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MINIMUM FLOWS AND LEVELS (MFLS) REEVALUATION FOR THE WEKIVA RIVER AT STATE ROAD 46, WEKIWA SPRINGS, ROCK SPRINGS, PALM SPRINGS, SANLANDO SPRINGS, STARBUCK SPRINGS AND MIAMI SPRINGS; AND MFLS DETERMINATION FOR THE LITTLE WEKIVA RIVER, LAKE, ORANGE, AND SEMINOLE COUNTIES

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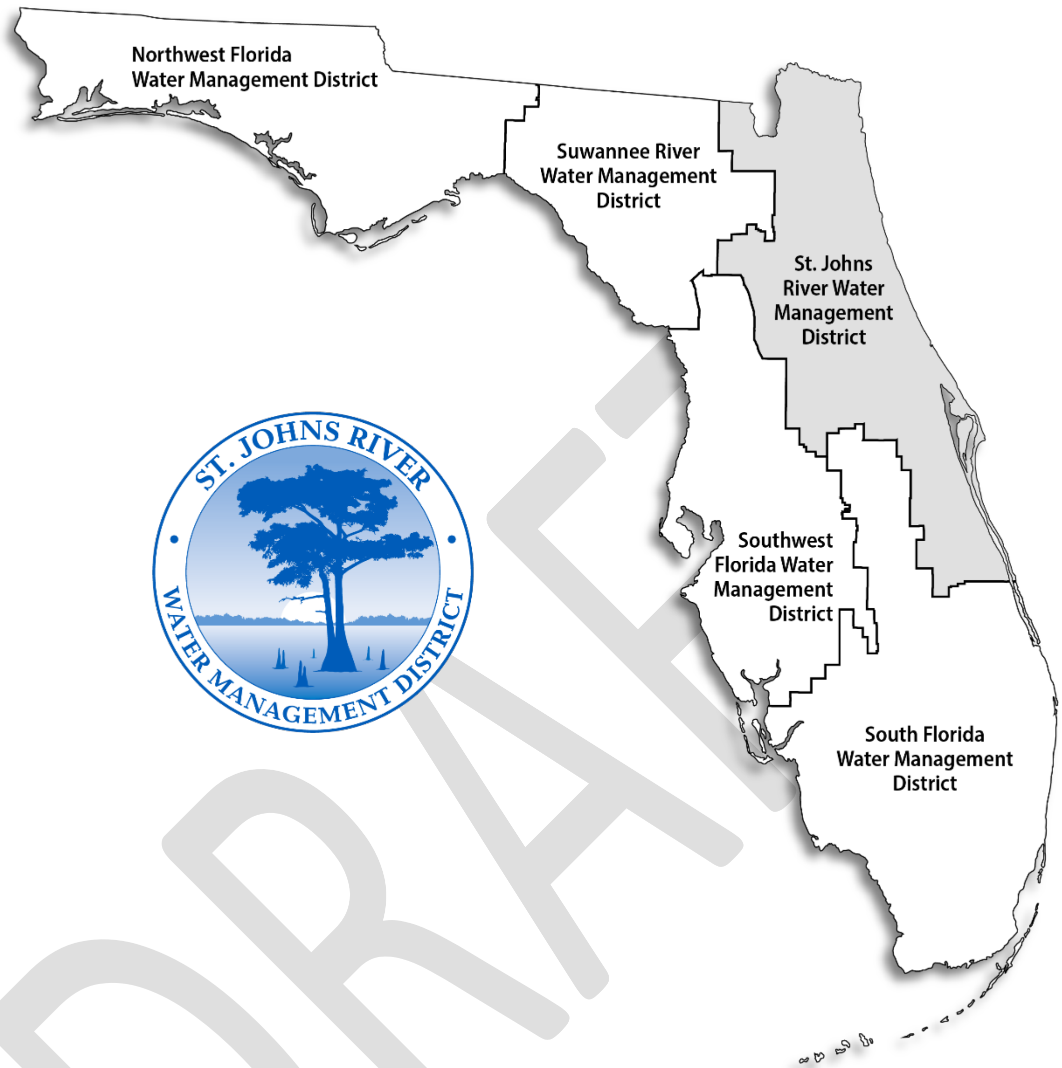

The St. Johns River Water Management District was created in 1972 by passage of the Florida Water Resources Act, which created five regional water management districts. The St. Johns District includes all or part of 18 counties in northeast and east-central Florida. Its mission is to preserve and manage the region's water resources, focusing on core missions of water supply, flood protection, water quality and natural systems protection and improvement. In its daily operations, the district conducts research, collects data, manages land, restores and protects water above and below the ground, and preserves natural areas.

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EXECUTIVE SUMMARY

As a part of fulfilling its mission and statutory responsibilities, the St. Johns River Water Management District (SJRWMD) establishes minimum flows and levels (MFLs) for priority waterbodies within its boundaries. MFLs establish a minimum hydrologic regime and define the limits at which further consumptive use withdrawals would be significantly harmful to priority water bodies. MFLs are one of many tools used by SJRWMD to assist in making sound water management decisions and preventing significant adverse impacts due to water withdrawals.

Minimum flows were adopted in 1992 for the Wekiva River at State Road (SR) 46, Wekiwa Springs, Rock Springs, Palm Springs, Sanlando Springs, Starbuck Springs and Miami Springs in Lake, Orange and Seminole counties, Florida. SJRWMD MFLs are typically reevaluated when new data becomes available and/or methodologies are updated. The MFLs for the aforementioned waterbodies were set over 30 years ago and were therefore added to the MFLs Priority List and Schedule for reevaluation. In addition to reevaluating these systems, new MFLs were also developed for the Little Wekiva River at Springs Landing Boulevard (SLB), Seminole County, Florida. All of these Wekiva River basin systems are important resources within the Central Florida Water Initiative's (CFWI) regional network of MFL water bodies and serve as critical indicators of potential impacts due to groundwater pumping.

The Wekiva River basin’s unique, biologically diverse, and regionally significant ecosystems have received numerous designations and special protections at local, state and federal levels. The Wekiva River system is one of two National Wild and Scenic rivers in Florida recognized for its “outstandingly remarkable” environmental values. Wekiwa and Rock Springs are Outstanding Florida Springs, large portions of the basin are designated as Outstanding Florida Waters, and the majority of the mainstem of the Wekiva River and Little Wekiva River are protected by the Florida Aquatic Preserves Act. The minimum flows recommended herein were developed to protect these outstanding biological, scenic, and recreational resources.

The recommended minimum flows for Wekiva River basin systems are based on current SJRWMD MFLs determination and assessment methodologies including analysis of an additional 30 years of hydrologic data collected since the original MFLs were adopted and development of hydrologic regimes under current and no-pumping conditions using the most recent surface and groundwater models. Minimum flows were developed for Wekiva River basin systems using a variety of metrics that were developed to protect important ecological structure and functions, including in-channel and floodplain attributes, as well as human beneficial uses (e.g., recreation and aesthetic values).

The SJRWMD MFLs approach involves two separate but interrelated processes: 1) the MFLs Determination; and 2) the MFLs Assessment. The first process involves establishing the MFLs condition by determining a minimum hydrologic regime necessary to protect environmental metrics that represent a suite of relevant water resource values. The second process involves comparing the MFLs condition to a current-pumping condition to determine the current status of each environmental metric. Once all metrics are evaluated, the most limiting metric(s), in terms of available water, forms the basis of the overall MFLs.

The Wekiva River at SR 46 is the most downstream system assessed in the Wekiva River basin. The Wekiva River at SR 46, and Wekiwa Springs are the most constraining systems assessed in the basin. Both have an MFLs condition equal to the current-pumping condition (i.e., their constraining metrics are barely met by the current-pumping condition). Because other water bodies evaluated are upstream of and contribute the majority of the flow to the Wekiva River at SR 46, the recommended allowable impact for all other systems in the basin is also equal to the current-pumping condition. This is necessary because any further flow reduction in the springs upstream of SR 46 gage (from current-pumping condition) would decrease the flows at SR 46 and result in violation of the MFLs at that location. Therefore, the proposed upstream MFLs will ensure the provision of flow sufficient to meet the most downstream constraint at SR 46.

In addition to the constraining metrics at Wekiwa Springs and the Wekiva River at SR 46 (the minimum frequent high and minimum average levels), other metrics also suggest that limiting water withdrawal in the Wekiva River basin to the current-pumping condition is warranted and reasonable. These include several water resource values, listed in Rule 62-40.473, *Florida Administrative Code, (F.A.C.),* as well as a basin-wide wetland inundation analysis that indicates a moderate (15.6%) reduction in wetland inundation under current water withdrawal conditions. Further, an analysis of biologically-relevant hydrological statistics, called Indicators of Hydrologic Alteration, indicates that many of these parameters are exhibiting changes under the current-pumping condition. Taken as a whole, these analyses indicate that biologically meaningful changes to the flow regime are currently occurring and using the current-pumping condition as the basin-wide MFLs condition is reasonable and prudent.

Recommended minimum average flows, for the eight Wekiva River basin systems assessed, are provided below (Table ES-1). Current (adopted) minimum average flows, for a subset of systems, are also presented below; an adopted minimum flow was not originally adopted for the Wekiva River at SR 46 (original MFLs are event-based, not average flows) or for the Little Wekiva River.

The East Central Florida Transient Expanded version 2.0 (ECFTX v2.0) groundwater model was used for the Wekiva River basin groundwater pumping impact analysis to develop the current-pumping condition timeseries data needed for the MFLs assessment. The current-pumping condition is defined as the average pumping condition between 2014 and 2018 and

Table ES-1. Original (adopted) and recommended minimum average flows for Wekiva River basin MFLs water bodies; SR 46 = Florida State Road 46; SLB = Springs Landing Boulevard. NA = Not available, because adopted MFLs for SR 46 are event-based, not average flow, and because MFLs were not originally adopted for the Little Wekiva River.

System	Original (adopted) Minimum Average Flow (cfs)	Recommended Minimum Average Flow (cfs)
Wekiva River at SR 46	NA	278.5
Little Wekiva R. at SLB	NA	71.3
Rock Springs	53.0	55.8
Wekiwa Springs	62.0	64.4
Miami Springs	4.0	5.6
Palm Springs	7.0	5.6
Sanlando Springs	15.0	21.0
Starbuck Springs	13.0	12.8

represents water withdrawals influenced by the range of climatic conditions (e.g., rainfall) present over that period. If these conditions are repeated over the next ~71 years (i.e., the length of the period of record), and average pumping remains the same, current-pumping condition flows are expected to reflect future flows.

Because the recommended MFLs condition in the basin equals the current-pumping (i.e., defined as the 2014 - 2018 average) condition, the current-pumping condition freeboard (or the allowable change in flow from current pumping) for each MFLs water body in the Wekiva River basin is zero cubic feet per second (cfs).

However, in recent years water use has increased relative to the CP (i.e., 2014 - 2018 average) condition. Therefore, all Wekiva River basin systems are in recovery, and a recovery strategy must be developed concurrently with the MFLs. Consistent with the provisions for establishing and implementing MFLs provided for in section 373.0421, F.S., the recovery strategy identifies a suite of projects and measures that, when implemented, will recover these priority water bodies from impacts due to groundwater pumping withdrawals and prevent the MFLs from not being met due to future consumptive uses of water. The recovery strategy will also provide sufficient water supply options to meet existing and projected reasonable beneficial uses.

The MFLs condition equates to an allowable flow reduction, relative to the pre-withdrawal (referred to as no-pumping) condition, of 26.0 cfs for the Wekiva River at SR 46, 8.9 cfs for the Little Wekiva River at SLB, 4.6 cfs at Wekiwa Springs, 11.1 cfs at Rock Springs, 5.0 cfs at Sanlando Springs, 2.2 cfs at Starbuck Springs, 1.1 cfs at Palm Springs, and 0.8 cfs at Miami Springs.

The recommended minimum flow for the mainstem of the Wekiva River at SR 46 equates to an allowable reduction in flow, relative to the no-pumping condition, of 8.5%. This is similar to the allowable change (10% reduction from pre-withdrawal condition) conventionally considered protective for large river systems with outstanding ecological attributes. The allowable reduction in flow (8.5%) based on the recommended Wekiva River MFLs is also within the range (3.0 – 19.0%) and similar to the average (7.6%) allowable flow reduction of adopted MFLs for spring-fed rivers in Florida.

An adaptive management approach will be used to ensure the protection of water bodies within the Wekiva River basin. As part of this approach, and in an effort to ensure that MFLs springs in the Wekiva basin will not be significantly harmed by groundwater pumping, UFA well OR0548 at Wekiwa Springs State Park will be monitored to evaluate groundwater level trends and the relationship between aquifer levels and spring flows.

SJRWMD concludes that the recommended minimum flows for the Wekiva River basin will protect relevant Rule 62-40.473, *F.A.C.*, environmental values from significant harm due to water withdrawals. The recommended minimum flows presented in this report are preliminary and will not become effective until adopted by the SJRWMD Governing Board and incorporated into Rule 40C-8.031, Florida Administrative Code.

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GLOSSARY

Atlantic Multidecadal Oscillation (AMO): Long-term variability of the sea surface temperature occurring in the North Atlantic Ocean, including cool and warm phases with an estimated quasi-cycle period of 60-80 years. These changes are natural and have been occurring for at least the last 1,000 years.

Consumptive Use Permit (CUP): A permit which allows water to be withdrawn from groundwater or surface water for reasonable-beneficial uses — such as public supply (drinking water), agricultural and landscape irrigation, commercial use and power generation — in a manner that does not interfere with other existing legal water uses and protects water resources from harm.

Current-pumping Condition Flow or Level: Long-term simulated flow or water level time series that represents what flows or water levels would be if "current" groundwater pumping was present throughout the entire period of record. The average groundwater pumping available over the latest five-year period is used to estimate "current" groundwater pumping.

Deficit: The amount of water needed to recover MFLs, that is not currently being achieved. For a spring or spring-fed river MFL, deficit is expressed as the amount of recovery (in cfs) needed in spring or river flow.

El Nino Southern Oscillations (ENSO): periodic departures from expected sea surface temperatures (SSTs) in the equatorial Pacific Ocean, ranging from about three to seven years. These warmer or cooler than normal ocean temperatures can affect weather patterns around the world by influencing high- and low-pressure systems, winds, and precipitation.

Environmental criteria: Specific ecological or human use functions or values in Rule 62-40.437(1), F.A.C., that are evaluated when setting or assessing an MFL.

Event: A component of an MFL composed of a magnitude and duration.

Freeboard: The amount of water available for withdrawal before an MFL is not achieved. For a spring or river MFL, freeboard is expressed as the allowable reduction in flow in cubic feet per second (cfs).

Frequency Analysis: a statistical method used to estimate the annual probability of a given hydrological (exceedance or non-exceedance) event; used to assess the current status of an event-based MFL by comparing the frequency of critical hydrological events under current-pumping conditions to recommended minimum frequency of these events.

Hydrologic Regime: A timeseries of flows (or water levels) within a specified period of record for a specific water body. Flows (or water levels) typically vary over time, and this variation is an important component of the regime, maintaining critical environmental functions and values.

Minimum Hydrologic Regime: A hydrologic regime with an average flow (or level) that is lower than the no-pumping condition, that protects relevant environmental values from significant harm.

MFLs Condition: The MFLs Condition is a specific “minimum hydrologic regime” (see definition above) that is based on the most constraining MFLs metric and is necessary to protect a water body from significant harm. The MFLs condition represents an allowable change from the no-pumping condition for the entire period of record. It represents a lowering of the no-pumping condition, but only to the degree that still protects a water body from significant harm. The MFLs Condition is based upon the minimum flow or level that is most constraining to water withdrawal, for a given water body.

Minimum Flows and Levels (MFL): Environmental flows or levels expressed as hydrological statistics, based on the most constraining environmental value, that defines the point at which additional water withdrawals will result in significant harm to the water resources or the ecology of the area (Sections 373.042 and 373.0421, *F.S.*).

No-pumping Condition Levels: A long-term simulated time series that represents what flows or water levels would be if there were no impact due to water withdrawal.

Pacific Decadal Oscillation (PDO): a long-lived El Niño-like pattern of Pacific climate variability with an estimated quasi-cycle period of 20-30 years.

ACRONYMS AND ABBREVIATIONS

AMO	Atlantic Multidecadal Oscillation
AWS	Area-Weighted Suitability
BMAP	Basin Management Action Plan
BOD	Biological Oxygen Demand
CFWI	Central Florida Water Initiative
CP	Current-pumping [condition]
CUP	Consumptive Use Permit
ECFTX	East-Central Florida Transient Expanded [groundwater model]
ENSO	El Nino Southern Oscillation
F.A.C.	*Florida Administrative Code*
FDEP	Florida Department of Environmental Protection
FH	Frequent High [MFL level]
FLUCCS	Florida Land Use Classification Code System
F.S.	*Florida Statutes*
GIS	Geographic Information System
GPP	Gross Primary Productivity
HAT	[CFWI] Hydrologic Analysis Team
H/HE	Histosol and Histic Epipedon
HEC-RAS	Hydrologic Engineering Center River Analysis System
IFIM	Instream Flow Incremental Methodology
IHA	Indicators of Hydrologic Alteration
LiDAR	Light Detection and Ranging
MA	Minimum Average [MFL level]
MFLs	Minimum Flows and Levels
NAVD 88	1988 North American Vertical Datum
NEXRAD	Next Generation Weather Radar

NFR	Natural Flow Regime
NOAA	National Oceanic and Atmospheric Administration
NP	No-pumping [condition]
NRCS	Natural Resources Conservation Service
OFS	Outstanding Florida Spring
OFW	Outstanding Florida Water
PDO	Pacific Decadal Oscillation
PLRG	Pollutant Load Reduction Goal
POR	Period of Record
SEFA	System for Environmental Flow Analysis
SJRWMD	St. Johns River Water Management District
SLB	Springs Landing Boulevard
SPI	Standardized Precipitation Index
SRWMD	Suwannee River Water Management District
SR 46	[Florida] State Road 46
SWFWMD	Southwest Florida Water Management District
SSURGO	Soil Survey Geographic database
SWIDS	Surface Water Inundation and Dewatering Signatures
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
UFA	Upper Floridan aquifer
USGS	U.S. Geological Survey
USDA	U.S. Department of Agriculture
WRV	Water Resource Value

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) completed a minimum flows and levels (MFLs) reevaluation for seven systems within the Wekiva River basin, located in Lake, Orange and Seminole counties, Florida. These water bodies include the mainstem of the Wekiva River (assessed at State Road 46), Wekiwa Springs, Rock Springs, Palm Springs, Sanlando Springs, Starbuck Springs and Miami Springs (Figure 1). New MFLs have also been developed for the Little Wekiva River. The following describes the development of eight Wekiva River basin MFLs (i.e., seven reevaluations and one new MFL).

MFLs were originally adopted for the Wekiva River at SR 46, Wekiwa Springs, Rock Springs, Palm Springs, Sanlando Springs, Starbuck Springs and Miami Springs on September 16, 1992 (Chapter 40C-8, *Florida Administrative Code* [*F.A.C.*]); Hupalo et. al. 1994; Appendix A). As standard practice, MFLs are reviewed periodically and revised if appropriate (Section 373.042, *Florida Statutes* [F.S.]). The Wekiva River basin systems were prioritized for MFLs reevaluation because of their cultural and ecological significance and potential for impact due to consumptive use of water (i.e., water withdrawal). Further, these systems were reevaluated to ensure that the Wekiva basin MFLs are based on the latest data and most up to date methods. MFLs have also been established for the Little Wekiva River to protect this important tributary to the Wekiva River and provide protection for three small contributing springs: Palm, Sanlando and Starbuck Springs. The systems within the Wekiva River basin are important water resources within the Central Florida Water Initiative (CFWI) area. They are a vital part of the CFWI's regional network of MFLs and are critical indicators of potential impacts due to groundwater pumping.

The Wekiva River is the third largest tributary of the St. Johns River and receives a majority of its flow from numerous named and un-named springs flowing within its approximately 376 square-mile watershed (Figure 2). The Wekiva River changes character as it travels north for 15 miles, transforming from cool, clear headwater springs, into wide and sunny middle reaches and then into the deep, narrow, and shady river before its confluence with the St. Johns River.

The Wekiva River system's unique, biologically diverse, and regionally significant ecosystems have received numerous designations and special protections at local, state and federal levels. The Wekiva River system was designated as a National Wild and Scenic River in 2000, making it only the second Florida river afforded this protection. This designation, conferred by the U.S. Congress and administered by the National Park Service is for riverine ecosystems with "outstandingly remarkable" scenic, recreational, or other functions and values that merit protection. Large portions of the basin are also designated as Outstanding Florida Waters (OFW; Chapter 62-302, *F.A.C.*) and the majority of the mainstem of the Wekiva River and Little Wekiva River are protected by the Florida Aquatic Preserve Act (Part II of Chapter 258, F.S.) in Section 258.39(30), F.S. (Figure 3). The Act's

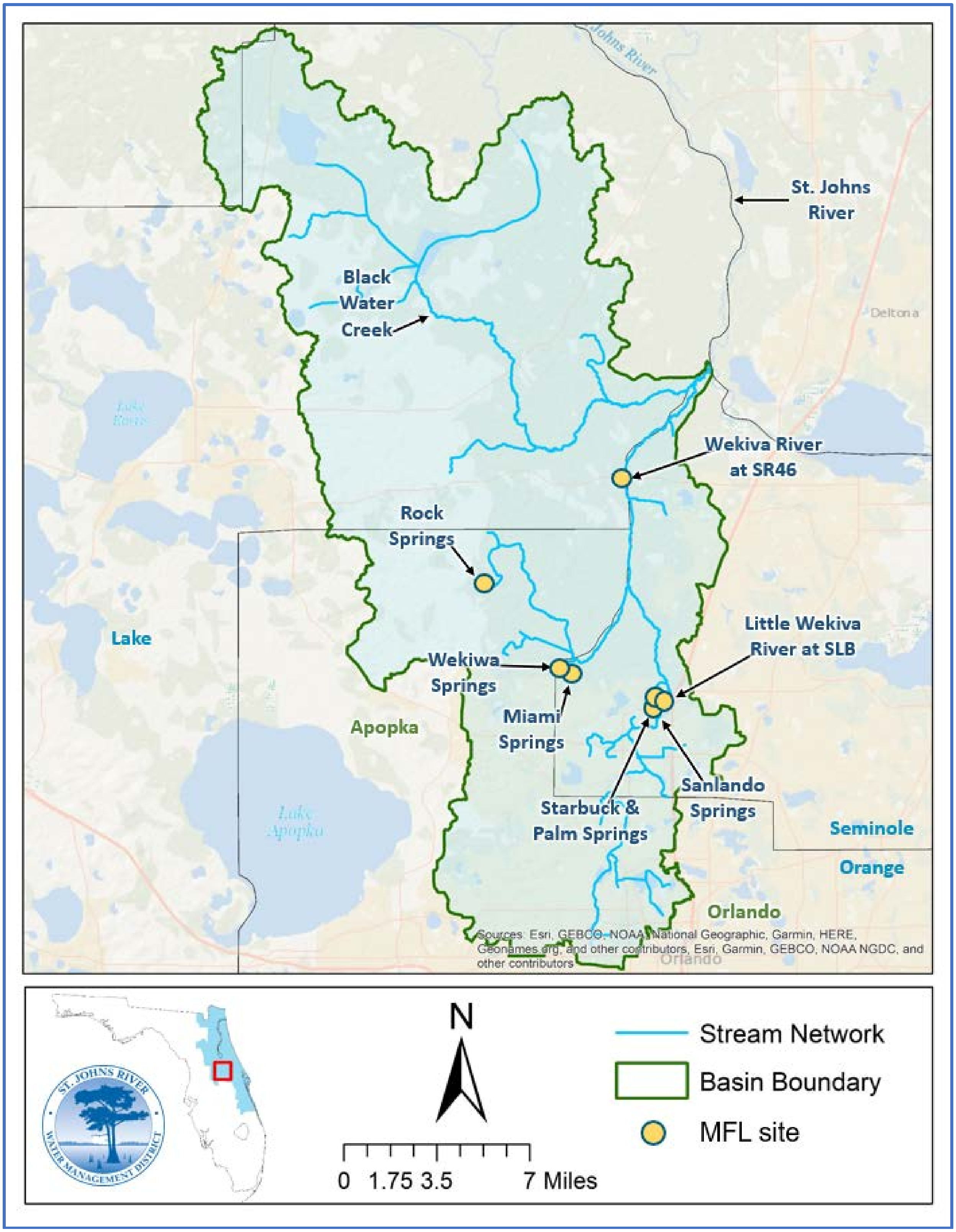

Figure 1. Location of MFLs water bodies within Wekiva River basin boundary.

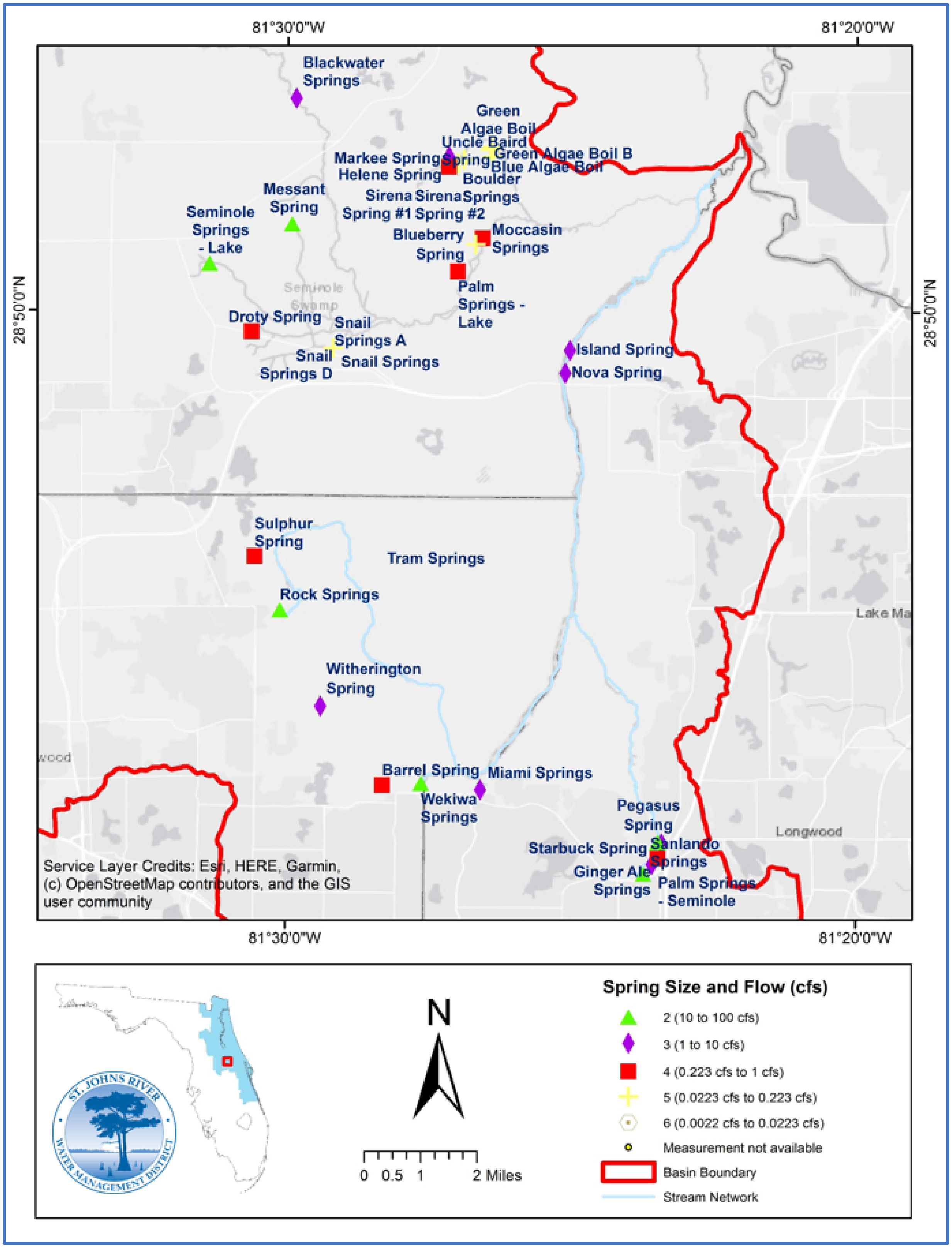

Figure 2. Location of named springs within Wekiva River basin; numerous unnamed springs are not depicted.

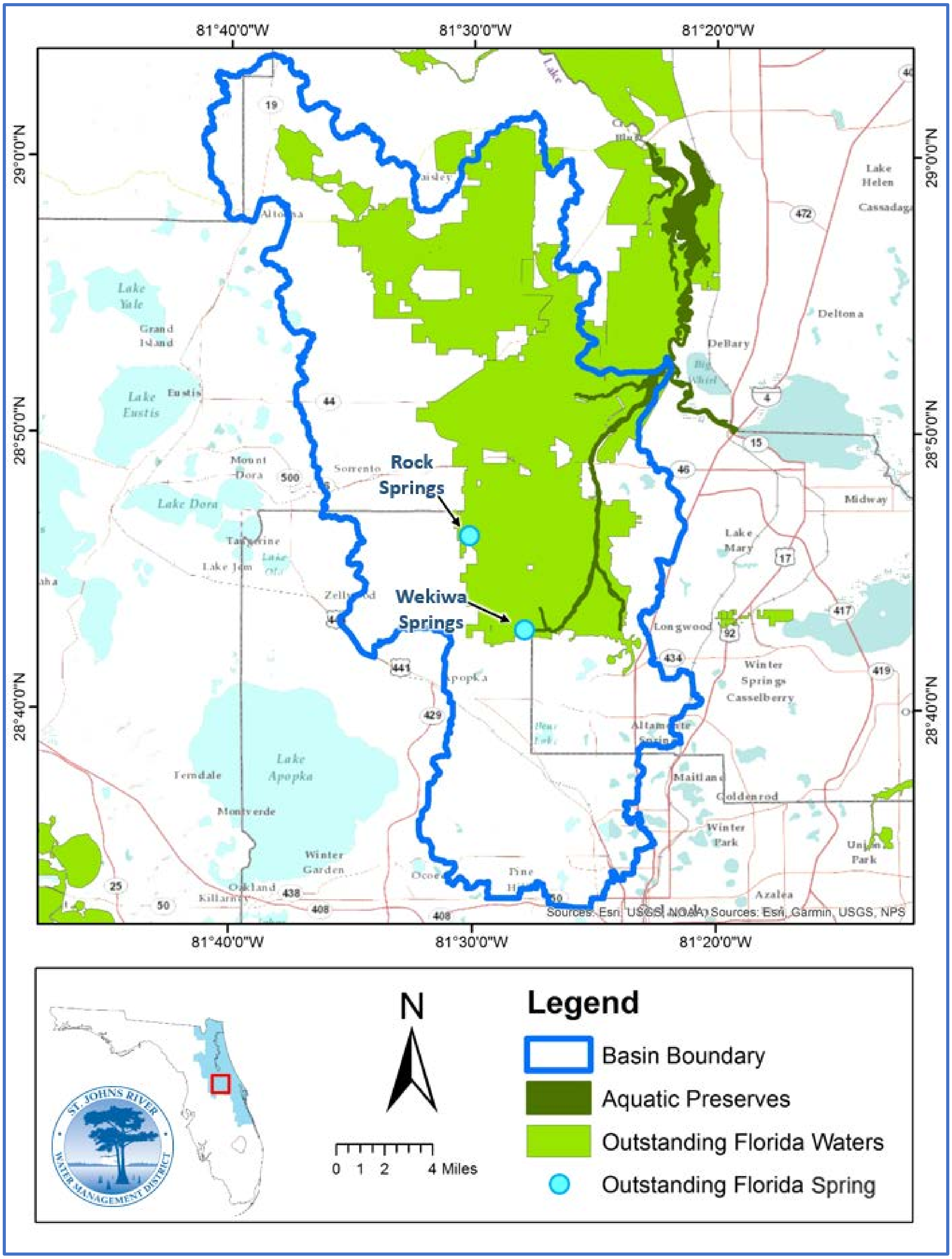

Figure 3. Areas within the Wekiva River basin protected by Outstanding Florida Waters (OFW), Outstanding Florida Spring (OFS) and Aquatic Preserve designations.

intent statement provides an apt summary of the importance of the Wekiva River's ecological and human-use values:

"It is the intent of the Legislature that the state-owned submerged lands in areas which have exceptional biological, aesthetic, and scientific value, as hereinafter described, be set aside forever as aquatic preserves or sanctuaries for the benefit of future generations."

Wekiwa Springs and Rock Springs, the two largest contributing springs to the Wekiva River, are both second magnitude and both designated as Outstanding Florida Springs (OFS) in Section 373.802(4), F.S. In addition to these designations, the Wekiva River is also a Florida Scenic and Wild River, a State Canoe Trail, and considered Regionally Significant by the East Central Florida Regional Planning Council. Numerous stakeholder groups also work to protect these unique natural systems including the non-profit Friends of the Wekiva River and the Aquatic Preserve Alliance of Central Florida, Inc.

As pressures from population growth and urbanization increase in the Wekiva River basin and springshed, the value of these unique resources becomes all the more apparent. External changes highlight the rarity and importance of the Wekiva River system and the 110 square miles of adjacent public lands as recreational resources for residents of central Florida, and beyond. The springs, rivers and adjacent lands are year-round destinations for hiking, swimming, bird watching, canoe and kayak paddling, and many other outdoor pursuits.

The MFLs determination described herein resulted in the recommendation to modify the adopted MFLs for the Wekiva River, Rock Springs, Wekiwa Springs, Miami Springs, Palm Springs, Sanlando Springs, and Starbuck Springs and to establish new MFLs for the Little Wekiva River. These recommendations are based on current SJRWMD MFLs determination and assessment methodologies and data from updated surface and groundwater models. This report describes environmental analyses used to develop protective criteria and minimum flows for eight Wekiva Basin systems. Hydrological analyses and current and future status assessment of recommended minimum flows are also provided. The recommended MFLs for the Wekiva Basin are intended to support the protection of aquatic and wetland ecosystems, as well as human beneficial uses, from significant harm caused by the consumptive use of water.

LEGISLATIVE OVERVIEW

SJRWMD establishes MFLs for priority water bodies within its boundaries (section 373.042, F.S.). MFLs for a given water body are the limits "at which further withdrawals would be significantly harmful to the water resources or ecology of the area" (section 373.042, F.S.). MFLs are established using the best information available (section 373.042(1), F.S.), with consideration also given to "changes and structural alterations to watersheds, surface waters, and aquifers and the effects such changes or alterations have had, and the constraints such changes or alterations have placed, on the hydrology of the affected watershed, surface water, or aquifer...," provided that none of those changes or alterations shall allow significant harm caused by water withdrawals (section 373.0421(1)(a), F.S.).

The minimum flows and levels section of the State Water Resources Implementation Rule (Rule 62-40.473, *F.A.C.*) requires that "consideration shall be given to natural seasonal fluctuations in water flows or levels, non-consumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology." The environmental values described in Rule include:

1. Recreation in and on the water;
2. Fish and wildlife habitats and the passage of fish;
3. Estuarine resources;
4. Transfer of detrital material;
5. Maintenance of freshwater storage and supply;
6. Aesthetic and scenic attributes;
7. Filtration and absorption of nutrients and other pollutants;
8. Sediment loads;
9. Water quality; and
10. Navigation.

MFLs are used in SJRWMD's regional water supply planning process (section 373.0361, F.S.), the consumptive use permitting program (Chapter 40C-2, *F.A.C.*), and the environmental resource permitting program (Chapter 62-330, *F.A.C.*).

SJRWMD MFLs Program Overview

The SJRWMD continues its district-wide effort to develop MFLs to protect priority surface water bodies, watercourses, associated wetlands, and springs from significant harm caused by water withdrawals. MFLs provide an effective tool for decision-making regarding planning and permitting of surface water or groundwater withdrawals. The purpose of setting MFLs is to answer an overarching question:

"*What minimum hydrologic regime is necessary to protect the critical environmental values of a priority water body, from significant harm due to water withdrawals?"*

These environmental values typically include ecological structure and function as well as human beneficial uses. Conversely, MFLs are *not* meant to represent *optimal* conditions. Rather, they are mandated by statute to set the limit to water withdrawals, beyond which significant harm will occur. A fundamental assumption of SJRWMD's approach is that alternative hydrologic conditions exist that are lower than pre-withdrawal conditions, but that still protect the environmental functions and values of MFLs water bodies from significant harm caused by water withdrawals.

For the Wekiva Basin MFLs, significant harm is defined in different ways depending on the environmental metric being evaluated. There are "event-based" metrics for which significant harm is associated with a change in hydrologic event frequency. MFLs events are composed of a magnitude and duration; events are typically assessed by evaluating the effect of water withdrawal on their return interval (frequency; Neubauer et al. 2008). MFLs are developed to ensure that withdrawal-related changes in return interval of critical events, are not sufficient to cause significant harm, defined as impairment or loss of ecological structure or function. In addition to event-based metrics, there are other metrics (e.g., in instream fish habitat area) for which significant harm is defined as a 15% reduction relative to a pre-withdrawal condition.

The SJRWMD MFLs approach involves two separate but interrelated processes: 1) the MFLs Determination; and 2) the MFLs Assessment. The first process involves establishing the MFLs condition by determining a minimum hydrologic regime necessary to protect each specific water resource value (i.e., environmental metric). The second process involves comparing this "MFLs condition" to a current-pumping condition to determine the current status of each metric. Once all metrics are evaluated, the most limiting metric(s), in terms of available water, forms the basis of the overall MFLs. The overall process involves environmental assessments, hydrologic modeling, independent scientific peer review, and rulemaking.

Many SJRWMD MFLs define a minimum hydrologic regime by establishing a protective frequency of high, intermediate, and low hydrologic events (e.g., setting multiple event-based metrics). For some priority water bodies, a protective regime is established based on a percentage of change allowable from a pre-withdrawal condition. No matter how environmental thresholds are set, or how many MFLs are adopted for a given water body, the most constraining (i.e., most sensitive to pumping) MFL is always used for water supply planning and permitting.

If the status assessment indicates that an MFL is currently not being met or is projected to not be met during the 20-year planning horizon, a water management district or the FDEP must adopt a recovery or prevention strategy concurrently with the adoption of the MFL. A recovery strategy is required when an MFL is not currently being met. A prevention strategy is required when an MFL is projected to not be met over the 20-year planning horizon.

SETTING AND DESCRIPTION

LOCATION AND PHYSIOGRAPHIC SETTING

The headwaters of the Wekiva River basin are located north of Orlando and east of the city of Apopka (Figure 1). The Wekiva River basin is in the Middle St. Johns River surface water basin, has a drainage area of approximately 376 square miles and encompasses three primary watercourses: the Wekiva River, the Little Wekiva River, and Black Water Creek (Figure 1). There are at least 35 named springs within the Wekiva River sub-basin, including Rock Springs, Wekiwa Springs, Miami Springs, Palm Springs, Sanlando Springs, Starbuck Springs, Seminole Springs, and Messant Springs (Figure 2).

The Wekiva River begins 0.8 miles downstream from Wekiwa Springs at the confluence of Wekiwa Springs Run and Rock Springs Run (Figure 4). The Wekiva River flows north for approximately 15 miles to the St. Johns River, defining portions of the county lines of Orange, Seminole and Lake Counties. Wekiwa Springs is a second magnitude spring located within Wekiwa Springs State Park, in Orange County. It is approximately 16 miles north of downtown Orlando and approximately 4 miles east of the City of Apopka. Rock Springs, also in Orange County, is within the County-owned Kelly Park, and is also adjacent to the town of Apopka, FL (Figure 4). Surface waters associated with Rock Spring include the 9-mile Rock Springs Run.

The Little Wekiva River flows north approximately 17 miles from Lawne Lake, in the Pine Hills neighborhood of Orlando, to its confluence with the Wekiva River in Seminole County (Figure 5). The lower reach of the Little Wekiva River, which extends immediately north of Highway 434 to the River's confluence with the Wekiva River, is designated as an OFW for its natural attributes and ecological values (Chapter 62-302, *F.A.C.*).

The Wekiva River occupies the solution valley of the St. Johns Offset sub-district of the Central Lakes District located in the Atlantic Coastal Plain Province (Brooks and Merrit, 1981; Brooks 1982; Figure 4). The Central Lakes District features uplifted limestones of the Floridan aquifer positioned unconformably below surficial sands. This region consists primarily of xeric sand hill karst areas with solution basins as typified by the Apopka Upland, Casselberry-Oviedo-Geneva-Chuluota Hills, and Orlando Promontory sub-districts. This region is characterized by active collapsed sinkhole development.

The St. Johns Offset subdistrict is an ancient portion of the St. Johns River Valley, partially filled with Pleistocene estuarine depositions and Eocene limestone very near the surface. Historically, flatwoods typified these Pleistocene terraces and river swamps occur on the floodplain (Brooks 1982). The Wekiva River drains the lowlands of the St. Johns Offset and receives water from the springs located along the Apopka Upland to the south. The Wekiva River floodplain is near sea level, as well as near the potentiometric surface of the Floridan

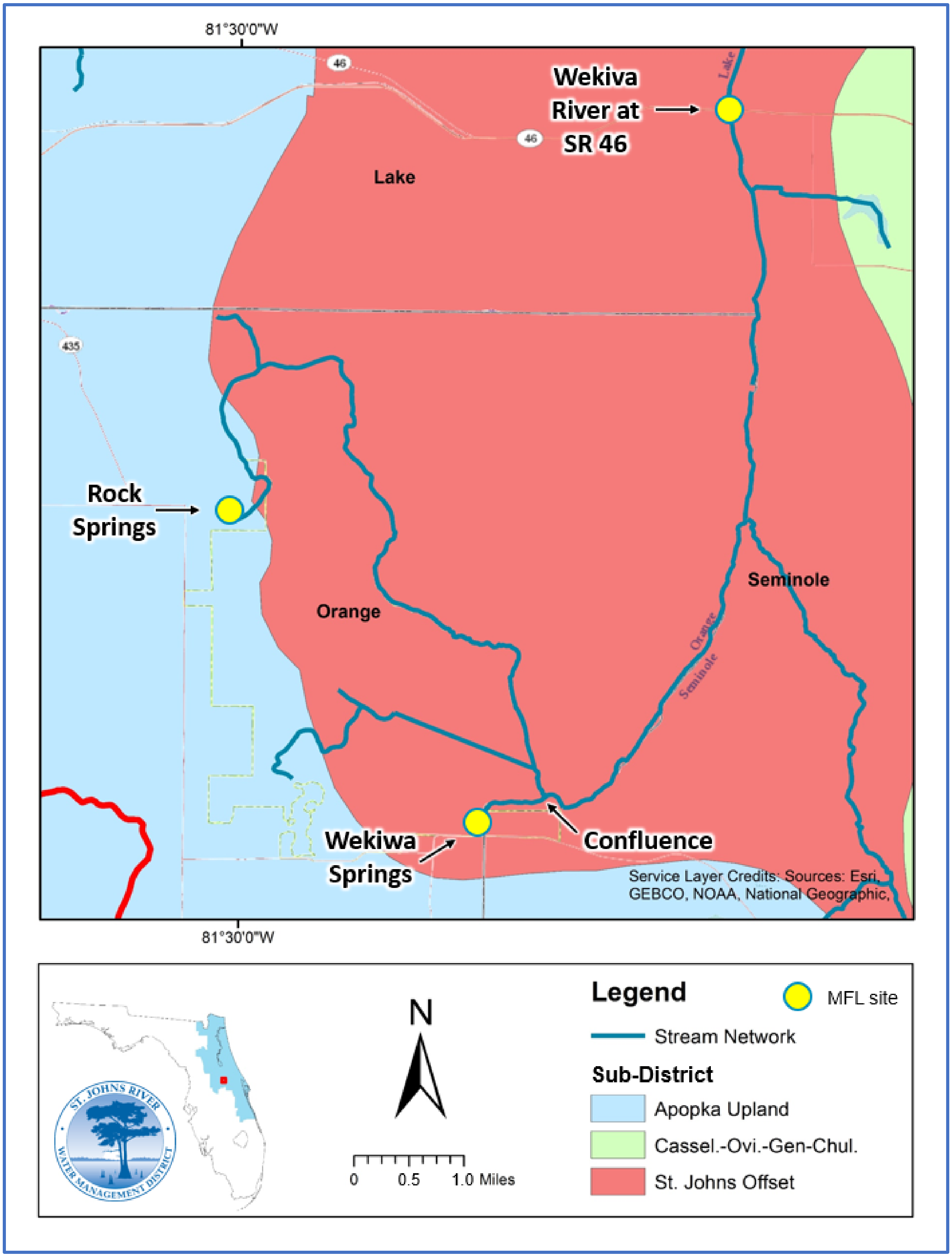

Figure 4. Close-up map of Wekiwa Springs, Rock Springs, and SR 46 MFLs sites, depicting physiographic province.

