Flint River Basin Regional Water Development and Conservation Plan

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Introduction

The Flint River Basin Water Development and Conservation Plan ("the Plan") was initiated in October 1999 in response to a prolonged drought, increased agricultural irrigation in southwest Georgia since the late 1970's, and scientific studies that predicted severe impacts on streamflow in the Flint River Basin (FRB) due to withdrawals from area streams and the Floridan aquifer. As defined in Georgia statutes, regional water development and conservation plans "shall promote the conservation and reuse of water within the state, guard against a shortage of water within the state, promote the efficient use of the water resource, and be consistent with the public welfare of the state." (O.C.G.A. 12-5-31(h)). Similar language is found in the Groundwater Use Act, which also requires plans to address "sustainable use".

Because agricultural irrigation uses the largest volume of water in the FRB, this report and its recommendations will focus on irrigation and farm-use withdrawal permits. The report summarizes the most recent and comprehensive scientific studies available on water use and hydrogeology in the FRB, evaluates impacts of water use on the stream-aquifer system and stream ecology of the lower FRB, and establishes EPD permitting actions based on stakeholder-developed recommendations. The Plan covers agricultural water use in the entire FRB, but the focus is on the lower Flint River Basin where agricultural water use is greatest.

The FRB extends from Hartsfield-Jackson International Airport in Atlanta to the southwestern corner of Georgia (Fig. 0.1). It's southern half lies within the Coastal Plain physiographic province. South of Dooly County, the Flint River and some of its tributaries are in hydraulic connection with the Floridan aquifer, and either receive water from the aquifer or lose water to it depending on the head difference between the streams and the aquifer. This area where the streams are connected to the Floridan aquifer is known as “Subarea 4 of the Apalachicola-Chattahoochee-Flint (ACF) Basin”, and it includes part of the lower Chattahoochee watershed as well as a narrow strip on the eastern edges of the Ochlockonee and Suwannee River Basins. For simplicity, these areas adjacent to Subarea 4 will be included in all subsequent discussions of the FRB.

Water use in the FRB below the fall line is dominated by agricultural irrigation, which comprises as much as 90% of the water used during the April-September growing season. Overall, a total of approximately 160,000 acres are irrigated from surface-water throughout the FRB and approximately 403,000 acres from Floridan aquifer wells in Subarea 4 (Fig. 0.1). Approximately 250 mgd are used basin wide by agricultural surface-water users in July (the peak month) of a typical irrigation season during a drought year, and approximately 950 mgd are withdrawn from Floridan aquifer irrigation wells at the peak of the irrigation season during a drought year. These withdrawals reduce streamflow, and can degrade aquatic habitat in the lower FRB. Surface-water withdrawals have a more direct effect than do ground-water withdrawals.

Permitted municipal and industrial (M&I) water withdrawals throughout the FRB total approximately 120 mgd on a monthly average from surface-water sources (mostly north of the fall line), 88 mgd from aquifers other than the Floridan aquifer, and 30 mgd from the Floridan aquifer in Subarea 4. Actual surface water use in 2004 was approximately 50 mgd (Table 5.3). M&I withdrawals from the Floridan are equivalent to 3% of the agricultural ground-water use, and thus will not be discussed in any further detail in this report. The permitted withdrawals of consumptive M&I surface-water usage is offset by water returned as treated wastewater, which in the Flint River Basin is approximately 126 mgd. Actual discharges are much smaller. Thus, the amount of M&I water removed and not returned from the Flint River and its tributaries is only a fraction of the total consumptively used surface-water withdrawals. Because agriculture irrigation uses the largest volume of water in the FRB, this report and its recommendations will focus on irrigation and farm-use withdrawal permits.

Surface-water and ground-water withdrawals in the FRB can have a negative impact on stream ecology and the viability of sensitive aquatic species. Specifically, the FRB is home to species of federally protected freshwater mussels, whose populations have been declining precipitously since the early 1900's. During the drought of 1999-2002, mussel populations in many locations in the lower FRB were substantially reduced, especially in parts of Ichawaynochaway Creek and Spring Creek sub-basins (Fig. 0.1). Significant declines in surveyed mussel populations also occurred in other watersheds, mostly inside Subarea 4. The lower FRB also contains a significant population of gulf striped bass. In summer, the bass take thermal refuge in the cooler water of the blue-hole springs that are dependent on adequate ground-water discharge. Ground-water withdrawals from the Floridan aquifer may lower aquifer head, reduce spring flow, and deprive the bass of thermal refuge.

Two hydrologic modeling systems were used to evaluate the effects of ground-water and surface-water (irrigation) withdrawals on streamflow in the lower FRB. The ground-water model was developed by the U.S. Geological Survey (USGS) and modified by EPD, and simulates flow between the Floridan aquifer and streams that are hydraulically connected to the Floridan aquifer. The streamflow modeling system, Hydrologic Simulation Program Fortran (HSPF), was used by EPD to simulate the extent to which streamflow is affected by surface-water irrigation withdrawal and reduced base flow as calculated by the USGS ground-water model. HSPF modeling included a series of "future scenario" analyses that imposed irrigation stresses on likely rainfall patterns for the next 50 years.

Simulated streamflow was modeled under a range of scenarios and compared with in-streamflow criteria. It is thought that sustaining flows that meet the criteria will prevent further harm being done to the freshwater mussels. The criteria against which flows were compared were developed by the U.S. Fish and Wildlife Service (USFWS) for regulated and un-regulated streams in the ACF basins (U.S. Fish and Wildlife Service, 1999). EPD used the specific criteria for unregulated streams since the Flint River downstream from Lake Cheehaw is free flowing, and the major tributaries have no significant impoundments. The criteria for unregulated streams evaluate the one-day minima that occur in a stream, the frequency with which those minima occur, and the duration of low flows. According to these criteria, the lowest daily flows, the lowest quartile of all daily flows, and the median of all daily low flows are not to be exceeded a certain number of times, and they are not to be exceeded for prescribed lengths of time.

Food and fiber production is a major aspect of the FRB economy, and the majority of agricultural production is for human consumption. Combined with processing facilities, direct manufacturing, and the agriculture-related trade sector, the total impact of agriculture in the lower FRB is approximately $5.8 billion, or 34% of the regional economy. Irrigation greatly increases crop yields, crop quality, crop diversity, gross and net return, land values, etc., and thus plays a major role in the regional economy. Economic models were used to estimate the economic impact of reducing irrigation in parts of the FRB.

The Flint River Basin Regional Water Development and Conservation Plan incorporates recommendations developed by a Stakeholder Advisory Committee (SAC) during a year-long series of public meetings, and technical findings of several sound-science studies conducted in the Basin. The Plan is presented in three parts following an executive summary. Part I contains a summary of technical findings and the permitting actions EPD will take to manage agricultural water use in the Flint River Basin. Part II consists of a description of the Stakeholder process and the recommendations adopted by the SAC for permitting strategies and regulatory reform. Part III consists of detailed discussions of the sound-science studies and the technical foundations of the Plan. Appendices containing detailed hydrologic and geologic data follow Part III.

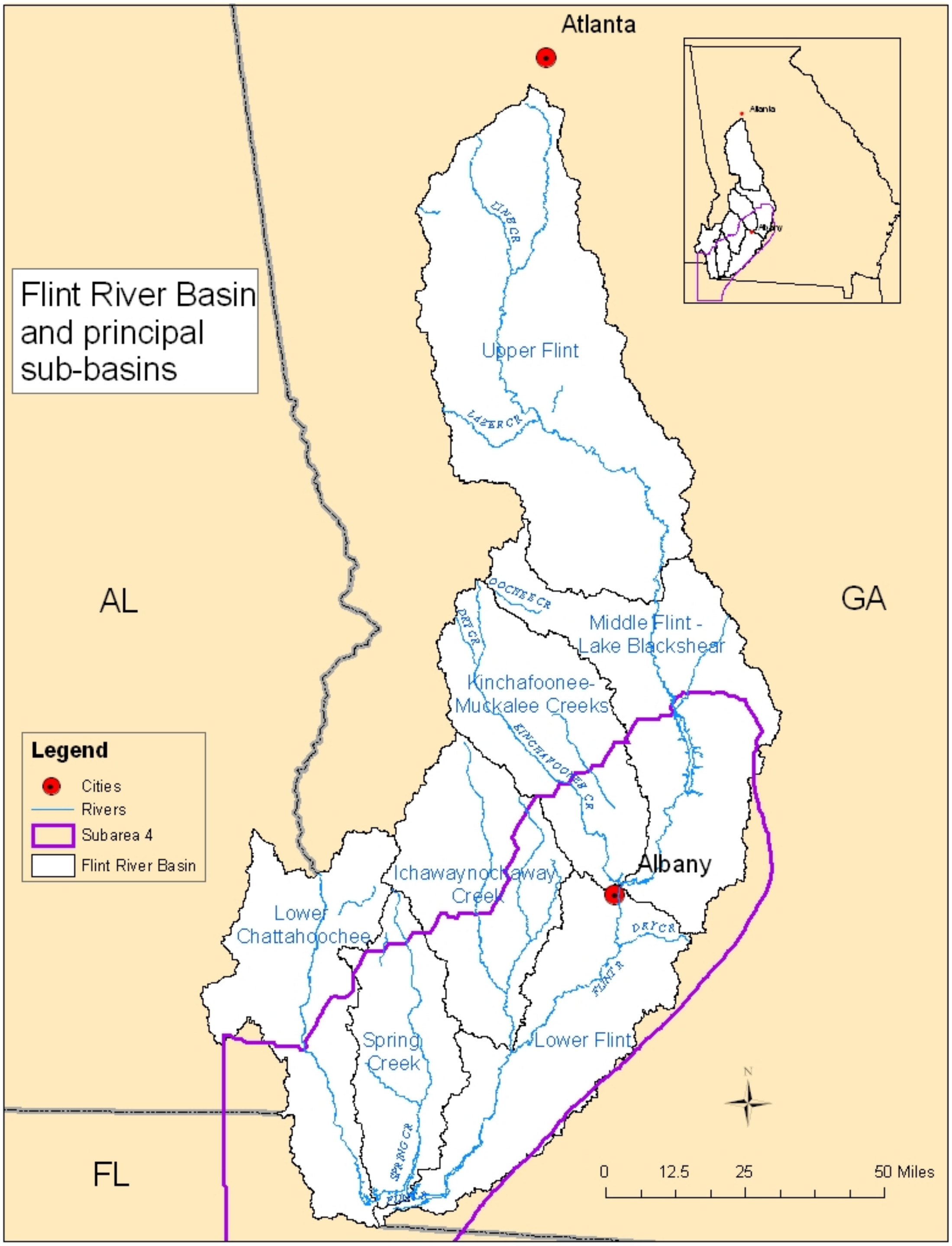


Figure 0.1: The Flint River Basin and sub-basins

Acknowledgements

The Flint River Regional Water Development and Conservation was developed through the close cooperation of many different people and organizations. Specifically, the members of the Stakeholder Advisory Committee (SAC) and their associates in southwest Georgia have been instrumental in developing and maintaining an excellent working relationship among themselves and with the Georgia EPD. The hard work and dedication of the SAC were essential to completion of this Plan. The Stakeholder Advisory Committee consisted of the following southwest Georgia residents:

Mr. James Lee Adams, Mitchell County
Mr. Lucius Adkins, Farmer, Baker County
Mr. Dan Bollinger, Director, Southwest Georgia RDC
Mr. John Bridges, Farmer, Decatur County
Mr. Charles (Chop) Evans, Farmer, Macon County
Mr. Thomas C. Chatmon, Jr., CEO Albany Tomorrow, Inc.
Mr. Vince Falcione, Proctor and Gamble, Albany
Mr. Tommy Gregors, Georgia Wildlife Federation, Albany
Mr. Hal Haddock, Chairman, Flint River Water Council and Farmer, Early County
Mr. Chris Hobby, City Manager, Bainbridge
Mr. Bubba Johnson, Farmer, Mitchell County
Mr. John Leach III, Developer, Lee County
Ms. Janet Sheldon, Southwest Georgia Water Task Force, and Georgia Conservancy
Mr. Mike Newberry, Farmer, Early County
Mr. Kim Rentz, Farmer, Decatur County
Mr. Steve Singletary, GSWCC Commissioner and Farmer, Early County
Mr. Marcus Waters, Crisp County Power, Cordele
Mr. Jimmy Webb, Farmer, Calhoun County
Mr. Joe Williams, Farm owner, Crisp County

Technical Advisory Committee (TAC) meetings were held mostly at the J.W. Jones Ecological Research Center at Ichauway as a result of the generosity of Dr. Lindsay Boring and the Robert W. Woodruff Foundation. The TAC provided the scientific foundation of the Plan through extreme diligence and hard work. The TAC consisted of the following scientists and technical experts:

Dr. Steve Golladay. J.W. Jones Ecological Research Center, Baker County
Mr. Mike Harris, DNR Wildlife Resources Division, Non-Game Section, Social Circle
Mr. Kerry Harrison, Cooperative Extension Service, Tifton
Mr. Woody Hicks, J.W. Jones Ecological Research Center, Baker County
Dr. James Hook,, University of Georgia/NESPAL, Tifton
Dr. Mark Masters, Director, Flint River Water Policy and Planning Center
Mr. Rob Weller, DNR Wildlife Resources Division, Fisheries Section, Albany
Mr. Joe Williams, Farm owner, Crisp County
Mr. Rad Yeager, Superintendent, Stripling Irrigation Research Park, Camilla

SAC meetings were very ably facilitated by staff from the Fanning Institute of the University of Georgia under contract with EPD. The facilitators kept the meetings, and thus the entire process, on track for more than a year. The facilitators were:

Mr. Dennis Epps, University of Georgia Fanning Institute
Ms. Courtney Tobin, University of Georgia Fanning Institute
Ms. Louise Hill, University of Georgia Fanning Institute

This document was written by a variety of people; specifically, Sections 5.3 and 5.4 on municipal and industrial permitting in Georgia were written by Bill Frechette and Kevin Farrell of the Georgia EPD; Sections 6.2 and 6.3 on surface water models and scenario impact evaluation, and Appendix I were written by David Hawkins of the Georgia EPD; Section 8 (Economic Status of the Flint River Basin) was written by Dr. Mark Masters, Director of the Flint River Planning and Policy center; Section 9 (Water Conservation in the Flint River Basin) was written by Alice Miller-Keyes of the Georgia EPD); the remainder of the document was written and assembled by Rob McDowell of the Georgia EPD.

Flint River Basin Regional Water Development and Conservation Plan

PART I: SUMMARY OF TECHNICAL FINDINGS AND EPD PERMITTING ACTIONS

The authority of the Georgia Environmental Protection Division (EPD) to develop and implement water development and conservation plans is provided in the Water Quality Act (O.C.G.A. 12-5-31(h)) and the Groundwater Use Act (O.C.G.A. 12-5-96(e)). This Plan sets forth how EPD will conduct management of agricultural water use and permitting in the Flint River Basin. The goals of the Plan, as defined by statute, are to promote conservation and reuse of water, guard against a shortage of water, promote the efficient use of the water resource, manage the water resources of the Flint River Basin such that they are used sustainably, and to be consistent with the public welfare. All farm-use permits issued after adoption of this Plan by the Director of EPD must, under Georgia law, be consistent with the Plan.

A. Summary of technical findings

The technical findings summarized below are accompanied by page and section references from Part III of the Flint River Basin Regional Water Development and Conservation Plan. Detailed information, analyses, and discussion may be found at those referenced sections.

1. Timing and volume of agricultural irrigation are extremely variable, and vary based on local rainfall distribution and other weather phenomena, crop type and planting date, soil conditions, and growers experience and preferences. However, for the Flint River Basin as a whole, large-scale crop irrigation typically starts in April and lasts through September. During that time, irrigation usage typically reaches a maximum in June, July, or August (Section 5.2).

2. Agricultural withdrawals from the Floridan aquifer decrease base flow to streams that are in hydrologic connection with the Floridan aquifer. However, depending on the nature of the connection between streams and the aquifer, groundwater withdrawals in some parts of the Basin reduce stream flow more than in other parts. There are 6 major sub-basins in the Flint River Basin, and these sub-basins can be divided into smaller watersheds. In some watersheds, computer models of stream-aquifer relations indicate that groundwater withdrawals from the Floridan aquifer have almost no effect on stream flow. Elsewhere, groundwater withdrawals have a more direct effect and decrease baseflow by a significant percentage of the total baseflow reduction in a sub-basin. In other words, groundwater withdrawals in some small watersheds account for most of the total baseflow reductions for the whole sub-basin. Withdrawals from surface water affect stream flow more directly than do groundwater withdrawals (Section 6.1; Appendix II).

3. Since extensive development of irrigation in the lower Flint River Basin, drought-year low flows are reached sooner and are lower than before irrigation became widespread. Furthermore, low-flow criteria established by the U.S. Fish and Wildlife Service designed to protect aquatic habitats are not met more frequently and for longer periods of time since development of irrigation. These data provide the clearest evidence that agricultural irrigation compounds the effect of climatic drought on stream flow in the Basin. This effect is magnified during droughts, and is minimal during normal to wet years (Section 6.3; Section 7; Appendix I).

4. Of the six sub-basins in the Flint River basin, Spring Creek sub-basin has the greatest density of irrigation. It also exhibits a very close connection between the Floridan aquifer and surface water. Statistical studies of stream discharge and biological studies of endangered fresh-water mussels indicate that Spring Creek

sub-basin has exceeded its safe yield in terms of farm-use withdrawals (Section 5.2; Section 6.1; Section 7.2).

5. A review of historical stream flow data indicate that 7Q10 flow used by EPD to set current permit discharge limits in the Flint River basin was based on pre-1970 data. Since then, extensive development of irrigation, combined with severe droughts, has caused post-1970 7Q10 flows to be lower. This implies that water quality standards may be violated more frequently if point and non-point-source loadings are not reduced, or if permitted water withdrawals reduce stream flows below quantities necessary to maintain water quality standards (Section 6.3.3; Appendix I).

6. If, under the Rules for Flint River Drought Protection (Chapter 391-3-28) irrigation withdrawals are reduced by 20% in those sub-basins with the greatest risk of experiencing irrigation-induced low flows, stream discharges that will prevent stream drying and harm to endangered fresh-water mussels will likely be sustained (Section 6.3).

B. EPD permitting and water resource management actions

1. Moratorium lifted.

The permit moratorium on new farm-use permits from the Floridan aquifer in Subarea 4 is hereby lifted according to permitting actions listed below. For purposes of implementing these actions and restrictions, three categories of smaller (HUC-12) watersheds are identified. These categories are: Capacity Use Areas, Restricted Use Areas and Conservation Use Areas (Figs. 0.2-0.5). Existing limits and restrictions on new withdrawal permits from the Floridan aquifer and surface waters will continue in Capacity Use areas after issuance of all Letters of Concurrence for applications in the ‘backlog’. However, Floridan aquifer withdrawal permits will be issued if an individual farm straddles the divide between a Capacity Use Area and Restricted or Conservation Use Area.

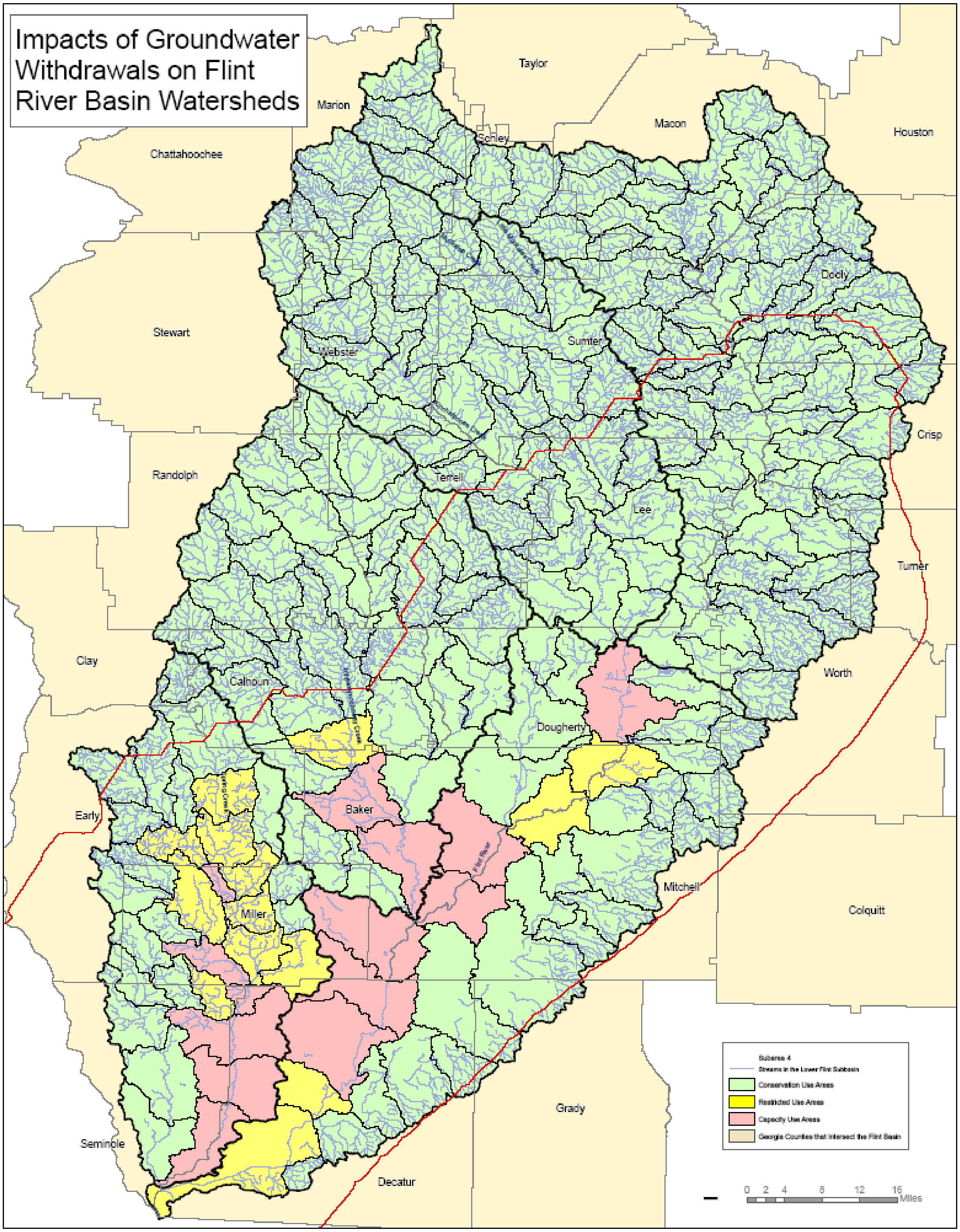


Figure 0.2. Classification of HUC-12 watersheds in the lower Flint River Basin.

(a) **Capacity Use Areas**: Those watersheds in Spring Creek sub-basin (Fig. 0.4) in which hydrologic models indicate decreased baseflow of more than 5 cfs in any month of a drought year, and more than 10 cfs in Ichawaynochaway Creek sub-basin (0.3), are hereby termed Capacity Use Areas, in which irrigation use from the Floridan aquifer is at the maximum permittable capacity. In the Lower Flint River sub-basin (Fig. 0.5), Capacity Use Areas are defined as those watersheds in which baseflow is reduced by more than 30 cfs in any month of a drought year (Section 6.1, Appendix II). Capacity Use Areas are shown in red on the accompanying map.

(b) **Restricted Use Areas:** Those watersheds in Spring Creek sub-basin (Fig. 0.4) in which hydrologic models indicate decreased baseflow of 1-5 cfs in any month of a drought year, and 1-10 cfs in Ichawaynochaway Creek (Fig. 0.3), are hereby termed Restricted Use Areas, in which additional irrigation must be restricted in order to prevent the watershed from becoming a Capacity Use Area. In the Lower Flint River sub-basin (Fig. 0.5), Restricted Use Areas are defined as those watersheds in which baseflow is reduced by 3-30 cfs (Section 6.1, Appendix II). Restricted Use Areas are shown in yellow on the accompanying map.

(c) **Conservation Use Areas**: Those watersheds in the Spring Creek and Ichawaynochaway Creek sub-basins (Figs. 0.3-0.4) in which hydrologic models indicate decreased baseflow of less than 1 cfs in any month of a drought year, and less than 3 cfs in the Lower Flint River sub-basin (Fig. 0.5; Section 6.1, Appendix II), are hereby termed Conservation Use Areas. Conservation Use Areas are shown in green on the accompanying map.

The designation of Capacity Use, Restricted Use, and Conservation Use areas is based on current understanding of hydrogeology and current irrigation practices in the lower Flint River Basin. These designations may change as irrigation patterns and amounts change, or as computer modeling of the stream-aquifer relationship improves.

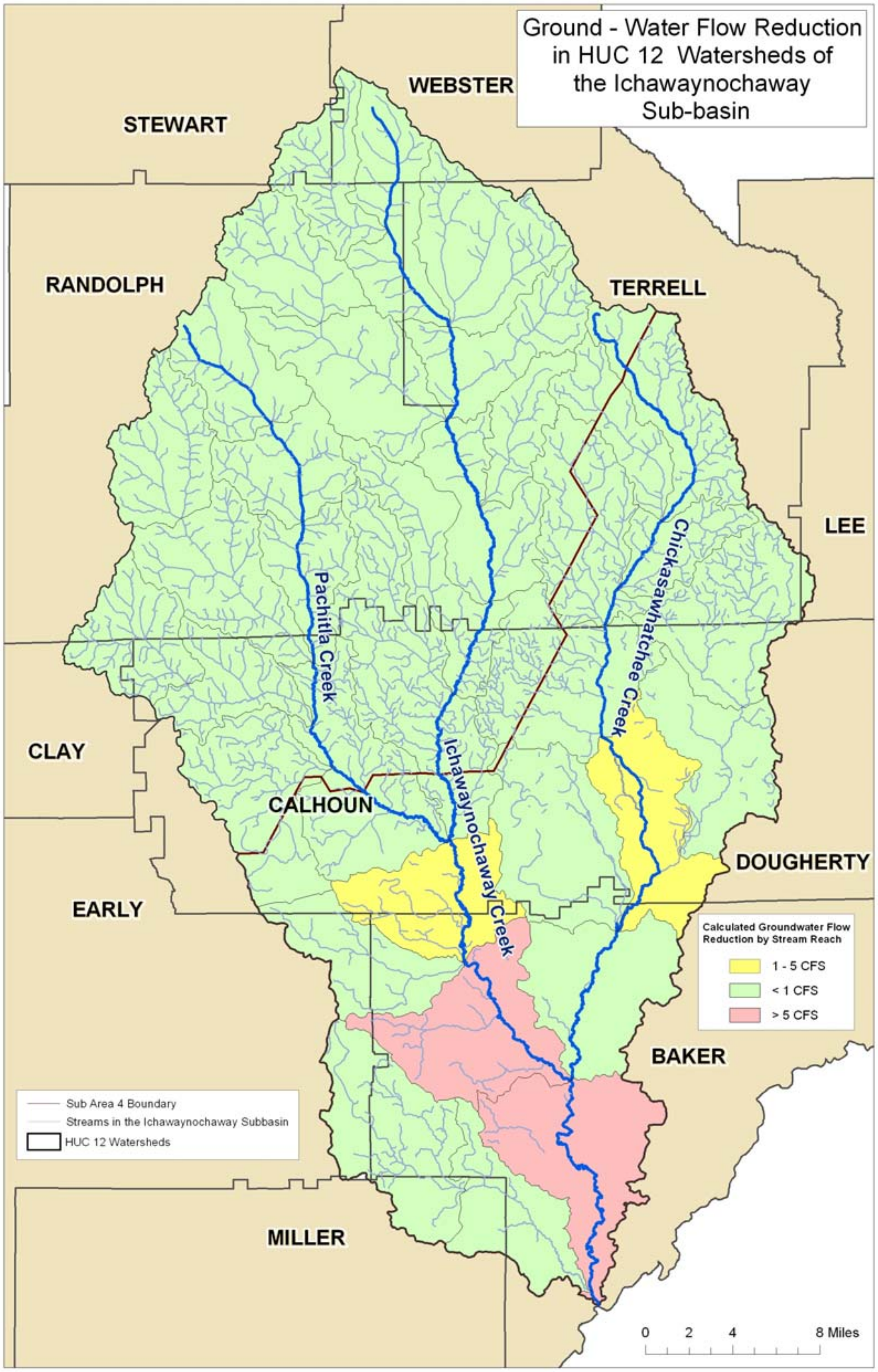


Figure 0.3. Classification of HUC-12 watersheds in the Ichawaynochaway Creek sub-basin.

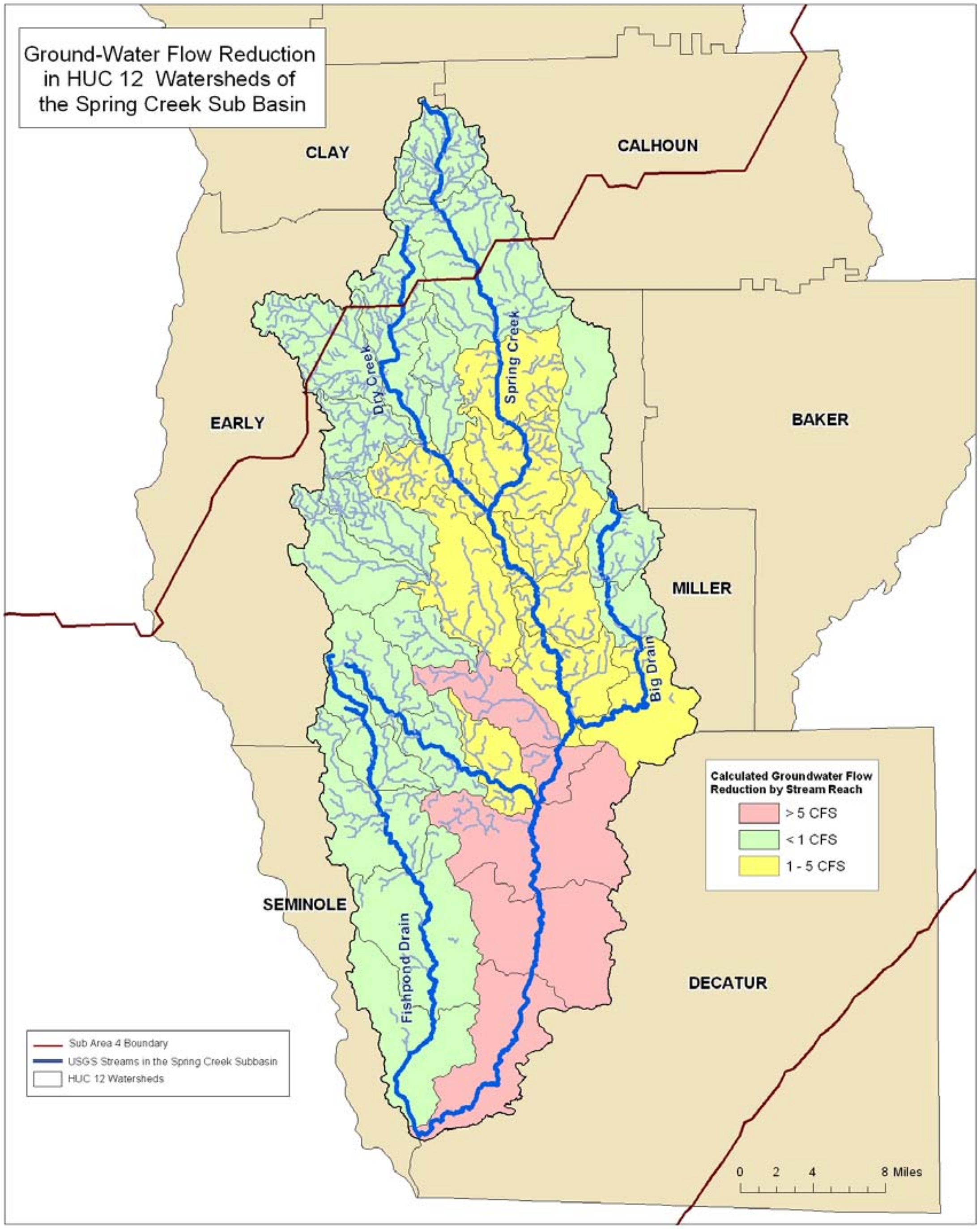


Figure 0.4. Classification of HUC-12 watersheds in the Spring Creek sub-basin.

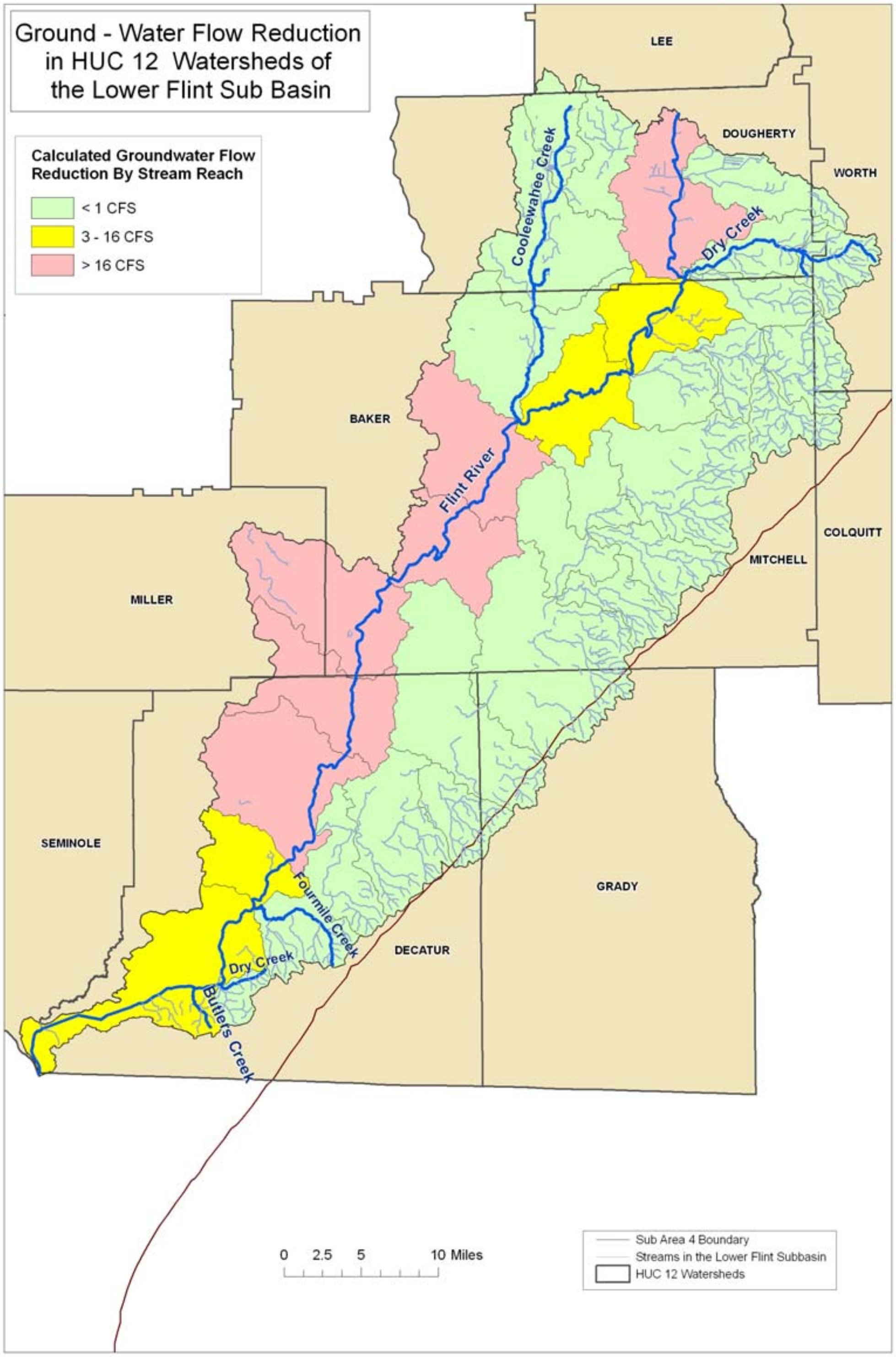


Figure 0.5. Classification of HUC-12 watersheds in the Lower Flint River sub-basin.

2. Sub-basin management.

The largest scale on which water management and permitting decisions will be based will be a sub-basin level corresponding to the USGS HUC-8 designation. Where necessary, and/or where data are available, permitting and management decisions will take into account site-specific conditions and local stream impacts down to a HUC-12 watershed scale. The HUC-8 sub-basins in the Flint River Basin are:

A. Upper Flint

B. Middle Flint

C. Kinchafoonee-Muckalee Creeks

D. Lower Flint

E. Ichawaynochaway Creek

F. Spring Creek

A map of the Flint River Basin showing these sub-basins and smaller (HUC-12) watersheds accompanies this document. Permitting decisions in these sub-basins will be based on the proposed volume of water to be pumped, surface-water and ground-water connections as determined by USGS and EPD groundwater modeling studies, the calculated impact of existing withdrawals on stream flows, the calculated impact of each proposed withdrawal on stream flow, and the presence of endangered or threatened species in each sub-basin.

3. Processing the pending (backlog) permits

The goals of the Plan, combined with the need to protect drought-year flows, will require a much more careful evaluation of farm-use permit applications than before the plan was initiated. Because of the large number of permit applications (1134) held in abeyance since December 1999 (i.e., the ‘backlog’), EPD cannot process and issue all letters of concurrence or a withdrawal permit before the 2006 April-October growing season. After the ‘backlog’ applications have all been evaluated according to this Plan, applicants in the Flint River Basin should expect a much shorter response time of approximately 30 days.

(a) For all groundwater permit applications held in abeyance during the permit moratorium which began on December 1, 1999, EPD will evaluate them in the following order:

(1) Groundwater applications for wells in Conservation Use Areas, starting with the earliest ones received before October 23, 1999, the date of the announcement of the permit moratorium.

(2) Groundwater applications for wells in Restricted and Capacity Use Areas, starting with the earliest ones received before October 23, 1999, the date of the announcement of the permit moratorium.

(3) All other groundwater applications received <u>after</u> October 23, 1999, the date of the announcement of the permit moratorium.

(b) For surface water permit applications held in abeyance during the permit moratorium which began on December 1, 1999, EPD will evaluate them in the following order:

(1) Surface water applications for wells in Conservation Use Areas, starting with the earliest ones received before October 23, 1999, the date of the announcement of the permit moratorium.

(2) Surface water applications for wells in Restricted and Capacity Use Areas, starting with the earliest ones received before October 23, 1999, the date of the announcement of the permit moratorium.

(3) All other surface water applications received <u>after</u> October 23, 1999, the date of the announcement of the permit moratorium.

4. Requirements for pending & new farm permit applications

EPD received more than 1500 permit applications after the Plan was announced on October 23, 1999. This was approximately 5 times the normal rate of application submission, suggesting that many post-October 23 applications were duplicates of existing applications or permits, or speculative applications. Subsequent inquiries by EPD have shown this to be true for many applications.

(a) For all permit applications, EPD will require proof of ownership or a lease before a letter of concurrence is issued to the applicant. EPD will also require accurate latitude/longitude coordinates of a proposed well or surface-water pump location to be included on the permit application. This data will be used to determine whether the proposed well will impact adjacent users, nearby springs, or streams.

(b) All farm-use permit applicants who have not yet received a permit must demonstrate a need for a farm-use permit as defined by the Water Quality Act (O.C.G.A. 12-5-31 (b)(3)) and the Groundwater Use Act (O.C.G.A. 12-5-92 (5.1)).

5. Application Evaluation Procedures

In considering new and existing applications for both ground-water and surface-water withdrawals, EPD will evaluate the effect of the proposed water use on existing users and stream flow, and issue the new permit in such a way that the new permit will not adversely impact stream flow or the water available to existing users. Maps of the watersheds and sub-basins described below accompany this document. Specific permitting strategies are:

(a) All Floridan aquifer irrigation well permits will be evaluated to determine the calculated radius of influence of a proposed well and its relationship to the radii of influence of nearby Floridan aquifer wells on adjacent property. This evaluation may result in EPD issuing a permit for less than the applicant requested; requiring the applicant to use a different aquifer than requested; requiring the applicant to drill in a different location to avoid overlapping radii of influence or unacceptable impacts on an adjacent stream or surface-water withdrawal point.

(1) EPD will no longer issue permits for proposed Floridan aquifer irrigation wells that are within 0.25 miles of another user's well, unless hydrogeologic evaluation indicates that the proposed well would not cause or contribute to excessive drawdown in the other user's well. Excessive drawdown can be defined as that which would lower the static, non-pumping water level in an existing well by more than 5% of the intake depth recorded in EPD's permit database. For example, if the pump intake for an existing irrigation well is at a depth of 100 feet below ground surface, calculated drawdown from a new well could not the lower water level by more than 5 ft in the existing well. If hydrogeologic evaluation indicates excessive drawdown, the location of the proposed well may need to be changed, an alternative aquifer may need to be used, or the permitted pump capacity decreased, for the well to be permitted.

(b) Regardless of their location, all proposed Floridan aquifer wells will be evaluated for their impact on nearby streams and springs. Proposed irrigation wells that would draw from the Floridan aquifer within 0.5 miles of an in-channel spring or stream which exhibits a demonstrable connection with the Floridan aquifer will not be permitted if hydrogeologic evaluation indicates that, for the stream reach closest to the proposed well, the well would lower the Floridan aquifer water level to below the average stream stage or decrease the discharge of the spring. Streams to which this action applies are identified in Part III of the Plan.

6. Conservation provisions for farm permits

Irrigation water conservation measures are encouraged for all existing farm permittees. For new or modified permits issued after January 1, 2006 conservation measures will be a condition of the permits.

(a) In those watersheds termed Capacity Use Areas, all permits issued or modified after March 1, 2006 for irrigation systems supplied by wells withdrawing from the Floridan aquifer or any surface water will be required to: 1) have end-gun shut off switches installed to prevent irrigation of non-cropped areas by center pivot systems, 2) be maintained to prevent and repair leaks, 3) have pump-safety shutdown systems installed on center-pivot systems that will stop water delivery in the event of an irrigation system malfunction; 4) have rain-gage shut-off switches for traveler, solid set, or drip irrigation systems.

(b) In those watersheds termed Restricted Use Areas, all permits issued or modified after March 1, 2006 for irrigation systems supplied by wells withdrawing from the Floridan aquifer or any surface water will be required to: 1) have end-gun shut off switches installed to prevent irrigation of non-cropped areas by center pivot systems, 2) be maintained to prevent and repair leaks; 3) have pump-safety shutdown systems installed on center-pivot systems that will stop water delivery in the event of an irrigation system malfunction; 4) have rain-gage shut-off switches for traveler, solid set, or drip irrigation systems.

(c) In those watersheds termed Conservation Use Areas, all irrigation systems supplied by newly permitted wells drawing from the Floridan aquifer or any surface water will require end-gun shut off switches to prevent irrigation of non-cropped areas, and maintenance to prevent and repair leaks.

(d) Those sub-basins for which no detailed hydrologic modeling has yet been completed; specifically, Middle Flint and Kinchafoonee-Muckalee Creek Sub-basins, are termed Conservation Use Areas. All newly permitted wells drawing from the Floridan aquifer or any surface water will require, as a condition of the permit, end-gun shut off switches such that non-cropped areas are not watered, and maintenance to prevent and repair leaks. All proposed Floridan wells will be evaluated for their impact on existing nearby wells, streams, and springs.

(e) EPD will conduct random site inspections to ensure that all new permittees are following their required conservation plans. In the event that a required conservation plan is not being followed, the permittee will be issued a notice of violation requiring correction of the problem and compliance with the conservation plan in such a way that irrigation during a growing season is not interrupted. However, the violator will have his or her permit suspended if the problem is not corrected before the next growing season.

7. Drought season provisions for farm permits

Although low-flow protection plans will be used to protect flow in Spring Creek and Ichawaynochaway sub-basins, all permittees are encouraged to adopt conservation measures to assure that flow, and hence irrigation, continue as long as possible into drought seasons. Innovative new technologies or appropriate existing technologies adopted from other regions, particularly arid or drought-prone regions, will also be considered when they show potential to reduce seasonal water withdrawal amounts.

(a) For all newly issued surface water withdrawal permits in Spring Creek and Ichawaynochaway sub-basins, low-flow protection plans will be a standard permit condition. These plans will require a complete cessation of irrigation from the newly permitted source when discharge at the withdrawal location falls below 25% of the average annual discharge as calculated at that point based on the period of record for the nearest downstream continuous flow gauge, plus a prorated portion of the permitted amount of downstream users. Permittees subject to this requirement will be notified by EPD via e-mail and phone call when irrigation from the newly permitted source must stop; however, permittees are required to abide all permit conditions regardless of whether or not they have been contacted by EPD. During times of drought, EPD will be conducting regular inspections to ensure compliance with all low-flow protection plans.

8. Public Notice

Because all new withdrawals may potentially affect other water users in the basin, and because it is in the public's interest that EPD act expeditiously on farm-use permit applications, EPD will publicize via the Internet the name of current and new farm-use permit applicants, the location of their proposed withdrawal (county, latitude/longitude, stream name), proposed pump capacity, date of application, and the date a letter of concurrence was issued. No other information will be provided, such as address, phone number, or acreage to be irrigated. Posted information will be available on EPD's web page at http://www.gaepd.org/Documents/index_water_wrb.html. Upon issuance of a farm-use permit, the applicant's name and all information associated with the application will be removed from publication.

9. Revocation of duplicate or unactivated permits

All existing permits known to be duplicate permits will be revoked by EPD. All existing permits for which initial use of water has not commenced will be considered null and void, and revoked. Upon revocation of a permit, the permittee will have 30 days to appeal the revocation, and will be required to provide proof that the permit was being used for farm use prior to the date of issuance of the notice of revocation. If the permit was in use at the time of the notice of revocation, the permittee may continue to irrigate during the appeal process.

10. Conservation and Development Plan revisions

The Flint River Regional Water Development and Conservation Plan will be re-evaluated every 3 years based on new scientific information such as groundwater models or model results, observed impacts on endangered species in the lower Flint River Basin, observed impacts on other threatened species in the lower Flint River basin to ensure that no more species become endangered, regional economic impact of the current version of the Plan, and other criteria as determined by scientists and stakeholders in the Flint River Basin.

PART II: STAKEHOLDER PROCESS AND RECOMMENDATIONS FOR REGULATION OF AGRICULTURAL WATER WITHDRAWALS

SECTION 1: BACKGROUND AND FRAMEWORK

1.1 Explanation and justification for the Flint Basin Plan

The Flint River Basin (Fig. 0.1) is one of 14 major river basins in Georgia. Water use in the Flint River Basin (FRB) is dominated by agricultural irrigation, although municipalities and industry use more than 10% of the water withdrawn. Because agricultural irrigation uses the largest volume of water in the FRB, this report and its recommendations will focus on irrigation and farm-use withdrawal permits. The report summarizes the most recent and comprehensive scientific studies available on water use and hydrogeology in the FRB, evaluates the impacts of water use on the stream-aquifer system and stream ecology of the lower FRB, and makes stakeholder-developed recommendations for water resource management and farm-use irrigation permitting. The two-part recommendations are for management under existing statute, and recommendations for management that require statutory and regulatory reform. These recommendations are submitted for the consideration of the Director to be incorporated into the FRB Water Development and Conservation Plan.

The FRB Water Development and Conservation Plan, hereafter referred to as “the Plan”, was announced on October 23, 1999, by the Director of the Georgia EPD. The Plan was initiated in response to several factors: 1) a drought that began in summer of 1998; 2) an increasing number of farm-use permit applications from southwest Georgia; and 3) hydrogeologic studies performed by the U.S. Geological Survey (USGS) that predicted a severe impact on the Flint River and some of its tributaries under conditions of drought and increased irrigation withdrawals from the Floridan aquifer (Torak and McDowell, 1996). These studies, when combined with surface-water flow models used by EPD, suggested that parts of the Flint River could cease flowing for brief periods of time during severe droughts. In order to prevent this, the Director announced the Plan under the authority of the statutes that regulate water withdrawal permitting in Georgia: the Water Quality Act and the Ground-water Use Act. Specifically, the Water Quality Act states:

> "In evaluating any application for a permit for the use of water for a period of 25 years or more, the director shall evaluate the condition [i.e. quantity] of the water supply to assure that the supply is adequate to meet the multiple needs of the citizens of the state as can reasonably be projected for the term of the permit **and ensure that the issuance of such permit is based upon a water development and conservation plan** for the applicant or for the region. Such **water development and conservation plan** for the applicant or for the region shall promote the conservation and reuse of water within the state, guard against a shortage of water within the state, promote the efficient use of the water resource, and be consistent with the public welfare of the state." (Official Code of Georgia Annotated 12-5-31(h)).

Similar language is found in the Ground-water Use Act:

> (e) The division or a party designated by the division may develop a **regional water development and conservation plan** for the state's major aquifers or any portion thereof. Such plan shall include water development, conservation, and sustainable use and shall be based on detailed scientific analysis of the aquifer, the projected future condition of the aquifer, and current demand and estimated future demands on the aquifer. Upon adoption of a regional plan, all permits issued by the division shall be consistent with such plan. The term of any permit and all provisions of any permit for which an application for renewal is made prior to the completion of any regional plan shall be extended at least until the completion of such plan. (OCGA 12-5-96(e)).

These statutes state that any permit issued for more than 25 years, such as farm-use permits, must be in accordance with a regional development and conservation plan, which EPD is authorized to initiate. Initiation of such a plan allows EPD to suspend issuance of permits until plan completion, after which all permits must be consistent with the plan. Thus, as part of the FRB Flint, and because agricultural water use is by far the largest use category in the FRB, the Director announced that EPD would not process farm-use permit applications for Floridan aquifer withdrawals in Subarea 4 and for surface-water withdrawals in the entire FRB after November 31, 1999. This moratorium would remain in place until the FRB Plan is adopted by EPD.

1.2 Agricultural permit and permit application trends

With the exception of the period 1988-91, the number less than 200 applications for farm use permits have been received annually by EPD for all regions of the State. During 1988-91, the early years of the permitting process ,more than 15,000 permit applications were received by EPD (Fig. 1.1). The vast majority of these permits were issued by 1992. The rate of application submittal rapidly declined until 1999 when the pending permit moratorium was announced (Fig. 1.2).

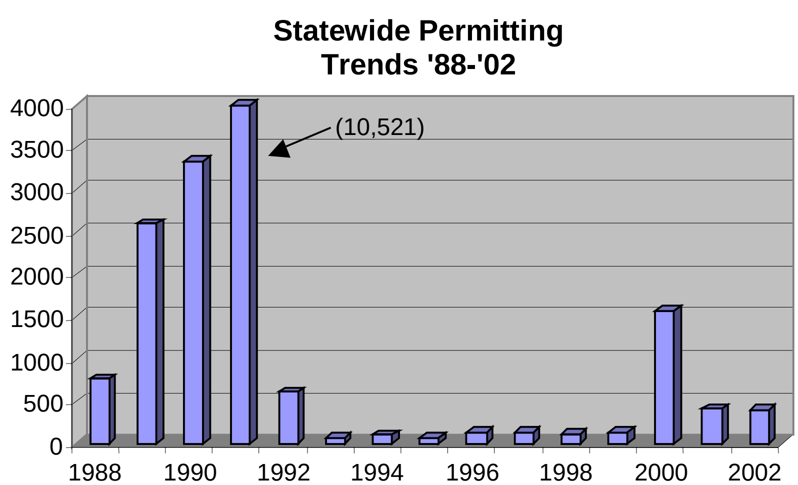


Figure 1.1: Statewide Permitting Trends 1988-2002 (REF)

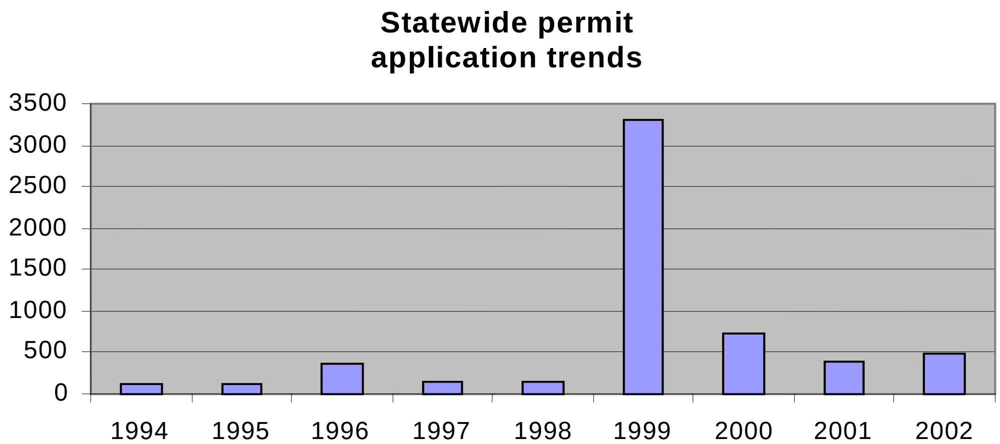


Figure 1.2: Statewide permit application trends

In early 1999, increased public concern over irrigation use in southwest Georgia, combined with the worsening drought, caused a gradual increase in the rate at which permit applications were submitted. In October 1999, it was announced that applications received after November 31, 1999, would not be reviewed until after the moratorium was lifted. This caused a drastic jump in the number of applications submitted, such that more than 1,500 were submitted during November 1999 (Fig. 1.3).

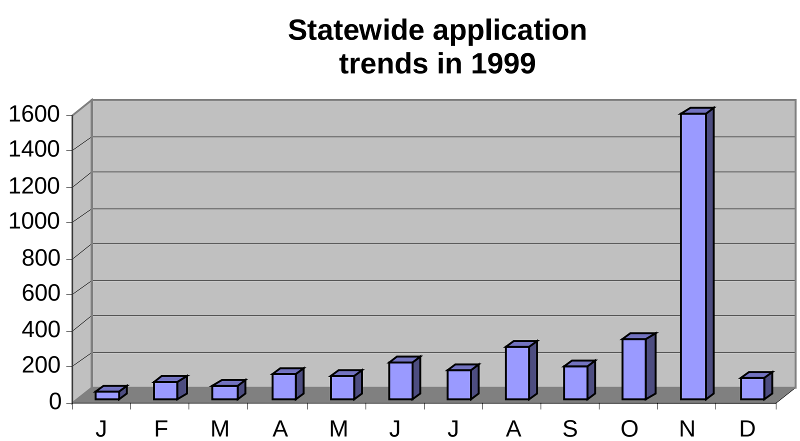


Figure 1.3: Statewide Application Trends in 1999 (REF)

Beginning in February 2000, DNR staff attempted to locate all un-permitted irrigation wells for which permit applications had been submitted. This work was mostly completed by November 1, 2000, by which time more than 800 irrigation wells and 100 surface-water pumps had been located and permitted. Applications for the remaining ("backlogged") proposed wells and surface-water pumps (Table 1.1) are filed with the EPD Agricultural Permitting Unit, and will not be processed until adoption of the Plan.

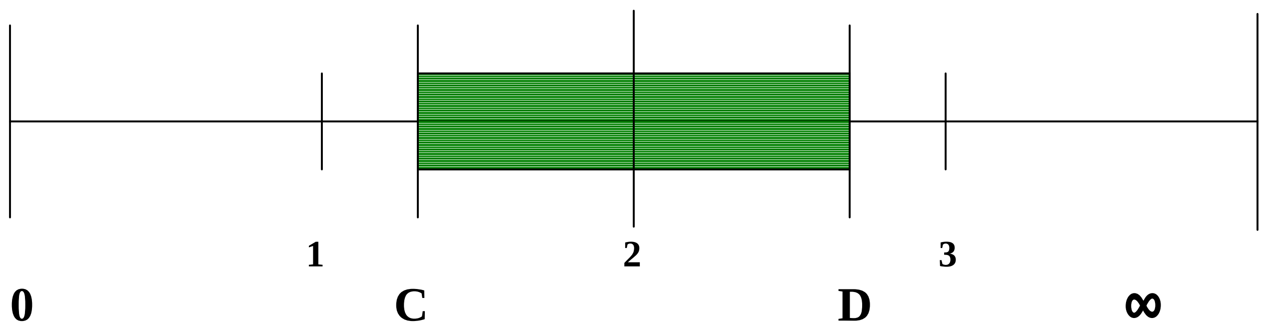
Acreage associated with permit application backlog				
Sub-basin	gw acres using Upper Floridan	surface-water irr_acres	well to pond acres	well to pond acres using Upper Floridan
Lower Flint	18506	1308		
Ichawaynochaway Ck.	6477	10040		
Spring Creek	14197	2708	350	200
Kinchafoonee-Muckalee creeks	5138	7732		
Middle Flint	19949	8701	785	128
Total Flint	64267	30489	1135	328

Table 1.1: Backlog acreage

1.3 Conservation, development, and ecologic sustainability

An important aspect of this Plan is to consider the economic impact of any actions that would affect agricultural irrigation. Agriculture in Georgia is a $9.9 billion industry, and $1.9 billion of that is derived from agriculture in southwest Georgia (McKissick, 2004a). However, although the success of Georgia farmers is dependent on a sustainable supply of water for irrigation, unlimited use of our water resources could result in a decline of farming in southwest Georgia due to degradation of the resource. Conversely, the FRB is ecologically significant due to its unique geology, long stretches of unimpeded flow, and threatened or federally protected and endangered aquatic species. Water use in southwest Georgia cannot occur at a level that would destroy or irreparably harm the ecological health and diversity of the FRB.

A balance must thus be struck between acceptable water use that allows for robust economic activity and strong communities, and acceptable conservation that maintains the aquatic health of the water resources. This balance can be expressed as a range of conditions that would exist between total conservation and total exploitation:



KEY:

0 = Pre-development; no artificial withdrawals from stream-aquifer system.
C = Maximum allowable conservation: Economic use of resource is entering optimal phase, perhaps because of farm and business synergies, but ecological impacts may begin to be noticed. Risks of low flows or competition among water users are beginning, probably noticeable in drought years or in selected locations in the basin.
D = Maximum allowable development: Ecological impacts become intolerable (illegal). No further gains in economics from water development are possible because declines in regional revenues would occur from low flows in streams or low water tables; i.e., businesses and other economic interests would avoid the region; competition among users becomes intolerable (illegal because some users are denied the right of reasonable use); or flows could not meet federally imposed state-line or other limits.
∞ = Complete development, no water or land available; ecological impacts severe and irreversible.

Shaded area represents acceptable working range of conditions in which conservation and development are reasonably balanced. Economically and ecologically, permitting cannot create a situation outside of this area.

1 = Potential existing situation where more permitting can occur; practical level of conservation not yet reached
2 = Potential existing [optimal] situation where conservation and development are balanced
3 = Potential existing situation where permitting has exceeded resource limits

Figure 1.3: “Decision line” displaying the range of management options in the FRB

1.3.1 Factors affecting maximum possible development

Maximizing withdrawals for economic purposes may have a number of legal restraints that could impose an upper limit on resource development. These factors include:

1. The Federal Endangered Species Act (ESA): The FRB is home to five species of endangered freshwater mussels. Certain provisions of the ESA could result in legal penalties against Georgia should permitted withdrawals cause extirpation or extinction of those mussel species. In addition, lawsuits from environmental groups could precipitate court action against Georgia and permitted water users.
2. The Federal Clean Water Act: Waters of the State in Georgia must be “fishable” and “swimable”, implying that a certain level of chemical and ecological health is required by law. This not only applies to wastewater discharges and non-point source pollution in the FRB, but to ensuring that there is sufficient stream flow to assimilate wastewater discharges and to maintain minimum water quality standards.
3. Georgia is a “regulated **riparian***” state, which provides property owners with “reasonable use” of the waters flowing on, past, or under their property. However, Georgia laws also demand that all potential users be guaranteed that use, meaning that a resource cannot be so over-allocated that legitimate, potential users (such as new farmers) do not have sufficient water for their needs.
4. The State must consider “injury to public health, safety, or welfare which would result if…[aquifer] impairment were not prevented or abated’, and the extent of any injury or detriment caused or expected to be caused to other water users, including public use” (O.C.G.A. 12-5-96). Thus, a maximum level of water withdrawals that caused injury or detriment would expose Georgia and existing users to legal action from the affected parties. This could include homeowners,

farmers, municipalities, recreational outfitters, or anyone adversely affected by excessively lowered ground-water or surface-water levels.

1.3.2 Factors limiting maximum conservation

Similar to scenarios of maximum development, there are limiting factors that would prevent, or at least argue against, complete conservation with little to no use of the water resources. These include:

1. The economic vitality of southwest Georgia communities is closely tied to the availability of water for irrigation. Those counties with the highest farm gate values and land prices are those where irrigation water is inexpensive and abundant. Those counties of the FRB with the lowest farm gate values are typically those that do not have abundant and inexpensive ground-water resources. Denying or severely limiting access to water for farm use would have a devastating economic impact on the entire region.
2. Georgia is a major agricultural producer in the nation and world. Most Georgia agriculture is in the Coastal Plain, south of the fall line, where water is abundant. Georgia's ability to compete in agricultural markets of all scales would be [1]severely affected if access to water were limited. This applies to in-state production as well, as producers in parts of south Georgia with no restrictions on water use would quickly out-produce FRB producers.
3. Crop patterns are driven by markets and subsidy structures. In southwest Georgia, the principal crops are cotton, corn, and peanuts. However, changing market trends are favoring an increase in vegetable and green industry production that require more water per acre than the more common crops.
4. The availability of water for irrigation is a financial consideration in determining property values, loan rates, profit margins, and other measures of economic security for farmers and their communities.
5. Georgia's legal structure provides for the reasonable use of the State's water resources through an EPD-managed riparian system. Denying, severely limiting,

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* Terms that are defined in the Glossary appear in bold face the first time they are used

or reducing water use in southwest Georgia would require substantial legislative changes to Georgia's legal codes. This includes 'grandfathered' farm use permits, whose access to reasonable use have few restrictions on the amount of water that can be legally used. Denying the reasonable use of water to any eligible user would be a violation of State law, and be grounds for legal action against the State (or more likely, EPD).

