SPECIAL PUBLICATION SJ2008-SP2

FINAL REPORT
HUMAN USE AND ECOLOGICAL WATER RESOURCE VALUES ASSESSMENTS OF ROCK AND WEKIWA SPRINGS (ORANGE COUNTY, FLORIDA) MINIMUM FLOWS AND LEVELS

Final Report

Human Use and Ecological Water Resource Values Assessments of Rock and Wekiwa Springs (Orange County, Florida) Minimum Flows and Levels

Prepared for

St. Johns River Water Management District

November 9, 2007

Wetland Solutions, Inc.

Executive Summary

In response to a 1988 legislative directive, the St. Johns River Water Management District (District) implemented minimum flows and minimum water levels (MFLs) for surface watercourses in the Wekiva River System (Wekiva River at SR46, Black Water Creek at SR44) and minimum water levels for the groundwater in the aquifer underlying the Wekiva Basin (eight named springs) in 1991. In March 2004, the Wekiva Parkway and Protection Act, Section 369.318(&), Florida Statutes, directed the District to up-date the minimum flow and levels standards for Rock Springs and Wekiwa Springs by December 1, 2007. As a part of this evaluation, the District contracted with Wetland Solutions, Inc. (WSI), an environmental consulting firm with prior project experience in the Wekiva River Basin, to assess whether the water resource and human use values (WRVs) for Rock and Wekiwa springs are protected under the District's MFL hydrologic regime.

When establishing MFLs, Section 62-40.473, Florida Administrative Code, requires water management districts to consider the natural seasonal fluctuations in water flows or levels, nonconsumptive uses, and ten environmental WRVs associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology, including: 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.

"Working" definitions for the ten WRVs developed previously by the District to clarify the development of this assessment include the following:

1. "Recreation in and on the water" - The active use of water resources and associated natural systems for personal activity and enjoyment. These legal water sports and activities may include but are not limited to: swimming, scuba diving, water skiing, boating, fishing, and hunting.
2. "Fish and wildlife habitats and the passage of fish" - Aquatic and wetland environments required by fish and wildlife, including endangered, endemic, listed,

regionally rare, recreationally or commercially important, or keystone species, to live, grow, and migrate. These environments include hydrologic magnitudes, frequencies and durations sufficient to support the life cycles of wetland and wetland dependent species.

3. "Estuarine resources" - Coastal systems and their associated natural resources that depend on the habitat where oceanic saltwater meets freshwater. These highly productive aquatic systems have properties that usually fluctuate between those of marine and freshwater habitats.
4. "Transfer of detrital material" - The movement by surface water of loose organic material and debris and associated decomposing biota.
5. "Maintenance of freshwater storage and supply" - Protection of an amount of freshwater supply for permitted users at the time of MFLs determination.
6. "Aesthetic and scenic attributes" - Those features of a natural or modified waterscape usually associated with passive uses such as: bird watching, sight seeing, hiking, photography, contemplation, painting and other forms of relaxation that usually result in human emotional responses of well-being and contentment.
7. "Filtration and absorption of nutrients and other pollutants" - The reduction in concentration of nutrients and other pollutants through the processes of filtration and absorption (i.e., removal of suspended and dissolved materials) as these substances move through the water column, soil or substrate, and associated organisms.
8. "Sediment loads" - The transport of inorganic materials, suspended in water, which may settle or rise; these processes are often dependent upon the volume and velocity of surface water moving through the system.
9. "Water quality" - The chemical and physical properties of the aqueous phase (i.e., water) of a water body (lentic) or a water course (lotic) not included in #7 (i.e., nutrients and other pollutants) above.

10. "Navigation" - The safe passage of commercial water craft (e.g., boats and ships), that is dependent upon sufficient water depth, sufficient channel width, and appropriate water velocities.

For this analysis of Rock and Wekiwa springs, WSI collected and summarized historical data that are pertinent to the evaluation of the relevant WRVs with a focus on data corresponding to high and low flow/level events. Data included all readily available hydrologic, geologic, ecologic, biologic, recreational, and physicochemical data. Additional data needs were determined following review of historical data. Limited collection of new data relevant to evaluation of the WRVs was authorized by the District. Additional data collection included the following items:

- Elevation cross sections by the District at the spring boil/upper spring run area at 14 locations at Rock Springs and six at Wekiwa Spring
- Ecosystem metabolism estimates from each spring boil study area during four separate sampling events of about two weeks each
- Estimates of particulate export in each of the two study areas during three seasonal sampling events

The District requested that WSI assume that the relevant WRVs at each of the two springs are currently protected by the historical long term flow and level regime. WSI was tasked with determining whether the adopted minimum annual mean flows for Rock and Wekiwa springs are adequate to protect WRVs directly supported in the area of the springs. District staff recommended that this evaluation be based on the use of non-equilibrium frequency analysis of historic hydrologic data to the extent possible. WSI utilized historical and new site specific information, when available, and best professional judgment when necessitated, to evaluate whether a change in hydrology (i.e., from the historical long-term hydrologic regime to that defined under the minimum flow regime) continues to protect the relevant WRVs. When available, quantitative measures were used to support conclusions. This analysis also relied upon literature citations for data from comparable spring systems to assess the protection of WRVs when site-specific quantitative measures were not readily available. Data gaps and uncertainties were found to be present for several of the WRVs being assessed at Rock and Wekiwa springs. For those cases where findings were inconclusive, WRVs were presumed to be protected by the existing spring MFLs with the recommendation for additional data collection and analyses.

Rock Springs was determined to be in a relatively natural state and similar to descriptions from the 1950s (H.T. Odum, unpublished data). All normal spring trophic levels are represented, in spite of a high level of public use in the portion of Rock Springs Run in Kelly Park. Measured rates of ecosystem metabolism in Rock Springs were similar to rates measured in other Florida springs in central Florida. The only apparent degradation observed at this spring was the consistently elevated concentrations of nitrate nitrogen in the source groundwater at the spring boil. This high nitrate concentration is apparently not correlated with increased cover by filamentous algae or reduced metabolism in this upstream area as was previously documented further downstream in Rock Springs Run.

Evaluation of historical data from Rock Springs with the frequency analysis approach found that the estimated return interval for potentially harmful changes to WRVs including ***WRV No. 1***: ***Recreation In and On the Water, WRV No. 2: Fish and Wildlife Habitat and Fish Passage*** and **WRV No. 7: *Filtration and Absorption of Nutrients and Other Pollutants*** could be measurably increased as a result of the District's MFL for this spring. However, considerable uncertainty surrounds the actual magnitude and frequency of these possible effects. For this reason these WRVs were presumed to be protected at Rock Springs with the caveat that additional data collection and analyses will be necessary to confirm this conclusion. Historical discharge data and an evaluation of existing consumptive uses in the springshed indicate that the spring MFL at Rock Springs is being approached and that additional water supply capacity may be nearly depleted due to consumptive use permits (CUPs) that have been approved since inception of the spring MFLs in 1991. For this reason and due to apparently declining flow rates in Rock Springs, ***WRV No. 5: Freshwater Storage and Supply*** may not be protected much longer. Based on historical data and analyses conducted for this evaluation, it is concluded that other relevant WRVs are protected in Rock Springs by the spring MFL (**Table ES-1**).

Wekiwa Spring is apparently degraded compared to its historic condition documented in the early 1950s (H.T. Odum, unpublished data). Physical changes in terms of an expanded spring pool, a stone retaining wall, and high levels of human recreational use activities, as well as elevated nitrate nitrogen concentrations and exotic species impacts have likely resulted in this degraded condition. The cumulative effect of these visible stressors is demonstrated in impaired ecosystem metabolism results compared to other springs in the area and a truncated food chain apparently limited to algae and primary consumers. These historical alterations and impacts at Wekiwa Springs make evaluation of spring MFL-related protection of ***WRV No. 2: Fish and Wildlife Habitat and Fish Passage, WRV No. 7: Filtration and Absorption of Nutrients and Other Pollutants,*** and ***WRV No.9: Water Quality*** difficult. For this reason these WRVs were presumed to be protected with the caveat that their status is obscured due to the observed impacts from recreational development.

The analysis of historical and new data from Wekiwa Springs also indicated the potential for additional impairment of this system based on reduced hydrology as a result of flow reductions as limited by the District's MFLs. In particular the relevant WRVs that appear to be most sensitive to the possible occurrence of reduced flow rates in Wekiwa Spring are ***WRV No. 8: Sediment Loads*** and ***WRV No. 9: Water Quality***. The District's spring MFL does appear to protect ***WRV No. 6: Aesthetic and Scenic Values*** at Wekiwa Springs as well as other relevant WRVs (***WRV No. 1: Recreation In and On the Water*** and ***WRV No. 4: Transfer of Detrital Material***).

Review of historical flow data and of CUPs issued in the vicinity of Wekiwa Springs also found that flows have been declining over the past five decades and that this declining spring discharge is approaching the limits of flow reductions allowed by the District's spring MFL. Based on the understanding that the District's existing steady-state groundwater model is the best estimator of the effects of permitted and un-permitted consumptive uses on spring MFLs, it is presumed that ***WRV No. 5: Freshwater Storage and Supply*** is protected at Wekiwa Springs at the time of this evaluation.

Evaluation of WRV protection in springs is currently an imprecise science, due primarily to a relative paucity of biological and human use data in these systems and also due to a lack of a consensus of most appropriate assessment methods. This evaluation for Rock and Wekiwa springs illustrates some new approaches to assessment of WRVs in springs and also recommends the establishment of more comprehensive data collection efforts in these complex ecosystems. While water quality and flow data are often available for these aquatic systems, recommended new and expanded data collection activities include ecosystem functions, fish and wildlife use, and detailed human uses.

TABLE ES-1
Summary of WRV Assessment Results at Rock and Wekiwa Springs

WATER RESOURCE VALUE	PROTECTED AT ROCK SPRINGS?	PROTECTED AT WEKIWA SPRINGS?
WRV No. 1 - Recreation in and on the Water	Yes*	Yes
WRV No. 2 - Fish and Wildlife Habitat and Fish Passage	Yes*	Yes**
WRV No. 3 - Estuarine Resources	Yes	Yes
WRV No. 4 - Detrital Transfer	Yes	Yes
WRV No. 5 - Freshwater Storage and Supply	Yes	Yes
WRV No. 6 - Aesthetic and Scenic Attributes	Yes	Yes
WRV No. 7 - Filtration and Absorption of Nutrients and Pollutants	Yes*	Yes**
WRV No. 8 - Sediment Loads	Yes	Yes*
WRV No. 9 - Water Quality	Yes	Yes**
WRV No. 10 - Navigation	Yes	Yes

* Indicates an assessment based on considerable uncertainty.

** Indicates this WRV is previously degraded, due to historical conditions other than flow reductions. This baseline condition makes the evaluation of effects due to the MFL subject to greater uncertainty.

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1.0 Introduction

1.1 Background

The Florida Legislature directed the St. Johns River Water Management District (District) to develop a groundwater basin resource availability inventory for the Wekiva River Protection Area (**Figure 1-1**) and establish minimum flows and minimum water levels (MFLs) for surface watercourses in the Wekiva River System and minimum water levels for the groundwater in the aquifer underlying the Wekiva Basin, no later than March 1, 1991 (Section 373.415[3], Florida Statutes [F.S.] 1988). To meet this directive, the District developed and adopted MFLs for the Wekiva River at State Road (SR) 46, Black Water Creek at SR 44, and minimum annual mean flows for eight springs (i.e., Messant, Miami, Palm, Rock, Sanlando, Seminole, Starbuck, and Wekiwa) in the Wekiva River Basin within this time frame (Hupalo *et al.* 1994).

Additionally, in July 2003, Governor Jeb Bush created the Wekiva River Basin Coordinating Committee by Executive Order 2003-112. The committee was created as a forum to identify land use planning strategies and development standards to assure protection of surface and groundwater resources, including recharge potential of the Wekiva Study Area. The Committee presented its report to the Governor and Department of Community Affairs on March 16, 2004. The recommendations of the Committee's report became the Wekiva Parkway and Protection Act, Section 369.318(7), F.S. The Act directed the District to update the minimum flow and level standards for Rock Springs and Wekiwa Springs by December 1, 2007.

In order to meet this Legislative directive, the District identified the following tasks to be completed:

1. Evaluate the MFLs established for the Wekiva River at the SR 46 Bridge based on the historical flow and stage data of the Wekiva River (1936-2004) to verify whether the adopted MFLs are being achieved. Additionally, data collected at a recently (1995) established upstream gauging station (Wekiva River at Old RR Crossing) will also be analyzed to determine the suitability of this location as an alternative MFLs

monitoring site. The findings will be presented in a report entitled: An Evaluation of Minimum Flows and Levels for the Wekiva River at the State Road 46 Bridge, Florida, using the 1935-2004 USGS Streamflow Data, scheduled to be completed by August 1, 2007.

2. Assess whether the hydrologic regime defined by the adopted minimum heads and discharges for Rock and Wekiwa springs (Section 40C-8.031(1)(b), Florida Administrative Code [F.A.C.]) protect the water resource and human use values (WRVs) identified in Section 62-40.473, F.A.C.

Wetland Solutions, Inc. was contracted by the District to complete the WRV assessment. This report assesses whether the relevant WRVs for Rock and Wekiwa springs are protected under the District's adopted minimum heads and discharges (springs MFLs).

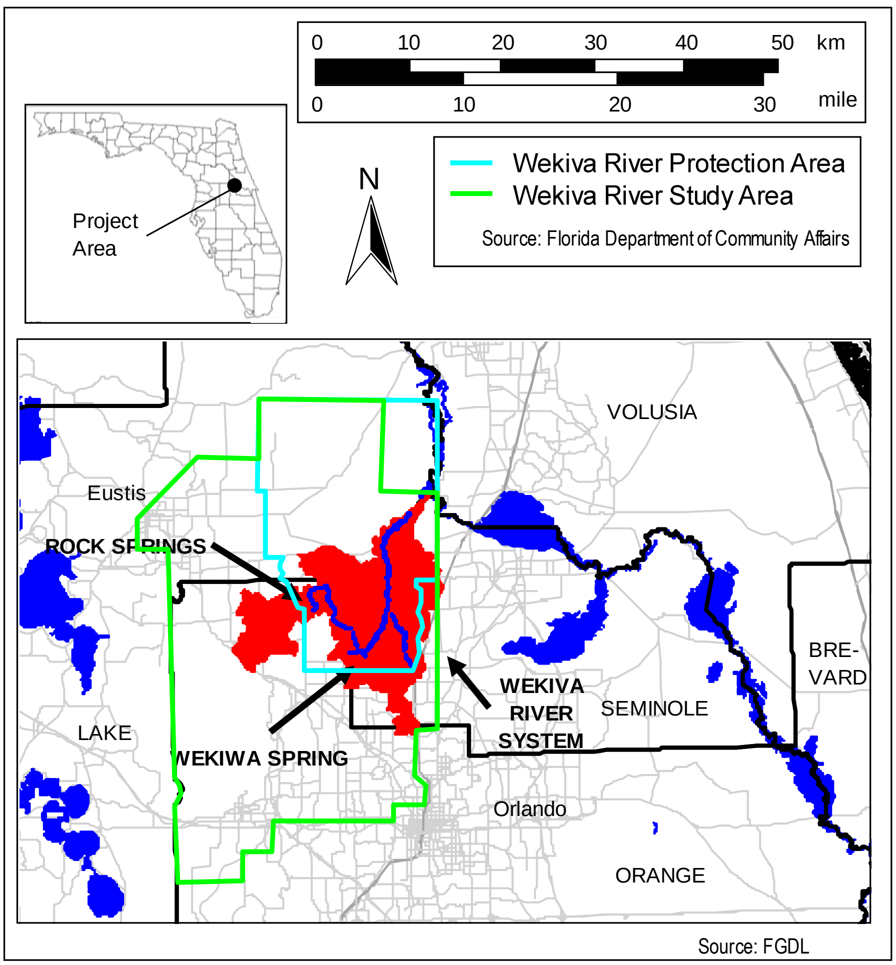

FIGURE 1-1
Wekiva River Protection and Study Areas. The Wekiva River watershed is highlighted in red

1.2 Description of Water Resource Values

The District's Minimum Flows and Levels (MFLs) Program is mandated by state water policy (Section 373.042, F.S.) and establishes MFLs for lakes, streams and rivers, wetlands, and groundwater aquifers. MFLs define the minimum frequencies or return intervals of high, intermediate, and low water events (defined by magnitude, frequency, and duration hydrologic components) necessary to prevent significant ecological harm to aquatic and wetland habitats from permitted water withdrawals (Neubauer *et al.* 2007). The MFLs Program is subject to the provisions of Chapter 40C-8, F.A.C., and provides technical support to the District's regional water supply planning process and the consumptive use permitting program.

MFLs define an environmentally protective hydrologic regime that prevents significant ecological harm and identify levels and/or flows above which water is available for reasonable beneficial use. The determination of MFLs gives consideration to non-consumptive uses of water including: navigation, recreation, fish and wildlife habitat, and other natural resources. MFLs take into account the ability of wetlands and aquatic communities to adjust to changes in the frequencies of hydrologic events. Therefore, MFLs allow for an acceptable level of hydrologic change to occur relative to the historical hydrologic conditions. However, when use of water resources shifts the hydrologic conditions below those defined by the MFLs, significant harm will likely occur. As it applies to wetland and aquatic communities, significant harm is a function of changes in the frequencies of water level and/or flow events of a defined duration causing unacceptable changes to ecological structures and/or functions. Florida law also requires that a recovery strategy be implemented for systems that are below established MFLs and that a prevention strategy be developed for systems that are projected to be below adopted MFLs within 20 years (Section 373.0421(2), F.S.).

When establishing MFLs, Section 62-40.473, F.A.C., requires water management districts to consider the natural seasonal fluctuations in water flows or levels, nonconsumptive uses, and ten environmental WRVs associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology, including: 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.

"Working" definitions for the ten WRVs developed previously by the District to clarify the development of this assessment include the following:

1. "Recreation in and on the water" - The active use of water resources and associated natural systems for personal activity and enjoyment. These legal water sports and activities may include but are not limited to: swimming, scuba diving, water skiing, boating, fishing, and hunting.
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4. "Transfer of detrital material" - The movement by surface water of loose organic material and debris and associated decomposing biota.
5. "Maintenance of freshwater storage and supply" - Protection of an amount of freshwater supply for permitted users at the time of MFLs determination.
6. "Aesthetic and scenic attributes" - Those features of a natural or modified waterscape usually associated with passive uses such as: bird watching, sight seeing, hiking, photography, contemplation, painting and other forms of relaxation that usually result in human emotional responses of well-being and contentment.
7. "Filtration and absorption of nutrients and other pollutants" - The reduction in concentration of nutrients and other pollutants through the processes of filtration

and absorption (i.e., removal of suspended and dissolved materials) as these substances move through the water column, soil or substrate, and associated organisms.

8. "Sediment loads" - The transport of inorganic materials, suspended in water, which may settle or rise; these processes are often dependent upon the volume and velocity of surface water moving through the system.
9. "Water quality" - The chemical and physical properties of the aqueous phase (i.e., water) of a water body (lentic) or a water course (lotic) not included in #7 (i.e., nutrients and other pollutants) above.
10. "Navigation" - The safe passage of commercial water craft (e.g., boats and ships), that is dependent upon sufficient water depth, sufficient channel width, and appropriate water velocities.

1.3 Project Approach

The following work tasks were performed by WSI to accomplish the Rock and Wekiwa springs WRV project.

1.3.1 Site Visit

WSI prepared for and participated in a site visit to each spring with the District Project Manager and staff. This site visit occurred on September 27, 2006. The objective of the site visit was to provide the project team with an overview of the study area and to agree on which of the ten WRVs were most relevant to the protection of these two spring-fed ecosystems.

1.3.2 Project Work Plan

WSI prepared a detailed written Project Work Plan describing: assumptions, steps, methods, and procedures required to assess the hierarchical framework of functions, criteria, thresholds, parameters, and measures that support the protection of relevant WRVs. The draft Project Work Plan was reviewed by the District's Project Manager and staff and discussed in detail at a Chartering Meeting held on November 27, 2006 in Palatka. The final

Project Work Plan incorporated the comments and recommendations provided by the District and was issued by WSI on December 8, 2006.

1.3.3 Collection and Analysis of Historical and New Data

WSI collected and summarized historical data that are pertinent to the evaluation of the relevant WRVs and consistent with the project work plan. Data included all readily available hydrologic, geologic, ecologic, biologic, recreational, and physicochemical data. Additional data needs were determined following review of historical data. Limited collection of new data relevant to evaluation of the WRVs was authorized by the District. Additional data collection included the following items:

- Elevation cross sections by the District at the spring boil/upper spring run area at 14 locations at Rock Springs and six at Wekiwa Springs
- Ecosystem metabolism estimates from each spring boil study area during four seasonal periods of about two weeks duration each
- Estimates of particulate export in each of the two study areas during three seasonal sampling events
- Estimates of diurnal recreational uses at Rock and Wekiwa springs

1.3.4 Water Resource and Human-Use Values (WRVs) Assessment

The specific methods used for the WRV assessments are recommended by qualified contractors, reviewed by District staff, and subjected to peer review. For the Rock and Wekiwa springs WRV assessments, WSI has utilized a combination of approaches to evaluate whether the District's springs MFLs are protective of the ten WRVs. The District requested that WSI assume that the WRVs of each of the two springs are currently protected by the historic long term flow and level regime. The minimum annual mean spring heads and discharges (springs MFLs) were determined based on providing adequate headwater flows downstream in the Wekiva River at the SR 46 bridge. No evaluation of harm to WRVs in the springs was conducted when the original Wekiva River MFLs were established in 1991.

WSI was tasked with determining whether the adopted minimum annual mean spring flows are still adequate to protect WRVs directly supported in the area of the springs. District staff recommended that the WRV assessment should utilize the long-term frequency analysis approach described by Neubauer *et al.* (2007). In addition to frequency analyses, WSI applied a variety of standard time series analyses, correlation analyses, statistical analyses, and spreadsheet simulation models to examine relationships between quantitative metrics for each WRV and spring discharge. While these methods relied on simplifying assumptions about environmental dynamics, they also provided a defensible basis for establishing an event-based assessment of WRV protection.

WSI utilized existing information, when available, and best professional judgment when necessitated, to evaluate whether a change in hydrology (i.e., from the historical long-term hydrologic regime to that defined under the minimum flow regime) continues to protect the relevant WRVs. When available, quantitative measures were used to support conclusions. This analysis also relied upon literature citations and data from similar spring systems to assess the protection of WRVs when site-specific quantitative measures were not readily available. Limited collection of new data was also utilized for this analysis.

This report documents the adequacy of data to support conclusions and recommendations; identifies sources of uncertainty; and describes the impact of uncertainty on conclusions and recommendations regarding the WRV assessments. This report describes and summarizes data gaps that impair the assessment of the minimum annual mean spring flows on relevant WRVs and provides preliminary monitoring recommendations to help fill identified critical data gaps.

2.0 Description of the Target Spring Systems

2.1 General Information

The scope of this project was limited to the assessment of the adopted minimum annual mean flows for Rock and Wekiwa springs and their initial spring runs. The defined area of each spring and spring run extended downstream to the first point of significant surface water inflows (**Figure 2-1**). Both the Wekiva River and Rock Springs Run below these points begin to take on increasing similarity to blackwater streams rather than spring runs due to seasonal influences of stormwater runoff from adjacent uplands and wetlands. The ecology of these downstream aquatic ecosystems becomes increasingly heterotrophic, relying on allochthonous organic inputs rather than autotrophic carbon production typical of spring boils and spring runs (WSI 2006). The MFLs adopted for the Wekiva River at SR 46 were intended to protect these more riverine systems and their associated floodplain wetlands from significant harm.

Rock Springs, the primary headwater spring of Rock Springs Run is located northwest of Wekiwa Springs (**Figure 2-1**). Rock Springs is located entirely within Orange County's Kelly Park. Rock Springs Run also receives input from Sulfur Spring and flows north, east, and then southeast for a distance of about 14.2 km (8.8 miles) before joining with Wekiwa Springs Run about 1,065 m (3,500 ft) east of Wekiwa Spring.

The Wekiva River flows east from Wekiwa Springs and then north to its confluence with Rock Springs Run. The Wekiva River then flows northeast from this confluence for about 5.9 km (3.7 miles) to its confluence with the Little Wekiva River whose headwaters are in north Orlando. From there, the Wekiva River flows north and northeast from its confluence with the Little Wekiva River for about 14.4 km (8.9 miles), crossing under SR 46 about 21 km (13 miles) east of Mount Dora and 14.5 km (9 miles) west of Sanford. The Wekiva River receives additional input of dark water at its confluence with Blackwater Creek, about one mile upstream of its confluence with the St. Johns River. The Wekiva River is the legal boundary between Orange and Seminole counties to the south and Lake and Seminole Counties.

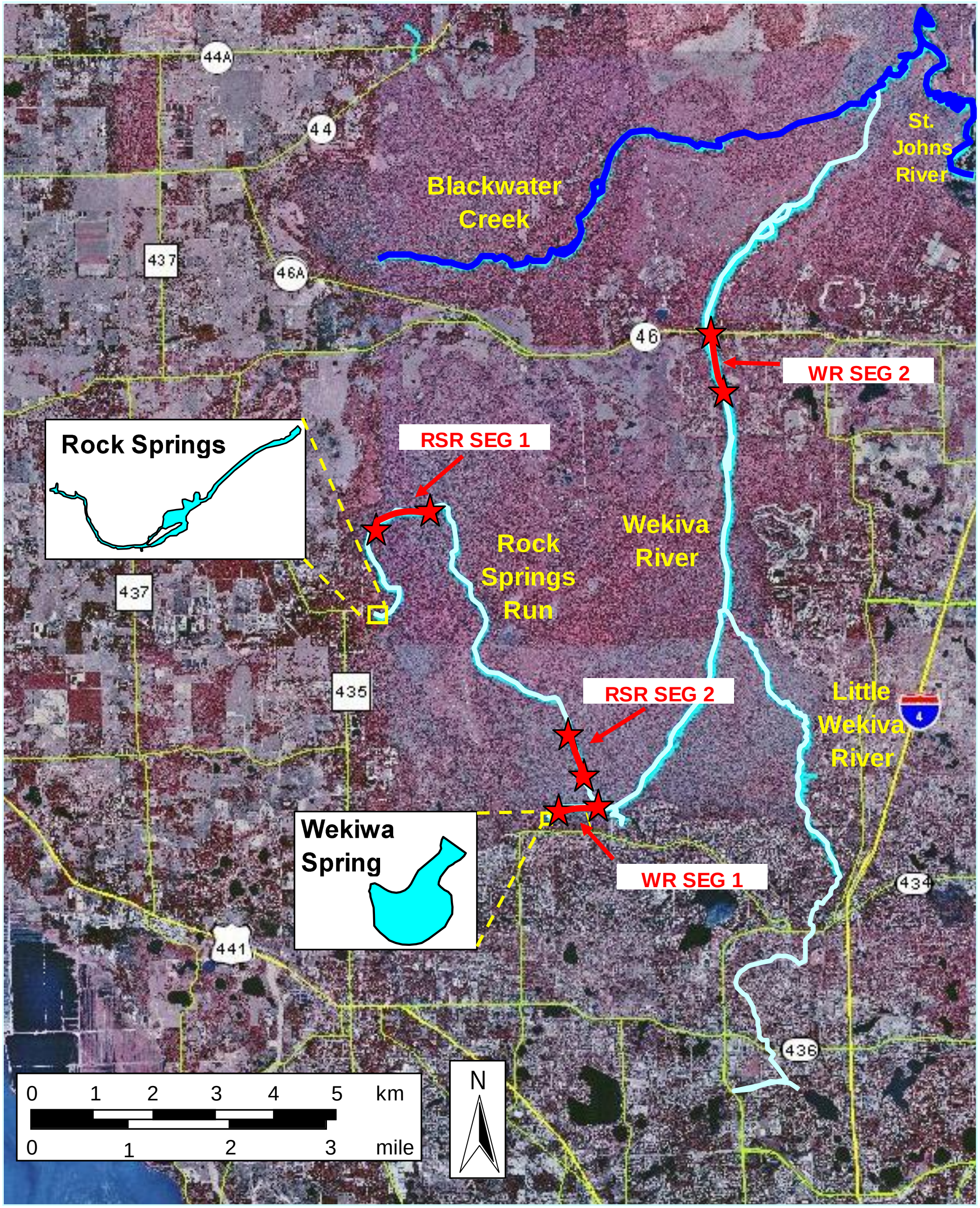


FIGURE 2-1
Rock and Wekiwa Springs Study Areas Illustrating their Relationship to Rock Springs Run and the Wekiva River. Segments for Pollutant Load Reduction Goal (PLRG) Analysis (WSI 2006) are indicated for Rock Springs Run (RSR) and for the Wekiva River (WR)

Wekiwa Springs State Park and Rock Springs Run State Preserve include about 7,850 ha (19,400 acres) of uplands, wetlands, and aquatic habitats surrounding Wekiwa Springs, Rock Springs, Rock Springs Run, and the southern end of the Wekiva River. The northern reach of the Little Wekiva River, northwest of Altamonte Springs, is located within the Wekiva River Buffer Conservation Area. The northern one third of the Wekiva River is located in the Seminole State Forest. The Wekiva River State Aquatic Preserve includes the Wekiva River, Rock Springs Run, the lower (north) reach of the Little Wekiva River, and Blackwater Creek. The Wekiva River and Rock Springs Run are listed as Outstanding Florida Waters (OFWs) and their water quality has a higher level of protection as a result of that designation. The Wekiva River and Rock Springs Run were designated as Wild and Scenic Rivers by the federal government in 1999.

The entire length of the Wekiva River and Rock Springs Run is a State Canoe Trail and is one of the most heavily used in the state of Florida. Attendance at the Wekiwa Spring State Park averages more than 200,000 human-use-days per year (FOWR 1985).

Average rainfall totals for the Wekiva River System area are 131 cm/yr (51.5 in/yr) based on data from multiple stations in the project area for the period 1931-2001 (WSI 2004). The maximum and minimum annual average rainfall amounts during this period were typically between 76 and 190 cm/yr (30 and 75 in/yr), respectively. There was no apparent trend in rainfall amounts within the analyzed period-of-record.

There are 13 named springs that directly contribute to flows into the Wekiva River in the project area. It has been demonstrated by several researchers that these springs are all artesian and discharge from the upper portion of the Floridan aquifer (Rao and Clapp 1996; Toth 1999). While most of this groundwater flow enters the system through named springs, some results from leakage between the Floridan aquifer and the surficial aquifer and then enters the rivers and spring runs as seepage flow.

2.2 Rock Springs and Kelly Park

2.2.1 Site Location

Rock Springs is located in Orange County, Florida, approximately 10.1 km (6.3 miles) north of Apopka in the Dr. Howard A. Kelly County Park (**Figure 2-2**). Driving directions include:

from the intersection of US 441 and State Road (SR) 435 in Apopka, drive north on SR 435 for 9.5 km (5.9 miles); turn east (right) on Rock Springs Road and drive 0.5 km (0.3 miles) to the park entrance; the springs are located southeast of the parking lot (SJRWMD: http://floridaswater.com/springs/).

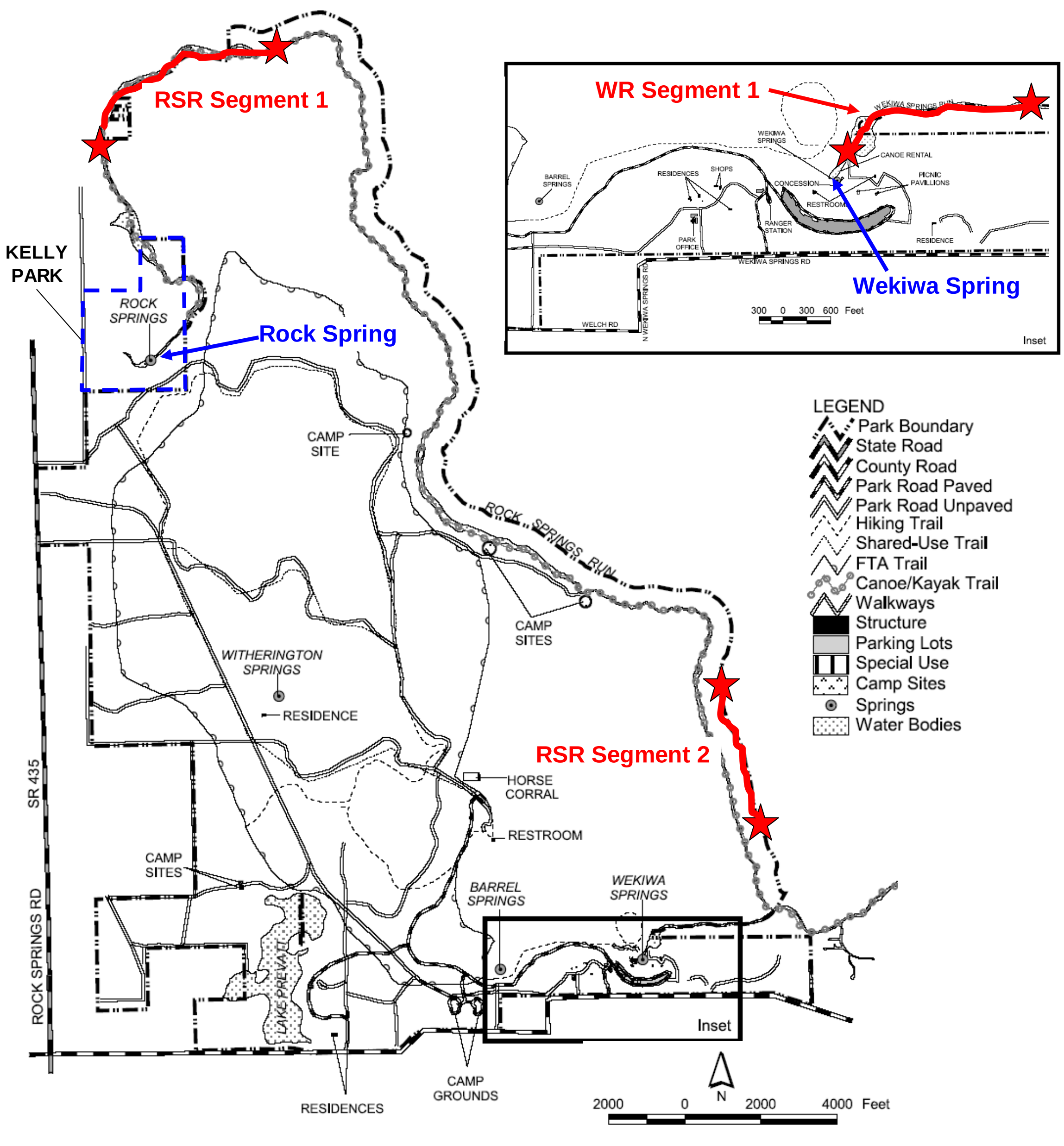


FIGURE 2-2
Rock and Wekiwa Springs Study Areas, Including Head Spring Areas (blue on map) and Spring Run Segments (red on map) from Related Pollutant Load Reduction Goal (PLRG) Study (WSI 2006). WR Segment 2 is located approximately 13 river miles north on the Wekiva River upstream from the SR 46 bridge (see **Figure 2-1**)

2.2.2 WRV Assessment Project Area

For the purposes of this project it is assumed that Rock and Wekiwa springs include the uppermost portion of the spring runs, downstream to a point where surface water inputs from other sources result in measurable changes to water quality and other environmental conditions (primarily due to the input of swamp surface waters with high color and low specific conductance). **Figures 2-3** and **2-4** illustrate the relevant project area for Rock Springs and Rock Springs Run. This area includes the main vent for Rock Springs and approximately 650 m (2,130 ft) of Rock Springs Run located in Kelly Park. The estimated water surface area for this portion of Rock Springs was estimated based on a series of fourteen survey cross sections (**Appendix F**) and is about 12,200 m^2 (3.0 ac) at the median recorded water stage.

2.2.3 Summary of Discharge and Stage Data

This analysis utilized discharge data for Rock Springs for the period November 24, 1959 to September 30, 2005 (**Figure 2-5**). A total of 2,414 discharge estimates were available for this time period (Intera 2006). Over this entire period-of-record (POR) the average spring discharge was 53.4 cubic feet per second (cfs) and the range of observed values was 34.1 to 83.2 cfs. Intera (2006) used interpolation and regression analyses to develop synthetic daily discharge estimates for Rock Springs (**Figure 2-5**).

For purposes of simulation, Intera (2006) divided the historical flow record into two data periods (1959-1997 and 1998-2005) that represented two different levels of available information. Based on their detailed analysis of these two sequential data periods, Intera (2006) concluded that the flow duration curve (FDC) for Rock Springs has changed over time (**Figure 2-6**). Although the cause of this change was not determined, the data for Rock Springs indicate a median flow reduction from about 60 cfs for the POR from 1959-1997 to about 54 cfs (10% decline) for the shorter POR from 1998-2005. **Figure 2-7** illustrates flow duration curves for Rock Springs for the last five decades using the Intera modeled flow data. This analysis shows that median and low flows have consistently declined in this spring for each of the past five decades with a median flow of 64.1 cfs estimated in the 1960s and a median flow of 55.0 cfs in the 2000s. Based on the Intera simulated data for Rock

Springs, the estimated average and median flows over the period-of-record are about 59 cfs, which is higher than the actual observed average flow (53.4 cfs). This difference is presumably due to the lower frequency of discharge measurements in the early record compared to the more recent flow record. The range of simulated flow data for Rock Springs was from 34.1 to 85.5 cfs.

German (2004) conducted an independent analysis of 280 physical discharge measurements for Rock Springs for the period from February 1931 to September 2003. He stated that trend testing indicated a downward trend in discharge for this spring over time. However, statistical tests found that this trend was not monotonic and therefore was inconclusive. He also indicated that the observed trend may have been due to decreased rainfall and that other evidence exists that indicates that discharge at Rock Spring may have increased in relation to rainfall. Tibbals *et al.* (2004) examined possible causes for observed declining flows (about 50% since the early 1960s) in the Upper Ocklawaha River Chain of Lakes located just west and southwest of Rock and Wekiwa springs in Lake and Orange counties. Lowered potentiometric levels in the Floridan aquifer due to groundwater pumping and drought were listed as two of the possible explanations for the observed flow reductions.

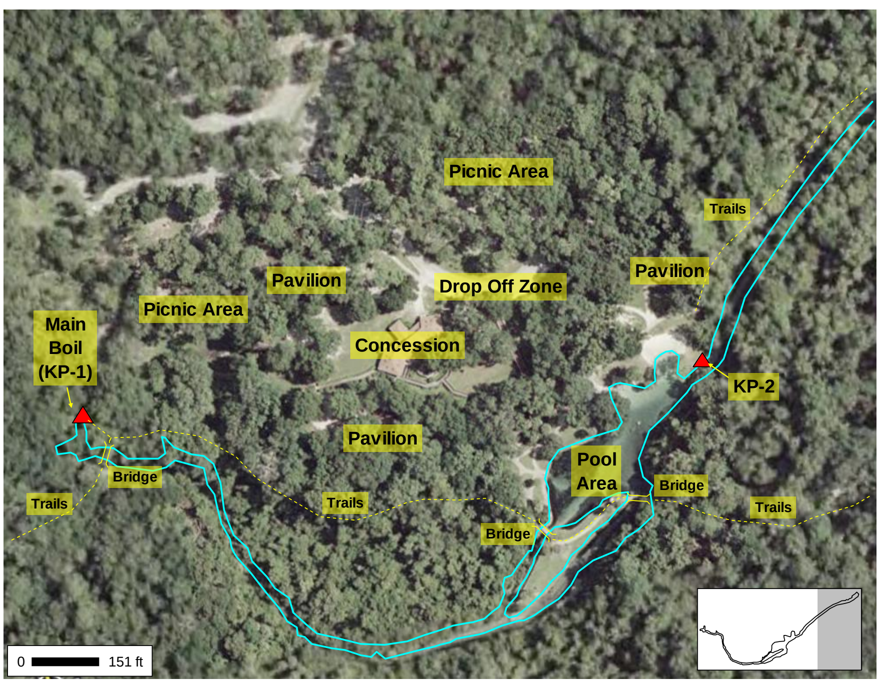


FIGURE 2-3
Rock Springs and Kelly Park Site Map Showing Sampling Locations Described in the Text [▲] (Map Part 1)

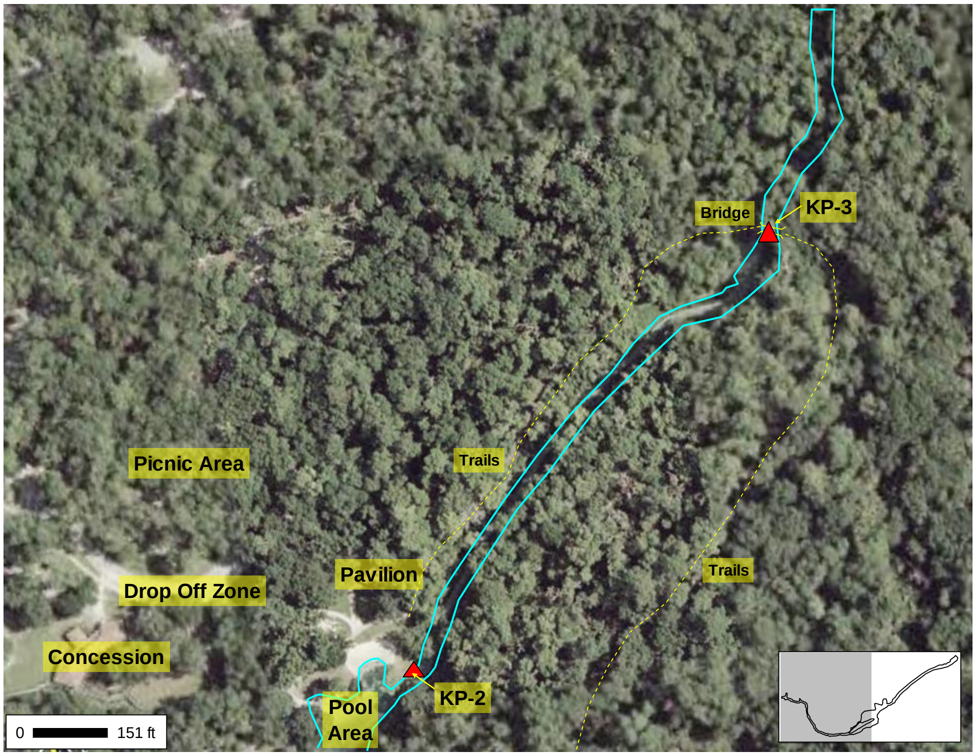


FIGURE 2-4
Rock Springs and Kelly Park Site Map (Map Part 2)

The Florida Department of Natural Resources (FDNR 1987) reported that the U.S. Geological Survey had found that based on a review of data for the period from 1969 to 1982, that flows in Rock Springs had declined by 20%.

Figure 2-7 illustrated a consistently declining trend by decade for flows at Rock Springs. **Figure 2-8** provides an alternate view of these trends based on the temporal series of annual average flows. **Figure 2-8** displays the actual and Intera modeled flow data for Rock Springs over the period-of-record from about 1960 through 2005. The District's minimum annual mean flow of 53 cfs for Rock Springs is shown on this figure as a horizontal line. Annual average flows have followed a declining trend through the past forty years. Actual and modeled flows began to occasionally drop below the MFL for Rock Springs beginning in 1981 and have subsequently fallen below that level seven times in the past 19 years (37%). These data indicate that the allowable spring MFL for Rock Springs is being approached, and within a possible range of uncertainty associated with these estimates, may have already been reached, presumably as a result of a combination of anthropogenic consumptive uses and climatic conditions.

Stage data at Rock Springs are available for the period from March 1984 to May 2007 (**Figure 2-9**). A total of 1,853 stage measurements were available for this POR. Average stage at the Rock Springs gauge (located about 1,400 ft downstream of the Main Boil) for this POR was 26.19 ft NGVD with a range of observed values from 25.61 to 26.93 ft NGVD.

2.2.4 Physical Conditions

Limited physical data are available for Rock Springs and the upper spring run within the project area. A total of 14 surveyed cross sections were made on February 20, 2007 in this area (**Appendix F**) when the recorded water surface elevation was 26.28 ft NGVD. These cross sections were used to estimate the physical dimensions (surface area, volume, and average depth) within the project area (**Table 2-1**). A complete bathymetry, indicating possible controlling water depths and obstacles for the stream, is not available. Based on field observations and interviews with individuals tubing the run, there are a number of rocks and shallow areas that affect the enjoyment of this popular recreational activity. For this reason, average depths only provide an available approximation of actual hydraulic controls on flows and recreation within Rock Springs Run within the study area.

Based on the 14 surveyed transects measured by the District for this project, **Figure 2-10** provides estimates of the relationships in Rock Springs Run between stage and surface area and water volume. At a median surface water elevation of 26.15 ft NGVD, the estimated wet surface area of the project area is 12,200 m^2 (3.02 ac) and the water volume is 7,460 m^3 (263,320 ft^3).

TABLE 2-1
Kelly Park / Rock Springs – Survey Cross Section Area/Volume Estimates (see **Appendix F** for transect locations and cross sections) at an Observed Water Surface Elevation of 26.28 ft NGVD

	Transect			Interval			
Transect	Channel Width (m)	Average Depth (m)	Cross-Sectional Area (m^2)	Distance Between Transects (m)	Estimated Area (m^2)	Average Cross-Sectional Area (m^2)	Estimated Volume (m^3)
2	18.6	0.66	12.3	---	---	---	---
3	9.1	0.62	5.5	67.7	938.5	8.9	602
4	10.7	0.50	5.2	50.6	501.3	5.4	271.8
5	26.2	0.44	11.3	104.9	1,933.4	8.3	866.1
6	25.9	0.50	12.9	58.5	1,523.5	12.1	708.5
7	37.8	1.20	45.4	45.4	1,445.4	29.2	1,325.3
8	22.9	0.89	20.0	26.8	813.5	32.7	878.0
9	20.0	0.87	17.2	25.0	535.2	18.6	464.5
11	12.8	0.70	8.9	73.2	1,198.5	13.0	951.8
12	15.8	0.67	10.7	59.1	847.1	9.8	577.2
13	16.8	0.55	9.1	61.3	999.0	9.9	603.6
14	17.4	0.59	10.0	75.6	1,647.2	10.7	806.4
Total	---	---	---	648	12,382	---	8,055
Average	19.5	0.68	14.0	58.9	1,125.7	14.4	732.3

Calculated Depth (m): 0.65

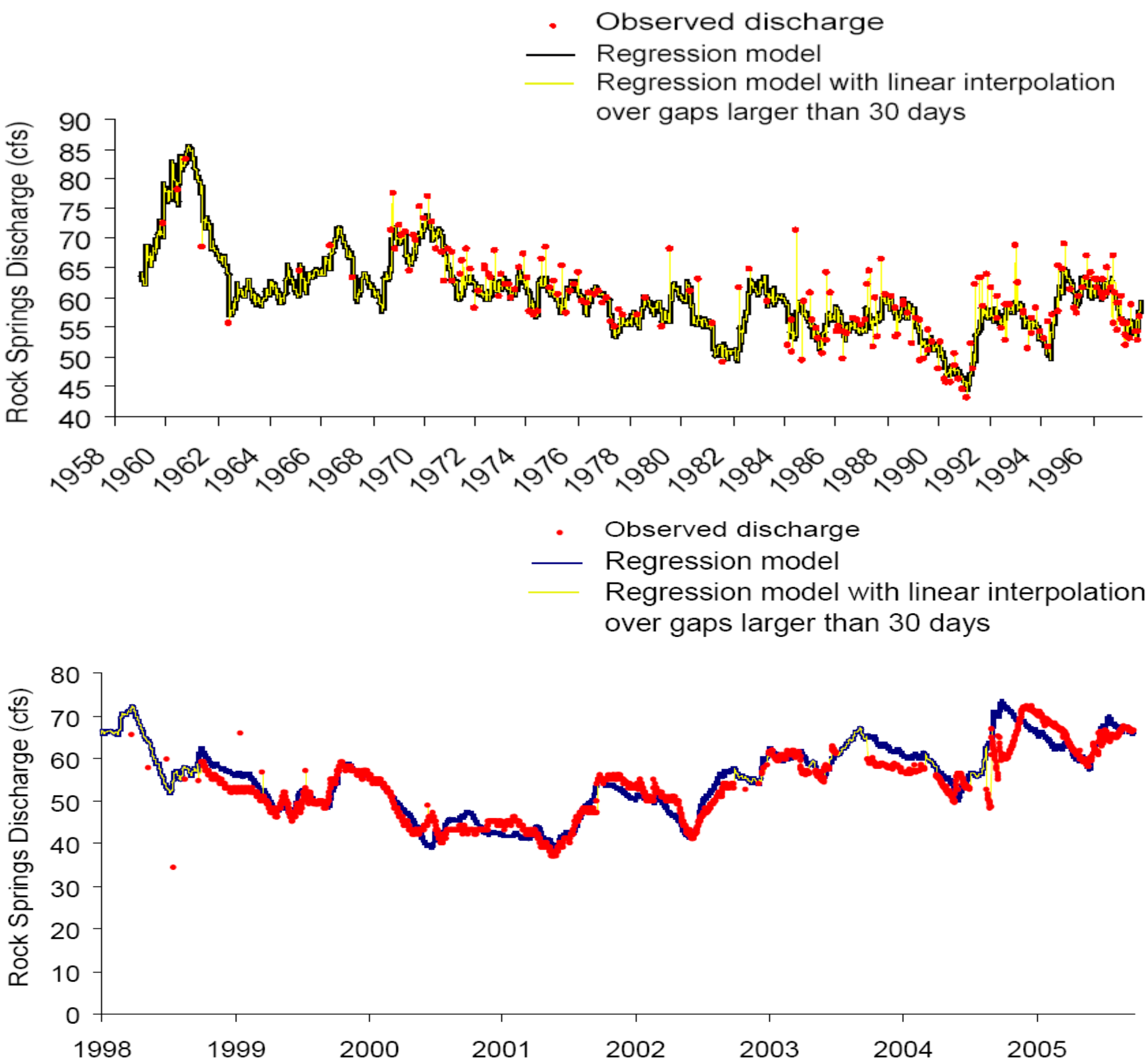


FIGURE 2-5
Time Series of Predicted and Observed Discharge for Rock Springs (Intera 2006)

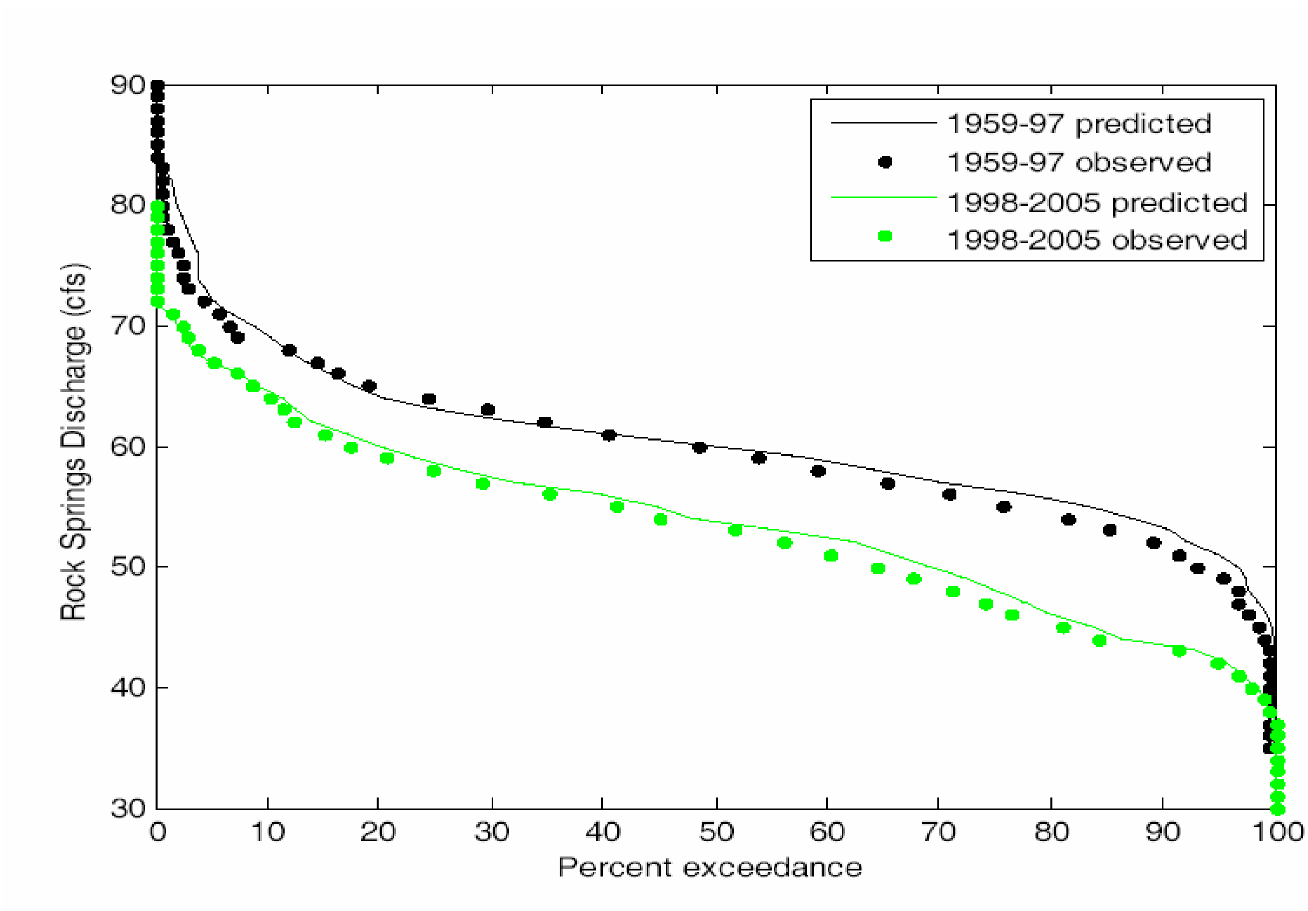


FIGURE 2-6
Flow Duration Curves for Rock Springs over 1959-1997 and 1998-2005 (Intera 2006)

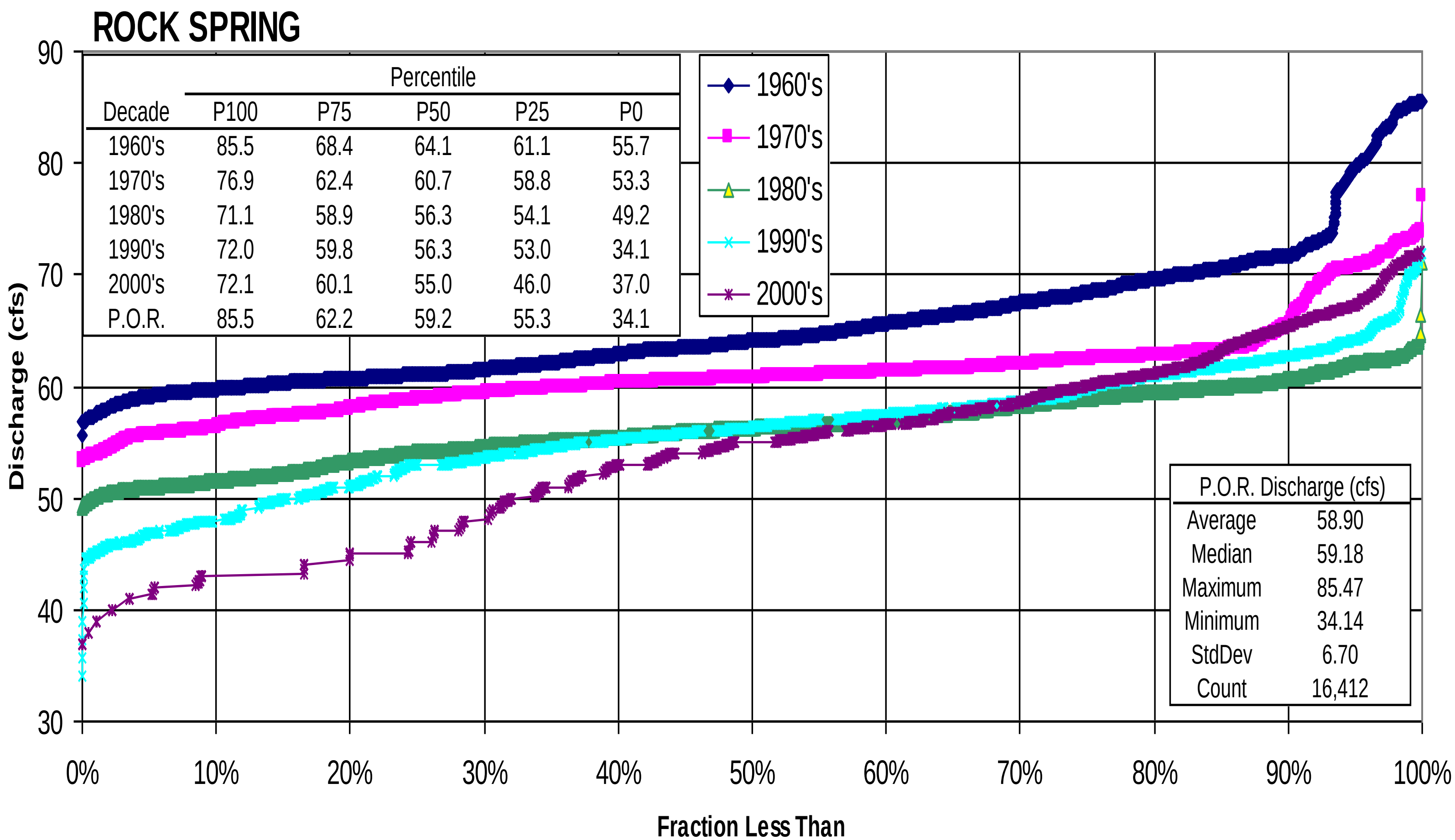


FIGURE 2-7
Rock Springs Flow Duration Curves for the Past Five Decades (based on simulated data from Intera 2006)

