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DEEP CREEK WEST REGIONAL STORMWATER TREATMENT FACILITY: TREATMENT WETLAND DESIGN AND MONITORING—TRI-COUNTY AGRICULTURAL AREA, LOWER ST. JOHNS RIVER BASIN

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by

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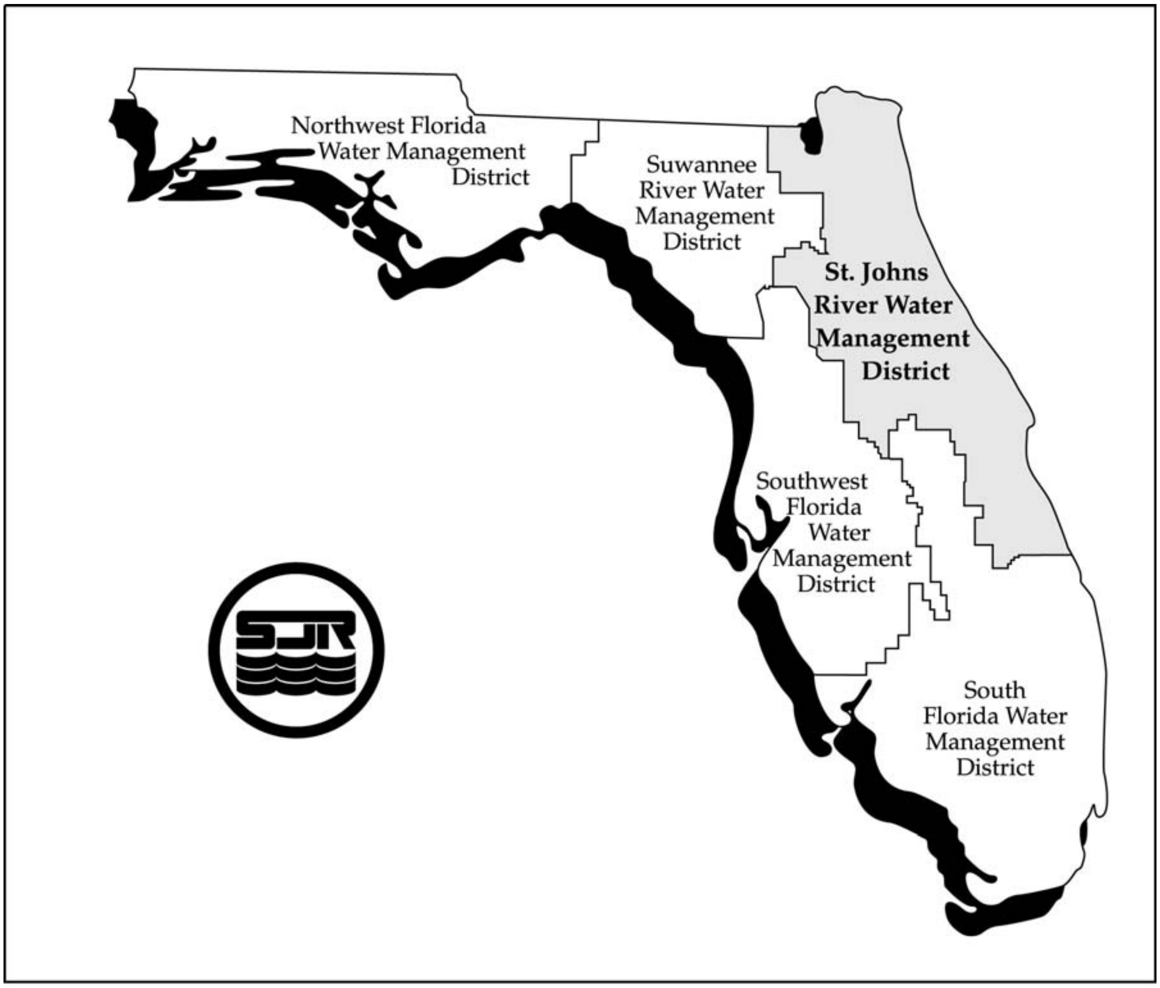
St. Johns River Water Management District
2009



The St. Johns River Water Management District (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or part of 18 counties in northeast Florida. The mission of SJRWMD is to ensure the sustainable use and protection of water resources for the benefit of the people of the District and the state of Florida. SJRWMD accomplishes its mission through regulation; applied research; assistance to federal, state, and local governments; operation and maintenance of water control works; and land acquisition and management.

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EXECUTIVE SUMMARY

The tri-county agricultural area (TCAA) encompasses 380,500 acres in Flagler, Putnam, and St. Johns counties within the freshwater segment of the Lower St. Johns River Basin (LSJRB). Approximately 31,424 acres of the TCAA watershed is irrigated cropland, predominantly potato, cabbage, and sod farms, according to a 2006 land use survey. Early spring production of irrigated vegetables grown on flat and poorly drained soils, with standard agricultural management practices of fertilization, irrigation, and drainage, effectively conveys nutrient-rich storm water to the freshwater zone of the river through a network of canals and ditches. Row crop agriculture contributes 82% of the existing total nitrogen and 72% of the phosphorus loads in the TCAA watershed (Livingston-Way 2001).

To meet required total maximum daily load (TMDL) allocations for the freshwater segment of the LSJRB enacted by the U.S. Environmental Protection Agency, the TCAA is obligated to implement best management practices (BMPs) on 100% of the total row crop acreage in an effort to meet the required 37% reduction in nitrogen and 15% reduction in phosphorus from the watershed. Model data suggest that nutrient reductions through implementation of current, in-field BMPs alone are not sufficient to meet nitrogen and phosphorus reductions required for the TMDL for the freshwater river section. Thus, SJRWMD constructed a regional stormwater treatment facility to improve water quality within the TCAA watershed and assist in meeting the TMDL allocations.

The first regional treatment system constructed was the Deep Creek West Regional Stormwater Treatment Facility, which began operating in 2006. The facility, located in St. Johns County within the Deep Creek Basin, is comprised of 38,928 acres and constructed within a subbasin that is of high priority for its 93% agricultural land use. The facility receives drainage from a 1,196-acre drainage area of the Hastings Drainage Control District Canal 1 and 2. The treatment system is a two-part system with a 15-acre wet detention pond at the forefront followed by a 38-acre, created treatment wetland. Project goals are to reduce nitrogen by 60%, total phosphorus by 50%, and total suspended soils by 70%.

Prior to operation of the treatment wetland, an alum drinking water treatment residual was added as a soil amendment to bind legacy soil phosphorus and prevent leaching of soil phosphorus that had accumulated when the site was historically used in agricultural production. Following soil amendment applications, water quality and hydrological monitoring stations were established throughout the treatment system to collect monthly ambient water quality data, storm event water quality data, and stage, flow, and rainfall data.

These data will be used to monitor water quality treatment through the system and the nitrogen, phosphorus, and total suspended solids reductions achieved. Wildlife, fisheries, and vegetation monitoring also have been implemented on a routine basis to track biological significance and facility usage.

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INTRODUCTION

The purpose and objective of the St. Johns River Water Management District's (SJRWMD) regional stormwater system initiative is to design, construct, and operate site-specific regional treatment systems in the tri-county agricultural area (TCAA) of Flagler, Putnam, and St. Johns counties, to improve water quality in the receiving surface waters and mainstem of the lower St. Johns River. These systems will improve water quality by removing nutrients in the form of dissolved and particulate material from the drainage waters of priority agricultural basins before discharge to surface waters at the basin outlet.

Specifically, the initiative objectives are to:

- Design, construct, and maintain treatment systems that reduce total nitrogen loading from the target subbasin by 50–90%.
- Design, construct, and maintain treatment systems that reduce nitrate nitrogen loading from the target subbasin by 45%.
- Design, construct, and maintain treatment systems that reduce total phosphorus loading from the target subbasin by 60–90%.
- Design, construct, and maintain treatment systems that reduce loading of suspended solids from the target subbasin by 60–90%.

The lower St. Johns River is a blackwater, tidal estuary that extends approximately 100 miles from the confluence of the Ocklawaha River to the mouth of the St. Johns River, where it empties into the Atlantic Ocean at Mayport. The lower St. Johns River can be divided into four ecological zones based on flow patterns, average salinity regime, and morphological characteristics: a freshwater riverine zone which extends from the city of Welaka north to Black Creek near Green Cove Springs; a predominantly oligohaline, lacustrine zone extending from Black Creek northward to the city of Orange Park; a mesohaline lacustrine zone reaching from Orange Park to the Fuller Warren Bridge in Jacksonville; and a polyhaline riverine zone downstream to the mouth of the river.

The TCAA encompasses 380,500 acres within the freshwater riverine zone of the lower St. Johns River. Approximately 31,424 acres within the TCAA watershed is irrigated cropland; predominantly potato, cabbage, and sod farms according to a 2006 land use survey. Row crop agriculture contributes 82% of the existing total nitrogen and 72% of the phosphorus loads in the TCAA watershed (Livingston-Way 2001). Early spring production of irrigated vegetables grown on flat and poorly drained soils, with standard agricultural management practices of fertilization, irrigation, and drainage, effectively conveys nutrient-rich storm water to the freshwater zone of the river through a network of canals and ditches. Since 1998, agricultural best management practices (BMPs) designed to reduce nutrient-rich runoff have been implemented in the TCAA, primarily through growers voluntarily participating in the St. Johns River Water Management District's TCAA Water Quality Protection Cost-Share Program. Annual reductions of nitrogen and phosphorus through implementation of in-field agricultural BMPs have been estimated to reduce watershed nitrogen loading by 24% and phosphorus loading by 14%, based on 2000 land use data for row crop acreage (Pam Livingston-Way, SJRWMD Division of Environmental Sciences, pers. comm. 2008).

In order to meet required total maximum daily load (TMDL) allocations enacted by the U.S. Environmental Protection Agency for the freshwater segment of the lower St. Johns River, the TCAA is obligated to implement BMPs on 100% of the total row crop acreage in an effort to meet the required 37% reduction in nitrogen and 15% reduction in phosphorus from the watershed. Ostensibly, nutrient reduction through the implementation of current, in-field BMPs is not sufficient to meet nitrogen and phosphorus reductions required for the TMDL for the freshwater section of the river. Thus, SJRWMD's regional stormwater system initiative will assist in meeting TCAA nutrient reduction requirements for the TMDL.

The first regional stormwater treatment (RST) facility constructed in the TCAA was the Deep Creek West RST Facility. SJRWMD purchased the Yarborough Tract for location of the Deep Creek West RST Facility to treat nutrient-laden runoff from the ranked as high-priority Deep Creek subbasin. Deep Creek Basin consists of 11 individual subbasins totaling approximately 38,928 acres. The RST facility receives drainage from a drainage area of 1,196 acres, which is predominantly 93% agricultural land use, conveyed to Canal 1 and 2 of the Hastings Drainage Control District. The purpose of this document is to provide an overview of the first RST system constructed in the TCAA, with emphasis on the design and monitoring of the treatment wetland.

LOCATION

SJRWMD purchased the entire Yarborough Tract in 1998, consisting of 1,103 acres located in southwest St. Johns County, Florida (Section 21 of Township 9 South, Range 28 East), approximately 1.5 miles from Hastings, Florida, within the Deep Creek Basin (Figure 1). The property was purchased using funds from ad valorem tax dollars and the Florida Department of Transportation (FDOT) fund (SJRWMD 2006). Historical land use records indicate that portions of the site were in agricultural production for approximately 20 years (Golder 1997) and appeared to have been a planted pine community for 12–15 years prior to 2004. The Deep Creek West RST Facility encompasses approximately 93 acres of the Yarborough Tract.

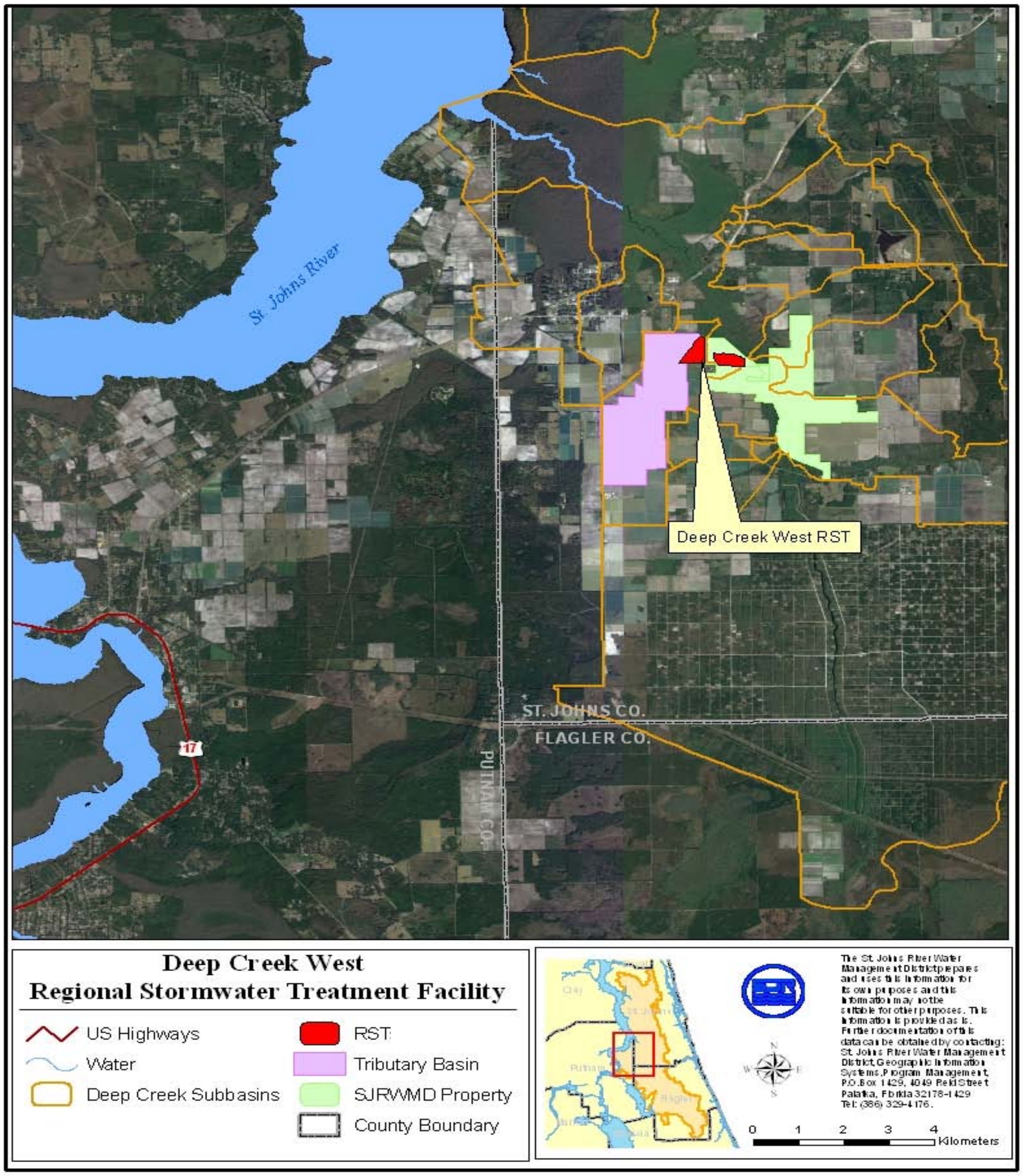


Figure 1. Location of the Deep Creek West Regional Stormwater Treatment (RST) Facility

PROJECT OVERVIEW

The Deep Creek West RST Facility is a BMP treatment train, consisting of a 15-acre wet detention pond and a 38-acre treatment wetland system, and is designed to treat agricultural runoff from a 1,196-acre watershed. George Miller Road separates the wet detention pond and the created treatment wetland (Figure 2). Facility construction was completed in 2005 and was operational beginning April 2006; however, the treatment wetland was not permanently online until July 2006. Original design recommendations by Camp, Dresser, and McKee 2003 (CDM) identified a wet detention pond as the most cost-effective treatment method. However, a 15-acre mitigation wetland area was mandatory as part of the project to satisfy requirements of the Florida Department of Transportation (FDOT) funding source that was used, in part, for land acquisition. Thus, SJRWMD staff modified the project design to include a 38-acre treatment wetland to enhance treatment capabilities and collectively satisfy the mitigation wetland requirement. Specific information pertaining to the as-built design and construction may be obtained from engineering drawings by contacting SJRWMD’s Division of Engineering or Department of Water Resources.