1.4 The Flint River Drought Protection Act

In response to the drought conditions of 1999-2000, the Georgia General Assembly created and passed into law the Flint River Drought Protection Act (O.C.G.A. 12-5-540). This Act created a program providing financial incentives to ensure that certain irrigated agricultural lands in the lower FRB are temporarily not irrigated during times of declared severe drought, thus protecting stream flow and aquatic species in the **basin** (391-3-28-.01).

The Flint River Drought Protection Act, and the Rules for the Flint River Drought Protection (391-2-28), developed a voluntary auction process by which permitted surface-water irrigators would be paid on a per-acre basis to not irrigate land covered by a specific surface-water permit during the entire calendar year after the "drought protection auction". Funds for this auction were provided by the Georgia Environmental Facilities Authority and were taken from the "One Georgia" fund.

Eligible auction participants were those with permitted farm-use surface-water withdrawals on perennial streams anywhere in the FRB. Because of the uncertainties surrounding the effects of ground-water withdrawals on stream flow, ground-water permittees were not eligible for participation.

A drought protection auction would be initiated only if the Director of EPD issued a severe drought declaration. On or before March 1 of each year, the Director must issue a prediction as to whether severe drought conditions are expected during that calendar year.

If ground-water and surface-water levels are below a critical threshold and climate predictions indicate an impending drought, then the Director makes a severe drought declaration. An auction must be completed before March 22 of that year.

To participate in the drought protection auction, eligible permittees must have an auction certificate that verifies the permit number and the acres irrigated by that permitted withdrawal. EPD must verify both the permit and its associated acreage. EPD must also determine the amount of irrigated acreage to be removed from irrigation, based on an acceptable flow to be maintained in the Flint River or targeted stream basin during the drought year. The Director of EPD shall determine the auction process by which irrigators offer to voluntarily retire their irrigated acreage in return for payment. (391-2-28).

To date, there have been two drought protection auctions: in 2001 and 2002. The first auction in 2001 proceeded by an iterative and interactive process by which participants submitted blind bids for a per acre price that they wanted in order to suspend irrigation. A linked computer network installed at auction stations throughout the lower FRB accomplished this. Auction participants submitted sealed bids, which were entered into the computer network and tabulated on a central computer in Atlanta. The Director of EPD was able to monitor the incoming bids, and either accepted or rejected bids based on the total cost of all bids presented. Participants whose bids were rejected could re-submit bids during subsequent rounds until the Director had accepted enough bids to remove the targeted amount of acreage from irrigation.

This auction process was very inefficient. Bids submitted over five auction rounds ranged from $75/-800/acre, but the highest bids were rejected. The average accepted bid was $135/acre. More than 33,000 acres were taken out of irrigation for a total cost of approximately $4.5 million.

In 2002, a second auction was held due to continuation of the drought. To maximize efficiency and still remove enough acres from irrigation, the Director announced that

EPD would not accept bids above $150/acre, but that all bids below that would be accepted up to the point where sufficient acreage was taken out of irrigation. In the sole auction round, bids ranged from $74-145/acre. The average bid was $128/acre. In this auction, more than 41,000 acres were removed from irrigation at a cost of $5.3 million.

Both auctions had problems and inconsistencies. Eligibility requirements for the first auction stipulated only that a participant have a surface-water permit with no requirement of recent use. Consequently, a significant number of participants were paid for very marginal or long-fallow land, or for land that is not typically irrigated (e.g. trees). This loophole was closed for the second auction such that only those permit holders who had irrigated in the previous three years could participate. However, both auctions failed to remove the highest water use cropland from irrigation. This probably reflects the low cost per acre of accepted bids, and their inability to compensate for loss of a high-value crop. Regardless of the auctions shortcomings, other states such as Washington, Kansas, and Nebraska are either considering or enacting drought auctions similar to Georgia's.

SECTION 2: RECOMMENDED WATER RESOURCE MANAGEMENT AND PERMITTING STRATEGIES FOR THE FLINT RIVER BASIN

2.1 General Plan goals

As defined in Georgia statutes, water development and conservation plans shall:

- promote the development, conservation, reuse, and sustainable use of water within the state;
- guard against a shortage of water within the state;
- promote the efficient use of the water resource;
- be consistent with the public welfare of the state;
- be based on detailed scientific analysis of the aquifer, the projected future condition of the aquifer, and current demand and estimated future demands on the aquifer.

Upon adoption of a regional plan, all permits issued by the division shall be consistent with such plan.

2.2 Stakeholder Advisory Committee

The Flint River Basin Regional Water Development and Conservation Plan was developed in two parts: the legal and technical background upon which policy recommendations could be made, and a set of policy recommendations consensually developed by a stakeholder advisory committee (SAC). The Flint River SAC was developed by EPD in the fall of 2004 with the goal of having qualified representatives of the following major groups:

•Farmers and agribusiness representatives
•Southwest Georgia Water Task Force
•Flint River Regional Water Council
•Local elected officials
•Utilities, municipal authorities
•Sportsmen, anglers, boaters
•Georgia Conservancy, League of Conservation Voters, etc.

To this end, EPD was successful in developing a broadly based Committee representing most of these major constituencies. The FRB Stakeholder Advisory Committee SAC held their first meeting in Albany, GA on September 12, 2004. The Committee is comprised of the following southwest Georgia stakeholders:

Mr. James Lee Adams, farmer and developer, Mitchell County
Mr. Lucius Adkins, farmer, Baker County
Mr. Dan Bollinger, Director, Southwest Georgia RDC
Mr. John Bridges, farmer, Decatur County
Mr. Charles (Chop) Evans, farmer, Macon County
Mr. Thomas C. Chatmon, Jr., CEO Albany Tomorrow, Inc.
Mr. Vince Falcione, Proctor and Gamble, Albany
Mr. Tommy Gregors, Georgia Wildlife Federation, Albany
Mr. Hal Haddock, Farmer, Miller County
Mr. Chris Hobby, City Manager, Bainbridge
Mr. Bubba Johnson, Farmer, Mitchell County
Mr. John Leach III, Developer, Lee County
Ms. Janet Sheldon, Georgia Conservancy
Mr. Mike Newberry, Farmer, Calhoun County

Mr. Kim Rentz, Farmer, Decatur County
Mr. Steve Singletary, Farmer and GSWCC Commissioner
Mr. Marcus Waters, Crisp County Power, Cordele
Mr. Jimmy Webb, Sunbelt Expo 2005 Farmer of the Year
Mr. Joe Williams, Farm owner, Crisp County

The roles of the SAC were to: 1) help craft a Plan for water withdrawal in the FRB that takes conservation and economic development into consideration; 2) deliver concrete recommendations, reached by consensus, that would best manage the water resources of the FRB under *existing* statutes and regulations; 3) deliver recommendations, also reached by consensus, for regulatory and statutory reforms that would fulfill the broader goals of a regional development and conservation plan.

A central aspect of the Plan is the current moratorium on farm-use permits in the FRB. The immediate goal of the Plan is to develop water management strategies that would allow the Director of EPD to lift the moratorium while protecting the resource during droughts. However, the FRB Plan will necessarily be a significant part of the developing Statewide Water Plan, and in many ways will be a model for it. Specifically, the FRB Plan illustrates the importance of long-term stakeholder development, the need for a transparent stakeholder involvement process, and the importance of comprehensive scientific studies upon which to base water management strategies.

Agricultural production is the biggest category of water use in the FRB. Agriculture is the economic engine of southwest Georgia, and water is the basis of successful agriculture. For this reason approximately half of the SAC members are farmers. Because the most immediate aspect of the Plan was the permit moratorium, and because agriculture will continue to be the biggest water user for the foreseeable future, most of the SAC's focus was on agricultural water use, management, and regulation.

2.3 Technical Advisory Committee

To assist the SAC in understanding the complex scientific issues involved in development of the Plan, a Technical Advisory Committee (TAC) was created by EPD in mid-2004. Experts were selected who were specialists in their field and who were familiar with the geological, bio-ecological, agricultural, and economic issues specific to southwest Georgia. The TAC consisted of the following individuals:

Dr. Steve Golladay, J.W. Jones Ecological Research Center, Baker County
Mr. Mike Harris, DNR Wildlife Resources Division, Non-Game Section, Social Circle
Mr. Kerry Harrison, Cooperative Extension Service, Tifton
Mr. Woody Hicks, J.W. Jones Ecological Research Center, Baker County
Dr. James Hook, University of Georgia/NESPAL, Tifton
Dr. Mark Masters, Director, Flint River Planning and Policy Center,, Albany
Mr. Rob Weller, DNR Wildlife Resources Division, Fisheries Section, Albany
Mr. Joe Williams, Farm owner, Crisp County
Mr. Rad Yeager, Superintendent, Stripling Irrigation Research Park, Camilla

Throughout the development of the Plan, the TAC provided scientific and analytical perspectives in review of the Plan and of EPD's models and conclusions. When called upon they provided independent data and analysis to EPD. They also prepared and presented information on the stream hydrology, hydrogeology, ecology, water use patterns and economy of the region to EPD and the SAC. However, their participation in the planning process should not be construed as an endorsement of the FRBP by the individual TAC members or by the institutions they represent. The TAC met approximately every month between SAC meetings, in order to address questions raised by the SAC at previous meetings and to discuss the on-going studies that were incorporated into this report.

2.4 Guiding principles of the Stakeholder Advisory Committee

The SAC consistently expressed a number of consensus opinions, which guided their deliberations and discussions of permitting and water management strategies. These opinions are listed and described below. Some relate to managing the water resources of the FRB under existing regulations, while others were expressions of how the Basin should be managed.

1. The lifting of the permit moratorium may mean that future water users may adversely impact existing users. Therefore, future permitting should be done such that existing users are protected.

2. Secure access to irrigation water is critical to the viability of a farm. Banks are reluctant to provide affordable financing if the availability of irrigation is unpredictable. Permitting strategies should not allow a reliable, predictable, and permitted water source to be interrupted.

3. Farmers in Georgia are currently practicing some of the most effective water conservation measures available. The steadily rising price of operating an irrigation system makes wasting water economically impractical. Further conservation, mandatory or otherwise, should be economically feasible to the farmer, and should convey positive conservation messages about Georgia farmers.

4. A number of other States, such as Florida, Texas, Kansas, and Nebraska manage water through regional water management districts. The structure of these varies, as does the level of regulatory authority, but the general concept of decentralized and local water management should be a future consideration for Georgia.

<u>2.5 Conclusions about “safe yield”</u>

As described in Sections 5 and 6 of this report, the combination of the USGS ground-water model, HSPF stream models, historical stream flow, and simulated future stream flow scenarios compared to Federal in-stream flow guidelines demonstrated that the amount of water *currently* withdrawn for agricultural irrigation in drought years increases both the magnitude and duration of low flows in streams of the FRB, thus further harming endangered species and potentially limiting the amount of water available for all users. This is especially true in Spring Creek and Ichawaynochaway Creek sub-basins. Expanded drought-year irrigation will worsen this situation; reduced irrigation will improve it. *In normal to wet years, the impact of irrigation on stream flow and aquifer* *levels is insufficient to jeopardize the availability of water for all users, or to jeopardize stream ecology.* Therefore, some parts of the lower FRB have already reached their drought-year "safe yield". If more withdrawal permits are issued for the lower FRB, more aggressive drought-year management strategies will have to be employed, mostly (if not exclusively) in those parts of the Basin closest to their safe yield.

2.6 EPD regulatory limits

As the permitting agency for farm water use in Georgia, EPD must meet the following current statutory requirements, described in more detail in Section 1 of this report:

1. All legitimate requests for **farm use** permits must be granted in the FRB once the Plan is adopted.
2. The permit moratorium must be lifted upon completion of the Plan.
3. EPD may issue permits for less than the amount requested by the permit applicant.
4. In issuing new permits, EPD may decrease the permitted withdrawal amounts of all other permitted users including "grandfathered" permits.
5. EPD may initiate provisions of the Flint River Drought Protection Act during severe drought years in an effort to maintain critical stream flow.
6. EPD cannot revoke permits for non-use once initial use has commenced.

In this context, and after having been exposed over a period of months to the ground- and surface-water models and their conclusions, the SAC evaluated the existing permitting procedures, for both ground and surface-water permits, with the goal of making consensus recommendations as to how farm-use permitting could resume while protecting existing users and the resource. The results of the SAC discussions, begun at the August 12, 2005, meeting and concluded at the November14, 2005, meeting, are presented here.

2.8 Consensus recommendations for permitting strategies

1. The largest scale on which water management and permitting decisions should be based should be a sub-basin level corresponding to the USGS HUC-8 designation. In the FRB these are:

G. Upper Flint
H. Middle Flint
I. Kinchafoonee-Muckalee Creeks
J. Lower Flint
K. Ichawaynochaway Creek
L. Spring Creek

Permitting decisions in these sub-basins will take into account the water use characteristics, hydrology, geology, surface-water and ground-water interactions, and the ecology unique to each sub-basin. Where necessary, and where data are available, permitting and management decisions should also take into account site-specific conditions and local stream impacts down to a HUC-12 scale.

2. In considering new and existing applications both ground-water and surface-water, the goal of EPD will be to evaluate the effect of the proposed water use on existing users, and issue the new permit in such a way that the new permit will not adversely impact the water available to existing users. This evaluation may result in EPD issuing a permit for less than the applicant requested; requiring the applicant to use a different aquifer than requested; requiring the applicant to drill in a different location to avoid causing drawdown in an existing permitted well or unacceptable impacts on an adjacent stream or surface-water withdrawal point; and imposing more stringent low-flow protection requirements on surface-water users than are currently recommended (such as protecting a flow higher than 7Q10 or other appropriate tabulations of low flow characteristics.)

Because of the variable characteristics of the Floridan aquifer, there may be parts of the FRB in which ground-water withdrawals have no significant impact on nearby users or on stream flow. In these areas, permits should be issued as requested by the applicant as long as all other requirements are met (such as proof of ownership, conservation measures, etc.).

3. Newly issued permits in the FRB (i.e. those issued after January 1, 2006 regardless of when an application was submitted) will require an economically feasible, state-of-the-art conservation plan that reduces the volume of water withdrawn, used, or applied as a condition of the permit. Such plans may include end-gun shut off switches, rain-gauge shut-off systems, and leak repair. Applicants and EPD shall refer to conservation measures recommended by the University of Georgia Cooperative Extension Service or the Georgia Soil and Water Conservation Commission.

In the event that a required conservation plan is not being followed, the permittee will be issued a notice of violation requiring correction of the problem and compliance with the conservation plan in such a way that irrigation during a growing season is not interrupted. However, the violator will have his or her permit suspended if the problem is not corrected before the next growing season.

4. If irrigation is decreased during a drought year by 20% of current use in Ichawaynochaway Creek and lower Flint River sub-basins, critical low-flow criteria will be met. If irrigation is decreased during a drought year in the Spring Creek sub-basin by 20%, it is assumed this will have a beneficial affect on water levels and stream ecology even though critical low-flow criteria may not be met. This will require application of the Flint River Drought Protection Act in such a way that enough irrigated acreage is temporarily converted to dry-land acreage, which can be done either through the voluntary auction process or non-voluntary irrigation suspension with compensation as defined by State law.

5. For new permit applications, EPD will require proof of ownership or a lease before a letter of concurrence is issued to the applicant. EPD will also require accurate

latitudinal/longitudinal, coordinates of a proposed well or surface-water pump location to be included on the permit application.

6. All existing permits known to be duplicate permits will be revoked by EPD. All existing permits for which initial use of water has not commenced will be considered null and void, and revoked.

2.9 Stakeholder recommendations for regulatory and statutory reform

In addition to recommendations for permitting strategies that could be enacted under current statutes and rules, the SAC recognized the need for changes to those statutes and Rules that would result in better management of water resources. Specifically:

1. In order to minimize or eliminate speculative farm-use permit applications, EPD should charge a permit application fee of $250. This money should be dedicated to assisting management of agricultural water use or as an incentive for conservation, and should not be put into the State general fund.

2. For existing permits, those that are ‘grandfathered’ as defined by the Water Quality Act and Groundwater Use Act should be exempt from being modified in any way in order to provide new users with sufficient water.

3. For declared drought years, the Flint River Drought Protection Act should be modified to allow focus on individual sub-basins, including areas with critical habitats that are host to endangered species:

    a. Upper Flint
    b. Middle Flint
    c. Kinchafoonee-Muckalee Creeks
    d. Lower Flint
    e. Ichawaynochaway Creek

f. Spring Creek

4. Funding for the Flint River Drought Protection Act should be expanded and assured beyond its current limits such funding is available to pay higher per-acre prices for suspension of irrigation. This would allow the State to suspend irrigation on high-water use lands as opposed to marginal farmland; increase the likelihood of taking more land out of irrigation; allow the EPD Director to require non-voluntary suspension of irrigation with fewer challenges; and offset the direct and indirect costs of reducing irrigation.

5. Ground-water users should be included in the FRDPA, at the same payment rates as surface-water users, where the best available science indicates that they would directly impact stream flow.

6. Future permitting decisions, policing, review, etc. should be made at a local level, such as by a regional water management district or authority similar to those operating in other states.

7. The state should consider subsidies for conversion of permits from surface-water to ground-water, as this may be a cost effective way to maintain adequate streamflow in some areas.

8. The state should consider using existing wells or installing and operating wells during extreme droughts to supplement the flow in Spring Creek and other tributaries to maintain streamflow and protect endangered species.

9. The statutory requirement that EPD "shall" issue all new permits should be re-evaluated in order to protect existing users and the resource.

10. Alternatives to issuing permits based on rated pump capacity should be explored.

PART III: TECHNICAL AND STATUTORY BACKGROUND OF PLAN RECOMMENDATIONS

SECTION 3: STATE OF THE BASIN'S NATURAL RESOURCES

3.1 Basin hydrography

The FRB covers approximately 8,460 square miles, and extends 212 miles from Hartsfield-Jackson International Airport to the southwestern corner of Georgia, where it joins with the Chattahoochee River to form the Apalachicola River (Fig. 0.1). The Flint River flows through the Piedmont Province of North America, and at the fall line crosses into the Coastal Plain Province.

The FRB is divided into smaller sub-basins, or watersheds, by the U.S. Geological Survey (USGS). Watersheds of varying sizes are designated as Hydrologic Unit Codes, or **HUC**'s, which is the number of integers in the code. Smaller HUC's have more numbers in their code. For example, the FRB has a HUC-6 designation of 031300. In the FRB, there are six HUC-8 watersheds. These are: Upper Flint, Middle Flint, lower Flint, Kinchafoonee-Muckalee Creeks, Ichawaynochaway Creek, and Spring Creek (Fig. 0.1). Each HUC-8 has definable hydrologic characteristics, and will be treated individually in subsequent discussions of water use, effects of water use, and permitting strategies.

Each HUC-8 can be divided into HUC-10 and HUC-12 watersheds. The latter is the smallest scale designated by USGS. In some cases, depending on HUC-8 hydrology, discussions of water use and permitting strategies will be at the HUC-10 scale. HUC-12 watersheds are very small and their boundaries typically cut through individual farms, and even individual fields. This would make permitting and resource management decisions impractical.

3.2 Rainfall patterns: normal, drought, and long-term trends

Average annual rainfall in the FRB ranges from 48-54 in/yr (Fig. 3.1). Most of this falls between early November and mid-April, although frontal rainfall, convective storms in late spring through fall, and tropical storms can add significantly to annual rainfall totals.

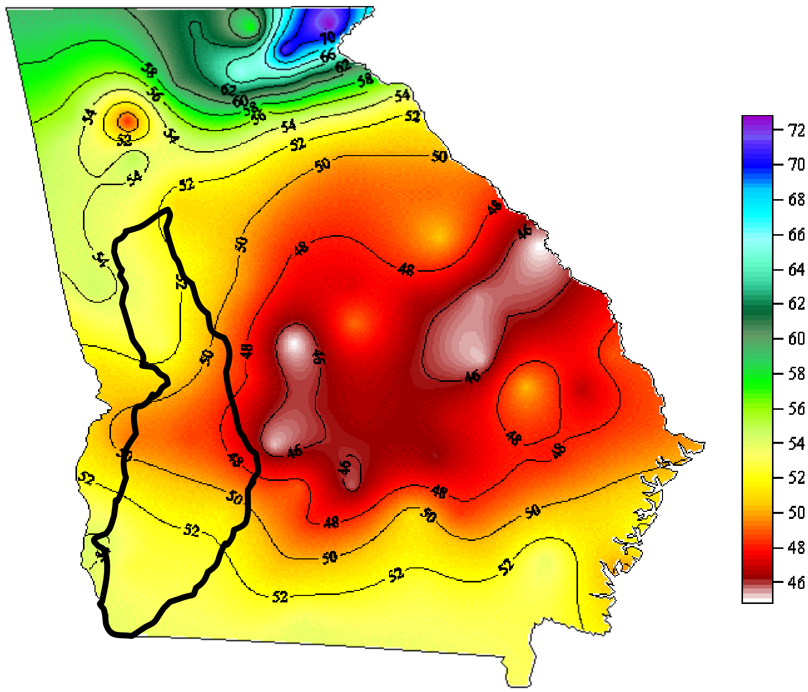


Figure 3.1: Average annual rainfall in Georgia. FRB outlined in black.
(Georgia Automated Environmental Monitoring Network)

During the drought of 1998-2002, rainfall patterns were significantly altered. The spring of 1998 was very wet, but normal seasonal rainfall trends ceased in summer of 1998. Subsequent winter rains did not occur until late winter or early spring of 1999, and were insufficient to make up for previous periods of low rainfall. A cumulative rainfall deficit developed in Georgia that, in some places, exceeded the annual average rainfall for that area (Georgia Automated Environmental Monitoring Network). During the 1998-2002 drought, many streams and aquifer levels reached record lows. Normal rainfall patterns resumed in September 2002, causing the Floridan aquifer in Subarea 4 to recharge fully.

Droughts are normal aspects of Georgia's climate. Since the 1950's there have been several periods of below-average rainfall in southwest Georgia: 1950-57; 1980-82; 1985-89; and 1992-2002 (Barber and Stamey, 2000). A one-year drought in 1968 ranked as the second driest year on record in terms of annual precipitation. (A ranking of years by precipitation can be found in Appendix I). From 1952 to the late 1980's, southwest Georgia had an accumulating rainfall deficit of as much as 60 inches (GAEMN, 2005). In other words, annual rainfall was, over a period of decades, cumulatively less than the average rainfall amount of 52 in. Individual years may have exceeded the annual average, but those years could not overcome the below-average rainfall of prior years. Thus, from 1952 until the late 1970's, southwest Georgia was in a comparatively dry period. In the 1970's, annual rainfall amounts increased, and created a cumulative rainfall surplus that persisted until 1998. From 1998-2003, the cumulative rainfall surplus decreased to near zero (Fig. 3.2). The period from the late 1980's until 1998 corresponds to the rapid and extensive growth of irrigation in the Dougherty Plain.

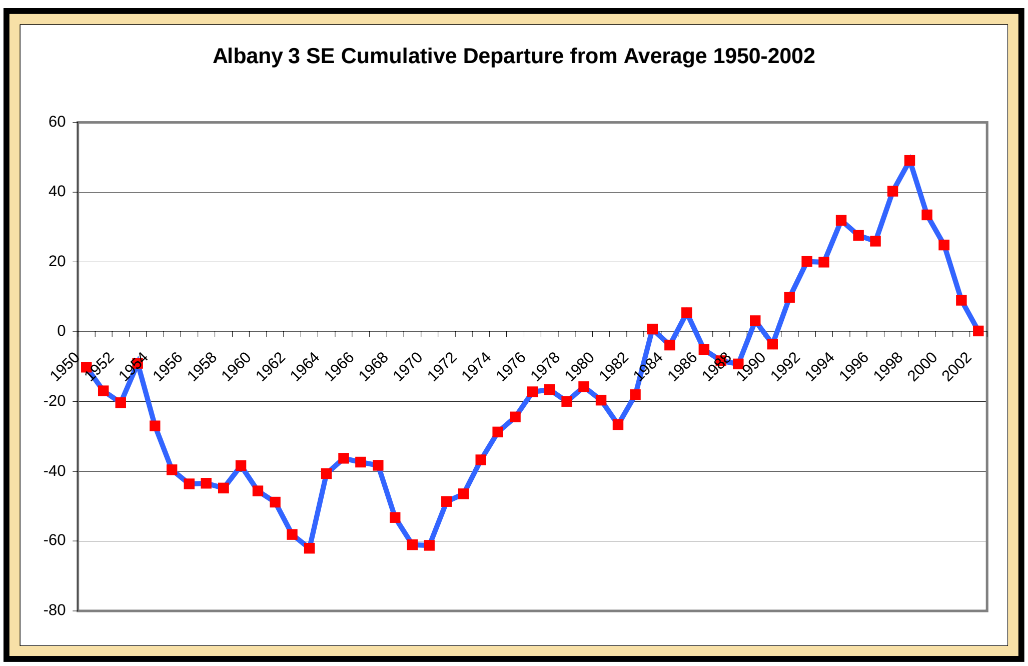
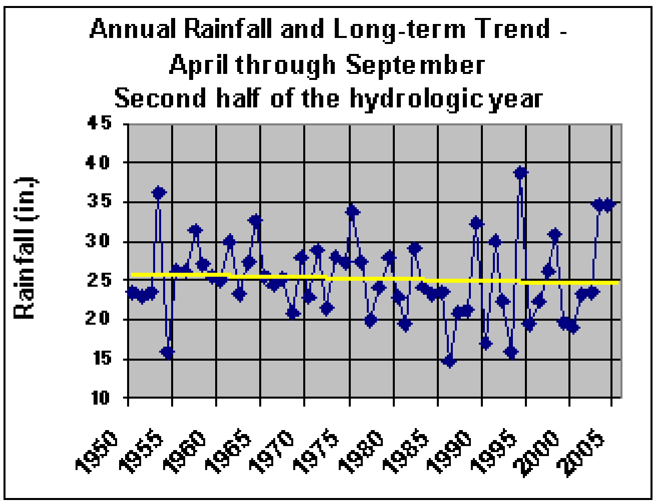


Figure 3.2: Long-term trends in average rainfall at Albany, showing the cumulative departure from average precipitation between 1950 and 2002

(W. Hicks, written communication).

An analysis of monthly rainfall patterns over the same time period indicates that rainfall patterns have been changing slightly. From April to September, which corresponds to the main agricultural growing season, monthly rainfall totals have declined slightly. Conversely, from October through March, rainfall totals have increased slightly. In other words, in addition to the multi-year cumulative deficits and surpluses, summers have been slightly drier and winters have been getting slightly wetter (Hook, 1998).



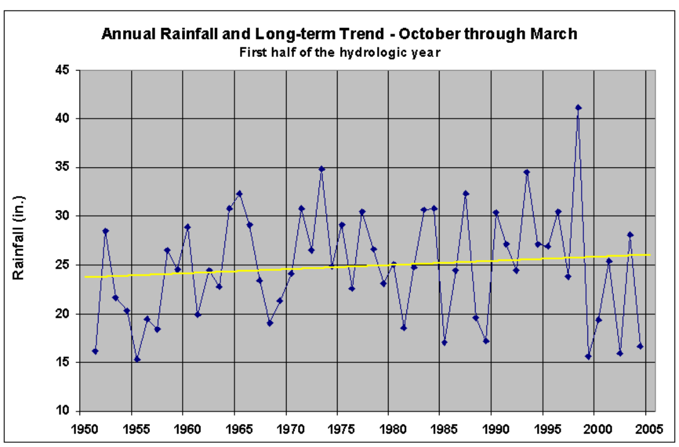


Figure 3.3: Comparison of rainfall for winter and summer seasons

(Hook, 1998)

3.4 Surficial geology

From its source in metro Atlanta to where Ga. Highway 128 crosses from Crawford to Taylor County, the Flint River flows over deformed **igneous** and **metamorphic** rocks of the Piedmont (Georgia Geologic Survey, 1976). These **crystalline** rock types are extremely non-porous and impermeable, and they do not weather as easily as the limestone rocks typical of Georgia's Coastal Plain. Flow of the Flint River in the Piedmont is mostly sustained by rainfall; however, streamflow is augmented by variable amounts of ground-water inflow (Hicks, 2000). Ground-water **base flow** to the Flint River in the Piedmont province is discharged through weathered fractures in the hard, crystalline bedrock (Kellam et al, 1993). Rainfall enters these fractures from outcrops, and from water stored in the soils and **saprolite**. Together, the soil and saprolite act as a sponge and store infiltrated rainwater. However, the low permeability of the saprolite and crystalline rocks limit the rate and volume of infiltration (Hicks, 2000). In the Piedmont, very large bedrock fractures, or collections of fractures, preferentially direct the streamflow and eventually become stream valleys; therefore, much of the Flint River channel north of the fall line may be locally controlled by the existence of bedrock fractures that supply a portion of the streamflow (Kellam et al, 1993).

Between Ga. Highway 36 and Ga. Highway 137 near Thomaston, the Flint River drops out of the Piedmont through a series of rocky shoals. It descends more than 300 feet in a distance of less than 15 miles. This rocky zone is called the fall line, and it marks the boundary between the Piedmont and the Coastal Plain Province of North America. The Coastal Plain is underlain by relatively soft, weakly consolidated rocks and unconsolidated sediments deposited by the sea or streams when the shoreline was at or near the fall line between 80 and 100 million years ago. These deposits thicken to the south and southeast, and they are very gently tilted (**dip**) in the same direction.

The upper section of the Coastal Plain, north of Dooly County, Americus, and Dawson, is called the fall line Hills district (Wharton, 1978). This area is underlain by sandy sediments of the Tertiary Clayton Formation (Tuscahoma Sand member) and sandy sediments of the Claiborne Formation (Georgia Geologic Survey, 1976; McFadden and Periello, 1983). These **formations** comprise aquifers at depth, and are only **recharged** in the fall line Hills area where they are near the land surface (Davis et al, 1989).

The Clayton aquifer consists of Clayton Formation limestone exposed in stream valleys of the upper Ichawaynochaway and Muckalee sub-basins, but its exposed recharge area is very small (McFadden and Periello, 1983; Davis et al, 1989). This, combined with an increase in irrigation pumping which began in the late 1970's, caused dramatic declines in water levels of the Clayton aquifer. For this reason, no additional permits are being issued in the Clayton aquifer and water-levels have stabilized.

The Claiborne aquifer consists mostly of saturated sands of the Tallahatta Formation. In those areas where the Claiborne is relatively shallow, it is a viable alternative aquifer to the Floridan, although well yields rarely if ever match those of Floridan aquifer wells (McFadden and Periello, 1983). The Claiborne has a much larger recharge area than the Clayton, and has not experienced long-term potentiometric declines like the Clayton aquifer.

The southern half of the basin is underlain by the Ocala Limestone, a fossil-rich limestone that is the main water-bearing unit of the Floridan aquifer. The up-dip extent of the Ocala Limestone coincides with the approximate northwestern limit of the Dougherty Plain and Subarea 4. Thickness of the Ocala ranges from 0 ft at its up-dip boundary, to more than 300 ft along the southeastern side of Subarea 4 (Miller, 1986; Torak and others, 1993). Intensive weathering of the Ocala Limestone and the formations that once overlaid it has generated an extremely uneven upper surface of the remaining limestone, and a highly variable thickness of the weathered material that mantels the limestone (Hayes et al, 1983; Hicks and others, 1987). This **residuum** typically has a clay layer directly overlying the limestone, which locally acts as the upper semi-**confining unit** to the Floridan, although under most of Subarea 4 the Floridan functions as an unconfined or semi-**confined aquifer** (Miller, 1986: Torak and McDowell, 1996). Where present, the upper clay layer ranges from less than 5 ft thick to more than 50 ft thick in the down-dip parts of the FRB. Above the clay layer is sandy-clay residuum of higher **permeability** that transmits precipitation to the underlying Floridan aquifer. In most of the FRB, the Floridan aquifer is confined below by low-permeability sediments of the Lisbon Formation (Wagner and Allen, 1984; Torak and McDowell, 1996).

The Floridan aquifer receives annual recharge directly from seepage through the overlying residuum, and through the numerous and extensive sinkholes in Subarea 4 (Torak and McDowell, 1996). Like streams in the area, aquifer heads are highest in late winter and early spring due to direct and rapid recharge, low usage, and low **evapotranspiration**. The lowest seasonal levels of the Floridan aquifer occur in middle to late autumn (Fig. 3.4). If normal rainfall follows the periods of lowest stream and aquifer levels, the aquifer recharges to levels comparable to those of the previous year (Groundwater Conditions in Georgia, USGS annual report). This suggests that, in some parts of Subarea 4, the Floridan aquifer is semi-confined. It also reflects the extremely permeable nature of the sandy residuum above the Ocala Limestone.

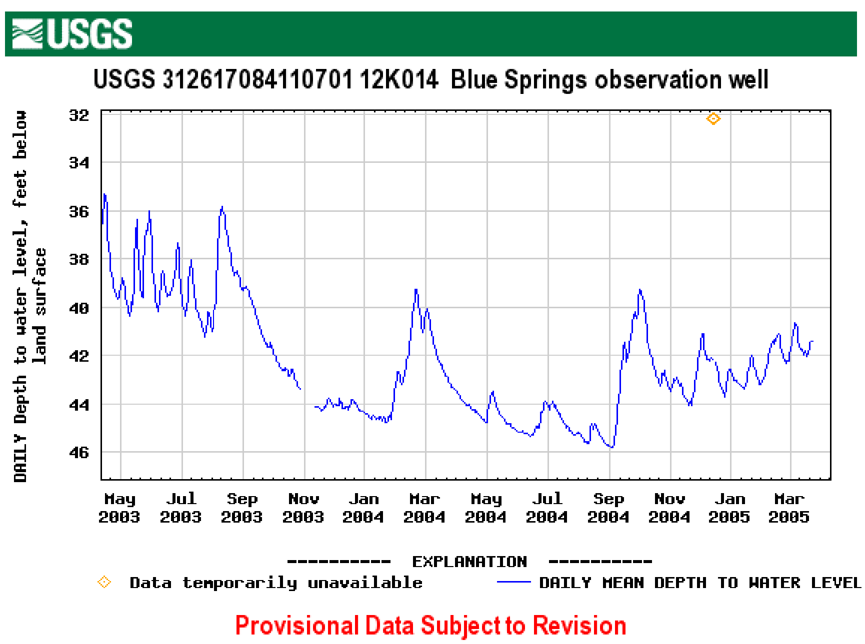


Figure 3.4: Hydrograph of well in Floridan aquifer in Subarea 4, showing typical seasonal variations in water level.

In most areas, the Floridan aquifer is a very prolific source of water because it has abundant cavities and fractures, widened by naturally acidic ground-water. For this reason, **transmissivity** values of the Floridan aquifer range from 2,000 to 1,300,000 ft^2/day (Torak and McDowell, 1996). Transmissivity values decrease towards the northern Subarea 4 boundary and the northwestern extent of the Floridan aquifer (Torak and McDowell, 1996) where aquifer yields will not support irrigation pumping. Yields are highest in the south and in areas adjacent to streams (Maslia and Hayes, 1988).

Because the Floridan aquifer is so highly transmissive and fractured, large ground-water withdrawals do not form deep cones of depression as in sandy, less transmissive aquifers. Instead, cones of depression in the Floridan aquifer are broad and shallow, and may be distorted by fracture zones into irregular or elongated shapes. Furthermore, withdrawals from the numerous irrigation wells in the Dougherty Plain region rarely create individual cones of depression (Torak, 1993). Because of the close spacing of the wells, their cones of depression overlap to create a regional lowering of the **potentiometric surface** rather than local declines adjacent to pumping wells (Torak and McDowell, 1996).

The high transmissivity and storage of the Floridan aquifer also causes rapid recovery of aquifer levels in many places. In other words, when pumping is initiated, there may be a rapid drawdown around the pumping well, but when the pumping ceases there is an equally rapid recovery as water flows quickly back into the area around the well with only a slight change in aquifer storage that is observed as a slight decline in static ground-water level (Fig. 3.5).

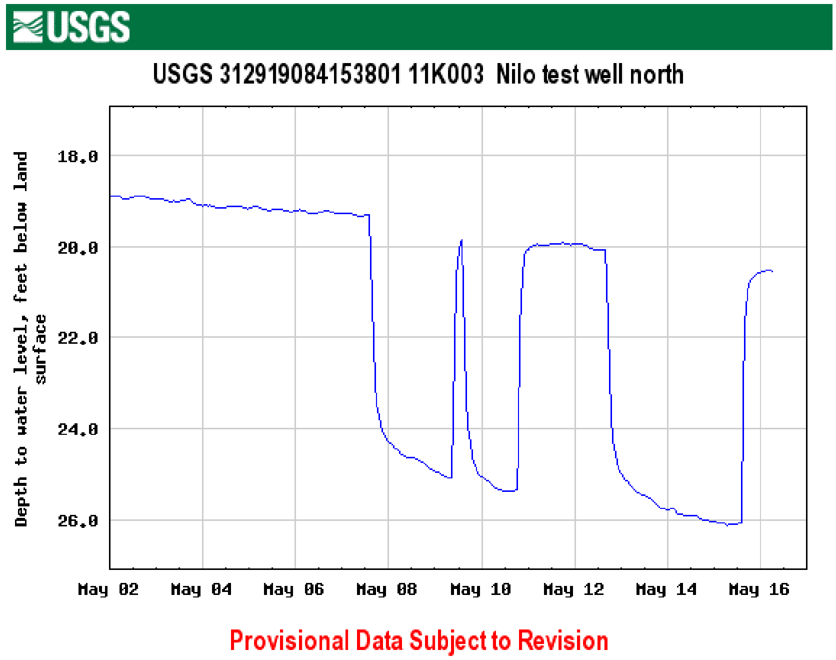


Figure 3.5: Hydrograph of Floridan aquifer well showing rapid recovery after cessation of pumping

3.5 Stream-aquifer interaction

From Vienna, Ga. in Dooly County, southward the Flint River is in hydraulic connection with the Floridan aquifer. In other words, the river has cut downward into the limestone, and exchanges water with the aquifer. For the remainder if its length, the Flint River remains in hydraulic connection with the Floridan aquifer to varying degrees. Similarly, many of the Flint's tributary streams are also in direct contact with the limestone and exchange ground-water discharge with it (Torak and McDowell, 1996).

This connection between streams and the aquifer is evident in potentiometric maps of the lower FRB, in which potentiometric contours bend strongly upstream where they cross the Flint River or some of its tributaries (e.g. Peck et al, 1999). The more pronounced the bend, the greater the hydraulic connection between stream and aquifer, and the greater the discharge from the aquifer to the stream. The flow of water back and forth from stream to aquifer is referred to as "stream-aquifer flux". When it is positive; that is, from aquifer to stream, the stream is said to be an “effluent” or “gaining” stream. When it is negative; that is, from stream back into aquifer, the stream is said to be an “influent” or “losing stream”. Under conditions of normal rainfall patterns, most stream reaches in the lower FRB are effluent, or gaining, streams.

Ground-water discharges to streams directly through the streambed or stream banks, but it may also be added in large quantities from in-channel springs (Torak and McDowell, 1996). In the FRB, these are called “blue-hole” springs from the striking blue appearance of the streambed around the springs (Fig. 3.6). This blue color is caused by precipitation of carbonate minerals around the opening of the spring.

Figure 3.6: “The Shaft”, a blue-hole spring on the Flint River between Albany and Newton, GA. (photo by S. Opsahl, J.W. Jones Ecological Research Center).

Some blue-hole springs have substantial discharges on the order of tens of millions of gallons per day. For example, the flow of Radium Springs in Albany, Ga has been measured at 49,000 gallons per minute (70.6 mgd). However, as a result of drought and increased withdrawals Radium Springs went dry in 1981 for the first time in recorded history, and has been going dry more frequently since then (W. Hicks, personal communication, 2005).

Blue-hole springs are more numerous and productive in the lower FRB. They are found on the major tributaries of the Flint, such as Ichawaynochaway Creek, Spring Creek, and others. Spring Creek takes its name from the numerous and prolific blue-hole springs along its length. A very high proportion of the streamflow of Spring Creek is derived from these springs: more so perhaps than in other tributaries of the Flint. The Flint River may receive as much as 500 mgd of ground-water discharge between Albany and Bainbridge (Torak and McDowell, 1996).

SECTION 4: FISH AND WILDLIFE RESOURCES OF THE LOWER FLINT RIVER BASIN

4.1 Mussels

Twenty-nine freshwater mussel species were historically known from the lower FRB with 22 species currently believed to still occur in the basin (Brimbox and Williams 2000). In 1998, the U.S. Fish and Wildlife Service listed three of these species as endangered and one as threatened under the U.S. Endangered Species Act (USFWS 2003). An additional species, the Fat Threeridge (*Amblema neislerii*) was also listed as endangered, but is presumed extirpated from Georgia.

North American mussels have experienced drastic declines in the past century as a result of dam construction, siltation, water pollution, and harvesting for pearl buttons (Brim Box and Williams, 2000). Today, formerly large populations of freshwater mussels have dwindled to small remnant populations that, in some cases, are functionally extinct; i.e., the populations are not capable of replacing themselves through reproduction (DNR, 1999; Golliday et al., 2002).

Freshwater mussels belong to the family *Unionidae* and are commonly referred to as "Unionids". Unionids generally live partially burrowed in the streambed, leaving only a small part of their shell exposed. They are able to move slowly by extending and retracting their muscular foot. This burrowing behavior as well as their slow movement leaves them unable to evade siltation and low levels of dissolved oxygen (DO).

The reproductive cycle of Unionids include~~s~~ a short phase in which larval mussels ~~is a~~ must parasitize specific fishes (Parmalee and Bogan 1998). Many mussel species release larvae throughout the spring and early summer when they must locate proper fish hosts quickly. After a few weeks upon the fish, larvae drop off the host fish and begin their life on the stream bottom as a mussel.

Because Unionids burrow into the streambed, filter feed, and depend on adequate fish populations to complete their life cycle, they are susceptible to the types of environmental stressors that commonly occur in the lower FRB. Specifically, soil erosion from human development, pollution, river impoundments, and natural or human-caused low flows have led to large declines in mussel populations (Brim Box and Mossa 1999).

The ability to survive desiccation varies among mussel species however, few species found in the lower FRB can tolerate prolonged drought. While some mussel populations are thought to naturally decline during droughts, they are believed to recover after conditions return to normal. However, droughts combined with other stresses on mussel populations threaten the long-term survival of many mussel species in southwestern Georgia.

Researchers were able to examine the impacts of the 2000 drought conditions on mussel populations (Fig. 4.1). In 2001, 21 stream reaches that contained recently surveyed populations of Unionids were resurveyed to determine the impact of the drought on the mussels. Some sites were non-flowing; i.e. the streambed was dry or had isolated pools of slack water during the drought; other sites maintained flow. The most severely impacted populations (those with the greatest population declines) were those at non-flowing sites, and most of the non-flowing sites were in the Dougherty Plain. Non-flowing sites with high amounts of woody debris had lower mortality rates than non-flowing sites without woody debris (Golladay et al, 2004).

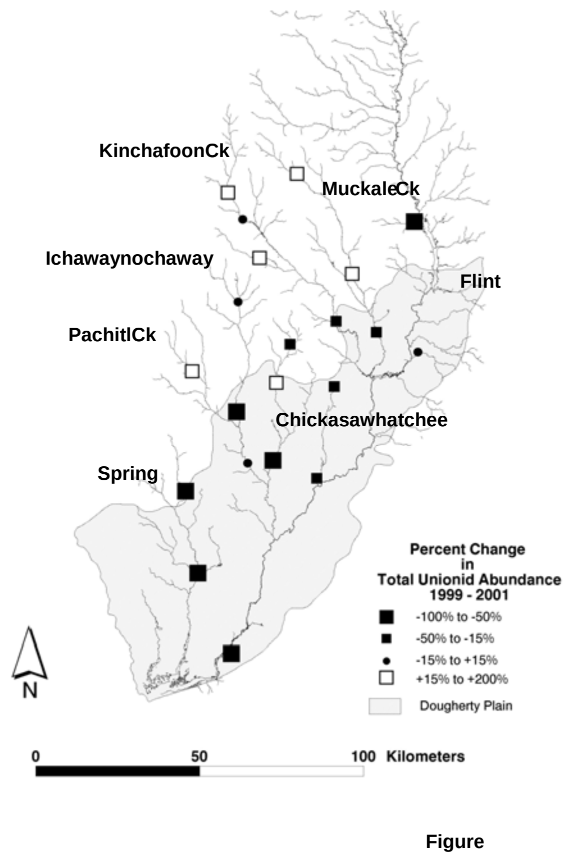


Figure 4.1: Percent change in total unionid abundance in the lower FRB, 1999 and 2001 *(from Golladay et al, 2004)*

The most extreme mussel mortality (of all surveyed sites) occurred in Ichawaynochaway sub-basin on Chickasawhatchee Creek near Elmodel. Although Chickasawhatchee Creek is normally a gaining stream above this location, it ceased flowing during 2000 (Golladay et al, 2004). This site is downstream of numerous large surface-water withdrawal points in Dougherty County, especially on Spring Creek north of Ga. Route 62. Although Chickasawhatchee Creek is not in good hydraulic connection with the Floridan aquifer upstream in Terrell County, it does become better connected in Calhoun County (Albertson and Torak, 2002).

On the main stem of Ichawaynochaway Creek where it flows into Subarea 4, mussel populations experienced large declines (a drop of between 50% and 100%, depending on species; Golladay et al, 2004). There is probably little ground-water contribution to the stream at this location, but under normal circumstances there is substantial tributary flow above this point, as well as significant of surface-water withdrawals. Even under drought conditions, flows at this point would have been substantially higher, almost certainly precluding a large mussel die-off.

One of the sites of greatest increases in surveyed mussel populations was also on Chickasawhatchee Creek near the Terrell-Dougherty County line (Golladay et al, 2004). Although this site is near and downstream of relatively dense distribution of ground-water irrigation, it is also in an area where the Floridan aquifer is very thin. Many wells in that area are not tapping the Floridan aquifer and thus have no impact on surface-water flow. The USGS has designated this stream segment as having a low susceptibility to ground-water withdrawals, but as the creek bends towards the south, deeper into Subarea 4, its susceptibility increases as its base flow contribution from the Floridan aquifer increases (Albertson and Torak, 2002).

Clearly, the 2000 drought conditions greatly impacted Unionids in the Dougherty Plain. Although the drought severely affected the whole southwest Georgia region, ground-water withdrawals in the Dougherty Plain area may have compounded drought stresses, and thus played a major role in mussel mortality. During the 2000 drought, researchers noted that many streams showed declining flows from their headwaters downstream across the Dougherty Plain (Johnston et al, 2001). This provided additional evidence irrigation in the Dougherty Plain decreases aquifer discharge, and thus exacerbates drought-related low streamflow.

In addition, patterns of mussel mortality may reflect competing effects of ground-water base flow and surface-water withdrawals. In those areas where there is little or no ground-water base flow, large surface-water withdrawals upstream may cause stream drying and possibly mussel die-offs. A possible example is the Morgan location where mussels died in large numbers downstream of numerous surface-water withdrawals from perennial streams. The locations upstream where mussels increased in population were in upland tributaries where surface-water withdrawals were not sufficient to cause dry streams or catastrophically low stream-flow. South of Morgan on Ichawaynochaway Creek, ground-water baseflow was sustained by the Floridan aquifer and offset surface-water withdrawals, allowing mussels to survive. The two locations in Terrell County where streamflow ceased were on upland tributaries with relatively small amounts of irrigation and no connection with the Floridan aquifer; therefore, mussel mortality there can be attributed mostly to drought conditions.

4.2 Gulf striped bass

The lower Flint River and its major tributaries contain a significant population of Gulf striped bass (*Morone saxatilis*) (Fig. 4.2). Striped bass are diadromous species, meaning that they can live in either fresh-water or salt-water, although in the lower ACF striped bass are a riverine species that rarely migrate into salt water (Dudley et al. 1977). Before construction of Jim Woodruff Lock and Dam (JWLD) in the 1950’s, striped bass would typically spawn in the Chattahoochee and Flint Rivers then return to the Gulf. Spawning still occurs above JWLD, but stocking is required to maintain sufficient populations (Gulf States Marine Fisheries Commission, 2005; Alabama Department of Conservation and Natural Resources et al, 2004).

Figure 4.2: Gulf striped bass in the blue-hole spring exhibit at the Flint RiverQuarium *(photo by Flint RiverQuarium).*

In the Flint River, Gulf striped bass are dependent on "thermal refuges." When river temperature exceeds 23^{o} C (usually by early May) striped bass seek out cool water (blue hole springs) to spend the summer months. At temperatures above 27^{o} C, mature bass (>15 lbs) stop feeding and die (Zale et al, 1990). The fish remain in or near these refuges throughout the summer, and by mid-October begin to vacate them (Alabama Department of Conservation and Natural Resources et al, 2004). Dissolved oxygen concentrations are critical for survival in summer thermal refuges (Coutant, 1985). However, crowding in the refuges due to temperature preferences or avoidance of low oxygen can lead to stress-induced pathology and over fishing, both of which can contribute to population declines Coutant (1985). To reduce the exploitation of Gulf striped bass in thermal refuges by anglers, the Flint River is closed to striped bass fishing from May 1st through October 31st (Georgia 2004-2005 Sport Fishing Regulation, Department of Natural Resources, Wildlife Resources Division).

Availability of the thermal refuges plays an important role in the survival of these fish, and limited summer thermal refuge habitat is probably the major factor for high adult striped bass mortality in Gulf Coast rivers (Lukens, 1988). In the lower FRB, blue-hole springs are the preferred thermal refuges for striped bass (Weeks and Van Den Avyle, 1996). Water discharging from the Floridan aquifer into blue-hole springs provides a further benefit to the bass' survivability in the Flint River, as alkalinity is beneficial to striped bass (Kerby 1993).

Striped bass are not a major species supporting saltwater recreational or commercial fishing in the Gulf of Mexico; however, the Flint River is one of the largest recreational striped bass fisheries in the Gulf region. There is a substantial directed recreational fishery for Gulf striped bass during the winter and spring months on the Flint River at the Georgia Power Dam in Albany and at the USACOE Andrews lock and dam on the Chattahoochee River (GA DNR unpublished data). Throughout the rest of their range, the majority of striped bass are caught incidentally by anglers targeting other fish such as catfish, bass, and sea trout (Gulf States Marine Fisheries Commission, 2005).

Conditions necessary for striped bass survival normally exist in the lower FRB, although low flows can impose stresses on the bass in addition to the unavailability of thermal refuges. Gulf striped bass population data collected by the Georgia Wildlife Resources Division (Department of Natural Resources) includes spring electrofishing surveys and counts of adults using thermal refuges during summer. These surveys have not indicated a substantial reduction in Gulf striped bass numbers in the Flint River. However, these methods of assessing the population may not adequately measure the impact drought has on this species. Decreased flow and increased temperatures that occur during drought conditions should be negatively correlated to the survival of Gulf striped bass. In addition, the Wildlife Resources Division has noted a decrease in the number of springs that are being utilized as thermal refuge habitat. These changes may be directly related to drought and low-flow conditions.

SECTION 5: WATER USE IN THE FLINT RIVER BASIN

5.1 Agricultural water withdrawal permitting

Ground-water withdrawals are regulated by EPD under the authority of the Groundwater Use Act (OCGA 12-5-90 et seq.) and Rules for Groundwater Use (391-3-2), and surface-water withdrawals are regulated by (EPD) under the authority of the Water Quality Act (OCGA 12-5-20 et seq.) and Rules for Water Quality Control (391-3-6). Permits for withdrawal of water for industrial, municipal, or agricultural use are required in Georgia for withdrawals that have the capacity to exceed 100,000 gallons per day (gpd) on a monthly average (O.C.G.A. 12-5-105).

Georgia law defines agricultural water use:

> "Farm-use permits are for the irrigation of any land used for general farming, forage, aquaculture, pasture, turf production, orchards, or tree and ornamental nurseries; provisions of water supply for farm animals, poultry farming, or any other activity conducted in the course of a farming operation. Farm uses shall also include the processing of perishable agricultural products and the irrigation of recreational turf, except in Chatham, Effingham, Bryan, and Glynn counties, where irrigation of recreational turf shall not be considered a farm use." (O.C.G.A. 12-5-92).

5.1.1 Application for a permit

When an applicant wishes to obtain a farm-use permit, they submit a permit application to EPD on forms supplied by EPD. Applicants provide information that must include, but not be limited to: Applicant's full name; mailing address; county in which existing or proposed water withdrawal is located and the purpose of the proposed withdrawal. If a withdrawal is for the purpose of irrigation, applicants are asked for the number of acres irrigated from this source and average number of inches of water applied from this source per year, as well as whether or not chemicals, fertilizers, fungicides, herbicides, insecticides, or nematicides are injected into the irrigation water. Applicants mark the withdrawal location of the water source on a county map supplied by the Division (or equivalent). If the application is for ground-water withdrawal, well construction data including (but not limited to) well depth; depth of pump intake below ground surface; design pumping capacity of well; depth of well casing; and month and year of well pump installation. Similarly if it is for a surface-water withdrawal, applicants are asked for the name of the withdrawal source (stream, lake, pond, etc. name); design pumping capacity of the pump or pumps at this location; number of pumps involved, if more than one; and month and year of pump installation. (O.C.G.A. Sec. 12-5-105).

5.1.2 Application evaluation – ground-water withdrawal permits

If the permit is for ground-water use, a geologic appraisal is performed to determine what aquifer the well will be using. This is a relatively simple procedure that compares surface elevation of the proposed well, the proposed well depth, and the known depths of aquifer tops and bottoms as shown in Georgia Geologic Survey Hydrologic Atlas 10 "Hydrologic evaluation for underground injection control in the Coastal Plain of Georgia" (Arora, 1984) and other published reports that describe the aquifers of Georgia. In the Coastal Plain, the heavily used Clayton aquifer has experienced extreme head declines, which causes adverse effects on other water users in those areas where the Clayton is currently being used. Under these circumstances, EPD can require future water users to withdraw "from other fresh-water aquifers than presently utilized" (391-3-2-.11). If the proposed well is using an aquifer in which EPD is still issuing permits, the applicant will be sent a "Letter of Concurrence to Drill an Irrigation Well" (391-3-2-.04). The applicant is required to drill the new well within one year to the approximate specifications described in the Letter of Concurrence. The proposed water user proceeds at their own risk if they do not obtain a letter of concurrence from EPD before constructing the well. (391-3-2-.04). After completion of the well, the applicant must return the Letter of Concurrence along with well completion data forms (also provided by EPD) describing well depth, casing depths, pump capacity, and other well construction details. If the well is drilled into an aquifer for which EPD is not issuing withdrawal permits, the applicant will be denied a permit and may be required to plug and abandon the well. If the well is constructed in accordance with the Letter of Concurrence, then a permit is issued to the applicant for the well.

5.1.3 Application evaluation – surface-water withdrawal permits

If a farm-use permit is for a surface-water withdrawal, then the applicant must specify their intended withdrawal capacity. The same criteria for issuance of a "grandfathered" ground-water permit apply to surface-water permits; however, in the case of surface-water permits for which an application was submitted before July 1, 1991, no low-flow protection plan is required and a permit is issued for the original pump capacity. All surface-water permits for which an application was submitted after July 1, 1991, must be evaluated to determine the need for a low-flow protection plan in order to protect the 7Q10 or the natural streamflow, whichever is less. The 7Q10 is defined as the minimum average flow for 7 consecutive days that occurs on average once every 10 years. If prior permitted withdrawals exist downstream, the new permit applicant must develop a drought contingency plan to protect the "non-depletable flow" (NDF) or the natural streamflow, whichever is less (391-2-3-.04). NDF is equal to the 7Q10 plus the calculated amount required to protect prior users. For withdrawals south of the fall line, where streams channels are not well defined, EPD has determined that it is necessary to protect only non-depletable flows of 1.0 cfs or greater. If evaluation of streamflow indicates that NDF would be less than 1.0 cfs, a low-flow plan is not required.

The process of evaluating an agricultural surface-water permit application involves establishing the presence and needs of downstream users, using EPD's **GIS** database of agricultural permits. The current methodology for processing surface-water withdrawal applications involves determining a local 7Q10 flow for each withdrawal point. This value is then used to determine if an applicant must submit a low-flow protection plan. Data from USGS gauging stations used to determine 7Q10 flows is available from "Low-Flow Frequency of Georgia Streams", or http://ga2.er.usgs.gov/lowflow. These gauging stations are located throughout the state, but are located in much fewer places in the

Coastal Plain. To obtain the most accurate information, 7Q10 flows are determined using continuous records obtained from USGS gauging stations. When a nearby gauging station can't be located, partial-record gauging stations are used. These, however, aren't always close to the applicant's withdrawal point. In these cases, "Effect of a Severe Drought (1954) on Stream flow in Georgia" (Thompson and Carter (REF)) is used to locate a gauging station with partial-record data. A 7Q10 flow can almost always then be calculated for the withdrawal point. Very rarely will a withdrawal point be located in close proximity to a gauging station, so the 7Q10 flow will almost always be interpolated from nearby gauges. In southern Georgia, however, some counties have very few (if any) gauging stations. Also, if a station is near a withdrawal point, they may not necessarily be in the same drainagebasin.

If 7Q10 data are not available for the proposed withdrawal location, it must be estimated from a known 7Q10 flow in the vicinity of the withdrawal using the drainage area (DA) ratio method (proposed withdrawal 7Q10 = known 7Q10 x proposed withdrawal DA/ known 7Q10 DA). Drainage areas above the proposed withdrawal can be obtained using a map and planimeter, or they can be calculated using advanced GIS software. Once 7Q10 is calculated for the proposed withdrawal point, the existing nearby downstream withdrawals must be totaled. If a major tributary enters the stream, then withdrawals below the **confluence** should not be considered. NDF is obtained by summing the 7Q10 flow and a prorated portion of nearby downstream withdrawals (determined by the DA ratio method).

5.1.4 "Grandfathered" farm-use permits

Agricultural withdrawal permitting began in Georgia in 1988 when the Ground-water Use Act of 1972 was amended. If a permit applicant could prove to EPD's satisfaction that a well or surface-water pump with a specified pumping capacity was installed before July 1, 1988, EPD granted a permit for such capacity from this well or pump. The application for such capacity had to have been received by the EPD on or before July 1, 1991. If submitted on of before that date, EPD granted a permit for the withdrawal of water at a rate of withdrawal equal to the greater of the operating capacity in place for withdrawal on July 1, 1988, or, when measured in gallons per day on a monthly average for a calendar year, the greatest withdrawal capacity during the 5-year period immediately preceding July 1, 1988. If the permit application was submitted after July 1, 1991, or, regardless of when submitted, if it is based upon a withdrawal of ground-water for farm uses occurring or proposed to occur on or after July 1, 1988, the application was subject to evaluation and classification as described in the Code Sections 12-5-96 and 12-5-97.

In other words, if a farmer had a well or pump that he or she could prove was in existence before July 1, 1988, and if they submitted a permit application before July 1, 1991, they would be issued a "grandfathered" permit for the *existing pump capacity*. Applications received after July 1, 1991, are not "grandfathered", and have been subject to evaluation according to the procedures described in the Rules for Groundwater Use and the Groundwater Use Act. To date, almost all permit applications received have been approved for the requested pump capacity.

5.1.5 Expiration, revocation, modification and transfer of agricultural permits

Farm-use permits have no expiration, and cannot be revoked for non-use in whole or in part after initial use has commenced (O.C.G.A. 12-5-105 (b)(2). However, the Director may suspend or modify a permit, grandfathered or not (see below) for farm use if he or she should determine through inspection, investigations, or otherwise that the quantity of water allowed would prevent other applicants from reasonable use of ground-water beneath their property for farm use (O.C.G.A. 12-5-105 (b)(3)), or if permitted withdrawals cause unreasonable adverse effects on other water users, including adverse effects on public and farm use (391-3-2-.11). A farm-use permit may be revoked if the proposed well was never drilled or if it was constructed in a manner significantly different from that indicated in supporting documentation. A farm-use permit is tied to a location, not a person, and may be transferred to subsequent owners of the land associated with the well, provided that EPD receives written notice of any transfer.

Under current State law, they cannot be transferred to different locations or between persons who are not owners of the land. Any modifications in the use or capacity conditions contained in the permit or lands which are the subject of the permit shall require the permittee to submit an application for review and approval by the Director (O.C.G.A. 12-5-105 (b)(1)).

5.2 Historical agricultural water use in southwest Georgia

Irrigation represents the largest category of agricultural water use in the FRB. For the 42 counties in which the Flint Basin lies, fewer than 25 % of agricultural permits have been requested solely for livestock, aquaculture, or other farm uses. However, it is understood that many small wells pumping less than 100,000 gpd (and would thus not require a permit), are also used for these purposes. Because of the importance of irrigation to the state and region, irrigation use has been surveyed and studied for many years.

5.2.1 Extension irrigation surveys

Since the onset of center-pivot irrigation in the 1970's, the Georgia Cooperative Extension Service (CES) has conducted periodic surveys of its agents to enumerate ongoing irrigation practices, acreage, and amounts (Harrison, 2005; Harrison and Hook, 2005). The statewide results of the most recent CES survey in 2004 can be found on-line at http://www.nespal.org/agwateruse/facts/survey/. The survey shows cotton, peanut, corn, vegetables, and pecans to be the most extensively irrigated crops, with 42, 22, 12, 8, and 5%, respectively, of the 1,550,000 acres irrigated statewide. In the 42 counties in which the Flint Basin lies, the same crops predominate with 48, 24, 12, 7, and 7%, respectively, according to the extension survey. The average amount applied to crops statewide is shown below (Fig. 5.1) for crops of importance.

