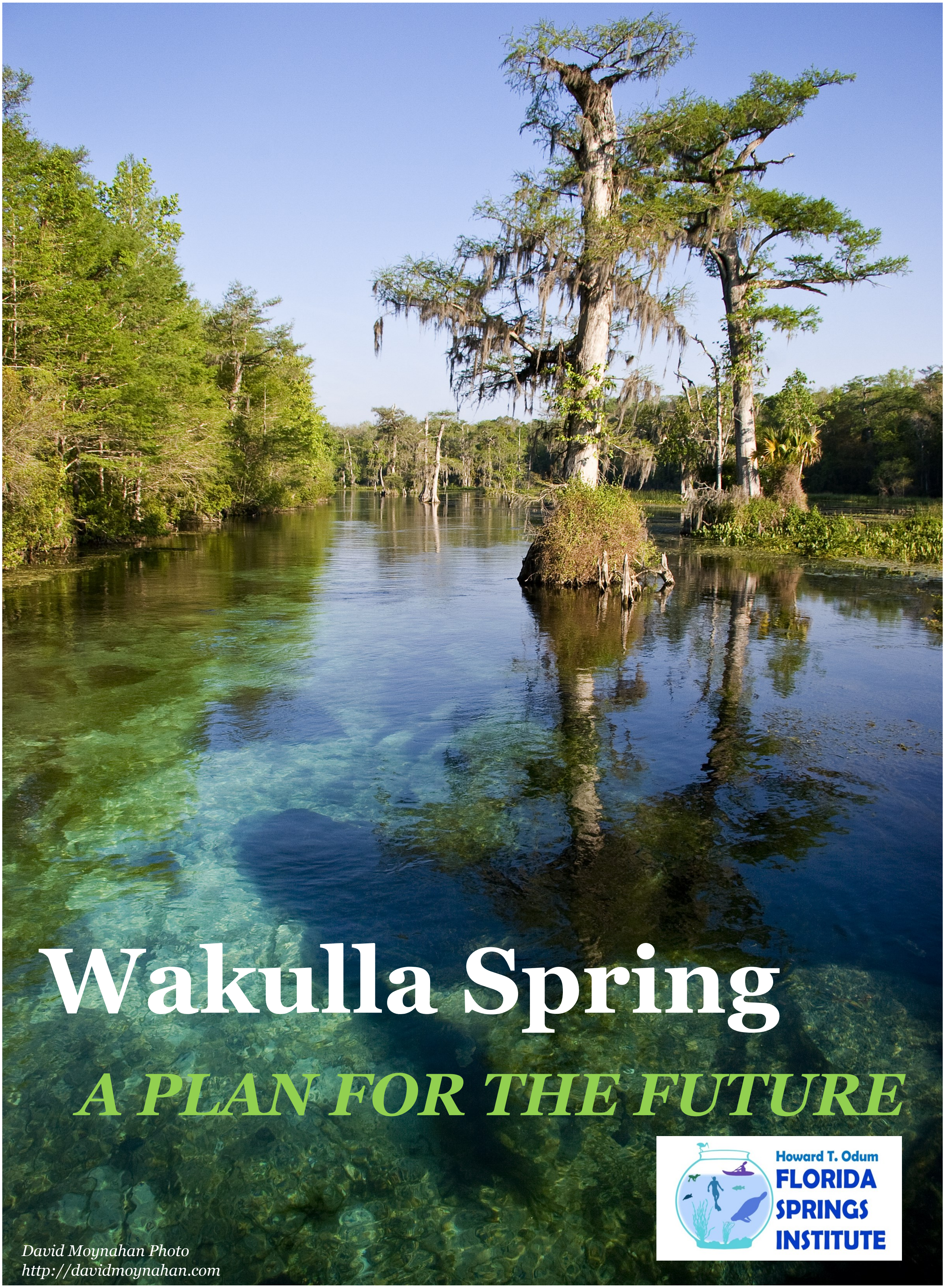
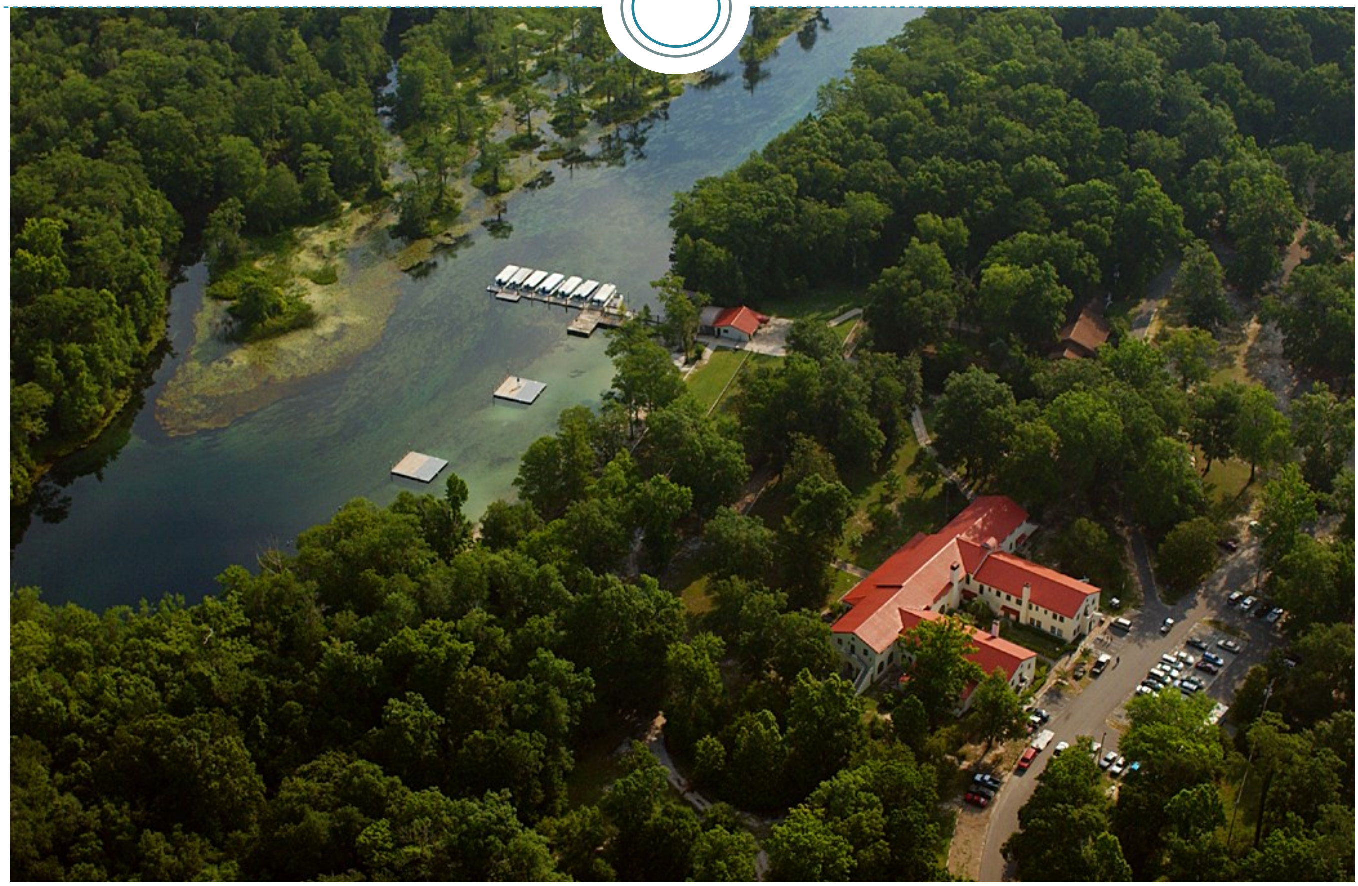


Wakulla Spring

A PLAN FOR THE FUTURE

Howard T. Odum
FLORIDA SPRINGS INSTITUTE

David Moynahan Photo
http://davidmoynahan.com



INTRODUCTION TO WAKULLA SPRING

Wakulla Spring is a true natural wonder. One of the largest artesian springs in Florida and in the United States, Wakulla Spring has flowed for tens of thousands of years and served as a water supply for humans and wildlife throughout that time. Wakulla Spring lies within the Edward Ball Wakulla Springs State Park and has for many years been an important recreational site for local residents and tourists. Wakulla Spring, Wakulla Springs Lodge, and the Edward Ball Wakulla Springs State Park continue to attract and entertain over 200,000 visitors each year.

Wakulla Spring's principal attraction has always been its vast flow of pure, clear groundwater. The primary source of this water is the Floridan Aquifer System, which occurs in a limestone formation that holds hundreds of billions of gallons of fresh, potable water and provides the primary drinking water source for residents of Leon, Wakulla, and surrounding counties. In addition to the humans who are dependent upon this groundwater resource, a complex and highly productive ecosystem of wild plants and animals is also dependent on abundant fresh water from Wakulla Spring for its livelihood. The source of this water is rainfall that falls on more than 1,000 square miles in Leon, Wakulla, Gadsden, and Jefferson Counties in Florida, and parts of at least three Georgia counties (Decatur, Grady, and Thomas) just north of the Florida-Georgia border.

Unfortunately, springs throughout North Florida and South Georgia, are experiencing degradation as a result of human development. The most common documented impacts have been reductions in the flow of clear groundwater and increases in concentrations of nitrate-nitrogen. Changes in the quantity and quality of spring flows as well as a diversity of other environmental stressors have often resulted in biological changes at affected springs.

Wakulla Spring has not been immune to these impacts. Wakulla Spring has a lower average nitrate concentration than springs in other parts of Florida due largely to the fact that its springshed does not include as much intensive agricultural development. However, existing nitrate-nitrogen concentrations are more than 1,400% higher at Wakulla Spring than typical historical spring concentrations, and the Upper Wakulla River has been deemed impaired by the Florida Department of Environmental Protection (FDEP) based on elevated nitrate-nitrogen and increased growth of hydrilla (*Hydrilla verticillata*) and filamentous algae. FDEP has set a target concentration for nitrate-nitrogen for the Upper Wakulla River of 0.35 mg/L, requiring an estimated reduction of about 56% in nitrogen loads within the springshed area.

> *"...existing nitrate-nitrogen concentrations are more than 1,400% higher at Wakulla Spring than typical historical spring concentrations"*