OPERATION AND SYSTEM HYDRAULICS

Agricultural drainage water gravity flows from the confluence of Hastings Drainage District Canals No. 1 and No. 2 into a small forebay prior to being pumped into the wet detention pond. The pump station was designed for up to 90% capture of an average storm event, accommodating peak flow rates of 20 cubic feet second (cfs) and using two pumps of 10 cfs capacity each. Pumps are programmed to operate individually under base-flow conditions and in tandem during storm events. Pumps are automatically activated when water levels inside the forebay/pump station reach a defined level, pumping canal water to the wet detention pond (Figure 3).

The wet detention pond is approximately 15 acres and has a mean depth of 12 feet (ft) with a side slope ratio of 4:1. Pond depth and slopes were maximized to increase pond residence time and settling of particulates. Preliminary estimates using available hydrologic data suggest average pond residence time is 41 days (Cindy Yang, SJRWMD Division of Engineering, pers. comm. 2008). When pond water levels rise, water is discharged over a concrete weir outfall structure and conveyed through a siphon culvert under George Miller Road. Hydrologic monitoring at the pond outfall structure includes stage measures and calculated flow rates, which are transmitted via telemetry to SJRWMD. The siphon culvert was sized based on a 25-year, 24-hour storm accommodating peak flow capacity of approximately 20 cfs (Cliff Gandy, SJRWMD Division of Engineering, pers. comm. 2008).

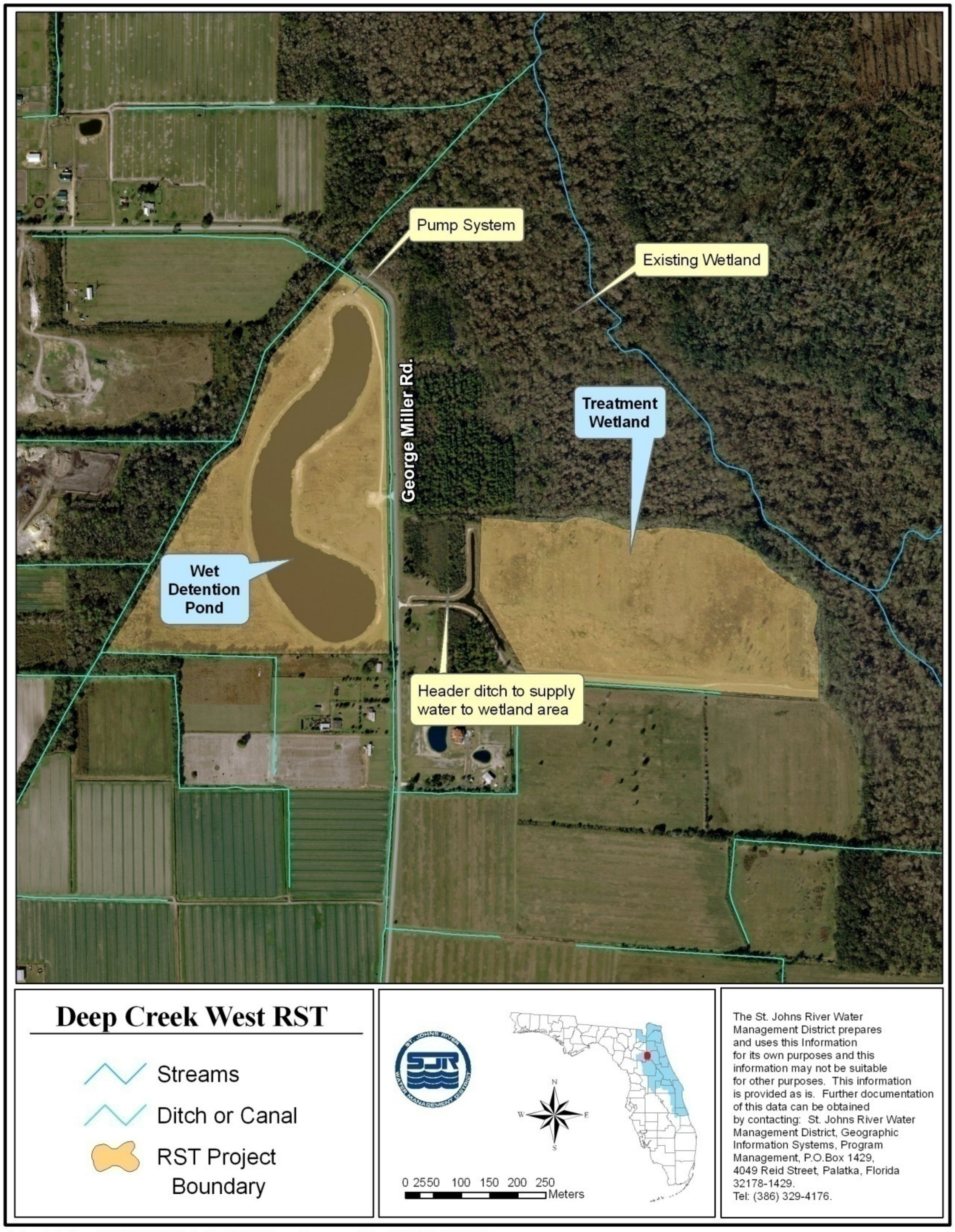


Figure 2. Design of the Deep Creek West Regional Stormwater Treatment (RST) Facility

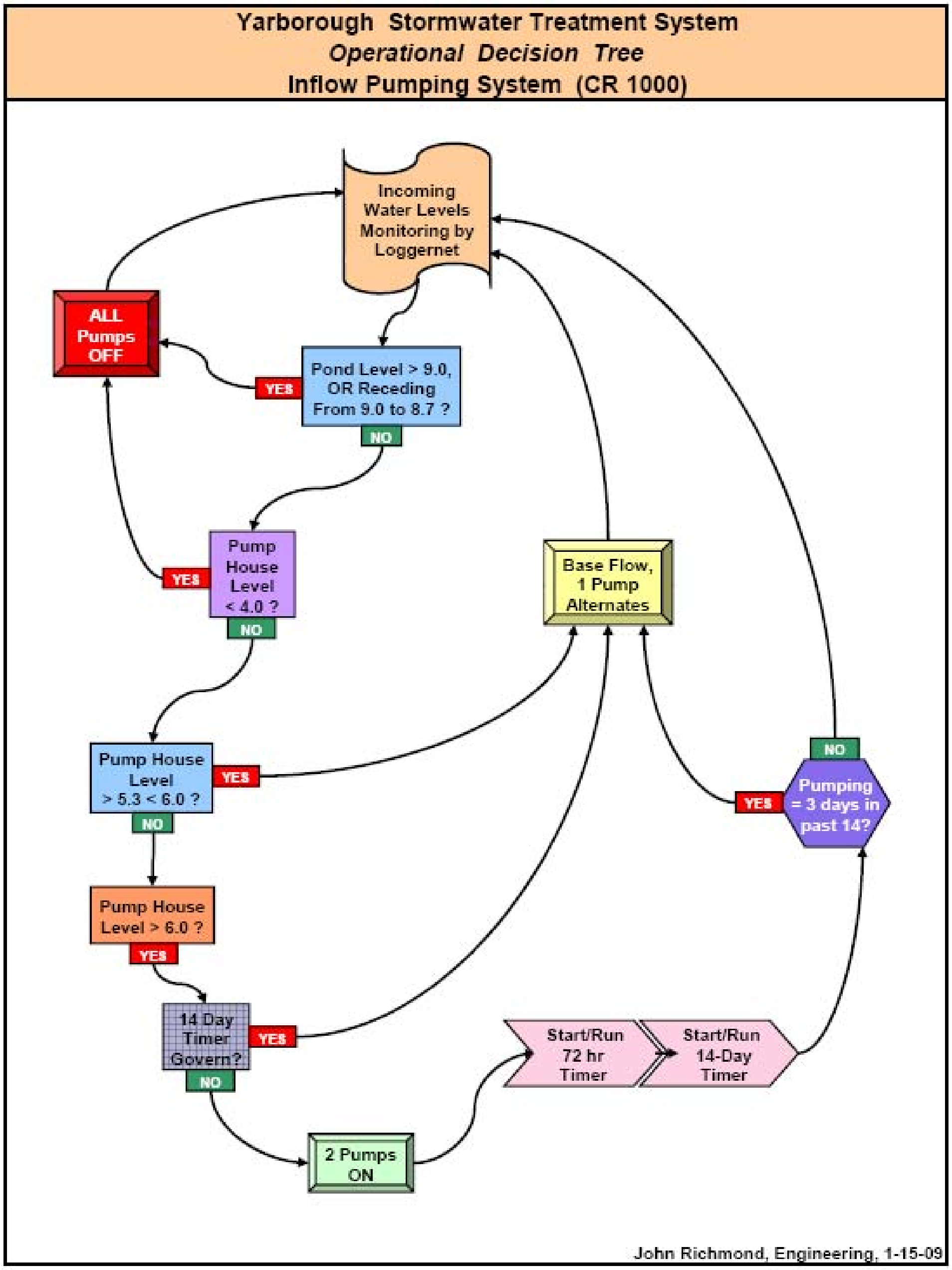


Figure 3. Inflow pumping system

Volume discharged to the wetland is determined by pond water level, which is driven by the volume of drainage water pumped from Canal 1 and 2 into the pond. Thus, pond discharge volumes and flow rates vary between storm events and base-flow conditions. Pond-treated water is supplied to the wetland through open conveyance header ditches, approximately 5 ft wide and 2 ft deep with 3:1 side slopes, located along portions of the southern and western perimeter of the wetland. Water saturates soils through lateral subsurface flow from the discharge header ditches. Surface flooding from the header ditches in lower elevations of the wetland also occurs. Water table observation wells were installed throughout the wetland to monitor subsurface hydrologic conditions (Figure 4).

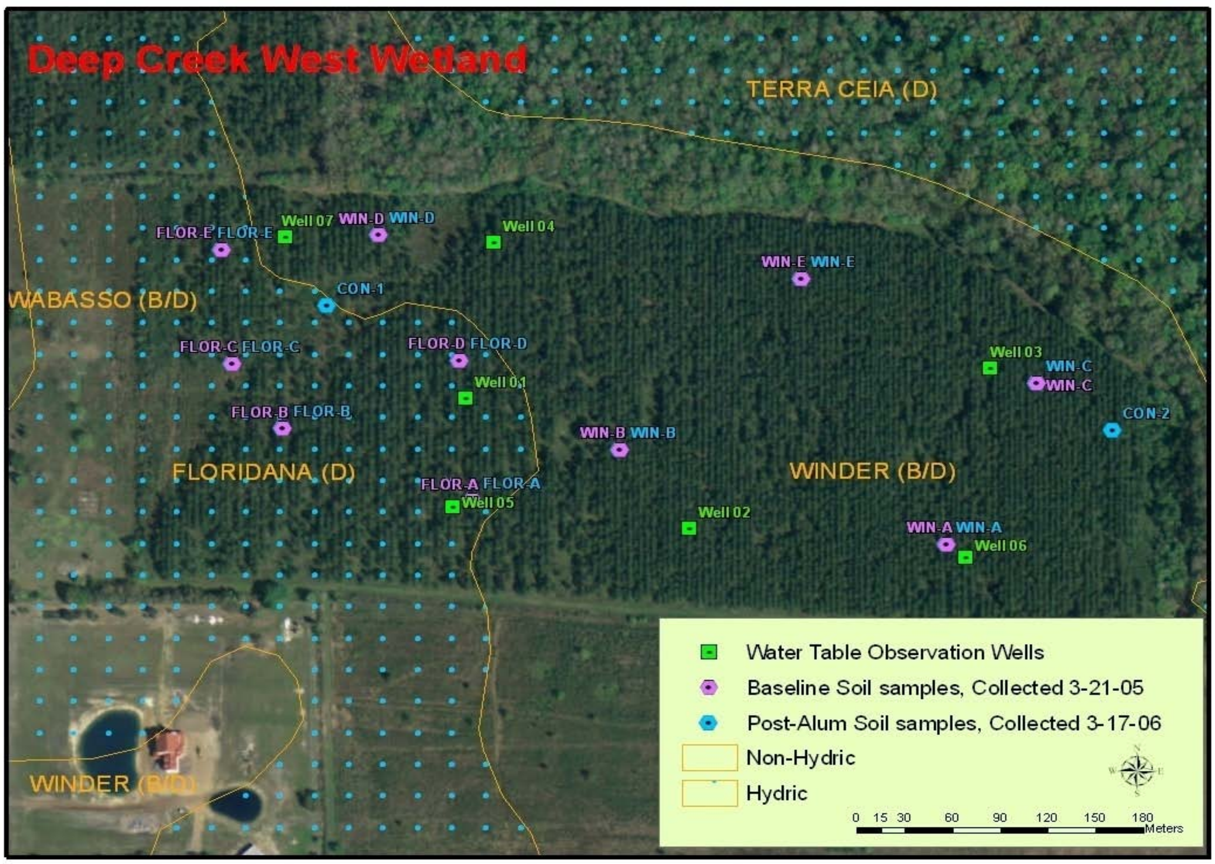


Figure 4. Water table observation wells and soil sample locations

A concrete weir control structure equipped with a sluice gate at the northeast corner of the wetland can be used to regulate water levels in the wetland and along perimeter relic berms by manually opening and closing the gate. The relic berm was historically used to maintain water levels when the area was an agricultural production field along the northern and eastern perimeter of the wetland. During the design phase of the project, it was determined there would be no alterations to the existing berm due to exorbitant cost and the presence of mature trees located in and around the berm. Hydrologic monitoring at the wetland water control structure includes stage measures and calculated flow rates, which are transmitted via telemetry to SJRWMD.

The elevation of the weir crest was originally constructed at a 5-ft elevation but was reengineered to a 4-ft elevation due to the unexpected high water levels along the northern berm during base-flow pumping conditions. Lowering the weir crest elevation provides 1 ft of freeboard under average base-flow conditions and prevents water from overtopping the north berm in areas, thus preventing subsequent erosion of the berm.

