Weeki Wachee Springs

Analysis and Restoration Proposal

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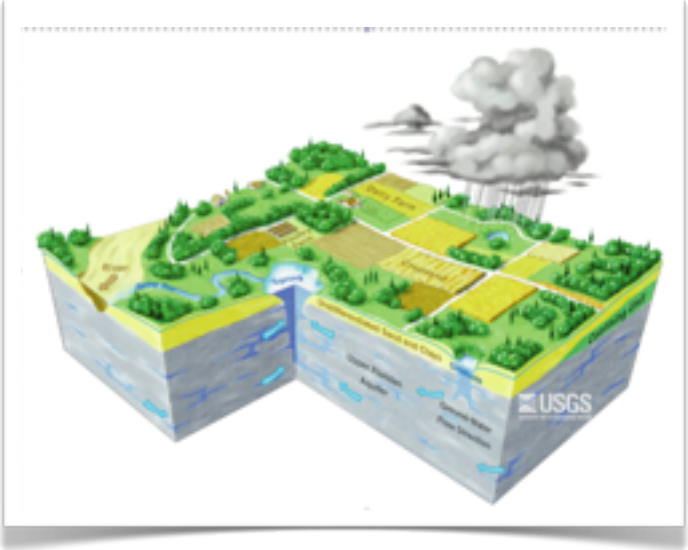
Springs of Florida

"Each spring is different from all the others; but in the intensity of its grace and color each is a jewel in which geology and biology have created a masterpiece of natural art."
Archie Carr

Even if you have never visited a spring in Florida, you have a vested interest in their health. "With over 600 freshwater springs, Florida is blessed with perhaps the largest concentration of these natural features in the world. Springs are intricately woven into the fabric of Florida's history. For thousands of years, humans have been drawn to their crystalline waters, as rich archeological remnants scattered on their banks attest." (DEP/DCA, 2002) Water flowing up through a spring head presents an opportunity to gather first hand information on water quality in the aquifers upon which people who live in and visit Florida depend.

Life in Florida is unimaginable without the collected water resident in the Floridan aquifer which provides drinking water for a large portion of the state. Already water shortages seem to be increasing. Further degradation and reduction of this resource could make continued existence in Florida unimaginable as well.

The large aquifer system of Florida lies below a highly permeable karst layer formed by dissolution and deposition of the underlying carbonate rock (Floridian aquifer) by fluctuating sea levels. This "swiss cheese" rock formation allows water to enter the aquifer, and also allows the aquifer to flow in a complex maze below the ground. The water that enters the aquifer carries with it a history of the surface activities and the porous, swift moving aquifer offers very little filtration to remove pollutants. Petroleum that washes off roads, fertilizers from lawns and crops, herbicides used by backyard gardeners, pesticides used for insect control, nutrients from wastewater treatment plants are transported to the aquifer by the water that recharges it.



The Spring and its history

Historically Springs have played a major role in Florida, from a source of drinking water and food source for early inhabitants to a source of recreation and entertainment for more recent visitors and residents. With the additional benefit of a convenient connection to the Gulf of Mexico, this spring was a focal point for the native indians who called it weekiwachee, or little spring/winding river.

The Weeki Wachee Spring System (WWSS) is located on the Springs Coast of Florida. (Appendix A)The spring pool is approximately 200 ft in diameter and is 45 ft. deep over the vent. Water temperature is 72 degrees. It originates in a relic dune system (Weeki Wachee Dune Field), transitions in to hardwood swamp and ultimately becomes coastal marsh. The spring pool, in Hernando County, is 7 miles from the Gulf of Mexico as the crow files, although a trip on the twisting spring run and river will result in something closer to a 12 mile cruise (www.weekiwachee.com) . Riparian vegetation consists of both upland and wetland vegetation, resulting in a very high species diversity. The upper portion of the spring run remains in a more natural condition, while the lower reaches of the river, closer to the coast, are highly developed.

In 1946 Newton Perry, a former Navy SEAL purchased the site for a new business. He cleared abandoned cars and rusted refrigerators from the spring and developed underwater breathing hoses that allowed the mermaids to have the appearance of thriving underwater. In 1947 the first mermaid show captured the public's imagination and created a new tourist destination. In 1959 the spring was purchased by the American Broadcasting Company (ABC) who enlarged the 7 seat underwater theater to a 500 seat facility embedded in the spring, 16 ft below the surface. They promoted it heavily, purchased elaborate props, developed underwater shows and story lines. In 1982 a water park,

Buccaneer Bay, was added.

In 2001, the SWFWMD took control of the springs and surrounding area. A once booming tourist attraction was now much diminished, no longer drawing the 1 million tourists per year that it had in the 1950's . The WMD continued ownership of the land for the next 7 years, with the attraction under private management.

The State of Florida acquired Weeki Wachee Springs in 2008. The acquisition included the land surrounding the spring for a total of 1,267 acres and a cost of $4,661,999 (FDEP, 2010) The state also acquired the tourist attraction and incorporated it into the State Park System. The park continues the tradition of the underwater mermaid shows, viewed from a below ground observation room (Mermaid Theater) and also has a water park (Buccaneer Bay), tour boats, gift shop and canoe/kayak rentals. Access is restricted in the immediate vicinity of the spring pool, however further down the spring run human/ boater access in unrestricted all the way to the Gulf of Mexico.

