Wekiva River and Rock Springs Run Pollutant Load Reduction Goals

Report to the Florida Department of Environmental Protection

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Executive Summary

The Wekiva Parkway and Protection Act of 2004 (Chapter 369, Part III, FS) required the St. Johns River Water Management District (SJRWMD) to develop Pollutant Load Reduction Goals (PLRGs) for the Wekiva Study Area (WSA, Figure 1). The major spring-fed ecosystems within the WSA are Wekiwa Springs, the Wekiva River, Rock Springs, and Rock Springs Run. It is for these systems that the SJRWMD developed PLRG recommendations. PLRGs are the reductions in pollutant loadings needed to meet water quality standards or goals. The development of a PLRG is a four-step process: 1) determine the nature and degree of impairment, 2) identify the causative pollutant(s), 3) determine the acceptable concentration of each causative pollutant, and 4) determine the reduction in loading required to achieve the acceptable concentration of each causative pollutant.

The SJRWMD designed a project to develop multiple lines of evidence for the PLRG: relevant information in the scientific literature; biological, chemical, and physical data for the Wekiva River and Rock Springs Run and reference (less impacted) streams; mesocosm studies in the Wekiva River and Rock Springs Run and reference streams; and data for other spring-fed streams in Florida. Two reference streams were used to aid the assessment of impairment: Alexander Spring Creek Run and Juniper Creek (Figure 2). This work indicates potential impairment of the Wekiva River and Rock Springs Run in terms of ecosystem processes, overgrowth of periphytic algae, dominance of the periphyton by Cyanobacteria (blue-green algae), and toxic effects on larvae of nitrate-sensitive aquatic organisms. Two causative pollutants create these potential effects: nitrate and total phosphorus (TP).

Two water quality standards apply to these effects: nutrients and toxicity. The standard for nutrients requires that they not cause an imbalance in flora and fauna (Chapter 62-302.530[48][b], FAC), such as algal blooms, changes in algal species richness or taxonomic composition, or presence of nuisance algal mats. State and Federal water quality standards require that any pollutant shall not be present at toxic levels (Chapter 62-302.530[62], FAC). Using these standards, there are several lines of evidence that the concentrations of nitrate and TP in the Wekiva River and Rock Springs Run are too high:

1) They are higher than in the reference streams and other less-impacted Florida springs and spring-run streams;
2) They are higher than historical data for springs and spring-run stream;
3) Various measures of ecosystem metabolism are altered in the Wekiva River and Rock Springs Run, as compared to the reference streams and these changes are correlated with higher concentrations of nitrate and TP;
4) In laboratory studies the growth of filamentous Cyanobacteria is accelerated by nitrate;
5) In field studies of other springs, the abundance and growth of epiphytes was correlated with TP;

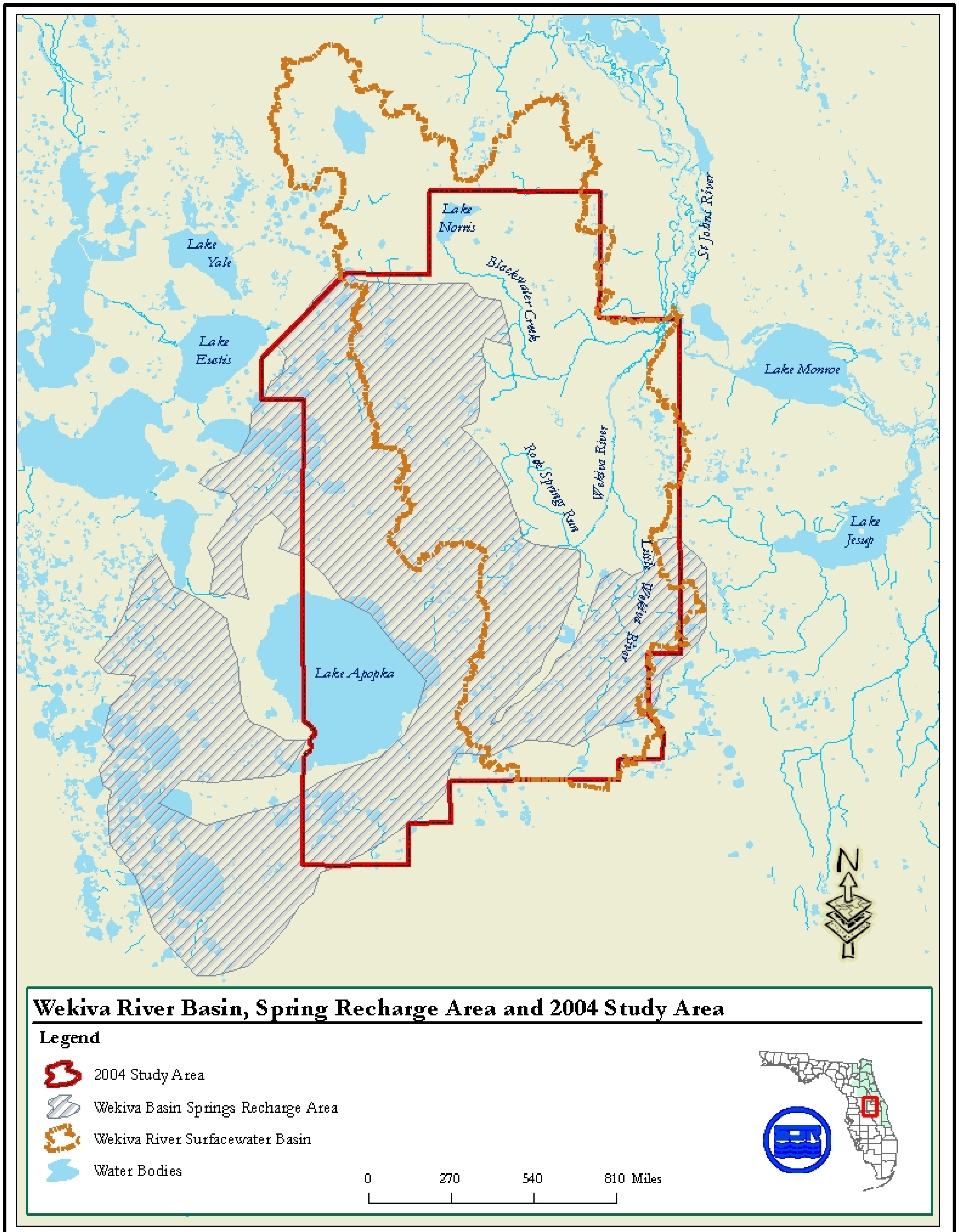

Figure 1 (Executive Summary). The Wekiva River basin, spring recharge area, and 2004 Wekiva Study Area. Source: SJRWMD data.

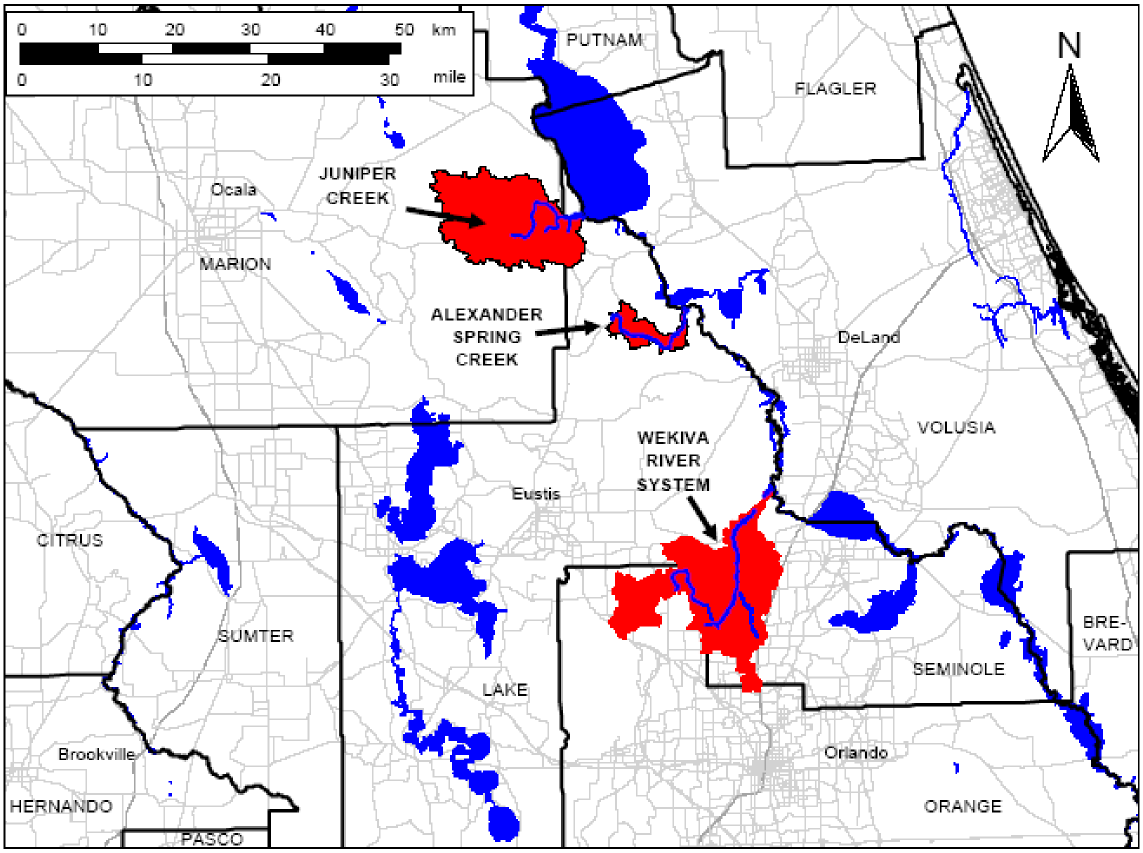

Figure 2 (Executive Summary). Location map showing the Wekiva River System (including the Wekiva River and Rock Springs Run) and the two reference spring-run streams; Alexander Spring Creek and Juniper Creek. Source: WSI, 2005 (Appendix C).

6) In the Wekiva River and Rock Springs Run , the relative abundance of Cyanobacteria and Chlorophyta (algae which are generally considered "nuisance" taxa) was higher in sites with higher TP;
7) Data from studies reported in the scientific literature indicate that nitrate is toxic to larvae of sensitive aquatic insects and amphibians at concentrations that have occurred in the Wekiva River and Rock Springs Run . Nitrate concentrations in the Wekiva River and Rock Springs Run have commonly exceeded estimated no-effects levels for these nitrate-sensitive aquatic organisms.

These observations lead to a variety of potential target concentrations for nutrients (Tables 1 and 2; Figures 3 and 4).

To reduce the potential for violation of water quality standards, the SJRWMD recommends that mean concentrations of nitrate and TP be reduced to 216 µg/L nitrate and 59 µg/L total phosphorus in the Wekiva River and 221 µg/L nitrate and 61 µg/L total phosphorus in Rock Springs Run. These concentrations include a margin-of-safety and were derived using statistical techniques that ensure a very low probability of exceeding thresholds that promote excessive or nuisance algal growth.

Impairment was also demonstrated for total coliform bacteria, which exceeded the state water quality standard. The SJRWMD recommends the state water quality standard of < 2,400 colonies/100 ml as the target concentration for total coliform bacteria.

In order to calculate PLRGs as percent reductions, pollutant concentrations were assumed to vary in direct proportion to the variation in pollutant loads. Thus, percent load reductions were assumed equivalent to the required percent reduction in concentrations:

$$\text{PLRG}(\%) = [(\text{cmc} - \text{tmc}) / \text{cmc}] \times 100,$$

Where cmc is the current mean concentration of the pollutant and tmc is the target mean concentration of the pollutant. This method yields load reductions for nitrate and TP ranging from 44 – 89% (Table 3). Reductions in total coliform counts were calculated based on EPA's percent-reduction method (Lehmensiek, 2005).

Spatial and temporal trends were considered in the calculation of PLRGs. Where there was a decreasing temporal trend, the cmc only reflected the recent period when there was no significant trend (i.e. data extending back from the present to that time when a non-significant trend became statistically significant). Spatial trends were also examined (from headspring to confluence with the next downstream system), and where appropriate, concentration reductions were applied to specific segments of each spring-run stream or to the entire stream.

Table 1 (Executive Summary). Potential nitrate-nitrite (NOx) concentration targets based on various lines of investigation.

Reference	Basis for Target	NOx (µg/L)	Statistic
Ecosystem metabolism in the Wekiva River and Rock Springs Run (WSI 2005)	Comparison to metabolism in less-impacted spring-run streams (Juniper & Alexander) Comparison to other springs in SJRWMD	100 - 200 200	Threshold Median
Nitrate toxicity to aquatic animals (Mattson et al. 2005)	90% probability of ≤1,400 µg/L (lowest toxicity threshold for caddisflies) Wekiwa Spring Rock Spring New thresholds after application of uncertainty factors 90% probability of <125 µg/L (lowest threshold with uncertainty factor): Wekiwa Spring Rock Spring	 1,200 1,240 125 - 140 108 111	 Mean Mean Threshold Mean Mean
Rainbow River algal bioassays (Cowell and Dawes 2004)	*Lyngbya wollei* biomass 90% probability of ≤ threshold of 250 µg/L: Wekiva River Rock Springs Run	300 – 600 216 221	Threshold Mean Mean
Suwannee River periphytic algae and nitrate levels (Hornsby et al. 2000)	Algal biomass Algal cell density	200 - 300 300	Threshold Threshold
Nutrients in Florida springs (WSI and DEP databases)	130 Florida springs, including impacted springs Juniper Spring, Fern Hammock Spring Alexander Spring	480 81, 90 51	Median Median Median
Nutrients in less-impacted spring-run streams in Florida (STORET database)	Juniper Creek Alexander Spring Creek Wacissa River	80 50 60	Median Median Median
Nutrients in undeveloped streams In the United States (Binkley et al., 2004; Clark et al. 2000)	Forested stream basins in the southeastern U.S. Undeveloped watersheds in the U.S.	180 87	Mean Median
EPA proposed TMDL for Wekiwa Spring and Rock Springs Run (USEPA 2005)	Comparison to Juniper Spring	110	Threshold
FDEP wastewater treatment criteria in the Wekiva Study Area (FDEP 2004)	Comparison to less-impacted Florida springs	200	Threshold

Table 2 (Executive Summary). Potential total phosphorus (TP) concentration targets based on various lines of investigation.

Reference	Basis for Target	TP (µg/L)	Statistic
Ecosystem metabolism in the Wekiva River and Rock Springs Run (WSI 2005)	Comparison to metabolism in less-impacted spring-run streams (Juniper & Alexander) Comparison to springs in SJRWMD	50-80 50	Threshold Median
% Cyanobacteria and Chlorophyta in attached algae in Wekiva River and Rock Springs Run (analysis of data from GreenWater Labs 2005)	90% probability of $\leq$ 90 µg /L (threshold for increased levels of cyanobacteria and chlorophyta in attached algal community): Wekiva River Rock Springs Run	 59 61	 Mean Mean
Mapping and monitoring of submerged aquatic vegetation in the Ichetucknee River headsprings (PBS&J 2004)	Epiphytic algal biomass	55	Threshold
Phosphorus in selected Florida springs in the 1950s (Odum 1953)	Springs outside of phosphatic areas Springs within phosphatic areas	45 61	Mean Mean
Nutrients in Florida springs (WSI and DEP databases)	130 Florida springs, including impacted springs Juniper Spring, Fern Hammock Spring Alexander Spring	40 34, 31 44	Median Median Median
Nutrients in less-impacted spring-run streams in Florida (STORET database)	Juniper Creek Alexander Spring Creek Wacissa River	23 44 44	Median Median Median
Nutrients in undeveloped streams in the United States (Clark et al. 2000)	Undeveloped watersheds in the U.S.	22	Median

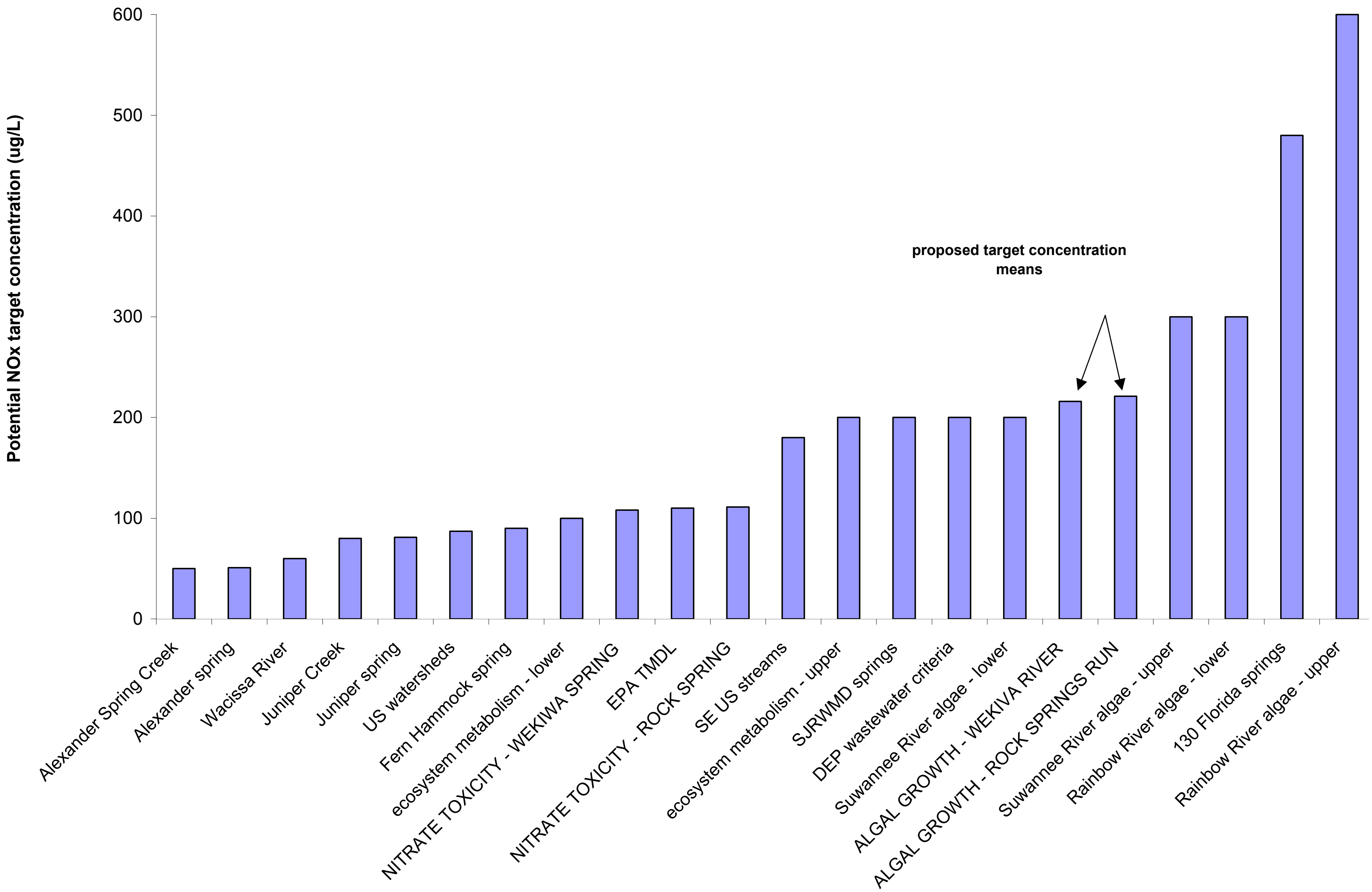

Figure 3 (Executive Summary). Potential and proposed nitrate targets based on Table 1.

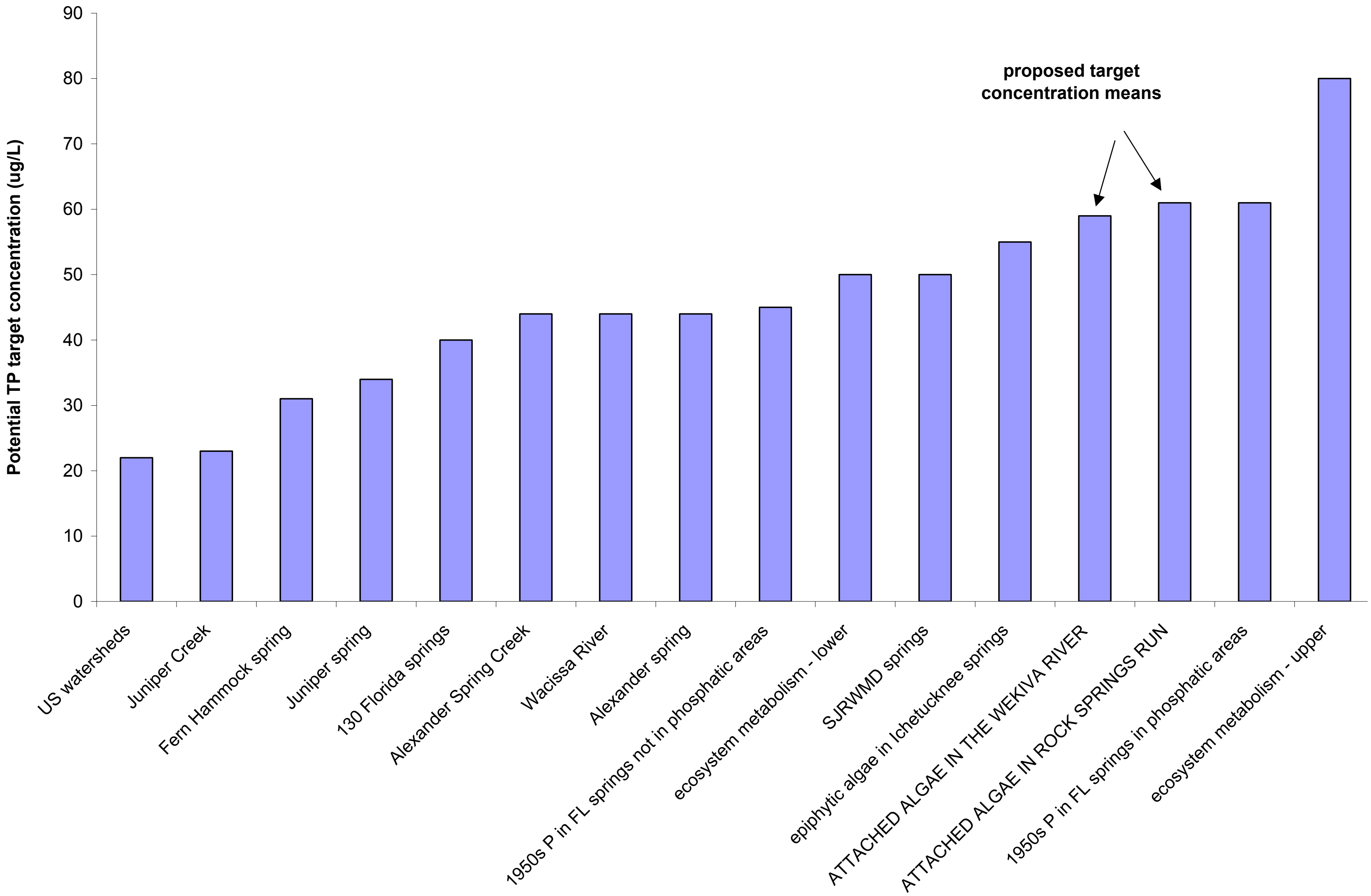

Figure 4 (Executive Summary). Potential and proposed total phosphorus targets based on Table 2.

