Appendix C

HEC-ResSim Modeling Report

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Alabama-Coosa-Tallapoosa (ACT) Watershed

HEC-ResSim Modeling of Reservoir Operations in Support of Water Control Manual Update

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Prepared for:
US Army Corps of Engineers
Mobile District
P.O. Box 2288
Mobile, AL 36628-0001

Prepared by:
US Army Corps of Engineers
Institute for Water Resources
Hydrologic Engineering Center
609 Second Street
Davis, CA 95616

(530) 756-1104
(530) 756-8250 FAX
www.hec.usace.army.mil

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I. Introduction

This report describes the reservoir system modeling activities performed in support of the Mobile District Water Control Manual Update Study for the Alabama-Coosa-Tallapoosa (ACT) River Basin (Figure 1). The reservoir system model performs simulations of project operations for a baseline condition and alternative operations, and allows comparison of the relative differences among the results. The primary output of the reservoir system modeling activities consists of 70 years (1939-2008) of continuously simulated, daily time step, lake levels and river flows throughout the ACT basin, for twelve different operating scenarios. The twelve scenarios include the baseline condition and eleven alternative operating plans. Study teams evaluated these results in terms of economic, environmental, and operational improvements or disadvantages and used this information, along with results from a flood model and a water quality model, to select a recommended alternative operating plan.

Figure 1. Alabama-Coosa-Tallapoosa (ACT) River Basin

The team began work in May 2008 and work continues through the Water Control Manual Update Environmental Impact Statement (EIS) process. Most of the initial effort went toward refinements to the baseline model. In concept, the Water Control Manual Update Study required only relative differences in the results, but in practice, the plan formulation process depended on results being as realistic as possible, to provide feedback regarding serious and complex questions posed along the way. Additionally, the Mobile District intends to apply models developed under this study for other purposes, including cooperative follow-up activities with

stakeholders, and operational use for real-time water control. Consequently, the baseline reservoir system model eventually grew to include the detailed physical characteristics (as available) and almost all the operational rules used at each project in the system.

The plan formulation process accounted for the bulk of the other activities. Ground rules for the study removed structure improvements or other physical changes from consideration, limiting the alternatives to differences in how to operate the federal projects. The team implemented and evaluated many individual changes to operations (i.e., "measures"). The measures underwent iterative refinements, both separately and in conjunction with other measures. The recommended plan consists of the most beneficial changes identified during this process.

A. Overview of Reservoir Projects

The following information is excerpted from the Mobile District's web page regarding "Master Water Control Manual Update Environmental Impact Statement for the Alabama-Coosa-Tallapoosa River Basin" (http://www.sam.usace.army.mil/pa/act-wcm/bg1.htm):

> Eighteen dams are in the ACT basin, which form 16 major reservoirs (Jordan and Bouldin share a common reservoir and Carters Dam and Carters Reregulation Dam function as a single system). Six dams are federally owned by the Corps and 12 are privately owned projects. Of the 18 dams, 2 are on the Coosawattee River, 1 on the Etowah River, 7 on the Coosa River, 4 on the Tallapoosa River, 1 on the Cahaba River, and 3 on the Alabama River. *Note -- the dam on the Cahaba River is not included in the ResSim model. Therefore, for the purposes of the ResSim model, there are 17 dams in the ACT watershed.*
>
> Water Control Manuals are required for four of Alabama Power Company's projects that have flood control. On June 28, 1954, the 83rd Congress, second session, enacted Public Law 436, which suspended the authorization under the River and Harbor Act of March 2, 1945, insofar as it concerned federal development of the Coosa River for the development of electric power, to permit development by private interests under a license to be issued by the Federal Power Commission (Federal Energy Regulatory Commission). The law stipulates that the license must require the provision of flood control storage and further states that the projects will be operated for flood control and navigation in accordance with reasonable rules and regulations of the Secretary of the Army. Thus, the water control manual requirement for the four dams Weiss, H. Neely Henry, Logan Martin, and Harris.

(end of excerpt from http://www.sam.usace.army.mil/pa/act-wcm/bg1.htm)

B. Model Selection

This analysis used HEC-ResSim Version 3.1 "Release Candidate 3, Build 42" (USACE, 2010a). The label "Release Candidate" means that the software is undergoing final testing before distribution as an official version. HEC-ResSim is the Next Generation GUI-based reservoir operations simulation software that takes place of its precursor, HEC-5 (USACE, 1998).

Per ECB 2007-6 (USACE, 2007) and EC 1105-2-407 (USACE, 2005b), HEC-ResSim falls under the category of "engineering models used in planning studies," leaving certification to the Science & Engineering Technology (SET) initiative associated with the Corps Technical Excellence Network (TEN). The Corps Hydrologic Engineering Center developed this software which is now the standard for Corps reservoir operations modeling. As of January 2010, the TEN guidance listed HEC-ResSim as "Community of Practice Preferred" for the purpose of reservoir system analysis.

The Water Control Manual Update Study team selected HEC-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. In 2006 Mobile District began working with HEC to create ResSim watershed models based on established HEC-5 models simulating 1977, 1995, and 2008 physical and operational conditions. The three HEC-5 models hold significance as the tools "of record" used for analyses concerning the previous Environmental Impact Statement and the 1990's Comprehensive Study. After ensuring that the corresponding ResSim models could effectively reproduce the HEC-5 results, Mobile District and HEC created another ResSim model that captured the most significant operations as of 2008. This model was presented to stakeholders in October 2008 and generally accepted as a promising improvement to ACT reservoir system modeling.

Other considerations factoring into Mobile District's selection of ResSim include ease of adaptation to other studies or operational use, availability of training, access to software developers for model extensions, opportunity for linkage with water quality models, and ability to share with partners and stakeholders without licensing cost or restriction. Since the Water Control Manual Update Study was heavily accelerated but subject to unpredictable changes in scope, the long-standing relationship between Mobile District and HEC also afforded an important element of organizational trust that provided flexibility.

For the purpose of showing a general location map of the study area within the ResSim model, the main window of the Watershed Setup module for the ACT ResSim watershed model named "ACT_WCM-March2011" is shown in Figure 2. Details of the watershed model will be presented in subsequent sections and appendices of this report.

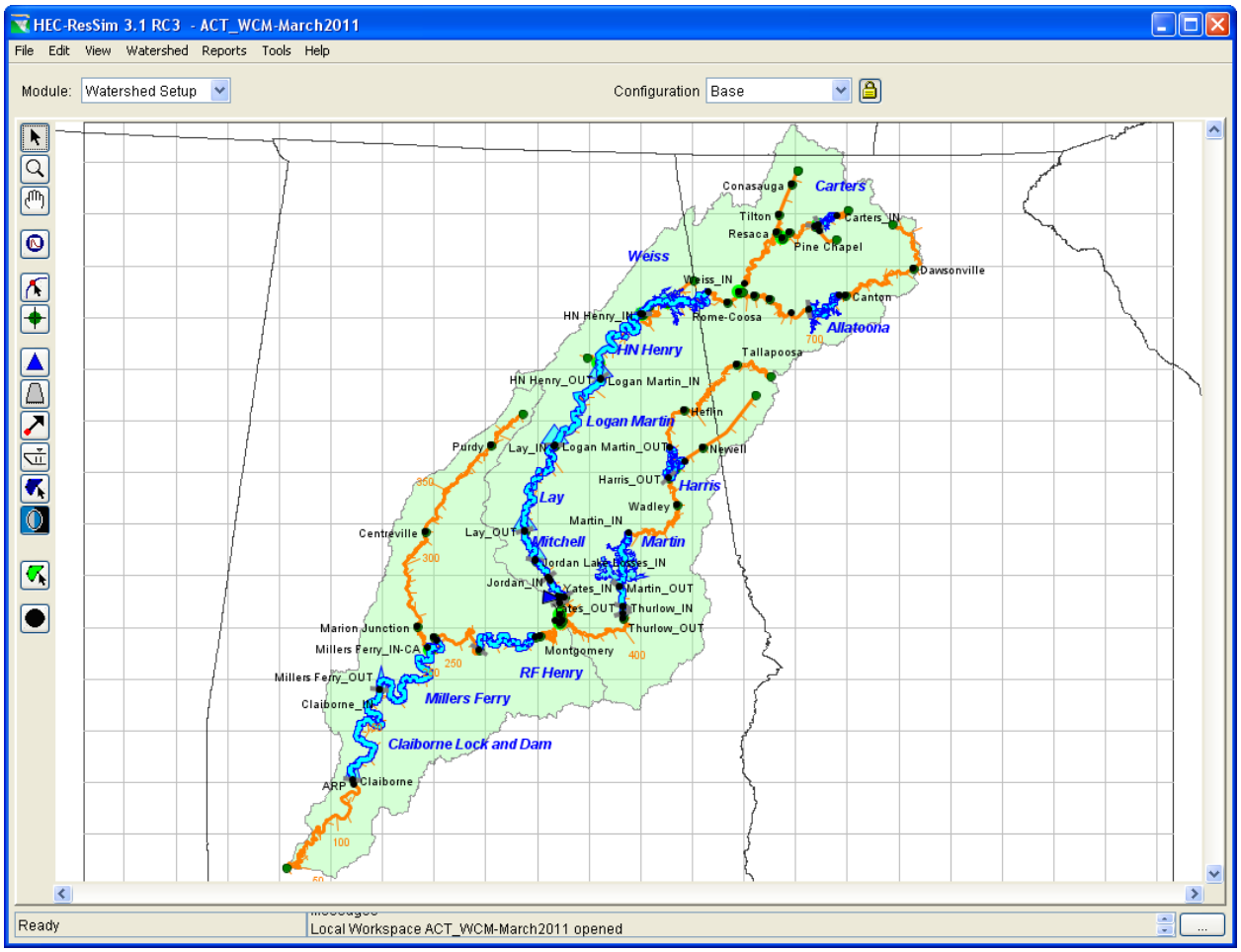


Figure 2. ACT Model – Watershed Setup Module

C. HEC-ResSim Improvements

The prior model verifications and comparisons with HEC-5 identified three ResSim improvements required for the Water Control Manual Update Study. The ACT (and corresponding ACF) Water Control Manual Update Study funded the following improvements to the ResSim source code, which are now available to all users of ResSim 3.1 (and later versions):

- Allow the specification of both positive and negative diversions amounts
- Allow the null routing method to translate negative flow downstream
- Allow the power plant generating capacity to vary as a function of head (or elevation, storage, or release)

The negative values found in the unimpaired inflows and diversion data sets require that ResSim handle negative diversions and translate (not route) negative flows downstream in order to satisfy the continuity equation.

The variable power capacity feature resembles an HEC-5 capability that allows a better estimate of energy produced as a result of Mobile District's water management operations than previously possible with ResSim. The feature allows head vs. energy ratings based on either "best gate" (most efficient flow) or "full gate" (maximum flow) through each unit.

Operations in the ACT system typically reflect the "full gate" situation. Mobile District and HEC worked with the Corps' Hydropower Analysis Center to derive updated ratings for each unit at the Corps reservoirs to conform to the ResSim power plant parameter definitions.

II. Overview of ACT Study Model

This section describes the basic attributes of the ResSim model used to simulate the baseline condition and other alternatives. The appendices contain more detailed information, including descriptions of differences between the baseline and other alternatives. Figure 3 shows the location of the reservoirs, junctions, and diversions of the ACT basin in the "2009" network (used for modeling the baseline operations).

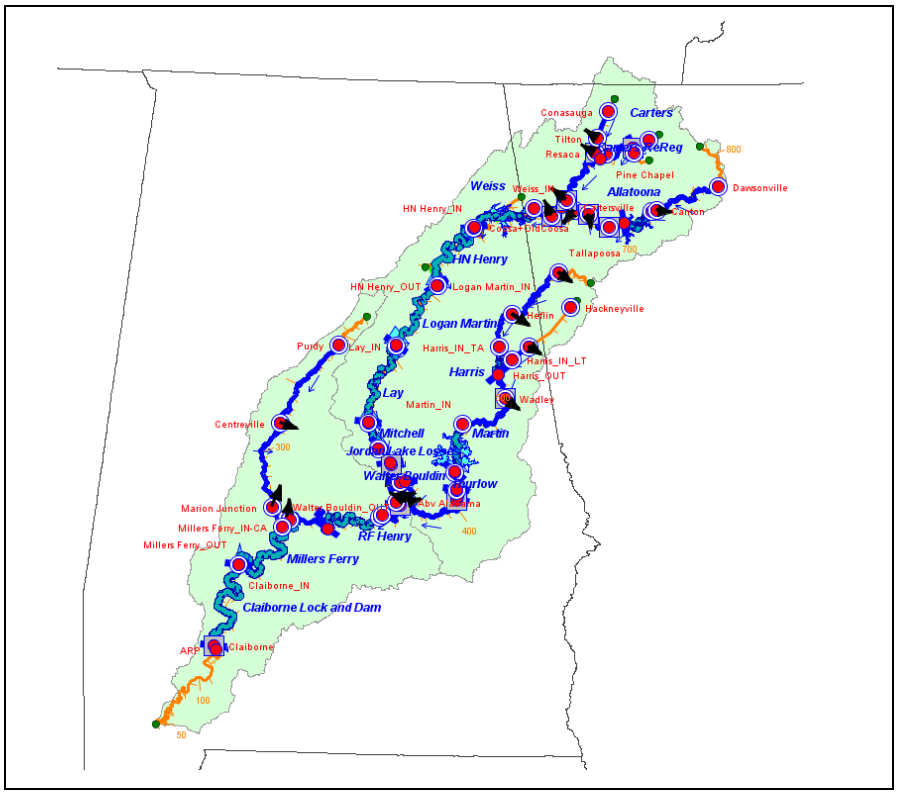


Figure 3. HEC-ResSim Network Module – 2009 Network (for ACT Baseline Modeling)

A. Simulation Time Step

The ACT model uses a daily time step to simulate operations. The selection of a daily time step was made based on previous models, available input data, and compute time considerations. This interval provides consistency with previous HEC-5 modeling activities in the basin and maintains a degree of familiarity for partners and stakeholders. The boundary condition data (i.e., diversion amounts and unimpaired inflows) exist only as daily or monthly values, and offer no advantage from a finer time interval. Study time constraints precluded development and vetting of sub-daily boundary condition data for period-of-record analysis. Finally, for such a complex study (many alternatives, complicated operations, and long simulation period), a daily time step makes it feasible to compute all alternatives in an efficient and timely manner.

Evaluation of flood control impacts required analysis on a shorter time step and using inflows beyond those observed for historical events. A special hourly model was developed to evaluate flood control measures by applying various synthetic flood hydrographs as inflows. This model focused on a sub-region of the watershed, including only the Army Corps reservoirs above Rome, GA (Carters, Carters ReReg and Allatoona). This topic is covered in Section G of this report.

The daily time step provides adequate granularity to capture the effects of conservation operations, provided that hydropower generating rules and certain flood control operations are formulated properly according to the interval. A sub-daily interval (used in the flood model) allows refinement of hydropower generating and flood control rules.

B. Routing

Although initial versions of the ACT model did not use channel routing, the final delivered model includes routing at some locations. Prior to the Agency Technical Review (ATR) team meeting, during the ACF model review (in May 2010), the development of the ACF and ACT daily time step models used null routing in all reaches of the model. Null routing implies that an inflow hydrograph at the upstream end of a reach matches the outflow hydrograph at the downstream end of the reach (before adding local inflows), which effectively neglects lag and flow attenuation effects through the routing reaches. In the system operation and storage balance between projects, an HEC-ResSim model using null routing essentially assumes that releases from the most upstream reservoirs in the watershed would influence flows in the lower portion of the watershed on the same day. This approach was consistent with prior studies and models of the basin. However, in advance comments from the ATR team during the ACF model technical review, it was strongly suggested that the modeling team consider adding some form of routing to the ACF model. The modeling team anticipated similar comments during the ACT technical review, and decided to add routing to the ACT model as well.

ResSim routing capabilities include the ability to consider the effects of routing when operating for downstream requirements. ResSim also provides features to allow a system of reservoirs to operate together for a common objective. The typical system operation is for two parallel reservoirs to operate together for a common downstream control point.

This operation accounts for routing effects, but it uses a simple linear routing assumption for the total routing from each reservoir to the control point. This assumption can be very good if all reaches use a linear routing method and very poor if one or more reaches use a very non-linear routing method. Other system operations, like tandem balancing and system hydropower operation, lack the sophistication to fully account for flow changes due to routing. This may show up in the results as an oscillation in operation of the reservoirs in the system as they attempt to compensate for one another's releases.

