

Ground Water Chemical Characterization of the
St. Marks River Rise, Florida
Water Resources Special Report 06-01



PREPARED BY:

THE NORTHWEST FLORIDA WATER MANAGEMENT DISTRICT

July 2006

GROUND WATER CHEMICAL CHARACTERIZATION OF THE ST. MARKS RIVER RISE, FLORIDA

Water Resources Special Report 06-01

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July 15, 2006

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July 2006

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Introduction

In 2001, the Florida Legislature funded the first phase of the Florida Springs Initiative (FSI) to study and preserve the quality of Florida's springs. The Florida Department of Environmental Protection (FDEP), administrator of FSI funding, contracted with the Northwest Florida Water Management District (NFWFMD) to monitor first magnitude springs within the District, delineate springsheds, and perform other research regarding springs water quality and distribution. The 2005 Florida Legislature continued funding and FDEP requested project proposals for additional work. The NFWFMD proposed completion of a ground water chemical characterization of the St. Marks Rise basin in an effort to aid in delineation of the spring basin. This study was performed under FDEP contract GW245 (July 2005) during the period of September 2005 through June 2006.

Two primary goals formed the foundation for this study. The first was to apply statistical methods (principle component analysis and hierarchical cluster analysis) for characterizing spring basin water quality developed in other areas of the state to Morrison Spring and the St. Marks River Rise. Previous works by Dalton and Upchurch (1978), Jones, et al (1996), and Barrios and DeFosset (2005) demonstrated the effectiveness of the statistical analysis of common ions in identifying intra-basin relationships and geochemical facies for Floridan Aquifer springs. The second objective was to apply these same statistical methods towards the delineation of the spring basin boundary and/or the identification of the principle contribution area(s) within the spring basin boundary.

Study Area and Hydrogeology

St. Marks Rise Characterization Study Area

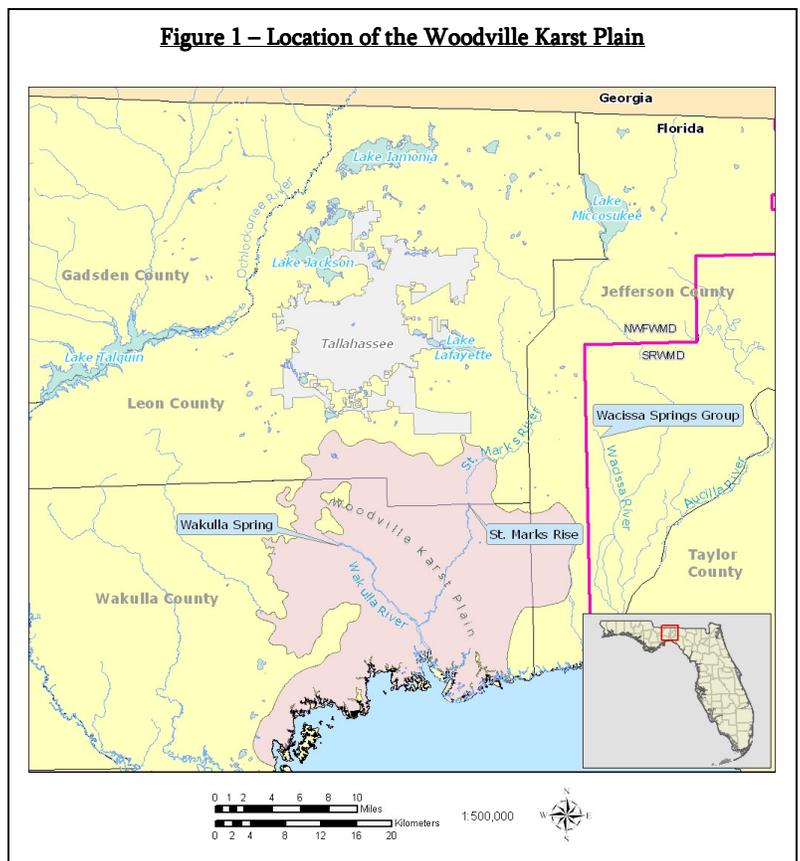
The St. Marks River originates in east Leon County near the town of Capitola. At its headwaters the St. Marks River appears to be little more than a collection of connected wetlands. As the river continues south it picks up the drainage from swamps located in the surrounding area and flow increases to a recognizable dark-water creek by the time the St. Marks crosses U.S. Highway 27. The character of the river remains much the same until it collects the discharge from Horn Spring and Chicken Branch Spring approximately ten kilometers downstream from Tram Road. The combined discharge from these two second magnitude springs provides the majority of the base flow for the upper St. Marks River and allows the navigation of the river with a canoe or kayak. At Natural Bridge, the St. Marks River is taken by a swallet and resurges at the St. Marks Rise one kilometer to the south where its flow is greatly augmented by ground water discharge. Discharge measurements collected by NFWMD staff indicate that, on average, only 24 percent of the discharge at the river rise is contributed by inflow at the Natural Bridge swallet. An average measured discharge of 13.7 cubic meters per second (410 cfs) places the St. Marks Rise among the thirty-three first magnitude springs in Florida.

Based on previous work by the United States Geological Survey (Davis 1996), a preliminary ground water basin was delineated and used to determine the study area for this report. This preliminary basin indicated a ground water contribution area for the St. Marks Rise trending north along the Leon County-Jefferson County border into southern Georgia. This investigation focuses on the portion of the basin located within Florida.

Hydrogeology of Jefferson, Leon and Wakulla Counties

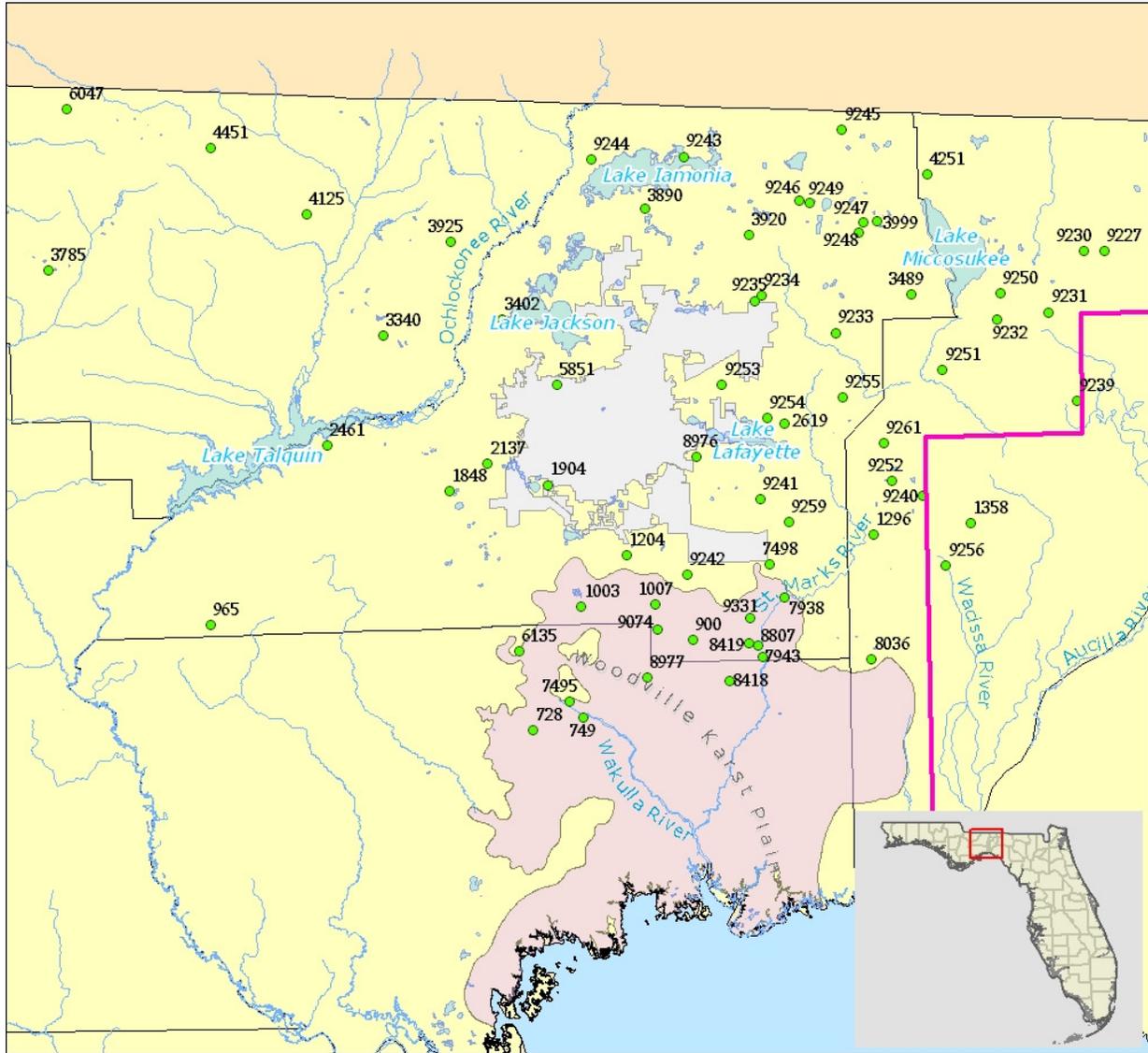
In Jefferson, Leon and Wakulla counties, the Floridan Aquifer consists of the Miocene St. Marks Formation, the Oligocene Suwannee Limestone, and the Eocene Ocala Limestone (Scott 2001). The thickness of the aquifer increases from 305 to 822 meters, north to south, however only the first hundred meters are utilized due to high availability in the upper aquifer and increased mineralization and lower availability of the aquifer beginning in the Ocala Limestone (Pratt et al. 1996). Miller (1986) separated the Floridan Aquifer into an upper and lower component in the vicinity of the study area based on an order-of-magnitude change in transmissivity values. The limestone units comprising the uppermost Floridan Aquifer in the study area are the primary source of consumptive use and consist of the St. Marks Formation and the Suwannee Limestone (Pratt et al. 1996). Both units are of varying thickness within the study area due to karst and channel erosion features (Hendry and Sproul 1966).

North of the Cody Escarpment, an east-west trending physiographic feature of modest relief created by the erosion of sediments at a higher stand of sea level, the Floridan Aquifer transitions from unconfined to semi-confined with the addition of the Miocene Torreya and Pliocene Miccosukee Formations, clastic units of variable thickness and low permeability. Where present, these clastic units may contain minor surficial and intermediate aquifers; however, they primarily function as aquitards - restricting local recharge to the Floridan Aquifer. Where the Torreya and Miccosukee Formations are thick, transmissivity of the underlying Floridan Aquifer decreases precipitously due to slower dissolution of the limestone matrix (Miller, 1986). There are a few notable locations in the St. Marks Basin where the clastic units are breached by sinkholes, directly connecting the Floridan Aquifer to the surface. These sinks are concentrated in the vicinity of Lake Miccosukee and collectively take in the surface drainage for most of the tributaries to the St. Marks River. The tributaries - including Lloyd Creek, Burnt Mill Creek, Still



Creek, and Hall Branch - were originally complete surface features whose channels were lowered and captured by erosion and solution of the underlying limestone. The broad shallow lakes of the region, including Jackson, Iamonia, Lafayette, and Miccosukee, are likely former surface streams enlarged laterally by sinkhole formation (Yon, 1966).

Figure 2 – Study Area and Site Locations



The area of south Leon County, southwest Jefferson County and east Wakulla County - where the limestone units comprising the Floridan Aquifer are only covered, if at all, by a thin veneer of permeable Pleistocene sands - was first termed the Woodville Karst Plain by Hendy and Sproul (1966). The Woodville Karst Plain is characterized by high ground water recharge rates of 38 to 50 centimeters per year (Bush and Johnson, 1988), abundant sinkholes, and few surface drainage features in the upland areas. The area is

also home to over fifty Floridan Aquifer springs (Barrios 2006) including three first magnitude springs: Wakulla Spring, the Spring Creek Group, and the focus of this investigation – the St. Marks River Rise.

