Rainbow *Springs*

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AN EXECUTIVE SUMMARY PLAN FOR RESTORATION

WINTER, 2013

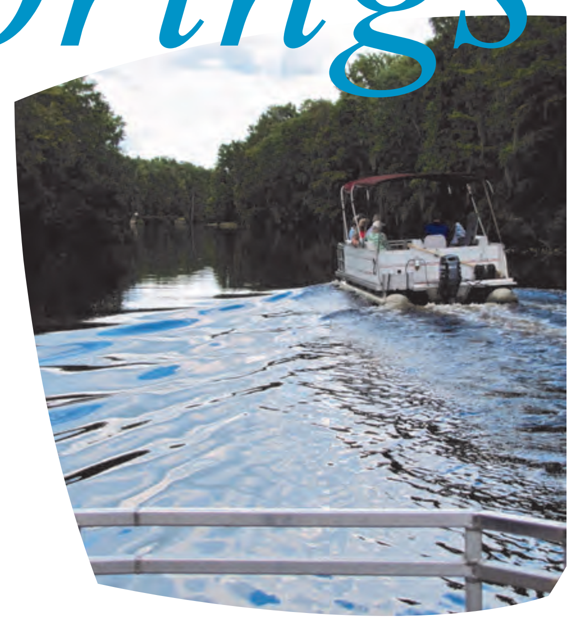
▶ Ecosystem Services

▶ Wildlife

▶ Environment

Rainbow Springs

A PLAN FOR RESTORATION



Background

With over 1,000 artesian springs identified, north Florida is home to a world-class hydrological wonder. Biologically, springs support a wide array of aquatic organisms—from submerged aquatic plants to the turtles and manatees that feed on these plants. Economically, springs are a great source of value for humans, especially for aesthetics and recreation, but also as a supply of pure drinking water.

In spite of their value, human activities are destroying our springs. Intensive recreation can impart a significant toll on the ecological biodiversity and productivity of springs. Groundwater extractions reduce spring flows. Residential development brings use of nitrogen-based fertilizers, septic tanks, and wastewater and stormwater discharges that pollute springs. Increasing human populations and a global market provide a ready outlet for agricultural products that also impacts springs due to nitrogen fertilizers and high groundwater pumping for irrigation.

As highly sensitive biological communities, springs are negatively impacted from decreased flows, increased nitrate nitrogen pollution, and excessive recreational disturbances. Springs are dependent on plentiful and pure groundwater, and as such, can provide an important early warning system for humans who are also dependent on plentiful and pure groundwater.

The increasingly obvious degradation of Florida's springs is serving to raise public awareness that the Floridan Aquifer is in trouble, and that an effective response is needed to protect the environment that supports Florida's economy. This Restoration Action Plan has been prepared as a roadmap for protecting Rainbow Springs and Rainbow River from further harm, and for restoring the Rainbow Springs system back to a healthy springs ecosystem.

Description of the Resource

Rainbow Springs, the Rainbow River, and the surrounding springshed are referred to in this plan as the Rainbow Springs System. Rainbow Springs and the Rainbow River are located in southwestern Marion County in west central Florida, approximately 4 miles north northeast of Dunnellon and 19 miles west southwest of Ocala (Exhibit 1, page 4).

The spring and river offer significant recreational opportunities including kayaking, canoeing, tubing, swimming, snorkeling, scuba diving, boating, and other water-related activities. The Rainbow river flows approximately six 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.

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Rainbow Springs consists of twelve named vents that discharge groundwater from the Floridan Aquifer System at a combined historic average discharge of more than 485 million gallons per day (MGD), making it one of the largest first magnitude spring systems in Florida. The springs discharge into the Rainbow River, which flows south to the Withlacoochee 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. The state park attracts over 260,000 visitors annually, making it a major tourist attraction in Marion County. Additionally, the Marion County Parks and Recreation Department manages the K.P. Hole County Park, located on the west bank of the Rainbow River, which is enjoyed by an additional 70,000 visitors each year.

The Rainbow Springs System has received regulatory protections including recognition as a National Natural Landmark, designation as an Outstanding Florida Water, inclusion in a Florida Aquatic Preserve, and State Park status. In spite of these regulatory safeguards, the Rainbow Springs System has experienced significant degradation during the last half century from agricultural, urban, and industrial development in the surrounding springshed. These land use changes include groundwater withdrawals, use of nitrogen fertilizers, and animal and human wastewater disposal.

Groundwater withdrawals have resulted in declining spring flows that no longer support the size and complexity of the Rainbow Springs ecosystem. Also, increasing concentrations of nitrate nitrogen in the Floridan Aquifer have caused impairment at Rainbow Springs that is characterized by algal proliferation and changes to the aquatic plant community.

Parallel management and restoration activities are underway by the Florida Department of Environmental Protection and Southwest Florida Water Management District to establish a lower minimum flow threshold, and 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 any degradation of the Rainbow Springs system are not appropriate for an “Outstanding Florida Water” and a “National Natural Landmark.” The Rainbow Springs system is too important to the people, plants, animals, and future economic health of Dunnellon, Marion County, and all of Florida to allow any harm to be tolerated.

The environmental attributes of the Rainbow Springs System have received considerable scientific documentation over the past 60+ years. A full-length Rainbow Springs Restoration Action Plan was written by the H.T. Odum Florida Springs Institute with the goal of summarizing existing environmental data, establishing a baseline of the environmental data, describing the types of impairments suffered by the Rainbow Springs System, and presenting a logical series of restoration actions that are needed to protect, restore, and preserve the natural biological functions of this precious ecosystem.

The full-length Rainbow Springs Restoration Action Plan can be downloaded from the Florida Springs Institute website (**www.floridaspringsinstitute.org**). This document provides an Executive Summary of the full-length Action Plan.