The Muskingum and Coefficient methods were used for routing. The Muskingum routing method (which provides an easy means of representing both lag and attenuation) and the Coefficient routing method (which assumes no attenuation and distributes flow for reach travel times between 6 to 18 hours) were selected for use in the final model because these methods were used in developing the unimpaired inflow data set. Table 1 lists the routing parameters used in each reach. *(Note: in the "Logan Martin to Lay" and "Tallassee to Abv Alabama" reaches, the routing parameters were replaced by **Null routing** to minimize negative impacts on the daily operation for downstream minimum flow requirements at the JBT Goal. This was necessary due to the complex parallel operation of Logan Martin and Martin reservoirs and the ResSim logic having difficulty in accounting for the attenuation effects in the reaches below the reservoirs and above the minimum flow requirement control point. The actual routing methods and parameters are included using a strike-through format in Table 1.)*

Table 1. Routing Parameters Used in the ACT Watershed

River	Reach	Length (mi)	Routing Method	… "Muskingum" …		
				K (hrs)	X	Steps
				or … "Coefficients" …		
Conasauga River	Conasauga to Tilton	31	*Null*			
Conasauga River	**Tilton** to Coosawattee-Conasauga	16 (to Resaca)	**Coefficient**	**0.75**	**0.25**	
Talking Rock Creek	Talking Rock to Carters ReReg_IN	*n/a*	*Null*			
Coosawattee River	Carters_OUT to Carters ReReg_IN	2	*Null*			
Coosawattee River	Carters ReReg_OUT to Pine Chapel	16	**Coefficient**	**0.45**	**0.55**	
Coosawattee River	**Pine Chapel** to Coosawattee-Conasauga	13 (to Resaca)	**Coefficient**	**0.58**	**0.38**	**0.04**
Oostanaula River	Coosawattee-Conasauga **to Resaca**	---	*Null*			
Oostanaula River	**Resaca** to Rome-Oostaunala	50 (to Rome-Coosa)	**Muskingum**	**36**	**0.0**	**1**
Oostanaula River	Rome-Oostaunala to Oostanaula-Etowah-Coosa	---	*Null*			
Etowah River	Dawsonville to Canton	51	**Muskingum**	**24**	**0.5**	**1**
Etowah River	Canton to Allatoona_IN	30	*Null*			
Etowah River	**Allatoona**_OUT to Cartersville	26 (to Kingston)	**Coefficient**	**0.75**	**0.25**	
Etowah River	Cartersville **to Kingston**	---	**Coefficient**	**0.75**	**0.25**	
Etowah River	Kingston to Rome-Etowah	20	**Coefficient**	**0.58**	**0.38**	**0.04**
Etowah River	**Rome-Etowah** to Oostanaula-Coosa	9	*Null*			

… Continued …

Table 1. Routing Parameters Used in the ACT Watershed -- *Continued*

River	Reach	Length (mi)	Routing Method	… "Muskingum" …		
				K (hrs)	X	Steps
				or … "Coefficients" …		
Coosa River	Oostanaula-Coosa **to Rome-Coosa**	---	*Null*			
Coosa River	Rome-Coosa to Weiss_IN	53	**Coefficient**	**0.58**	**0.38**	**0.04**
Coosa River	**Weiss**_OUT to Coosa+OldCoosa	74	*Null*			
Coosa River	Coosa+OldCoosa **to HN Henry_IN**	---	**Coefficient**	**0.58**	**0.38**	**0.04**
Coosa River	HN Henry_OUT to Logan Martin_IN	52	**Coefficient**	**0.75**	**0.25**	
Coosa River	Logan Martin_OUT to Lay_IN	46	** *NULL* ** ~~Coefficient~~	~~0.75~~	~~0.25~~	
Coosa River	Lay_OUT to Mitchell_IN	15	*Null*			
Coosa River	**Mitchell**_OUT to Jordan Lake Losses_IN	17	*Null*			
Coosa River	Jordan Lake Losses_OUT to J.D.Minimum	---	*Null*			
Coosa River	J.D.Minimum **to Jordan**_IN	---	*Null*			
Coosa River	Jordan_OUT to Coosa	15	*Null*			
Bouldin Canal	Walter Bouldin_OUT to Coosa	---	*Null*			
Coosa River	**Coosa** to **JBT Goal**	31 (to Montgomery)	*Null*			
Little Tallapoosa River	Newell to Harris_IN_LT	45	**Coefficient**	**0.62**	**0.38**	
Tallapoosa River	Tallapoosa to Heflin	74	**Muskingum**	**24**	**0.5**	**1**
Tallapoosa River	Heflin to Harris_IN_TA	48	**Coefficient**	**0.62**	**0.38**	
Tallapoosa River	Harris_OUT to Wadley	14	**Coefficient**	**0.75**	**0.25**	
Tallapoosa River	Wadley to Martin_IN	65	**Coefficient**	**0.58**	**0.38**	**0.04**
Tallapoosa River	Martin_OUT to Yates_IN	8	*Null*			
Tallapoosa River	Yates_OUT to Thurlow_IN	3	*Null*			
Tallapoosa River	Thurlow_OUT to Tallassee	2	*Null*			
Tallapoosa River	**Tallassee** to Abv Alabama	75 (to Montgomery)	** *NULL* ** ~~Muskingum~~	~~36~~	~~0.0~~	~~1~~
Tallapoosa River	Abv Alabama to **JBT Goal**	---	*Null*			
Alabama River	**JBT Goal** to Alabama-Coosa	---	*Null*			
Alabama River	Alabama-Coosa **to Montgomery**	---	**Muskingum**	**18**	**0.0**	**1**
Alabama River	Montgomery to RF Henry_IN	42	*Null*			
Alabama River	RF Henry_OUT to Selma	31	*Null*			
Alabama River	Selma to Millers Ferry_IN-AL	73	**Coefficient**	**0.75**	**0.25**	
Cahaba River	Purdy to Centreville	71	**Muskingum**	**24**	**0.5**	**1**
Cahaba River	Centreville to Marion Junction	60	**Muskingum**	**36**	**0.2**	**1**
Cahaba River	Marion Junction to Millers Ferry_IN-CA	77	**Muskingum**	**24**	**0.2**	**1**
Alabama River	**Millers Ferry**_OUT to Claiborne_IN	66	*Null*			
Alabama River	Claiborne **to ARP**	---	**Coefficient**	**0.75**	**0.25**	

C. Boundary Conditions

The operational ACT model extends from Carters Dam (on the Coosawattee River in the state of Georgia), Allatoona Dam (on the Etowah River in the state of Georgia), and Harris Dam (on the Tallapoosa River in the state of Alabama) to the tailwater of the Claiborne Lock and Dam Project (assumed to be represented by the USGS Claiborne gage 02428401 on the Alabama River in the state of Alabama). The upper extents of the complete ACT watershed model include: the headwaters of the Conasauga River above Tilton, GA; the headwaters of the Coosawattee River above Carters; the headwaters of the Etowah River above Dawsonville, GA; the Tallapoosa and Little Tallapoosa Rivers above Harris Reservoir; and, the headwaters of the Cahaba River above Purdy, AL. This complete model also extends through the confluence of the Oostanaula and Etowah Rivers (to form the Coosa River) and the confluence of the Coosa and Tallapoosa Rivers (to form the Alabama River).

The 70-year period of record that was modeled with ResSim includes calendar years 1939-2008. The unimpaired incremental local flows, evaporation data, and diversion data were obtained from CESAM. Development of these data sets are described in unimpaired flow reports (USACE, 1997) and (USACE, 2004[2009]). Use of unimpaired inflows allows simulation to capture the natural variability of supplies to the system in terms of flow frequency and volume.

D. Reservoir Projects

The ACT Basin consists of the Alabama River and three main tributaries: the Cahaba River, the Coosa River (and its upstream tributaries), and the Tallapoosa River. The Coosa and Tallapoosa Rivers join to form the Alabama River as previously shown in Figure 1. The major stream regulation in the upper basin by Corps of Engineers (COE) federal projects is provided by Carters and Allatoona Reservoirs, located about 60 miles and 30 miles, respectively, northwest of Atlanta, Georgia. These projects provide the total conservation and flood control storage capacity available above Rome, Georgia for flow regulation. Significant amounts of storage in the middle portion of the watershed are provided by eleven Alabama Power Company (APC) projects on the Coosa and Tallapoosa Rivers. Additional federal projects being modeled on the Alabama River include RF Henry, Millers Ferry and Claiborne Reservoirs. The Cahaba River is essentially unregulated.

On the Coosa River, there are seven projects that are owned and operated by Alabama Power Company (APC). From upstream to downstream they are Weiss, H. Neely Henry, Logan Martin, Lay, Mitchell, Jordan, and Walter Bouldin Reservoirs. On the Tallapoosa River, there are four projects that are owned and operated by APC. From upstream to downstream they are Harris, Martin, Thurlow, and Yates Reservoirs. Five of the APC projects (Lay, Mitchell, Walter Bouldin, Thurlow, and Yates) do not have much operational storage and are modeled as pass-through (flow-thru) projects in the daily ResSim model. These projects depend largely upon inflows controlled by upstream

reservoirs. The ResSim model included these projects initially as a carryover from the HEC-5 models, and their utility for modeling within the Water Control Manual Update Study consists mainly of providing flow through the project and approximate hydropower generated. The Corps' Claiborne Lock and Dam project is also represented as a flow-through and has little water management impact within the ResSim model, but is required to perform quality calculations linked to the reservoir simulations.

Appendices A through D include screen captures of reservoir representation in ResSim, for each of the four major Corps' projects: (A) Carters and ReReg; (B) Allatoona; (C) RF Henry; and, (D) Millers Ferry. Appendices E through J include screen captures of reservoir representation in ResSim for each of the five major APC projects, plus Jordan: (E) Weiss; (F) HN Henry; (G) Logan Martin; (H) Harris; (I) Martin; (J) Jordan and Bouldin. Included in these appendices are physical data and Baseline operations for the major reservoirs. Appendix K contains information for the four APC projects (Lay, Mitchell, Thurlow, and Yates) and one Corps' project (Claiborne L&D) that are modeled as flow-through reservoirs. The reservoirs are described below, listed in order of position in the basin, from upstream to downstream.

1. Carters Reservoir (and Carters Reregulation Reservoir)

Carters Reservoir and Dam and Carters Reregulation Dam (ReReg) are operated by the Mobile District of the Army Corps of Engineers. They are located on the Coosawattee River 1.5 miles upstream of Carters in northwest Georgia. This location is 60 miles north of Atlanta, Georgia and 50 miles southeast of Chattanooga, Tennessee. The reregulation dam is 1.8 miles downstream from the main dam in Murray County. The pool extends into both Gilmer and Gordon Counties.

Carters Reservoir is designed for flood control and hydroelectric power. It increases protection to farmlands along the Coosawattee and Oostanaula Rivers. This project helps reduce flood stages approximately 72 miles downstream. Carters has a powerhouse with four generators and a modeled variable capacity from 496.93 to 605.27 MW. Two of the generators also function as pumps. Carters Project is 11 miles long and 62 miles in circumference. The dam is a massive rolled rock structure with a height of 445 ft and a length of 2,053 ft. It also contains a gated spillway with five 40 ft wide gates.

Carters Dam is modeled in ResSim to limit the flow going into the ReReg to either 3,200 cfs or 5,000 cfs depending on the time of year. These amounts can be exceeded during an induced surcharge operation or due to power generation requirements. Pump-back operations in the flood pool are a function of the inflow between Carters and Carters ReReg. With increasing inflow, there is increased pumping. In the conservation pool, the pump-back operations are a function of the pool elevation at Carters ReReg. Higher pools elevations lead to greater pumping amounts. Carters ReReg maintains a minimum release of 240 cfs for all zones above the inactive zone. Appendix A provides detailed ResSim modeling information for Carters and Carters ReReg.

2. Allatoona Reservoir

Allatoona Reservoir is operated by the Mobile District of the Corps of Engineers. It is located in Georgia about 32 miles northwest of Atlanta, Georgia along the Etowah River. It is a multiple purpose project with principal purposes of flood control, hydropower, navigation, water quality, water supply, fish and wildlife enhancement and recreation. Its major flood protection area is Rome, Georgia, about 48 river miles downstream. The drainage area above Allatoona Dam is 1,110 square miles. The dam is made of concrete and is 1250 ft long. The top of the dam is at an elevation of 880 ft. The pool lies within Bartow, Cobb, and Cherokee Counties.

The dam has three outlets which are the spillway, the flood control sluice, and the power plant. The spillway consists of 11 gates with nine gates being 40 ft wide by 26 ft high and two gates being 20 ft wide by 26 ft high. The crest of the spillway is at elevation 835 ft. The flood control sluice consists of four sluices that are 5 2/3 ft x10 ft. Allatoona has a power plant with two large generators and a modeled variable capacity from 83.75 to 94.88 MW.

This project is modeled in ResSim with a minimum release of 215 cfs in all zones. Releases can be affected by the downstream conditions at Cartersville, Kingston, and Rome-Coosa. The maximum release from the project is limited to 9,500 cfs unless an induced surcharge operation is activated. This project is also modeled with required power generation as well as drawdown limits during the fish spawn. Appendix B provides detailed ResSim modeling information for Allatoona.

3. Weiss Reservoir

Weiss Reservoir is owned by the Alabama Power Company. It is located on the Coosa River 50 miles upstream of Gadsden, Alabama. The reservoir lies within Cherokee County, Alabama and Floyd County, Georgia. The principal purpose of Weiss Reservoir is for the production of hydropower and to provide flood control benefits. The reservoir is also a source of water supply for domestic, agricultural, municipal and industrial use. It also provides recreational opportunities.

Weiss Dam has a concrete gated spillway section with compacted earth abutment dikes. The spillway has five tainter gates 40 ft wide and 38 ft high and one tainter gate 16 ft wide and 22 ft high. The crest of the portion of spillway with five gates is at elevation 532 ft while the crest of the portion of spillway with one gate is at elevation 550.0 ft. Weiss has a powerhouse with three generators and a modeled capacity of 76.3 MW. The total drainage area above Weiss Dam is 5,270 square miles. The flood control storage is limited at Weiss and may not contribute a large reduction in peak flows during major flood events. The degree of control varies with the time of year.

This project is modeled in ResSim with a maximum release of 40,000 cfs in and above the flood pool when not in induced surcharge. This maximum is reduced to

the power plant capacity of 26,021 cfs when in the conservation pool. In addition to having a required power generation, this project is also operated in tandem with the downstream project, HN Henry. Appendix E provides detailed ResSim modeling information for Weiss.

4. H. Neely Henry Reservoir

H. Neely Henry (HN Henry) Reservoir is operated by the Alabama Power Company. The dam is on the Coosa River about 27 miles downstream from the city of Gadsden, Alabama. The reservoir lies within St. Clair, Calhoun, Etowah and Cherokee Counties. The drainage area of HN Henry Dam is 1,330 square miles, between HN Henry and Weiss, and the total drainage area is 6,600 square miles. The dam has a concrete gated spillway section with compacted earth abutment dikes. The crest of the spillway is at elevation 480 ft. The spillway contains six gates which are 40 ft wide and 29 ft high. HN Henry has a powerhouse with three generators and a modeled capacity of 58.9 MW.

The primary purpose of the dam is the production of hydro power for the Alabama Power Company. The reservoir is also a source of water supply for domestic, agricultural, municipal and industrial uses. It also creates a large recreational area.

The project is modeled in ResSim with a 96,000 cfs maximum release in all zones, along with a required power generation rule in the flood control and conservation zones. The project is operated in tandem with the downstream reservoir, Logan Martin. Appendix F provides detailed ResSim modeling information for HN Henry.

5. Logan Martin Reservoir

Logan Martin Reservoir is owned by the Alabama Power Company. The project is located 99 river miles upstream of the confluence of the Coosa and Tallapoosa Rivers. It extends about 48.5 miles upstream on the Coosa River and is situated within Calhoun, St. Clair, and Talladega Counties in Alabama. The total drainage area contributing flow at this location is 7,700 square miles. The lake is primarily used for the production of hydropower and flood control. There is limited flood control storage in Logan Martin Reservoir, but it is used in conjunction with other power generating reservoirs owned by Alabama Power Company to attempt to minimize flooding. Other purposes include navigation flow augmentation, water quality, water supply, and fish and wildlife.

The dam is a concrete gravity structure. It includes a spillway that has six tainter gates which are 40 ft wide and 38 ft high. The crest of the spillway is at elevation 432 ft. Logan Martin has a powerhouse with three generators and a modeled capacity of 134.6 MW.

Logan Martin is modeled in ResSim with minimum release requirements in all zones for both JBT Goal and J.D. Minimum, along with required power

generation in the flood control and conservation zones. Appendix G provides detailed ResSim modeling information for Logan Martin.

6. Lay Reservoir

Lay Reservoir is owned by the Alabama Power Company. It is located on the Coosa River and lies within Chilton, Coosa, Shelby, St. Clair and Talladega Counties in Alabama. It is 51 river miles upstream of the confluence of the Coosa River and Tallapoosa River. The total drainage area contributing flow at this location is 9,087 square miles. The main purpose of this project is the production of hydroelectric power. Other purposes include water supply, recreation, and fish and wildlife. There is no flood control storage in Lay Reservoir and the project is operated in a run-of-river mode where the peak inflows are passed directly downstream.

The dam is 2,120 ft long and includes a gated spillway. The spillway contains 26 vertical lift gates that are 30 ft wide and 17 ft high. Lay has a powerhouse with six generators and a modeled capacity of 165.5 MW.

The baseline operation set for Lay Reservoir contains no rules of operation, making it a flow-through reservoir. The pool elevation will remain at the top of conservation unless the inflow exceeds the total release capacity. Appendix K provides detailed ResSim modeling information for Lay.

7. Mitchell Reservoir

Mitchell Reservoir is owned by the Alabama Power Company. It is located on the Coosa River in Chilton and Coosa Counties, Alabama. It is 37 river miles upstream of the confluence of the Coosa and Tallapoosa Rivers. The reservoir extends approximately 14 miles upstream of Mitchell Dam. The lake is used for hydroelectric generation, industrial and municipal water supply, water quality, recreation, and fish and wildlife. Mitchell is basically a run-of-river project where daily outflow equals daily inflow.