Data Collection and Analysis Methods

Sample sites were selected from the NFWFMD Well Inventory and Construction Permitting databases and conformed to the following requirements: wells must possess an open hole or screened interval entirely within the Floridan Aquifer, wells with in-place plumbing must be functioning with a sample withdrawal site located before any filtration equipment, and site location allows for adequate coverage of the study area. A total of forty-eight ground water samples were collected from wells and karst features in the vicinity of the St. Marks Rise during the fall quarter of 2005. In addition, twenty-six water quality samples collected by NFWFMD staff in the fall quarter of 2004 were added to the analysis of the St. Marks Rise basin. Water quality sampling was conducted in accordance with FDEP standard operating procedures listed under DEP-SOP-002/02 (revised 6/28/2004). Lab samples and equipment blanks were submitted to the FDEP Central Chemistry Lab for analysis. Field parameters and laboratory analyses are summarized in **Table 1**.

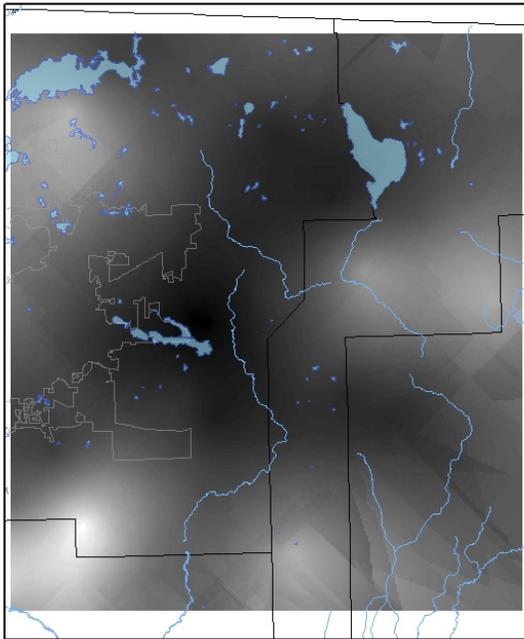
Table 1 – Statistical Summary of Water Quality Data

Variable	Reported Unit	n	Mean	Median	St. Dev.	Skew.	Kurt.
Water Temperature	°C	66	21.1	21.0	0.8	0.91	1.81
Specific Conductance	µS/cm	66	289	286	53	0.35	0.30
Dissolved Oxygen	mg/L	66	3.85	3.31	2.89	0.22	-1.30
pH	su	66	7.3	7.4	0.2	-0.47	-0.58
Alkalinity, Total	mg/L	67	135	129	30	0.89	0.99
Ammonia*	mg/L	67	0.025	0.010	0.052	6.01	41.60
TKN*	mg/L	67	0.107	0.080	0.110	5.43	34.46
Nitrate-Nitrite, Total	mg/L	67	0.338	0.260	0.344	1.53	2.46
Phosphorus, Total	mg/L	67	0.032	0.030	0.023	2.15	6.26
Orthophosphate, Dissolved	mg/L	67	0.028	0.025	0.022	2.19	6.58
TOC*	mg/L	41	1.2	1.0	0.5	3.47	12.67
Calcium, Total	mg/L	67	44.1	42.0	13.2	1.21	1.42
Magnesium, Total	mg/L	67	8.9	8.8	4.4	0.57	1.18
Sodium, Total	mg/L	67	3.43	3.29	1.18	1.48	2.95
Potassium, Total	mg/L	67	0.62	0.50	0.41	2.99	9.73
Chloride, Total	mg/L	67	4.9	4.5	2.3	4.35	27.35
Sulfate, Total	mg/L	67	7.11	5.20	7.29	2.58	10.30
Fluoride, Total	mg/L	67	0.19	0.17	0.09	1.94	5.28
Silica, Total	mg/L	41	14.7	14.0	5.1	2.05	7.00
Iron, Total	mg/L	41	0.280	0.065	0.710	4.02	16.67
TDS	mg/L	67	160	154	34	0.75	1.52

*variable not used in analysis due to frequency of results below detection limit

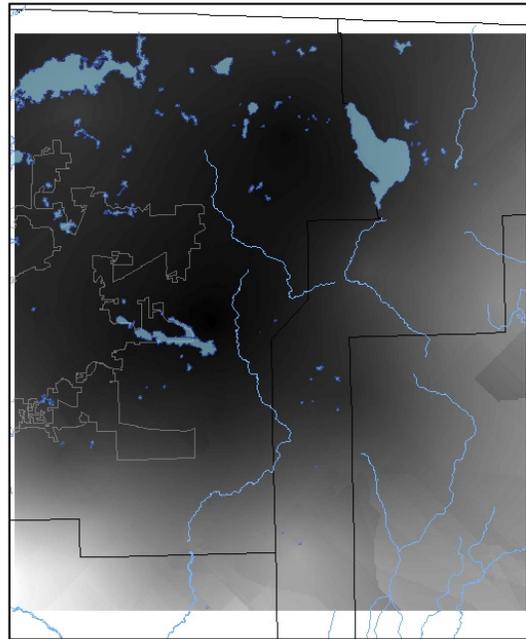
A total of sixty-seven water chemistry samples were analyzed for the St. Marks Rise Chemical Characterization (mapped in **Figure 2**). Site information and well construction data are provided in **Appendix A**. Field and laboratory results are provided in **Appendix B**. Individual parameter concentration gradients for the study area are plotted in **Figures 3-7**.

Figure 3 – Concentration Gradients for Alkalinity, Calcium, Chloride, and Conductance



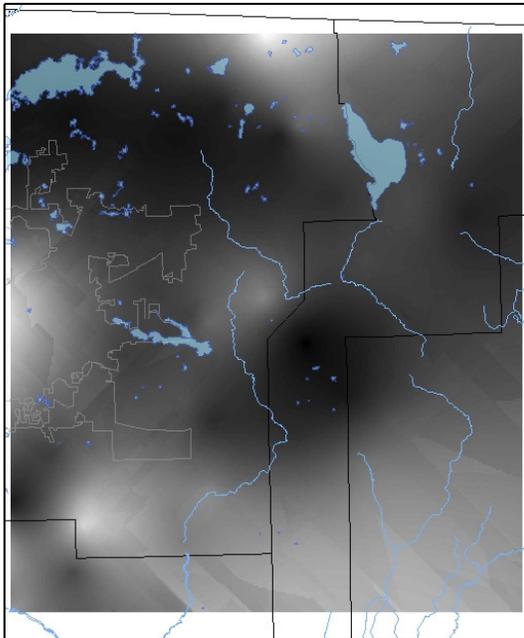
Alkalinity (mg/L CaCO3)

Value
High : 183
Low : 92.0



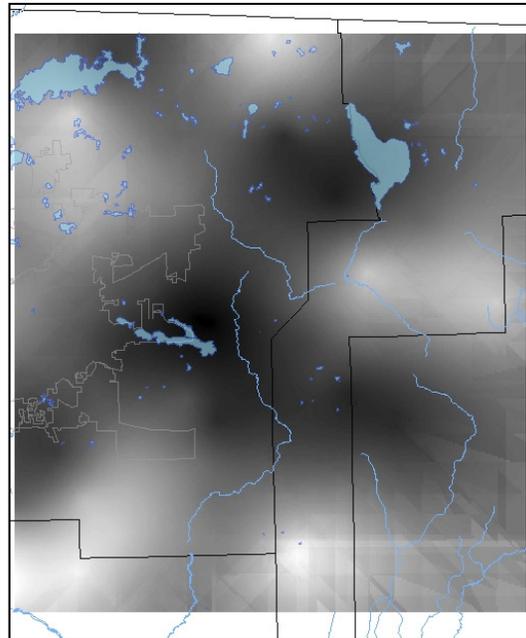
Calcium (mg/L)

Value
High : 61.5
Low : 34.3



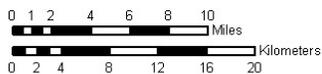
Chloride (mg/L)

Value
High : 6.38
Low : 3.87



Specific Conductance (uS/cm)

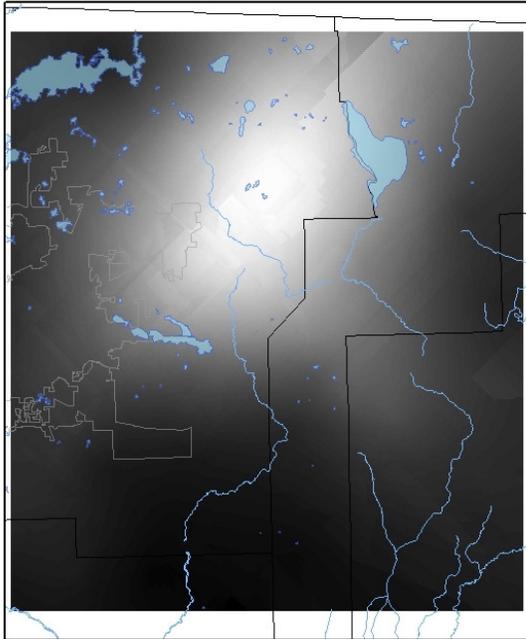
Value
High : 349
Low : 211



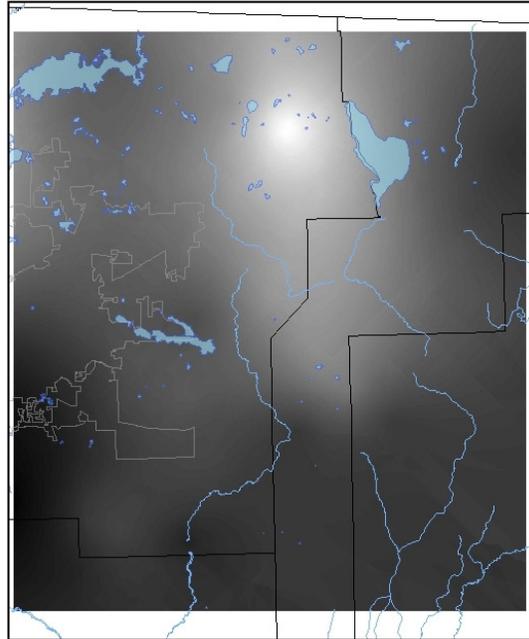
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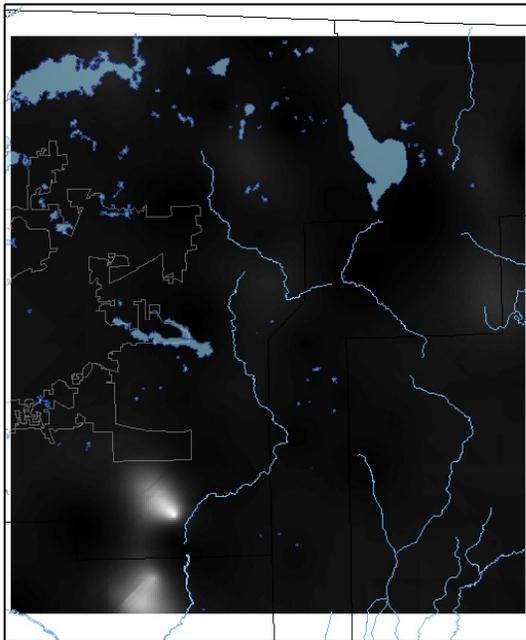
Figure 4 – Concentration Gradients for DO, Fluoride, Iron, and Magnesium



