Jackson Blue Spring

Water Resources Assessment 11-01

Northwest Florida Water Management District
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Havana, Florida 32333-4712

June 2011

Jackson Blue Spring

Water Resources Assessment

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NORTHWEST FLORIDA WATER MANAGEMENT DISTRICT

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Cover photo credit: ***Jackson Blue Spring*** by J. Patrick Casey

Introduction

Jackson Blue is a first magnitude spring located in Jackson County, Florida within the Apalachicola River Basin (**Figure 1**). The Jackson Blue springshed encompasses approximately 130 square miles and extends into southern Alabama. The springshed is located within the Marianna Lowlands physiographic province, which is characterized by gently rolling hills and numerous karst features such as sinkholes, springs, and limestone outcroppings. Land surface elevations in the springshed range from approximately 90 to 190 ft. NAVD 88 (**Figure 2**).

Jackson Blue and several other smaller springs are located in the 270-acre Merritt's Mill pond and contribute flow into the pond. The water level in Merritt's Mill Pond is managed by a water control structure located at the southern end of the pond along US 90/SR 71. Outflow from Merritt's Mill Pond provides the majority of the flow in Spring Creek, which flows into the Chipola River. The Chipola is the largest tributary in Florida to the Apalachicola River.

Since the surficial and intermediate aquifers are, for the most part, absent in the upper reach of the Chipola River, baseflow is primarily determined by discharge from the Floridan Aquifer. The Chipola River receives discharge from over sixty-three Floridan Aquifer springs, including Jackson Blue Spring. Cumulatively Jackson Blue Spring and all the other springs which discharge into the upper reaches of the Chipola River comprise the majority of its baseflow.

Because it is a first magnitude spring, Jackson Blue Spring is on the Northwest Florida Water Management District's Priority List for the establishment of Minimum Flows and Levels. Based on the current schedule, Jackson Blue Spring will be evaluated in 2012. This assessment characterizes the Jackson Blue Spring basin and Merritt's Mill Pond system and summarizes ongoing District activities to monitor and evaluate the water resources and water supply availability within the springshed.

Hydrogeology

Jackson Blue Spring is located within the Dougherty Karst Plain which encompasses the northern portions of Bay and Calhoun counties, all of Jackson County and the majority of Washington and Holmes counties. In this region, the Floridan Aquifer is recharged through the overlying Intermediate System and discharges to springs and rivers. The rate of recharge has been estimated at 12 to 18 inches per year overall for the spring basin. Given the near absence of surface drainage in the basin, this amount is essentially the remainder of precipitation after accounting for evapotranspiration. The semi-confined condition of the Floridan Aquifer across the Dougherty Karst Plain allows for large amounts of local recharge, but also makes the Floridan Aquifer especially vulnerable to contamination from activities occurring on the land surface.

In Jackson County, the Floridan Aquifer is comprised of the Chattahoochee Formation, the undifferentiated Marianna/Suwannee Limestone, and the Ocala Limestone (Scott, 1993; Campbell, 1993). The region is characterized by a thin, generally less than 50-ft thick Intermediate System confining unit that is often absent or breached by sinkholes. The Floridan Aquifer itself is relatively thin, with a thickness of approximately 100 feet in north Jackson County, where it is composed only of the Ocala Limestone (Moore 1955). Continuing south to the Jackson County – Calhoun County line, the Floridan Aquifer thickens to approximately 500 feet with the occurrence of the younger limestone formations (Pratt et al. 1996)

Figure 1. Location of the Jackson Blue Springshed within the Apalachicola River Basin

Springshed Delineation

Hydrogeologic investigations have previously delineated a ground water contribution area for Jackson Blue Spring of an approximate tear-drop shape that extends just north of the Florida-Alabama state line (Chelette, et al. 2002, and Jones and Torak 2004). This springshed delineation relied principally on land surface elevations derived from USGS topographic maps.

In 2007, the District completed a refinement of the Jackson Blue Springshed (**Figure 2**) with the goal of improving vertical accuracy to approximately one foot, allowing for an improved understanding of ground water flow directions within the study area. To this end, land surface elevations were determined utilizing both instrument survey and LiDAR (Light Detection and Ranging) elevation models. A total of seventy-seven observation, domestic and public supply wells were used as measurement locations to determine the depth of water. Water measurements were conducted with an electronic water level indicator or steel tape, both with a measurement accuracy of 0.01-foot. The water level measurements were combined with land surface elevation data to arrive at the elevation (in MSL, NAVD) of the Floridan Aquifer potentiometric surface. **Figure 3** shows the refined Floridan Aquifer Potentiometric surface map. In March 2007, potentiometric surface elevations in the Jackson Blue Springshed ranged from 77 to 111. The refined springshed delineation was based on this potentiometric surface map as well as on other figures contained within this assessment. Spring basins are variable in nature due to changes in rainfall, hydraulic head levels, and ground water pumpage; therefore the springshed represents only a snapshot of conditions in March 2007. Further refinements are likely to occur as additional data are collected and more detailed technical analyses are completed.

Rainfall

The District is currently operating one rainfall gauge in the vicinity of the Jackson Blue Spring ground water basin. In addition, the National Weather Service (NWS) operates a rainfall station at the Marianna Municipal Airport. The District also has gauge-adjusted radar rainfall data available for the region as monthly and daily totals. The closest long-term annual rainfall total data for Jackson County is located at the Chipley NWS station. Based on the average of observations at the NWS Marianna station from 1971-2000, the mean annual rainfall total is 58.2 inches. Typically 38 percent of the annual rainfall occurs during the summer rainy season from June through September. May and October are typically the driest months.

Spring Discharge

Actual discharge measurements at Jackson Blue Spring range from a low of 28.1 cubic feet per second (cfs) in September 2007 to a high of 305 cfs in April 2003. The gaged average discharge at Jackson Blue Spring is 126 cfs based on the available water level record measured continuously since 2003 through 2010 at the NWFWMD Pittman monitoring well using the method described below.

District staff measures the discharge at Jackson Blue Spring and the discharge downstream of the Merritt's Mill Pond impoundment on Spring Creek quarterly. The difference between the two measurements represents the additional discharge contributed to Merritt's Mill Pond from other sources in the system than Jackson Blue Spring. These additional flow contribution sources are primarily smaller springs within Merritt's Mill Pond. This additional spring discharge measured between 2006 and 2010 ranged from a low of 6.7 cfs in January 2008 to a high of 142 cfs in June 2009 (**Figure 4**). Measurements were timed to avoid rainfall events to eliminate the added discharge contributed from local surface water runoff.

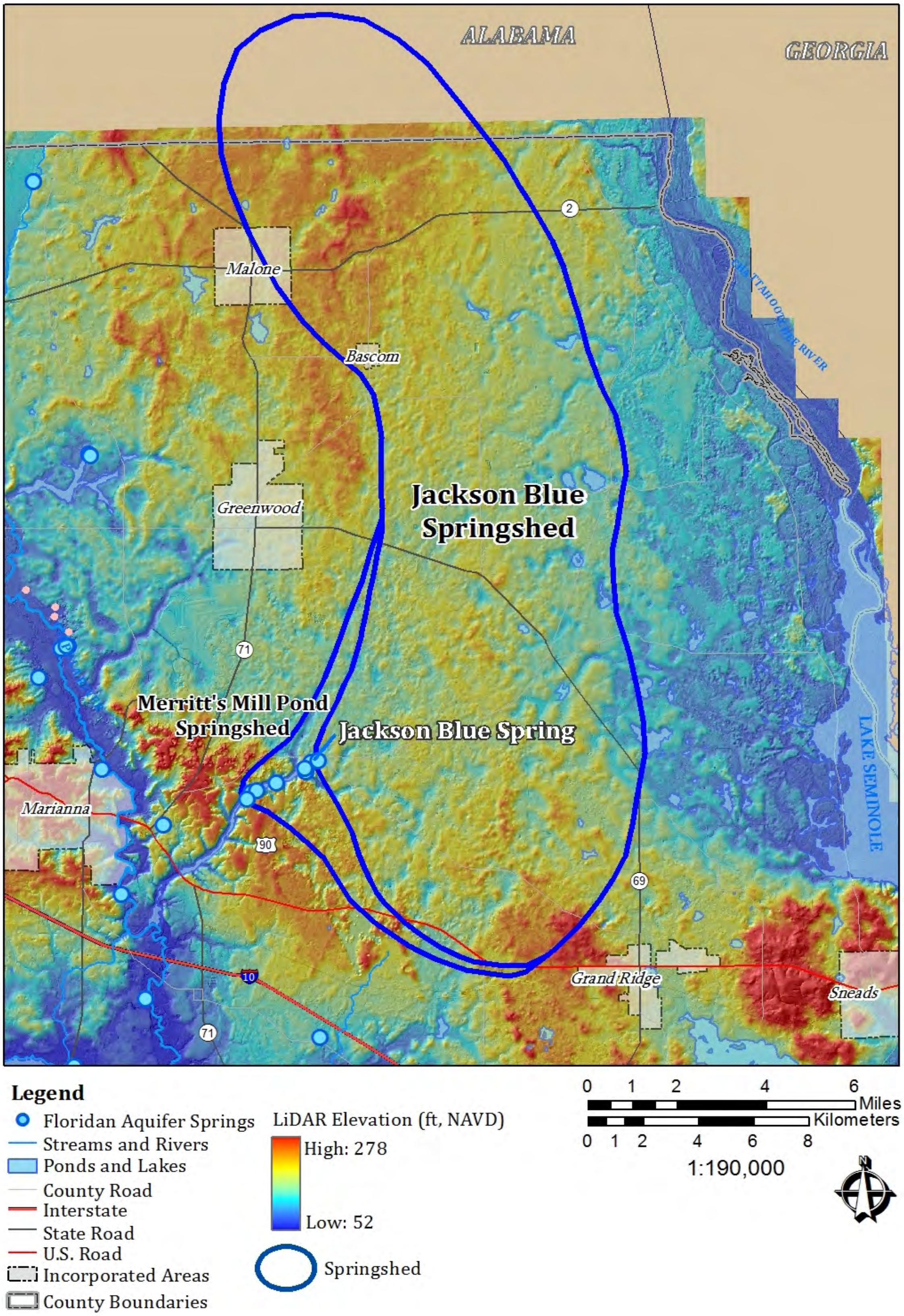

Figure 2. Topography in the Vicinity of the Jackson Blue Springshed

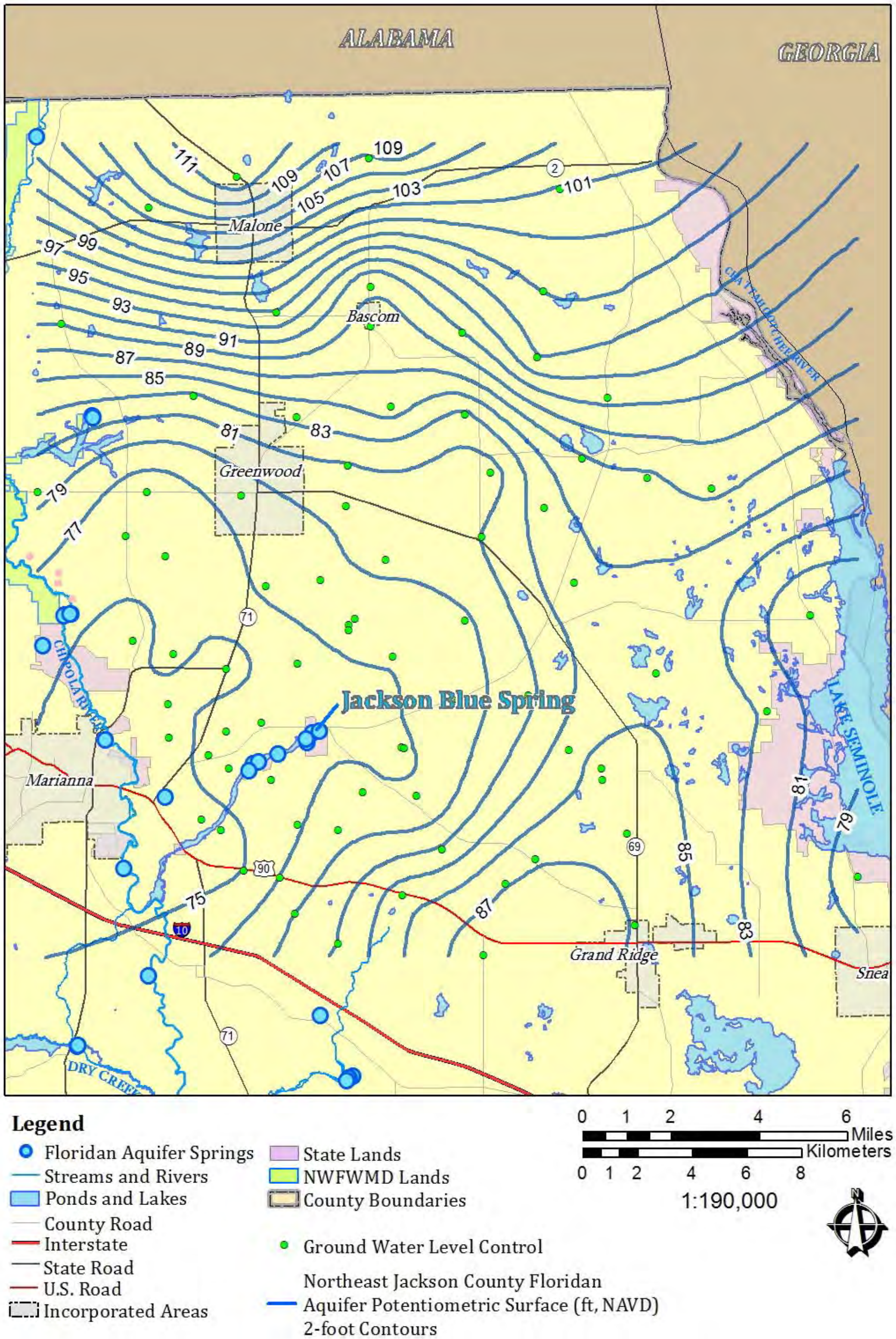

Figure 3. Estimated Potentiometric Surface in Northeast Jackson County, March 2007

The District contracted with Karst Environmental Services (KES) to conduct submerged discharge measurements within the exit conduits of six spring vents located in Merritt's Mill Pond. These measurements were conducted once at each spring during July 2007. In most cases, conventional discharge measurements were not obtainable due to the lack of a confined channel, the presence of diffuse discharge, or the presence of aquatic vegetation. **Table 1** summarizes the results. The total measured spring discharge was 49.64 cfs. In comparison, the measured outflow from Merritt's Mill Pond was 56.3 cfs. Thus, Jackson Blue Spring contributed approximately 69% of the total flow, the minor springs contributed 14%, and the remaining 17% was from other unmeasured sources. Based on measurements of discharge and pond outflow taken during October 2006 - April 2009, Jackson Blue Spring accounts for 70% of the pond outflow on average (**Figure 4**).

