EFFECTS OF IRRIGATION WITHDRAWALS IN THE DOUGHERTY PLAIN ON BASE-FLOW IN THE APALACHICOLA RIVER

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INTRODUCTION

Maintenance of the base-flow of the Apalachicola River is important to the ecological functioning of its floodplain and estuary and for the provision of a federally authorized navigation project. This paper analyzes the impacts of irrigation activities in the lower Flint basin on base-flow of the Apalachicola River. Figure 1 shows the location of the Apalachicola-Chattahoochee-Flint (ACF) drainage basin and major features mentioned in this paper.

BACKGROUND

The Downstream Uses. The Flint River joins with the Chattahoochee River at the Florida border to form the Apalachicola River. Throughout the early 1980s the Apalachicola River's estuary provided about 90 percent of the state's and 10 percent of the nation's oyster harvest and sizable shrimp, blue crab, and fin fish yields. Annual seafood landings are valued in the tens of millions of dollars, but the real value of the estuary, however, is in its role as a nursery. Over 95% of the commercial species harvested in the Gulf spend some critical portion of their life-cycle in an estuary (Weber 1990). The Apalachicola estuary's productivity is the result of good water quality, the estuary's physical form, it's salinity regime, and energy subsidies in the form of nutrient/ detrital transport from the river's floodplain. It is keyed to a diurnal tidal cycleand a salinity regime defined by an annual cycle of spring floods and winter low-flows and cyclical long-term fluctuations in river flow (Livingston 1984).

The Apalachicola River is federally authorized to be maintained at a nine by one-hundred foot dimension as a commercial navigation channel. The availability of this depth is dependent on the flow in the Apalachicola River. Current authority calls for channel dimensions to be provided by 1) dredging, cutoffs, training works and other open-river methods, 2) a series of locks and dams, and 3) flow regulation from upstream storage projects. To date, numerous structural modifications have been made in an attempt to provide the authorized channel on a year-round basis. These include five dams on the Chattahoochee River, an extensive network of dike fields on the Apalachicola River, six cutoffs, removal of rock shoals at 10 locations and annual maintenance dredging and snagging. Despite these efforts, the channel is not available on a year-round basis. The authorized dimensions were available only 80 percent of the time between 1970 and 1980, a period which was relatively wet (Leitman et al. 1983; Raney et al. 1985) and has been available considerably less since then. The flow at which the authorized channel can be provided after dredging, 11,300 cubic feet per second (cfs) at the Blounts-town, Florida gage, has been available only 80 percent of the time for the sixty-five year period-of-record. The discharge that has been available on a reliable, year-round basis (i.e., 95% of the time) is 7,800 cfs.

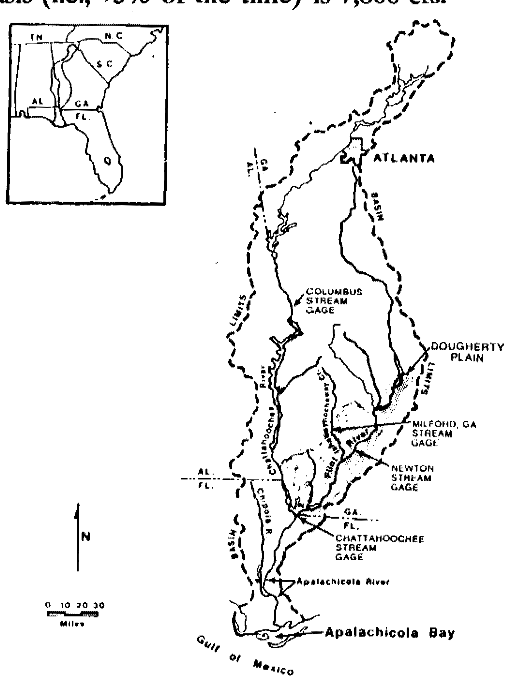

Figure 1. Location of the ACF drainage basin.

Water Resources. From a surface water perspective, the areas of concern regarding the impacts of irrigation withdrawals are all three river basins. Although the Chattahoochee and Flint sub-basins are nearly equal in area, their effects on flow in the Apalachicola River differ. The Chattahoochee is a regulated stream whose flow is predominantly from surface runoff. It typically contributes the major portion of flow in mean- to high-water events. The Flint, in contrast, is unregulated and has a major spring-fed flow component and therefore should contribute the larger share of flow during low-flow periods.

