No. 142, Original

In The
Supreme Court of the United States

STATE OF FLORIDA,

Plaintiff,

v.

STATE OF GEORGIA,

Defendant.

DIRECT TESTIMONY OF PHILIP B. BEDIENT, Ph.D., P.E.

October 26, 2016

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1. I, Philip B. Bedient, Ph.D., P.E., offer the following as my Direct Testimony.

2. I am an expert in hydrology, hydrologic modeling, civil engineering, river and lake studies, and reservoir operations.

3. I have been retained by the State of Georgia to study the hydrology of the Apalachicola-Chattahoochee-Flint ("ACF") Basin and the operation of federal reservoir projects in the ACF Basin by the U.S. Army Corps of Engineers ("Corps").

SUMMARY OF OPINIONS

4. Based on my analysis of the hydrology and reservoir operations of the ACF Basin, and in light of my experience in hydrology, hydrologic modeling, civil engineering, reservoir operations, and river and lake studies, I offer the following opinions:

- **Any change in the amount or timing of flow crossing the Georgia-Florida state line and entering Florida must be coordinated and executed by the Corps.** The Corps regulates the amount of water entering the Apalachicola River through its operation of a complex system of federal dams and reservoirs in the ACF Basin. All water from the Chattahoochee and Flint Rivers that enters Florida must first pass through the Corps' reservoirs, including Woodruff Dam at the Georgia-Florida state line. Releases from Woodruff Dam are determined by the Corps according to a set of complex rules for basin-wide water management that balance multiple federal project purposes. As a result, additional water entering the system does not automatically translate into additional flow across the state line. This is especially true during low-flow or drought conditions. The only way to ensure any particular flow regime into Florida is to set specific releases of water from Woodruff Dam, and any change to the current rules would require both modification of the Corps' current basin-wide reservoir operating rules and involvement by the Corps and other federal agencies.

- **Florida's proposed reductions in Georgia's water use would not materially increase state-line flows, especially during low-flow and drought periods.** I conducted modeling of consumption caps on Georgia using HEC-ResSim, the Corps' official reservoir simulation and water management model for the ACF

Basin. I found that reducing Georgia's total water use in the ACF Basin by as much as 30% of its current levels—or even down to its 1992 rates, as Florida suggests—would provide little to no increase in flow into Florida. This is especially true for low-flow or drought conditions, when the Corps operates its reservoirs to maintain storage in the reservoirs while providing a minimum flow of 5,000 cfs into Florida. The Corps' reservoir rules and reservoir model both confirm that under these conditions, increases in flow from the Flint River would be regulated and offset by decreased releases from the reservoirs on the Chattahoochee River and would not automatically translate into increased flow into Florida.

- **Georgia's total consumptive water use—both historical and projected—has not had and will not have a significant impact on state-line flows, especially under low-flow and drought conditions.** I reviewed the existing data on Georgia's total consumptive use, including projections for future demands, and streamflow in the ACF Basin. I conclude that Georgia's consumptive use has not materially reduced state-line flows. This is primarily because the Corps reservoirs work to "smooth out" the effects of upstream water use and because Georgia's consumptive use already represents a relatively small fraction of total flows entering Florida, even when water is in its greatest demand and flows are at their lowest. My modeling confirms that projected increases in Georgia's water use through 2040 would not significantly increase consumptive use levels, and would have only negligible effects at the state line.

- **Georgia's total impact on the ACF river system must include analysis not only of consumptive water use, but also of Georgia's contributions of water to the system resulting from land use changes, which exceed the total amount of water that Georgia consumptively removes.** I studied land use changes in Georgia and found that urban development has led to increased runoff into the Chattahoochee and Flint Rivers. I found that the total amount of runoff *contributed* to these rivers over the decades from increased impervious surfaces and improved drainage systems has exceeded the total amount of water *removed* from the system through consumptive uses. Florida's experts acknowledge the effect of land use changes in increasing runoff, but none has estimated how much water is *contributed* to the system from land use changes, instead focusing solely on water *removed*. My analysis of Georgia's impact on streamflow includes estimates of water removed as well as added by Georgia.

- **The primary cause of recent observed declines in streamflow in the Apalachicola River is recent changes in climate in the ACF Basin, not Georgia's water use.** In recent years, the amount of streamflow in rivers and streams throughout the ACF Basin and in the region have declined as a result of climate variability—including declining precipitation resulting from three significant multi-year drought periods—and not as a result of Georgia's consumptive water use. I have observed that the amount of rainfall in Florida that gets converted to streamflow in the Apalachicola River has declined over the past few decades by a long-term average of 4,000 cfs. The data show that since 1978, Georgia's percent share of flow contributed to the Apalachicola River has actually increased, while Florida's contribution of flows to the Apalachicola River has decreased. This decline occurs entirely below the state line, and therefore has nothing to do with Georgia's consumptive use.

5. I also reviewed the testimony of Dr. George Hornberger, Dr. Peter Shanahan, and Dr. Dennis Lettenmaier regarding the hydrology and reservoir operations of the ACF Basin. I offer the following opinions:

- **Contrary to Dr. Shanahan's conclusion, the Corps reservoir operations confirm that the Corps operates to offset increased inflows from the Flint River using storage on the Chattahoochee River. This is part of the Corps' balanced operation of the reservoirs as a single system.** Dr. Shanahan's conclusion that the Corps has no capacity to regulate flows from the Flint River ignores nearly one third of total storage and focuses entirely on Lake Lanier. The data confirm that the Corps operates to offset flows under the RIOP during low-flow periods. Dr. Shanahan's analysis shows otherwise only because he focuses largely on pre-RIOP operating rules (which are not in place today) and because his results include high-flow conditions (when the offset would not occur).

- **The Corps' releases from Woodruff Dam are very close to 5,000 cfs during low-flow and drought conditions. The Corps does not desire to drain its reservoirs during the summer and fall to support any one project purpose over all the others, as Dr. Shanahan speculates.** The Corps does not use its "discretion" to regularly and deliberately release water in excess of the 5,000 cfs minimum releases called for under the current rules. Dr. Shanahan's opinion is based on review of official USGS flow measurements, which have been adjusted after the fact. The correct dataset for evaluating the Corps' intended releases from Woodruff Dam is the Corps' daily recorded releases from the project, which show releases far closer to 5,000 cfs. Dr. Shanahan does not identify any real-world evidence that the Corps is "incentivized" by any one project purpose to deliberately drain their reservoirs when they are at critical levels to support a single project purpose, fish and wildlife, at the expense of all other federal project purposes. Just the opposite: during low-flow periods, the Corps prioritizes maintaining storage in the reservoirs as part of its careful balance of all federal project purposes in the ACF Basin while maintaining certain minimum flow requirements.

- **Dr. Hornberger's modeling results of consumption caps using a slightly modified version of ResSim are consistent with mine, *i.e.*, they show that hypothetical reductions in Georgia's water use would generate minimal, if any, increase in state-line flow during dry months.** Dr. Hornberger modeled the state-line flow impacts from reductions in Georgia's consumptive use using his "data driven" ResSim model, which operates similar to the Corps' ResSim model, which I use and which the Corps uses. Dr. Hornberger's modeling shows that during dry months of dry years, even a 50% reduction in Georgia's agricultural consumptive use on the Flint River would often produce little or no increase in flow entering Florida. Dr. Hornberger did not report the results of this

ResSim modeling analysis in his expert report, but I reviewed those results and confirmed that they corroborate my conclusions.

- **Dr. Hornberger's "Lake Seminole" model, which is engineered to show that all increased flows on the Flint River will pass through to Florida, is a fundamentally flawed model based on a programmed result. The "Lake Seminole" model contains numerous problems that make it entirely inappropriate for modeling the complex, integrated operations of the ACF reservoir system.** Dr. Hornberger's "Lake Seminole" model is a simplified reservoir routing model of a single pass-through reservoir (Lake Seminole) that cannot simulate any of the upstream reservoirs. Dr. Hornberger built the model to be "consistent with" Dr. Shanahan's view of the reservoir operations, and the model operates by forcing excess inflow to the reservoir into Florida. By attempting to rewrite the Corps' ResSim to conform to Dr. Shanahan's view, which is contradicted by real-world evidence, Dr. Hornberger introduced numerous problems into his model that render it entirely unsuitable for modeling any scenario involving the complex operations of the ACF reservoirs.

- **Contrary to conclusions by Dr. Hornberger and Dr. Lettenmaier, there has not been a "fundamental shift" in the hydrology of the ACF Basin since 1970, much less one caused by Georgia's consumptive use.** Dr. Hornberger and Dr. Lettenmaier both offer opinions regarding the existence of "shifts" or "trends" in basin hydrology since 1970, and attribute those shifts to Georgia's consumptive use. I find no evidence of a "fundamental shift" in the hydrology of the ACF Basin since 1970, much less one caused by Georgia's consumptive use. Instead, the data show that recent declines in streamflow in the ACF Basin are associated with the occurrence of three multi-year droughts in the last 17 years, which bias the long-term "trends" presented by Dr. Hornberger and Dr. Lettenmaier.

- **Dr. Hornberger and Dr. Lettenmaier rely on unreliable and biased hydrologic models to "infer" the impact of Georgia's water use on streamflow in the ACF Basin.** Dr. Hornberger and Dr. Lettenmaier each use hydrologic models to "forecast" flows in the ACF Basin under "unimpacted" or "natural" conditions. Dr. Hornberger and Dr. Lettenmaier conclude that differences between what their models predict and what the observed flows show reflect how much water has been "depleted" from the system due to Georgia's water use. Both Dr. Hornberger and Dr. Lettenmaier's models contain inherent error and uncertainty in excess of the "depletion" that they attribute to Georgia. These models also suffer from significant bias that exaggerates the amount of flow under "natural" conditions, thereby exaggerating the impact of Georgia's consumptive use on streamflow.

BACKGROUND AND PROFESSIONAL QUALIFICATIONS

6. I am the Herman Brown Professor of Civil and Environmental Engineering at Rice University in Houston, Texas.

7. I have a Ph.D. (1975) in Environmental Engineering from the University of Florida, a Master's degree (1972) in Environmental Engineering from the University of Florida, and a Bachelor's degree (1969) in Physics from the University of Florida. I am a registered Professional Engineer.

8. I have over 40 years of experience performing hydrologic and hydraulic modeling of lakes, rivers, and watersheds. My experience has generally focused on running rainfall-runoff models for large watersheds in the Southern and Southeastern United States, including in Florida, Texas, and Louisiana. I have been performing statistical analysis of rainfall and streamflow data for decades. I direct operations for the first real-time flood warning system in the United States, which I invented, based on analysis of real-time radar, rainfall, and streamflow data. I began installing gages with the U.S. Geological Survey ("USGS") in the 1970s, and I have 15 years of experience installing stream gages. I have studied flood and drought flows and the impact of land use changes (*e.g.*, urban development) on runoff, which refers to the amount of rainfall that makes its way into the river system.

9. I have been working on federal and non-federal reservoir projects since the 1970s. My experience with federal reservoir projects includes analysis and modeling of reservoir and dam operations by the Corps using hydrologic, hydraulic, and reservoir simulation models developed by the Corps Hydrologic Engineering Center ("HEC"), the Corps' premier modeling

and research center in the United States. I regularly use Corps HEC models to support reservoir operations and flood warning systems. For instance, I was involved for over 5 years with the redesign of Houston's infrastructure to manage flood flows, based on analysis conducted using hydrologic and HEC models. For my work on this case, I directed a team of professional modelers and civil engineers with experience working at the Corps on reservoir operations and conducting reservoir system modeling with HEC-ResSim.

10. I teach and conduct research at Rice University in surface water hydrology, groundwater hydrology, floodplain analysis, flood prediction systems, and water quality control. I have directed 60 research projects over the past 40 years.

11. I have written over 180 articles in journals and conference proceedings, and I have authored or co-authored four textbooks on hydrology. I am the lead author of *Hydrology and Floodplain Analysis* (Prentice Hall, 5th ed., 2012), one of the leading hydrology textbooks used in over 75 universities across the United States.

12. I am an elected Fellow to the American Society of Civil Engineers ("ASCE"), an honor held by fewer than 3.5% of ASCE members. I am a member of the American Institute of Hydrology ("AIH") as well as other professional associations. In 2007, I received the AIH's C.V. Theis Award for my contributions to the field of hydrology. I also held the Shell Distinguished Chair in Environmental Science (1988-1993) from Rice University.

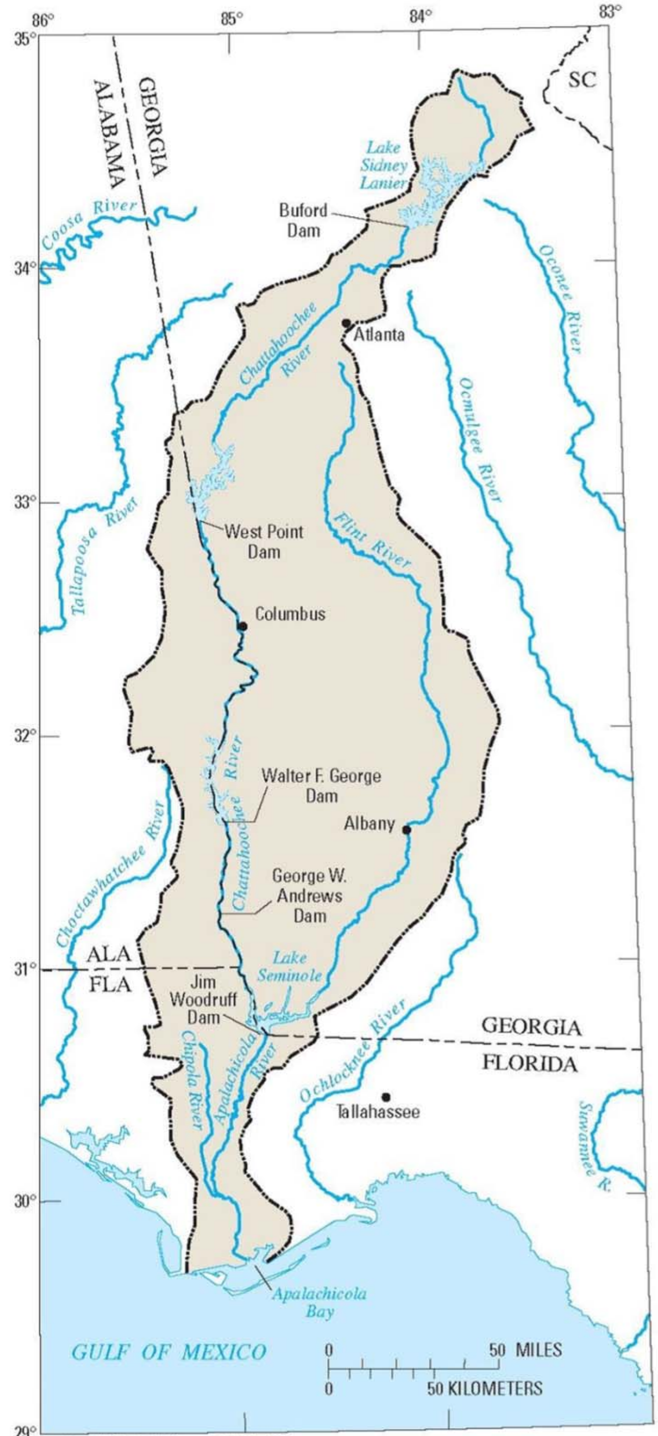
13. Further detail regarding my qualifications is provided in my CV (GX-1022).

ANY CHANGE IN THE AMOUNT OR TIMING OF STATE-LINE FLOW MUST BE COORDINATED AND EXECUTED BY THE CORPS

14. The ACF Basin encompasses approximately 19,600 square miles. It is comprised of three major river basins: the Chattahoochee River Basin, the Flint River Basin, and the Apalachicola River Basin. The Chattahoochee and Flint Rivers in Georgia join together at the Georgia-Florida state line. The Apalachicola River in Florida begins at the state line, flows south through Florida, and empties into the Apalachicola Bay in the Gulf of Mexico.

15. The Corps operates five reservoirs in the ACF Basin. In downstream order, these are Lake Lanier/Buford Dam, West Point Lake/Dam, Walter F. George Lake/Dam, George P. Andrews Lake/Dam, and Lake Seminole/Jim Woodruff Dam. The first four are located on the

Chattahoochee River, while Lake Seminole is located at the state line. Bedient Demo. 1 below shows the ACF Basin, including the Corps' five reservoirs.



Base from U.S. Geological Survey digital data, 1972
Albers Equal-Area Conic projection
Standard Parallels 29°30' and 45°30', central meridian -83°00'

Bedient Demo. 1. ACF Basin (Source: JX-72)

I. The Corps Operates the Federal Reservoir Projects in the ACF Basin as a Single, Integrated System to Balance Multiple Project Purposes

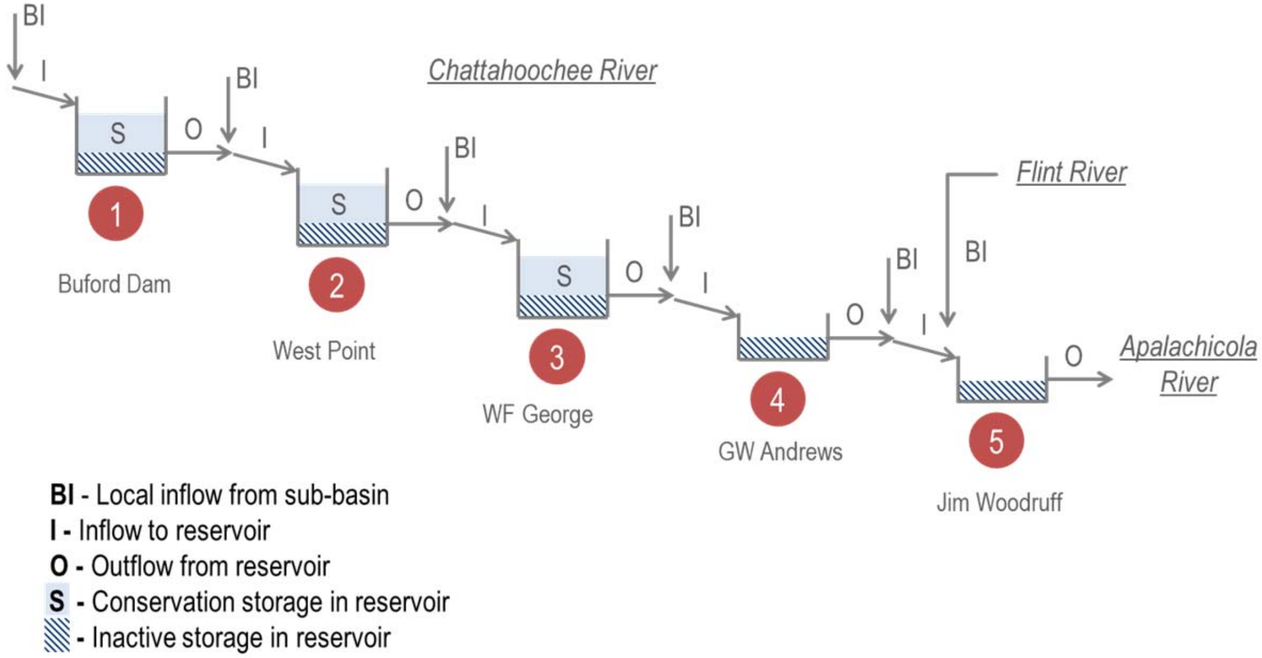
16. The Corps plays a central role in regulating streamflow in the ACF Basin (JX-124, at 2-23). The Corps reservoir operations in the ACF Basin are discussed extensively in JX-124. JX-124 is a true and accurate copy of the Corps' Draft Environmental Impact Statement ("DEIS"), published in October 2015. The DEIS was prepared by the Corps as part of its ongoing revision to the Master Water Control Manual ("WCM") for the ACF Basin. I have reviewed and relied on the Corps' DEIS and experts in my field regularly rely on official publications from the Corps such as JX-124.

17. The Corps operates its reservoirs and dams to satisfy multiple federally authorized project purposes, including water supply, flood control, navigation, water quality, fish and wildlife, recreation, and hydropower (JX-124). In order to satisfy these project purposes, the Corps operates its complex system of reservoir projects in the ACF Basin as a single, integrated system (JX-124, GX-544). GX-544 is a true and accurate copy of the Corps' 2013 Final Scoping Report, also associated with the Corps' WCM update. I have reviewed and I am familiar with this document, and experts in my field regularly rely on documents such as this. The purpose of the reservoirs is to regulate reservoir and streamflow levels throughout the year to regulate the effects of natural variability in streamflow (JX-124). The reservoirs store water during times of relative plenty and release water to "augment" streamflow by releasing water from the reservoirs during times of relative scarcity (JX-124, GX-544).

18. The Corps decides how much water to store or release from each reservoir according to complex rules established for the reservoirs. These rules are coordinated to balance and satisfy all of the basin-wide project purposes. The role of the Corps in controlling the amount and timing of flows in the ACF Basin is most apparent at Woodruff Dam, which sits at the Georgia-Florida state line directly below Lake Seminole and controls flows from both the Chattahoochee and Flint Rivers, and eventually entering the Apalachicola River. The Revised Interim Operating Plan ("RIOP") sets rules for minimum flows from Woodruff Dam into Florida primarily for fish and wildlife purposes (JX-124). The RIOP also includes rules for the amount of water that is available to be stored in the upstream reservoirs and used for other project purposes. The RIOP has been adopted by the Corps after significant review and consultation with federal and state agencies, including the U.S. Fish and Wildlife Service ("USFWS"). The

RIOP has received approval from federal agencies based on evaluation of potential environmental impacts and the ability for the Corps to satisfy all other project purposes under the RIOP's rules. The RIOP is currently in the process of being replaced by a new set of reservoir operating rules under the WCM. The proposed set of rules for replacing the RIOP are known as the Proposed Action Alternative ("PAA"). The PAA is expected to be adopted and incorporated into the new WCM, which will control all federal reservoir operations in the ACF Basin.

19. The Corps' complex rules for operating the reservoirs in the ACF Basin involve coordinating and scheduling storage and releases from upstream to downstream reservoirs as a single, unified system. A simple schematic of the ACF reservoir system is shown in Bedient Demo. 2.

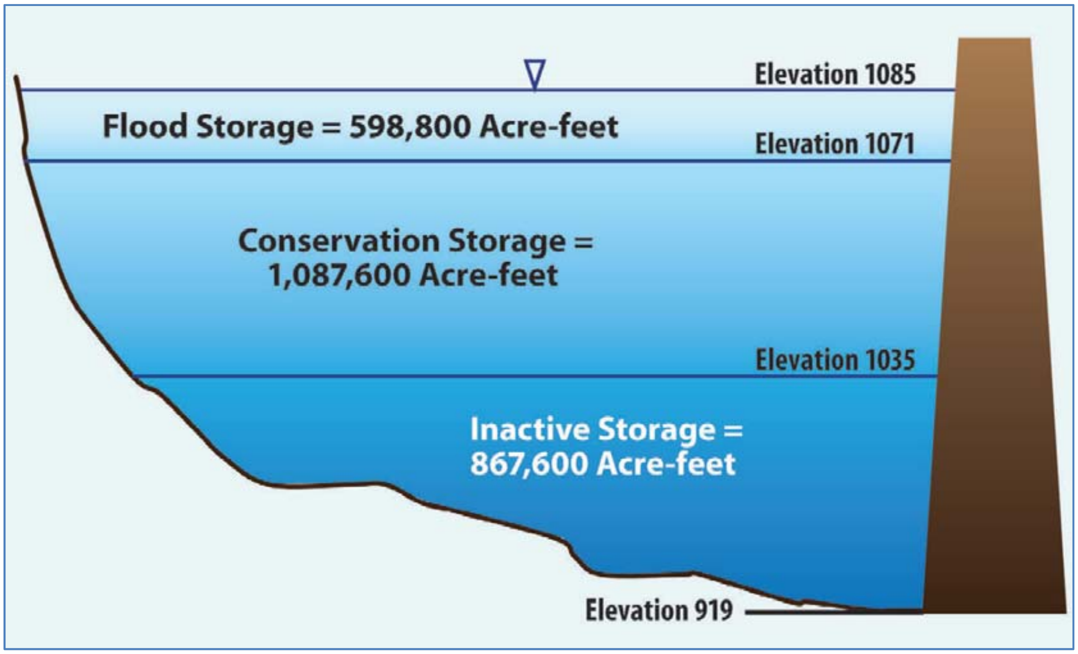


Bedient Demo. 2. Schematic of ACF Reservoir System

20. As Bedient Demo. 2 shows, virtually all water entering the reservoirs is either stored or released. The water that enters the reservoir is typically referred to as inflow, and the releases from the reservoir are typically referred to as outflow. The total amount of inflow to the reservoir system at a given time is referred to by the Corps as "Basin Inflow" (JX-124 at 4-24). As discussed below, Basin Inflow is a key factor informing basin-wide reservoir operations, especially releases from Woodruff Dam into Florida.

21. As Bedient Demo. 2 shows, Lake Lanier, West Point Lake, and Walter F. George Lake are the only three Corps reservoirs in the ACF Basin that have substantial conservation storage capacity. These three reservoirs are typically called "storage reservoirs"; together, they provide a combined conservation storage capacity of approximately 1.64 million acre-feet (JX-124 at 2-25). The other two reservoirs in the ACF Basin, Lake Seminole and George W. Andrews, have limited storage capacity and are typically referred to as "pass-through," or "run of river," reservoirs.

22. Each of the Corps' storage reservoirs is divided into separate storage levels, as shown in Bedient Demo. 3. Bedient Demo. 3 is a true and accurate copy of a figure from the Corps' DEIS (JX-124). The lowest level is the inactive pool, below which no storage releases are made. The next level is the conservation pool, where water is stored and released to help support the various project purposes. The amount of water in the conservation pool is referred to as "conservation storage." The next level is the flood risk pool, where water is stored during large storms to reduce downstream flooding. Conservation storage and flood storage essentially reflect all the water that is available to meet downstream needs through strategic releases.

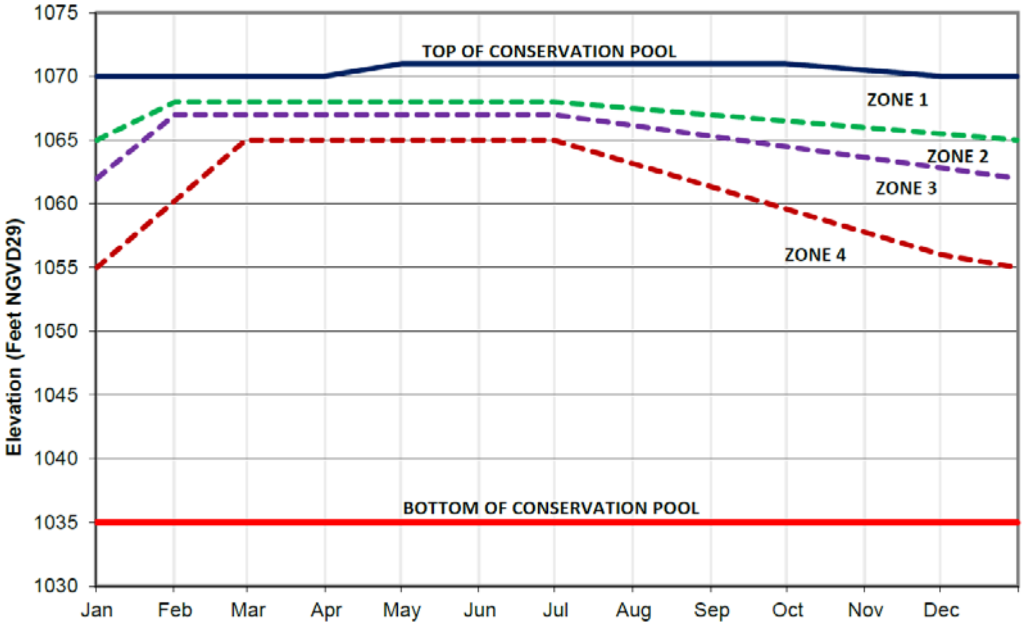


Bedient Demo. 3. Typical Storage Pools in ACF Reservoirs (Source: JX-124)

23. The sum of the conservation storage in all of the reservoirs in the ACF Basin is called "Composite Conservation Storage." Composite Conservation Storage and flood storage

together represent the entirety of usable storage throughout the reservoir system to meet project purposes. Like Basin Inflow, Composite Conservation Storage is a key factor considered by the Corps as part of its basin-wide regulation of the reservoirs.

24. The Corps has defined "action zones" for each of the three storage reservoirs in the ACF Basin, which subdivide the conservation storage pool in each reservoir to guide reservoir operators in meeting project purposes during a variety of hydrologic conditions. Bedient Demo. 4 shows "action zones" for a reservoir (using Lake Lanier as an example). Each action zone has a set of operational rules or guidelines that govern operations for the reservoir when the pool elevation is within that zone (JX-124 at 2-25). Zone 1, the highest action zone, is where all the federal project purposes can be satisfied. Zone 4, the lowest zone, reflects when the reservoirs are considered to be at critically low levels.



Bedient Demo. 4. Action Zones in ACF Storage Reservoirs (Source: JX-124)

25. When Composite Conservation Storage falls into Zone 4, the RIOP calls for the Corps to institute "Drought Operations." Drought Operations refer to a set of protective rules for reservoir operations that prioritize maintaining storage in the reservoirs when they are at critical levels. Having adequate reservoir storage allows the Corps to satisfy as many project purposes as possible, including having the storage available to augment flows into Florida to guarantee minimum prescribed flow levels during low-flow conditions. In large part due to the importance

of reservoir storage, Drought Operations are triggered based on lake levels, rather than strictly according to short-term hydrologic or streamflow conditions. Drought Operations conclude only when Composite Conservation Storage returns from Zone 4 all the way up to Zone 1.

26. During Drought Operations, during the winter "refilling" season, and under low-flow conditions, the Corps reservoirs are operated to guarantee a minimum flow of 5,000 cfs into Florida. The purpose of the 5,000 cfs flow requirement is to provide an approved minimum flow for downstream fish and wildlife while also facilitating reservoir storage replenishment at critical times. Under the RIOP's 5,000 cfs minimum flow requirement, the Corps releases as close to 5,000 cfs from Woodruff Dam as possible, consistent with the RIOP rules and without going below the mandatory minimum. By releasing the minimum and storing excess water in the reservoirs, the Corps is able to refill its reservoirs toward the top of conservation storage.

27. The fact that the Corps targets releases from Woodruff Dam very close to 5,000 cfs during low-flow conditions can be shown from the Corps' actual daily recorded releases from Woodruff Dam. The Corps releases all of its project data for the reservoirs in the ACF Basin, including recorded releases from each of the reservoirs, on a daily basis. The daily project data are maintained by Georgia EPD's Hydrology Unit in the regular course of business (GX-143).[1] I have reviewed and am familiar with GX-143, including the Corps' recorded releases from Woodruff Dam. Bedient Demo. 5 and Bedient Demo. 6 are true and accurate representations of Corps daily recorded releases from Woodruff Dam for the drought years of 2011 and 2012, respectively.

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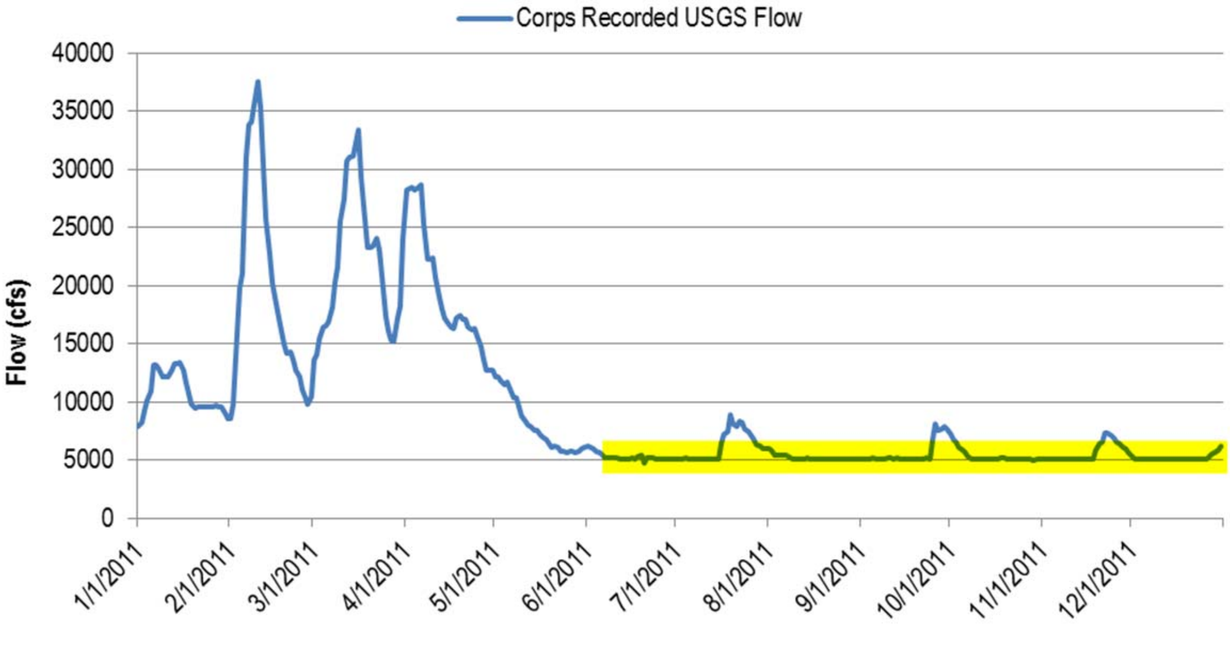
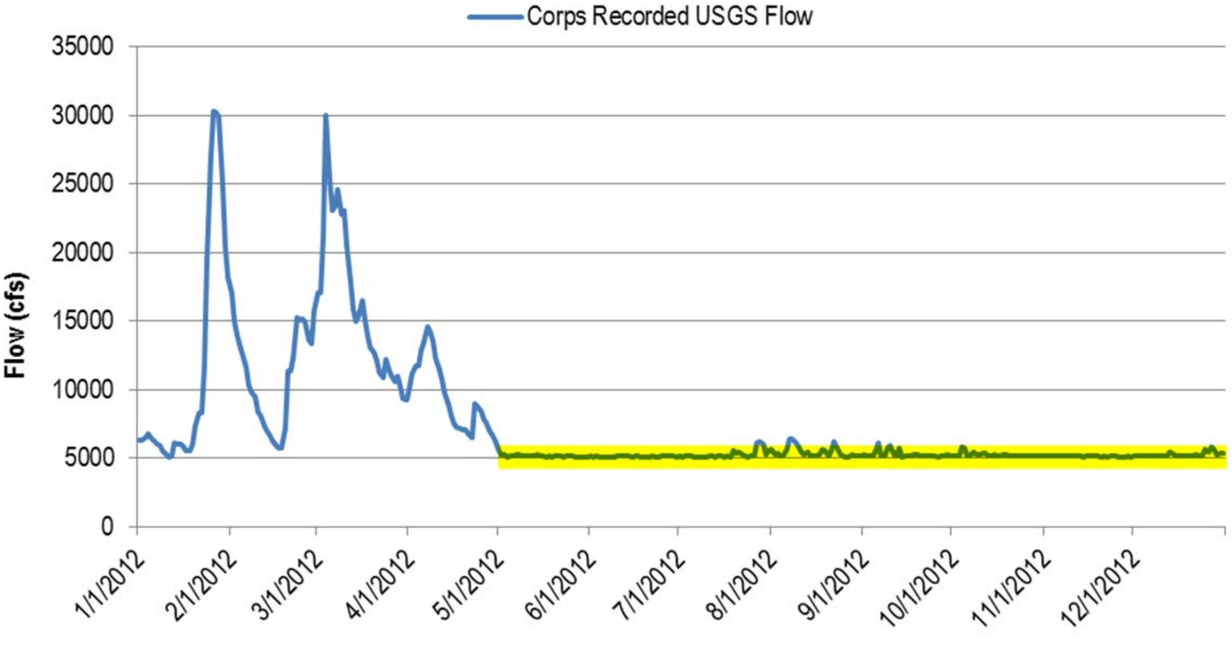
[1] For discussion of the Hydrology Unit's database of daily Corps project data, see Direct Testimony of Wei Zeng, Ph.D. (October 26, 2016).