Table 1. Discharge Measurements in Merritt's Mill Pond (submerged)

Spring	Date	Depth (ft)	Discharge (cfs)
Jackson Blue Spring	7/16/2007	8-20	39.1
Shangri-La Spring Main	7/18/2007	7-10	3.69
Shangri-La Spring Fissure	7/20/2007	18	0.18
Shangri-La Spring Total	-	-	3.87
Twin Caves Spring	7/19/2007	14-20	1.60
Hole-In-The-Wall Spring	7/17/2007	35-36	1.28
Heidi Hole Spring	7/20/2007	22-23	0.16
Gator Hole Spring	7/20/2007	13-17	0.93
Total			49.94

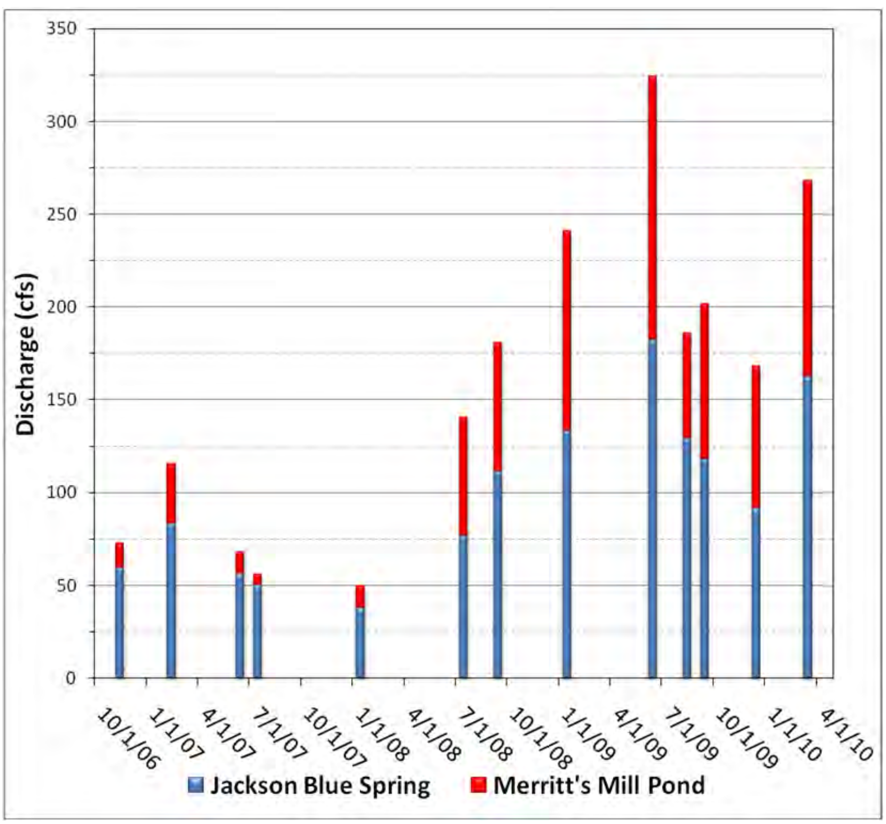

Figure 4. Contribution of Jackson Blue Spring to Merritt's Mill Pond Discharge

In December 2004, the District installed a ground water level recorder within a Floridan Aquifer well located in the Jackson Blue Spring basin to determine if a relationship exists between the ground water level in the Floridan Aquifer and measured Jackson Blue Spring Discharge. **Figure 5** displays ground water levels and the 56 spring discharge measurements collected since December 2004. As can be seen on the graph, there is a significant correlation between spring discharge and the ground water level; enough so that the data can be used to develop a rating curve to estimate spring discharge. The District has created a discharge rating for Jackson Blue Spring based on this relationship (**Figure 6**). The rated discharge hydrograph is displayed as **Figure 7**. Summary statistics for Jackson Blue spring flow are given in **Table 2**.

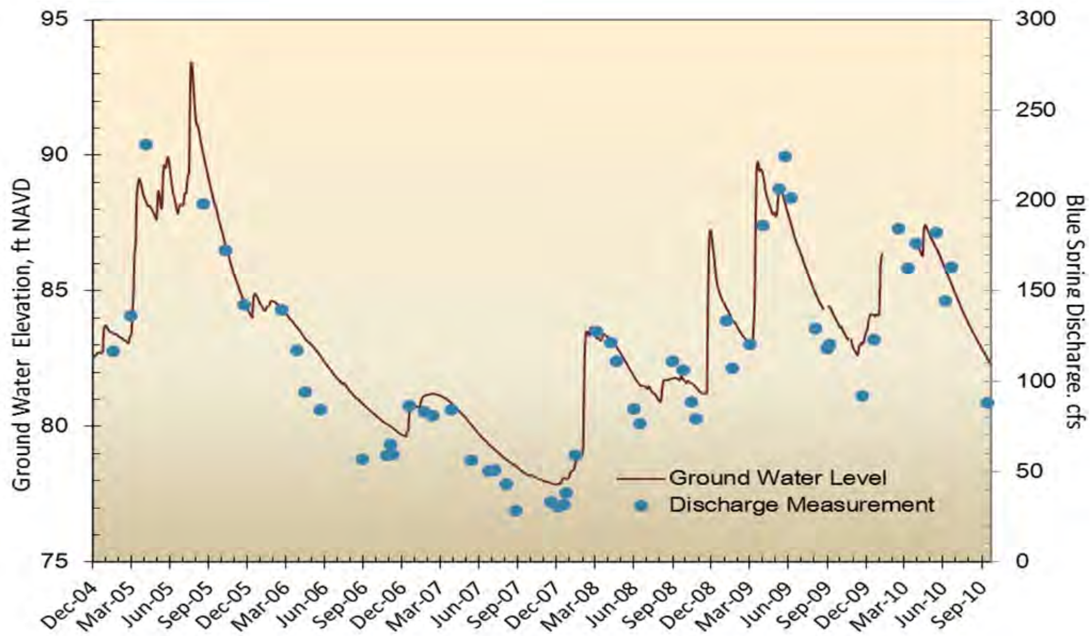

Figure 5. Discharge Measurements and Ground Water Levels Measured at the Pittman Well

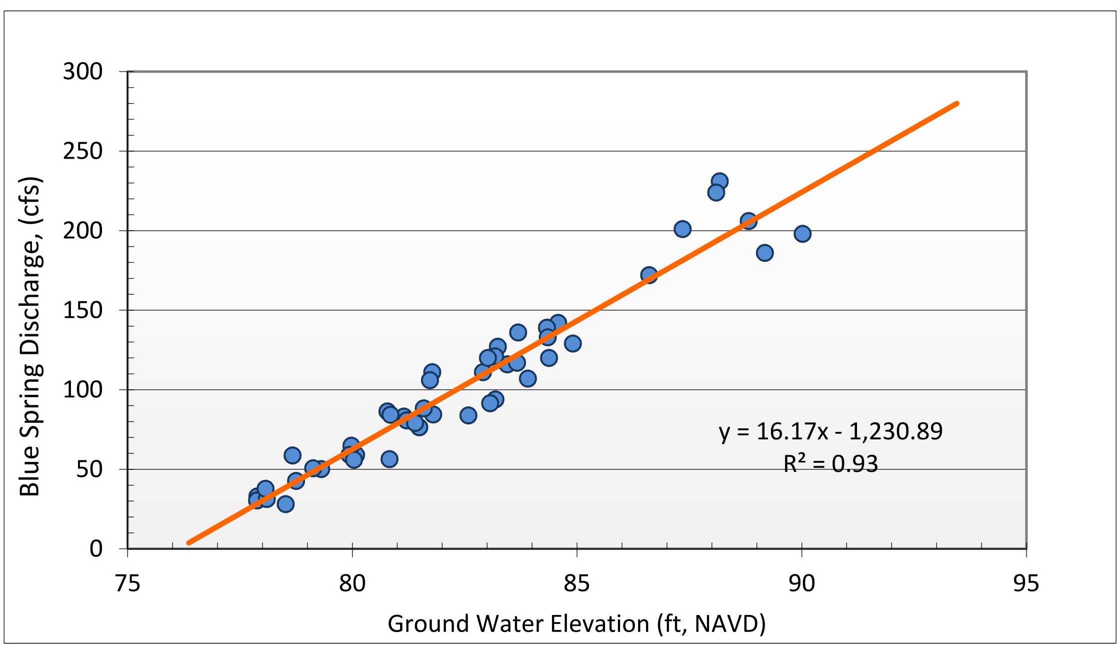

Figure 6. Ground Water-Discharge Relationship for Jackson Blue Spring

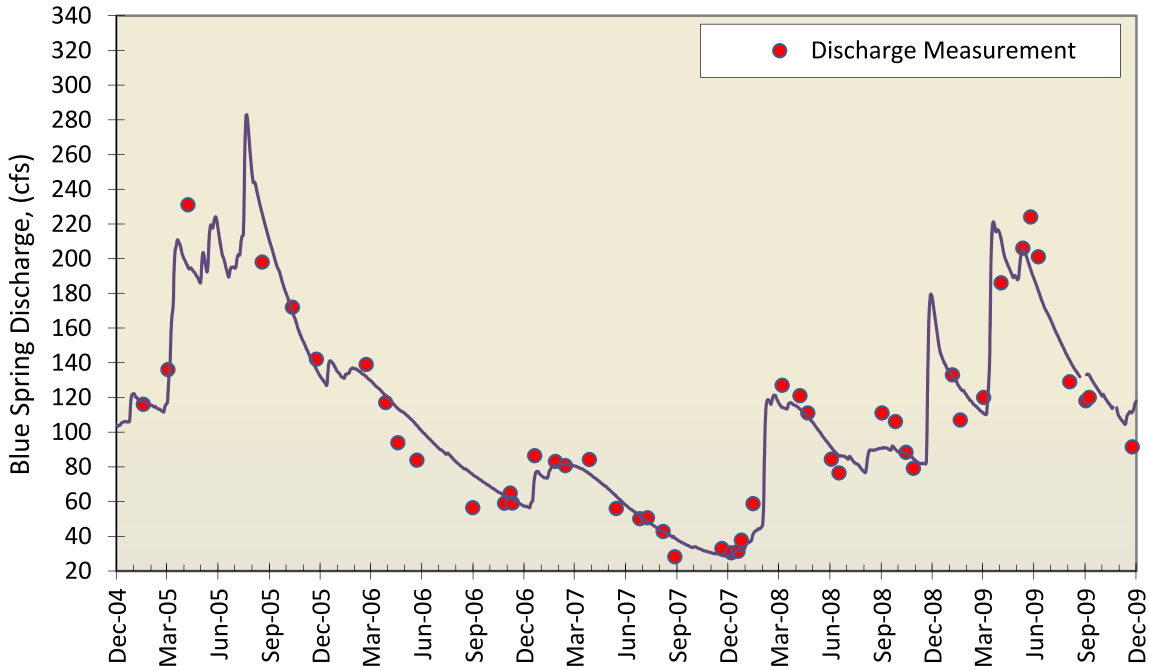

Figure 7. Time Series Plot of Blue Spring Discharge, Measured and Calculated: 2004-2010

Table 2. Jackson Blue Spring Summary Discharge Statistics, 2004-2010

Mean	113
Median	110
Minimum	28
Maximum	283
90% exceedance	44
80% exceedance	69
70% exceedance	81
60% exceedance	90
50% exceedance	110
40% exceedance	118
30% exceedance	132
20% exceedance	158
10% exceedance	196

Merritt's Mill Pond

Merritt's Mill Pond was originally created in the late 1860's with the impoundment of Spring Creek by Coker Dam at a point located approximately halfway down the existing lake. In the 1920s, the mill pond was expanded to its current extent with the construction of the dam and weir structure at U.S. Highway 90. For most of the 20th century, the impoundment at US 90 was used as a small hydroelectric generation plant. During 1994-1996, the generator turbine was removed and the dam spillway and headwall were modified. Over the course of the pond's history, the water level has been drawn down five times for varying lengths of time: 1956, 1971-1972, 1980, 1990, and 1994-1996. With the exception of the 1994-1996 drawdown event associated with the dam modification, the drawdowns have been for the purpose of maintaining or improving the aquatic health of the pond. Merritt's Mill Pond is renowned for its fishing, in particular redear sunfish (*Lepomis microlophus)* for which the pond holds the state record.

Merritt's Mill Pond measures approximately 4.25 miles in length from its headwaters at Jackson Blue Spring to the outfall into Spring Creek and has an average width of 500 feet. Depths are generally in the 10 to 12 foot range. Because of the water control structure, levels in the pond only fluctuate from 6 to 12 inches over the course of a year. This structural alteration affects water levels at the Jackson Blue Spring because the spring vent is directly connected to Merritt's Mill Pond. This is or may be an important consideration when establishing minimum flows and levels pursuant to Florida Statutes 373.042. In essence no degradation of the water levels caused by withdrawals should be expected due to this dam structure, although discharge from the spring may be diminished somewhat during extreme periods of drought. The control structure at the pond outlet consists of a modified rectangular-notch weir over a lift gate that opens from the bottom (**Figure 8**). Although the outlet structure does have the capability of changing the water level in the pond, the structure has remained closed since the 1994-1996 drawdown event.