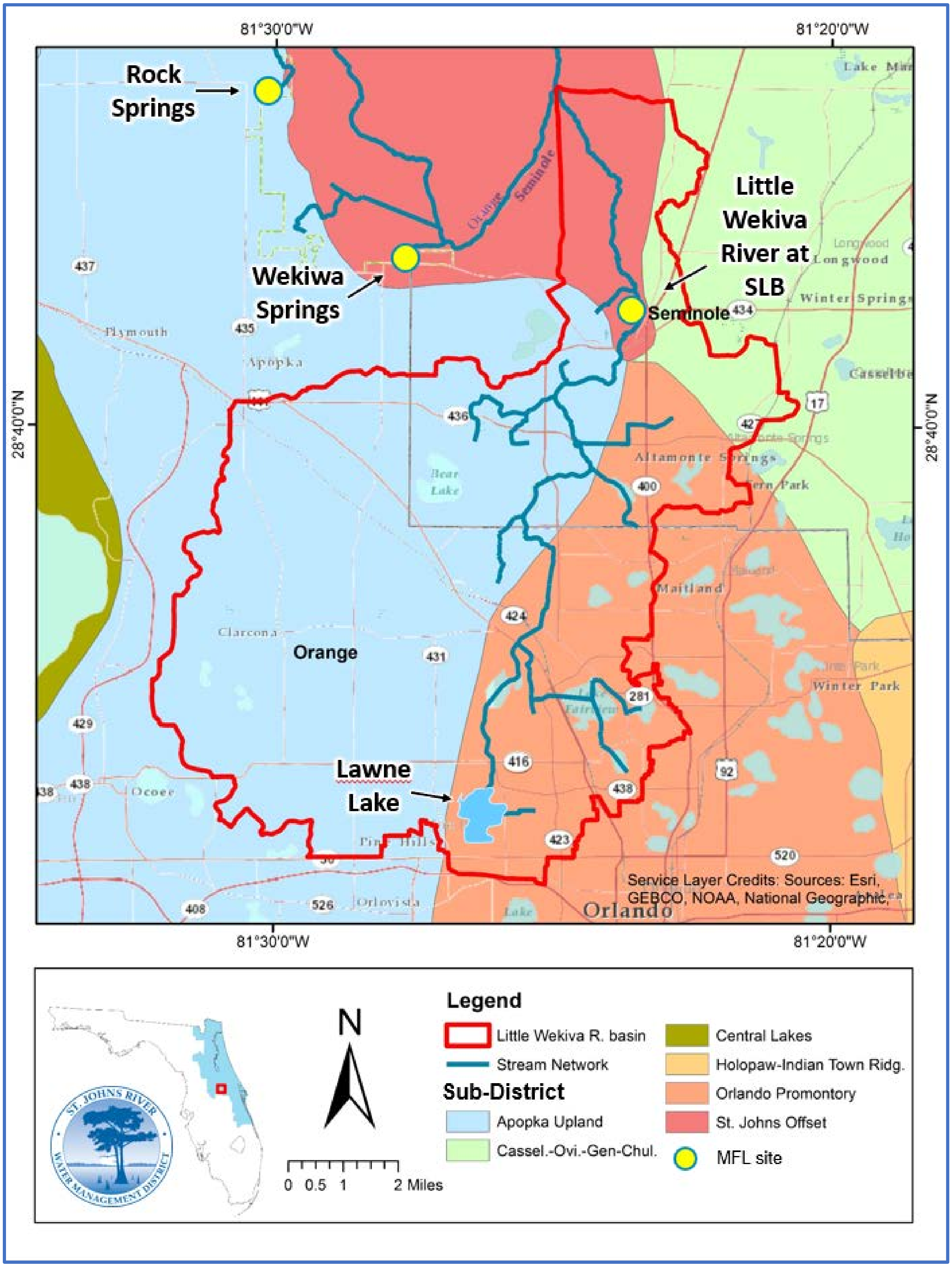

Figure 5. Close-up map of Little Wekiva River MFLs site, depicting physiographic Provinces.

aquifer (USGS 2000). The physiography of the Rock Springs planning unit is split between the Apopka Upland and the St. Johns Offset subdistricts of the Central Lakes District (Brooks 1982; Figure 4). The physiography of the Little Wekiva River surface water sub-basins is divided between the Apopka Upland, the St. Johns Offset, the Orlando Promontory, and the Casselberry-Oviedo-Geneva-Chulota Hills sub-districts of the Central Lakes District (Brooks 1982; Figure 5). The northern reach of the Little Wekiva River lies within the St. Johns Offset sub-district.

HYDROLOGY

Water Level and Flow Data

Water level and flow data used to develop and assess the Wekiva River basin MFLs were collected from both SJRWMD and USGS gaging stations (Table 1). Continuous flow data were not measured directly, but rather calculated from continuously measured water level data, using rating curves generated based on occasional flow measurements. Data from additional gages were also used to develop the surface water model used in the MFLs determination and assessment (see Appendix B for information about these additional gages and see Seong and Wester 2019 for details about the Wekiva River basin surface water model).

The period of record (POR) for water level and flow data at the Wekiva River at SR 46 gage (USGS station 02235000) is from 1935 to the present (Tables 1, 2 and 3). During this period, Wekiva River flow at SR 46 has fluctuated from approximately 105 to 2,270 cubic feet per second (cfs) with average flow (287 cfs) higher than median flow (249 cfs; Figure 6, Table 2). Water levels at SR 46 have fluctuated between 5.0 and 10.8 ft based on the 1988 North American Vertical Datum (NAVD 88), with both median and average water levels equaling 6.6 ft NAVD 88 (Figure 6; Table 3). Wekiva River channel morphology at the SR 46 gage has changed dramatically over the POR, with channel down cutting resulting in declines in river stages in 1957, 1973, and 1990 (Figure 7; Rao 2008). Increases in river stage after 2004 are related to channel sedimentation that occurred up until Hurricane Irma in 2017. Record high river stages and flows at SR 46 due to high rainfall from Hurricane Irma resulted in channel down cutting and is thought to be related to more recent low river stages at that site (Figure 7). See Appendix B for additional information on water level and flow data.

Flow data has been collected at Wekiwa Springs (SJRWMD/USGS station 00371831) since 1932, although only a few measurements are available prior to 1968. Continuous flow measurements began in 1999. During this period Wekiwa Springs flow has ranged from 48.6 to 91.7 cfs with average and median flows equal to 62.9 and 63.0 cfs, respectively (Figure 8; Table 2). Surface water level data collection at Wekiwa Springs began in 1984. During this period water levels have ranged from 9.9 to 14.9 ft NAVD 88 with both median and average water levels equaling 12.1 ft NAVD 88 (Figure 8; Table 3).

Table 1. Water level and flow gaging stations used for the Wekiva River basin MFLs; SLB = Spring Landing Boulevard; POR = period of record. See Appendix B for details about additional river and spring gage data used in the Wekiva River Basin surface water model.

System	Agency	Station No.	Flow POR	Water Level POR
Wekiva River at SR 46	USGS	02235000	1935 – Present (Continuous)	1935 – Present (Continuous)
Wekiwa Springs	SJRWMD / USGS	00371831	1932 – 1968 (few random measurements) 1968-2002 (few measurements per year) 2002-Present (Continuous)	1984-1999 (few measurements per month) – 1999-Present (Continuous)
Miami Springs	SJRWMD	00421834	1945 – 1972 (three measurements) 1973-2003 (few measurements per year) 2003-Present (Continuous)	1985 – 1992 (three measurements) 1993-2002 (few measurements per year) 2003-Present (Continuous)
Rock Springs	SJRWMD	00330830	1931 – 1968 (few random measurements) 1968-1999 (few measurements per year) 1999- Present (Continuous)	1959-1990 (few measurements per year) 1990-2002 (few measurements per month) 2002- Present (continuous)
Little Wekiva River at SLB	SJRWMD	09502132	2002 – 2009; 2016 – Present (Continuous)	1995 – 2009; 2016 – Present (Continuous)
Palm Springs	SJRWMD	00441845	1941 – 1960 (few random measurements) 1972-2002 (few measurements per year) 2002-Present (Continuous)	1985 (one measurement) 1986-2002 (few measurements per year) 2002-Present (Continuous)
Sanlando Springs	USGS	00451840	1941 – 1960 (few random measurements) 1972-2002 (few measurements per year) 2002-Present (Continuous)	1980 – 1986 (three measurements) 1989-2002 (few measurements per year) 2002-Present (Continuous)
Starbuck Springs	SJRWMD	00471851	1944 – 1960 (two measurements) 1972-2002 (few measurements per year) 2002-Present (Continuous)	1986-2002 (few measurements per year) 2002-Present (Continuous)

Table 2. Flow (cfs) summary statistics for Wekiva River Basin gage locations.

	Period of Record	Discharge (cfs)			
		Minimum	Median	Average	Maximum
Wekiva River at SR 46	1935 - Present	105	249	287	2270
Wekiwa Springs	1932 - Present	48.6	63.0	62.9	91.7
Miami Springs	1945 - Present	2.7	5.2	5.2	7.8
Rock Springs	1931 - Present	37.0	56.0	55.8	83.2
Little Wekiva River at SLB	2002 – 2009; 2016 - Present	18.6	64.8	86.8	888.3
Palm Springs	1941 to Present	0.3	5.4	5.4	12.2
Sanlando Springs	1941 to Present	8.1	19.6	19.9	40.4
Starbuck Springs	1944 to Present	6.1	11.8	12.0	22.8

Table 3. Water level (ft; NAVD 88) summary statistics for Wekiva River Basin gage locations.

	Period of Record	Water level (ft; NAVD 88)			
		Minimum	Median	Average	Maximum
Wekiva River at SR 46	1935 - Present	5.0	6.6	6.6	10.8
Wekiwa Springs	1984 - Present	9.9	12.1	12.1	14.9
Miami Springs	1985 - Present	13.4	14.0	14.1	16.2
Rock Springs	1959 - Present	24.3	25.0	25.1	26.8
Little Wekiva River at SLB	1995 – 2009; 2016 - Present	16.0	17.9	17.9	22.0
Palm Springs	1985 - Present	19.7	21.1	21.2	26.1
Sanlando Springs	1980 - Present	6.2	25.5	25.6	40.3
Starbuck Springs	1986 - Present	19.1	19.7	19.9	23.6

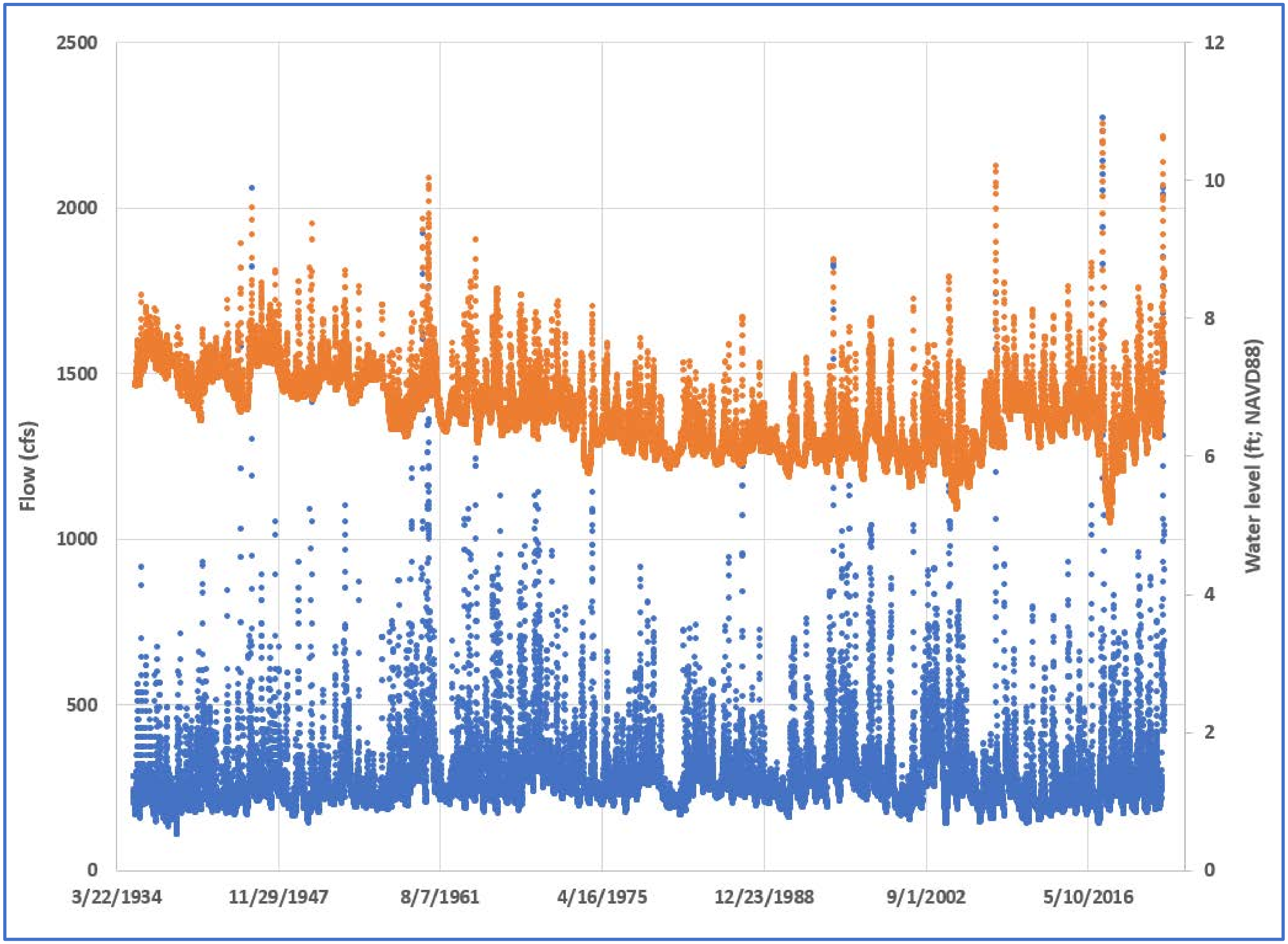

Figure 6. Wekiva River at SR 46 flow (blue) and water level (orange) data from 1935 to 2022.

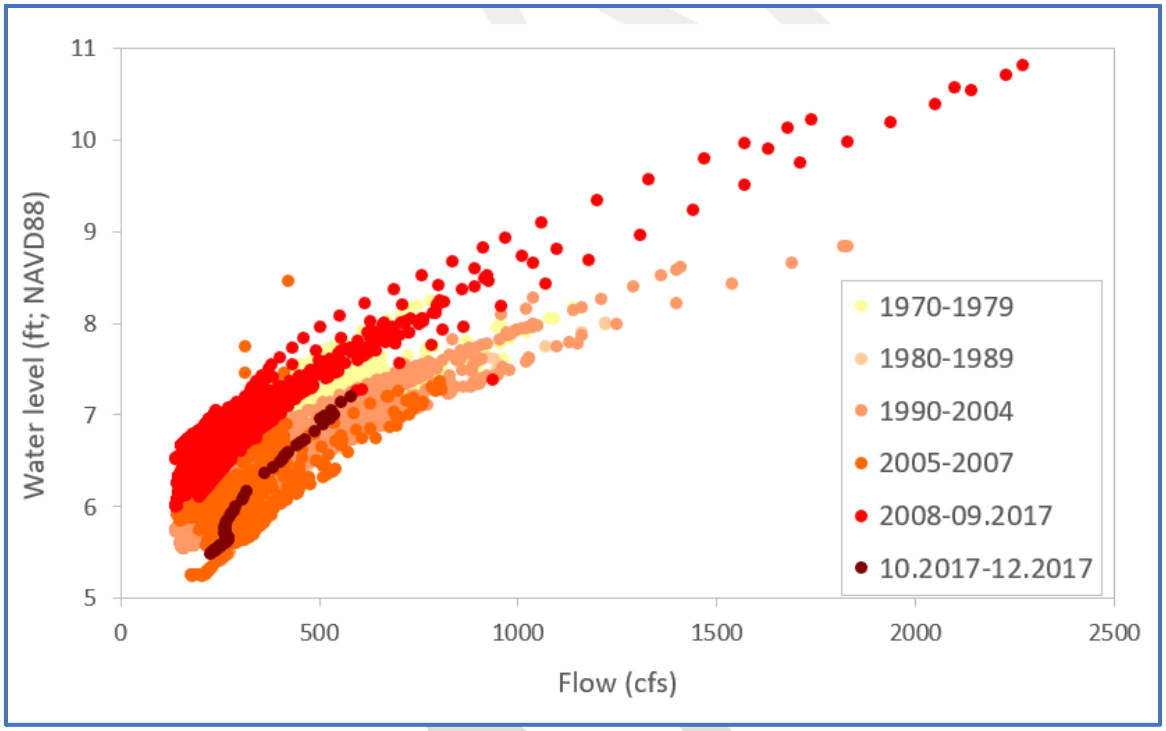

Figure 7.USGS field measurements of flows and water levels showing relationship between the two for the Wekiva River at SR 46

Spring flow contributes a significant, though varying, portion of the Wekiva River flow (60-≥ 80% annually). During droughts Wekiwa Springs alone can constitute up to 40% of the flow at SR 46, and all spring flows combined can make up almost 90% of the Wekiva River flows during low flow periods (Seong and Wester 2019).

Similar to Wekiwa springs, only a few flow measurements are available for the period before 1968 for Rock springs. The data collected after 1968 were not continuous (i.e., there were only a few measurements per year) until 1998. Daily Rock Springs flow data (SJRWMD station 00330830) are available from October 1, 1998, to present. Daily flow data are calculated from field collected monthly flow measurements and daily water level data from Rock Springs and nearby Floridan aquifer wells. During the POR, Rock Springs flow has varied between 37.0 and 83.2 cfs with the average and median flow equal to 55.8 and 56.0 cfs, respectively (Figure 9; Table 2). Rock Springs water level data, collected from 1959 to the present, has ranged from 24.3 to 26.8 ft NAVD 88 with median and average stages equal to 25.0 and 25.1 ft NAVD 88, respectively (Figure 9; Table 3).

Little Wekiva River flow and level data have been collected at Spring Landing Boulevard (SLB; SJRWMD station 09502132) but for a discontinuous time period. Flow has been collected from 2002 to 2009 and 2016 to present, and water level from 1995 to 2009 and 2016 to present (Figure 10). During this period, flow at this gage has varied between 18.6 and 888.3 cfs with an average and median flow equal to 86.8 and 64.8 cfs, respectively

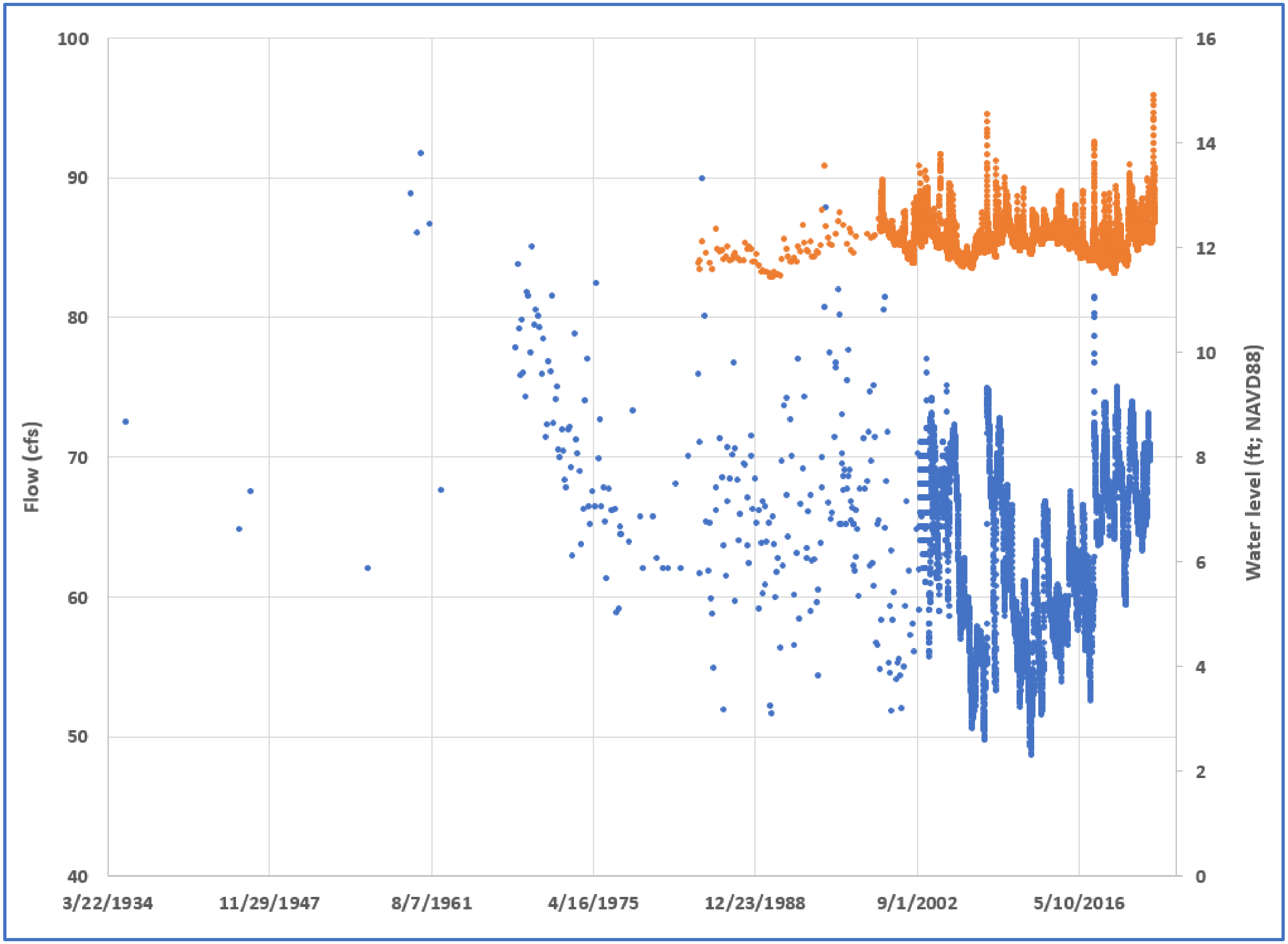

Figure 8. Wekiwa Springs flow data (blue) from 1932 to 2022, and water level data (orange) from 1984 to 2022.

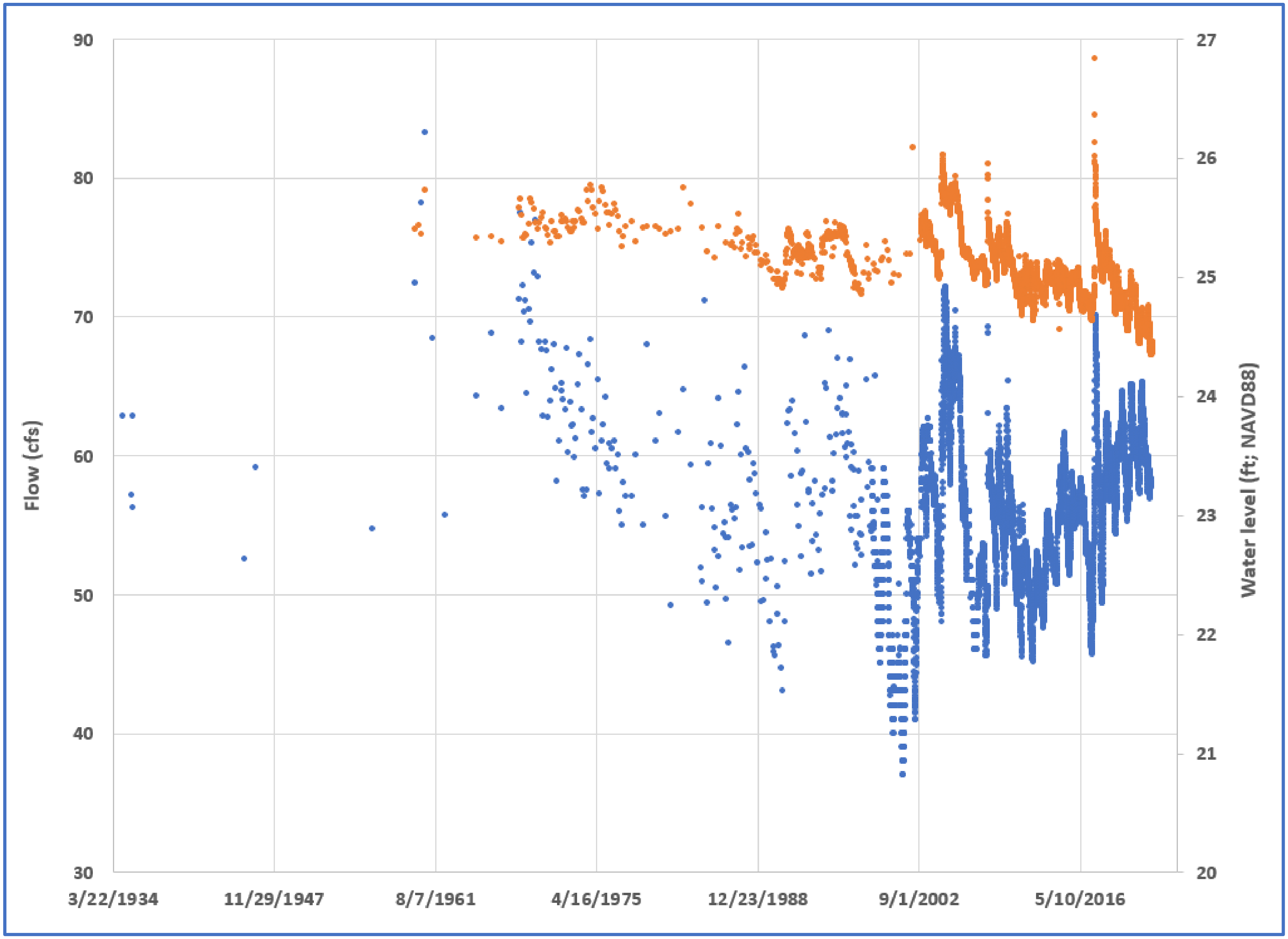

Figure 9. Rock Springs flow data (blue) from 1931 to 2022, and water level data (orange) from 1959 to 2022.

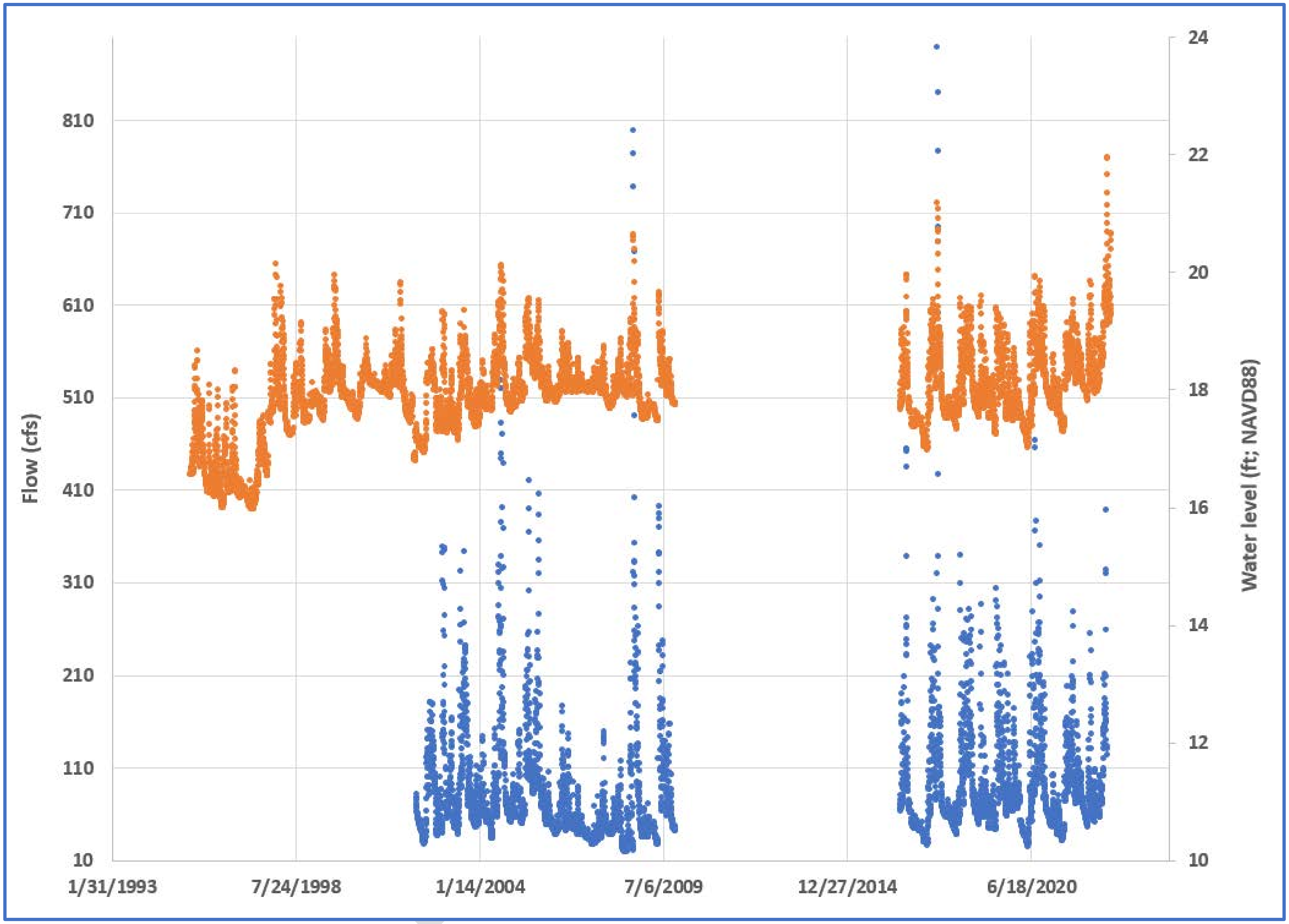

Figure 10. Little Wekiva River at Springs Landing Boulevard. flow data (blue) from 2002 - 2009 and 2016 - 2022, and water level data (orange) from 1995 - 2009 and 2016 - 2022.

Figure 10, Table 2). Water levels at the SLB gage have ranged between 16.0 and 22.0 ft NAVD 88 with an average and median stage equal to 17.9 ft NAVD 88 (Figure 10; Table 3). Little Wekiva River flow and level data have also been collected near Altamonte Springs at Highway 434 (USGS station 02234990) from 1972 to the present. During this period Little Wekiva River flow varied between 0.13 and 753 cfs with the average and median flow equal to 34 and 19 cfs, respectively. The 434 gage is not being used as a status assessment location, but data from this gage were used in development of the surface water model (see Appendix B and Seong and Wester 2019 for more details).

Four of the gaging stations described above are MFLs status assessment locations points (i.e., the locations at which site-specific MFLs will be assessed). These include the Wekiva River at SR 46 (02235000 / Wekiva River Near Sanford, FL), Wekiwa Springs (00371831), Rock Springs (00330830) and the Little Wekiva River at SLB (09502132). Long-term daily flow and level data from these gages and three other gages along the main stems of Black Water Creek, the Little Wekiva River, and the Wekiva River were used for model calibration (see Appendix B; Seong and Wester 2019). Additional MFLs gages are discussed below in the *MFLs Assessment* section.

Rainfall

National Oceanic and Atmospheric Administration (NOAA) daily rainfall data from four weather stations were used for the Wekiva River Basin surface water model. The weather stations are at Deland, Clermont, Lisbon, Orlando, and Sanford. Missing rainfall data were filled using SJRWMD NEXRAD radar rainfall. Over the long-term, average annual rainfall has varied across the basin (i.e., among the four rainfall stations) from 48.4 to 56.1 inches with rainfall standard deviation varying from approximately 8 to 10 inches (Table 4).

Table 4. Rainfall summary statistics for five weather stations around the Wekiva River Basin for the POR 1948 to 2018

	Deland	Clermont	Lisbon	Orlando	Sanford
Average	56.1	51.4	48.4	50.2	52.1
Median	54.6	50.6	48.3	50.9	51.2
Standard Deviation	9.6	9.7	8.2	8.1	8.9
Minimum	38.5	28.9	29.3	30.4	32.8
Maximum	76.7	86.4	67.6	68.7	74.1

Long-term Flow Trend Analysis

Reliable long-term flow data are not available for Wekiwa Springs and Rock springs. Only a few measurements are available from 1930 to 1969. The frequency of measurements has increased after 1969 but they were still sparse (a few measurements per year) until the early 2000s when continuous data became available (see Figures 8 and 9 in the *Hydrology* section above). Based on the best available data, the highest flows measured for Rock Springs and Wekiwa Springs are 83 cfs and 92 cfs, respectively, in 1960 and the lowest flows measured are 37 cfs in 2001 for Rock Springs and 49 cfs in 2012 for Wekiwa Springs.

In the current period (from early 2000s to present), for which there is a good continuous record, both springs have fluctuated considerably over short-time periods. Rock Springs increased by about 30 cfs in only 3 years from 2001 to 2004 and later declined about 25 cfs in the following four years. These sudden changes likely reflect responses to intraannual (i.e., seasonal) as well as interannual (i.e., El Nino southern Oscillation (ENSO)) climate cycles occurring every 3-7 years (Obeysekera, et al 2011). Similarly, Wekiwa springs increased by about 25 cfs from June to October 2008 and later declined about 26 cfs in the following 4 years. As a result of hurricane Irma, Rock Springs increased from about 46 cfs in May 2017 to 70 cfs in October 2017 whereas Wekiwa Springs increased from about 52 cfs in May 2017 to 81 cfs in October 2017.

Evaluation of long-term trends based on available flow data indicates that average spring flows declined significantly (more than 15 cfs) from 1960s to 1980s and then remained relatively stable afterwards. Due to the lack of continuous data in 1960s, it is difficult to determine whether the drop after the 1960s was due to natural variation or from anthropogenic effects such as groundwater pumping. This is especially true considering that the few measurements taken in the 1930s indicate flows of similar magnitude to those in recent years. Because of the absence of long-term continuous reliable data, the significant short-term flow variations in these springs makes analysis of long-term spring flow trends even more challenging.

In contrast to Wekiwa Springs and Rock Springs, flows measured in the Wekiva River at SR 46 have been measured continuously since 1935. Because the river gage at SR 46 is downstream of all major important springs within the Wekiva River basin, the majority of the total baseflow at SR 46 is likely from the springs upstream of the SR 46 gage. Thus, analyzing long-term trends of baseflow at SR 46 should help with understanding the long-term trends of spring flows in the basin.

Baseflows were estimated for Wekiva river at SR 46 using several hydrograph separation methods including those available in the USGS Groundwater toolbox (Barlow et al. 2014 and 2017), Perry's low pass filter (Perry 1995) and Lyne-Hollick recursive digital filter (Lyne and Hollick 1979). Annual baseflows estimates were compared with the total observed/estimated flows of springs upstream of the SR 46 gage for the 2005-2018 time period. This period was used because this is when good continuous spring flow data are available for Wekiwa Springs and Rock springs. Although all methods of estimation yield similar patterns, the Lyne-Hollick method was chosen for the analysis because it produced flows closest to the observed total spring flows (Figure 11).

To further assess the suitability of SR 46 baseflow for long-term trend analysis of spring flows, the standardized values of baseflows and spring flows were compared. Standardization is the process of converting a variable to one with an average of 0 and standard deviation of 1 so that two different variables can be compared on the same scale. A dataset is standardized by subtracting each value from the average and dividing the difference by its standard deviation.

The plots of standardized values for both Wekiwa Springs and Rock Springs show that SR 46 baseflow follows a similar trend to the variation of available spring flows (Figures 12 and 13). Therefore, long-term trend analysis of SR 46 baseflow should provide some insight into the long-term trend of spring flows.

A polynomial trendline was used to understand the long-term trend of baseflows. This indicated that baseflows increased from the 1930s to 1960s and afterwards there was generally a period of no trend until the 1980s. Following this, baseflows declined until the 2010s and appeared to begin increasing again since then. Current flows appear slightly higher than those measured in the 1930s (Figure 14).

Long-term rainfall trends in the region were also analyzed to better understand the relationship between rainfall and Wekiva River baseflows. Flows in Wekiva River basin are

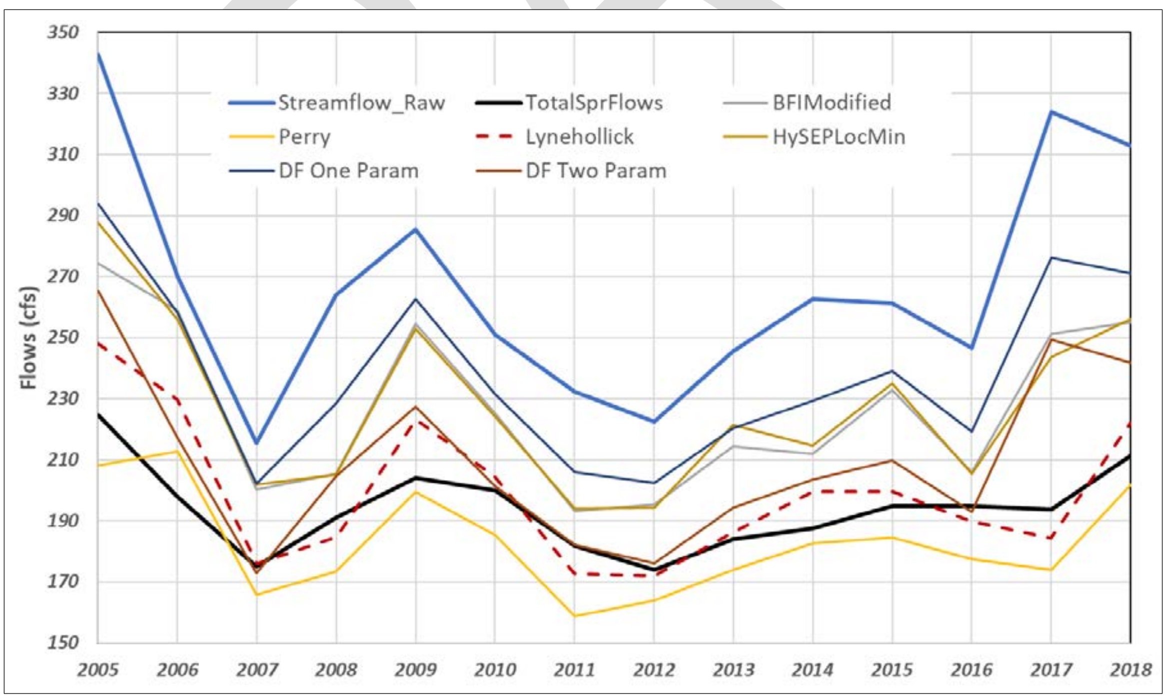

Figure 11. Wekiva River at SR 46 annual baseflow estimates, based on various different methods (described in text) compared with the total observed/estimated flows of upstream springs.