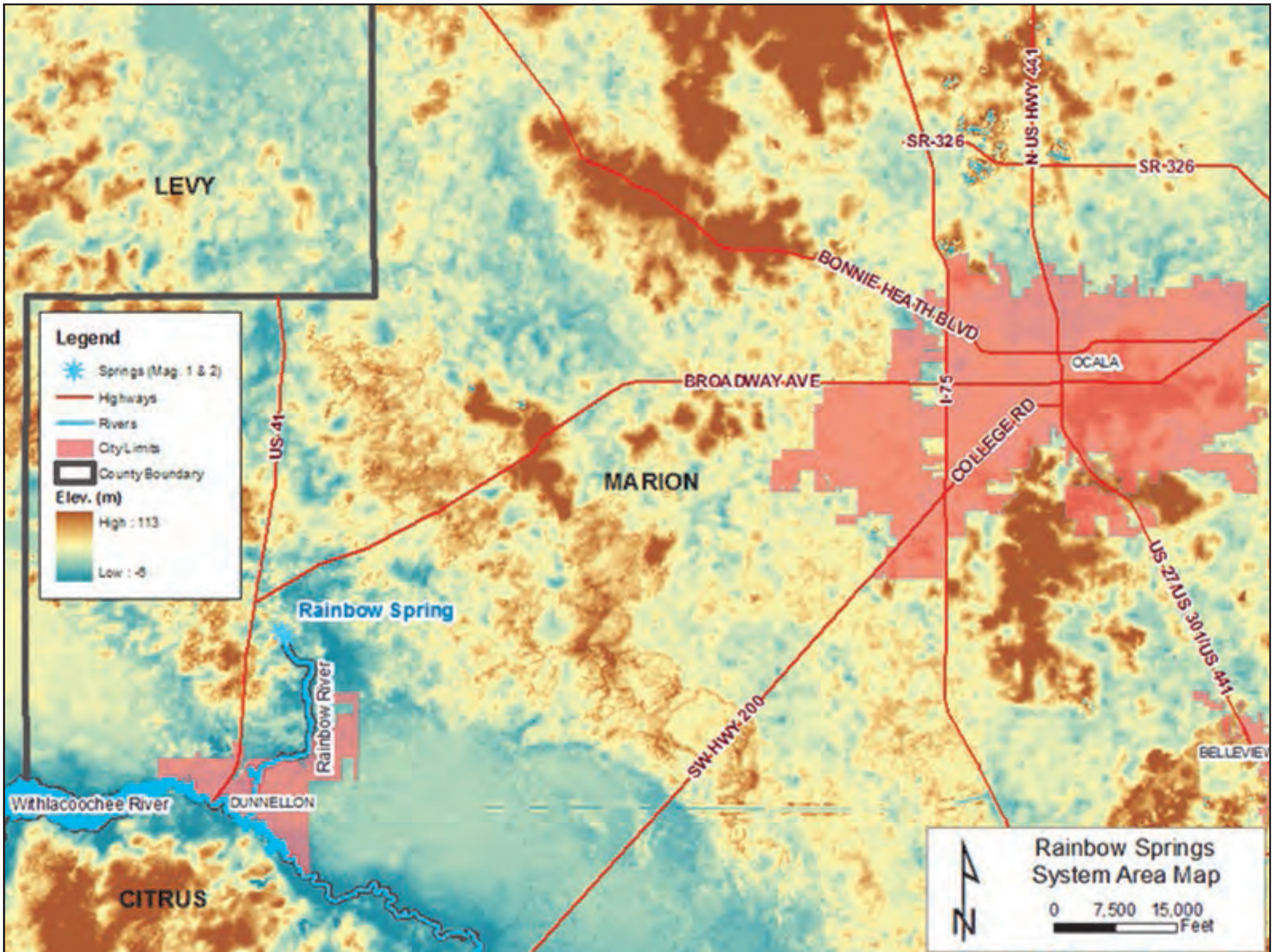
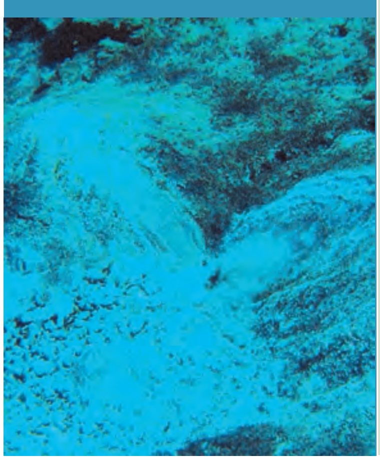


Exhibit 1. (above)

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.



A Karst Environment

North Central Florida is dominated by a "karst" landscape of underground limestone formations. Rainfall that does not evaporate or get taken up by plants or drains into surface water bodies, percolates through the ground and recharges the Floridan Aquifer. Water generally flows through underground limestone formations that make up the Floridan Aquifer, and eventually discharges at a spring, such as at one of Marion County's three first magnitude springs—Rainbow, Silver, or Silver Glen springs.

Most of the groundwater that exits the Floridan Aquifer at Rainbow Springs is derived from the Ocala Limestone in the upper 100 ft of the Floridan Aquifer, a water-bearing zone with rapid flow rates and relatively short residence times.

A springshed is defined as the area surrounding a spring that contributes groundwater to a spring vent or series of vents. Springsheds can be defined based on the "potentiometric surface" (water elevation map) of the contributing aquifer as measured from monitoring wells. While surface 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 from areas with higher water pressure to areas with lower water pressure.

The Rainbow River Springshed includes por-

tions of Alachua, Levy, and Marion Counties, and is estimated to have a land area of about 737 square miles (471,700 ac) (Exhibit 3, page 7). The travel time of water underground and the age of water discharged at a spring can be highly variable, and are based on preferential flow paths, or underground conduits. Large underground conduits will transport more water at a faster rate, whereas water will flow at a slower rate through small conduits. In a study of the adjacent Silver Springs Springshed, a dye trace was used to estimate travel times and found that water flowing underground to Silver Springs flowed at velocities ranging from 84 to more than 3,600 feet/day.

An additional complexity of determining underground water flow patterns is the overlapping nature of the Rainbow Springs and adjacent Silver Springs springsheds. The interface between these two adjacent springsheds moves 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 of the Rainbow River at the upstream springs is approximately 10 ft lower than the water level at Silver Springs. Thus, the lower topographic position of Rainbow Springs relative to Silver Springs, and the relatively level potentiometric surface of the aquifer in this area of the county (about 35 ft of vertical head difference), provide a greater flow advantage to Rainbow Springs at the expense of reduced flows to Silver Springs.

Water Budget

Rainfall and Evapotranspiration

Rainfall averaged 54 inches per year during the period of 1915 through 2011 (Exhibit 2, page 6). The LOESS (locally-weighted scatterplot smoothing) procedure was used to better understand 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 period of the dataset at approximately 50 inches per year, and more recently is at the lowest point during the period of record with about 49 inches per year. The highest annual rainfall during the period-of-record was 73 inches (1953) and the minimum was 33 inches (2000).

Evapotranspiration (ET) is the combined result of evaporation and transpiration by plants. Average ET in the vicinity of Rainbow Springs is estimated at 37.9 inches per year. Due to water availability, ET tends to be higher during wetter years and lower during drier years.

Groundwater Extractions

Determining the volume of groundwater withdrawals is imprecise because many groundwater withdrawal wells are not monitored. However, the Consumptive Use Permits within the Rainbow River Springshed authorize an average daily groundwater pumping rate of approximately 50 MGD.

Approximate locations of Consumptive Use Permits and permitted capacities in the Rainbow Springshed are shown in Exhibit 4 (page 7). It is important to note that on an annual average basis most users will not withdraw their full permitted allocation. However, during the driest years more water is typically used.

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 for the Rainbow Springshed is estimated to be between 13.9 and 15.2 inches per year, resulting in an average flow of about 468 MGD. In the absence of groundwater pumping, the majority of the recharge within the mapped springshed is reflected as flow from the Rainbow Springs Group.

