# Hydrogeology Consortium

*"…to cooperatively provide scientific knowledge of ground and surface water resources and advocate for the effective application of that knowledge toward management, conservation and protection."*



# Wakulla Springs Alliance

## Revised October 6, 2013

### Safeguarding the Wakulla Spring/Spring Creek System

The *Wakulla Springs Alliance* works in partnership with other public and private organizations to protect and improve the Wakulla Spring/Spring Creek system. Wakulla Spring (and Spring Creek to which it is connected) is one of the largest spring systems in the world. That complex system deserves the highest level of protection. That is achievable only if we understand the springs and river better from a scientific standpoint. It also means careful monitoring of possibly harmful changes. This paper lays out how the *Wakulla Springs Alliance* will assist in those efforts.

Wakulla Spring has a long-term average flow of over 300 million gallons each day. In light of recent reductions in flow at Silver Springs, Wakulla may now have the largest average flow of any spring in Florida. It is one of Florida's finest state parks, attracting up to 200,000 visitors a year. Renowned for extremely clear water, the river water is now frequently so murky that glass bottom boat tours cannot be scheduled. Wakulla Springs State Park generates an annual employee payroll of $1.8 million and has a total local economic impact of $22 million per year. It is one of the premiere wildlife observation areas in the state. In recent winters, the park has attracted up to 75 manatees seeking warm water refuge. Wakulla Spring is the reason for Wakulla Spring State Park but the nine-mile long Wakulla River extends several miles past park boundaries to the Gulf of Mexico. The river supports fresh water fisheries and significant estuarine resources.

Wakulla Spring has a very remarkable direct connection with the Spring Creek springs that discharge into the Oyster Bay in the Gulf of Mexico. At times, Spring Creek springs have a flow several times that of Wakulla but in recent times the springs are reversing flow. The recent flow reversals have resulted in saltwater intrusion to the Floridan aquifer that extends for at least three miles inland from Oyster Bay and influences both water color and the volume of flow in Wakulla Spring. The connection between Wakulla and Spring Creek springs is known to be a network of long underwater caves that extend from near the Leon/Wakulla County border to Spring Creek and connect to multiple springs in

between including: Indian, Sally Ward, Wakulla, and Spring Creek. No other set of large springs in the world is known to have this extraordinary degree of interdependence.

The ecology and health of Wakulla River is in trouble. Part of this is due to 460 tons of nitrates that flow daily from the massive spring vent. The majority of the nitrate flowing to the spring originates from wastewater and stormwater discharges in Leon and Wakulla counties. City of Tallahassee wastewater operations have been the largest single contributor of the excessive quantities of nitrate nutrients. Fortunately, city leaders decided to spend $227 million to upgrade their wastewater treatment plant to advanced standards with nitrogen removal. Other local governments, including Leon and Wakulla counties, are also undertaking at least limited efforts to reduce nutrient inputs to Wakulla Springs from septic tanks and stormwater runoff. These efforts will augment and enhance the Basin Management Action Plan (BMAP) that is currently being developed for the Wakulla Springs basin.

Another part of the problem is a demonstrable reduction in flow to the Spring Creek springs that is causing an increase in flow of darker colored water to Wakulla Spring and saltwater intrusion to the Floridan aquifer through the cave system that connects the two springs. The ecologies of these two spring systems are therefore impacted by the reduction in flow to Spring Creek: one by the transformation of freshwater and brackish water systems into saltwater systems, and the other by the transformation of periodically clear water to permanently dark water conditions. These issues will hopefully be addressed as part of the effort to establish Minimum Flow and Level criteria (MFLs) for Wakulla Spring and the Wakulla River.

The ecological health of the springs and river is of regional importance because of the influence of this large volume of water on local estuaries and the Gulf of Mexico, all of which affect Wakulla County. A comprehensive ecological assessment and monitoring effort is necessary to document the current health of the spring system. It is not possible to protect the Wakulla/Spring Creek system if we do not understand the state of that system, its ecological drivers, and the major threats to system health. This research is essential to measure ecological changes and to guide management restoration efforts. Wakulla Springs monitoring needs to be reinvigorated and expanded to include the Spring Creek and the St. Marks Systems. The activities included in this proposal will expand and enhance the development of the St. Marks Rise and Wakulla Springs MFLs. All biological, hydrologic and water quality data will meet federal and state regulatory standards for inclusion in TMDL and MFL programs.

## Total Maximum Daily Load Program (TMDL)

The Total Maximum Daily Load Program (TMDL) is a watershed management approach for restoring and protecting state waters and addressing TMDL Program requirements. The watershed approach, which was implemented using a cyclical management process cycling through the state's 52 river basins, in 5-year cycles, is the framework of the TMDL Program, a requirement of the 1972 Federal Clean Water Act and the 1999 Florida Watershed Restoration Act (FWRA) (Chapter 99-223, Laws of Florida).

The TMDL represents the maximum amount of a given pollutant that a waterbody can assimilate and still meet water quality standards, appropriate for its designated usage. Elevated nitrate concentrations, in the spring water, were found to be the cause of impairment, or an imbalance in biological integrity and a failure to meet its designated use. A TMDL was issued by FDEP for Wakulla Springs, the Final Nutrient (Biology) TMDL for the Upper Wakulla River (WBID 1006), by Douglas Gilbert, Watershed Evaluation and TMDL Section, FDEP, March 22, 2012. This TMDL mandated a percent load reduction to achieve a monthly average nitrate concentration of less than or equal to 0.35 mg/L. This represents a 56.2% reduction in the current nitrate concentration in the water. The removal of this much nitrogen from the spring will be attempted with a $227 million upgrade the City of Tallahassee's

Wastewater Treatment Plant, which is located in the heart of the springshed, to Advanced Wastewater Treatment (AWT) with nitrogen removal. This TMDL Report is currently followed by the development and implementation of a Basin Management Action Plan, or BMAP, to ensure the reduction of nutrients necessary to reverse the verified impairment of the Upper Wakulla River. These activities will depend heavily on the active participation of the NWFWMD, local governments, businesses, and other stakeholders, like the Wakulla Springs Alliance who have prepared this monitoring plan to augment and enhance the BMAP monitoring plan without performing duplication or replication but to extend the BMAP monitoring plan, which is limited to WBID 1006, and will extend to the lower Wakulla River, the St. Marks River, into which the Wakulla flows, and Spring Creek, to which it is linked by underground caverns. The Wakulla Springs Alliance will work with FDEP, NWFWMD and other organizations and individuals to undertake or continue reductions in the discharge of pollutants and achieve the biological integrity in the Wakulla Springs System.