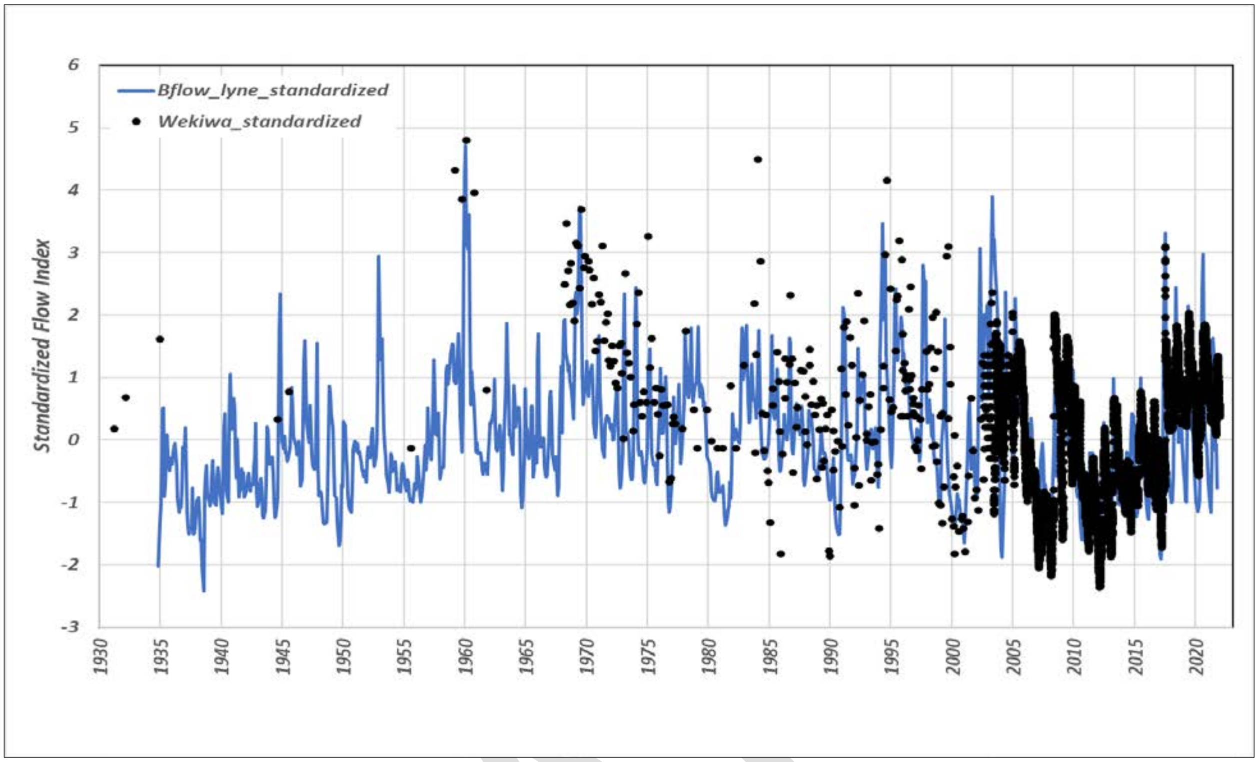

Figure 12. Comparison of the standardized SR 46 baseflows with the standardized Wekiwa springs flows

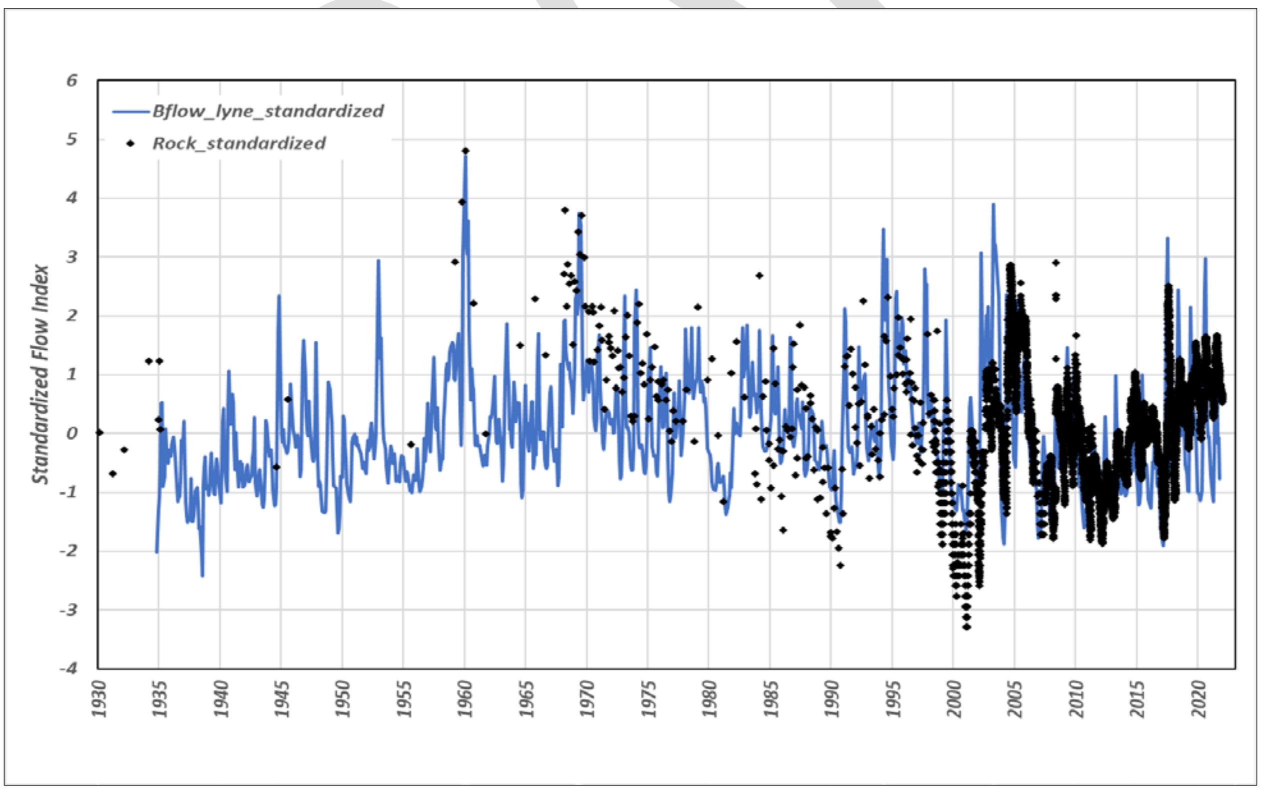

Figure 13. Comparison of the standardized SR 46 baseflows with the standardized Rock springs flows

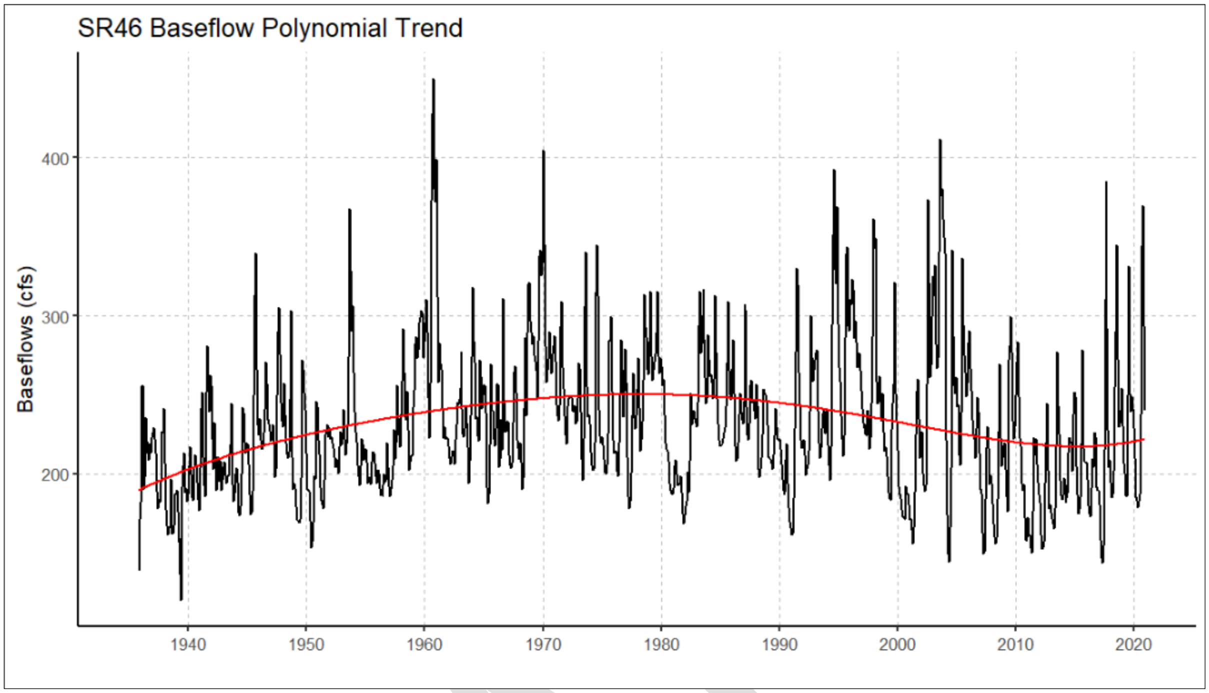

Figure 14. Long-term polynomial trend of SR 46 baseflows

thought to be potentially influenced by nearby rainfall, measured at nearby rainfall stations (Clermont, Orlando, Sanford and Lisbon). Rainfall data is used to develop the Standardized Precipitation Index (SPI) at different time scales to consider seasonality and short-term climatic cycles such as ENSO. According to NOAA, SPI is a widely used index for understanding drought on different timescales. The SPI can also be related to groundwater storage at longer timescales (Keyantash, 2014). The SPIs were calculated for lengths of 12, 24, 36, 48 and 60-months using the rainfall data from these stations and correlated with monthly baseflows (Figure 15).

A review of the data from all four rainfall stations indicated that none correlated well with Wekiva River baseflows. The poor correlations between SPIs and baseflows are most likely due to noise in both datasets and uncertainty in baseflow estimation. The 12-month SPI derived from Clermont rainfall data had the highest correlation with the baseflow (r =0.5). The 12-month Clermont SPI indicated very wet years in 1958-1960, 2004-2005 and 2018-2019 periods and severe droughts in 1961-1962, 1999-2001 periods (Figure 16).

Despite only moderate correlation between 12-month Clermont SPI and the baseflows, a good relationship can be discerned when both datasets were standardized and plotted on the same scale (Figure 17). Baseflow at SR 46 generally follows a similar trend to the 12-month SPI derived from the rainfall at Clermont.

There does not appear to be any significant long-term decline in flows since the 1930s and no obvious deviation between rainfall and baseflows trends (Figure 17). Further, discerning any anthropogenic influences such as groundwater pumping impact on flows using the available

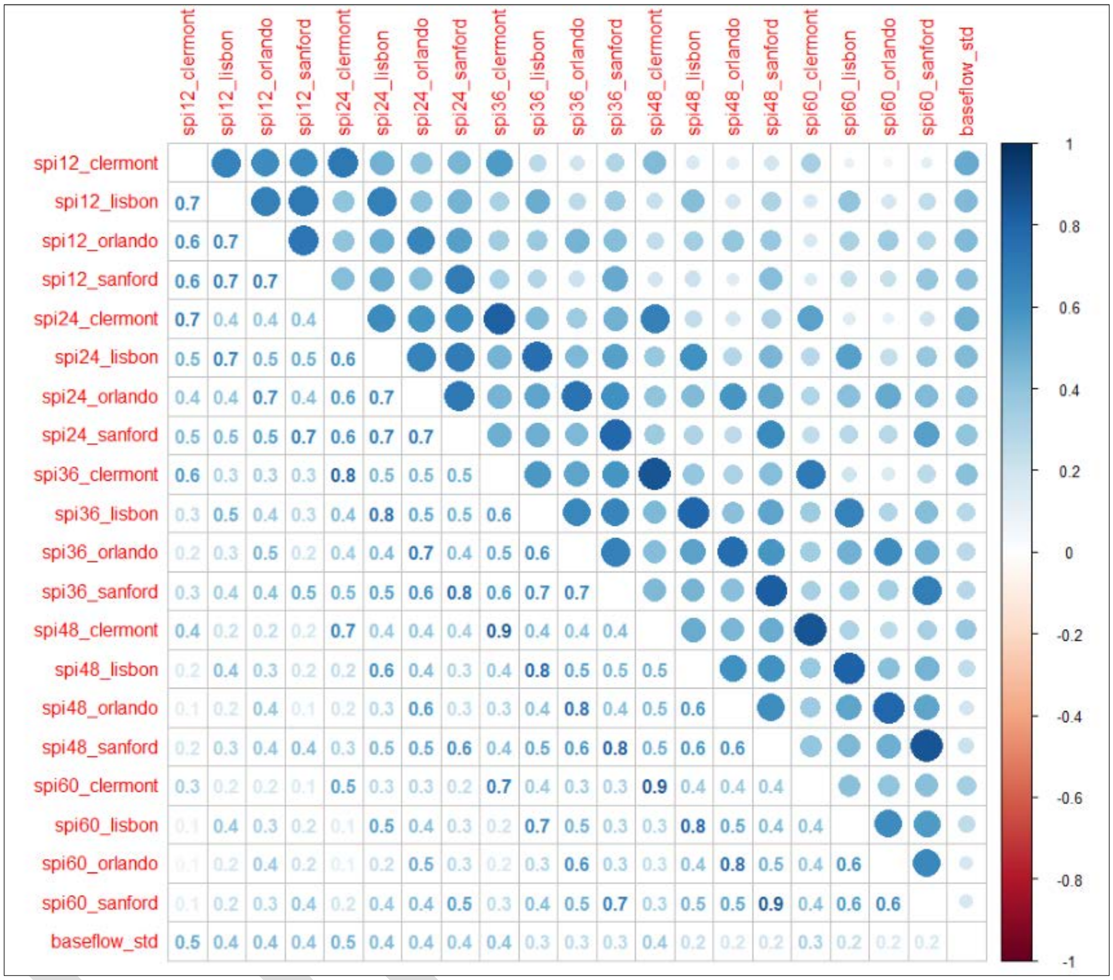

Figure 15. Correlation between the rainfall and SR 46 baseflows

data is not possible due to insufficient long-term spring flows and uncertainties in baseflow estimation techniques and flow measurements. Therefore, numerical groundwater models such as the East-Central Florida Transient Expanded (ECFTX) remain the best available tool to estimate impact of groundwater pumping on spring flows.

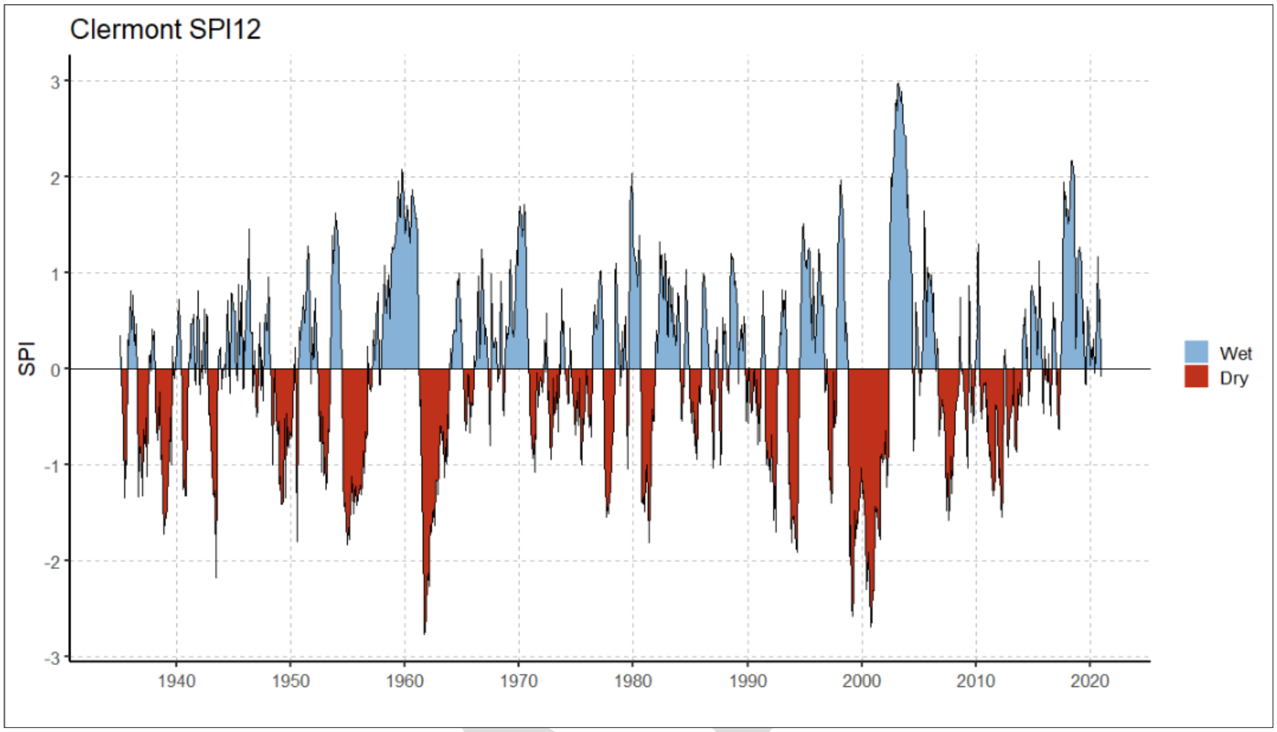

Figure 16. 12-month Standard Precipitation Index derived from Clermont rainfall data

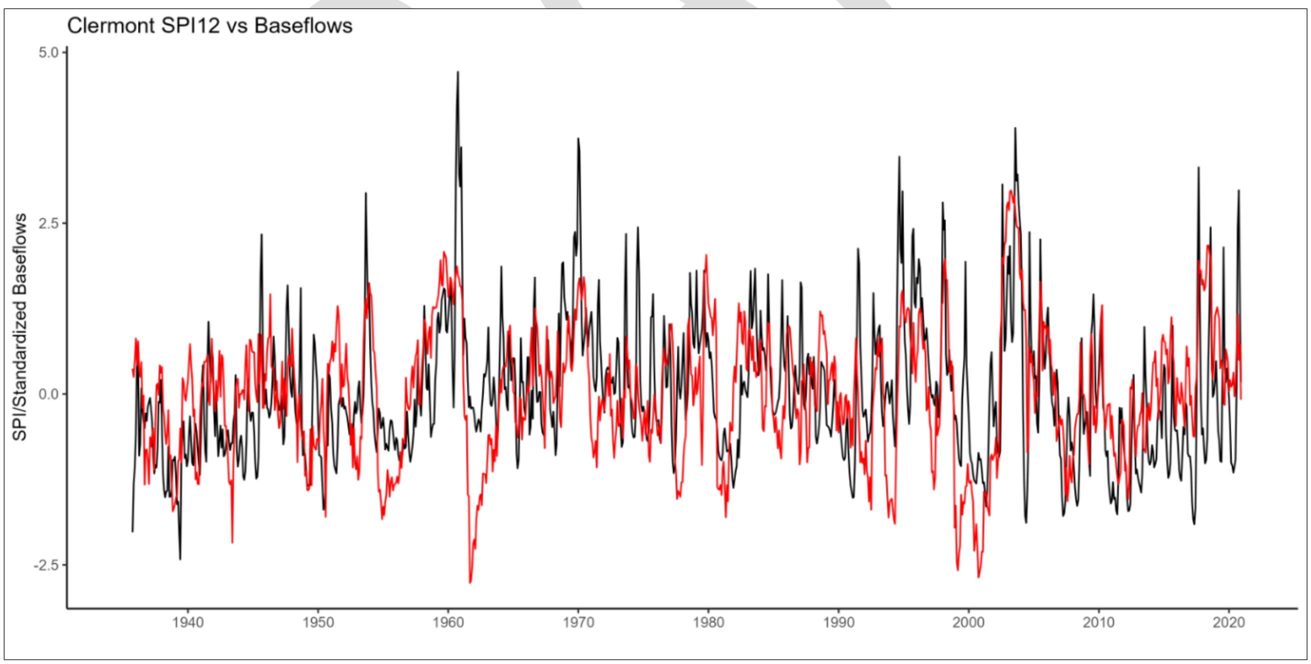

Figure 17. The Clermont 12-month SPI versus standardized SR 46 baseflows

Surface Water Basin Characteristics

Land Use

The most current land use data (SJRWMD 2014; Florida Land Use Classification Code System [FLUCCS]) indicate that the majority (> 72%) of the Wekiva River basin remains undeveloped (Figure 18). The second and third largest land use categories (Forested and Wetland) combined comprise over 47% of the basin area (Table 5, Figure 18). Urban land, which includes residential, industrial and commercial uses, make up approximately 27.7% of basin area. Most of the development is located to the south, while the northern portion of the basin remains largely undeveloped (Figure 18).

Mapped Vegetation

Wetland communities within the Wekiva River basin are extensive (Figure 19). Based on 2014 SJRWMD geographic information system (GIS) land cover data, fifteen vegetation communities exist within the basin (i.e., including uplands as a single category). The most common upland communities in the Wekiva River sub-basin are xeric and mesic hammocks. The three most common wetland communities are hydric hammock, hardwood swamp, and open water (which includes submerged and aquatic species; Table 6). Wetland communities

Table 5. 2014 FLUCCS land use in the Wekiva River surface water sub-basin

Land Use	Acres	Percent
Urban	66,560	27.7
Agriculture	34,220	14.3
Upland Nonforest	14,036	5.8
Forested	58,388	24.3
Water	9,663	4.0
Wetland	54,858	22.9
Barren Land	2,275	0.9
Total	**240,000**	**100.0**

in the Rock Springs planning unit typically occur in and adjacent to Rock Springs Run (Figure 20).

The most common communities in the Rock Springs sub-basin are uplands, hardwood swamp, hydric hammock, wet prairie and forested flatwoods depressions (Table 6). Wetlands in the Little Wekiva River sub-basin typically occur in and adjacent to Little Wekiva River (Figure 21). Vegetation communities in the Little Wekiva River basin are dominated by uplands, followed by hardwood swamp and hydric hammock (Table 6).

This characterization is based on 2014 mapped data. In addition, all common vegetation communities were surveyed and characterized at each MFLs system along field transects established as part of the MFLs Determination (see below). Detailed vegetation community descriptions at each transect are presented in Appendix C.

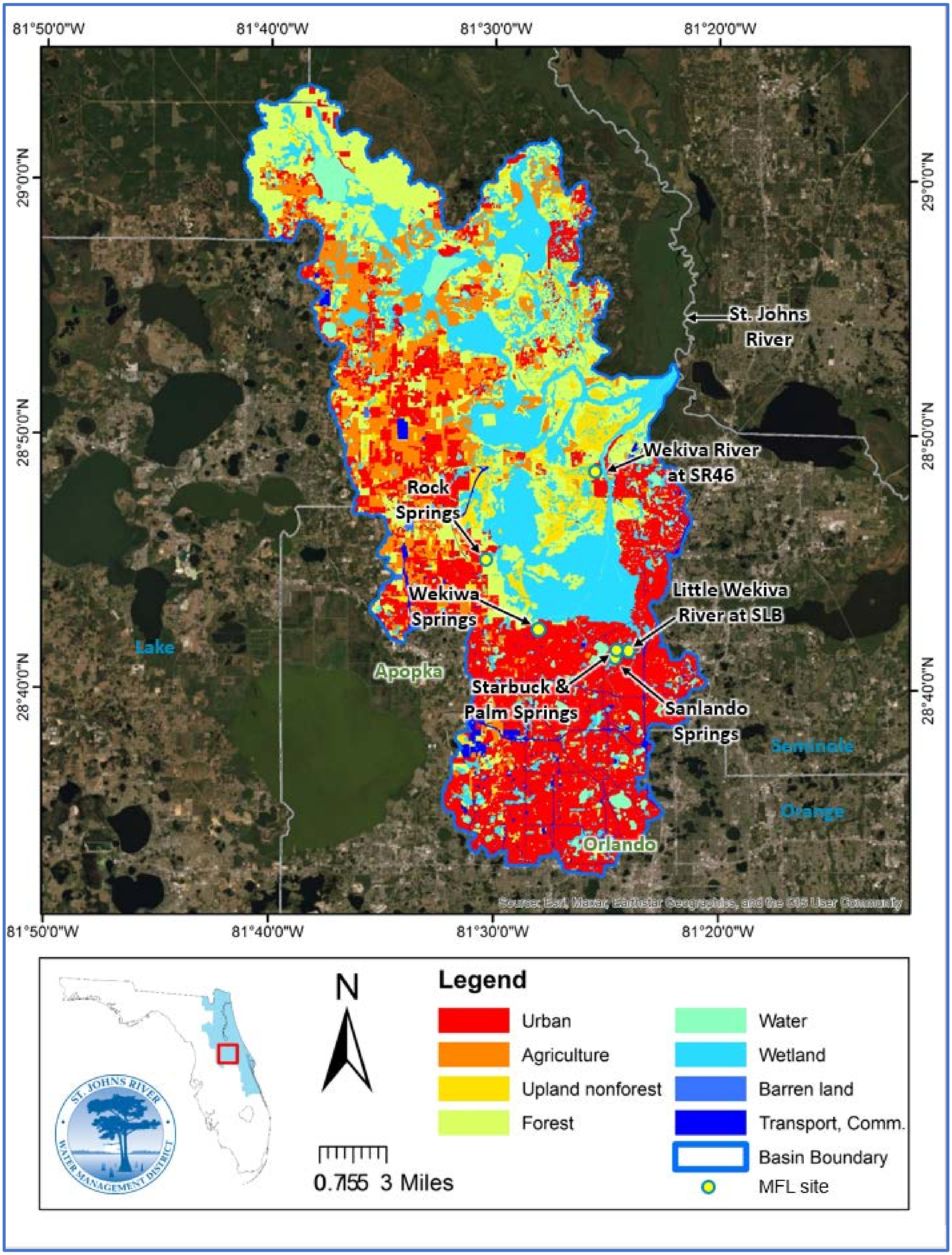

Figure 18. Land uses within the Wekiva River basin (SJRWMD 2014)

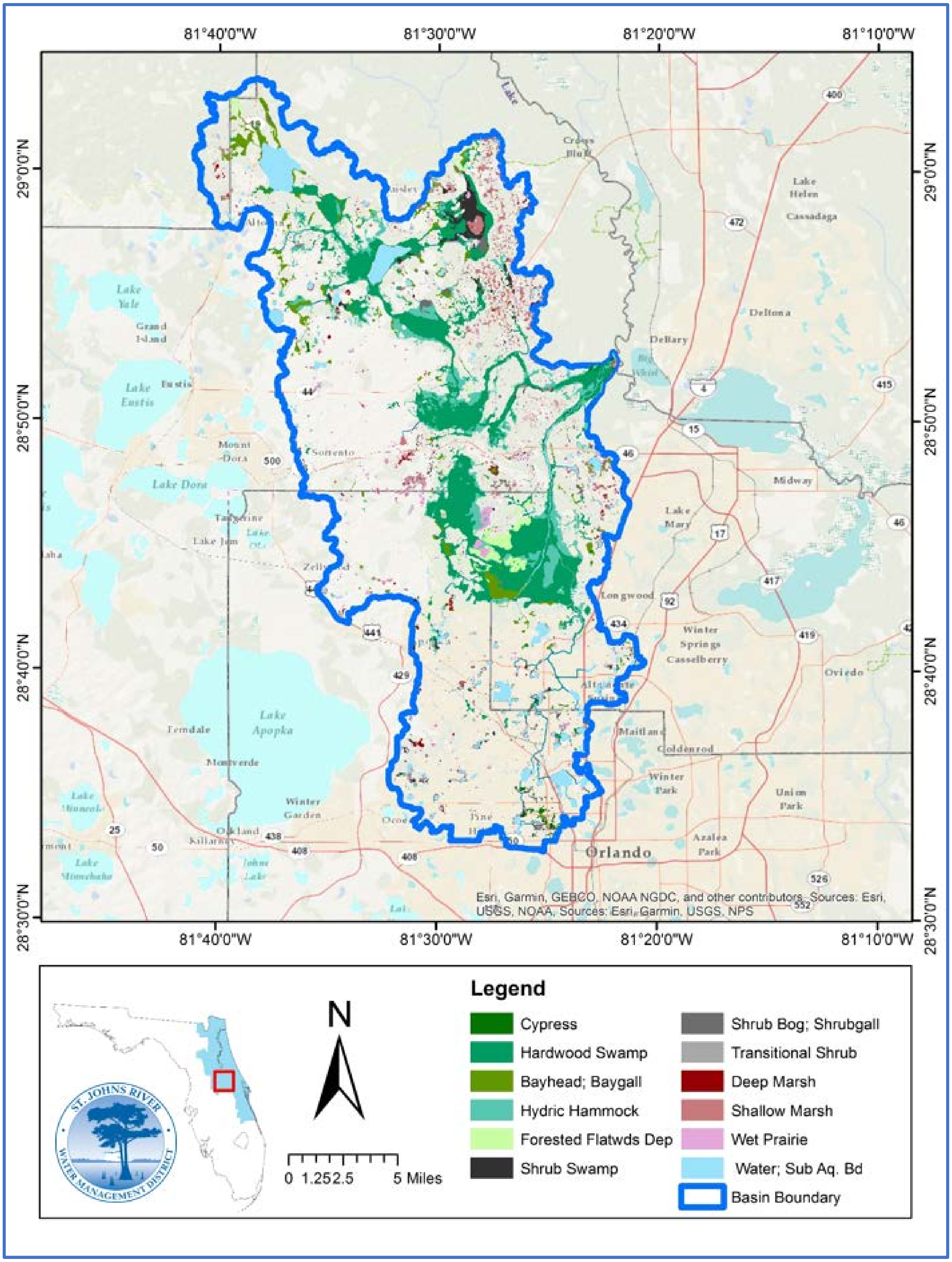

Figure 19. Wetland communities in the Wekiva River surface water basin (SJRWMD 2014)

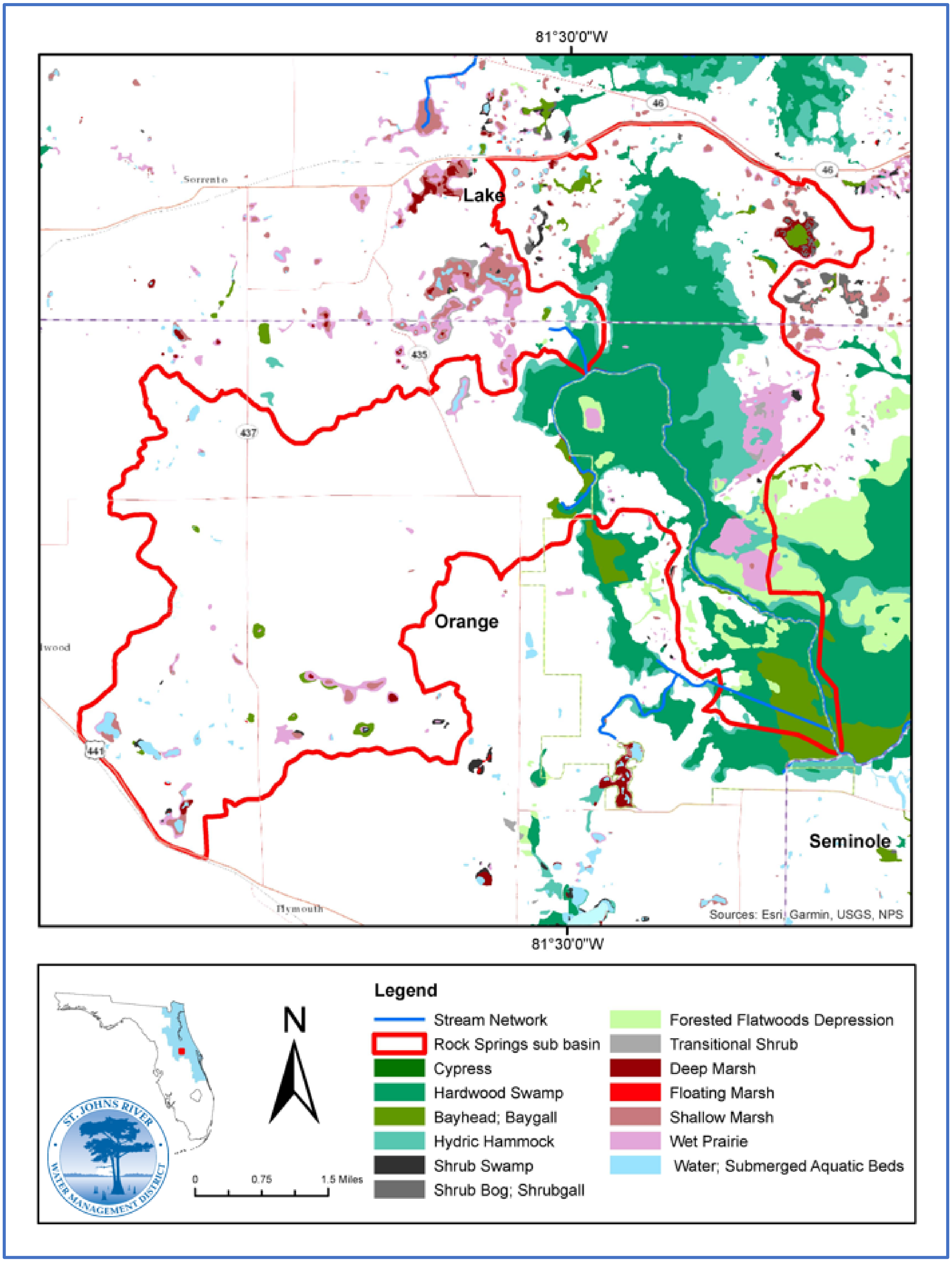

Figure 20. Wetland communities in the Rock Springs/Rock Springs Run surface water basin (SJRWMD 2014)

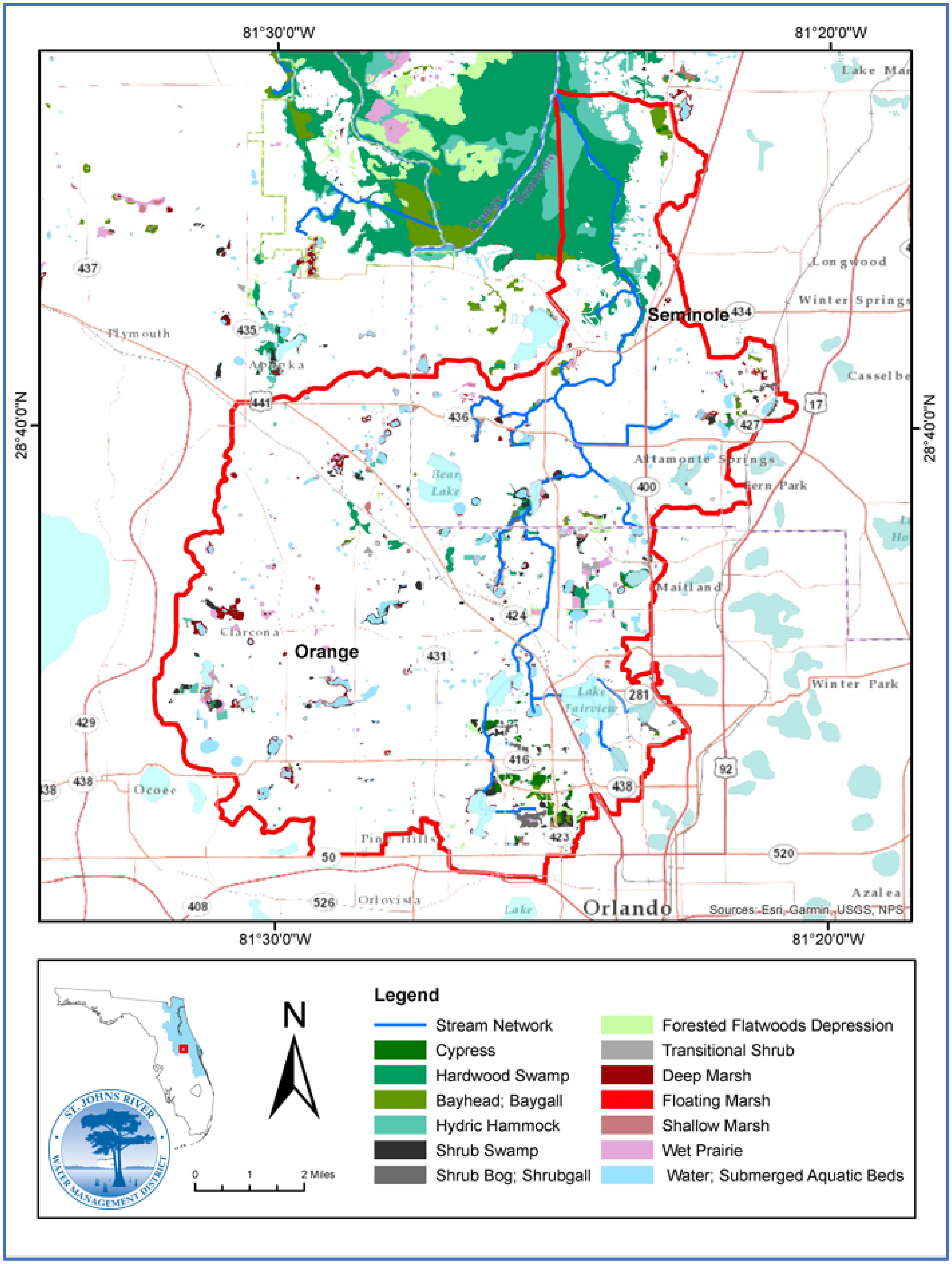

Figure 21. Wetland communities in the Little Wekiva River surface water basin (SJRWMD 2014)

Table 6. Wetland communities in the Wekiva River basin by size (acres)

Wetland Community	Wekiva R./ Wekiwa Spring Run	Little Wekiva River	Rock Spring / Rock Run	Basin
Bayhead / Baygall	3,823	269	424	4,516
Cypress	253	211	0	464
Deep marsh	556	261	52	869
Floating marsh	0	0	34	34
Forested flatwoods depression	1,653	98	418	2,169
Freshwater flats	0	44	0	44
Hardwood swamp	18,259	2,080	3,831	24,170
Hydric hammock	7,295	901	880	9,076
Shallow marsh	4,061	317	174	4,552
Shrub bog / Shrub gall	791	237	44	1,072
Shrub swamp	1,873	444	42	2,359
Transitional shrub	130	130	30	290
Wet prairie	1,628	390	572	2,590
Water	5,796	3,174	126	9,096
Uplands	117,411	46,656	14,710	178,777
Total	**163,529**	**55,238**	**21,337**	**240,104**

Mapped Hydric Soils

Hydric and non-hydric soils were mapped for the Wekiva River basin using USDA NRCS Soil Survey Geographic (SSURGO) GIS data (Figure 22; USDA NRCS 2015). Predictably, mapped hydric soils occur adjacent to the Wekiva River mainstem and tributary channels, with a broad extent of hydric soils occurring along the upper Wekiva River in an area known as the Wekiva Swamp. This area includes portions of the Little Wekiva River and Rock Springs Run floodplains. Hydric soils were also mapped extensively along the lower Wekiva River and are associated with the Wekiva River's confluence with Black Water Creek and the St. Johns River (Figure 22).

Mapped hydric soils within the Rock Springs Run sub-basin exhibit similarities in location with wetlands, land cover, and physiographic subdistrict extent (Figure 23). Hydric soils are collocated with undeveloped wetlands in the east section of the Rock Springs surface water planning unit within the St. Johns Offset subdistrict, while non-hydric soils dominate the upland areas in the western portion of the planning unit in the Apopka Uplands subdistrict.

Similarly, hydric soils are associated primarily with undeveloped wetlands in the northern area of the Little Wekiva River surface water sub-basins within the St. Johns Offset sub-district. Non-hydric soils dominate developed areas in the majority of the sub-basins in the Apopka Uplands, Casselberry-Oviedo-Geneva-Chuluota Hills, and Orlando Promontory sub-districts (Figure 24).

As with vegetation, site-specific soil samples were collected and characterized along multiple field transects within the basin. Soils were characterized at multiple stations along each transect, and detailed soil descriptions are presented in Appendix C. Soils-related environmental metrics are discussed below (see MFLs Determination for details).

Water Quality

Background

The Wekiva River, Wekiwa Springs, Rock Springs and the Little Wekiva River are designated as Class III waterbodies by the State of Florida. Designated beneficial uses for Class III waters include recreation and supporting the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. Pursuant to the Wekiva Parkway and Protection Act (Chapter 2004-384, §1, Laws of Florida), the SJRWMD established a pollutant load reduction goals (PLRG) for the Wekiva River Study Area (Mattson et al., 2006). The Wekiva River Study Area includes the Wekiva River, Rock Springs Run, the Little Wekiva River, and other tributaries and springs collectively located in Seminole, Orange, and Lake Counties. Impairments documented in the PLRG were due to elevated nitrate and phosphorus concentrations and manifested through elevated algal biomass, dominance of benthic algal communities by blue-green algae (e.g., *Lyngbya wolli*), and depressed ecosystem metabolism.

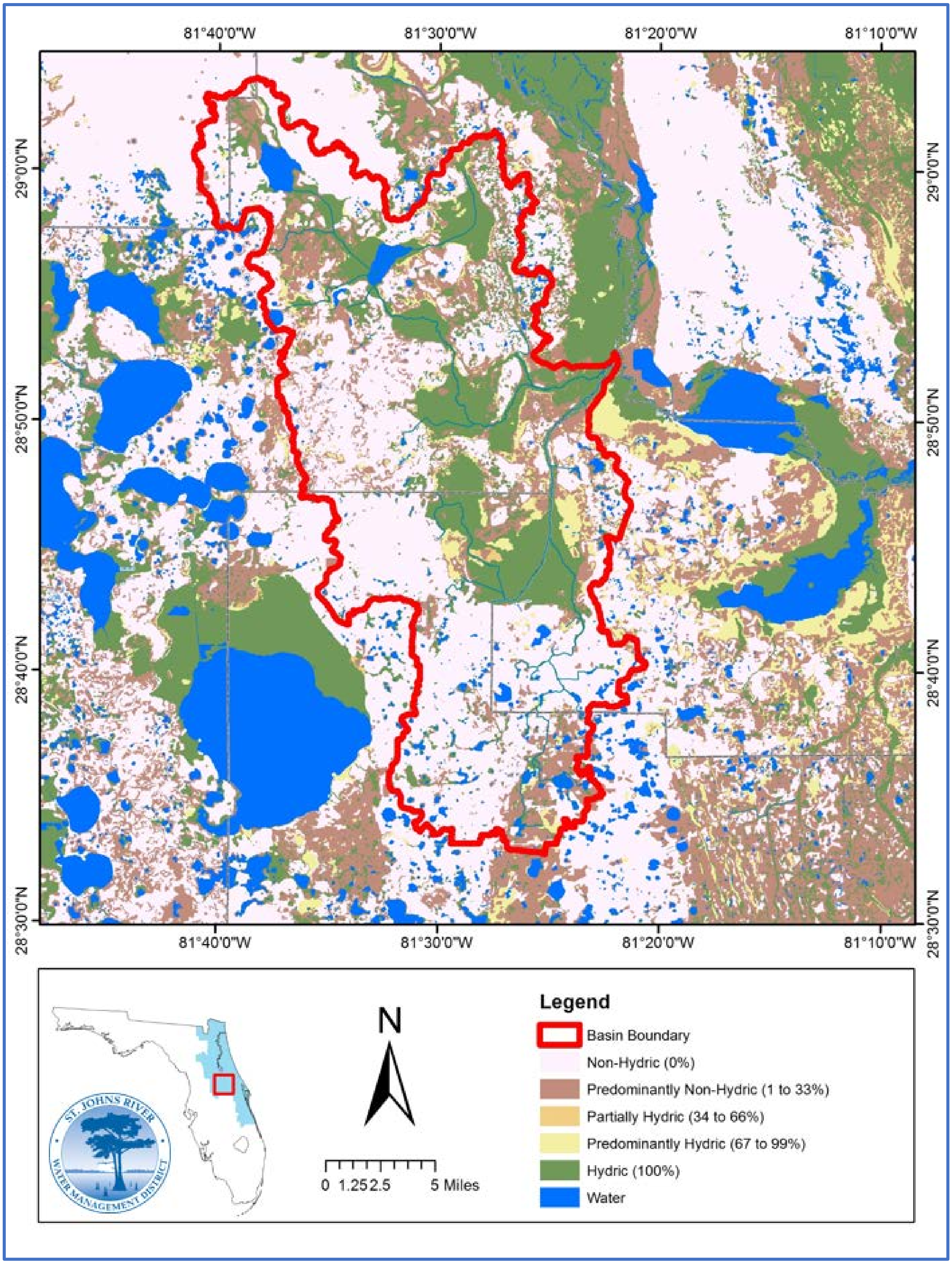

Figure 22. Hydric and non-hydric soils in Wekiva River surface water basin (USDA NRCS 2015)

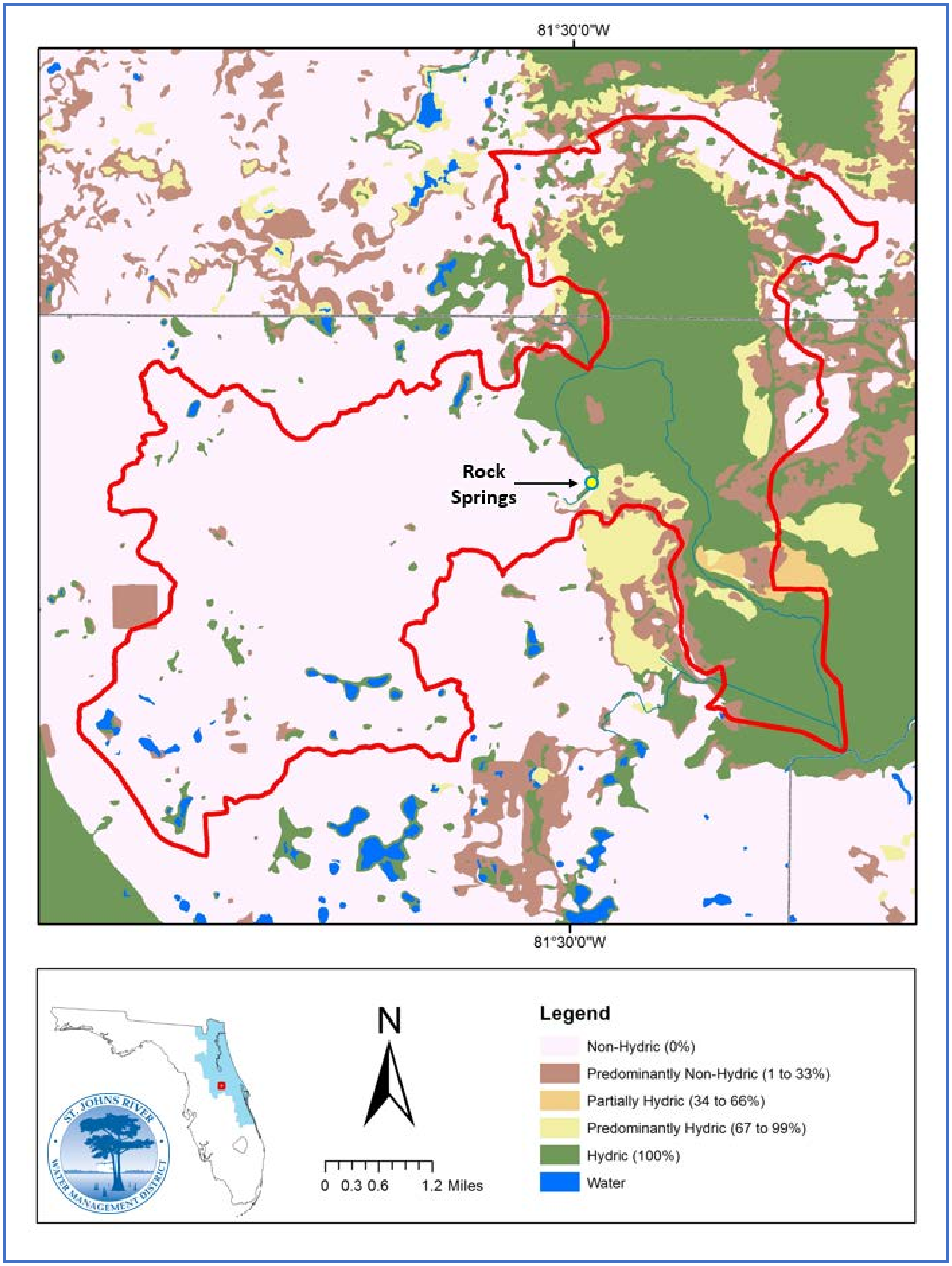

Figure 23. Hydric and non-hydric soils in the Rock Springs sub-basin (USDA NRCS 2015)

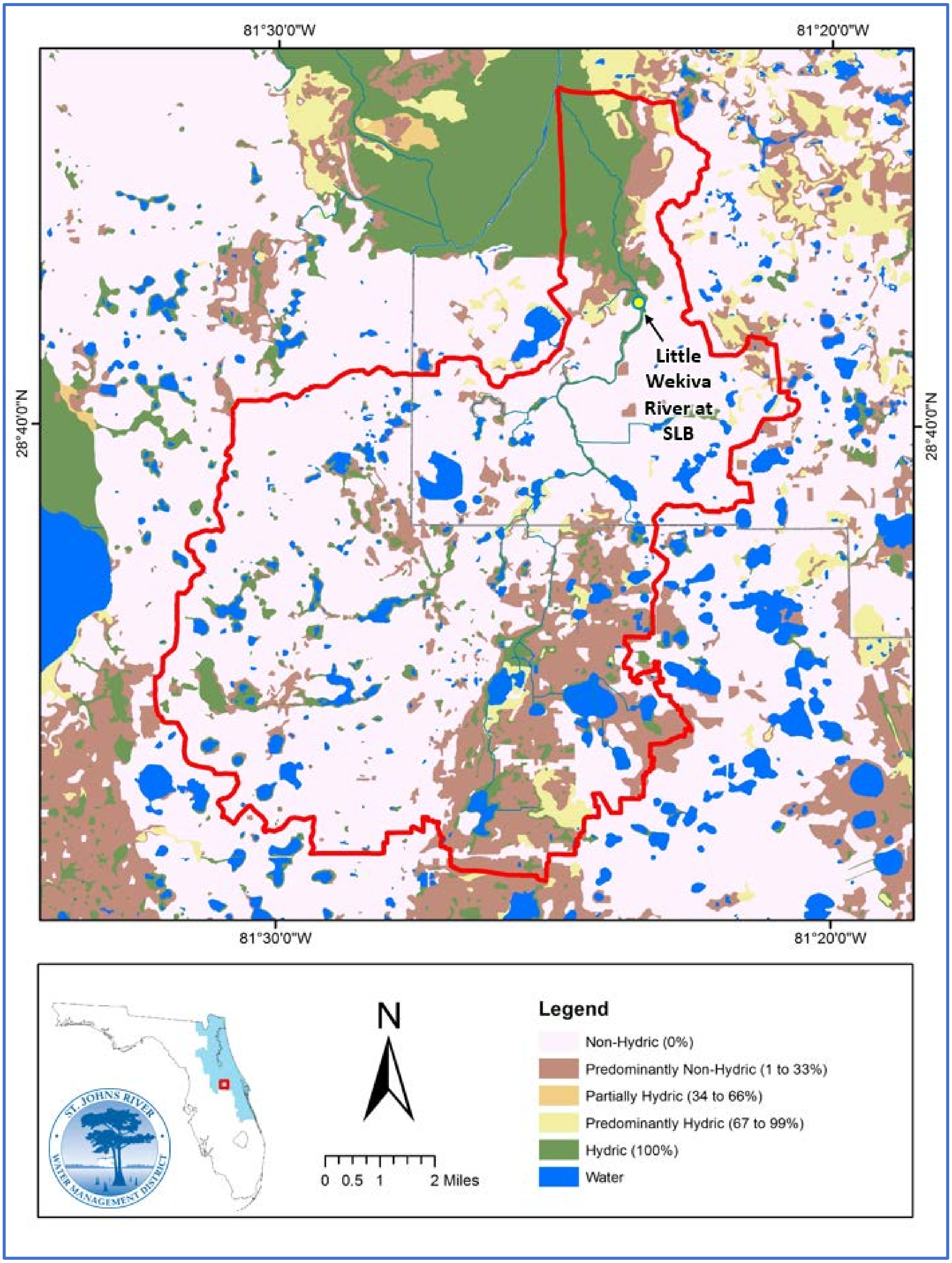

Figure 24. Hydric and non-hydric soils in the Little Wekiva River sub-basin (USDA NRCS 2015)

Water quality for the Wekiva River and Rock Springs Run was designated by the state as impaired for nutrients in 2007 due to elevated total phosphorus and nitrate-nitrogen (FDEP 2015). Subsequently, the Florida Department of Environmental Protection (FDEP) adopted nutrient TMDLs for the Wekiva River, the Little Wekiva River, and Rock Springs Run quantifying pollutant loads beyond which these waterbodies would no longer achieve their designated uses (Gao 2008). FDEP adopted a Basin Management Action Plan (BMAP) in 2015 to implement nutrient and biological oxygen demand (BOD) reductions in the Wekiva River basin.