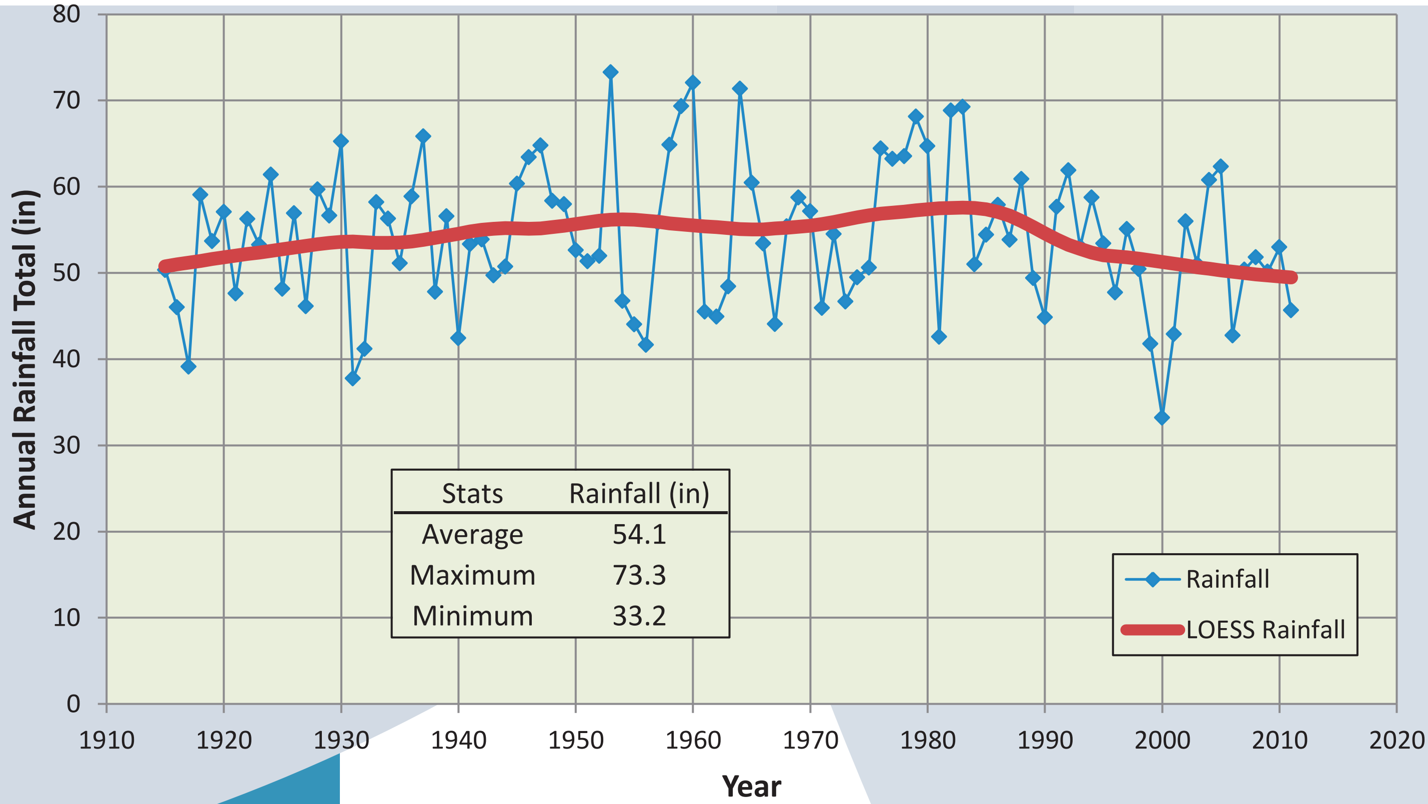


Exhibit 2. *(above)*

Annual rainfall record for Marion County in the Florida Springs Coast Area (1915 – 2011).

Springflow

Groundwater discharge from the Rainbow Springs Group contributes almost all of the flow in the Rainbow River (as measured at County Road 484). The annual average spring discharge reported by the U.S. Geological Survey from 1917 to 2012 was 453 MGD, with a minimum annual mean of 324 MGD in 2011, and a maximum annual mean of 588 MGD in 1965. Average flows in the Rainbow River have declined by about 28% or 142 MGD, from 500 MGD in the early 1900s to about 360 MGD in 2012.

Precipitation vs. Flow

Rainfall is the principal source of water that recharges Rainbow Springs. However, rainfall and pumping must both be considered to explain continuing reductions in flow rates in these springs. 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 indicates that this relationship is changing over time. Where an annual rainfall of 50 inches per year generated an average spring discharge of 452 MGD in the 1960s, the same annual rainfall only generated about 388 MGD of spring flow during the 2000-2012 period, for a 14% estimated decline independent of annual average rainfall.

Aquifer Levels

Aquifer level declines are most evident in areas of Florida where high groundwater pumping occurs and groundwater recharge is low due to the presence of overlying confinement (Exhibit 4). Areas of greatest aquifer drawdown are located in Hillsborough and Polk Counties (about 60 ft of drawdown), Orange County (about 30 ft of drawdown), and Duval and Nassau Counties (50 to 60 ft of drawdown). Based on an analysis of long-term aquifer declines, the average long-term aquifer drawdown in the Rainbow Springshed is between 8 and 15 ft.

Groundwater levels strongly dictate spring flows. 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 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. Groundwater levels can be used to measure the driving forces on spring flow.

When groundwater levels in the Floridan Aquifer increase within the springshed, flows at springs increase. When groundwater levels decline, spring flows decline. In a highly transmissive portion of the aquifer such as in the vicinity of Rainbow Springs, a relatively small decline in aquifer levels results in a significant reduction in spring flow. For example, a 2 ft decline in aquifer levels at Rainbow Springs equates to a 129 MGD flow reduction, or an average decline of about 22%.