The Spring and the Sprinshed

Springs are fed or "recharged" by water that percolates down through the ground and enter the aquifer. Activities on the land above the aquifer have a direct impact on the water quality that is transported through the soil. The land area over which this recharge occurs is termed the springshed, but unlike the watersheds and basins that feed rivers, the boundaries of a spring shed can change over time based on ambient water pressure in the aquifer.. Most recently, these movements in springshed boundaries are attributable to consumptive uses which result in large scale changes in potentiometric - the controlling feature in recharge boundaries. Figure 1 shows a potentiometric map of the Weeki Wachee Springshed produced by the USGS.The the establishment of Minimum Flows and Levels (MFL) for Florida springs generated some of the funding for much needed research into the extent of springsheds and the factors that influence them. The Heyl 2008 report provided this research for the Weeki Wachee system, and resulted in the final recommendation for MFL in the Weeki Wachee River System. Ultimately the report suggests that the WWSS has already reached its minimum acceptable flow level and any further decrease woiuld result in harm to the ecosystem.

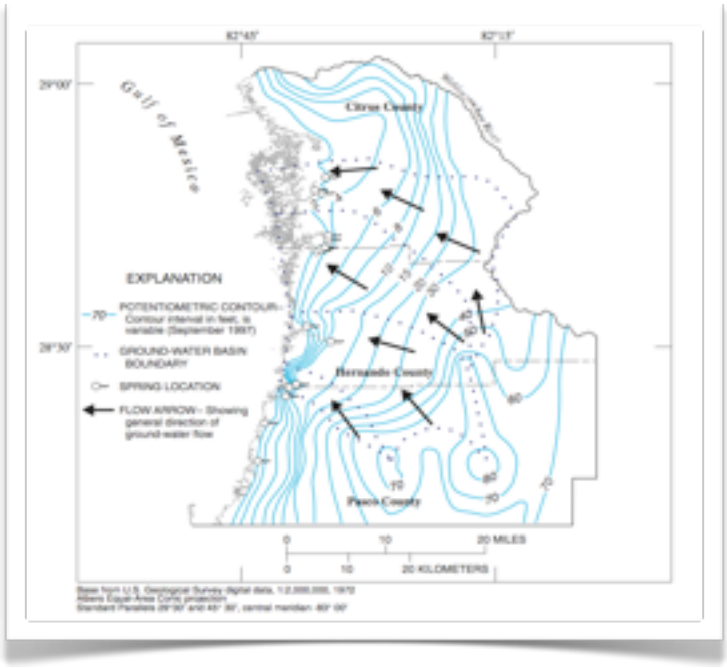


Figure 1. Potentiometric map of the Springs Coast. The WWSS springshed spans portions of Hernando and Pasco Counties. (See figure 2 below)

Weeki Wachee is a first magnitude spring that has an area of nearly 2,000 sq.m., a volume of just under 6,000 cu.m. and a pool discharge of 54.8 MGD. This flow

rate means that the entire volume of the spring pool is turned over every 54 minutes. It should be noted that several smaller springs also contribute brackish water downstream of the main spring and include Twin Dees, Salt and Mud River Springs. (Jones et al, 1997) The substrate of the spring run is predominately sand. The springshed for Weeki Wachee Springs cover 260 sq. mi. and is split between Hernando and Pasco Counties. (see Figure 2).

Figure 2. Green line denotes the boundary for the 260 sq. mi. WWSS sprpingshed (D. Witt, SWFWMD)

An analysis of the land use for the springshed found that upland and wetland forests along with non-forested wetlands account for 41% of the landmass. Urbanized areas represent 27% of the land use, and agriculture makes up 29% (see figure 3).

Springshed Land Use -1999		
	acres	Percent
Citrus	1,779	1%
Mines	415	0%
Nonforested Wetlands	12,234	7%
Other Agriculture	45,342	27%
Rangeland	4,041	2%
Upland Forests	43,004	26%
Urban	44,693	27%
Water	3,564	2%
Wetland Forests	13,223	8%

Figure 3. Land uses for WWSS springshed in 1999. (Frazer, 2006)

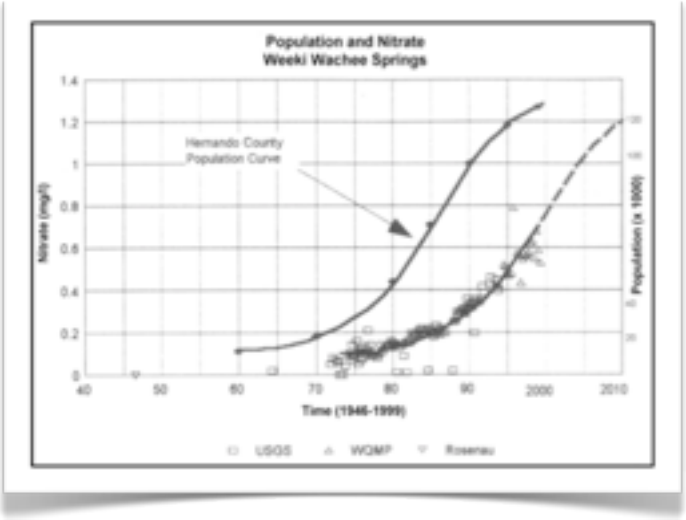
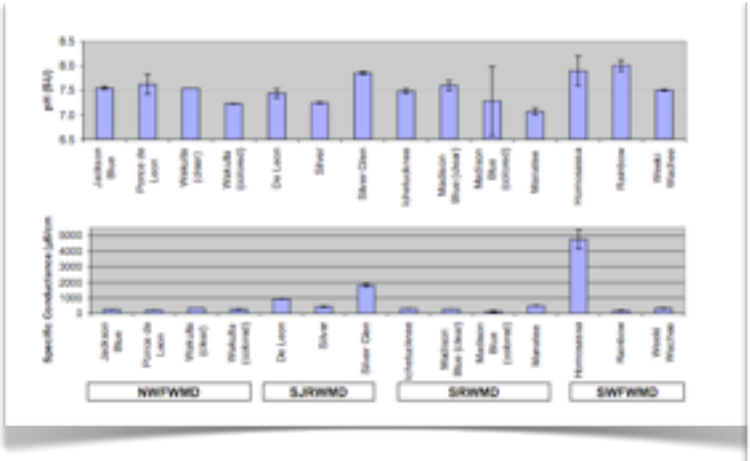