The CES survey also asked agents to estimate the average amount of water applied to each crop in the agent's county during the year of the survey. For the most recent survey, the statewide irrigation application depths varied from about 4 to 20 inches. The amount applied to crops on average statewide is shown below for crops of importance to the Flint Basin. In the 2004 survey, as in most other years of the survey, cotton, peanuts, and corn received 6 to 8 inches of water; vegetables and pecans, 8 to 10 inches; and athletic areas, sod, and nursery plants, greater than 15 inches.

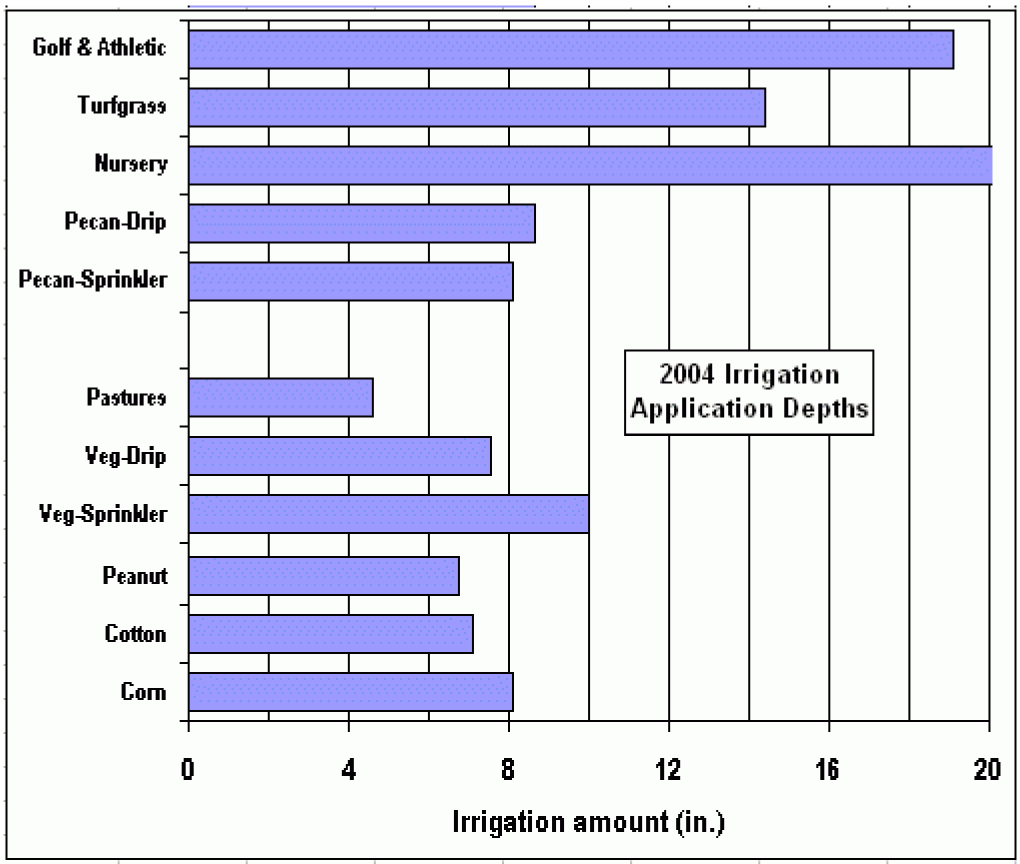


Figure 5.1: Statewide irrigation application depth in the 2004 survey of Cooperative Extension agents

excerpted from the on-line data
http://www.nespal.org/agwateruse/facts/survey/amtbycrop.asp 28 Sep 2005)

5.2.2 Subarea 4 and Flint Basin Sound Science Studies – Irrigated acreage

While CES irrigation surveys provided practical estimates of irrigation areas, application amounts, and crops produced, they provided too little detail on specific watershed areas, and the estimates were based on surveys of agents only.

To provide a working knowledge of specific withdrawal locations, area under current irrigation systems, and identification of permits used with those irrigation water withdrawals, EPD commissioned two Sound Science studies under the auspices of the ACF Compact negotiation and the FRB Plan to map irrigated area in Subarea 4 and beyond. In the first effort, Litts et al. (2001) measured center-pivot irrigation systems visible in aerial photographs and estimated non-pivot acres. They reported approximately 475,800 irrigated acres could be found in the Subarea 4 portions of the lower FRB and adjacent parts of the Chattahoochee Basin.

Subsequently, EPD, UGA-NESPAL and the J.W. Jones Ecological Research Center worked with farmers and other permit holders to identify specific sources and irrigated areas associated in an effort to map each permitted withdrawal. In Subarea 4, they identified 570,000 acres that were under irrigation. Of these, approximately 79,000 acres were irrigated by surface-water and 466,000 acres by ground-water, while the remainder were supplied by multiple sources of ground-water and surface-water (Danna Betts, UGA-NESPAL, personal communication, summary of areas mapped Jan. 5, 2005). The permit mapping initiated under this Sound Science study was extended northward to include the entire FRB. Since specific irrigation sources and irrigation systems were mapped in a Geographic Information System (GIS), these data were used in subsequent Flint Basin analyses and models that form the basis of this Plan.

An evaluation of irrigated acres by sub-basins within the FRB (Fig. 5.5) indicates that the highest concentration of irrigation is in the lower Flint River and Spring Creek sub-basins. Irrigation in these areas is almost exclusively supplied by ground-water. The Ichawaynochaway sub-basin is equally divided between ground-water and surface-water. This is particularly evident in the southern half of the sub-basin in Subarea 4, in contrast to the northern half, which is supplied by a combination of surface-water and ground-water. The Middle Flint and Kinchafoone-Muckalee Creek sub-basins, have lesser amounts of land under irrigation. Irrigation is dominated by surface-water withdrawals. The Upper Flint sub-basin has a comparatively small irrigated area and was not examined closely for impacts in this Flint Basin Plan.

Thus, irrigation from ground-water is most heavily concentrated in the Dougherty Plain section of the Coastal Plain where the Floridan aquifer is relatively shallow and generally prolific. Outside of Subarea 4, especially north of it, surface-water use exceeds ground-water use (Figs. 5.2, 5.3).

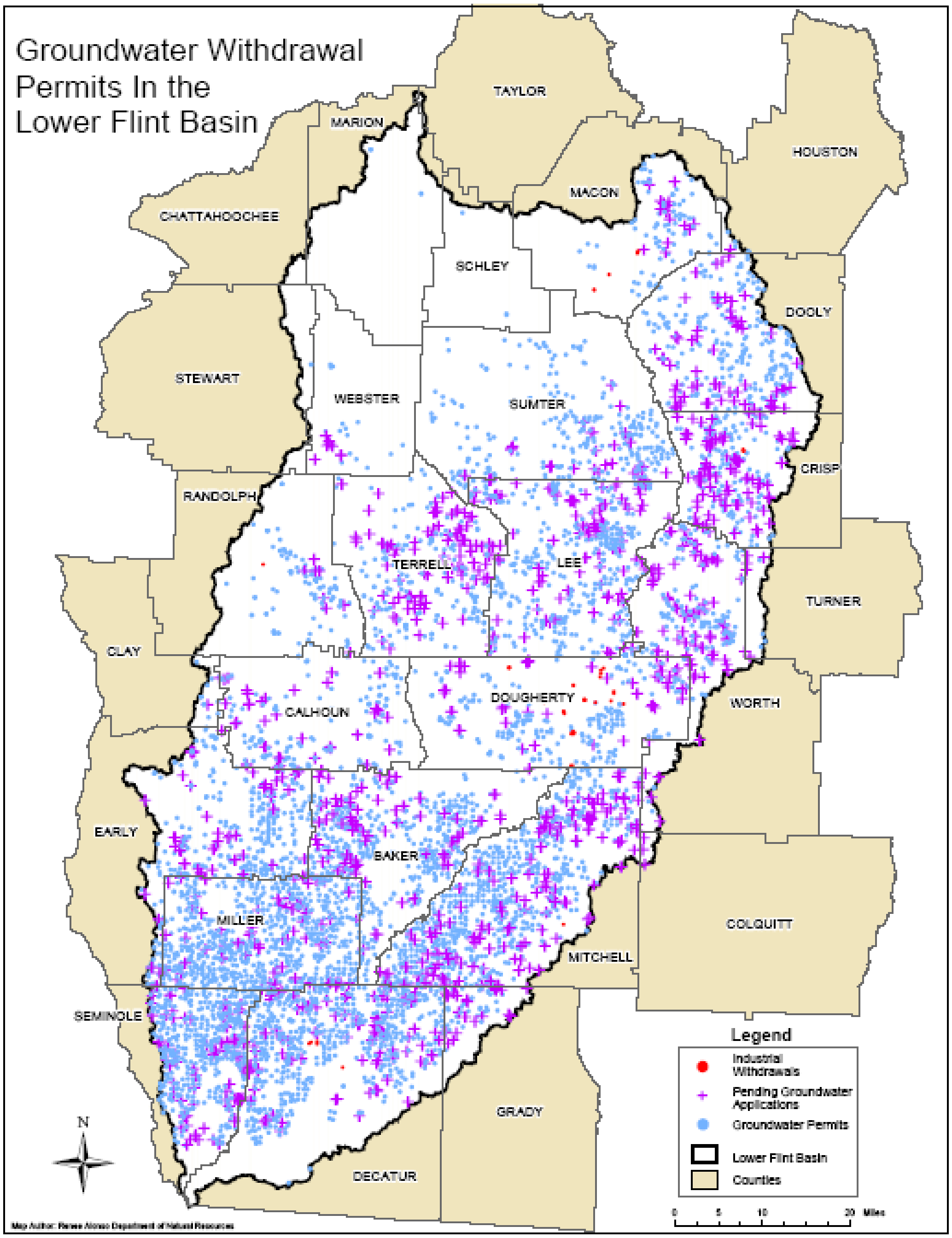


Figure 5.2: Pending and permitted ground-water locations

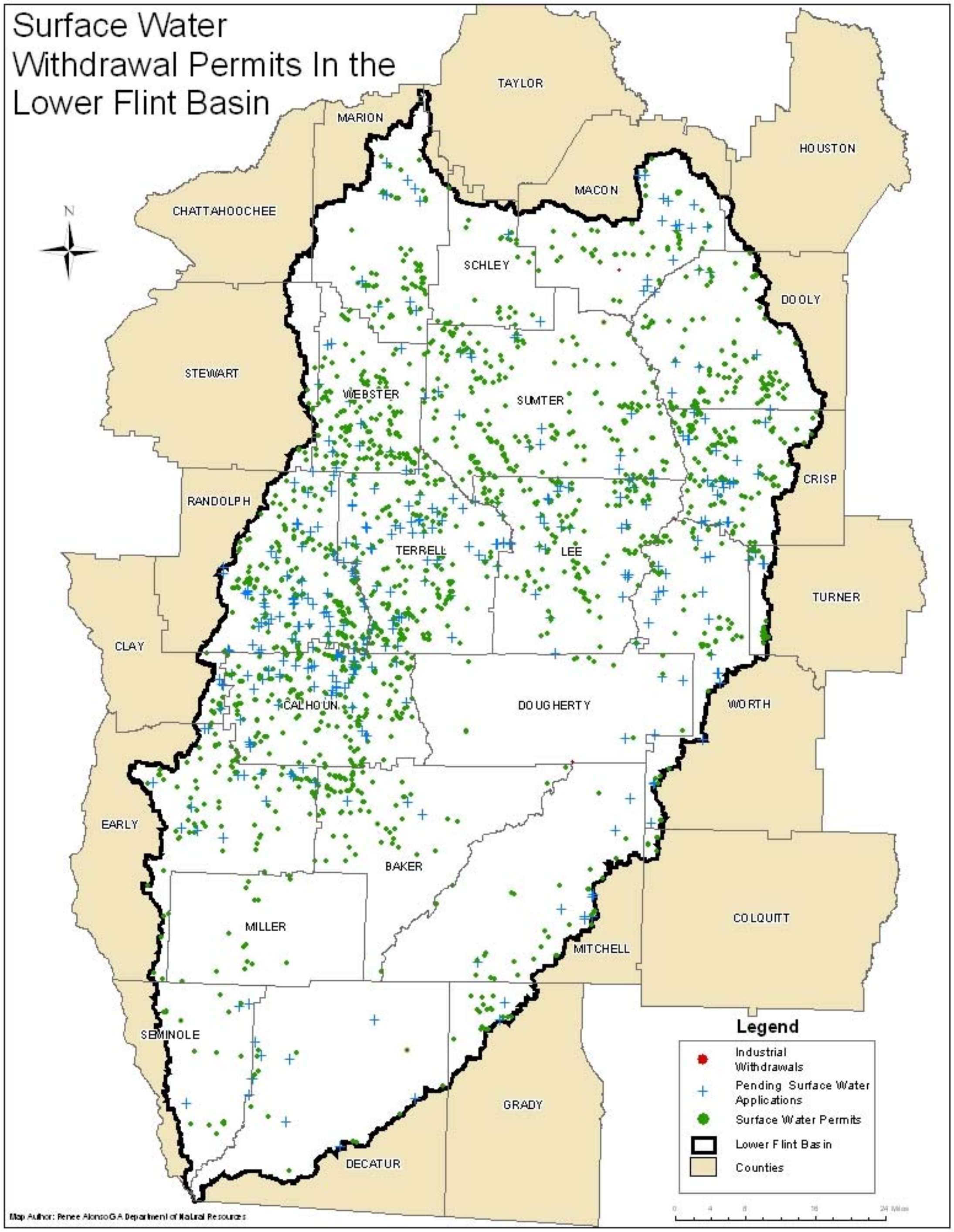


Figure 5.3. Pending and permitted surface-water withdrawal locations

5.2.3 Subarea 4 and Flint Basin Sound Science Studies – Irrigation amounts

With funding from EPD, agricultural water use in Georgia was extensively studied by The University of Georgia Agricultural Experiment Station and CES. From 1999 through 2004, a random 2% sample of irrigation systems was metered across Georgia (Hook et al, 2005), and a random 5% sample of ground-water-supplied systems in Subarea 4 was metered. Together this resulted in multi-year, monthly measurement of irrigation application amounts on 41,500 acres (7.3% of Flint Basin acres) for 305 permitted withdrawals (7% of Flint Basin permits). Flow rates on sampled irrigation systems were measured with "strap-on" digital flow meters, and usage hours were recorded monthly for each system. Additionally, crop type, wetted area, power source, and water source were determined during each observation. The final report of this statewide irrigation monitoring research, "Ag Water Pumping" (or AWP), as well as summaries from the research, was placed on-line (http://www.nespal.org/awp/2005.02.AWP-Final.pdf). The combination of irrigation amounts obtained from AWP (Fig. 5.4), combined with irrigation surveys and permit mapping provided most of the agricultural water-use data used for the hydrologic models discussed below.

Most irrigation systems in the Dougherty Plain, whether supplied by surface-water or ground-water, are center-pivot systems (Table 5.1). These are the most efficient systems in the very low topography of the Dougherty Plain. In the Fall Line Hills where topography is more rolling, traveler irrigation systems are more common.

System Type	Acres
Portable Pipe	2190
Cable Tow	43666
Hose Reel	26327
Center Pivot	557632
Lateral Move	428
Solid Set Sprinkler	19197
Drip/Trickle	28813
Athletic Field/Golf	3733
SDI	73

Table 5.1: Irrigated acres by system type in southwest Georgia (NESPAL, 2005)

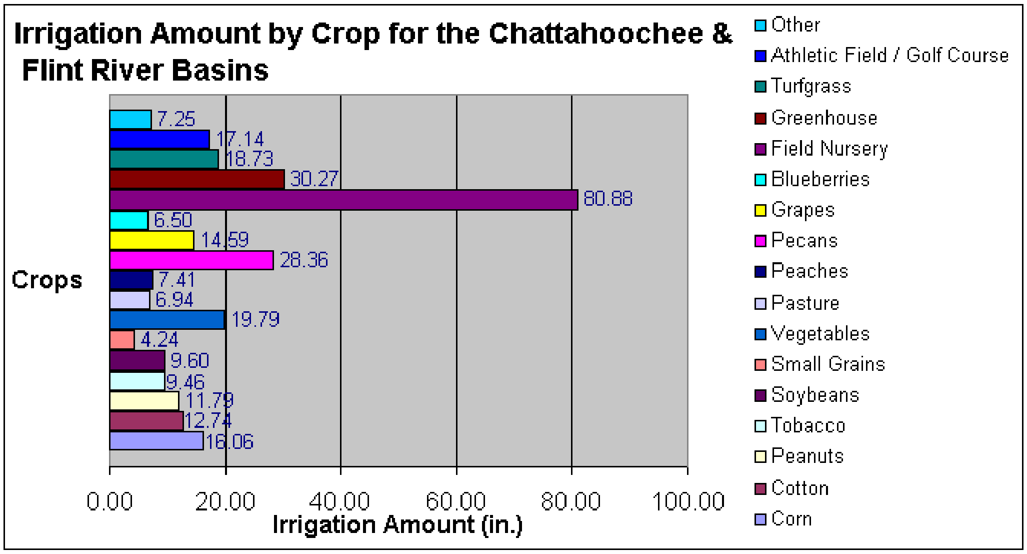


Figure 5.4. Irrigation amounts by crop in southwest Georgia

As part of the AWP study, permitted irrigation wells and surface-water pumps and the acreage wetted by them were mapped by NESPAL and EPD using advanced GIS software. This provided invaluable data relevant to water-use patterns and geographic trends in irrigation. More than 95% of the permitted wells and surface-water pumps and associated irrigated fields have been mapped. Results of the permit mapping reveal the distribution of irrigation by sub-basin in southwest Georgia (Figure 5.5). The lower Flint sub-basin has the largest area under irrigation, but it is also the largest HUC-8 sub-basin in the study area. Significantly, Spring Creek is one of the smaller sub-basins in the FRB, but it has the highest percentage of land under irrigation (REF).

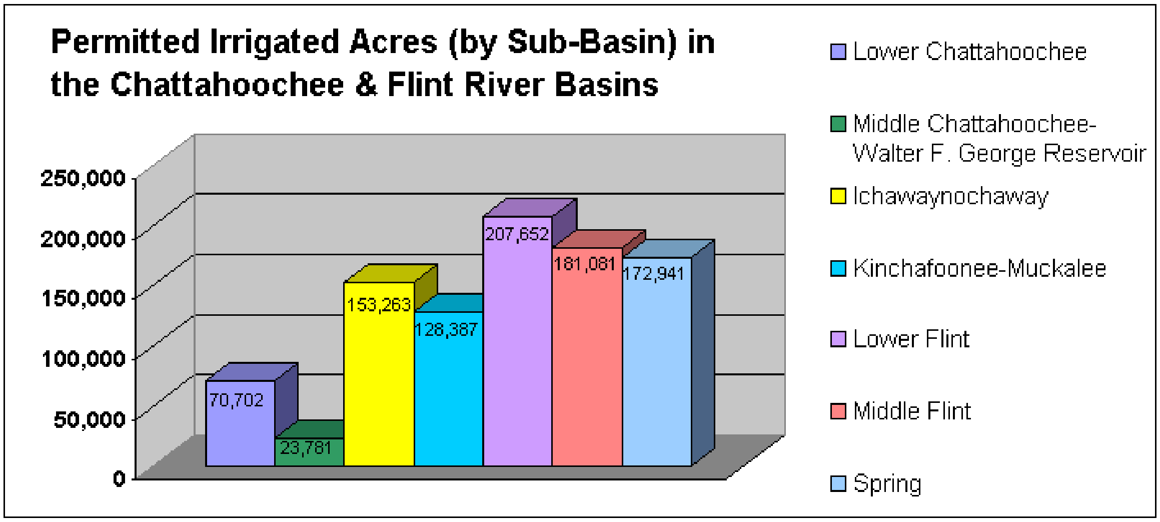


Figure 5.5: Distribution of irrigated acreages by sub-basin in southwest Georgia (NESPAL, 2005)

The AWP study also revealed details about the distribution of irrigation throughout the year (Fig. 5.6). Irrigation does not occur uniformly throughout any given growing year; rather, it mostly occurs during the main growing season from April through September. Variations in irrigated depths and amounts within the growing season depend on rainfall patterns, crop needs, and crop distribution. Typically, however, irrigation volume peaks in June, July, or August, and drops rapidly after September. Not coincidentally, this corresponds with the hottest and/or driest parts of the year when evapotranspiration is highest, and streams and ground-water levels are approaching their seasonally lowest levels. Very little water is applied outside of the May-September growing season (Hook et al, 2005).

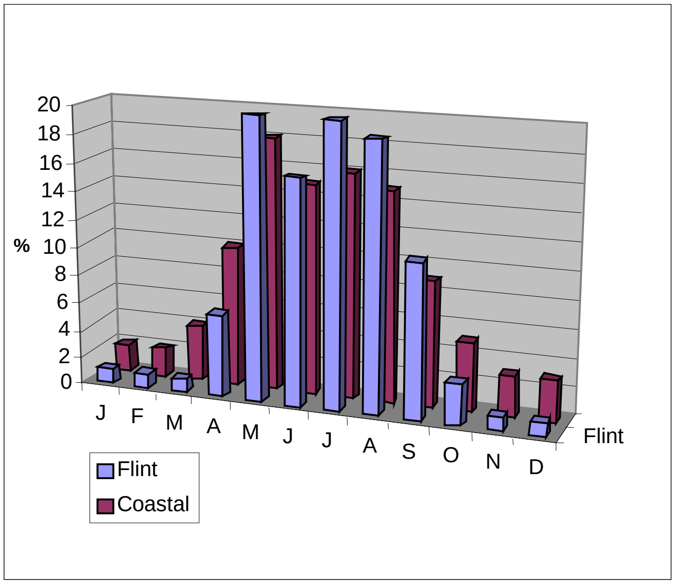


Figure 5.6. Temporal distribution of irrigation during 2000-2001 (NESPAL, 2005).

Irrigation depths and volumes measured and calculated during the AWP study for southwest Georgia are shown in Table 5.2. The period 2000-2002 represents moderate to severe drought conditions; 2003 was a relatively wet year. Year 2004 is categorized as an "average" to dry year in terms of precipitation (AEMN, 2004).

Mean annual area-weighted irrigation depths and calculated withdrawals, southwest Georgia							
Year	GW	SW	W2P	GW	SW	W2P	All
	in./yr			Mgal/yr			
2000	12.0	7.5	9.4	178,000	34,000	18,000	230,000
2001	9.1	5.3	7.5	140,000	24,000	15,200	180,000
2002	10.0	7.5	7.4	157,000	34,000	14,600	206,000
2003	5.3	2.5	4.5	80,000	13,100	9,000	102,000
2004	8.5	6.8	5.9	130,000	31,000	11,400	172,000

Table 5.2: Mean annual area-weighted irrigation depths and calculated withdrawals, southwest Georgia (Hook et al, 2005).

Application depths varied substantially depending on crop type, soil type, local rainfall patterns, location, and individual farmer preference, and were computed from individual application depths that varied from 0 to over 300 in./yr (Hook et al, 2005). Average regional values were combined with wetted acreages to calculate irrigation amounts in million gallons per day.

It is notable that ground-water-supplied irrigation systems consistently applied more water than surface-water systems. This may have been a result of greater reliability of ground-water supply in a drought in which many streams and ponds dried; the ability to produce higher value crops with ground-water; or the relative availability of ground-water in many areas (Hook et al, 2005). The FRB also has the highest volume of ground-water withdrawn for irrigation in the State (123 billion gal/yr in 2002) and the highest volume of surface-water withdrawn for irrigation (27 billion gal/yr in 2002). The FRB has the second highest basin-wide mean irrigation application depth (1.02 in/yr) after the Ochlockonee River Basin, and the highest percentage of area under irrigation. It is important to note that the irrigation volumes applied are quite small when compared to the amount of annual precipitation (Hook et al, 2005).

5.3 Municipal and industrial ground-water withdrawal permitting

5.3.1 Municipal and industrial ground-water permitting

The Georgia Groundwater Use Act of 1972 requires all non-agricultural ground-water users (i.e. municipal and industrial users statewide and in addition, recreational turf irrigation (golf courses) in the four coastal counties of Bryan, Chatham, Effingham and Glynn) or projected users of more than 100,000 gpd for any purpose to obtain a Ground-water Use Permit from EPD.

For a complete ground-water withdrawal application, at a minimum the following forms and information are required (O.C.G.A. 12-5-96 et seq.):

• **Part A Form:** General system and contact information, along with maximum monthly and annual average requested from an aquifer, for a specific defined use. Sufficient justification of the requested water amount is essential. Justification, including current needs and future water demand projections, population growth, business growth, annexation or any additional factors related to increased (or an explanation for decreased) water usage, must be provided to determine if the water can be allocated.

• **Part B Form:** Drillers log of each system well indicating depth and lithologies to allow a determination of the source aquifer used. Also specific well construction/completion information such as casing size, depths, and screened interval, is required. Location maps of the wells must be provided.

• **Ground-water Use Report:** Provide the previous, historic water use for a system or operation along with required reporting of monthly production values, sent to EPD every six months. This is to justify the amount of water needed and to assure permit compliance with production limits once a permit is issued.

• **Water Conservation Plan:** A permittee must incorporate water conservation into long-term water demand and supply planning following an approved outline for developing an effective water conservation plan based upon specific needs and conditions of the water system. This provides EPD with adequate information showing the applicant is a good steward of the ground-water resource, and making efficient use of the water. This material defines current and proposed 20-year plans for discouraging waste and encouraging conservation.

• **Water Conservation 5 year report:** A requirement of the law is that five years after permit issuance, the permit holder must provide to EPD a synopsis of their water usage over the previous five years. This must include an accounting of previous and current water conservation efforts and their impact, along with a description of future plans to increase efficiency. An applicant must also explain where their wastewater goes once the ground-water is used. This is to assure that the treatment option is large enough to be able to handle the amount of water withdrawn.

• **Service Delivery Strategy:** Municipal users must provide documentation that their water withdrawal, in some defined service delivery area, is consistent with the County planning and the planning of neighboring municipalities, to avoid duplication of services in any area. EPD cannot issue a withdrawal permit if such a service delivery agreement is not provided.

Other information may be required depending on the particular situation or the amount of water requested. This may include detailed hydrologic testing to assure that the aquifer can deliver adequate water without detrimental impacts to other users.

Once a complete ground-water withdrawal application is received, EPD will then place the list of applicants out for at least 30 days of public comment. If there is limited public interest in an application, this will then be followed by at least 30 days of public notice on the draft permit. Only after these comment periods are complete does the Director of EPD recommend any municipal and industrial ground-water permit for approval. If at any stage of the permitting process sufficient internal or external comments or questions are received, the applicant must provide adequate information to address those concerns. In select cases an official public hearing on the application might be scheduled by EPD.

In any case, after an analysis of all the above materials, taking into account hydrologic impacts and the operation's need for the water, any application for a ground-water withdrawal permit might either be approved and a permit issued, or a permit denied. There is no requirement that a municipal or industrial ground-water withdrawal permit be issued to every applicant.

If approved, an EPD issued Ground-water Use Permit identifies the allowable monthly average and annual average withdrawal maximum, sets a permit expiration date (generally ten years out), defines a specific withdrawal purpose, accounts for the number of wells allowed, and enumerates standard and any additional special conditions for ground-water resource use. Standard conditions define statutory provisions, permit transfer restrictions and reporting requirements (e.g. semi-annual ground-water use reports), while special conditions identify such things as the source aquifer and conditions of well replacement, or any unique requirements specific to this permit.

Failure to follow any of the required permit conditions can result in compliance actions being taken against the permit holder, up to and including permit revocation.

Once a ground-water withdrawal permit is issued to any party, any changes in permit operator, permitted water withdrawal amount, number of wells allowable, the defined permitted use of the water, standard or special conditions, etcetera, can only occur with written EPD approval and the issuance of a modified withdrawal permit.

5.4 Municipal and industrial surface-water withdrawal permitting

The Georgia Water Quality Control Act requires that an EPD-issued Surface-water Withdrawal Permit be sought and obtained by all those users of surface-waters who intend to withdraw, divert, or impound water at a rate of at least 100,000 gallons per day (on monthly average basis). The Permit identifies the allowable monthly average and 24-hour maximum withdrawal rates, permit expiration date, designated withdrawal purpose, source of water, and standard and any special conditions for resource use.

To obtain a withdrawal permit, the Rules for Water Quality Control (391-3-6) require submitting a permit application to EPD. This application requires information about proposed withdrawal location, historic water use, water demand projections, water conservation, drought contingency planning, and other pertinent information on the water's source. Municipal and Industrial surface-water users must report their monthly water use to EPD. EPD requires, among other things, the following of a permit applicant before a draft permit can be developed and made available for public review prior to the issuance of a Surface-water Withdrawal Permit:

1. EPD requires every applicant to develop a Water Conservation Plan that addresses items such as system management, plant management, ratemaking policies, plumbing ordinances, recycle and reuse, public education, long range planning forecasts, etc. The applicant is required to track statistics such as per capita use, and un-accounted for water and report trends in the service areas via Water Conservation Progress Reports.

2. EPD requires every applicant to develop a Drought Contingency Plan aimed at reducing water use during critical low flow periods. Additionally the applicant must defer to the Georgia Drought Management Plan (which restricts all outdoor water use to 3 days per week even during non-drought periods) when it is more stringent.
3. EPD requires every applicant to maintain a base stream-flow (non-depletable flow) below the intake to provide for the aquatic habitats and downstream needs.
4. EPD requires every applicant within one of the 16 counties of the Metropolitan North Georgia Water Planning District to operate in accord with District's Water Supply and Water Conservation Management Plan.

EPD is empowered to modify or revoke any permit if the withdrawal is not in compliance with the terms of the permit or if there is an unreasonable adverse effect upon other water uses or users in the area. EPD may deny a permit application if the application is found to be contrary to the public interest or general welfare.

Enforcement authority

Under the Rules and Statutes referenced above, EPD has the legal authority to enforce violations of permit conditions. EPD also has the right to conduct investigations into permit violations and to enter any property, public or private, to conduct such investigations with or without the consent of the permit holder. When the Director of EPD has reason to believe that a permit violation has occurred, he or she shall attempt to remedy the violation by conference, conciliation, or persuasion. If this approach fails, the Director may issue an order requiring compliance by the violator, and file this order in the superior court of the county where the violation is taking place. The permittee may appeal the order and obtain a hearing. On the basis of this hearing, EPD shall continue the order, revoke it, or modify it. If a person or entity fails to comply with the final order, they are liable for a civil penalty not to exceed $1,000.00 per day for each violation, and an additional civil penalty not to exceed $500.00 for each day during which the violation continues.

5.5 Permitted municipal and industrial withdrawals

In the FRB, permitted municipal and industrial water use is substantially less than agricultural water use. Most of the surface-water usage is in the northern part of the basin; i.e. in the Piedmont region north of the fall line (Table 5.3).

Permitted municipal and industrial surface-water withdrawals in the Flint River Basin

County	Facility	Permit number		Source	Monthly avge. (MGD)	Monthly average use (2004
Clayton	Clayton County Water Auth - Shoal	031-1101-01	M	J.W. Smith Res./Shoal Cr.	**17**	**4.4**
Coweta	Senoia, City Of	038-1102-05	M	Hutchins Lake	0.3	.223
Fayette	Board Of Commissioners Of Fayette Co.	056-1102-09	M	Line Cr (McIntosh Site)	2	0.000
Fayette	Board Of Commissioners Of Fayette Co.	056-1102-10	M	Whitewater Creek	2	.734
Fayette	Fayette County Water System	056-1102-03	M	Lake Peachtree	0.5	1.70
Fayette	Fayette County Water System	056-1102-12	M	Horton Creek Reservoir	14	6.9
Fayette	Fayetteville, City Of	056-1102-14	M	Whitewater Creek	3	1.142
Macon	Weyerhaeuser Company	094-1191-01	I	Flint River	12	10.189
Meriwether	Roosevelt Warm Springs Rehab	099-1106-04	M	Cascade Creek	0.14	.144
Meriwether	Woodbury, City Of	099-1106-02	M	Cain Cr Res On Pond Cr	0.5	.167
Pike	Griffin, City of	114-1104-03	M	Still Branch Reservoir	42	0
Pike	Zebulon, City Of	114-1104-01	M	Elkins Creek	0.3	0
Spalding	Griffin, City Of	126-1190-01	M	Flint River	12	8.479
Talbot	Manchester, City of	130-1106-05	M	Rush Creek Reservoir	1.44	1.015
Taylor	Unimin Georgia Company, L.P.	133-1109-01	I	Remote Pond on Black Creek	1.73	1.344
Taylor	Unimin Georgia Company, L.P.	133-1109-02	I	Black Creek (Remote Jr.)	0.38	.353
Upson	Southern Mills, Inc.	145-1104-02	I	Thundering Springs Lake	0.5	.205
Upson	Thomaston, City Of	145-1105-01	M	Potato Creek	3.4	0
Upson	Thomaston, City Of	145-1105-02	M	Potato Creek	0.4	.015
Upson	Thomaston, City Of	145-1105-03	M	Raw Water Cr Res	4.3	2.789
TOTAL					**117.39**	**50.545**
	Hydropower and cooling-water use					
Dougherty	Georgia Power Co - Plant Mitchell	047-1192-01	I	Flint River	232	232
Worth	Crisp County Power Comm - Hydro	159-1112-02	I	Lake Blackshear	4,847.30	4,847.30
Worth	Crisp County Power Comm - Steam	159-1112-01	I	Lake Blackshear	15	15
TOTAL					**5502.7**	**5094.3**

Table 5.3: Permitted municipal and industrial surface-water withdrawals in the FRB

Surface-water withdrawals for hydropower usage are considered to be non-consumptive, as almost all of the water is returned to the river. Furthermore, in the case of the Crisp County Power's permitted withdrawals, that water is not retained or pumped out of the river; instead, it is locally diverted into hydropower turbines and returned immediately to the Flint River. Thus, its withdrawal amount is totally non-consumptive.

Municipal and Industrial ground-water users south of the fall line withdraw water from the Floridan, Claiborne, Clayton, and Cretaceous aquifers.(Table 5.4). Withdrawals from aquifers other than the Floridan do not significantly impact streamflow. Floridan aquifer withdrawals are more substantial, but the total M&I withdrawals represent less than 3 % of agricultural irrigation withdrawals. Thus, their cumulative impact on stream-aquifer flux and the regional ground-water **budget** is negligible.

GEORGIA COUNTY	GW W/D PERMIT NUMBER	GROUND-WATER PERMIT HOLDER	PERMITTED MONTHLY AVG W/D (MGD)	PERMITTED YEARLY AVG W/D (MGD)	Aquifer
Baker	**004-0001**	Newton, City of	**0.250**	**0.250**	Claiborne
Calhoun	**019-0001**	Leary, City of	**0.300**	**0.300**	Claiborne, Tallahatta
Calhoun	**019-0002**	Edison, City of	**0.300**	**0.200**	Clayton
Calhoun	**019-0003**	Arlington, City of	**0.350**	**0.300**	Floridan
Calhoun	**019-0004**	Morgan, City of	**0.350**	**0.300**	Clayton
Clayton	**031-0002**	Clayton County Water Authority	**0.729**	**0.729**	Crystalline Rock
Crawford	**039-0001**	Roberta, City of	**0.240**	**0.180**	Cretaceous Sand
Crawford	**039-0002**	Crawford County Board of Commissioners	**0.300**	**0.250**	Cretaceous Sand
Crisp	**040-0001**	Cordele, City of	**4.100**	**3.000**	Floridan, Claiborne, Wilcox
Crisp	**040-0002**	Norbord Georgia Inc - Cordele OSB Mill	**0.225**	**0.210**	Floridan
Crisp	**040-0004**	Crisp County - Waterworks	**1.000**	**0.800**	Claiborne
Decatur	**043-0001**	Florida Rock Industries - Bainbridge Sand Plant	**0.285**	**0.235**	Floridan
Decatur	**043-0002**	Propex Fabrics, Inc - Bainbridge Mills	**0.900**	**0.750**	Floridan
Decatur	**043-0003**	Bainbridge, City of	**5.000**	**4.400**	Floridan
Decatur	**043-0004**	Decatur County Industrial Airpark	**0.650**	**0.550**	Floridan
Decatur	**043-0005**	Z.A. Adams Construction Company	**0.400**	**0.400**	Floridan

Dooly	**046-0002**	Vienna, City of	**2.609**	**2.153**	Cretaceous Sand, Claiborne
Dougherty	**047-0001**	Cooper Tire & Rubber Company	**0.720**	**0.720**	Floridan
Dougherty	**047-0002**	Albany, City of - Water, Gas & Light Com	**36.000**	**24.000**	Clayton, Claiborne, Floridan, Providence
Dougherty	**047-0003**	Merck & Company, Inc	**10.440**	**8.550**	Floridan
Dougherty	**047-0004**	Florida Rock Industries - Albany Sand Plant	**0.250**	**0.160**	Floridan
Dougherty	**047-0005**	Procter & Gamble Paper Products Company	**10.500**	**10.500**	Floridan
Dougherty	**047-0007**	Miller Breweries East, Inc	**3.000**	**3.000**	Clayton, Tallahatta
Dougherty	**047-0008**	Marine Corps Logistics Base	**2.000**	**1.500**	Floridan, Claiborne, Tallahatta, Wilcox, Clayton
Dougherty	**047-0010**	Young Pecan Company - Nut Tree Division	**0.180**	**0.100**	Floridan
Dougherty	**047-0011**	Doublegate Country Club	**0.720**	**0.720**	Floridan
Dougherty	**047-0012**	Georgia Power Company - Plant Mitchell	**0.250**	**0.250**	Floridan
Dougherty	**047-0013**	Barton Brands / Viking Distillery, Inc	**0.200**	**0.200**	Clayton, Floridan
Fayette	**056-0001**	Fayette County Water System	**0.875**	**0.825**	Crystalline Rock
Fayette	**056-0002**	Fayetteville, City of	**0.937**	**0.937**	Crystalline Rock
Fulton	**060-0005**	Ford Motor Co - Atlanta Assembly Plant	**0.291**	**0.291**	Crystalline Rock
Lee	**088-0001**	Leesburg, City of	**0.320**	**0.300**	Tallahatta, Wilcox, Paleocene
Lee	**088-0002**	Lee County Utilities Authority	**2.500**	**2.000**	Claiborne, Clayton, Providence
Macon	**094-0001**	Montezuma, City of	**1.250**	**0.810**	Cretaceous Sand
Macon	**094-0002**	Flint River Foods	**2.000**	**1.000**	Cretaceous Sand
Macon	**094-0003**	Marshallville,City of	**0.155**	**0.120**	Cretaceous Sand
Macon	**094-0004**	C-E Minerals - Plant #5 Mulcoa	**0.100**	**0.100**	Midway, Providence
Macon	**094-0005**	Weyerhaeuser Company - Flint River Operations	**1.836**	**1.836**	Cretaceous Sand
Macon	**094-0006**	Oglethorpe, City of	**0.370**	**0.330**	Cretaceous Sand
Marion	**096-0001**	Buena Vista, City of	**2.000**	**1.750**	Cretaceous Sand
Marion	**096-0002**	Marion County Water System	**0.637**	**0.482**	Cretaceous Sand
Meriwether	**099-0003**	Georgia-Pacific - Warm Springs Plywood	**0.200**	**0.200**	Crystalline Rock
Miller	**100-0001**	Colquitt, City of	**1.000**	**0.800**	Floridan
Mitchell	**101-0002**	Camilla, City of	**5.500**	**5.000**	Floridan
Mitchell	**101-0003**	Mitchell County - State	**0.300**	**0.300**	Floridan,

		Prison			Oligocene
Mitchell	**101-0004**	Gum Pond, LLC - Power Plant	**1.100**	**1.100**	Floridan
Randolph	**120-0001**	Cuthbert, City of	**1.000**	**0.800**	Clayton, Providence (K)
Randolph	**120-0002**	Shellman, City of	**0.180**	**0.150**	Clayton
Randolph	**120-0003**	Georgia Feed Products, Inc	**0.200**	**0.200**	Clayton
Schley	**123-0001**	Ellaville, City of	**0.350**	**0.275**	Cretaceous Sand
Schley	**123-0002**	Schley County Board of Commissioners	**0.133**	**0.100**	Cretaceous Sand
Seminole	**125-0001**	Donalsonville, City of	**1.000**	**0.800**	Floridan
Spalding	**126-0001**	Griffin, City of	**1.461**	**1.461**	Crystalline Rock
Stewart	**128-0001**	Richland, City of	**0.100**	**0.100**	Cretaceous Sand
Sumter	**129-0001**	Americus, City of	**4.200**	**3.750**	Cretaceous Sand
Sumter	**129-0002**	Plains, City of	**0.220**	**0.195**	Claiborne (Tallahatta)
Sumter	**129-0003**	C. E. Minerals - Plant #1	**0.360**	**0.360**	Cretaceous Sand
Sumter	**129-0004**	C. E. Minerals - Plant #2	**0.684**	**0.684**	Cretaceous Sand
Talbot	**130-0001**	Talbotton, City of	**0.200**	**0.200**	Crystalline Rock
Taylor	**133-0002**	Reynolds, City of	**0.450**	**0.255**	Cretaceous Sand
Taylor	**133-0003**	Butler, City of	**0.750**	**0.550**	Cretaceous Sand
Taylor	**133-0004**	Natural Water, LLC	**0.500**	**0.500**	Cretaceous Sand
Terrell	**135-0001**	Dawson, City of	**3.000**	**2.000**	Clayton
Upson	**145-0001**	Sunset Village Water System (Upson County)	**0.106**	**0.106**	Crystalline Rock

	Active Monthly Permitted	Active Annual Permitted
Active GW permits…….PERMITTED TOTALS ……………………………	**118.513 mgd**	**95.374 mgd**

Table 5.4: Permitted municipal and industrial ground-water withdrawals in the FRB

SECTION 6: HYDROLOGIC MODELS IN THE LOWER FLINT RIVER BASIN

6.1 Ground-water models

6.1.1 Model area and boundaries

The flow of water between the Floridan aquifer and streams in the lower FRB was mathematically simulated using the USGS' Modular Finite Element Model (**MODFE**) (Cooley, 1992; Torak, 1993). The part of southwestern Georgia and adjacent parts of Florida and Alabama where the Floridan aquifer is in hydraulic connection with surface-water is referred to as "Subarea 4", one of eight divisions delineated for the ACT-ACF Comprehensive Study. Although Subarea 4 extends outside of Georgia, subsequent discussion of it and the ground-water models will only relate to the part inside Georgia (Fig. 6.0).

Model boundaries are discontinuities in aquifer extent and hydrologic properties that influence the flow of water in an aquifer area (Torak, 1992). Water can enter or leave a model area across the boundaries. Model boundaries may be external, such as the physical extent of an aquifer, or internal to the model area, such as a stream. The northern boundary of Subarea 4 is defined by the approximate up-dip limit of the Ocala Limestone. The southeastern boundary was originally defined by the existence of a no-**flow boundary**, a ground-water "divide" that separates easterly ground-water flow into the FRB from westerly flow out of the basin and Subarea 4 (Torak and McDowell, 1996). Subsequent modeling indicated that this divide is not entirely a no-flow boundary. Ground-water can and does flow across it into and out of Subarea 4, although more than half it does indeed act as a no-flow boundary (Jones and Torak, in review).

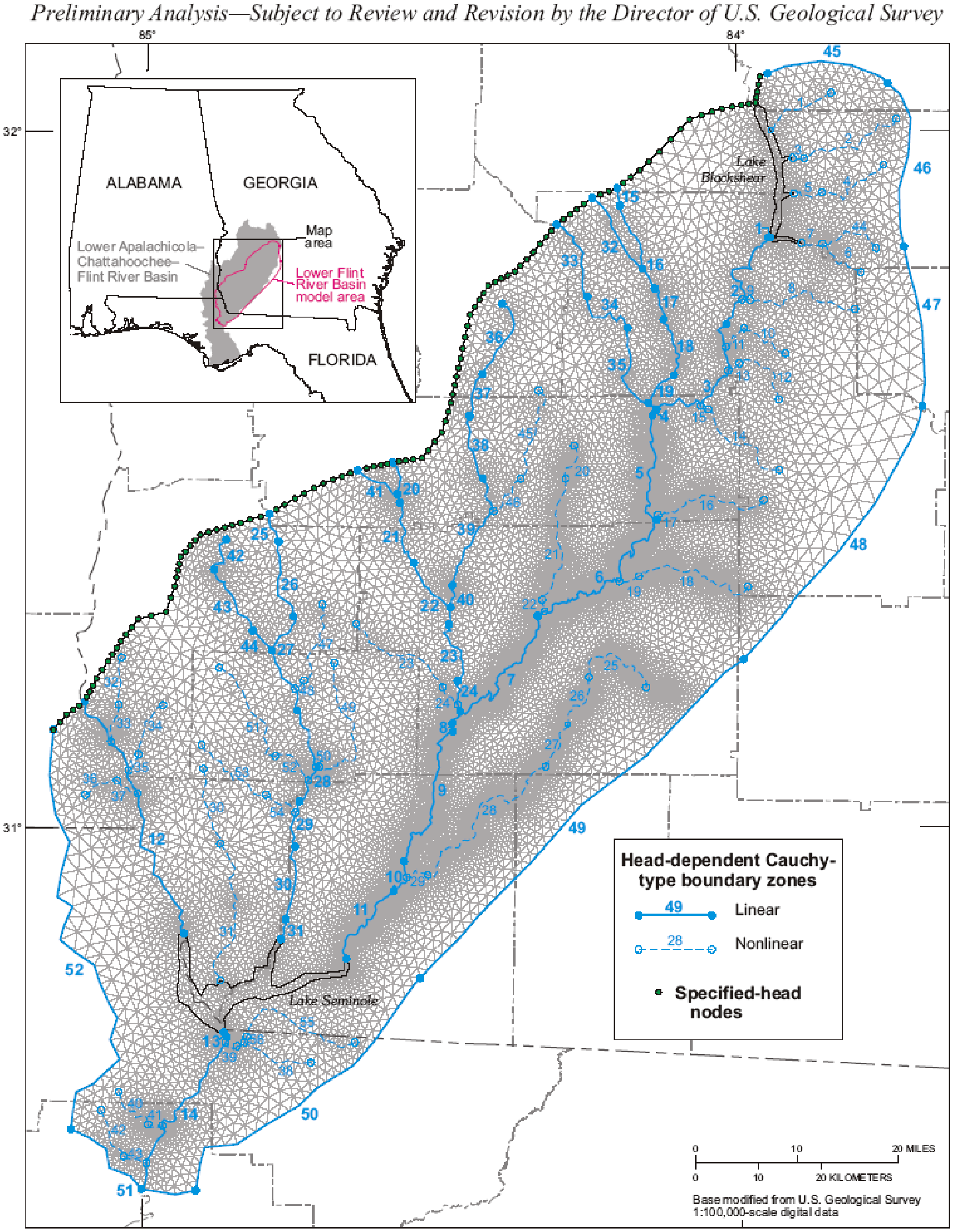


Figure 3. Finite-element mesh, linear and nonlinear head-dependent (Cauchy-type) boundary zones of element sides, and specified-head nodes in the lower Flint River Basin model.

Figure 6.1: MODFE model area, showing finite-element mesh, model boundaries, and simulated stream segments
(Jones and Torak, in review).

Internal boundaries in the model area consist of: 1) streams that can receive water from the Floridan aquifer, supply water to the aquifer, or both; 2) the outcrop of the Ocala Limestone; and 3) the sediments and soils overlying the Floridan aquifer (**overburden**). Whether water leaves or enters the Floridan aquifer, or the model area, depends on the head difference between the aquifer and the overburden; the aquifer and outcrop area; the aquifer and surface streams; or the model area and the area outside of it. The direction of water flow across a boundary may change through time as water levels change due, for example, to seasonal fluctuations in aquifer head or to pumping-induced changes in head.

6.1.2 Model application and results

MODFE is based on the complex mathematical relationships that govern fluid flow in aquifers. To simulate the stream-aquifer system in two or three dimensions, the model employs a detailed grid, or mesh, consisting of triangular "elements" that graphically represent the complex drainage network and extent of the Floridan aquifer in Subarea 4, and the potentiometric surface of the Floridan aquifer (Fig. 6.1). For each triangular element, a **hydraulic head** is assigned to the corners (nodes) such that the slope of the potentiometric surface can be calculated for that element. Pumping wells are also located at element nodes (Torak, 1992). Using 1) water levels in the Floridan aquifer as measured in observation wells; 2) hydraulic properties of the aquifer as determined by aquifer tests performed throughout Subarea 4; 3) water levels in the overburden as measured in observation wells; 4) stream levels; and 5) pumping rates at model mesh nodes, MODFE can simulate the movement of water across the model boundaries, especially between streams and the Floridan aquifer (Torak 1993, Torak and McDowell, 1996). This can be done for steady state conditions, when the flow of water between the stream and aquifer is occurring at a constant rate, or for **transient** conditions, when stream-aquifer flow and pumping rate are changing through time. For the FRB Plan, transient conditions were simulated to see how the stream-aquifer flow changed as irrigation amounts and aquifer head changed during a drought year.

Calculated volumes of water flowing across all external and internal model boundaries are expressed as individual components of a total water budget. The budgets are broken into main categories: recharge and discharge. Recharge budget components consist of downward **leakage** of water from the overburden, direct **infiltration** of water into the aquifer, regional ground-water flow entering the model area from outside Subarea 4, water that enters the aquifer from its outcrop exposures, and water that seeps into the aquifer from losing streams. Discharge budget components consist of water flowing from the aquifer into the streams, water pumped from wells, water leaving the model area to regional ground-water flow, water leaking upwards into the overburden, water leaking out of the outcrop area, and water discharging to springs (Torak and McDowell, 1996).

6.1.3 Water budget analysis

A principal goal of the stream-aquifer modeling was to determine, in the water budget of the model area, what portion of the ground-water used for irrigation is intercepted base flow. In other words, how much of the water pumped from the Floridan aquifer would otherwise have seeped into the Flint River and its tributaries? Water pumped from the Floridan aquifer is derived from **storage** within the aquifer, infiltration from the Floridan aquifer outcrop, downward leakage from the overburden, regional ground-water flow, and intercepted base flow to streams. Using precipitation records, well levels, and metered irrigation usage derived from the AWP Study, the transient model simulated monthly changes to the ground-water budget for the drought period extending from March 2001 to February 2002. Results were calculated as percentages of total change in the water budget components for all of Subarea 4 and the percentage of ground-water withdrawals comprised of those components (Fig. 6.2).

Because of differing pumping rates throughout the year and changing hydrologic conditions, the proportion of water coming from different budget components likewise varied. For example, in July 2001, when ground-water withdrawals were the highest for that year, 28% of the water pumped came from intercepted base flow (Fig. 6.2).

Preliminary Analysis—Subject to Review and Revision by the Director of U.S. Geological Survey

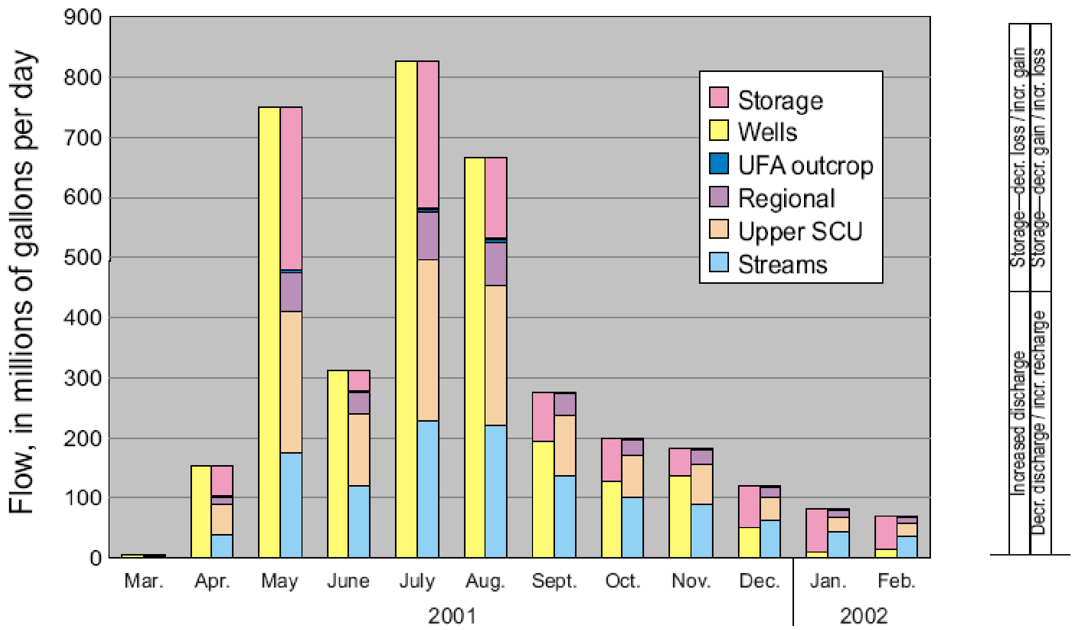


Figure 30. Simulated change in ground-water-budget components and storage gain or loss in the Upper Floridan aquifer due to irrigation pumpage for the March 2001February 2002 transient lower Flint River Basin model.

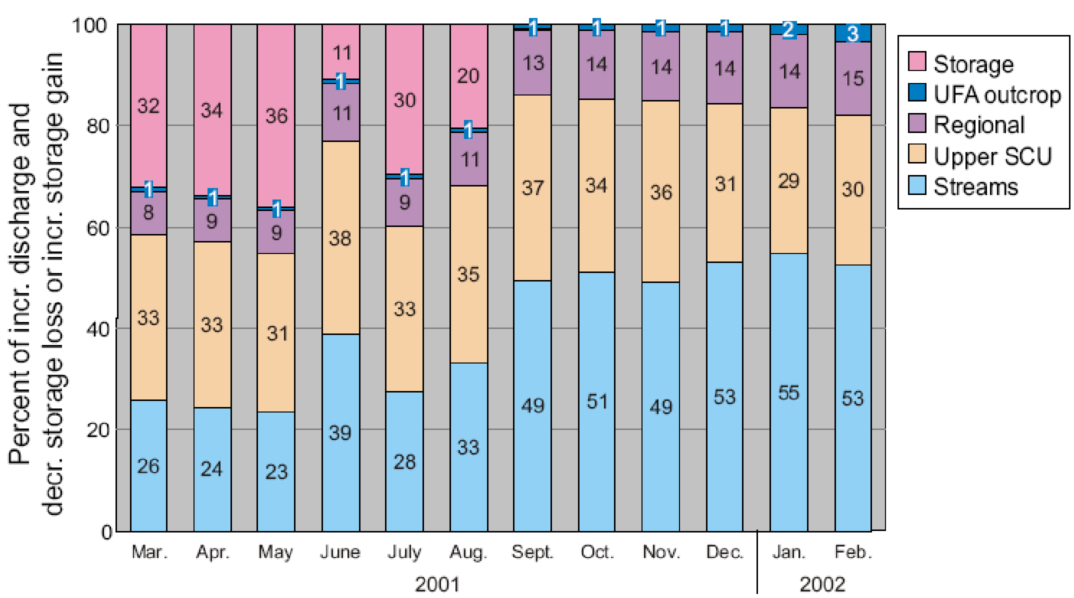


Figure 6.2. Simulated changes in ground-water budget components in the Floridan aquifer caused by pumpage from March 2001-February 2002 (L.E. Jones,in review).

Approximately 33% was derived from the overburden (i.e. local rainfall and recharge); 9% came from intercepted regional flow, 30% was derived from aquifer storage, and only 1% was derived from outcrops of the aquifer (Jones and Torak, in review). In other words, for every million gallons per day of water pumped from the Floridan aquifer in July 2001, streamflow in the entire Subarea 4 portion of the FRB was reduced by 280,000 gallons per day. The percentage of ground-water withdrawals derived from intercepted base flow varies from month to month, but during the 6-month growing season of 2001 the ratio of pumpage to intercepted base flow never exceeded 49%. Other monthly water budget analyses can be seen in Figure 6.2. It is important to realize that these percentages can and do change every year as hydrologic conditions change; therefore, it is difficult to apply one particular percentage of base flow reduction when calculating the effect of ground-water withdrawals on the Flint River and its tributaries. However, it may be reasonably assumed that the percentages shown in the figure below represent the approximate range of base flow decreases in a severe drought year.

Previous studies simulating steady-state conditions (e.g. Torak and McDowell, 1996) indicated a base flow reduction ratio of 0.61, such that for every one million gallons of ground-water pumped per day streamflow was reduced by 610,000 gpd. However, accurate measurements of irrigation volumes and new information on aquifer properties were not available to those studies. Irrigation pumping rates and depths used for the steady-state model were almost certainly too high, and it is unlikely that steady-state conditions are ever reached at the simulated pumping rates. Thus, the ratio of base flow reduction was overestimated.

6.1.4 Base flow reduction by HUC-12 and HUC-8 sub-basin

The USGS Subarea 4 model was adapted by EPD to analyze water budgets for three sub-basins of the FRB: Ichawaynochaway Creek, Spring Creek, and the lower Flint River (Fig 6.3). Water budget components were calculated for individual stream reaches in Subarea 4, using normal and drought year conditions and irrigation depths. The latter were compiled using the highest monthly values of irrigation measured during the 1998-

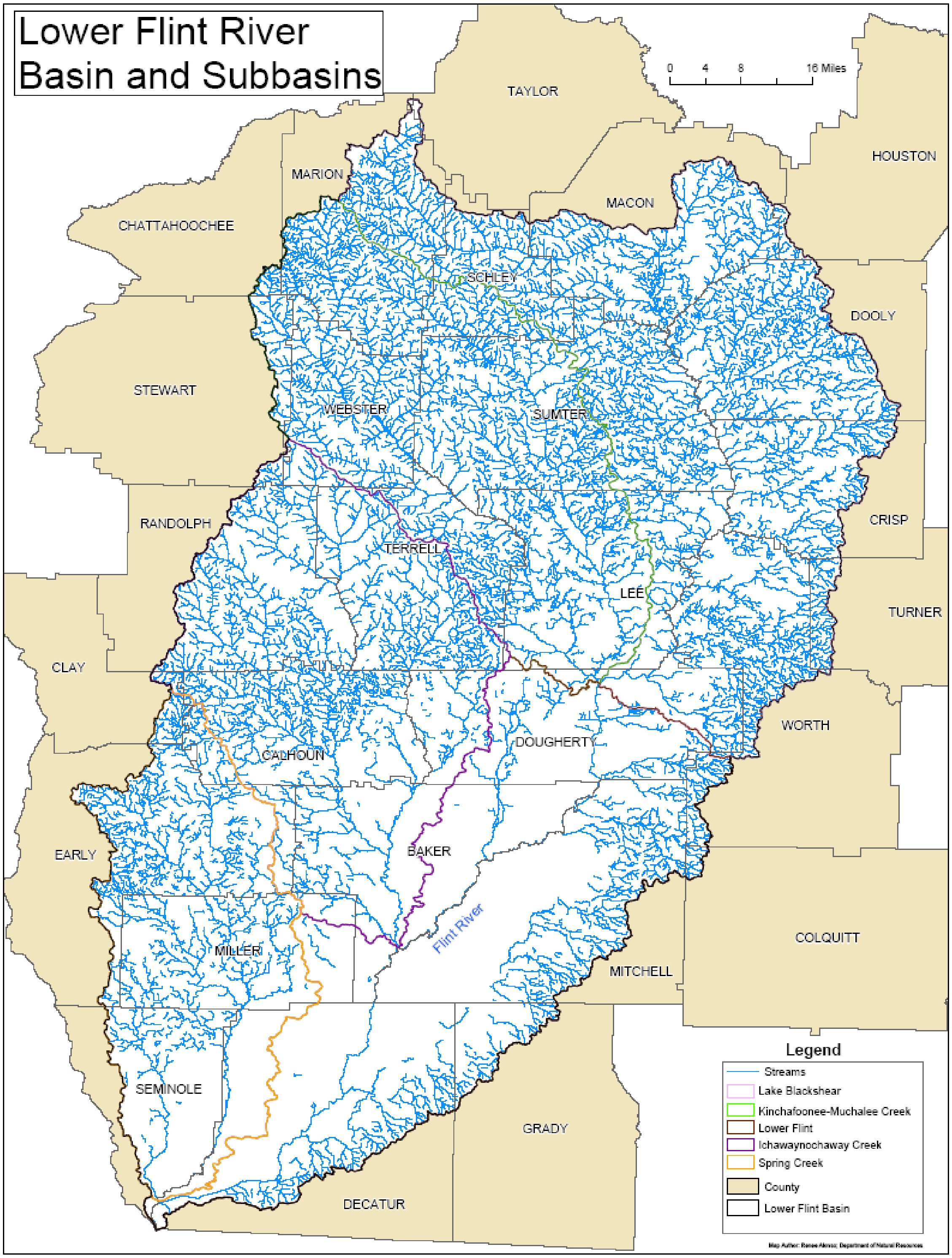


Figure 6.3. HUC-8 sub-basins of the lower FRB

2002 drought. “Normal year” irrigation depths were compiled using measured irrigation depths from 2003-2004. Results were expressed in terms of streamflow reduction in cubic feet per second for individual HUC-12 watersheds, for the entire sub-basin, and for each major stream gauge. Modeled stream reaches are shown in Figure 6.1, and the HUC-12 watersheds associated with these reaches are shown in Figures I2.1 (Ichawaynochaway Creek sub-basin), I.2-11 (Spring Creek sub-basin), and. I.2-20 (Lower Flint River sub-basin). Tables 6.1 (a)-(c) shows calculated reductions in streamflow caused by reduced ground-water discharge to HUC-12 watersheds. Color coding of the table columns matches the color coding of HUC-12’s shown in Figures 0.2-0.5.

