus geminata*	518.8	36.5
UPL	*Quercus virginiana*	41,983.5	184.1
UPL	*Vaccinium arboreum*	62.6	18.3
UPL	*Ximenia americana*	53.2	17.4

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



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

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

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

	Transect	Willow Marsh	Tupelo Swamp	Hardwood Swamp	Pine/ Laurel Oak Hammock	Laurel Oak/ Pine Hammock	Pine / Maple Hammock	Laurel Oak Hammock	Palm Hammock	Oak Scrub
Upstream	VEG15				5.3	7.0	8.4	79.2		
	VEG14		14.6			3.4	24.9	57.1		
	LMAN3	15.5						84.5		
	VEG10							100.0		
↓	TOSCANY							100.0		
	VEG2				21.5			24.5	54.0	
	LMAN6				36.5		8.4	13.3	3.6	38.2
	MASONIC			11.3		39.3		43.3		6.1
	LMAN7	19.2		5.0	30.5			8.6		36.7
Downstream	VEG3				26.2	35.4		30.6	7.8	

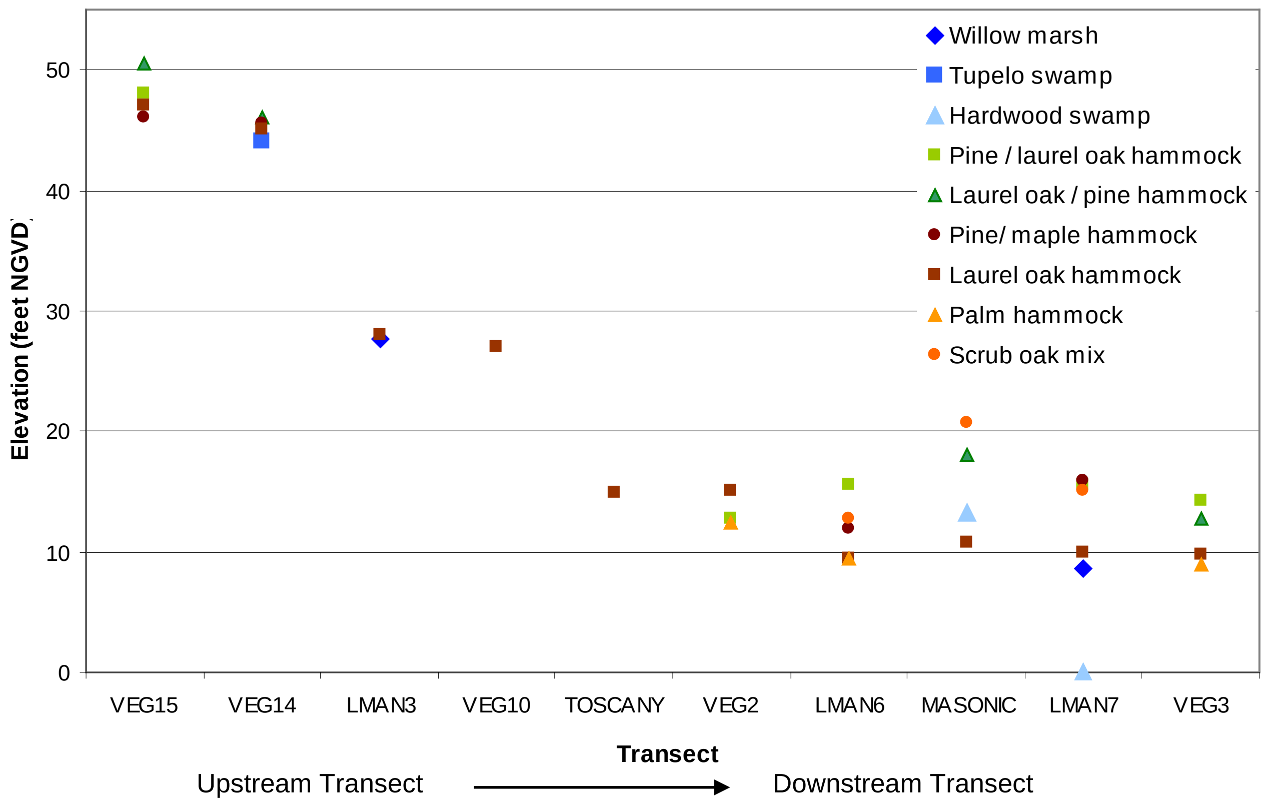
*Shaded cells indicate absence of vegetation class.

4.4.1 Elevations and Vegetation Classes

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

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

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

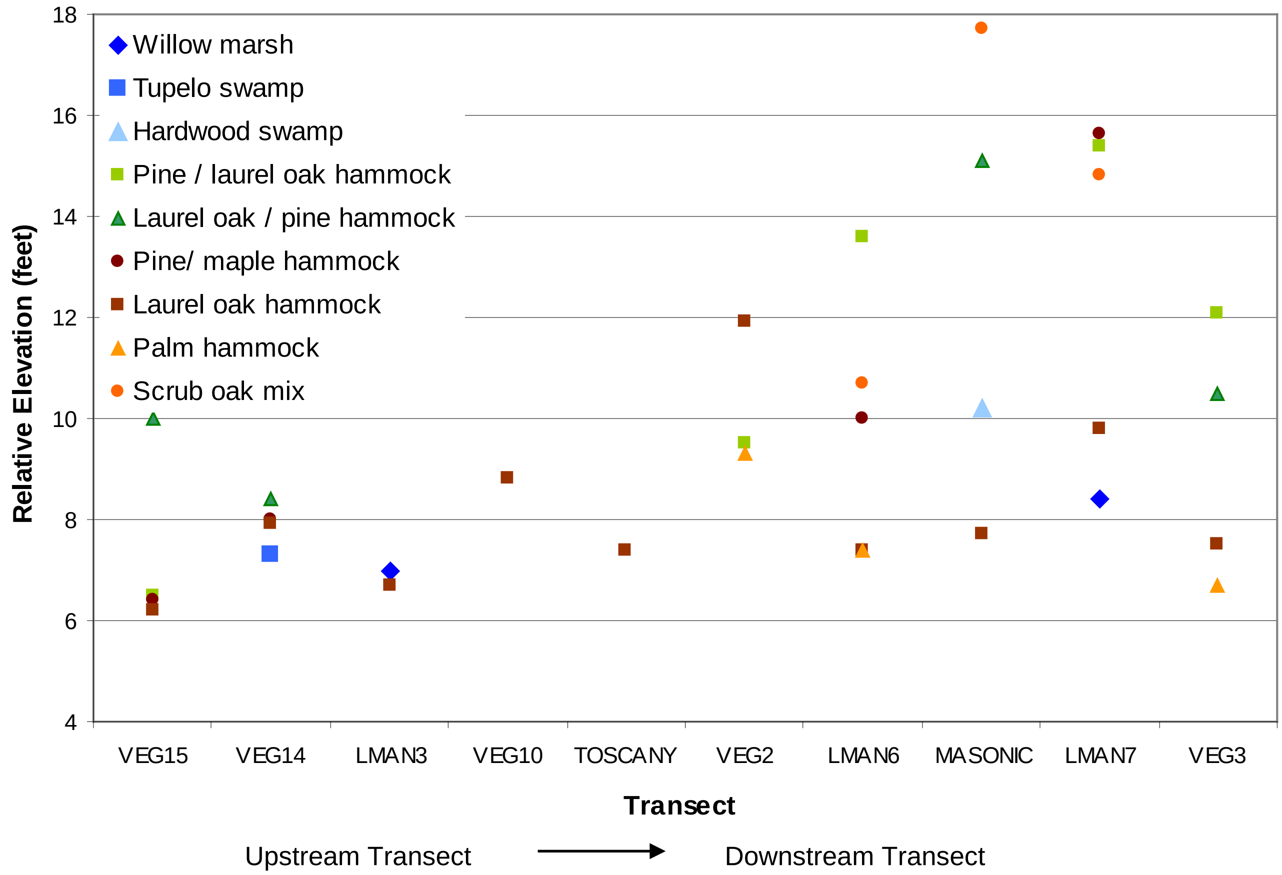


4.4.2 Soils, Distance to Channel, and Vegetation Classes

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

Results indicate that soils were a more consistent indicator of wetlands along the Little Manatee River than elevation changes. Median relative elevations of hydric soils by vegetation class indicated that in vegetation classes with both hydric and nonhydric soils, hydric soils occurred at lower elevations. Also, median elevations (feet NGVD) of hydric soils in wetland classes were the same as the elevations of the wetland class (Table 4-10), i.e. wetlands had almost exclusively hydric soils, while hydric soils were not limited to wetlands (consequently, the cells filled in Table 4-10 do not always coincide with Tables 4-8 and 4-9). Muck soils were found along several transects (Figure 4-3), but did not occur at elevations that were any lower than hydric (but not muck) soils.

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



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

Distance to river channel may provide a proxy for combinations of elevation, wave energy, soils, and vegetation if distance coincides with these other variables. Such a pattern was not apparent along the Little Manatee River transects and may also be a result of the small number of wetlands sampled. Mean distances of vegetation classes from the river channel were not correlated strongly with vegetation class. The willow marsh vegetation class occurred along or close to the river channel (mean distance = 76.9 feet from the channel). The tupelo swamp class occurred at a mean distance of 739.4 feet from the river channel, followed by hardwood swamp at a mean distance of 321.2 feet. The remaining vegetation classes ranged from 160.6 to 1,073.0 feet from the river channel.

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

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

*Shaded cells indicate absence of vegetation class.

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

Transect		Willow Marsh	Tupelo Swamp	Hardwood Swamp	Pine / Maple Hammock	Pine / Laurel Oak Hammock	Laurel Oak / Pine Hammock	Laurel Oak Hammock	Palm Hammock	Oak Scrub
Upstream	VEG15				6.5	10.0	6.4	6.2		
	VEG14		7.3			8.4	8.0	7.9		
	LMAN3	7.0						6.7		
	VEG10							8.8		
↓	TOSCANY							7.4		
	VEG2				9.5			11.9	9.3	
	LMAN6				13.6		10.0	7.4	7.4	10.7
	MASONIC			10.2		15.1		7.7		17.7
	LMAN7	8.4		2.3	15.4		15.7	9.8		14.8
Downstream	VEG3				12.1	10.5		7.5	6.7	

*Shaded cells indicate absence of vegetation class.