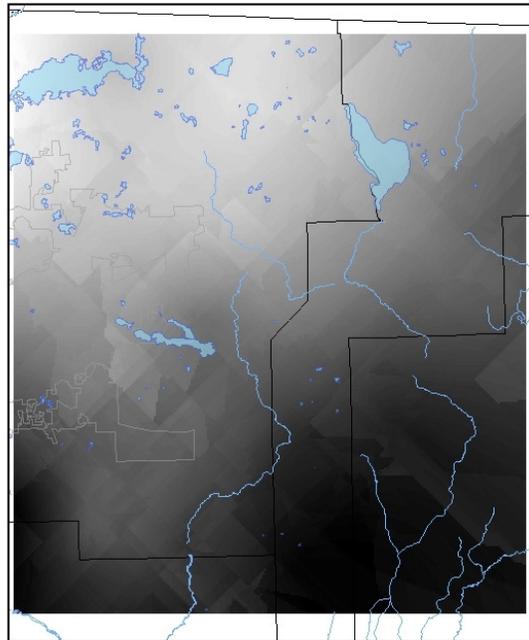
Dissolved Oxygen (mg/L)
Value
 High : 13.3
 Low : 0.82



Fluoride (mg/L)
Value
 High : 0.263
 Low : 0.097



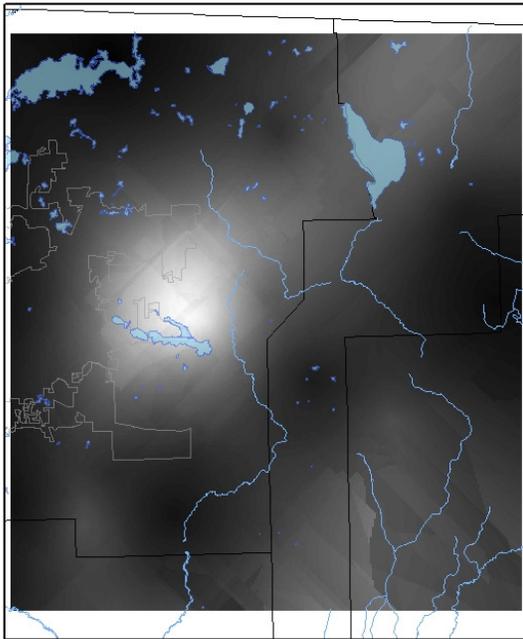
Iron (mg/L)
Value
 High : 3.57
 Low : 0.005



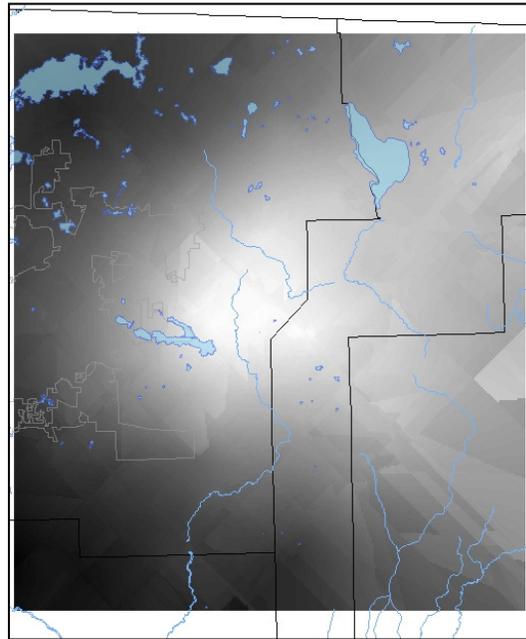
Magnesium (mg/L)
Value
 High : 13.1
 Low : 5.56



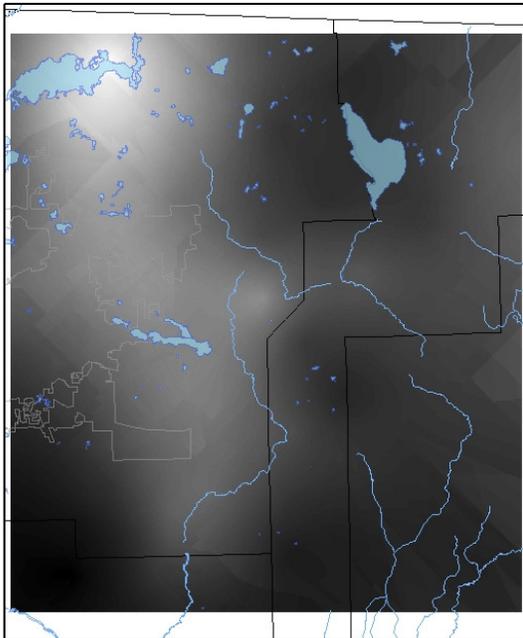
Figure 5 – Concentration Gradients for Nitrate-Nitrite, pH, Orthophosphate, and Potassium



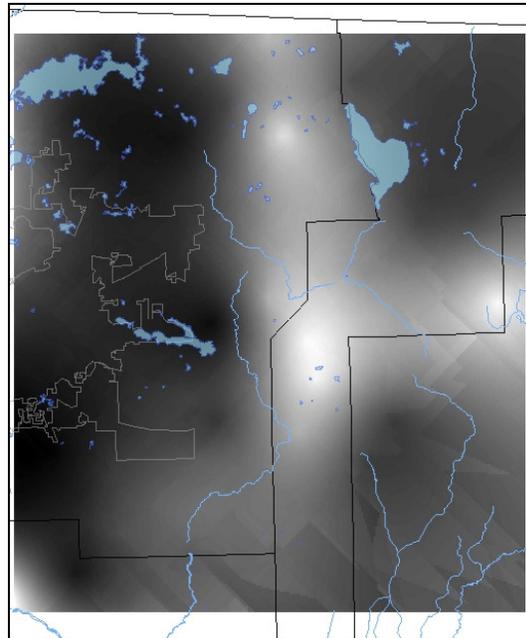
Nitrate-Nitrite (mg/L)



pH (su)



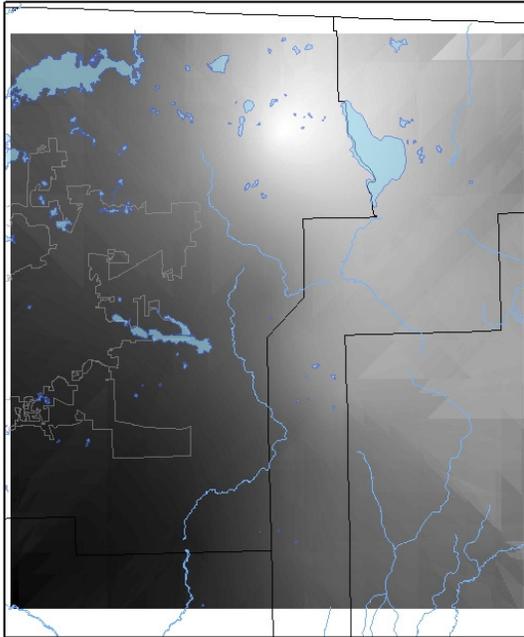
Orthophosphate (mg/L)



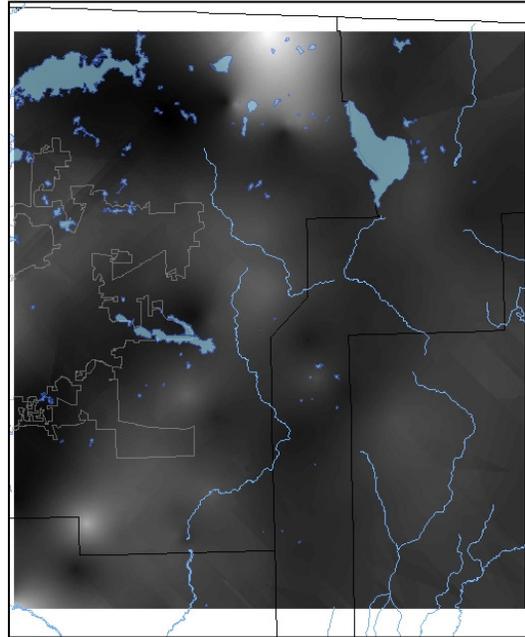
Potassium (mg/L)



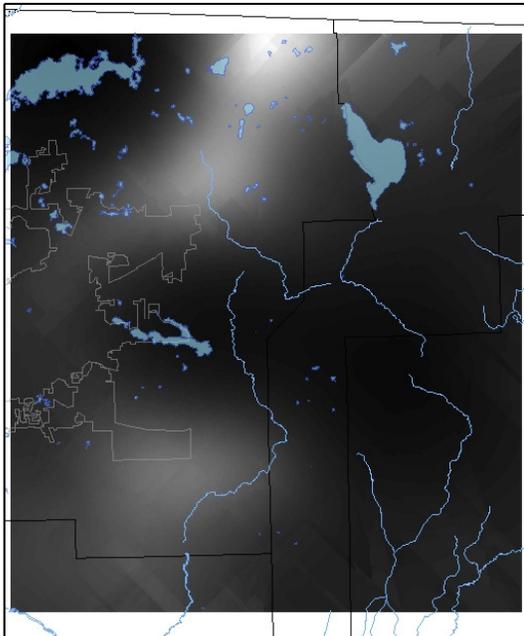
Figure 6 – Concentration Gradients for Silica, Sodium, Sulfate, and TDS



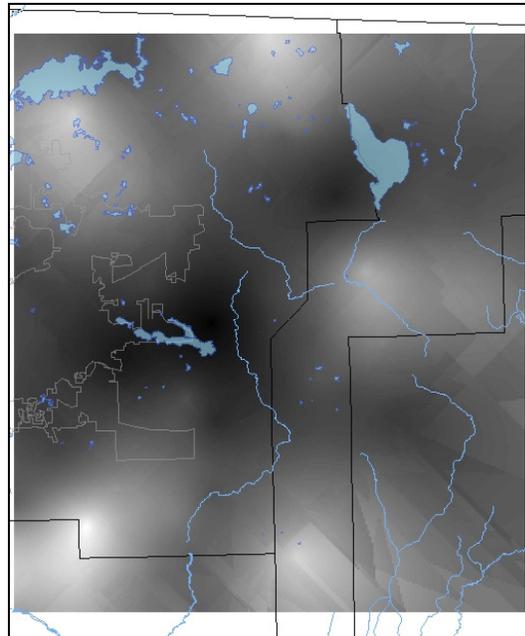
Silica (mg/L)
Value
High : 17.4
Low : 11.6



Sodium (mg/L)
Value
High : 6.13
Low : 1.94



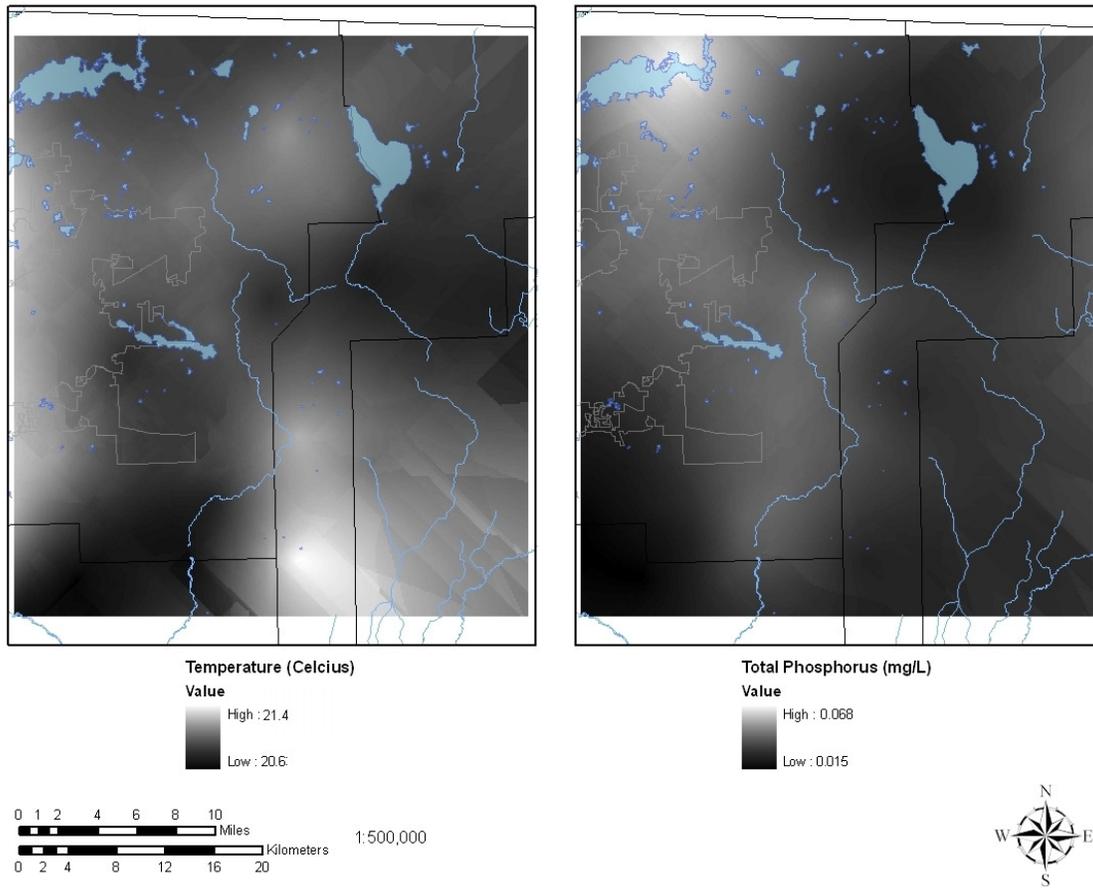
Sulfate (mg/L)
Value
High : 26.5
Low : 1.12