Mitchell Dam has a length of 1,264 ft with a gated concrete spillway. The spillway consists of 23 timber, 30 ft wide and 15 ft high, radial gates and three steel-faced, 30 ft wide and 25 ft high, radial gates. The spillway crest for the timber gates is at elevation 297 ft while the spillway crest for the steel-faced gates is at elevation 287 ft. Mitchell has a powerhouse with four generators (total of seven, but three are retired) and a modeled capacity of 167.5 MW.

The baseline operation set for Mitchell Reservoir contains no rules of operation making it a flow-through reservoir. The pool elevation will remain at the top of conservation unless the inflow exceeds the total release capacity. Appendix K provides detailed ResSim modeling information for Mitchell.

8. Jordan Reservoir (and Jordan Lake Losses)

Jordan Reservoir is on the Coosa River in central Alabama. It is owned and operated by the Alabama Power Company. The reservoir lies within Chilton, Coosa, and Elmore Counties. It stretches 18 miles upstream of Jordan Dam. The dam is approximately 19 miles above the confluence of the Coosa and Tallapoosa Rivers. There are 10,165 square miles of drainage area contributing flow at this location. The Bouldin project, located on a man-made canal off the Coosa River, also receives flow from Jordan Lake and discharges into the Coosa River. The main purpose of the lake is the production of hydroelectric power. Other purposes include navigation, water quality, water supply, recreation, and fish and wildlife.

Jordan is operated in a run-of-river mode, where daily outflow equals the daily inflow. This is because there is no flood control storage in Jordan Reservoir. The project has a 1,330 ft long gated concrete spillway. The crest elevation for 724 ft of this spillway is at elevation 245 ft. This section has 18 radial gates that are 34 ft wide and 8 ft high. The other 606 ft has a crest elevation of 234 ft. This section has 17 vertical lift gates that are 30 ft wide and 18 ft high. Jordan has a powerhouse with four generators and a modeled capacity of 127.6 MW.

The only rule modeled for Jordan in ResSim is the relationship between the inflow into Jordan and the amount of water diverted to Walter Bouldin Reservoir. A pseudo-reservoir (or “dummy” reservoir) called Jordan Lake Losses was used to represent the local inflows and the evaporation and diversion losses from Jordan Lake. This “dummy” reservoir does not represent a physical structure; its addition to the model was a modeling technique used to represent certain operations. Appendix J provides detailed ResSim modeling information for Jordan and Jordan Lake Losses.

9. Walter Bouldin Reservoir

Walter Bouldin Reservoir is owned by the Alabama Power Company. It is located in Elmore County, Alabama, on a man-made canal off the Coosa River. A three mile long forebay canal connects with Jordan Reservoir, approximately one mile upstream from Jordan Dam. The water retaining structures at Walter Bouldin Dam have a total length of 9,428 ft. This length includes two earth embankments of 2,200 ft and 7,000 ft. The remaining 228 ft is a concrete intake section. There is no spillway structure at this project since the spillway at Jordan Dam serves both projects. Walter Bouldin has a powerhouse with three generators and a modeled capacity of 228.3 MW.

The baseline operation set for Walter Bouldin Reservoir contains no rules of operation making it a flow-through reservoir. This project is supplied by a canal from Jordan Reservoir. The capacity of this canal is limited to the capacity of the power plant at Walter Bouldin. Inflow into Walter Bouldin will only exceed the power plant capacity if the canal flow plus the local inflow into Bouldin exceeds 28,296 cfs. Appendix J provides detailed ResSim modeling information for Walter Bouldin.

10. Harris Reservoir

RL Harris Reservoir is on the Tallapoosa River in Randolph County, Alabama. The reservoir is 24 miles long and extends up both the Tallapoosa and Little Tallapoosa Rivers and lies within Randolph and Clay Counties. Crooked Creek is just downstream of the dam. The dam is located halfway (as the crow flies) between Montgomery, Alabama and Atlanta, Georgia. The total drainage area that contributes flow at this location is 1,453 square miles. The dam is owned and operated by the Alabama Power Company.

The project consists of a concrete gravity dam about 150 ft high and 1,142 ft long. It includes a 310 ft long spillway. The spillway contains six tainter gates, each 40.5 ft wide and 40 ft high. The spillway crest elevation is 753.0 ft. Harris has a powerhouse with two generators and a modeled capacity of 138.9 MW.

This project is modeled in ResSim with both a minimum requirement and a maximum constraint at the downstream gage at Wadley. This maximum limit can be exceeded when Harris is in the flood pool and follows the induced surcharge function. There is also a minimum release requirement based on the flow at the upstream gage of Heflin. The flood control and conservation zones also contain a required power generation rule. The project is operated in tandem for the downstream reservoir, Martin, when the pool is in either the conservation or drought zones. Appendix H provides detailed ResSim modeling information for Harris.

11. Martin Reservoir

Martin Reservoir is owned by the Alabama Power Company. It is located on the Tallapoosa River near the town of Dadeville, Alabama. It is eight miles upstream from Yates Dam and lies within Elmore and Tallapoosa Counties. At the time of construction (in 1926) the 40,000 acre reservoir was the largest artificial body of water in existence. The total area of watershed draining into the reservoir is 3,000 square miles. The dam is a concrete gravity-type 2,000 ft long and 168 ft high. There are twenty spillway gates which are 30 ft by 16 ft each. Martin has a powerhouse with four generators and a modeled capacity of 183.8 MW. The primary purposes of the reservoir are the production of hydro power and flood control storage.

Martin Reservoir is modeled in ResSim with a minimum flow requirement at the downstream location named JBT Goal. Martin also contains rules setting a minimum release based on the time of year. This minimum can be based on flow values at three upstream gages or can be a minimum flow at the downstream gage of Tallassee, depending on time year. The maximum release is dependent on the pool elevation at Martin. With increasing pool elevations, there is an increasing maximum release. This maximum release can be exceeded by the induced surcharge operation. There is also a minimum power generation requirement in both the flood control and conservation zones. Appendix I provides detailed ResSim modeling information for Martin.

12. Yates Reservoir

Yates Reservoir lies on the Tallapoosa River near Tallassee between the reservoirs of Martin and Thurlow. The project is owned by Alabama Power Company. It is a small reservoir, relative to other Alabama Power Company impoundments. Yates has a powerhouse with three generators and a modeled capacity of 45.8 MW. It also has an uncontrolled spillway.

The baseline operation set for Yates contains no rules of operation, making it a flow-through reservoir. The pool elevation will remain at the top of the conservation pool, unless the inflow exceeds the total release capacity. Appendix K provides detailed ResSim modeling information for Yates.

13. Thurlow Reservoir

Thurlow Reservoir is owned by the Alabama Power Company. It is the smallest reservoir in the chain of Alabama Power Company impoundments. The dam is located in east central Alabama, about 30 miles northeast of Montgomery in the City of Tallassee on the Tallapoosa River. The reservoir is 574 acres and its main purpose is the production of hydroelectric power. Other uses include water supply and recreation. Thurlow Reservoir is directly downstream of Yates and Martin Reservoirs. Thurlow has a powerhouse with two generators and a modeled capacity of 78.5 MW. The project also has a gated spillway.

The baseline operation set for Thurlow contains no rules of operation making it a flow-through reservoir. The pool elevation will remain at the top of the conservation pool, unless the inflow exceeds the total release capacity. Appendix K provides detailed ResSim modeling information for Thurlow.

14. RF Henry Lock and Dam

Robert F. Henry (RF Henry) Reservoir includes a lock and dam and is owned by the Mobile District of the Army Corps of Engineers. It is located on the Alabama River 245.4 miles upstream of the mouth. Most of the dam and reservoir lie within Autauga County and the rest lies within Lowndes, Montgomery, and Elmore Counties. The operating purposes of the RF Henry Project are navigation and hydropower. There is no flood control storage in this project. Access and facilities are provided for recreation, but water is not normally controlled for that purpose.

The RF Henry project consists of a gravity-type dam with gated spillway supplemented by earth dikes, a navigation lock and a control station. The spillway has eleven tainter gates, 50 ft wide and 35 ft high. It has a crest elevation of 91 ft. The lock chamber is 84 ft wide and 655 ft long. RF Henry has a powerhouse with four generators and a modeled variable capacity from 20.0 to 81.80 MW.

There is only one rule governing the operations at RF Henry in ResSim. This rule operates RF Henry in tandem with the downstream project, Millers Ferry. Appendix C provides detailed ResSim modeling information for RF Henry.

15. Millers Ferry Lock and Dam

Millers Ferry Reservoir includes a lock and dam and is operated by the Mobile District of the Army Corps of Engineers. It is located in the southwestern part of the state of Alabama about 142 miles upstream of the mouth of the Alabama River. It is located about 10 miles northwest of Camden and 30 miles southwest of Selma. The reservoir lies within Wilcox and Dallas Counties. The total drainage area contributing flow at this location is 20,700 square miles. Millers Ferry serves as a major unit of the navigation system on the Alabama River and for the production of hydroelectric power. Other project purposes include recreation, fish and wildlife conservation, and wildlife mitigation.

Millers Ferry Dam is a concrete gravity-type dam with a gated spillway, supplemented by earth dikes, a navigation lock and a control station. The lock chamber is 84 ft wide and has a usable length of about 600 ft. The spillway consists of 17 tainter gates which are 50 ft wide by 35 ft high. The spillway crest elevation is 46 ft. Millers Ferry has a powerhouse with three generators and a modeled variable capacity from 16.6 to 101.24 MW.

In the ResSim model, there is a downstream control function rule in the flood control and conservation pools that sets a downstream flow requirement for the inflow junction at Claiborne Lock and Dam. The minimum flow at this location is a function of the flow at the upstream location named JBT Goal. In the operating inactive zone, the project minimum release is modeled as a function of the net inflow into the project. Appendix D provides detailed ResSim modeling information for Millers Ferry.

16. Claiborne Lock and Dam

Claiborne Reservoir (or Claiborne Lock and Dam) includes a lock and dam and is operated by the Mobile District of the Army Corps of Engineers. The dam is located in the southwestern part of the state of Alabama, approximately 82 miles above the mouth of the Alabama River. The drainage area from Millers Ferry to Claiborne is 820 square miles, with a total drainage area of 21,473 square miles contributing flow at this location. The Claiborne Dam is primarily a navigation structure. It also reregulates the peaking power releases from the upstream Millers Ferry project, providing navigable depths in the channel below Claiborne. The project is also used for water quality, public recreation, and fish and wildlife conservation.

Claiborne consists of a concrete gravity-type dam with both a gated spillway section and a free overflow section, supplemented by earth dikes. It also contains a navigation lock and control station. The spillway has two sections. One section is a controlled broad crested weir with a crest elevation of 15 ft. This section is controlled by six tainter gates that are each 60 ft wide and 21 ft high. The other spillway section is an ogee-type, free overflow that has a length of 500 ft and a crest elevation of 33 ft.

The baseline operation set for Claiborne Reservoir contains no rules of operation, making it a flow-through reservoir. The pool elevation will remain at the top of conservation unless the inflow exceeds the total release capacity. Appendix K provides detailed ResSim modeling information for Claiborne Lock and Dam.

E. System Operations

The reservoirs in the ACT watershed are represented as several systems in which each reservoir has its role to play. Many interests and conditions must be continually considered and balanced when making water control decisions for the basin. Many factors must be evaluated in determining project or system operation, including project requirements, time-of-year, weather conditions and trends, downstream needs, and the amount of water remaining in storage. In the daily model, two state variables were created for the purpose of operating Carters and Carters ReReg (described in detail in Appendix L).

Both parallel and tandem systems are included in the ResSim model. The daily model operation for the JBT Goal creates a parallel operation between APC projects Logan Martin and Martin and relies on upstream tandem rules in APC reservoirs for balancing conservation storages between upstream and downstream projects. The ResSim model includes an explicit storage balance definition designed to preserve balance across similar zones of the five APC storage projects. Figure 4 shows the Reservoir System editor where the “APC for JBT” Reservoir System is reflected for the System Storage Balance named “Even-by-Zone_Baseline” (which is used by the Baseline alternative).

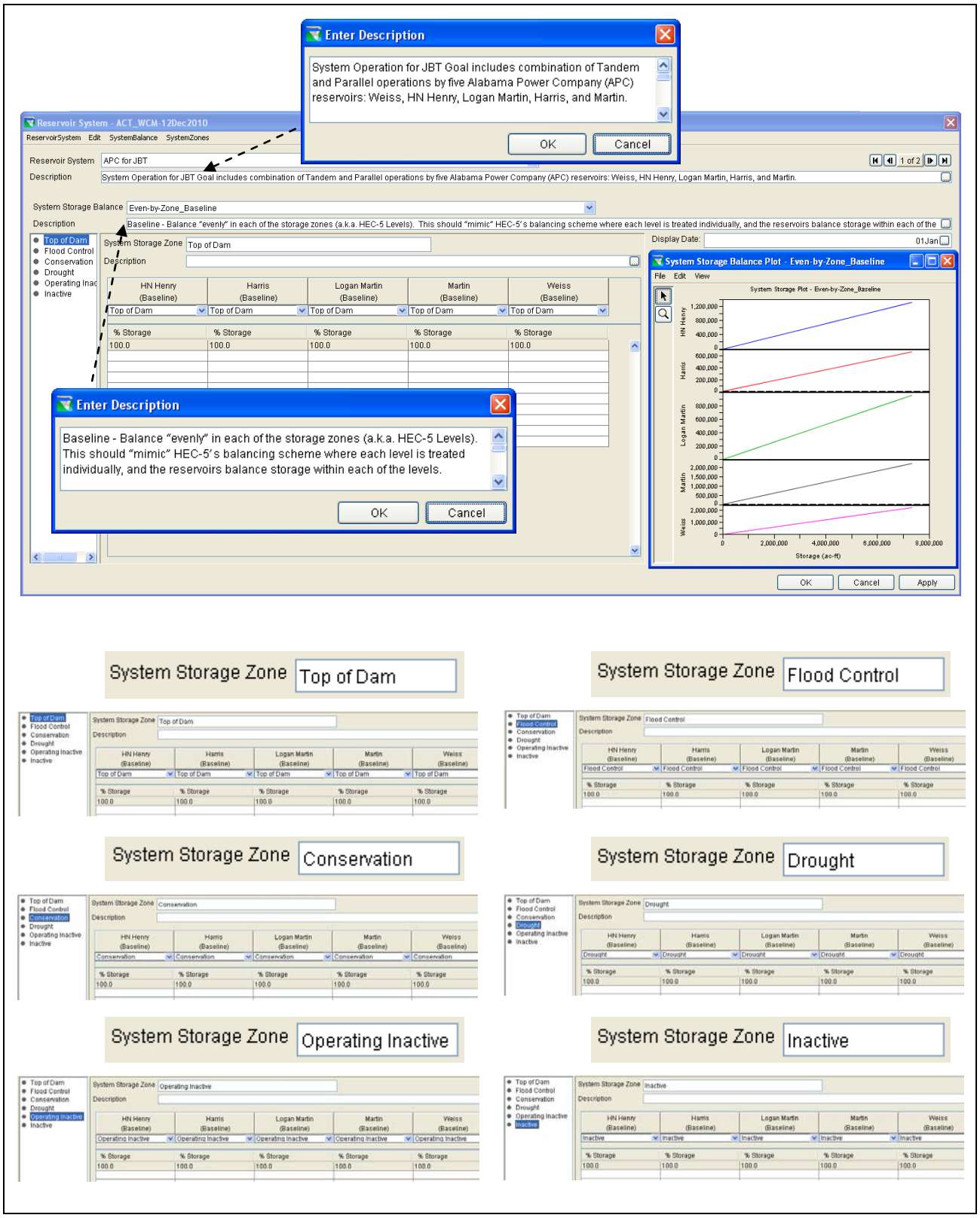


Figure 4. Reservoir System Balancing for Baseline Operations:
Reservoir System = "APC for JBT"
System Storage Balance = "Even-by-Zone_Baseline"

F. Water Supply/Diversions

Flow withdrawals occur in the ACT basin for various purposes. Water is diverted from the federal and APC projects as well as from the rivers. Flow withdrawals from the reservoirs and from the rivers are modeled differently using the following methods:

1. Withdrawals from a reservoir are modeled at the reservoir inflow junction as a negative local inflow specified as an external time-series, so that a diversion from a reservoir can never be "shorted."

2. Withdrawals from a river are modeled more flexibly as diversion elements (black arrows) from junctions. These withdrawals might be constant, specified as an external time-series, or represented as a function of a model variable.

For both method 1 (negative local inflow) and method 2 (diversion element), the amount of flow diverted is included in the net inflow calculation. In other words, the net inflow to a reservoir accounts for the flow withdrawal, and is calculated before release decisions from the pool are made. The difference between these two methods is that there is no control on the flow withdrawal for method 1, even if there's insufficient inflow from upstream. If the withdrawal (represented as a negative inflow) is greater than the (positive) inflow in a time step, the withdrawal will be subtracted from the pool. Even if the pool is at the bottom of a conservation zone, withdrawal will still take place until the pool is dry (regardless of any outlet elevations). This scenario represents the actual withdrawal conditions occurring in all the COE and APC projects. For method 2, if the amount withdrawn is greater than the inflow, withdrawals will be shorted. This scenario reflects the actual withdrawals from the river reaches. Figure 5 shows examples of both methods being used in the modeling of reservoir and non-reservoir diversions.