Figure 4. Increased nitrate levels from 1940 - 1999 follow population increases in Hernando county. (DEP/DCA 2002)

Changes in landuse along with increasing population density show a high correlation with declines in the quality of water emerging from a spring. "Numerous studies by FLorida's water management districts and the United States Geological Survey clearly demonstrate contamination attributable to changes in land use in springsheds." (DEP/DCA, 2002) It is this relationship, the specific activities that cause this shift within the springshed and opportunities to improve water quality in Weeki Wachee springs that will be explored in the subsequent sections of this report

Current water quality

Many factors are considered when determining the health and function of a spring system, including nutrient enrichment, gross and net productivity, water clarity, spring discharge, dissolved oxygen content and more. As awareness of the change in groundwater quality has grown, more in-depth studies have been commissioned. One common thread echoed in the conclusions of each of these analyses is the correlation between increased population density and increased nutrients, specifically nitrates.



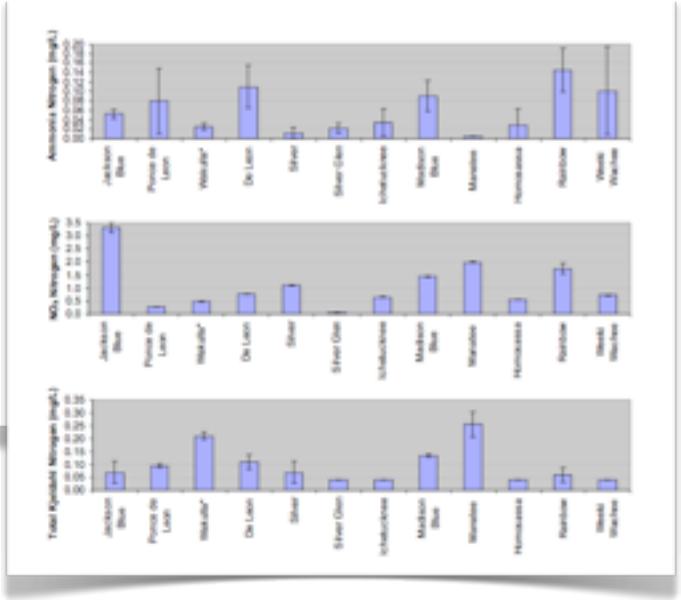


Figure 5. (above) A comparison of pH and Specific conductance levels in 12 springs (WSI 2010)
Figure 6. (right) A comparison of nitrate and ammonia levels in 12 springs. (WSI, 2010)

Studies have been conducted comparing the health of various springs. A synopsis of 12 Florida springs - including Weeki Wachee Springs - is presented in the Wetlands Solutions, Inc 2010 report. Taking this comparative view, Weeki Wachee stacks up well against the other 11 springs. It boasts excellent water clarity as measured by PAR and secchi disc distances. The WWS is in the Average - above average range for nitrites, total nitrogen and in the average - low range for pH,, specific conductance, chlorides and phosphates.
The spring shows comparatively low readings for dissolved oxygen and high readings for ammonia (with a noted high standard deviation) See figures5 and 6. The ammonia levels that appear high in comparison with other springs are considered to be below any major impact threshold and are generally discounted in analyses that have been conducted on the WWSS. Low dissolved oxygen levels may be an indication that an older water source is contributing to the flows and recharge is occurring slowly. The oxygen levels rise rapidly with downstream distance from the springhead as a result of oxygen diffusion and SAV productivity.(Frazer 2001)
Finally the head spring's discharge rate has decreased 8% since 1961. (Heyl, 2008; Frazer,2006)

