

Rainbow Springs Restoration Action Plan

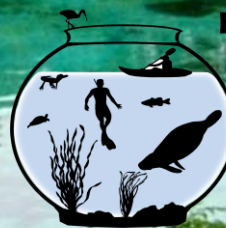
Prepared for
Rainbow River Conservation, Inc.

August 14, 2013

Prepared by
Wetland Solutions, Inc.

in cooperation with

**The Howard T. Odum
Florida Springs Institute**



Howard T. Odum

**FLORIDA
SPRINGS
INSTITUTE**



**Wetland
Solutions,
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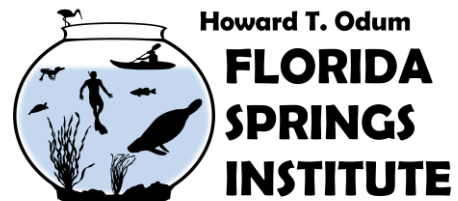


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A work that attempts to encompass the entirety of a subject is always reliant on the work of others. This Restoration Action Plan incorporates the work of professionals from virtually every environmental research institution and agency in Florida, including the SWFWMD, USGS, FDEP, FWC, UF, USF, and consultants. A debt of gratitude is owed to the Rainbow Springs Working Group for many years of data collection and discussion of restoration activities, and especially to Peter Colverson of Normandeau Associates, Inc. for his leadership of the group and preparation of the 2011 draft Rainbow Springs Restoration Plan under contract to FDEP. Although this report may not agree with all aspects of every prior report reviewed, continuing scientific studies by these organizations and institutions provide a valuable current and historical record that can be used to develop a restoration context.

The authors would especially like to acknowledge the assistance provided by members of RRC, including Burt Eno, Paul Marraffino, and Bill Vibbert for their personal observations and thorough review.

The principal authors of the report included Robert Knight, Ph.D., Scott Knight, P.E., and Ron Clarke, M.S., of Wetland Solutions, Inc.

Executive Summary

Rainbow Springs and River comprise the Rainbow Springs System in southwest Marion County, Florida. The Rainbow Springs System is a first magnitude springs group with an historic average combined flow of nearly 500 million gallons per day (MGD). A diverse and productive aquatic ecosystem dependent upon relatively constant flows, water temperature, water chemistry, and high light availability has occupied the Rainbow Springs System for thousands of years. However, Florida's rapid population expansion over the past 100 years, and the accompanying changes in land use intensity in Marion and surrounding counties, are taking a toll on the health and abundance of the fish and other wildlife that inhabit the Rainbow spring run ecosystem. Physical and chemical impairments affecting the Rainbow Springs system include flow reductions, increases in the concentration and load of nitrate nitrogen, and impacts associated with increasing recreational use of this attractive natural resource.

The environmental attributes of the Rainbow Springs System have received considerable scientific documentation over the past 60+ years. In this Restoration Action Plan existing data are summarized to establish a baseline and context for future actions intended to protect, restore, and preserve the natural biological functions of this precious ecosystem. This Restoration Action Plan was prepared by the Howard T. Odum Florida Springs Institute with assistance from Wetland Solutions, Inc. and with financial support from Rainbow River Conservation, Inc. and the Felburn Foundation.

Parallel management/restoration activities are underway by the Florida state government to establish a lower minimum flow threshold and to determine a maximum amount of nitrogen pollution that the spring ecosystem can tolerate before being "significantly harmed". However, the state's focus on setting limits that allow degradation of the Rainbow Springs system to the threshold of harm are not compatible with the importance of or the level of legal protections appropriate for an "Outstanding Florida Water" and a "National Natural Landmark". The Rainbow Springs system is too important to the plants and animals that call it home and to the future economic health of Marion County and all of Florida to allow any amount of harm to be tolerated.

This Rainbow Springs System Restoration Action Plan has been prepared to provide an outline for more comprehensive recovery and lasting protection of this unique natural wonder. This plan makes the following findings of fact:

- The Rainbow River System includes at least 12 named spring vents and many lesser vents and feeds water to about 5.7 miles of the Rainbow River, including 1,470 acres in the Rainbow Springs State Park;
- The historic mean groundwater inflow to these springs was about 720 cfs or 465 MGD fed by a maximum springshed area of about 737 mi² (472,000 acres) with an average annual groundwater recharge rate of about 13 inches (33.4 cm) traveling as much as 45 miles (73 km) underground;
- This Rainbow Springs System springshed is dominated by semi-intensive land uses, including agriculture (37%), forestry (33%), and urban (17%); has an estimated 2010

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human population of nearly 112,000; and is located in Marion (54%), Levy (28%), and Alachua (18%) counties;

- Long-term (97 year) average rainfall in the springshed is about 54 in/yr, and more recently is averaging about 50 in/yr, with an estimated average rate of groundwater recharge of about 14 to 15 in/yr;
- Flows from the Rainbow Springs System have declined by about 25% since the 1960s with an estimated 11% of the decline due to rainfall declines and the remaining 14% decline (about 100 cfs or 65 MGD) due to human groundwater extractions, both local and regional;
- Regional groundwater use in the Southwest Florida Water Management District is over 1,700 cfs (1,100 MGD), and comprises about 98% of the total freshwater use in the area, resulting in an estimated decline in the level of the Floridan Aquifer System in the Rainbow Springshed of about 8 to 15 ft since pre-development conditions;
- All of the Rainbow Springs System springshed is vulnerable to groundwater contamination by nitrogen from fertilizers and human/animal waste disposal practices, resulting in an average load of about 1,000 tons of nitrogen per year (917 MT/yr) discharging from the springs into the Rainbow River at a concentration of more than 2 mg/L of nitrate nitrogen, and requiring a reduction of about 82% to comply with state water quality standards;
- The Rainbow Springs System receives more than 300,000 human visitors each year, all of whom have some effect on the vitality of the natural aquatic ecosystems.

This Restoration Action Plan calls for significant changes in human activities both within the springshed and in the entire area of the Floridan Aquifer System. Existing estimates of the regional groundwater balance indicate that current permitted groundwater uses from Georgia and Florida equal about 33% of the average recharge for the entire Floridan Aquifer System and as much as 50% during typical dry years. The result of this overuse of the resource is that groundwater levels are lowered throughout the entire aquifer and especially in areas of low natural recharge and high pumping (e.g., Tampa Bay, Polk County, Orlando, and Jacksonville, etc.). The only practical way to provide comprehensive springs flow restoration over North Florida is to reduce the total quantity of groundwater that is being pumped. An overall reduction of 60% or more from current pumping rates will be required to restore springs to healthy flow rates.

Control of nitrate pollution evident in the Rainbow Springs System is equally daunting. An 82% reduction in total nitrogen loading will likely be required to achieve the state's water quality standard. Inputs of nitrogen fertilizer in the springshed are estimated to be about 2,800 tons per year (2,540 MT/yr). To meet the State's proposed springs nitrate standard of 0.35 mg/L, this imported fertilizer nitrogen needs to be reduced to an annual total of about 500 tons per year (457 MT/yr). Additional reductions in nitrogen loads are needed to achieve even lower nitrate concentrations that reflect historic, pre-development conditions. In addition to reductions in fertilizer use, all wastewater disposal practices need to be addressed to lower their collective load by an equal percentage through connection of existing septic tanks where possible to central wastewater treatment facilities, and by upgrades at all wastewater facilities to advanced nitrogen removal to achieve average concentrations less than about 3 mg/L.



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Recreational activities in the Rainbow Springs System need to be limited to a human carrying capacity that is based on resource protection. Specific recommendations include the restriction of all motor boats on the river with engines over 10 horsepower, division of the river into separate use zones for diving and boating, reducing the number of and hardening entry and exit points to eliminate shore damage, and better in- and on-water user education.

This report provides a detailed list of specific actions for various state and non-governmental groups that will be needed to ultimately achieve comprehensive restoration of the Rainbow Springs System. While there is not likely to be any disagreement about the importance of protecting and restoring this ecologic and economic engine, there will be much controversy about how to best accomplish that worthy goal. All residents of Marion, Levy, and Alachua counties, as well as all users of the regional Floridan Aquifer System will need to be aware of, and in part be responsible for, life-style changes to reduce the unintentional effects of their human "footprint" on this water resource. The eventual outcome of those changes will be long-term sustainability of our natural water environments, both above and below-ground, and will benefit every citizen and tourist who spends time in Florida.

Section 1.0 Introduction

Rainbow Springs, the Rainbow River, and the springshed they depend upon are referred to in this report as the Rainbow Springs System and are located in west central Florida (Exhibit 1-1). Rainbow Springs and the Rainbow River are located in southwestern Marion County approximately 4 miles north northeast of the Dunnellon city center and 19 miles west southwest of the Ocala city center. The spring and river offer significant recreational opportunities to visitors including kayaking, canoeing, tubing, swimming, snorkeling, scuba diving, boating, and other water-related activities. The river flows approximately 6 miles south to merge with the Withlacoochee River upstream of Lake Rousseau along the Marion-Citrus county line. The Withlacoochee River ultimately discharges to the Gulf of Mexico near Yankeetown, Florida.

Rainbow Springs includes more than twelve named vents with a combined historic average discharge of more than 750 cubic feet per second [cfs] (485 million gallons per day [MGD]), making it one of the largest first magnitude spring systems in Florida. The Rainbow Springs System begins at a collection of spring vents (*e.g.*, Bridge Seep North, Rainbow Spring #1, Rainbow Spring #2, Bubbling Spring, Rainbow Spring #3) discharging groundwater from the Floridan Aquifer System. The Rainbow River then flows south, collecting additional groundwater inflows from vents and diffuse sources within and adjacent to the channel along the length of the river.

The head springs and a large portion of the eastern bank of the Rainbow River are located within 1,470-acre Rainbow Springs State Park and are managed by the Florida Department of Environmental Protection (FDEP). The state park attracts over 260,000 visitors annually making it a large tourist attraction in Marion County, Florida. Additionally the Marion County Parks and Recreation Department manages the K.P. Hole County Park located on the west bank of the river which serves as an access point for an estimated 70,000 visitors each year to the Rainbow River.

Portions or all of the Rainbow Springs System have regulatory protections at the national and state levels, including recognition as a National Natural Landmark, designation as an Outstanding Florida Water (OFW), inclusion in a Florida Aquatic Preserve, and State Park status. In spite of these regulatory safeguards, the Rainbow Springs System has experienced significant degradation over approximately the past half century as the result of agricultural, urban, and industrial development in its surface and groundwater recharge basins. These land use changes include significant groundwater withdrawals, excessive use of nitrogen fertilizers, and animal and human wastewater discharges from both rural and the urban environments. Groundwater withdrawals have lowered the average potentiometric surface of the Floridan Aquifer in the springshed of the Rainbow Springs System, resulting in declining spring flows that no longer support the size and complexity of the pre-development aquatic ecosystem. Increasing concentrations of anthropogenic nitrate nitrogen in the Floridan Aquifer have caused impairment characterized by algal proliferation and changes to the submerged aquatic plant community.

Florida's state agencies are moving forward with piecemeal and often contradictory efforts that effect the state's water resources and springs. Thus the Florida Department of Environmental Protection (FDEP) is developing pollutant load reduction strategies to reverse water quality

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degradation, while the Southwest Florida Water Management District (SWFWMD) has developed a Surface Water Management and Improvement (SWIM) plan for the Rainbow Springs System and is currently developing regulatory limits to protect and restore minimum flows. A third state agency, the Department of Agriculture and Consumer Services (FDACS) is assuring that agricultural interests are exempt from land modification and water quality standards, and receive a higher prioritization for protection than the natural ecosystems affected by the agricultural industry. The state’s Department of Economic Opportunity (DEO) emphasizes the encouragement of businesses and focuses their efforts on streamlining environmental review and permitting. The existing deterioration of the Rainbow Springs System is the end result of more than 50 years of regulatory neglect or inadequate enforcement of existing laws by these agencies and their predecessors.

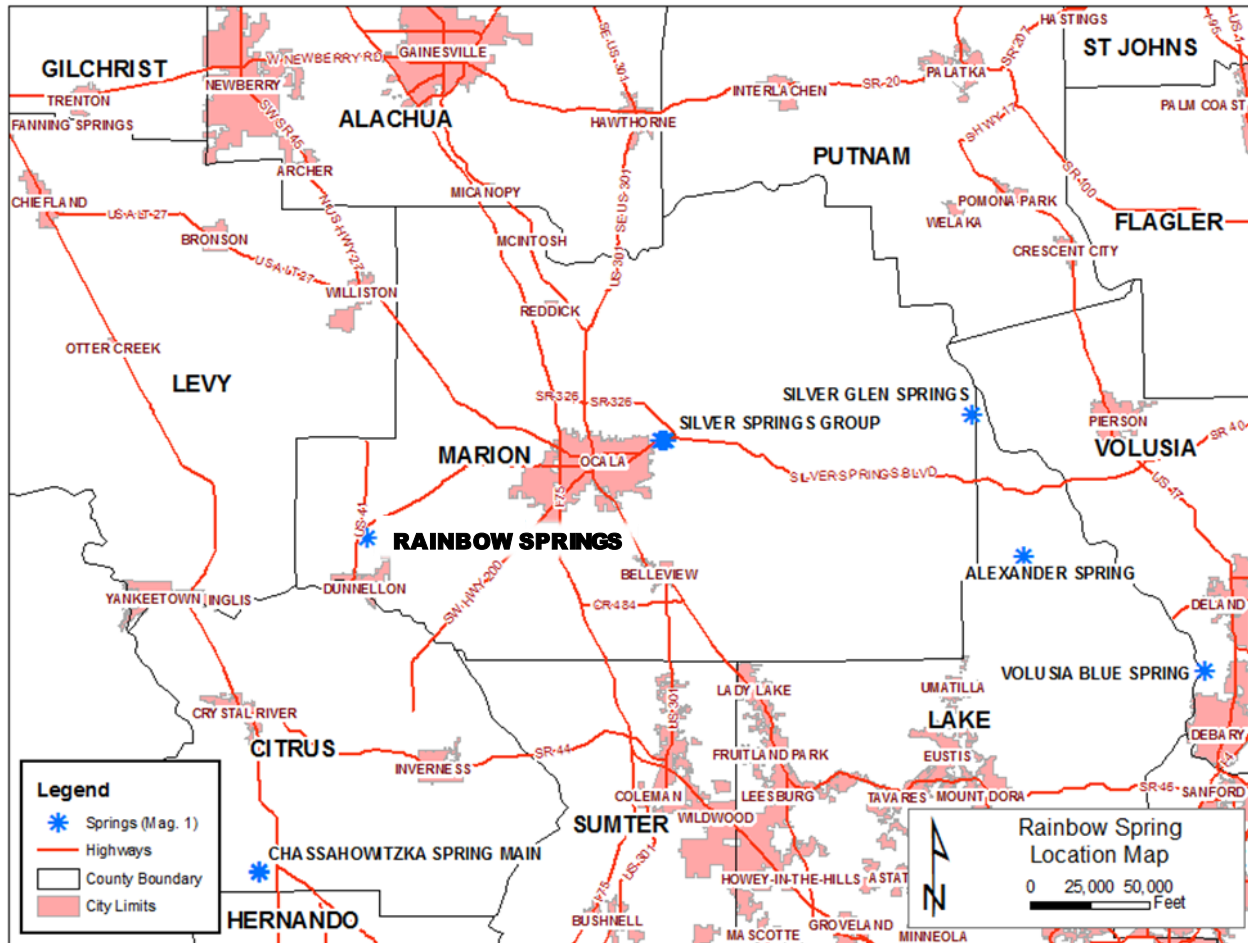


Exhibit 1-1. Rainbow Springs location map. Marion County includes approximately 1,663 square miles and is the home of three of Florida’s largest springs – Rainbow, Silver, and Silver Glen.

In many if not most of Florida’s 1,000+ artesian springs, flow reduction and nitrate increases have caused significant ecological alterations to the point that pristine springs are now a memory from by-gone days. A new paradigm of citizen education and involvement will be necessary to reverse these sad trends and to hold our public officials accountable for effective and timely protection and restoration of the Rainbow Springs System. The Rainbow Springs Restoration Action Plan (this document) provides a comprehensive summary of the existing

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Rainbow Springs System environmental data and impairments, and presents a logical series of actions that will be needed to reverse these undesirable changes. State agencies and local stakeholders will need to come together to embrace the importance of restoring and protecting the Rainbow Springs System and work together to accomplish restoration and lasting protection. This Rainbow Springs Restoration Action Plan is a living document that will be revisited and updated as progress is made and additional information becomes available.

Section 2.0 Description of the Rainbow Springs System

2.1 General Location and Features

Rainbow Springs is located in southwestern Marion County as shown in Exhibit 2-1. The nearest city is Dunnellon located near the mouth of the Rainbow River, several miles south of the spring assemblage. This first magnitude spring complex has a long history of human usage. Based on archaeological evidence Native Americans used the area around Rainbow Springs as far back as 10,000 years ago. By the 1920s, visitors and locals were using the springs and river for recreation. From the 1930s through the 1970s, it was a privately-owned attraction. Because of competition from other attractions the spring was closed from the 1970s until the FDEP's Florida Park Service (FPS) purchased the property in 1990.

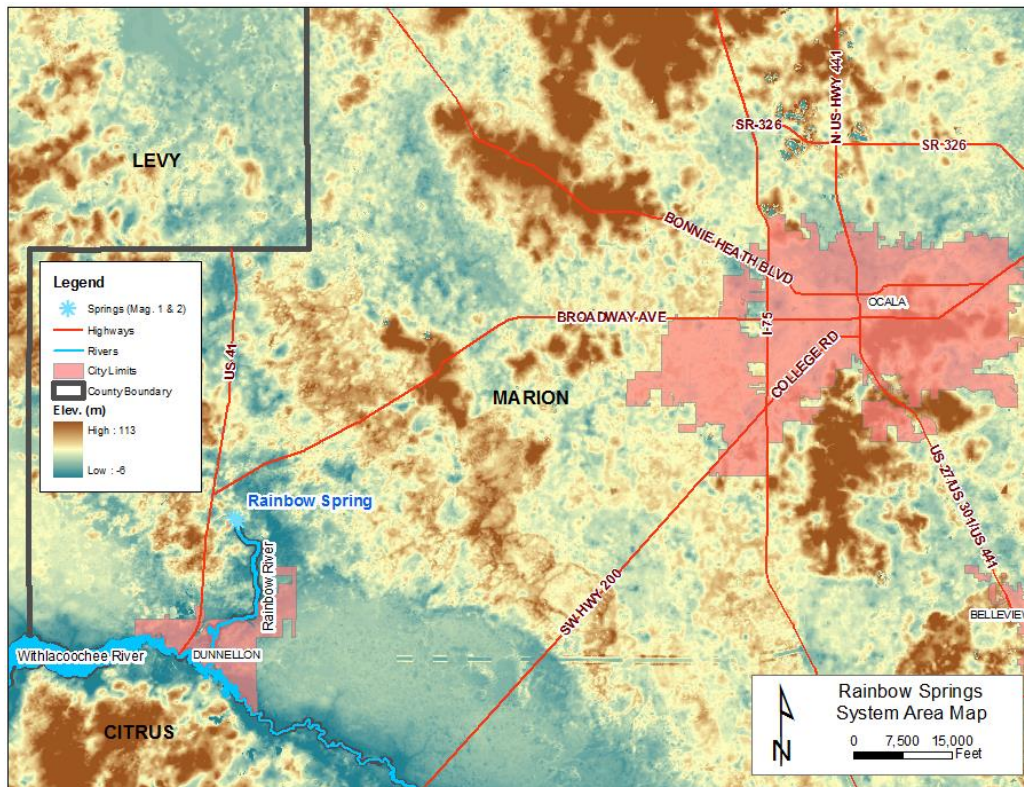


Exhibit 2-1. Rainbow Springs System area topographic map. Rainbow Springs is located southwest of Ocala, the largest city in Marion County, and is just north of Dunnellon and the Withlacoochee River.

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The entire Rainbow River was added to the National Registry of Natural Landmarks in 1971, an Aquatic Preserve in 1986, and an Outstanding Florida Waterway in 1987. In 1989, the SWFWMD adopted the Rainbow River as a SWIM water body. The state purchased the original area that was the Rainbow Springs Attraction in 1990. Volunteers cleared the overgrown property and opened the park on weekends to the public. The FPS officially opened Rainbow Springs State Park on a full time basis on March 9, 1995. The park facilities are well developed and include gardens, camping, pavilions, swimming, tubing, and canoe rentals. This site is a regionally popular swimming, SCUBA, and tubing destination. Rainbow River is also utilized by the Marion County Parks and Recreation Department, at the K.P. Hole County Park, where tubes, canoes, kayaks, and boat launching are available.

Rainbow Springs forms the headwaters of the Rainbow River which is nearly 6 mi (10 km) long and merges with the Withlacoochee River (south) at Dunnellon. From there, the Withlacoochee River travels west to form Lake Rousseau and ultimately discharges into the Gulf of Mexico at Yankeetown, Florida.

Rainbow Springs begins as a collection of vents distributed around the spring pool, e.g., Bridge Seep North, Rainbow Spring #1, Rainbow Spring #4, Bubbling Spring, Rainbow Spring #6 (Exhibit 2-2). These multiple springs create the main spring pool area which is semicircular and approximately 350 ft (107 m) in diameter and approaching 10 ft (3 m) in depth. Spring vents are generally surrounded by karst geology and lack navigable caverns; there are numerous smaller sand boils around the pool as well. The pool is partially enclosed by a concrete wall and swim entry dock. A central component of the spring pool is the defined swim area overlying bare quartz sand. The lands immediately surrounding the head spring are hilly and maintained as open grass, scattered trees, and park buildings (Exhibit 2-3).

The spring run averages approximately 150 ft (46 m) wide and travels for about 5.7 mi (9.2 km) before joining the Withlacoochee River (south) near the town of Dunnellon. Along the spring run, which is also known as Blue Run or Rainbow River, there are numerous small spring vents which discharge into the river bed through conduits in the underlying karst. During mapping of the aquatic vegetation in Rainbow River, 87 unique spring vents were identified (SWFWMD 2007). About 1 mi (1.6 km) south of the head spring area, a spring-fed tributary (Indian Creek) joins the Rainbow River on its east side. The lands along the eastern banks of the spring run are primarily undeveloped, in contrast to the western banks which are largely developed as residential properties. Quartz sand derived from Miocene and Pliocene marine deposits makes up the majority of sediments in the spring and run (GARI 2007). In portions of the spring run the underlying karst geology is visible as limestone outcrops, particularly around the spring vents.

2.2 Geology and Hydrogeology

The geology of Marion County consists of Pliocene to Recent age sands overlying Cretaceous and Tertiary clays and carbonates which were sequentially deposited in shallow seas during interglacial periods (SWFWMD 1987). Clastic sediments which overlie limestone units are Miocene age and younger. The unconsolidated Holocene and Pleistocene age sediments consist of sand, clay, peat and marl. The Holocene sediments are mostly alluvial lake and windblown deposits, while the Pleistocene units are marine sediments from former shoreline terraces (MacNeil 1950).

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Rainbow River overlies an area where the Ocala Limestones are relatively close to the surface and contains deposits of limestone and dolostones with shell fragments of marine origin. Avon Park limestone underlies the Ocala Limestone formation with the two units together comprising the Floridan Aquifer. Historical phosphate mining operations can be found on both sides of the Rainbow River.

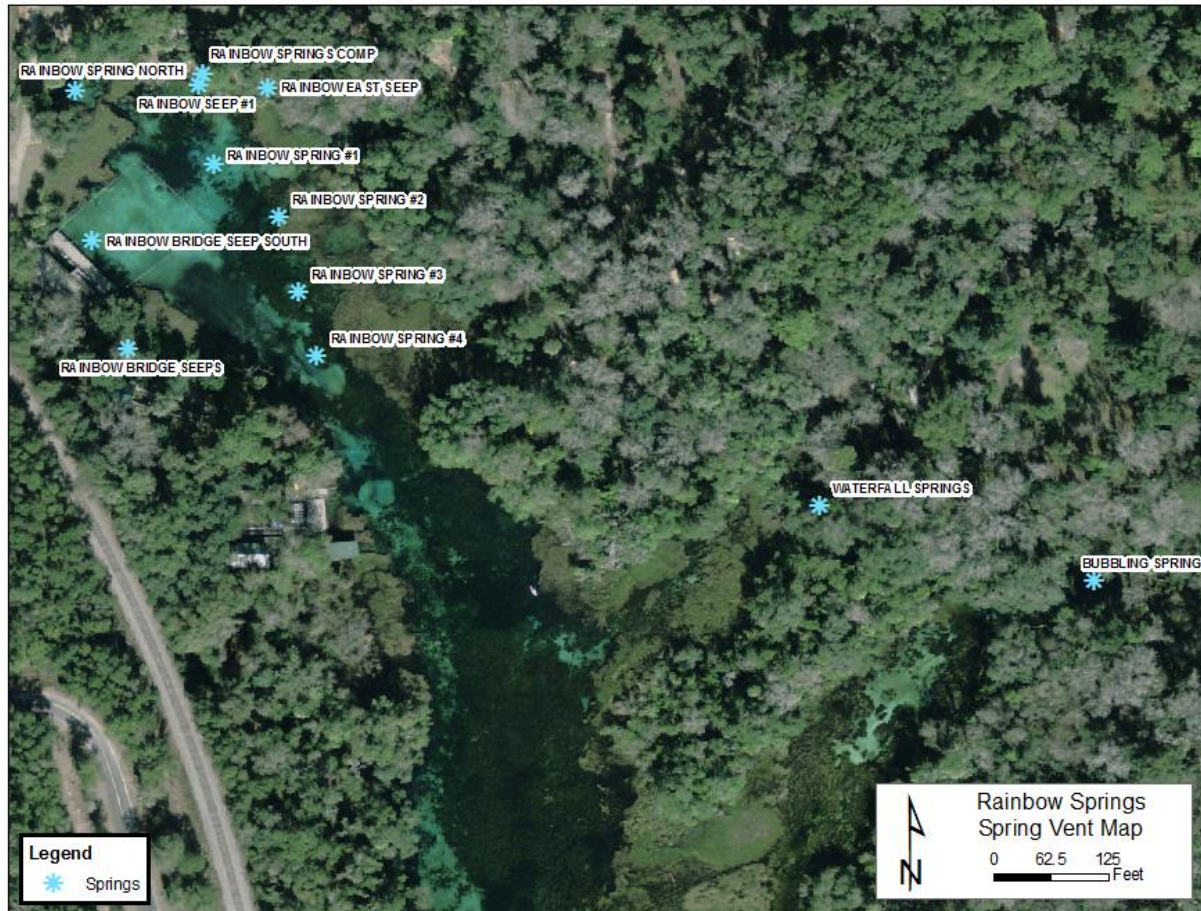


Exhibit 2-2. Rainbow Springs vent locations and names

The Hawthorn Formation, which outcrops near Rainbow Springs, consists of an upper part made up of shallow marine sand mixed with layers of clay and clayey sand and a lower unit comprised of permeable limestone and dolostones (SWFWMD 1987). The upper portion acts as a confining unit to the Floridan Aquifer, although where the Rainbow River crosses the exposed Hawthorn formation limestone numerous spring vents can be found.

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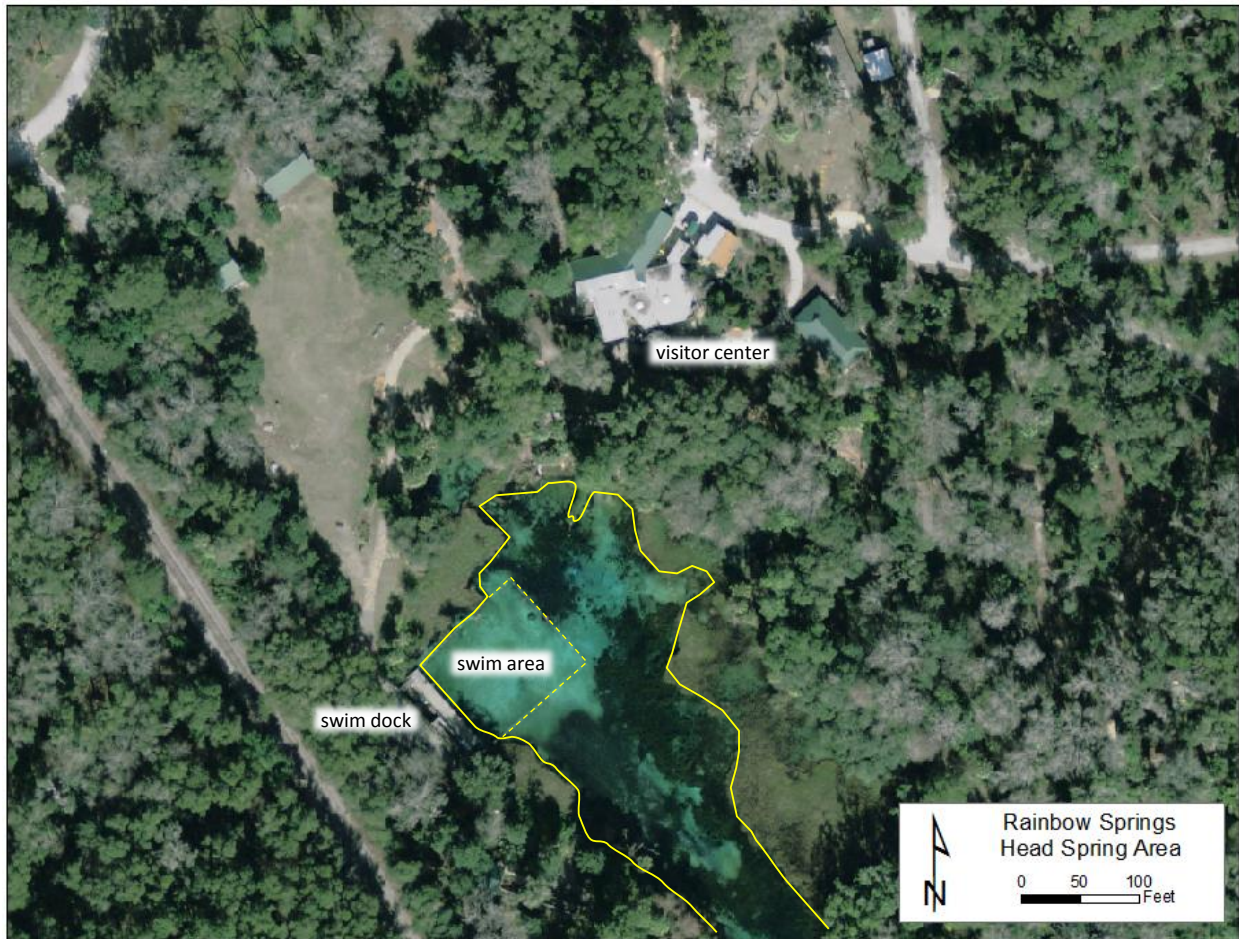


Exhibit 2-3. Rainbow Springs Head Spring and surrounding park buildings

2.2.1 Hydrogeology

Rainfall within Marion County not lost to surface drainage and evapotranspiration, percolates through the surficial unconsolidated material or enters into sinkholes to recharge the Floridan Aquifer. The internal drainage route generally follows the potentiometric surface of the pressurized limestone units making up the Floridan Aquifer and eventually, the water reappears at points of major discharge, such as Marion County's three first order springs - Rainbow, Silver, and Silver Glen Springs. Faulkner (1973) reported that most of the groundwater that exits the Floridan Aquifer at Rainbow Springs is derived from the Ocala Limestone in the upper 100 ft (30.5 m) of the Floridan Aquifer, a water-bearing zone with rapid flow rates and relatively short residence times.

2.2.2 Springshed

A springshed is defined as the area that contributes groundwater, via pressure, to a spring vent or series of vents. Springsheds can be defined based on the potentiometric surface (water elevation map) of the contributing aquifer. Potentiometric surface maps are drawn using groundwater levels from monitoring wells developed into the aquifer of interest. While surface

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watershed boundaries are generally fixed based on ground surface topography, springsheds are variable based on the balance between groundwater recharge and discharge, and the hydraulic water conveyance properties of the aquifer. As with watersheds, the elevation gradient of the potentiometric surface allows water to “flow” downhill. Unlike watersheds, physical movement of groundwater does not immediately contribute to flow at spring vents, rather water pressure and the movement of water towards preferential flow paths causes changes in flow at the spring vent. This distinction is important because it can mean travel times and the age of water discharged at a spring can be highly variable based on preferential flow paths also referred to as conduits. These conduits can in some cases be large in size (adequate for human divers to traverse them) and travel for many miles.

In some springsheds large underground conduits move flow at rates vastly exceeding flow through the soil or limestone matrix. In one study in the adjacent Silver Springs springshed a dye trace was used to estimate travel times and found mean velocities ranging from 84 to more than 3,600 feet/day (26 to 1,105 m/d) (URS 2011). The difference in flow rates through different components of the aquifer means that water age can be highly variable within a springshed. Additionally it is important to understand that the only water that contributes pressure to cause flow at the spring vent is water that is at a higher elevation than the water surface elevation in the spring boil. So even if the aquifer is hundreds of feet thick this has no bearing on flow at the spring vent. At Rainbow Springs there is a maximum pressure head of approximately 35 feet (10.7 m) based on the 2008 potentiometric map (Exhibit 2-4).