## Minimum Flows and Levels Assessment

State law (Section 373.042, Florida Statutes; hereafter F.S.) directs the Department of Environmental Protection or the Water Management Districts to establish minimum flows and levels for lakes, wetlands, rivers and aquifers. The Wakulla Springs system with its dramatic flow fluctuations and reversal (mostly in the Spring Creek vents) needs to be a top priority for MFL determination. As currently defined by statute, the minimum flow for a given watercourse, "shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area," and the minimum level of an aquifer or surface water body is, "the level of groundwater in the aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area." Minimum flows and levels are established and used for water resource planning, as one of the criteria used for evaluating water use permit applications, and for the design, construction and operation of surface water management systems. An adequate Wakulla/Spring Creek ecological assessment program would have to gather and interpret data on all of the “water resource values” that must be considered in establishing a minimum flow and level:

> 62-40.473 Minimum Flows and Levels.
>
> (1) In establishing minimum flows and levels pursuant to Sections 373.042 and 373.0421, F.S., consideration shall be given to natural seasonal fluctuations in water flows or levels, nonconsumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology, including:
>
> (a) Recreation in and on the water;
>
> (b) Fish and wildlife habitats and the passage of fish;
>
> (c) Estuarine resources;
>
> (d) Transfer of detrital material;
>
> (e) Maintenance of freshwater storage and supply;
>
> (f) Aesthetic and scenic attributes;
>
> (g) Filtration and absorption of nutrients and other pollutants;
>
> (h) Sediment loads;
>
> (i) Water quality; and
>
> (j) Navigation.

One of the critical water resource values at Wakulla Spring will be sufficient water clarity to support seasonal operation of the glass bottom boats. This value is currently threatened due to the relative increase in dark water flow to the spring. Re-establishing and maintaining this value will therefore depend on developing and monitoring the balance of dark and clear water flows to the spring. The groundwater flow monitoring stations described in #6 above are designed, in part, to establish and monitor this balance of flows. The NWFWMD estimates that the annual cost of developing MFLs for the St. Marks River to be approximately $365,000. The cost of developing MFLs for Wakulla Spring and River will be defined by the District's final scope of work but are likely to be similar.

## Studying the Effects of Ongoing Reductions in Nutrients

In addition to supporting the BMAP and MFL efforts, there is presently a unique opportunity at hand to understand and document the impact of substantial improvements in wastewater treatment and disposal engaged by the City of Tallahassee on the ecological health of Wakulla Springs. A large-scale experimental platform for documenting the effects of nitrate reductions on springs impairment and ecological health is currently available at Wakulla Springs. There is no other spring in Florida that will experience the magnitude of nitrate concentration reduction that Wakulla will see in the next decade. This nitrate reduction will be the result of the City of Tallahassee's nitrogen reduction project at their Tram Road Facility. This large expenditure of public funds is very commendable. Without a scientifically sound data collection and assessment effort before, during, and after the City's nitrogen reduction project is complete, the opportunity to assess the benefits of the City's upgrades will be lost. This chance for advancing the knowledge necessary for more effective management of other springs will not be repeated in the near future.

The *Wakulla Springs Alliance*, in cooperation with the Florida Springs Institute, proposes the formation of a collaborative team to fully fund and conduct a comprehensive research protocol to evaluate the effects of nitrate reduction on the ecology of Wakulla Springs. Key collaborators would include the City of Tallahassee, Leon and Wakulla counties, FDEP, the NWFWMD, USGS, and FSU. We would gain verification of the success of the nitrate reduction because of the Florida Department of Environmental Protection's TMDL/BMAP process. Not only could we verify the success of this process but we would be able to apply that knowledge to the large number of other impaired springs statewide. The District would acquire essential information concerning the importance of spring flows on the ecological health of Wakulla Spring and River. The public would have the assurance that our state's water managers are effectively managing and protecting these priceless water bodies.

The proposed study needs to be comprehensive, both in terms of duration and in terms of monitored parameters. Simply measuring water quality and flow at Wakulla Springs (the only parameters currently measured) will not provide verification that reduced nitrate concentrations and loads are actually benefiting the ecology of Wakulla Spring. An ecosystem-level study that includes measurement of physical, chemical, and biological parameters, and integrates those data into an understanding of the overall ecosystem response will be needed to benefit from this large-scale experiment. This study should be conducted over a period of ten or more years to encompass a baseline period, a period of ecosystem transition/adaptation to the new nitrate concentration, and a stable post-project period.

Time is running out and data collection is needed as the nitrate reduction affects the springs. The Wakulla Spring Working Group and the Wakulla Spring Adaptive Management Strategy already laid out an outline of a comprehensive Wakulla monitoring protocol. This monitoring is coordinated with the BMAP and MFL efforts by FDEP and the NWFWMD. We may wish to request targeted funding from Wakulla County's share of the BP oil spill settlement. Funding of this project would be a wise move to help preserve and protect Wakulla Springs for future generations.