CREATED TREATMENT WETLAND DESIGN

Sizing

Several factors were considered when sizing the treatment wetland, such as the original design proposed by CDM (2003), available land area, and mitigation requirements. The resulting wetland design size was a 38-acre treatment wetland that better utilized available land area and satisfied FDOT mitigation requirements, while providing additional water quality treatment. Three of the general wetland sizing methods presented by Kadlec and Knight (1996) and Knight (2004) were compared to the final RST wetland size to determine if the modified final design met general wetland sizing guidelines. The three general wetland sizing methods for determining land area requirements for treatment wetlands during the initial design phase are: (1) percentage of the contributing watershed for which the wetland size should be between 1% and 5% of the watershed area; (2) design storm detention where the wetland is sized to accommodate storm events of a particular frequency or occurrence; and (3) annual averaging that requires inputs such as event mean concentrations of target constituents, water quality goals, and estimates of hydraulic loading rates.

Results from design methods 1 and 2, as described above, were more similar than results of method 3; method 3 indicated a significantly larger area requirement. The difference in the design method results may be attributed to the increased level of estimation that was required to fulfill variables in method 3. Thus, only design methods one and two were used for comparisons to the final design size. Percentage of contributing watershed (method 1) indicated the 38-acre wetland was within the recommended 1% to 5% size of the contributing 1,196-acre watershed (i.e., 3%) and the mean annual design storm detention (method 2) indicated a 28.7-acre wetland, which is 2.4% of the contributing watershed area.

Site Preparation

The wetland site was predominantly a planted pine community at the time of purchase. In preparation for development of the wetland, most of the pine trees were removed, but approximately 50 pine trees were retained along with stumps from the removed trees and existing litterfall. The site was cut and graded in the inflow area of the wetland to achieve an elevation lower than the pond discharge for conveyance of pond-treated effluent to the wetland. The remainder of the wetland was maintained at the existing grade.

Soils

Soils on the wetland site have been classified in the soil survey of St. Johns County, Florida, as Floridana and Winder fine sand (USDA-SCS 1990). Floridana soils are poorly drained sandy soils with most having a black fine sand surface layer; a light brownish gray and gray fine sand subsurface layer; and a gray sandy clay loam subsoil to a depth of 46 inches (in.). Floridana soils are classified in the (D) hydrologic group as soils that are characterized by a very slow infiltration rate through the soil surface when saturated, clays with a high shrink-swell potential, a permanent high water table, a claypan or clay layer at or near the surface, and a slow rate of water transmission. Specifically, Floridana fine sand in its natural state has a seasonal high water table within a depth of 10 in. for 4 to 6 months, with rapid permeability in the surface and subsurface layers and very slow permeability in the subsoil. Floridana soils are considered excessively wet and must have adequate water control systems for uses such as agriculture and development. Natural fertility is high in Floridana fine sand and has a high potential for growing cultivated crops (USDA-SCS 1990).

Winder fine sand soils are poorly drained sandy soils consisting of very dark gray fine sand in the surface layer; dark gray fine sand in the subsurface layer; gray fine sandy loam with areas of dark gray fine sand and light gray fine sandy loam in the subsoil; and gray to light gray sandy clay loam down to 38 in., in the subsoil. Winder soils are classified in the (B/D) hydrologic group. Soils in hydrologic group B are moderately infiltrated through the soil surface when saturated and are primarily moderately deep to deep, moderately well drained to well-drained soils. Soils characterized by two hydrologic classes such as Winder are defined as having a seasonal high water table but can be drained, with the first letter corresponding to the drained condition of the soil and the second letter corresponding to the undrained condition. Winder fine sand has a seasonal high water table within a depth of 10 in. for 2 to 6 months during most years, with rapid permeability in the surface and subsurface layers, moderately slow to very slow in the subsoil, slow in the upper part of the substratum, and with rapid permeability at lower depths. Similar to Floridana soils, Winder soils are excessively wet and must have adequate water control systems. Crop production potential is considered medium for Winder soils (USDA-SCS 1990).

Given the aforementioned characteristics of the soils, on-site maintenance of saturated soil conditions should be easily attainable. A continuously saturated condition is desirable to maintain low redox potentials in the soil to prevent rapid remineralization of assimilated nutrients during dry conditions. Mitsch and Cronk (1992) recommend additional clay layer to treatment wetland sites to prevent treatment water from seeping to groundwater; however, the existing clay layer on-site was determined sufficient to provide this barrier. Results of six geotechnical auger borings indicated presence of primarily clayey sands and sandy clays from the surface down to 6 ft, while fine sand to slightly clayey fine sand was found from the surface to 2.5 ft followed by sandy clay to 6 ft for only one of the auger borings. Hydraulic permeabilities estimated from grain size distribution tests for the fine sand to slightly clayey fine sand was 5.6×10^{-3} centimeters per second (cm/sec), and 3.1×10^{-6} cm/sec for the clayey sands and sandy clays (CSI 2004). According to Bear (1988), these values indicate a semipervious and impervious media, respectively.

Soil Phosphorus Testing

Soil samples were collected within the proposed treatment wetland area to assess the potential for internal phosphorus loading since the site was historically in agricultural production; however, the site has been a planted pine community for the last 12–15 years. Soils that were formerly used in agriculture have the potential to release stored phosphorus upon flooding (Pant and Reddy 2003). Soil amendments such as aluminum sulfate drinking water treatment residuals (WTRs) can be used to reduce soil phosphorus leaching.

Soil samples were collected from four depths (0–6 in., 6–12 in., 12–18 in., and 18–24 in.) at 10 randomly selected locations. The samples were allowed to air-dry and then submitted to the University of Florida Extension Soil Testing Laboratory for testing (Figure 4). Samples were analyzed for Mehlich-1 soil test phosphorus (P), iron (Fe), and aluminum (Al) concentrations, soil pH, and percent organic matter. Results of the soil testing indicated that approximately 58% of the soil samples were categorized by the lab as having high to very high phosphorus levels (i.e., 31 milligrams per kilogram [mg/kg] to greater than 60 mg/kg). Mean soil test P was 81 mg/kg from 0–24 in.; 118 mg/kg from 0–12 in.; and 139 mg/kg from 0–6 in. ranging from 9–299 mg/kg.

Soil test P has historically been used for agronomic purposes, rather than assessment of potential environmental impact; however, recent studies suggest that soil test P can be used as a tool for assessing the potential for P loss from lands used intensively for agricultural and livestock production (Sharpley et al. 1994; Hyde and Morris 2000; Nair and Graetz 2002; Nair et al. 2004; Novak and Watts 2005). Methods for assessing the environmental risk of P using inexpensive, agronomic soil testing results have been further developed for sandy soils in Florida, where soil test P, Fe, and Al content are analyzed to assess labile P as well as potential Fe/Al-bound P, typical in Florida sandy soils.

Soil test results of P, Fe, and Al were used to calculate a phosphorus saturation ratio (PSR). PSR results indicated a potential for environmental risk because they exceeded the 0.15 threshold for Florida soils. PSRs above 0.15 are considered the threshold at which phosphorus in Florida sandy soils may adversely affect the environment. Soil test results for Fe and Al were then combined with the PSR value to estimate the remaining phosphorus storage capacity of the soil. The soil phosphorus storage capacity (SPSC) provides a "… direct estimate of the amount of P a soil can sorb before exceeding a threshold soil equilibrium concentration" (Nair and Harris 2004). This method has been used in the Suwannee River Basin and the Okeechobee Basin on upland, aerobic soils intensively used for poultry and dairy operations (Nair and Harris 2004). This same concept was applied to the Deep Creek West treatment wetland site prior to flooding to assess the potential for internal P loading.

Average PSR by depth was calculated as Mehlich-1 Phosphorus (moles) / (Mehlich-1 Aluminum (moles) + Mehlich-1 Iron (moles) (Nair et al. 2004) and, SPSC was calculated and averaged by depth as SPSC = (0.15 – PSR) × (Mehlich-1 Aluminum + Mehlich-1 Iron). Our calculated PSRs were above the 0.15 environmental risk thresholds of 0–12 in. for soil depth and slightly over the threshold of 12–18 in. (Figure 5). In addition, SPSC values indicated that additional phosphorus could not be stored in the soil under aerobic conditions of 0–12 in. and could serve as a phosphorus source rather than a sink. Soils of 12–18 in. appeared to be at equilibrium with no additional P adsorption sites available (Figure 6).

While the SPSC calculation does not provide an estimate of the amount of potential Fe-bound P release from an anaerobic soil as typically provided by phosphorus flux experiments, it however, does provide an estimate of remaining phosphorus storage capacity or the potential for release of phosphorus from aerobic soils. Using potential phosphorus release estimates from the SPSC equation, the amount of phosphorus that had potential to be released from the iron fraction in the soil under anaerobic conditions, and the subsurface depth to which phosphorus had potential to be released, we estimated that 25 wet tons/acre of a specific alum water treatment residual (WTR) should be mixed into the top 12 in. of the soil profile to bind legacy soil phosphorus.

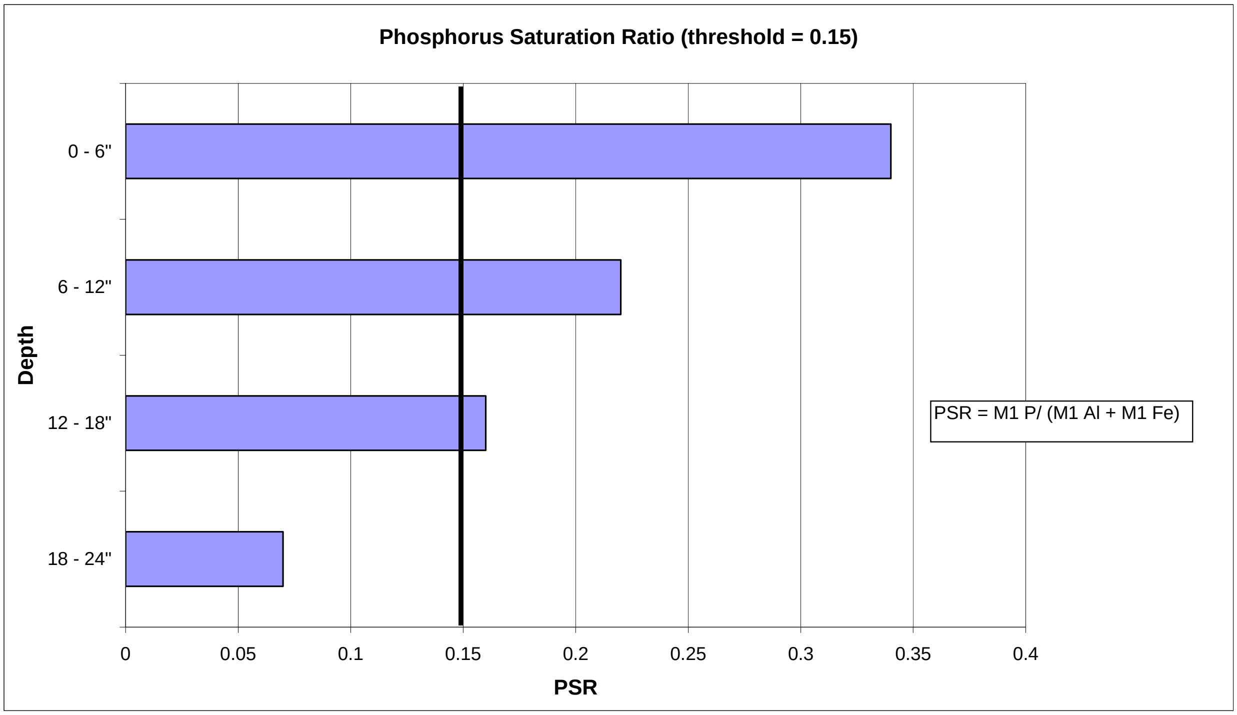


Figure 5. Phosphorus saturation ratio (PSR) of soil

Treatment of Legacy Soil Phosphorus

Alum WTR is an aluminum sulfate by-product produced from the drinking water treatment process; other chemicals such as ferric sulfate or ferric chloride are also commonly used coagulants. These resulting by-products of the treatment process can be land applied to former agricultural lands or lands that receive dairy or poultry litter to reduce soil phosphorus leaching. A review of the literature suggests WTR application rates can vary widely and are primarily dependent on the phosphorus sorption capabilities of the WTR being applied as well as soil phosphorus concentrations being treated. According to Makris and O'Connor (2007), application rates typically range from 11 to 25 tons/acre; Haustein (2000) surface applied an alum WTR at 8 tons/acre; Hoge et al. (2003) surface applied an alum WTR at 6.5 and 10 wet tons/acre at SJRWMD's Lake Apopka Restoration Area; whereas, Agyin-Birikorang et al. (2007) applied 51 tons/acre and disked the WTR into the soil. In addition, literature and SJRWMD studies have demonstrated that WTR phosphorus sorption capacities are site-specific and can differ significantly among treatment processing plants and parent chemicals used. Thus, WTRs must be laboratory tested using phosphorus sorption isotherms before application rates can be calculated. The

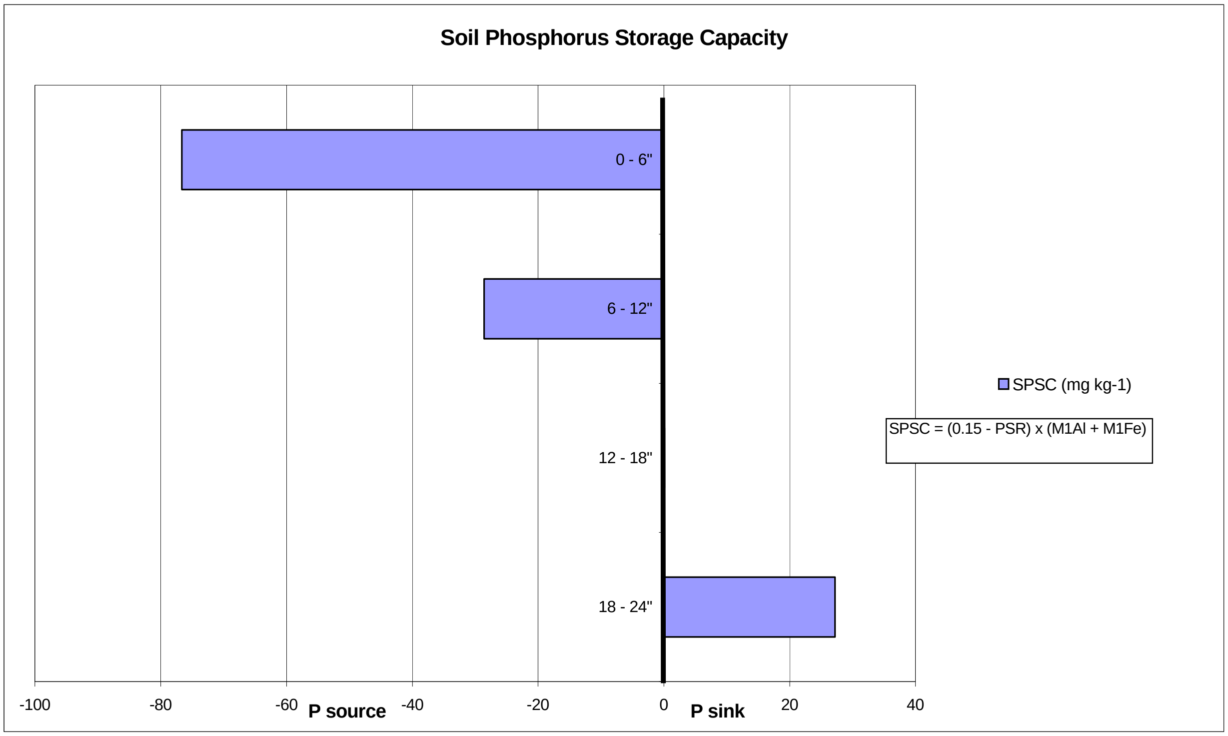


Figure 6. Soil phosphorus sorption capacity (SPSC)

maximum sorption capacity of the alum WTR applied at the Lake Apopka Project and the Deep Creek project wetland site was estimated to be greater than 60 milligrams per gram (mg/g) (DB Environmental Laboratories, Inc. 1998, 1999).