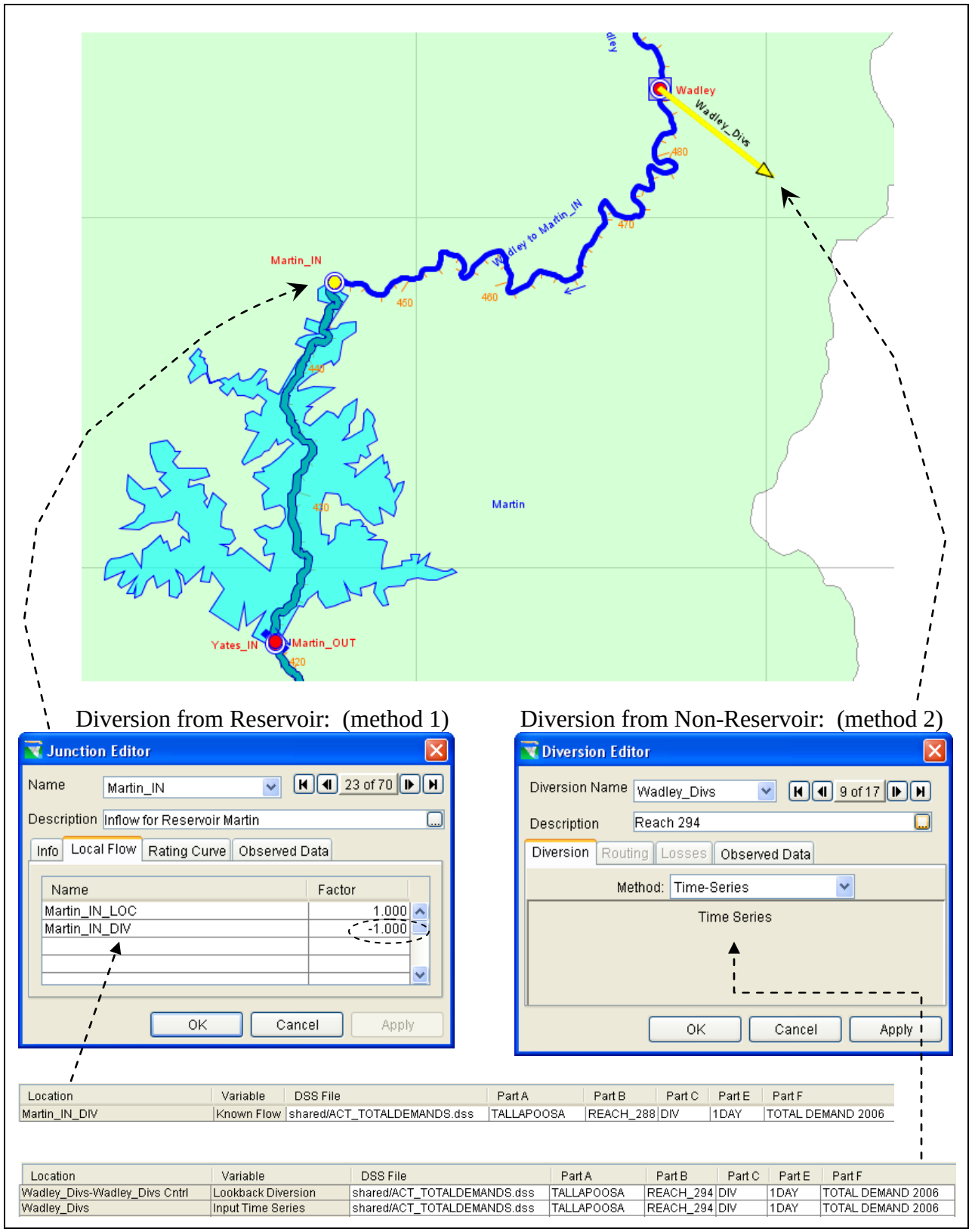


Figure 5. Two Methods Used in Modeling Diversions (for Reservoirs and Non-Reservoirs)

G. Flood Modeling

An hourly flood study model for the Upper ACT watershed was developed to evaluate any downstream flooding impact from proposed modifications to flood operations at Allatoona Reservoir. The flood model consists of a sub-region of the watershed, including Carters and Allatoona Reservoirs, and extending downstream to Rome, Georgia (Figure 6). Hypothetical unregulated hydrographs were developed at several frequencies and used to run the flood model to obtain monthly regulated frequency hydrographs at Etowah River at Kingston and the Coosa River at Rome. The regulated frequency curves for the Etowah River at Kingston and the Coosa River at Rome for the baseline and alternative conditions were generated and compared to evaluate the flooding impact from the modified flood operations at Allatoona Reservoir. For details of the flood modeling and results, refer to Appendix M.

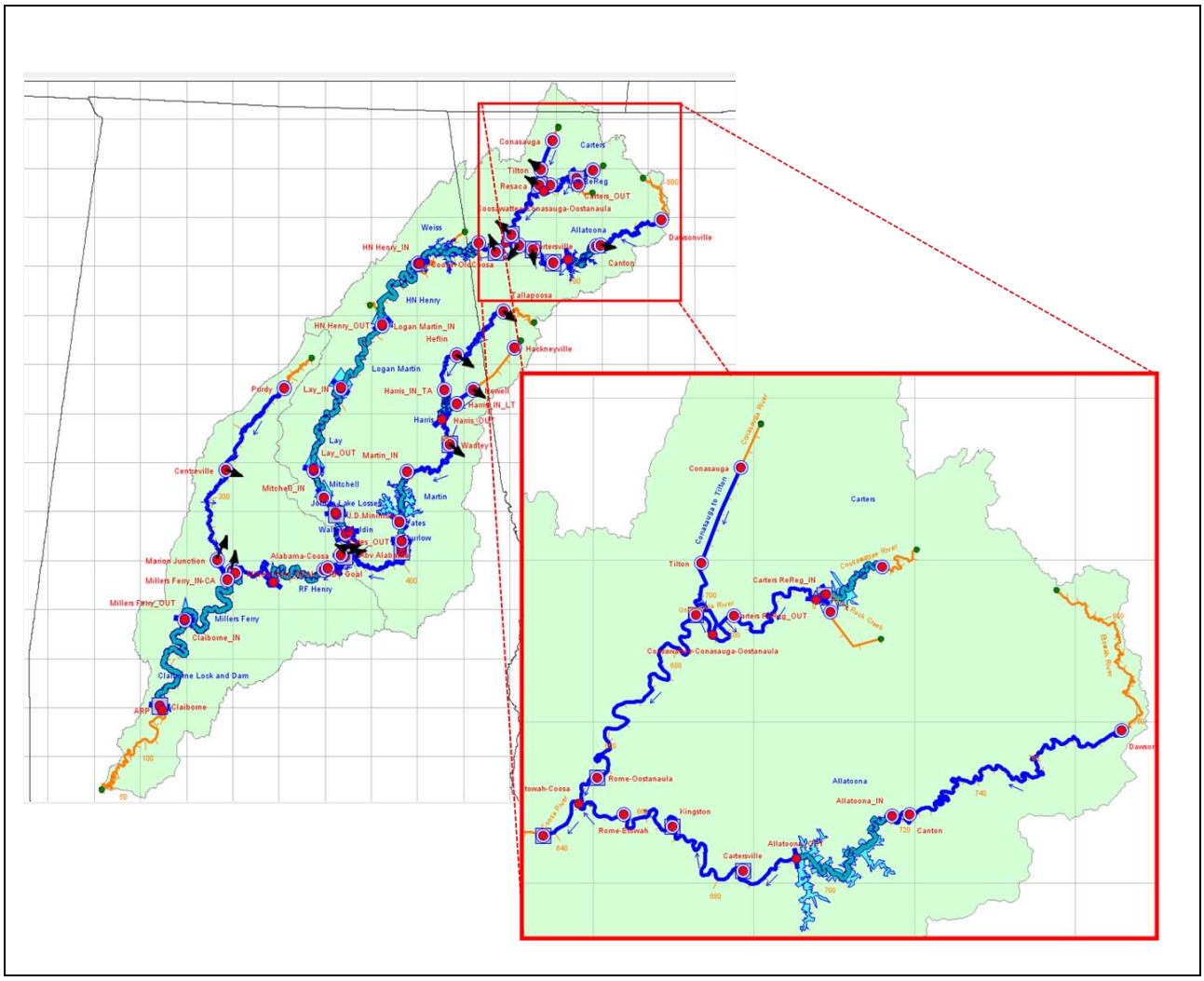


Figure 6. ResSim Network for ACT Flood Modeling (Upper Coosa above Rome, Georgia)

1. Boundary Conditions

The synthetic inflow hydrographs used for the hourly flood model were developed in a multi-stage process that began with the development of a relationship between daily and instantaneous peak flow at various locations. A flood frequency analysis was performed to compute instantaneous, 1-, 3-, 5-, and 45-day unimpaired peak flow frequency curves at Rome. The 1961, 1979, and 1990 events were selected to develop hourly unimpaired hydrographs, which were used to develop and calibrate an HEC-HMS (USACE, 2010b) model (Figure 7). The 1961, 1979, and 1990 unimpaired hourly hydrographs were scaled in an iterative manner and routed in the HEC-HMS model, such that the hydrographs at Rome from the HEC-HMS model match the computed instantaneous, 1-, 3-, 5-, and 45-day peak flow volumes within 10 percent. The resulting input hourly hydrographs are the synthetic inflow hydrographs for the 5-, 2-, 1-, 0.5-, and 0.2 percent-annual chance events.

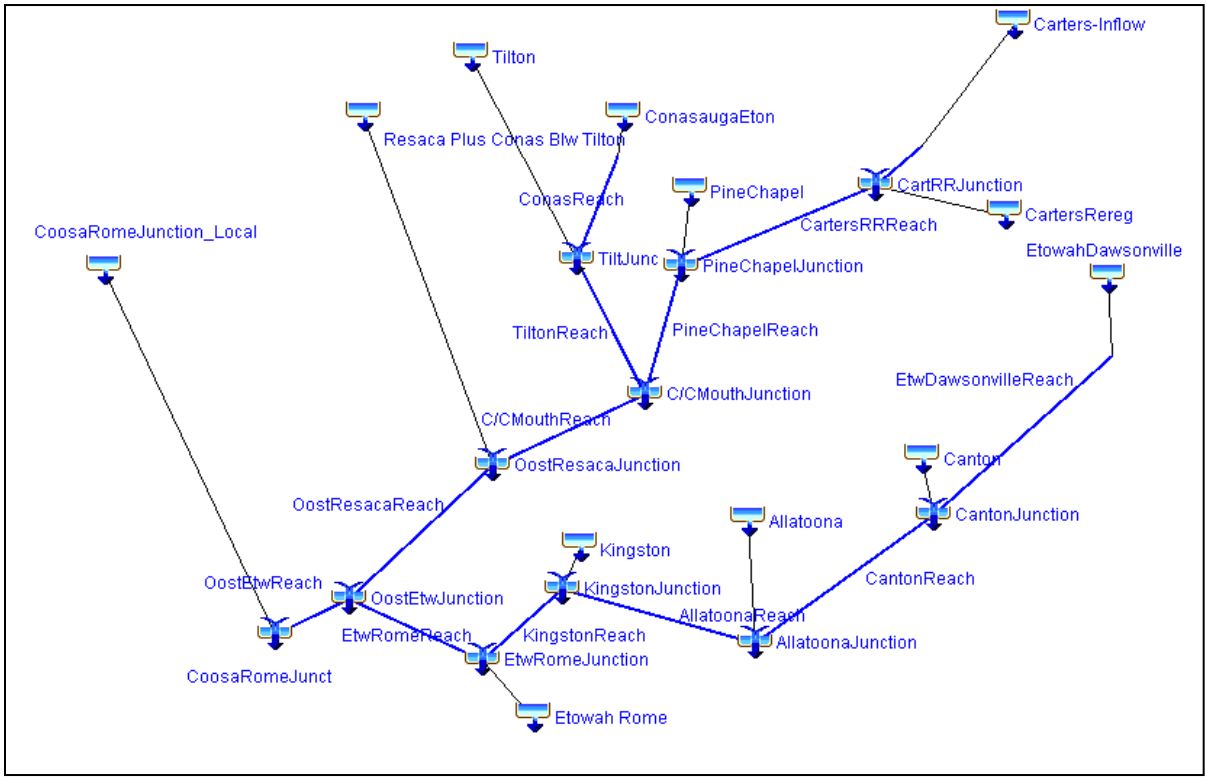


Figure 7. HEC-HMS Schematic for Generating Flood Hydrographs

The volumes for each frequency event determined according to this procedure were distributed throughout the storm duration according to observed events in 1961, 1979, and 1990, resulting in a series of similarly shaped but differently scaled inflow hydrographs similar to those shown in Figure 8. The final step was to temporally shift each hydrograph to center it on each of the 12 months of the calendar year, allowing simulation of storms centered during different seasons and amounts of available flood control space.

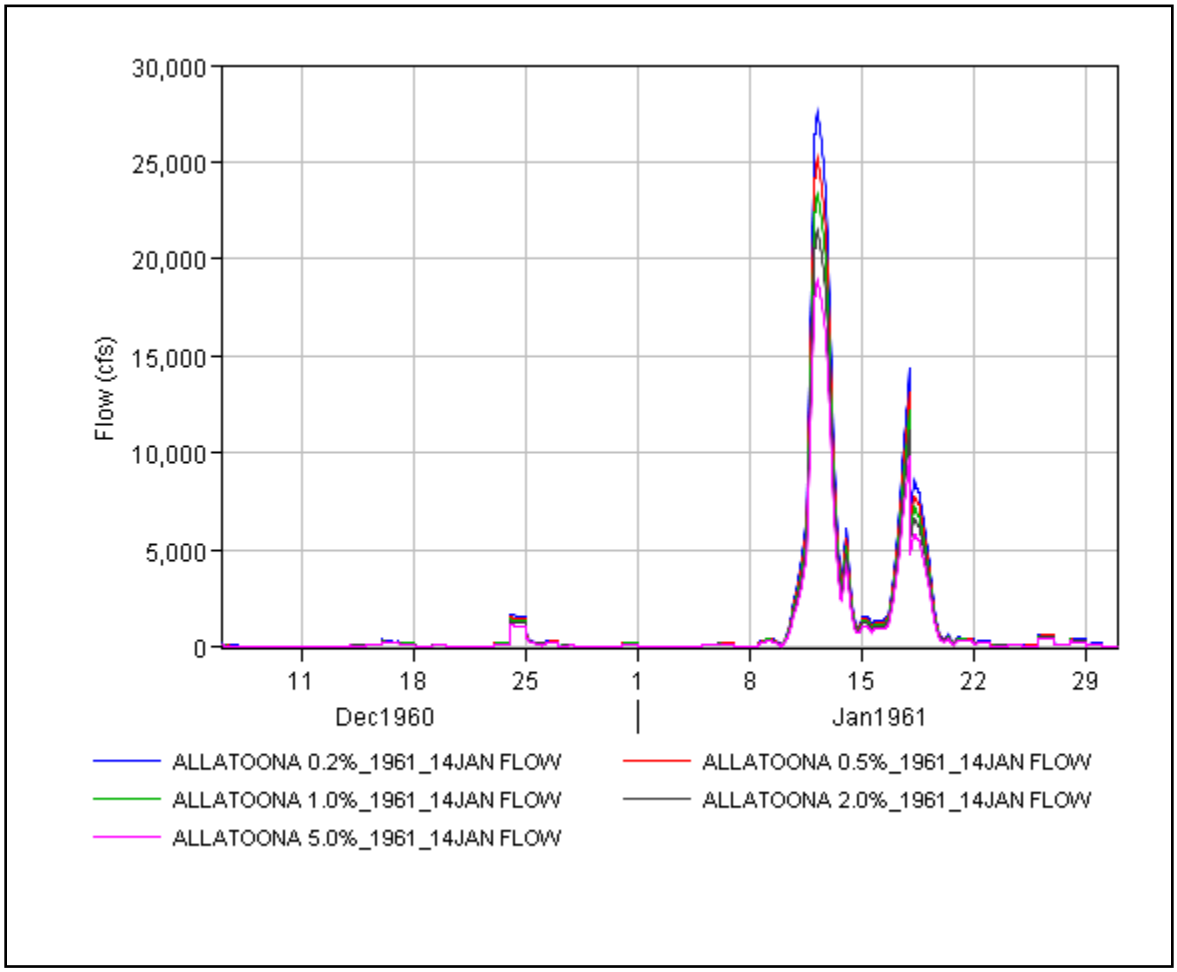


Figure 8. Synthetic Unimpaired Hourly Hydrographs at Kingston Based on 1961 Event

Appendix O provides a more detailed explanation of the processes used to develop the inflow hydrographs for HEC-ResSim flood modeling.

2. Model Adaptation from Daily to Hourly

The hourly ResSim flood model covers the system only in the Upper ACT, and was extracted from the master daily model. In addition to the different extents, a few physical and operational differences exist:

- Diversions were neglected, as they were determined to be too small to affect flood modeling.
- The flood model carries additional details regarding induced surcharge operations.
- The fish spawning rule from the daily model was left out of the flood model as it was determined to be an unnecessary complexity.

3. Verification and Analysis

A large storm event in September 2009 occurred during the ACT modeling effort, and offered a timely opportunity for verification of the reservoir flood operations. Mobile District and HEC developed incremental inflow hydrographs for the inflow junctions of the hourly ResSim model from analysis of observed flows from the event. The HEC-HMS model, previously calibrated for use in developing synthetic events, facilitated the hydrograph arithmetic by routing observed flows on the Etowah, Oostanaula, and Coosa Rivers from one gage to the next. The difference between the hydrograph at a gage and the one routed from upstream represents the incremental inflow between the observation points, which coincided with ResSim junctions.