The Indicators

Sometimes average is just not good enough, and that is the case with the NOx and pH levels reported above. While it is true that nitrogen levels are average for present day springs (Figure 6) they are substantially above historic levels of 0.05 mg/l. Significantly, levels of NOx-N that were measured in 1970 at 0.113mg/L grew to 0.765 mg/L in 2000. A 76% increase in nitrates was observed between a 1998 - 2000 sampling period and a subsequent 2003-2005 study. (Figure 7) Frazer, 2006) Nitrate levels are currently 7 times the levels measured in 1970 and 15 times higher than they were just 50 years ago. This change tracks well with the six-fold increase in populations living in the Hernando County portion of the Weeki Wachee Springshed from 1946 - 1999. (figure 4) The effect of this change can be witnessed in the flora and fauna that dominate the Weeki Wachee springs systems today. Native vegetation can become stressed as nitrates increase well above the normal range. Filamentous algae have taken hold, out competing the vascular plants that had evolved in the spring system. Additionally increased nitrate levels cause the increased growth of periphyton on the remaining natural vegetation and inhibit subsequent growth - a classic indication of a transition to eutrophication. (Frazier, 2006). These changes make the springs environment less hospitable for fish, snails, crayfish, turtles and other animals that depend on this habitat, (Harrington et al 2008) Increased phosphorus levels are troubling as well. Although much less attention has been paid to phosphorus levels in the past, more recent work indicates the potential that phosphorus is a limiting factor for algal growth. Phosphorus levels in the Weeki Wachee spring complex have risen 21% since 1998.

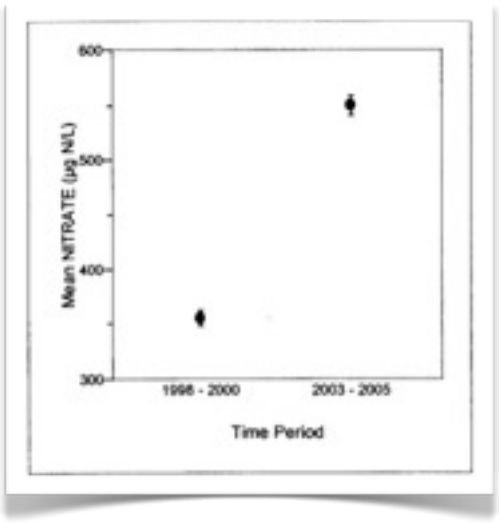


Figure 7. Changes in mean nitrate levels for WWSS (Frazer, 2006)

The pH values appear average for springs in general, however they represents a marked decline over time (Figure 8). A continued move toward acidity will serve to further unbalance the native ecosystem. An imbalance in water chemistry will

increase stress on the flora and fauna. The increased stress will decrease the resiliency of the springs population and result in continued loss of native species. Crowell and Botts (1994) observed that conductivity and alkalinity and conductivity were the best predictors of algal abundance. Brown et al. 2008 note the need for additional research in this area.

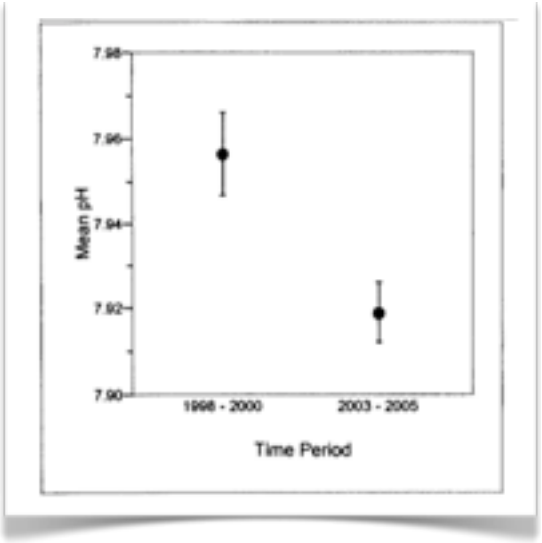


Figure 8. Decline in pH levels measures in the WWSS, Frazer, 2006)

Declines in submerged aquatic vegetation (SAV) have followed the increasing levels of nutrients and general change in water chemistry. Overall, Weeki Wachee has seen a 75% reduction in SAV since the mid-1900's (Frazier, 2006).

Figure 9. Change in species composition within the WWSS (Frazer, 2006)

Species	1998 – 2000 Frequency of Occurrence (%)	2003 – 2005 Frequency of Occurrence (%)	Percentage Change
Chara sp.	0.3	8.3	2400
Filamentous algae	59.3	52.3	-12
Hydrilla verticillata	46.7	31.7	-32
Najas guadalupensis	39.0	40.7	4
None	16.7	26.0	56
Ruppia maritima	0.0	0.3	100
Sagittaria kurziana	9.7	5.3	-45
Vallisneria americana	9.0	8.0	-11

There is also a marked change in SAV composition as a transition occurs from native vascular species such as Sagittaria and vallisneria to algae such as chara and invasive species such as hydrilla. (Figures 9 and 10)

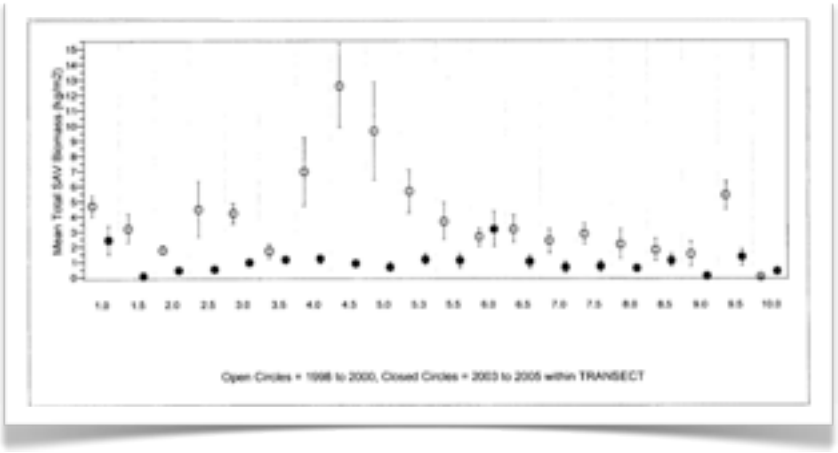


Figure 10. General decline in SAV with time, plotted as distance from spring head. (Frazer, 2006)