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

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

*Shaded cells indicate absence of hydric soils.

4.4.3 Discriminant Function Analysis (DFA)

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

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

Vegetation classes were distinct in terms of species composition and IV, and environmental variables were significant in accounting for these differences. The wetland vegetation classes (willow marsh, tupelo swamp, and hardwood swamp) generally, but not always, had lower mean elevations and more hydric soils characteristics. Only the willow marsh occurred closer to the river channel when compared with the other vegetation classes. The tupelo swamp was a depressional swamp rather than connected to the river as the willow marsh and hardwood swamp often were. The hydric soils conditions were the best predictors of wetland vegetation.

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

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

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

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

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

Vegetation classes were distinct in terms of species composition and IV, and environmental variables were significant in accounting for differences between vegetation classes. Elevations, relative elevations along transects, distance from channel, and hydric soil index were significant in separating vegetation classes from each other, although overlap in environmental parameters between vegetation classes was frequent. Correlations between environmental variables and vegetation class were not strong.

Table 4-11
DFA Results for Vegetation Classifications*

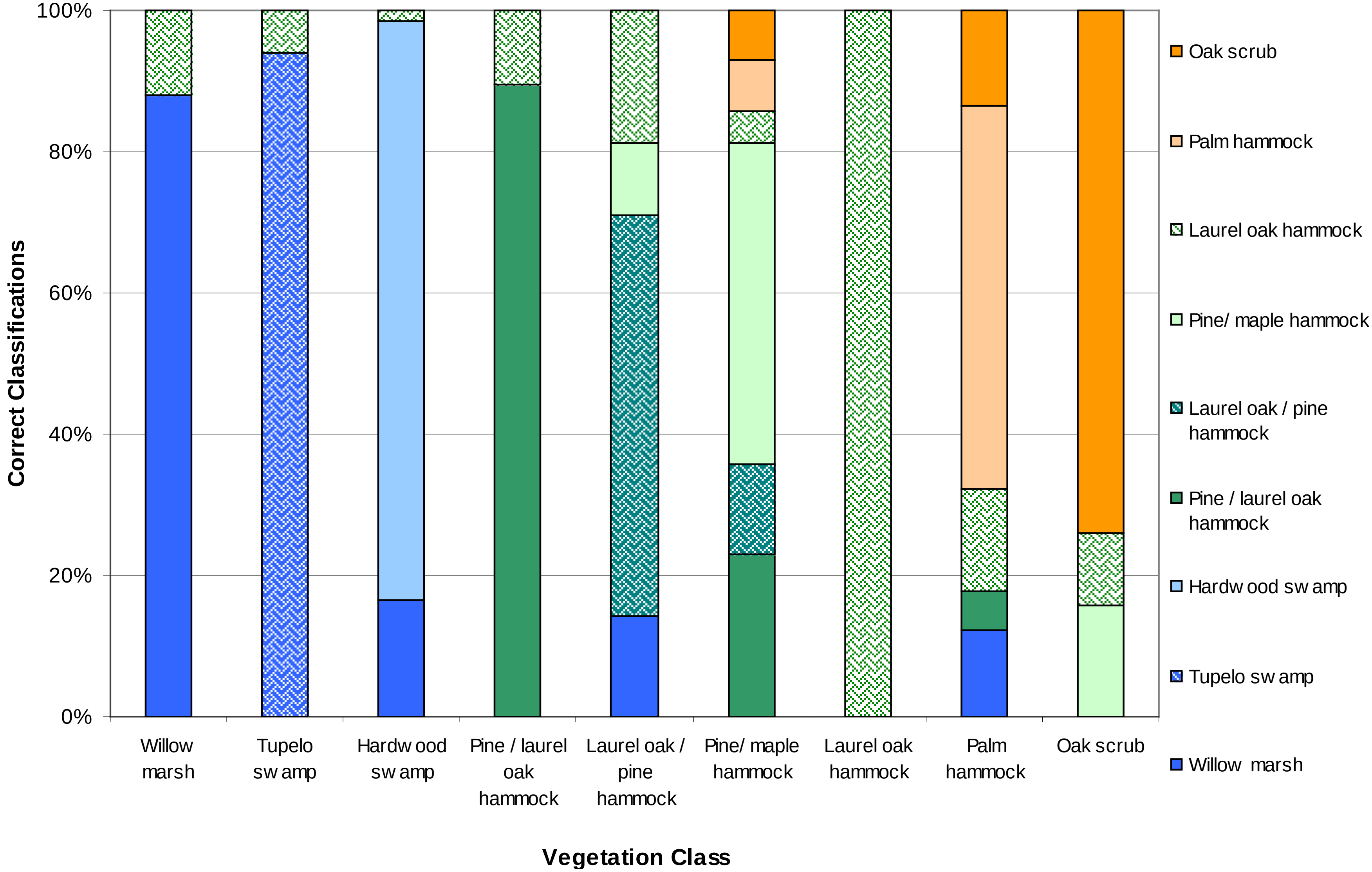
Vegetation Class	Willow Marsh	Tupelo Swamp	Hardwood Swamp	Pine / Laurel Oak Hammock	Laurel Oak / Pine Hammock	Pine / Maple Hammock	Laurel Oak Hammock	Palm Hammock	Oak Scrub	Total
Willow marsh	40 (2)		20 (1)		20 (1)			20 (1)		100 (5)
Tupelo swamp		100 (3)								100 (3)
Hardwood swamp			100 (3)						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

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

Variable	R-Square	F Value	Pr>F
Elevation	0.2262	6.21	<.0001
Relative elevation	0.3232	10.15	<.0001
Soils	0.2936	8.83	<.0001
Distance	0.2756	8.08	<.0001

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

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



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

- Tupelo swamp and hardwood swamp were classified correctly 100 percent of the time, followed by palm hammock (88.9 percent) and laurel oak / pine hammock (80 percent).

- The laurel oak hammock class was classified incorrectly 85 percent of the time, predominantly as laurel oak/ pine hammock (26.4 percent) and palm hammock (23.6 percent), overlapped with all the remaining vegetation classes, and was the most common vegetation class sampled.

- Vegetation classes were significantly correlated with measured environmental variables, although no correlation accounted for more than 32 percent of the variability.

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

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

Table 4-12
Mean Values of Parameters Used in DFA for Vegetation Classes along the Little Manatee River Study Corridor

	Willow marsh	Tupelo swamp	Hardwood swamp	Pine/ laurel oak hammock	Laurel oak/ pine hammock	Pine / maple hammock	Laurel oak hammock	Palm hammock	Oak scrub
Elevation (NGVD)	20.3	44.9	13.6	32.5	38.8	19.4	28.8	9.3	17.0
Relative Elevation (feet)	7.9	7.3	10.6	10.0	7.8	11.9	7.6	6.7	15.3
Soil Index	0.6	3.0	1.3	0.2	0.2		0.3	0.3	
Distance (feet)	76.9	739.4	321.2	1,073.0	421.8	563.9	376.8	160.6	238.7

4.4.4 Wetted Perimeter

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

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

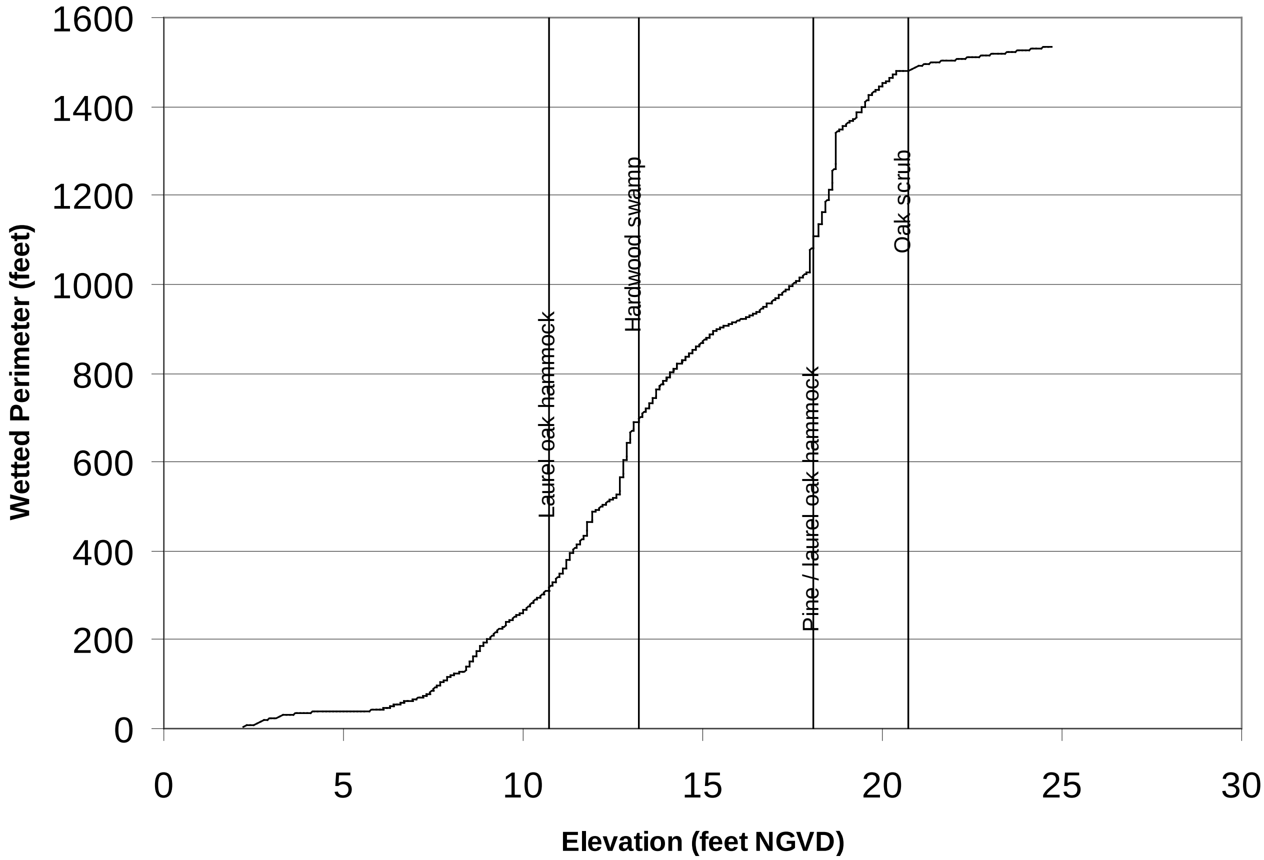
Typically, a sigmoid-shaped wetted perimeter curve coincides with a large increase in habitat across a small elevation gradient in floodplains (e.g. VEG15 and VEG14, Appendix B). Changes in wetted perimeter are also typically greater over more gradual changes in elevation than across steeper gradients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