The verification effort confirmed that the model's representation of flood operations corresponded well with the District's actual operations (Figure 9). During the September 2009 event, one of the two power plants at Allatoona Dam was offline. The ACT ResSim flood model was not developed to simulate the circumstance of a power plant being offline. This caused differences between observed and modeled results as discussed below.

With only one power plant available, the release capacity of Allatoona Dam (without operation of the spillway) varies within the range of approximately 3,500 to 4,000 cfs. When both power plants are available, the release capacity is in the range of 7,500 to 8,500 cfs. Because the flood model simulates the availability of both power plants, the simulated releases in the days leading up to the high reservoir inflows (approximately September 8 through September 18) are greater than the observed releases by about a factor of two. This caused the simulated pool elevation to become about two feet lower than the observed elevation. This difference in elevation carries through the remainder of the simulation period.

Allatoona Dam operates for downstream control at three locations: the Etowah River at Cartersville, the Etowah River at Kingston, and the Coosa River at Rome. During the simulation period, the simulated releases from Allatoona Dam are equal to the minimum release during the period from September 19 through September 22. During this time, the local inflows downstream of Allatoona Dam are high and the dam is operating for downstream control. Beginning late on September 22, the local inflows downstream decrease enough that releases can be made from Allatoona Dam without exceeding downstream flow limits. It is during this time period (from September 22 through the end of the simulation period) that two additional differences between the simulated and observed releases are seen.

1) Because of the availability of only one power plant during the September 2009 event, it was necessary to operate the spillway in order to mimic the availability of both power plants to facilitate the lowering of the the Allatoona pool. This causes slight variations in the releases during the September 23 through October 8 time period. The ResSim model assumes

the availability of both power plants and the spillway is not operated. This causes the uniform simulated release seen in the later days of the simulation period.

2) The ResSim model has "perfect foresight" when it comes to operating for downstream control. The model is therefore very effective at limiting releases so as not to exceed downstream flow limits and increasing releases to lower the pool elevation when local inflows downstream decrease. Real-time operations, inherently, do not have the luxury of this "perfect foresight." Therefore, some differences are expected between the timing of the observed and simulated releases during periods when local inflows downstream of the dam decrease to levels that allow for increased releases from the dam or when local inflows downstream increase to levels that call for restricted releases from the dam. This difference in timing between observed and simulated releases is seen during the period from September 23 through September 30. Essentially, the ResSim model is more effective at operating for downstream control than is possible in real-time operations.

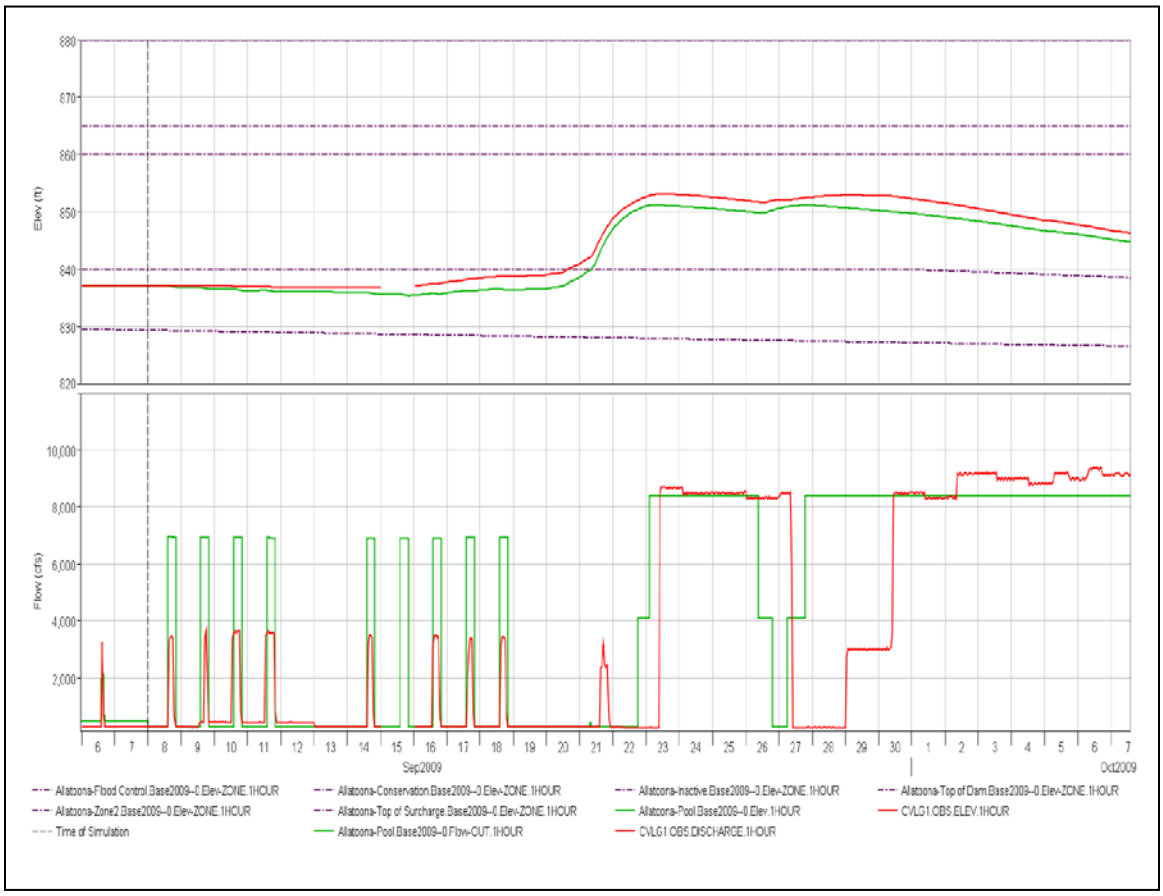


Figure 9. HEC-ResSim Results for September 2009 Event

4. Evaluation of Results

The flood frequency flow for the Etowah River at Kingston and the Coosa River at Rome depends on the storm inflow hydrographs and the month during which the storm hydrographs are applied. For each month, a regulated flood frequency curve was generated using the regulated hydrographs for various frequency events that were simulated in the flood HEC-ResSim model. These curves were combined to produce a "composite" regulated flood frequency curve at the Etowah River at Kingston and the Coosa River at Rome by considering the exceedance probabilities of flood events occurring in different months. This was developed for both the baseline and alternative conditions. The combined regulated flood frequency curves for the baseline and alternative conditions were compared to evaluate any impact on downstream flood conditions from the modifications to the flood operations at Allatoona Dam. Appendix M describes the calculation procedure and presents the results in detail.

III. Description of Alternatives

The ACT Water Control Manual Update Study follows the National Environmental Policy Act (NEPA), (EPA, 1969[2000]) process toward the ultimate goal of adopting a new set of water management guidelines for the Corps projects in the ACT system. This requires comparison of anticipated effects due to a proposed new plan against those of a "no action alternative," (i.e., baseline conditions).

In October 2007, the Secretary of the Army directed the Corps to develop updated Water Control Plans and Manuals for the projects of the Alabama-Coosa-Tallapoosa (ACT) River Basin. (The Water Control Manuals for the individual projects are collectively referred to as the ACT Basin Master Water Control Manual or Master Manual.) In response to this directive, the Mobile District began the initial Environmental Impact Statement scoping process. The Corps current ACT Basin Master Manual is dated 1951. The update of the manual requires inclusion of additional projects constructed after 1951 and operational refinements to meet authorized project purposes. Various alternative system operations were developed to formulate a recommended plan. The study considers no physical improvements to the projects. The alternatives differ solely in the water management operations defined for the projects and inter-related assumptions regarding diversions.

A. Process of Developing Alternatives

Based upon many years of operational experience and extensive stakeholder input during scoping, the Corps identified numerous operational measures for possible consideration in the updated ACT Master Water Control Manual (WCM). These measures included variations for revising reservoir drawdown and refill periods, reshaping reservoir action zones, revising hydropower objectives, revising drought procedures and environmental flows, and developing navigation-specific operations.

The Corps used an iterative process to identify the various measures that would be further developed, analyzed, and refined toward the goal of developing an updated ACT Basin Master WCM. Using ResSim, the Corps modeled the effects of changing individual and multiple operational measures (for instance, revising hydropower generation objectives per action zone or reshaping action zones) at individual reservoirs and across the entire ACT system. The software provided data outputs (hydropower generation, reservoir levels, river flows and stages, etc.) across the entire hydrologic period of record (1939 – 2008) which were then evaluated for performance in terms of project and watershed criteria (channel availability, generation and capacity, reservoir recreation impact levels, and other authorized purposes, intended benefits, and existing uses within the system). Once results were reviewed, the operational measures were adjusted and retested until satisfactory results were obtained. This iterative process is shown graphically below (Figure 10).

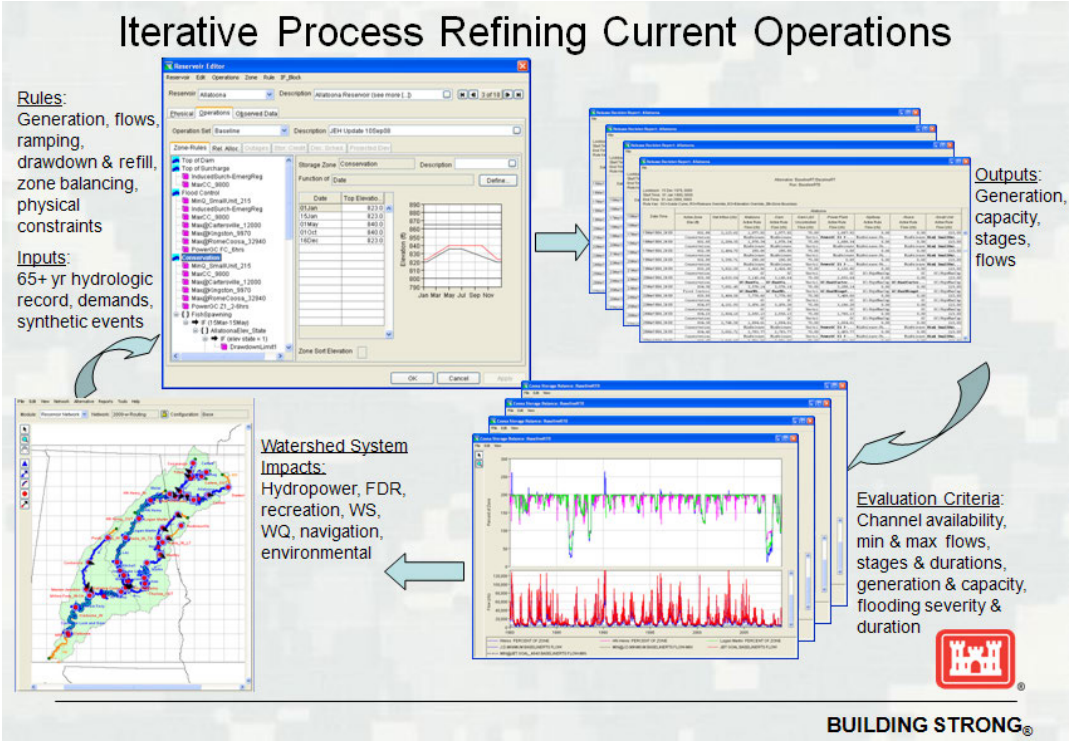


Figure 10. Development of Alternative Operating Plans

The modeling team and PDT considered each measure individually and iteratively refined it, then evaluated its performance in combination with other measures. Results were shared among team members, incorporating feedback on measure effectiveness from operational, environmental, and economic specialists. Ultimately, the updated WCM will reflect the combination of measures that balances system operations, meeting the various types of objectives.

B. Measures / Components of Alternative

The modeling process began with formulating a model of "Baseline" conditions, which reflects current operations. Then several alternative operations were modeled (Plan Alternatives) and contrasted with each other and the Baseline condition in effort to select a Recommended Plan. Each Alternative combines one or more measures, which reflect deviations from the Baseline condition in order to meet specific objectives. The measures considered are adjustments that meet system needs related to water supply, navigation support, fish and wildlife interest, drought plans, action zones, hydropower demand, seasonal minimum flow, and guide curve drawdown. The Baseline condition (current operations) and each measure are described in the following section.

1. Current Operations

On the basis of the nature of the proposed action, the No Action/Baseline Alternative represents no change from the current management direction or level of management intensity. This condition represents continuation of the current water control operations at each of the federal projects in the ACT Basin. The

Corps' operations have changed incrementally since completion of the 1951 ACT Master Manual. Except in very general terms, it is not possible to describe a single set of reservoir operations that apply to the entire period since completion of the 1951 ACT Master Manual.

Current operations include the following:

- Operations consistent with the Master Manual of 1951 and project-specific water control manuals. For the Corps, those manuals and their dates are: Allatoona Dam (1993), Carters Dam and Reregulation Dam (1975), Robert F. Henry Lock and Dam (1999), Millers Ferry Lock and Dam (1990), and Claiborne Lock and Dam (1993). For APC projects, the applicable manuals and their dates are Weiss Dam (1965), H. Neely Henry Dam (1979), Logan Martin Dam (1968), and Harris Dam (2003).

- The Corps continues to recognize that APC generates power under a FERC (Federal Energy Regulatory Committee) license, which requires specific operational actions. The FERC license could be amended in light of APC's request to modify winter pool levels at the Weiss Dam and Logan Martin Dam projects; however, the current operations do not include these modifications.

- The H. Neely Henry Dam, which operates under a revised guide curve, would return to operation under its original guide curve. The baseline condition (505' winter level) represents the rules and guidelines in the most recent water control manuals. HN Henry currently uses a temporary guide curve (507'winter level) approved by the Corps of Engineers (agreed to in 2003). It is anticipated that the interim guide curve (507') will become permanent at the conclusion of the ACT Basin manual update, by including as an alternative operation. Using the original guide curve (505') allows the PDT to perform an effects analysis. The NEPA documentation supporting the basin manual update provides the effects analysis required to remove the interim label.

- Specified flow requirements apply to several projects. Allatoona Dam and Carters Dam must provide for a 240 cfs minimum flow. The Corps must also ensure a minimum flow rate of 6,600 cfs from Claiborne Lake during normal conditions. The APC must ensure a 4,640 cfs release, measured at Montgomery, Alabama, for navigation during normal conditions.

- The Corps reserves a total of 19,511 AF of storage in Lake Allatoona for water supply. Of this, 6,371 AF is allocated to the city of Cartersville, Georgia, which is expected to provide (yield) 16.8 million gallons per day (mgd); and 13,140 AF is reserved for the Cobb County-Marietta Water Authority (CCMWA), which is expected to yield 34.5 mgd.

- The Corps reserves 818 AF in Carters Lake for water supply for the city of Chatsworth, Georgia, which is expected to yield 2 mgd.

- The Corps continues to manage fish spawning operations at Lake Allatoona, as outlined in the South Atlantic Division Regulation (DR) 1130-2-16, Project Operations, Lake Regulation and Coordination for Fish Management Purposes (USACE, 2001) and draft Standing Operational Procedure (SOP) Reservoir Regulation and Coordination for Fish Management Purposes (USACE, 2005a). During the largemouth bass spawning period, from March 15 to May 15, the Corps seeks to maintain generally stable or rising reservoir levels at Lake Allatoona. Generally stable or rising levels are defined as not lowering the reservoir levels by more than 6 inches, with the base elevation generally adjusted upward as levels rise from increased inflows or refilling of the reservoir.

2. Water Supply/Diversions

In developing its updated Water Control Manuals, the Corps considered the historic 2006 net water withdrawals through the ACT Basin and the existing water storage contracts for Allatoona and Carters (listed in Table 2).

Table 2. Net 2006 ACT Basin Withdrawals

Location	Storage Volume	Anticipated Yield
Allatoona		
CCMWA	13,140 AF	34.5 MGD
City of Cartersville	6371 AF	16.76 MGD
Carters		
City of Chattsworth	818 AF	2.0 MGD

Year 2006 represented the greatest annual amount through the 1939-2008 simulation period. The 2006 net water withdrawals are modeled as diversions, as described in Section II-F. Starting with average monthly values, average daily values were calculated for each month, resulting in a year of daily values. The values were repeated and applied to each calendar year in the simulation. In other words, the diversions for 1939 are the same as 2008 and every year in between. Each alternative used the same 2006 net withdrawal values. This measure remained the same for each alternative.

Each state provided the historical water use data for the 1980 to 2008 through the appropriate state agency. The Corps combined the data and prepared for inclusion into the ResSim model and development of the unimpaired flow. Annual total ACT net withdrawals for years 1994 to 2008 are presented in Figure 11 and year 2006 is the largest value. Consequently, each alternative includes the maximum historic water use year data with monthly variability.