Approximately 25 wet tons/acre of alum WTR was applied to the treatment wetland site in February 2006. The objective of the alum application was to: (1) bind residual phosphorus in the soils to reduce the likelihood of phosphorus transport off-site upon flooding; and (2) increase the phosphorus sorption capacity of the soil for storage of phosphorus in the influent water discharged from the pond. The alum WTR was applied on approximately 37 acres of the wetland. Several small areas within the wetland did not receive alum treatment due to extremely wet zones that precluded use of the spreading equipment (Figure 7). Alum WTR was transported to the site from SJRWMD's Lake Apopka Project in Zellwood, Florida, which had originated from the Lake Washington Water Treatment Plant in Melbourne, Florida. Before the alum was applied, the site was harrowed down to a depth of 12 in. to disturb the soil surface and then the alum WTR was applied using manure spreaders. The site was then harrowed a second time to mix the alum within the top 12 in. of the soil profile, and then, lastly, the site was smoothed with a farm disk.

Figure 7. Aerial photo of alum water treatment residual (WTR) application

Soil samples were recollected approximately 27 days after the alum WTR application at the same locations where baseline soil samples were previously collected. Air-dried soil samples were analyzed by the University of Florida Extension Soil Testing Laboratory for soil pH and Mehlich-1 extracts for P, Fe, and Al. The SPSC was recalculated and compared to pre-alum WTR treatment soil conditions. SPSC results indicated that soluble phosphorus was reduced by approximately 94% from 76.66 mg/kg to 4.3 mg/kg in the top 6 in. and an overall 83% reduction in the top 12 in. from 105.26 mg/kg to 17.65 mg/kg with the addition of the alum WTR residual. Although soluble phosphorus was significantly reduced, SPSC results suggested that soil equilibrium was not achieved and soils could potentially release phosphorus (Figure 8).

However, total phosphorus (TP) water quality concentrations measured from the pond outfall and the wetland outfall for the period October 2006–June 2008 suggest there has not been a release of soil phosphorus from the wetland. Although the alum was applied in February 2006, the wetland did not begin discharging treated water until

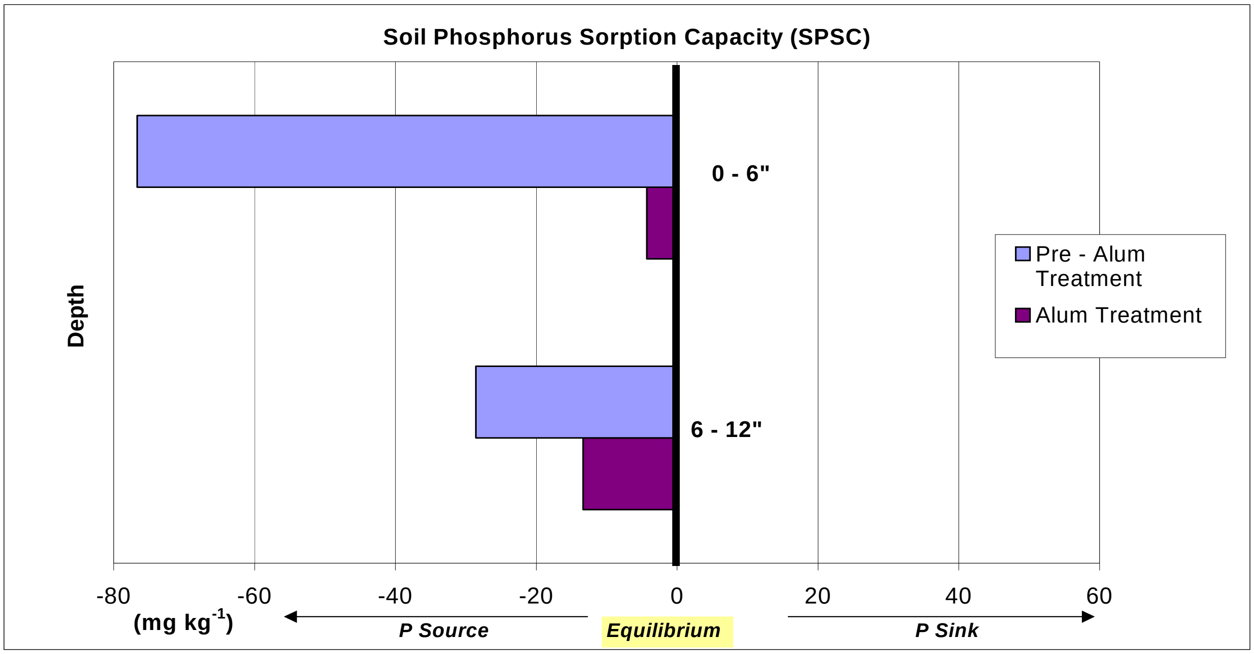


Figure 8. Soil phosphorus storage capacity (SPSC) post-alum water treatment residual (WTR) treatment

October 2006. Pond outfall water quality TP concentrations, which were on average 67% dissolved inorganic P, ranged from 0.11 to 2.06 milligrams per liter (mg L^{-1}) with a mean concentration of 0.66 mg L^{-1}. In contrast, wetland outfall mean TP concentration was 0.61 mg L^{-1} ranging from 0.10 to 1.48 mg L^{-1}, which was on average 72% dissolved inorganic P. Moreover, it is presumed that TP reductions achieved by the wetland may have been due to a decrease in particulate P since there was a 5% increase in dissolved inorganic phosphorus from the pond outfall to the wetland outfall. Continuous monthly ambient water quality monitoring of phosphorus concentrations discharged from the wetland will assist in verifying the treatment wetland continues to serve as phosphorus sink. Treatment performance will be calculated cumulatively as data become available, as well as annually.

Vegetation

Herbaceous vegetation has a high nutrient uptake rate, but provides only short-term storage when there is a lack of soil accretion; thus, periodic harvesting of aboveground biomass is sometimes necessary (Reddy and Debusk 1987). In contrast, trees assimilate nutrients at a much slower rate than herbaceous vegetation, but provide long-term storage in woody tissue. However, a portion of the absorbed nutrients by woody vegetation are not permanently stored in wood, but are returned to the system through litterfall, where these nutrients are either released or stored in soils by peat accumulation (Reddy and Debusk 1987). Some initial release of nutrients into the wetland from litterfall (e.g., primarily phosphorus) can be expected as the wetland develops and peat formation occurs. However, the pond at the forefront of the wetland is anticipated to remove a significant portion of nutrients (e.g., primarily particulate phosphorus) from drainage water before release into the wetland, whereas the wetland is expected to remove the preponderance of nitrogen and dissolved phosphorus.

Plant establishment at the wetland was achieved primarily through natural succession of herbaceous vegetation supplemented by planting bald cypress, (*Taxodium* spp.), red maple (*Acer rubrum*), and black gum (*Nyssa sylvatica*) trees. A total of 3,800 trees were planted at varying densities in April 2006: 200 trees per acre of red maple, black gum, and bald cypress on 12 acres; 100 trees per acre of black gum and bald cypress on 15 acres.

In future decades, if vegetation within the wetland reaches a maximum assimilation of nutrients and the soil accretion is lacking or insufficient to provide adequate nutrient removal, vegetation harvesting will be investigated. Cypress and black gum trees could potentially be harvested as a commercially valuable crop; however, only 23 of the 38 acres of the wetland can be harvested. Fifteen acres of the treatment wetland are part of a wetland mitigation plan approved by SJRWMD's Environmental Resource Permitting Program for the State Road 207 widening in St. Johns County by the Florida Department of Transportation (FDOT). The boundaries of the 15-acre FDOT mitigation area will be delineated after the wetland has had an opportunity for development through at least one growing season.

TREATMENT WETLAND PERFORMANCE

PREDICTED REMOVAL EFFICIENCIES

The average annual estimated removal efficiencies of the treatment wetland component of the regional stormwater treatment (RST) are 22% or 2,411 pounds of total nitrogen and 29% or 1,558 pounds of total phosphorus. Predicted seasonal efficiencies under storm and base-flow conditions are presented in Table 1. Estimated load reductions are based on prediction formulas using available ambient water quality data collected from the watershed and average flow into the facility under base-flow and storm conditions. These ambient water quality data were used by CDM to calculate an event mean concentration and seasonal mass load and were presented in a 2003 technical memorandum (CDM 2003). The predicted removal efficiencies for total nitrogen were calculated using the area-based, first-order k-c* model for total nitrogen (Kadlec and Knight 1996), which is written as:

$$\ln[C_{TN,O} - C^*_{TN}/C_{TN,I} - C^*_{TN}] = -k_{TN}/q(y),$$

where

C^*_{TN} = background concentration (0.4 mg/L)
C_{TNI} = input concentration (mg/L)
C_{TNO} = output concentration (mg/L)
k_{TN} = area-based, first-order TN rate constant (15 m/yr)
y = fractional distance through the wetland
q = hydraulic loading or flow/area.

Since the prediction is for the outflow, y = 1 and drops out of the equation. Rearranging to solve for C_{TNO} results in the following:

$$C_{TNO} = C^*_{TN} + (C_{TNI} - C^*_{TN}) \exp -^{(kTN/q)},$$

as provided in the regional facility BMP treatment decision matrix developed by CDM (2004).

The predicted total phosphorus removal was calculated using the mass balance model with first-order areal uptake for phosphorus removal (Kadlec and Knight 1996), shown as:

$$Co = Ci \exp^{-(k/q)},$$

where

C_O = output concentration (mg/L)
C_I = input concentration (mg/L)

k = area-based, first-order rate constant (12.1 m/yr)
q = hydraulic loading or flow/area.

Based on the nutrient removal efficiencies calculated from the prediction equations, the treatment wetland may more effectively treat effluent during the nongrowing season (Table 1). It should be noted that the first-order rate constants and, therefore, the equations are only valid over long periods (years). Despite this, however, they can provide a reliable predictor of the average behavior of a treatment wetland with a cyclic hydrology.

Table 1. Estimated seasonal nutrient load reductions for the Deep Creek West wetland treatment component of the regional stormwater treatment facility. These estimations were derived from predicted removal efficiency equations provided in Kadlec and Knight (1996). Actual load reductions for the wetland and the treatment train (i.e., wet detention and wetland combined) will be calculated after the facility is operational and a water quality monitoring program is implemented.

Treatment Wetland		
Total nitrogen	Growing season	Nongrowing season
Storm	180 lb/11%	683 lb/11%
Base flow	221lb/33%	1,327 lb/51%
Average annual	2,411 lb/ 22%	
Total phosphorus	Growing season	Nongrowing season
Storm	41 lb/10%	336 lb/10%
Base flow	191 lb/76%	990 lb/75%
Average annual	1,558 lb/29%	

Historical water quality data for the TCAA suggests that mean total nitrogen and mean total phosphorus concentrations in agricultural drainage basins are highest during the nongrowing season (e.g., June–December). Florida’s convective rainfall patterns increase during the months of June to September, native uplands consisting primarily of pine flatwoods and saw palmetto, experience rising water tables. This effect will stimulate the leaching of organic solutes as interstitial water flows into surface water and increases total nitrogen in primarily organic nitrogen forms (Livingston-Way 2001). Rainfall patterns also increase off-site transport of phosphorus in farm sediments and solubilize legacy soil phosphorus, thus increasing total phosphorus.

While prediction equations and performance estimations are useful, actual removal efficiencies and performance will likely differ from formula predictions. Thus, actual load reductions and treatment efficiencies for the wetland and the treatment train (i.e., wet detention and wetland combined) will be calculated cumulatively as data become available, as well as annually. Monitoring of water quality, hydrologic, vegetation, and biological components are presented in the Regional Stormwater Treatment Performance Monitoring section of this report and summarized in the Appendix A.

Nitrogen Removal

Nitrogen removal mechanisms from treatment wetlands include mineralization of organic nitrogen to ammonium (NH_4) followed by nitrification of NH_4 to nitrate (NO_3) in the aerobic soil layer and denitrification of NO_3 to nitrogen gas (N_2) in the anaerobic soil layer; adsorption/desorption of NH_4 in soil; ammonia (NH_3) volatilization in the water column; and assimilation of nitrogen species by plankton and other aquatic vegetation (Reddy and D'Angelo 1994). Of these processes, denitrification in anaerobic soil layers has been identified as the primary pathway of nitrogen removal from wetlands (Moshiri 1993; White and Reddy 1999).

It has been suggested that surfaces available in wetlands (e.g., litter, wood, macrophytes, and algae) for the attachment of nitrifying and denitrifying bacteria may be as important in nitrogen transformations as the sediment since these surfaces are in contact with the overlying water. Bastviken et al. (2003) conducted nitrification and denitrification comparisons among biofilms (e.g., microbial communities in polysaccharide matrixes) attached to old pine and spruce twigs (woody pieces less < 2 cm in diameter), green parts of *Eurasian watermilfoil* (submerged plant), filamentous algae, and sediment in two independent wetlands. The two wetlands used in the study were formerly forested land with peat soils and agricultural land with sandy soils. Comparison of the four surfaces indicated that nitrification rates were highest in biofilms on twigs and denitrification rates were highest in sediments; there were no differences in denitrification rates between the two wetlands having different former land uses and soils. Results of the study suggest that surfaces such as twigs present in wetlands could have the potential to increase overall nitrogen removal rates by providing additional, preferred material for the attachment of nitrifying bacteria. Although the majority of the pine tree community was removed, the residual pine straw and debris from timber removal and litterfall from the planted trees may have provided a potential source of additional surfaces for attachment of nitrifying bacteria.

Phosphorus Removal

In contrast to nitrogen removal in wetlands, phosphorus is not lost in gaseous forms and, therefore, can accumulate in wetlands, thereby acting as a source or a sink for phosphorus loading. Important phosphorus removal mechanisms in wetlands are assimilation by algae in the water column, uptake by macrophytes, and binding of phosphorus to soils and creation of new soil or peat. Depending on the type of vegetation, uptake by plants can provide short or long-term storage of phosphorus. Decaying plant matter can become a source of phosphorus to the wetland or function as a sink for the organic fractions resulting in peat accumulation over time (Reddy and D'Angelo 1994). Inorganic phosphorus has the potential to bind to soils depending on soil pH and the presence of specific minerals. Acidic soils with aluminum, and alkaline soils with calcium and magnesium minerals, can bind inorganic phosphorus (Brady 1990; Reddy and D'Angelo 1994).

Regional Stormwater Treatment (RST) Performance Monitoring

During the life span of the treatment system, the primary monitoring objective will be to maintain the optimum performance of the system and its ability to reduce nutrients and sediments from agricultural runoff that is conveyed through the facility. Specifically, the project charter document identified minimum reductions in outflow versus inflow parameters as 60% reduction in total phosphorus, 50% in total nitrogen, and 70% in total suspended solids. The secondary objective will be to maintain the physical and biological health of the system itself.