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

Transect		Willow marsh	Tupelo swamp	Hardwood swamp	Pine / maple hammock	Pine / laurel oak hammock	Laurel oak / pine hammock	Laurel oak hammock	Palm hammock	Oak scrub
Downstream ←→ Upstream	**VEG 15**				1383	2,235	351	1,132		
	VEG 14		867			2,204	1,786	1,634		
	LMAN3	729						678		
	VEG 10							485		
	TOSCANY							482		
	VEG 2				431			671	318	
	LMAN6				944		461	205	205	600
	MASONIC			699		1,108		319		1,482
	LMAN7	246		186	419		436	284		388
	VEG 3				689	550		268	153	

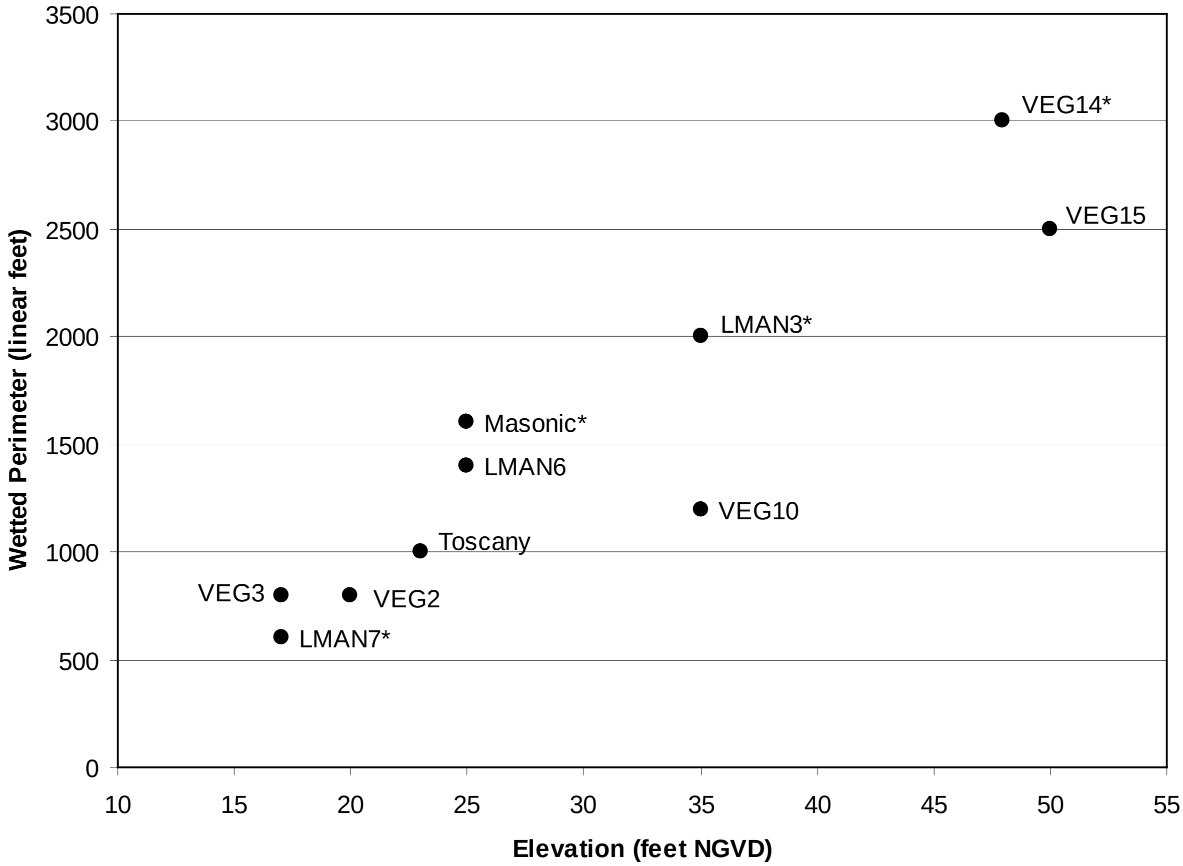
*Shaded cells indicate absence of vegetation class.

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



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

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



4.5 Relationship of Vegetation with Environmental Variables

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

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

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

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

Inundation Periods in Southeastern Wetlands. The vegetation classes along the Little Manatee River are not typical of forested southeastern flood plains (described by Light *et al*. 2002 and Wharton *et al*. 1982), but are more consistent with seasonally and temporarily flooded river systems that are characterized by a wider range of environmental conditions and extremes, similar to the Braden River in Manatee County. Seasonal and temporarily flooded wetlands may be more sensitive to changes in natural flow regimes and hydrological variability (quantity, timing and duration of flows and floods, and periods of low flows) and subsequent effects on biodiversity and fisheries (Poff *et al.* 1997).

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

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

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

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

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

5.0 Conclusions

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

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

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

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

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

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

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

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

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

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

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

6.0 Relevant Literature

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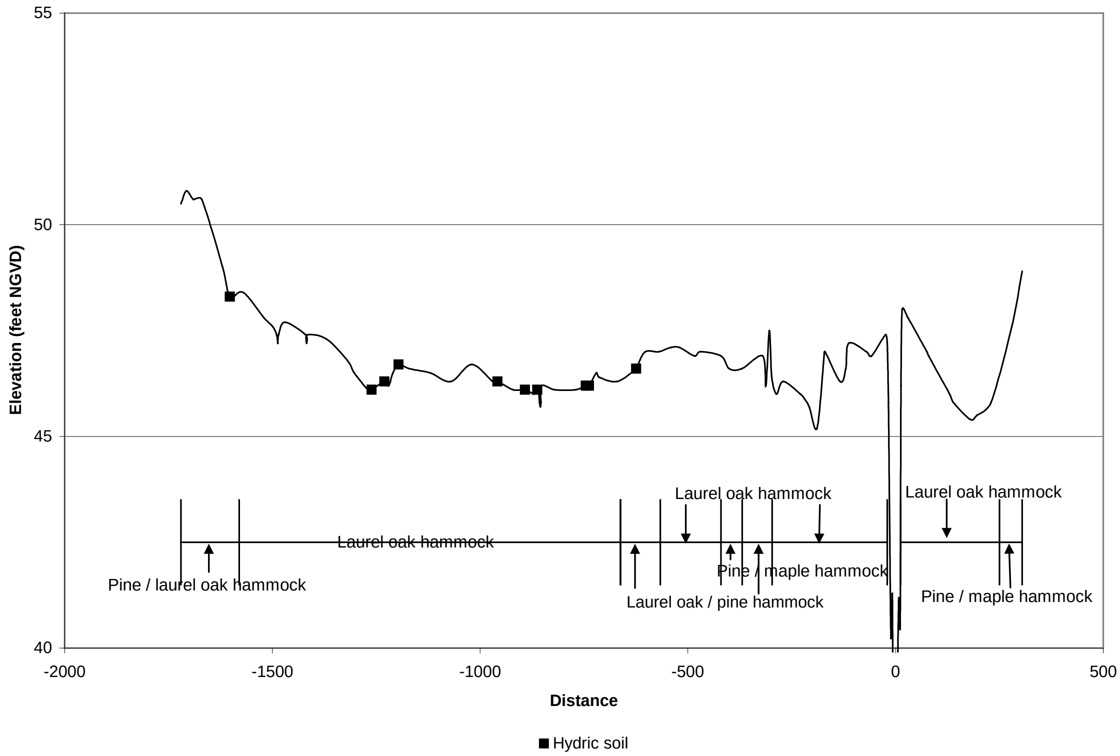
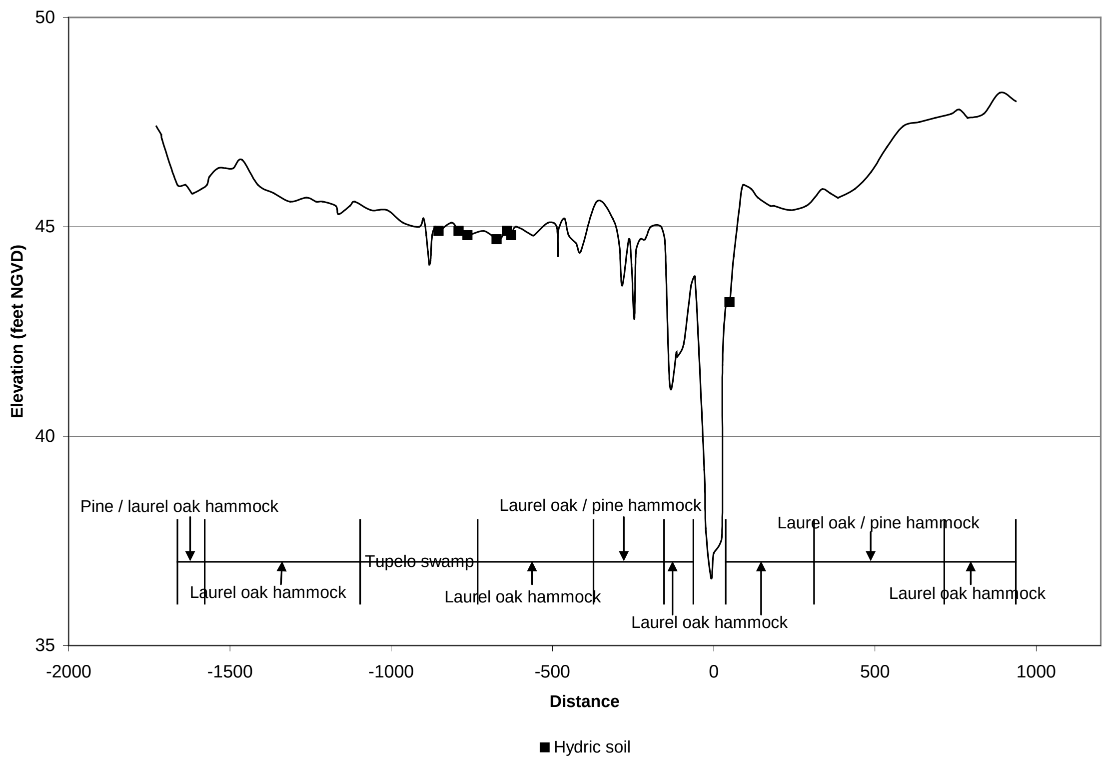
Appendix A