The sections below document water quality parameter descriptive statistics and general trends in the Wekiva River basin. An analysis of water quality parameters versus flow as well as temporal trends are discussed in the WRVs Assessment summary below, and Appendix E.

Wekiwa Springs and Rock Springs

USGS, SJRWMD, FDEP, and other agencies have collected water quality data for Wekiwa and Rock Springs since 1931. Summary statistics for select water quality parameters document the relatively stable physicochemical condition of Wekiwa and Rock Springs (Tables 7 and 8). While most parameters are stable, nitrate levels are high at both springs. Statewide, reference springs typically have nitrate levels below 0.06 mg/L, as compared to statewide median nitrate concentrations for springs, as a whole, of 0.58 mg/L (Gao 2008). The nitrate standard for Florida springs is 0.35 mg/L NOx (NO3 + NO2), measured as an annual geometric mean, not to be exceeded more than once in any three-calendar-year period. Levels at or above the state standard can lead to overgrowth of nuisance algae and other nuisance aquatic plants. (Gao 2008).

Median nitrate levels at both Wekiwa and Rock Springs are much higher than values in the average Florida spring, and much higher than the state standard. For the POR sampled at Wekiwa Springs (1977 – 2010) and Rock Springs (1984 – 2010) median nitrate concentration was 1.21 mg/L and 1.44 mg/L, respectively (Tables 7 and 8). Recent data (2003 – 2022) collected by the SJRWMD indicate that nitrogen levels are slightly lower, and while stable remain at high levels, with median concentrations of 1.06 mg/L and 1.33 mg/L at Wekiwa Springs and Rock Springs, respectively (Figures 25 and 26).

Wekiva River at SR 46

A study on the Wekiva River conducted as part of the FDEP's Statewide Stream Bioassessment Program reported nitrate concentrations of 1.2 mg/L and 1.1 mg/L in the Wekiva River and Rock Springs Run respectively (FDEP 2000). The primary driver of water quality degradation due to increased nitrogen concentrations is the increased urbanization in the Wekiva River headwaters over the past several decades (FDEP 2000). At the time of the FDEP study, nitrogen levels in the Wekiva River were greater than 95 percent of the streams and rivers in Florida. An interesting note is that this same study scored the Wekiva River and

Table 7. Water quality summary statistics for Wekiwa Springs (SJRWMD 2015)

Wekiwa Springs	Min	Average	Median	Max	Count	Period
Alkalinity, total, mg/L as $CaCO_3$	72.0	118.1	122.0	140.0	133	1956−2010
Calcium, total, mg/L as Ca	25.6	39.7	40.0	45.5	103	1992−2010
Chloride, total, mg/L as Cl	7.0	14.1	14.1	27.0	139	1956−2010
Dissolved Oxygen	0.18	0.27	0.27	0.41	18	2006−2010
Fluoride, total, mg/L as F	0.12	0.16	0.15	0.21	54	1994−2009
Magnesium, total, mg/L as Mg	7.7	11.3	11.3	13.1	103	1992−2010
Nitrate + nitrite, total, mg/L as N	0.34	1.21	1.21	2.00	108	1977−2010
Orthophosphate, total, mg/L as P	0.06	0.11	0.11	0.15	80	1972−2010
pH, field	6.13	7.39	7.41	8.22	142	1956−2010
Phosphorus, total, mg/L as P	0.01	0.14	0.12	2.04	66	1972−2010
Potassium, total, mg/L as K	1.2	1.6	1.6	2.5	103	1992−2010
Sodium, total, mg/L as Na	4.7	9.3	9.5	11.0	103	1992−2010
Specific conductance, field, µmhos/cm at 25°C	191	322	326	398	111	1984−2010
Specific conductance, lab, µmhos/cm at 25°C	192	304	316	371	135	1956−2010
Sulfate, total, mg/L as SO_4	6.0	18.4	19.1	23.0	139	1956−2010
Total dissolved solids, mg/L	101	179	183	218	130	1959−2010
Water temperature, °C	22.0	23.7	23.7	25.7	217	1956−2010

µmhos/cm = micromhos per centimeter
mg/L = milligrams per liter
cfs = cubic feet per second

Table 8. Water quality summary statistics for Rock Springs (SJRWMD 2015)

Rock Springs	Min	Average	Median	Max	Count	Period
Alkalinity, total, mg/L as $CaCO_3$	66.0	92.5	92.3	126.0	131	1956−2010
Calcium, total, mg/L as Ca	26.0	31.1	31.0	39.0	102	1992−2010
Chloride, total, mg/L as Cl	5.0	8.9	8.8	24.0	138	1956−2010
Dissolved Oxygen	0.49	0.70	0.69	1.04	18	2006−2010
Fluoride, total, mg/L as F	0.10	0.14	0.14	0.18	52	1994−2009
Magnesium, total, mg/L as Mg	8.0	9.4	9.4	11.0	102	1992−2010
Nitrate + nitrite, total, mg/L as N	0.67	1.41	1.44	2.50	100	1984−2010
Orthophosphate, total, mg/L as P	0.04	0.08	0.08	0.10	73	1994−2010
pH, field	6.40	7.59	7.62	8.31	143	1956−2010
Phosphorus, total, mg/L as P	0.05	0.08	0.08	0.10	62	1999−2010
Potassium, total, mg/L as K	1.1	1.4	1.3	2.0	101	1992−2010
Sodium, total, mg/L as Na	4.0	5.4	5.3	9.4	102	1992−2010
Specific conductance, field, µmhos/cm at 25°C	143	251	255	300	105	1984−2010
Specific conductance, lab, µmhos/cm at 25°C	210	251	252	356	132	1956−2010
Sulfate, total, mg/L as SO_4	15.0	18.4	18.0	24.0	138	1956−2010
Total dissolved solids, mg/L	118	147	144	289	129	1960−2010
Water temperature, °C	21.5	23.8	23.8	28.5	225	1931−2010

µmhos/cm = micromhos per centimeter
mg/L = milligrams per liter
cfs = cubic feet per second

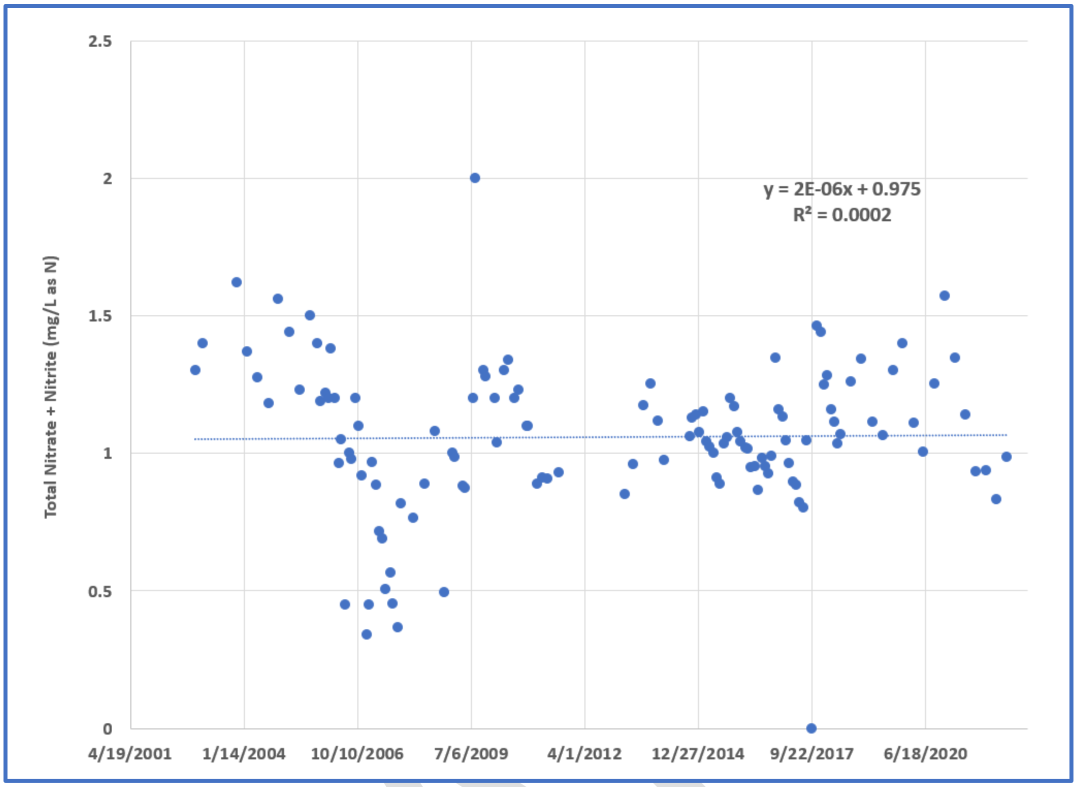

Figure 25. Recent (2003-2022) nitrate + nitrite concentrations at Wekiwa Springs (SJRWMD 2022)

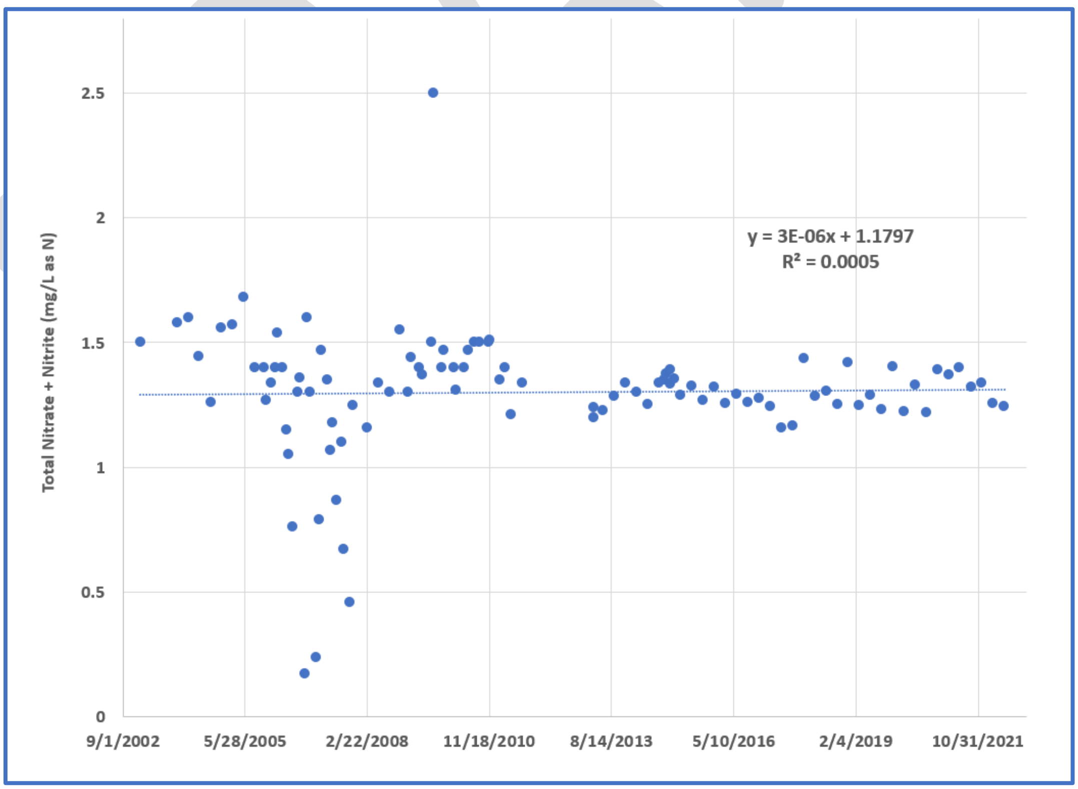

Figure 26. Recent (2003-2022) nitrate + nitrite concentrations at Rock Springs (SJRWMD 2022)

Rock Springs Run as good to excellent for macroinvertebrate habitat. The conditions in the early 2000s are in stark contrast to water quality data collected by USGS and Orange County in the 1970s, which indicated good conditions for both the Wekiva River and Wekiwa Spring Run (FDEP 2000). More recently, median nitrogen levels for the Wekiva River at SR 46 are lower than reported by FDEP in 2000 (Table 9 and Figure 27), and markedly lower than nitrogen levels sampled at both Wekiwa and Rock Springs (Tables 7 and 8). This reduction at SR 46 indicates nitrogen assimilation by in-stream vegetation and adjacent floodplain communities during overbank events. This fits the conceptual model of alluvial streams and rivers with floodplains acting as nitrogen and phosphorus removers and as pollutant sinks (Kitchens et al. 1975, Wharton and Brinson 1979). Additional discussion of nitrogen concentrations, and the relationships between flow and nutrients, is provided in the WRVs Assessment (summary below and Appendix E).

Little Wekiva River

The Little Wekiva River is designated by the State of Florida as a Class III water. The north reach of the Little Wekiva River, immediately north of Highway 434 to the River’s confluence with the Wekiva River, is designated as an OFW and State Aquatic Preserve (Figure 3). Despite these designations, the Little Wekiva River and the Little Wekiva Canal were verified as impaired in 2007 for fecal coliform bacteria (FDEP 2008a). Additionally, the Little Wekiva Canal was verified as impaired for dissolved oxygen (DO) and nutrients based on elevated levels of chlorophyll-a attributed to elevated total nitrogen (TN) and biochemical oxygen demand (BOD) (FDEP 2008b). The Little Wekiva Canal is the headwater reach of the Little Wekiva River, located 14 miles upstream from the confluence of the Wekiva and Little Wekiva Rivers (FDEP 2015).

In 2008, FDEP adopted total maximum daily loads (TMDLs) for the Little Wekiva River and the Little Wekiva Canal (Magley 2017; Table 10). In 2015 FDEP adopted the Wekiva River, Rock Spring Run, and Little Wekiva Canal BMAP as part of its statewide watershed management plan (FDEP 2015).

Water quality data collection on the Little Wekiva River at the SJRWMD station LW-MP has occurred from 2006 to the present (Table 11). This sampling point is located approximately 1.1 miles downstream of Springs Landing Boulevard (the Little Wekiva River assessment location). Average total nitrogen (TN) concentration at LW-MP equaled 0.92 mg/L over the POR (Table 11), which is slightly below the TMDL target of 1.02 mg/L (Table 10) with TN concentrations increasing slightly over the POR (Figure 28). Average total phosphorus (TP) concentration equaled 0.17 mg/L over the POR, exceeding the TMDL target of 0.065 mg/L. TP concentrations have declined slightly during over the POR (Figure 29). Average dissolved oxygen (DO) equaled 6.05 mg/L (Table 11), meeting the DO TMDL target of > 5.0 mg/L (Table 10) with concentrations increasing slightly over the POR (Figure 30). It is worth noting that the location of the LW-MP water quality sampling station is well within the Little Wekiva River reach designated as an OFW and approximately 11 miles downstream of the Little

Table 9. Water quality summary statistics for the Wekiva River at SR 46, Orange and Seminole Counties, Florida (SJRWMD 2015)

Wekiva River at SR 46	Min	Average	Median	Max	Count	Period
Alkalinity, total, mg/L as $CaCO_3$	52.2	105.7	107.83	131.0	146	1995−2014
Calcium, total, mg/L as Ca	28.7	42.19	42.2	64.1	145	1995−2014
Chloride, total, mg/L as Cl	18.0	34.04	35.08	92.0	146	1995−2014
Dissolved Oxygen	0.68	6.30	5.88	11.7	146	1995−2014
Fluoride, total, mg/L as F	0.11	0.166	0.160	0.22	66	2004-2011
Magnesium, total, mg/L as Mg	7.53	11.70	11.80	16.3	145	1995−2014
Nitrate + nitrite, total, mg/L as N	0.004	0.378	0.368	0.734	146	1995−2014
Orthophosphate, total, mg/L as P	0.002	0.092	0.095	0.2	121	1995−2014
pH, field	5.8	7.394	7.43	8.48	145	1995−2014
Phosphorus, total, mg/L as P	0.004	0.115	0.112	0.31	146	1995−2014
Potassium, total, mg/L as K	-2.52	1.926	1.891	6.02	145	1995−2014
Sodium, total, mg/L as Na	12.0	19.744	19.00	46.0	145	1995−2014
Specific conductance, field, µmhos/cm at 25°C	275.0	389.17	383.25	619.0	146	1995−2014
Sulfate, total, mg/L as SO_4	19.33	35.169	31.0	98.69	146	1995−2014
Total dissolved solids, mg/L	163.0	236.402	230.50	385	128	1995−2011
Water temperature, °C	9.725	22.444	22.930	28.4	146	1995−2014

µmhos/cm = micromhos per centimeter
mg/L = milligrams per liter
cfs = cubic feet per second

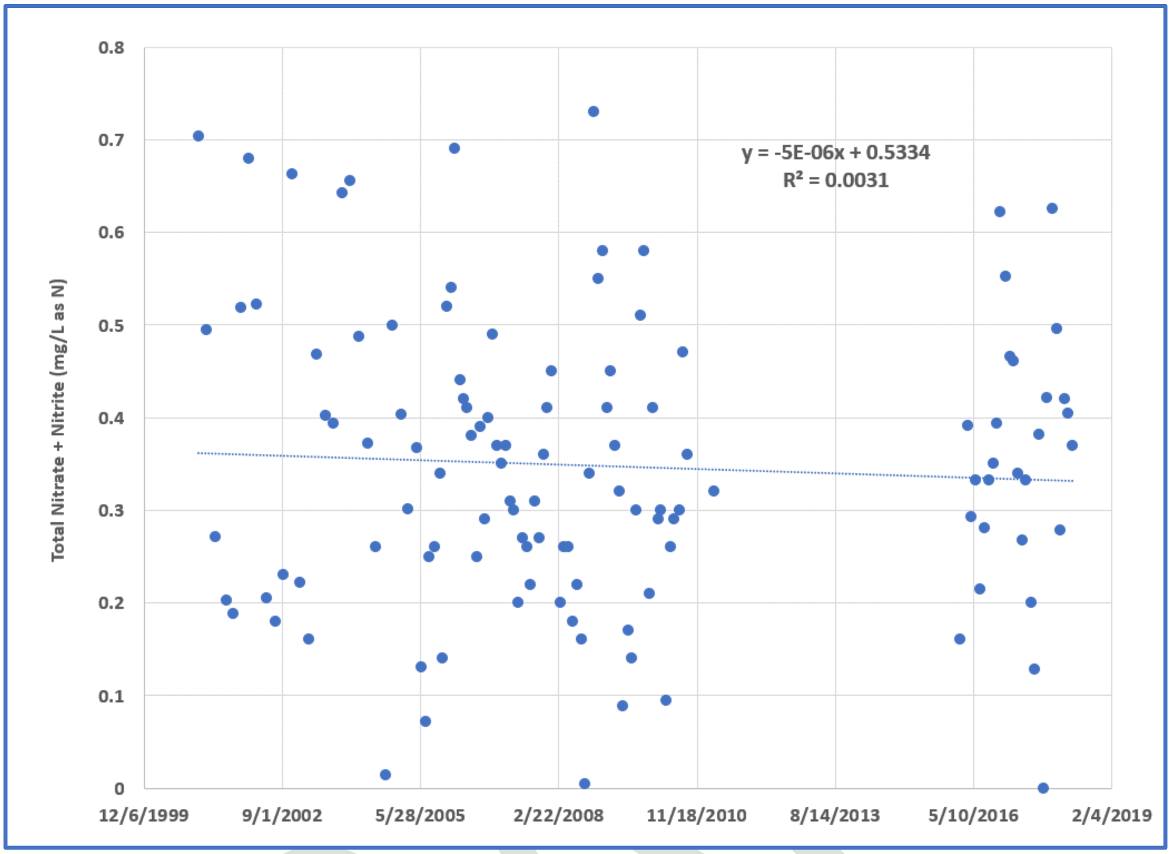

Figure 27. Recent (2001-2017) nitrate + nitrite concentrations for the Wekiva River at SR 46 (SJRWMD 2022)

Table 10. Little Wekiva River and Canal adopted TMDLs (FDEP 2008a and FDEP 2008b)

Location	Parameter	TMDL Target	TMDL Target % reduction
Little Wekiva Canal	TN	1.02 (mg/l)	45.2%
Little Wekiva Canal	TP	0.065 (mg/l)	78%
Little Wekiva Canal	DO	≥5.0 (mg/l)	11%
Little Wekiva River and Canal	Fecal coliform	2.06 E11 colonies /day	42.6%

Table 11. Water Quality statistics for the Little Wekiva River at Sabal Point transect, located approximately 1.1 miles downstream from Spring Landing Blvd (SJRWMD 2019)

Parameter	Number	Minimum	Maximum	Median	Average	Sampling Initiated	End Date of Analyses
Alkalinity, mg/L	149	59.44	264.00	114.87	112.27	10/4/2006	2/19/2019
Ca-T, mg/L	106	22.53	47.63	39.31	38.35	11/8/2006	1/17/2019
Chl-a ug/L	87	0.17	20.19	2.10	3.22	10/11/2011	2/19/2019
Cl, mg/L	149	7.69	55.83	23.90	23.55	10/4/2006	2/19/2019
Conductivity-Field µmhos/cm at 25°C	149	106.10	398.00	347.00	329.51	10/4/2006	2/19/2019
DO	149	3.10	8.77	6.04	6.05	10/4/2006	2/19/2019
K-T, mg/L	106	1.53	3.09	2.00	2.05	11/8/2006	1/17/2019
Mg-T, mg/L	106	3.54	13.15	9.75	9.48	11/8/2006	1/17/2019
Nitrate + nitrite, total, mg/L as N	151	0.995	1.384	0.163	0.514	10/4/2006	2/19/2019
Na-T, mg/L	106	8.50	20.47	14.55	14.69	11/8/2006	1/17/2019
SO4, mg/L	149	7.67	27.94	20.20	19.40	10/4/2006	2/19/2019
TN, mg/L	149	0.49	1.79	0.87	0.92	10/4/2006	2/19/2019
TP-T, mg/L	149	0.11	0.48	0.16	0.17	10/4/2006	2/19/2019
Water Temp °C	149	16.93	28.07	23.88	23.67	10/4/2006	2/19/2019
pH-Field	149	6.69	8.44	7.46	7.45	10/4/2006	2/19/2019

µmhos/cm = micromhos per centimeter
mg/L = milligrams per liter
cfs = cubic feet per second

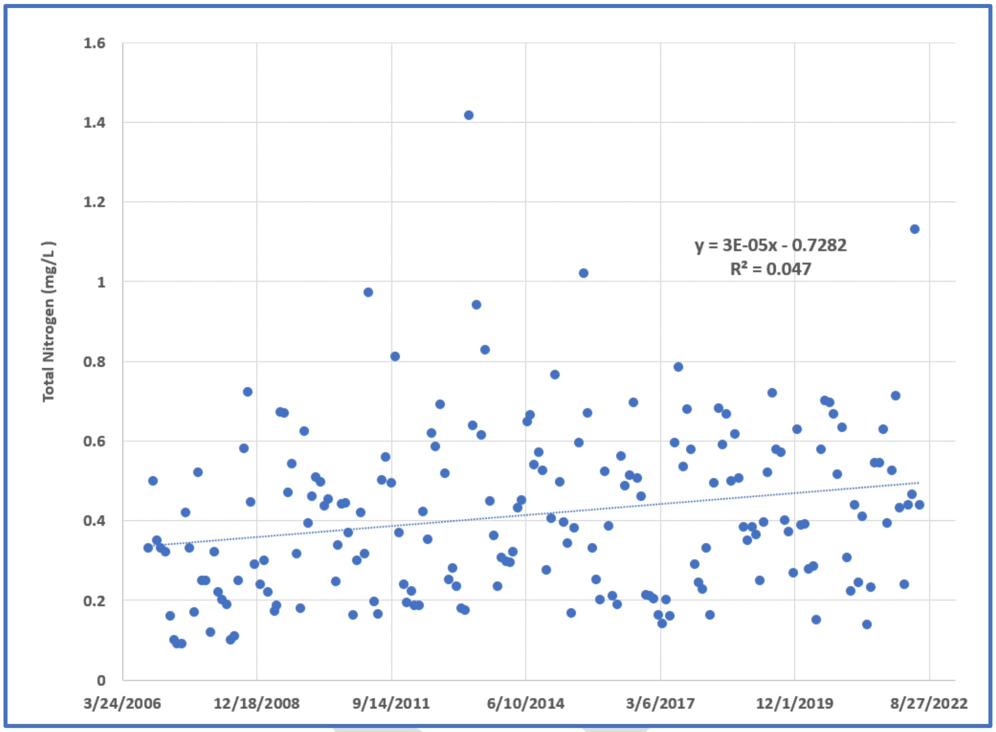

Figure 28. Total nitrogen trend (2006-2022) in the Little Wekiva River at LW-MP, located ~ 1 mile downstream of Springs Landing Blvd (SJRWMD 2022)

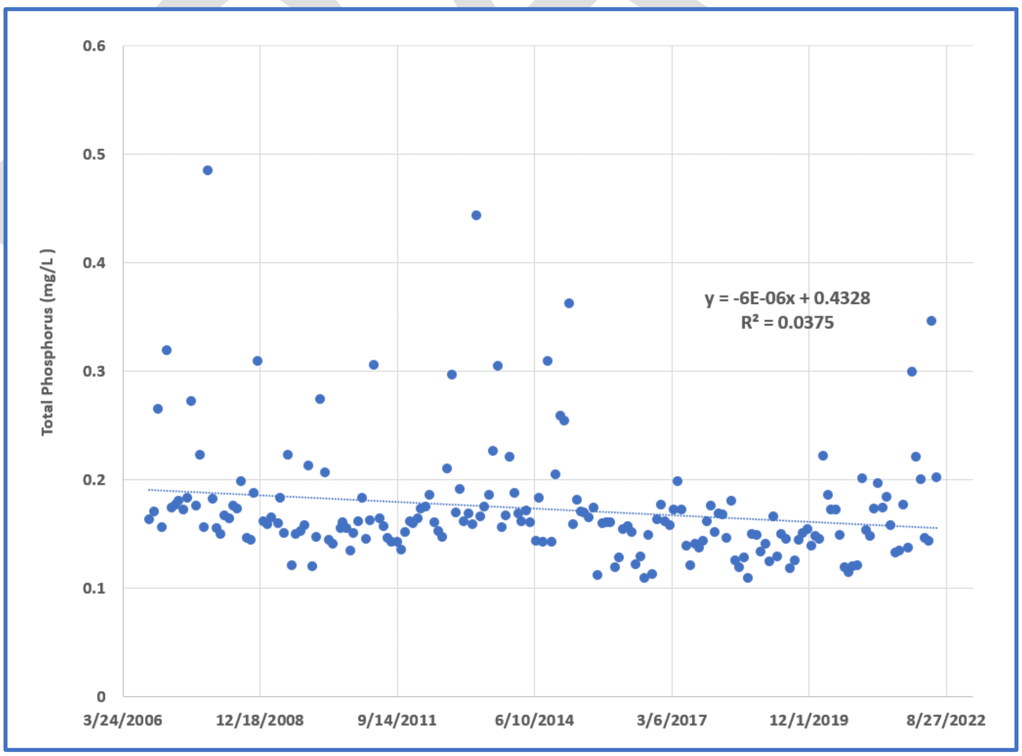

Figure 29. Total phosphorus trend (2006-2022) in the Little Wekiva River at LW-MP, located ~ 1 mile downstream of Springs Landing Blvd (SJRWMD 2022)

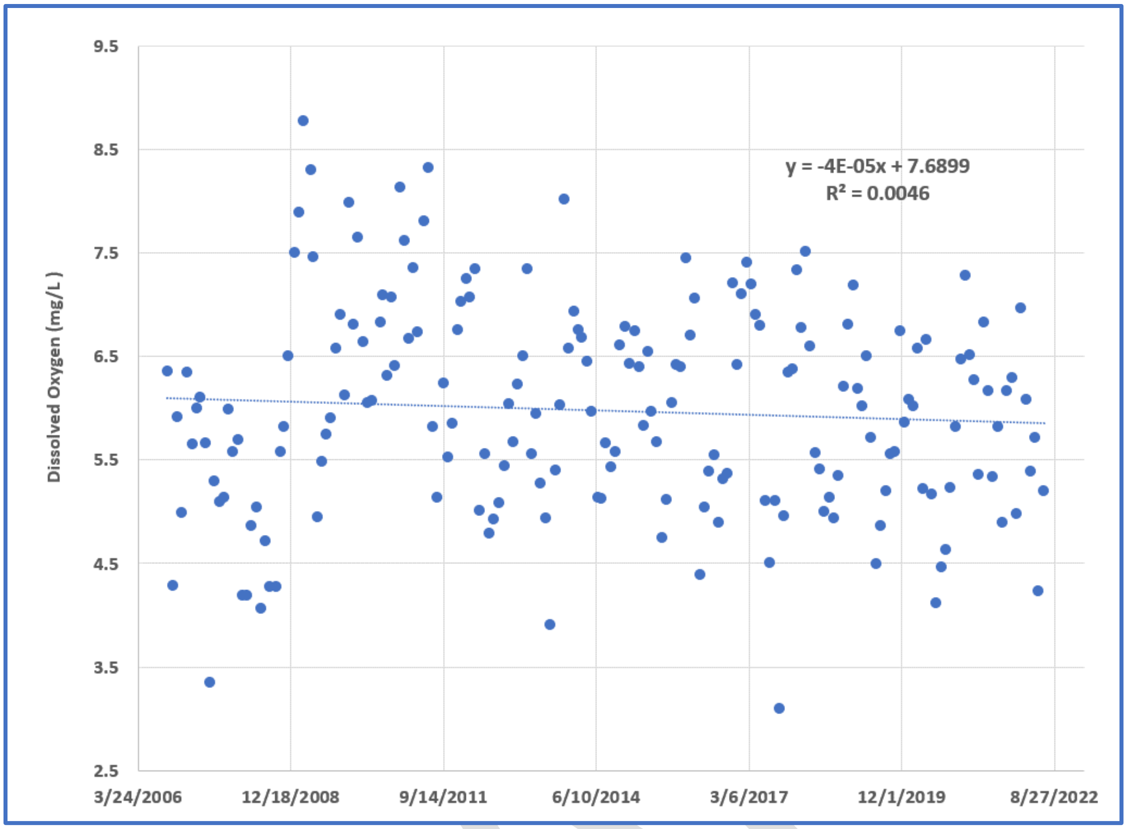

Figure 30. Dissolved oxgen trend (2006-2022) in the Little Wekiva River at LW-MP, located ~ 1 mile downstream of Springs Landing Blvd (SJRWMD 2022)

Wekiva Canal reach where the nutrient TMDLs were established. The relationship between nutrient concentration and flow is discussed further in the WRVs Assessment section (summary below and Appendix E).

MFLs DETERMINATION

The MFLs determination for the Wekiva River at SR 46, Wekiwa Springs, Rock Springs and the Little Wekiva River involved hydrological and environmental analyses. The *Hydrological Analyses* section below provides a brief description of modeling and data analyses used to develop long-term flow and water level time series datasets, which were used to develop minimum flows for Wekiva River basin systems. More details on hydrological analyses are provided in Appendix B.

The *Environmental Analyses* section provides a brief description of each of the environmental criteria evaluated as part of the MFLs determination for each Wekiva River basin system. In addition to methods descriptions, results are also presented, including the calculation of a recommended MFLs condition (i.e., threshold condition) for each criterion. Criteria were chosen in an effort to ensure the consideration and protection of both ecological structure and function as well as human beneficial uses.

Current status of each system, based on the most constraining criterion, is summarized in the *MFLs Assessment* section that follows this section (also see Appendix D). In addition to the development and assessment of primary criteria, on which each system's minimum flows are based, consideration was also given to the protection of a suite of 10 environmental values, listed in Rule 62-40.473, F.A.C. The evaluation of these Water Resource Values (WRVs) is summarized in the *MFLs Assessment* section below and details are provided in Appendix E. The general approach for determining minimum flows and levels for Wekiva River basin systems is presented below and details regarding data and analyses are provided in Appendix B and Appendix C.

HYDROLOGICAL ANALYSES

Significant hydrological analyses are required for establishing and assessing MFLs. The primary purpose of these analyses is to better understand the impact from groundwater pumping on spring and river flows and water levels. This information is then used to develop no-pumping and current-pumping condition long-term flow and level time series which are then used for MFLs determination and assessment. Several steps were involved in performing these hydrological analyses, including:

1. Review of available data;
2. Historical groundwater pumping impact assessment;
3. Development of spring flow, river flow and level datasets representing no-pumping and current-pumping conditions; and
4. Estimating available water (freeboard or deficit).

Flow and water level data are discussed in the *Hydrology* section above. Groundwater impact analysis and development of no-pumping and current-pumping timeseries are summarized below. Additional details are available in Appendix B. Appendix D includes a description of the estimation of flow freeboard (i.e., available water).

Historical Groundwater Pumping Impact Assessment

In the Wekiva River basin system, springs are the main contributor of groundwater to spring runs and rivers. They are, therefore, highly susceptible to changes in groundwater levels, either due to climate or water withdrawal. Because of this vulnerability, impacts were assessed for all Wekiva River basin systems from both local and regional pumping. As described below, the contribution of climate versus pumping was also estimated by developing a pre-withdrawal condition, termed the no-pumping condition, for all systems evaluated.

Groundwater Use

MFLs are established to set the limit at which further water withdrawals would be significantly harmful to water resources. Groundwater pumping within the Wekiva River springshed (Figure 31) has a direct impact on springs in the Wekiva River basin, because the springshed defines the primary groundwater contributing area for spring flows. Therefore, to estimate the impact of pumping on groundwater levels, monthly groundwater use data was compiled or estimated at all stations within the springshed boundary from 1930 to 2018 (Figure 32). It should be noted that the groundwater pumping within the springshed was only used as a proxy to understand the variation of regional groundwater pumping from 1930 to 2018. The full impact of groundwater pumping on springs flows (and other downstream receiving water bodies) were assessed based on the entire groundwater pumping within the groundwater model domain. As shown in Figure 32, the total groundwater use reached its highest level within the springshed in approximately 2000 (~ 245 mgd) and declined until 2018 (~100 mgd). Average groundwater use over the five-year period of 2014–2018 is approximately 110 mgd. which is similar to groundwater use in the early 1970s.

Groundwater Modeling

The ECFTX groundwater flow model was developed by the Central Florida Water Initiative (CFWI) to support regional water supply planning and understand groundwater resource limitations for sustainable water supplies while protecting natural systems (CFWI HAT, 2020). The ECFTX model was recalibrated in 2022, referred to as ECFTX v2.0, to improve simulation of groundwater levels and flows within the Wekiva river basin (Gordu et al. 2022). ECFTX v2.0 was used for this pumping impact analysis.