Although the Chattahoochee is regulated, the management capabilities of it's reservoirs is limited by the fact that the two reservoirs which contain over 80% of the conservation storage impound less than 18% of the watershed. There-fore, the potential for refilling these reservoirs during low-flow events is constrained and they must be managed conservatively. In addition, the majority of the designated storage capacity in these two reservoirs has been captured by recreational interests and adjacent land-owners or allocated for municipal water supply. Historically, the reservoir system has been shown to have had a limited effect on the overall flow regime of the Apalachicola River (Maristany 1981, Leitman et al. 1983, Raney et al. 1985).

Management options of the reservoirs are further constrained because hydropower facilities are managed as part of a grid with the Alabama-Coosa-Tallapoosa and Savannah basins. Providing water to Apalachicola Bay is not an authorized purpose of the federal reservoirs; thus water is not released from the reservoir system to enhance shellfish productivity or major nursery areas. Florida's federal legislative delegation are putting forth efforts to change this authorization.

From a groundwater perspective, the area of concern is the Dougherty Plain district of the Coastal Plain physiographic province. The porous nature of the underlying Floridan aquifer in the Dougherty Plain region means both that the area is well suited for irrigation wells and that the Floridan aquifer is closely linked to the Flint River. Aquifer discharge to the Flint River downstream from the Lake Worth dam has been computed to be one billion gallons per day (Torak et al. 1991). The ground water level in the Upper Floridan Aquifer is generally at a maximum during February through April, declines through summer, and is at a minimum during November and December, when flows in the Apalachicola River are also at a minimum. Near major agricultural and industrial centers, seasonal water fluctua-tions can exceed 30 feet (Torak et al. 1991). These seasonal depressions of the aquifer in turn translate into reduced flow in the Flint and it's tributaries as they recharge the Floridan Aquifer. This, in turn, translates into a reduction of base-flow in the Apalachicola River.

Table 1. Irrigated Acreage in Georgia: 1970-1989

	TOTAL ACREAGE (all systems)	PIVOT SYSTEMS (number)
1970	144,627	87
1973	193,857	238
1975	307,416	478
1978	722,075	1,636
1980	988,356	2,858
1982	1,104,992	3,597
1984	1,069,221	3,794
1986	1,128,584	4,191
1989	1,223,836	4,865

Source: University of Georgia, 1989.

Irrigation. As Table 1 shows, in the past twenty years the use of ground water for irrigation and the use of center-pivot type irrigation systems, such as those used in southwest Georgia, have increased significantly. The combination of technological innovations in irrigation, a robust aquifer, and favorable profit margins for field crops in the early- and mid-1970's provided the incentive for the conversion of marginal land (wood-land and pasture) into row crops. This increased agricultural usage of marginal land resulted in a need for additional fertilizers and pesticides, which conveniently could be applied via sprinkler irrigation systems. Nearly three-fourths of the new marginal farmland were used to grow soybeans and corn, crops with high water requirements (White 1980).

Southwest Georgia typically receives about fifty inches of rainfall annually for crop production. However, most of this occurs in the early spring when seedling row crops require less water. During the summer, when many crops require more water, the rainfall typically declines.

Although the amount of irrigated acreage has stabilized in recent years, Table 1 shows that the number of center-pivot systems continues to increase. Center-pivot systems have the advantage of being relatively low in cost as compared to other types of irrigation systems, adaptable to the sandy soils found in this region, easy to operate and have low maintenance requirements (Smajstrla et al. 1988). Center-pivot irrigation systems provide the most efficient vehicle for chemigation (Dowler 1982) and provide the most uniform application of water to both foliage and soil of all irrigation systems. Although less efficient than drip or line source systems, center-pivot systems are more efficient than some other conventional systems and in recent years versions have been developed to make these systems more efficient (Smajstrla et al. 1988a). In 1970, the 22 county area in southwest Georgia and the middle Flint withdrew 13.19 million gallons per day (MGD) for irrigation purposes, 3.20 MGD being withdrawn from ground water sources and 9.89 MGD from surface water sources (Carter and Johnson 1974). In 1990, the same counties withdrew 211.22 MGD, 54.34 from ground water sources 156.88 MGD from surface water for irrigation (Fanning et al. 1992). Over 80 percent of the increase in water use in this region from 1970 to 1990 can be attributed to increases in irrigation withdrawals.

Because of these recent increases in irrigation activity, the physical relationship between the Floridan aquifer and the Flint River and the importance of inflow from the Flint River to base-flow in the Apalachicola River during periods of low-flow,, this paper investigates whether base-flow in the Flint and Apalachicola Rivers has been affected by the recent increases in irrigation withdrawals.