Bedient Demo. 5. Corps Recorded Releases from Woodruff Dam During 2011 (Source: GX-143)



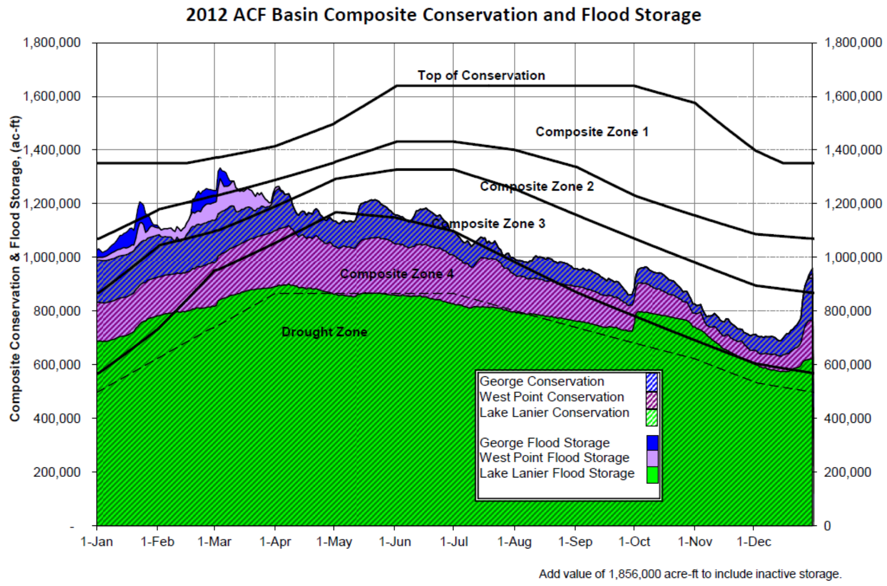
Bedient Demo. 6. Corps Recorded Releases from Woodruff Dam During 2012 (Source: GX-143)

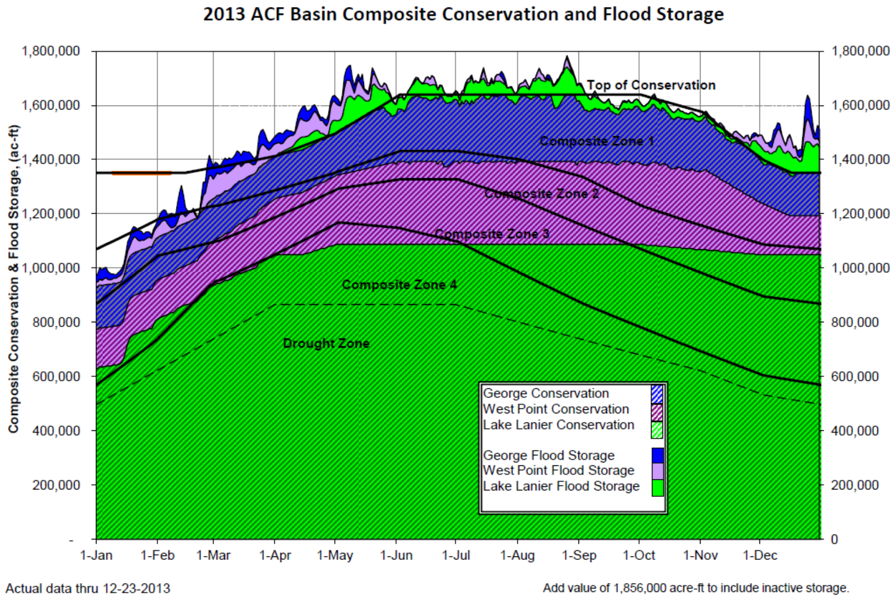
28. As shown in Bedient Demo. 5 and Bedient Demo. 6, the Corps' recorded releases from Woodruff Dam are at or very close to 5,000 cfs for large parts of the year, as highlighted in yellow.

- Bedient Demo. 5 shows releases very close to 5,000 cfs from June-December 2011. Basin Inflow was below 5,000 cfs for most of this period, and the Corps was "augmenting" streamflow by releasing water from the reservoirs to satisfy the 5,000 cfs minimum at this time. The three small increases over and above 5,000 cfs in mid-July, late September, and late November reflect three occasions where Basin Inflow temporarily increased above 5,000 cfs. Under the RIOP rules, these short-term increases in Basin Inflow over 5,000 cfs are matched by releases from Woodruff Dam (except during Drought Operations). The observed "ramp-downs" following the increases are the result of the RIOP's rules for Maximum Fall Rate, which limits how quickly releases can "fall" from higher to lower flows.
- Bedient Demo. 6 shows releases very close to 5,000 cfs from May-December 2012. The reservoirs entered "Drought Operations" in May 2012 and lasted into 2013. The 5,000 cfs minimum flow was in effect for the entire May-December period. The "spikes" that occur from late July through December reflect local precipitation events. These flash rainfall events occurred in a very short period of time, and caused the Corps to make releases from Woodruff Dam according to the RIOP's rules for "head limitation." These rules mandate releases from Woodruff Dam when the difference between the "head" water (*i.e.*, above the dam) and "tail" water (*i.e.*, below the dam) reaches or exceeds a specified level. This can occur if a heavy amount of rainfall enters the reservoir over a brief period of time. These rules are part of the Corps standard operating procedures, and are designed for safe dam operations. Unlike in 2011, there is no "ramp-down" following the spikes in 2012. This is because the Maximum Fall Rate provisions are suspended under Drought Operations. Therefore, in 2012, the short-term spikes were not followed by slow ramp-downs, but instead were quickly dropped back down to 5,000 cfs.

29. As 2012 shows, Drought Operations can last for a long time. In 2012, Drought Operations began on May 1 and lasted until March 1, 2013, for a total of 304 days, or 10 months (GX-543). It was not until the reservoirs recovered all the way back up to Zone 1 in March 2013 that Drought Operations were lifted and normal operations resumed.

30. During Drought Operations, the Corps attempts to follow the 5,000 cfs minimum flow requirement and the rules allowing excess Basin Inflow to be placed into storage. This is shown in Bedient Demo. 7, which compares composite storage in 2012 and 2013.





Bedient Demo. 7. Use of Drought Operations to Refill Storage (2012-2013) (GX-924)

31. As Bedient Demo. 7 shows, despite severe and prolonged drought conditions in 2012-2013, total reservoir storage increased from 2012 (top panel) to 2013 (bottom panel). This is because the rules are designed to balance all project purposes, including downstream, while replenishing storage in the reservoirs.

32. The Corps' policy of generally keeping the reservoirs as full as possible is reflected in the concept of the "guide curve." The guide curve is the Corps' "desired" reservoir elevation for each reservoir, being at the top of the conservation pool (JX-124). Thus, the desired reservoir elevations are at the highest point of reservoir conservation storage. There is also a "composite" guide curve, which reflects the desired amount of storage in the entire ACF reservoir system.

33. Because the guide curve is the desired pool elevation, Corps operations are designed to approach the guide curve at all times of the year while also satisfying the project purposes. At times when the reservoir levels are below the guide curve, the Corps operates the reservoirs so as to recover "up" to the guide curve, and during high-flow season, when flood risk management is a priority, the Corps will release reservoir storage to go "down" to the guide curve (allowing the Corps to have excess space in its reservoirs to store flood waters if necessary). The purpose of the guide curves is to ensure reservoirs are kept as full as possible while also satisfying and balancing all authorized project purposes.

II. The RIOP Controls Basin-Wide Storage and Releases of Water in the Federal Reservoirs

34. The Corps currently sets minimum releases from Woodruff Dam according to the RIOP.[2] The RIOP is the product of inter-agency consultation between the Corps and the USFWS regarding protection of fish and wildlife in the Apalachicola River. The RIOP controls minimum releases from Woodruff Dam year-round. The RIOP sets rules for how much water will be available to be stored in the storage reservoirs and how much water must be released from Woodruff Dam into Florida based on three factors, each of which is discussed in detail below:

- Composite Conservation Storage;

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[2] The current RIOP reflects the 2012 revisions to the 2008 RIOP, which itself is a revision to the 2006 Interim Operating Plan ("IOP").

- Season; and
- Basin Inflow.

35. The RIOP's rules for storage availability and releases are reflected in Bedient Demo. 8 below. Bedient Demo. 8 is a true and accurate copy of Table 2.1-5 from JX-124. These rules are described at length in JX-124.

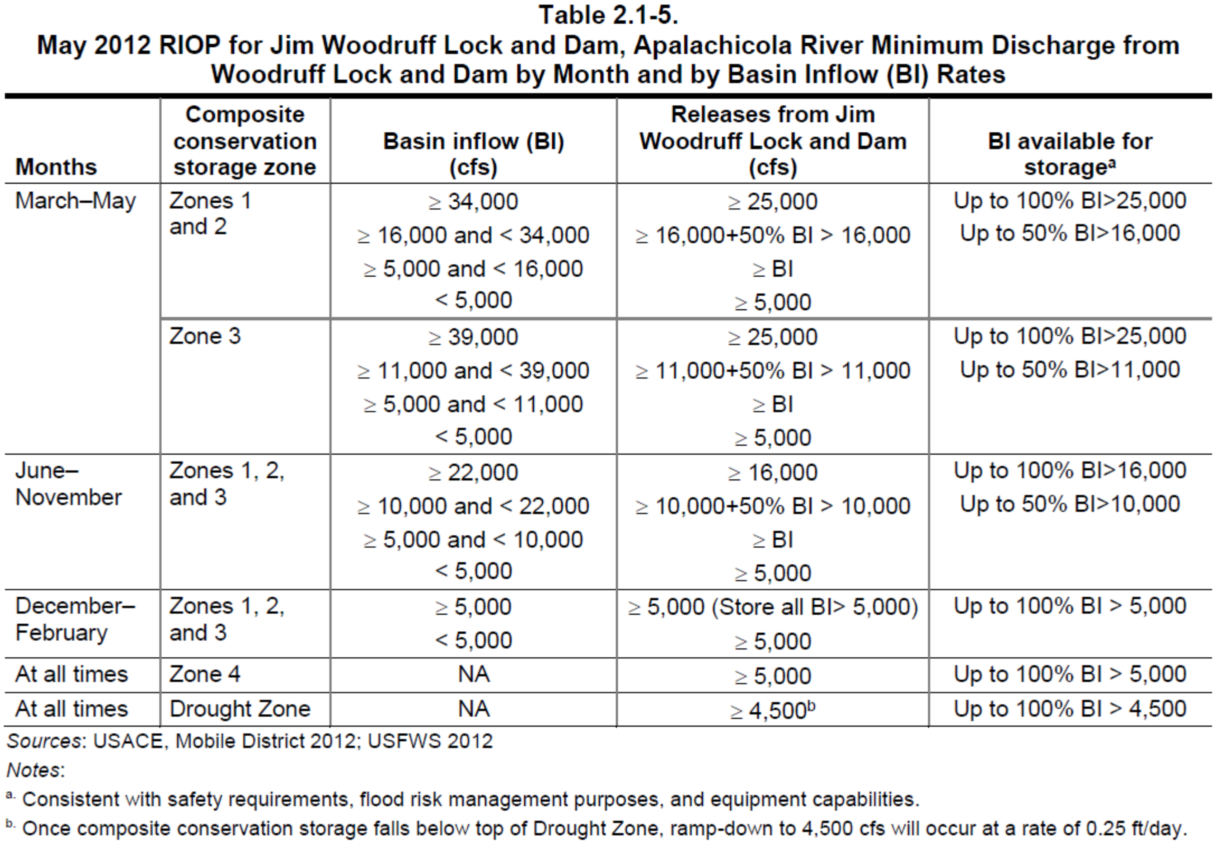

Table 2.1-5.
May 2012 RIOP for Jim Woodruff Lock and Dam, Apalachicola River Minimum Discharge from Woodruff Lock and Dam by Month and by Basin Inflow (BI) Rates

Months	Composite conservation storage zone	Basin inflow (BI) (cfs)	Releases from Jim Woodruff Lock and Dam (cfs)	BI available for storage^{a}
March–May	Zones 1 and 2	≥ 34,000	≥ 25,000	Up to 100% BI>25,000
		≥ 16,000 and < 34,000	≥ 16,000+50% BI > 16,000	Up to 50% BI>16,000
		≥ 5,000 and < 16,000	≥ BI	
		< 5,000	≥ 5,000	
	Zone 3	≥ 39,000	≥ 25,000	Up to 100% BI>25,000
		≥ 11,000 and < 39,000	≥ 11,000+50% BI > 11,000	Up to 50% BI>11,000
		≥ 5,000 and < 11,000	≥ BI	
		< 5,000	≥ 5,000	
June–November	Zones 1, 2, and 3	≥ 22,000	≥ 16,000	Up to 100% BI>16,000
		≥ 10,000 and < 22,000	≥ 10,000+50% BI > 10,000	Up to 50% BI>10,000
		≥ 5,000 and < 10,000	≥ BI	
		< 5,000	≥ 5,000	
December–February	Zones 1, 2, and 3	≥ 5,000	≥ 5,000 (Store all BI> 5,000)	Up to 100% BI > 5,000
		< 5,000	≥ 5,000	
At all times	Zone 4	NA	≥ 5,000	Up to 100% BI > 5,000
At all times	Drought Zone	NA	≥ 4,500^{b}	Up to 100% BI > 4,500

Sources: USACE, Mobile District 2012; USFWS 2012

Notes:

[a] Consistent with safety requirements, flood risk management purposes, and equipment capabilities.

[b] Once composite conservation storage falls below top of Drought Zone, ramp-down to 4,500 cfs will occur at a rate of 0.25 ft/day.

Bedient Demo. 8. RIOP Rules for Storage and Releases from Woodruff Dam (Source: JX-124, at 2-71)

36. **Composite Conservation Storage:** Under the RIOP, Composite Conservation Storage (*i.e.*, total amount of usable water stored in the Corps' reservoir system), is a key factor controlling whether additional water is placed into storage in the reservoirs or is released from Woodruff Dam into Florida. As shown in Bedient Demo. 8 , the rules are based on which "zone" total reservoir storage is currently in.

- **Zones 1, 2, or 3:** When Composite Conservation Storage is in Zones 1, 2, or 3, the Corps operates under Normal Operations, and the amount of water released from Woodruff Dam is generally a product of the other two factors, *i.e.*, season and Basin Inflow. Those two factors are described in the next two sections.

- **Zone 4:** When Composite Conservation Storage falls into Zone 4, the RIOP triggers Drought Operations. Drought Operations do not conclude until Composite Conservation Storage returns all the way back up to Zone 1. Thus, until the reservoirs return to healthy levels, any excess Basin Inflow over and above 5,000 cfs will go to filling the reservoirs subject to the availability of storage space. This is because Drought Operations are based exclusively on total storage levels, not hydrologic conditions. Therefore, excess water will go to refilling the reservoirs until they are at healthy levels even if "drought" conditions (*i.e.*, rainfall and streamflow) improve.

- **"Drought Zone":** When Composite Conservation Storage falls into the "Drought Zone," which is a specified sub-zone within Zone 4, the Corps will trigger Exceptional Drought Operations ("EDO"). Under EDO, the RIOP's 5,000 cfs minimum flow is lowered to 4,500 cfs, and Basin Inflow in excess of 4,500 cfs is placed into reservoir storage if possible.

37. To provide an example of how Drought Operations and EDO work, if Basin Inflow was 6,000 cfs, the Corps would target a release of 5,000 cfs from Woodruff Dam, and would place the extra 1,000 cfs into storage. If Basin Inflow increased by 1,000 cfs (to 7,000 cfs), the Corps would still release that 5,000 cfs from Woodruff Dam, and would place the extra 2,000 cfs into storage. Thus, contrary to the opinions offered by Florida's experts, Florida would not receive these additional flows that might result from reductions in Georgia's consumptive use at these times.[3] Any increase in state-line flow as a result of reducing Georgia's

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[3] I have reviewed statements by Florida officials, which acknowledge that additional Basin Inflow over 5,000 cfs does not automatically materialize as additional state-line flow, and would often be stored in the Corps under the operating rules for the reservoirs. FL-ACF-01457637 ¶ 131 (Florida's 2d Amended & Supplemented Compl. for Declaratory & Injunctive Relief, *In re Tri-State Water Rights Litig.*, M.D. Fla., 3:07-cv-00250-PAM-JRK (filed Jan. 10, 2008) ("FL 2d Am. *Tri-State* Compl.") (noting that "[the Corps' drought operations] *allow[] the Corps to store 100% of the water that would otherwise flow to the Apalachicola from the Chattahoochee River*") (emphasis added); GX-420 at FL-ACF-02290908 (July 20, 2012 Letter from Douglas Barr, Executive Director NWFWMD, to Dr. Donald Imm, USFWS (produced at FL-ACF-02290903) ("*[T]here is no requirement to share the added storage with*

consumptive use[4] could occur only during normal operations, and even then the releases from Woodruff Dam would be subject to specific rules for releases determined by Composite Conservation Storage, season, and Basin Inflow.

38. **Season:** The RIOP also defines threshold levels for storage and releases by three seasons: winter "refilling" season (December-February), spawning season (March-May), and non-spawning season (June-November).

- **Winter "refilling" season (December-February):** During the winter "refilling" season, the Corps' priority is refilling the reservoirs, which are typically low in storage following releases made in the summer and fall. This is especially true in dry or drought years. During the winter "refilling" season, the RIOP provides that the Corps maintains a minimum of 5,000 cfs flow into Florida at all times. If possible, any additional Basin Inflow above 5,000 cfs is stored in the reservoirs until the reservoirs are full. Thus, unless the reservoirs are full, Florida would not receive any additional state-line flow as a result of reducing Georgia's upstream water use during this three-month "refilling" season. Furthermore, even if reducing Georgia's water use or increasing Basin Inflow would result in additional state-line flow during this season, water is typically more abundant in the winter than in the summer and fall, and typically there is little need to supplement flows during winter.
- **Spawning season (March-May):** The "spawning" season is determined according to fish and wildlife considerations, in particular spawning activities of Gulf sturgeon. During the spawning season, if Basin Inflow is between 5,000 and 16,000 cfs, the RIOP provides for releases into Florida at least equal to Basin Inflow.[5] When BI is higher than 16,000 cfs (but lower than 34,000 cfs), half of

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Florida to provide increased flow during the spring spawning period or for low flow augmentation in the summer and early fall.").

[4] I use the term "consumptive use" to refer to the amount by which water withdrawals remove water from the river system, *i.e.*, reduction in surface water flows.

[5] This threshold is lowered to 11,000 cfs if Composite Storage drops to Zone 3.

the excess flow is put to storage while the other half is released on top of 16,000 cfs.

- **Non-spawning season (June-November):** During the non-spawning season, the RIOP provides for lower releases into Florida and higher amounts of storage in the reservoirs. For instance, instead of "matching" Basin Inflow between 5,000 and 16,000 cfs, the RIOP calls for "matching" Basin Inflow between 5,000 and 10,000 cfs. Half of the water above 10,000 cfs would go into reservoir storage, while the other half is released on top of 10,000 cfs.

39. **Basin Inflow:** Finally, the RIOP rules for storage in the reservoirs and releases into Florida consider Basin Inflow. Under the RIOP, four threshold ranges of Basin Inflow dictate how much water will be available for storage in the reservoirs or released into Florida. I refer to the RIOP's four threshold ranges of Basin Inflow as "Augmentation," "No-Storage/Matching," "Half-Storage," and "All-Storage."

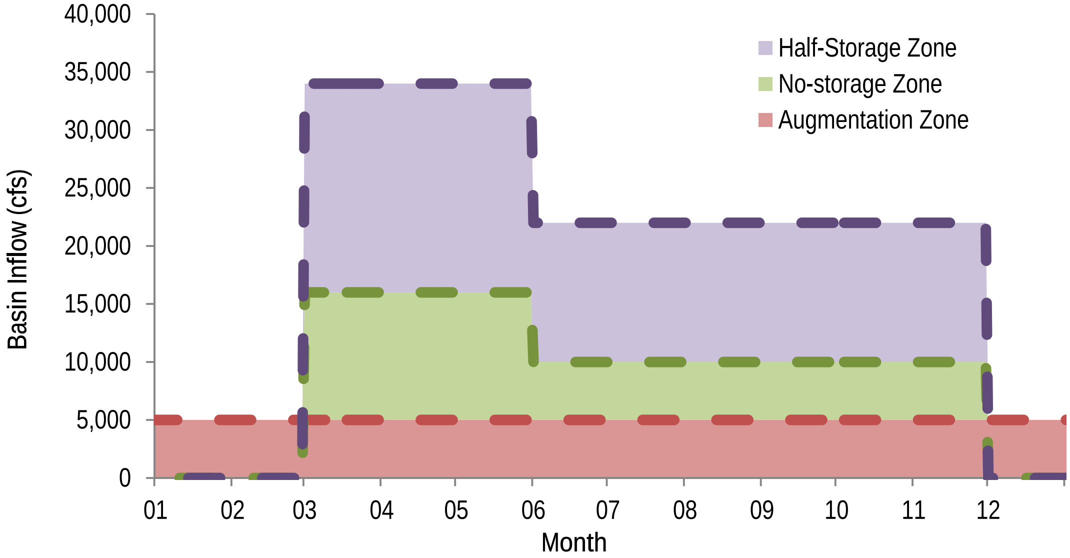
- **Augmentation:** Augmentation refers to a range of Basin Inflow (<5,000 cfs) where the Corps is required to augment flows by releasing reservoir storage in order to guarantee 5,000 cfs into Florida. During this time period, regardless how far Basin Inflow is below the 5,000 cfs threshold level, the RIOP calls for the Corps to release the 5,000 cfs. If Basin Inflow is less than 5,000 cfs, Florida would not receive any additional state-line flow as a result of reducing Georgia's consumptive use at that time. For instance, if Basin Inflow were 4,000 cfs, the Corps would augment flows by releasing 1,000 cfs from storage to maintain the 5,000 cfs. If reductions in Georgia's consumptive use increased Basin Inflow by 250 cfs (resulting in Basin Inflow of 4,250 cfs), the Corps would simply release 750 cfs from storage (instead of 1,000 cfs) to maintain the 5,000 cfs. Florida would not receive the 5,000 cfs plus the incremental 250 cfs; that 250 cfs would instead be effectively placed into storage by reducing releases from the reservoirs. This is the offset operation I describe. As a result, when Basin Inflow is below 5,000 cfs, Florida would not receive additional flows at that time as a result of any reduction in Georgia's consumptive use.

- **No-Storage/Matching:** No-Storage/Matching reflects a threshold range of Basin Inflow where the Corps operates to "match" releases from Woodruff Dam with Basin Inflow. During the spawning season (March-May), No-Storage/Matching occurs when Basin Inflow is between 5,000 and 16,000 cfs. During the non-spawning season (June-November), No-Storage/Matching occurs between 5,000 and 10,000 cfs. As explained below, the total amount of time during a dry or drought year during which Basin Inflow is between 5,000 and 16,000 cfs is relatively infrequent and unpredictable.

- **Half-Storage:** Half-Storage reflects a range of Basin Inflow whereby 50% of excess Basin Inflow above 10,000 or 16,000 cfs is available to be stored in the reservoirs, and the other 50% is released into Florida. Similar to No-Storage, the range of Basin Inflow for Half-Storage varies by season. During the spawning season (March-May), Half-Storage occurs when Basin Inflow is between 16,000 and 34,000 cfs. During the non-spawning season (June-November), Half-Storage occurs when Basin Inflow is between 10,000 and 22,000 cfs. Under Half-Storage, if an additional 250 cfs entered the reservoir system, Florida would most likely receive an incremental increase in state-line flows of only 125 cfs. Again, as shown below, the total number of days the system is in Half-Storage is not predictable and can be infrequent in a drought or dry year.

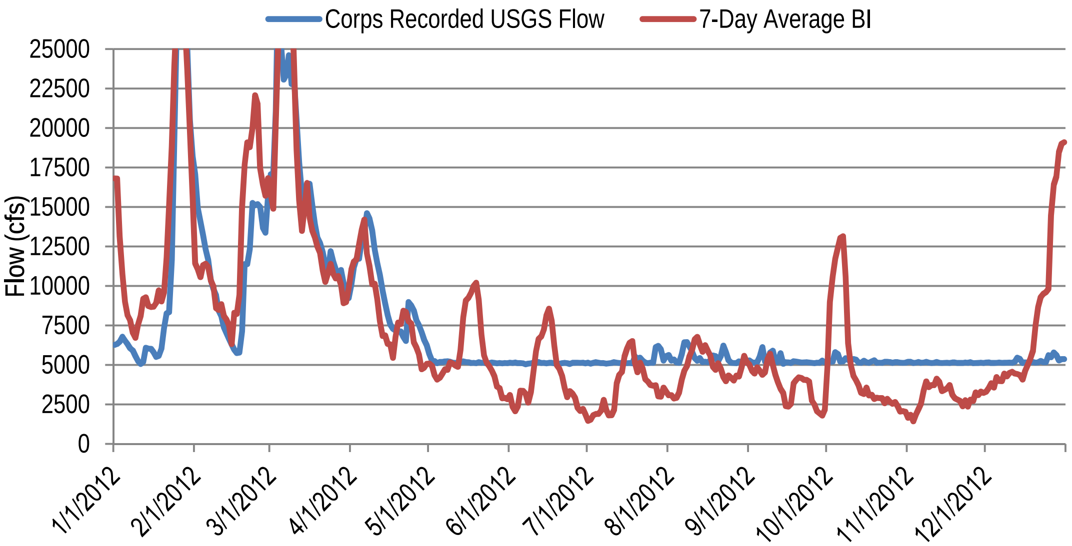
- **All-Storage:** All-Storage Zone reflects a range of Basin Inflow whereby 100% of water over and above the Half-Storage threshold range would be available to go to storage in the reservoirs. All-Storage includes the winter "refilling" season, when state-line flows are maintained at the 5,000 cfs. Thus, under All-Storage, Florida would not receive additional state-line flow as a result of reducing Georgia's water use unless the Corps' reservoirs were full such that there was no available storage capacity (which would be at a time when water is typically more plentiful in the Basin).

40. Bedient Demo. 9 is a true and accurate representation of the four Basin Inflow threshold ranges: "Augmentation," "No Storage"/"Matching," "Half Storage," and "All Storage."



Bedient Demo. 9. RIOP's Basin Inflow Threshold Ranges (Source: JX-124, at 2-71)

41. Since Woodruff Dam releases are made pursuant to multiple factors, not just Basin Inflow, there is no direct correlation between Basin Inflow and Woodruff Dam releases for most of the year, especially during dry and drought years. Bedient Demo. 10 is a plot of Basin Inflow compared to Corps recorded releases from Woodruff Dam.

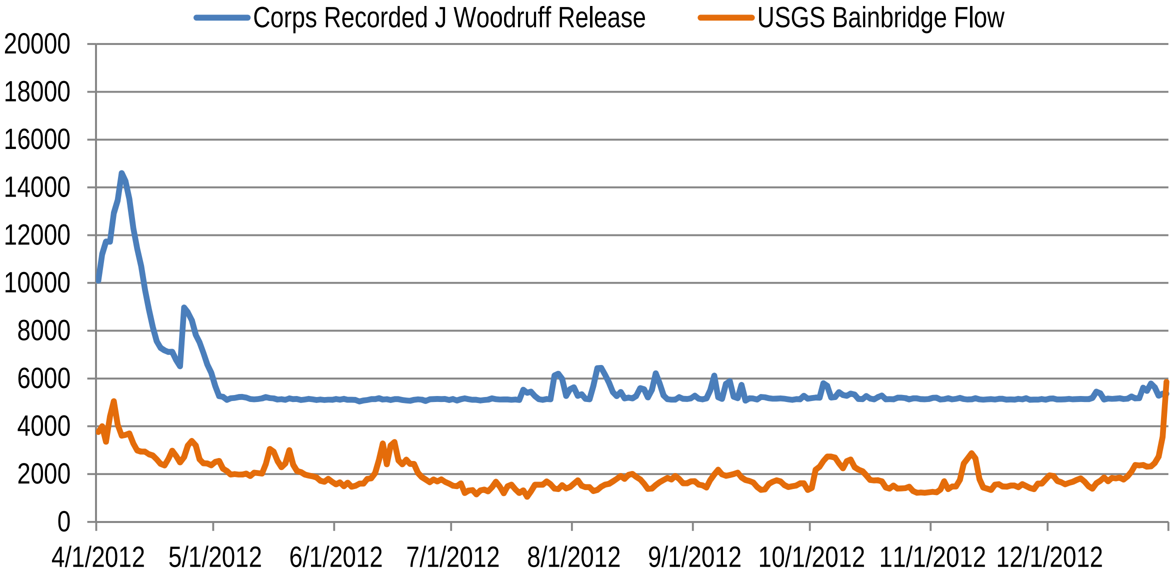


Bedient Demo. 10. Basin Inflow vs. Woodruff Dam Outflow (Source: GX-143)

42. Bedient Demo. 10 shows that as a matter of historical record in the ACF Basin, Basin Inflow is not correlated with recorded releases from Woodruff Dam during the low flow

periods. This is apparent by the lack of any clear relationship between the 7-day average Basin Inflow (red) and the outflow from Woodruff Dam into Florida (blue) from May through December. This shows that "what comes in" to the system often has little if any relationship to "what goes out."

43. During low-flow periods, Woodruff Dam releases are also not directly correlated with inflow entering Lake Seminole from the Flint River. Bedient Demo. 11 is a true and accurate comparison of Corps recorded releases from Woodruff Dam (blue line) with observed inflow to Lake Seminole from the Flint River (orange line) for 2012, as measured by the USGS stream gage at Bainbridge.



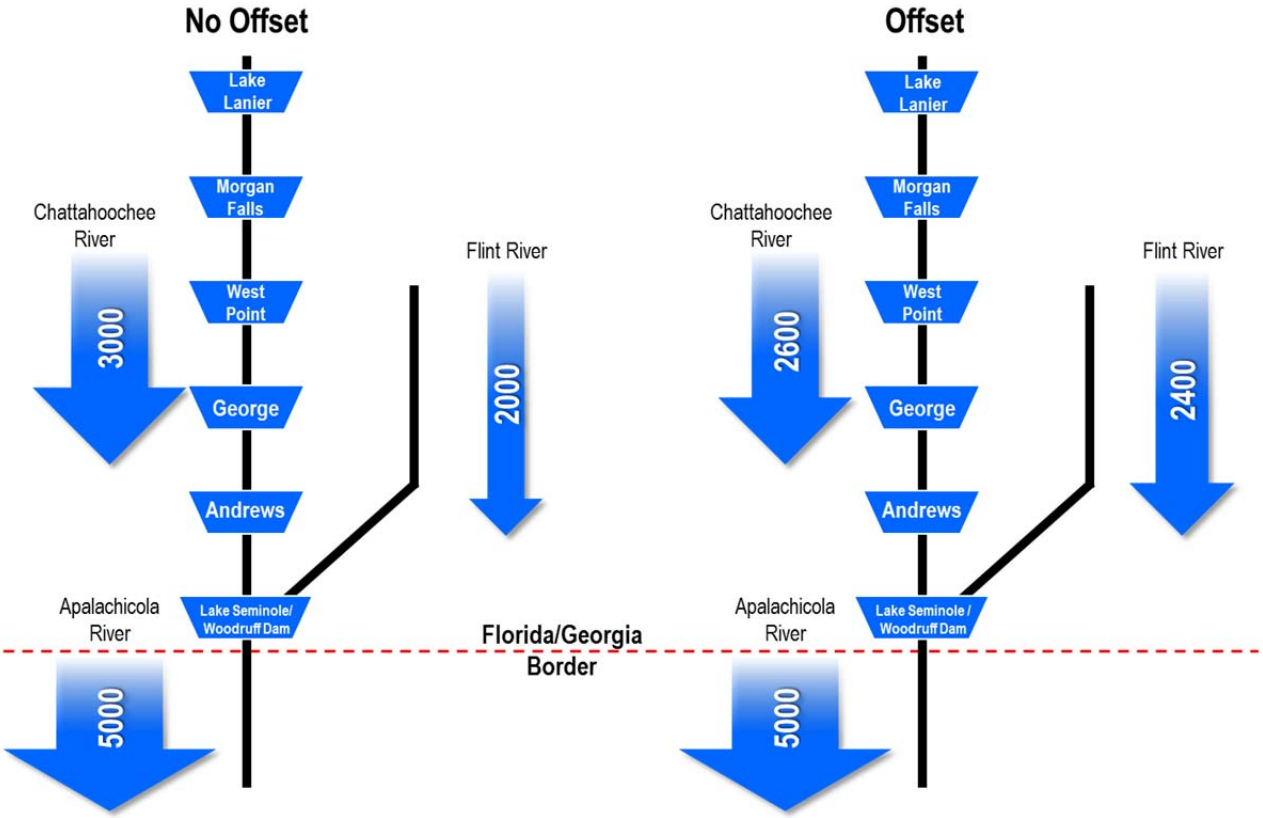
Bedient Demo. 11. Woodruff Dam Outflow vs. Flint River Inflow (2012) (Source: GX-143)

44. Bedient Demo. 11 show that there is no apparent relationship or correlation between inflow to Lake Seminole from the Flint River and Corps recorded releases from Woodruff Dam in 2012. For instance, Flint River flow (orange) increase by more than 1,000 cfs (and nearly 2,000 cfs) in May and June 2012, but the Corps' recorded releases from Woodruff Dam are unaffected. Thus, the flows do not "pass through" to Florida. There are other examples throughout the year.