Observed reduction in discharge rate has roots in climatic fluctuations as well as human intervention. Analysis has shown that rainfall is positively related to discharge rates with a 1 year lag (Figure11). At the same time, development in the springshed has flourished and with it, groundwater pumping has increased. (Figure 12) Statistical evaluations and modeling have confirmed that groundwater withdrawals are resulting in reduced discharge rates at Weeki

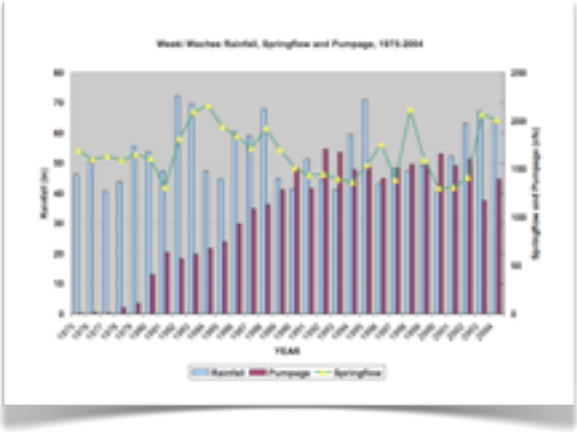


Figure 11

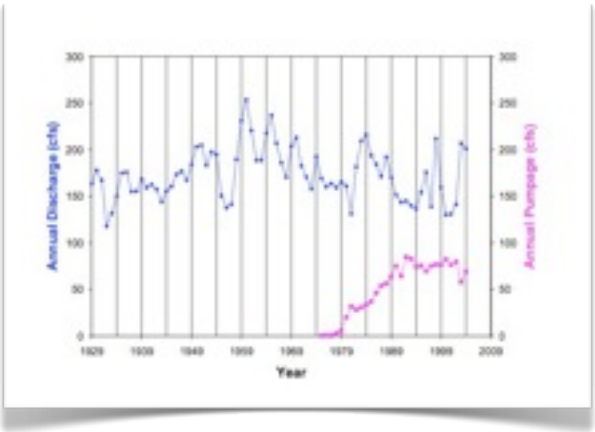


Figure 12

Wachee Spring.(Heyl 2008). Heyl, 2008 notes that statistical evaluations and modeling have confirmed that groundwater withdrawals are correlated with reduced discharge rates at Weeki Wachee Spring., however Knochenmus and Yobbi, 2001 state that ground water withdrawal rates show no discernible affect on spring flows. Disagreement is also voiced in the peer review section of the MFL which states:

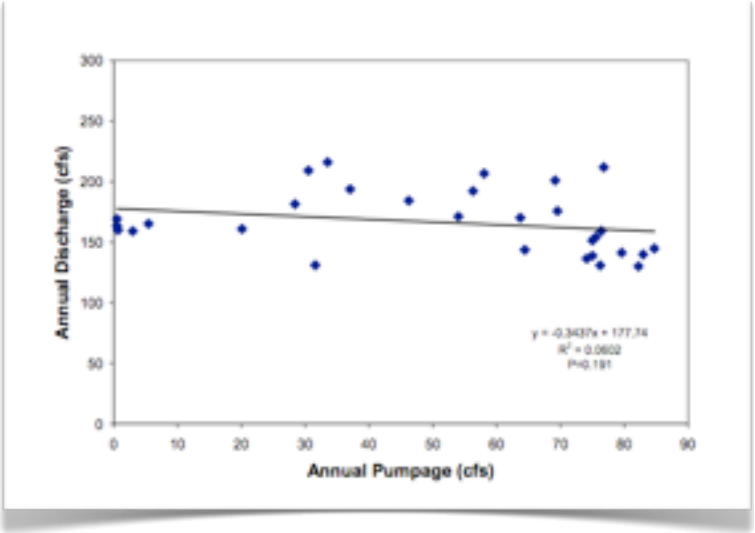


Figure 13

"Further, the District's MFL report states that 'Annual pumpage was compared

with annual spring discharge and a significant inverse relationship was found.' However, a graphical analysis of the data prepared by the Panel did not confirm this" (Figure 13) The panel explained that the MFL was based on a 38 sq.mi. drainage basin wholly contained in Hernando County. The springshed for Weeki Wachee is much larger (260 sq.mi.) and spans both Hernando and Pasco County. In fact, the largest wells that account for the majority of water withdrawn are in Pasco County. Obviously more study is needed to resolve this issue.

Restoration Activities:

Weeki Wachee Headspring Before Project Implementation

Figure 14

Weeki Wachee Headspring after Project Implementation

Figure 15

Florida Water Management District has been busy since acquisition of the park in 2001, setting restoration activities in motion. The District knew that sand, silt and muck had accumulated in the headspring. They also knew that nuisance algae was proliferating, and that all of this was happening as results of runoff and erosion.

First the SWFWMD analyzed runoff coming from the facility itself and constructed two new stormwater ponds to increase pollutant removal.