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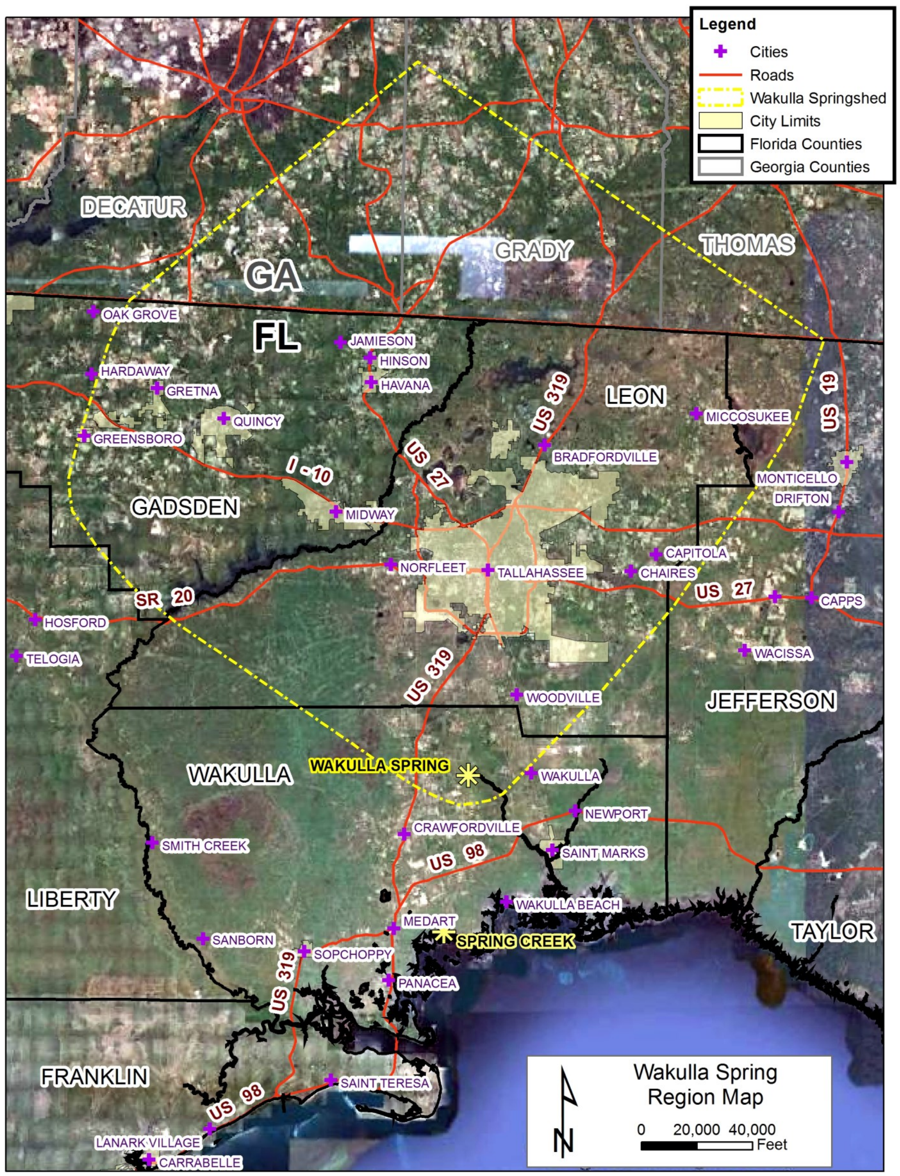


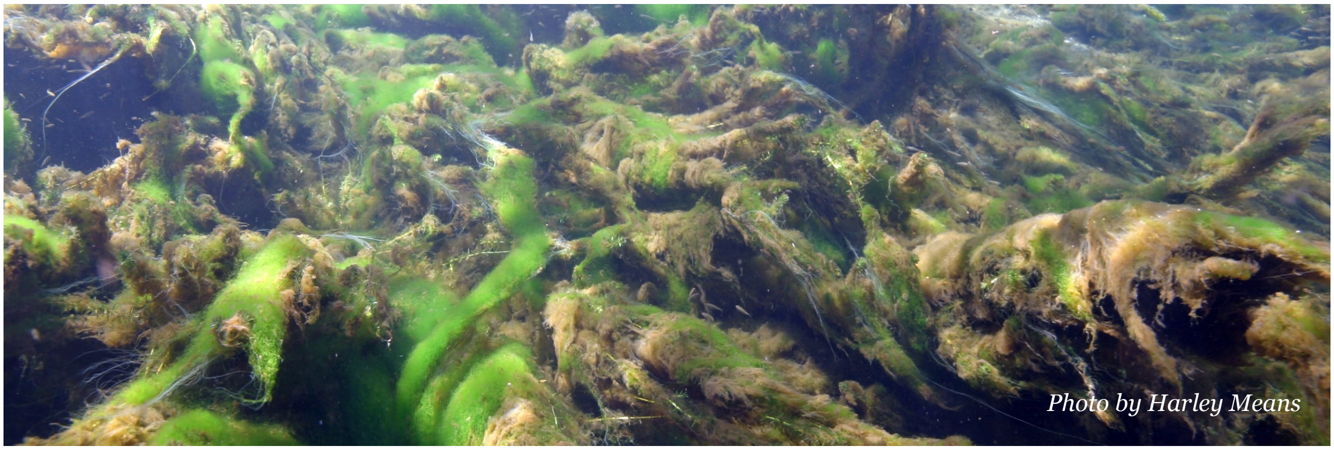
Figure 1. Location of Wakulla Spring South of Tallahassee in the Florida Panhandle

In addition to the nitrate pollution issue facing Wakulla Spring, there is increasing evidence that the historical water balance of the spring has been significantly altered. While Wakulla Spring was previously known for its extreme clarity, except during high rainfall periods, this clarity has been replaced by an increasing frequency of "dark-colored" and "green" water days of low light transparency that not only reduce the aesthetic properties of the spring and river for nature-based tourism, but also decrease primary productivity of the plant community (due to reduced light availability for the underwater plants), thus altering the entire food chain. Based on existing information it appears that the increase in dark water flows at Wakulla Spring is the combined result of rising sea levels and declining clear, artesian water flows from the Floridan Aquifer due to excessive groundwater pumping.

Increases in nitrate concentrations and dark water at Wakulla Spring have been causes for concern for more than two decades. The Wakulla Springs Basin Working Group was founded in 1992 to increase the understanding of these problems and to pursue feasible restoration solutions. While technical understanding of these issues has greatly increased and led to implementation of dozens of large and small projects at the spring and in its springshed; some conditions at the spring (especially the occurrence of dark water and changes to the submerged plant communities) have continued to worsen during this time. There is no doubt that on-going restoration and protection strategies have resulted in some benefits for the spring; however, these efforts have been unsuccessful at reversing the overall degradation experienced at Wakulla Spring. The goal of the Wakulla Spring Restoration Plan is to summarize detrimental changes that have occurred at Wakulla Spring and to recommend decisions and actions that should be made to achieve the desired restoration of Wakulla Spring.

RESEARCH AND RESTORATION PROJECTS AT WAKULLA SPRING

- Dye trace studies positively linking water movement from many of the sinkholes and swallets and the City of Tallahassee sprayfield to Wakulla Spring.
- The Woodville Karst Plain Project achieved world records by mapping the extensive cave systems leading to Wakulla Spring. A portion of the cave mapping was sponsored by National Geographic.
- The first Spring Protection Zone ordinance in the state was passed by the Wakulla County Commission in 1994.
- Wakulla County expanded the Protection Zone in 2009 to include the entire spring basin.
- Leon County established a Wakulla Spring Protection Zone in 2008.
- The State acquired nearly 12,000 acres in the Wakulla Spring Basin to protect the spring. Some of the land was added to the state park for management and additional land was used to create the new Wakulla State Forest.
- Leon County acquired 132 acres along Munson Slough to protect Wakulla Spring.
- The Florida Department of Transportation stopped fertilizing road shoulders in the basin.
- The City of Tallahassee stopped fertilizing the wastewater sprayfield, passed a fertilizer ordinance, and spent over $80 million on stormwater management.
- The State park facilities were connected to central sewer and nitrate reducing septic systems were installed.
- The Wakulla County Comprehensive Plan amendment required use of nitrate reducing septic systems in the county.
- The City of Tallahassee, Leon County, and Wakulla County jointly funded a comprehensive septic tank study within the spring basin.
- The City of Tallahassee spent about $225 million to upgrade its municipal wastewater facilities for nitrogen removal and the City also removed cattle from the sprayfield & stopped applying sewage sludge at the airport;.
- St. Joe Corporation protected vulnerable sinkholes on their lands and leased lands to hunt clubs which stopped abuse.
- The first springs' ambassador position was created for Wakulla Spring with the goal to educate the local public and to survey karst windows within the spring basin.
- The TAPP (Think About Personal Pollution) water conservation and prevention program was implemented by the City of Tallahassee.
- Wakulla County implemented the LIFE (Learning in Florida's Environment) program with the middle schools.
- The Wakulla Spring Wildlife Festival is held annually.
- Several educational videos have been produced by the Woodville Karst Plain Project.
- The Department of Transportation installed road signs to identify the Wakulla Spring Basin, Munson Slough drainages to Wakulla Spring, and Wakulla Spring cave systems.
- Twelve Wakulla Spring educational and scientific special events have been held since 1998.



WAKULLA SPRING RESTORATION PLANNING PROCESS

Numerous activities have already taken place or are currently underway to protect and restore the historic character of Wakulla Spring. While all of these actions are necessary and important, alone and in combination none of them to-date appear to be sufficient to achieve the ultimate success of returning Wakulla Spring to a desirable historic condition within a reasonable time frame. A more comprehensive, holistic effort is necessary to achieve fundamental restoration of many of the attributes of Wakulla Spring. An adaptive management approach that constantly evolves, monitors progress, and implements improvements is recommended to focus limited resources and energy to solving the problems, large and small, that are apparent at Wakulla Spring.

In August 2011, the Howard T. Odum Florida Springs Institute (FSI), a private, non-profit corporation, decided to continue the momentum generated by the Wakulla Springs Basin Working Group stakeholders. The Wakulla Spring Adaptive Management Strategy was developed by FSI based largely on technical information collected and summarized during the FDEP-funded project.

The Wakulla Spring Restoration Plan builds on the work initiated by FDEP, FSI, and the Wakulla Spring stakeholders and contains more detailed and complete essential elements and information, including:

- A description of the environmental resources at Wakulla Spring and changes in these resources over time;
- A shared vision for the goals of restoration developed by stakeholders who attended the quarterly Wakulla Springs Basin Working Group meetings;
- A description of the existing impairments at Wakulla Spring and the factors and forcing functions causing those impairments;
- A set of specific actions and responsibilities needed to eliminate or substantially reduce the factors resulting in impairment of Wakulla Spring; and
- A plan for assessing the progress towards restoration and updates to the strategy through adaptive management of the restoration process.

The full Wakulla Spring Restoration Plan is available at www.floridaspringsinstitute.org and provides a flexible road map for the constantly-evolving activities that need to be completed to achieve the vision of the Wakulla Spring Alliance and the stakeholders in the former Wakulla Springs Basin Working Group. It is hoped that the major stakeholder groups will unite and share the responsibility for reviewing progress, and continuing on the path to restoration and protection of Wakulla Spring.

DESCRIPTION OF THE WAKULLA SPRING SYSTEM

One of Florida's largest springs, Wakulla Spring is located in Wakulla County, Florida, and is approximately 14 miles south of Tallahassee (Figure 1). Wakulla Spring and the surrounding area was developed as a retreat/attraction in the 1930s by Edward Ball. In 1986 Wakulla Spring became a state park administered by FDEP and the Florida Division of Recreation and Parks (FPS), consisting of approximately 6,055 acres. Wakulla Springs State Park and Lodge are listed on the Natural Register of Historic Places and are a designated National Natural Landmark.

The park facilities include the original Edward Ball Lodge and restaurant, museum, and guided river and glass-bottomed boat tours in the upper one mile of the Wakulla River. A swimming beach area, diving platform, and two swim platforms provide in-water recreational opportunities and the spring is a popular regional swimming destination. Visitors to the park are not allowed to SCUBA dive, although research divers have extensively explored and mapped the underwater cave system connected to the spring. Private boat access is prohibited in the park-managed portion of the Wakulla River (the upper three miles of the spring run). Alligators, turtles, birds, and other wildlife can be observed along the spring run. Historic underwater images of the spring and spring run are available since several films were made at Wakulla Spring, including *Airport '77*, *Tarzan's Secret Treasure* and sequels of the Creature from the Black Lagoon movie - *Return of the Creature* and *Revenge of the Creature*.