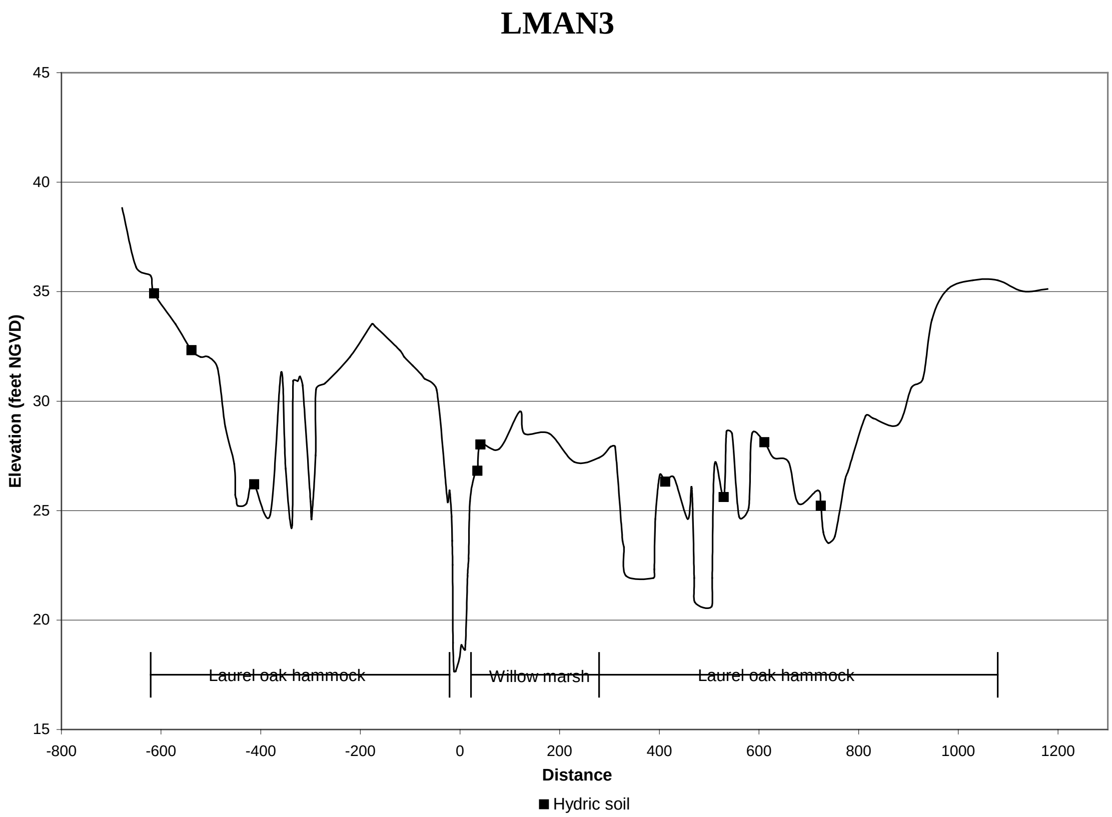
Elevation and Vegetation Profiles for the Little Manatee River Study Corridor

VEG15

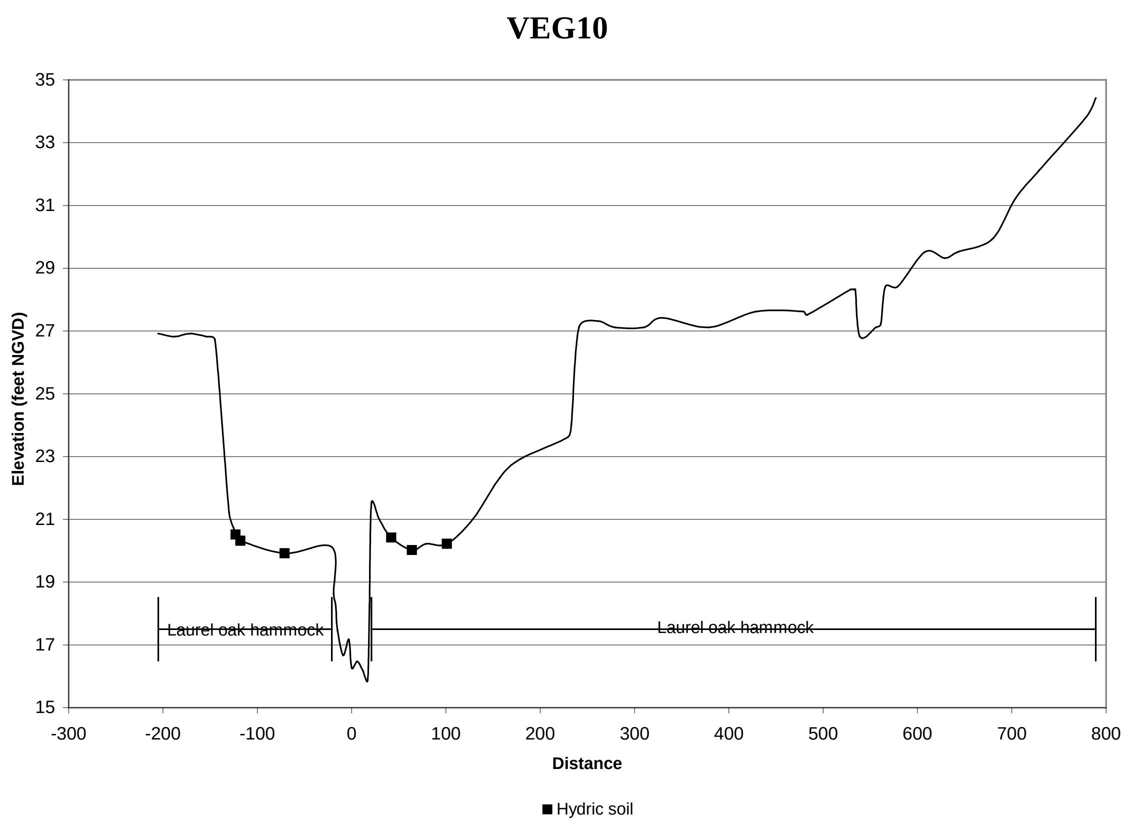

55
50
45
40
Elevation (feet NGVD)
-2000
-1500
-1000
-500
0
500
Distance
Laurel oak hammock
Pine / laurel oak hammock
Laurel oak hammock
Laurel oak hammock
Pine / maple hammock
Laurel oak / pine hammock
Pine / maple hammock
■ Hydric soil

VEG14


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

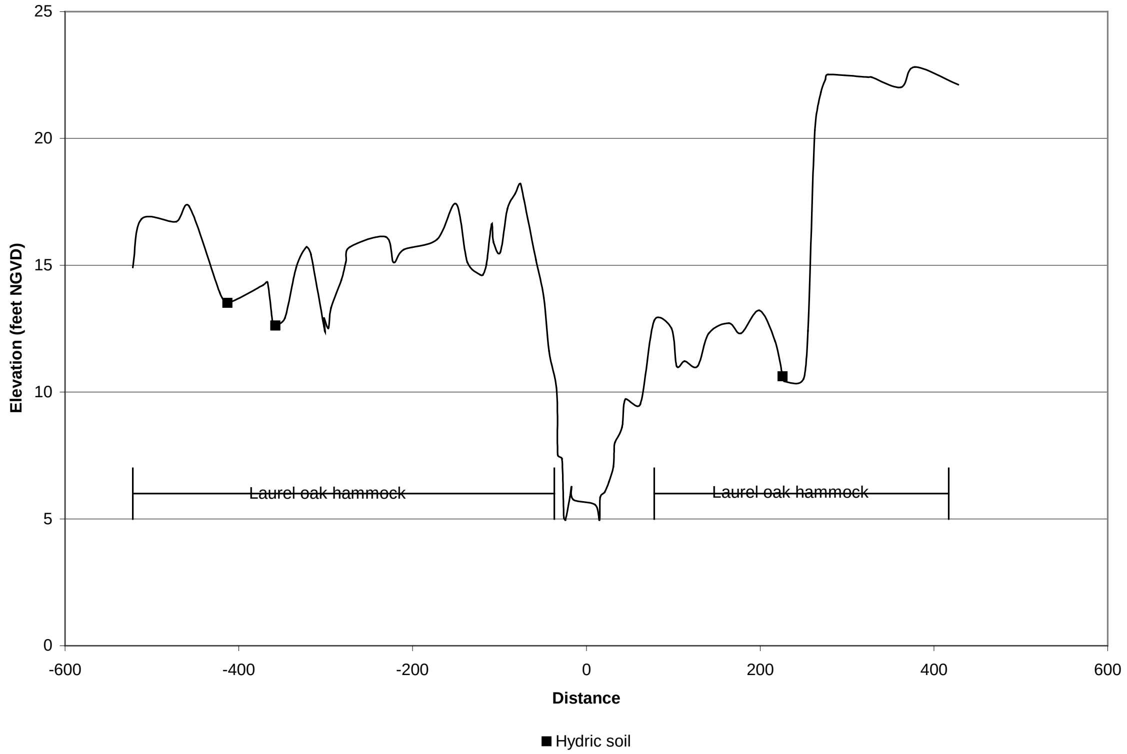


LMAN3
45
40
35
30
25
20
15
Elevation (feet NGVD)
-800
-600
-400
-200
0
200
400
600
800
1000
1200
Distance
Laurel oak hammock
Willow marsh
Laurel oak hammock
Hydric soil