Next the sediment removal element was implemented. Estimates placed the volume of Lyngbya (a cyanobacteria) to be removed at just over 1,000 cy and the volume of uncompressed sediments and organic matter at 5,000 cy. Over 6,000 cy was removed from an area encompassing the spring vent and the Park's boat dock. Divers removed the material using hand vacuums designed specifically for this project (Figures 14 and 15) and a marked improvement was evident immediately. Subsequent to dredging, and work to remove invasive riparian vegetation (St. Petersburg Times 5/12/2009) over 100,000 eel grass plants and 6,400 native riparian plants were installed. The total cost of the project was approximately $650,000 which was provided by the state's Water Management Lands Trust Fund.

The SWFWMD is looking at this restoration project as a prototype for restoration actives in the future. In depth monitoring will be conducted to document success and challenges. Lessons learned from this project will be applied to the upcoming Chassahowitzka Spring restoration project.

Opportunities and Recommendations:

The foregoing discussion certainly gives reason for concern, but also calls for further scientific investigation to more fully understand the complicated relationships between the many factors presented here. Additionally, the concern should be used as a catalyst for outreach, education and positive actions. In general, efforts should be made to implement strategies provided in "Protecting Florida's Springs: An Implementation Guidebook". Recommendations moving from the general to those specifically geared to the WWSS are provided below.

- In 2006, the Florida Springs Task Force noted that the "major issues impacting springs include population growth, urban sprawl, growing demand for ground water and introduction of fertilizers, pesticides, and other pollutants in sprinsheds". It is important to support funding/sources for Florida Springs Initiative to continue overall education and outreach. Their work, in cooperation with local WWSS support groups can help to foster increased awareness and appreciation of the springs ecosystem and result in voluntary support instead of enforcement of regulations. Target audiences for this work include the general public, elected officials, groundskeepers (residential, commercial, golf course), school teachers and their students, and visitors to the area.

- Ongoing efforts of the SWFWMD should be supported, and partnerships should be explored to increase protection efforts specifically for he WWSS. The agency should function as a data clearinghouse, actively searching out existing data sets, vetting them, and incorporating them in to a GIS database.

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- Additionally, overall water conservation efforts by SWFWMD in their Water Supply Plans should be embraced by WWSS supporters as this will result in less water withdrawn from the aquifer. It will also result in less polluted water being re-introduced into the system. However, SWFWMD should reconsider the

separation of Hernando and Pasco Counties into separate water supply planning regions.

- Funding for current programs should be maintained, and increased where possible. The florida SpringsInitiative has monitored water quality in springs, including Weeki Wachee Springs on a quarterly basis, beginning in 2001. Discharge readings have been added more recently and should be continued.

- Tampa Bay should be encouraged to follow through with the required water wellfield reduction as part of the Northern Tampa wellfield recovery plan. Heyl, 2008 showed that the proposed changes could result in the restoration of up to 50% of the noted discharge reductions.

- Funding, in all areas, will continue to be a major obstacle for the foreseeable future. Public/private partnerships, volunteer groups, alliances with other related environmental groups, car washes and bake sales (no stone left unturned) should be investigated.

- Using the general boundaries of the springshed, a Weeki Wachee Management District should be established and include decision makers from both Hernando and Pasco Counties with an advisory council comprised of local experts, NGO's and stakeholder groups. Ideally, this would be done as a formal political subdivision, but even an informal group would be helpful. This group would focus on remedies for the spring system, absent the political line that divides the springshed. Inter-county task forces could be established to focus on specific issues, and public

- The majority of improved land use in the WWSS is from urban development. Building on the work of the Florida Yards program (figure ____) a fertilizer awareness programs and restrictions on fertilizer composition should be implemented. The Lee County ordinance on fertilizer sales could be used as a starting point. Additionally, outreach activities emphasizing the importance of slow growth and controlled growth should be implemented with all types of clubs, organizations or groups. A grassroots approach will give elected officials cover when called on to make difficult decisions in the face of well financed developers.

- The fertilizer initiative also must reach out to manufacturers of fertilizer to increase the efficiency of their product and thereby reduce the overall volume of fertilizer applied each year.

- A golf course management certification should be established. Managers and groundskeepers should, at a minimum be required to read the Golf Course siting, design and management section of "Protecting Florida's Springs - Landuse planning strategies and best management practices". Certification would be based on the applicant's ability to demonstrate a high level of understanding and ability to implement this information in their day to day practices. A program like DEP's "Clean Marinas" of the Audubon "international Signature Program" could be established to certify a golf course is "Florida Spring Friendly".

- Public education efforts should also include a primer of political/legislative avenues to protect springs. A mailing list can alert interested parties when important legislation or policy is up for discussion. Links to email addresses for elected officials and agency officials should be provided. Local action such as monitoring County governments when Comprehensive Plan review is ongoing should be explained.

- The importance of the WWSS ecology should be incorporated into the public education system. Field trips and age appropriate projects can make up elements of each grade's curriculum. Hands on experience at an early age will spill over into community action now and in the future.