METHODS

The process of evaluating man-induced changes to the flow regime of a river is complicated by the fact that flow normally varies both seasonally and annually. In a typical year, average daily flow in the Apalachicola River varies about ten-fold. The annual minimum flow has varied nearly three-fold over the period-of-record. Therefore, the task is to discern a significant long-term change in flows in a system that has considerable inherent variation. To accomplish this, the effects of irrigation activities in the Flint basin on base-flow in the Apalachicola River are evaluated through two methods: 1) comparison of the relative contributions of the Flint and Chattahoochee to flow in the Apalachicola River over time; and 2) analysis of changes in the flow of the Flint relative to similar rivers in the region through the use of multiple mass balance analysis.

For the relative contribution analysis, monthly mean flow data for USGS gages on the Flint and Chattahoochee were compared with data from a gage on the Apalachicola River. Data from the gages for the Flint River at Newton, Georgia (USGS gage # 02353000) and Ichawaynochaway Creek at Milford, Georgia (USGS gage # 02353500) were combined for the Flint flow. These were compared with data for the Chattahoochee River at Columbus, Georgia (USGS gage # 02341500) and the Apalachicola River at Chatta-hoochee, Florida (USGS gage # 02358000). These gages were chosen because of their available period of record and location within each sub-basin. All three gages had continuous records from 1937 to 1992 water years, with the exception of the Newton gage which was missing 1945, 1947, and 1950 to 1956. The Flint River gages were located in the middle of the Dougherty Plain and downstream from some of the most intense irrigation activity in the region. The Chattahoochee River gage was the lowest gage on the river with long-term flow record. The Apalachicola River gage provided a measurement of flow immediately below the confluence of its two main tributaries.

The analysis consisted of individually dividing the monthly mean flow values on the Flint and Chattahoochee Rivers into the corresponding monthly mean flow of Apalachicola River at the Chattahoochee gage for the period 1938-1992. Data were grouped into two periods, before irrigation use increased (before 1970) and after the growth (1978 to the present).

For the multiple mass balance analysis, flow at a gage on the Flint River at Newton, Georgia, was compared with the aggregate flow of other streams in the region. This analysis isolates a trend in the divergence of one data set from another which has been labeled as a control. Selection of rivers for the control was based on similarities to the Flint basin in rainfall, the existence of a spring-fed flow and land use. Rivers included in the analysis include the Econfina, Ochlockonee, Choctawhatchee, Withlacoochee and Chipola Rivers. The analysis consisted of a time-series comparison of the ten-year moving average of monthly data for the Flint gages to the combined and individual flow of the above rivers.

RESULTS

Figures 2 and 2a display the relative contribution of the Flint and Chattahoochee Rivers to the minimum monthly flows of the Apalachicola River before and after the recent increase in irrigation activity in the lower Flint. These figures show the relative contribution of the Flint and Chattahoochee River to flow in the Apalachicola River has changed dramatically since irrigation activity in southwest Georgia increased in the mid-1970s. When compared with the pre-irrigation period, the relative contribution of the Flint to flow in the Apalachicola decreases in the post-irrigation period as flow in the Apalachicola River decreases. This is contrary to the expected relationship.

Possible explanations for this change include: 1) a lowering of base-flow in the Flint River; 2) low-flow augmentation releases from the reservoir system in the Chattahoochee basin have altered the relative-contribution relationship between the Flint and Chattahoochee Rivers; 3) the rainfall patterns in the Flint and Chattahoochee basins have changed over time; 4) there have been concluded that although there is a significant land use changes in one of the basins which altered its hydrology; or 5) some combination of the above.

A review of rainfall data for gages throughout the Flint and Chattahoochee basins did not show differences to cause the above changes in the relative-flow relationship. A recent review of land use changes in the basin general trend in land use in the ACF basin from farmland into urban areas or reversion of farmlands to woodland, the changing land use patterns were believed to not have a significant effect on river flows in the drainage basin (Raney et al. 1985).