BASEFLOW REDUCTION IN HUC-12 WATERSHEDS OF ICHAWAYNOCHAWAY SUB-BASIN (CFS)

Current irrigated acres (drought year)

	HUC-12																		
	15	16	17	18	19	22	23	23	24	25	26	35	37	39	40	41	42	43	SUM
Mar	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.5	0.8	0.0	0.0	2.0
Apr	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.1	0.2	0.0	0.0	0.0	0.0	0.4	1.5	1.5	0.1	0.0	4.3
May	0.0	0.0	0.0	0.0	0.6	0.0	0.7	0.0	0.6	0.0	0.0	0.0	0.0	1.6	4.6	5.9	0.2	0.1	14.4
Jun	0.0	0.0	0.0	0.1	1.1	0.0	0.9	0.2	0.7	0.0	0.0	0.0	0.1	2.7	7.6	7.8	0.3	0.2	21.7
Jul	0.0	0.0	0.0	0.1	1.2	0.0	1.0	0.0	0.9	0.0	0.0	0.0	0.1	4.0	10.6	9.8	0.4	0.2	28.4
Aug	0.1	0.1	0.0	0.1	1.4	0.0	1.1	0.0	1.0	0.0	0.0	0.0	0.0	5.4	13.5	11.8	0.5	0.3	35.3
Sep	0.1	0.1	0.0	0.1	1.1	0.0	0.8	0.0	0.6	0.0	0.0	0.0	0.0	6.2	13.0	5.0	0.2	0.3	27.5
Oct	0.0	0.0	0.0	0.1	0.6	0.0	0.4	0.0	0.2	0.0	0.0	0.0	0.0	6.0	11.4	1.6	0.1	0.3	20.7
Nov	0.0	0.0	0.0	0.1	0.7	0.0	0.3	0.0	0.2	0.0	0.0	0.0	0.0	5.7	10.1	1.2	0.1	0.3	18.8
Dec	0.1	0.0	0.0	0.1	0.5	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.0	5.3	8.7	0.7	0.0	0.3	16.0

Current irrigated acres + 'backlog' (drought year)

	HUC-12																		
	15	16	17	18	19	22	23	23	24	25	26	35	37	39	40	41	42	43	SUM
Mar	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.2	0.6	0.9	0.0	0.03	2.36
Apr	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.1	0.2	0.0	0.0	0.0	0.0	0.5	1.7	2.0	0.1	0.05	5.05
May	0.1	0.1	0.0	0.0	0.8	0.0	0.8	0.0	0.7	0.0	0.0	0.0	0.1	1.7	5.4	8.2	0.3	0.13	18.3
Jun	0.2	0.1	0.0	0.1	1.4	0.0	1.1	0.2	0.9	0.0	0.0	0.0	0.1	2.9	8.6	10.4	0.4	0.29	26.8
Jul	0.2	0.1	0.0	0.1	1.5	0.0	1.2	0.0	1.0	0.0	0.0	0.0	0.1	4.2	11.6	11.9	0.5	0.32	32.7
Aug	0.2	0.1	0.0	0.1	1.7	0.0	1.2	0.0	1.1	0.0	0.0	0.0	0.1	5.6	14.5	13.5	0.6	0.35	39
Sep	0.2	0.1	0.0	0.1	1.4	0.0	0.9	0.0	0.7	0.0	0.0	0.0	0.0	6.4	13.8	5.9	0.3	0.41	30.2
Oct	0.2	0.1	0.0	0.1	0.8	0.0	0.4	0.0	0.2	0.0	0.0	0.0	0.0	6.3	12.0	1.9	0.1	0.35	22.4
Nov	0.2	0.1	0.0	0.1	0.9	0.0	0.4	0.0	0.2	0.0	0.0	0.0	0.0	6.0	10.6	1.4	0.1	0.4	20.3
Dec	0.2	0.1	0.0	0.1	0.7	0.0	0.3	0.0	0.1	0.0	0.0	0.0	0.0	5.5	9.2	0.9	0.1	0.36	17.5

Table 6.1 (a): Calculated streamflow reduction due to irrigation pumping from the Floridan aquifer, simulated for HUC-12 watersheds in Ichawaynochaway Creek sub-basin for drought years (cubic feet/sec.)

BASEFLOW REDUCTION IN HUC-12 WATERSHEDS OF SPRING CREEK SUB-BASIN (CFS)

Current irrigated acres (drought year) — **HUC-12**

	2	4	5	6	7	8	9	10	11	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	33	34	35	SUM
mar	0.0	0.0	0.1	0.0	0.0	0.3	0.2	0.2	0.0	0.2	0.1	0.0	0.0	0.2	0.3	0.2	0.7	0.0	0.2	0.0	0.2	0.7	0.0	1.9	0.8	1.7	0.2	0.0	0.1	0.8	9.1
apr	0.0	0.1	0.3	0.1	0.0	0.6	0.6	0.5	0.0	0.4	0.3	0.0	0.0	0.4	0.4	0.5	1.6	0.0	0.1	0.0	0.5	1.7	0.0	4.4	1.9	3.9	0.5	0.0	0.2	2.0	21.1
may	0.0	0.4	1.8	0.3	0.0	1.0	3.1	2.1	0.0	1.2	1.1	0.0	0.0	1.6	0.8	1.9	5.1	0.0	0.0	0.0	2.0	7.7	0.0	21.1	9.3	18.8	2.7	0.2	0.5	9.4	92.1
jun	0.1	0.5	2.1	0.3	0.0	1.4	3.6	2.6	0.0	1.4	1.4	0.0	0.0	2.2	1.2	2.6	6.7	0.0	0.0	0.0	2.4	9.2	0.0	24.6	10.7	21.3	3.1	0.2	0.9	10.4	108.8
jul	0.1	0.4	1.7	0.3	0.0	1.0	2.9	2.1	0.0	1.2	1.2	0.0	0.0	1.9	0.9	2.2	5.4	0.0	0.0	0.0	2.0	7.6	0.0	20.2	8.7	17.4	2.5	0.2	0.6	8.6	89.0
aug	0.1	0.3	1.4	0.3	0.0	0.9	2.4	1.8	0.0	1.1	1.1	0.0	0.0	1.7	0.8	2.0	4.8	0.0	0.0	0.0	1.7	6.5	0.0	17.1	7.3	14.7	2.0	0.1	0.5	7.3	75.8
sep	0.1	0.2	0.8	0.2	0.0	0.7	1.5	1.3	0.0	0.8	0.6	0.0	0.0	1.5	0.8	1.8	4.0	0.0	0.0	0.0	1.2	4.5	0.0	11.1	4.6	9.4	1.1	0.1	0.3	4.7	51.2
oct	0.1	0.1	0.3	0.1	0.0	0.3	0.6	0.6	0.0	0.3	0.2	0.0	0.0	0.9	0.4	1.0	1.9	0.0	0.0	0.0	0.5	1.9	0.0	4.3	1.7	3.1	0.4	0.0	0.1	1.4	20.4
nov	0.1	0.1	0.2	0.1	0.0	0.3	0.4	0.5	0.0	0.2	0.2	0.0	0.0	0.6	0.4	0.8	1.4	0.0	0.0	0.0	0.4	1.4	0.0	3.1	1.2	2.2	0.3	0.0	0.1	1.0	14.9
dec	0.1	0.1	0.2	0.1	0.0	0.1	0.3	0.3	0.0	0.2	0.1	0.0	0.0	0.3	0.2	0.3	0.8	0.0	0.0	0.0	0.3	0.9	0.0	2.2	0.9	1.8	0.2	0.0	0.1	0.8	10.2

Current irrigated acres + 'backlog' (drought year) — **HUC-12**

	2	4	5	6	7	8	9	10	11	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	33	34	35	SUM
mar	0.0	0.0	0.2	0.0	0.0	0.3	0.3	0.2	0.0	0.2	0.1	0.0	0.0	0.2	0.4	0.2	0.7	0.0	0.2	0.0	0.3	0.8	0.0	2.1	1.0	2.0	0.2	0.0	0.1	1.0	10.4
apr	0.0	0.1	0.4	0.1	0.0	0.6	0.6	0.5	0.0	0.4	0.3	0.0	0.0	0.5	0.5	0.6	1.7	0.0	0.1	0.0	0.6	1.9	0.0	5.0	2.2	4.6	0.5	0.0	0.2	2.3	23.9
may	0.0	0.5	2.0	0.3	0.0	1.1	3.3	2.3	0.0	1.2	1.1	0.0	0.0	1.7	0.8	2.0	5.3	0.0	0.0	0.0	2.1	8.3	0.0	23.1	10.4	21.2	2.9	0.2	0.6	10.6	100.9
jun	0.1	0.6	2.4	0.4	0.0	1.4	3.8	2.7	0.0	1.4	1.4	0.0	0.0	2.3	1.2	2.7	6.9	0.0	0.0	0.0	2.6	9.8	0.0	26.6	11.8	23.7	3.3	0.3	1.0	11.7	118.2
jul	0.1	0.5	1.9	0.4	0.0	1.1	3.1	2.3	0.0	1.2	1.2	0.0	0.0	2.0	0.9	2.4	5.6	0.0	0.0	0.0	2.1	8.3	0.0	22.4	9.9	19.9	2.6	0.2	0.7	9.8	98.5
aug	0.1	0.4	1.5	0.3	0.0	0.9	2.6	2.0	0.0	1.1	1.1	0.0	0.0	1.9	0.8	2.2	5.1	0.0	0.0	0.0	1.8	7.2	0.0	19.1	8.4	16.9	2.1	0.2	0.5	8.4	84.6
sep	0.1	0.3	0.9	0.2	0.0	0.7	1.6	1.4	0.0	0.8	0.7	0.0	0.0	1.6	0.8	2.0	4.4	0.0	0.0	0.0	1.4	5.1	0.0	12.8	5.5	11.3	1.2	0.1	0.4	5.8	59.0
oct	0.1	0.2	0.3	0.2	0.0	0.3	0.7	0.7	0.0	0.3	0.3	0.0	0.0	1.0	0.5	1.2	2.2	0.0	0.0	0.0	0.6	2.2	0.0	4.9	1.9	3.6	0.4	0.0	0.1	1.7	23.4
nov	0.1	0.2	0.2	0.2	0.0	0.3	0.5	0.6	0.0	0.2	0.2	0.0	0.0	0.8	0.5	0.9	1.7	0.0	0.0	0.0	0.4	1.6	0.0	3.6	1.4	2.6	0.3	0.0	0.1	1.2	17.5
dec	0.1	0.2	0.2	0.1	0.0	0.2	0.3	0.3	0.0	0.2	0.1	0.0	0.0	0.3	0.2	0.4	0.9	0.0	0.0	0.0	0.3	1.0	0.0	2.5	1.0	2.0	0.3	0.0	0.1	0.9	11.4

Table 6.1 (b): Calculated streamflow reduction due to irrigation pumping from the Floridan aquifer, simulated for HUC-12 watersheds in Spring Creek sub-basin for drought years (cubic feet/sec.)

BASEFLOW REDUCTION IN HUC-12 WATERSHEDS OF LOWER FLINT SUB-BASIN (CFS)

Current irrigated acres (drought year)

													HUC-12												
	1	3	5	6	8	9	10	11	12	13	15	16	17	20	21	22	23	24	25	26	28	29	31	33	SUM
Jan	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.0	1.0	0.0	0.0	0.2	0.6	3.1
Feb	0.0	0.0	0.4	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.0	1.0	0.0	0.0	0.2	0.7	3.5
Mar	0.1	0.4	7.4	0.0	0.6	3.2	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	2.1	2.7	6.0	2.5	0.0	0.0	2.1	6.4	36.9
Apr	0.0	0.3	8.8	0.0	1.0	5.2	0.0	0.0	0.0	0.0	0.0	5.4	0.0	0.0	0.0	0.0	6.5	7.1	12.6	4.1	0.0	0.0	4.3	12.9	68.3
May	0.0	0.0	26.4	0.0	1.5	15.1	0.0	0.0	0.0	0.0	0.0	15.3	0.0	0.0	0.0	0.0	20.0	22.8	46.3	13.6	0.0	0.0	16.9	36.3	214.2
Jun	0.0	0.4	34.6	0.0	2.9	18.0	0.0	0.1	0.0	0.0	0.0	18.2	0.0	0.0	0.0	0.0	29.6	31.0	48.3	13.7	0.0	0.0	17.1	52.0	265.8
Jul	0.0	0.0	35.4	0.0	1.7	18.2	0.0	0.0	0.0	0.0	0.0	17.4	0.0	0.0	0.0	0.0	35.9	34.7	45.8	12.5	0.0	0.0	15.3	60.5	277.4
Aug	0.0	0.0	37.0	0.0	1.2	18.4	0.0	0.0	0.0	0.0	0.0	17.1	0.0	0.0	0.0	0.0	39.3	36.3	44.8	11.9	0.0	0.0	14.3	65.5	285.9
Sep	0.0	0.0	38.7	0.0	1.4	18.8	0.0	0.0	0.0	0.0	0.0	17.9	0.0	0.0	0.0	0.0	41.4	36.6	41.3	10.4	0.0	0.0	12.1	68.7	287.3
Oct	0.0	0.0	24.4	0.0	0.6	11.1	0.0	0.0	0.0	0.0	0.0	9.9	0.0	0.0	0.0	0.0	34.8	25.1	13.8	3.4	0.0	0.0	3.0	55.0	181.0
Nov	0.0	0.0	19.1	0.0	0.3	8.3	0.0	0.0	0.0	0.0	0.0	7.2	0.0	0.0	0.0	0.0	27.2	17.5	10.1	2.8	0.0	0.0	2.3	42.6	137.4
Dec	0.0	0.0	15.9	0.0	0.3	6.2	0.0	0.0	0.0	0.0	0.0	5.1	0.0	0.0	0.0	0.0	20.8	11.8	6.0	2.0	0.0	0.0	1.4	32.2	101.7

Current irrigated acres + 'backlog' (drought year)

													HUC-12												
	1	3	5	6	8	9	10	11	12	13	15	16	17	20	21	22	23	24	25	26	28	29	31	33	SUM
Jan	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.0	1.0	0.0	0.0	0.2	0.6	3.1
Feb	0.0	0.0	0.4	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.0	1.0	0.0	0.0	0.2	0.7	3.5
Mar	0.1	0.5	7.7	0.0	0.6	3.5	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	2.2	3.0	6.4	2.6	0.0	0.0	2.2	6.8	39.2
Apr	0.0	0.3	9.4	0.0	1.1	5.8	0.0	0.0	0.0	0.0	0.0	5.9	0.0	0.0	0.0	0.0	7.0	8.0	13.6	4.4	0.0	0.0	4.6	13.8	73.7
May	0.0	0.0	28.2	0.0	1.6	16.7	0.0	0.0	0.0	0.0	0.0	16.6	0.0	0.0	0.0	0.0	21.5	26.4	50.7	14.7	0.0	0.0	18.1	39.2	233.7
Jun	0.0	0.4	37.1	0.0	3.2	20.2	0.0	0.1	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	32.0	36.3	53.5	15.0	0.0	0.0	18.4	56.7	292.8
Jul	0.0	0.0	38.3	0.0	1.8	20.6	0.0	0.0	0.0	0.0	0.0	19.1	0.0	0.0	0.0	0.0	38.8	40.0	50.5	13.6	0.0	0.0	16.5	65.9	305.3
Aug	0.0	0.0	40.0	0.0	1.3	20.7	0.0	0.0	0.0	0.0	0.0	18.8	0.0	0.0	0.0	0.0	42.5	41.3	48.7	12.8	0.0	0.0	15.3	71.1	312.6
Sep	0.0	0.0	41.8	0.0	1.4	21.0	0.0	0.0	0.0	0.0	0.0	19.4	0.0	0.0	0.0	0.0	44.5	40.5	44.0	11.0	0.0	0.0	12.8	73.9	310.3
Oct	0.0	0.0	26.9	0.0	0.6	12.7	0.0	0.0	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	37.4	27.7	15.1	3.6	0.0	0.0	3.2	59.4	197.7
Nov	0.0	0.0	21.3	0.0	0.4	9.7	0.0	0.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	29.5	19.3	11.0	2.9	0.0	0.0	2.4	46.1	150.6
Dec	0.0	0.0	17.8	0.0	0.3	7.1	0.0	0.0	0.0	0.0	0.0	5.7	0.0	0.0	0.0	0.0	22.6	13.1	6.6	2.1	0.0	0.0	1.6	35.1	112.1

Table 6.1 (c): Calculated streamflow reduction due to irrigation pumping from the Floridan aquifer, simulated for HUC-12 watersheds in Lower Flint River sub-basin for drought years (cubic feet/sec.)

Table 6.2 (a)-(f) shows calculated reductions in streamflow caused by reduced ground-water discharge to HUC-8 sub-basins. The table columns show, from left to right, the total calculated streamflow reduction for the entire sub-basin; the reduction for the part of the sub-basin upstream from the referenced gauge; the calculated reduction that would result if the permit backlog were issued; the calculated reduction that would result if the backlog were issued and irrigation volume were increased by 25%; and the observed average monthly streamflow at the referenced gauge.

Table 6.2 (a): Streamflow reduction due to irrigation pumping from the Floridan aquifer, simulated at Milford gauge on Ichawaynochaway Creek for drought years (cubic feet/sec.)

		current acres	backlog	1.25 x backlog	
Month	sub-basin (current acres)	Simulated flow reduction at Milford (cfs)			Observed (2000)
March	2	0.2	0.2	0.3	495
Apr	4	0.3	0.4	0.5	379
May	15	0.9	1.3	1.6	124
Jun	23	1.6	2.1	2.7	42
Jul	31	1.9	2.3	2.9	103
Aug	38	2.2	2.6	3.2	87
Sep	30	1.7	2.1	2.6	182
Oct	23	1.0	1.2	1.6	138
Nov	20	1.1	1.4	1.7	296
Dec	17	0.9	1.1	1.4	388

Table 6.2 (b): Streamflow reduction due to irrigation pumping from the Floridan aquifer, simulated at the Milford gauge on Ichawaynochaway Creek for normal years (cubic feet/sec.)

		current acres	backlog	1.25 x backlog	
Month	Whole sub-basin (current acres)	Simulated flow reduction at Milford (cfs)			Observed (1958)
March	**1**	**0.1**	**0.1**	**0.1**	**1897**
Apr	**3**	**0.2**	**0.2**	**0.3**	**1698**
May	**9**	**0.6**	**0.8**	**1.0**	**658**
Jun	**14**	**1.0**	**1.2**	**1.5**	**516**
Jul	**19**	**1.2**	**1.5**	**1.9**	**575**
Aug	**21**	**1.2**	**1.5**	**1.9**	**430**
Sep	**21**	**0.9**	**1.2**	**1.5**	**299**
Oct	**13**	**0.6**	**0.8**	**0.9**	**298**
Nov	**11**	**0.6**	**0.8**	**1.0**	**327**
Dec	**9**	**0.5**	**0.6**	**0.8**	**472**

Table 6.2 (c): Streamflow reduction due to irrigation pumping from the Floridan aquifer, simulated at the Iron City gauge on Spring Creek for drought years (cubic feet/sec.)

		current acres	backlog	1.25 x backlog	
Month	Whole sub-basin (current acres)	Simulated flow reduction at Iron City (cfs)			Observed (2000)
March	**9**	**3.5**	**3.8**	**4.8**	**262**
Apr	**20**	**8.1**	**8.8**	**11.0**	**164**
May	**93**	**30.9**	**32.9**	**41.1**	**25**
Jun	**109**	**38.5**	**40.9**	**51.1**	**2**
Jul	**88**	**31.4**	**33.7**	**42.1**	**1**
Aug	**76**	**27.3**	**29.5**	**36.9**	**.13**
Sep	**48**	**19.9**	**21.9**	**27.4**	**.08**
Oct	**17**	**9.3**	**10.5**	**13.2**	**1**
Nov	**11**	**7.0**	**8.3**	**10.3**	**10**
Dec	**11**	**4.2**	**4.7**	**5.9**	**61**

Table 6.2 (d): Streamflow reduction due to irrigation pumping from the Floridan aquifer, simulated at the Iron City gauge on Spring Creek for normal years (cubic feet/sec.)

Month	Whole sub-basin (current acres)	current acres	backlog	1.25 x backlog	Observed (1958)
		Simulated flow reduction at Iron City (cfs)			
March	**4**	**1.7**	**1.8**	**2.3**	**1625**
Apr	**15**	**6.1**	**6.5**	**8.1**	**1505**
May	**53**	**19.7**	**20.8**	**26.0**	**599**
Jun	**58**	**23.1**	**24.6**	**30.7**	**458**
Jul	**56**	**20.8**	**22.6**	**28.3**	**486**
Aug	**47**	**17.8**	**19.6**	**24.5**	**396**
Sep	**47**	**11.0**	**12.3**	**15.4**	**166**
Oct	**10**	**3.9**	**4.4**	**5.5**	**114**
Nov	**5**	**2.3**	**2.4**	**3.0**	**85**
Dec	**5**	**2.1**	**2.2**	**2.7**	**96**

Table 6.2 (e): Streamflow reduction due to irrigation pumping from the Floridan aquifer, simulated at the Bainbridge gauge of the lower Flint River for drought years (cubic feet/sec.)

Month	Whole sub-basin (current acres)	current acres	backlog	1.25 x backlog	Observed (1954)*
		Simulated flow reduction at Bainbridge (cfs)			
March	**59**	**39**	**42**	**52**	**8714**
Apr	**90**	**73**	**79**	**98**	**7903**
May	**236**	**229**	**252**	**315**	**5293**
Jun	**288**	**287**	**320**	**399**	**3739**
Jul	**299**	**306**	**338**	**422**	**3337**
Aug	**308**	**321**	**352**	**440**	**3052**
Sep	**309**	**315**	**341**	**426**	**2409**
Oct	**203**	**202**	**220**	**275**	**2213**
Nov	**159**	**156**	**171**	**214**	**2424**
Dec	**124**	**118**	**130**	**162**	**3627**

* 1954 was used as a drought year because Bainbridge gauge data is unavailable for 1999-2000.

Table 6.2 (f): Streamflow reduction due to irrigation pumping from the Floridan aquifer, simulated at the Bainbridge gauge of the lower Flint River for normal years (cubic feet/sec.)

		current acres	backlog	1.25 x backlog	
Month	Whole sub-basin (current acres)	Simulated flow reduction at Bainbridge (cfs)			Observed (1958)
March	**37**	**16**	**17**	**22**	**21970**
Apr	**51**	**32**	**35**	**44**	**19440**
May	**112**	**98**	**110**	**137**	**10090**
Jun	**150**	**140**	**156**	**195**	**7650**
Jul	**191**	**186**	**207**	**258**	**9262**
Aug	**201**	**199**	**220**	**275**	**6871**
Sep	**160**	**153**	**169**	**212**	**3873**
Oct	**115**	**105**	**116**	**145**	**3920**
Nov	**80**	**69**	**76**	**95**	**4094**
Dec	**64**	**51**	**56**	**70**	**5003**

Several observations can be made: 1) in all three sub-basins, the simulated streamflow reduction increased with added acreage (i.e. the application backlog) and increased irrigation volume; 2) the proportionately greatest increases in streamflow reduction, compared to observed flows, occurred in Spring Creek, where the simulated streamflow reduction caused by aquifer withdrawals represents the highest proportion of observed flow. Indeed, in drought years the simulated reduction is actually greater than the observed flows during a drought year. This happened only in Spring Creek; 3) simulated reductions for the entire Ichawaynochaway sub-basin are substantially higher than those calculated for the Milford gauge. This is because much of the sub-basin above the Milford gauge is outside of Subarea 4, and Floridan aquifer withdrawals would have the greatest effect on streamflow downstream of the Milford gauge. A similar relationship is true for Spring Creek below the Iron City gauge, although not to the same degree as in Ichawaynochaway sub-basin. It is important to note that these figures do not include surface-water withdrawals, which for Ichawaynochaway sub-basin would have a *significant* impact on the total reduction to streamflow caused by all withdrawals.

Figures 0.2-0.5 indicate that, within the larger sub-basins, HUC-12 watersheds with closer hydrologic connections to the Floridan aquifer and larger volumes of groundwater withdrawals experience greater decreases in baseflow to streams. Some stream reaches are not in hydrologic connection with the Floridan aquifer, and thus experience little or no baseflow reduction from nearby irrigation withdrawals. Comparing Figures 0.2-0.5 with Tables 6.1 (a) –(c) and 6.2 (a) -(f), it is evident that only a few HUC-12 watersheds can account for much or most of the decreased streamflow in a HUC-8 sub-basin. For example, more than 71% of the total baseflow reduction in Ichawaynochaway Creek during August of a drought year, irrigating existing acreage, is caused by groundwater withdrawals in only two HUC-12 watersheds (40 and 41).

In all three sub-basins, HUC-12 watersheds could be grouped into three categories based on the amount of decreased baseflow caused by Floridan aquifer withdrawals in each. The watersheds are color coded based on these categories in Figures 0.2-0.5 and Tables 6.1 (a) -(c). Green-colored watersheds, referred to as “Conservation Use Areas: are those in which baseflow reduction is less than 1 cfs during drought years. These streams either have a week hydrologic connection with the Floridan aquifer, have a low amount of irrigation withdrawals from the Floridan, or both. Watersheds with intermediate levels of reduced baseflow are colored yellow, and referred to as “Restricted Use Areas”. These watersheds may have large volumes of withdrawals from the Floridan aquifer, but the degree of hydrologic connection with the aquifer is greater than in the Conservation Use Areas. Those watersheds with the highest amount of reduced baseflow are colored pink, and referred to as “Capacity Use Areas”. These watersheds experience the largest volume of baseflow reduction due to a close connection between streams and the Floridan aquifer, and the largest volume of irrigation withdrawals. In most cases, these categories reflect a natural grouping in the calculated volumes of decreased baseflow. There is typically very little gradation between categories. Most Capacity Use Areas individually account for more than 10% of total baseflow reduction in a sub-basin, and together they may account for more than 50% of total baseflow reduction in a HUC-8 sub-basin.

6.1.5 Ground-water flow directions

Under pre-development or wet-season conditions, ground-water flow is generally towards the Flint River and its major tributaries (Clarke, 1987; Mosner, 2002). This may change locally as heads in the aquifer decline during the year. Figure 6.4 shows the modeled potentiometric surface of the Floridan aquifer and Figure 6.5 shows flow directions for the Ichawaynochaway Creek sub-basin, which are generally perpendicular to the potentiometric contours, superimposed on the potentiometric map. (Flow direction maps for other sub-basins of the lower FRB are found in Appendix II). Widely spaced potentiometric contours on Figure 6.4 indicate high aquifer transmissivity, whereas contours that are more closely spaced indicate lower transmissivity. Where contours are deflected upstream, such as along the Flint River and in the lower reaches of Ichawaynochaway, Pachitla, Kinchafoonee, and Spring Creeks, ground-water discharges to that stream. Where contours are not deflected by streams, such as in the upper reaches of Spring Creek, those streams are not in direct hydraulic connection with the Floridan aquifer.

Figure 6.4 indicates that, from the northern model boundary, ground-water flow is to the south and southeast towards the Flint River and its tributaries. East of the Flint River, ground-water flow is almost parallel to the Flint River except close to it, where it diverges abruptly towards the river. The color of the modeled stream segment indicates the ground-water flow rate, such that pink and red hues indicate high flow rates, and blue indicates lower rates. As can be seen along the Flint River, ground-water discharges along its length from Lake Chehaw to Lake Seminole. Significant volumes of ground-water are discharged into Spring Creek south of Iron City, as well as to sections of Ichawaynochaway Creek, Pachitla Creek, Kinchafoonee Creek, and Muckalee Creek. The volume of ground-water received by these stream segments changes throughout the year. In the summer when stream and aquifer levels are dropping and irrigation pumpage is typically high, ground-water discharges may decrease such that some stream segments become losing reaches (Jones and Torak, in review) and streamflow may be lost to the aquifer.

Preliminary Analysis—Subject to Review and Revision by the Director of U.S. Geological Survey

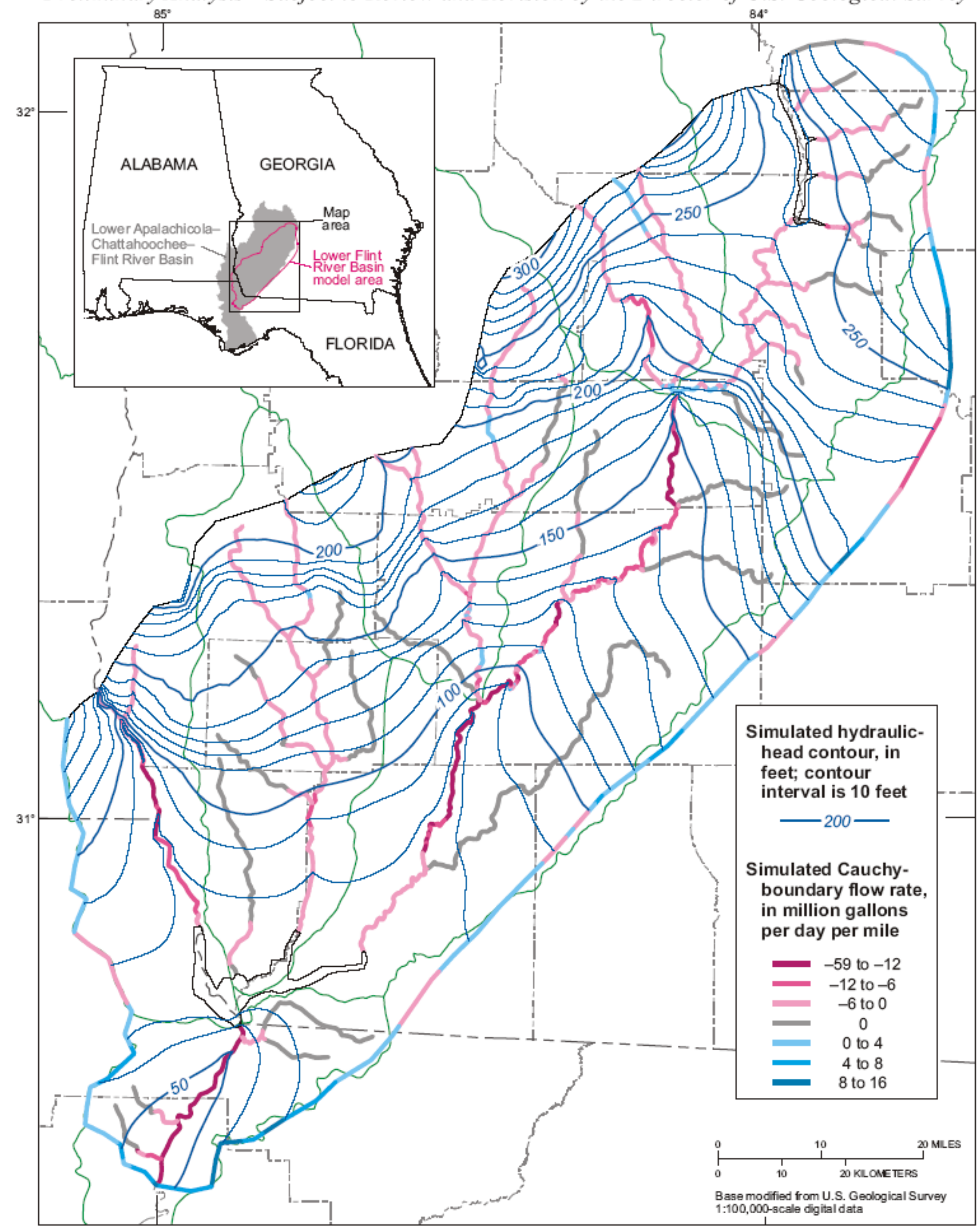


Figure 6.4: Simulated potentiometric contours, USGS Subarea 4 model (Jones and Torak, in review)

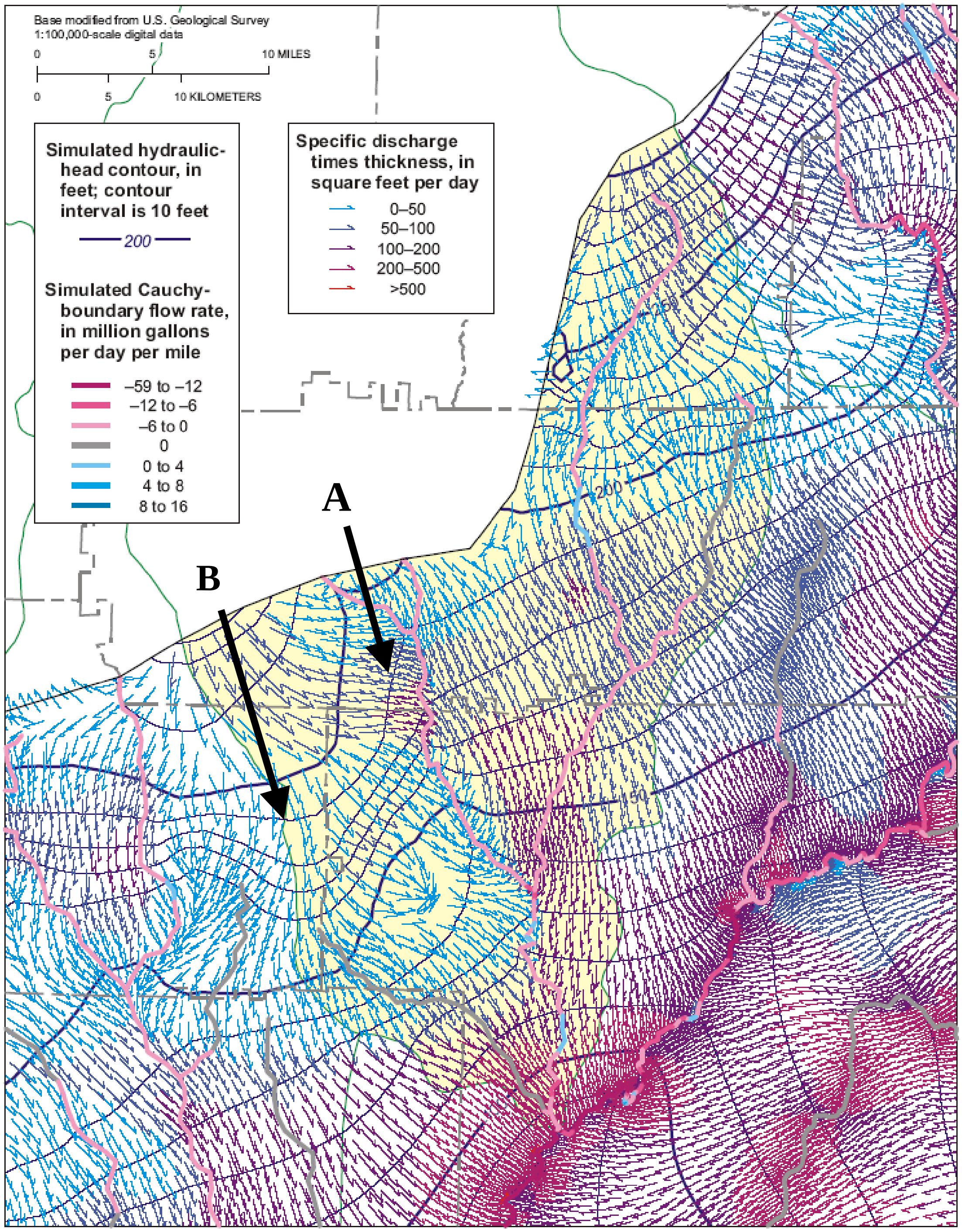


Figure 6.5: Ground-water flow directions in the Ichawaynochaway sub-basin (Jones and Torak, in review).

Although ground-water generally flows towards the Flint and its tributaries, the ground-water flow lines shown in Figure 6.5 reveal local complexities to the direction of ground-water flow caused by local changes in pumping, aquifer properties, topography, and the presence of streams. Also, the ground-water flow lines indicate that the impact of a well may not occur along the stream reach nearest the well; rather, the impact (as reduced flow) may occur miles downstream from the well. In areas where ground-water flows into streams at a high angle to the stream channel, the impact of a ground-water well near that stream segment may have a more direct impact due to decreased base flow. An example of this would be a pumping well within several miles of Ichawaynochaway Creek ('A', Fig. 6.5). Thus, the impact of pumping wells on base flow is not the same throughout Subarea 4. Wells close to streams segments that have a high degree of connectedness to the aquifer will have a volumetrically greater and more rapid impact on base flow than wells that are farther away from streams (e.g. 'B', Fig. 6.5), especially those streams with a poor connection to the Floridan aquifer.

6.2 Surface-water models

6.2.1 Description of Model Scenarios

The challenge faced in developing a management plan for water use in the lower FRB requires that likely future scenarios of agricultural water use be tested for their effects on streamflow. The tool to be used to test these scenarios is a combination of the USGS MODFE ground-water model, and the calibrated HSPF surface-water models.

Estimated current acreages irrigated from surface-water and ground-water sources in the Flint sub-basins are shown in Table 6.3. Among the three sub-basins being modeled, the lower Flint has the most irrigated land (about 170,000 acres), 98% of which are irrigated from the Upper Floridan aquifer. Spring Creek has about 139,000 irrigated acres, 92% from ground-water, and Ichawaynochaway Creek has 100,000 acres, with 66% irrigated from surface-water sources. Current application rates in inches per month are given for typical rainfall and drought years, by sub-basin, and for ground-water, surface-water, and well-to-pond sources in Table I.3-2 (Hook et al, 2005).

sub-basin	gw acres using Upper Floridan	surface-water acres	well to pond irr_acres	well to pond acres using Upper Floridan
Lower Flint	166187	3941	198	182
Ichawaynochaway Ck.	33474	65938	1344	402
Spring Creek	128011	10213	1531	1126
Kinchafoonee-Muckalee	12714	44223	951	355
Middle Flint	25533	36147	2756	1331
Total Flint	365919	160461	6781	3396

(a)

basin	gw acres using Upper Floridan	surface-water irr_acres	well to pond acres	well to pond acres using Upper Floridan
Lower Flint	18506	1308		
Ichawaynochaway Ck.	6477	10040		
Spring Creek	14197	2708	350	200
Kinchafoonee-Muckalee	5138	7732		
Middle Flint	19949	8701	785	128
Total Flint	64267	30489	1135	328

(b)

Table 6.3 (a): Estimated current irrigated acres in FRB, obtained from NESPAL/EPD permit mapping; (b) Proposed new irrigated acres associated with permit application "backlog"

Tables 6.3(a) and (b) are the basis for the Current Irrigation Scenario. Other scenarios modeled include the Backlog Scenario, which accounts for the option of approving all of the permit applications received by EPD during the permit moratorium (i.e. the "backlog"). This is equivalent to an increase of about 18% in irrigated acreage. A further increase in water use is represented by increasing the application rates shown in Table 3-2 for the Backlog Scenario by 25%, for example as a result of an extensive Crop Mix Scenario change. Finally, in case the evaluations of model results show that the Current Scenario over-allocates the water supply under drought conditions, Cutback Scenarios of 80%, 70%, and 60% of current water use rates are also modeled.

6.2.2 Model Results

The USGS MODFE model was used to compute the estimated monthly reduction in streamflow rates in each of the modeled sub-basins for each scenario in both drought and normal rainfall years. Tables 6.2 (a-f) provide comparison of the streamflow reductions at key gauges: Milford on Ichawaynochaway Creek, Iron City on Spring Creek, and Bainbridge in the lower Flint, for the Current, Backlog, and 1.25xBacklog scenarios in the growing season months of a drought year. The computed daily flow reductions obtained from MODFE are subtracted from the corresponding daily flow rates in the HSPF models to yield the estimated streamflow rates for each scenario at each model node.

Figure 6.5 (and Figure I.3-1) compares the computed flow exceedance curves for the Current, Backlog, and 1.25 X Backlog scenarios at Milford on Ichawaynochaway Creek. The flow rate exceeded 95% of the time can be seen to decrease from about 120 cfs for the Current Scenario to 110 cfs for the Backlog Scenario and 95 cfs for the 1.25 X Backlog Scenario. At Spring Creek near Iron City, the flow rate exceeded 95% of the time can be seen to decrease from about 25 cfs for the Current Scenario to about 20 cfs for the Backlog Scenario and to about 10 cfs for the 1.25 × Backlog Scenario (Fig. 6.6). At Flint River at Bainbridge, the flow rate exceeded 95% of the time is about 2280 cfs for the Current Scenario; it is reduced to about 2250 cfs for the Backlog Scenario, and further reduced to about 2200 cfs for the 1.25 × Backlog Scenario (Fig. 6.6). These effects include the computed ground-water reductions described in Section 3.2.1 from the MODFE model.

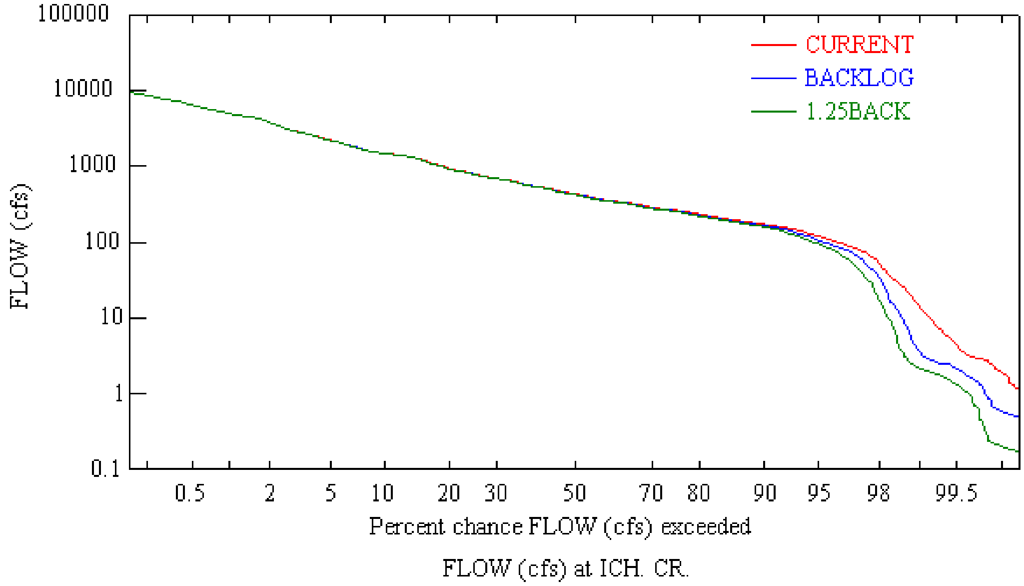


Figure 6.6: Flow exceedance (duration) curve of scenarios Current, Backlog, and 1.25X backlog at Ichawaynochaway Creek at Milford

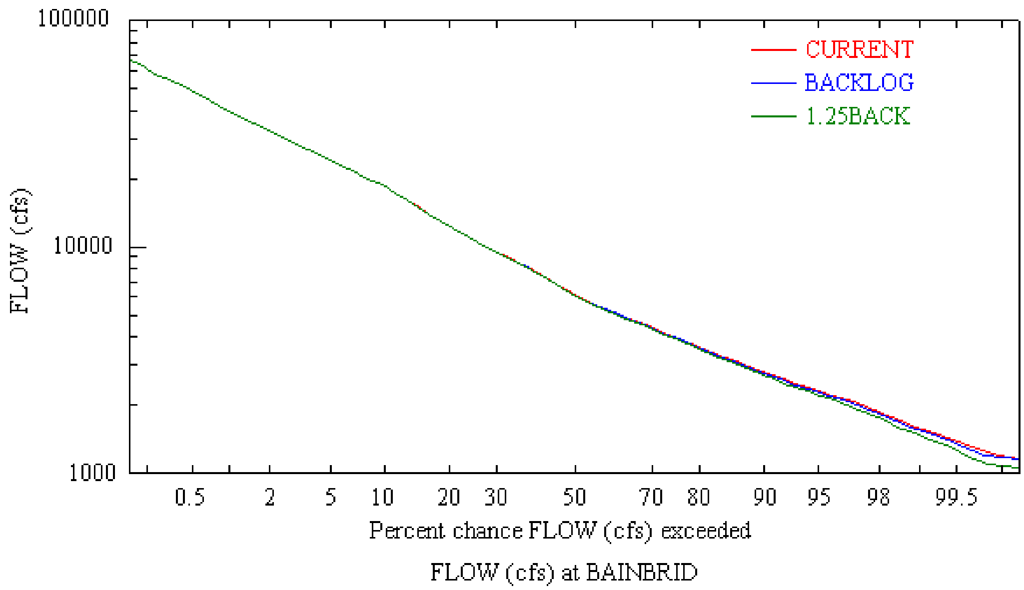


Figure 6.7: Flow exceedance (duration) curves of scenarios Current, Backlog, and 1.25Xbacklog at Flint River at Bainbridge

Another view of the modeled effect on streamflow can be illustrated by looking at daily flow computed for specific years at the same model nodes. Using the same years chosen to illustrate the model calibration results in section I.2.1.1 (drought, wet, and normal year), Figures I.3-4 thru I.3-12 present these comparisons for the same three selected scenarios. It can be seen that the most significant difference in simulated streamflow occurs in drought years. For example, the lowest flow rate at Ichawaynochaway Creek near Milford, given the 1955 meteorology (Fig. 6.7 and Fig. I.3-4), is about 60 cfs under the Current Irrigation Scenario. The flow rate is reduced to less than 40 cfs under the Backlog Irrigation Scenario, and to less than 20 cfs under the 1.25 × Backlog Scenario."

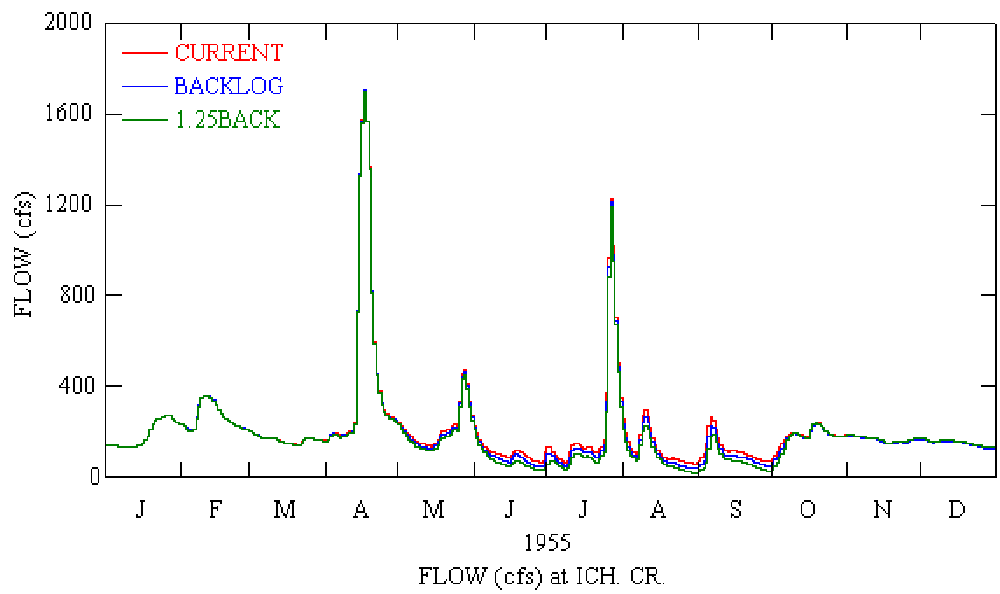


Figure 6.8: Sample hydrograph of simulated flow rates for current, backlog, and 1.25 X backlog scenarios

6.3 Scenario Impact Evaluation

6.3.1 Discussion of In stream Flow Impact Criteria

Having computed streamflow resulting from several possible future irrigation scenarios, results were compared to two sets of criteria: 1) low flow criteria that would be protective of endangered aquatic species; and 2) the effect on streamflow protective of water quality standards.

6.3.2 Aquatic Habitat Protection Streamflow Criteria

As part of the federal agency preparation for review of negotiated ACT and ACF basins Water Allocation Formulas, the USFWS and U. S. Environmental Protection Agency (USEPA) developed a set of draft guidelines for protection of the basins' riverine ecosystems. The guidelines were intended for evaluation under the USFWS's Endangered Species Act authority and EPA's Clean Water Act authority. The guidelines were not intended to be exclusive, but it was stated that an allocation formula that did not comply with the guidelines would require a more detailed review by both agencies. It was felt that the guidelines would protect both the present structure and function of the riverine ecosystems as well as endangered species (USFWS and USEPA, October 25, 1999).

The selected guidelines were developed for unregulated streams and consisted of the Monthly 1-day Flow Minima (U1) and the Annual Low-Flow Duration (U2) (USFWS and USEPA, October 25, 1999). Specifically, these were defined as:

Monthly 1-day minima ("U1")

These criteria are derived from the complete daily **discharge** record for the stream. From this record, the <u>lowest</u> 1-day minimum flow for each month of the year in all years is identified. From the complete record of all 1-day minimum flows for a particular month, the lowest 25th percentile and median of these values are calculated. For each future month, the 1-day minimum flow guideline is to:

a. Exceed the lowest 1-day minimum in all years.
b. Exceed the 25th percentile in 3 out of 4 years.
c. Exceed the median in half of the years.

Annual low-flow duration (“U2”)

These criteria are also derived from the complete daily **discharge** record for the stream. From this, the average annual **discharge** (AAD) for each calendar year is calculated, and then these yearly averages are themselves averaged. The number of days per year for all calendar years during which daily **discharge** is less than 25 percent of the AAD is then calculated. The maximum number of days per year for all calendar years in which discharge is less than 25% AAD, the 75th percentile of the number of days per year in which discharge is less than 25% AAD, and median of the number of days are computed. For each year the guideline is:

a. Do not exceed the maximum number of days in all years.
b. Do not exceed the 75th percentile in 3 out of 4 years.
c. Do not exceed the median in half the years.

6.3.3 Water Quality Guidelines

Potential impacts to water quality are also important to the evaluation of scenario model results in the Flint Basin. Georgia EPD develops waste load allocations and associated National Pollutant Discharge Elimination System (NPDES) permit limits for municipal and industrial surface-water discharges that protect the State in-stream dissolved oxygen concentration water quality standards and other in-stream criteria. NPDES permits are developed to protect water quality standards using a minimum streamflow equal to the 7Q10. The 7Q10 is the minimum 7-day average streamflow having a 10% chance of occurrence in any year, or a theoretical recurrence interval of 10 years. Changes to surface-water hydrology that cause streamflow to be less than the 7Q10 streamflow used to determine the NPDES limits could adversely affect a stream’s ability to meet the dissolved oxygen water quality standard and other criteria during critical low streamflow conditions. Reduced 7Q10 streamflow may require that the waste allocation loading, which determines the NPDES permit limits, may need to be decreased to prevent the standards from being violated.

A review of historic streamflow data and NPDES permit conditions, as well as computation of the 7Q10 flow rates for various time periods, indicates that the 7Q10 used by EPD to set current permit discharge limits in southwest Georgia was based on pre-1970 historic flow data. The computed 7Q10 for this period is 2500 cfs for the Flint River at Bainbridge, 140 cfs for Ichawaynochaway Creek near Milford, and 15 cfs for Spring Creek near Iron City.

6.3.4 Computation of Criteria

For the purposes of this Plan, streamflow criteria are calculated at three representative gauge locations, Ichawaynochaway Creek at Milford, Spring Creek near Iron City, and the Flint River at Bainbridge. The first two of these (Figures I2.-1 and I2.-11) are locations with long-term USGS gauging stations spanning the periods before and after significant irrigation. The Bainbridge gauge is located in the headwaters of Lake Seminole and has very little gauge data since 1970; therefore, the historical data does not represent pre-irrigation conditions. The Newton and Albany gauges are the only other stations with long periods of record; these gauges are located further upstream in the HSPF-modeled lower Flint sub-basin and therefore do not fully include all the rainfall-driven modeled conditions in the sub-basin as completely as the Bainbridge gauge.

6.3.5 Evaluation of In-Stream Flow Criteria

Table I.4-1 presents the in-stream flow criteria guidelines computed for each of the gauge locations based on the entire period of record.

The effects on U1 and U2 streamflow guidelines can be computed for the future irrigation scenarios described in Section 3.0. In these model runs, assumed irrigation distribution patterns and application rates for each scenario are modeled for the 54-year hydrologic pattern observed for the period from 1950-2003. The irrigation acreage is not changed from year to year (see Table 6.3) and the application rates change only according to whether a particular year was a drought or not (Table I3-2).

<u>Ichawaynochaway Creek at Milford.</u>

Table 6.4 (and Tables I4.2 and I4.3) shows how the modeled scenario streamflow perform with respect to the USFWS in-stream flow guidelines. The monthly 1-day minimum flow rates computed for the future scenarios should never be less than the monthly minimum U1 criteria. Observed gauge flow rates meet this criterion, (all “0’s”), but modeled flows do not meet the criterion as many as five times (Table VV) for the scenarios with the highest level of irrigation use; that is, the Backlog and 1.25xBacklog Scenarios, and in late summer months. Reducing irrigation by 20% from the Current Scenario would reduce the number of times the criteria are not met to two in September. In other words, modeled future scenarios of increased irrigation would cause the 1-day flow minimum to be exceeded more often. Reducing irrigation by at least 20% would not eliminate the exceedance, but would reduce the number of times more than if irrigation were increased above current levels.

For the U1B guideline (Table 6.4), the criterion should not be exceeded more than 1 in every 4 years, or 25% of the time. This does occur with the observed data for the period from 1953-2003, but only by a very small margin. However, as with the 1-day minimum criterion, it happens more often for the Backlog Scenarios and in August and September. The U1C guideline should not be exceeded more than 50% of the time (1 in 2 years), but this does occur in late summer for those scenarios of increased irrigation and for existing irrigation over the next 50 years.

The differences between scenario U1 variances can be seen for selected years (1980’s) in Figure I.4-1, which shows the modeled minimum 1-day flow rates during the month of August vs. the minimum (U1A), 25% (U1B), and 50% (U1C) criteria. U1A is not met in 1986 with the Current and Backlog Scenarios, but is met in all other years and scenarios. Variances occur for the U1B guideline in 1981 and 1986 (all scenarios) and in 1985 and 1988 for some scenarios, but a 25% variance rate is acceptable for U1B. Only 1980, 1982, 1984, and 1989 have no U1C variances, though a 50% variance rate is acceptable.

Lowest monthly 1-day minimum flow (U1-A)						
(Number. of years that flow was below the monthly criteria - should not exceed zero)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	175	43	12	21	6	10
Observed 1939-1975	0	0	0	0	0	0
Observed 1953-2003	0	0	0	0	0	0
No irr 1953-2003	**1**	0	0	0	0	0
Calibrated 1953-2003	**1**	0	0	0	**1**	**2**
0.6 x Current irrigation	**1**	0	0	0	0	0
0.7 x Current irrigation	**1**	0	0	0	0	**1**
0.8 x Current irrigation	**1**	0	0	0	**1**	**2**
Current irr. over 50 yrs	**1**	0	0	**2**	**3**	**4**
Backlog	**1**	0	**1**	**2**	**3**	**5**
1.25 x Backlog	**1**	0	**1**	**3**	**4**	**5**

25 percentile of monthly 1-day minimum flows (U1-B)						
(Percent of years with that flow was below monthly criteria - should not exceed 25%)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	342	228	162	153	139	148
Observed 1939-1975	23.1%	15.4%	15.4%	7.7%	3.8%	15.4%
Observed 1953-2003	21.6%	23.5%	**25.5%**	23.5%	**25.5%**	24.0%
No irr 1953-2003	19.6%	11.8%	7.8%	9.8%	7.8%	12.0%
Calibrated 1953-2003	19.6%	15.7%	13.7%	11.8%	11.8%	16.0%
0.6 x Current irrigation	19.6%	15.7%	19.6%	13.7%	15.7%	22.0%
0.7 x Current irrigation	19.6%	15.7%	19.6%	13.7%	17.6%	22.0%
0.8 x Current irrigation	19.6%	15.7%	19.6%	15.7%	17.6%	**26.0%**
Current irr. over 50 yrs	19.6%	19.6%	19.6%	15.7%	**27.5%**	**28.0%**
Backlog	21.6%	21.6%	19.6%	23.5%	**27.5%**	**32.0%**
1.25 x Backlog	21.6%	23.5%	**25.5%**	**29.4%**	**35.3%**	**32.0%**

Median of monthly 1-day minimum flows (U1-C)						
(Percent of years that flow was below the monthly criteria - should not exceed 50%)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	473	308	228	227	223	197
Observed 1939-1975	46.2%	38.5%	34.6%	38.5%	34.6%	38.5%
Observed 1953-2003	39.2%	**51.0%**	43.1%	49.0%	**52.9%**	50.0%
No irr 1953-2003	37.3%	27.5%	23.5%	23.5%	29.4%	22.0%
Calibrated 1953-2003	39.2%	33.3%	29.4%	31.4%	37.3%	38.0%
0.6 x Current irrigation	39.2%	33.3%	31.4%	31.4%	43.1%	36.0%
0.7 x Current irrigation	39.2%	37.3%	33.3%	31.4%	45.1%	42.0%
0.8 x Current irrigation	39.2%	41.2%	33.3%	35.3%	45.1%	50.0%
Current irr. over 50 yrs	45.1%	45.1%	37.3%	43.1%	**52.9%**	**56.0%**
Backlog	45.1%	49.0%	43.1%	49.0%	**60.8%**	**58.0%**
1.25 x Backlog	45.1%	**51.0%**	43.1%	**51.0%**	**64.7%**	**60.0%**

Table 6.4: U1 guideline effects for Ichawaynochaway Creek near Milford: Monthly 1-day Minima Criteria – Variances Criteria are from full period of record

Table 6.4 shows the results of comparisons of the duration of U2 computed scenario flows below 25% of the annual average for Ichawaynochaway Creek. The allowable number of years in which the maximum duration is exceeded is zero; however, this is exceeded in all model runs. The U2B criterion is not to be exceeded more than 25% of the time, or 1 in 4 years, but this is exceeded in several scenarios simulating current irrigation and expanded irrigation. The U2C criterion, based on the median number of years in which flow is less than 25% annual average discharge is not exceeded in the modeled scenarios. Recalling that these scenarios project identical climatic patterns from the past 54 years into the future, Ichawaynochaway Creek would not meet the U2 criteria only in the worst drought years of the past 54 years. Specifically, in future years with conditions like those of 1954, 1955, 1968, 1986, 1999, and 1990, Ichawaynochaway Creek would likely not meet the U2 criteria. The likelihood of this increases if the backlogged permits are issued, and if the volume of irrigation increases over current levels.

Annual Low Flow Duration (U2) Statistics			
25% Annual Average Discharge	171 cfs		
	Maximum	1 in 4 yrs	1 in 2 yrs
Criteria: Annual Low Flow Duration (days)	168	28	0
Allowable years of variance	0	<25%	<50%
Observed 1939-1975	0	8.0%	18.0%
Observed 1953-2002	0	**28.0%**	48.0%
No irr 1953-2002	**1**	14.0%	28.0%
Calibrated 1953-2003	**2**	22.0%	34.0%
0.6 x Current irrigation	**5**	22.0%	34.0%
0.7 x Current irrigation	**5**	24.0%	34.0%
0.8 x Current irrigation	**6**	**28.0%**	34.0%
Current irr. over 50 yrs	**6**	**28.0%**	42.0%
Backlog	**6**	**32.0%**	48.0%
1.25 x Backlog	**6**	**36.0%**	50.0%

Table 6.5: guideline effects for Ichawaynochaway Creek near Milford: Annual Low Flow Duration Variances Criteria are from full period of record

In summary, simulations of future irrigation scenarios indicate that Ichawaynochaway Creek will not meet the U1 and U2 USFWS in-stream flow criteria in late summer of drought years. Furthermore, if more permits are issued, or if irrigation volumes increase over current levels, the violation of the criteria will become more frequent. A 20% reduction in irrigation below current levels during drought years would cause the creek to meet the in-stream criteria virtually all the time (Table 5-4). If irrigation is increased over existing levels, a greater reduction in irrigation will be required in drought years to meet the U1 flow criteria.

Spring Creek

Tables 6.6 and I.4-4 summarize USFWS in-stream flow guideline results for Spring Creek. Spring Creek model results indicate that the criteria fail at very high rates, except in August and September (U1A), but including scenarios in April and May with no irrigation and scenarios with drastic cutbacks in irrigation. This contrasts with the U2A low-flow duration criteria in which there are no violations of the criteria. These highly unlikely results suggest that the USFWS in-stream flow guidelines cannot be applied to Spring Creek. This may be the result of Spring Creek's tendency to reach low flows early in the year; the karstic nature of the sub-basin, such that surface-water flows do not operate independently of ground-water; or the extreme low flows that occurred after 1976 skewing the streamflow statistics towards an unworkable standard. If the USFWS criteria cannot be used to develop a management strategy for Spring Creek, then other criteria must be used or it must be assumed that a management strategy that would protect in-stream flows and riverine habitat for other sub-basins of the FRB would have a beneficial effect on Spring Creek.