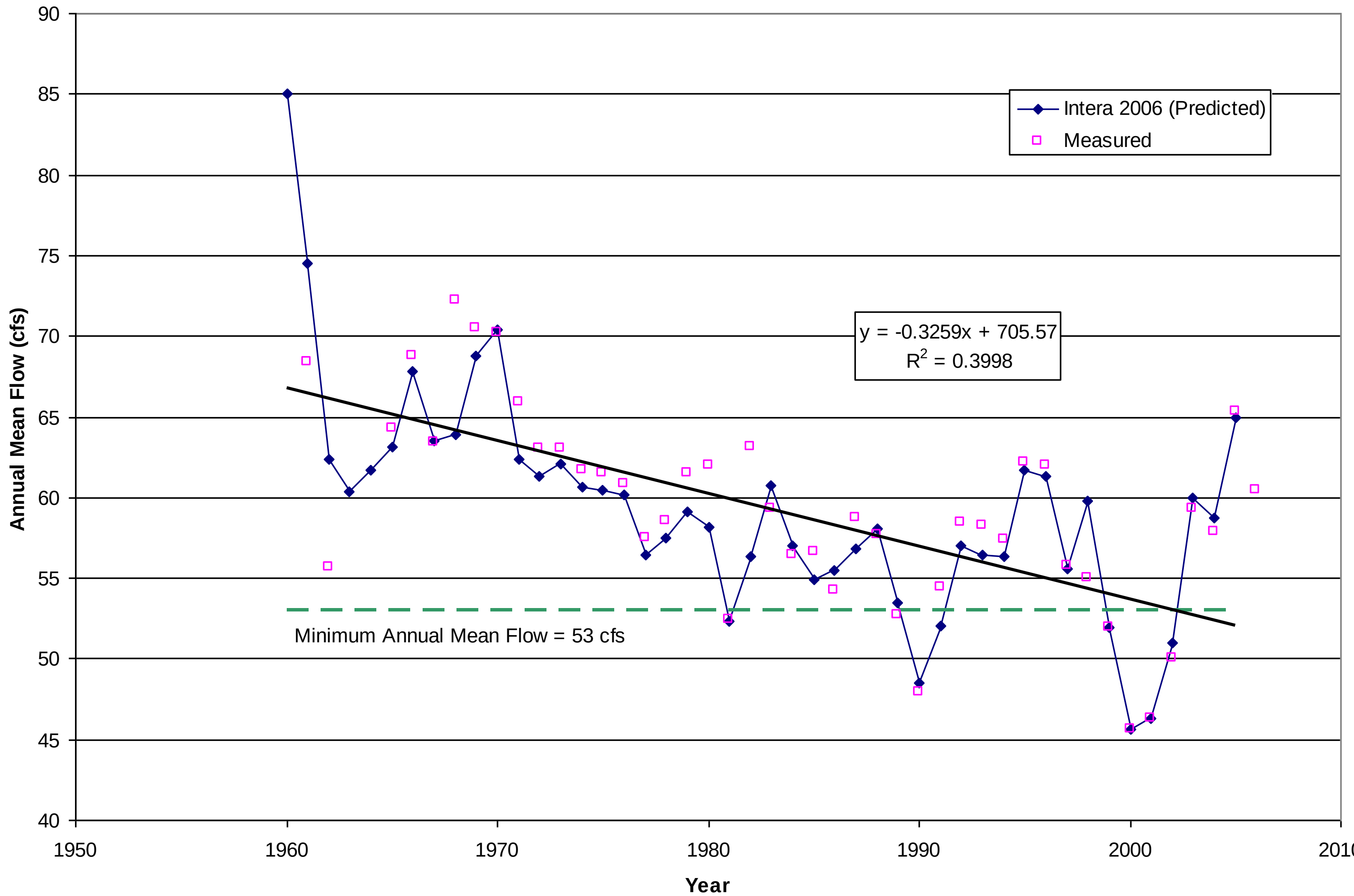


FIGURE 2-8
Time Series Plot of Annual Average Flows (Measured and Modeled) at Rock Springs Compared to the Existing District MFL of 53 cfs

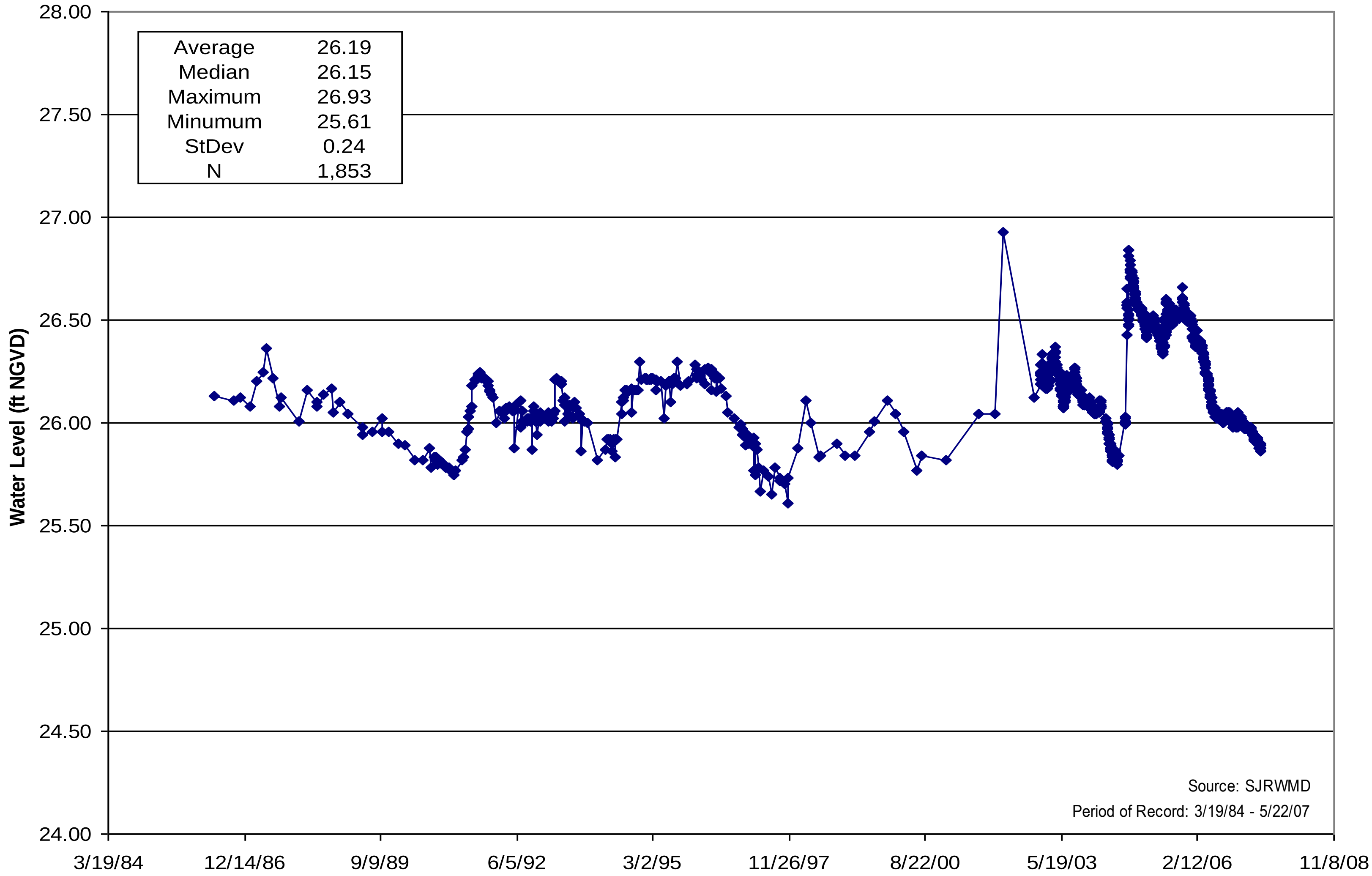


FIGURE 2-9
Time Series of Water Levels for Rock Springs 1984 - 2007

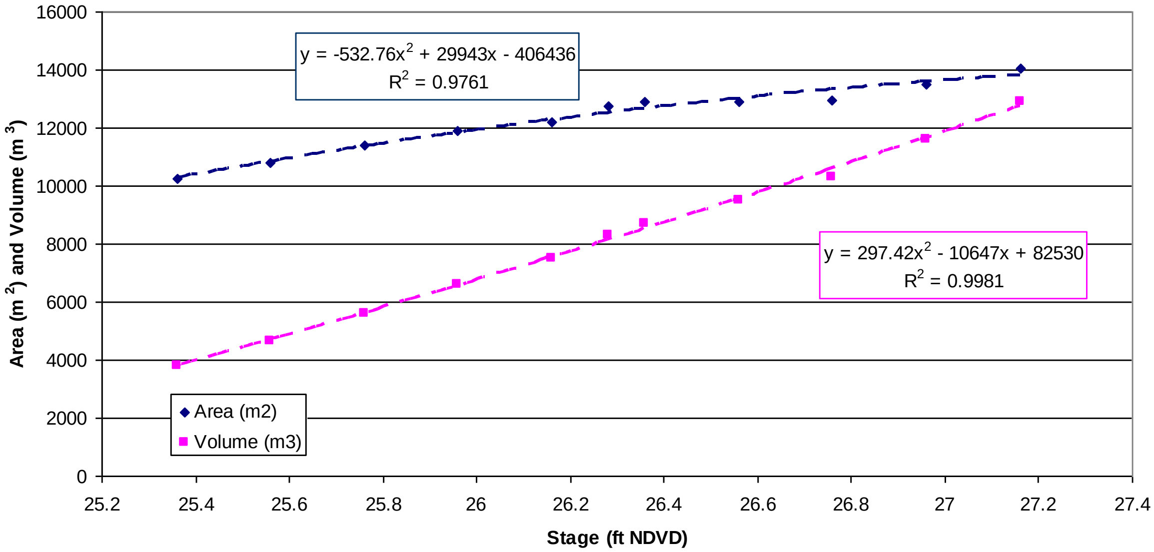


FIGURE 2-10
Rock Springs Estimated Stage/Area and Stage/Volume Relationships

An effort was made to use historical information to estimate the effects of discharge at Rock Springs on the hydraulics of the study area. The most recent stage vs. discharge relationship for the Rock Springs gauge located in Kelly Park at KP2 (see **Figure 2-3**) is illustrated in **Figure 2-11** plotted with all pairs of stage and discharge data available from the District. At Rock Springs most of the recorded data generally fall along a predictive line (R^2 = 0.41), although some of the data points illustrate a weaker relationship between discharge and gage height under some conditions (as much as 0.6 m (2 ft) of variation in stage for a given discharge rate). This discrepancy is probably related to some backwater effects in the Rock Springs Run downstream of Rock Springs (Tom Mirti, St. Johns River Water Management District, personal communication, 2007). The regression equation presented in **Figure 2-11** for Rock Springs appears to provide a reasonable relationship between stage and discharge during most water conditions in the Rock Springs Run. This regression indicates that stage (and resulting water volume) decline in rough proportion to spring discharge. Based on the stage vs. discharge regression illustrated in **Figure 2-11** and on the survey data summarized in **Appendix F**, **Table 2-2** provides estimates of the spring discharge, the wetted surface area, the water volume, the nominal hydraulic residence time (nHRT), and the mean velocity of water in the Rock Springs study area as a function of water stage at the District's recorder station located in Kelly Park. The nHRT was estimated by dividing the estimated water volume at a given water stage by the discharge rate corresponding to that stage. Mean flow velocities were estimated based on dividing the total flow distance (about 650 m) by the nHRT.

Within the range of historical water levels observed at Rock Springs, the estimated current velocities in this section of Rock Springs Run range from about 13 to 16 cm/s and nHRTs range from 1.1 to 1.4 hrs. **Table 2-3** provides estimates of channel cross-sections with a depth of at least 0.45 m (1.5 ft) at Rock Springs Run in Kelly Park over a range of water stage elevations at the recorder station. At the average recorded stage of 26.19 ft NGVD, the estimated limiting channel width at this depth is about 2.1 m (7 ft) on Transect 6 (see **Appendix F**). This "pinch-point" is assumed to be a limiting width for various recreational activities as described below.

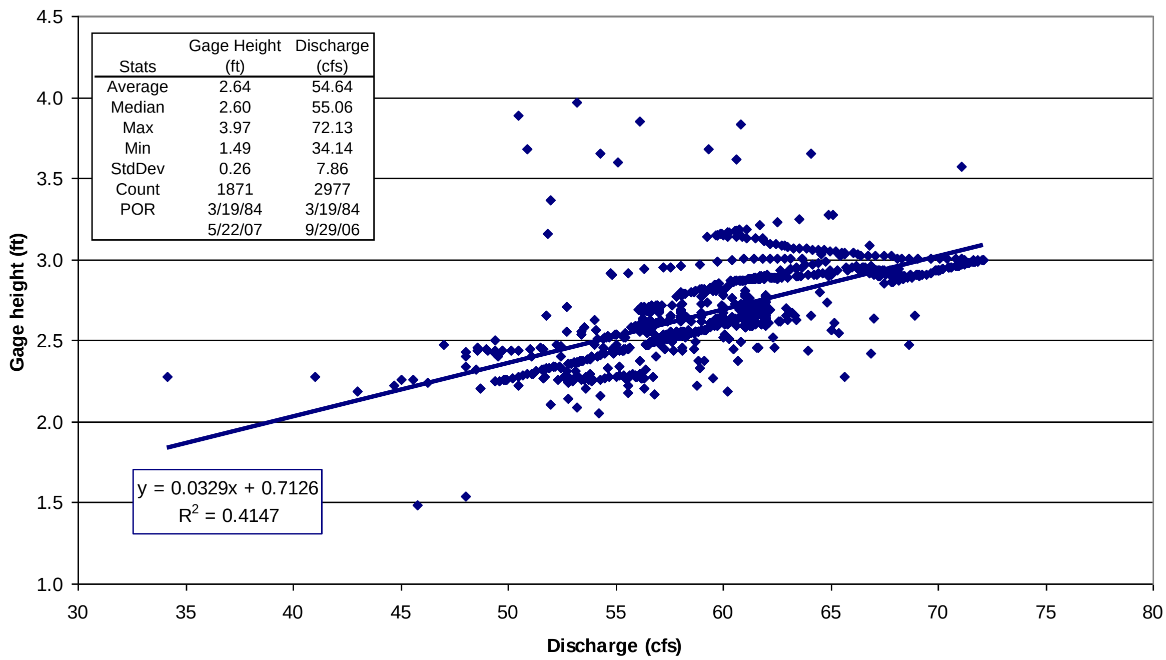


FIGURE 2-11
Rock Springs Estimated Discharge vs. Stage Relationship and Historical Data

TABLE 2-2
Rock Springs Estimated Current Velocities and Nominal Hydraulic Residence Times (nHRTs) as a Function of Spring Discharge

Stage		Depth		Flow		Area	Volume	HRT	Velocity
ft	ft NGVD	ft	m	cfs	m^3/d	m^2	m^3	hr	m/s
1.80	25.36	1.21	0.37	33.1	80,862	10,285	3,802	1.13	0.160
2.00	25.56	1.41	0.43	39.1	95,735	10,848	4,701	1.18	0.153
2.20	25.76	1.61	0.49	45.2	110,607	11,368	5,625	1.22	0.148
2.40	25.96	1.81	0.55	51.3	125,480	11,846	6,572	1.26	0.143
2.60	26.16	2.01	0.61	57.4	140,353	12,281	7,543	1.29	0.140
2.80	26.36	2.21	0.67	63.4	155,225	12,673	8,537	1.32	0.136
3.00	26.56	2.41	0.74	69.5	170,098	13,023	9,556	1.35	0.134
3.20	26.76	2.61	0.80	75.6	184,971	13,331	10,598	1.38	0.131
3.40	26.96	2.81	0.86	81.7	199,844	13,595	11,664	1.40	0.129
3.60	27.16	3.01	0.92	87.8	214,716	13,817	12,754	1.43	0.126

TABLE 2-3
Rock Springs Run Estimated Channel Widths at a Minimum Water Depth of 0.45 m (1.5 ft) as a Function of Water Stage at the Recorder Station

	Width (ft) of Channel Cross-Section > 1.5 foot													% of Channel Cross-Section > 1.5 foot												
Stage (ft)	2	3	4	5	6	7	8	9	11	12	13	14	Avg	2	3	4	5	6	7	8	9	11	12	13	14	Avg
27.16	60	26	30	70	29	124	74	64	38	48	48	44	55	78	76	77	78	91	94	88	83	72	80	74	70	80
26.96	60	25	28	62	29	124	72	62	38	45	41	41	52	78	74	72	69	91	94	86	80	72	75	63	65	76
26.76	60	21	27	52	28	124	70	62	36	43	39	41	50	78	62	69	58	88	94	84	80	68	72	60	65	73
26.56	60	21	22	45	26	124	68	60	36	41	37	40	48	78	62	56	50	82	94	81	78	68	68	57	63	70
26.36	48	19	21	43	17	124	68	58	35	38	35	38	45	63	56	54	48	52	94	81	75	66	63	54	60	64
26.28	48	19	19	40	11	124	66	58	33	38	33	38	44	63	56	49	44	33	94	79	75	62	63	51	60	61
26.16	44	19	18	37	6	124	64	55	33	37	27	38	42	58	56	46	41	18	94	77	73	62	62	42	60	57
25.96	40	17	14	32	5	124	60	51	32	33	22	37	39	53	50	36	36	15	94	72	68	60	55	34	59	53
25.76	35	13	9	26	4	124	60	47	31	31	20	36	36	45	38	23	29	12	94	72	63	58	52	31	57	48
25.56	33	12	6	16	2	120	58	45	29	26	17	34	33	43	35	15	18	6	90	70	60	55	43	26	54	43
25.36	19	12	6	8	0	118	58	45	24	23	14	26	29	25	35	15	9	0	88	70	60	45	38	22	41	37

Note(s):
Stage at staff gauge downstream of swimming area
Detailed cross-sections presented in Appendix B

2.2.5 Water Quality

Water quality data for Rock Springs in Kelly Park and from the upstream end of Rock Springs Run Segment 1 (see **Figure 2-2** and WSI 2006 for description of Pollutant Load Reduction Goal [PLRG] sampling segments) are summarized in **Table 2-4** for the POR from February 1931 to May 2007. Sampling frequencies for different parameters were variable so that many more records are available for some parameters than for others. Rock Springs POR averages for several key parameters are:

- Water temperature – 23.8 ^{o}C
- Dissolved oxygen – 0.46 mg/L
- pH – 7.58 s.u.
- Specific conductance – 253 uS/cm
- Turbidity – 0.042 NTU

- Color – 8.3 CPU
- Total chloride – 8.77 mg/L
- Sulfate – 18.4 mg/L
- Nitrate+nitrite nitrogen – 1.41 mg/L
- Total phosphorus – 0.081 mg/L

The District studied water quality and stable isotope concentrations in Rock Springs to determine groundwater origin and age (Toth 1999). Rock Springs was found to be discharging groundwater from the shallow to intermediate flow system of the Upper Floridan aquifer with an estimated mean age of 19.8 ± 0.5 yr.

2.2.6 Biological Conditions

Rock Springs and the upper portion of Rock Springs Run are habitat for a wide variety of plants and wildlife. The Wekiva River Basin State Parks Unit Management Plan (FDEP 2005) lists plant and animal species that have been observed and reported from the project area and lists the habitat areas those species are associated with. Spring boil and spring run habitats have the following species totals (see **Appendix A** for species lists):

- Vascular plants – 28
- Damselflies and dragonflies – 19
- Mayflies – 1
- Crayfish – 3
- Snails – 4; Clams and mussels – 7
- Fish – 35
- Amphibians – 1
- Turtles – 10
- Snakes – 5
- Birds – 24
- Mammals -1

Walsh and Kroening (2007) sampled benthic macroinvertebrate populations in Rock Springs using multi-habitat sampling with a D-frame dip net (500 um mesh, 0.3 m wide) to assess species richness and diversity and a petite ponar dredge to estimate abundance (density per area) between December 2005 and September 2006. Their quarterly sampling identified 50 species of macroinvertebrates represented by the following numbers of species by major taxonomic group:

- Oligochaeta – 8
- Gastropoda – 8
- Arachnida – 3
- Ephemeroptera -1
- Odonata – 1
- Hemiptera – 3
- Trichoptera – 1
- Diptera – 20
- Isopoda – 1
- Amphipoda – 3
- Decapoda -1

Average macroinvertebrate density based on the petite ponar dredge sampling was 6,192 organisms/m^2 with a range of seasonal densities from 2,497 to 8,838 organisms/m^2.

Walsh and Kroening (2007) conducted electroshock fish sampling on August 25, 2006 in Rock Springs Run, downstream of Kelly Park boil and public use area. A total of 17 fish species were collected, including the following species arranged in order of decreasing dominance:

- *Notemigonus crysoleucas* (golden shiner)
- *Lepomis auritus* (redbreast sunfish)

TABLE 2-4
Rock Springs Historic Water Quality Summary

			ROCK SPRINGS							RSR-SEG1-UP						
Parameter Group	Parameter	Units	Average	Maximum	Minimum	StdDev	Count	Period of Record		Average	Maximum	Minimum	StdDev	Count	Period of Record	
Temperature	Temp	C	23.8	28.5	21.5	0.732	189	2/5/31	2/14/07	23.3	25.8	19.1	1.71	13	4/1/05	5/9/07
Dissolved Oxygen	DO	%	5.50	7.10	5.15	0.50	249	9/15/06	5/23/07	64.5	93.0	36.1	13.7	13	4/1/05	5/9/07
		mg/L	0.46	0.60	0.43	0.04	249	9/15/06	5/23/07	5.51	7.79	3.09	1.15	13	4/1/05	5/9/07
Physical	pH	SU	7.58	8.30	6.40	0.315	107	4/26/56	2/14/07	7.84	8.10	7.51	0.199	13	4/1/05	5/9/07
	Sp Cond	uS/cm	253	300	222	13.3	69	6/12/84	2/14/07	246	330	228	26.5	13	4/1/05	5/9/07
	Color	cpu	8.3	15.0	5.00	5.77	3	6/23/05	8/10/05	26.4	100	5.00	27.7	11	4/1/05	1/18/07
	TURB	ntu	0.042	0.050	0.025	0.014	3	6/23/05	8/10/05	0.589	1.60	0.250	0.392	11	4/1/05	1/18/07
Oxygen Demand	BOD	mg/L	0.51	0.80	0.27	0.27	3	6/23/05	8/10/05	0.587	1.20	0.200	0.405	7	4/1/05	2/16/06
Solid	TSS	mg/L	1.00	3.00	0.00	1.73	3	6/23/05	8/10/05	1.32	5.00	0.00	1.42	11	4/1/05	1/18/07
	TDS	mg/L	145	289	118	19.5	94	10/17/60	2/14/07	135	174	0.005	43.5	12	4/1/05	1/18/07
	VSS	mg/L	2.00	5.00	0.00	2.65	3	6/23/05	8/10/05	2.71	7.00	1.00	2.34	7	4/1/05	2/16/06
General Inorganic	ALK	mg/L	90.6	117	66.0	6.60	95	4/26/56	2/14/07	89.6	102	85.9	5.55	7	4/1/05	2/16/06
	Cl -	mg/L	8.77	24.0	5.00	2.23	103	4/26/56	2/14/07	9.27	10.7	8.40	0.793	7	4/1/05	2/16/06
	SILICA	mg/L	5.08	14.0	4.00	1.73	46	7/14/87	7/16/02	9.86	12.3	4.50	2.64	7	4/1/05	2/16/06
	SO4	mg/L	18.4	24.0	15.0	1.82	103	4/26/56	2/14/07	19.4	20.1	17.2	1.03	7	4/1/05	2/16/06
	TC	mg/L	12.1	24.5	0.500	12.2	6	7/10/90	8/10/05	26.7	31.0	22.1	3.07	7	4/1/05	2/16/06
General Organic	DOC	mg/L	0.51	1.01	0.00	0.51	3	6/23/05	8/10/05	3.18	6.92	0.00	2.92	7	4/1/05	2/16/06
Nitrogen	NH3	mg/L	0.005	0.005	0.005	0.00	4	2/27/01	8/10/05	0.005	0.010	0.005	0.002	11	4/1/05	1/18/07
	NO2 + NO3	mg/L	1.41	1.84	0.170	0.285	67	6/12/84	2/14/07	1.16	1.27	1.01	0.073	11	4/1/05	1/18/07
	TKN	mg/L	0.16	0.26	0.11	0.07	4	2/23/05	8/10/05	0.150	0.390	0.005	0.117	13	4/1/05	1/18/07
	TN	mg/L	1.52	1.66	1.38	0.13	4	2/23/05	8/10/05	1.32	1.53	1.15	0.102	11	4/1/05	1/18/07
Phosphorus	SRP	mg/L	0.084	0.087	0.079	0.004	3	6/23/05	8/10/05	0.085	0.107	0.069	0.010	11	4/1/05	1/18/07
	TP/D/SPEC	mg/L	0.081	0.082	0.080	0.001	2	8/16/99	2/27/01	0.088	0.100	0.079	0.007	7	4/1/05	2/16/06
	TP/T/SPEC	mg/L	0.078	0.093	0.057	0.008	26	8/16/99	2/14/07	0.094	0.115	0.085	0.008	11	4/1/05	1/18/07
Metal	CA/T/ICP	mg/L	30.4	37.4	26.0	1.61	66	7/7/92	2/14/07	30.4	32.6	26.7	2.20	7	4/1/05	2/16/06
	FE/T/ICP	ug/L	48.7	213	2.20	80.6	7	7/20/93	8/12/03	30.1	75.7	11.4	23.6	7	4/1/05	2/16/06
	MG/T/ICP	mg/L	9.23	11.0	8.00	0.456	66	7/7/92	2/14/07	9.19	9.73	8.00	0.584	7	4/1/05	2/16/06
	NA/T/ICP	mg/L	5.28	9.08	4.00	0.661	66	7/7/92	2/14/07	5.12	5.36	4.90	0.177	7	4/1/05	2/16/06

Note: Statistics calculated using half of the detection limit if reported as below the detection limit.
Source: ROCK SPRINGS (SJRWMD/WSI); RSR-SEG1-UP (WSI)

- *Lepomis macrochirus* (bluegill sunfish)
- *Lepomis punctatus* (spotted sunfish)
- *Erimyzon sucetta* (lake chubsucker)
- *Micropterus salmoides* (largemouth bass)
- *Lepomis microlophus* (redear sunfish)
- *Pterygoplichthys disjunctivus* (armored catfish)
- *Lepomis gulosus* (warmouth)
- *Amia calva* (bowfin)

During the site reconnaissance on September 27, 2006 and during subsequent particulate export sampling events on March 29, April 25, and May 23, 2007, WSI observed the following additional common flora and fauna species in the spring boil and spring run:

- Filamentous green and blue-green algae (benthic, epelithic, and periphytic)
- *Nitella* sp. (stonewort)
- *Vallisneria americana* (eelgrass)
- *Ceratophyllum demersum* (coontail)
- *Typha* sp. (cattail)
- *Pontederia cordata (*pickerelweed*)*
- *Pistia stratiotes* (water lettuce)
- *Hydrocotyle umbellata* (water pennywort)
- *Nuphar luteum* (spatterdock)
- *Hymenocallis occidentalis* (spiderlily)
- *Cladium jamaicense* (saw-grass)
- *Dorosoma petenense* (threadfin shad) (very large school [1,000s] of small fish)
- Pond turtles

- *Alligator mississippiensis* (American alligator)
- *Lutra canadensis* (river otter)

Numerous other plant and animal species likely occur in Rock Springs and Rock Springs Run or are partially dependent upon it for portions of their life history requirements.

Figure 2-12 provides a historical map of the major physical and biological conditions in this area of Rock Springs Run 57 years ago (Odum 1951). The locations of dominant plant and animal communities appear to be essentially unchanged compared to the historic condition. No flow data were available for the period coinciding with Odum's plant community map of Rock Springs Run.

2.2.7 Ecosystem Functions

While no natural systems are in true dynamic equilibrium or "steady state", springs are one of the systems that come closest to this theoretical state (Odum 1957a). The primary reasons for their quasi steady state behavior are the relatively constant flows and water quality typically observed in spring ecosystems. For many springs the most dynamic forcing function is incoming solar radiation (insolation) which varies seasonally and daily. Indigenous spring flora and fauna have become adapted to efficiently use insolation and were shown by Odum (1957b) to be among the most energetically efficient of natural ecosystems. Unlike many other aquatic ecosystems, springs can be revisited and reassessed for structural and functional changes at anytime in the future based on additional data collection (Odum 1957a). Also, different springs that have relatively minor levels of anthropogenic physical disturbance can be compared to assess their intrinsic efficiencies at converting insolation to fixed carbon (Odum 1957b). Ecosystem measures have a greater likelihood of being responsive and consistent in their magnitude of responses to variations in a forcing function, such as flow, compared to other structural ecosystem measures such as aquatic plant community zonation or biomass.

New data collection at Rock Springs was conducted to provide a comparison of ecosystem functions with other springs. Detailed method descriptions, raw data, and data analyses for those additional sampling activities are presented in a companion report (WSI 2007) and detailed data summaries are provided as **Appendices B** (**Daily Metabolism Estimates**), **C** (**Field Parameter Measurements**), **D** (**Light Attenuation Estimates**), and **E** (**Particulate**

Export Measurements). Four ecosystem function sampling events were completed in September 2006, and in March, April, and May 2007. Continuously-recording data sondes (field-measured parameters included: water temperature, pH, dissolved oxygen, and specific conductance) were installed at the downstream end of the Rock Springs Run segment of interest for up to two weeks during each sampling event. During the September 2006 event, an identical data sonde was deployed just downstream from the main boil to provide data concerning the variability of field parameters at the upstream end of the segment. The upstream-downstream dissolved oxygen method (Odum 1956) was applied to the resulting data to estimate rates of gross primary productivity (GPP), community respiration (CR or R24), and net primary productivity (NPP or NPP24). Ecological efficiency (EE) of the spring community was estimated as the quotient of GPP and total daily photosynthetically active radiation (PAR). Particulate export measurements were also conducted to provide an independent measure of the community net production and of the movement of mineral sediments within the flowing spring run. Ecosystem data collected during the 2006-2007 period corresponded to relatively low flow (drought) conditions at both sites. Previously collected data just downstream from the WRV study areas (WSI 2006) were used for comparisons and for correlation analyses. Those data were collected during a period of higher spring discharge rates.

Historical water quality data were utilized to estimate nutrient assimilation rates in the Rock Springs Run segment. **Table 2-5** provides a summary of estimated nutrient assimilation rates for this upper reach of Rock Springs Run. These data are also compared to similar estimates for two downstream segments previously collected by WSI (2006).

Table 2-6 provides a summary of the ecological measures in the Rock Springs Run segment. New data were collected at three stations from upstream to downstream (**Figures 2-3** and **2-4**): the Main Boil (KP1), just downstream of the main swimming area (KP2), and from the bridge at the downstream end of the tubing run (KP3). Average GPP in the Rock Springs Run segment was 5.96 g $O_2/m^2/d$. Average CR was estimated as 6.92 g $O_2/m^2/d$ for an estimated mean NPP of -0.95 g $O_2/m^2/d$. Average EE was estimated as 0.59 g O_2/mole. Particulate export averaged 0.31 g ash-free dry weight/m^2/d. A significant diurnal pattern was observed for particulate export as illustrated in **Figures 2-13** through **2-15**. This pattern for higher ash-free dry weight particulate export on a diurnal basis is no doubt due to

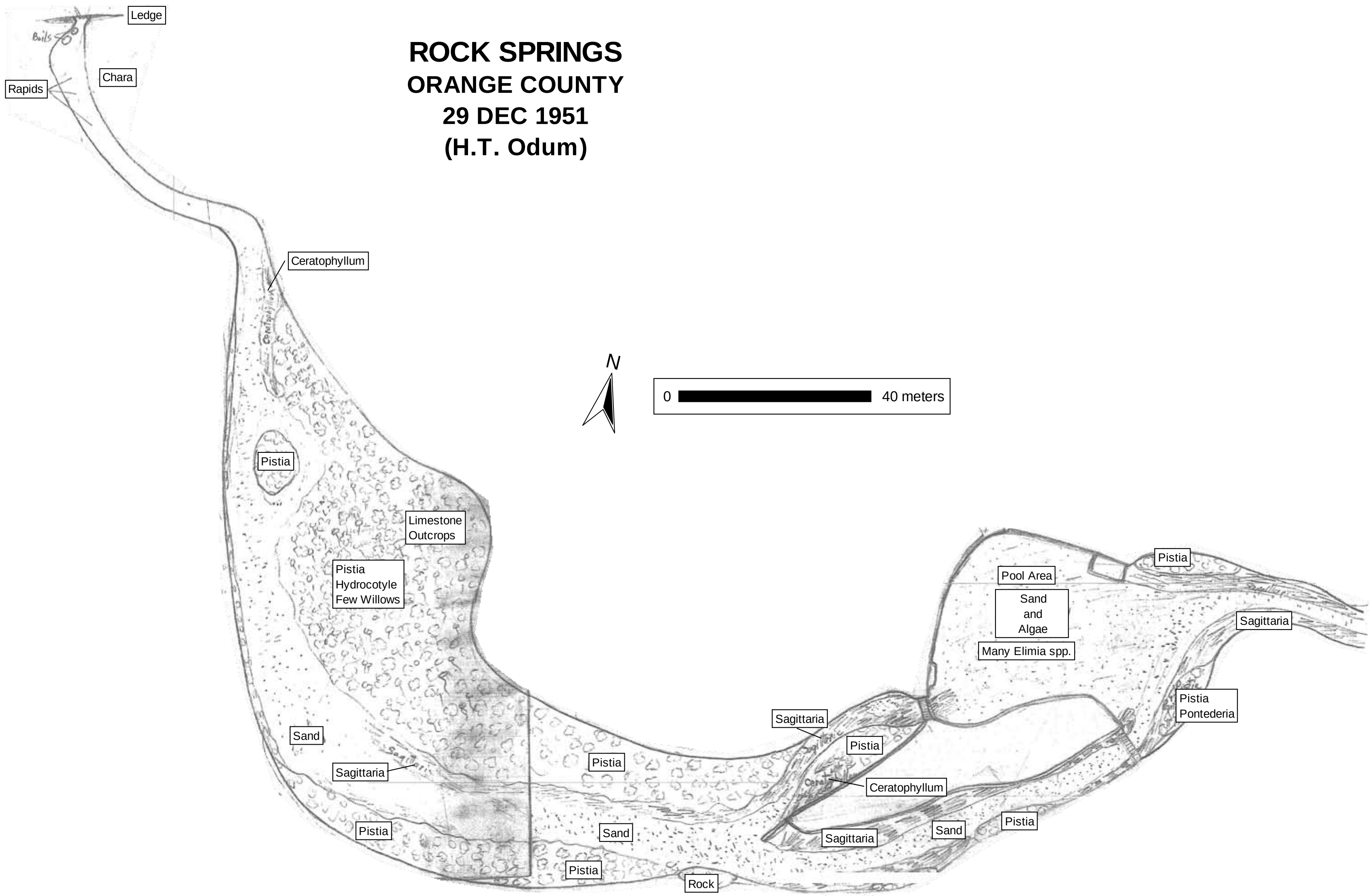


FIGURE 2-12
Map of Rock Springs and Upper Rock Springs Run Showing Overall Stream Configuration, Plant Communities, and Interesting Fauna (Odum 1951)

TABLE 2-5
Summary of Estimated Nutrient Mass Removals in Rock Springs in Kelly Park (Rock Springs to Segment 1 Up) and in Rock Springs Run Segments 1 and 2 (see **Figure 2-2**)

		Inflow				Outflow				Removal				
		Segment - Up				Segment - Down								
		Conc	Flow	Mass	Mass	Conc	Flow	Mass	Mass	Conc		Mass		
Parameter	Stream Segment	(mg/L)	(m^3/d)	(kg/d)	(kg/ha/d)	(mg/L)	(m^3/d)	(kg/d)	(kg/ha/d)	(mg/L)	(%)	(kg/d)	(kg/ha/d)	(%)
Total Phosphorus	Rock Springs to Segment 1 Up	0.080	161,407	12.9	7.28	0.093	161,407	15.0	8.49	-0.013	-16.60	-2.14	-1.21	-16.6
	Rock Springs Run Segment 1	0.093	161,407	15.0	5.92	0.094	161,407	15.1	5.95	0.000	-0.53	-0.08	-0.03	-0.5
	Rock Springs Run Segment 2	0.108	144,485	15.7	3.26	0.114	144,485	16.4	3.42	-0.005	-5.04	-0.79	-0.16	-5.0
Ortho Phosphorus	Rock Springs to Segment 1 Up	0.073	161,407	11.7	6.64	0.086	161,407	13.9	7.85	-0.013	-18.27	-2.15	-1.21	-18.3
	Rock Springs Run Segment 1	0.086	161,407	13.9	5.47	0.085	161,407	13.7	5.39	0.001	1.61	0.22	0.09	1.6
	Rock Springs Run Segment 2	0.088	144,485	12.7	2.65	0.096	144,485	13.8	2.88	-0.008	-8.67	-1.10	-0.23	-8.7
Nitrate Nitrogen	Rock Springs to Segment 1 Up	1.43	161,407	231	130.29	1.14	161,407	184	104.05	0.288	20.14	46.44	26.24	20.1
	Rock Springs Run Segment 1	1.14	161,407	184	72.56	1.09	161,407	175	69.00	0.056	4.91	9.04	3.56	4.9
	Rock Springs Run Segment 2	0.27	144,485	39	8.09	0.26	144,485	38	7.87	0.008	2.79	1.08	0.23	2.8

Rock Springs to Segment 1 Up	1.77	ha
Rock Springs Run Segment 1	2.54	ha
Rock Springs Run Segment 2	4.80	ha

Period of Record: April 2005 - March 2006 (WSI 2006) higher rates of organic matter production during the day light hours. High rates of ash in the particulate export during the daylight hours indicate that human recreational activities (wading, bathing, and tubing) in this park are also increasing the downstream movement of sand and finer mineral solids.

Figure 2-16 displays the observed relationship between estimated discharge and the ecosystem metabolism estimates during this limited period-of-record. Downstream estimates of ecological metabolism and particulate export rates from ongoing PLRG studies are also included in **Table 2-7** for comparison.

TABLE 2-6
Summary of Estimated Ecological Measures in Kelly Park for the Period-of-Record from February 24, 2005 through May 23, 2007 (Rock Springs and Rock Springs to Rock Springs Run SEG 1 UP)

Parameter	Average	Minimum	Maximum	StdDev	N
GPP (g $O_2/m^2/d$)	5.97	1.67	11.16	1.82	91
NPP24 (g $O_2/m^2/d$)	-0.95	-8.54	7.01	3.30	91
R24 (g $O_2/m^2/d$)	6.92	1.34	15.08	3.17	91
P/R Ratio	1.05	0.19	4.77	0.70	91
PAR (24hr) (mol/m^2/d)	14.14	1.52	28.26	6.54	90
PAR Efficiency (%)	4.28	1.61	14.52	2.48	90
EE (g O_2/mol)	0.53	0.20	1.80	0.31	90
Discharge (m^3/d)	142,326	124,786	166,734	16,046	91
Depth (m)	0.61	0.52	0.72	0.08	91
Particulate Export					
Dry Wt (g/m^2/d)	0.86	0.29	3.42	0.57	45
Organic Matter (g/m^2/d)	0.31	0.12	0.67	0.14	45

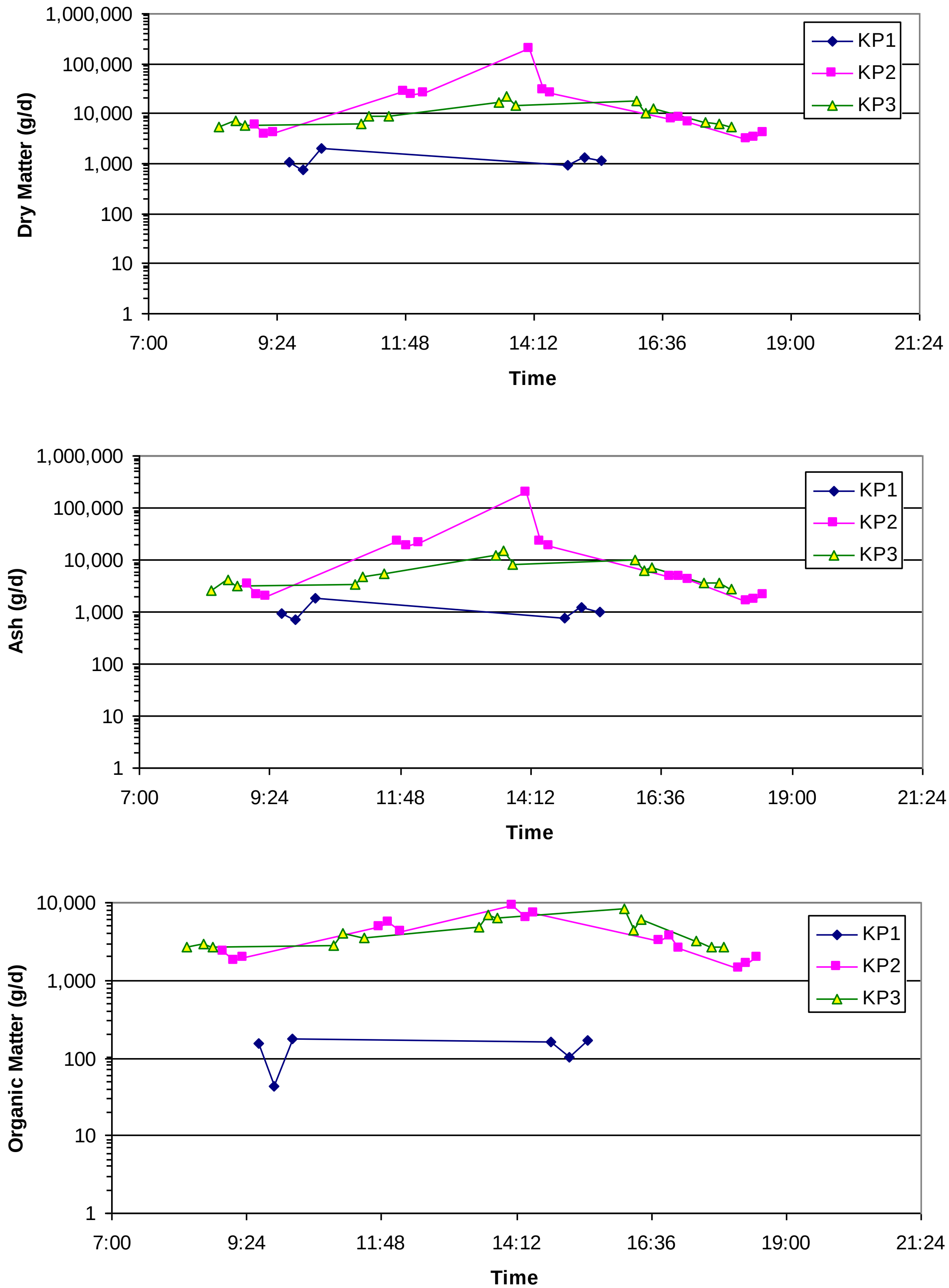


FIGURE 2-13
Rock Springs Particulate Export Measurements – 3/29/07 (see **Figures 2-3** and **2-4** for station locations)

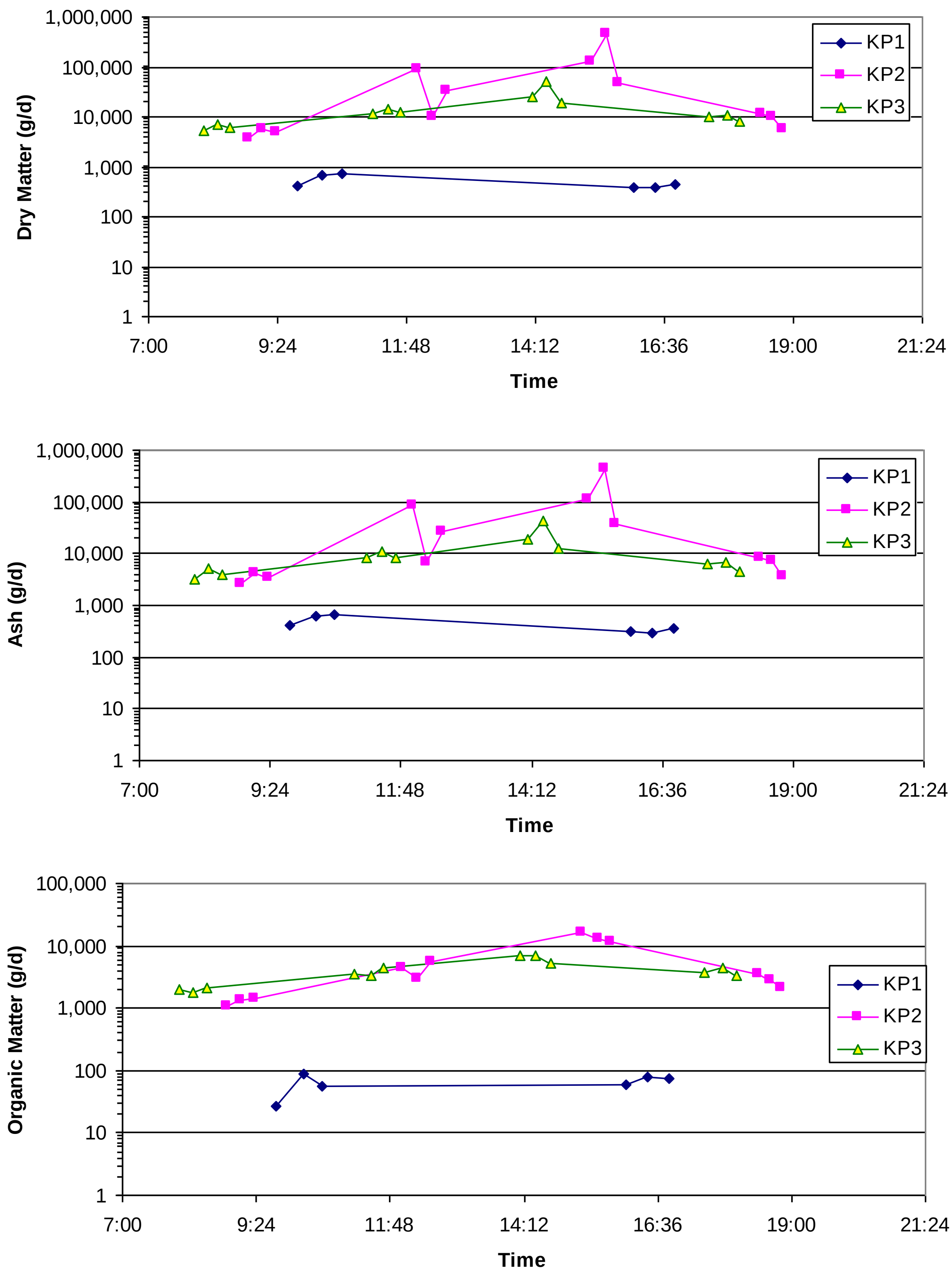


FIGURE 2-14
Rock Springs Particulate Export Measurements – 4/25/07 (see **Figures 2-3** and **2-4** for station locations)

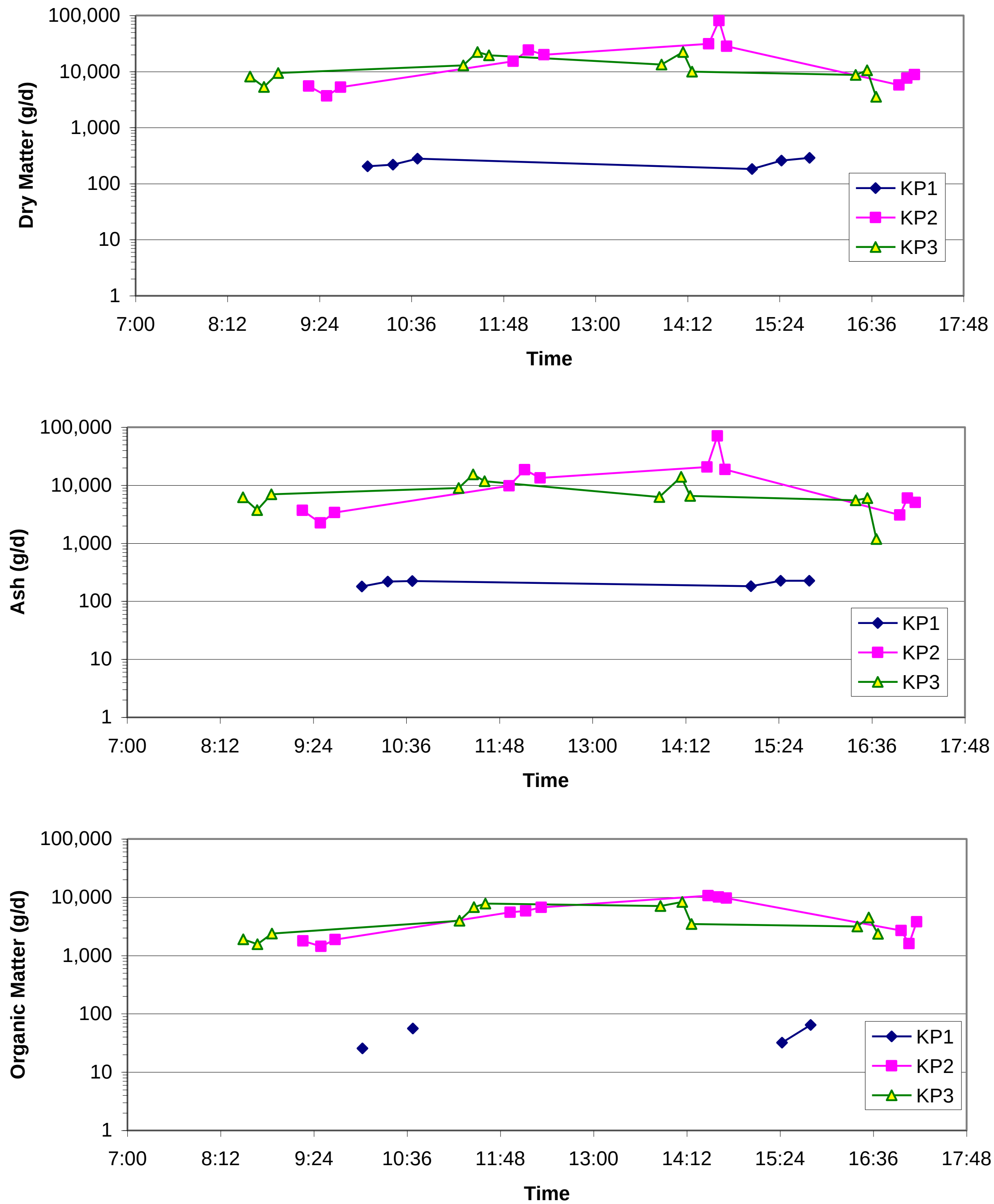
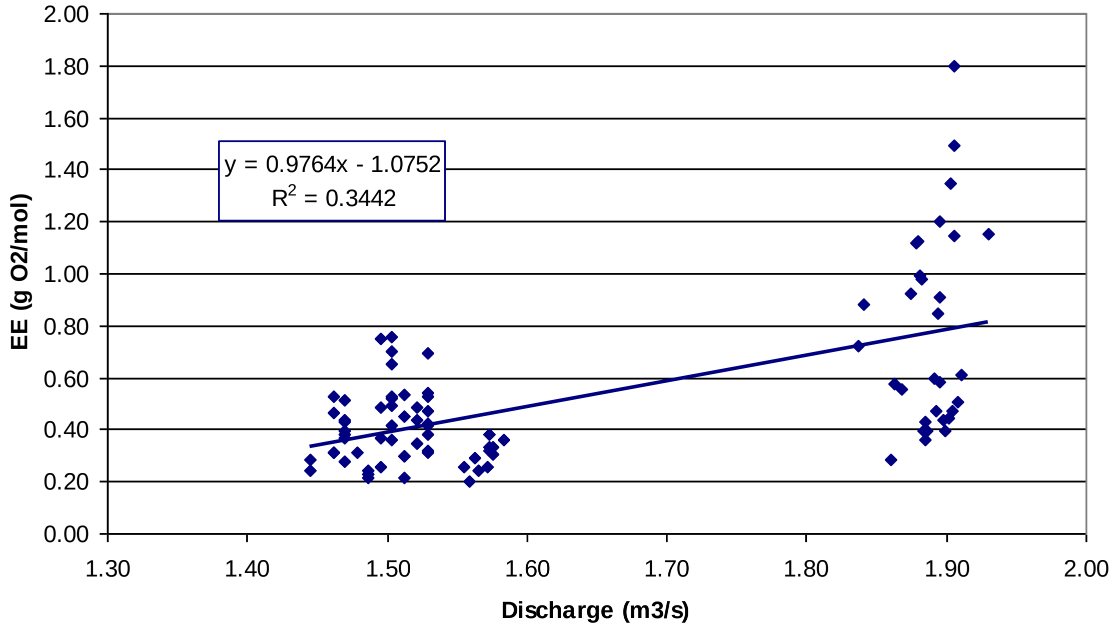


FIGURE 2-15
Rock Springs Particulate Export Measurements – 5/23/07 (see **Figures 2-3** and **2-4** for station locations)



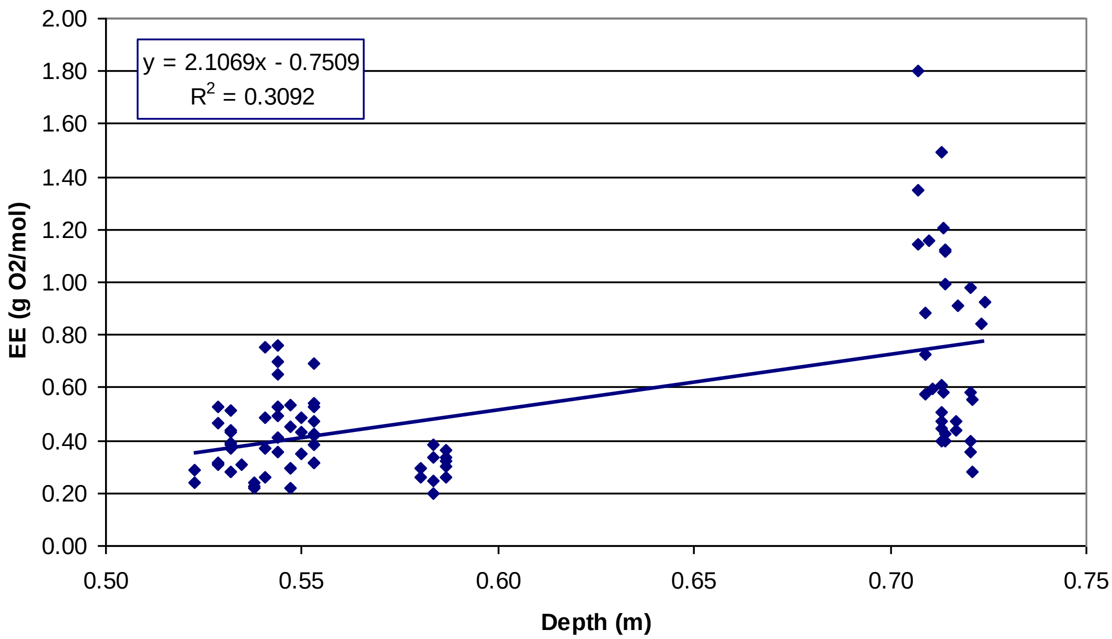


FIGURE 2-16
Relationship between Estimated Discharge/Depth and Ecological Efficiency Estimates in Rock Springs Run

TABLE 2-7
Summary of Estimated Ecological Measures in the Rock Springs Run PLRG Segments (see **Figure 2-2** for station locations)

Parameter	Segment 1	Segment 2
GPP (g $O_2/m^2/d$)	1.14	0.66
NPP24 (g $O_2/m^2/d$)	-7.13	-9.95
R24 (g $O_2/m^2/d$)	8.30	10.68
P/R ratio	0.16	0.07
Plant Depth (m)	0.50	0.25
PAR corr. (mol/m^2/d)	14.67	13.52
PAR Eff.		
g O_2/mol	0.10	0.06
%	0.78	0.47
Velocity (cm/s)	7.27	17.14
HRT (hrs)	3.15	2.19
Particulate Export		
Dry Wt (g/m^2/d)	0.073	0.079
Organic Matter (g/m^2/d)	0.052	0.054

Period of Record: April 2005 - March 2006

2.2.8 Human-Use Attendance and Activities

Public use records are available for Kelly Park for the POR from January 1998 through December 2005 (**Figure 2-17)**. Total paid attendance totals by year varied from a high of 214,983 in 1998 to a low of 73,626 in 2005. Beginning in 2000 Kelly Park instituted a maximum allowable attendance rule to preserve the integrity of the spring run. This rule caps daily maximum entry to no more than 285 filled parking spots or about 1,000 people at any time (assuming 3.5 people per car). While the observed decline in paid attendance during the POR was large, it was not significantly related to year. Analysis of monthly attendance records for Kelly Park indicate a strong seasonal pattern (**Figure 2-18)** with maximum public use of the park during the summer (June) and lowest use in the winter (December – January). This pattern as well as other observations, indicate that the primary water-dependent human uses of the Kelly Park are related to the attractions of swimming, wading, tubing, and snorkeling in Rock Springs Run during the warmest seasons. All of these uses were verified during multiple visits to Kelly Park for this project (quarterly sampling during weekdays on September 15 and 28, 2006, March 29, 2007, April 25, 2007, and May 23, 2007; and a peak-season weekend visit on August 11, 2007).

Kelly Park has had relatively few closures over the past three years when records were available (Joseph Brandon, Kelly Park manager, personal communication, 2007). Within the historical period-of-record (2004-2007) Kelly Park has been closed three times for high fecal coliform counts (see **Figure 2-19**, twice in 2004 and once in 2007). The park was also closed over a period of several months during the fall of 2004 due to Hurricanes Charlie, Francis, and Jean and the subsequent cleanup, twice due to alligator sightings in the public use area (once for a week), twice due to "cave ins", presumably near the main spring, and once due to lack of staff.