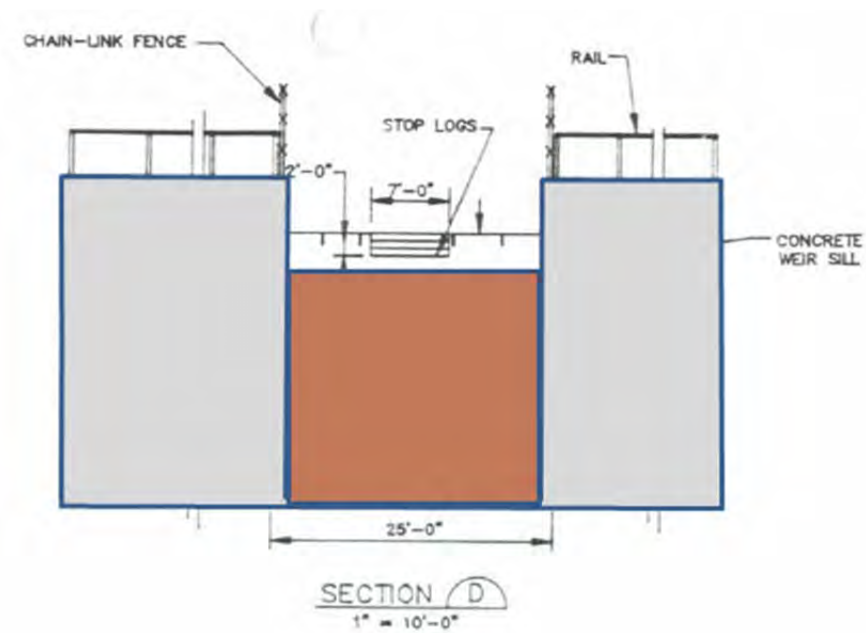

Figure 8. Merritt's Mill Pond Outflow Control Structure

In 2003, the USGS installed a pond level monitoring station located near Jackson Blue Spring with funding provided by the Florida Department of Environmental Protection. At the time, the monitoring site was installed under the hypothesis that the Mill Pond water level was primarily determined by the volume of flow discharged from Jackson Blue Spring. **Figure 9** compares the pond stage and measured spring discharge from 2003 through 2009. The stage data collected to date indicates that Jackson Blue Spring discharge is a substantial factor in determining pond level; however, enough variability is contributed by other factors which make the development of a rating curve based on pond stage problematic. Therefore, the District uses and recommends the ground water level – discharge relationship be used as the basis for estimating the discharge from Jackson Blue Spring.

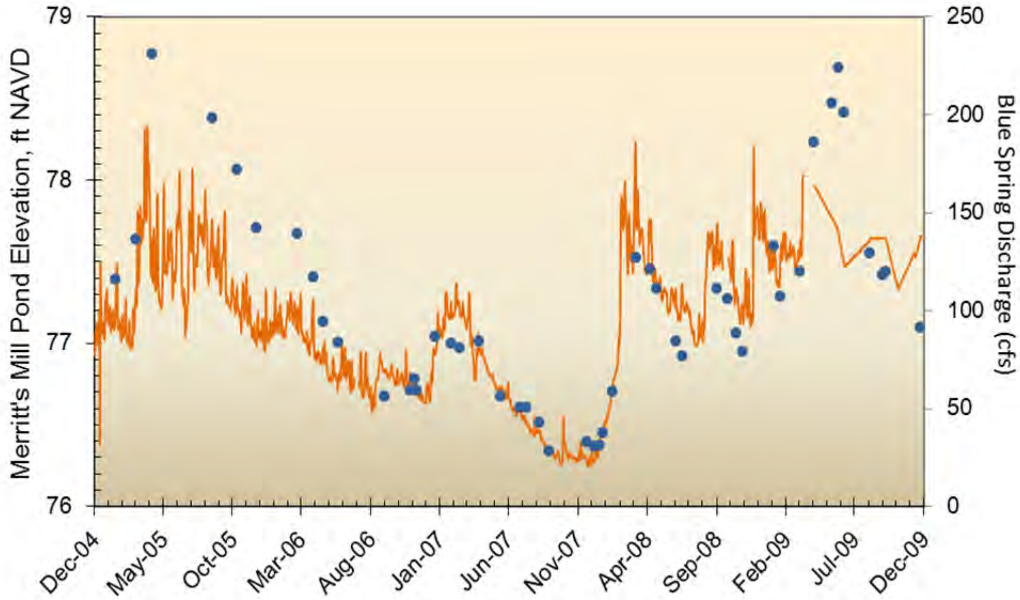

Figure 9. Merritt's Mill Pond Elevation and Measured Spring Discharge

Land Use

Land use in the Jackson Blue springshed is dominated by agriculture and pine plantation with scattered areas of residential development (**Figure 10**). Based on the population density for Jackson County, the 2008 population in the springshed totaled approximately 6,750 persons. Cities near Jackson Blue Spring include Marianna and Bascom, Grand Ridge, Greenwood, and Malone. Jackson County has traditionally been one of Florida's most productive agricultural communities. In 2007 the county ranked first in the state for cotton, peanut, and corn acreage (FASS 2008).

In 2007, the District published a study of land use change in the Jackson Blue Spring Basin from 1994 to 2004 (TFR-0701). The results are summarized in **Table 3**. The Jackson Blue Spring Basin, as delineated in 2001, comprised approximately 69,000 acres. Compared to 1994, 2004 land use remained essentially unchanged with respect to the categories of Wetlands and Water. Agricultural Land increased slightly while Open Land and Developed Land increased significantly. Although Developed Land comprised a minor portion of the total land use, the increase in Developed Land by 1,699 acres came at the expense of Upland Forest. The increase in Open Land can be attributed to the harvesting of pine plots as well as the clearing of forested land for other uses.

Table 3. Land Use Change from 1994 to 2004 in the Jackson Blue Springshed

Land Use Category	Acreage 1994	Acreage 2004	Change in Acreage	% Change
Agricultural Land	33,410	33,938	528	2%
Upland Forest	31,005	28,765	-2240	-7%
Developed Land	2,095	3,794	1699	81%
Wetlands	1,662	1,663	1	0%
Water	215	215	0	0%
Open Land	113	198	86	76%

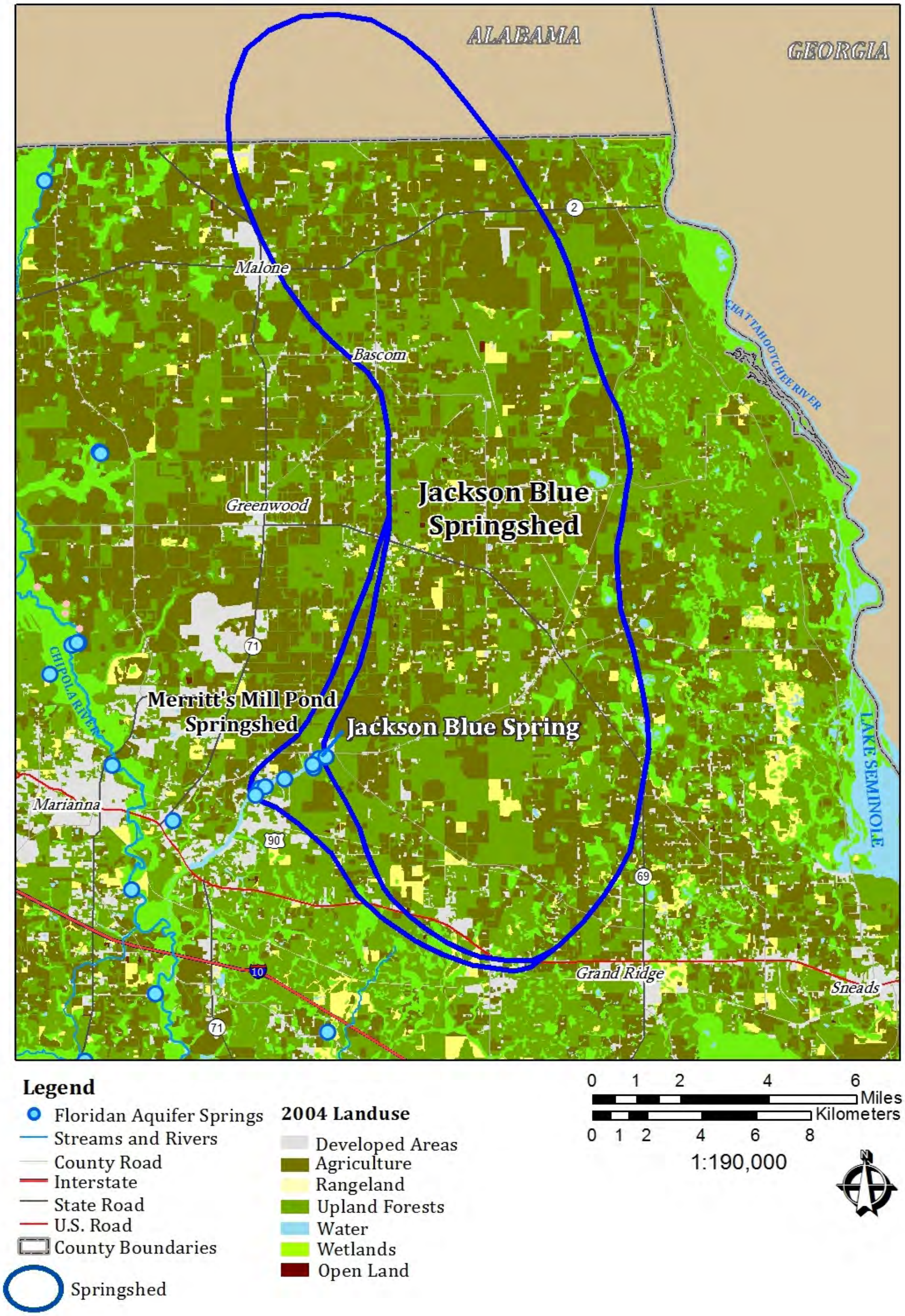

Figure 10. Land Use in the Jackson Blue Springshed

The land use analysis does not indicate that developed land is replacing agricultural land in the Jackson Blue Spring basin. Instead, over the ten years between the snapshots provided by the aerial photography, both land uses increased with a corresponding loss of forested land. The significance of this result is that the nutrient loading associated with both development and agriculture has likely increased as well. Another influence is the irrigated acreage in the basin which is currently estimated at 12,520 acres or approximately 37% of the agricultural land use.

Water Quality

Ground water quality within the Jackson Blue Spring Basin is defined by the properties of the geologic units comprising the Floridan Aquifer in the region as well as by the anthropogenic impacts associated with land use and water consumption. Generally speaking, the ground water in the springshed is carbonate; its mineral components reflect the dissolution of the Ocala/Marianna Limestone sequence which forms the matrix of the aquifer in the basin. The District's chemical characterization of water quality in the basin, published in WRSR-0501, provides a detailed explanation of spatial variability of geochemistry in the springshed.

Based on the 2007 springshed refinement, approximately 80% of the Jackson Blue Spring Basin is located within Jackson County with an additional 20% located in southern Houston County, Alabama. The small size of the basin compared to other historic first magnitude springs in Florida supports the estimates of high basin recharge. The USGS completed an analysis of samples for stable isotopes and tritium from Jackson Blue Spring in 2001 as part of a larger work focused on estimating the ground water recharge age and nutrient sources for twelve first and second-magnitude springs located in Florida (Katz 2004). The analysis resulted in an estimated average ground water age of 17 years for Jackson Blue Spring. In 2008, the District completed an additional round of isotopic analysis that included five more springs discharging to Merritt's Mill Pond (TFR-1001 draft). The results of the sulfur hexafluoride analysis (determined to be the most reliable metric in the study) agreed with the USGS estimated average ground water age. The relatively young age of ground water discharging from spring vents in Merritt's Mill Pond is supported by high concentrations of dissolved oxygen measured both basin wide and in quarterly monitoring at Blue Spring.

Unfortunately, the agricultural success of the county has had an adverse impact on water quality at many of the springs in the area. Nitrate levels in Jackson Blue Spring have increased over time and current levels are ranging from 3.2 to 3.5 milligrams per liter (mg/L). A time series chart displaying the increase in nitrate concentration over time is included in **Figure 11**. Two separate analyses of stable nitrogen isotopes at Jackson Blue Spring have revealed that elevated nitrate values in the spring are predominantly due to the leaching of manufactured fertilizer into the aquifer within the spring's contribution area (Katz 2004, Barrios 2011). Concentrations of chloride and potassium also correspond to elevated levels of nitrate, further supporting the fertilizer origin of nutrient contamination in ground water within and surrounding the Jackson Blue Spring springshed (Barrios and DeFosset 2005).