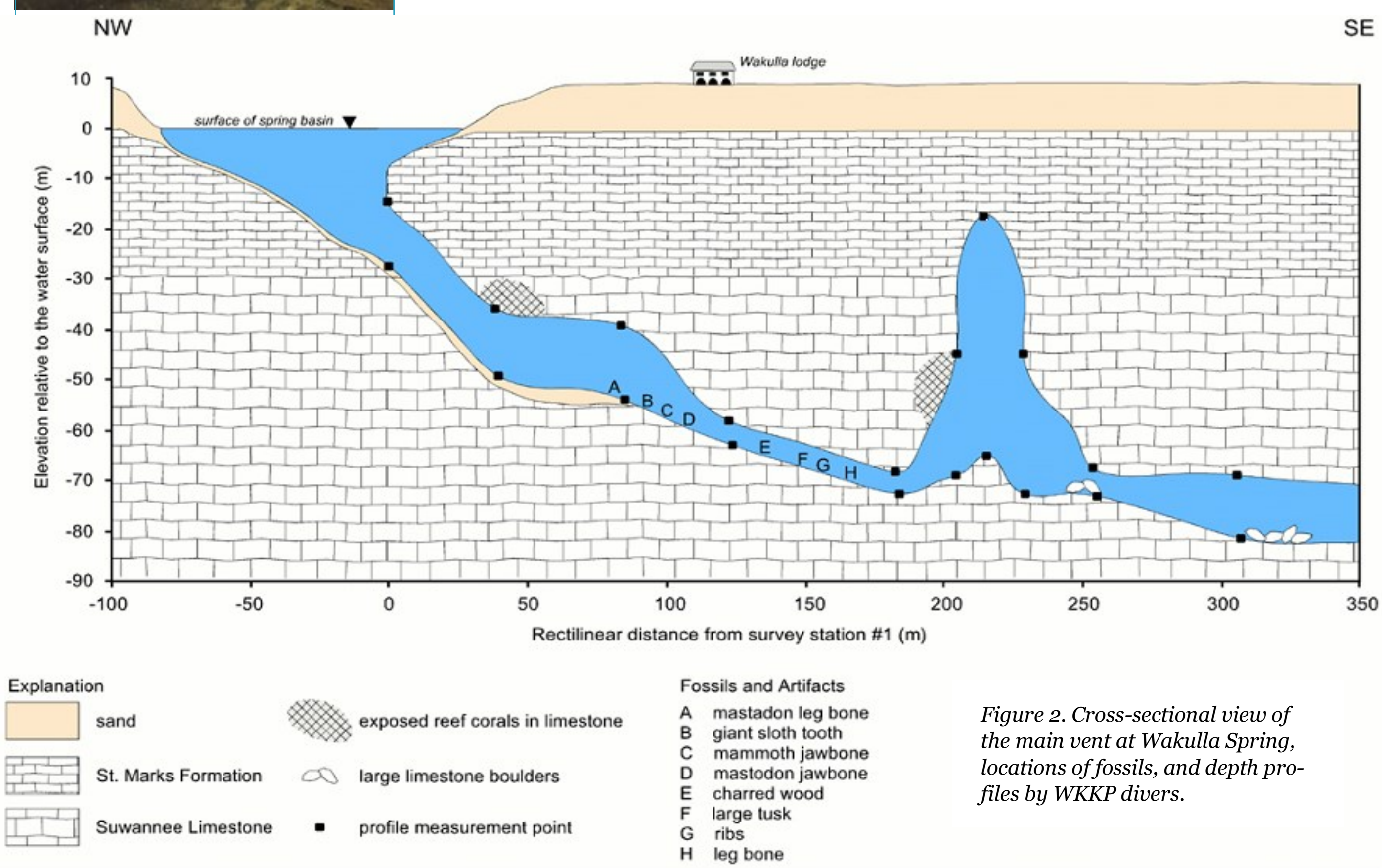


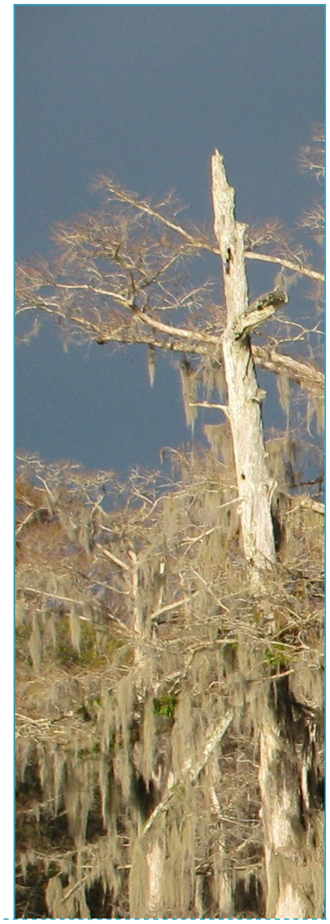
Figure 2. Cross-sectional view of the main vent at Wakulla Spring, locations of fossils, and depth profiles by WKKP divers.

PHYSICAL

Wakulla Spring is an unusual spring due to its large physical size. The circular pool is roughly 300 feet in diameter and about 100 feet in depth, with an immense vent opening of 50 feet by 82 feet (Figure 2). The estimated volume of the Wakulla Spring basin (from the western edge of the spring basin to the boat dock) is 13.1 million gallons with a surface area of 3.9 acres and a calculated average depth of 10 feet.

The Wakulla Spring cave system (Figure 3) has been extensively explored by cave divers, including most recently the members of the Woodville Karst Plain Project (WKPP). This network of explored passages extends more than 32 miles, connecting 27 named sinkholes and springs. The full extent of this submerged cavern has yet to be determined.

The highly karst nature of this region creates variable water quality conditions in the spring pool. Water clarity can vary between “air-clear”, “tannin-stained”, to “turbid green”, as a result of groundwater recharge through swallets receiving surface runoff from wetlands and swamps. A small spring to the northwest, Sally Ward, and its own spring run braid along the northern shore of the main run (upper Wakulla River). The spring-fed McBride’s Slough also discharges to the upper river, contributing to its flow. In total, the Wakulla River travels southeast for about nine miles before joining the St. Marks River. The lodge is approximately 14 miles north of the Gulf of Mexico.

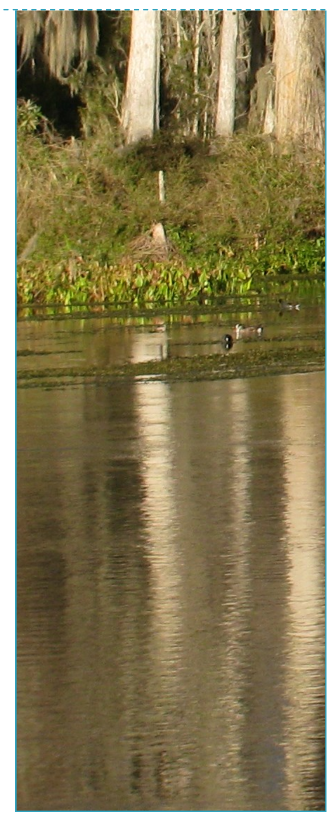


“The estimated volume of the Wakulla Spring basin is 13.1 million gallons “

GEOLOGY

The Wakulla Springshed vicinity generally consists of marine sedimentary deposits including sands, clay, limestone, and dolostone. Of particular note are the remnant deposits of clays and limestones of the Hawthorn Group overlying the northern portion of the springshed and absent from the southern portion of the springshed (Woodville Karst Plain). Groundwater recharge rates are dependent on the presence/absence and thickness of the Hawthorn formation whose edge is marked by a relic marine terrace called the Cody Scarp. Below the Cody Scarp this confining layer is generally absent and above the scarp the confining layer may or may not be perforated by sinkholes and swallets that allow recharge from surface watersheds that include lakes and streams.

The limestone formations that underlay the Wakulla Springshed include solution channels and conduits that have formed as the limestone has slowly dissolved as a result of the percolation of acidic rainfall and surface water over many thousands of years. The development of karst features like sinkholes and solution channels depends on the amount of exposure the limestone has had to this acidic water. In the Woodville Karst Plain, the development of these features is the most advanced. In the upslope region where the Floridan Aquifer is partially confined under lower-permeability soils, limestone dissolution and conduit development is much less advanced.



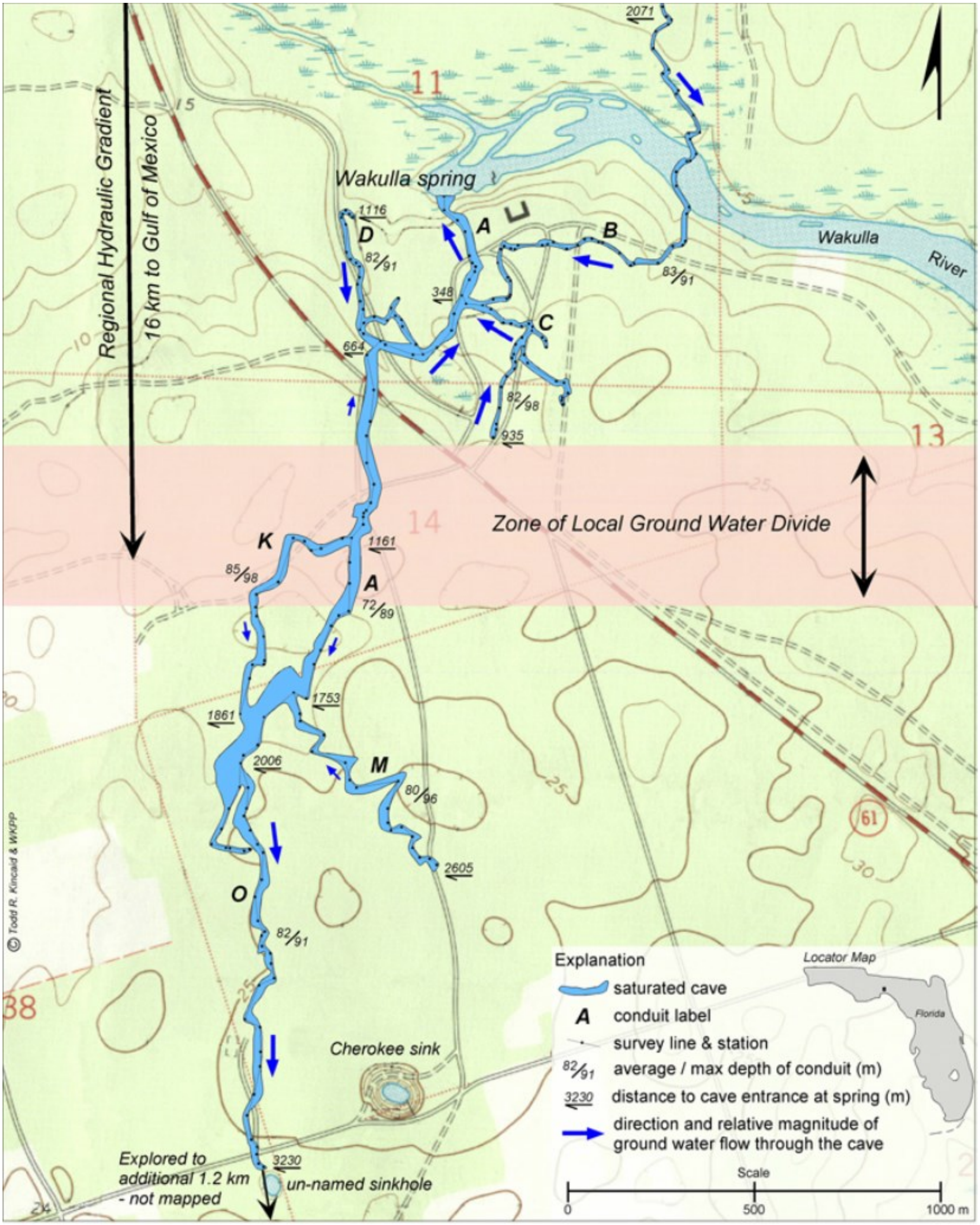


Figure 3. Map of Wakulla Spring cave system showing the local groundwater divide which crosses the conduit system and is marked by a broad zone of low groundwater velocities. The southern conduits typically convey groundwater toward the Gulf of Mexico while the northern conduits convey groundwater to Wakulla Spring.

HYDROGEOLOGIC SETTING

Wakulla Spring is within the St. Marks River Basin, which has four hydrostratigraphic units: the surficial aquifer system, the intermediate aquifer system, the Floridan Aquifer System, and the sub-Floridan confining unit. Wakulla Spring represents a natural outflow from the Floridan Aquifer. Because of the karstic nature of this region, surface water and groundwater mixing can occur as evidenced by the variable water quality observed at Wakulla Springs. Groundwater travels south from areas in Georgia with higher groundwater levels through cave conduits toward the Gulf of Mexico.