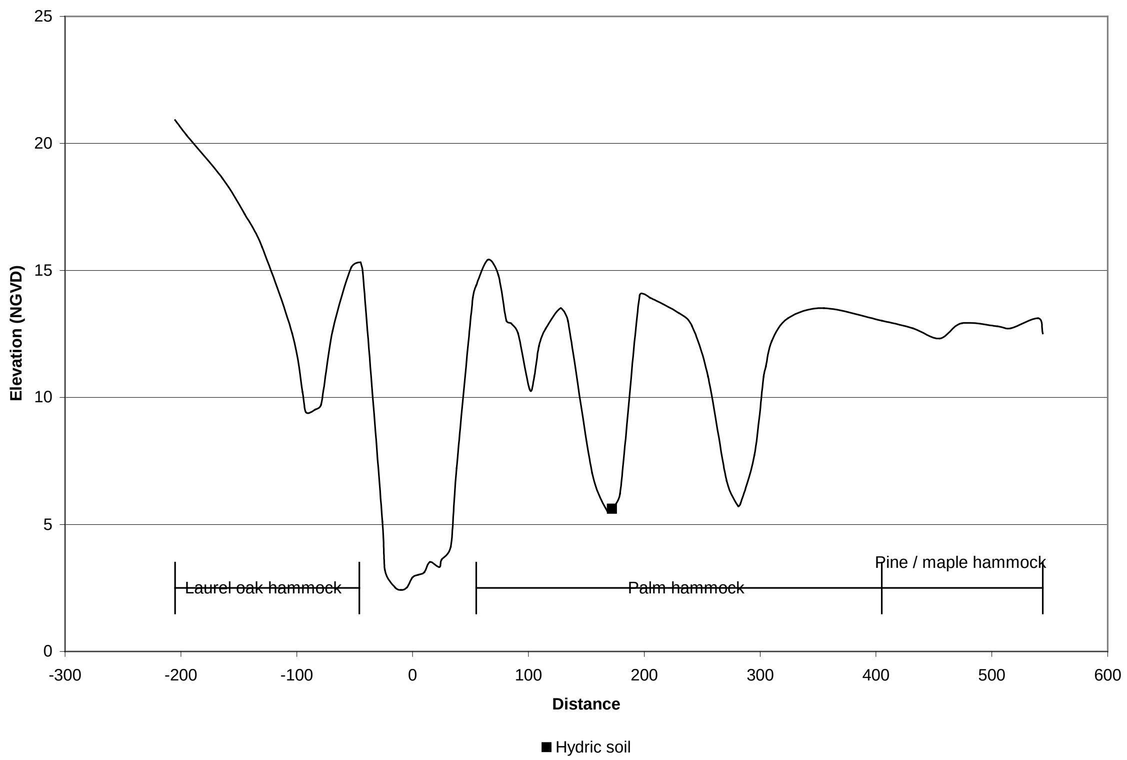


VEG10
35
33
31
29
27
25
23
21
19
17
15
Elevation (feet NGVD)
-300
-200
-100
0
100
200
300
400
500
600
700
800
Distance
Laurel oak hammock
Laurel oak hammock
Hydric soil