A detailed assessment of water-dependent human uses was conducted at Kelly Park on August 11, 2007. Estimated average spring discharge on this date was 46.6 cfs and the estimated average stage was 26.12 ft NGVD (Tom Mirti, SJRWMD, personal communication, 2007). An observation station was selected to allow a survey of the entire swim area, from the upstream end of the island downstream to the entry to the final spring run segment at the District's water level gauge (**Figure 2-20**). The spring run area within this observation area was 0.37 ha (0.91 ac). Ten primary uses were identified (**Table 2-8**), and counts of all persons within the observation area were rapidly conducted at about 15 minute intervals from the time the park opened at 08:00 until final park closing at 19:00. Six of the observed uses were considered to be dependent on water contact. The four remaining uses were not in direct contact with the water, but were also water dependent because they all corresponded to the water resource either as an aesthetic point of focus or as the ultimate attraction before or after returning to the shore.

Figure 2-21 illustrates the daily pattern of human use activities at Rock Springs during this typical maximum-use day (summer, weekend, no rain). The maximum total number of people observed using the entire observation area on August 11 was 323 people, with a maximum count of 156 individuals participating in water contact activities at any one time, representing a maximum human density in the water of 424 people/ha (172 people/ac). The average human use during the hours of park operation was 197 people with an average of 109 people using upland areas and 88 people participating in water contact activities. The average human density in the water during this period was 238 people/ha (97 people/ac). It was estimated by park staff that a total of 2,085 different individuals were admitted to Kelly Park on August 11 and that there were approximately between 1,000 and 1,300 people in the park at any one time. Estimates conducted during the same day indicated that there were up to 100 people upstream between the main boil and the end of the first spring run at the head of the island and another 50 to 100 people downstream from the water gauge to the final tube takeout point at any one time. The park was closed three times during the day as illustrated on **Figure 2-21**. Once people left and opened up parking spaces, park staff would reopen until parking spaces were filled. While **Figure 2-21** illustrates that the total water dependent population within the observation area peaked a little before noon and then declined throughout the remainder of the day, the water contact numbers were more consistent throughout the day, indicating that a higher percentage of the visitors were engaged in water contact activities during the latter half of the day when the air temperature was probably highest. **Figure 2-22** provides a pie-chart summary of the observed activities at Rock Springs on August 11. Water contact activities were fairly evenly split at Kelly Park between bathing (15%), tubing (14%), and wading (13%). On this hot summer day approximately 45% of the visitors in the observation area were involved in a water contact activity at all times, and based on observations of bathing attire, it was estimated that at least 80 to 90% of those individuals were in the water at sometime during the day. The observations conducted on August 11 indicate that about 40 to 50% of the people in the park were on trails, in the picnic area away from the spring run, or in the camping area at any given time while the remaining 50 to 60% were participating in water-dependent activities associated with the spring and spring run. It is likely that the majority of people entering the park were at some point in the day part of the crowd observed around the swim area. Based on this assumption, the total attendance records provided below in **Figures 2-17 and 2-18** for the period-of-record are considered to provide a good indication of the number of individuals involved in a spring-dependent activity for some time during their visit to Kelly Park and Rock Springs.

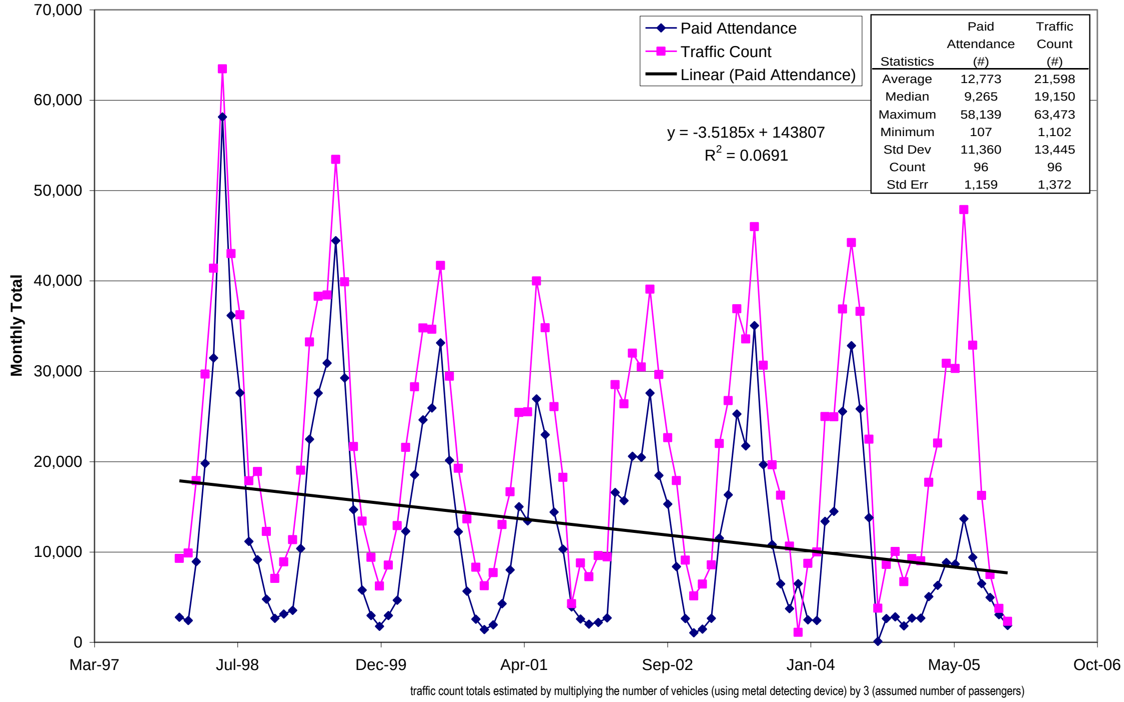


FIGURE 2-17
Time Series of Kelly Park Attendance Data (January 1998 – December 2005)

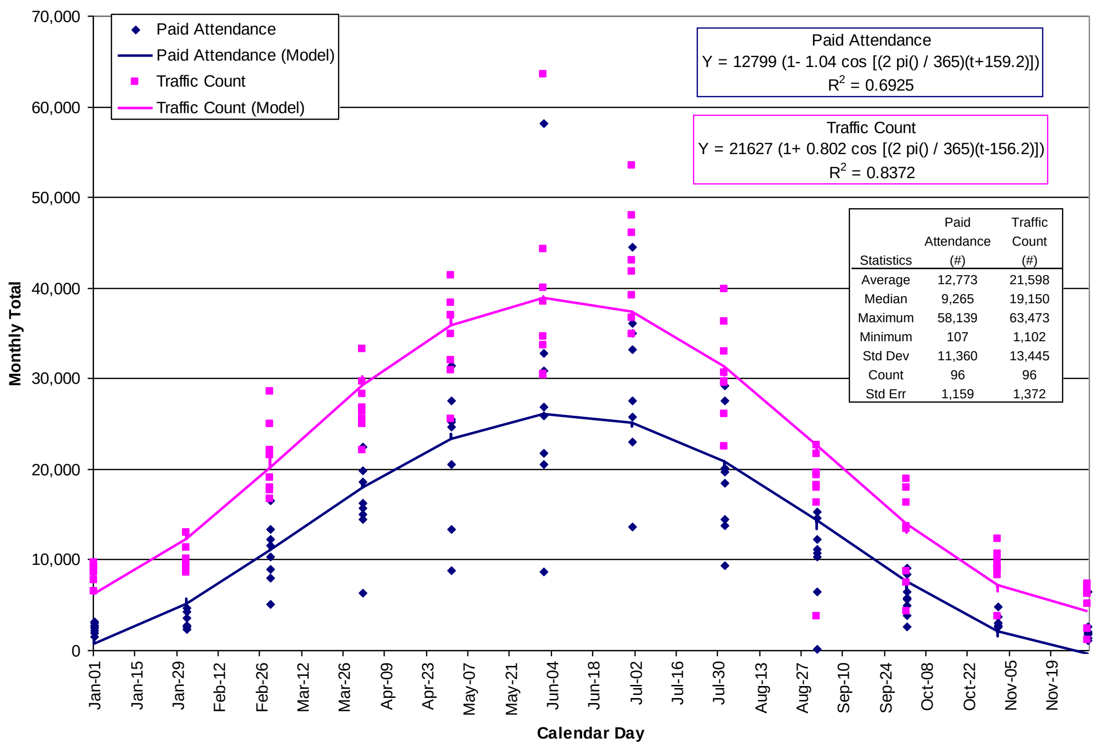


FIGURE 2-18
Kelly Park Attendance Data (January 1998 – December 2005)

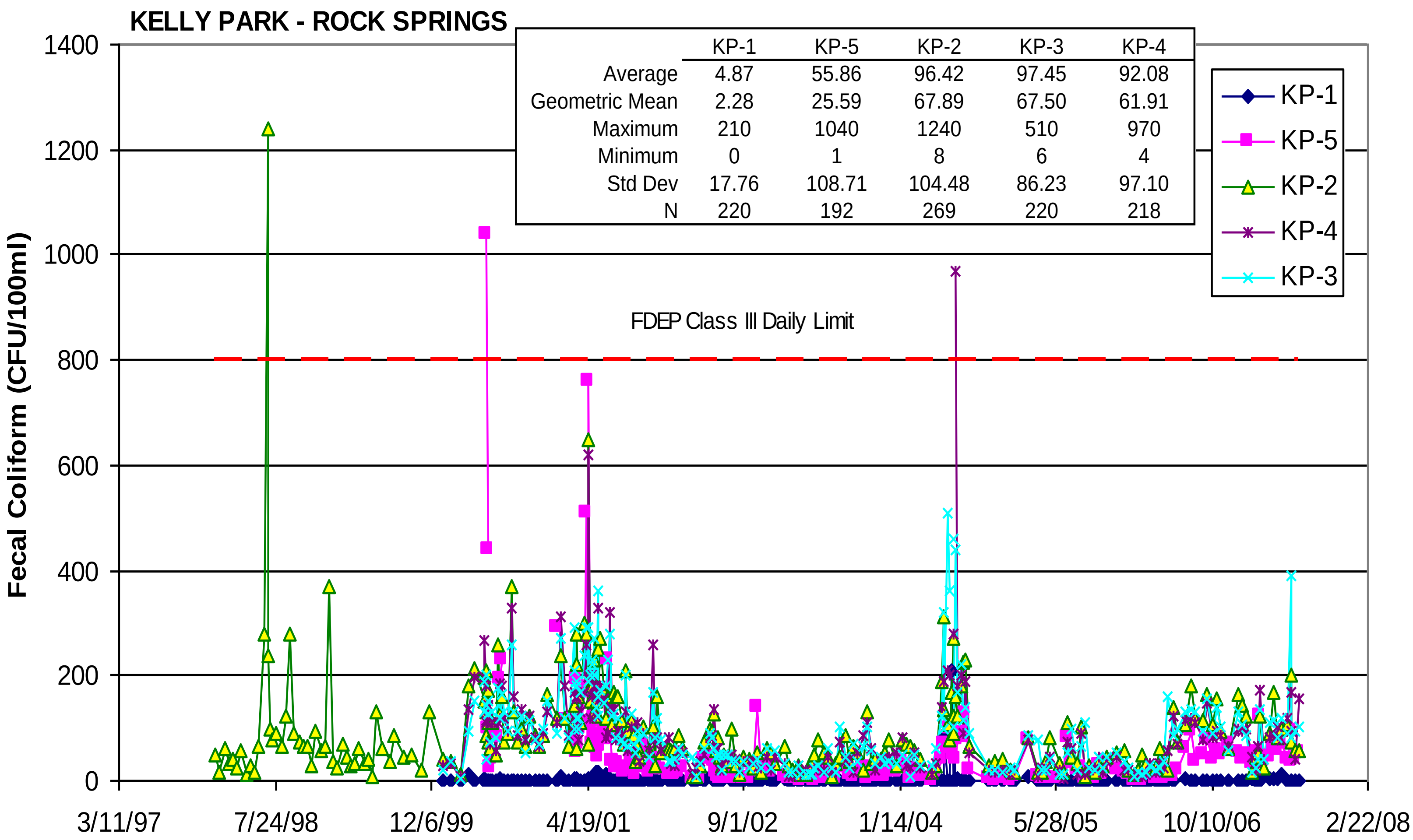


FIGURE 2-19
Rock Springs Fecal Coliform Data for the Period from 1998 through 2007 (source: Orange County Environmental Protection Division)

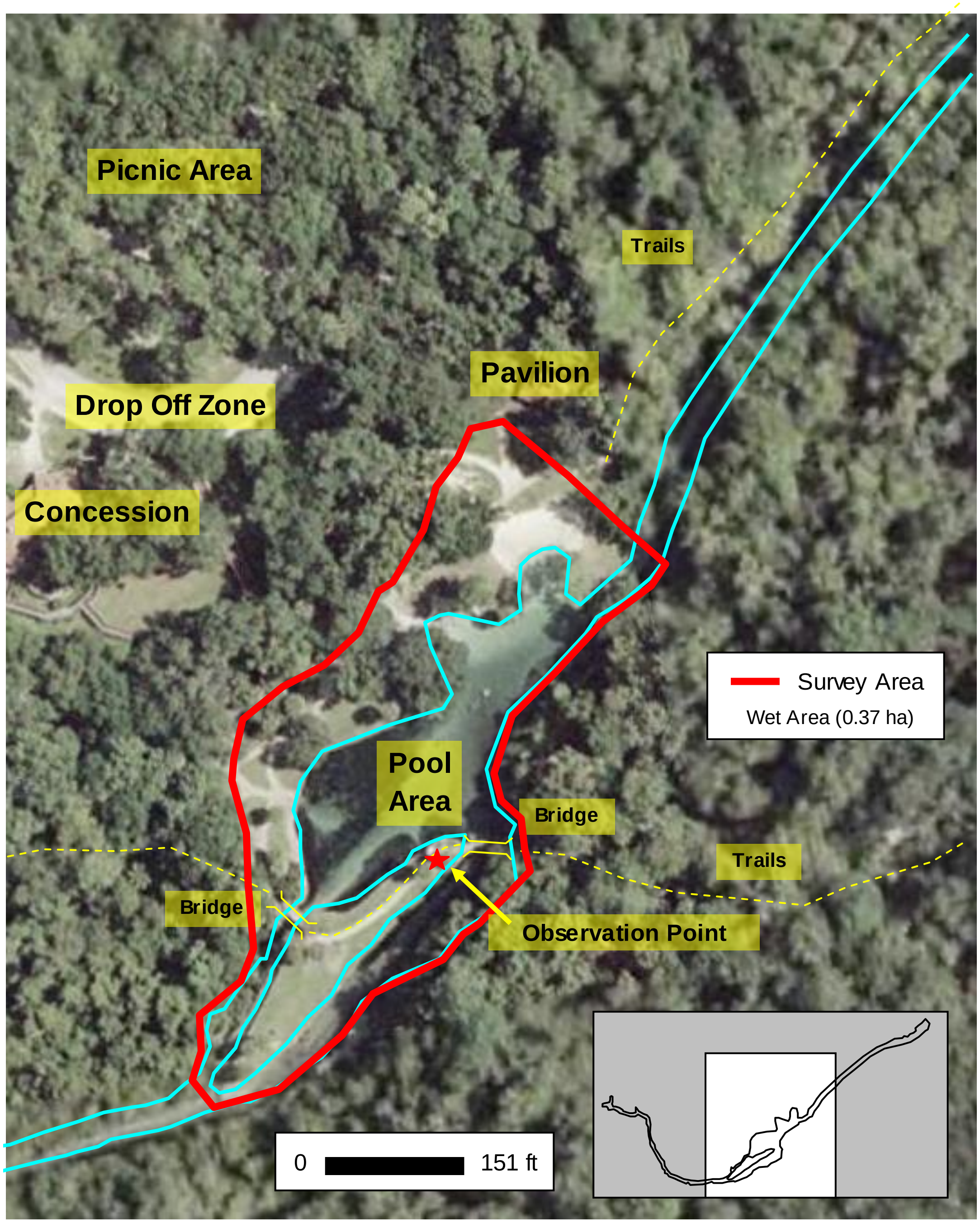


FIGURE 2-20
Kelly Park and Rock Springs Run Showing the Limits of the Human Use Observation Study Conducted on August 11, 2007

TABLE 2-8
Water-Dependent Human Uses Documented at Kelly Park on August 11, 2007

Activity Name	Description	Water Contact?
Swimming	Swimming for exercise. Generally swimmer is wearing goggles but any purposeful swimming is included.	Yes
Wading	Contact with the water no more than knee deep. This includes people wading in shallower water, standing on stairs, and people sitting on walls with their feet in the water.	Yes
Bathing	This category indicates significant body immersion in the water (greater than knee deep).	Yes
Tubing	Use of innertubes or rafts to be propelled by flowing water.	Yes
Snorkeling	Indicated by having a mask or goggles on and actively placing face under water.	Yes
Fossiling	Standing or sitting in the water and gathering gravel to sift through with or without a screen.	Yes
Sunbathing	Lying prone in the sun and partially clothed.	No
Picnicking	Actively preparing or eating food.	No
Nature study	Generally not attired in a bathing suit and carrying a camera or binoculars.	No
Relaxing	All other upland activities, including: sitting, standing, sleeping, talking, walking, entering or leaving water, setting up or taking down umbrellas, etc.	No

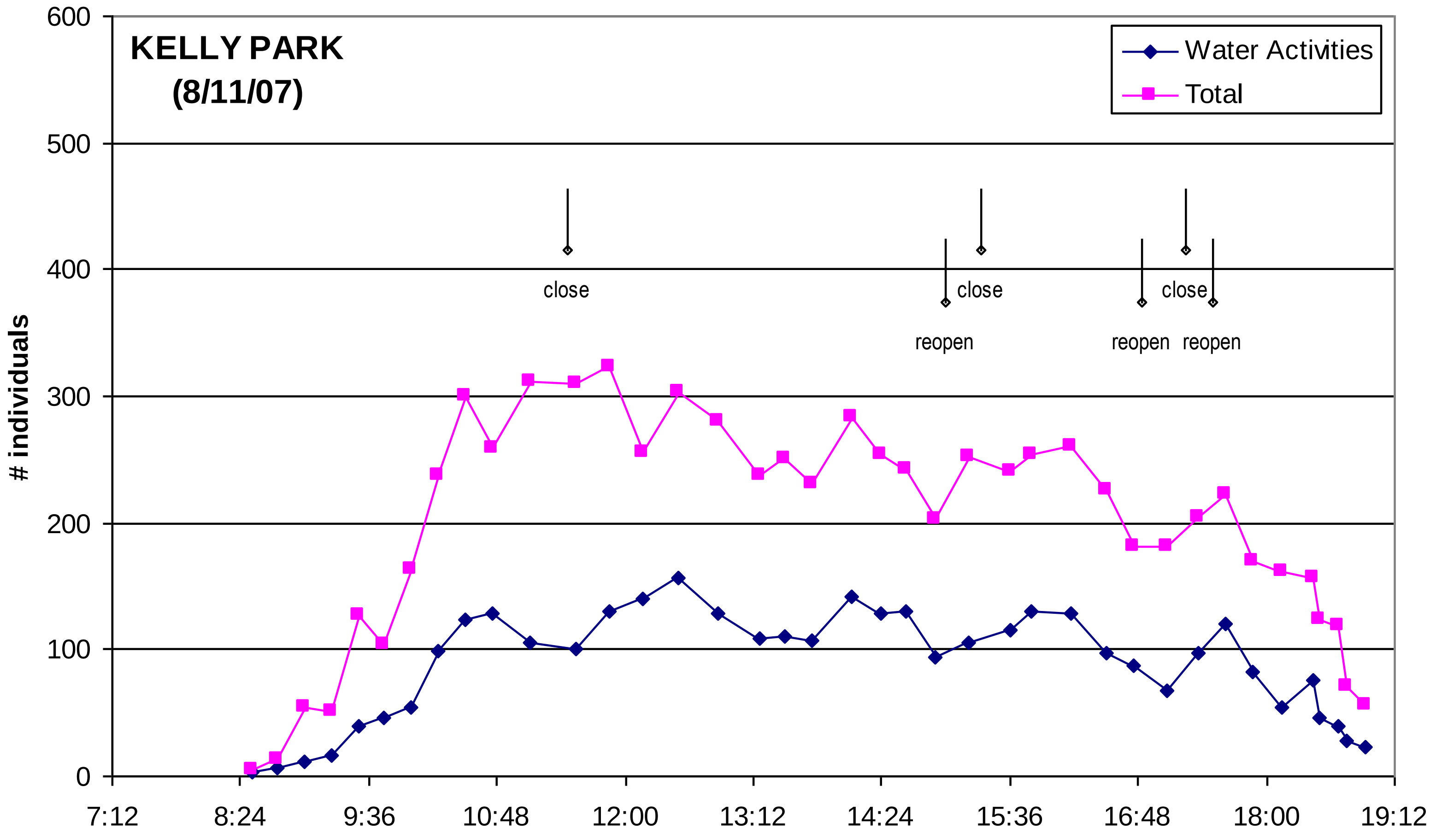


FIGURE 2-21
Daily Pattern of Water-Dependent Human Use Observed at Kelly Park on Saturday, August 11, 2007

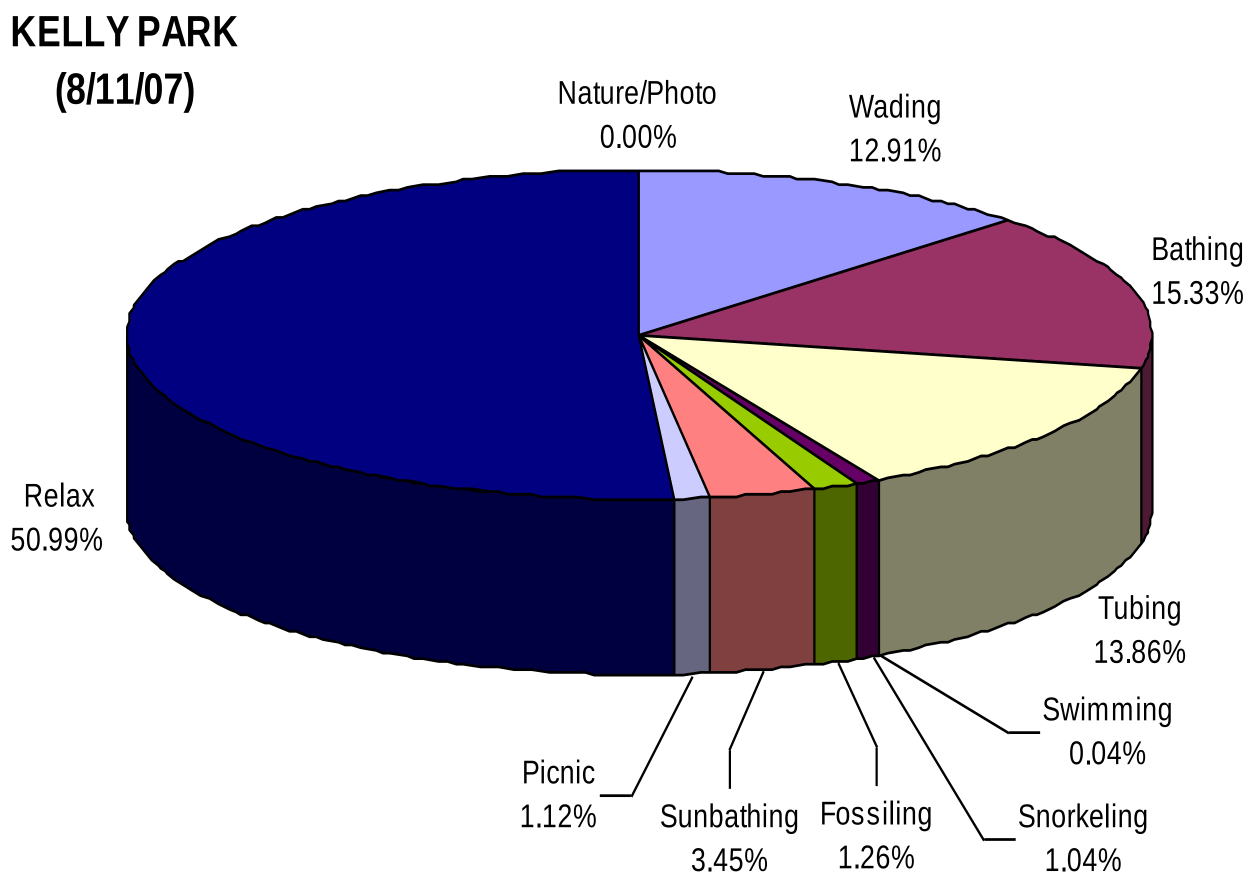


FIGURE 2-22
Average Distribution of Water-Dependent Uses Observed at Kelly Park on Saturday, August 11, 2007

2.3 Wekiwa Springs and Wekiwa Springs State Park

2.3.1 Site Location

Wekiwa Springs is located in Orange County, Florida within the Wekiwa Springs State Park about 4 miles northeast of Apopka (**Figure 2-23**). Driving directions include: from the intersection of US 441 and SR 436 on the east side of Apopka drive 1.6 miles east on SR 36; turn north onto Wekiwa Springs Road and continue 2.9 miles to the park entrance; follow the park entrance road for 0.25 miles north and east to the parking lot; the springs are north of the parking lot at the bottom of the hill.

2.3.2 WRV Assessment Project Area

Figure 2-23 illustrates the relevant project area for Wekiwa Springs and the Wekiva River. This area includes the main spring vent and walled swimming area at Wekiwa Springs past the wooden bridge to the canoe launch area (approximately 131 m (430 ft) downstream of the northern spring vent). The estimated water surface area for this portion of Wekiwa Springs is about 3,800 m² (1.0 ac).

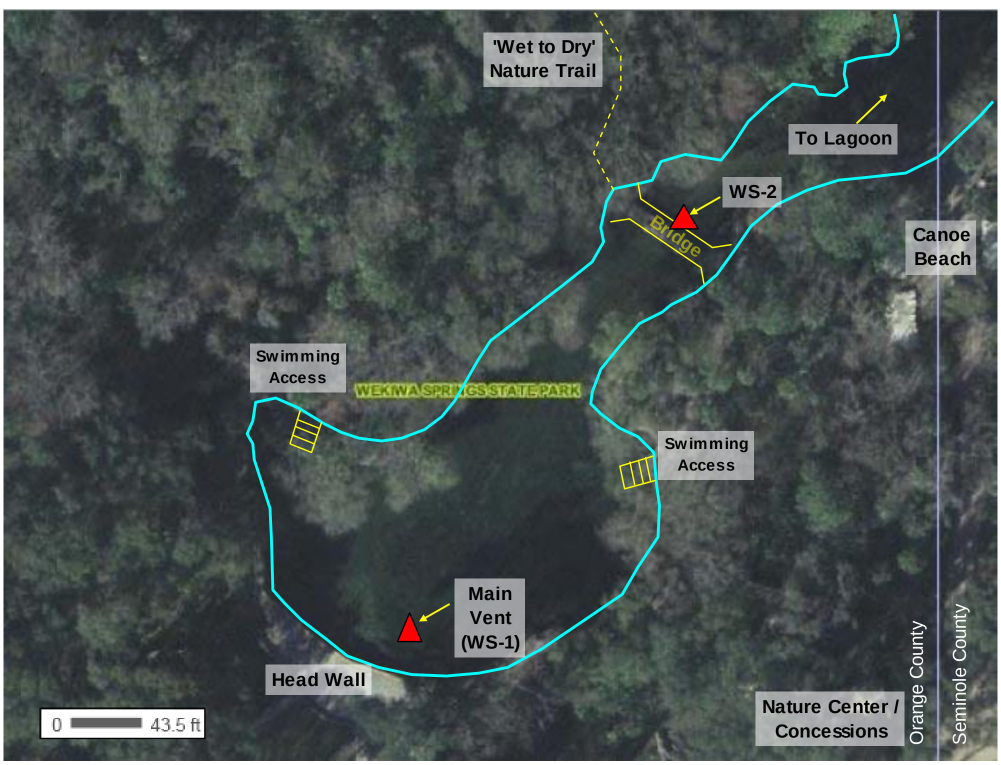


FIGURE 2-23
Wekiwa Springs Site Map. WSI Sampling Station Locations are indicated by Red Triangles [▲]

2.3.3 Summary of Discharge and Stage Data

This analysis utilized discharge data for Wekiwa Springs for the period from November 25, 1959 to September 30, 2005 (**Figure 2-24**). A total of 660 discharge estimates were available for this time period (Intera 2006). Over this entire period-of-record (POR) the average spring discharge was 66.8 cfs and the range of observed values was between 38.6 to 91.7 cfs. Intera (2006) used linear interpolation and regression analyses to develop synthetic daily discharge estimates for Wekiwa Springs. The historical flow record was broken into two components that represented two different levels of available information. Based on their detailed analysis of these two sequential data periods, Intera (2006) concluded that the flow duration curve (FDC) for Wekiwa Springs has changed over time (**Figure 2-25**). Although the cause of this change was not determined, the data for Wekiwa Springs indicate a median flow reduction from about 70 cfs for the POR from 1959-2002 to about 67 cfs (4% decline) for the POR from 2003-2005.

Figure 2-26 illustrates flow duration curves for the Intera Wekiwa Springs synthetic data by decade over the period-of-record. This plot provides additional evidence that minimum and median flows at Wekiwa Springs have been declining for the past five decades with median decadal flows stepping down from 73.4 cfs in the 1960s to 63.7 cfs in the 2000s. Based on the Intera simulated data for Wekiwa Springs, the estimated average and median flows over the period-of-record are about 68 cfs, which is only slightly higher than the actual observed average flow (66.8 cfs). This difference is presumably due to the lower frequency of discharge measurements in the early record compared to the more recent flow record. The range of simulated flow data for Wekiwa Springs was from 38.6 to 93.5 cfs.

German (2004) conducted an independent analysis of 267 discharge measurements for Wekiwa Springs for the period from March 1932 to September 2003. He stated that trend testing indicated a downward trend in discharge for this spring over time. However, statistical tests found that this trend was not monotonic and therefore was inconclusive. He also indicated that the observed trend may have been due to decreased rainfall and that other evidence exists that indicates that discharge at Wekiwa Springs may have increased in relation to rainfall. Tibbals *et al.* 2004 examined possible causes for observed declining flows (about 50% since the early 1960s) in the Upper Ocklawaha River Chain of Lakes located in Lake and Orange counties just west and southwest of Wekiwa Springs. Lowered potentiometric levels in the Floridan aquifer due to groundwater pumping and drought were listed as two of the possible explanations for the observed flow reductions. The Florida Department of Natural Resources (FDNR 1987) reported that the U.S. Geological Survey had found that based on a review of data for the period from 1969 to 1982, that flows in Wekiwa Springs had declined by 25%.

Figure 2-26 illustrated a consistently declining trend by decade for flows at Wekiwa Spring. **Figure 2-27** provides an alternate view of these trends based on the temporal series of annual average flows. **Figure 2-27** displays the actual and Intera modeled flow data for Wekiwa Spring over the period-of-record from about 1960 through 2005. Modeled and measured annual average flows at Wekiwa Springs have been below the 62 cfs minimum annual mean discharge target three times during the past 26 years (12%). These data indicate that the allowable spring MFLs for Wekiwa Spring are being approached, and within a possible range of uncertainty associated with these estimates, may have already been reached, presumably as a result of a combination of anthropogenic consumptive uses and climatic conditions.

Stage data are available for the period from March 1984 to May 2007 (**Figure 2-28**). A total of 2,624 stage measurements were available for this POR. Average stage at the Wekiwa Springs gauge (located about 250 ft downstream of the Main Boil for this POR was 13.06 ft NGVD with a range of observed values from 12.26 to 14.94 ft NGVD.

2.3.4 Physical Conditions

Limited physical data are available for Wekiwa Springs and the upper spring run within the project area. A total of 6 surveyed cross sections were made on February 22, 2007 in this area (**Appendix F**) when the recorded water level was 12.85 ft NGVD. These cross sections were used to estimate the physical dimensions (surface area, volume, and average depth) within the project area (**Table 2-9**). **Figure 2-29** provides estimates of the relationships between stage and surface area and water volume. At a median surface water elevation of 13.01 ft NGVD, the estimated wet surface area of the project area is 3,900 m^2 (0.96 ac) and the water volume is 4,360 m^3 (153,970 ft^3).

TABLE 2-9
Wekiwa Springs – Survey Cross Sections – Area/Volume Estimates (see **Appendix F** for transect locations and cross sections)

	Transect			Interval			
Transect	**Channel Width (m)**	**Average Depth (m)**	**Cross-Sectional Area (m^2)**	**Distance Between Transects (m)**	**Est. Area (m^2)**	**Avg Cross-Sectional Area (m^2)**	**Est. Volume (m^3)**
1	79.7	1.15	91.8	---	---	---	---
2	46.9	1.27	59.9	---	---	---	---
3	34.9	1.25	43.4	32.4	1,324.6	51.6	1,672
4	42.4	1.22	51.5	13.4	515.9	47.5	633.6
5	19.5	1.00	19.3	24.7	763.1	35.4	873.2
6	20.7	0.61	12.6	60.6	1,219.5	16.0	967.8
Total	---	---	---	131.0	3,823	---	4,146
Average	32.9	1.07	37.3	32.8	955.8	37.6	1,036.6

Calculated Depth (m): 1.08

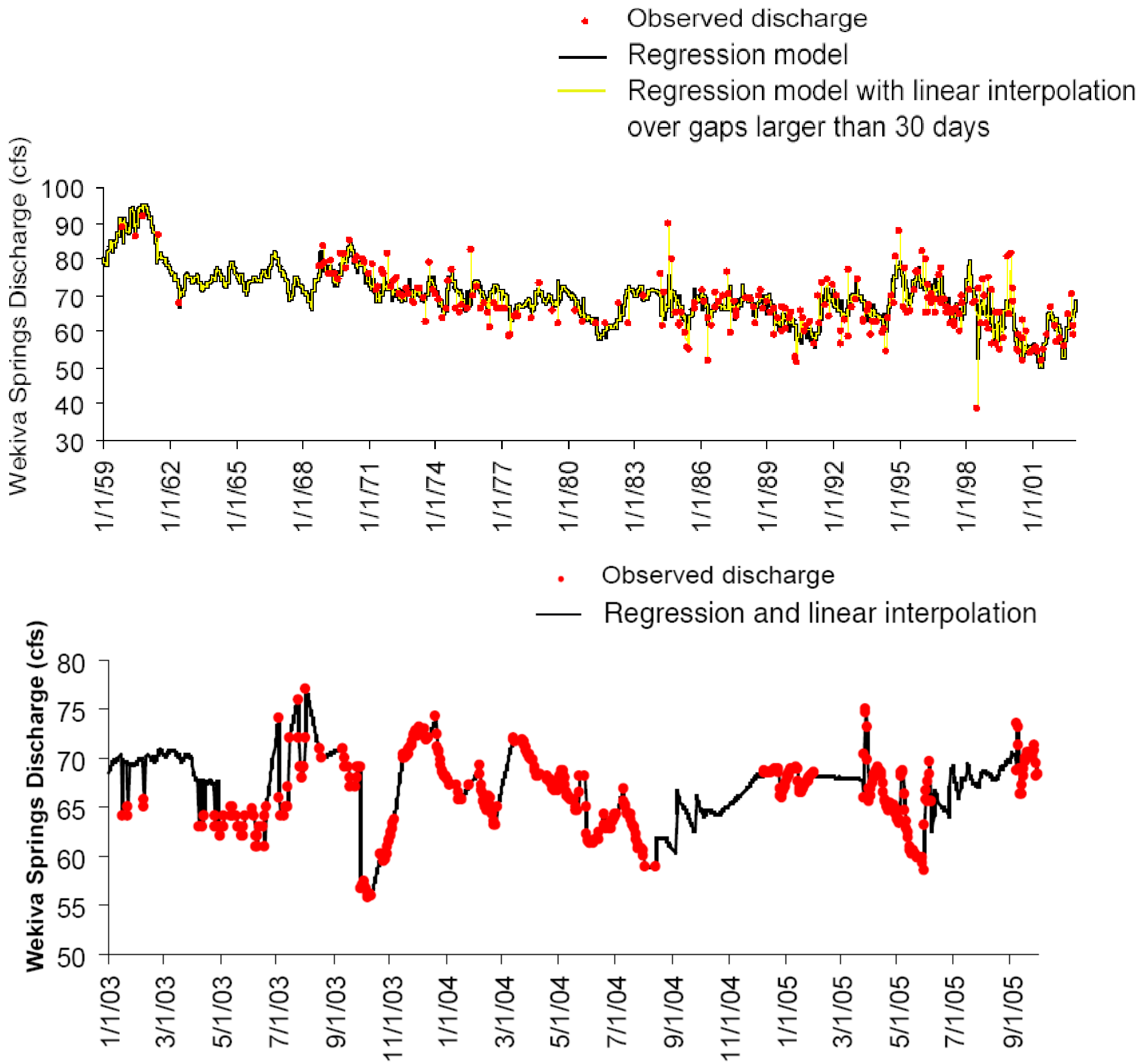


FIGURE 2-24
Time Series of Predicted and Observed Discharge for Wekiwa Springs (Intera 2006)

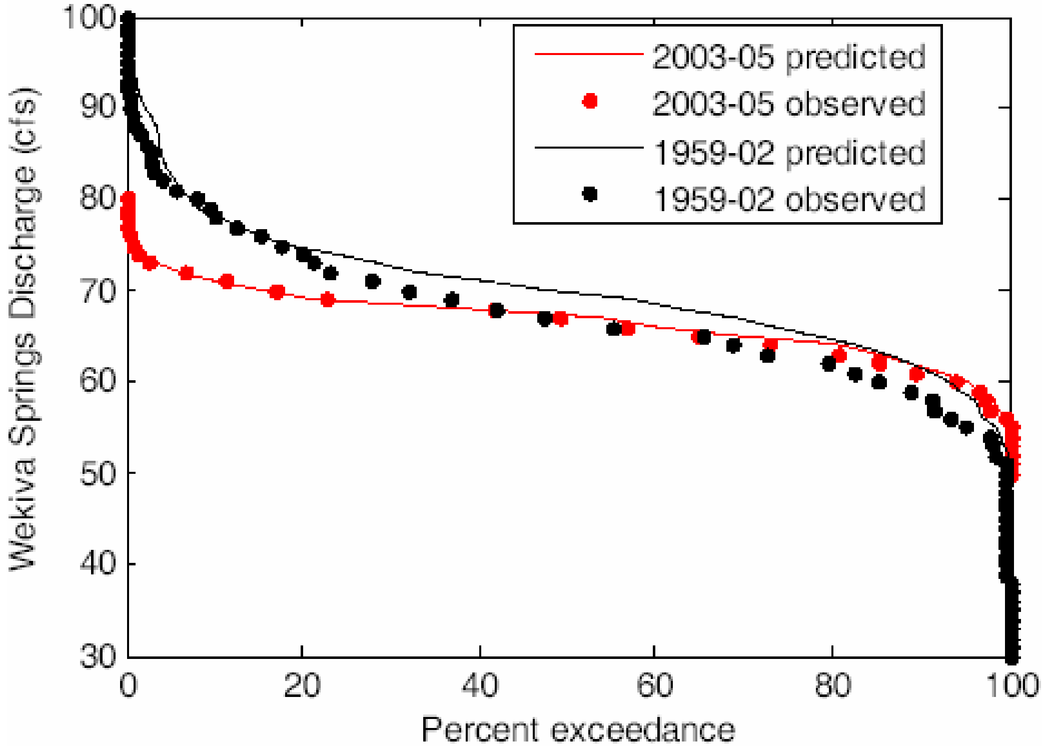


FIGURE 2-25
Flow Duration Curves for Wekiwa Springs over 1959-2002 and 2003-2005 (Intera 2006)

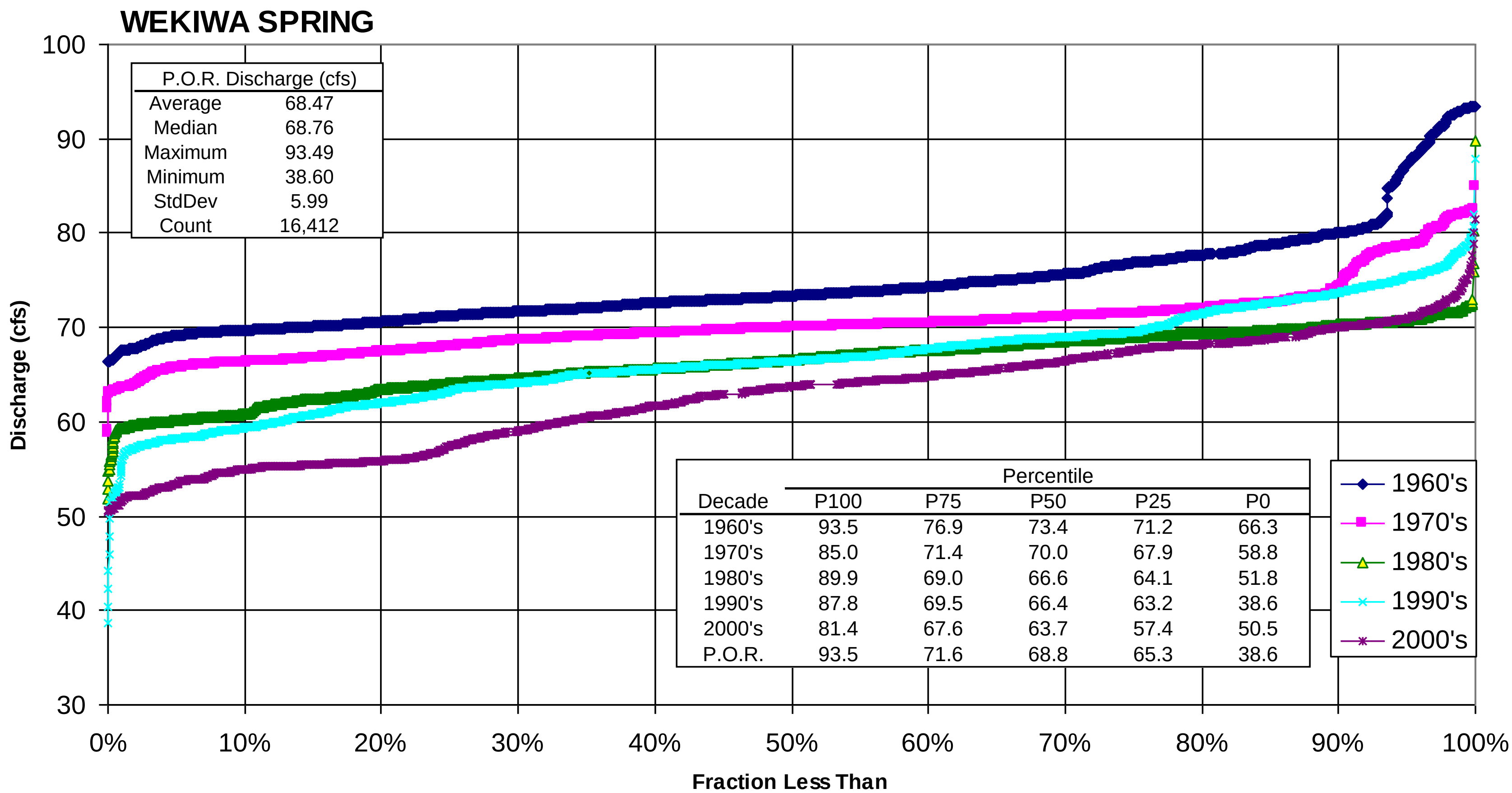


FIGURE 2-26
Wekiwa Springs Flow Duration Curves for the Past Five Decades Based on Simulated Discharge Data from Intera (2006)

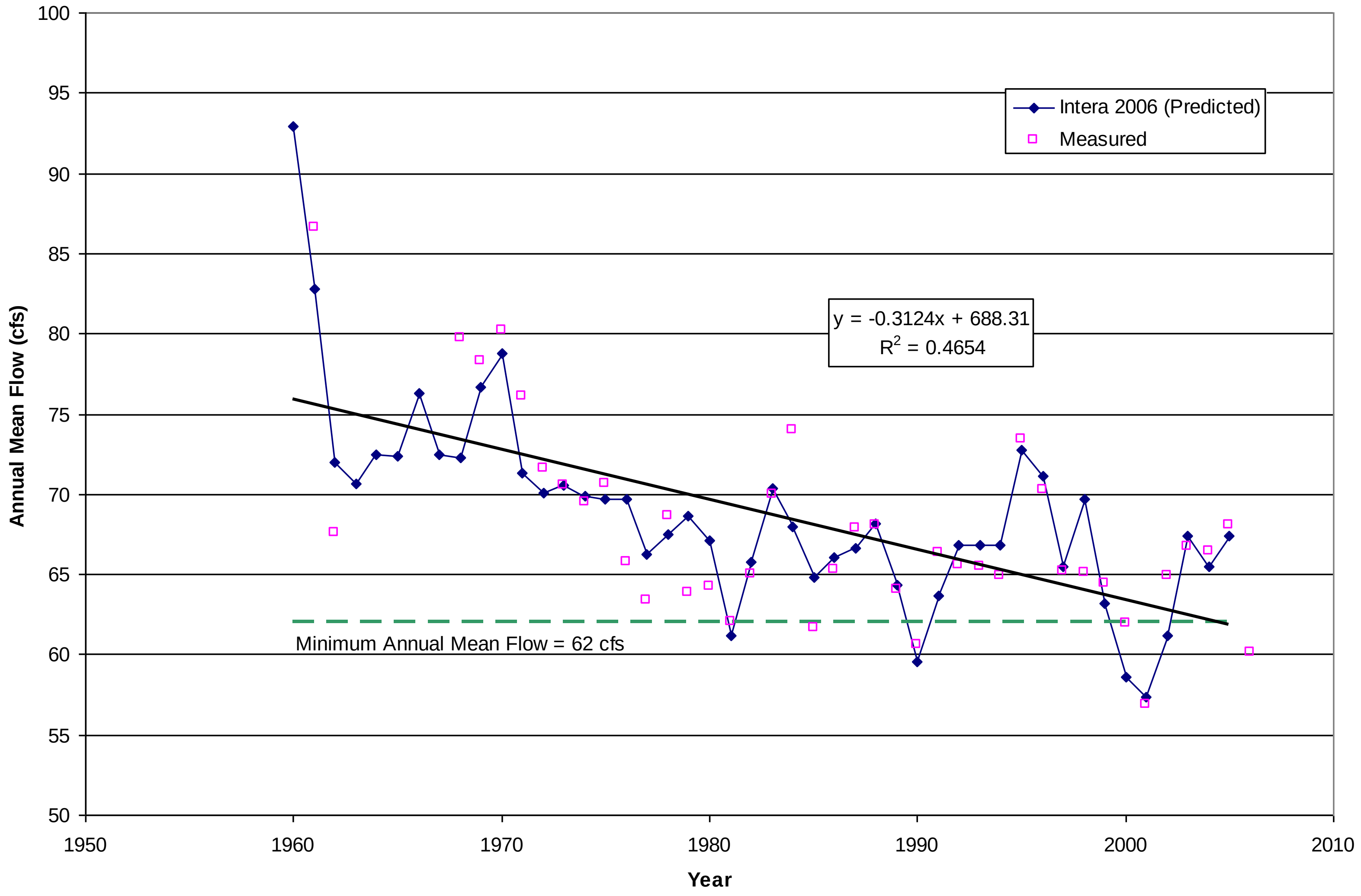


FIGURE 2-27
Time Series Plot of Annual Average Flows (Measured and Modeled) at Wekiwa Spring Compared to the Existing District Spring MFL of 62 cfs

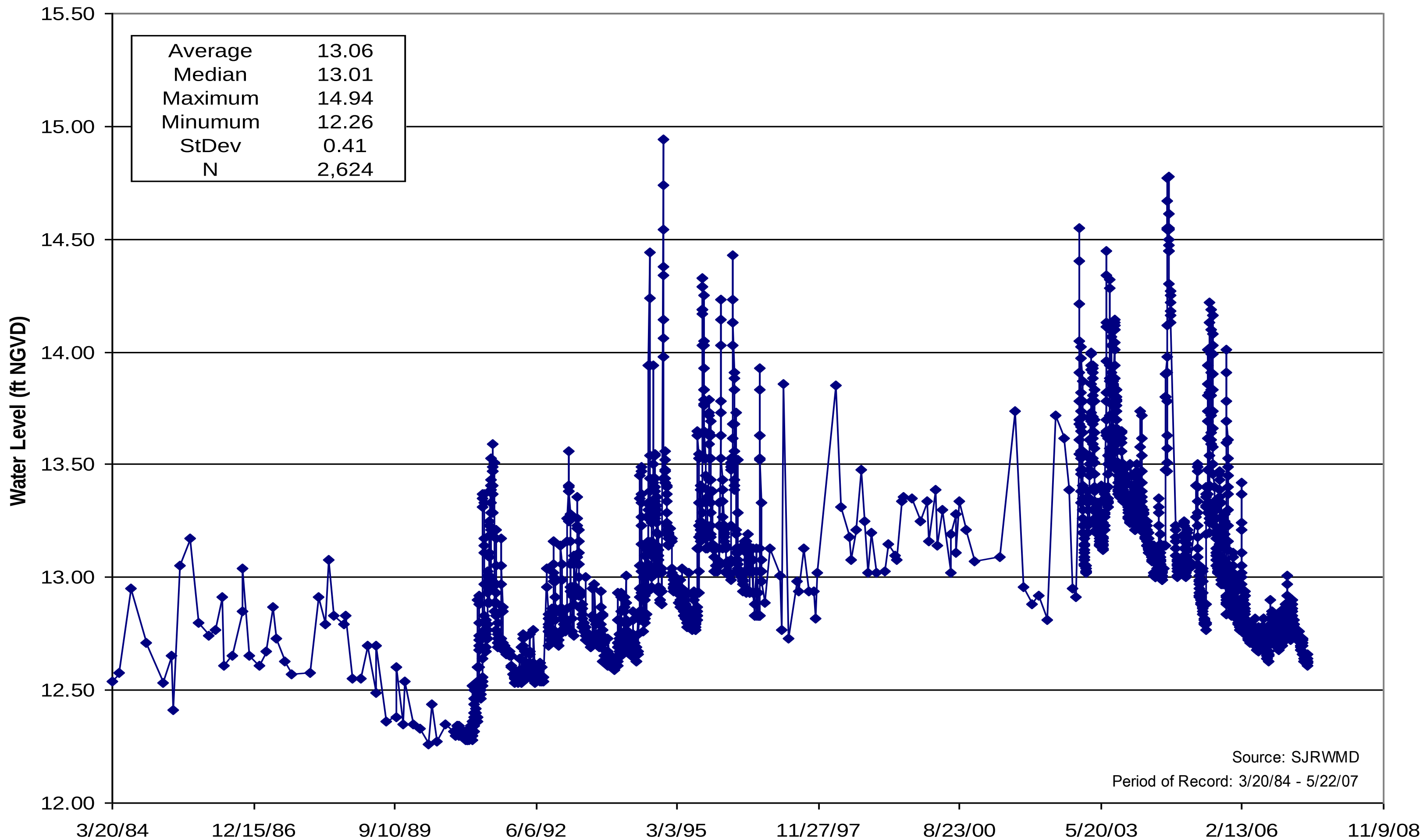


FIGURE 2-28
Time Series of Water Levels for Wekiwa Springs 1984 - 2007

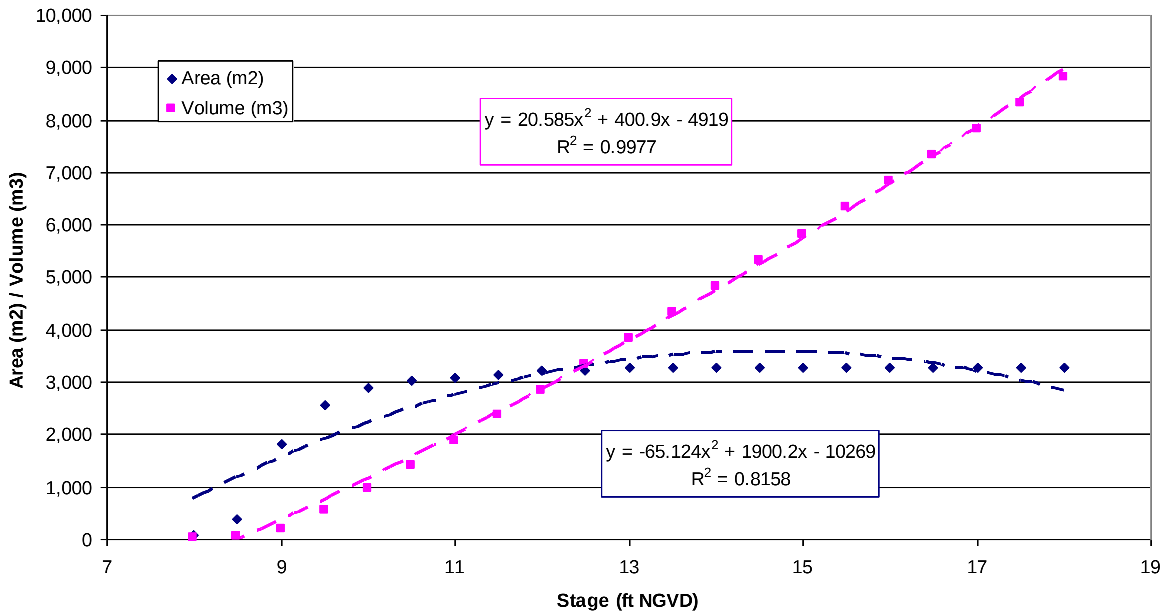


FIGURE 2-29
Wekiwa Springs Estimated Stage/Area and Stage/Volume Relationship

An effort was made to use historical information to estimate the effects of discharge at Wekiwa Springs on the hydraulics of the study area. The stage vs. discharge relationship for the Wekiwa Springs gauge located at the bridge at the north end of the swim area (see station WS2 in **Figure 2-23**) is illustrated in **Figure 2-30** plotted with all pairs of stage and discharge data available from the District. A linear regression line is also plotted through all of the points on **Figure 2-30**. While some of the recorded data generally fall along the best-fit regression line, many of the data points illustrate a relatively weak relationship between discharge and gage height with as much as 0.75 m (2.5 ft) of variation in stage at a given discharge rate. This discrepancy is probably related to backwater effects in the Wekiva River downstream of Wekiwa Springs (Tom Mirti, SJRWMD, personal communication, 2007). The regression equation presented in **Figure 2-30** appears to provide a reasonable relationship between stage and discharge during low water conditions in the Wekiva River. This regression indicates that under non-backwater conditions, stage (and resulting water volume) declines in rough proportion to spring discharge. However, it can also be concluded from these data that there is little effect of spring discharge on water stage during periods of elevated water levels downstream of Wekiwa Springs. For the purposes of the subsequent WRV analyses described in Section 5 of this report, it is assumed that backwater conditions are negligible and that the regression presented in **Figure 2-30** provides a reasonable method for estimating the effects of changes in discharge on changes in water stage and resulting wetted area, water volume, nHRT, and current velocity (Tom Mirti, SJRWMD, personal communication, 2007).

Table 2-10 provides a summary of these estimates over the range of observed simulated discharge measurements in Wekiwa Springs. Based on the use of the regression between discharge and stage shown in **Figure 2-30,** the estimated range in average current velocities is from 4 to 7 cm/s at the highest and lowest reported flows and stages. The resulting nHRT estimates range from 0.5 to 0.8 hours.

Table 2-11 provides estimates of channel cross-sections with a depth of at least 0.75 m (2.5 ft) or greater at Wekiwa Springs over a range of water stage elevations at the recorder station. At the average recorded stage of 13.06 ft NGVD, there is no constraint on recreational activities in the spring pool with a minimum estimated pool width of about 19 m (62 ft) on Transect 5 (see **Appendix F**). At lower water stages this estimated minimum depth is not available, possibly limiting various recreational activities as described below.