To accomplish the monitoring objectives, various parameters must be monitored: water quality (nutrient and metals), hydrology, plant, fish tissue analyses, seasonal vegetation mapping, and wildlife use. The complete monitoring plan is included in Appendix A. Monitoring parameters were, in part, based on information compiled during the Site and Design Technical Report, the Eco-Risk Assessment, and Biological Assessment reports.

For successful system management, Kadlec and Knight (1996) suggest that wetland systems should be monitored, at a minimum, for inflow and outflow water quality, water levels, and indicators of biological condition. Additional measurements include flow rate at the inflow and outflow, and rainfall rates, which are all necessary to quantify both water and nutrient budgets and treatment system efficiency. Table 2 lists the recommended minimum monitoring parameters from Kadlec and Knight (1996), which were used as monitoring guidelines for the both the wetland and pond.

Table 2. Recommended minimum monitoring parameters

Recommended Parameters	Recommended Sample Location	Minimum Sample Frequency
Inflow and outflow water quality—temperature, DO, pH, conductivity, TSS, NOX, NH4, TKN, TP, TPO4, metals	Inflow(s) and outflow(s)	Monthly (ambient) storm events
Flow	Inflow(s) and outflow(s)	Daily
Rainfall	Adjacent to system	Daily
Water stage	Within system	Daily
Plant cover for dominant species	Near inflow, center and outflow	Annual

Water Quality Monitoring

The primary objective of the Deep Creek West RST Facility is to reduce nutrients and sediments from agricultural runoff that are conveyed through the system. Subsequently, both water and nutrient budgets will be calculated for each treatment component to determine system efficiency. Further, monitoring is conducted so that both spatial and temporal trends can be measured and evaluated. These measurements will allow project managers to make decisions regarding site-specific operational changes for evaluating and improving performance of the Deep Creek West RST Facility.

Vadose zone samples were collected prior to operation of the wetland as a baseline sampling measure. Samples were collected at 10 locations in the wetland to sufficiently represent the wetland gradient. Analytical constituents included nitrogen and phosphorus species.

Current water quality monitoring includes ambient sampling at the canal inflow (system inflow), pond inflow, pond outflow, wetland inflow in the header ditch, and wetland outflow (system outflow); storm event sampling occurs only at the canal inflow, pond outflow and wetland outflow due to limited resources (Figure 9). Ambient samples are collected monthly as same-day sampling, whereas automated refrigerated samplers are programmed to collect time-paced composite samples for storm events. Automated samplers are triggered by stage increases representative of storm events and then continue sampling for 7 days once triggered. An analysis of representative storm hydrographs at the canal inflow indicated a seven-day sampling regime captured the complete hydrograph of most storm events (e.g., rising limb, peak, and falling limb). Samples are collected every 8 minutes for the first 2 hours to

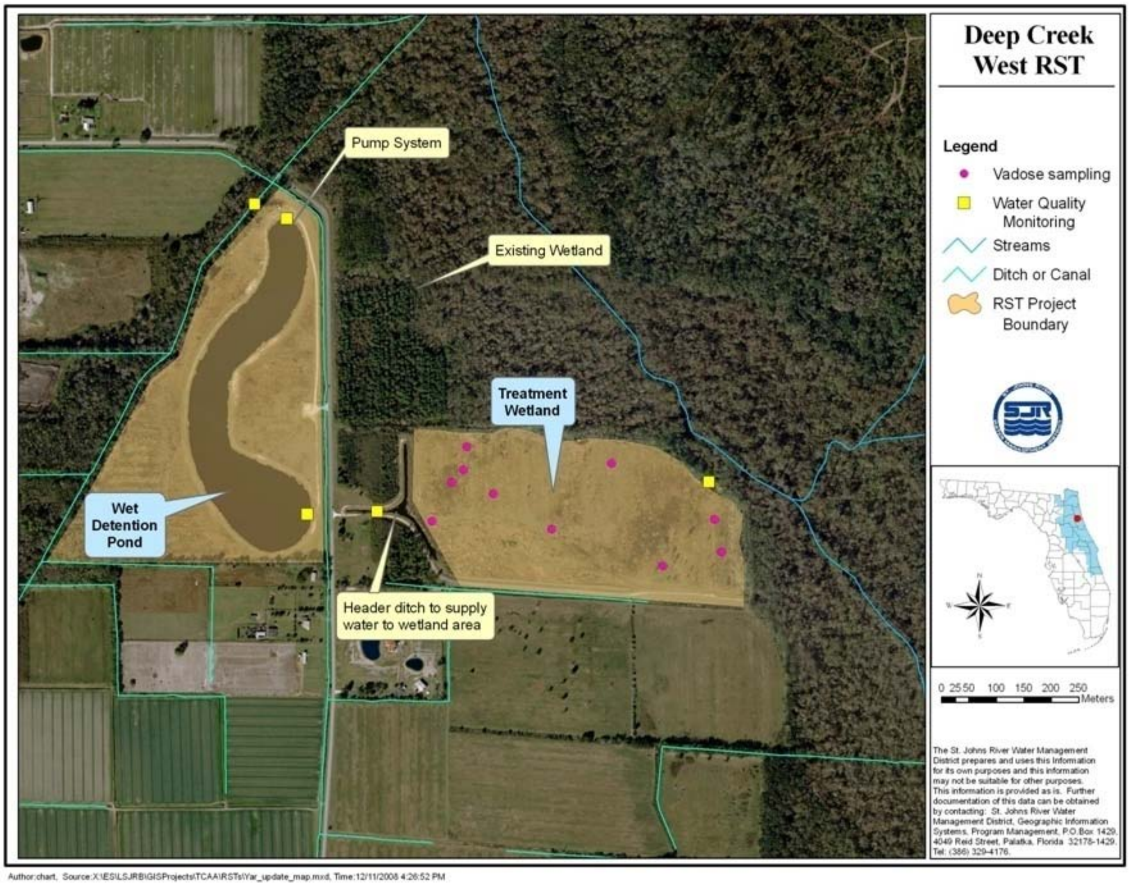


Figure 9. Water quality monitoring stations at Deep Creek West Regional Stormwater Treatment (RST) Facility

capture rise of the storm hydrograph and "first-flush" nutrient effect, succeeded by sampling in equal time intervals for the remainder of the first day of the storm, and then every 3 hours for the next six days. The first 2 hours of sampling captures close to 100% of the rising limb. Analytical constituents include nitrogen and phosphorus species, total suspended solids, and specific metals (metal analyses for ambient sampling only). In addition, metal analyses were included since the facility receives drainage from an agricultural watershed that routinely uses pesticides. Metals analysis results will be evaluated after 2 years of monitoring to determine if there is a need to continue metals analysis. Atmospheric nitrogen is not currently measured, but previously collected data within close proximity to the project site could be used in the nutrient budget.

Independent monitoring of the inflow and outflow of each system will allow managers to monitor treatment effectiveness associated with each system. If in the event outflow nutrient concentrations exceed inflow nutrient concentrations into each system, the source of nutrient export can be better identified. For instance, possible export of nutrients from the wetland could be a release of phosphorus from wetland soils; release of nitrogen due to little or no denitrification within the soil layers as a result of aerobic conditions; or exceedence of wetland vegetation nutrient uptake capacity. Thus, methods to impede the release of phosphorus will be considered, such as wetland water level drawdown and aerial application of dry alum, liquid alum injection, or other chemical amendment; or harvesting of wetland vegetation. Hydrologic conditions within the soil profile and oxidation-reduction (redox) potential measurements may need to be evaluated to determine if sufficient anaerobic conditions are being met to support denitrification, the primary nitrogen removal pathway.

Performance of the system for removal of solids, nitrogen, and phosphorus will be calculated and adjustments will be made to further enhance the performance of the system. Treatment system performance can be calculated using a mass balance approach. Moustaffa (1999) used a simple input-output model to evaluate the effectiveness of the Everglades Nutrient Removal project where the nutrient mass leaving the wetland is compared to the mass entering; and the difference between the nutrient input and output is considered the nutrient retention. This approach can be used to assess most treatment systems, be it a wetland or stormwater pond.

However, there is an inherent lag period between nutrient load exiting compared to nutrient load entering the treatment system that must be considered when calculating nutrient removal. Thus, preliminary average retention time for both the pond and wetland were estimated using available hydrologic data. Average pond retention was calculated as 41 days (pers. comm., Cindy Yang, Division of Engineering); whereas, average retention time for the wetland was estimated by SJRWMD’s Division of Environmental Sciences to be 7 days, using methods provided in Bottcher (1996) and wetland header ditch storage volume. These preliminary estimations will likely be refined as more data are collected and/or a tracer dye study may be executed to determine a more precise retention period to better estimate nutrient removal.

Hydrologic Monitoring

The following hydrologic parameters are measured and transmitted via telemetry to SJRWMD:

- Water stage: canal inflow (system inflow), pond inflow, pond outflow, and wetland outflow (system outflow)
- Flow: calculated using programmed rating curves and weir equations at the canal inflow (system inflow), pond outflow, and wetland outflow (system outflow)

- Rainfall: pond inflow

The hydrologic information will be used to develop a water budget for the Deep Creek West RST Facility and for calculating nutrient removal. Flow measurement is essential for quantifying mass balances in wetland systems (Kadlec and Knight 1996). This data acquisition system, combined with the control structures into and out of each system will provide a high degree of both hydrologic information and control. Evapotranspiration data used to calculate a water budget will be estimated with pan evaporation data from a nearby weather station. Groundwater data is not currently being measured but may be implemented later if deemed necessary to complete the water budget.

Fish Monitoring

The degree of fish monitoring is founded on the results and recommendations of the Eco-Risk Assessment and Biological Assessment reports for the Deep Creek West RST Facility. Sample collection commenced approximately 6 months after the site had been flooded sufficiently to maintain a fish stock. Whole body fish are collected from at least six different locations within the pond and are consistent with prey size (2.5–25cm). Multiple species are collected if present, and multiple individuals of a single species are composited into one sample (minimum 20 grams dry weight). Fish are also collected in the wetland where standing water persists. Fish samples are collected from at least two sites in the standing water area by setting minnow traps. If there are separate standing water zones that are not connected, then at least one sample is collected from each of the separate areas. All other sampling techniques and analyses follow the same protocol as fish collected from the pond. Sampling continues until a minimum total of 10 samples are collected from the pond and wetland.

Samples are analyzed for organochlorine pesticides (EPA 8081), as well as lipid analysis. If results for organochloride pesticide levels in the fish tissue are at or below one-half of the fish trigger values (dichlorodiphenyltrichloroethane [DDT] 2.4 mg/kg, toxaphene 4.3 mg/kg, dieldrin 0.69 mg/kg, total chlordane 0.285 mg/kg) from the Lake Apopka Marsh Flow-way Phase I Project Biological Opinion (USFWS, 2003), sampling continues every 6 months for 3 years. At the end of the 3-year period, SJRWMD will submit a report and consult with USFWS regarding future monitoring requirements. If the results of the fish tissue monitoring are above one-half the fish trigger values, sampling continues quarterly and SJRWMD submits an annual monitoring report to the U.S. Fish and Wildlife Service (USFWS). If results exceed absolute fish trigger values, SJRWMD will consult with USFWS within 30 days.

In the event of a fish kill, dead fish will be removed and disposed of within 24 hours of initial observation and USFWS will be notified within one week. If historical analyses have been below fish trigger values, an attempt to identify the cause of the fish kill will be made and no further action is required. If historical analyses have been above fish trigger values, the pond will be seined in areas where water depth is less than 2 ft to remove potential prey items for piscivorous birds. SJRWMD will remove fish from within the shallow area within 24 hours of initial observation of the fish kill, and an attempt to identify the cause of the fish kill will be made. If the fish kill occurs during the normal agricultural growing season (January–June), or a fish kill occurs upstream during the normal growing season, SJRWMD will also analyze fish tissue for organophosphate/carbamate pesticides. SJRWMD will consult with USFWS within 10 days regarding further action.

Fish sampling requires an annual permit from the Florida Fish and Wildlife Conservation Commission that must be renewed either 30 days prior to the expiration date or 30 days prior to the date needed; the permit expires on December 31 of each year. Refer to Appendix B for a copy of the permit, which includes specific permit conditions and reporting requirements.

Vegetation Monitoring

Vegetation monitoring is conducted semiannually at 60 locations throughout the treatment wetland. Monitoring sites form a grid pattern over the area, which are approximately 45 meters apart. At each site, species identification, individual species percent cover, mean canopy height for each species, and water depth are measured within a 1-meter diameter circle.

Wildlife Survey

Surveys for rare and threatened species are conducted quarterly. This monitoring provides a record of biological changes that may occur due to possible hydrologic alterations or conditions in the system. Survey data can be analyzed to determine population trends and reflect changes in the management of the system. Data collected are recorded and maintained in a biological spreadsheet database. Surveys are conducted by recording wildlife observed or heard, specifically mammals, avian species, and herps. Herps are surveyed quarterly by deploying three pairs of 2-in. diameter PVC casings, 4 ft aboveground. Casings are installed at random locations, within moist, shady areas of the wetland. Any herp found is identified to the lowest practical taxonomy and released, with the exception of exotics, which may be removed from the site.

Land Use Surveys

To more precisely describe the performance of the treatment facility, upland watershed land use changes will be inventoried at least every 3 to 5 years and any BMP influences will be monitored annually. Changes in the upland watershed will alter inflow concentrations and flow rates to the RST and subsequently influence system efficiency and treatment.

LITERATURE CITED

Agyin-Birikorang, S., G.A. O'Connor, L.W. Jacobs, K.C. Makris, and S.R. Brinton. 2007. Long-term phosphorus immobilization by a drinking water treatment residual. *Journal of Environmental Quality* 36: 316–23.

Bastviken, S.K., P.G. Eriksson, I. Martins, J.M. Neto, L. Leonardson, and K. Tonderski. 2003. Potential nitrification and denitrification on different surfaces in a constructed treatment wetland. *Journal of Environmental Quality* 32: 2414–20.

Bear, J. 1988. *Dynamics of fluids in porous media.* New York: Dover Publications.

Bottcher, D. 1996. *Phase II final report-tri-county agricultural area best management practices study.* Gainesville: Soil and Water Engineering Technology Inc.

Brady, N.C. 1990. *The nature and properties of soils.* New York: Macmillan.

Braun-Blanquet, J. 1932. *Plant sociology: The study of plant communities.* New York: McGraw-Hill (1965 English translation).

Bureau of Land Management. 1996. Sampling vegetation attributes. Interagency technical reference BLM/RS/ST-96/002+1730. U.S. Dept. of the Interior, Bureau of Land Management, National Applied Resource Sciences Center, Denver, Colo.

[CDM] Camp, Dresser, and McKee. 2003. Implementation of regional stormwater treatment systems Yarborough Tract tri-county agricultural area. Technical memorandum prepared for the St. Johns River Water Management District.

[CDM] Camp, Dresser, and McKee. 2004. Regional facility BMP treatment decision matrix for Yarborough Tract tri-county agricultural area. Prepared for the St. Johns River Water Management District.

Canfield R.H. 1941. Application of the line-intercept method in sampling range vegetation. *Journal of Forestry*. 39: 388–94.

[CSI] Civil Services Inc. 2004. Geotechnical exploration and evaluation report for the Yarborough wetland site. Prepared for the St. Johns River Water Management District.

DB Environmental Labs. 1998. Phosphorus uptake capacity of polymerized aluminum hydroxide residuals. Prepared for the St. Johns River Water Management District.

DB Environmental Labs. 1999. Phosphorus uptake capacity of polymerized aluminum hydroxide residuals. Prepared for the St. Johns River Water Management District.