Total Dissolved Solids (mg/L)
Value
High : 217
Low : 97



Figure 7 – Concentration Gradients for Temperature and Total Phosphorus

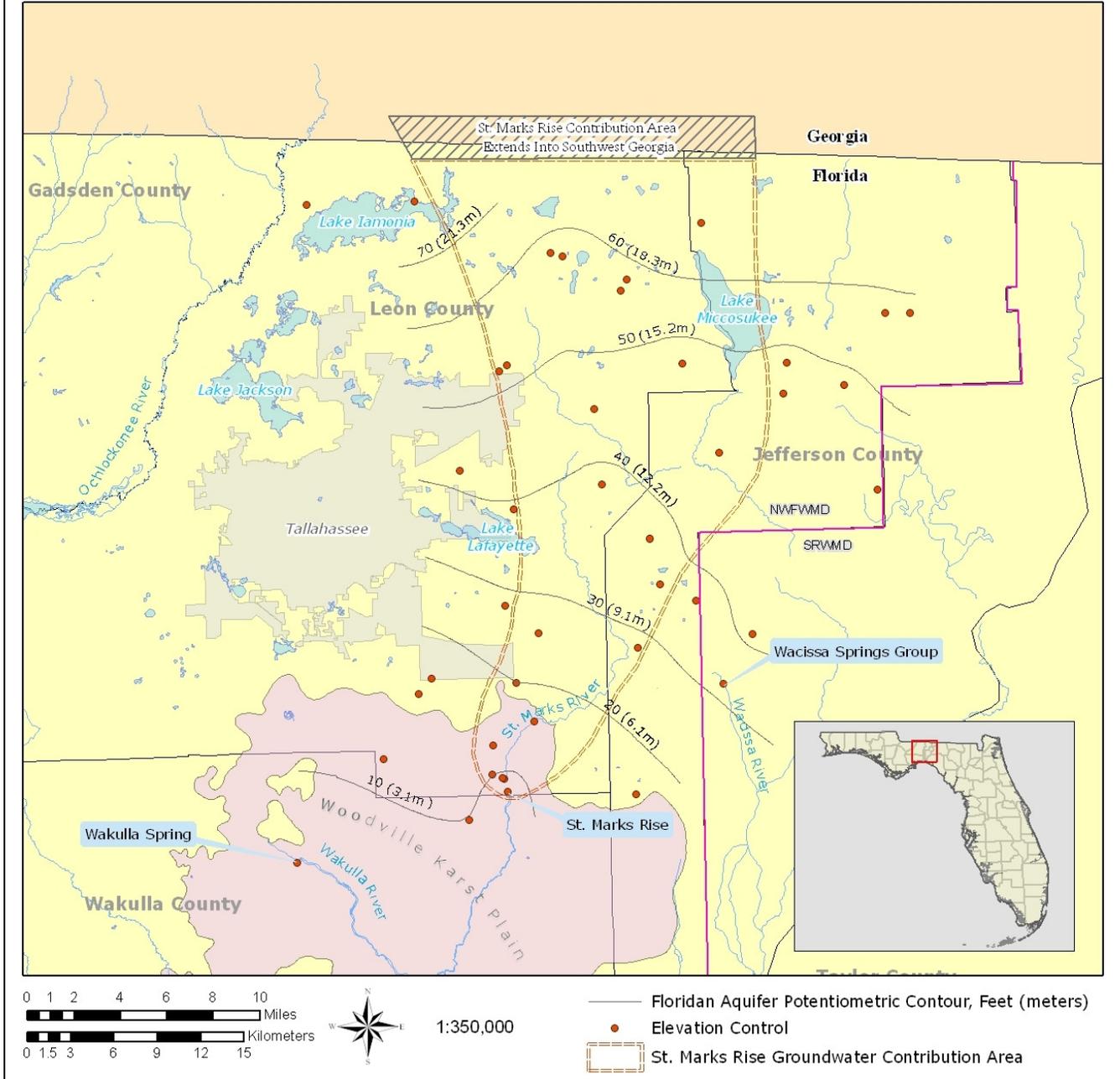


Floridan Aquifer Potentiometric Surface
St. Marks Rise Ground Water Contribution Area

Water level measurements were collected from thirty-six wells visited for this investigation. The elevation of the Floridan Aquifer potentiometric surface was determined from subtracting the depth to water at the measurement location from the land surface elevation. The topographic elevations of springs and other karst features were included to refine the surface. The Floridan Aquifer potentiometric surface presented in **Figure 8** displays the regional flow pattern in the study area – as flow through the aquifer is generally normal to isopotential contours.

Based on this surface a ground water contribution area can be delineated for the St. Marks Rise. The ground water basin extends northward along a relatively narrow band, gradually widening as it approaches the Georgia border. The contribution area most likely trends west of north out of the study area to the ground water divide with the Flint River in southwest Georgia. A more numerous and expansive set of surveyed water level measurements could be used to more precisely define the spring basin boundaries.

Figure 8 – Floridan Aquifer Potentiometric Surface and St. Marks Rise Ground Water Contribution Area



St. Marks Rise Chemical Characterization

The calculated charge balance for the St. Marks Rise dataset ranges from 5.7 to 14.9. Under ideal conditions, all components of the water chemistry can be sampled and identified and the resulting charge balance will be zero. Usually a charge balance less than five is acceptable.

Principle Component Analysis

Once the water chemistry results were received, the samples were checked for consistency with Floridan Aquifer characteristics and reviewed for entry errors. Ammonia, TKN, and TOC (parameters with significant results below the laboratory method detection limit) were removed to eliminate an artificial influence on variance within the population. Results below the method detection limit for the balance of the parameters were assigned the detection limit value. The water quality results from five well sites were removed from the analysis due to water level and chemical data indicating a casing interval wholly or partially intersecting the Intermediate Aquifer System. In addition, the water chemistry results for the SE22A well were removed due to influence from a DEP-permitted facility. Once edited, these data were combined with the dataset from the Wakulla Springs Chemical Characterization performed in 2004. The combined dataset was then used to create a predictive concentration surface for each analyte with ESRI ArcGIS Geostatistical Analyst. Each predictive surface consists of a grid of cells identified by a coordinate number and assigned a value based in the spatial variation of the dataset. The cell values were then exported into tables for completion of the Principle Component Analysis. In order to allow the comparison of parameters with different units and widely ranging scales, the parameter results were converted into units of standard deviation.

Table 2 – Component Loading Coefficients

Variable	i	ii	iii	iv	Communality (%)
Water Temperature	0.15	0.17	0.23	-0.21	71
Specific Conductance	-0.89	0.20	-0.21	0.00	88
Dissolved Oxygen	0.61	-0.46	-0.53	-0.16	89
pH	0.81	-0.03	-0.26	0.37	88
Alkalinity, Total	-0.89	0.24	-0.05	0.19	89
Nitrate-Nitrite, Total	0.66	0.09	0.03	-0.46	68
Phosphorus, Total	-0.09	-0.84	0.25	0.05	79
Orthophosphate, Dissolved	0.02	-0.93	0.19	-0.02	90
Calcium, Total	-0.58	0.73	0.16	0.21	94
Magnesium, Total	0.07	-0.86	-0.36	-0.22	92
Sodium, Total	-0.10	0.29	-0.58	-0.41	90
Potassium, Total	0.12	0.24	-0.65	0.51	87
Chloride, Total	-0.22	0.69	0.04	-0.47	76
Sulfate, Total	-0.18	-0.06	-0.46	-0.71	82
Fluoride, Total	0.35	-0.53	-0.71	0.01	93
Silica, Total	-0.84	0.16	-0.35	0.03	86
Iron, Total	-0.33	0.01	0.08	0.03	50
TDS	0.41	-0.17	-0.66	0.36	76

The Principle Component Analysis (PCA) method is used to group the parameters into common components, or root causes of variability, within the sample population. The PCA is also useful in assisting with the clustering of similar samples and determination of the dominant chemical processes in the study area. The PCA used for this study was conducted in Microsoft Excel using methods established by Darlington (2004), Arsham (2006), Tyne, et al (2004) and Dalton and Upchurch (1978). Matrix and linear algebra operations for Excel were completed with the MATRIX.XLA add-in created by the Foxes Team at Calcolo Numerico (Volpi 2006). After standardization of the water quality variables, a correlation matrix was generated for the data set. The Jacobian eigenvalue and eigenvector matrices were then created. Components with eigenvalues satisfying Kaiser's criterion (eigenvalue >1) were retained and the associated eigenvectors were transformed into component loading coefficients. Varimax rotation was employed to concentrate

variables within a single component. Component scores were then calculated for each sampling location by adding the products of the component loading coefficient and the standardized value for each variable.

The PCA for the St. Marks Rise dataset resulted in four principle components derived from the original data, together accounting for 82 percent of the variability within the sample population. Individual component loading coefficients are listed in **Table 2**. An elevated positive or negative component loading indicates a positive or negative correlation for the variable with that component. The communality represents the percent variance for any single parameter explained by the four components.