Extensive physical exploration in the cave systems feeding Wakulla Spring over the past two decades has provided a fairly detailed understanding of the complex hydrogeology in the area. Wakulla Spring is hydraulically connected by submerged conduits to the Spring Creek Springs, a group of 14 known springs located in a tidal marsh at the edge of the Apalachee Bay. The Spring Creek group and Wakulla Spring share the same delineated springshed because they are hydraulically connected. Analysis of extensive flow and water quality data collected at Wakulla Spring and at Spring Creek Springs indicate that fluctuations in groundwater flow and spring discharge occur at these springs as a result of this interconnection.

The actual set of hydraulic head conditions that tip this balance between Wakulla Spring and the Springs Creek Group are not precisely known. Factors that likely affect this delicate balance in flow between Wakulla Spring and Spring Creek Springs include the following: the groundwater gradient throughout the Wakulla/Spring Creek Springshed; hydrological factors that affect groundwater recharge and the height of the potentiometric surface, including rainfall, evapotranspiration, and groundwater pumping; and the sea level elevation in Apalachee Bay at the Spring Creek Springs vents, which is affected by the tidal stage, storm tides, atmospheric pressure, and sea level rise affected by climate change.

Within the historical record at Wakulla Spring there have always been periodic documented events of dark water reaching the spring following high rainfall events. Based on information from Wakulla Spring over the past 60+ years, the occurrence of dark water days during this period has increased from occasional in the past (prior to 1950s), to frequent under more recent conditions. Quantitative data concerning dark water days affecting glass bottom boat tours has been collected by state park staff for the past 28 years (Figure 4). These data indicate that the frequency of dark water days has been increasing for at least the past 15 years. Over the past five years (2010-2014) the frequency of dark water days has increased to over 95% compared to about 57% during the first five years of measurement (1987-1991). The recorded increase in dark water days may be related to greater frequency and longevity of periods when the Spring Creek Springs are "plugged" with denser salt water, and thus water from the Lost Creek swallet is flowing to Wakulla Spring.

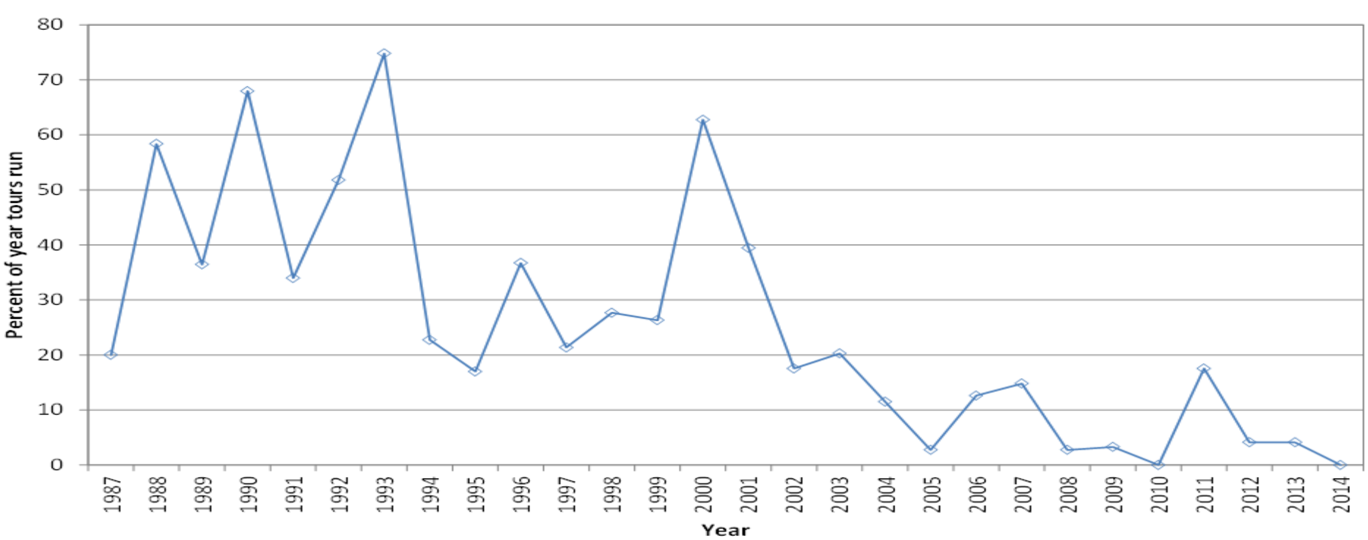


Figure 4. Percent of time water clarity allowed glass bottom boat use at Wakulla Springs State Park.

SPRINGSHED CHARACTERISTICS

The springshed for Wakulla Spring, developed by Florida Geological Survey (Figure 5), is approximately 1,569 square miles, and includes portions of four Florida counties (Gadsden, Jefferson, Leon, and Wakulla – 1,157 mi² or 73.7%) and portions of three South Georgia counties (Decatur, Grady, and Thomas – 412 mi² or 26.3%). There is considerable variability in the estimation of the absolute area of any springshed due to the density of wells used to map the groundwater potentiometric surface and the normal year-to-year variation in hydrologic conditions. It should be kept in mind that comprehensive restoration at Wakulla Spring will require significant land use changes in a large region of South Georgia.

GROUNDWATER FLOW PATHS AND TRAVEL TIMES

A number of groundwater flow tracer studies have been conducted in the vicinity of Wakulla Spring. Groundwater recharging the Floridan aquifer north of Wakulla Spring travels to the south and southwest towards the springs as well as to Indian and Sally Ward springs. Average measured groundwater flow rates from the City of Tallahassee Tram Road Sprayfield site to these springs was in the range from 671 to 977 feet per day. These are very high rates for groundwater flow and confirm the presence of large natural conduits in the limestone formations that feed these springs.

LAND USE

Figure 6 illustrates the principal land uses within the portion of the springshed located within Florida and Georgia in 2006-2008. Slightly different land use categories were used in the Georgia and Florida mapping efforts. The dominant land uses in the Wakulla springshed include forestry (43%), followed by wetlands and lakes (23%), agriculture and pasture (about 21%), and urban/commercial (about 13%).

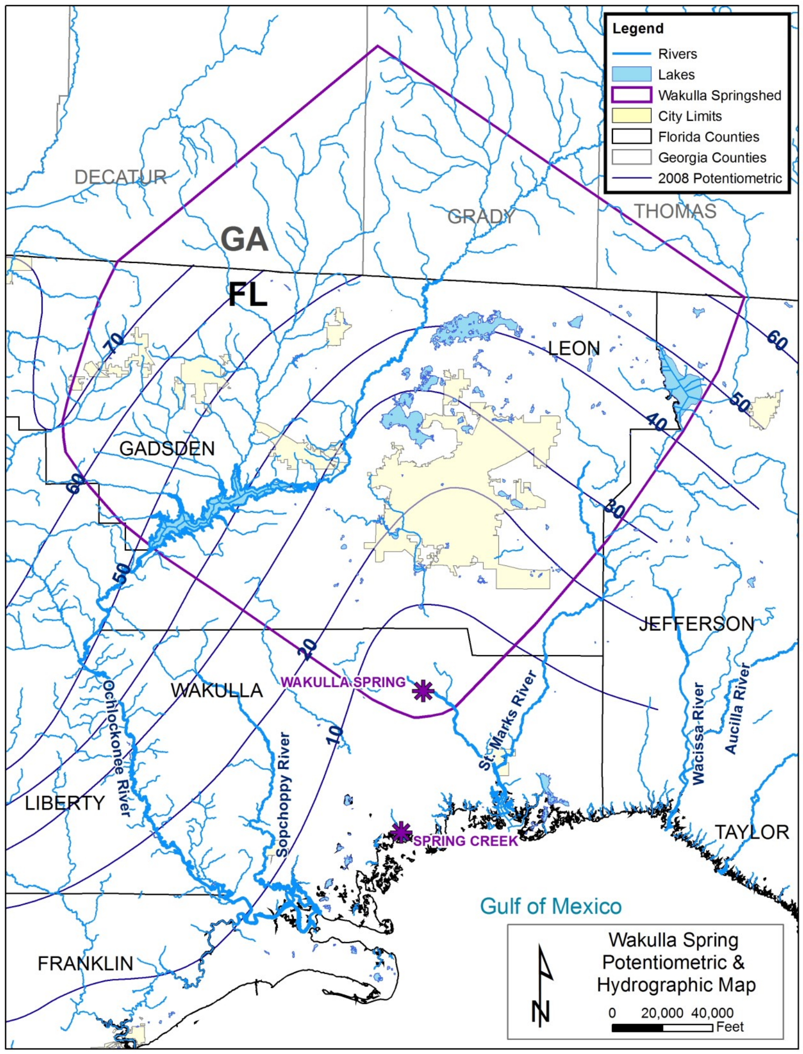


Figure 5. Approximate delineation of Wakulla Springshed prepared by the Florida Geological Survey based on 2008 Floridan Aquifer groundwater levels.

AQUIFER VULNERABILITY

All groundwater and aquifer systems are susceptible to some extent to contamination from surface sources of pollution. An aquifer vulnerability assessment provides a data-based method of estimating that susceptibility to groundwater contamination. Based on work completed by the Florida Geological Survey, essentially all of the land in the Florida portion of the Wakulla Springshed is mapped as Vulnerable or More Vulnerable to polluting activities at the land surface. South Georgia aquifer vulnerability has not been assessed but is expected to be similar to Florida conditions.

HUMAN POPULATION

The City of Tallahassee, suburbanized Leon County, and developed portions of Wakulla County overlie the Wakulla Spring springshed and groundwater capture zone. The 2010 U.S. Census recorded an estimated 471,246 people residing in the seven counties that encompass the Wakulla springshed. Based on the fraction of each county that is in the delineated Wakulla springshed, the estimated human population in the springshed in 2010 was 303,685, with 7.4% in the Georgia portion and 92.6% in Florida. About 40% of the Wakulla Springshed is in Leon County, Florida, with 25.6% in Gadsden County, Florida, 13.9% in Grady County, Georgia, and smaller percentages in the remaining four counties. About 89% of Leon County is in the Wakulla Springshed.