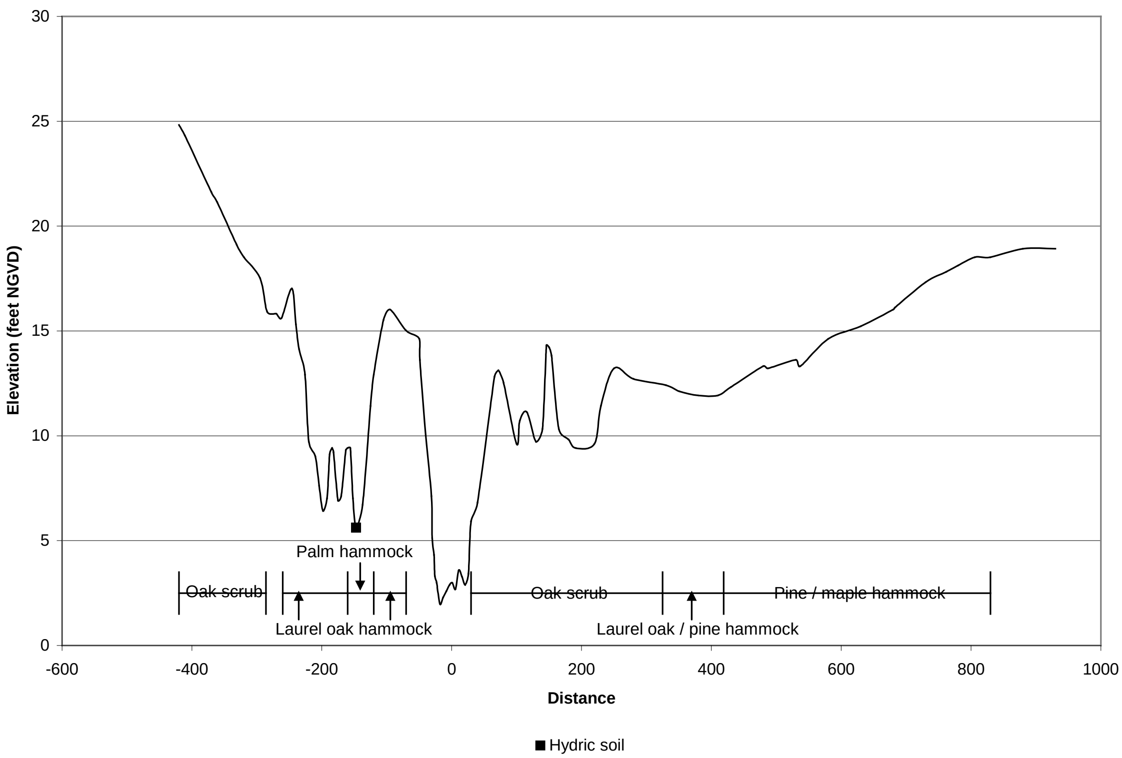
TOSCANY



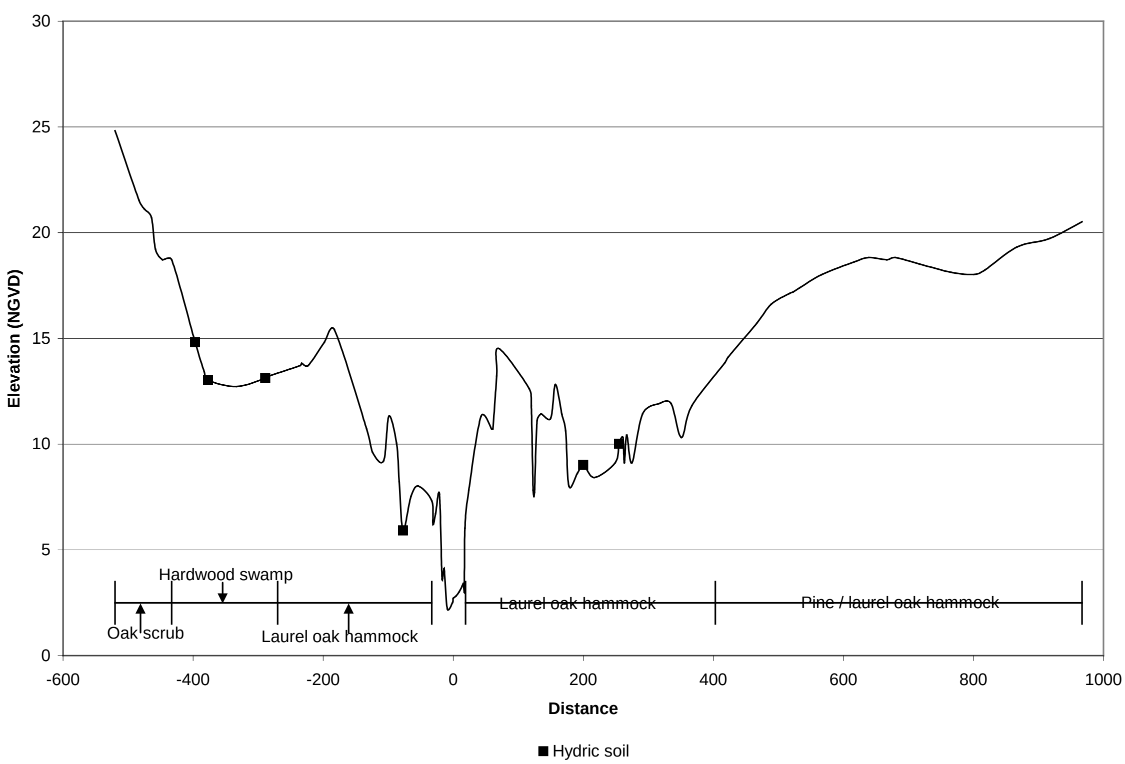
VEG2

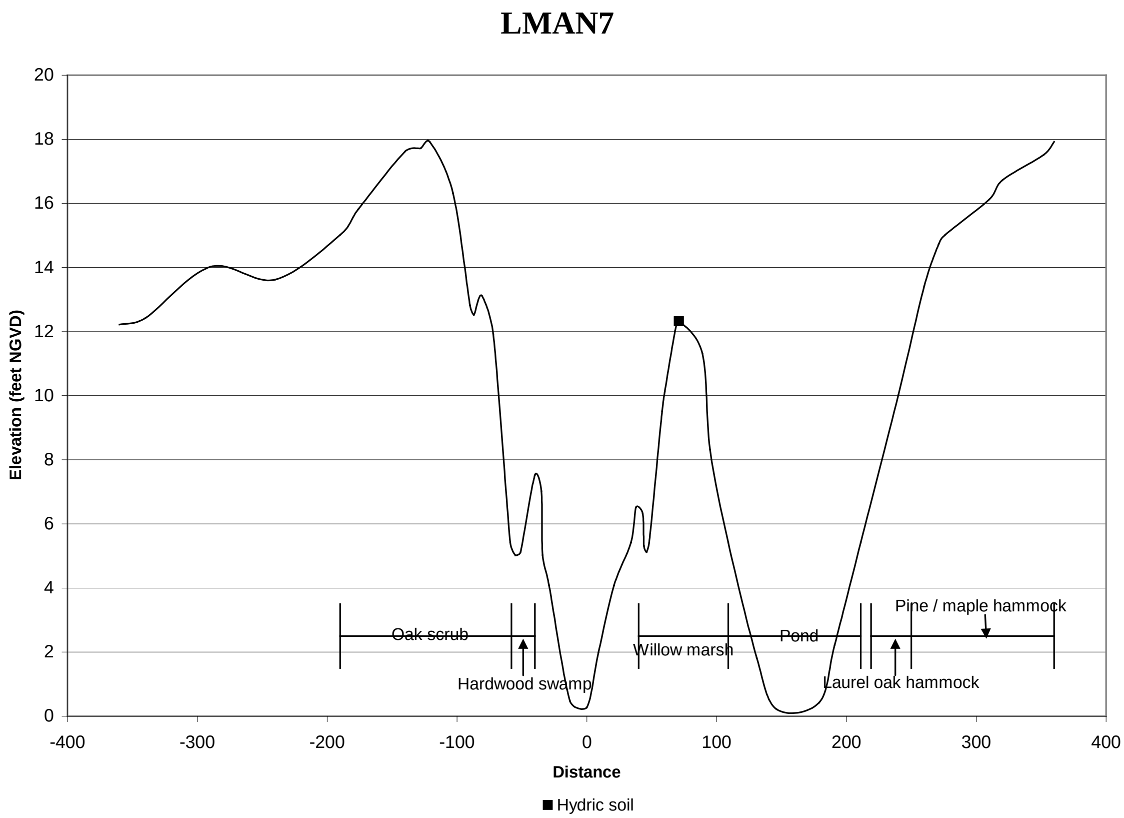


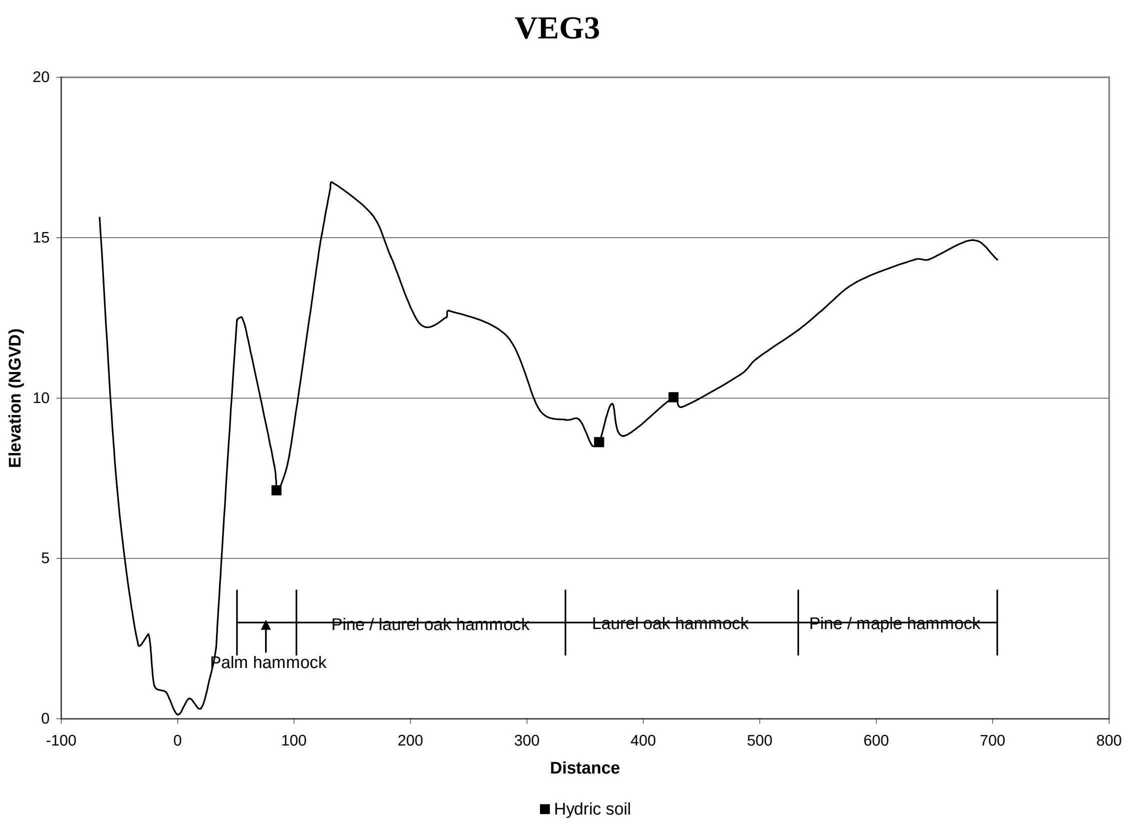
LMAN6



MASONIC PARK



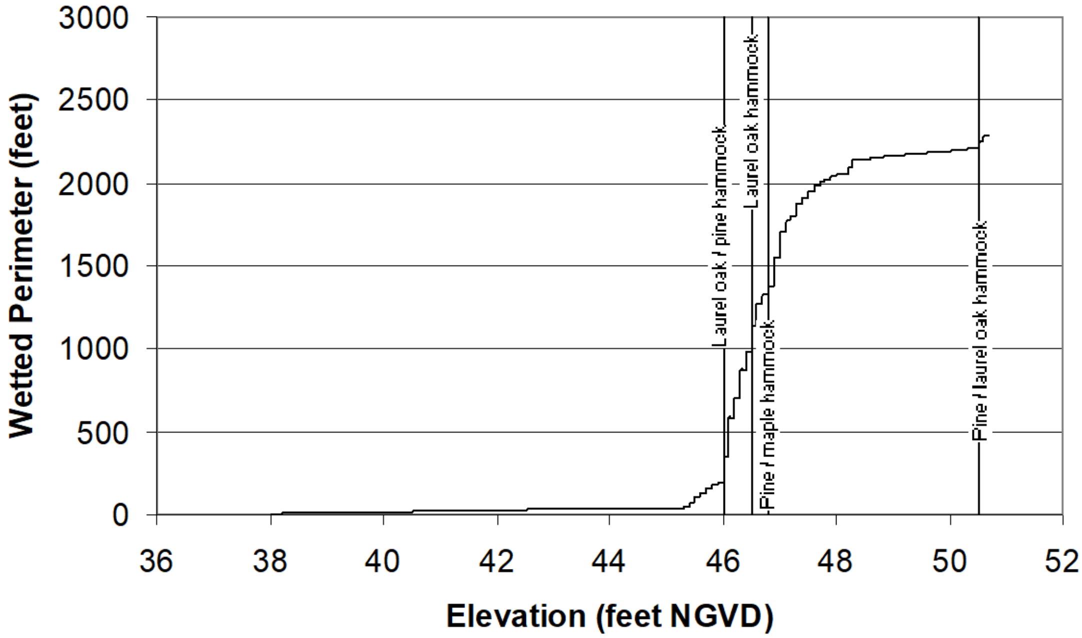

LMAN7
Elevation (feet NGVD)
Distance
Hydric soil
Oak scrub
Hardwood swamp
Willow marsh
Pond
Laurel oak hammock
Pine / maple hammock
-400
-300
-200
-100
0
100
200
300
400
0
2
4
6
8
10
12
14
16
18
20


VEG3
Elevation (NGVD)
Distance
Hydric soil
Palm hammock
Pine / laurel oak hammock
Laurel oak hammock
Pine / maple hammock
-100
0
100
200
300
400
500
600
700
800
0
5
10
15
20