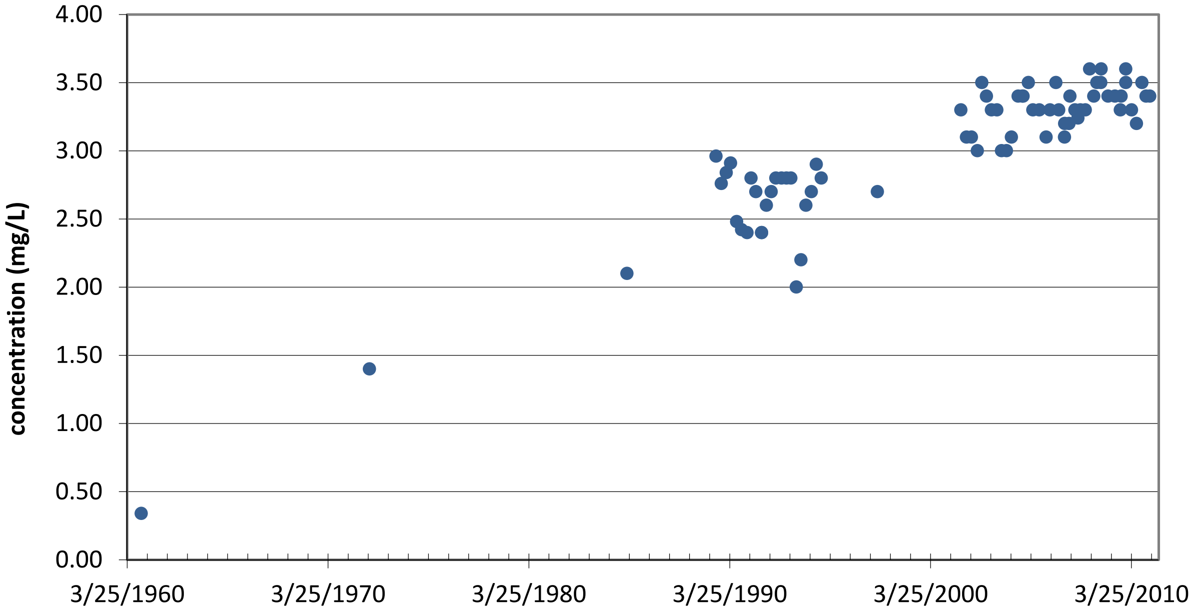

Figure 11. Blue Spring Historic Nitrate Concentration

As depicted in **Figure 12**, the variability of nitrate concentrations in recent years falls within about 10% of the median value. This low variation is despite an order-of-magnitude difference between low and high discharge measured during the same period. The significance of this observation is twofold. The first is that nitrate concentrations in the Blue Spring Basin are not subject to dilution during variable flow regimes and are therefore endemic to the aquifer. The second is that the source water for Blue Spring is consistently composed of ground water with relatively little or no influence from surface drainage into sinkholes or swallets. This also, in part, explains why the head difference between the upper basin and discharge point (the spring) serves as a viable proxy for discharge.

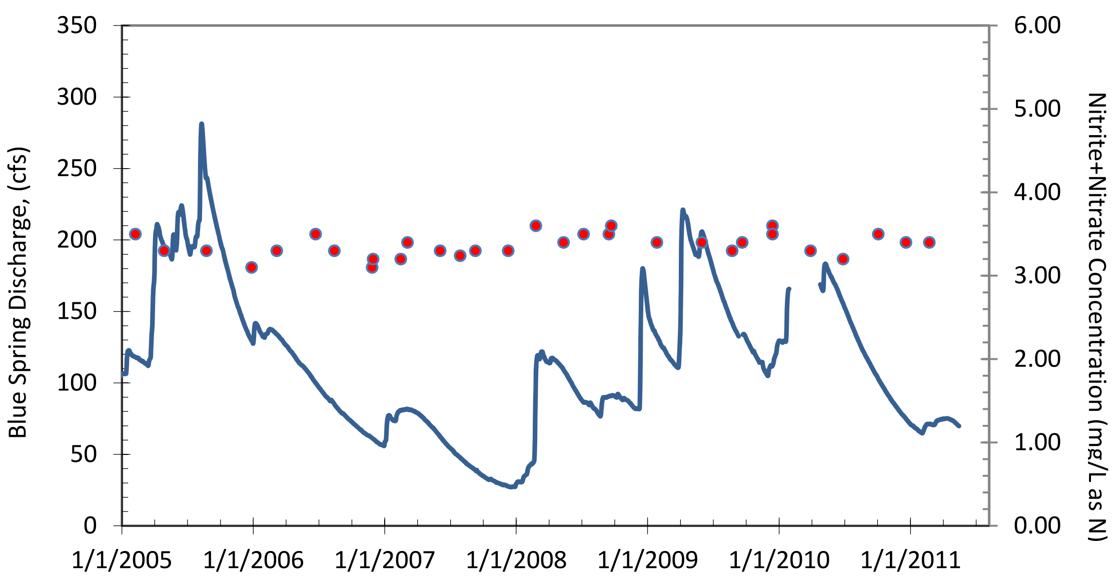

Figure 12. Nitrate Concentration vs. Discharge

Although nitrate levels are relatively high in the spring discharge, levels are still well below the primary drinking water standard for nitrate of 10 mg/L. In the northeast quarter of Jackson County another compound associated with past agricultural practices in the region, Ethylene Dibromide (EDB) a fumigant pesticide in common use until the mid-1980s, has been commonly detected in wells above the primary drinking water standard concentration of 0.02 micrograms per liter (μg/L). EDB is common enough that the entire northeast quarter of Jackson County is listed as a Chapter 62-524, FAS ground water contamination delineation area. Wells constructed within this area are subject to more rigorous construction and testing standards. Also, drinking water wells that have tested positive for the compound are eligible for filter treatment. To date, EDB has not been detected in the discharge from Jackson Blue Spring. High concentrations of nitrates in ground water throughout Jackson County and EDB in northeast Jackson County result from direct impacts of land use activities on ground water quality due to the semi-confined nature of the Floridan Aquifer in this area.

Ground Water Withdrawals

The Floridan Aquifer is the primary source of water for consumptive use (i.e. public supply, domestic supply, irrigation, etc.) in Jackson County. Ground water withdrawals from the Floridan Aquifer are regulated by the Northwest Florida Water Management District. Within Jackson County, a Consumptive Use Permit must be obtained if maximum daily withdrawal exceeds 1.44 million gallons per day (mgd) or if one or more wells has a diameter or 10 inches or larger.

For surface water withdrawals, a permit must be obtained if pumpage exceeds 100,000 gallons per day. However, the District Governing Board has established a reservation for surface water from the Chipola River. Consumptive surface water withdrawals from the main stem or the Chipola River cutoff have been determined to be “not in the public interest.” The magnitude, duration, and frequency of observed flows are reserved for the protection of fish and wildlife of the Chipola River, Apalachicola River, and associated floodplains and Apalachicola Bay (*Ch. 40A-2.223 F.A.C).*

Ground water withdrawals in the springshed totaled 8.58 mgd on an annual average daily rate (ADR) basis in 2008 (**Table 4**). Approximately 94% of this total or 8.03 mgd was used for agricultural irrigation. Of the remaining 0.55 mgd of water used in the springshed in 2008, about 0.52 mgd was used for domestic self-supply (e.g. private wells and small public water systems) and the remaining 0.03 mgd was used for landscape irrigation. There are no permitted surface water withdrawals in the Jackson Blue springshed.

Table 4. 2008 Estimated Annual Water Use in the Jackson Blue Springshed

Use Category	Average Daily Rate (mgd)
Agricultural irrigation	8.03
Domestic self-supply	0.52
Recreation and landscape Irrigation	0.03
Total	8.58

The total agricultural water use of 8.03 mgd reflects the sum of pumpage quantities reported to the District by Consumptive Use Permit holders and includes agricultural pumpage quantities estimated for non-permit holders. Estimated agricultural irrigation quantities were based on average permitted irrigation rates and irrigated acreage estimated from aerial photography.

The total amount of ground water pumpage permitted by the District in the Jackson Blue Springshed is approximately 12.3 mgd on an average daily basis (ADR). However, agricultural irrigation exhibits considerable monthly and yearly variation due to the rainfall variability and the seasonality of crop irrigation requirements. During 2005-2008, reported agricultural ground water withdrawals (ADR) ranged from 4.5 mgd in 2005 to 9.5 mgd in 2007. Monthly withdrawal rates ranged from less than 0.01 mgd in January 2008 to 21.8 mgd in July 2007 (**Figure 13**). The years of 2006-2007 were back to back drought years and had the second lowest two-year cumulative rainfall on record. Storage conditions in the aquifer just prior to 2006 were also relatively low. Based on existing stream flow records as discussed below this resulted in what is believed to be the hydrologic drought of record.

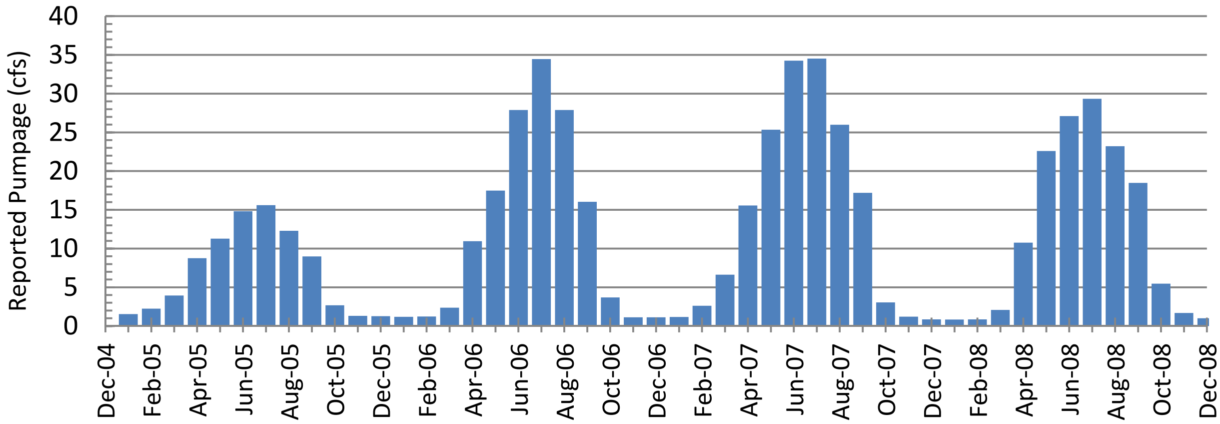

Figure 13. Monthly Reported Agricultural Irrigation (mgd): 2005 – 2008

Irrigated land accounts for approximately 18% of the total springshed area. **Figure 14** shows the locations of irrigated areas and wells within the springshed. There are also additional agricultural lands that are not irrigated. Cotton, peanuts, and corn together account for 62% of the irrigated acreage for Consumptive Use permit holders. Other frequently occurring irrigated crops include sod, potatoes, melons, and soybeans. **Table 5** summarizes permitted and reported irrigated acreages by crop type for 2005-2009.

Table 5. Farmer Reported Irrigated Crop Estimates, Jackson Blue Spring Basin 2005-2009

Crops Irrigated	2005 Reported Acres	2006 Reported Acres	2007 Reported Acres	2008 Reported Acres	2009 Reported Acres
Corn	755.0	418.0	779.0	1,045.0	649.5
Peanuts	3,065.6	2,627.0	2,292.0	2,530.0	3,138.0
Cotton	2,228.7	3,459.5	2,777.0	2,937.0	2,659.0
Grass/Pasture	294.0	690.0	1,035.0	894.0	206.0
Soybeans	0.0	0.0	132.0	182.0	270.0
Wheat	334.5	63.5	0.0	175.0	30.0
Vegetables/Melons	410.0	1,044.0	1,522.0	1,579.0	1,388.5
Other	2,512.0	500.0	500.0	77.0	0.0
TOTALS	**6,677.8**	**7,258.0**	**7,015.0**	**7,763.0**	**6,952.5**

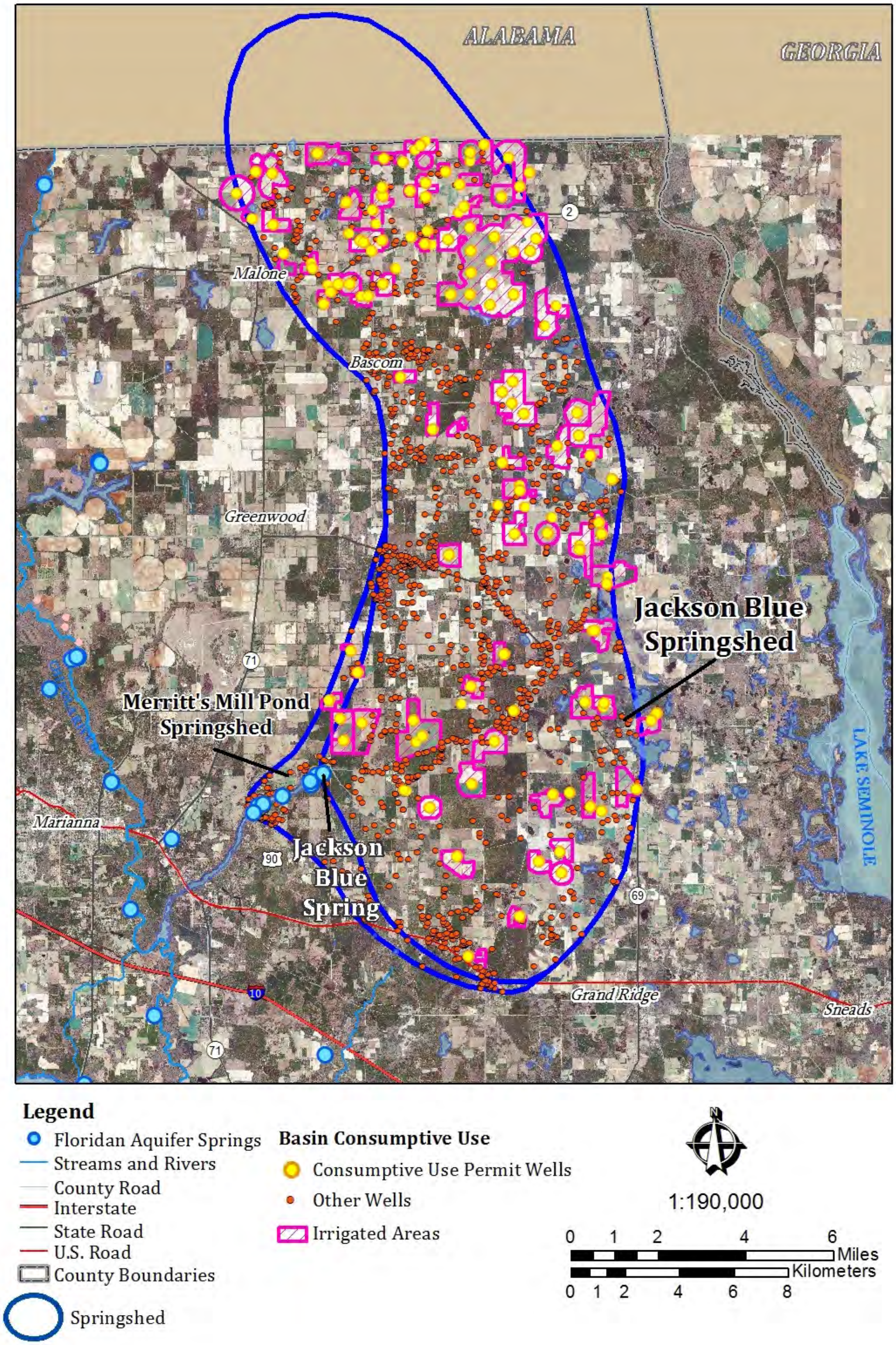

Figure 14. Irrigated Acreage and Well Locations in the Jackson Blue Springshed

Relationships between Spring Discharge, Rainfall, Ground Water Pumpage, and Climate

Figure 15 shows monthly average ground water withdrawals and discharge from Jackson Blue Spring. **Figure 16** shows monthly average rainfall compared to Jackson Blue Spring discharge. A graphical representation of the gage-adjusted radar rainfall annual departure from 1971-2000 annual rainfall average from 2003-2009 is presented in **Figure 17**. The relationship between pumpage and spring flow is influenced by existing storage in the aquifer (i.e. water levels) and by temporal and spatial patterns in rainfall. As mentioned earlier, 2006-2007 was the second driest two-year period on record. The graphs suggest that periods of low spring discharge may follow periods of low rainfall and high ground water pumpage. Periods of high spring discharge may similarly follow periods of higher rainfall and lower pumpage. Changes in spring flow appear to lag rainfall and pumpage by several months. This is not unlike conditions found elsewhere such as the nearby Flint River Basin in Georgia. Torak, et al (2004) document the seasonal lag effects and Huyakorn, et al (2004) further elaborate on the transient behavior of these spring fed systems and the significant relationship between ground water pumpage and surface water discharge.