Lowest monthly 1-day Minimum flow (U1-A) (Number of years that flow was below the monthly criteria - should not exceed zero)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	51.30	3.51	0.81	0.16	0.00	0.00
Observed 1937-1971	0	0	0	0	0	0
Observed 1953-2003	0	0	0	0	0	0
No irr 1953-2002	**2**	0	0	0	0	0
Calibrated 1953-2003	**3**	**3**	**4**	**5**	0	0
0.6 x Current irrigation	**4**	**3**	**8**	**7**	0	0
0.7 x Current irrigation	**6**	**4**	**9**	**7**	0	0
0.8 x Current irrigation	**6**	**4**	**11**	**8**	0	0
Current irr. over 50 yrs	**7**	**5**	**14**	**11**	0	0
Current irr. over 50 yrs(updated)	**7**	**4**	**14**	**8**	0	0
Backlog	**7**	**7**	**16**	**11**	0	0
1.25 x Backlog	**7**	**11**	**17**	**12**	0	0

25 percentile of monthly 1-day minimum flows (U1-B) (Percent of years that flow was below monthly criteria - should not exceed 25%)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	197.1	87.8	48.2	45.9	36.7	32.4
Observed 1937-1971	11.8%	6.1%	2.9%	5.9%	11.8%	11.8%
Observed 1953-2003	**26.2%**	**26.8%**	**29.3%**	**31.0%**	**33.3%**	**29.3%**
No irr 1953-2002	**33.3%**	**45.1%**	**29.4%**	**25.5%**	13.7%	16.0%
Calibrated 1953-2003	**33.3%**	**51.0%**	**33.3%**	**35.3%**	**27.5%**	18.0%
0.6 x Current irrigation	**33.3%**	**56.9%**	**47.1%**	**41.2%**	**31.4%**	22.0%
0.7 x Current irrigation	**33.3%**	**56.9%**	**49.0%**	**43.1%**	**31.4%**	22.0%
0.8 x Current irrigation	**33.3%**	**58.8%**	**51.0%**	**43.1%**	**33.3%**	**30.0%**
Current irr. over 50 yrs	**33.3%**	**60.8%**	**52.9%**	**47.1%**	**39.2%**	**38.0%**
Current irr. over 50 yrs(updated)	**33.3%**	**58.8%**	**52.9%**	**45.1%**	**37.3%**	**36.0%**
Backlog	**33.3%**	**60.8%**	**56.9%**	**49.0%**	**41.2%**	**38.0%**
1.25 x Backlog	**33.3%**	**60.8%**	**58.8%**	**54.9%**	**47.1%**	**44.0%**

Median of monthly 1-day minimum flows (U1-C) (Percent of years that flow was below the monthly criteria - should not exceed 50%)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	299.7	122.4	90	92.7	79.2	58.95
Observed 1937-1971	26.5%	15.2%	20.6%	23.5%	20.6%	23.5%
Observed 1953-2003	50.0%	**56.1%**	**53.7%**	**57.1%**	**52.4%**	**56.1%**
No irr 1953-2002	**52.9%**	**58.8%**	**56.9%**	**52.9%**	45.1%	38.0%
Calibrated 1953-2003	**52.9%**	**64.7%**	**60.8%**	**58.8%**	**51.0%**	50.0%
0.6 x Current irrigation	**52.9%**	**62.7%**	**70.6%**	**58.8%**	**54.9%**	**58.0%**
0.7 x Current irrigation	**52.9%**	**62.7%**	**70.6%**	**58.8%**	**54.9%**	**58.0%**
0.8 x Current irrigation	**52.9%**	**64.7%**	**72.5%**	**60.8%**	**56.9%**	**58.0%**
Current irr. over 50 yrs	**52.9%**	**66.7%**	**74.5%**	**64.7%**	**58.8%**	**62.0%**
Current irr. over 50 yrs(updated)	**52.9%**	**64.7%**	**72.5%**	**62.7%**	**58.8%**	**62.0%**
Backlog	**52.9%**	**68.6%**	**74.5%**	**64.7%**	**60.8%**	**62.0%**
1.25 x Backlog	**54.9%**	**74.5%**	**74.5%**	**70.6%**	**62.7%**	**70.0%**

Table 6.6: U1 guideline effects for Spring Creek near Iron City: Monthly 1-day Minima Criteria – Variances Criteria are from entire period of record

Lower Flint River

The lower Flint River model results show very few examples of the criteria not being met (and Tables 6.7 and I.4-6). Even projecting climatic patterns of the past 50 years into the future, the criteria are met except for scenarios of increased irrigation in July. However, as with Ichawaynochaway Creek, the flow criteria results indicate that if more irrigation occurs in the lower Flint River sub-basin, irrigation will have to be reduced in drought years for the flow criteria to be met.

Lowest monthly 1-day minimum flow (U1-A)						
(Number. of years that flow was below the monthly criteria - should not exceed zero)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	3077	1463	1151	1165	988	1003
No irr 1953-2003	0	0	0	0	0	0
Calibrated 1953-2003	0	0	0	0	0	0
0.6 x Current irrigation	0	0	0	0	0	0
0.7 x Current irrigation	0	0	0	0	0	0
0.8 x Current irrigation	0	0	0	0	0	0
Current irr. over 50 yrs	0	0	**1**	**1**	0	0
Backlog	0	0	**1**	**2**	0	**1**
1.25 x Backlog	0	0	**1**	**2**	**1**	**1**

25 percentile of monthly 1-day minimum flows (U1-B)						
(Percent of years with that flow was below monthly criteria - should not exceed 25%)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	4448	3107	2377	2516	2398	2062
No irr 1953-2003	17.6%	17.6%	9.8%	17.6%	13.7%	10.0%
Calibrated 1953-2003	17.6%	17.6%	13.7%	19.6%	17.6%	18.0%
0.6 x Current irrigation	17.6%	17.6%	19.6%	21.6%	21.6%	20.0%
0.7 x Current irrigation	17.6%	17.6%	19.6%	21.6%	21.6%	22.0%
0.8 x Current irrigation	17.6%	17.6%	21.6%	21.6%	21.6%	22.0%
Current irr. over 50 yrs	17.6%	17.6%	23.5%	23.5%	25.5%	22.0%
Backlog	17.6%	17.6%	23.5%	23.5%	25.5%	24.0%
1.25 x Backlog	17.6%	23.5%	**25.5%**	**29.4%**	**29.4%**	**30.0%**

Median of monthly 1-day minimum flows (U1-C)						
(Percent of years that flow was below the monthly criteria - should not exceed 50%)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	6165	4248	3363	3400	3022	2549
No irr 1953-2003	45.1%	45.1%	37.3%	33.3%	33.3%	30.0%
Calibrated 1953-2003	45.1%	47.1%	39.2%	35.3%	43.1%	36.0%
0.6 x Current irrigation	45.1%	47.1%	39.2%	35.3%	45.1%	38.0%
0.7 x Current irrigation	45.1%	47.1%	39.2%	35.3%	45.1%	40.0%
0.8 x Current irrigation	45.1%	47.1%	39.2%	35.3%	45.1%	40.0%
Current irr. over 50 yrs	45.1%	47.1%	39.2%	39.2%	47.1%	44.0%
Backlog	45.1%	47.1%	39.2%	41.2%	47.1%	44.0%
1.25 x Backlog	45.1%	47.1%	41.2%	41.2%	49.0%	48.0%

Table 6.7: U1 guideline effects for lower Flint River at Bainbridge: Monthly 1-day Minima Criteria – Variances Criteria are from full period of HSPF calibrated model (1953-2003)

6.3.6 Water Quality Guidelines

Table 6.8 (and Table I.4-8) compares the computed 7Q10 for Ichawaynochaway Creek at Milford, for Spring Creek at Iron City, and for the lower Flint River at Bainbridge for pre-1970's gauge data (the current basis for NPDES Permit discharges in southwest Georgia), and the model results from four future irrigation scenarios. The differences between each of the future scenario low-flow computations and the pre-irrigation computation are significant in each case. This implies that either water quality standards will be violated more frequently in the future or pollutant loadings will have to be significantly reduced.

7Q10 Stream flow Rates (cfs)			
Modeling Scenario	Ichawaynochaway Ck. near Milford	Flint River at Bainbridge	Spring Ck. near Iron City
Pre-1970's Data	140	2500	15
60% Current Model	65	1650	0
Current Model	20	1500	0
Backlog Model	10	1460	0
125% Backlog Model	3.5	1380	0

Table 6.8: Calculated 7Q10 Streamflow for FRB Modeling Scenarios

Location	7Q10	Historic	0.6 x Current	Current	Backlog	1.25xBacklog
Milford	140 cfs	2.9%	4.6%	6.5%	7.2%	8.1%
Iron City	15 cfs	3.5%	3.9%	5.8%	6.3%	7.8%
Bainbridge	2500 cfs	5.4%	5.9%	6.9%	7.2%	8.0%

Table 6.9: Frequency of Flow Less than 7Q10

The computed frequency of flows less than the 7Q10 is shown for the three modeled scenarios at the three modeled locations in Table 6.9 (and Table I.4-9). For Milford, the frequency of occurrence of the pre-1970 7Q10 flow rate is 2.9%. This increases to 6.5% for the Current Scenario and 7.2% for the Backlog Scenario. For Iron City the pre-1970 frequency of 3.5% increases to 6.3% for the Backlog Scenario and for Bainbridge the increase is from 6.4% to 7.2%. This implies that the frequency of flow conditions under which water quality standards may be violated could more than double at Milford and could increase by 70% at Iron City and by 40% at Bainbridge in the future, if pollution loadings are not decreased or steps taken to reduce irrigation withdrawals under severe drought conditions.

6.4 Interpretation of Scenario Impact Model Results

There is a wide range of results for the various conditions represented by the MODFE ground-water and HSPF surface-water model simulations, as well as the observed data. The most extreme differences are between the low criteria failure rate for the lower Flint River and the almost complete failure of Spring Creek. But there are also differences in how the guidelines are missed in Ichawaynochaway and Spring Creeks and the fact that observed data at those locations do not indicate any variances (since the guidelines were developed from those data).

These widely divergent failure rates may result from at least three possible aspects of the evaluation process: 1) the calibration of the models; 2) the uncertainties in the measurement and modeling process, especially for very low flows; or 3) the appropriateness of applying the criteria to Spring Creek.

The process of model calibration has uncertainties: rainfall and gauge flow observations; surface-water and ground-water characteristics that affect water movement, water withdrawal and return rates; exchange rates (and direction) between ground-water and surface-water under different seasonal conditions; and others. HSPF models are rainfall driven and the capability of detecting the rainfall events that drive the streamflow, especially during summer, is limited and uneven in effectiveness. The comparisons of calibration results with gauge observed streamflow (shown in Section I2.0 for Spring Creek and Ichawaynochaway Creek) reveal many instances of significant deviation, even though the calibration coefficients are quite good.

With the primary concern being low flows, then uncertainties are magnified. The errors in observed gauge flows alone probably exceed the 7Q10 of Spring Creek at Iron City, for example. This may not be true at Milford, but the uncertainties are still a significant fraction of the 7Q10. On the lower Flint the flow rates are much greater, even under drought conditions, but there is another reason for both the much better calibration match at Bainbridge and the lack of guideline variance; the lower Flint HSPF model is much less dependent on rainfall input as the driver and more dependent on the more reliable flow measurements from the gauge at Albany, where upstream inflow is incorporated into the model. The other two sub-basins do not have gauged flows that control a large percentage of the surface-water flow at then modeled locations.

Because of these uncertainties and limitations, the model results should be interpreted with consideration for the differences between scenario results rather than strictly in terms of a direct comparison with the guidelines. In general, models are most accurate when used to determine differences between scenarios. The differences between computed scenarios relative to the allowable criteria may be more meaningful than whether the scenarios fail to meet the allowable criteria, as the differences may indicate the changes to the flow regime that may occur. For example, in Spring Creek there is only about a 2% increase in the failure rate of U1C for the backlog scenario versus the current scenario compared to a 50% variance allowance. Similarly, the U2 criteria are not met for the observed period, but the same variance rates appear for the current irrigation. Therefore, in some situations it may be more appropriate to compare failure rates and reduced irrigation scenarios against existing performance rather than against the actual criteria.

SECTION 7: HYDROLOGIC EVALUATION OF SPRING CREEK, ICHAWAYNOCHAWAY, AND LOWER FLINT SUB-BASINS

7.1 Ichawaynochaway Creek sub-basin

Approximately 22% of the total land area in Ichawaynochaway Creek sub-basin is irrigated (Fig. 7.1). Irrigation in the Subarea 4 part of Ichawaynochaway sub-basin has increased by approximately 34% since 1993 (Litts et al, 2001), and by more than 90% since 1970 (Pierce et al, 1984). The distribution of permitted and proposed irrigation withdrawal points is shown on Figures 4.2 and 4.3. Several trends are immediately clear.First is the greater density of permitted ground-water withdrawals in the Subarea 4 part of the sub-basin, especially in Baker County west of Ichawaynochaway Creek.The same pattern exists for proposed new well locations. Secondly, with only a few exceptions, most notably the heavy concentration of surface-water withdrawals in the northwestern corner of Baker County, permitted and proposed surface-water withdrawals in the southern half of Ichawaynochaway sub-basin comprise only a fraction of the ground-water withdrawals. Almost all the proposed new surface-water withdrawal locations are north of the Subarea 4 boundary.

The higher density of permitted surface-water withdrawals in the northern half of the basin reflects the absence of the Floridan aquifer there. Exceptions to this trend are two “bands” of ground-water wells in eastern Randolph County and western Terrell County. Wells in these areas are tapping the Claiborne and Clayton aquifers, and thus have very little impact on local streamflow.

In summary, Ichawaynochaway Creek sub-basin is almost evenly divided by the Subarea 4 model boundary, such that irrigation in the northern half of the sub-basin is mostly from surface-water, and mostly from the Floridan aquifer in the southern half of the basin.

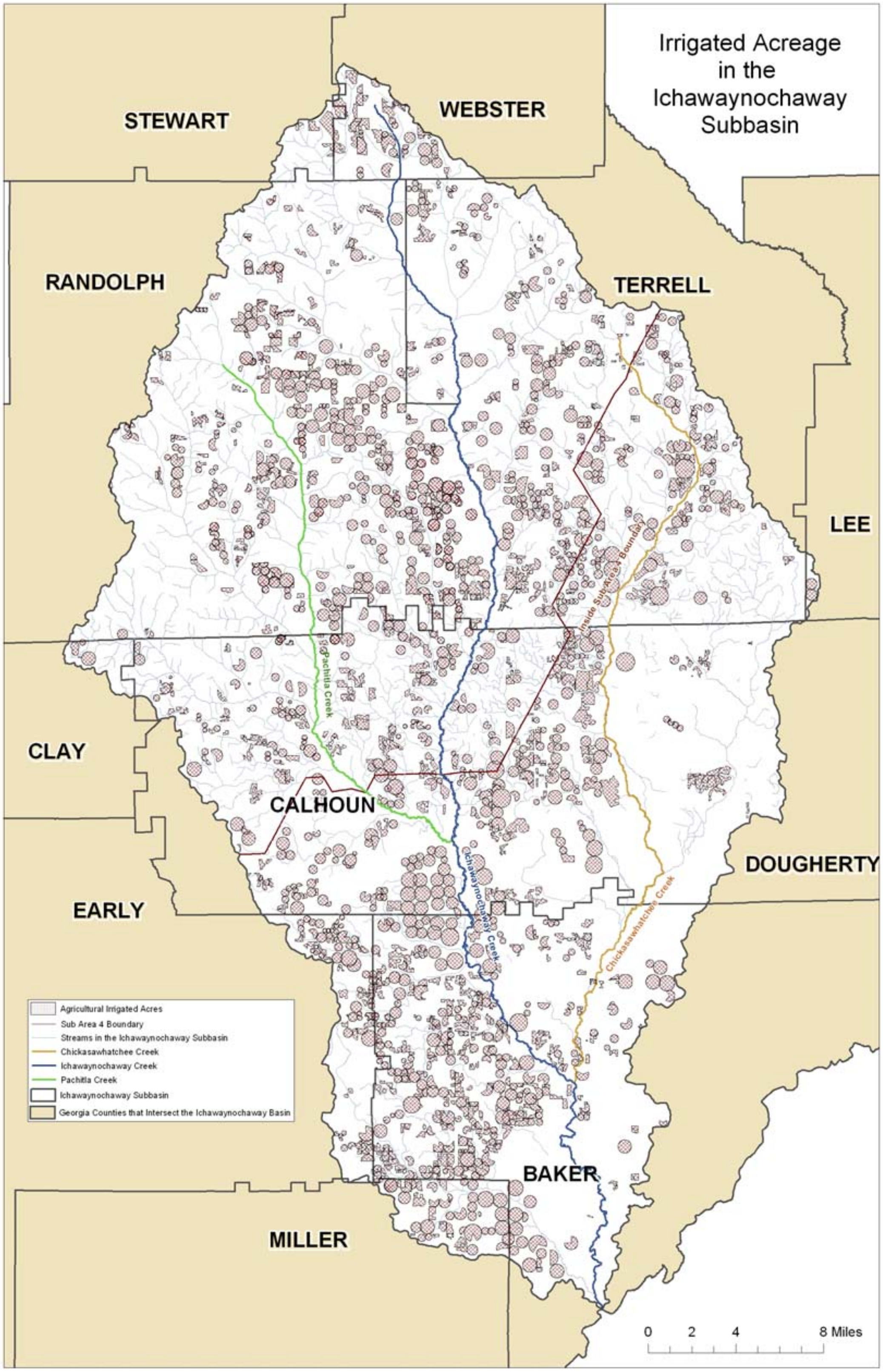


Figure 7.1. Irrigated acreage in Ichawaynochaway sub-basin

Like other streams in southwest Georgia, Ichawaynochaway Creek has experienced record or near-record low flows during the drought periods described above. One of the worst droughts on record occurred in 1954. A hydrograph of Ichawaynochaway Creek at Milford is shown in Figure 7.2. The lowest discharge (120 cfs) occurred in September 1954. From the beginning of the year to that point the hydrograph displays a typical decrease in discharge, with rainfall-driven increases superimposed.

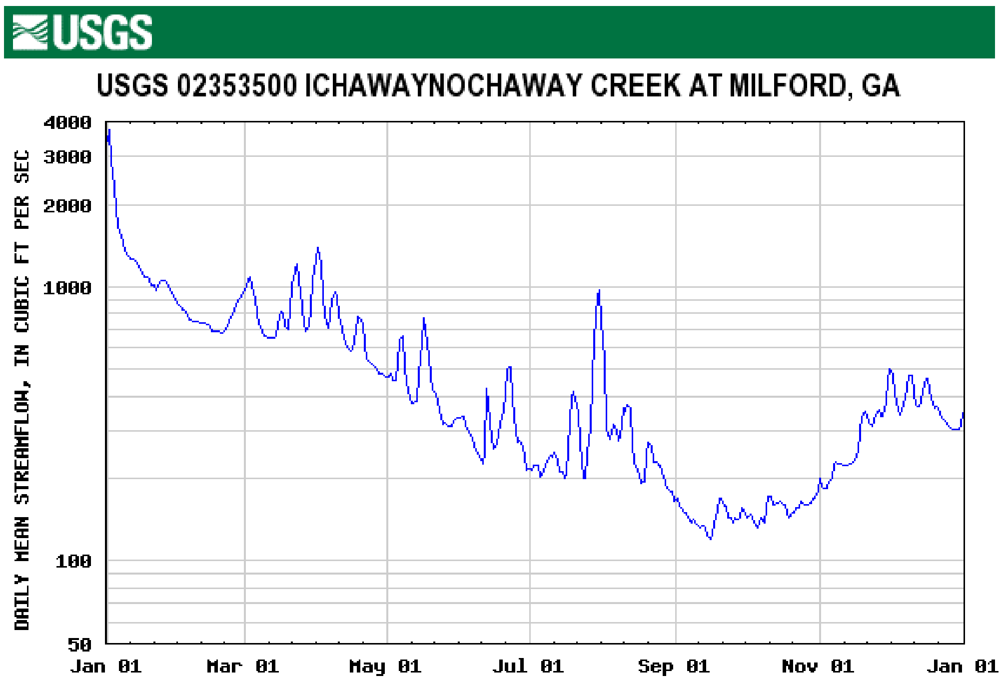


Figure 7.2. Streamflow of Ichawaynochaway Creek near Milford for 1954

Another major drought occurred in 1986, after agricultural irrigation had become widespread. The hydrograph of Ichawaynochaway Creek at Milford (Figure 7.3) shows the decline in discharge that occurred in 1986. The decline is much steeper than that which occurred in 1954, and reached a lower discharge (48 cfs) in spite of significant rainfall events that occurred early in the year. The discharge peaks associated with those events display a typically logarithmic, or concave-upward, decline typical of gradually waning flow after a major precipitation pulse. That gradual decline in discharge does not occur after the sharp rise in discharge that occurred in August 1986; rather, discharge drops off almost linearly. This suggests that the streamflow of Ichawaynochaway Creek in 1986 was affected by irrigation withdrawals.

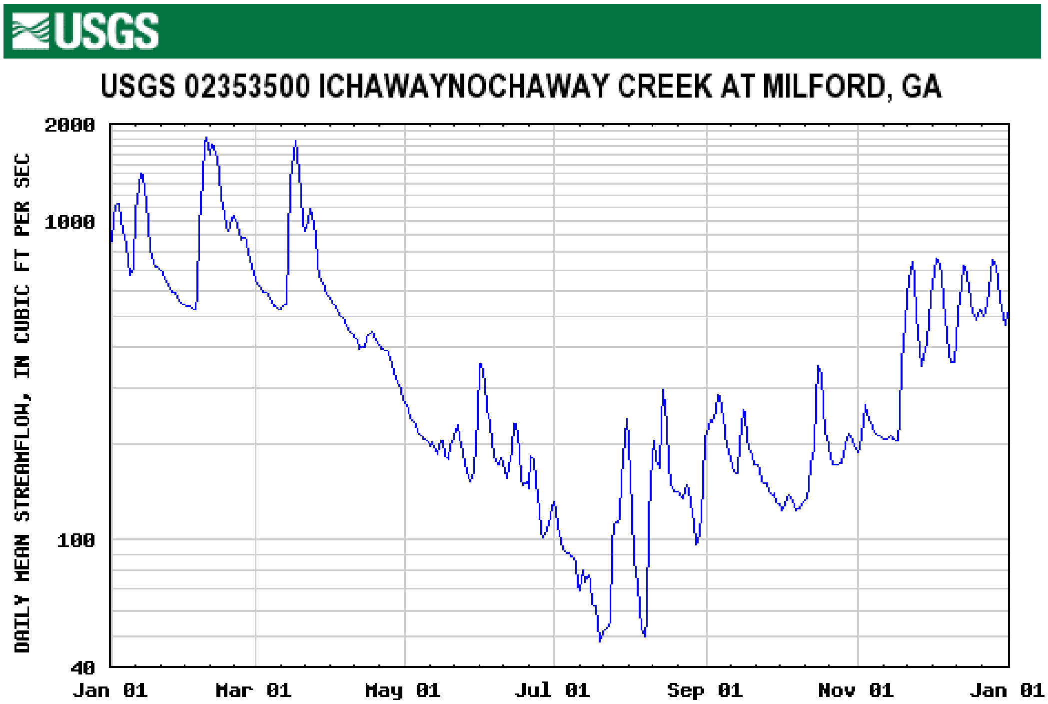


Figure 7.3. Streamflow of Ichawaynochaway Creek near Milford for 1986

A third hydrograph is shown that records the severe drought conditions of 2000, during which Ichawaynochaway Creek reached its lowest recorded flows (Fig. 7.4). It is important to note that early-year streamflow was significantly lower than in either 1954 or 1986. This may have resulted in more rapid streamflow decline than in 1986. However, beginning in June and continuing through September 2000, the hydrograph shows a very unusual pattern of very steep increases and decreases in discharge that could not be easily attributed to natural streamflow fluctuations. This is especially evident during August 20-22, when discharge declined from 102 cfs to a record low of 6.6 cfs in the 3-day period. The extreme discharge fluctuations are almost certainly due to alternating patterns of rainfall and irrigation pumping from Ichawaynochaway Creek and its tributaries at the typical peak of the irrigation season. Since the Milford gauge is near the boundary of Subarea 4, irrigation withdrawals causing the fluctuations in streamflow would have been mostly surface-water as opposed to Floridan aquifer withdrawals.

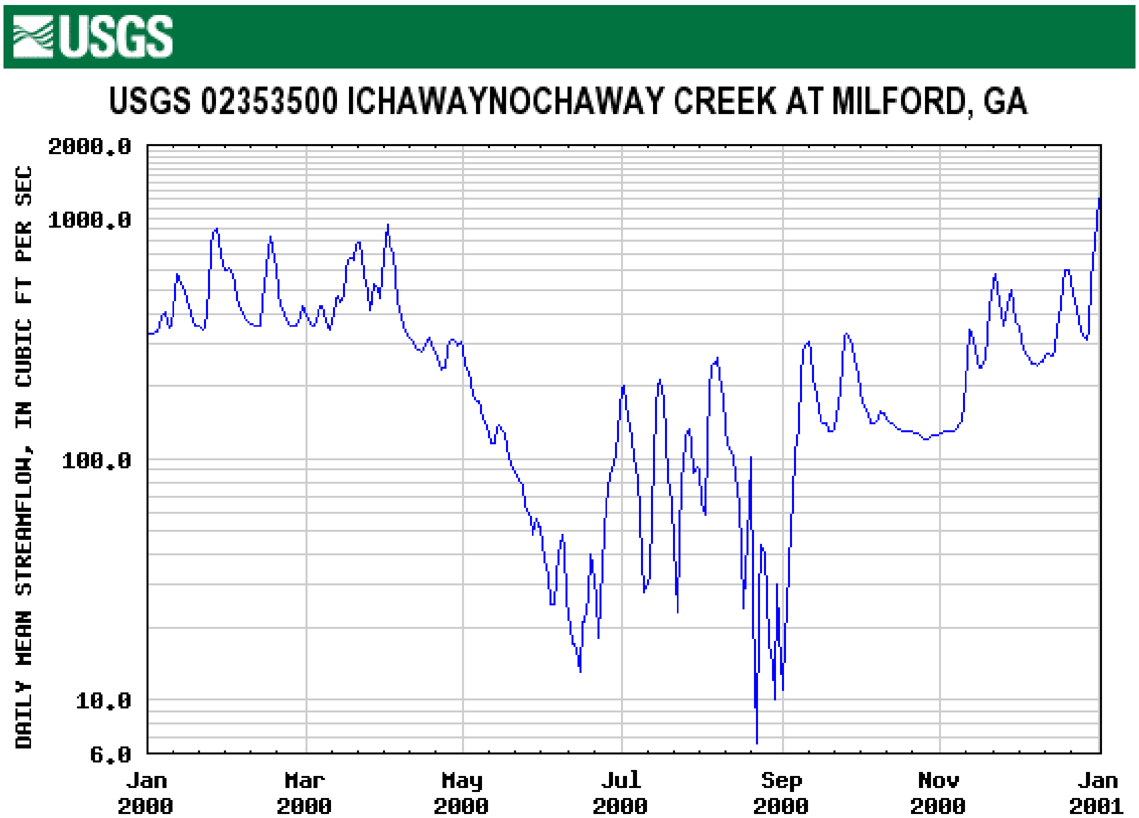


Figure 7.4. Streamflow of Ichawaynochaway Creek near Milford for 2000

As described above, ground-water withdrawals in the Ichawaynochaway Creek sub-basin do not decrease baseflow by more than a few percent (Table 7.1(a)). The greatest baseflow decline result from ground-water withdrawals in the sub-basin downstream of the Milford gauge where Floridan aquifer withdrawals are greatest. Therefore, other than drought, any artificial impacts on the flow of Ichawaynochaway Creek at, and upstream of, Milford can be attributed to surface-water withdrawals.

7.2 Spring Creek sub-basin

Approximately 30% of the land area in the Spring Creek sub-basin (Fig. 7.5) is irrigated. As its name implies, Spring Creek is strongly influenced by ground-water input from the Floridan aquifer. The creek flows almost entirely within Subarea 4, and is thus in hydraulic connection with the Floridan aquifer for most of its length.

Because of the shallow depth and prolific nature of the Floridan aquifer, ground-water pumpage for agricultural irrigation is extremely heavy in Spring Creek sub-basin. Specifically, ground-water usage comprises more than 89% of permitted agricultural withdrawals in the watershed. As with Ichawaynochaway Creek sub-basin, most of this is center-pivot irrigation, which has increased by approximately 34% since 1993 (Litts et al, 2001). The distribution of permitted and proposed irrigation wells and surface-water pumps is shown in Figures 4.2, 4.3, and 7.6.

7.2.1 Basin hydrography

A USGS stream gauge provides real-time data on Spring Creek near Iron City in Seminole County. This gauge has a long period of record, and like the gauge at Milford on Ichawaynochaway Creek has recorded streamflow during the severe droughts that have occurred since 1950. Figure 7.7 is the stream hydrograph from 1954, generally considered to be the worst, or one of the worst, droughts in southwest Georgia history. Streamflow reached its lowest rate gradually, achieving a low flow of 9.1cfs in early November. A local farmer reports that Spring Creek actually ceased flowing just upstream from the Iron City gauge although stream guage records do not confirm this observation (J. Bridges, personal communication 2005). Irrigation was extremely rare in 1954; thus, streamflow was not affected by irrigation withdrawals that would have reduced baseflow significantly.

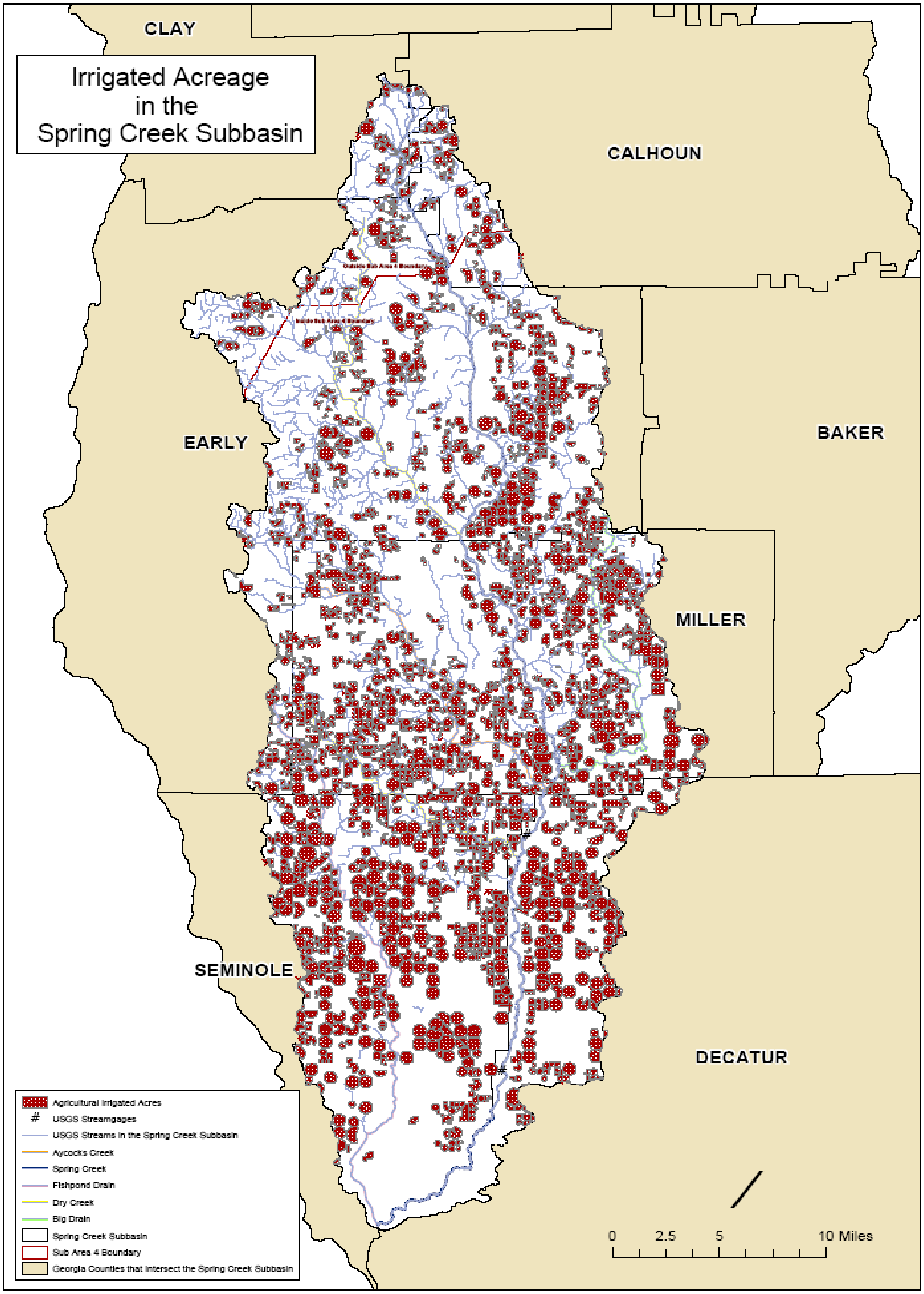


Figure 7.5. Irrigated acreage in Spring Creek sub-basin

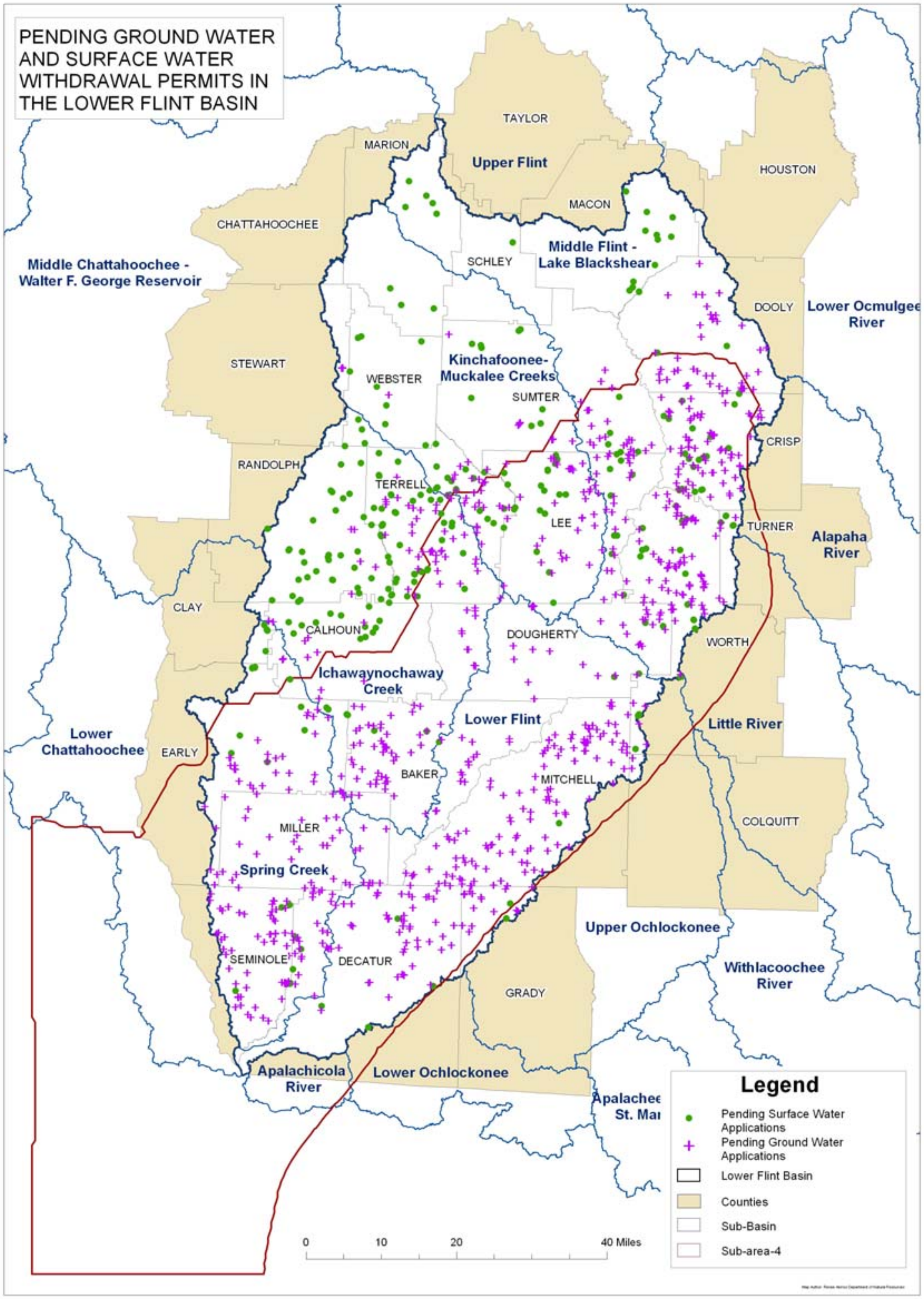


Figure 7.6. Proposed ground-water and surface-water withdrawals in the lower FRB.

Figure 7.7: Streamflow of Spring Creek near Iron City for 1954

The effect of the drought of 1986 on the flow of Spring Creek is shown in Figure 7.8. Discharge declined steadily with no significant runoff events recorded. The annual low (5.1 cfs) was reached in August, almost three months sooner than the 1954 annual low was reached even though the seasonal decline began in both years at approximately the same stream level. A similarly accelerated decline was recorded in Ichawaynochaway Creek during this same time period.

The most severe drought conditions observed in the Spring Creek sub-basin was arguably the drought of 2000. A critical factor that affected the heavily ground-water-fed stream was that winter rains were insufficient to recharge the Floridan aquifer in that area, such that baseflow was already far lower than normal going into 2000. Figure 7.9 shows the stream hydrograph for 2000. Maximum discharge during the spring was less than one-third what it was in 1954 and 1986, and Spring Creek reached extreme low flow conditions

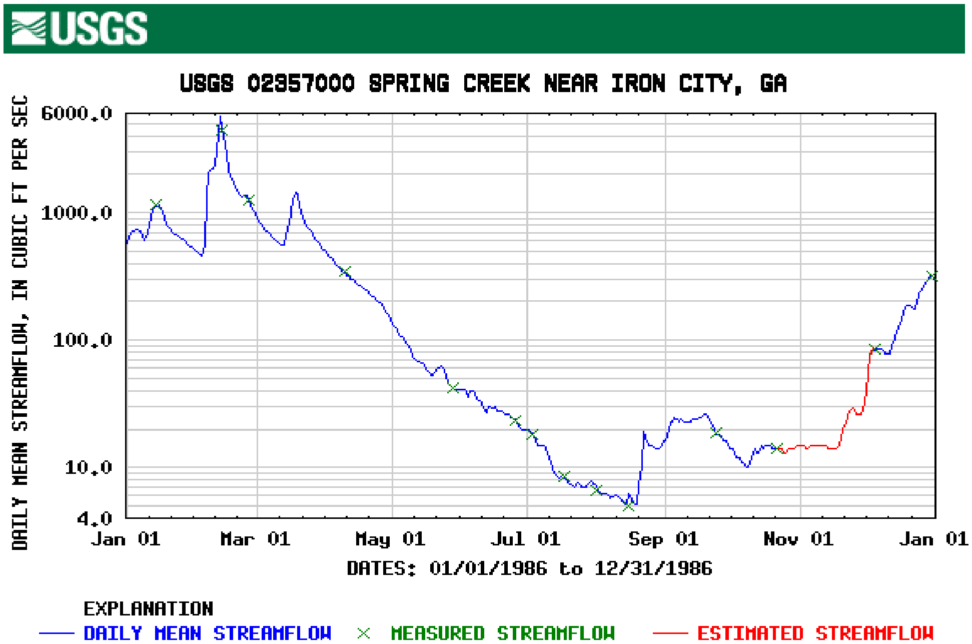


Figure 7.8: Streamflow of Spring Creek near Iron City for 1986

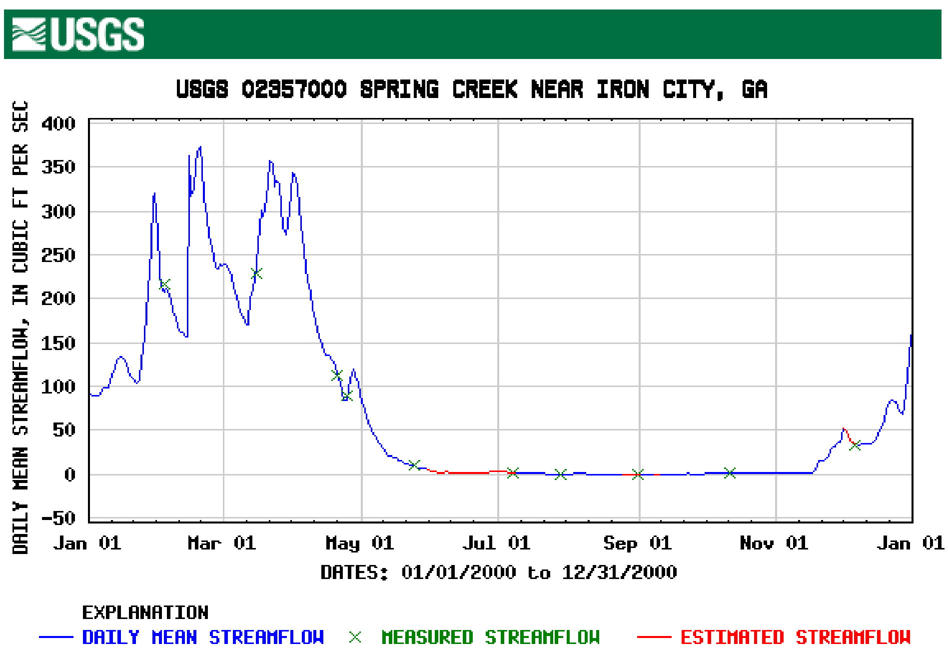


Figure 7.9: Streamflow of Spring Creek near Iron City for 2000

early in the year (May). On July 7, 2000, discharge fell below 1.0 cfs, and the creek ceased to flow from August 25 to September 10. Discharges remained below 1.0 cfs for another month.

Comparing the three worst droughts that affected Spring Creek since 1950, it can be seen that annual low flows were lower and were reached sooner with each successive drought. The lack of abrupt declines in discharge as seen on Ichawaynochaway Creek reflects the relative lack of surface-water withdrawals upstream of Iron City. However, the MODFE stream-aquifer models indicate that Floridan aquifer withdrawals can significantly reduce baseflow to Spring Creek. If this is the case, then it can be logically assumed that ground-water withdrawals significantly affected the discharge in Spring Creek during the drought years described above. This may have been especially true in 2000, when irrigation was necessarily intense because of the drought, but the aquifer had not recharged from the previous year.

An interesting contrast to the Iron City hydrograph for 2000 is the hydrograph for Spring Creek at Reynoldsville (Fig. 7.10), approximately 9 miles downstream from the Iron City gauge. During the drought of 2000, this gauge did not record the extreme low flows observed at Iron City. The gauge did record sharp, but brief, declines in flow in late August and September that could only have been the result of direct surface-water withdrawals upstream of the gauge. More importantly, in the southern parts of Spring Creek sub-basin, the Floridan aquifer is more than 300 feet thick, is extremely karstic, and has very high transmissivity. In that area, filling of Lake Seminole has raised and stabilized ground-water levels in much of lower Seminole and Decatur Counties. In northern Seminole County near Donalsonville, aquifer heads were raised approximately 10 feet when the lake filled. The potentiometric levels progressively increased southward Lake Seminole, such that near Reynoldsville heads were raised as much as 25 feet (Jones and Torak, 2003). Thus, the Reynoldsville gauge is strongly affected by higher and more stable heads in the Floridan aquifer as well as backwater conditions created by the impoundment.

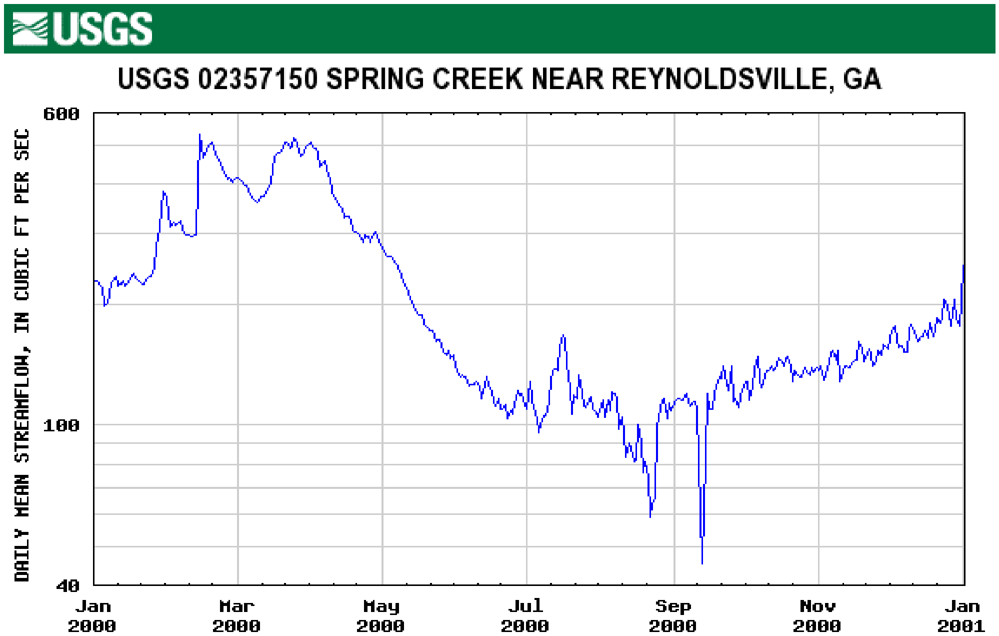


Figure 7.10: Streamflow of Spring Creek near Reynoldsville for 2000

<u>7.3 Lower Flint River sub-basin</u>

The Lower Flint River sub-basin (Figure 5.3) is substantially larger in area than either Ichawaynochaway Creek or Spring Creek sub-basins. Also, it is heavily irrigated with wells drawing almost exclusively from the Floridan aquifer. Surface-water withdrawals are concentrated along the western side of the Pelham Escarpment, which forms the eastern topographical boundary of the sub-basin. The streams associated with these withdrawals commonly sink into, and recharge, the Floridan aquifer in that area and never reach the Flint River; therefore, the majority of surface-water withdrawals in the lower Flint River sub-basin do not directly affect flows of the Flint River as do direct withdrawals from the river or its tributaries. These are volumetrically very small compared to ground-water withdrawals.

As described above, the USGS gauge at Bainbridge was affected by construction of Lake Seminole in 1957. The gauge is at the upstream end of the lake, and is thus affected by lake levels. Lake Seminole is maintained at a nearly constant elevation of 76-77 ft above MSL;

therefore, from 1957 until the gauge was modeified in 2003, the gauge does not accurately reflect flow of the Flint River.

The 1954 hydrograph of the Flint River at Bainbridge (Fig. 7.11) does record the effects of that year's drought. As with Spring Creek, discharge declined steadily through the year until an annual low flow (1,930 cfs) was reached in late October. Irrigation was rare at this time, so this hydrograph would not be significantly affected by irrigation from the Floridan aquifer, the Flint River, or its tributaries.

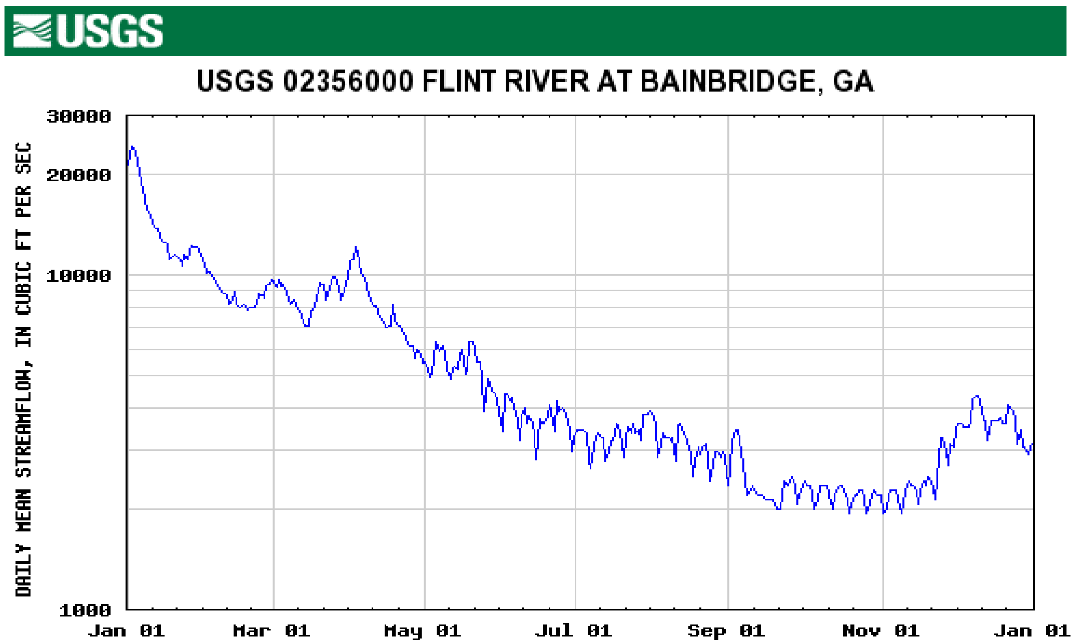


Figure 7.11: Streamflow of the Flint River Creek at Bainbridge for 1954

Because the post-1957 gauge readings at Bainbridge are affected by Lake Seminole and the USGS ceased continuous operation of the station after 1971, a comparison of subsequent droughts with 1954 is of limited value if another gauge is used such as the Flint River gauge at Newton. The Newton gauge is upstream of both the confluences of Spring Creek and Ichawaynochaway Creek, and is affected by surface-water and ground-water withdrawals and flows originating outside of the sub-basin. Thus, the impact of irrigation and drought on streamflow in the lower Flint River sub-basin must be based on other criteria, such as the stream-aquifer MODFE model. As discussed, this model indicates that drought year Floridan aquifer withdrawals do not have as great an impact on flow of the Flint River as they do in Spring Creek or Ichawaynochaway Creek.

SECTION 8: ECONOMIC STATUS OF THE LOWER FLINT RIVER BASIN

8.1 Agriculture

Agriculture is one of the largest economic sectors in the lower FRB. The 18 counties of the lower FRB generate approximately 18% of Georgia's total agricultural value (Doherty and McKissick, 2000), and agriculture in the FRB generates $1.92 billion in farm gate value. This represents 12% of the total FRB economy. The top ten agricultural commodities produced in the FRB are cotton, broilers, peanuts, tomatoes, sweet corn, beef, timber, field corn, container nurseries, watermelons, and "other". This last category includes vegetables, fruits and nuts, aquaculture, poultry and eggs, ornamental horticulture, and agritourism (McKissick, 2004a).

Much of the agricultural production in the FRB is dependent on irrigation. In fact, in the FRB, almost 40% of the harvested cropland is irrigated (McKissick, 2004a). For some commodities, such as vegetables, container nurseries, and ornamental horticulture, irrigation is a prerequisite. For other crops, irrigation significantly increases crop yields, which increases the farm gate value and the total economic impact of agriculture.

Farm income in Georgia, and the FRB, increased fairly steadily from 1969-1996 (McKissick, 2004b). The causes for this increase have been the growth in irrigation, improved production technologies, and a growing consumer demand. Since 1996, farm income has been generally declining as a result of global competition and increased production costs, even though government payments have been steadily increasing over the same time frame. The number of farms has declined since 1945 while the size of farms has increased; yet, the total amount of acreage in harvested cropland has remained relatively steady since the early 1980's (McKissick, 2004b). Employment projections from 2002 to 2012 suggest that agriculture-based employment will decline in southwest Georgia by as much as 14% (Ga. Dept. of Labor). These statistics suggest that row-crop agriculture in Georgia may not expand as rapidly as some other sectors of the economy. Whether or not this affects irrigation water use in the FRB will depend in part on changes in crop mix, as traditional row crops such as cotton, corn, and peanuts are replaced by increased vegetable production or specialty nichemarket crops. However, if the current distribution of crops and rainfall patterns in the FRB does not change substantially, irrigation amounts will not increase much above current levels.

8.2 Manufacturing and other sectors

Manufacturing is the largest economic sector in southwest Georgia, accounting for more than 50% of the FRB economic output and approximately 14% of the employment (Ga. Dept. of Labor; McKissick, 2004a). The biggest industries in the manufacturing sector are food, paper, textile mills, apparel manufacturing, wood products manufacturing, plastics and rubber products, and fabricated metal manufacturing. Of these only beverage and tobacco, and plastics and rubber manufacturing are projected to experience growth from 2002-2012 (Ga. Dept. of Labor).

Other major economic sectors in southwest Georgia are, in decreasing order of employment, health care and social assistance; retail trade, educational services; administrative and support/waste remediation services; wholesale trade; construction; transportation and warehousing; and finance and insurance (Table VV, Ga. Dept. of Labor). The largest projected growth sector of these is administrative and support/waste remediation services (+55%); the sector projected to shrink by the largest margin is finance and insurance (-25%).

8.3 Modeled economic impacts of reducing irrigation

As part of the FRB Water Development and Conservation Plan, a preliminary economic analysis was performed to examine the potential impact of irrigated acreage reductions in the lower FRB. The model scenarios used in the economic analysis were patterned after similar scenarios used in the EPD HSPF surface-water models. Specifically, the impacts of a 20%, 30%, and 40% reduction in irrigated acreage in both the Ichawaynochaway (HUC 03130008) and Spring Creek (HUC 031300010) watersheds were evaluated. Also examined was the potential economic benefit to each region by issuing all the backlogged permits currently being held by EPD. A general discussion of the modeling procedure, specific assumptions made in this analysis, and a presentation of results and limitations is given below.

Given the time constraints and the desire to have a quick "first-glance" at some potential impacts of water management strategies discussed in previous Stakeholder Advisory Committee meetings, the IMPLAN (IMpact analysis for PLANning) model was chosen to provide the requested information. Other models exist such as REMI (Regional Economic Modeling, Inc.) that are more robust and can be configured for any region within a multi-area framework such as HUC 8 sub-basins within the larger area of southwest Georgia. While IMPLAN can aggregate combinations of areas into a single region (i.e. a group of counties into a region), the results cannot be reported at the area (county) level. Unfortunately, the use of REMI for this analysis was both time and cost prohibitive. IMPLAN is an input-output model in which purchases for final use (final demand) drive the model. Industries produce goods and services for final demand and purchase goods and services from other producers. These other producers in turn purchase goods and services. The buying of goods and services (indirect purchases) continues until leakages from the region stops the cycle. These indirect effects can be mathematically derived and the resulting set of multipliers describe the change of output for each and every regional industry that is caused by a one-dollar change in final demand for any given industry (Lindall and Olson, 1999). IMPLAN was used to estimate the reduction in total regional output caused by a reduction in final demand to the farming industry. This reduction in final demand is simply the revenue lost to the farming industry resulting from inability to irrigate. In order to look at the impact of reducing irrigated acreage by watershed within the IMPLAN county framework, the Ichawaynochaway Region was designated as Terrell, Randolph, Calhoun, and Baker Counties. The Spring Creek Region was designated as Early, Miller, Seminole, and Decatur Counties.

The reduction in final demand, in this case the output lost from a lack of irrigation, that drives the IMPLAN model was calculated based on acreage data, assumptions of crop mix, and yield/price information, each of which are discussed below. First, the base number of acres from which the above percentage reductions were computed was provided by EPD. These "eligible" acres were determined by summing (a) all areas in Ichawaynochaway Creek and Spring Creek sub-basins that are irrigated using surface-water and (b) those areas in Ichawaynochaway Creek and Spring Creek sub-basins that are irrigated using ground-water from the Upper Floridan. Total acreage meeting the above criteria includes 100,890 in Ichawaynochaway and 140,130 acres in Spring Creek. This amounts to roughly 66% and 81% of the total permitted acres in Ichawaynochaway Creek and Spring Creek sub-basins, respectively (Hook et al., 2003).

The second integral part of the calculation involved several key assumptions regarding basin-wide crop mix and cropping strategies: (a) it was assumed that any reduction/increase in irrigated acreage would only impact the production of corn, cotton, and peanuts. While we recognize the significant impact of vegetable production in this region, especially in the Spring Creek sub-basin, our basis for exclusion of these commodities is two-fold: First, the number of acres in vegetable production is relatively small when compared to that of the "big-three"; and second, irrigation is considered necessary rather than supplementary for meaningful vegetable production (Doherty and McKissick, 2000). We deem it highly unlikely that vegetable production would be considered without irrigation. (b) reduction in crop acreage is assumed to follow a distribution similar to current trends in irrigated acreage. That is, 15% corn, 50% cotton, and 35% peanut for the southwest Georgia area (USDA Farm Service Agency, 2005). Therefore, if irrigated acreage will be reduced in Ichawaynochaway by 100 acres, we assume that 15 acres of corn production will be lost, 50 acres of cotton, and 35 acres would come out of irrigated peanut production; and (c) production will still occur on the retired acres on a dry-land basis. The acres per crop used for all can be found in Table 1.

Finally, assumptions on yield and price were incorporated. Utilizing data collected in 2004 from the USDA National Peanut Research Laboratory's Multi-Crop Irrigation Research Farm located in Randolph County (Upper Ichawaynochaway), an average irrigated and average dry-land yield was determined for corn, cotton, and peanut. In the absence of reliable county-level yield information, these average crop yields were assumed to be consistent throughout both Ichawaynochaway Creek and Spring Creek sub-basins. Price information was obtained from "2004 Estimated Georgia Prices" as compiled by the University of Georgia College of Agricultural and Environmental Sciences. A summary of irrigated and dry-land crop yields as well as price information can be found below in Table 2.

The reduction or increase in final basin demand was calculated by multiplying the per-acre change in revenue between irrigated and dry land by the acreages associated with the various scenarios. For example, a 20% reduction in irrigated acreage in Ichawaynochaway amounts to 20,178 acres (3,027 corn, 10,089 cotton, and 7,062 peanuts). From Table 2, we can calculate the per acre change from dry land to irrigated production to be $197.20, $620.16, and $521.36 for corn, cotton, and peanuts respectively. By multiplying though by each respective crop and then summing, we arrive at the total reduction in final revenue of $10,535,562.96. This loss in final demand, which serves as the main input to the IMPLAN model, may be explained more clearly as the money that is no longer available to purchase goods and services from other sectors.

The IMPLAN model was run independently for both the Ichawaynochaway and Spring Creek Regions. Results showed up to a $24.9 million loss in total output and a loss of 341 jobs with a 40% reduction in irrigated acreage. Conversely, issuing the backlog created 140 jobs and an additional $12 million in output. Sectors most impacted by the reduction in demand were Farm, Ag Services, Retail and Wholesale Trade and Financial, Insurance, and Real Estate (FIRE). Similar results were found in Spring Creek but with a higher magnitude. Reducing irrigated acreage by 40% caused a reduction in total output of $44.6 million and nearly 600 jobs. Issuing the backlog in the Spring Creek region would increase output by $13.5 million and create an additional 197 jobs. A detailed breakdown of the IMPLAN model results can be found in Tables 3-7. Table 3 provides a summary of the direct and total change in output and jobs for both regions. Tables 4-7 provide detailed sector analysis for both regions at 20%, 30%, and 40% reductions and backlog issuance respectively. It should be noted again that the results provided from this preliminary study do not reflect the total impact of agriculture on the lower FRB economy. Rather, we have demonstrated the effect, through final demand spending of farmers, of a loss of revenue attributed to a reduction of irrigated acreage in these two sub-basins. While we can trace the impact of this reduction in spending through various other sectors (multipliers), there are further impacts that are beyond the scope and measurement capabilities of this IMPLAN study. For example, the value of output and jobs lost or gained by processing such as cotton gins or peanut shellers is not captured in the results discussed above. Further, the reader should be mindful of the assumptions leading to the results discussed and be prudent when making comparisons to other economic analyses.