Table 3 (Executive Summary). Recommended percent reductions in loading of nitrate, TP, and total coliform bacteria for the Wekiva River and Rock Springs Run.

	Nitrate	Total Phosphorus	Total Coliform Bacteria
Wekiwa Spring	82%	- - -	- - -
Upper Wekiva River (to Little Wekiva River)	69%	50%	49%
Lower Wekiva River (to Blackwater Creek)	36%	50%	30%
Rock Spring	85%	- - -	- - -
Rock Springs Run	52%	29%	50%

The recommended PLRGs are based on the best information available within the time frame required by the Wekiva Parkway and Protection Act. There was insufficient time to delineate seasonal and yearly fluctuations in biological conditions. Algal surveys and ecosystem metabolism studies in the Wekiva River and Rock Springs Run were conducted when there were significant impacts from the unusually strong hurricane season of 2004. Sediments had been eroded and deposited in new areas, vegetation had been buried and removed by scouring, and water quality was atypical. In addition to the problems associated with the short time frame for the work, an understanding of the influence of nutrient concentrations on the structure and function of spring-fed streams is still developing. These ecosystems have not been extensively studied, and much additional research is needed before they are as well understood as are lakes and wetlands. The potential for nitrate toxicity is also poorly known. Additional research is needed to decrease the uncertainty associated with the recommended PLRGs.

In recognition of the numerous sources of uncertainty, these PLRG recommendations should be considered provisional. Large safety margins were employed to ensure that the PLRGs will be protective. Additional research may allow these safety margins to be reduced, resulting in higher concentration targets than those currently proposed. This will reduce the pollutant load reductions required to meet these higher targets.

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LIST OF ACRONYMS AND ABBREVIATIONS

AFDW	-	ash free dry weight
cfs	-	cubic feet per second
EOG	-	Executive Office of the Governor
FAC	-	Florida Administrative Code
FCREPA	-	Florida Committee on Rare and Endangered Plants and Animals
FDEP	-	Florida Department of Environmental Protection
FNAI	-	Florida Natural Areas Inventory
FS	-	Florida Statutes
g	-	grams
IWR	-	Impaired Waters Rule
m^2	-	square meters
mi^2	-	square miles
MFL	-	Minimum Flows and Levels
mg/L	-	milligrams per liter
mgd	-	million gallons per day
MSJRB	-	Middle St. Johns River Basin
MSL	-	mean sea level
NOx	-	Nitrate-nitrite (NO_3/NO_2) – nitrogen
N	-	Nitrogen
P	-	Phosphorus
PLRG	-	Pollutant Load Reduction Goal
SCI	-	Stream Condition Index
SJRWMD	-	St. Johns River Water Management District
SR	-	State Road
SWFWMD	-	Southwest Florida Water Management District
SWIM	-	Surface Water Improvement and Management
TMDL	-	Total Maximum Daily Load
TP	-	Total Phosphorus
USEPA	-	U.S. Environmental Protection Agency
WBID	-	Water Body Identification
WQI	-	Water Quality Index
WRBCC	-	Wekiva River Basin Coordinating Committee
WSA	-	Wekiva Study Area

1 INTRODUCTION

The Wekiva River, its main tributaries (Rocks Springs Run, Little Wekiva River, and Blackwater Creek) and their 30 contributing groundwater springs (Figure 1-1) are resources of regional and statewide significance (Wekiva River Basin Coordinating Committee, 2004). Public conservation lands in the Wekiva River basin are some of the last remaining large natural areas in central Florida, a rapidly urbanizing region. The Wekiva River and its primary upstream tributary, Rock Springs Run, are classified by the Florida Natural Areas Inventory as spring-run streams and are considered imperiled in Florida.

1.1 Wekiva River Protection Area

Efforts to protect the Wekiva River basin began in 1988 when Governor Bob Martinez appointed the Wekiva River Task Force to recommend strategies to protect the Wekiva River basin (EOG #88-26). As a result of this group's work, the Florida Legislature passed the Wekiva River Protection Act (Chapter 369, Part II, Florida Statutes [FS]). The purpose of this Act was to protect the ground and surface water resources of the Wekiva River basin through establishment of a "Wekiva River Protection Area" within which local governments were required to meet additional criteria in their comprehensive land-use plans (established in the statute). The Legislature also amended the Water Resources Act (Chapter 373, Florida Statutes [FS]) to require development of Minimum Flows and Levels (MFL) for the river and development of a scientifically defensible buffer adjacent to the river and its tributaries (Chapter 373.415, FS). The Wekiva River Protection Act of 1988 also required development of basin-specific criteria for surface water management permits issued in the basin. Basin-specific criteria addressed drawdown of surface water, erosion control, riparian habitat protection zones, and local government authorization within the Wekiva River Protection Area.

1.2 Wekiva Parkway and Protection Act

In 2002, Governor Jeb Bush appointed the Wekiva Basin Area Task Force (EOG #2002-259) to make recommendations on the best route for a limited-access expressway to connect State Road (SR) 429 and Interstate 4 in Seminole and Orange Counties. The Task Force was directed to make protection of the Wekiva River ecosystem a priority. This group submitted a report to the Governor in January 2003. Governor Bush then appointed the Wekiva River Basin Coordinating Committee (WRBCC) to expand on the Task Force recommendations and develop implementation strategies (EOG #2003-112).

As a result of the recommendations of the WRBCC, the Florida Legislature passed the Wekiva Parkway and Protection Act in 2004 (Chapter 369, Part III, FS). One element instructed the St. Johns River Water Management District (SJRWMD) to develop Pollutant Load Reduction Goals (PLRGs) for the Wekiva Study Area:

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Figure 1-1. The Wekiva River system showing major tributaries and 30 contributing springs.

"By December 1, 2005, the St. Johns River Water Management District shall establish pollution load reduction goals for the Wekiva Study Area to assist the Department of Environmental Protection in adopting total maximum daily loads for impaired waters within the Wekiva Study Area by December 1, 2006" (Chapter 369.318 [8], FS)

The WRBCC identified the Wekiva River and its primary upstream tributary, Rock Springs Run, as high-priority for protection. Consequently, SJRWMD focused its initial efforts, beginning in the summer of 2004, on development of PLRGs for these two important spring-run streams. This report and its recommendations were prepared to address the PLRG requirements of the Wekiva Parkway and Protection Act.

1.3 Other Protective Designations

1.3.1 Surface Water Improvement and Management Program

The Wekiva River basin is part of SJRWMD's Surface Water Improvement and Management (SWIM) Program for the Middle St. Johns River Basin. The primary goal of the SWIM program is protection and restoration of aquatic resources of the Middle St. Johns River Basin (SJRWMD, 2002). Specific goals set forth in the Middle Basin SWIM plan include:

- To preserve natural and functional components of the ecosystem while restoring, where feasible, such conditions to the degraded portions of the system;
- To preserve, or where necessary restore, the quantity and quality of water necessary to support thriving biological communities, containing appropriate diversities of native species within the riverine and lacustrine systems of the St. Johns River Middle Basin;
- To pursue the development and implementation of stormwater management plans.

Developing PLRGs for the Wekiva River and Rock Springs Run implements goals stated in the Middle St. Johns River Basin SWIM Plan.

1.3.2 Outstanding Florida Waters

The Wekiva River is designated an Outstanding Florida Water (OFW; Chapter 62-302.700, Florida Administrative Code [FAC]). This designation is conferred on water bodies within state and federal conservation areas and that have exceptional recreational or ecological significance (Chapter 62-302.700 [5], FAC). An important rule requirement is that discharges to OFWs cause no degradation of water quality (Chapter 62-302.700[1], FAC).

1.3.3 Aquatic Preserve

The Wekiva River is in the Wekiva River Aquatic Preserve, first designated in June 1975 by the Florida Legislature. The Preserve includes the Wekiva River, Rock Springs

Run, portions of the Little Wekiva River and Blackwater Creek, and a portion of the Middle St. Johns River (added in 1985). Aquatic Preserves are areas of submerged land with exceptional biological, aesthetic, and scientific value (Chapter 258.36, FS). They are established and managed "for the purpose of being preserved in an essentially natural or existing condition so that their aesthetic, biological and scientific values may endure for the enjoyment of future generations" (Chapter 18-20.001 [2], FAC).

1.3.4 National Wild and Scenic River

Most recently, the Wekiva River and portions of its major tributaries were designated Florida's third National Wild and Scenic River system (U.S. House of Representatives Bill H.R. 3155). This is a federal designation applied to rivers considered worthy of protection due to their ecological and aesthetic attributes and recreational value. The Wild and Scenic designation imposes additional requirements for federal activity that may affect the river and is an additional designation that recognizes the environmental and recreational value of this river system.

1.4 Pollutant Load Reduction Goals

Pollutant Load Reduction Goals are defined as "the estimated numeric reductions in pollutant loadings needed to preserve or restore designated uses of receiving bodies of water and maintain water quality consistent with applicable state water quality standards" (Chapter 62-40.210 [20], FAC). The legal basis for PLRGs is found in state law.

- Chapter 373.016 (FS) indicates that it is state policy to "minimize degradation of water resources caused by the discharge of stormwater; and to preserve natural resources, fish, and wildlife . . ."

- The State Water Resource Implementation Rule (Chapter 62-40, FAC) indicates that it is state policy to "Restore and protect the quality of ground and surface water by solving current problems and ensuring high quality treatment for stormwater and wastewater." (Chapter 62-40.310 [2][a], FAC).

PLRGs are part of the Surface Water Improvement and Management (SWIM) planning process. They may also be developed as part of a watershed management plan or may be adopted as part of a basin-specific rule (Chapter 62-40.430 [5][d], FAC). For the Wekiva River and Rock Springs Run, PLRGs were developed as required by the Wekiva Parkway and Protection Act.

The PLRG process involves several steps:

1. Determine the nature and extent of impairments, if any.

Collect and analyze data to determine if the stream's designated-use is impaired because of a violation of water-quality standards and/or because of an imbalance of flora and fauna.

2. Identify the causative pollutants, if any.

Assess the degree to which pollutant(s) such as nutrients are the cause of impairment. Impairments may stem from factors other than pollutants, such as altered hydrology, physical damage to biota, exotic species, species losses, and altered bathymetry. Impairments such as these cannot be addressed by PLRGs.

3. Determine concentration of causative pollutants that will not result in impairments.

Identify concentrations of pollutants that are safely below the levels associated with impairment.

4. Calculate necessary pollutant load reductions.

Relate acceptable pollutant targets to pollutant concentrations, and where feasible calculate pollutant load reductions needed to meet the target concentration.

2 WEKIVA RIVER SYSTEM DESCRIPTION

The Wekiva River Study Area ("WSA"; Figure 2-1) was delineated by the WRBCC (2004) and encompasses 473 square miles. The word Wekiva (alternate spelling Wekiwa – which is applied to the spring itself) derives from the Seminole/Creek for "spring" or "spring of water" (Morris 1995). Human use of the river dates back about 12,000 years before present (Weisman 1993) when small groups of hunter-gatherers obtained freshwater, game, and fish from the river and its headspring, called Wekiwa Spring. Over the past century the river floodplain has served as a source of timber, and its springs as a respite for their "healing waters", with various resorts and spas nearby. The Wekiva River and Rock Springs Run and their headsprings currently provide a variety of recreational opportunities including canoeing, swimming, snorkeling, tubing, boating, and fishing.

2.1 Physiography and Geology

<u>Physiography</u>. The area that includes the Wekiva River surface water basin and "springshed" (the groundwater contributing area; Figure 2-1) lies within portions of the Marion Upland, Orlando Ridge, and Osceola Plain physiographic regions (Schmidt 1997). Land elevations range from a high of 175 feet above mean sea level (MSL) in the western part of the region to a low of 10 feet above MSL at the confluence of the Wekiva River and Blackwater Creek (WSI 2004). Five marine terraces in the region were formed by sediment deposition and reworking during periods of higher sea level (Schmidt 1997). Wekiwa Spring and Rock Springs appear to emerge at the base of the Penholloway Terrace, which exhibits about 40 feet of relief. In the western and southern portions of the region, the land is a series of high (>75 feet above MSL) terraces and ridges with well-draining sandy soils. In the eastern and northeastern portions of the region, land elevations are generally $\leq$ 25 feet above MSL with poorly draining wetland and flatwoods soils.

The region also lies within the Southern Coastal Plain ecoregion (Berndt et al. 1996) and encompasses two stream-type subecoregions (Griffith et al. 1994); the Eastern Florida Flatwoods and Central Florida Ridges and Uplands. The Eastern Flatwoods subregion is characterized by variable soils, ranging from moderately draining sandy soils of the flatwoods to poorly draining clay or muck soils of wetlands. The Central Ridges subregion is characterized by deep, moderate- to well-draining sands supporting sandhill, scrubby flatwoods, or scrub ecosystems.

<u>Geology and Hydrogeology</u>. The Wekiva River basin and springshed lie in a karst-influenced landscape. The top of the limestone unit bearing the Floridan Aquifer ('Floridan') lies 50 to 100 feet beneath land surface (Osburn et al. 2002). A generalized hydrogeologic framework of the region is presented in Table 2-1. This region of the SJRWMD is where the Floridan is at or near land surface (Osburn, et al. 2002). Many of the lakes in the region were likely formed from solution (sinkhole) processes. The karst nature of the area means that there is a high degree of interconnection between surface water and groundwater.

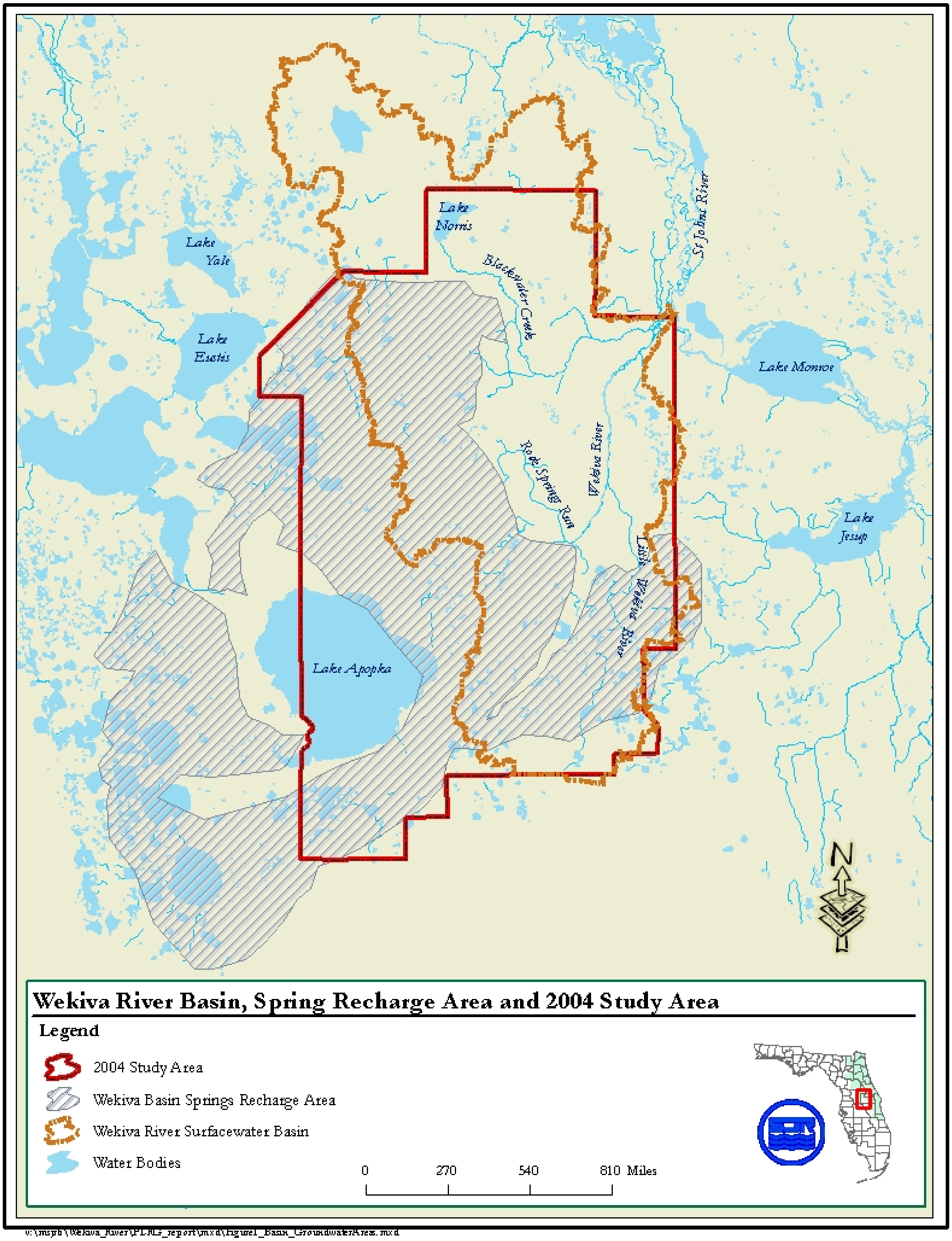

Figure 2-1. The Wekiva River basin, spring recharge area, and 2004 Wekiva Study Area. Source: SJRWMD data.

Table 2-1. Hydrogeologic framework for the Wekiva region (adapted from Osburn et al. 2002).

Hydrogeologic Unit	Epoch	Stratigraphic Unit
Surficial Aquifer System	Holocene and Pleistocene	Surficial sands and marine terrace deposits
Intermediate Aquifer System (or intermediate confining unit)	Pliocene	Undifferentiated deposits
	Miocene	Hawthorne Group
Floridan Aquifer System	Oligocene	Suwannee Limestone
	Eocene	Ocala Limestone
		Avon Park Formation
		Oldsmar Formation

The Floridan Aquifer is the main water source for springs that discharge to the Wekiva River and its tributaries (Toth and Fortich 2002; Osburn et al. 2002). Figure 2-2 shows the potentiometric surface of the Floridan Aquifer in the Wekiva region in 2002. Water flow is perpendicular to the contours of the potentiometric surface. The principal areas of rainfall recharge to the Floridan are in the western and southern portions of the region (Osburn et al. 2002), with recharge of up to 12" of rainfall annually. Much of the lengths of the Wekiva River and Rock Springs Run lie within the discharge zone of the Floridan Aquifer, resulting in a predominance of spring flow in these streams.

Water quality of the Floridan Aquifer in the Wekiva region is generally hard and high in dissolved calcium bicarbonate, reflecting the limestone matrix of the aquifer. Toth and Fortich (2002) identified areas of the Floridan aquifer in the region with elevated levels of nitrate, which they defined as >0.2 mg/L nitrate-nitrogen. Other sources (e.g., Scott et al. 2004 and references therein) define "natural background" for nitrate in the Floridan Aquifer as ≤0.05 mg/L.

2.2 Climate and Hydrology

Climate Characteristics. Climate in the region is subtropical. Mean annual air temperature is 72 degrees F, ranging from an average monthly high of 90-95 degrees F during the summer (August/September) to an average monthly low of 59-60 degrees F in winter (December/January). Rainfall across the region averages 51.5 inches annually (WSI 2004). The highest annual rainfall in the period of record is 75 inches and the lowest annual total is 30 inches (WSI 2004). The majority of the rainfall occurs between June and September in association with convectional thunderstorms. Highest monthly total rainfall in the region is about 7-8 inches, typically in August, and lowest is about 2-3 inches in April (Fernald and Purdum, 1998). WSI (2004) found no apparent long-term temporal trend in rainfall based on data from seven stations in or near the Wekiva River.

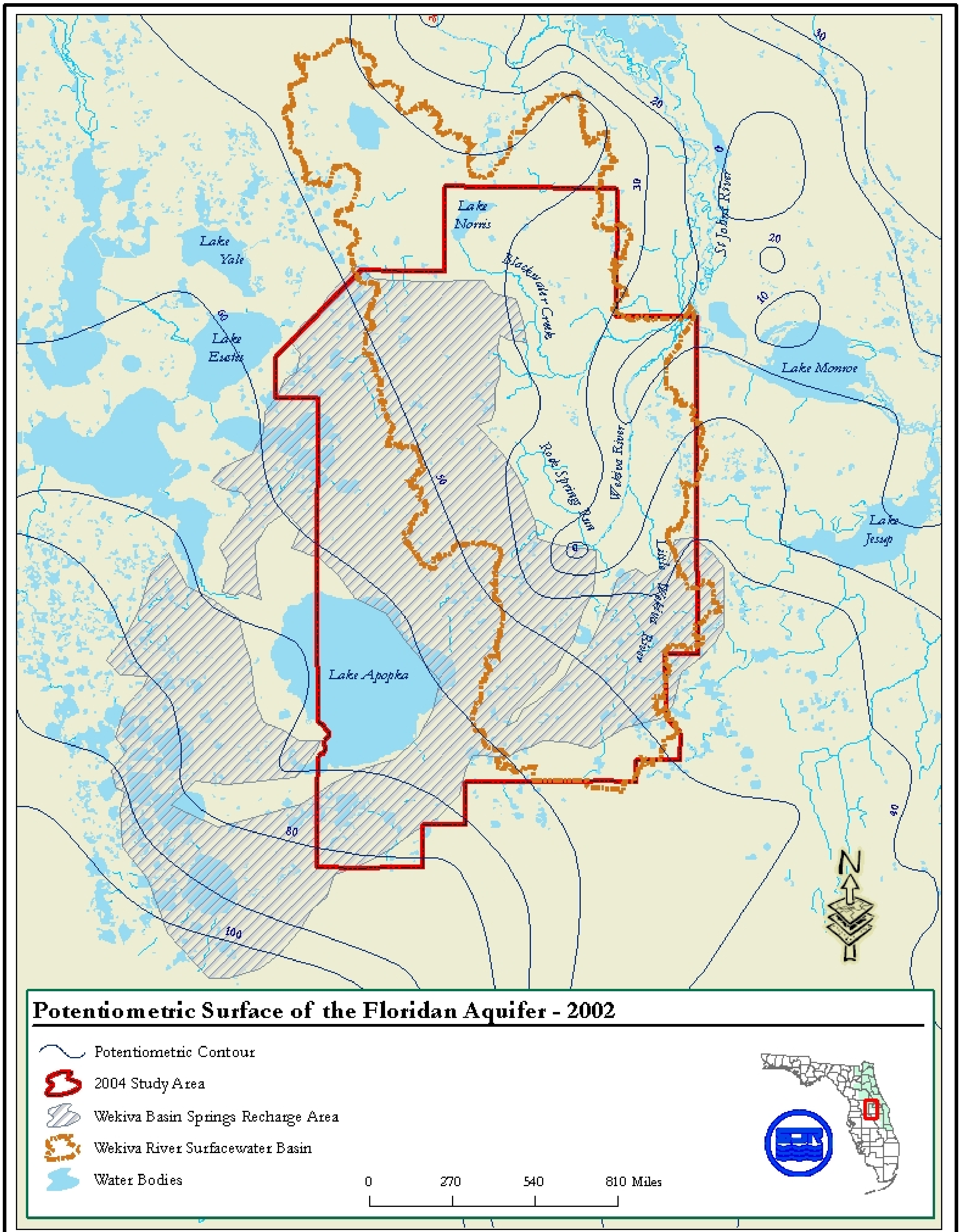

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Figure 2-2. Potentiometric surface of the Floridan Aquifer in the Wekiva Study Area. Source: SJRWMD data.

