Appendix F

Characterization of Woody Wetland Vegetation Communities Along the Rainbow River, Draft. Prepared by PBS&J for the Southwest Florida Water Management District, Brooksville, Florida. 2008.

Characterization of Woody Wetland Vegetation Communities along the Rainbow River

DRAFT

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Executive Summary

The purpose of this study was to characterize relationships among vegetation, soils, and elevations in wetlands along the Rainbow River and assist the Southwest Florida Water Management District (District) in establishing minimum flows and levels (MFLs) for the river. Vegetation classes, plant species importance, soil characteristics, and elevations were characterized along 11 transects in the Rainbow River study corridor. The study corridor extended approximately 5.7 miles downstream of Rainbow Springs to the confluence of the Rainbow River with the Withlacoochee River near Dunellon in southwest Marion County.

Vegetation. The permanent ground water flows and clear water of spring-fed rivers, like those of the Rainbow River, differentiate it from streams and rivers dominated by surface water flows. These differences also focus vegetation studies on instream vegetation and water quality rather than wetland vegetation and water levels. Several studies of the Rainbow River have been devoted to submerged aquatic vegetation (SAV), while this study may be the first to quantify wetland vegetation along the river corridor.

Differences in vegetation classes along the Rainbow River study corridor were significant based on importance values (IVs) that were calculated using tree species density and basal area and provided a relative measure of species dominance (no units). Three vegetation classes were characterized as wetland classes, two as transition classes between wetlands and uplands, and one as upland vegetation. The three wetland classes could be differentiated based on dominance of cypress (*Taxodiuim distichum*), red maple (*Acer rubrum*), and ironwood (*Carpinus caroliniana*), and are briefly described below.

- Cypress swamp: comprised of the obligate wetland species cypress, the facultative wetland species sweetgum (*Liquidambar styraciflua*) and American elm (*Ulmus americana*), and few other species.

- Maple hammock: characterized by predominantly the facultative wetland species red maple (*Acer rubrum)* and laurel oak (*Quercus laurifolia*), and more than ten percent obligate wetland species, including holly (*Ilex cassine*), sweet bay magnolia (*Magnolia virginiana*), swamp bay (*Persea palustris*), and buttonbush (*Cephalanthus occidentalis*).

- Ironwood hammock: characterized largely by ironwood, laurel oak, and red maple, and more than ten percent of obligate wetland species, including sweet bay magnolia and tupelo (*Nyssa sylvatica*).

The two transition classes were dominated by laurel oak in combinations with different species. The laurel oak mix class included a substantial components of water oak (*Q. nigra*), while the laurel oak/ pine mix class included a large component of the facultative species loblolly pine (*Pinus taeda*). The single upland vegetation class was dominated by hackberry (*Celtis laevigata*), a facultative wetland species, and the upland species southern magnolia (*Magnolia grandiflora*). This class is referred to as the hackberry upland and occurred along only one study transect.

Species IVs for the 29 tree species in the six vegetation classes indicated a shift in importance from cypress, red maple, and ironwood to greater dominance by laurel oak, pine, and cabbage palm, to hackberry in the single upland community. Overall trends in species dominance and diversity are summarized below.

- Laurel oak, hackberry, cypress, and sweet gum made up approximately 50 percent of the total IVs (by species) among all classes and each of these species made up from nine to 19 percent of the total IVs.
- Seven species (cabbage palm, American elm, red maple, loblolly pine, ironwood, southern magnolia, and water oak) made up another 40 percent of the total IVs and each of the seven species accounted for only five to seven percent of the total IVs.
- The remaining ten percent of the total IVs was accounted for by 18 species, each of which made up less than two percent of the total IVs.
- Cabbage palm, laurel oak, red maple, sweetgum, and American elm occurred in all classes except the hackberry upland.
- The maple hardwood hammock had the largest number of species (23), followed by the ironwood hardwood hammock (15), and laurel oak/pine mix (14). The cypress swamp included only seven tree species and the hackberry upland included only two species (hackberry and southern magnolia, both of which were present only in this class).
- Basal areas were greatest in the maple hardwood hammock (15,903 in^2/acre) and laurel oak/ pine mix (13,551 in^2/acre) classes, and densities were lowest in these two classes (maple hammock = 18 trees/acres, laurel oak/pine mix = 29 trees/acre), indicating older and more established trees when compared with the other classes.
- The average tree density among vegetation classes was 33.2 trees/acre and ranged from 18 (maple hardwood hammock) to 205 trees/acre (hackberry upland). The hackberry upland also had the lowest basal area (583 in^2/acre), indicating a younger stand of trees, while the maple hardwood hammock also had the highest basal area (15,902 in^2/acre) indicating fewer, larger trees more characteristic of an older stand of trees.
- The average basal area for all species was 3,089 in^2/acre. Cypress trees in the cypress swamp had the largest basal area (19,843 in^2/acre) of any other species, followed by laurel oak (13,722 in^2/acre) and loblolly pine (12,780 in^2/acre).

Elevations and Soils. River channel elevations ranged from 20.0 to 22.6 feet NGVD among the three upstream transects in the study corridor and from 19.8 feet NGVD to 23.6 feet NGVD at five transects along the middle reaches. Channel elevations decreased at the three downstream transects and ranged from 11.8 to 17.7 feet NGVD. The net decline in elevation along the study corridor from the most upstream transect (Veg7) to the most downstream transect (below the borrow pit) was 2.6 feet over 5.7 miles (0.46 feet/mile). Elevation gradients along transects were steeper and increased an average of 364 feet along transects that averaged 0.1 mile in length. Median elevations along transects ranged from 22.6 feet NGVD to 28.3 feet NGVD.

Hydric and muck soils occurred along all 11 study transects and in all vegetation classes except the hackberry upland. Only in the cypress swamp were exclusively hydric soils found. Median elevations of hydric soils were lower when compared with nonhydric soils. Elevation differences between hydric and nonhydric soils were smaller (0.6 feet to 0.8 feet) at two transects associated with shoals and larger (2.0 to 4.0 feet) at the two most upstream and two most downstream transects.

Changes in vegetation were more conspicuous along individual transects when compared with differences between transects or along the upstream to downstream river gradient and corresponded to steeper elevation gradients along transects. Wetland vegetation classes were absent at two transects, one in the upstream reach and one in the mid-reach of the study corridor. These two transects were characterized by the laurel oak mix vegetation class and intercepted shallow segments (shoals and riffles) of the river channel.

Wetland vegetation classes (cypress swamp, maple hardwood hammock, ironwood hardwood hammock) corresponded to lower elevations when compared with transition classes (laurel oak mix and laurel oak/pine mix) and the hackberry upland along transects. Variations in channel elevations along the river channel were large enough to obscure any upstream-downstream elevation pattern among vegetation classes. Median elevations among wetland vegetation classes ranged from 28.4 to 29.4 feet NGVD for the cypress swamp vegetation class, from 28.0 to 32.7 feet NGVD for the maple hammock vegetation class, and 30.5 to 32.7 feet NGVD for the ironwood hammock class. Median elevations ranged from 31.3 to 33.4 feet NGVD for the laurel oak mix class, 31.3 to 39.1 feet NGVD for the laurel oak/ pine class, and the single hackberry upland had a median elevation equal to 34.7 feet NGVD.

Discriminant Function Analysis (DFA). DFA was successful in differentiating among vegetation classes based on measures of elevation, distance from river channel, and soil parameters along the Rainbow River study corridor. 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. Distance to channel ($r^2 = 0.44$) was more strongly correlated with vegetation class than elevation ($r^2 = 0.37$), soils ($r^2 = 0.35$), and relative elevation ($r^2 = 0.30$), respectively.

Wetland vegetation classes were classified correctly 80 percent of the time for cypress swamp, 52 percent of the time for the maple hammock, and 57 percent of the time for the ironwood hammock. Transition classes laurel oak mix and laurel oak/pine vegetation were classified correctly 46 and 80 percent of the time, respectively. There was only one classification of the hackberry upland and it was classified correctly (therefore 100 percent of the time). Overlap between wetland classes and between transition classes was greater than between wetland and upland classes due to similarity in environmental parameters between classes.

Wetted Perimeter. A steep increase in cumulative wetted perimeter (inundated habitat) coincident with a particular shift in vegetation classes was apparent along the study transects. Wetland classes consistently aligned with the steeper portion of the sigmoid-shaped curve and corresponded to a more gradual slope and greater wetted perimeter among wetland classes. The three transition and upland classes corresponded to the portion of the curves that indicates a steeper elevation gradient (and less wetted perimeter). These results reflect the small elevation change across wetlands and illustrate the large change in the extent of inundation in wetlands that can occur as a result of a relatively small change in water level along the Rainbow River.

Conclusions. Six distinct vegetation classes were identified along the Rainbow River study corridor based on woody species composition and IV and were significantly, but not highly, correlated (correlations ranged from 30 to 44 percent) with soils, elevations, and distances from river channel. Cypress swamp and maple and ironwood hardwood hammocks consistently occurred at lower elevations in combination with hydric and muck soils and greater wet perimeter when compared with the laurel oak transition classes and the single hackberry upland along the Rainbow River study corridor. Channel elevations along the Rainbow River did not consistently decline from upstream to downstream and three transects intercepted shallow areas (higher elevations) along the river associated with shoals or riffles. Consequently, elevations measured in NGVD corresponded better with vegetation classes than relative elevations.

Elevations ranged from 27.8 to 33.8 feet NGVD (median = 31.4 feet NGVD) for wetland classes and from 30.0 to 45.4 feet NGVD (median = 33.2 feet NGVD) for transition and upland classes. Lower elevations generally corresponded to downstream transects. Median elevations of cypress swamps ranged from 28.4 feet NGVD at downstream transects to 29.4 at the midreach transects (cypress swamp was absent along upstream transects). Maple hardwood hammocks ranged from 28.0 to 32.7 feet NGVD from downstream to upstream transects, and ironwood hammocks ranged from 30.5 to 32.7 feet NGVD from midreach to upstream transects (absent at downstream transects). These elevations provide an indication of the water levels at which these communities should be inundated seasonally for approximately a minimum of one month to maintain wetland characteristics.

Based on the results of this study, the cypress swamp is the only vegetation class characterized by semi-permanent or permanent inundation and may provide a criterion on which to establish MFLs for vegetation communities along the Rainbow River. Ninety-eight percent of the flow in the Rainbow River is due to ground water inflows that vary seasonally with aquifer levels, but variation is small when compared to rivers with large surface water influence. Consequently, cypress swamps are limited to the river edges where soils are permanently or semi-permanently flooded. Maple and ironwood hammock vegetation classes made up the two other wetland vegetation classes and are likely seasonally flooded. MFLs that rely on fish passage will address freshwater needs in the shallow portions of the river corridor.

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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 Rainbow 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 Rainbow 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:

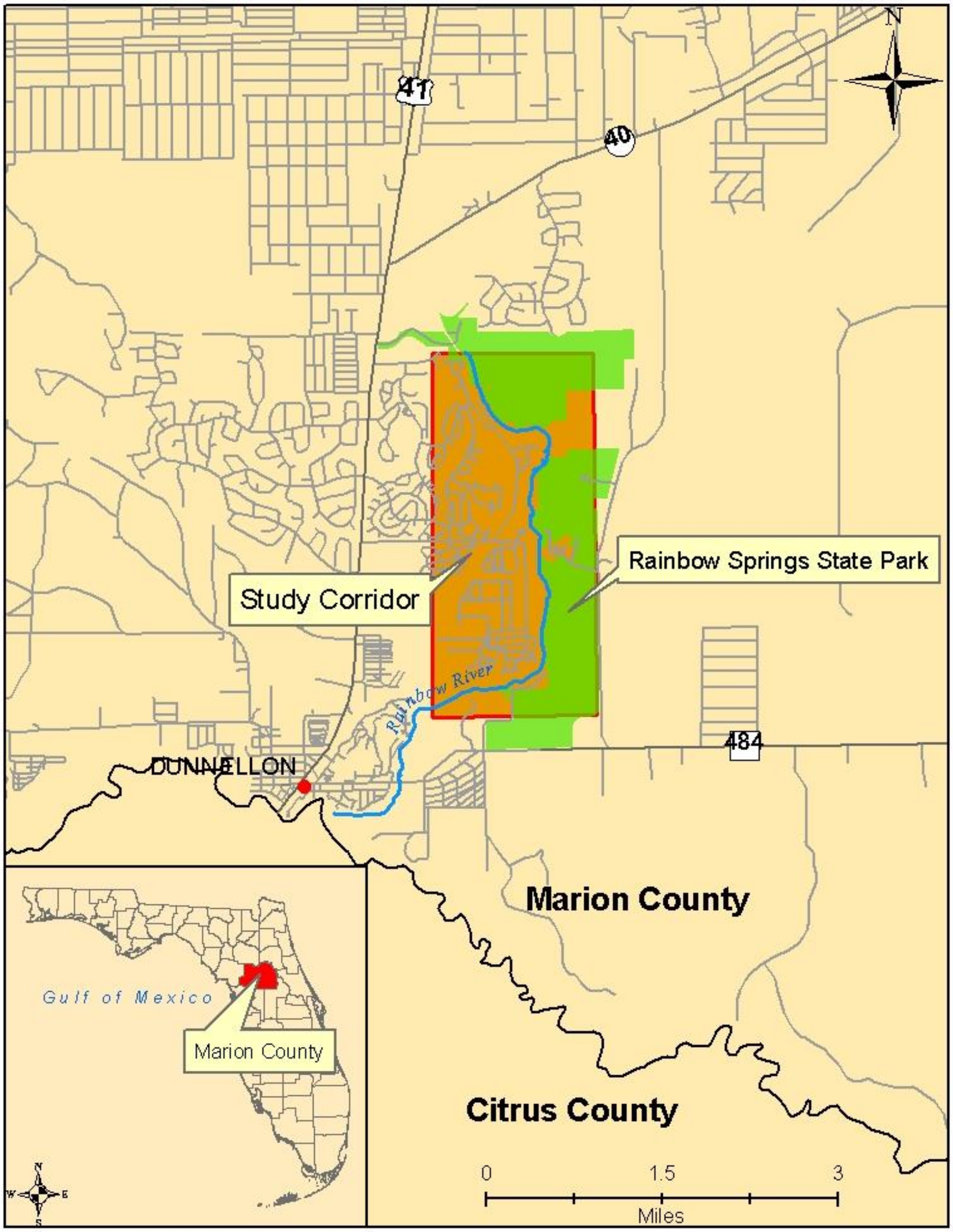
- Address Florida Statute 373.042(1)(a)&(b)
- Protect water resources and ecology
- Determine water availability

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 Rainbow River study corridor and may be used in establishing MFLs for vegetation communities.

Figure 1-1
Location of the Rainbow River Study Corridor
in Marion County, Florida



2.0 Background

The Rainbow River is located approximately 75 miles north of Tampa and 20 miles southeast of Ocala in Marion County and has a watershed of approximately 74 square miles. The river flows south about 5.7 miles from its origin at Rainbow Springs to it's confluence with the Withlacoochee River, near Dunnellon, Florida. The Withlacoochee River continues west to the Gulf of Mexico. The Rainbow River is a designated Outstanding Florida Water (OFW), an Aquatic Preserve, and a SWIM priority water body. Rainbow Springs was designated a National Natural Landmark by the National Park Service in 1972.

Discharge from the Rainbow River into the Withlacoochee River averages 727 cfs (470 mgd) (Rosenau *et al.* 1977), ranking it fourth among 33 first order magnitude spring runs in Florida. As a result, the river is a major recreation area in Florida and activities include canoeing, boating, tubing, swimming, snorkeling, SCUBA, fishing, and sightseeing. The river can be accessed via KP Hole county park, Rainbow Springs State Park at the headsprings, Rainbow Springs State Park Campground, the State Road (S.R.) 484 Bridge, the City of Dunnellon Beach, and at the Dunnellon City Park on the Withlacoochee River just downstream from the mouth of the Rainbow River. Rainbow River Campground is owned by the State of Florida and is operated under a concession arrangement with Marion County.

Much of the land along and surrounding the Rainbow River was logged and converted to citrus by the 1880s (Dinkins 1997). In 1890, hard rock phosphate was discovered near Dunnellon and dozens of mines operated along the banks of the Withlacoochee River and the lower reaches of the Rainbow River. In 1909, the Inglis Dam was constructed across the Withlacoochee River and Lake Rousseau, a 4,163 acre water body, was created (Downing *et al.* 1989). A power facility operated at the dam until 1965. The Inglis Lock, located adjacent to the dam, was completed in 1969 by the United States Army Corps of Engineers as part of the former Cross Florida Barge Canal project.

Land use in the Rainbow River watershed has shifted from mining and agriculture to primarily residential (largely rural) since the 1940s (Jones *et al.* 1996). Residential and commercial development increased from about 64 acres in 1944 to 7,151 acres in 1999, and an additional 10,349 acres have been platted for development. Agricultural lands increased from 7,454 acres in 1944 to 18,418 acres in 1999, while forested lands decreased from 36,969 to 9,620 acres during the same time period (SWFWMD 2004).

2.1 Physiography

The Rainbow River is part of the Ocala Uplift physiographic district and is characterized by hardwood forest, pine flatwoods, and sandhills. Tertiary limestones (chiefly Eocene, Oligocene, and Miocene) are at or near the surface and low, rolling karst plains are conspicuous in the watershed in Marion County in general. The landscape includes streams that cut through hills, flats and swamps, and sandhills. The karst plains transition to sandy flatwoods.

The Rainbow River watershed is also part of the Dunnellon Gap and the Western Valley physiographic provinces. These physiographic lowlands lie between the highland ridges, including the Brooksville and Cotton Plant Ridges. The Withlacoochee River flows along the Western Valley west through the Dunellon Gap, which forms a break in the north-south Brooksville Ridge. These provinces are part of the Central or Mid-peninsular physiographic zone (White 1970) in west Marion County.

A relatively thin layer of Tertiary and Quaternary marine, transitional, and terrestrial deposits overlay approximately 2,000 to 2,500 feet of early to middle Tertiary marine carbonates in southwest Marion County. Sands and clays of alluvial and terrace marine deposits of the Holocene and Pleistocene geologic ages overlay the older stratigraphic units (Hawthorne Group, Ocala Limestone, and Avon Park Formations) of the Eocene and Miocene ages that are composed of phosphate sands and clays, limestones, and dolostones.

The Hawthorne Group stratigraphic unit corresponds to the Brooksville Ridge, through which the Dunellon Gap opens. The Ocala Limestone and Avon Park Formations represent the Upper Floridan Aquifer and the Middle confining unit of the Floridan Aquifer System, respectively. The Ocala Limestone overlays the Avon Park Formation and it is generally at or near the land surface in the watershed. The presence of limestone at or near land surface is responsible for the mature karst terrain, including rolling hills and numerous sinkhole depressions with little to no surface drainage.

Land surface elevations in southwest Marion County range from 50 feet NGVD near Dunnellon to about 100 feet NGVD along the Rainbow River corridor and upstream to the springs. Elevations increase to nearly 200 feet along the Brooksville Ridge just west of the river and decline to around 25 feet to the east along the Dunnellon Gap between the Brooksville Ridge and the Sumter Upland east of the Rainbow River. West of Dunnellon and the Brooksville Ridge, the Coastal Lowlands gradually transition to the west toward the coastal swamps of Levy County.

2.2 Soils

Soil series along the Rainbow River study corridor are characterized by primarily Candler soils along the upper river, Anclote soils along the mid-reaches, and arents (developed, disturbed soils) along the lower river. Anclote series soils are very deep, very poorly drained, rapidly permeable soils that often include muck. These soils are generally associated with floodplains, depression ponds, flats, and poorly-defined drainage ways and native vegetation on these soils generally consists of cypress, swamp bay, popash, cabbage palm, red maple, and needle rush (*Juncus*). Anclote soils are saturated and often inundated during the wet season if undeveloped. The water table is generally within 10 inches of land surface for six or more months during the wet season and can fall more than 20 inches below land surface during the dry season.

The upper reaches of the Rainbow River include smaller areas of sandy, well drained, permeable Tavares soils in addition to the Anclote series. Tavares soils are typical of the lower slopes of hills. Native vegetation is often slash and longleaf pines and turkey oak, although large areas of these soils have been converted to citrus. The water table is typically 40 to 80 inches below land surface and recedes even farther below land surface during extended droughts.

Pomona and Candler soil series dominate along the middle reaches of the river and are sandy and well drained and more typical of uplands when compared with the Anclote soils. Native vegetation includes upland species such as slash and longleaf pine, saw palmetto, and wax myrtle. The water table is generally more than six to 18 inches below land surface for one to three months during the wet season and recedes to 10 to 40 inches below land surface for six or more months of the year, although depressions may be ponded for six to nine months. The Candler soils are very deep, excessively drained, rapidly permeable sands of uplands. The texture is sand or fine sand in the upper horizons. Native vegetation includes live (*Quercus virginiana*), bluejack (*Q. incana*), and turkey (*Q. laevis*) oaks, longleaf pine (*Pinus serotina*), and wiregrass (*Aristida* sp.). The water table is usually more than 80 inches below land surface.

The lower reaches of the river include the Arents soils are typically associated with disturbed and/or created soils of developed (mined, farmed, urban) settings. The two downstream transects were outside the Rainbow Springs State Park and associated with Blue Cove, an old phosphate mine pit. The berm of this pit was removed in the mid-1900s in an effort to improve the water quality in the pit and a canal connects it with the Rainbow River approximately 4.0 miles downstream of the headspring.

2.3 Climate and Precipitation

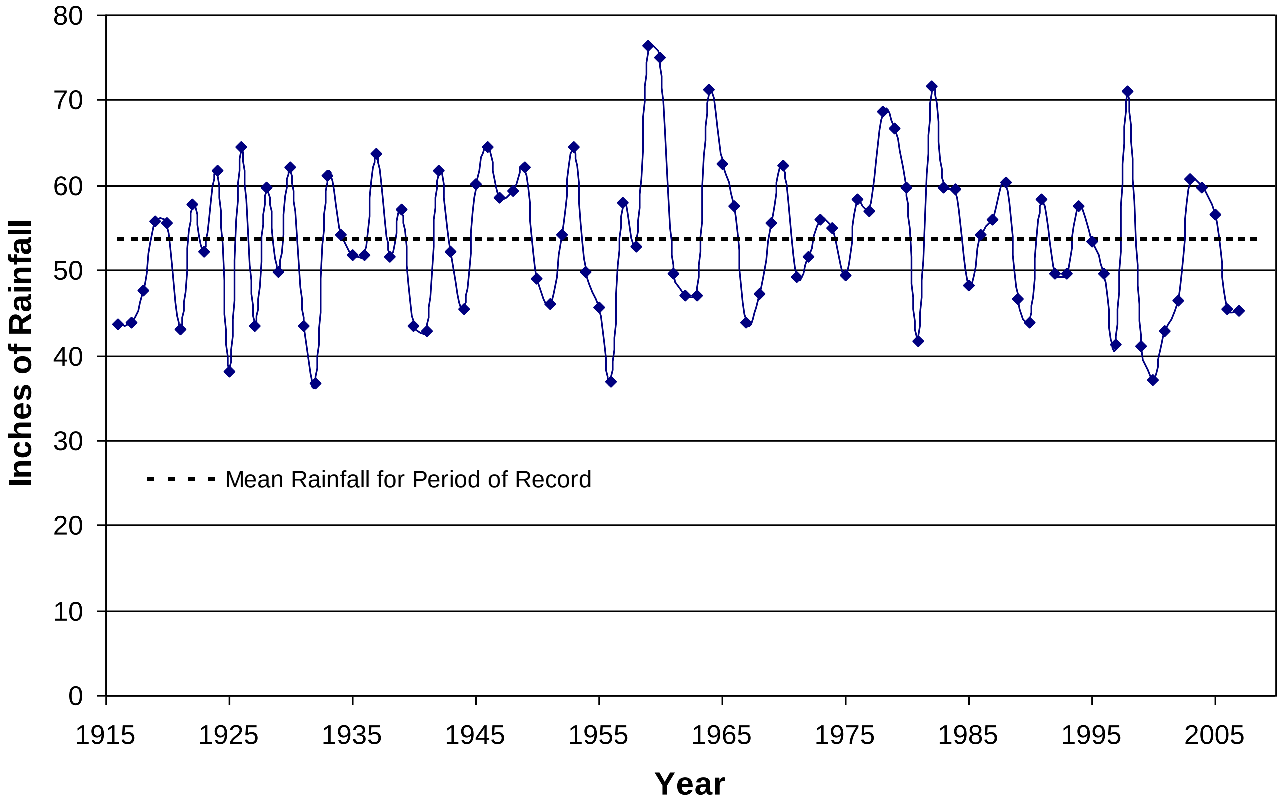
Marion County and the Rainbow River watershed have a humid and subtropical climate that is strongly influenced by Gulf of Mexico waters that moderate winter cold fronts and high summer temperatures. The average mean daily temperature is approximately 70^{o}F (21^{o}C). Mean summer temperatures are in the low eighties and mean winter temperatures are in the upper fifties. Winter temperatures are influenced by tropical air masses in the spring and summer and by cold continental air masses during the fall and winter.