Exhibit 2-4 shows the overlapping nature of the maximum-extent Rainbow Springs and the adjacent Silver Springs springsheds. For any specific set of conditions there is a theoretical boundary where groundwater flows westerly to Rainbow Springs and easterly to Silver Springs. This relatively indeterminate springshed boundary is due to the relatively flat potentiometric surface in western Marion County between the two springs, making exact delineation of the boundary variable in this area. Evidence provided by the St. Johns River Water Management District (SJRWMD) indicates that the interface between these two adjacent springsheds moves to the east or west depending on changes in the potentiometric surface caused by rainfall, recharge, and groundwater pumping. Low aquifer levels caused by low rainfall and high pumping tend to increase the size of the Rainbow Springshed and reduce the size of the Silver Springshed. Wet periods when aquifer levels are higher and pumping is less result in the opposite effect. The average water level at Rainbow Springs is approximately 10 ft (3.0 m) lower than the water level at Silver Springs. This topographic position and the level nature of the potentiometric surface in this area of the county provide an advantage to Rainbow Springs at the expense of reduced flows at Silver Springs (Fay Baird, SJRWMD personal communication, November 2010).

Rainbow Springs Restoration Action Plan

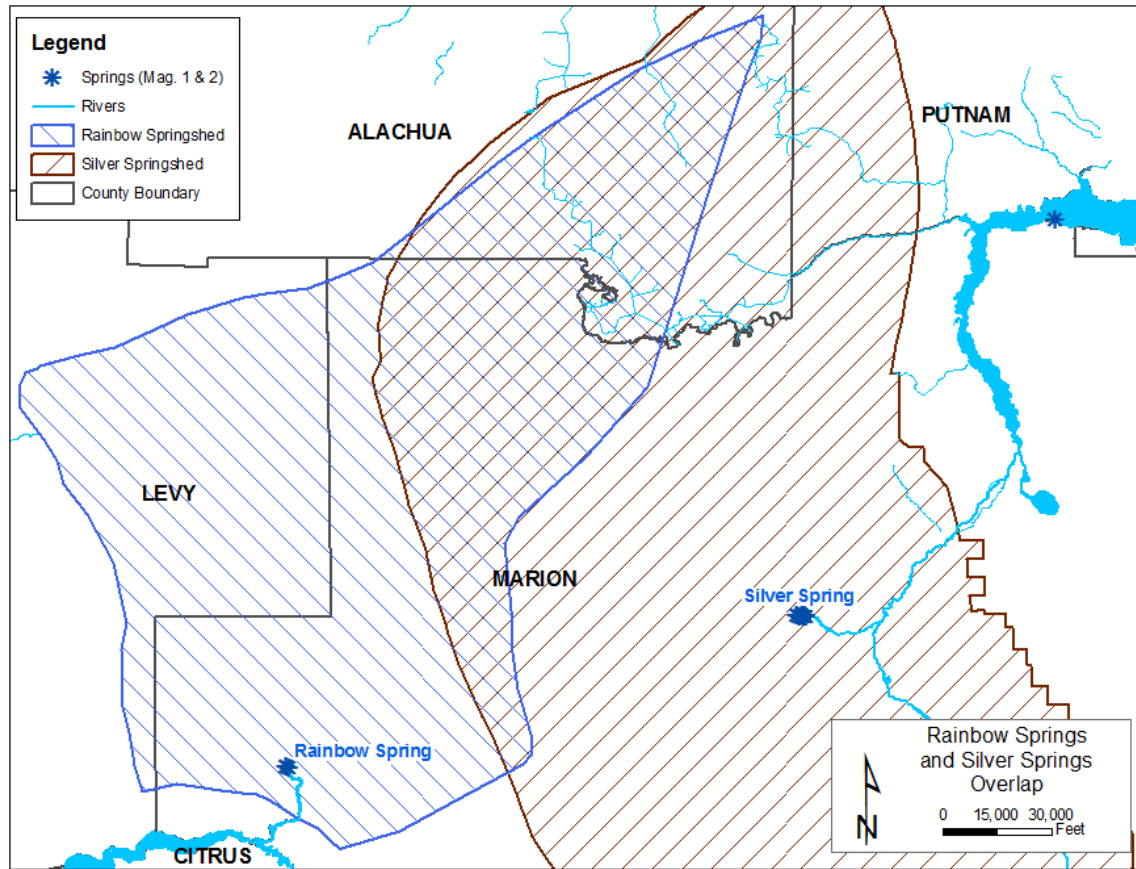


Exhibit 2-4. Rainbow Springs and Silver Springs potentiometric surface and approximate maximum springshed boundaries. The Silver Springs discharge elevation is approximately 38 ft (NGVD) while the Rainbow Springs discharge elevation is about 28 ft (NGVD), resulting in a head difference of about 10 ft between the two springs.

2.2.2.1 Aerial Extent

The Rainbow River surface watershed boundary lies within the USGS defined Withlacoochee Hydrologic Unit (Seaber *et al.* 1987, Foose 2000) and is approximately 73 mi² (189 km² or 46,700 ac, FGS 2007). However the vast majority of water discharged from the Rainbow River (97 to 99%) results from groundwater rather than surficial inputs (WAR 1991).

The maximum springshed for Rainbow Springs includes portions of Alachua, Levy, and Marion Counties. Several estimates of the groundwater recharge area have been made; Faulkner (1973) and Jones *et al.* (1996) reported the dry season Rainbow Springs groundwater basin having an area of approximately 645 mi² (1,671 km² or 412,798 ac). Jones *et al.* (1996) reported the wet season recharge area as approximately 771 mi² (2,000 km² or 493,440 ac, Exhibit 2-4). Based on Florida Geological Survey delineations (FGS 2007), the Rainbow Springs maximum springshed is estimated to be 737 mi² (1,909 km² or 471,700 ac).

2.2.2.2 Groundwater Flow Paths and Travel Times

Groundwater from as far away as 45 miles in the large Rainbow springshed contributes to the spring vents on the Rainbow River. Estimates of travel time have been made based on the age of

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water at different spring vents on the river. Katz (2004) estimated ages of water at several vents based on multiple isotopes. This research yielded estimated average water ages between approximately 5 and 25 years. This is the combination of different age waters that mix prior to discharging from the vent. As summarized above, based on dye trace studies (URS 2011), groundwater travel times in the adjacent Silver Springshed ranged from 84 to 3,600 ft/day (26 to 1,105 m/day). It is reasonable to assume that such fast travel times also occur in portions of the Rainbow Springshed.

2.3 Springshed Characteristics

2.3.1 Land Use

Land uses and cover types within the Rainbow Springshed have transitioned from a dominance of forested uplands to agricultural and urban uses (Jones *et al.* 1996, SWFWMD 2004). Land uses within the springshed in 2004 are shown in Exhibit 2-5. This shows that a majority of the land is used for agriculture (37%), followed by upland forested land (33%), and urban (17%). These three land uses cover almost 90% of the springshed. In southern Alachua County there are several large lake and wetland areas that cover most of the remainder of the springshed (7%). In closer proximity to the Rainbow and Withlacoochee Rivers urban land uses generally dominate.

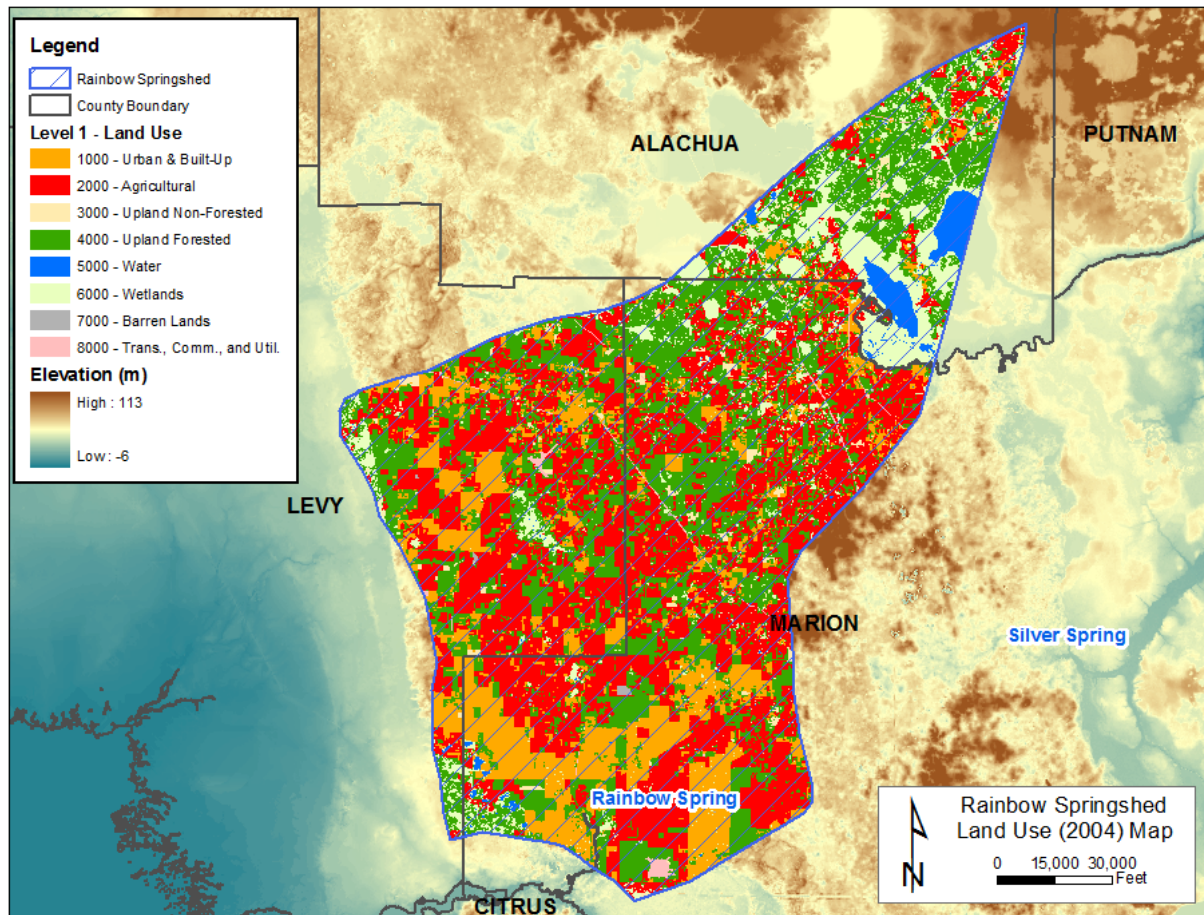


Exhibit 2-5. Rainbow River 2004 Springshed land uses

2.3.2 Population

Population estimates were made based on U.S. Census data and the area of the springshed. The portion of the springshed lying in each county was calculated using the county boundaries and the springshed delineation produced by FGS. The estimated 2010 total population in the three counties that include the Rainbow Springshed was 619,435. Populations for the portion of the springshed in each county were estimated assuming that the population was evenly distributed across the county. Based on this method it was estimated that 111,747 people were living in the Rainbow River Springshed as of 2010.

Exhibit 2-6. Rainbow River Springshed 2010 population estimates

County	County Area (ac)	2010 County Population ¹	Area Springshed (ac)	2010 Estimated Springshed Population ²	% Springshed in County	% County in Springshed
Alachua	620,233	247,336	77,718	30,992	17.7%	12.5%
Levy	722,049	40,801	124,942	7,060	28%	17%
Marion	1,063,080	331,298	236,473	73,694	54%	22%
Total	2,405,362	619,435	439,133	111,747	100%	

¹ Population estimate for 2010 from US Census Bureau

² Springshed population estimate based on % of county in springshed

2.3.3 Nitrogen Loading

Long-term records of spring water quality show that nitrate nitrogen concentrations have increased in the Rainbow Springs Group from background concentrations of ≤ 0.1 mg/L (SWFWMD 2008) to an average concentration of 2.1 mg/L in 2012 (Exhibit 4-5). Unlike phosphorus, which sorbs onto metal oxides and carbonate minerals in calcitic soils and in the limestone matrix of the aquifer (Phelps 2004), nitrate is highly soluble, does not sorb to mineral soils or limestone, and is readily transported into and through aquifers (Katz *et al.* 1999). These chemical properties result in groundwater that is highly susceptible to nitrate contamination due to land applications of nitrogen (Katz *et al.* 1999). While the exact partitioning of nitrogen sources is difficult owing to the complexity of land use patterns (Vasques *et al.* 2010) and hydrologic flow paths within the aquifer (Martin and Dean 2001), average nitrate loading rates from general land use categories have been estimated for a number of springsheds (Munch *et al.* 2006; MACTEC 2010a; MACTEC 2010b).

A detailed study of nitrogen sources in the Rainbow Springs basin was conducted by Jones *et al.* (1996), who sampled 60 wells within the basin and multiple springs within the Rainbow Springs Group. They found that the majority of the wells had nitrate nitrogen levels above what is considered the background concentration (<0.1 mg/L); 29% had concentrations between 1 and 5.2 mg/L, 54% had concentrations between 0.1 and 1.0 mg/L, and 17% had concentrations ≤ 0.1 mg/L. Nitrate concentrations were all above 1.0 mg/L for the largest springs in the Rainbow Springs Group. Jones *et al.* (1996) reported the highest groundwater nitrate concentrations west of Ocala, which coincides with a fracture zone trending northwest from the head springs. High nitrate concentrations were also found along the fracture zone trending northeast from the head springs. The lowest concentrations were found in Fairfield Hills, in the north central portion of the basin, and this observation was attributed to the presence of Hawthorn clays overlying the aquifer that impede direct infiltration of water, possibly resulting in the denitrification of soluble nitrogen seeping through the confinement layer. The FDEP Springs Initiative

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Monitoring Network (begun in 2001) reported that of the 222 wells in the Rainbow Spring Basin with nitrate data, 41% had concentrations >1 mg/L and that the highest concentrations (>10 mg/L) were found in the central portions of the springshed (Harrington *et al.* 2010).

Jones *et al.* (1996) identified ten anthropogenic sources of nitrogen that contribute to groundwater-nitrate loading in the Rainbow Springs study area (an area close to the springs that only includes about 350 mi² or about one-half of the maximum-extent springshed): septic tanks, residential turf fertilizer, golf courses, sewage effluent disposal, land disposal of sewage sludge, land disposal of septic sludge, row crops, cattle operations, horse farms, and pasture fertilization with inorganic nitrogen. Fertilization of pastures, horse farms, and cattle farms were reported to be the three largest sources, with estimated total nitrogen applications to the surface of the ground of 3,963 tons/year, 1,501 tons/year, and 1,256 tons/year, respectively. Estimated nitrogen loading from rainfall was estimated by Jones *et al.* (1996) as 1,442 tons per year.

Nitrogen isotope analyses ($\delta^{15}\text{N}$) from groundwater samples supported the finding that inorganic fertilizer was the principal source of nitrogen in the basin; 19 wells and five springs had $\delta^{15}\text{N}$ values between -0.5 and +4.6 ‰, which fall within the range that indicates an inorganic fertilizer source (Jones *et al.* 1996). Albertin (2009) found $\delta^{15}\text{N}$ values of +3.9 to 4.2 ‰ in the waters of the Rainbow Springs Group, again within the range typical of inorganic fertilizer contamination.

Data from the Florida Department of Agriculture and Consumer Services (FDACS) were analyzed to further evaluate the inputs of nitrate in the Rainbow Springshed. The FDACS data summarize the total nitrogen in fertilizer sold in each county. The FDACS data indicate that nitrogen fertilizer sold in the three counties that comprise the Rainbow springshed averaged about 10,122 tons of nitrogen per year between 1997 and 2000 and about 8,045 tons per year for the reporting period from 2000 to 2010. In an effort to apportion this fertilizer use just to the springshed, nitrogen fertilizer sold in each county was treated as being evenly applied across the county, and then multiplied by the fraction of each county lying within the springshed as shown in Exhibit 2-7. These calculations provide an estimated fertilizer nitrogen load in the springshed of 1,771 tons per year for the years from 1997-2000 and approximately 1,430 tons per year for 2000-2010. This analysis indicates a possible 19% decrease in nitrogen application during the past decade when compared to the previous period. However these more recent estimates are 60% less than the 3,963 tons per year fertilizer nitrogen load estimated by Jones *et al.* (1996) for only half of the springshed.

It would appear that the range of average fertilizer nitrogen use in the Rainbow Springs springshed is in the general range of 1,600 to 4,000 tons per year, with a professional best-guess estimate of about 2,800 tons per year during the past two decades.

2.3.4 Aquifer Vulnerability

To better understand where contamination may enter the aquifer the Florida Geologic Survey (FGS) developed a model to estimate aquifer vulnerability. The dataset termed the Florida Aquifer Vulnerability Assessment (FAVA) was created using a Weights of Evidence approach as discussed by Arthur *et al.* (2007). This modeling leveraged GIS datasets that provided spatial representations of depth to water, confining layers, soil permeability, etc. Models were then validated using independent training (reference) points. For several counties in Florida this

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modeling was improved to provide finer resolution of aquifer vulnerability. For Marion County the more detailed aquifer vulnerability assessment was prepared by Advanced Geospatial Inc. (2007). For the Rainbow Springshed the improved aquifer vulnerability and FAVA data were combined to provide the highest resolution data sets available for the springshed (Exhibit 2-8).

Exhibit 2-7. Estimated fertilizer use within the Rainbow River Springshed

County	Average Annual Fertilizer Use in the Rainbow River Springshed ¹ (Tons N)		% of Fertilizer Load
	July 1997- June 2000	July 2000- June 2010	
Alachua	385	291	21.12%
Levy	637	466	34.47%
Marion	749	673	44.41%
Total	1771	1430	100%

¹ Fertilizer sold in the county was assumed to be applied in the county based on the Data source: Florida Department of Agriculture and Consumer Services

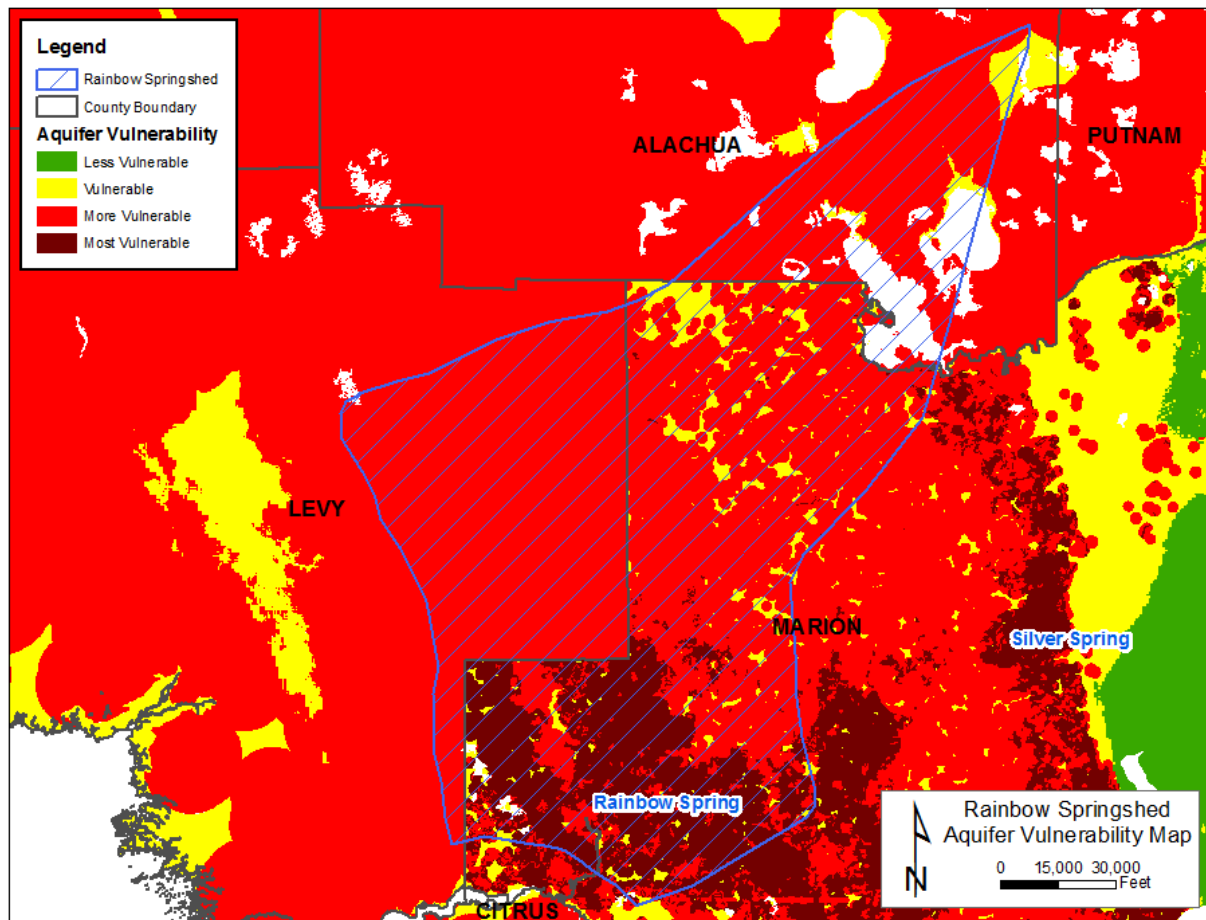


Exhibit 2-8. Rainbow River Springshed Aquifer Vulnerability

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The entire Rainbow Springs springshed is mapped as susceptible to groundwater contamination, with the majority of the springshed considered “More or Most Vulnerable”, and a smaller portion considered “Vulnerable.” More detailed vulnerability mapping was conducted for Marion County and indicated that the “Most Vulnerable” category is prevalent in the vicinity of the Rainbow Springs and River as shown in Exhibit 2-9. With 95% of the springshed considered to be “More” or “Most Vulnerable” the potential for groundwater contamination due to nitrogen loading from anthropogenic sources is high in the entire area feeding the Rainbow Springs.

Exhibit 2-9. Estimated areas (acres) of Aquifer Vulnerability within the Rainbow Springshed

County	Aquifer Vulnerability		
	Vulnerable	More Vulnerable	Most Vulnerable
Alachua	3,757	58,757	0
Levy	1	126,454	0
Marion	19,288	158,534	68,726
Total	23,047	343,745	68,726
% by Type	5%	79%	16%

The aquifer vulnerability was also evaluated based on land use (2004). These data are summarized in Exhibit 2-10 and indicates most of the area is dominated by urban, agriculture, and upland forest. These land uses make up a majority of the “More” and “Most Vulnerable” categories. The urban and agricultural land uses make up 54% of the “More Vulnerable” and 72% of the “Most Vulnerable” categories. These land uses also are the most likely to contribute to nitrate contamination of the aquifer as a result of fertilizer application. The prevalence of these land uses within vulnerable areas presents a challenge that needs to be addressed to minimize contamination of the Floridan Aquifer.

Exhibit 2-10. Estimated areas (acres) of Aquifer Vulnerability by land use (2004) within the Rainbow Springshed

Land Use	FLUCCS	Aquifer Vulnerability			Total
		Vulnerable	More Vulnerable	Most Vulnerable	
Urban and Built-Up	1000	2,225	47,288	26,606	76,118
Agriculture	2000	8,209	138,054	23,108	169,370
Upland Non-Forested	3000	425	6,068	210	6,704
Upland Forested	4000	8,581	121,928	16,942	147,451
Water	5000	98	1,068	26	1,192
Wetlands	6000	3,157	26,873	1,204	31,234
Barren Lands	7000	8	301	196	505
Trans., Comm., and Util.	8000	345	2,170	435	2,950
Total		23,049	343,749	68,726	435,524

Section 3.0 Hydrology

To understand the movement of water within the springshed it is necessary to consider the hydrology of the basin. Spring flow results from a complex interaction between precipitation, evapotranspiration, recharge, and groundwater withdrawals.

3.1 Water Inputs and Outputs

3.1.1 Precipitation

Rainfall was evaluated by using a data set prepared by the SWFWMD for Marion County. This data set provides annual rainfall totals for the period of record from 1915 through 2011 as shown in Exhibit 3-1. These data show an average precipitation of 54 inches per year over the 97 year period. The LOESS (locally-weighted scatterplot smoothing) procedure was used to better understand the long-term patterns in rainfall. During the 1980s, rainfall peaked at an annual average of about 57 inches. These data show that rainfall was lower in the early portion of the dataset at approximately 50 inches per year and more recently is at the lowest point during the period of record with a LOESS estimate of about 49 inches per year. The highest annual rainfall during the period-of-record was 73 inches in 1953 and the minimum was 33 inches in 2000.

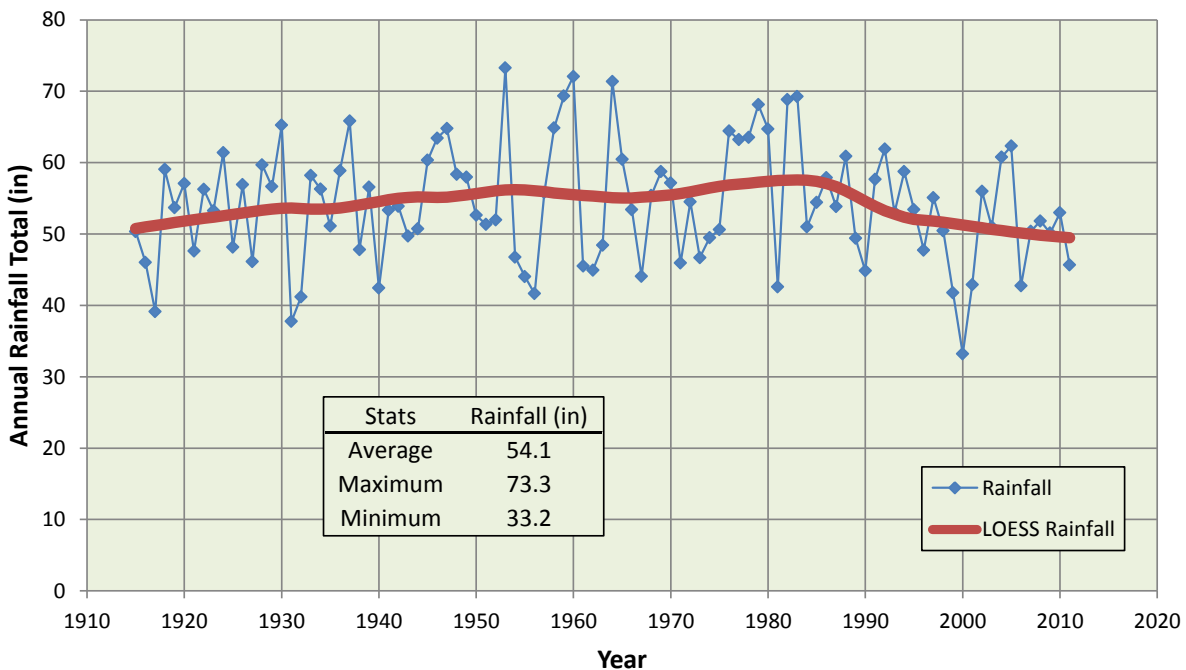


Exhibit 3-1. Annual rainfall record for Marion County in the Florida Springs Coast Area (1915 - 2011)

3.1.2 Evapotranspiration

Evapotranspiration (ET) is typically reported for agricultural purposes as potential ET (PET). This is the theoretical requirement assuming near uniform, excess water availability. In natural systems the ET is influenced by the available water, moisture capacity of the soil, plant species, plant cover, and other factors. These differences generally result in actual ET rates that are substantially lower than PET estimates and result in variable ET rates from year to year. Knowles (1996) conducted a study of ET in Marion County by back-calculating from a water balance. This analysis was done for the period from 1965-94 and yielded an average ET of 37.9 inches per year with a minimum of 29.5 inches per year and a maximum of 50.0 inches per year. Due to water availability, ET tends to be higher during wetter years and lower during drier years (Exhibit 3-2).

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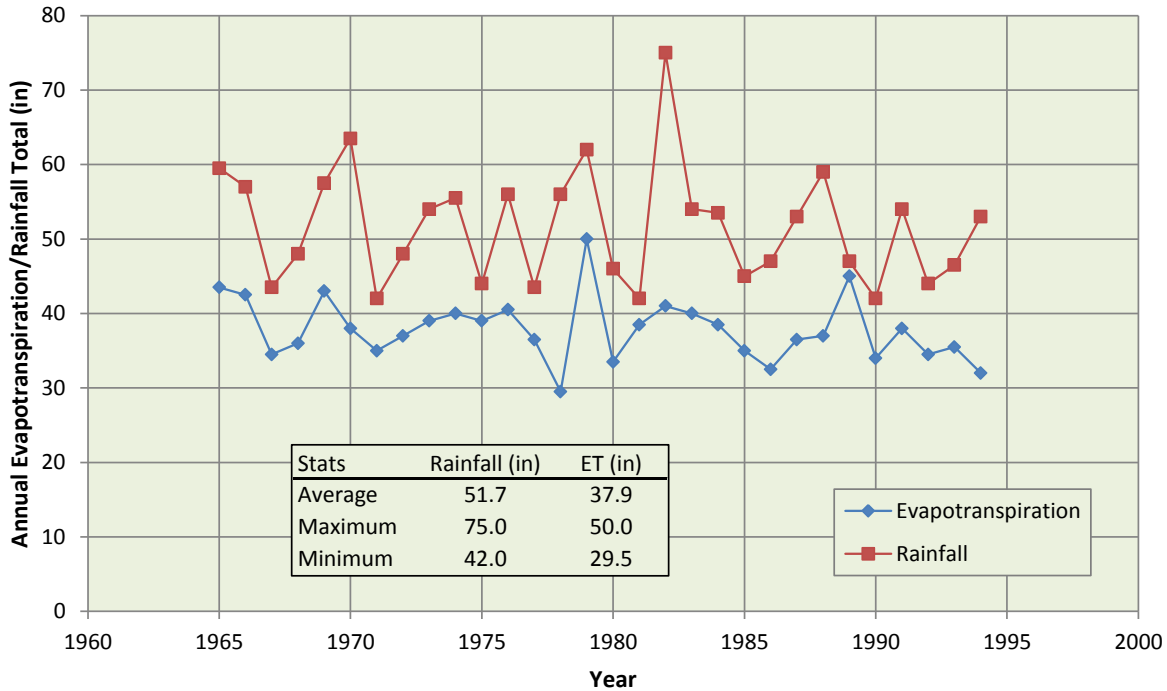


Exhibit 3-2. Marion County estimated annual average evapotranspiration and rainfall for the study period from 1965 through 1994 (Knowles 1996)

3.1.3 Groundwater Recharge

Since there are no significant surface water drainages in the area other than the Rainbow River, the difference between rainfall and ET provides a reasonable estimate of groundwater recharge in the Rainbow Springshed. The average recharge rate was estimated between 1965 and 1994 as about $51.7 - 37.9 = 13.9$ inches per year. Over the springshed area estimated by Jones *et al.* (1996) this is equivalent to an average recharge of about 662 cfs (428 MGD). Faulkner (1973) estimated a higher recharge to the dry season springshed of about 15.2 inches per year or about 724 cfs (468 MGD). During the 1965 to 1994 period, measured flows in the Rainbow River were 713 cfs (461 MGD). In the absence of groundwater pumping, the majority of this estimated average recharge within the mapped springshed was evident as flow from the Rainbow Springs Group.

Groundwater recharge rates can be highly variable based on elevation and subsurface conditions as well as ground cover. The aquifer vulnerability includes recharge potential as part of the analysis based on depth to groundwater and soil permeability. This data set can be used to provide a surrogate for groundwater recharge potential.

3.1.4 Groundwater Withdrawals

Determining the volume of groundwater withdrawals is imprecise because of varying monitoring/reporting requirements for many consumptive use permit (CUP) holders. In some cases water users do not need to report their actual water use and the only available information is the land use and the permitted amount. Existing CUPs within the Rainbow River springshed authorize an average daily groundwater pumping rate of approximately 50 MGD. Approximate locations of CUPs and permitted capacities are shown in Exhibit 3-3. It is

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important to note that on an annual average basis most users will not be using their full permitted allocation. However, during the driest years more water is typically used.

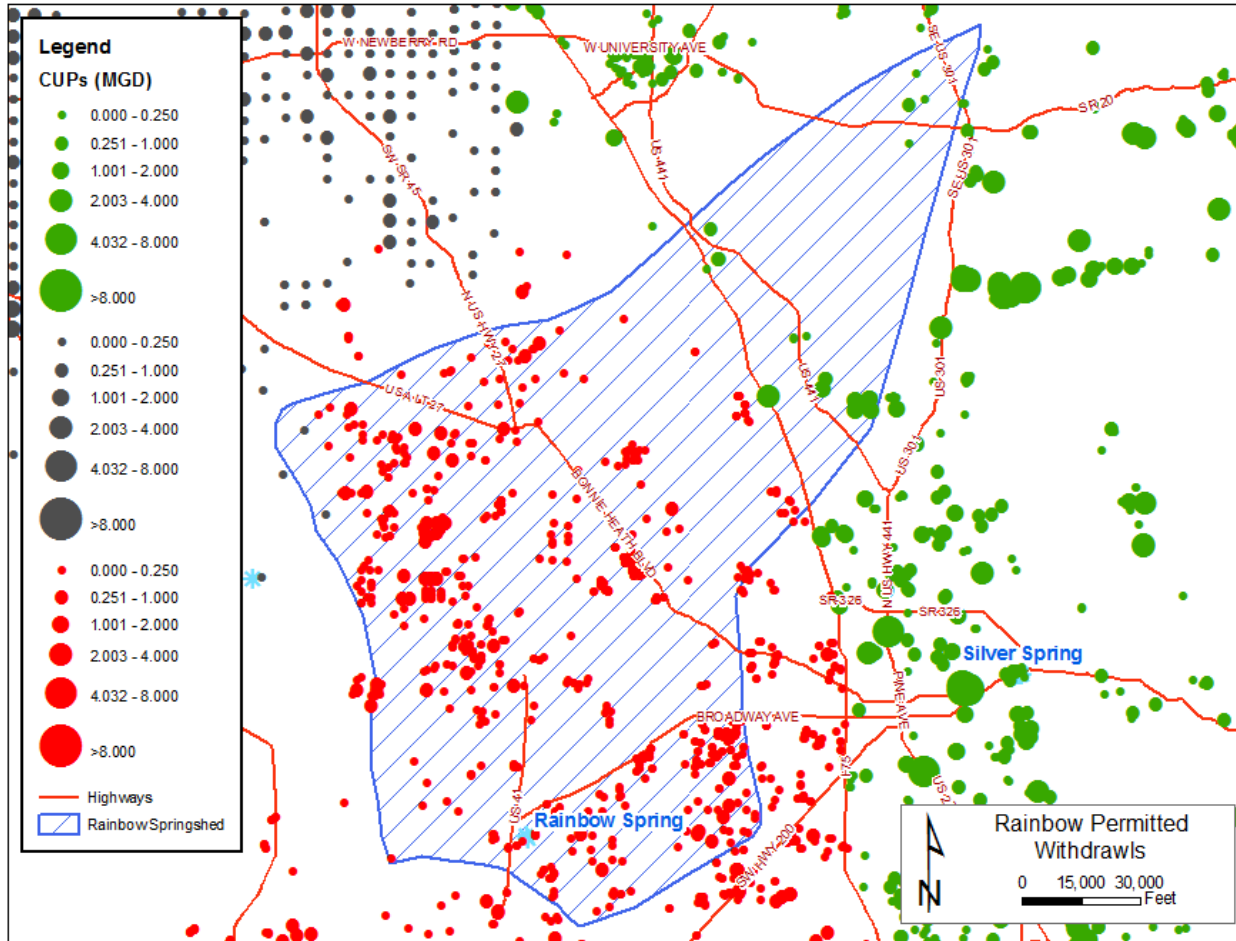


Exhibit 3-3. Consumptive Use Permits within the Rainbow River Springshed by Water Management District (green = SJRWMD, yellow = SRWMD, and red = SWFWMD)

Exhibit 3-4 provides a summary of all of the existing water use permits in North Florida through 2012. The 28,630 permits authorize approximately 4.63 BGD of groundwater extraction. The estimated average extraction in these three WMDs was about 2.62 BGD in 2010 (Marella 2013). The estimated groundwater pumping rate in the Southwest Florida Water Management District from 22,800 water use permits in 2010 was 1.1 BGD and the permitted pumping rate is 2.83 BGD.