Hydrology of the Wekiva River and Rock Springs Run. Stream flows in the Wekiva River basin are derived from surface drainage from the watershed and groundwater inflow from the Floridan Aquifer. Location of springs and stream flow-gaging stations in the basin are shown in Figure 2-3. A summary of stream-flow characteristics for the Wekiva River and Rock Springs Run are shown in Table 2-2.

Spring inflow appears to account for a majority of base flow in the Wekiva River. Thirty springs have been identified in the Wekiva River basin (Figure 2-3). Mean flows in these springs range from 67.1 cfs (Wekiwa Spring) to <1cfs in a number of the smaller springs. All appear to be fed by the Floridan Aquifer (Toth and Fortich 2002; WSI 2004). Average flow of Wekiwa Spring, Rock Spring and Miami Spring total about 135 cfs (Hupalo et al. 1994). Using the 2-year/30-day low flow of 202 cfs as typical base flow in the river at SR 46 (10 miles downstream of Wekiwa Spring), spring flow represents at least 67% of the base flow of the Wekiva River. This figure is probably low because it does not include groundwater inflow from other springs and other base flow sources. FDEP (2003) stated that spring inflow accounted for 64% of the base flow of the Wekiva River. Because of the predominance of spring flow in these streams, water quality in the springs exerts a major influence on water quality in the spring-run streams.

Three tropical storm systems (Hurricanes Charley, Frances, and Jeanne) crossed the Wekiva basin in 2004, increasing flows in the Wekiva River (Figure 2-4) and Rock Springs Run. This caused atypically high flows and resulted in scouring of vegetation, higher water color due to leaching of tannins from the floodplain forests, and transfer of sediment.

Table 2-2. Summary of stream-flow characteristics for the Wekiva River and Rock Springs Run.

	Mean Flow (cfs)	**Median Flow (cfs)**	**Minimum Flow (cfs)**	**Maximum Flow (cfs)**
Wekiva River (at State Road 46)	290.7	253	105	2,060
Rock Springs (in Kelly Park)	60.1	59.2	48.2	72.1

2.3 Water Quality – Description, Status, and Trends

2.3.1 Water Quality Description

The Wekiva River and Rock Springs Run are hardwater streams with relatively high conductivity and alkalinity, indicating water rich in dissolved minerals (Table 2.3). Color increases downstream in the Wekiva River and Rock Springs Run due to inflow of surface water from the adjacent drainage area. During the course of these studies,

Figure 2-3. Location of springs and flow gaging stations in the Wekiva River system.

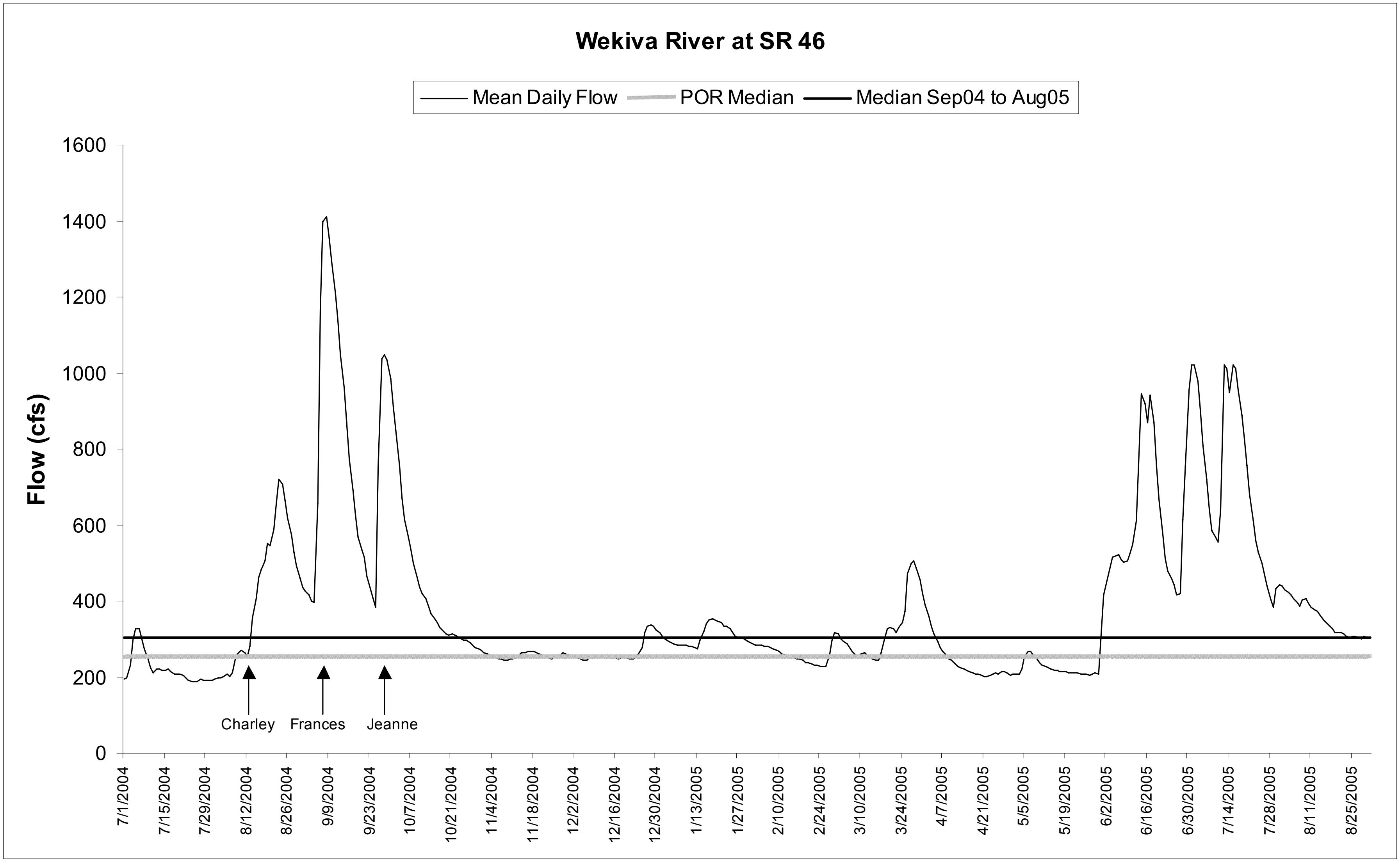


Figure 2-4. Mean daily flows in the Wekiva River prior to and during the studies conducted for the PLRG effort, showing median flows for the period of record (1935-2005), for the study period (Sept. 2004 to Aug. 2005), and dates of passage of hurricanes.

Table 2-3. Summary of water quality data from the Wekiva River and Rock Springs Run. Values are means of available data for the period of record indicated. Source: WSI 2004. e = estimated by adding TKN and NOx-N.

Analyte	**Wekiva River @ SR 46**	**Rock Springs Run above Wekiva River**
Period of Record	*1954-2003*	*1973-2003*
Conductivity (ɥmhos/cm)	624	244
pH (units)	7.42	7.31
Alkalinity (mg/L as $CaCO_3$)	94.9	86.6
Color (pcu)	61.5	203
Turbidity (NTU)	3.34	1.60
Dissolved O_2 (mg/L)	7.10	5.84
Total Organic Carbon (mg/L)	8.31	21.9
Total Nitrogen (mg/L)	1.25	1.68 e
Total Kjeldahl Nitrogen (mg/L)	0.632	0.896
NO_3/NO_2-N (mg/L)	0.578	0.784
Ammonia (mg/L)	0.045	0.047
Orthophosphorus (mg/L)	0.108	0.084
Total Phosphorus (mg/L)	0.141	0.118
Chlorophyll a - corrected (ɥg/L)	1.70	2.90
Fecal Coliform (#/100ml)	100	54.2
Total Coliform (#/100 ml)	1,351	1,649

water levels were high and subsequently color was high due to contribution of tannins from the floodplain forests. Nitrate levels in the headsprings are relatively high (1.4-1.5 mg/L) but decline downstream, probably due to a combination of dilution and biological uptake (WSI 2004). Rock Springs Run exhibits higher color and total organic carbon than the Wekiva River.

2.3.2 Water Quality Status and Trends

<u>FDEP Bioassessment</u>. FDEP conducted habitat assessments, water quality sampling, and macroinvertebrate and algal assessments for the Wekiva River and Rock Springs Run in 1999 as part of their Statewide Stream Bioassessment Program (FDEP 2000). Results indicated nitrate enrichment in both streams because nitrate concentrations exceeded those found in 95% of other Florida streams. Ammonia, total Kjeldahl nitrogen and total phosphorus levels approximated the statewide stream median.

Habitat Assessment scores at all sites in both streams fell within the optimum range for peninsular streams. Macroinvertebrate Stream Condition Index scores were all in the good or excellent range based on reference levels for peninsular streams (FDEP 2000). Average Algal Growth Potential (AGP) scores exceeded the “problem threshold”, indicating that nutrient levels were high enough to potentially support high levels of algal growth in both streams.

SJRWMD Water Quality Analysis. In 2004, SJRWMD staff analyzed water quality status and trends for the Wekiva River and Rock Springs Run using data from stations located in the spring-run streams. Water quality variables examined were water clarity (turbidity or Secchi depth), bacteria (total and fecal coliform), oxygen demand, dissolved oxygen levels, and nutrients. Water quality in the Wekiva River and Rock Springs Run was also compared to about 50 other springs in the SJRWMD.

For both the Wekiva River and Rock Springs Run, nitrate (NOx), and total phosphorus (TP) were high relative to springs in the SJRWMD, status was poor for nitrate and total coliform bacteria (based on FDEP criteria), and there was a degrading trend in total coliform bacteria in both streams (Table 2-4). Since the Outstanding Florida Waters designation for both streams, total coliform bacteria levels had degraded (=increased). For Rock Springs Run, nitrate had also degraded since OFW designation.

Table 2-4. Results of SJRWMD 2004 water quality analyses.

	Nitrate	**Total Phosphorus**	**Total Coliform Bacteria**
Wekiva River	high relative to springs in SJRWMD poor status	high relative to springs in SJRWMD	poor status degraded since OFW designation degrading trend
Rock Springs Run	high levels relative to springs in SJRWMD poor status degraded since OFW designation	high relative to springs in SJRWMD	poor status degraded since OFW designation degrading trend

SJRWMD staff conducted additional statistical analyses of water quality trends in 2005 with a more comprehensive data set than used in 2004. Total phosphorus decreased in both the Wekiva River and Rock Springs Run since 1974 (Figures 2-5 and 2-6), with decreases in both wet and dry seasons. Nitrate concentration decreased in the Wekiva River since 1984 (Figure 2-5) due to wet season decreases. Nitrate did not decrease in Rock Springs Run since 1984 (Figure 2-6) except during the wet season.

There were statistically significant decreasing downstream trends in nitrate concentration in both the Wekiva River and Rock Springs Run (Figures 2-7 and 2-8), which was evident in both the wet and dry seasons. These decreasing downstream trends in nitrate are partly due to dilution, but they also suggest that a considerable fraction of the nitrate load from the headsprings is being assimilated in the spring-run streams, with lesser amounts exported downstream to the St. Johns River. There was no downstream trend in total phosphorus in either stream (Figures 2-7 and 2-8), although Rock Springs Run showed an increasing downstream trend in total phosphorus during the wet season.

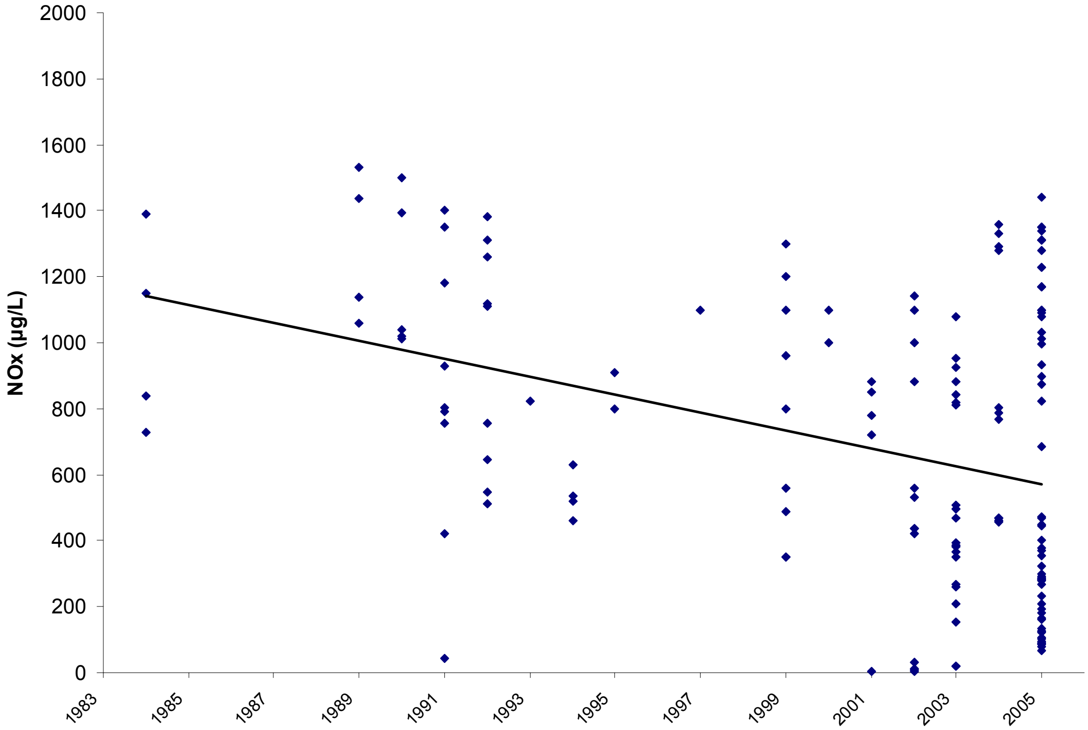
2.3.3 Water Quality Issues

Nitrate concentrations are elevated in many springs throughout Florida due to urban and agricultural development in the spring recharge areas (Florida Springs Task Force 2000; Scott et al. 2004; Osburn et al. 2002; Toth and Fortich 2002). Consequently, spring-run streams receive unnaturally high loads of nitrate, causing concern about potential impacts to aquatic flora and fauna. Recent observations of large amounts of algal growth in springs and spring-run streams, and perceptions that large amounts of algae constitute a “nuisance,” have led to speculation that elevated nitrate levels cause excessive algae growth, with possible detrimental impacts associated with this algal growth.

As a result of these concerns, the Wekiva Parkway and Protection Act directed FDEP to study and, if appropriate, initiate rulemaking for enhanced water quality and central wastewater treatment standards to achieve nitrogen reductions in surface water and groundwater. The Florida Department of Health was directed to study the effects of on-site waste disposal systems in the Wekiva Study Area, and if necessary to institute rulemaking to develop criteria to reduce nitrogen loading to surface and ground water from on-site systems. For these reasons, SJRWMD emphasized investigations into nitrates and algae growth in the PLRG development process.

2.4 Ecological Overview

<u>Natural Community Types</u>. Large portions of the Wekiva River basin are public conservation lands containing high quality natural communities. These are listed here and briefly described in Appendix A, using the Florida Natural Areas Inventory (FNAI) classification system (FNAI and FDNR 1990). Figure 2-9 shows natural community types based on the Florida Land Use, Cover and Forms Classification System (FLUCFCS). Natural community types include:



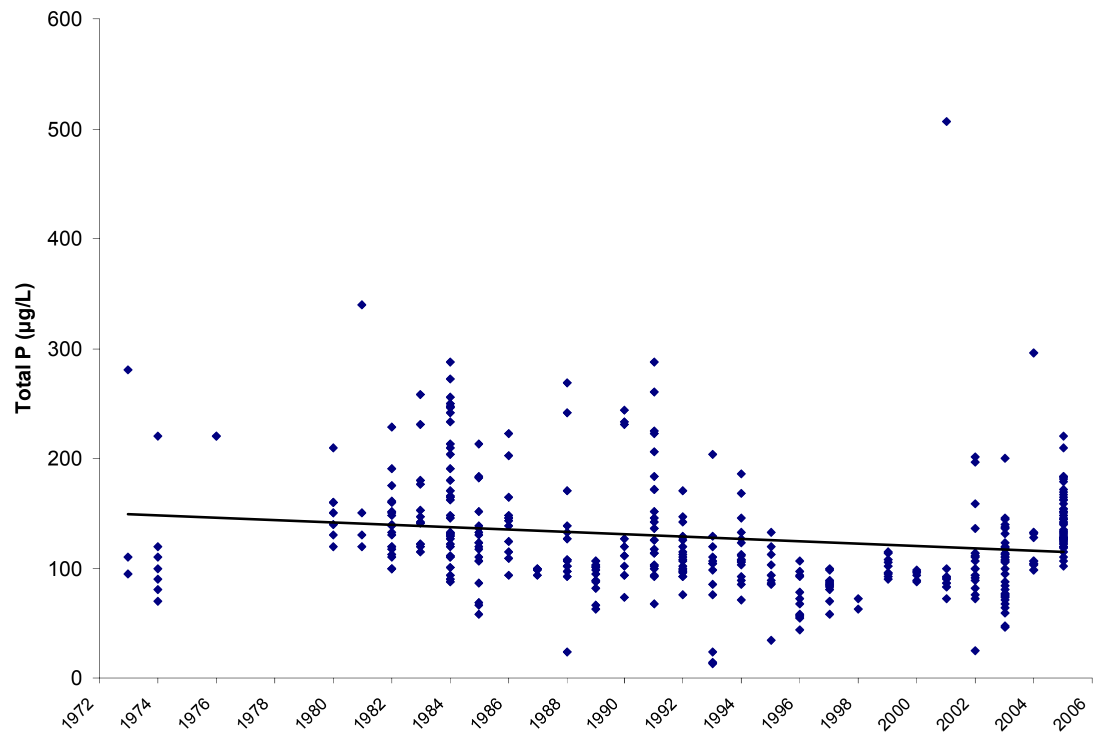


Figure 2-5. Temporal trends in nitrate and total phosphorus in the Wekiva River for the period of record. Line indicates statistically significant decreasing trend.

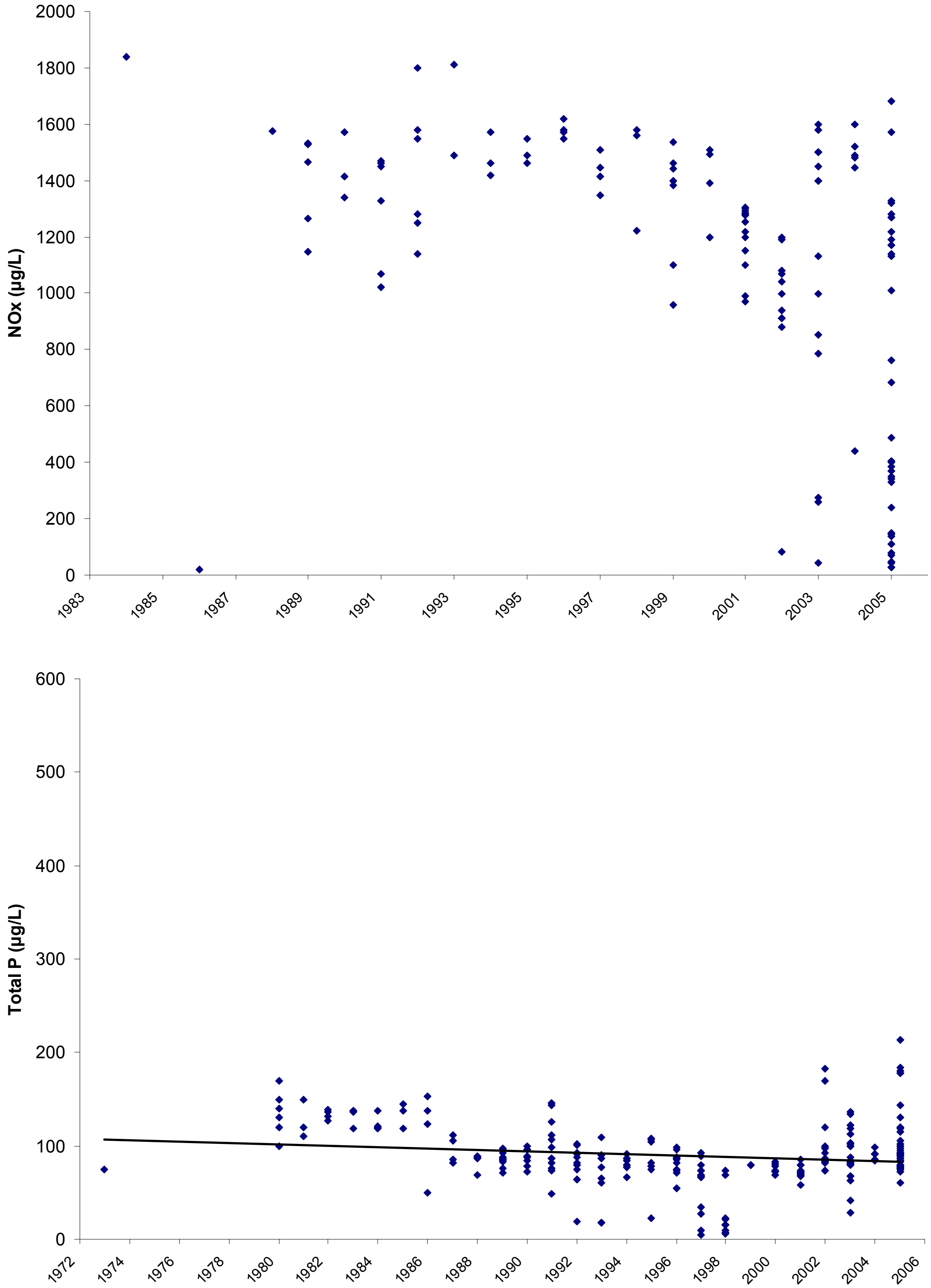
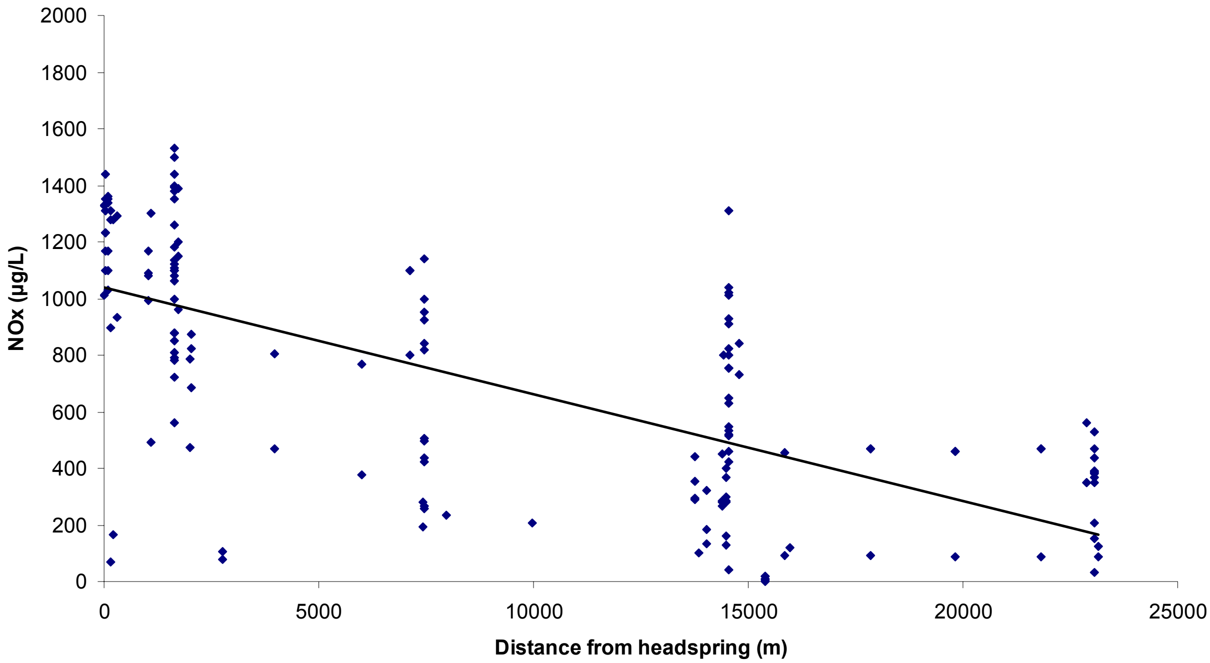


Figure 2-6. Temporal trends in nitrate and total phosphorus in Rock Springs Run for the period of record. Line indicates statistically significant decreasing trend.