Rainfall in Marion County is a function of frontal, convective, and tropical cyclonic systems. Most of the rainfall is associated with summer convective storms, although there are two distinct peak rainfall periods: June through September and February through April. Average rainfall totals vary from 54 to 58 inches per year and the highest monthly rainfall is in August (Figure 2-1). High flows caused by heavy rains due to the El Niño phenomenon occurred in the Rainbow River in 1997, followed by the most severe recorded drought in the history of Florida in 2000.

2.4 Surface and Ground Water

Only about 25 percent of the rainfall in Marion County contributes to surface water drainage in the county (Rohrer 1984) while the remainder, excluding evapotranspiration, drains internally into the Floridan aquifer or is temporarily perched over thin, discontinuous clay layers due to the extensive karst terrain. Much of the water percolated into the Floridan aquifer in western Marion County reappears as surface flow at Rainbow Springs.

Figure 2-1
Mean Total Annual Rainfall for the Northern Withlacoochee River Basin



Aquifers. The surficial aquifer is limited in Marion and Levy counties due to unconfined nature of the Floridan aquifer and is composed of sands and clays. Aquifers in the Rainbow River watershed are formed by a discontinuous surficial aquifer system and the deeper Floridan aquifer system. Most of the flow to Rainbow Springs is probably concentrated in the Ocala Limestone in the upper 100 feet of the Floridan aquifer (Faulkner 1970). The upper Floridan aquifer is composed primarily of limestones and is the principle source of water for the springs and domestic, agricultural, and industrial water supply in the region. In contrast, the water quality of the lower Floridan aquifer is relatively poor and not used as a water supply.

In general, the upper Floridan aquifer is unconfined in the Rainbow River watershed. The Floridan aquifer in the Rainbow Springs ground water basin is recharged from local rainfall. Recharge is high (>10 inches per year) over most of the study area because the area is an internally drained karst terrain (Faulkner 1970). Along the Withlacoochee River, the surficial aquifer is generally thin to non-existent and the Floridan aquifer is exposed in several locations. The surficial aquifer found along the Brooksville Ridge is discontinuous and perched above the Floridan aquifer.

The Rainbow River, unlike southwest Florida Rivers, is not included in the Southern Water Use Caution Area (SWUCA) designated by the SWFWMD that identifies areas of declining ground water potentiometric surfaces. 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.

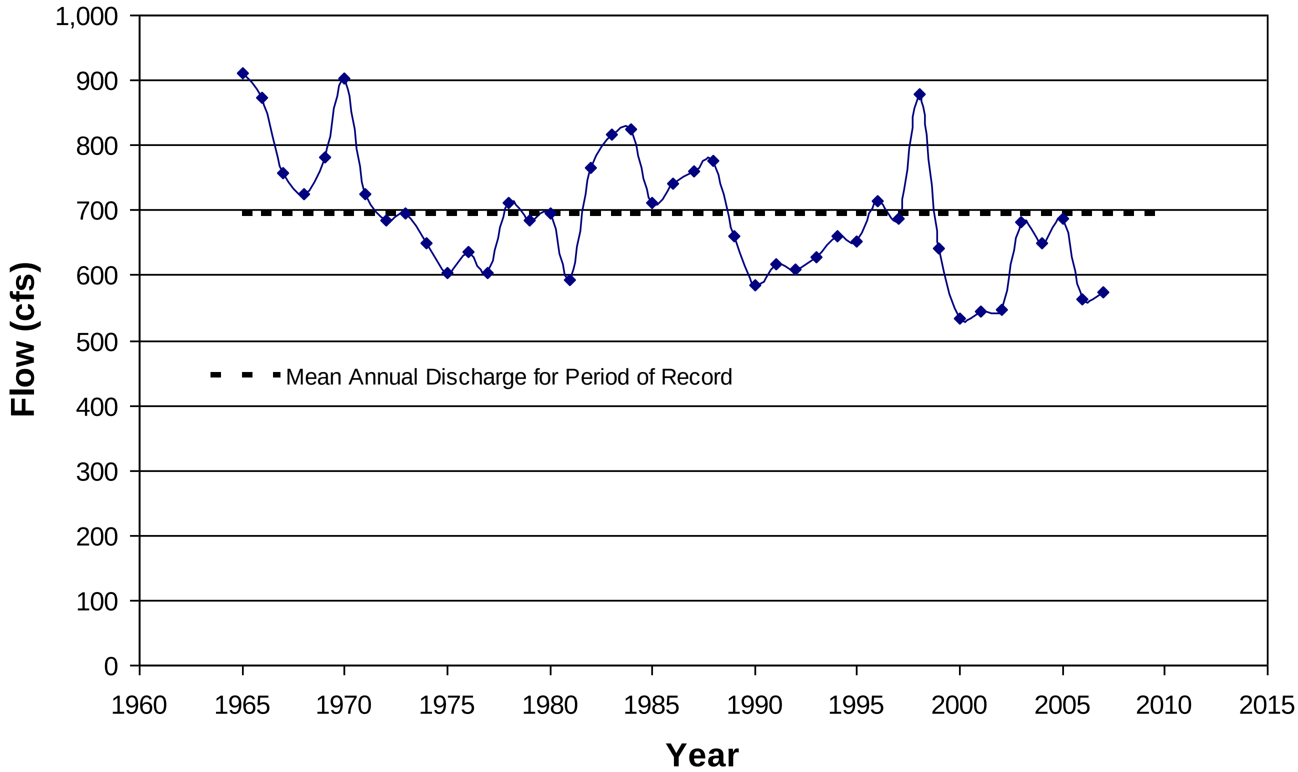
Flows. Spring discharge accounts for about 98 percent of the water in the Rainbow River, compared with less than one percent attributed to surface water runoff, and less than one percent is attributable to lateral inflow. Precipitation, point sources, and septic tanks combined contribute less than one percent to the annual water budget of the river. Treated effluent historically discharged into the river by the City of Dunnellon is now diverted to percolation ponds.

Long term stream flow data for the Rainbow River have been recorded continuously since 1930 and intermittently since 1989 (USGS Well 290514082270701 at Dunnellon) and are graphed in Figure 2-2. Average seasonal flow data in the Rainbow River ranged from 658.8 cfs in May to 745.1 cfs in October through 2007 (USGS 2008). The minimum and maximum flows were 538 and 1,060 cfs, respectively. Highest flows occur from September through December and average 734.5 cfs, compared with 678.9 cfs from January through August. The average difference between wet and dry season flows in the river is only about 10 percent of the historic average.

Water level data are available for the head springs of the Rainbow River on a monthly basis for the period 1965 to 2007 (not continuously monitored) from the USGS (2008). Seasonal water level changes average 0.72 feet for the period of record. Similarly, data for the Homosassa, Chassahowitzka, and Silver rivers indicate an average seasonal range in water levels at the headsprings of 0.57 to 0.68 feet (USGS data 2008). This seasonal change of less than one foot in water levels maintains the integrity of the cypress fringe along the river and precludes the invasion by less flood tolerant species, including maple and ironwood.

Nutrients. Nutrient inputs to the Rainbow River originate from spring flow, land use activities, atmospheric deposition, and naturally occurring nutrients on the land surface and/or in the soils and sediments. Springs discharges account for nearly all the river flow and consequently account for 85 percent of the total nitrogen and 83 percent of the total phosphorus annual loads to the river (WAR 1991). Under a worst case scenario (failure of all systems within 500 feet of the river), septic systems along the river accounted for no more than seven percent of the total nitrogen load and eight percent of the total phosphorus load to the river. These studies also indicated that the major source of nitrate-nitrogen in the springs discharge was agriculturally applied fertilizers (Jones et. al. 1996). Anecdotal evidence suggests that mat forming blue green alga (*Lyngbya wollei*) have increased in biomass in the Rainbow River, as well as other spring runs in the District (Crystal River, Weekiwachee, Chassahowitzka) and some have speculated that the increases may be attributable directly or indirectly to increases in nitrate loading (Hoyer and Canfield 1997).

Figure 2-2
Annual Mean Daily Stream Flows from Rainbow Springs
(USGS Station 0231300 near Dunnellon, Florida)



Springs discharges to the Rainbow River are typically fresh and total dissolved solids (TDS) concentrations are typically less than 200 mg/l. Sulfate concentrations increase from less than 10 mg/l in the head spring area to greater than 30 mg/l in springs near the confluence of Rainbow River and Indian Creek. Chloride concentrations in the springs are generally less than 10 mg/l and suggest that recharge to the springs is also attributable to rainfall in close proximity to the springs. Nitrate concentrations at Rainbow Springs are significantly greater than background concentrations in the Floridan aquifer (<0.01 mg/l) and are typically around 1 mg/l.

2.5 Vegetation

Wetland vegetation along the Rainbow River is generally characterized by seasonally flooded hardwood hammocks that include species such as oak, maple, ironwood, swamp bay, cabbage palm, and tupelo. Cypress trees are scattered along the edges of the river, primarily along the lower reaches where soils are permanently or semi-permanently flooded as a result of permanent ground water flows from Rainbow Springs. The mid-reaches of the river have fewer wetlands within a narrower corridor when compared with the upstream and downstream reaches and are dominated by laurel oak and cabbage palm. Farther landward, uplands are characterized by upland species such as loblolly and slash pine and saw palmettos.

Emergent and submerged aquatic vegetation (SAV) in the Rainbow River were not included in this study, although several previous studies have addressed instream vegetation in the river. The Rainbow River supports a wide variety of native emergent and submerged vegetation communities and these macrophytes provide wildlife habitat (FFWCC 1992), help maintain water clarity (LeConte 1961), and help to stabilize sediments. The dominant SAV species is the native *Sagittaria kurziana* which forms tall, underwater meadows. Based on results from a 2000 vegetation mapping effort (FDEP 2000), *Sagittaria* occurs over about 53 percent of the river, and may cover up to 74 acres of the total 140 acres of submersed area along the river. *Vallisneria americana* (eelgrass) is the second most common native plant, found in 12 percent of the river. While native grasses, especially *Sagittaria*, form extensive meadows in the upper and middle reaches of the river, they are nearly absent from the lower region. Also, a comparison between the 1996 and 2000 vegetation mapping results indicates that the presence of *Sagittaria* and *Vallisneria* decreased by six and seven acres, respectively (FDEP 2000). Other native species, such as *Najas guadalupensis* and *Chara* sp. also decreased during this time period. Bare substrate increased by about five acres from 1996 to 2000, primarily in the State Park swimming area (FDEP 2000) and may be a result of recreation activities (Dutoit 1979, Mumma *et al*. 1996). During the summer, it is not uncommon to have more than 500 visitors on the river (Pridgen *et al*. 1992, after SWFWMD 2004).

In the lower portion of the river the blue green algae *Lyngbya* sp. and the exotic *Hydrilla* are dominant and the native species are relatively scarce. Results of 1996 and 2000 vegetation mapping indicated that that the distribution of *Hydrilla* expanded approximately 500 feet farther upstream. The distribution of *Lyngbya* sp., which may contribute to the loss of submerged plants by forming dense mats that can shade and uproot native vegetation, may also be expanding in the Rainbow River (FDEP 2000) and some studies have attributed the loss of native SAV to increases in nutrients (such as nitrates) in the river (Frazer 2001).

2.6 Issues

An analysis of stream sediments was conducted in 1991 to determine the effects of historic effluent discharges on river sediments downstream of the point of discharge of the City of Dunnellon's wastewater plant into Rainbow River (WAR 1991). Sediments in Rainbow River downstream of the site of historic discharge did not show any contamination (WAR 1991). There are concerns, however, that sediment quality and/or sediment accumulation in the lower river may adversely impact the vegetation communities. Sediment samples collected upstream of the S.R. 484 bridge consisted of 94 percent sand, and six percent silt and clay. Four downstream sample locations ranged from 36 to 70 percent sand, and 30 to 64 percent silt and clay. These preliminary data suggest a possible shift in sediments from primarily sand to a mixture of sand, silt, and clay (WAR 1991).

The main source of nitrate-nitrogen in Rainbow Spring and the Rainbow River is inorganic fertilizers and there is evidence to suggest that agriculture may be a major contributor (Jones *et al.* 1996), although specific load allocations associated with the different land use practices within the recharge area are not well understood.

Water clarity in the river rapidly declines along the upper 2.0 kilometers of the river and continues to decline farther downstream, but at a much slower rate. In an effort to better quantify the spatial and temporal variations in water clarity, as well as water quality, the District initiated a study in June 2002 to identify the major factors contributing to the observed differences in water clarity. Results from this study will provide insight to the causes of the decline in water clarity from the headsprings to the mouth, and whether this pattern is a natural phenomenon, a result of anthropogenic impacts, or a combination of both. Other relevant data sources including the FDEP biological and water quality monitoring program will be included as part of this plan. Additional actions may be recommended based on these results.

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 Rainbow River. The methods used in transect selection, data collection, and data analyses are described in the following sections.

3.1 Transect Selection

Eleven sampling transects were established along the Rainbow 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 Rainbow 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, disturbance, or other issues. Transects were subsequently assigned the prefix such as VEG (vegetation transect) or PHAB (also a transect for the District's instream studies) or arbitrarily assigned the name of a nearby feature (e.g. VEG Below Borrow Pit, shortened to VegBBP).

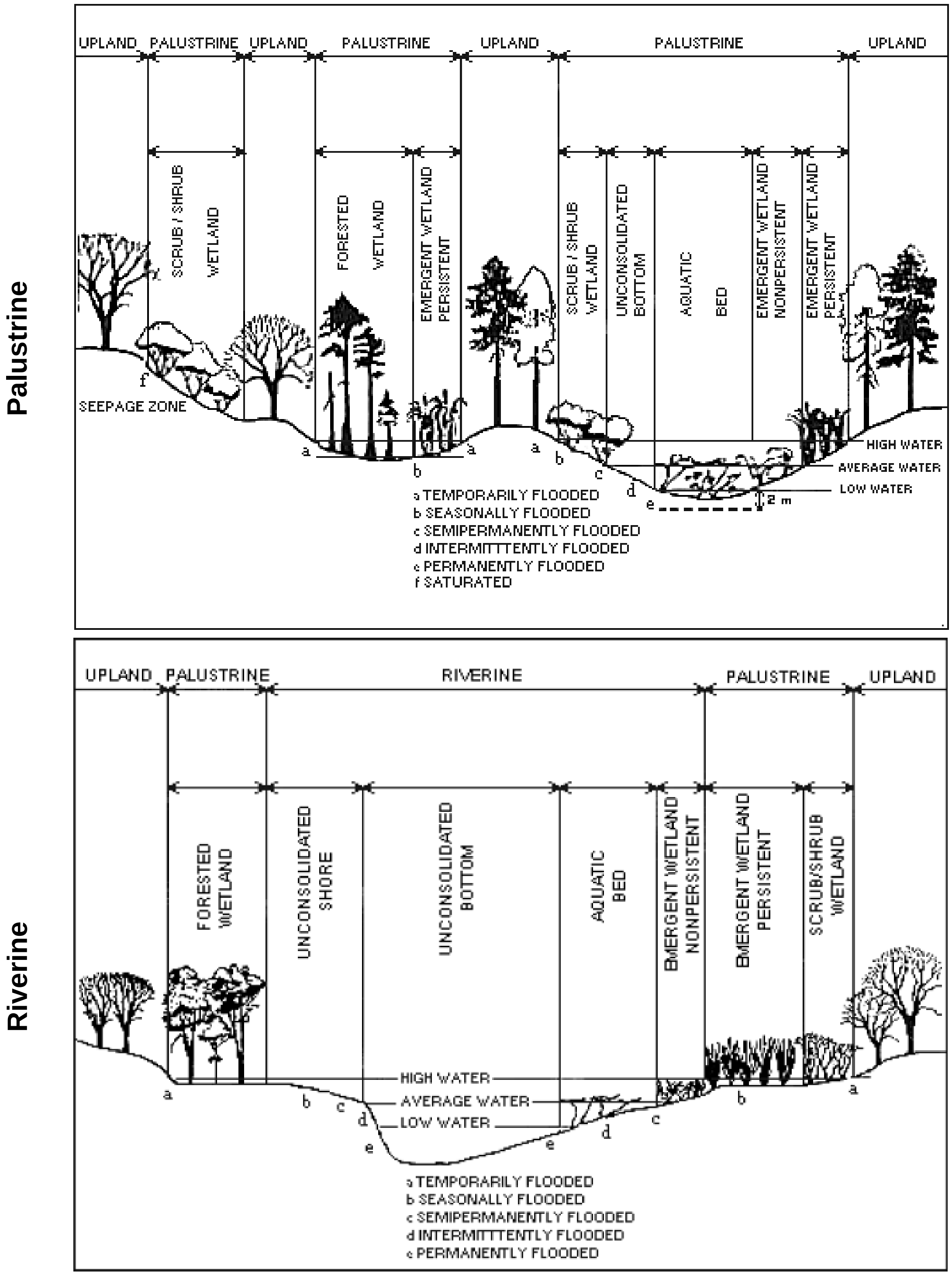
An analysis of the NWI vegetation classes was used as the basis on which to allocate transects among vegetation communities along the river channel. NWI vegetation classes were quantified for corridors 500 feet wide along each transect. The percent of each NWI vegetation class present along the 11 sampling transects is 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 species (P_FO3 or P_FO6) 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 although cypress can be a component of the P_FO6 class. Upstream transects included only temporarily flooded wetlands, while downstream transects included seasonally flooded wetlands.

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

NWI Classification	Description	Acres	Percent of Total	
			Including Uplands	Excluding Uplands
U	Uplands	145.8	27.1	0.0
R_2_AB3H	Riverine Lower Perennial Aquatic Bed Rooted Vascular Permanently Flooded	135.8	25.3	34.7
P_FO6 / FO3C	Palustrine Forested Deciduous / Broad-leaved Evergreen Seasonally Flooded	130.1	24.2	33.2
P_FO6 / FO3A	Palustrine Forested Deciduous / Broad-leaved Evergreen Temporarily Flooded	45.3	8.4	11.6
R_2_UBH	Riverine Lower Perennial Unconsolidated Bottom Permanently Flooded	42.1	7.8	10.7
P_FO6C	Palustrine Forested Deciduous Seasonally Flooded	10.7	2.0	2.7
P_AB3 / FO6H	Palustrine Aquatic Bed Rooted Vascular / Forested Deciduous Permanently Flooded	9.4	1.8	2.4
P_SS_6C	Palustrine Scrub-Shrub Deciduous Seasonally Flooded	7.2	1.3	1.8
P_FO6 / FO3F	Palustrine Forested Deciduous / Broad-leaved Evergreen Semi-permanently Flooded	5.5	1.0	1.4
6 additional classes	Palustrine classes each comprising < one percent of the corridor	5.5	1.0	1.4
Total		537.4	100.0	100.0

Figure 3-1
Features and Examples of Habitats in the Palustrine and Riverine Systems



*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 Rainbow River Study Corridor

NWI Class		Class Description
P_ Palustrine (no further classification)		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.
P_EM Palustrine Emergent		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
P_FO Palustrine Forested		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.
	_3 Broad-leaved Evergreen	In the SE US Broad-leaved Evergreen Wetlands reach their greatest development. Red bay (*Persea borbonia*), loblolly bay (*Gordonia lasianthus*), and sweet bay (*Magnolia virginiana*) are prevalent, especially on organic soils.
	_6 Indeterminate Deciduous	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.
R_2 Riverine Lower Perennial		A Riverine system contains all wetlands and deepwater habitats contained within a channel except wetlands dominated by trees, shrubs, persistent emergents and habitats with water containing ocean-derived salts in excess of 0.5 ppt. In a Lower Perennial subsystem the gradient is low and velocity is slow. There is no tidal influence and some water flows throughout the year.
	_AB_3 Aquatic Bed Rooted Vascular	The class Aquatic Bed includes wetlands and deepwater habitats dominated by plants that grow principally on or below the surface of the water for most of the growing season in most years.
	_UB Unconsolidated Bottom	The class Unconsolidated Bottom includes wetlands and deepwater habitats with at least 25% cover of particles smaller than stones and less than 30% vegetation cover.
Hydrologic Modifiers For Classes and Subclasses (see Figure 3-1 for detail)		
A		Temporarily Flooded
B		Saturated
C		Seasonally Flooded
D		Seasonally Flooded/Well Drained
E		Seasonally Flooded/Saturated
F		Semipermanently Flooded
H		Permanently Flooded

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

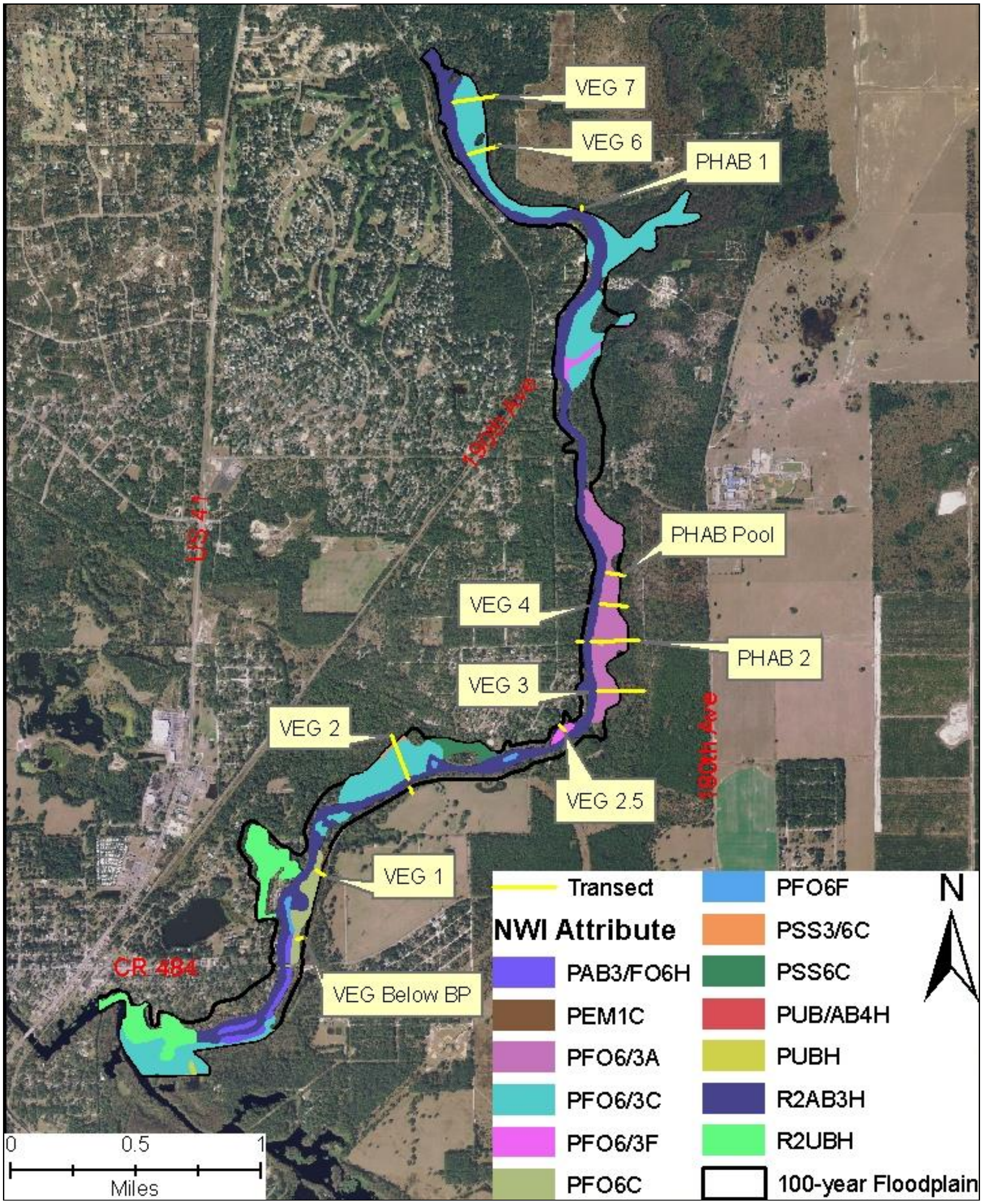


Table 3-3
Percent Cover by NWI Class and Transect in the Rainbow River Study Corridor

	Transect	Percent of Mapped NWI Class* along each Transect								
		Palustrine (P_)						Riverine (R_)	Upland	Total
		Forested (P_FO)				Shrub Scrub (SS)	Unconsol-idated Bottom	Lower Perennial (2)		
		Indeterminate Deciduous (6) and/or Broad-leaved Evergreen (3)						Aquatic Bed (AB)		
		Temporarily Flooded (A)	Seasonally Flooded (C)		Semi-permanently Flooded (F)	Seasonally Flooded (C)	Permanently Flooded (H)			
		P_FO6/3A	P_FO6/3C	P_FO6C	P_FO6/3F	P_SS3/6C	P_UBH	R_2_AB3H		
Upstream	**Veg 7**		58					2	40	100
↓	**Veg 6**		57						43	100
	PHAB 1								100	100
	PHAB Pool	60							40	100
	Veg 4	64							36	100
	PHAB 2	56					10	2	32	100
	Veg 3	39							61	100
	Veg 2.5				64				36	100
	Veg 2		62			6		4	28	100
	Veg 1			53					47	100
Downstream	**Veg BBP**			45					55	100

*NWI class codes are illustrated in Figure 3-1 and described in Table 3-2. Shaded cells indicate absence of a class.