- The 2008 Final Recommendation for MFL on the Weeki Wachee system noted inconsistencies in data and analysis for reduced flows and consumptive uses (also noted in Knochenmus and Yobbi, 2001). The uncertainty is increased as consumptive use was analyzed in only 1 of the 2 counties that comprise the WWSS springshed. In that analysis, only rainfall fluctuations provided any predictive capability for flow reduction. At best, the analysis of consumptive uses showed a correlation but could not be used as a predictive tool. Solid policy can not be grounded on such flimsy evidence. Based on these facts:

1. Further and more comprehensive studies should be conducted on actual consumption of water within the springshed, and this should be shown in contrast to the more general category of consumptive use permits. (Knochenmus and Yobbi state that little if any of the ground water pumped from the Coastal Springs Groundwater Basin is exported from the area.)
2. Water quality data collection must continue. Confirmation is needed for statements like that made in a 2008 letter from Mary Ann Pool, Director, Office of Policy and Stakeholder Coordination for Florida Fish and Wildlife Conservation Commission: that the proposed MFL 10% reduction in baseline flow of Weeki Wachee River system "has already largely occurred and represents the current system."
3. The salinity envelope must be carefully monitored, especially during low flow periods. Currently the nitrogen load is lost by the time the spring water enters the Gulf waters. Phosphorus, the limiting factor, typically <0.01 ppm in the spring run is in abundant supply in the marine water. Encroachment of marine water into the WWRS would supply the missing phosphorus and result in increased phytoplankton biomass and eventual eutrophication of tidal river segments.
4. Perhaps a public partnership could be established with members of the public adopting an section of the spring/river and collect water samples on a regular basis and delivered to a central location for analysis. Updated results from the volunteer monitoring effort could be displayed on a website designed to be user friendly, and offering more "springs friendly" advice.

- Public education on the legacy of the stormwater that runs off of impermeable surfaces must be increased. Rooftops, roads, parking lots, driveways and sidewalks are things that most people don't give a second thought to, however their impact on the water supply can be substantial. Greater awareness on the impact these features have should facilitate better planning and public acceptance of alternative solutions that incorporate landscape infiltration, permeable surfaces and other innovative solutions that increase the filtration and purification of stormwater runoff.

- Land acquisition and conservation easements are always in the toolbox, however with dwindling budgets they may not be the most viable strategies. Potential land acquisitions should be prioritized by establishing a series of "impact zones" in the springshed. Areas with the most direct recharge value should be a higher priority that land that is on the fringe or is otherwise less influential on recharge water quality.

- Work with the Park Service to step up visitor education on the impacts of "loving our springs to death". These types of efforts have been very successful in protecting coral reefs in our offshore waters, and should be easily adapted to this case. A program with local hotels, campgrounds, restaurants, dive shops, kayak/canoe rentals and other focal points of the community could be developed. Brochures and table top displays could be designed and distributed to the member groups, and informational kiosks should be set up at the parks.

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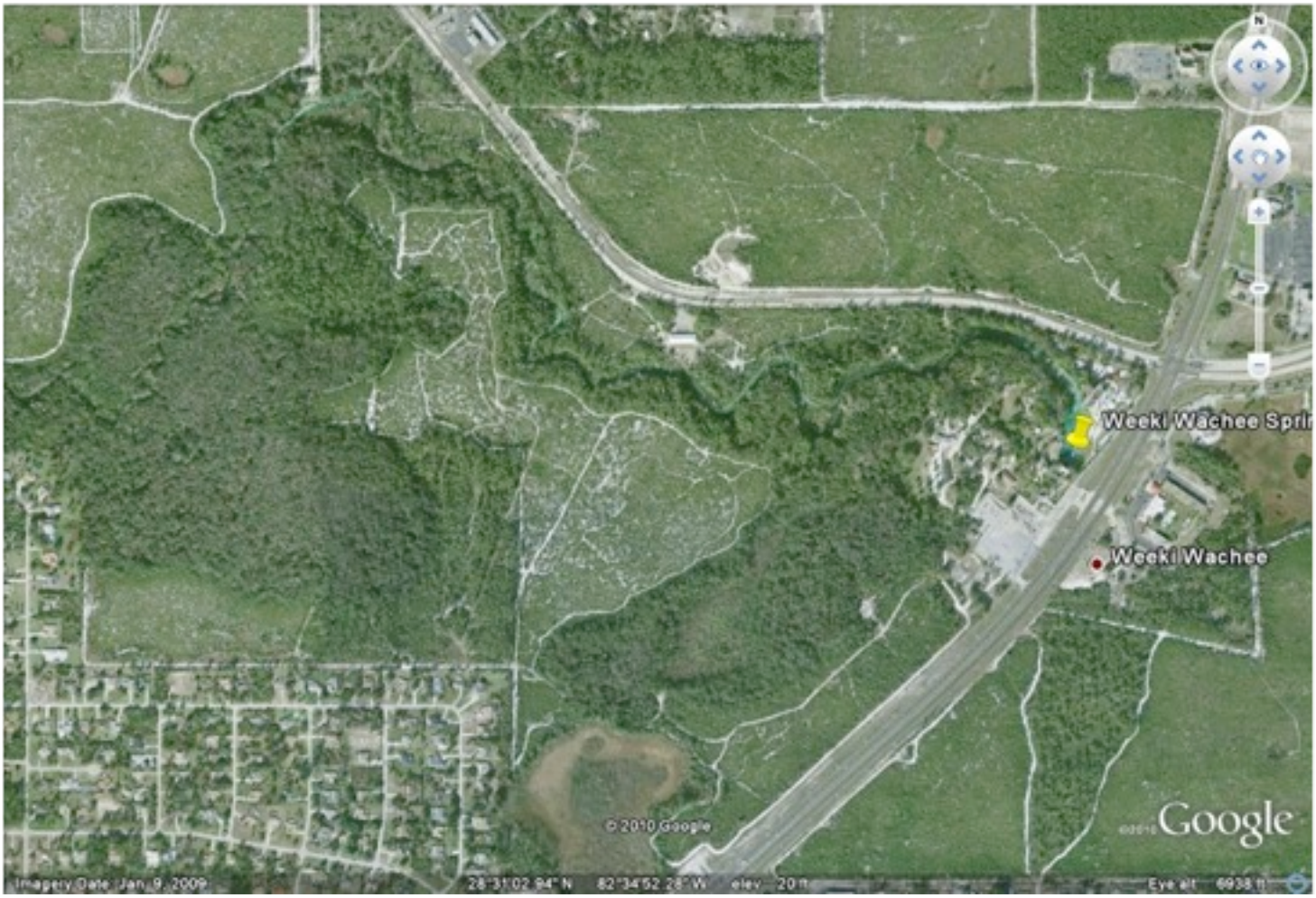
www.floridayards.org
www.weekiwachee.com