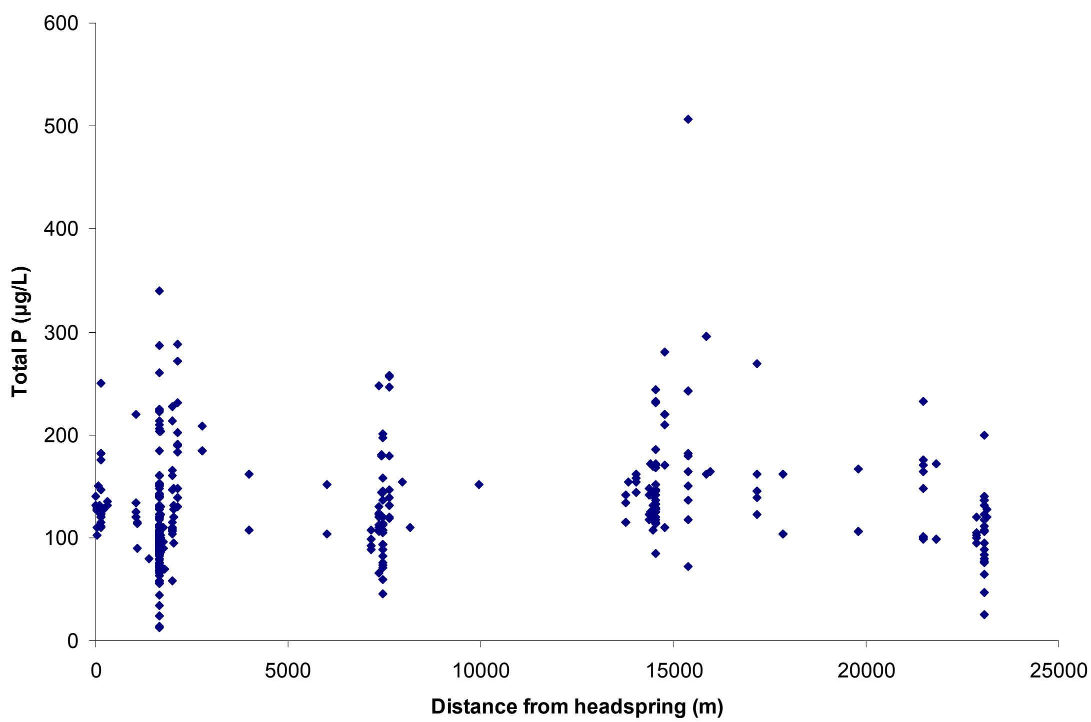
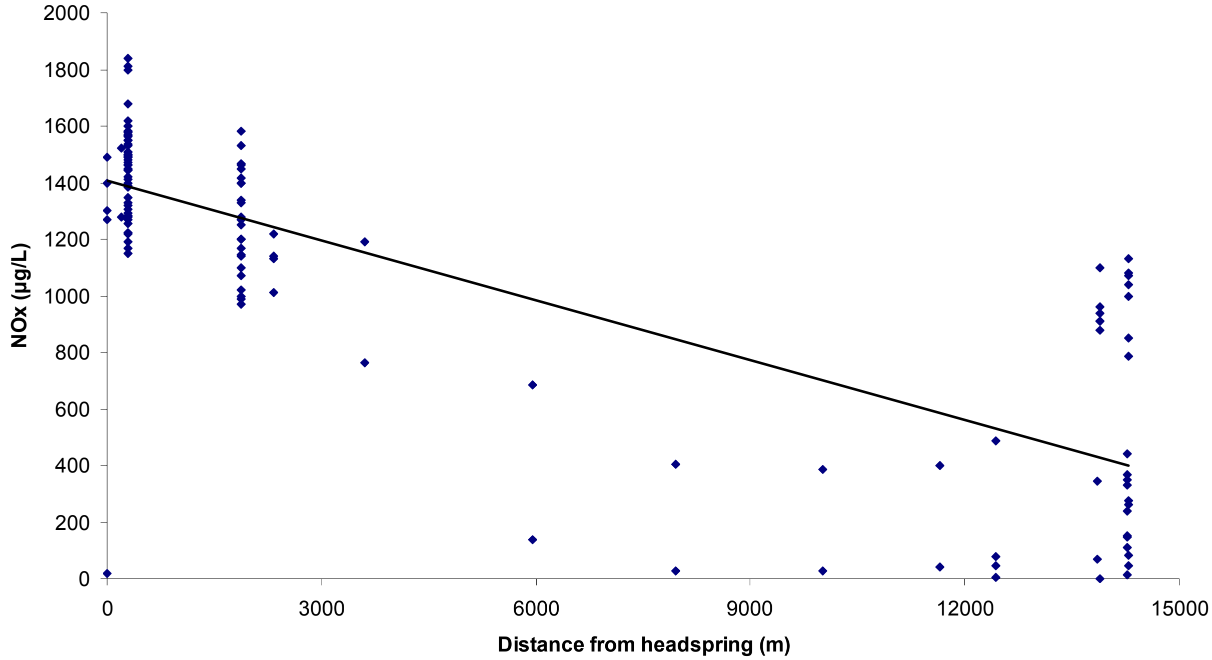


Figure 2-7. Spatial trends in nitrate and total phosphorus in the Wekiva River for the period of record. Line indicates statistically significant decreasing trend.



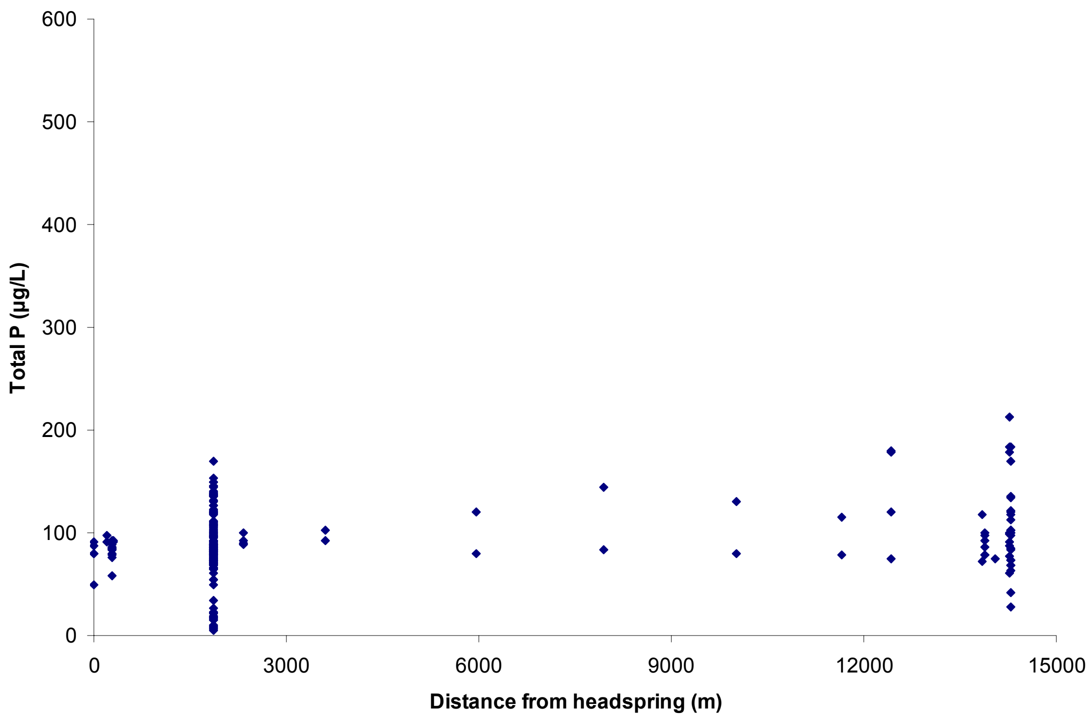


Figure 2-8. Spatial trends in nitrate and total phosphorus in Rock Springs Run for the period of record. Line indicates statistically significant decreasing trend

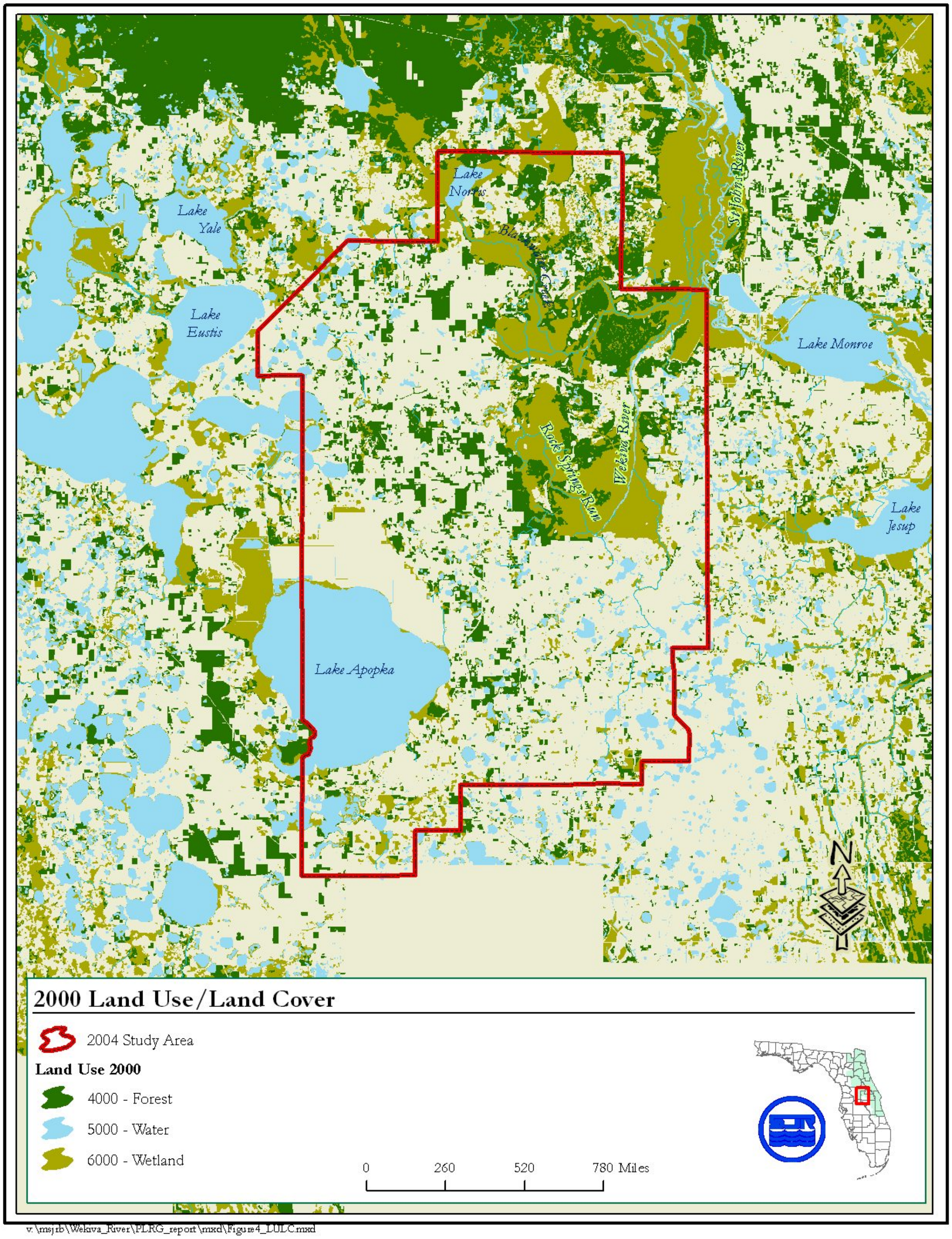


Figure 2-9. 2000 land use and land cover, showing forest and wetland areas in the Wekiva Study area.

Upland Communities (FLUCFCS '4000 – Forest')
Mesic Flatwoods
Scrubby Flatwoods
Sandhill
Scrub
Xeric hammock.
Upland hardwood or Upland mixed forest

Wetland Communities (FLUCFCS '6000 – Wetland')
Wet flatwoods
Floodplain swamp
Hydric hammock
Baygall
Freshwater marsh

Aquatic Communities (FLUCFCS '5000 – Water')
Spring-run stream
Blackwater stream
Clastic upland lake
Sandhill upland lake

Aquatic Habitats. Aquatic habitats in the Wekiva River and Rock Springs Run were described in FDNR (1987), Hupalo, et al. (1994) and the National Park Service (1999). Overall, there have been few detailed biological studies of these two spring-run streams, and currently there is no regular program of biological monitoring.

One of the principal aquatic habitats of the Wekiva River and Rock Springs Run are beds of submerged aquatic vegetation (SAV), primarily dominated by eelgrass, *Vallisneria americana* (WSI 2004; Canfield and Hoyer 1988). Other taxa of SAV present include spring-tape (*Sagittaria kurziana*), Brazilian elodea (*Egeria densa*), hydrilla (*Hydrilla verticillata*), variable-leaf milfoil (*Myriophyllum heterophyllum*), and sago pondweed (*Potamogeton pectinatus*). Associated with the SAV is a community of epiphytic algae growing attached to the leaves, which is a natural component of this habitat (Whitford 1956; Odum 1957). SAV beds provide important fish and macroinvertebrate habitat. Warren, et al. (2000) conducted macroinvertebrate surveys in SAV beds in the Wekiva River and found 127 taxa of invertebrates in these habitats. VanGenechten (1999) similarly found that SAV beds supported high fish densities compared to other habitats in the Wekiva River.

Submerged wood debris, generally referred to as "snag habitat", is a second important aquatic habitat. Studies in other southeastern coastal plain streams have documented the importance of wood snag habitat to macroinvertebrates and fishes (Benke et al. 1984; Benke et al. 1985). Warren et al. (2000) found a total of 163 taxa of macroinvertebrates on snag habitat in the Wekiva River. Many of these taxa are important components of the diet of redbreast and spotted sunfish (Benke et al. 1985), two important sportfish on the river.

Bare sediment (mud or sand) is a third major aquatic habitat type in the streams, and supports a diverse assemblage of macroinvertebrates. Warren et al. (2000) found highest total invertebrate taxa richness in this habitat in the Wekiva River (166 taxa). Invertebrate densities (#/m^2) were also high in this habitat. A number of fish taxa (catfish, sucker, and minnows) generally prefer to forage on bare sediments as opposed to vegetated habitats.

Areas of floating and emergent aquatic vegetation are a fourth aquatic habitat. Areas of floating vegetation (primarily pennywort, *Hydrocotyle* spp.) support diverse macroinvertebrate and abundant fish populations (Warren et al. 2000). However other areas of this habitat, particularly monospecific beds of cattail (*Typha* sp.), are poor habitat for invertebrates and fish.

Aquatic Fauna. Major groups of fauna on the Wekiva River and Rock Springs Run are benthic macroinvertebrates, fishes, herpetofauna (reptiles and amphibians) birds and mammals. Some of these taxa are, or tend to be, most associated with spring-run streams (Table 2-5).

Benthic macroinvertebrates include aquatic insects, mollusks, worms and crustaceans associated with aquatic habitats. Warren et al. (2000) collected a total of 268 invertebrate taxa in the Wekiva River, in 39 major taxonomic groups. Generally, the non-biting midges (Chironomidae) dominated the invertebrate diversity and abundance in most habitats. Mayflies (Ephemeroptera), caddisflies (Trichoptera), aquatic beetles (Coleoptera) and amphipods were the other abundant groups in the river. Eight taxa of hydrobiid snails (a group most frequently associated with springs and spring-run streams, with many endemics) were collected in this survey.

A total of 51 species of fishes are known to occur in the river. Dominant taxa, by abundance, include sunfish, shiners, and killifish (Walsh and Williams 2003; VanGenechten 1999; Canfield and Hoyer 1988). VanGenechten (1999) determined that mats of floating vegetation and SAV beds constituted some of the best fish habitat in the Wekiva River in terms of fish taxa richness or abundance. Water depth and velocity appeared to be more important than water temperature and dissolved oxygen in explaining fish community structure. VanGenechten (1999) compared his fish data to those collected by Canfield and Hoyer (1988) about 10 years earlier and found no major changes in fish communities of the Wekiva River.

We found few quantitative studies of other vertebrates (herpetofauna, birds and mammals) on the Wekiva River or Rock Springs Run. Aquatic Preserve staff have recently begun coordinating bird surveys in conjunction with volunteers (D. Shelley, Wekiva River Aquatic Preserve, personal communication).

Species of Conservation Interest. Four federally-listed species occur in the basin along with many state-listed species and other rare and endemic species (Table 2-6). Additionally, searches for ivory-billed woodpeckers from 1987-1992 included the Wekiva

Table 2-5. Taxa primarily associated with, or that reach high abundance in, spring-run streams. Adapted from Simons (1990) and Mattson et al. (1995). All taxa listed here are known to occur in the Wekiva River basin except (?), which are likely to occur in the basin.

		Spring-run Stream "Best Habitat"	Spring-run Stream "Good Habitat"
Plants			
Eelgrass	*Vallisneria americana*		XX
Springtape	*Sagittaria kurziana*	XX	
Chara	*Chara* spp.		XX
Invertebrates			
Siltsnails	Hydrobiidae (most freshwater taxa)	XX	
River horn snails	*Elimia* spp.	XX	
Apple snail	*Pomacea paludosa*		XX
Grass shrimp	*Palaemonetes paludosus*		XX
Mayfly	*Stenacron* spp.		XX
Mayfly	*Tricorythodes albilineatus*		XX
Aquatic butterfly	*Paraponyx* sp.		XX
Spiral-cased caddisfly (?)	*Helicopsyche* spp.	XX	
Fishes			
Longnose gar	*Lepisosteus osseus*	XX	
Florida gar	*Lepisosteus platyrhincus*	XX	
Golden shiner	*Notemigonus chrysoleucas*		XX
Redeye chub (?)	*Notropis harperi*	XX	
Coastal shiner	*Notropis petersoni*	XX	
Sailfin shiner	*Pteronotropis hypselopterus*	XX	
Channel catfish	*Ictalurus punctatus*	XX	
Seminole killifish	*Fundulus seminolis*	XX	
White catfish	*Ameiurus catus*	XX	

Table 2-5. Continued.

TAXON		Spring run "Best Habitat"	Spring run "Good Habitat"
Bluefin killifish	*Lucania goodei*		XX
Bluegill sunfish	*Lepomis macrochirus*		XX
Redear sunfish	*Lepomis microlophus*	XX	
Spotted sunfish	*Lepomis punctatus*	XX	
Amphibians			
River Frog (?)	*Rana heckscheri*	XX	
Reptiles			
American alligator	*Alligator mississippiensis*		XX
Florida snapping turtle	*Chelydra serpentina osceola*	XX	
Stinkpot	*Sternotherus odoratus*		XX
Loggerhead musk turtle	*Sternotherus minor minor*	XX	
Florida red-bellied turtle	*Pseudemys nelsoni*	XX	
Brown water snake	*Nerodia taxispilota*	XX	
Rainbow snake	*Farancia erytrogramma erytrogramma*	XX	
Birds			
Great blue heron	*Ardea herodias*		XX
Great egret	*Casmerodius albus*		XX
Little blue heron	*Egretta caerulea*		XX
Limpkin	*Aramus guarauna*	XX	
Wood duck	*Aix sponsa*		XX
Swallow-tailed kite	*Elanoides forficatus*		XX
Red-shouldered hawk	*Buteo lineatus*		XX
Barred owl	*Strix varia*		XX
Belted kingfisher	*Ceryle alcyon*	XX	

Table 2-5. Continued.

TAXON		Spring run "Best Habitat"	Spring run "Good Habitat"
Acadian flycatcher	*Empidonax virescens*		XX
Prothonotary warbler	*Protonotaria citrea*	XX	
Mammals			
Southeastern myotis (?)	*Myotis austroriparius*	XX	
Red bat	*Lasiurus borealis*	XX	
Seminole bat	*Lasiurus seminolus*		XX
Evening bat	*Nycticeius humeralis*	XX	
Florida manatee	*Trichechus manatus latirostris*		XX

Table 2-6. Listed and endemic taxa largely dependent upon aquatic and wetland habitats that occur in the Wekiva River system. U.S. = species officially listed under the Endangered Species Act; Florida = species listed by the State of Florida; FNAI = species listed by the Florida Natural Areas Inventory; FCREPA = species listed by the Florida Committee on Rare and Endangered Plants and Animals. See bottom of table for definitions of status designations.

TAXON		Endemic	U.S.	Florida	FNAI	FCREPA
Plants						
Needle palm	*Rhapidophyllum hystrix*			T		
Cardinal flower	*Lobelia cardinalis*			T		
Hand fern	*Ophioglossum palmatum*			E	S2	
Star anise	*Illicium parviflorum*	Y (?)		E	S2	
Invertebrates						
Wekiva springs hydrobe	*Aphaostracon monas*	Y			S1	T
Wekiva siltsnail	*Cincinnatia wekiwae*	Y			S1	
Rock springs siltsnail	*Cincinnatia petrifons*	Y				
Sanlando siltsnail	*Cincinnatia ponderosa* (extinct?)	Y			S1	
Seminole siltsnail	*Cincinnatia vanhyningi*	Y			S1	
Rock springs horn snail	*Elimia vanhyningiana*	Y				
Orlando cave crayfish	*Procambarus acherontis*	Y			S1	T
S.E. spinyleg dragonfly	*Dromogomphus armatus*				S3	R
Everglades sprite	*Nehalennia pallidula*	Y				SSC
Microcaddisfly	*Orthotrichia instabilis*					T
Triaenode caddisfly	*Triaenodes furcella*					T
Fishes						
Bluenose shiner	*Pteronotropis welaka*	Y		SSC		SSC
Reptiles						
American alligator	*Alligator mississippiensis*		T	SSC		

Table 2-6. Continued.