TABLE 2-10
Wekiwa Springs Estimated Current Velocities and Nominal Hydraulic Residence Time (nHRT) as a Function of Spring Discharge

Stage		Depth		Flow		Area	Volume	HRT	Velocity
ft	ft NGVD	ft	m	cfs	m^3/d	m^2	m^3	hr	m/s
12.00	11.98	2.86	0.87	30.87	75,526	3,225	2,843	0.90	0.040
12.15	12.13	3.01	0.92	35.23	86,194	3,225	2,990	0.83	0.044
12.30	12.28	3.16	0.96	39.59	96,862	3,225	3,137	0.78	0.047
12.45	12.43	3.31	1.01	43.95	107,531	3,225	3,285	0.73	0.050
12.60	12.58	3.46	1.05	48.31	118,199	3,225	3,432	0.70	0.052
12.75	12.73	3.61	1.10	52.67	128,867	3,225	3,580	0.67	0.055
12.90	12.88	3.76	1.15	57.03	139,536	3,277	3,728	0.64	0.057
13.05	13.03	3.91	1.19	61.39	150,204	3,277	3,878	0.62	0.059
13.20	13.18	4.06	1.24	65.75	160,872	3,277	4,028	0.60	0.061
13.35	13.33	4.21	1.28	70.11	171,540	3,277	4,177	0.58	0.062
13.50	13.48	4.36	1.33	74.48	182,209	3,277	4,327	0.57	0.064
13.65	13.63	4.51	1.37	78.84	192,877	3,277	4,477	0.56	0.065
13.80	13.78	4.66	1.42	83.20	203,545	3,277	4,627	0.55	0.067
13.95	13.93	4.81	1.47	87.56	214,214	3,277	4,777	0.54	0.068
14.10	14.08	4.96	1.51	91.92	224,882	3,277	4,926	0.53	0.069
14.25	14.23	5.11	1.56	96.28	235,550	3,277	5,076	0.52	0.070
14.40	14.38	5.26	1.60	100.64	246,219	3,277	5,226	0.51	0.071
14.55	14.53	5.41	1.65	105.00	256,887	3,277	5,376	0.50	0.072
14.70	14.68	5.56	1.69	109.36	267,555	3,277	5,526	0.50	0.073
14.85	14.83	5.71	1.74	113.72	278,223	3,277	5,676	0.49	0.074
15.00	14.98	5.86	1.79	118.08	288,892	3,277	5,825	0.48	0.075

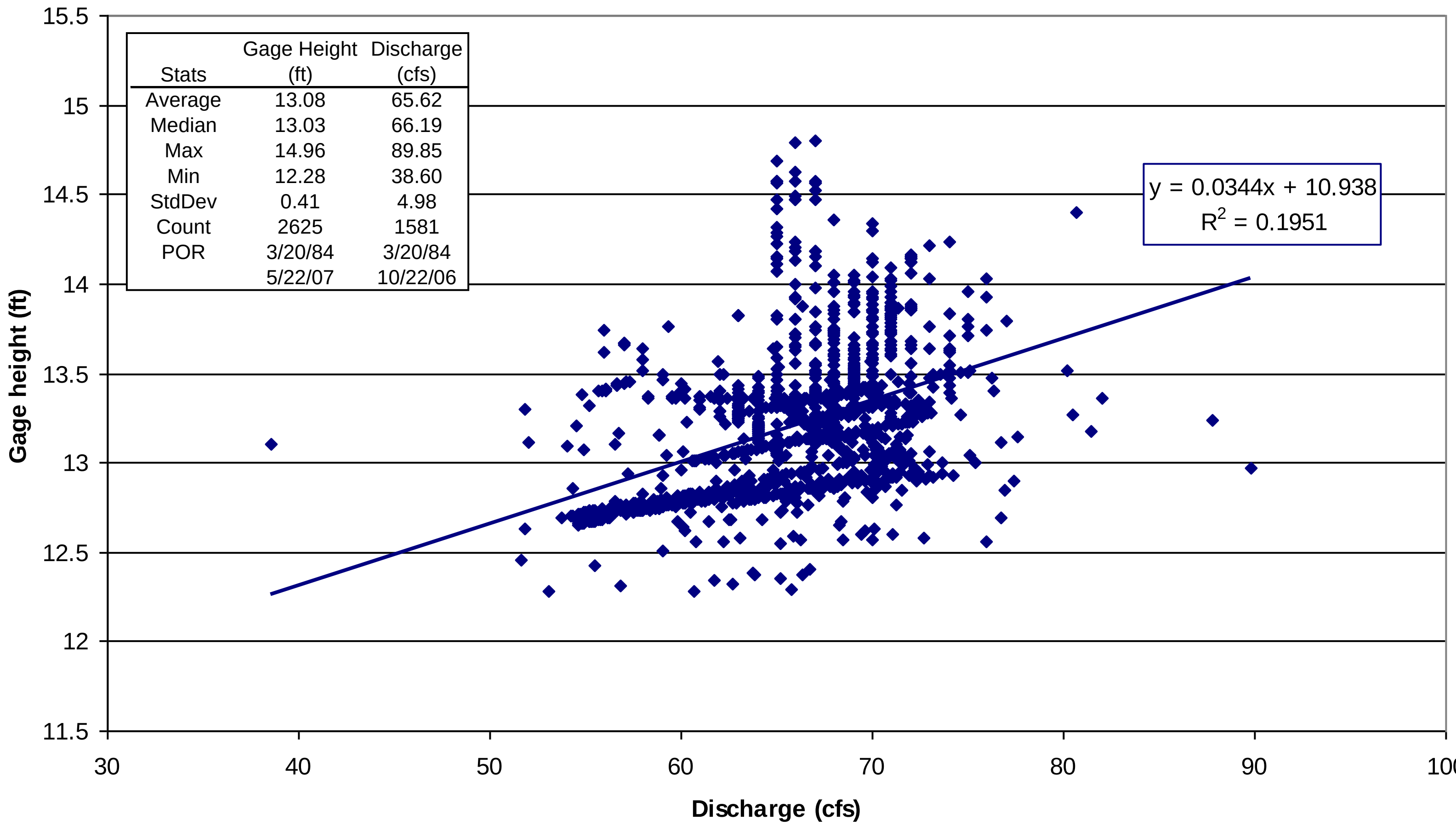


FIGURE 2-30
Wekiwa Springs Estimated Discharge vs. Stage Relationship for Historical Data. The regression equation was used for estimating relationships between stage and discharge and for estimating current velocity and nHRT

TABLE 2-11
Wekiwa Springs Estimated Pool Widths based on a Minimum Water Depth of 0.75 m (2.5 ft) as a Function of Water Stage at the Recorder Station

	Width (ft) of Channel Cross-Section > 2.5 foot							% of Channel Cross-Section > 2.5 foot						
Stage (ft)	1	2	3	4	5	6	Avg	1	2	3	4	5	6	Avg
18.0	263	162	120	142	67	85	140	99	99	99	99	99	99	99
17.5	263	162	120	142	67	85	140	99	99	99	99	99	99	99
17.0	262	154	120	141	66	85	138	99	97	99	98	96	99	98
16.5	262	154	115	139	64	82	136	99	97	96	97	93	95	96
16.0	262	154	115	139	64	75	135	99	97	96	97	93	89	95
15.5	262	154	115	139	64	71	134	99	97	96	97	93	85	94
15.0	261	153	114	139	63	68	133	98	96	94	95	90	80	92
14.5	261	153	114	139	63	68	133	94	96	94	95	90	80	92
14.0	261	153	114	139	62	43	129	94	96	94	95	89	51	87
13.5	261	153	114	139	62	34	127	98	96	94	95	89	40	85
13.0	254	153	114	139	62	23	124	95	96	94	95	89	29	83
12.5	244	147	114	139	62	12	120	91	92	94	95	89	15	79
12.0	210	144	114	139	33	3	107	79	90	94	95	47	4	68
11.5	142	120	97	119	0	0	80	53	76	80	81	0	0	48
11.0	33	67	22	0	0	0	20	12	42	18	0	0	0	12
10.5	4	15	0	0	0	0	3	1	9	0	0	0	0	2
10.0	4	0	0	0	0	0	1	1	0	0	0	0	0	0

Note(s):
Stage at staff gauge adjacent to bridge
Detailed cross-sections presented in Appendix B

2.3.5 Water Quality

Water quality data for Wekiwa Springs and from the nearby station WR-SEG1-UP (located at the downstream end of the WRV project area at the bridge - WSI 2006) are summarized in **Table 2-12** for the POR from April 1956 to February 2006. Sampling frequencies for different parameters were variable so that many more records are available for some parameters than for others. Wekiwa Springs POR averages for several key parameters are:

- Water temperature – 23.7 ^{o}C
- Dissolved oxygen – 0.07 mg/L
- pH – 7.41 s.u.
- Specific conductance – 320 uS/cm
- Turbidity – 0.16 NTU
- Color – 6.75 CPU
- Total chloride – 13.4 mg/L
- Sulfate – 21.8 mg/L
- Nitrate+nitrite nitrogen – 1.33 mg/L
- Total phosphorus – 0.176 mg/L

In his study of stable isotope concentrations, Toth (1999) reported that water discharging from Wekiwa Springs had an estimated mean age of 17.1 ± 0.5 yr. Elevated nitrate N concentrations in Wekiwa Springs were determined to be largely due to groundwater contamination by animal waste and/or human sewage discharges with a fraction of nitrates derived from soil organic N. The presence of elevated nitrate N levels in spring water suggests a shallow to intermediate flow system in the Upper Zone of the Floridan aquifer.

Toth and Fortich (2002) continued the District's evaluation of nitrate in springs in the Wekiva River Basin. The concentration of nitrate N appeared to increase during the period-of-record to a maximum of about 2.0 mg/l in 1995 and has been declining since that time (1.3 mg/L in 1999). A total of 50 additional sites in the Wekiva River Basin were sampled for groundwater nitrate N concentrations for their study. Highest concentrations were detected to the west of Lake Apopka; however, the data indicated that the areas of highest nitrate N concentrations probably do not contribute to the nitrate discharging at Wekiwa Springs (Toth and Fortich 2002).

Land use changes between 1973 and 1990 suggest that this elevated nitrate is probably derived from septic tanks and lawn fertilizer applications (Toth and Fortich 2002). The source of these inputs was determined to be the high-rate recharge areas just south and southwest of the spring. Declining nitrate N concentrations may be due to the construction of a wastewater treatment facility in Seminole County in 1973 or to an increasing fraction of the spring discharge from the deeper part of the aquifer.

2.3.6 Biological Conditions

The Wekiwa Springs Main Boil and swimming area are located within a man-made retaining wall constructed of concrete and native limestone. The entire area is intensively used for recreation and is relatively unvegetated by vascular plants. Flora and fauna species totals for spring boil and spring run habitats in Wekiwa Springs State Park were listed above for Rock Springs (see **Appendix A** for species lists).

TABLE 2-12
Wekiwa Springs Water Quality Summary (see **Figure 2-2** for WR-SEG 1-UP location)

Parameter Group	Parameter	Units	WEKIWA BOIL Average	WEKIWA BOIL Maximum	WEKIWA BOIL Minimum	WEKIWA BOIL StdDev	WEKIWA BOIL Count	WEKIWA BOIL Period of Record		WR-SEG1-UP Average	WR-SEG1-UP Maximum	WR-SEG1-UP Minimum	WR-SEG1-UP StdDev	WR-SEG1-UP Count	WR-SEG1-UP Period of Record	
Temperature	Temp	C	23.7	25.5	22.0	0.526	181	4/27/1956	2/14/07	23.6	24.0	21.8	0.651	12	1/26/05	2/15/06
Dissolved Oxygen	DO	%	0.78	1.50	0.30	0.26	71	3/30/2007	5/22/2007	5.72	6.70	4.80	0.573	12	1/26/05	2/15/06
		mg/L	0.07	0.13	0.03	0.02	71	3/30/2007	5/22/2007	0.474	0.580	0.360	0.059	12	1/26/05	2/15/06
Physical	pH	SU	7.41	8.22	6.13	0.307	106	4/27/1956	2/14/07	7.34	7.67	6.64	0.252	12	1/26/05	2/15/06
	Sp Cond	uS/cm	320	398	246	23.5	75	6/12/1984	2/14/07	317	320	310	2.56	12	1/26/05	2/15/06
	Color	cpu	---	---	---	---	---	---	---	6.75	15.0	2.50	3.74	10	5/9/05	2/15/06
	TURB	ntu	---	---	---	---	---	---	---	0.157	0.800	0.00	0.243	10	5/9/05	2/15/06
Oxygen Demand	BOD	mg/L	---	---	---	---	---	---	---	0.295	0.800	0.00	0.319	10	5/9/05	2/15/06
Solid	TSS	mg/L	---	---	---	---	---	---	---	1.30	2.00	0.00	0.789	10	5/9/05	2/15/06
	TDS	mg/L	192	1,880	101	176	95	11/25/1959	2/14/07	189	211	166	14.7	10	5/9/05	2/15/06
	VSS	mg/L	---	---	---	---	---	---	---	2.25	5.00	0.00	1.77	10	5/9/05	2/15/06
General Inorganic	ALK	mg/L	115	140	72.0	12.6	97	4/27/1956	2/14/07	119	123	110	3.56	10	5/9/05	2/15/06
	Cl -	mg/L	13.4	27.0	7.00	2.65	104	4/27/1956	2/14/07	16.0	19.0	13.4	1.31	11	1/26/05	2/15/06
	SILICA	mg/L	5.09	14.0	4.00	1.91	46	7/23/1987	7/16/02	9.56	10.8	4.30	1.92	10	5/9/05	2/15/06
	SO4	mg/L	---	---	---	---	---	---	---	21.8	22.2	20.8	0.412	10	5/9/05	2/15/06
	TC	mg/L	1.12	2.30	0.00	0.814	8	4/11/1972	10/19/06	31.7	39.7	27.4	3.41	10	5/9/05	2/15/06
General Organic	DOC	mg/L	---	---	---	---	---	---	---	1.77	5.38	0.00	1.97	10	5/9/05	2/15/06
Nitrogen	NH3	mg/L	0.031	0.031	0.031	---	1	2/26/2001	2/26/01	0.007	0.029	0.005	0.008	10	5/9/05	2/15/06
	NO2 + NO3	mg/L	1.33	2.00	0.342	0.360	72	9/2/1977	2/14/07	1.24	1.35	1.10	0.080	11	1/26/05	2/15/06
	TKN	mg/L	---	---	---	---	---	---	---	0.125	0.400	0.020	0.108	11	1/26/05	2/15/06
	TN	mg/L	---	---	---	---	---	---	---	1.37	1.75	1.20	0.152	11	1/26/05	2/15/06
Phosphorus	SRP	mg/L	---	---	---	---	---	---	---	0.134	0.161	0.119	0.013	10	5/9/05	2/15/06
	TP/D/SPEC	mg/L	0.120	0.141	0.110	0.018	3	4/19/1995	2/26/01	0.125	0.135	0.107	0.008	10	5/9/05	2/15/06
	TP/T/SPEC	mg/L	0.176	2.04	0.012	0.353	30	4/11/1972	2/14/07	0.130	0.150	0.126	0.007	10	5/9/05	2/15/06
Metal	CA/T/ICP	mg/L	39.0	66.9	25.6	4.72	68	7/7/1992	2/14/07	40.0	43.1	38.0	1.71	10	5/9/05	2/15/06
	FE/T/ICP	ug/L	49.2	100	6.00	32.6	14	9/2/1977	8/12/03	5.79	8.20	3.80	1.83	10	5/9/05	2/15/06
	MG/T/ICP	mg/L	11.3	29.3	7.65	2.35	68	7/7/1992	2/14/07	11.5	12.3	11.0	0.389	10	5/9/05	2/15/06
	NA/T/ICP	mg/L	12.5	246	4.67	28.7	68	7/7/1992	2/14/07	9.49	10.1	8.73	0.395	10	5/9/05	2/15/06

Note: Statistics calculated using half of the detection limit if reported as below the detection limit.
Source: WEKIWA BOIL (SJRWMD/WSI); WR-SEG1-UP (WSI)

Walsh and Kroening (2007) sampled benthic macroinvertebrate populations in the spring run downstream of Wekiwa Springs using multi-habitat sampling with a D-frame dip net (500 um mesh, 0.3 m wide) to assess species richness and diversity and a petite ponar dredge to estimate abundance (density per area) between December 2005 and September 2006. Their quarterly sampling identified 33 species of macroinvertebrates represented by the following numbers of species by major taxonomic group:

- Oligochaeta – 9
- Turbellaria - 2
- Gastropoda – 6
- Ephemeroptera -1
- Odonata – 1
- Diptera – 11
- Isopoda – 2
- Amphipoda – 1

Average macroinvertebrate density based on the petite ponar dredge sampling was 19,849 organisms/m^2 with a range of seasonal densities from 6,438 to 35,802 organisms/m^2.

Walsh and Kroening (2007) electroshocked fish on July 27, 2006 in the Wekiva River, downstream of the Wekiwa Springs boil and public use area. A total of 15 fish species were collected, including the following dominants arranged in order of decreasing dominance:

- *Lepomis punctatus* (spotted sunfish)
- *Lepomis auritus* (redbreast sunfish)
- *Erimyzon sucetta* (lake chubsucker)
- *Micropterus salmoides* (largemouth bass)
- *Notemigonus crysoleucas* (golden shiner)
- *Amia calva* (bowfin)

Populations of small and medium sized fish (probably rainwater killifish [*Lucania parva*]) were observed throughout the head spring area during site reconnaissance efforts in September 2006. Walsh and Williams (2003) inventoried fish and mussels in the Wekiwa Springs' Main Boil area in April 2000. A total of 24 fish species were collected in the Main Boil area and downstream in the Wekiva River. Fish species specifically noted in the Main Boil area included the rainwater killifish and the non-native sailfin catfish (*Pterygoplichthys disjunctivus*). Sailfin catfish were observed to hide in the spring vents during the day with short trips to the surface to get better-oxygenated water and to feed throughout the spring boil area at night, presumably on algae and detritus. Walsh and Williams (2003) did not observe any mussels in the Main Boil area at Wekiwa Springs but did observe four species downstream in the Wekiva River.

During the site reconnaissance on September 27, 2006 and during subsequent particulate export sampling on March 30, April 26, and May 22, 2007, WSI observed the following additional common flora and fauna species in the Wekiwa Springs boil or downstream in the spring run:

- Filamentous green and blue-green algae (benthic, epelithic, and periphytic)
- *Pistia stratiotes* (water lettuce)
- *Nuphar luteum* (spatterdock)
- Pond turtles
- *Alligator mississippiensis* (American alligator)

Numerous other plant and animal species no doubt occur in Wekiwa Springs and in the upper portion of the Wekiva River or are partially dependent upon it for portions of their life history requirements.

Figure 2-31 provides an historic map of the major physical and biological conditions in Wekiwa Springs 55 years ago (Odum 1951). Major physical and biological changes have apparently occurred in this spring during this time span. A comparison between **Figure 2-23** and Odum's map indicates that the area of the spring boil has been enlarged to the west. All of the dominant plant communities observed by Odum around the spring boil are gone, including peripheral beds of submerged aquatics such as southern naiad (*Najas*

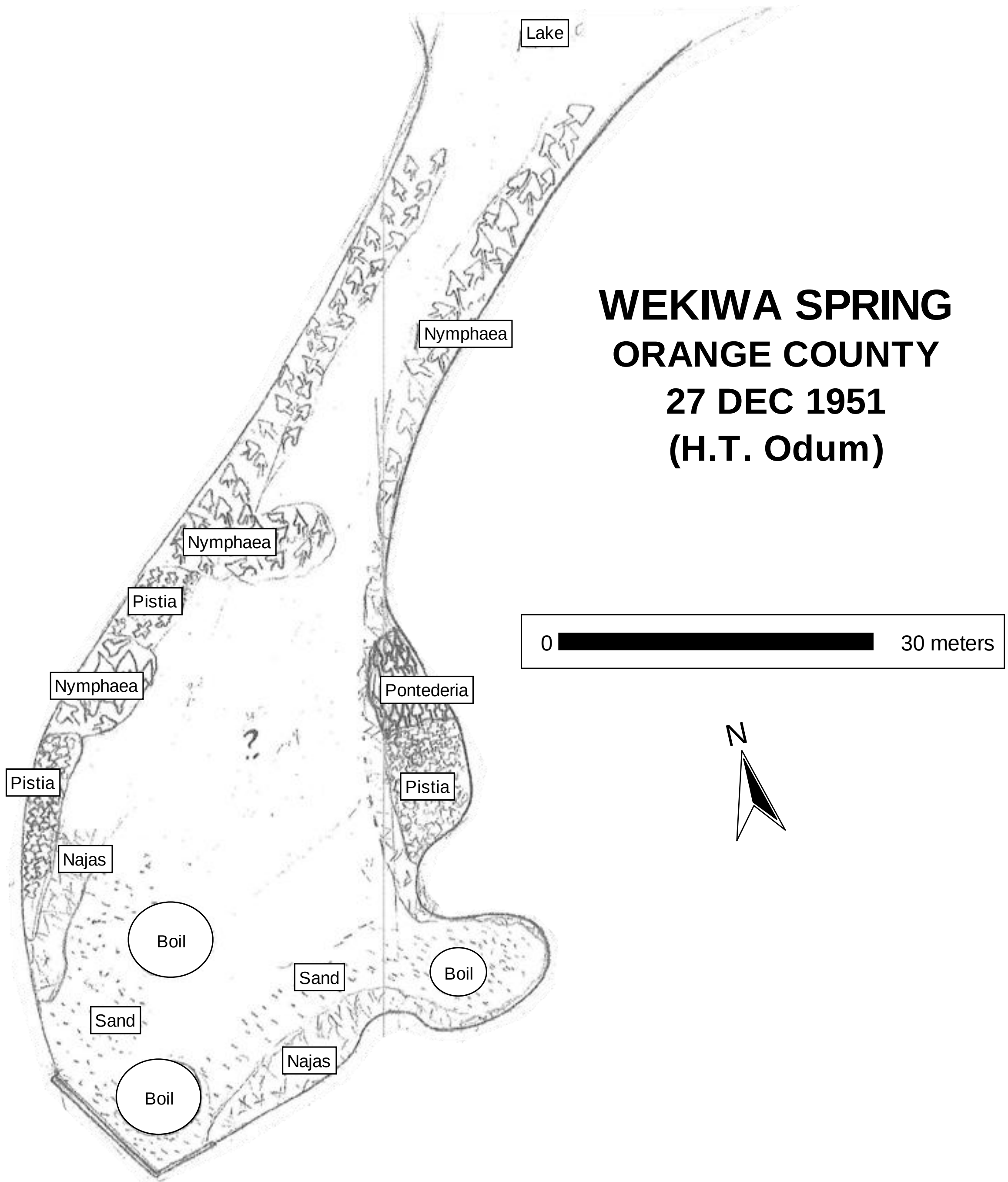


FIGURE 2-31
Map of Wekiwa Springs Showing Overall Basin Configuration, Observed Spring Boils, and Plant Communities (Odum 1951)

guadalupensis) , floating aquatics such as water lettuce and white water lily (*Nymphaea odorata*), and pickerelweed (*Pontederia cordata*). In 1951 the stone retaining wall only extended along the south edge of the spring boil compared to completely encircling the swimming area today. Odum also documented a third boil north of the main boil that was not observed during the course of our field work in the spring.

2.3.7 Ecosystem Functions

New data collection at Wekiwa Springs was conducted by WSI to provide for comparison of ecosystem functions with conditions in other springs. A companion document (WSI 2007) provides a complete description of the methods and results of those data collection efforts and detailed data summaries are provided in this report as **Appendices B** (**Daily Metabolism Estimates**), **C** (**Field Parameter Measurements**), **D** (**Light Attenuation Estimates**), and **E** (**Particulate Export Measurements**). Four sampling events were completed in September 2006, and in March, April, and May 2007. New data were collected at two stations: the Main Boil (WS1) and from the bridge at the downstream end of the walled swimming area (WS2). Continuously-recording data sondes (field-measured parameters included: water temperature, pH, dissolved oxygen, and specific conductance) were installed at the downstream end of the Wekiwa Springs segment (WS2) for up to two weeks during each sampling event. During the September 2006 event, an identical data sonde was deployed just below the main boil to provide data concerning the variability of field parameters at the upstream end of the segment. The upstream-downstream dissolved oxygen method (Odum 1956) was utilized to estimate rates of gross primary productivity (GPP), community respiration (CR or R24), and net primary productivity (NPP or NPP24). Ecological efficiency (EE) of the spring community was estimated as the quotient of GPP and total daily photosynthetically active radiation (PAR).

Historical water quality data were utilized to estimate nutrient assimilation rates in the Wekiwa Springs segment. **Table 2-13** provides a summary of estimated nutrient assimilation rates for this Wekiwa Springs area. These data are also compared to similar estimates for two downstream segments.

Table 2-14 provides a summary of the ecological measures in the Wekiwa Spring segment. Average GPP in the Wekiwa Springs segment was 2.76 g $O_2/m^2/d$. CR was estimated as

TABLE 2-13
Summary of Estimated Nutrient Mass Removals in Wekiwa Springs and Wekiva River Segments (see **Figure 2-2** for station locations)

		Inflow				Outflow								
		Segment - Up				Segment - Down				Removal				
		Conc	Flow	Mass	Mass	Conc	Flow	Mass	Mass	Conc		Mass		
Parameter	Stream Segment	(mg/L)	(m^3/d)	(kg/d)	(kg/ha/d)	(mg/L)	(m^3/d)	(kg/d)	(kg/ha/d)	(mg/L)	(%)	(kg/d)	(kg/ha/d)	(%)
Total Phosphorus	Wekiwa Spring to Segment 1 Up	0.117	163,814	19.1	64.96	0.131	163,814	21.4	72.79	-0.014	-12.06	-2.30	-7.83	-12.1
	Wekiva River Segment 1	0.131	163,814	21.4	6.36	0.139	163,814	22.7	6.75	-0.008	-6.11	-1.31	-0.39	-6.1
	Wekiva River Segment 2	0.119	584,049	69.4	7.04	0.121	584,049	70.8	7.19	-0.003	-2.12	-1.47	-0.15	-2.1
Ortho Phosphorus	Wekiwa Spring to Segment 1 Up	0.110	163,814	18.0	61.20	0.133	163,814	21.8	74.20	-0.023	-21.25	-3.82	-13.00	-21.2
	Wekiva River Segment 1	0.133	163,814	21.8	6.48	0.127	163,814	20.8	6.18	0.006	4.61	1.01	0.30	4.6
	Wekiva River Segment 2	0.105	584,049	61.5	6.24	0.105	584,049	61.5	6.25	0.000	-0.07	-0.04	0.00	-0.1
Nitrate Nitrogen	Wekiwa Spring to Segment 1 Up	1.29	163,814	211	718.53	1.24	163,814	203	689.01	0.053	4.11	8.68	29.52	4.1
	Wekiva River Segment 1	1.24	163,814	203	60.19	1.09	163,814	179	53.04	0.147	11.88	24.08	7.15	11.9
	Wekiva River Segment 2	0.39	584,049	229	23.24	0.37	584,049	218	22.17	0.018	4.59	10.51	1.07	4.6

Wekiwa Spring to WR Seg 1	0.29	ha
Wekiva River Segment 1	3.37	ha
Wekiva River Segment 2	9.85	ha

Period of Record: April 2005 - March 2006 (WSI 2006)

7.56 g $O_2/m^2/d$ for an estimated NPP of -4.80 g $O_2/m^2/d$. Average EE was estimated as 0.26 g O_2/mole. Particulate export averaged 0.24 g ash-free dry weight/m^2/d. A significant diurnal pattern was observed for particulate export as illustrated in **Figures 2-32** through **2-34.** Daytime total organic matter export at Wekiwa Springs was lower than was observed at Rock Springs while export rates normalized by spring boil/run area were similar. As previously noted for Rock Springs, an increase in ash content of the particulate export at Wekiwa Springs was noted during periods of maximum human use in the spring boil area.

Figure 2-35 displays the observed relationship between Wekiwa Springs estimated discharge and the ecosystem metabolism estimates during this limited period-of-record. Downstream estimates of ecological metabolism and particulate export rates from ongoing PLRG studies are also included in **Table 2-15** for comparison.

TABLE 2-14
Summary of Estimated Ecological Measures in Wekiwa Springs

Parameter	Average	Minimum	Maximum	StdDev	N
GPP (g $O_2/m^2/d$)	2.76	0.31	6.92	0.99	137
NPP24 (g $O_2/m^2/d$)	-4.80	-13.12	2.34	3.18	137
R24 (g $O_2/m^2/d$)	7.56	0.16	13.88	2.99	137
P/R Ratio	0.62	0.04	15.55	1.49	137
PAR (24hr) (mol/m^2/d)	14.89	1.10	27.34	6.95	137
PAR Efficiency (%)	2.08	0.28	9.04	1.63	137
EE (g O_2/mol)	0.26	0.03	1.12	0.20	137
Discharge (m^3/d)	149,576	104,850	189,389	20,243	137
Depth (m)	1.15	1.06	1.34	0.06	137
Particulate Export					
Dry Wt (g/m^2/d)	1.30	0.05	7.95	1.83	45
Organic Matter (g/m^2/d)	0.24	0.00	1.18	0.29	45

Period of Record: 4/30/05 5/22/07

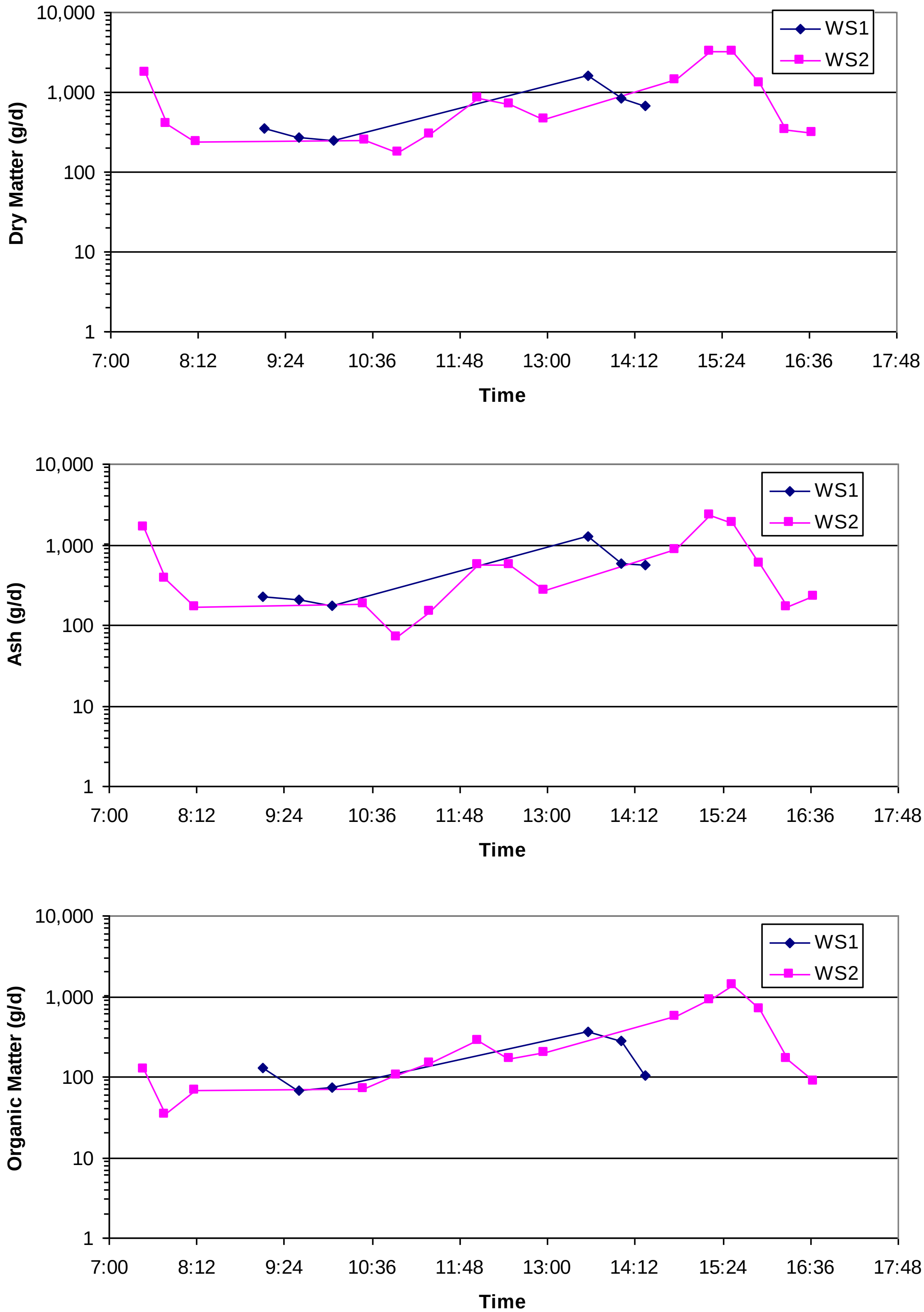


FIGURE 2-32
Particulate Export Measurements from Wekiwa Springs - 3/30/07 (see **Figure 2-23** for station locations)

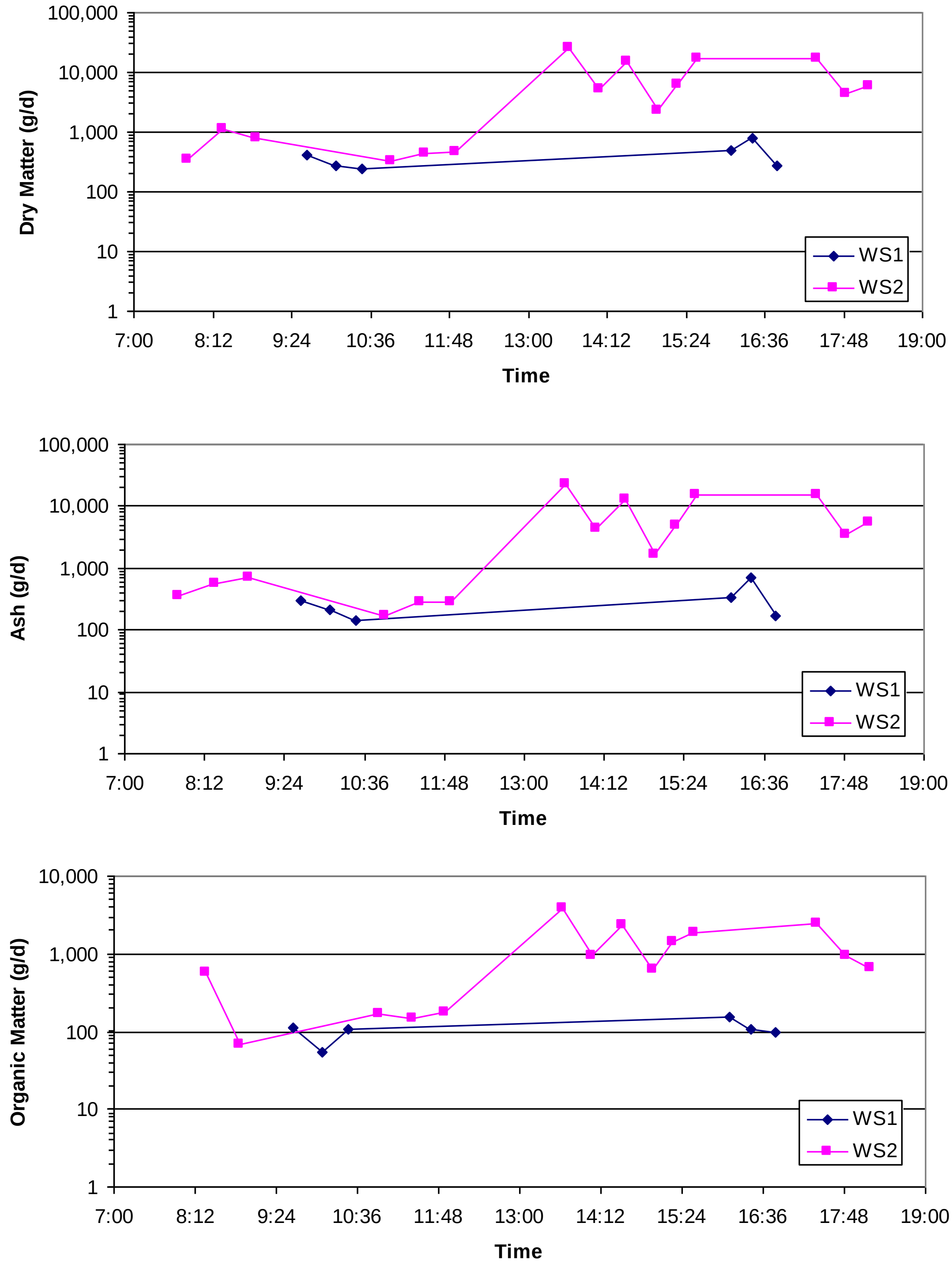


FIGURE 2-33
Particulate Export Measurements from Wekiwa Springs – 4/24/07(see **Figure 2-23** for station locations)

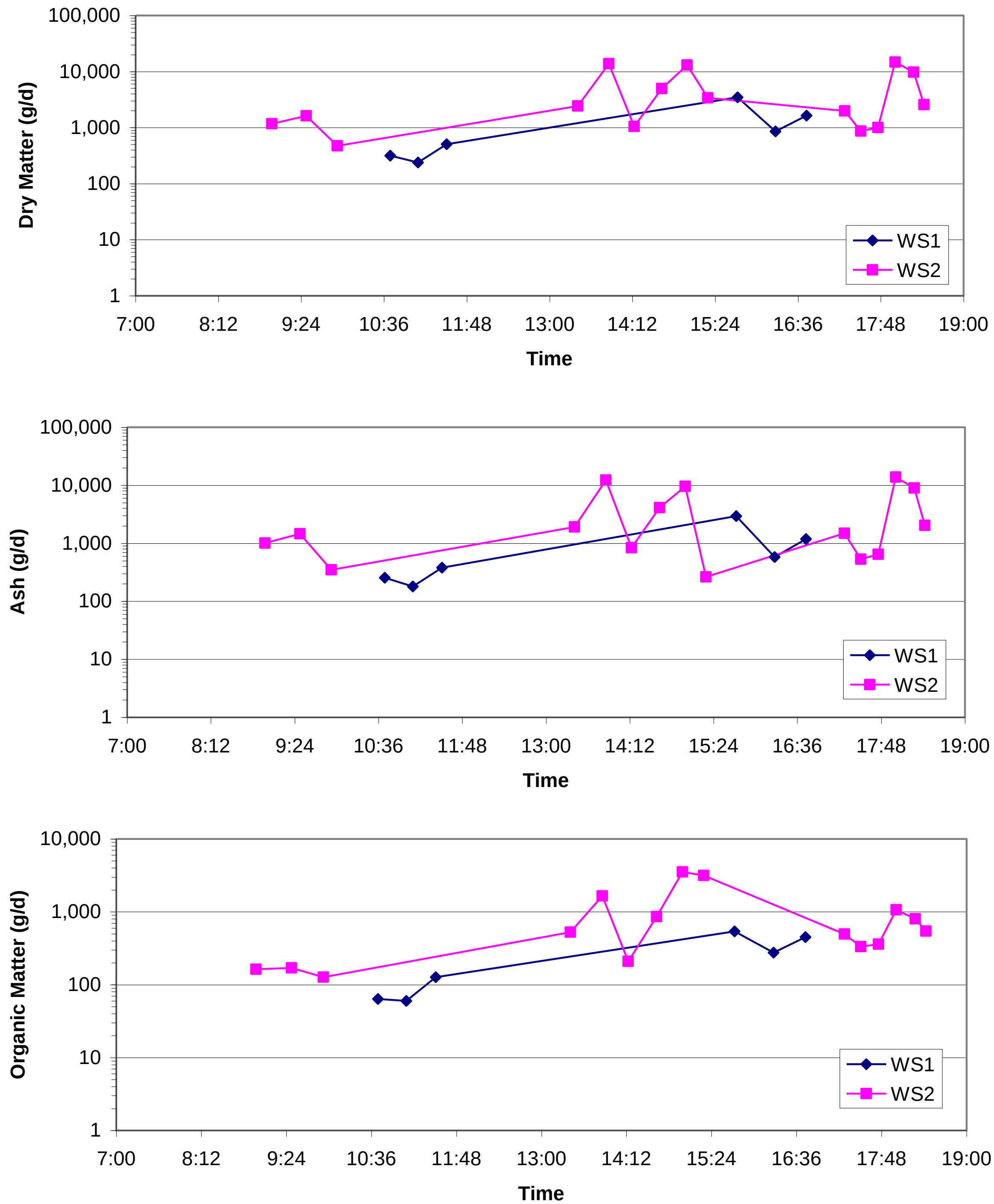


FIGURE 2-34
Particulate Export Measurements from Wekiwa Springs – 5/22/07 (see **Figure 2-23** for station locations)

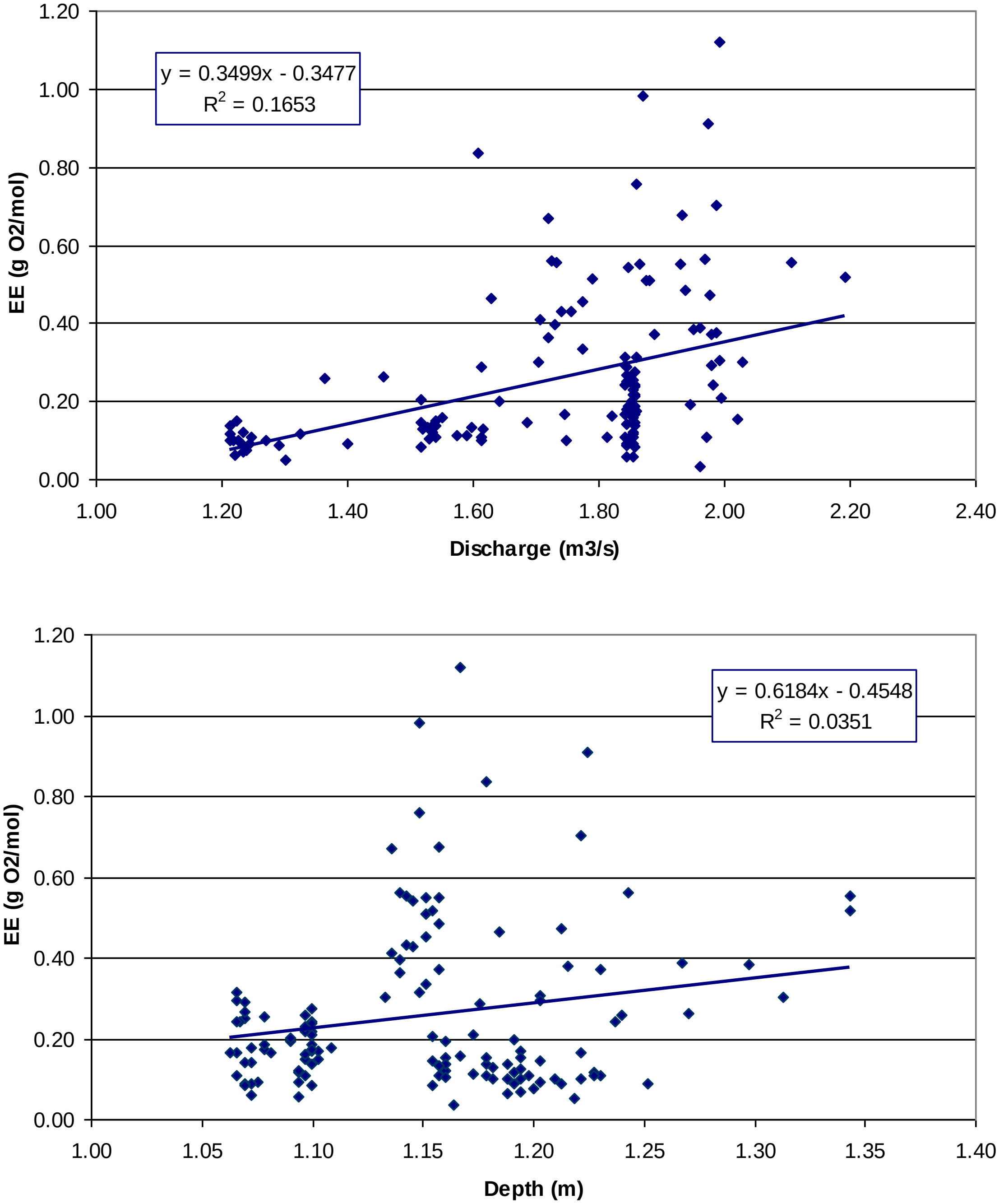


FIGURE 2-35
Relationship between Estimated Discharge/Depth and Ecological Efficiency Estimates in Wekiwa Springs

TABLE 2-15
Summary of Estimated Ecological Measures in the Wekiwa Springs PLRG Segments

Parameter	Segment 1	Segment 2
GPP (g $O_2/m^2/d$)	1.22	4.11
NPP24 (g $O_2/m^2/d$)	-3.58	-3.66
R24 (g $O_2/m^2/d$)	4.82	7.77
P/R ratio	0.30	0.68
Plant Depth (m)	1.50	0.10
PAR corr. (mol/m^2/d)	10.29	20.72
PAR Eff.		
g O_2/mol	0.17	0.24
%	1.38	1.95
Velocity (cm/s)	3.41	9.83
HRT (hrs)	8.24	2.21
Particulate Export		
Dry Wt (g/m^2/d)	2.07	0.033
Organic Matter (g/m^2/d)	0.640	0.019

Period of Record: April 2005 - March 2006

2.3.8 Human-Use Attendance and Activities

Wekiwa Springs State Park supplied attendance data for the period-of-record (POR) from July 1993 through December 2006 (**Figure 2-36**). Annual day visitor attendance totals ranged from a low of 94,962 in 1997 to a high of 166,738 in 2006. Attendance is frequently restricted during the summer (about 50 days per year) when the 300 available parking spaces are full (Coy Helms, Wekiwa Springs State Park assistant manager, personal communication, 2007). The admission of visitors is opened, closed, and re-opened through a typical busy summer day, corresponding to parking space availability. Monthly attendance is seasonal and typically was highest in mid-summer (**Figure 2-37**) with peak usage about four times higher than winter use. There are no apparent trends in the number of day visitors to the park over the POR. Use data for canoe and kayak rentals at the park are available for the POR from May 2003 through December 2006 (**Figure 2-38**). Boat rentals averaged about 1,514 per month over this POR with peak usage during the spring and summer months (**Figure 2-38**). As with Rock Springs, these seasonal data analyses indicate that key human use activities at the Wekiwa Springs State Park are associated with the use of the Main Boil for wading, swimming, and snorkeling when the weather is warm and that canoe and kayak rentals are highest during fairer weather in the spring and summer. All of these water-dependent

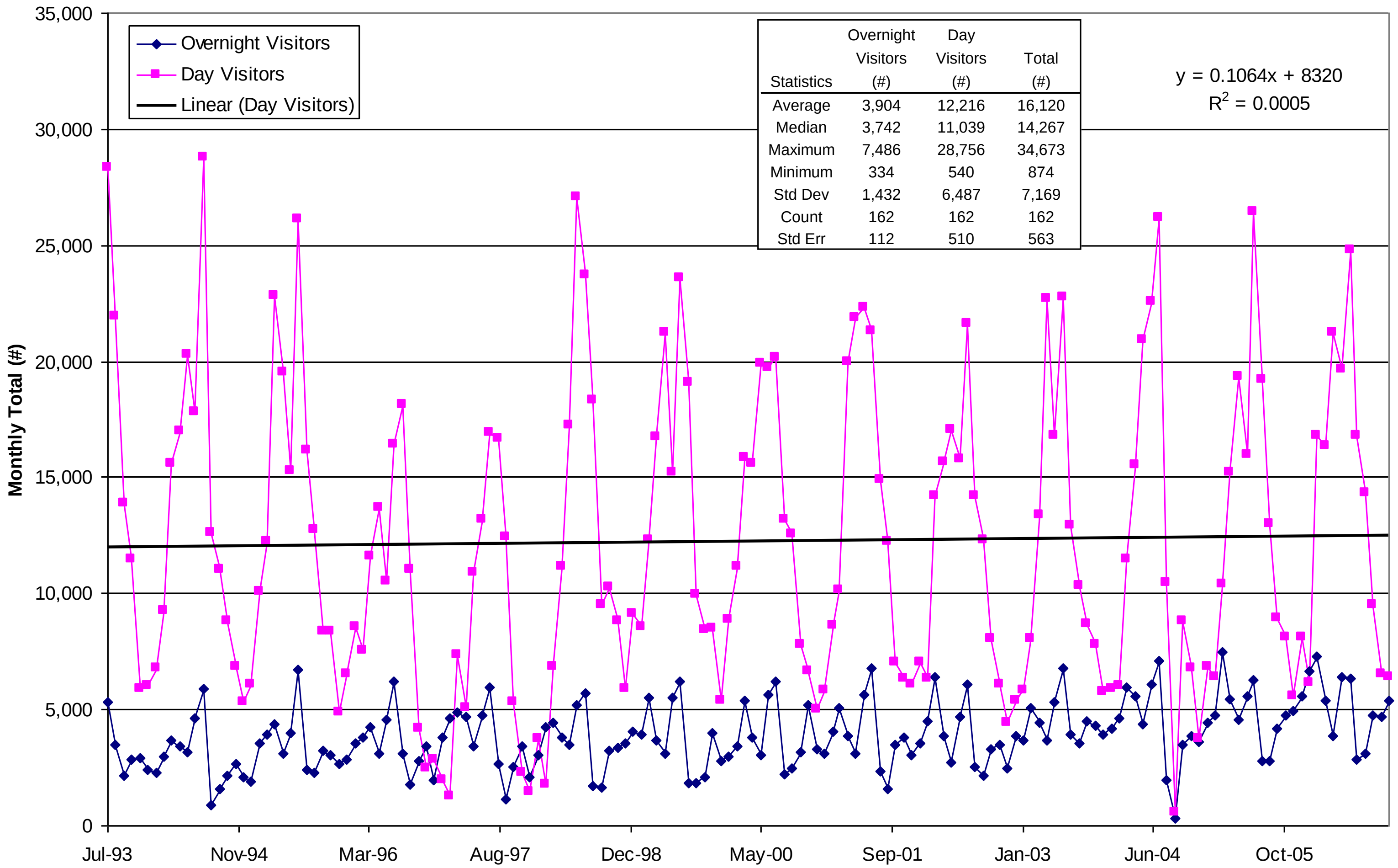


FIGURE 2-36
Time Series of Monthly Total Number of Overnight and Daily Visitors to Wekiwa Springs State Park (July 1993 – December 2006)

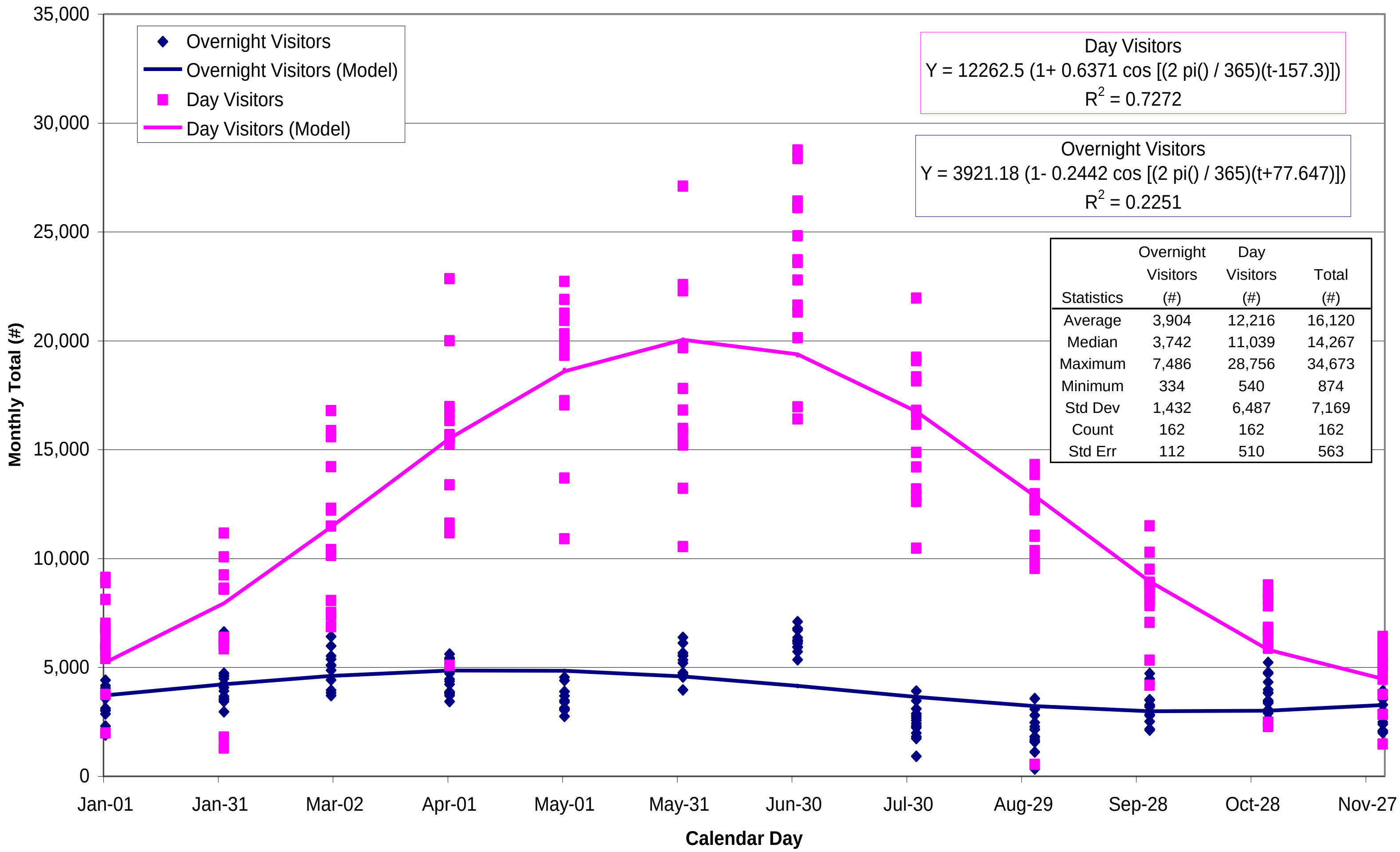
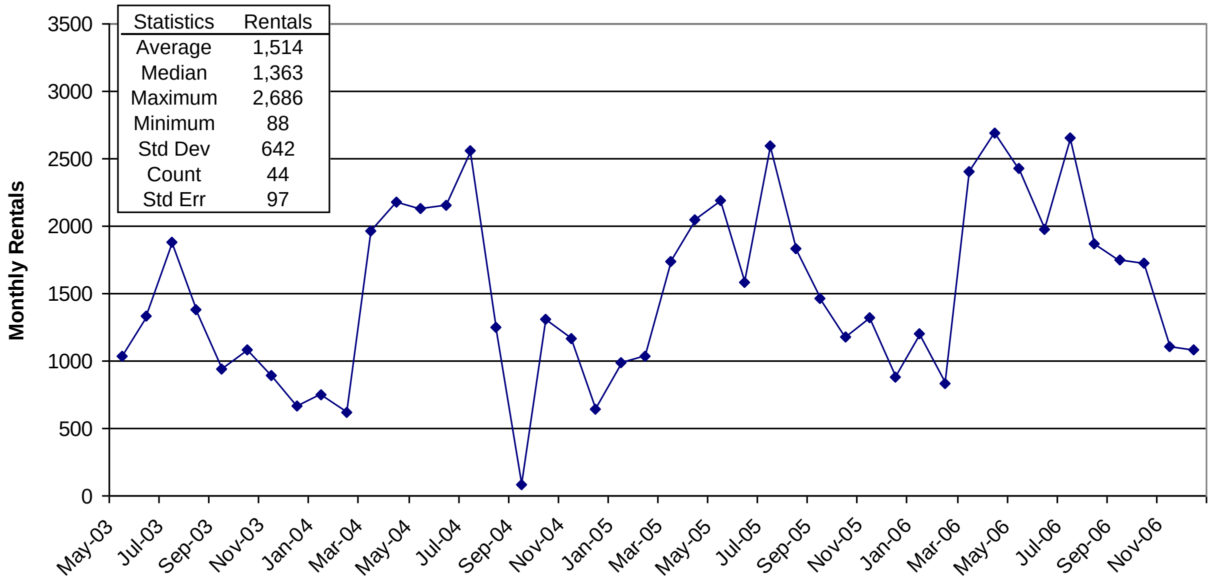


FIGURE 2-37
Monthly Total Number of Overnight and Daily Visitors to Wekiwa Springs State Park (July 1993 - December 2006)



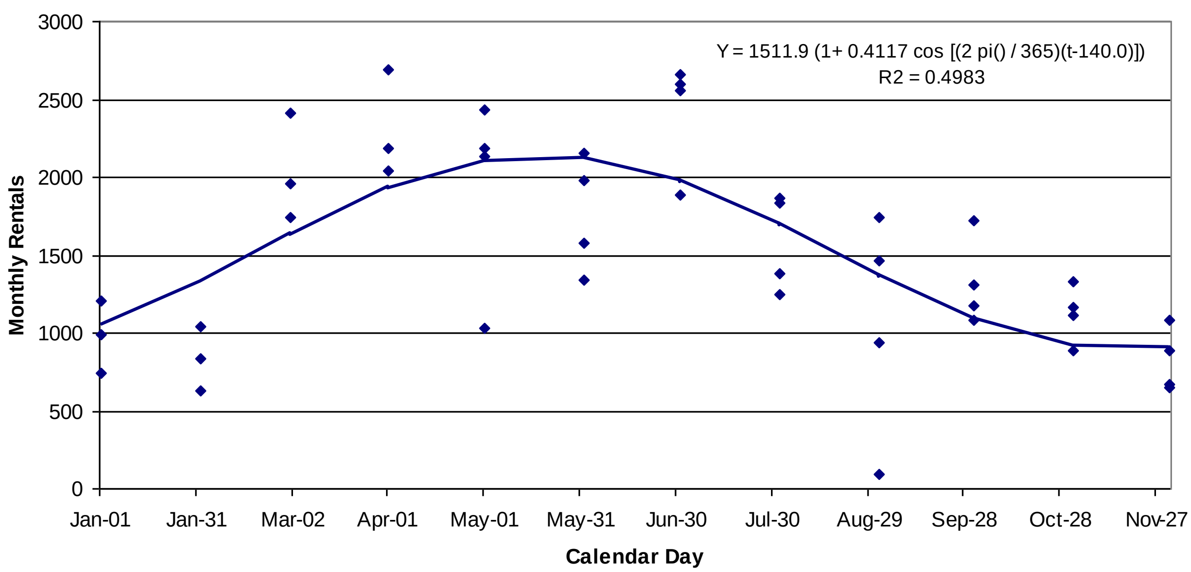


FIGURE 2-38
Monthly Total Canoe and Kayak Rentals at Wekiwa Springs State Park (Nature Adventures data from May 1993 - December 2006)

human uses were verified by WSI during field work at Wekiwa Springs State Park (quarterly sampling during weekdays on September 15 and 28, 2006, March 30, 2007, April 24, 2007, and May 22, 2007; and a peak-season weekend visit on August 12, 2007).

Wekiwa Springs State Park is open year round and rarely has unscheduled closings (Coy Helms, Wekiwa Springs State Park assistant manager, personal communication, 2007). During the period-of-record the park has never closed due to high fecal coliform levels (see **Figure 2-39**) and has only been closed due to the effects of the 2004 hurricane season as described above for Kelly Park.