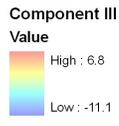
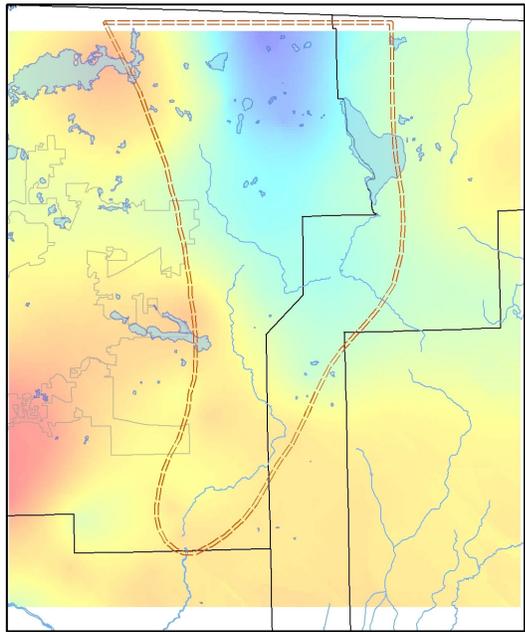
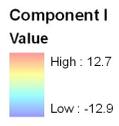
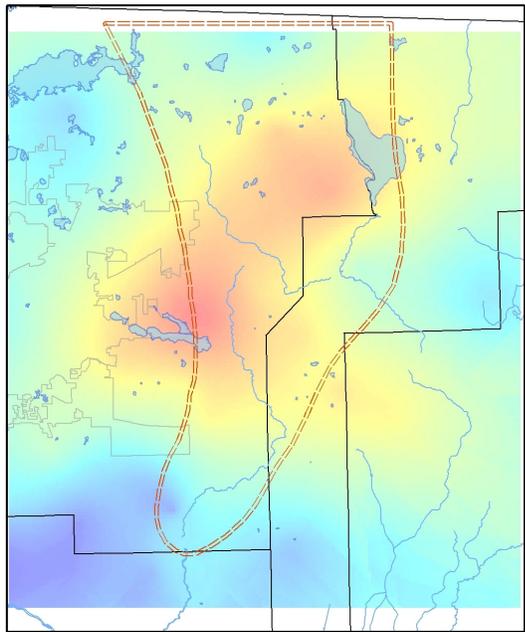
As indicated by **Table 2**, Component I is primarily influenced by the variables Specific Conductance, Dissolved Oxygen, Alkalinity, pH, Calcium, and TDS. The variables included in this component indicate that the component is a measure of the availability and contact with soluble solids (Hem 1992). As shown in **Figure 9**, locations with higher scores for Component I are concentrated near the center of the study area. This central demarcation is visible with the individual variables as well. The depressed carbonate chemistry values in the central area appear to be due to increased recharge to the aquifer from surface drainage, notably Lafayette, Copeland, Bird, Wood, Lloyd, and Burnt Mill sinks (a geologic map based on the 2001 FGS Geologic Map of Florida is included in **Appendix C** to aid explanation of the ground water chemistry). Increased concentrations of dissolved oxygen are also indicative of relatively younger water (Hem 1992). The variable Nitrate is also included within this component; with elevated nitrate values present in the area where the semi-confining Torreya and Miccosukee Formations are frequently breached by sinks and swallets. Nitrate in ground water above natural concentrations is associated with anthropogenic sources such as onsite sewage disposal systems (OSDS), waste water treatment facilities, and fertilizer application.

Component II is primarily influenced by the variables Calcium, Chloride, Total Phosphorus, Orthophosphate, and Magnesium. Elevated Component II scores correspond with higher calcium and chloride values and lower phosphorus and magnesium values. As indicated in **Figure 9**, there is a clear gradient of increasing Component II values from north to south. The presence of magnesium in ground water indicates contact with dolomitized limestone (Hem 1992). The degree of dolomitization is represented by the magnesium/calcium ratio. The Suwannee Limestone is partially dolomitized through its entire thickness, while the St. Marks Formation has undergone only minor dolomitization. The St. Marks Formation is often partially unsaturated in the northern portion of the study area and, in the vicinity of lakes Iamonia and Miccosukee, has been removed by erosion and solution (Hendry and Sproul 1966). Therefore, the uppermost Floridan Aquifer transitions from Suwannee to predominantly St. Marks towards the south. Also, nearing the coast, the interface of the Floridan Aquifer with the underlying highly-mineralized waters approaches the land surface, manifested as increasing chloride concentrations (Pratt et al 1996). Reduced concentrations of phosphorus appear to be the result of removal of the phosphate containing clastics of the Torreya Formation south of the Cody Scarp.

Component III consists primarily of the variables Dissolved Oxygen, Sodium, Potassium, Fluoride, and Silica – all of which are inversely related to the component score. Areas with low Component III scores are located in the north-central region of the study area. Sodium, potassium, and silica are the products of the chemical weathering of the clays comprising the Torreya and Miccosukee Formations, mostly palygorskite and montmorillonite with minor amounts of sepiolite, illite and kaolinite (Scott 1988). As stated previously, elevated dissolved oxygen indicates relatively younger water. The water chemistry variability represented by this component is therefore indicative of increased local recharge to the Floridan Aquifer through the overlying semi-confining units.

Component IV is primarily influenced by two inversely related variables, Sulfate and Potassium. In the study area, sulfate (SO_4^-) may be associated with either connate water or the gypsiferous low permeability limestone forming the base of the upper Floridan Aquifer (Bush and Johnson 1988). The area of elevated sulfate in the north-central region of the study area corresponds with a low permeability gypsiferous semi-confining unit located in the Ocala Limestone (Miller 1986). Potassium, in this instance, appears to be associated with the chemical weathering of clastic silicates (Hem 1992) indicating the presence of the confining Miccosukee Formation. Beneath the Miccosukee and Torreya confining units, the transmissivity of the Floridan Aquifer declines (Miller 1986), therefore possibly increasing the stratigraphic heterogeneity of the aquifer. Lower Component IV scores appear to indicate increased transmissivity between the lower and upper areas of the Floridan Aquifer.

Figure 9 – Component Score Gradient Maps



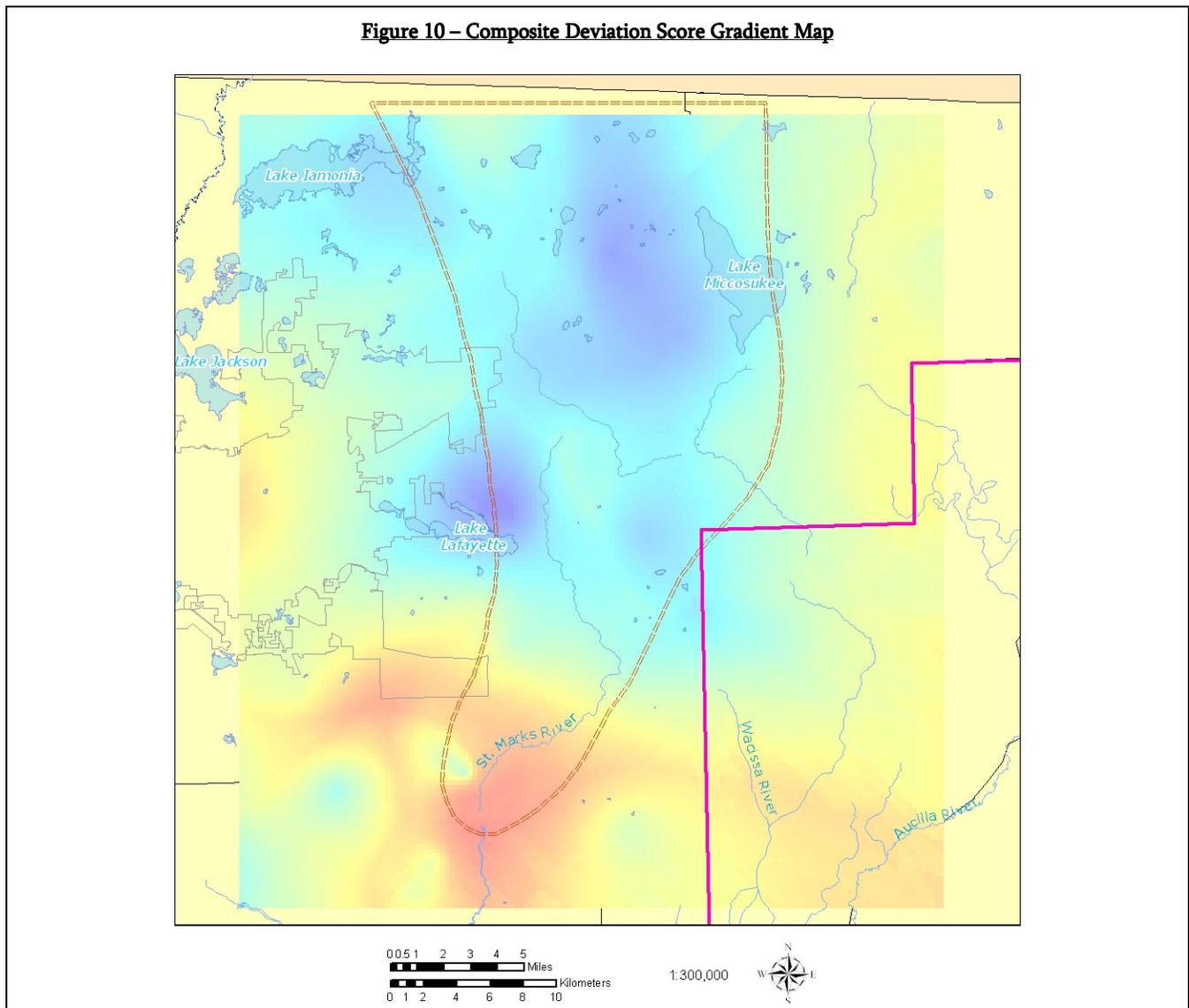
1:500,000



Component Score Deviation

Given that a spring discharges ground water from a discrete contribution area, it is logical to expect the spring's water chemistry to represent the aggregate mixing of ground water within its contribution area. Areas within the spring contribution zone with a chemical signature deviating significantly from the spring should therefore contribute less than areas with a chemical signature close to that of the spring. Of course, this assumes that changes in water chemistry during transport to the spring are minimal.

A graph of composite water chemistry within the spring basin can be thought of as a distribution curve with the spring's chemical fingerprint representing the mean value of the distribution. Under this ideal condition, the greater the deviation from the spring, the less mass an area can contribute to the spring without skewing the curve in one direction or another. In order to quantitatively express each sample location in terms of deviation from the spring's water quality, deviations from the St. Marks Rise component score were calculated by taking the absolute value of the component score minus the component score for the spring. The composite deviation score was then calculated by adding the weighted absolute component scores.

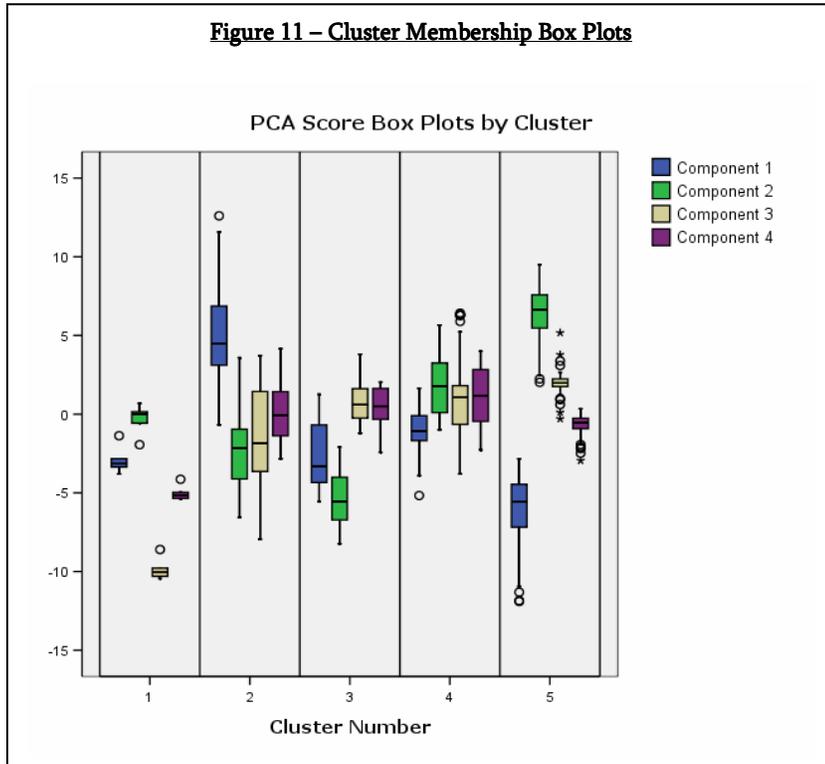


The results from the calculation of the composite deviation scores are presented in **Figure 9**. Areas within the figure that have a composite score closer to zero, therefore more similar to the spring in chemical composition, are represented with warm shades while those with higher scores gradually cool. In order for the spring's water chemistry to reflect the net contribution from within its basin, areas containing the dominant chemical signature influencing the spring's water chemistry must then represent the primary

contribution area within the spring basin. This core does not delineate the boundary of the spring contribution area; rather, it enhances the understanding of processes within the spring basin.