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 within the 100 year floodplain elevations on the east and west 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. In some cases, transects included only the east side of the river due to development, including concrete walls, along the west side. 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 transects were located based on NWI wetlands mapping data (Table 3-1). NWI data indicated that mid-reach transects were drier (temporarily flooded), compared with seasonally flooded wetlands farther upstream and downstream. Vegetation along transects was identified as indeterminate deciduous and/or broad leaved evergreen tree species with different hydrologic regimes, indicating a mix of broad leaved and needle leaved deciduous species (maple, popash, oak, pines, cypress) as well as broad leaved evergreen species (oaks and bays).

Two upstream transects (Veg6 and Veg7) and three downstream transects (Veg1, Veg2, and VegBBP) included both evergreen and deciduous broad leaved, forested wetlands and a mix of the evergreen and deciduous species. One upstream transect (PHAB1) had no NWI designated wetlands. The four mid-reach transects (Veg2.5, Veg3, Veg4, and PHAB Pool) were designated as temporarily flooded. Only one transect (Veg2.5) was mapped as semi-permanently flooded. Permanently flooded wetlands made up two to 10 percent of three transects. These wetlands were mapped as consolidated or aquatic bed vegetation and were part of the river channel.

The river corridor was composed predominantly of temporarily and seasonally flooded forested wetlands (48 percent) classified as deciduous/broad leaved evergreen by NWI (Table 3-1). Approximately 45 percent of the corridor was classified as riverine. Less than three percent of the study corridor was classified as permanently flooded aquatic bed/rooted vascular. Eight vegetation classes made up the remaining 4.6 percent of the study corridor. NWI vegetation classes that individually made up no more than one percent each of the study corridor totaled 5.5 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. cypress to oak, obligate wetlands to facultative wetlands)
- Elevation (e.g. scarp presence)
- Soils (e.g. hydric or nonhydric)

Vegetation classes were further differentiated as part of this study using data from transects and subsequently identifying and quantifying species along individual transects. 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 and basal area of tree species

Sampling plots were located randomly in each vegetation class along transects 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. 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 along the Rainbow River were predominantly sandy with varying degrees of permeability (described earlier in Section 2.0). Well drained, sandy, nonhydric soils, including Candler (24 percent) and Pomona (14 percent) sands characterized the upper half of the study corridor and arents soils are associated with the former mining pit were prevalent along the lower portion of the river (Figure 3-3). Similar upland soils (Tavares, Arredondo, Hague, and Gainesville) made up less than 10 percent of the study corridor. Hydric Anclote soils characterize the middle and lower reaches of the river made up the single most dominant soil series (36 percent) in the study corridor. Other poorly drained wetland soils made up less than one percent of the study area.

The hydrologic soils group (HSG) classification for the Anclote soils indicates poorly drained soils with a relatively high water table and high runoff due to saturated or inundated conditions. The Candler sands, in contrast, are excessively drained sands with low runoff due to high permeability, even when wet. 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

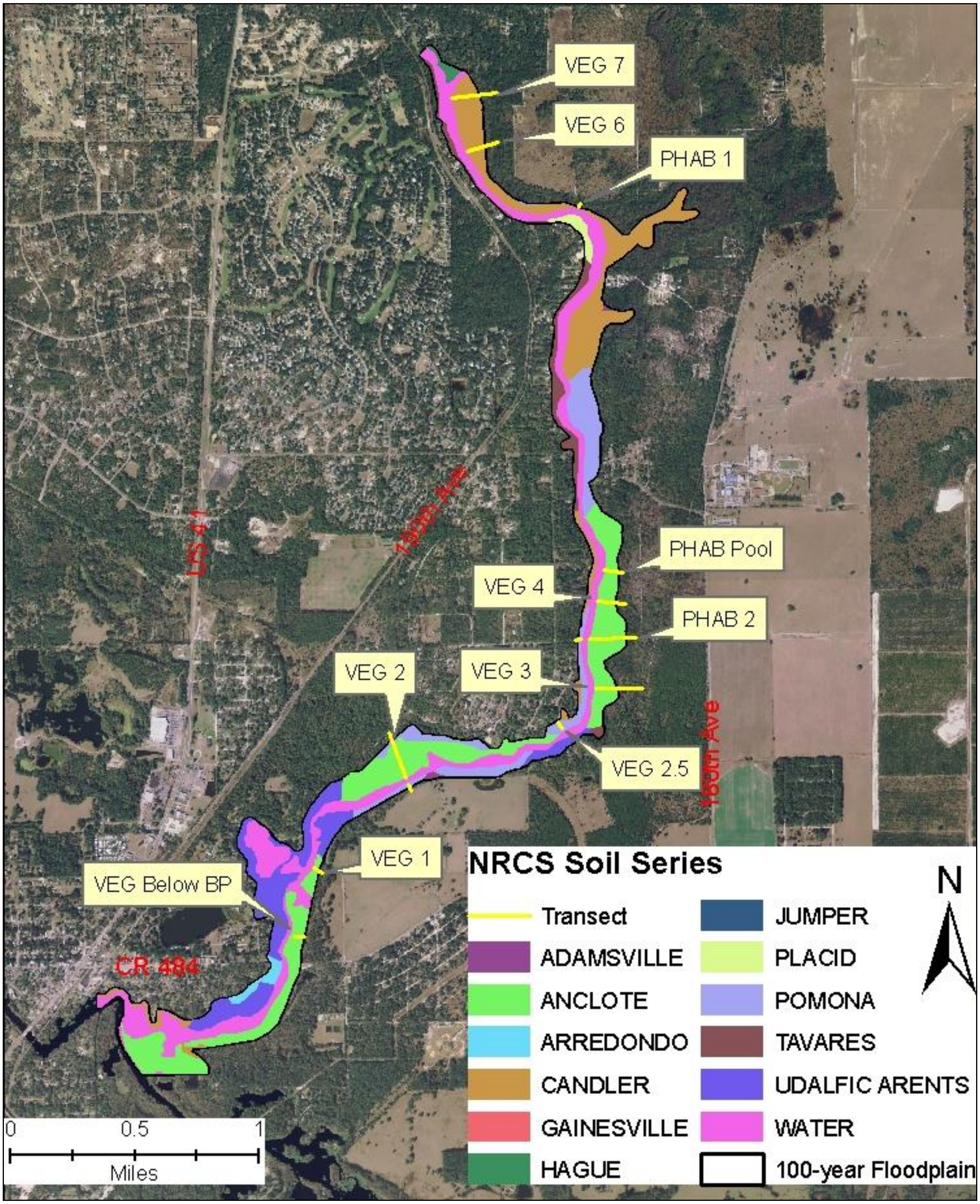
Evidence in soil profiles can also indicate flooding in soils that may not be hydric. Importantly, hydric soils are used in characterizing wetlands, not river channels in which organics are washed downstream. For example, flooded river banks that have a high sand content and occur at elevations high 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 soil probe. 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

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



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 = 11 transects, N = 6 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 Rainbow River study corridor were evaluating using discriminant function analysis (DFA). Elevations, soils, and distance to channel were significant in characterizing environmental conditions of vegetation classes along the river. Overlap was more frequent between wetland classes and between upland classes than between wetland and upland classes due to greater similarity of elevation, soils, and/or distance to river channel. These relationships are described in the following sections.

4.1 Elevations

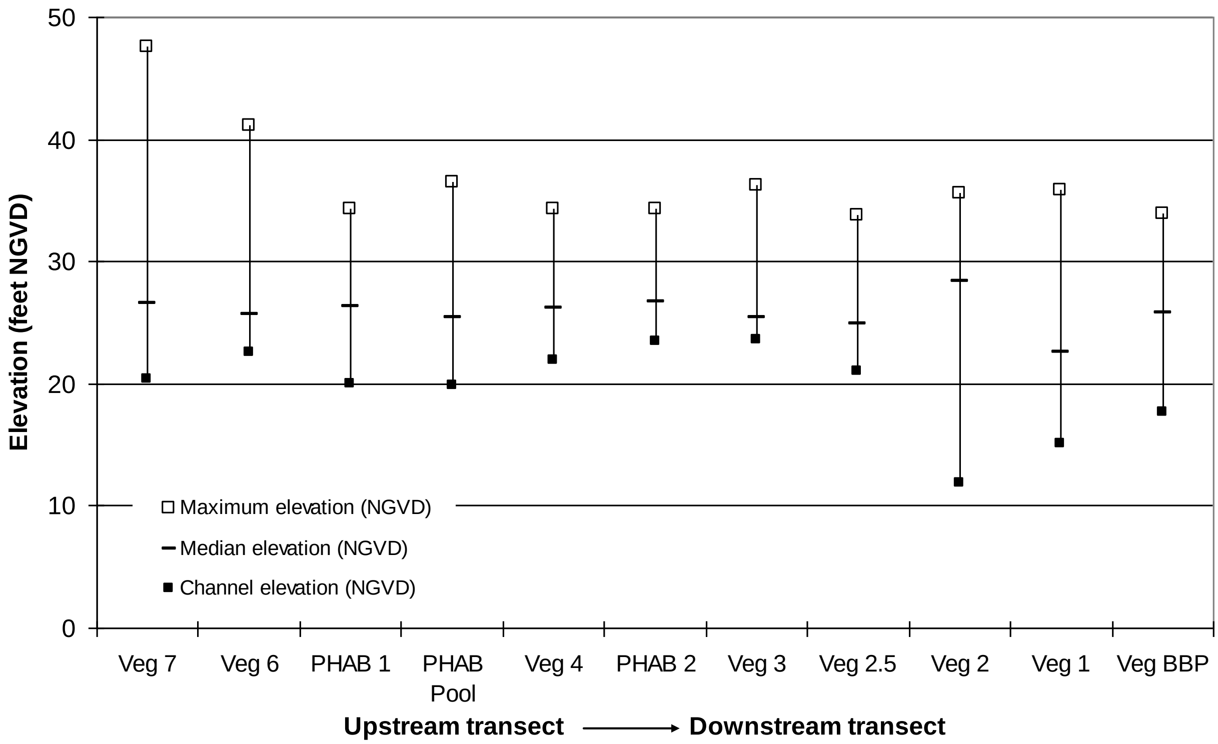
Elevations along the Rainbow River ranged from 20.0 to 20.6 feet NGVD along the first mile or so of the channel (encompassing the three upstream transects) and ranged from 11.8 to 17.7 feet NGVD along the lower two miles of the channel (the three transects farthest downstream). Elevations along transects at the mid-reaches of the river ranged from 19.8 to 23.6 feet NGVD. The net decline in elevation from just downstream of the spring head to the transect below the borrow/mining pit (VegBBP) was 2.6 feet over about 5.7 miles (0.5 feet/mile). However, the total change in elevation along the river was 8.5 feet between the higher mid-reaches of the river and the downstream reaches (Table 4-1 and Figure 4-1).

Table 4-1
Elevation and Distance along the Rainbow River Transects

Transect		Transect Distance (feet)	Transect Maximum Elevation (NGVD)	Transect Minimum Elevation (NGVD)	Channel Minimum Elevation (NGVD)	Maximum Elevation Change	Median Elevation (NGVD)	Median Relative Elevation	N
Upstream ↓ Downstream	**Veg 7**	981	47.6	30.3	20.3	27.3	26.6	12.7	25
	Veg 6	700	41.1	30.3	22.6	18.5	25.7	9.5	21
	PHAB 1	100	34.3	29.8	20.0	14.3	26.3	12.6	6
	PHAB Pool	400	36.5	29.0	19.8	16.7	25.4	11.5	9
	Veg 4	600	34.3	28.7	21.9	12.4	26.2	9.8	17
	PHAB 2	1,130	34.3	15.2	23.4	19.1	26.7	7.7	36
	Veg 3	1,000	36.2	28.5	23.6	12.6	25.4	8.5	23
	Veg 2.5	176	33.7	28.4	21.0	12.7	24.9	8.5	22
	Veg 2	1,150	35.6	28.3	11.8	23.8	28.3	17.9	31
	Veg 1	220	35.8	27.8	15.1	20.7	22.6	14.4	10
	Veg BBP	215	33.9	27.8	17.7	16.2	25.8	11.6	15

Relative elevations (elevations above the channel bottom) along individual transects ranged from 1.1 feet (PHAB1) to 5.9 (Veg6) feet NGVD along 10 of the 11 transects. Elevations at the farthest upstream transect (Veg7), however, increased by 14 feet from the river channel to the end of the transect. Changes in elevation were smallest at transects that intercepted shoals or riffles. For illustrative purposes, the elevation profile and associated vegetation along the Veg3 transect are graphed in Figure 4-2 and graphs of all 11 transects are presented in Appendix A.

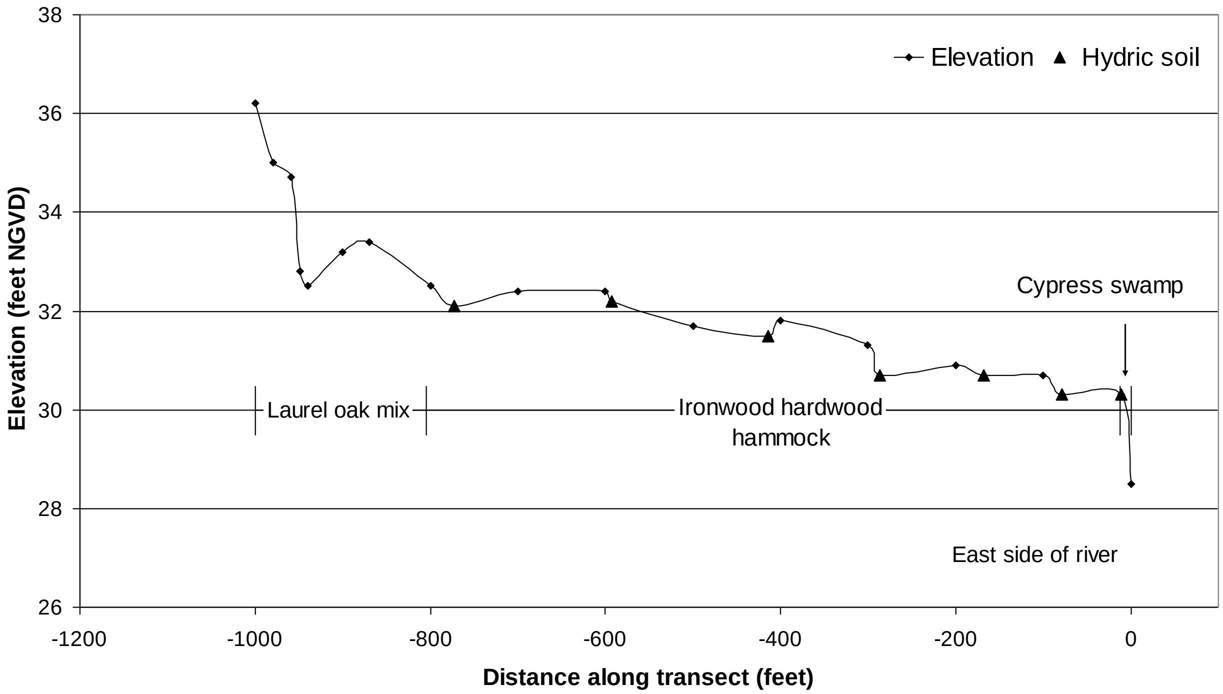
Figure 4-1
Channel Bottom, Maximum, and Median Elevations along Transects in the Rainbow River Study Corridor



4.2 Soils

Spodosols, or flatwoods, soils are the dominant soil order throughout Florida and characterize the Rainbow River watershed. In contrast, Entisols, Alfisols, and Ultisols form the central ridge. These sandy soils are nearly level, somewhat poorly to poorly drained, with dark sand subsoil layers. Natural systems associated with spodosols are generally flatwoods and wet to dry prairies with ponds and cypress domes (refer back to Figure 3-3) (Myers and Ewel 1990). Sand, limestone, and clay (USDA/SCS 1986) components dominate these soils rather than organic materials. In contrast, soils along the St. Johns and Wekiva rivers in the eastern flatwoods physiographic are primarily sandy with significant peaty deposits that indicate extreme anaerobic conditions and saturation for at least 30 consecutive days in most years.

Figure 4-2
Elevation and Vegetation Profile along Transect Veg3 in the Rainbow River Study Corridor



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 inundation period necessary for hydric soil conditions is shorter than the two to three weeks required to exclude upland vegetation.

Hydric soils were found along all 11 study transects and in all vegetation classes except the hackberry upland (present at only one transect). Muck soils were found in the three wetland vegetation classes (cypress swamp and maple and ironwood hardwood hammocks) along all transects and in three of 11 soil samples in laurel oak mix class (Table 4-2 and Figure 4-3). The cypress swamp was the only class with exclusively hydric soils.

Overall, elevation differences ranged from 0.6 feet to 4.7 feet among all transects (Table 4-3). Median elevations of hydric soils were lower when compared with nonhydric soils (Wilcoxon Signed Rank test; S values ranged from 22.5 to 175; $p < 0.01$). Elevation differences between hydric and nonhydric soils ranged from 0.6 to 2.6 feet at the three upstream transects (Veg7, Veg6, PHAB1) and from 1.1 to 4.7 feet at the three downstream transects (Veg2, Veg1, VegBBP). Elevation differences between hydric and nonhydric soils ranged from 0.6 to 3.1 feet at the mid-reach transects (PHABPool, PHAB2, Veg4, Veg3, Veg2.5). The single exception was the small maple hardwood hammock along Transect Veg2.5 in which the elevation difference was very small (0.1 foot).

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

	Transect	Hydric	Not Hydric	Muck	Not Muck
Upstream	**Veg 7**	32.5 (7)	35.1 (6)	32.5 (8)	35.9 (5)
	Veg 6	31.8 (9)	34.6 (3)	31.8 (8)	33.9 (4)
	PHAB 1	32.4 (1)	33.0 (2)	32.4 (1)	33.0 (2)
	PHAB Pool	31.0 (1)	32.4 (2)	31.0 (1)	32.4 (2)
	Veg 4	31.2 (4)	32.3 (4)	31.2 (4)	32.3 (4)
↓	**PHAB 2**	31.4 (7)	32.1 (2)	31.6 (6)	31.2 (3)
	Veg 3	31.1 (8)	34.2 (2)	31.1 (8)	34.2 (2)
	Veg 2.5	29.3 (2)	30.8 (2)	29.3 (2)	30.8 (2)
	Veg 2	29.1 (4)	30.1 (4)	29.1 (4)	30.1 (4)
	Veg 1	29.2 (3)	33.6 (1)	29.1 (1)	29.6 (3)
Downstream	**Veg BBP**	28.1 (4)	32.8 (3)	28.0 (3)	32.2 (4)

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

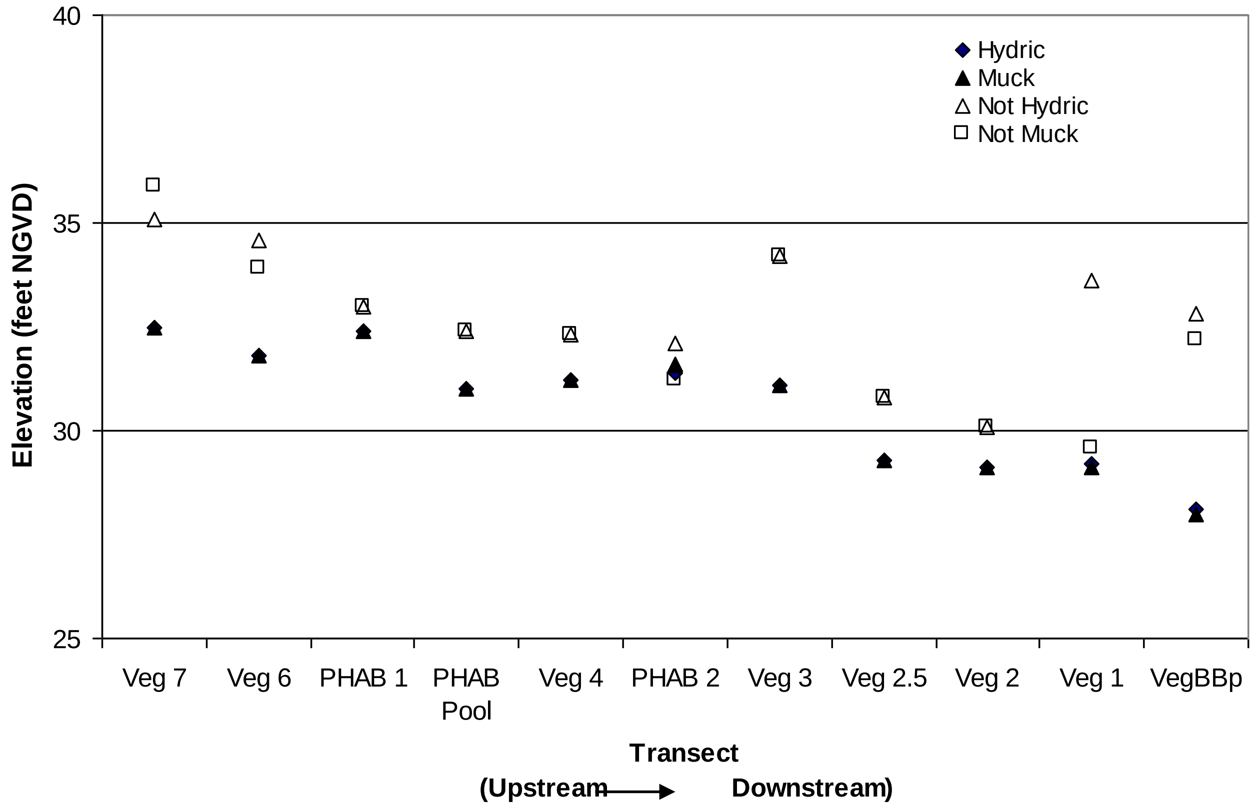


Table 4-3
Differences between Median Elevations (feet) of Hydric and Nonhydric Soils, by Transect and Vegetation Class, in the Rainbow River Study Corridor *

Transect		Cypress Swamp	Maple Hardwood Hammock	Ironwood Hardwood Hammock	Laurel Oak Mix	Laurel Oak / Pine Mix	Hackberry Upland
Upstream → Downstream	Veg 7	All hydric soils in this class		0.2		No Hydric	No hydric soils in this class
	Veg 6		1.4			2.9	
	PHAB 1				0.6		
	PHAB Pool				1.4		
	Veg 4			1.5			
	PHAB 2		0.9	0.6			
	Veg 3			All Hydric	1.7		
	Veg 2.5		-0.1		No Hydric		
	Veg 2					No Hydric	
	Veg 1		All Hydric				
	Veg BBP		All Hydric		No Hydric		

* shaded cells indicate vegetation class absence; negative number indicates nonhydric soil elevation is higher

4.3 Vegetation Relationships

Differences in vegetation classes along the Rainbow River study corridor were significant based on importance values (IVs) that were calculated using tree species density and basal area 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 consistent with seasonally or temporarily flooded conditions, as described in the NWI mapping. Cypress swamp, however, was frequently associated with permanently or semi-permanently flooded wetlands that were not large enough to be mapped.

Class Comparisons. Differences between vegetation classes along the Rainbow River study corridor were significant based on IVs and provided a relative measure of species dominance (no units) (Table 4-4). For example, species IVs were consistently different between the cypress swamp (first row heading) and the maple hardwood hammock (second column heading) regardless of transect (Wilcoxon Signed Rank test, $p < 0.01$ level), as well as between these two classes and any of the remaining nine vegetation classes. IVs of individual species for each of these vegetation classes are summarized in Table 4-4 and graphed in Figure 4-4.