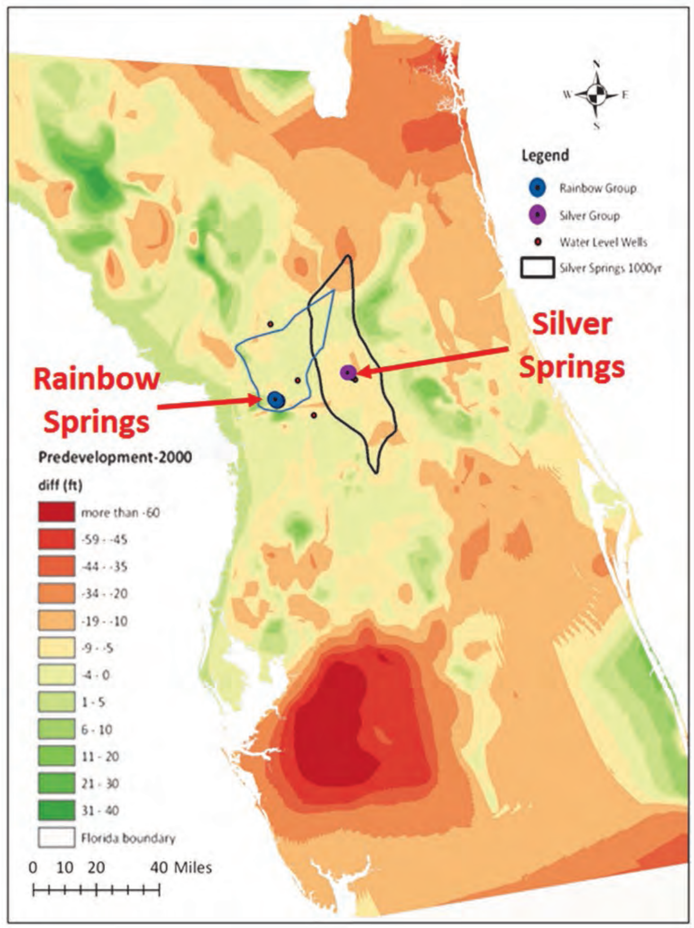


Exhibit 3. *(above)*

Estimated drawdown in the Floridan Aquifer through 2000 in North and Central Florida (Florida Geological Survey). Locations of Rainbow Springs, Silver Springs, their springsheds, and intervening monitoring wells are illustrated.

Springshed Characteristics

Land Use and Population

Land uses within the Rainbow Springshed have transitioned from a dominance of forested uplands to agricultural and urban uses. As of 2004, agriculture was the dominant land use (37%), followed by upland forested land (33%), and urban (17%) (Exhibit 5, page 8). These three land uses cover almost 90% of the springshed. In close proximity to the Rainbow and Withlacoochee rivers, urban land uses generally dominate. Based on the 2010 U.S. Census data, 111,747 people were estimated to be living in the Rainbow River Springshed.

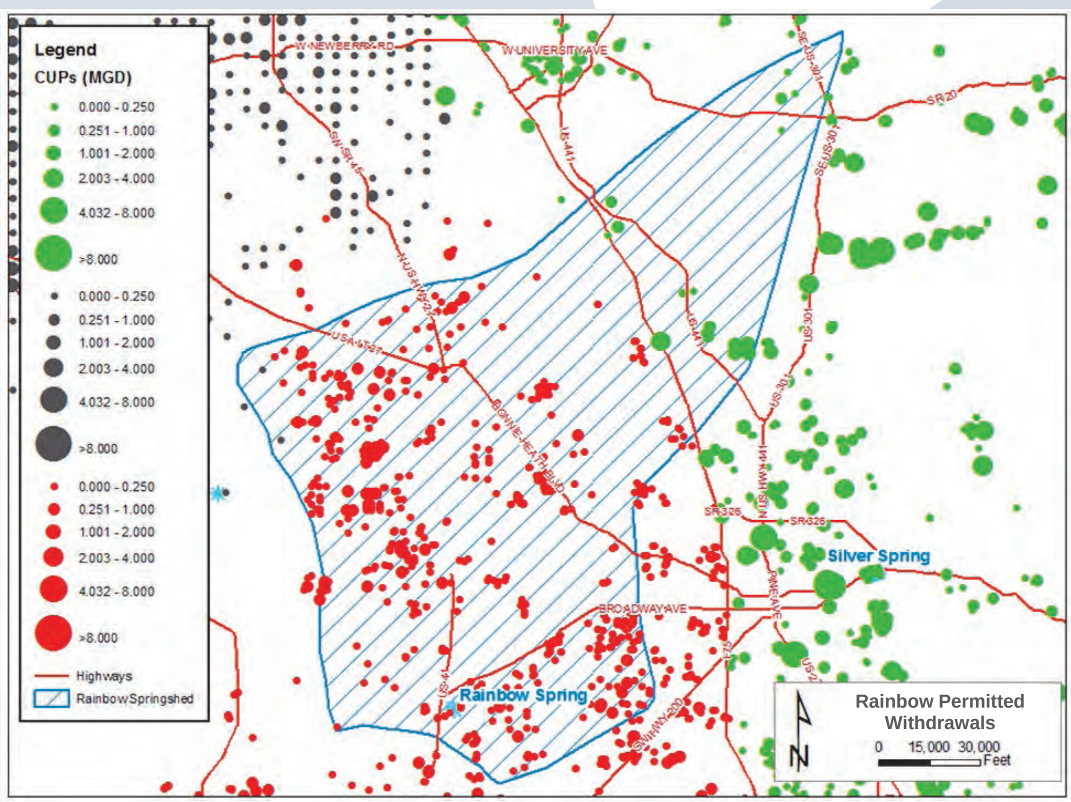


Exhibit 4. *(left)*

Consumptive Use Permits within the Rainbow Springs Springshed by Water Management District
(green = SJRWMD, dark gray = SRWMD, and red = SWFWMD).