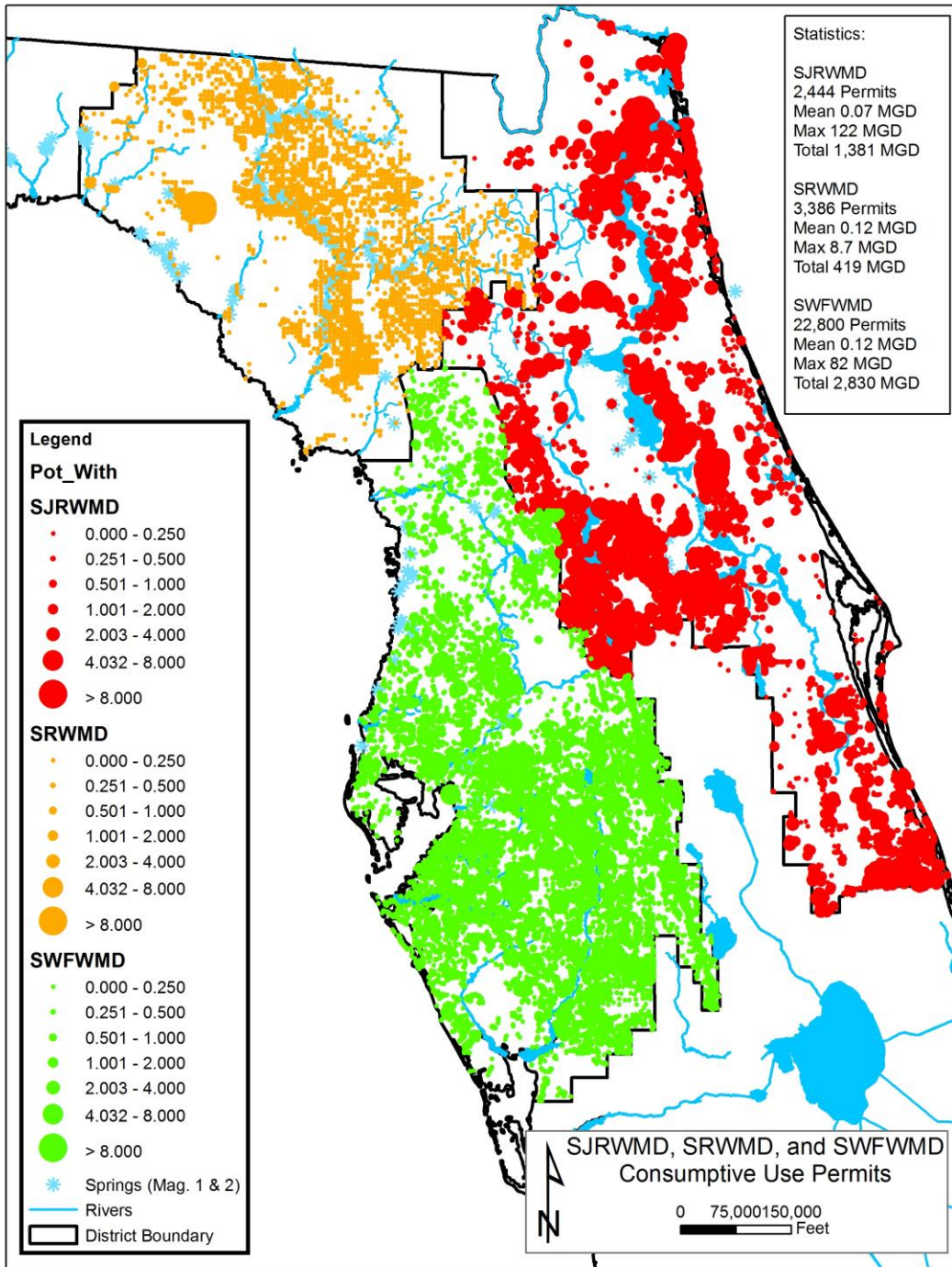


Exhibit 3-4. Consumptive Use Permits within North Florida likely affecting the Rainbow River Springshed by Water Management District (red = SJRWMD, yellow = SRWMD, and green = SWFWMD). In 2012 there were a total of 28,630 existing water use permits in these three WMDs, authorizing the average pumping of up to 4.63 BGD or roughly 33 percent of the estimated annual average recharge to the entire Floridan Aquifer.

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Freshwater uses in the vicinity of the Rainbow Springshed have been summarized by county by the U.S. Geological Survey (Marella 2013). Uses for public supply, commercial/industrial, and recreation are considered to be relatively accurate while other water uses for agriculture and self-supply are estimates. All of the Rainbow Springshed is included in three counties: Alachua, Levy, and Marion. The combined 2010 total freshwater use in these three counties was 158 MGD. If the estimated water use in each county is multiplied by the estimated percentage of each county in the Rainbow Springshed the total freshwater use is estimated at about 28 MGD.

Marion and Levy Counties make up an estimated 82 percent of the mapped springshed and are the most intense water users in the immediate vicinity of Rainbow Springs. The USGS estimates that about 98 percent of the freshwater used by humans in Marion and Levy Counties is pumped from the groundwater aquifer. The total estimated freshwater use in 2010 for these two counties was estimated as 103.8 MGD, with 71.3 MGD pumped in Marion County and 32.6 MGD pumped in Levy County. The biggest user of freshwater in these two counties is agriculture with 41.2 percent of the total (42.9 MGD). The second biggest use is public supply with 30.2 percent of the total (31.4 MGD). The next two highest uses are for domestic self-supply (14.8 percent) and recreational irrigation (7.2 percent).

3.2 Spring and River Discharge and Stage

Groundwater discharge from the Rainbow Springs Group, the springs along Indian Creek, and the numerous vents along the river account for 97 to 99% of the total flow of the river (Water and Air Research 1991). Of the total flow 89% of the water discharges in the upper 1.5 miles of the Rainbow River (Jones *et al.* 1996).

The US Geological Survey computes discharge of the Rainbow River (station # 02313100) based on the relation between discharge measurements (made 0.25 mi upstream of SR 484) and artesian pressure at a well near the head springs (well # 290514082270701, USGS 2008). Annual average discharge and well elevation data are presented in Exhibit 3-5. The USGS discharge measurements include daily average estimates from 1965 to 2012, with field measurement readings before 1965. Daily average well elevation data was available from 1964 to 2012. The annual average discharge from 1917 to 2012 was 702 cfs (453 MGD), with a minimum annual mean of 502 cfs (324 MGD) from 2011, and a maximum annual mean of 911 cfs (588 MGD) from 1965.

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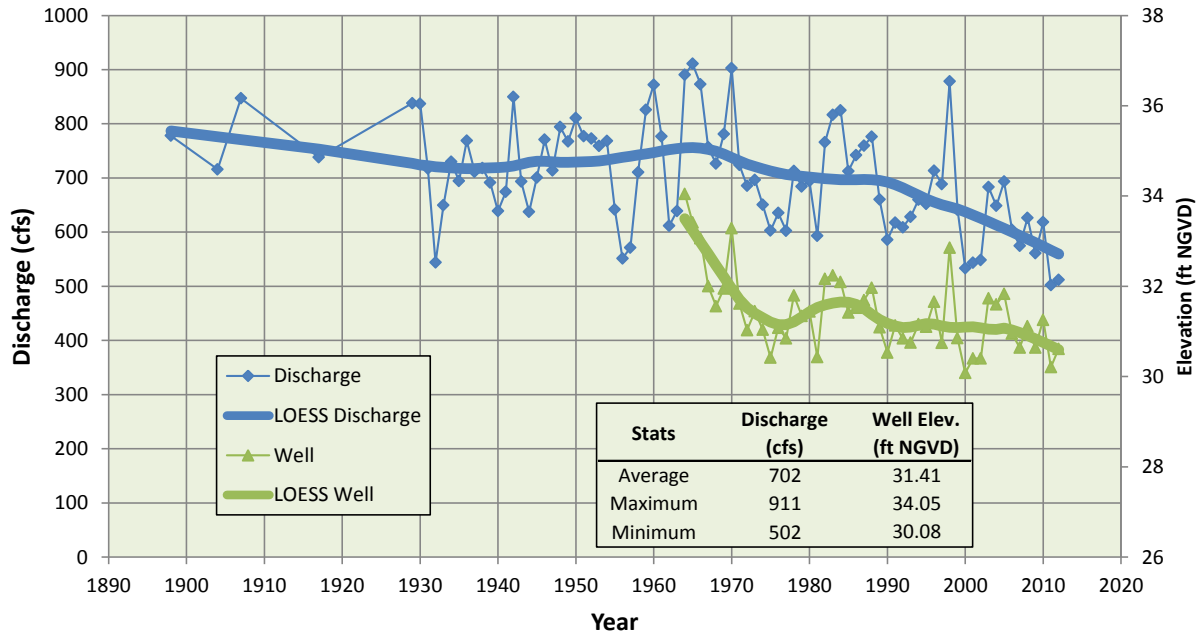


Exhibit 3-5. Rainbow River Discharge (1917 - 2012) and Rainbow Springs Well Elevation (1964 - 2012) with LOESS trend lines

The observed historic variation in discharge for the Rainbow Springs Group has been attributed to normal climatologic variability by the SWFWMD (Ron Basso, personal communication, August 31, 2012). Based on a comparison of seasonal flows at Rainbow and Weeki Wachee springs, Champion and Starks (2001) noted that the lowest discharge values for both spring systems are observed in June and highest discharge values are observed in October, a response which roughly corresponds to typical rainfall patterns in central Florida. In turn, annual average discharge data between these two spring systems are similar and suggests that rainfall inputs broadly control spring discharge rates.

The District’s conclusion that rainfall variability is the predominant factor currently affecting flows at Rainbow Springs is called into question in the analysis illustrated in Exhibit 3-6. Since 1960 average rainfall totals in Marion County have declined by about 11 percent while average spring discharge has decreased by 25 percent. An analysis of the response between annual average rainfall and annual average spring discharge for Rainbow Springs (Exhibit 3-6) indicates that this relationship is changing over time. Where an annual rainfall of 50 inches per year generated an average spring discharge of 700 cfs in the 1960s, the same rainfall only generates about 600 cfs of spring flow during the 2000-2012 period, for a 14% estimated decline independent of annual average rainfall. This observation reflects a continuing drawdown in the surface of the Floridan Aquifer in the vicinity of Rainbow Springs. WSI (2010) previously concluded that long-term flows at Rainbow Springs are reduced by about 15% due to factors other than rainfall declines.

This analysis indicates that average Rainbow Springs discharge prior to 1950 was about 750 cfs (485 MGD). Based on the estimated 14% decline independent of rainfall, recent flows at Rainbow Springs are reduced by an estimated 100 cfs (65 MGD), presumably due to regional groundwater pumping and resulting lower Floridan Aquifer levels.

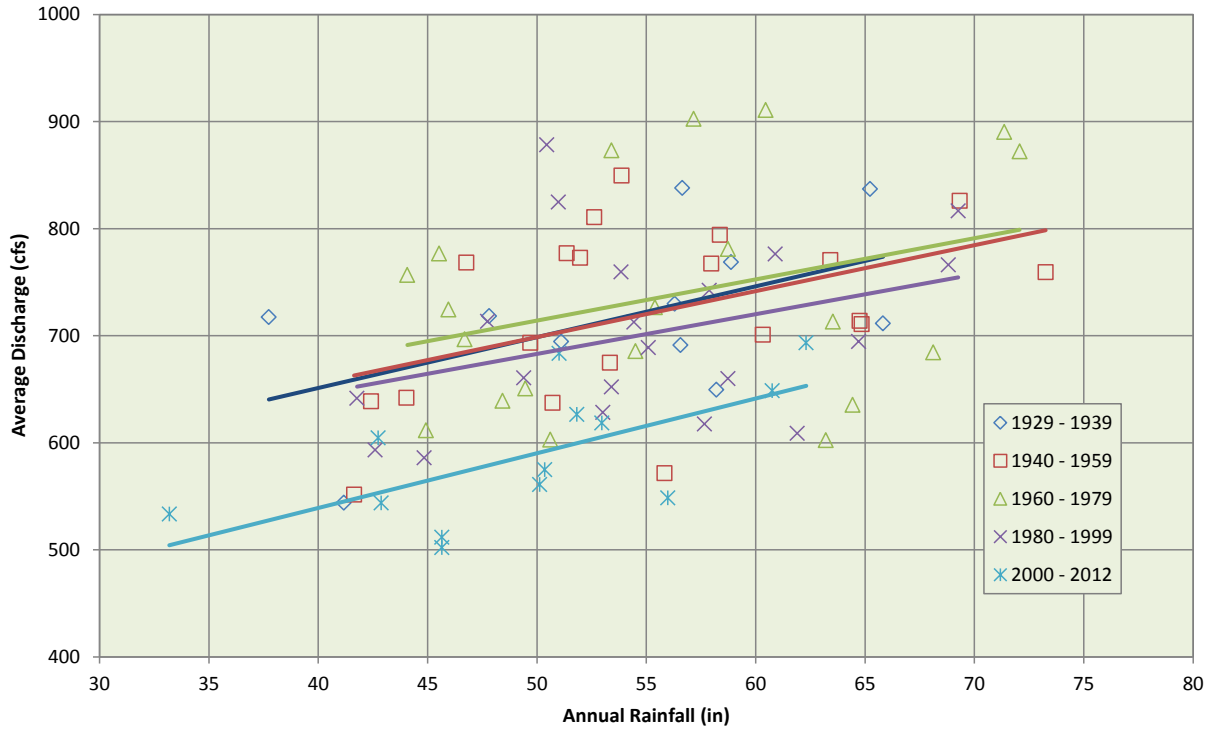


Exhibit 3-6. Marion County rainfall and Rainbow River discharge by 10-20 year periods

3.3 Floridan Aquifer Levels

Aquifer declines are most evident in areas of Florida with high groundwater extraction rates and minimal groundwater recharge due to the presence of overlying confinement (Exhibit 3-7). Areas of greatest average aquifer drawdown since pre-development in North and Central Florida are located in Hillsborough and Polk Counties (about 60 feet), Orange County (about 30 feet), and Duval and Nassau Counties (50 to 60 feet). Aquifer level declines in the Rainbow Springshed over the past century are much less but are still evident. Based on data reported by the USGS (Williams *et al.* 2011) and the analysis of long-term aquifer declines summarized in Exhibit 3-7 (Tom Greenhalgh, FGS, personal communication, May 2013), the average long-term aquifer drawdown in the Rainbow Springshed is between 8 and 15 feet (2.4 to 4.6 m).

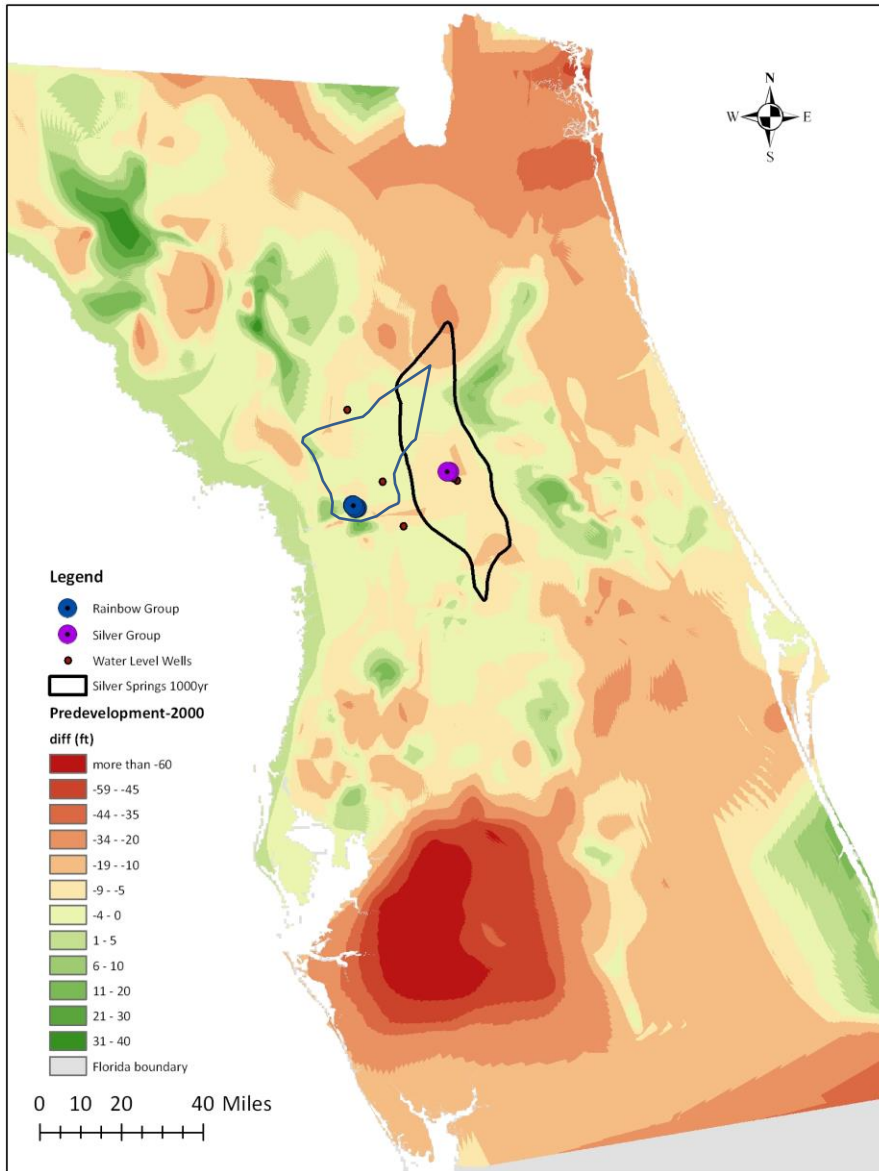


Exhibit 3-7. Estimated Drawdown in Floridan Aquifer Between Pre-Development and 2000 in North and Central Florida (Florida Geological Survey). The locations of the Rainbow and Silver Springs Groups and intervening monitoring wells are illustrated.

3.4 Relationship between Groundwater Levels and Spring Discharge

Groundwater levels dictate spring discharge. When water infiltrates to the groundwater table it raises the water level and due to the effects of gravity the mounded water creates hydrostatic pressure. Spring vents provide naturally-occurring outlets from the Floridan Aquifer System that allow this pressure to dissipate. Because springs are typically connected to conduits that allow large volumes of water to move quickly, springs receive preferential flow from changes in the level of water pressure head in the aquifer. The concept is similar to a hydraulic jack working in reverse where a small pressure (water infiltrating) applied over a large area

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(springshed) is converted to a large pressure over a small area (spring vent). Groundwater levels can be used to measure the driving forces on spring flow. When groundwater levels in wells increase within the springshed, flows at spring vents increase. When the potentiometric surface of the aquifer declines, spring flow declines. In a highly transmissive portion of the aquifer such as occurs in the vicinity of Rainbow Springs, a relatively small decline in aquifer levels results in a significant reduction in spring flows (Exhibit 3-8). This analysis indicates that a 2-ft (0.6 m) decline in aquifer levels equates to a 200 cfs (129 MGD) flow reduction or an average decline of about 22%.

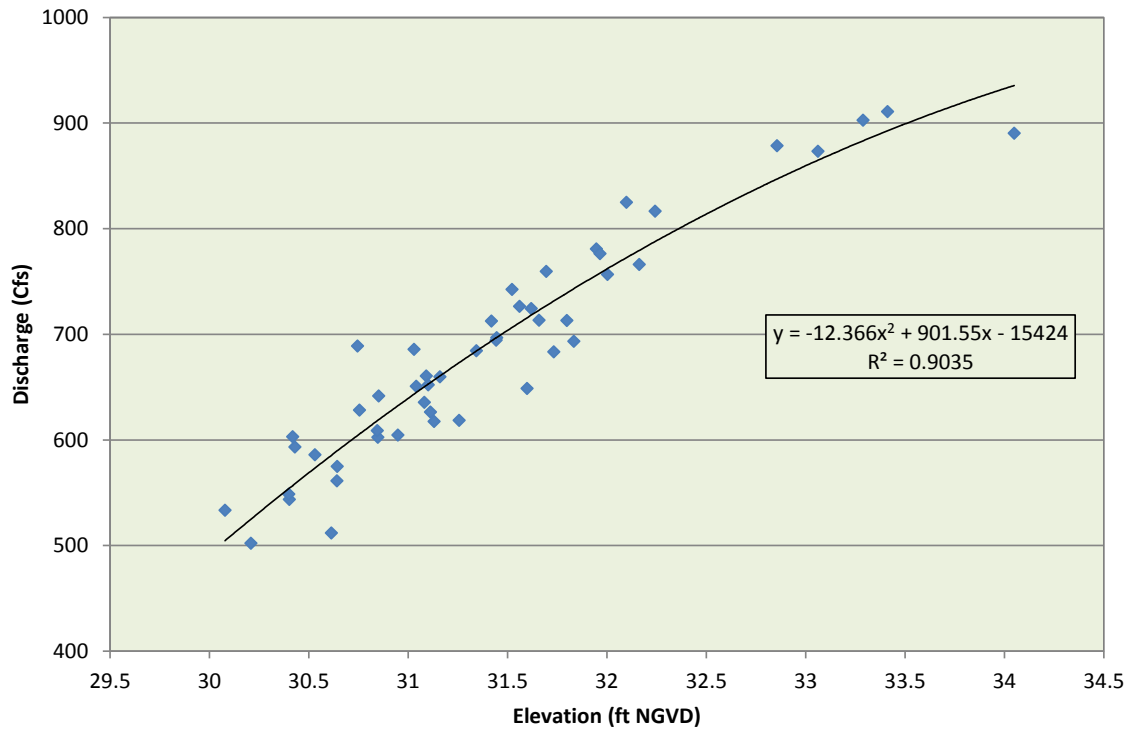


Exhibit 3-8. Relationship between annual average Rainbow Springs Well elevations and Rainbow River discharge (1964-2012)

3.5 Rainbow and Silver Springs Divide

The groundwater divide between the Silver River and Rainbow River springsheds is poorly defined. This potentially overlapping area is at least 286 square miles based on the maximum extent springsheds mapped for Silver River and Rainbow River Springs (Exhibit 2-4). The Rainbow River springshed is 686 square miles meaning that this overlapping area is 40% of the total area of the springshed. In this area, as shown previously, the potentiometric surface is assumed to be nearly flat. In part, this appearance of flatness could be an artifact of insufficient groundwater level data in this area. Assuming that the level of the FAS between Rainbow and Silver is relatively flat, the groundwater divide between these two springs has the ability to move during wet or dry years (Exhibit 3-9). Because of the flatness of the potentiometric surface of the FAS in this area, slight decreases in the aquifer water level can cause shifts in the springshed boundaries by miles, resulting in changes in the areas contributing recharge to the springs by hundreds of square miles.

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The surface elevation of the Silver River in the vicinity of the spring vents (38.60 feet above mean sea level [msl]) is approximately 10 feet higher than the Rainbow River spring boil (28.34 feet msl). Because of the difference in spring boil elevations the SJRWMD hypothesized that springs on the Rainbow River are “pirating” flow from the Silver River springs.

The theory that Rainbow Spring’s flows are higher as a result of captured water that previously recharged Silver Springs is supported by the observation that spring flow declines are greater in the Silver River versus the Rainbow River. Annual average discharge rates for Rainbow and Silver springs are illustrated in Exhibit 3-10. Over this entire 61-year period-of-record, prior to 1985 the typical difference between average flows for these two first-magnitude springs was about 70 cfs (45 MGD). This balance started to change in 1985 when average flows at Silver Springs began to decline faster than flows at Rainbow Springs (Exhibit 3-11). Beginning in 1999, average flows at Rainbow Springs have been higher than average annual flows at Silver Springs. The combined flows for these two springs have declined by about 24% (354 cfs or 229 MGD) since 2000 compared to the previous period-of-record. In 2011 both spring groups had record low flows, and Rainbow Springs’ flows were 117 cfs (76 MGD) higher than at Silver Springs.

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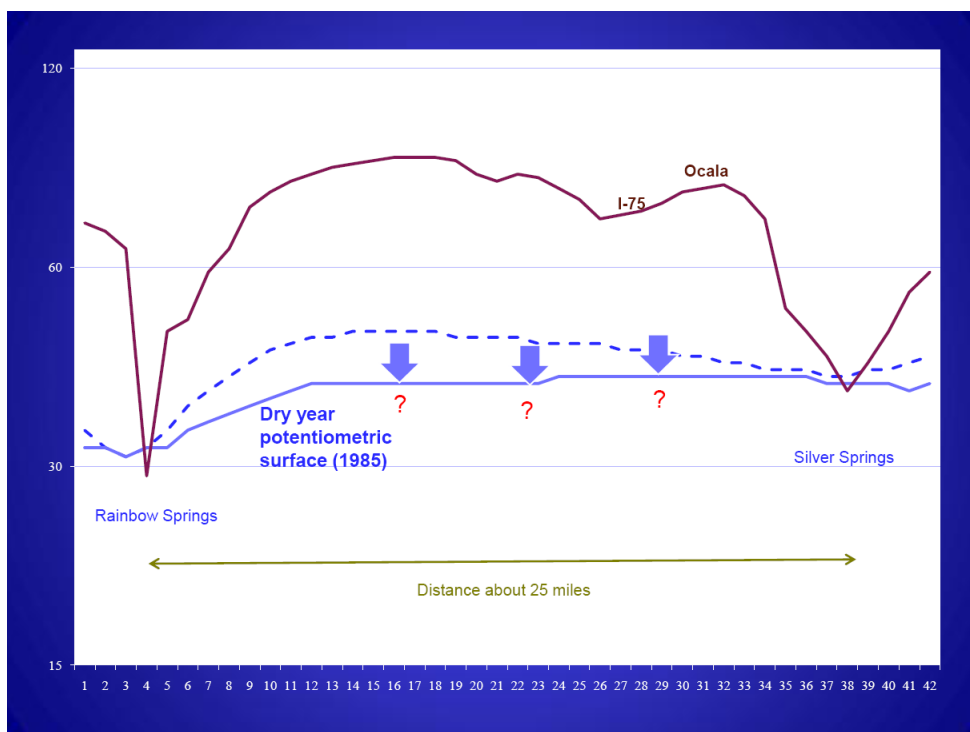
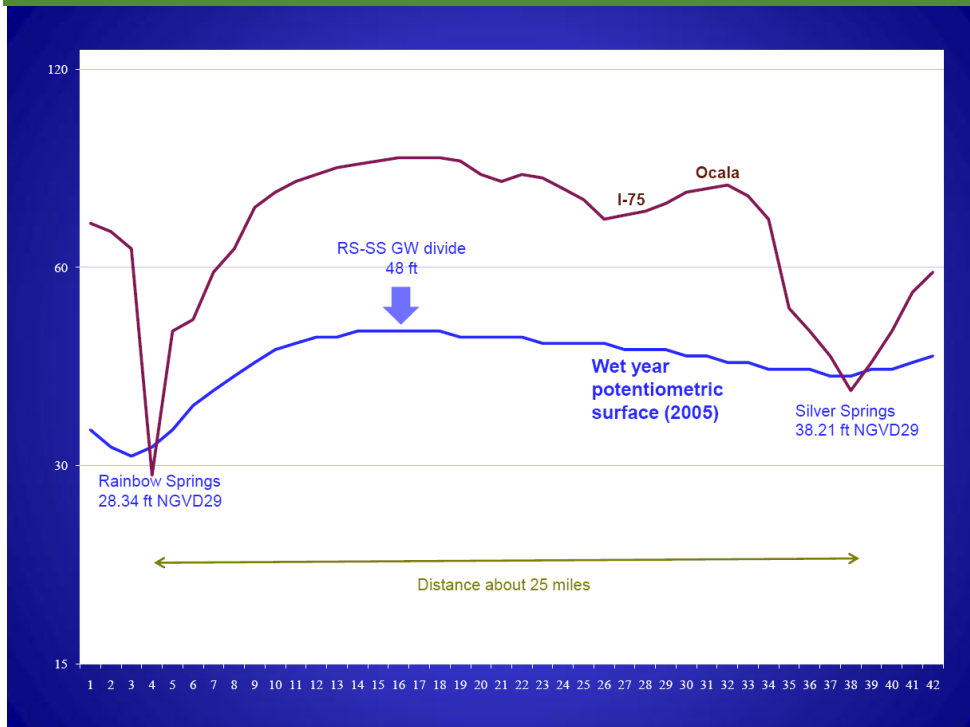


Exhibit 3-9. Cross-section between Rainbow Springs and Silver Springs illustrating typical wet and dry year potentiometric surfaces in the Floridan Aquifer. The arrows on the two figures illustrate the estimated position of the groundwater divide. During dry years it is estimated that the springshed area feeding Silver Springs declines significantly while the springshed for Rainbow Springs increases by an equal amount (SJRWMD 2010).

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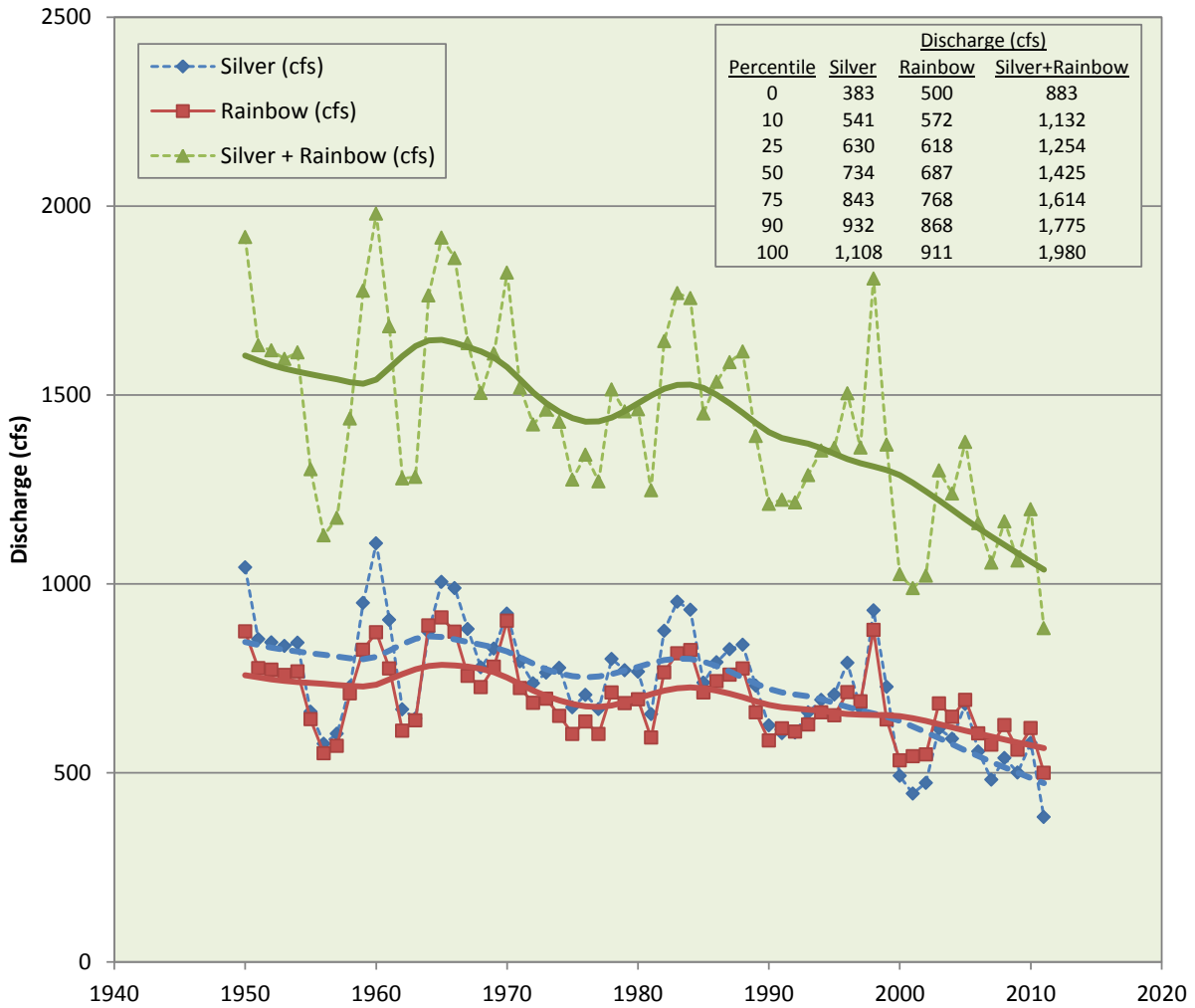


Exhibit 3-10. Annual average discharge measured at Rainbow and Silver Springs in Marion County. LOESS trend lines are also shown. The combined and individual flow rates of these two springs have been declining since the 1950s. The median combined flow for the two springs for the period from 1950 through 2011 was 1,425 cfs (920 MGD). Over the entire period the median annual flow at Rainbow Springs was 687 cfs (444 MGD) and 734 cfs (474 MGD) at Silver Springs.