# The Wakulla Springs Alliance Proposal

The *Wakulla Springs Alliance*, an organization of volunteers dedicated to improving the Wakulla/Spring Creek system, will undertake its own projects to better understand the system and contribute to the effective development and implementation of both the BMAP and the MFLs as well as the documentation of the beneficial impacts of Tallahassee's infrastructural investments. This working draft proposal lays out a comprehensive effort that we believe will be necessary to meet the goals and objectives of these three programs. The scope is well beyond the capacity of the Alliance itself and can therefore only succeed with significant funding and the cooperation of many other entities. Your suggestions for improving this working draft proposal are requested. The following examples describe some of the needed work and an estimated budget for each main task.

**1) Wildlife Monitoring of birds, alligators, turtles, snakes and deer (Ongoing)**: This monitoring has been underway at Wakulla Springs State Park since 1992. Biologists conduct weekly surveys on the first boat tour (9:30am), on Saturday mornings. They count and record the number of animals observed on one boat tour. Counts are currently performed for: Mammals (Florida manatee); Reptiles (American alligator, Cooter turtle, Snakes); and Birds (Herons, Egrets, Green heron, Little blue heron, Snowy egret, Tricolored heron, Yellow-crowned night heron, American widgeon, Blue-winged teal, Hooded merganser, Lesser Scaup, Woodduck, Gallinules, American coot, Common moorhen, Purple gallinule, Anhinga, Double-crested cormorant, Limpkin, Osprey, Pied-billed grebe and White ibis). Amphibians will be monitored (like frogs and salamanders). Significant decreases in the numbers of fish eating animals, like alligators and anhingas have been noted. The current wildlife survey efforts at the park will continue unaltered however this survey will be expanded, quarterly, to the areas of the Wakulla River outside the Park and the St Marks River, from the St. Marks Rise to the coast.

*Total cost for one year $50,000*

**2) Fish Monitoring (Proposed):** Fish synoptic surveys should be performed quarterly with aerial photography, and net sampling (fish only) following FWC methodology. This should be a complete count of the number of manatees, which are rapidly increasing in the Wakulla River and evaluate the fish population in the river which is said to be declining.

The staff of Wakulla Springs State Park has not authorized electroshocking (the normal mode for fish surveys), and electrofishing, so we are utilizing various sizes and types of nets for the fish surveys. We will utilize passive techniques to collect data for the fish surveys. Passive techniques do not involve the movement of the sampling gear to collect fish. These gears are typically anchored and stationary allowing fish to move into them. Passive techniques can be grouped by their method of capture: entanglement, entrapment, and angling. Entanglement gear captures fish by ensnaring or tangling (i.e. gill and trammel nets). Entrapment gear captures organisms as they enter an enclosed area and are unable to escape. Entrapment devices include hoop nets, fyke nets, slat traps, and crap pots. Angling methods involve setting an individual or line of stationary hooks that are baited such as a trotline. These synoptic surveys are to be conducted quarterly.

*Total cost for one year $20,000*

**3) Submerged Aquatic Vegetation Monitoring (Ongoing):** The health of Wakulla Springs is threatened by abundant invasive plants. Historical monitoring involved twice-yearly Wakulla River aquatic plant surveys timed for before and after

the herbicide treatment. This included nine surveys from 2002-2008. Surveys quantified the percent coverage of both aquatic plants and algal mats over 2.2 miles of the Upper Wakulla River, all within the State Park. A visual survey station occurred every 200 feet and an underwater picture was taken every 30 feet. All stations and pictures were geopositioned with GIS. This method did not utilize any horizontal transects of the river, but unlike the transect method used by FDEP, where discrete transect stations are set up as a grid in small areas of the river; these surveys examined the central portion of the entire Upper River.

The current surveying effort is directed by Scott Savory, a Park Ranger, and the Senior Biologist at Wakulla Springs State Park. This started in March 2013. We will utilize traditional transect methods. To conduct the sampling, we will establish transects, in each bioregion of the river. A transect line will be stretched across the River and SAV monitored at 10 equidistant points per transect marked by three randomly tossed meter squares. We will determine the presence, percent coverage of the bottom, thickness or height in the water column of vascular plants and algae. Additionally, a densitometer will be used to determine canopy coverage in each transect. The species and genus of each plant species surveyed will be recorded.

The photographic aerial photography for the Manatee Surveys would facilitate the vegetative surveys, enabling vegetative community mapping and allowing a more complete analysis of the vegetation. These would be need to be high resolution orthoimagery with adequate pixel resolution for survey purposes. The aerial photography will be adapted to aid in the vegetative surveys, the high-resolution ortho-imagery, digital images of ortho-rectified aerial photographs can be used to identify community types and eco-zones for the vegetation within the entire river. These surveys are to be conducted twice a year, before and after the herbicide treatment (weather permitting). The NWFWMD begins biannual combined RPS and LVS at Boat Repair facility plus combined RPS, LVS, and SCI at CR365 Bridge in October 2013.

*Total cost for one year $30,000*

**4) Macrobenthic Invertebrate Monitoring (Ongoing):** It is important to monitor benthic invertebrates in the spring system. Many are good indicators of water quality or other forms of aquatic stress. Dragonflies, damselflies, mayflies, stoneflies and crawfish are important components of any lotic ecosystem. Each sample site will be randomly cored 12 times, yielding a representative sample of the benthic invertebrate fauna according to the FDEP SOP, FS 7000, GENERAL BIOLOGICAL COMMUNITY SAMPLING. Samples will be preserved according to the same protocol. The samples will be picked and preserved in Ethanol and sent to an expert taxonomist for identification (Dr. John Epler). The organisms will be identified to species level, when possible, and broken down by phylum, class, family, genus and species. From this data, the following will be calculated: the number of individuals per species; the abundance of species; species richness; the total number of individuals; the relative abundance of each species; the Shannon-Weiner Diversity Index; the Simpson Diversity Index; and the Adjusted Simpson Diversity Index. We will apply statistics techniques to analyze the data such as a Custer Analysis, a multivariate analysis technique that organizes information about variables to form relatively homogeneous groups, or "clusters." All data will follow EPA and FDEP approved sediment samples.