Appendix A

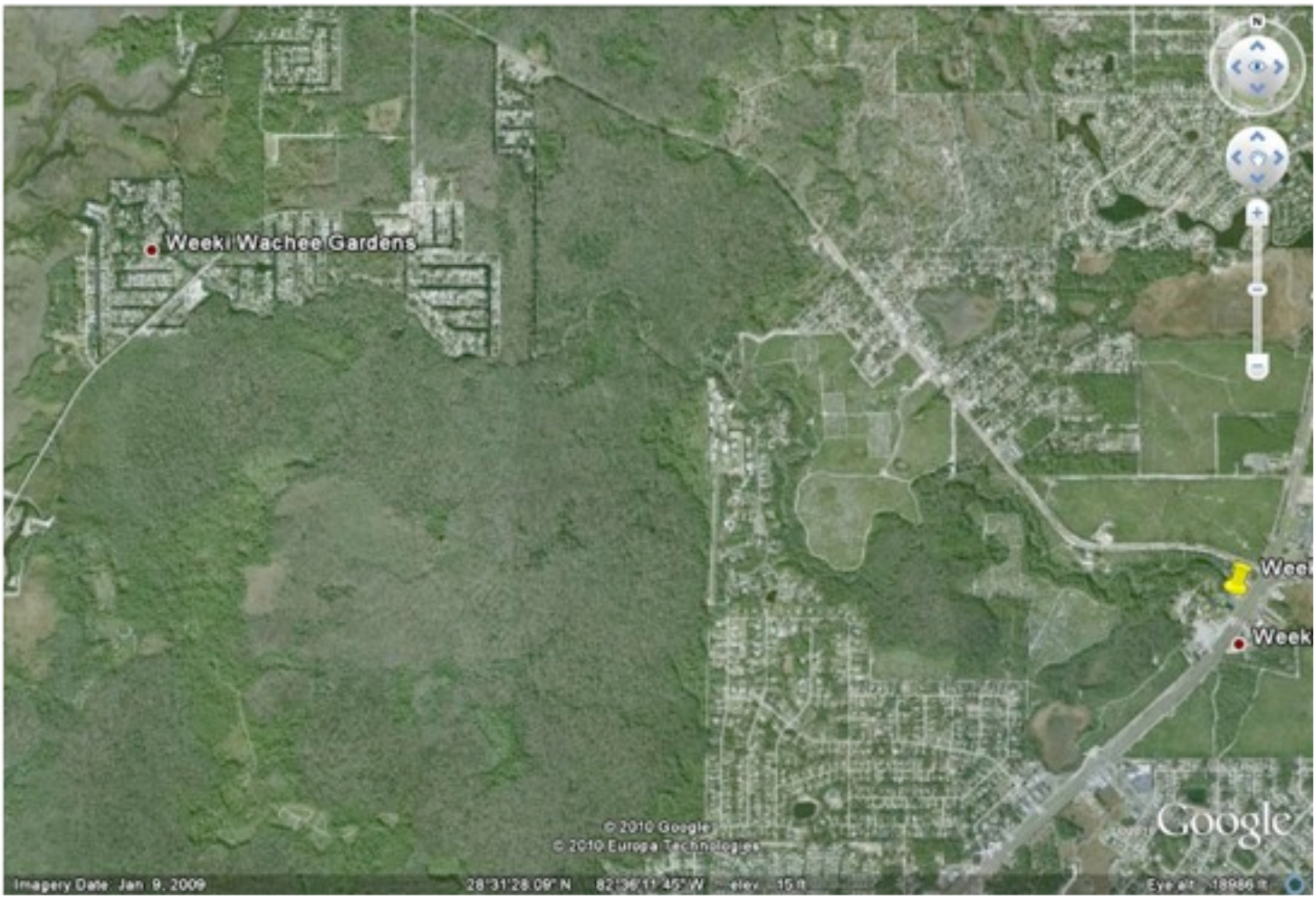
Maps
of
Weeki Wachee Springs
and
Weeki Wachee River

Weeki Wachee Springs Complex

Weeki Wachee Springs and upper springs run



Weeki Wachee Springs and Weeki Wachee River



Weeki Wachee Springs Location Map