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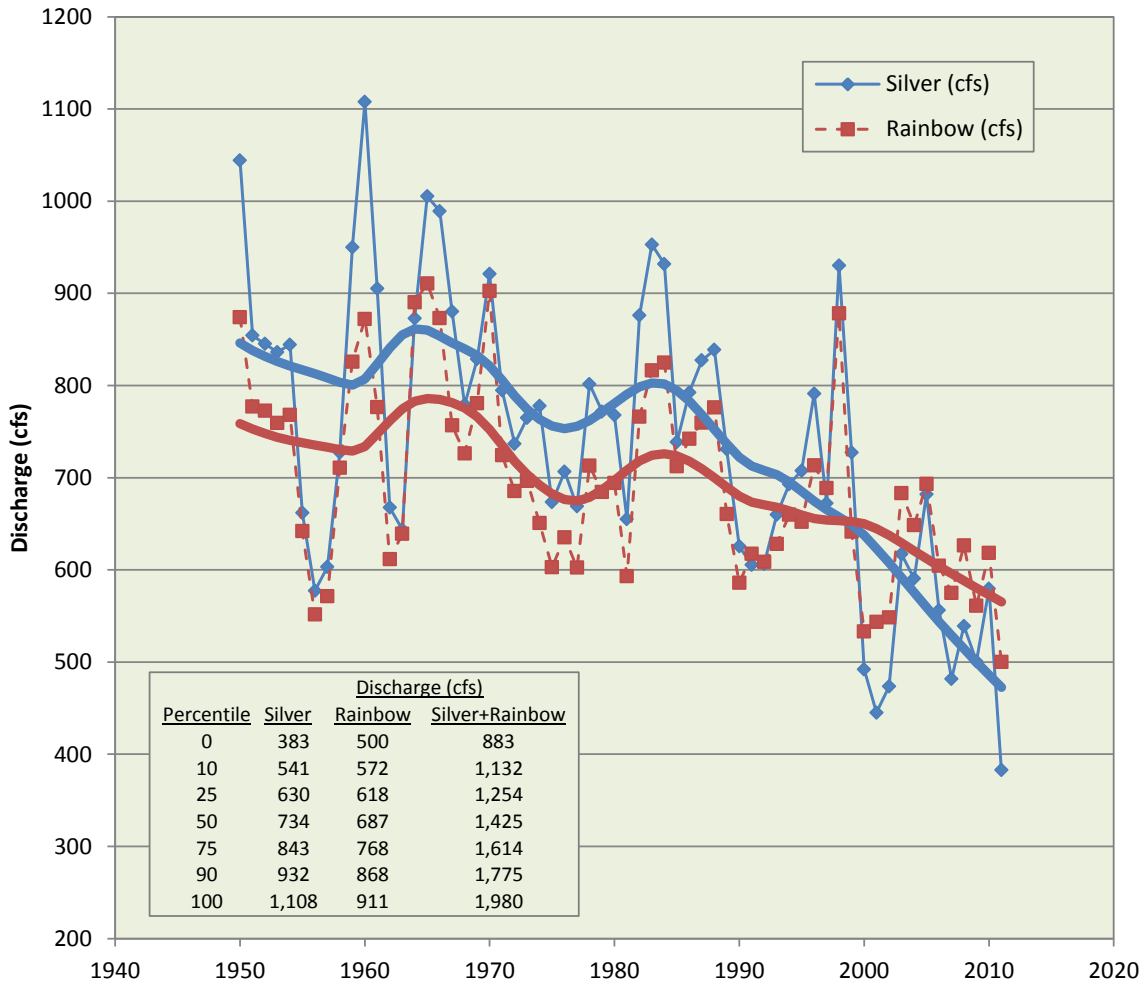


Exhibit 3-11. Expanded view of annual average flow data at Rainbow and Silver Springs with LOESS trend lines. Silver Springs consistently average about 70 cfs (45 MGD) higher than Rainbow Springs until 1985. Since 1998 average annual flows at Rainbow Springs have been higher than at Silver Springs. In 2011 flows at both spring groups were the lowest in recorded history and the difference in flows was 117 cfs (76 MGD).

3.6 Rainbow Springs Water Balance

Knowles (1996) presented an estimated 30-year (1965-94) average and annual water budget for Rainbow and Silver Springs. For his analysis he used average springshed areas of 640 mi² for Rainbow and 912 mi² for Silver, for a combined springshed of 1,552 mi². The average combined discharge from the two springs during this period was measured as 1,500 cfs (969 MGD), and the individual average discharge rates were 715 cfs (462 MGD) for Rainbow Springs and 783 cfs (506 MGD) for Silver Springs. Because of the prevalence of karst topography and the general lack of other surface water discharge points, in this combined springshed basin, Knowles concluded that recharge is essentially equivalent to spring discharge and pumping.

Over this 30-year period centered on 1979, Knowles estimated for the combined Silver and Rainbow Springsheds that average rainfall was 51.7 in (131 cm), an amount equal to the long-term rainfall measured over this portion of North Florida. ET was estimated as 37.9 in (96 cm),

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springflow was 13.1 in (33 cm), and that the difference (0.7 in or 1.8 cm) was accounted for by pumping and other stream flow (none observed). There was also a 0.6 in (1.5 cm) decline in the volume of the groundwater in the Floridan Aquifer during this period-of-study. These estimates indicate that groundwater pumping and loss of groundwater storage were approximately 9 percent of recharge during the period of the Knowles study. Thus springflow in the combined system was effectively being reduced by an average of about 9% or 135 cfs (87 MGD) due to groundwater extractions as early as 1979.

The estimated average water balance for Rainbow Springs during this 30-year period was:

- Rainfall - 53.2 in (135 cm)
- ET - 38.5 in (98 cm)
- Recharge - 14.7 in (37 cm)
- Springflow - 15.2 in (39 cm)
- Pumping - 0.3 in (0.8 cm)
- Loss of storage - 0.8 in (2.0 cm)

Knowles' estimates indicated that groundwater pumping and aquifer depletion was already reducing spring flows at Rainbow Springs by about 7% or 50 cfs (32 MGD) as early as 1979.

There is increasing evidence that regional pumping of the Floridan Aquifer is resulting in regional declines in the potentiometric surface of the aquifer and declining springs flows (Williams *et al.* 2011, Bush and Johnson 1988). The observed flow decline at Rainbow Springs over the past decade, independent of rainfall declines is estimated at about 14 percent or 100 cfs (65 MGD). This observed decline is considerably higher than estimated pumping rates within the historic springshed of Rainbow Springs, previously estimated in this report as 43 cfs (28 MGD).

Long-term flow declines at Rainbow Springs are most likely explained by the regional drawdown of the Floridan Aquifer, especially through the effects of high groundwater extraction rates in areas of low recharge (Williams *et al.* 2011). As the spatial area of large regional drawdowns increases, the adjacent springshed boundaries migrate away from the pumping centers and towards the springs, effectively reducing the areas that contribute flows to the springs (Grubbs 2011).

The historic combined discharge from Silver and Rainbow Springs was estimated by Knowles (1996) at about 1,500 cfs (969 MGD). For the 10-year period of record from 2002 to 2011, the estimated combined reduction of the average flow from the two springs is about 354 cfs (229 MGD). No more than about 155 cfs (100 MGD) of this average flow reduction can be explained by current estimated pumping rates in the two springsheds. This simple water balance indicates that a minimum of about 200 cfs (129 MGD) or more than 50 percent of the observed flow reduction in these two springs is likely due to the effects of regional groundwater extractions from the Floridan Aquifer System.

Section 4.0 Water Quality

Water quality data for Rainbow Springs are available from as early as 1927, as reported by Rosenau *et al.* (1977). However STORET data (USGS and FDEP data) primarily spans the period from the 1990s to as recent as 2010 at multiple stations, with limited data back to the 1950s. Additionally the SWFWMD has completed sampling in the Rainbow River at multiple stations from the 1990s to the present. Between the 1990s and 2000s the SWFWMD has reported water quality data from a total of nine currently-active stations and 23 inactive stations.

All available Rainbow Springs and River water quality data are summarized in Appendix A, along with statistics for the available water quality parameters, as well as annual averages (if available), and the period-of-record (POR) dates. Exhibit 4-1 provides an example of the typical water quality at Rainbow Springs POR averages at the SWFWMD station RR1 (located immediately downstream of the head springs) for several key parameters (with the number of samples).

Exhibit 4-1. Selected water quality parameters at SWFWMD Station RR1 for the Period-of-Record (2002-2012)

Parameter	Units	Average	# of Samples
Total Alkalinity	mg/L	68.0	48
Dissolved Oxygen	mg/L	7.31	45
Nitrate+Nitrite (as N)	mg/L	1.56	63
pH	SU	7.84	82
Total Phosphorus (as P)	mg/L	0.028	67
Secchi-horizontal	m	65.9	34
Specific Conductance	uS/cm	184	45
Temperature	deg C	23.1	45
Turbidity	NTU	0.089	66

4.1 General

Water quality sampling has taken place on the Rainbow River for nearly a century. Sampling was performed initially in the vicinity of the main boil. Over time the area of water quality sampling was expanded to include stations in individual spring vents. Later the SWFWMD also began sampling at multiple points downstream from the head spring area along the Rainbow River. The locations of these river stations have varied over time and currently include nine stations along the length of the river.

Generally water quality data are relatively consistent between recent and historic values. General water quality conditions that have not changed appreciably over the last century include temperature (about 23.1 °C year-round), a pH of 7.84 standard units (s.u.) which varies diurnally at downstream stations in response to primary productivity, a specific conductance of about 184 uS/cm, a total alkalinity of about 68 mg/L as CaCO₃, and a total phosphorus of about 0.03 mg/L. Other water quality parameters that have shown changes over time at Rainbow Springs and Rainbow River are described in more detail below.

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4.2 Water Clarity

Water clarity, or transparency, in the Rainbow River is very high at over 60 m (200 ft) near the headspring area. This makes the Rainbow River one of the clearer spring systems that has been studied in Florida. However clarity has been observed to decrease with increasing distance downstream. Much of this decline in water clarity, as measured using the horizontal Secchi disc method (Odum 1957), is the direct result of increasing particulate matter, resulting from the release of microscopic attached algal cells from plants and sediments (pseudo-plankton) with distance downstream (Exhibit 4-2). Anastasiou (2006) reported that approximately 80% of the variation in water clarity in the Rainbow River can be explained by algal chlorophyll-a concentrations (Exhibit 4-3) with most of the loss of water clarity occurring at chlorophyll-a concentrations of 1 ug/L or less.

In a complementary study conducted by Cowell and Dawes (2005), phytoplankton were shown to be the primary source of the chlorophyll-a. Laboratory experiments indicated that up to 4-fold increases in either nitrate or phosphate had no significant effect on phytoplankton biovolume. However, algal biovolume increased when nitrate and trace metals were at elevated concentrations (Cowell and Dawes 2007) indicating a possible relationship.

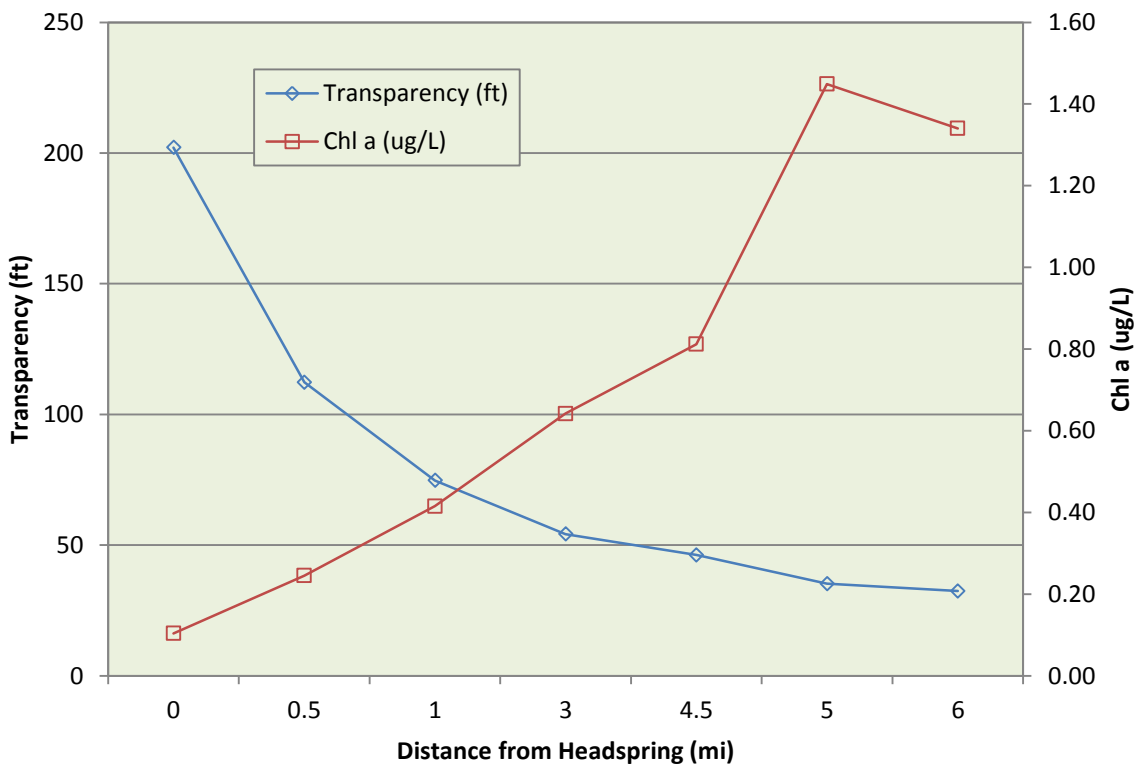


Exhibit 4-2. Horizontal Secchi measurements and chlorophyll-a concentrations in the Rainbow River (SWFWMD 2008)

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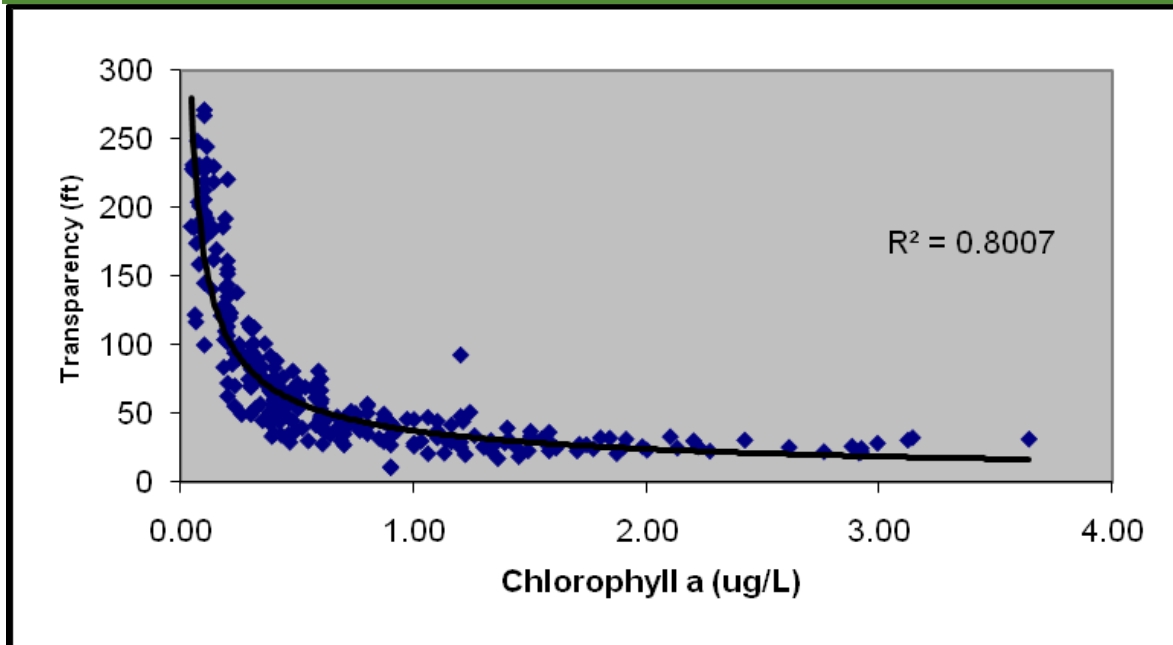


Exhibit 4-3. Relationship between Secchi measurements and chlorophyll-a concentrations in the Rainbow River (SWFWMD 2008)

4.3 Dissolved Oxygen

Dissolved oxygen (DO) concentrations in the Rainbow Springs Group are some of the highest in any large spring in the state. From 2001 to 2006, mean average DO was 6.58 mg/L at Rainbow #1, 5.74 mg/L at Rainbow #6, 5.17 mg/L at Rainbow #4, and 4.45 mg/L at Bubbling Springs (Harrington *et al.* 2010). The most commonly accepted explanation for high DO at spring vents is that the water being released is mostly derived from the upper portion of the aquifer and is therefore comparatively “young” water whose residence time in the aquifer has been relatively short (Katz *et al.* 1999).

DO concentrations generally increase with distance downstream in the Rainbow River as a result of high levels of primary productivity (WSI 2010). A distinct diurnal pattern of dissolved oxygen concentrations is evident along the length of the Rainbow River due to a release of produced oxygen from submerged plants and algae during daylight hours and respiratory consumption of dissolved oxygen by all submerged organisms in the dark (Exhibit 4-4, WSI 2010).

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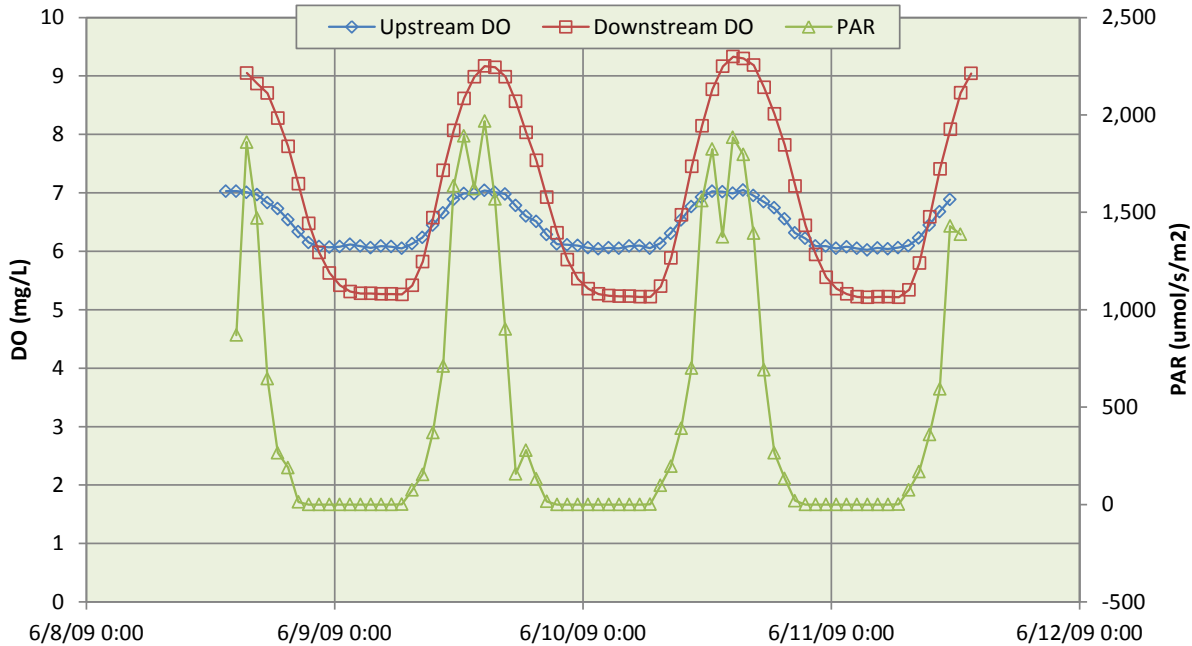


Exhibit 4-4. Dissolved oxygen (DO) diurnal pattern along the length of the Rainbow River (WSI 2010). PAR is photosynthetically active radiation or useable sunlight in the visible portion of the electromagnetic spectrum.

4.4 Nitrate

Rainbow Springs has experienced a significant increase in nitrate concentrations over the past four decades (SWFWMD 2008). Nitrate concentrations reported from the main spring pool during March 1927 were 0.08 mg/L (Ferguson *et al.* 1947). Recent nitrate concentrations at the Rainbow Springs complex (RR1) are consistently above 2.2 mg/L, an increase of about 2,650%. To develop a long term trend in nitrate concentrations in Rainbow Springs, a temporal analysis was developed that combined FGS, USGS, and SWFWMD data. The FGS data from 1927 and 1946 do not have a specific spring source included and were assumed to be collected from main boil stations. Similarly, the USGS station was a main boil station. Finally SWFWMD sampling site RR1 was used because of its location at the outlet from the head spring area.

These water quality data show an increase in nitrate from 0.08 mg/L in 1927 to over 2 mg/L in 2012 (Exhibit 4-5). The nitrate value in 1927 of 0.08 mg/L is approximately what is considered the background level although a value of 0.05 mg/L was reported at Silver Springs in December 1907 (Ferguson *et al.* 1947). As observed from the graph, the rate of nitrate increase appears to have accelerated since 2000 with a recent rate-of-increase of more than 0.1 mg/L per year.

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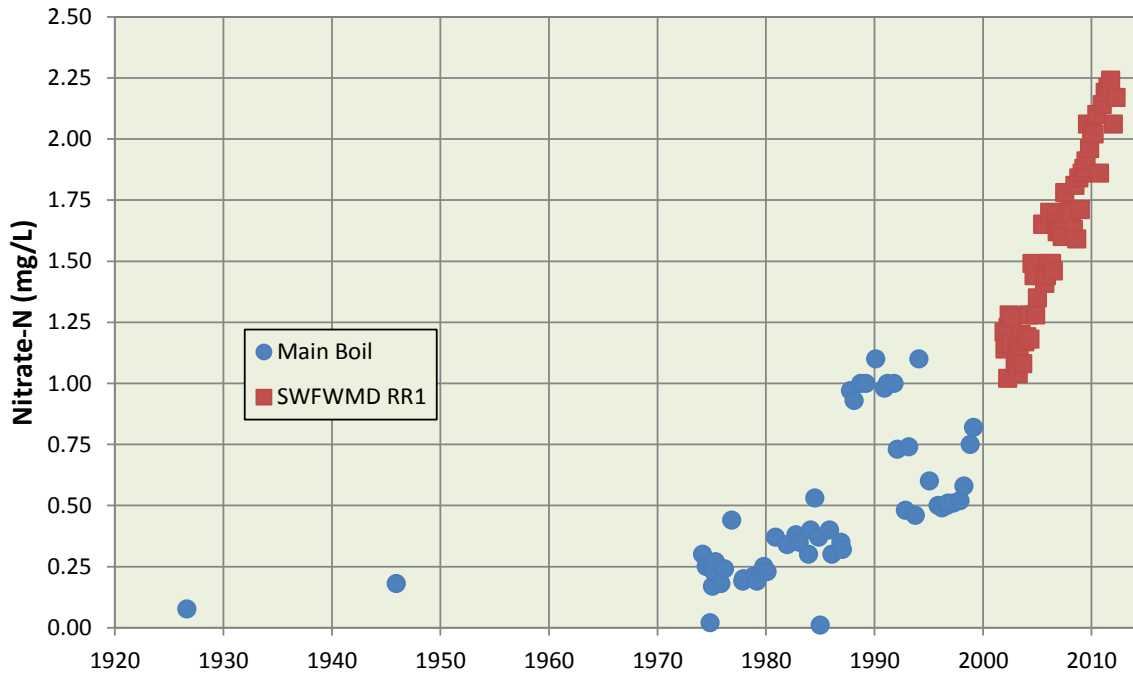


Exhibit 4-5. Nitrate concentrations in the vicinity of the Main Boil at Rainbow Spring from 1927-2012. Average nitrate concentrations have risen by 27 fold since the 1920s.

Based on average flows at Rainbow Springs and average nitrate concentrations in the Rainbow Spring boil area, the total nitrate mass was calculated by decade (Exhibit 4-6). This exhibit documents the observation that the total mass of nitrate discharged from the groundwater to the Rainbow River has sharply increased from about 54 tons per year (49 MT per year) before 1934 to about 1,011 tons per year (917 MT per year) on average between 2005-12 or more than 1,700% at the same time that average flows have decreased more than 18%.

Exhibit 4-6. Mass load of nitrate by decade for Rainbow Springs Head Spring Area

Period	Avg. Flow (cfs)	Avg. Nitrate-N (mg/L)	Nitrate-N Annual Load (MT)
1925-1934 ¹	719	0.08	49
1935-1944	708	--	--
1945-1954 ²	763	0.18	123
1955-1964	709	--	--
1965-1974 ²	771	0.30	207
1975-1984	693	0.26	161
1985-1994	675	0.69	415
1995-2004	653	0.97	565
2005-2012	587	1.75	917

¹Flow is for 1929-1934 with Nitrate-N from 1927

²Only a single Nitrate-N concentration available

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Water samples collected by the SWFWMD Water Quality Monitoring Program from 2002 to 2012 also illustrate the trend of increasing nitrate concentrations in the Rainbow River at the existing active stations (Exhibit 4-7). This graph documents a decline in nitrate concentrations with distance downstream from the headspring. This downstream decline in nitrate concentrations is presumably due to uptake by submerged aquatic plants and algae and dissimilatory (denitrification) microbial processes (Heffernan and Cohen 2010). Detailed nitrate studies conducted in eight spring runs (Cohen *et al.* 2011) indicate that nitrate dissimilation is closely linked to the previous day's primary productivity, emphasizing the need to preserve optimum conditions for autotrophic productivity in polluted spring runs.

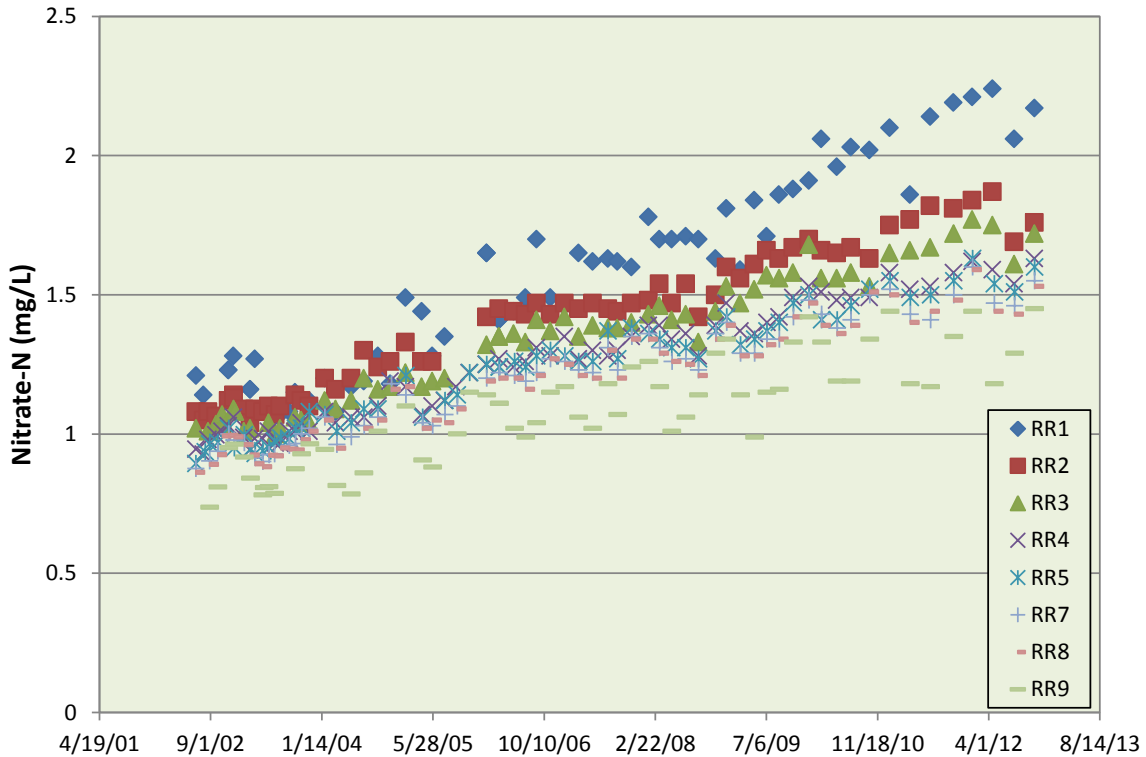


Exhibit 4-7. Rainbow River nitrate concentrations at SWFWMD monitored stations. Average nitrate concentrations at all stations have been on the rise throughout the period-of-record. Average nitrate concentrations generally decline from upstream to downstream.

The FDEP has primarily sampled nitrate from three spring vents in the area of the main boil (#1, #4, and #6) with samples taken from 2001 to 2010 (Exhibit 4-8). As shown previously, these data indicate increasing nitrate concentrations over time. The data also indicate that the source of water feeding Rainbow Spring #6 is somewhat different than the sources feeding the other two vents. As shown previously all three of these spring vents are showing large increases in nitrate with Rainbow Spring #1 consistently reporting values greater than 2 mg/L.

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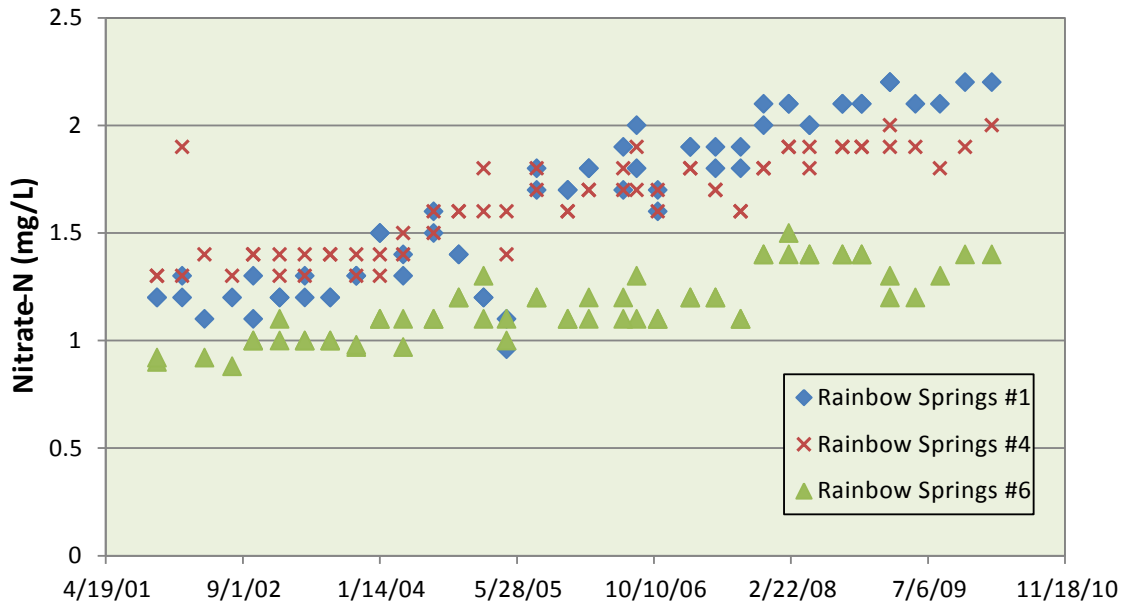


Exhibit 4-8. FDEP Spring Boil Nitrate Samples (2001-2010)

The source of nitrates delivered to the Rainbow Springs System has been investigated by Jones *et al.* (1996) and inorganic fertilizer (via agricultural application) was implicated as the dominant source. Current sources of nitrate loading also include residential and golf course fertilizers as well as septic systems (SWFWMD 2004). To date, SWFWMD monitoring has not detected any priority pollutants (e.g., cyanide, mercury, heavy metals, pesticides, and volatile organic compounds) from spring vent samples (SWFWMD 2008).

Section 5.0 Biology

5.1 Vegetation

The earliest published record of submerged aquatic vegetation (SAV) and benthic algae in the Rainbow River was provided by Odum (1957), who characterized the river as being comprised of strap-leaved sagittaria (*Sagittaria kurziana*) beds in the upper reaches and then shifting largely to the macroscopic alga musk grass (*Chara* sp.) as turbidity increased downstream.