III. The Corps Operates Its Reservoir System as a Single Unit, and Under Low-Flow Conditions Offsets Increased Flint River Flows by Decreasing Chattahoochee River Releases

45. As shown in Bedient Demo. 11, even if reductions in Georgia's water use occurred only on the Flint River during times of drought or low flows, the increase in inflow to Lake Seminole would not necessarily result in any increase in state-line flow into Florida. This is because inflows to Lake Seminole from the Flint River are calculated as part of Basin Inflow. Basin Inflow is then considered by the Corps as one factor under the RIOP rules for determining releases from Woodruff Dam. Under low-flow conditions and Drought Operations, additional water entering Lake Seminole would be regulated by the Corps and offset by corresponding reductions in releases from the reservoirs on the Chattahoochee River. This is because the Corps is already operating its reservoirs to augment flows, and increased flows from the Flint River simply mean that the Corps would not have to release as much from its reservoirs to augment flows.

46. An illustration of the offsetting operation is shown in Bedient Demo. 12 below. In this hypothetical, inflow from the Flint River is increased from 2,000 to 2,400 cfs (increase of 400 cfs). Releases from the Chattahoochee River are decreased from 3,000 cfs to 2,600 cfs (decrease of 400 cfs). State-line flow remains at 5,000 cfs. In this hypothetical, the Corps would release 400 cfs less from the reservoirs, and the equivalent amount of water would be retained in the reservoirs on the Chattahoochee River.



Bedient Demo. 12. Operation of Corps Reservoirs to Offset Increased Inflows from Flint River

47. The offsetting operation shows that the Corps' operation of its reservoirs in the ACF Basin as a single, integrated system means that increased inflow from the Flint River would be balanced out by releases from the Chattahoochee River to satisfy the 5,000 cfs minimum flow target. As a result, during drought or low-flow periods, increases in Flint River flow would generally not lead to any increases in state-line flow into Florida during those times.

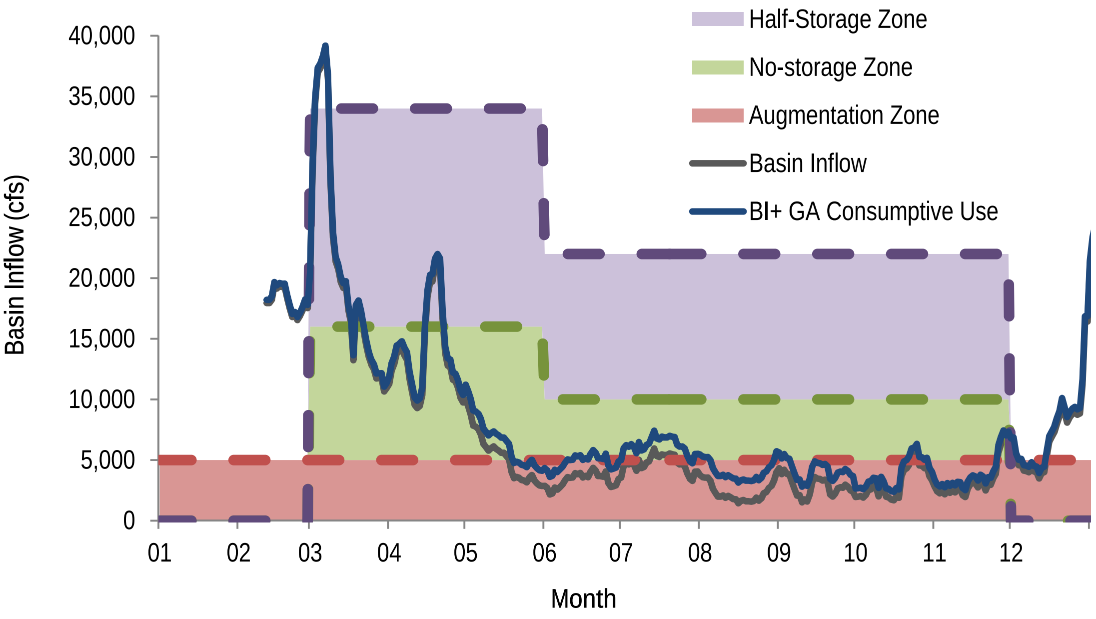
IV. Increases in Basin Inflow Would Not Increase State-Line Flows into Florida During Low-Flow Conditions or Drought Operations

48. As the above review of the RIOP rules shows, reducing Georgia's consumptive use would only lead to additional state-line flow into Florida under specific and limited circumstances. First, the Corps cannot be in Drought Operations or EDO. Second, Basin Inflow cannot be below 5,000 cfs, even if the Corps is in normal operations. Third, composite conservation storage levels must be in the No-Storage Zone or the Half-Storage Zone while the reservoirs are not yet full. During normal operations, moreover, the RIOP rules must be

followed regarding the amount of water that must be stored in the reservoirs or released at Woodruff Dam.

49. I found that the occasions where reducing Georgia's water use would lead to an increase in state-line flow into Florida are few and far between. I performed a simple calculation that compared the RIOP's rules for minimum releases from Woodruff Dam to actual recorded Basin Inflow for 2007 and 2012, two recent dry years to see how many days of the year decreases in Georgia's water use would actually result in increases in state-line flows into Florida under hydrologic conditions similar to those in 2007 and 2012.

50. Bedient Demo. 13 is a true and accurate copy of the results of my analysis of RIOP flow thresholds and Basin Inflow for 2007 (GX-949).



Bedient Demo. 13. RIOP Thresholds and Basin Inflow for 2007 (Drought Year)

51. As Bedient Demo. 13 shows, in 2007 Basin Inflow (gray line) started at about 18,000 cfs in mid-February and peaked in early March around 40,000 cfs, followed by a general decline into the summer and fall months before again increasing in December. In 2007, Basin Inflow passes through all four threshold ranges. Starting in May and continuing through November, Basin Inflow was generally below 5,000 cfs (*i.e.*, in Augmentation).

52. If 2007's Basin Inflow were repeated today and Drought Operations were not triggered,[6] there would be approximately:

- **273 total days** when Florida would receive no additional state-line flow that would result from any reductions of Georgia's water use.
- **21 total days** when Florida would receive only 50% of any additional state-line flow that would result from any reductions of Georgia's water use.
- **71 total days** when Florida would receive additional state-line flow equal to the increase in Basin Inflow resulting from reducing Georgia's water use.

53. This hypothetical shows that under 2007 hydrologic conditions, any additional Basin Inflow produced by reducing Georgia's water use would not result in any increase in state-line flow for approximately 75% of the year (273 days), and would result in corresponding increases in state-line flow for only approximately 19% of the year (71 days). Only 19 of these 71 days would occur during the summer and fall months, when streamflow was at its lowest. The majority of days during this 71-day period would occur when water in the ACF Basin would be relatively plentiful.

54. Again, the above analysis assumes the reservoirs do not enter Drought Operations at any time. If Drought Operations did occur, the number of days when reducing Georgia's water use might lead to any increases in state-line flow would decrease. The number of days the Corps would be under Drought Operations in 2007 can be estimated using the Corps' ResSim model of the reservoir system.[7] According to ResSim, if the RIOP were in place in 2007, the number of days above would be revised to: 278 days when Florida would not receive any additional flow, and 66 days when Florida would receive 100% of additional flows resulting from reducing Georgia's water use (of which only 14 days would occur during the summer and fall months, when streamflow was at its lowest).

55. Bedient Demo. 14 is a true and accurate copy of the results of my analysis of RIOP's flow thresholds compared to Basin Inflow for 2012. Because the RIOP was in place in

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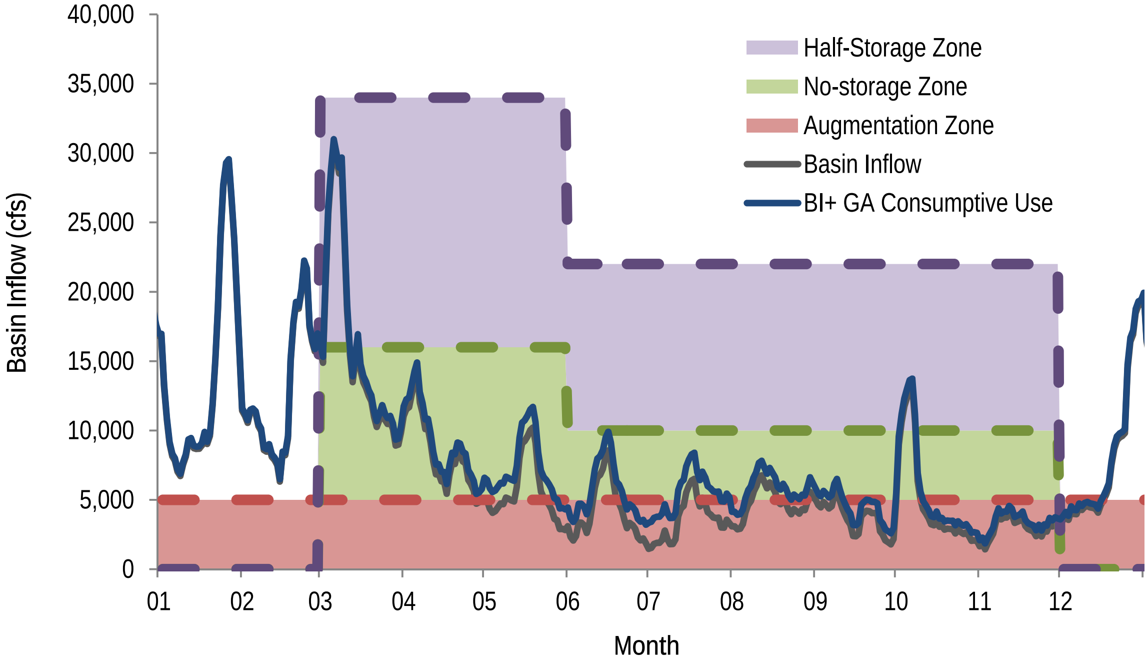
[6] The RIOP did not exist until April 2008, and thus the RIOP's rules, including Drought Operations, did not govern Corps reservoir operations in the ACF Basin in 2007.

[7] The ResSim model is discussed in detail in the next section.

2012, Bedient Demo. 14 provides an example of the relationship between recorded Basin Inflow and Corps reservoir operations during a drought year when the RIOP rules were actually in place.



Bedient Demo. 14. RIOP's Thresholds and Basin Inflow for 2012 (Drought Year)

56. As Bedient Demo. 14 shows, Basin Inflow in 2012 was above 5,000 cfs during January and February, entered March at about 15,000 cfs, and rose to 30,000 cfs before declining into the summer and fall months to a flow of generally less than about 10,000 cfs, with flows again increasing starting in December. If 2012 were repeated today, there would be:

- **307 total days** when Florida would receive no additional state-line flow that would result from any reductions of Georgia's water use.
- **10 total days** when Florida would receive 50% of any additional state-line flow that would result from any reductions of Georgia's water use.
- **49 total days** when Florida would receive a corresponding increase in state-line flow that would result from any reductions of Georgia's water use.

57. This analysis shows that under 2012 hydrologic conditions, any additional Basin Inflow produced by reducing Georgia's water use would not result in any increase in state-line

flow for approximately 85% of the year (307 days), and would result in corresponding increases in state-line flow for only approximately 13% of the year (49 days). None of these 49 days would occur during the summer and fall months, when streamflow was at its lowest. This is largely because the Corps entered Drought Operations on May 1, 2012, which lasted throughout the rest of the year.

58. As this analysis shows, while there may be days where Florida might receive additional state-line flows as a result of increases in Basin Inflow (*e.g.*, from reducing Georgia's water use), these times are rare and unpredictable, and most often are not during low-flow periods. In order to generate a material change in state-line flow on a reliable or predictable basis, especially during low-flow conditions, the Corps must change its operating rules to deliver that flow. Because the RIOP sets Woodruff Dam releases according to basin-wide conditions and as part of a basin-wide balance of operations, the Corps must be involved in coordinating and executing any change in the amount or timing of releases from Woodruff Dam.

59. Mr. James Barton, Florida's expert on Corps reservoir operations, has 30 years of experience in Corps reservoir operations and water resources management, including managing the Corps' Columbia River System in the Pacific Northwest. Mr. Barton testified that the only way to ensure a predictable flow of water into Florida would be with the involvement and cooperation of the Corps. Barton Dep. Tr. 205:14-20. As he put it: "because the Corps operates the Woodruff Dam and that's what releases the water into Florida, there would probably need to be some involvement of the Corps." *Id*. at 204:13-16. I agree with Mr. Barton.

REDUCTIONS IN GEORGIA'S WATER USE WOULD NOT RESULT IN INCREASED STATE-LINE FLOWS DURING LOW-FLOW PERIODS

60. I also performed a detailed modeling analysis of the impact of reductions in Georgia's total consumptive use (*i.e.*, consumption caps) on state-line flows. This modeling analysis, performed using ResSim, illustrates the impact of water use reductions on state-line flows on a monthly, seasonal, and annual basis under a variety of hydrologic conditions.

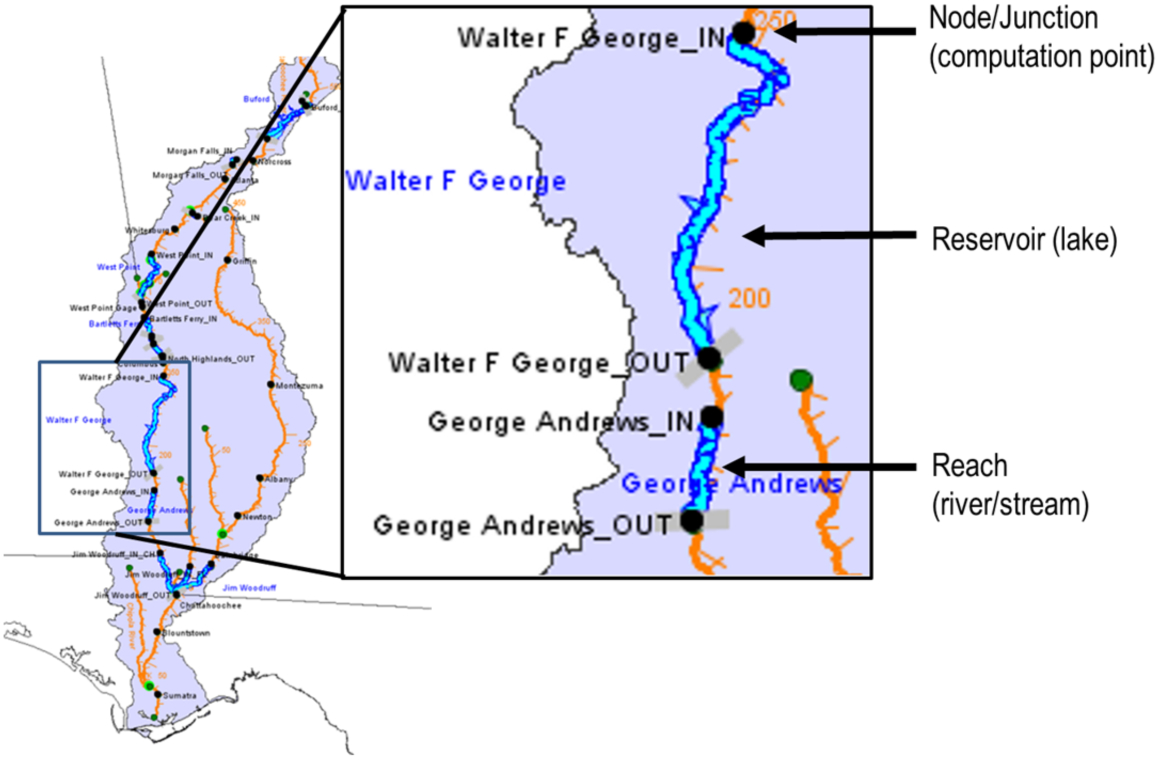
61. Based on my modeling analysis of 19 consumption cap scenarios using the highest-recorded levels of Georgia's total consumptive use in the ACF Basin (*i.e.*, during the drought year of 2011), I conclude that reductions in total consumptive use by as much as 30%—

or even reductions from dry-year values down to Georgia’s 1992 levels—would provide little to no increase in the amount of water crossing the state line, especially during low flow months of dry and drought years.

I. ResSim Is the Best Available Tool for Evaluating the Impact of Reduction Scenarios on State-Line Flows

62. ResSim, short for “Reservoir Simulation,” is the Corps’ official model for reservoir simulation and water management studies for the ACF Basin. ResSim was developed and is used by the Corps HEC. ResSim is used by the Corps to model regulated watersheds throughout the United States “for flood management, low flow augmentation and water supply for planning studies, detailed reservoir regulation plan investigations, and real-time decision support” (GX-1095). The HEC “is the designated Center of Expertise for the U.S. Army Corps of Engineers in the technical areas of surface and groundwater hydrology, river hydraulics and sediment transport, hydrologic statistics and risk analysis, reservoir system analysis, planning analysis, real-time water control management and a number of other closely associated technical subjects” (GX-1231).

63. ResSim simulates basin-wide reservoir operations, including the total amount of water stored in each of the reservoirs and released from each of the reservoirs, based on water demand levels, operating rules, and hydrologic conditions. ResSim has the reservoir operation rules, including the RIOP, built into the model. ResSim’s basic computational structure for the ACF Basin is shown in Bedient Demo. 15 below. Bedient Demo. 15 is a true and accurate copy of a demonstrative I prepared showing the ResSim model’s computational structure.



Bedient Demo. 15. ResSim Model Computational Structure

64. As shown by Bedient Demo. 15, ResSim represents the ACF reservoir and river system based on nodes (computation points), reaches, and reservoirs. The model computes reservoir responses to a number of factors, such as inflow. The model also incorporates the main river reaches in the ACF Basin, including those entering and exiting each of the reservoirs, by defining the time it takes water to travel along the various river reaches. Finally, the model includes nodes (or junctions) at various locations throughout the basin where computations will be made as to water flow.

65. The Corps relies on ResSim modeling and modeling results to evaluate the impact of various current and proposed reservoir operations as part of its WCM/DEIS update, including evaluating its ability to satisfy all federal project purposes and the potential environmental impacts of these operations (JX-124). ResSim is also used by the Corps to assess the impact of current and proposed water supply changes in the ACF Basin and on the ability to satisfy basin-wide project purposes (*e.g.*, the RIOP's 5,000 cfs minimum flow) in light of changes in water demands. A direct example of this is the Corps' reliance on ResSim model outputs to evaluate Georgia's 2013 and 2015 Water Supply Requests for Metropolitan Atlanta (JX-86; JX-126).

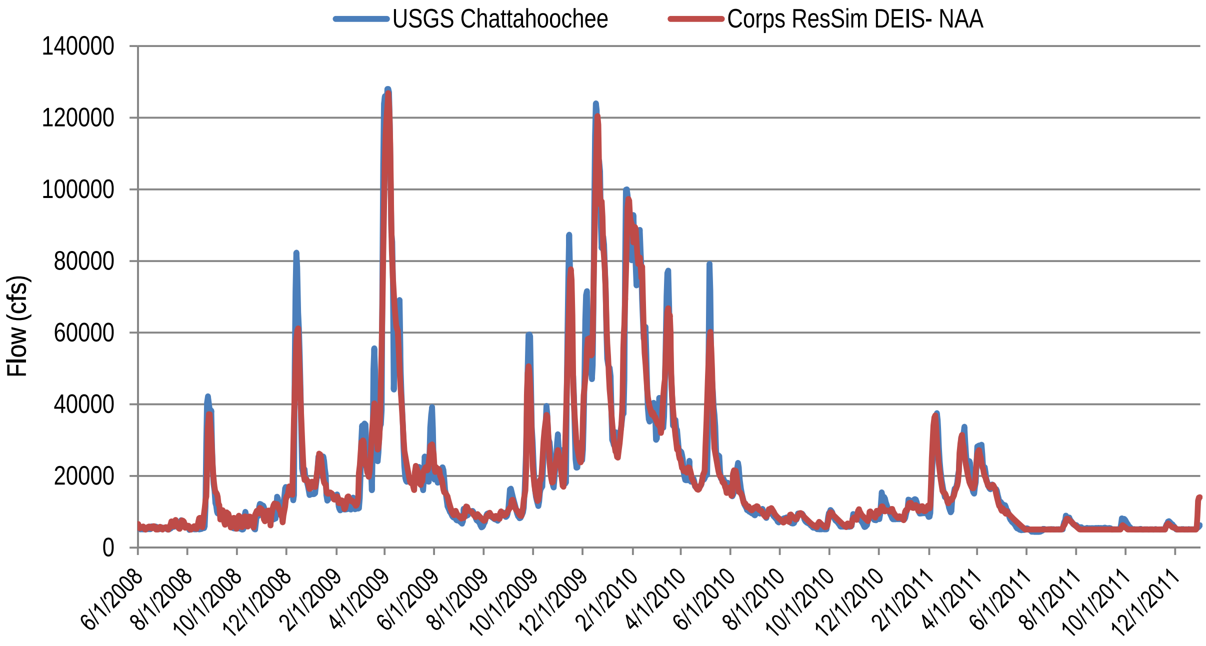
This type of modeling involves changing the amount of upstream consumptive use and determining how these changes impact lake levels and streamflow under the operating rules according to ResSim. This type of modeling is used regularly and relied upon by the Corps to satisfy various project purposes. This is precisely the type of modeling I conducted for my consumption cap scenarios below.

66. The Corps has described ResSim as "the tool most capable of faithfully representing District water management practices as the culmination of a three-year model development and verification process" (JX-118). I agree that ResSim is the best available software for evaluating the impact of alternative management practices (*e.g.*, increases or decreases in consumptive use or changes in reservoir operating rules) on state-line flow.

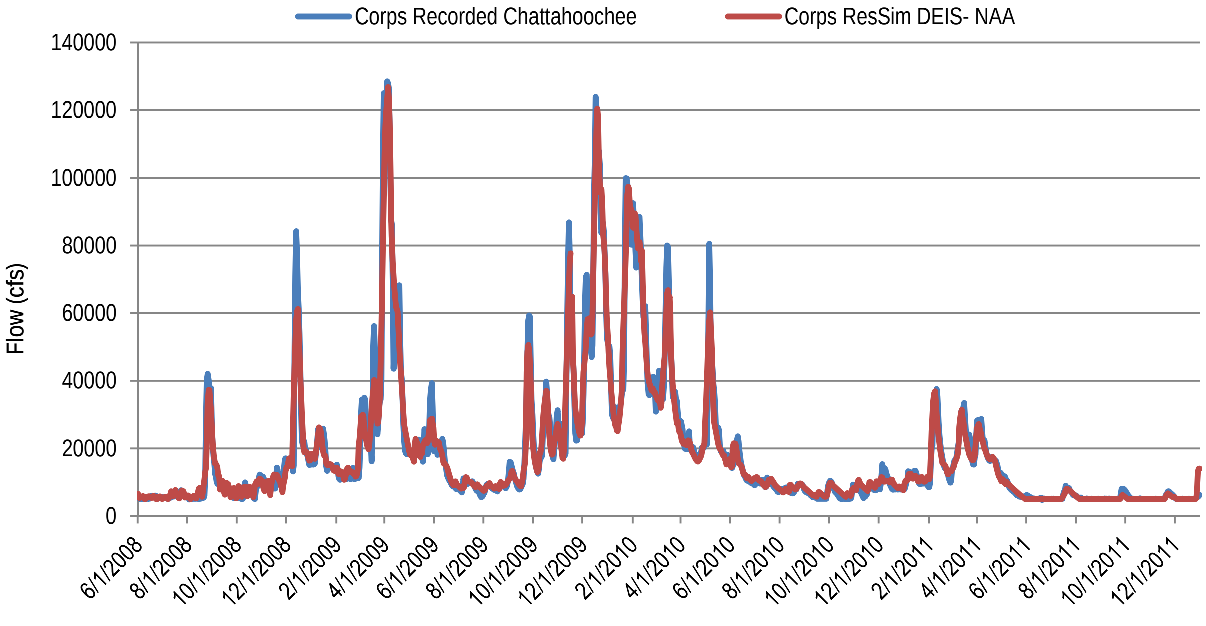
67. To demonstrate the ability of ResSim to accurately reproduce the reservoir operations of the ACF Basin, I performed a goodness-of-fit analysis. A goodness-of-fit analysis is a standard method of evaluating the ability of a model to predict, or "fit," the data. In this case, I evaluated the ability of ResSim to reproduce observed outflow from Woodruff Dam. For all of my modeling, I used ResSim version 3.2, which is the most updated version of the software. This version of the model for the ACF Basin was released by the Corps in October 2015 in conjunction with the 2015 WCM/DEIS.

68. I conducted simulations of predicted ResSim releases for the period June 2008-December 31, 2011. (This period represents the full period of hydrologic record available for conducting hydrologic modeling in the ACF Basin during which the RIOP rules, which came into effect in June 2008, were also in place.) I then compared ResSim's modeled outflow from Woodruff Dam with two sets of observed flows: (1) the USGS's final, official discharge (flow) records for the Chattahoochee gage (Bedient Demo. 16); and (2) the Corps' recorded releases from Woodruff Dam, according to the Corps daily project data (Bedient Demo. 17).

69. As shown in Bedient Demo. 16 and Bedient Demo. 17, ResSim's modeled outflows match exceptionally well to the observed flows. Bedient Demo. 16 and Bedient Demo. 17 are true and accurate copies of demonstratives I prepared using generally accepted scientific principles and methods, and show ResSim's goodness of fit to both sets of flow data.



Bedient Demo. 16. ResSim vs. USGS Final Discharge for Chattahoochee Gage (2008-2011) (Source: GX-143; JX-128)



Bedient Demo. 17. ResSim vs. Corps Recorded Release from Woodruff Dam (2008-2011) (Source: GX-143; JX-128)

70. ResSim's excellent fit to the actual system is apparent in each of the figures above. The differences between the various recorded flow into Florida (blue) and ResSim (red) are generally very small. ResSim's goodness of fit is confirmed by the below numerical

goodness of fit indices. These indices provide numerical values, or scores, for standard goodness of fit tests, including the Nash-Sutcliff Efficiency ("NSE") and the PBIAS. For NSE, a value of "1" is a perfect fit. For PBIAS, a value of "0" means the model has no bias. Bedient Demo. 18 is a true and accurate copy of a demonstrative I prepared using generally accepted scientific principles and methods, depicting the goodness of fit of ResSim.

USGS Final Discharge for Chattahoochee Gage (June 2008-2011)

"Goodness of Fit" Metric	ResSim Results
NSE	0.959
PBIAS	0.314

Corps Recorded Release from Woodruff Dam (June 2008-2011)

"Goodness of Fit" Metric	ResSim Results
NSE	0.960
PBIAS	0.800

Bedient Demo. 18. ResSim "Goodness of Fit" Results (GX-143; JX-128)

71. As Bedient Demo. 18 shows, ResSim is excellent at reproducing actual observed releases, both for the USGS final discharge and for the Corps recorded releases. For example, ResSim has an NSE of 0.959 for the period from June 2008 to December 2011 for USGS Final Discharge Data. ResSim has an NSE of 0.960 for the same period for the Corps' Recorded Release. Although not shown in Bedient Demo. 18, ResSim also had an excellent fit when only the dry months of the year are considered. For the dry months during the period June 2008 to December 2011, ResSim has an NSE of 0.915 for both the USGS final discharge data and the Corps' recorded release. ResSim's ability to reproduce actual reservoir operations confirms that it is the best available model for modeling the reservoir system in the ACF Basin.

72. ResSim is further described in JX-46 and GX-150. JX-46 is a true and accurate copy of the HEC-ResSim Reservoir System Simulation User's Manual Version 3.1 (May 2013). I have reviewed and am familiar with JX-46, and experts in my field regularly rely on official publications from the Corps such as JX-46. GX-150 is a true and accurate copy of the HEC-ResSim Reservoir System Simulation User's Manual Version 3.0 (April 2007). I have reviewed

and am familiar with GX-150, and experts in my field regularly rely on official publications from the Corps such as GX-150.

II. Development of "Baseline" (2011) and Reduction Scenarios for ResSim

73. To perform my modeling analysis, I first developed a "baseline" consumptive water use scenario for ResSim reflecting Georgia's total consumptive use in the ACF Basin in 2011. For each reduction scenario, I kept the reservoir rules and hydrology the same and changed only the amount of water entering the reservoir according to different consumption cap scenarios, allowing me to isolate the effect of Georgia's consumptive use on state-line flow. For reservoir operations, I used the Corps' PAA reservoir operations.[8]

74. The consumptive use figures that I use as inputs for my modeling are based on data reported to and collected by Georgia EPD. I understand that the consumptive use data that I obtained from Georgia EPD has been independently validated by a number of Georgia experts Peter Mayer (M&I) and Dr. Suat Irmak and Dr. Sorab Panday (agricultural).

75. After developing the baseline scenario, I developed 19 consumption cap scenarios, reflecting hypothetical reductions in Georgia's current (2011) water use in the ACF Basin by 5-30% across both M&I and agricultural water use sectors, both individually as well as collectively. I also modeled the impact of reducing Georgia's consumptive water use to 1992 levels, as suggested by Florida in its complaint. This reflected the equivalent of about a 40% reduction in Georgia's total water use.

76. The 19 consumption cap scenarios are shown in Bedient Demo. 19 below.

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[8] I selected the PAA because it was the set of reservoir operations contained in the Corps' latest version of ResSim (version 3.2), released in October 2015. I understand the PAA is the set of operations most likely to be adopted by the Corps, and thus would most accurately reflect a hypothetical consumption cap in the future. I conducted simulations using the 2012 RIOP, as opposed to the PAA, and I did not find any material difference between the two with respect to state-line flows.

Bedient Demo. 19. ResSim Consumption Cap Scenarios

Scenario	M&I Only	Ag Only	M&I + Ag
-5%	✓	✓	✓
-10%	✓	✓	✓
-15%	✓	✓	✓
-20%	✓	✓	✓
-25%	✓	✓	✓
-30%	✓	✓	✓
1992			✓

77. The outputs generated from the ResSim model reflect a time series of state-line flows (in cfs) showing the impact of consumption caps under historical hydrologic conditions for a 37-year period, generally reflecting those that occurred from January 1, 1975 to December 31, 2011. This period represents the full series of flow conditions following the existence of the reservoirs (post-1975) for which hydrologic data is available for the computer model. The model runs therefore reflect how the consumption caps affect state-line flow under the historical hydrologic conditions. My modeling analysis is based on generally accepted principles and methods regularly used by experts in my field, including the Corps in conducting its modeling analysis for the WCM/DEIS.

III. ResSim Shows That Even Significant Reductions in Georgia's Water Use Would Not Materially Increase State-Line Flow, Especially During Low-Flow Periods

78. Based on my ResSim modeling, I conclude that the reduction in Georgia's consumptive use by up to 30%, or even to 1992 levels, does not have a material impact on the amount of water crossing the state line as compared to 2011 levels. This is especially true for dry years (*e.g.*, 2007 and 2011), when even significant changes in Georgia's consumptive use would lead to virtually no change in state-line flows during the low-flow months (*e.g.*, June, July, August, September). This is due to the Corps' reservoir operations, which control the amount of water flowing across the state line and into Florida.