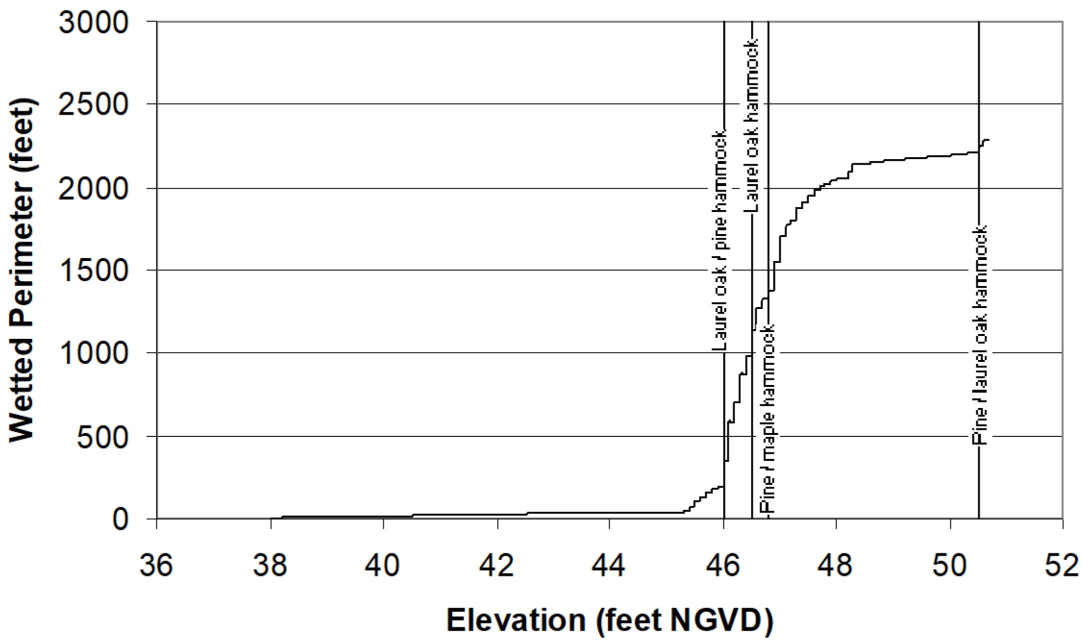
Appendix B

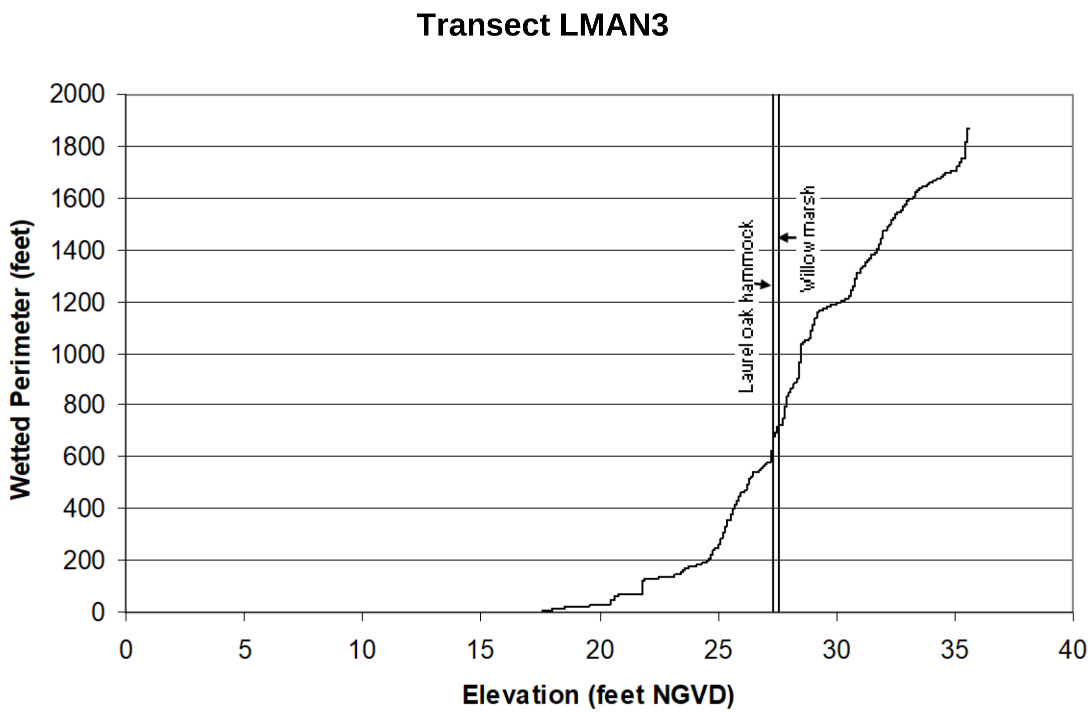
Wetted Perimeter Graphs for the Little Manatee River Study Corridor (In upstream-to-downstream order)