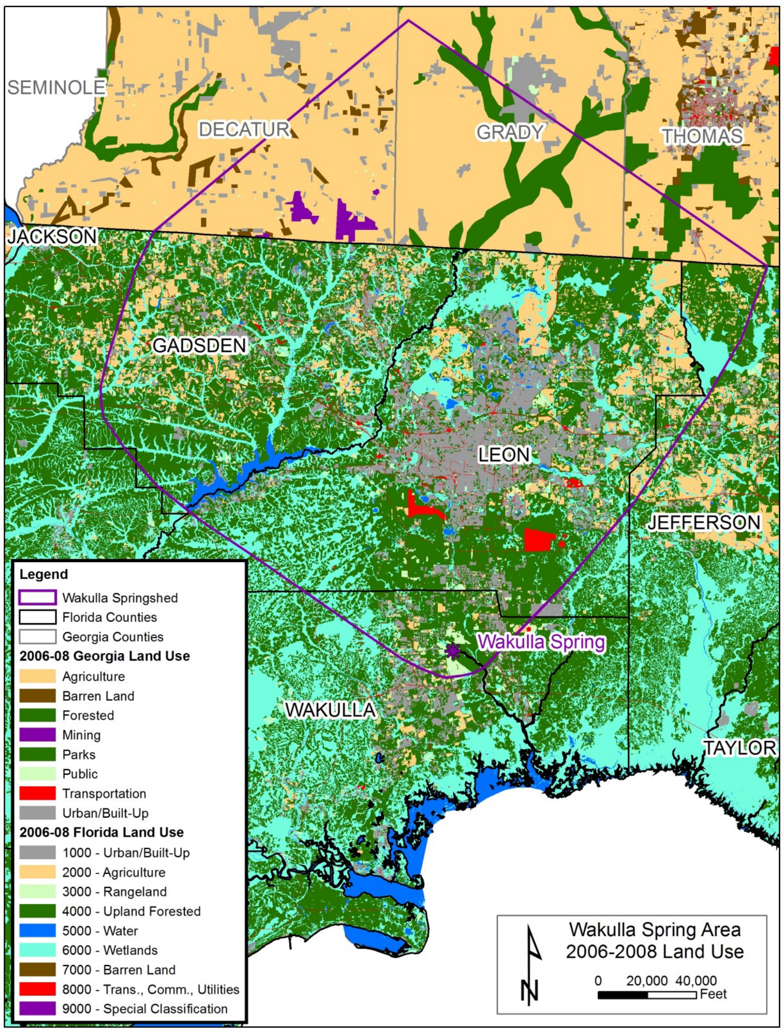


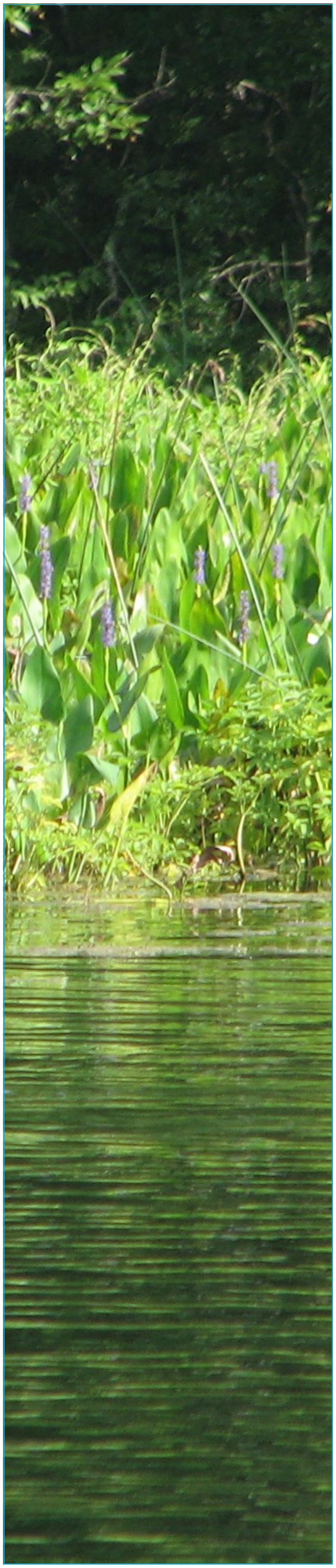
Figure 6. Land use map for the Wakulla Spring recharge area (based on FGS springshed delineation and land use data for 2006-2008). Florida land uses are based on the Florida Land Use and Cover Classification System and reflect both land use and dominant land cover types. Georgia land use categories were less detailed and assumptions concerning their similarity to Florida codes were made in preparation of this map.

"essentially all of the land in the Florida portion of the Wakulla Springshed is mapped as Vulnerable or More Vulnerable to polluting activities at the land surface"

GROUNDWATER USE

Groundwater is the principal source of supply for most withdrawals in the Wakulla Springshed. Total estimated groundwater withdrawals increased from about 14 MGD for the period from 1965-1970 to about 42 MGD for the period from 1990-2010. The dominant groundwater uses are for public and domestic supply. The City of Tallahassee is the single largest groundwater user with a total of 28 water-supply wells. The most recent data indicate that total combined withdrawals in the Florida portion of the springshed were about 43 MGD in 2010. Groundwater withdrawals in the Georgia portion of the Wakulla Springshed for 2005 were about 14 MGD, with agricultural irrigation being the dominant groundwater use (76%). The estimated total current groundwater withdrawal in the combined Georgia/ Florida Wakulla Springshed is about 57 MGD.

A fraction of the water withdrawn by wells from the Floridan Aquifer in the Wakulla Springshed is returned to the aquifer upgradient of Wakulla Spring and subsequently is part of the spring's discharge. The fraction of this water that is not returned to the Floridan Aquifer is referred to in this report as the "net consumption". This net consumption is the difference between the total amount of groundwater withdrawn and the amount that recharges the Floridan Aquifer. Different groundwater uses have inherently different net consumption fractions.



Estimated net consumption of groundwater within the Florida portion of the Wakulla Springshed has increased from about 4.3 MGD in the period from 1965-1970 to about 13.9 MGD during 2010. The overall average estimated net consumption for the Florida portion of the springshed is about 32% of the total water withdrawn from the aquifer. Estimated net consumption of groundwater within the Georgia portion of the Wakulla Springshed was 8.1 MGD during 2005, or about 58% of the total water withdrawn from the aquifer. Based on these data and assumptions, an estimated average 22 MGD of Floridan Aquifer groundwater is currently being removed from the sources of groundwater inflow to Wakulla Spring.

WAKULLA SPRING WATER BALANCE

The median annual rainfall in the Wakulla Springshed for the period-of-record from 1968 to 2010 was 62.2 inches per year. Based on an estimated springshed area of 1,569 square miles, the estimated median annual rain input to the Wakulla Springshed is about 4,650 MGD.

Evapotranspiration (the sum of evaporation and plant transpiration) is second only to rainfall in importance for constructing water budgets for Florida. Evapotranspiration for this portion of Florida can be estimated as about 42 inches per year or about 3,120 MGD, for an estimated net precipitation in the springshed of about 20 inches per year or about 1,530 MGD.

Wakulla Spring has the largest known range of discharge measurements among Florida springs. Historical discharge data ranged from 16 MGD on June 18, 1931 to 1,234 MGD on April 11, 1973; with an average discharge of 252 MGD for the period from 1970 to 1974. The variability of discharge and stage in this spring system is highly responsive to rainfall events in the springshed. Some of the variability in this spring's discharge has also been attributed to tidal influence.

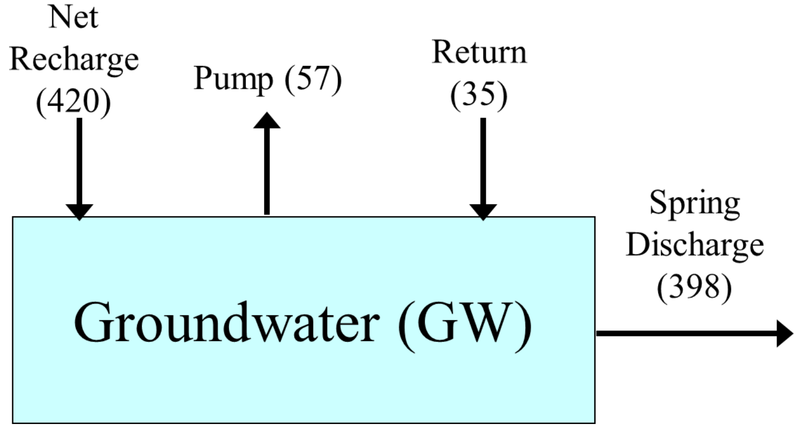


Figure 7. Wakulla Spring estimated water balance in million gallons per day. These inputs and outputs include the entire Georgia-Florida springshed and have been independently estimated by FSI.

Of particular note for the discharge measurements at Wakulla Spring and downstream in the Wakulla River is a marked increase in median and average flows during the past 30 years. The average flow at Wakulla Spring was 84% higher in the decade from 2000-2009 than during the entire 100+ year period-of-record. The observed increase in Wakulla Spring discharge is not typical of other springs in Florida during this same period and cannot be tied to an increase in precipitation in the Wakulla Spring recharge area. As described above, there appears to be a delicate balance in the flows between Wakulla Spring and Spring Creek Springs that is affected by multiple factors, possibly including changes in sea level and an increase in net groundwater withdrawals in the combined springshed of these two inter-connected large springs.

Recent studies noted significant reductions (up to 16 feet) in groundwater levels measured at the Lake Jackson Floridan Aquifer Monitoring Well and in northern Leon County beginning in the late 1990s. These are the lowest levels measured in the Floridan Aquifer for the entire 35 year period-of-record.

The estimated reduction in average artesian groundwater levels and flows from the north to south is potentially a significant fraction of the total flow feeding Wakulla Spring. Small increases in the hydraulic head level of the Floridan Aquifer result in significant increases in discharge at Wakulla Spring. Conversely, small declines in the potentiometric surface in the Floridan Aquifer near the spring are expected to result in significant flow declines. Depending on the delicacy of the "balanced" nature of the factors affecting flows to Wakulla Spring and Spring Creek Springs, this estimated change might provide an important factor responsible for increased flows of dark water at Wakulla Spring.

The recent (2004-2009) median discharge at Wakulla spring is about 398 MGD while Spring Creek Springs are apparently flowing intermittently. Using the recently measured spring flow and the estimate of net groundwater consumption of 22 MGD, the groundwater recharge estimate is 420 MGD for an average of 5.6 inches per year over the springshed area. Figure 7 summarizes this estimated Wakulla Spring water balance.

"These are the lowest levels measured in the Floridan Aquifer for the entire 35 year period-of-record."

WATER QUALITY

Water quality data for Wakulla Spring were summarized for the period-of-record from February 1907 to May 2008. Wakulla Spring (main vent) water quality averages for several key parameters are:

- Water temperature – 20.7 °C
- Dissolved oxygen – 2.07 mg/L
- pH – 7.51 SU
- Specific conductance – 308 μS/cm
- Turbidity – 0.44 NTU
- Color – 4.16 CPU
- Chlorophyll a – 1.63 ug/L
- Total chloride – 8.43 mg/L
- Sulfate – 10.5 mg/L
- Nitrate+nitrite nitrogen – 0.759 mg/L
- Total nitrogen – 0.750 mg/L
- Total phosphorus – 0.03 mg/L

Wakulla Spring has experienced a significant increase in nitrate concentrations over the entire period-of-record. Wakulla Spring nitrate concentrations were less than 0.05 mg/L between 1956 and 1973. Nitrate concentrations at Wakulla Spring increased significantly from the mid-1970s to the early 1990s and have decreased slightly since then. Based on data from 1971 through 1977, the median nitrate concentration was 0.26 mg-N/L, while data from 1989 through 2000, had a median nitrate concentration of 0.89 mg-N/L, and concentrations appear to have peaked above 1 mg/L in the late 1980s to early 1990s.

NITROGEN SOURCES

To better understand the contributions of nitrate-nitrogen to Wakulla Spring, FDEP has prepared a nitrogen mass balance as part of their Basin Management Action Plan (BMAP). Summarized in Figure 8, FDEP's nitrogen mass balance only includes sources within the Florida portion of the springshed. FDEP estimates that of the 380 tons per year that is entering the Upper Floridan Aquifer flowing to Wakulla Spring, approximately 51% (386,400 pounds per year) is from septic tanks, 12% (93,000 pounds per year) is from urban and agricultural fertilizer uses, 11% (80,600 pounds per year) is from storm runoff into sinking streams, 7% (54,000 pounds per year) is from livestock wastes, and 6% (48,000 pounds per year) is from municipal wastewater disposal.

Discharge and concentration data for Wakulla Spring indicate that the nitrate load in the groundwater exiting the spring vent increased from about 50 tons per year in the 1960s to about 470 tons per year during the most recent decade, with a peak load of about 670 tons per year in the 1980s. These mass balances indicate that about 90 tons (180,000 pounds per year) of additional nitrogen per year may be discharging at Wakulla Spring due to nitrogen loading occurring in Georgia. Recent declines in nitrogen concentrations and mass loads over the past two decades have been in part due to dilution due to higher inflows of lower nitrogen surface water to Wakulla Spring.