79. GX-986 is a true and accurate copy of the results of my ResSim model simulations for the consumption cap scenarios.[9]

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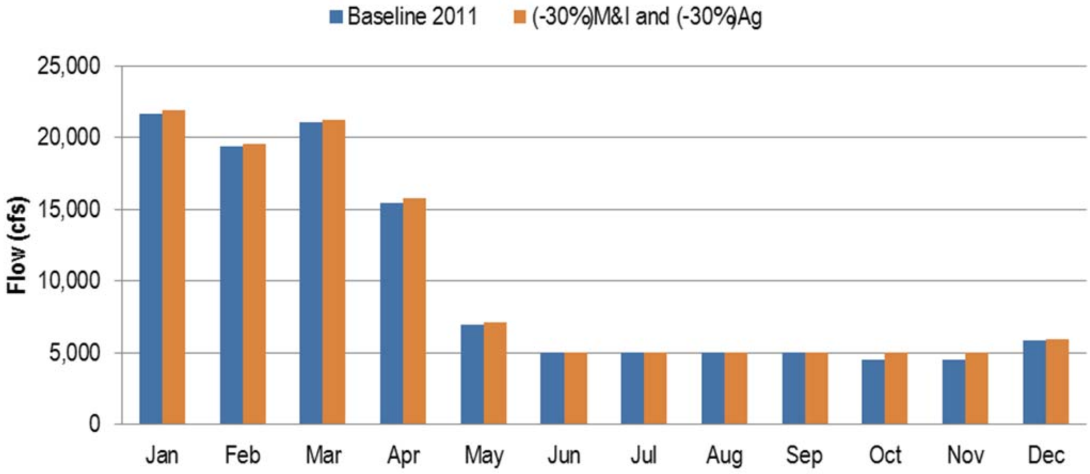
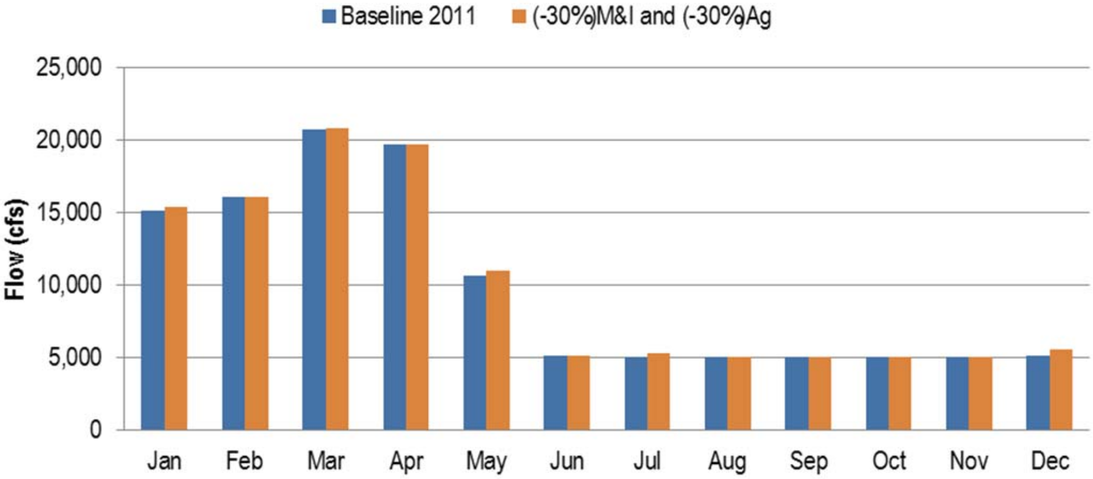
[9] I provided Dr. Charles Menzie the results of my ResSim modeling results for the Baseline (2011) and 1992 consumption cap scenarios. GX-936 is a true and accurate copy of these model outputs.

80. Bedient Demo. 21 and Bedient Demo. 22 are true and accurate copies of ResSim model outputs I prepared using generally accepted scientific principles and methods, showing the impact of 30% consumption caps across the board on state-line flows for 2007 and 2011 hydrologic conditions. The results are shown in terms of monthly average state-line flows. The blue bar shows the baseline scenario (no consumption cap) and the orange bar shows the reduction scenario (30% consumption cap). The difference between the two represents the amount of additional state-line flow created as a result of the 30% reduction in Georgia's total water use.



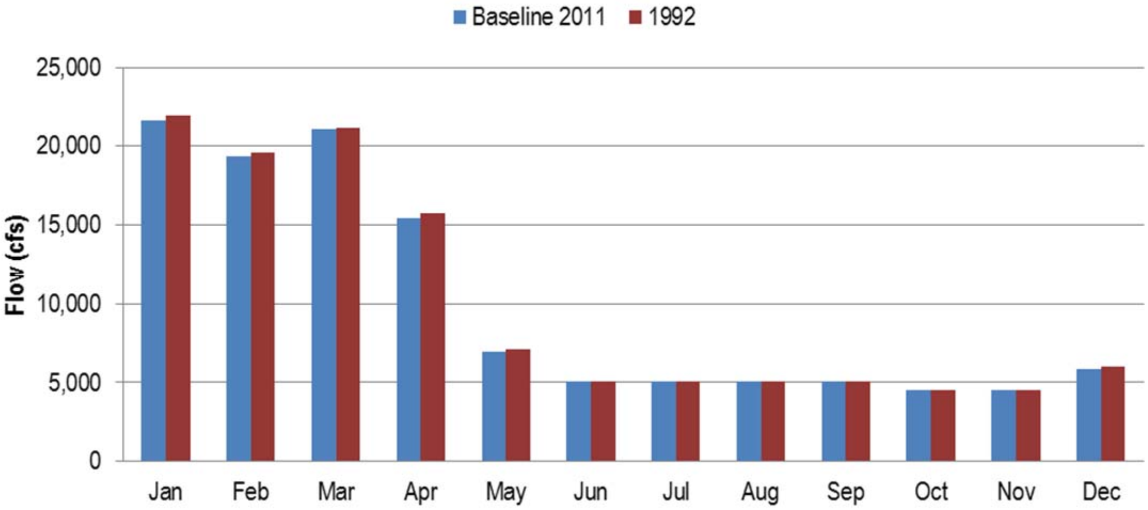
Bedient Demo. 20. State-Line Flows Under Baseline (2011) Water Use and 30% Consumption Cap (2007 Hydrologic Conditions) (Source: GX-986)



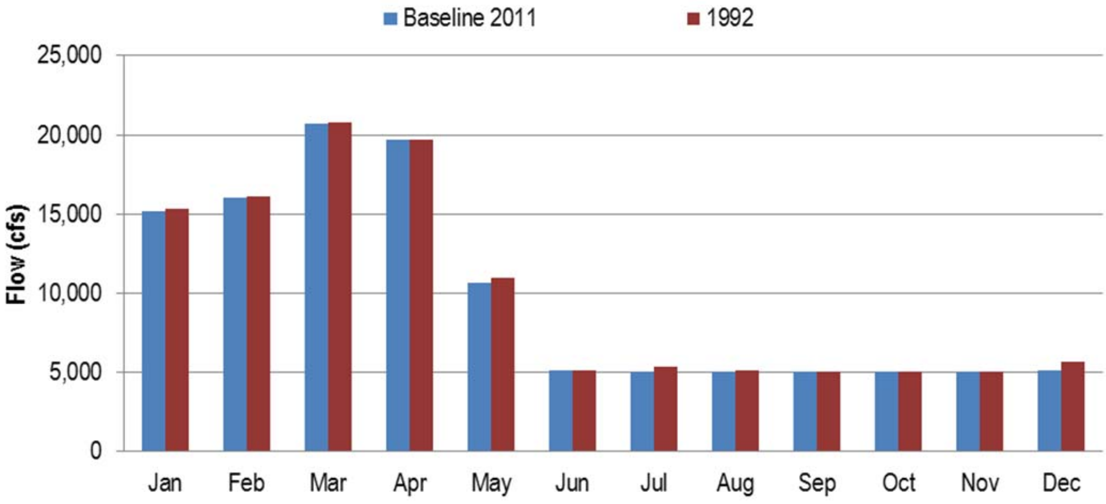
Bedient Demo. 21. State-Line Flows Under Baseline (2011) Water Use and 30% Consumption Cap (2011 Hydrologic Conditions) (Source: GX-986)

81. As these figures show, during drought years, even significant reductions in Georgia's water use do not have a significant impact on state-line flows. The results of these model simulations show that for the months of June through September, the flow of at least 5,000 cfs at the state line was maintained, even while Georgia's consumptive use was being reduced by up to 30% of both its M&I and agricultural use. In other words, the reservoir model results confirm that additional water entering the ACF Basin and resulting from Georgia's reduced consumptive use would not translate to *any* increase in flow at the state line during these critical low flow months, due to the manner in which the Corps operates its reservoirs.

82. Even with a reduction in Georgia's water use by almost 50% (down to its 1992 rates), low flows at the state line during the dry summer and fall months (averaging about 5,000 cfs) generally would not increase at all. Bedient Demo. 22 and Bedient Demo. 23 are true and accurate copies of demonstratives I prepared using generally accepted scientific principles and methods, showing ResSim model outputs of the impact of 1992-level consumption caps across the board on state-line flows for 2007 and 2011 hydrologic conditions. Like the 30% caps, the results are shown in terms of monthly average state-line flows. The blue bar shows the baseline scenario (no consumption cap) and the red bar shows the reduction scenario (1992 levels of water use). The difference between the two represents the amount of additional state-line flow created as a result of the 1992-level consumption cap.



Bedient Demo. 22. State-Line Flows Under Baseline (2011) Water Use and 1992 Consumption Cap (2007 Hydrologic Conditions) (Source: GX-986)

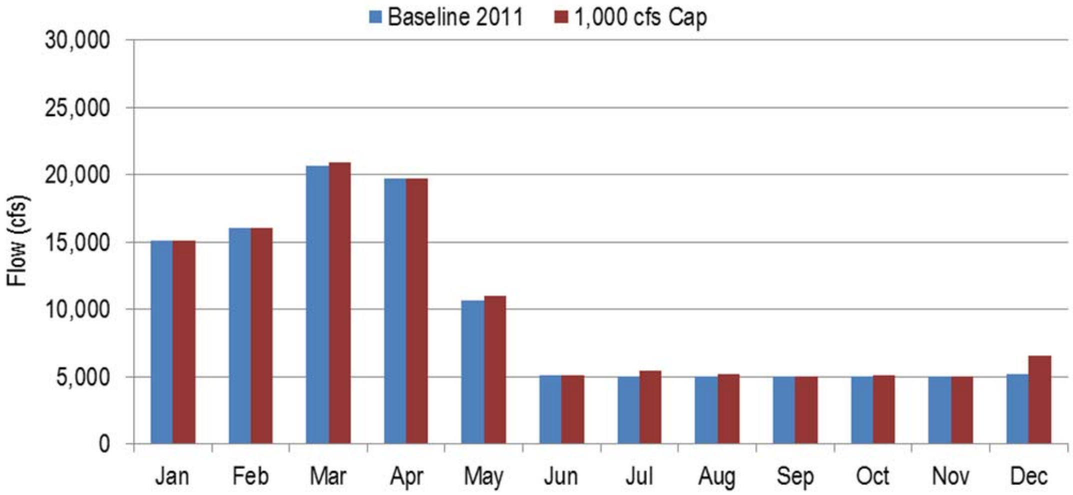


Bedient Demo. 23. State-Line Flows Under Baseline (2011) Water Use and 1992 Consumption Cap (2011 Hydrologic Conditions) (Source: GX-986)

83. As these figures show, even cutbacks to 1992 levels do not have a major impact on state-line flows during dry years.

84. Florida's expert, Dr. David Sunding, has offered the opinion that Georgia can increase streamflow in the ACF Basin by as much as 1,000 cfs during peak summer months. This is his 1,000 cfs "conservation scenario." I modeled the state-line flow impact of Dr. Sunding's 1,000 cfs "conservation scenario." For this modeling, I simply assumed an increase in Flint River flow of 1,000 cfs during certain peak summer months, regardless of whether any such increase would be possible or feasible as a result of Georgia's consumptive use.

85. GX-911 is a true and accurate copy of my ResSim model results for the state-line flow impacts of Dr. Sunding's 1,000 cfs scenario. Bedient Demo. 24 is a true and accurate copy of a demonstrative I prepared using generally accepted scientific principles and methods, showing ResSim model outputs for this scenario under 2011 (drought year) hydrologic conditions.



Bedient Demo. 24. State-Line Flows Under Baseline (2011) and +1,000 cfs in Flint River (Dr. Sunding's Proposal) (2011 Hydrologic Conditions) (Source: GX-911)

86. As Bedient Demo. 24 shows, even if Flint River inflow to Lake Seminole were increased by 1,000 cfs during peak summer months, the increase in state-line flow would still be relatively small under these hydrologic conditions. For example, despite an increase of inflow to Lake Seminole of 1,000 cfs in June 2011, the increase in outflow from Woodruff Dam would be a mere 30 cfs. In September 2011, with an increase of inflow to the lake of over 1,000 cfs, there is no change in the average monthly outflow from Woodruff Dam.

87. The reason that even significant reductions in Georgia's consumptive use and Dr. Sunding's 1,000 cfs "conservation scenario" do not have a significant impact on state-line flows is because of the Corps' operating rules for the reservoirs. The Corps' reservoir operations moderate ("smooth out"), and often cancel out entirely, the impact of Georgia's water use, especially during low flow periods. The Corps reservoirs offset increased inflow with decreased releases from the reservoirs. Thus, reductions of water use in the Flint River would not necessarily lead to any increased flow at the state line. Instead, they would often lead to increased water being stored in the reservoirs.

IV. The Only Reliable Way to Ensure a Particular Flow Regime into Florida Is by Altering the Corps' Reservoir Operating Rules

88. Unlike cutting or capping Georgia's water use, changing the reservoir operations in the ACF Basin can substantially impact state-line flows, and can do so effectively and predictably, even without any increase or decrease in the amount of water entering the ACF river

system. This is illustrated by the Corps' own reservoir modeling analysis performed as part of the WCM/DEIS process.

89. As part of the DEIS, the Corps evaluated several different proposed sets of reservoir operations. The Corps used ResSim to model and evaluate the impact of these different operational scenarios. In these ResSim simulations, the Corps changed the reservoir operations, but did not change upstream water use conditions so as to isolate the effect of each of the reservoir operations, and each's ability to satisfy and balance the various authorized project purposes. The Corps' modeling results were published in October 2015 as part of the WCM/DEIS.[10]

90. The Corps evaluated 7 different alternative reservoir operations scenarios ("Alt 1" through "Alt 7"). In evaluating these alternatives, the Corps ran the ResSim model and looked at the change each scenario produced on a number of metrics (*e.g.*, reservoir elevation and streamflow). GX-1216 is a true and accurate copy of the Corps' ResSim modeling results for the alternative reservoir operations scenarios. Bedient Demo. 25 and Bedient Demo. 26 are true and accurate copies of documents I prepared reproducing these scenarios. Bedient Demo. 25 and Bedient Demo. 26 illustrate how the 7 different reservoir operations scenarios can significantly affect state-line flow under hydrologic conditions for 2011, a dry year.

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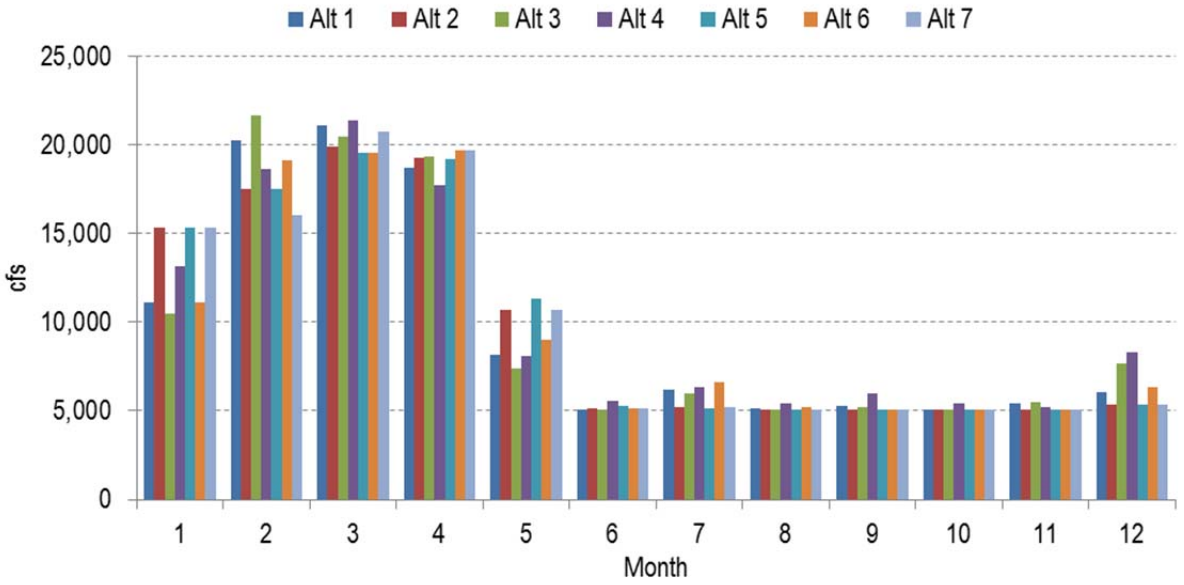
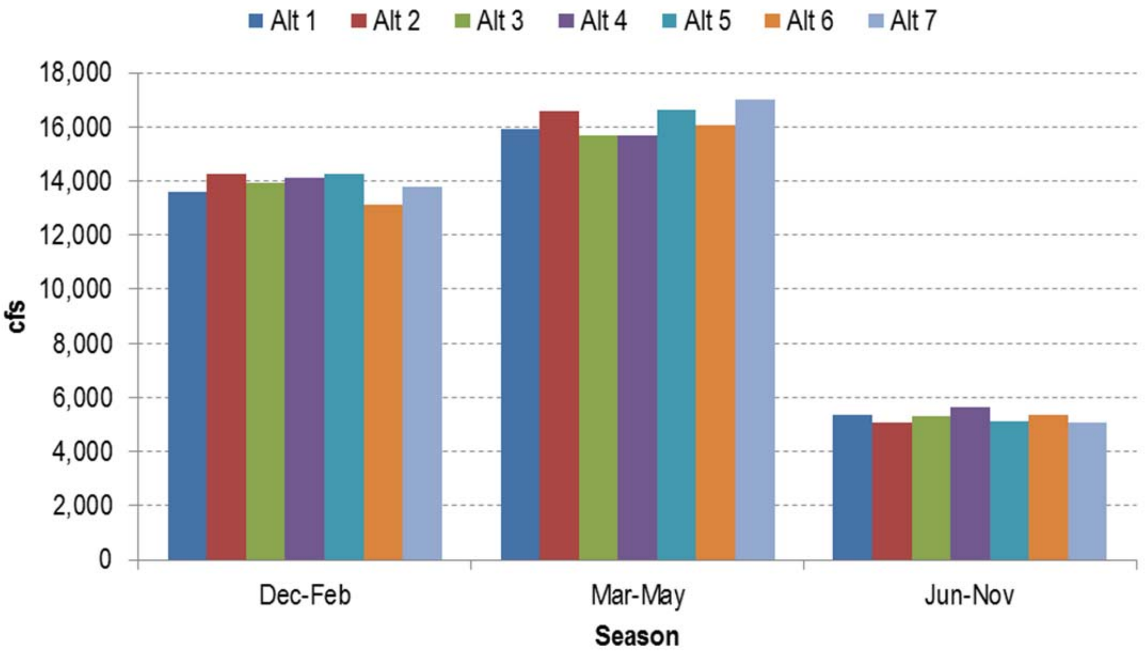
[10] The DEIS is available at the following website: http://www.sam.usace.army.mil/Missions/PlanningEnvironmental/ACFMasterWaterControlManualUpdate/ACFDocumentLibrary.aspx.



Bedient Demo. 25. State-Line Flow Impact of Alternative Reservoir Operations (Source: GX-1216)



Bedient Demo. 26. State-Line Flow Impact of Alternative Reservoir Operations (Source: GX-1216)

91. As Bedient Demo. 25 and Bedient Demo. 26 show, simply changing the Corps reservoir operations—without any change in the amount of water entering the reservoir system, including any change in upstream water use levels—can produce changes of hundreds or even

thousands of cfs in state-line flow, even during the low-flow summer months. For example, in July, the low flow of 5,050 cfs under the RIOP can be increased to 6,016 cfs under the operating plan of Alt4. Even the average flow for the entire period of June-November can be increased from an average of 5,050 cfs under the RIOP to 5,423 cfs under Alt4.

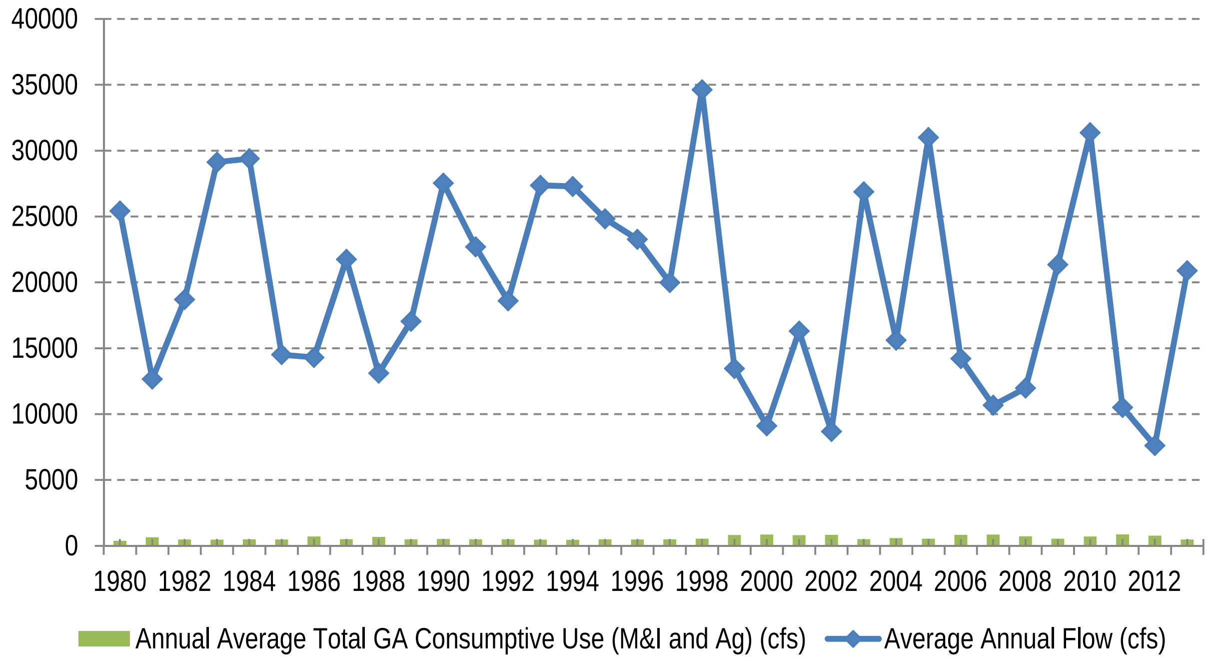
92. The above modeling using the Corps' official model for reservoir simulation and water management indicates that the reservoir operations are the primary factor influencing the amount of streamflow crossing the state line, especially during times of drought and seasonal low flows. Unless the rules are changed, increased inflow to the reservoir system will not necessarily "pass through" to Florida. As a result, the only way to guarantee any additional flow or to ensure any particular flow regime into Florida is to set specific flow requirements at Woodruff Dam for a particular time or for a given set of circumstances. Any such change would require both modification of the Corps' reservoir operations and involvement by the Corps.

GEORGIA'S HISTORICAL, CURRENT, AND PROJECTED WATER USE HAS NOT HAD AND WILL NOT HAVE A SIGNIFICANT IMPACT ON STATE-LINE FLOWS

93. Georgia's water use—past, present, and future—has not reduced and will not materially reduce flows crossing the state line and entering Florida because the Corps' reservoir system and its operating rules help to "smooth out" variations in streamflow in the ACF Basin, thereby moderating, and often canceling out entirely, the impact of increases or decreases in Georgia's water use on state-line flows. Additionally, one of the reasons even significant reductions in Georgia's water use would not materially increase state-line flows—at any time of the year—is because Georgia's water use in the ACF Basin is relatively small compared to the amount of water entering into Florida.

I. Georgia's Total Water Use Is a Small Fraction of Streamflow in the ACF Basin

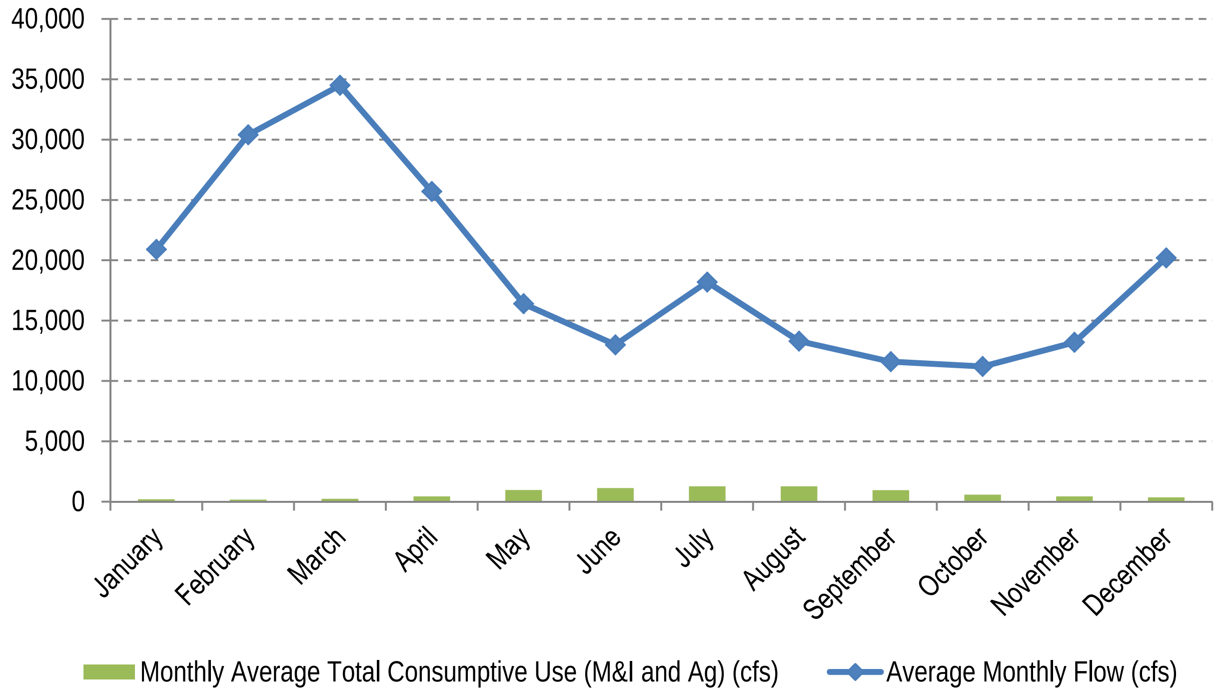
94. Georgia's water use represents a relatively small percentage of streamflow entering Florida. Bedient Demo. 27 is a true and accurate representation of USGS streamflow data for the Chattahoochee gage compared with Georgia's total average annual water use (1980-2013). Bedient Demo. 27 provides a sense of the magnitude of Georgia's total water use compared to the amount of water entering Florida on an annual average basis.



Bedient Demo. 27. Georgia's Total Annual Consumptive Water Use vs. Average Annual State-Line Flow (1980-2013) (Sources: GX-939, JX-128)

95. As Bedient Demo. 27 shows, Georgia's total water use is, on an annual average basis, less than 5% of state-line flow.

96. Bedient Demo. 28 is a true and accurate copy of a demonstrative I prepared using generally accepted scientific principles and methods, comparing Georgia's total water use with state-line flow on a monthly, rather than annual, basis. This provides a better sense of the monthly variability in Georgia's recent water use and state-line flow in an average year (1980-2013).



Bedient Demo. 28. Georgia's Total Average Monthly Water Use vs. Total Average Monthly State-Line Flow (1980-2013) (Sources: GX-940, JX-128)

97. As shown in Bedient Demo. 28, Georgia's total water use during the months of May-September averages about 1,170 cfs per month, with the months of July and August having the highest use of about 1,330 cfs. This compares to the average monthly flow crossing the state line during May-September of about 15,000 cfs. Although higher than the annual consumptive water use values, these monthly and seasonal numbers confirm that even when water is in its greatest demand, Georgia's total consumptive water use still represents a small percentage of water as compared to the amount of streamflow that crosses the state line.

98. The total consumptive use (*i.e.*, streamflow impact) in Georgia does not generate a direct or corresponding reduction in reductions of state-line flow because of the role of the Corps' reservoir operations in the ACF Basin, especially Woodruff Dam at the state line. This is especially true during dry and drought years, when the Corps augments flow using reservoir storage, which more than compensates for Georgia's consumptive use and provides the Apalachicola River with more flow than would enter Florida in the absence of the reservoirs.

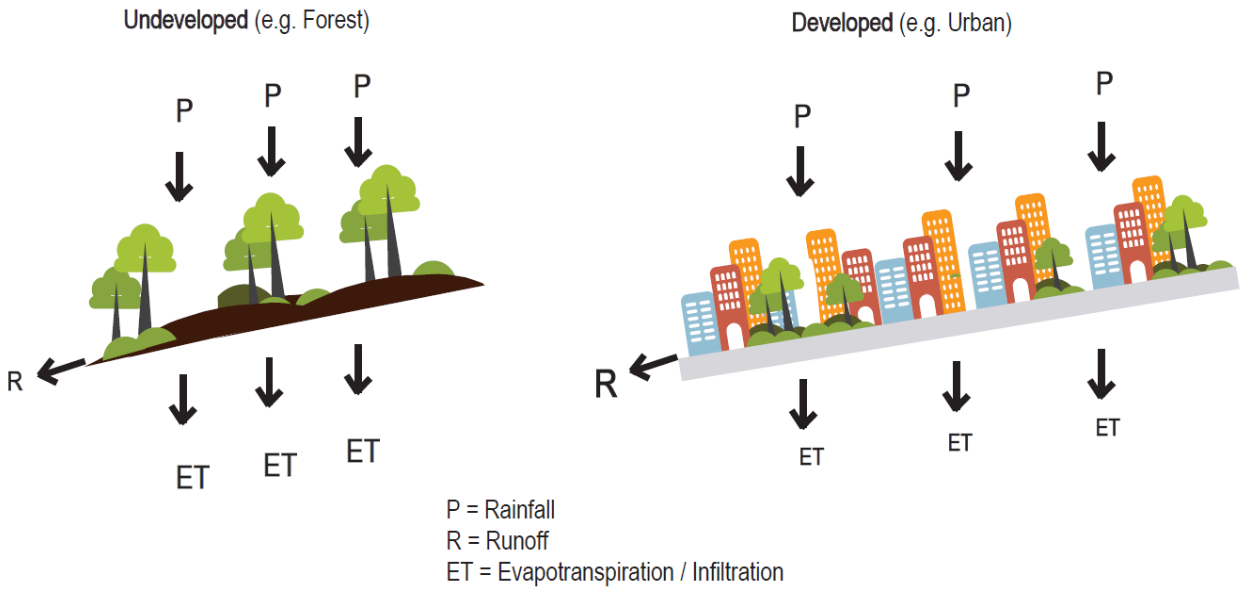
II. Georgia's Land Use Changes Have Added a Significant Amount of Water to the ACF Basin

99. Land use changes can impact the amount of rainfall that enters a river system as runoff. Runoff is the total amount of precipitation that eventually ends up in the river system, and is the primary source of streamflow. Runoff travels overland in a down-gradient direction, eventually entering streams and rivers. Runoff consists of water that is not removed due to evaporation, transpiration, or infiltration. In order to comprehensively assess Georgia's total historical consumptive water use in the ACF Basin, one must also take into account the amount of water contributed to the river system resulting from land use changes in Georgia.

100. In Georgia's portion of the ACF Basin, historically forested areas have been altered for urban development, pasture land, and agricultural use. These land use changes have led to construction of streets, buildings, parking lots, and other structures, and they have also been accompanied by improved drainage systems. These land use changes increase the amount of impervious cover, which generates more runoff into rivers than natural, pervious surfaces. The increase in impervious cover and the improved drainage both result in increased runoff.

101. Urban development and its associated land use changes cause more of the rainfall in the ACF Basin to be converted into streamflow in the rivers, tributaries, and streams in the Basin. This is because less of the rain can infiltrate into the ground or be lost due to evapotranspiration.

102. Bedient Demo. 29 is a simple illustration of the phenomenon of increased runoff resulting from land uses changes. Bedient Demo. 29 illustrates that for the same amount of precipitation, developed (*e.g.*, urban) land generates more runoff and less evapotranspiration/infiltration than undeveloped (*e.g.*, forest) land.



Bedient Demo. 29. Increased Runoff from Developed vs. Undeveloped Land

103. When considering how much water has been removed from the river system by Georgia’s consumptive use, it is important to also consider how much water is contributed back to the system as a result of Georgia’s land use changes.

104. The concept of land use changes from urban development contributing water to river systems has been acknowledged by USGS as an issue worthy of study for the ACF Basin. In 2006, the USGS wrote that “[i]ncreases in impervious surfaces from urbanization have occurred in the ACF Basin, with the greatest increases occurring in metropolitan Atlanta” and that “[i]ncreases in frequency and magnitude of high flows, and other changes in streamflow characteristics, are known to occur as a result of increased imperviousness.”[11] The USGS noted that “[u]pdated estimates of the percentage of the watershed covered with impervious surfaces are needed, along with a better understanding of the runoff characteristics that existed in those areas prior to urbanization.”[12]

105. The USGS later evaluated this issue with respect to land use changes in the Upper Flint River Basin, based on analysis of changes in impervious cover resulting from urban

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[11] *See* GX-88 (Light, H.M., Vincent, K.R., Darst, M.R., and Price, F.D., 2006, Water-Level Decline in the Apalachicola River, Florida, from 1954 to 2004, and Effects on Floodplain Habitats: U.S. Geological Survey Scientific Investigations Report 2006-5173, 83 p., plus CD).

[12] *Id.*

development. I reviewed and relied on the USGS paper, and experts in my field regularly review and rely on scientific publications. The USGS developed a rainfall-runoff model to evaluate the impact of land use changes on runoff in the Upper Flint.[13] The USGS modeling analysis confirmed that as urban development and impervious cover increase, runoff and streamflow in the Flint River will increase, as well. The USGS's modeling and analysis is very similar to the LSPC model used by Georgia EPD, and the USGS's results are very similar to those that I have reached.

106. I performed an independent analysis of land use changes using LSPC, a well-established rainfall-runoff model created by Tetra Tech, a contractor for Georgia EPD. The LSPC model that I used is similar to the USGS PRMS model.

107. Tetra Tech ran simulations using the LSPC models to evaluate 1974 and 2008 land use conditions. The 1974 land use condition has about 1.6% impervious cover in the Basin, and the 2008 land use condition has about 3.5% impervious cover in the Basin.

108. I re-ran Tetra Tech's models and simulations to verify their results. I confirmed that the net effect of land use changes between 1974-2008 in the Chattahoochee and Flint River Basin in Georgia has been to increase the amount of water entering the ACF river system. In other words, the total amount of water contributed to the ACF river system resulting from land use changes is, on an annual average basis, greater than the total amount of Georgia's consumptive use from the entire ACF Basin (for both M&I and agricultural purposes, including both surface water and groundwater withdrawals).