*Total cost for one year $50,,000*

**5) Surface Water Quality Monitoring (Ongoing):** This assessment was designed to provide baseline data on general chemistry and discharge that can be used to evaluate influences due to salinity, interaction with surface water, recharge, and discharge. These surveys are to be conducted quarterly (except for the three continuously monitored nitrate stations). Salinity and nutrients need to be run on selected stations along the Big Bend coast. We are already monitoring water quality at the St. Marks

Lighthouse and Shell Point. These stations should be augmented to include the coastal zone where the Wakulla, St. Marks and Spring Creek waters mix with the Gulf of Mexico. These surveys are to be conducted quarterly. The sampling and data collection must meet regulatory standards for monitoring activities, and will specifically follow FDEP SOPs for water quality sampling FC-1000, FD-1000, FM-1000, FQ-1000, FS-1000 through 8200, and FT-1000 through 3000. Field Parameters, we will run the set FDEP is running: Dissolved Oxygen, pH, Sample Depth, Secchi Depth, Specific Conductance, and Water Temperature. Core laboratory parameters are, like FDEP: Ammonia (as N), Nitrate + Nitrite (as N), Total Kjeldahl Nitrogen. Supplemental laboratory parameters are, also those of FDEP: Alkalinity, Calcium, Chloride, Chlorophyll-a, Color (true), Fluoride, Hardness, Magnesium, Sodium, Specific conductance (lab), Sulfate, Potassium, Total Phosphorous, Total Suspended Solids, Total Dissolved Solids, Total Organic Carbon, and Turbidity (lab). All tests will be NELAC certified and FDEP TMDL approved.

*Total cost for one year $20,000*

**6) Productivity Monitoring (proposed):** Productivity will be monitored at six locations, three in the Wakulla River (at the swimming area in the Park and at the two bridges south of the park) and three in the St Marks River (just below the St Mark Rise, and the Highway 98 Bridge and south of the confluence of both rivers). Productivity will be measured with three data sondes equipped with optical dissolved oxygen probes and internal memory as well as temperature, pH and specific conductance. Data will be downloaded from each sonde weekly with associated calibrations and cleansing from biofouling.

*Total cost for one year $25,000.*

**7) Conduit Sampling (proposed):** The monitoring activities are currently being conducted by the Florida Geological Survey, Dr. Todd Kincaid, and the Woodville Karst Plain Project are a critical component of understanding changes in the quality of the source waters supply Wakulla Spring. It is very important to constrain tunnel (source) contributions to Wakulla springs flow and quality, but it is not necessary to monitor every single tunnel for nitrates. Rather, the loading of all the tunnels can be constrained with three nitrate meters deployed insitu in the caverns and the individual loading can be determined by a mass balance model. Additional stations will be monitored for salinity changes as well as to track source water indicators including temperature and conductivity. Here we propose to maintain some of the existing meters that have been installed and continue to maintain the database and ongoing interpretations that have been underway since 2003

Experimental Design

- Discharge sources should be constrained (three insitu nitrate meters)
    - *B-tunnel*
    - *D-tunnel*
    - *Vent*
- *Salinity variation should be constrained (two salinity probes)*
    - *A tunnel south of K-tunnel*
    - *Vent*
- *Nitrate variation should be constrained by two meters (same two meters as above)*
    - *B-tunnel*
    - *Vent*
- *Ideally, discharge variation and distribution should be further constrained by meters at (monthly grab sampling, nitrate)*
    - *Spring Creek*

    - *Kelly Sink (a karst window part of the Ames sink complex)  or Indian Springs – Upstream Tunnel*
    - *Turner Sink*
    - *a point in the tunnel upstream of Sullivan sink which would require a new well*
    - *note that the combination of Turner and the point upstream of Sullivan would allow us to constrain Fisher Creek and Black Creek contributions*
    - *Lost Creek*
- *Salinity should be further constrained (three salinity probes)*
    - *Spring Creek*
    - *Punch Bowl Sink*
    - *Revel Sink*
- *Nitrate should be further constrained by (monthly grab sampling, nitrate)*
    - *Kelly Sink (a karst window part of the Ames sink complex)  or Indian Springs – Upstream Tunnel*
    - *a point in the tunnel upstream of Sullivan sink which would require a new well – or one of the National forest wells that we installed near Sullivan Sink*

*Total cost for one year $25,000.*

**8) Cave Exploration (Ongoing):** The exploration and logistical support activities currently being conducted by the Woodville Karst Plain Project need to be encouraged and supported in this project. In particular, these activities will support as it is a vital part of the monitoring the objectives of task #8. This funding is designed to offset some of the material expenses associated with the diving necessary for some of the sampling associated with task #8 and will help to ensure that all tasks are performed in a timely manner sufficient to meet the program objectives.

*Total cost for one year $30,000.*

**9) Numerical Groundwater Flow Modeling:** Dr. Kincaid's team, through support from the Florida Geological Survey have completed a draft version of a comprehensive numerical groundwater flow model that explicitly simulates the conduit flow patterns that have been documented through groundwater tracing in the Woodville Karst Plain. The model was last updated in 2011 to include all documented groundwater pumping that likely affects flow to the major springs in the Big Bend region including: Wakulla, Spring Creek, and Wacissa Springs, and the St. Marks River Rise such that it can be used to assess the effect of pumping and sea level rise on spring discharge. The model needs to be re-calibrated to recent conditions before it can be implemented. This task provides funding for Dr. Kincaid's team to perform the necessary recalibration and develop impact scenarios associated with existing groundwater extractions and sea-level rise. We expect that it will take approximately one year to complete this recalibration and the scenario analyses. The results will contribute to both the MFL and BMAP efforts by providing reliable delineations of springshed boundaries, vulnerability zones, and the impacts of existing groundwater extractions for Wakulla as well as the St. Marks River Rise and the other springs in the Woodville Karst Plain.