Exhibit 5. *(below)*

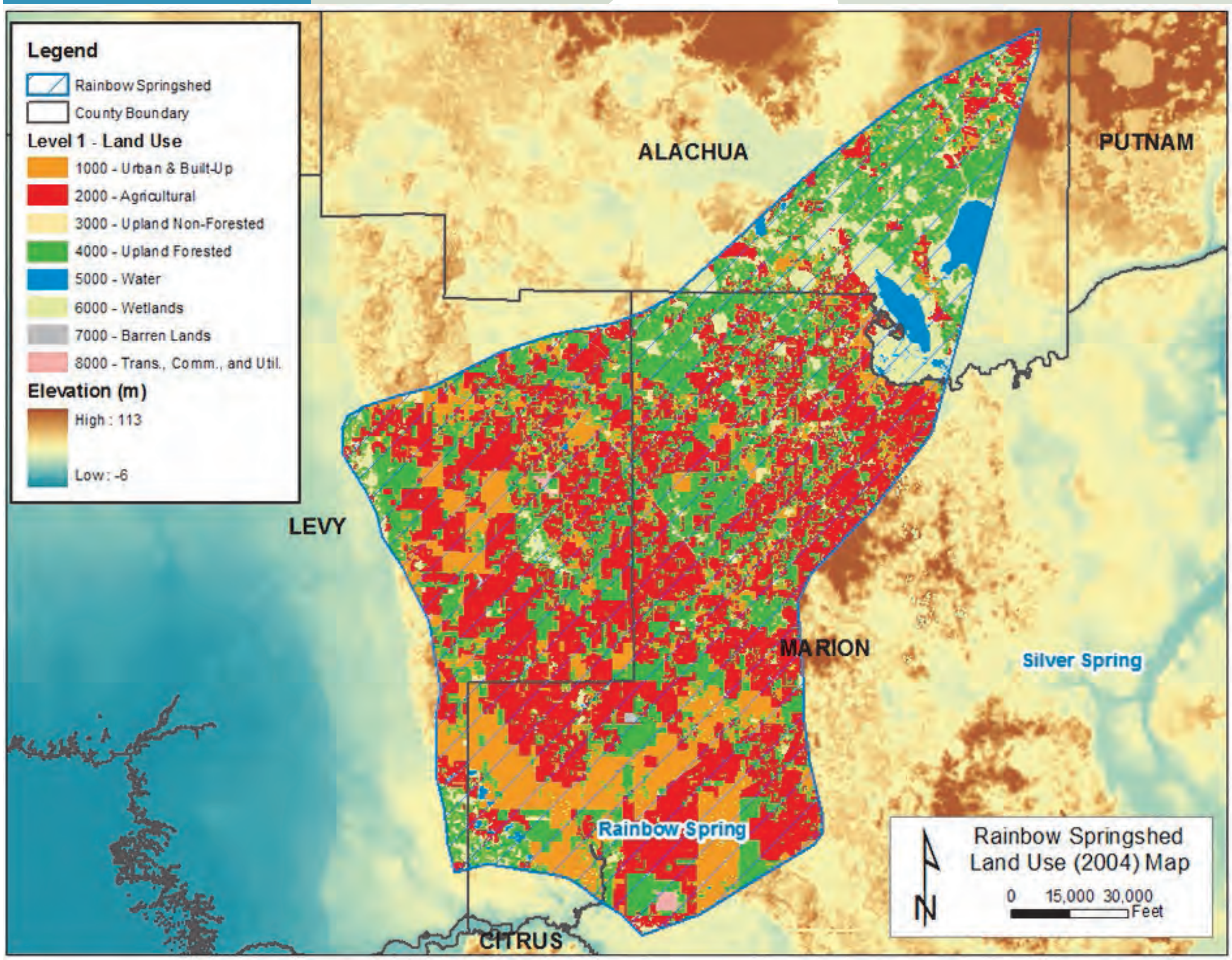
Rainbow River 2004 Springshed land uses

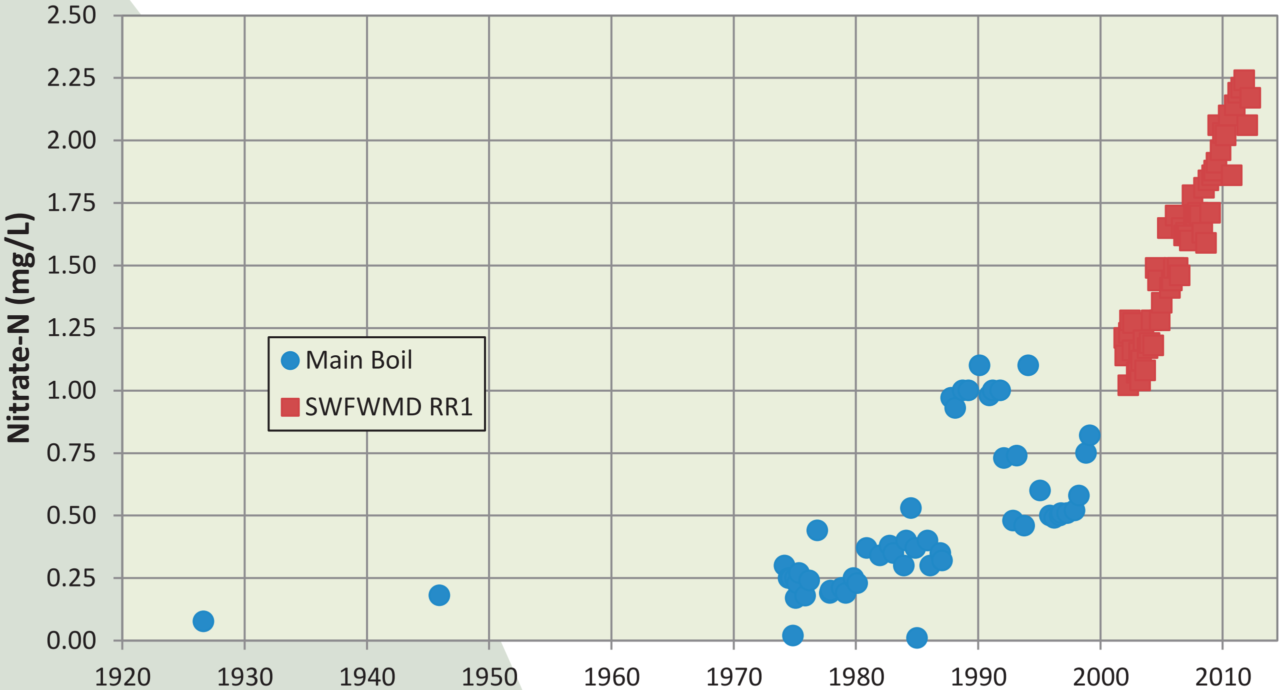
Nitrogen Loading

Long-term records of spring water quality data indicate that nitrate-nitrogen concentrations have increased in the Rainbow Springs Group from background concentrations of ≤ 0.1 mg/L to an average concentration of 2.1 mg/L in 2012 (Exhibit 6).

Unlike phosphorus, which accumulates onto soil and limestone minerals, nitrate is highly soluble, does not collect on mineral soils or limestone, and is readily transported into and through the aquifer. These chemical properties result in groundwater that is highly susceptible to nitrate contamination due to land applications of nitrogen fertilizers and wastewaters.

The primary human-derived sources of nitrogen that contribute to groundwater-nitrate loading in the Rainbow Springs Springshed are septic tanks, lawn fertilizer, golf course fertilizer, sewage effluent disposal, land disposal of sewage sludge, land disposal of septic sludge, row crop fertilizer, cattle operations, horse farms, and pasture fertilizer. Fertilization of pastures, horse farms, and cattle farms were reported to be the three largest sources of nitrogen contamination to the Floridan Aquifer within the Rainbow Springs Springshed. The average fertilizer nitrogen use in the Rainbow Springs Springshed during the past two decades is estimated at about 2,800 tons of nitrogen per year.





Aquifer Vulnerability

The entire Rainbow Springs springshed is susceptible to groundwater contamination, with the majority of the springshed considered "More or Most Vulnerable", and a smaller portion considered "Vulnerable." With 95% of the springshed considered to be "More" or "Most Vulnerable" the potential for groundwater contamination due to nitrogen loading from human-derived sources is high in the entire springshed of Rainbow Springs.

Water Quality

Rainbow Springs has high dissolved oxygen, possibly indicating a relatively rapid groundwater movement to the springs. Rainbow Springs also has exceptional water clarity, however, water clarity decreases significantly with distance downstream due to the presence of drifting microscopic algae sloughed off the leaves of aquatic plants. Two water quality indicators—nitrate nitrogen and chlorophyll *a* —are measurably elevated in Rainbow Springs.