Hierarchical Cluster Analysis

Hierarchical cluster analysis has traditionally been used as an exploratory method to formulate an initial understanding of a dataset by grouping objects to form a structure that reveals the degree of similarity or dissimilarity between samples. In hydrological investigations, hierarchical clustering is used along with component or factor analysis to acquire a spatial understanding of the geochemical and/or anthropogenic processes influencing the chemical character of water throughout a study area.



Hierarchical clustering involves determination of similarity/dissimilarity by algorithms and linkage of groups once the degree of similarity is determined. The approach of the combined application of principal component analysis and hierarchical clustering has differed between various studies. The method of Suk and Lee (1999) appears to be the most applicable to the current study. Particular to hierarchical clustering, Suk and Lee utilized factor scores to complete the cluster analysis. The clustering was completed with the software SYSTAT 11 and involved the random sampling of 284 locations from the principle component score surfaces. The random locations were clustered using the Squared Euclidean distance determination and Ward’s linkage method, producing a structure that best organized the samples into clusters of common water type. The hierarchical structure resulted in the identification of five clusters. The box plots of principle component scores detailed in **Figure 11** illustrate the relative signatures for each cluster. Cluster locations are plotted in **Figure 12**.

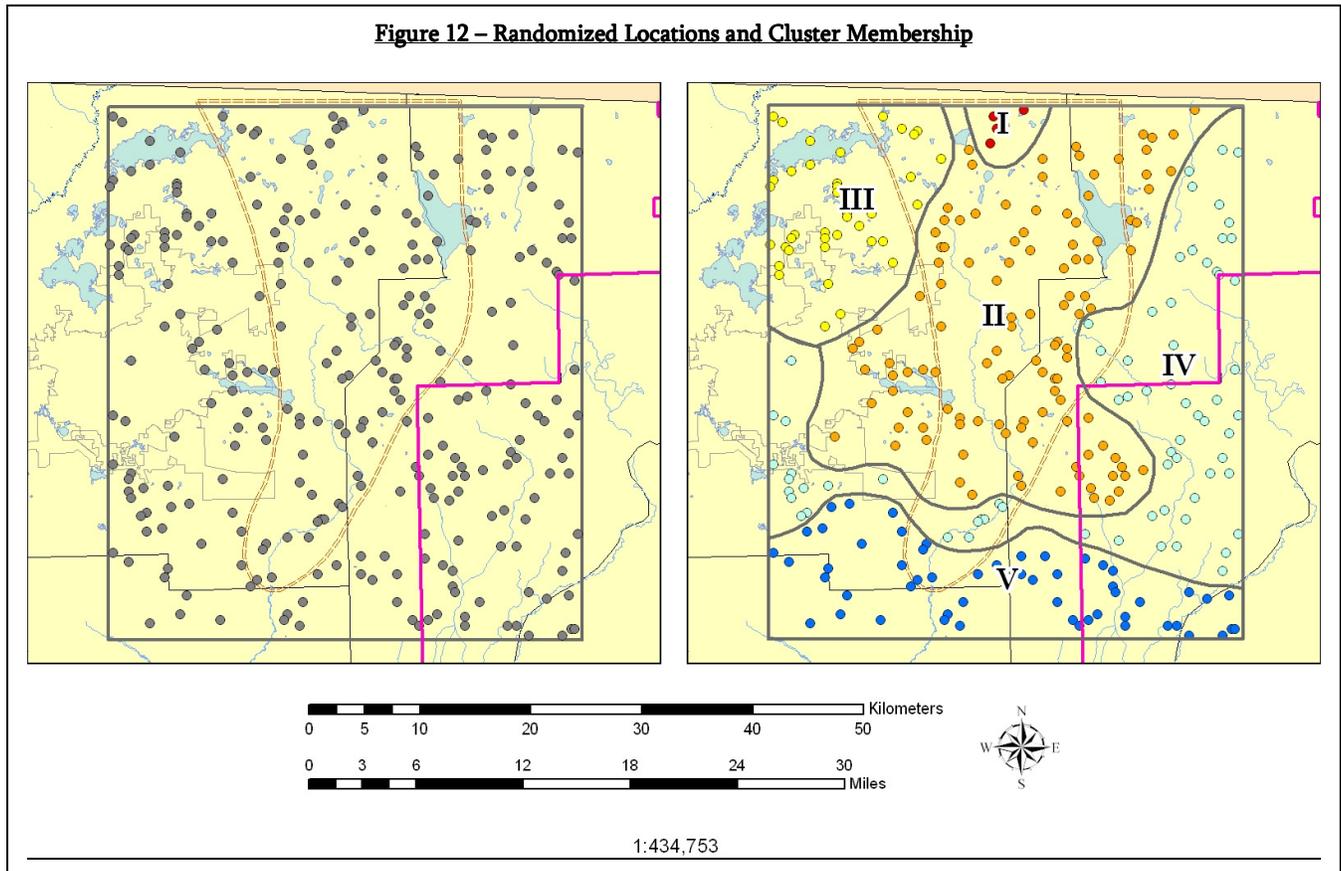
Cluster I is characterized by low Component 3 and 4 scores indicating increased transmissivity and more consistent overlying semi-confining units. This cluster displays moderately low scores for Component 1 which, based on the previous analysis of this component, indicates low recharge from surface drainage as well as reduced impact from anthropogenic sources. Component 2 scores are near midrange suggesting the Floridan Aquifer in this area has likely saturated both the Suwannee Limestone and St. Marks Formation.

Cluster II is characterized by elevated Component 1 scores – identifying the area as frequently breached by surface water drainage and under greater influence from anthropogenic activities. Because of the unconfined condition of the Floridan in this area the St. Marks formation may be partially unsaturated. Also, the St. Marks Formation is thin or missing in the vicinity of Lake Miccosukee. Both conditions resulting in an increased Suwannee Limestone signature and relatively low Component 2 score. The moderately low but wide ranging Component 3 scores for this cluster indicate a present but highly variable and frequently breached semi-confining unit. Component 4 scores for this cluster are near the mid-range indicating moderately high transmissivity.

Cluster III is represented by relatively low Component 1 scores, indicating low direct recharge through surface water drainage and relatively low impact from anthropogenic sources. Because the St. Marks Formation has been partially removed by solution in the Lake Iamonia and Lake Jackson areas, the low Component 2 scores represent the dominance of the Suwannee Limestone in the Floridan Aquifer carbonate chemistry. Slightly elevated scores for Components 3 and 4 represent a relatively less consistent confining unit and moderate transmissivity.

Cluster IV is characterized by slightly depressed Component 1 scores, indicating low recharge through surface water drainage and only a moderate impact from anthropogenic sources. Component 2 is elevated, indicating in increased St. Marks formation imprint on Floridan Aquifer carbonate chemistry. Component 3 is also slightly elevated, indicating variable confinement by the Torreya and Miccosukee Formations. Of all the clusters, Cluster IV possesses the highest Component 4 scores, indicating relatively low transmissivity.

As apparent in **Figure 12**, Cluster V is positioned south of the Cody Escarpment and represents the transition of the Floridan Aquifer to the Woodville Karst Plain. Cluster V is characterized by very low Component 1 scores, indicating minimal direct recharge from surface drainage. Because of the high permeability of the surface sediments in the area there is little chance for surface drainage to form. The high Component 2 scores represent the increased influence of the St. Marks Formation on the carbonate chemistry of the Floridan Aquifer. Elevated Component 3 scores indicate a very thin or absent confining system, reflected by the absence of the Torreya and Miccosukee formations. The low Component 4 scores indicate increased transmissivity.



The majority of the St. Marks Rise ground water contribution basin is located within the area identified with a Cluster II ground water signature. This same area is associated with markedly elevated Component I scores, indicating elevated local recharge. Because of the relatively narrow ground water basin for the St. Marks Rise compared to other first magnitude springs, it can be concluded that recharge in the basin must be high to support the volume of discharge. The rapid transition of composite water chemistry (**Figure 10**) towards similarity with the St. Marks Rise water chemistry and coinciding with the Woodville Karst Plain boundary is indicative of a facies shift from an area of ground water recharge to an area of probable discharge. Also, wells located above the Cody Escarpment are more likely to be placed within the upper regimes of the Floridan Aquifer flow system and thus are more likely to possess a younger, recharge-type signature and miss the deeper and older ground water passing below. Proceeding towards the Gulf of Mexico, the lower mineralized lens of fresh water comprising the potable portion of the aquifer thins – resulting in wells capturing a mixed water chemistry signature of older ground water from up-gradient recharge and local recharge through the highly permeable overlying sediments.

Conclusion

1. The principle component analysis of the St. Marks Rise Chemical Characterization water quality data resulted in the distillation of four components in each basin explaining the majority of the variance within the sample population.
2. The principle components appear to represent understood physiographic, stratigraphic, and anthropogenic influences upon the chemical composition of the Floridan Aquifer within the spring basin.
3. The primary contribution area for the St. Marks Rise, as defined by the composite deviation score, coincides with established spring basin boundaries and ground water flow directions.
4. The primary contribution area is useful in understanding the dynamics within the spring basin and complements the development of a spring basin boundary or springshed.
5. The Squared Euclidian distance determination and the Ward's linkage method produced clusters whose individual samples share common chemical character and have a common spatial relationship. The mapped clusters serve as a composite view of the water types as determined by the four components.
6. The area represented by Cluster II is sensitive to contamination of the Floridan Aquifer due to 1) concentration and volume of direct recharge to the Floridan Aquifer through surface drainage, 2) an inconsistent and frequently breached semi-confining unit, and 3) expansion to the east of urban/suburban land use and increasing population density.
7. The use of principle component analysis and hierarchical cluster analysis in their interpretation of spring basin ground water chemistry assumes that samples from individual wells are representative of the ground water chemistry in the vicinity of the well and that isolated land use impacts are not great enough to cause the chemistry to deviate significantly from surrounding conditions.

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Appendix A: Table 3 – Well Location and Construction Data