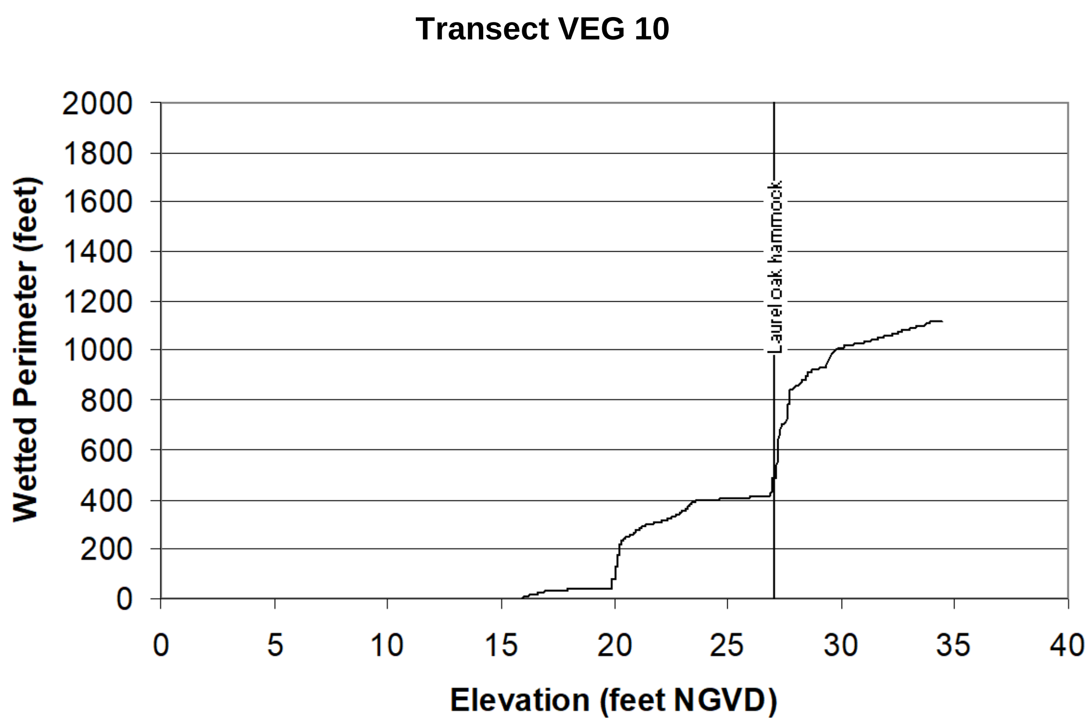
Transect VEG 15

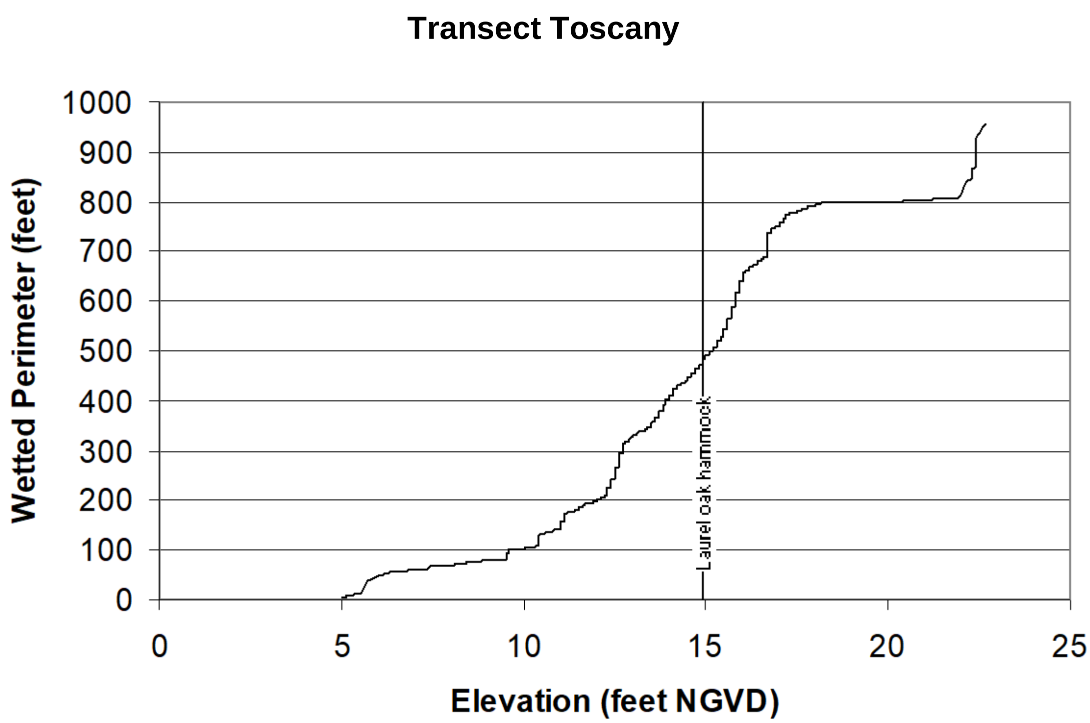


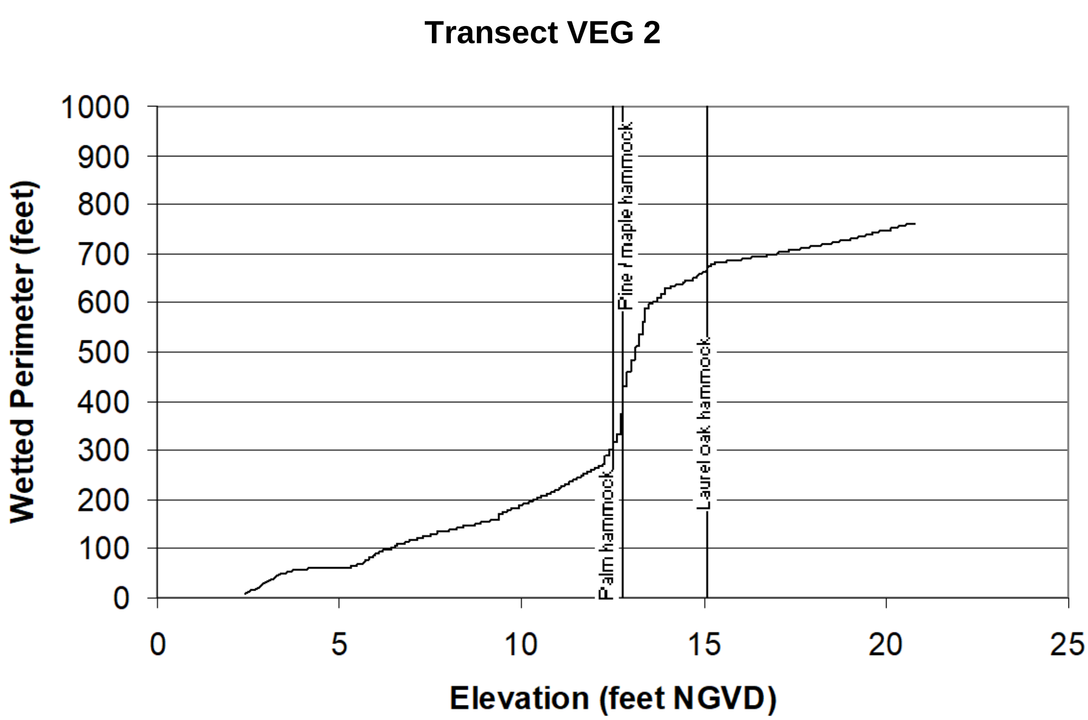
Transect VEG 14



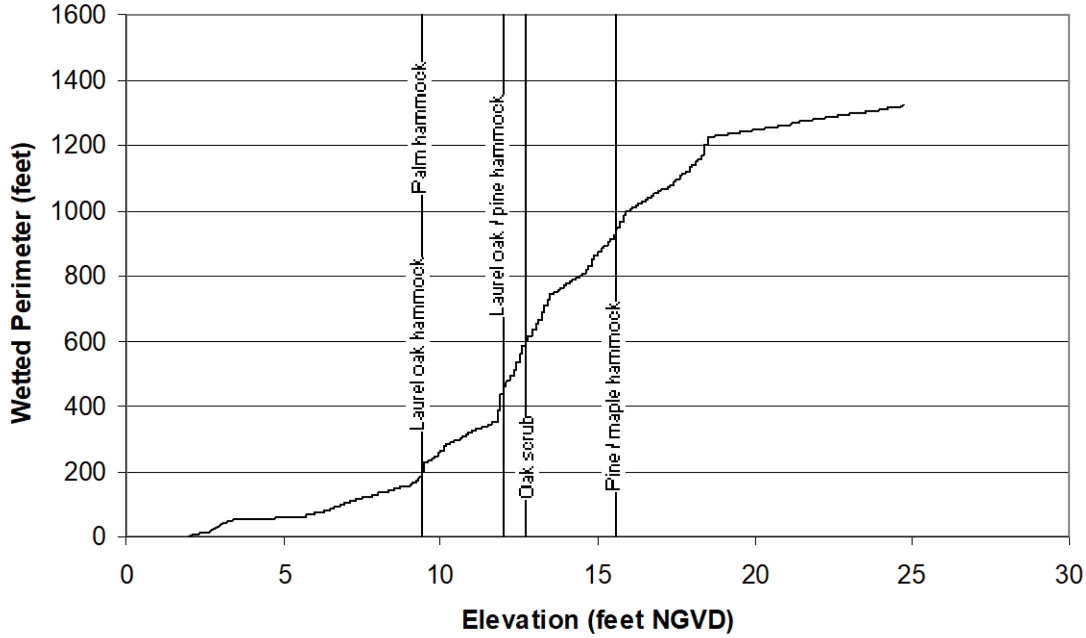

Transect LMAN3
Wetted Perimeter (feet)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
35
40
Elevation (feet NGVD)
Laurel oak hammock
Willow marsh


Transect VEG 10
Wetted Perimeter (feet)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
35
40
Elevation (feet NGVD)
Laurel oak hammock

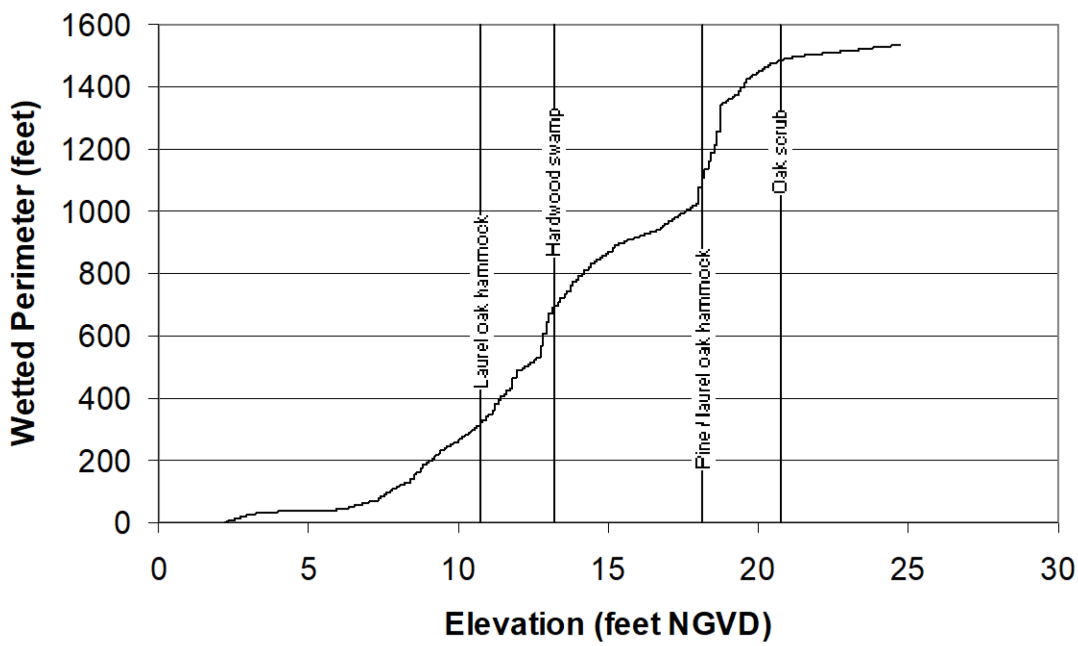

Transect Toscany
Wetted Perimeter (feet)
1000
900
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
Elevation (feet NGVD)
Laurel oak hammock


Transect VEG 2
Wetted Perimeter (feet)
1000
900
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
Elevation (feet NGVD)
Palm hammock
Pine / maple hammock
Laurel oak hammock

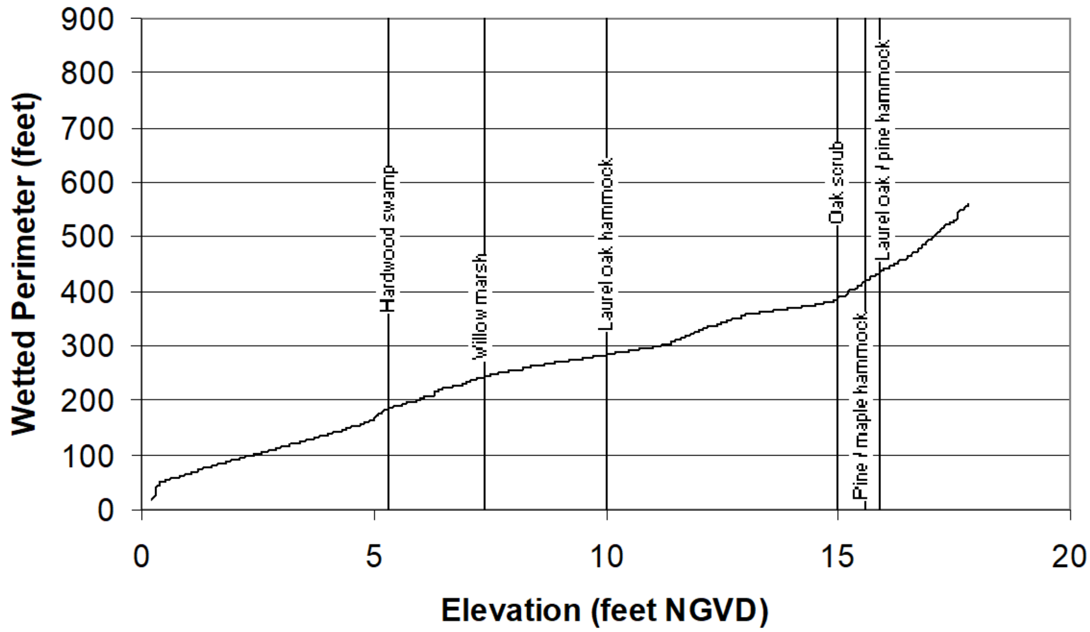
Transect LMAN 6



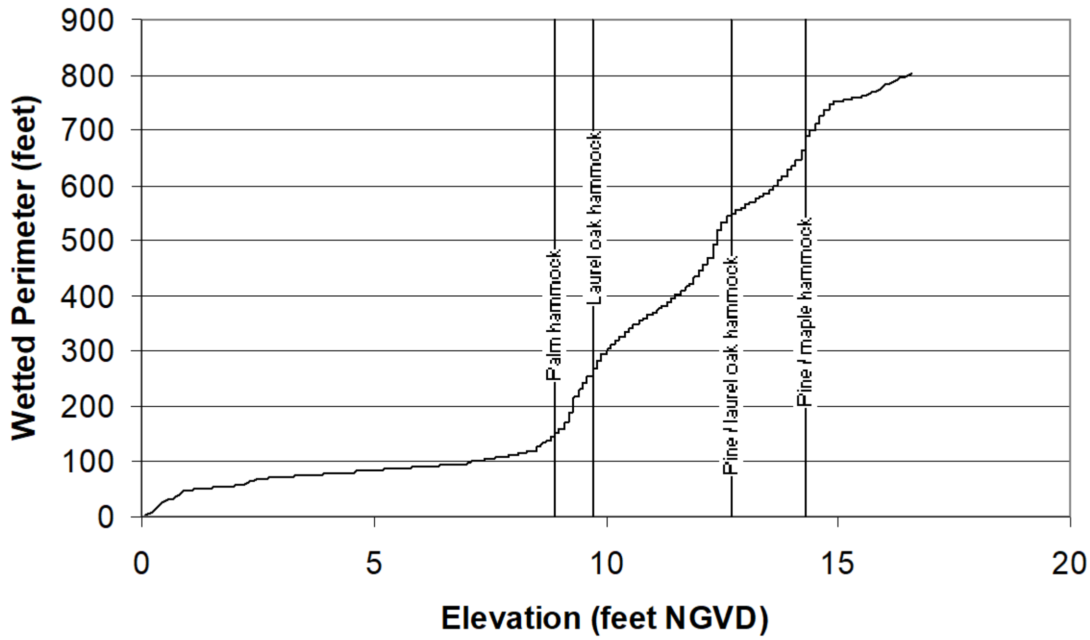
Transect Masonic Park



Transect LMAN 7



Transect VEG 3



Appendix C

Photographs from the Little Manatee River Study Corridor

Willow Marsh

Tupelo Swamp

Hardwood Swamp

Pine / Laurel Oak Hammock

Laurel Oak / Pine Hammock

Laurel Oak Hammock

Palm Hammock

Oak Scrub