	Baseline	**20%**	**30%**	**40%**	**Bklg.**
Ichawaynochaway	*100,890*	*-20,178*	*-30,267*	*-40,356*	*+16,517*
Peanut		-7,062	-10,593	-14,124	+5,781
Cotton		-10,089	-15,133	-20,178	+8,258
Corn		-3,027	-4,541	-6,054	+2,478
Spring	*140,130*	*-28,026*	*-42,039*	*-56,052*	*+17,255*
Peanut		-9,809	-14,714	-19,618	+6,039
Cotton		-14,013	-21,019	-28,026	+8,627
Corn		-4,204	-6,306	-8,408	+2,589

Table 8.1: Acreage Totals per Crop/Basin Under Each Scenario

Crop	**Irrigated Yield**	**Non-Irrig Yield**	**Irrig (ac/in)**	**$/unit**
Peanut	5256 lb/ac	2512 lb/ac	10.5	$.19
Cotton	1402 lb/ac	433 lb/ac	11.15	$.64
Corn	185 bu/ac	117 bu/ac	14.95	$2.90

Table 8.2: Yield and Price Data per Crop

Ichawaynochaway Region				
	Output (1.395)		**Employment (1.686)**	
	Direct	Total	Direct	Total
Ich – 20%	-$10,535,660	-$14,699,214	-101	-170
Ich – 30%	-$15,803,660	-$22,048,819	-151	-254
Ich – 40%	-$21,071,320	-$29,398,430	-202	-341
Ich – Bklg.	+$8,624,120	+$12,032,259	83	+140
Spring Creek Region				
	Output (1.525)		**Employment (1.946)**	
	Direct	Total	Direct	Total
Spr – 20%	-$14,633,383	-$22,331,058	-152	-296
Spr – 30%	-$21,950,075	-$33,496,590	-228	-445
Spr – 40%	-$29,266,767	-$44,612,051	-310	-596
Spr – Bklg.	+$9,009,457	+$13,460,439	+102	+197

Table 8.3: Summary IMPLAN Output by Region, All Scenarios

	Ichawaynochaway Region		**Spring Creek Region**	
	Output	Employment	Output	Employment
Manufacturing				
Non-Durables	-$74,086	-0.7	-$364,286	-1.8
Durables	-$108,026	-0.6	-$167,930	-0.8
Non-Manufact.				
Ag Services	-$738,282	-29.8	-$1,668,524	-71.5
Mining	$0	0	-$4,740	0
Construction	-$53,054	-1	-$145,239	-2.1
Trans/Utilities	-$374,669	-2.7	-$519,583	-3.6
Ret/Whl Trade	-$1,046,811	-7.7	-$1,578,065	-30.2
Fin/Ins/Real Est	-$796,157	-3.1	-$1,562,687	-8.3
Services	-$414,627	-7.3	-$1,029,382	-17.8
Government	-$184,349	-1.9	-$206,966	-2.5
Farm	-$10,909,152	-105.5	-$15,083,655	-157.7
TOTAL	***-$14,699,214***	***-170***	***-$22,331,058***	***-296.5***

Table 8.4: Detailed IMPLAN Output by Region, 20% Reduction

	Ichawaynochaway Region		Spring Creek Region	
	Output	Employment	Output	Employment
Manufacturing				
Non-Durables	-$111,130	-1.1	-$546,430	-2.7
Durables	-$162,040	-0.8	-$251,895	-1.3
Non-Manufact.				
Ag Services	-$1,107,423	-44.5	-$2,502,786	-107.3
Mining	$0	0	-$7,111	0
Construction	-$79,581	-1.4	-$217,859	-3.2
Trans/Utilities	-$562,003	-4.2	-$779,375	-5.3
Ret/Whl Trade	-$1,570,217	-26.5	-$2,367,098	-45.4
Fin/Ins/Real Est	-$1,194,235	-4.7	-$2,344,031	-12.5
Services	-$621,941	-10.9	-$1,544,073	-26.7
Government	-$276,523	-2.8	-$310,450	-3.8
Farm	-$16,363,727	-157.6	-$22,625,485	-236.6
TOTAL	***-$22,048,819***	***-254***	***-$33,496,590***	***-444.7***

Table 8.5: Detailed IMPLAN Output by Region, 30% Reduction

	Ichawaynochaway Region		Spring Creek Region	
	Output	Employment	Output	Employment
Manufacturing				
Non-Durables	-$148,174	-1.3	-$724,498	-3.6
Durables	-$216,052	-1.2	-$336,546	-1.7
Non-Manufact.				
Ag Services	-$1,476,564	-59.5	-$3,294,180	-141.1
Mining	$0	0	-$9,459	-0.1
Construction	-$106,108	-1.8	-$289,287	-4.4
Trans/Utilities	-$749,338	-5.6	-$1,034,991	-7
Ret/Whl Trade	-$2,093,621	-35.4	-$3,148,931	-60.4
Fin/Ins/Real Est	-$1,592,313	-6.3	-$3,126,011	-16.6
Services	-$829,255	-14.5	-$2,061,299	-35.6
Government	-$368,697	-3.8	-$413,899	-5.1
Farm	-$21,818,306	-211	-$30,172,949	-320.8
TOTAL	***-$29,398,430***	***-341***	***-$44,612,051***	***-596.4***

Table 8.6: Detailed IMPLAN Output by Region, 40% Reduction

	Ichawaynochaway Region		Spring Creek Region	
	Output	Employment	Output	Employment
Manufacturing				
Non-Durables	+$51,056	+0.6	+$212,800	+1.2
Durables	+$74,446	+0.5	+$99,355	+0.6
Non-Manufact.				
Ag Services	+$604,332	+24.5	+$959,078	+46.6
Mining	$0	0	+$2,851	0
Construction	+$43,428	+0.7	+$83,649	+1.5
Trans/Utilities	+$306,690	+2.3	+$302,677	+2.3
Ret/Whl Trade	+$856,883	+14.6	+$946,823	+19.9
Fin/Ins/Real Est	+$651,706	+2.6	+$879,247	+5.4
Services	+$339,400	+6	+$570,261	+11.7
Government	+$150,901	+1.6	+$115,282	+1.7
Farm	+$8,929,848	+86.6	+$9,288,415	105.8
TOTAL	***+$12,032,259***	***+139.8***	***+$13,460,439***	***+196.6***

Table 8.7: Detailed IMPLAN Output by Region, Issuance of Backlog

SECTION 9 : WATER CONSERVATION IN THE FLINT RIVER BASIN

8.1 Definition

Irrigation is a critical aspect of agricultural life in Georgia. Many farmers in the state have been practicing water conservation for decades. The potential water savings increase every year, thanks to improved technology and innovative on-farm management practices (Vickers 2001). Water conservation is not only good stewardship of the resource, but it also saves money and in many cases, increases productivity.

EPD defines water conservation as the beneficial reduction in water use, waste, and loss. This definition includes issues related to the efficient use of water and resource management. Such a broad definition applies to all water users, and does not single out any one user group. For example, when faced with the challenges presented by limited water resources, all those who use that resource must ask about the rate at which water is withdrawn (efficiency), how much water can be withdrawn without depleting the resource, and if there other alternatives to that source (resource management). By defining water conservation in this way, all water users can contribute to discussions about the management and conservation of our water resources.

EPD is currently drafting the first comprehensive statewide water management plan that will be completed by January 2008. Because water conservation is one of the cornerstone elements of the statewide plan, water conservation practices and measures included in the Flint Plan should inform the statewide planning efforts. To ensure these two plans are compatible, the definitions used in each must be consistent, particularly related to water conservation. The statewide plan will encourage all water use groups to implement water-conserving practices in order to meet the statewide management objective of minimizing water withdrawals. Water-conservation practices for farms are well documented and generally include source management, the use of reclaimed water, and irrigation efficiency. Efforts to minimize water withdrawals are particularly important in sub-areas of the FRB where water resources are already strained.

9.2 Proposed strategies

For the purpose of this plan, water-conserving efforts related to source management, reuse, and efficiency will be collectively referred to as water conservation. The water conservation strategy described below was compiled to capture four critical elements of successful water conservation planning: education and outreach, technical assistance, funding, information management and data analysis, and permitting.

Conservation education and outreach

- Enhance partnerships between EPD and other State agencies (such as DNR Wildlife Resources Division, Soil and Water Conservation Commission, the Cooperative Extension Service) and other entities in the area to develop messages about the importance of implementing efficient irrigation practices and *reducing* water withdrawals. Target educational efforts in those sensitive sub-basins and extend efforts to the rest of the basin.

Technical assistance

- EPD will partner with and assist these agencies and non-profit entities in the region to provide technical consultation, training, and recommendations for agricultural efficiency improvements and technical assistance for activities that can effectively reduce water withdrawals. Target technical assistance in the sensitive sub-basins.
- Information about *statewide* water use and regional water issues will be available to the farming community on the EPD website.
- EPD will work with other agencies to develop guidance documents to promote voluntary best management practices (BMPs) for minimizing water withdrawals while maintaining and enhancing economic, social, and environmental sustainability of soil and crop production. Such guidance documents will be provided to all applicants seeking a water withdrawal permit.

Funding for water conservation practices

- EPD will work with Georgia Soil and Water Conservation Commission to secure more federal funding for water-conservation programs, especially programs targeted to help communities in the FRB reduce withdrawals in sensitive sub-basins. The programs currently include water efficiency efforts such as end-gun shut off, leak detection and repair, and retrofitting of irrigation systems. Programs also include those related to site management, including conservation tillage, shifting from high-water using crops, etc.
- EPD will work with NRCS and the Georgia Environmental Facilities Authority (GEFA) to give preference, in the consideration of funding, to applicants who implement water-conserving practices.

Information management and data analysis

- As scheduled in the amended Water Quality Act and Groundwater Use Act, EPD will use information collected and compiled by the GSWCC through the irrigation metering program. This information will help EPD and other state and federal agencies to identify target areas where enhanced water conservation practices are needed. This type of monitoring can help target education and outreach and financial assistance programs (as described above) most appropriately.
- EPD will work with other state and federal agencies to develop a process for determining success of water conservation practices. This process should be built around the data colletion currently being conducted by the GSWCC and used to identify those areas that need additional resources for more conservation implementation and/or education efforts.

Permit conditions

In ecologically and hydrologically sensitive sub-basins, all new, modified or transferred water withdrawal permits (for farm and non-farm activities) can be conditioned in the following way:

- By statute, all permitees are required to install flow meters and report annual water use, developed in conjunction with the SWCC metering program;

- To eliminate water loss and water waste, all new farm permits will be required to submit a conservation plan as a condition of the permit. Such plans could involve use of cost-effective, water-efficient conservation technology. These technologies could include, but not be limited to, end gun shutoffs, rain gauge shut offs, and pivot-nozzle retrofitting. Also, applicants for new, modified, or transferred water withdrawal permit applicants could be required to implement water conservation measures. Practices and technology that qualify as water efficient will be identified by EPD and other agencies, and periodically reviewed to ensure information is current.

Water loss control

- EPD will partner with SWCC and other agencies to develop a program to help irrigators identify and repair leaks and eliminate off-target application. Program development should include the irrigation manufacturers and providers in southwest Georgia. Initially the program should target the largest irrigation water users in the basin and then expand to the other irrigation users.
- EPD and its partners will encourage development of individual field irrigation scheduling to ensure optimal water, land, and crop input efficiency

Water withdrawal control during drought

- As much as possible, EPD will work with surface-water withdrawal permit holders to coordinate and/or schedule water use among multiple users of surface-water sources that are home to sensitive aquatic species.

GLOSSARY

Aquifer: a saturated geologic formation capable of storing and transmitting economic quantities of water

Base flow: the portion of s stream's discharge derived from ground-water seepage

Basin: An area drained by a river or stream network. Drainage divides separate adjacent basins.

Boundary condition: Used for simulating ground-water or surface-water flow, the mathematical representation of springs, irrigation drains, wells, streams, faults, lakes, precipitation, evapotranspiration, drainage divides, and region beyond the model area.

Calibration: The process by which a computer model's validity is checked against known, measured conditions.

Cone of depression: The 3-dimensional area of drawdown around a pumping well

Confined aquifer: an aquifer sealed above and below by impermeable layers, such that water in a tightly cased well completed in the aquifer would rise above the top of the aquifer

Confining Unit: an impermeable layer of very low hydraulic conductivity that prevents water from leaking out of an aquifer

Correlation coefficient: a measure of how well two variables are related to each other. A perfect correlation has a correlation coefficient of 1.0; that is, changes to one variable cause a direct change in the other variable. The closer a correlation coefficient is to 1.0, the better the relationship between the two variables being analyzed. Correlation coefficients close to –1.0 indicate a strong opposite correlation between two variables.

Confluence: the point where two streams meet

Crystalline: rocks composed of interlocking crystals as opposed to fragments or particles

Dip: The "tilt", or inclination, of a rock layer, fault, fracture, or any other planar geologic feature.

Discharge: the amount of water flowing through or past a point or model boundary

Duration curve: a graph showing the percentage of time a flow is equaled or exceeded

Ecology: the scientific study of the processes influencing the distribution and abundance or organisms, the interactions among organisms, and the interactions between organisms and the transformation and flux of energy and matter

Effluent stream: A stream that gains water from the ground or an aquifer. Also called a gaining stream.

Equilibrium: a state of balance, in which flow conditions and model parameters are no longer changing. Roughly equivalent to "steady state".

Evapotranspiration (ET): The loss of ground-water to the atmosphere by direct evaporation from the soil and transpiration from plants (which take ground-water and release it as vapor into the air).

Farm use: irrigation of any land used for general farming, forage, aquaculture, pasture, turf production, orchards, or tree and ornamental nurseries; provisions of water supply for farm animals, poultry farming, or any other activity conducted in the course of a farming operation. Farm uses shall also include the processing of perishable agricultural products and the irrigation of recreational turf, except in Chatham, Effingham, Bryan, and Glynn counties, where irrigation of recreational turf shall not be considered a farm use. (O.C.G.A. 12-5-92)

Flow boundary: the point, line, or area across which water flows in a basin. They are approximated in a model by flow boundaries.

Flux: same as flow. "Stream-aquifer flux" refers specifically to the exchange of water between streams and the aquifer

Formation: an aerially extensive geologic layer of unique physical characteristics that can be traced laterally, either underground or at the ground surface, for one mile or more.

HSPF: a computer surface-water model that simulates streamflow, taking into account precipitation, runoff, infiltration, etc. Stands for "Hydrologic Simulation Program - Fortran".

Hydrologic Unit Code (HUC): a USGS watershed designation based on the size of the watershed. The smaller a watershed is, the larger its HUC designation (e.g. a HUC-10 is smaller than a HUC-8). The HUC number refers to the number of digits in the HUC code (e.g. 031300090104 is a HUC-12).

Hydraulic Conductivity: a physical property of a geologic formation that determines the relative ability of water to flow through that formation; expressed as a velocity, such as feet per day. It relates aquifer permeability, hydraulic head, cross sectional area, and discharge. Sometimes called "coefficient of permeability", and represented by the letter 'K'. Formations with high values of K are good aquifers, such as the

Floridan aquifer (K = 2000); those with low values of K are poor aquifers, like the Lisbon Formation that underlies the Floridan (K < 1).

Hydraulic head: the potential for water to flow in an aquifer, commonly known as water level, but comprised of pressure, elevation, and velocity components.

Hydrograph: a graph showing ground-water levels, stream discharge, or stream stage (height above a reference level)

GIS: Geographic Information System. A complex set of computer mapping software and techniques in which many different types of information can be retained and displayed in map form.

GPS: Global Positioning System. A network of satellites that constantly transmit accurate locational data to any hand held or fixed receivers on the ground.

Igneous: a type of rock formed from the cooling and crystallization from a melt

Influent stream: A stream that loses water to the ground or aquifer. Also called a losing stream.

Infiltration: The process by which precipitation or surface-water soaks into the ground

Interflow: shallow lateral ground-water flow that occurs between the surface and the water table

Leakage: flow or seepage of water across a model boundary, either laterally (such as to streams, irrigation wells, or springs) or vertically

Metamorphic: a rock type that has enjoyed increased conditions of temperature and pressure below the melting point

MODFE: A ground-water flow model developed by USGS, which uses a grid composed of thousands of small triangles to simulate ground-water flow between triangles. Stands for Modular Finite Element model.

Overburden: sediment overlying an aquifer

Overland flow: water flowing directly across the land surface, outside of stream channels

Parameter: a factor or variable used to describe a physical process such as ground-water flow, values of which are input to a model, such as transmissivity, infiltration rate, head, etc

Percolation: downward seepage of water from the ground surface

Recession: decline in ground-water or stream levels on a hydrograph

Residual water level: in MODFE, a calibration criterion calculated as the difference between simulated water level and a measured water level. The greater the difference, the higher the residual water level. Ideally, residuals in a calibrated model should be small, randomly distributed over a model area, and have an average value near zero.

Riparian: the zone along either side of a stream or wetland

Routing: a modeling process that calculates the amount of time it takes a “slug” of water to move through a basin

Runoff: the process by which precipitation or surface-water flows across the land surface towards streams, lakes, or ponds

Porosity: the percentage of a geologic formation that is empty space. Primary porosity consists of open spaces between individual grains or particles; secondary porosity consists of fractures and bedding planes that cut through the formation.

Permeability: the ease with which water flows through a formation. A formation may be very porous but not very permeable.

Potentiometric surface: A surface that represents the level to which water would rise in tightly cased wells (Fetter)

Recharge: the addition of water to an aquifer by vertical leakage. Typically, leakage is downward from the surface or an aquifer outcrop area, but it may be upwards out of a confined aquifer into a layer of lower pressure.

Residuum: the “residual” material left on top of an aquifer, derived from the weathering of the aquifer itself

Saprolite: heavily weathered crystalline bedrock, which retains the original fabric of the rock, but in which the more easily dissolved minerals have been weathered to clay.

Saturated zone: The part of a soil profile or aquifer that is completed saturated with water.

Sedimentary: a rock type formed from the settling or precipitation of rock, mineral, plant, or animal fragments, or mineral crystals from a solution.

Sensitivity: a measure of how much a parameter affects a model outcome. A model may be very sensitive to a parameter, meaning that small changes in that parameter cause large changes in the model results.

Steady state: the point where a model has achieved equilibrium

Storage: the process of storing or releasing water stored in an aquifer when the hydraulic head changes. This may come from water in pore spaces (such as in an unconfined aquifer), or the actual decompression of water and the aquifer when pumping occurs and head is lowered in a confined aquifer.

Transient: time-varying hydrologeologic conditions. A transient model analyzes flow under time-varying conditions of withdrawals, stream stage, changing head, etc.

Transmissivity: the rate at which water moves through a width of a fully saturated aquifer or confining bed under a hydraulic gradient of 1. It is a function of the nature of the aquifer and its thickness; specifically, it is the product of hydraulic conductivity and aquifer thickness. Aquifers with high values of transmisssivity, such as the Floridan aquifer ($T > 1{,}000{,}000 ft^2/day$) are very productive aquifers.

Unconfined aquifer: an aquifer sealed below by an impermeable layer, but open to atmospheric pressure above. Also called "water table aquifers". The water level in an unconfined aquifer is at or below the top of the aquifer, and defines the water table.

Unimpaired flow: a model simulation of streamflow that removes the effects of dams, withdrawals, etc. It seeks to re-create pre-development streamflow.

Unlithified: not yet turned to rock

Water budget: a tally of where, and how much, water is entering or leaving a model area

Water table: the surface or narrow zone below which all open spaces are filled with water. Also referred to as the top of the saturated zone.

Watershed: An area drained by a stream network. Multiple watersheds comprise a river basin.

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APPENDIX I:
SURFACE-WATER MODEL AND APPLICATION

I.1.1 Surface Water Model Development

EPD identified the following key objectives for the FRB surface-water modeling component of the study. The surface water modeling should:

- Simulate and predict stream flow conditions (historic, current and future scenarios) in any place of interest in the modeled sub-basins;
- Evaluate and assess the impact of various management alternatives on stream flow conditions as a management tool;
- Be able to predict changes in water quantity response to a variety of future management scenarios; and
- Be flexible so the tool can be refined to include results of future studies.

Although USGS stream flow gauge data provides valuable hydrologic information for this study, the number of gauge stations with sufficient period of record is limited. Methods are needed to provide calculations of stream flow data in ungauged places of interest such as known habitats of federal protected mussels to develop a detailed water resources management model. Based on these objectives, the BASINS modeling platform (Duda et al, 2001) was selected for the watershed modeling. The HSPF modeling component within BASINS was used to develop the hydrological model and water resources management model for the FRB management.

I.1.2 Introduction

The Hydrological Simulation Program-FORTRAN, also known as HSPF, is a comprehensive, continuous watershed model and computer software package developed under EPA sponsorship for use on digital computers to simulate hydrology and associated water quality processes on pervious and impervious land surfaces and in natural and man-made water systems such as streams, well-mixed lakes, reservoirs, and impoundments

(Duda et al, 2001). HSPF is an analytical computational tool, which can be used in the planning, management, design, and operation of water resources systems. The model uses historical time-series information of rainfall, evaporation, temperature, and parameters related to land use and coverage patterns, soil properties, river channel characteristics, and agricultural practices and other water uses to simulate a comprehensive range of water quantity and quality processes that occur in a watershed or river basin. (At present, the HSPF models developed for the Flint River sub-basins do not incorporate water quality, although the models have this capability.) The output of an HSPF simulation is a time series of the quantity and quality of water transported over the land surface to the streams/rivers, and also through various soil zones down to the groundwater aquifers. Runoff flow rate, sediment loads, nutrients, pesticides, toxic chemicals, and other quality constituent concentrations can be calculated. The model then uses these results and stream channel information to simulate instream processes.

I.1.3 Applications

HSPF is considered the most comprehensive and flexible watershed model available for hydrology and water quality simulation. It is currently one of the very few available models that can simulate a continuous, dynamic event, or steady-state behavior of both hydrologic / hydraulic and water quality processes in a watershed. HSPF uses existing meteorologic and hydrologic data; soils and topographic information; and land use, drainage, and system (physical and man-made) characteristics to simulate water quantity and quality response occurring in a watershed with reasonable accuracy. The potential applications and uses of the model include: (Aqua Terra Consulting website)

- Flood control planning and operations
- Hydropower studies
- River basin and watershed planning
- Storm drainage analyses
- Water quality planning and management
- Point and nonpoint source pollution analyses
- Soil erosion and sediment transport studies
- Evaluation of urban and agricultural best management practices
- Fate, transport, exposure assessment, and control of pesticides, nutrients, and toxic substances

I.1.4 Model Structure and Functionality

HSPF contains three application modules and five utility modules. The three application modules simulate the hydrologic/hydraulic and water quality components of the watershed. The utility modules are used to manipulate and analyze time-series data. Brief descriptions of the modules follow: (Bicknell et al. 2001)

Application Modules:

The three application modules are:

- PERLND - Simulates runoff and water quality constituents from pervious land areas in the watershed. It is the most frequently used part of HSPF. To simulate these processes, PERLND models the movement of water along three paths: overland flow, interflow, and groundwater flow. Each of these three paths experiences differences in time delay and differences in interactions between water and its various dissolved constituents. A variety of storage zones are used to represent the processes that occur on the land surface and in the soil horizons. Some of the capabilities available in the PERLND module include the simulation of: water budget, snow accumulation and melt, sediment production and removal, nitrogen and phosphorous behavior, pesticide behavior, movement of a tracer chemical.
- IMPLND - Simulates impervious land area runoff and water quality. IMPLND is used in urban areas where little or no infiltration occurs. IMPLND includes all of the pollutant wash off capabilities of the commonly used urban runoff models, such as the STORM, SWMM, and NPS models.
- RCHRES - Simulates the movement of runoff water and its associated water quality constituents in stream channels and mixed reservoirs. RCHRES is used to route runoff and water quality constituents simulated by PERLND and IMPLND through stream channel networks and reservoirs. The processes that can be modeled include: Hydraulic behavior, Water temperature; Inorganic sediment deposition, scour, and transport by particle size; Chemical partitioning, hydrolysis, volatilization, oxidation, biodegradation, and radionuclide decay; DO and BOD balances; Inorganic nitrogen and

phosphorous balances; Plankton populations, pH, carbon dioxide, total inorganic carbon, and alkalinity.

Utility Modules

The five utility modules are used to access, manipulate, and analyze time series information stored by the user in HSPF's TSS (Time Series Store) and WDM (Watershed Data Management) files. These time series, such as hourly precipitation, daily evaporation, daily stream flow, are used by the application modules. The five utility modules are:

- COPY - copy data in the TSS to another file
- PLTGEN - generates a plot file for data display on a plotter
- DISPLY - creates data display tables
- DURANL - performs frequency, duration, and excursion analyses; computes statistics; and performs toxicity/lethality analysis
- GENER - permits the transformation of a time series to produce a second, different time series

I.1.5 Basic Concept and Principle in HSPF Model

HSPF has its origin in the Stanford Watershed Model developed by Crawford and Linsley (1966). The model is classed as a general-purpose model; “general purpose” is defined as a comprehensive representation of the hydrologic cycle, which can be used to represent a broad variety of catchments regimes. This model has been widely recognized as one of the best watershed models available and has been applied to many catchments throughout the world.

The model is a conceptual representation of the complete land phase of the hydrological cycle and is based on the following principles: (Computer Simulation In Hydrology)

- The model should represent the hydrological regimes of a wide variety of streams and rivers with a high order of accuracy.
- It should be easily applied to different watersheds with existing hydrological data.
- The model should be physically relevant so that estimates of other useful data in addition to stream flow, such as overland flow or actual evapotranspiration, can be obtained.

Fig. I-1 is a flowchart depicting the structure of the SWM IV. (Crawford and Linsley, 1966)

In SWM, the various hydrologic processes are represented mathematically as flows and storages. Each flow is an outflow from a storage, usually expressed as a function of the current storage amount and the physical characteristics of the subsystem. Thus, the overall model is physically based, although many of the flows and storages are represented in a simplified or conceptual manner. For simulation with the model, the basin has to be represented in terms of land segments and reaches/reservoirs. A land segment is a subdivision of the simulated watershed. A segment of land that has the capacity to allow enough infiltration to influence the water budget is considered pervious. Otherwise it is considered impervious. The two groups of land segments are simulated independently. (Hydrocomp, Inc. Website)

SWM divides land and ground into three different zones: upper zone, lower zone and groundwater storage, plus a zone above the ground. The model simulates the water movement along three paths: overland flow, interflow and groundwater flow. Water goes from clouds to ground surface, then to upper zone, lower zone and finally to groundwater. In each zone, the hydrologic processes include flow, interception or storage, and evapotranspiration. All these processes are part of the hydrologic cycle and follow the water balance equation.

When rain or snow falls to land surface, part of the precipitation is retained on the plants, called interception. From there, it is evaporated without adding to moisture storage of the soil. The portion of precipitation intercepted by plants is measured by the parameter CEPSC. The rest of precipitation goes to the upper zone, in which, water first fills upper zone storage measured by parameter UZSN, then some of the water goes through the upper zone directly to the lower zone, some becomes the interflow measured by parameter INTFW in the upper zone, and finally, overland flow is formed when infiltration capability is exceeded. Infiltration capability is measured by parameter, INFILT. The overland flow and interflow go directly to the stream, while the water in upper zone storage eventually goes to lower zone or groundwater storage through depletion in addition to evapotranspiration. The water that goes to the lower zone first fills lower zone storage (capacity measured by parameter LZSN), then the rest of the water goes to groundwater storage, in which, some of the groundwater will go to the deep or inactive groundwater storage (amount measured by parameter DEEPER), while some will recharge into stream flow (amount is measured by parameter AGWRC). Notice that waters in any storage zone are all subject to evapotranspiration.

The hydraulic processes that occur in the river channel network are simulated by reaches. The outflow from a reach or a completely mixed lake may be distributed across several targets to represent normal outflow, diversions and multiple gates on a lake or reservoir. Evaporation, precipitation and other fluxes that take place in the surface are also represented. Routing is done using a modified version of the kinematic wave equation.

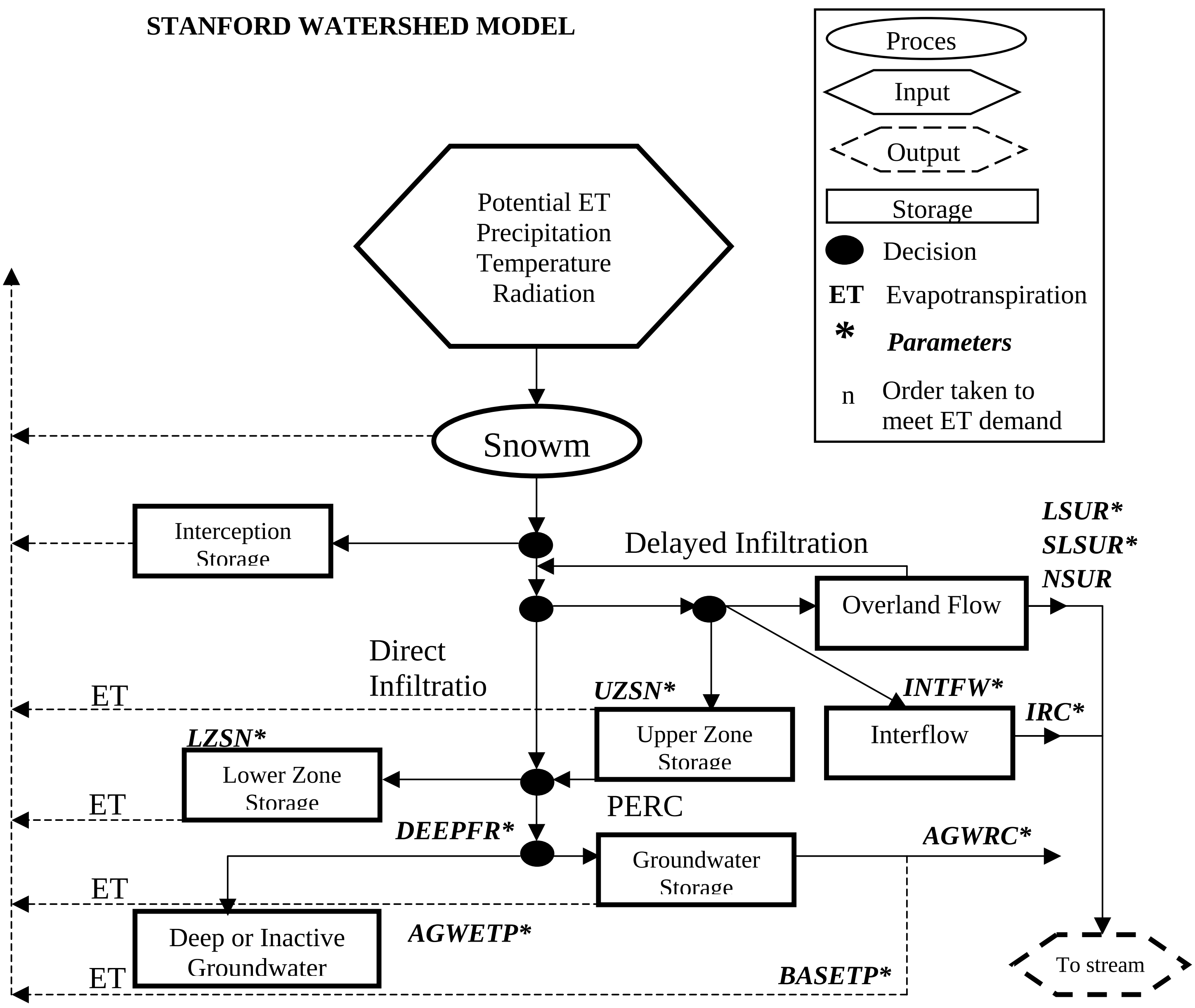

Figure I.1: Flow Chart of Concept Model of SWM

I.1.6 Data Needed for HSPF

- Meteorological Data

Precipitation and Other Meteorological data: hourly time series data including evaporation, air temperature, cloud cover, dew point temperature, wind speed, and solar radiation. For hydrological modeling purposes, such as the FRB study, only evaporation and air temperature are needed.

- Land Cover Data
    - Stream Channel Characterization: the hydraulic characteristics of each stream reachincluding the flow rate, surface area, and volume as a function of the water depth, channel slope and roughness coefficient etc.
- Hydrologic and Water Quality Data: these include observed flow and water quality data.

Water Withdrawals: these include surface water and groundwater withdrawals due to agriculture irrigation, municipal and industrial water use etc., and surface water reduction due groundwater pumping.

I.1.7 Model Development Process

The processes of a hydrological model development by using HSPF include following steps:

- Data preparation

To develop the model using WinHSPF, the study area needs to be delineated into a number of sub-basins and the data described above needs to be collected as model input. The delineation and data collection are conducted in the BASIN 3.1 platform based ARCVIEW GIS. The data is then input into WINHSPF to construct the watershed model.

- Model Assembling

Based on the data collected in the previous step, an initial hydrologic model is constructed and assembled in WINHSPF.

- Model Calibration

The initial model is tuned so that the simulated flow resembles the observed flow as closely as possible (Aqua Terra et al, 2004). This is completed by adjusting various input parameters within the WinHSPF model. Several indices, including Correlation Coefficient, Coefficient of Determination and Nash-Sutcliffe Coefficient, were used to measure "the goodness of fit" between the simulated flow and observed flow at the calibration station.

- Model Validation

After model calibration, the calibrated model needs to be verified and validated by comparing simulated flow and observed flow for different time periods. A reasonable match between the two flows should be achieved; otherwise, the model needs to be recalibrated.

- Model Applications

The validated model then can be used for application and analysis for various future scenarios.

I.2 Model Calibration and Validation

HSPF models must first be calibrated to available, long-term flow data before they can be used to estimate effects of future water use. The purpose of calibration is to match simulated stream flow with observed stream flow for the period before irrigation was widely used. Simulated streamflow is based on historic water use, rainfall, land use, soil properties, and river channel hydraulic characteristics during periods of limited irrigation. Model parameters are then adjusted within acceptable bounds to obtain a satisfactory correlation with observed flow in the sub-basins. The calibration period selected is prior to 1976, when there was relatively little irrigation in southwest Georgia. Using the calibrated model and parameter values obtained from calibration, estimates of post-1975 irrigation usage, rainfall, and other data were input to the model and computed flow rates from were compared to observed post-

1975 data in a process called model validation. Data sources and results of this process are presented in the following subsections for the Ichawaynochaway Creek, Spring Creek, and Lower Flint sub-basins. Very similar methods were used to calibrate and validate the HSPF models for each sub-basin; however, it was necessary to consider and incorporate differences in data such as periods of record and rainfall data.

I.2.1. Model Calibration

I.2.1.1. Ichawaynochaway Creek Sub-Basin

The USGS gauge at Milford (#02353500) on Ichawaynochaway Creek (Figure I.2.-1) is the only stream gauge in the sub-basin with an extensive period of record pre- and post-irrigation and therefore the only location suitable for model calibration. Hourly or daily meteorological records were available at several stations (Figure I.2-1) in or near the sub-basin (Cuthbert, Dawson, Morgan, Albany, Edison, Colquitt, and Camilla) from which rainfall data could be obtained for 1950 through 1975 and 1976 through 1995, periods of time considered sufficient for calibration and validation. Gaps in the precipitation data, found at every meteorological station, have been filled using available data from the nearest stations

Flow and meteorological data from 1950 through 1975 were input to the HSPF surface-water model, and a series of simulations was run for comparison with observed flow at Milford under conditions of no agricultural irrigation. Calibration indices, including Correlation Coefficient, Coefficient of Determination, and Nash-Sutcliffe Coefficient, were computed as a measure of “goodness of fit”. Parameters were varied to best match dry-season flows, as these are most important to analyzing how permit management policies may affect critical (low) flow conditions during droughts. Generally, the fit to historical data was reasonably good. Selection of the “best” model parameters was influenced by the need to keep these parameters within acceptable ranges; consistency with the characteristics of the other sub-basins; and the hydrologic and geologic characteristics of the modeled sub-basins. The

Ichawaynochaway Creek model calibration parameters are listed in Table I.2-1 and the calibration indices are listed in Table I.2-2.

Comparisons of model simulation and historical flows at the Milford gauge for years 1955 (a drought year), 1958 (a normal year), and 1973 (a wet year) are shown in Figures I.2-2 thru I.2-4. Despite the statistically "good" fit, as measured by the calibration indices, the simulations do not precisely match measured flow rates. The HSPF model uses rainfall as the driving mechanism for simulated stream flow. When meteorological stations do not record a rainfall event responsible for the Milford stream flow at any given time period, flow peaks will be missed during simulation, or if a localized storm occurs at a meteorological station but does not affect streamflow, peaks will be simulated which did not actually occur. Other mismatches in calibration can be caused by errors in gauge measurements, and in water withdrawal or return rates (most evident during post 1975 irrigation periods, see Section I.2.1.2). Extremely low flows cannot be accurately simulated with consistency by the model due to the cumulative uncertainty in the process (i.e. measurement errors, modeling uncertainties, etc.). However, the model is considered to be sufficiently accurate to indicate conditions that should be avoided, or corrected in some way, to prevent extended low-flow conditions.

Another method of displaying the comparison between the calibrated model and measured flow data for the period 1950 through 1975 is the flow duration, or flow exceedance, curve in Figure I.2-5. As an example, this curve shows that 10% of the time (horizontal axis) simulated and measured flow at Milford (vertical axis), over the whole period of record from 1950 through 1975, exceeds about 2000 cfs. The calibration simulation exceeds the observed flow rate over the upper 8% of the flow range and is slightly below observed flows over the lowest 80% of the flows.

I.2.1.2. Model validation

The process of model calibration was performed for the period prior to extensive agricultural irrigation. Consequently, no irrigation withdrawals were used in calibration simulations. Before the model can be used for estimation of future irrigation water use scenarios, however, it should first be validated for a different period of time. For the HSPF models, the validation period was chosen to be one in which significant irrigation withdrawals were taken from the sub-basin. Based on estimates shown in Figure I.2-6, widespread irrigation started around 1976 (Hook, 2005).

Model validation started with the calibrated model developed as described in Section I.2.1.1, but with the addition of estimated agricultural withdrawal rates believed to correspond to historically varying rates for the period 1976 thru 2003. Estimated irrigation rates and distributions (Hook et al, 2005) from which sub-basin specific estimates were derived for 2001-2002 were used in the validation model (Table I.2-3). These rates were then adjusted for each year of the validation period by applying the regression curve formula shown in Figure I.2-6.

Also required for the validation simulation is the effect of assumed historical groundwater withdrawal on surface water flow. The USGS calibrated the transient MODFE model for the period from March 2001 to February 2002, which includes all of the growing season months of 2001. Based on the USGS calibration, EPD divided the USGS modeling area into additional sub-basins and computed flow reductions by stream reaches for each sub-basin based on the calibrated pumping rates by comparing to the rates with no pumping. Table I.2-4 provides the estimated cumulative flow reductions derived from the MODFE model at Milford on the Ichawaynochaway, Iron City on Spring Creek, and Bainbridge on the Lower Flint for estimated pumping rates in 2001.

With the estimated surface and groundwater irrigation rates and the calculated reduction in surface water flow due to groundwater withdrawal, the validation model was run for the period 1976 through 1995. Surface and groundwater pumping rates for this period were estimated from current irrigation acreage, modified by the historic rate of growth of irrigation over this period, and the drought and normal year application rates as discussed above.

As was done for model calibration in Subsection I.2.1.1, comparisons of model validation and historic flows at the Milford gauge for years 2000 (a drought year), 1983 (a normal year), and 1998 (a wet year) are shown in Figures I.2-7 thru I.2-9. Again, the simulations do not perfectly match. In these validation simulations, there are additional uncertainties of irrigation water use rate and distribution and the effect of groundwater withdrawal on stream flow. However, the overall model validation indices listed in Table I.2-5 are still acceptable.

The validation period exceedance curve comparison is shown in Figure I.2-10. This graph shows that deviations above and below the historical exceedances are focused at the upper and lower ends of the flow range, respectively.

I.2.2. Spring Creek Sub-Basin

I.2.2.1 Model Calibration

The USGS gauge on Spring Creek (#02357000) near Iron City (Figure I.2-11) is the only flow gauge in the sub-basin with an extensive period of record both pre- and post-irrigation and therefore is the only location suitable for model calibration. Hourly or daily meteorological records were available at several stations (Figure I.2-11) within or near the sub-basin (Edison, Blakely, and Colquitt) from which rainfall data could be obtained for periods from 1950 thru 1975 and from 1976 thru 2003, periods of time considered sufficient for the purposes of calibration and validation.

The Spring Creek model calibration parameters are listed in Table I.2-1 and the calibration indices are listed in Table I2-2. Comparisons of model simulation and historical flows at the Iron City gauge for years 1956(a drought year), 1958 (a “normal” year) and 1965(a wet year) are shown in Figures I.2-12 thru I.2-14. Despite the statistically “good” fit, as measured by the calibration indices, the simulations do not precisely match measured flow rates. As with the calibration for Ichawaynochaway Creek, extremely low flows cannot be accurately simulated with consistency by the model.

A flow exceedance curve for the Spring Creek model calibration is shown in Figure I.2-15. This curve shows that 80% of the time (horizontal axis) the simulated and measured flow at Iron City (vertical axis), over the whole period of record from 1950 thru 1971 (gauge flow data is absent from 1971-1975), exceeds about 100 cfs. The calibration simulation slightly exceeds the measured flow rate over the upper 7% of the flow range and is below the measured flows over the lowest 1% of the flows.

I.2.2.2. Model Validation

The Spring Creek validation model was run for the period from 1982 thru 2001 (gauge flow data is missing from 1976 to 1982). Comparisons of model simulation and historical flows at the Iron City gauge for years 1988(a drought year), 1983(a normal year), and 1989(a wet year) are shown in Figures I.2-16 thru I.2-18. Again, the simulations are not a perfect match; in this case there are the additional uncertainties of the irrigation water use rate and distribution and the groundwater withdrawal effect on streamflow. However, the overall model validation indices listed in Table I.2-5 are acceptable.

The validation period exceedance curve comparison is shown in Figure I.2-19. This graph shows that simulated flow is slightly higher than observed flow statistically, but in general, both match satisfactorily.

I.2.3 Lower Flint River Sub-Basin

I.2.3.1 Model Calibration

Inside the Lower Flint River Sub-Basin, two USGS gauging stations have long-term observations enabling calibration. These two stations are Flint River near Newton (#02353000) and Flint River near Bainbridge (#02356000). The record at the Newton station contains data of in-stream flow rates for the period from 1956 to present; and the record at the Bainbridge station contains the same type of data for the period from 1928 to 1971. Date at both stations can be used in the calibration process. Because the Bainbridge gauge covers significantly more drainage area in the basin, that data was chosen for HSPF model calibration. Daily meteorological data at five different rain gauges, both inside and outside (but close to) the Lower Flint Sub-Basin, are available. These rain gauges are located at Albany, Bainbridge, Cairo, Camilla, and Colquitt. Most of these gauges have recorded historic precipitation data from 1950 to August of 2003

A map showing the delineation of the Lower Flint River Sub-Basin, locations of the USGS gauges, and locations of the meteorological stations is shown in Figure I.2 – 20. It is worth noting that this sub-basin has two points of inflow from upstream: the Flint River at Albany and Ichawaynochaway Creek. Recorded historic flow at Flint River near Albany (#02352500) was used as inflow to the most upstream sub-watershed (No. 5). Simulated flow at the outlet of the Ichawaynochaway Creek (see Section I.2.1 for details) was used as inflow to sub-watershed 23. The locations of these inflows are shown in the map with blue downward arrows.

The Lower Flint River Sub-Basin model parameters obtained from the calibration process are listed in Table I.2 – 1 and the calibration indices in Table I.2 – 2.

Comparison of simulated and observed historic flows at Flint River at Bainbridge for years 1955 (a drought year), 1958 (a normal year), and 1965 (a wet year) are shown in Figures I.2 – 21 through I.2 – 23. As shown by both these figures and the calibration indices, the match between simulated flow and observed flow is quite good. This is in part due to the dominant effect of the inflow from upstream. Tributary flow originating within this sub-basin is relatively small compared to the magnitude of the inflow. Nonetheless, tributary flow simulated from rainfall-driven runoff by the HSPF model contributed to satisfactory matching between simulated and observed flow at Bainbridge, which provides confidence in using the model to assist management decisions in this sub-basin.

Exceedance curves of simulated and observed flow at Bainbridge are shown in Figure I.2 – 5. The close match at all levels of the exceedance curves strongly indicates satisfactory calibration of the Lower FRB surface water model.

I.2.3.2. Model Validation

Ideally, the validation of the Lower Flint River Sub-Basin should be conducted using an independent flow data set on the Flint River at Bainbridge, the same location used for calibration. However, USGS ceased operating the Bainbridge gauge after September 30, 1971; the gauge did not resume operation until October 1, 2001. Given the absence of an independent data set at Bainbridge, we chose to validate the model using flow rates observed on the Flint River at Newton (#02353000) in the period from 1976 to 2003, even though the Newton gauge only includes about 40% of the drainage area above the Bainbridge gauge within this Sub-Basin.

As was done for the calibration in Subsection I.2.3.1, comparisons of model simulation and historical flows at the Newton gauge for years 2000 (a dry year), 1983 (a normal year), and 1998 (a wet year) are shown in Figures 2.3 – 25through 2.3 – 27. Slight deviations from the observed flow can be seen; however, the simulation followed observed flows closely. In fact, the model's indices, shown in Table I.2 – 5, indicate a satisfactory validation.

The validation period exceedance curve comparison is shown in Figure I.2 – 9. It can be seen that the simulated data closely matches the observed data, providing additional confidence in the application of the surface water model.

I.3. Model Simulations

I.3.1. Description of Model Scenarios

The challenge faced in developing a permit management plan for agricultural water use in the FRB requires that representative future scenarios of agricultural water use be tested for their likely effects on surface-water. The tool to be used to test these scenarios is a combination of the USGS MODFE groundwater model and the calibrated HSPF surface-water models. The computer models have been described in Sections I.1. and I.2. Scenarios for future water usage are described in this subsection.

Estimated current and backlog (i.e., irrigation permit applications which have been submitted to EPD during the moratorium but not yet acted upon) acreages irrigated from surface water and groundwater sources in the Flint sub-basins are shown in Table I.3-1. Among the three sub-basins being modeled, the Lower Flint has the most irrigated land (about 170,000 acres), 98% of which are irrigated from Upper Floridan aquifer groundwater. Spring Creek has about 139,000 irrigated acres, 92% from groundwater, and Ichawaynochaway Creek has 100,000 acres, with 66% irrigated from surface water sources. Current application rates in inches per month are given for typical rainfall and drought years, by sub-basin, and for groundwater and surface water sources in Table I.3-2. .

Tables I.3-1 and I.3-2 are the basis for the <u>Current Irrigation Scenario</u>. Other scenarios modeled include the <u>Backlog Scenario</u>, which accounts for the option of approving all permit applications received by EPD during the permit moratorium, which began in 1999. This is equivalent to an increase in irrigation acreage of about 18% above currently mapped acreage irrigated by ground and surface water permits for the entire Flint Basin. A further increase in irrigation water use is represented by increasing the application rates for the Backlog Scenario by 25%, for example as a result of an extensive <u>Crop Mix Scenario</u> change. Finally, in case the evaluations of model results show that the <u>Current Scenario</u> over-allocates the water supply under drought conditions, <u>Cutback Scenarios</u> of 80%, 70%, and 60% of current irrigation use rates are also modeled.

I.3.2. Model Results

I.3.2.1. Groundwater Model Results

The USGS MODFE model was used to compute the estimated reduction in surface water flow rates in each of the modeled sub-basins for each scenario in both dry and normal rainfall years. The computations are made monthly for each stream reach in the model area and can therefore be accumulated for each node in the model. Table I.3-3 provides an example comparison of the calculated stream flow reductions (compared to simulated scenarios of no pumping) at selected nodes (the Milford gage on Ichawaynochaway Creek, the Iron City gauge on Spring Creek, and the Bainbridge gauge on the Lower Flint) for the Current, Backlog, and 1.25xBacklog scenarios in the growing season months of a drought and normal year. Streamflow reductions are much greater at the Bainbridge gauge in the Lower Flint sub-basin and at Iron City in the Spring Creek sub-basin than at the Milford gauge in the Ichawaynochaway Creek sub-basin due to the larger number of irrigation wells in the former two basins. The computed daily flow reductions obtained from MODFE for these locations are subtracted from the corresponding daily flow rates in the HSPF models to yield the estimated surface flow rates for each scenario at each model node (See Section I.3.2.2).

I.3.2.2. Surface Water Model Results

In order to evaluate the effect of a range of future agricultural irrigation pumping rates, the calibrated HSPF sub-basin models were applied to the hydrologic period extending from1950 thru 2003 with the pumping scenarios described in Section I.3.1. Using the criterion that unimpaired flow rates at the Newton gauge (US Army Corps of Engineers, 1997) be among the lowest 25% in the historical record for the growing season, years that met the criterion were considered drought years and thus chosen for higher irrigation rates in the model runs were 1951, 1954, 1955, 1956, 1968, 1977, 1981, 1985, 1986, 1988, 1990, 1995, 1999, 2000, and 2002. This 54-year sequence of climatic conditions represents one possible view of the future. Due to the complexity of changing data input for both models in their current formats, multiple sequences of statistically comparable, yet randomly varying, hydrologic conditions can not be set up and computed in an efficient manner. This is a goal for future analysis.

To illustrate the range of modeled flow effects, Figures I.3-1, I.3-2, and I.3-3 compare the computed flow exceedance curves for the Current, Backlog, and 1.25 × Backlog (the latter representing future, significantly higher irrigation rates, such as may be due to a crop mix requiring much greater irrigation rates) scenarios in the Ichawaynochaway Creek, Spring Creek, and Lower Flint River sub-basins. For example, on Ichawaynochaway Creek near Milford, the flow rate exceeded 95% of the time can be seen to decrease from about 120 cfs for the Current Scenario to about 110 cfs for the Backlog Scenario and to about 95 cfs for the 1.25 × Backlog Scenario. On Spring Creek near Iron City, the flow rate exceeded 95% of the time can be seen to decrease from about 25 cfs for the Current Scenario to about 20 cfs for the Backlog Scenario and to about 10 cfs for the 1.25 × Backlog Scenario. On the Flint River at Bainbridge, the flow rate exceeded 95% of the time is about 2280 cfs for the Current Scenario; it is reduced to about 2250 cfs for the Backlog Scenario, and further reduced to about 2200 cfs for the 1.25 × Backlog Scenario. These effects include the computed groundwater reductions described in Section I.3.2.1 from the MODFE model.

Another view of the modeled effects on flow rates can be illustrated by looking at daily flow rates computed for specific years at the same model nodes. Using the years chosen to illustrate the model calibration results in Section I.2.1.1 (a drought, wet, and normal year), Figures I.3-4 thru I.3-12 present comparisons of the simulated flow rates for the Current, Backlog, and 1.25xBacklog Scenarios. Specifically, Figures I.3-4 through I.3-6 show simulated stream flow on Ichawaynochaway Creek near Milford under the three scenarios in 1955 (drought year), 1958 (normal year), and 1973 (wet year). Figures I.3-7 through I.3-9 show simulated stream flow on Spring Creek near Iron City under the three scenarios in 1988 (drought year), 1958 (normal year), and 1965 (wet year), and Figures I.3-10 through I.3-12 show simulated stream flow on the Flint River at Bainbridge under the three scenarios in 1955 (drought year), 1958 (normal year), and 1973 (wet year). It can be seen that the most significant differences in simulated stream flow rates occur in drought years. For example, the lowest flow rate at Ichawaynochaway Creek near Milford, given the 1955 meteorology

(Figure I.3-4), is about 60 cfs under the Current Irrigation Scenario. The flow rate is reduced to less than 40 cfs under the Backlog Irrigation Scenario, and to less than 20 cfs under the 1.25 × Backlog Scenario.

I.4 Scenario Impact Evaluation

I.4.1. Discussion of Instream Flow Impact Criteria

Having computed stream flows resulting from several possible future irrigation scenarios, the next step is to evaluate the impact of these reduced flow rates ontwo sets of criteria: 1) low flow criteria that would be protective of endangered aquatic species and 2) the effect on streamflows protective of water quality standards.

I.4.1.1. Aquatic Habitat Protection Stream Flow Criteria

As part of the federal agency preparation for review of negotiated ACT and ACF basins Water Allocation Formulas between Georgia, Alabama, and Florida, the U.S. Fish & Wildlife Service and U. S. Environmental Protection Agency (USEPA) developed a set of draft guidelines for protection of the basins' riverine ecosystems. The guidelines were intendedfor evaluation under the FWS's Endangered Species Act authority and EPA's Clean Water Act authority. The guidelines were not intended to be exclusive, but stated that an allocation formula that did not comply with the guidelines would require a more detailed review by both agencies. It was felt that the guidelines would protect both the present structure and function of the riverine ecosystems as well as endangered species (USFWS and USEPA, October 25, 1999).

The Flint River Technical Advisory Committee agreed that the Monthly 1-day Flow Minima (U1) and the Annual Low-Flow Duration (U2) guidelines would be an appropriate measure of the impact on streamflows resulting from the range of irrigation scenarios described above. Specifically, these guidelines (USFWS and USEPA, October 25, 1999) are defined as:

U1: Monthly 1-day minima

Computational definition: using the complete daily discharge record for the reach, compute the 1-day minimum flow for each month of the year in all years. Compute the minimum, 25th percentile, and median of these minimum flow values. For each future month, the 1-day minimum flow guideline is to:

d. Exceed the minimum in every year.
e. Exceed the 25th percentile in 3 out of 4 years.
f. Exceed the median in half of the years.

U2: Annual low-flow duration

Computational definition: using the computed daily discharge record for the reach, compute the average annual discharge (AAD) for each calendar year, and then the average of these annual values. Compute the number of days per year for each calendar year during which daily discharge is less than 25 percent of the AAD. Compute the maximum, 75th percentile, and median of these values. For each future year the guideline is:

d. Do not exceed the maximum duration in any years.
e. Do not exceed the 75th percentile in 3 out of 4 years.
f. Do not exceed the median in half the years.

Maintenance of the U1 and U2 guidelines in the Flint Basin would be an attempt to prevent irrigation in the Flint Basin from lowering the monthly historical 1-day low flow minima and also from increasing the duration of annual low flow conditions.

I.4.1.2. Water Quality Guidelines

Potential impacts to water quality may also be important to the evaluation of scenario model results in the FRB. Georgia EPD develops waste-load allocations and associated National Pollutant Discharge Elimination System (NPDES) permit limits for municipal and industrial surface water discharges that protect in-stream dissolved oxygen standards and other in-stream water quality criteria. NPDES permits are developed to protect water-quality standards using a minimum stream flow equal to the annual 7Q10; i.e. the minimum 7-day average stream flow having a 10 percent chance of occurrence in any year, or a theoretical recurrence interval of 10 years. Changes to surface water hydrology that cause stream flows to more frequently be less than the 7Q10 used to determine NPDES limits could adversely affect a stream's ability to meet the dissolved oxygen standard and other criteria during critical low flow conditions. If decreased stream flows persist for a long period, such that annual 7Q10 must be re-calculated downward, allowable waste-load allocations may need to be decreased to prevent the new, more rigorous standards from being violated. This could impose an additional water treatment burden on those municipalities or industries with NPDES permits.

To address this, ririgation scenario model results were evaluated for their potential effect on the frequency of 7Q10 flows at selected locations in the sub-basins.

I.4.2. Computation of In-stream flow criteria

For the purposes of this Plan, in-stream flow criteria are calculated at three representative gauge locations: Ichawaynochaway Creek at Milford, Spring Creek near Iron City, and the Flint River at Bainbridge.

I.4.2.1 Aquatic Habitat Protection Stream Flow Criteria

Table I4-1 presents comparisons of the aquatic habitat guidelines computed for each of the gauge locations based on the full period of record at each gauge location.

I.4.2.2 Water Quality Guidelines

A review of historic streamflow data and NPDES permit conditions, as well as computation of 7Q10 flow rates for various time periods, indicates that the 7Q10 used by EPD to set current permit discharge limits in Southwest Georgia was based on pre-1970 historic flow data. The computed 7Q10 for this period is 2500 cfs for Bainbridge, 140 cfs at Milford, and 15 cfs for Iron City.

I.4.3 Model Scenario Effects

I.4.3.1. Aquatic Habitat Protection Stream Flow Guidelines

The effects on U1 and U2 stream flow guidelines can be computed for the future irrigation scenarios described in Section I.3. In these model runs, assumed irrigation distribution patterns and application rates for each scenario are modeled for the 54-year hydrologic pattern observed for the period from 1950-2003. The irrigation acreage does not change from year to year in these scenarios (see Table I.3-1) and the application rates change only according to whether a particular year was a drought or not (Table I.3-2). The 54-year series of computed flow rates can be viewed as being representative of the likelihood that particular surface water flow rates will be observed if the climatological conditions and irrigation patterns do not significantly change from those modeled.

. Thus, to meet the U1 guidelines described and computed in Sections I.4.1 and I.4.2, and shown in Table I.4-1, none of the monthly 1-day minimum flow rates computed for the future scenarios as shown in Table I.4-2 for Ichawaynochaway Creek at Milford should be less than the criteria. Observed gauge flow rates show no variances (all “0’s”), but model results show as many as 5 variances in the month of September, generally being greatest for the more intensive irrigation scenarios (i.e., Backlog and 1.25x Backlog Scenarios) and in the August-September months of the growing season. For the U1-B guideline, variances should not exceed 1 in 4 years (25%), but this does occur, again mostly for the Backlog Scenarios in August and September. The U1-C guideline should not show variances greater than 50% (1 in 2 years), but this occurs in late summer.

The differences between scenario U1 variance computations at the three gauge locations can be seen for selected years (1980’s) in Figure I.4-1 which shows the modeled minimum 1-day flow rates during the month of August vs. the minimum (U1-A), 25% (U1-B), and mean (50%) (U1-C) criteria. U1-A is not met in 1986 with the Current and Backlog Scenarios, but is met in all other years and scenarios. Variances occur for the U1-B guideline in 1981 and 1986 (all scenarios) and in 1985 and 1988 for some scenarios, but a 25% variance rate is acceptable for U1-B. Only 1982, 1984, and 1989 have no U1-C variances, though a 50% variance rate is acceptable.

Table I.4-3 displays the results of comparisons of the duration of U2 computed scenario flows below 25% of the annual average for Ichawaynochaway Creek. The maximum allowable duration is exceeded in each of the model runs. The 1 in 4 year allowance is exceeded in several scenarios. The median allowable duration is equaled only in the 1.25xBacklog Scenario.

Tables I.4-4 and I.4-5 and Figure I.4-2 summarize guideline results for Spring Creek and Tables I.4-6 and I.4-7 and Figure I.4-3 for the Lower Flint. Spring Creek model results indicate very high rates of variance for U1 and for U1C and low rates for U2A compared to Ichawaynochaway Creek. Flint River model results show virtually no variances for any of the criteria. Section I.4.4 presents discussions of reasons for some of the variability in sub-basin guideline variance computations and comments on the interpretation of these model results.

I.4.3.2. Water Quality Guidelines

Table I.4-8 compares the 7Q10 streamflows at Milford on Ichawaynochaway Creek, on Spring Creek near Iron City, and at Bainbridge on the Lower Flint, computed from pre-1970's gauge data and using model simulation results from four future irrigation scenarios. The differences between the future scenario low-flow computations and the pre-irrigation computation are significant in each case. This implies that water quality standards would be violated more frequently in the future if permitted constituent loadings are not reduced.

One way to estimate the increased frequency of potential water quality standard violations implied by this analysis, if loadings are not reduced, is to compute the change in frequency of occurrence of the pre-1970 7Q10 flow rate for the scenarios in Table I.4-8. These are shown for the three modeled locations in Table I.4-9. For the Milford gauge, the frequency of flows less than the pre-1970 7Q10 flow rate is 2.9%. This increases to 6.5% for the Current

Scenario and 7.2% for the Backlog Scenario. For the Iron City gauge, the frequency of flows less than pre-1970 7Q10 increases from 3.5% for the Current Scenario to 6.3% for the Backlog Scenario; for the Bainbridge gauge, the increase is from 5.4% to 7.2%.

I.4.4. Interpretation of Scenario Impact Model Results

Tables I.4-2 thru I.4-9 show a wide range of results for the various conditions represented by the MODFE groundwater and HSPF surface water model simulations, as well as the observed data. The most extreme differences may be the small number of variances from the U1 and U2 guidelines for the Flint River at Bainbridge compared to Ichawaynochaway and Spring Creeks. However, there are also differences in how the guidelines are missed in the latter two locations and the fact that the observed data at those locations do not indicate any variances (since the guidelines were developed from those data).

The reason for these apparent discrepancies is primarily due to: 1) the calibration of the models, and 2) the uncertainties in the measurement and modeling process, which are especially evident at low flows.

Uncertainties inherent in model calibration have been discussed previously. , These uncertainties are magnified at low flows. For example, measurement errors in gauged flow probably exceed the 7Q10 of Spring Creek at Iron City. This may not be true at Milford on the Ichawaynochaway, but the uncertainties are still a significant fraction of the 7Q10. On the Lower Flint the flow rates are much higher, even under drought conditions, but the much better calibration match at Bainbridge and the lack of guideline variance are becausethe Lower Flint HSPF model is much less dependent on rainfall input as the driver and much more dependent on the more reliable flow gauge at Albany, where upstream inflow is incorporated into the model. The other two basins do not have gauged inflows that control a large percentage of the surface water flow at the modeled locations. In other words, the large inflow to the Lower Flint sub-basin numerically “overwhelms” measurement and modeling uncertainties, whereas in Spring Creek and Ichawaynochaway sub-basins those uncertainties make up a larger portion of the simulated stream flow.

Because of the uncertainties and limitations described above, the model results should be interpreted with consideration for the differences between scenarios relative to the guidelines rather than strictly in terms of a direct comparison with the guidelines. In general, models are most accurate when used to determine differences between scenarios. The differences between computed scenario criteria relative to the magnitude of the allowable criteria may be more meaningful than whether the scenario criteria exceed the allowable criteria. For example, for Spring Creek (Table I.4-4) there is only about a 2% increase in U1-C for the Backlog Scenario vs. the Current Scenario compared to a 50% variance allowance. Even the calibrated results are 8 to 10% above the variance limit in most summer months. Another example can be taken from comparisons of flows against 7Q10 (Tables I4-8 and I4-9). The difference between modeled scenario results may be more meaningful than the difference from the historical data.