Golder Associates Inc. 1997. Report on phase I environmental site assessment, Yarborough Parcel, St. Johns County, Fla. Golder Associates Inc., Jacksonville, Fla.

Haustein, G.K., T.C. Daniel, D.M. Miller, P.A. Moore Jr., and R.W. McNew. 2000. Aluminum-containing residuals influence high-phosphorus soils and runoff water quality. *Journal of Environmental Quality* 29: 1954–59.

Hoge, V.R., R. Conrow, M. Coveney, and J. Peterson. 2003. The application of alum residual as a phosphorus abatement tool within the Lake Apopka Restoration Area. Presented at the WEF/AWWA/CWEA Joint Residual and Biosolids Management Conference and Exhibition, "Partnering for a Safe, Sustainable Environment," February 19–22, 2003, Baltimore, Md.

Hyde, J.E., and T.F. Morris. 2000. Phosphorus availability in soils amended with dewatered water treatment residual and metal concentrations with time in residual. *Journal of Environmental Quality* 29: 1896–1904.

Kadlec, R.H., and R.L. Knight. 1996. *Treatment wetlands*. Boca Raton, Fla.: Lewis Publishers.

Knight, R.L. 2004. "Constructed and Natural Treatment Wetlands for Stormwater Management." Seminar presentation for the St. Johns River Water Management District, prepared by Wetland Solutions, Inc.

Livingston-Way, P.K. 2001. *Water quality monitoring and assessment of agricultural best management practices in the tri-county agricultural area.* Phase II final report (June 2001) submitted to Florida Department of Environmental Protection in fulfillment to Contract No. WM602.

Makris, K.C., and G.A. O'Connor. 2007. Beneficial utilization of drinking-water treatment residuals as contaminant-mitigating agents. *Developments in Environmental Science*. Volume 5.

Mitsch, W.J., and J.K. Cronk. 1992. Creation and restoration of wetlands: Some design consideration for ecological engineering. *Advances in Soil Science*. Volume 17.

Moshiri, G.A. (ed.). 1993. Mechanisms of wetland-water quality interaction. In *Constructed Wetlands for Water Quality Improvement*, pp. 293–98. Boca Raton, Fla.: Lewis Publishers.

Moustafa, M.Z. 1999. Nutrient retention dynamics of the Everglades nutrient removal project. *Wetlands* 19 (3): 689–704.

Nair, V.D., and D.A. Graetz. 2002. Phosphorus saturation in spodosols impacted by manure. *Journal of Environmental Quality* 31:1279–85.

Nair, V.D., and W.G. Harris. 2004. A capacity factor as an alternative to soil test phosphorus in phosphorus risk assessment. *New Zealand Journal of Agricultural Research* 47: 491–97.

Nair V.D., K.M. Portier , D.A. Graetz, and M.L. Walker. 2004. An environmental threshold for degree of phosphorus saturation in sandy soils. *Journal of Environmental Quality* 33: 107–13.

Novak, J.M., and D.W. Watts. 2005. An alum-based water treatment residual can reduce extractable phosphorus concentrations in three phosphorus-enriched coastal plain soils. *Journal of Environmental Quality* 34: 1820–27.

Pant, H.K., and K.R. Reddy. 2003. Potential internal loading of phosphorus in a wetland constructed in agricultural land. *Water Research* 37: 965–72.

Reddy, K.R., and W.F. DeBusk. 1987. Nutrient storage capabilities of aquatic and wetland plants. In *Aquatic plants for water treatment and resource recovery*, K.R. Reddy and W.H. Smith, eds., pp. 337–57. Orlando, Fla.: Magnolia Publishing.

Reddy, K.R., and E.M. D'Angelo. 1994. Soil processes regulating water quality in wetlands. In *Global wetlands: Old world and new, pp. 309–24.* Amsterdam: Elsevier.

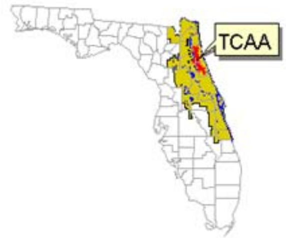
Sharpley A.N., S.C. Chapra., R. Wedepohl, J.T. Sims, T.C. Daniel, and K.R. Reddy. (1994). Managing agricultural phosphorus for protection of surface waters: Issues and options. *Journal of Environmental Quality* 23: 437–51.

[SJRWMD] St. Johns River Water Management District. 2006. Deep Creek conservation area land management plan, Yarborough and Edgefield parcels.

[USDA-SCS] U.S. Dept. of Agriculture, Soil Conservation Service. 1990. *Soil survey of Putnam County area, Florida.*

White, J.R., and K.R. Reddy. 1999. Influence of nitrate and phosphorus loading on denitrifying enzyme activity in Everglades wetland soils. *Soil Science Society American Journal* 63: 1945–54.

APPENDIX A. DEEP CREEK WEST REGIONAL STORMWATER TREATMENT FACILITY WATER QUALITY AND BIOLOGICAL MONITORING PLAN



Deep Creek West Regional Treatment Monitoring

This document was developed to identify the monitoring

A. Project Information/Physical Characteristics

1. Project Name	Deep Creek West (Yarborough) RST
Project Location	St. Johns County
Drainage Basin being treated	Deep Creek
Tributary Area (TA)	1,196 Acres

Overview - The Yarborough Regional Treatment System is a combination treatment system designed to remove nutrients from agricultural drainage water in the form of dissolved and particulate material before being discharged to surface waters at the basin outlet. The Yarborough RST is designed to remove 50% and 60% of the total nitrogen and phosphorus load associated with nutrient loading from Canal No. 1 respectively, and prior to discharging into Deep Creek.

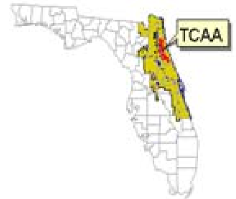
The Yarborough RST treatment train includes a wet detention pond and wetland. The hydrology of the Hastings Drainage District, requires that a pump station be used to lift water from Canal No. 1 to a wet detention pond. The pump treatment rate will allow for a 90% storm capture and provide a peak flow rate of 20 cfs and a baseflow rate of 1.54 cfs through the system. The RST will be monitored by the Environmental Sciences staff for the criteria listed below and used to measure and manage the performance of the system over time.

B. Project BMPs and Monitoring Criteria

Identifies which BMP(s) are being monitored at the site.

Identifies which criteria are being monitored for each BMP.

			Water Quality	Hydrology	Fish	Vegetation	Sediment	Wildlife
☑	1.	**Wet Detention**	☑	☑	☑	☑	☐	☑
☐	2.	**Dry Detention**	☐	☐	☐	☐	☐	☐
☐	3.	**Retention**	☐	☐	☐	☐	☐	☐
☐	4.	**Exfiltration**	☐	☐	☐	☐	☐	☐
☐	5.	**Swales**	☐	☐	☐	☐	☐	☐
☑	6.	**Wetland**	☑	☑	☑	☑	☐	☑
☐	7.	**Wetland + Chemical**	☐	☐	☐	☐	☐	☐
☐	8.	**Recirculating Wetland**	☐	☐	☐	☐	☐	☐
☐	9.	**High Rate Sedimentation**	☐	☐	☐	☐	☐	☐
☐	10.	**High Rate Sedimentation+Settling Pond**	☐	☐	☐	☐	☐	☐
☐	11.	**End of Pipe Technologies**	☐	☐	☐	☐	☐	☐
☐	12.	**BMP Treatment Train**	☐	☐	☐	☐	☐	☐



Deep Creek West Regional Treatment Monitoring

This document was developed to identify the monitoring criteria conducted at the RST.

C. Monitoring Criteria - Water Quality

			Inflow		Outflow		Vadose
			Ambient	Storm	Ambient	Storm	
☐	1.	Wet Detention	☑	☑	☑	☑	☐
☐	2.	Dry Detention	☐	☐	☐	☐	☐
☐	3.	Retention	☐	☐	☐	☐	☐
☐	4.	Exfiltration	☐	☐	☐	☐	☐
☐	5.	Swales	☐	☐	☐	☐	☐
☐	6.	Wetland	☑	☑	☑	☑	☑
☐	7.	Wetland + Chemical	☐	☐	☐	☐	☐
☐	8.	Recirculating Wetland	☐	☐	☐	☐	☐
☐	9.	High Rate Sedimentation	☐	☐	☐	☐	☐
☐	10.	High Rate Sedimentation+Settling Pond	☐	☐	☐	☐	☐
☐	11.	End of Pipe Technologies	☐	☐	☐	☐	☐
☐	12.	BMP Treatment Train	☐	☐	☐	☐	☐

Water quality monitoring includes both ambient and storm event sampling. Ambient samples are collected monthly at the canal inflow, pond inflow and outflow, and wetland inflow and outflow. Automated refrigerated samplers are programmed to collect time-paced composite samples during storm events from the canal inflow, pond outflow and wetland outflow. When the soils were sufficiently hydrated, ten vadose samples were collected as baseline samples at the wetland using vacuum lysimeters . These data will be used for comparison if at some time the performance efficiency of the wetland declines. If so, lysimeters will be installed in the wetland to monitor the internal wetland processes. Analytical constituents are identified below.

Water Quality Analytical List

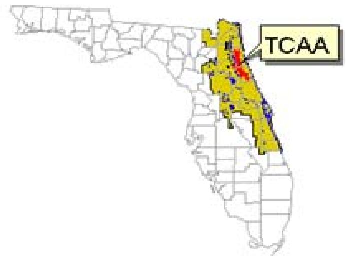
Constituent List	*Select Analytical List*		**Sample Type*** Indicate the type of sample		
Ag-D (Silver-D)	☐				
Ag-T (Silver-T)	☑	Ag-T (Silver-T)	A		
Al-D (Aluminum-D)	☐				
Al-T (Aluminum-T)	☑	Al-T (Aluminum-T)	A		
Alkalinity	☑	Alkalinity	A		
As-D (Arsenic-D)	☐				
As-T (Arsenic-T)	☑	As-T (Arsenic-T)	A		
Ba-D (Barium-D)	☐				
Ba-T (Barium-T)	☑	Ba-T (Barium-T)	A		
Be-D (Beryllium-D)	☐				
Be-T (Beryllium-T)	☐				
BOD	☐				
Ca-D (Calcium-D)	☐				
Ca-T (Calcium-T)	☑	Ca-T (Calcium-T)	A		
Cd-D (Cadmium-D)	☐				
Cd-T (Cadmium-T)	☑	Cd-T (Cadmium-T)	A		
Chlorophyll Scan	☑	Chlorophyll Scan	A		
Cl (Chloride)	☑	Cl (Chloride)	A		V
Color	☑	Color	A		
Conductivity	☐				
Cr-D (Chromium-D)	☐				
Cr-T (Chromium-T)	☑	Cr-T (Chromium-T)	A		
Cu-D (Copper-D)	☐				
Cu-T (Copper-T)	☑	Cu-T (Copper-T)	A		
DOC	☑	DOC	A		
F (Fluoride)	☐				
Fe-D (Iron-D)	☐				
Fe-T (Iron-T)	☑	Fe-T (Iron-T)	A		
Hardness, Calc	☑	Hardness, Calc	A		
Hg-D (Mercury-D)	☐				
Hg-T (Mercury-T)	☐				
K-D (Potassium-D)	☐				
K-T (Potassium-T)	☑	K-T (Potassium-T)	A		
Mg-D (Magnesium-D)	☐				
Mg-T (Magnesium-T)	☑	Mg-T (Magnesium-T)	A		
Mn-D (Manganese-D)	☐				
Mn-T (Manganese-T)	☑	Mn-T (Manganese-T)	A		
Na-D (Sodium-D)	☐				
Na-T (Sodium-T)	☑	Na-T (Sodium-T)	A		
NH4-D	☑	NH4-D	A	S	V
NH4-T	☑	NH4-T	A		
Ni-D (Nickel-D)	☐				
Ni-T (Nickel-T)	☑	Ni-T (Nickel-T)	A		
NOx-D	☑	NOx-D	A	S	V
NOx-T	☑	NOx-T	A		
Pb-D (Lead-D)	☐				
Pb-T (Lead-T)	☑	Pb-T (Lead-T)	A		
PO4-D	☑	PO4-D	A	S	V
PO4-T	☑	PO4-T	A		
Sb-D (Antimony-D)	☐				
Sb-T (Antimony-T)	☐				
Se-D (Selenium-D)	☐				
Se-T (Selenium-T)	☑	Se-T (Selenium-T)	A		
Si-T (Silicon-T)	☐				
SiO2-D (Silica-D)	☐		A		
Sn-D (Tin-D)	☐				
Sn-T (Tin-T)	☐				
SO4 (Sulfate)	☑	SO4 (Sulfate)	A		V
Sr-D (Strontium-D)	☐				

Constituent List (continued)	*Select Analytical List*		**Sample Type*** Indicate the type of sample		
Sr-T (Strontium-T)	☐				
TDS	☑	TDS	A	S	V
TKN-D	☑	TKN-D	A		
TKN-T	☑	TKN-T	A	S	V
Tl-D (Thallium-D)	☐				
Tl-T (Thallium-T)	☐		A		
TOC	☑	TOC	A	S	V
TP-D	☑	TP-D	A		
TP-T	☑	TP-T	A	S	V
TSS	☑	TSS	A	S	
VSS	☑	VSS	A		
High-Volume TSS	☐				
High-Volume VSS	☐				
Turbidity	☑	Turbidity	A		
V-D (Vanadium-D)	☐				
V-T (Vanadium-T)	☐				
Zn-D (Zinc-D)	☐				
Zn-T (Zinc-T)	☑	Zn-T (Zinc-T)	A		
pH	☑	pH	A		
Temperature	☑	Temperature	A		
Conductivity	☑	Conductivity	A		
Dissolved Oxygen	☑	Dissolved Oxygen	A		

* A = Ambient
S = Stormflow
V = Vadose

Deep Creek West Regional Treatment Monitoring

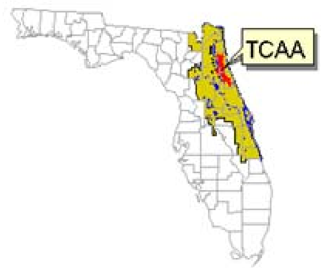
This document was developed to identify the monitoring criteria conducted at the RST.



D. Monitoring Criteria - Hydrology

			Flow			
			Inflow	Outflow	Rainfall	Stage
☑	1.	Wet Detention	☑	☑	☑	☑
☐	2.	Dry Detention	☐	☐	☐	☐
☐	3.	Retention	☐	☐	☐	☐
☐	4.	Exfiltration	☐	☐	☐	☐
☐	5.	Swales	☐	☐	☐	☐
☑	6.	Wetland	☐	☑	☐	☑
☐	7.	Wetland + Chemical	☐	☐	☐	☐
☐	8.	Recirculating Wetland	☐	☐	☐	☐
☐	9.	High Rate Sedimentation	☐	☐	☐	☐
☐	10.	High Rate Sedimentation+Settling Pond	☐	☐	☐	☐
☐	11.	End of Pipe Technologies	☐	☐	☐	☐
☐	12.	BMP Treatment Train	☐	☐	☐	☐

Hydrology - The hydrologic information will be used to develop a water budget for the system and for calculating the performance of the system. Flow is essential for quantifying mass balances in wetland systems (Kadlec and Knight, 1996). Hydrologic monitoring includes a combination of stage, flow and rainfall measurements communicated to the District via telemetry. Stage and flow data are also monitored at the canal inflow. This data acquisition system, combined with the control structures into and out of each system, will provide a high degree of both hydrologic information and control. Evapotranspiration data used to calculate a water budget will be estimated with pan evaporation data from a nearby weather station.