A detailed assessment of water-dependent human uses was conducted by WSI at Wekiwa Springs State Park on Sunday, August 12, 2007. Estimated average spring discharge on this date was 56.7 cfs and the estimated average stage was 12.9 ft NGVD (Tom Mirti, SJRWMD, personal communication, 2007). An observation station was selected to allow a survey of the entire swim area, including the grassy embankment south of the spring up to the wooden fence and downstream to and including the pedestrian bridge (**Figure 2-40**). The spring pool area within this observation area was approximately 0.38 ha (0.94 ac). Eight primary uses were identified at Wekiwa Springs (**Table 2-16**), and counts of all persons within the observation area were rapidly conducted at about 15 minute intervals from before the park opened at 08:30 until just before final park closing at 20:00. Five of the observed uses were considered to represent direct water contact. The remaining three uses were not in contact with the water but were also water dependent as they were all directed at the water resource either as an aesthetic point of focus or as the ultimate attraction before or after returning to the shore.

Figure 2-41 illustrates the daily pattern of human use activities at Wekiwa Springs during this typical maximum-use day (summer, weekend, no rain). The maximum total number of people observed using the entire observation area on August 12 was 531 people. The maximum count of individuals participating in water contact activities at any one time was 290, for an estimated maximum density of 763 people/ha (309 people/ac). The estimated average human use during the hours of park operation was 246 people with an average of 125 people using upland areas and 121 people participating in water contact activities. The average human density in the water during this period was 318 people/ha (129 people/ac). It was estimated by park staff that a total of 2,369 different individuals (2,033 day use and the 146 campers) were admitted to Wekiwa Springs State Park on August 12 and that there were approximately 1,200 people in the park at any one time.

Casual estimates conducted during August 12, 2007 indicated that there were about 50 people downstream at the canoe launch on the river and another 50 people up by the snack bar and restrooms at any given time during the day. According to staff, the park was closed seven times during the day as the 300 car parking spaces filled to capacity. Once people left and opened up parking spaces, park staff would readmit new visitors until spaces were full. **Figure 2-41** illustrates that the total water dependent population within the observation area peaked about one to two hours after noon at this park and then declined throughout the remainder of the day. The water contact numbers at Wekiwa Springs on August 12 were more consistent throughout the day, indicating that a higher percentage of the visitors were in and on the water during the latter half of the day when the air temperature was probably highest. **Figure 2-42** provides a pie-chart summary of the observed activities at Wekiwa Springs State Park on August 12. Water contact activities were dominated by bathing (40%), with much smaller populations of people floating on rafts and tubes, snorkeling into the main boil, and wading and swimming. On average about 50% of the visitors to the spring observation area were involved in a water contact activity at all times. Based on observations of bathing attire it is estimated that more than 95% of those individuals were in the water at sometime during the day.

These counts and the attendance data for Wekiwa Springs State Park indicate that an estimated 40 to 50% of the people in the park were involved in water-dependent relaxation and recreation at any time during the day. As estimated at Kelly Park, it is considered likely that a very large fraction of all park attendees spent some time in water dependent activities on August 12. With this conclusion the total attendance records provided in **Figures 2-36 and 2-37** for the period-of-record are assumed to provide a good estimate of the number of individuals involved in a water-dependent activity for some time during their visit to Wekiwa Springs State Park.

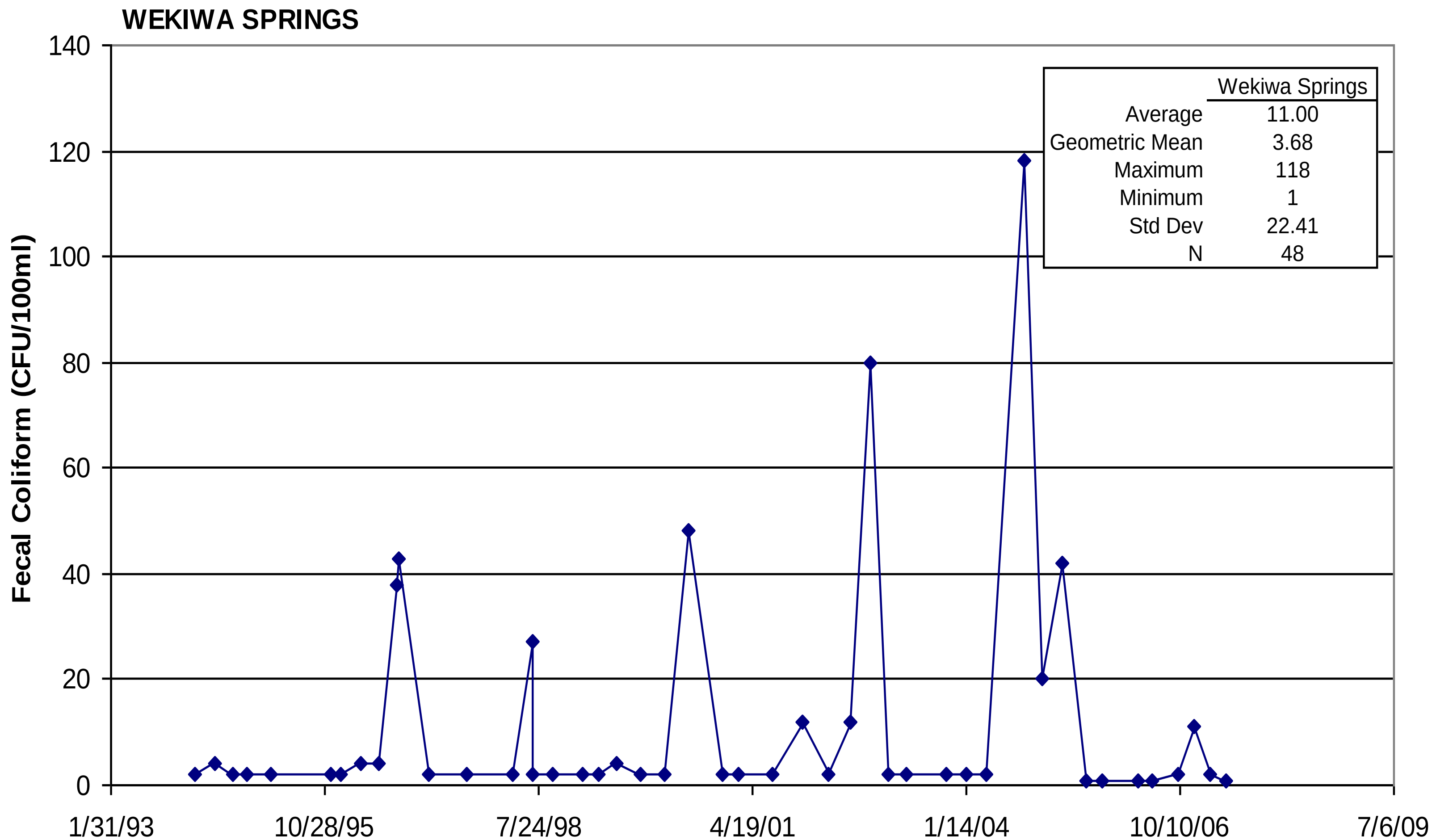


FIGURE 2-39
Wekiwa Springs Fecal Coliform Data for the Period from 1994 through Early 2007 (source: Orange County Environmental Protection Division

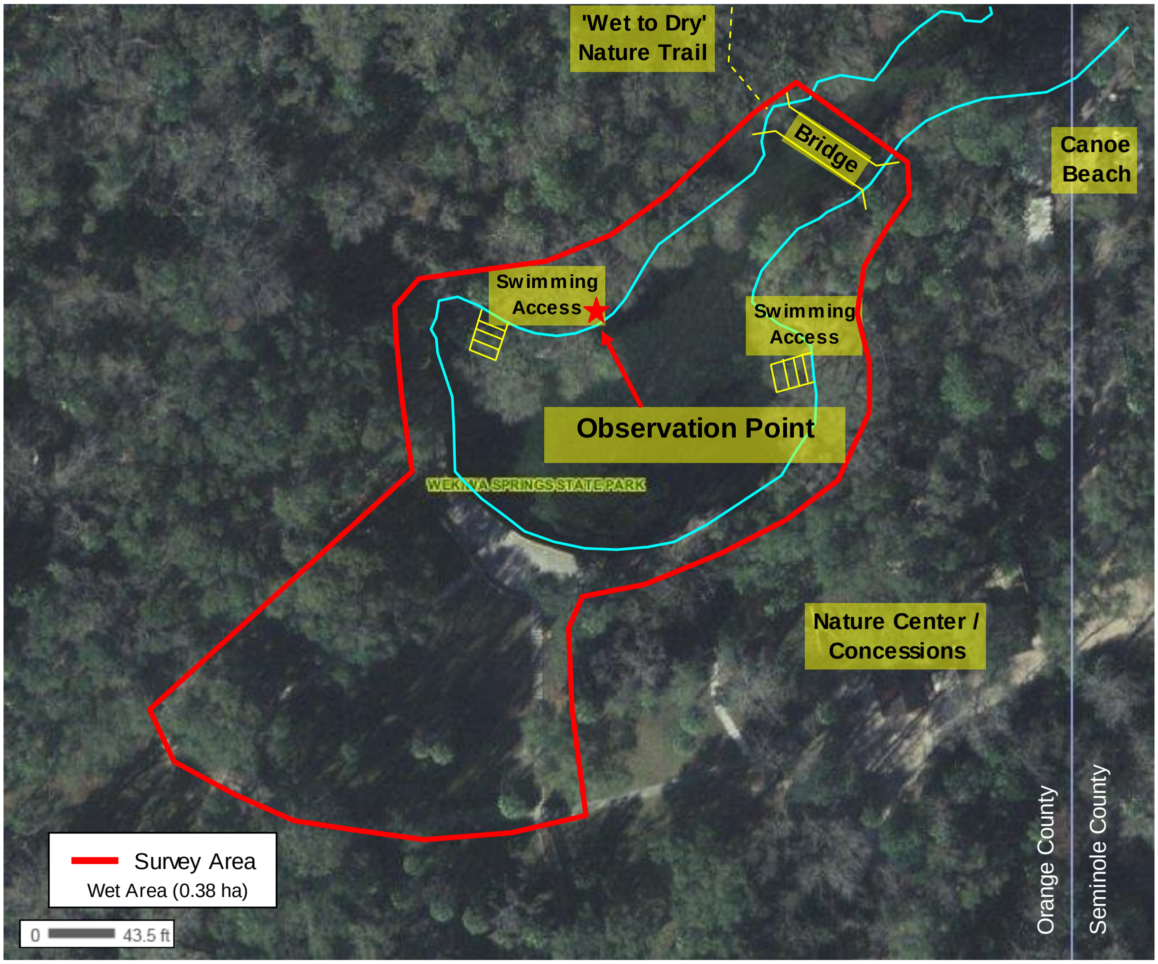


FIGURE 2-40
Wekiwa Springs Showing the Limits of the Human Use Observation Study Conducted on August 12, 2007

TABLE 2-16
Water-Dependent Human Uses Documented at Wekiwa Springs State Park on August 12, 2007

Activity Name	Description	Water Contact?
Swimming	Swimming for exercise. Generally swimmer is wearing goggles but any purposeful swimming is included.	Yes
Wading	Contact with the water no more than knee deep. This includes people wading in shallower water, standing on stairs, and people sitting on walls with their feet in the water.	Yes
Bathing	This category indicates significant body immersion in the water (greater than knee deep).	Yes
Floating	Use of innertubes, rafts, noodles, etc. to keep a significant part of the body above the water but without purposeful movement.	Yes
Snorkeling	Indicated by having a mask or goggles on and actively placing face under water.	Yes
Sunbathing	Lying prone in the sun and partially clothed.	No
Nature study	Generally not attired in a bathing suit and carrying a camera or binoculars.	No
Relaxing	All other upland activities, including: sitting, standing, sleeping, talking, walking, entering or leaving water, setting up or taking down umbrellas, etc.	No

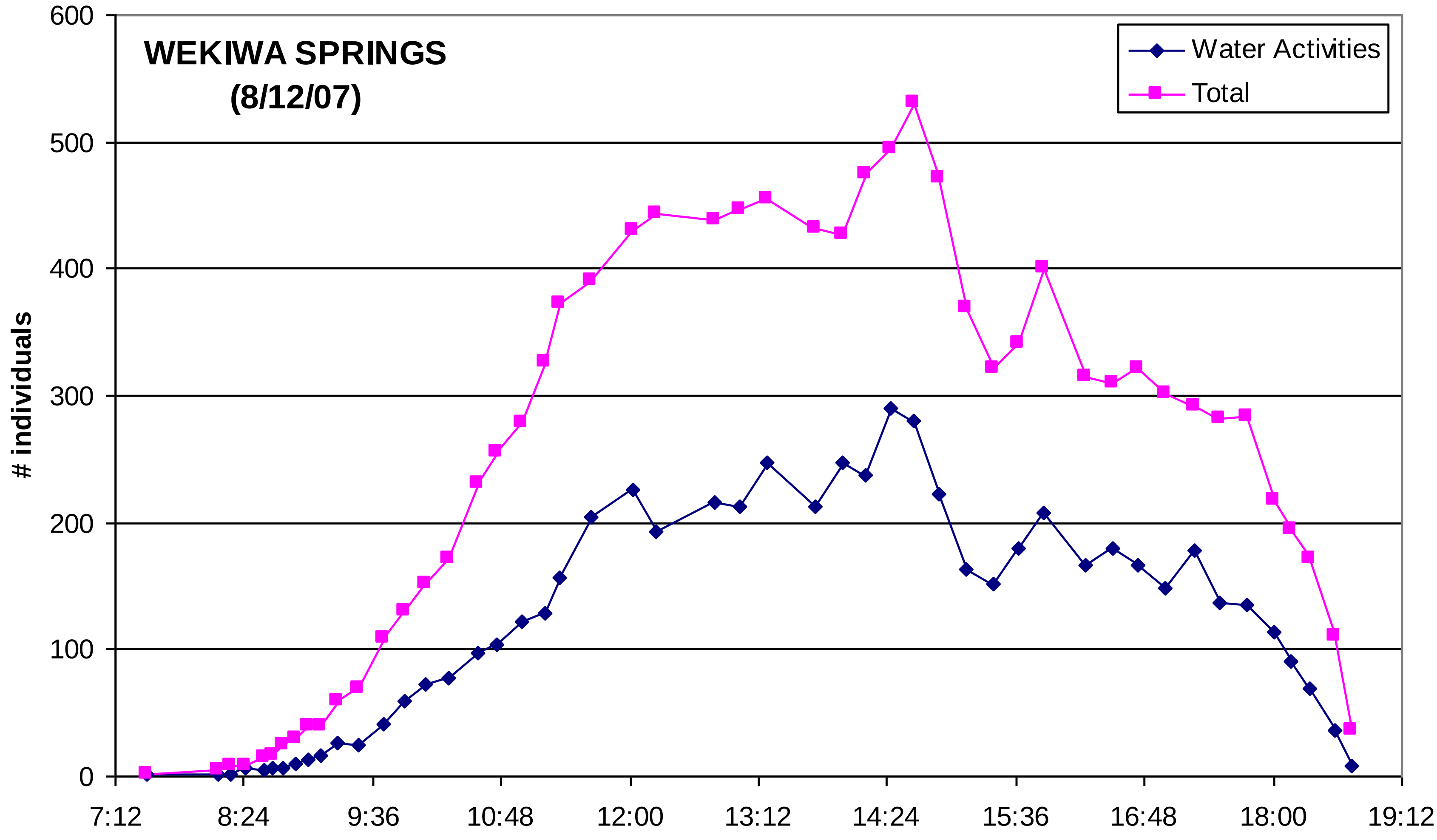


FIGURE 2-41
Daily Pattern of Water-Dependent Human Use Observed at Wekiwa Springs on Sunday, August 12, 2007

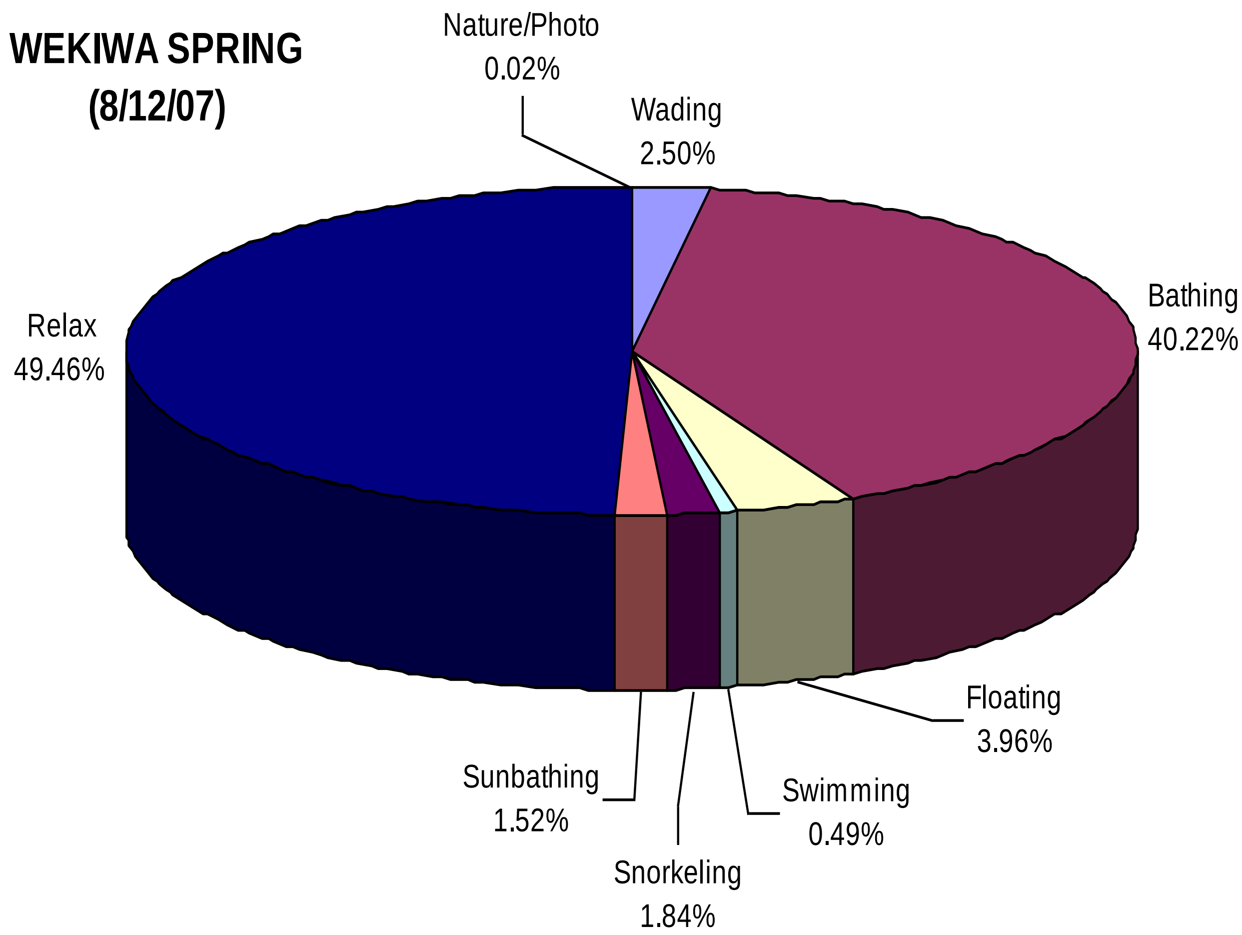


FIGURE 2-42
Average Distribution of Water-Dependent Uses Observed at Wekiwa Springs on Sunday, August 12, 2007

3.0 Adopted Minimum Flows and Levels

The adopted minimum annual mean flows for Rock and Wekiwa springs were developed by the District and are described in Hupalo *et al.* (1994). These springs MFLs were determined based on providing minimum spring flows from eight springs in the Wekiva River Basin (Wekiwa, Rock, Seminole, Sanlando, Starbuck, Messant, Palm, and Miami) necessary to meet minimum flow and level requirements at the Wekiva River at State Road (SR) 46 and on Black Water Creek at SR 44. Multiple minimum levels were established at those downstream stations based on protection of plant communities (forested floodplain wetlands and submerged aquatic eelgrass beds) and muck soils along two transects on the lower Wekiva River near SR 46 and six transects along Black Water Creek near SR 44 and downstream near Sulphur Run. Modeled spring flows contributing to downstream base flows were incrementally reduced until a simulated exceedance of one or more of the downstream minimum levels were reached. This estimated spring flow and an associated model groundwater level were then chosen as the MFL for that spring. The downstream minimum levels most sensitive to this analysis were the Minimum Frequent Low level, followed closely by the Minimum Average level. The resulting spring minimum annual mean flows were comparable to a 1-day low-flow event with a 4.5 to 6-year recurrence interval based on an analysis of the actual spring flow data from 1931 to 1990 (Hupalo *et al.* 1994).

The springs MFLs for the Wekiva River springs (including Wekiva and Rock springs) were originally set based on the MFLs of the river itself. The hydrologic model used to simulate river flows for the springs MFLs determination process included simple rainfall-deficit models for each of the significant springs in the basin (C. Price Robison, SJRWMD, personal communication, 2007). These rainfall-deficit models attempted to fit historic spring flow measurements with monthly spring flow values. Until better spring flow models are developed, these spring flow simulations must be assumed to account for all users up to the time of model development and springs MFLs determination. Therefore, if the simulated spring flows are shown to be meeting the minimum flow at the time of springs MFLs determination, then users at the time of springs MFLs determination are protected. This is the case for both Rock and Wekiwa springs. Flow reductions caused by cumulative consumptive use increases beyond the year of springs MFLs determination (as estimated by the appropriate regional groundwater model) have been applied to the simulated historical spring flows to determine springs MFLs compliance.

The published Wekiva River System minimum spring flows are listed in **Table 3-1** reproduced from Hupalo *et al.* (1994). Unlike District MFLs for lakes and rivers, the Rock and Wekiwa springs minimum annual mean flows do not consist of multiple flows and levels. However, as described above the minimum annual mean spring flows are intended to protect multiple flows and levels downstream at SR 46.

TABLE 3-1
Summary of Wekiva River System Minimum Spring Flows (Hupalo *et al.* 1994)

Spring Name	Flow (cfs)	Spring Pool Elevation (ft NGVD)	Spring Conductance (sfd)	Florida Aquifer System Potentiometric Surface Level (ft NGVD)
Wekiwa Springs	62	13	4.92×10^5	24
Rock Springs	53	30	4.080×10^6	31
Seminole Springs	34	32	1.295×10^6	34
Sanlando Springs	15	26	7.450×10^5	28
Starbuck Springs	13	26	2.100×10^5	31
Messant Spring	12	26	1.720×10^5	32
Palm Springs	7	26	7.450×10^5	27
Miami Springs	4	15	2.800×10^4	27

ft NGVD = feet National Geodetic Vertical Datum
cfs = cubic feet per second
sfd = square feet per day

Minimum annual mean spring flows adopted in 1991 were based on an intermittent discharge record from 1931 to 1990. The measured spring discharge record has recently been updated for the District through 2005 (Intera 2006). Basic summary statistics for observed spring discharge and local rainfall data for these stations are provided in **Table 3-2**. Period-of-record average spring flow estimates based on Intera's simulated data were higher than the observed values listed in **Table 3-2**: Rock Springs – 58.9 cfs and Wekiwa Springs – 68.5 cfs.

A comparison of spring discharge estimates for the periods 1959-1997 and 1998-2005 indicate that average flows at Rock Springs have declined from about 60.8 to 53.4 cfs and from 70.0 to 66.8 cfs at Wekiwa Springs. Intera (2006) noted that flow duration curves (FDC) for Rock and Wekiwa springs were significantly lower during the 2003-2005 period compared to the previous data record for 1959-2002. It should be noted that the later period contained some significant drought events and is a shorter period than the previous data record.

TABLE 3-2
Basic Statistics for Observed Discharge Data for Rock and Wekiwa Springs and for Orlando Rainfall, 1931-2005 (Intera 2006)

Data type	Date Range	N obs	Min	Max	Average	Std Dev
Rock Springs Discharge (cfs)	2/5/1931 - 9/30/2005	2,426	34.1	83.2	53.4	8.0
Wekiva Springs Discharge (cfs)	3/8/1932 - 9/30/2005	666	38.6	91.7	66.8	5.8
Orlando Rainfall (in)	1/1/1942 - 12/31/2004	22,643	0	8.4	0.1	0.4

4.0 Water Resource Value Assessment Methodology

4.1 Introduction

The District has developed a MFLs method that has been applied to rivers, lakes, wetlands, and springs (Neubauer *et al.* 2007). Multiple MFLs are usually defined as a minimum hydrologic regime designed to protect high, intermediate, and low hydrologic conditions in the target water body, water course, or aquifer that are critical to the protection of ecological criteria and indicators. Long-term hydrologic statistics are used in MFLs determinations to incorporate the three major forcing functions of magnitude (flow and/or level), duration (days), and return interval (years). In addition, timing and rates of change, two other critical hydrologic components, are considered in MFL establishment. Established MFLs are implemented by use of water budget models that simulate long-term system hydrology under various consumptive use scenarios.

The District recommends assessment of WRV protection with frequency analysis methods (i.e., identifying and evaluating magnitude, duration, and return interval components that are biologically meaningful), in concert with other relevant methods. Each WRV needs to be assessed with respect to high or low flow and level events:

- High flow (flood) -related WRVs are considered to be protected if, under the proposed MFLs regime, the high flow event of a specified magnitude and duration does not occur too infrequently when compared to the high flow event frequency under long-term historical conditions.
- Low flow (drought or drawdown) -related WRVs are considered to be protected if, under the proposed MFLs regime, the low flow event of a specified magnitude and duration does not occur too frequently when compared to the low flow event frequency under historical conditions.

Each WRV may represent a broad class of functions, processes and/or activities that require consideration of protection. To facilitate the process of determining if the MFLs are protective of these classes of functions/processes/activities, a four-level hierarchical approach to the assessment was recommended by the District. This approach, described below, moves from broad, general definitions to more specific criteria of protection, then to general indicators of protection and, finally, to specific indicators of protection that can be measured and assessed.

- Level 1. Restates the WRV in terms of **criteria** that are specific to the water body being evaluated. Includes the definition of the WRV as provided by the District.
- Level 2. Identifies a **representative function, process,** or **activity** of that specific WRV. This criterion is selected based on a high level of sensitivity to changes in the return interval of high or low water events (defined by magnitude and duration components).
- Level 3. Identifies a **general indicator** parameter for the protection of that function/process/activity, such as river flow and/or depth. This criterion includes the appropriate definition of protection for either high or low water events that are directly related to each WRV.
- Level 4. Identifies **specific indicator** parameter(s) for the protection of the specific WRV in terms of magnitude (flow and or water level), duration (number of days), and return interval (years). This criterion includes an assessment of the change in the number of events per 100 years under historical long-term hydrologic conditions and MFLs hydrologic conditions.

4.2 WRV Assessment Methods

The specific methods used for the WRV assessments are recommended by qualified contractors, reviewed by District staff, and subjected to peer review. For the Rock and Wekiwa springs WRV assessments, WSI has utilized a combination of approaches to evaluate whether the District's springs MFLs are protective of the ten WRVs. District staff recommended that the WRV assessment utilize the long-term frequency analysis approach described by Neubauer *et al.* (2007). In addition to frequency analyses, WSI utilized a variety of standard time series analyses, correlation analyses, statistical analyses, and spreadsheet simulation models to examine relationships between quantitative metrics for each WRV and spring discharge. While these methods relied on simplifying assumptions about environmental dynamics, they also provided a defensible basis for establishing an event-based assessment of WRV protection.

WSI's methodology followed in this report includes three primary steps:

- Review of Historical Flow and Level Data. Available hydrologic data were reviewed for this WRV assessment. Period-of-record flow and level data were examined based on a variety of graphical and statistical methods. These included time series graphs and trend analysis; estimation of means, medians, and extremes; flow-duration graphs, both for the entire POR and also for shorter time intervals to confirm data trends; and long-term frequency curves that included magnitude, duration, and return intervals for various hydrologic events. The variability inherent in these historical data was then examined in terms of the spatial extent (wet area), depth, volume, and nHRT of the spring/spring run of interest. The primary purpose of this data review was to assess any historical trends in flows and levels and to make a comparison between historical flows and levels and the District's MFLs.
- Determination of the general applicability of the ten possible WRVs to existing conditions at Rock and Wekiwa springs. For example, no commercial boats (commercial navigation) are allowed in either spring boil area. For this reason, WRV #10 is not considered relevant for this analysis.
- Development of the most appropriate quantitative metrics available to assess the effects of high and low flows on the various relevant WRVs in Rock and Wekiwa springs. These metrics are described under the District's hierarchy of: Criteria, General Indicators, and Specific Indicators. Selection of metrics is based on applicability and availability of data needed to estimate effects. Historical data for the physical, biological, and anthropogenic WRVs were evaluated in light of their observed or possible dependence upon flows and levels. Correlation analysis was used to detect relationships between aquatic structure and function, recreational and aesthetic uses, physical/chemical functions, and flows and levels. While it is recognized that correlation does not mean causation, this analysis was conducted to

determine whether variables were directly or indirectly correlated or showed no correlation with flow and levels. Literature information was also evaluated when available to indicate the effect of hydrological changes and return intervals on the WRVs. Spreadsheet simulation models were utilized to assess more complicated interactions between spring discharge and several of the quantitative WRV metrics.

Possible positive or negative effects of the existing springs MFLs on each WRV metric were assessed, based first on the predicted changes to flow frequency curves, on known relationships (if any) between flows and levels and dependent variables from the literature and finally, based on actual data from Rock and Wekiwa springs. For WRVs with adequate data, a quantitative analysis was performed to estimate the magnitude of positive or negative changes of each WRV metric based on a range of flows and levels below the adopted springs MFLs. All other WRV metrics were assessed based on the literature review and/or best professional judgment. If data indicating the possible effects of springs MFLs on a specific WRV are not available, then the protection of that WRV was determined based on best professional judgment. When present, uncertainties and inconclusive results concerning WRV protection by the Rock and Wekiwa springs MFLs are identified in the report.

5.0 Water Resource Values Assessment

5.1 Confirmation of Relevant WRVs and Quantitative Metrics

5.1.1 Inventory of Existing WRVs

Table 5-1 summarizes the determined relevancy of the ten WRVs at Rock and Wekiwa springs. Eight of the ten WRVs were found to be relevant for assessment at each spring. Relevant WRVs are:

- WRV 1: Recreation In and On the Water
- WRV 2: Fish and Wildlife Habitats and the Passage of Fish
- WRV 4: Transfer of Detrital Material
- WRV 5: Maintenance of Freshwater Storage and Supply
- WRV 6: Aesthetic and Scenic Attributes
- WRV 7: Filtration and Absorption of Nutrients and Other Pollutants
- WRV 8: Sediment Loads
- WRV 9: Water Quality

The two WRVs that were not found to be directly relevant to Rock and Wekiwa springs were:

- WRV 3: Estuarine Resources
- WRV 10: Navigation

The downstream importance of these two WRVs was previously assessed in a report concerning the proposed MFLs for the St. Johns River near Deland (ECT 2002, 2004). In regard to WRV 3, possible flow reductions occurring at Rock and Wekiwa springs constitute a very small fraction (<1%) of the low flows that were evaluated downstream in the St. Johns River near Deland. The WRV 10 is not applicable as commercial watercraft are prohibited from the spring boils and do not utilize the river sections of these two systems.

TABLE 5-1
Rock and Wekiwa Springs Summary of Water Resource Values Relevance

Water Resource Value (WRV)	WRV Name	SJRWMD Description	Relevant at Rock Springs?	Relevant at Wekiwa Spring?	Basis
1	Recreation In and On the Water	The active use of water resources and associated natural systems for personal activity and enjoyment. These legal water sports and activities may include but are not limited to: swimming, scuba diving, water skiing, boating, fishing, and hunting.	Yes	Yes	Both springs are the central attraction in highly popular recreational areas with well-documented public use over an extended period-of-record.
2	Fish and Wildlife Habitats and the Passage of Fish	Aquatic and wetland environments required by fish and wildlife, including endangered, endemic, listed, regionally rare, recreationally or commercially important, or keystone species, to live, grow, and migrate.	Yes	Yes	Both springs are utilized by aquatic flora and fauna as evidenced through repeated biological studies.
3	Estuarine Resources	Coastal systems and their associated natural resources that depend on the habitat where oceanic saltwater meets freshwater. These highly productive aquatic systems have properties that usually fluctuate between those of marine and freshwater habitats.	No	No	Both systems are well-removed from coastal and riverine estuarine systems. These aquatic resources are purely fresh water dominated.
4	Transfer of Detrital Material	The movement by surface water of loose organic material and debris and associated decomposing biota.	Yes	Yes	Spring flows in both systems were observed to be effective at the transport of detrital materials. This seston or particulate export is a recognized significant process in Florida spring ecosystems.
5	Maintenance of Freshwater Storage and Supply	Protection of an amount of freshwater supply for permitted users at the time of MFLs determination.	Yes	Yes	Neither spring is part of a public water supply system *per se* . Both springs are affected by consumptive water uses in the adjacent Floridan aquifer and both systems contribute to downstream flows in the St. Johns River.
6	Aesthetic and Scenic Attributes	Those features of a natural or modified waterscape usually associated with passive uses such as: bird watching, sight seeing, hiking, photography, contemplation, painting and other forms of relaxation that usually result in human emotional responses	Yes	Yes	Aesthetic and scenic attributes of both of these springs are an important part of the experience for many visitors to Kelly Park and Wekiwa Springs State Park.
7	Filtration and Absorption of Nutrients and Other Pollutants	The reduction in concentration of nutrients and other pollutants through the processes of filtration and absorption (i.e., removal of suspended and dissolved materials) as these substances move through the water column, soil or substrate.	Yes	Yes	Both Rock Springs Run and the Wekiva River downstream of Wekiwa Springs have elevated concentrations of dissolved nitrate nitrogen and have been determined to be impaired based on nutrient (nitrogen and phosphorus) effects on downstream ecosystem metabolism (Mattson *et al.* 2006). Nitrate assimilation was demonstrated in both of these streams during the Pollutant Load Reduction Goal (PLRG) analysis (WSI 2005, 2006).
8	Sediment Loads	The transport of inorganic materials, suspended in water, which may settle or rise; these processes are often dependent upon the volume and velocity of surface water moving through the system.	Yes	Yes	The transport of sandy sediments has been demonstrated in both the Wekiva River and Rock Springs Run PLRG analyses (WSI 2006). Sediment transport is essential for maintaining adequate water depths for wildlife and human uses in both spring systems.
9	Water Quality	The chemical and physical properties of the aqueous phase (i.e., water) of a water body (lentic) or a water course (lotic) not included in #7 (i.e., nutrients and other pollutants) above.	Yes	Yes	Both spring systems are Florida Waters of the State and Outstanding Florida Waters and are protected from any lowering of water quality. Also, both springs serve as the principal headwaters of their respective spring runs downstream.
10	Navigation	The safe passage of commercial water craft (e.g., boats and ships), that is dependent upon sufficient water depth, sufficient channel width, and appropriate water velocities.	No	No	No commerical watercraft are allowed by law in either of these two spring boil areas.

5.1.2 Appropriate General Criteria and Specific Indicators for Each WRV

Table 5-2 summarizes the general criteria and specific indicators for each of the eight relevant WRVs at Rock and Wekiwa springs. **Table 5-3** provides a detailed list of the quantitative specific indicators or metrics that were used for assessment of each relevant WRV at Rock Springs. **Table 5-4** provides a similar list for Wekiwa Springs. Each of these metrics is further described in the following section of this report.

5.2 Analysis of Effects of MFLs on WRV Metrics

5.2.1 Recreation In and On the Water

5.2.1.1 Introduction

A variety of legal recreational activities are promoted at both Rock and Wekiwa springs. Based on observed uses during multiple visits to both sites, WSI concludes that the following list summarizes water-contact and water-dependent recreational activities (defined above in **Table 2-7**) in terms of declining occurrence at the two springs:

- Rock Springs
  - Water Contact
    - Wading and bathing
    - Tubing
    - Skin diving/snorkeling
    - Swimming
  - Water-Dependent
    - Relaxing
    - Sunbathing
    - Picnicking
- Wekiwa Spring
  - Water Contact
    - Wading and bathing

    - Skin diving/snorkeling
    - Swimming
  - Water-Dependent
    - Relaxing
    - Sunbathing
    - Picnicking

From the above list it can be summarized that the two springs are similar in a number of ways but also have some important differences with respect to the recreational activities they support. Wekiwa Springs is primarily a bathing and swimming spring where recreational boating occurs downstream from the immediate WRV project area. Snorkeling and skin diving are also important at Wekiwa Springs as there is consistently a group of individuals circling the main boil so they can peer into and free dive into the fissure and caves. Tubing is not practical in the public use area at Wekiwa Springs since the current velocity is too slow in the swim area. Water depths throughout the Wekiwa Springs preclude many recreational uses by unattended small children.

On the other hand, Rock Springs is heavily used for tubing throughout the run in Kelly Park to the Second Landing and is also used for bathing and wading. Water depths in most areas are shallow enough for small children to wade and play in the water with relatively minor supervision. A small amount of swimming at Rock Springs occurs downstream in an open pool area but the main water dependent activities are tubing, bathing, and wading. Both sites are similar in terms of relaxing, sunbathing, picnicking, and other non-water-contact activities.

Recreational uses of the springs are closely related to ***WRV No.6: Aesthetic and Scenic Attributes*** described below. Much of the enjoyment the public receives by visiting springs comes from relaxing, picnicking, and sunbathing in sight of the spring where the aesthetic value is high and with the expectation of entering or re-entering the clear, cool water to enjoy water contact recreational activities. Since bathing, wading, and tubing appear to be the dominant recreational uses at Rock Springs, the evaluation of the ***WRV No.1: Recreation In and On the Water*** focuses on those observed uses. At Wekiwa Springs, the focus is on bathing, snorkeling, and swimming. The other water-dependent uses (relaxing, sunbathing, picnicking, nature study, etc.) are evaluated below under ***WRV No.6: Aesthetic and Scenic Attributes***.

TABLE 5-2
Hierarchy of Quantitative Metrics for Evaluation of Effects of Springs MFLs on Relevant WRVs at Rock and Wekiwa Springs

WRV	Criteria	Function	General Indicator(s)	Specific Indicator(s) and Event
1. Recreation In and On the Water	Legal water sports and activities	Passive water contact sports	Water depth, velocity, clarity, and temperature	Stage and flow needed to allow wading/bathing and transport tubers (14-day low flow); adequate swimming depth (30-day low flow); adequate flushing to prevent elevated bacteria counts (1-day low flow)
2. Fish and Wildlife Habitat and the Passage of Fish	Aquatic and wetland environments required by fish and wildlife	Ecosystem productivity for support of aquatic foodweb	Ecosystem metabolism, flora and fauna	Gross and net primary productivity; ecological efficiency (30-day low flow); habitat area (30-day low flow)
3. Estuarine Resources	Coastal systems and associated natural resources	Normal range of salinity fluctuations in the estuary	Spring discharge contributing to downstream flows	Previously evaluated for St. Johns River at Deland (ECT 2004)
4. Transfer of Detrital Material	The movement of loose organic material and debris and associated decomposing biota	Transport of fine particulate matter in the spring run	Flow velocity in the spring run	Particulate export rate as measured by plankton net method (30-day low flow)
5. Maintenan-ce of Freshwater Storage and Supply	Current permitted users at the time of MFLs determination	The maintenance of adequate aquifer levels to allow legal consumptive uses, and adequate spring discharges to allow permitted downstream surface water withdrawals	Adequate spring flows and levels to allow permitted consumptive uses at time of MFLs determination	Presumed to be met at time of MFLs determination; evaluation of the effects of existing CUPs on groundwater availability; occurrence of mean annual spring flows above the target MFLs
6. Aesthetics and Scenic Attributes	Overall scenery associated with spring recreational areas	Visually healthy spring ecosystem	Protection of native vegetation; water clarity; visible spring boil	Minimal weedy plant growth including filamentous algae; high water clarity; visible spring boil/flow; (14-day low flow)

TABLE 5-2
Hierarchy of Quantitative Metrics for Evaluation of Effects of Springs MFLs on Relevant WRVs at Rock and Wekiwa Springs

	WRV	Criteria	Function	General Indicator(s)	Specific Indicator(s) and Event
7.	Filtration and Absorption of Nutrients and Other Pollutants	Assimilative processes that reduce pollutant concentrations and loads	Reduction in the concentration and load of nutrients	Hydraulic residence time and ecosystem metabolic activity	Rate of nitrate nitrogen assimilation (14-day low flow)
8.	Sediment Loads	The process of sediment movement and deposition	Water velocities and flow	Velocity for sediment transport	Discharge associated with velocity necessary for sediment transport (30-day low flow)
9.	Water Quality	Chemical and physical properties of the water	Concentration/intensity of chemical parameters	No reduction in existing ambient water quality due to OFW designations	Water temperature, dissolved oxygen, and turbidity 30-day low flow)
10.	Navigation	Legal operation of commercial vessels	Access (channel width and water depth) needed for commercial vessels	Spring discharge contributing to downstream flows in the SJR	Previously evaluated for St. Johns River at Deland (ECT 2002)

TABLE 5-3
Rock Springs Water Resource Values, General Criteria, and Specific Metrics for Human Use and Water Resource Values Assessment

				Criterion #1			Criterion #2		
Water Resource Value (WRV)	**WRV Name**	**SJRWMD Description**	**Relevant?**	**Description**	**Specific Metric**	**Data Availability**	**Description**	**Specific Metric**	**Data Availability**
1	Recreation In and On the Water	The active use of water resources and associated natural systems for personal activity and enjoyment. These legal water sports and activities may include but are not limited to: swimming, scuba diving, water skiing, boating, fishing, and hunting.	Yes	Wading, bathing; tubing	Minimum water depth needed for wading, bathing, snorkeling	Stage vs. discharge relationship	Water contact activities	Closures due to bacterial contamination	Weekly data
2	Fish and Wildlife Habitats and the Passage of Fish	Aquatic and wetland environments required by fish and wildlife, including endangered, endemic, listed, regionally rare, recreationally or commercially important, or keystone species, to live, grow, and migrate. These environments include hydrologic magnit	Yes	Habitat availability for fish, herptiles, birds, and mammals	Community Metabolism (GPP, NPP, CR, EE)	Limited data available; metric can be estimated from similar environments	Habitat availability for fish, herptiles, birds, and mammals	Effective habitat area as a function of stage	Limited data available; metric can be estimated
3	Estuarine Resources	Coastal systems and their associated natural resources that depend on the habitat where oceanic saltwater meets freshwater. These highly productive aquatic systems have properties that usually fluctuate between those of marine and freshwater habitats.	Yes, downstream	Discharge contributes to downstream flows	Evalauated by others in St. Johns River at Deland	ECT (2004)	NA	NA	NA
4	Transfer of Detrital Material	The movement by surface water of loose organic material and debris and associated decomposing biota.	Yes	Downstream export of particulate organic matter	Mass flux of ash-free dry weight particulate material at downstream boundary	Limited data available; metric can be estimated from similar environments	NA	NA	NA
5	Maintenance of Freshwater Storage and Supply	Protection of an amount of freshwater supply for permitted users at the time of MFLs determination.	Yes	Groundwater withdrawal capacity at the time of MFLs determination	Permitted CUPs at the time of MFLs determination	District data/model	NA	NA	NA
6	Aesthetic and Scenic Attributes	Those features of a natural or modified waterscape usually associated with passive uses such as: bird watching, sight seeing, hiking, photography, contemplation, painting and other forms of relaxation that usually result in human emotional responses of we	Yes	Spring vista including the following specific attributes: clear water, visable spring boil, and water circulation/flow	Human-Use Days for water viewing activities (picnicking, sunbathing, relaxing)	Approximate by park entry rates with estimated correction factors	Water clarity	Horizontal secchi length	Use of analogous data from Silver Springs
7	Filtration and Absorption of Nutrients and Other Pollutants	The reduction in concentration of nutrients and other pollutants through the processes of filtration and absorption (i.e., removal of suspended and dissolved materials) as these substances move through the water column, soil or substrate, and associated o	Yes	Nitrate nitrogen assimilation	Difference in nitrate nitrogen mass between vent and downstream boundary	Limited data available; metric can be estimated from similar environments	NA	NA	NA
8	Sediment Loads	The transport of inorganic materials, suspended in water, which may settle or rise; these processes are often dependent upon the volume and velocity of surface water moving through the system.	Yes	Non-volatiles suspended solids transport	Non-volatile suspended solids mass transported through downstream boundary	Limited data available; metric can be estimated from similar environments	NA	NA	NA
9	Water Quality	The chemical and physical properties of the aqueous phase (i.e., water) of a water body (lentic) or a water course (lotic) not included in #7 (i.e., nutrients and other pollutants) above.	Yes	Dissolved oxygen, pH, conductivity, and turbidity	Oxygen reaeration rate, historic data	Limited data available; metric can be estimated with models calibrated from similar environments	Water temperature	Winter minimum and summer maximum values	Limited data available; metric can be estimated with models calibrated from similar environments
10	Navigation	The safe passage of commercial water craft (e.g., boats and ships), that is dependent upon sufficient water depth, sufficient channel width, and appropriate water velocities.	Yes, downstream	Discharge contributes to downstream flows	Evalauated by others in St. Johns River at Deland	ECT (2004)	NA	NA	NA

TABLE 5-4
Wekiwa Spring Water Resource Values, General Criteria, and Specific Metrics for Human Use and Water Resource Values Assessment

				Criterion #1			Criterion #2		
Water Resource Value (WRV)	**WRV Name**	**SJRWMD Description**	**Relevant?**	**Description**	**Specific Metric**	**Data Availability**	**Description**	**Specific Metric**	**Data Availability**
1	Recreation In and On the Water	The active use of water resources and associated natural systems for personal activity and enjoyment. These legal water sports and activities may include but are not limited to: swimming, scuba diving, water skiing, boating, fishing, and hunting.	Yes	Exercise swimming; bathing	Minimum water depth needed for swimming and bathing	Stage vs. discharge relationship	Water contact activities	Closures due to bacterial contamination	Weekly data
2	Fish and Wildlife Habitats and the Passage of Fish	Aquatic and wetland environments required by fish and wildlife, including endangered, endemic, listed, regionally rare, recreationally or commercially important, or keystone species, to live, grow, and migrate. These environments include hydrologic magnitudes, frequencies and durations sufficient to support the life cycles of wetland and wetland dependent species.	Yes	Habitat availability for fish, herptiles, birds, and mammals	Community Metabolism (GPP, NPP, CR, EE)	Limited data available; metric can be estimated from similar environments	NA	NA	NA
3	Estuarine Resources	Coastal systems and their associated natural resources that depend on the habitat where oceanic saltwater meets freshwater. These highly productive aquatic systems have properties that usually fluctuate between those of marine and freshwater habitats.	Yes, downstream	Discharge contributes to downstream flows	Evalauated by others in St. Johns River at Deland	ECT (2004)	NA	NA	NA
4	Transfer of Detrital Material	The movement by surface water of loose organic material and debris and associated decomposing biota.	Yes	Downstream export of particulate organic matter	Mass flux of ash-free dry weight particulate material at downstream boundary	Limited data available; metric can be estimated from similar environments	NA	NA	NA
5	Maintenance of Freshwater Storage and Supply	Protection of an amount of freshwater supply for permitted users at the time of MFLs determination.	Yes	Groundwater withdrawal capacity at the time of MFLs determination	Permitted CUPs at the time of MFLs determination	District data/model	NA	NA	NA
6	Aesthetic and Scenic Attributes	Those features of a natural or modified waterscape usually associated with passive uses such as: bird watching, sight seeing, hiking, photography, contemplation, painting and other forms of relaxation that usually result in human emotional responses of well-being and contentment.	Yes	Spring vista including the following specific attributes: clear water, visable spring boil, and water circulation/flow	Human-Use Days for water viewing activities (picnicking, sunbathing, relaxing)	Approximate by park entry rates with estimated correction factors	Water clarity	Horizontal secchi length	Use of analogous data from Silver Springs
7	Filtration and Absorption of Nutrients and Other Pollutants	The reduction in concentration of nutrients and other pollutants through the processes of filtration and absorption (i.e., removal of suspended and dissolved materials) as these substances move through the water column, soil or substrate, and associated organisms.	Yes	Nitrate nitrogen assimilation	Difference in nitrate nitrogen mass between vent and downstream boundary	Limited data available; metric can be estimated from similar environments	NA	NA	NA
8	Sediment Loads	The transport of inorganic materials, suspended in water, which may settle or rise; these processes are often dependent upon the volume and velocity of surface water moving through the system.	Yes	Non-volatiles suspended solids transport	Non-volatile suspended solids mass transported through downstream boundary	Limited data available; metric can be estimated from similar environments	NA	NA	NA
9	Water Quality	The chemical and physical properties of the aqueous phase (i.e., water) of a water body (lentic) or a water course (lotic) not included in #7 (i.e., nutrients and other pollutants) above.	Yes	Dissolved oxygen, pH, conductivity, and turbidity	Oxygen reaeration rate, historic data	Limited data available; metric can be estimated with models calibrated from similar environments	Water temperature	Winter minimum and summer maximum values	Limited data available; metric can be estimated with models calibrated from similar environments
10	Navigation	The safe passage of commercial water craft (e.g., boats and ships), that is dependent upon sufficient water depth, sufficient channel width, and appropriate water velocities.	Yes, downstream	Discharge contributes to downstream flows	Evalauated by others in St. Johns River at Deland	ECT (2004)	NA	NA	NA

5.2.1.2 Recreational Human Use Specific Criteria and Metrics

A possible quantitative metric for bathing and wading is the total Human-Use Days (HUD) devoted to these activities at each of the two parks. Long-term counts of these specific recreational activities do not currently exist at either spring. Total HUD data do exist and were summarized in Section 2 above. In addition to the total HUD data, a single peak-season count was made at each spring to assess the typical types and distribution of water contact activities. Based on quantitative observations at both sites during peak summer usage, it is estimated that on average over the entire year, roughly 75% of the total visitors at each site spend some of their time in each park wading, bathing, or swimming in the spring boils/runs in the study area. Summer usage includes a higher percentage of water contact activity, estimated during the August 2007 survey to be about 90% of all visitors recorded, while winter uses are estimated to include a lower percentage of water contact recreational activities (assume 60%). The Human Use metric is applied below for assessing protection of ***WRV No.6: Aesthetic and Scenic Attributes***.

Based on interviews with park users, water temperature was determined to be an important factor affecting spring water contact uses. As indicated in Section 2, total attendance at the two springs is fairly accurately described by a sinusoidal curve with maximum amplitude in June and minimum in December. These data as well as observations by WSI indicate that wading and bathing (as well as tubing and swimming) occur at all seasons, but at the highest rate during the summer months when air temperatures are highest. Summer usage for bathing and wading appears to be based on increased individual tolerance for entering the relatively cool spring waters when air temperatures are near their annual high and based on the differential between the warmer air and the cooler waters. On the other hand, winter usage for wading, bathing, and swimming is still an important recreational activity at both parks (estimated as about 4,000 to 5,000 HUDs monthly) and appears to be at least partially related to individual tolerance to enter the relatively warmer spring waters when air temperatures are lower. In both cases, one factor that is known to be important for attracting people to these recreational activities is the relatively constant temperature of the spring water.

A second important factor that makes these two spring areas popular for recreational bathing and wading is the water depth. Public use areas at the two springs differ in magnitude, and are relatively shallow at both sites. Based on the limited survey data and on historic water levels recorded at the two sites, the average and extreme water depths throughout the main public use areas are:

- Rock Springs – mean depth: 0.65 m (2.1 ft); range: 0.46 to 0.87 m (1.5 to 2.8 ft)
- Wekiwa Springs – mean depth: 1.1 m (3.7 ft); range: 0.88 to 1.7 m (2.9 to 5.6 ft)

Greater depths present a hazard to non-swimmers and shallower depths eliminate the opportunity to float inner tubes or completely immerse in the refreshing waters. Shallower water depths at Rock Springs result in a narrower flow path, crowd tubers together in "tube jams", result in tubers hitting and becoming stranded on shallow rock outcrops, and force tubers to walk part of the run rather than being able to stay on their tubes. Shallower water depths at Wekiwa Springs result in a diminished experience during hot summer days and exercise swimmers complained that they could not make their flip turns in water less than 0.9 m (3 ft) deep. A total of fourteen individuals were interviewed during the recreational use surveys conducted on August 11 and 12, 2007. All individuals surveyed indicated they did not wish to see any decrease in water depth.

A third important factor for recreational water contact at these springs is water clarity. As long as clear spring systems are available for these activities, recreational users will avoid turbid water bodies due to concerns about health risks and possible encounters with unseen wildlife such as snakes and alligators. Spring and spring run water clarity is an important attraction for snorkeling and swimming based on the resulting ability to observe underwater plants, fish, and other wildlife. Since water clarity is closely tied to aesthetics it is evaluated further as a sensitive indicator for ***WRV No.6: Aesthetic and Scenic Attributes*** below.

A fourth possible limiting factor for human water contact uses is the periodic presence of high levels of fecal pathogen contamination in the swimming areas. As described earlier, Rock Springs has occasionally recorded excessive populations of fecal coliform bacteria in the water and the swimming area has been closed when levels exceed public health standards. Within the historical period-of-record (1993 to 2006) there have been no recorded fecal coliform exceedances at Wekiwa Springs and the swimming area has not been closed for health-related reasons.

Reduced flows have the potential to change these four important factors at these two spring boil areas, namely narrow temperature ranges, adequate water depths, high water clarity, and adequate spring flows to flush out fecal contaminants. Higher flows buffer water temperature changes and resist increasing water temperatures in the summer and falling temperatures in the winter. Under lower flow conditions, water temperatures could be too warm in the summer to be refreshing and too cold in the winter to allow any but the hardiest to use the parks for recreational bathing and wading. Lower flows reduce water depths and limit the useable area and volume for wading and bathing. Highly reduced flows in deeper water areas may also increase the hydraulic residence time (HRT) for spring waters in their headspring areas and allow undesirable growth of planktonic algae, resulting in greater turbidity and green coloring of the water, slower flushing of suspended sediments due to recreational activities, and subsequent reduction of water clarity.

5.2.1.2.1 Water Temperature

While water temperature is an important factor in recreational enjoyment of Rock and Wekiwa springs, the relatively slight changes anticipated due to reductions in spring flows are not expected to measurably alter recreational activities. For this reason water temperature is not considered further in this section. Water temperature fluctuations in the springs due to reduced flows associated with the spring MFLs are more fully analyzed in Section 5.2.9 of this section under ***WRV No.9: Water Quality***.

5.2.1.2.2 Water Depth

Water depth and HRT in these spring runs was estimated based on the cross section survey information described above in Section 2**.** For the analysis of effects of changes in water depth, best-fit linear regression equations were used to estimate the relationships between discharge and water depth (see **Table 5-5**).

Wading was observed to be the preferred recreational use in Rock Springs at water depths less than about 0.6 m (2 ft). Adults are generally comfortable wading about knee deep in clear water and will keep their children in shallower water (typically less than about one foot). Wading is an important use at Rock Springs, but there are no areas in the Wekiwa Spring pool generally shallow enough for wading.

TABLE 5-5
Mean Water Depth as a Function of Discharge Estimated for Rock and Wekiwa Springs (based on best fit linear regressions from historical stage and discharge data)

Stage		Est. Depth		Est. Flow		Area	Volume	HRT	Velocity
gage ft	ft NGVD	ft	m	cfs	m^3/d	m^2	m^3	hr	m/s
ROCK SPRINGS									
1.82	25.38	1.23	0.38	33.7	82,349	10,369	3,901	1.14	0.158
2.00	25.56	1.41	0.43	39.1	95,735	10,843	4,674	1.17	0.154
2.20	25.76	1.61	0.49	45.2	110,607	11,337	5,578	1.21	0.149
2.40	25.96	1.81	0.55	51.3	125,480	11,797	6,524	1.25	0.144
2.60	26.16	2.01	0.61	57.4	140,353	12,223	7,504	1.28	0.140
2.80	26.36	2.21	0.67	63.4	155,225	12,615	8,514	1.32	0.137
3.00	26.56	2.41	0.74	69.5	170,098	12,973	9,547	1.35	0.134
3.20	26.76	2.61	0.80	75.6	184,971	13,298	10,596	1.37	0.131
3.40	26.96	2.81	0.86	81.7	199,844	13,588	11,656	1.40	0.129
3.60	27.16	3.01	0.92	87.8	214,716	13,845	12,720	1.42	0.127
WEKIWA SPRING									
12.0	11.98	2.857	0.871	30.87	75,526	3224.7	2,843	0.90	0.040
12.2	12.13	3.007	0.917	35.23	86,194	3224.7	2,990	0.83	0.044
12.3	12.28	3.157	0.962	39.59	96,862	3,225	3,137	0.78	0.047
12.5	12.43	3.307	1.008	43.95	107,531	3,225	3,285	0.73	0.050
12.6	12.58	3.457	1.054	48.31	118,199	3,225	3,432	0.70	0.052
12.8	12.73	3.607	1.10	52.67	128,867	3,225	3,580	0.67	0.055
12.9	12.88	3.757	1.145	57.03	139,536	3,277	3,728	0.64	0.057
13.1	13.03	3.907	1.191	61.39	150,204	3,277	3,878	0.62	0.059
13.2	13.18	4.057	1.237	65.75	160,872	3,277	4,028	0.60	0.061
13.4	13.33	4.207	1.282	70.11	171,540	3,277	4,177	0.58	0.062
13.5	13.48	4.357	1.328	74.48	182,209	3,277	4,327	0.57	0.064
13.7	13.63	4.507	1.374	78.84	192,877	3,277	4,477	0.56	0.065
13.8	13.78	4.657	1.42	83.2	203,545	3,277	4,627	0.55	0.067
14.0	13.93	4.807	1.465	87.56	214,214	3,277	4,777	0.54	0.068
14.1	14.08	4.957	1.511	91.92	224,882	3,277	4,926	0.53	0.069
14.3	14.23	5.107	1.557	96.28	235,550	3,277	5,076	0.52	0.070
14.4	14.38	5.257	1.60	100.6	246,219	3,277	5,226	0.51	0.071
14.6	14.53	5.407	1.648	105	256,887	3,277	5,376	0.50	0.072
14.7	14.68	5.557	1.694	109.4	267,555	3,277	5,526	0.50	0.073
14.9	14.83	5.707	1.74	113.7	278,223	3,277	5,676	0.49	0.074
15.0	14.98	5.857	1.785	118.1	288,892	3,277	5,825	0.48	0.075

Bathing describes wading and floating in deeper water, typically above knee level and with a minimum depth of about 0.75 to 0.9 m (2.5 to 3 ft). Bathing is an important public use at both springs. Bathing includes wading in deeper water and periodic partial or entire immersion in areas where the water level is no deeper than about chest height (about 1.2 m or 4 feet for many adults). Bathing was the most important water contact recreational activity observed at Wekiwa Springs.