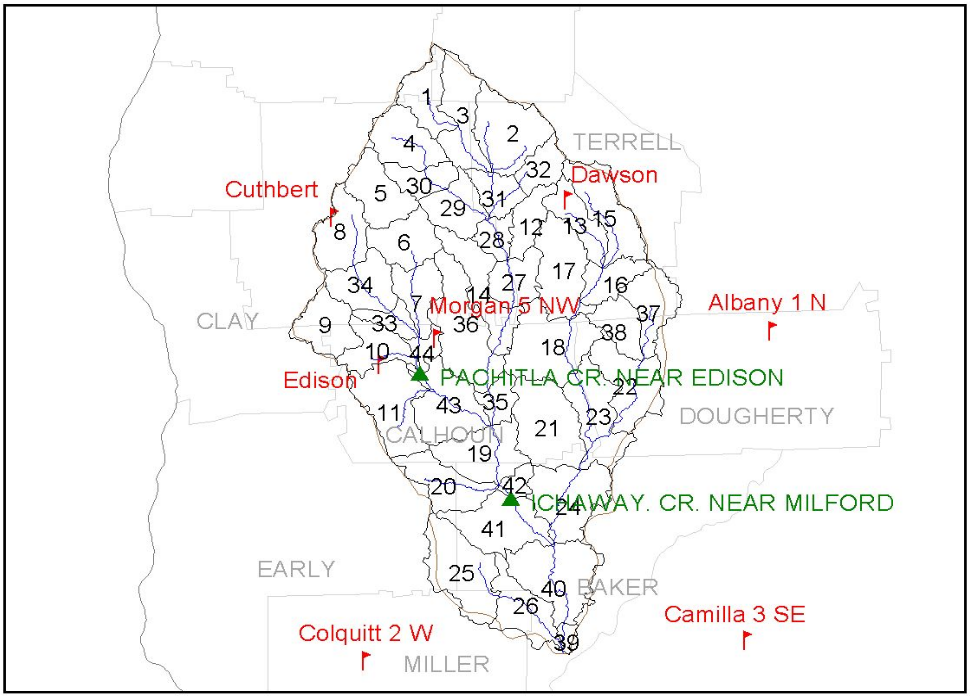

Figure I.2 – 1: Ichawaynochaway Creek Sub-Basin with Gauging Stations, Met Stations, and sub-basin delineations

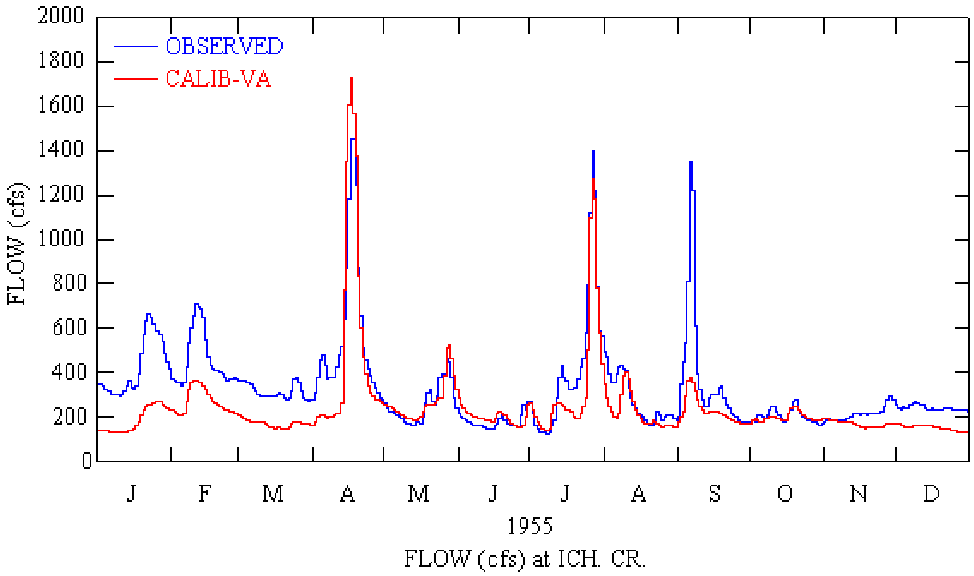

Figure I.2 – 2: Observed vs. calibrated streamflow of Ichawaynochaway Creek near Milford for 1955 (dry year)

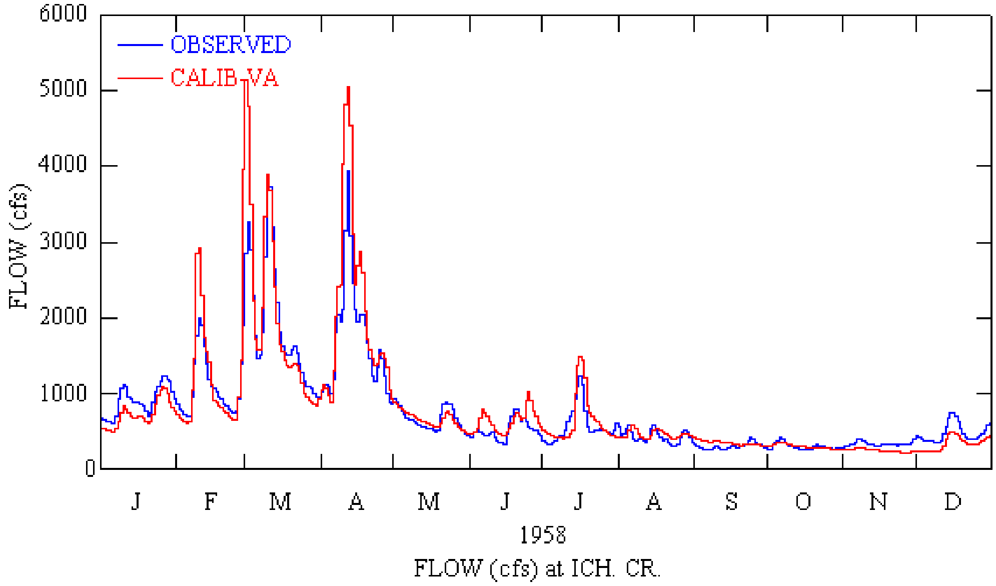

Figure I.2 – 3: Observed vs. calibrated streamflow of Ichawaynochaway Creek near Milford for 1958 (Normal Year)

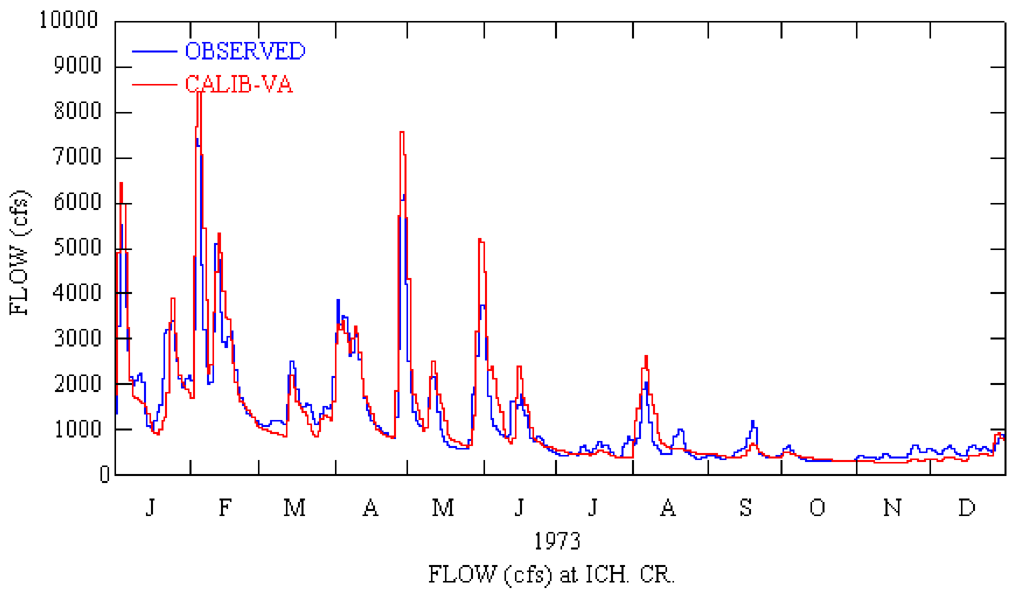

Figure I.2 – 4: Observed vs. calibrated streamflow of Ichawaynochaway Creek near Milford for 1973 (Wet Year)

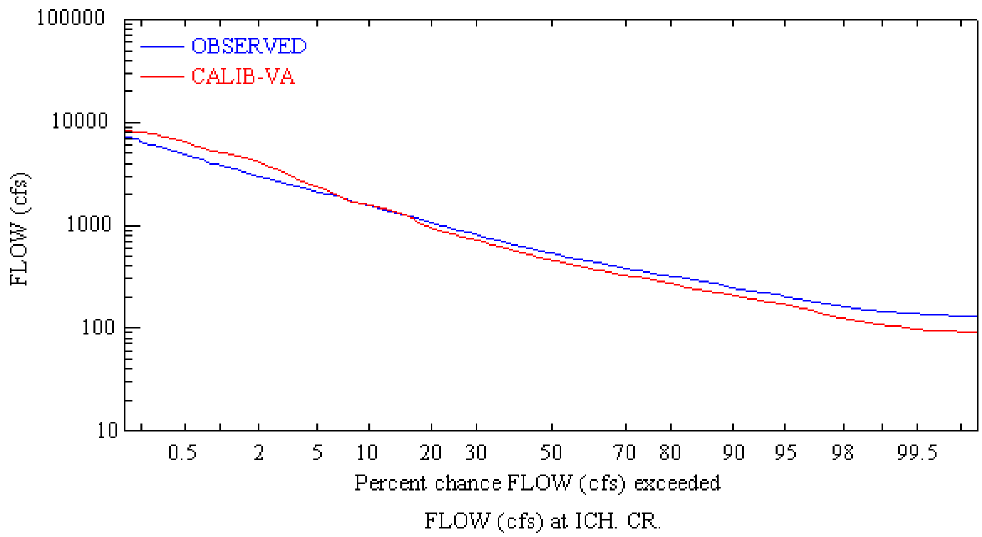

Figure I.2 – 5: Duration Curve for Calibrated vs. Observed Flow of Ichawaynochaway Creek at Milford

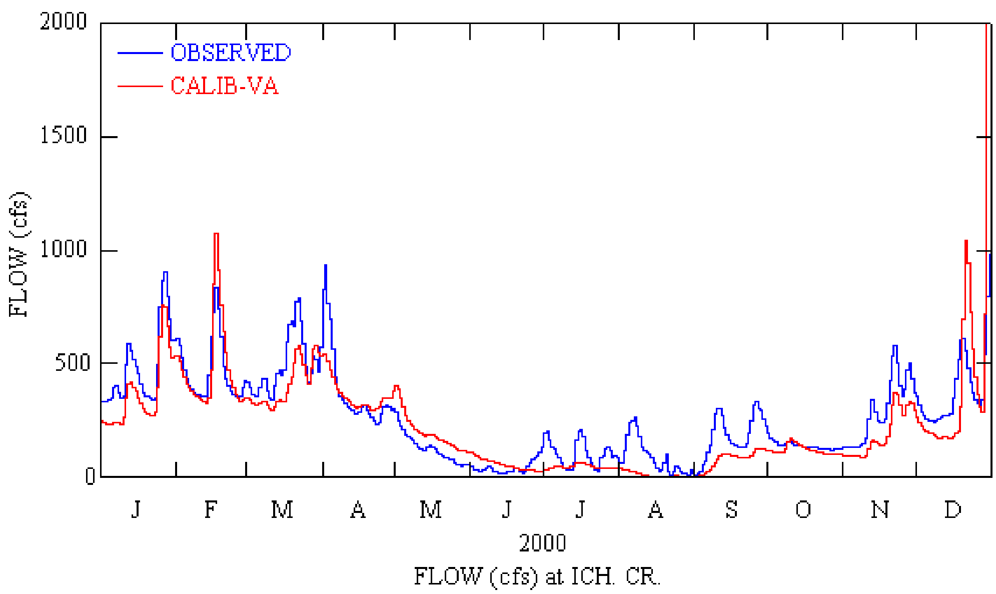

Figure I.2.1 – 7: Observed vs. calibrated streamflow of Ichawaynochaway Creek near Milford for 2000 (Dry Year)

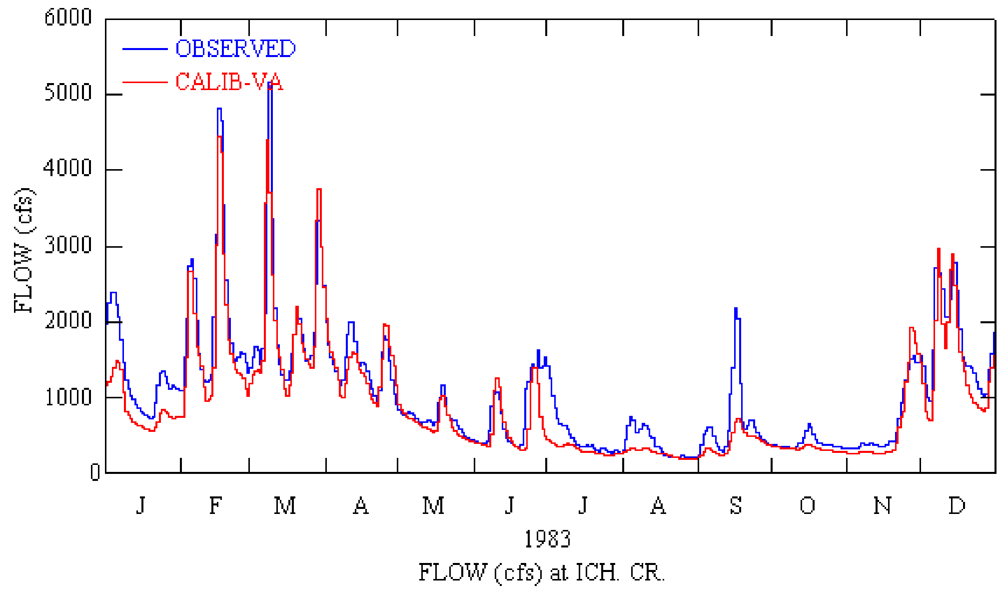

Figure I.2 – 8: Observed vs. calibrated streamflow of Ichawaynochaway Creek near Milford for 1983 (Normal Year)

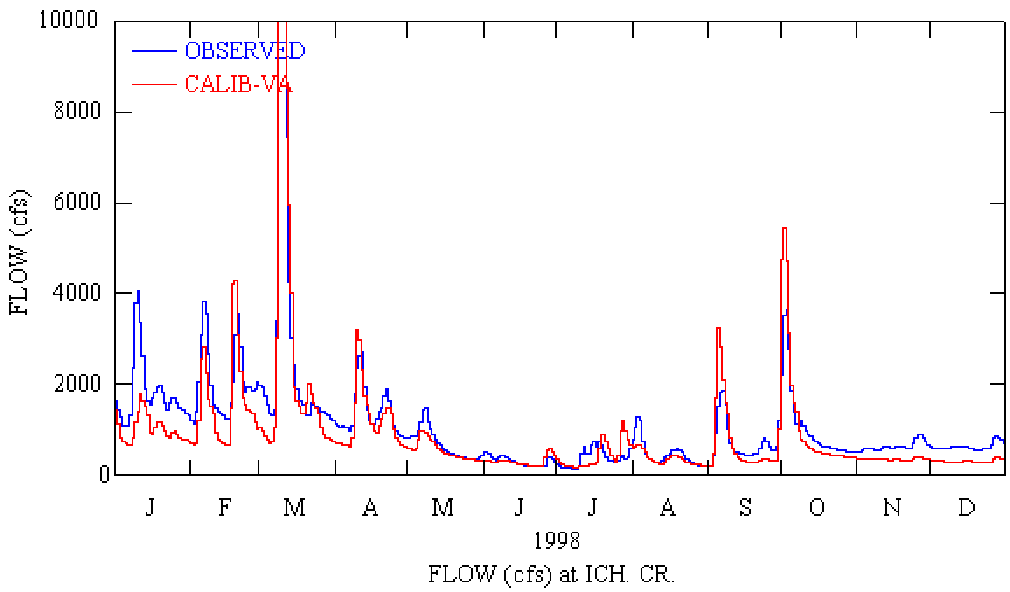

Figure I.2 – 9: Observed vs. calibrated streamflow of Ichawaynochaway Creek near Milford for 1988 (Wet Year)

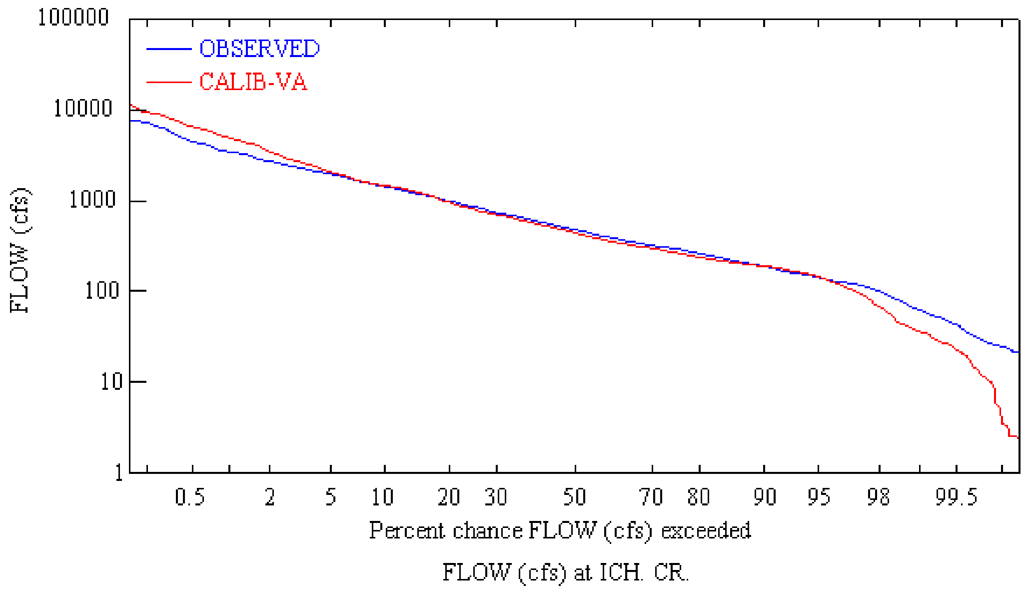

Figure I.2 – 10: Duration Curve of Validated vs. Observed Flow of Ichawaynochaway Creek near Milford

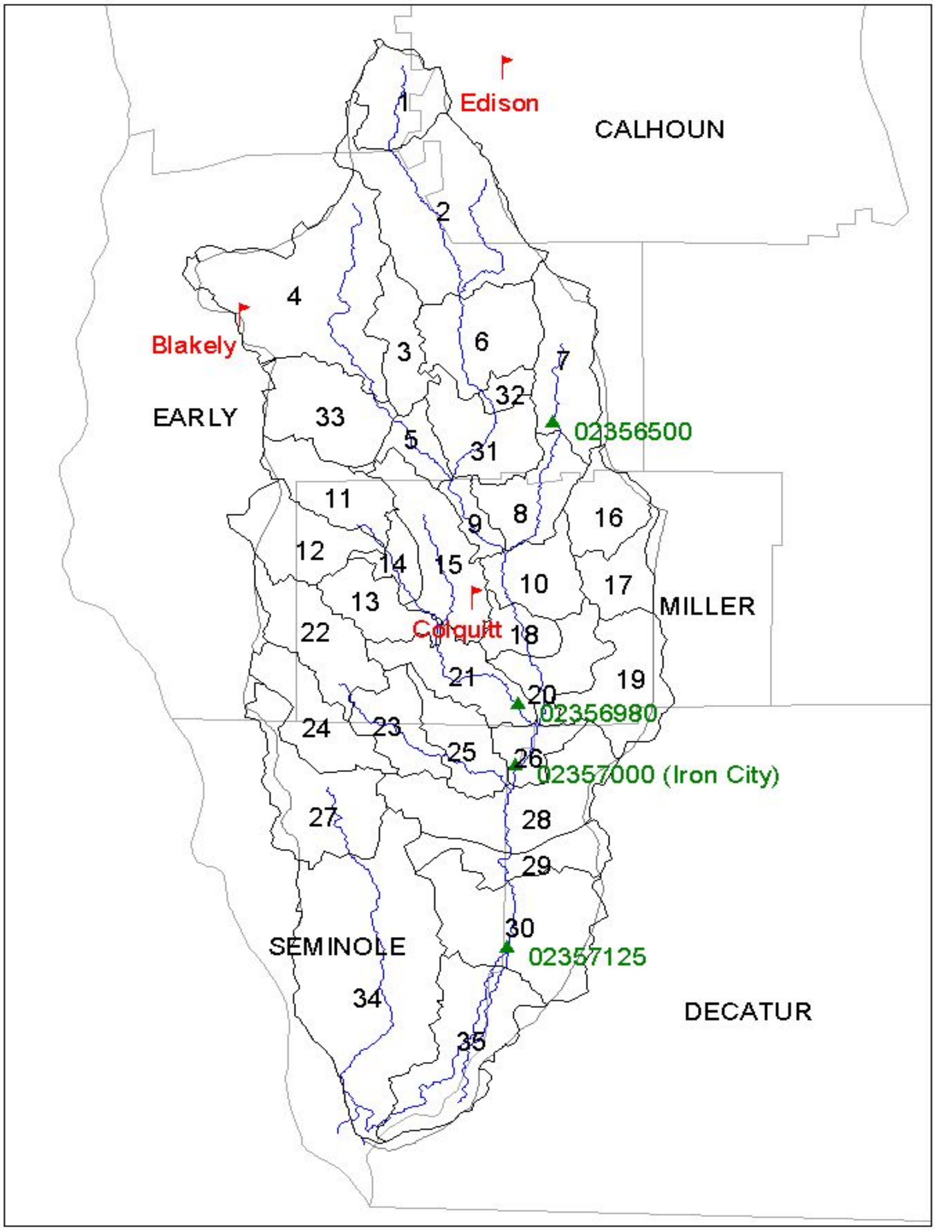

Figure I.2 – 11: Map of Spring Creek sub-basin showing gauge stations, meteorologic stations and sub-basin delineation.

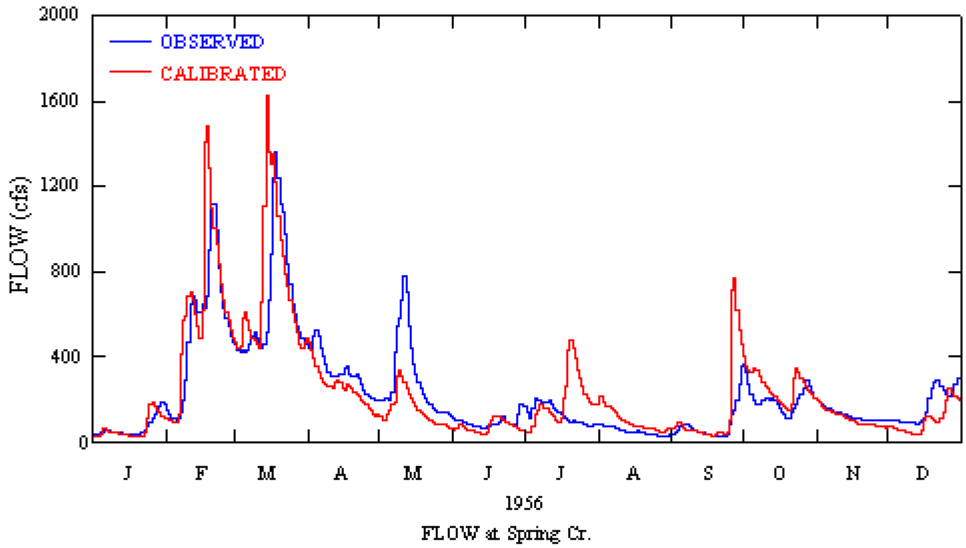

Figure I.2 – 12: Observed vs. calibrated streamflow of Spring Creek near Iron City for 1956 (Dry Year)

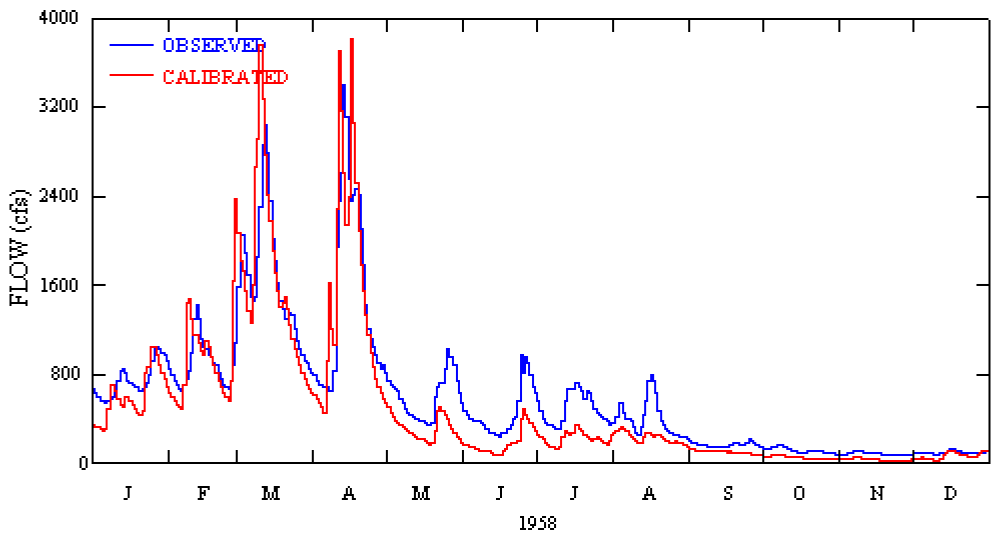

Figure I.2 – 13: Observed vs. calibrated streamflow of Spring Creek near Iron City for 1958 (Normal Year)

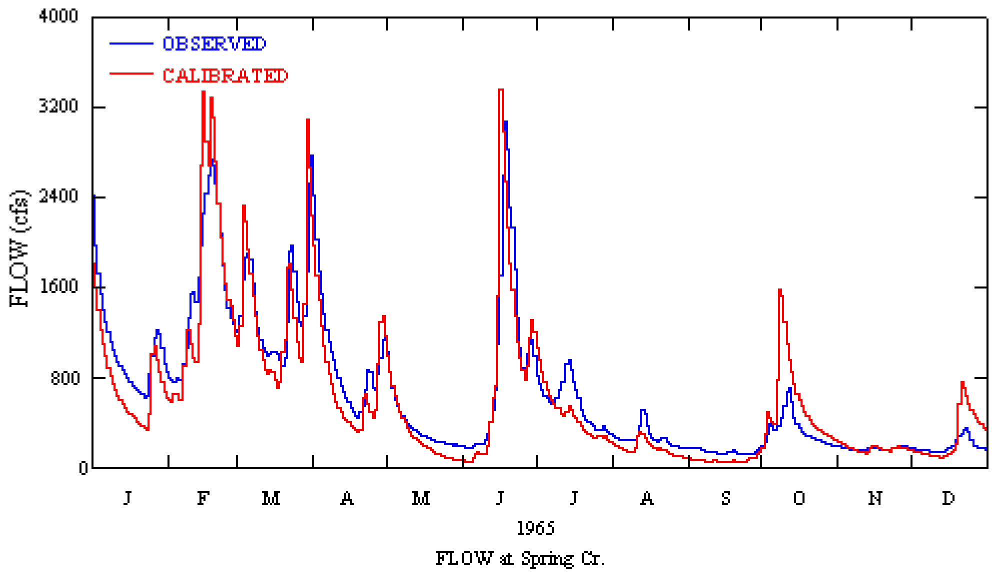

Figure I.2 – 14: Observed vs. calibrated streamflow of Spring Creek near Iron City for 1965 (Wet Year)

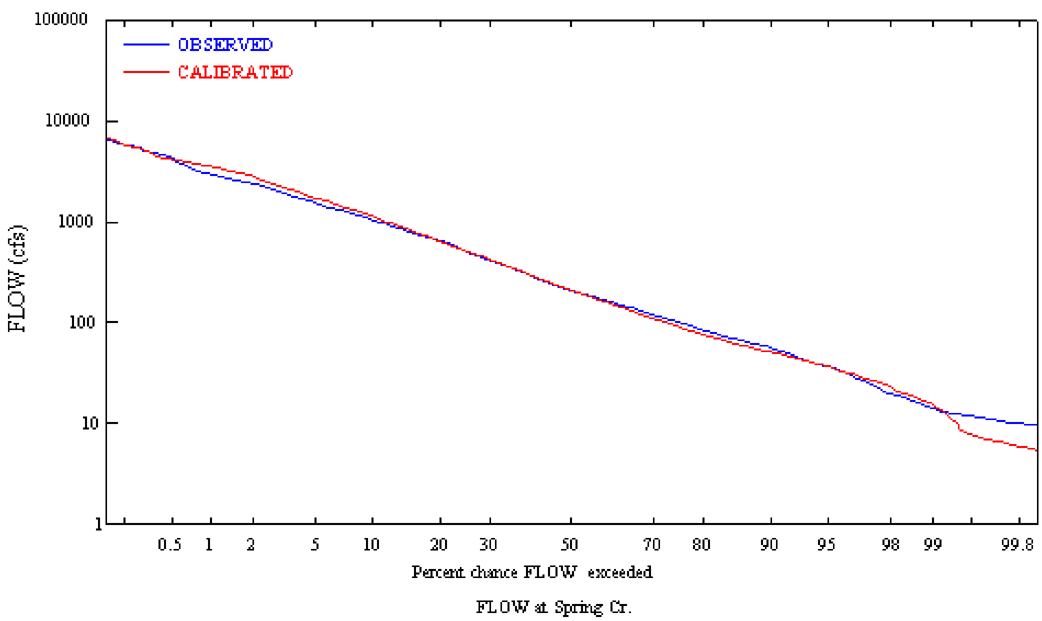

Figure I.2 – 15: Duration curve for calibrated vs. observed flow for Spring Creek near Iron City

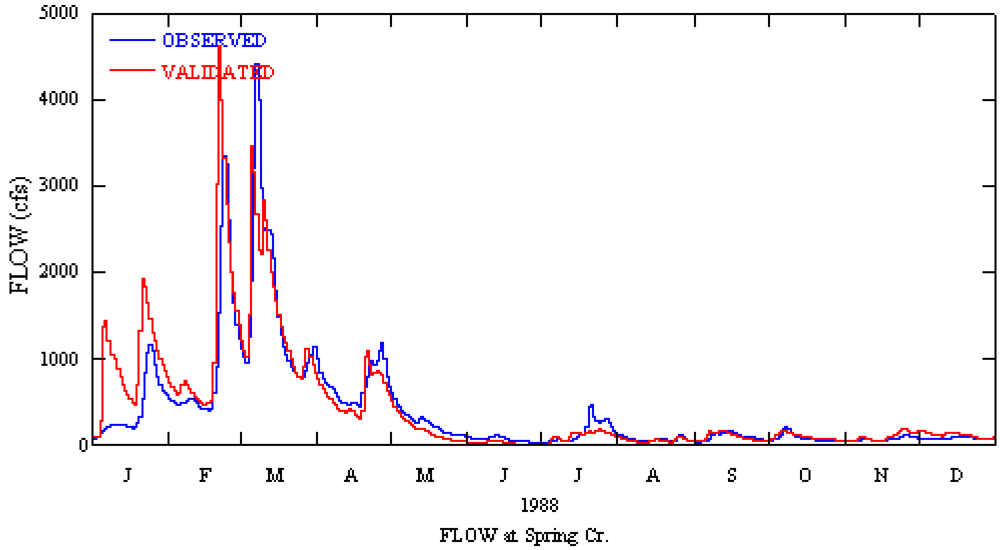

Figure I.2 – 16: Observed vs. calibrated streamflow of Spring Creek near Iron City for 1988 (Dry Year)

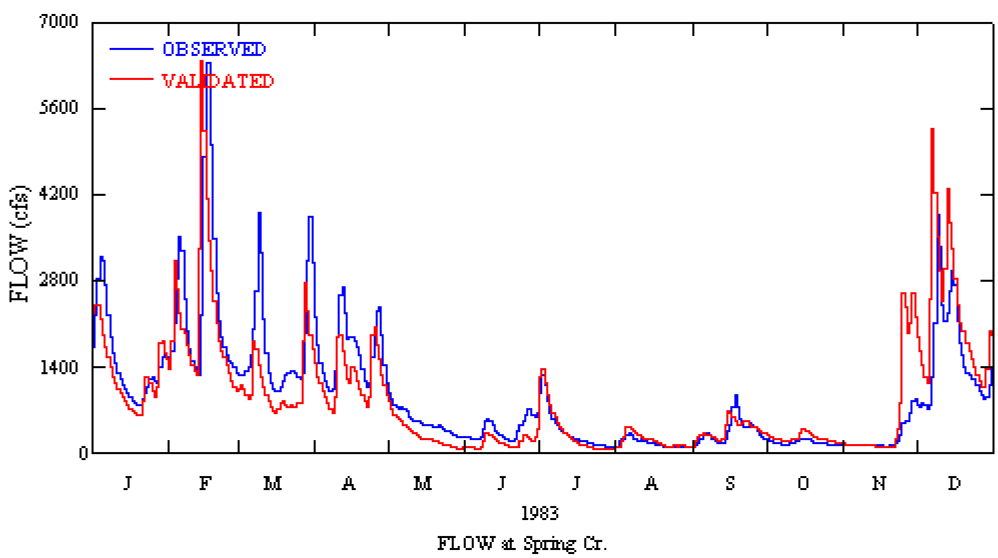

Figure I.2 – 17: Observed vs. calibrated streamflow of Spring Creek near Iron City for 1983 (Normal Year)

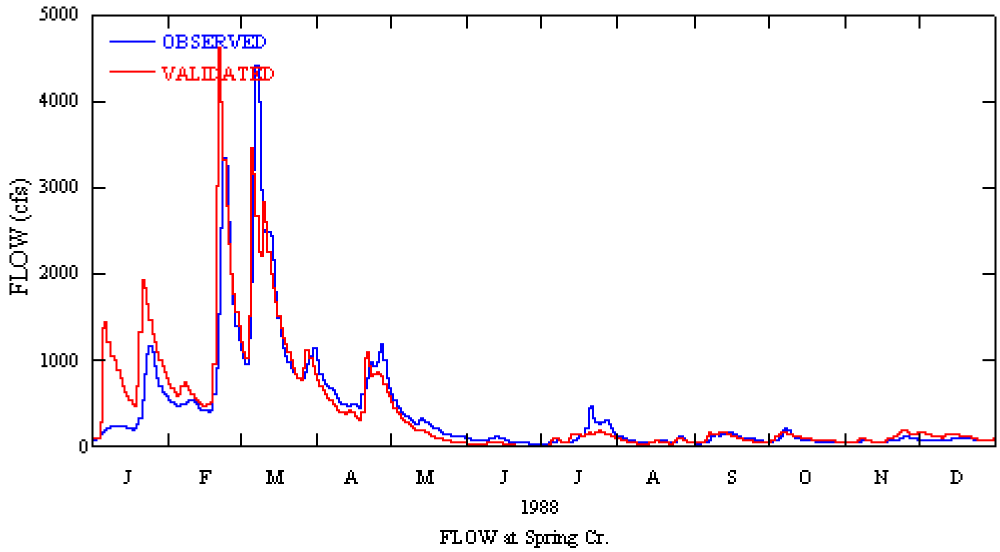

Figure I.2 – 18: Observed vs. calibrated streamflow of Spring Creek near Iron City for 1989 (Wet Year)

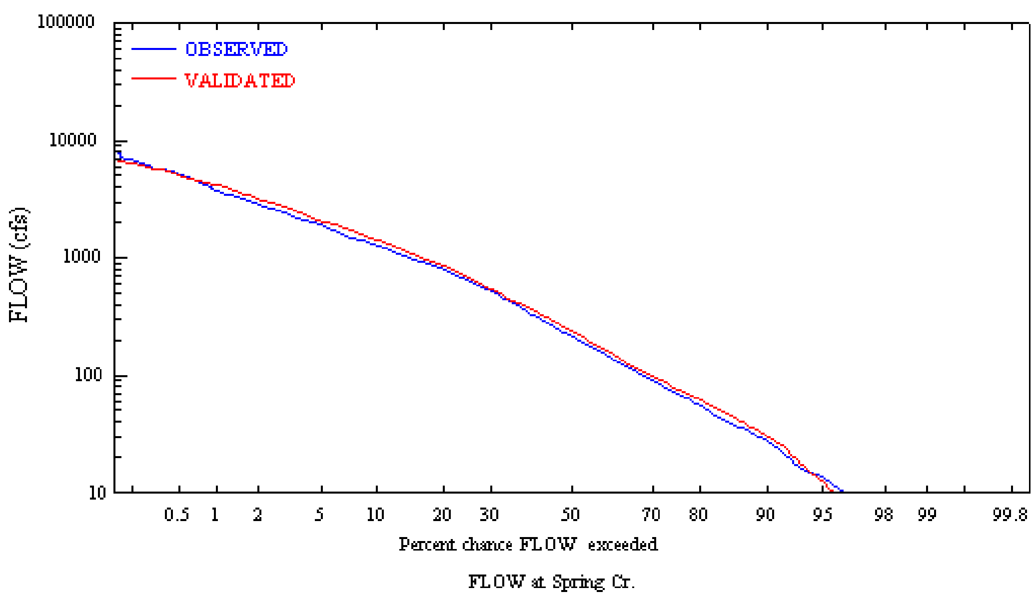

Figure I.2 – 19: Duration Curve of Validated vs. Observed flow at Spring Creek near Iron City

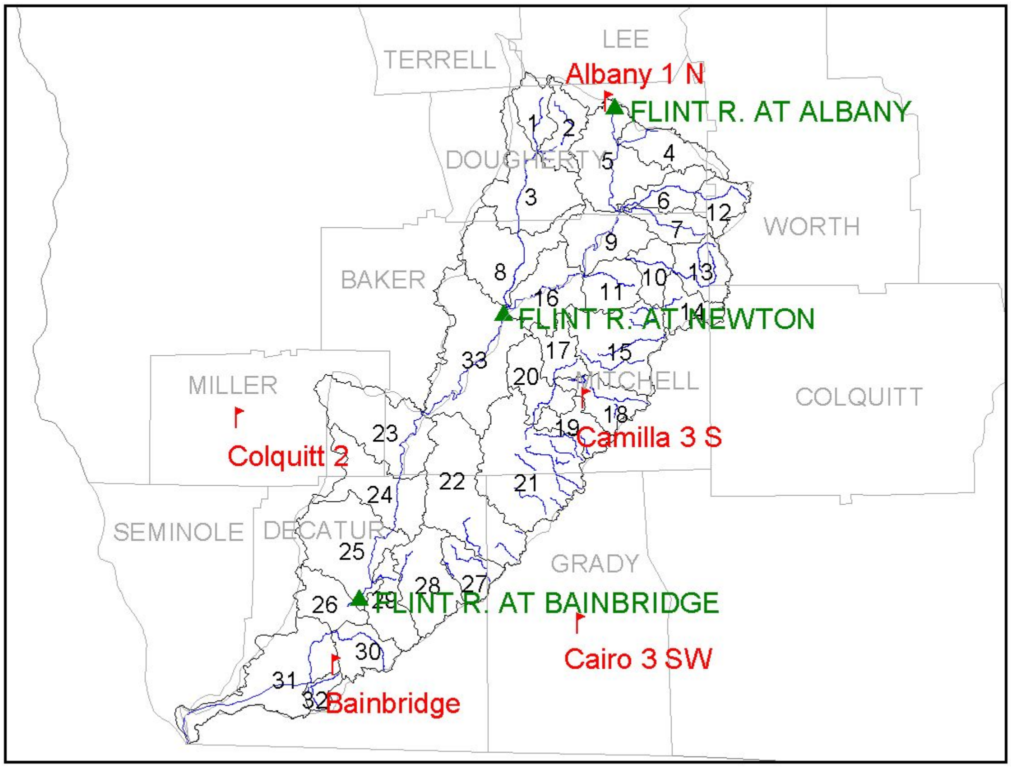

Figure I.2 – 20: Lower Flint River Sub-Basin with Gauging Stations, Met Stations, and sub-basin delineations

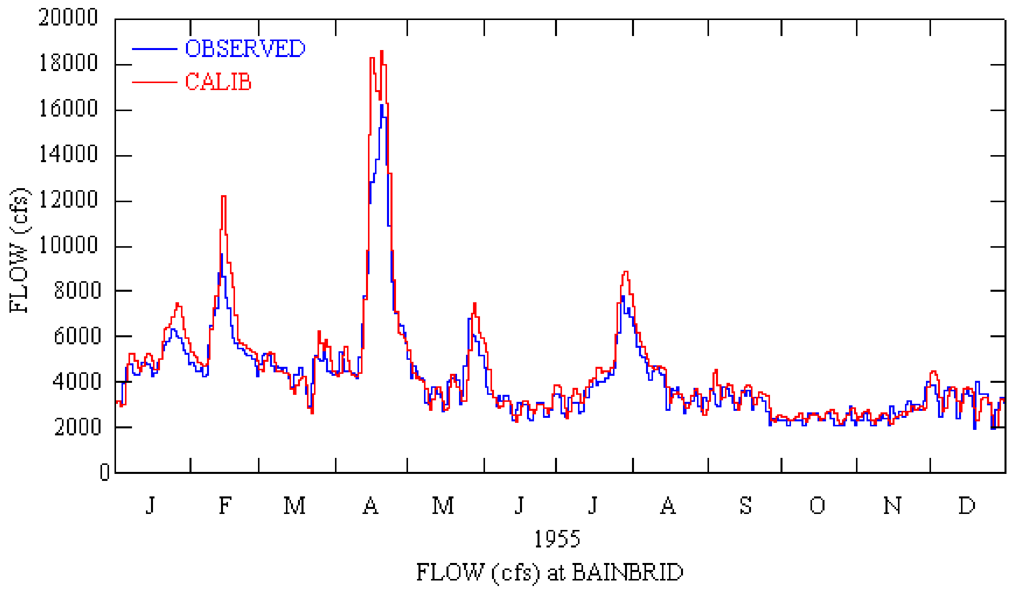

Figure I.2 – 21: Observed vs. calibrated streamflow of the Flint River at Bainbridge for 1955 (Dry Year)

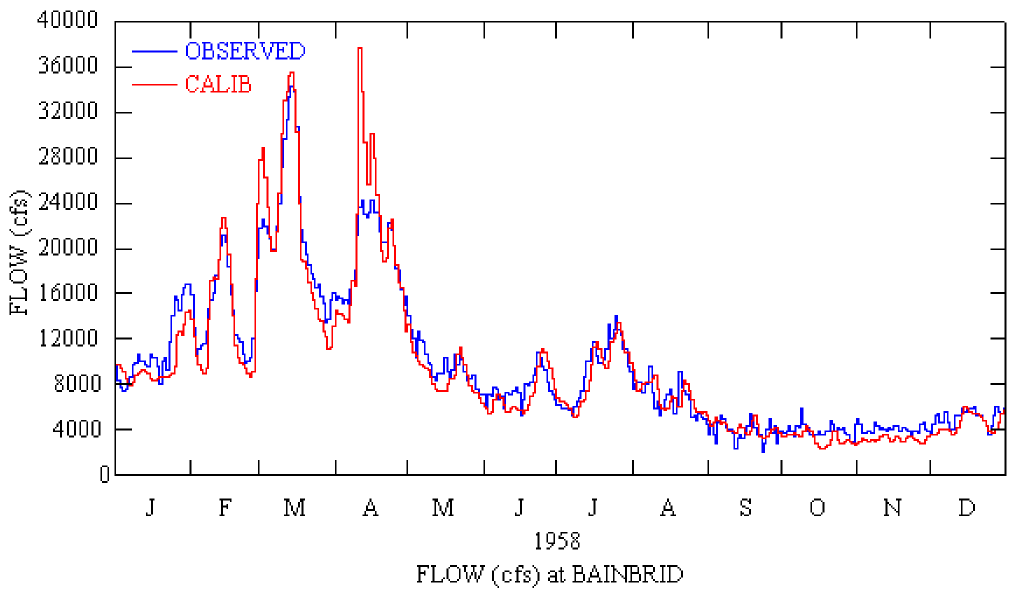

Figure I.2 – 22: Observed vs. calibrated streamflow of the Flint River at Bainbridge for 1958 (Normal Year)

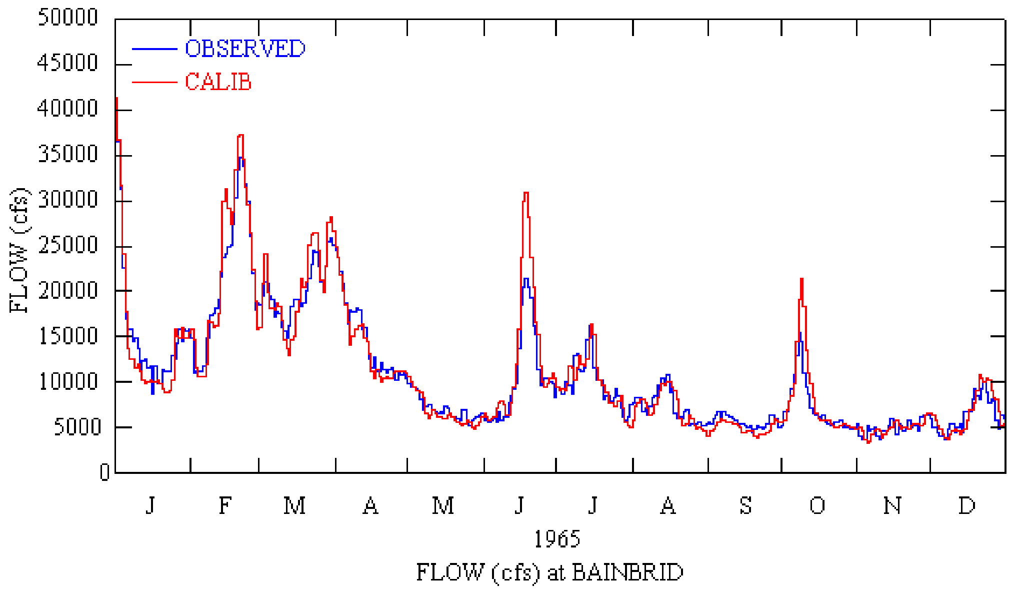

Figure I.2 – 23: Observed vs. calibrated streamflow of the Flint River at Bainbridge for 1965 (Wet Year)

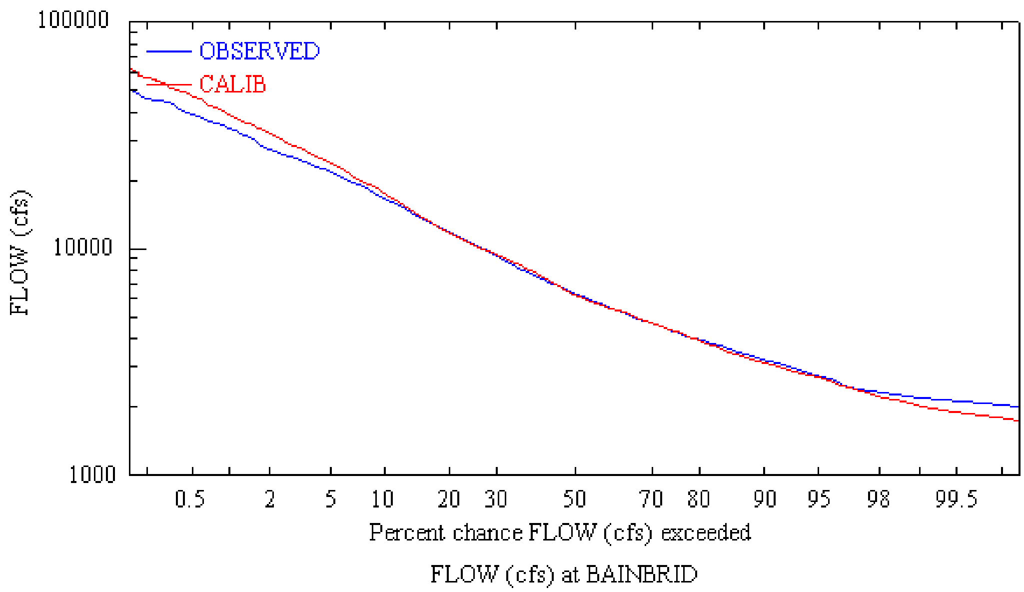

Figure I.2 –24: Duration Curve of Calibrated vs. Observed Flow of Flint River at Bainbridge (for period 1953 to 1971)

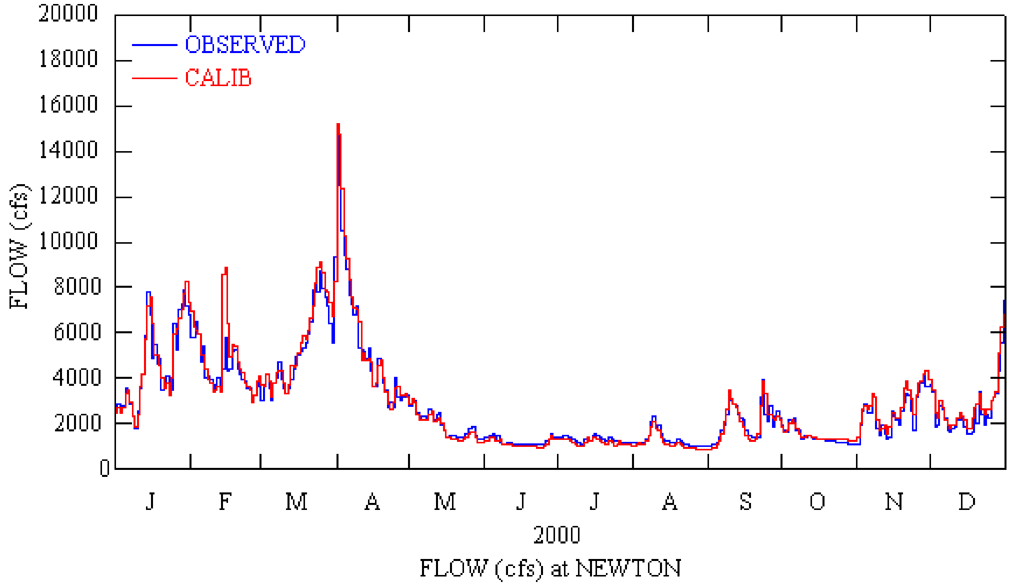

Figure I.2 – 25: Observed vs. calibrated streamflow of the Flint River at Newton for 2000 (Dry Year)

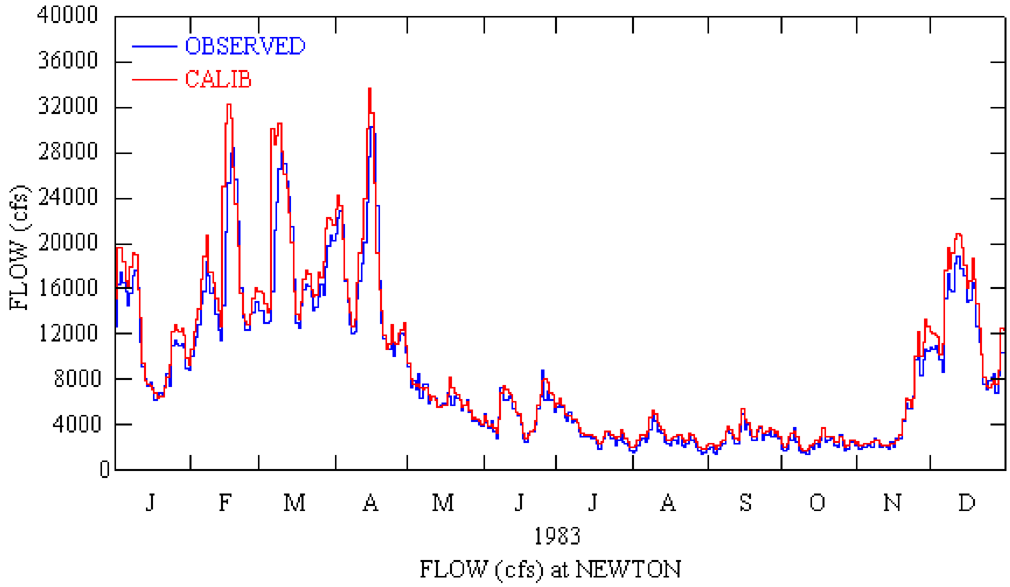

Figure I.2 – 26: Observed vs. calibrated streamflow of the Flint River at Newton for 1983 (Normal Year)

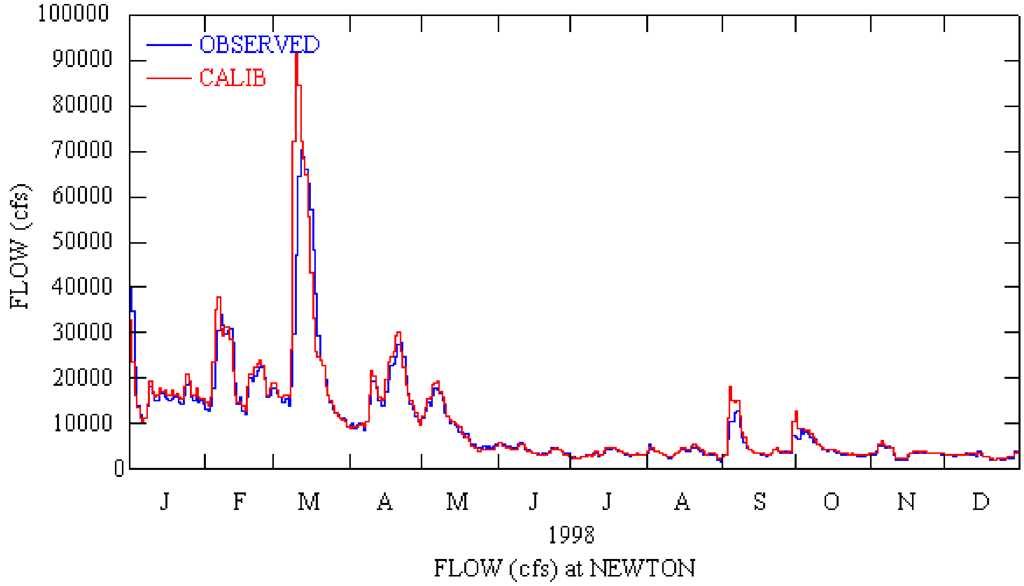

Figure I.2 – 27: Observed vs. calibrated streamflow of the Flint River at Newton for 1998 (Wet Year)

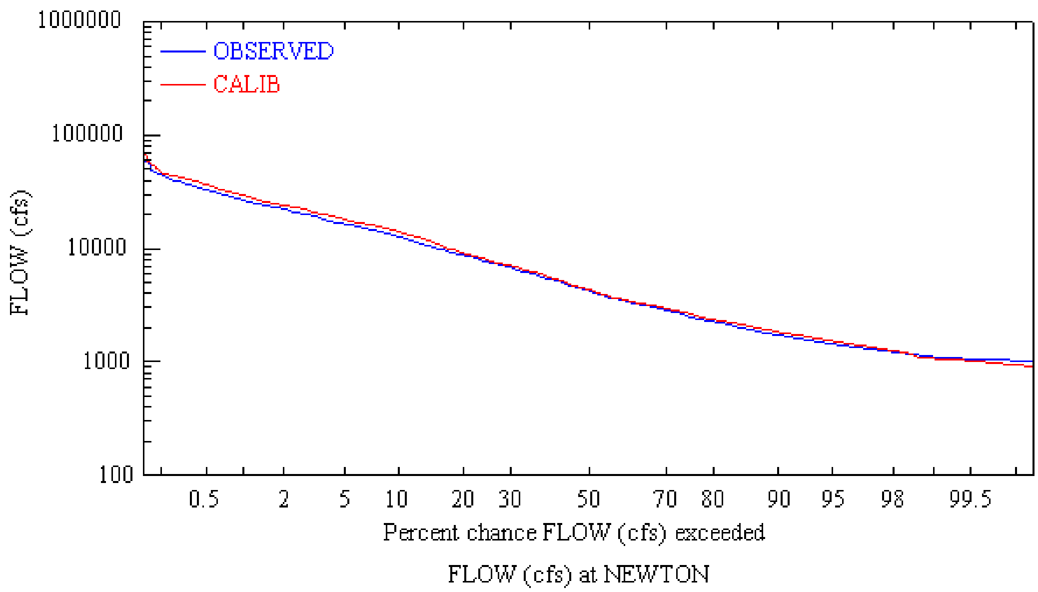

Figure I.2 – 28: Duration Curve for Calibrated vs. Observed Flow of Flint River at Newton (period 1976 to 2003)

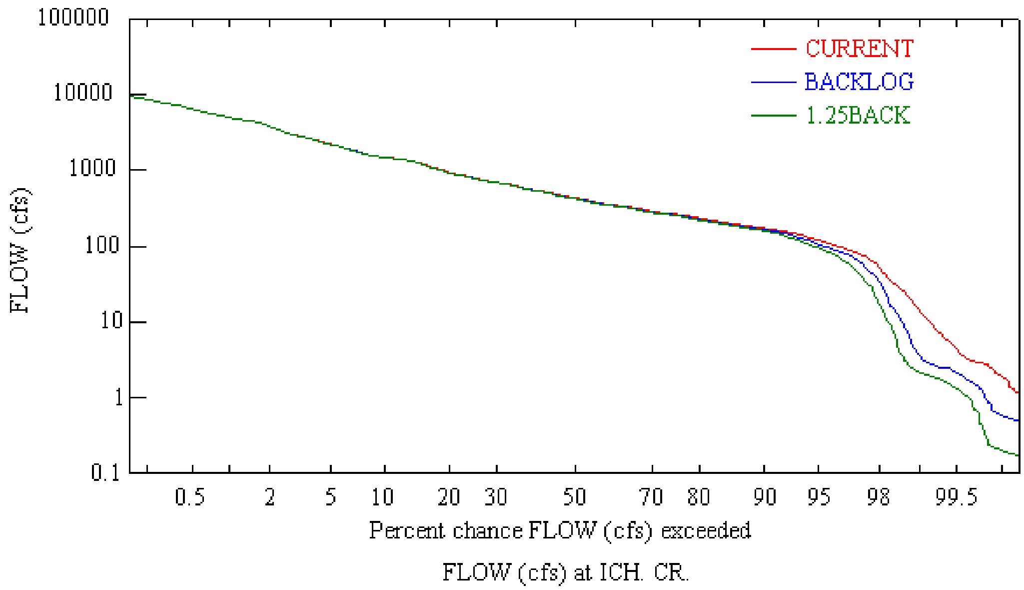

Figure I.3 – 1: Duration Curves of Scenarios Current, Backlog, and 1.25Xbacklog of Ichawaynochaway Creek near Milford

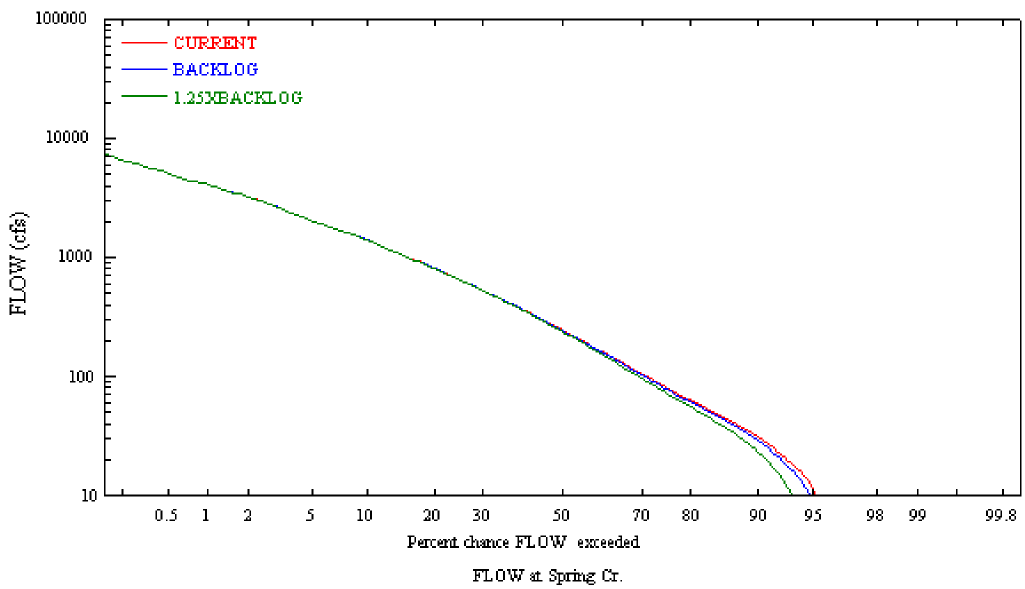

Figure I.3 – 2: Duration curves of Scenarios Current, Backlog, and 1.25Xbacklog at Spring Creek near Iron City

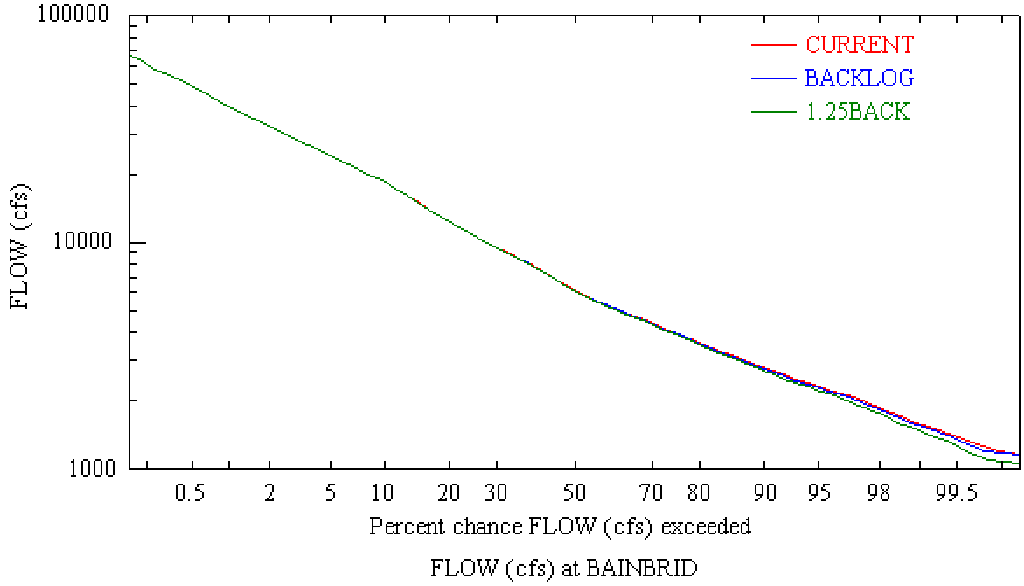

Figure I.3 – 3: Duration Curves of Scenarios Current, Backlog, and 1.25Xbacklog of Flint River at Bainbridge

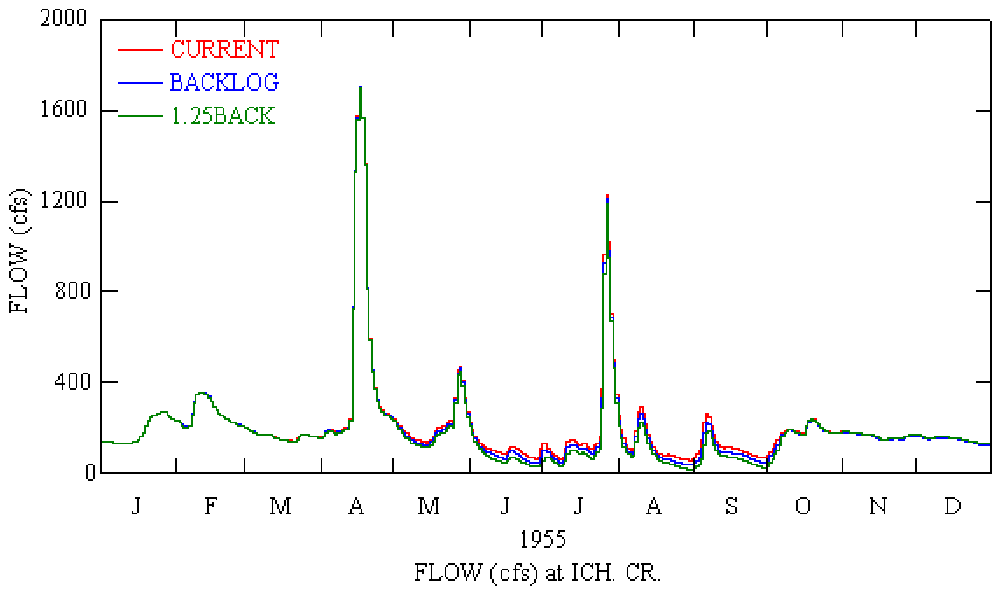

Figure I.3 – 4: Simulated streamflow of Ichawaynochaway Creek near Milford for 1955 (Dry Year)