During a reconnaissance trip made by Wetland Solutions, Inc. on August 13, 2008, the submersed aquatic vegetation (SAV) of the spring pool and upper 1.5 km (0.9 mi) of the spring run were qualitatively noted (WSI 2010). Within the Rainbow Springs pool, SAV was confined to areas outside of the designated swimming zone, with strap-leaved sagittaria and Illinois pondweed (*Potamogeton illinoensis*) being the most common SAV species. Similarly, SAV was excluded in portions of the spring run, especially just below the aquatic preserve sign (1,700 m downstream), where recreational boats commonly anchor and in areas with rocky substrate. The percent area coverage of SAV was approximately 80 % in the upper 3.5 km (2.2 mi) of the spring run. SAV species in the spring run from most to least common were: strap-leaved sagittaria, Illinois pondweed, tape grass (*Vallisneria americana*), bladderwort (*Utricularia* sp.), red ludwigia (*Ludwigia repens*), hydrilla (*Hydrilla verticillata*), and coontail (*Ceratophyllum demersum*).

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Hydrilla was more common with distance downstream in the Rainbow River. Benthic algae were observed growing on some sediments as well as small clumps of floating filamentous algae, but neither type of algae was abundant in the upper spring run. In shallow shoreline areas bordering the spring pool and upper spring run, emergent aquatic plants are common, with Egyptian paspalidium (*Paspalidium geminatum*) being the dominant species in these areas.

The Rainbow River (downstream to Dunnellon for a sampling area of about 82 ha [203 ac]) was surveyed for SAV in 1991, 1996, 2000, and 2005 (Mumma 1996, SWFWMD 2007, Atkins 2012). For the 2005 survey, the primary objectives were to produce a GIS map of emergent and SAV and to conduct an analysis of change in SAV coverage relative to previous surveys (SWFWMD 2007). The project resulted in thorough and detailed distribution maps of SAV by species. Based on the 2011 evaluation (Atkins 2012) changes in SAV were evaluated. This report found that the four most common SAV species decreased in prevalence between 2005 and 2011. Atkins (2012) also evaluated the spatial extent of algae in the Rainbow River. This showed that the upper river had better vegetation index scores that decreased downstream. Benthic algae were observed to have nearly 60% coverage along the river with epiphytic algae having 27% coverage.

Findings from the 2011 SAV survey identified strap-leaved sagittaria, hydrilla, tape grass, and southern naiad (*Najas guadalupensis*) as the four most common species in the Rainbow River (as well as for all mapping efforts in the previous 20 years); while coontail and musk grass were next two most abundant species (Atkins 2012). The percent coverage of the most common SAV species has decreased between 1996 and 2011 with a combined reduction of about 22 percent or 11.4 ha (28 ac). The areas of bare substrate in the Rainbow River were also noted, and between the 1996 to 2011 time periods there was a substantial increase in bare substrate (161%, Exhibit 5-1). In addition, other important landmarks along the Rainbow River during the 2011 sampling were noted: there were 251 docks on the river, 87 spring vents of varying size were identified, and of the 21.6 km (13.4 ac) of shoreline mapped, 24% was classified as hardened (Atkins 2012).

Vegetation maps of the upper kilometer of the Rainbow Springs and River for 2005 for the four most common and the seven less common SAV species (as well as emergent vegetation and bare zones) are presented in Exhibit 5-2 and Exhibit 5-3, respectively (from SWFWMD 2007). The Atkins (2012) vegetation report also contains detailed SAV maps for the Rainbow River (to Dunnellon) for each of the surveyed time periods as well as detailed change analyses and discussions by species between the 1996, 2000, 2005, and 2011 time periods.

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Exhibit 5-1. Percent cover of SAV species and bare substrate in the Rainbow River from 1996, 2000, 2005, and 2011 surveys (Atkins 2012)

RELATIVE AREAS													
	Hectares	Hectares	Hectares	Hectares	Hectares	Hectares	Hectares	Hectares	Hectares	%	%	%	%
SAV Species	1996 Relative Area	2000 Relative Area	2005 Relative Area	2011 Relative Area	96-'00 Change	00-'05 Change	05-'11 Change	96-'11 Change	96-'00 Change	00-'05 Change	05-'11 Change	96-'11 Change	
Sagittaria kurziana	20.36	19.87	19.65	15.63	-0.48	-0.23	-4.02	-4.73	-2%	-1%	-20%	-23%	
Hydrilla verticillata	9.67	10.43	10.90	4.05	0.76	0.47	-6.86	-5.63	8%	5%	-63%	-58%	
Vallisneria americana	2.47	2.34	3.27	3.10	-0.13	0.93	-0.17	0.64	-5%	40%	-5%	26%	
Najas quadalupensis	1.02	0.39	1.86	2.30	-0.63	1.47	0.45	1.29	-62%	376%	24%	126%	
Chara sp.	0.57	0.84	0.39	1.22	0.27	-0.45	0.83	0.65	47%	-53%	213%	115%	
Ceratophyllum demersum	1.06	0.63	1.09	0.73	-0.43	0.46	-0.36	-0.33	-40%	73%	-33%	-31%	
Utricularia sp.	0.40	0.06	0.51	0.87	-0.35	0.45	0.37	0.47	-86%	783%	73%	116%	
Potamogeton illinoensis	0.23	0.29	0.27	0.60	0.06	-0.01	0.33	0.38	27%	-5%	120%	167%	
Ludwigia repens	0.02	0.03	0.10	0.09	0.004	0.07	-0.01	0.07	16%	266%	-8%	291%	
Fontinalis sp.	0.00	0.00	0.03	0.07	0.000	0.03	0.05	0.07			171%		
Myriophyllum sp.	0.00	0.01	0.00	0.05	0.005	0.00	0.05	0.05	125%	-51%	1228%	1365%	
Zizania aquatica	0.00	0.00	0.01	0.04	0.000	0.01	0.03	0.04			267%		
Nasturtium sp.	0.001	0	0.003	0.01	-0.001	0.003	0.01	0.01	-100%	100%	399%	1207%	
Hydrocotyle sp.	0.001	0	0.001	0	-0.001	0.001	-0.001	-0.001	-100%	100%	-100%	-100%	
Total	35.81	34.88	38.09	28.80	-0.92	3.21	-9.30	-7.01	-3%	9%	-24%	-20%	
Native Species	26.13	24.45	27.19	24.75	-1.68	2.73	-2.44	-1.39	-6%	11%	-9%	-5%	
Exotic Species**	9.67	10.43	10.90	4.05	0.76	0.47	-6.86	-5.63	8%	5%	-63%	-58%	
TOTAL AREAS													
	1996 Total Area	2000 Total Area	2005 Total Area	2011 Total Area	96-'00 Change	00-'05 Change	05-'11 Change	96-'11 Change	96-'00 Change	00-'05 Change	05-'11 Change	96-'11 Change	
Total SAV Occupied Area	52.92	51.15	53.57	41.48	-1.76	2.42	-12.09	-11.43	-3%	5%	-23%	-22%	
Bare	7.11	8.87	6.45	18.54	1.76	-2.42	12.09	11.43	25%	-27%	187%	161%	
Emergent	9.97	10.15	11.56	12.72	0.18	1.40	1.16	2.75	2%	14%	10%	28%	
Forested	10.84	10.55	10.64	10.53	-0.28	0.08	-0.11	-0.31	-3%	1%	-1%	-3%	
Total River Area	80.84	80.73	82.22	83.27	-0.10	1.49	1.05	2.44	0%	2%	1%	3%	

Notes: ** Hydrilla

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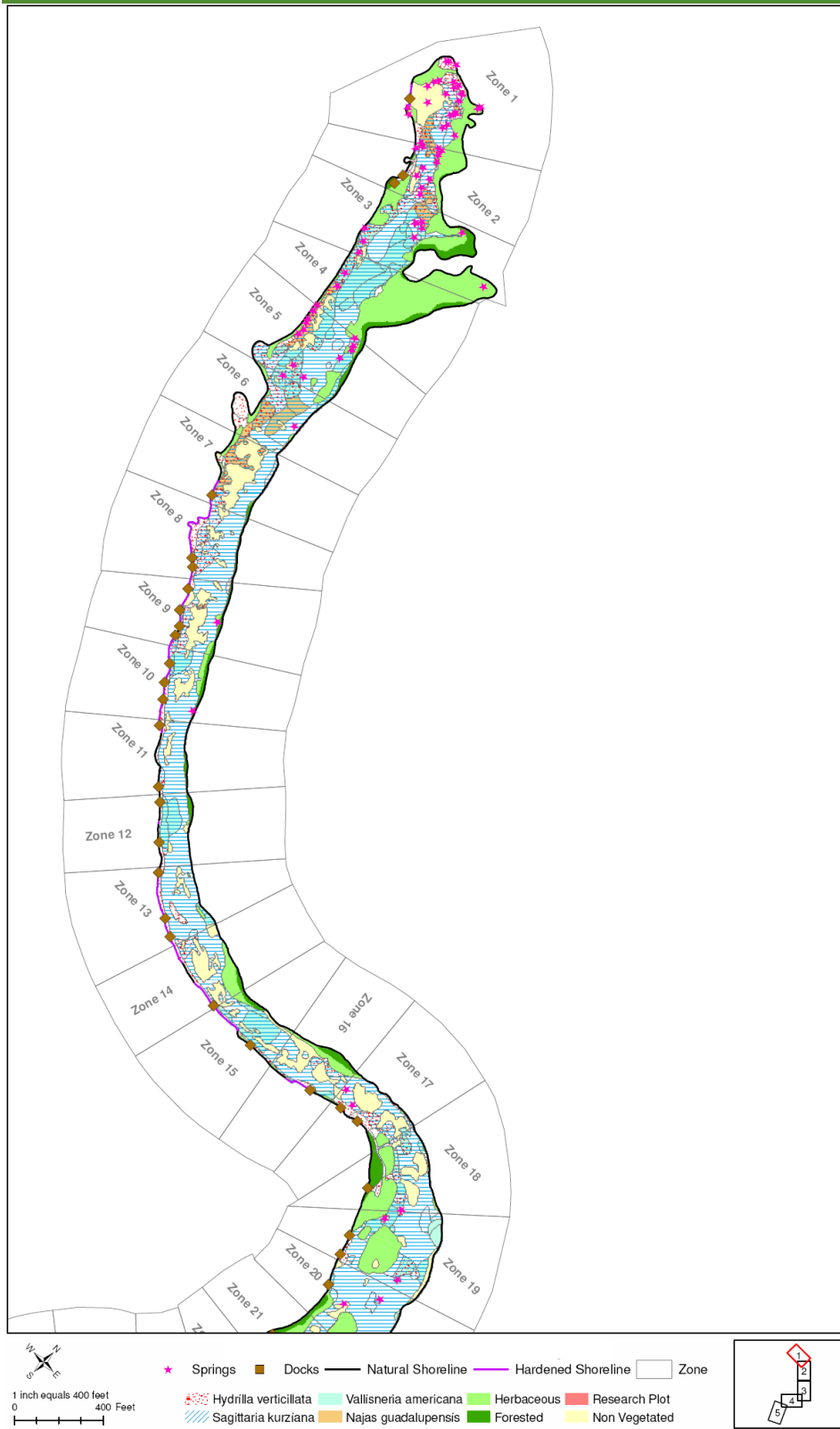


Exhibit 5-2. 2005 Map of the four most common SAV species, emergent plant communities, and bare areas (SWFWMD 2007)

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Exhibit 5-3. 2005 Map of the seven less common SAV species, emergent plant communities, and bare areas (SWFWMD 2007)

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Non-indigenous aquatic plants (primarily hydrilla) in the Rainbow River have been managed by the state through a variety of herbicide applications. During the 2006-2007 fiscal period, 7.3 ha (18 ac) of floating aquatic plants and 17 ha (42 ac) of hydrilla were treated (FDEP 2007a). Based on the SAV mapping and change analyses completed through 2011, the SAV community within the Rainbow River appears to be decreasing although in the context of hydrilla extent current management techniques are reducing hydrilla abundance (Atkins 2012). The effort of FDEP personnel to reduce the abundance of hydrilla within the pool and upper spring run of Rainbow Springs appears to have been successful.

During April 4, and November 12, 2003 the filamentous algae community of Rainbow Springs was surveyed by Stevenson *et al.* (2007) who concluded that elevated nutrient concentrations were contributing to the abundance of filamentous algae observed. At the headsprings area, filamentous algae coverage was 40.7% with a thickness of 3.4 cm (1.3 in) in April and coverage was 24.7% with a thickness of 6.1 cm (2.4 in) in November. The average algal species percent cover during these sampling periods was 19.8% *Lyngbya sp.*, 8% diatoms, and 6.8% *Aphanothece sp.* (the tiny, ball-like structures observable in the swim area).

5.2 Macroinvertebrates

Macroinvertebrates are an important part of the food chain and can provide an indication of ecosystem health. Several of the major vents surrounding the Rainbow Springs headpool area were sampled for crustaceans on June 6, 2002 by staff from the Florida Museum of Natural History (Franz 2002). Crustaceans collected included the freshwater shrimp (*Palaemonetes paludosa*), amphipods (*Hyaella sp.*), and crayfish (*Procambarus fallax*). Other crayfish species which have been documented for Marion County, and therefore may inhabit the Rainbow Springs system, include: *Procambarus franzi*, *P. geodytes*, *P. lucifugus*, *P. paeninsulanus*, and *Troglocambarus maclanei* (Franz 2002).

Walsh and Williams (2003) surveyed mussels in the upper spring run (above KP Hole Park) at four locations, resulting in two species: an unidentified spike mussel (*Elliptio sp.*; 78%) and Florida pondhorn (*Unio merus carolinianus*; 22%). In the sampled locations, no specimens of the non-indigenous Asian clam (*Corbicula fluminea*) were observed or collected (Walsh and Williams 2003).

During the 2007 sediment survey of Rainbow River, mollusks collected in benthic cores were reported (GARI 2007). Seven species/types of mollusks were encountered from core samples (Exhibit 5-4), with their relative abundance from most to least common being: quilted melania (*Tarebia granifera*), banded mystery snail (*Viviparus georgianus*), an unidentified spike (*Elliptio sp.*), Asian clam (*Corbicula fluminea*), Mesa rams horn (*Planorbella scalaris*), rams horn snails (Planorbidae), and apple snails (*Pomacea sp.*).

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Exhibit 5-4. Frequency of occurrence of mollusks collected from Rainbow River sediment cores during 2007 (GARI 2007)

Rank Order*	Species	common name	status	cores context
1	<i>Tarebia granifera</i>	quilted melania	non-indigenous	multiple, sandy, rocky, detrital, grassy
2	<i>Viviparus georgianus</i>	banded mystery snail	native	multiple, sandy, detrital, grassy
3	<i>Elliptio sp.</i>	unidentified spike	native	multiple, sandy, rocky, detrital
4	<i>Corbicula fluminea</i>	Asian clam	non-indigenous	multiple, grassy, detrital
5	<i>Planorbella scalaris</i>	Mesa Rams-horn	native	multiple, grassy, detrital
6	<i>Planorbidae</i>	rams horn snails	native	multiple, grassy, detrital
7	<i>Pomacea sp.</i>	apple snails	native	multiple, grassy, detrital

* Rank order denotes frequency of occurrence from all cores, where 1 is the most common and 7 is the least common.

There have been twelve assessments of the Rainbow Springs macroinvertebrate community by FDEP (*i.e.*, EcoSummary, FDEP 2000, 2001a, 2001b, 2002a, 2002b, 2003a, 2003b, 2004a, 2004b, 2005a, 2007b, and 2007c - Exhibit 5-5). The Rainbow River monitoring site is a 100 meter stretch located in the spring run, which begins approximately 100 meters south of the headspring. Over these sampling events, the habitat assessments were consistently in the optimal range, the total number of taxa collected ranged from 16 to 34, and the number of sensitive taxa ranged from one to five (FDEP 2008). Stream condition index (SCI) values greater than 21 were considered healthy, but after re-calibration in June 2004, values greater than 34 were rated as healthy. SCI values are typically rated as healthy in the Rainbow Springs system (FDEP 2008). Closer examination of the macroinvertebrate data in Exhibit 5-5 indicates a decreasing trend in the total taxa (species) and in the number of sensitive taxa.

5.3 Macrofauna

5.3.1 Fish

During the August 2008 reconnaissance of Rainbow Springs by WSI, fish commonly observed included largemouth bass (*Micropterus salmoides*), several species of sunfish (*Lepomis sp.*), and lake chubsucker (*Erimyzon sucetta*), less commonly observed were long nose gar (*Lepisosteus osseus*) and Atlantic Needlefish (*Strongylura marina*). While not observed during that trip, the non-indigenous sailfin catfish (*Pterygoplichthys disjunctivus*) has been observed and collected in limited numbers by Aquatic Preserve staff.

Rainbow Springs has been sampled for fish by Walsh and Williams (2003); and these researchers also summarized the Florida Museum of Natural History (FLMNH) fish collections. Based on their review of museum data, a total of 19 species of 15 genera and 7 families of fishes had previously been collected. Utilizing electrofishing techniques, Walsh and Williams (2003) collected a total of 20 species of 16 genera and 10 families from the upper spring run area. Electrofishing results of the most common families in descending order of relative abundance were: Poeciliidae (3 species; 39.4%), Centrarchidae (5 species; 24.3%), Fundulidae (2 species; 13.8%), Atherinopsidae (2 species; 8.2%), and Cyprinidae (2 species; 7.7%). Walsh and Williams (2003) noted that fish biomass was dominated by centrarchids and relatively few specimens of lake chubsucker and gizzard shad. A listing of fish species for Rainbow Springs from Walsh and Williams (2003) is provided in Exhibit 5-6.

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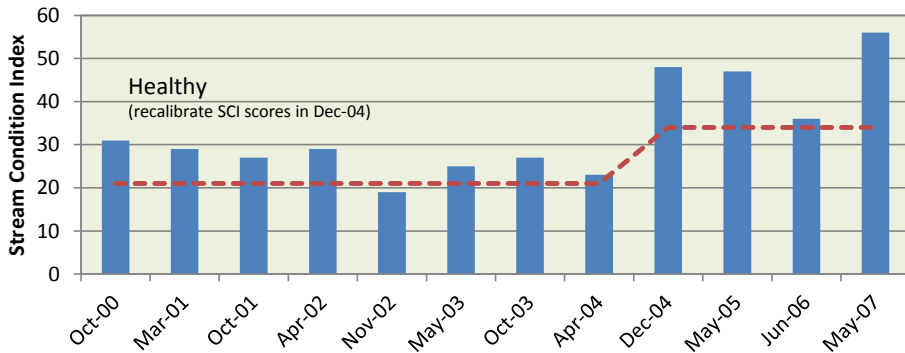
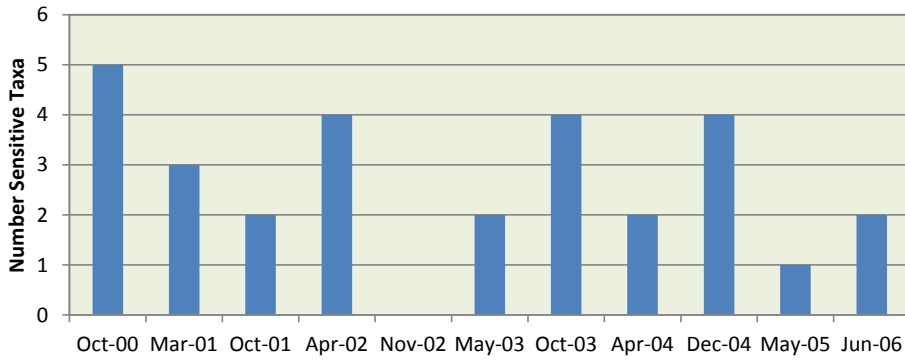
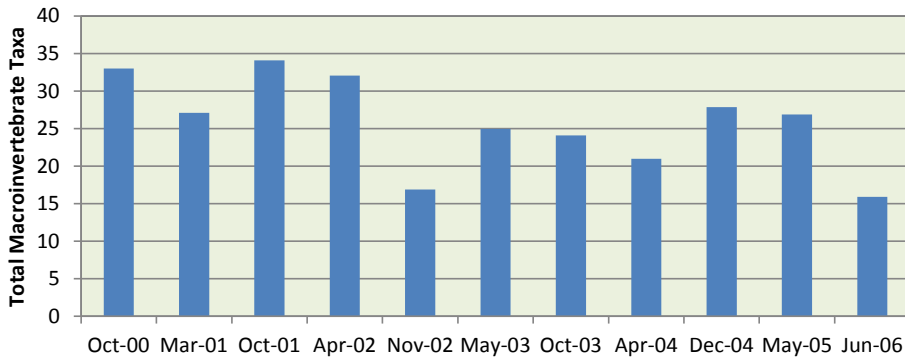
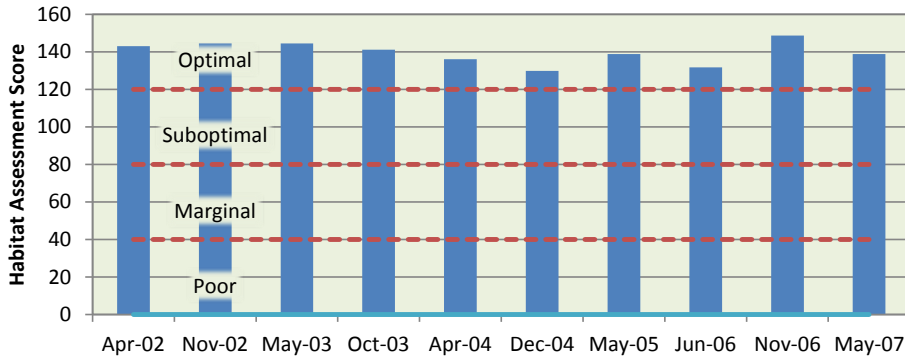


Exhibit 5-5. Rainbow Springs habitat assessment, total number of macroinvertebrate taxa, number of sensitive invertebrate taxa, and stream condition index values (from FDEP 2008).

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Exhibit 5-6. Summary of fish species recorded in the Rainbow River (Walsh and Williams 2003). USGS is the U.S. Geological Survey. FLMNH is Florida Museum of Natural History.

Family	Species	USGS		FLMNH Material	
		N	Relative Abundance (%)	Specimens	%
Lepisosteidae	<i>Lepisosteus platyrhincus</i>	2	0.5	---	---
Amiidae	<i>Amia calva</i>	1	0.3	---	---
Clupeidae	<i>Dorosoma cepedianum</i>	10	2.6	---	---
Cyprinidae	<i>Notemigonus chrysoleucas</i>	---	---	2	0.3
	<i>Notropis harperi</i>	24	6.1	334	43.3
	<i>Notropis petersoni</i>	6	1.5	6	0.8
Catostomidae	<i>Erimyzon sucetta</i>	11	2.8	---	---
Ictaluridae	<i>Ameiurus natalis</i>	1	0.3	1	0.1
	<i>Noturus gyrinus</i>	1	0.3	2	0.3
Atherinopsidae	<i>Labidesthes sicculus</i>	25	6.4	48	6.2
	<i>Menidia beryllina</i>	7	1.8	26	3.4
Fundulidae	<i>Fundulus seminolis</i>	25	6.4	15	1.9
	<i>Jordanella floridae</i>	---	---	1	0.1
	<i>Lucania goodei</i>	29	7.4	208	27.0
Poeciliidae	<i>Gambusia holbrooki</i>	115	29.4	18	2.3
	<i>Heterandria formosa</i>	19	4.9	15	1.9
	<i>Poecilia latipinna</i>	20	5.1	36	4.7
Centrarchidae	<i>Lepomis auritus</i>	20	5.1	11	1.4
	<i>Lepomis macrochirus</i>	17	4.3	3	0.4
	<i>Lepomis microlophus</i>	2	0.5	1	0.1
	<i>Lepomis punctatus</i>	31	7.9	14	1.8
	<i>Micropterus salmoides</i>	25	6.4	21	2.7
Elassomatidae	<i>Elassoma okefenokee</i>	---	---	9	1.2
Total number of species		20		19	
Total number of specimens		391		771	

During sampling in 2009 (WSI 2010), a total of 16 fish species were observed (Exhibit 5-7). Based on the geometry of the river fish biomass and density were calculated for the sampled segment. The density was lower than most of the other 11 springs sampled with 1,889 individuals per hectare. The estimated fish live-weight biomass was 113.6 kg/ha which was also lower than most of the other sampled springs. It is possible that fish counts in large springs and spring runs may be lower on a per-area basis due to the smaller ratio between stream edge and total spring surface area that is typical of a larger and deeper spring run.

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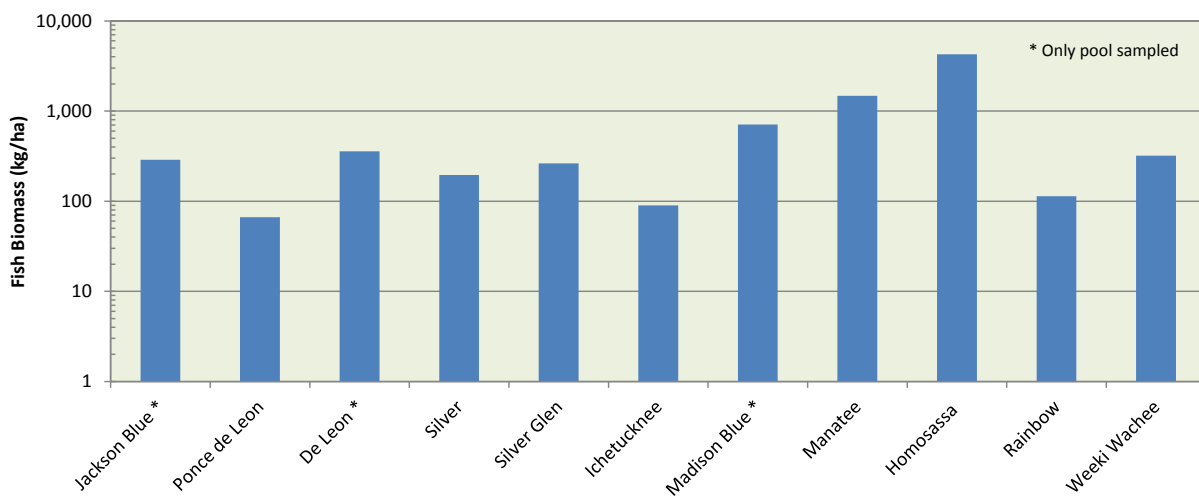
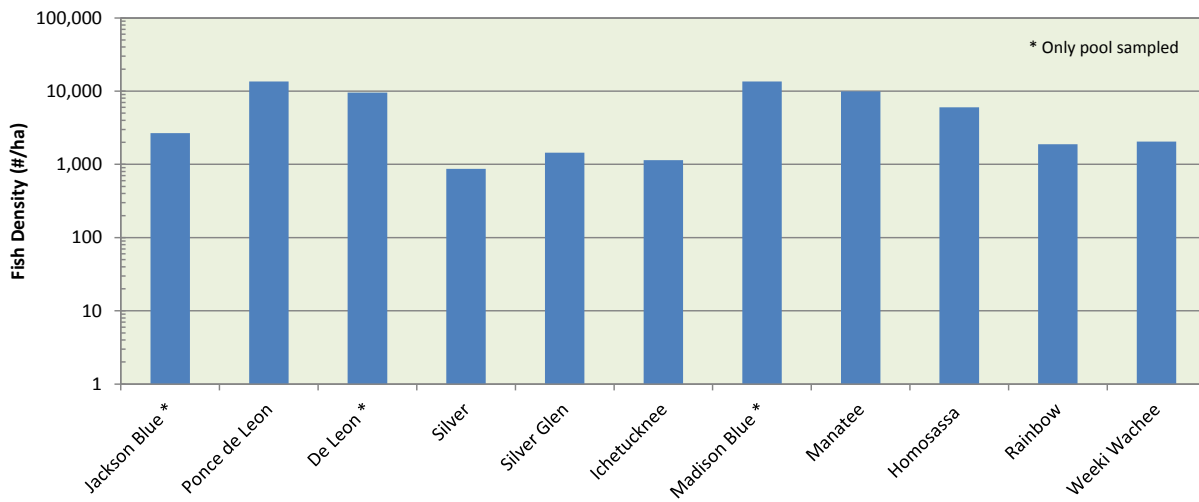
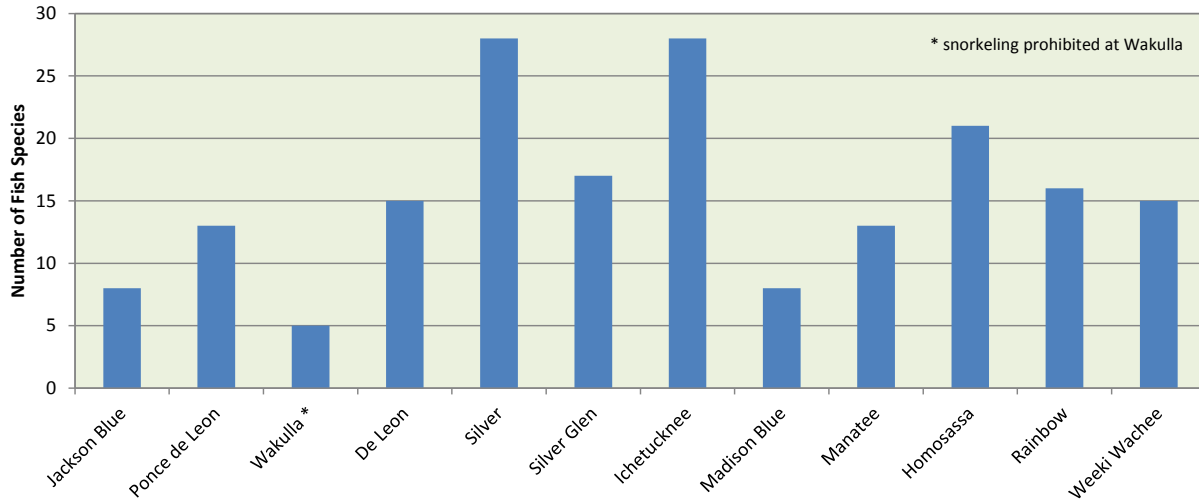


Exhibit 5-7. Number of fish species, average density (#/ha) and biomass (kg/ha) by spring (WSI 2008)

5.3.2 Reptiles

The aquatic turtle community of the Rainbow River is diverse, relatively abundant, and has a long history of study including: Marchand 1942, 1945a, 1945b who provided observations of conditions in the early 1940s; Iverson (1977) for geographic variation of loggerhead musk turtles (*Sternotherus minor*); and Giovanetto (1992) who focused on the headsprings area. For one of the more common species, loggerhead musk turtles, the growth rates and age distributions of 482 individuals collected between 1990 and 1992 were reported by Onorata (1996). Results indicated that loggerhead musk turtles of five years age or less comprised approximately 65% of the population and that some of these turtles reach ages of 21 or more years Onorata (1996).

The most comprehensive study of Rainbow River turtles, with data spanning 1990 to 2003 has been conducted by Huestis and Meylan (2004, research continues to-date). Over this time period, eight species of aquatic turtles have been collected, from most common to least: loggerhead musk turtle, eastern river cooter (*Pseudemys concinna*), Florida cooter (*Pseudemys floridana*), common musk turtle (*Sternotherus odoratus*), Florida red-bellied cooter (*Pseudemys nelsoni*), Florida softshell turtle (*Apalone ferox*), striped mud turtle (*Kinosternon baurii*), and chicken turtle (*Deirochelys reticularia*). Particular detail is given to the *Pseudemys* sp. as population estimates, growth rates, sexual dimorphism are described for this group of herbivorous basking turtles (Huestis and Meylan 2004). Huestis and Meylan (2004) reported that there appeared to be a major shift towards smaller species (e.g., musk turtles, Exhibit 5-8) in comparison to a survey made six decades earlier by Marchand (1942). Turtle harvesting for food and export was observed to be common in the Rainbow River prior to a ban on commercial turtle harvest in 2009 (FWC 2013) that limited taking to one per day with no commercial sales except as allowed for breeders with a license. However, based on anecdotal accounts poaching of turtles still occurs.