TAXON		Endemic	U.S.	Florida	FNAI	FCREPA
Birds						
Little blue heron	*Egretta caerulea*			SSC		SSC
Snowy egret	*Egretta thula*			SSC	S3	SSC
Great egret	*Ardea alba*					SSC
Tricolored heron	*Egretta tricolor*			SSC		SSC
Reddish egret	*Egretta rufescens*			SSC	S2	R
Limpkin	*Aramus guarauna*			SSC	S3	SSC
Yellow-crowned night heron	*Nyctanassa violacea*				S3	SSC
Black-crowned night heron	*Nycticorax nycticorax*				S3	SSC
White ibis	*Eudocimus alba*			SSC		SSC
Glossy ibis	*Plegadis falcinellus*				S3	SSC
Wood stork	*Mycteria americana*		E	E	S2	E
Florida sandhill crane	*Grus canadensis pratensis*	Y		T	S2/S3	T
Swallow-tailed kite	*Elanoides forficatus*				S2	T
Peregrine falcon	*Falco peregrinus*			E	S2	E
S. E. American kestrel	*Falco sparverius paulus*			T	S3	T
Bald eagle	*Haliaeetus leucocephalus*		T	T	S3	T
Mammals						
Florida black bear	*Ursus americanus floridanus*	Y		T	S2	T
Florida manatee	*Trichechus manatus latirostris*	Y	E	E	S2	E

E=Endangered; T=Threatened; SSC=Species of Special Concern; R=Rare; S1=critically imperilled in Florida because of extreme rarity or because of extreme vulnerability to extinction due to some natural or man-made factor; S2=imperilled in Florida because of rarity or because of vulnerability to extinction due to some natural or man-made factor; S3=either very rare and local in Florida or found locally in a restricted range or vulnerable to extinction from other factors.

River floodplain because these swamp forests were considered to be potential habitat for this endangered species (Jackson, 1996). In many cases, the water quality and habitat requirements of species of conservation interest are poorly understood in Florida, so the data do not exist to incorporate the needs of these taxa into this phase of PLRG development.

Another relevant conservation issue is the documented global decline in amphibian diversity (Stuart et al. 2004; Sparling et al. 2000). In many regions of the world, amphibian species are disappearing or their range is dramatically declining. Related to this is an apparent increase in the incidence of deformities in amphibians (Sparling et al. 2000). Mechanisms postulated for these include increasing levels of ultraviolet radiation due to degradation of the ozone layer, increased infestation of amphibian populations by parasites, toxicity from pesticides and other chemicals, and toxicity from nitrate due to fertilizer use (Marco et al. 1999; Rouse et al. 1999).

2.5 Surrounding Land Use

Current and past land use in the surface water drainage areas of the Wekiva River and Rock Springs Run were analyzed by WSI (2004). More intensive development (urban, suburban, and transportation) increased by about 350% between 1973 and 2000 (Table 2-7), with much of the change occurring between 1973 and 1990. Nitrogen isotope analyses conducted by SJRWMD to evaluate sources contributing nitrates to Wekiwa Spring and Rock Springs indicated a combination of organic (wastewater, manure, etc.) and inorganic (fertilizer) sources, attributed largely to urban development in the spring recharge area (Toth and Fortich 2002). Although high nitrate concentrations were measured in the Floridan Aquifer beneath agricultural lands in the western part of the contributing area, Toth and Fortich believed that leachate from those agricultural lands was not influencing nitrate levels in Wekiwa Spring and Rock Springs.

Table 2-7. Urban and developed land use in the surface drainage area of the Wekiva River and Rock Springs Run. Source: WSI 2004 (Appendix B).

LAND USE (acres)	1973	1990	1995	2000
Urban (including residential, commercial, & industrial)	4,390	15,010	16,090	17,492
Transportation & Utilities (roads, powerlines, water supply, sewage, and generating facilities)	42.5	483	526	612
Total drainage area	59,280	59,280	59,280	59,280
% urban and built up land	7.5%	26.1%	28.0%	30.5%

3 DISTRICT STUDIES CONDUCTED FOR PLRG DEVELOPMENT

Beginning in 2004, after passage of the Wekiva Parkway and Protection Act, SJRWMD contracted with private consultants to conduct investigations that would contribute to PLRG development for the Wekiva River and Rock Springs Run. District staff also reviewed scientific literature and analyzed water quality data. Information from these various lines of investigation was used to develop the pollutant concentration targets and related reductions recommended in this report. Following are brief descriptions of the objectives and methods of these concurrent efforts. Details can be found in the appendices.

3.1 Ecosystem Metabolism in the Wekiva River, Rock Springs Run, and in Reference Spring-run Streams

Wetland Solutions Inc. (WSI) was contracted by SJRWMD in summer 2004 to compile and summarize existing data and information for the Wekiva River and Rock Springs Run and to develop a work plan for rapid PLRG development. WSI's 2004 Work Plan Report is in Appendix B.

The purpose of the work plan was to provide a scientifically based approach for verifying whether nutrients are elevated in the Wekiva River and Rock Springs Run, and to document nutrient impacts, if any, on ecosystem metabolism of these spring-run streams. Work plan methods included:

1. Review and analysis of existing information on the Wekiva River and Rock Springs Run and similar reference spring-run streams to characterize a baseline for the streams' designated uses
2. Review of existing information and planning of focused studies to link specific nutrients to impaired conditions
3. Implementation of those studies and analysis of resulting data
4. Identification of nutrient reductions necessary to preserve or restore the Wekiva River and Rock Springs Run to an unimpaired condition.

Two "reference" spring-run streams were recommended to help determine background conditions for the Wekiva River and Rock Springs Run. These were Juniper Creek and Alexander Springs Creek, both less impacted, low-nutrient spring-run streams in nearby Ocala National Forest.

WSI was then contracted in fall 2004 to implement the Wekiva PLRG work plan. Impairment was evaluated by measuring ecosystem metabolism in upstream and downstream segments of the Wekiva River and Rock Springs Run and in comparable segments in Juniper Creek and Alexander Springs Creek, the two less impacted, reference spring-run streams in nearby Ocala National Forest. Tasks included:

1. Reconnaissance of the four spring-run streams
2. Water and nutrient mass-balance estimation for the four spring-run streams

3. Detailed ecological evaluation under conditions of differing nutrient availability in segments in the Wekiva River, Rock Springs Run, Juniper Creek and Alexander Spring Creek
4. Collection of ecosystem-level data (physical environment, water quality, plant communities, gross primary productivity, net primary productivity, ecological efficiency)
5. Analysis and interpretation of data to evaluate impairment

To identify pollutants of concern, ecosystem metabolism data from the Wekiva River and Rock Springs Run were compared to the reference streams to determine whether, and to what extent, nutrients affected ecosystem function. Water quality spatial trends were examined and compared to ecosystem data to look for onset of impairment. Nutrient concentrations and loads in the Wekiva River and Rock Springs Run were also compared to data from other Florida springs.

Existing pollutant loadings were estimated for the four spring-run streams . This analysis also considered assimilation rates of nutrients and used the two reference streams to determine acceptable nutrient targets. Existing pollutant loads causing impairment were determined by calculation of water and nutrient mass balances. Overall nutrient mass balance loads and assimilation rates were estimated for the Wekiva River, Rock Springs Run, Alexander Springs Creek, and Juniper Creek. Diffuse runoff and nutrient loading rates for land use mapped in the year 2000 were used to estimate external contributions. Spring flows and nutrient concentrations were used to estimate groundwater loads. Upstream-downstream load changes were used to estimate assimilation rates in each stream reach.

The relationship between pollutant loading rates and in-stream nutrient concentrations was determined using a simplified regression model relating nutrient mass loading rates to in-stream nutrient concentrations. This model includes estimated water and associated nutrient inputs from springs, non-point source runoff, tributaries, and from atmospheric inputs. Nutrient transformation rates were estimated from published reaction rates. Necessary pollutant load reduction was estimated as the difference between the existing pollutant load and the estimated load that will result in meeting the in-stream nutrient target, the concentration at which no impairment is likely to occur. Nutrient PLRGs were recommended for nitrate and total phosphorus, nutrient forms for which impairment is already occurring or for which impairment is considered to be likely in light of increasing trends in pollutant loading rates. Results of this work are presented in the pertinent sections of the PLRG Development chapter. Details on Wetland Solutions' 2005 work can be found in Appendix C.

3.2 Attached Algae in the Wekiva River and Rock Springs Run

GreenWater Labs Inc. was contracted to assess the distribution, composition and biomass of attached algae and to characterize habitats of attached algae in the Wekiva River and Rock Springs Run. A visual survey was conducted of attached algae in the Wekiva River and Rock Springs Run in 2004. Attached algae species composition, density and biomass were analyzed from 15 sites in Wekiwa Spring and the Wekiva River and 9 sites from Rock Springs and Rock Springs Run in winter 2004/05 and summer 2005. Algae were described and collected from various substrates (vegetation, rocks, and wood) at regular intervals along the streams. Algae growing on the sediment surface were not sampled. Field water quality parameters were measured concurrent with algal sampling, and water quality samples were collected for laboratory analysis. Results of this work are presented in the pertinent sections of the PLRG Development chapter. Details on this work can be found in GreenWater's report in Appendix D.

3.3 SJRWMD Review of Literature and Data

SJRWMD staff conducted additional reviews of the scientific literature and analysis of available data to augment the contracted PLRG development work described above. Objectives and methods are summarized here. Results will be summarized in the upcoming PLRG Development chapter. Details for most of these efforts can be found in the appendices. Those not included in the Appendices can be obtained via the internet (URL links provided in the Literature Cited section) or are available from the scientific literature.

3.3.1 Nitrate Toxicity to Aquatic Animals

SJRWMD staff (Mattson et al. 2005) conducted a review of the scientific literature on nitrate toxicity to determine threshold levels of nitrate that have been demonstrated (experimentally or with field surveys) to cause adverse lethal or sub-lethal effects to aquatic animals. Toxicity values gleaned from the literature were in most cases derived from short-term acute laboratory assays. Uncertainty factors are a means of accounting for various sources of uncertainty, extrapolation from short-term laboratory results to long-term effects in the field, from one species to others, and from lethal thresholds to sublethal thresholds (Newman and Unger 2003). Uncertainty factors were applied to the literature-derived toxicity values to estimate protective threshold concentrations for nitrate. Details on this literature review and data analysis can be found in Appendix E.

3.3.2 Coliform Bacteria Impairment

SJRWMD staff (Lehmensiek 2005) analyzed water quality data collected by Orange County from 1997 through 2005 to determine if the Wekiva River and Rock Springs Run were impaired for total and fecal coliform bacteria levels according to numeric criteria in the Impaired Waters Rule (Chapter 62-303, FAC). Reductions in total coliform counts were calculated based on EPA's percent-reduction method. Details on this coliform assessment can be found in Appendix F.

3.3.3 Total Phosphorus Thresholds for Attached Algae Growth

SJRWMD conducted additional analysis of the attached algae data collected by GreenWater Labs (2005) in the Wekiva River and Rock Springs Run to evaluate whether there was a relationship between phosphorus and the occurrence and proportion of algae generally considered to be “nuisance” taxa. These are primarily taxa in the Cyanobacteria and green algae (Chlorophyta). This additional analysis was prompted by the findings in the Upper St. Johns River basin (Keenan et al. 2003), which found that increased phosphorus accounted for increased biovolume of Cyanobacteria. The analysis is described in Appendix G

3.3.4 Rainbow River Algal Bioassays

The University of South Florida (Cowell and Dawes 2004) conducted laboratory assays for the Southwest Florida Water Management District (SWFWMD), examining nitrate levels and growth of the cyanobacterium, *Lyngbya wollei,* from the Rainbow River, a spring-run stream in western Marion County.

3.3.5 Suwannee River Algae and Nutrients

The Suwannee River Water Management District (Hornsby et al 2000) collected long-term (3 -10 years) quarterly data on periphyton in the Suwannee River and its major tributaries, concurrent with water chemistry sampling. These data were analyzed to evaluate relationships between algal abundance (as cell density and ash-free dry weight biomass) and nitrate. Relevant excerpts from their report are found in Appendix H.

3.3.6 Nutrients in Less-Impacted Spring-Run Streams and in 130 Florida Springs

Existing nitrate and total phosphorus data were retrieved from STORET for three Florida spring-run streams (Juniper Creek, Alexander Springs Creek, Wacissa River) considered to be less-impacted due to minimal urban and/or agricultural development in their springsheds, and for 130 Florida springs, including impacted springs. These data were analyzed and compared to the Wekiva River and Rock Springs Run. Results of these analyses are in Appendix I.

3.3.7 Nutrients in Undeveloped Streams in the United States

Clark et al. (2000) analyzed various forms of nitrogen and phosphorus and their yields from 85 sites representing relatively undeveloped watersheds in the continental U.S. Their data came from various U.S. Geological Survey water quality assessment programs conducted between 1990-1995. Binkley et al. (2004) extracted data from the published literature on nitrogen and phosphorus concentrations in 300 streams draining largely forested watersheds in the U.S. They examined regional and nationwide spatial trends in water quality using these data.

3.3.8 Nitrate Targets for EPA’s TMDL

The U.S. Environmental Protection Agency (USEPA 2005) issued a final Total Maximum Daily Load (TMDL) for nitrate in the Wekiwa Spring and Rock Springs Run in December 2005, as required by a Consent Decree. The TMDL was based on comparison with Juniper Spring, a less-impacted lower-nutrient spring-run stream in

Ocala National Forest. A target concentration was selected based on the 90th percentile level of nitrate for Juniper Spring. The URL link to this report is listed in the Literature Cited section.

3.3.9 Total Phosphorus and Epiphytic Algae in Ichetucknee Springs

A contractor for Suwannee River Water Management District sampled epiphytic algae and water quality in headsprings contributing to the Ichetucknee River, a spring-run stream in Columbia County, Florida (PBS&J 2004). The relationship between nitrogen and phosphorus and algal biomass (as mg chlorophyll a per gram wet weight of host plant) was examined. Relevant excerpts from the final report from this effort are in Appendix J.

3.3.10 Phosphorus in Florida Springs in the 1950's

The University of Florida (Odum 1953) collected phosphorus data from a variety of surface and ground waters in Florida (including springs) in the early 1950's prior to more intensive agricultural and urban land use changes in many springsheds. These data were evaluated to determine potential historic or background conditions of phosphorus in springs.

3.3.11 Nitrate Targets for FDEP's Wastewater Treatment Criteria

FDEP (2004) proposed a nitrate concentration target for development of enhanced central wastewater treatment standards and criteria for the Wekiva Study Area, as mandated by the Wekiva Parkway and Protection Act. This target was based on comparison with nitrate levels in less developed spring-run streams such as Juniper Creek, Alexander Springs Creek, and Silver Glen Run (C. Ferraro, FDEP Central District, personal communication; R. Drew, FDEP Tallahassee, personal communication). The URL link to this report is listed in the Literature Cited section.

4 PLRG DEVELOPMENT

To briefly reiterate, the steps followed in this PLRG development process are:

1. Identify the nature and extent of impairments, if any;
2. Identify causative pollutants, if any;
3. Determine acceptable concentrations of causative pollutants;
4. Calculate necessary pollutant load reductions.

The various investigations described in Chapter 3 each contributed to one or more of these steps. Key results of these investigations are briefly summarized in the following sections. Detailed reports for most of these efforts are in the Appendices. Prior to presentation of the findings, however, is a discussion of issues involved in identifying impairment and in defining nuisance algae.

4.1 Determining Impairment

Surface-water quality in Florida is managed by assigning “designated uses” (Chapter 62-302.530, FAC). The Wekiva River and Rock Springs Run have a designated use of Class III, meaning they are managed for “recreation, propagation of a healthy, well-balanced population of fish and wildlife”. A water body must meet a set of water quality standards specific to its designated use. If it does not meet those standards, it is considered impaired. Chapter 62-303, FAC (Identification of Impaired Surface Waters) establishes the criteria by which the State of Florida identifies impaired water bodies. An impaired water is defined in this rule as:

“a water body or water body segment that does not meet its applicable water quality standards as set forth in Chapters 62-302 and 62-4, FAC, as determined by the methodology in Part III of this chapter, due in whole or in part to discharges of pollutants from point or nonpoint sources.” (Chapter 62-303.200[6], FAC)

Water bodies are placed on FDEP’s Verified List of Impaired Waters if:

- any of the water quality criteria listed in Chapter 62-302, FAC have exceedances surpassing a threshold (based on eligible data) with at least a 90% level of confidence that the actual exceedance frequency is $\geq$10%;
- the water body fails a bioassessment, conducted using one of the department-approved methods (SCI, BioRecon, or LCI);
- acute or chronic toxicity is determined;
- a determination is made that there is a violation of the narrative nutrient criterion in the Class III water quality standards. For streams, this determination is made if: (1) algal mats are present in sufficient quantities to “pose a nuisance” or “hinder reproduction of a threatened or endangered species”, and/or (2) annual mean chlorophyll-a levels are >20 µg/L or have increased by more than 50% over “historical values” for “at least two consecutive years”. The rule also notes, however, that “Other information indicating an imbalance of flora or fauna due to

nutrient enrichment, including, but not limited to, algal blooms, excessive macrophyte growth, decrease in the distribution (either in density or areal coverage) of seagrasses or other submerged aquatic vegetation, changes in algal species richness, and excessive diel oxygen swings, shall also be considered." (Chapter 62-303.350[1], FAC);

- the water body was subject to swimming area closures due to exceedance of primary contact bacteriological quality;
- the water body is under a fish or shellfish consumption advisory;
- the water body is used as a source of drinking water and exceedances of human health-based water quality criteria are demonstrated.

Water bodies placed on this Verified List of Impaired Waters are then subject to the development of Total Maximum Daily Loads (TMDLs).

4.1.1 FDEP Assessment of Impairment

FDEP conducted a water quality assessment of the Wekiva River and its tributaries as part of its process to identify impaired water bodies in the Middle St. Johns River Basin (MSJRB). FDEP is required by the federal Clean Water Act to develop and implement TMDLs for these water bodies to reduce or eliminate impairment caused by pollution. The assessment of the MSJRB (FDEP 2003) considered water quality, biological and fish tissue data collected between 1991 and 2000. Water quality criteria analyzed were metals, chlorophyll-a, dissolved oxygen (DO), fecal and total coliforms, pH and unionized ammonia. Additional information from the FDEP Bioassessment program and fish tissue data/consumption advisories were also considered. See the FDEP website (link listed in Literature Cited) for a copy of the MSJRB Assessment Report. Based on their criteria and analysis, FDEP does not consider the Wekiva River and Rock Springs Run to be impaired for any constituent.

4.1.2 SJRWMD Analysis of Impairment

Impairment has to be scientifically demonstrated and causal pollutants identified before PLRGs can be developed. Consequently SJRWMD work focused on determining if the Wekiva River and Rock Springs Run are impaired according to criteria not considered by FDEP in their standard water-quality assessments described above. The broad range of issues that were considered in making a determination of impairment are listed in Table 4-1.

Consideration of numeric water quality criteria is relatively straightforward – if numeric criteria are violated due to anthropogenic effects, then there is impairment. Consideration of ecological factors (e.g., ecosystem processes and biological communities) can be more difficult, particularly since the state standard for nutrients is narrative (Chapter 62-302.530 (48): "In no case shall nutrient concentrations of a body of water be altered as to cause an imbalance in natural populations of aquatic flora and fauna." In some instances, such as impacts on populations of a listed species, there is a clear legal threshold that permits a finding of imbalance and impairment. In other

Table 4-1. Issues that were considered in determining impairment of the Wekiva River and Rock Springs Run.

Water Quality	Comparison to Class III standards Comparison to "typical values" for other spring-run streams (or to reference spring-run systems) Evaluate against OFW standard (i.e., degrading trends) Toxicity to animals
Ecosystem Processes (production, respiration, etc.)	Imbalance considerations (what's "natural" for a spring-run stream?) Important limiting nutrients/nutrient thresholds for algal production Stream metabolism Comparison to other spring-run systems
Habitats/Communities/Populations	Habitat alterations due to algal growth Invertebrate and or fish community impacts Aquatic macrophyte communities (aquatic plant management) Impacts on listed species Disruption by non-native species Changes in taxa composition of algal community (increased proportion of "undesirable" taxa)
Recreation/Aesthetics	"Nuisance" algae (interference with recreational use; odors; visual impacts) Fishery impacts
Human Health	Coliform levels/Swim area closures Algal toxicity/allergic reactions
Hydrology	Potential changes in flows and levels (frequency, duration, magnitude) Interactions with established MFL for the Wekiva River

cases (alterations in species composition of algal or benthic communities, impacts on sportfish habitat), a scientific judgment regarding what constitutes a balanced biota must be made. Florida law defines the natural background condition as “the condition of waters in the absence of man-induced alterations based on the best scientific information available to the Department. The establishment of natural background for an altered waterbody may be based upon a similar unaltered water body or on historical pre-alteration data.” (Chapter 62-302.200[15], FAC). Assuming that the natural background condition maintained a balanced biota, the determination of nutrient impairment can be based on comparisons to historical data predating impacts or to the biota of similar water bodies that are unimpacted (reference water bodies).

Because data pre-dating anthropogenic effects are generally lacking for many aquatic ecosystems, a current approach towards assessing anthropogenic effects is to define a “reference” condition using minimally impacted, similar systems for a particular region (Hughes 1995; Bunn et al. 1999). The reference condition is generally interpreted to mean the condition of the system prior to human development of the landscape, and is assumed to represent optimal “biological integrity” or “ecosystem health” (Hughes 1995). Karr (1991), citing some of his earlier work, defines biological integrity as:

“the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region. ”

He defines ecological health as:

(a biological system) “. . . can be considered healthy when its inherent potential is realized, its condition is stable, its capacity for self-repair when perturbed is preserved, and minimal external support for management is needed.”

In a “reference” approach, deviation from the reference condition is inferred as impairment, including the above considerations regarding biological integrity and ecological health.

For the Wekiva River system, water quality or ecological degradation that can be demonstrated to have occurred since 1979 (the baseline year for evaluating the non-degradation standard for OFWs) would constitute a violation of the no degradation standard in Chapter 62-302.700 [1], FAC and also may be considered impairment.

Florida water quality standards also prohibit the presence of “Substances in concentrations which injure, are chronically toxic to, or produce adverse physiological or behavioral response in humans, plants, or animals” (Chapter 62-302.530 [62], FAC). Because nitrate can be toxic to aquatic organisms, our investigation included an assessment of the potential for nitrate toxicity and an analysis of concentrations that would result in minimal or no toxicity effects.

4.2 Defining Nuisance Algae

For purposes of this report, periphyton refers to the community of attached organisms, on submerged surfaces. This community includes microscopic algae (diatoms, green algae, blue-green bacteria and euglenophytes), as well as bacteria, protozoa, and microscopic animals embedded in a polysaccharide matrix (Lock et al. 1984). This community has been variously described as a "biofilm" or "benthic turf". The periphyton can also include filamentous macrophytic algae or macroalgae. These species are macroscopic (easily visible), primarily filamentous green (Chlorophyta) and yellow-green (Xanthophyceae) algae and Cyanobacteria. They may form thick benthic or floating mats and may become nuisance species. In this report, growth of periphyton and growth/occurrence of filamentous "nuisance algae" are both considered. While some amount of periphyton growth is ecologically beneficial (due to increased food resources and additional habitat), excessive periphyton growth, especially of the filamentous macroalgae, can inhibit the growth of beneficial species of submersed aquatic vegetation (SAV), can have detrimental effects on faunal habitat, and/or can constitute an aesthetic nuisance. A determination of the level of periphyton that is harmful was beyond the scope of this work and is not available in the scientific literature. To reduce the potential for harmful levels of periphyton, we looked for inflection points between the growth potential of periphyton (at species and community levels) and levels of nitrate and total phosphorus. By limiting concentrations to levels below these points excessive growth of periphyton should be prevented.

The perception of "nuisance" algae (primarily the filamentous macroalgae in the Cyanobacteria and Chlorophyta) and its possible link to elevated nitrate levels is of relevance in this PLRG analysis. Florida's Impaired Waters Rule (Chapter 62-303.200, FAC) defines "nuisance species" as:

". . . species of flora or fauna whose noxious characteristics or presence in sufficient number, biomass, or areal extent may reasonably be expected to prevent, or unreasonably interfere with, a designated use of those waters."