Nitrate concentrations have significantly increased in Rainbow Springs over the past four decades (Exhibit 6). Nitrate concentration reported from the main spring pool in 1927 was 0.08 mg/L. Recent nitrate concentrations at the Rainbow Springs complex exceeded 2.2 mg/L, an increase of about 2,650%. As observed from the graph, nitrate concentration increases have accelerated since 2000 with a recent rise of more than 0.1 mg/L per year. The total mass of nitrate discharged from the groundwater to the Rainbow River has also increased sharply from about 54 tons per year before 1934 to about 1,011 tons per year on average between 2005 and 2012, an increase of more than 1,700%.

Water samples collected between 2002 and 2012 at a series of stations along the Rainbow River illustrate a temporal increase in nitrate concentrations in the Rainbow River, and declining nitrate concentrations with distance downstream from the headspring. This downstream decline in nitrate concentrations is partially attributed to uptake of nitrate by submerged aquatic plants and algae, and microbial processes. Essentially, the Rainbow River functions as a natural water purification system and helps to reduce nutrient effects in the downstream Withlacoochee River and Lake Rousseau.

Exhibit 6. *(above)*

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.

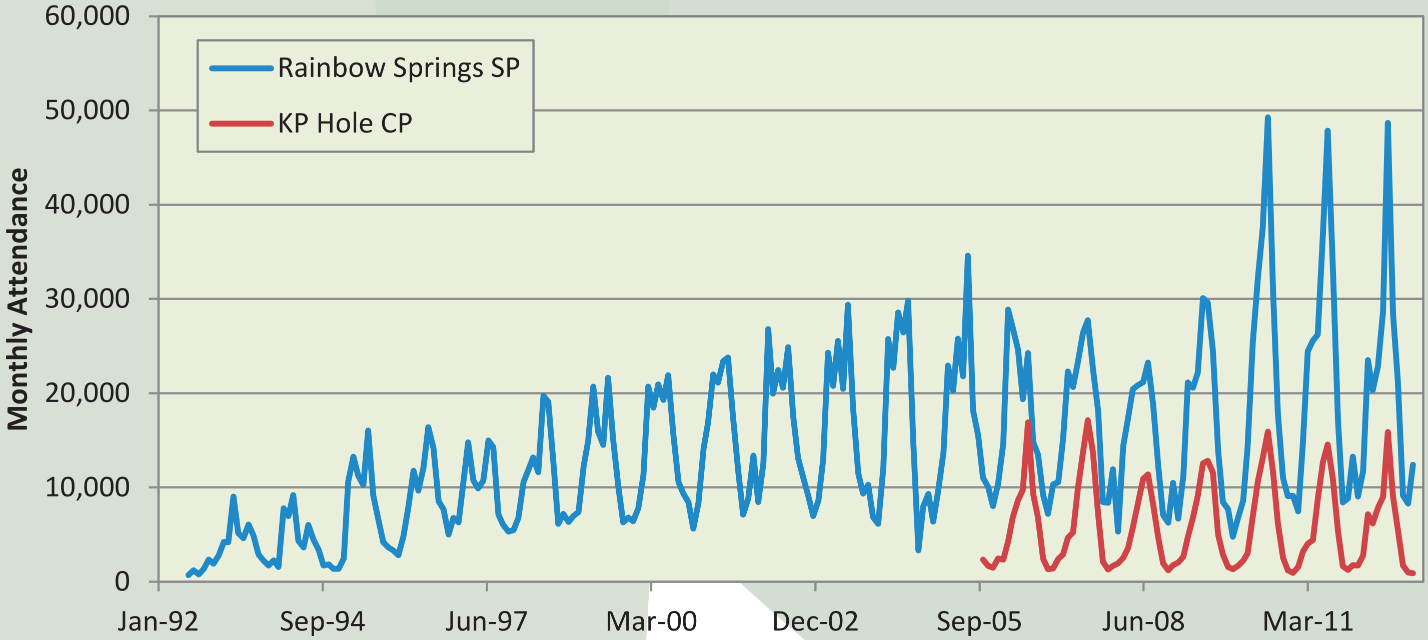


Exhibit 7. (above)

Rainbow Springs State Park and KP Hole County Park Monthly Use

Recreation

Rainbow Springs and River receive hundreds of thousands of visitors per year (Exhibit 7). The cool, clear water draws nature-based tourists from across the state, nationally, and internationally to enjoy canoeing, boating, tubing, swimming, skin-diving, SCUBA-diving, wading, nature study, and fishing.

Attendance in 2011 was estimated at 264,000 people. Maximum monthly use occurred in July 2010, when 65,149 users recreated on the river through the state and county parks. Thousands of additional visitors access the Rainbow River from private docks, boat ramps and from the Withlacoochee River. Recreational boating is popular along the river, and a Marion County ordinance has established an idle speed zone along its entire length.

High recreational use can lead to environmental degradation within the river, especially to the submerged aquatic vegetation that is growing on the bottom of the shallow river. The environmental effects caused by recreation include increased suspended solids; and trampling, prop scarring, and uprooting of the submerged plants. Tubing and canoeing/kayaking were found to have minimal environmental effects, whereas boating contributed to the greatest environmental harm, especially boats with large motors.

Exhibit 8. (right)

The Economic Impact of Four Florida Springs State Parks

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%**

Rainbow Springs Economic Impact

The Rainbow Springs and River provide substantial economic value to southwestern Marion County, due largely to the clean and abundant water that flows from Rainbow Springs.

In 2003, Florida State University studied the economic impacts of four spring-based state parks —Ichetucknee, Volusia Blue, Wakulla, and Homosassa Springs (Exhibit 8). This study measured the amount spent on lodging, restaurants, groceries, transportation, shopping, entertainment, and admission fees to parks.

If applied to Rainbow Springs with an annual visitor estimate of about 400,000 people, the total economic impact of the Rainbow Springs System just for recreation is estimated at about $28 million and creation of about 426 local jobs. This figure does not include additional economic value for real estate.

Considerable real estate development has occurred during the last three decades around Rainbow Springs and River. 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.

Thus, Rainbow Springs and River are clearly integral to the economic value of residential properties and businesses in the area.

Impairments

The Rainbow Springs System is an important natural and cultural resource in North Central Florida, which attracts a large number of tourists and provides a substantial boost to the local economy. To acknowledge the importance of this natural and cultural resource, the river and spring have received three separate designations at state and federal levels—Outstanding Florida Water, Aquatic Preserve, and National Natural Landmark.

However, the Rainbow Springs and River have been found by the Florida Department of Environmental Protection to be impaired due to nitrate. Moreover, the spring and river are likely impaired by at least two additional principal stressors— reduced flows and recreational uses. All three of these principal impairments at the Rainbow Springs System need to be addressed together in order to properly restore and protect this significant environmental and economic feature.

Protection

Counties and municipalities have a number of legal 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, 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.

Informal bird counts have been conducted by members of the Marion County Audubon Society, where 146 bird species have been reported along the river and in Rainbow Springs State Park.

These nesting Double-crested Cormorants are one of the many important bird species that comprise the vibrant bird community of Rainbow River and Springs. Photograph by Sandra Maraffino.