Estimated Historical Impact on Spring Flows

An estimate of daily spring flow reduction at each spring within the Wekiva river springshed, resulting from regional pumping for the period of 1948 to 2018, was used to develop the no-pumping condition spring flow. Because the ECFTX v2.0 model was not designed to simulate monthly conditions over this long-term period, a methodology was developed using available ECFTX v2.0 model data to estimate the impact of regional pumping on spring flow outside of the model simulation period. This methodology included the development of a

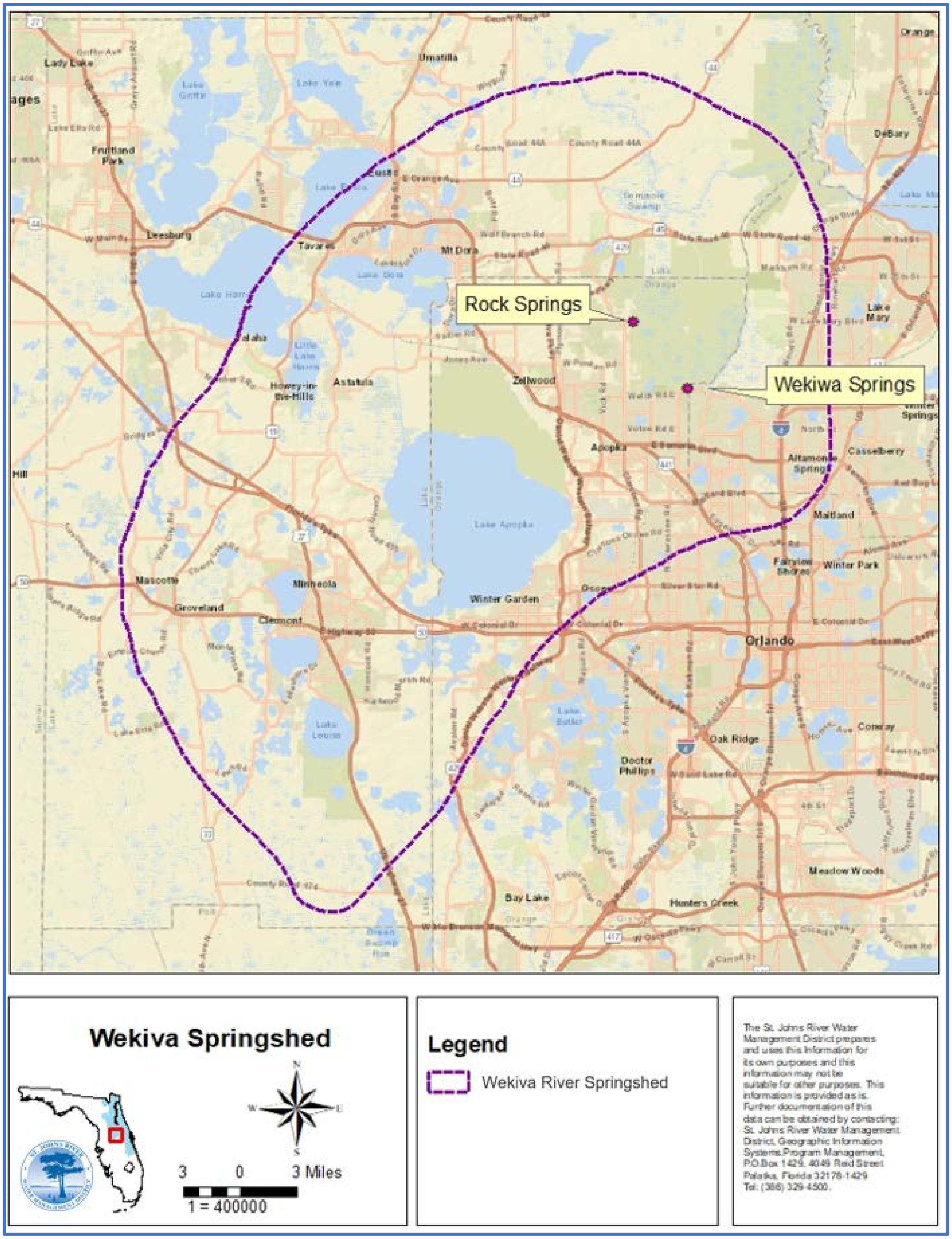

Figure 31. Wekiva River Basin springshed

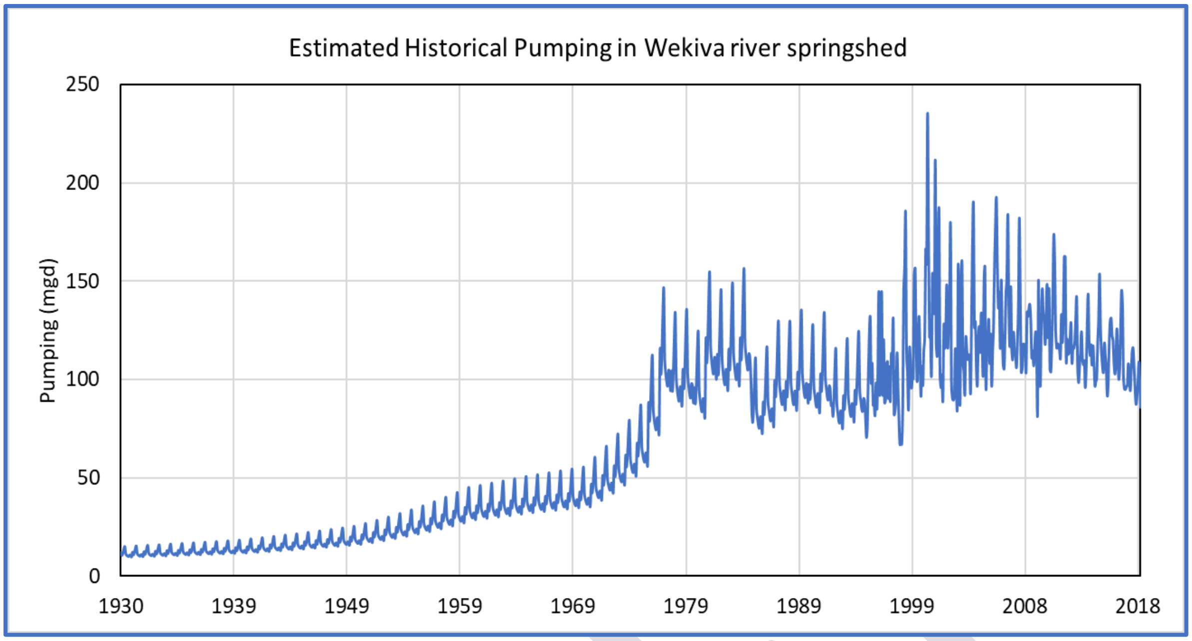

Figure 32. Estimated monthly historical groundwater pumping in Wekiva River Basin springshed from 1930 to 2018

relationship between groundwater pumping and spring flow reduction at each spring within the springshed using the ECFTX v2.0. The pumping-impact relationships were used to calculate a monthly historical spring flow impact from long-term (1948 to 2018) estimated monthly pumping data within the springshed boundary. The monthly estimated historical impact due to pumping was disaggregated to a daily time series extending from 1948 to 2018 using linear interpolation. The daily estimated historical impacts from pumping for the period of 1948 to 2018 at Rock and Wekiwa Springs are shown in Figure 33.

No-pumping and Current-pumping Condition Spring Flows

Long-term flow time series, representative of a no-pumping condition and a current-pumping condition, are needed for both MFLs determinations and assessments. Estimated spring flow declines caused by groundwater pumping (described above) is added to the observed dataset to create the no pumping condition dataset. The no-pumping condition time series represent hydrologic conditions of the springs in which impacts from groundwater pumping are assumed to be minimal. See Appendix B for more details on the calculation of impact due to pumping and creation of the no-pumping condition flow time series.

Current-pumping condition flow datasets were developed by subtracting an estimate of impact due to current groundwater pumping (average 2014–2018) from the no-pumping flow time series. The current-pumping condition dataset represents a reference hydrologic condition for a particular water body in which the total regional groundwater pumping impact is assumed to be constant from 1948 to 2018. Figures 34 and 35 show the daily

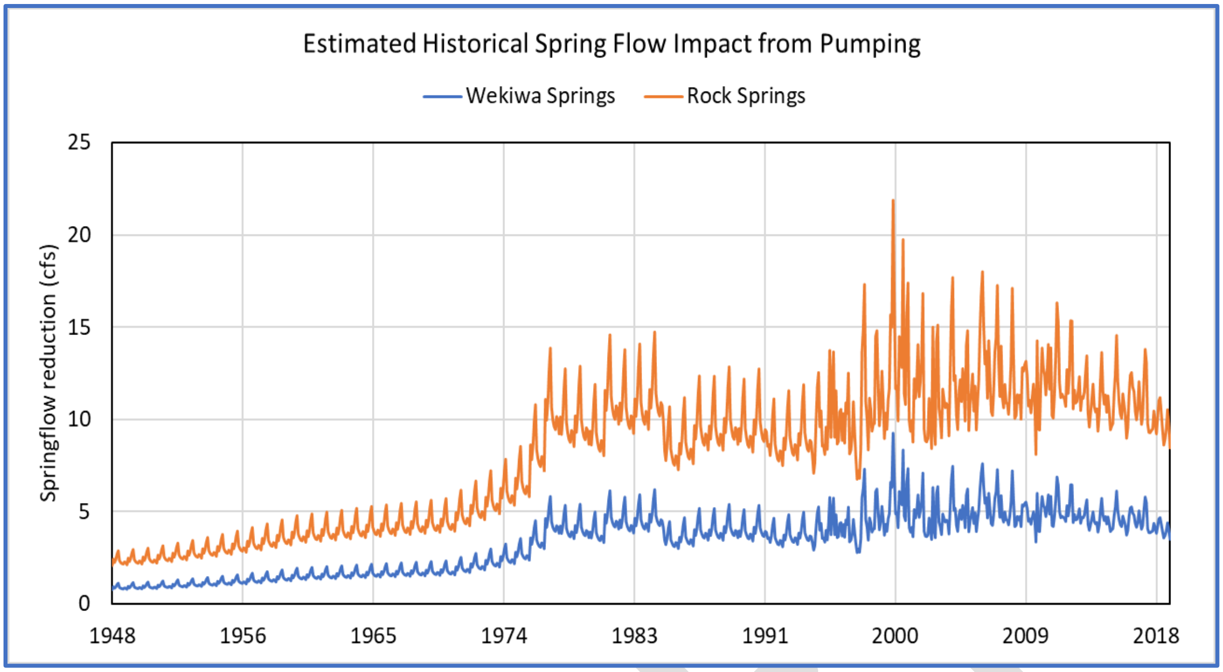

Figure 33. Estimated impact of historical groundwater pumping on Rock and Wekiwa springs from 1948 to 2018.

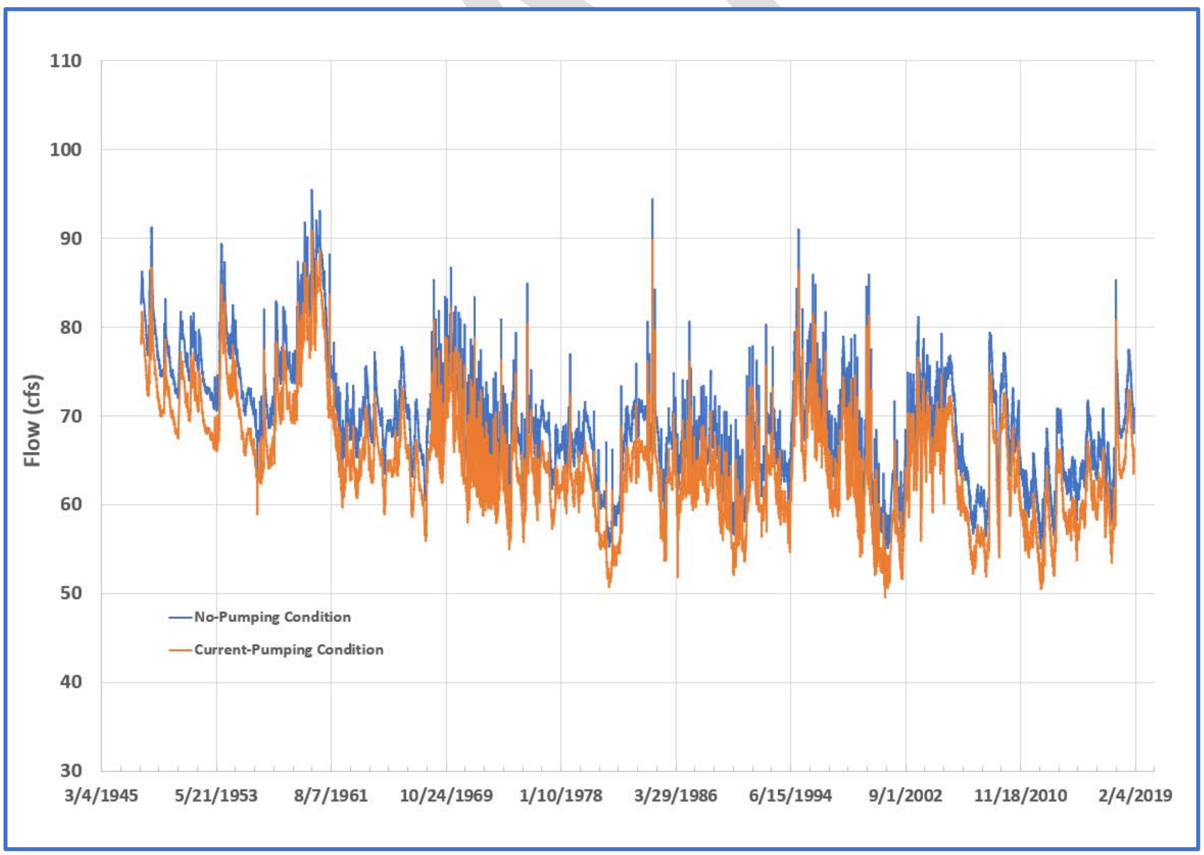

Figure 34. Estimated no-pumping and current-pumping condition flows for Wekiwa Springs

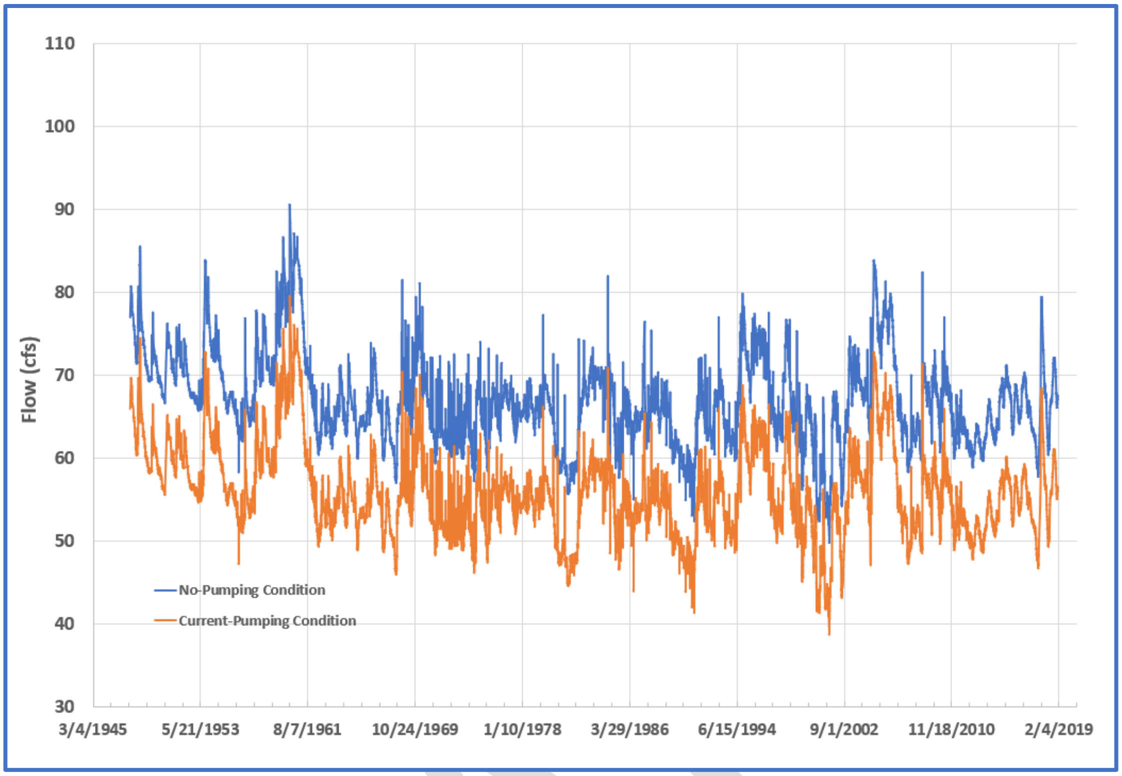

Figure 35. Estimated no-pumping and current-pumping condition flows for Rock Springs

no-pumping and current-pumping condition flows at Rock and Wekiwa Springs, respectively. Wekiva River basin system flows and levels were also expressed as exceedance probabilities to facilitate evaluation of certain MFLs criteria. Figures 36 and 37 depict the no-pumping and current-pumping conditions flow exceedance curves for Wekiwa Springs and Rock Springs, respectively.

Assuming climatic, rainfall, and other conditions present from 1948 to 2018 are repeated over the next 70 years, the current-pumping condition reflects the future condition of spring flows if the average regional groundwater pumping does not change from the 2014–2018 condition. The current-pumping time series can then be used to determine current available water (i.e., freeboard or deficit) by assuming future climatic variability is similar to the past, and future pumping impact is held constant at the current condition. Our understanding of possible future climatic conditions is limited and there are significant uncertainties in global climate model predictions. According to the Florida Climate Institute, the climatic cycles such as El Nino Southern Oscillations (ENSO), Atlantic Multidecadal Oscillation (AMO) and the Pacific Decadal Oscillation (PDO) have the strongest influence on Florida’s climate variability (Kirtman et al., 2017). ENSO cycles typically range from two to seven years, PDO cycles typically range from 15 to 25 years and AMO cycles typically range 60 to 70 years (Schlesinger and Ramankutty, 1994; Obeysekera et al., 2011; and Kuss and Gurdak, 2014).

There are strong relationships of short- and long-term climatic cycles such as ENSO and AMO to rainfall, river flows and groundwater levels in Florida (Enfield et al., 2001, Kelly, 2004 and

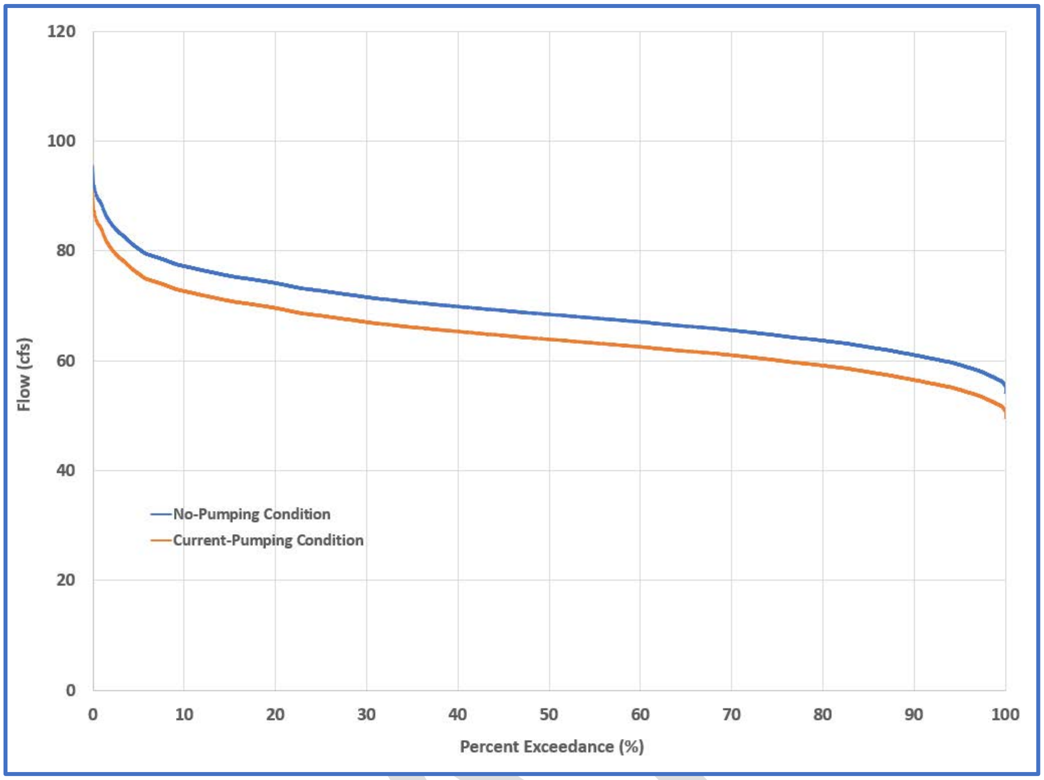

Figure 36. No-pumping and current-pumping condition percent exceedance curves for Wekiwa Springs flows.

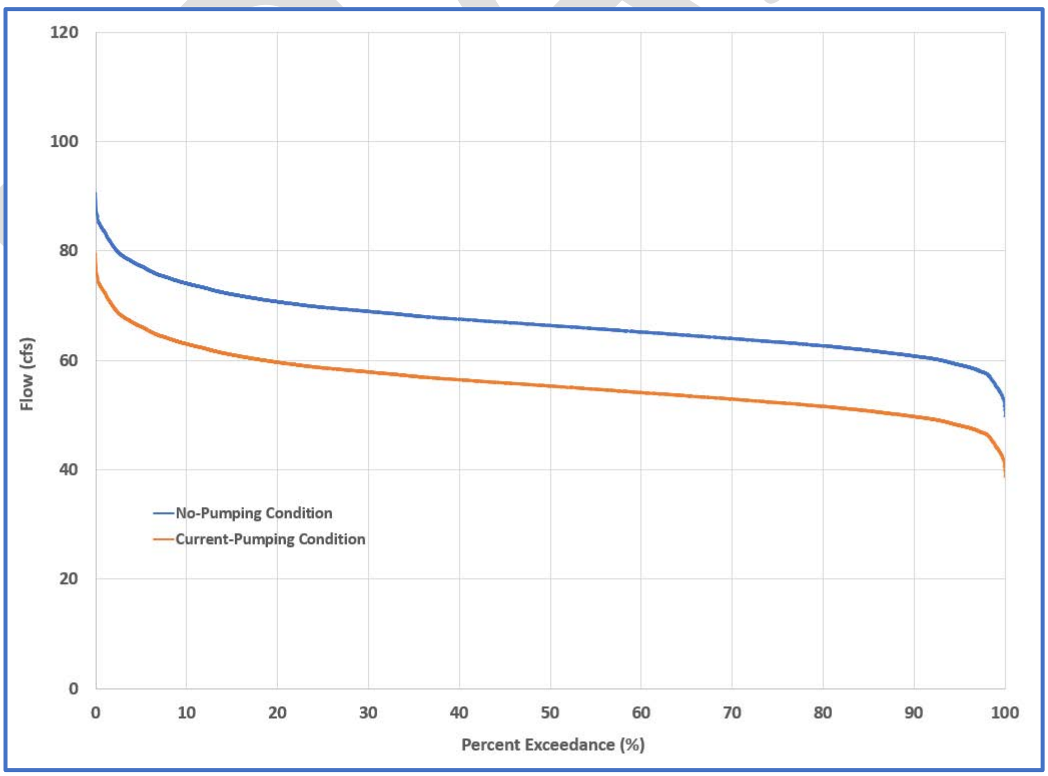

Figure 37. No-pumping and current-pumping condition percent exceedance curves for Rock Springs flows.

Kuss and Gurdak, 2014). These strong relationships are not expected to disappear in the foreseeable future. Because of this, MFLs determinations require the use of long-term flow and level simulations to capture the effects of short- and long-term climatic variations such as ENSO and AMO.

SJRWMD acknowledges that the MFLs analyses assume that hydrological history will repeat itself. Given the uncertainties in future rainfall and temperature predictions by global climate models, this assumption is thought to be appropriate but needs to be regularly tested by implementing an adaptive management strategy.

The SJRWMD implements an adaptive management strategy (described later in this report) to address continuing challenges and uncertainties in ecohydrological data and tools. Moreover, MFLs are established to prevent water bodies from being significantly harmed by water withdrawals, not changes in rainfall conditions. Therefore, using historical conditions to generate current-pumping condition time series is considered reasonable.

No-pumping and Current-pumping Condition River Levels

No-pumping and current-pumping condition spring flows were used as boundary conditions and inputs to the unsteady state Wekiva River Hydrologic Engineering Center River Analysis System (HEC-RAS) model to simulate no-pumping and current-pumping river flows and levels.

For Wekiwa Springs, Rock Springs and the Wekiva River at SR 46 gages, simulated no-pumping and current-pumping river levels were adjusted for periods when observed levels were available. The differences between the simulated no-pumping and the historical simulated river levels were added to the historical observed levels to obtain final no-pumping river level time series.

Similarly, the differences between the simulated no-pumping and the simulated current-pumping river levels were subtracted from the final no-pumping levels to obtain final current-pumping river level time series (see Appendix B for more details). Figures 38 and 39 depict no-pumping and current-pumping conditions water levels for Wekiwa Springs and Rock Springs, respectively (see Appendix B for water level data for other Wekiva River basin systems).

Environmental Analyses

Overview

MFLs environmental analyses are focused on the determination of relevant environmental attributes and beneficial uses for a given water body, as well as determining criteria and thresholds to protect these functions and values. The criteria evaluated are meant to protect both ecological and human beneficial uses. This process typically includes:

- collection and analysis of site-specific field-based ecological and soils data;

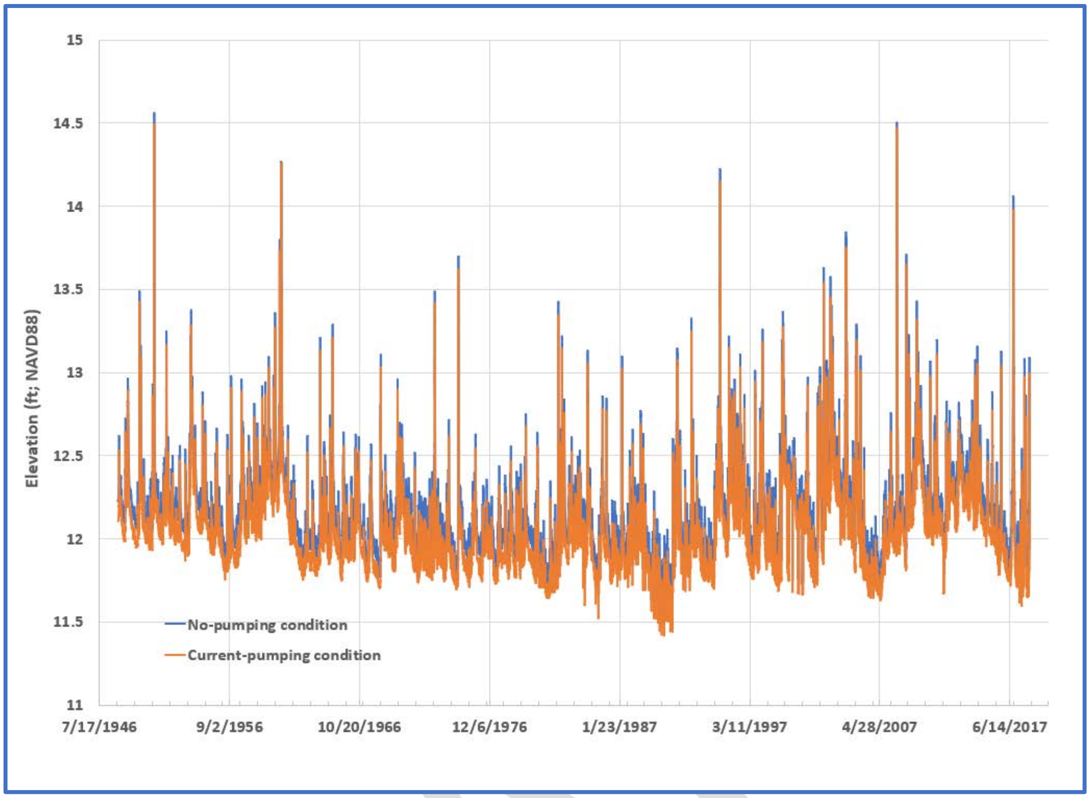

Figure 38. Estimated no-pumping and current-pumping condition water levels for Wekiwa Springs

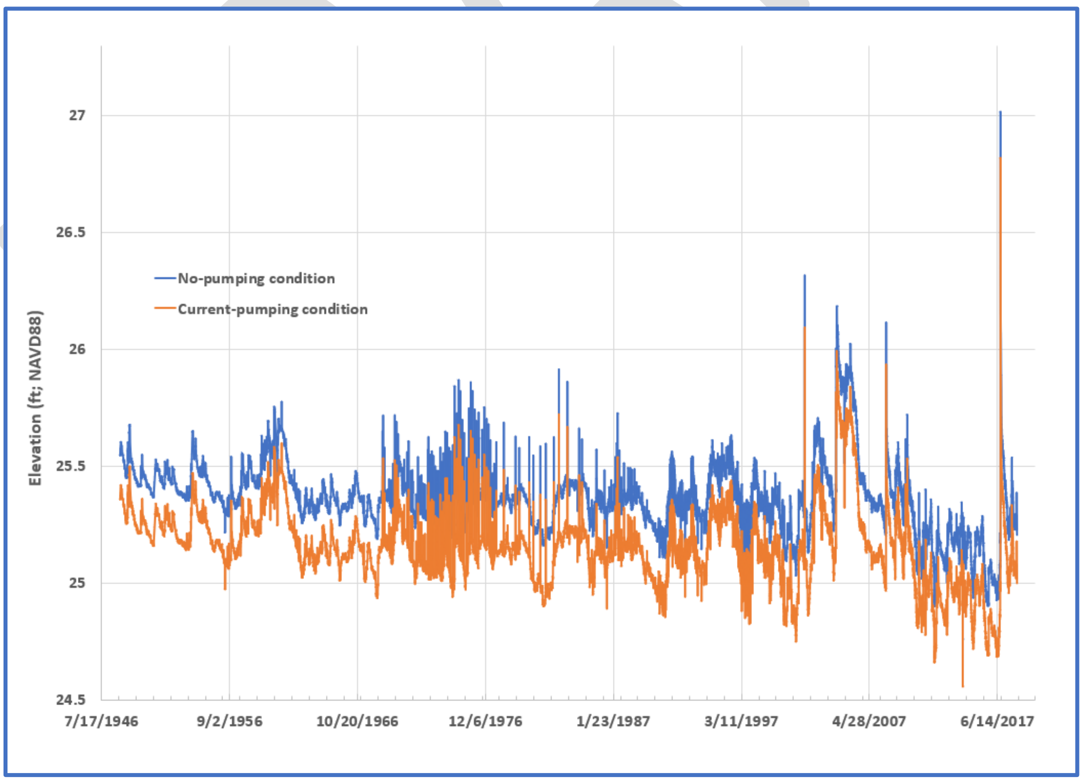

Figure 39. Estimated no-pumping and current-pumping condition water levels for Rock Springs

- consideration of non-ecological environmental data (e.g., data used to assess recreational values);
- consideration of topographical information;
- consideration of historical, remotely sensed and mapped data, aerial photographs; and
- consideration of scientific literature and agency reports.

Using this information, relevant environmental values are selected for a given water body. Next, appropriate criteria are determined to represent these environmental values, and a minimum hydrologic regime (MFLs condition) is determined to protect each value.

A variety of environmental criteria were evaluated in an effort to ensure protective minimum flows were developed for all Wekiva River basin systems. However, the majority of criteria were developed and assessed for four primary water bodies: the Wekiva River at SR 46, Wekiwa Springs, Rock Springs and the Little Wekiva River at Springs Landing Boulevard. Due to the small size and lack of data at the four small Wekiva River basin springs (i.e., Palm, Sanlando, Starbuck and Miami Springs), these were assessed by ensuring that nearby or downstream MFLs waterbodies are protected by their site-specific MFLs. A swimming/wading metric was explored for Palm, Sanlando and Starbuck Springs but was not pursued because of a lack of relationship between flow and water level data at these sites (see below and Appendix E for details). The following sections on primary criteria focuses on the four primary water bodies mentioned above.

SJRWMD's standard event-based criteria were first evaluated to determine whether this approach was appropriate for the four primary Wekiva River basin systems. In recent years, it has been demonstrated that this conventional approach may not be appropriate for all systems (e.g., see Sutherland et al. 2021). Where appropriate, event-based metrics are typically developed to protect ecological and soils-based functions and values in floodplain and near-shore environments (e.g., see Sutherland et al. 2017). For two Wekiva River basin systems where event-based metrics were deemed not appropriate (because they either allowed a very large amount of flow reduction or were not able to be met under the no-pumping condition), the protection of floodplain soils and vegetation was evaluated using two new criteria. In addition to these two new floodplain metrics, in-channel fish habitat suitability was also evaluated for the four primary Wekiva River basin systems.

After evaluating primary criteria, numerous other metrics were evaluated as part of a comprehensive water resource value (WRV) assessment. These include hydrodynamic (i.e., critical velocity threshold) metrics, and exceedance of important elevations needed for passage of fish and manatees. Finally, a variety of human-use metrics were evaluated to ensure that important recreational values are protected in the Wekiva River basin. The variety and type of criteria evaluated are meant to ensure that environmental functions and values beyond floodplain vegetation are protected. Further, the State's Water Resource Implementation Rule states that "consideration shall be given" to the breadth of environmental values that are relevant to a given priority water body (Rule 62-40.473, F.A.C.). Examining in-channel and human-use values is necessary to meet the spirit of this Rule and critical to protection of all relevant functions and values in the Wekiva River basin. Final criteria, evaluated as part of the MFLs determination and the WRVs assessment, were selected based on their relevance to Wekiva River basin systems and their sensitivity to groundwater withdrawal.

Event-based Metrics

Approach

A water body's hydroperiod is the primary driver of wetland plant distribution and diversity, hydric soils type and location, and to a varying degree freshwater fauna (Foti et al., 2012, Murray-Hudson et al., 2014). A system's natural hydrologic regime, represented by variable flooding and/or drying events, is necessary to maintain the extent, composition, and function of wetland and aquatic communities (Poff et al. 1997, Thorp et al. 2008, Arthington 2012). Wetland and aquatic species, and hydric soils require a minimum frequency of critical hydrologic events for long-term persistence (Richter et al. 1997, Winemiller 2005, Arthington 2012).

Event-based MFLs metrics are developed to protect a minimum hydroperiod necessary for the maintenance of specific environmental values. They are described with a magnitude component (i.e., water level or flow), a duration, and a return interval; the latter is also expressed as frequency of exceedance or non-exceedance. SJRWMD's conventional event-based approach defines ecologically relevant events as the combination of their magnitude and duration components. The return interval/frequency of these events is often described as the manageable component (i.e., minimum thresholds are associated with an allowable change in the frequency of events; Neubauer et al., 2008), however it is recognized that a minimum hydroperiod could be developed that holds magnitude and frequency constant and associates a change in duration with significant harm; both methods would still (theoretically) arrive at the same minimum hydroperiod.

The aim of SJRWMD's event-based metrics is to prevent significant harm due to an excessive change in event frequency caused by water withdrawal. Significant harm is associated with impairment or loss of ecological structure (e.g., reduction in wetland acreage) or function (e.g., insufficient fish reproduction or nursery habitat).

Protective event frequencies (i.e., recommended return intervals) are determined using hydrologic event probabilities called Surface Water Inundation and Dewatering Signatures (SWIDS). SWIDS of vegetation species or communities provide a hydrologic range for a population of water bodies, that exhibit a transition from drier conditions on one side of the range to wetter conditions on the other side. A primary assumption is that these hydrologic signatures are for a group of similar water bodies and thus provide an estimate of the shift in return interval of flooding or drying events that can occur before causing significant harm to the species or community in question.

Because hydroperiods vary spatially and temporally (Mitsch and Gosselink, 2015), and because species and communities are adapted to different parts of a system's hydrologic regime, multiple event-based (or other) criteria are typically used to protect different portions of a system ecological structure and function (Neubauer et al. 2008). For many systems, SJRWMD sets three MFLs; minimum frequent high (FH), minimum average (MA), and minimum frequent low (FL) water levels. In some cases, a minimum infrequent high (IH) and/or minimum infrequent low (IL) water level may also be set (Figure 40).

The FH, MA and FL are typically used for systems with low fluctuation range (e.g., lowland or spring-fed runs and rivers). However, only two event-based MFLs were evaluated for each of the four primary Wekiva River basin systems: a FH level, and MA level, both with associated durations and minimum recommended return intervals. The recommended MFLs define the minimum number of flooding events per century (FH) or the maximum number of dewatering events per century (MA), on average, needed to protect ecologically important and hydrologically sensitive functions from significant ecological harm caused by groundwater withdrawals.

The recommended FH provides sufficient numbers of flood events to protect the entire extent of floodplain wetlands and their wildlife habitat values. These flood events also promote filtration and absorption of nutrients and other pollutants on the floodplain. The recommended MA prevents an excessive number of dewatering events to protect organic soils from oxidation and subsidence and avoid adverse impacts to habitat and water quality.

A minimum FL was not developed for any of the Wekiva Basin systems because the resultant low elevations were determined to be extremely insensitive to changes in water level. Low-elevation and in-channel functions and values were evaluated using different

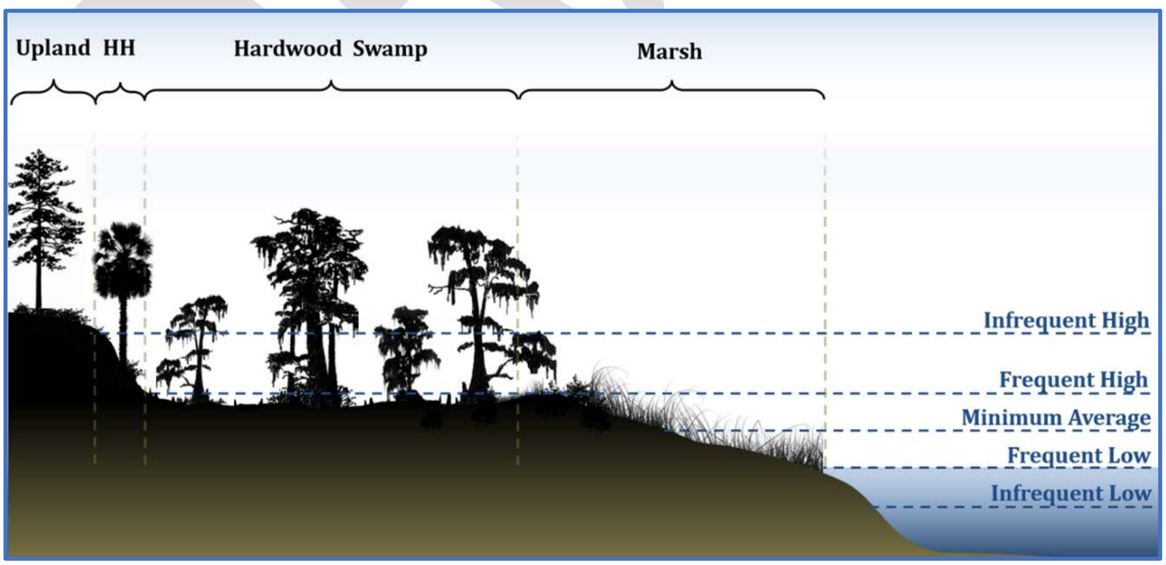

Figure 40. Conceptual drawing showing the five most common minimum flows and/or levels developed using SJRWMD's event-based approach; HH = Hydric Hammock.

metrics and analyses that focused on fish and invertebrate habitat suitability, fish passage, critical velocities for different hydrodynamic functions, and recreational values among others (see below following event-based metrics).

Site Selection and Data Collection

Vegetation, soils, and elevation data were collected along thirteen transects for the Wekiva River basin MFLs (Figure 41). Transects typically extended from uplands, across multiple wetland communities, to open water (river channel). Some transects extended from upland to upland, across the floodplain on both sides of the channel. A search of aerial photographs, and remotely sensed data (e.g., mapped vegetation, soils and other data) was conducted prior to establishing field transects. Proposed transects were inspected prior to intensive data collection to confirm the presence of desired features, including:

- representative examples of common wetland communities;
- unique or high-quality wetlands;
- edge of uplands or open water; and
- deep organic and other hydric soils.

Vegetation and soil sampling followed standard field procedures. More information on field transect selection and data collection methods are provided in Appendix C. Elevation and soundings data were also collected at transects within springs pools and boat launches to characterize channel and spring pool features that influence recreational uses.

Minimum Frequent High (FH)

The general indicator of protection for the FH, for Wekiva River basin systems, is maintaining frequently inundated conditions within hardwood swamp communities, sufficient to maintain species composition, vegetative structure, and associated biogeochemical and ecological functions. The purpose of the FH is to ensure that water withdrawals do not reduce the frequency of flooding events in hardwood swamps beyond the recommended return interval threshold. These high-water level events occur during wet seasons in periods of normal or above normal precipitation. The specific indicator of protection is a water level at the average elevation of the hardwood swamps, calculated by averaging the ground elevations of communities located at multiple representative field transects located in each system's floodplain (Figure 41). The FH is a high-water threshold that is meant to protect and maintain the following ecological structure and function:

- protection of the active floodplain, structuring the physical environment by creating geomorphic features and establishing boundaries with adjacent uplands;
- support for hydrophytic vegetation and hydric soils of hardwood swamps and emergent marshes;
- maintenance of the boundary between wetlands and uplands by preventing long-term downhill migration of upland species resulting in loss of wetland area;

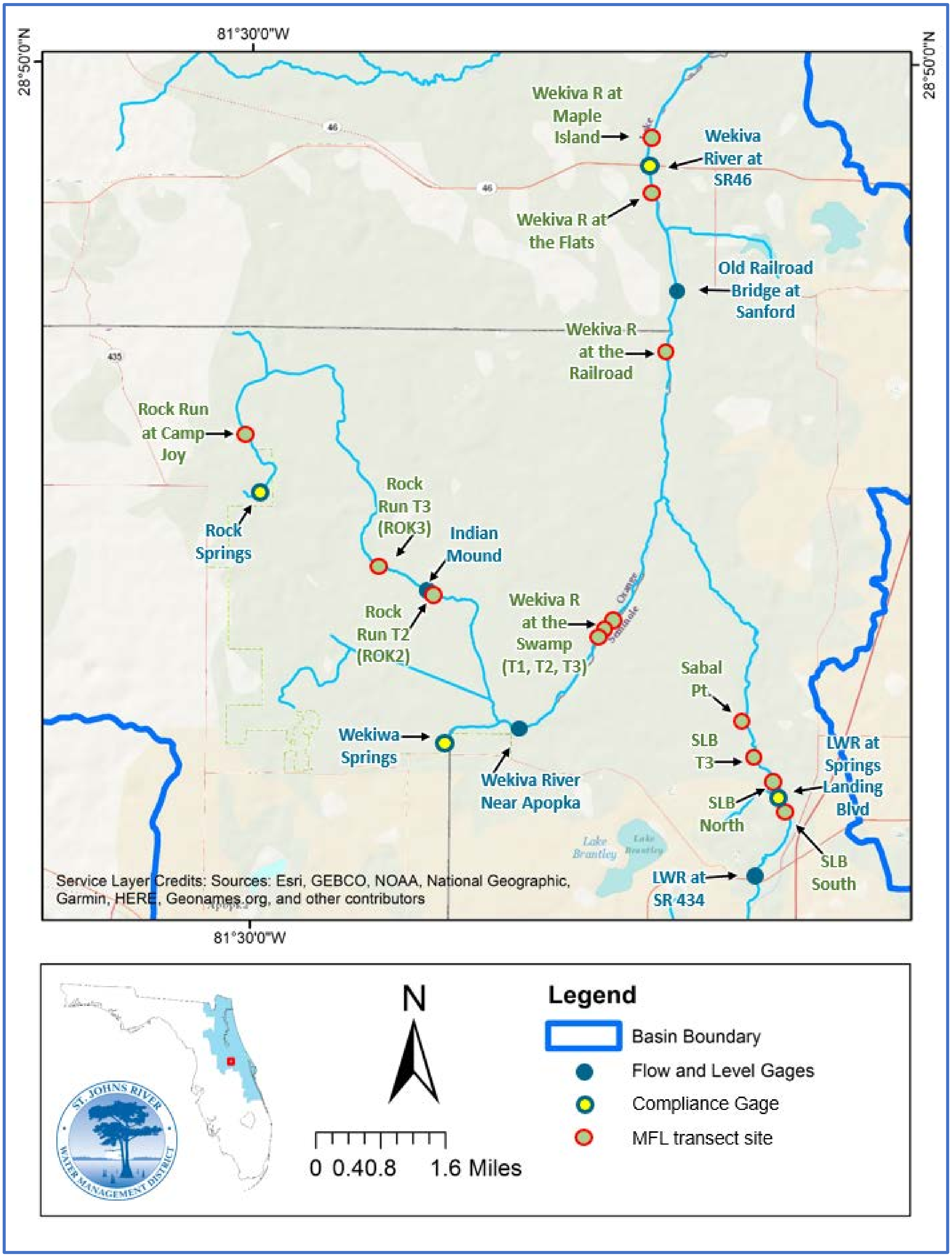

Figure 41. Wekiva River basin MFLs field transect and gage locations.

- connection between the river proper and floodplain to provide opportunities for aquatic fauna to feed, spawn, and seek refuge; and
- promotion of denitrification and nutrient cycling processes and organic soil accrual by providing long duration inundation at low elevations in the floodplain.

<u>FH Magnitude</u>

The FH magnitude for each Wekiva River basin system equals the average hardwood swamp elevation measured at multiple transects. Protection of average hardwood swamp elevations is meant to ensure direct connection between the Wekiva River, Rock Springs Run and the Little Wekiva River and corresponding floodplain ecosystems.

This connection will allow fish and other organisms access to forage and provide refugial habitats in the inundated floodplain. A goal of the FH is to also allow for extensive shallow inundation of hardwood swamp communities to create habitat for small forage fish, while also providing deeper inundation for larger species in secondary channels with shallow and deep marsh vegetation.

The inundation of hardwood swamp communities throughout the Wekiva River basin will also promote the interaction of surface waters with biologically and chemically reactive substrates (e.g., vegetation, soils, detritus, microbial mats, etc.). The physiochemical environment of the floodplain is a function of interactions of processes occurring in the overlying water column, in soil, and at the soil-water interface (Wharton et al. 1982). The resulting anaerobic soil conditions favor conditions for NOx removal and persistence of hydrophytic vegetation. Prolonged periods of flooding facilitate these processes by saturating the soils and the subsequent periodic intervals of soil dewatering (drying). This cyclic wet/dry regime imparts a unique chemical environment that has promotes nutrient cycling and supports floodplain biotic communities (Wharton et al. 1982).

