USE OF HISTORIC DATA TO EVALUATE EFFECTS OF PUMPING STRESS ON STREAMS IN SOUTHWEST GEORGIA

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Abstract Beginning in the mid 1970's, row-crop farmers in southwest Georgia began a rapid transition from rain-dependent to irrigation-supplemented crop production. Presently there are more than 7,000 irrigation permits issued in the southwest Georgia area, and approximately 74% withdraw water from the Upper Floridan aquifer and 26% directly from area streams and ponds. Because many area streams are hydrologically connected to the Upper Floridan aquifer, groundwater withdrawals may significantly alter flows in streams that are tributary to the lower Flint River. An analysis of historic U.S. Geological Survey streamflow records suggests that combined groundwater and stream withdrawals are reflected in sharpened baseflow recession behavior in Ichawaynochaway Creek during early summer months, and have significantly reduced 1-, 7-, 14, and 30-day streamflows in both Ichawaynochaway and Spring Creek. Frequency of summer and early fall zero-flow periods have also increased in the Spring Creek watershed since implementation of high volume agricultural withdrawals.

INTRODUCTION

Widespread implementation of center pivot irrigation systems in the lower Flint River Basin over the past thirty years has raised concerns over whether current levels of water usage are sustainable. Tributaries of the lower Flint provide habitat for endangered and threatened mussel species, as well as other aquatic organisms adapted to pre-irrigation flows, physiochemical conditions and refugia provided within these systems. Understanding the hydrologic connectivity between surface and sub-surface water systems in the lower Flint is essential to designing sustainable water policy for this economically important and ecologically sensitive region. We summarize previous flow analyses on multiple tributaries of the lower FRB since extensive groundwater and surface water extractions began around 1976 and introduce results of two recent analyses performed on the long-term USGS stream gage datasets on the Ichawaynochaway and Spring Creek gaging stations (Fig. 1).

BACKGROUND

The lower Flint River Basin (FRB) lies south of the Fall Line within the Coastal Plains region of southwest Georgia. Geology of the Coastal Plain is dominated by karst, mainly limestone, formations from Paleocene to Miocene periods (Hicks et al. 1987), which underlie and outcrop through an overburden of slightly acidic sandy-loam soils. The Upper Floridan Aquifer lies under most of the lower Flint River Basin and provides excellent permeability and potential for infiltration and storage of regional precipitation which approximates 52 in annually. This prolific karst aquifer stores trillions of gallons of water and has been shown to be hydraulically connected to surface waters throughout the Coastal Plain (Torak and Painter 2006).

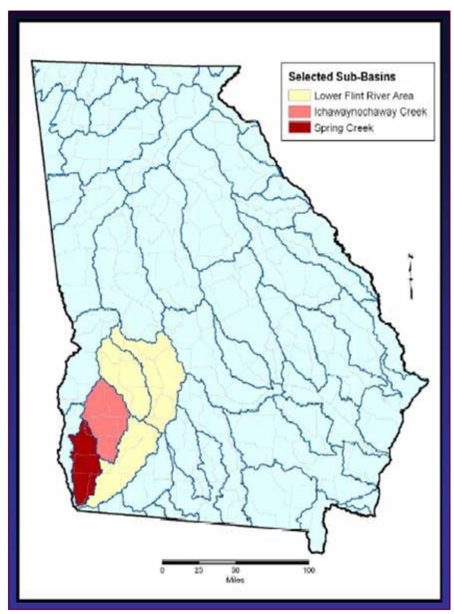

Figure 1. Ichawaynochaway and Spring Creek sub-basins located within the lower Flint River Basin located in southwest Georgia.

Low-nutrient soils in this area lack organic matter and are unable to retain adequate moisture for profitable agricultural yields. Depending on timing of rainfall and climatic conditions, there is often insufficient rain for crops during the growing season, making irrigation vital to sustain current yields and returns. Row crop revenues in the Lower Flint, combined with farm gate industries, account for approximately 34% of the regional economy. (McKissick 2004).

Widespread implementation of center pivot irrigation systems began in the lower FRB around 1975. The Ichawaynochaway and Spring Creek watersheds are two of the most intensely irrigated sub-basins in the lower FRB (Couch and McDowell 2007). Groundwater represents 89% of the water permitted for irrigation in the Spring Creek sub-basin, totaling 1.34 billion gallons per day (BGD). The Ichawaynochaway Creek sub-basin is permitted for 412 million gallons per day (MGD) of groundwater and 368 MGD of surface water withdrawals (Hook et al. 2005).

Tributary streams of the lower FRB originate in the Fall Line Hills as springs and seeps and flow across the Dougherty Plain and receive seasonal discharge (baseflow) from the Upper Floridan aquifer through streambeds and limestone outcroppings within the stream. Historically, baseflows have kept perennial waters flowing in these streams during summer months, providing essential refugia for aquatic species such as mussels and Gulf Striped Bass. Critical habitat has been designated for four species of mussels which are listed as endangered or threatened in the lower FRB and the USFWS is in the process of designating critical habitat for these species (Albertson and Torak 2002).