Excessive Groundwater Consumption

Florida's hydrogeology provides ample underground storage for groundwater. Unlike many areas with more topographic relief, Florida has highly permeable sandy soils which promote groundwater infiltration, and 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 of the Floridan Aquifer is unconfined or poorly confined, resulting in high surface water infiltration rates and high potential for contaminants to reach the underlying aquifer.

Florida's porous limestone represents 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 parts of Georgia, South Carolina, and Alabama. The depth of the Floridan Aquifer exceeds 4,000 feet, however, this depth is misleading since much of the Floridan Aquifer is filled with salt water.

The freshwater portion of the Floridan Aquifer rests on top of the salt water, and provides high quality drinking water for a large fraction of the state's residents and businesses. In 2010, the Floridan Aquifer was estimated to provide about 62 percent of the 4,150 MGD of groundwater utilized in the state.

The estimated pre-development annual average recharge to the entire Floridan Aquifer System in Florida was about 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 5.5 BGD. Prior to groundwater pumping, the majority of the annual recharge flowed out of the aquifer at more than 1,000 artesian springs. The USGS estimated that in 2010, approximately 2.6 BGD of water was pumped from the Floridan Aquifer in North and Central Florida. This quantity is equivalent to an average-year reduction in spring flows of about 29%.

In addition to this current groundwater pumping rate of 2.6 BGD, another 2 BGD has been allocated to existing water use permit holders in Florida. Existing and permitted groundwater uses in North Central Florida equate to about 50% of the average annual recharge to the Floridan Aquifer System in Florida, and adds more than 80% during a drought year.

Groundwater pumping is analogous to withdrawals from a bank account (Floridan Aquifer). By withdrawing and reducing the capital (i.e., storage of groundwater in the aquifer), spring flows decline and the benefits they provided to nature and human society are reduced. Under extreme cases where aquifer levels have been drawn down by more than 20 to 90 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. When intense groundwater pumping occurs and aquifer levels decline, more sinkholes open up and greater coastal saltwater intrusion occurs.

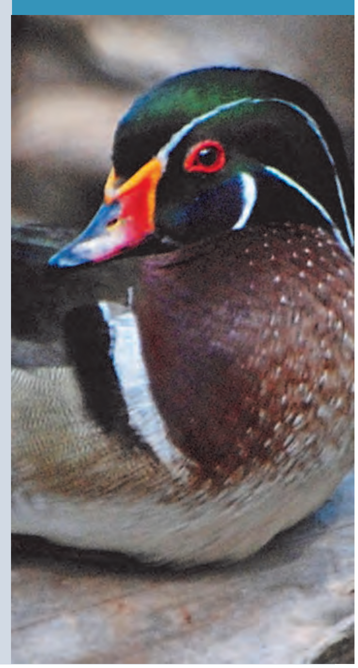
Florida's water management districts implement groundwater models to estimate impacts to the aquifer and springs that are attributed to groundwater pumping activities. These groundwater models are overly-simplistic and tend to under-estimate impacts to the Floridan Aquifer and associated springs and rivers . The basic assumption used in crafting these models is that the aquifer is a relatively homogeneous matrix ("sand box" analogy). However, the Floridan Aquifer limestone is highly variable in porosity, with intermixed areas of dense rock lying adjacent to areas that are honeycombed by large caverns and passageways sufficient to allow rapid groundwater movement.

Did you know?

Although manatee fossils have been recovered from the Withlacoochee River and Rainbow Springs, manatees can no longer use Rainbow Springs and the Rainbow River due to downstream barriers on the Withlacoochee River which prevent access.

The Withlacoochee River was originally dammed in 1909 to provide electric power. The Cross Florida Barge Canal, lock, dam, and bypass facilities were later constructed in the 1960's, and subsequently abandoned in the 1970's.

The lock is not functional and has not been operational since 1999, eliminating manatee access to the Rainbow River.



Did you know?

Of Florida's 1,700 rivers and streams, the Rainbow River is one of 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 water quality degradation.

No activity is allowed in OFWs 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. Projects within OFWs can be approved only if they are in the public interest or not contrary to public interest.

Extensive research on groundwater flow travel times using conservative dyes as tracers have proven that the underlying assumptions in the simplistic water management district models are not realistic. The consequence of using flawed assumptions is excessive uncertainty in model estimates of groundwater pumping effects on spring flows and levels.

Comparison of groundwater level maps suggest that groundwater levels in the springshed that feeds Rainbow Springs have declined up to 15 feet. Since spring flows come from the top of the aquifer, this decline has resulted in reduced flows at Rainbow Springs by more than 25% below the historic average due to the combined effects of natural and human-induced impacts on aquifer water levels.

Rainbow Springs is topographically lower than Silver Springs, and consequently, Rainbow tends to "pirate" flows from Silver during periods of low recharge and high pumping rates. The cumulative reduction in flows from these two first magnitude springs is about 25%, or 220 MGD over the past decade. For purposes of springs restoration and protection, these two large spring complexes should be treated as a single 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 equally responsible for at least half of the spring flow reductions. Thus, a reduction in groundwater pumping both within and outside of the two springsheds will need to be implemented in order to restore the historic flows to Rainbow and Silver springs.

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, many Federal, State, and local laws and policies are aimed 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 St. John's River WMD).

Protections at the county and municipal level also vary widely, in part because of differing levels of environmental activism, but also because of variations in economies, demographics, and geology.

Water Quality

Water quality in Rainbow Springs and River has been relatively consistent during the last several decades, with the exception of nitrate and water clarity. Nitrate has increased by nearly 100% over the past decade, and by more than 2,700% in the vicinity of the main boil since 1927. Nitrate is a primary nutrient for plant growth and contributes to algal proliferation in many aquatic and terrestrial ecosystems. In 2009 the Florida Department of Environmental Protection listed Rainbow Springs and River as impaired by nitrate.

Florida springs are renowned for their exceptional water clarity, and exceptional water clarity is one of the primary features that attracts recreational users to Florida's springs. However, increases in nitrate often promote excessive algal growth, which in turn, decreases water clarity. Rainbow Springs and River is no exception. Water clarity has declined by nearly 75% in the first kilometer of the river, and is attributed to drifting algae cells.

Biology

Submerged aquatic vegetation covers extensive areas along the bottom of the Rainbow River. One visible sign of a healthy spring and spring-fed river is a thick and vigorously-growing population of submerged aquatic vegetation.

A decline of submerged aquatic vegetation has been noted throughout the Rainbow River, and much of this vegetation has been replaced with or covered by algae.
An estimated decline of 22% cover of submerged aquatic vegetation was noted between 1996 and 2011. The dominant native plant species—strap-leaved sagittaria (*Sagittaria kurziana*) declined in cover by 23 percent. Coontail (*Ceratophyllum demersum*) also declined in cover, while eelgrass (*Vallisneria americanum*) increased in cover. Hydrilla (*Hydrilla verticillata*), a non-native, invasive species, was the second-most dominant submerged aquatic plant species in the Rainbow River in 2000, occupying about 13% of the entire river bottom.