Three vegetation classes were characterized as wetland classes, two as transition classes, and one as an upland class. The wetland classes included obligate and facultative wetland tree species, including cypress (*Taxodiuim distichum*), holly (*Ilex cassine*), swamp bay (*Persea palustris*), sweet bay magnolia (*Magnolia virginiana*) tupelo (*Nyssa sylvatica*), red maple (*Acer rubrum)*, and ironwood (*Carpinus caroliniana*). The three wetland classes could be differentiated based on dominance of cypress, holly, and swamp bay:

- Cypress swamp: comprised of the obligate wetland species cypress, the facultative wetland species sweetgum (*Liquidambar styraciflua*) and American elm (*Ulmus americana*), and few other species.

- Maple hardwood hammock: characterized by predominantly the facultative wetland species red maple and laurel oak (*Quercus laurifolia*), and more than ten percent obligate wetland species including holly, sweet bay magnolia, swamp bay, and buttonbush (*Cephalanthus occidentalis*).

- Ironwood hardwood hammock: characterized largely by ironwood, laurel oak, and red maple, and more than ten percent of obligate wetland species, including sweet bay magnolia and tupelo (*Nyssa sylvatica*).

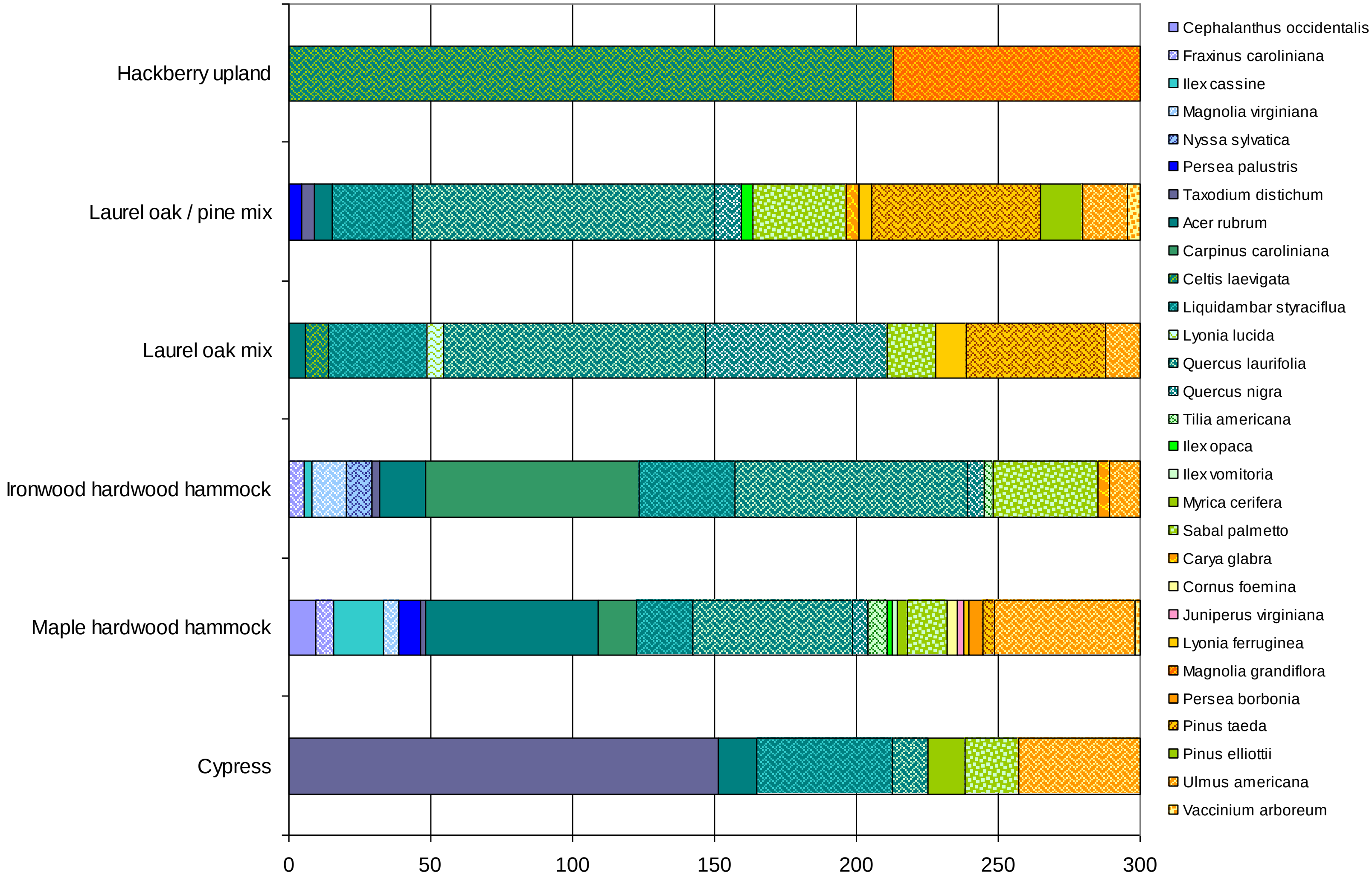
Two of the three remaining vegetation classes are referred to as transition classes and were dominated by laurel oak in both classes. The laurel oak mix class included a substantial components of water oak (*Q. nigra*), while the laurel oak/pine class included a large component of the facultative species loblolly pine (*Pinus taeda*). The third vegetation class (hackberry upland) was dominated by hackberry (*Celtis laevigata*), a facultative wetland species, and the upland species southern magnolia (*Magnolia grandiflora*). This class is referred to as the upland class and occurred along only one of the study transects.

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

Wetland Status	Species	Vegetation Class						
		Wetlands			Transition		Upland	Total IV
		Cypress Swamp	Maple Hardwood Hammock	Ironwood Hardwood Hammock	Laurel Oak Mix	Laurel Oak / Pine Mix	Hackberry Upland	
OBL	*Cephalanthus occidentalis*	0	9	0	0	0	0	9
OBL	*Fraxinus caroliniana*	0	6	6	0	0	0	12
OBL	*Ilex cassine*	0	18	3	0	0	0	20
OBL	*Magnolia virginiana*	0	5	12	0	0	0	17
OBL	*Nyssa sylvatica* var. *biflora*	0	0	9	0	0	0	9
OBL	*Persea palustris*	0	8	0	0	4	0	12
OBL	*Pinus taeda*	0	4	0	49	60	0	113
OBL	*Taxodium distichum*	151	2	3	0	5	0	161
FACW	*Acer rubrum*	14	61	16	6	6	0	103
FACW	*Carpinus caroliniana*	0	13	75	0	0	0	89
FACW	*Celtis laevigata*	0	0	0	8	0	213	221
FACW	*Cornus foemina*	0	4	0	0	0	0	4
FACW	*Liquidambar styraciflua*	48	20	33	37	29	0	167
FACW	*Lyonia lucida*	0	0	0	6	0	0	6
FACW	*Quercus laurifolia*	12	56	82	92	106	0	349
FACW	*Quercus nigra*	0	6	6	63	9	0	84
FACW	*Tilia americana*	0	6	3	0	0	0	10
FACW	*Ulmus americana*	43	49	11	12	16	0	131
FAC	*Ilex opaca*	0	2	0	0	4	0	6
FAC	*Ilex vomitoria*	0	2	0	0	0	0	2
FAC	*Myrica cerifera*	13	4	0	0	0	0	17
FAC	*Sabal palmetto*	19	14	37	17	33	0	119
UPL	*Carya glabra*	0	0	4	0	5	0	9
UPL	*Juniperus virginiana*	0	2	0	0	0	0	2
UPL	*Lyonia ferruginea*	0	2	0	10	4	0	17
UPL	*Magnolia grandiflora*	0	0	0	0	0	87	87
UPL	*Persea borbonia*	0	5	0	0	0	0	5
UPL	*Pinus elliottii*	0	0	0	0	15	0	15
UPL	*Vaccinium arboreum*	0	2	0	0	4	0	6

* Each column totals 300. Wetland Status is according to Florida DEP.

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



Species Composition in Vegetation Classes. Species IVs for the 29 tree species in the six vegetation classes indicated a shift in importance from cypress, red maple, holly, and swamp and sweet bay to greater dominance by cabbage palm, laurel oak, and pine, to upland species such as southern magnolias in the single upland community. Cabbage palm, laurel oak, red maple, sweetgum, and American elm occurred in all classes except the hackberry upland.

The maple hammock had the largest number of species (23), followed by the ironwood hammock (15), and laurel oak/pine hammock (14). The cypress swamp included only seven tree species and the hackberry upland included only two species (hackberry and southern magnolia), both of which were present only in the hackberry upland.

Species Importance. Species IVs comparisons (Table 4-4) indicated a shift in importance from cypress, maple, and ironwood in wetlands to laurel oak and loblolly pine in transition vegetation classes. Laurel oak, which occurred in all six vegetation classes, had the largest overall IV (349) when compared with all other species. Hackberry followed with the second highest IV (221), a primarily a result of the presence of only one other species (southern magnolia) in the vegetation class. No other species had an IV greater than 200, i.e., no other vegetation class had a single species making up such a large component.

Six other species had IVs greater than 100: lobllolly pine (113), cypress (161), red maple (103), sweetgum (167), American elm (131), and cabbage palm (119). The remaining 11 species had IVs ranging from two to 87. Overall trends in species dominance and diversity are summarized below.

- Laurel oak, hackberry, cypress, and sweet gum made up approximately 50 percent of the total IVs (by species) among all classes and each of these species make up from nine to 19 percent of the total IVs.
- Seven species (cabbage palm, American elm, red maple, loblolly pine, ironwood, southern magnolia, and water oak) made up another 40 percent of the total IVs and each of the seven species accounted for only five to seven percent of the total IVs.
- The remaining ten percent of the total IVs was accounted for by 18 species, each of which made up less than two 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 (cypress swamp) to those farthest from the channel (hackberry upland and laurel oak/pine mix).

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 Rainbow River Study Corridor

Vegetation Class	Density (trees/acre)	Basal Area (in^2/acre)	Basal Area/ Tree
Cypress	51	23,977	4,684
Maple hardwood hammock	18	28,313	15,902
Ironwood hardwood hammock	29	25,157	8,601
Laurel oak mix	41	25,410	6,205
Laurel oak / pine mix	29	39,639	13,551
Hackberry upland	205	11,938	583

Basal area and densities varied among vegetation classes along the river. The maple hardwood hammock had the lowest density and the second highest basal area, while the hackberry upland had the greatest density and smallest basal area. The largest trees occurred in the maple hardwood hammock, followed by the laurel oak/pine mix. In general:

- Basal areas were largest in the maple hammock (15,903 in^2/acre) and laurel oak/pine hammock (13,551 in^2/acre) classes and densities were lowest in these two classes (maple hammock = 18 trees/acres, laurel oak/pine hammock = 29 trees/acre). The basal area per tree was also greatest for these two vegetation classes, indicating that these two classes were older and more established when compared with the other classes.

- The average tree density for all species was 33.2 trees/acre. The hackberry upland had the highest tree density (205 trees/acre) and lowest basal area (583 in^2/acre), indicating a much younger stand of trees. The three remaining vegetation classes were very similar to each other in density and basal area.

- The average basal area for all species was 3,089 in^2/acre. Cypress trees in the cypress swamp had the largest basal area (19,843 in^2/acre) of any other species, followed by laurel oak (13,722 in^2/acre) and loblolly pine (12,780 in^2/acre).

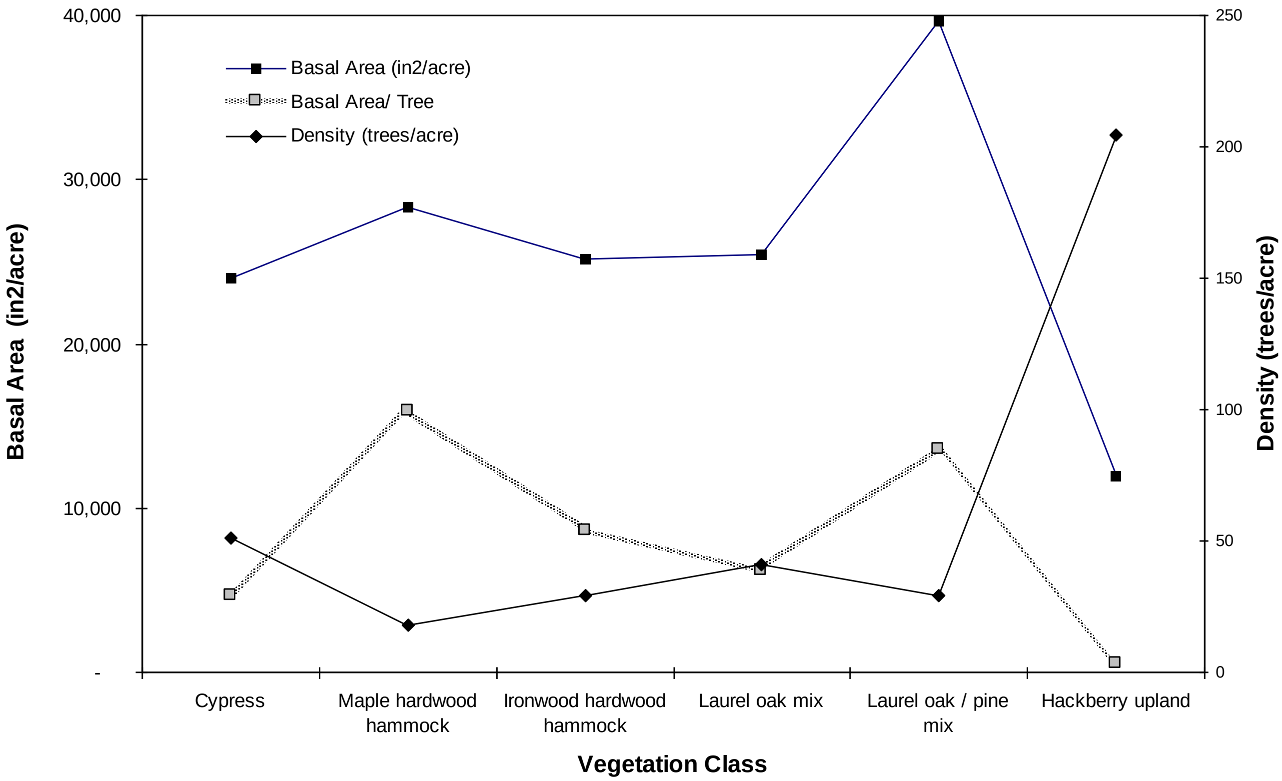
Cabbage palms, like all palms, have no “bark” (secondary phloem) and consequently do not grow in diameter as they grow in height. All the cabbage palms measured were approximately 11 inches in diameter. Therefore, basal area can be considered a constant among cabbage palms and differences in IV among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

Cabbage palm had its highest IV and was the dominant species in the ironwood hardwood hammock class.

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

Wetland Status	Species	Total Basal Area (in^2)	Density (trees/acre)
OBL	*Cephalanthus occidentalis*	71	16
OBL	*Fraxinus caroliniana*	222	25
OBL	*Ilex cassine*	1,098	44
OBL	*Magnolia virginiana*	637	23
OBL	*Nyssa sylvatica*	122	13
OBL	*Persea palustris*	20,021	20
OBL	*Taxodium distichum*	8,023	179
FACW	*Acer rubrum*	2,128	149
FACW	*Carpinus caroliniana*	10,568	182
FACW	*Cornus foemina*	89	7
FACW	*Celtis laevigata*	13,365	326
FACW	*Liquidambar styraciflua*	16	236
FACW	*Lyonia lucida*	42,807	9
FACW	*Quercus laurifolia*	3,604	416
FACW	*Quercus nigra*	1,397	160
FACW	*Tilia americana*	26	8
FAC	*Ilex opaca*	7	11
FAC	*Ilex vomitoria*	249	3
FAC	*Myrica cerifera*	12,223	27
FAC	*Sabal palmetto*	451	156
UPL	*Carya glabra*	15	12
UPL	*Juniperus virginiana*	137	3
UPL	*Lyonia ferruginea*	1,418	39
UPL	*Magnolia grandiflora*	175	102
UPL	*Persea borbonia*	23,105	10
UPL	*Pinus taeda*	3,373	73
UPL	*Pinus elliottii*	8,987	15
UPL	*Ulmus americana*	43	183
UPL	*Vaccinium arboreum*	56	11

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



Percent Occurrence along Transects. Based on NWI data along transects (Table 4-7), vegetation along most transects was broad leaved deciduous and evergreen in temporarily flooded (mid-reach transects) and seasonally flooded (upstream and downstream transects). Consequently, upstream and downstream transects would be expected to have better developed wetlands.

The vegetation classes described in NWI for the study corridor were general enough that it included all of the vegetation classes identified along the 11 field transects in the study corridor. NWI did not specifically call out cypress swamp and none of our transects had more than 10 percent cypress. The remaining vegetation classes frequently included large components of broad leaved deciduous and evergreen species such as oak and palm, which are also not inconsistent with the NWI data. The data collected in this study, therefore, appear to represent more specific subsets of the more general NWI vegetation classes.

Differences between NWI data and field data were more apparent in comparisons of hydrologic regimes. Three of the four transects in the mid-reaches of the Rainbow River classified as temporarily flooded by NWI were 100 percent laurel oak mix, while the fourth (PHAB2) was approximately 69 percent maple hardwood hammock. The NWI-designated semi-permanently flooded wetland corresponded to primarily maple hardwood hammock in the field. Transects identified as predominantly seasonally flooded wetlands by NWI generally corresponded with cypress swamp and maple hardwood hammock in the field.

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

	Transect	Cypress Swamp	Maple Hardwood Hammock	Ironwood Hardwood Hammock	Laurel Oak Mix	Laurel Oak / Pine Mix	Hackberry Upland
Upstream	Veg 7**		17.7	43.4		35.1	
	Veg 6		78.7			21.3	
	PHAB 1				100.0		
	PHAB Pool				100.0		
↓	Veg 4			100.0			
	PHAB 2**		69.2	13.2	9.4		
	Veg 3	1.2		79.3	19.5		
	Veg 2.5**		37.5		5.7		
	Veg 2	3.7	63.9			32.3	
	Veg 1		76.8				23.2
Downstream	Veg BBP**	10.2	58.6		16.3		

* Shaded cells indicate absence of vegetation class. ** Totals < 100% due to a non-vegetated depression not included in a vegetation class (Veg7), a pond not included in a vegetation class (PHAB2), a secondary channel not included (Veg2.5), and a non-vegetated berm not included (Veg Below Borrow Pit).

4.4.1 Elevations and Vegetation Classes

Changes in vegetation associated with elevation were more conspicuous along individual transects due to the steeper elevation changes along transects when compared with the change in elevation along the river channel. Wetland vegetation classes were absent at two transects, one in the upstream reach and one in the mid-reach of the study corridor. These two transects were characterized by the laurel oak mix vegetation class and intercepted shallow segments of the river channel (shoals and riffles).

Wetland vegetation classes (cypress swamp, maple hardwood hammock, ironwood hardwood hammock) corresponded to lower elevations when compared with transition (laurel oak mix and laurel oak/pine mix) and upland (hackberry upland) classes along transects, although the variation in elevation along the river channel seemed to obscure any upstream-downstream elevation pattern among vegetation classes. Median elevations among wetland vegetation classes (Figure 4-6, Table 4-8) ranged from 5.8 to 16.6 feet for the cypress swamp vegetation class, from 8.1 to 17.8 for the maple hammock vegetation class, and 7.1 to 12.4 for the ironwood hammock class. Median relative elevations (Figure 4-7, Table 4-9) ranged from 9.8 to 14.4 feet for the laurel oak mix class, 7.4 to 20.0 for the laurel oak/ pine class, and the single hackberry upland had a median relative elevation equal to 19.6. Vegetation along transects that intercepted shoals and riffles may account for some of these inconsistencies.

River channel elevations ranged from 20.0 to 22.6 feet NGVD among the three upstream transect in the study corridor and from 19.8 NGVD to 23.6 feet NGVD at the five mid-reach transects and corresponded to shifts in vegetation classes. Channel elevations decreased at the three downstream transects and ranged from 11.8 to 17.7 feet NGVD. The net decline in elevation along the study corridor from the most upstream transect (Veg7) to the most downstream transect (VegBBP) was 2.6 feet over 4.7 miles (0.55 feet/mile). In contrast, elevation gradients along transects were much steeper and averaged an increase of 364 feet along transects that averaged 0.1 mile in length. Median elevations along transects ranged from 22.6 feet NGVD to 28.3 feet NGVD and were recorded at two of the three downstream transects.

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

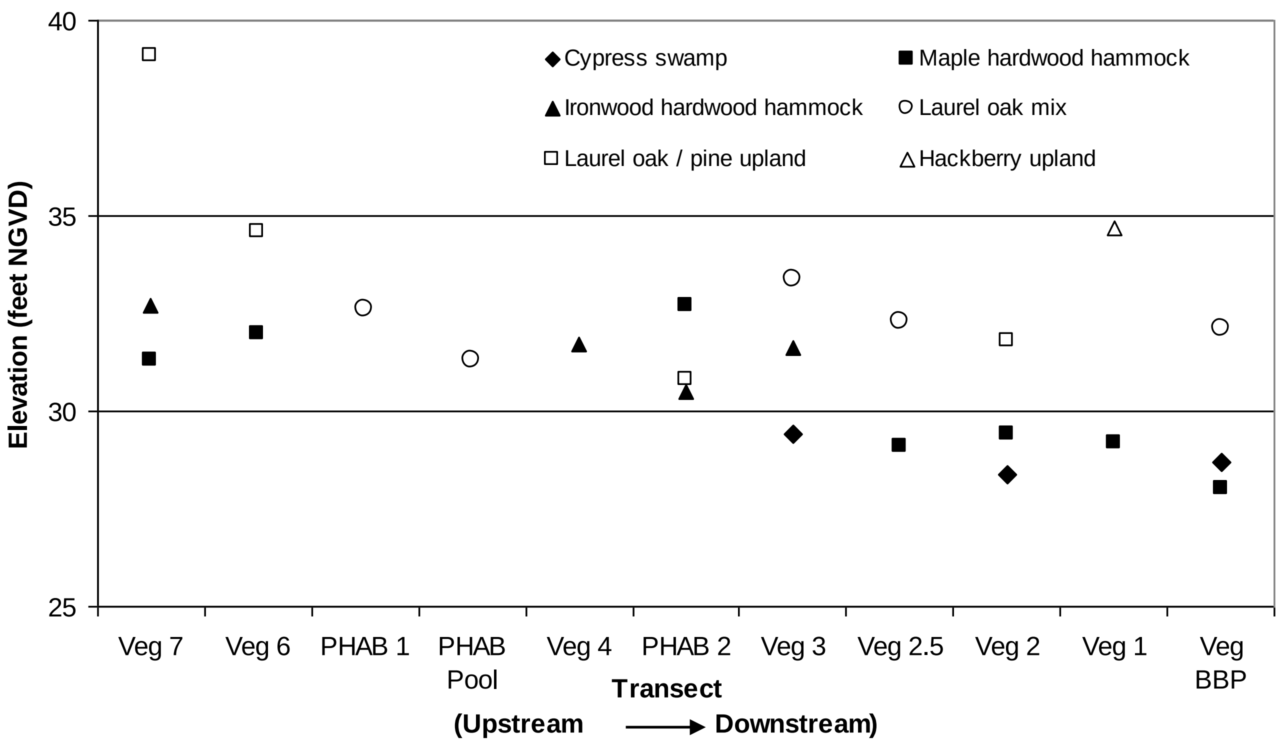


Figure 4-7
Median Relative Elevations of Vegetation Classes along Transects in the Rainbow River Study Corridor

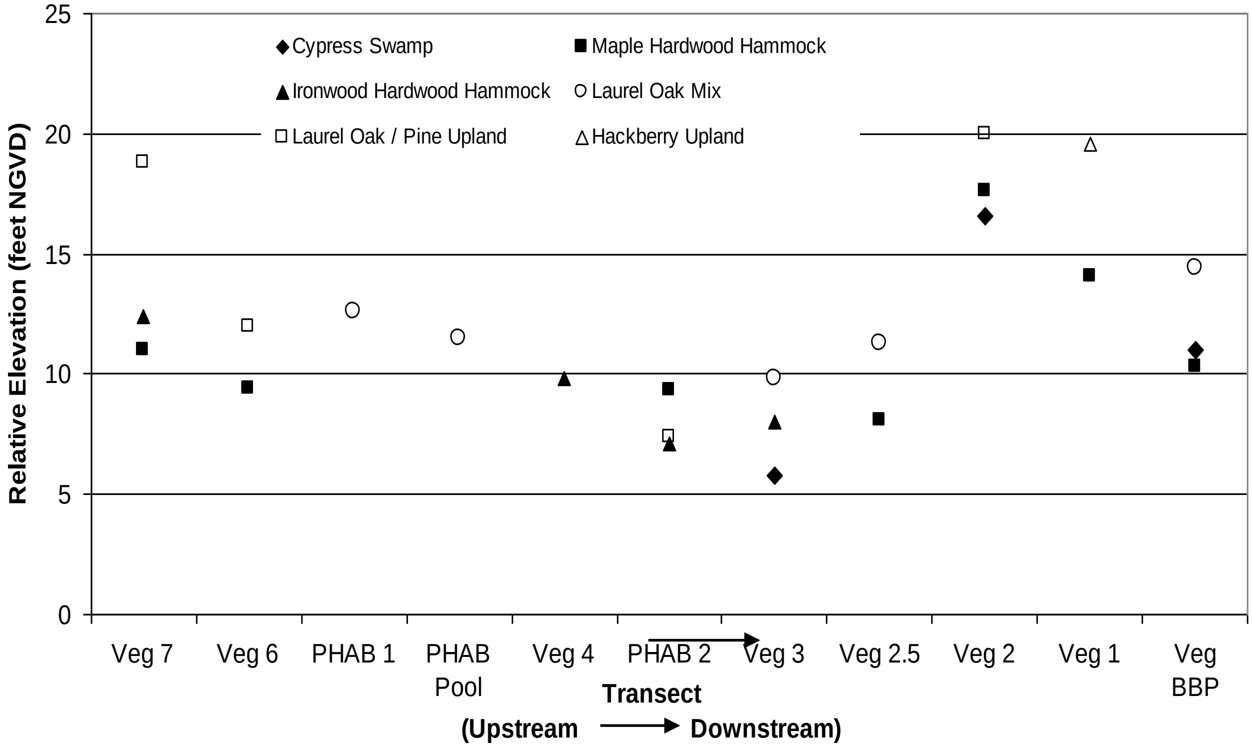


Table 4-8
Median Elevation (NGVD) of Vegetation Classes along the Rainbow River Transects*

	Transect	Cypress Swamp	Maple Hardwood Hammock	Ironwood Hardwood Hammock	Laurel Oak Mix	Laurel Oak / Pine Upland	Hackberry Upland
Upstream	Veg 7		31.3	32.7		39.1	
	Veg 6		32.0			34.6	
	PHAB 1				32.6		
	PHAB Pool				31.3		
↓	Veg 4			31.7			
	PHAB 2		32.7	30.5		30.8	
	Veg 3	29.4		31.6	33.4		
	Veg 2.5		29.1		32.3		
	Veg 2	28.4	29.4			31.8	
	Veg 1		29.2				34.7
Downstream	Veg BPP	28.7	28.0		32.1		

*Shaded cells indicate absence of vegetation class.