*Total cost for one year $75,000*

| Station | Location | Wildlife | Fish | SAV | Macroinverts | Water Quality | Productivity | Water Quality |
|---|---|---|---|---|---|---|---|---|
| | | Item 1 | Item 2 | Item 3 | Item 4 | Item 5 | Item 6 | Item 7 |
| McBride Slough | Wakulla County | | | 1 | 1 | 1 | | |
| Sally Ward | State Park | | | 1 | 1 | 1 | | |
| T7 | State Park | 1 | 1 | 1 | 1 | 1 | 1 | |
| T1 | State Park | | | 1 | 1 | 1 | | |
| T6 | State Park | | | 1 | 1 | 1 | | |
| T2 | State Park | | | 1 | 1 | 1 | | |
| T3 | State Park | | | 1 | 1 | 1 | | |
| T5 | State Park | | | 1 | 1 | 1 | | |
| T4 | State Park | | | 1 | 1 | 1 | | |
| Tiger Hammock | Wakulla River | | | 1 | 1 | 1 | | |
| Tiger Hammock (Trans) | Wakulla River | 1 | 1 | 1 | 1 | 1 | 1 | |
| Lower Bridge (98) | Wakulla River | | | 1 | 1 | 1 | 1 | |
| Big Boggy | Wakulla River | | | 1 | 1 | 1 | | |
| T8 | Wakulla River | | | 1 | 1 | 1 | 1 | |
| T13 | St Marks River | 1 | 1 | 1 | 1 | 1 | | |
| St Marks Bridge (98) | St Marks River | | | 1 | 1 | 1 | 1 | |
| T12 | St Marks River | | | 1 | 1 | 1 | | |
| T11 | St Marks River | | | 1 | 1 | 1 | | |
| T10 | St Marks River | 1 | 1 | 1 | 1 | 1 | | |
| T9 | St Marks River | | | 1 | 1 | 1 | 1 | |
| offshore-1 | Apalachee Bay | 1 | 1 | 1 | 1 | 1 | | |
| offshore-2 | Apalachee Bay | 1 | 1 | 1 | 1 | 1 | | |
| offshore-3 | Apalachee Bay | 1 | 1 | 1 | 1 | 1 | | |
| Spring Vent | State Park | | | | | | | 2 |
| B-Tunnel | Cavern | | | | | | | 2 |
| D-Tunnel | Cavern | | | | | | | 2 |
| Spring Creek | Wakulla County | | | | | | | 1 |
| Turner Sink | Wakulla County | | | | | | | 1 |
| Kelly Sink | Wakulla County | | | | | | | 1 |
| Sullivan Sink | Wakulla County | | | | | | | 1 |
| Lost Creek | Wakulla County | | | | | | | 1 |
| Punch Bowl | Wakulla County | | | | | | | 1 |
| Revel Sink | Wakulla County | | | | | | | 1 |
| Extra Sink | Wakulla County | | | | | | | 1 |
| | | | | | | | | |
| Annual Frequency | | 4 | 4 | 4 | 4 | 4 | 24 | 12 |
| Annual Number | | 7 | 7 | 23 | 23 | 23 | 6 | 14 |
| Unit Cost (Taxonomy) | | $75.00 | $198.29 | $50.00 | $250.00 | $0.00 | $50.00 | $0.00 |
| Field Cost | | $1,711.00 | $516.00 | $276.08 | $290.00 | $144.00 | $123.61 | $118.33 |
| Laboratory Cost | | $0.00 | $0.00 | $0.00 | $0.00 | $400.00 | $0.00 | $90.00 |
| Annual Cost | | $50,008.00 | $20,000.12 | $29,999.36 | $49,680.00 | $50,048.00 | $24,999.84 | $34,999.44 |
| Target | | $50,000.00 | $20,000.00 | $30,000.00 | $50,000.00 | $50,000.00 | $25,000.00 | $35,000.00 |