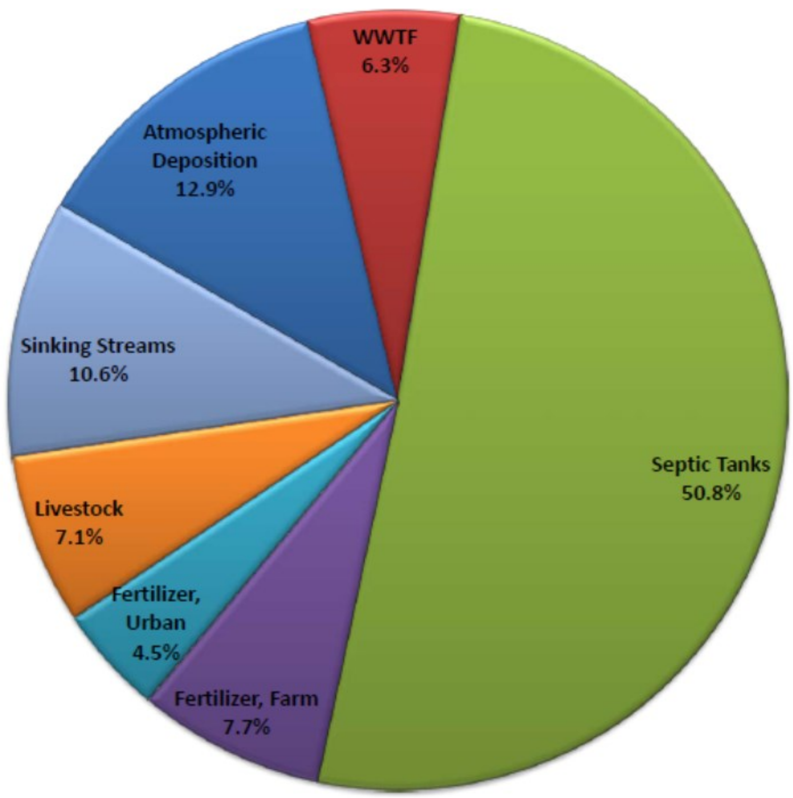


Figure 8. Relative nitrogen loads to the UFpper Floridan Aquifer from the nitrogen source categories evaluated by FDEP for the Wakulla Spring and River BMAP area.

BIOLOGY

Native submerged aquatic species that formerly dominated Wakulla Spring and the Wakulla River included eelgrass (*Vallisneria americana*), strap-leaved sagittaria (*Sagittaria kurtziana*), coontail (*Ceratophyllum demersum*), southern naiad (*Najas guadalupensis*), muskgrass (*Chara* sp.), and elodea (*Elodea* sp.). Non-native hydrilla is conspicuously present in the upper Wakulla River, and although observed in 1983 during surveys by FDEP, it was not until the early 1990's that hydrilla abundance had become problematic (Figure 9). Since 2001, aquatic plants in the Wakulla River have been managed by the state through a variety of herbicide applications and mechanical harvesting methods. Hydrilla coverage declined from 50% in May 2001 to 9% in May 2003 due to herbicide applications. The cover of eelgrass also decreased from 50% to 30% during this period of herbicide use.

Increasing algal mats in the Wakulla River were first quantified in 2001 and have increased since that time. An apparent relationship between these plant community changes and nitrate-nitrogen was described by FDEP in 2010. Hydrilla and algal mats were generally most prevalent in areas of elevated nitrate concentrations.

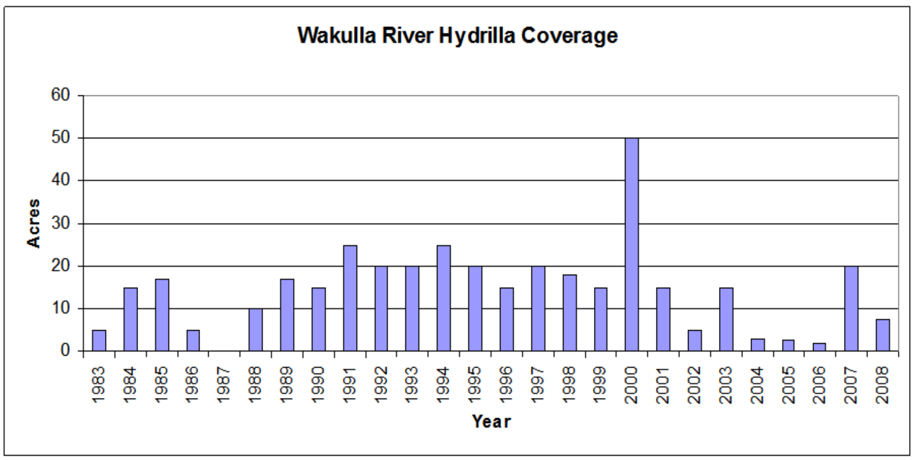


Figure 9. Areal extent of hydrilla cover in the by year.

The Wakulla River was monitored up to four times a year from 2000 through 2007 as part of FDEP's EcoSummary sampling. Results indicated that the habitat assessment rating was usually in the optimal range, the total number of invertebrate taxa ranged from 11 to 28, and the total number of sensitive taxa ranged from one to three. For the period-of-record, only four out of 27 (or 15%) SCI scores indicated a healthy invertebrate community in the river.

Crustaceans were monitored at Wakulla Spring on May 17-18, 2002 by staff from the Florida Museum of Natural History. In the main spring and run, freshwater shrimp (*Palaemonetes paludosus*), amphipods (*Hyalella* sp.), and the crayfish (*Procambarus paeninsulanus*) were collected.

Fish have been surveyed at Wakulla Spring by review of the Florida Museum of Natural History fish collections and by electrofishing. Based on this review, a total of 43 species of 31 genera and 20 families of fishes had been collected from the headspring, river, and McBride Slough. The relative abundance of fish were dominated by redeye chub (*Notropis harperi*; 28.1%), spotted sunfish (*Lepomis punctatus*; 17.2%), and coastal shiner (*Notropis petersoni*; 15.9%). Additional fish species commonly observed in Wakulla spring and river include striped mullet (*Mugil cephalus*), lake chub sucker (*Erimyzon sucetta*), largemouth bass (*Micropterus salmoides*), Florida gar (*Lepisosteus platyrhincus*), long nosed gar (*Lepisosteus osseus*), bowfin (*Amia calva*), and several species of sunfish (*Lepomis* spp.). Based on recent anecdotal observations, populations of freshwater fish species in Wakulla Spring appear to be declining.

Figure 10 presents a summary of the average number of alligators and turtles observed during Wakulla tour route surveys by the Florida Park Service from September 1992 to May 2014. The American alligator has shown a steady decline since 2001, with an average of 32 individuals observed per monitoring event from 1992 to 2001, to an average of 14 per event from 2012 to present. The average number of observed Florida cooter turtles has remained relativity stable with an average of 18 turtles observed per event over the period of record. The Florida softshell turtle was observed infrequently with an average of less than 1 per monitoring event.

Wakulla Springs State Park has been surveyed as part of the Audubon Christmas bird count since 1947. Twenty aquatic bird species have been documented through this survey, with the five most commonly observed species being American widgeon (48.7%), American coot (16.2%), lesser scaup (9.6%), white ibis (5.4%), and common moorhen (4.1%). A number of long-term trends for individual bird species are evident in the Christmas count data. Annual counts of a number of aquatic bird species have increased during the 60+ year period, including anhinga, little blue heron, green heron, white ibis, common moorhen, and hooded merganser. Numbers for several aquatic bird species have remained relatively constant, including pied-billed grebe, double-crested cormorant, great blue heron, tricolored heron, great egret, yellow-crowned night-heron, lesser scaup, and bald eagle. Anhingas, moorhens, and wood ducks have declined.

A few notable bird species have displayed a boom or bust population trend as noted by the Audubon Christmas bird count data. For example the American widgeon, a migratory waterfowl, increased from very low counts in 1940s through the 1960s, to high counts from 500 to over 2,000 individuals from the 1970s through the early 2000s, and have declined back to zero over the most recent decade. Limpkins increased precipitously at Wakulla Spring beginning in 1969 to over 70 individuals in 1971 and then gradually declined to previous numbers (fewer than 10) until 2000 when the population suddenly collapsed. The limpkin, a relatively uncommon wading bird whose preferred prey is apple snails, has been considered by some to be a sensitive indicator of spring health. Limpkins have not been recorded on Christmas bird counts at Wakulla Spring since 1999.

Numbers of manatees utilizing Wakulla Spring have been steadily increasing over the past decade. The current known high manatee count at the spring is 50, documented during the winter of 2012-2013. FDEP records indicate that 12 manatees utilized the spring during the 2007 to 2008 winter period. Wakulla Spring is considered a secondary warm-water site by the Florida manatee recovery team and does not appear to have accessibility issues despite some relatively shallow areas in the spring run.

During an ecosystem study at Wakulla Spring in 2009, gross primary productivity for the aquatic plants and algae was twice as high during clear water conditions than during a subsequent dark water period. Community respiration doubled between clear and dark water periods. The combined effect of these changes was a shift from positive net primary productivity during clear water conditions to negative net productivity during the dark water period.

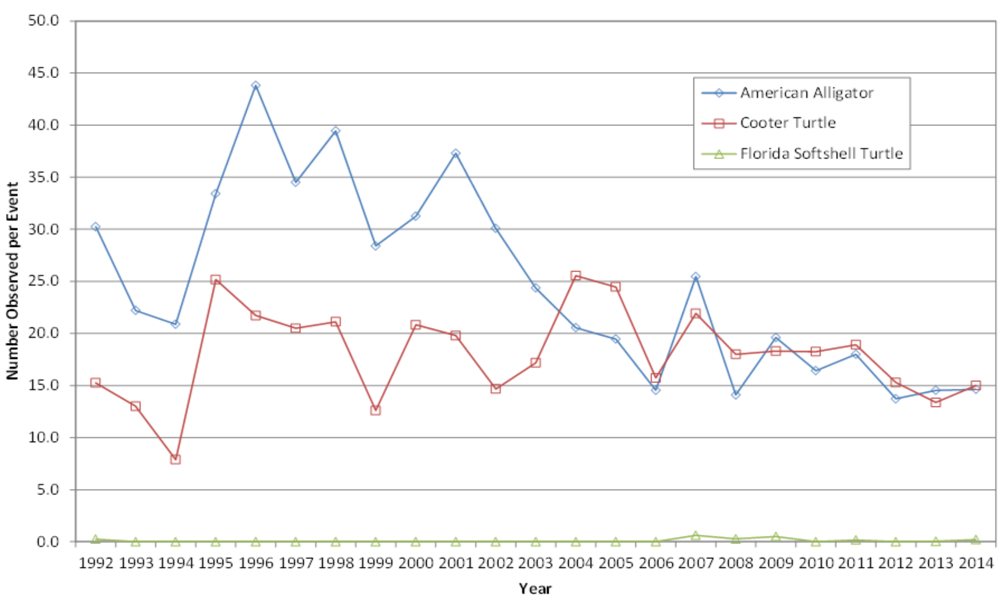


Figure 10. Time series of alligator and turtle species observed during the Wakulla tour route survey

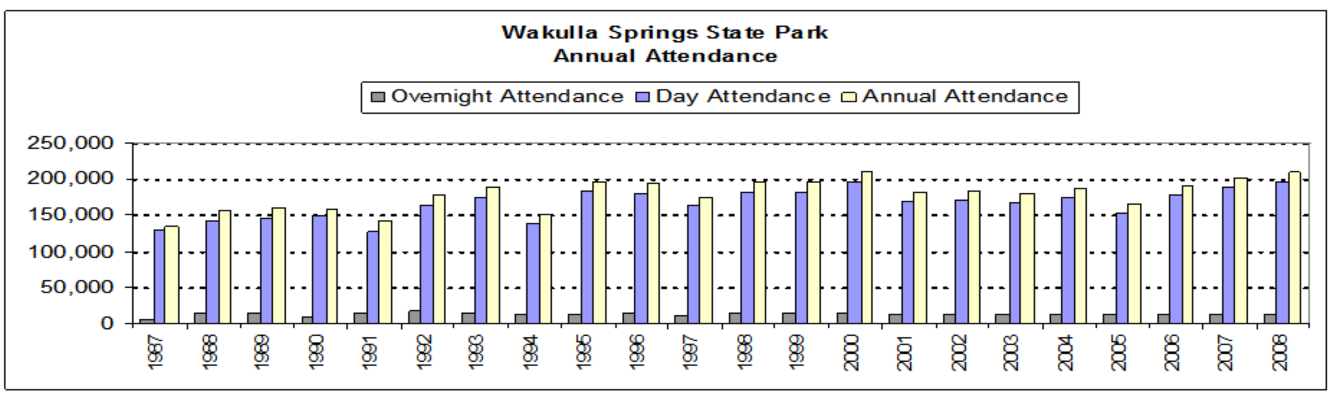
These data provide evidence that dark water conditions in Wakulla Spring and in the downstream spring run result in a significant shift in the aquatic ecosystem from an autotrophic condition to a heterotrophic condition. The long-term effect of reduced sunlight reaching the submerged plants due to dark water is a net reduction in the biomass and types of plants and animals supported by the Wakulla Spring and Wakulla River ecosystem.