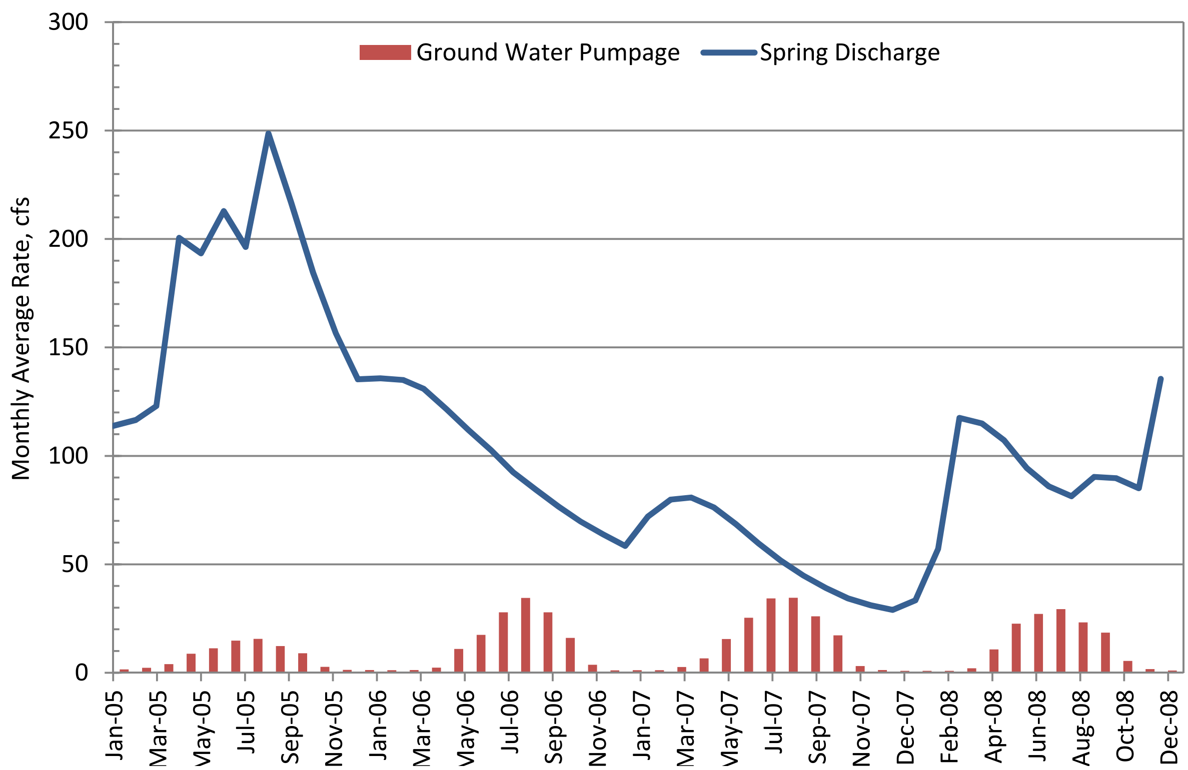

Figure 15. Ground Water Pumpage and Jackson Blue Spring Discharge, 2005-2008

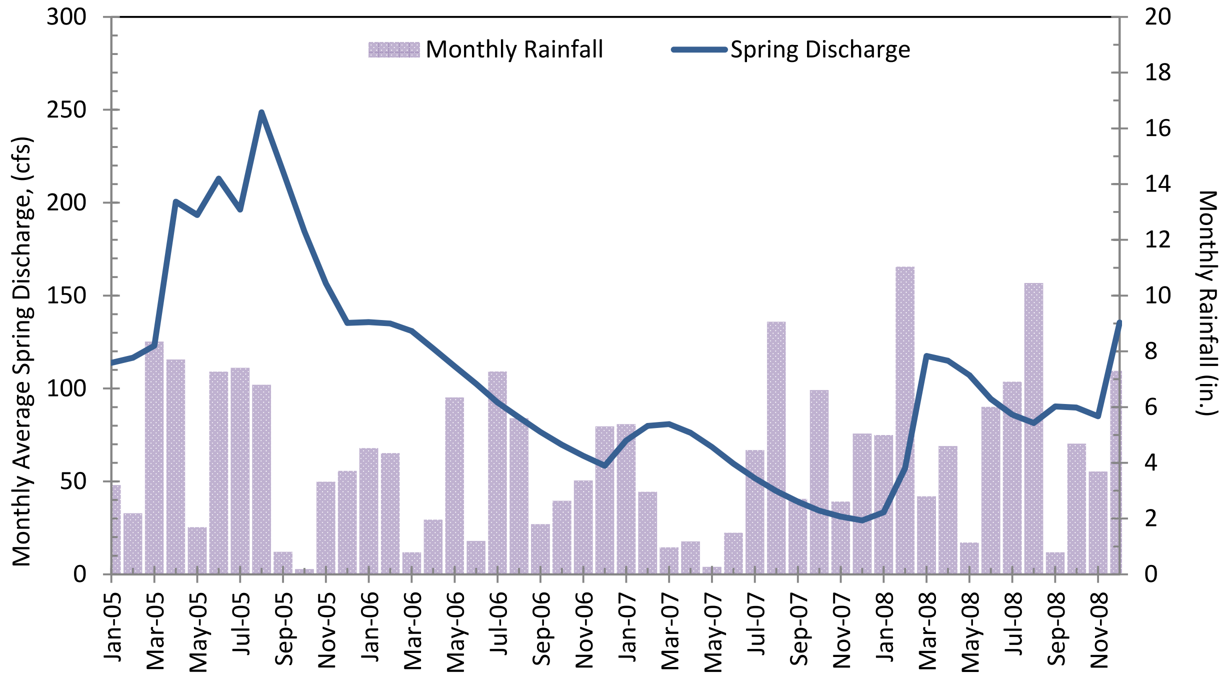

Figure 16. Monthly Rainfall and Jackson Blue SPRING Discharge: 2005-2008

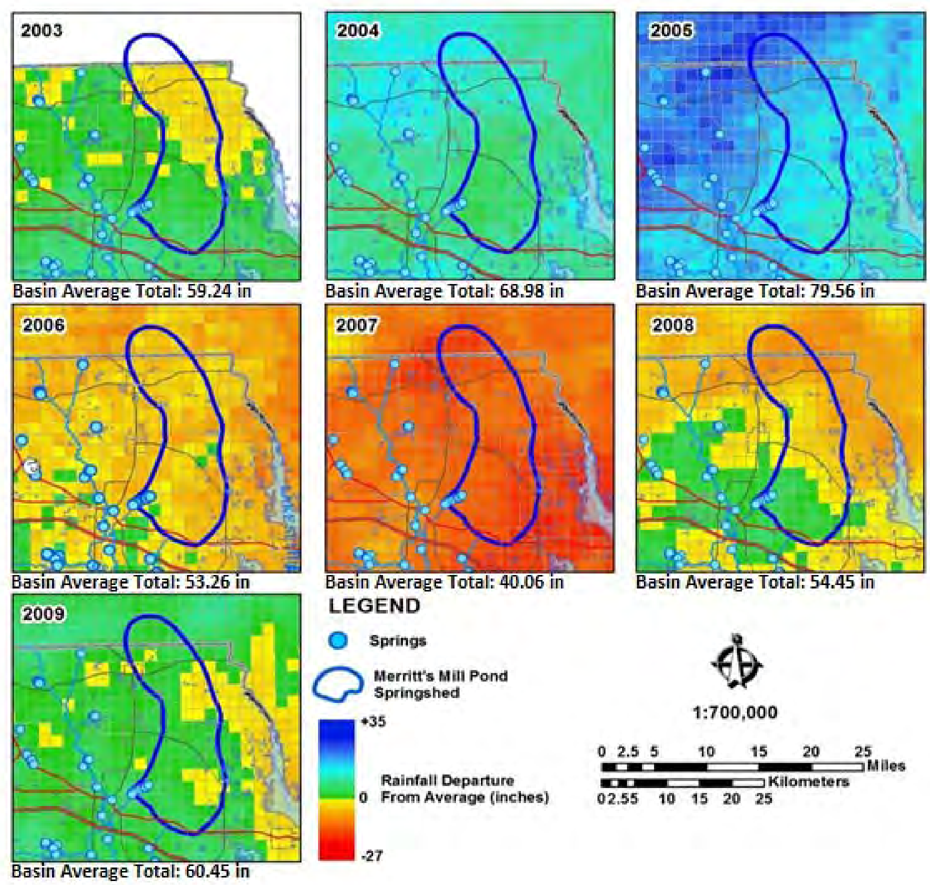

Figure 17. Annual Rainfall Departure from NWS Long Term Average (58.24 in, 1971-2000).

The most significant droughts according to nearby rain gages occurred in 1954-55, 2000-2001, and most recently in 2006-2007. According to **Table 6**, 1954-55 was the reported lowest amount of rainfall reported in any two year period. The second lowest was in 2006-2007 when Jackson Blue Spring discharge fell to record levels of about 25 cfs. The close relationship between ground water elevation and spring discharge in the Jackson Blue Spring basin presented the opportunity to use historic flow data for the Chipola River to backcast a discharge record for Jackson Blue Spring. As part of this analysis it was possible to backcast springflow back to 1953 based on the long term streamflow records at the nearby USGS gage on the Chipola River at Altha. Baseflow (defined as low flow contributed by ground water and subsurface discharge to streams) at the Altha gage was calculated using the WHAT (Web-based Hydrograph Assessment Tool) digital filtering method (**Figure 18**). The calculated baseflow for the Altha gage was then compared to Jackson Blue Spring discharge for the overlapping period of the two records (2004-current). The strong correlation (R^2=0.98) between spring discharge and baseflow at Altha indicates a reasonable method to backcast and estimate historic Jackson Blue Spring discharge. Using the resulting spring discharge hydrograph, charted in **Figure 19**, the severity of historic drought periods can be compared.

Table 6. Ten Lowest Biannual Rainfall Totals

Period	Rank	Two-Year Cumulative Rainfall (Inches)
1954-1955	1	69.75
2006-2007	2	87.94
1940-1941	3	88.79
1951-1952	4	89.66
1968-1969	5	90.91
1980-1981	6	91.34
1967-1968	7	93.71
1953-1954	8	95.68
1971-1972	9	96.10
1955-1956	10	97.36

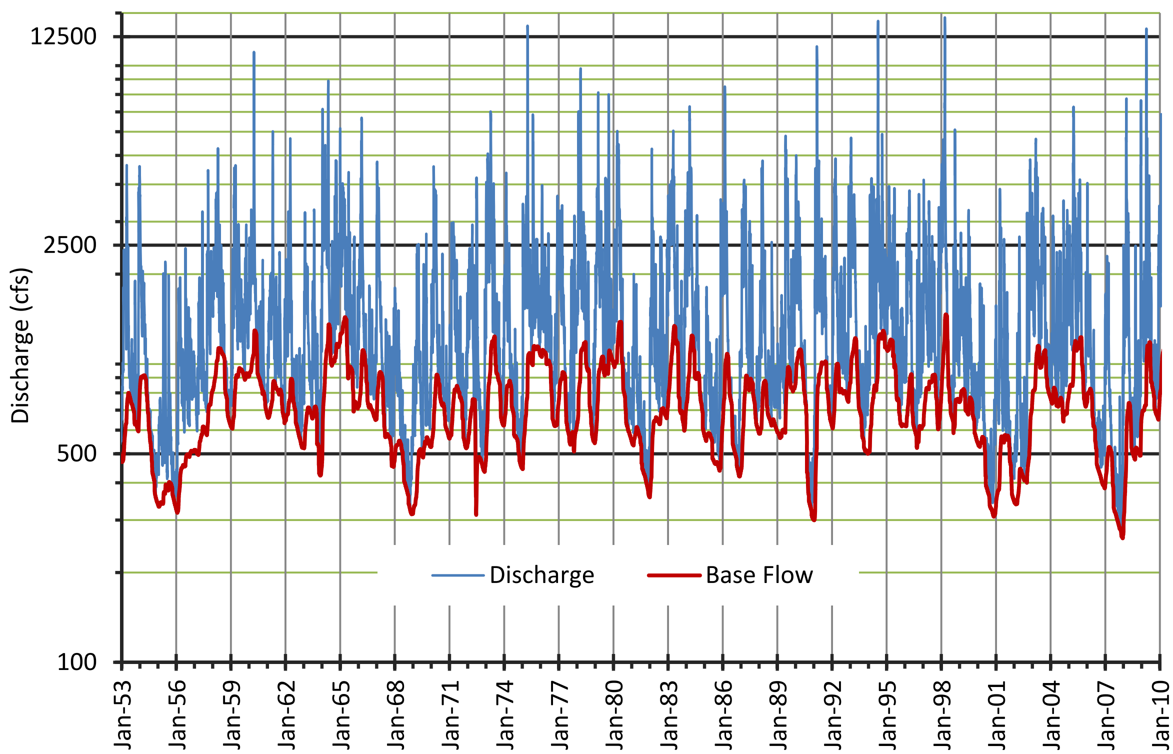

Figure 18. USGS Altha Gage Baseflow Hydrograph

Of particular interest in this analysis is a comparison of the Jackson Blue Spring discharge during the droughts of 1954-1955 and 2006-2007. Based on reported NWS rainfall values in Chipley, FL, the lowest two-year rainfall total occurred during 1954-1955 (69.75 in) followed by 2006-2007 (87.94 in). However, an analysis of the long-term Altha gage record indicates that the lowest flows on the Chipola River occurred during 2007. Thus, it appears that the cumulative effects of the 2006-2007 drought period resulted in record low spring flow at Jackson Blue Spring. An analysis of the data confirms this would be the case even if irrigation withdrawal records were added back into the spring discharge record. Thus, as can be seen in the record displayed in **Figure 19,** the 2006-2007 drought was the worst on record primarily because aquifer storage and the resulting baseflow condition was low to begin with in the Spring of 2006 prior to entering the extended drought period.