109. Bedient Demo. 30 below is a true and accurate copy of a demonstrative I prepared showing the LSPC model's results for the 1974 and 2008 land use conditions.

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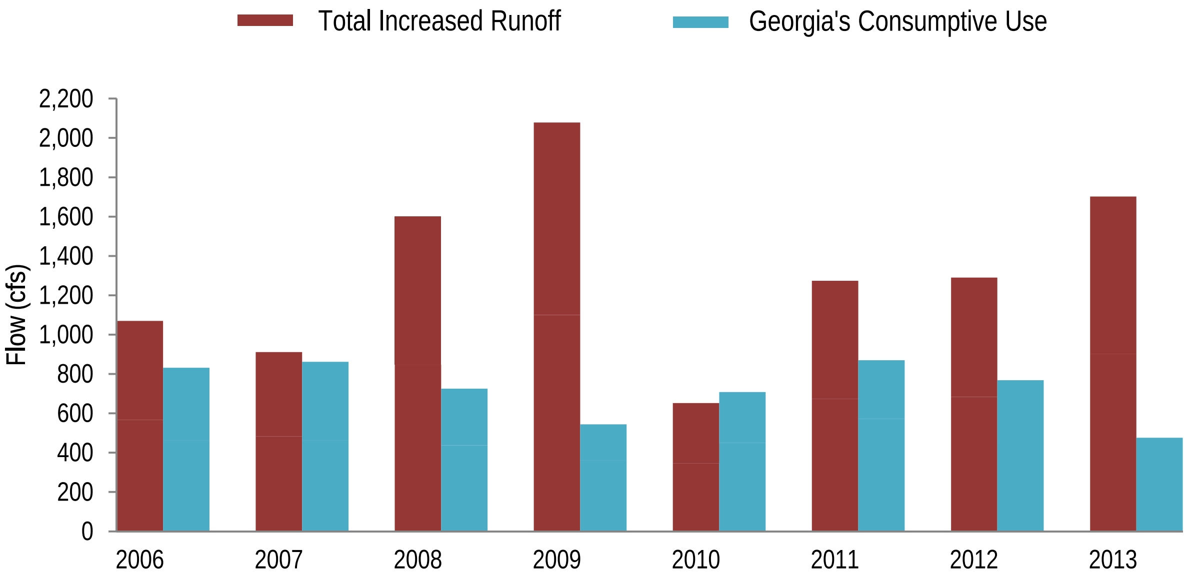
[13] Viger, Roland J., *et al.* USGS, "Hydrologic Effects of Urbanization and Climate Change on the Flint River Basin, Georgia," 2011.



Bedient Demo. 30. Georgia's Total Water Use vs. Runoff Contributed by Land Use Changes in the ACF Basin

110. As Bedient Demo. 30 shows, the total amount of increased runoff contributed to the ACF river system by land use changes in Georgia's portion of the ACF Basin has exceeded the total amount of water use in Georgia's portion of the ACF Basin. The LSPC model shows that just the land use changes between 1974 and 2008 contributed an average of about 600 cfs in runoff per year to the ACF river system. When considering the land use changes prior to 1974, the contribution of additional runoff increases to about 1,200 cfs per year. This more than compensates for Georgia's total consumptive water use for both M&I and agricultural purposes, which averages about 600 cfs during normal or wet years and about 900 cfs in dry or drought years.

111. Although these land use changes contribute water to the ACF river system, the effect that these changes have on state-line flow must also take into account the Corps reservoir operations. As a result of the Corps reservoir operations, these contributions to streamflow from land use change—just like Georgia's consumptive uses—are not immediately realized at the state line. Instead, these additions to streamflow contribute to reservoir storage, which ultimately supports streamflow entering Florida.

112. Dr. Lettenmaier, Florida's expert on hydrology and climate change, cites the USGS paper and acknowledges the role of urban development in increasing runoff contributions

to rivers. But while he and other experts for Florida discuss at length Georgia's withdrawals from the river system resulting from consumptive water use, neither he nor any other expert for Florida acknowledges how much of the additional water is contributed to the river system by land use changes in Georgia. My analysis includes estimates of water removed as well as water added to the system.

III. Projected Increases in Georgia's Water Demands Through 2040 Would Not Materially Decrease State-Line Flows

113. As part of my analysis of the impact of Georgia's water use on state-line flows, I also evaluated Georgia's projected water supply needs for the entire ACF Basin through 2040 (including M&I water supply needs for Metro Atlanta as well as agricultural and other water demand levels throughout the rest of the ACF Basin). As part of this analysis, I conducted ResSim modeling comparing the impact of baseline (2011) water demand levels with projected 2040 water demand levels.

114. Based on my analysis and modeling, I conclude that Georgia's projected water demand levels through 2040 would lead to minimal, if any, decrease in state-line flows compared to current (baseline) levels. The decrease would often be 0 cfs as a result of the Corps' regulation of water in the ACF Basin.

115. Georgia's projected water demand levels through 2040 were developed by Georgia for its 2013 Water Supply Request to the Corps. These projected demand levels reflect an extensive process by Georgia EPD and regional water planning districts for evaluating the State's water supply needs in the ACF Basin, including in Metro Atlanta and throughout the rest of the Basin.

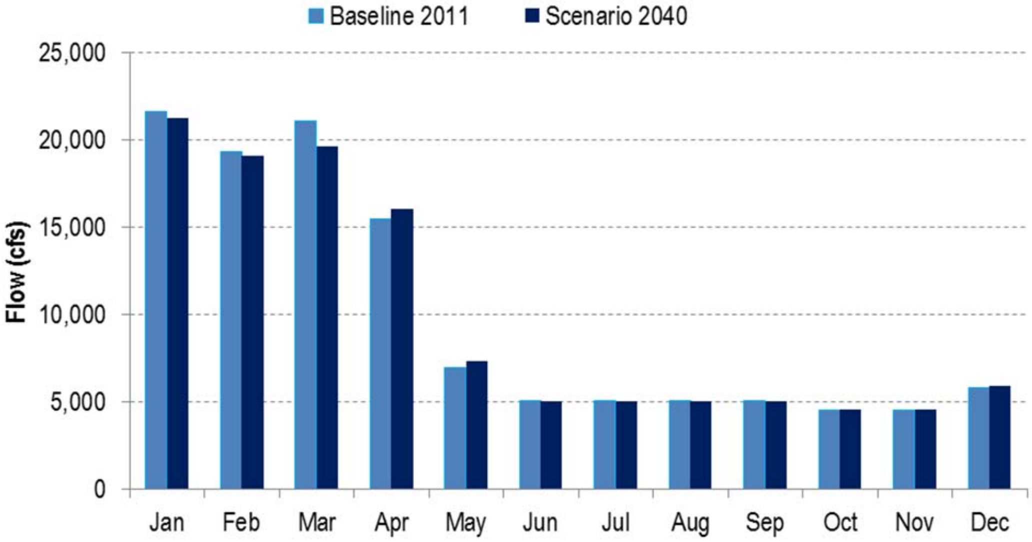
116. In December 2015, Georgia submitted a revised Water Supply Request to the Corps (GX-822). I have reviewed and am familiar with GX-822. In Georgia's revised Water Supply Request, its projected water supply needs for the Metro Atlanta area were revised downward, from total withdrawals of 705 mgd to about 621 mgd annually, reflecting net consumptive M&I withdrawals of 155.1 and 155.4 mgd, respectively. I modeled the impact of the 2013 Water Supply Request for two reasons: first, the 2013 water demand projections included not only projections of Georgia's M&I water use for 2040, but also a forecast of agricultural water use needs throughout the rest of the Basin through 2040 (whereas the 2015

Water Supply Request focused primarily on Metro Atlanta); and second, because the water demands were revised downward from 2013 to 2015, my analysis would be based on a conservative (higher) level of demand than actually projected by Georgia.

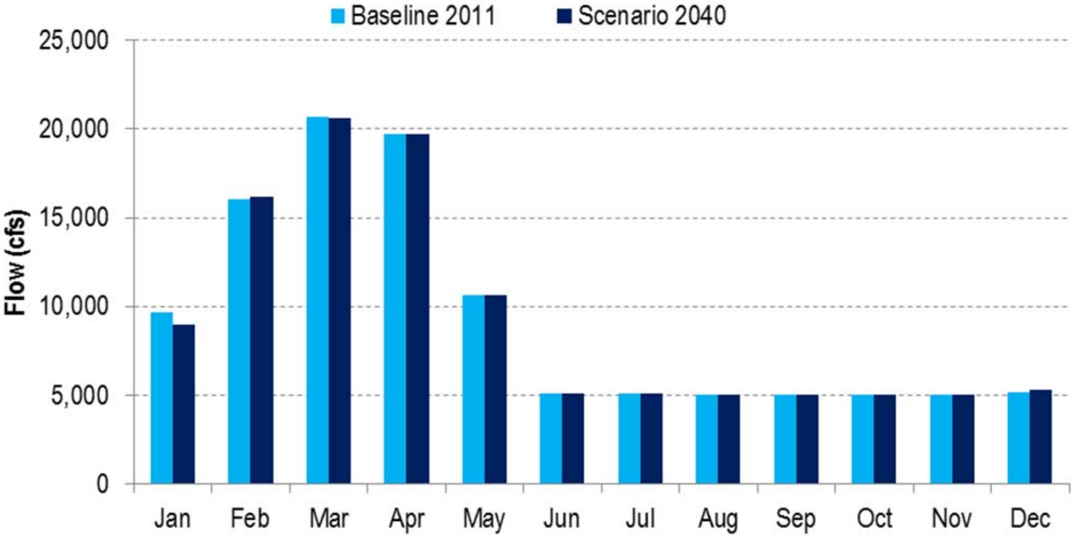
117. Georgia's projections for basin-wide demand levels show that Georgia's consumptive use would net increase by 10% through 2040. Georgia's projected water supply needs for the entire ACF Basin through 2040 for a typical dry year would amount to an increase in net consumptive water use of about 62 cfs, or less than a 10% increase in Georgia's highest recorded levels of water use (2011).

118. To perform my modeling analysis of the impact of increasing Georgia's water use from 2011 to 2040 levels on state line flows into Florida, I ran ResSim under two different scenarios: one involving how the reservoirs would respond to baseline (2011) levels of consumptive use under the entire hydrologic period of record (1975-2011) and a second involving how the reservoirs would respond to projected (2040) levels of consumptive use, using the same set of reservoir operations and same hydrologic period of record. Similar to my consumption cap modeling, this isolates the impact of the changing water demand levels.

119. Bedient Demo. 31 and Bedient Demo. 32 below are true and accurate representations of the results of my ResSim modeling in terms of monthly, seasonal, and annual state-line flows for dry years (2007 and 2011).



Bedient Demo. 31. State-Line Flows Under Baseline (2011) and Projected 2040 Water Demands (2007 Hydrologic Conditions)



Bedient Demo. 32. State-Line Flows Under Baseline (2011) and Projected 2040 Water Demands (2011 Hydrologic Conditions)

120. As Bedient Demo. 31 and Bedient Demo. 32 show, for many of the low-flow months depicted in these figures, there is no change in the flow at the state line due to the projected increase in consumptive water use by Georgia to 2040. For instance, for both 2007 and 2011, there is a change of roughly 0 cfs during the low flow months (i.e., June, July, August, September, October, November).

121. I conclude that Georgia's projected growth in future consumptive water use through 2040 would not materially decrease the streamflow entering Florida, especially during low-flow periods. Additional results of my ResSim modeling of projected 2040 water demands on state-line flows are contained in Appendix B.

122. When the small increase in Georgia's projected 2040 consumptive water use is coupled with the additional water that will flow into the ACF river system due to increased runoff from land use changes in Georgia due to the urban development, there would continue to be a net increase in the amount of streamflow being contributed by Georgia to the ACF river system.

THE AMOUNT OF STREAMFLOW IN THE ACF BASIN IS PRIMARILY ATTRIBUTABLE TO NATURAL CLIMATIC AND HYDROLOGIC FACTORS, NOT GEORGIA'S WATER USE

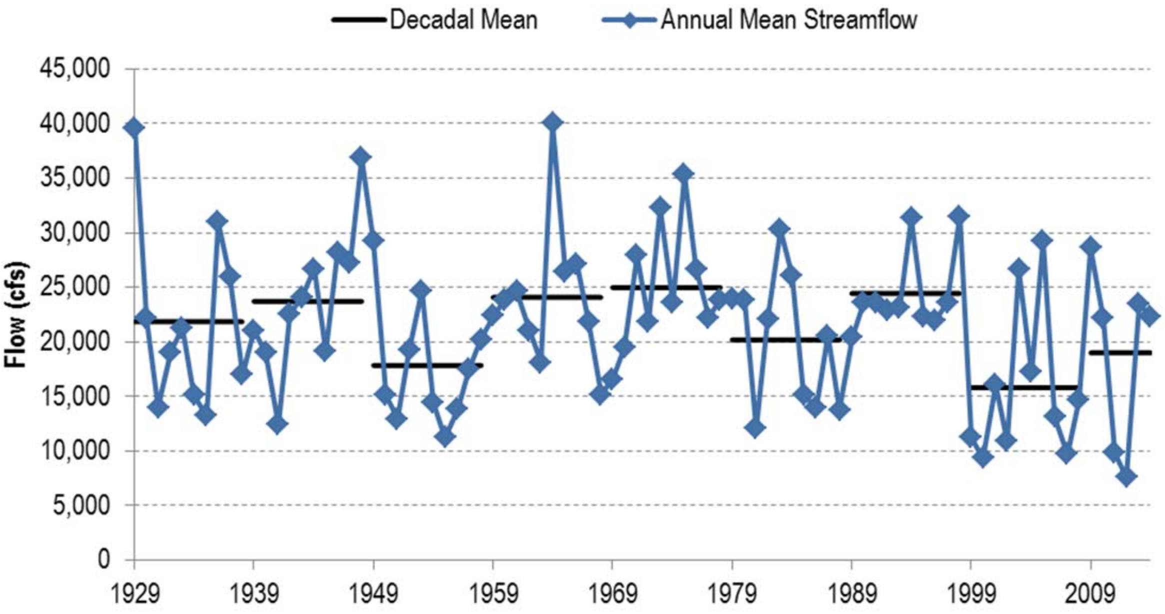
123. I have studied the natural hydrology of the ACF Basin, including using standard hydrologic methods and reviewing climate and hydrologic data, including records of rainfall and streamflow throughout the Basin. I demonstrate that precipitation and streamflow are intricately linked in the ACF Basin, such that monthly and annual variability in streamflow is largely attributable to monthly and annual variability in rainfall. I show that the slight decline in Apalachicola River flows in recent years is strongly correlated with a slight decline in rainfall over the ACF Basin. I also demonstrate how the amount of runoff generated in the Apalachicola River has declined on average, by over 4,000 cfs over the past four decades. This phenomenon, which is based on observed flow records from the USGS, is occurring entirely within the State of Florida and thus does not relate to consumptive use above the state line.

I. Streamflow Is Directly Correlated with Precipitation (Rainfall) Over the Basin

124. The primary factor influencing the total amount of streamflow in the ACF Basin, including the total amount of flow in the Chattahoochee, Flint, and Apalachicola Rivers at any particular time, is the amount of precipitation (rainfall) over the Basin.

125. The total amount of precipitation in the ACF Basin, and in the Apalachicola River, varies from year to year, month to month, and day to day. Similarly, the total amount of streamflow in the ACF Basin varies on an annual, monthly, and daily basis.

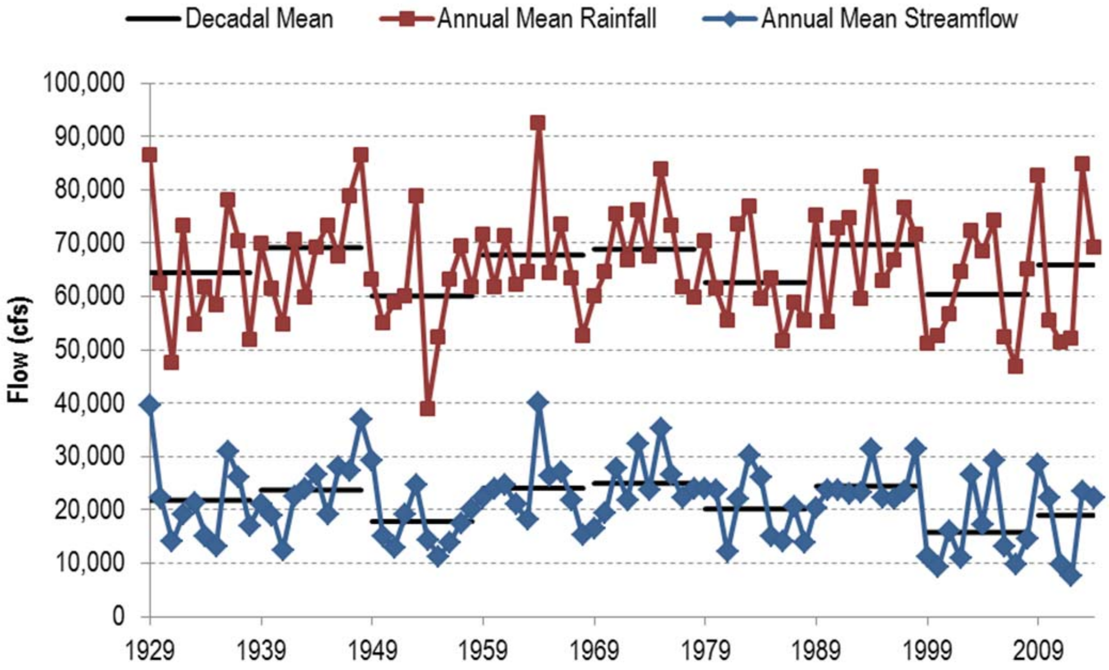
126. Bedient Demo. 33 is a true and accurate representation of the annual and decadal average streamflow entering the Apalachicola River for the period of record (1929-2014).



Bedient Demo. 33. Average Streamflow in the Apalachicola River (1929-2014)

127. As Bedient Demo. 33 shows, the overall average annual flow (1929-2014) is approximately 21,400 cfs. In recent years (*i.e.*, since 1999), the average streamflow in the Apalachicola River has declined, to about 17,000 cfs.

128. It is very clear that long-term variations in streamflow are directly correlated with long-term variations in precipitation. Bedient Demo. 34 is a true and accurate representation of annual and decadal average streamflow in the Apalachicola River compared with annual and decadal average precipitation over the ACF Basin.



Bedient Demo. 34. Correlation Between Rainfall and Streamflow in the Apalachicola River (1929-2014)

129. Bedient Demo. 34 shows a strong, direct correlation between the amount of rainfall over the ACF Basin and the amount of streamflow in the ACF Basin. In particular, the recent declines in streamflow during the multi-year drought periods since 1998 (1999-2001, 2006-2008, 2011-2012) are associated with similar declines in precipitation. This strongly indicates that lower rainfall, not Georgia's water use, is the primary cause of lower streamflow over the past 15 years.

II. In Recent Decades, Florida's Share of Flow Contributions to the Apalachicola River Has Declined, While Georgia's Has Increased

130. As part of my streamflow and rainfall analysis, I also considered the portion of the ACF Basin below the state line that contributes to flows into the Apalachicola Bay. As shown in Bedient Demo. 35 below, a drainage area of about 2,000 mi^2, or 10% of the ACF Basin lies between the state line and the Sumatra Gage in Florida (an additional 400 mi^2 of area drain into this ACF Basin between the Sumatra Gage and Apalachicola Bay). I call the portion of the ACF Basin that's below the state line and solely within Florida the "Florida Portion" and the portion of the ACF Basin that's in Georgia and Alabama above the state line in the "Non-Florida Portion."

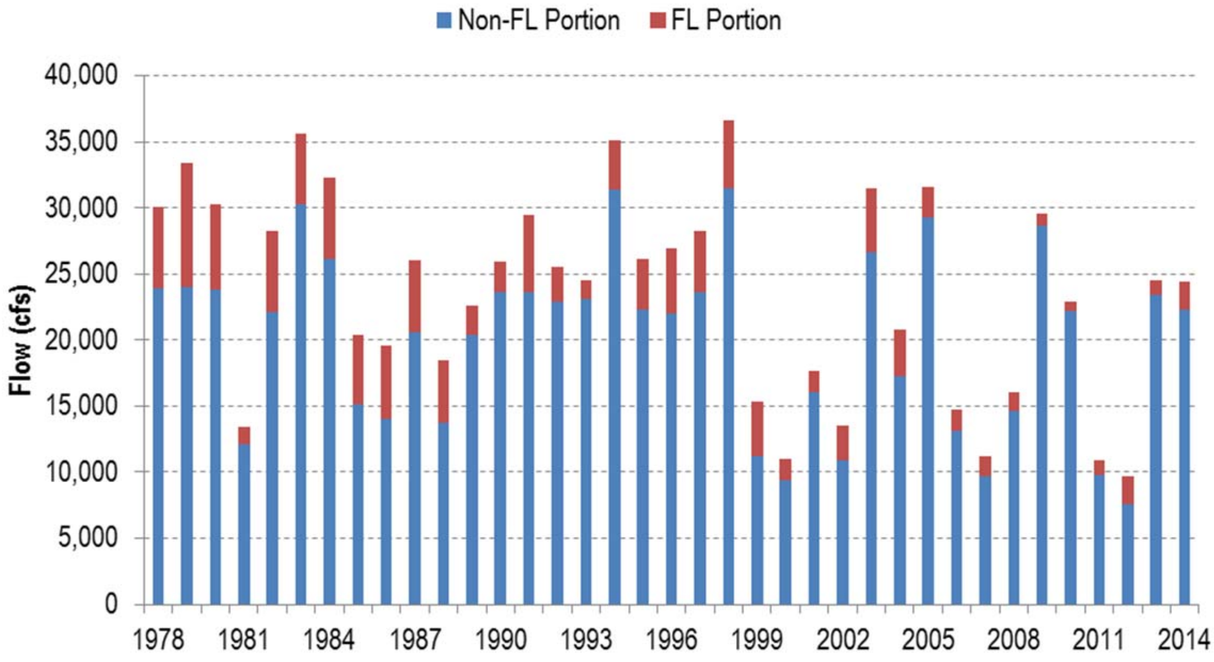
Bedient Demo. 35. Non-Florida and Florida Portions of the Drainage Area for the ACF Basin at Sumatra, Florida

	Drainage Area (mi^2)	Percent (%) of ACF Basin
Non-Florida Portion	17,200	90%
Florida Portion	2,000	10%
Total	**19,200**	**100%**

131. To understand the specific portion of flows that Florida contributes to the total flows within the ACF Basin, I analyzed the difference between flows along the Apalachicola River at the Chattahoochee Gage and the Sumatra Gage. The flows reported at the Chattahoochee Gage for the Apalachicola River equate to the flows from both the Chattahoochee and Flint Rivers and resulting releases from the Jim Woodruff Dam; whereas flows seen at the Sumatra Gage equate to these flows as well as flows being added or subtracted as the Apalachicola River flows through Florida. By subtracting the flows at the Chattahoochee Gage from the flows at the Sumatra Gage, this incremental flow contribution from Florida to the streamflow in the Apalachicola River and ultimately into the Apalachicola Bay can be determined.

132. I found that Florida's contribution to flows entering the Apalachicola River and eventually entering Apalachicola Bay has been generally decreasing since 1978, and especially during the most recent drought periods. During the recent drought periods, the flow contribution to the Apalachicola River fell from averaging about 6,000 cfs to as low as 1,000 cfs as an annual average, even during times when rainfall increased over the ACF Basin within Florida. Since 1978, Florida's contribution to streamflow in the Apalachicola River has generally been declining, falling from about 20% in 1978 to approximately 10% in 2014.

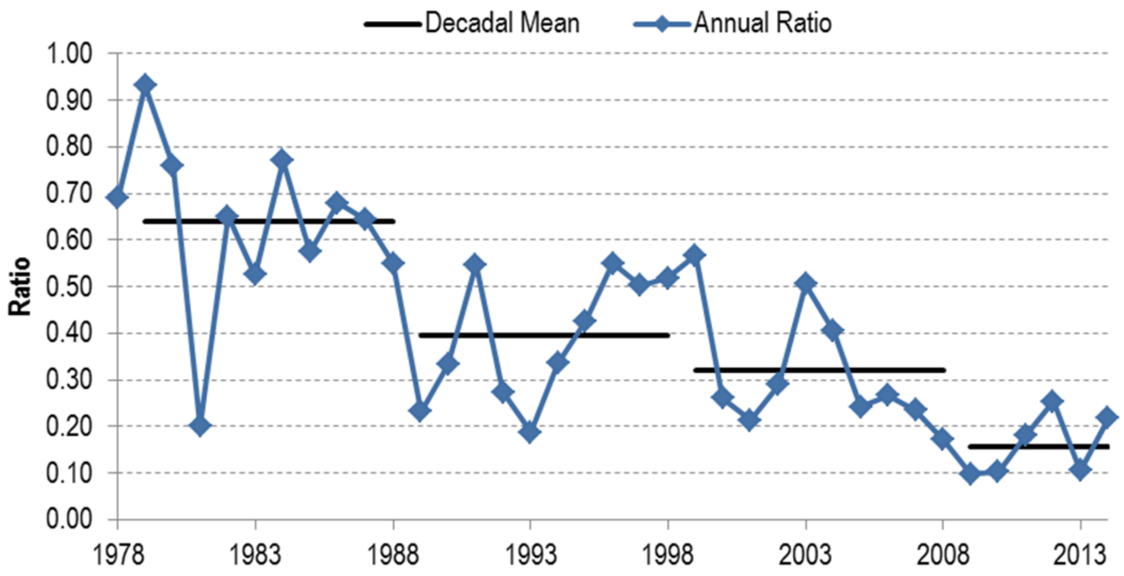
133. Bedient Demo. 36 is a true and accurate representation of absolute average annual flow contributions of the non-Florida and Florida portions of the ACF Basin.



Bedient Demo. 36. Average Annual Flow Contributions of Non-Florida and Florida Portions of ACF Basin (1978-2014)

134. As shown in Bedient Demo. 36, the Florida contribution (red) has been shrinking since 1978, and particularly since 1998, for a long-term average decline of approximately 4,000 cfs. In Bedient Demo. 36, the blue bar represents the "non-Florida" portion of the flow, *i.e.*, the total amount of water entering the Apalachicola River from above the state line as recorded at the Chattahoochee gage. The red bar represents the "Florida" portion of the flow, *i.e.*, the incremental amount added in Florida between the Chattahoochee and Sumatra gages.

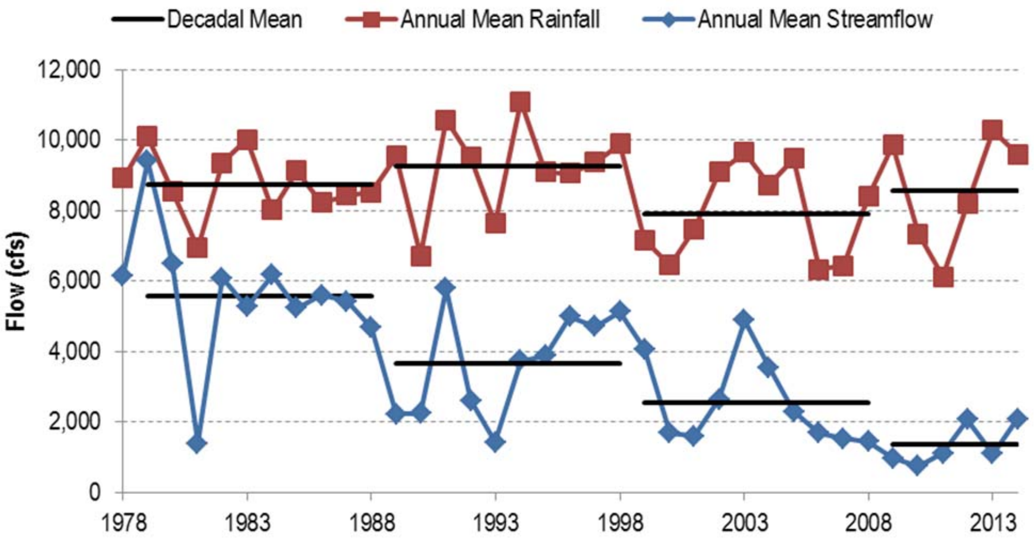
135. The decline in "incremental flow" cannot be explained solely by rainfall. I conducted an analysis of how the decline in flows in Florida compared to rainfall occurring over Florida's portion of the ACF Basin over the same time to determine if this trend of reduced contributions of flow from Florida was correlated with reduced rainfall. Bedient Demo. 37 is a true and accurate representation of the ratio of flow to rainfall for the Florida portion of the ACF Basin. This is also sometimes referred to as a "runoff coefficient." (Dr. Hornberger calls it "basin yield.")



Bedient Demo. 37. Ratio of Flow vs. Rainfall for Florida Portion of ACF Basin (1978-2014)

136. As shown by Bedient Demo. 37, the runoff coefficient for the Apalachicola Basin has been steadily declining since 1978. This means that for the same amount of rainfall, less streamflow is being generated solely within the Florida portion of the Basin.

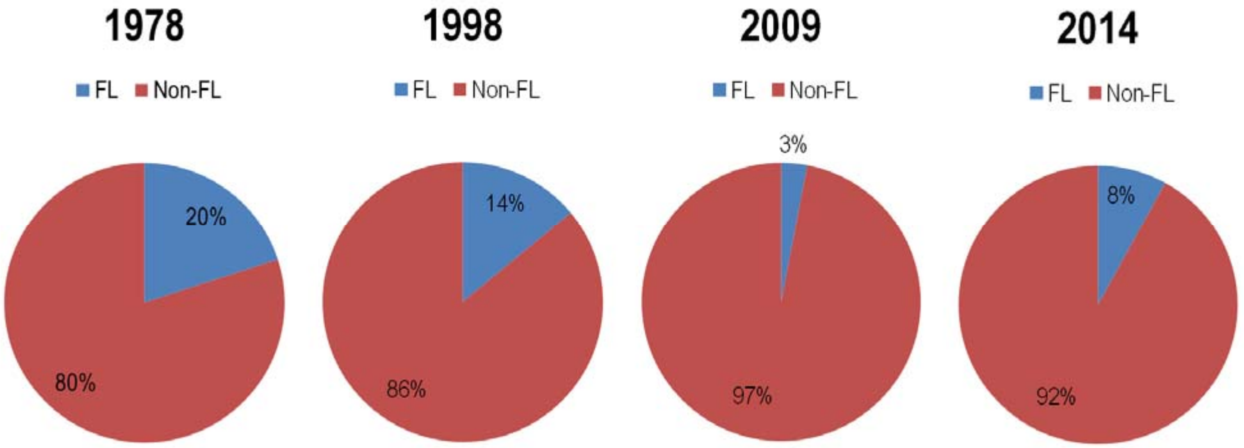
137. Bedient Demo. 38 is a true and accurate representation of average annual and decadal flow and rainfall in the Florida portion of the ACF Basin.



Bedient Demo. 38. Average Annual and Decadal Flow and Rainfall for Florida ACF (1978-2014)

138. As shown in Bedient Demo. 38, the corresponding rainfall does not show the same consistent decline observed in runoff in the Florida portion of the ACF Basin. Instead, it follows the pattern for the entire ACF Basin. Likewise, the strong relationship between rainfall and streamflow that has been seen at the state line does not appear in the data shown for the Florida portion of the ACF Basin. This suggests a change in the hydrologic process that is taking place in the Florida portion of the ACF Basin. Whatever the cause of this change, it is apparent that the runoff generated exclusively in the Florida portion of the basin has been declining at a faster rate than the decline of state-line flow. The decline in runoff in Florida—and any hydrologic change(s) in Florida responsible for it—is not attributable to anything that takes place north of the state line.

139. Florida's contributions have not only declined as a matter of absolute flows; they have also declined in terms of percentage of overall flows. Bedient Demo. 39 is a true and accurate representation of the declining trend in the percentage of the streamflow being contributed by the Florida portion of the ACF Basin.



Bedient Demo. 39. Florida's Percent Contribution of Flows to the Apalachicola River (1978-2014)

140. As shown in Bedient Demo. 39, Florida's percent share of contribution of flows to the Apalachicola River has been declining over time, from an average of around 20% in 1978 to an average of around 8% in 2014. In other words, while Georgia (and Alabama) used to contribute an average of around 80% of flows to the Apalachicola River in 1978, the upstream states now contribute an average of around 92% of flows to the Apalachicola River.

141. It is not clear why Florida's portion of flow into the ACF Basin has continued to consistently drop, but it is clear that Florida's relative contribution to flow in the ACF Basin has been decreasing. In other words, for the same relative amount of rainfall, the amount of streamflow being contributed from the Florida portion of the ACF Basin and entering into the Apalachicola River and Bay has been decreasing. Because this decline represents the flow difference between an upstream and downstream gage on the Apalachicola River in Florida, it reflects less rainfall being translated to runoff within Florida's borders. The incremental flow decline, by definition, has nothing to do with Georgia's water use.

RESPONSES TO FLORIDA OPINIONS ON CORPS RESERVOIR OPERATIONS

142. Dr. Shanahan offers opinions regarding Corps reservoir operations and reservoir models. Dr. Shanahan offers three basic opinions: First, Dr. Shanahan opines that increases in streamflow in what he calls "Area A" (primarily the Flint River Basin) would not be offset by releases from Corps reservoir operations in what he calls "Area B" and "Area C" (primarily the Chattahoochee River Basin). Second, Dr. Shanahan opines that the Corps uses its "discretion" to release more than required under the RIOP from Woodruff Dam into Florida because of its "strong incentive" to support downstream fish and wildlife. Third, Dr. Shanahan opines that the Corps' ResSim model cannot accurately model Corps "discretion" in operating the reservoirs.