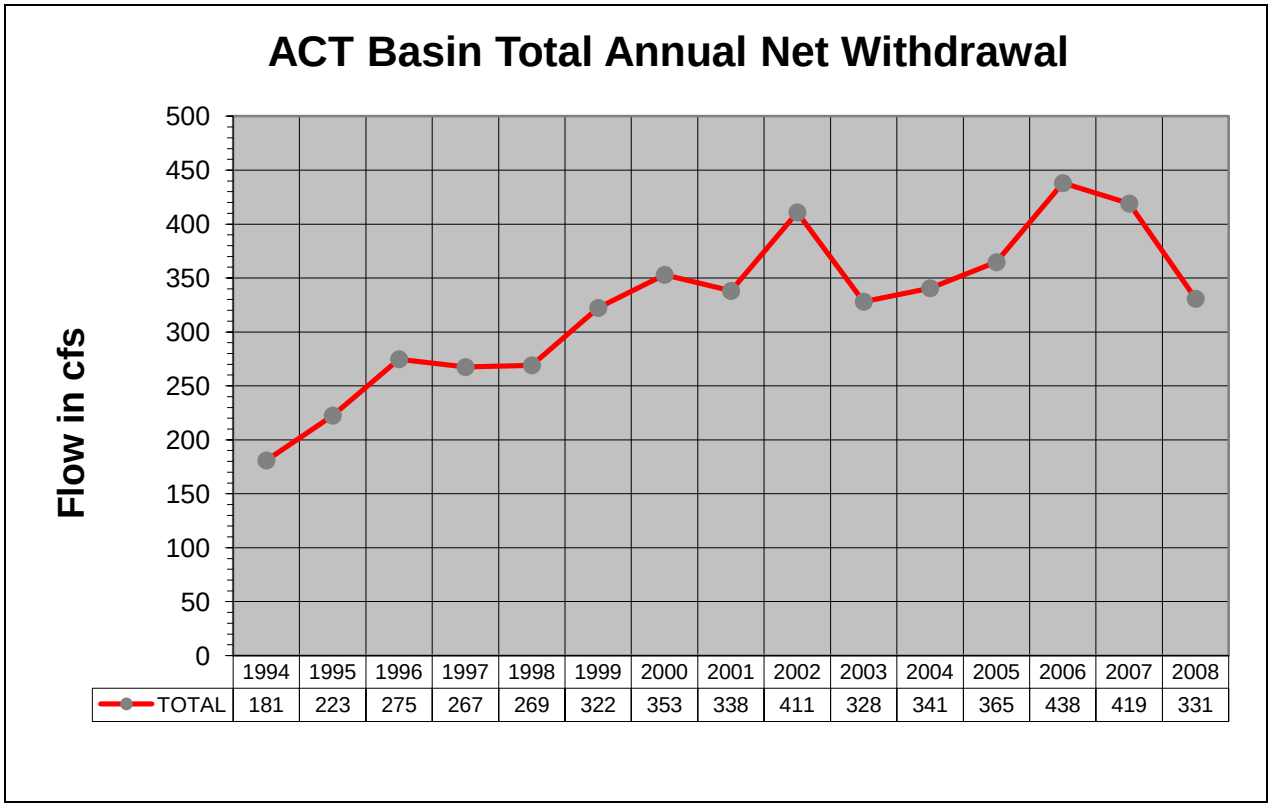


Figure 11. Annual ACT Net Withdrawals for Years 1994 to 2008

Monthly water withdrawals and returns of individual entities (users) are summed by model reaches to produce the net withdrawal. Modeled diversions from reservoirs (Section II-F, Method 1) and reaches (Section II-F, Method 2) are listed in Table 3. Figure 12 plots the monthly distribution of the 2006 withdrawal for the entire ACT Basin. Figure 13 plots the monthly diversion for the Weiss Dam reach.

Table 3. List of Diversions Modeled in ResSim

Diversion	Description
Reservoir Diversions (Method 1)	
Allatoona_IN_DIV	Allatoona diversion from inflow node
Carters_IN_DIV	Carters diversion from inflow node
Claiborne_IN_DIV	Claiborne diversion from inflow node
Harris_IN_DIV	Harris diversion from inflow node
HN Henry_IN_DIV	HN Henry diversion from inflow node
Jordan_IN_DIV	Jordan diversion from inflow node
Lay_IN_DIV	Lay diversion from inflow node
Logan Martin_IN_DIV	Logan Martin diversion from inflow node
Martin_IN_DIV	Martin diversion from inflow node
Millers Ferry_IN_DIV	Millers Ferry diversion from inflow node
Mitchell_IN_DIV	Mitchell diversion from inflow node
RF Henry_IN_DIV	RF Henry diversion from inflow node
Thurlow_IN_DIV	Thurlow diversion from inflow node
Weiss_IN_DIV	Weiss diversion from inflow node
Yates_IN_DIV	Yates diversion from inflow node
Reach Diversions (Method 2)	
Abv Alabama_Div	Reach 130T
Canton_Divs	Reach 164
Centreville_Divs	Reach 480
Coosa_Divs-1	Reach 130C
Coosa_Divs-2	Reach 131 (Wetumpka Water Works and Sewer Board waste water discharge)
Heflin_Divs	Reach 326
Kingston_Divs	Reach 158
Marion Junction_Divs	Reach 470
Newell_Divs	Reach 310
Resaca_Divs	Reach 170
Rome-Coosa_Divs	Reach 154E
Rome-Etowah_Divs	Reach 156
Rome-Oostanaula_Divs	Reach 154O ("Oh")
Selma_Divs	Reach 126
Tallapoosa_Divs	Reach 329
Tilton_Divs	Reach 386
Wadley_Divs	Reach 294

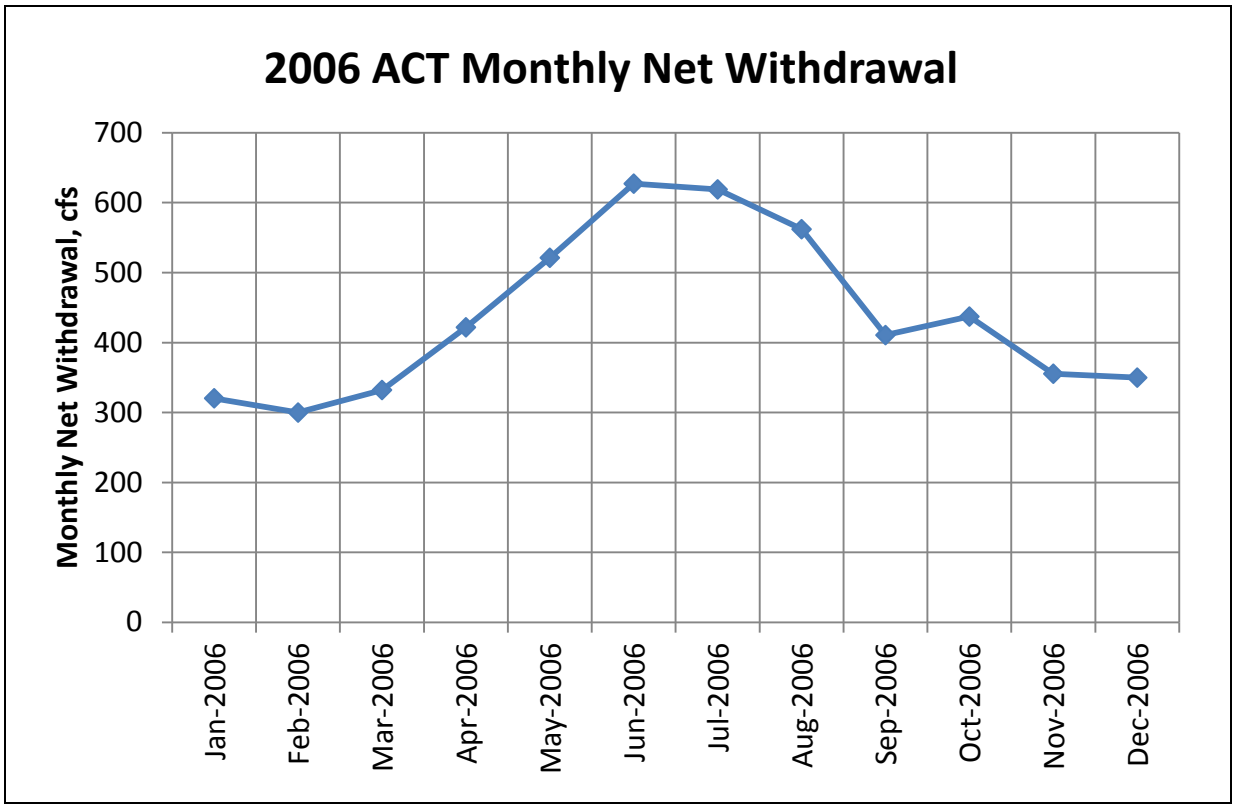


Figure 12. 2006 ACT Monthly Net Withdrawal

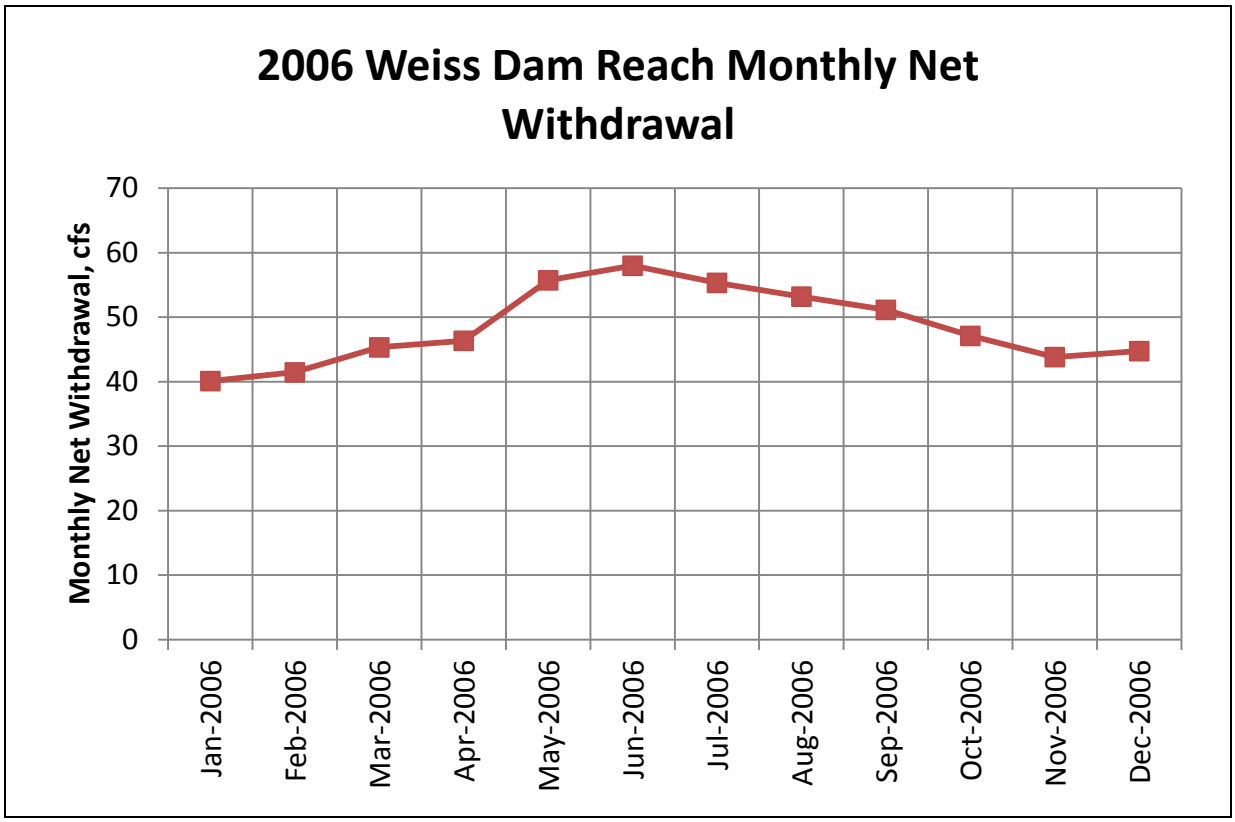


Figure 13. 2006 Weiss Dam Reach Monthly Net Withdrawal

3. Fish and Wildlife

Management measures considered for fish and wildlife operations were based on the following: recommendations provided by the USFWS in their Planning Aid Letter dated May 3, 2010; previous discussions with the USFWS; and, current Corps operations. The management measures considered by the Corps from the USFWS letter were the seasonally varying flows from Carters Reregulation Dam and changes in releases under the drought plan for the Tulatoma snail below Jordan Dam. The USFWS letter included recommendations for the development of alternatives and mitigation, hydrologic modeling, and methods used to evaluate the effects of Corps alternatives (USFWS, 2010). These recommendations were considered in updating the WCM.

The Corps would continue to manage fish spawning operations at Lake Allatoona, as outlined in the South Atlantic Division Regulation (DR) 1130-2-16, Project Operations, Lake Regulation and Coordination for Fish Management Purposes and draft standing operational procedure (SOP) Reservoir Regulation and Coordination for Fish Management Purposes (Mobile District SOP 1130-2-9, draft, February 2005). During the largemouth bass spawning period, from March 15 to May 15, the Corps seeks to maintain generally stable or rising reservoir levels at Lake Allatoona. Generally stable or rising levels are defined as not lowering the reservoir levels by more than 6 inches, with the base elevation generally adjusted upward as levels rise from increased inflows or refilling of the reservoir.

4. Navigation Support

The Corps considered several factors in developing options to support navigation on the ACT. First, it reviewed historic channel availability, flow depth patterns, and the relationship between basin inflows and storage usage in order to determine flows levels necessary to support navigation on the system. To accomplish this, the Corps also considered dredging impacts (timing and extent) during low and high flow periods. Since dredging typically occurs in the summer and fall months, less flow is required during these periods to provide the necessary channel depths. The Corps also examined storage relationships between Corps and APC projects, taking into account such factors as drainage areas, storage volumes, and historic contributions to flows. The following section describes examples of these analyses, from the initial development, to later, improved calculations.

The critical element to developing options that support navigation is the identification of flow values that will accommodate navigation on the system. Once these have been established, the next step is to develop rules to provide those flows. Figure 14, below, depicts the impact of dredging on flow requirements for different navigation channel depths during normal hydrologic conditions. A flow-depth template was developed based on reports of channel depths from navigation bulletins issued by the Mobile District (and associated

flows) and Claiborne tailwater gage readings. The bulletins report the tailwater readings several times during the year and the coincident associated navigation depths. The tailwater gage/navigation depth relation was assumed to be reasonably stable unless changed by high water or dredging. Temporary rating curves were developed from daily values for recent years 2005 and 2007 for both the high water season (Dec – May) and the low water season (Jul – Nov). For each year the two rating curves were used to develop flows required prior to dredging and after dredging for various channel depths. The 2006 year was not used because there was no dredging that year. The results were averaged to show the flow requirement for the years 2005 and 2007. The template is shown in Figure 14.

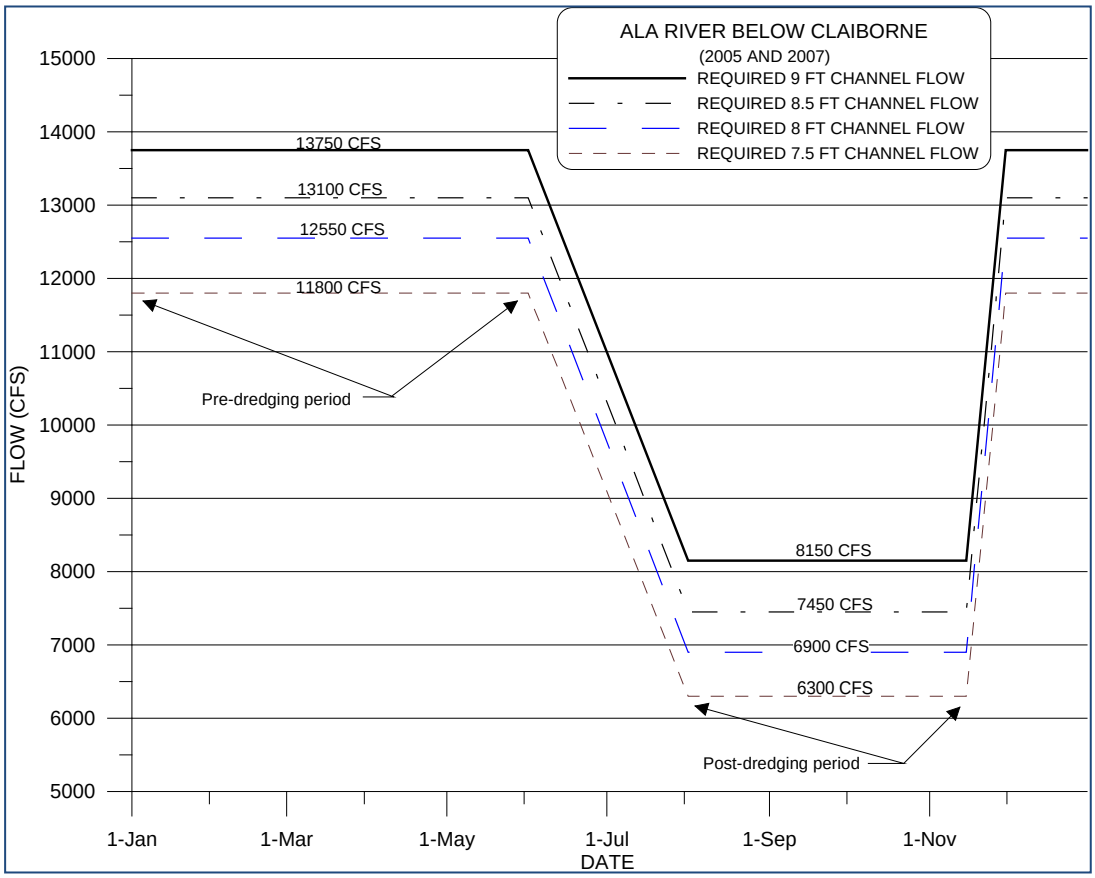


Figure 14. Flow-Depth Pattern with 2005-2007 Data

The template indicates that during the years 2005 and 2007, an average flow of 13,750 cfs was required during the high flow season prior to dredging to maintain a 9-ft channel and an average flow of 8150 cfs after dredging during the low flow season. The required flow in the high flow period is dependent on variables such as: shape and duration of prior flow hydrographs, extent of prior dredging, and extent of bank caving. During the low flow period, once the channel is restored to project conditions, the channel is reasonably stable if there is little flow to alter the depths. Such was the case in 2007, when the maximum flow after June was

only 6200 cfs. However, because of this, low flow project depths are not available even for a 7.5-ft draft vessel.