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

Transect		Cypress Swamp	Maple Hardwood Hammock	Ironwood Hardwood Hammock	Laurel Oak Mix	Laurel Oak / Pine Upland	Hackberry Upland
Upstream	**Veg 7**		11.0	12.4		18.8	
	Veg 6		9.4			12.0	
	PHAB 1				12.6		
	PHAB Pool				11.5		
↓	**Veg 4**			9.8			
	PHAB 2		9.3	7.1		7.4	
	Veg 3	5.8		8.0	9.8		
	Veg 2.5		8.1		11.3		
	Veg 2	16.6	17.6			20.0	
	Veg 1		14.1				19.6
Downstream	**Veg BBP**	11.0	10.3		14.4		

*Shaded cells indicate absence of vegetation class.

4.4.2 Soils, Distance to Channel, and Vegetation Classes

Soils, elevation, and distance to channel were relatively good indicators of wetlands along the Rainbow River. Hydric and muck soils were found along all 11 study transects and in all vegetation classes except the hackberry upland. Median elevations of hydric soils were lower when compared with nonhydric soils (Table 4-10 and Figure 4-8). Elevation differences between hydric and nonhydric soils ranged from 0.6 feet to 0.8 feet at two shoals transects to differences of two to four feet and the two most upstream and 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 the hackberry upland.

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 4-11), i.e. wetlands had almost exclusively hydric soils and hydric soils occurred much less frequently in transition and upland vegetation classes. Muck soils were found along several transects (refer back to Figure 4-3), but did not occur at elevations that were any lower than hydric soils.

Inconsistencies in vegetation-elevation relationships are likely due to the broad environmental tolerance of wetland species. Upland species can out-compete wetland species within the upland species' range of tolerance, but have a narrower range of environmental tolerance that limits them to uplands. 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.

Distance to river channel may provide a proxy for combinations of elevation, wave energy, soils, and vegetation if distance coincides with these other variables. This pattern was apparent along the Rainbow River transects and average distances of vegetation classes from the river channel increased from wetland to transition to upland vegetation classes. The cypress swamp had the shortest average distance to the river channel (18.0 feet), followed by the maple hardwood hammock (288.4 feet) and ironwood hardwood hammock (322.4 feet). The laurel oak mix and laurel oak/pine mix classes averaged 352.2 and 771.9 feet, respectively, from the river channel. The hackberry upland averaged 186.0 feet from the channel, but occurred only once along a single, short transect.

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

	Transect	Cypress Swamp	Maple Hardwood Hammock	Ironwood Hardwood Hammock	Laurel Oak Mix	Laurel Oak / Pine Upland	Hackberry Upland
Upstream	**Veg 7**		31.8	32.5			
	Veg 6		31.8			3.03	
	PHAB 1				32.4		
	PHAB Pool				31.0		
	Veg 4			30.8			
	PHAB 2		32.0	30.6			
	Veg 3	30.3		31.3	32.5		
	Veg 2.5		29.3				
	Veg 2	28.8	29.5				
	Veg 1		29.3				
Downstream	**VegBBP**	29.5	28.0				

*Shaded cells indicate absence of condition.

Figure 4-8
Relative Elevations of Hydric and Nonhydric Soils, by Vegetation Class, along the Rainbow River Study Corridor

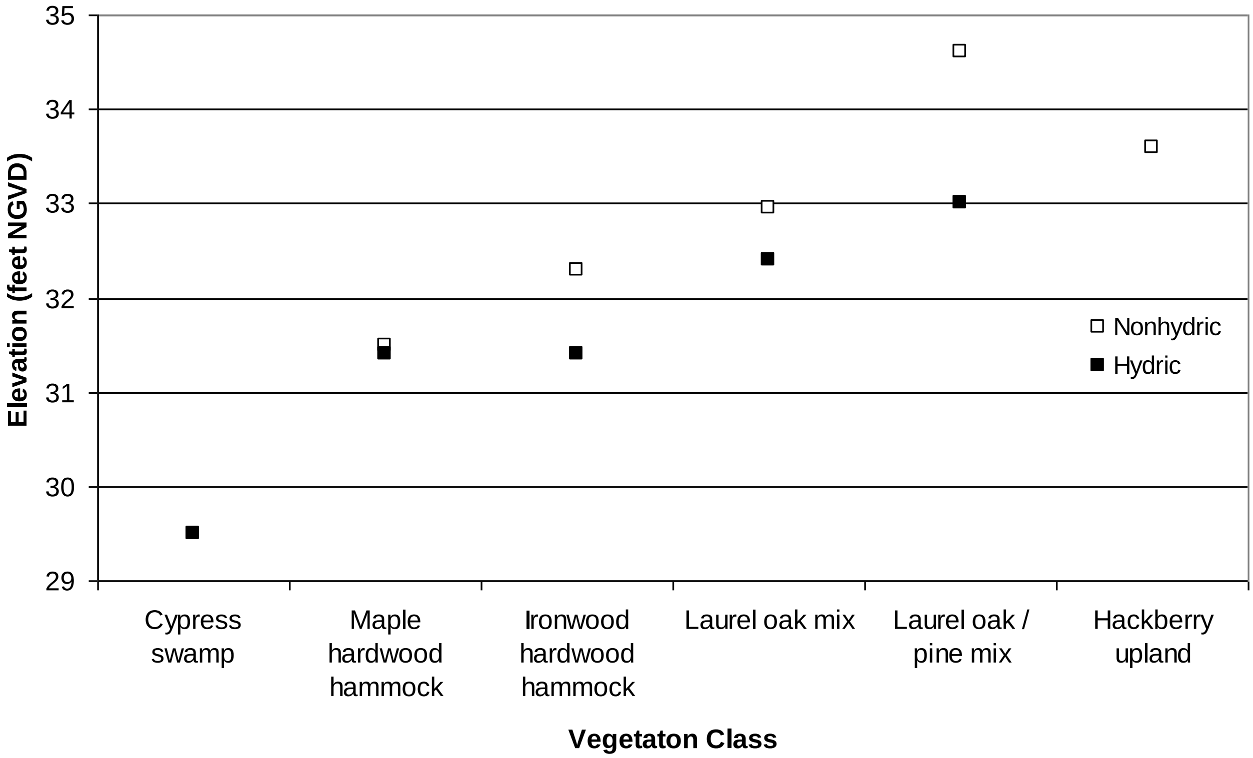


Table 4-11
Relative Elevations (and number of samples) of Hydric and Nonhydric Soils, by Vegetation Class, along the Rainbow River Study Corridor*

Vegetation Class	Elevation (feet NGVD)	
	Hydric	Not Hydric
Cypress Swamp	29.5 (3)	
Maple Hardwood Hammock	31.4 (25)	31.5 (4)
Ironwood Hardwood Hammock	31.4 (16)	32.3 (7)
Laurel Oak Mix	32.4 (3)	33.0 (8)
Laurel Oak / Pine Mix	33 (1)	34.6 (9)
Hackberry Upland		33.6 (3)

*Shaded cells indicate absence of condition.

4.4.3 Discriminant Function Analysis (DFA)

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

Correlation Results. The contributions of elevation, distance from river channel, and hydric soils index were significant in separating vegetation classes (Wilks' Lambda = 5.99; $p < 0.0001$) (Table 4-12). 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. Distance to channel (r^2 = 0.44) was more strongly correlated with vegetation class than elevation (r^2 = 0.37), soils (r^2 = 0.35), and relative elevation (r^2 = 0.30), respectively. (r^2 = 0.29) and distance from river channel (r^2 = 0.28) were lower.

Classifications and Misclassifications. Wetland vegetation classes were classified correctly 80 percent of the time for cypress swamp and 52 percent of the time for the maple hammock, and 57 percent of the time for the ironwood hammock. Transition classes laurel oak mix and laurel oak/pine vegetation were classified correctly 46 and 80 percent of the time, respectively. There was only one classification of the hackberry upland and it was classified correctly (100 percent of the time). Overlap among classes was greatest among classes that were sampled less frequently, had greater variability in species, and occurred along more transects. Overlap was greatest with "adjacent" classes, i.e. cypress swamp was misclassified as another wetland class rather than a transition or upland class.

Row totals (the "to" classes) in Table 4-12 indicate the percent of the time (and number of times) a vegetation class was classified correctly and incorrectly. For example, cypress swamp was identified in the field on five occasions (100 percent) and was classified as cypress swamp based on environmental measures on four of those occasions (80 percent correct classifications). Cypress swamp was incorrectly classified as maple hardwood swamp once. In contrast, maple hardwood hammock was correctly classified as maple hardwood hammock 56.5 percent of the time (in 13 out of a total of 23 cases).

Column totals in Table 4-12 (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 cypress swamp example again, the total number of observations classified as cypress swamp was 13 (16.5 percent) based on field measurements alone. While cypress swamp was correctly classified 80 percent of the time (four times), maple hardwood hammock (row heading) was also classified (incorrectly) as cypress swamp (column heading) 24.1 percent of the time (in seven of the 13 times it was encountered), and ironwood hardwood hammock was classified (incorrectly) as cypress swamp twice (8.7 percent of the time).

Table 4-12
DFA Results for Vegetation Classifications

Community	Cypress Swamp	Maple Hardwood Hammock	Ironwood Hardwood Hammock	Laurel Oak Mix	Laurel Oak / Pine Mix	Hackberry Upland	Total Class-Ifications
Cypress swamp	80 (4)	20 (1)					100 (5)
Maple hardwood hammock	24.1 (7)	51.7 (15)	10.3 (3)	6.9 (2)	6.9 (2)		100 (29)
Ironwood hardwood hammock	8.7 (2)	4.4 (1)	56.5 (13)	26.1 (6)		4.4 (1)	100 (23)
Laurel oak mix		9.1 (1)	9.1 (1)	45.4 (5)	27.3 (3)	9.1 (1)	100 (11)
Laurel oak / pine upland			10.0 (1)	10.0 (1)	80.0 (8)		100 (10)
Hackberry upland						100 (1)	100 (1)
Total	16.5 (13)	22.8 (18)	22.8 (18)	17.7 (14)	16.5 (13)	3.8 (3)	100 (79)

Wilks' Lambda= 0.252895; F= 5.99; DF= 20; p<0.0001

Variable	R-Square	F Value	Pr>F
Elevation (NGVD)	0.37	8.63	<.0001
Relative Elevation (feet)	0.31	6.45	<.0001
Soils	0.35	7.72	<.0001
Distance	0.44	11.67	<.0001

Cypress swamp, maple hardwood hammock, and ironwood hardwood hammock were classified correctly 80, 51.7, and 56.5 percent of the time, respectively. Laurel oak mix and laurel oak/pine mix were classified correctly in 45.5 and 80.0 percent of the cases. The hackberry upland was classified correctly 100 percent of the time, but occurred along only one transect. Misclassifications occurred most frequently with adjacent classes. For example, cypress swamp was incorrectly classified as maple hardwood hammock. Maple hardwood hammock was classified incorrectly as cypress swamp and ironwood hardwood hammock 34.4 percent of the time, and misclassified 13.8 percent of the time as a transition or upland class.

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 ranged from 31 to 44 percent.

Environmental parameters accounted for a significant amount of variation among vegetation classes and correct classifications ranged from 45.4 percent to 100 percent. Percent correct classifications (outlined in bold in Table 4-12) are graphed in Figure 4-9 and described below.

- Hackberry upland was classified correctly 100 percent of the time, followed by cypress swamp (80 percent) and laurel oak/pine mix (80 percent).
- Missclassifications generally occurred with adjacent vegetation classes. For example, wetland classes generally overlapped with wetland classes and transition classes overlapped most frequently with other transition classes.
- Vegetation classes were significantly correlated with measured environmental variables, although no correlation accounted for more than 41 percent of the variability.

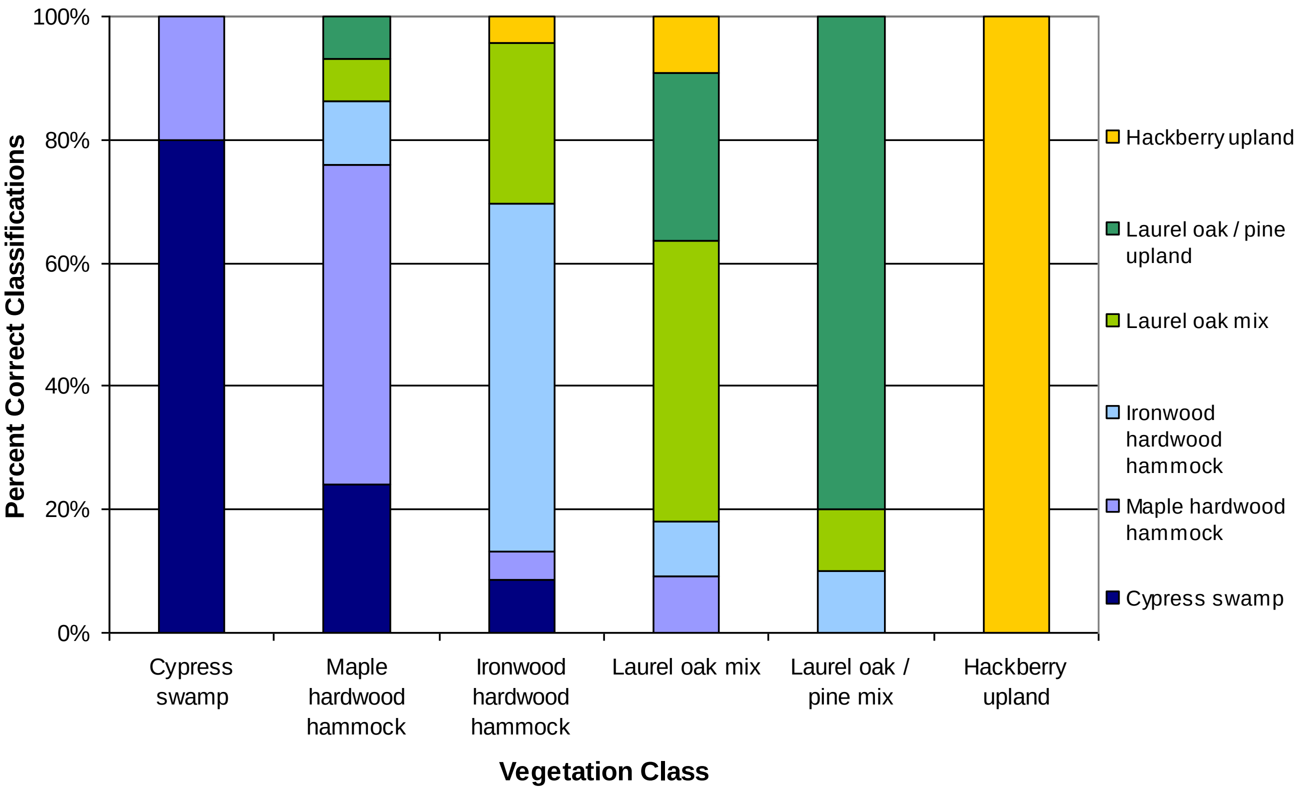
Misclassifications in a DFA occur when a vegetation class is not successfully paired with corresponding environmental parameters and subsequently overlaps with other vegetation classes in regards to soil index, relative elevation, and distance from channel. Overlapping vegetation classes can indicate 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 4-13. 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 4-13
Mean Values of Parameters Used in DFA for Vegetation Classes along the Rainbow River Study Corridor

	Cypress Swamp	Maple Hardwood Hammock	Ironwood Hardwood Hammock	Laurel Oak Mix	Laurel Oak / Pine Upland	Hackberry Upland
Elevation (NGVD)	29.2	30.9	31.7	32.6	35.2	33.6
Relative Elevation (feet)	13.9	12.5	10.6	12.0	17.0	18.5
Soil Index	1.6	1.2	0.9	0.4	0.1	0.0
Distance (feet)	18.0	288.4	322.4	352.2	771.9	186.0

Figure 4-9
Percent Correct Classifications of Vegetation Classes along the Rainbow River Study Corridor



4.4.4 Wetted Perimeter

A steep increase in cumulative wetted perimeter (inundated habitat) coincident with a shift in vegetation classes was apparent along the Rainbow River transects. The sigmoid-shaped curve generally associated with corresponding changes in habitat and elevation was apparent along most of the 11 transects. Wetland classes consistently aligned with the steep portion of the curve and corresponded to a more gradual slope and greater wetted perimeter. An example of a wetted perimeter graph (Transect Veg3) is presented in Figure 4-10 and similar graphs for the 11 transects are provided in Appendix B. The three transition and upland classes corresponded to the portion of the curves that indicates a steeper elevation gradient (and less wetted perimeter). These results reflect the small elevation change across wetlands and illustrate the large change in inundated wetlands that can occur as a result of a relatively small change in water level along the Rainbow River.

The wetted perimeters of vegetation classes in the Rainbow River study corridor are listed in Table 4-14 and indicate the linear distance inundated along a transect at a particular elevation or water level (river stage) in the 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 of the cypress swamp vegetation class at the Veg3 transect, 207.4 linear feet of habitat would be inundated below that median elevation (Table 4-14). Similarly, at a river stage equal to the median elevation of the laurel oak/pine mix vegetation class along the Veg7 transect, 1,159.6 linear feet of habitat would be inundated.

Average wetted perimeter (based on median elevation of each vegetation class) increased with elevation among the cypress swamp and maple and ironwood hardwood hammocks. In contrast, average wetted perimeter decreased in the hackberry upland and laurel oak mix vegetation classes in spite of increases in median elevation of one to two feet (Figure 4-11). The laurel oak/pine mix, however, exhibited increases in wetted perimeter similar to the wetland classes. This class also had the highest median elevation of any of the vegetation classes, as well as the greatest average distance from the river channel and represented the landward extent of the floodplain where it occurred.

Table 4-14
Cumulative Wetted Perimeter (linear feet), by Vegetation Class and Transect, along the Rainbow River Study Corridor

Transect		Cypress Swamp	Maple Hardwood Hammock	Ironwood Hardwood Hammock	Laurel Oak Mix	Laurel Oak / Pine Mix	Hackberry Upland
Upstream ↓	Veg 7		337.2	730.3		1,159.6	
	Veg 6		459.2			908.0	
	PHAB 1				282.7		
	PHAB Pool				370.5		
	Veg 4			193.6			
	PHAB 2		955.8	416.2		457.7	
	Veg 3	207.4		817.8	1,395.3		
	Veg 2.5		395.8		454.6		
	Veg 2	159.5	613.5			1,156.2	
	Veg 1		310.7				468.5
Downstream	Veg BBP	253.6	206.9		334.2		

*Shaded cells indicate absence of vegetation class.

Figure 4-10
Wetted Perimeter and Associated Median Elevations along Transect VEG3 in the Rainbow River Study Corridor

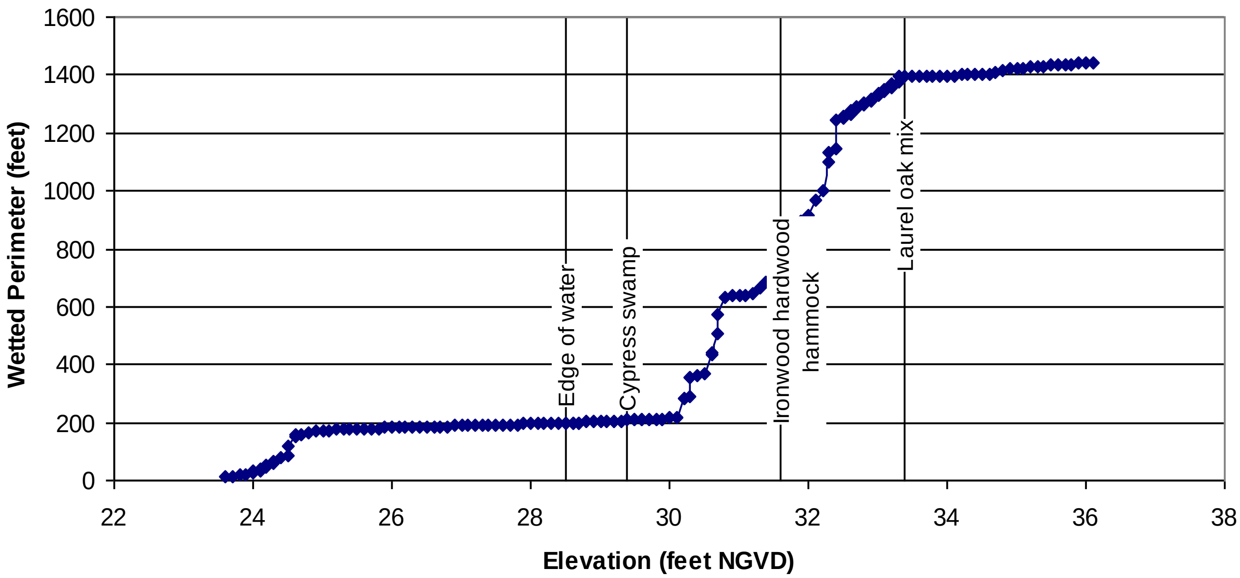
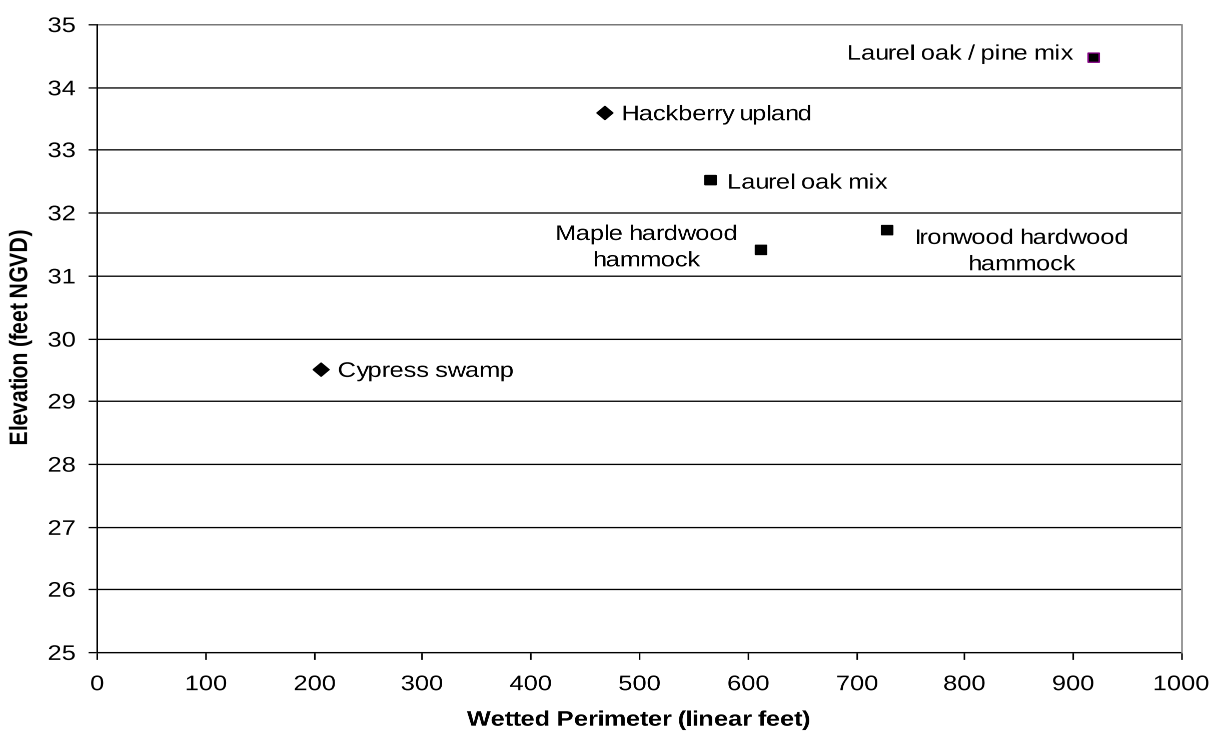


Figure 4-11
Wetted Perimeter and Median Elevations Associated with Vegetation Classes in the Rainbow River Study Corridor



4.5 Relationship of Vegetation with Environmental Variables

Relationships among river stage, flow, and elevations were developed by the District for the Rainbow 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 it is tolerant of inundation. 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 Rainbow 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 by a species such as cypress. The basal area and densities of oaks in the laurel oak mix and laurel oak/pine mix vegetation classes 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 study transects. Nor were any signs of serious invasion by nonnative and invasive species observed.