Average hardwood swamp elevations were measured at six transects for the Wekiva River at SR 46 MFLs, and at three transects each for the remaining three systems (Wekiwa Springs, Rock Springs and the Little Wekiva River; Table 12; Figure 41). At the Wekiva Swamp transect number one (T1) the elevation used for the FH was the mean from hardwood swamp number 2 (HS#2; Appendix C); HS#2 is dominated by cypress and tupelo, whereas other hardwood swamp communities are further upslope and are characterized by a mixture of hardwood swamp and hydric hammock species. Also note that the Sabal Point transect originally established for the Little Wekiva River MFLs was ultimately not used due to changes in channel morphology due to excessive sedimentation.

The recommended FH elevation for each system was calculated by transferring average field elevations to corresponding assessment gages (Figure 41) using output from the Wekiva River basin HEC-RAS model. Hardwood swamp elevations were transferred to the gaging stations at the Wekiva River at SR 46 (USGS 02235000), Wekiwa Springs (USGS 00371831), Rock Springs at Kelly Park (SJRWMD 00330830) and the Little Wekiva River at

Springs Landing Boulevard (SJRWMD 09502132), for each of the respective MFLs (Table 12, Figure 41). After transferring to corresponding gaging stations, average hardwood swamp elevations were averaged yielding a single FH elevation for each system at each assessment point (Table 12).

Table 12. Minimum FH elevations at field transects and corresponding assessment gages for each Wekiva River basin system (Wekiva River at SR 46, Wekiwa Springs, Rock Springs and the Little Wekiva River at Springs Landing Blvd [SLB]).

Level	Transect	Environmental Criterion	Field Transect Elevation (ft; NAVD 88)	Assessment Gage Elevation (ft; NAVD 88)
Wekiva River at SR 46				
FH	Maple Isl.	Average hardwood swamp	6.8	6.6
FH	Flats	Average hardwood swamp	7.0	6.6
FH	Railroad	Average hardwood swamp	9.5	6.7
FH	Average of Swamp T1*, T2 and T3	Average hardwood swamp	11.0	6.6
			Average	**6.6**
Wekiwa Springs				
FH	Average of Swamp T1*, T2 and T3	Average hardwood swamp	11.0	12.1
			Average	**12.1**
Rock Springs				
FH	Rock T1	Average hardwood swamp	17.8	25.4
FH	Rock T2	Average hardwood swamp	19.0	25.1
FH	Camp Joy	Average hardwood swamp	22.4	24.6
			Average	**25.0**
Little Wekiva River at SLB				
FH	SLB South	Average hardwood swamp	18.7	18.6
FH	SLB North	Average hardwood swamp	18.0	18.3
FH	SLB T3	Average hardwood swamp	17.8	19.1
			Average	**18.7**

*Wekiva Swamp T1 elevation is the average elevation of hardwood swamp #2

FH Duration

The typical FH duration of 30 days is based on scientific literature that suggests seasonally flooded hardwood swamps are inundated for one to two months during the growing season (Hill et al. 1991; Mitsch and Gosselink 2015). For some systems, a 30-day continuous flooding event represents a sufficiently long period of soil saturation or inundation to protect the structure and functions of seasonally flooded wetland plant communities (Hill et al. 1991). The species composition and structural development of floodplain plant communities are influenced by the duration of floods occurring during the growing season (Huffman 1980). Short-term flooding events are important to the redistribution of plant seeds within aquatic habitats (Schneider and Sharitz 1986; Junk et al. 1989).

A minimum flooding duration of 30 days is sufficient to cause the mortality of young upland plant species that get established within transitional zones during low water events, maintaining the hydrophytic structure and diversity of the wetland communities (Ahlgren and Hansen 1957; Menges and Marks 2008).

Research shows that abundant hypertrophied lenticels and adventitious roots develop in loblolly pine and pond pine after 30 continuous days of anaerobic conditions (Topa and McLeod 1986). Bell and Johnson (1974) found that species intolerant of flooding exhibited severe effects with less than 50 days of flooding during the growing season.

The 30-day flooding duration roughly corresponds to the durations of saturation that define the upper boundaries of many wetlands. From a regulatory standpoint, the U.S. Army Corps of Engineers uses durations of saturation between 5 and 12.5% of the growing season in most years as the standard in its wetland delineation manual (Environmental Laboratory 1987). Given the year-round growing season in Florida, this corresponds to durations of 18 to 46 days.

However, the National Research Council (1995) has recommended a shorter duration hydroperiod to define wetland hydrology: saturation within 1 ft of the soil surface for a duration of two weeks (14 days) or more during the growing season in most years. This shorter duration hydroperiod may approximate the hydrology of the transitional wetland communities that occur upslope of hardwood swamps within the mainstem Wekiva River floodplain.

The 30-day FH flooding duration will also provide longer duration flooding for hardwood swamp species at elevations lower than the overall average. Therefore, the 30-day duration provides flooding to the majority of the hardwood swamp communities for fish and other aquatic fauna to feed, reproduce, and/or use the flooded habitat for refuge.

The recommended FH duration equals the standard (i.e., used for numerous other adopted MFLs) minimum duration of 30-days continuously flooded at or above the associated FH magnitude elevation (Table 12).

FH Return Interval

The FH is typically associated with a "seasonally flooded" hydroperiod (Rule 40C-8.021(19), F.A.C.) *"…where surface water is typically present for extended periods (30 days or more) during the growing season, resulting in a predominance of submerged or submerged and transitional wetland species. During extended periods of normal or above normal rainfall, lake levels causing inundation are expected to occur several weeks to several months every one to two years."*

For many MFLs systems, a FH return interval of 2 to 3 years is typical. For the Wekiva River basin systems, the FH return interval was informed by hydroperiod data collected for other riverine hardwood swamp communities in Florida. A FH return interval of 2.0 years was selected for the Wekiva River basin systems, based on a SWIDS analysis of 14 transects located in river floodplain hardwood swamps (Table 13), which equals the average, plus standard error, return interval for these Florida riverine swamps.

This recommended 2-year return interval is the same as FH return intervals for other adopted MFLs and results in 50 flooding events per century, on average. The 2-year return interval recommendation will help to maintain a flood pulse that recurs sufficiently often to maintain hardwood swamp vegetation communities, while also protecting strong year classes of short-lived forage fish and sufficient numbers of older individuals, resulting in a diverse age class of spawning stock (Houde 2008). Regular flooding increases floodplain fertility, and the abundance of food resources for fishes and other aquatic and wetland-dependent species.

Recommended FH for Wekiva River basin systems

The minimum FH recommended for the Wekiva River at SR 46 is composed of an elevation of 6.6 ft. NAVD 88, with a corresponding flooding duration of 30 continuous days, and a return interval of 2.0 years (i.e., 50 out of 100 years, on average; Table 14).

The minimum FH recommended for Wekiwa Springs is composed of an elevation of 12.1 ft. NAVD 88, with a corresponding flooding duration of 30 continuous days, and a return interval of 2.0 years.

The minimum FH recommended for Rock Springs is composed of an elevation of 25.0 ft. NAVD 88, with a corresponding flooding duration of 30 continuous days, and a return interval of 2.0 years.

The minimum FH recommended for the Little Wekiva River at SLB is composed of an elevation of 18.7 ft. NAVD 88, with a corresponding flooding duration of 30 continuous days, and a return interval of 2.0 years.

Table 13. Return intervals for 30-day flooding events for hardwood swamp communities at 14 Florida river system transects. The average plus standard error return interval was used for the Wekiva River at SR 46 and Wekiwa Springs FH.

Florida River System	Return Interval (yr)
St. Johns River at Lake Monroe	1.6
St. Johns River at Pine Island	1.6
St. Johns River at Emmanuel Bend (average of 2 transects)	2.0
Silver River (average of average of 4 transects)	1.8
Rainbow River (average of 3 transects)	2.7
Ocklawaha River (average of 3 transects)	1.3
Average	1.8
Average + SE	2.0

Table 14. Minimum Frequent High (FH) for Wekiva River basin systems, including recommended magnitudes (transferred to assessment gage), durations and return intervals. SR 46 = State Road 46; SLB = Springs Landing Blvd.

Wekiva River Basin System	Minimum Frequent High Components		
	Level* (ft NAVD 88)	Duration (days)	Return Interval (years)
Wekiva River at SR 46	6.6	30	2.0
Wekiwa Springs	12.1	30	2.0
Rock Springs	25.0	30	2.0
Little Wekiva River at SLB	18.7	30	2.0

*Level at assessment gage

Importance of FH for Wetland Structure and Function

A frequently occurring high water level is necessary to maintain the structure and function of wetlands contiguous with lakes (CH2M Hill 2005). Frequent short-duration flooding events redistribute plant seeds within aquatic habitats (Schneider and Sharitz, 1986) and influence species composition and structural development of plant communities (Huffman, 1980). Frequent flooding events support anaerobic soil conditions within wetlands, favoring hydrophytic vegetation and eliminating upland vegetation that invades during low water events (CH2M Hill, 2005).

The recommended FH level should allow sufficient water depths for fish and other aquatic organisms to feed, spawn, and seek refuge in the flooded habitats of the lake (Guillory 1979; Ross and Baker 1983) and should occur for a duration sufficient to complete critical portions of their life cycles. Inundation is also necessary for wetland processes involving exchange of particulate organic matter and nutrients within the floodplain (McArthur 1989). Dissolved and particulate organic matter and nutrients are assimilated by bacteria and fungi, which serve as food for invertebrate populations (Cuffney 1988) and ultimately for larger fauna. The frequency of recurrence of such flood events varies widely, but generally ranges from 1-5 years.

Habitat and food resources available to aquatic fauna (e.g., fishes, amphibians, reptiles, invertebrates) expand when lakes inundate higher elevation areas. Surface water connections between aquatic and wetland habitats are restored and previously isolated areas become available for feeding and spawning (Guillory 1979; Ross and Baker 1983). The amount of vegetative structure available to aquatic organisms increases; fish productivity increases correspondingly (Light et al. 1998; Kushlan 1990). The life cycles of many fishes are related to seasonal water level fluctuations, particularly the annual flood pattern (Hill and Cichra 2005; Guillory 1979). Floodplains and wetlands provide critical refugia for juvenile fishes of many species (Hill and Cichra 2005; Ross and Baker 1983; Finger and Stewart 1987).

A frequent flooding regime maintains important biogeochemical processes. Water quality improves as water filters through wetland vegetation and soils. Wetlands can transform or retain dissolved and suspended constituents (Wharton et al. 1982). The FH provides for flooding events that promote organic soil accrual, which balance losses of organic matter that may occur during droughts. Long durations of saturation create anaerobic and/or anoxic conditions that slow microbial activity and allow plant productivity to exceed decomposition (Sahrawat 2004; Reddy and DeLaune 2008). Frequent, short-term flooding creates alternating anaerobic and aerobic conditions, which maintains hydric soil functions such as denitrification (Reddy and DeLaune 2008).

Minimum Average (MA)

The goal of the recommended MA is to prevent excessive drying of deep organic soils on river floodplains, which could cause soil oxidation and subsidence and other adverse environmental impacts. The general indicator of protection is a low water level during typical years that, while exposing the surface of organic soils, keeps the average elevation saturated or inundated frequently enough to maintain natural structure and associated ecological functions. These events are usually associated with dry season conditions during periods of normal precipitation. For many systems the MA event recurs, on average, every year or two for approximately six months during the dry season. The purpose of the MA is to ensure groundwater withdrawals do not increase the number of these low water events beyond the recommended return interval of this event.

The specific indicator of protection is a low water level that is 0.3 foot below the average surface elevation of Histosols and histic epipedons (i.e., soils with organic layers ≥ 8 inches thick) within the floodplain.

MA Magnitude

The MA magnitude for each system equals the average elevation of thick (≥ 8 inches) organic soils measured at multiple transects (i.e., the same transects/system used in the FH; see above), minus 0.3 ft and transferred to the corresponding assessment gage. The MA is a low water threshold that is meant to protect and maintain the following ecological structure and function:

- Maintenance of soil organic matter, which protects swamp tree root integrity;
- Maintenance of intermittent ponding across lower elevations of the floodplain which favors wetland species adapted to very long hydroperiods (e.g. bald cypress); Intermittent ponds may also favor certain wildlife species adapted to long-term flooding or soil saturation;
- Sequestration of carbon and nutrients within floodplain soils, which may help mitigate nutrient pulses; and
- Promotion of nitrification and denitrification in aerobic and anaerobic soil zones across the floodplain, which removes nitrogen from the system and improves water quality.

The 0.3-foot offset from average elevation of deep organic soils is an adjustment that accounts for the zone of soil saturation above the water table known as the capillary fringe. The thickness of the capillary fringe depends on the type of soil material, distribution of roots, and varies temporally and thus cannot be precisely defined (Hillel 1998).

However, redox profiles have been used to estimate the thicknesses of saturated and anaerobic zones above the water table. Saturated soils are typically anaerobic and microbial breakdown of organic matter is very slow under these conditions. Low redox potentials (200 to -400 millivolts [mV]) are associated with reduced, anaerobic submerged soils; aerobic soils have redox potentials of about 300 to 800 mV (Ponnamperuma 1972). Reddy et al. (2006) measured redox potentials in situ in organic soils of the upper St. Johns River marsh, as well as in soil cores subjected to lowered water tables in the laboratory. These data can be used to infer capillary fringe thickness.

The capillary fringe estimate was 5 to 10 cm (0.2 to 0.3 ft) above the static water level. Deeper water table depths (e.g., -30cm [1 ft]) appeared to have even greater rises (+10 cm [0.3 ft]) in the capillary fringe (Reddy et al. 2006). This research indicates that a water level 0.3 feet below the surface elevation of organic soils is sufficient to produce anaerobic conditions in that surface layer and thereby prevent oxidation of soil carbon.

More recently, work by Osborne et al (2014) in the upper basin of the St. Johns River supports the use of an approximate 0.3 ft offset for soils saturation necessary to prevent oxidation and subsidence. Their work suggests a maximum drawdown from average organic soil of 0.28 ft, very similar to the standard MA offset of 0.3 ft.

After transferring to corresponding assessment gaging stations (Figure 41), elevations of average thick organic soils minus 0.3 ft were averaged yielding a single MA elevation for each system at each assessment location (Table 15).

<u>MA Duration</u>

The recommended MA 180-day duration is supported by soil dewatering characteristics described in the USDA - NRCS Official Soil Series Descriptions (NRCS 2018). Typical durations of dry season soil water table depths for the soils identified in the Wekiva River floodplain at the MFLs transects are listed in Table 16.

For Wekiva River mainstem floodplain transects (i.e., those used for the SR 46 and Wekiwa Springs MFLs) soil saturation and shallow ponding occurs at lower elevations within hardwood swamps when river levels are near the recommended MA levels. This condition typifies annual dry season conditions (magnitude and duration) in these depressional wetland communities, as described by the NRCS. Additionally, the soil water table depths and durations predicted to occur upslope in the transitional and hydric hammock communities when the Wekiva River equals the MA level are within reported dry season levels (NRCS 2018). The 180-day MA duration will allow for numerous, short duration, alternating anaerobic and aerobic (i.e., flooding and drying) events for organic and mineral soil surface elevations.

Field and laboratory experiments by Reddy et al. (2006) with organic soils in the Upper St Johns River Basin found that short duration dewatering events, alternating aerobic and anaerobic conditions, are less likely to result in oxidation of organic matter. The wicking action of the capillary fringe in these soils likely inhibits soil oxidation. Work by Osborne et al. (2014) suggests that this duration threshold may be around 7 to 8 days, beyond which harmful oxidation and subsidence may occur. This potentially critical drying duration is evaluated as part of a separate analysis; see below.

Table 15. Minimum average (MA) elevations at field transects and corresponding assessment gages for each Wekiva River basin system (Wekiva River at SR 46, Wekiwa Springs, Rock Springs and the Little Wekiva River at Springs Landing Blvd).

Level	Transect	Environmental Criterion	Field Transect Elevation (ft; NAVD 88)	Assessment Gage Elevation (ft; NAVD 88)
Wekiva River at SR 46				
MA	Maple Isl.	Average H/HE minus 0.3 ft	6.5	6.3
MA	Flats	Average H/HE minus 0.3 ft	6.5	6.6
MA	Average of Swamp T1, T2 and T3	Average H/HE minus 0.3 ft	10.7	6.5
			Average	**6.5**
Wekiwa Springs				
MA	Average of Swamp T1, T2 and T3	Average H/HE minus 0.3 ft	10.7	11.9
			Average	**11.9**
Rock Springs				
MA	Rock T1	Average H/HE minus 0.3 ft	17.4	25.1
MA	Rock T2	Average H/HE minus 0.3 ft	18.4	24.7
MA	Camp Joy	Average H/HE minus 0.3 ft	22.1	24.3
			Average	**24.7**
Little Wekiva River (LWR)				
MA	SLB South	Average H/HE minus 0.3 ft	17.9	17.9
MA	SLB North	Average H/HE minus 0.3 ft	17.4	17.6
MA	SLB T3	Average H/HE minus 0.3 ft	17.6	18.9
			Average	**18.1**

Table 16. Wekiva River floodplain typical soil water table depth durations (NRCS 2018)

Soil Series	Typical Soil Water table depth and duration
EauGallie	Water table within 6 to 18 inches of the surface for periods of 1 to 4 months and is within 40 inches for more than 6 months.
Okeelanta	Water is at depths of less than 10 inches below the surface or the soil is flooded 6 to 12 months during most years
Samsula	Water is at or above the soil surface except during extended dry periods*
Nittaw	Water is at or above the soils surface for 6-8 months
Gator	Water always at or above soil surface except during extended droughts*

*Duration not quantified

Wetland soils are a medium for denitrification which can promote improved aquatic/wetland water quality. The denitrification process is most effective in wetlands that are subject to alternating aerobic and anaerobic conditions because the aerobic conditions allow for conversion of ammonium to nitrate (nitrification), which is then subject to denitrification (Payne 1981; Reddy and DeLaune 2008) under anaerobic conditions. The benefits of alternating wet and dry events supports the use of a 180-day average event duration, rather than a continuous flooding or drying event.

<u>MA Return Interval</u>

MA non-exceedance events typically occur for long average durations with short return intervals and are usually described by the "typically saturated" hydroperiod category (Rule 40C-8.021(22), F.A.C.)

"…where for extended periods of the year the water level should saturate or inundate. This results in saturated substrates for periods of one-half year or more during non-flooding periods of typical years. Water levels causing inundation are expected to occur 50 to 60 percent of the time over a long term period of record. This water level is expected to have a recurrence interval, on the average, of one or two years over a long term period of record."

For many MFLs systems, a MA return interval of 1.7 to 1.8 years is typical. For Wekiva River basin systems, the MA return interval was based on hydroperiod data collected for other riverine hardwood swamp communities in Florida. The data used for this analysis were average dewatering probabilities for average elevations of deep organic soils minus 0.3 ft at ten transects in low gradient river floodplains in Florida (Table 17). Based on these data, a

Table 17. Return intervals for 30-day flooding events for hardwood swamp communities in 14 Florida river systems. The average minus standard error return interval was used for the Wekiva River at SR 46 and Wekiwa Springs MA.

Florida River System	Return Interval (yr)
St. Johns River at Lake Monroe	1.0
St. Johns River at Pine Island	2.1
St. Johns River at Emmanuel Bend (average of 2 transects)	2.2
Silver River	1.6
Rainbow River (average of 3 transects)	1.6
Average	1.7
Average - SE	1.4

MA return interval of 1.4 years (~71% probability) was selected for the Wekiva River basin systems and equals the average (minus standard error) return interval for these other Florida riverine swamps.

The recommended MA return interval (1.4 years) equals the average hydrologic signature for landward extent of histic epipedon estimated for 16 central Florida lakes (Richardson et al. 2009). Because this study found that *landward* histic epipedons were, on average, inundated/ saturated every 1.4 years, this suggests that the *average* elevation of deep organics (including deeper Histosols) are de-watered at a lower frequency (i.e., higher return interval). This supports using 1.4 years as a *minimum* de-watering (non-exceedance) return interval for average deep organics. Using this study as support for a deep organics metric also assumes that the processes leading to soil organic matter accrual (i.e., net primary production and decomposition suppression due to inundation/saturation) are fundamentally the same in river floodplains and at the lakes used in this study.

Recommended MA for Wekiva River basin systems

The minimum MA recommended for the Wekiva River at SR 46 is composed of an elevation of 6.5 ft. NAVD 88, with a corresponding average dewatering duration of 180 days, and a return interval of 1.4 years (i.e., 71 out of 100 years, on average; Table 18).

Table 18. Minimum Average (MA) for Wekiva River basin systems, including recommended magnitudes (transferred to assessment gage), durations and return intervals.

Wekiva River Basin System	Minimum Average Components		
	Level* (ft NAVD 88)	Duration (days)	Return Interval (years)
Wekiva River at SR 46	6.5	180	1.4
Wekiwa Springs	11.9	180	1.4
Rock Springs	24.7	180	1.4
Little Wekiva River at SLB	18.1	180	1.4

*Level at assessment gage

The minimum MA recommended for Wekiwa Springs is composed of an elevation of 11.9 ft. NAVD 88, with a corresponding average dewatering duration of 180 days, and a return interval of 1.4 years.

The minimum MA recommended for the Rock Springs is composed of an elevation of 24.7 ft. NAVD 88, with a corresponding average dewatering duration of 180 days, and a return interval of 1.4 years.

The minimum MA recommended for the Little Wekiva River at SLB is composed of an elevation of 18.1 ft. NAVD 88, with a corresponding average dewatering duration of 180 days, and a return interval of 1.4 years.

<u>Importance of MA for Soils and Wetland Plant Communities</u>

Organic soils are important to wetland biogeochemical cycles, particularly as sinks for carbon (Mitsch et al. 2015; Reddy and DeLaune 2008). Frequent anaerobic conditions impede microbial activity and primary production exceeds decomposition. Organic soils gradually accrue as a result. The recommended MA maintains organic soil structure and function by ensuring that dewatering events do not occur often enough to cause organic soils to oxidize and subside. By preventing permanent loss of deep organic soils, the MA provides conditions that support retention of soil carbon and nutrients and provides for the filtration of metals and toxins.

Wetland soils are a medium for denitrification, a process important in maintaining aquatic/wetland water quality. The periodic, short duration alternating aerobic/anaerobic conditions will ensure effective nitrification (the conversion of ammonium to nitrate), which is then subject to denitrification, while the combination of inundation and dewatering will maintain the composition and productivity of wetlands and associated biota adapted to long-term saturation (Payne 1981; Reddy and DeLaune 2008).

Soil organic matter in wetlands provides long-term nutrient storage and is a source of mineralizable nutrients for plant growth. Slow release of nutrients occurs at a level sufficient to sustain plant growth within native plant communities. Organic soils also sustain productivity within the larger system by releasing dissolved organic material, which supports downstream (or within system) aquatic life (Mitsch and Gosselink 2015).

Additional metrics to protect organic soil and floodplain inundation

The SJRWMD's procedure for selecting potential MFLs criteria typically starts with an evaluation of our standard event-based metrics. These metrics (e.g., the FH and MA described above) are preferred, when possible and appropriate because they have been vetted through numerous peer reviews and are backed by scientific literature and field data collected at water bodies with similar characteristics. This is the reason that the FH and MA were initially evaluated for all four primary Wekiva River basin systems.

However, both conventional event-based metrics yielded allowable flow reductions for Rock Spring/Run that are much greater than those typically found to be protective for springs, rivers or lakes. The draft FH and MA evaluated for this OFS yielded a freeboard that would allow a greater than 50% increase to the current-pumping condition impact (*see MFLs Assessment below for details*). This equates to an allowable reduction in long-term mean flow of greater than 25%.

A greater than 25% reduction in long-term mean flow would be outside the range and significantly greater than the mean allowable change for adopted springs/spring-fed river MFLs (allowable flow reduction range = 2.5% to 19%; mean = 8.4%) and for OFW/OFSs (allowable flow reduction range = 2.5% to 15%; mean = 7.2%). As such it was deemed prudent to investigate alternative metrics to protect both seasonally flooded wetland inundation and the maintenance of deep organic soils. This was the purpose for evaluating the two metrics described below.

In addition to Rock Springs / Run, preliminary evaluation of event-based metrics were deemed inappropriate for a second system, the Little Wekiva River at SLB. However, this conclusion was for a different reason. At the LWR at SLB, both the FH and MA were not met under the pre-withdrawal (i.e., no-pumping) condition. Therefore, both event-based metrics are not appropriate for this system.

The development and evaluation of new metrics, when standard metrics are found to be inappropriate, is not new for the SJRWMD MFLs program. Examples of this approach include the recently adopted MFLs for Lakes Brooklyn and Geneva in Clay and Bradford counties and Lake Butler in Volusia county. For all three of these sandhill lakes, the SJRWMD's standard event-based metrics were found to be inappropriate for setting protective MFLs; event-based metrics resulted in an allowable impact that was significantly greater than for typical lake MFLs. Further, event-based metrics did not protect all of relevant environmental values identified for these lakes. New criteria were necessary to ensure that important ecological and human-use functions and values were protected.

At both Rock Springs/Run and LWR at SLB, there is uncertainty regarding whether the SJRWMD's standard event-based metrics can provide protection for important ecological structure and function. Therefore, other metrics were evaluated to measure the effects of water withdrawal on these values. These metrics are described below.

Organic Soils – Protection from Harmful Drying

An organic soil drying event metric was developed to ensure that deep wetland soils are protected at sites where the standard MA is not appropriate for use or does not provide protection from excessive water withdrawal. This metric is supported by a recent University of Florida (UF) study on the relationship between organic soil stability and hydrology in the Upper St. Johns River Basin (Osborne et al. 2014). This study, by researchers in UF's Soil and Water Science Department, investigated the effect of water table drawdown on gaseous carbon emissions, which can lead to soil loss through oxidation and subsidence.

In general, higher water-tables reduce CO_2 emission (Komulainen et al. 1999) and subsidence (Wosten et al. 1997) in organic soils. Soil CO_2 flux is an indicator of soil oxidative processes and potentially soil subsidence (Reddy et al. 2006). Through in-situ (field-based) measurements and laboratory experiments Osborne et al. (2014) and Reddy et al. (2006) determined that water level drawdown below the soil surface leads to dramatic increases in carbon emissions. Carbon dioxide flux observations, related to varying hydrology, indicates that in order to maintain quality, depth, and elevation of organic soils (i.e., prevent oxidation and/or subsidence), long-term minimum water table levels should be no more than 0.28 ft (rounded to 0.3 ft for this analysis) below the average soil surface over the long-term (Figure 42; Osborne et al. 2014; Reddy et al. 2006).

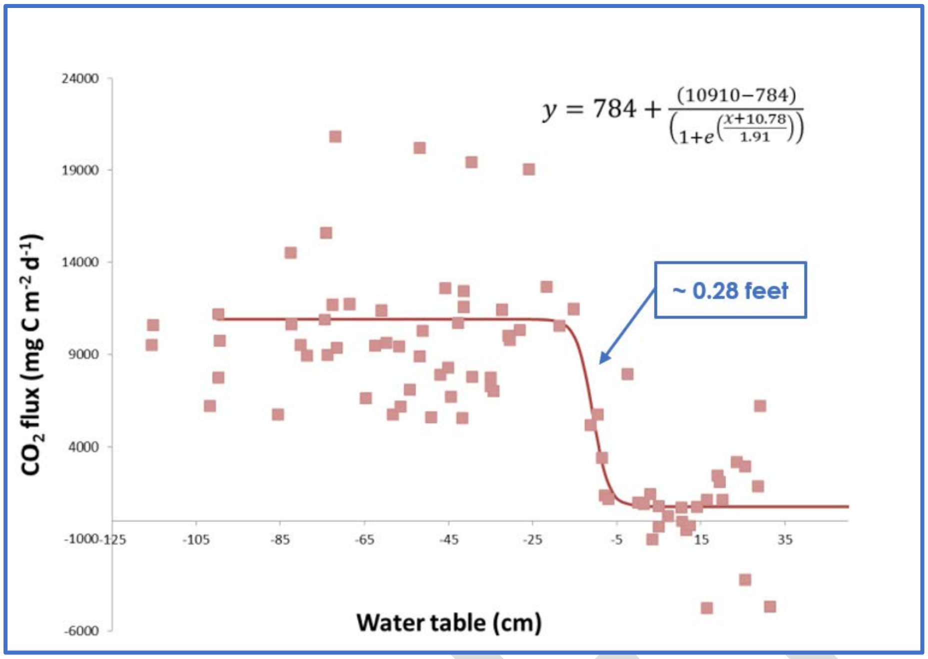

Figure 42. Relationship between carbon dioxide flux and long-term water table (distance of water from surface); modified from Osborne et al., 2014

In addition to supporting the SJRWMD's standard 0.3 ft offset when setting a protective elevation to maintain organic soils, the UF study also indicates that there is a lag of approximately 8 days after which "physical soil elevation change" (i.e., oxidation and subsidence) may adversely affect organic soils (Osborne et al. 2014). Based on this research and personal communications with the lead scientist of this study, the following metric was developed as an alternative (to the standard MA) way to evaluate the effect of pumping on deep organic soils.

Organic Soil Drying Event:

- Critical elevation: average deep organic soils (Histosol / histic Epipedon) minus 0.3 ft;
- Non-exceedance duration: ≥ 8 days (drier than critical elevation for 8 or more days)

Impact Threshold:

- Allow no more than a 15% increase in the total duration of drying events, relative to a no-pumping condition.

Organic soil drying events are assessed based on total duration rather than an increase in number of drying events. This is because, relative to no-pumping condition, water withdrawal can increase the total duration of drying events, and thus increase the cumulative impact (i.e., oxidation and subsidence of soils), while simultaneously *decreasing* the number of discrete drying events. An impact threshold of 15% (relative to a reference condition) has been used by Florida water management districts as a significant harm standard for numerous adopted MFLs throughout the state (Munson and Delfino 2007). It is deemed reasonable given the lack of statutory guidance and lack of threshold response in this metric, caused by flow decline.

<u>Little Wekiva River at SLB</u>

Preliminary modeling results indicated that the recommended MA for the Little Wekiva River at SLB may not be an appropriate metric for protecting deep organic soils because it could not be met under the no-pumping condition (and therefore could not be used as a metric to assess pumping impact). Therefore, the new organic soils drying event metric was evaluated for the Little Wekiva River to ensure that deep organic soils are protected at this site. The critical elevation for this metric is 18.1 ft (NAVD 88) and equals the average elevation of thick (≥ 8 inches) organic soils minus 0.3 ft, transferred from three field transects to the assessment gage at Springs Landing Blvd (Figure 41).

Under the no-pumping condition, the critical soils elevation at the Little Wekiva River experienced 436 drying events (≥ 8 days; Table 19). The length of harmful drying events under the no-pumping condition varied from 8 days to 268 days, with the distribution of events skewed towards low duration events and the average duration of events equaling approximately 37 days (Figure 43). The total duration of drying events under the no-pumping condition equals 16,152 days. The minimum condition (i.e., MFLs-condition) for this metric is equal to a 15% increase in the total duration of drying events under the no-pumping condition; this equals an allowable increase of 2,423 days, for a total duration of 18,575 days (see *MFLs Assessment* section below for assessment of this metric).

Table 19. Little Wekiva River drying event summary under the no-pumping condition.

	NP Condition
Number of organic soil drying events (≥ 8 days)	436
Average (±SE) length of organic soil drying events (≥ 8 days; days)	37.1 (±1.9)
Total duration of organic soil drying events (days)	16,152

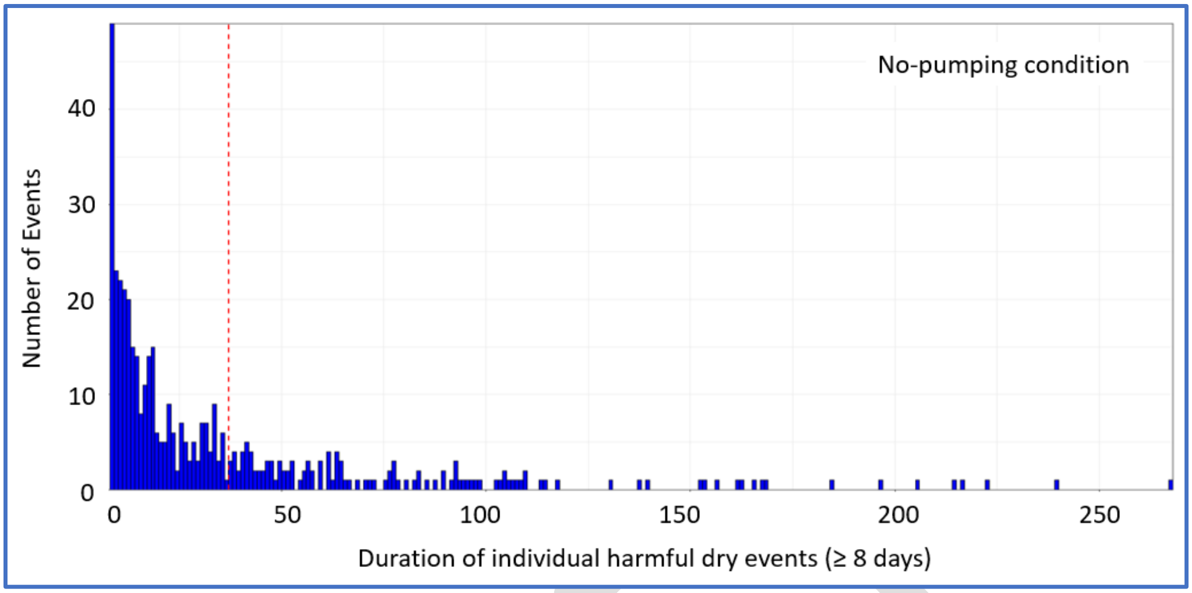

Figure 43. Distribution showing number of harmful drying events, of varying duration, under the no-pumping condition; the red dashed line represents the average duration of harmful drying events.

Rock Springs / Rock Springs Run

As with the Little Wekiva River, preliminary modeling indicated that setting a MA for Rock Springs / Rock Springs Run may not protect organic soils at this site, although for a different reason than at the Little Wekiva River. In the floodplain of Rock Springs Run, the average elevation of organic soils, minus a 0.3 ft offset, equals 24.7 ft (NAVD 88) at the Kelly Park gage. The average elevation of organic soils has a much lower exceedance (i.e., based on simulated historical water levels) than is typical. For riverine systems and many lakes, the average elevation of deep organic soils typically falls between the 40th and 60th percentile. All no-pumping and current-pumping condition water levels for the entire simulated POR are above this critical soils elevation (i.e., exceedance equals 100%). Further, this critical elevation at Rock Springs / Rock Springs Run is insensitive to water withdrawal.

Current-pumping condition average flow for Rock Springs is 16.6% lower than no-pumping condition flow, and because of the insensitivity of the MA at Rock Springs, this metric would allow a greater than 50% increase in current pumping impact (i.e., > 50% reduction in water levels relative to CP). Part of the reason for the insensitivity of the standard MA, may be that organic soils at Rock Springs / Rock Springs Run are a function of a hydroperiod that is different from the conventional metric (i.e., 180-day average non-exceedance; 1 – 2 year return interval), but this is not known.

For these reasons, the organic soil drying event metric was evaluated for Rock Springs Run to ensure that deep organic soils are protected at this site. The critical elevation for this metric is the same as for the MA and equals the average elevation of thick (≥ 8 inches) organic soils minus 0.3 ft, transferred from three field transects to the assessment gage at

Kelly Park (Figure 41). The critical elevation for Rock Springs Run equals 24.7 ft (NAVD 88).

In addition to the MA not providing protection for Rock Springs deep organic soils, the new drying event metric is also not useful as an MFLs metric. Under the no-pumping condition, there were zero drying events relative to the critical soils elevation for Rock Springs Run (Table 20). Because of this, it is not possible to calculate a 15% increase in the number of no-pumping drying events. However, there were only four drying events under the current-pumping condition. The small change relative to the NP-condition (from 0 to 4 events) over the 71-year POR, is not considered to cause significant harm.

Table 20. Rock Springs / Rock Springs Run drying event summary under the no-pumping condition.

Rock Springs / Rock Springs Run	NP Condition
Number of organic soil drying events (≥ 8 days)	0
Average (±SE) length of organic soil drying events (≥ 8 days; days)	0
Total duration of organic soil drying events (days)	0

Floodplain Inundation Protection

The Wekiva River floodplain harbors thousands of acres of hardwood swamps, bottomland forest, hydric hammocks and other ecosystems, support myriad fish and wildlife species. The event-based FH is meant to protect these critical environments. However, similar to the MA, the conventional FH may not be an appropriate metric for all water bodies.

In the case of the Little Wekiva River, detailed information regarding the relationship between flooding frequency and wetland hydrology is minimal. Preliminary modeling suggests that the standard 30-day duration (used in the FH) is extremely insensitive to change due to water withdrawal (i.e., excessive groundwater level and flow decline can occur before this metric is tripped; see *MFLs Assessment*). In addition, an alternative 5-day FH was also determined to be insensitive to pumping. This may be because the average hardwood swamp elevation at the Little Wekiva River is relatively high on the exceedance curve, relative to lower gradient sites, and may be augmented by seepage and ponding; this is not known.

Preliminary analysis suggests that the FH is also insensitive to water withdrawal at Rock Springs /Rock Springs Run. However, instead of swamp communities located high on the landscape (as at the Little Wekiva River), at Rock Springs Run the average swamp elevation is located low on the flood exceedance curve.

The conventional FH is not an appropriate metric for protecting hardwood swamp communities at the Little Wekiva River or Rock Springs Run because it is insensitive to water withdrawal. However, ensuring that floodplains are inundated periodically is nonetheless important. Floodplains require protection from excessive water withdrawal due to the numerous ecosystem benefits they provide. The importance of floodplain inundation to the long-term maintenance of a river's physical structure, biogeochemistry and ecological integrity is widely recognized (Junk et al. 1989; Poff et al. 1997; Lytle and Poff 2004; Tockner et al. 2008; Arthington 2012).

Floodplain inundation increases nutrient removal and transformation, which is especially important within the Wekiva River basin. Flood stage and flows increase the area, diversity and complexity of aquatic habitat by connecting the main channel to temporarily isolated areas (floodplains, sloughs, backwater pools, minor channels, etc). Flow and stage dynamics also create a diverse mosaic of habitat patches of varying depth, inundation and vegetation successional stage. This expansion of habitat provides important nursery areas for fish and abundant forage habitat for invertebrates, fish, amphibians, reptiles and birds.

Regular flooding increases floodplain fertility, and the abundance of food resources for fishes and other aquatic and wetland-dependent species. Forage for invertebrates and vertebrates may increase to the point where it is not limiting to species abundance or individual growth (Junk et al. 1989). Some research suggests that flood flows may remove exotic fish species while also improving spawning habitat conditions for natives (Marchetti and Moyle 2001).

For low-gradient floodplain river systems like the Wekiva River basin, continued connectivity between the channel and floodplain is critical to their diversity, production and long-term ecological integrity (Junk et al. 1989; Arthington 2012). Riparian vegetative communities are also structured by flood flows that scour floodplain soils, remove competitors, and saturate soils (Bunn and Arthington 2002).

Because of the insensitivity of the FH at the Little Wekiva River and Rock Springs Run (see *MFLs Assessment*), and in an effort to ensure that the floodplain values described above are protected, an alternative metric was developed to assess the effects of pumping on these critical floodplain ecosystems at these two water bodies.

This floodplain exceedance metric is based on preventing excessive alteration of flooding dynamics of swamp ecosystems relative to a pre-withdrawal (no-pumping) condition. Basing allowable change on percent change from a no-pumping condition is a simpler criterion than the minimum FH but is nonetheless necessary to provide protection of swamp communities in cases where a representative or protective duration and return interval are not known and in cases where conventional FH parameters are deemed not protective (i.e., would allow excessive water withdrawal).

Floodplain exceedance metric:

- Critical elevation: average hardwood swamp elevation at the assessment gage.

Impact Threshold:

- Allow no more than a 15% reduction in exceedance of the average hardwood swamp elevation, relative to a no-pumping condition.

This metric was evaluated for the Little Wekiva River and Rock Springs Run because the FH was insensitive and did not provide protection for hardwood swamp communities or the various ecological functions afforded by floodplain inundation at these sites.

The NP-condition exceedance for the Little Wekiva River is relatively low, due to swamp communities being located higher in the landscape (Table 21). The opposite is true for Rock Springs Run. In contrast, many riverine MFLs sites have hardwood swamps that are typically associated with exceedances from 40 to 60%.

Table 21. Hardwood swamp average elevation, NP condition exceedance and MFLs condition (NP-15%) exceedance for the Little Wekiva River and Rock Springs / Rock Springs Run.

System	Average Hardwood Swamp Elevation (ft; NAVD 88)	NP Condition Exceedance (%)	MFLs Condition Exceedance (%)
Little Wekiva River	18.7	9.5	8.1
Rock Springs / Rock Springs Run	25.0	98.7	83.9

System for Environmental Flow Analysis (SEFA)

The event-based metrics, harmful drying metric and floodplain inundation metric discussed above were developed to protect ecological structure and function provided by healthy floodplain ecosystems. For systems where these metrics are insensitive to water withdrawal, or where standard minimum hydroperiods for these metrics are not appropriate, other criteria are required to ensure that all relevant environmental values are protected from significant harm due to pumping.

Further, other criteria are necessary to ensure that *in-channel* functions and values are protected, in addition to those protecting the floodplain. Also, metrics that evaluate the effects of water withdrawal on *human-use* values are critical, in addition to those focused solely on ecological metrics (See *WRVs Assessment* for details).

The System for Environmental Flow Analysis (SEFA) was employed to evaluate in-channel habitat suitability for numerous fish species, life stages and functional groups found in the

Wekiva River basin (Aquatic Habitat Analysts, Inc. 2012; Milhous and Waddle 2001; Jowett et al. 2014). SEFA is a Windows-based computer software system that was developed as a tool for use in studies that utilize the Instream Flow Incremental Methodology (IFIM).

SEFA allows the use of HEC-RAS model output to calculate a habitat suitability index (“area-weighted suitability”; AWS) for fish (or other taxa) within the existing model domain. AWS is a weighted *index* of habitat suitability, not an area. Expressed in ft^2/ft, AWS is calculated by multiplying a suitability index (combining depth, velocity and in many cases substrate) at each point in a cross section by the proportion of the reach area represented by that point; this is then summed over the modeled reach.

SEFA relies on HEC-RAS cross sectional estimates of both the area of inundated channel at a particular HEC-RAS cross section as well as velocities at specific channel locations across the main channel. Using these data, SEFA derives a single index value for each date in a timeseries that describes relative habitat suitability throughout the model domain. This method was used to relate flows, at a specific assessment gage, to specific cross sections. At each cross-section a timeseries of AWS was calculated. Substrate index codes were not used for these calculations because of the generally uniform sediment composition (silty sand) present throughout the study area, as described by Hood et al. (2011).

The HEC-RAS model was used to estimate water depths and velocities as a function of river flow at each of the transects considered (see Appendix E for details). Each river flow timeseries (e.g., no-pumping condition for a specific system) was input into SEFA and AWS was calculated for each day in that time series. AWS was estimated for:

- Three areas on the mainstem of the Wekiva River: 1) upstream of SR 46 to the Railroad Bridge cross-section; 2) from the Railroad cross-section to the confluence of the Little Wekiva River; and 3) downstream of SR 46 to approximately river mile 2.5 (Figure 44);
- Wekiwa Spring Run from the Wekiwa Springs gage to approximately river mile 14.5;
- Rock Springs Run from the Kelly Park gage to the confluence with the Wekiva River;
- The Little Wekiva River from SR434 to the confluence with the Wekiva River.