The scientific literature generally defines "nuisance algae" in reference to interference with human uses; e.g., decreasing water flow, clogging water intakes, or interfering with recreational uses (Dodds and Welch 2000; Lembi 2003). Welch et al. (1988) considered a chlorophyll-a standing crop of >150 mg/m^2 (which equated to a cover of about 20% filamentous macroalgae) as a nuisance level in northern rocky streams. They interpreted nuisance to mean "aesthetically displeasing and interfere(s) with foot travel by fishermen." Large mats of filamentous algae (Cyanobacteria and Chlorophyta) are also a aesthetic nuisance in that anaerobic decomposition of dead filaments within the mats produces a characteristic "sewage" or "septic" odor.

To date, a determination of what constitutes a "nuisance level" of algae in Florida springs or spring-run streams has not been made. Based on the definition of nuisance species for a Class III water body, per the Impaired Waters Rule, algal growth that interferes with recreational uses or causes ecological changes which affect "health or balance" of fish or wildlife populations could be considered a nuisance, and thus an impairment of the water body.

One algal group of major concern in Florida springs is the filamentous Cyanobacteria, primarily in the genus *Lyngbya*. With increased nutrient loading to a water body, it is frequently the Cyanobacteria that respond most prolifically (Komárek 2003; Brönmark and Hansson 1998), exhibiting large increases in abundance and excluding other algal taxa. Increase in *Lyngbya* biomass is a management issue in many Florida springs (Burns, unpublished paper; Stevenson et al. 2004). *Lyngbya*, and other Cyanobacteria, produce toxins that may be associated with skin reactions (dermatitis) and respiratory distress (Burns, unpublished paper; Komárek 2003). In some instances the allergic reaction may be severe enough to result in anaphylactic shock. The toxins may also have ecological impacts, but these have received much less attention than the human health effects. Large mats (= blooms) of filamentous Cyanobacteria may also adversely affect macroinvertebrate and fish habitat, water quality, and SAV.

4.3 Results of PLRG Investigations

4.3.1 Ecosystem Metabolism in the Wekiva River, Rock Springs Run, and in Reference Spring-run Streams

Impairment. Data collected by WSI during 9 months in 2004-2005 demonstrated that nitrate and total phosphorus concentrations were elevated in the Wekiva River and Rock Springs Run compared to Juniper Creek and Alexander Spring Creek (WSI, 2005; Figure 4-1). Mass loading of total inorganic nitrogen (TIN) was higher in upstream segments of the Wekiva River and Rock Springs Run than in the Juniper and Alexander segments. Measures of ecosystem metabolism (gross primary productivity, net primary productivity, and ecological efficiency) were consistently lower in the Wekiva River and Rock Springs Run than in the two reference streams (Figure 4-2). High nutrient loading in the Wekiva River and Rock Springs Run appears to be causing disruption of ecosystem function in these aquatic ecosystems, evidenced by reductions in productivity and ecological efficiency (WSI 2005).

WSI (2005) noted other impacts to the Wekiva River and Rock Springs Run that could contribute to degradation and imbalances in flora and fauna. These impacts included high erosion rates in the contributing watershed, flow reduction due to increasing groundwater withdrawals, high-intensity aquatic plant management efforts, and recreation-related disturbance.

Nutrient Target Concentrations. Wetland Solutions (WSI 2005) recommended nutrient concentration targets for the Wekiva River and Rock Springs Run calculated to avoid degradation of aquatic ecological structure and function. These were based on evaluation of ecosystem metabolism data and water quality data for 130 Florida springs. Ecosystem metabolism data suggested an NOx target of 100 – 200 µg/L. About half of the 130 Florida springs had mean NOx concentrations greater than 500 µg/L and mean

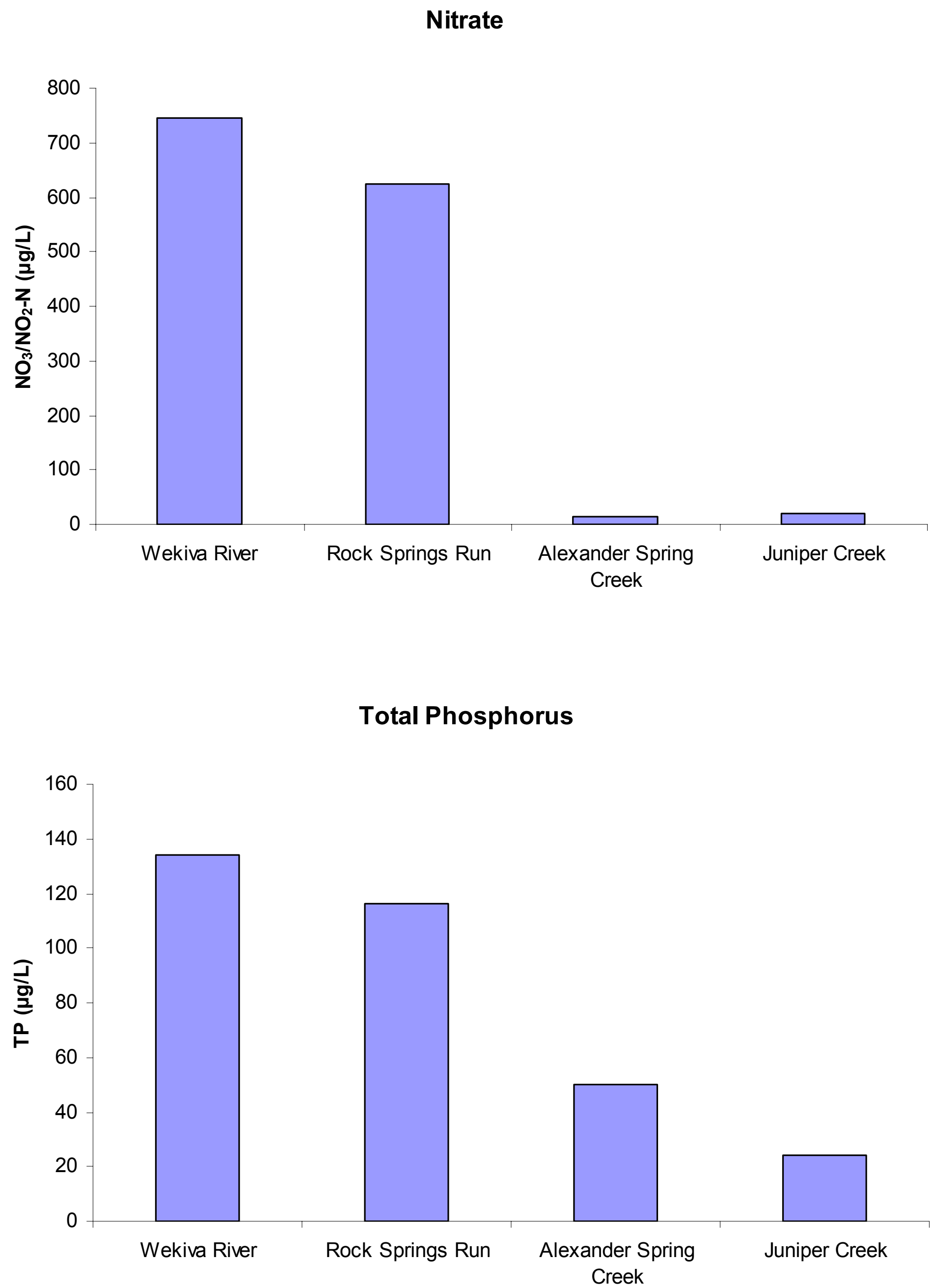
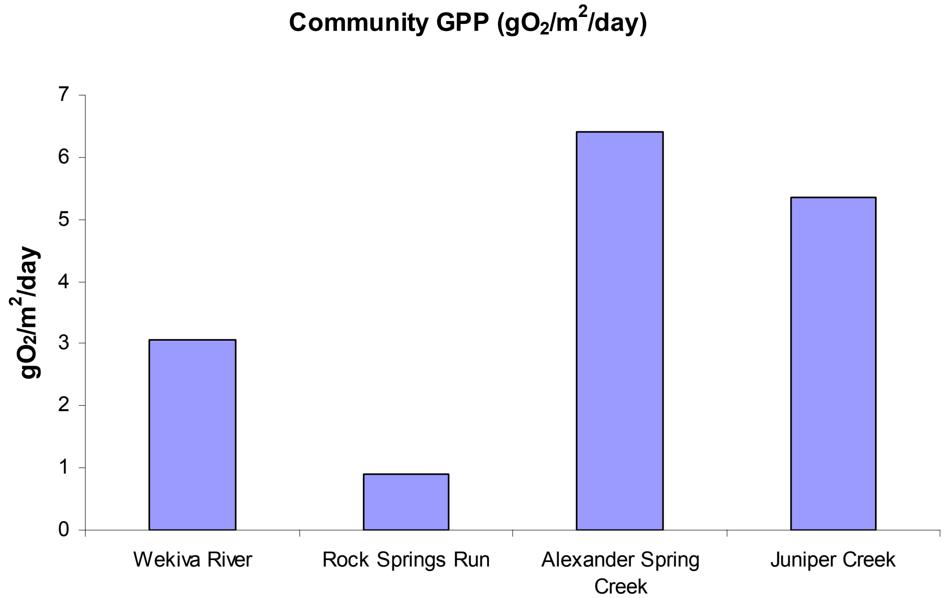


Figure 4-1. Mean nitrate and total phosphorus concentrations in intensive-study segments of the Wekiva River, Rock Springs Run, Alexander Spring Creek and Juniper Creek (from WSI 2005).



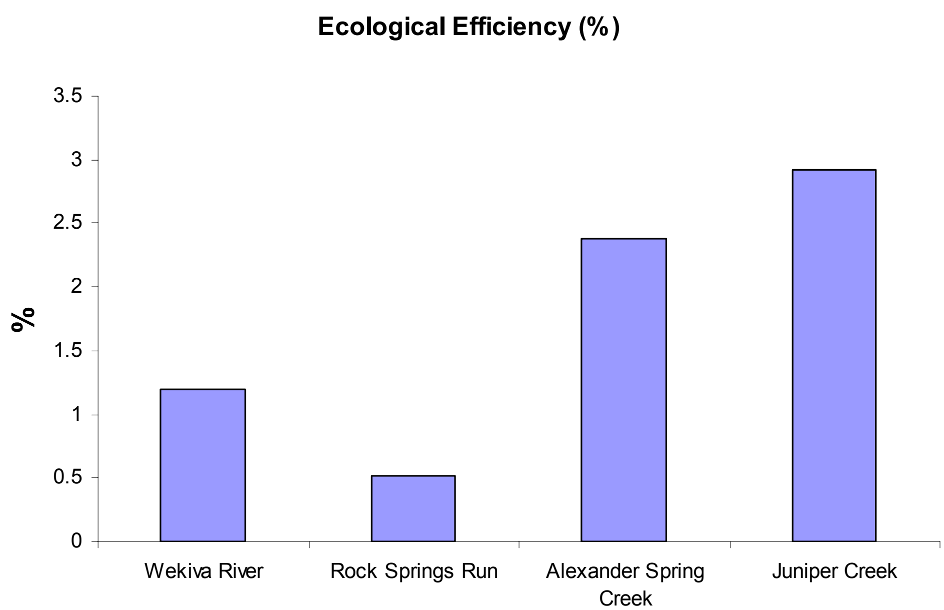


Figure 4-2. Mean gross primary productivity and ecological efficiency in the Wekiva River, Rock Springs Run, Alexander Spring Creek, and Juniper Creek (from WSI 2005).

TP concentrations greater than 50 µg/L. Based on these lines of evidence, WSI calculated PLRGs for target concentrations of 100 µg/L NOx and 50 µg/L TP.

PLRGs. Preliminary NOx and TP load reductions necessary to meet these concentration targets were calculated using simple linear models relating nutrient loading rates and in-stream nutrient concentrations for downstream points in each stream. These model relationships were weak and would need to be improved through additional data collection. Load reductions of 67% NOx would be required to meet the 100 µg/L NOx target at a downstream point in the Wekiva River. A TP load reduction of 76% would be required to meet the 50 µg/L TP target at a downstream point in the Wekiva River.

See Appendix C for Wetland Solutions' detailed methodology and data.

4.3.2 Attached Algae in the Wekiva River and Rock Springs Run

The highest biomass of attached algae was found at sites in and around the springs for both Wekiva River (WR) and Rock Springs Run (RSR). Diatoms were the dominant algal group in terms of biomass and diversity at the majority of sites (GreenWater Labs 2005). Filamentous Cyanobacteria (particularly *Lyngbya wollei* and *Phormidium*) were most abundant in terms of biomass at sampling sites nearest the headsprings, although the thin cyanophyte filament *Heteroleibleinia* was important at some downstream sites.

Cyanobacteria comprised a greater percentage of total biovolume in summer than in winter (GreenWater Labs 2005). Chlorophyta (particularly *Spirogyra*, *Mougeotia* and *Cladophora glomerata*) were most abundant in terms of biomass at the sites nearer the headsprings although accumulations of filamentous green algae (*Cladophora glomerata* and *Oedogonium*) were observed in the wide, shallow section of the Wekiva River upstream of the SR46 bridge. The filamentous red alga *Batrachospermum* was found in both the WR and RSR, but was more abundant and at a higher percentage of sites in the WR. The filamentous xanthophyte *Vaucheria* was more abundant in WR and RSR than indicated by this study. The sampling method excluded benthic mats, of which some extensive ones composed of *Vaucheria* were present at times in both systems. Ash free dry weight (AFDW) and chlorophyll-a were both higher at sites nearer the headsprings on both spring-run streams. See Appendix D for details.

4.3.3 Nitrate Toxicity to Aquatic Animals

Camargo and Ward (1995) estimated safe levels of nitrate for two species of caddisflies based on 96 h LC50s. Using multifactor probit analysis they extrapolated from the acute LC50 concentrations to estimate "safe concentrations" for chronic exposure for early instar larvae: 1,400 ug/L for the genus *Hydropsyche* and 2,400 ug/L for the genus *Cheumatopysche*. Both genera occur in the Wekiva River (Warren et al. 2000). Mosquitofish, which also occur in the Wekiva River (Warren et al. 2000), have exhibited adverse sublethal effects at nitrate levels of 4,000 µg/L and above (Edwards et al. 2004; Edwards 2005). Selected frog genera in Canada (*Rana* sp. and *Pseudacris* sp.) showed adverse sublethal effects at nitrate levels as low as 2,500 µg/L (Hecnar, 1995). Representatives of these frog genera are present in the Wekiva River and Rock Springs Run (*Rana* spp.) and its adjacent floodplain (*Pseudacris* spp). Many of the experimental studies were conducted over the larval lifetime of an animal (e.g., frogs from egg to adult).

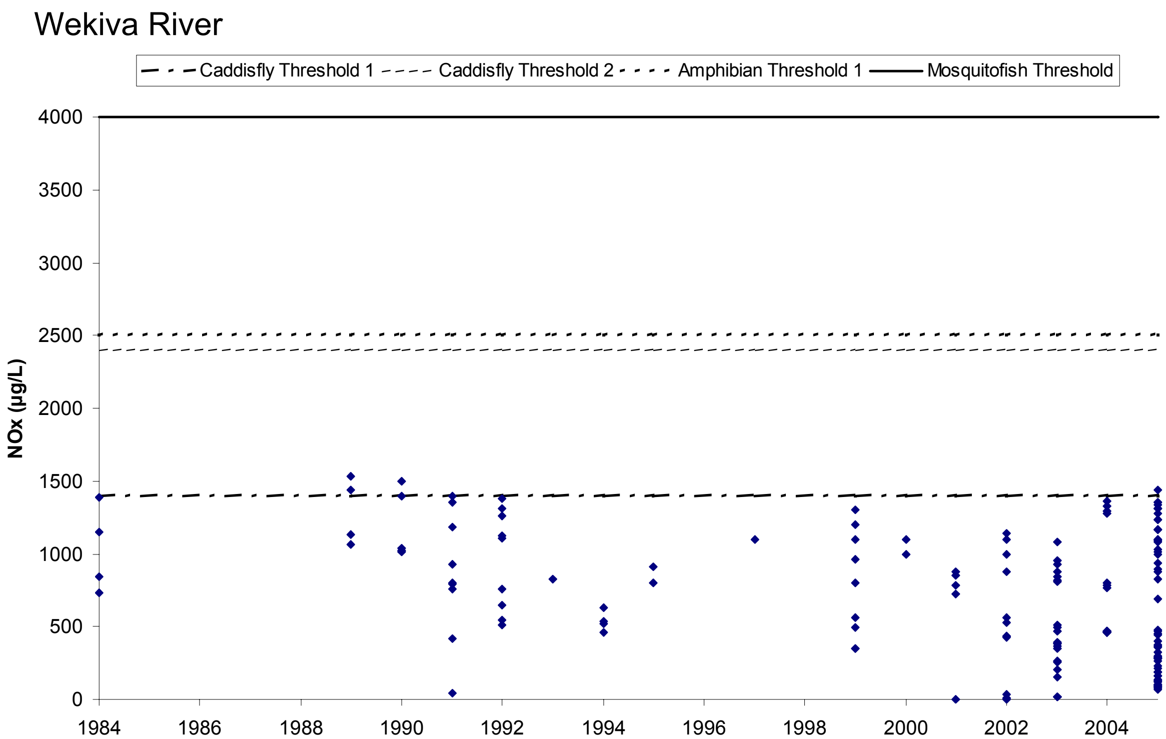
Figure 4-3 illustrates the reported toxicity thresholds for different aquatic animals relative to nitrate concentrations in the Wekiva River and Rock Springs Run. Maximum nitrate concentrations recorded through 2005 for the Wekiva River and Rock Springs Run were 1,500 and 1,800 µg/L, respectively. These concentrations may be toxic to at least one genus of caddisfly found in the Wekiva River and Rock Springs Run. An increase in maximum nitrate of 1000 µg/L (67%) for the Wekiva River and 700 µg/L (39%) in Rock Springs Run would meet or exceed toxicity thresholds for other caddisflies and for certain frogs.

Derivation of a protective nitrate concentration requires consideration of the sources of uncertainty inherent in the limitations of the data derived from short-term, acute toxicity assays. The USEPA (1995a; 1995b), USFWS (2003), and USFWS et al. (2001) have employed up to four uncertainty factors to set protective exposure limits for toxic contaminants:

1) an interspecies uncertainty factor (UF_A);
2) an exposure duration uncertainty factor (subchronic to chronic: UF_S);
3) an exposure endpoint uncertainty factor (UF_L) – equivalent to a concentration between the “Lowest Observed Effect Level” (LOEL) and the “No Observed Effect Level” (NOEL), and;
4) an intraspecific uncertainty factor (UF_I).

These factors were applied to the lowest nitrate toxicity thresholds derived from the literature review for caddisflies (1,400 µg/L) and amphibians (2,500 µg/L). Application of uncertainty factors yielded concentration thresholds of 140 and 125 µg/L, respectively. Detailed description of this procedure is in Appendix E.

A statistical approach was developed to take the nitrate toxicity thresholds derived from application of uncertainty factors and use them to determine what a new mean nitrate level would be if the threshold were set at the upper end of the population of nitrate data. Nitrate data from the headspring regions of the Wekiva River and Rock Springs Run were used since these were the highest levels (Section 2.3) and thus potentially the most toxic. In order to use this statistical approach, the data must approximate a normal distribution or be transformed to conform to a normal distribution. The existing nitrate data from Wekiwa and Rock Springs met this requirement by deleting a very few outlier values from the dataset. From an ecologically conservative standpoint, the threshold criterion were set at the upper end of the population distribution, at the 90 % probability level, in order to build in an explicit margin of safety. Using this as a starting point, the new mean nitrate concentration was calculated based on the probability of a



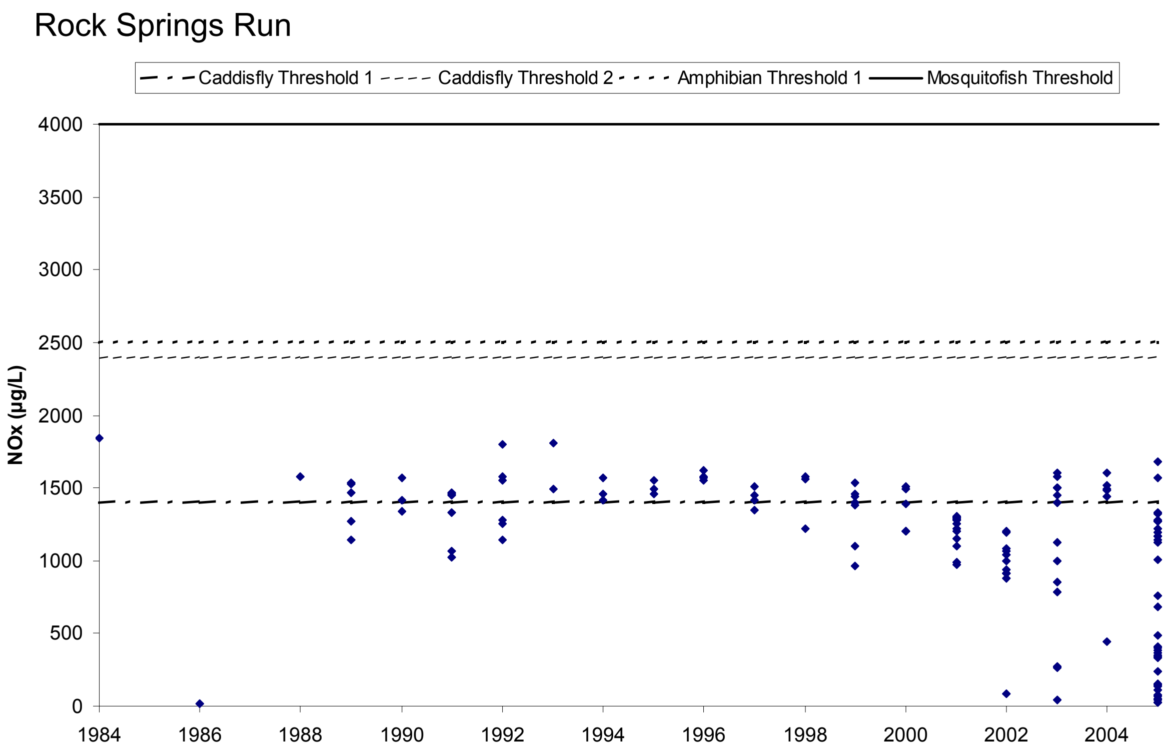


Figure 4-3. Nitrate concentration in the Wekiva River and Rock Springs Run, showing selected toxicity thresholds for aquatic insects, amphibians, and mosquitofish. Source: SJRWMD data analysis and literature review (Mattson et al. 2005).

randomly collected water sample having a nitrate concentration at or less than the specific threshold. To determine the target mean nitrate concentration:

$$M + Z\ score*S = threshold\ concentration \qquad \text{(Equation 1)}$$

M is the target mean nitrate concentration, S is the standard deviation of the target population distribution, and the Z score is the normal deviate associated with the probability assigned (these are obtained from standard tables in most statistics textbooks). This equation enables calculation of the percentage of samples in the new population which will have nitrate concentrations at or less than the established threshold target.