Deep Creek West Regional Treatment Monitoring

This document was developed to identify the monitoring criteria conducted at the RST.

E. Monitoring Criteria - Fish

Methods

Collection - A small boat equipped with electro-shocking equipment collects the required fish samples in the pond. Sample collection commenced approximately six months after the site had been flooded sufficiently to maintain a fish stock. Whole body fish are collected from at least six different locations within the stormwater pond and are consistent with prey size (2.5-25cm). Multiple species are collected if present and multiple individuals of a single species are composited into one sample (minimum 20 grams dry wt).

Fish are also collected in the wetland where standing water persists. Fish samples are collected from at least two sites in the standing water area by setting minnow traps. If there are standing water zones that are not connected, then at least one sample is required from each of the separate areas. All other sampling techniques and analyses follow the same protocol as fish collected from the pond. Sampling continues until a minimum total of ten samples are collected from the pond and wetland.

Analysis and Reporting - Samples are analyzed for organochlorine pesticides (EPA 8081), as well lipid analysis. If results for organochloride pesticide levels in the fish tissue are at or below one-half of the fish trigger values (DDTx 2.4 mg/kg, Toxaphene 4.3 mg/kg, Dieldrin 0.69 mg/kg, total Chlordane 0.285 mg/kg) from the Lake Apopka Marsh Flow-way Phase I Project Biological Opinion (USFWS, 2003), sampling continues every six months for three years. At the end of the three-year period, the District will submit a report and consult with USFWS regarding future monitoring requirements.

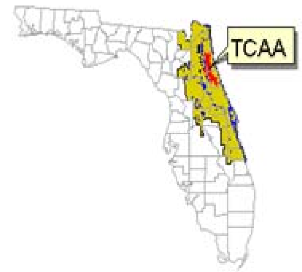
If the results of the fish tissue monitoring are above one-half the fish trigger values, sampling continues quarterly and the District submits an annual monitoring report to USFWS. If results exceed absolute fish trigger values, the District will consult with USFWS within 30 days.

Emergency Contigency Plan - In the event of a fish kill, dead fish will be removed and disposed of within twenty-four hours of initial observation and USFWS will be notified within one week. If historical analyses have been below fish trigger values, an attempt to identify the cause of the fish kill will be made and no further action is required. If historical analyses have been above fish trigger values, the pond will be seined in areas where water depth is less than two feet to remove potential prey items for piscivorous birds. The District will remove fish from within the shallow area within twenty-four hours of initial observation of the fish kill, and an attempt to identify the cause of the fish kill will be made. If the fish kill occurs during the normal agricultural growing season (January-June), or a fish kill occurs upstream during the normal growing season, the District will also analyze fish tissue for Organophosphate/Carbamate pesticides. The District will consult with USFWS within 10 days regarding further action. All fish data will be be recorded and maintained in a biological spreadsheet database.

Fish sampling requires an annual permit from the Florida Fish and Wildlife Conservation Commission; refer to a copy of the permit in Appendix B for specific permit conditions and reporting requirements.

Deep Creek West Regional Treatment Monitoring

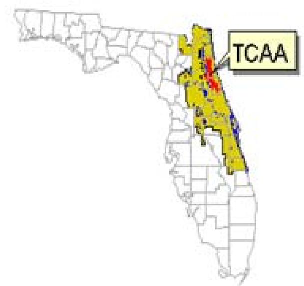
This document was developed to identify the monitoring criteria conducted at the RST.



F. Monitoring Criteria - Vegetation

Methods

Monitoring - **Wetland vegetation monitoring is conducted semi-annually at sixty locations throughout the treatment wetland. Monitoring points are approximately 45 meters apart and form a grid pattern over the area. At each of the sixty points, species present within a 1.0 meter diameter circle are noted, as well as percent cover and mean canopy height for each species and water depth.**



Deep Creek West Regional Treatment Monitoring

This document was developed to identify the monitoring criteria conducted at the RST.

G. Monitoring Criteria - Wildlife Survey

Methods

Monitoring - Surveys for rare and threatened species are conducted quarterly at both the pond and wetland properties. This monitoring provides a record of biological changes that may occur due to possible hydrologic alterations or conditions in the system. Survey data can be analyzed to determine population trends and reflect changes in the management of the system. Data collected are recorded and maintained in a biological spreadsheet database. Surveys are conducted at both the pond and wetland properties, recording wildlife observed or heard, specifically mammals, avian species, and herps. Herps are surveyed quarterly by deploying three pairs of 2" diameter PVC casings, 4 feet aboveground. Casings are installed at random locations, within moist, shady areas of the wetland. Any herp found is identified to the lowest practical taxonomy and released, with the exception of exotics, which may be removed from the site.

Appendix B. Florida Fish and Wildlife Conservation Commission Permit for Fish Sampling

FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION

DENNIS DAVID, Regional Director
1239 SW 10th Street
Ocala, Florida 34474
(352) 732-1225
FAX (352) 732-1391

25 January 2005

Ms. Pam Livingston-Way
St. Johns River Water Management District
P.O. Box 1429
Palatka, FL 32178-1429

Dear Ms. Livingston-Way:

Attached is Scientific Collector's Permit FNE-2005-41 permitting you, Lori McCloud, Alicia Steinmetz, David Girardin, Dean Campbell, Michele Lockwood, Michael Dupont, Michelle Jeansonne, Michael Bowman, Jessica Beecher, Mandy Livingston, Dean Dobberfuhl, John Hendrickson and Jennifer Tallerico of the St. Johns River Water Management District (SJRWMD) to take freshwater fish from Yarborough West and East in St. Johns County and Edgefield in Putnam for scientific purposes only. Please review carefully the provisions stated on the Scientific Collector's permit, because it contains specific conditions. Permit to collect endangered, threatened or species of special concern or request to collect prohibited or restricted species requires approval from Lawson Snyder, 620 South Meridian Street, Tallahassee, FL 32399-1600, phone number 850-488-4066.

Please mark your boat or other equipment with the name of the institution or agency you represent so the public will be informed as to your purpose.

All Scientific Collector's Permits expire December 31 of the year issued, unless otherwise stated on your permit. If you wish to renew your permit, write to us 30 days before the expiration date or 30 days before you will need the permit. A report which shall include all species, total number, total weight, and disposition of collected fish (live release, buried, preserved, etc.) by waterbody(s) shall be submitted to our Fisheries Division at 1239 SW 10th Street, Ocala, FL 34474 within 90 days following permit expiration date. Interim reports may be requested.

A report(s) including the above mentioned information is required by the terms of the permit. Failure to do so is just cause for revoking your permit or refusal to reissue your permit.

Sincerely,

Samuel P. McKinney

Samuel P. McKinney
Biological Administrator II

SPM/wmc

cc: Dennis David
Darrell Scovell
Major Andy Love

FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
JAN 28 2005
PALATKA, FLORIDA MAIL CENTER

ENNETH D. HADDAD, Executive Director
ICTOR J. HELLER, Assistant Executive Director

DENNIS DAVID, Regional Director
1239 SW 10th Street
Ocala, Florida 34474
(352) 732-1225
FAX (352) 732-1391

SCIENTIFIC COLLECTOR'S PERMIT

Number: FNE-2005-42
Date: 25 January 2005

Under authority of Title 68A-9.002 Florida Administrative Code, permission to collect freshwater fish is hereby granted to:

Pam Livingston-Way, Lori McCloud, Alicia Steinmetz, David Girardin, Dean Campbell, Michele Lockwood, Michael Dupont, Michelle Jeansonne, Michael Bowman, Jessica Beecher, Mandy Livingston, Dean Dobberfuhl, John Hendrickson and Jennifer Tallerico of the St. Johns River Water Management District (SJRWMD)

PERMIT CONDITIONS:

- Electrofishing devices, nets and minnowtraps may be used to collect freshwater fish from Yarborough West and East in St. Johns County and Edgefield in Putnam for scientific purposes only. Use of fish toxicants such as rotenone is specifically prohibited.
- No species classified as endangered, threatened or species of special concern or freshwater aquatic life classified as prohibited or restricted may be taken.
- Bag, length and season limits are exempt for the purposes of this permit.
- Up to a maximum of 10 fish of each species listed on Attachment "A" may be taken per sampling trip.
- Prior to sampling a public waterbody contact the Northeast Regional office at 352-732-1228.
- This permit shall not apply to State and Federal Wildlife refuges, management areas or parks unless specifically provided herein.
- Permittee must be in possession of this permit while collecting.
- A report is required 90 days after completion of collection activities or upon request for permit renewal.
- This permit may be revoked for failure of the permittee to abide by permit conditions and rules of the Commission.

This permit is not transferable and expires **31 December 2005**.

Kenneth Haddad
Executive Director

BY: Samuel P. McKinney
Samuel P. McKinney
Biological Administrator II
Division of Freshwater Fisheries

SPM/wmc
LIC 6-1
cc: Dennis David
Darrell Scovell
Major Andy Love

ATTACHMENT "A"

Common Name	***Scientific Name***
Sea lamprey	*Petromyzon marinum*
Atlantic stingray	*Dasyatis Sabina*
Longnose gar	*Lepisosteus osseus*
Bowfin	*Amia Calva*
Redfin pickerel	*Esox americanus*
Chain pickerel	*E. niger*
Golden shiner	*Notemigonus crysoleucas*
Pugnose minnow	*Notropis Emiliae*
Taillight shiner	*N. maculatus*
Coastal Shiner	*N. Petersoni*
Lake chubsucker	*Erimyzon succetta*
American eel	*Anguilla rostrata*
Blueback herring	*Alosa aestivalis*
American shad	*A. sapidissima*
Hickory shad	*A. mediocris*
Gizzard shad	*Dorosoma cepadianum*
Threadfin shad	*D. petenese*
Atlantic thread herring	*Opisthnema Oglinum*
Mosquito fish	*Gambusia affinis*
Least Killifish	*Heterandria formosa*
Sailfin molly	*Poecilia latipinna*
Brook silversides	*Labidesthes sicculus*
Inland silversides	*Manidia beryllina*
Everglades pygmy sunfish	*Ellassoma evergladei*
Bluespotted sunfish	*Enneeacanthus gloriosus*
Banded sunfish	*E. obesus*
Redbreast sunfish	*Lepomis auritus*
Warmouth	*L. gulosis*
Bluegill	*L. macrochirus*
Dollar sunfish	*L. marginatus*
Redear sunfish	*L. microlophus*
Spotted sunfish	*L. punctatus*
Largemouth bass	*Micropterus salmoides*
Black crappie	*Pomoxis nigromaculatus*
Swamp darter	*Etheostoma barrati*
Brown darter	*Etheostoma edwini*
Blackbanded darter	*Percina nigrofasciata*
White catfish	*Ameiurus catus*
Yellow bullhead	*A. natalis*
Brown bullhead	*A. nebulosus*
Channel catfish	*Ictalurus punctatus*
Tadpole madtom	*Noturus gyrinus*
Pirate perch	*Aphredoderus sayanus*
Atlantic needlefish	*Strongylura marina*

Common Name	***Scientific Name***
Sheepshead, pupfish	*Cyprinodon variegates*
Golden topminnow	*Fundulus chrysotus*
Marsh killifish	*F. confluentus*
Seminole killifish	*F. seminolis*
Florida flagfish	*Jordanella floridae*
Bluefin killifish	*Lucania goodie*
Atlantic croaker	*Micropogon undulates*
Blue tilapia	*Tilapia aurea*
Striped mullet	*Mugil cephalus*
Naked goby	*Gobiosoma Bosci*
Clown goby	*Microgobius gulosis*
Southern flounder	*Paralichthys lethostigma*
Walking catfish	*Clarias batrachus*
Armored catfish	*Liposarcus multiradius*

<u>68A-9.002 Permits to Take Wildlife or Freshwater Fish for Justifiable Purposes.</u>

(1) The executive director may issue permits authorizing the taking or possession of wildlife or freshwater fish or their nests or eggs for scientific, educational, exhibition, propagation, management or other justifiable purposes. Such permits shall be subject to such terms, conditions and restrictions as may be prescribed therein, provided that no such permits shall be operative as to migratory birds unless the holder thereof has a permit from the U.S. Fish and Wildlife Service permitting the taking, exhibiting, or
possession of such birds, their nests or eggs. Failure to abide by all terms and conditions stipulated in any written permit issued by the executive director shall be a violation of this section.

(2) Employees of the Commission may take wildlife or freshwater fish or their nests or eggs for scientific, educational, propagation, exhibition or other justifiable purposes when such taking has been authorized by the executive director or is essential to the performance of their assigned duties. The authority granted under this section shall not be construed to exempt any person from purchasing hunting or fishing licenses as required by Section 372.57, F.S. The executive director may issue permits authorizing the taking or managing of wildlife or freshwater fish for specified commercial purposes.

(3) The Executive Director shall issue permits to fishing tournaments, with 10 or more participants, to allow temporary possession of fish not meeting applicable size restrictions, provided that all fish caught in the tournament are live-released following weigh-in, that fish are handled in accordance with the Commission's scientific guidelines, and that reports of fish taken in the tournament are made available to the Commission. Applications for permits shall be made on FWC Form BT-1000, effective July 1, 1992, incorporated herein by reference and obtainable at the Commission's Tallahassee and regional offices.

68A-27.0011 Killing Endangered Species.
No person shall kill, attempt to kill or wound any endangered species as designated in Rule 68A-27.003, F.A.C.

68A-27.0012 Procedures for Listing, Delisting and Reclassifying Endangered, Threatened and Species of Special Concern.
(1) Petition to list, delist, or reclassify a species in Rule 68A-27.003, 68A-27.004 or 68A-27.005, F.A.C.
(a) Persons wishing to add, delete or reclassify species in Rule 68A-27.003, 68A-27.004 or 68A-27.005, F.A.C., shall submit a written petition to the Commission.
1. Petitions shall be clearly identified as such, and must contain the following in order to be considered complete:
a. The rule to which the species is proposed to be added, removed from or reclassified to,
b. The name, address and signature of the petitioner, and
c. Sufficient information on the biology and distribution of the species to warrant investigation of its status using the criteria
contained in definitions of endangered, threatened or species of special concern in Rule 68A-1.004, F.A.C.
(b) Incomplete petitions will be returned to the petitioner with insufficiencies clearly noted in writing. Corrected petitions may be resubmitted for consideration.
(c) Complete petitions will be evaluated in accordance with the provisions in subsection (2).
(d) If, in the opinion of the Executive Director, immediate inclusion of a species in Rule 68A-27.003, F.A.C., is essential to prevent imminent extinction, such listing may be effected on a temporary basis by Executive Order; provided that the Executive Order shall be approved or terminated at the next regularly scheduled meeting of the Commission. The Commission shall, within
240 days after the effective date of such approval, conduct the evaluations prescribed in subsections (2) and (3) of this rule to determine the appropriate final classification of the species. The Commission shall take final action on the listing at the next regularly scheduled meeting following the 240 day evaluation period.
(2) Review of petitions to determine biological status; Phase 1.
(a) The Commission shall establish a deadline for completion of the biological review of each complete petition.
(b) The Commission shall provide notice by mail to parties who request such notification and shall publish in the Florida Administrative Weekly a solicitation of information on the biological status of the petitioned species. Written comments regarding biological status shall be accepted by the Commission for a period of no less than 45 days following public notice.
(c) The Commission shall summarize information provided in the petition, information obtained from the public and other available biological data on status of the petitioned species into a preliminary biological status report. The preliminary biological status report shall contain a recommended classification for the petitioned species consistent with the available biological data and based on the criteria established in Rule 68A-1.004, F.A.C.
(d) The Commission shall designate a biological review panel with a minimum of three scientists with demonstrated knowledge and expertise pertaining to species conservation and management. This panel shall independently evaluate information compiled on the petitioned species' biological status relative to its proposed classification in Rules 68A-27.003, 68A-27.004 or 68A-27.005, F.A.C.
(e) The biological status report and the information referenced in paragraph (c) shall be provided to members of the panel of scientific experts for the review mandated in paragraph (d) of this rule. Panel members shall have no fewer than 45 days to review the document and provide recommendations to the Commission.
(f) The Commission shall consider the final biological status report, biological recommendations from the panel of scientific experts and public testimony regarding biological status in making a final determination whether addition, deletion or reclassification of the petitioned species in Rule 68A-27.003, 68A-27.004 or 68A-27.005, F.A.C., is warranted.
(g) If the petitioned species is determined by the Commission to warrant inclusion in Rule 68A-27.003, 68A-27.004 or 68A-27.005, F.A.C., the Commission shall:
1. Specify the appropriate listing category for the species based on biological status.
2. Establish a deadline for completion of Phase 2 for the species as described in subsection (3) below, considering the recommendation of Commission employees and other interested parties.