Another factor which has been shown to influence rainfall conditions in the southeastern United States is the El Niño/Southern Oscillation (ENSO) climatic cycle. These large scale ocean-atmosphere climate patterns are caused by warmer than normal sea surface temperatures (El Niño) or colder than normal temperatures (La Niña) across the equatorial region of the Pacific Ocean. The La Niña component of the cycle and have been reported by National Oceanic and Atmospheric Administration Climate Prediction Center (CPC) to lead to drier than normal conditions in the southeast United States. Periods of La Niña influence are presented in **Figure 19** as blocks of time that roughly match low spring discharge for Jackson Blue Spring.

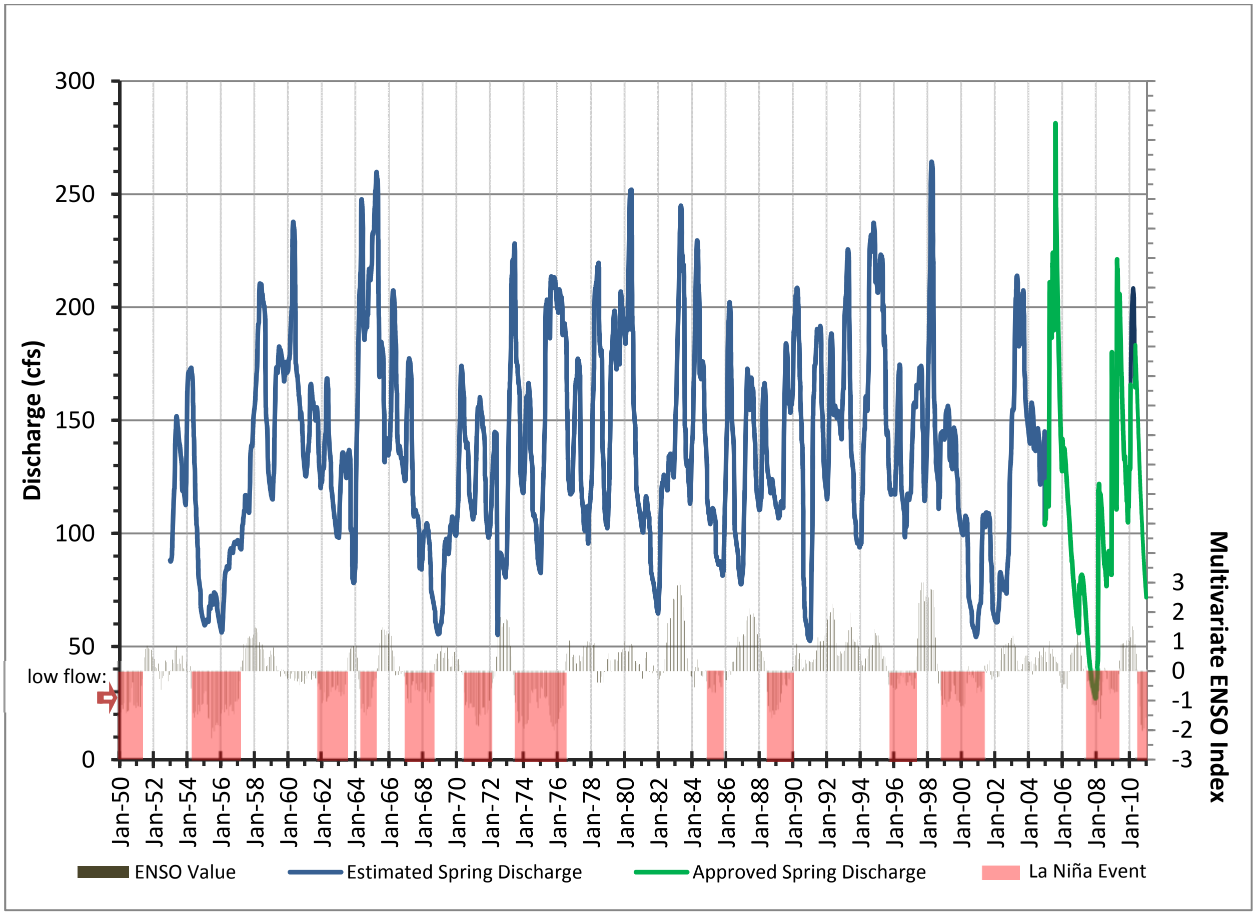

Figure 19. Estimated Historic Jackson Blue Spring Discharge

Ground Water Flow Modeling and Water Budget Analysis

Numerical ground water flow modeling utilizing the USGS MODFLOW model (McDonald and Harbaugh, 1988) has been ongoing by the Northwest Florida Water Management District, most notably in the last few years since the spring was placed on the MFL priority list following Florida Statutes. Modeling work began several years prior with Roaza (1989). This model was originally calibrated to predict annual average conditions with a spatially coarse grid, but has been recently refined for the purpose of developing a water budget in this springshed basin. This improved working model of USGS MODFLOW (Harbaugh et al., 2000) provides a better understanding of recharge rates, storage properties, and Floridan Aquifer transmissivity in the Jackson Blue Spring study area. Several calibration steps have been undertaken to enhance the predictive capability and utility of the model for water management purposes. This work focused on increasing model accuracy for Jackson Blue Spring by incorporating the more recent hydrologic data into the model calibration and verification process. Additionally, the District has used newly acquired elevation data (LiDAR) to increase both the scale and the precision of the model grid. The model derived steady state water budget estimates are depicted in **Figure 20**. The annual water budget calculations **(Table 7)** were determined based on an average annual recharge to the 133 square mile Jackson Blue Spring Basin of 14.5 inches (92 mgd, 143 cfs)**.** At steady state, the recharge rate should equal the average pumping rate of all wells in the Jackson Blue Spring Basin, which is the 8 mgd (12.4 cfs) incorporated into the model, plus the average spring flow of 73 mgd (113cfs). Since the average annual recharge rate exceeds the average pumping rate plus the average spring flow rate, a larger springshed than delineated in 2007 is suggested. Total inflow and outflow from the basin suggest a larger area on average. With future model analyses and calibration efforts, springshed delineations may be refined to more closely match the numerical model results.

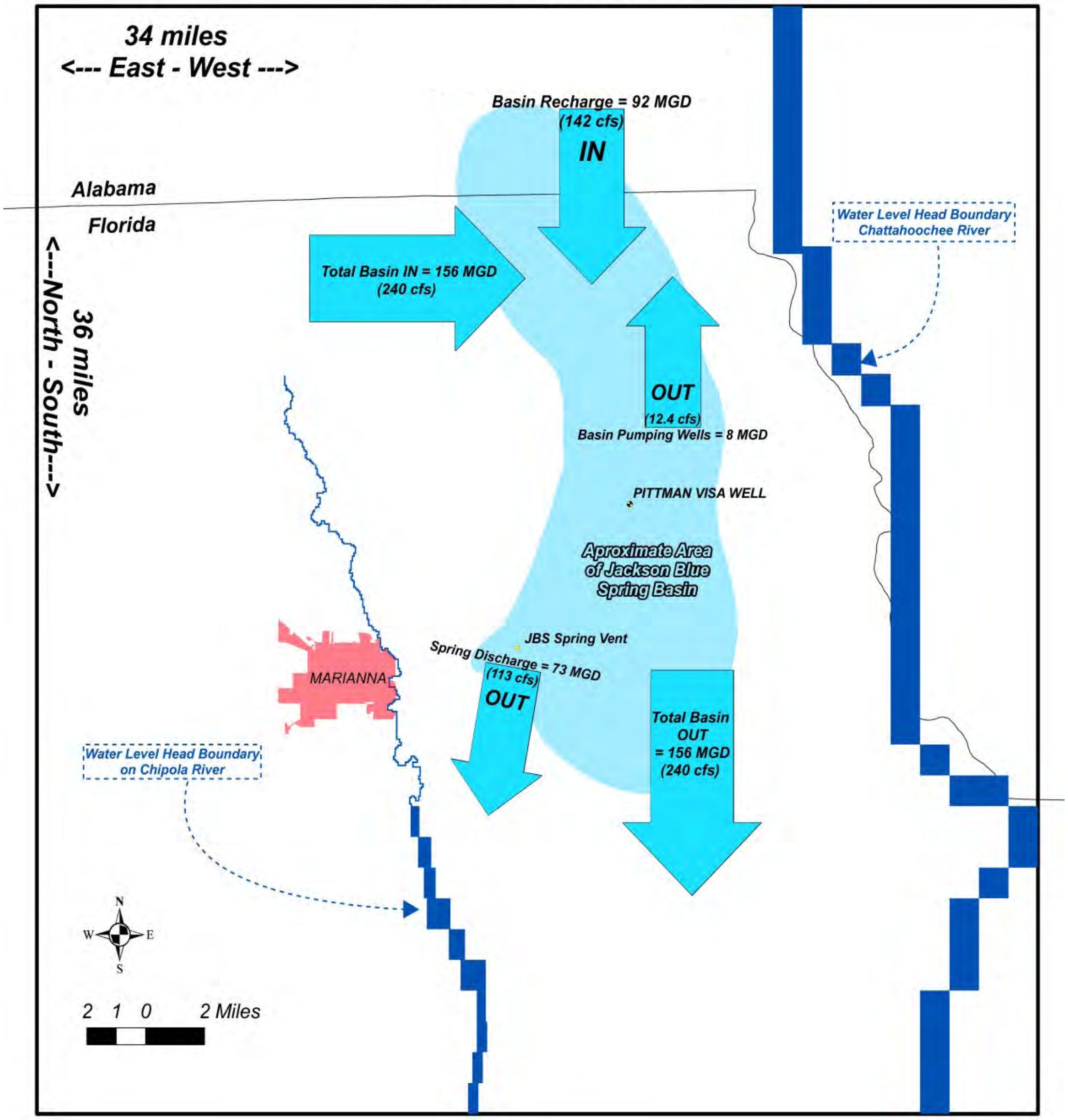

Figure 20. Jackson Blue Spring Model Domain and Water Budget

Table 7. Jackson Blue Spring Annual Water Budget

Aquifer inflow at basin boundaries:	98 cfs (9.9 in)	Aquifer outflow at basin boundaries:	114.6 cfs (11.6 in)
Recharge:	143 cfs (14.5 in)	Spring Discharge:	113 cfs (11.5 in)
Irrigation & Other Returns	0 (assumes 100% is consumed)	Withdrawals	12.4 cfs (1.25 in)
Total Inflow:	240 cfs (24.3 in)	Total Outflow:	240 cfs (24.3 in)

In addition to steady state simulation, an attempt was also made to perform a long term transient simulation. This effort was intended to provide more insight into the impacts of irrigation pumping and aquifer storage influence on spring flow as discussed previously. This was an important step towards improving model accuracy, to increase its ability to simulate transient ground water conditions and reflect the high growing seasonal water demands, and the aquifer-spring discharge relationship discussed earlier. To calibrate the transient model a period with "low rainfall" and small or negligible amount of pumpage was selected. The dry period selected was the month of March, 2006 based upon a single rain gage located in Marianna, FL. This allowed the model storage coefficients to be uniformly adjusted until a match with observed water levels was attained at the Pittman well, which is centrally located in the springshed. **Figure 21** summarizes the transient model results and shows the model data compares favorably to the observed water level data. However, to obtain these transient results 0.50 inches of recharge had to be added to the model which was much higher than expected. This is because precipitation amounts in the location of the rain gauge were not representative of the amount that fell in the entire springshed. **Figure 22** shows an average springshed basin estimate of 2.46 inches of total precipitation for March 2006 from the National Weather Service Doppler Radar. The radar data indicate that the average precipitation in the delineated springshed was greater than the single point measured rain gauge data of 0.79 inches for March 2006. This would explain why a recharge of 0.50 inches for March 2006 was necessary for calibration efforts to match the Pittman observation well levels for the daily transient simulation during this time period shown in **Figure 21**. Some model improvements or refined aquifer storage estimates may be possible in the future by utilizing the radar gage adjusted rainfall data to find a more suitable period with little or no rainfall and negligible pumpage.