NWF ID	State ID	Site ID	Site Name	Latitude (ddmsss.sss)	Longitude (ddmsss.sss)	Location Datum	Land Surface Elevation (ft)	Elevation Datum	Depth of Well (ft)	Depth of Casing (ft)	Well Diameter (inches)
728	AAA6522	301337084204001	SANDY CAMPBELL	301335.989	842039.067	WGS84	18.32	NGVD29	75	36	4
749		301405084181001	WAKULLA SPRING MAIN VENT	301405.240	841805.290	WGS84	6.5	NGVD29	Spring Vent		
900	AAA0296	301725084122601	WALTER GERREL	301725.620	841227.070	WGS84	29.34	NGVD29	70	40	4
1003	AAA0262	301857084180401	KENT SPRIGGS	301857.520	841804.010	WGS84	25.04	NGVD29	148	110	4
1007	AAA3055	301900084141801	TALLAHASSEE #34	301859.579	841419.674	WGS84	35	NGVD29	200	122	14
1204	AAA0281	302109084154701	NFWWMD-BIKE TRAIL	302110.735	841542.997	WGS84	37.33	NGVD29	90	80	4
1296	AAE0502	302143084031201	ROGER TWITCHELL	302148.766	840309.370	WGS84	37	NGVD29	75	60	4
1358	AAE5954	302213083581102	WACISSA TOWER	302212.945	835811.013	WGS84	182	NGVD29	260	126	4
1848		302411084243801	SILVER LAKE	302411.270	842438.710	WGS84	90	NGVD29	202	63	6
1904	AAA5356	302423084193801	LAKE BRADFORD TRL PK	302423.000	841938.000	WGS84	72	NGVD29	170	137	6
2137	AAA0249	302522084224001	NFWWMD-BRADFORD BROOK DEEP	302521.560	842239.050	WGS84	45.76	NGVD29	140	133	4
2461	AAF4635	302621084305201	FT. BRADEN #2	302621.000	843052.000	WGS84	150	NGVD29	328	187	6
2619	AAE1367	302655084073001	GAY	302655.000	840730.000	WGS84	125	NGVD29	167	74	4
3340	AAA6954	303109084275403	NFWWMD-HQ FLORIDAN OBS	303106.497	842749.134	WGS84	200.06	NGVD29	356	232	4
3402	AAA0283	303142084214601	USGS-LAKE JACKSON FLORIDAN	303141.510	842145.850	WGS84	122.2	NGVD29	225	100	6
3489	AAA0285	303216084005201	JERRY LACKEY	303222.770	840053.315	WGS84	164.3	NGVD29	158	99	4
3785	AAA0377	303418084444701	GREENSBORO #3	303417.032	844447.890	WGS84	275.26	NGVD29	420	264	6
3890	AAF4639	303459084141402	TEC-KILLEARN LAKES #2	303626.678	841421.716	WGS84	210	NGVD29	350	260	12
3920	AAF4641	303510084090401	TEC-BAKER	303510.509	840904.966	WGS84	180	NGVD29	340	232	12
3925	AAE1368	303514084241701	EDWIN HERRING	303514.000	842417.000	WGS84	150	NGVD29	250	169	4
3999	AAA0284	303539084023401	TEC-MICCOSSKEE	303537.337	840233.830	WGS84	214	NGVD29	320	224	6
4125	AAA7687	303632084313401	TEC-#5-ST HEBRON	303631.818	843133.735	WGS84	253	NGVD29	465	210	6
4251	AAF8099	3037360833595201	ERETHA ISOM	303737.668	835955.115	WGS84	142	NGVD29	160	120	4
4451	AAA0232	303931084362401	ST JOHNS ELEM SCHOOL	303931.030	843624.250	WGS84	297.57	NGVD29	426	283	6
5851	AAA3156	302847084190502	TALLAHASSEE #26	302847.275	841903.349	WGS84	135	NGVD29	407	309	24
6047	AAA7690	303435084232301	TEC-#11-OAK GROVE	304122.574	844343.315	WGS84	289	NGVD29	469	331	12
6135	AAB2409	301712084211401	AVERY SCOTT	301714.090	842115.900	WGS84	24.05	NGVD29	28	22	4
7495	AAB2440	301448084184601	NFWWMD-NITRATE #4	301448.235	841846.882	WGS84	13.46	NGVD29	70	50	4
7498	AAB2441	302037084082701	NFWWMD-NITRATE #5	302037.881	840827.329	WGS84	28.56	NGVD29	270	253	4
7938		301909084074401	HORN SPRING/S445	301909.340	840743.710	WGS84	15.2	NGVD29	Spring Vent		
7943		301633084085601	ST MARKS RIVER RISE	301633.755	840855.936	WGS84	8	NGVD29	Spring Vent		
8036	AAE0518	301624084032401	JAMES BRUMBLEY	301619.969	840323.038	WGS84	33	NGVD29	58	21	4
8418	AAG8894	301532084103701	WAKULLA CORRECTIONAL INST.#1	301532.737	841037.492	WGS84	19.31	NGVD29	160	103	4
8419	AAG8893	301818084093201	NFWWMD-OLD PLANK #1	301818.033	840931.271	WGS84	20	NGVD29	160	100	4
8807	AAA3059	301710084090501	NATURAL BRIDGE REC. AREA	301703.719	840909.048	WGS84	25.4	NGVD29	70	42	4
8943		301757084232301	R. SCOTT	301757.840	842323.280	WGS84	52	NGVD29	65	48	4
8976	AAB1903	302527084120001	C.B. HUGGINS	302527.360	841200.720	WGS84	140	NGVD29	275	170	4
8977	AAB1887	301545084144901	D. BURNS	301546.084	841449.352	WGS84	30	NGVD29	90	42	4
9074		301728084141001	NATURAL WELLS	301754.110	841414.880	WGS84	10	NGVD29	Karst Window		
9227	AAF8826	3034020835059	CHARLES FRICK	303402.324	835059.658	WGS84	172	NGVD29	185	130	4
9230	AAF8785	303404083520201	WILLIAM BECKER	303404.013	835203.474	WGS84	162	NGVD29	200	165	4

NWF ID	State ID	Site ID	Site Name	Latitude (ddmmss)	Longitude (ddmmss)	Location Datum	Land Surface Elevation (ft)	Elevation Datum	Depth of Well (ft)	Depth of Casing (ft)	Well Diameter (inches)
9231	AAG8398	303122083535401	DAN LEDFORD	303124.758	835355.274	WGS84	121	NGVD29	220	159	4
9232	AAF8669	303110083563101	GORDON MCCLEERY	303110.520	835634.040	WGS84	147	NGVD29	200	98	5
9233	AAD9925	303045084044601	BO KELLY	303045.798	840446.026	WGS84	121.6	NGVD29	160	99	4
9234	AAB1039	303244084082401	PETER MCGINNIS	303229.324	840830.734	WGS84	134.9	NGVD29	215	125	4
9235	AAD8704	303216084085001	WAYNE ASHLEY	303215.892	840850.814	WGS84	151.1	NGVD29	180	100	4
9239	AAI8181	302728083523701	JIM TULLEY	302728.560	835237.691	WGS84	169	NGVD29	220	167	4
9240	AAI5538	302330084003401	AMY BROWN	302330.609	840034.234	WGS84	189	NGVD29	240	156	5
9241	AAD8654	302330084084901	KEDRA BAUMGARDNER	302330.556	840849.949	WGS84	84.2	NGVD29	160	110	4
9242	AAE0586	302036084133401	TINA MAZANEK	302016.812	841239.681	WGS84	27.4	NGVD29	100	94	4
9243	AAE0587	303842084121801	JAMES HENDRICKS	303841.155	841218.298	WGS84	106.4	NGVD29	200	160	4
9244		303844084070001	WILLIAM OUTLAW	303839.831	841700.463	WGS84	149.2	NGVD29	200	120	4
9245	AAA8935	303941084005001	LOVERIDGE PLANTATION	303941.802	840411.855	WGS84	156	NGVD29	280	139	6
9246	AAF8758	303637084062701	EDWARD KNOWLES	303638.005	840628.743	WGS84	143.1	NGVD29	180	135	4
9247	AAF8673	303534084031301	KENNETH HUNGERFORD	303534.942	840314.013	WGS84	243.9	NGVD29	280	164	4
9248	AAI5244	303510084032801	GLEN HOLLIS	303509.976	840328.800	WGS84	212.7	NGVD29	232	191	4
9249	AAE0008	303629084055701	NELL STAGER	303629.752	840557.501	WGS84	183.9	NGVD29	260	194	4
9250	AAF8786	303218083562201	SALLY MANN	303218.848	835622.600	WGS84	130	NGVD29	205	120	4
9251	AAF8100	302900083592401	BEAR PAW FARM	302900.132	835924.373	WGS84	135	NGVD29	180	80	4
9252	AAI5536	302409084020601	MARK JEFFERY	302409.790	840206.718	WGS84	128	NGVD29	210	120	4
9253	AAB1044	302835084103801	KENNETH HAYES	302835.657	841038.673	WGS84	114.4	NGVD29	120	80	4
9254	AAB2563	302706084082201	RON GILLEY	302706.437	840822.323	WGS84	106.5	NGVD29	175	115	4
9255	AAD8691	302755084043201	RAY WATKINS	302755.623	840432.048	WGS84	74.3	NGVD29	120	60	4
9256		302023083592901	WACISSA SPRING #2	302023.666	835929.301	WGS84	32	NGVD29	Spring Vent		
9259	AAG8301	302228084072401	NORMAN CARPENTER	302228.017	840724.599	WGS84	112.4	NGVD29	155	100	4
9261	AAA7737	302552084023001	CHRIS BROOKS	302552.078	840230.759	WGS84	140	NGVD29	200	101	4
9331		301712084093501	RHODES SPRING #2B	301712.040	840935.361	WGS84	15	NGVD29	Karst Window		