Since S is unknown for the new population distribution, the coefficient of variation (CV) of the existing population (= the existing data) multiplied by the mean can substitute for S in the equation:

$$M + (Z\ score)(CV \times M) = threshold\ target \qquad \text{(Equation 2)}$$

CV is the Coefficient of Variation of the existing population distribution. This assumes that the population variance will vary in proportion to the mean with the coefficient of proportionality being the CV. As such, the CV will be the same for the existing and new distributions of data. To obtain the new target population mean, Equation 2 was solved for M:

$$M = threshold\ concentration/[Z\ score * CV* (1+Z)] \qquad \text{(Equation 3)}$$

For consideration, the threshold selected was a nitrate level of 125 µg/L at a probability of 90% (i.e., 90% of the time, nitrate must be $\leq$125 µg/L). This was the threshold determined by applying uncertainty factors to the lowest amphibian threshold of 2,500 µg/L NOx. Using the statistical methodology described above, the new population mean nitrate/nitrite nitrogen concentrations were 108 µg/L in the Wekiva River and 111 µg/L in Rock Springs Run. These are the suggested nitrate targets in each spring run based on toxicity considerations.

Results of SJRWMD's nitrate toxicity literature review and the application of uncertainty factors are in Appendix E.

4.3.4 Coliform Bacteria Impairment

An analysis of recent data indicates that the Wekiva River and Rock Springs Run are impaired for total coliform bacteria according to criteria in Florida's Impaired Waters Rule. The Class III standard of "no exceedance of 2,400 units/100ml at any time" was used to evaluate total coliform bacteria exceedances Since 1997, the upstream segment of the Wekiva River has exceeded the standard 40% of the time, the downstream segment 45% of the time, and Rock Springs Run 43% of the time. Additionally, the swim area in Kelly Park, at the headwaters of Rock Springs Run, was closed five times between 2000 and 2005 because of exceedance of primary contact bacteriological standards. The Wekiva River and Rock Springs Run are not impaired for fecal coliform bacteria. For details of SJRWMD's coliform analysis, see Appendix F.

4.3.5 Total Phosphorus Thresholds for Attached Algae Growth

Although the study by GreenWater Labs (2005) sampled algae from a limited range of habitat types, these data can be used in an algae-based water quality assessment (Potapova and Charles 2005). Analysis of the attached algal data from the Wekiva River and Rock Springs Run indicated that % Cyanobacteria in the algal community (by biovolume) was positively correlated with total phosphorus (TP) and % Chlorophyta was not significantly correlated with TP. Graphical analysis of the data indicated that above TP concentrations of 90 µg/L, increased amounts of both Cyanobacteria and Chlorophyta were present in the algal community (Figure 4-4). The statistical procedure described in Section 4.3.3. on nitrate toxicity, was used to calculate a mean TP concentration for the Wekiva River and for Rock Springs Run by setting a threshold of maintaining TP levels $\leq$90 µg/L with a probability of 90%. This probability was selected to be ecologically protective.

Mean TP resulting from this analysis was 59 µg/L for the Wekiva River and 61 µg/L for Rock Springs Run. Results of these analyses are summarized in Appendix G.

4.3.6 Rainbow River Algal Bioassays

Cowell and Dawes (2004) performed laboratory assays of nitrate concentration and growth of *Lyngbya wollei* from the Rainbow River and found a nitrate threshold of 300-600 µg/L, above which growth of *Lyngbya* was significantly higher They recommended a reduction to <300 µg/L nitrate would be necessary to reduce growth of *Lyngbya* in the Rainbow River. A threshold nitrate target concentration of 250 µg/L was selected largely based on this scientific data and recommendation.

4.3.7 Suwannee River Algae and Nutrients

Long-term periphyton and water quality data collected on the Suwannee River (Hornsby et al. 2000) with glass-slide settling racks (periphytometers) indicate that periphyton biomass and abundance increase at threshold concentrations of 200 - 300 µg/L nitrate (Figure 4-5). This lends support to the threshold of 250 µg/L nitrate indicated in the Section above. An upper threshold of about 600 µg/L nitrate appears to be evident, above which nitrate is evidently not limiting to algal growth. Much of the length of the Suwannee is heavily influenced by spring inflow, and the algal communities appear to be generally similar in composition to those in the Wekiva River and Rock Springs Run. Therefore, the Suwannee results are considered applicable to the Wekiva River and Rock Springs Run. See Appendix H for details of the Suwannee River work.

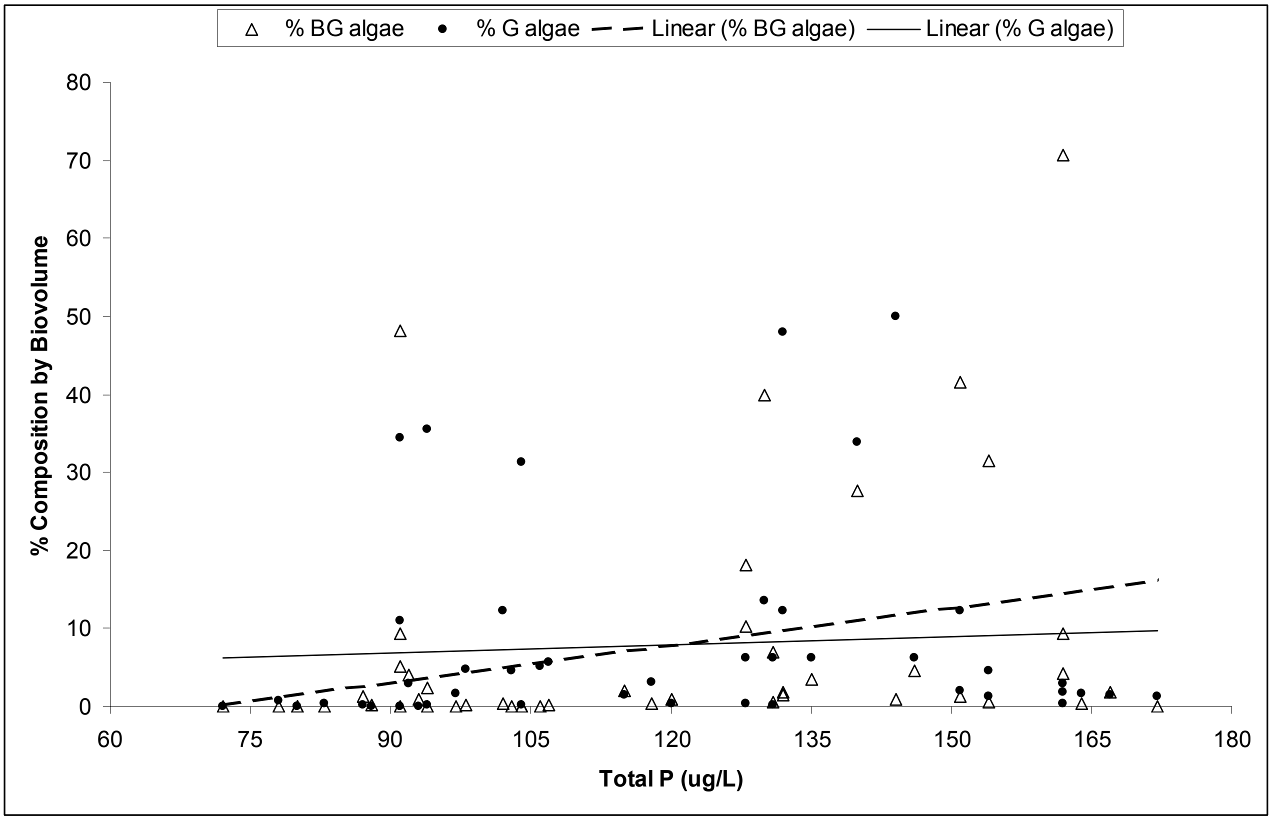


Figure 4-4. Plot of percent Cyanobacteria (= "BG algae") and Chlorophyta (= "G algae") versus total phosphorus concentrations in the attached algal community in the Wekiva River and Rock Springs Run. Data from GreenWater Labs (2005) survey.

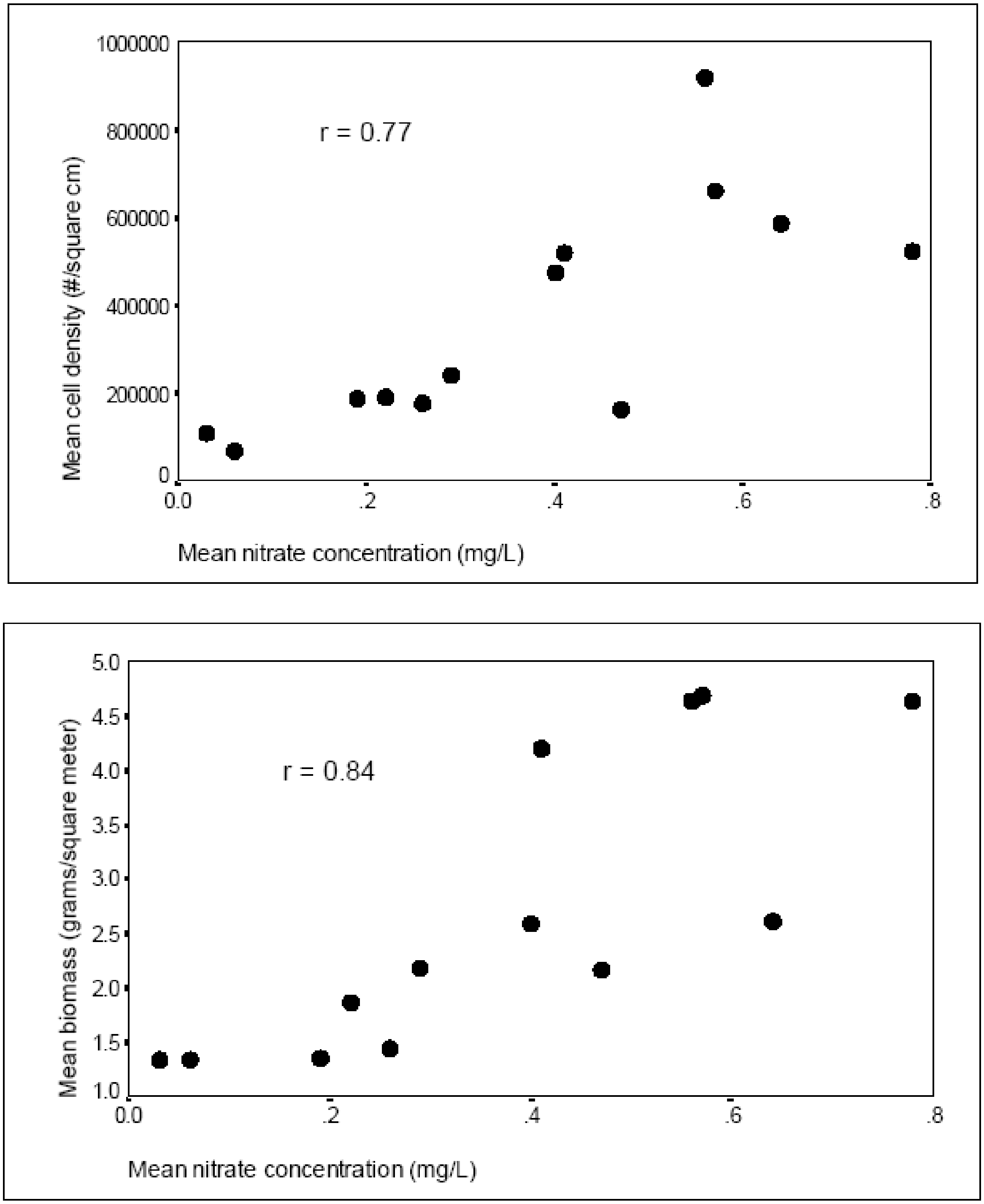


Figure 4-5. Plots showing relationships between mean nitrate concentration and mean periphyton cell density and biomass from long term monitoring stations on the Suwannee River. Source: Hornsby et al. (2000)

4.3.8 Nutrients in Less-Impacted Spring-Run Streams and in 130 Florida Springs

Median nitrate concentrations in three less-impacted Florida spring-run streams (Alexander Springs Creek, Juniper Creek, Wacissa River) were all <100 µg/L. Median total phosphorus concentrations in these streams were all <50 µg/L (Appendix I).

Median nitrate concentration in 130 Florida springs, including springs known to be impacted by elevated nitrate loading, was 480 µg/L and median total phosphorus was 40 µg/L. Median nitrate/total phosphorus levels in Alexander Spring were 51/44 µg/L, in Juniper Spring 81/34 µg/L and in Fern Hammock Spring 90/31 µg/L. These correspond to the results reported above for less impacted spring runs (i.e., nitrate <100 µg/L and total phosphorus <50 µg/L).

Data are summarized in Appendix I.

4.3.9 Nutrients in Undeveloped Streams in the United States

Median nitrate concentrations in streams draining undeveloped watersheds nationwide were 87 µg/L (Clark et al. 2000). Median total phosphorus levels in these streams nationwide were 22 µg/L. In forested watersheds in the southeastern U.S. (Binkley et al. 2004) mean nitrate levels were 180 µg/L and median levels were 50 µg/L. Nationwide, mean nitrate levels in these forested watersheds were 310 µg/L, with a nationwide median of 150 µg/L nitrate. Phosphate levels (whether this was PO_4 or PO_4-P was not specified in the paper) in the southeastern U.S. from these forested watersheds showed a mean of 14 µg/L and a median of 7 µg/L (Binkley et al. 2004).

4.3.10 Nitrate Targets for EPA's TMDL

The US Environmental Protection Agency defined a target concentration of 110 µg/L NOx for Wekiwa Spring and Rock Springs based on the 90th percentile of nitrate concentration in Juniper Spring. Using this concentration target, USEPA proposed a 91-95% reduction in nitrogen load to restore Wekiwa Spring and Rock Springs to natural background conditions. A TMDL for total phosphorus was not established by EPA.

4.3.11 Total Phosphorus and Epiphytic Algae in Ichetucknee Springs

No significant relationships were observed between biomass of epiphytic algae in springs of the Ichetucknee River and nitrate or total nitrogen (PBS&J 2004). Algal biomass was positively correlated with both total phosphorus and soluble reactive phosphorus (SRP), which were almost identical in these springs. Epiphytic algal biomass notably increased above a threshold of about 50-55 µg/L SRP or TP (PBS&J 2004). Results and excerpts from this report are in Appendix J.

4.3.12 Phosphorus in Florida Springs in the 1950's

Historic levels of phosphorus in Florida springs were identified by using data from Odum (1953). Springs within "phosphatic regions" (regions underlain with phosphorus-rich geologic strata) had a mean TP concentration of 61 µg/L (Odum 1953). Florida springs outside of phosphatic regions had a mean TP concentration of 45 µg/L. Odum's map suggests the Wekiva River is outside of the phosphatic region, although the phosphorus-rich Hawthorn Formation is present in the Wekiva study area (Section 2.1). The concentrations from these earlier periods likely reflect conditions closer to the natural background condition.

4.3.13 Nitrate Targets for FDEP's Wastewater Treatment Criteria

FDEP proposed a target nitrate level of 200 µg/L NOx for Wekiwa Spring (FDEP 2004). This was based on NOx levels exhibited by less-impacted reference springs such as Juniper and Alexander.

4.4 Evidence of Impairment and Causative Pollutants

4.4.1 Nutrients - Imbalance of Flora and Fauna

Several lines of evidence indicate that the Wekiva River and Rock Springs Run are impaired due to an imbalance of flora and fauna caused by enrichment with nitrate and total phosphorus:

- Gross and net primary productivity and ecological efficiency are lower than in less-impacted spring-run streams (Juniper Creek and Alexander Spring Creek). This indicates an "imbalance in natural populations of flora and fauna" as prohibited by Chapter 62-302.530[48b], FAC These effects are correlated with nutrient concentrations;

- Laboratory and field studies indicate that present concentrations of nitrate and total phosphorus create the potential for high biomass and productivity of periphyton and potentially nuisance algal species, especially Cyanobacteria, again, constituting an imbalance of flora and fauna.

4.4.2 Nitrate - Potential for chronic toxicity

- Nitrate concentrations have been demonstrated to exceed nitrate toxicity thresholds for sensitive aquatic insects and frogs as prohibited by Chapter 62-302.530[62], FAC

4.4.3 Nutrients - Non-compliance with OFW designation

- The high concentrations of nitrate and total phosphorus indicate anthropogenic enrichment that is not in compliance with part of the narrative nutrient standard (Chapter 62-302.530[48a], FAC); and is not permissible in OFWs (Chapter 62-4.242[2], FAC);

- One analysis indicated there has been an increase in nitrate concentrations in Rock Springs Run since the stream was designated an Outstanding Florida Water. This is prohibited by Chapter 62-4.242[2].

4.4.4 Total Coliform Impairment

The Wekiva River and Rock Springs Run are impaired for total coliform bacteria based on the following evidence:

- greater than 40% exceedance of the 2,400 counts/100 ml impairment criterion in the Impaired Waters Rule;

- swim area closures in Kelly Park (Rock Springs Run);

- increasing levels of coliform bacteria (i.e., a degrading trend in water quality) since OFW designation, a violation of the OFW Rule.

4.5 Pollutant Target Concentrations

4.5.1 Nutrients

Potential nutrient concentration targets for PLRG development were discussed above (Section 4.3) and are summarized in Tables 4-2 (nitrate) and 4-3 (total phosphorus). These findings from multiple lines of investigation (Tables 4-2 and 4-3) were collectively considered to arrive at targets for nitrate and total phosphorus.

4.5.2 Nitrate

SJRWMD proposes mean target concentrations of **216 µg/L NOx** for the Wekiva River and **221 µg/L NOx** for Rock Springs Run. These mean nitrate targets will.

- maintain nitrate levels $\leq$250 µg/L at a probability of 90% in order to limit excessive accumulation of periphyton biomass and limit growth of potential nuisance species of macroalgae such as *Lyngbya*;
- restore ecological efficiency to that found in less-impacted spring-run streams;
- maintain nitrate concentrations at levels that would be minimally toxic to aquatic fauna. The proposed mean concentrations are reduced by a factor of 11 to 12 for the lowest observed amphibian toxicity threshold and by a factor of about 6

Table 4-2. Potential nitrate-nitrite (NOx) concentration targets based on various lines of investigation.

Reference	Basis for Target	NOx (µg/L)	Statistic
Ecosystem metabolism in the Wekiva River and Rock Springs Run (WSI 2005)	Comparison to metabolism in less-impacted spring-run streams (Juniper & Alexander)	100 - 200	Threshold
	Comparison to other springs in SJRWMD	200	Median
Nitrate toxicity to aquatic animals (Mattson et al. 2005)	90% probability of ≤1,400 µg/L (lowest toxicity threshold for caddisflies)		
	Wekiwa Spring	1,200	Mean
	Rock Spring	1,240	Mean
	New thresholds after application of uncertainty factors	125 - 140	Threshold
	90% probability of <125 µg/L (lowest threshold with uncertainty factor):		
	Wekiwa Spring	108	Mean
	Rock Spring	111	Mean
Rainbow River algal bioassays (Cowell and Dawes 2004)	*Lyngbya wollei* biomass	300 – 600	Threshold
	90% probability of ≤ threshold of 250 µg/L:		
	Wekiva River	216	Mean
	Rock Springs Run	221	Mean
Suwannee River periphytic algae and nitrate levels (Hornsby et al. 2000)	Algal biomass	200 - 300	Threshold
	Algal cell density	300	Threshold
Nutrients in Florida springs (WSI and DEP databases)	130 Florida springs, including impacted springs	480	Median
	Juniper Spring, Fern Hammock Spring	81, 90	Median
	Alexander Spring	51	Median
Nutrients in less-impacted spring-run streams in Florida (STORET database)	Juniper Creek	80	Median
	Alexander Spring Creek	50	Median
	Wacissa River	60	Median
Nutrients in undeveloped streams In the United States (Binkley et al., 2004; Clark et al. 2000)	Forested stream basins in the southeastern U.S.	180	Mean
	Undeveloped watersheds in the U.S.	87	Median
EPA proposed TMDL for Wekiwa Spring and Rock Springs Run (USEPA 2005)	Comparison to Juniper Spring	110	Threshold
FDEP wastewater treatment criteria in the Wekiva Study Area (FDEP 2004)	Comparison to less-impacted Florida springs	200	Threshold

Table 4-3. Potential total phosphorus (TP) concentration targets based on various lines of investigation.

Reference	Basis for Target	TP (µg/L)	Statistic
Ecosystem metabolism in the Wekiva River and Rock Springs Run (WSI 2005)	Comparison to metabolism in less-impacted spring-run streams (Juniper & Alexander) Comparison to springs in SJRWMD	50-80 50	Threshold Median
% Cyanobacteria and Chlorophyta in attached algae in Wekiva River and Rock Springs Run (analysis of data from GreenWater Labs 2005)	90% probability of $\leq$ 90 µg /L (threshold for increased levels of cyanobacteria and chlorophyta in attached algal community): Wekiva River Rock Springs Run	 59 61	 Mean Mean
Mapping and monitoring of submerged aquatic vegetation in the Ichetucknee River headsprings (PBS&J 2004)	Epiphytic algal biomass	55	Threshold
Phosphorus in selected Florida springs in the 1950s (Odum 1953)	Springs outside of phosphatic areas Springs within phosphatic areas	45 61	Mean Mean
Nutrients in Florida springs (WSI and DEP databases)	130 Florida springs, including impacted springs Juniper Spring, Fern Hammock Spring Alexander Spring	40 34, 31 44	Median Median Median
Nutrients in less-impacted spring-run streams in Florida (STORET database)	Juniper Creek Alexander Spring Creek Wacissa River	23 44 44	Median Median Median
Nutrients in undeveloped streams in the United States (Clark et al. 2000)	Undeveloped watersheds in the U.S.	22	Median

- for the estimated no effects threshold of caddisflies as reported in Mattson et al. (2005);
- restore NOx concentrations to that characteristic of less-impacted springs and spring-run streams in Florida and in undeveloped watersheds in the southeastern U.S. and nationwide.

These proposed targets fall within the upper mid-range of the range of possibilities considered in Table 4-2 (Figure 4-6). The Wekiva River and Rock Springs Run targets fall at the 29th percentile for the database of 130 Florida springs assembled by WSI (2005), thus both are in the lower third relative to springs in Florida. Scott et al. (2004) list a nitrate-nitrite measurement of 70 µg/L for Rock Spring in 1946, so the proposed targets are not as low as these springs may have historically been, but should be low enough to protect the ecological integrity of the spring-runs. Toth and Fortich (2002) suggest that levels in springs above 200 ug/L constitute a “problem threshold”, and the proposed targets are very close to this level.

4.5.3 Total Phosphorus

Orthophosphate is the analyte most frequently analyzed in groundwater and spring vents (Osburn et al. 2002; Scott et al. 2004). No research appears to have been done in Florida springs to separate the phosphate derived from natural leaching vs. that derived from surficial recharge. Orthophosphate is also rapidly taken up by plants and bacteria, while total phosphorus is less labile. Because of these reasons, SJRWMD made the decision to use total phosphorus (TP). Wastewater treatment and stormwater management are primarily focused on reductions in TP, so any improvements due to load reductions should be measureable by sampling TP in the spring-run streams. SJRWMD proposes mean target concentrations of **59 µg/L TP** for the Wekiva River and **61 µg/L TP** for Rock Springs Run. These mean TP concentration targets will:

- maintain TP concentrations below the threshold for increased growth of Cyanobacteria and green algae (90 µg/L) with a probability of 90%;
- restore ecological efficiency to that found in less-impacted spring-run streams;
- Limit accumulation of epiphytic algal biomass by keeping TP concentrations ~60 µg/L;
- restore TP concentration to that found in Florida springs in the 1950s;
- restore TP concentration to that found in less-impacted springs and spring-run streams in Florida, and in undeveloped watersheds in the southeastern U.S. and nationwide.