Inundation Periods in Southeastern Wetlands. The incised nature of the Rainbow River channel and the associated narrow floodplain are a result of the karst terrain of the watershed and the permanent (although seasonally variable) flows. The wetland vegetation classes along the river are subject to seasonal rise and fall in the water table rather than surface water runoff and the relative absence of any soil confining unit limits the accumulation of water long enough to support extensive wetlands. The wetlands along the Rainbow 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 and a wider range of environmental conditions and extremes, similar to other rivers along the Florida Springs Coast, such as the Chassahowitska and Homosassa rivers. The permanently flooded cypress swamps are limited to narrow bands along the river's edge.

Spring-fed rivers differ from blackwater streams and other streams and rivers dominated by surface water in that flows are permanent and the water has greater clarity. Consequently, vegetation studies of the Rainbow River and other springs focus on instream vegetation and water quality rather than wetland vegetation. Descriptions of the Rainbow River watershed are generally based on land use, soils, and physiography and characterize vegetation along the river as hammocks and pinelands with cypress trees scattered along the shoreline. These descriptions of the cypress along the shoreline are consistent with that found in this study.

Alterations in the historical inundation patterns in the upper reaches of the Rainbow River have not been documented. The vegetation along the study corridor appears consistent with species of temporarily and seasonally flooded hardwood hammocks described for the southeastern U.S. (Table 4-14) with the exception of the river banks of the lower river that appear to be seasonally or permanently flooded.

The banks of the Rainbow River are generally characterized by narrow, permanently flooded swamps along the river edges that include species such cypress and tupelo. 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 other species documented as part of this study. Consequently, cypress trees appear limited to the river edge where the water table is closer to the land surface and inundation is more persistent. Cypress cannot germinate under flooded conditions and do not grow quickly enough to successfully compete with other wetland tolerant species landward of the river. In addition, fire following logging or drainage (historically common in the watershed) can destroy seeds and roots and favor replacement by willows and then mixed hardwoods (Myers and Ewel 1990).

Species that are less flood tolerant, such as cabbage palm and maple occur landward of the cypress, but may reach the banks of the river where the transition to open water is steep. Marshes characterized by grasses and sedges such as wild rice (*Zizania aquatica*) and bulrushes (*Scirpus* spp.), as well as broad-leaved species such as climbing hempweed (*Mikania scandens*) and climbing aster (*Aster carolinianus*) occur at the edges of the river where the break in the canopy permits more light and the elevation change from land to open water is more gradual.

Climate. Large-scale climatic events may also influence long term stream flows and should be considered when establishing MFLs for the Rainbow 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 ground water flows, 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. Flows in the in the Rainbow River are also influenced by ground water withdrawals for agriculture and potable use.

Table 4-15
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 wetlands within the 100 year floodplain of the Rainbow River study included six distinct vegetation classes based on tree species diversity and IV. Soils, elevations, and distances from river channel were significantly related to vegetation classes and correlations ranged from 30 to 44 percent. Cypress swamp and maple and ironwood hardwood hammocks consistently occurred at lower elevations in combination with hydric and muck soils and greater wet perimeter when compared with the laurel oak transition classes and the single hackberry upland along the Rainbow River study corridor. Wetlands were absent along two transects located adjacent to shallow portions of the river channel. Based on the results of this study, the cypress swamp is the only vegetation class characterized by semi-permanent or permanent inundation and may provide a criterion on which to establish MFLs for vegetation communities along the Rainbow River. Maple and ironwood hammock vegetation classes made up the two other wetland vegetation classes and are likely seasonally flooded. MFLs that rely on fish passage will address freshwater needs in the shallow portions of the river corridor.

Vegetation. Differences in vegetation classes were significant based on importance values (IVs). Three wetland classes were identified and included obligate and facultative wetland tree species, including cypress (*Taxodiuim distichum*), holly (*Ilex cassine*), tupelo (*Nyssa sylvatica*), red maple (*Acer rubrum)*, and ironwood (*Carpinus caroliniana*). The three wetland classes could be differentiated based primarily on dominance of cypress, holly, and swamp and sweet bay.

Two of the three remaining vegetation classes were dominated by laurel oak and were referred to as transition classes. The laurel oak mix class included a substantial components of water oak (*Q. nigra*), while the laurel oak/ pine class included a large component of the facultative species loblolly pine (*Pinus taeda*). A third vegetation class (hackberry upland) occurred at a single transect. It was dominated by hackberry (*Celtis laevigata*), a facultative wetland species, and the upland species southern magnolia (*Magnolia grandiflora*).

Species IVs for the 29 tree species in the six vegetation classes indicated a shift in importance from cypress, red maple, holly, and swamp bay to greater dominance by laurel oak, loblolly pine, and cabbage palm, to upland southern magnolias in the single upland community. Seven species (cabbage palm, American elm, red maple, loblolly pine, ironwood, southern magnolia, and water oak) made up another 40 percent of the total IVs and each accounted for only five to seven percent of the total IVs. The remaining ten percent of the total IVs was accounted for by 18 species, each of which made up less than two percent of the total IVs.

The maple hammock had the largest number of species (23), followed by the ironwood hammock (15), and laurel oak/pine hammock (14). The cypress swamp included only seven tree species and the hackberry upland included only two species (hackberry and southern magnolia), both of which were present only in the hackberry upland. Cypress trees in the cypress swamp had the largest basal area (19,843 in^2/acre) of any other species, followed by laurel oak (13,722 in^2/acre) and loblolly pine (12,780 in^2/acre).

Elevations and Soils. Elevations in vegetation classes ranged from 27.8 to 33.8 feet NGVD (median = 31.4 feet NGVD) in wetland classes and from 30.0 to 45.4 feet NGVD (median =33.2 feet NGVD) in transition and upland classes. Median elevations of cypress swamps ranged from 28.4 feet NGVD at downstream transects to 29.4 at the midreach transects (absent along upstream transects). Maple hardwood hammocks ranged from 28.0 to 32.7 feet NGVD from downstream to upstream transects, and ironwood hammocks ranged from 30.5 to 32.7 feet NGVD from midreach to upstream transects (absent at downstream transects). These elevations are an indication of water levels at which the maple and ironwood hardwood hammocks should be inundated seasonally for approximately a minimum of one month to maintain wetland characteristics. The cypress swamp appears to be semi-permanently to permanently inundated and reduced inundation would likely expand the distribution of maple trees into the swamp.

Hydric soils consistently occurred at lower elevations when compared with nonhydric soils, regardless of vegetation class. Hydric and muck soils were found at all 11 study transects. Median elevations of hydric soils were lower when compared with nonhydric soils and elevation differences ranged from 0.6 feet to 0.8 feet at two shoals transects to differences of two to four feet at the two most upstream and two most downstream transects. Soils in the cypress swamp were exclusively hydric, while no hydric soils were found in the hackberry upland. Both hydric and nonhydric soils occurred in the remaining four vegetation classes.

Discriminant Function Analysis (DFA). DFA was successful in differentiating among vegetation classes based on measures of elevation, distance from river channel, and soil parameters along the Rainbow River study corridor. 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. Distance to channel ($r^2 = 0.44$) was more strongly correlated with vegetation class than elevation ($r^2 = 0.37$), soils ($r^2 = 0.35$), and relative elevation ($r^2 = 0.30$), respectively.

Wetland vegetation classes were classified correctly 80 percent of the time for cypress swamp and 52 percent of the time for the maple hammock, and 57 percent of the time for the ironwood hammock. Transition classes laurel oak mix and laurel oak/pine vegetation were classified correctly 46 and 80 percent of the time, respectively. There was only one classification of the hackberry upland and it was classified correctly (100 percent of the time). Overlap was greatest with "adjacent" classes, i.e. cypress swamp was misclassified as another wetland class more frequently than as a transition or upland class.

Wetted Perimeter. A steep increase in cumulative wetted perimeter (inundated habitat) coincident with a particular shift in vegetation classes was apparent along the Rainbow River transects. Wetland classes consistently aligned with the steep portion of the curve and corresponded to a more gradual slope and greater wetted perimeter. The transition and upland classes corresponded to the portion of the curves that indicates a steeper elevation gradient (and less wetted perimeter). These results reflect the small elevation change across wetlands and illustrate the large change in inundated wetlands that can occur as a result of a relatively small change in water level along the Rainbow River.

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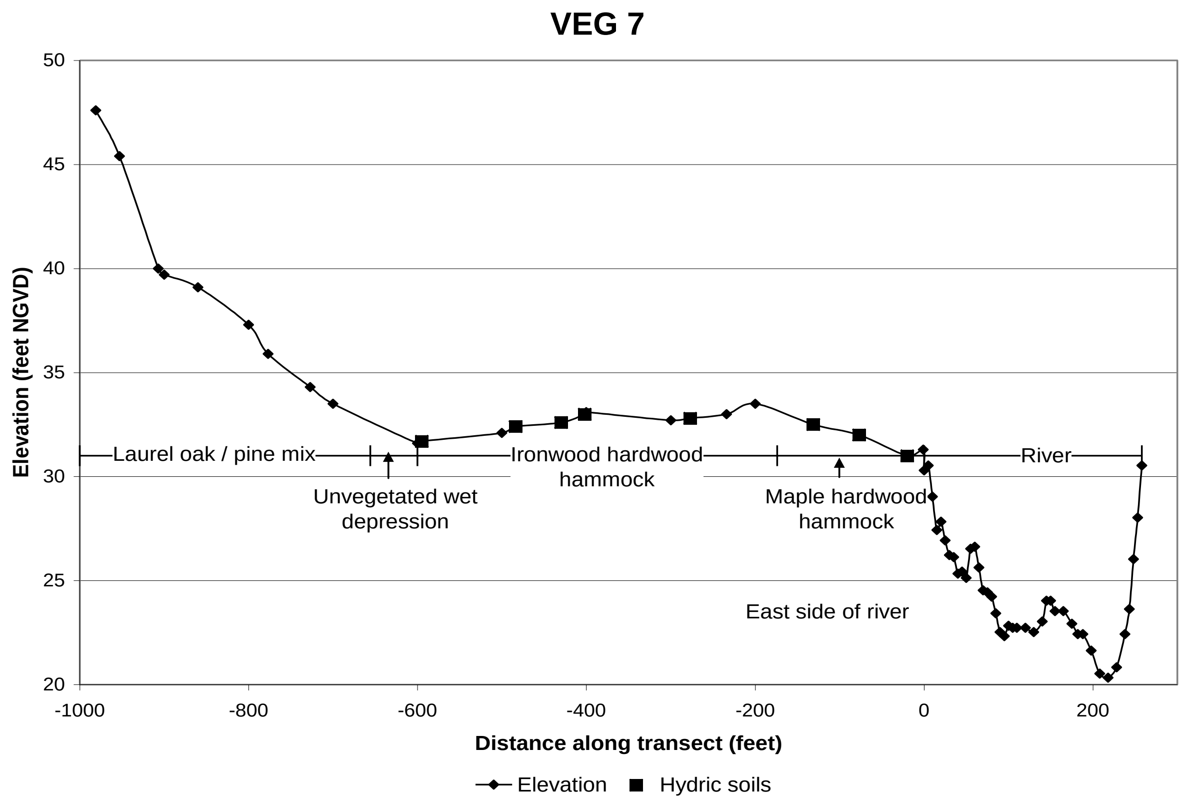
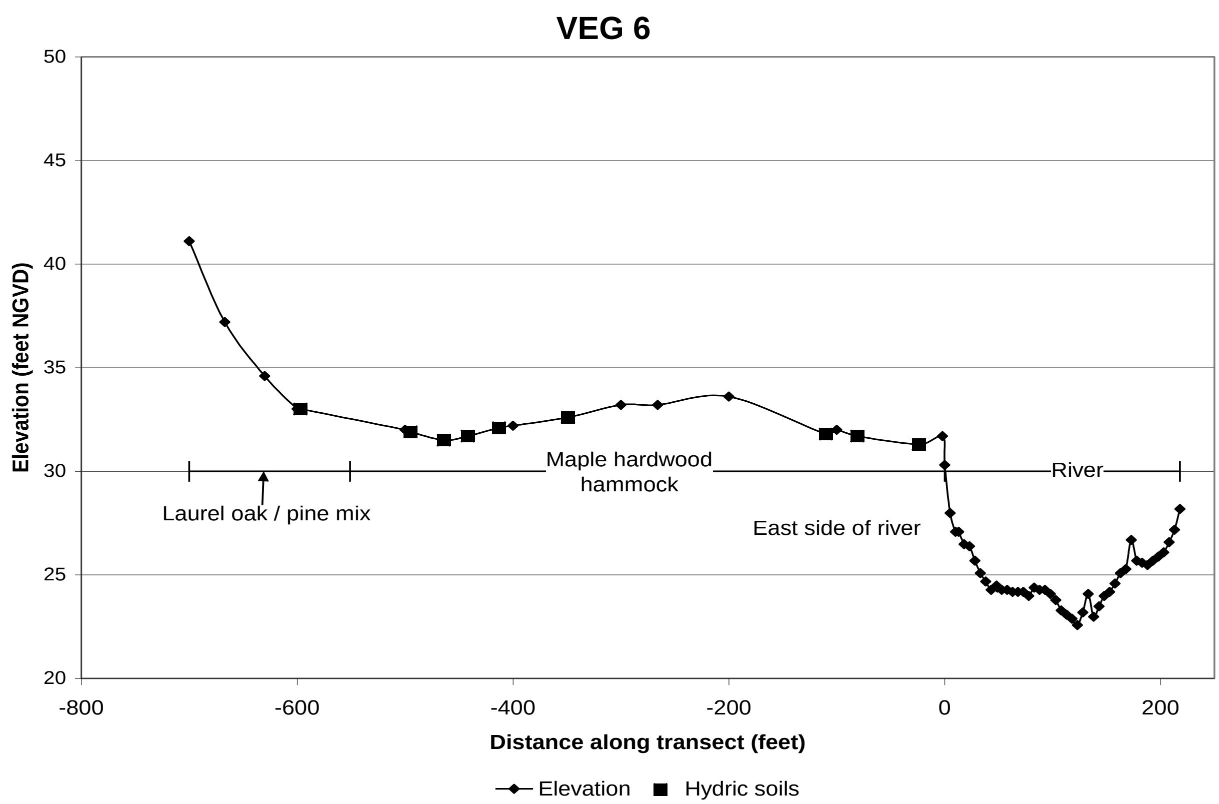
Appendix A

Elevation and Vegetation Profiles for the Rainbow River Study Corridor


VEG 7
50
45
40
35
30
25
20
Elevation (feet NGVD)
-1000
-800
-600
-400
-200
0
200
Distance along transect (feet)
Laurel oak / pine mix
Unvegetated wet depression
Ironwood hardwood hammock
Maple hardwood hammock
River
East side of river
Elevation
Hydric soils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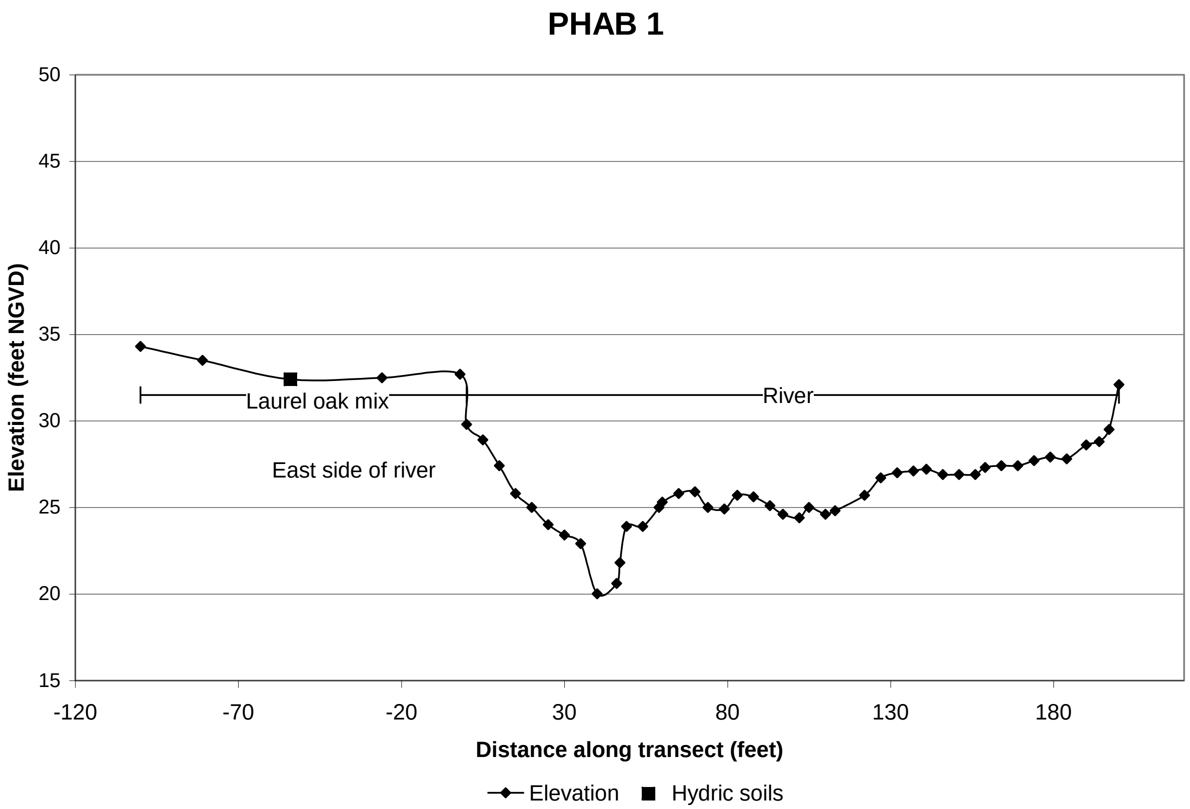
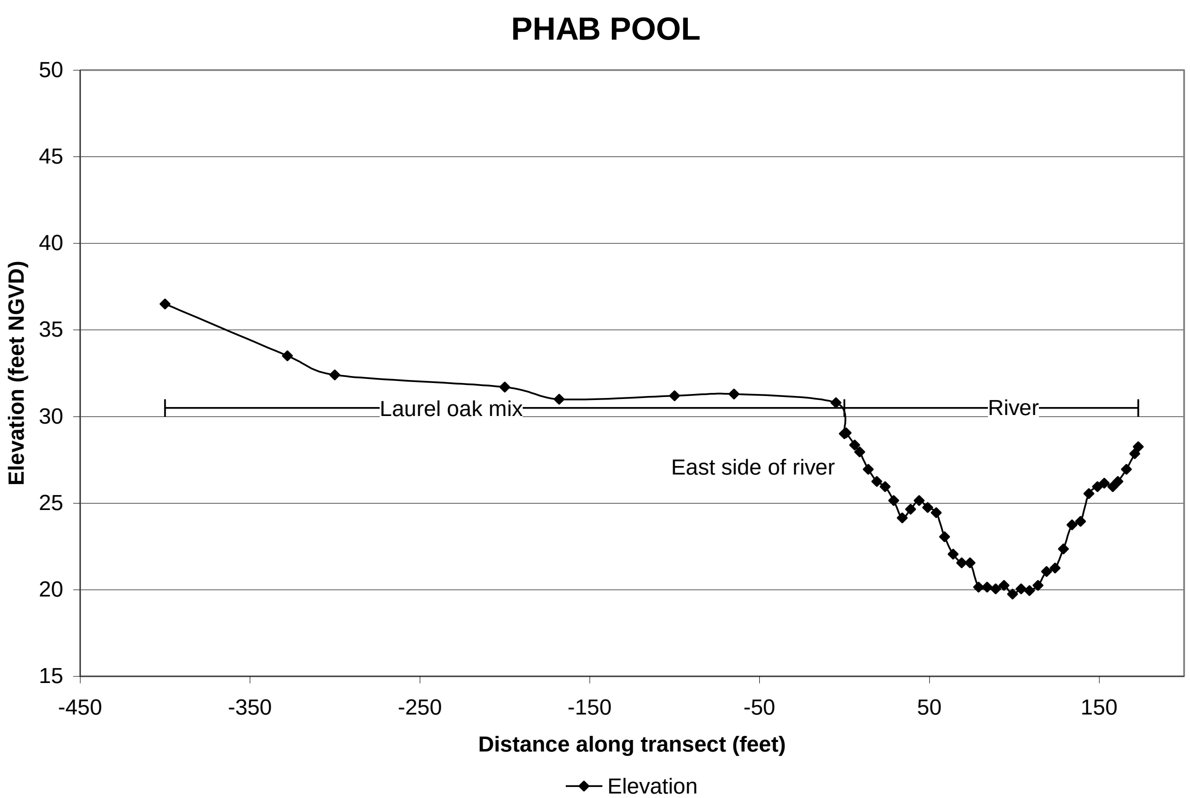
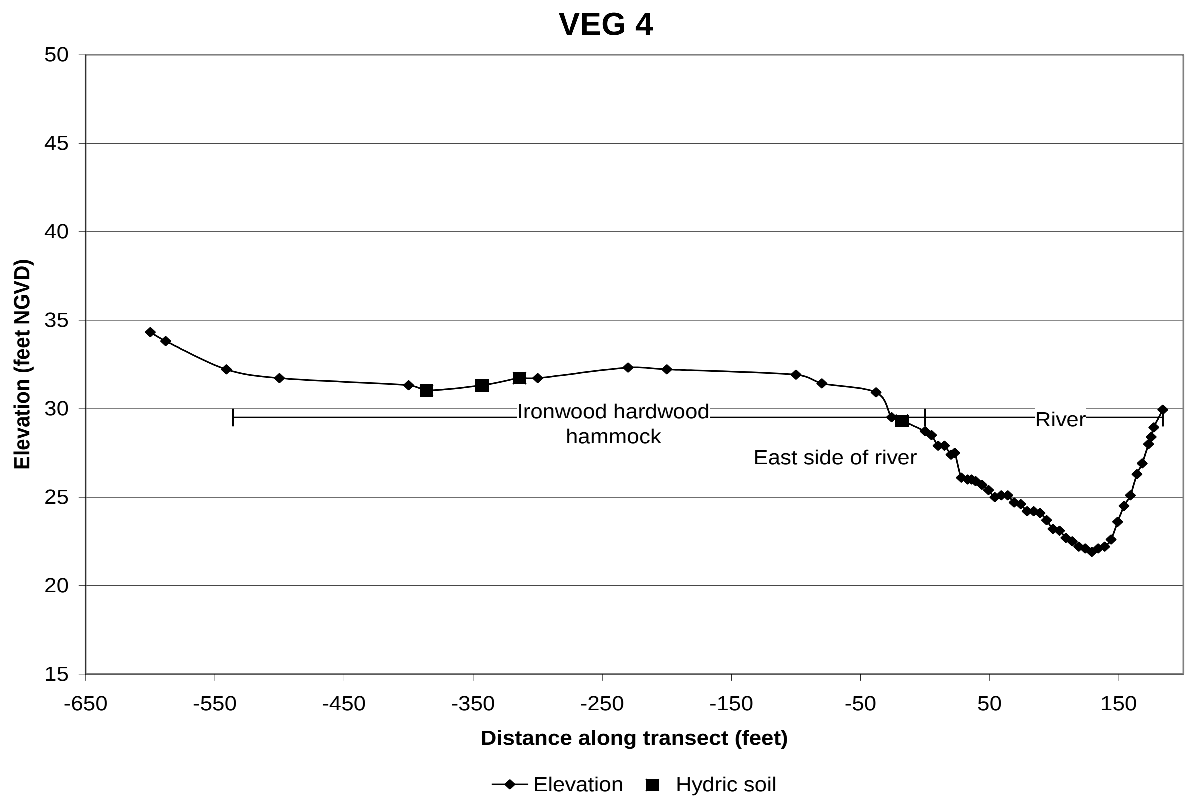
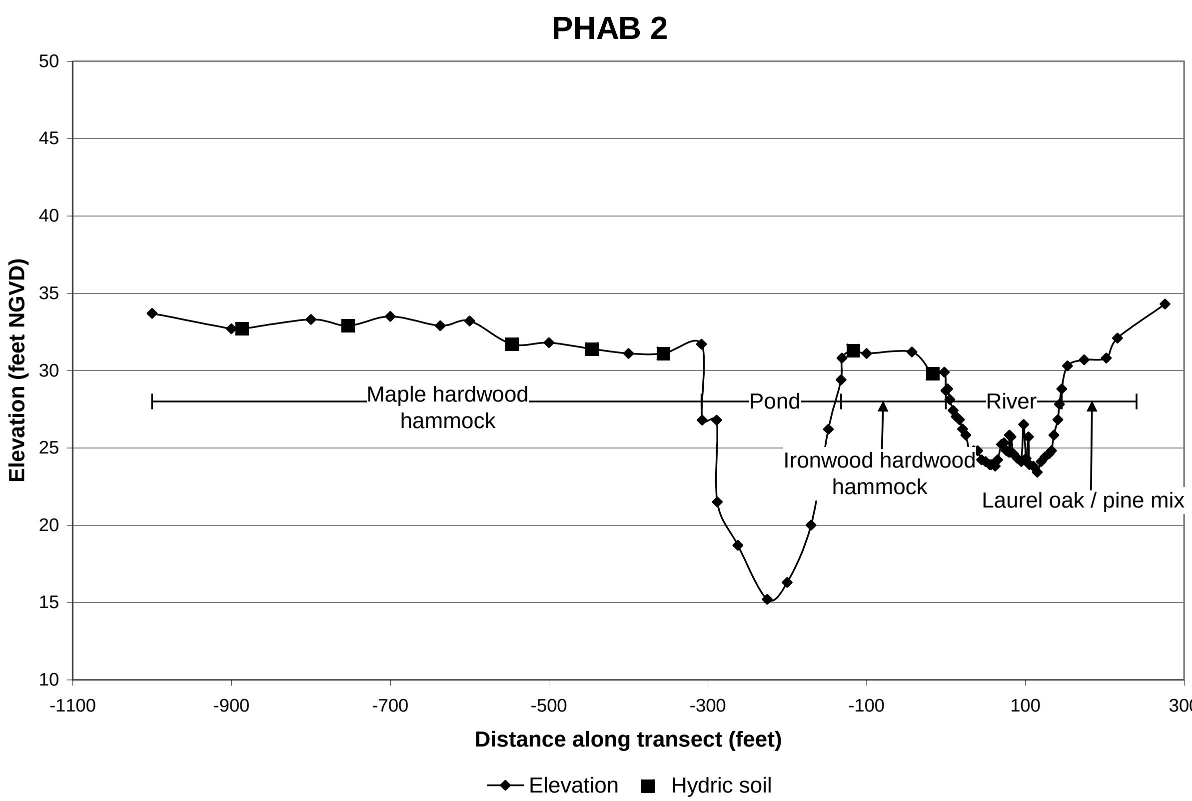
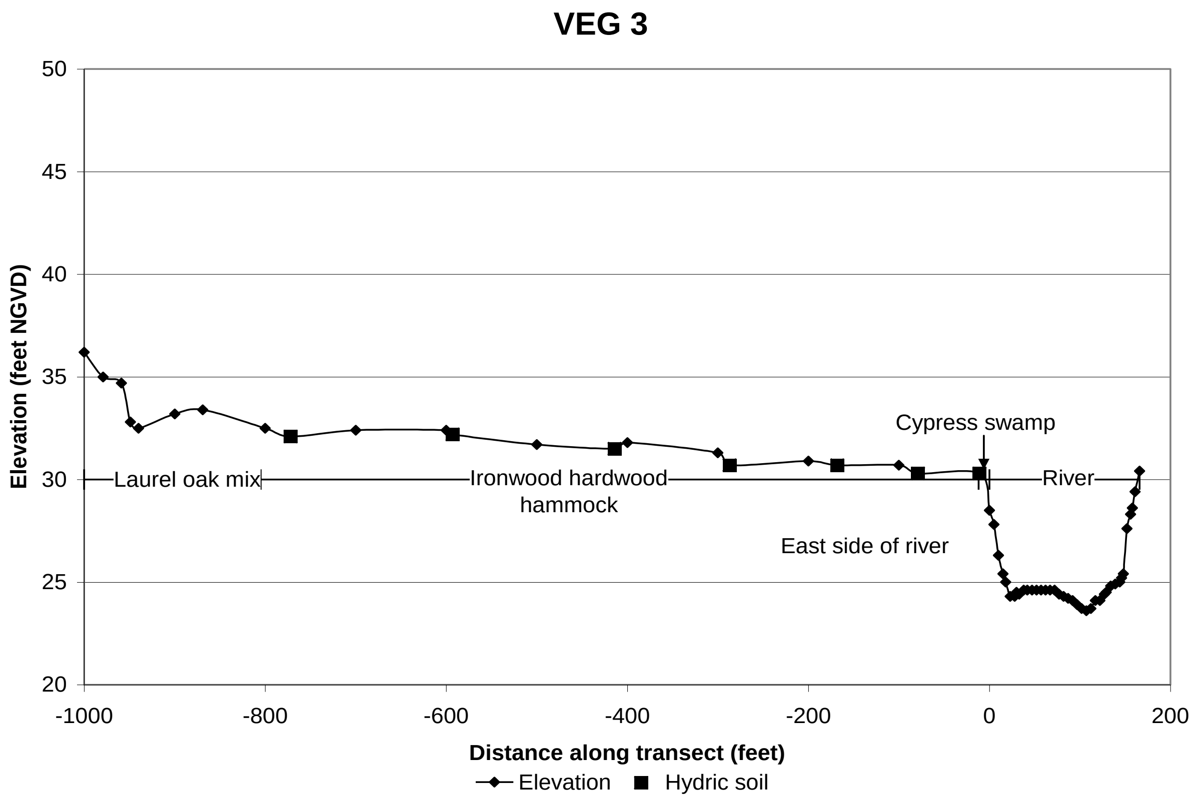
50
45
40
35
30
25
20
Elevation (feet NGVD)
-800
-600
-400
-200
0
200
Distance along transect (feet)
Laurel oak / pine mix
Maple hardwood hammock
River
East side of river
Elevation
Hydric soils