The U.S. Geological Survey (USGS) has maintained stream flow records in this area since around 1940, including a long-term discharge record on Spring Creek near Iron City, in Decatur County, GA (Station 02357000), and Ichawaynochaway at Milford, in Baker County, GA (Station 02353500). These records have been used by multiple investigators to examine possible effects of groundwater and surface water extraction on streams in the lower FRB. Stamey (1996) observed a decrease of 30% in mean low flows at Ichawaynochaway Creek (Milford gage) compared to pre-irrigation years. Albertson and Torak (2006) modeling various pumping scenarios, concluded that eight reaches in the lower FRB, including Spring Creek, were highly sensitive to pumping and going dry, threatening instream populations of threatened and endangered mussels. Golladay et al. (2007) showed that since the implementation of center pivot irrigation systems (pre-irrigation period 1940-1974, post-irrigation period 1975-2004), 1-day minimum stream flows had been reduced by 40% and 46% in Ichawaynochaway and Spring Creek, respectively, with no significant change in annual rainfall over the same period (Fig. 2). Those analyses also revealed reductions in 7-,10-, and 30-day flows and monthly percentile flows.

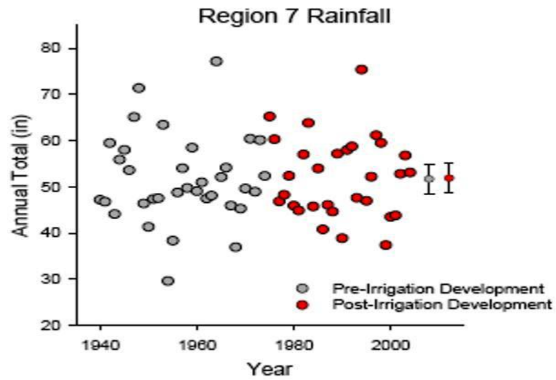

Figure 2. Annual rainfall totals for Region 7 in southwestern Georgia. Dots with error bars are means and standard deviations for pre- and post-irrigation period (adapted from Golladay et al 2007).

METHODS AND RESULTS

Flow Duration Curve Analyses

We generated flow duration curves (FDCs) following Searcy (1959) for five USGS gaging stations including Ichawaynochaway Creek at Milford, and Spring Creek near Iron City, based on pre- and post-irrigation periods. We performed 1- and 2-tail t-tests to compare day of occurrence and streamflows associated with mean 7-, 14-, and 30-day low flows of pre- and post-irrigation years. Two rounds of t-tests were run: one assuming equal variances and one assuming unequal variances. Kolmogorov-Smirnov test was run to test normality of all flow and julian day data sets. Pre-irrigation period was considered to be 1940-1969 (n=30) and post-irrigation period was 1976-2007 (n=32). All analyses were performed at α=0.05 level using SAS Analyst (SAS 2003).

For the scope of this publication we report the data from only 2 gaging stations: Ichawaynochaway at Milford, GA (Fig. 3a), and Spring Creek near Iron City, GA (Fig. 3b). T-test results reflected default assumption of unequal variances. Data showed significant differences in pre- and post-irrigation annual flow duration curves for both Ichawaynochaway and Spring Creek. The flow rate exceeded 95% of the time was reduced by an order of magnitude in both streams in the post-irrigation period and zero flow periods increased approximately 2% of the time in Spring Creek record.

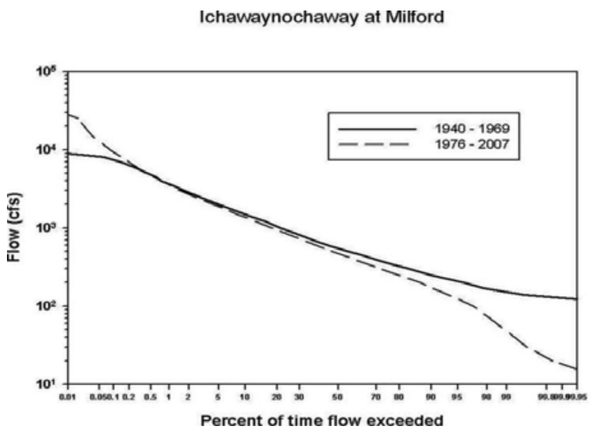

Figure 3a. Flow duration curves for pre- and post-irrigation periods on Ichawaynochaway Creek at Milford, GA.