"Recreational activities at Wakulla Spring include swimming, guided boat tours, picnicking, and lodging."

HUMAN USE

Recreational activities at Wakulla Spring include swimming, guided boat tours, picnicking, dining, and lodging. As a state park, annual statistics of human attendance are available between 1987 and 2008. Peak total annual attendance occurred in 2000 (slightly more than 210,000 people) and peak season use occurs in summer months (Figure 11).

One of the major public-use attractions at the Wakulla Springs State Park is boat rides around the spring basin and along the upper spring run. Two types of boats are used: glass-bottom boats for underwater and above-water viewing and "jungle" cruise tour boats for wildlife viewing. Glass-bottom boats are only run when water visibility equals or exceeds 75 feet as measured by park staff. Clear-water conditions occur at Wakulla Spring when older groundwater predominates in the Floridan Aquifer and is discharged at the spring. The frequency of glass-bottom boat tours at Wakulla Spring has declined over the last 25 years.



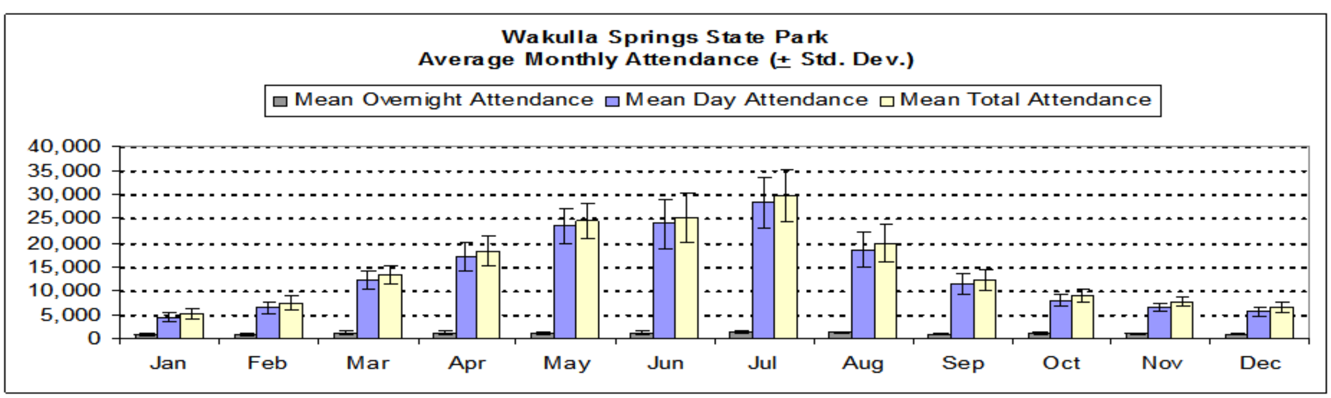


Figure 11. Wakulla Springs State Park annual and monthly attendance data.

WAKULLA SPRING REGULATORY STATUS

Like many of Florida's large, artesian springs, Wakulla Spring is protected through existing federal, state, and local ordinances that are intended to limit or totally prevent ecological impairment. These laws and policies are aimed, directly or indirectly, at protecting the springshed and the springs that nourish the Wakulla River. However, as documented by the environmental information collected for this report, the existing level of enforcement of existing regulations has not been successful at halting the continuing decline in the ecological health of Wakulla Spring or the Floridan Aquifer it depends on for nourishment.

FEDERAL

The Federal Clean Water Act (CWA) protects all of the nation's surface water bodies from the uncontrolled discharge of pollutants. Passed in 1972, the objective of the CWA, is to restore and maintain the chemical, physical, and biological integrity of the nation's waters by preventing point and nonpoint pollution sources, providing assistance to publicly owned treatment works for the improvement of wastewater treatment, and maintaining the integrity of wetlands. The CWA does not directly address groundwater contamination. Groundwater protection provisions are included in the Safe Drinking Water Act, Resource Conservation and Recovery Act, and the Superfund Act.

FLORIDA

Four major pieces of state environmental legislation were enacted by the 1972 Florida legislature: the Environmental Land and Water Management Act, the Comprehensive Planning Act, the Land Conservation Act, and the Water Resources Act. Five water management districts were established by the 1972 Florida Water Resources Act and were given the responsibility to provide conservation and allocation of water supply, water quality protection, flood protection, and natural systems management. The Northwest Florida Water Management District (NWFWMD) extends from the middle of Jefferson County to the western terminus of the Florida Panhandle and includes Wakulla Spring, the Wakulla River, and the Florida portion of the ground and surface water springshed that feeds these waterbodies.

Of Florida's 1,700 rivers, the Wakulla River was designated a "Special Water" as one among only 41 which are recognized as Outstanding Florida Waters (OFW). The OFW designation recognizes diverse ecosystems and is meant to protect the water body from degradation of ambient water quality "under all circumstances" (antidegradation requirement from the CWA).

By setting 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 water management district. MFLs apply to decisions affecting water withdrawal permits, declaration of water shortages, environmental resource permitting, and assessment of water supply sources. Each water management 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.

As of 2014, the NWFWMD has not set any MFLs for the District's springs and other surface waters. The District did update their MFL priority list in 2014 and included Wakulla, Jackson Blue, and the Gainer springs group as required for all first magnitude springs. Based on this list as approved by the FDEP, the NWFWMD started the MFL technical data collection at Wakulla Spring in 2013, and plans to complete their MFL technical assessment by 2021, and adopt an MFL rule for Wakulla Spring in 2023.

The Impaired Surface Waters Rule (IWR) was adopted in April 2001 to satisfy the requirements of the Florida Watershed Restoration Act. Based on the definitions within the IWR, in June 2008 the FDEP verified that the Wakulla River biology is impaired for elevated concentrations of nitrate nitrogen. This impairment was evidenced by excessive algal growth and smothering of desirable plants, by invasion of the river by the exotic submerged aquatic plant hydrilla, by low dissolved oxygen concentrations and slightly elevated specific conductance, and by increasing invasion of tannic or "colored" waters that limit recreational and aesthetic uses of the spring and river. This designation as an impaired water initiated the Total Maximum Daily Load (TMDL) regulatory process to develop loading estimates to maintain or reduce impairment.

A TMDL represents the estimated 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. According to FDEP, achieving a monthly average nitrate nitrogen concentration target of 0.35 mg/l will require a 56% decrease in nitrogen loading in the springshed and will be sufficient to prevent an imbalance in the Wakulla River and will be protective of the aquatic flora and fauna in Wakulla Spring.

The means of achieving the TMDLs for Wakulla Spring and the Wakulla River is development and implementation of a Basin Management Action Plan (BMAP). A BMAP is a restoration plan developed by FDEP and basin stakeholders that formalizes the activities that will are necessary to reduce the pollutant loads and achieve the TMDL. The BMAP process for the Wakulla River began in January 2013 and is expected to be complete by 2015.

Photo by David Rhea
Courtesy Woodville Karst Plain Project
www.wkkp.org

LOCAL GOVERNMENTS

Counties and municipalities have a number of regulatory tools that can be used either to protect or to compromise the health of springs and other water bodies. These tools include comprehensive plans, zoning, land development regulations, and water quality/quantity ordinances. Comprehensive springshed protection language has been adopted by Leon and Wakulla Counties.

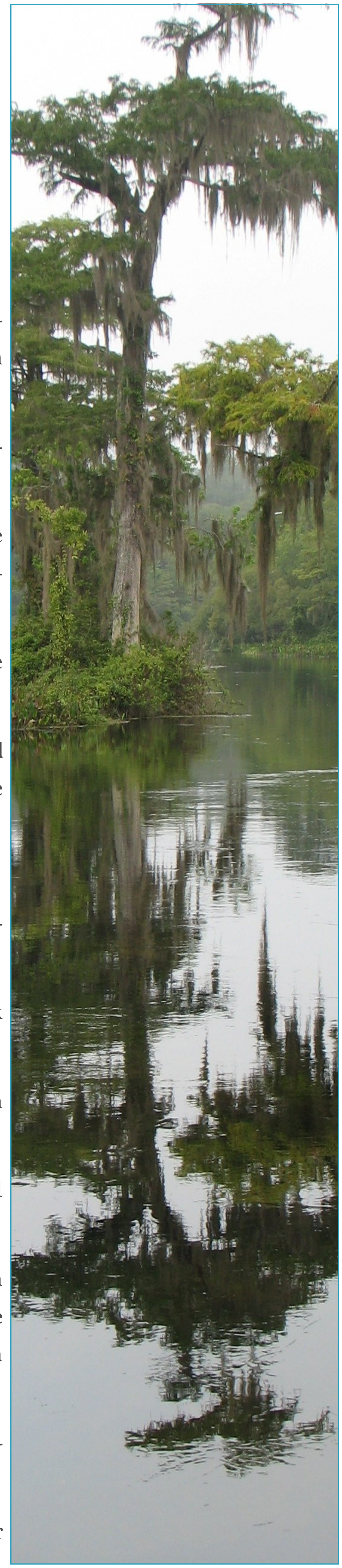
DESCRIPTION OF IMPAIRMENTS

A review of the existing literature, studies, and available data for Wakulla Spring determined the following principal impairments:

- Wakulla River has been found by FDEP to be impaired for nitrate-nitrogen due to excessive growth of hydrilla and filamentous algae. FDEP has found that the primary source of the nitrate in the river is groundwater from the spring. The overall mass of nitrogen discharged at the spring vent has been about 460 tons per year during the most recent decade.
- FDEP's TMDL analysis indicates that the concentration of nitrate-nitrogen will need to be lowered by at least 56%. FDEP has concluded that successful restoration of the river will depend on achieving significant reductions in the sources of nitrate nitrogen within the Wakulla Spring springshed.
- The average discharge from Wakulla Spring during the most recent decade was about 85% greater than the long-term average flow recorded at the spring.
- Wakulla Springs State Park has had an increasing number of "dark" and "green water" days over the last 25 years as measured by park staff. Research has demonstrated that this tannic and chlorophyll-stained water is originating from inputs of surface water runoff into swallets that feed the Wakulla/Spring Creek Springs springshed. These sources include creeks flowing from the Apalachicola National Forest to the west, Lake Munson to the north, and the Bradford chain of lakes on the south side of Tallahassee. Preliminary hydrogeologic research suggests that the increased frequency of black and green water events appears to be the result of a shift in the delicate balance of the inter-connected cave system that feeds both Wakulla Spring and Spring Creek Springs.
- An updated analysis described in this report for the most recent decade found that an estimated average of 22 MGD of clear, artesian water that formerly discharged at these two springs has been removed from the water balance due to groundwater pumping. Increased net consumption of upgradient, clear groundwater appears to be a significant factor resulting in increased flows and dark water days at Wakulla Spring.
- There is evidence that an increase in the number of dark water days results in reduced primary productivity in the spring run, and in turn, reduces the amount of plant biomass available to all organisms in the aquatic food web.
- The upper Wakulla River at Wakulla Spring has suffered from an invasion of hydrilla and filamentous algae. Hydrilla control in Wakulla Spring and Wakulla River is dependent upon annual applications of the herbicide, Aquathol, and periodic mechanical harvesting.
- Herbicide control of hydrilla may result in unintended consequences such as invertebrate mortality, depressed dissolved oxygen levels, loss of desirable submerged plant species, increased algal cover, and excessive formation of organic sediments. Other biological changes have been observed over the same period, including the extirpation of limpkins, a relatively rare bird that was formerly emblematic of Wakulla Springs State Park, and the bird's primary food – the native apple snail.