Tubing is dependent upon the presence of moving water in this same general minimum depth range or deeper as bathing. Rock Springs Run from the main spring down to the second landing is used for tubing. An estimated minimum current velocity that is suitable for tubing at Rock Springs Run is about 0.14 m/s (1 hour and 17 minutes to ride the 650 m distance to the second landing). The estimated minimum average depth that is compatible with tubing at Rock Springs appears to be about 0.6 m (2 ft). A critical depth at Rock Springs that alters the behavior of tubers, thereby diminishing the experience (tubers have to stand up and wade through the shallowest areas of the run) is about 45 cm (1.5 ft). An average water depth that would eliminate tubing entirely is about 30 cm (1.0 ft). This depth is based on the cross section data for Rock Springs Run summarized in **Tables 2-2** and **2-3** above and illustrated in **Appendix F**. At a water stage of 25.65 ft NGVD at the recorder station and an average overall average depth of 45 cm (1.5 ft), the analysis in **Table 2-3** indicates that the minimum channel width at Transect 6 is reduced to less than 0.9 m (3 ft), prohibiting travel by tube and requiring walking through the constriction next to the island. A water stage of 25.15 ft corresponds to the depth where tubing is no longer practical. There is no tubing in the Wekiwa Spring pool although some people use floats and rafts to reduce their contact with the water and to protect small children.

Swimming in the Wekiwa Springs head spring area is dependent upon water depths greater than about 90 cm (3 ft). At shallower depths swimmers stated that they contact the bottom, interrupting their stroke and flip turns. Observations of exercise swimmers at Wekiwa Springs indicated that some follow unmarked swim lanes that maximize their linear distance over the deeper parts of the pool area while others swim counterclockwise around the swim area so that no turns are needed. Most exercise swimmers were observed between 8 and 11 AM, apparently to avoid crowded conditions later in the day. Swimming also takes place in the "pool" area at Rock Springs to a limited extent. Based on these observations it is estimated that a mean water depth of 75 cm (2.5 ft) or less would alter the behavior of exercise swimming activities in Wekiwa Springs and 60 cm (2.0 ft) would preclude swimming in this head spring area. These conclusions are based on the transect data for Wekiwa Springs summarized in **Tables 2-10** and **2-11** and illustrated in **Appendix F**. At a water stage of about 12 ft NGVD, and an overall spring basin average water depth of about

0.75 m (2.5 ft), there is insufficient area available for swimming at the north end of the spring pool (Transect 5).

Based on these estimates any increased periods of low flows that significantly modify or prohibit these uses in areas of the spring runs where they typically occur could be considered to be an indication of harm. An interruption of these popular activities continuously lasting from 14 days in Rock Springs (high level of tubing use) to 30 days in Wekiwa Springs (lower use for swimming) appears to be a reasonable duration for analysis. Based on WSI's professional judgment, the target elevations that would cause a "serious" interruption of these activities in each spring are estimated as:

- 25.65 ft NGVD at Rock Springs (average water depth 0.45 m [1.5 ft])
- 12.00 ft NGVD at Wekiwa Spring (average water depth of 0.87 m [2.9 ft])

Based on the estimated flow vs. depth data in **Table 5-5** the estimated 14- and 30-day, critical low flows (continuously not exceeded) for this criterion are:

- Rock Springs – 42.4 cfs
- Wekiwa Spring – 30.9 cfs

At Wekiwa Springs neither a level nor a flow this low have been observed in the historical data and are not considered to be likely within the constraints of the existing spring MFL.

Water stages that could preclude these activities entirely are estimated as:

- 25.15 ft NGVD at Rock Springs (average water depth 0.30 m [1.0 ft]
- 11.5 ft NGVD at Wekiwa Springs (average depth 0.73 m [2.4 ft])

Neither of these lower water stages are considered to be possible within the range of historical flows or under the existing springs MFLs for these springs.

5.2.1.2.3 Fecal Coliform Contamination

Epting (2007) has developed a model that was used to estimate closure of public water contact activities at Ponce de Leon Springs State Park. Based on a site-specific calibration with historical fecal coliform monitoring data, Epting's model estimates bacteria populations as a function of spring discharge, physical dimensions of the spring boil and run area used for water contact recreation, and observed fecal coliform disappearance or die-off rates. The Epting model was applied to the issue of predicting the frequency of park closures due to excessive fecal coliform counts at Rock Springs. The Florida Class III fresh water criterion for bacteriological quality (fecal coliform bacteria) states that the maximum daily value will be 800 colonies per 100 mL of sample (Chapter 62-302.530 (6), F.A.C.).

Based on historical conditions at Rock Springs there have been 3 days with fecal coliform violations in 10 years (equivalent to 13.5 days in 45 years). The results of Epting's analysis are displayed in **Figure 5-1**. Model estimates indicate that the number of additional park closings due to fecal coliform bacterial contamination of the swimming area might be expected to increase from about one during the entire period-of-record at a minimum annual mean flow of 56 cfs from Rock Springs to about eight during the period-of-record at a mean flow of 50 cfs (Bob Epting, SJRWMD, personal communication, 2007). Based on a possible reduction in flow from 59 cfs to 53 cfs under the existing spring MFL, **Figure 5-1** indicates that we might expect 2.5 additional violations of this standard over the 45 year simulation period (13.5+2.5 = 16 per 45 years). This estimate is equivalent to an increased annual probability of occurrence from 30% (13.5/45) to 36% (16/45).

Based on historical records, park closures due to excessive fecal coliform populations are not anticipated at Wekiwa Springs within the range of historical and MFL flows.

5.2.1.2.4 Frequency Analysis

The District's frequency analysis approach is applicable to evaluation of this WRV since the recreational uses described above are likely to be affected by changes in hydrologic regime. Water temperature fluctuations, adequate depth for wading/bathing, and excessive bacteria levels are most likely to be affected during low flow conditions and are unlikely to be adversely impacted by high flow conditions. **Figure 5-2** illustrates the historical and estimated MFL low flow continuously not exceeded frequency plots for Rock Springs for 1-day, 14-day, and 30-day durations based on data provided by Intera (2006). The estimated increases in the annual non-exceedance probability and return intervals for these low flow conditions at Rock Springs are: wading, bathing, and tubing – 7 to 17% (once in 14 yrs to once in 6 yrs).

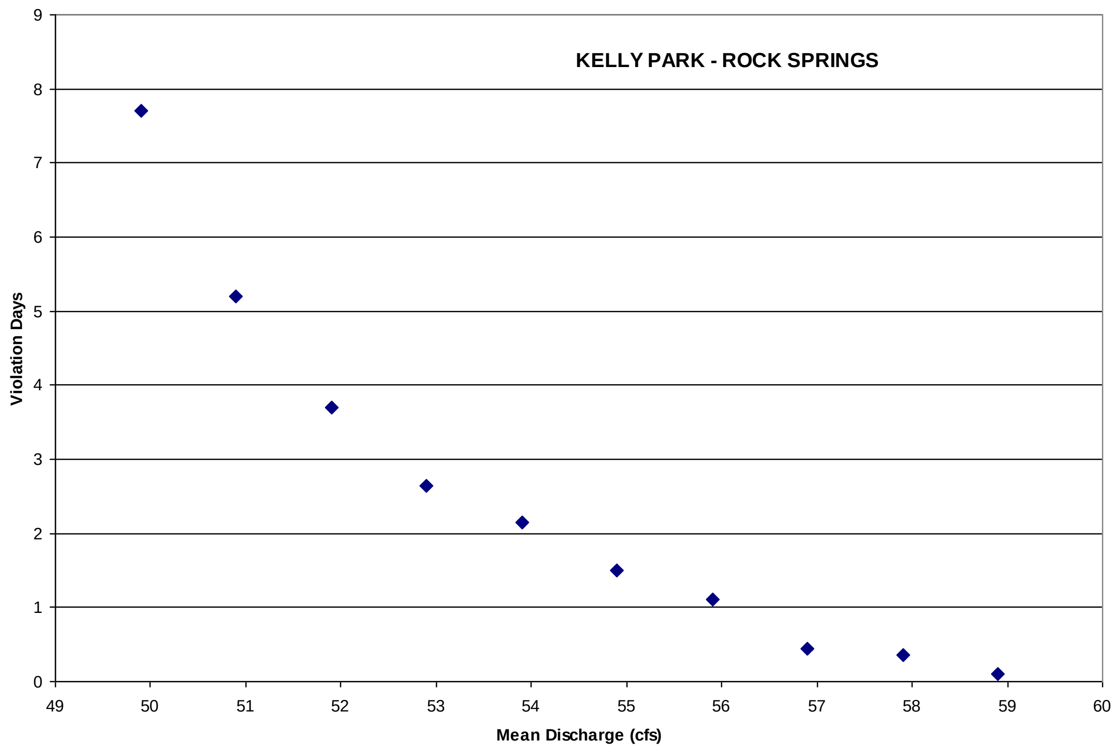


FIGURE 5-1
Estimated Number of Additional Occurrences of One-Day Events during the 45 Year Period-of-Record when Fecal Coliform Bacteria Counts would exceed the FDEP Class III Criterion as a Result of Mean Discharge from Rock Springs (Epting 2007)

Figure 5-3 illustrates the historical and estimated MFL low flow continuously not exceeded frequency plots for Wekiwa Springs for 1-day, 14-day, and 30-day durations. Based on the estimated critical flows for the most sensitive indicator of impaired recreational use (water depth decline below optimal useable levels over a 30-day duration), there is no estimated increase in the annual non-exceedance probability and return intervals for these low flow conditions at Wekiwa Springs. Based on a shorter duration (1-day), **Figure 5-3** indicates that the estimated increase in the annual non-exceedance probability for conditions limiting bathing and swimming is 1.5 to 2.5% (once in 67 yrs to once in 40 yrs).

Based on the estimated critical flows for the most sensitive indicator of impaired recreational use (water depth decline below optimal useable levels over a 14-day duration), the estimated increase in the annual non-exceedance probability and return intervals for these low flow conditions are:

- Rock Springs – 14-day bathing, wading, tubing – 7 to 17% (from once in 14 yrs to once in 6 yrs)
- Wekiwa Springs – 30-day bathing and swimming – no measurable increase in frequency (determined to be unlikely to occur)
- Rock Springs – 1-day park closure due to public health concerns – 30 to 36% (13.5 days in 45 years to 16 days in 45 years)

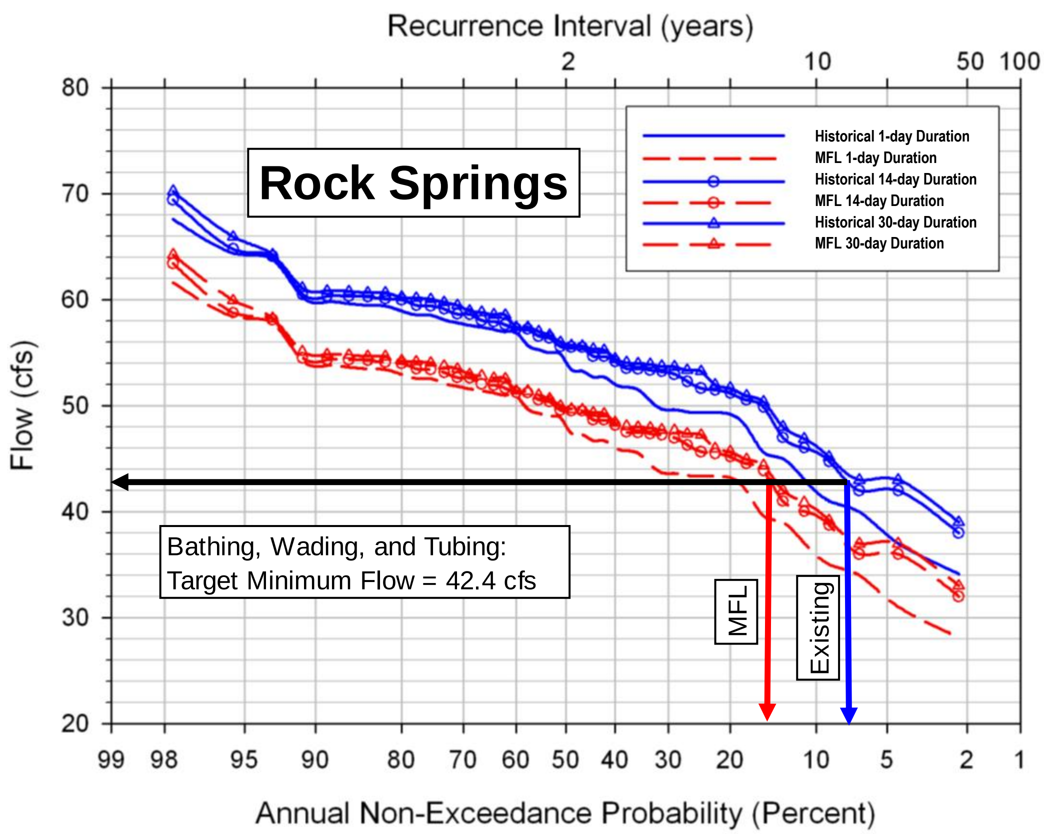


FIGURE 5-2
Historical and Estimated MFL Low Flow (14-day duration Continuously Not Exceeded) Frequency Analysis for Rock Springs Needed to Protect Water Contact Activities (data from Intera 2006)

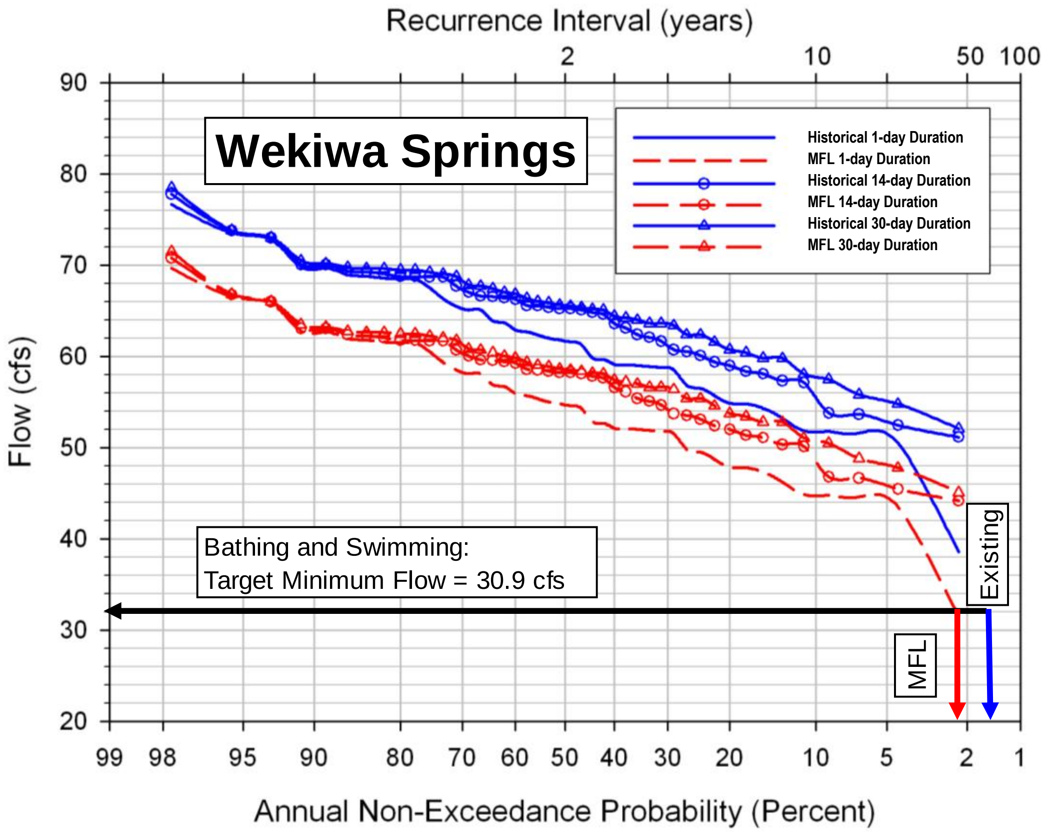


FIGURE 5-3
Historical and Estimated MFL Low Flow (1-day Duration Continuously Not Exceeded) Frequency Analysis for Wekiwa Springs Needed to Protect Water Contact Activities (data from Intera 2006)

5.2.1.3 Effect of Spring MFLs on Most Sensitive Specific Criterion/Criteria

The existing Spring MFLs for Rock and Wekiwa springs allow an average flow reduction of about 10% compared to the historic record. Based on the above analysis and the assumptions in that analysis, issuance of permits up to the limit imposed by the existing MFL may impact recreational activities at Rock Springs due to an increased frequency of lower water levels. These increased frequencies would modify tubing activities and would constitute a relatively low level of harm to ***WRV No. 1: Recreation In and On the Water*** at Rock Springs. Lower water levels in Rock Springs that would totally preclude recreational activities are not expected to occur within the range of allowable flows under this MFL. Based on this analysis, this WRV appears to be protected at Wekiwa Springs by the existing MFL. No significant increase in beach closures at Rock and Wekiwa springs due to fecal contamination are expected within the allowable range of flows under this MFL.

5.2.1.4 Summary

The primary water-contact recreational activities at Rock and Wekiwa springs appear to be wading, bathing, swimming, and tubing, all of which are dependent upon water temperature, clarity, depth, and public health considerations. Historical fluctuations observed for water temperature in both springs are relatively small and not likely to be noticeable within the range of reduced flows allowed by the MFL. Best professional judgment was used to estimate critical water levels for the various dominant recreational activities. Effects of flow reductions on water clarity were also estimated and are more fully evaluated below under ***WRV No. 6: Aesthetic and Scenic Attributes***. Frequency of fecal contamination events was estimated for a range of mean spring discharge rates.

These analyses indicated that spring flows only a little lower than historical median levels at Rock Springs could be a lower threshold below which recreational benefits might be measurably reduced (behavior modifications for tubers). The existing spring MFLs would possibly allow an increased frequency (probability) of occurrence for these lower flow conditions, about 10% more often at Rock Springs based on an event duration of 14 days. Based on this analysis, it is concluded that this WRV will be marginally protected in the Rock Springs study area by the spring MFLs. This conclusion is contingent on the caveat that additional data collection and analysis will be necessary to more precisely assess the possible effects of reduction in spring discharge on recreational activities at Rock Springs.

Lower water levels that would effectively eliminate tubing in Rock Springs and exercise swimming in Wekiwa Springs are not considered to be likely under these spring MFLs. Increased frequency of beach closures due to fecal coliform contamination are also not considered to be a likely consequence of the spring MFLs at Rock Springs.

At Wekiwa Springs water depths appear to be adequate to protect these recreational activities within the range of flows that would be allowed by the spring MFLs.

5.2.2 Fish and Wildlife Habitats and the Passage of Fish

5.2.2.1 Introduction

Rock and Wekiwa springs are complex aquatic ecosystems comprised of flora and fauna typical of such ecosystems in Florida. Detailed studies in other springs and reconnaissance work in these specific spring runs indicates that a biomass pyramid is typical in these systems and that this ecological structure of decreasing biomass with distance up the foodchain is supported by relatively high levels of community metabolism (Odum 1957). Gross primary productivity (GPP), primarily in the spring supports most of the fish and wildlife habitat in the spring run. Community respiration (CR) is an estimate of the total system metabolic activity and is roughly proportional to the amount of living and dead organic material. Net primary productivity (NPP) refers to the amount of organic carbon that is produced in excess of the amount consumed by respiration. Autotrophic spring ecosystems produce more organic carbon than they consume (positive NPP). Heterotrophic systems have an external carbon source and may have a NPP < 0. Most springs are dependent upon autotrophic production of reduced carbon; however, some heterotrophic carbon from leaves and other plant and animal tissues from the surrounding upland forests, or from littoral wetland vegetation does contribute to the system's net productivity. Ecological efficiency (EE) is equal to the ratio between GPP and useable incoming solar radiation and provides a normalized estimate of ecosystem metabolism corrected for seasonally and diurnally-varying inputs of sunlight, the principal forcing function in autotrophic spring ecosystems.

In most spring ecosystems, including Rock and Wekiwa springs, the majority of the available base of the food chain for all aquatic wildlife is the GPP. This fixed carbon is in turn used for plant growth and respiration, forming the basis for the food chain of herbivores and higher consumers. All wildlife species inhabiting a spring may be affected if the amount of internal GPP or the external inputs of NPP from surrounding ecosystems are reduced.

5.2.2.2 Fish and Wildlife Habitats and Fish Passage Metrics

Four possible metrics were considered for a preliminary analysis of the effects of flows and levels on fish and wildlife habitats in these two spring systems:

- Community metabolism (normalized for daily solar energy inputs as Ecological Efficiency)
- Wet habitat area (m^2)
- Fish density ($\#/m^2$) and biomass (g/m^2)
- Fish passage depth

There were no available data that indicated the presence of any listed wildlife species of concern in the Rock or Wekiwa springs study areas.

Quantitative metabolism data from these two spring ecosystems (**Table 5-6**) indicate that their GPP is quite different, possibly due to different levels of human modifications. Rock Springs and Rock Springs Run is a more natural spring run plant community consisting of submerged aquatic vegetation and attached periphyton surrounded by a fringing emergent and floating aquatic wetland plant community. This relatively high plant density results in a relatively high estimated average GPP of 5.96 g $O_2/m^2/d$. On the other hand, the Wekiwa Springs area is largely enclosed in a concrete wall and most of the area is subject to direct impacts from human bathing and swimming. Downstream of the bridge at the Wekiwa Spring swimming area the channel is more natural and colonized with fringing aquatic vegetation. The measured GPP at Wekiwa Springs was only 2.76 g $O_2/m^2/d$ and consistently lower than the measured ecosystem metabolism at Rock Springs. Based on estimates of incoming photosynthetically active radiation (PAR) measured in units of moles of photons (Einsteins) at both sites corrected based on an estimated 20% shading from overhanging trees, the ecological efficiency (EE) at Rock Springs was estimated as 0.59 g O_2/mol and only 0.26 g O_2/mol at Wekiwa Springs. Comparable GPP and EE rates from "control" spring systems at Juniper Run and Alexander Springs Creek based on a complete annual data record were between 4.9 and 5.4 g $O_2/m^2/d$ for GPP and 0.35 and 0.46 g O_2/mol for EE (WSI 2006), respectively. Resulting net primary productivity was negative at Rock Springs Run (-0.95 g $O_2/m^2/d$) and negative at Wekiwa Springs (-4.80 g $O_2/m^2/d$), suggesting that the springs receive some allochthonous inputs of organic matter and consume the majority of their own internal production. For this reason they have fairly limited downstream foodchain support functions. Based on previous studies (WSI 2006), both control streams had average NPP values that were slightly negative (-0.34 to -2.1 g $O_2/m^2/d$, respectively).

Current velocity was hypothesized to be an important stimulant of community metabolism in spring ecosystems (Odum 1957) and the most important factor controlling the distribution of natural periphyton populations in springs (Whitford 1956). Odum (1957) measured an 80% reduction in GPP and EE based on a comparison between the rapidly flowing upstream portion of the Silver River and the relatively quiescent boat basin located 5 miles downstream.

Figures 5-4 and **5-5** illustrate the observed effects of discharge and water depth on GPP and EE at Rock and Wekiwa springs. GPP was not consistently correlated with discharge / depth at Rock and Wekiwa Springs, while EE (GPP normalized for actual photosynthetically active radiation on the day of measurement) was positively correlated with discharge / depth at Rock and Wekiwa Springs. Based on this regression analysis, it is concluded that a reduction in average discharge at these springs may be associated with a reduction in ecosystem efficiency. The correlation between spring discharge and EE was higher at Rock Springs than at Wekiwa Springs based on the new data collected for this assessment. However, the correlation coefficients between these variables are relatively weak at both springs and it will be necessary to collect and analyze additional data from these systems to more precisely assess the likely effects of possible reductions in spring discharge and ecological responses.

In response to these differences between Rock and Wekiwa springs, observed wildlife habitat and wildlife use is also different between the two sites. A normal aquatic foodchain of herbivores and multiple carnivore levels is present in Rock Springs while only herbivores feeding on algae and primary carnivores feeding on insect larvae were observed in Wekiwa Springs. Insufficient quantitative fish and wildlife density and biomass data are currently available to assess responses of faunal groups to low or high flow events.

Fish passage does not appear to be a limiting constraint at either of these sites based on the spring MFLs since minimum water depths at the lowest observed flows are typically greater than 0.3 m (1 ft).

Aquatic habitat area for the Rock Springs study area was estimated earlier (see **Table 5-5**) based on the limited surveyed cross sections and as a function of flows. At the median observed stage of 26.15 ft NGVD the estimated aquatic habitat area is 12,200 m^3 (3.02 ac). This habitat area would be reduced to approximately 10,370 m^3 (15% reduction) at an

TABLE 5-6
Measured Rates of Ecosystem Metabolism and Related Variables for Rock and Wekiwa Springs During the Period from 2005-2007

	Rock Spring					Wekiwa Springs				
	Average	Minimum	Maximum	StdDev	N	Average	Minimum	Maximum	StdDev	N
GPP (g $O_2/m^2/d$)	5.97	1.67	11.16	1.82	91	2.76	0.31	6.92	0.99	137
NPP24 (g $O_2/m^2/d$)	-0.95	-8.54	7.01	3.30	91	-4.80	-13.12	2.34	3.18	137
R24 (g $O_2/m^2/d$)	6.92	1.34	15.08	3.17	91	7.56	0.16	13.88	2.99	137
P/R Ratio	1.05	0.19	4.77	0.70	91	0.62	0.04	15.55	1.49	137
PAR (24hr) (mol/m^2/d)	14.14	1.52	28.26	6.54	90	14.89	1.10	27.34	6.95	137
PAR Efficiency (%)	4.28	1.61	14.52	2.48	90	2.08	0.28	9.04	1.63	137
EE (g O_2/mol)	0.53	0.20	1.80	0.31	90	0.26	0.03	1.12	0.20	137
Discharge (m^3/d)	142,326	124,786	166,734	16,046	91	149,576	104,850	189,389	20,243	137
Depth (m)	0.61	0.52	0.72	0.08	91	1.15	1.06	1.34	0.06	137
Period of Record		2/24/05	5/23/07				4/30/05	5/22/07		

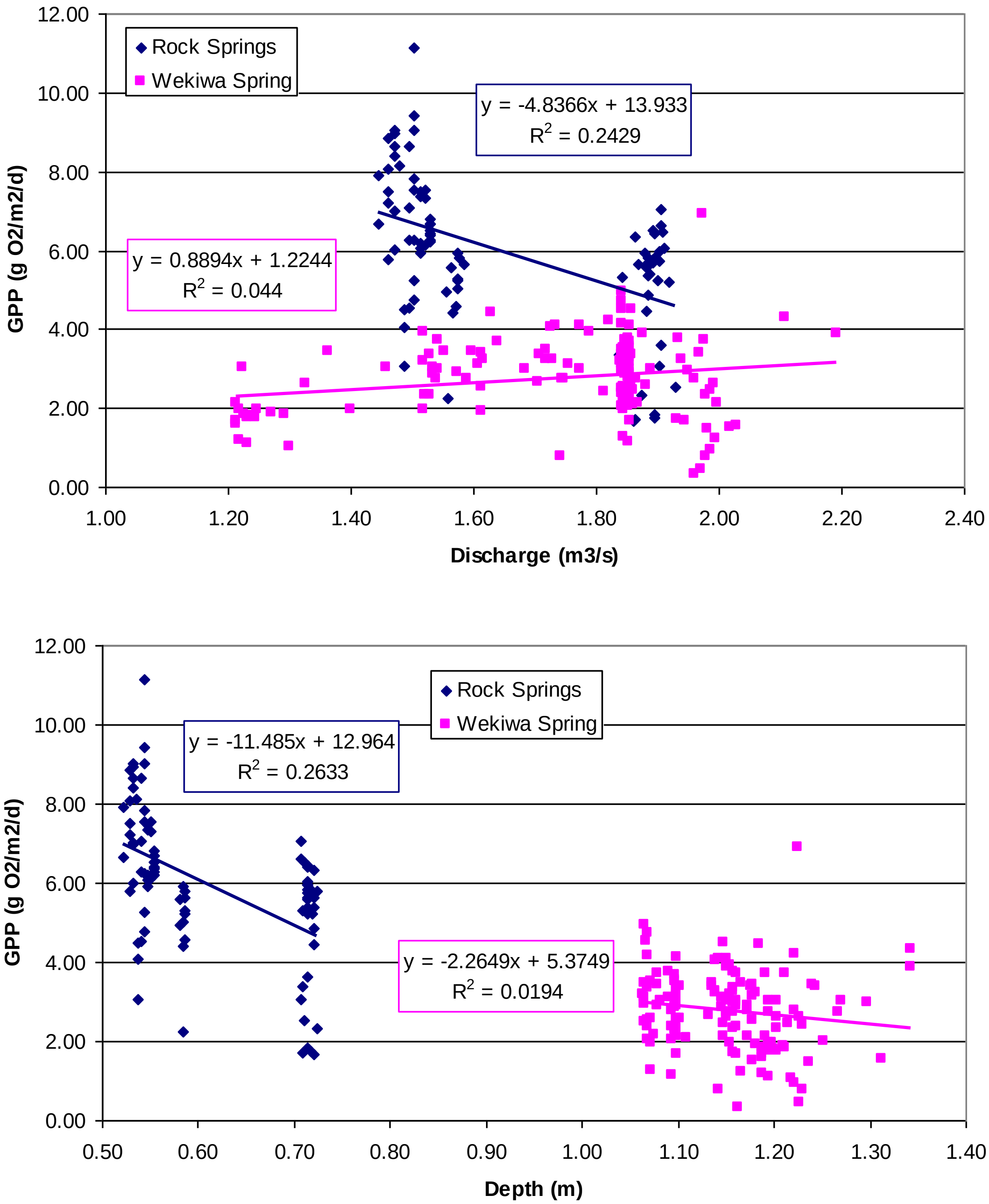


FIGURE 5-4
Rock and Wekiwa Springs Gross Primary Productivity Correlations with Discharge and Depth (data from 2005-2007)

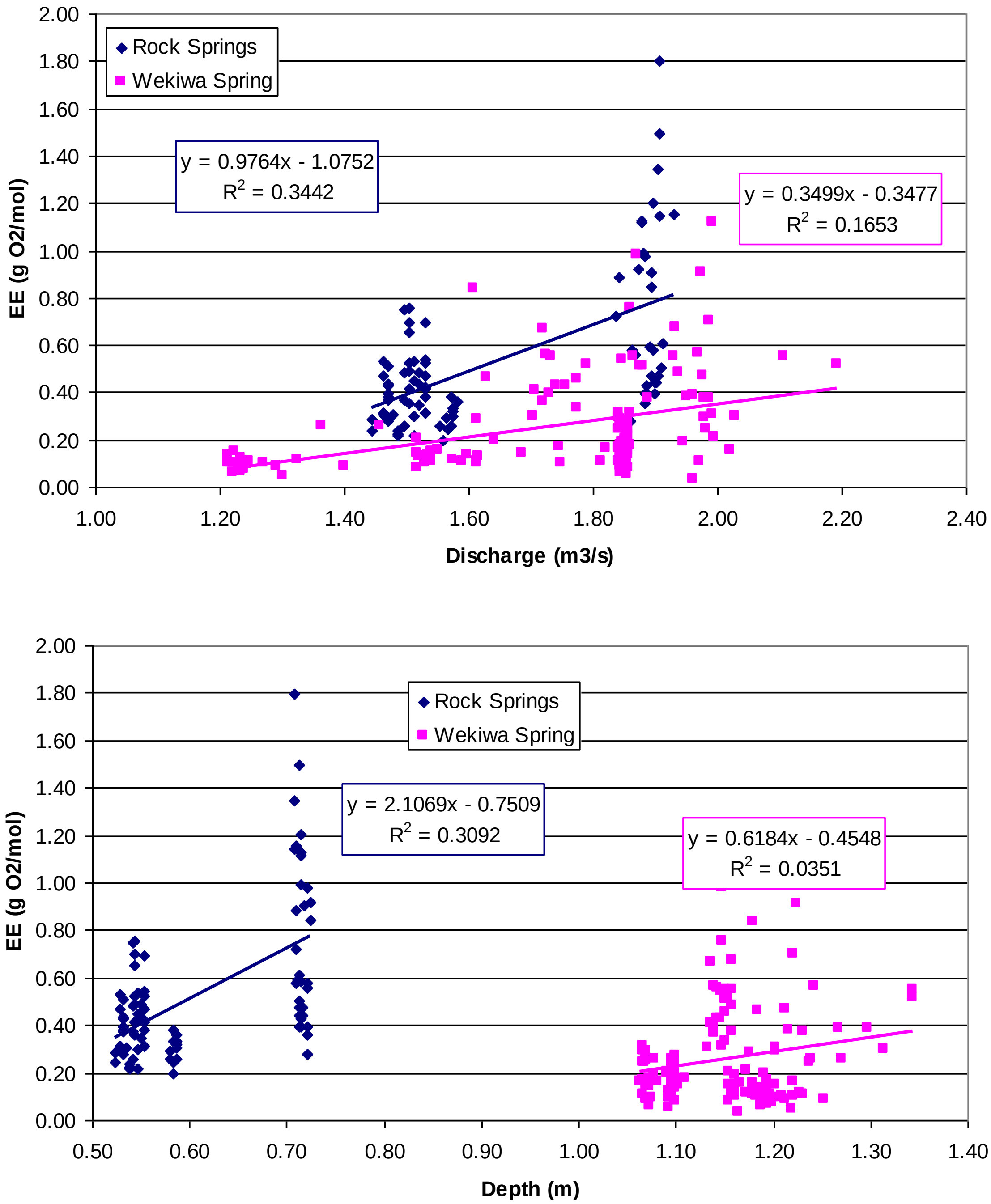


FIGURE 5-5
Rock and Wekiwa Springs Ecological Efficiency Correlations with Discharge and Depth (data from 2005-2007)

estimated flow of about 33.7 cfs (0.95 m^3/s). Since aquatic habitat at Wekiwa Springs is apparently degraded due to intense recreational activities, this approach was not utilized at that spring for evaluating protection of ***WRVNo.2: Fish and Wildlife Habitats and the Passage of Fish***.

5.2.2.3 Effect of Spring MFLs on Most Sensitive Specific Criterion/Criteria

New data collected from Rock and Wekiwa springs indicate a positive but relatively weak correlation between spring discharge and water depth as independent variables and GPP and EE as dependent variables. A critical minimum EE for these systems is estimated as about 0.20 based on one-half of the average of the EE values measured previously at Alexander and Juniper Creeks (WSI 2005, 2006). The Wekiwa Springs main boil area is already often below this EE level, probably due to the intensity of human alterations and recreational activities at the site. Therefore, Wekiwa Springs is not considered further under the fish and wildlife habitat WRV. Based on the regression equation in **Figure 5-5** above, the critical flow that correlates with this EE at Rock Springs is 46 cfs (1.31 m^3/s). Based on the low flow, non-exceedance curves for Rock Springs presented in **Figure 5-6**, the probability for a 30-d duration for this annual non-exceedance flow would be increased from about 10 to 20% (10 to 5 year recurrence interval). This increased occurrence of lowered plant productivity may translate into a loss of production at higher trophic levels, i.e., indigenous wildlife, including turtles, fish, otters, etc.

Using the aquatic habitat area approach described above, the critical low flow was estimated as 33.7 cfs (0.95 m^3/s). This estimated low flow is below historic simulated discharge data for Rock Springs but is possible under the MFL for the spring. Estimated increased probability for a 30-day event for this flow would increase from about once in 100 years to about once in 50 years (see **Figure 5-6** for Rock Springs non-exceedance curves).

Based on these estimated potential habitat losses and the uncertainties associated with the quantitative methods applied to this analysis, it is concluded that this WRV is only marginally protected at Rock Springs by the District's spring MFLs. Additional data collection will be necessary to fully evaluate the effects of spring discharge on habitat protection at Rock Springs.

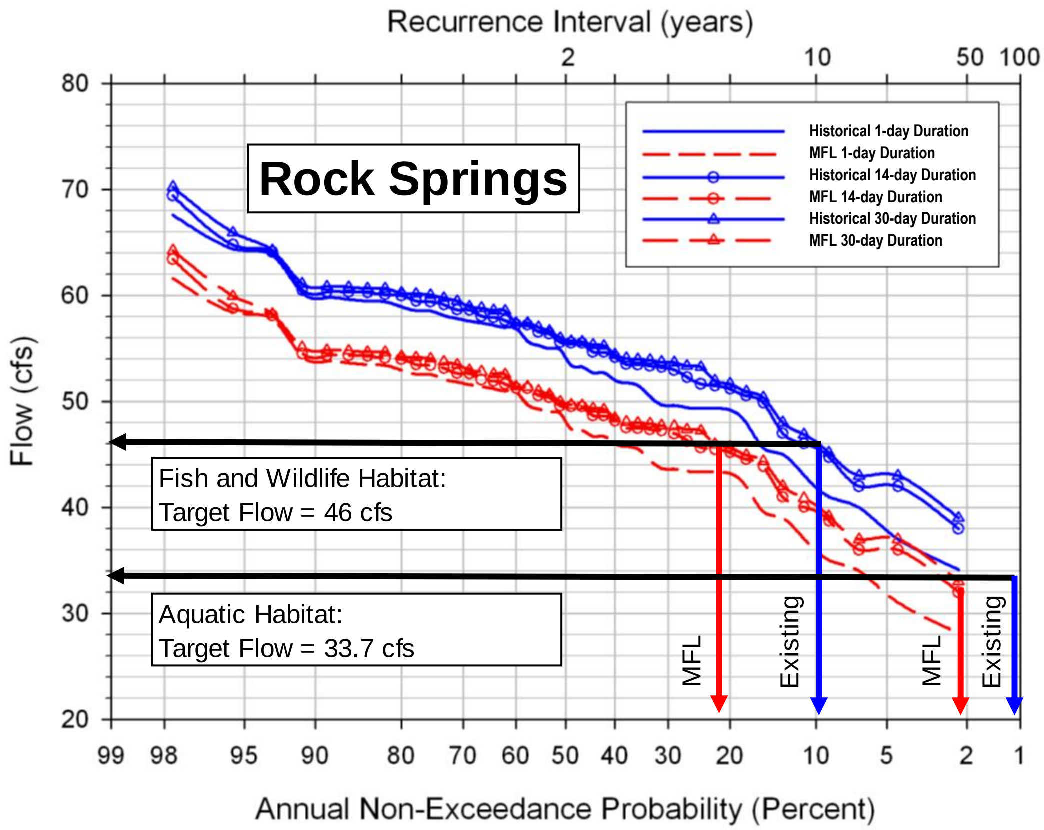


FIGURE 5-6
Historical and Estimated MFL Low Flow (30-day duration Continuously Not Exceeded) Frequency Analysis for Rock Springs Needed to Protect Fish and Wildlife Habitat (data from Intera 2006)

5.2.2.4 Summary

Community metabolism measurements provide the most comprehensive and readily measurable index of spring ecosystem response to changing environmental forcing functions. Stream velocity has been found to be an important determinant of community metabolism in spring runs. New metabolism data collected as part of this effort at Rock and Wekiwa springs found evidence for a similar relationship between spring discharge (flow) and ecological efficiency. Based on this correlation, the decline in flows allowed by the District's spring MFL at Rock Springs may measurably reduce ecosystem metabolism and the area of aquatic habitat in this spring run, in turn reducing the overall foodchain support and wildlife productivity in this aquatic community. This conclusion is based on limited data and incorporates considerable uncertainty because the correlations between flow and ecological efficiency are relatively weak. The estimated increased frequency of periods with lower support of fish and wildlife habitat are relatively minor. Based on this analysis it is concluded that ***WRV No.2: Fish and Wildlife Habitats and the Passage of Fish*** will be marginally protected in the Rock Springs study area by the existing minimum annual mean flows. This conclusion is contingent on the caveat that additional data collection and analysis will be necessary to more precisely assess the possible effects of reductions of spring discharge on wildlife habitat in this spring run. This WRV is not currently prominent at Wekiwa Spring due at least partially to non-discharge related human factors and is not considered likely to be harmed further as a result of further flow reductions permitted under the District's minimum annual mean flow.

5.2.3 Estuarine Resources

5.2.3.1 Introduction

Estuarine Resources include coastal systems and associated environmental structure and functions that depend upon the mixing of salty oceanic waters and inland fresh waters. Estuaries are often biologically productive and popular for human recreational pursuits due to the availability of nutrients, high levels of primary productivity, and resulting high populations of commercial and recreational fisheries and other large fauna (particularly birds and marine mammals). Rock and Wekiwa springs are located about 165 water miles upstream of the mouth of the St. Johns River at the Atlantic Ocean, however saltwater fauna are known to come up river at least as close as Volusia Blue Spring and Deland. None of those saltwater species have been reported in the vicinity of the Rock and Wekiwa springs boils or upper spring runs. Flows of fresh water from Rock and Wekiwa springs do contribute to downstream estuarine productivity and habitat for biota and humans but constitute a very small percentage of the flows reaching those tidal areas.

5.2.3.2 Summary

ECT (2004) evaluated the effects of possible water withdrawals from the St. Johns River on downstream Estuarine Resources. The ECT evaluation was based on District model simulations using the Environmental Fluid Dynamics Computer Code (EFDC). The model was used to project changes in the salinity regime of the Lower St. Johns River (LSJR) which is the section of the St. Johns River downstream of Buffalo Bluff to the river's terminus at Mayport, as a result of the possibility of increased cumulative surface water withdrawals from reaches of the St. Johns River upstream of State Road 40 in Astor. This work was performed in support of the MFL WRV evaluations of the St. Johns River near DeLand (SJRND) which includes the river reach from the Wekiva River confluence to State Road 40 at Astor. ECT (2004) also assessed the effect the projected salinity changes on aquatic life in the lower St. Johns River. The EFDC model was run for the baseline flow conditions and for three other flow scenarios, which reflect the withdrawal of surface water from the SJRND at the maximum rate of 120, 240, and 360 cfs. Statistical analyses for the four simulated scenarios were performed and comparisons were made to quantify the changes in average salinity regime.

Based on the results of their salinity assessment in the lower St. Johns River, ECT (2004) concluded that a maximum withdrawal of 240 cfs from the SJRND, as limited by the preliminary MFLs regime, will protect the estuarine resources in the LSJR. Any reductions in flow at Rock and Wekiwa springs as limited by the Wekiva River MFLs at SR 46 would be included in the 240 cfs cumulative maximum withdrawal downstream.

For the purposes of this report, the assessment completed by others (ECT 2004), is considered sufficient to indicate that ***WRV No.3: Estuarine Resources***, is protected by the Rock and Wekiwa springs' minimum mean annual flows.

5.2.4 Transfer of Detrital Material

5.2.4.1 Introduction

Detrital material transport is an important ecological function in many riverine systems (Wetzel 2001) including spring runs (Odum 1957). This detrital material forms the basis for a detritus food web in which microbes and aquatic insects utilize the reduced carbon in the dead plant material from an upstream ecosystem to fuel their own growth and metabolism. These organisms are in turn food for the wildlife in that downstream segment. Particulate export is a measure of ecosystem net productivity as well as allochthonous inputs from external systems (such as leaf litter from surrounding upland plant communities). When flows are reduced in a lotic system, the allochthonous transport process may be reduced and these downstream systems may become less ecologically productive. This type of upstream autotrophic production and transport of a portion of this biomass downstream to a less autotrophic stream reach is particularly important in Rock Springs Run and in the Wekiva River. The upper portion of a spring run is generally productive due to high water clarity and ample light while the next stream segments downstream are more shaded and their community metabolism and foodchains are somewhat dependent upon imported reduced carbon. Export and downstream transport of detrital material was directly measured on three occasions in 2007 in both Rock and Wekiwa springs for this WRV assessment.

5.2.4.2 Transfer of Detrital Material Specific Criteria and Metrics

Figure 5-7 illustrates the observed relationship between particulate organic export and discharge at each of the two spring systems. These data are reported in two different units: total mass of ash-free dry matter per day (g/d) and ash-free dry matter per area per day ($g/m^2/d$). Measured detrital export rates were typically higher for Rock Springs than for Wekiwa Springs, based on total load and on load per area. These limited data indicate a negative correlation between flows and particulate export for Rock and Wekiwa springs. Lower spring discharge rates were found to be associated with higher particulate organic export rates.

5.2.4.3 Effect of Spring MFLs on Most Sensitive Specific Criterion/Criteria

Limited data collected at Rock and Wekiwa springs found that rates of detrital export are higher at lower spring discharge rates. This finding may indicate that in Rock Springs less of the autochthonous organic matter is being respired during the shorter HRTs apparently associated with lower spring discharges, resulting in a higher fraction of the internal production being exported downstream. A second possible explanation is that lower flows result in reduced community respiration and a greater net production of fixed carbon. Intuitively it appears that at larger flow reductions than those observed during this study, detrital export would be adversely affected as a result of lower autochthonous production within the reduced spring run area and less organic matter available for export. However, a threshold for reduced organic matter export, if it exists, could not be defined based on existing data analysis. These data indicate that within the level of flow reduction allowable under the Rock and Wekiwa springs MFLs (about 10%) there is no anticipated loss and possibly an increase in detrital export as a result of reduced flows.

5.2.4.4 Summary

Based on the new data collected as part of this WRV assessment it is concluded that ***WRV No.4: Transfer of Detrital Material*** is not likely to be adversely affected in Rock and Wekiwa springs as a result of the spring MFLs at Rock and Wekiwa springs.

5.2.5 Maintenance of Freshwater Storage and Supply

5.2.5.1 Introduction

This WRV is defined as: "protection of an amount of fresh water supply for permitted users at the time of MFLs determination". The hydrologic data used in this report to evaluate historical long-term hydrologic regimes in the Wekiva River and Rock Springs Run and in Rock and Wekiwa springs incorporates existing and historical permitted users. The MFLs regime developed for the Wekiva River at SR 46 in 1991 was based on conditions in existence at that time and did not account for changes to human use and water resource values that may have occurred prior to that time. Additional legal consumptive uses, both permitted and unpermitted have also come on-line during the past 16 years since the MFLs in the Wekiva River at SR 46 was developed. Current flows at Rock and Wekiwa springs may have been reduced compared to historic flows by these existing anthropogenic consumptive uses, in addition to any climatic variations occurring due to rainfall and evapotranspiration long-term trends.

Permitted groundwater withdrawals in the vicinity of Rock and Wekiwa springs are illustrated in **Figure 5-8**. Total permitted consumptive uses of groundwater within three miles of the two springs include a permitted total withdrawal rate of 4,553 million gallons per year (19.3 cfs). Other legal and unauthorized anthropogenic withdrawals in the immediate vicinity of the two springs were not estimated for this report. The three-mile radius used for this analysis is arbitrary and does not include all CUPs within the springsheds for these two springs. It is likely that there are other permitted consumptive uses outside the three-mile radius around the springs which may be having direct or indirect effects on spring flow reductions. The existing SR 46 MFLs for the Wekiva River and the minimum annual mean spring flow targets at Rock and Wekiwa springs allow a combined reduction of 13 cfs to be allocated in consumptive use permits (CUPs) developed since 1991. The fraction of this designated allowable flow reduction that has already been previously allocated is estimated to be about 90% (Price Robison, SJRWMD, personal communication, 2007).

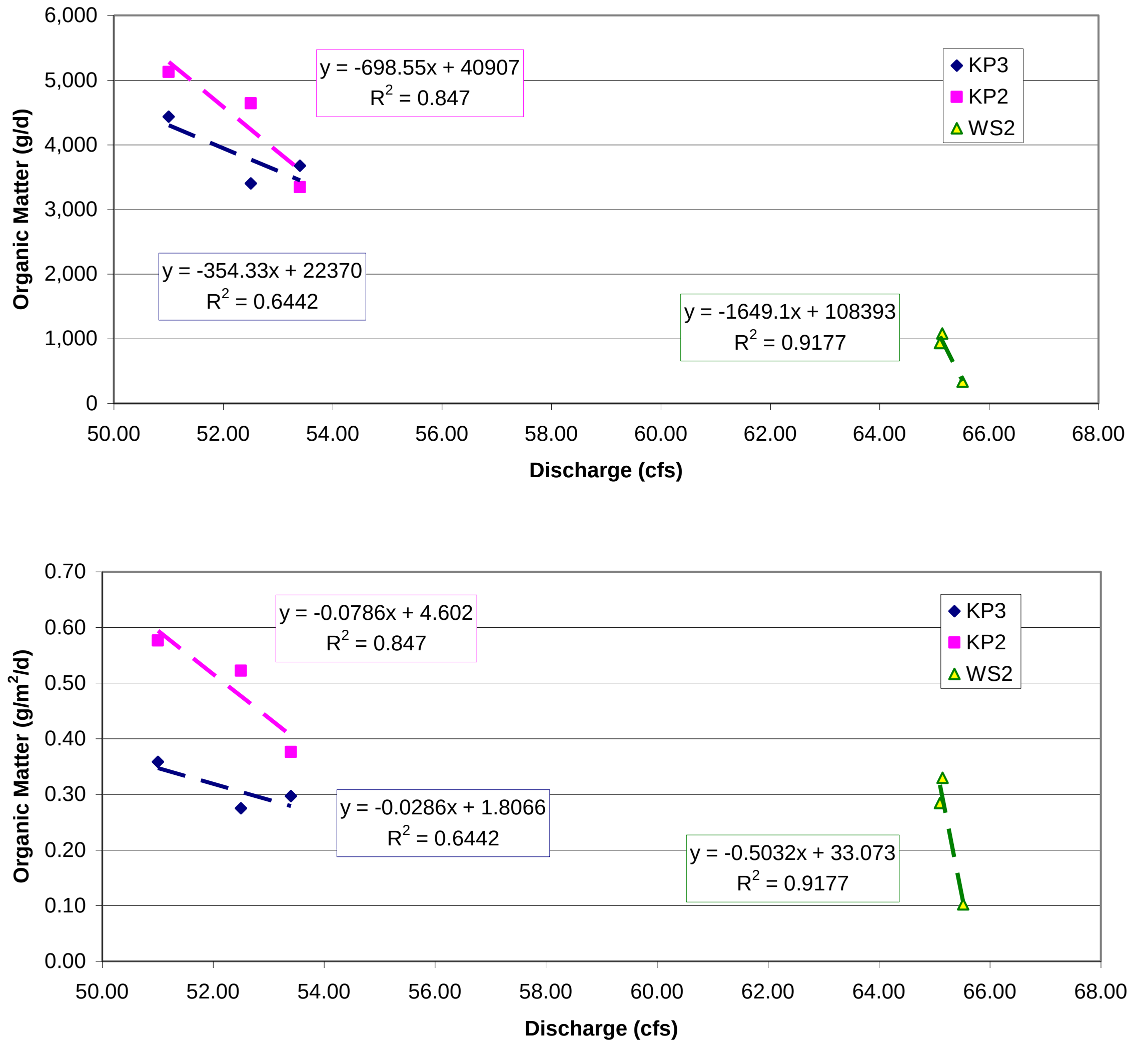


FIGURE 5-7
Observed Relationship between Particulate Organic Export and Flow at Rock and Wekiwa Springs

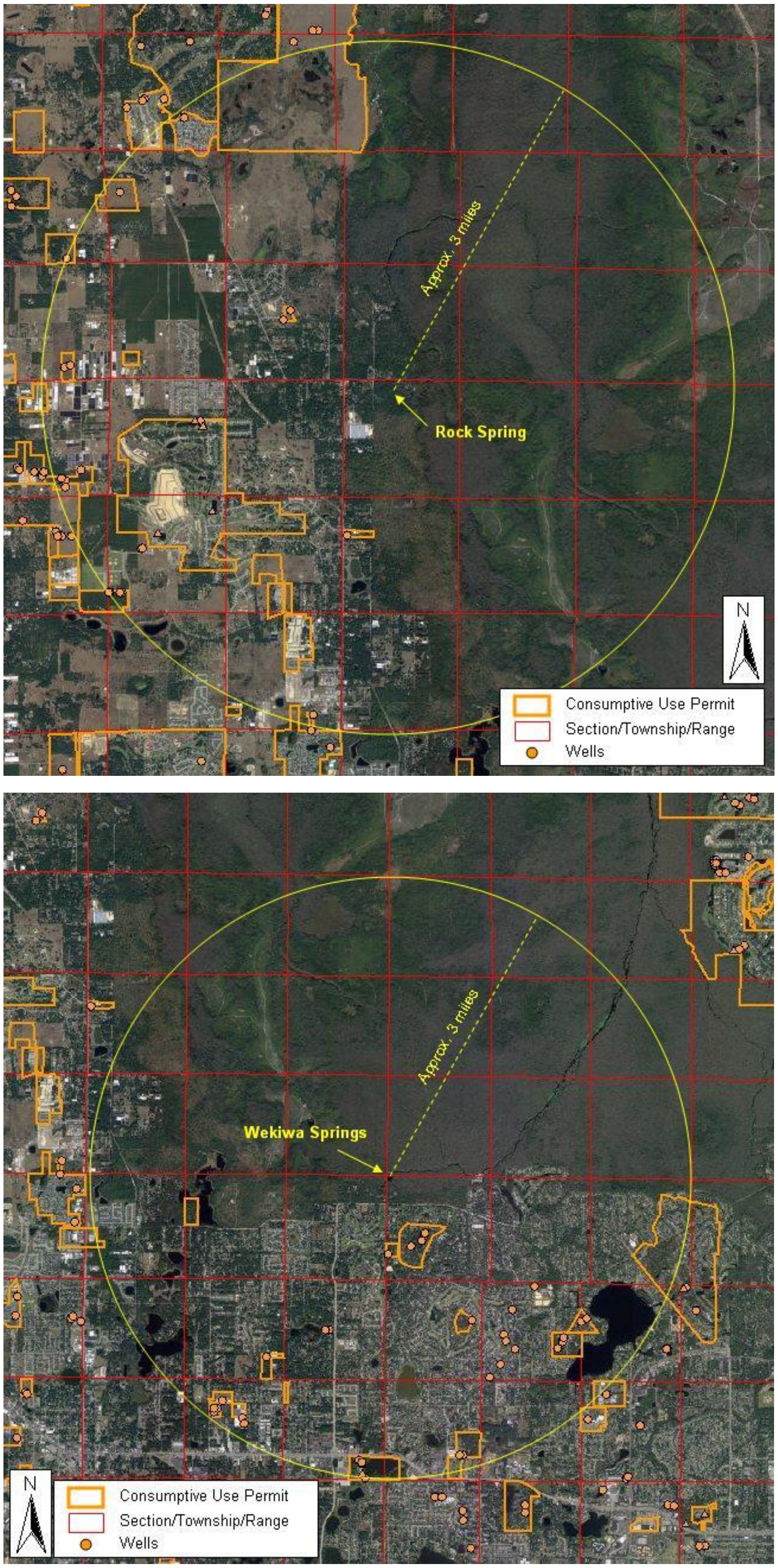


FIGURE 5-8
Existing Consumptive Use Permits within a Three-Mile Radius of Rock and Wekiwa Springs, Orange and Seminole Counties, Florida (source: SJRWMD)

A number of springs in Florida have been targeted for water supply development (i.e., Weeki Wachee, Sulphur, Jenny, Madison Blue, etc.). This water supply development generally involves the placement of wells into the porous aquifer formations near the spring boils and in some cases direct withdrawals from the spring boils. Neither Rock nor Wekiwa springs are directly available for freshwater storage and supply. The management plans for both parks prohibit development of water supplies associated with these springs. There are no permitted withdrawals of surface water from the Wekiva River below Rock and Wekiwa springs. Water withdrawals from the St. Johns River downstream of its confluence with the Wekiva River have been evaluated in a separate report (ECT 2002) and presumably allow protection of freshwater storage and supply at that location.

5.2.5.2 Summary of Findings

The District's groundwater flow model as well as review of historical spring discharge data indicates that the targets for these springs are being approached but have not been exceeded based on current permitted groundwater withdrawals. Evaluation of ***WRV No. 5: Maintenance of Freshwater Storage and Supply*** is based on the presumption that the existing springs MFLs protect permitted users at the time of MFLs determination. On this basis it is concluded that this WRV is protected by the springs MFLs. Additional CUPs in this basin have been issued since the time of MFLs determination and a review of these permits as well as spring discharge data indicates that the capacity allocated based on the MFLs may be nearing exhaustion. Analyses with improved District groundwater models need to be conducted to determine if additional capacity for new consumptive use permits remains in the area of these two springs.

5.2.6 Aesthetic and Scenic Attributes

5.2.6.1 Introduction

Crystal-clear springs and spring runs are among the most important and valued natural wonders in the state of Florida (Bonn and Bell 2003). Economists at Florida State University analyzed the economic value of four state parks that include major springs (Bonn and Bell 2003) and eight priority springs in the St. Johns River Water Management District (Bonn 2004). Annual economic impact of these springs ranged from as little as $12,000 to $82,000 (Green, Apopka, and Bugg springs) to over $61,000,000 (Silver Springs) for local economies. A prime function of the surveyed springs was their aesthetic and scenic attributes as indicated by a 61% response by visitors that their main purpose was to "enjoy the outdoors" (Bonn 2004). Aesthetic and scenic attributes most directly attributable to the springs include the following:

- Spring vista including surrounding vegetation and landscaping
- Spring clarity and visible aquatic plants and animals
- Visible spring boil rise and water movement

Based on observed uses at Kelly Park and Wekiwa Springs State Park, WSI estimates that on an annual average basis over 90% of the human-use days (HUDs) are to some extent based on enjoyment of the springs' aesthetic and scenic attributes. All of the visitors interviewed expressed enjoyment related to the clarity of the spring waters and the natural beauty of the surroundings. Scenic and aesthetic attributes are probably a greater attraction for visitors during the fall, winter, and spring months when air temperatures are lower, than during the summer when wading/bathing in response to higher air temperatures may be the more important attraction.