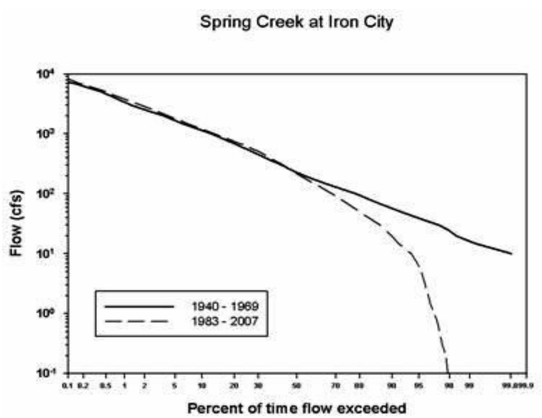

Figure 3b. Flow duration curves for pre- and post-irrigation periods on Spring Creek near Iron City, GA.

Baseflow Recession Curve Analyses

Streamflow data from the USGS website for Ichawaynochaway Creek at Milford, GA, and Spring Creek near Iron City, GA, were divided into pre- and post-irrigation years (1940-1969 and 1980-2007, respectively) excluding all data from the 1970's and the floods of 1994 and 1998. We identified 228 storm events from Spring Creek within this period and 249 storm events from Ichawaynochaway Creek. We isolated approximately eight days of consecutive flow data (starting on the third day following peak flow) in the recession limb of each storm event and fit a power slope to the receding baseflow data. Using power slope as the experimental unit we compared pre- and post-irrigation year mean slopes in early summer (May 1-July 15), late summer (July 16-October 31), and winter months (November 1-April 30). We performed paired t-tests and oneway analyses on the mean power slopes by season using JMP7 (SAS 2007) on all datasets and performed analyses of covariance to account for differences in beginning discharge.

Results of baseflow recession analyses on pre- and post-irrigation years showed a significant difference in recession behavior during early summer periods on Ichawaynochaway Creek at Milford ($\alpha=0.05$, $p=0.001$, $df=5$) (Fig. 4a). No significant difference was detected between pre- and post-irrigation recession slope behavior in the record for Spring Creek near Iron City (Fig. 4b). ANCOVA results showed a significant relationship between beginning discharge and recession slope.

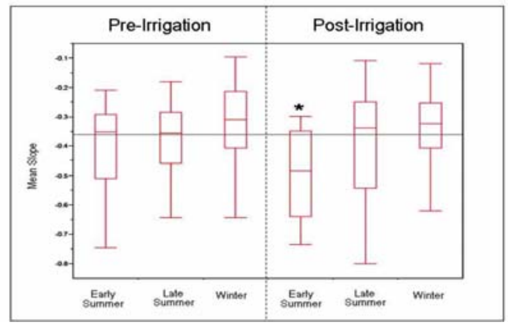

Figure 4a. Baseflow recession slope comparisons by season for pre- and post-irrigation periods on Ichawaynochaway Creek at Milford, GA. (Horizontal line indicates mean baseflow recession slope for period of record)

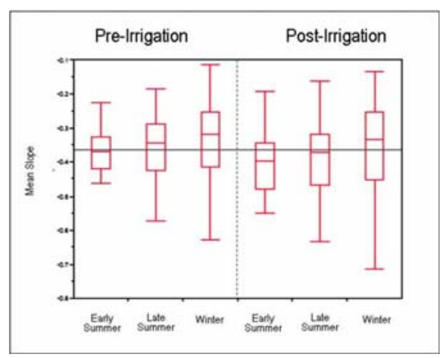

Figure 4b. Baseflow recession slope comparisons by season for pre- and post-irrigation periods on Spring Creek near Iron City, GA.

DISCUSSION

Extraction of groundwater has been linked to lowered growing season aquifer levels and losing stream conditions within the lower Flint River Basin. The analyses presented here support previous evidence that steam behavior is being affected along the Ichawaynochaway and

Spring Creek tributaries of the lower Flint within the post-irrigation period. The Spring Creek gage, in particular, shows a significant increase in no-flow periods lasting up to six months since extensive irrigation began in this region. These data concur with the spatial distributions of sensitivities predicted by the USGS modeling which projected flow reductions and drying conditions within Spring Creek tributaries under current pumping scenarios (Alberton and Torak 2002). The significant changes seen in early summer baseflow recession slopes of Ichawaynochaway Creek coincide with increased seasonal pumping during the post-irrigation period. Water use in the Ichawaynochaway sub-basin is from both surface and groundwater sources which results in a more rapid stream flow response time (Couch and McDowell 2006). The short-term baseflow recession analysis presented here may not be adequate for capturing the long-term, delayed effects of groundwater water removal on baseflow within the Spring Creek sub-basin.

CONCLUSIONS

Communities in the Coastal Plains region of southwest Georgia generate substantial farm gate revenues while placing high demands on water resources. Peak water withdrawals coincide with periods of low summer flows and high evapotranspiration rates, lowering baseflow and placing stress on aquatic organisms in these streams. Reduced flow can result in the loss of contiguous pathways between head and back waters (Light and Vincent 2005), lowering dissolved oxygen, altering water temperature, and threatening aquatic species such as mussels and striped bass, highly dependent on high oxygen and cool summer refuge (Zale et al. 1990; Golladay et al. 2004).

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