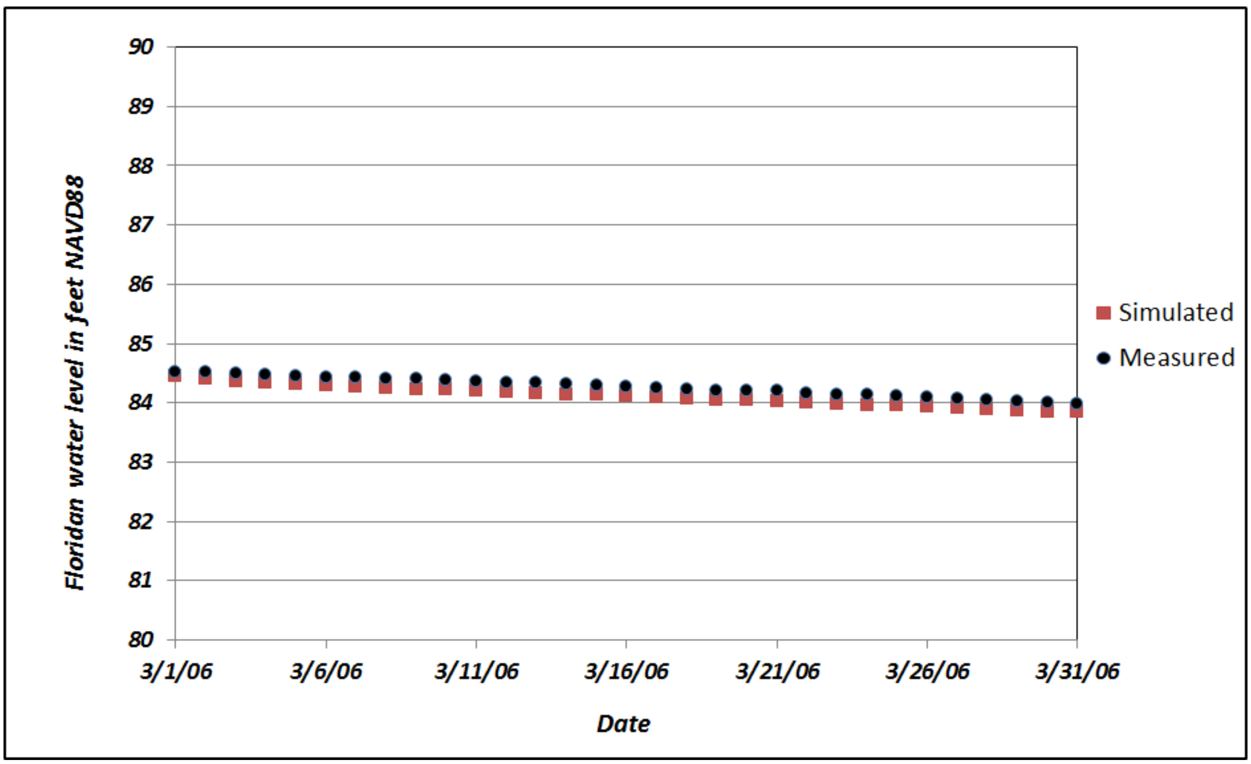

Figure 21. Pittman Visa Well Model Simulated Water Levels vs. Measured Water Levels

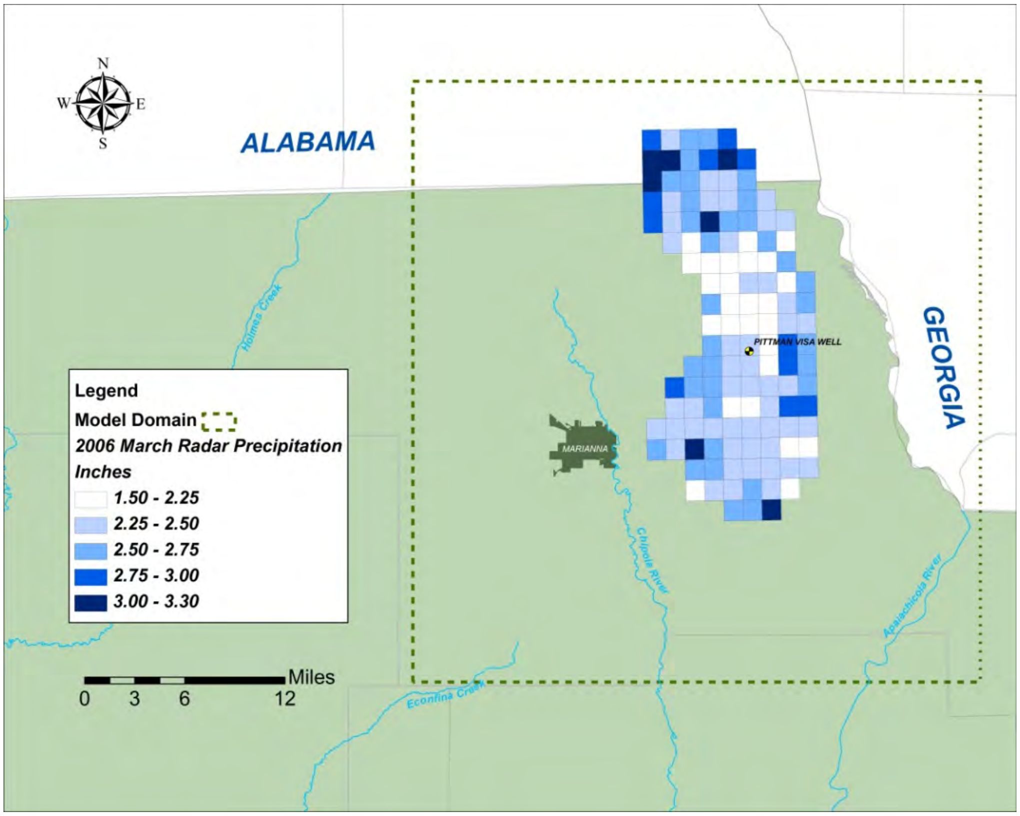

Figure 22. Gauge Adjusted Radar Rainfall for March 2006

Subsequent to transient model calibration results, the model was set up to simulate long term hydrologic conditions based upon reported agricultural irrigation pumpage and precipitation records. To perform this analysis, recharge rates are determined through a trial and error process for each monthly time step. Initial estimates were based on monthly rainfall but adjusted according to simulated water levels. The model currently does not employ a methodology to estimate recharge or net infiltration as a function of precipitation, evapotranspiration, and soil moisture, although recharge estimates are reasonably what may be expected. Long term transient model results compared to monthly observations of spring discharge and water levels at the Pittman Visa Well are provided in **Figure 23**. These results agree with earlier discussion (Figures 15 and 16) confirming that precipitation and aquifer pumping are correlated with measured water levels in the Pittman Visa observation well and spring discharge with a delayed response. This delayed well level and spring discharge response is due to transient storage effects. The model recharge rates may need to be further refined to make the model useful as a forecasting tool to predict spring discharge and water availability during extreme droughts. Currently the model is set up as a planning tool to evaluate what effects increased pumping would have had on water levels and discharge during historical drought periods. One example is shown in **Figure 24**. In this unlikely scenario seasonal pumping rates are increased by a factor of 2.5. This results in a model simulated monthly discharge of approximately 28 cfs at the spring. When the pumping is curtailed, there is slightly more recovery for the 2.5 times pumping scenario, this is a model artifact due in part because the basin actually expands to cover a larger area when pumping is increased. The model does not account for possible increased pumping rates which may occur outside of the predefined springshed boundary. It is also of interest to note that under this scenario the contribution of flow from the Chattahoochee River and Lake Seminole aquifer boundary increases.

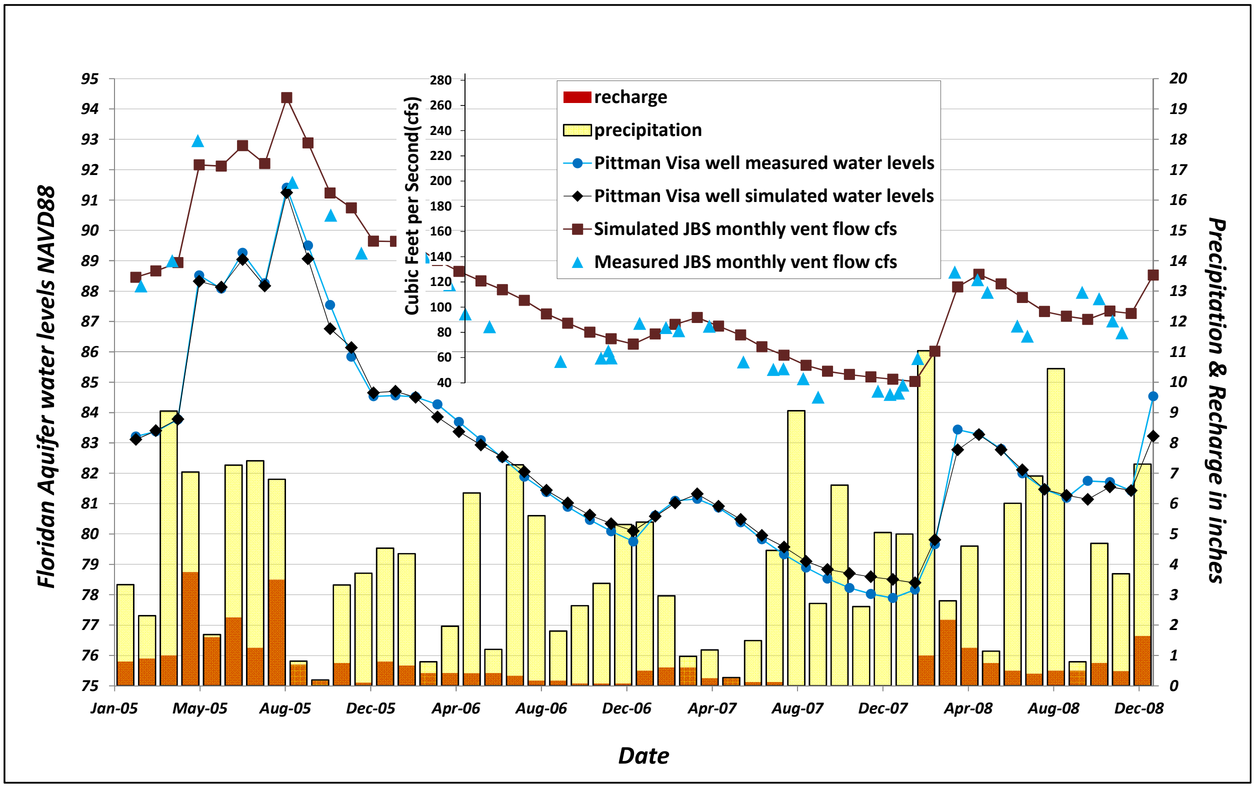

Figure 23. Transient Model Results

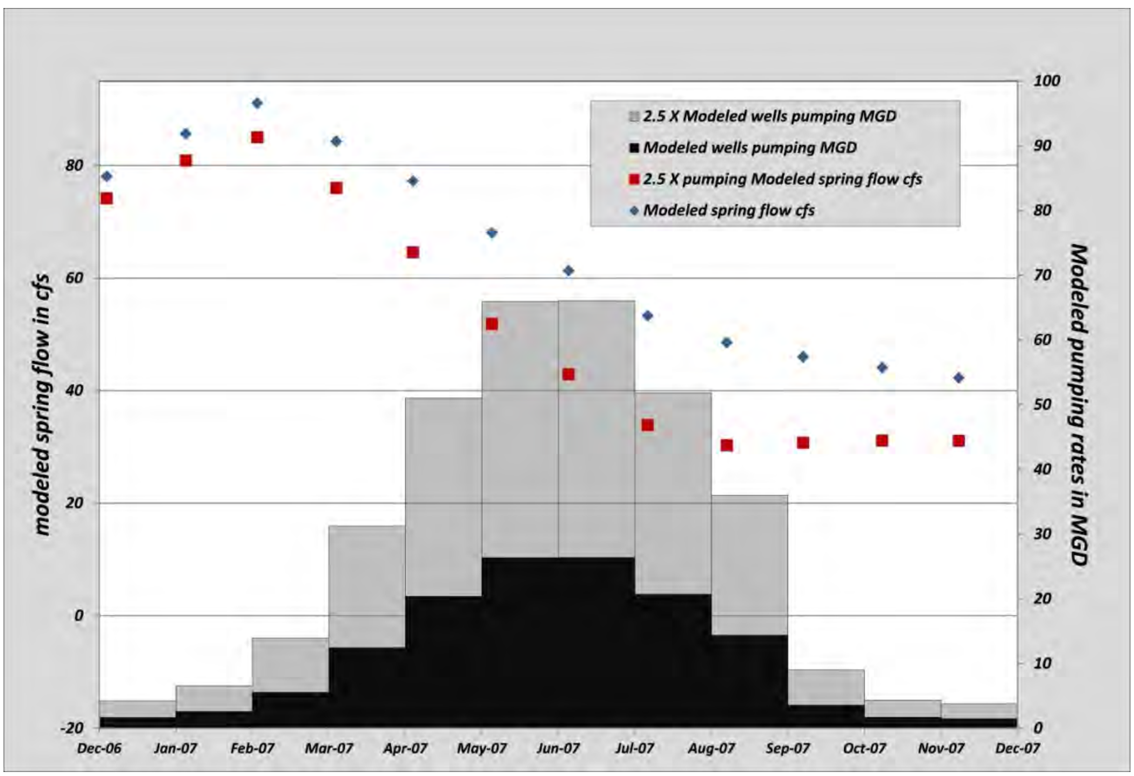

Figure 24. Comparison of Calibrated Model Results with an Increased Pumping Rate Scenario During the 2007 Extreme Drought Period

Though the model has its use as a planning tool as shown above it does have some limitations. Jackson County hydrogeology has been previously investigated by the District and others (USGS), however few data pertaining to the local hydraulic properties of the Floridan Aquifer as used in this model have been field verified. Previous studies provide hydraulic characteristics of the Floridan aquifer that relate to a large regional scale and rely on existing field data without any local verification of aquifer properties. Transient model calibrations and validation with aquifer water levels measured at various wells through time penetrating the Floridan Aquifer may also result in model improvement. Additional aquifer testing in the springshed may, therefore, be beneficial to refine estimates of transmissivity and storativity for this karst system. With a better understanding of Floridan Aquifer hydraulic properties as well as better way to estimate recharge, the District would have an enhanced ability to accurately model spring discharge and forecast extreme drought conditions as they occur. The model is also an appropriate tool to determine an amount of water to reserve or conserve to avoid springflow cessation. It may also be useful to simulate future periods of more extreme drought which have yet to be observed. The model will also be a useful tool for considering other demand management practices, future water supply planning initiatives, and the development of other conservation options as discussed in this report. These additional efforts would be more proactive and intended to avert the conditions expected during droughts and to explore the effectiveness of conservation options.