Habitat suitability curves (HSCs) for 32 fish species, life stages and functional groups were evaluated using the SEFA habitat model (Table 22). These curves reflect the relative habitat suitability for fish taxa that are commonly found in peninsular Florida. The fish guilds used are generally based on either similar feeding habits (e.g., predation, herbivory, and filtering) or taxonomic relatedness. HSCs for American shad (*Alosa sapidissima*) were based on Dutterer et al. (2011). HSCs for the imperiled bluenose shiner (*Pteronotropis welaka*) were based on the Delphi Technique (i.e., based on questionnaires and professional round-table discussions) and provided by Eric Nagid of the Florida Fish and Wildlife Conservation Commission [FWC]. Each taxon, group of taxa or lifestage has a suitability profile for both

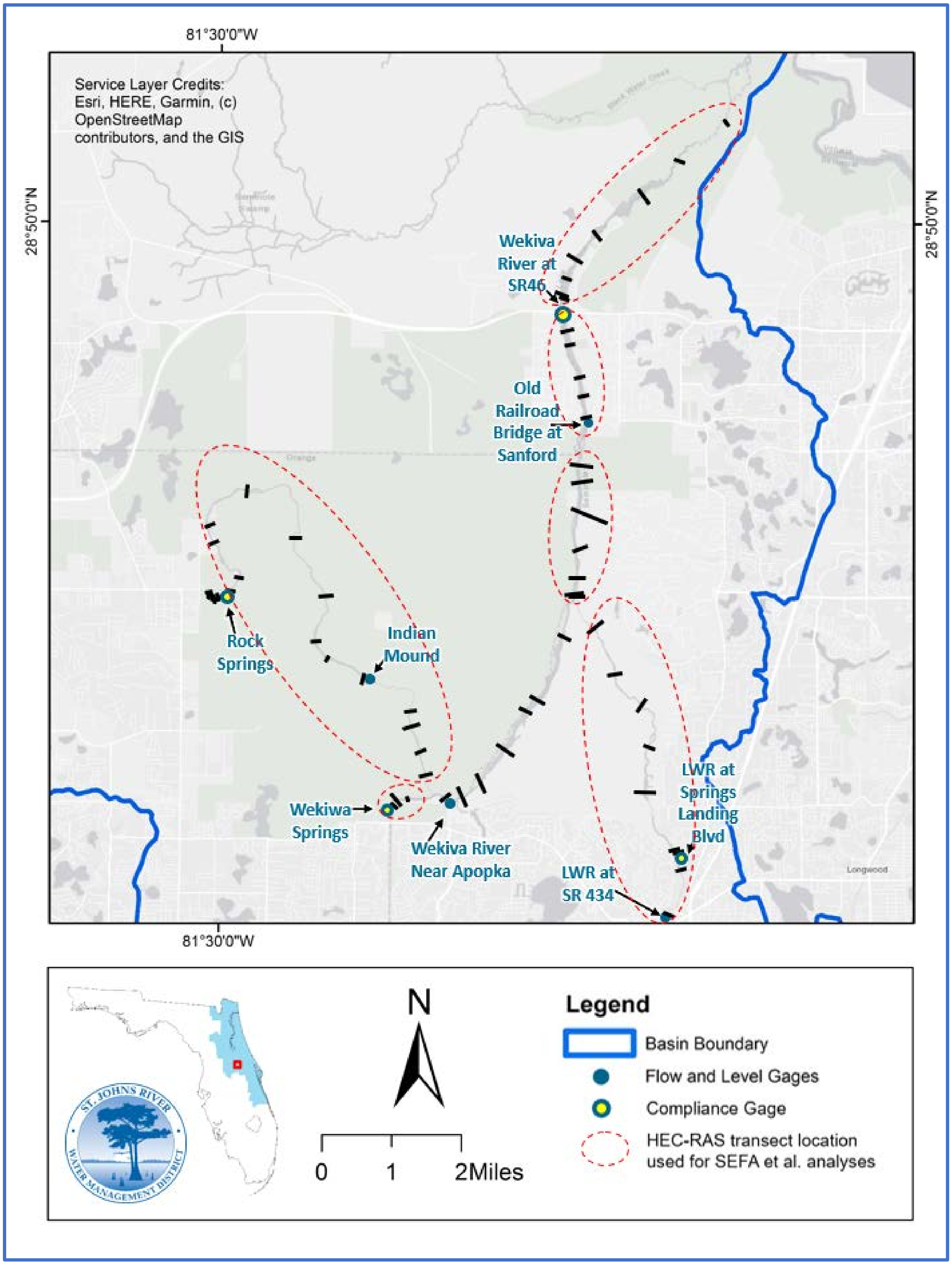

Figure 44. HEC-RAS transect locations within the Wekiva River basin; transects used for SEFA, critical velocities, and other analyses.

Table 22. Fish species, functional groups and life stages evaluated using SEFA.

Common Name	Scientific Name	Life Stage	Common Name	Scientific Name	Life Stage
American Shad	*Alosa sapidissima*	Adult	Generic darter	Percidae	Adult
Bluegill	*Lepomis macrochirus*	Adult	Largemouth Bass	*Micropterus salmoides*	Adult
		Juvenile			Juvenile
		Fry			Fry
		Spawning			Spawning
Bluenose shiner	*Pteronotropis welaka*	Adult	Minnows / Shiners	Cyprinidae	Adult
Channel Catfish	*Ictalurus punctatus*	Adult	Redbreast Sunfish	*Lepomis auritus*	Adult
		Juvenile			Juvenile
		Fry			Fry
		Spawning			Spawning
		Spring	Spotted Sunfish	*Lepomis punctatus*	Adult
		Summer			Juvenile
		Fall			Fry
Blackbanded Darter	*Percina nigrofasciata*	Adult			Spawning
Habitat Guilds					
Deep and slow habitats			Shallow and fast habitats		
Deep and fast habitats			Shallow and slow habitats		

velocity and depth, as depicted in Figure 45 for the spotted sunfish (*Lepomis punctatus*) adults and juveniles.

Habitat suitability metric:

- Average AWS for a given fish species, functional group or life stage, over the POR under the no-pumping condition.

Impact Threshold:

- Allow no more than a 15% decrease in average AWS, relative to the no-pumping condition.

A reduction of 15% from a pre-withdrawal condition has been used by other water management districts as a significant harm threshold for MFLs (Munson and Delfino 2007). This threshold has been peer reviewed and has been the basis for numerous adopted MFLs (e.g., SWFWMD MFLs for Crystal River, Gum Slough, Chassahowitzka River, and Homosassa River, among others). This threshold is within the range (10 to 33%) of percent allowable change documented in other studies (Munson and Delfino 2007). Using a 15% reduction of habitat availability as a threshold for significant harm is deemed acceptable for cases where, as noted by Shaw et al. (2005), *"… changes in available habitat due…occur along a continuum with few inflections or breakpoints where the response dramatically shifts."*, and therefore *"…loss or reduction in a given metric occurs incrementally."*

Further, we agree with Shaw et al. (2005) that *"…in the absence of any clear statutory guidance…the use of a 15 percent for loss of habitat is reasonable and prudent."*

No-pumping condition AWS and MFLs condition (15% reduction in NP condition) AWS for each Wekiva River basin system were calculated for only those species, functional groups or life stages with AWS that increases with increasing flow (Figure 46; Table 23). Taxa whose AWS decreases with increasing flow do not serve the purposes of an MFLs determination (Figure 47). Also, those taxa with minimal NP condition habitat were not evaluated further.

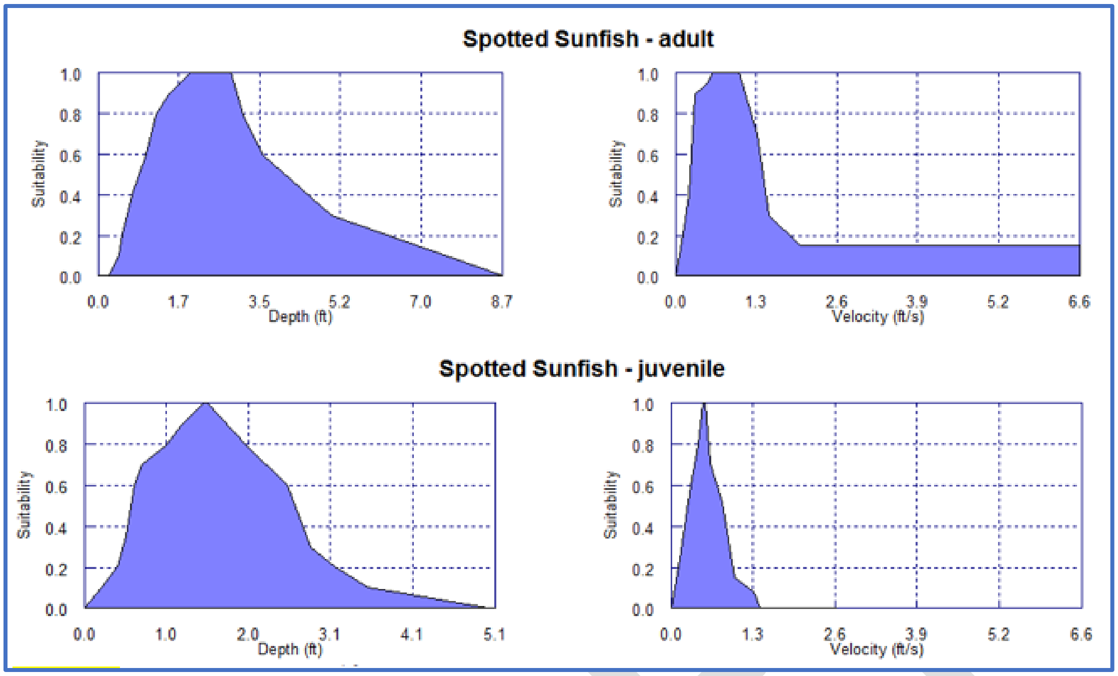

Figure 45. Example HSI (habitat suitability index) curves; Top: spotted sunfish adults; Bottom: spotted sunfish juveniles. Both depict habitat suitability as a function of depth (left) and velocity (right).

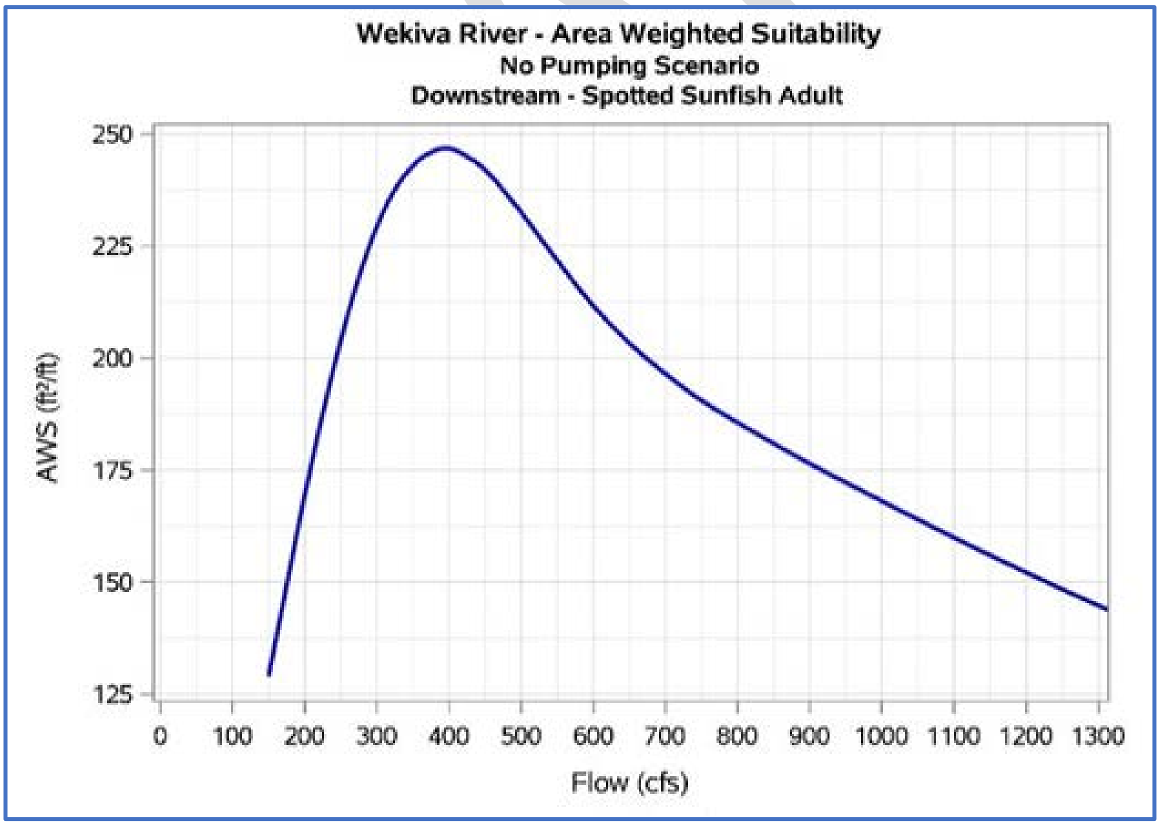

Figure 46. Example of species with AWS positively related to flow.

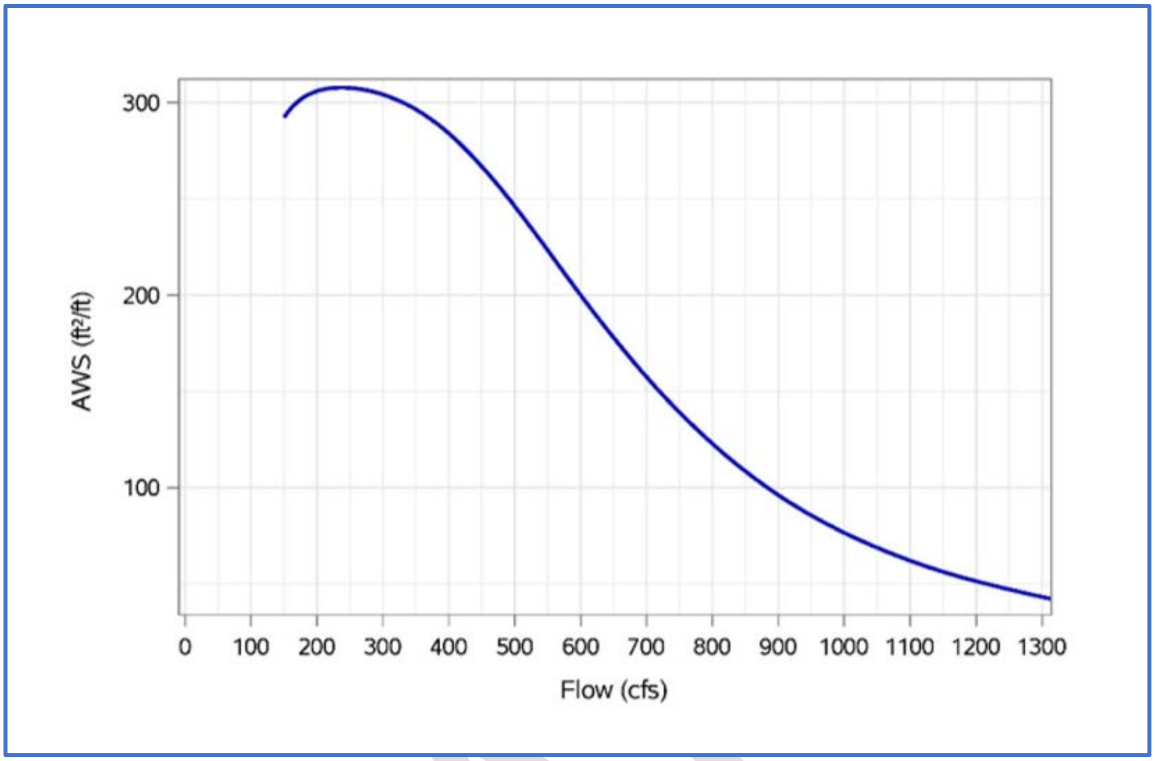

Figure 47. Example of species/life stage whose AWS decreases with increasing flow

The NP and MFLs condition results for the four Wekiva Basin systems assessed are provided in Table 23. The comparison of MFLs condition to current-pumping condition AWS is provided in the MFLs Assessment below.

Table 23. NP condition and MFLs threshold (NP-15%) AWS (ft^2/ft) for select taxa/life stages and habitat guilds, for six locations in the Wekiva River basin.

River Reach	Taxon / Life Stage / Guild	NP Condition Average AWS	NP Condition minus 15% AWS
Wekiva River Mainstem Downstream from SR 46 to RM 2.5	Largemouth Bass Adult	136.9	116.4
	Channel Catfish Fry	147.5	125.4
	Generic Darters adult	136.5	116.0
	Habitat Guilds Deep Slow	147.0	125.0
	Redbreast Sunfish Adult	147.0	125.0
	American Shad	119.5	101.6
	Bluenose Shiner	142.4	121.0
	Redbreast Sunfish Juvenile	162.9	138.5

River Reach	Taxon / Life Stage / Guild	NP Condition Average AWS	NP Condition minus 15% AWS
	Largemouth Bass Juvenile	114.8	97.6
Wekiva River Mainstem Upstream from SR 46 to Railroad	Redbreast Sunfish Fry	99.3	84.4
	Habitat Guilds Deep Fast	164.5	139.8
	Largemouth Bass Adult	196.0	166.6
	Channel Catfish Juvenile Spring	141.6	120.4
	Channel Catfish Fry	293.0	249.1
	Generic Darters adult	270.3	229.8
	Spotted Sunfish Spawning	152.4	129.5
	Habitat Guilds Deep Slow	287.6	244.5
	Redbreast Sunfish Adult	287.6	244.5
	American Shad	245.8	208.9
	Spotted Sunfish Juvenile	205.3	174.5
	Largemouth Bass Juvenile	298.5	253.7
	Channel Catfish Juvenile	138.4	117.6
Wekiva River Mainstem Upstream from SR 46 to Railroad, continued	Channel Catfish Juvenile Summer	154.9	131.7
	Spotted Sunfish Adult	296.8	252.3
	Spotted Sunfish Fry	114.5	97.3
	Redbreast Sunfish Juvenile	342.8	291.4
	Blackbanded Darter Adult	276.8	235.3
Wekiva River Mainstem Upstream from Railroad to Little Wekiva River	Channel Catfish Fry	142.8	121.4
	Generic Darters adult	127.1	108.0
	American Shad	118.3	100.6
	Blackbanded Darter Adult	102.6	87.2
	Habitat Guilds Deep Slow	150.4	127.8
	Redbreast Sunfish Adult	150.4	127.8
	Spotted Sunfish Adult	101.4	86.2

River Reach	Taxon / Life Stage / Guild	NP Condition Average AWS	NP Condition minus 15% AWS
	Redbreast Sunfish Juvenile	169.9	144.4
	Largemouth Bass Adult	154.5	131.3
	Redbreast Sunfish Spawning	96.9	82.4
Little Wekiva River from Wekiva River Upstream to SR434	Habitat Guilds Deep Fast	14.8	12.6
	American Shad	22.1	18.8
	Habitat Guilds Deep Slow	17.6	15.0
	Redbreast Sunfish Adult	17.6	15.0
	Bluenose Shiner	15.0	12.8
	Channel Catfish Fry	17.7	15.0
	Spotted Sunfish Adult	16.6	14.1
	Generic Darters adult	16.3	13.9
Wekiwa Springs Run from Gage to RM 14.5	Channel Catfish Spawning	89.2	75.8
	Largemouth Bass Adult	135.8	115.4
	Habitat Guilds Deep Slow	135.5	115.2
	Redbreast Sunfish Adult	135.5	115.2
Wekiwa Springs Run from Gage to RM 14.5, continued	Redbreast Sunfish Juvenile	172.4	146.5
	Largemouth Bass Spawning	137.7	117.0
	Bluenose Shiner	134.0	113.9
	Redbreast Sunfish Fry	88.1	74.9
Rock Springs Run from Gage to Wekiva River	Habitat Guilds Deep Fast	30.6	26.0
	Largemouth Bass Adult	26.5	22.5
	Channel Catfish Juvenile Spring	20.9	17.8
	American Shad	41.9	35.6
	Habitat Guilds Deep Slow	43.7	37.1
	Redbreast Sunfish Adult	43.7	37.1
	Channel Catfish Fry	46.6	39.6

River Reach	Taxon / Life Stage / Guild	NP Condition Average AWS	NP Condition minus 15% AWS
	Channel Catfish Juvenile Summer	25.6	21.8
	Generic Darters adult	43.0	36.6
	Spotted Sunfish Adult	41.9	35.6
	Blackbanded Darter Adult	42.7	36.3
	Redbreast Sunfish Juvenile	53.8	45.7
	Bluenose Shiner	39.2	33.3
	Largemouth Bass Spawning	18.9	16.1
	Redbreast Sunfish Spawning	33.7	28.6
	Channel Catfish Juvenile Fall	17.9	15.2
	Spotted Sunfish Spawning	21.9	18.6
	Largemouth Bass Juvenile	35.8	30.4
	Channel Catfish Juvenile	20.9	17.8
	Bluegill Spawning	34.3	29.2
	Spotted Sunfish Juvenile	30.3	25.8

MFLs Determination Summary

The MFLs Determination for Wekiva River basin systems involved evaluation of five primary criteria developed to provide protection for both in-channel and floodplain ecological functions and values; these include:

- Two conventional event-based metrics used for numerous SJRWMD MFLs, including a minimum flooding event (FH) and minimum drying event (MA);
- An event metric that was developed to minimize the number of days associated with harmful (≥ 8 days) drying of organic soils for sites where the MA is insensitive;
- An exceedance metric used to protect functions associated with floodplain inundation for sites where the FH is insensitive; and
- An index to evaluate in-channel fish habitat suitability using SEFA.

The standard event-based approach is preferred when possible and appropriate. These metrics have been vetted through numerous peer reviews and are backed by scientific literature and field data (i.e., for SWIDS analysis). This is the reason that the FH and MA were developed for all four primary Wekiva River basin systems.

However, there are systems for which the conventional metrics do not provide protection or are not usable because they cannot be met under a pre-withdrawal (i.e., no-pumping) condition (e.g., the MA for the Little Wekiva River; see above for details). In these cases, where important environmental values will not be protected through reliance on standard event-based metrics, other ways are needed to measure the effects of water withdrawal on those values.

Therefore, new metrics were developed to prevent excessive drying of deep organic soils and to protect floodplain inundation, and the various functions and values this provides. In addition, an in-channel fish habitat analysis (SEFA) was performed to ensure environmental values, beyond those afforded by healthy floodplains, were considered. Evaluation of a suite of other metrics, including critical velocities, depths and human-use (recreational) metrics was also conducted as part of the WRVs Assessment (see Appendix E).

Environmental criteria, no-pumping condition values and MFLs condition values (i.e., minimum condition) for each criterion are summarized in Table 24. Note that not all metrics were assessed for each water body.

Table 24. Summary of environmental criteria for Wekiva River at SR 46, Wekiwa Springs, Rock Springs and the Little Wekiva River, Lake, Orange and Seminole counties, Florida; SR 46 = Florida State Road 46; SLB = Springs Landing Blvd; NP = no-pumping condition and MFLs = minimum condition values are provided; Dur. = Duration (days); RI = return interval (years); NA = not assessed.

<table>
<tr><th>Metric</th><th colspan="6">Wekiva R. at SR 46</th><th colspan="6">Wekiwa Springs</th><th colspan="6">Rock Springs</th><th colspan="6">L. Wekiva River at SLB</th></tr>
<tr><td></td><td colspan="2">Level (ft)</td><td colspan="2">Dur. (d)</td><td colspan="2">RI (yr)</td><td colspan="2">Level (ft)</td><td colspan="2">Dur. (d)</td><td colspan="2">RI (yr)</td><td colspan="2">Level (ft)</td><td colspan="2">Dur. (d)</td><td colspan="2">RI (yr)</td><td colspan="2">Level (ft)</td><td colspan="2">Dur. (d)</td><td colspan="2">RI (yr)</td></tr>
<tr><td>Minimum Frequent High (FH)</td><td colspan="2">6.6</td><td colspan="2">30</td><td colspan="2">2.0</td><td colspan="2">12.1</td><td colspan="2">30</td><td colspan="2">2.0</td><td colspan="2">25.0</td><td colspan="2">30</td><td colspan="2">2.0</td><td colspan="2">17.8</td><td colspan="2">30</td><td colspan="2">2.0</td></tr>
<tr><td>Minimum Average (MA)</td><td colspan="2">6.5</td><td colspan="2">180</td><td colspan="2">1.4</td><td colspan="2">11.9</td><td colspan="2">180</td><td colspan="2">1.4</td><td colspan="2">24.7</td><td colspan="2">180</td><td colspan="2">1.4</td><td colspan="2">18.1</td><td colspan="2">180</td><td colspan="2">1.4</td></tr>
<tr><td></td><td colspan="3">NP</td><td colspan="3">MFLs</td><td colspan="3">NP</td><td colspan="3">MFLs</td><td colspan="3">NP</td><td colspan="3">MFLs</td><td colspan="3">NP</td><td colspan="3">MFLs</td></tr>
<tr><td>Organic Soils Drying Event (days)</td><td colspan="3">NA</td><td colspan="3">NA</td><td colspan="3">NA</td><td colspan="3">NA</td><td colspan="3">0</td><td colspan="3">NA</td><td colspan="3">16,152</td><td colspan="3">18,575</td></tr>
<tr><td>Floodplain Exceedance (%)</td><td colspan="3">NA</td><td colspan="3">NA</td><td colspan="3">NA</td><td colspan="3">NA</td><td colspan="3">98.7</td><td colspan="3">83.8</td><td colspan="3">9.5</td><td colspan="3">8.1</td></tr>
<tr><td>SEFA</td><td colspan="24">NP and MFLs condition habitat availability (AWS; ft^2/ft) was calculated for numerous species, life stages and guilds for each water body; see Table 23 above for threshold (i.e., MFLs) condition.</td></tr>
</table>

MFLs Assessment

MFLs are not meant to represent optimal conditions, but rather set the limit to water withdrawals, beyond which significant harm would occur. A fundamental assumption of SJRWMD's approach is that alternative hydrologic regimes exist that are lower than pre-withdrawal conditions but still protect environmental functions and values of water bodies from significant harm caused by water withdrawals. The MFLs determination defined an alternative regime (i.e., minimum regime termed the "MFLs Condition") for relevant environmental criteria (Table 24).

The MFLs assessment involves comparing the MFLs condition with the hydrologic regime subject to impacts from current groundwater withdrawals (termed the current-pumping condition). This comparison determines whether each criterion, at each system, is being achieved under the current-pumping condition and if there is water available for additional withdrawal (freeboard), or whether water is necessary for recovery (deficit). If any of the MFLs environmental criteria are not being achieved under the current-pumping condition, indicating a deficit of water, a recovery strategy is necessary. If the MFLs are currently being achieved, but a deficit is projected within the 20-year planning horizon, a prevention strategy is needed. No-pumping and current-pumping condition water level datasets developed for Wekiva River basin systems were used to calculate freeboard or deficit for each water body and determine whether each system is in recovery, prevention or neither (see *Hydrological Analyses* section above and Appendix B for more details).

Current Status Assessment

Current MFLs status for Wekiva River basin systems was based on the 2014–2018 current-pumping condition (see Appendix B for details) and was assessed for each of the environmental criteria used in the MFLs determination. The MFLs condition required to protect each of the final criteria was compared to the current-pumping condition to determine a flow freeboard for each criterion. Flow freeboards were compared to determine the most constraining environmental criterion for each water body. The most constraining criterion is the basis for recommended minimum flows for each of the Wekiva River basin systems.

Event-based metrics

Current status for event-based metrics (i.e., FH and MA) was assessed using frequency analysis. The current-pumping condition frequency of each event was compared to the recommended minimum frequency to determine if the level was met under current conditions. The difference between the current-pumping condition water level and MFLs magnitude represents the freeboard or deficit in the river / floodplain (see Appendix D for details). Flow freeboards represent the amount of allowable change in flows and are calculated after determining the river / floodplain freeboard. Flow freeboard calculations are discussed below and in Appendix D.

Frequent High (FH)

Wekiva River at SR 46

Under the current-pumping condition, the FH flooding event (6.6 feet NAVD 88, duration of 30 days) has a probability of 50% (2.0-year return interval), which is the same probability under the MFLs condition (Figure D-1 in Appendix D). Based on the current-pumping elevation and return interval, the FH is met under current conditions, with a river floodplain (i.e., water level) freeboard of 0.0 ft. See below for flow freeboard.

Wekiwa Springs

Under the current-pumping condition, the FH flooding event (12.1 feet NAVD 88, duration of 30 days) has a probability of approximately 57% (1.8-year return interval), which is slightly higher than under the MFLs condition (i.e., 50%; 2.0-year return interval; Figure D-2 in Appendix D). Although the event frequency under the current-pumping condition is slightly higher than that of the MFL, the difference in magnitude (i.e., elevation) under current-pumping is less than 0.05 ft from the MFL and is therefore considered zero. As such the FH is met under current conditions, with a river floodplain (i.e., water level) freeboard of 0.0 ft.

Rock Springs Run

Under the current-pumping condition, the FH flooding event (25.0 feet NAVD 88, duration of 30 days) has a probability of approximately 94% (~1.1-year return interval), which is a much higher exceedance probability than under the MFLs condition (i.e., 50%; 2.0-year return interval; Figure D-3 in Appendix D). Based on the current-pumping elevation and return interval, the FH is met under current conditions, with a water level freeboard of 0.2 ft. See below for flow freeboard calculation.

Little Wekiva River at SLB

Under the current-pumping condition, the FH flooding event (18.7 feet NAVD 88, duration of 30 days) has a probability of 0%; all of the current-pumping condition data are below the critical FH elevation; Figure D-4 in Appendix D). Further, the FH is also not met under the no-pumping condition, and so it was deemed inappropriate to assess the FH for the Little Wekiva River.

Minimum Average (MA)

Wekiva River at SR 46

Under the current-pumping condition, the MA drying event (6.5 feet NAVD 88, duration of 180 days) has a probability of 69% (1.45-year return interval) compared to a probability of 71.4% (1.4-year return interval) under the MFLs condition. Although the event frequency under the current-pumping condition is slightly less than that of the MFL, the difference in magnitude (i.e., elevation) under current-pumping is less than 0.05 ft from the MFL and is therefore considered zero (see Figure D-5 in Appendix D). As such, the MA is met under current conditions, with a river floodplain (i.e., water level) freeboard of 0.0 ft.

Wekiwa Springs

Under the current-pumping condition, the MA drying event (11.9 feet NAVD 88, duration of 180 days) has a probability of 46.5% (2.2-year return interval; Figure D-6 in Appendix D) compared to a probability of 71.4% (1.4-year return interval) under the MFLs condition. Based on the current-pumping elevation and return interval, the MA is met under current conditions, with a water level freeboard of approximately 0.1 ft. See below for flow freeboard calculation.

Rock Springs Run

Under the current-pumping condition, the MA drying event (24.7 feet NAVD 88, duration of 180 days) has a probability of approximately 0% compared to a probability of 71.4% (1.4-year return interval; Figure D-7 in Appendix D) under the MFLs condition. Based on the current-pumping elevation and return interval, the MA is met under current conditions, with a water level freeboard of approximately 0.5 ft. See below for flow freeboard calculation.

Little Wekiva River at SLB

Under the current-pumping condition, the MA drying event (18.1 feet NAVD 88, duration of 180 days) has a probability of 97% compared to a probability of 71.4% (1.4-year return interval) under the MFLs condition. However, because the MA was also not met under the no-pumping condition it was deemed inappropriate to assess the MA for the Little Wekiva River (Figure D-8 in Appendix D).

Flow Freeboard

The next step in the current status assessment is to determine the amount of change in spring or river flow required to just meet each event-based metric (i.e., to calculate flow freeboard or deficit; see Appendix D for details). A summary of current status results, including flow freeboard for each metric, is presented below (Table 25). This represents the allowable reduction in spring flow (or river flow based on reduction from contributing springs), relative to the current-pumping condition.

Flow freeboard for the Wekiva River at SR 46 is 0.0 cfs because the MFLs condition for the minimum FH and MA is equal to the current-pumping condition (i.e., both minimum levels are just met at the current-pumping condition; Figures D-1 and D-5 in Appendix D). For this same reason, the flow freeboard for the Wekiwa Springs FH equals 0.0 cfs (Figure D-2 in Appendix D). The flow freeboard for the Wekiwa Springs MA, and the flow freeboards for both Rock Springs levels are listed as “greater than” a given allowable change in flow (e.g., greater than 2.3 cfs for Wekiwa Springs). This is because the maximum flow change assessed was a 50% increase in the current-pumping impact. Even with this large increase in impact these metrics were not tripped, and so the flow freeboards are shown as “greater than” the flow change associated with this 50% increase in impact. The FH and MA for the Little Wekiva River are listed as NA, because these metrics were not met under the no-pumping condition, and therefore it is not appropriate to assess them for this system.

Table 25. Flow freeboards for event-based metrics for Wekiva River basin MFLs water bodies; NA = not applicable (see text above).

System	Flow freeboard (cfs)	
	FH	MA
Wekiva River at SR 46	0.0	0.0
Wekiwa Springs	0.0	> 2.3
Rock Springs	> 5.5	> 5.5
Little Wekiva River at SLB	NA	NA

Organic Soils – Protection from Harmful Drying

The organic soil drying event metric was developed to ensure that deep wetland soils are protected at Little Wekiva River and Rock Springs, both sites where the standard MA was not appropriate for use as an MFLs metric, either because the metric was not met under the pre-withdrawal condition or not sensitive to water withdrawal. Current-pumping status of the organic soil drying metric was assessed for each system by comparing the total duration (days) of harmful drying events (events ≥ 8 days in duration; see above for metric details) under the current-pumping condition with the MFLs condition.

A 5% increase in current-pumping condition impact was necessary to increase the duration of harmful drying events from the current-pumping to MFLs condition (i.e., from 18,486 to 18,575 days). This increase in allowable impact equates to a river flow freeboard of 0.4 cfs for the Little Wekiva River at SLB (Table 26). At Rock Springs Run there were zero harmful drying events (≥ 8 days in duration) under the no-pumping condition, and so it was not possible to determine an MFLs condition or flow freeboard for this metric at this site (Table 26).

Table 26. Organic soils drying event summary under no-pumping, MFLs and current-pumping conditions.

	Total Duration of Harmful Drying Events			
	NP Condition	MFLs Condition	CP Condition	Flow Freeboard (cfs)
Little Wekiva River at SLB	16,152	18,575	18,486	0.4
Rock Springs	0	NA	NA	NA

Floodplain Inundation Protection

As discussed above, the minimum FH was found to be not appropriate at the Little Wekiva River because it was not met under the pre-withdrawal condition. The FH was also found to be insensitive to water withdrawal at Rock Springs / Rock Run. However, ensuring that the floodplains of these two systems are inundated periodically is nonetheless important. Floodplains require protection from excessive water withdrawal due to the numerous ecosystem benefits they provide, such as maintaining healthy nutrient and carbon exchange, and providing various types of habitat for many fish and wildlife species. See Appendix D for details regarding exceedance and flow freeboard calculations; results are provided below (Table 27).

Table 27. Hardwood swamp average elevation, NP condition exceedance and MFLs condition (NP-15%) exceedance for Wekiva River basin systems.

System	Average Hardwood Swamp Elevation (ft; NAVD 88)	MFLs Condition Exceedance (%)	CP Condition Exceedance (%)	Flow Freeboard (cfs)
Little Wekiva River at SLB	18.7	8.1	8.4	3.1
Rock Springs Run	25.0	83.9	86.3	0.5

Habitat suitability - SEFA

Current status of fish habitat suitability (i.e., AWS; see above for details) was assessed for each system by comparing the average suitability under the current-pumping condition with the MFLs condition, for each of 32 species, life stages and guilds. The MFLs condition for each SEFA metric is defined as a 15% reduction in average AWS under the no-pumping condition. If the average AWS for a given SEFA metric under the current-pumping condition is greater than or equal to average AWS under the MFLs condition, then the metric is considered met under current conditions (i.e., freeboard is ≥ 0 ft or cfs).

A total of 192 SEFA analyses were conducted, equaling the number of taxa/life stages/guilds (i.e., 32) times the six locations assessed: three locations on the mainstem Wekiva River, Wekiwa Springs Run, Rock Springs Run and the Little Wekiva River (see Appendix D for details).

Habitat suitability (i.e, AWS) under the current-pumping condition and the two additional water withdrawal scenarios tested, exhibited a minor reduction compared to the no-pumping condition. The largest reduction was less than 15% and was limited to only a few species, life stages or guilds (Table D-4 in Appendix D). In only 7.8% of cases (i.e., only 15 of the possible 192 cases) was there a reduction in AWS of greater than 5%. The remaining 177 location/taxa combinations exhibited a reduction in habitat availability that was less than 5%, and for many it was much less; note that taxa with very low no-pumping condition AWS values are not presented in Table D-4.

Overall, there was a very small reduction in habitat availability for all species, life stages and guilds under the water withdrawal scenarios tested. The largest change was to a single life stage of a ubiquitous generalist species (redbreast sunfish fry).

There was a relatively small reduction in AWS under current-pumping conditions relative to the no-pumping condition for species of special concern like the bluenose shiner (0.6 – 3.3% reduction) and American shad (1.9 – 6.9% reduction; Table D-4 in Appendix D). Therefore, it is concluded that fish habitat suitability will be protected by other more constraining metrics for at each of the Wekiva River basin systems assessed (i.e., in-channel fish habitat is protected from significant harm under the current-pumping condition).

Current-Status Summary

System Specific Freeboards

Current status for the four Wekiva River basin systems are based on criteria assessments described above. Flow (cfs) freeboard values were determined for the most constraining metric for each Wekiva River basin water body (Table 28). As described above, springs flows in the Wekiva Basin surface water model were increased or decreased by small increments to determine the change in flow necessary to just meet a particular metric threshold. In some cases, if a given metric did not exceed a threshold with a certain amount of flow reduction, the freeboard is expresses as “greater than” a given value (Table 28).

Both minimum levels (FH and MA) are equally constraining for the Wekiva River at SR 46 (i.e., flow freeboard equals zero for both metrics). Th most constraining metric for Wekiwa Springs is the FH with a flow freeboard of zero. The Little Wekiva River has a flow freeboard of 0.4 cfs, based on the organic soils drying metric. Rock Springs has a freeboard of 0.5 cfs, based on the floodplain inundation metric (Table 28). All of these system-specific constraints are more constraining (i.e., more limiting to water withdrawal) than the SEFA analysis for each water body. This is why the flow freeboards for SEFA are presented as greater than each system-specific freeboard value.

Based on the system-specific MFLs summarized above (Table 28), the most constraining MFLs water bodies in the Wekiva River basin are the Wekiva River at SR 46 and Wekiwa Springs, both with a freeboard of zero cfs. This means that the allowable impact is equal to that represented by the current-pumping condition (i.e., freeboard is defined as reduction from current-pumping condition). The freeboard for the Little Wekiva River (0.4 cfs) and Rock Springs (0.5 cfs) is equal to the current-pumping condition plus 5% impact (Table 28).

Table 28. Flow (cfs) freeboards for metrics evaluated at all Wekiva River basin water bodies; system-specific freeboards are highlighted.

Environmental Metric	Wekiva River at SR 46	Wekiwa Springs	Rock Springs	Little Wekiva River at SLB
Minimum Frequent High	0.0	0.0	> 5.5	> 4.4
Minimum Average	0.0	> 2.3	> 5.5	NA
Organic Soils - Drying	NA	NA	NA	0.4
Floodplain Inundation	NA	NA	0.5	3.1
In-channel Fish Habitat (SEFA)	>0.0	>0.4	>0.5	>0.4

Basin-wide Freeboard

Rock Springs and the Little Wekiva River at SLB are both less constraining (i.e., have greater freeboards) than Wekiwa Springs and the Wekiva River at SR 46. However, both are also upstream of and contribute a large proportion of the flow at SR 46. In fact, the majority of the flow at SR 46 (70 - 85%) is from other MFLs water bodies upstream. Because the MFLs constraining metrics at SR 46 (i.e., the minimum FH and MA) are met by the current-pumping condition (which yields a freeboard of zero cfs), it is recommended that all water bodies in the upper portion of the basin also be limited to the current-pumping condition. This is necessary because any further flow reduction in the springs upstream of SR 46 gage (from current-pumping condition) would decrease the flows at SR 46 and result in violation of the MFLs at that location. This recommendation also stems from the fact that the Wekiva River at SR 46 is an indicator for conditions throughout the basin, and the minimum flow at SR 46 is based on transects (used for the minimum FH and MA) whose locations extend from upstream of the confluence of the Little Wekiva River to downstream of SR 46 (i.e., the SR 46 FH and MA protect floodplain conditions throughout the basin, not only at SR 46; Figure 41). This recommendation is also supported by the constraint at Wekiwa Springs which has a flow freeboard of zero.

In addition to the four primary waterbodies described above, minimum flows are also recommended for the four smaller Wekiva River basin springs that currently have adopted MFLs. These include Miami Springs, Palm Springs, Sanlando Springs and Starbuck Springs. The recommended minimum flow for these four small (second and third magnitude) springs is equal to the site-specific average flow under the current-pumping condition. This recommendation is for the same reasons described above (i.e., to limit the basin to current pumping to meet the most sensitive and most downstream metric at SR 46; Table 28). As described below (see WRVs Assessment section and Appendix E), an effort was made to evaluate the effects of water withdrawal on swimming and wading, the primary environmental function, at three of these springs (Palm, Sanlando and Starbuck Springs). However, because of the lack of relationship between flow and water level, it was deemed inappropriate to develop a water-level-based swimming or wading metric at these three springs. At these three springs, flow can be reduced by a large amount before a significant change in water level (or swimming depth) will occur (see WRVs Assessment for details). At Miami Springs, swimming depth is not an appropriate metric because of its very small size and the fact that it is not used for swimming. Its primary environmental values are aesthetics and contribution of baseflow to the Wekiwa Springs run. The small reduction in flow under the current-pumping condition (i.e., 0.8 cfs; Table 29) will protect these values at Miami Springs.

Based on a basin-wide impact equaling the current-pumping condition, the recommended freeboard for each MFLs water body in the Wekiva River basin is zero cfs (i.e., allowable change under current-pumping condition). The resulting minimum flows recommended for these four water bodies are presented below (Table 29). These minimum flows equate to an allowable flow reduction, relative to the no-pumping condition, of 26.0 cfs for the Wekiva River at SR 46, 8.9 cfs for the Little Wekiva River at SLB, 4.6 cfs at Wekiwa Springs, 11.1 cfs at Rock Springs, 5.0 cfs at Sanlando Springs, 2.2 cfs at Starbuck Springs, 1.1 cfs at Palm Springs, and 0.8 cfs at Miami Springs (Table 29).

Table 29. Average current-pumping (CP) flow for Wekiva River systems, based on setting freeboard equal to SR 46 (i.e., freeboard = 0 cfs), so that impact is limited to current pumping for all systems; also presented are average no-pumping (NP) flow, and the allowable reduction (cfs and percent) from NP to CP average flow.

System	Average NP Flow (cfs)	Average CP (Basin-wide MFL) Flow (cfs)	Flow (cfs) Reduction from NP to CP	Flow (%) Reduction from NP to CP
Wekiva River at SR 46	304.5	278.5	26.0	8.5
Little Wekiva R. at SLB	80.2	71.3	8.9	11.1
Rock Springs	66.9	55.8	11.1	16.6
Wekiwa Springs	69.0	64.4	4.6	6.7
Miami Springs	6.4	5.6	0.8	12.5
Palm Springs	6.7	5.6	1.1	16.4
Sanlando Springs	26.0	21.0	5.0	19.2
Starbuck Springs	15.0	12.8	2.2	14.7

Current Status for Wekiva River Basin MFLs

Because the recommended MFLs condition in the basin equals the current-pumping (i.e., defined as the 2014 - 2018 average) condition, the current-pumping condition freeboard (or the allowable change in flow from current pumping) for each MFLs water body in the Wekiva River basin is zero cubic feet per second (cfs).