Because of the extreme low flow during the 2005-2007 period, a similar template, developed for the 1992-1994 period, is also presented. Note that this template was developed with data from relatively wet years. The template is shown below (Figure 15).

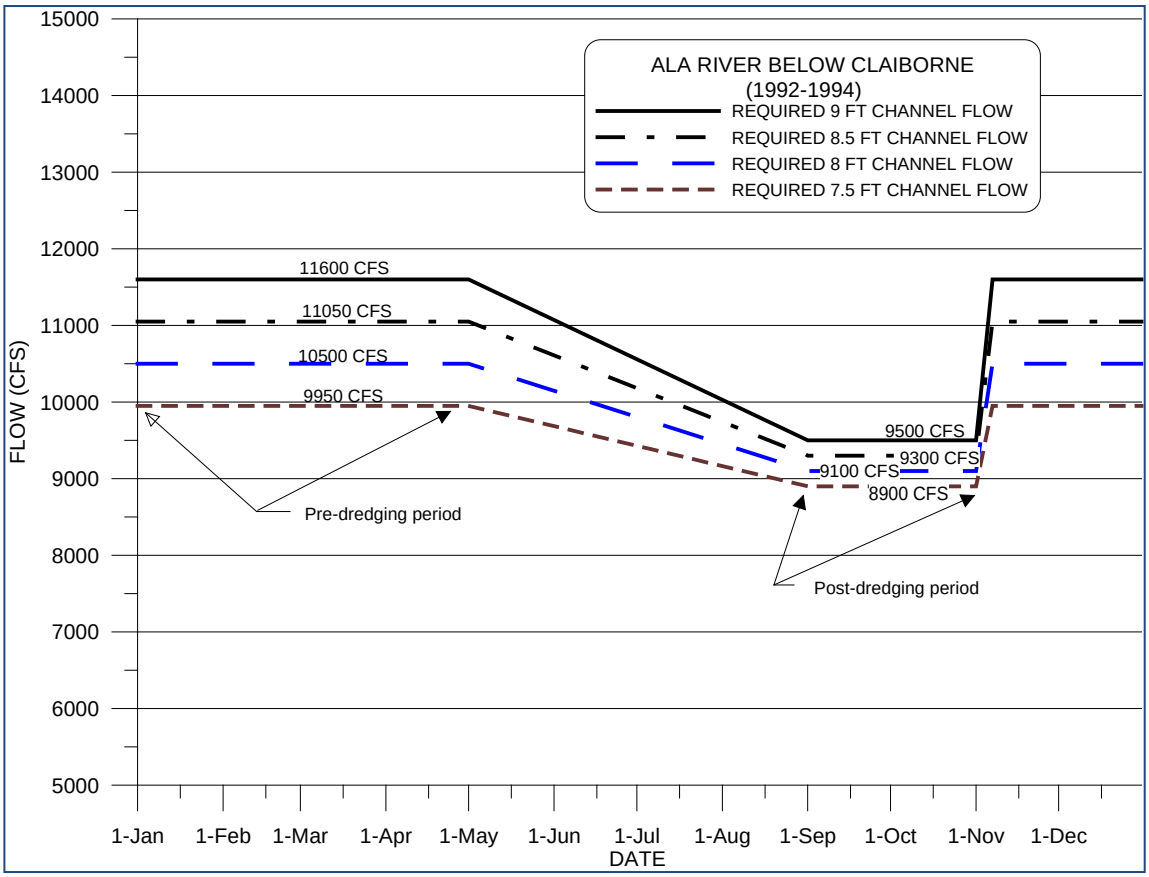


Figure 15. Flow-Depth Pattern from 1992-1994 Data

Figure 15 indicates that in order to achieve a 9-ft channel, a flow of 11600 cfs is required for the Jan – May pre-dredging period and a flow of 9500 cfs is required during the post-dredging season. The two flow-depth charts show the variance of flow required during different periods caused by the variance in the extent of the dredging program and flow patterns.

After careful consideration and discussions with the Corps navigation experts, the Navigation Template based on the 1992-1994 was selected as the navigation flow target for the Alabama River below Claiborne Lock and Dam (Table 4). Monthly flow targets for a 9-ft and 7.5-ft channel were incorporated into the alternatives to represent the system navigation demand. When a 9-ft channel cannot be met, the shallower 7.5-ft channel still allows for light loaded barges moving through the navigation system. This Navigation Flow Target measure remained the same for each alternative that included navigation.

Table 4. Monthly Navigation Flow Target in cfs for 9-ft and 7.5-ft Channel Depth

Month	9' Navigation Target	7.5' Claiborne Target
Jan	11600	9950
Feb	11600	9950
Mar	11600	9950
Apr	11600	9950
May	11100	9740
Jun	10600	9530
Jul	10100	9320
Aug	9600	9110
Sep	9100	8900
Oct	9100	8900
Nov	11600	9950
Dec	11600	9950

Historically, navigation has been supported by releases from storage in the ACT Basin. Another critical component of the navigation concept includes utilizing an amount of storage similar to the historic value, but in a more efficient manner. This can be accomplished by counting the natural flows towards the navigation target flow. By computing the anticipated volume of water stored during the wet period and released during dryer periods, the additional volume of water Mother Nature needs to provide to support navigation can be calculated. This is achieved by algebraically subtracting the storage usage from the navigation target. For example, for the month of November:

Required Flow to support Navigation = [Navigation Target] – [November storage usage]
Required Flow to support Navigation = [11,600 cfs] – [4,000 cfs] = 7,600 cfs.

Therefore, 7,600 cfs in total run-off above the Claiborne Lock and Dam is required to meet the 9 foot channel depth if an additional 4,000 cfs is released from storage. In real world conditions this natural run-off flow is subject to water use depletions and lake evaporative losses. Instead of this natural flow we use Basin Inflow in the calculation. Basin Inflow is natural flow adjusted to reflect the influences of reservoir evaporative losses, inter-basin water transfers, and consumptive water uses, such as municipal water supply and agricultural irrigation. The revised equation is listed below:

Required *Basin Inflow* to support Navigation = Navigation Target – November storage usage
where: *Basin Inflow* = Natural inflow – evaporation – diversions.

Therefore, 7,600 cfs is the total Basin Inflow above the Claiborne Lock and Dam required to meet the 9-ft channel depth if 4,000 cfs is released from storage. Figure 16 depicts historic storage usage by project on a monthly basis from 1982 to 2008.

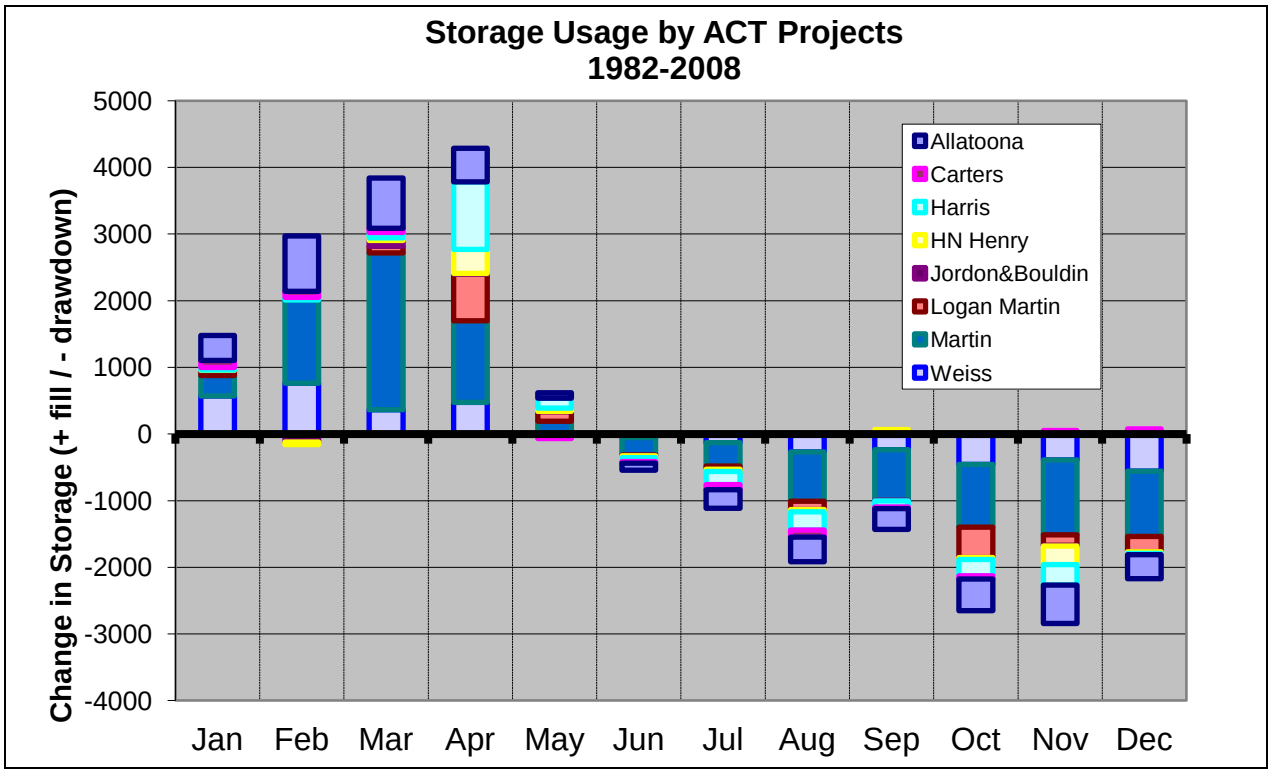
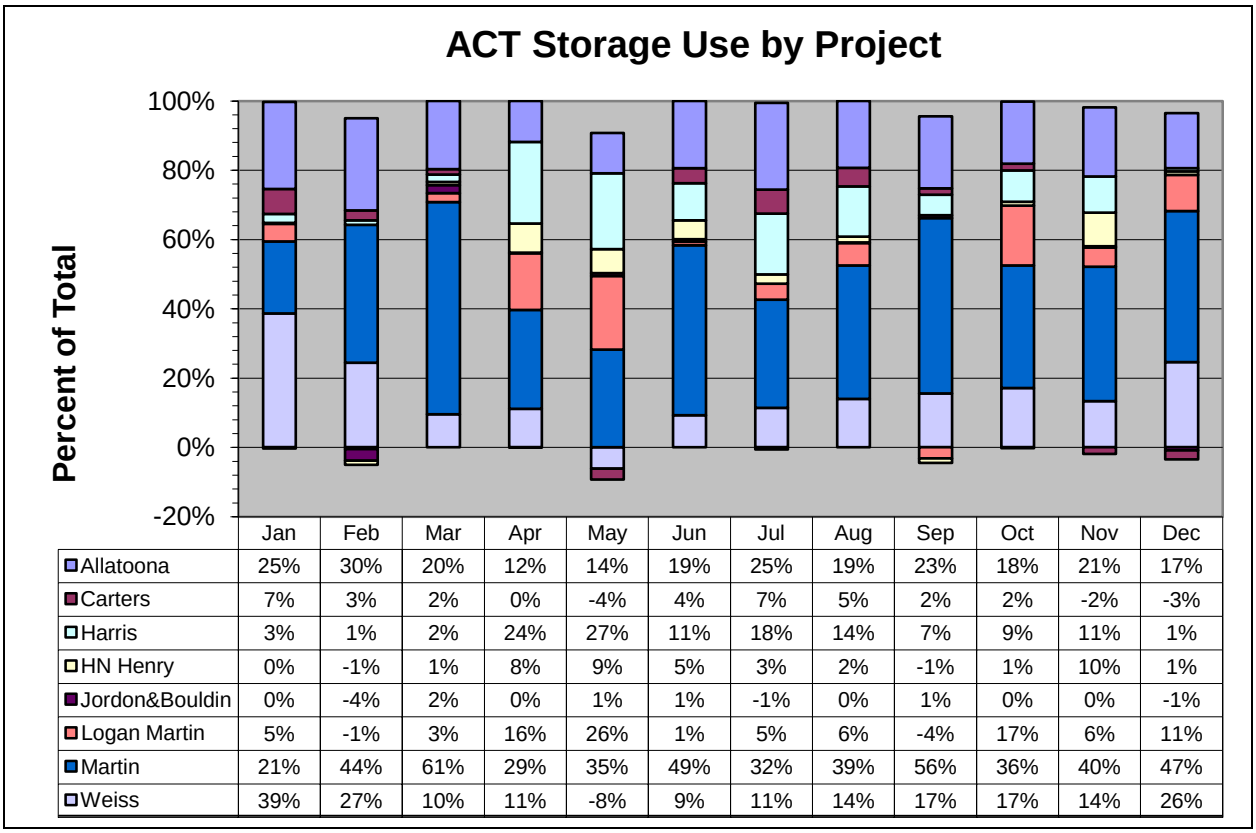


Figure 16. Average Monthly Storage Usage by ACT Projects, 1982-2008

Currently, there is no required contribution of storage usage by project within the basin to meet navigation. Each project operates to meet its project purposes. Since 1972, APC projects on the Coosa and Tallapoosa Rivers have included operations to meet a minimum 7-day average flow of 4,640 cfs from the two basins. At the time of the 1972 agreement between the Corps and APC, the 4,640 cfs was designated to provide for full navigation on the Alabama River. The 7-day average flow of 4,640 cfs is based on the 7Q10 flow of the USGS gage below Claiborne Lock and Dam (6500 cfs), prorated on the basis of the portion of the total drainage area controlled above the APC projects. APC has the discretion to use storage from any of its projects to meet the 4,640 cfs flow requirement when inflow into system is less than 4,640 cfs. Allatoona and Carters are not regulated specifically for navigation. However, all water released from Allatoona and Carters contributes to inflow into Weiss Dam, the most upstream project on the Coosa system, and therefore, indirectly contributes to meeting the downstream navigation target. The Corps lock and dam projects on the Alabama River (RF Henry, Millers Ferry, and Claiborne) are authorized for navigation, but these are run-of-river projects with inadequate storage to support navigation.

Figure 17 depicts historic storage usage by project on a monthly basis from 1982 to 2008 as percentages. The largest Corps project, Allatoona, ranges from 12% to 30% storage usage during filling and 17% to 25% during drawdown periods. Martin, the largest APC project, ranges from 21% to 61% storage usage during filling and 32% to 56% during drawdown period. Figure 18 depicts the ACT individual project contribution to the system total conservation storage. The Corps total contribution is 19 percent and the remaining 81 percent is from Alabama Power Company projects.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Allatoona	25%	30%	20%	12%	14%	19%	25%	19%	23%	18%	21%	17%
Carters	7%	3%	2%	0%	-4%	4%	7%	5%	2%	2%	-2%	-3%
Harris	3%	1%	2%	24%	27%	11%	18%	14%	7%	9%	11%	1%
HN Henry	0%	-1%	1%	8%	9%	5%	3%	2%	-1%	1%	10%	1%
Jordon&Bouldin	0%	-4%	2%	0%	1%	1%	-1%	0%	1%	0%	0%	-1%
Logan Martin	5%	-1%	3%	16%	26%	1%	5%	6%	-4%	17%	6%	11%
Martin	21%	44%	61%	29%	35%	49%	32%	39%	56%	36%	40%	47%
Weiss	39%	27%	10%	11%	-8%	9%	11%	14%	17%	17%	14%	26%

Figure 17. ACT Storage Use by Project as Percent of Total

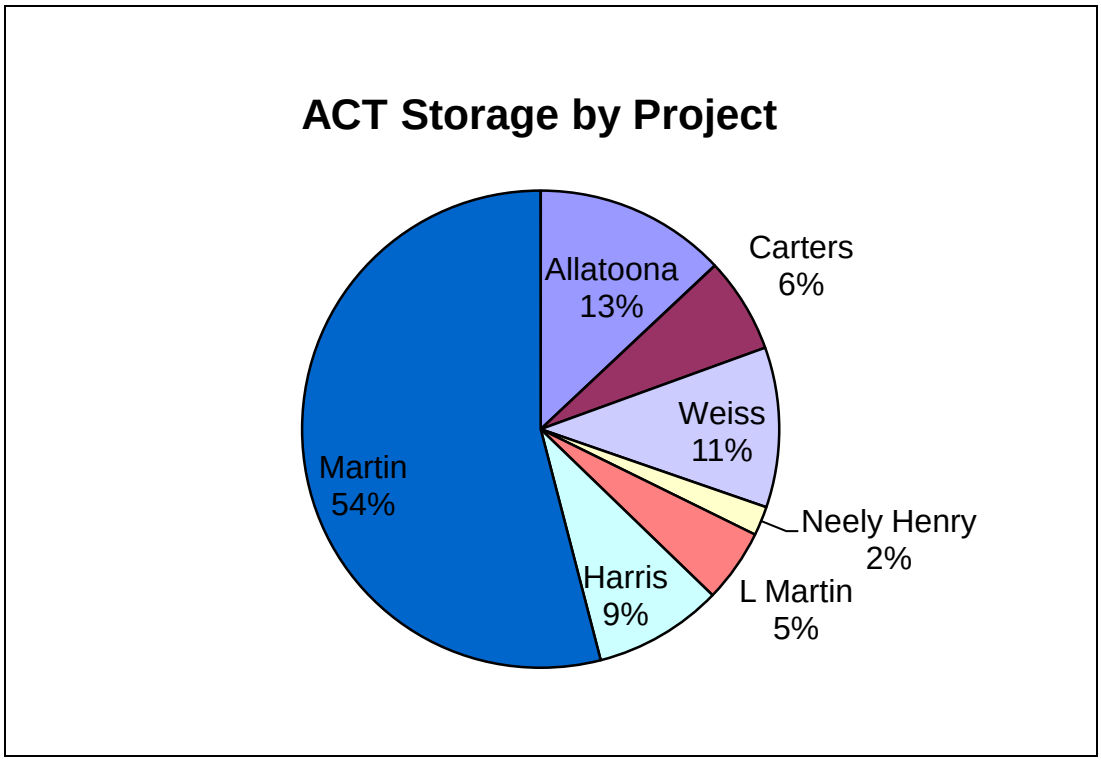


Figure 18. ACT Conservation Storage by Project as a Percent of Total Conservation Storage

Table 5 lists project annual storage usage from 1982 to 2008 and individual project storage contribution to total system storage as percentages. As previously stated, there is no required contribution of storage usage by projects within the basin. Values in Table 5 indicate the annual average project storage usage from 1982 to 2008 is similar to contribution of total storage.