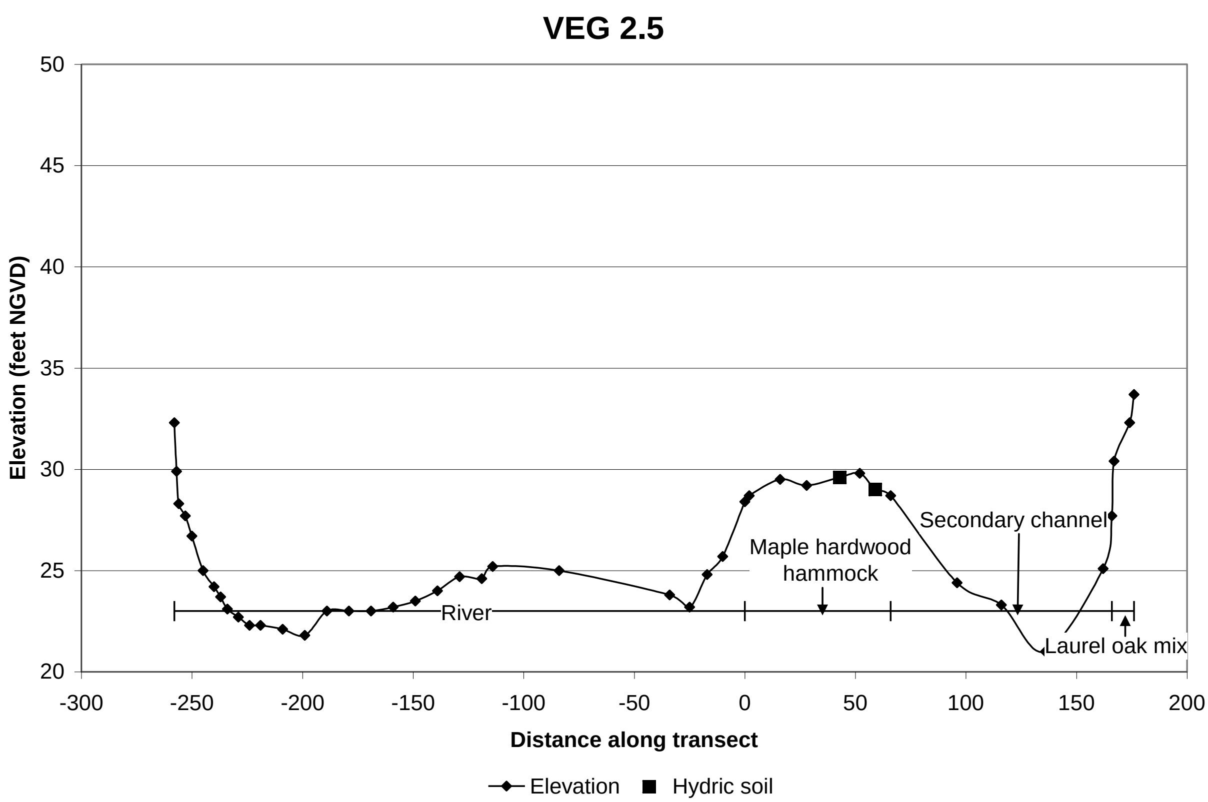

PHAB 1
50
45
40
35
30
25
20
15
Elevation (feet NGVD)
-120
-70
-20
30
80
130
180
Distance along transect (feet)
Laurel oak mix
River
East side of river
Elevation
Hydric soils

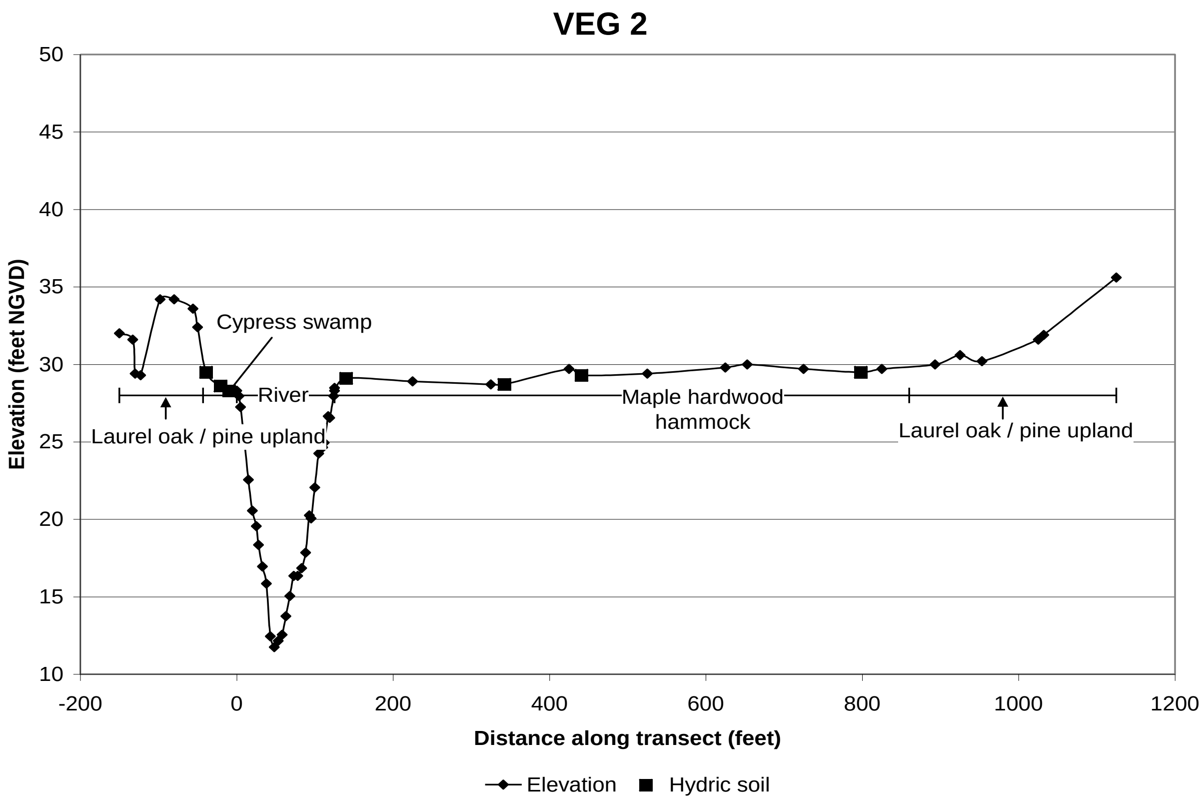

PHAB POOL
50
45
40
35
30
25
20
15
Elevation (feet NGVD)
-450
-350
-250
-150
-50
50
150
Distance along transect (feet)
Laurel oak mix
River
East side of river
Elevation

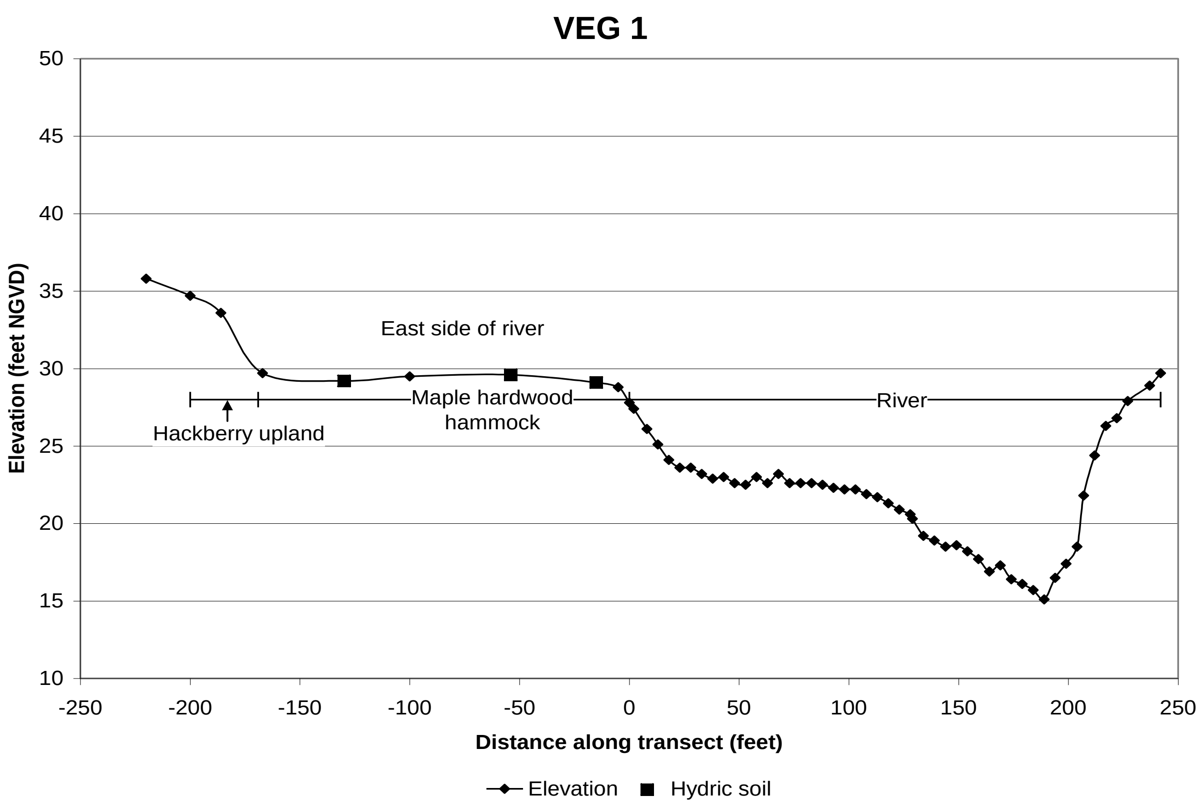

VEG 4
Elevation (feet NGVD)
50
45
40
35
30
25
20
15
-650
-550
-450
-350
-250
-150
-50
50
150
Ironwood hardwood
hammock
East side of river
River
Distance along transect (feet)
Elevation
Hydric soil

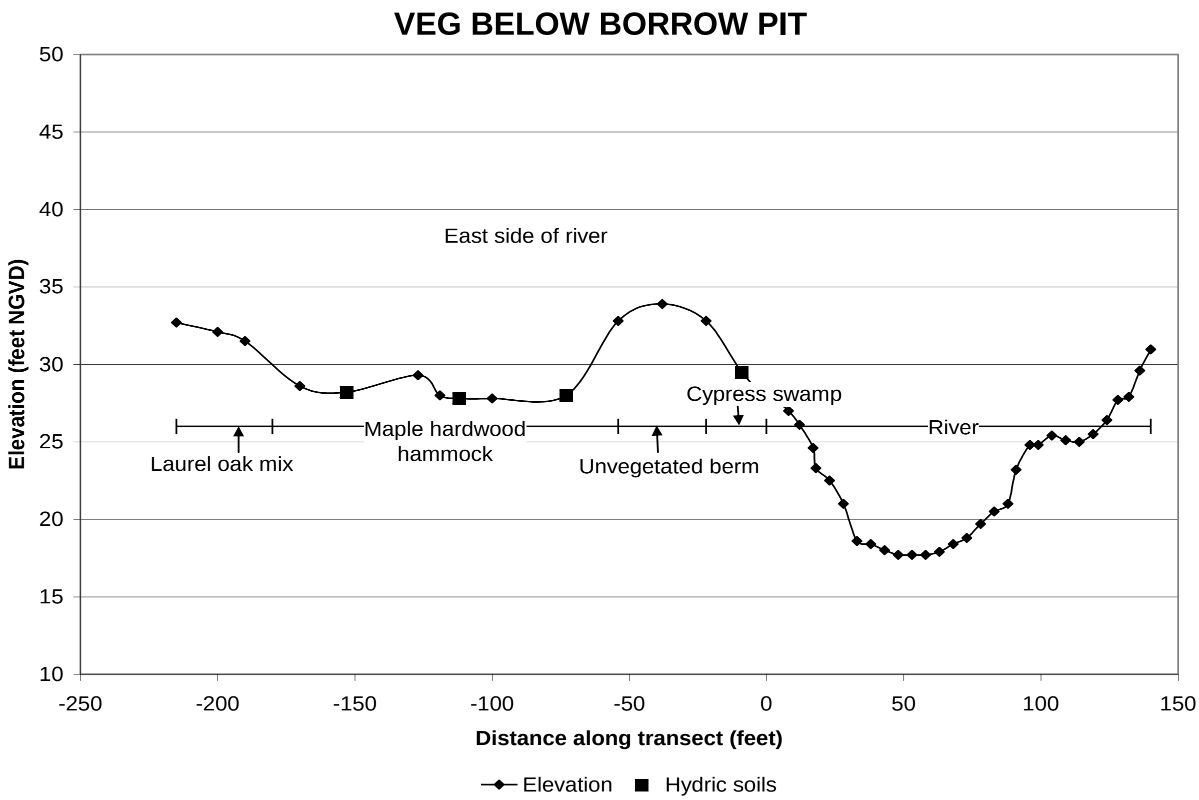

PHAB 2
Elevation (feet NGVD)
50
45
40
35
30
25
20
15
10
-1100
-900
-700
-500
-300
-100
100
300
Maple hardwood
hammock
Pond
River
Ironwood hardwood
hammock
Laurel oak / pine mix
Distance along transect (feet)
Elevation
Hydric soil


VEG 3
Elevation (feet NGVD)
50
45
40
35
30
25
20
-1000
-800
-600
-400
-200
0
200
Distance along transect (feet)
Laurel oak mix
Ironwood hardwood hammock
Cypress swamp
River
East side of river
Elevation
Hydric soil


VEG 2.5
Elevation (feet NGVD)
50
45
40
35
30
25
20
-300
-250
-200
-150
-100
-50
0
50
100
150
200
Distance along transect
River
Maple hardwood hammock
Secondary channel
Laurel oak mix
Elevation
Hydric soil

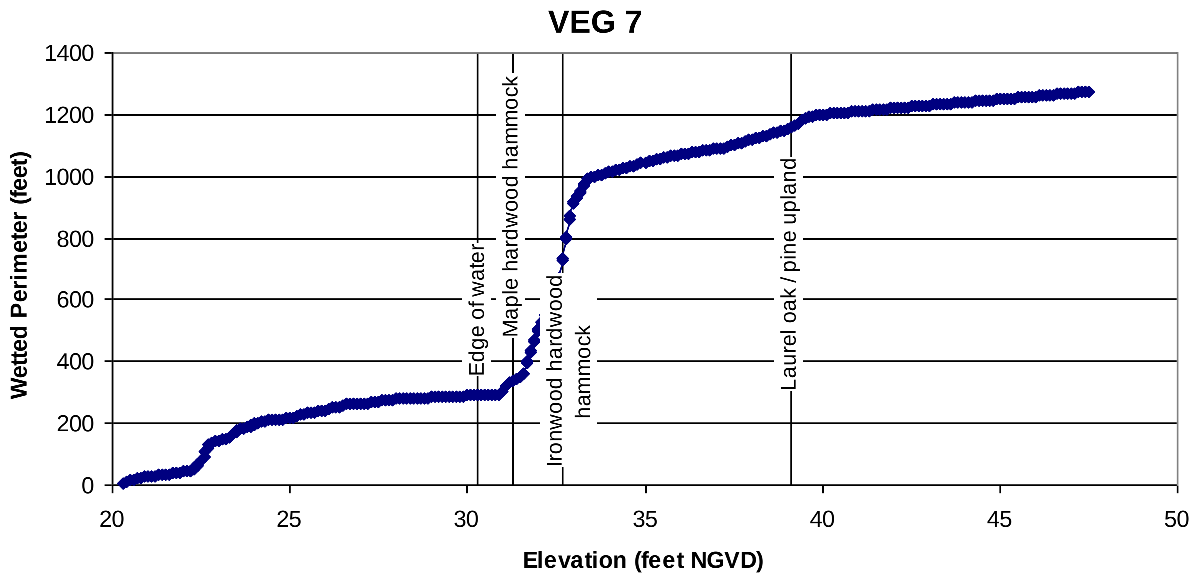

VEG 2
Elevation (feet NGVD)
50
45
40
35
30
25
20
15
10
Cypress swamp
River
Maple hardwood hammock
Laurel oak / pine upland
Laurel oak / pine upland
-200
0
200
400
600
800
1000
1200
Distance along transect (feet)
Elevation
Hydric soil