3. If the species is not already listed in Rule 68A-27.003, 68A-27.004 or 68A-27.005, F.A.C., it shall be added to the list of candidate species in Rule 68A-27.0021, F.A.C., and the protective provisions therein shall apply to the species.
(3) Development of management plans, regulations, permit requirements for candidate species; Phase 2.
(a) Within 45 days following designation of a candidate species, the Commission shall provide notice by mail to parties who request such notification and shall publish in the Florida Administrative Weekly a solicitation of information on the conservation needs of the species, and any economic and social factors that should be considered in its management.
(b) The Commission shall use information obtained from the public and other available information to develop a draft management plan for each candidate species that addresses:
1. Biological status as determined in Phase 1,
2. Conservation objectives,
3. Recommended management actions,
4. Recommended Commission regulations and incentives,
5. Anticipated economic and social impacts of implementing or not implementing the recommended conservation actions.
(c) The Commission shall provide notice by mail to parties who request such notification and shall publish in the Florida Administrative Weekly a notice of the availability of the draft management plan. Written comments regarding conservation recommendations and expected economic and social impacts of implementation of the management plan shall be accepted by the Commission for a period of no less than 45 days following public notice.
(d) Final Commission action on the petition shall include:
1. Deletion of the species from Rule 68A-27.0021, F.A.C., if appropriate, and addition to and/or deletion from Rule 68A-27.003, 68A-27.004 or 68A-27.005, F.A.C., in accordance with the determination made in subsection (2) of this rule.
2. A determination on any proposed regulations in the management plan.

68A-27.002 Provision for Harassment of Endangered, Threatened and Species of Special Concern on Airport Property.
Species of birds and mammals protected in Rules 68A-27.003, 68A-27.004, and 68A-27.005, F.A.C., may be harassed on airport property as specified in subsection 68A-12.009(7), F.A.C., if aircraft safety and human lives are in imminent jeopardy.

68A-27.0021 Designation of Candidate Species; Prohibitions; Permits.
(1) The species in subsection (3) are hereby declared to be candidate species for inclusion in Rule 68A-27.003, 68A-27.004 or 68A-27.005, F.A.C.
(2) No person shall engage in direct take of any candidate species except as authorized by specific permit from the Executive Director.
(3) The following species are hereby declared to be candidate species: none.

68A-27.003 Designation of Endangered Species; Prohibitions; Permits.
(1) The following species, listed prior to June 23, 1999, are hereby declared to be endangered and shall be afforded the protective provisions specified. No person shall pursue, molest, harm, harass, capture, possess, or sell any of the endangered species included in this subsection, or parts thereof or their nests or eggs except as authorized by specific permit, permits being issued only when the permitted activity will clearly enhance the survival potential of the species.
(a) Pillar coral (*Dendrogyra cylindrus*)
(b) Blackmouth shiner (*Notropis melanostomus*)
(c) Okaloosa darter (*Etheostoma okaloosae*)
(d) Shortnose sturgeon (*Acipenser brevirostrum*)
(e) American crocodile (*Crocodylus acutus*)
(f) Green seaturtle (*Chelonia mydas*)
(g) Hawksbill seaturtle (*Eretmochelys imbricata*)
(h) Kemp's ridley seaturtle (*Lepidochelys kempii*)
(i) Leatherback seaturtle (*Dermochelys coriacea*)
(j) Striped mud turtle (*Kinosternon bauri*) (lower keys population only)

(k) Wood stork (*Mycteria americana*)
(l) Snail kite (*Rostrhamus sociabilis plumbeus*)
(m) Peregrine falcon (*Falco peregrinus*)
(n) Ivory-billed woodpecker (*Campephilus principalis*)
(o) Bachman's warbler (*Vermivora bachmanii*)
(p) Kirtland's warbler (*Dendroica kirtlandii*)
(q) Florida grasshopper sparrow (*Ammodramus savannarum floridanus*)
(r) Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*)
(s) Gray bat (*Myotis grisescens*)
(t) Indiana bat (*Myotis sodalis*)
(u) Florida mastiff bat (*Eumops glaucinus floridanus*)
(v) Silver rice rat (*Oryzomys argentatus*)
(w) Choctawhatchee beach mouse (*Peromyscus polionotus allophrys*)
(x) Perdido Key beach mouse (*Peromyscus polionotus trissyllepsis*)
(y) St. Andrews beach mouse (*Peromyscus polionotus peninsularis*)
(z) Anastasia Island beach mouse (*Peromyscus polionotus phasma*)
(aa) Key Largo cotton mouse (*Peromyscus gossypinus allapaticola*)
(bb) Key Largo woodrat (*Neotoma floridana smalli*)
(cc) Florida saltmarsh vole (*Microtus pennsylvanicus dukecampbelli*)
(dd) Lower Keys marsh rabbit (*Sylvilagus palustris hefneri*)
(ee) Florida manatee (*Trichechus manatus latirostris*)
(ff) Florida panther (Puma *concolor coryi*)
(gg) Key deer (*Odocoileus virginianus clavium*). No person shall feed Key deer (Odocoileus virginianus clavium) by hand or
by placing any food that serves to attract such species.
(hh) North Atlantic right whale (*Eubalaena glacialis*)
(ii) Fin whale (*Balaenoptera physalus*)
(jj) Sei whale (*Balaenoptera borealis*)
(kk) Humpback whale (*Megaptera novaeangliae*)
(ll) Sperm whale (*Physeter macrocephalus*)
(mm) Schaus' swallowtail butterfly (*Heraclides aristodemus ponceanus*)
(nn) Stock Island tree snail (*Orthalicus reses*)
(2) The Miami blue butterfly (*Cyclargus [= Hemiargus] thomasi bethunebakeri*), listed after June 23, 1999, is hereby declared
to be endangered, and shall be afforded the protective provisions specified in this subsection. No person shall take, harm, harass,
possess, sell, or transport any Miami blue butterfly (*Cyclargus [= Hemiargus] thomasi bethunebakeri*), or parts thereof or their
eggs, larvae or pupae except as authorized by permit from the executive director. Permits will be issued based upon whether
issuance would further management plan goals and objectives.

68A-27.004 Designation of Threatened Species; Prohibitions; Permits.
(1) The following species are hereby declared to be threatened, and shall be afforded the protective provisions specified.
(a) No person shall take, possess, transport, molest, harass or sell any of the threatened species included in this subsection or
parts thereof or their nests or eggs except as authorized by specific permit from the Executive Director, permits being issued only
for scientific or conservation purposes and only upon a showing by the applicant that the permitted activity will not have a negative
impact on the survival potential of the species.
1. Crystal darter (*Crystallaria asprella*)
2. Key silverside (*Menidia conchorum*)
3. Loggerhead seaturtle (*Caretta caretta*)
4. Bluetail mole skink (*Eumeces egregius lividus*)

5. Sand skink (*Neoseps reynoldsi*)
6. Key ringneck snake (*Diadophis punctatus acricus*)
7. Rim rock crowned snake (*Tantilla oolitica*)
8. Short-tailed snake (*Stilosoma extenuatum*)
9. Florida brown snake (*Storeria dekayi victa*) (lower keys population only)
10. Florida ribbon snake (*Thamnophis sauritus sackeni*) (lower keys population only)
11. Eastern Indigo snake (*Drymarchon corais couperi*)
12. Atlantic salt marsh water snake (*Nerodia clarkii taeniata*)
13. Bald eagle (*Haliaeetus leucocephalus*)
14. Southeastern American kestrel (*Falco sparverius paulus*)
15. Crested caracara (Caracara cheriway)
16. Florida sandhill crane (*Grus canadensis pratensis*)
17. Roseate tern (*Sterna dougalli*)
18. Least tern (*Sterna antillarum*)
19. White-crowned pigeon (*Columba leucocephala*)
20. Florida scrub jay (*Aphelocoma coerulescens*)
21. Snowy plover (*Charadrius alexandrinus*)
22. Piping plover (*Charadrius melodus*)
23. Big Cypress fox squirrel (*Sciurus niger avicennia*)
24. Florida black bear (*Ursus americanus floridanus*) (other than those found in Baker and Columbia counties or in Apalachicola National Forest or which are held in captivity under permit)
25. Everglades mink (*Mustela vison evergladensis*)
26. Southeastern beach mouse (*Peromyscus polionotus niveiventris*)

Specific Authority Art. IV, Sec. 9, Fla. Const. Law Implemented Art. IV, Sec. 9, Fla. Const. History–New 8-1-79, Amended

68A-27.005 Designation of Species of Special Concern; Prohibitions; Permits.

(1) The following species are hereby declared to be of special concern, and shall be afforded the protective provisions specified.

(a) No person shall take, possess, transport, or sell any species of special concern included in this paragraph or parts thereof or their nests or eggs except as authorized by Commission regulations or by permit from the executive director or by statute or regulation of any other state agency, permits being issued upon reasonable conclusion that the permitted activity will not be detrimental to the survival potential of the species.

(b) The following species were listed prior to January 1, 2001, and have been further categorized by the numbers in parentheses under the following criteria: (1) has a significant vulnerability to habitat modification, environmental alteration, human disturbance, or human exploitation which, in the foreseeable future, may result in its becoming a threatened species unless appropriate protective or management techniques are initiated or maintained; (2) may already meet certain criteria for designation as a threatened species but for which conclusive data are limited or lacking; (3) may occupy such an unusually vital or essential ecological niche that should it decline significantly in numbers or distribution other species would be adversely affected to a significant degree; (4) has not sufficiently recovered from past population depletion, and (5) occurs as a population either intentionally introduced or being experimentally managed to attain specific objectives, and the species of special concern prohibitions in Rule 68A-27.002, F.A.C., shall not apply to species so designated, provided that the intentional killing, attempting to kill, possession or sale of such species is prohibited.

1. Atlantic sturgeon (*Acipenser oxyrinchus*) (1)
2. Lake Eustis pupfish (*Cyprinodon variegatus hubbsi*) (1)
3. Saltmarsh topminnow (*Fundulus jenkinsi*) (1)
4. Rivulus (*Rivulus marmoratus*) (1)
5. Southern tessellated darter (*Etheostoma olmstedi maculaticeps*) (1)
6. Harlequin darter (*Etheostoma histrio*) (1)
7. Shoal bass (*Micropterus cataractae*) (1, 2)
8. Suwannee bass (*Micropterus notius*) (1)
9. Key blenny (*Starksia starcki*) (1)
10. Gopher frog (*Rana capito*) (1, 2)

11. Pine Barrens treefrog (*Hyla andersonii*) (1)
12. Florida bog frog (*Rana okaloosae*) (2)
13. Georgia blind salamander (*Haideotriton wallacei*) (1, 2)
14. Alligator snapping turtle (Macroclemys temminckii) (1)
15. Suwannee cooter (*Pseudemys concinna suwanniensis*) (1, 2)
16. Barbour's map turtle (*Graptemys barbouri*) (1, 2)
17. Gopher tortoise (*Gopherus polyphemus*) (1, 2, 3)
18. American alligator (*Alligator mississippiensis*) (1, 3)
19. Florida key mole skink (*Eumeces egregius egregius*) (1)
20. Red rat snake (*Elaphe guttata*) (lower keys population only) (1)
21. Brown pelican (*Pelecanus occidentalis*) (1)
22. Florida pine snake (*Pituophis melanoleucus mugitus*) (2)
23. Little blue heron (*Egretta caerulea*) (1, 4)
24. Osprey (*Pandion haliaetus*) (Monroe County population only) (1, 2)
25. Black skimmer (*Rynchops niger*) (1)
26. White ibis (*Eudocimus albus*) (2)
27. Snowy egret (*Egretta thula*) (1)
28. Reddish egret (*Egretta rufescens*) (1, 4)
29. Tricolored heron (*Egretta tricolor*) (1, 4)
30. Roseate spoonbill (*Platalea ajaja*) (1, 4)
31. Whooping crane (*Grus americana*) (5)
32. Limpkin (*Aramus guarauna*) (1)
33. American oystercatcher (*Haematopus palliatus*) (1, 2)
34. Burrowing owl (*Athene cunicularia*) (1)
35. Marian's marsh wren (*Cistothorus palustris marianae*) (1)
36. Worthington's marsh wren (*Cistothorus palustris griseus*) (1)
37. Scott's seaside sparrow (*Ammodramus maritimus peninsulae*) (1)
38. Wakulla seaside sparrow (*Ammodramus maritimus juncicolus*) (1)
39. Sherman's fox squirrel (*Sciurus niger shermani*) (1, 2)
40. Eastern chipmunk (*Tamias striatus*) (1)
41. Florida mouse (*Podomys floridanus*) (1)
42. Sherman's short-tailed shrew (*Blarina carolinesis [= brevicauda] shermani*) (2)
43. Homosassa shrew (*Sorex longirostris eionis*) (2)
44. Sanibel Island rice rat (*Oryzomys palustris sanibeli*) (1, 2)
45. Florida tree snail (*Liguus fasciatus*) (1)
46. Bluenose shiner (*Pteronotropis welaka*) (1, 2)
47. Black Creek crayfish (*Procambarus pictus*) (1)
48. Panama City crayfish (*Procambarus econfinae*) (1)
49. Sims Sink crayfish (*Procambarus erythrops*) (1)

(2) The following species, listed after January 1, 2001, are hereby declared to be of special concern, and shall be afforded the protective provisions specified.

(a) Flatwoods salamander (*Ambystoma cingulatum*). No person shall directly take any flatwoods salamander or parts thereof or their eggs except as authorized by Commission rule or by permit from the executive director.

(b) Red-cockaded woodpecker (*Picoides borealis*). No person shall take, harass, possess, sell, or transport any red-cockaded woodpecker or parts thereof or their eggs or their nests or dens except as authorized by permit from the executive director. Permits will be issued based upon whether issuance would further management plan goals and objectives.