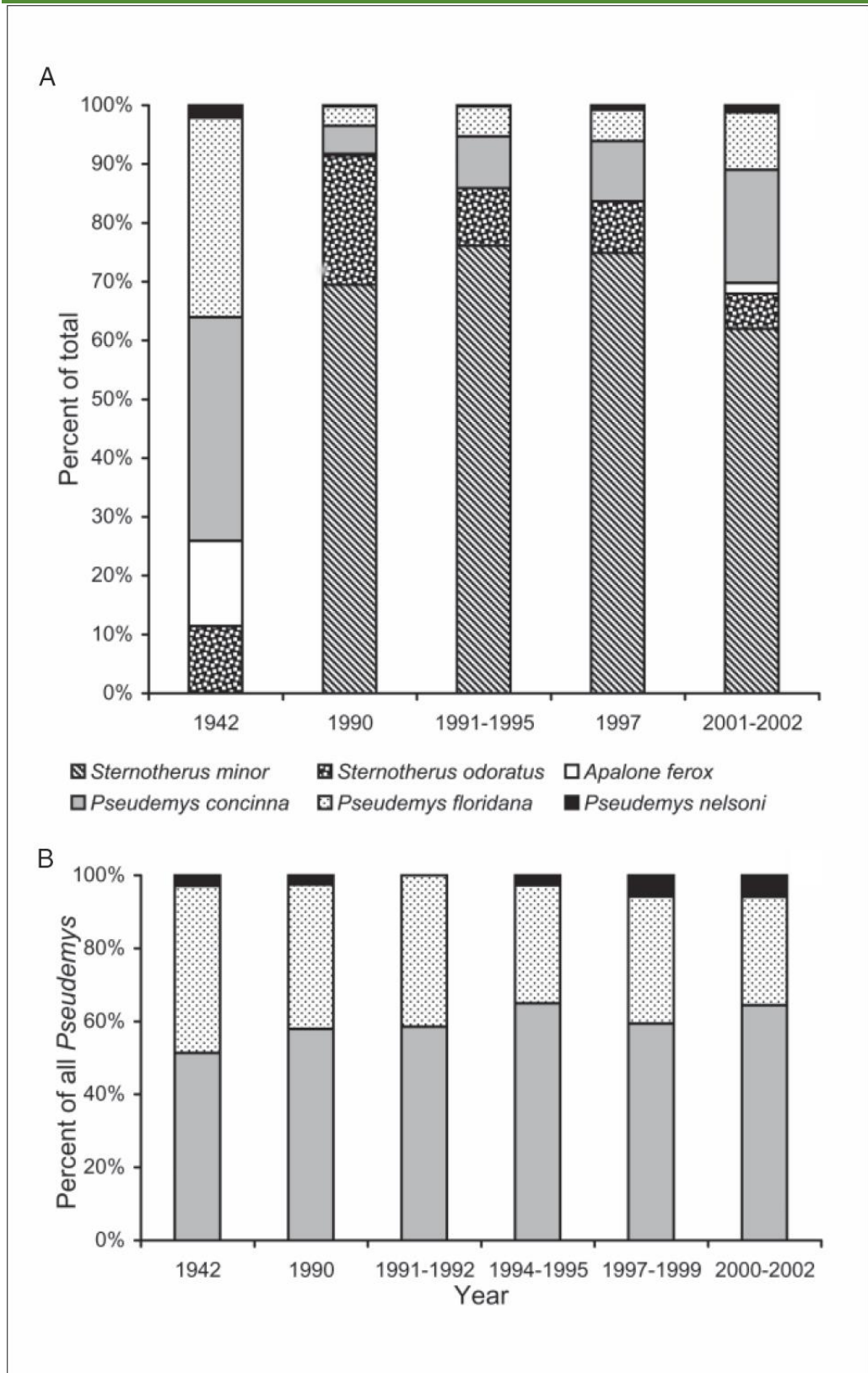


Exhibit 5-8. Turtle Observations for the Rainbow River (Huestis and Meylan 2004)

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5.3.3 Birds

In 2009, Wetland Solutions, Inc. (WSI) conducted a comparative ecological analysis at twelve Florida springs/springs runs (WSI 2010). This study included bird counts with results reported for spring pool and spring run observations. A total of 21 bird species were observed at the Rainbow River with one shared observation in the pool and run and 20 additional bird species observations in the run. The count was done as an ancillary part of the study and was purely qualitative with no total count completed. Informal bird counts along the Rainbow River are made by members of the Marion County Audubon Society (Sandra Marraffino, personal communication). A total of 146 bird species have been reported along the river in Rainbow Springs State Park. Exhibit 5-9 provides a summary of six years of Christmas bird counts made by members of Marion County Audubon along the Rainbow River and in the Rainbow Springs State Park.

5.3.4 Manatees

Although manatee fossils have been recovered from the Withlacoochee River and Rainbow Springs (Laist and Reynolds 2005), the utilization of Rainbow Springs and the Rainbow River by manatees is precluded due to downstream barriers on the Withlacoochee River which prevent access. The Withlacoochee River was originally dammed in 1909 to provide electric power; and as part of the Cross Florida Barge Canal project, a lock, dam, and bypass facilities were constructed in the town of Inglis during the 1960's and subsequently abandoned in the 1970's (FDEP 2005b). The lock is currently not functional and has not been operational since 1999, eliminating manatee access to the Rainbow River (FDEP 2005b).

A single modern manatee occurrence in the Rainbow River has been reported from December 1976 (Powell and Rathbun 1984, Beeler and O'Shea 1988); presumably this manatee would have traveled through the Inglis lock on the Withlacoochee River to access Lake Rousseau and then the Rainbow River. There has been one known manatee mortality at the Inglis lock on July 8, 1986 (Taylor 2006, from FWC manatee mortality database).

5.3.5 Ecological Functions

Based on field parameters (temperature, specific conductance, dissolved oxygen, and pH) measured in the spring pool and spring run during the WSI reconnaissance trip of August 13, 2008, this spring is suitable for measuring ecosystem metabolism based on changes in dissolved oxygen following discharge from the spring vent. The FDEP deployed recording data sondes during August 10 to 24, 2004 at two stations (headsprings and state park sign at 1,700 ft). These data revealed diel oxygen curve patterns, however a lack of ancillary data (e.g., spring discharge, water depth, plant depth, and light availability) prevented the accurate usage of these data to calculate primary production rates.

A historic primary productivity estimate of Rainbow Springs was made about 2.1 km downstream of the head pool during the summer of 1955 (Odum 1957). Results of that study indicated gross primary production to be 23.9 g O₂/m²/d. Although a relatively high production value, it was consistent with other spring systems given the amount of available light (Odum 1957). During more recent measurements of primary productivity during 2008-09 by WSI (2010), the gross primary productivity was 18.6 g O₂/m²/d, the community respiration was 18.7 g O₂/m²/d, and the net primary productivity was -0.15 g O₂/m²/d.

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Exhibit 5-9. Marion County Audubon Christmas bird counts along the Rainbow River and in the Rainbow Springs State Park

Bird Type	Bird Family	Common Name	Scientific Name	Wetland Status	Rainbow Spring State Park						Rainbow River								
					2007	2008	2009	2010	2011	2012	Average	2007	2008	2009	2010	2011	2012	Average	
Birds of Prey	Buteos	Red-shouldered Hawk	<i>Buteo lineatus</i>	0.8	4	2	6		3	3	3.0	5	12	5	10	10	8	8.3	
		Red-tailed Hawk	<i>Buteo jamaicensis</i>	0.2	1				4	1	1.0	2		1					0.5
		American Kestrel	<i>Falco sparverius</i>	0.2	1		1	1	1	4	1.3					1			0.2
		Osprey	<i>Pandion haliaetus</i>	1.0							2	0.3	2	1	3	1		2	1.5
	Eagles	Bald Eagle	<i>Haliaeetus leucocephalus</i>	0.5		1	2		1	2	1.0		1	2	1	1	1		1.0
	Owls	Eastern Screech-Owl	<i>Otus asio</i>			1				1	0.3								
		Barred Owl	<i>Strix varia</i>		2				1	1	0.7								
	Vultures	Black Vulture	<i>Coragyps atratus</i>	0.5	7	4	15	22	6	30	14.0	19	11	7	3	8	5		8.8
		Turkey Vulture	<i>Cathartes aura</i>	0.5	35	21	48	130	31	12	46.2	24	41	58	23	63	24		38.8
	Land Birds	Blackbirds	Boat-tailed Grackle	<i>Quiscalus major</i>	0.2		1				0.2	14	1	2	20	13	3		8.8
Common Grackle			<i>Quiscalus quiscula</i>	0.2	3	7	9		2	3.5	30		6	1	30			11.2	
Red-winged Blackbird			<i>Agelaius phoeniceus</i>	0.7	60			10	5	10	14.2	103	12	94	45	197	23		79.0
Bluebirds		Eastern Bluebird	<i>Sialia sialis</i>	0.0	2	5	7	5	46	14	13.2	3	8	4	11	2	2		5.0
Crows, Jays		American Crow	<i>Corvus brachyrhynchos</i>	0.3	19	73	148	95	74	49	76.3	51	39	45	44	56	53		48.0
		Fish Crow	<i>Corvus ossifragus</i>	0.3	2	9	1	4		3	3.2	2	13	5	157	3	2		30.3
		Blue Jay	<i>Cyanocitta cristata</i>	0.0		5	9	11		29	9.0				21	3	3		4.5
Doves, Pigeons		Mourning Dove	<i>Zenaidura macroura</i>	0.0	3		9	57	1	24	15.7	3	4	2	6	3	5		3.8
		Common Ground-Dove	<i>Columbina passerina</i>	0.0				3		2	0.8								
		Eurasian Collared-Dove	<i>Streptopelia decaocto</i>	0.0			1				0.2								
Flycatchers		Eastern Phoebe	<i>Sayornis phoebe</i>	0.2	9	11	12	10	18	17	12.8	14	13	21	17	14	15		15.7
		Great Crested Flycatcher	<i>Myiarchus crinitus</i>	0.2					1		0.2								
Hummingbirds		Ruby-throated Hummingbird	<i>Archilochus colubris</i>	0.1					1		0.2								
Kingfisher		Belted Kingfisher	<i>Ceryle alcyon</i>	1.0	1			2	2	4	1.5	20	18	18	15	24	16		18.5
Mockingbirds and Thrashers		Northern Mockingbird	<i>Mimus polyglottos</i>	0.2	4	7	8	15	6	10	8.3		2		1		1		0.7
		Gray Catbird	<i>Dumetella carolinensis</i>	0.0	8	10	2	9		2	5.2				3				0.5
		Brown Thrasher	<i>Toxostoma rufum</i>	0.1	1	1	1	3	1	1	1.3								
Pipits		American Pipit	<i>Anthus rubescens</i>	0.5					53		8.8								
Shrikes		Loggerhead Shrike	<i>Lanius ludovicianus</i>	0.1	1		2				0.5	1							0.2
Sparrows, Finches		American Goldfinch	<i>Carduelis tristis</i>	0.0	6	45		1	6	42	16.7	49		10	14				12.2
		Chipping Sparrow	<i>Spizella passerina</i>	0.2	7	3	46	54	25	2	22.8			2					0.3
		House Finch	<i>Carpodacus mexicanus</i>	0.0	1				2		0.5	1		2		1			0.7
		Northern Cardinal	<i>Cardinalis cardinalis</i>	0.2	13	46	18	29	14	10	21.7	9	58	14	28	7	12		21.3
		Song Sparrow	<i>Melospiza melodia</i>	0.3		2					0.3								
		Swamp Sparrow	<i>Melospiza georgiana</i>	0.7													1		0.2
Starlings		European Starling	<i>Sturnus vulgaris</i>	0.0			1				0.2	14	8		1				3.8
Swallows		Tree Swallow	<i>Tachycineta bicolor</i>	0.0									2			3			0.8

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Exhibit 5-9. Marion County Audubon Christmas bird counts along the Rainbow River and in the Rainbow Springs State Park

Bird Type	Bird Family	Common Name	Scientific Name	Wetland Status	Rainbow Spring State Park						Rainbow River								
					2007	2008	2009	2010	2011	2012	Average	2007	2008	2009	2010	2011	2012	Average	
Land Birds	Thrushes	American Robin	<i>Turdus migratorius</i>	0.3	85	165	74	136	111	22	98.8	64	25	76	241	220	44	111.7	
		Blue-gray Gnatcatcher	<i>Poliophtila caerulea</i>	0.3	15	25	15	12	1	6	12.3	14	9	27	7				9.5
		Golden-crowned Kinglet	<i>Regulus satrapa</i>	0.1				3				0.5						10	1.7
		Hermit Thrush	<i>Catharus guttatus</i>	0.5		4	2	4	3			2.2							
		Ruby-crowned Kinglet	<i>Regulus calendula</i>	0.1	11	40	12	20	27	1		18.5							
	Titmice	Carolina Chickadee	<i>Poecile carolinensis</i>	0.1	4	14	7	41	21	32	19.8		15	3	7	2	2		4.8
		Tufted Titmouse	<i>Baeolophus bicolor</i>	0.1	9	22	21	53	38	24	27.8	6	28	7	16	5	15		12.8
	Towhee	Eastern Towhee	<i>Pipilo erythrophthalmus</i>		2	8	5	19	1	8	7.2				1				0.2
	Turkey	Wild Turkey	<i>Meleagris gallopavo</i>	0.3									8						1.3
	Vireos	Blue-headed Vireo	<i>Vireo solitarius</i>	0.1		7	1		6		2.3								
		White-eyed Vireo	<i>Vireo griseus</i>	0.2	2	3	2	9	11		4.5	2	1						0.5
	Waxwing	Cedar Waxwing	<i>Bombocilla cedrorum</i>	0.1	1	45		40	17	30	22.2	2			19	21			7.0
	Wood Warblers	Common Yellowthroat	<i>Geothlypis trichas</i>	0.8		2		1	2	3	1.3			3	13				2.7
		Northern Parula	<i>Parula americana</i>	0.5	1						0.2								
		Palm Warbler	<i>Dendroica palmarum</i>		19	54	36	106	122	12	58.2	9	19	23	21	6	1		13.2
		Prairie Warbler	<i>Dendroica discolor</i>						1		0.2								
		Yellow-throated Warbler	<i>Dendroica dominica</i>		1	2	1	3			1.2		1	2					0.5
		Black-and-white Warbler	<i>Mniotilta varia</i>			6	2	2	3	2	2.5		2	1	3				1.0
		Orange-crowned Warbler	<i>Vermivora celata</i>	0.1		3					0.5								
		Pine Warbler	<i>Dendroica pinus</i>	0.0	3	9	13	60	47	4	22.7		2	2	7		6		2.8
		Yellow Warbler	<i>Dendroica petechia</i>	0.5										1					0.2
	Yellow-rumped Warbler	<i>Dendroica coronata</i>	0.2	40	13	6	83	65	10	36.2	42	86	23	135	52	109		74.5	
	Woodpeckers	Downy Woodpecker	<i>Picoides pubescens</i>	0.1	2	12	3	14	13	4	8.0		4	4	7	1	2		3.0
		Northern Flicker	<i>Colaptes auratus</i>	0.2		1			1		0.3								
		Pileated Woodpecker	<i>Dryocopus pileatus</i>	0.5	4	10	6	9	3	16	8.0	4	10	4	7	3	9		6.2
		Red-bellied Woodpecker	<i>Melanerpes carolinus</i>	0.2	10	17	18	17	11	16	14.8	11	12	5	21	8	9		11.0
		Red-headed Woodpecker	<i>Melanerpes erythrocephalus</i>	0.2		5	3	1	4	1	2.3								
Yellow-bellied Sapsucker	<i>Sphyrapicus varius</i>	0.1	4	3	1	4			2.0										
Wrens	Carolina Wren	<i>Thryothorus ludovicianus</i>	0.4	8	35	5	25	3	13	14.8	5	16	16	8	1	10		9.3	
	House Wren	<i>Troglodytes aedon</i>	0.1	3	3		4	6		2.7		11	1					2.0	
	Marsh Wren	<i>Cistothorus palustris</i>	0.8		1					0.2									
Wading Birds	Herons, Bitterns	American Bittern	<i>Botaurus lentiginosus</i>	1.0		1					0.2								
		Great Blue Heron	<i>Ardea herodias</i>	1.0	4		2	4	4	3	2.8	23	15	19	10	12	18		16.2
		Great Egret	<i>Ardea alba</i>	1.0	1	2	2	2	1	5	2.2	21	13	20	14	16	17		16.8
		Green Heron	<i>Butorides virescens</i>	1.0				1		2	0.5	3	2		4	1	3		2.2
		Least Bittern	<i>Ixobrychus exilis</i>	1.0														1	0.2
		Little Blue Heron	<i>Egretta caerulea</i>	1.0	1	1	1	1	1	5	1.7	5	9	8	5	10	7		7.3
		Snowy Egret	<i>Egretta thula</i>	1.0			1		1	1	0.5			5				4	1.5
		Tricolored Heron	<i>Egretta tricolor</i>	1.0					1		0.2	2	3	2	2	2			1.8

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Exhibit 5-9. Marion County Audubon Christmas bird counts along the Rainbow River and in the Rainbow Springs State Park

Bird Type	Bird Family	Common Name	Scientific Name	Wetland Status	Rainbow Spring State Park							Rainbow River						
					2007	2008	2009	2010	2011	2012	Average	2007	2008	2009	2010	2011	2012	Average
Wading Birds	Ibises, Spoonbills	White Ibis	<i>Eudocimus albus</i>	0.8	5	1	17	59	4	14.3	45	25	47	23	41	35	36.0	
	Plovers, Turnstone	Killdeer	<i>Charadrius vociferus</i>	0.3	36		25	12	36	5	19.0				1		0.2	
	Rails	Sora	<i>Porzana carolina</i>	1.0						1	0.2							
Water Birds	Anhingas	Anhinga	<i>Anhinga anhinga</i>	1.0	5	7	8	8	25	15	11.3	91	74	66	70	48	52	66.8
	Coots, Gallinules	Common Moorhen	<i>Gallinula chloropus</i>	1.0	2	6	3	7	6	9	5.5	66	34	19	33	7	16	29.2
		American Coot	<i>Fulica americana</i>	1.0	8	9	2	9	5	7	6.7	41	64	16	73	78	48	53.3
	Cormorants	Double-crested Cormorant	<i>Phalacrocorax auritus</i>	1.0	1	4	3	3	11	8	5.0	47	56	60	37	49	60	51.5
	Cranes	Sandhill Crane	<i>Grus canadensis</i>	1.0			21	15	1	3	6.7		2			1		0.5
	Grebes	Horned Grebe	<i>Podiceps auritus</i>	1.0								2						0.3
		Pied-billed Grebe	<i>Podilymbus podiceps</i>	1.0	5	1	4	5	38	21	12.3	63	34	62	58	78	56	58.5
	Gulls	Ring-billed Gull	<i>Larus delawarensis</i>	0.5						10	1.7		23					3.8
	Limpkin	Limpkin	<i>Aramus guarana</i>	1.0								4	3	2	2	1	3	2.5
	Loons	Common Loon	<i>Gavia immer</i>	1.0								2						0.3
	Marsh Ducks	Mallard	<i>Anas platyrhynchos</i>	1.0						4	0.7							
		Wood Duck	<i>Aix sponsa</i>	1.0	17	16	11	3	58	1	17.7	13	8	21	7	25	14	14.7
	Mergansers	Hooded Merganser	<i>Lophodytes cucullatus</i>	1.0											1			0.2
Turns	Caspian Tern	<i>Sterna caspia</i>	1.0											1			0.2	
Total Number Observed																		
	Birds of Prey				50	29	72	153	47	56	68	52	66	76	38	83	40	59
	Land Birds				364	734	507	974	774	423	629	479	421	423	897	675	353	541
	Wading Birds				42	9	32	38	102	26	42	99	67	101	59	82	85	82
	Water Birds				38	43	52	50	144	78	68	329	298	246	281	288	249	282
	Total				494	815	663	1215	1067	583	806	959	852	846	1275	1128	727	965
Total Number of Species																		
	Birds of Prey				6	5	5	3	7	9	9	5	5	6	5	5	5	7
	Land Birds				35	40	35	38	39	32	54	24	28	29	30	23	23	41
	Wading Birds				4	4	6	7	6	8	10	6	6	6	7	6	7	9
	Water Birds				6	6	7	7	7	9	9	9	9	7	8	9	7	13
	Total				51	55	53	55	59	58	82	44	48	48	50	43	42	70

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These results indicate a nearly balanced system where inputs and outputs are almost equal. These results indicate a possible decrease in productivity since 1955, when Odum made his measurements. Whole ecosystem productivity was lower in Silver Springs during 2004-2005 compared to previous estimates (Munch *et al.* 2006). This decline was attributed in part to reductions in spring discharge and increased nitrate concentrations.

Section 6.0 Human Use and Economic Impact

6.1 Human Use

Rainbow Springs and River receive hundreds of thousands of visitors per year. The cool, clear water draws nature-based tourists from across the state, nationally, and internationally every year. Activities on the river include: canoeing, boating, tubing, swimming, skin-diving, SCUBA-diving, wading, nature study, and fishing.

6.1.1 Rainbow Springs State Park

Recreational activities at Rainbow Springs State Park include swimming, tubing, canoeing and kayaking, picnicking, and camping. Annual statistics of human attendance at Rainbow Springs State Park are available between 1993 and 2012. Peak total annual attendance occurred in 2011 (almost 264,000 people, 213,000 day users) as shown in Exhibit 6-1. The annual pattern of use shows that a majority of users visit the spring during summer (Exhibit 6-2).

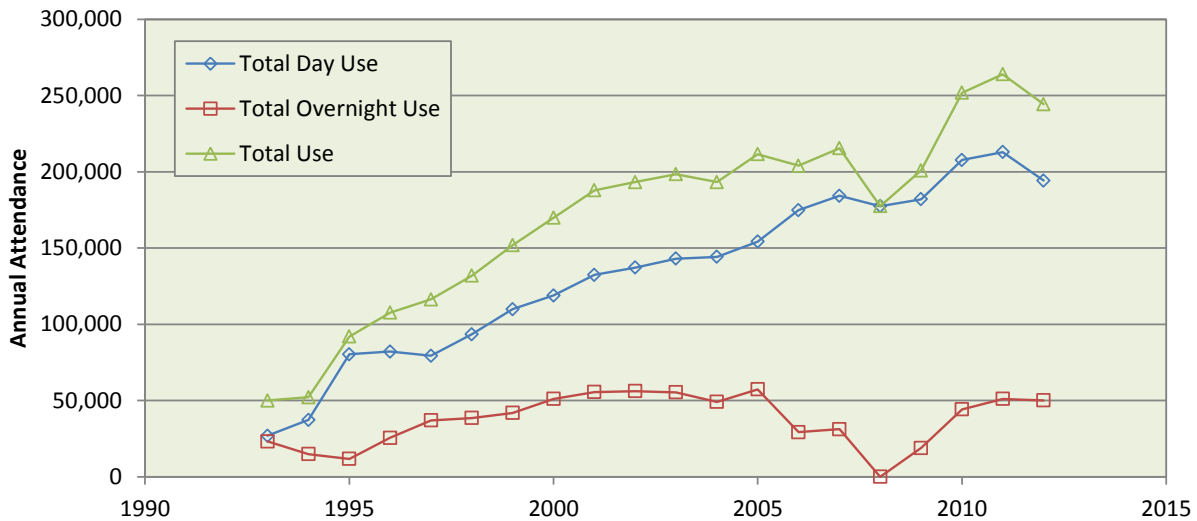


Exhibit 6-1. Rainbow Springs State Park Total Annual Attendance

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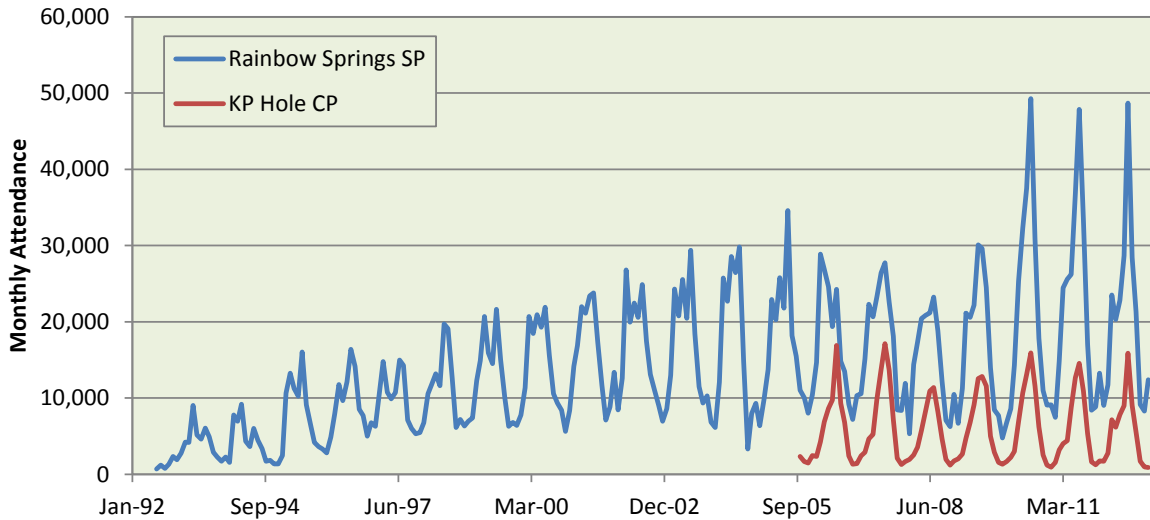


Exhibit 6-2. Rainbow Springs State Park and KP Hole County Park Monthly Use

6.1.2 K.P. Hole County Park

Rainbow River is also accessed for recreation through the KP Hole County Park as a tube, canoe and kayak rental site as well as a boat launch point. Recreational boating is popular along the river, and a Marion County ordinance (No. 88-7) has established an idle speed zone along its entire length (SWFWMD 2004). Human use at KP Hole County Park reached an annual maximum in 2007, with nearly 82,000 visitors. In 2011, an estimated combined total of nearly 334,000 visitors used the Rainbow River through the state and county parks. Maximum monthly use occurred in July 2010, when 65,149 users made use of the river through the state and county parks, or an average of 2,100 users per day. It is considered likely that thousands of additional visitors access the Rainbow River from private docks and boat ramps and from the Withlacoochee River.

6.1.3 Human Recreation Studies

Pridgen *et al.* (1993) conducted peak season recreational surveys on the Rainbow River in 1991 and 1992. Typical number of daily users exceeded 500 per day with a peak human user count of 940 per day. An average of 151,913 human use hours were recorded for aquatic recreation (tubing and boating) during a 12-week study period during each year. An average of 3,840 hours were expended on fishing during the 12-week study periods. Average recreational trip lengths ranged from 4.2 to 4.6 hours and costs per hour ranged from \$0.67 for fishing to \$1.43 per hours for pleasure boating. Species specific catch rates, harvest weight, and catch per unit effort declined between 1991 and 1992, but the decline was not statistically significant. Aquatic vegetation was reported to be healthy during both years and the authors concluded that recreational uses were not excessive and were sustainable.

Mumma *et al.* (2009) conducted a study on the effects of recreation on submersed aquatic plants within the Rainbow River. The study involved the collection of drifting vegetation below a high recreational use area (KP Hole County Park) while concurrently counting the number of tubers, canoes, and boats. Sampling was conducted over periods of low, medium, and high recreational use. The biomass of damaged and drifting plants was significantly correlated to upstream

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recreation on high-use days. However, vegetation quadrat sampling in areas with high recreation use did not have significantly lower plant coverage or leaf densities.

Cichra and Holland (2012) conducted a human dimensions and environmental study of the Rainbow River between May 2011-May 2012. This study used six time lapse camera-recorders to document the types, locations, and degree of recreational use and the effect of recreational use on the natural environment in the Rainbow River. The six primary recreational activities observed were canoes, kayaks, motorboats, SCUBA divers, swimmers, and inflatable tubes. Peak recreational use occurred between the end of May and the end of August. Lowest use occurred during the middle of winter. Compared to similar data recorded in 1994, peak tuber use days increased by about 3.7 times, motorboat use increased by 46%, and canoe/kayak use increased by 60%. Estimated total annual use by use category from May 2011 to May 2012 was: tubers - 84,000, kayaks - 11,000, swimmers/divers - 9,000, motorboats - 6,600, canoes - 5,500, and scuba boats - 1,000.

Various environmental effects of these recreational activities were reported by Cichra and Holland (2012). These included: increased inorganic suspended solids levels in the water column due to motor boat traffic; increased biomass of drifting, damaged submerged aquatic vegetation (SAV), primarily related to motorized boat traffic; larger boats (pontoon and bay fishing with engines exceeding 75 HP) were implicated in greater damage to the SAV plant communities; and conflicts between divers and boats, resulting in trampling or prop scarring of SAV in shallow areas. The authors cautiously concluded that from an environmental harm perspective, the river can sustain additional recreational activity. Tubing and canoeing/kayaking were found to have minimal environmental effects.

6.2 Rainbow Springs Economic Impact

Florida State University studied the economic impacts of four spring-based state parks in 2003, including Ichetucknee, Volusia Blue, Wakulla, and Homosassa Springs (Exhibit 6-3). This study by Bonn and Bell (2003) measured spending on lodging, restaurants, groceries, transportation, shopping, entertainment, and admissions fees to parks. It used a formula that assumed additional expenditures by visitors beyond the park vicinity based on studies previously conducted by the Florida Park Service. The Bonn and Bell study noted that Volusia Blue was the only park to have a decrease in attendance over a ten-year period (1992-2002) despite being close to Orlando and Daytona Beach. This appeared to be related to environmental degradation suggesting that the quality of the springs affected the attendance and thus the economic impact.

Exhibit 6-3. The Economic Impact of Four Florida Springs State Parks (Bonn and Bell 2003)

Spring	Economic Impact	Wages & Salaries	Jobs	Number of Visitors	Non-Resident Visitors
Ichetucknee	\$22.7 million	\$5.09 million	311	188,845	90%
Wakulla	\$22.2 million	\$4.33 million	347	180,793	70%
Homosassa	\$13.6 million	\$3.13 million	206	265,977	64%
Volusia Blue	\$10.0 million	\$2.38 million	174	337,356	65%
Average	\$17.13 million	\$3.73 million	259.5	243,243	70.48%

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Assuming that these economic estimates are representative of the types of springs-related activities that occur at Rainbow Springs, and an annual visitor estimate of about 400,000 people, the estimated total economic impact of the Rainbow Springs System just for recreation is estimated at about \$28 million with creation of about 426 local jobs. This figure does not include any additional economic value for real estate.

A second study by Bonn in 2004 for the St. Johns River Water Management District included profiles of eight springs in state and federal ownership: Silver Glen, Silver, Alexander, Apopka, Bugg, Ponce de Leon, Gemini, and Green Springs. The annual economic impact as well as employment and wages created for each of these springs parks was estimated by Bonn. Silver Springs led the other springs with an estimated one million visitors annually who expended \$248 per party creating an annual economic impact of \$61.45 million with \$12.61 million in wages and 1,060 full or part time jobs being directly related to the springs. More than 70% of the visitors came from outside of Marion County.

The Florida State Parks Economic Assessment for 2009-10, released in September 2010, estimated a \$950 million impact on local economies that are in close proximity to Florida State Parks. Additionally, \$66 million was generated in sales taxes to the state of Florida, and 18,900 jobs were supported by this economic activity. The share of this value contributed by Rainbow Springs State Park in 2009-10 was estimated to be \$8.4 million, providing \$587,954 in state sales taxes and supporting 168 jobs.

The Rainbow Springs and River provide economic value to southwestern Marion County. That value is directly dependent upon the physical and biological health of the system. Visitors come to the springs and river for a variety of reasons, including sightseeing, swimming, boating, diving, fishing, and tubing. There are also several festivals held both in Dunnellon and in Rainbow Springs State Park that attract large crowds. There has been considerable real estate development over the last three decades in the area around the spring and along the river. Most new developments are part of the Villages of Rainbow Springs Property Owners Association. Billboards in the area advertise these developments with images of people recreating on the river, and most of the developments have the word "Rainbow" in their name. It seems clear that the Rainbow River is integral to the economic value of residential properties and businesses in the area. If the springs and river became severely impacted by declining flows, poor water quality, recreation beyond its carrying capacity, or some combination of these factors, the impact on the local economy could be severe.

Section 7.0 Regulatory Status

As Rainbow Springs has suffered from increasing pollutant loads and declining flows, its protection has not been ignored by policy-makers. In fact, there is a bewildering array of Federal, State, and local laws and policies aimed, directly or indirectly, at protecting the springshed; with each passing year additional protections are being considered and in some cases implemented. Whether these existing and new protections will be adequate to reverse the decline in Rainbow Springs remains to be seen.

The strength and timing of these environmental protections vary significantly across jurisdictions. For example, MFLs (Minimum Flows and Levels) are being developed on different schedules for Rainbow Springs (by the SWFWMD) and for neighboring Silver Springs (by the

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St. John's River WMD). Protections at the county and municipal levels also vary widely, in part because of the differing levels of their residents' environmental activism but also because of variations in their economies, demographics, and geology. Rainbow Springs lies within Marion County, which with its economically important springs and urban centers has the most comprehensive and longstanding springs protections in the area. The Rainbow Springshed includes portions of both Alachua and Levy Counties, and while Alachua County has adopted limited springshed protections, Levy County has been slower to act on springs protection measures.

A compendium of legal protections at the Federal, State, and local levels for Silver Springs may be found in the draft document "Restoration Plan for the Rainbow Springs and River"¹ by NAI (2011). Most of these protections also apply to neighboring Silver Springs.

7.1 Federal and State Designations

Rainbow Springs has been recognized as an important natural feature by formal designations at the state and federal level – designations which are meant to provide recognition as well as protection.

In 1971, the National Park Service listed Rainbow Springs as a National Natural Landmark, recognizing the site for its geological or biological resources that should be conserved, but without specific plans for acquisition or protection beyond voluntary conservation.

In the mid-1990s, Rainbow Springs was re-opened as a Florida state park.

Of Florida's 1,700 rivers and streams, the Rainbow River is one among only 41 which are recognized as Outstanding Florida Waters (OFW). The OFW designation recognizes high quality and diverse ecosystems and is meant to protect the water body from a degradation of ambient water quality "under all circumstances". No activity is allowed that would lower the ambient water quality based on the quality of the preceding year or the quality at the time of the designation, whichever is better. There is also a requirement that approved projects should be in the public interest or at least not contrary to public interest.

The Rainbow Springs and River were designated in 1986 by FDEP as a State Aquatic Preserve, meant to maintain the resource in "essentially natural condition". The 150 acres covered by this designation includes all portions of the river from the head spring to the Withlacoochee River. Florida Statute Section 258.36 states that "*It is the intent of the Legislature that the state-owned submerged lands in areas which have exceptional biological, aesthetic, and scientific value, as hereinafter described, be set aside forever as aquatic preserves or sanctuaries for the benefit of future generations.*" Special restrictions exist for these protected areas beyond those required for other sovereign submerged lands in the state.

The Rainbow River was recently named as a site on the Great Florida Birding Trail.

¹ Tables 6.1 – 6.3 list nine Federal laws and policies, 12 State and regional agencies' laws and policies, and a variety of policies and comprehensive plan amendments adopted by counties and municipalities located in the river/springs basin.