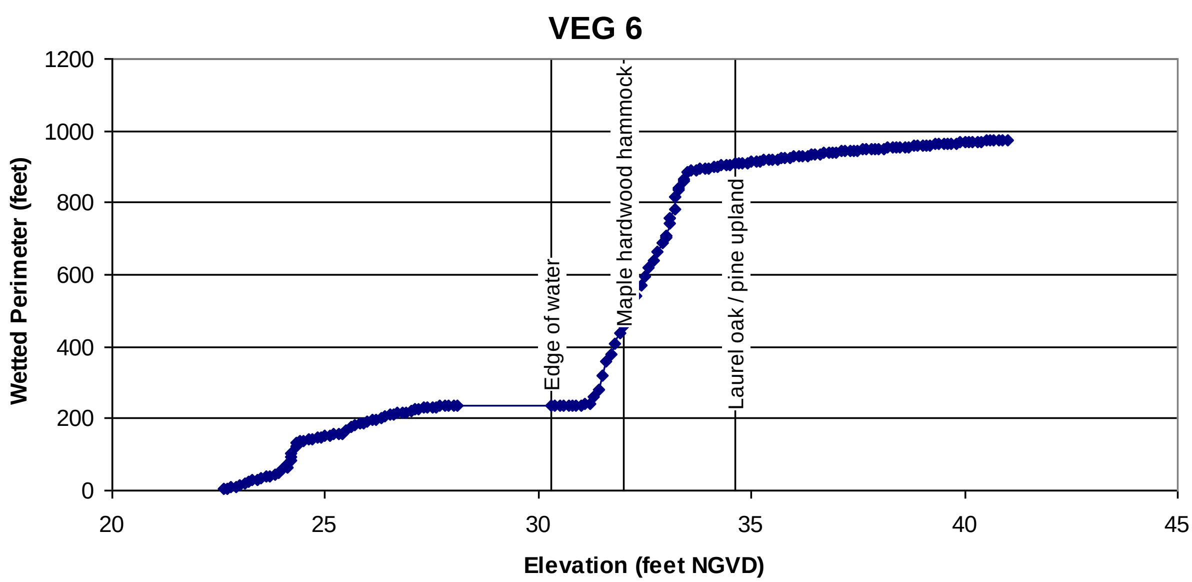

VEG 1
Elevation (feet NGVD)
50
45
40
35
30
25
20
15
10
East side of river
Maple hardwood hammock
River
Hackberry upland
-250
-200
-150
-100
-50
0
50
100
150
200
250
Distance along transect (feet)
Elevation
Hydric soil

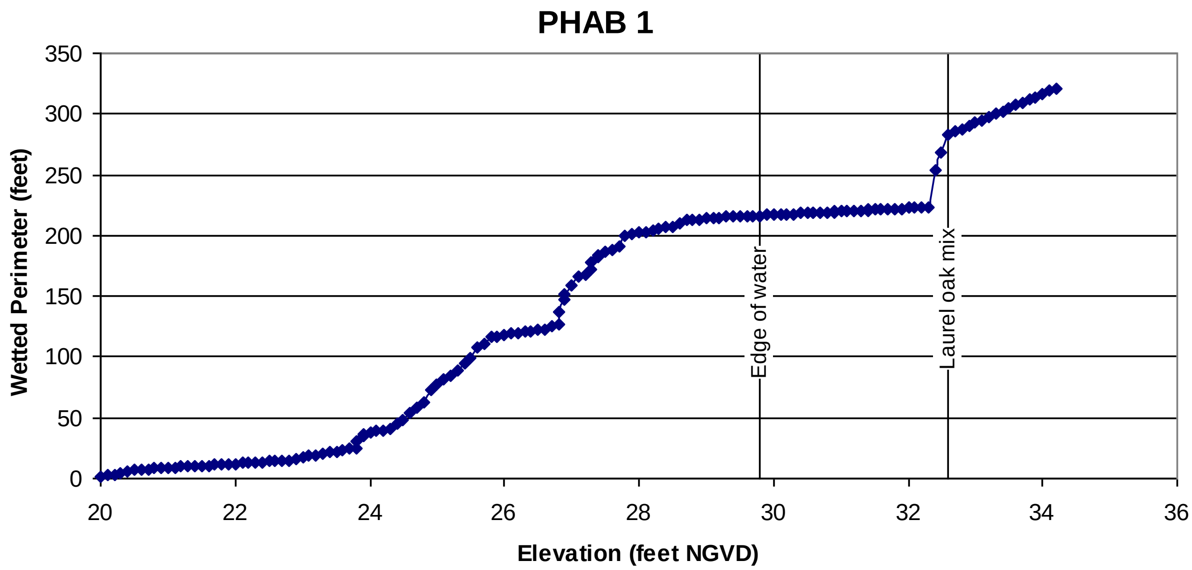

VEG BELOW BORROW PIT
East side of river
Elevation (feet NGVD)
50
45
40
35
30
25
20
15
10
-250
-200
-150
-100
-50
0
50
100
150
Distance along transect (feet)
Laurel oak mix
Maple hardwood hammock
Unvegetated berm
Cypress swamp
River
Elevation
Hydric soils

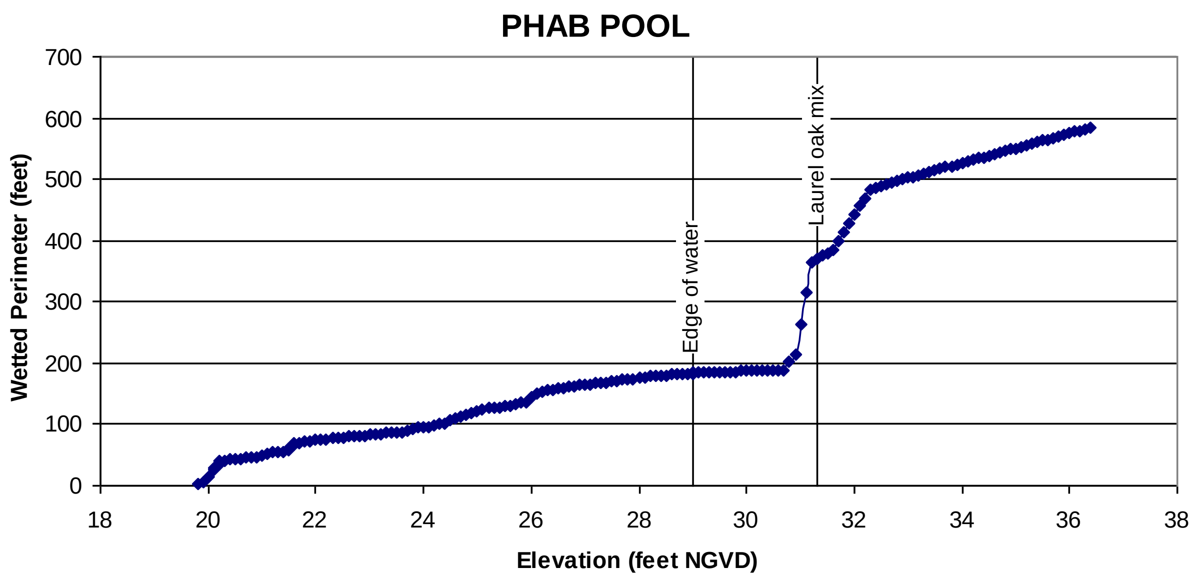
Appendix B

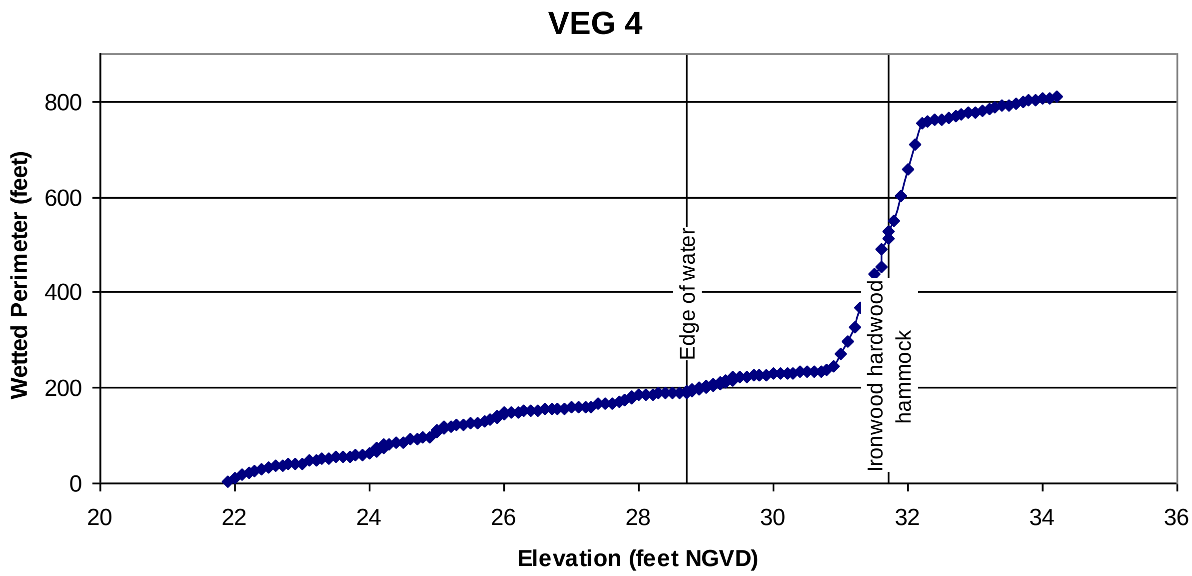
Wetted Perimeter Graphs for the Rainbow River Study Corridor (In upstream-to-downstream order)

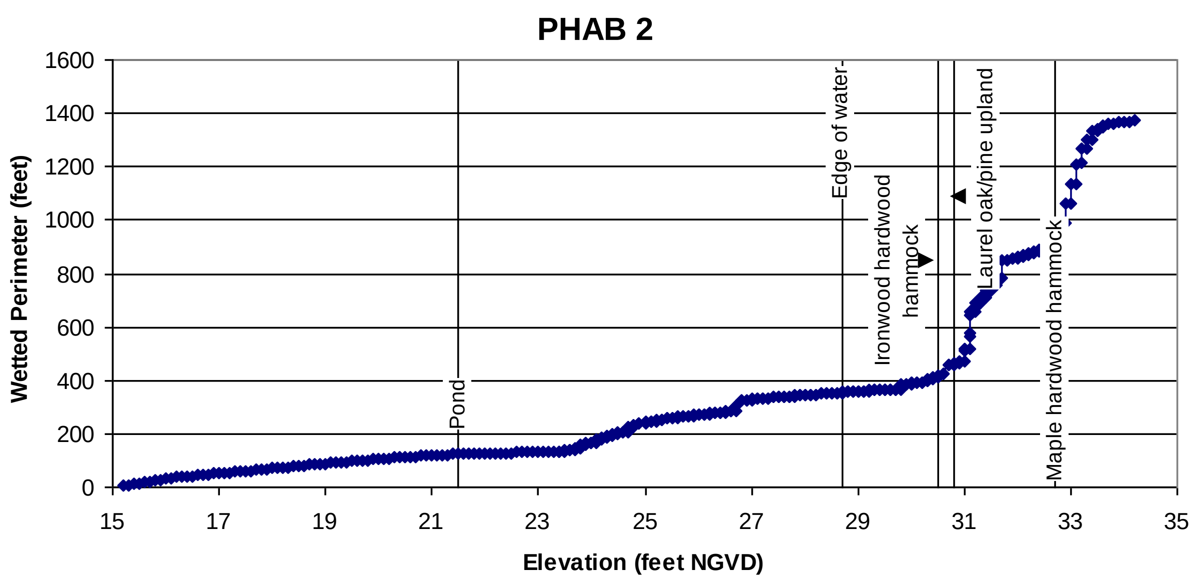

VEG 7
Wetted Perimeter (feet)
Elevation (feet NGVD)
Edge of water
Maple hardwood hammock
Ironwood hardwood hammock
Laurel oak / pine upland
1400
1200
1000
800
600
400
200
0
20
25
30
35
40
45
50


VEG 6
Wetted Perimeter (feet)
Elevation (feet NGVD)
Edge of water
Maple hardwood hammock
Laurel oak / pine upland
1200
1000
800
600
400
200
0
20
25
30
35
40
45


PHAB 1
Wetted Perimeter (feet)
0
50
100
150
200
250
300
350
Elevation (feet NGVD)
20
22
24
26
28
30
32
34
36
Edge of water
Laurel oak mix


PHAB POOL
Wetted Perimeter (feet)
0
100
200
300
400
500
600
700
Elevation (feet NGVD)
18
20
22
24
26
28
30
32
34
36
38
Edge of water
Laurel oak mix


VEG 4
Wetted Perimeter (feet)
Elevation (feet NGVD)
Edge of water
Ironwood hardwood hammock
0
200
400
600
800
20
22
24
26
28
30
32
34
36


PHAB 2
Wetted Perimeter (feet)
Elevation (feet NGVD)
Pond
Edge of water
Ironwood hardwood hammock
Laurel oak/pine upland
Maple hardwood hammock
0
200
400
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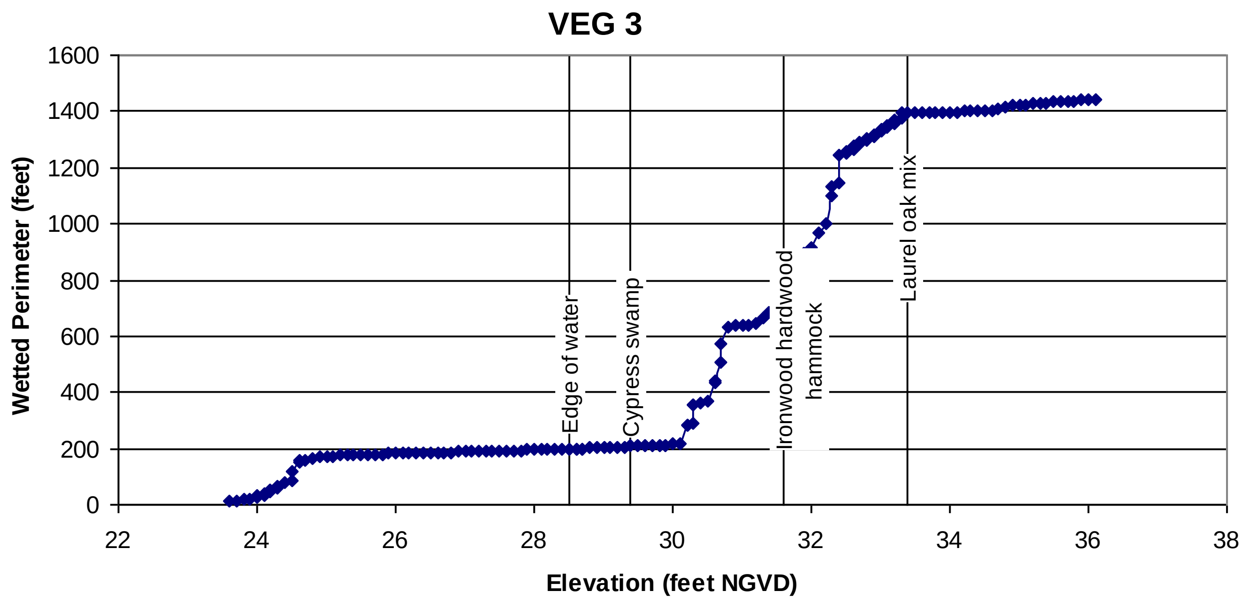
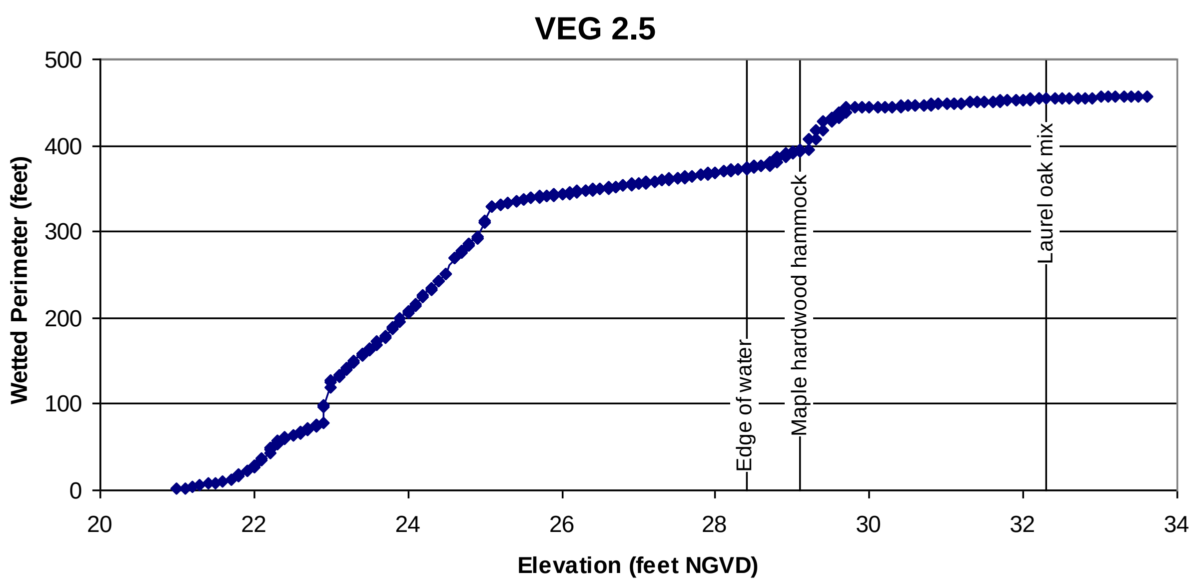
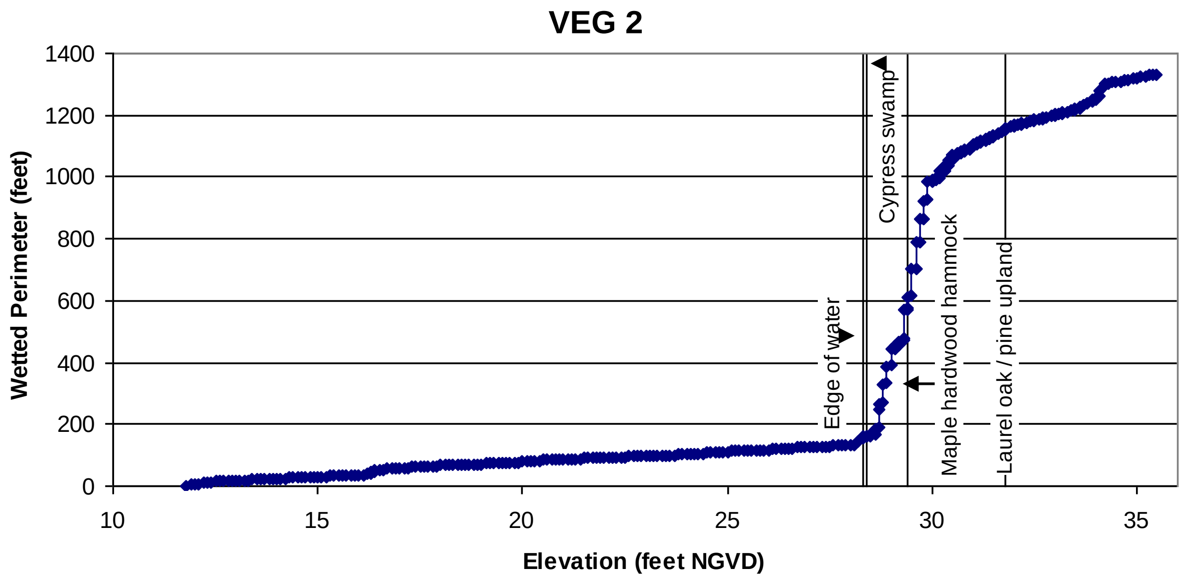
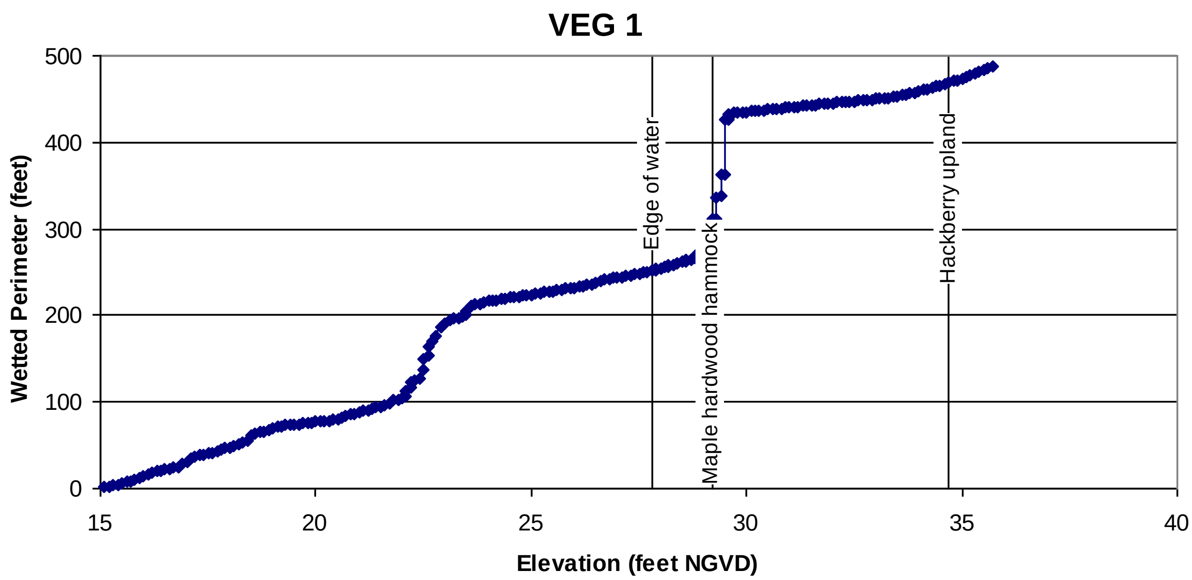
27
29
31
33
35


VEG 3
Wetted Perimeter (feet)
1600
1400
1200
1000
800
600
400
200
0
22
24
26
28
30
32
34
36
38
Elevation (feet NGVD)
Edge of water
Cypress swamp
Ironwood hardwood hammock
Laurel oak mix


VEG 2.5
Wetted Perimeter (feet)
500
400
300
200
100
0
20
22
24
26
28
30
32
34
Elevation (feet NGVD)
Edge of water
Maple hardwood hammock
Laurel oak mix


VEG 2
Wetted Perimeter (feet)
1400
1200
1000
800
600
400
200
0
10
15
20
25
30
35
Elevation (feet NGVD)
Edge of water
Cypress swamp
Maple hardwood hammock
Laurel oak / pine upland


VEG 1
Wetted Perimeter (feet)
500
400
300
200
100
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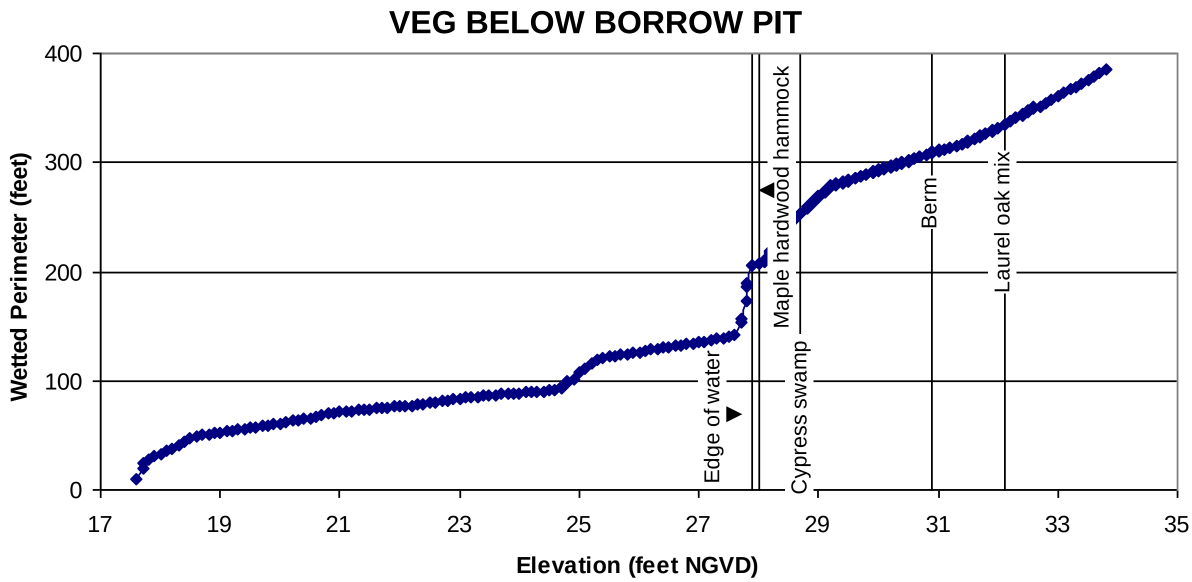
15
20
25
30
35
40
Elevation (feet NGVD)
Edge of water
Maple hardwood hammock
Hackberry upland


VEG BELOW BORROW PIT
Wetted Perimeter (feet)
400
300
200
100
0
17
19
21
23
25
27
29
31
33
35
Elevation (feet NGVD)
Edge of water
Maple hardwood hammock
Cypress swamp
Berm
Laurel oak mix

Appendix C

Photographs from the Rainbow River Study Corridor

VEG 7

Continued VEG 7

VEG 6

Continued VEG 6

PHAB 1

PHAB POOL

VEG 4

PHAB 2

Continue PHAB 2

VEG 3

VEG 2.5

VEG 2

VEG 1

Continued VEG 1

Veg Below Borrow Pit (VegBBP)