Assessment of Water Availability

Overall, an assessment of the water availability of water resources in the Jackson Blue Spring basin is good. Even during dry years there are no known adverse impacts which have occurred at in the vicinity of the spring and low flow events have been relatively short lived. Low flows occur during extreme drought years and are rare events. These low flows are primarily climate related but are influenced during the growing season by high agricultural pumping rates when storage and ground water level conditions are low to begin with. As previously discussed these impacts are not permanent and flows rebound very quickly once the irrigation growing season comes to an end and the area receives near average rainfall amounts.

The management of surface and ground water withdrawals in the Jackson Blue Springshed continues to be addressed through the Consumptive Use Permitting process. Consumptive user permits include seasonal limits and each permit contains authorized amounts for the average daily, maximum daily, and maximum monthly withdrawals. Permit applicants must demonstrate that the requested ground water withdrawal amounts are reasonable-beneficial and in the public interest, and that proposed withdrawals will not cause harm to existing users and water resources and related natural systems. As noted previously, the District Governing Board has reserved flows in the Chipola River for the protection of fish and wildlife and has prohibited consumptive surface water withdrawals.

The District is continuing to work on a number of monitoring and data analysis activities to assess water resource availability in the Jackson Blue springshed. Data collection activities include measurement of continuous rainfall and ground water level, compilation of reported ground water pumpage data, and quarterly measurements of Jackson Blue Spring water quality and discharge.

Water Conservation Opportunities Discussion

This section discusses some of the opportunities the District has at its disposal to implement water conservation as well as demand management practices to either more efficiently use water for agricultural irrigation or curtail its use. Some of these are already implemented in which case the potential for improvements are discussed. Their effectiveness will ultimately influence availability of water for all water users in the basin.

Mobile Irrigation Lab

Over the past seven years, the NWFWMD has partnered with the Florida Department of Agriculture and Consumer Services (FDACS) to fund a service provided to farmers that measures their irrigation system's efficiency and recommends improvements they may make in the field to increase efficiency. The water savings potential of the Mobile Irrigation Lab program has been documented based annual auditing reports to be about 0.3 MGD annually. In addition, the program has promoted an awareness and stewardship by farmers of the need to protect and conserve local water resources. The program may also be instructive to help or ensure farmers are properly reading and reporting their meters.

Meters

The economics and benefits of meters are well documented (Baum et. al. 2003) and are relatively inexpensive to purchase, install and operate. The costs of a meter may be as low as $400 to $800 per irrigation system and only a small water savings would be required to pay for the cost of metering. There are an estimated 87 wells within the basin many of which are metered although a precise inventory has not been obtained. Currently the installation and operation of meters are not required as a condition of all consumptive use permits and some farmers may use less accurate and non-verifiable means of recording and reporting their use of water. Water and cost savings can be realized immediately through accurate record keeping and more precise knowledge of the irrigation water actually applied. Metering and accurately reporting water use is a benefit to both water managers and farmers. With a meter the farmer has a clear and accurate account of how much water was applied and used. Farmers are wise to measure water use as accurately as possible because they will not only save water, fertilizer, and pesticides, but also greatly reduce related operational costs for fuel and labor needed to pump water and apply supplements. Water managers can in turn more accurately allocate water on a basin-wide basis for all existing and legal users to insure they have an adequate future supply of water. If, for example, an existing user pumps more than permitted that need can be validated by accurate meter reports to insure that he is not merely wasting water. This further assures the farmer that an accurate allocation of water is made by the District in the future.

Sod-based Rotation

Sod-based rotation has been quoted by some as a "best system management practice" as it combines conservation tillage with intervals of perennial grass rotation (http://edis.ifas.ufl.edu/ag255). It has the greatest potential for conserving or reducing irrigation water use in the basin while also increasing farm income. Water savings potential is currently estimated to be from 2 to 4 MGD (average daily rate) depending on how many farms with irrigation systems in the basin would in the long term convert to this practice. Reduced pumpage during the growing season would of course be much greater than the average daily rate estimate although precise estimates of this potential have not been obtained. There are many economic advantages of this practice, including reduced risk of crop failure, significantly reduced costs of applying water, fertilizer, and pesticides and significant fuel savings. There are also economic incentives for adopting this practice through the USDA's EQUIP program. The primary obstacle of adopting this practice is first year costs associated with establishing the perennial grass, which may result in negative income gains or a less than profitable year. However, beyond the 1st year, and without any other economic incentives, profitability is favorable. Farmers in the Flint River Basin in Georgia in cooperation with The Nature Conservancy have been willing to enter into this new cultural practice under a pilot program sponsored with limited funds by the U.S. EPA. When farmers received a slight financial incentive in the first year to get them started and actually experienced the economic benefits, they appeared to be willing to adopt this practice for the long term without continued financial subsidies. Http://Nfrec.Ifas.Ufl.Edu/Programs/Sod_Rotation.Shtml shows a simple business model.

The District currently provides cooperator funds to IFAS as one of its many cooperators to run a full scale demonstration and research farm at its Marianna field office which also helps instruct farmers in the implementation of this practice. An aerial view of the farm is depicted in **Figure 25** with a surface view of the livestock grazing phase in **Figure 26**. Water savings data is also being collected to more accurately measure the water usage of this practice as well as other savings including increased production of crops. The support of IFAS in this effort to encourage this new agricultural practice within the springshed will also benefit other agricultural regions in the District as well as in the Flint River Basin in Georgia.

Figure 25. Aerial Photograph of Sod-Based Rotation Plot

Figure 26. Sod Based Rotation in Grazing Phase

Water Shortage Declaration

The District has regulatory authority to declare a water shortage (under Chapter 40A-21; http://www.nwfwmd.state.fl.us/permits/rules/ch40A21.pdf) and call for a cut back of water use during extreme periods of drought. The District has currently and in the past declared a water shortage warning for the entire District which calls for voluntary measures to conserve or reduce water consumption. The District has at its disposal a more stringent and legally enforceable approach that would be require declaration of a water shortage which would actually be used to realize short term or temporary water savings. A water shortage declaration may also be used as demand management tool. For example stricter cut backs in water use may be required when low aquifer storage conditions are observed again (as was seen in 2006 prior to the 2007 drought) and lower springflow is forecast. It is only during these exceptional drought periods when more stringent restrictions in water use are likely to be needed (second year of a two year extreme drought) to prevent cessation of spring flow. These restrictions would be appropriate for water use permit holders who must abide by water shortage declarations. The District may also have the authority to further condition new permit users to incorporate demand management techniques so that existing users (permit holders) are protected. Demand management options are a possibility in this basin if the demand for irrigation water increases. Demand management may essentially be expressed as a condition in consumptive use permits issued to new or possible existing (through renewal) agricultural users of water and used in conjunction with water shortage declarations.

Reservations and MFLs

A “reservation” is in essence a water conservation measure whereby the Governing Board has the authority to adopt an amount of water reserved for the spring. For this type of measure, it is useful but not necessary to determine the amount to be reserved through a model and other hydrologic analyses. A reservation is also a strong regulatory tool the district has because the amount of water reserved is treated in the total allocation of water it permits through its consumptive use permitting program and in cumulative impacts analysis to protect water resources. Establishment of a reservation in the Jackson Blue Spring basin may lead to limitations in pumping rates specified within consumptive use permits in the basin because as previously indicated there is very little water left to reserve at least during exceptional multiple year droughts (e.g. estimated less than 25 cfs to prevent spring flow cessation in exceptional two year droughts). Hence, this option and the ramifications of adopting a reservation amount including additional conditions of the reservation should be carefully considered beforehand. Also, it may still be feasible to permit new withdrawals which will not result in springflow cessation for agricultural demand when less than extreme drought conditions are present. A minimum flow and level (MFL) is similar to a reservation, however an MFL requires specific evidence of "significant harm to resources" and without such evidence may result in significantly lower flows and less protection of springflow than those which the District's other regulatory tools already provide.

Conservation Lands

Land acquisition to buy or put irrigated lands in conservation easements to create non-irrigated "green" space are another management tool option to consider. In the future, there may be opportunities to combine this option with green programs such as carbon sequestration programs or other conservation based programs. However, it should be pointed out that although reduced nutrients and water would be applied to these areas they are usually planted in trees which grow year round and net annual evapotranspiration rates may eventually exceed that of the crops grown on agricultural land. Conversely, forest lands will generally slow runoff rates, conserve water during high rainfall periods and increase recharge. Even though trees, as do other non-irrigated cultivated perennial plants, have reduced transpiration rates when soils become dry they will have at least equal and perhaps higher evapotranspiration rates overall than seasonal irrigated crops in this basin. Thus, a considerable amount of irrigated land would need to be purchased and converted to conservation before any benefits of this measure were realized. One option would be to just buy conservation easements on irrigated lands incrementally each time a major drought occurred. This would allow dry farming practices to continue and less irrigation would be permitted assuming a moratorium on future permits is established. This water conservation measure would likely require a contingency fund be established as well since the occurrence of drought is generally not predictable. This approach is already practiced, at least occasionally, in the nearby Flint River Basin in the State of Georgia. However, Georgia's approach may be too expensive and not be sustainable in the long run because it is only set up on a temporary year to year basis.

Forecasting Tools

Improved forecasting is included as a water conservation tool because it provides a means for understanding when to implement water conservation measures during periods of high demand. Improvements in local soil moisture forecasting for example would be very beneficial to agricultural operators because they would more precisely know when and how much water to apply. Improvements in the ground water model to forecast springflow during the growing season would be useful to estimate how much water (irrigation) withdrawal would have to be curtailed or conserved if necessary to prevent springflow cessation during exceptional droughts.

Summary and Recommendations

Overall Jackson Blue Spring flow conditions have not been negatively impacted by current levels of withdrawal and only warrant attention during periods of extreme drought. Agricultural water demand for irrigation of crops is the major consumptive use in the basin. The extreme droughts and low flows are primarily driven by the climatic variability which is cyclical and produces a broad spectrum of conditions. Even during extreme droughts the impacts of current agricultural withdrawals during peak demand periods are a short duration and relatively much less than the climatic influences. However, close attention must be given to future irrigation water demands, including seasonal pumpage amounts, to prevent springflow cessation during these extreme low flow periods. Recommendations include continuation of efforts to constantly monitor springflow and rainfall within the Jackson Blue Spring Basin as well as the continued collection and analysis of hydrologic data. Collection of hydrologic data in the springshed is essential to provide the information necessary for assessing the impacts of climactic variability and resource management and conservation efforts. While the water resource limits of the basin may be reached during extreme drought conditions irrigation water supply is generally sufficient to meet demands except during extreme drought years.

Currently the NWFWMD manages and monitors the amount of agricultural pumpage through its consumptive use permitting program. Water pumped by regulated permittees is self-reported as required by permits. Some adjustments may be necessary to this program to assure self-reporting of agricultural water use are accurate, may be verified through the use of meters, and seasonal demand limits may be established. If irrigated agricultural acreage demand increases in the spring's basin, this increase must be carefully evaluated to determine the potential cumulative impacts of all withdrawals permitted in the basin during low flow periods in order to prevent spring flow cessation. Follow up visits with farmers in the basin through the Mobile Irrigation Lab Program or by NWFWMD staff to insure all irrigation systems and pumped water is accurately metered and reported with a flow meter is also important. This may entail actual purchase of meter(s) for the farmer and supervision by the MIL or other staff to help insure the meter data is being properly recorded and reported as well as providing information on the associated economic benefits of properly metering. The monitoring well at Pittman is a very good reference well not only for estimating the Jackson Blue Spring discharge but it also reflects aquifer storage and indicates baseflow contribution for the whole Chipola River Basin. Every effort should be taken to avoid construction of new pumping wells in the vicinity of this spring flow observation well. For example, information from this well indicating that annual ground water storage is low prior to the growing season would alert water managers of the likely limits on ground water availability and the possible need for conservation measures if forecasts indicated impending drought conditions. The monitoring well at Pittman may be viewed at: http://www.nwfwmd.state.fl.us/hydrology/realtime/661.htm.

Efforts to explore a reservation for ground water withdrawals should continue and may lead to further withdrawal limits and enhanced conservation requirements in water use permits.. These efforts will be greatly enhanced by refinement of the ground water models being developed which are capable of cumulatively estimating the seasonal impacts of agricultural water demand on springflow. Other demand management techniques may also be explored as conditioned in new permits issued by the NWFWMD. The overall intent is to protect the flow of the spring while permitting the beneficial use of water by the farming community.

Other non-regulatory programs should continue to be promoted, including financial incentives and outreach to encourage best system practices. These programs include sod based rotation farming as a best system cultural practice to save water and reduce chemical loading as well as reduce fuel consumption. This farming method also holds the promise of improved long term profitability and sustainability through the use of more diverse practices and does not rely on the success of one crop.

There are a number of other water supply management options which may require Governing Board action to fund, develop, and implement. These include, but not limited to, a water supply plan in the region as well as making adjustments in regulatory efforts. Most of the water resource management options to evaluate are conservation based and are directly applicable to the Jackson Blue Spring basin. Water resource management options which are incentive based should be emphasized because they are attractive to the agricultural community interested in protecting the springs while sustaining and developing their own local economy.

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