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7.2 Protections – Water Quality

In 2012, FDEP verified that the Rainbow Springs Group and Run were impaired by nitrate (algal mats). In 2013, under the TMDL (total maximum daily load) requirements of the 1972 federal Clean Water Act and the 1999 Florida Watershed Restoration Act, FDEP determined the threshold concentration of nitrate for the Rainbow Springs Group and the Rainbow Springs Group Run that will allow these water bodies to meet the applicable water quality criterion for nutrients. A TMDL represents the maximum amount of a given pollutant that a water body can assimilate and still meet water quality standards, including its applicable water quality criteria and its designated uses. TMDLs are developed for water bodies that are verified as not meeting their water quality standards and provide important water quality goals that are intended to guide restoration activities. According to FDEP, achieving a monthly average nitrate target of 0.35 mg/L should be sufficiently protective of, and will not cause an imbalance in, the aquatic flora or fauna in the Rainbow Springs Group and the Rainbow Springs Group Run. Given that the average monthly nitrate levels were 1.92 mg/L for the Rainbow Springs Group and 1.42 mg/L for the Rainbow Springs Group Run during the verified period, FDEP proposed that an 82% reduction in nitrate concentrations for both water bodies would be needed to satisfy the nutrient reduction requirement for the system (Holland and Hicks 2012).

7.3 Rainbow BMAP

The means of achieving the TMDLs for Rainbow Springs will be a Basin Management Action Plan (BMAP) – a restoration plan developed by FDEP and basin stakeholders that formalizes the activities that will reduce the pollutant loads and achieve the TMDL. Stakeholders in the BMAP include the SWFWMD, local governments, agriculture and other businesses, and interested local citizens and the BMAP represents a formal commitment for various responsible parties who will take corrective actions to meet the TMDL. Given that agricultural activities are a significant source of the nutrient loads, the State Department of Agriculture and Consumer Services (FDACS) will play an important role in the implementation of restoration activities. The BMAP process for Rainbow Springs began with the first public meeting on July 30, 2013.

7.4 Federal, State, and Regional Protections – Water Quantity

By setting minimum flows and levels (MFLs), water management districts are responsible for determining the point at which further withdrawals within a watershed will cause “significant harm” and for ensuring that there is enough water in the Floridan aquifer to protect the hydrological and ecological integrity of lakes, streams, and springs in the district. The establishment of MFLs is required both by Florida statute and by the state comprehensive plan. MFLs apply to decisions affecting water withdrawal permits, declaration of water shortages, environmental resource permitting, and assessment of water supply sources. Each district is required to develop recovery or prevention strategies in cases where a water body currently does not or will not meet an established MFL.

The Rainbow River MFL will set recommended levels for minimum frequent highs, minimum averages, and minimum frequent lows for both flows and levels in the Rainbow Springs System. The District’s models have been criticized in the past for over-estimating the impact of annual rainfall variations and underestimating the importance of groundwater pumping on

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declining flows. The Rainbow and Silver systems are inter-related; in fact, Rainbow Springs has apparently “pirated” so much groundwater from the Silver springshed that it now surpasses the latter in average flow rate.

Currently, there is no draft or final MFL for the Rainbow River. The last schedule adopted by the SWFWMD indicates that an MFL for the Rainbow River will be approved in 2014. However, SWFWMD is involved in legal action relating to its recommended 3% flow reductions in the Homosassa and Chassahowitzka Rivers and over its position that OFW and anti-degradation rules do not apply to the MFL program. Until these legal matters are resolved, it appears that other SWFWMD MFLs, including the Rainbow River MFL, may languish.

7.4.1 County and Municipal Protections for Water Quality and Quantity

Counties and municipalities have a number of legislative tools that can be used either to protect or alternatively to compromise the health of springs and other water bodies. These tools include comprehensive plans, zoning, land development regulations (LDRs), and water quality/quantity ordinances. Many of these tools – for instance regulations on dumping of hazardous materials – have been on the books for years. However, comprehensive springshed protection language like that adopted in Marion County is still the exception in north-central Florida counties rather than the rule.

In 2009, the Marion County Commission approved the Springs Protection Ordinance, which added Article 6.4, Springs Protection Overlay Zone (SPOZ), to the LDRs and amended Article 8.2.10, Landscape Standards, to reflect language in Article 6.4. The SPOZ is considered an overlay to other zoning districts so its regulations supersede those of other zoning districts. When the ordinance was adopted, there were two zones within the county, with some portions of the county not fitting into either zone. After adoption, the County changed the overlay map so that anything that was not included in the “primary protection zone” was included in the “secondary protection zone” (Exhibit 7-1). These delineations are meant to protect groundwater quality based on the importance of the county as a recharge area for the Floridan Aquifer. Land uses, development, and environmental regulations may differ between the primary and secondary zones.

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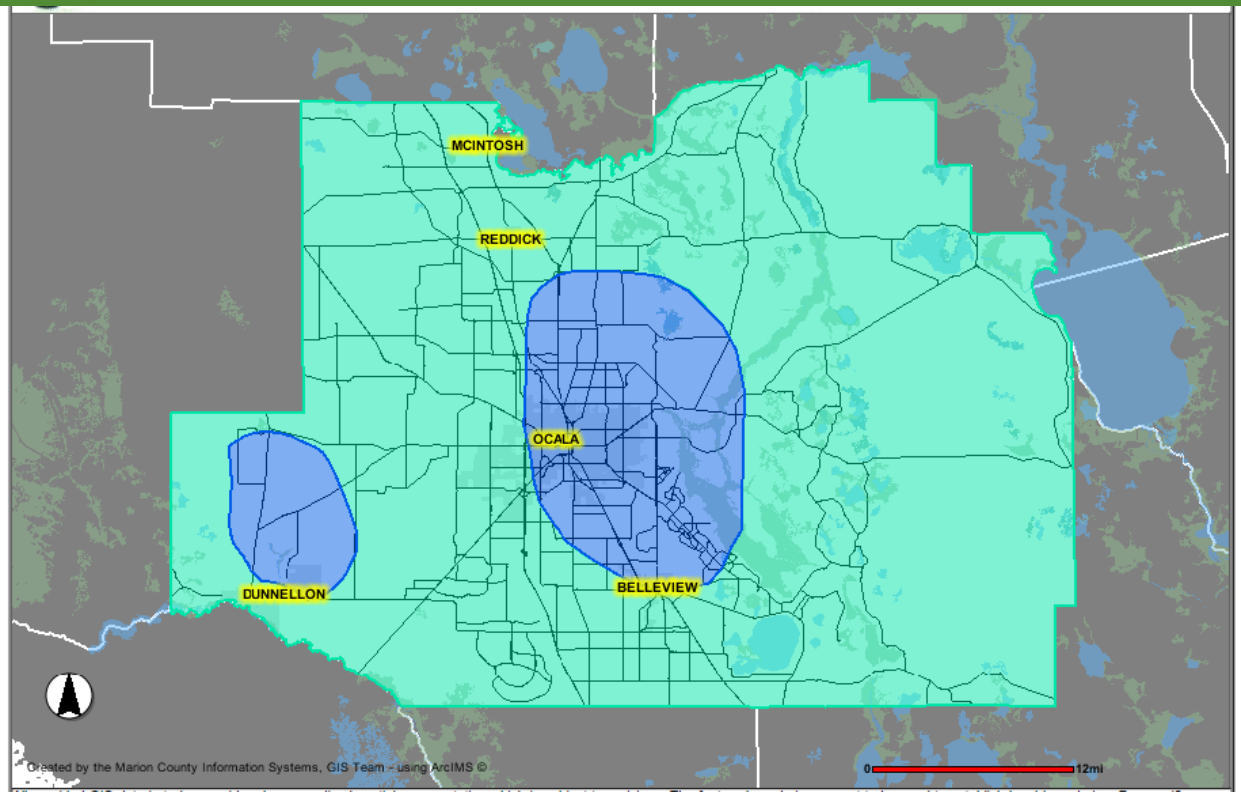


Exhibit 7-1. Marion County's "Primary Protection Zone is shown in dark blue and the "Secondary Protection Zone" in sea green.

Land uses and activities which could adversely affect the quality and quantity of groundwater within the SPOZ are regulated under the Ordinance. A number of activities are prohibited within the primary zone, and detailed standards are provided for sewer connections, agriculture, stormwater runoff management, water supply management, and on-site disposal systems (septic systems). Some specifics include:

- Concentrated animal feeding operations are prohibited within the SPZ
- Irrigated acreage and BMPs are specified for new golf courses
- Restrictions are applied for mining operations and for construction/demolition debris operations
- Manure management practices are specified
- New developments are encouraged to use water-conservation practices (e.g., planting drought-tolerant species and re-using water)
- Criteria are in place for required connections to sewer lines
- Effluent total nitrogen limits for wastewater treatment in new developments
- Voluntary farm best management practices for manure, crops, and pastures, with advice to owners provided by the County Extension Service

Section 19 of the Marion County code includes an ordinance which codifies the SJRWMD's irrigation rules, as well as a residential fertilizer ordinance which provides for training of

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applicators, recommended rates of fertilizer application, and fertilizer setback distances from water bodies.

Although Marion County has been as legislatively active as any north-central Florida county in protection of its springs, county requirements for septic systems have actually been weakened over the years. In recent years, the County Commission repealed a previous requirement that low-pressure dosing septic systems be used in new construction and for replacement of failing systems. Also, about five years ago, the County approved a mandatory septic tank/drainfield inspection and pumping program, but repealed the plan when a State-wide version of inspection/pumping seemed to supersede the County's program. However, after the State law was repealed, the County did not act to re-instate its own inspection program.

7.4.2 Other Local Activities and Provisions

The Rainbow Springs and River are protected by several specific Marion County Ordinances. These include Article IV, Section 5-51 to 5-55, which prohibits disposable containers and alcoholic beverages and provides for a no-wake zone along the length of the river. Chapter 3, Section 3-8 prohibits the possession of alcoholic beverages on the entirety of the Rainbow River. Article I, Section 5-2 prohibits scuba diving in the headwaters of the Rainbow River. Fertilizer is prohibited from being applied within 75 feet of the ordinary high water line of the Rainbow River as part of Article V, Section 19-249.

Additionally, the City of Dunnellon developed Ordinances 2008-01 (River Corridor Protection) and 2011-08 (River Etiquette) to limit development in the river corridor and adverse user experiences on the Rainbow River, respectively. The River Corridor Protection Ordinance is designed to limit and guide development within the river corridor, defined as within 150 feet of the shoreline of the river and its coves. Specific criteria are provided in the ordinance to limit the impact of development on the river and users of the river. This ordinance is currently under review and is being modified to provide greater freedom to property owners along the river. The River Etiquette Ordinance includes language relating to all user classes on the river and was crafted to minimize potentially dangerous interactions for users. This is accomplished through limits on the sizes of individual tubes and groups of tubes attached to each other. It also lays out a specific guide to right-of-way on the river to dispel any question of who must yield in interactions. Furthermore the ordinance provides multiple items designed to reduce the impacts of littering and boats on the Rainbow River.

Section 8.0 Impairments

The Rainbow Springs System is an important natural and cultural resource in North Central Florida. The spring and river attract large numbers of tourists and provide a substantial boost to the local economy. Additionally, the ecosystem that is supported by the river provides abundant wildlife habitat that is unique to both Florida and spring systems. To acknowledge the importance of this natural and cultural resource, the river and spring have received three separate designations at the state and federal levels. However, the Rainbow Springs and river have been found to be an impaired water body and a draft nutrient TMDL has been established by the FDEP (Holland and Hicks 2012). That designation only refers to the impact of water quality pollutants, specifically nitrate nitrogen, at the spring and spring run. In fact the ecology

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of the spring and river are likely impaired by at least two additional principal stressors: reduced flows and human recreational uses. All three of these principal impairments at the Rainbow Springs System need to be addressed together to restore and protect this significant environmental and economic feature.

8.1 Introduction

For more than a century Florida has attracted new residents because of the moderate climate and natural beauty of the state. This attraction has spurred residential, commercial, and urban development to support the infrastructure necessary to provide for residents and tourists. Additionally, agriculture has taken advantage of North Florida's moderate climate to produce row crops, livestock, dairy goods, pulp wood, timber, sod, and ornamental plants. This increasing development has resulted in inevitable stresses on Florida's natural environment.

The human population of Florida was approximately 18.8 million in 2010. Given the area of the state (53,900 square miles) and assuming that these people are evenly distributed indicates that the average density of Florida residents is about 350 people per square mile. This density represents a significant increase from about 2.8 million residents in 1950 (51 people per square mile). Population expansion and high intensity life styles characterized by excessive irrigation, fertilizer use, and recreational activities, are ultimately responsible for the observed impairments at Rainbow Springs. Reversal of the negative trends described in this report will only occur by a collective acknowledgement of the detrimental consequences of this human footprint and purposeful reduction of impacting behaviors. This section quantitatively describes the key factors resulting in the impairments visible at Rainbow Springs.

8.2 Excessive Groundwater Consumption

Due to its very low topographic relief, the State of Florida has less capacity for storage of surface waters than many other states. Natural surface water storage systems in the state include shallow wetlands, lakes, and rivers. While in a few instances these water resources have been exploited for human water uses, there is very limited opportunity to construct cost-effective surface water reservoirs to augment water supplies during seasonal dry periods.

However, Florida's hydrogeology provides ample storage volume for groundwater resources. Unlike many areas with more topographic relief, Florida has highly permeable sandy soils over much of its area as well as many internally draining basins that direct rainfall and runoff into groundwater aquifers. Throughout much of the northern half of the Florida peninsula the extensive karst limestone Floridan Aquifer is unconfined or poorly confined, resulting in high vulnerability for contamination of the underlying groundwater.

Florida's porous limestones represent one of the largest groundwater aquifers on the planet. The Floridan Aquifer System encompasses about 100,000 square miles and extends under the entire State of Florida and under significant parts of Georgia, South Carolina, and Alabama (Exhibit 8-1). The depth of the Floridan Aquifer exceeds 4,000 feet under parts of Florida. However, this depth is misleading since much of the Floridan Aquifer is filled with salt water. The freshwater portion of the Floridan Aquifer provides high quality drinking water for a large fraction of the state's residents and provides high quality potable water for many other uses and

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users in the State of Florida. In 2010 it was estimated that the Floridan Aquifer provided about 62 percent of the 4,150 MGD of groundwater utilized in the state (Marella 2013)

Because of highly permeable areas in portions of the state the potentiometric surface of the aquifer is generally high enough to cause artesian flow from more than 1,000 springs. These springs are the result of conduits within the Floridan Aquifer that allow large flows to be discharged in areas where fractures and surrounding high potentiometric surfaces can drive water to the surface and drain via a surface feature (creek/river).

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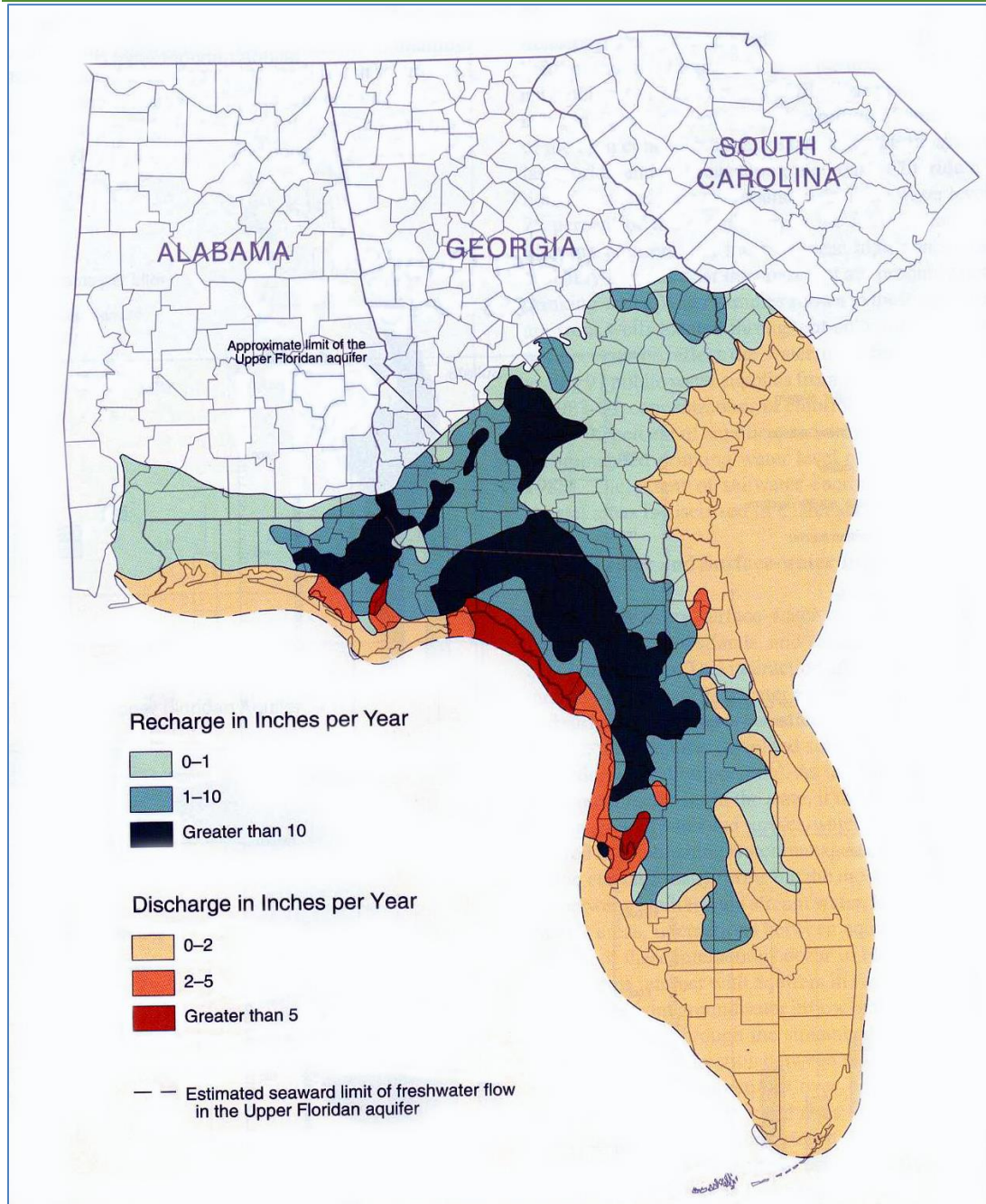


Exhibit 8-1. Extent of the Floridan aquifer system and estimated annual recharge in Florida and portions of Georgia, Alabama, and South Carolina (adapted from Bush and Johnson 1988).

8.2.1 Precipitation and Recharge

There are five primary components of the natural hydrologic cycle that are responsible for a majority of the movement of water in Florida. These are precipitation, evapotranspiration (ET), runoff, groundwater recharge, and groundwater discharge. The Florida water budget can be

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compared to a household budget with precipitation as income and the outflows as debits. In the simplest sense rainfall is analogous to gross income. A portion of the rainfall is lost to ET just as a portion of monetary income must be used to pay expenses such as loans, insurance, utilities, maintenance, etc. If there is any rain (income) left after these inevitable expenses, then it either runs off as surface water to lakes, streams, and rivers or it recharges the aquifer (put into a protected savings account for future expenses). Like a mortgage or car payment, ET tends to be relatively consistent. Utility or food costs depend on how much is consumed; similarly runoff is dependent on when and how much precipitation occurs. Finally whatever is left over can infiltrate and be put in savings (Floridan Aquifer). The estimated pre-development annual average recharge to the entire Floridan Aquifer System was estimated by Bush and Johnson (1988) as about 13.9 billion gallons per day (BGD). During dry years when rainfall is as little as 65 percent of average, the recharge estimate would be reduced to about 9 BGD.

Similar to a bank savings account, water stored in the Floridan Aquifer provides an important socioeconomic return manifested as artesian springs that naturally provide high quality wildlife habitat, recreational opportunities, and aesthetic/economic values. Spring flow in turn supports diverse downstream aquatic resources ending as highly productive estuaries where these freshwater flows mix with the ocean and Gulf of Mexico. Also like a bank account, if the principal of the account is spent (falling aquifer levels and storage) with no regard for future security, there will be negative consequences for the individual and society as a whole. This is the case with unchecked pollution and over-exploitation of high quality groundwater as evidenced at Rainbow Springs.

8.2.2 Groundwater Pumping

The USGS has estimated that during an average rainfall year (2000), approximately 26% of the entire average annual recharge to the 100,000 square mile Floridan Aquifer System, or approximately 3.64 billion gallons per day (BGD) was being pumped (Williams *et al.* 2011). Approximately 2.6 BGD of this total is being pumped in North and Central Florida (Marella 2013) and the rest or about 1 BGD is being pumped in Georgia, Alabama, and South Carolina.

In addition to this 3.64 BGD, another one billion gallons per day has already been promised to existing water use permit holders in Florida alone. Existing and permitted groundwater uses in North Central Florida equate to about 33% of the average annual income of recharge to the entire Floridan Aquifer System, and add up to more than 50% during a drought year.

As discussed previously, groundwater pumping is analogous to withdrawals from a bank account (Floridan Aquifer). By withdrawing and reducing the capital (storage of groundwater in the aquifer), spring flows decline and the services they provided to nature and human society are reduced. Under extreme cases where aquifer levels have been drawn down by more than 20 to 40 feet, springs have stopped flowing during periods of low rainfall. Notable Florida examples include White Springs in Hamilton County and Kissengen Springs in Polk County. Also, massive increases in the formation of sinkholes and of coastal saltwater intrusion occur during periods of intense groundwater pumping.

With the exception of smaller withdrawals for domestic self-supply, groundwater pumping in Florida requires a water use permit from one of the five Water Management Districts (WMDs). The water use permitting process is designed to protect state water resources against ecological damage by determining the impact of withdrawals. Three criteria must be met to issue a water

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use permit: the use must be reasonable and beneficial, it must protect existing users, and it must be in the public interest.

The WMDs utilize steady-state groundwater models to estimate impacts caused by groundwater pumping permits. Admittedly, the groundwater models that are used to estimate impacts to aquifer levels and spring flows are overly-simplistic and tend to under-estimate impacts to groundwater resources. The basic assumption used in crafting these models is that the aquifer is a relatively homogeneous matrix of constant porosity (“sand box” analogy). In fact the Floridan Aquifer limestones are highly variable in porosity with areas of dense rock and adjacent areas honeycombed by large caverns and passageways sufficient for cave divers to travel miles underground.

Extensive research on groundwater flow travel times using conservative dyes as tracers have proven that the underlying assumptions in the simplistic WMD models are not realistic (Kincaid and Werner no date, URS 2011). The consequence of using flawed assumptions is excessive uncertainty in model estimates of groundwater pumping effects on spring flows and levels. And contrary to common professional standards, the WMDs do not report the likely magnitude of uncertainty present in model predictions used for water use permitting. In fact, the companies and individuals preparing these simplistic models strongly recommend against their use for estimating the effects of groundwater pumping on individual springs and spring groups (Planert 2007). Nevertheless the District’s North District Groundwater Flow Model (HydroLogic, Inc. 2010) is used for estimating groundwater pumping impacts at Rainbow Springs.

Based on comparison of groundwater level maps for estimated pre-development conditions and during the last decade (Exhibit 3-7) the groundwater levels in the springshed that feeds Rainbow Springs have declined on average between 8 and 15 feet. Since spring flows come from the top of the aquifer, this decline has resulted in lower average flows at Rainbow Springs. The average flow decline at Rainbow Springs independent of rainfall variability has been about 14 to 15% over the past decade compared to the previous period-of-record. Rainfall in Marion County has also declined during this period by about 11%. Thus actual flows at Rainbow Springs during the past five years have been more than 25% below historic average flows due to the combined effects of natural and human-induced impacts on aquifer water levels. While loss of more than one fourth of the entire flow from this spring ecosystem results in proportional impacts to the natural biota, only a portion of these declines are the result of human groundwater extractions and therefore controllable. To protect spring ecosystems from significant harm during periods of low rainfall and recharge, it is even more important to reduce the controllable human groundwater extraction activities.

Since Rainbow Springs is topographically lower than Silver Springs by about 10 feet, Rainbow tends to “pirate” flows from Silver Springs during low recharge/high pumping periods. The observed overall reduction in combined flows from these two first magnitude springs is about 25% or 340 cfs (220 MGD) over the most recent decade. For purposes of springs restoration and protection, these two large spring complexes should be treated as a unit, regardless of political boundaries.

While groundwater pumping within Marion County is a significant drain on aquifer levels at Rainbow and Silver Springs and is clearly taking a big toll on the ecological health of these spring giants, groundwater pumping outside of Marion County is responsible for at least half of

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the controllable spring flow reductions and will also need to be reduced substantially to effect recovery at these springs.

8.3 Water Quality Impairments

The water quality in the Rainbow River has been relatively consistent over the period-of-record for most parameters. However, there have been a few significant changes in water quality in the river. The most obvious of these changes has been the increase in nitrate. There have also been documented changes in water clarity along the length of the river.

8.3.1 Nitrate Nitrogen

The changes in nitrate concentration on the Rainbow River have been significant, with concentrations increasing by nearly 100% over the past decade and by more than 2,700% in the vicinity of the main boil since 1927. Over the last decade the rate of increasing nitrate concentrations has been nearly linear at a rate of approximately 0.1 mg/L per year. Nitrate is one of the primary nutrients required for plant growth and is limiting for algal proliferation in many aquatic and terrestrial ecosystems. Cowell and Dawes (2007) found that increased nitrate levels in combination with increased trace metals caused highly significant increases in biovolume of phytoplankton. Additionally the Rainbow River was included in a FDEP (2009) report that provided justification to list water bodies based on nutrient impairment. In all samples verified by FDEP at Rainbow Springs, concentrations of nitrate exceeded the threshold for preliminary listing of 0.6 mg/L.

8.3.2 Water Clarity

Water clarity is one of the key features of the Florida Springs both for tourism and ecological function and Rainbow River is one of the clearest near its headspring. Light availability contributes to the highly productive wildlife food webs found in Florida Springs that favors submerged aquatic vegetation even at depths greater than ten feet. Exceptional water clarity is also one of the primary features that attract recreational users to Florida's springs.

Anastasiou (2006) evaluated the relationship between clarity and water quality in the Rainbow River with distance downstream. A strong inverse correlation was found between distance downstream and water clarity. Water clarity was negatively correlated with chlorophyll-a concentration with an R^2 of 0.80. A drop in clarity of nearly 75% was observed in the first kilometer of the river.

8.4 Biology

8.4.1 Reduced Dominance by Submerged Aquatic Vegetation

Over the entire river the prevalence of SAV was observed to have decreased and algae was observed to be increasing in dominance in many areas as more bare areas have become available for algal colonization (Atkins 2012). The total estimated decline in SAV cover was 22 percent between 1996 and 2011. The dominant native SAV species, *Sagittaria kurziana* (strap-leaved sagittaria) had a cover decline during this period of 23 percent. Coontail (*Ceratophyllum demersum*) also declined during this period, while eelgrass (*Vallisneria americanum*) cover increased during the same period.

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Hydrilla verticillata (hydrilla), a non-native, invasive SAV species, was the second-most dominant SAV species in the Rainbow River in 2000, occupying about 13 percent of the entire river bottom area. In their study of the Rainbow River Cichra and Holland (2012) found that the prevalence of *Hydrilla verticillata* had increased on the river since the 1994-95 study, but that at some locations prevalence in individual transects had decreased. This decrease was also noted in the 2011 evaluation of vegetation in the river (about 58 percent decline in cover since 1996) and is believed to be the result of treatment with herbicides (Atkins 2012).

In addition FDEP (2009) in their documentation to support listing the Rainbow River as nutrient impaired noted the presence of algae indicating eutrophication and the presence of the invasive species *Hydrilla verticillata*.

8.4.2 Faunal Impacts

Declining spring flows and degraded vegetative structure have the potential to impact faunal populations on the Rainbow River. Existing research has shown that the turtle population communities have changed over the past 60 years to favor smaller turtle species (Huestis and Meylan 2004). Additionally beginning in 2009 the Florida Wildlife Commission in FWC Rule 68A-25.002(6) passed a restriction on commercial harvest of turtles. This law allows for only one turtle to be taken daily and prohibits the buying or sale of any wild turtle and is meant to end the exploitation of wild turtles for commercial purposes.

Because of the significant recreational use of the river in summer there is the possibility that reptiles may be unable to sun to regulate body temperature. Huestis and Meylan (2004) propose that the lack of basking sites may be a contributor to the smaller sizes of turtles observed in the 13 year study.

FDEP's EcoSummaries and Stream Condition Index (SCI) rankings for the Rainbow River have generally been in the Healthy range. However, the total number of macroinvertebrate taxa and sensitive taxa declined during the limited period of the State's study.

8.4.3 Ecosystem Function

The impacts of reduced flows and increased nutrients (primarily nitrate) in the Rainbow Springs and River have not been well studied. In their research, Cichra and Holland (2012) found that during periods of low water in 2012, damage to submerged aquatic vegetation was more severe as less depth was available for motorboat props. Metabolism can be used to assess the function of spring ecosystems. Calculations of metabolism have been made for the Rainbow River; however no continuous measurements or long-term studies have evaluated temporal changes in gross primary productivity.

In 2009, Wetland Solutions Inc. (2010) completed a study of 12 Florida springs. Rainbow Springs was one of the systems evaluated. Ecosystem productivity was evaluated and found to have the second highest gross primary productivity of the springs studied, after Silver Springs. The gross primary productivity was measured to be 18.6 g O₂/m²/day although net primary productivity was found to be very slightly negative with a value of -0.15 g O₂/m²/day.

WSI (2010) linked extremely high rates of gross primary productivity to nutrient eutrophication in spring runs. The effects of nitrate loading on springs productivity was found to follow a subsidy-stress pattern where nitrate apparently stimulates this production up to a certain point

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that is spring specific, presumably due to ambient concentrations of dissolved oxygen, and then results in reduced primary productivity as nitrate concentrations continue to increase past a threshold value.

8.5 Human Use and Activities

Human use in spring ecosystems can be both a positive and/or a negative forcing function. From the positive standpoint human use creates awareness among the public that can contribute to a desire to preserve, protect, and restore springs. Unfortunately springs, like most natural areas, can be overused and damaged if human use is excessive or not well managed. Additionally as human use increases, the user experience can be diminished because of competition for the resource. Rainbow River is one of the most popular springs in Florida with high-intensity human use through both the state and county park access points. Additionally there is a large volume of boat traffic on the river that launches from Dunnellon and travels up the river from the Withlacoochee River.

In 1994-95, Mumma (1996) collected data regarding human use and impacts to macrophyte vegetation in the channel. Also observed were suspended solids (organic, inorganic, and total) downstream of motorboats, canoes, and tubers. Concentrations of organic and total suspended solids were significantly correlated to upstream activities indicating that human use does have a direct impact on the downstream export of material. Additionally biomass of damaged and drifting plants was significantly correlated to upstream recreation on high-use days. However, despite the removal of large amounts of vegetation, recreation was observed to remove only a small fraction of overall plant biomass. Inorganic suspended solids were not correlated to upstream human uses.

Cichra and Holland (2012) conducted a study between May 2011-May 2012 documenting the types, locations, and degree of recreational use and the effect of recreational use on the natural environment in the Rainbow River. The six recreational activities evaluated were canoes, kayaks, motorboats, SCUBA divers, swimmers, and inflatable tubes.

Motor boating was found to have the greatest impact on the river. A change in total and inorganic suspended solids was positively correlated to the number of motorized boats. Total suspended solids were not found to be significantly correlated to any other user group. The majority of the damage to aquatic plants observed was caused by power boats. Cichra and Holland (2012) concluded that most of the damage was caused by a small number of irresponsible boat operators driving in shallow water and/or not having the motor trimmed. Damage is also caused by boat operators steering into shallow water in order to avoid divers, tubers, and other users during periods of high recreational use. It was also suggested that carrying capacity appears to be reached for some users groups (primarily motorboats) on high use days (Cichra and Holland 2012).

Tubers cause damage to SAV plant communities in the areas where they enter and exit the river. These areas are denuded of vegetation in the peak summer season and subsequently become populated by hydrilla and/or filamentous algae, during the low recreational-use period. Canoeists and kayakers caused minimal damage to the river as they readily used access ramps to get in and out of their boats and rarely had to enter the water to any degree.

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Swimmers and SCUBA divers caused some damage to aquatic plants, but this damage was limited in nature.

Management recommendations laid out by Cichra and Holland (2012) were primarily focused on the boating community which had the most significant impact on vegetative communities. Recommendations include providing educational materials both as pamphlets and placards at all boat points of entry, meeting with boaters and boating organizations to explain the damage that is occurring and provide continuing assessments to evaluate any reductions in impacts, and evaluating alternative management strategies that were proposed to provide better facilities to minimize the impact of boating on the river. It was also mentioned that during low water events closure to motorboats of a portion of the river may be advisable to avoid damage. Although tubers were observed to cause damage at put-in and take-out points it was expected that attempts to limit this behavior would only cause damage to be moved to other areas. It was also proposed that homeowners be educated about managing vegetation near their homes.

Section 9.0 Recommendations

9.1 Introduction

Based on work by the Rainbow Springs Working Group organized by FDEP during the period from 2009 through 2011 a vision statement was crafted by participating members (NAI 2011). This vision statement expresses an optimistic outcome of multi-faceted restoration efforts affecting the springs and river:

Rainbow Springs and the Rainbow River form a healthy and sustainable natural system due to the deep connection and sense of stewardship of the community. A broad range of educational efforts have resulted in a voluntary reduction of land use impacts and water consumption in the spring basin. The ecosystem promotes a viable, self-sustaining community of fish, wildlife, and vegetation which supports low-impact recreational activities contributing to a diverse and sustainable economy. Water quality, specifically associated with nutrients including nitrates and phosphates, and water discharge are both maintained within parameters to support a healthy ecosystem. Informed citizens actively protect the basin through continued monitoring and research.