Appendix B: Table 4 – Field and Laboratory Results

NWF ID	Collection Date	Water Temperature (Celsius)	Specific Conductance (µS/cm)	Oxygen, Dissolved, Field	pH (standard units)	Alkalinity, Total (as CaCO3)	Ammonia, Total (as N)	Ammonia+Organic Nitrogen, Total (as N)	Nitrate+Nitrite, Total (as N)	Phosphorus, Total (as P)	Orthophosphate Dissolved (as P)	Organic Carbon, Total	Calcium, Total	Magnesium, Total	Sodium, Total	Potassium, Total	Chloride, Total	Sulfate, Total	Fluoride, Total	Silica, Total	Iron, Total	Total Dissolved Solids (TDS measured)
9241	10/4/2005	20.7	311	3.26	7.3	133	0.010 U	0.060 U	0.390	0.040	0.040	1.4	45.1	12.0	4.00	0.53	5.3	17.00	0.20	14.0	0.067	171
1296	10/4/2005	22.0	247	0.69	7.3	113	0.010 U	0.060 U	0.130	0.045	0.039	1.0 U	45.1	3.3	2.50	0.66	4.3	5.20	0.09	9.3	0.034	140
9074	10/4/2005					232	0.010 U	0.082	1.300	0.017	0.011	1.0 U	62.9	24.2	5.10	0.47	7.2	7.80	0.18	10.0	0.010 U	255
9242	10/4/2005	21.1	311	0.23	7.1	147	0.040	0.066	0.059	0.026	0.021	1.0 U	53.6	6.6	3.60	0.50	5.5	4.50	0.13	11.0	0.451	164
9235	10/5/2005	21.4	297	6.16	7.3	127	0.010 U	0.120	0.460	0.035	0.030	1.0 U	39.8	11.1	3.19	0.43	4.3	15.00	0.18	14.0	0.005 U	155
9234	10/5/2005	21.0	286	6.12	7.5	121	0.010 U	0.120	0.320	0.029	0.026	1.0 U	36.4	11.8	3.41	0.45	4.3	18.00	0.19	14.0	0.011	151
9240	10/5/2005	21.0	211	9.99	7.5	102	0.010 U	0.120	0.200	0.016	0.008	1.0 U	29.6	6.3	2.54	0.55	3.7	0.72	0.28	23.0	0.052	137
9230	10/12/2005	20.9	285	2.61	7.5	133	0.010 U	0.060 U	0.440	0.041	0.035	1.0 U	47.7	6.4	2.77	0.44	4.4	3.50	0.12	13.0	0.296	141
9227	10/12/2005	21.0	289	2.64	7.5	134	0.010 U	0.060 U	0.500	0.043	0.039	1.0 U	47.9	6.4	2.78	0.45	4.4	3.60	0.13	13.0	0.012	145
9231	10/12/2005	21.0	296	0.85	7.4	143	0.010 U	0.060 U	0.030	0.036	0.030	1.0 U	49.7	6.7	2.66	0.43	3.9	1.40	0.14	13.0	0.199	144
9239	10/12/2005	20.5	354	0.77	7.3	173	0.010 U	0.060 U	0.011	0.037	0.026	1.0 U	61.7	9.3	3.31	0.81	4.7	3.00	0.17	15.0	0.946	171
9233	10/13/2005	21.1	266	7.70	7.7	107	0.010 U	0.060 U	0.580	0.019	0.016	1.0 U	35.2	9.8	3.73	0.56	4.6	16.00	0.20	14.0	0.110	139
9232	10/13/2005	21.1	268	5.79	7.5	122	0.010 U	0.060 U	0.340	0.017	0.017	1.0 U	39.1	8.7	3.29	0.43	4.9	5.20	0.18	16.0	0.005 U	141
9245	10/19/2005	20.7	369	5.74	7.3	134	0.010 U	0.160	0.220	0.035	0.022	1.0 U	45.0	14.9	6.16	0.70	7.2	45.00	0.24	17.0	0.014	217
9243	10/19/2005	20.8	228	0.21	7.3	108	0.120	0.180	0.004 U	0.110	0.092	2.4	37.3	3.6	2.28	0.39	4.5	0.20 U	0.13	8.4	0.769	136
9244	10/19/2005	20.9	288	6.94	7.2	140	0.010 U	0.160	0.540	0.052	0.040	1.0 U	34.6	14.2	2.57	0.49	4.7	0.51	0.18	16.0	0.136	161
4251	10/20/2005	21.0	277	7.08	7.3	126	0.010 U	0.080	0.490	0.019	0.014	1.0 U	38.6	9.2	3.02	0.41	4.9	6.90	0.19	16.0	0.246	162
9247	10/20/2005	21.6	266	7.95	7.5	112	0.010 U	0.080	0.120	0.015	0.014	1.0 U	31.1	12.1	4.12	0.65	4.7	19.00	0.35	25.0	0.006	173
9248	10/20/2005	21.5	195	8.71	7.6	95	0.010 U	0.080	0.069	0.018	0.017	1.0 U	23.1	8.9	2.63	0.79	3.3	0.65	0.33	36.0	0.120	138
9246	10/20/2005	20.8	281	5.64	7.2	125	0.010 U	0.080	0.250	0.034	0.042	1.0 U	38.7	10.7	2.34	0.38	3.6	11.00	0.17	14.0	0.035	163
9249	10/26/2005	20.9	314	7.18	7.3	125	0.010 U	0.160	0.260	0.032	0.034	1.0 U	42.4	12.7	4.50	0.55	5.1	24.00	0.19	15.0	0.284	180
9250	10/26/2005	20.4	274	6.37	7.4	125	0.010 U	0.160	0.460	0.017	0.019	1.0 U	41.7	8.5	3.39	0.43	4.9	4.60	0.16	16.0	0.005 U	152
9251	10/26/2005	20.2	374	3.61	7.2	184	0.010 U	0.160	0.300	0.038	0.056	1.0 U	64.2	9.1	2.87	0.50	4.9	1.30	0.20	18.0	0.005 U	211
9252	10/26/2005	21.0	279	1.27	7.3	131	0.010 U	0.160	0.011	0.024	0.024	1.0 U	40.7	9.9	3.56	0.74	4.3	4.40	0.22	19.0	0.071	156
9253	10/27/2005	21.0	274	6.14	7.4	121	0.010 U	0.080	0.680	0.050	0.049	1.0 U	38.1	11.9	3.16	0.43	4.5	11.00	0.17	14.0	0.065	149
9254	10/27/2005	20.9	183	8.22	7.6	81	0.010 U	0.080	1.400	0.029	0.032	1.0 U	31.7	3.1	2.22	0.44	4.2	0.20 U	0.11	12.0	0.008	102
3489	10/27/2005	21.4	201	7.24	7.6	94	0.010 U	0.080	0.410	0.011	0.013	1.0 U	28.3	8.0	2.76	0.58	4.2	2.80	0.22	16.0	0.031	103
1358	10/27/2005	21.1	227	8.39	7.5	103	0.010 U	0.080	1.300	0.025	0.025	1.0 U	42.0	2.0	3.58	0.37	5.1	0.34	0.10	14.0	0.081	128
9255	10/27/2005	20.1	264	7.10	7.4	122	0.010 U	0.080	0.170	0.120	0.110	1.1	34.8	13.2	3.91	0.68	6.4	6.20	0.23	7.7	0.490	142
7943	11/1/2005	20.1	286	1.99	7.5	128	0.010 U	0.096	0.200	0.049	0.038	1.0 U	43.7	8.5	3.52	0.47	5.4	8.00	0.15	13.0	0.031	146
9331	11/1/2005	20.7	294	0.21	7.5	127	0.010 U	0.150	0.220	0.045	0.041	1.0 U	43.7	8.9	3.64	0.50	5.4	9.80	0.16	13.0	0.035	154
9256	11/1/2005	20.6	280	2.92	7.6	129	0.010 U	0.860	0.410	0.036	0.030	1.0 U	42.6	8.5	3.28	0.41	5.5	5.20	0.15	14.0	0.023	154
7498	11/3/2005	21.3	293	0.47	7.0	131	0.010 U	0.160	0.086	0.032	0.027	1.4	45.6	8.3	3.34	0.51	5.0	12.00	0.16	12.0	0.069	160
8036	11/3/2005	22.4	381	0.24	6.8	183	0.054	0.098	0.520	0.012	0.007	1.9	76.0	2.4	2.82	0.52	5.7	2.40	0.16	20.0	0.084	218

U = Not Detected - Value Given is Detection Limit

Blank = Analysis Not Performed

Unless otherwise specified, data is reported in milligrams per liter

NWF ID	Collection Date	Water Temperature (Celsius)	Specific Conductance (µS/cm)	Oxygen, Dissolved, Field	pH (standard units)	Alkalinity, Total (as CaCO3)	Ammonia, Total (as N)	Ammonia+Organic Nitrogen, Total (as N)	Nitrate+Nitrite, Total (as N)	Phosphorus, Total (as P)	Orthophosphate Dissolved (as P)	Organic Carbon, Total	Calcium, Total	Magnesium, Total	Sodium, Total	Potassium, Total	Chloride, Total	Sulfate, Total	Fluoride, Total	Silica, Total	Iron, Total	Total Dissolved Solids (TDS measured)
8419	11/3/2005	20.6	298	0.31	7.0	137	0.047	0.190	0.004 U	0.051	0.043	3.6	47.8	7.7	3.35	0.52	5.1	6.70	0.16	13.0	3.720	176
9259	11/3/2005	20.8	209	4.13	7.7	91	0.010 U	0.080	0.480	0.043	0.036	1.0 U	31.4	6.4	2.77	0.35	3.9	6.80	0.14	12.0	0.084	111
8807	11/3/2005	20.7	317	2.32	7.0	150	0.010 U	0.080	0.220	0.032	0.023	1.0 U	62.0	1.2	3.12	0.52	5.0	3.80	0.05 U	6.8	0.071	165
8418	11/3/2005	21.1	289	0.03	7.3	129	0.010 U	0.080	0.130	0.041	0.034	1.1	44.5	8.8	3.61	0.50	5.6	10.00	0.16	12.0	2.690	155
749	11/18/2005	19.2	310	1.18	7.5	131	0.010 U	0.160	0.580	0.016	0.008	1.0 U	46.3	10.8	5.71	0.56	7.8	10.00	0.14	10.0	0.006	166
7938	12/14/2005	20.0	270	2.01	7.6	118	0.010 U	0.160	0.290	0.048	0.044	2.5	40.0	9.1	3.82	0.52	5.8	11.00	0.16	13.0	0.062	136
9261	12/22/2005	21.2	247	7.69	7.7	121	0.010 U	0.080	0.360	0.021	0.011	1.0 U	39.2	7.5	2.57	0.73	3.1	0.51	0.22	21.0	0.045	139
728	10/25/2004	23.1	371	4.38	7.0	186	0.010 U	0.072	0.910	0.022	0.026		70.2	2.0	1.69	0.85	2.4	5.40	0.13			193
900	10/28/2004	20.7	334	2.81	7.2	158	0.010 U	0.060 U	0.480	0.014	0.015		52.3	8.8	3.66	0.54	5.9	9.50	0.19			181
965	10/25/2004	21.1	390	0.04	6.9	201	0.400	0.450	0.004 U	0.120	0.120		72.4	2.5	3.64	0.89	3.0	0.20 U	0.16			224
1003	10/28/2004	21.5	241	2.77	7.3	118	0.062	0.076	0.009	0.010	0.013		47.5	1.0	1.97	0.31	2.8	4.90	0.06			132
1007	12/1/2004	20.7	354	3.35	7.2	166	0.010 U	0.060 U	0.780	0.031	0.029		44.0	14.5	3.84	0.42	6.0	8.20	0.19			180
1204	11/17/2004	21.6	229	4.88	7.5	106	0.010 U	0.060 U	0.380	0.018	0.018		32.8	6.3	2.38	0.34	4.3	4.60	0.10			135
1848	11/18/2004	19.9	217	1.51	6.8	106	0.027	0.060 U	0.005	0.030	0.025		36.6	3.8	1.51	0.22	2.6	1.20	0.07			125
1904	11/17/2004	21.7	278	3.36	7.4	132	0.010 U	0.060 U	0.320	0.016	0.013		45.2	5.5	2.98	0.30	5.8	2.20	0.07			154
2137	11/9/2004	21.2	322	0.18	7.0	145	0.080	0.100	0.007	0.034	0.025		42.3	19.2	5.33	1.00	8.8	14.00	0.17			189
2461	11/18/2004	22.3	288	3.09	7.4	149	0.120	0.150	0.004 U	0.013	0.012		46.2	6.8	4.00	0.72	1.9	0.20 U	0.23			169
2619	11/23/2004	21.5	187	6.20	7.7	80	0.010 U	0.060 U	1.400	0.036	0.034		24.4	5.7	3.38	0.23	5.8	0.20 U	0.16			79
3340	11/16/2004	23.9	300	0.14	7.5	145	0.010 U	0.060 U	0.004 U	0.017	0.011		32.7	14.6	4.10	1.50	3.3	7.80	0.35			156
3402	11/9/2004	22.0	283	2.44	7.2	142	0.010 U	0.060 U	0.240	0.017	0.016		35.3	14.3	2.38	0.88	3.2	2.00	0.22			154
3785	11/17/2004	22.4	267	3.89	7.7	126	0.039	0.060 U	0.004 U	0.004 U	0.004 U		29.1	11.3	7.53	2.00	2.5	10.00	0.47			153
3890	11/16/2004	20.8	380	3.14	6.9	195	0.010 U	0.060 U	0.210	0.056	0.057		57.2	11.2	2.19	0.38	3.7	1.20	0.16			225
3920	11/16/2004	20.8	267	7.98	7.1	126	0.010 U	0.060 U	0.240	0.042	0.039		35.7	10.1	2.05	0.33	3.8	7.80	0.18			152
3925	11/23/2004	21.0	308	0.69	7.4	155	0.049	0.060 U	0.009	0.010	0.007		40.9	13.1	3.07	0.81	2.8	3.70	0.29			146
3999	11/16/2004	20.8	314	6.82	7.0	128	0.010 U	0.060 U	0.520	0.047	0.038		40.6	10.9	4.30	0.51	6.3	23.00	0.24			177
4125	11/15/2004	22.7	273	0.25	7.4	127	0.022	0.060 U	0.004 U	0.004 U	0.004 U		29.0	14.1	5.09	2.30	2.6	11.00	0.57			151
4451	11/17/2004	22.6	311	1.81	7.5	153	0.010 U7	0.060 U	0.004 U	0.004 U	0.004 U		30.4	16.8	7.41	2.40	2.8	8.30	0.46			168
5851	12/1/2004	21.2	307	1.01	7.2	143	0.063	0.067	0.024	0.053	0.047		43.2	8.3	4.13	0.45	7.6	4.10	0.20			128
6047	11/15/2004	22.0	261	6.60	7.4	128	0.010 U	0.060 U	0.310	0.011	0.011		34.2	11.6	2.76	0.50	3.5	2.10	0.17			159
6135	10/28/2004	22.5	443	4.93	6.8	193	0.010 U	0.060 U	0.850	0.008	0.006		88.0	1.6	5.22	0.57	20.0	8.20	0.06			267
7495	10/28/2004	20.4	379	0.10	7.0	192	0.047	0.068	0.004 U	0.016	0.016		73.6	4.1	2.52	1.10	4.2	2.50	0.11			203
8976	11/23/2004	20.2	227	6.26	7.5	104	0.010 U	0.060 U	0.600	0.031	0.030		29.6	8.0	2.48	0.46	4.3	4.00	0.19			97
8977	11/22/2004	20.2	367	7.41	6.9	182	0.010 U	0.060 U	0.400	0.006	0.004 U		69.1	5.2	2.54	0.26	4.0	4.80	0.10			210

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Appendix C: Figure 13 – Geologic Map of Study Area

Basemap modified from Scott, T.M. et al. "Geologic Map of the State of Florida", Florida Geological Survey, Map Series 146, 2001.