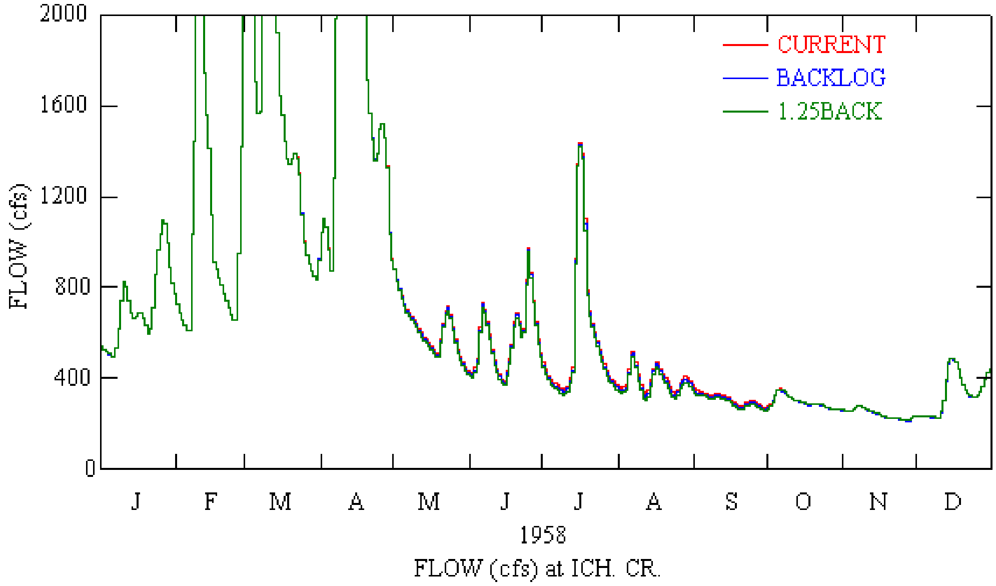

Figure I.3 – 5: Simulated streamflow of the Flint River at Bainbridge for 1958 (Normal Year)

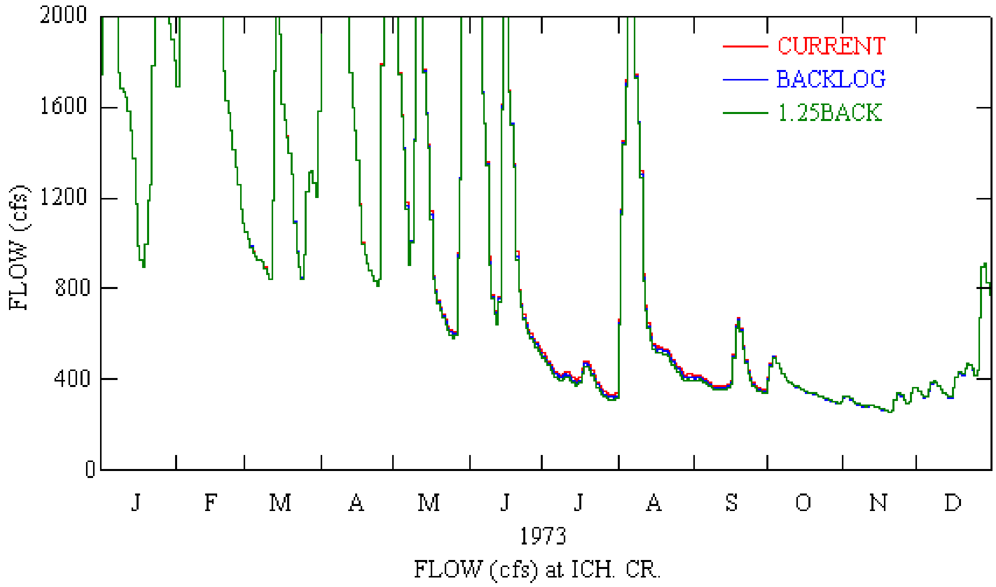

Figure I.3 – 6: Simulated streamflow of Ichawaynochaway Creek near Milford for 1973 (Wet Year)

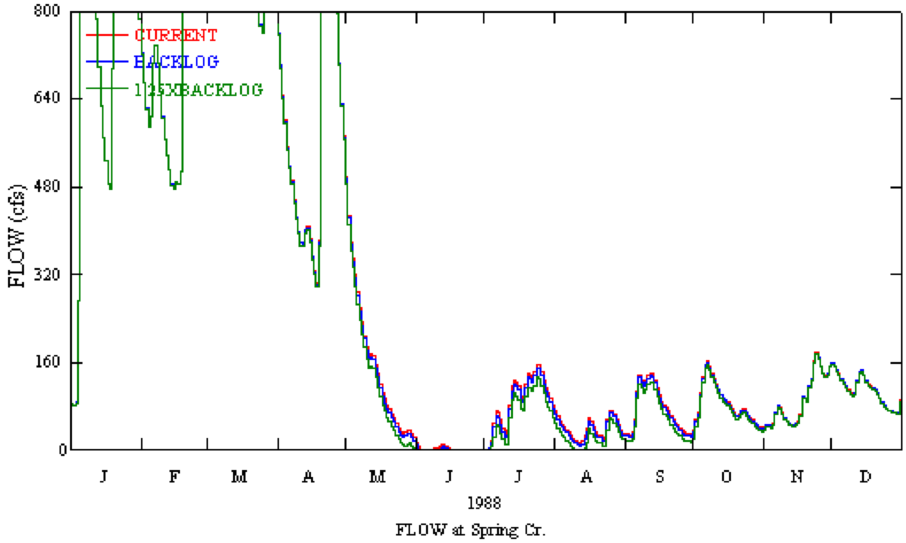

Figure I.3 – 7: Simulated streamflow of Spring Creek near Iron City for 1988 (Dry Year)

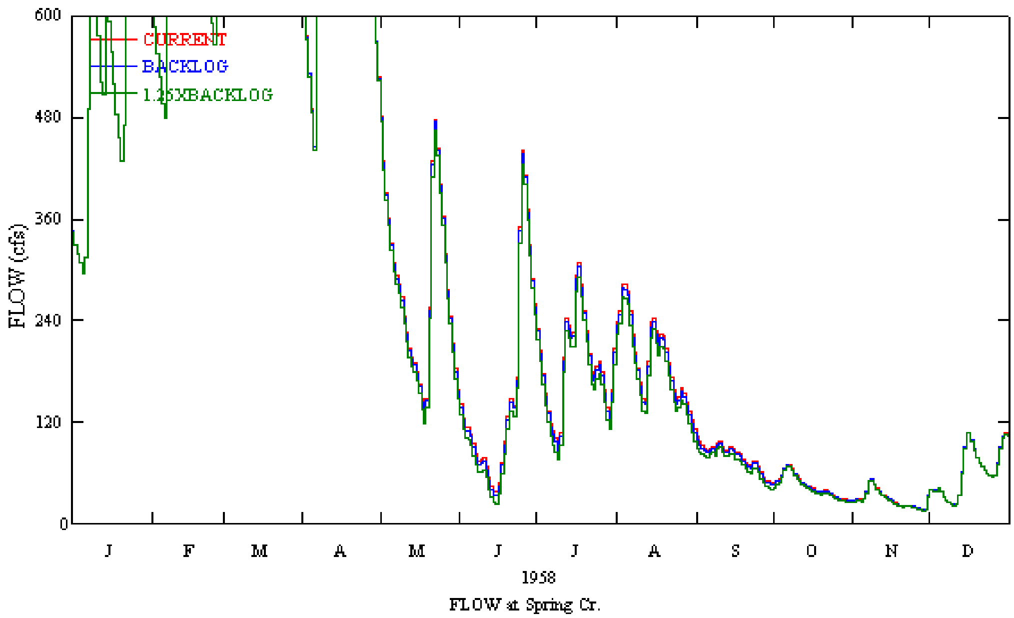

Figure I.3–8: Simulated streamflow of Spring Creek near Iron City for 1958 (Dry Year)

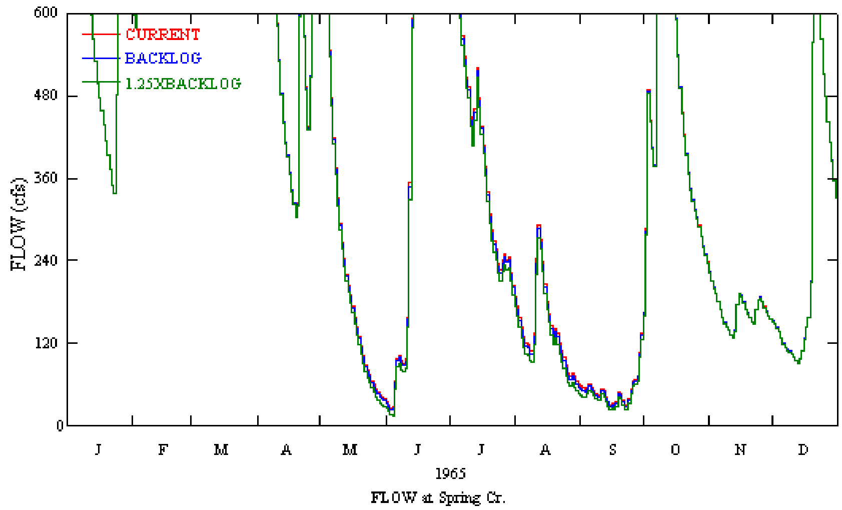

Figure I.3 – 9: Simulated streamflow of Spring Creek near Iron City for 1965 (Wet Year)

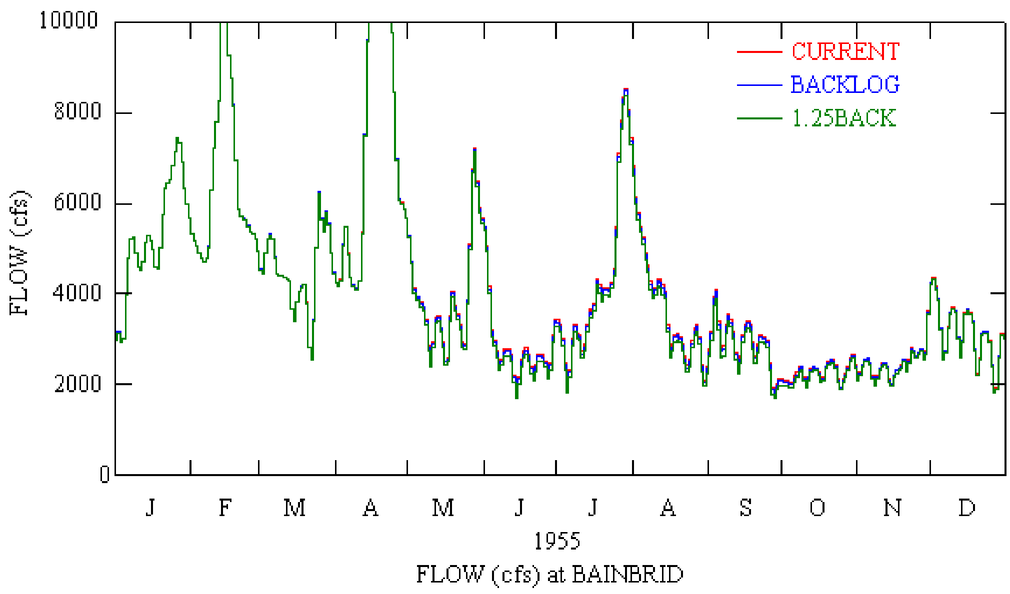

Figure I.3 – 10: Simulated streamflow of the Flint River at Bainbridge for 1955 (Dry Year)

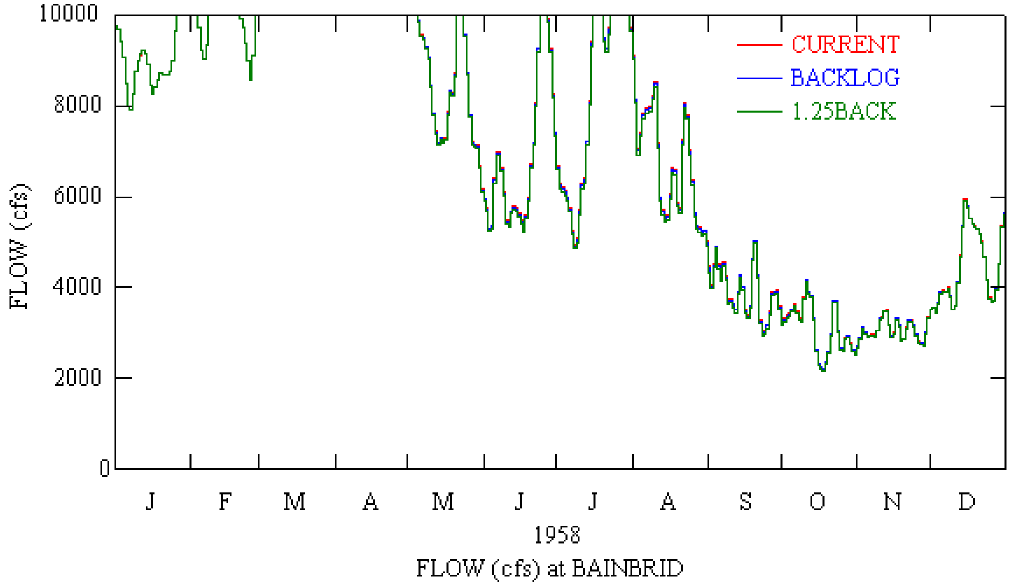

Figure I.3 – 11: Simulated streamflow of the Flint River at Bainbridge for 1958 (Normal Year)

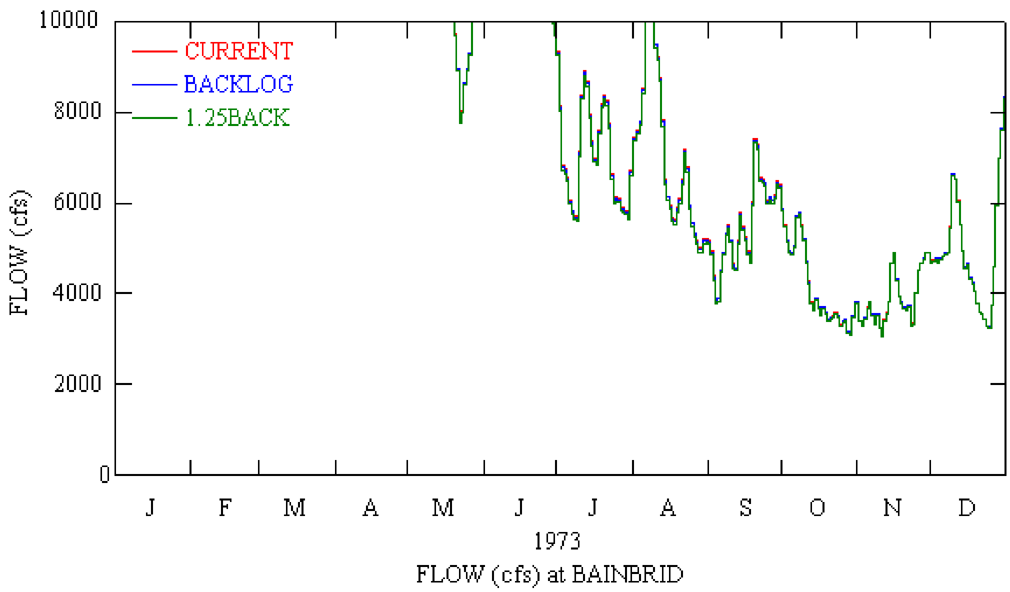

Figure I.3 – 12: Simulated streamflow of the Flint River at Bainbridge for 1973 (Wet Year)

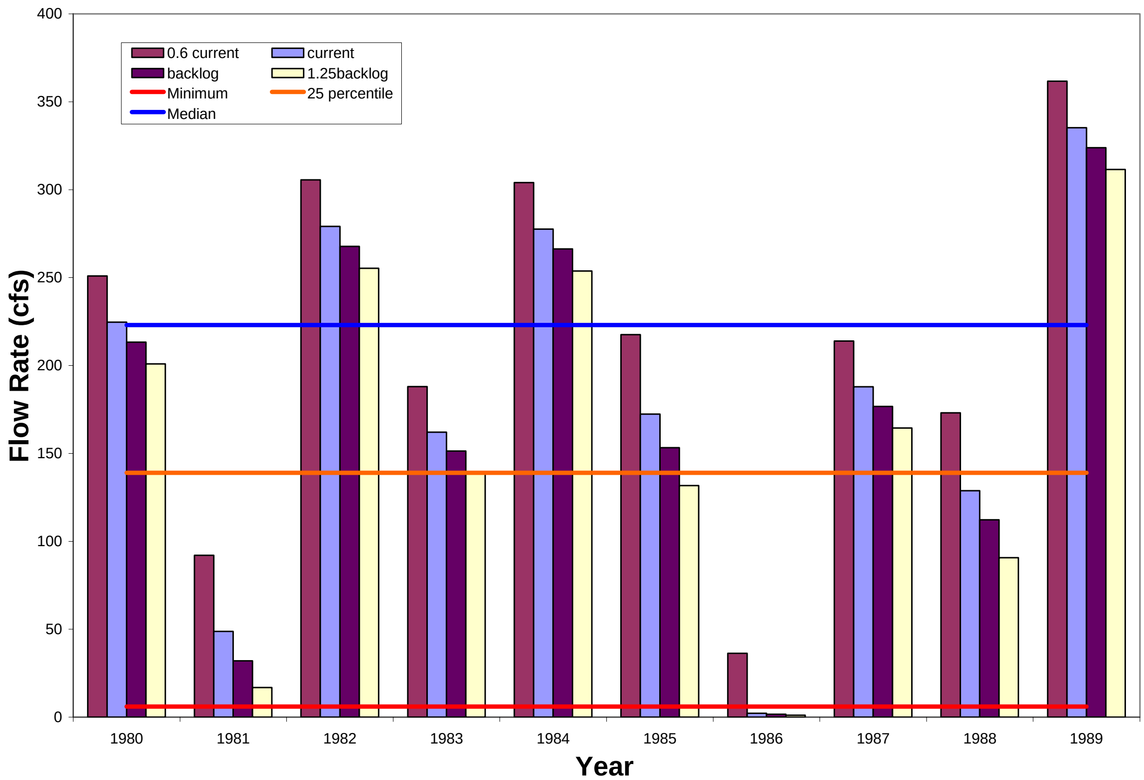

Figure I.4 – 1: Evaluation of Scenarios Using U1 Criteria Ichawaynochaway Creek near Milford (month of August)

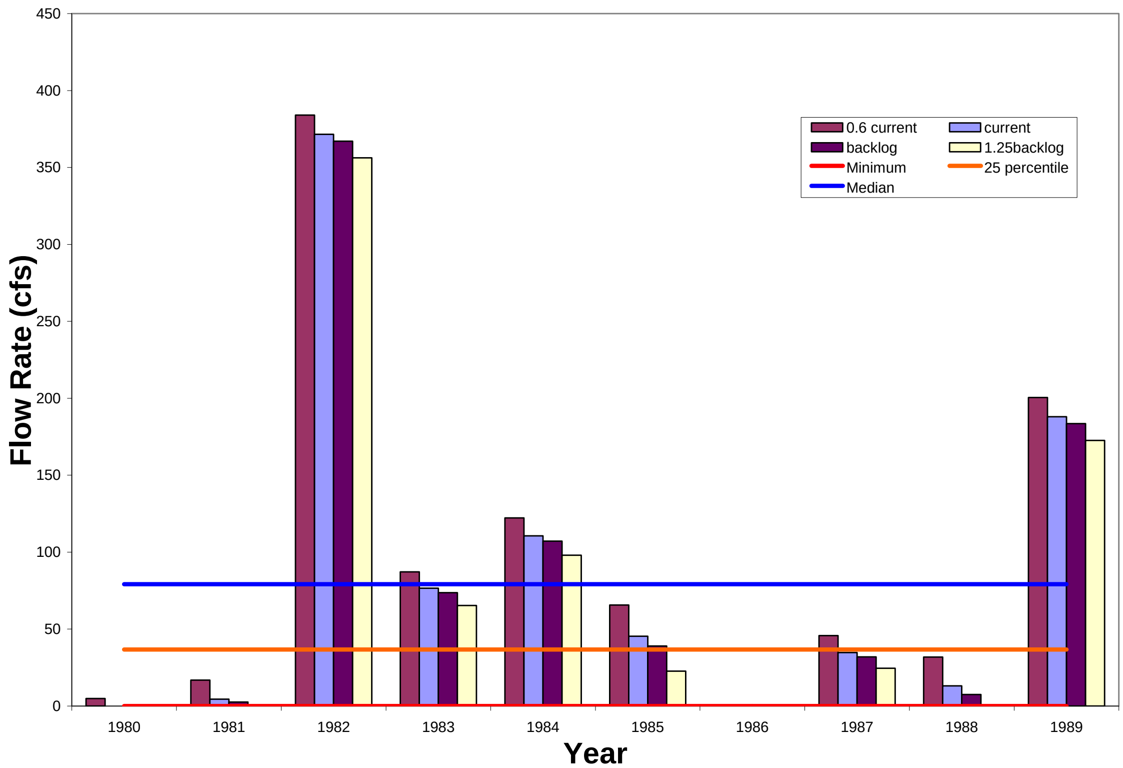

Figure I.4 – 2: Evaluation of Scenarios Using U1 Criteria Spring Creek at Iron City (month of August)

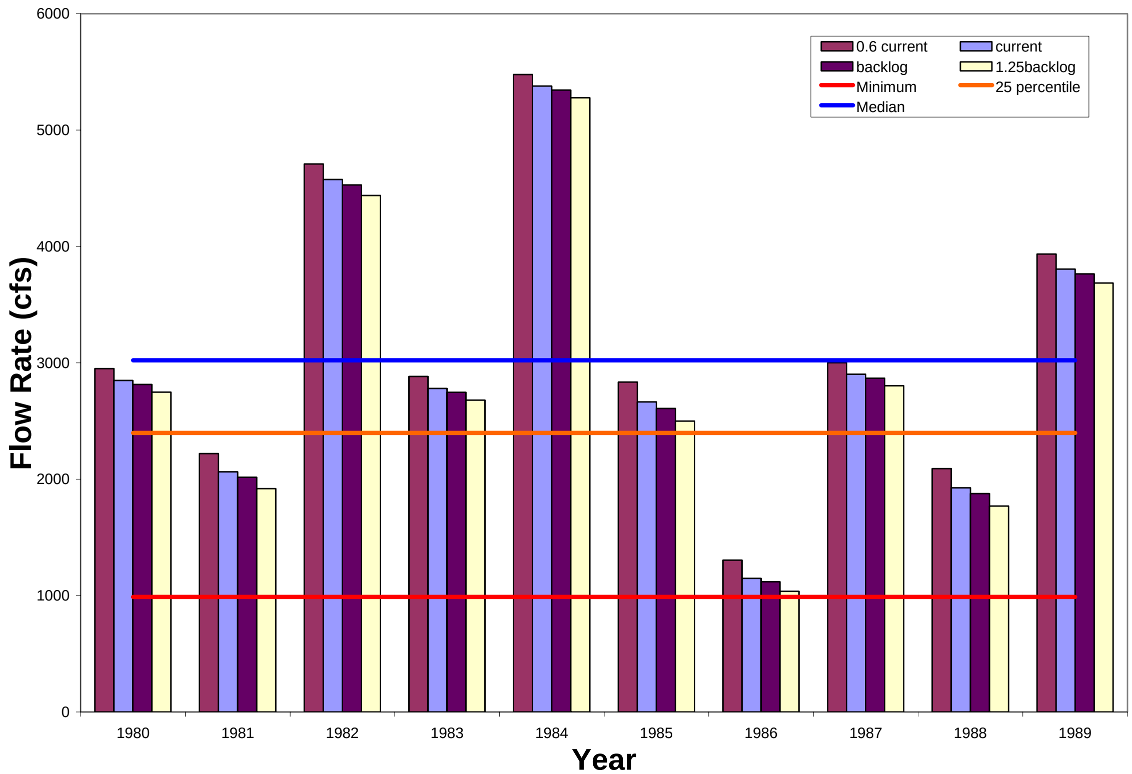

Figure I.4 – 3: Evaluation of Scenarios Using U1 Criteria Flint River at Bainbridge (month of August)

Table I.4 – 1: Computed guideline for U1 and U2 for full period of record
(a) Guideline for U1 and U2 for Ichawaynochaway Ck. at Milford for full period of record

Ichawaynochaway Creek at Milford			
U1-Daily minimum flows derived from full period of record 10/1939-9/2003 plus part of 1905, all 1906 and 1907			
Month	lowest daily minimum	25 percentile of daily minima	median of daily minima
Jan	193	381	482
Feb	224	451	576
Mar	220	478	603
Apr	175	342	473
May	43	228	308
Jun	12	162	228
Jul	21	153	227
Aug	6	139	223
Sep	10	148	197
Oct	98	179	235
Nov	115	222	274
Dec	200	289	365

Annual Low Flow Duration (U2) Statistics			
25% Annual Average Discharge	171cfs		
	Maximum	1 in 4 yrs	1 in 2 yrs
Criteria: Annual Low Flow Duration (days)	168	28	0

(b) Guideline for U1 and U2 for Spring Ck. near Iron City for full period of record

Spring Creek at Iron City U1-Criteria derived from full period of record 7/1937-9/2003			
	U1-A	U1-B	U1-C
monrhly Statistics	minimum	25percentile	median
Jan	12.6	108.0	226.8
Feb	31.5	204.3	387.9
Mar	47.7	256.5	459.0
Apr	51.3	197.1	299.7
May	3.5	87.8	122.4
Jun	0.8	48.2	90.0
Jul	0.2	45.9	92.7
Aug	0.0	36.7	79.2
Sep	0.0	32.4	59.0
Oct	0.3	28.8	63.9
Nov	0.6	34.2	65.7
Dec	10.8	49.5	97.2

Annual Low flow Duration (U2) Statistics			
25% Average Annual Discharge	110 cfs		
	Maximum	1 in 4 yrs	1 in 2 yrs
Criteria: Annual Low Flow Duration (Days)	272	174.25	111

(c) Guideline for U1 and U2 for lower Flint River at Bainbridge for full period of record

Lower Flint at Bainbridge U1-Daily minimum flows derived from whole period of HSPF calibrated model,1953-2003			
Month	lowest daily minimum	25 percentile of daily minima	median of daily minima
Jan	1888	3757	5430
Feb	2368	4672	7164
Mar	2349	5848	7449
Apr	3077	4448	6165
May	1463	3107	4248
Jun	1151	2377	3363
Jul	1165	2516	3400
Aug	988	2398	3022
Sep	1003	2062	2549
Oct	1358	2035	2542
Nov	1442	2055	2832
Dec	1784	2585	3374

Annual Low Flow Duration (U2) Statistics			
25% Annual Average Discharge	1998 cfs		
	Maximum	1 in 4 yrs	1 in 2 yrs
Criteria: Annual Low Flow Duration (days)	140	8	0

Table I.4 – 2: U1 guideline effects for Ichawaynochaway Creek at Milford: Monthly 1-day Minima Criteria – Variances Criteria are from full period of record

Lowest monthly 1-day minimum flow (U1-A)						
(Number. of years that flow was below the monthly criteria - should not exceed zero)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	175	43	12	21	6	10
Observed 1939-1975	0	0	0	0	0	0
Observed 1953-2003	0	0	0	0	0	0
No irr 1953-2003	**1**	0	0	0	0	0
Calibrated 1953-2003	**1**	0	0	0	**1**	**2**
0.6 x Current irrigation	**1**	0	0	0	0	0
0.7 x Current irrigation	**1**	0	0	0	0	**1**
0.8 x Current irrigation	**1**	0	0	0	**1**	**2**
Current irr. over 50 yrs	**1**	0	0	**2**	**3**	**4**
Backlog	**1**	0	**1**	**2**	**3**	**5**
1.25 x Backlog	**1**	0	**1**	**3**	**4**	**5**

25 percentile of monthly 1-day minimum flows (U1-B)						
(Percent of years with that flow was below monthly criteria - should not exceed 25%)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	342	228	162	153	139	148
Observed 1939-1975	23.1%	15.4%	15.4%	7.7%	3.8%	15.4%
Observed 1953-2003	21.6%	23.5%	**25.5%**	23.5%	**25.5%**	24.0%
No irr 1953-2003	19.6%	11.8%	7.8%	9.8%	7.8%	12.0%
Calibrated 1953-2003	19.6%	15.7%	13.7%	11.8%	11.8%	16.0%
0.6 x Current irrigation	19.6%	15.7%	19.6%	13.7%	15.7%	22.0%
0.7 x Current irrigation	19.6%	15.7%	19.6%	13.7%	17.6%	22.0%
0.8 x Current irrigation	19.6%	15.7%	19.6%	15.7%	17.6%	**26.0%**
Current irr. over 50 yrs	19.6%	19.6%	19.6%	15.7%	**27.5%**	**28.0%**
Backlog	21.6%	21.6%	19.6%	23.5%	**27.5%**	**32.0%**
1.25 x Backlog	21.6%	23.5%	**25.5%**	**29.4%**	**35.3%**	**32.0%**

Median of monthly 1-day minimum flows (U1-C)						
(Percent of years that flow was below the monthly criteria - should not exceed 50%)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	473	308	228	227	223	197
Observed 1939-1975	46.2%	38.5%	34.6%	38.5%	34.6%	38.5%
Observed 1953-2003	39.2%	**51.0%**	43.1%	49.0%	**52.9%**	50.0%
No irr 1953-2003	37.3%	27.5%	23.5%	23.5%	29.4%	22.0%
Calibrated 1953-2003	39.2%	33.3%	29.4%	31.4%	37.3%	38.0%
0.6 x Current irrigation	39.2%	33.3%	31.4%	31.4%	43.1%	36.0%
0.7 x Current irrigation	39.2%	37.3%	33.3%	31.4%	45.1%	42.0%
0.8 x Current irrigation	39.2%	41.2%	33.3%	35.3%	45.1%	50.0%
Current irr. over 50 yrs	45.1%	45.1%	37.3%	43.1%	**52.9%**	**56.0%**
Backlog	45.1%	49.0%	43.1%	49.0%	**60.8%**	**58.0%**
1.25 x Backlog	45.1%	**51.0%**	43.1%	**51.0%**	**64.7%**	**60.0%**

Table I.4 – 3: U2 guideline effects for Ichawaynochaway Creek at Milford: Annual Low Flow Duration Variances Criteria are from full period of record

Annual Low Flow Duration (U2) Statistics			
25% Annual Average Discharge	171 cfs		
	Maximum	1 in 4 yrs	1 in 2 yrs
Criteria: Annual Low Flow Duration (days)	168	28	0
Allowable years of variance	0	<25%	<50%
Observed 1939-1975	0	8.0%	18.0%
Observed 1953-2002	0	**28.0%**	48.0%
No irr 1953-2002	**1**	14.0%	28.0%
Calibrated 1953-2003	**2**	22.0%	34.0%
0.6 x Current irrigation	**5**	22.0%	34.0%
0.7 x Current irrigation	**5**	24.0%	34.0%
0.8 x Current irrigation	**6**	**28.0%**	34.0%
Current irr. over 50 yrs	**6**	**28.0%**	42.0%
Backlog	**6**	**32.0%**	48.0%
1.25 x Backlog	**6**	**36.0%**	50.0%

Table I.4 – 4: U1 guideline effects for Spring Creek near Iron City: Monthly 1-day Minima Criteria – Variances Criteria are from full period of record

Lowest monthly 1-day Minimum flow (U1-A) (Number of years that flow was below the monthly criteria - should not exceed zero)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	51.30	3.51	0.81	0.16	0.00	0.00
Observed 1937-1971	0	0	0	0	0	0
Observed 1953-2003	0	0	0	0	0	0
No irr 1953-2002	**2**	0	0	0	0	0
Calibrated 1953-2003	**3**	**3**	**4**	**5**	0	0
0.6 x Current irrigation	**4**	**3**	**8**	**7**	0	0
0.7 x Current irrigation	**6**	**4**	**9**	**7**	0	0
0.8 x Current irrigation	**6**	**4**	**11**	**8**	0	0
Current irr. over 50 yrs	**7**	**5**	**14**	**11**	0	0
Current irr. over 50 yrs(updated)	**7**	**4**	**14**	**8**	0	0
Backlog	**7**	**7**	**16**	**11**	0	0
1.25 x Backlog	**7**	**11**	**17**	**12**	0	0

25 percentile of monthly 1-day minimum flows (U1-B) (Percent of years that flow was below monthly criteria - should not exceed 25%)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	197.1	87.8	48.2	45.9	36.7	32.4
Observed 1937-1971	11.8%	6.1%	2.9%	5.9%	11.8%	11.8%
Observed 1953-2003	**26.2%**	**26.8%**	**29.3%**	**31.0%**	**33.3%**	**29.3%**
No irr 1953-2002	**33.3%**	**45.1%**	**29.4%**	**25.5%**	13.7%	16.0%
Calibrated 1953-2003	**33.3%**	**51.0%**	**33.3%**	**35.3%**	**27.5%**	18.0%
0.6 x Current irrigation	**33.3%**	**56.9%**	**47.1%**	**41.2%**	**31.4%**	22.0%
0.7 x Current irrigation	**33.3%**	**56.9%**	**49.0%**	**43.1%**	**31.4%**	22.0%
0.8 x Current irrigation	**33.3%**	**58.8%**	**51.0%**	**43.1%**	**33.3%**	**30.0%**
Current irr. over 50 yrs	**33.3%**	**60.8%**	**52.9%**	**47.1%**	**39.2%**	**38.0%**
Current irr. over 50 yrs(updated)	**33.3%**	**58.8%**	**52.9%**	**45.1%**	**37.3%**	**36.0%**
Backlog	**33.3%**	**60.8%**	**56.9%**	**49.0%**	**41.2%**	**38.0%**
1.25 x Backlog	**33.3%**	**60.8%**	**58.8%**	**54.9%**	**47.1%**	**44.0%**

Median of monthly 1-day minimum flows (U1-C) (Percent of years that flow was below the monthly criteria - should not exceed 50%)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	299.7	122.4	90	92.7	79.2	58.95
Observed 1937-1971	26.5%	15.2%	20.6%	23.5%	20.6%	23.5%
Observed 1953-2003	50.0%	**56.1%**	**53.7%**	**57.1%**	**52.4%**	**56.1%**
No irr 1953-2002	**52.9%**	**58.8%**	**56.9%**	**52.9%**	45.1%	38.0%
Calibrated 1953-2003	**52.9%**	**64.7%**	**60.8%**	**58.8%**	**51.0%**	50.0%
0.6 x Current irrigation	**52.9%**	**62.7%**	**70.6%**	**58.8%**	**54.9%**	**58.0%**
0.7 x Current irrigation	**52.9%**	**62.7%**	**70.6%**	**58.8%**	**54.9%**	**58.0%**
0.8 x Current irrigation	**52.9%**	**64.7%**	**72.5%**	**60.8%**	**56.9%**	**58.0%**
Current irr. over 50 yrs	**52.9%**	**66.7%**	**74.5%**	**64.7%**	**58.8%**	**62.0%**
Current irr. over 50 yrs(updated)	**52.9%**	**64.7%**	**72.5%**	**62.7%**	**58.8%**	**62.0%**
Backlog	**52.9%**	**68.6%**	**74.5%**	**64.7%**	**60.8%**	**62.0%**
1.25 x Backlog	**54.9%**	**74.5%**	**74.5%**	**70.6%**	**62.7%**	**70.0%**

Table I.4 – 5: U2 guideline effects for Spring Creek near Iron City: Annual Low Flow Duration Variances Criteria are from full period of record

Annual Low flow Duration (U2) Statistics 25% Average Annual Discharge 110cfs			
Criteria: Annual Low Flow Duration (Days)	Maximum 272	1 in 4 yrs 174.25	1 in 2 yrs 111
Allowable years of Variance	0	<25%	<50%
Observed 1937-1970	0	12.1%	27.3%
Observed 1953-2002	0	**30.0%**	**52.5%**
No irr 1953-2002	0	12.0%	46.0%
Calibrated 1953-2002	0	16.0%	**52.0%**
0.6 x Current irrigation	0	18.0%	**52.0%**
0.7 x Current irrigation	0	20.0%	**54.0%**
0.8 x Current irrigation	0	22.0%	**54.0%**
Current irr over 50 yrs	0	**26.0%**	**56.0%**
Current irr over 50 yrs (updated)	0	**26.0%**	**56.0%**
Backlog	0	**28.0%**	**56.0%**
1.25 x Backlog	0	**30.0%**	**56.0%**

Table I.4 – 6: U1 guideline effects for Flint River at Bainbridge: Monthly 1-day Minima Criteria – Variances Criteria are from full period of HSPF calibrated model (1953-2003)

Lowest monthly 1-day minimum flow (U1-A)						
(Number. of years that flow was below the monthly criteria - should not exceed zero)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	3077	1463	1151	1165	988	1003
No irr 1953-2003	0	0	0	0	0	0
Calibrated 1953-2003	0	0	0	0	0	0
0.6 x Current irrigation	0	0	0	0	0	0
0.7 x Current irrigation	0	0	0	0	0	0
0.8 x Current irrigation	0	0	0	0	0	0
Current irr. over 50 yrs	0	0	**1**	**1**	0	0
Backlog	0	0	**1**	**2**	0	**1**
1.25 x Backlog	0	0	**1**	**2**	**1**	**1**

25 percentile of monthly 1-day minimum flows (U1-B)						
(Percent of years with that flow was below monthly criteria - should not exceed 25%)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	4448	3107	2377	2516	2398	2062
No irr 1953-2003	17.6%	17.6%	9.8%	17.6%	13.7%	10.0%
Calibrated 1953-2003	17.6%	17.6%	13.7%	19.6%	17.6%	18.0%
0.6 x Current irrigation	17.6%	17.6%	19.6%	21.6%	21.6%	20.0%
0.7 x Current irrigation	17.6%	17.6%	19.6%	21.6%	21.6%	22.0%
0.8 x Current irrigation	17.6%	17.6%	21.6%	21.6%	21.6%	22.0%
Current irr. over 50 yrs	17.6%	17.6%	23.5%	23.5%	25.5%	22.0%
Backlog	17.6%	17.6%	23.5%	23.5%	25.5%	24.0%
1.25 x Backlog	17.6%	23.5%	**25.5%**	**29.4%**	**29.4%**	**30.0%**

Median of monthly 1-day minimum flows (U1-C)						
(Percent of years that flow was below the monthly criteria - should not exceed 50%)						
	Apr	May	Jun	Jul	Aug	Sep
Criteria (cfs)	6165	4248	3363	3400	3022	2549
No irr 1953-2003	45.1%	45.1%	37.3%	33.3%	33.3%	30.0%
Calibrated 1953-2003	45.1%	47.1%	39.2%	35.3%	43.1%	36.0%
0.6 x Current irrigation	45.1%	47.1%	39.2%	35.3%	45.1%	38.0%
0.7 x Current irrigation	45.1%	47.1%	39.2%	35.3%	45.1%	40.0%
0.8 x Current irrigation	45.1%	47.1%	39.2%	35.3%	45.1%	40.0%
Current irr. over 50 yrs	45.1%	47.1%	39.2%	39.2%	47.1%	44.0%
Backlog	45.1%	47.1%	39.2%	41.2%	47.1%	44.0%
1.25 x Backlog	45.1%	47.1%	41.2%	41.2%	49.0%	48.0%

Table I.4 – 7: U2 guideline effects for Flint River at Bainbridge: Annual Low Flow Duration Variances Criteria are from full period of HSPF calibrated model (1953-2002)

Annual Low Flow Duration (U2) Statistics			
25% Annual Average Discharge	1998cfs		
	Maximum	1 in 4 yrs	1 in 2 yrs
Criteria: Annual Low Flow Duration (days)	140	8	0
Allowable years of variance	0	<25%	<50%
No irr 1953-2003	0	8.0%	22.0%
Calibrated 1953-2003	0	10.0%	22.0%
0.6 x Current irrigation	0	12.0%	24.0%
0.7 x Current irrigation	0	12.0%	26.0%
0.8 x Current irrigation	0	14.0%	28.0%
Current irr. over 50 yrs	0	14.0%	30.0%
Backlog	0	16.0%	32.0%
1.25 x Backlog	0	20.0%	34.0%

Table I.4 – 8: Calculated 7Q10 Streamflow Rates for FRB Modeling Scenarios

	7Q10 Streamflow Rates (cfs)		
Modeling Scenario	Ichawaynochaway Ck. near Milford	Flint River at Bainbridge	Spring Ck. near Iron City
Pre-1970's Data	140	2500	15
60% Current Model	65	1650	0
Current Model	20	1500	0
Backlog Model	10	1460	0
125% Backlog Model	3.5	1380	0

Table I.4 – 9: Frequency of Flow Less than 7Q10

Location	7Q10	Historic	0.6 x Current	Current	Backlog	1.25xBacklog
Milford	140 cfs	2.9%	4.6%	6.5%	7.2%	8.1%
Iron City	15 cfs	3.5%	3.9%	5.8%	6.3%	7.8%
Bainbridge	2500 cfs	5.4%	5.9%	6.9%	7.2%	8.0%

APPENDIX II:
GROUND-WATER MODEL AND APPLICATION

Table I.3 –1: Current Irrigation Acres in the FRBFRB

sub-basin	gw acres using Upper Floridan	surface-water acres	well to pond irr_acres	well to pond acres using Upper Floridan
Lower Flint	166187	3941	198	182
Ichawaynochaway Ck.	33474	65938	1344	402
Spring Creek	128011	10213	1531	1126
Kinchafoonee-Muckalee	12714	44223	951	355
Middle Flint	25533	36147	2756	1331
Total Flint	365919	160461	6781	3396

(a) Additional Backlog Acres in the FRB

basin	gw acres using Upper Floridan	surface-water irr_acres	well to pond acres	well to pond acres using Upper Floridan
Lower Flint	18506	1308		
Ichawaynochaway Ck.	6477	10040		
Spring Creek	14197	2708	350	200
Kinchafoonee-Muckalee	5138	7732		
Middle Flint	19949	8701	785	128
Total Flint	64267	30489	1135	328

Table I.3 – 2: Irrigation Application Depth (inches) by Month for Ground-water and Surface-water, Drought and Normal Year

2004.

Source	Scenario	Sub-basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
			----	----	----	----	----	----	in.	----	----	----	----	----
G	Typical	Ichaway-Nochaway	0.0	0.0	0.1	0.3	1.1	1.3	1.7	1.7	0.6	0.2	0.1	0.1
		Kinchafoonee-Muckalee	0.1	0.1	0.2	0.4	1.4	1.4	1.7	1.4	0.8	0.2	0.1	0.1
		Lower Flint	0.1	0.1	0.2	0.7	1.8	1.8	1.7	1.7	1.0	0.3	0.1	0.1
		Middle Flint	0.0	0.0	0.1	0.3	1.1	1.3	1.8	1.7	0.8	0.3	0.0	0.0
		Spring	0.0	0.0	0.1	0.4	1.5	1.6	1.5	1.2	0.6	0.2	0.1	0.1
	Drought	Ichaway-Nochaway	0.1	0.1	0.2	0.4	1.6	2.1	2.7	3.3	1.2	0.3	0.2	0.1
		Kinchafoonee-Muckalee	0.1	0.1	0.4	0.7	2.1	2.3	2.9	2.0	1.3	0.5	0.2	0.1
		Lower Flint	0.1	0.1	0.4	0.8	2.9	2.7	2.6	2.6	2.5	0.5	0.4	0.2
		Middle Flint	0.1	0.1	0.4	0.7	1.7	2.4	3.0	2.3	1.0	0.5	0.1	0.1
		Spring	0.0	0.0	0.2	0.5	2.7	3.1	2.4	1.9	1.0	0.3	0.2	0.2
S	Typical	Ichaway-Nochaway	0.0	0.0	0.1	0.1	0.7	0.8	1.0	1.1	0.6	0.0	0.0	0.0
		Kinchafoonee-Muckalee	0.0	0.0	0.1	0.3	0.7	0.9	1.5	1.4	0.6	0.0	0.0	0.1
		Lower Flint	0.1	0.0	0.1	0.4	1.2	0.9	0.5	0.4	0.4	0.2	0.3	0.1
		Middle Flint	0.0	0.0	0.0	0.2	0.9	0.9	2.2	2.0	0.3	0.0	0.0	0.0
		Spring	0.0	0.0	0.0	0.2	0.6	0.8	1.1	1.4	0.5	0.1	0.0	0.0
	Drought	Ichaway-Nochaway	0.0	0.1	0.1	0.3	1.0	1.8	1.8	1.9	2.0	0.1	0.0	0.0
		Kinchafoonee-Muckalee	0.0	0.1	0.5	1.0	1.0	1.5	2.1	2.3	1.0	0.1	0.2	0.4
		Lower Flint	0.3	0.0	0.3	0.6	1.6	1.5	0.8	0.7	1.0	0.4	1.2	0.3
		Middle Flint	0.0	0.1	0.1	0.4	1.5	1.6	2.9	3.7	0.9	0.0	0.0	0.1
		Spring	0.0	0.1	0.2	0.4	1.5	1.5	1.9	2.3	1.7	0.7	0.1	0.0
W	Typical	Ichaway-Nochaway	0.0	0.0	0.0	0.1	0.7	1.2	1.5	1.5	0.7	0.1	0.0	0.0
		Kinchafoonee-Muckalee	0.0	0.1	0.3	0.8	1.6	1.9	1.7	1.4	0.7	0.2	0.1	0.1
		Lower Flint												
		Middle Flint	0.0	0.0	0.0	0.1	0.3	0.4	0.5	0.6	0.3	0.0	0.0	0.0
		Spring	0.0	0.0	0.2	0.3	1.4	1.1	1.8	1.2	0.3	0.0	0.0	0.0
	Drought	Ichaway-Nochaway	0.0	0.0	0.1	0.3	1.6	2.0	1.9	2.5	1.9	0.3	0.0	0.0
		Kinchafoonee-Muckalee	0.0	0.4	0.7	1.1	2.7	3.5	2.6	2.2	1.3	0.6	0.5	0.5
		Lower Flint												
		Middle Flint	0.0	0.0	0.0	0.3	0.9	1.3	0.9	0.8	0.9	0.1	0.0	0.0
		Spring	0.0	0.2	0.5	0.7	1.8	2.0	3.3	1.9	0.6	0.1	0.0	0.0

Source: Jim Hook of University of Georgia, 2005
*G: ground-water application
*S: surface-water application
*W: well to pond, it is a combination of using surface/ground-water

Table I.3-3 (a): Streamflow Reduction due to the Irrigation Pumping from the Upper Floridan at Milford in Ichawaynochaway Creek for Drought Years (cubic feet/sec.)

Month	current acres	backlog	1.25 x backlog
March	0.2	0.2	0.3
Apr	0.3	0.4	0.5
May	0.9	1.3	1.6
Jun	1.6	2.1	2.7
Jul	1.9	2.3	2.9
Aug	2.2	2.6	3.2
Sep	1.7	2.1	2.6
Oct	1.0	1.2	1.6
Nov	1.1	1.4	1.7
Dec	0.9	1.1	1.4

Streamflow Reduction due to the Irrigation Pumping from the Upper Florida at Milford of Ichawaynochaway Creek for Normal Years (cubic feet/sec.)

Month	current acres	backlog	1.25 x backlog
March	0.1	0.1	0.1
Apr	0.2	0.2	0.3
May	0.6	0.8	1.0
Jun	1.0	1.2	1.5
Jul	1.2	1.5	1.9
Aug	1.2	1.5	1.9
Sep	0.9	1.2	1.5
Oct	0.6	0.8	0.9
Nov	0.6	0.8	1.0
Dec	0.5	0.6	0.8

Note: the reduction is the accumulated effect of ground-water pumping up to Milford Gauge instead of the effect of the whole Ichawaynochaway Creek sub-basin.

Table I.3 - 3 (b): Streamflow Reduction due to the Irrigation Pumping from the Upper Floridan at Iron City of Spring Creek for Drought Years (cubic feet/sec.)

Month	current acres	backlog	1.25 x backlog
March	3.5	3.8	4.8
Apr	8.1	8.8	11.0
May	30.9	32.9	41.1
Jun	38.5	40.9	51.1
Jul	31.4	33.7	42.1
Aug	27.3	29.5	36.9
Sep	19.9	21.9	27.4
Oct	9.3	10.5	13.2
Nov	7.0	8.3	10.3
Dec	4.2	4.7	5.9

Streamflow Reduction due to the Irrigation Pumping from the Upper Floridan at Iron City of Spring Creek for Normal Years (cubic feet/sec.)

Month	current acres	backlog	1.25 x backlog
March	1.7	1.8	2.3
Apr	6.1	6.5	8.1
May	19.7	20.8	26.0
Jun	23.1	24.6	30.7
Jul	20.8	22.6	28.3
Aug	17.8	19.6	24.5
Sep	11.0	12.3	15.4
Oct	3.9	4.4	5.5
Nov	2.3	2.4	3.0
Dec	2.1	2.2	2.7

Note: the reduction is the accumulative effect up to Iron City instead of the effect of the whole Spring Creek sub-basin.

Table I.3 - 3 (c): Streamflow Reduction due to the Irrigation Pumping from the Upper Floridan at Bainbridge of lower Flint River for Drought Years (cubic feet/sec.)

Month	current acres	backlog	1.25 x backlog
March	39	42	52
Apr	73	79	98
May	229	252	315
Jun	287	320	399
Jul	306	338	422
Aug	321	352	440
Sep	315	341	426
Oct	202	220	275
Nov	156	171	214
Dec	118	130	162

Streamflow Reduction due to the Irrigation Pumping from the Upper Floridan at Bainbridge of lower Flint River for Normal Years (cubic feet/sec.)

Month	current acres	backlog	1.25 x backlog
March	16	17	22
Apr	32	35	44
May	98	110	137
Jun	140	156	195
Jul	186	207	258
Aug	199	220	275
Sep	153	169	212
Oct	105	116	145
Nov	69	76	95
Dec	51	56	70

Note: the reduction is the effect up to Bainbridge gauge. It is the combination of the whole Ichawaynochaway Creek and most of the lower Flint River Sub-basins.

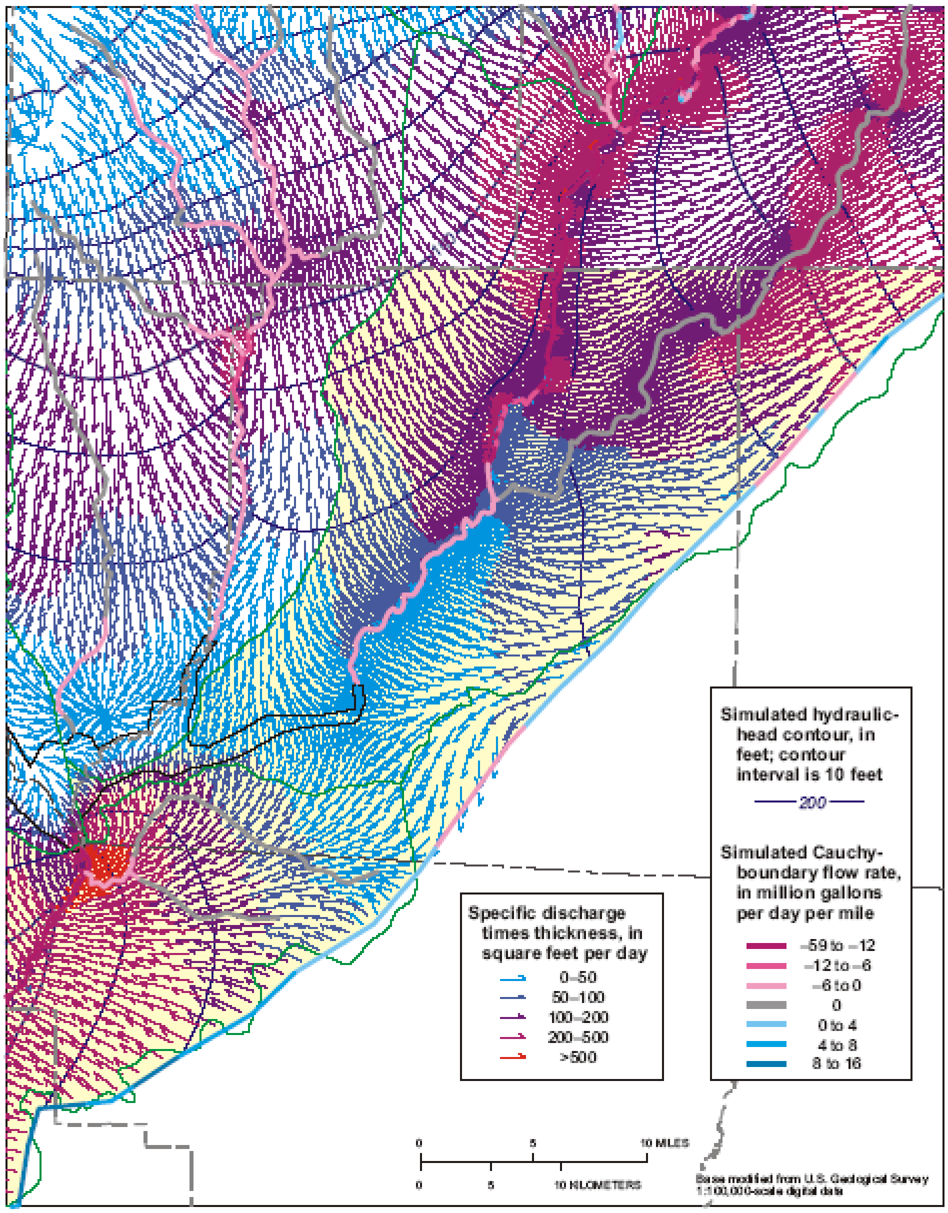

Figure II.1: Simulated hydraulic head contours, ground-water flow direction by element, and Cauchy-boundary flow by element side in the southern part of the lower Flint River sub-basin for the October 1999 calibrated lower FRB model (Jones and Torak, in review).

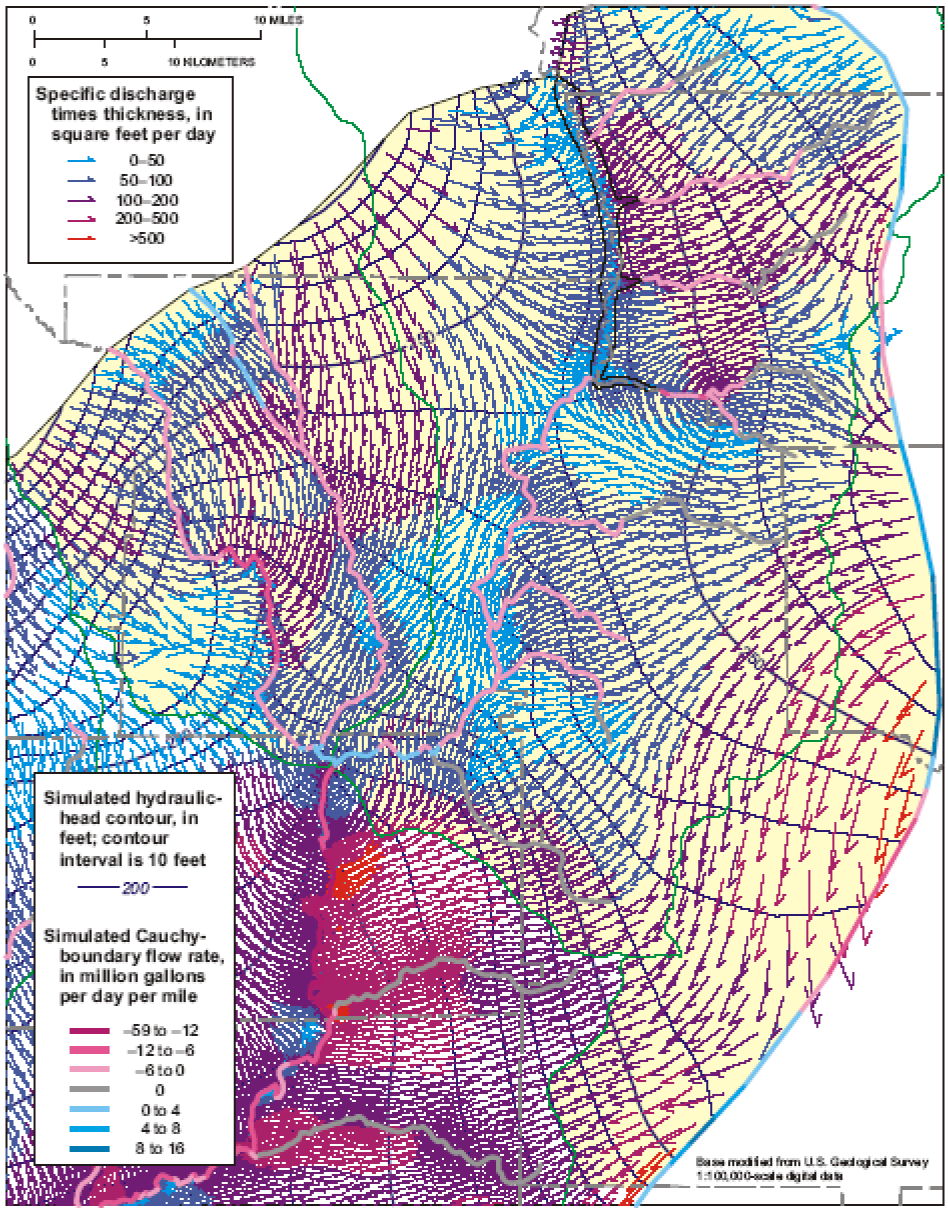

Figure II.2: Simulated hydraulic head contours, ground-water flow direction by element, and Cauchy-boundary flow by element side in the northern part of the lower Flint River sub-basin for the October 1999 calibrated lower FRB model (Jones and Torak, in review).

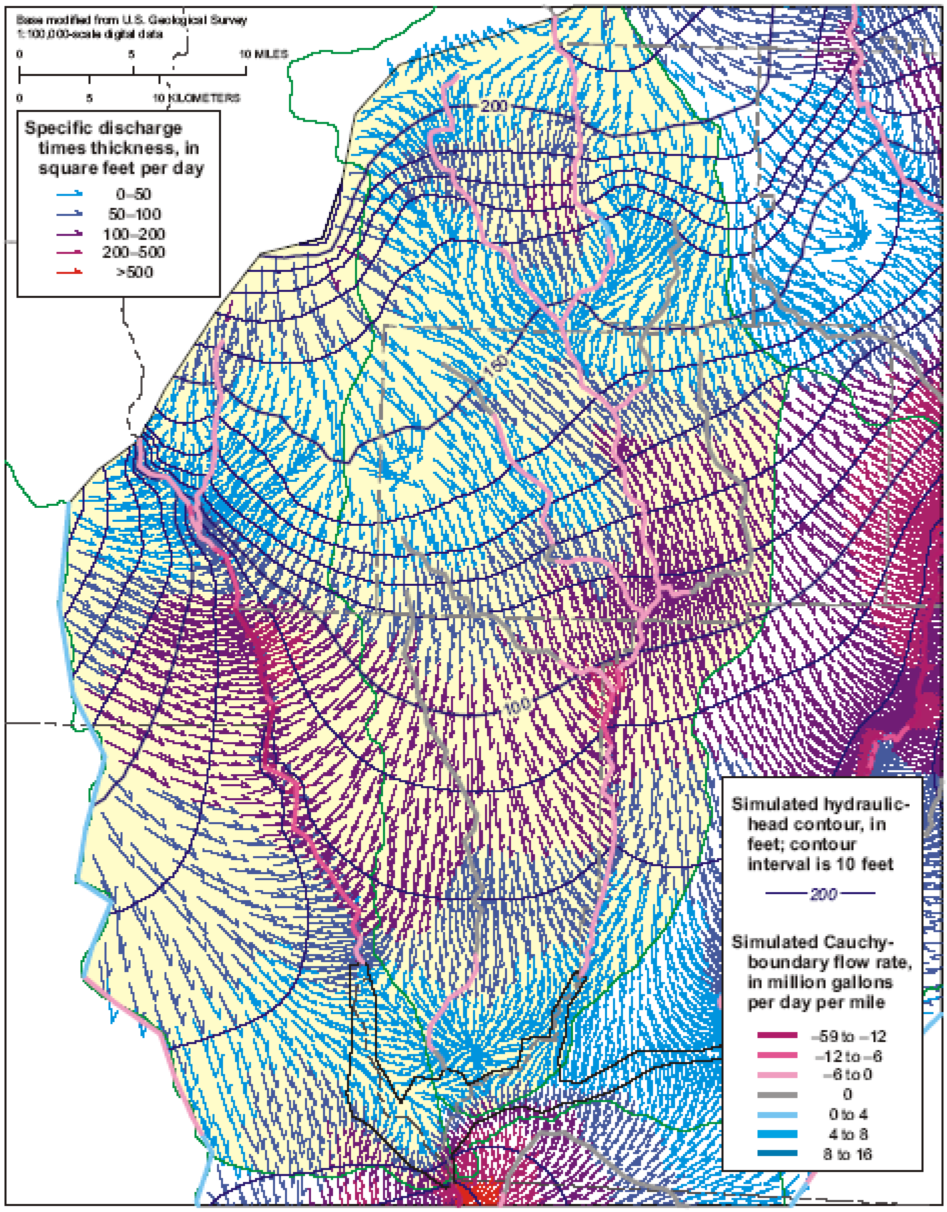

Figure II.3: Simulated hydraulic head contours, ground-water flow direction by element, and Cauchy-boundary flow by element side in Spring Creek sub-basin for the October 1999 calibrated lower FRB model. (Jones and Torak, in review).