The preliminary goal for restoration in this Action Plan is to return the Rainbow Springs and River as closely as possible to the physical, chemical, and biological conditions it had before 1987, the year it became an Outstanding Florida Water. While a nutrient TMDL has been developed for the Rainbow Springs and River by FDEP, none of the outcomes identified in the vision statement above have been achieved to-date. Also, restoration of low nitrate conditions in Rainbow Springs and Rainbow River will only achieve one aspect of restoration. Significant restoration of this surface water body will require at a minimum:

- Restoration of historic spring discharges to pre-1987 flows
- Reduction of nitrate nitrogen concentrations and loads to pre-1987 conditions
- Reduction in the intensity of recreational activities in the Rainbow River

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- Additional protections for the river in the face of continuing urban development along its banks and in the springshed

The preliminary goal of this updated Rainbow Springs Restoration Action Plan is to develop a specific set of actions that will begin to improve the natural condition of the river in the short-term (next five years) and will ultimately (next 20 years) restore it to its much more pristine condition typical of the mid-1980s. The ultimate goal for the springs and river is to provide an even higher level of restoration so that it is essentially in near-pristine ecological health.

These are ambitious goals and as such will require the dedicated and combined efforts of individuals, municipalities, and the state. Without a change in the way the state “does business”, restoration of Rainbow Springs and the Rainbow River will not be possible. However, existing educational campaigns, grassroots organizations, and scientific research are having a positive impact on springs state-wide. Water conservation efforts and fertilizer reduction programs are beginning to improve surface water resources statewide. This report is intended to be an important part of continuing education that will surely be necessary for state and local governments to be a part of the solutions.

9.2 Developing a Restoration Road Map

A Restoration Roadmap for Rainbow Springs and the Rainbow River will include the following components:

- Summary of Existing Conditions (this report)
- Specific Goals for Restoration
 - Practical Steps Needed to Achieve Those Goals
 - A Timeline for Implementing the Restoration Action Plan
 - Responsible Parties
- Monitoring of Progress with Continuing Adaptive Management in Response to Progress

9.3 Specific Goals for Restoration

9.3.1 Water Quantity Restoration

The preliminary water quantity restoration goal for Rainbow Springs and Rainbow River is to restore it to >90% of its historic average flow (733 cfs or 474 MGD) or an interim average flow goal of about 660 cfs (426 MGD). The average flow of the Rainbow River over the past decade was about 606 cfs (391 MGD). This preliminary flow recovery goal will require an estimated average groundwater pumping reduction of about 54 cfs (35 MGD) in the regional area that affects flows at Rainbow Springs.

The ultimate goal for springs recovery should be to attain 95% of historic flows or an average flow of about 696 cfs (450 MGD). Achieving this ultimate goal would require an estimated average reduction of groundwater pumping region-wide of 90 cfs (58 MGD). As described above, a rough estimate of the existing pumping in the springshed that feeds Rainbow Springs is about 43 cfs (28 MGD). Therefore, these preliminary and ultimate water quantity goals will require pumping reductions throughout the District.

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Perhaps the most practical alternative that allows this level of reduced pumping is to spread it over the entire region that is affecting flows at Rainbow Springs and other North Florida springs. Spring flows across the entire North Florida area are estimated to be reduced by about 25% due to current pumping rates from the Floridan Aquifer System. If that area is found to include the entire SWFWMD with a current estimated pumping rate of about 1,131 MGD, then the necessary reduction is about 60 percent to a maximum District-wide pumping allowance of about 450 MGD. This same level of reduction will also be needed in the St. Johns and Suwannee River WMDs to restore spring flows across North Florida. Additional analysis needs to be conducted to better quantify the water balance for both Silver and Rainbow Springs. This analysis may indicate that a higher percent reduction in groundwater uses is needed to address the suspected underground transfer of water from Silver Springs to Rainbow Springs.

Reductions in groundwater pumping need to be prioritized based on their regional economic importance and can be made through a combination of the following proactive measures:

- Increased water use efficiency
- Increased water conservation
- Increased reliance on rainfall storage and surface water supplies

Until a detailed economic evaluation is conducted, it is reasonable to assume that all existing users need to reduce their water use by an equal percentage. An estimated overall reduction of 60% across the board for all groundwater users in Levy, Marion, and surrounding counties could achieve the ultimate goal for restoration of flows at Rainbow Springs.

Public and domestic self-supplies could reasonably achieve this water use reduction goal by reducing or eliminating landscape and lawn irrigation with groundwater. If rainfall could be stored locally in ponds, cisterns, or rain barrels, then these outside water use activities could be permitted and continued.

Agricultural production in North and Central Florida has relatively recently developed a dependency on center pivot irrigation using groundwater. This use cannot be sustained at current rates if restoring spring flows and springs health is a priority. The most practical first step is to stop issuance of any new water use permits for crop irrigation in North Florida. The next step is to revise existing agricultural permits to restrict water uses to the most necessary and efficient cropping methods and to meter all uses.

Conversion of a large percentage of crops being grown on over-drained, highly vulnerable lands, to non-irrigated crops such as long-leaf pine plantations or in some cases unimproved pasture will be necessary to attain the water quantity restoration goal. Springs protection zones should be developed based on the aquifer vulnerability maps reproduced in this report. No new high-intensity agricultural operations should be permitted on moderately to highly vulnerable lands (approximately 95% of the springshed area), unless they can rely totally on rainfall and surface water storage. Subsidies and tax incentives need to be developed to lessen the impact of these types of restrictions on existing agricultural producers in these most vulnerable areas of Levy and Marion Counties.

Other significant water uses, including commercial/industrial and recreational will also need to reduce their reliance on groundwater supplies by about 60%.

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9.3.2 Water Quality Restoration

The preliminary target for nitrate nitrogen concentrations at Rainbow Springs is 0.35 mg/L as determined by DEP in the Rainbow Springs TMDL (DEP 2012). This goal will require an estimated 82% reduction in nitrogen loads to the vulnerable portions of the springshed. This report estimates that there is approximately 2,800 tons per year of total nitrogen (TN) introduced into the springshed in the form of nitrogen fertilizer. Other important nitrogen sources include horse manure (1,501 tons TN per year) and cattle manure (1,256 tons TN per year) estimated by Jones *et al.* (1996). Jones *et al.* (1996) also estimated that rainfall contributes on average about 1,442 tons TN per year of nitrogen to the surface of the springshed area.

Additional nitrogen loads to the groundwater result from the disposal of human wastewaters in the springshed. This report estimates a human population of approximately 111,747 persons in the springshed. The reported nitrogen load per person in domestic wastewater is about 7.3 pounds TN per year. For the estimated human population and assuming a 50 percent reduction in nitrogen loads through wastewater treatment facilities and septic tanks, the estimated human waste nitrogen load to the surface of the ground is an additional 408 tons TN per year.

The combined load of total nitrogen reaching the surface of the ground in the Rainbow Springshed from all of these sources is about 7,407 tons per year. The average nitrate nitrogen load discharging through Rainbow Springs for the period from 2005 through 2012 was about 917 tons per year. Based on the estimated change in nitrogen load between what is applied and what is exiting the springs, the estimated attenuation of nitrogen between the ground surface and the Floridan Aquifer due to a combination of uptake and removal from the springshed, as well as the natural process of microbial denitrification, is about 88 percent. Nevertheless, the measured 917 tons per year of nitrogen being discharged from the spring vents needs to be reduced by an additional 82 percent.

Full (100%) implementation of existing agricultural and residential Best Management Practices (BMPs) will not solve the problem of excessive nitrogen reaching the Floridan Aquifer. Published research indicates that as much as 50 to 100 pounds of TN per acre each year reach the aquifer below traditional row crop agriculture in highly vulnerable areas (Munch *et al.* 2006). Golf course fertilization loads up to 260 pounds of TN per acre per year (Munch *et al.* 2006). For comparison, a natural forested land use results in an estimated annual average TN load of about 0.6 pounds per acre. To achieve an overall groundwater nitrate concentration goal of 0.35 mg/L it is estimated that the average annual TN load reaching the aquifer should be no more than about 3 to 4 pounds per acre. An “advanced” BMP for agricultural lands on vulnerable karst areas would of necessity be an unfertilized, non-irrigated long leaf pine or mixed hardwood forest.

A significant portion of the necessary nitrogen reduction could be accomplished in concert with the water quantity restoration described above. About 95 percent of the springshed is considered more or most vulnerable in terms of groundwater contamination by surface pollutants. Replacing all fertilized agriculture and fertilized residential landscaping by unfertilized/non-irrigated forest or Florida Friendly plant communities would reduce the estimated nitrogen inputs by about 75 percent. A realistic incentive for this conversion would be to charge a significant “Aquifer Protection Fee” for all nitrogen fertilizers used in the springshed. Revenues from this fee would be used to assist agricultural producers to shift land uses to “advanced” BMPs as described above. Following establishment of this Aquifer

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Protection Fee, a possible phased approach would be to initially cut nitrogen fertilizer use in the springshed to about 50 percent of existing levels in the first five years, followed by a second phased reduction of an additional 50 percent over the next five years. A phased ban on fertilizer use would allow greater flexibility for agricultural producers to develop less polluting cropping strategies.

Nutrient loads originating from livestock will also need to be reduced by about 82 percent to achieve the TMDL nitrate limit for Rainbow Springs. One way to accomplish this goal is to eliminate all pasture fertilization and then to limit the density of grazing animals to what can be supported by unimproved pasture. A second proposal is to collect all animal manure and to recycle it as an alternative to using inorganic nitrogen fertilizers. Ultimately, the number of large grazing animals in the springshed will need to be reduced significantly to achieve the nitrate TMDL goal. This goal might be more achievable if the three counties that comprise the springshed altered agricultural tax exemptions to favor forestry rather than large animal operations.

Human wastewater nitrogen loads in the springshed can be reduced by implementing advanced nitrogen removal for all central wastewater plants and by providing centralized collection and wastewater treatment for all high-density septic tank areas. A detailed analysis evaluating and comparing nitrogen removal measures using advanced nitrogen removal technologies such as constructed wetlands, biological nutrient removal processes, and nitrogen-removal on-site disposal (septic) systems should be prepared as part of the current Basin Management Action Planning process.

In summary, the BMAP must provide realistic but stringent nitrogen reduction measures, regardless of whether or not they affect agriculture or urban land use practices. Costs for these upgrades are likely to be significant and should in turn be compared to costs to reduce other nitrogen inputs to the aquifer from fertilizers and animal/human wastes. The nitrate contamination at Rainbow Springs will not be solved unless all options are on the table and evaluated for cost effectiveness (\$ per pound of nitrogen that is prevented from reaching the aquifer).

9.3.3 Reduction of Recreational Impacts

Unlike some smaller spring runs, the Rainbow River has minimal tree cover, is relatively wide and deep, and is subjected to high-intensity human uses. When not properly managed recreational uses can cause unintended damage. In the case of the Rainbow River, the average depth (~1.8 meters) protects some of the bottom of the river from direct adverse impacts by recreation (Cichra and Holland 2012). However, motor boats have been implicated in several studies as the dominant cause of damage to benthic plant communities in the Rainbow River (Mumma 1996, Cichra and Holland 2012). Also tubers, and to a lesser extent canoeists and kayakers, have been found to cause damage, directly or indirectly, in the vicinity of launch points and take-outs.

There has also been concern that SCUBA divers impact submerged grass beds. In the study by Cichra and Holland (2012) SCUBA divers were observed to cause minimal damage although there were incidents of SCUBA divers entering SAV plant beds typically to avoid other users. An important observation made by Cichra and Holland (2012) is that during periods of heavy recreational use the competition for space causes users to enter areas of the spring run where

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damage is more likely to occur. Damage may result when SCUBA divers move into grass beds to avoid tubers or boats; when tubers avoid canoeists or kayakers at take-outs damaging emergent vegetation; or when motorboats try to avoid SCUBA divers, tubers, canoeists, and kayakers by veering into shallow water. The bottom line is that on days with heavy recreational use competition for space is a problem and the greatest impact occurs to the ecology of the spring run.

Recommended options to reduce recreational impacts are provided below and should be evaluated by stakeholders to select alternatives that allow maintenance of a healthy SAV plant community and a reasonable but protective level of recreation:

- Develop hardened entry and exit points for tubers (similar to Ichetucknee River) to avoid trampling of vegetation in the vicinity of these areas.
- Add tie-up points for dive boats in areas along the river that are used for exit and entry.
- Place signs in strategic areas to identify shallow or vulnerable areas to educate the public to avoid submerged aquatic vegetation.
- Limit the number of dive boat operators by instituting a permit system.
- Separate the river into separate use zones (similar to Ichetucknee River) with no motor boating allowed above the tuber exit points.
- Only allow boats with four-stroke motors below a specified horsepower (possibly <10 HP), and limit the shaft length of all outboard motors.

One other change that may be worthy of further consideration is to limit tuber access to a single point (either the State Park or KP Hole, but not both) and to one exit point (preferably the State Park exit).

9.3.4 Exotic Vegetation

Hydrilla and benthic algae prevalence on the Rainbow River is well known and documented (SWFWMD 2007, Atkins 2012, Cichra and Holland 2012). These studies have indicated varying extents of hydrilla and algae on the river that have changed over time due to expansion, contraction, physical removal, and herbicide application. A river-wide approach should be taken to manage exotic vegetation that includes education and coordinated efforts of interested groups to maximize the effective and environmentally-sound solutions. Cichra and Holland (2012) reported that during their study residents were observed manually removing hydrilla and letting it float downstream. To avoid colonization in other areas a hydrilla clean-up could be organized to remove hydrilla and dispose of it in an off-site upland disposal area. Also mentioned by Cichra and Holland (2012) was the rapid colonization of trampled areas in the vicinity of entry and exit points by hydrilla. This could be mitigated by developing hardened structures at these points to minimize the interaction between users and submerged vegetation and targeted removal to encourage re-colonization by native species. Chemical control of exotic and native plants in the Rainbow River should be limited in areal extent and only used as a last resort, following manual removal.

9.4 Monitoring and Adaptive Management

Improved monitoring of the Rainbow River System is essential to ascertain existing conditions and changes resulting from implementation of actions described in this plan. A comprehensive and on-going monitoring plan should be developed and fully funded to include the following types of data collection:

- Hydrology – rainfall, ET, aquifer levels, spring and river flows and annual springshed water balances
- Water Quality – groundwater and surface water
- Ecology – populations and productivity of macroinvertebrates, fish, turtles and other reptiles, mammals, and birds; whole ecosystem metabolism (productivity and respiration)
- Human Uses – boating, tubing, diving, nature-study, etc.

These data should be collected at multiple stations to provide adequate coverage to understand and document changing conditions and to direct adaptive management of the resource. A detailed evaluation of the economic importance of the Rainbow River system and of the non-monetary ecosystem services should be conducted at least every five years.

9.5 Education Initiatives

Ongoing public education about the threats facing the long-term health of Rainbow Springs and the Rainbow River will be essential for achieving ultimate restoration. This Restoration Action Plan provides a preliminary roadmap to fully accomplish restoration goals. However, getting this information out to the public and to the State officials who are most concerned with springs' protection is an important part of this educational process. This will require public presentations, public meetings, newspaper and TV reporting, rallies at Rainbow Springs, and many partnerships. Rainbow River Conservation, Inc. will most likely be the leader in this effort, with technical support from the Howard T. Odum Florida Springs Institute and other Springs Alliance advocacy groups throughout North Florida.

9.6 Regulatory Assistance

The FDEP is currently preparing a BMAP to achieve the TMDL nitrate nitrogen goal at Rainbow Springs. Active participation in this process will be critical to adopt a BMAP that has potential to actually turn around the increasing nitrate levels and declining flows so visible in the springs and river. This Restoration Action Plan can serve as the "People's BMAP" if the DEP plan does not provide a realistic and timely plan to achieve success with restoration and protection of this spring system.

It is assumed that the SWFWMD will be developing Minimum Flows and Levels (MFLs) for the Rainbow Springs and River over the next few years. Based on their draft work to-date it appears that the District's hydrogeologists believe that there is minimal effect of groundwater pumping on the existing evident spring flow reductions. This conclusion is contrary to the evidence assembled in this report. If the District does not change their technical assessment of the cause of spring flow reductions at Rainbow Springs, then they will likely conclude that additional

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permits for groundwater extraction and additional flow reductions are warranted. If so, this conclusion will need to be challenged by the public in front of the Governing Board and possibly in the courts. Denial of the true magnitude of spring flow reductions due to groundwater pumping throughout North Central Florida will need to end, if Rainbow Springs will ever experience true restoration and protection.

The Florida Department of Agriculture and Community Services (FDACS) is the state agency responsible for regulating agricultural practices in Florida. This agency has a long history of encouraging agricultural development to the detriment of environmental protection. A paradigm shift is necessary at FDACS and in the development of agricultural BMPs. For example, existing BMPs are developed to maximize economic yield while minimizing environmental damage. This prioritization will not result in springs protection. Agricultural BMPs must be re-designed to first achieve necessary environmental protections and secondly to provide reasonable economic returns. In areas of high groundwater vulnerability the only agricultural crop that is consistently capable of maintaining an average groundwater nitrate concentration less than 0.35 mg/L is probably long leaf pine. A forestry crop should probably constitute the preferred agricultural “advanced” BMP for the karst areas of the state.

9.7 Responsible Parties

Specific recommendations to implement water quantity, water quality, and resource management restoration actions for the Rainbow Springs System are described above in this report. A summary of the general challenges and solutions as well as specific recommendations and entities most likely to be responsible for implementing those actions is summarized as follows:

The Challenges

- Increased awareness by all stakeholders (the public and their local, state, and federal leaders) is necessary to accomplish restoration of the Rainbow Springs System (Rainbow Springs and River)
- Reduced consumption of groundwater within and outside of the Rainbow Springshed is needed to restore spring and river flows
- Natural drainage and water storage patterns in wetlands and streams in the Rainbow Springshed need to be restored to enhance spring and river flow and water quality
- Fertilization and wastewater disposal practices need to be improved to reduce the load of nitrogen leaching into the aquifer
- Technical uncertainties still exist concerning the magnitude of flow reductions and sources of increased nitrogen loads and their effects on the health of the Rainbow Springs System
- Management and protection of the Rainbow Springs System is shared by many different state and local entities who do not work cooperatively and effectively

The Solutions

- Educate the public and local, state, and federal leaders of the importance of restoring the Rainbow Springs System and its natural biodiversity

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- Develop a phased plan to restore Rainbow Springs and River flows by cutting back on consumptive uses of groundwater within and outside of the Rainbow Springs Springshed
- Increase protection and restoration of natural drainage and storage patterns in wetlands and streams in the Rainbow Springs watershed
- Implement consequential improvements in fertilization and wastewater disposal practices in the Rainbow Springs Springshed
- Develop a coordinated and comprehensive management plan for the Rainbow River system and assess the costs and benefits of restoration efforts
- Initiate a phased restoration timeline, establish adequate monitoring of the Rainbow Springs System to be able to document whether these efforts are resulting in improved springs health, and apply an adaptive management approach to use this improved knowledge to improve and optimize restoration success.

Goal #1: Overall Springs Protection

Responsible Entity: Florida Legislature

The Florida Legislature has the ultimate statutory power to provide comprehensive springs protection and funding to implement restoration actions. In one form or another springs legislation was attempted annually from 2005 through 2010 and again in 2013. All of those efforts failed. It will take a significant effort to convince the Florida Legislature to prioritize the importance of springs and water resource protection during a time of fiscal hardship for the state. However, as with rainfall, political priorities tend to be somewhat cyclical. In the event that the political focus shifts back to protecting Florida's unique and priceless environment, including springs, the following recommendations are offered for consideration by the Florida Legislature:

- Place flow meters on all groundwater extraction wells (CUPs and domestic self-supply wells) and require routine reporting to the public
- Fund improved water management (conservation measures), nutrient reduction strategies (advanced BMPs and wastewater upgrades), and springs research by charging a use fee (Aquifer Protection Fee) on all groundwater extractions and all fertilizer nitrogen uses affecting the Floridan Aquifer System
- Amend Chapter 373.042, Florida Statutes to require that alternative water supplies be developed before consumptive use permits create water supply deficits
- Require all water management districts to establish a Regional Sustainable Groundwater Yield that protects all surface water resources, including springs, from significant harm and Outstanding Florida Waters (OFWs) from any harm
- Strengthen groundwater protection by requiring that water use permits can only be issued when minimum flows and levels for all priority waters are complete and being met
- Change the groundwater nitrate standard (currently 10 mg/L based on human health) to be protective of springs health (less than 0.35 mg/L)

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- Adequately fund the Florida Department of Environmental Protection (including the Florida Geological Survey and the Florida Park Service) to be able to provide comprehensive springs resource monitoring and management

Responsible Entity: Florida Park Service (FPS)/Marion County/City of Dunnellon/Florida Fish and Wildlife Commission (FWC)

FDEP and the FPS have ultimate authority to regulate human uses and management priorities in the Rainbow Springs State Park with Marion County and the City of Dunnellon jurisdictions covering the remainder of the river. During 2011 and 2012 additional research was conducted to reevaluate the human carrying capacity of the Rainbow Springs System. While no decisions were made and no specific new actions implemented, there was a general consensus among managers and enthusiasts that the recreational carrying capacity of the Rainbow Springs Run is currently being exceeded.

- Enhance the regulations in Chapter 18, Florida Administrative Code pertaining to the Rainbow River Aquatic Preserve to better protect the diverse natural communities within the preserve, including the important riparian and upland habitats adjoining the river
- Redefine the recreational carrying capacity of the entire Rainbow Springs System to better protect the river from vegetation trampling, erosion, and sedimentation, with particular emphasis on tubing, access by motorboats, and SCUBA diving
- Consider dividing the river into user sections that minimize user conflicts during peak recreational periods and improve visitor experience (*e.g.*, SCUBA diving zones, motorboat corridor, etc.)
- Consolidate tubing for KP Hole and the state park into a single area that share a put-in point and take-out to minimize shore disturbance and user conflicts
- Implement the Rainbow River Corridor Project to acquire available land parcels adjacent to the spring run that are identified in the report. Land purchases by this project have already been approved by the Florida Acquisition and Restoration Council (ARC)
- Work closely with the Rainbow River Conservation (RRC) group to develop and implement recreational changes
- Improve enforcement coordination. The current enforcement of various rules including the Florida Administrative Code, Marion County ordinances, Dunnellon ordinances, etc. is divided between a number of agencies including FDEP, FWC, Marion County, Florida Recreation and Parks, and the Rainbow River Aquatic Preserve (DEP Office of Coastal and Managed Areas), and is not presently an efficient and coordinated program. Enforcement jurisdictions and authorities should be examined and streamlined. Cross training between all agencies should be formalized
- City of Dunnellon and Marion County should strengthen their River Corridor Protection Ordinance and River Protection and Environmentally Sensitive Overlay Zone, respectively
- Make all fishing on the river catch and release with artificial bait to allow for competing uses of fishing and wildlife observation
- Consider closing areas (*e.g.*, Ichetucknee snail habitat or Crystal River) for designated wildlife protection sanctuaries including bird rookeries and turtle basking areas

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Goal #2: Restoring Spring Flows

Responsible Entity: Southwest Florida Water Management District (SWFWMD)

The SWFWMD has the responsibility to regulate all human water uses in the Rainbow Springs basin. This responsibility includes the evaluation of the environmental flow requirements of the Rainbow Springs System as well as the need to provide adequate water quantities to meet reasonable beneficial human uses. Development of MFLs for the Rainbow Springs System is a critical part of this responsibility. But the SWFWMD also needs more information to effectively manage a finite groundwater resource. This information, namely how much groundwater is available considering the mandate to provide adequate flows for environmental needs, is not available to the SWFWMD governing board. The recommendations provided below would insure that adequate information is available for effective and sustainable water management.

- Estimate the harm already caused to the Rainbow Springs System from the lowered discharge
- Establish minimum flows and levels and/or an estimate of the Regional Sustainable Groundwater Yield that will protect the Rainbow Springs and River and all of its principal springs from further flow reductions
- Fund the U.S. Geological Survey to prepare a water budget for the Rainbow Springs springshed that specifies the total allowable groundwater available for human uses and reserves adequate groundwater for the natural systems
- Endorse the USGS reports that demonstrate a regional lowering of ground water levels and consequent reduction of historic Rainbow Springs System discharge due to human withdrawals
- Set a timeline for overall reductions in groundwater pumping necessary to return the Rainbow Springs System flows to >90% and >95% of historic conditions, with a focus on development of alternative surface water sources and a moratorium on issuance of new water use permits if deadlines are not met
- Require agricultural and residential water use metering throughout the SWFWMD and implement strict water use conservation measures as needed to achieve protective aquifer levels

Goal #3: Groundwater Assessment

Responsible Entity: Southwest Florida Water Management District

- Prepare a database of all existing wells (agricultural, industrial, municipal, and domestic self-supply) in the District with geographic coordinates, estimated pumping rates, and historic levels
- Implement a network of additional monitoring wells as needed to continuously and more accurately record changes in groundwater levels throughout the springshed
- Instrument all agricultural and private wells with water meters to increase knowledge of existing and future groundwater pumping rates

Goal #4: Implement Strong Conservation Measures

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Responsible Entity: Southwest Florida Water Management District

The SWFWMD should work closely with the other regional water management districts to quantify the finite capacity of the Floridan Aquifer to supply all of the public and environmental needs for the current and future residents of north central Florida

- The SWFWMD should work with the Suwannee River and St. Johns River water management districts to estimate a Regional Sustainable Groundwater Yield, and to implement a strict water conservation program throughout the historic Rainbow Springs Springshed as well as all of North and Central Florida that includes increased public education, significantly higher fees for municipal and commercial water uses, and enforcement of watering restrictions based on groundwater levels

Goal #5: Restoring Water Quality

Responsible Entity: Florida Department of Environmental Protection (FDEP)

FDEP has ultimate responsibility to protect water quality in the Rainbow Springs System and in the groundwater that re-nourishes those surface water resources. Continuing pollution of the Rainbow Springs System by elevated nitrate nitrogen concentrations and the need to address the nitrate TMDL for the Rainbow River is evidence that FDEP's long-standing responsibility to protect surface water quality has not been realized. FDEP's diligent efforts to direct many nutrient-contaminated wastewater and stormwater discharges to the groundwater has resulted in widespread nitrate contamination of the Floridan Aquifer System and springs. The regulatory approach of TMDL followed by BMAP is the existing tool that FDEP intends to use to rectify the resulting ground and surface water eutrophication that resulted from this misguided policy. Unfortunately for the future of the Rainbow Springs System, this regulatory process lacks enforcement power in areas dominated by agricultural nitrogen inputs and is not likely to result in timely, measureable benefits.

The following recommendations are offered to help expedite and improve this BMAP process.

- Work with the SWFWMD to bridge the existing gap between water quality and quantity which are inextricably linked
- Support implementation of the Basin Management Action Plan (achieving the Rainbow Springs and Rainbow River Basin Total Maximum Daily Loads and Best Management Practices) on an accelerated schedule
- Routinely conduct bioassessments and EcoSummaries to track the health of biotic communities
- Phase in advanced nitrogen removal (less than 3 mg/L total nitrogen) at all municipal wastewater treatment facilities
- Require wastewater biosolids and septage to be converted to a beneficial fertilizer product or disposed of outside the springshed
- Evaluate feasibility of cluster sewage collection and advanced treatment for all areas in the Rainbow Springs Springshed with high densities of septic systems
- Strengthen rules for the State Aquatic Preserve program to meet the stated intent of maintaining the system in its "essentially natural condition."

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Responsible Entity: Department of Agriculture and Consumer Services (FDACS)

FDACS has the responsibility to encourage the economic vitality of Florida's agricultural community as well as the responsibility to work with other state agencies (i.e., SWFWMD and FDEP) to insure that existing and new agricultural production does not cause unnecessary harm to the state's environment. With these goals in mind, the following recommendations are offered for FDACS to help support restoration and protection to the Rainbow Springs System.

- Assess and support the most cost-effective strategies to reduce overall agricultural nitrogen loads to the Floridan Aquifer in the Rainbow Springs Springshed – necessary reductions are on the order of 82 percent of current uses
- Prepare draft legislation that incentivizes agricultural producers in vulnerable aquifer areas to voluntarily convert to crops that require less or no fertilizer use (Advanced BMPs)
- Prepare draft legislation that incentivizes confined animal operations (CAOs) to voluntarily cut their discharge of nitrogen to the groundwater
- Prohibit new CAOs in the entire Rainbow Springs Springshed

Responsible Entity: Marion County and City of Dunnellon

Marion County is the local government entity with greatest interest in the protection and restoration of the Rainbow Springs and River which are entirely in the county's jurisdiction. The County is reliant on the more resourceful state agencies with the authority to manage water quality and quantity. However, Marion County can help to protect its future economic interests by using its zoning and taxing authority to encourage springs protection by following these recommendations.

- Enforce land use restrictions in Primary and Secondary Aquifer Protection Zones in the Rainbow Springs Springshed based on aquifer vulnerability
- Phase in mandatory reductions in residential and commercial lawn and landscape fertilization accompanied by an intensive public information campaign that relates excessive fertilizer use to springs degradation
- Re-permit all County wastewater treatment and disposal facilities to achieve less than 3 mg/L TN
- Within the Primary Aquifer Protection Zone, restrict installation of new on-site wastewater treatment systems (septic tanks) to properties with a minimum of five acres, and require smaller lots to be connected to a centralized wastewater treatment system that achieves advanced nitrogen reduction (less 3 mg/L total nitrogen)
- Provide a "nitrogen-credit" assessment (property tax reduction) for all properties in the most vulnerable portions of the Rainbow Springs Springshed (protection zones) that are in non-fertilized, non-irrigated forested land uses
- Establish local ordinances for protection of submerged aquatic vegetation (SAV) in the river

Goal #6: Reducing Agricultural Impacts

Responsible Entity: Marion County Soil and Water Conservation District (SWCD)

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Petition FDACS and the SWFWMD for authority to provide local oversight of all agricultural operators with “Advanced” BMPs that are intended to eliminate wasteful water uses and the load of nitrate nitrogen and other pollutants that are released into the ground and surface water environment. Considering the good relationship between the SWCD and the agricultural community which is largely responsible for achieving water quantity and quality improvements at the Rainbow Springs System, the SWCD should consider implementing the following recommendations:

- Educate and encourage local agricultural producers to shift to crops that use less or no groundwater and nitrogen fertilizer
- Work with University of Florida Institute of Food and Agricultural Sciences to develop “Advanced BMPs” that reduce nitrogen loads to achieve target nitrate concentration in the groundwater of 0.35 mg/L
- Work with producers to implement existing and “Advanced” BMPs

Goal #7: Effective Communication

Responsible Entity: Rainbow River Conservation (RRC)

RRC is the primary citizen group concerned with lasting protection and restoration of the Rainbow Springs System. The following activities are recommended for the organization:

- Advocate for the implementation of these goals for restoration of the Rainbow Springs System
- Seek funding to continue the efforts of the Rainbow Springs Working Group to continue to engage all stakeholders and to implement the Rainbow Springs Restoration Action Plan
- Continue garnering support and funding for acquisition of properties described within the Rainbow River Corridor Plan
- Initiate and support a Rainbow Springs SPRINGSWATCH program of citizen volunteers
- Fund annual or bi-annual Rainbow Springs Health Report Cards

Responsible Entities: Ocala Star Banner/WCJB TV 20/Riverland News/Media Outlets

A vocal and active press can provide effective communication of issues that affect the public’s best interests. This recommendation provides a useful role for the press with informing the public about the condition of their common resource and whether or not progress is being made towards recovery from its existing degraded condition.

- Report easily understandable groundwater level, river flow and stage, and spring flow data summaries (provided daily or weekly by the SWFWMD), and other new research findings, as appropriate, in newspapers and other news outlets of wide circulation to allow the public to see the results of these efforts and the health (improving/ declining condition) of their local water resources

Goal #8: Documenting Spring Health

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Responsible Entities: Florida Springs Institute/Marion County Audubon/U.S. Geological Survey/University of Florida/Florida Department of Environmental Protection/Florida Park Service

These non-profit, federal, and state-funded organizations are primarily interested in studying and protecting the environmental attributes of the Rainbow Springs and River. Good science is necessary to provide good resource management. In the absence of the FDEP Florida Springs Initiative, discontinued in 2011, the Howard T. Odum Florida Springs Institute (FSI) was formed to help fill the gap in springs knowledge that was created. Marion County Audubon (MCA) is a local chapter of Audubon of Florida, the statewide group of bird and environmental advocates. MCA has particular interest in all aspects of environmental protection at Rainbow Springs State Park. Scientists with the U.S. Geological Survey have conducted much of the basic applied groundwater and faunal research throughout the Rainbow Springs System. University of Florida researchers have conducted numerous applied ecological and human use studies in the Rainbow Springs and River. FDEP/FPS continues to conduct environmental studies in the Rainbow Springs System focused on informing wise environmental management. These groups could be most effective at implementing the following recommendations:

- Implement an ecological monitoring program in the Rainbow Springs and River
- Expand water quality and biological sampling in the Rainbow Springs and River to accurately track trends
- Prepare Springs Health Report Cards bi-annually

9.8 Closing Statement

Implementation of the recommendations listed above will require significant will-power and changes to “business as usual”. Eventual restoration and long-term protection of the Rainbow Springs System will require a shift from focusing on short-term needs of individuals and businesses, and taking a longer view for conservation and protection of clean and abundant groundwater, which is arguably one of the most important natural resources in Florida. Currently, the groundwater that feeds the Rainbow Springs System is neither clean nor abundant. As evidenced so clearly by the deteriorating condition of Rainbow Springs, Marion County and North-Central Florida’s groundwater resources are also on a declining trajectory. Fortunately, as long as it rains, groundwater is a renewable resource. Hope for the future health of the Rainbow Springs System, for Florida’s springs, and the entire Floridan Aquifer System in general, is in the hands of the people who have learned to appreciate the unique value of these public resources.

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