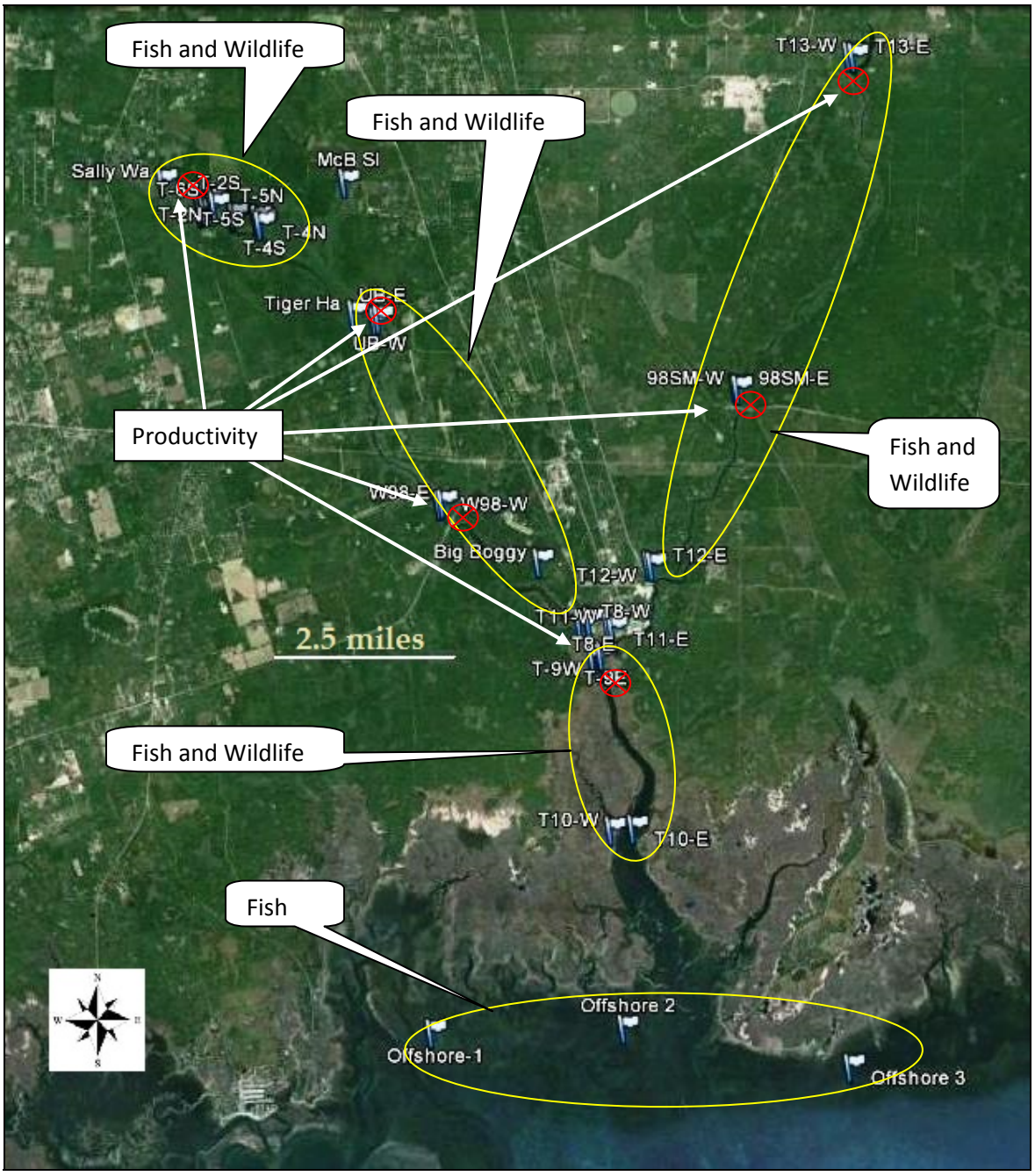
| First Year Only | Number | Number | Cost | Total |
|---|---|---|---|---|
| Salinity meters | Item # 7 | 2 | $6,000 | $12,000 |
| Prod. (DO) meters | Item # 6 | 6 | $6,000 | $36,000 |
| Nitrate meters | Item # 7 | 3 | $25,000 | $75,000 |
| Explore | Item # 8 | 1 | $30,000 | $30,000 |
| Modeling | Item #9 | 1 | $75,000 | $75,000 |

| Costs by Category | Total |
|---|---|
| Field,Lab and Tax Costs | $260,000 |
| Equipment Cost | $123,000 |
| Total #8 and #9 | $105,000 |
| Total First year | $488,000 |
| Additional Years | $260,000 |
| Admin, Costs (3%) | $22,440 |
| | |
| Total Cost (6 years) | $1,810,440 |

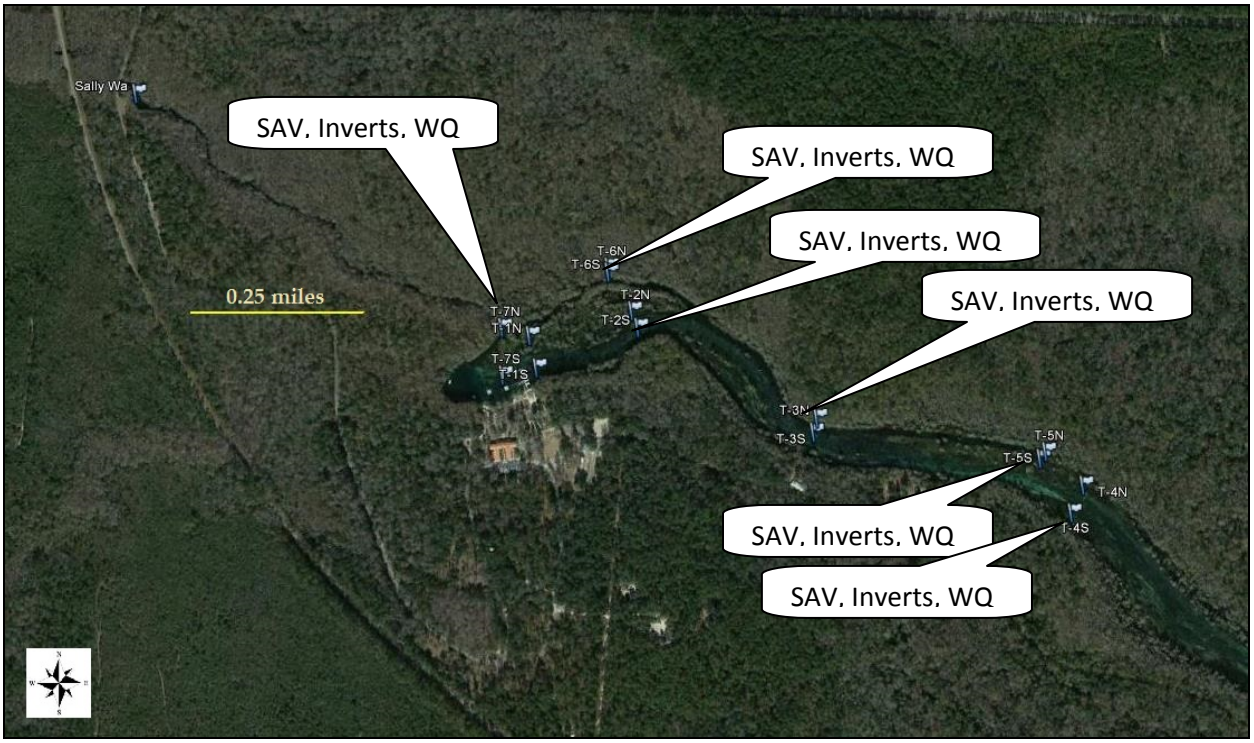
To avoid duplication of results with the FDEP BMAP monitoring program we will not sample at their stations