However, in recent years water use has increased relative to the CP (i.e., 2014 - 2018 average) condition. Therefore, all Wekiva River basin systems are in recovery, and a recovery strategy must be developed concurrently with the MFLs. Consistent with the provisions for establishing and implementing MFLs provided for in section 373.0421, F.S., the recovery strategy identifies a suite of projects and measures that, when implemented, will recover these priority water bodies from impacts due to groundwater pumping withdrawals and prevent the MFLs from not being met due to future consumptive uses of water. The recovery strategy will also provide sufficient water supply options to meet existing and projected reasonable beneficial uses.

Assessment Gages

Assessment gages used for the Wekiva River basin MFLs are flow data collection stations used for current and future status assessments, as contemplated by Rule 40C-8.031(13), *F.A.C.* (Figure 48); these stations are listed below.

- **Wekiva River** (USGS gage 02235000 / Wekiva River Near Sanford, FL);
- **Wekiwa Springs** (SJRWMD gage 00371831 / Wekiwa Springs at Altamonte Springs);
- **Rock Springs** (SJRWMD gage 00330830 / Rock Springs at Apopka);
- **Little Wekiva River** (SJRWMD gage 09502132 / Little Wekiva River at Springs Landing Boulevard);
- **Palm Springs** (SJRWMD gage 00441845 / Palm Springs at Longwood);
- **Sanlando Springs** (USGS gage 00451840 / Sanlando Springs at Longwood);
- **Starbuck Springs** (SJRWMD gage 00471851 / Starbuck Springs at Longwood); and
- **Miami Springs** (SJRWMD gage 00421834 / Miami Springs at Longwood).

UFA Levels - Additional Springs Protection

In an effort to ensure that springs in the Wekiva basin will not be significantly harmed by groundwater pumping, the UFA well OR0548 at Wekiwa Springs State Park will be monitored periodically to evaluate groundwater level trends (Figure 48; see Appendix D for more details). There is a good relationship between well OR0548 water levels and Wekiva Basin MFLs spring flows (see hydrographs in Appendix D). Because there is less uncertainty in groundwater level measurements than in spring flow measurements, the former will be monitored over time to ensure that Wekiva Basin springs continue to meet their minimum flows.

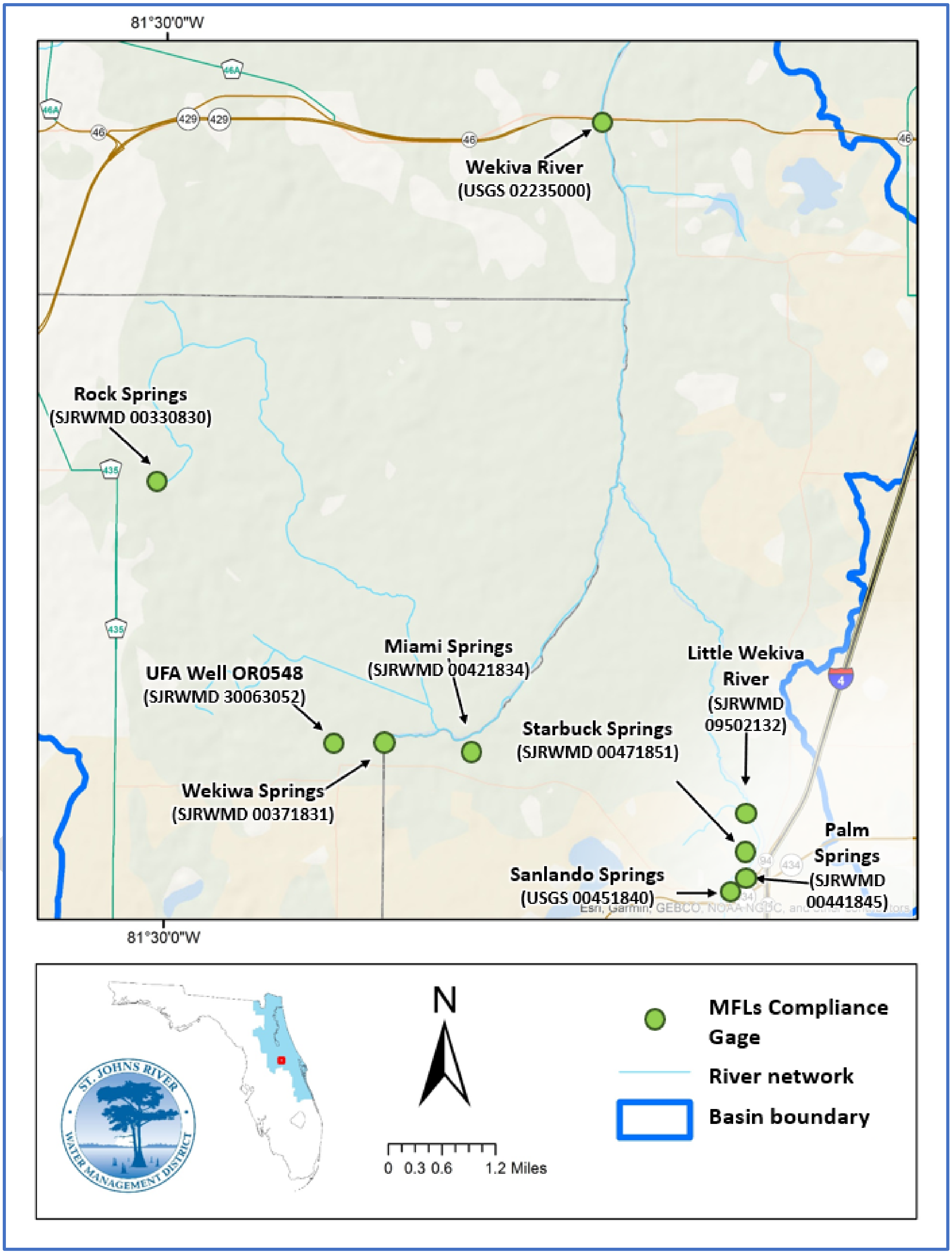

Figure 48. Locations of assessment gages to be used for future status assessment for the Wekiva River basin MFLs.

WRVs Assessment

The following section provides a summary of the WRVs assessment conducted for the Wekiva River basin water bodies. See Appendix E for details regarding the WRVs metrics used and how they were analyzed.

The minimum flows and levels section of the State Water Resources Implementation Rule (Rule 62-40.473, *Florida Administrative Code* [*F.A.C.*]) requires that “consideration shall be given to…environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology.” The environmental values described in Rule include:

1. Recreation in and on the water;
2. Fish and wildlife habitats and the passage of fish;
3. Estuarine resources;
4. Transfer of detrital material;
5. Maintenance of freshwater storage and supply;
6. Aesthetic and scenic attributes;
7. Filtration and absorption of nutrients and other pollutants;
8. Sediment loads;
9. Water quality; and
10. Navigation.

Consideration of these environmental values, referred to here as water resource values (WRVs), is meant to ensure that recommended MFLs condition for the Wekiva River basin protects the full range of water-related functions that provide beneficial use to humans and ecological communities. The recommended MFLs condition equals the flow necessary to meet the most downstream MFLs (i.e., SR 46) and thus is equal to the current-pumping condition for each Wekiva River basin water body (Table 30).

Typically, all ten WRVs are not applicable to every priority water body, because of site-specific differences, including varying hydrologic characteristics (e.g., riverine vs. lake systems or the presence/absence of tidal influence). Two of the environmental values listed above (estuarine resources and navigation) are not applicable and thus were not considered as part of this assessment. Protection of boat passage within the Wekiva River basin was not assessed as part of WRV #10: Navigation, but rather was assessed as part of WRV #1: Recreation in and on the water (for kayaking, canoeing, and small motor boats).

Also, WRV #5 (Maintenance of freshwater storage and supply) was not explicitly evaluated. The purpose of this environmental value is to protect an adequate amount of freshwater for non-consumptive uses and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology. This environmental value encompasses all other environmental values identified in Rule 62-40.473 F.A.C. Because the overall purpose of the MFLs is protect environmental resources, and other non-consumptive beneficial uses while also providing for consumptive uses, this environmental value is considered protected if the remaining relevant values are protected.

Numerous metrics, in addition to the primary criteria described above in the *MFLs Determination* section, were evaluated to ensure all relevant environmental values are protected. These metrics were assessed to determine if the recommended basin-wide MFLs condition (equal to the current-pumping condition for all water bodies) will protect all relevant environmental values in the basin.

WRVs metrics evaluated:

The following provides a brief summary of the metrics evaluated, and the overall conclusions from the WRVs assessment. See Appendix E for details.

Recreation in and on the water

- *Paddling depth:* depths sufficient for canoes, kayaks, paddle boards, etc.;
- *Boat passage:* depths and widths sufficient for small motorboats;
- *Boat ramp usage:* depth for boat drafts at the end of Wekiva basin boat ramps;
- *Tubing depth:* depths sufficient for tubing in Rock Springs Run; and
- *Swimming and wading depth:* average depths at important swimming areas.

Fish and wildlife habitats and the passage of fish

- *Primary metrics:* metrics to protect wetland communities and organic soils;
- *Fish passage:* sufficient depth and width for passage of large-bodied fish;
- *Manatee passage:* sufficient depth and width for passage of manatee;
- *Shad spawning habitat:* available habitat (depths and velocities) at low flows;
- *Bluenose shiner habitat:* SEFA habitat availability for state Threatened shiner; and
- *Basin wetland inundation:* protection of areal coverage of inundated wetlands.

Transfer of detrital material

- *Primary metrics:* floodplain inundation by primary metrics; and
- *Algal scour:* critical velocities necessary for algal scour.

Aesthetic and scenic attributes

- *Other WRVs:* protection of fish and wildlife, recreation, filtration of nutrients and water quality maintenance.

Filtration and absorption of nutrients and other pollutants

- *Primary metrics:* floodplain inundation by primary metrics; and
- *GPP:* critical velocities necessary for maximizing gross primary production.

Sediment loads

- *Sediment transport:* critical velocities necessary for entrainment and transport of sediment.

Water quality

- *Nutrients:* trend analyses and comparisons of nutrient concentrations under NP and CP conditions; and
- *Other parameters:* trend analyses and comparisons between NP and CP conditions for physical parameters and non-nutrient water quality parameters.

WRVs Assessment Results Summary

The suite of metrics outlined above were evaluated to ensure that the recommended MFLs condition (basin-wide current-pumping condition) is protective of important, relevant environmental functions and values. The following provides a very brief summary of assessment results (see Appendix E for details).

Recreation in and on the water

Paddling is one of the most important recreational activities in the Wekiva River basin (see Appendix E; Figure 49). The reductions in exceedance of critical paddling depth was very small (0 to 3%) for all Wekiva River basin cross-sections evaluated. This was also true for motorboat passage (depth ≥ 20 inches across ≥ 20 feet of river channel) for the most constraining (shallowest) portions of the Wekiva River (i.e., cross-sections 332.58 and 344.64). The exceedance of critical elevations for boat ramp usage exhibited some change,

Figure 49. Left: Kayaking on Rock Run; Right: Canoe launch site at Wekiwa Springs State Park.

but did not exceed the significance threshold (i.e., 15% reduction from NP condition exceedance; see Appendix E for details). The CP condition resulted in a very small change in number of days that the Rock Springs critical tubing elevation is exceeded; it rounded to the same exceedance as the NP exceedance (i.e., 100%; see Appendix E). The average depth of the Wekiwa Springs State Park swimming area under the CP condition is reduced 0.2 ft (from 4.7 to 4.5 ft) relative to the NP condition. The average depth of the Kelly Park swimming area under the CP condition is reduced 0.3 ft (from 3.5 ft to 3.2 ft). Both represent less than a 15% reduction from the no-pumping condition.

Because of the lack of relationship between flow and water level at the three small Little Wekiva River springs (Palm, Sanlando and Starbuck Springs), it was deemed inappropriate to develop a water-level-based swimming or wading metric for these sites (see Appendix E). Water-level metrics (e.g., swimming depth) would be very insensitive metrics, and further, if they were used, they would allow large flow reductions before a significant change in water level (or depth) would occur. Therefore, although an effort was made to create a recreational metric for these small springs, it was not deemed prudent (nor useful) to do so (see Appendix E for details).

Fish and wildlife habitats and the passage of fish

The primary metrics evaluated as part of the main MFLs Determination are designed to protect the long-term maintenance of wetland communities and organic soils (i.e., FH, MA, organic soil drying metric and floodplain inundation metric), as well as in-channel fish habitat suitability (i.e., SEFA analysis). The five primary metrics tested are achieved under the CP condition. As such, many Wekiva River basin fish and wildlife habitats are protected under the recommended basin-wide MFLs condition.

However, other in-channel functions and values that protect fish and wildlife also needed to be evaluted to ensure the protection of WRV#2. Therefore, in addition to the five primary metrics, several other fish and wildlife metrics were evaluated (See Appendix E for details). Critical water levels (and depths) needed for fish passage (≥ 0.8 feet over ≥ 25% of a given cross-section) exhibited small differences in exceedance between the NP and CP conditions, and were met at all Wekiva River basin cross-sections tested. This was also true for manatee passage (3 feet depth). Of the twelve cross-sections evaluated, only one (cross-section 292.23) did not meet the critical depth criterion under the NP condition. Under the CP condition, no new cross-sections failed to achieve the critical depth threshold (see Appendix E for details).

Potential spawning habitat availability for several river herrings (*Alosa* spp.) was estimated at historically low flows in the lower Wekiva River. Even under these low flows, that would be experienced less than 10% of the time under the current-pumping condition, velocities and depths were suitable along almost the entire Wekiva River and will support spawning by all three species that use the river. Therefore, the recommended MFLs for the basin is sufficient to prevent significant harm to these anadromous herring species. Also, SEFA analysis results for American shad suggest a small (1.9 – 6.9%) reduction in habitat suitability (i.e., AWS) under the CP condition relative to the NP condition. The greatest reduction in American shad habitat was at Rock Springs run (6.9% reduction), but equated to a small amount of change in habitat suitability (a reduction of 3 ft^2/ft, from 41.9 to 38.9 ft^2/ft).

Recent collections by FWC of the bluenose shiner (*Pteronotropis welaka;* Figure 50) suggests that this State-designated threatened species has populations that are still persisting in parts of the Wekiva River basin where they have been documented historically. Further, habitats favored by bluenose shiners are common throughout both the Wekiva River and Rock Springs Run. SEFA analysis results for bluenose shiner suggest a very small (0.6 – 3.3%) reduction in habitat suitability (i.e., AWS) under the CP condition relative to the NP condition. When weighted by river mile, the total average AWS reduction under the current-pumping condition, for the river system is 1.1%. Rock Springs run exhibited the largest change with a 3.3% reduction. However, the amount of habitat availability under the no-pumping condition was relatively small (39.2 ft^2/ft), and the 3.3% reduction equates to approximately a reduction of 1 ft^2/ft. For most of the rest of the basin the reduction was zero, or less than 1 ft^2/ft. In addition, there was no change to AWS for the bluenose shiner at Rock Spring Run when impact was increased by 5% (Appendix D).

Figure 50. The Wekiva River basin provides habitat for the State-designated Threatened species bluenose shiner.

WRV#2 was also evaluated by assessing the effect of the MFLs condition (i.e., the current-pumping condition) on basin-wide wetland inundation (Figure 51; see Appendix E for details). This analysis puts the event-based minimum Frequent High (the most constraining metric for the Wekiva River at SR 46) into spatial context. Total basin wetland area inundated under the no-pumping condition is ~ 2,166 acres. Under the MFLs (i.e., current-pumping) condition wetland area inundated equals ~ 1,828 acres (Figure 52). This constitutes a 15.6% (338 acre) reduction in area of wetlands inundated under the recommended MFLs condition, relative to the no-pumping condition. This percent change is similar to the allowable flow reduction (15%) in the Rainbow River MFLs, which is based on a similar floodplain wetland inundation metric (Holzwart et al. 2017). Given the various sources of uncertainty in the current Wekiva

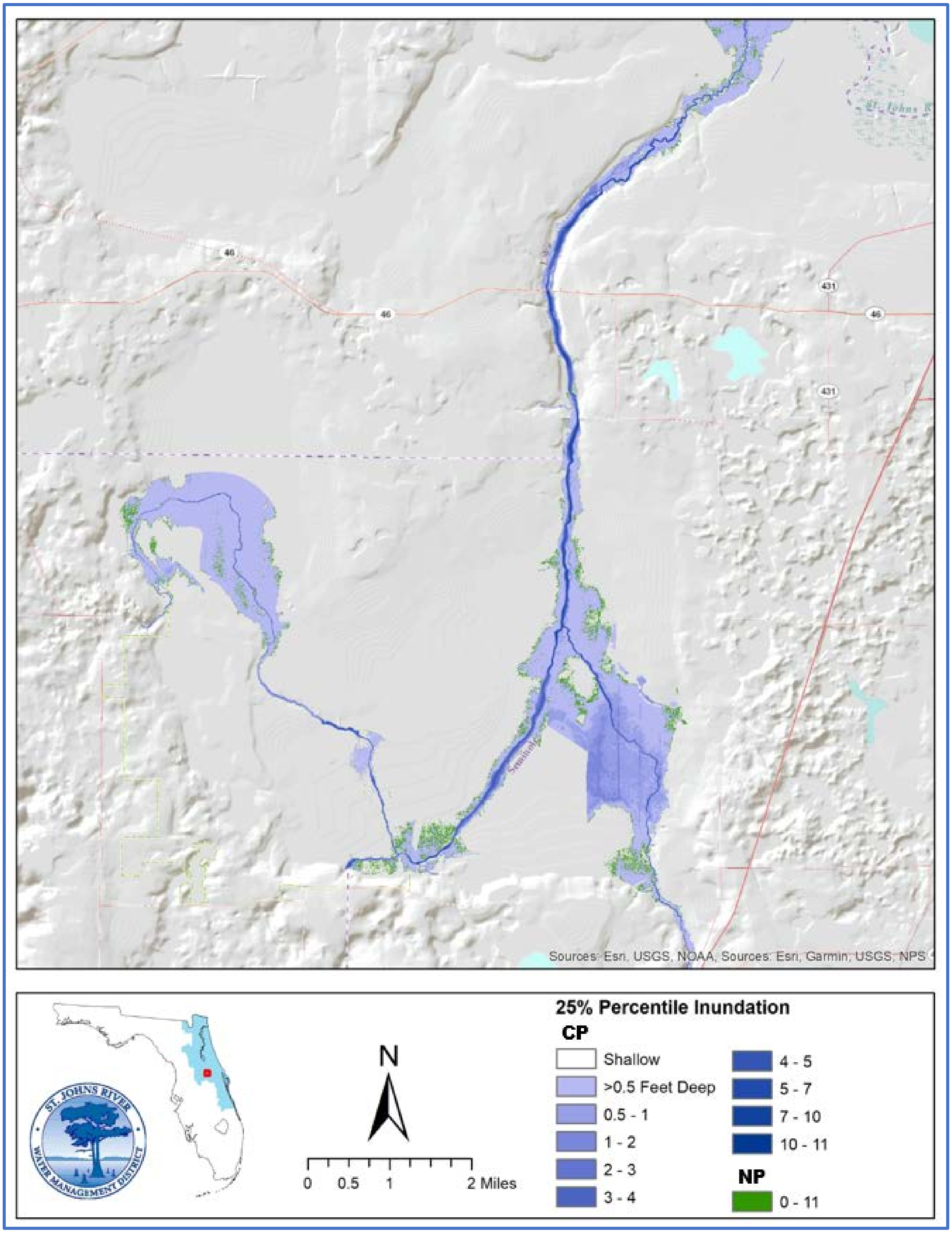

Figure 51. Wetland inundation in the Wekiva River basin under the no-pumping (green) and current-pumping (blue) conditions, at the 25th percentile flow condition.

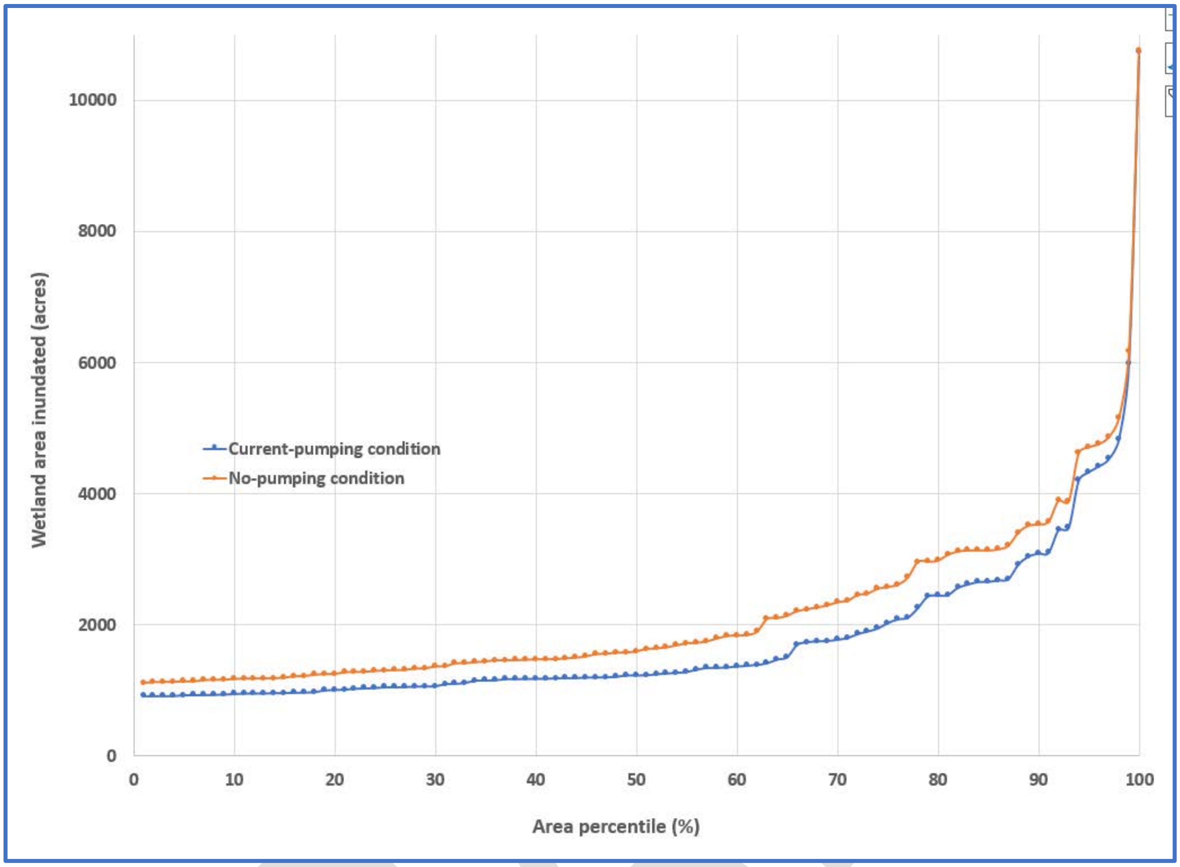

Figure 52. Wekiva River basin wetland area (acres) inundated under the NP and CP conditions; average area difference equals 15.6%; percentiles based on total inundated area.

River basin wetland inundation analysis, the SJRWMD has chosen to use these results as a way to put the MFLs condition into spatial context, as opposed to using this metric as a primary criterion for determining the MFLs condition. The wetland inundation analysis indicates that the MFLs condition is not overly constraining, but rather that a moderate amount of change is occurring to wetland inundation dynamics under the current-pumping condition.

Transfer of detrital material

Compliance with the primary floodplain metrics should provide for the protection of flooding events necessary for the transfer of detrital material throughout the Wekiva River system. Therefore, the recommended minimum flows for each Wekiva River basin system, which are based on the current-pumping condition, are considered to be protective of this WRV.

In the Wekiva River, critical velocities necessary for algal scour were reduced under the CP condition by more than 15% relative to the NP condition. However, this occurred at only four cross-sections, which equates to approximately 16.6% of the length of the Wekiva River.

Also, the magnitude of change in velocities was very small (0.02 to 0.03 ft/s). Because of the very few cross-sections applicable (that constitute a small portion of the river length), and the very small reduction in velocity, algal scour velocities are considered protected under the CP condition. Only a single additional cross-section exhibited a greater than 15% change relative to the NP condition. This was in the Little Wekiva River, and the magnitude of change was also very small (0.04 ft/sec).

Aesthetic and scenic attributes

Enjoying the aesthetics and scenic attributes of the Wekiva River and its numerous springs (Figure 53) is one of the primary reasons people visit these resources. Public surveys at Wekiwa and Rock Springs and other springs throughout Florida have demonstrated that enjoyment aesthetic and scenic attributes is a key motivation for 60 - 90% of people visiting these springs (Bonn 2004, WSI 2007). These important values are dependent upon the long-term maintenance of other environmental values including WRV-1 (Recreation in and on the Water), WRV-2 (Fish and Wildlife Habitat and the Passage of Fish), WRV-7 (Filtration and Absorption of Nutrients and other Pollutants) and WRV-9 (Water Quality). Therefore, it is anticipated that the development of MFLs to protect these other WRVs will also protect aesthetics and scenic attributes (see Appendix E for details regarding assessment of these other WRVs).

Figure 53. Protecting fish and wildlife habitat and other WRVs will help preserve the scenic attributes of the Wekiva River basin.

Filtration and absorption of nutrients and other pollutants

The minimum FH, which is the constraint for the Wekiva River, is based on providing a sufficient number of high-water (flooding) events to protect floodplain wetlands and associated wildlife habitat values. Maintaining sufficient high-water events will also ensure that the ability of floodplains within the Wekiva River basin continue to provide the important functions associated with filtration of nutrients and other pollutants . Therefore, the recommended minimum flows for each Wekiva River basin system, which are based on the current-pumping condition, are considered to be protective of this WRV. As with algal scour velocities, of the 43 Wekiva River cross-sections, only four exhibited reduced exceedance of the GPP critical velocity (0.82 ft/sec) under the CP condition by more than 15% relative to the NP condition. However, as with algal scour velocities, the magnitude of change in velocities was very small (0.01 to 0.03 ft/s). Because of the very few cross-sections applicable (that constitute a small portion of the river length), and the very small reduction in velocity, exceedance of the GPP critical velocity is considered protected under the CP condition.

Sediment loads

Similar to other critical velocities evaluated, the effect of the CP condition on sediment entrainment and transport velocities was minimal at the four Wekiva River basin systems assessed (see Appendix E). Rocks Springs exhibited the largest reduction in velocity exceedances. However, because all cross-sections exhibited no change for sediment entrainment velocities and only three of 19 exhibited a small change for sediment transport velocities, this metric is considered protected under the CP condition.

Water quality

Numerous water quality parameters were analyzed for the four Wekiva River basin water bodies. These include nutrients associated with eutrophication (ammonium, nitrate-nitrite, total Kjeldahl nitrogen, total nitrogen, orthophosphate, and total phosphorus), as well as various other important parameters including total organic carbon, chlorophyll, conductivity, dissolved oxygen, oxygen percent saturation, total dissolved solids, total suspended solids, alkalinity, turbidity, and color.

The relationship between these parameters and flow was evaluated, as well as any changes in parameters over time. The data analyses described in Appendix E demonstrate that excessive nitrogen in the Wekiva River basin is related to loading from the landscape and not flow. At Wekiwa Springs, Rock Springs and the Wekiva River at SR 46 nitrogen concentrations increase with increasing flow. This positive relationship between nutrients and flow is consistent with observations made for other springs and spring-fed rivers (Munch et al. 2006, Heyl 2012). In addition to nutrients being related to loading and not flow, the remaining parameters had nearly flat regression slopes and wide confidence intervals (see Appendix E), indicating a weak or nonexistent relationship with flow. Therefore, water quality within the Wekiva River basin is not significantly related to flow reduction and is considered protected under the recommended basin-wide MFLs condition (i.e., the current-pumping condition).

The WRVs assessment results indicate that the eight WRVs relevant to the Wekiva River basin systems are protected by the recommended MFLs (Table 30; see Appendix E). As discussed above, the recommended minimum flow for the mainstem of the Wekiva River at

SR 46 equates to an allowable reduction in flow, relative to the no-pumping condition, of 8.5% (Table 29).This is similar to the allowable change (10% reduction from natural baseline condition) deemed protective for large river systems with outstanding biological / ecological attributes (Acreman and Ferguson 2010, Richter et al. 2011). The allowable change for the Wekiva River is also within the range (3.0 - 19.0%) and similar to the average 7.6%) allowable flow reduction based on adopted MFLs for spring-fed rivers in Florida (Table 31).

Table 30. Criteria evaluated to determine protection of Rule 62-40.473 environmental values by the recommended MFLs condition for each Wekiva River basin system.

WRV	Environmental Criteria Evaluated	Protected by the MFLs Condition?
Recreation in and on the water	Paddling depth; boat passage; boat ramp usage; tubing depth, swimming/wading depth	Yes
Fish and wildlife habitats and the passage of fish	FH, MA, organic drying metric, floodplain inundation metric, SEFA, fish passage, manatee passage, shad spawning habitat, basin-wide wetland inundation	Yes
Estuarine resources	NA	NA
Transfer of detrital material	Primary floodplain metrics; algal scour	Yes
Maintenance of freshwater storage and supply	Other relevant WRVs are protected by the MFLs condition, thereby providing balance between consumptive and non-consumptive uses.	Yes
Aesthetic and scenic attributes	Protection of fish and wildlife, recreation and water quality metrics	Yes
Filtration and absorption of nutrients and other pollutants	Primary floodplain metrics; GPP	Yes
Sediment loads	Sediment entrainment and transport velocities; relationship between TSS and flow	Yes
Water quality	Nutrients (NOx, TN and TP) and other parameters; comparisons with flow and temporal trends	Yes
Navigation	Covered as part of “Recreation in and on the water”	NA

Table 31. Allowable reduction in average flow based on adopted MFLs for Florida spring-fed river systems; average allowable reduction is 7.6%.

Spring-fed River System	Adopted MFLs allowable reduction to average flow (%)
Chassahowitzka River System	3.0
Homosassa River System	3.0
Rainbow River	5.0
Wacissa River	5.1
Ichetucknee River	5.8
Aucilla River	6.5
Silver River	6.5
Peace River at Zolfo Spring	8.0
Lower Santa Fe River	8.0
Weeki Wachee River System	10.0
Crystal River System and Kings Bay Springs	11.0
Lower Alafia River	19.0
Average	**7.6**

Indicators of Hydrologic Alteration

Indicators of Hydrologic Alteration (IHA) is a commonly used approach for characterizing temporal variability in the hydrologic regimes of flowing systems. It is also used to quantify the degree of system alteration resulting from perturbation (e.g., water withdrawal, dam operation, flow diversion, etc.; Richter et al. 1997). The IHA approach is based on calculating and interpreting a suite of ecologically relevant flow statistics (i.e., indicators) that are important to river ecosystems and sensitive to disturbance.

The Nature Conservancy's IHA software (version 7.1; *https://www.conservationgateway.org*) was used to calculate the standard suite of hydrologic indicators for the Wekiva River at SR 46, for both the no-pumping and current-pumping condition flow timeseries (see Appendix F for details). IHA results for each condition were then compared to determine whether water withdrawal results in a significant change to one or more of these ecologically relevant parameters. For each flow condition, 30 IHA parameters were calculated; these statistical parameters are divided into the following five groups:

- **Group 1:** Parameters that characterize seasonal patterns using magnitude and timing of monthly flows; indicators of habitat availability (wetted area, volume);
- **Group 2:** Parameters that characterize extreme conditions; magnitude and duration of annual extreme events important for physical structure and timing of reproduction for some species;
- **Group 3:** Parameters that characterize the timing of annual extreme (high and low) water conditions that can be key to some species' life-cycle stages;
- **Group 4:** Parameters that characterize the frequency and duration of high (above the P25 exceedance flow) and low (below the P75 exceedance flow) flood pulses; and
- **Group 5:** Parameters that characterize the rate and frequency of flow changes.

In addition to the 30 IHA parameters (Table F-2 in Appendix F), 32 environmental flow components (EFCs) were also calculated, including low flows, extreme low flows, high flow pulses, small floods and large floods (Table F-3 in Appendix F).

Low flows have a strong influence on the diversity and abundance of river flora and fauna. High flows increase access to habitats, especially during important migration seasons, inundate floodplains supporting important nutrient and carbon pathways including the base of production for different food webs in river ecosystems.

Overall, the magnitude of change (difference between medians) for all IHA parameters was moderate (about 9%), which is similar to the difference in long-term average flow difference (8.5%) between the NP and CP conditions. Only a few EFC parameters exhibited a significant change to central tendency (median) or variability (coefficient of dispersion); these include several of the low flow parameters (see Appendix F for details).

Given that numerous IHA parameters are right on the edge of exhibiting significant differences (e.g., deviations factors ≥ 10%, and significance counts < 0.05), and that numerous low flow EFCs are exhibiting change, this analysis indicates that the current-pumping condition is not overly constraining (i.e., changes in important flow statistics are starting to exhibit significant changes at current-pumping). This supports setting the limit of pumping at the current-pumping condition for the Wekiva River and contributing water bodies.

For the most part, the recommended MFLs condition protects the general flow regime of the Wekiva River. As recognized in the Natural Flow Regime (NFR) paradigm, maintaining a river's magnitude, frequency, duration, timing, and rate of change is key to conserving biodiversity as well as critical ecosystem functions and services (Poff 2018). The recommended MFLs condition preserves the shape, dynamics, and a majority of the magnitude of the no-pumping condition hydrologic regime and is therefore consistent with the key tenants of the NFR paradigm.

Conclusions and Recommendations

Minimum flows were originally adopted for the Wekiva River at SR 46, Wekiwa Springs, Rock Springs, Palm Springs, Sanlando Springs, Starbuck Springs and Miami Springs in 1992 (Chapter 40C-8, F.A.C.; Hupalo et. al. 1994). Upon review, it was determined that minimum flows for these systems should be reevaluated to ensure that they are based on the latest data and most up to date methods. A new minimum flow has also been established for the Little Wekiva River to protect a large tributary to the Wekiva River and help preserve small contributing springs, including Palm, Sanlando and Starbuck Springs. All of these Wekiva River basin systems are important resources within the CFWI's regional network of MFLs and critical indicators of potential impacts due to groundwater pumping.

The Wekiva River basin's unique, biologically diverse, and regionally significant ecosystems have received numerous designations and special protections at local, state, and federal levels. The Wekiva River system is one of two National Wild and Scenic rivers in Florida recognized for its "outstandingly remarkable" environmental values. Wekiwa and Rock Springs are Outstanding Florida Springs, large portions of the basin are designated as Outstanding Florida Waters, and the majority of the mainstem of the Wekiva River and Little Wekiva River are protected by the Florida Aquatic Preserve Act. The minimum flows recommended herein were developed to protect these outstanding biological, scenic, and recreational resources.

This work has resulted in the recommendation to modify the adopted MFLs for the Wekiva River, Wekiwa Springs, Rock Springs, Palm Springs, Sanlando Springs, Starbuck Springs and Miami Springs and to establish new minimum flows for the Little Wekiva River at Springs Landing Boulevard. These recommendations are based on current SJRWMD MFLs determination and assessment methodologies including analysis of an additional 30 years of hydrologic data collected since the original MFLs were adopted and development of hydrologic regime under current and no-pumping conditions using the most recent surface and groundwater models.

Recommended Minimum Flows

Minimum flows were developed for Wekiva River basin systems using a variety of metrics that were developed to protect important ecological structure and functions, as well as human beneficial uses. The assessment of the recommended minimum flows included evaluating primary ecological metrics as well as assessing a comprehensive suite of both ecological and human-use criteria (see WRVs Assessment summary and Appendix E). These criteria were developed to ensure that both in-channel and floodplain attributes and functions are protected by the recommended MFLs condition.

The Wekiva River at SR 46 is the most downstream system assessed in the Wekiva River basin. The Wekiva River at SR 46, along with Wekiwa Springs are determined to be the most constraining systems in the basin. Both have an MFLs condition equal to the current-pumping condition (i.e., their constraining metrics are barely met by the current-pumping condition; see Appendix D). All other MFLs water bodies (i.e., Rock Springs, Little Wekiva River, Palm Springs, Sanlando Springs, Starbuck Springs and Miami Springs) and Wekiwa Springs are upstream of and contribute 70-85% of the flow at SR 46. Given this fact and that the constraint at SR 46 is met by the current-pumping condition, the recommended minimum flows for all water bodies in the upper portion of the basin are also equal to the current-pumping condition. This is necessary because any further flow reduction in the springs upstream of SR 46 gage (from current-pumping condition) would decrease the flows at SR 46 and result in violation of the MFLs at that location. This recommendation will ensure the provision of flow sufficient to meet the most downstream constraint at SR 46. This is also supported by the MFLs condition equaling the current-pumping condition at Wekiwa Springs. The recommended minimum average flows for the eight Wekiva River basin water bodies are provided below; original (adopted) minimum average flows for springs are also presented (Table 32). An adopted minimum flow was not originally adopted for the Wekiva River at SR 46 (original MFLs are event-based, not average flows) or for the Little Wekiva River.

Table 32. Original (adopted) and recommended minimum average flows for Wekiva River basin MFLs water bodies; SR 46 = Florida State Road 46; SLB = Springs Landing Boulevard.

System	Original (adopted) Minimum Average Flow (cfs)	Recommended Minimum Average Flow (cfs)
Wekiva River at SR 46	NA*	278.5
Little Wekiva R. at SLB	NA**	71.3
Rock Springs	53.0	55.8
Wekiwa Springs	62.0	64.4
Miami Springs	4.0	5.6
Palm Springs	7.0	5.6
Sanlando Springs	15.0	21.0
Starbuck Springs	13.0	12.8

**Original (adopted) MFLs for SR 46 are event-based; a minimum average (i.e., mean) flow was not adopted; however event-based MFLs were adopted; see Rule 40C-8.031(2), F.A.C.*

***MFLs have not been adopted for the Little Wekiva River*

The ECFTX v2.0 groundwater model was used for the Wekiva River basin groundwater pumping impact analysis. This impact analysis was used to develop the current-pumping condition timeseries data used in the MFLs assessment (See Appendix B for details of the groundwater pumping impact analysis). Current-pumping condition is defined as the average pumping condition between 2014 and 2018 and represents water withdrawals influenced by the range of climatic conditions (e.g., rainfall) present over that period. If these conditions are repeated over the next ~70 years (i.e., the length of the POR), and average pumping remains the same, the current-pumping condition flows are expected to reflect future flows.

Because the recommended MFLs condition in the basin equals the current-pumping condition, the freeboard for each MFLs water body in the Wekiva River basin is zero cfs. This equates to an allowable flow reduction, relative to the no-pumping condition, of 26.0 cfs for the Wekiva River at SR 46, 8.9 cfs for the Little Wekiva River at SLB, 4.6 cfs at Wekiwa Springs, 11.1 cfs at Rock Springs, 5.0 cfs at Sanlando Springs, 2.2 cfs at Starbuck Springs, 1.1 cfs at Palm Springs, and 0.8 cfs at Miami Springs (Table 29).

Because the recommended MFLs condition in the basin equals the current-pumping (i.e., defined as the 2014 - 2018 average) condition, the current-pumping condition freeboard (or the allowable change in flow from current pumping) for each MFLs water body in the Wekiva River basin is zero cubic feet per second (cfs).

However, in recent years water use has increased relative to the CP (i.e., 2014 - 2018 average) condition. Therefore, all Wekiva River basin systems are in recovery, and a recovery strategy must be developed concurrently with the MFLs. Consistent with the provisions for establishing and implementing MFLs provided for in section 373.0421, F.S., the recovery strategy identifies a suite of projects and measures that, when implemented, will recover these priority water bodies from impacts due to groundwater pumping withdrawals and prevent the MFLs from not being met due to future consumptive uses of water. The recovery strategy will also provide sufficient water supply options to meet existing and projected reasonable beneficial uses.

The recommended minimum flow for the mainstem of the Wekiva River at SR 46 equates to an allowable reduction in flow, relative to the no-pumping condition, of 8.5% (Table 29). This is similar to the allowable change (10% reduction from natural baseline condition) deemed protective for large river systems with outstanding biological / ecological attributes (Acreman and Ferguson 2010, Richter et al. 2011). The allowable reduction in flow for the Wekiva River is also within the range (3.0 - 19.0%) and similar to the average (7.6%) allowable flow reduction based on adopted MFLs for spring-fed rivers in Florida (Table 31).

The evaluation of numerous environmental values, listed in Rule 62-40.473, F.A.C., also suggests that the MFLs condition protects all relevant water resource values for Wekiva River basin systems (see above and Appendix E for details). This evaluation includes a basin wetland inundation analysis that indicates that a moderate (15.6%) amount of change is occurring to wetland flooding dynamics under the current-pumping condition. Further, an IHA analysis performed demonstrates that numerous biologically-relevant hydrological statistics are starting to exhibit changes under the current-pumping condition (see above, and Appendix F). While the magnitude of change is generally moderate (< 10%) for the majority of IHA parameters, this analysis indicates that biologically meaningful changes to the flow regime are occurring and using the current-pumping condition as the basin-wide MFLs condition is reasonable.

A total of nineteen metrics were evaluated as part of the MFLs Determination, WRVs Assessment (including wetland inundation analysis) and IHA analysis. Taken as a whole, these metrics provide a weight of evidence that it is prudent to limit water withdrawal impact to the current-pumping condition for the Wekiva River basin, given its high ecological and human-use value.

SJRWMD concludes that the recommended minimum flows for the Wekiva River basin will protect relevant Rule 62-40.473, *F.A.C.*, environmental values, from significant harm due to water withdrawals. The information presented in this report is preliminary and will not become effective until adopted by the SJRWMD Governing Board, as directed in Rule 40C-8.031, *F.A.C.*

ONGOING STATUS / ADAPTIVE MANAGEMENT

Given data, modeling and other ecohydrological analysis uncertainties, it is prudent to test implicit assumptions made as part of setting and assessing MFLs. The SJRWMD acknowledges that the MFLs determination and assessment methods, described herein, assume that the Wekiva River basin's hydrological history will repeat itself in the future.

Given the lack of information about the future, and substantial uncertainties in future rainfall and temperature predictions by global climate models, this assumption is thought to be appropriate, but needs to be regularly tested by implementing an adaptive management strategy.

The SJRWMD will implement an adaptive management strategy to address continuing challenges and uncertainties in ecohydrological data and tools. This screening level analysis, which incorporates changes in rainfall trends and uncertainty, will be performed to monitor the status of the adopted minimum flows for each of the eight Wekiva River basin systems.

This analysis will be performed approximately every five years, as well as when permit applications are considered that may impact the MFLs. MFLs status will also be monitored periodically by reviewing the status of system-specific constraining metrics (e.g., the FH for the Wekiva River at SR 46).

If the average long-term observed flow for a given water body falls below the adopted minimum flow, this will trigger a more detailed analysis. This analysis will determine whether reductions in flows are caused by groundwater pumping or rainfall, and whether a further evaluation of the MFLs is necessary. If the screening level analysis shows that MFLs are still being met, then no further actions are required beyond continued monitoring.

If the analysis shows that MFLs are not being met or are trending toward not being met, SJRWMD will conduct a cause-and-effect analysis to independently evaluate the potential impacts of various stressors on the water body in question. Part of this analysis will be to periodically monitor UFA well OR0548 at Wekiwa Springs State Park to evaluate groundwater level trends and the relationship between aquifer levels and spring flows (see Appendix D for details).

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APPENDICES