A VISION FOR WAKULLA'S FUTURE

Specific recommendations to implement water quantity, water quality, and resource management restoration actions for the Wakulla Spring System are provided in the full Wakulla Spring Restoration Plan. A summary of the general challenges and solutions as well as the monitoring and assessment needed for an adaptive management approach to full restoration of Wakulla Spring 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 Wakulla Spring System (Wakulla Spring and River);
- Reduced consumption of groundwater within and outside of the Wakulla Springshed is needed to restore spring and river flows;
- Natural drainage and water storage patterns in wetlands and streams in the Wakulla 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; and
- Technical uncertainties still exist concerning the magnitude of human-induced flow reductions and sources of increased nitrogen loads and their effects on the health of the Wakulla Spring System.

THE SOLUTIONS

- Educate the public and local, state, and federal leaders of the importance of restoring the Wakulla Spring System and its natural biodiversity;
- Develop a phased plan to restore Wakulla Spring and River flows by cutting back on consumptive uses of groundwater within and outside of the springshed;
- Increase protection and restoration of natural drainage and storage patterns in wetlands and streams in the Wakulla Springshed;
- Implement consequential improvements in fertilization and wastewater disposal practices in the Wakulla Springshed;
- Assess the costs and benefits of restoration efforts, develop a phased restoration timeline, and establish adequate monitoring of the Wakulla Spring System to be able to document whether these efforts are resulting in improved springs health or continued degradation;
- The FDEP should accelerate the development and implementation of a truly protective BMAP; and
- The NWFWMD should accelerate the development of a truly protective MFL for the Wakulla Spring System.

WHY ARE SPRINGS SO SPECIAL?

Springs and spring runs are a unique class of freshwater ecosystems. They are different from the majority of fresh surface waters due to the following recognized properties:

- Relatively minor variation in flows (hydrostatic) compared to the majority of streams and rivers;
- High water clarity/transparency unlike most streams and rivers, with optimal light availability for primary productivity; and
- Consistent chemistry (chemostatic) and water temperature (thermostatic) due to their reliance on groundwater inflows.

This unique combination of physical and chemical properties imparts the following opportunities for optimizing ecological efficiency and wildlife habitat support in Florida's springs and in associated spring runs:

- Highly stable environmental conditions that promote the evolution of complex, adapted plant and animal communities;
- Maximum use of available light for conversion to useful gross primary productivity that supports a high secondary productivity of primary, secondary, and advanced consumer organisms;
- Autotrophic ecosystems that approach ecological perfection for the full utilization of locally-produced organic carbon; and
- Export of internally-produced organic matter that augments downstream aquatic ecosystems and attracts the immigration of downstream fauna that complete various portions of their life histories in the springs and spring runs, imparting additional services that help to maximize photosynthetic efficiency.

For these reasons springs and spring-fed rivers like Wakulla are among the most productive freshwater aquatic ecosystems on earth in terms of the production of plants and wildlife. The wildlife habitat function of springs is well documented. In addition to the importance of spring runs for the support of highly productive warm-water fisheries, and their support for turtles, alligators, and water-dependent birds, they are critical for the life history of other large and economically-important migratory wildlife such as striped bass, sturgeon, mullet, channel catfish, shad, eels, and manatees. In fact, spring runs in Florida are essential for the life histories of all of these species. This importance is a direct result of the unique physical/chemical properties of healthy springs and their resulting optimum photosynthetic productivity.

RESTORATION GOALS

A future-scenarios visualization and goal setting exercise was conducted by the Wakulla Springs Basin Working Group in March 2011. After lengthy review and discussion, the stakeholders recommended the following restoration goals:

Restoration Goal # 1 – Reduce Nitrate -Nitrogen Concentration

- Meet or exceed the target nitrate-nitrogen goal of 0.35 mg/L that is noted in the Wakulla Spring TMDL;
- Develop an enforceable BMAP within two years;
- Reduce the nitrogen loading from septic tanks in the springshed; and
- Decrease fertilizer use in the springshed.

Restoration Goal # 2 – Reduce Dark Water Days

- Conduct a hydrogeologic assessment to better quantify recharge and withdrawals and their influence on the spring systems;
- Continue to promote water conservation & education;
- Continue research regarding a water budget and flow patterns;
- Enhance groundwater recharge; and
- Reduce net groundwater withdrawals.

Restoration Goal # 3 – Restore Spring Ecology

- Decrease nitrate-nitrogen concentrations in order to decrease hydrilla and filamentous algal growth;
- Increase clear water days by reducing net groundwater withdrawals, promoting water conservation & education, and continuing research regarding a water budget and flow patterns;
- Continue limited hydrilla management; and
- Increase ecological research.

EVALUATION OF SUCCESS

Wakulla Spring restoration goals may be costly and take many years to accomplish. As specific restoration activities occur it will be important to document changes in the target measures of success. A comprehensive restoration assessment program (monitoring plan) is needed to track progress with adaptive management of the resource. The key to encourage stakeholders to continue on the path leading to eventual restoration is to collect and summarize relevant data about the condition of the Wakulla Springshed and Wakulla Spring. Frequent and coherent status reports are essential for success. A comprehensive monitoring effort will include the following elements:

Springshed Monitoring and Analysis

- Springshed aquifer levels;
- Springshed delineation (once every three to five years);
- Springshed land use and land cover updates (once every three to five years);
- Springshed water balance (annual updates); and
- Springshed nitrogen balance (annual updates).

Wakulla Monitoring and Analysis

- Discharge and levels (daily);
- Water chemistry (weekly to monthly);
- Biology (quarterly); and
- Human use (daily).

Photo by Steve Auer
Global Underwater Explorers

CLOSING STATEMENT

The City of Tallahassee's wastewater upgrade project was a significant first step in the restoration process and should result in a measurable reduction in the total load of nitrate-nitrogen discharging from Wakulla Spring during this decade. However, evidence is presented in this report that indicates that more action is needed to fully restore Wakulla Spring to its desired condition. Major obstacles to comprehensive restoration still include replacement of on-site (septic tank) waste disposal systems, significant water conservation needs, and the resolution of inter-state issues between Florida and Georgia over excessive water and fertilizer uses. There is widespread sentiment among the majority of the stakeholders that significant restoration actions are long overdue. Comprehensive restoration should not wait for additional studies so that Wakulla Spring can progress towards recovery rather than suffer from further degradation.

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 Wakulla Spring ecosystem 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 one of the most important natural resources in Florida. Currently, the groundwater that feeds the Wakulla Spring System is neither clean nor abundant. As evidenced so clearly by the deteriorating water quality and declining flows of Wakulla Spring, North and 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 Wakulla Spring System and for Florida's springs in general is in the hands of the people who have learned to appreciate the unique value of these public resources.

ABOUT THE

HOWARD T. ODUM FLORIDA SPRINGS INSTITUTE

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.

The Florida Springs Institute fulfills this mission by: 1) developing a defensible baseline of ecological data that documents their existing environmental conditions and trends over time; 2) disseminating current information about the ecology and environmental condition of Florida's springs and recommending management actions needed to reverse adverse changes occurring in many springs; 3) promoting wise land use practices to reduce pollution and to maintain historic flows that support healthy spring, plant, and animal communities; and 4) increasing the public's awareness of the threats to springs and the need to fund basic springs science .

The Florida Springs Institute is a 501c3 non-profit organization funded entirely through grants and private donations.

Please consider supporting the work of the Florida Springs Institute by contributing at: www.floridaspringsinstitute.org

ACKNOWLEDGEMENTS

The full Wakulla Spring Restoration Plan provides an update of the Wakulla Spring Adaptive Management Strategy previously published in August 2011 by the Howard T. Odum Florida Springs Institute. Information included in that earlier report was gathered under a project completed by Wetland Solutions, Inc. for the Florida Department of Environmental Protection in June 2011.

Following the publication of the Wakulla Spring Adaptive Management Strategy report in August 2011, some members of the Wakulla Springs Basin Working Group reorganized as the Wakulla Springs Alliance (WSA), a group of scientists and advocates with deep interest in the future of Wakulla Spring. The WSA is the principal citizens group actively promoting and advocating for the restoration and protection of Wakulla Spring.

The full restoration plan and this executive summary were prepared by FSI with review by members of the WSA and the Friends of Wakulla Springs State Park, and represents another step in a continuing journey to eventual recovery and protection of Wakulla Spring. It should not be construed to be the final word of the authors or members of the Wakulla Springs Alliance on any of these complex issues.

Partial funding for development of the Wakulla Spring Restoration Plan and Executive Summary was provided by Wildlife Foundation of Florida, Protect Florida Springs Tag Grant PFS 1314-09.

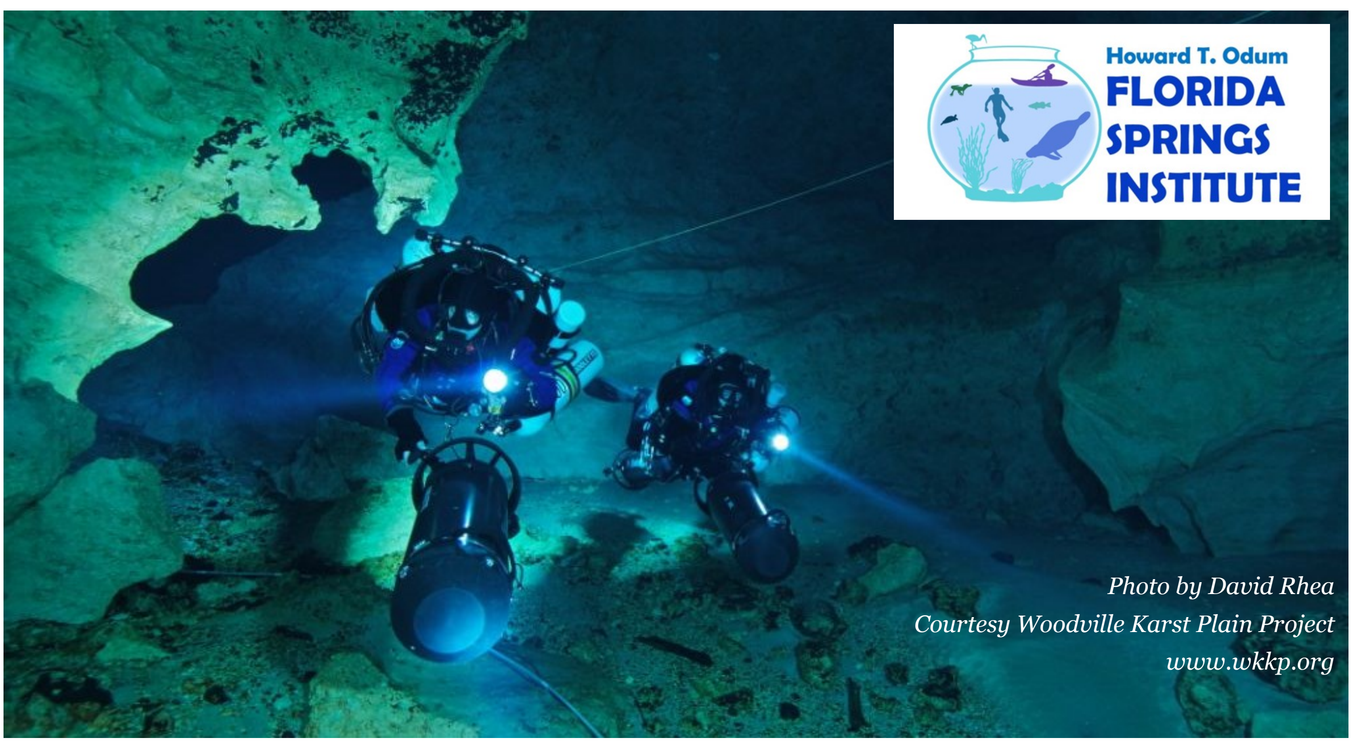


Photo by David Rhea
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