5.2.6.2 Aesthetic and Scenic Attribute Specific Criteria and Metrics

As described above, an estimated fraction of the total HUDs at Rock and Wekiwa springs can be attributed to participation in aesthetic and scenic related activities. The overriding signal detected in the HUD data is one of seasonality (see **Figures 2-18 and 2-37** above); however, a relatively strong temporal trend was observed for human use at Kelly Park during the historical period-of-record (see **Figure 2-17** above). Human use data from Kelly Park were found to be weakly but negatively correlated with discharge and water depth (**Figure 5-9**), providing some evidence of relationships between these variables. A similar weak correlation was also found for Wekiwa Spring (**Figure 5-10**).

Water clarity may be impaired as water levels decline due to greater suspension of particulate matter at higher velocities and/or increased HRT allowing more plankton production within the water column if HRT is increased. This loss of clarity has been observed by WSI in the Santa Fe River (during dominant spring flow conditions three times in the past seven years) and in Crystal River during annual visits over the past decade. The "trigger" for this observed phenomenon is not precisely known but appears to be related to an increased HRT or increasingly stagnant conditions in deeper water areas and subsequent growth of "pseudo" plankton (Odum 1957). A similar phenomenon was documented in Silver Springs (SJRWMD *et al*. 2006) as measured by declining horizontal secchi depth readings and increasing particulate loads with downstream travel distance (see **Figure 5-11** for a summary). The regression equation from Silver Springs indicates that this effect can be approximated by the equation:

$$HSL = -16.6(nHRT) + 77.4 \qquad R^2 = 0.74 \qquad [5\text{-}1]$$

where:

HSL = horizontal secchi length, m

nHRT = nominal hydraulic residence time, hr

This analysis indicates that an increase in nominal HRT from about 1 hr to 1.1 hr (10% increase) could result in a 3% loss in water clarity (horizontal secchi length).

Using this model, the estimated effects of discharge on water depth, water volume, and nHRTs in these springs are summarized in **Table 5-5.** As an example calculation, the nHRT is estimated as 1.27 hr at a mean flow of 57 cfs and 1.15 hrs at a flow of 36 cfs at Rock Springs. Based on the Silver Springs regression, these estimated changes in hydraulic residence time would possibly result in increased water clarity at Rock Springs under reduced flow conditions. At Wekiwa Springs the model estimates an increase in nHRT from about 0.61 hrs to about 0.73 hrs over a range of flows between 63 to 44 cfs. This range in flows would only reduce the estimated horizontal secchi distance by about 3% (67.2 to 65.3 m). These estimated changes are not considered likely to create aesthetic problems for individuals using these parks.

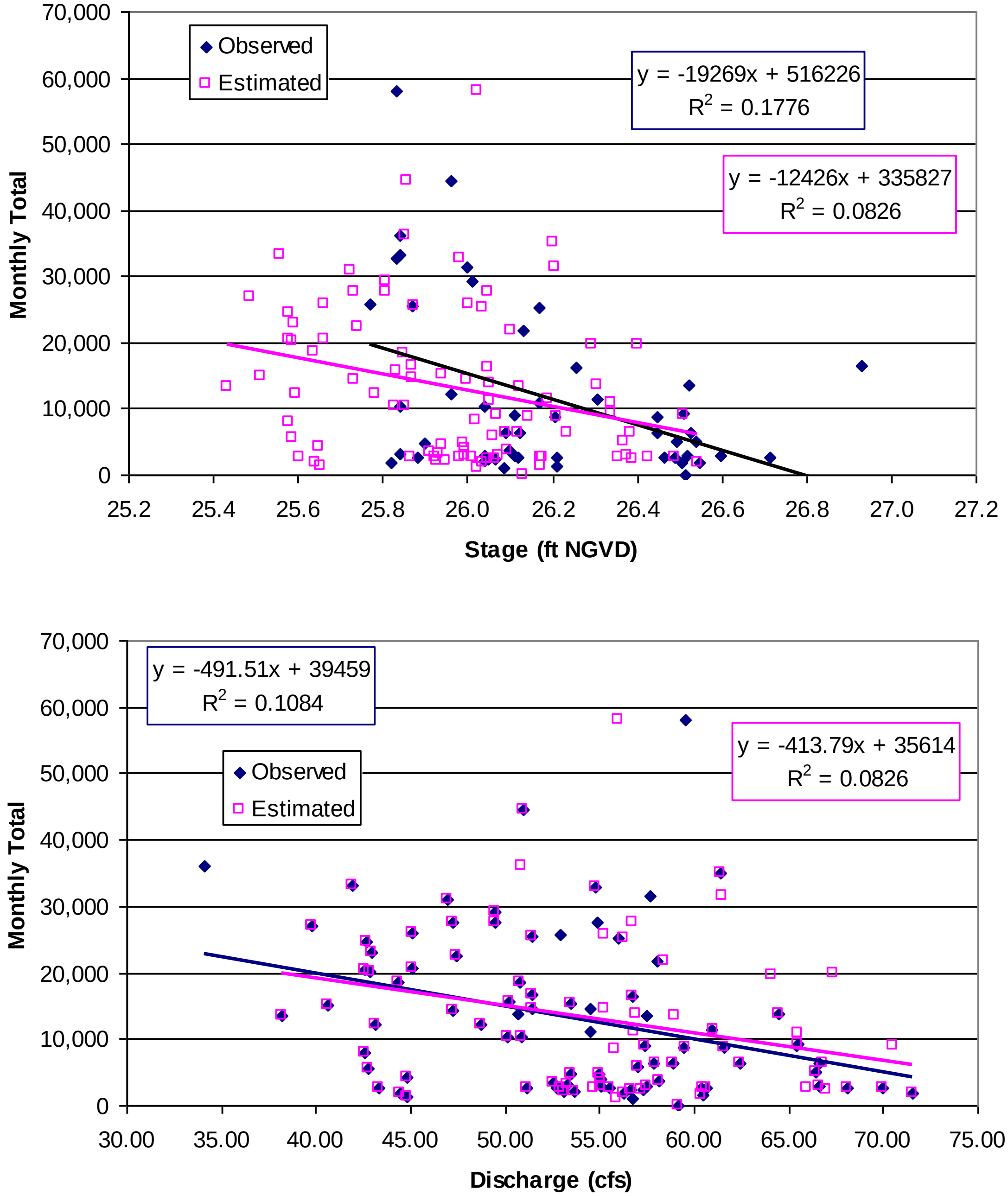


FIGURE 5-9
Observed Relationship between Monthly Attendance and Actual and Estimated Water Stage and Flows at Rock Springs in Kelly Park

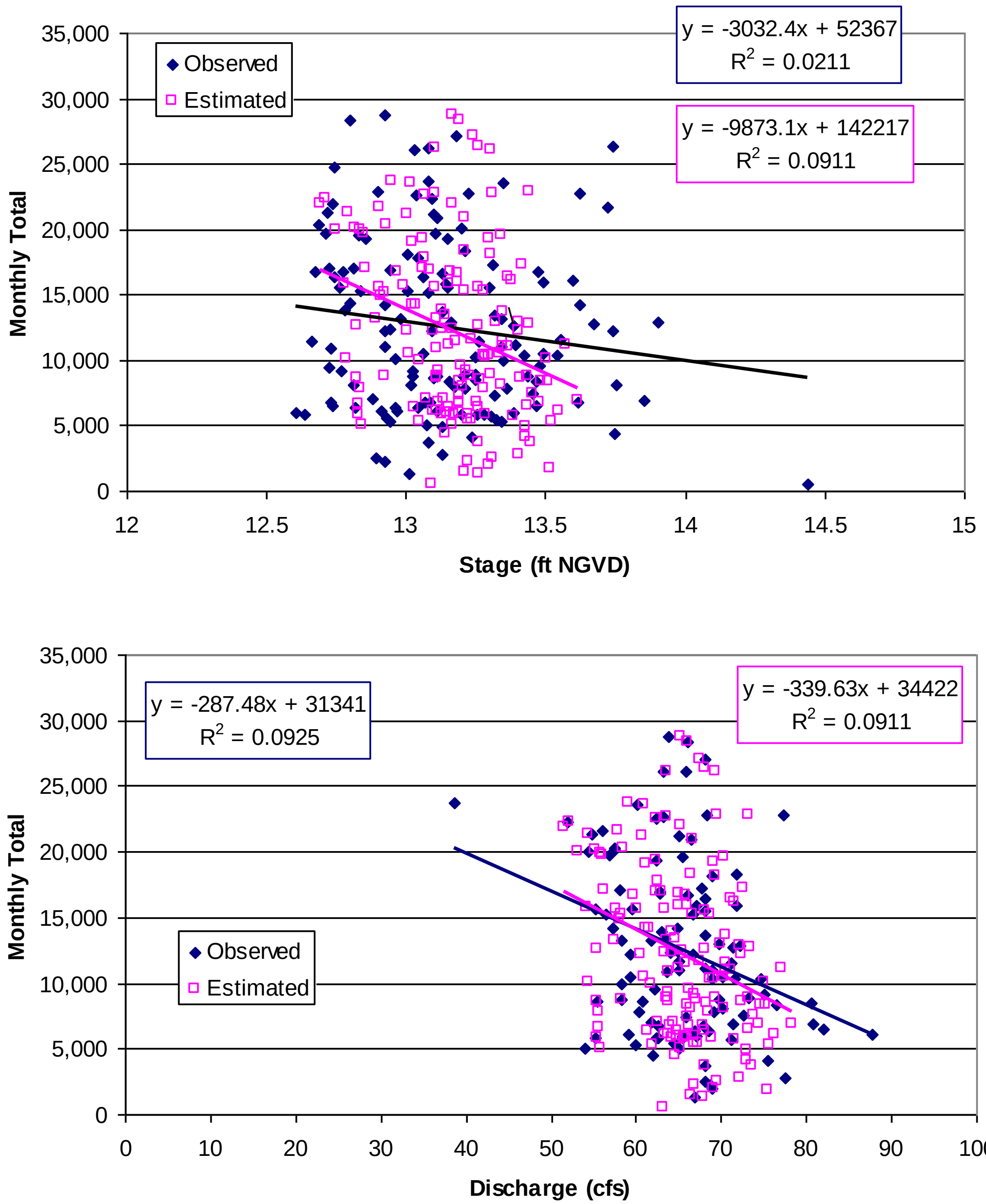


FIGURE 5-10
Observed Relationship between Monthly Attendance and Actual and Estimated Water Stage and Flows at Wekiwa Springs State Park

5.2.6.3 Effect of Springs MFLs on Most Sensitive Specific Criterion/Criteria

The historical data from Rock and Wekiwa springs indicate that within the range of existing data utilized for this analysis, there is no significant correlation between spring discharge and park visitation. Also, the analysis of water clarity indicates that possible reductions in water clarity as a result of declining flows within the range allowable under the springs MFLs is not likely to be noticed by the general public. While reduced flow rates might affect other determinants of human attraction to the springs (e.g., depth for water contact, water temperature, flushing effects on fecal coliform concentrations, etc.) the historical data indicate that ***WRV No. 6: Aesthetic and Scenic Attributes*** as measured by park attendance has been protected in spite of any flow reductions that may have occurred as a result of the Rock and Wekiwa springs MFLs.

5.2.6.4 Summary

Aesthetic and Scenic Attributes are an important WRV in many Florida springs and especially in parks whose primary purpose is spring access. Observations at Rock and Wekiwa springs validate this general conclusion. Existing historic quantitative data for attendance at Kelly Park and Wekiwa Springs State Park show no significant correlation with spring discharge. Also, estimated changes in water clarity that are expected to occur within the range of allowable decline in spring discharges under the springs MFLs are predicted to be difficult for the general public to detect. Based on this analysis it is concluded that this WRV is protected as a result of the Rock and Wekiwa springs MFLs.

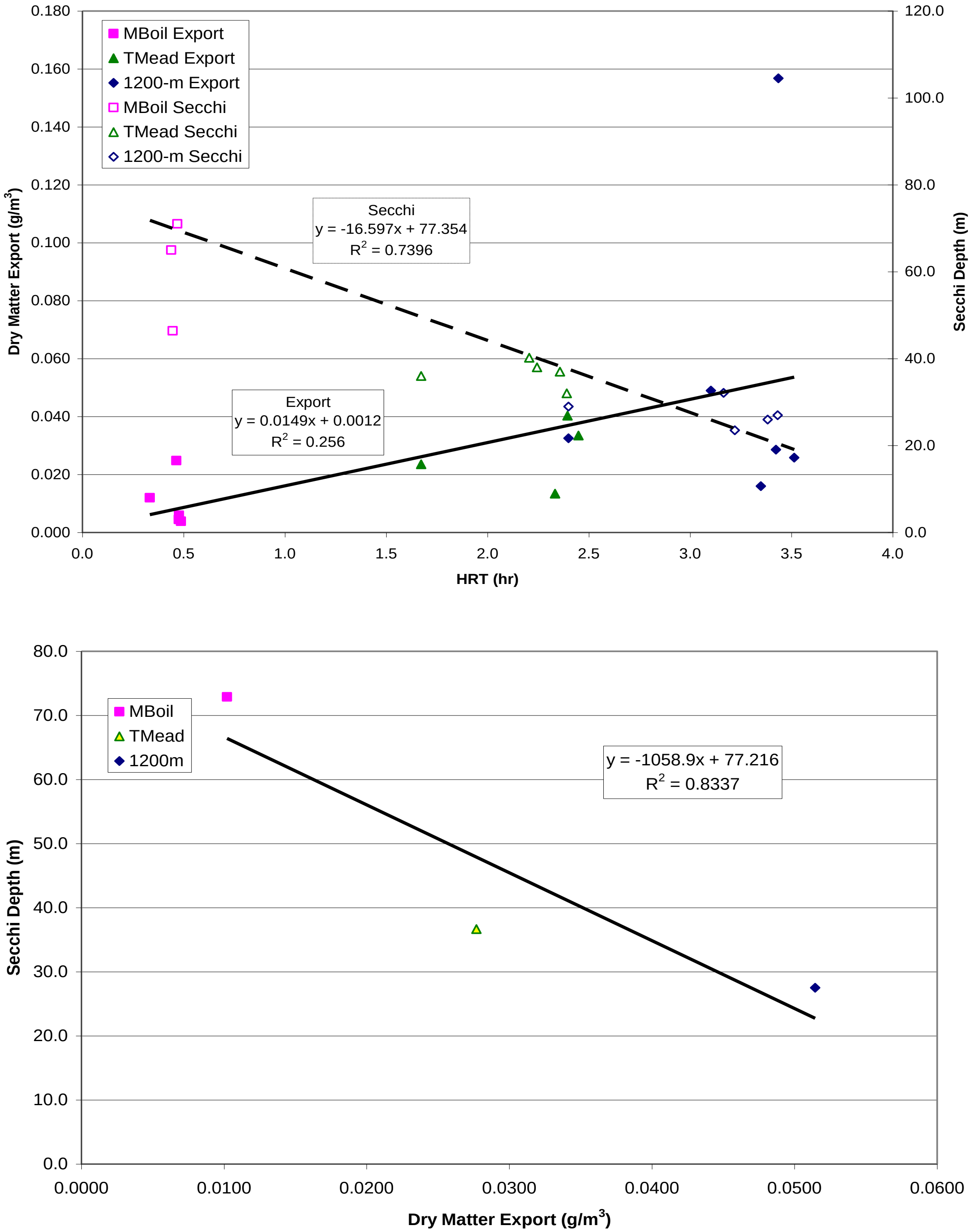


FIGURE 5-11
Relationship between Nominal Hydraulic Residence Time (nHRT), Horizontal Secchi Depth, and Dry Matter Export in Silver Springs (SJRWMD *et al.* 2006)

5.2.7 Filtration and Absorption of Nutrients and Other Pollutants

5.2.7.1 Introduction

Nutrient and pollutant assimilation is an important natural function of aquatic ecosystems (Wetzel 2001, Mitsch and Gosselink 2000). Rock Springs Run and the Wekiva River have previously been shown to assimilate elevated nitrate nitrogen concentrations present in their source waters (WSI 2005, 2006). Nitrate assimilation in these streams is consistently positive in all segments tested and is generally proportional to concentration, indicating a first-order removal process. The relationships between nitrate assimilation and discharge were found to be variable in these two streams (**Figure 5-12**). Nitrate assimilation rate was found to be inversely correlated with discharge in Rock Springs Run, based on estimates for the entire stream (WSI 2005) and on individual segment estimates (for locations of segments see **Figures 2-1** and **2-2** and WSI 2006). Lower flows apparently allow greater assimilation due to a longer effective hydraulic residence time in the system. This pattern was also demonstrated for the downstream Wekiva River segment (the last kilometer of river upstream [south] of the SR 46 bridge) but was not observed for the upper Wekiva River segment or for the analysis of nutrient assimilation for the entire Wekiva River upstream of the SR 46 bridge. Assimilation rates for other forms of nitrogen (total kjeldahl and ammonium) were inconsistent (both positive and negative rates were observed), therefore, these pollutant absorption rates were not evaluated in this WRV assessment.

During a previous study, phosphorus was also found to be elevated in Rock Springs Run and in the Wekiva River (Mattson *et al.* 2006; WSI 2005, 2006). However, there was no consistent assimilation observed (both positive and negative rates were documented) in either Rock Springs Run or in the Wekiva River for both total and ortho-phosphorus. For this reason, the effect of low or high flow changes on assimilation of total phosphorus was not evaluated for this WRV assessment. Assimilation rates for other possible pollutants in these spring runs have not been documented.

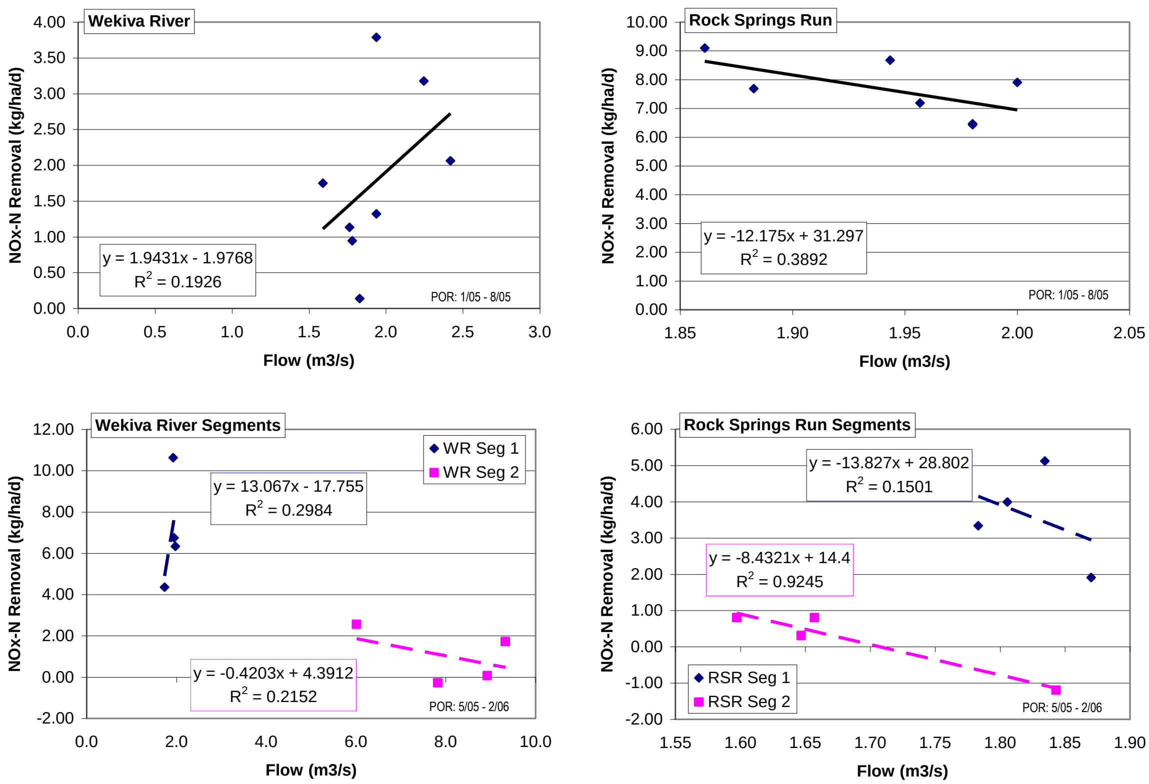


FIGURE 5-12
Nitrate+Nitrite-N Removal Efficiencies for the Wekiva River / Rock Springs Run Reaches and Segments

5.2.7.2 Filtration and Absorption of Nutrients and Other Pollutants Specific Criteria and Metrics

This WRV can be quantitatively assessed based on knowledge of mass removal of nitrate nitrogen loads. The existing observed relationship between flows and nitrate assimilation rate in Rock Springs Run is used to provide an assessment of the effect of the springs MFLs on this WRV. The first-order, area-based, plug-flow pollutant removal model used to describe this phenomenon is described by Kadlec and Knight (1996):

$$\ln (C_1/C_2) = (kA)/Q \qquad [5\text{-}2]$$

where:

C_1 = upstream concentration, mg/L

C_2 = downstream concentration, mg/L

k = first-order, area-based removal rate constant, m/y

A = wetted area, m^2

Q = flow rate, m^3/y

Figure 5-13 illustrates a calibration of the first-order nitrate removal model based on data from Rock Springs Run. Based on these data the estimated first-order removal rate was 228 m/y for nitrate nitrogen disappearance. This model can in-turn be applied to estimating nitrate removal as a function of spring discharge in the Rock Springs Run study area. **Table 5-7** summarizes the results of applying this model to nitrate nitrogen reduction in the Rock Springs study area based on the assumption that wetted area changes with flow and using the regression model presented earlier in **Figure 2-10**. This model estimates that total nitrate nitrogen load removed decreases at lower spring discharge rates and that higher nitrate mass reduction rates occur at higher flow rates. Lower nitrate nitrogen mass removal rates are expected to occur in Wekiwa Springs due to its biologically degraded condition. For that reason this analysis was not conducted for the Wekiwa Springs study area although the results are expected to be similar but of a lower magnitude.

These model estimates are based on site specific data and calibrations; however, they still contain a number of uncertainties. For example, the nitrate nitrogen concentrations are known to vary in direct proportion with discharge in Rock and Wekiwa springs but the correlation coefficients for these relationships are small (see **Figure 5-20** below). Also as described earlier, there is considerable uncertainty concerning spring discharge, water depth, wetted area available for nutrient assimilation, and nHRT. All of these physical factors are expected to affect nitrate assimilation but are not included in the model presented above. For these reasons these model results provide a preliminary direction for WRV analysis but also need additional confirmation through water quality and flow monitoring at Rock Springs.

Rock Springs - Nitrate N (ug/L)

Total length (m) =	14500	k (m/yr) =	228	q (m/yr) =	143
Total area (ha) =	41.9	C* =	0	C1 =	1430

Station	Distance	Fractional Distance	Measured Concentration	Estimated Concentration
	(m)	y	(ug/L)	(ug/L)
Main Boil	0	0.00	1430	1430
Seg1 UP	2300	0.16	1140	1110
Seg1 DN	3300	0.23	1090	994
Seg2 UP	13300	0.92	270	331
Seg2 DN	14500	1.00	260	290

C2 = C* + [(C1-C*)/(e^(ky/q))]

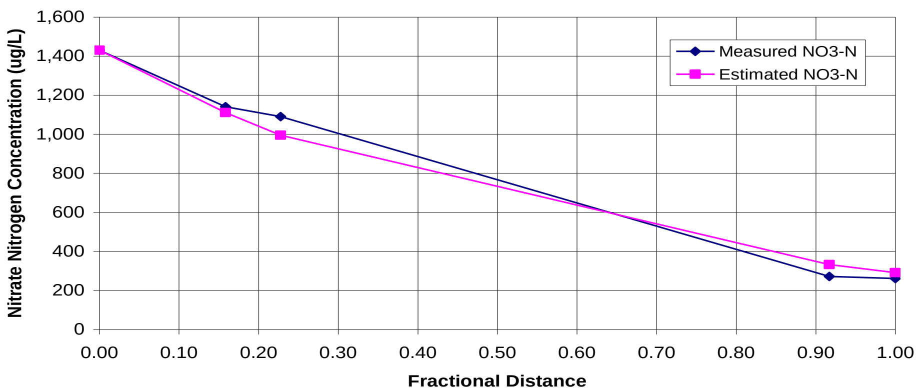


FIGURE 5-13
Calibration of an Area-Based, First-Order, Plug-Flow Contaminant Removal Model to Nitrate Nitrogen Data for Rock Springs Run (data from WSI 2005, 2006)

TABLE 5-7
Estimated Nitrate Nitrogen Load and Concentration Reductions in the Rock Springs Study Area based on the First-Order, Contaminant Removal Model Illustrated in **Figure 5-13**

Area (m2)	Discharge (cfs)	HLR (m/y)	C1 (mg/L)	C2 (mg/L)	Mass In (kg/d)	Mass Out (kg/d)	Mass Rem (kg/d)
10369	34	2899	1.41	1.30	116	107	8.8
10843	39	3223	1.41	1.31	135	126	9.2
11337	45	3561	1.41	1.32	156	146	9.7
11797	51	3882	1.41	1.33	177	167	10.1
12223	57	4191	1.41	1.34	198	187	10.5
12615	63	4491	1.41	1.34	219	208	10.8
12973	70	4786	1.41	1.34	240	229	11.2
13298	76	5077	1.41	1.35	261	249	11.5
13588	82	5368	1.41	1.35	282	270	11.7
13845	88	5661	1.41	1.35	303	291	12.0
k =	228	m/y					

5.2.7.3 Effect of Springs MFLs on Most Sensitive Specific Criterion/Criteria

Nitrate assimilation is an important WRV in Rock Springs and Rock Springs Run and to a lesser magnitude it is also important in Wekiva Springs and in the Wekiva River. Model analyses indicate that flow reductions in the Rock Springs study area may reduce nitrate assimilation on a mass basis. Possible reductions in nitrate assimilation as a result of reduced spring discharge may affect the environmental health of downstream water bodies, both in Rock Springs Run and the Wekiva River, but also in the St. Johns River. There is no known threshold discharge rate or level that triggers impairment of nitrate assimilation in Rock Springs. For that reason any reduction in minimum mean annual flows will result in some reduction of this WRV. No basis for selecting an event of specific concern is apparent.

Observations of the absence of significant plant communities in Wekiwa Springs indicate that this WRV may be impaired, probably due to recreational impacts. For that reason the WRV assessment focuses on Rock Springs and assumes that Wekiwa Springs will respond in a similar fashion but at a reduced magnitude.

5.2.7.4 Summary

Based on this analysis, it is concluded that ***WRV No.7: Filtration and Absorption of Nutrients and Other Pollutants*** will be marginally protected in the Rock Springs study area by the spring MFLs. This conclusion is contingent on the caveat that additional data collection and analysis will be necessary to more precisely assess the possible effects of reduction in spring discharge on filtration and absorption of nutrients in this spring run. This WRV is assumed to already be reduced in Wekiwa springs due to that spring's existing low biological activity. Additional data regarding the effects of spring discharge on water levels, wetted area, water volume, and hydraulic residence time in these two spring head areas need to be collected and analyzed to better evaluate the effect of spring discharge on this WRV.

5.2.8 Sediment Loads

5.2.8.1 Introduction

Sediment transport is an important function in these spring boil areas since it prevents the accumulation of excessive sand and finer sediments and loss of available aquatic area and volume occupied by plants, wildlife, and humans in these springs. Erosion in the watershed surrounding the springs occurs continuously, both in response to rain and runoff and as a result of relatively high levels of human use. Sand from areas with bare or partially denuded soils is being constantly transported by gravity and sporadically by runoff into the spring boils and runs. Spring flows are constantly moving this sand out of the spring boil area and out of the run. Sediment is moved faster in areas of higher water velocities and slower in areas where water velocities are lower. Reductions in flows have the potential to reduce this sediment transport, both into the spring boil from the aquifer, but more importantly, the transport of eroding sediments from the surrounding watershed out of the spring boil and downstream. Reduced flows, in terms of a reduced number of flow events all along the spectrum from high flows to low flows, in turn reduces sediment transport out of the spring boil and run and results in sediment accumulations that smother habitat and reduce WRVs related to water volume (e.g., recreation, fish habitat, pollutant and nutrient assimilation, etc.). Reduction in the frequency of high flow events that are capable of moving larger sediment particles may not protect this WRV.

5.2.8.2 Sediment Load Specific Criteria and Metrics

Sediment load was indirectly measured during three diurnal plankton tow sampling events during 2007. Ash weight in those samples consists of a combination of mineral ash from the detrital materials themselves and also sand and other suspended non-organic sediments moving downstream with the spring flow. This sediment load was observed to be diurnal and roughly proportional to human use in the upper spring boil/run areas. **Table 5-8** summarizes those particulate export results, assuming that the majority of the ash in these samples is mineral sediments (sand). This sampling effort demonstrated that export of mineral sediments (approximately equal to the ash weight) is an important process in both spring boil areas. Sand export was highest at the middle Rock Springs sampling station and was observed to be directly related to human use activities in that area.

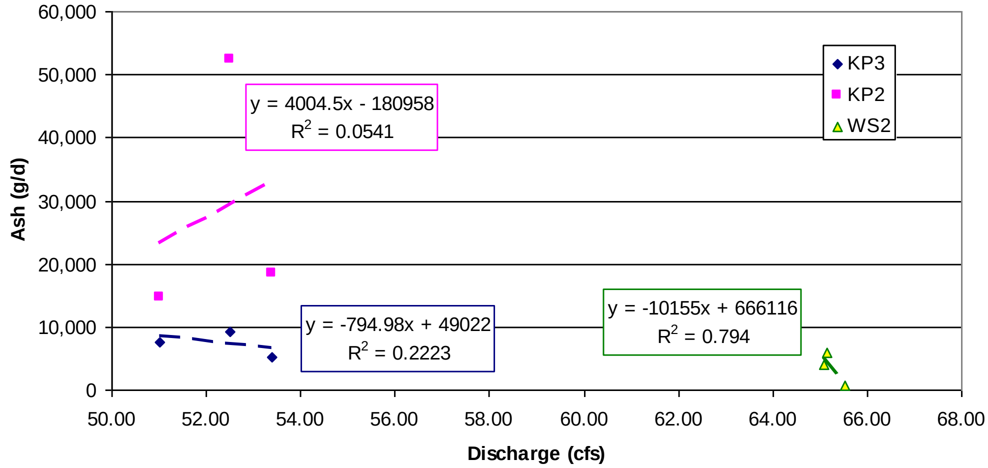
Figure 5-14 illustrates the observed relationship between flow and sediment load transport. These data were collected over relatively narrow range of spring flows and are inconclusive concerning a relationship between flow and sediment transport in these two springs. Nevertheless, it is intuitive that higher flows are more likely to result in higher sediment transport rates and that lower flow rates would decrease the magnitude of this WRV.

TABLE 5-8
Rock Spring Run and Wekiwa Spring Particulate Export Summary

Station	Date	Dry Matter ($g/m^2/d$)	Organic Matter ($g/m^2/d$)	Ash ($g/m^2/d$)	Dry Matter (g/d)	Organic Matter (g/d)	Ash (g/d)
KP1	3/29/2007	---	---	---	1,050	116	934
	4/25/2007	---	---	---	430	54	376
	5/23/2007	---	---	---	239	30	209
KP2	3/29/2007	2.45	0.38	2.07	21,737	3,344	18,393
	4/25/2007	6.43	0.52	5.91	57,145	4,641	52,504
	5/23/2007	2.22	0.58	1.64	19,709	5,123	14,586
KP3	3/29/2007	0.72	0.30	0.43	8,955	3,675	5,280
	4/25/2007	1.03	0.27	0.75	12,744	3,401	9,342
	5/23/2007	0.98	0.36	0.62	12,137	4,434	7,702
WS1	3/30/2007	---	---	---	673	170	503
	4/24/2007	---	---	---	417	106	312
	5/22/2007	---	---	---	1,171	253	918
WS2	3/30/2007	0.30	0.10	0.20	995	335	661
	4/24/2007	2.11	0.33	1.78	6,902	1,080	5,822
	5/22/2007	1.49	0.28	1.20	4,867	931	3,936

Hjulstrom (1935) developed a diagram (**Figure 5-15**) which relates particle grain size to flow velocity required to achieve erosion, transport, or deposition. Richards (1982) modified the Hjulstrom diagram to distinguish between bed and suspended load. Medium sand typical of Rock and Wekiwa Springs has an average grain size diameter between 0.25 and 0.5 mm (SCS 1981). According to **Figure 5-14**, an entrainment velocity of at least 10 cm/s or more is required to achieve transport of median sand in unconsolidated sediments. This estimated threshold velocity is exceeded throughout much of the area of Rock Springs at all discharge rates within observed minimum and maximum extremes (see estimated average current velocities in **Table 5-5)**.

Based on available information this velocity is rarely achieved in the Wekiwa Springs swimming area except at lower spring discharge rates (see **Table 5-5**). However there is considerable uncertainty about the linear water velocities estimated for Wekiwa Springs in **Table 5-5**. It was observed that during periods of high public use, considerable sediment resuspension and downstream export does occur in Wekiwa Springs due to the lower required velocity for transport of finer suspended matter. Based on WSI's field observations additional sand suspension and resulting transport occurs as a result of recreational activities (bathing and wading in the spring systems).



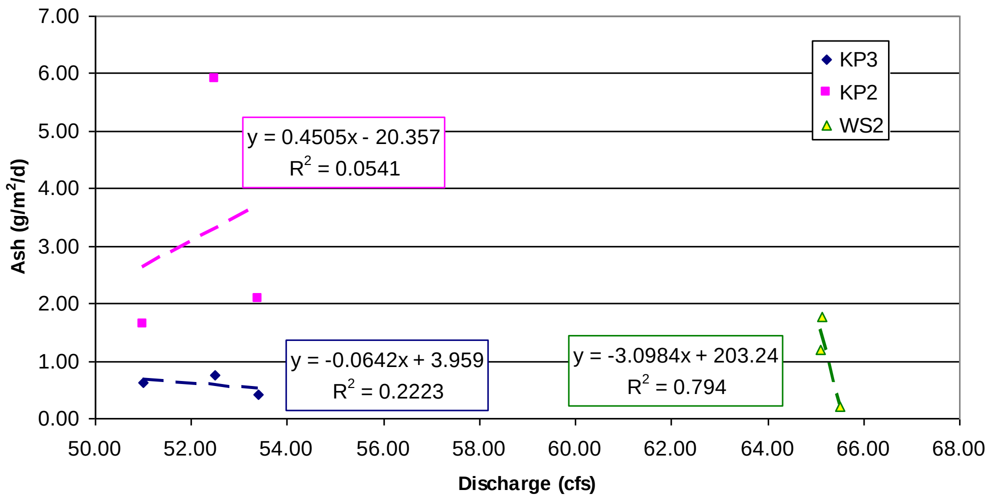


FIGURE 5-14
Relationship between Flow and Particulate Export

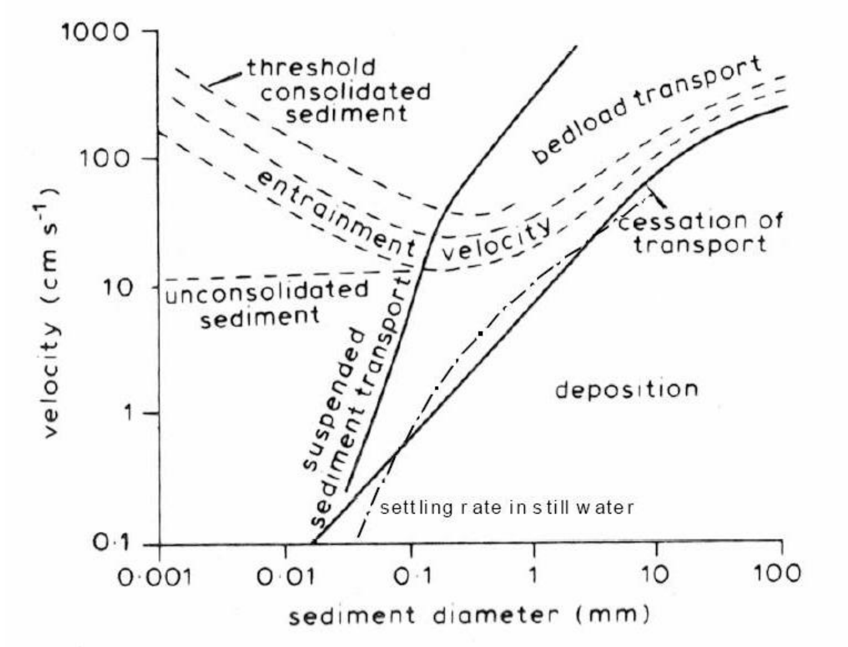


FIGURE 5-15
Hjulstrom diagram as modified by Richards (1982) showing sediment transport as a function of particle grain size and flow velocity

5.2.8.3 Effect of Springs MFLs on Most Sensitive Specific Criterion/Criteria

As described in Section 2 of this report, the effect of reductions in spring discharge rates on flow velocities is not clear. The historical stage vs. discharge regression for Rock Springs indicates that higher velocities may occur at lower spring discharge rates (see **Table 5-5**). A reduction in current velocity with lower discharge is predicted at Wekiwa Springs. Available particulate transport data from these springs are inadequate to validate these estimates (**Figure 5-14**). If flow velocities are indeed increased as a result of decreased spring discharge at Rock Springs, then the existing MFL for that spring is not expected to cause any harm to this WRV. For Wekiwa Springs, permitted reductions in discharge allowed by the MFL may result in lower current velocities and even less transport of sediment loads, possibly resulting in a more rapid accumulation of mineral solids in the spring area. Additional collection of hydraulic and sediment transport data from these springs would be helpful to better assess the effects of the springs MFLs on **WRV No.8: Sediment Loads**.

5.2.8.4 Summary

Based on limited data it is concluded that the existing spring MFL for Rock Springs will not result in impairment of ***WRV No.8: Sediment Loads***. It is also concluded that flow reductions allowed by the spring MFL for Wekiwa Springs may result in reduced sediment transport, possibly increasing rates of sediment accretion in the study area and the time required for re-establishment of water clarity during and following periods of high public use. While it is concluded that this WRV will be marginally protected at Wekiwa Springs by the existing spring MFL, this conclusion is contingent on the caveat that additional data collection and analysis will be necessary to more precisely assess the possible effects of reductions in spring discharge on sediment transport in Wekiwa Springs.

5.2.9 Water Quality

5.2.9.1 Introduction

This WRV is based on water quality that is in the normal range for unaffected springs and that meets or exceeds applicable surface water criteria as defined by the Florida Department of Environmental Protection (FDEP) in Chapter 62-302.530, F.A.C. Rock and Wekiwa springs are both listed as Outstanding Florida Waters (OFWs) which are water bodies worthy of special protection because of their natural attributes (Chapter 62-302.700, F.A.C.). As OFWs, Rock and Wekiwa springs' good water quality at the time of designation as an OFW (March 1979 for Wekiwa Spring and December 1988 for Rock Springs) must be protected during consideration of discharge permits, even if that quality is above normal Class III water quality standards. While FDEP does not typically regulate spring discharge rates, the OFW designation does come into play when considering ***WRV No. 9: Water Quality*** since the definition of harm is raised for OFWs to any measurable decrease in their water quality, even if that quality is better than required by Florida surface water criteria.

Water quality criteria of particular interest in Rock and Wekiwa springs are:

- Temperature
- Dissolved oxygen
- pH
- specific conductance
- turbidity

- nutrients

Each of these important water quality indicators is discussed below.

5.2.9.2 Water Quality Specific Criteria and Metrics

5.2.9.2.1 Water Temperature

The water quality criterion for temperature prohibits any increase in ambient temperature in an area of 2/3 of the stream width and in 1/4 of the stream cross section in freshwater systems as a result of a thermal discharge (effluents from commercial or industrial activities or other regulated heat sources). The maximum allowable thermal discharge at any point must be no greater than 5 ^oF (about 2.7 ^oC). While this rule does not specifically relate to temperature fluctuations in springs it is important to consider what affect a change of water temperature may have on biological and recreational values. As stated previously the OFW rule protects designated waters from most detrimental water quality changes compared to conditions in existence at the time of OFW designation. For the purpose of the Rock and Wekiwa Springs MFL WRVs evaluation these rules are interpreted to mean that this WRV might be considered to be harmed if the ambient temperature change due to a change in average flows or levels is greater than 1.8^oF (1.0 ^oC) above or below the average temperature change without the springs MFLs.

Effects of spring flows on ambient water temperatures can be estimated with an energy balance approach. An empirical exponential energy budget model may be calibrated and used to describe the approach of the spring run water temperature to the balance temperature:

$$T_w = T_b + (T_{wi} - T_b)\exp\left(-\frac{\eta t}{\rho c_p h}\right) + R_n H_s/h \qquad [5\text{-}3]$$

where;

c_p = heat capacity of water, 4.182 × 10^6 J/kg·°C
h = water depth, m
T_w = wetland water temperature, °C
T_b = wetland balance temperature, °C
T_{wi} = inlet water temperature, °C
η = accommodation coefficient, MJ/m^2·d·°C
ρ = heat capacity of water, MJ/kg·°C
t = nominal detention time to an internal point, d
R_n = net solar radiation heat input, MJ/m^2/d

H_s = specific heat of water, 4.186 $MJ/m^3/^oC$

For this analysis the accommodation coefficient was assumed to be about 2.5 $MJ/m^2/d/^oC$ and the air temperature was assumed to be approximately equal to the balance temperature.

The spring residence time reduction and resulting water temperature fluctuation that could result in observable (significant) changes in recreational uses has not been quantified and must be estimated based on best professional judgment. Median water temperatures at the two spring boils during the period-of-record were:

- Rock Springs – 23.8 ^oC
- Wekiwa Spring – 23.7 ^oC

WSI's detailed monitoring of field parameters at the downstream ends of each spring study area indicated an average measured fluctuation of about 0.87 ^oC around the daily median value at the downstream Rock Spring site (Second Landing) and 0.20 ^oC at the Wekiwa Spring downstream (bridge) station during the 2005-2007 period-of-record under the historical flow regimes. Maximum observed daily temperature fluctuations at these stations were about 1.24 ^oC for the downstream Rock Springs station (KP3) and 0.48 ^oC for the Wekiwa Springs bridge station (WS2) for this study period. Measured water temperatures at the downstream end of the Rock Springs study area had an observed range from 22.5 to 24.7 ^oC (annual maximum fluctuation of 2.2 ^oC), and the Wekiwa Springs study area had an observed annual temperature range between 23.4 and 24.1 ^oC (annual maximum fluctuation 0.7 ^oC).

For this analysis it is assumed that a temperature change of 1.0 ^oC in addition to (above or below) the normal daily variation (combined maximum daily variation of 2.87 ^oC at Rock Springs and 2.20 ^oC at Wekiwa Springs) would be detectable by recreational users during all seasons. At Rock Springs the stage vs. discharge relationship indicates that water depth decreases in proportion to discharge, resulting in an estimated increase in velocity and a decrease in hydraulic residence time at lower flows. For these reasons water temperature fluctuations are expected to be less under a reduced flow regime allowed by the MFL for Rock Springs.

At Wekiwa Springs there is much less certainty about the relationship between discharge and hydraulic residence time, apparently due to periodic backwater effects that may artificially increase water depths, even under lower spring discharge rates. Based on the heat balance model described above as well as the estimated velocity and nHRT estimates summarized in **Table 5-5** above, the heat balance model indicates that ambient water temperature in the study area could be reduced by 1.1 ^{o}C at a spring flow of 48.3 cfs (1.37 m^3/s).

An extended period of excessive temperature variation that would be noticeable to the public might be about 30 days. Under current conditions these flow events are infrequent (1.2% probability or about 1.2 events in 100 years for Wekiwa Springs, see **Figure 5-16**). The increased frequency of these events under the MFL for Wekiwa Springs would be 6% (i.e., 6 events in 100 years). This estimated temperature shift is not considered to be significant.

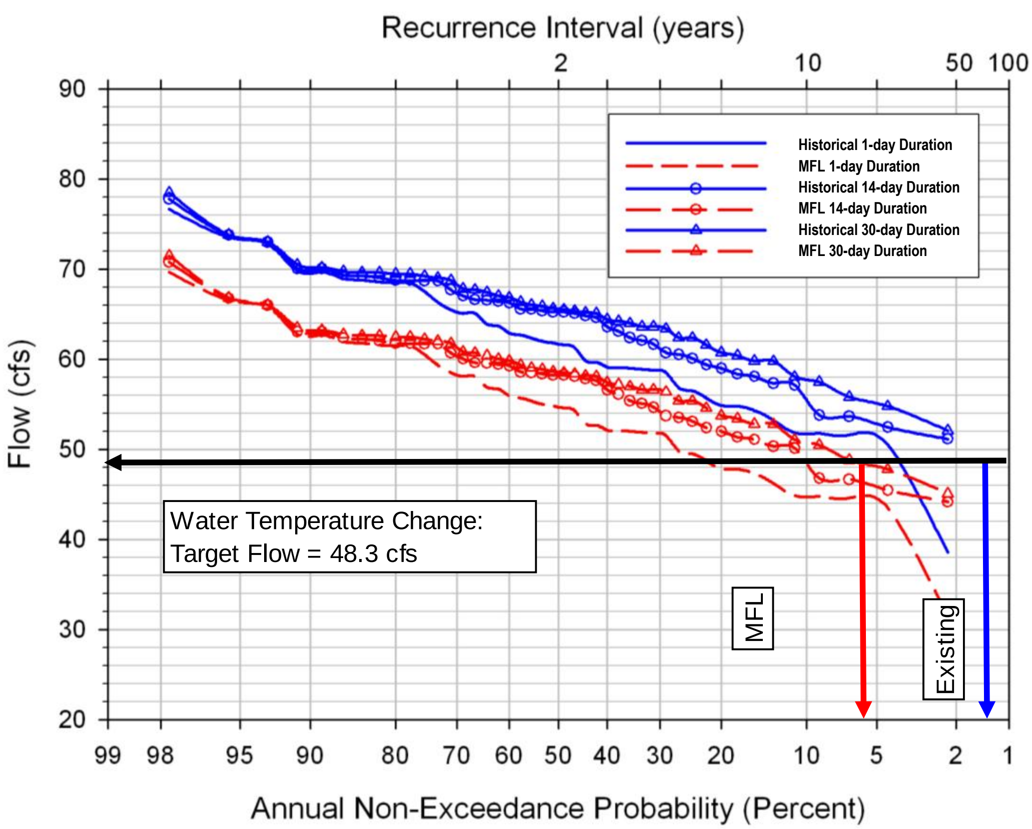


FIGURE 5-16
Historical and Estimated MFL Low Flow (30-day Duration Continuously Not Exceeded) Frequency Analysis for Wekiwa Springs Needed to Protect Water Temperature (data from Intera 2006)

5.2.9.2.2 Dissolved Oxygen

Dissolved oxygen is naturally low in many spring boils and frequently does not meet the Class III freshwater criterion (5 mg/L) due to natural non-abatable conditions. Dissolved oxygen concentrations do typically rise rapidly below spring boils due to atmospheric diffusion (reaeration) and by primary production of submerged algae and aquatic macrophytes, and may meet the Florida water quality criterion downstream of the spring boil. The diffusion of dissolved oxygen is dependent upon current velocity, surface area of the water body, and to a lesser extent, water depth (O'Conner and Dobbins 1958). WSI (2006) showed that oxygen diffusion rates increased linearly with current velocity in the Silver River and found a similar relationship for the four spring runs studied for the Wekiva River Pollutant Load Reduction Goal (PLRG) project (WSI 2005), including the Wekiva River and Rock Springs Run (**Figure 5-17**). However, while a decrease in current velocity is likely to lower the rate of diffusion, it may also increase the hydraulic residence time and allow more time for diffusion to occur in a given spring run segment. The balance between these two processes must be analyzed by use of a mass balance model. No consistent relationship was found between oxygen diffusion rates and water depth in previous springs studies (WSI 2005, 2006).

Estimates of spring cross sections and resulting nominal HRTs and current velocities were provided in Section 2 of this report. There is considerable uncertainty at this time whether or not a flow reduction in these springs will consistently result in an increase or a decrease in flow velocity and nHRTs. Based on the assumptions described earlier in **Table 5-5** that velocity increases as spring discharge decreases at Rock Springs and that velocity decreases with declining spring flows at Wekiwa Springs, a simple spreadsheet simulation model was prepared to estimate the increase in dissolved oxygen concentration within the study areas based only on reaeration (primary productivity is assumed to be the same under all scenarios).

Table 5-9 provides this estimated mass balances for dissolved oxygen in Rock and Wekiwa springs as a function of spring discharge. Based on these estimates it is concluded that the net effect of lower flows on both spring run's water quality is an overall net increase in the downstream dissolved oxygen concentration.

While this simplified oxygen mass balance model provides insight into the competing processes at work on oxygen reaeration in this spring run, additional work is recommended to develop a more robust empirical stage vs. discharge relationship for both of these spring boil areas, empirical velocity and oxygen diffusion rate measurements, and to include primary productivity effects in the model to confirm that lowered flows will indeed protect dissolved oxygen reaeration rates in these springs.

5.2.9.2.3 pH and Specific Conductance

Florida Class III criteria state that pH shall not be raised or lowered by more than one standard unit above or below natural background. The natural background pH in these two springs is about 7.5 s.u. Class III criteria also state that specific conductance shall not be raised by more than 50% compared to back ground and no more than 1,275 umhos/cm. Once again the OFW classification for both of these springs requires a more stringent effort to maintain good water quality in existence at the time of OFW designation.

Average specific conductance in Rock Springs is about 250 umhos/cm and 310 umhos/cm in Wekiwa Springs. Based on historical water quality data there are no apparent relationships between discharge and pH or specific conductance at either Rock Springs (**Figure 5-18**) or Wekiwa Spring (**Figure 5-19**). Based on these data, flow reductions possibly allowed by the springs MFLs for Rock and Wekiwa springs are not expected to result in impairment of these water quality criteria.

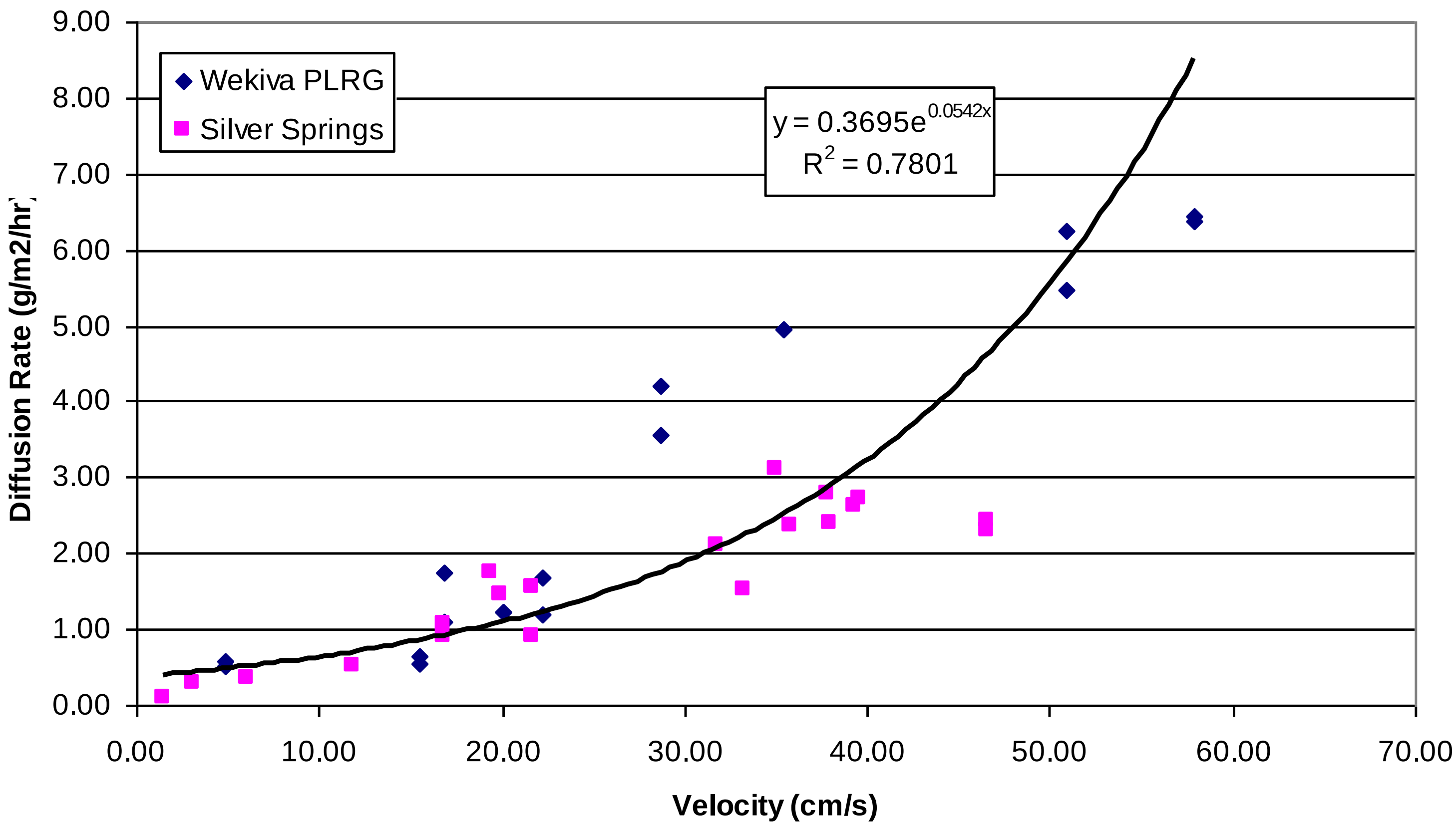


FIGURE 5-17
Measured oxygen diffusion rate as a function of current velocity in the Silver River, Wekiva River, Rock Springs Run, Alexander Springs, and Juniper Creek (WSI 2005)

TABLE 5-9
Estimated Dissolved Oxygen Reaeration Rates in Rock and Wekiwa Springs Study Areas Based on the Stage vs. Depth Relationships Summarized in **Table 5-5**

Flow (cfs)	Depth (m)	Volume (m3)	Velocity (m/s)	Area (m2)	HRT (hrs)	K Rate (g O2/m2/hr)	DO (%)	Diffusion DO (g O2/m2/hr)	Diffusion DO (kg O2/hr)	Est. DO Increase (mg/L)
Rock Springs										
33.7	0.38	3,901	0.158	10,369	1.14	0.87	15.00	0.74	7.68	2.24
39.1	0.43	4,674	0.154	10,843	1.17	0.85	15.00	0.72	7.83	1.96
45.2	0.49	5,578	0.149	11,337	1.21	0.83	15.00	0.70	7.97	1.73
51.3	0.55	6,524	0.144	11,797	1.25	0.81	15.00	0.69	8.10	1.55
57.4	0.61	7,504	0.140	12,223	1.28	0.79	15.00	0.67	8.21	1.40
63.4	0.67	8,514	0.137	12,615	1.32	0.78	15.00	0.66	8.32	1.29
69.5	0.74	9,547	0.134	12,973	1.35	0.76	15.00	0.65	8.41	1.19
75.6	0.80	10,596	0.131	13,298	1.37	0.75	15.00	0.64	8.49	1.10
81.7	0.86	11,656	0.129	13,588	1.40	0.74	15.00	0.63	8.57	1.03
87.8	0.92	12,720	0.127	13,845	1.42	0.73	15.00	0.62	8.64	0.97
Wekiwa Springs										
30.9	0.87	2,843	0.040	3,225	0.90	0.46	15.00	0.39	1.26	0.40
35.2	0.92	2,990	0.044	3,225	0.83	0.47	15.00	0.40	1.28	0.36
39.6	0.96	3,137	0.047	3,225	0.78	0.48	15.00	0.40	1.31	0.32
44.0	1.01	3,285	0.050	3,225	0.73	0.48	15.00	0.41	1.33	0.30
48.3	1.05	3,432	0.052	3,225	0.70	0.49	15.00	0.42	1.34	0.27
52.7	1.10	3,580	0.055	3,225	0.67	0.50	15.00	0.42	1.36	0.25
57.0	1.15	3,728	0.057	3,277	0.64	0.50	15.00	0.43	1.40	0.24
61.4	1.19	3,878	0.059	3,277	0.62	0.51	15.00	0.43	1.42	0.23
65.8	1.24	4,028	0.061	3,277	0.60	0.51	15.00	0.44	1.43	0.21
70.1	1.28	4,177	0.062	3,277	0.58	0.52	15.00	0.44	1.44	0.20
74.5	1.33	4,327	0.064	3,277	0.57	0.52	15.00	0.44	1.45	0.19
78.8	1.37	4,477	0.065	3,277	0.56	0.53	15.00	0.45	1.47	0.18
83.2	1.42	4627	0.067	3,277	0.55	0.53	15.00	0.45	1.48	0.17
87.6	1.47	4777	0.068	3,277	0.54	0.53	15.00	0.45	1.49	0.17
91.9	1.51	4926	0.069	3,277	0.53	0.54	15.00	0.46	1.50	0.16
96.3	1.56	5076	0.070	3,277	0.52	0.54	15.00	0.46	1.51	0.15
100.6	1.60	5226	0.071	3,277	0.51	0.54	15.00	0.46	1.52	0.15
105.0	1.65	5376	0.072	3,277	0.50	0.55	15.00	0.47	1.52	0.14
109.4	1.69	5526	0.073	3,277	0.50	0.55	15.00	0.47	1.53	0.14
113.7	1.74	5676	0.074	3,277	0.49	0.55	15.00	0.47	1.54	0.13
118.1	1.79	5825	0.075	3,277	0.48	0.56	15.00	0.47	1.55	0.13

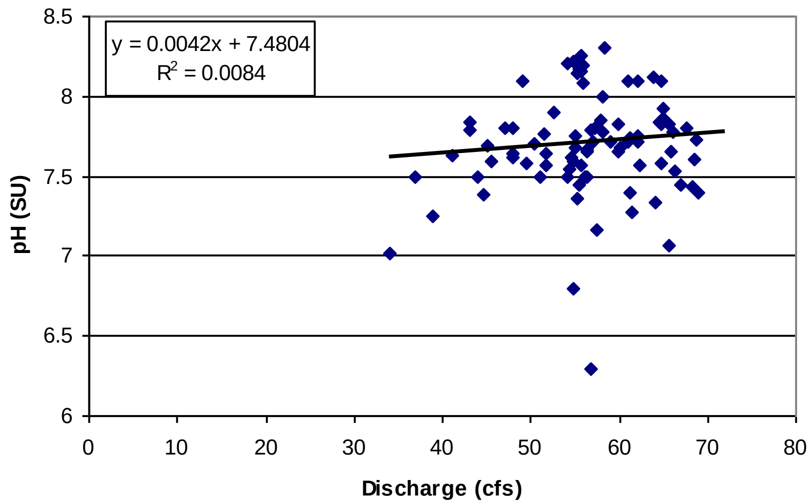
5.2.9.2.4 Turbidity and Transparency

Turbidity is regulated in Class III waters to avoid changes greater than 29 nephelometric turbidity units (NTUs) above back ground conditions (Chapter 63-302.530 [70], F.A.C.). Transparency is also regulated so that the depth of the compensation point for photosynthetic activity is not reduced by more than 10% compared to the natural background level (Chapter 62-302.530 [68], F.A.C.). In Rock Springs general observations as well as the Silver Springs regression for horizontal secchi length indicate that neither of these criteria are likely to be impacted by an allowable decline in discharge of 6 cfs. Turbidity increases due to "pseudoplankton" are assumed to be much lower than 29 NTUs and the photosynthetic compensation depth is always much greater than the actual water depth (adequate light reaches the bottom). Based on general observations these water quality criteria are also generally protected in Wekiwa Springs in the range of observed and allowed flows. However, this was not the case as observed at Wekiwa Springs on August 12, 2007 during the public use evaluation. Turbidity and compensation depth were both visibly impacted in Wekiwa Springs as a result of the high level of recreation that was occurring (over 300 people in the swim area during the maximum time of the day). Reduced spring discharge will not be able to flush out this turbidity as rapidly as higher flows so the combination of flow reductions coupled with excessive public use is considered likely to result in water quality violations. The magnitude and frequency of these violations is likely to increase under the MFL regime.