The proposed TP targets fall within the upper mid-range of the range of possibilities considered in Table 4-3 (Figure 4-7). The Wekiva River target falls at the 66th percentile for the database of 130 Florida springs assembled by WSI (2005) and Rock Springs Run falls at the 67th percentile, thus both exceed the median TP level relative to springs in Florida. They conform to the potential historic levels of TP found in Florida springs (45-61 µg/L) as reported in Odum (1953), which may be regarded as “natural background”. Reference springs in the Ocala National Forest, such as Alexander and

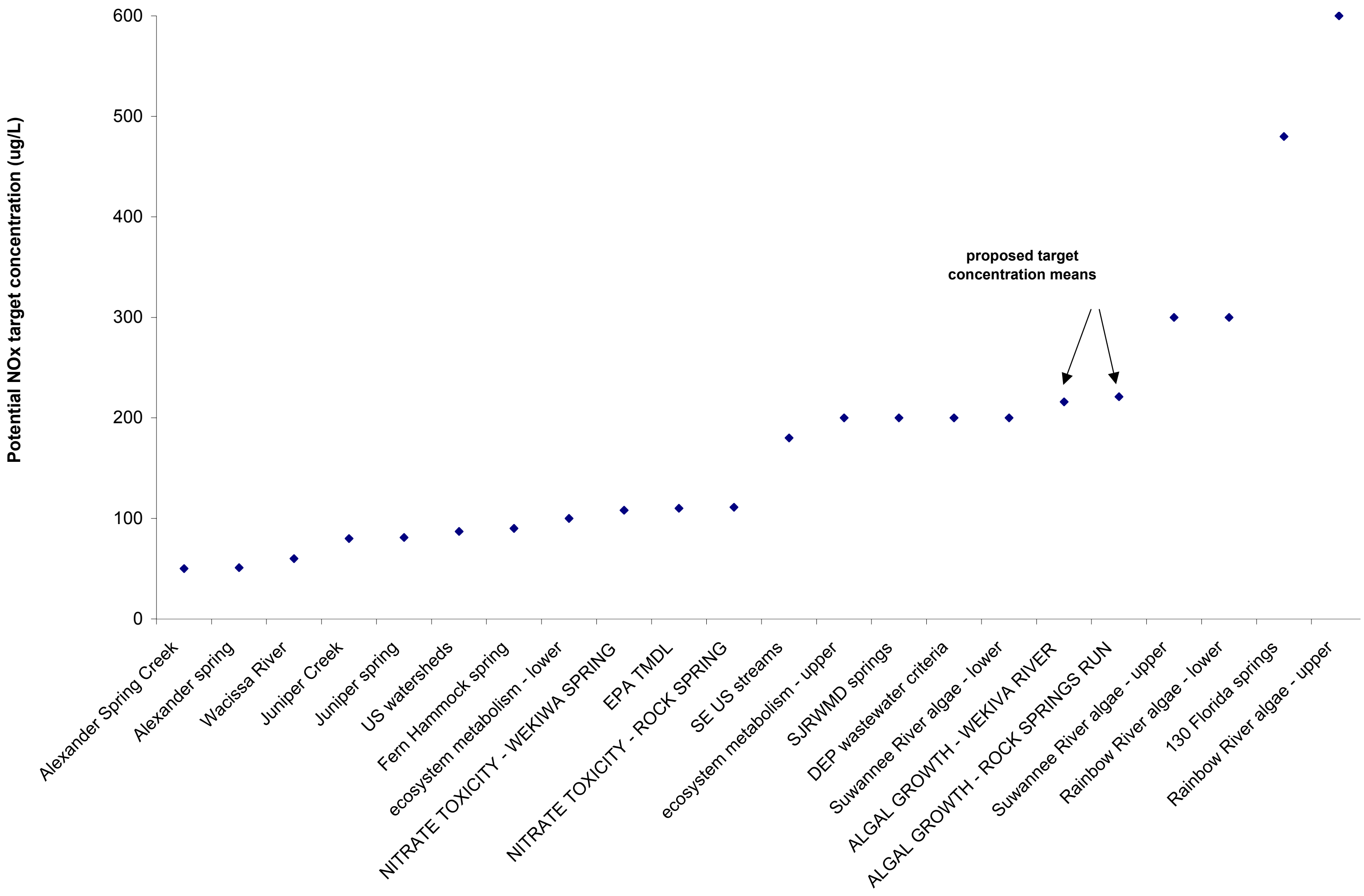
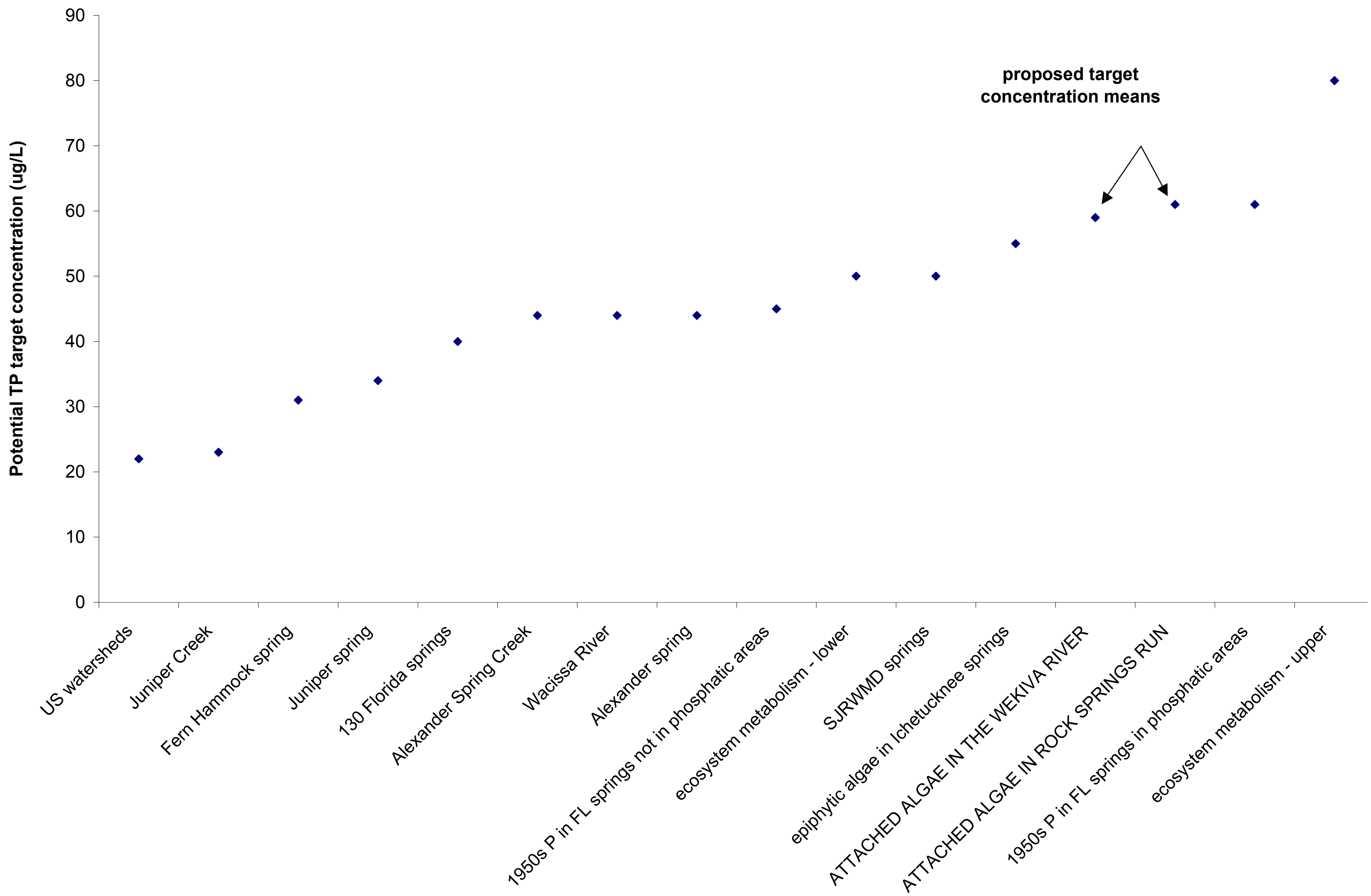


Figure 4-6. Chart showing nitrate concentration targets that were considered and mean concentration targets proposed for the Wekiva River and Rock Springs Run.

Figure 4-7. Chart showing total phosphorus concentration targets that were considered and mean concentration targets



proposed for the Wekiva River and Rock Springs Run.

Juniper also have TP values within or less than this range (40-60 µg/L). Odum (1953) reported TP values of 120-127 µg/L TP for Rock Spring in 1951. This approximates existing concentrations in the spring run (Figure 4-1), indicating either that this is the natural concentration or that anthropogenic TP loading affected the 1951 measurements and has continued, either via groundwater and/or surfacewater inflow. Rock Spring continues to average around 80 µg/L TP and Wekiva Spring 200-600 µg/L (WSI 2004; Osburn et al. 2002), which lie above the apparent natural background levels of TP based on historic data (Odum 1953) and existing reference springs (Alexander and Juniper). It is likely that the TP levels seen in the Wekiva River and Rock Springs Run in part reflect both anthropogenic enrichment and phosphorus leached from geologic deposits in the region.

4.5.4 Total Coliform Bacteria

SJRWMD proposes a not-to-exceed target concentration of **2,400 counts/100 ml total coliform bacteria**, which is the state water-quality standard for Class III waters.

4.6 Pollutant Load Reduction Goals

There are limited data available to calculate nutrient and coliform loading from various sources to the Wekiva River and Rock Springs Run and to relate in-stream concentrations to external loads. Therefore, only reductions in pollutant concentration could be calculated at this time. We assume that pollutant load reductions need to be proportional to pollutant concentration reductions. Throughout the remainder of this document, the percent load reduction is considered equal to the percent concentration reduction.

4.6.1 Nutrients

Nutrient load (concentration) reductions were calculated based on the formula:

$$[(\text{current mean} - \text{target mean}) / \text{current mean}] \times 100 \qquad \text{(Equation 4)}$$

Spatial and temporal trends were considered in development of NOx and TP target concentrations. As appropriate, the required concentration reduction was calculated either for specific segments of each spring-run stream or for the entire stream.

<u>Nitrate</u>

Temporal Trends. Nitrate has significantly decreased in the Wekiva River since 1984 (Figure 2-5). To address the temporal decrease in NOx, a “current condition” data set was created for each segment (see below) that consisted of the most recent and largest data set that showed no significant temporal trend. NOx load reductions were calculated based on the mean of the current condition data for each segment (Table 4-4).

Spatial Trends. Nitrate concentrations significantly decrease from upstream to downstream in the Wekiva River and Rock Springs Run, probably due primarily to assimilation (Figures 2-7 and 2-8). To address the downstream decrease in NOx in calculating load reductions, both spring-run streams were divided into segments (Figure 4-8; Table 4-4) with the headspring as the uppermost segment. The Wekiva River has two downstream segments separated by the confluence of the Little Wekiva River and corresponding to USEPA Water Body Identification (WBID) numbers. Rock Springs Run had one downstream segment consisting of the entire stream. Nitrate load reductions were calculated for each segment to account for the downstream decline in NOx (Table 4-5).

NOx PLRGs - Wekiva River. Based on the proposed mean target concentration of 216 µg/L, nitrate load reductions required to restore the Wekiva River range from 36-82%, with the higher reductions needed in Wekiwa Spring and the Upper Wekiva River (Table 4-5).

NOx PLRGs – Rock Springs Run. Based on the proposed mean target concentration of 221 µg/L, nitrate load reductions required to restore Rock Springs Run range from 52-85%, with the higher reductions needed in Rock Spring (Table 4-5).

<u>Total Phosphorus</u>

Temporal Trends. Total phosphorus significantly decreased over the period of record in both the Wekiva River and Rock Springs Run (Figures 2-5 and 2-6). To address the temporal decrease in TP, a "current condition" data set was created for each spring-run stream that consisted of the most recent and largest data set the showed no significant temporal trend. Total phosphorus load reductions were calculated based mean of the current condition for each spring-run stream (Table 4-5).

Spatial Trends. Total phosphorus showed no spatial trend in the Wekiva River or Rock Springs Run for the period of record (Figures 2-7 and 2-8). Consequently, total phosphorus load reductions were calculated for the entire length of each spring-run stream, with the exception of the headspring portion (Table 4-5).

TP PLRGs - Wekiva River. Based on the proposed mean target concentration of 59 µg/L, the total phosphorus load reduction required to restore the Wekiva River is 50% (Table 4-5).

TP PLRGs - Rock Springs Run. Based on the proposed mean target concentration of 61 µg/L, the total phosphorus load reduction required to restore Rock Springs Run is 29% (Table 4-5).

The PLRGs for total phosphorus are applied to the upper and lower Wekiva River (as defined for nitrate) and the length of Rock Springs Run downstream from the headspring. The PLRGs will not be applied to the headsprings of either spring-run stream at this time due to the uncertainty of how much of the spring TP load is natural

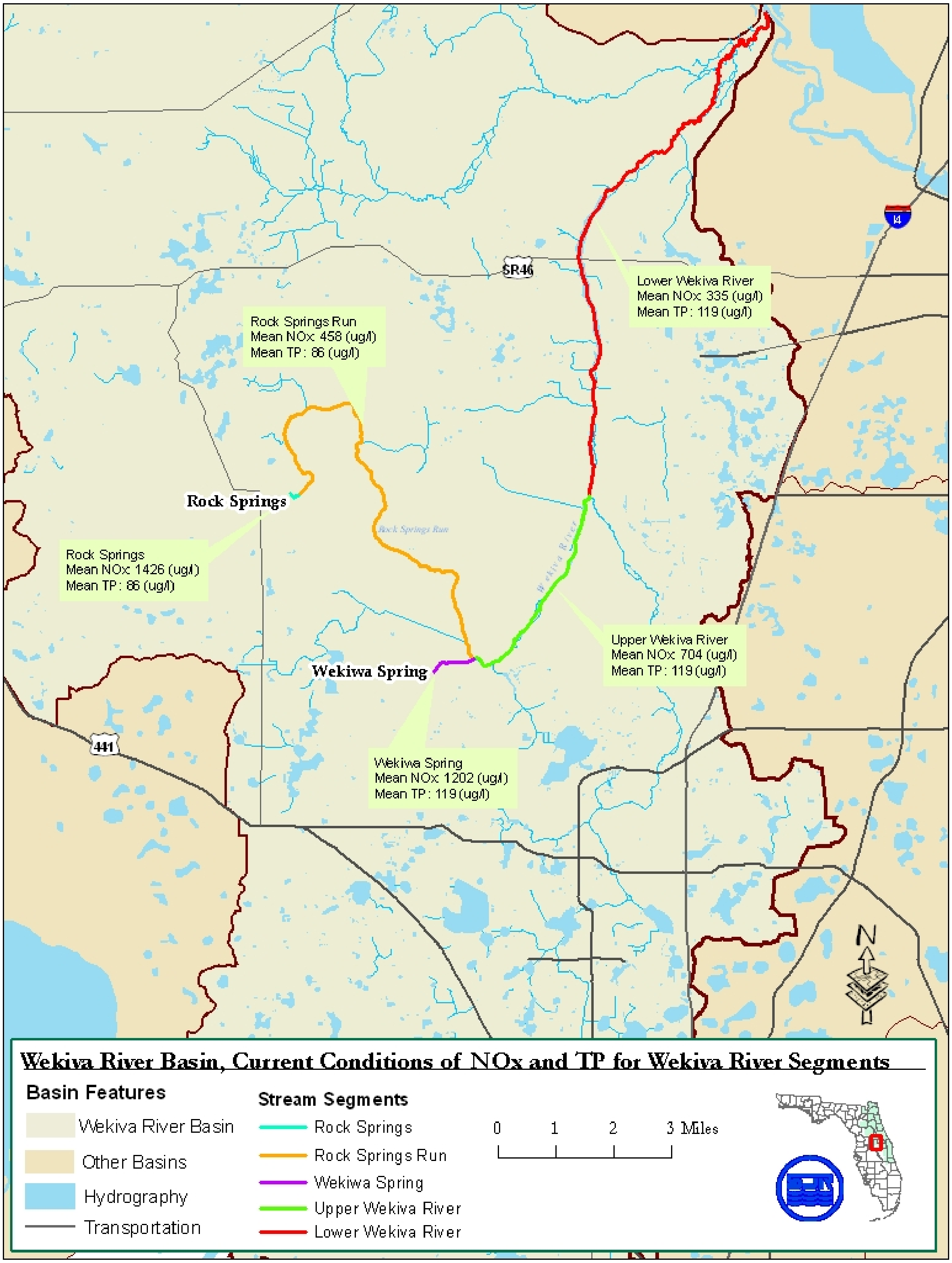


Figure 4-8. Map showing Wekiva River system segments and current conditions for nitrate (NOx) and total phosphorus (TP).

Table 4-4. Segments in the Wekiva River and Rock Springs Run used for determination of nutrient load reductions.

Segment	Distance from Headspring (meters)	USEPA Water Body Identification (WBID)
Wekiwa Spring	0-1,267	2956C
Upper Wekiva River	1,267-7,306	2956
Lower Wekiva River	7,306-23,409	2956A
Rock Spring	0-369	None
Rock Springs Run	369-14,344	2967

Table 4-5. Percent load reduction in nitrate, total phosphorus, and total coliform bacteria required to meet target mean concentrations proposed and applicable water quality standards in the Wekiva River and Rock Springs Run.

	Current Condition Mean Concentration	Target Mean Concentration	% Reduction Required to Meet Target (Concentration & Load)
Nitrate			
Wekiwa Spring	1,202 µg/L	216 µg/L	82%
Upper Wekiva River	704 µg/L	216 µg/L	69%
Lower Wekiva River	335 µg/L	216 µg/L	36%
Rock Spring	1,426 µg/L	221 µg/L	85%
Rock Springs Run	458 µg/L	221 µg/L	52%
Total Phosphorus			
Upper Wekiva River	119 µg/L	59 µg/L	50%
Lower Wekiva River	119 µg/L	59 µg/L	50%
Rock Springs Run	86 µg/L	61 µg/L	29%
Total Coliform		**Class III standard**	
Upper Wekiva River	- - -	2,400 units/100 ml	49%
Lower Wekiva River	- - -	2,400 units/100 ml	30%
Rock Springs Run	- - -	2,400 units/100 ml	50%

vs. anthropogenic. Further work will better separate these two components in the spring inflow.

4.6.2 Total Coliform Bacteria

Coliform concentration reductions were calculated by subtracting the target (2,400 colonies/100 ml) from each data point that equaled or exceeded the target, determining the % reduction needed based on this difference and obtaining the median % reduction for all of the data in two segments in the Wekiva River (upper and lower) and in Rock Springs Run. Details are provided in Appendix F.

Based on the proposed target concentration of 2,400 units/100ml, the total coliform bacteria load reduction required to restore the Upper Wekiva River is 49%, the Lower Wekiva River is 30%, and Rock Springs Run is 50% (Table 4-5).

4.7 Discussion and Conclusions

The Wekiva Parkway and Protection Act of 2004 directed SJRWMD to establish PLRGs for the Wekiva Study Area to assist FDEP in adopting Total Maximum Daily Loads (TMDLs) for impaired waters within the Wekiva Study Area. Consequently, SJRWMD and FDEP staff spent considerable time discussing and reviewing the various lines of evidence for PLRG development. The proposed Pollutant Load Reduction Goals represent the consensus of SJRWMD and FDEP.

SJRWMD acknowledges that there is still considerable uncertainty in the proposed nutrient targets, given the limitations of the data and studies used to derive the targets. The approach taken was to err on the side of resource protection, deriving targets that should be highly protective of what are widely regarded to be two spring-run streams of regional and statewide significance. These nutrient targets are water-body specific; they are intended to apply to the Wekiva River and Rock Springs Run, and may not be applicable to other spring-run systems in the SJRWMD or other areas of the state.

The pollutant concentration reductions proposed here by SJRWMD for nitrate, total phosphorus, and total coliform bacteria are based on the best data and information available within the time frame provided by the Wekiva Parkway and Protection Act. The proposed levels and load reductions should be highly protective but additional work is recommended to address remaining areas of uncertainty. The major areas of uncertainty are:

1. The studies conducted by SJRWMD were necessarily short-term in order to meet the legislative deadline, and covered less than one year. This was an insufficient period of time to reflect the range of natural intra- and inter-annual variation in spring-run streams. This problem was compounded by the fact that, during these studies, hurricanes caused atypical conditions of high water flows, scouring of vegetation, transfer of sediments and atypical water quality conditions.

2. There are no specific state standards, and no general scientific consensus, on criteria for identifying impairment of spring-run streams. Throughout the state there is attention being focused on nitrate, phosphorus and algal growth in springs and spring-runs, yet almost none of these systems are listed for these pollutants on the FDEP Verified List of Impaired Waters. Their characteristics are such that criteria in the Impaired Waters Rule for listing streams based on violations of the Narrative Nutrient Standard do not appear to apply to spring-run streams. Subsequent work will be used to refine the nutrient targets, which will most likely not be any lower than what is currently proposed in this report.

3. The potential for nitrate toxicity needs further study. Fish eggs from some species have shown nitrate toxicity at very low concentrations. These studies used species not native to Florida and there were problems with fungal contamination, so these very low reported nitrate levels were not adopted as thresholds of toxicity. Further toxicological work is needed to confirm that the proposed nitrate target concentrations are protective of the aquatic life of the Wekivia River system.

4. The relationships between periphytic algal growth and nutrient concentrations under varying conditions of current velocity and light are poorly known. These relationships need further study. Criteria for determining what levels of periphyton or macroalgae constitute a “nuisance” level need to be developed.

5. The inhibitory effects of periphyton on SAV growth, and the effects of filamentous algal growth on macroinvertebrate and fish habitat is not understood quantitatively. Further work is needed to delineate the levels of algae associated with adverse impacts on SAV and aquatic fauna.

To address some of the research needs described above, SJRWMD is performing additional work that could result in refinement of nutrient concentration targets and PLRGs for the Wekiva River and Rock Springs Run in the future. The work includes:

- Wetland Solutions is repeating data collection on stream ecosystem metabolism in all four spring-run streams (Wekiva River, Rock Springs Run, Juniper Creek and Alexander Springs Creek) in the fall and winter of 2005/06 to obtain a full year of data collection;

- Post, Buckley, Schue, and Jernigan (PBS&J), in conjunction with the University of North Carolina, are completing evaluation of in-stream surveys of algal communities and nutrients in the Wekiva River and Rock Springs Run, and are performing laboratory assays in mesocosms to determine limiting nutrients and the effects of nutrient reductions on algal growth;

- Staff is reviewing additional scientific literature on nitrate toxicity effects on aquatic animals.

Other research efforts are planned to further define impairment, pollutant impacts, and required reductions to restore and maintain the ecological integrity of these spring-run streams. SJRWMD is developing a five-year work plan for the Wekiva basin that will focus on improving understanding of spring-run stream ecosystems, impairment of spring-run streams, other pollutants of concern (including nutrient forms), and pollutant sources and loadings. These will contribute to future revisions of PLRGs proposed in this report.

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6 APPENDICES