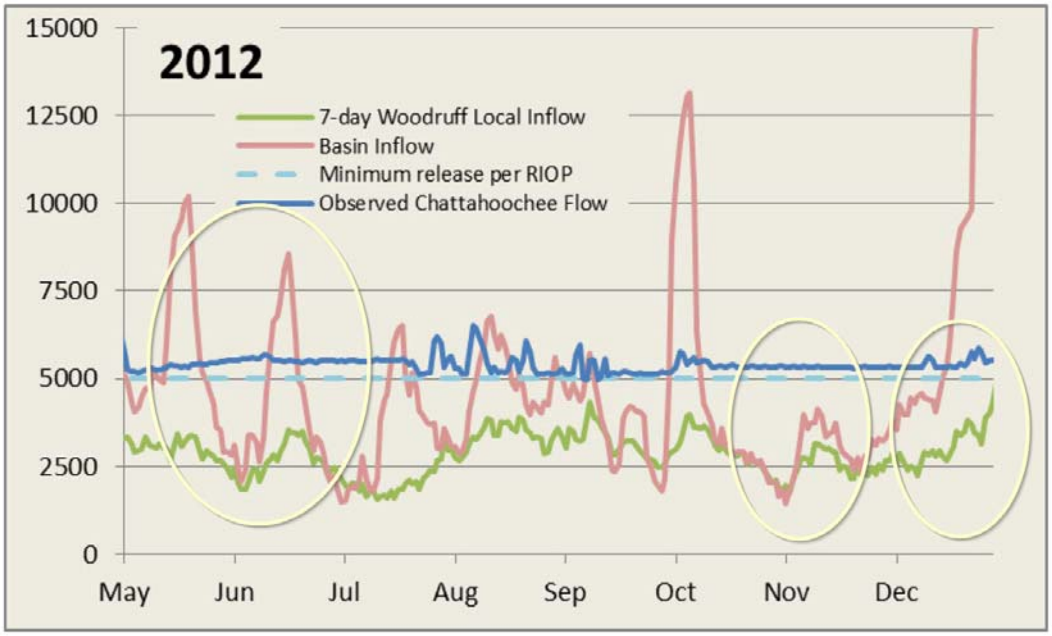
143. I have reviewed the testimony of Dr. Peter Shanahan regarding Corps reservoir operations and reservoir models, and I have reached the following broad opinions based on his testimony:

- Dr. Shanahan's conclusion that offset would not occur is based on analysis of different reservoir operations (pre-RIOP) and data that includes high flows, rather than low flows. Dr. Shanahan should have looked solely at whether the Corps offsets flows during low-flow periods under the RIOP, which shows that the Corps does, in fact, offset Flint River flows using reservoir storage on the Chattahoochee River. Dr. Shanahan also ignores the Corps' active regulation of the reservoir system as a single, integrated unit that includes all three major storage reservoirs, instead focusing entirely on the capacity of Lake Lanier to offset Flint River flows.

- The Corps does not use its “discretion” to deliberately drain its reservoirs. There is no evidence of any “discretionary” releases from Woodruff Dam over 5,000 cfs, and the Corps is not “incentivized” to support a single project purpose at the expense of all the others. Instead, the Corps balances its reservoir operations to satisfy multiple project purposes, which under low-flow conditions involve prioritizing reservoir storage and releasing the minimum flow of 5,000 cfs from Woodruff Dam.

I. Dr. Shanahan’s Own Data Disproves Any Relationship Between Woodruff Dam Outflow and Either Basin Inflow or Inflow to Lake Seminole

144. Dr. Shanahan’s primary conclusion appears to be that increases in streamflow into the reservoir system, especially from the Flint River, will lead to increases in releases from Woodruff Dam into Florida. But Dr. Shanahan’s own analysis shows just the opposite. For example, in Bedient Demo. 40 below, which is reproduced from Dr. Shanahan’s February 29th expert report, the lack of relationship between USGS flow records for the Chattahoochee gage and either Basin Inflow or inflow to Lake Seminole is apparent.

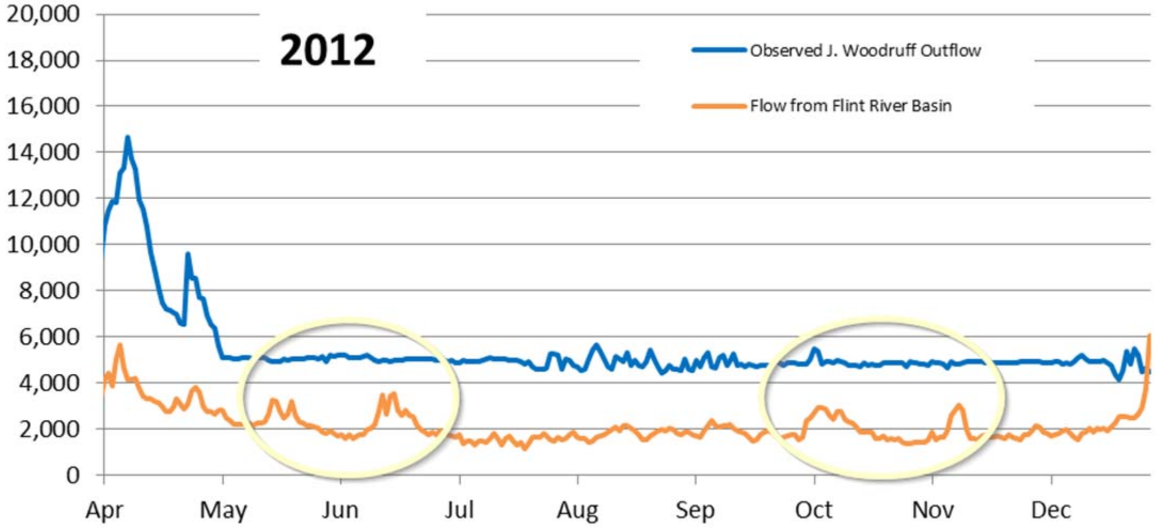


Bedient Demo. 40. Dr. Shanahan’s Figure Shows No Relationship Between Chattahoochee Flow and Either Basin Inflow or Lake Seminole Inflow (Source: FX-811, at 20)

145. As shown in Bedient Demo. 40, Basin Inflow (the pink line) can vary by thousands of cfs—or by as much as tens of thousands of cfs—and the observed Chattahoochee

gage flow remains virtually unchanged. Similarly, inflow to Lake Seminole can vary by hundreds or thousands of cfs, and the observed Chattahoochee gage flow can remain virtually unchanged. This is represented by the yellow circles, which highlight where Basin Inflow varies up and down by thousands of cfs while observed Chattahoochee River flow remains relatively stable. Thus, even when there are increased flows coming into Lake Seminole from the Flint River under low-flow conditions, there is no increased flow in the Apalachicola River corresponding to the change in inflow to Lake Seminole.

146. The same can be seen by reviewing Dr. Shanahan's data comparing observed Chattahoochee gage flow with inflow to Lake Seminole from the Flint River only. This is shown in Bedient Demo. 41, below.



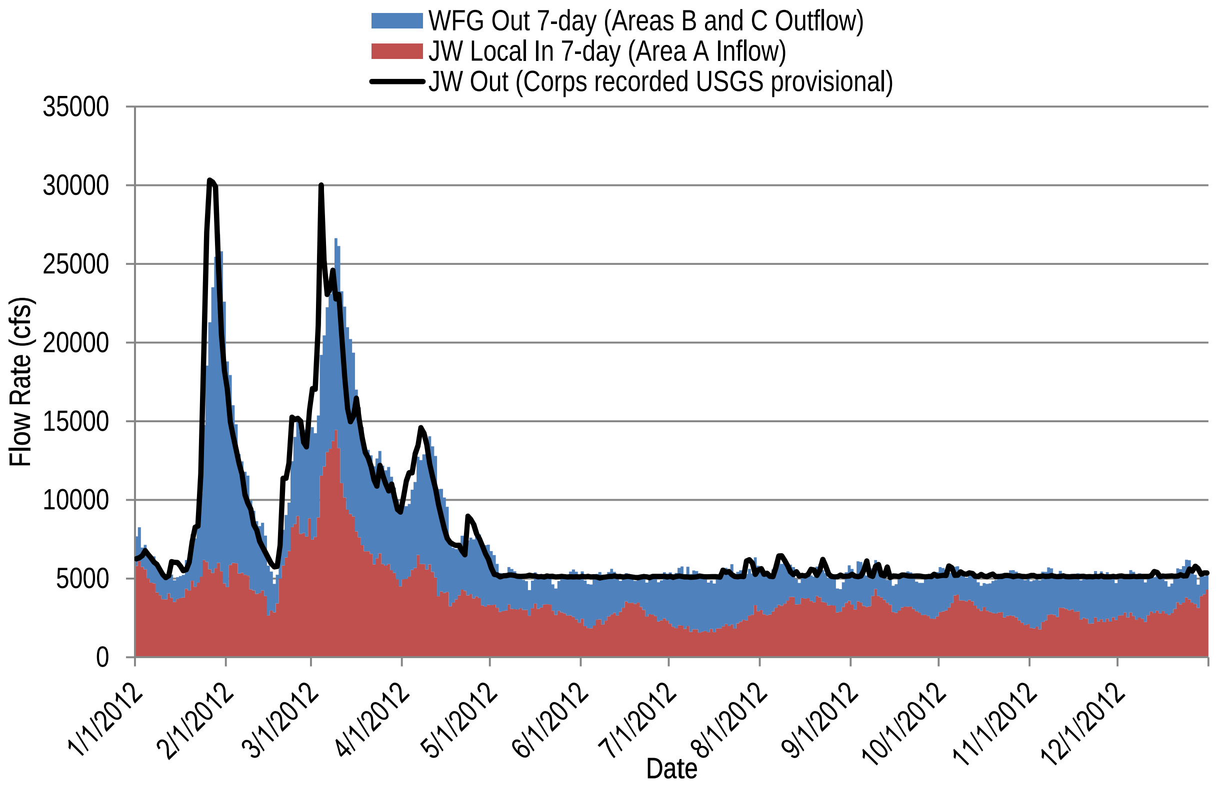
Bedient Demo. 41. Dr. Shanahan's Figure Shows No Relationship Between Woodruff Release and Inflow from the Flint River (Source: FX-794, at 34)

147. As shown in Bedient Demo. 41, inflow from the Flint River (orange line) can increase by thousands of cfs, and the observed Chattahoochee gage flow (blue line) remains relatively stable, especially under low-flow conditions. The yellow circles highlight where Flint River inflow increases by hundreds or thousands of cfs and there is no corresponding change (or any change at all) in flow in the Apalachicola River. Therefore, Dr. Shanahan's own figures prove that increases in Basin Inflow, increases in inflow to Lake Seminole, or increases in inflow from the Flint River do not simply translate into more flow into Florida.

II. Dr. Shanahan Fails to Properly Evaluate the Corps' Offset of Flint River Flows Under the RIOP or Under Low-Flow Conditions

148. Dr. Shanahan concludes that "flows on the Flint River are well correlated with releases from Lake Seminole," and thus that no offset would occur. Shanahan Written Direct ¶ 37. Dr. Shanahan's analysis is flawed for two reasons. First, his analysis includes both dry times and wetter times when the lower reservoirs are overwhelmed by inflow and water is relatively plentiful. Including high flows will generally show inflow correlated with outflow more often. Instead, the relevant question is whether inflows from the Flint River correlate with outflows from Woodruff Dam during low-flow or dry periods. Dr. Shanahan's focus on the period 1980-2012 involves looking at 28 years of data when the RIOP was not in place and only 4 years of data when the RIOP was in place (including the 2008 RIOP). It is meaningless to evaluate the offset under pre-RIOP reservoir rules, which are significantly different to the current RIOP rules.

149. The historical data contradicts Dr. Shanahan. Bedient Demo. 42 is a true and accurate representation of inflows and outflows to the ACF reservoir system, including local inflows to and outflows from Woodruff Dam and outflows from Walter F. George. The black line represents the Corps' recorded releases from Woodruff Dam in 2012, according to the Corps project data. The red bars represent daily local inflow to Lake Seminole in 2012. This is the same thing as what Dr. Shanahan refers to as inflow from "Area A." The blue bars represent daily outflow from Walter F. George in 2012, representing all outflow from Dr. Shanahan's "Areas B and C." Dr. Shanahan's opinion is that flows from "Area A" would not be offset by flows from "Areas B and C."



Bedient Demo. 42. Corps Releases Showing Offset of "Area A" with "Areas B and C" (GX-143)

150. Bedient Demo. 42 confirms that increased inflow from the Flint River is, in fact, offset by decreased releases from the reservoirs on the Chattahoochee River under low-flow conditions and RIOP operations. This historical data shows that the Corps releases just enough from Walter F. George (representing the combined release from all of the reservoirs on the Chattahoochee River) to satisfy the 5,000 cfs to flow across the state line. As Bedient Demo. 42 shows, inflow from Area A (red) can increase or decrease by hundreds or even thousands of cfs, while at the same time, the sum of the red and blue (total amount of water flowing into Florida) remains relatively stable around 5,000 cfs. As a result of this offsetting, increased inflows from the Flint River (Area A) will not automatically lead to increases in state-line flow into Florida, but instead would generally be offset by Areas B and C.

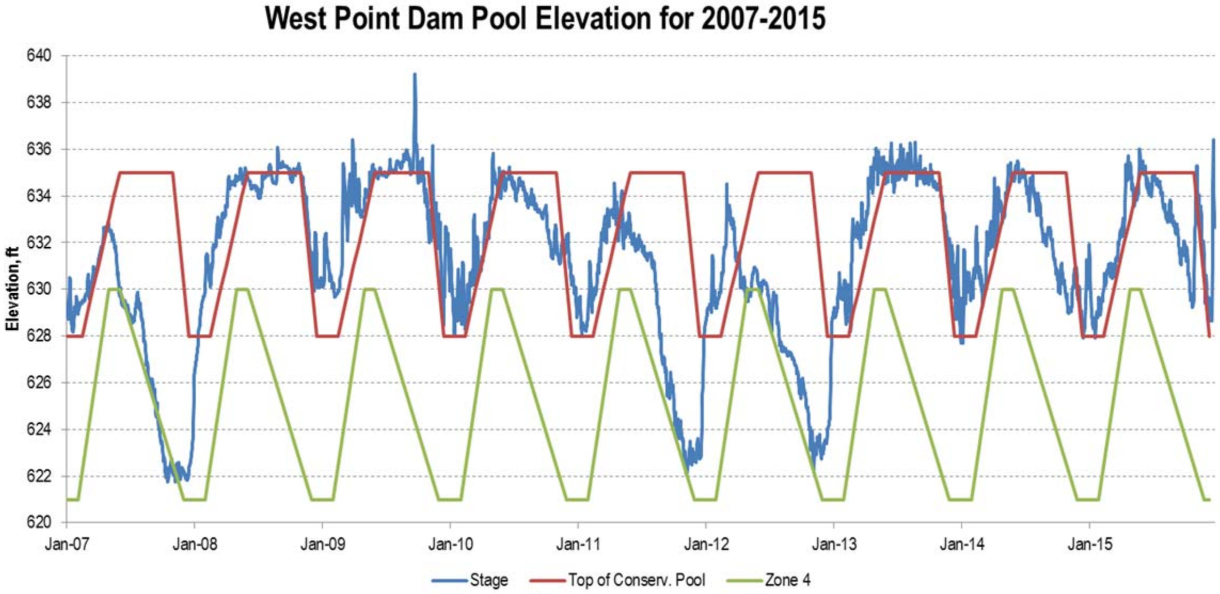
III. Dr. Shanahan Focuses Exclusively on Lake Lanier, Ignoring One-Third of All Storage; West Point and Walter F. George Are Not "Pass Through" Reservoirs

151. Dr. Shanahan offers the opinion that "it is a physical impossibility to offset or trade significant quantities of water conserved in Area A for additional water stored in Lake

Lanier (*i.e.*, Area C)." Shanahan Written Direct ¶ 8.c. He also offers the opinion that "the Corps would have little or no reason to respond and try to offset this by releasing less from the Area B reservoirs" (*i.e.*, West Point and Walter F. George). *Id.* ¶ 8.b. As shown by the above Bedient Demo. 42, the offset occurs for increases of multiple thousands of cfs.

152. Dr. Shanahan's analysis is also flawed because it focuses entirely on the conservation capacity of Lake Lanier and ignores West Point and Walter F. George, the other two major storage reservoirs in the ACF Basin. Dr. Shanahan incorrectly suggests that West Point and Walter F. George are operated "largely in pass through mode," *i.e.*, there is no increase or decrease in conservation storage. He also concludes that annual local inflows to both lakes "greatly exceed each reservoir's conservation-storage capacity" and therefore there would be "little or no reason" for the Corps to offset Flint River flows using storage in West Point or Walter F. George. Dr. Shanahan's conclusions are refuted by review of basic reservoir storage data.

153. Bedient Demo. 43, below, is a true and accurate copy of a demonstrative I prepared showing historical reservoir storage levels in West Point for January 2007-October 2015. The blue line shows the actual lake level in West Point. The red line shows the top of conservation storage (*i.e.*, the desired pool elevation). The yellow line shows the top of Zone 4, where if reservoirs dip below that zone the Corps enters Drought Operations. The red curve shows that the desired reservoir elevation is highest in the summer (peaks) and lowest in the winter (valleys).



Bedient Demo. 43. West Point Storage Levels (2007-Present)

154. As shown in Bedient Demo. 43, West Point Lake is not operated in "pass through" mode. There is a considerable amount of variability in the storage level of the lake (represented by the blue line) over the years, including during dry years. The variability indicates that the reservoir is not operated in "pass through" mode.

155. The figure also indicates that the reservoir levels are declining solely because reservoir storage is being used to satisfy downstream project purposes. Contrary to Dr. Shanahan's suggestion that lake levels are drawn down in every summer or fall, this figure shows that lake levels do not decline in some wetter years at all (*e.g.*, 2008, 2009, 2013). This is because in wetter years, it is not necessary to release water from the reservoirs to satisfy downstream purposes. The declines in dry years (*e.g.*, 2007, 2011, 2012) occur because the Corps *has* to release flows to meet project purposes, not because the Corps *wants* to release flows or has a *policy* to release flows during those times.

156. When West Point levels are low, that means that there is not much available storage left in the lake to help meet downstream needs, thus putting more pressure on upstream reservoirs (*e.g.*, Lake Lanier) to provide such flow augmentation. Lake Lanier is more difficult to refill, so the Corps does not have any incentive to empty West Point or Walter F. George in

order to rely on Lake Lanier. Instead, they replenish the lower reservoirs wherever possible so they do not have to draw down Lake Lanier. The Corps has stated this strategy:

> [T]he strategy of operating the projects also calls for water to be taken first from storage *in the lower lakes on the system* and gradually pulling water from the upper lakes over time. Thus, *Walter F. George*, which contains most of the storage on the lower system because Lake Seminole does not have much storage, *will be the first lake to be affected by operations on the system during periods of low water*. If conditions remain dry, *water will also be pulled from West Point Lake* and eventually Lake Lanier.[14]

157. Bedient Demo. 43 also shows that West Point Lake levels not only fall during dry years they also fail to rebound, or refill, quickly during those times. In some years (*e.g.*, 2007, 2011, 2012), the lake fails entirely to recover to full reservoir storage. This clearly indicates that inflows are not "exceeding the capacity" of the reservoir, as stated by Dr. Shanahan. The significant drop in lake levels during dry years shows that during dry times, there is not enough inflow to make up for the outflow. The decline in storage during dry months also shows the considerable capacity of storage available for offsetting of flows. The amount of reservoir storage available is represented by the area between the blue line (actual storage level) and the red line (top of conservation pool, where the reservoir would be considered "full"). Thus, Dr. Shanahan is incorrect to the extent he is suggesting that the reservoir inflow capacity exceeds storage capacity, or that there is no storage available in West Point Lake or Walter F. George. Dr. Shanahan points to *annual* average inflows, which fails to speak to inflows and outflows in the reservoir during *dry* months, during which inflows are clearly insufficient.

158. Furthermore, Dr. Shanahan acknowledges that even under his own analysis, Lake Lanier alone can be used to offset, or trade, up to 341 cfs of water (annual average) under conditions similar to the 12 driest years since 1980. As a comparison, Dr. Sunding's 1,000 cfs "conservation scenario" contemplates increase of flows by 438 cfs in annual average amounts. This means that even under Dr. Shanahan's view of how the reservoirs operate, Lake Lanier alone could offset 78% of any increase in flows in the Flint River under Dr. Sunding's 438 cfs annual-average increase. This is based on only one-third of reservoir storage. If Dr. Shanahan

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[14] JX-113.

had considered West Point or Walter F. George, his analysis likely would have shown even greater capacity to offset.

IV. The Corps Does Not Deliberately Drain Its Reservoirs at Any Time, Much Less During Low-Flow or Drought Conditions

159. Contrary to Dr. Shanahan's suggestion, the Corps has a stated policy of keeping the reservoirs as full as possible during the low-flow season and only making releases as necessary to satisfy project purposes. For instance, the Corps writes:

> USACE operates the reservoirs in the ACF Basin as a system, keeping the drawdown levels and rates balanced among the reservoirs. USACE gives those considerations greater attention during the primary recreation season of May through early September. *Reservoirs are managed to maintain a steady pool at as high a level as possible, consistent with other authorized purposes, particularly during [May-September].* To sustain reasonable access to the reservoir during periods of declining inflows to the reservoirs, drawdowns are performed at as steady a rate as possible. *There may be times during drought conditions when water releases are reduced to levels that satisfy only downstream water supply/water quality requirements.* This conservation of storage generally allows the pools to be maintained at a higher level throughout [May-September]."[15]

160. The releases of water during the summer and fall do not indicate a preference or desire to draw down reservoir levels. Instead, it is a result of using these reservoirs to release water, *when necessary*, to meet project purposes (*e.g.*, minimum flows in the Apalachicola River). Ideally, the Corps would keep its reservoirs as full as possible so long as there was enough water to achieve all project purposes.

V. The Corps Does Not Deliberately Make Releases in Excess of 5,000 cfs from Woodruff Dam to Support Only a Single Downstream Project Purpose at the Expense of All Others

161. Dr. Shanahan opines that "the Corps routinely releases more water—often significantly more water—than the minimum set by the RIOP" (Shanahan Written Direct ¶ 57). Dr. Shanahan reasons that because the USGS's official flow records show discharge levels in excess of 5,000 cfs, the Corps must be exercising its "discretion" to deliberately release more water into the Apalachicola River than the RIOP's minimum. In fact, this is not the case. Dr. Shanahan is relying on the wrong data for determining the Corps' intended releases from

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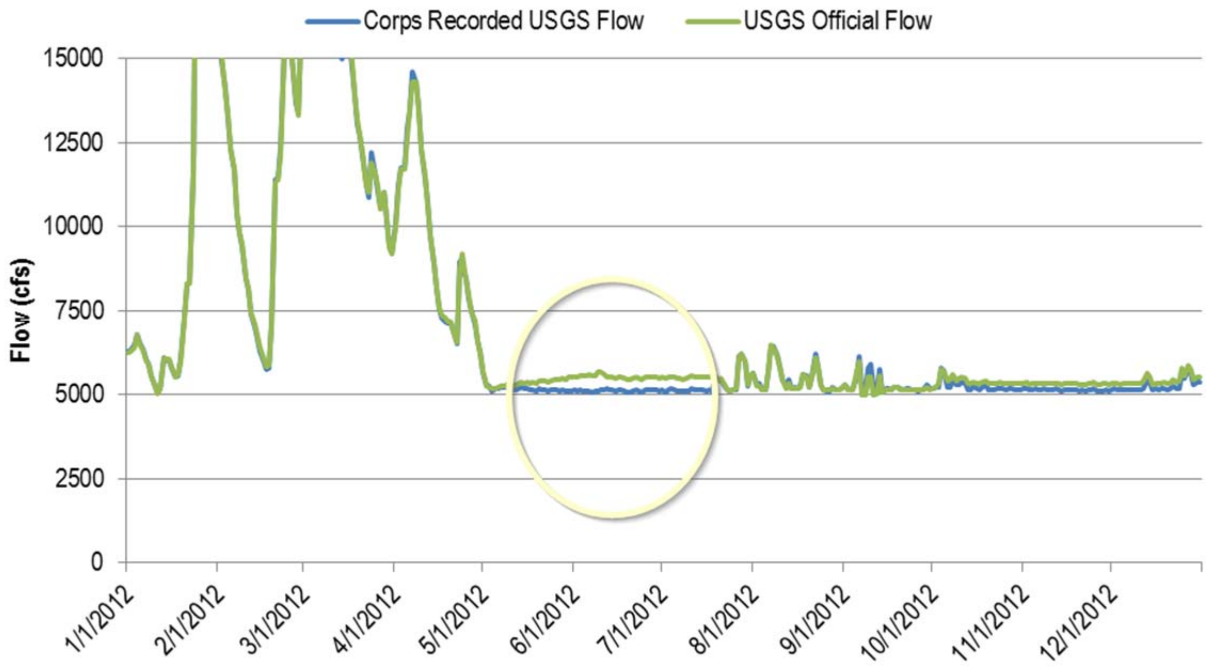
[15] JX-124 at 2-74/75 (emphases added).

Woodruff Dam. These intended releases are reflected in the Corps' daily recorded releases from Woodruff Dam. The USGS final flow data is adjusted after-the-fact to determine the final discharge level, and at times can be hundreds of cfs higher than the provisional data available at the time the Corps makes its release decision.

162. Bedient Demo. 44 is a true and accurate copy of a demonstrative I prepared showing the difference between the USGS official flow records and the Corps recorded releases can be significant.



Bedient Demo. 44. USGS Final Flow Data (Green) vs. Corps Recorded Release (Blue) (GX-143; JX-128)

163. As shown in Bedient Demo. 44, the final, adjusted USGS discharge data show significantly higher flow rates throughout much of the year. The Corps' recorded releases are far closer to 5,000 cfs during the dry summer and fall months. The yellow circle highlights a difference of several hundred cfs between the two datasets. The USGS final data shows releases of approximately 5,500 cfs, whereas the Corps' recorded releases are approximately 5,000 cfs. Dr. Shanahan incorrectly relies on the USGS discharge data to conclude that the Corps uses its "discretion" to release more than the minimum, without taking into account what each of the datasets represents.

164. The only exception to the Corps' recorded releases of 5,000 cfs in 2012 occur in the late summer and fall, during which there are multiple short-term "spikes" in flows above 5,000 cfs. I have previously testified that these are the result of local rainfall events, not the Corps' exercise of "discretion" to release flows above 5,000 cfs. I have compared the below "spikes" to local rainfall events, and confirmed that this is true.

Date	USGS Chattahoochee Flow (cfs)	Rainfall (in)	
		Columbia Gage[16]	Bainbridge Gage[17]
07/28/12	6,190	0.5	2.4
08/07/12	6,490	1.5	2.4
08/22/12	6,090	0.4	0.9
09/06/12	5,960	3	1.1

Bedient Demo. 45. Local Rainfall Events Near the Chattahoochee Gage in 2012

165. Bedient Demo. 45 shows precipitation data for four instances of flows in excess of 5,000 cfs in the late summer and fall of 2012. This shows that each of these "spikes" is associated with a significant rainfall event in which the inflow to the reservoir compelled additional releases to ensure safe dam operations under the Maximum Head Differential rule of the RIOP. I determined this based on reviewing USGS rainfall data for the Columbia gage (just upstream of Lake Seminole on the Chattahoochee River) and the Bainbridge gage (just upstream of Lake Seminole on the Flint River), which are regularly used and relied upon by experts in my field, as well as reviewing the Corps' rules for releases necessary for reducing the head differential at Woodruff Dam (JX-124, Appendix A, at E-C-3).

166. Dr. Shanahan does not cite to any Corps document for the proposition that the Corps uses its "discretion" to make releases over 5,000 cfs, nor does he identify any specific releases over 5,000 cfs that he believes are the result of the Corps' use of "discretion." I do not find any support for Dr. Shanahan's interpretation of Corps "discretion" in the data or in the Corps' own documents. In fact, I find substantial evidence contradicting Dr. Shanahan's opinion. Dr. Shanahan's opinion essentially is that the Corps deliberately releases more than the

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[16] USGS 02343801 CHATTAHOOCHEE RIVER NEAR COLUMBIA, AL, http://nwis.waterdata.usgs.gov/ga/nwis/uv?cb_00045=on&format=gif_default&site_no=02343801.

[17] USGS 02356000 FLINT RIVER AT BAINBRIDGE, GA, http://nwis.waterdata.usgs.gov/ga/nwis/uv/?cb_00045=on&format=gif_default&site_no=02356000.

RIOP's 5,000 cfs minimum flow in order to favor one project purpose (downstream fish and wildlife) at the expense of all the others. Such an operation would be contrary to the Corps' purpose of operating the reservoirs in balance for all project purposes and to support these purposes equally:

> "[T]he federal projects in the ACF Basin are operated as a system rather than as a series of individual, independent projects. *The balancing of water control operations to meet each of these purposes* varies between the individual projects and time of year."[18]
>
> "The reservoir projects are operated in a balanced manner within the system to support all authorized project purposes within the ACF system to the extent practicable."[19]

167. Based on the premise that this "discretion" exists, Dr. Shanahan claims that ResSim is "imperfect" because it cannot model this "discretion." Shanahan Written Direct ¶ 57. This is a faulty premise, because the Corps use of "discretion" as described by Dr. Shanahan is not supported by the data. I agree that ResSim is not "perfect" and cannot model "discretion," but no reservoir model is perfect or can model discretion, as opposed to rules. This does not minimize the value of ResSim, nor does it speak to the lack of complexity of the ResSim model. As I have discussed at length above, ResSim is an exceptional representation of the Corps' *actual* operations, in part because it is governed by the same set of rules that govern the actual operations. As a result, there is a remarkable consistency between the rules, the operations, and ResSim.

168. Mr. Barton, Florida's other expert in reservoir operations, testified to the robustness and reliability of ResSim. He described ResSim as "widely used," "very dependable," "reliable," and "state of the art." Barton Tr. 130:5-134:23. Mr. Barton testified that he was not aware of any other model that better represents the ACF reservoir operations, and that "everyone agreed that the model was very much acceptable for use on the ACF system." *Id.* 133:19-134:3, 134:24-135:2. I agree with Mr. Barton (and with the Corps) that the ResSim, while not perfect, is the best available model for simulating the ACF reservoir system.

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[18] JX-124, at 2-62 (emphasis added).

[19] JX-113, at 3.

RESPONSES TO FLORIDA OPINIONS ON THE IMPACT OF INCREASES OR DECREASES IN GEORGIA'S WATER USE ON STATE-LINE FLOWS

169. I have reviewed Dr. George Hornberger's testimony and computer modeling associated with his "data driven" ResSim and the "Lake Seminole" models,[20] and I have reached the following opinions:

- Dr. Hornberger's modeling results using his "data driven" ResSim model, which are not reported, are consistent with mine, *i.e.*, they show that even significant hypothetical reductions in Georgia's water use (50% reduction in agricultural consumptive use in the Flint River Basin) would generate minimal, if any, increase in state-line flow during dry months, including months of zero change.
- Dr. Hornberger's "Lake Seminole" model, which is engineered to show that all increased flows on the Flint River will necessarily pass through a single run-of-river reservoir to Florida, is a flawed model based on a programed result. The "Lake Seminole" model contains numerous flaws that render it fundamentally unsuitable inappropriate for modeling the complex, integrated operations of the ACF reservoir system.

I. Dr. Hornberger's Unreported "Data Driven ResSim" Modeling Results Are Consistent with My ResSim Modeling

170. Dr. Hornberger conducted analysis using his "data driven" ResSim model to evaluate the impact of both projected future increases and hypothetical decreases in Georgia's water use on state-line flow. Dr. Hornberger's "data driven" ResSim model is simply a modified version of the Corps' ResSim model.[21]

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[20] Florida recently provided additional analysis conducted by Dr. Hornberger on October 14, and new materials he relied upon in support of this analysis as recently as October 23. Given the limited time I have had to review this new analysis and materials, I reserve my right to supplement or modify my testimony related to this topic after I have had more time to review.

[21] Dr. Hornberger's modifications to the ResSim model primarily involved replacing the inputs, which do not affect how the model operates, though it will affect the magnitude of the inflows and outflows to the model.

A. “Data Driven ResSim” 2050 Scenario

171. For Dr. Hornberger’s 2050 scenario, the estimated additional withdrawals due to Georgia’s projected future increased water use for the year 2050 were inputted to his “data driven” ResSim model on an average monthly basis. Dr. Hornberger then studied the impact of these reduced inflows to the reservoir system under hydrologic conditions similar to the nine dry years since 2000 (2000, 2001, 2002, 2006, 2007, 2008, 2010, 2011, 2012). The reduced inflows to the river system for the 2050 scenario averaged as high as about 1,500 cfs for the June-September period of those years. In other words, over that four-month period, an average of about 1,500 cfs less water was entering the Corps’ reservoir system in the ACF Basin under Dr. Hornberger’s projected 2050 scenario.

172. Despite this substantial reduction in the inflows to the Corps’ reservoir system, Dr. Hornberger’s “data driven” ResSim model often showed no change in state-line flow for entire months, especially during dry years. For example, Dr. Hornberger’s “data driven” ResSim model showed that under the 2050 scenario, the change (decrease) in flow at the Chattahoochee gage would be:

- 0 cfs for June, July, and October 2000;
- 4 cfs for February 2002;
- 0 cfs for June, July, and August 2002;
- 0 cfs for June, October, and November 2007;
- 1 cfs for June 2011; and
- 0 cfs for May and June 2012.[22]

173. This finding is consistent with my modeling analysis of projected 2040 levels of basin-wide water demands using ResSim, which likewise showed limited impact on state-line flows during low-flow months as a result of the reservoir operations of the Corps in “smoothing out” the seasonal variations in streamflow.