1) no stations or sampling at boat dock

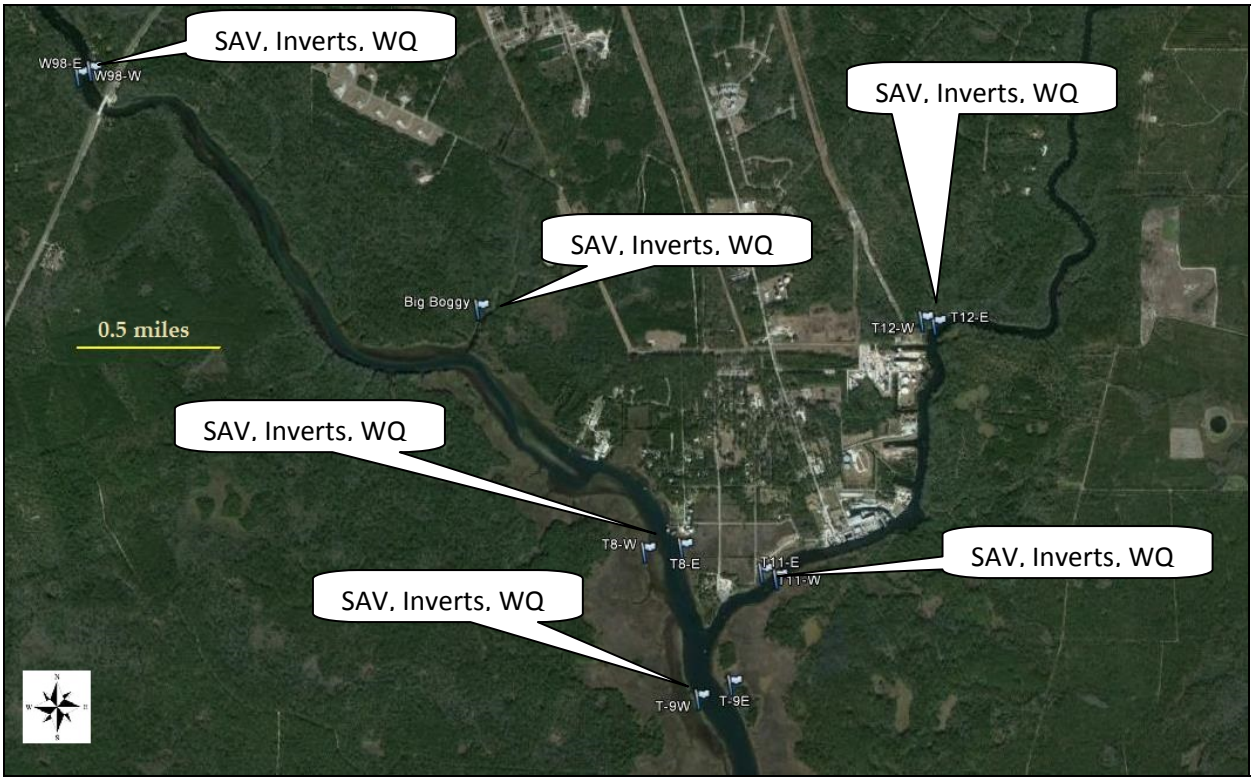
2) no stations of sampling at the Upper Bridge