Declining spring flows and degraded submerged plant communities have the potential to impact wildlife populations in the Rainbow River. The turtle population has changed during the past 60 years to favor smaller turtle species. Although the Florida Wildlife Commission adopted a rule in 2009 to limit the commercial harvest of turtles, reports of illegal harvesting still continues.

Did you know?

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

Exotic aquatic plants (primarily hydrilla) in the Rainbow River have been managed by the state through a variety of herbicide applications.

Human Uses

Human use in springs can promote both a positive and negative influence on springs. From a positive standpoint, a keen public awareness with the desire to preserve, protect, and restore springs can result when a spring becomes a popular public attraction. However, springs can be overused and damaged if human activity is excessive or not well managed. Additionally, as human use increases, the user experience can be diminished because of competition for the resource.

Rainbow Springs and River is one of the most popular spring systems in Florida, with high-intensity human use originating at both the state and county park access points. Additionally, a large volume of boat traffic accesses the Rainbow River from the Withlacoochee River.

Human use activity in the Rainbow River has resulted in impacts to the submerged aquatic plant community by both uprooting individual plants and causing increased turbidity. Motor boats have the greatest impact on the river, with most of the damage occurring from a small number of careless operators.

Tubers, swimmers, and divers can also damage submerged vegetation by trampling and in some cases, uprooting plants. When submerged aquatic plants are disturbed, algae will often cover the area that was previously colonized by plants, thereby decreasing the food supply and habitat for aquatic organisms.

Summary

This Executive Summary provides the following findings of fact:

- The Rainbow River System includes at least 12 named spring vents and many lesser vents, and discharges water to about 5.7 miles of the Rainbow River, including 1,470 acres in the Rainbow Springs State Park.
- Long-term (97-year) average rainfall in the springshed is about 54 in/yr, and more recently has averaged about 50 in/yr. The historic mean groundwater discharge at these springs was about 465 MGD, and was fed by a maximum springshed area of about 737 mi^2 (472,000 acres), with an average groundwater recharge rate of about 14 to 15 inches per year. Water travels as much as 45 miles underground before discharging at Rainbow Springs.
- The Rainbow Springs Springshed is dominated by semi-intensive land uses, including agriculture (37%), forestry (33%), and urban (17%). The springshed covers parts of Marion (54%), Levy (28%), and Alachua (18%) counties, and supported approximately 112,000 people in 2010.
- Flows from the Rainbow Springs System have declined by about 25% since the 1960s, with an estimated 11% decrease due to rainfall declines and the remaining 14% decline (about 65 MGD) due to groundwater pumping, both local and regional.
- Regional groundwater use in the Southwest Florida Water Management District is over 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 in the Rainbow Springshed of about 8 to 15 ft since pre-development conditions.
- The entire Rainbow Springs Springshed is vulnerable to groundwater contamination by nitrogen. Fertilizers and human/animal waste disposal practices within the springshed result in an average load of about 1,000 tons of nitrogen per year (917 MT/yr) discharging at Rainbow Springs at a concentration of more than 2 mg/L of nitrate nitrogen. A reduction of about 82% nitrate is needed to comply with state water quality standards.
- The Rainbow Springs System receives nearly 350,000 visitors each year, all of whom have some effect on the vitality of the natural aquatic ecosystem.

The goal of the Rainbow Springs Restoration Action Plan is to recommend 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 a more pristine condition that is indicative of greater flows, lower nitrate concentrations, higher water clarity, a healthier submerged aquatic plant population, and less algae.

These are ambitious goals and as such will require the dedicated and combined efforts of individuals, municipalities, and the state. Existing educational campaigns, dedicated grassroots efforts, and scientific research are all having a positive impact on Rainbow and other springs in Florida. 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 the continuing educational effort for springs restoration.

The full-length Rainbow Springs Restoration Action Plan can be downloaded in full online at **www.floridaspringsinstitute.org**.

Recovery

The ultimate goal for recovery of Rainbow Springs should be to attain 95% of historic flows, or an average flow of about 450 MGD.

Achieving this ultimate goal would require an estimated average reduction of groundwater pumping region-wide of 58 MGD.

Existing groundwater pumping in the springshed that feeds Rainbow Springs is about 28 MGD. Groundwater pumping will need to be reduced throughout the Southwest Florida Water Management District in order to restore historic flows to Rainbow Springs.

Recommendations

Florida's state agencies have implemented piecemeal and often contradictory programs that affect the state's water resources and springs. For instance, the Florida Department of Environmental Protection is developing pollutant load reduction strategies to reverse water quality degradation, while the Southwest Florida Water Management District 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.

On the contrary, a third state agency, the Department of Agriculture and Consumer Services 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. Similarly, the Department of Economic Opportunity encourages business development, and focuses 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.

The Rainbow Springs Restoration Action Plan calls for significant changes in human activities both within the springshed and in the entire Floridan Aquifer System. Existing estimates of the regional groundwater balance indicate that current permitted groundwater uses are excessive and severely damaging to aquifer levels and spring flows. The only practical way to provide comprehensive springs flow restoration throughout 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 likely 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. To meet the State's proposed springs nitrate standard of 0.35 mg/L, nitrogen fertilizer needs to be reduced to an annual total of about 500 tons per year. Additional reductions in nitrogen loads are needed to achieve even lower nitrate concentrations that reflect historic, pre-development conditions.

Additionally, wastewater disposal practices need to be upgraded in order to lower the load of nitrogen that leaches into the Floridan Aquifer. Wastewater upgrades include connection of existing septic tanks to central wastewater treatment facilities, and upgrading wastewater treatment facilities to provide advanced nitrogen removal to achieve average concentrations less than about 3 mg/L.

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 restricting motor boats on the river with engines over 10 horsepower, dividing the river into separate use zones for diving and boating, reducing the number of entry and exit points to eliminate shore damage and hardening those ingress and egress locations, and implementing more effective public use education.

Final Comments

Implementation of the recommendations listed 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, to embracing long-term practices that promote 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, the Floridan Aquifer in Central Florida is on a declining trajectory. Hope for the future health of the Rainbow Springs System, Florida’s springs, and the entire Floridan Aquifer System is in the hands of the government and local residents and businesses.

In almost all 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 the past. A new paradigm of citizen education and involvement is 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 provides a detailed list of specific actions that are 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, need to embrace life-style changes in order to reduce the unintentional effects of our collective “footprint” on the water resource.

The eventual outcome of those changes will be long-term sustainability of our natural water environment, both above and below-ground, and will benefit every citizen and tourist who spends time in Florida.

Did you know?

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.

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The mission of the Florida Springs Institute is to provide a focal point for improving the understanding of springs ecology and to foster the development of science-based education and management actions needed to restore and protect springs throughout Florida.

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