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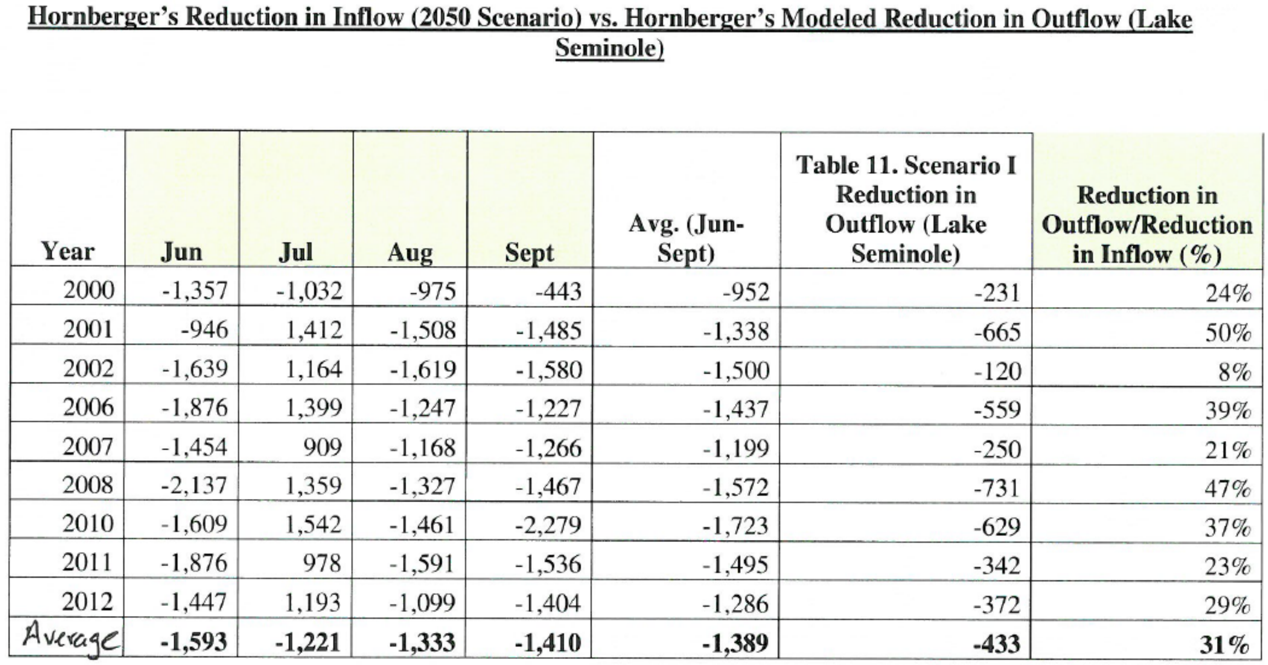
[22] FX-785, at 74-78.

174. For other low-flow months, Dr. Hornberger's "data driven" ResSim model showed that the decreases in state-line flow as a result of the 2050 increases would be less than half of the amount by which streamflow was reduced in Georgia. In other words, for an average reduction of 1,500 cfs in the Chattahoochee and Flint Rivers in June-September, streamflow into Florida would be reduced *by no more than* 731 cfs. Further, for an average reduction of 1,500 cfs in Georgia during June-September, streamflow into Florida was reduced *by as little as* 120 cfs, or less than 10%.

175. The results of Dr. Hornberger's "data driven" ResSim modeling for the 2050 scenario are shown in Bedient Demo. 46, below. The table shows the reduction in *inflow* to the reservoir system for the June-September period of the nine dry years since 2000 (under 2050 water demand levels), as well as the reduction in *outflow* from Woodruff Dam (i.e., state-line flow) resulting from that reduced inflow to the system. Then, the table shows the percentage of outflow over inflow.



Hornberger's Reduction in Inflow (2050 Scenario) vs. Hornberger's Modeled Reduction in Outflow (Lake Seminole)

Year	Jun	Jul	Aug	Sept	Avg. (Jun-Sept)	Table 11. Scenario I Reduction in Outflow (Lake Seminole)	Reduction in Outflow/Reduction in Inflow (%)
2000	-1,357	-1,032	-975	-443	-952	-231	24%
2001	-946	1,412	-1,508	-1,485	-1,338	-665	50%
2002	-1,639	1,164	-1,619	-1,580	-1,500	-120	8%
2006	-1,876	1,399	-1,247	-1,227	-1,437	-559	39%
2007	-1,454	909	-1,168	-1,266	-1,199	-250	21%
2008	-2,137	1,359	-1,327	-1,467	-1,572	-731	47%
2010	-1,609	1,542	-1,461	-2,279	-1,723	-629	37%
2011	-1,876	978	-1,591	-1,536	-1,495	-342	23%
2012	-1,447	1,193	-1,099	-1,404	-1,286	-372	29%
Average	**-1,593**	**-1,221**	**-1,333**	**-1,410**	**-1,389**	**-433**	**31%**

Bedient Demo. 46. "Data Driven ResSim" Inflow vs. Outflow Under 2050 Scenario

176. As shown in Bedient Demo. 46, Dr. Hornberger's "data driven" ResSim modeling results for the 2050 scenario show that for the nine dry years since 2000, the average reduction in state-line flow for the June-September period was only 31% of the average reduction in streamflow in Georgia's rivers over that time period. In other words, even though reducing

Georgia's water use would lead to an average reduction in streamflow in Georgia's rivers of 1,389 cfs, this would only translate to a decrease in state-line flow into Florida of 433 cfs. Thus, only 31% of the reduced flow in Georgia actually materialized as reduced flow into Florida during these months.

B. "Data Driven ResSim" Consumption Cap Scenario

177. Dr. Hornberger also used his "data driven" ResSim model to evaluate the impact of proposed *decreases* in Georgia's water use on state-line flows. This modeling analysis evaluates the effect of hypothetical consumption caps.

178. Dr. Hornberger's modeling results show that for multiple months of dry or drought years, even significant reductions in Georgia's water use would lead to no change in state-line flow. For instance, Dr. Hornberger's "data-driven ResSim" model shows that a hypothetical reduction of 50% in Georgia's agricultural water use in the Flint River Basin would produce an increase of 0 cfs in state-line flows in multiple months of dry years, including:

- 0 cfs for most of June and July 2000;
- 0 cfs for May 24 through June 19, 2007;
- 0 cfs for all of August 2007;
- 0 cfs for all of July 2012; and
- 0 cfs for all of November 2012.[23]

179. In other words, even if Georgia reduced its water use in the Flint River Basin by 50%, Dr. Hornberger found that these reductions would not generate any additional streamflow into Florida during conditions similar to each of these months. Dr. Hornberger did not report these results in his expert report. Instead, I located these model results in Dr. Hornberger's "data driven" ResSim modeling files produced to Georgia.

180. These results similarly confirm my analysis that the Corps reservoirs are operated to offset increased flows from the Flint River by releasing less water from the upstream reservoirs on the Chattahoochee River.

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[23] Dr. Hornberger model run: "Gradient_USACE_OIF_02192016_HalfAgIBTAddBack."

II. Dr. Hornberger's "Lake Seminole" Model Is Fundamentally Flawed and Completely Fails to Represent the ACF Reservoir System

181. Dr. Hornberger relies on a newly created "Lake Seminole" model to opine that reductions in Georgia's water use would "significantly increase Apalachicola River flows."[24] Dr. Hornberger concludes that "[t]he Lake Seminole model confirms that virtually all of the water that Georgia conserves by implementing a remedy will become flow in the Apalachicola River in the summer it is conserved."[25]

182. The "Lake Seminole" model was created specifically for this litigation by a consulting firm working for Florida using a computer language called MATLAB. The "Lake Seminole" model is fundamentally different from ResSim. The "Lake Seminole" model does not include any of the upstream federal reservoirs on the Chattahoochee River. Instead, it represents only the most downstream federal reservoir, Lake Seminole, which is a pass-through facility. It is not a model of the entire reservoir system, like the Corps' ResSim or Dr. Hornberger's "data driven" ResSim models. The "Lake Seminole" model has never before been used by anyone—including Florida, Georgia, or the Corps—for analysis or modeling of the ACF reservoir system.

183. By attempting to rewrite the Corps' well-established ResSim model to conform to Dr. Shanahan's "view" of Corps reservoir operations, Dr. Hornberger and Florida introduced numerous important flaws into the "Lake Seminole" model. I note the following significant problems with the "Lake Seminole" model:

- The model fails to include the vast majority of the ACF reservoir system's storage capacity because it eliminates Lake Lanier, West Point, and Walter F. George (the only storage reservoirs in the system) and instead simulates only a single pass-through facility, Lake Seminole;
- The model cannot simulate *decreased* inflow to the reservoir, and instead is only suitable for simulating *increased* inflow to the reservoir;

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[25] Hornberger Written Direct ¶ 123.

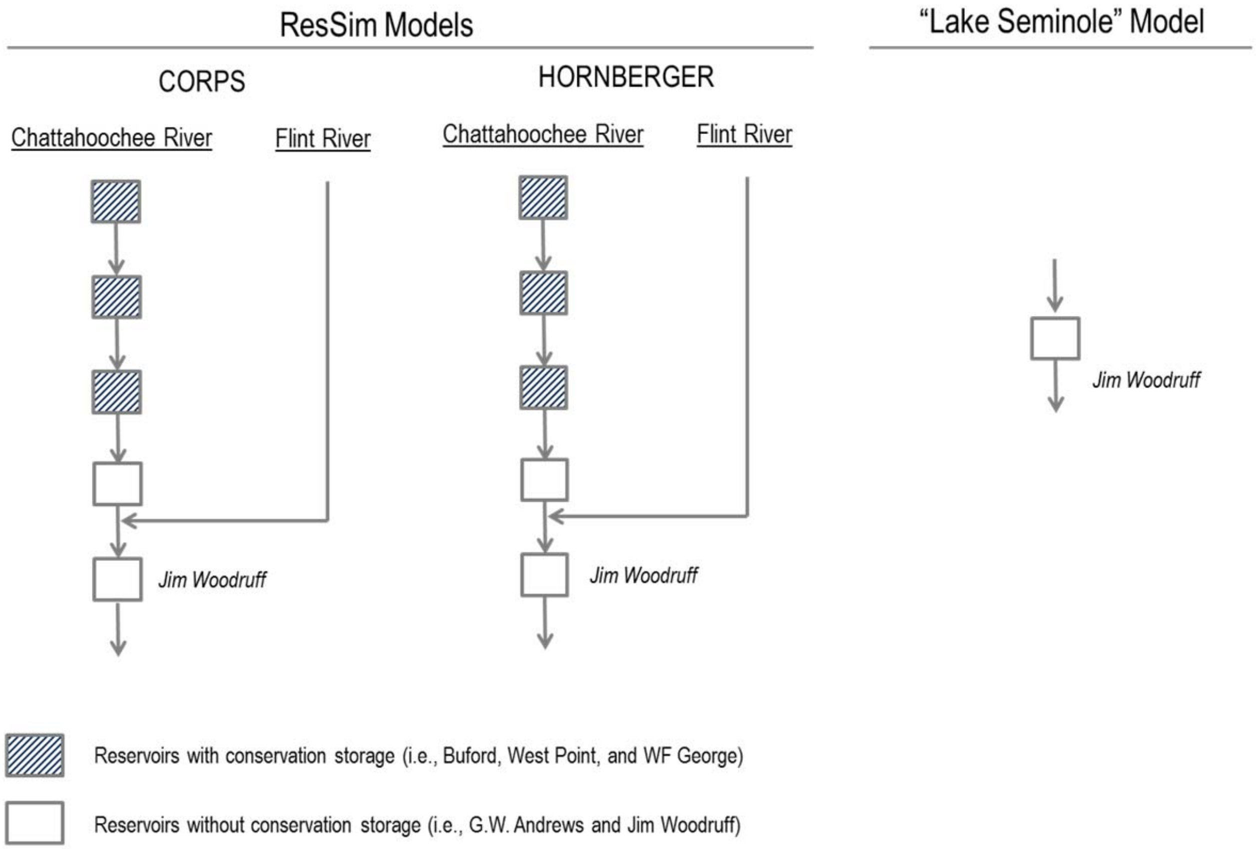
- The model violates the RIOP's rules for releases from Woodruff Dam, in part because the "Lake Seminole" model fails to properly incorporate the RIOP rules into the computer code that use Basin Inflow as a required input; and
- The model code violates the Law of Conservation of Mass, a fundamental principle of physics and engineering, because the model cannot balance inflows, outflows, and change in storage without creating or destroying water.

A. The "Lake Seminole" Model Ignores the Role of Reservoir Storage in the ACF System and Forces All Flows Through a Single "Pass-Through" Facility

184. The most fundamental flaw of the "Lake Seminole" model is that it completely fails to represent the Corps' complex, integrated operations of the ACF reservoir system. The "Lake Seminole" model includes only a single pass-through reservoir, Lake Seminole, and eliminates all of the other upstream Corps reservoirs in the ACF Basin. Three of those four upstream reservoirs—Lake Lanier, West Point, and Walter F. George—represent virtually all of the ACF reservoir system's composite conservation storage capacity, which is used to store and release water as needed to satisfy various federally authorized project purposes. In this sense, the model looks nothing like the Corps' ResSim model (or Dr. Hornberger's own "data-driven ResSim model).

185. By ignoring all upstream reservoirs and the Corps' adopted procedures for operating the reservoirs in tandem as a single, integrated system, the "Lake Seminole" model is mathematically engineered to force all increased flows from the Flint River to immediately pass through to Florida, regardless of how the Corps actually operates its reservoir system, including Lake Seminole. Essentially, the way Dr. Hornberger built his model guarantees that whatever additional inflows come into Lake Seminole (*e.g.*, from the Flint River) will pass through as additional outflow from Lake Seminole into Florida, with no ability for the Corps to operate its upstream reservoir system differently given these additional inflows coming into its system.

186. Bedient Demo. 47 is a true and accurate copy of a demonstrative I prepared showing a simple schematic showing the fundamentally flawed nature of the "Lake Seminole" model compared to the Corps' ResSim and Dr. Hornberger's "data driven" ResSim.



Bedient Demo. 47. Schematic of ResSim Models vs. Dr. Hornberger's "Lake Seminole" Model

187. As shown in Bedient Demo. 47, both of the ResSim models represent all five reservoirs in the ACF system, including the complex interactions and feedback between upstream and downstream reservoirs. The critical aspect of feedback between the reservoirs allows the model to represent the projects and their operations as a single, integrated system. The "Lake Seminole" model removes all of the upstream reservoirs from the calculation, and instead simulates inflow and outflow only for Lake Seminole only.

188. The "Lake Seminole" model does not allow for any increases in flows from the Flint River to be offset by increased storage on the Chattahoochee River. The model is engineered to force all increased flows from the Flint River to "pass through" the reservoir into the Apalachicola River. Under the ResSim models, by contrast, there is a feedback between upstream and downstream reservoirs that allows the reservoirs to "communicate" with one another and operate as a single, integrated system. This is how the Corps actually operates its reservoirs in the ACF Basin.

B. The "Lake Seminole" Model Is Incapable of Simulating Decreased Inflow, as Opposed to Increased Inflow, to Lake Seminole

189. Dr. Hornberger and Florida have described the "Lake Seminole" model as being incapable of modeling any scenario involving decreased inflows to Lake Seminole, such as under a scenario involving projected increases in Georgia's water use. Instead, they claim the model is only suitable for modeling a single scenario—increased inflows to Lake Seminole, such as under a consumption cap on Georgia.

190. In fact, the "Lake Seminole" model simulates decreased inflows to the reservoir system so poorly that the model crashed when attempting to simulate increases in Georgia's water use to projected 2050 levels. In this modeling analysis involving decreased inflows to Lake Seminole, Dr. Hornberger's model allowed the reservoir to "run dry," *i.e.*, reach a state of zero reservoir storage. While Lake Seminole is literally empty, the model predicted that the reservoir would be simultaneously releasing over 200,000 cfs of water into Florida.[26] This absurd, impossible result is further proof that the "Lake Seminole" model is fundamentally flawed. Dr. Hornberger does not contest these problems with the "Lake Seminole" model, and admits that these model results are not faithful to the actual reservoir system in the ACF Basin.

191. These modeling results were not reported by Dr. Hornberger. I located these model runs during my evaluation of the modeling files produced to Georgia.

192. One of the reasons this model "crashed" is because it ignores the role of upstream reservoirs: the model simply cannot prevent Lake Seminole from running dry because the upstream reservoirs cannot modify its contribution of flows to help maintain storage levels. Any model that purports to be able to represent the reservoir system in the ACF Basin must be able to measure both increases and decreases in flows, like the Corps' ResSim model. The fact that the "Lake Seminole" model can only model one type of scenario—and that such a scenario can only produce one result—is further evidence that the "Lake Seminole" model lacks any credible scientific basis.

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[26] Hornberger Tr. at 792-93.

C. The “Lake Seminole” Model Does Not Properly Incorporate the RIOP’s Release Rules for Woodruff Dam

193. In addition to the “Lake Seminole” model’s inability to represent the entire reservoir system and its inability to represent scenarios of decreased, as opposed to increased, inflow to the reservoirs, the “Lake Seminole” model fails to represent the Corps’ reservoir operations in the ACF Basin for other reasons.

194. First, even though the RIOP provides that Woodruff Dam releases are made based on Basin Inflow, Dr. Hornberger admitted that Basin Inflow is not an input to his model. Instead, his model makes release decisions based simply on inflow to Lake Seminole, which has the result of causing outflow from Lake Seminole to be determined based on completely different rules from the RIOP.

195. Second, the “Lake Seminole” model generates releases from Woodruff Dam that violate the RIOP rules. For instance, the model predicts flows from Woodruff Dam below 5,000 cfs and 4,500 cfs, which are the absolute minimum flows permitted by the RIOP (under Drought Operations and EDO, respectively). Dr. Hornberger’s “Lake Seminole” model output for the 2050 scenario calculates outflow from Woodruff Dam as low as 3,753 cfs.

196. As a result of these problems, the “Lake Seminole” model shows inferior goodness of fit to both the USGS final flow data and the Corps’ recorded release data for the RIOP period under the available hydrologic record (June 2008-2011), as compared to ResSim. The results are shown in Bedient Demo. 47 below:

USGS Final Discharge for Chattahoochee Gage (June 2008-2011)

“Goodness of Fit” Metric	ResSim Results
NSE	0.959
PBIAS	0.314

Corps Recorded Release from Woodruff Dam (June 2008-2011)

“Goodness of Fit” Metric	ResSim Results
NSE	0.960
PBIAS	0.800

"Lake Seminole" Goodness of Fit (June 2008-2011)

"Goodness of Fit" Metric	"Lake Seminole" Results[27]
NSE	0.761
PBIAS	3.499

Bedient Demo. 48. ResSim vs. "Lake Seminole" Model "Goodness of Fit" Results

197. As shown in Bedient Demo. 48, ResSim's ability to reproduce the observed flow data, including both USGS final flow data and the Corps' recorded release from Woodruff Dam, is superior to the "Lake Seminole" model.

D. The "Lake Seminole" Model Violates the Law of Conservation of Mass

198. A primary principle in physics generally and in a reservoir operation simulation specifically is the Law of Conservation of Mass, which states that the mass of a system must remain constant over time. The Law implies that mass is neither created nor destroyed. All physically based models must be internally consistent in that they respect the fundamental principle of mass balance. The basic equation in a reservoir operation per the Law of Conservation of Mass is

Change in Storage = Inflow - Outflow

199. Essentially, this mass balance equation says that if more water comes into the reservoir than comes out, that amount of water must be equal to how much more storage goes into the reservoir. If not, then mass has been either created or destroyed, and no such result is possible. To illustrate this concept very simply, if 1,000 cfs of water enters a reservoir but 500 cfs of water exits, then the change of storage is +500 cfs (1,000 - 500 = 500). Similarly, if 1,000 cfs of water enters a reservoir but 1,500 cfs of water exists, then the change in storage is -500 cfs. All reliable reservoir models must respect this fundamental principle of mass balance.

200. Dr. Hornberger's "Lake Seminole" computed modeling results fail to respect this fundamental principle. When I compared Dr. Hornberger's MATLAB model results showing the "Lake Seminole" model's calculated change in storage and the difference between the inflow and computed outflow, I found great discrepancies between the two.

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[27] The "goodness of fit" results for the "Lake Seminole" model for the RIOP period use the data provided by Dr. Hornberger.

201. Bedient Demo. 49 presents these results and demonstrates the "Lake Seminole" models' violation of the Law of Conservation of Mass by showing that water is being destroyed within the system, in large part as a result of the flawed computer code for the model.

	Change of Storage (cfs-day)	Cumulative (Inflow – Outflow) (cfs-day)
Corps historical record Lake Seminole data	-14,959	-20,650
Hornberger Lake Seminole Modeling	-14,959	13,278,604

Bedient Demo. 49. Cumulative Mass Balance of Observed and Simulated Lake Seminole Reservoir

202. As Bedient Demo. 49 shows, the overall change in storage over the entire simulation period (January 1, 1976 through December 31, 2012) should be the same as the cumulative difference between inflow and outflow over the period (or very close, recognizing the possibility of occasional rogue data in the record). This is the case with the Corps data. The overall change in storage differs from the cumulative difference between inflow and outflow by less than 6,000 cfs-day, within the operational range of the reservoir storage. Note this is the cumulative difference over a period of 37 years, so this equates to less than one-half cfs per day. On the other hand, the cumulative difference between inflow and outflow in Dr. Hornberger's "Lake Seminole" modeling is more than 13 million cfs-day (or 26 million acre-feet), or about 983 cfs being lost constantly every day.

RESPONSES TO FLORIDA OPINIONS ON HYDROLOGY, CLIMATE, AND CONSUMPTIVE USE

203. I reviewed the analysis and opinions of both Dr. George Hornberger and Dr. Dennis Lettenmaier regarding the hydrology and hydrology-climate interactions of the ACF Basin, and I have reached the following opinions:

- Dr. Hornberger and Dr. Lettenmaier both offer opinions regarding the existence of long-term "shifts" or "trends" in basin hydrology and attribute those shifts largely to Georgia's consumptive use. Dr. Hornberger and Dr. Lettenmaier's focus on long-term "trends" ignores the role of natural climate variability in causing changes in streamflow, especially in recent significant droughts.

- Dr. Hornberger and Dr. Lettenmaier each use hydrologic models to "forecast" flows in the ACF Basin under "unimpacted" or "natural" conditions and attribute any differences between what was observed and what their models predict to "depletions" caused by manmade factors, primarily Georgia's water use. Both Dr. Hornberger and Dr. Lettenmaier's models cannot be used to reliably infer the impact of Georgia's water use because they contain inherent error, uncertainty, and bias.

I. Dr. Hornberger Has Not Identified Any "Fundamental Shift" in the Hydrology of the ACF Basin, Much Less One Attributable to Georgia's Consumptive Use

204. Dr. Hornberger erroneously concludes that there has been a "fundamental shift" in the hydrology of the ACF Basin on the basis of several discrete hydrologic indicators, including a comparison of recent droughts to pre-reservoir droughts, a perceived decline in runoff coefficient (which he terms "basin yield"), and the existence of low-flow days. But each of these pieces of evidence can be demonstrably linked with hydrologic conditions, whereas there is no evidence that Georgia's consumptive use caused these changes.

A. Dr. Hornberger Compares Recent and Pre-Reservoir Droughts Based on a Selective Use of Data

205. Dr. Hornberger compares the historic 1954 drought to the multi-year drought of 2011-2012, concluding that "[t]here was more rainfall in the 2011-2012 drought than in the 1954-1955 drought . . . [y]et flow on the Apalachicola River from Georgia was approximately 3,500 to 4,000 cfs lower in the modern drought. This decline in flow was clearly not caused by climate (rainfall was higher in the modern drought), and the only remaining interpretation is that these declines are caused by human water."[28] In fact, the specific data points selected by Dr. Hornberger are all explained by rainfall.

206. In Bedient Demo. 50 below, I present a true and accurate representation of precipitation data from NOAA Climate Divisions 2, 4, and 7 (representing the ACF Basin) and streamflow at the Chattahoochee gage for 1953-1954.

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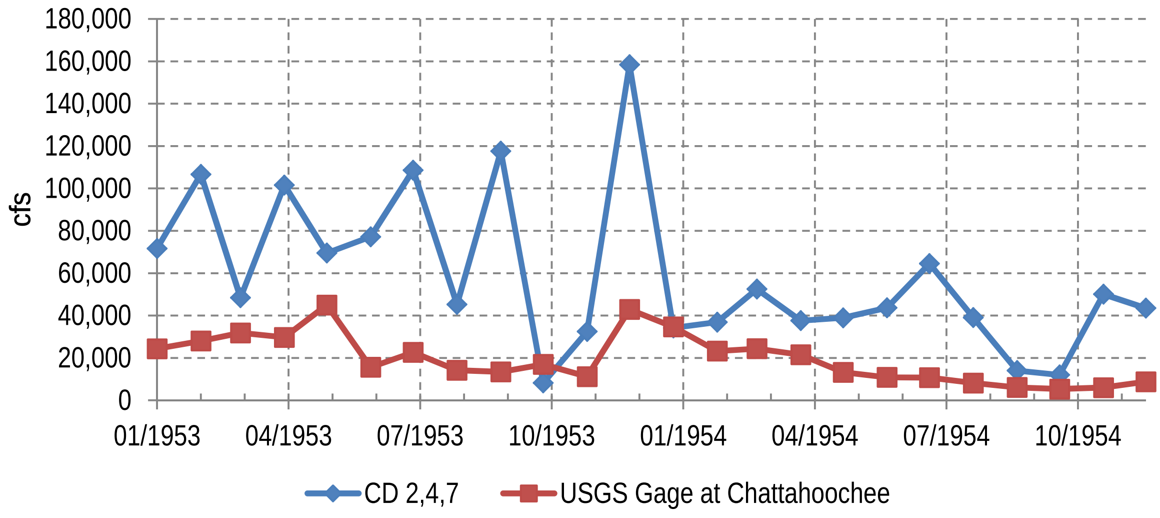
[28] Hornberger Written Direct ¶ 51.



Bedient Demo. 50. ACF Monthly Rainfall vs. State-Line Flow for 1953-1954

207. As shown in Bedient Demo. 50, while there was less rainfall in the calendar year of 1954, there was a significant amount of rainfall late in the preceding year, 1953. In fact, 1953 was a very wet year. For much of 1954, the rain was very low, but the flow was still relatively high as a result of the "carry-over" effect of the significant rainfall from the preceding calendar year. This can be seen in Bedient Demo. 50, which shows a significant "spike" in streamflow in November and December 1953, and a gradual decline over time after that. Dr. Hornberger's calculation of streamflow does not take into account 1953. Thus, the streamflow in 1954 is artificially inflated according to Dr. Hornberger's metric because he fails to account for the significant carry-over effect of rainfall on streamflow from the previous year.

208. In contrast to 1953, the year 2010 (the year before the 2011-2012 drought) was a normal, rather than wet, year. Thus, the antecedent hydrologic conditions for the two droughts identified by Dr. Hornberger are different. These antecedent conditions must be taken into account to conduct any fair comparison of the two periods. Dr. Hornberger's failure to account for antecedent conditions shows the inherently incomplete and misleading nature of cherry-picking data points from a single year.

B. Basin Yield Has Not Declined, Much Less as a Result of Georgia's Water Use; It Increased from 1971-1998, Until Recent Extreme Droughts

209. Dr. Hornberger's analysis of "basin yield" essentially says that for the same amount of rainfall today, there is less streamflow in the rivers of the ACF Basin compared to

earlier times. Dr. Hornberger concludes that Georgia's water use must be responsible for the observed decline in "basin yield." But basin yield has not actually declined over the long term; Dr. Hornberger's identified "trend" only exists because of the significant multi-year droughts in the latter part of the record (post-1998).

210. To illustrate the significant role of these multi-year droughts in biasing the "trends" identified by Dr. Hornberger, I plot basin yield values for the ACF Basin by breaking them up into sub-periods. My results are shown in Bedient Demo. 51 below. Bedient Demo. 51 below is a true and accurate copy of a demonstrative prepared using generally accepted scientific principles and methods showing the annual average basin yield at the state line.

Bedient Demo. 51. "Basin Yield" in Georgia's ACF Basin (1971-1998)[29]

Time Period	Annual Average (Basin Yield)
1924-1970	0.343
1971-1998	0.361
1999-2011	0.278

211. As Bedient Demo. 51 shows, there is no basin yield decline at all from the years 1971-1998, as compared to the pre-1971 period. In fact, over that time period, basin yield actually *i*ncreased relative to the prior period. It is only once the severe, multi-year droughts since 1999 are included does the overall "trend" from 1970 actually show a decline. This contradicts Dr. Hornberger's "declining trend" in basin yield since 1970. Furthermore, this is evidence of the significant influence of natural variability on flow conditions in the ACF Basin.

212. Furthermore, Dr. Hornberger ignores that low values of basin yield occurred in the years before 1970, and therefore are not indicators that recent low flows are attributable to increases in Georgia's consumptive use since 1970. For instance, the years 1935, 1941, and 1951 have much lower basin yield values, but these droughts are not referenced by Dr. Hornberger. These declines in basin yield are instead simply indicators of natural hydrologic

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[29] My analysis is based on Dr. Hornberger's "basin yield" values as disclosed prior to his submission of pre-filed testimony on October 14. It is apparent from Dr. Hornberger's testimony that he has changed his basin yield numbers from earlier versions. I reserve my right to supplement my testimony on the basis of Dr. Hornberger's newly disclosed basin yield numbers once I have the opportunity to review and assess these new calculations.

variability that occurs throughout the period of record, both before and after any influence of Georgia's consumptive use.

C. The Existence of Exceptional, Single-Year Low-Flow Events Under Extreme Drought Conditions Is Not Evidence of Georgia's Consumptive Use

213. Dr. Hornberger identifies 424 days of "zero flow" at the Iron City gage on Spring Creek "from 1980 to 2014" as evidence of hydrologic changes attributable to Georgia's water use since 1970. Dr. Hornberger acknowledges that 300 of those days, or 70%, occurred in only two years (the extreme drought years of 2007 and 2011). Once again, showing the overwhelming influence of the recent multi-year drought events, once these droughts are removed from the analysis, there is little difference between the pre-consumptive use and post-consumptive use periods. In Bedient Demo. 52 and Bedient Demo. 53 below, I present the total and average number of days below Dr. Hornberger's flow thresholds of 6,000 and 5,500 cfs at the Chattahoochee gage. I divide these into three periods: 1921-1970, 1971-1998, and 1971-2015 excluding multi-year droughts of 1999, 2001, 2006-2008, and 2011-2012.

Bedient Demo. 52. Total Days Below Flow Thresholds (Excluding Multi-Year Droughts) (JX-128)

	1921-1970	1971-1998	1971-2015 (excluding multi-year droughts)
< 6,000 cfs	249	154	246
< 5,500 cfs	122	85	125

Bedient Demo. 53. Annual Average Days Below Flow Thresholds (Excluding Multi-Year Droughts) (JX-128)

	1921-1970	1971-1998	1971-2015 (excluding multi-year droughts)
< 6,000 cfs	5.1	5.5	6.6
< 5,500 cfs	2.5	3.0	3.4

214. This analysis shows the significant role of the multi-year droughts in biasing the "trend" analysis put forward by Dr. Hornberger. Dr. Hornberger fails to account for any demonstrable impact of Georgia's consumptive use outside the specific drought years late in the record (since 1999), and he fails to show any "fundamental" impacts on hydrology outside of these extreme drought events or anywhere between the years 1970 and 1999.

II. Dr. Hornberger and Dr. Lettenmaier Ignore Significant Uncertainty, Error, and Bias in Their Rainfall-Runoff Models

215. To identify Georgia's past water use as the apparent "main cause" of the "fundamental shift," in Basin hydrology, Dr. Hornberger modified and re-calibrated the USGS's PRMS model of the ACF Basin for the pre-reservoir period (pre-1955) and "forecasted" what streamflow in the Basin "should have been" during the post-reservoir period (post-1955). Dr. Hornberger and Dr. Lettenmaier then compare those model-developed flows to observed flow records in the Basin, and conclude that the entire difference between what their models predict and what was observed (this difference is referred to by Dr. Hornberger and Dr. Lettenmaier as the "residual") is attributable to Georgia's water use.

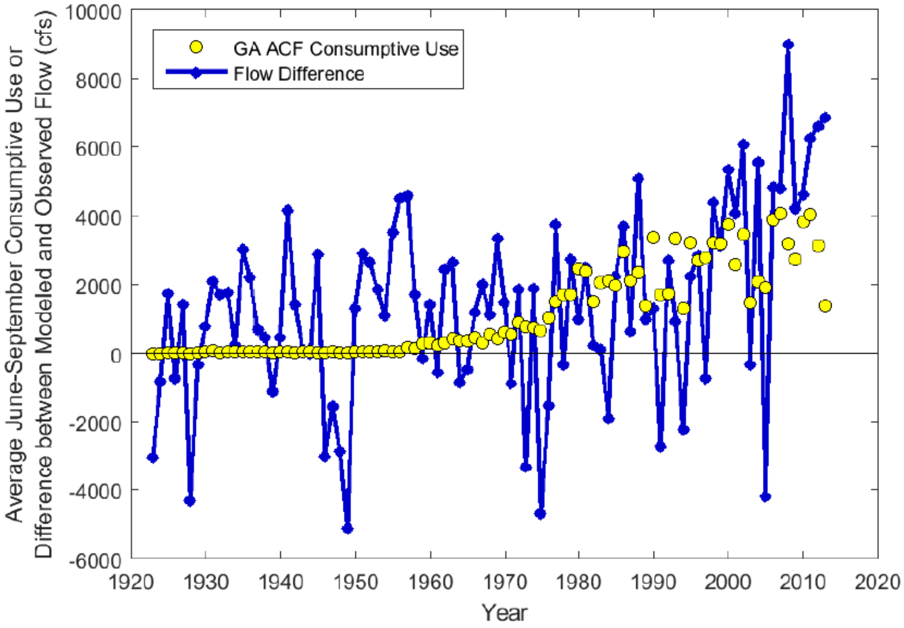
216. Dr. Hornberger's and Dr. Lettenmaier's approach based on the rainfall-runoff models is fraught with significant errors and uncertainties—none of which are quantified by Dr. Hornberger or Dr. Lettenmaier, even though each acknowledge such inherent error exists in their models. Collectively, the magnitude of these errors in their models can exceed the amount of water Dr. Hornberger and Dr. Lettenmaier erroneously attributes to Georgia's water use. Dr. Hornberger's and Dr. Lettenmaier's modeling analysis is also biased towards over-predicting low flows and under-predicting high flows so as to distort the erroneously claimed impact of Georgia's consumptive water use, especially during the low-flow months of recent drought years.