5.2.9.2.5 Nutrients

Florida Class III standards state that: "In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna" (Chapter 62-302-530 [48b]). The OFW classification requires that no change occur in nutrient concentrations in Rock and Wekiwa springs compared to conditions since their designation in 1988 and 1979, respectively. Available studies have determined that there is an existing nutrient problem in both Rock and Wekiwa springs (Mattson *et al.* 2006). The nutrient component of interest in both springs is the nitrate form of nitrogen. Nitrates are significantly elevated in both springs due to a variety of anthropogenic causes. However, unlike most springs in Florida with evident nitrate contamination, Rock and Wekiwa springs apparently hit a maximum nitrate concentration of about 2 mg/L in the mid 1980s and concentrations have declined slightly since that time to about 1.4 mg/L during the past two years.

No other elevated nutrient concentrations for other nitrogen forms or for any form of phosphorus is evident in historical data (WSI 2006). Based on historical data, nitrate nitrogen concentrations are positively correlated with spring discharge, weakly for Rock Springs (R^2 = 0.034) and more strongly for Wekiwa Spring (R^2 = 0.39) (**Figure 5-20**). These data appear to indicate that nitrate nitrogen impairment may be reduced during lower discharge periods and as a result of the District's springs MFLs.



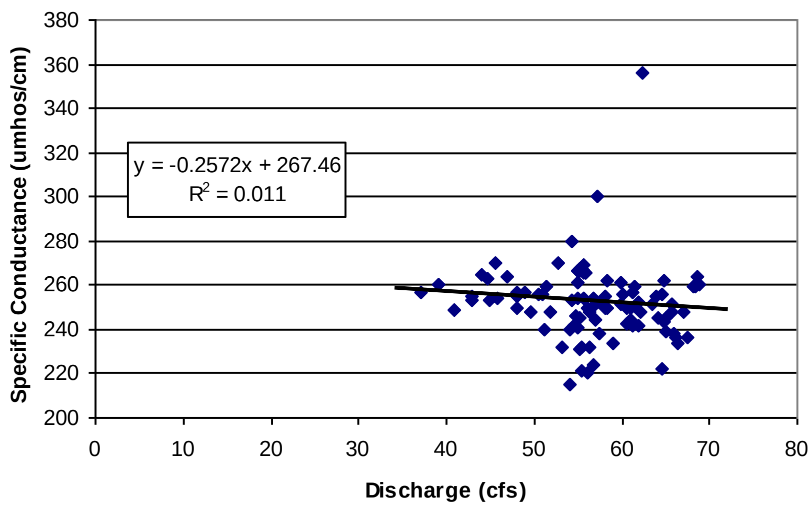
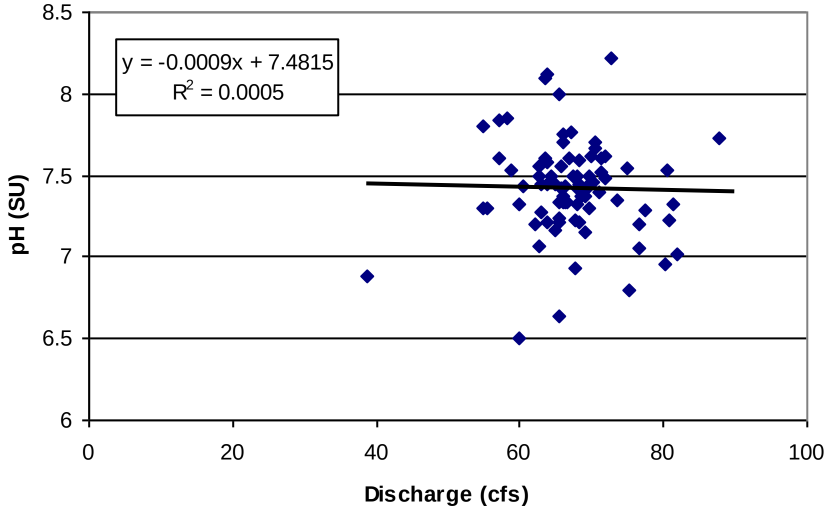


FIGURE 5-18
Observed Relationships between Stream Discharge and pH and Specific Conductance in the Rock Springs Study Reach



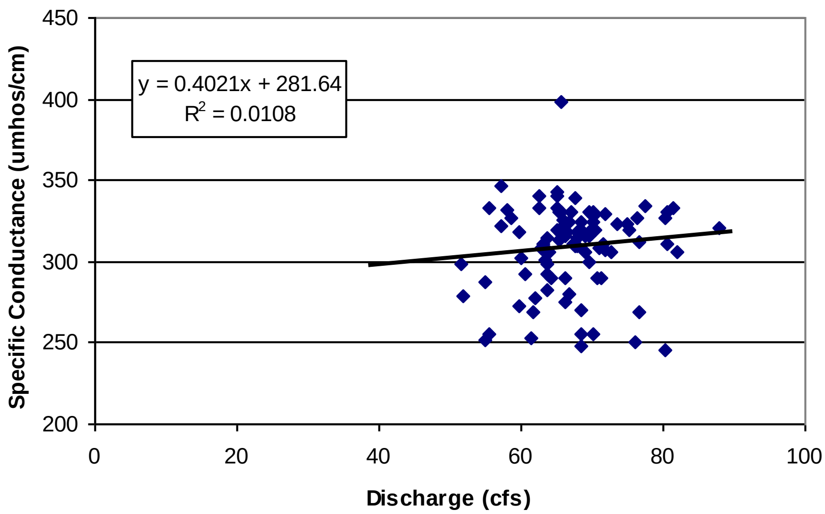


FIGURE 5-19
Observed Relationships Between Stream Discharge and pH and Specific Conductance in the Wekiwa Springs Study Reach

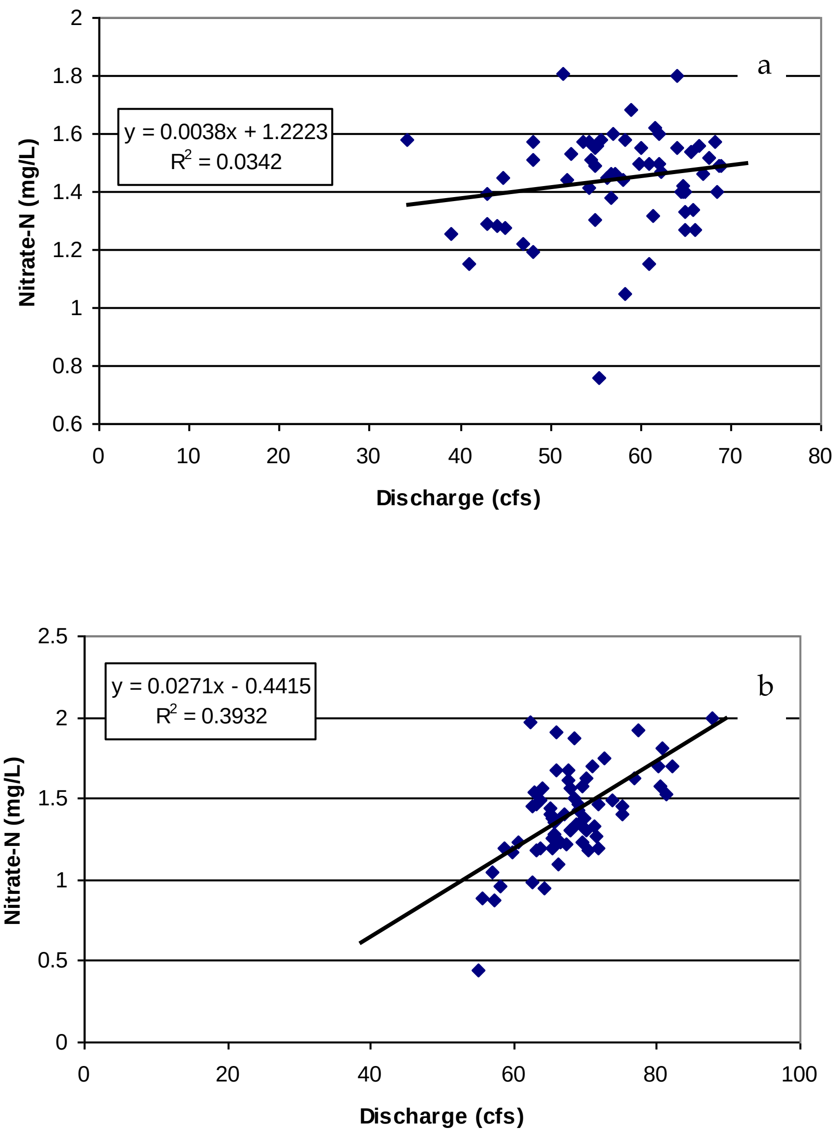


FIGURE 5-20
Observed Correlations Between Spring Discharge and Nitrate Nitrogen Concentrations at (a) Rock Springs and (b) Wekiwa Springs

5.2.9.3 Effect of Springs MFLs on Most Sensitive Specific Criterion/Criteria

Based on the data presented above, water quality conditions in Rock Springs for temperature, dissolved oxygen, pH, specific conductance, transparency, turbidity, and nutrients do not appear to be impacted due to the flow reductions allowed by the spring MFL. For Wekiwa Springs this analysis based on historical data indicates that the spring MFL may create a problem for water temperature but are unlikely to create problems with dissolved oxygen, pH, specific conductance, and nutrients. Transparency and turbidity criteria may already be impaired in Wekiwa Springs, largely as a result of recreational uses. Decreased discharge rates in this spring have the potential to exacerbate these water quality problems.

5.2.9.4 Summary

Based on this analysis, the District's spring MFL for Rock Springs appear to be protective of water quality. For Wekiwa Springs this analysis concludes with some uncertainty that the existing spring MFL is protective of water temperature fluctuations and transparency in Wekiwa Springs. Additional data collection and analysis is recommended to better quantify the effects of discharge at Rock and Wekiwa springs on relevant water quality parameters.

5.2.10 Navigation

5.2.10.1 Introduction

For the purposes of this WRV assessment, navigation is interpreted to mean "commercial" navigation. Although rental tubes are allowed in Kelly Park and kayaks and canoes are rented in Wekiwa Spring State Park below the spring pool area, neither use is interpreted in this analysis in the sense of commercial navigation. Rather those personal watercraft uses are considered above under ***WRV No.1: Recreation in and on the Water***.

5.2.10.2 Summary

Based on the absence of commercial navigation within each of these stream segments, it is concluded that ***WRV No. 10: Navigation*** is not directly relevant to this WRV assessment. However, commercial watercraft uses on the St. Johns River downstream of its confluence with the Wekiva River could theoretically be affected by allowable flow reductions in Rock and Wekiwa springs. The effect of MFLs in the St. Johns River near Deland on various WRVs have been evaluated previously by ECT (2002). Based on the conclusions in that report it appears that the springs MFLs for Rock and Wekiwa springs will have minimal effect on commercial navigation downstream in the St. Johns River near Deland and that ***WRV No.10: Navigation*** is protected by the allowable reductions in minimum annual mean flows at Rock and Wekiwa springs.

6.0 Summary, Conclusions, and Recommendations

6.1 Inventory of Existing Uses

Rock and Wekiwa springs were determined to have eight relevant WRVs of the ten listed in Section 62-40.473, F.A.C. :

- WRV No. 1: Recreation in and on the water
- WRV No. 2: Fish and wildlife habitats and the passage of fish
- WRV No. 4: Transfer of detrital material
- WRV No. 5: Maintenance of freshwater storage and supply
- WRV No. 6: Aesthetic and scenic attributes
- WRV No. 7: Filtration and absorption of nutrients and other pollutants
- WRV No. 8: Sediment loads
- WRV No. 9: Water quality

Of these eight relevant WRVs, ***WRV No. 2: Fish and Wildlife Habitats and the Passage of Fish, WRV No. 7: Filtration and Absorption of Nutrients and Other Pollutants,*** and ***WRV No.9: Water Quality*** appear to be previously degraded in Wekiwa Spring due to impacts unrelated to spring discharge and ***WRV No. 5: Maintenance of Freshwater Storage and Supply*** appears to be approaching the allowable limits in both Rock and Wekiwa Springs based on the existing springs MFLs.

6.2 Summary of Springs MFLs Protection of Relevant Water Resource Values

Table 6-1 summarizes the evaluation of WRV protection by the Rock and Wekiwa springs MFLs described in detail in Section 5. **Table 6-2** provides a more compact summary of these conclusions. Based on this assessment it was concluded that the District's existing springs MFLs are protective of all eight relevant WRVs at each spring with certain caveats related to data gaps and other uncertainties. Based on several lines of evidence it was determined that

TABLE 6-1

Rock and Wekiwa Springs Summary of Water Resource Values Applicability and Protection under Existing Springs MFLs

Water Resource Value (WRV)	WRV Name	SJRWMD Description	Relevant at Rock Springs?	Relevant at Wekiwa Spring?	Protected at Rock Springs?	Protected at Wekiwa Spring?	Basis for WRV Significant Harm at Rock Springs	Basis for WRV significant Harm at Wekiwa Spring
1	Recreation In and On the Water	The active use of water resources and associated natural systems for personal activity and enjoyment. These legal water sports and activities may include but are not limited to: swimming, scuba diving, water skiing, boating, fishing, and hunting.	Yes	Yes	Yes*	Yes	Low flow conditions allowed under this MFL have the potential to measurably increase the frequency of shallow water conditions that modify exisiting recreational uses including tubing. However, tubing and other water contact recreation activities will not be eliminated within the likely range of flows allowed under the MFL, Significant harm is not anticipated but with acknowledged uncertainty.For these reasons it is concluded that this WRV is protected by the MFL.	Observed water level fluctuations in this spring area are relatively small. Given the observed range of mean depths in the spring it appears that recreational uses such as bathing and swimming will be protected as a result of the MFL.
2	Fish and Wildlife Habitats and the Passage of Fish	Aquatic and wetland environments required by fish and wildlife, including endangered, endemic, listed, regionally rare, recreationally or commercially important, or keystone species, to live, grow, and migrate.	Yes	Yes	Yes*	Yes**	Spring discharge is correlated with ecosystem metabolism indices and with habitat area. Reduced discharge may result in a measurable decrease in these measures of food chain support. The estimated frequency of sub-critical conditions for GPP, EE, and aquatic habitat area are expected to increase as a result of the MFL but there is considerable uncertainty in the estimates of the frequency and magnitude of these changes..	Ecosystem metabolism is currently degraded in Wekiwa Spring, possibly due to site modifications and existing human recreational uses. Estimation of additional harm based on the MFLs was difficult because of the existing degraded state of this spring. The MFL is presumed to be protective of this system with acknowledged uncertainty.
3	Estuarine Resources	Coastal systems and their associated natural resources that depend on the habitat where oceanic saltwater meets freshwater. These highly productive aquatic systems have properties that usually fluctuate between those of marine and freshwater habitats.	No	No	Yes	Yes	Previously evaluated and found protected by ECT (2004).	Previously evaluated and found protected by ECT (2004).
4	Transfer of Detrital Material	The movement by surface water of loose organic material and debris and associated decomposing biota.	Yes	Yes	Yes	Yes	Existing data indicate that there will be no reduction in this WRV as a result of the MFL	Existing data indicate that there will be no reduction in this WRV as a result of the MFL.
5	Maintenance of Freshwater Storage and Supply	Protection of an amount of freshwater supply for permitted users at the time of MFLs determination.	Yes	Yes	Yes	Yes	Based on the definition of this WRV it is presumed to be protected at the time of MFL determination. However, existing data indicate that minimum mean annual flows at Rock Springs are approaching the existing MFL and the capacity of new consumptive uses is uncertain.	Based on the definition of this WRV it is presumed to be protected at the time of MFL determination. However, existing data indicate that minimum mean annual flows at Wekiwa Springs are approaching the existing MFL and the capacity of new consumptive uses is uncertain.
6	Aesthetic and Scenic Attributes	Those features of a natural or modified waterscape usually associated with passive uses such as: bird watching, sight seeing, hiking, photography, contemplation, painting and other forms of relaxation that usually result in human emotional responses.	Yes	Yes	Yes	Yes	Existing data indicate that there is little correlation between spring discharge and existing human use data over the range of observed flows in the period-of-record. Estimates of water clarity changes resulting from decreased flows also show no likely noticeable effect of the MFL.	Existing data indicate that there is little correlation between spring discharge and existing human use data over the range of observed flows in the period-of-record. Estimates of water clarity changes resulting from decreased flows also show no likely noticeable effect of the MFL.
7	Filtration and Absorption of Nutrients and Other Pollutants	The reduction in concentration of nutrients and other pollutants through the processes of filtration and absorption (i.e., removal of suspended and dissolved materials) as these substances move through the water column, soil or substrate.	Yes	Yes	Yes*	Yes**	Existing data indicate that at least one index of this WRV (nitrate nitrogen assimilation) may be measurably reduced at the MFL flows. The expected level of change is slight and this WRV is presumed to be protected by the MFL with acknolwedged uncertainty.	Existing data indicate that this WRV is not adequately protected in this spring under current conditions, probably as a result of existing excessive recreational uses.If this WRV was restored then it is considered likely that nitrate assimilation rate may be measurably reduced in this spring at the MFLflows. The expected level of change is slight and this WRV is considered to be protected by the MFL.
8	Sediment Loads	The transport of inorganic materials, suspended in water, which may settle or rise; these processes are often dependent upon the volume and velocity of surface water moving through the system.	Yes	Yes	Yes	Yes*	Estimates of flow velocities indicate that this WRV is not likely to be impaired even if minimum mean annual flows are lowered to the MFL.	Estimates of flow velocities in Wekiwa Springs indicate that existing current velocities are probably inadequate to effectively move sand out of this area. Transport of finer mineral solids may be impaired if spring discharge is reduced as a result of the MFL but there is uncertainty concerning the magnitude of effects on this WRV based on the existing MFL.
9	Water Quality	The chemical and physical properties of the aqueous phase (i.e., water) of a water body (lentic) or a water course (lotic) not included in #7 (i.e., nutrients and other pollutants) above.	Yes	Yes	Yes	Yes* *	Given the OFW status of these waters any significant detrimental change in good water quality is considered to be unacceptable. Water temperature was found to be a sensitive criterion for assessment of this WRV. Based on hydraulic assumptions for Rock Springs using historical stage vs. discharge data, none of the water quality parameters evaluated appear to be harmed by the MFL.	Given the OFW status of these waters any significant detrimental change in good water quality is considered to be unacceptable. Water temperature was found to be a sensitive criterion for assessment of this WRV. Based on a heat balance model it was estimated that flow reductions allowed by the MFL could result in increased frequency of unacceptable temperature variations. Also of possible concern in this spring is the combined effects of intense recreation and reduced flows on water transparency. This WRV is presumed to be protected but with considerable uncertainty due to the existing recreational uses and insufficient existing data.
10	Navigation	The safe passage of commercial water craft (e.g., boats and ships), that is dependent upon sufficient water depth, sufficient channel width, and appropriate water velocities.	No	No	Yes	Yes	Previously evaluated and found protected by ECT (2002).	Previously evaluated and found protected by ECT (2002).

* Indicates an assessment based on considerable uncertainty.

** Indicates this WRV is previously degraded, due to existing conditions other than flow reductions. This baseline condition makes the evaluation of effects due to the MFL subject to greater uncertainty.

existing flows at both the Rock and Wekiwa springs are currently approaching the levels allowed by the existing springs MFLs. For the purposes of this WRV assessment it was presumed that the springs MFLs have not yet been exceeded; however, this finding has considerable uncertainty due to the relatively imprecise nature of the regional steady state groundwater model as well as normal data gaps and climatic variability.

6.2.1 Rock Springs

At Rock Springs in Kelly Park ***WRV No. 1: Recreation in and On the Water*** is marginally protected by the existing spring MFL. Existing recreational activities such as tubing have the potential to be reduced (but not eliminated) at a significantly higher frequency under spring MFL flows than under historic flows. Based on historical data and the metrics examined for this analysis, ***WRVs Nos. 3, 4, 6, 8, 9,*** and ***10*** are considered to be protected at Rock Springs by the existing spring MFL. ***WRV No. 5: Maintenance of Freshwater Storage and Supply*** is assumed to be protected at Rock Springs with the caveat that the spring MFL is being approached under the current conditions and may be exceeded in the near future. The following two WRVs are also found to be protected by the spring MFL with the acknowledgement of considerable uncertainty about the margin of safety associated with their protection:

- ***WRV No.2: Fish and Wildlife Habitats and the Passage of Fish***
- ***WRV No. 7: Filtration and Absorption of Nutrients and Other Pollutants***

6.2.2 Wekiwa Springs

WRV No. 1: Recreation In and On the Water appears to be protected at Wekiwa Springs due to its greater depth and the assumed relationship between discharge and depth. WRVs that are assumed to be protected by the existing spring MFL but are apparently impacted by recreational uses at Wekiwa Springs include:

- ***WRV No. 2: Fish and Wildlife Habitats and Passage of Fish***
- ***WRV No. 7: Filtration and Absorption of Nutrients and Other Pollutants***
- ***WRV No. 9: Water Quality***

The following WRVs were found to be protected by the Wekiwa Springs spring MFL: ***WRV Nos. 1, 3, 4, 6,*** and ***10***. ***WRV No. 5: Maintenance of Freshwater Storage and Supply*** is assumed to be protected at Wekiwa Springs with the caveat that the spring MFL is being approached under the current conditions and may be exceeded in the near future. ***WRV No. 8: Sediment Loads*** is estimated to be reduced in magnitude at Wekiwa Springs as a result of the spring MFL's possible effects on reducing current velocity for this spring. The conclusion that this WRV is protected under the existing spring MFL has considerable uncertainty that could be reduced by additional data collection and analysis efforts.

6.3 Data Collection and Analysis Recommendations

As has been reported for other important artesian springs in Florida (Florida Springs Task Force 2006), quantitative historic data are insufficient at Rock and Wekiwa springs to provide a defensible basis for fully assessing the potential impacts of flow reductions on all WRVs. Additional data collection efforts were conducted as part of this project to fill in some of the most important data gaps for these two springs. These data collection efforts were useful for providing a basic amount of knowledge concerning the possible effects of spring discharge on ecosystem metabolism, nHRTs, community organic matter export, and sediment transport. Longer data records over a period of extreme flow cycles would be of even greater value to better understand the full range of consequences resulting from permitted flow reductions.

Perhaps the most critical data collection needs at Rock and Wekiwa springs are detailed information related to system hydraulics. Specifically the following types of data are needed to better assess the effects of flow reductions on the relevant WRVs:

- Detailed spring and spring run bathymetry
- Detailed velocity profiles throughout the swimming area, including rhodamine tracer tests to examine the effects of mixing on hydraulic residence times under a range of flows
- Hydraulic modeling of the upper portion of the Wekiva River downstream of Wekiwa Springs to develop a better method of predicting spring discharge as a function of water stage

In addition to the basic hydraulic data needed at both springs, the following data collection activities are recommended to add greater certainty to the evaluation of the effects of the springs MFLs on WRVs:

- Repeated recreational use surveys under the full range of seasonal activities
- Seasonal measurements of ecosystem metabolism
- Additional quantification of biological storages, including plant biomass and dominance and fish populations
- Studies of the effects of recreation on water quality, sediment transport, and wildlife habitat

In addition to these proposed studies it is recommended that the District utilize improved groundwater flow models (when available) to assess permitted and un-permitted consumptive uses within the springsheds for Rock and Wekiwa springs and determine the effects of those uses on spring discharge rates. The purpose of this effort would be to provide a better estimate of when these springs MFLs will be (or were) reached at both springs.

TABLE 6-2
Summary of WRV Assessment Results at Rock and Wekiwa Springs

WATER RESOURCE VALUE	PROTECTED AT ROCK SPRINGS?	PROTECTED AT WEKIWA SPRINGS?
WRV No. 1 - Recreation in and on the Water	Yes*	Yes
WRV No. 2 - Fish and Wildlife Habitat and Fish Passage	Yes*	Yes**
WRV No. 3 - Estuarine Resources	Yes	Yes
WRV No. 4 - Detrital Transfer	Yes	Yes
WRV No. 5 - Freshwater Storage and Supply	Yes	Yes
WRV No. 6 - Aesthetic and Scenic Attributes	Yes	Yes
WRV No. 7 - Filtration and Absorption of Nutrients and Pollutants	Yes*	Yes**
WRV No. 8 - Sediment Loads	Yes	Yes*
WRV No. 9 - Water Quality	Yes	Yes**
WRV No. 10 - Navigation	Yes	Yes

* Indicates an assessment based on considerable uncertainty.

** Indicates this WRV is previously degraded, due to historical conditions other than flow reductions. This baseline condition makes the evaluation of effects due to the MFL subject to greater uncertainty.

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Appendix A

Rock Springs and Wekiwa Spring Plant and Animal Species List

APPENDIX A

Plant and Animal Species Associated with Spring Boil and Spring Run Habitats - Wekiva River Basin State Parks

COMMON NAME	***SCIENTIFIC NAME***
PLANTS	
VASCULAR PLANTS	
Alligatorweed*	Alternanthera philoxeroides
Carolina mosquito fern	Azolla caroliniana
Jamaica swamp sawgrass	Cladium jamaicense
Wild taro; Dasheen; Coco yam *	Colocasia esculenta
Jointed flatsedge	Cyperus articulatus
Common water-hyacinth*	Eichhornia crassipes
Waterthyme*	Hydrilla verticillata
Dixie iris; Prairie iris	Iris hexagona
Southern cutgrass; Clubhead cutgras	Leersia hexandra
Duckweed	Lemna sp.
Cardinalflower	Lobelia cardinalis
Florida keys hempvine	Mikania cordifolia
Climbing hempvine	Mikania scandens
Lax hornpod	Mitreola petiolata
Spatterdock; Yellow pondlily	Nuphar lutea
Goldenclub; Neverwet	Orontium aquaticum
Egyptian paspalidium	Paspalidium geminatum
Water-lettuce*	Pistia stratiotes
Shortbristle horned beaksedge	Rhynchospora corniculata
Narrowfruit horned beaksedge	Rhynchospora inundata
Carolina willow	Salix caroliniana
Lizard's tail	Saururus cernuus
Cuban bulrush*	Scirpus cubensis
Giant bulrush; California bulrush	Scirpus californicus
Southern cattail	Typha domingensis
Tapegrass; American eelgrass	Vallisneria americana
Florida vetch	Vicia floridana
Annual wild rice; Indian rice	Zizania aquatica
INVERTEBRATES	
DAMSELFLIES	
Ebony jewelwing	Calopteryx maculate
Sparkling jewelwing	Calopteryx dimidiate
Fragile forktail	Ischnura posita
Variable dancer	Argia fumipennis
Duckweed firetail	Telebasis byersi
Smoky rubyspot	Hetaerina titia
Blue damselfly	Enallgma civile
DRAGONFLIES	
Common green darner	Anax junius
Regal darner	Coryphaeschna ingens
Blue dragonlet	Erythrodiplax connata minuscula
Eastern pondhawk	Erythemis simplicicollis
Two-striped forceptail	Aphylla williamsoni
Eastern amberwing	Perithemis tenera
Black-shouldered spinyleg	Dromogomphus spinosus
Prince baskettail	Epitheca princeps
Greater hyacinth glider	Miathyria marcella
Cypress clubtail	Gomphus minutus
Twilight darner	Gynacantha nervosa
Blackwater clubtail	Gomphus dilatatus
MAYFLIES	
Mayfly	Heptagenia flavescens

APPENDIX A (cont.)

Plant and Animal Species Associated with Spring Boil and Spring Run Habitats - Wekiva River Basin State Parks

COMMON NAME	***SCIENTIFIC NAME***
CRAYFISH/MUSSELS/SNAILS/AMPHIPODS/ISOPODS	
Orlando cave crayfish	Procambarus acherontis
Crayfish	Procambarus fallax
Crayfish	Procambarus geodytes
Wekiwa hydrobe	Aphaostracon monas
Wekiwa siltsnail	Cincinnatia wekiwae
Asian clam	Corbicula fluminea*
Mussel	Corbicula manilensis
Mussel	Elliptio sp
Mussel	Melanoides turriculus
Mussel	Planorbella duryi ssp.*
Iridescent liliput mussel	Toxoplasma paulus
Florida rainbow mussel	Villosa amygdala
Gastropod	Tryonia aequicostata
Gastropod	Palaemonetes paludosus
Amphipod	Hyalella sp.
Isopod	Lirceus sp.
Hobbs cave amphipod	Crangonyx hobbsi
Florida cave isopod	Caecidotea hobbsi
FISH	
DASYATIDAE	
Sea lamprey	Petromyzon marinus
LEPISOSTEIDAE	
Longnose gar	Lepisosteus osseus
Florida gar	Lepisosteus platyrhincus
AMIIDAE	
Bowfin	Amia calva
CYPRINIDAE	
Golden shiner	Notomigonus chrysoleucas
Ironcolor shiner	Notropis chalybaeus
Tailfin shiner	Notropis maculatus
Coastal shiner	Notropis petersoni
Bluenose shiner	Notropis welaka
Pugnose minnow	Opsopoeodus emiliae
Sailfin shiner	Pteronotropsis hypselopterus
Bluenose shiner	Pteronotropsis welaka
ATHERINOPSIDAE	
Brook silverside	Labidesthes sicculus
LORICARIIDAE	
Radiated Ptero*	Pterygoplichthys multiradiatus
Armored catfish*	Pterygoglichthys disjunctivus
CALLICHTHYIDAE	
Brown hopolo*	Hopolosternum littorale
ESOCIDAE	
Chain pickerel	Esox niger
APHREDODERIDAE	
Pirate perch	Aphredoderus sayanus
CYPRINODONTIDAE	
Golden topminnow	Fundulus chrysotus
Seminole killifish	Fundulus seminolis
Bluefin killifish	Lucania goodei
Rainwater killifish	Lucania parva

APPENDIX A (cont.)

Plant and Animal Species Associated with Spring Boil and Spring Run Habitats - Wekiva River Basin State Parks

COMMON NAME	***SCIENTIFIC NAME***
FISH	
POECILIIDAE	
Western mosquitofish	Gambusia affinis
Least killifish	Heterandria formosa
Sailfin molly	Poecilia latipinna
CENTRARCHIDAE	
Redbreast sunfish	Lepomis auritus
Warmouth	Lepomis gulosus
Bluegill	Lepomis macrochirus
Dollar sunfish	Lepomis marginatus
Redear sunfish	Lepomis microlophus
Spotted sunfish	Lepomis punctatus
Largemouth bass	Micropterus salmoides
Black crappie	Pomoxis nigromaculatus
PERCIDAE	
Swamp darter	Etheostoma fusiforme
Blackbanded darter	Percina nigrofasciata
MUGILIDAE	
Striped mullet	Mugil cephalus
AMPHIBIANS	
SIRENIDAE	
Greater siren	Siren lacertina
Lesser siren	Siren intermdia
AMPHIUMIDAE	
Two-toed amphiuma	Amphiuma means
REPTILES	
CROCODYLIDAE	
American alligator	Alligator mississippiensis
KINOSTERNIDAE	
Florida mud turtle	Kinosternon subrubrum steindachneri
Loggerhead musk turtle	Sternotherus minor minor
Common musk turtle	Sternotherus odoratus
EMYDIDAE	
Peninsula cooter	Chrysemys floridana peninsularis
Florida chicken turtle	Deirochelys reticularia chrysea
Florida redbelly turtle	Chrysemys nelsoni
Red-eared slider*	Trachemys scripta elegans
CHELYDRIDAE	
Florida snapping turtle	Chelydra serpentina
TRIONYCHIDAE	
Florida softshell	Apalone ferox
COLUBRIDAE	
Eastern mud snake	Farancia abacura abacura
Rainbow snake	Farancia erytrogramma erytrogramma
Florida water snake	Nerodia fasciata pictiventris
Brown water snake	Nerodia taxispilota
VIPERIDAE	
Florida cottonmouth	Agkistrodon piscivorus conanti

APPENDIX A (cont.)

Plant and Animal Species Associated with Spring Boil and Spring Run Habitats - Wekiva River Basin State Parks

COMMON NAME	***SCIENTIFIC NAME***
BIRDS	
DARTERS	
Anhinga	Anhinga anhinga
BITTERNS & HERONS	
Great blue heron	Ardea herodias
Great egret	Ardea alba
Snowy egret	Egretta thula
Little blue heron	Egretta caerulea
Tricolored heron	Egretta tricolor
Green heron	Butorides striatus
Yellow-crowned night-heron	Nyctanassa violaceus
STORKS	
Wood stork	Mycteria americana
IBISES	
White ibis	Eudocimus albus
Glossy ibis	Plegadis falcinellus
SPOONBILLS	
Roseate spoonbill	Ajaia ajaja
DUCKS & GEESE	
Wood duck	Aix sponsa
American wigeon	Anas americana
American black duck	Anas rubripes
Northern pintail	Anas acuta
Redhead	Aythya americana
RAILS	
Common moorhen	Gallinula chloropus
American coot	Fulica americana
LIMPKIN	
Limpkin	Aramus guarauna
SANDPIPERS	
Spotted sandpiper	Actitis macularia
KINGFISHERS	
Belted kingfisher	Ceryle alcyon
WRENS	
Sedge wren	Cistothorus platensis
Marsh wren	Cistothorus palustris
ICTERIDS	
Boat-tailed grackle	Quiscalus major
MAMMALS	
MUSTELIDAE	
River otter	Lutra canadensis

*Spring Run Stream Only
Source: FDEP 2005

Appendix B

Rock Springs and Wekiwa Spring Daily Metabolism Estimates

Appendix C

Rock Springs and Wekiwa Spring
Field Parameter Measurements

Appendix D

Rock Springs and Wekiwa Spring Light Attenuation Estimates

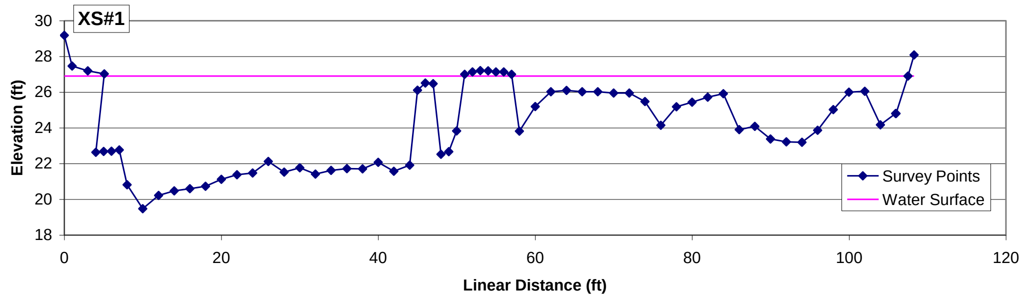
Appendix E

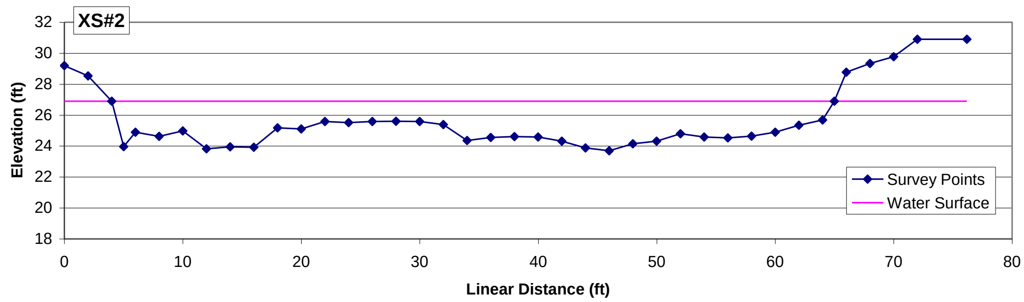
Rock Springs and Wekiwa Spring Particulate Export Measurements

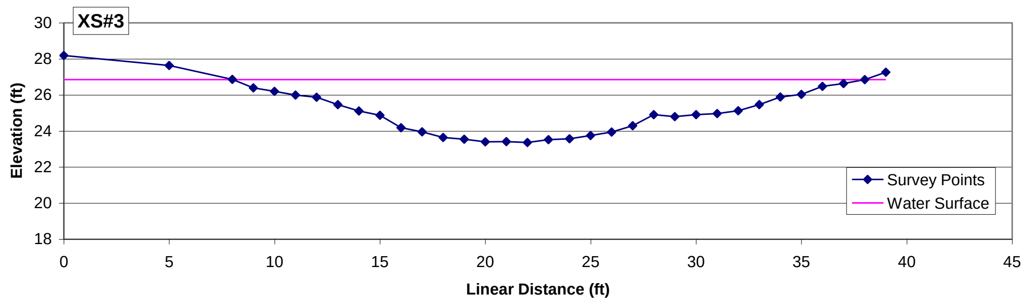
Appendix F

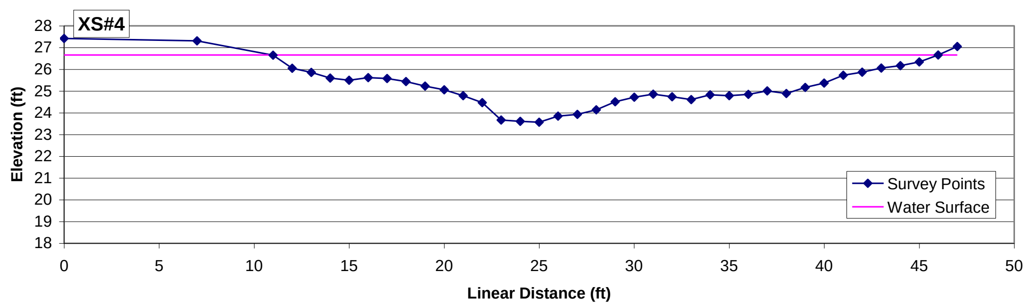
Rock Springs and Wekiwa Spring Survey Cross Sections

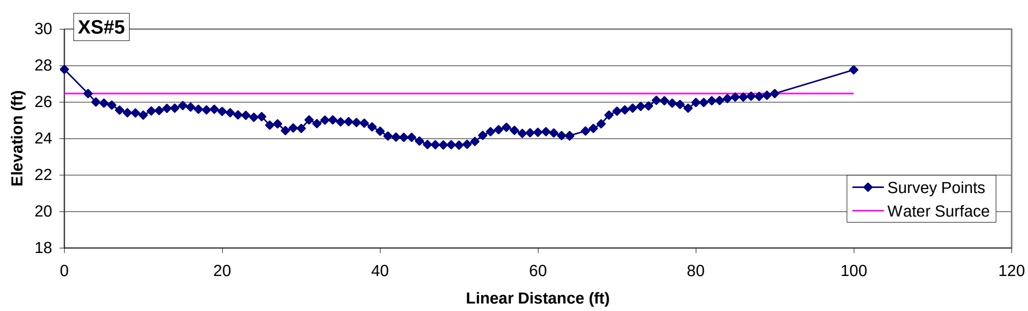
APPENDIX F
Kelly Park / Rock Spring – Survey Cross Section Locations











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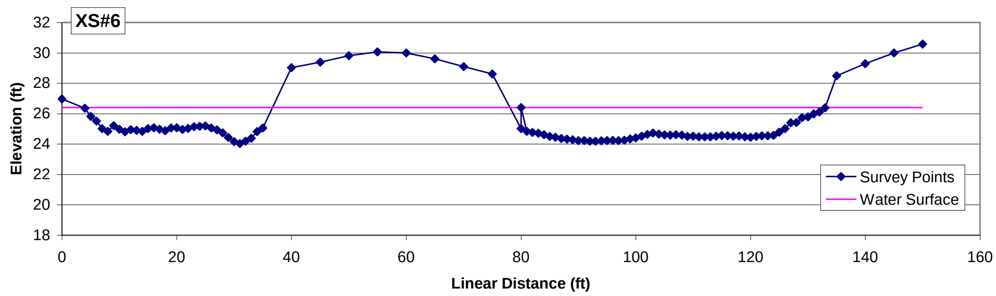

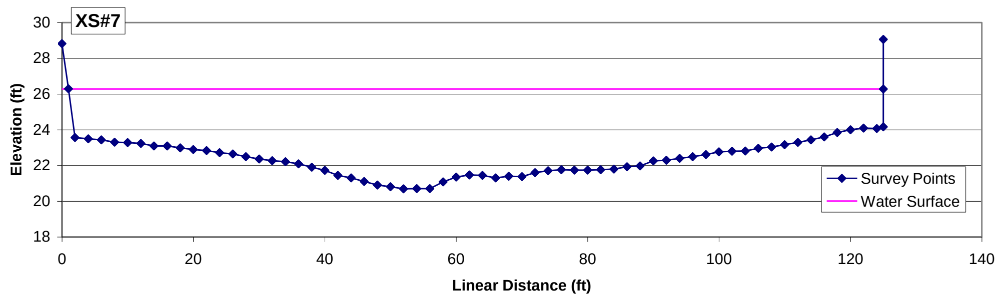

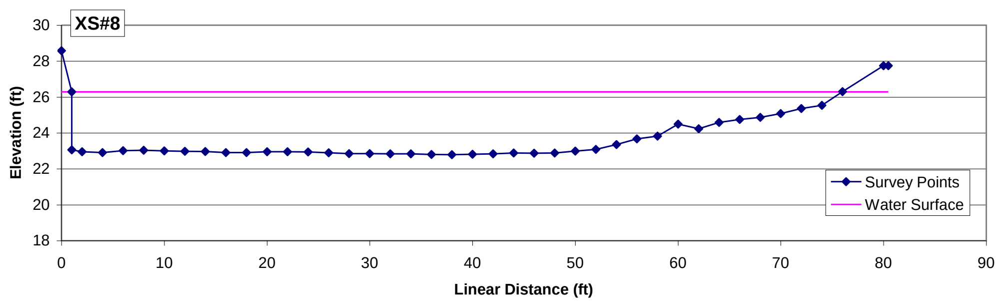

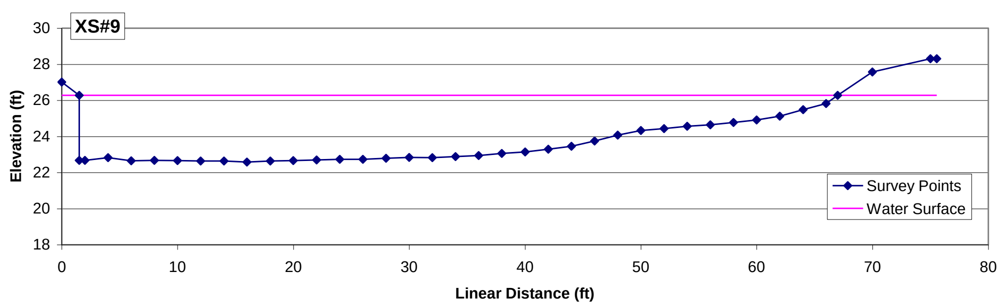

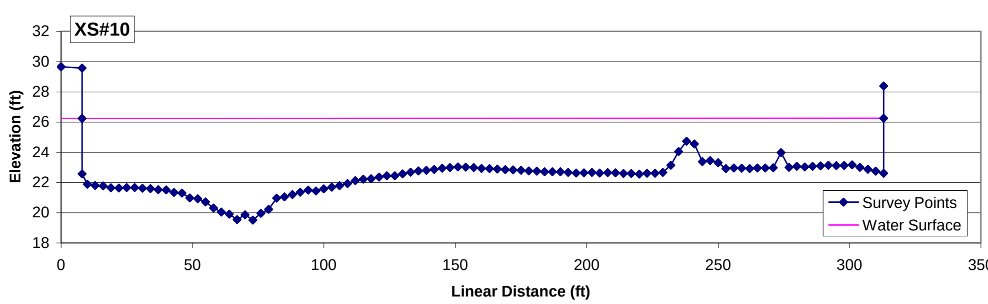

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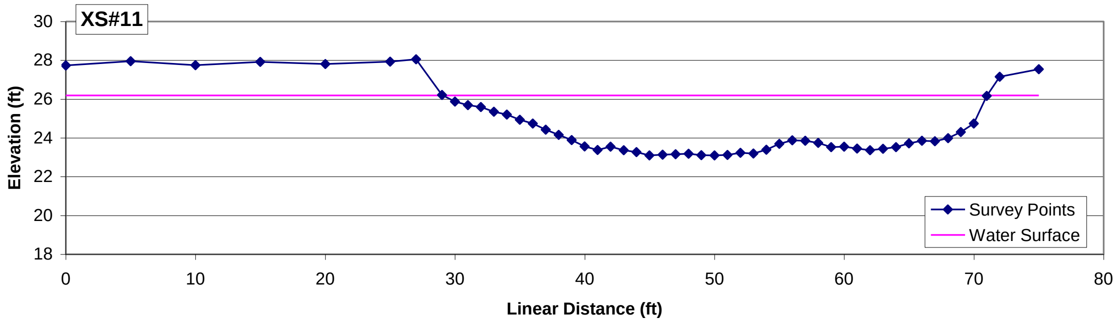
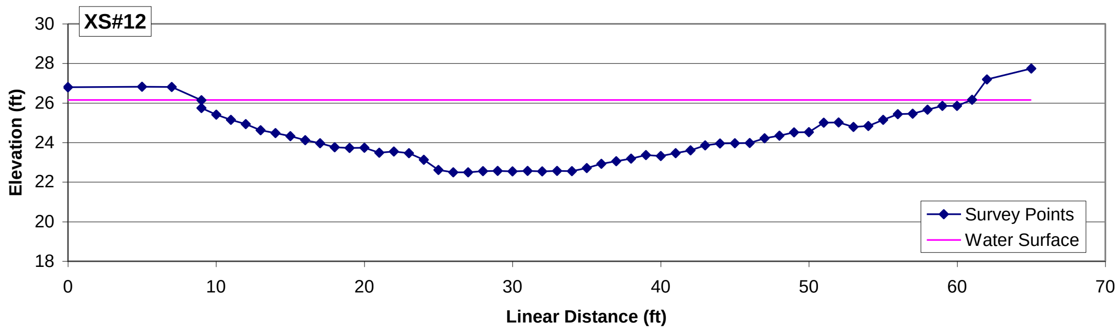
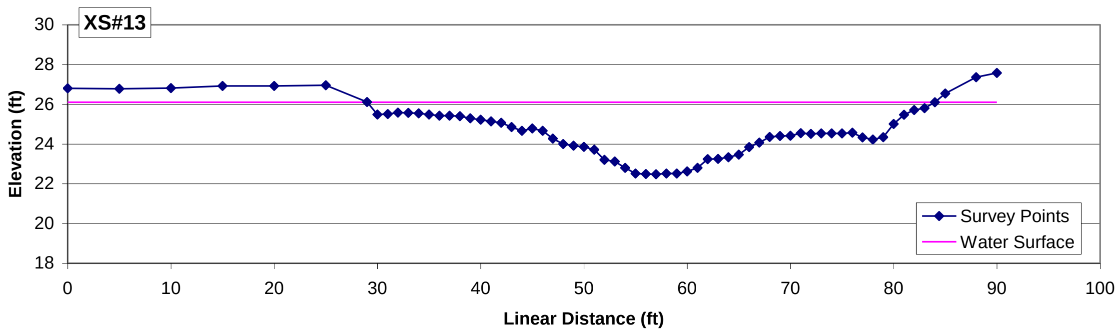
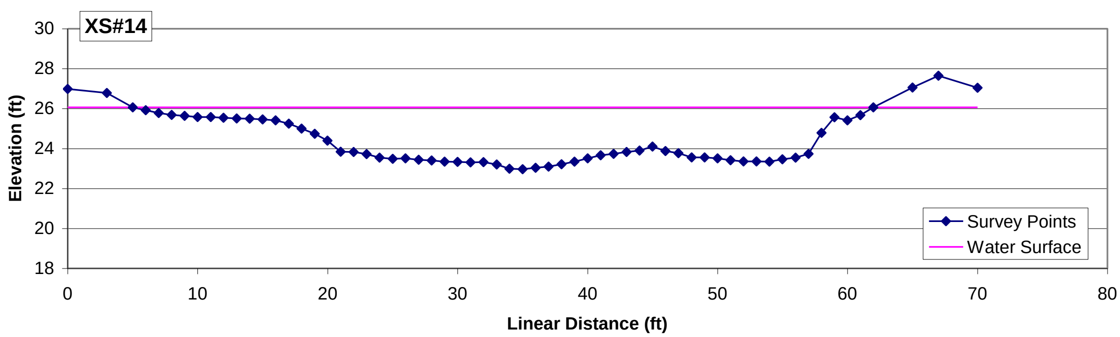




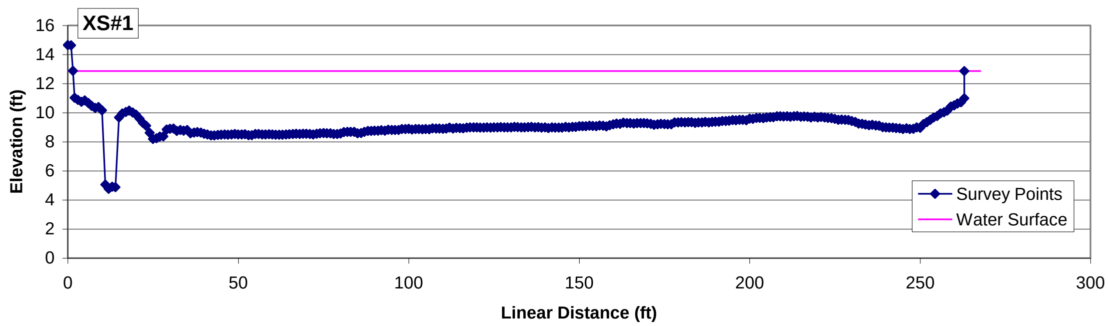


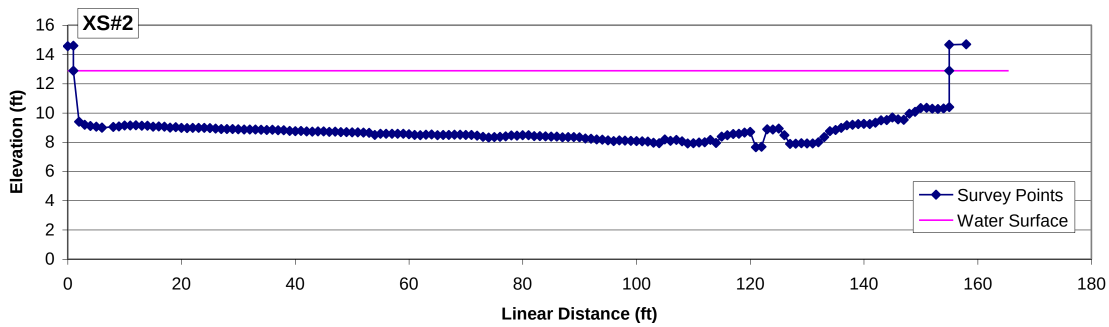


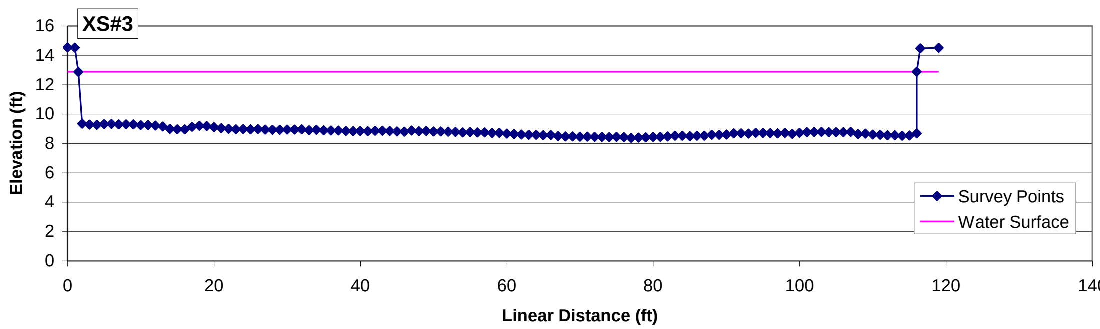
APPENDIX F

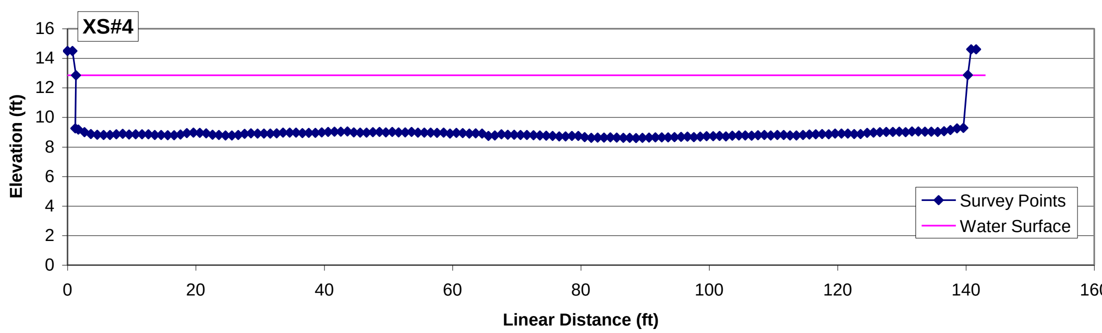
Kelly Park / Rock Spring – Survey Cross Sections

APPENDIX F
Wekiwa Spring – Survey Cross Section Locations









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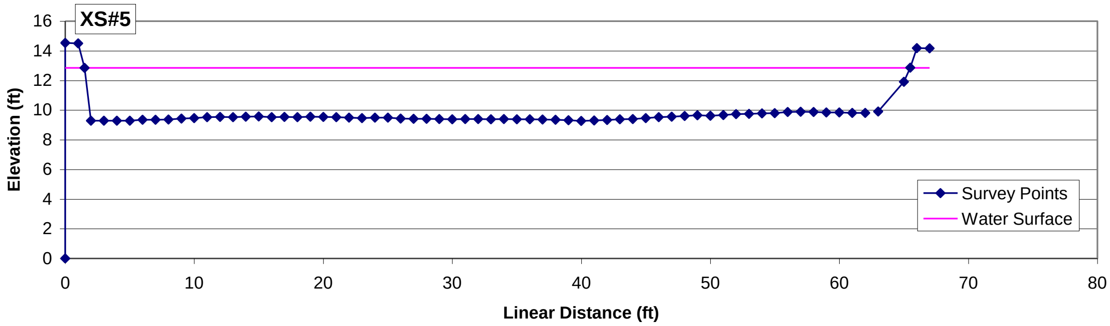
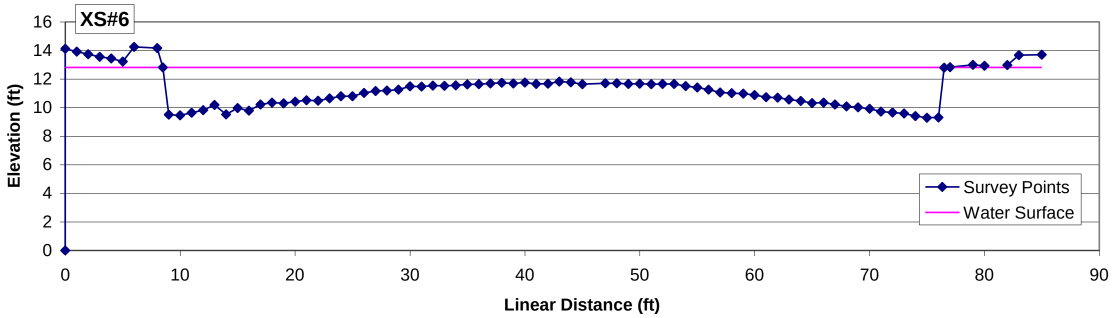
Wekiwa Spring – Survey Cross Sections





APPENDIX F
Wekiwa Spring – Survey Cross Sections