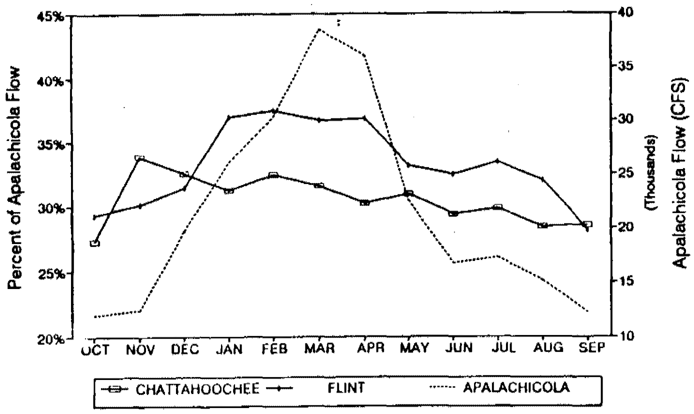

Figure 2. Relative contribution of the Flint and Chattahoochee Rivers to flow in the Apalachicola River: 1938-1970

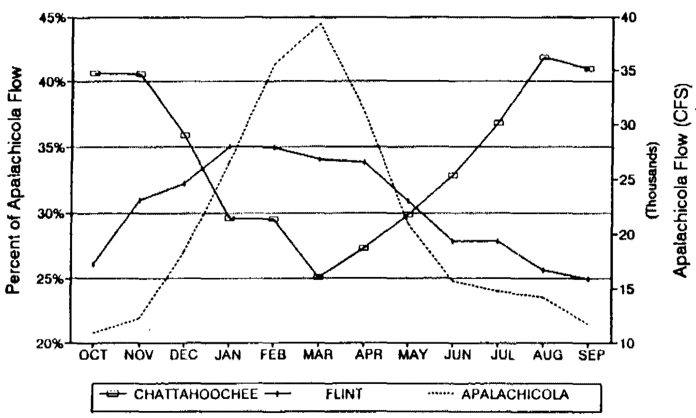

Figure 2a. Relative contribution of the Flint and Chattahoochee Rivers to flow in the Apalachicola River: 1978-1992

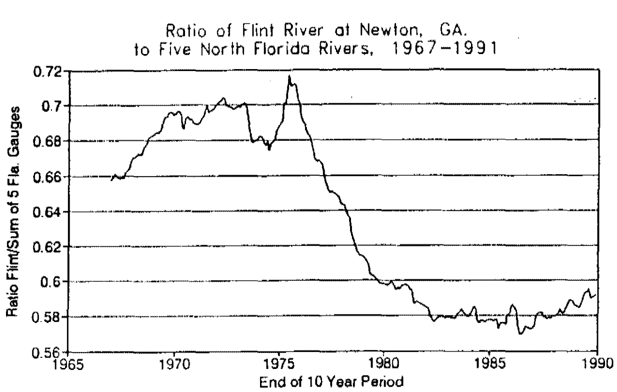

Figure 3. Comparison of flow at Newton, Georgia gage on the Flint to the aggregate of five gages in Florida.

Figure 3 shows the ratio of flow in the Flint to that of the five other rivers. This Figure also suggests that the base-flow of the Flint has been lowered since irrigation activities increased. These results support our conclusion that rainfall is not the cause of relationship changes noted in relative-flow contribution. As the Chattahoochee was not part of the comparison, the perceived lowering of base-flow in the Apalachicola River is independent of influence by low-flow augmentation releases from the reservoirs in the Chattahoochee basin.

CONCLUSIONS

Based on the above analyses, it is concluded that the base-flow of the Flint River has been reduced since the early 1970s. As irrigation withdrawals accounted for the majority of the increases in water use in the Flint basin, irrigation is the prime suspect for causing this reduction. This reduction of base-flow would translate into a concomitant reduction of base-flow in the Apalachicola River. Because of the ramifications of reduced fresh water inflow to Apalachicola Bay and to the availability of the federal navigation channel, the issue of irrigation withdrawals impacts on base-flow in the Flint and Apalachicola Rivers warrants closer inspection.

The effects of irrigation withdrawals in the Dougherty Plain on flow in the Flint River, and therefore also the Apalachicola River, clearly show that reservoir management and water management are not synonymous in the ACF basin. Much of the watershed is not regulated by reservoirs and the capacity of existing reservoirs is limited relative the flows in the lower portion of the basin.

Any hydrologic models developed in the ongoing Comprehensive Water Resources Management Study needs to account these apparent flow reductions. Using the long-term historical record for the Flint will provide an inaccurate portrait of the present and future conditions. Depletion analysis, as has been done in several basins in the western U.S., is needed.

If the base-flow of the Flint has been lowered as the result of irrigation activity, future withdrawals need to be controlled either through regulations or market mechanisms. At present, irrigation withdrawals in Georgia are essentially unregulated so long as the user does not seek to increase the capacity of an existing well. A root cause of the overuse of water by agriculture is a failure to price water properly. If the price of water reflects it's true value (including all environmental and social costs), users should behave more conservatively. The use of economic incentives and dis-incentives to encourage development and use of alternative irrigation systems warrants further consideration. As does programs to educate farmers on the effects of their behavior.

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