217. Neither Dr. Hornberger nor Dr. Lettenmaier conducted an uncertainty analysis to determine how much of the difference, or "residual," is from errors, uncertainty, or bias in their models as opposed to non-climate factors, such as Georgia's water use. This is a basic analytical step that must be conducted for any analysis to have any credibility or reliability given the way they are using these models. These significant errors, uncertainties, and biases render Florida's hydrologic modeling analysis invalid and unreliable. Dr. Hornberger and Dr. Lettenmaier cannot reach any reliable conclusions from their rainfall-runoff models when comparing to observed data.

A. There Is No Long-Term Trend in "Residuals"

218. At the outset, Dr. Hornberger and Dr. Lettenmaier each conclude that the "residual" has increased over time, and therefore the effect of Georgia's water use in causing

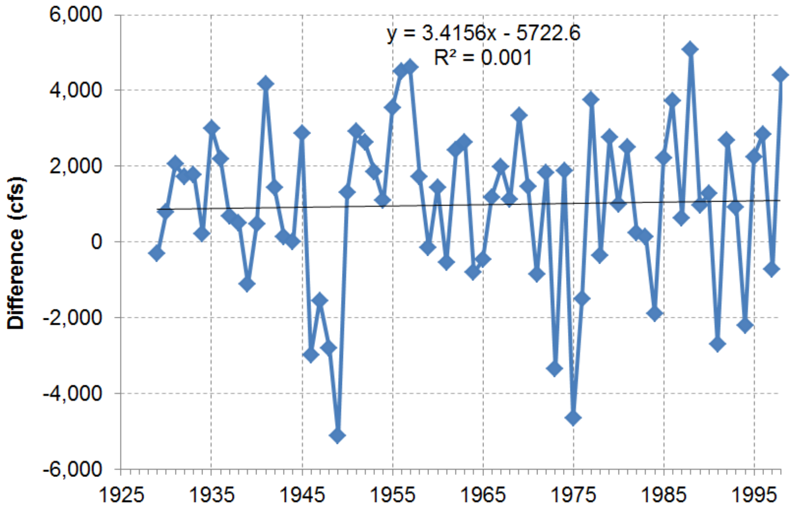
"streamflow depletions" has increased over time. The purported long-term "trend," however, is nonexistent. The increasing "trend" in residuals is depicted in Bedient Demo. 54 below (reproduced from Dr. Hornberger's May 20th expert report):



Bedient Demo. 54. Dr. Hornberger's "Residual" Attributed to Georgia's Water Use

219. Bedient Demo. 54 from Dr. Hornberger, shows that the "flow difference" (or residual) appears to be increasing over time, starting around 1970. Even though the residual is both positive and negative year by year, Dr. Hornberger concludes that there has been an overall increasing "trend" since 1970. Hornberger Written Direct ¶ 88. Dr. Hornberger suggests that this upward trend began around 1970 and is attributable to Georgia's consumptive use. *Id.*

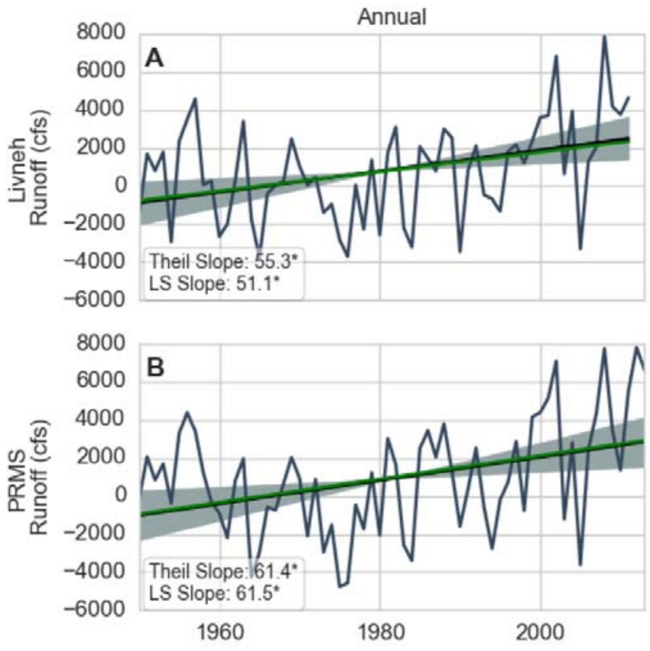
220. Contrary to the conclusions reached by Dr. Hornberger and Dr. Lettenmaier, there has not been an upward trend in "residuals" since 1970. Similar to the analysis of "basin yield," the "trend" in residuals is illusory and due entirely to the biasing effect of the years post-1998. When the last 15 years are removed, the upward "trend" in "residuals" identified by Drs. Hornberger and Lettenmaier disappears. Bedient Demo. 55, below, is a true and accurate copy of a demonstrative I prepared showing Dr. Hornberger's "residual" with the last 15 years removed:



Bedient Demo. 55. Dr. Hornberger's "Residual" Without Post-1999 Drought Periods

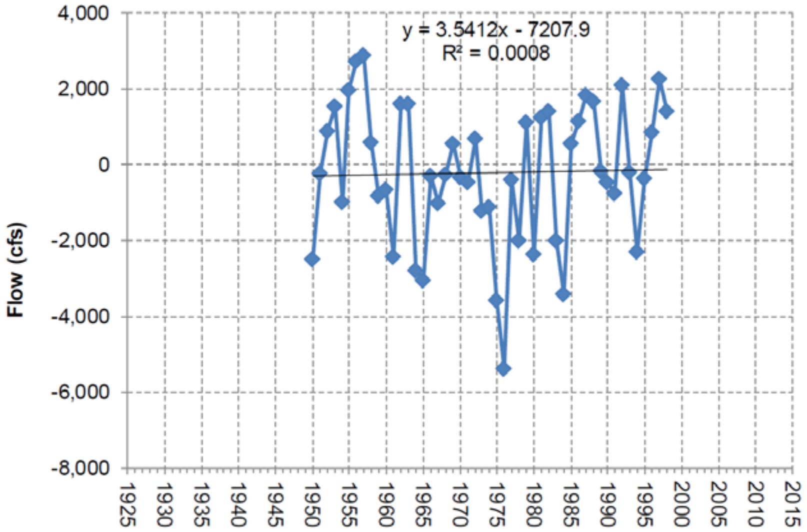
221. In Bedient Demo. 55, I re-plotted the same residual data as in Bedient Demo. 54, except I removed the years 1999-2013, and simply recalculated the trend. The upward "trend" that Dr. Hornberger attributes to Georgia's water use virtually disappears. This indicates that the upward "trend" in residuals in Bedient Demo. 54, which Dr. Hornberger attributes to increasing Georgia water use since 1970, is no trend at all until the years following 1999 are included, which are not correlated to Georgia's consumptive use.

222. The same lack of trend can be observed by evaluating Dr. Lettenmaier's "residuals" data. I reproduce Dr. Lettenmaier's residual data of annual averages for the period from 1950 to the present (see below Bedient Demo. 56, showing the apparent upward "trend" of approximately 3,800 cfs reproduced from Dr. Lettenmaier's Figure 5.1.9-1).



Bedient Demo. 56. Dr. Lettenmaier's "Residual" Since 1950

223. In Bedient Demo. 57, is a true and accurate copy of a demonstrative in which I re-plot Dr. Lettenmaier's residual data for the PRMS model by removing the last 15 years, using generally accepted scientific methods and principles. After removing the last 15 years, Dr. Lettenmaier's upward "trend" is eliminated, and there is a fairly flat trend line (of no more than a few hundred cfs, if any).



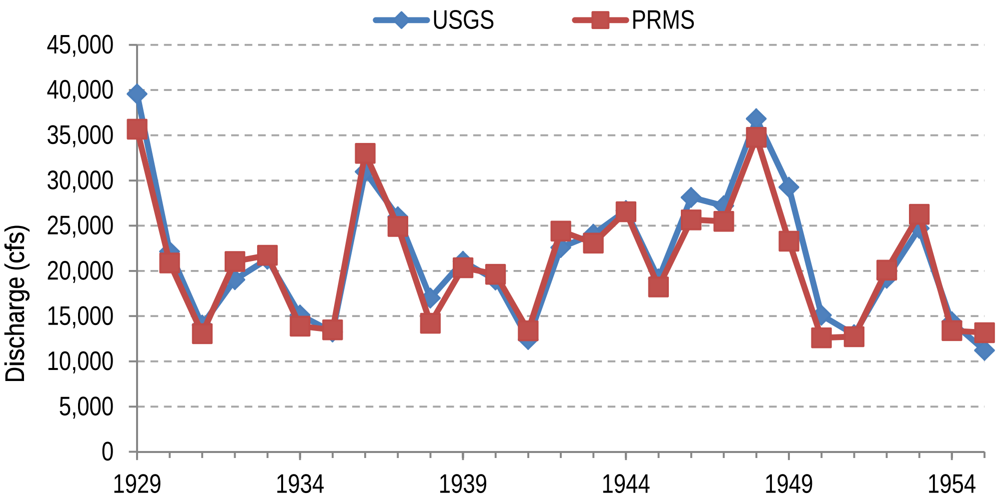
Bedient Demo. 57. Dr. Lettenmaier's "Residual" Without Post-1999 Droughts

224. The fact that Georgia's water use is not the cause of the "residuals" in these models can be seen clearly in Bedient Demo. 54 above, which does not show a clear relationship between Georgia's water use and the residual. In Bedient Demo. 54, Florida's own calculations of Georgia's water use are represented by yellow dots ("GA ACF Consumptive Use"). Those dots are plotted on top of the residual to purportedly show that increases in Georgia's water use are causing the increases in residuals. Aside from the fact that the increase in residuals did not occur until at least 1999, it is also apparent from Dr. Hornberger's own figure that there are declines in Georgia's water use in the last few years of the period of record, in stark contrast to the sharp increases in the residuals.

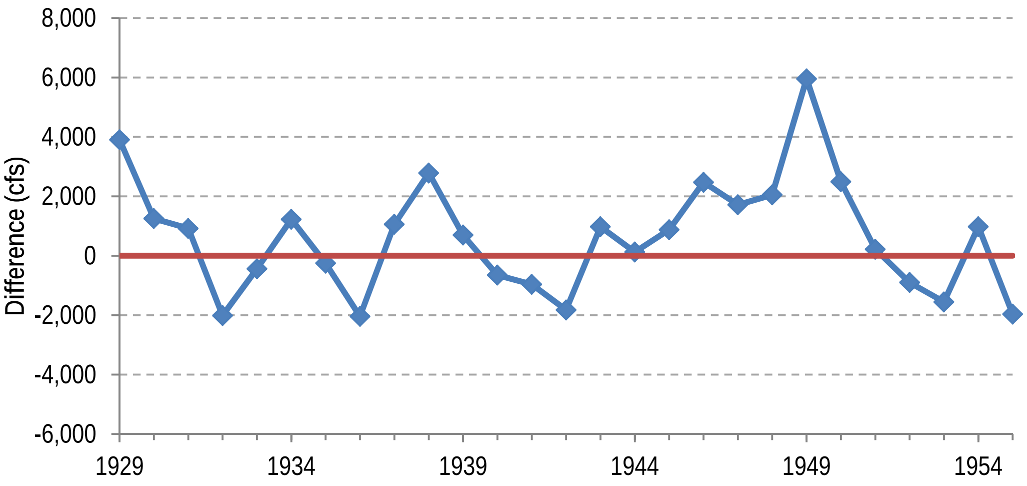
B. Dr. Hornberger's "PRMS" Model Contains Significant Error, Uncertainty, And Bias

225. Error in a model generally results in producing values that are sometimes higher and sometimes lower than the observed values, but tend to even out on average. Bias in a model tends to produce values that are more often either higher or lower than the observed, and do not even out on average.

226. Dr. Hornberger's "PRMS" model has significant error. As shown in Bedient Demo. 58, it appears at first that the "PRMS" model computes the average annual streamflow, or discharge (in cfs), at the state line for the period from 1929-1955 fairly well as compared to the observed streamflow values at the Chattahoochee gage. Bedient Demo. 58 is a true and accurate copy of a document I prepared, comparing Dr. Hornberger's modeled streamflow and observed streamflow. However, upon closer inspection, the range of error between the modeled results and the observed data is significant, as shown in Bedient Demo. 59. Bedient Demo. 59 is a true and accurate copy of a document I prepared, showing the difference between Dr. Hornberger's observed and modeled streamflow. As Bedient Demo. 59 shows, the range of inherent error in his model is typically on the order of 2,000 cfs, and can reach as high as 6,000 cfs.



Bedient Demo. 58. Dr. Hornberger's Modeled Streamflow (Using "PRMS") vs. Observed Streamflow (Pre-1956)



Bedient Demo. 59. Difference Between Dr. Hornberger's Observed and Modeled Streamflow

227. As shown by Bedient Demo. 59, the degree of error, or uncertainty, in Dr. Hornberger's modeled estimates of streamflow in the ACF Basin for the pre-1955 period (when the model should resemble the flows most closely) typically ranges from +/-2,000 cfs, and can be as high as +6,000 cfs. This error and uncertainty in Dr. Hornberger's model is larger than the "residual" he attributes to Georgia's consumptive use.

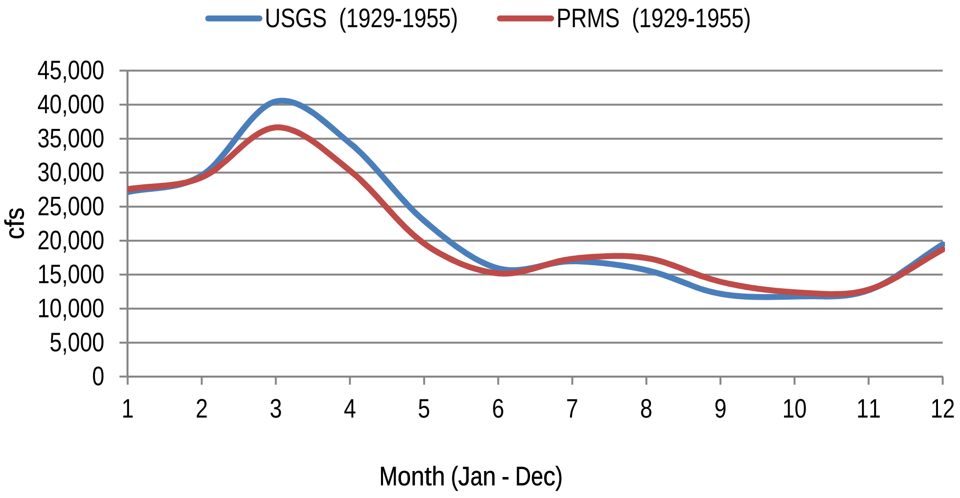
228. This range of inherent error is important because Dr. Hornberger compares recent observed flows to his model-generated, "forecasted" flows and attributes the entire residual to

"streamflow depletions" caused by Georgia's water use. In his testimony, Dr. Hornberger does not attribute any of the residual, or difference, to inherent error or uncertainty in his model. It is critical that the inherent error in his "PRMS" model be recognized and taken into account when comparing the "residual" (modeled vs. observed) in the post-reservoir period, but Dr. Hornberger fails to do this.

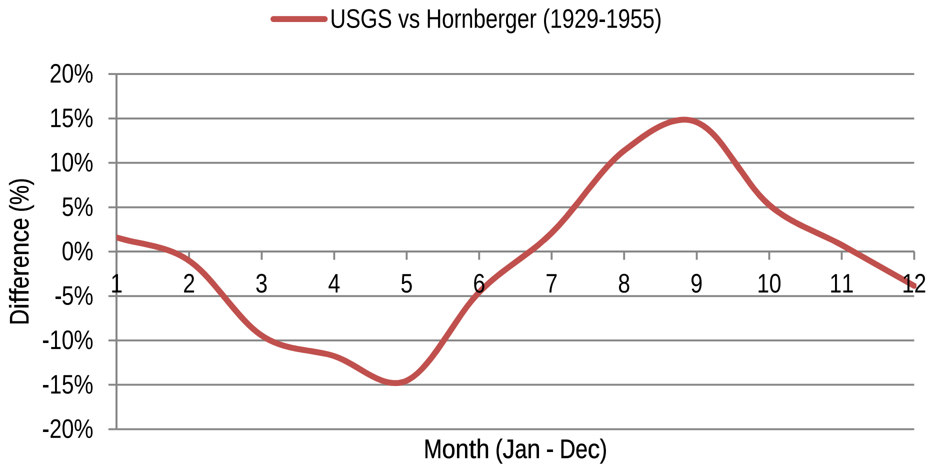
229. Dr. Hornberger acknowledged that he does not actually know how much of the "residual" is attributable to error or uncertainty in his own model. This is a significant admission, and a critical omission in his analysis. As a result of his failure to perform any uncertainty analysis, Dr. Hornberger does not know what portion of the residual is caused by inherent error in his model, and is therefore completely unreliable for use in reaching any opinions regarding the impact of Georgia's water use.

230. Not only does Dr. Hornberger's PRMS model have inherent errors in it, it also has errors in it that bias the results on a monthly or seasonal basis. Dr. Hornberger's model is biased such that it tends to over-predict low flows and under-predict high flows as compared to the observed data. Because the model over-predicts low flows in the summer months in the pre-reservoir period, the "residual" in the summer months of the post-reservoir period is artificially magnified, thereby exaggerating the "streamflow depletion" he attributes to Georgia's consumptive use.

231. Bedient Demo. 60 is a true and accurate copy of a demonstrative I prepared showing the average monthly values for the pre-reservoir period prior to 1956. Bedient Demo. 60 shows that Dr. Hornberger's "PRMS" model on average under-predicts flows during the first half of the year (when high flows are generally occurring) and over-predicts flows during the second half of the year (when low flows are generally occurring). The percent difference between the PRMS modeled monthly flows averaged over the pre-reservoir period and the USGS observed monthly flows is shown in Bedient Demo. 61. Bedient Demo. 61 is a true and accurate copy of a demonstrative I prepared also depicting this bias of under-predicting flows during the first half of the year and over-predicting flows during the latter half of the year.

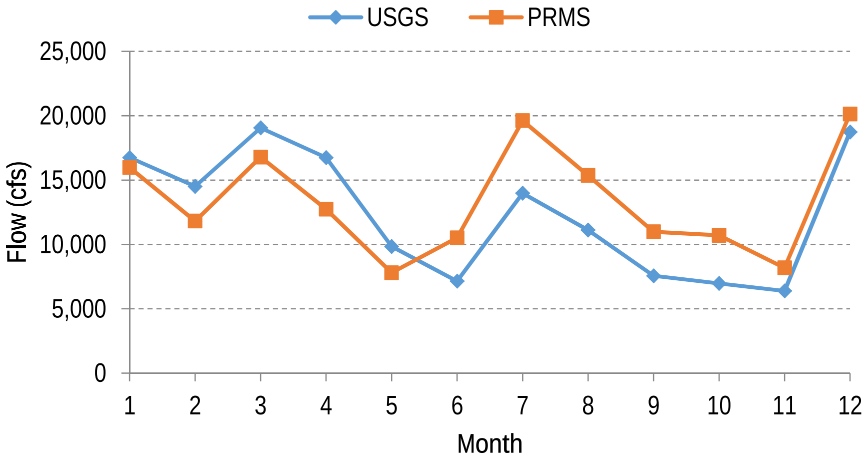


Bedient Demo. 60. Dr. Hornberger's "PRMS" Modeled vs. Observed Average Monthly Flows (cfs) at State Line for 1929-1955



Bedient Demo. 61. Percent Difference in Dr. Hornberger's "PRMS" Modeled vs. Observed Average Monthly Flows at State Line for 1929-1955

232. This over-prediction of low flows during the summer and fall months can be more easily seen for a given year, such as in Bedient Demo. 62, which shows monthly average streamflow for 1941, a dry year, for both the modeled values and the observed values. Bedient Demo. 62 is a true and accurate copy of a demonstrative I prepared showing the magnitude of his PRMS model's over-prediction of low flows during various months of dry years can be as much as 50%, or over 5,000 cfs.



Bedient Demo. 62. Dr. Hornberger's "PRMS" Modeled vs. Observed Average Monthly Flows at State Line for 1941 (Drought Year)

233. As can be seen from Bedient Demo. 62, the over-prediction of Dr. Hornberger's PRMS model during the summer months in 1941, prior to Georgia's increased water use, shows a difference, or "residual," of as much as 5,600 cfs (in July) and averages about 4,000 cfs for the period June-September. Using his PRMS model with this bias for over-predicting summer flows by such a large amount in the pre-reservoir period makes it impossible to credibly claim that any "residual" of this flow amount for these summer months in the post-reservoir period is attributable to Georgia's consumptive use rather than this bias in the model.

234. Once the inherent errors, uncertainty, and biases of Dr. Hornberger's PRMS model are taken into account, it becomes clear that the entire "residual" is a result of these problems with Dr. Hornberger's model itself, and not Georgia's consumptive use.

235. Bedient Demo. 62 below compares the error in Dr. Hornberger's post-1975 modeling with his pre-1955 modeling. The second set of values in the "Difference" column show newly disclosed values from Dr. Hornberger, which I received a few days ago. I plotted these additional values to show the "residuals," or differences, for these new values, as well. Bedient Demo. 62 is a true and accurate copy of a demonstrative I prepared showing the residuals for both periods of time (pre-1955 and post-1975) are basically of the same magnitude (3,000 cfs to 4,000 cfs). In other words, even though Dr. Hornberger claims that the post-1975 residual is caused by Georgia's water use, it can be proven that he has a residual in his pre-1955

period (before any water use) that is equally large. The error and uncertainty in Dr. Hornberger's model is causing the residual, not Georgia's water use.

Bedient Demo. 63. Comparison Between "PRMS" Versus "Observed" Flows for Pre-1956 and "PRMS with ResSim" vs. "Observed" Flows for Post-1975 Conditions (June-September Average)

Year		USGS Gaged Flow	Hornberger Predicted Flow	Difference
Pre-1955	1935	11,074	14,078	**3,004**
	1941	9,953	14,119	**4,166**
	1945	14,410	17,276	**2,866**
	1951	8,725	11,634	**2,909**
	1955	9,528	13,061	**3,533**
Post-1975	2000	5,410	9,844	**4,435/3,700**
	2001	11,627	14,762	**3,134/2,800**
	2006	6,358	10,478	**4,120/4,100**
	2007	5,250	9,510	**4,259/4,400**
	2010	9,352	12,890	**3,538/4,000**

236. Dr. Hornberger's "PRMS" model analysis does not provide a reliable basis for the conclusion that Georgia's water use was the cause of the low flows during the summer months in recent years. This is due to the magnitude of inherent errors, biases, and uncertainty in his PRMS. In fact, given these significant issues with his PRMS model, Dr. Hornberger cannot reliably reach any conclusion using this model regarding the impact of Georgia's water use.

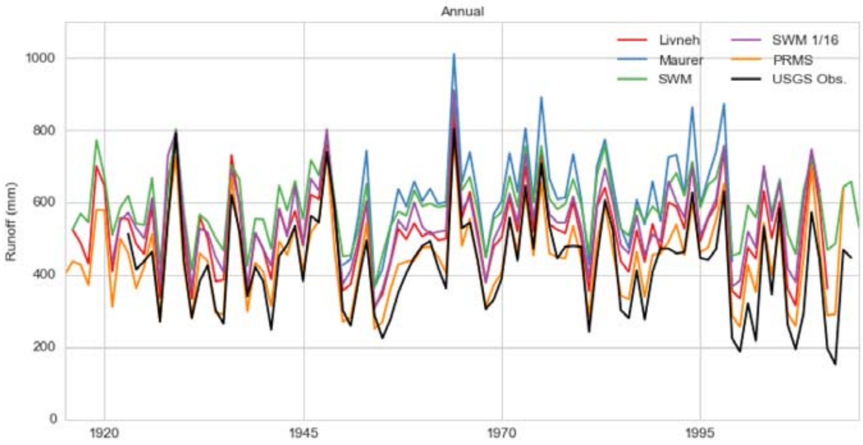
C. Dr. Lettenmaier's "Runoff" Models Are Biased and Erroneous

237. Dr. Lettenmaier's "runoff" models are equally uncertain and erroneous. He analyzed the streamflow calculated at the Chattahoochee gage and found that streamflow values "have declined substantially, mostly since about 1950" (FX-793 at 6). Dr. Lettenmaier fails to acknowledge that any part of his "residual" can be associated with the error in both his "observed" and "modeled" data sets.

238. Dr. Lettenmaier's various "modeled" results are generally significantly different than, and almost always higher than, his "observed" data set (the USGS gage data from the Chattahoochee gage). This gives an indication as to the degree of error, or "spread," in these "modeled" data sets in being able to match the "observed" data set. This degree of error (as

much as 50% or more) and the apparent bias of the error (i.e. always being higher than the "observed") is large enough that it would be nearly impossible, if not inappropriate, to reach any conclusions as to the meaning of this "residual" for the period "since about 1950" or from "1970-present," as Lettenmaier has done.

239. The "spread" and bias of Dr. Lettenmaier's runoff datasets is apparent in Bedient Demo. 64, below. Although the "spread" does not necessarily appear significant based on the scale of the image used by Dr. Lettenmaier, a difference in 100 mm of runoff is equivalent to about 5,000 cfs. Therefore, each of these runoff models is generating estimates of streamflow that are thousands of cfs (up to around 20,000 cfs) different from one another.



Bedient Demo. 64. Dr. Lettenmaier's Runoff Model Datasets

240. As acknowledged by Dr. Lettenmaier, the difference between the modeled streamflow estimates for each of these runoff datasets is as high as approximately 10,000 cfs, which is more than twice the size of the "residual" he attributes to manmade factors, including Georgia's water use. 10,000 cfs is also more than 5 times higher than the maximum observed monthly streamflow impact from Georgia's water use, which has never exceeded 2,000 cfs in a single month, even under extreme drought conditions.

241. Dr. Lettenmaier further concludes that the differences in these two estimates of streamflow show that "non-climate factors have resulted in statistically significant decreases in annual flows" at the state line (FX-793 at 6). He refers to his Figure 5.1.9-1 that shows annual residuals between his modeled flows and those for the Chattahoochee gage and concludes that "because the model-simulated runoff is an estimate of the naturalized flow in the basin, the

positive trend in Figure 5.1.9-1 indicates that the decline in observed streamflow at this location would not have occurred naturally" (*id.* at 41).

242. However, a review of the annual residuals in this figure provides an indication of the accuracy of the models he uses in his analysis, along with their inability in being able to reproduce the "observed" flows recorded at the USGS gage. These models have inherent errors and uncertainties of as much as 50% or more, which are not a result of man-made changes in the basin but rather just errors in the models.

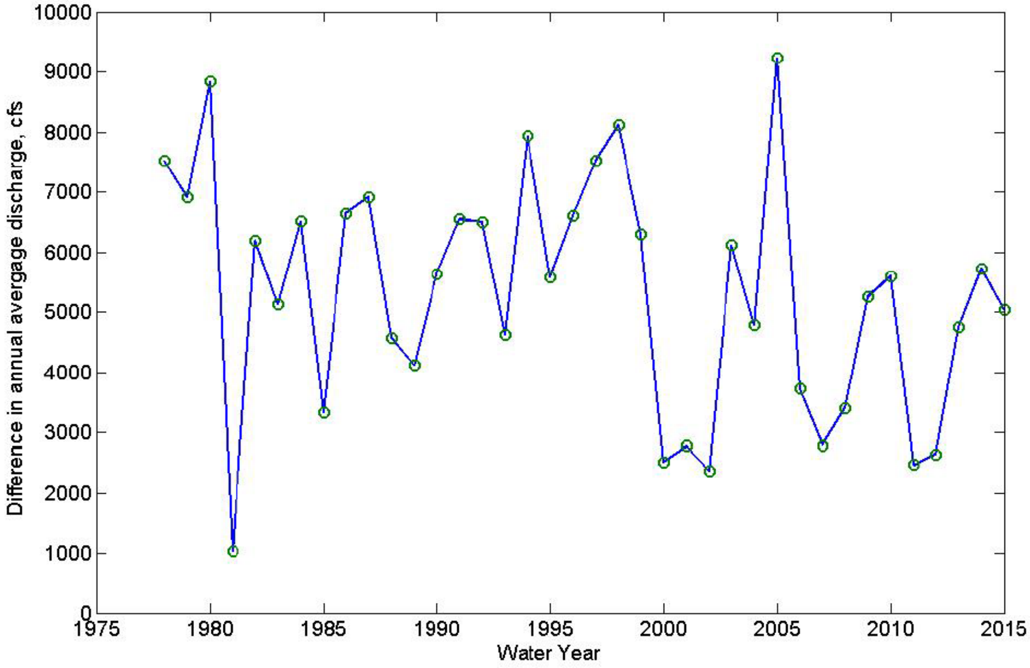
243. Prior to Georgia's increase in water use, which started around 1970, these models should have been able to fairly accurately reproduce the average annual flow at the USGS gage at the state line. Yet, these models are showing differences (or residuals) of over 4,000 cfs, indicating that they are not reliable in predicting "natural" flows at the state line to within 4,000 cfs. The inaccuracies are even greater for the growing season and low-flow season.

244. Furthermore, after 1970, when supposedly Georgia's increasing consumptive water use was resulting in an ever-increasing reduction in the "natural" flow crossing the state line, the model-simulated runoff should, therefore, always be higher than the "observed" flow at the USGS gage. Yet, there are instances when the model-simulated annual flow is less than the "observed" flow by over 4,000 cfs, and again, these inaccuracies are even greater for the growing and low-flow seasons. These inaccuracies are even greater for the recent years with significant low flow and rainfall, as there appears to be a bias in these "modeled" results that may magnify the difference or "residual" as compared to the "observed" values for low flow periods.

III. Dr. Hornberger Observed a "Flow Decline" in Florida, Even Using His Flawed "Adjustment" to the Sumatra Gage Data

245. I previously described a long-term decline of incremental flow in the Florida portion of the ACF Basin of approximately 4,000 cfs since 1978. Dr. Hornberger also looked into this issue. Similar to my findings, he also found an incremental flow decline, which he calls a "flow difference" between upstream and downstream gages. Dr. Hornberger disagrees over the magnitude of the decline, but he agrees it exists.

246. In Bedient Demo. 65 below, I reproduce Dr. Hornberger's Figure 11 from his May 20th expert report, showing the overall decline in "flow difference" between Chattahoochee and Sumatra gages. This is the same as the declining trend I observed in incremental flow.



Bedient Demo. 65. Dr. Hornberger's "Flow Difference" Showing Incremental Flow Decline in Florida's ACF

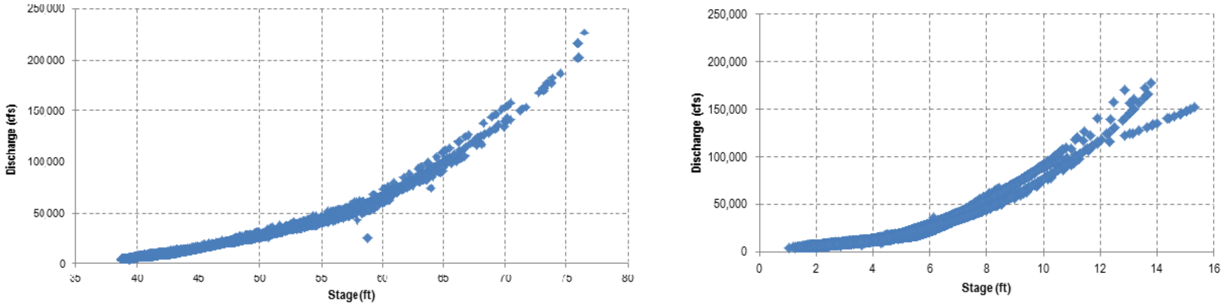
247. Dr. Hornberger acknowledges a flow decline in Florida's ACF Basin, but he attributes the flow decline to recent drought years. Dr. Hornberger's admission that the three recent, severe, multi-year drought periods are causing flow reductions in the Apalachicola River is consistent with my opinions that the three recent, severe, multi-year drought periods are causing flow reductions in the total flow crossing the state line.

248. Dr. Hornberger claims the observed flow data at the USGS Sumatra gage is in error and needs to be "adjusted" (FX-804 at 16). Dr. Hornberger takes no issue with the flow data at the USGS Chattahoochee gage. In fact, on page 9 of his report, Dr. Hornberger states that the Chattahoochee gage is "quite stable," as reflected by a reasonably "tight" curve for the relationship between stage and flow (known as a rating curve). He then contrasts this "tight" curve for the Chattahoochee gage with the various rating curves for the Sumatra gage, which appear at first glance to have much greater variability, suggesting the Sumatra gage data is more "unstable" and more variable than the Chattahoochee gage data. He then "corrects" USGS recorded, observed flow data for the Sumatra gage to match the initial rating curve developed by USGS for its Sumatra gage in 1978, and maintains that this "adjusted" flow data from a single

rating curve from the 1970s is more accurate for the entire period of record than the flow data actually reported by the USGS.

249. Dr. Hornberger's justification for his "correction" is flawed. His justification is based on a comparison between the "tight" curve for the Chattahoochee gage data (his Figure 3) as compared to the "variable" curve for the Sumatra gage data (his Figure 4). But Dr. Hornberger plotted the Chattahoochee gage data in his Figure 3 using a narrow x-axis, making it look like the curve is "tight," while a plot of the same data using a broader x-axis shows a more "variable" curve. By using two different scales, Dr. Hornberger distorts the actual variability of the data at the two gages. The effect of using two different scales for the two different gages is that the Sumatra data appeared to be more variable than the Chattahoochee data.

250. I re-plotted Dr. Hornberger's data using a similar x-axis scale, for a fairer comparison between the two. Bedient Demo. 66 is a true and accurate copy of a demonstrative I prepared in which I re-plotted Dr. Hornberger's Figures 3 and 4.



Bedient Demo. 66. Chattahoochee vs. Sumatra Gage Data (Employing Similar X-Axis Scale)

251. A comparison of the flow data at these two gages using comparable x-axis scales shows far less difference in the tightness or variability of the data. The data itself does not show the type of variability or unreliability that Dr. Hornberger and Dr. Lettenmaier discuss in their testimony. Instead, both gages show reliable discharge measurements.