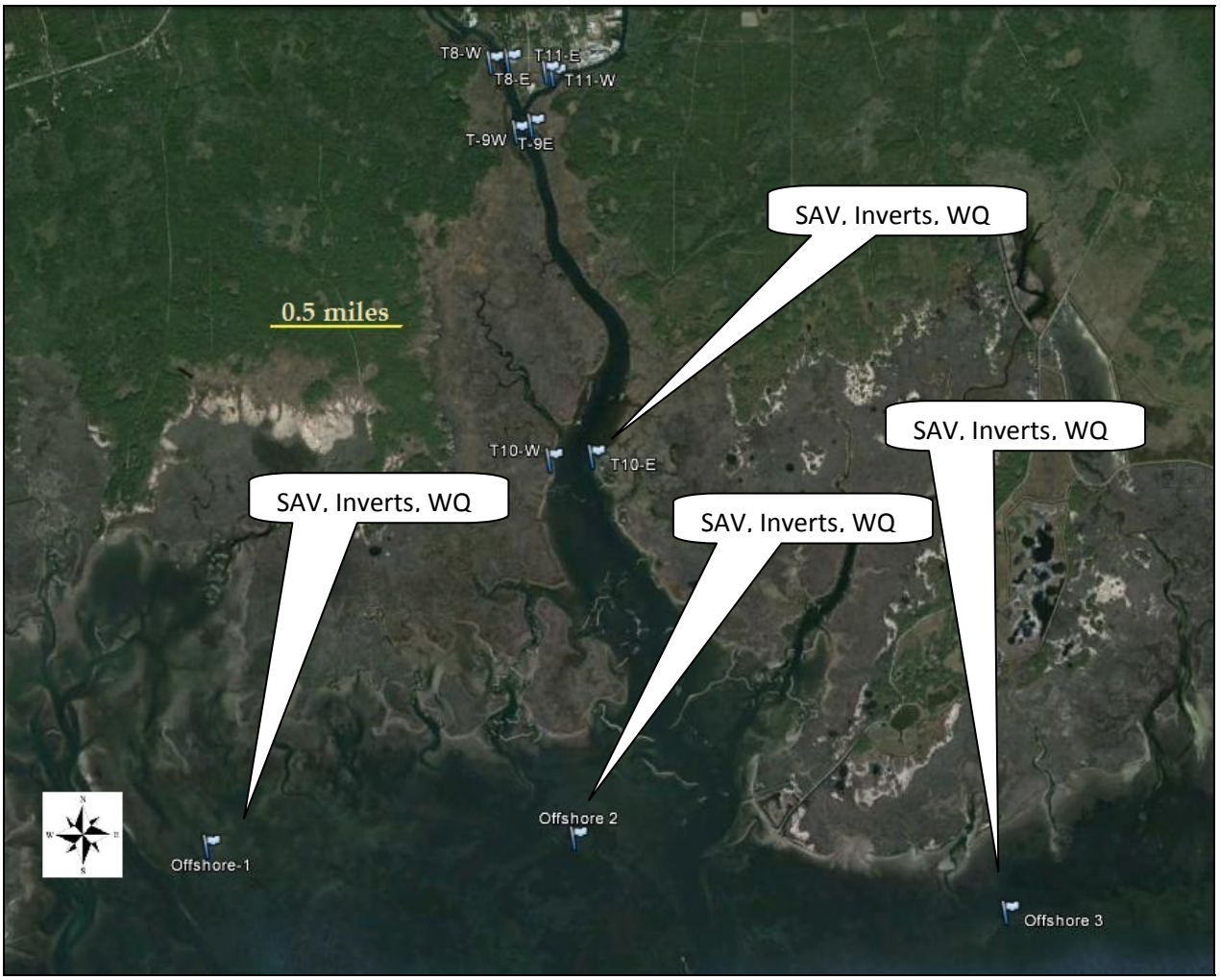

All stations in the Wakulla and St. Marks Rivers. Red crosses in the circle represent productivity stations. The yellow circles represent wildlife and fish river sections.



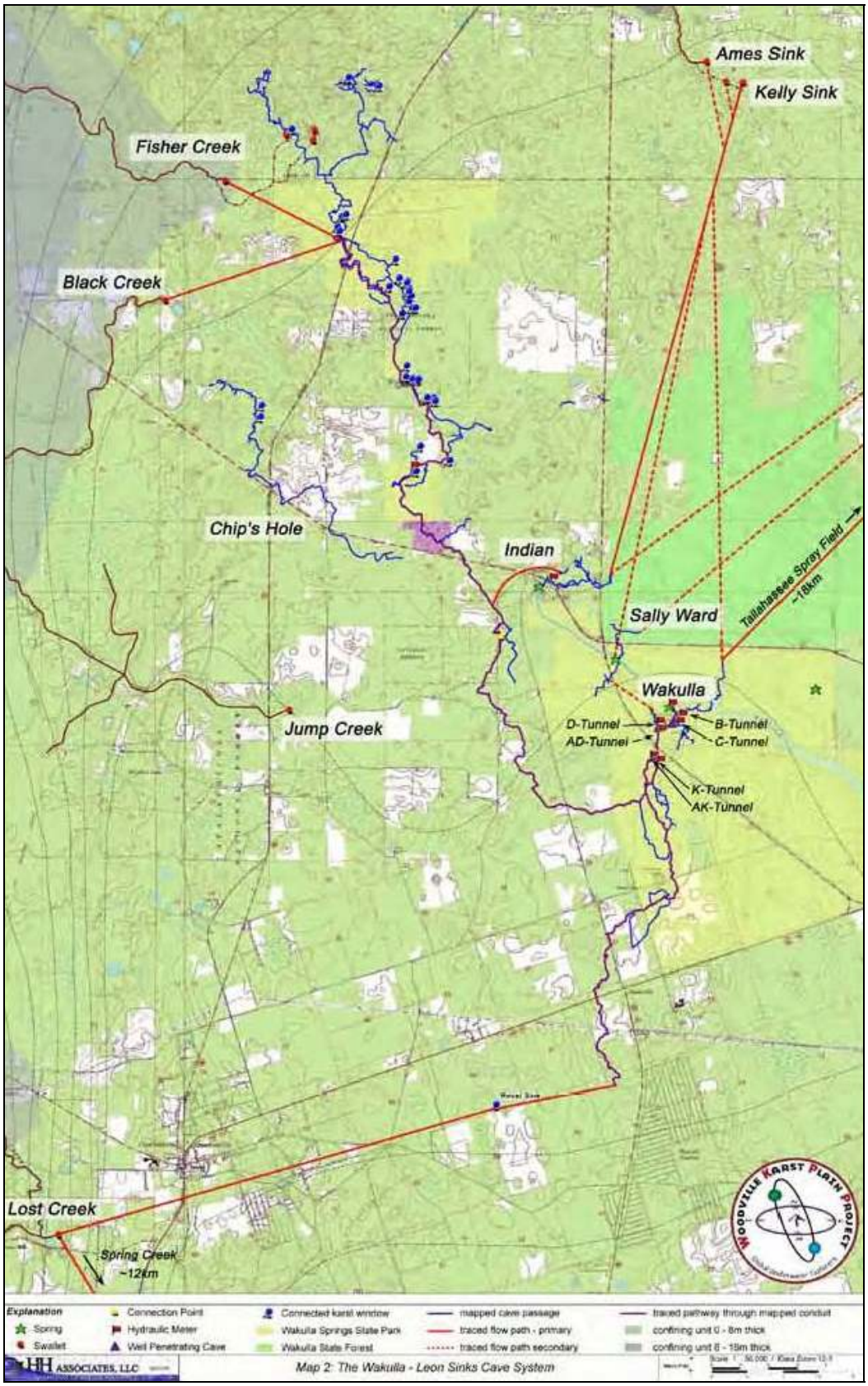
Upper Wakulla, Stations in the Wakulla Springs State Park



Lower Wakulla and St. Marks Rivers



St. Marks River and Apalachee Bay, marine and estuarine stations




**Cave Exploration and Tunnel Studies**