Table 5. Comparison of Project Contribution to System Storage and Storage Usage by Project

Project	ACT Storage Usage by Project (1982-2008)	Contribution to Total System Conservation Storage
Allatoona	20%	13%
Carters	2%	6%
HN Henry	3%	2%
Harris	11%	9%
Logan Martin	8%	5%
Martin	41%	54%
Weiss	16%	11%

The Basin Inflow required to support navigation was modified to remove Allatoona and Carters storage usage. There are two reasons for the revision. First, navigation is not an authorized project purpose for Allatoona and Carters. Second, because they are subject to congressional action, federal projects are more likely to experience future changes in storage usage than are the APC projects. Linking the basin inflow to an expected storage usage from federal projects may require a reciprocating change in storage usage from Alabama Power projects. In other words, if the navigation target remains the same and there is a reduction in releases from the federal projects due to congressional action, then there could be an expected increase in storage usage from Alabama Power projects. As stated earlier a critical component of the navigation concept includes utilizing similar historic storage usage amount. This is now refined to utilize similar historic storage usage only at Alabama Power projects, and this revision would allow for alternatives that change the historic storage usage at Allatoona and Carters.

Figure 19 depicts historic storage usage by APC projects on a monthly basis from 1982 to 2008.

So, the Basin Inflow computation is updated below:

Monthly Required Basin Inflow to support Navigation
= Monthly Navigation Target – Monthly APC storage usage

This Basin Inflow now becomes the monthly flow levels necessary to support navigation on the system.

Figure 20 depicts channel reliability based on natural flows and APC historic use of storage.

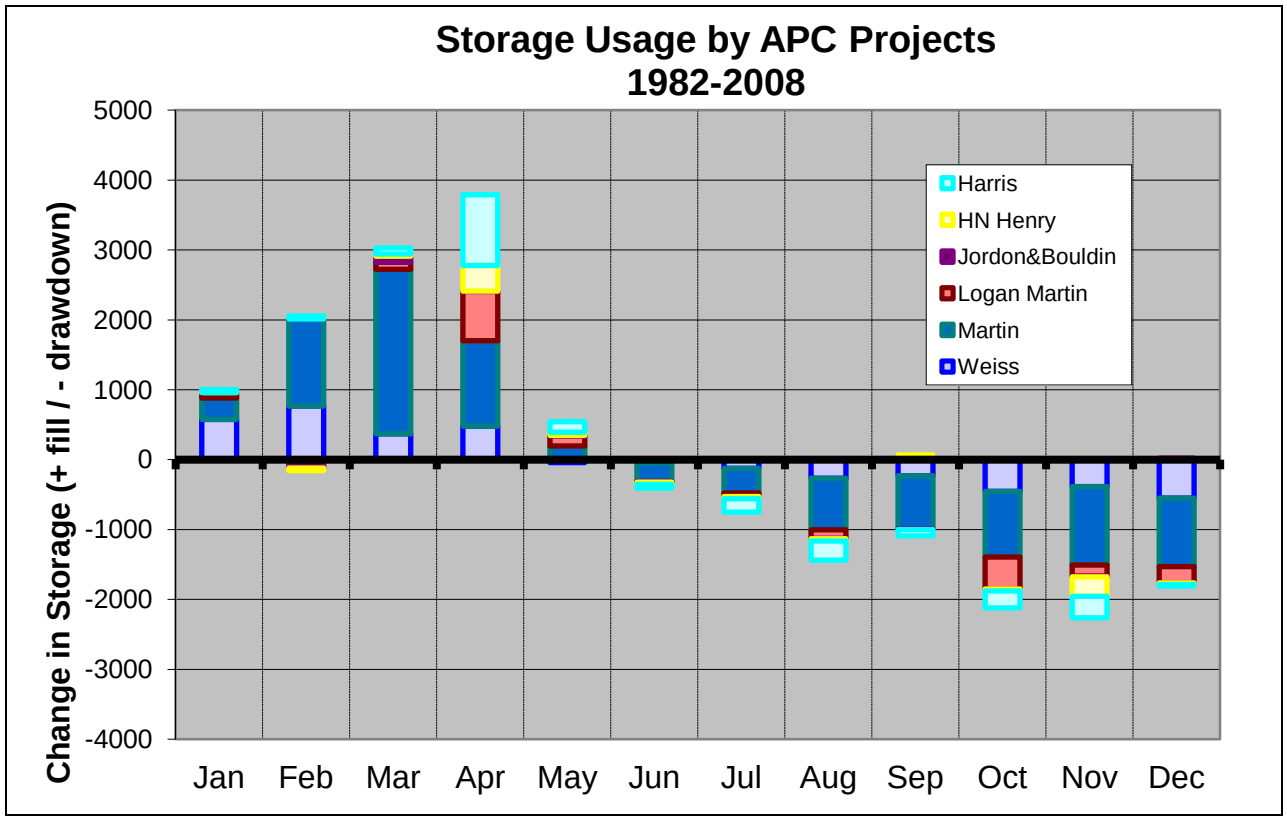
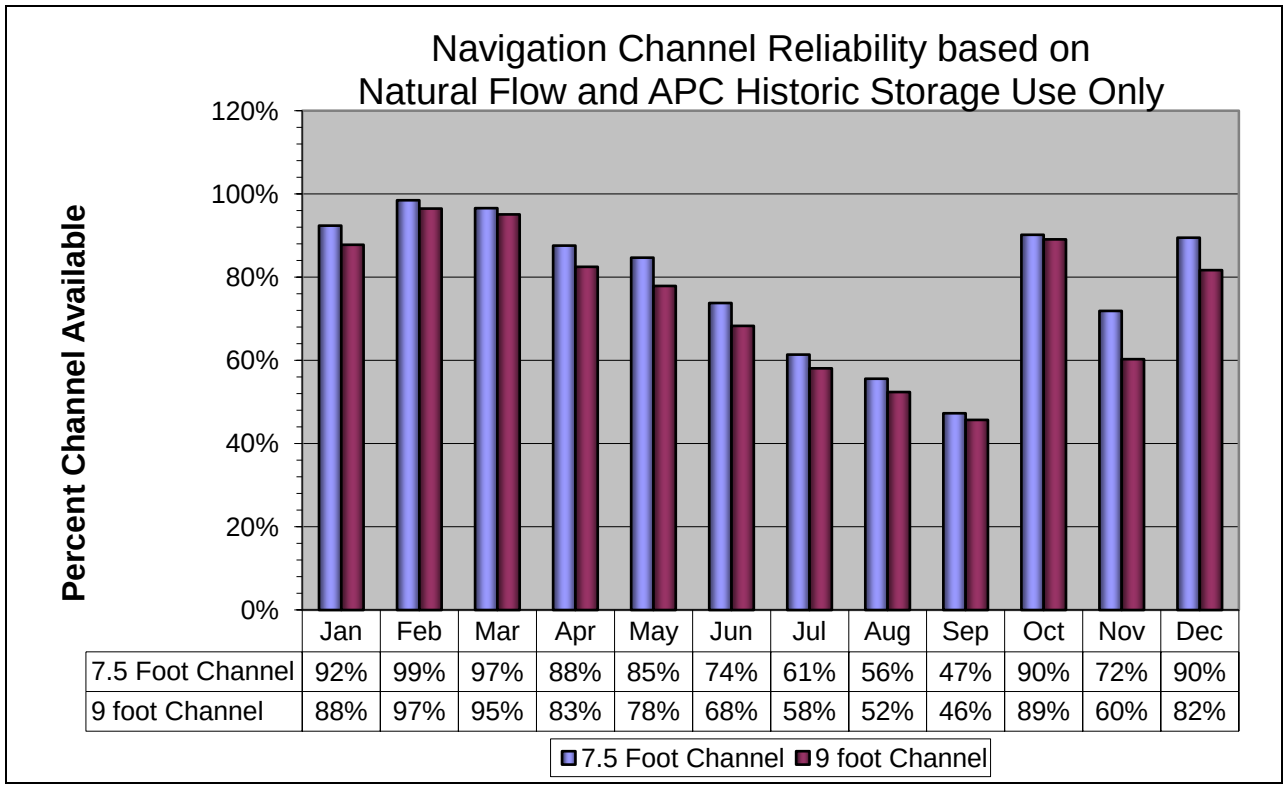


Figure 19. Average Monthly Storage Usage by Alabama Power Projects, 1982-2008



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7.5 Foot Channel	92%	99%	97%	88%	85%	74%	61%	56%	47%	90%	72%	90%
9 foot Channel	88%	97%	95%	83%	78%	68%	58%	52%	46%	89%	60%	82%

Figure 20. Navigation Channel Reliability based on Natural Flow and APC Historic Storage

With this backdrop, the Corps, in coordination with APC, developed a navigation operation based upon basin inflows and average storage usage by APC (e.g., navigation operations would not be predicated on use of additional storage) during normal hydrologic conditions. The Corps also examined the feasibility/impacts of varying channel depths (9.0-ft and 7.5-ft) during these conditions. Under this concept, the Corps and APC make releases for navigation when basin inflows meet or exceed seasonal targets for either the 9.0-ft or 7.5-ft channel templates. Triggers were also identified (e.g., when basin inflow are less than required natural flows) to change operational goals between the 9.0-ft and 7.5-ft channels. Similarly, basin inflow triggers were identified when releases for navigation will be suspended and only 7Q10 (4,640 cfs) releases will occur. During drought operations, releases to support navigation will be suspended until system recovery occurs as defined in the basin Drought Plan.

In order to determine the APC navigation flow requirements, navigation targets were prorated similarly to the proration of Claiborne Lock and Dam 7Q10 flow. Table 6 lists the monthly APC navigation flow targets to support a 9-ft and 7.5-ft channel.

Table 6. Prorated Claiborne Navigation Target at JBT Goal

Month	9' Navigation Target	**9' JBT Goal Target**	7.5' Claiborne Target	**7.5' JBT Goal Target**
Jan	11600	**9280**	9950	**7,960**
Feb	11600	**9280**	9950	**7,960**
Mar	11600	**9280**	9950	**7,960**
Apr	11600	**9280**	9950	**7,960**
May	11100	**8880**	9740	**7,792**
Jun	10600	**8480**	9530	**7,624**
Jul	10100	**8080**	9320	**7,456**
Aug	9600	**7680**	9110	**7,288**
Sep	9100	**7280**	8900	**7,120**
Oct	9100	**7280**	8900	**7,120**
Nov	11600	**9280**	9950	**7,960**
Dec	11600	**9280**	9950	**7,960**

The historic storage usage by APC projects on a monthly basis from 1982 to 2008 (Figure 19) is then used compute the required Basin Inflow above APC projects to support navigation. This now becomes the monthly flow levels or triggers that determine when APC must make releases to support navigation on the system. Table 7 lists, and Figure 21 plots, the required Basin Inflow for a 9-ft channel. Table 8 lists, and Figure 22 plots, the required Basin Inflow for a 7.5-ft channel.

Table 7. Basin Inflow above APC Projects Required to Meet 9-ft Navigation Channel

Month	APC Navigation Target	Monthly Historic Storage Usage	Required Basin Inflow
Jan	9,280	-994	**10,274**
Feb	9,280	-1894	**11,174**
Mar	9,280	-3028	**12,308**
Apr	9,280	-3786	**13,066**
May	8,880	-499	**9,379**
Jun	8,480	412	**8,068**
Jul	8,080	749	**7,331**
Aug	7,680	1441	**6,239**
Sep	7,280	1025	**6,255**
Oct	7,280	2118	**5,162**
Nov	9,280	2263	**7,017**
Dec	9,280	1789	**7,491**

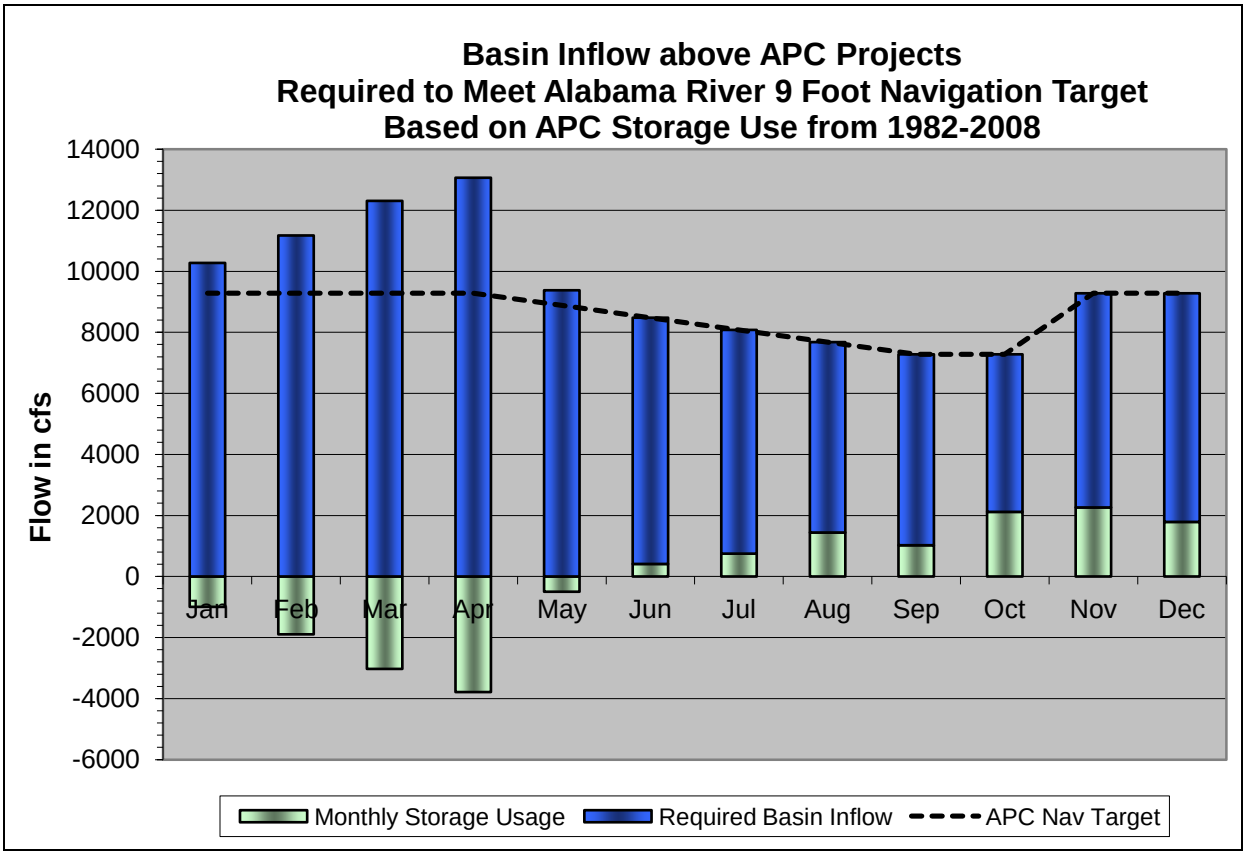


Figure 21. Basin Inflow above APC Projects Required to Meet 9-ft Navigation Channel

Table 8. Basin Inflow above APC Projects Required to Meet 7.5-ft Navigation Channel

Month	APC Navigation Target	Monthly Historic Storage Usage	Required Basin Inflow
Jan	7,960	-994	**8,954**
Feb	7,960	-1,894	**9,854**
Mar	7,960	-3,028	**10,988**
Apr	7,960	-3,786	**11,746**
May	7,792	-499	**8,291**
Jun	7,624	412	**7,212**
Jul	7,456	749	**6,707**
Aug	7,288	1,441	**5,847**
Sep	7,120	1,025	**6,095**
Oct	7,120	2,118	**5,002**
Nov	7,960	2,263	**5,697**
Dec	7,960	-994	**8,954**

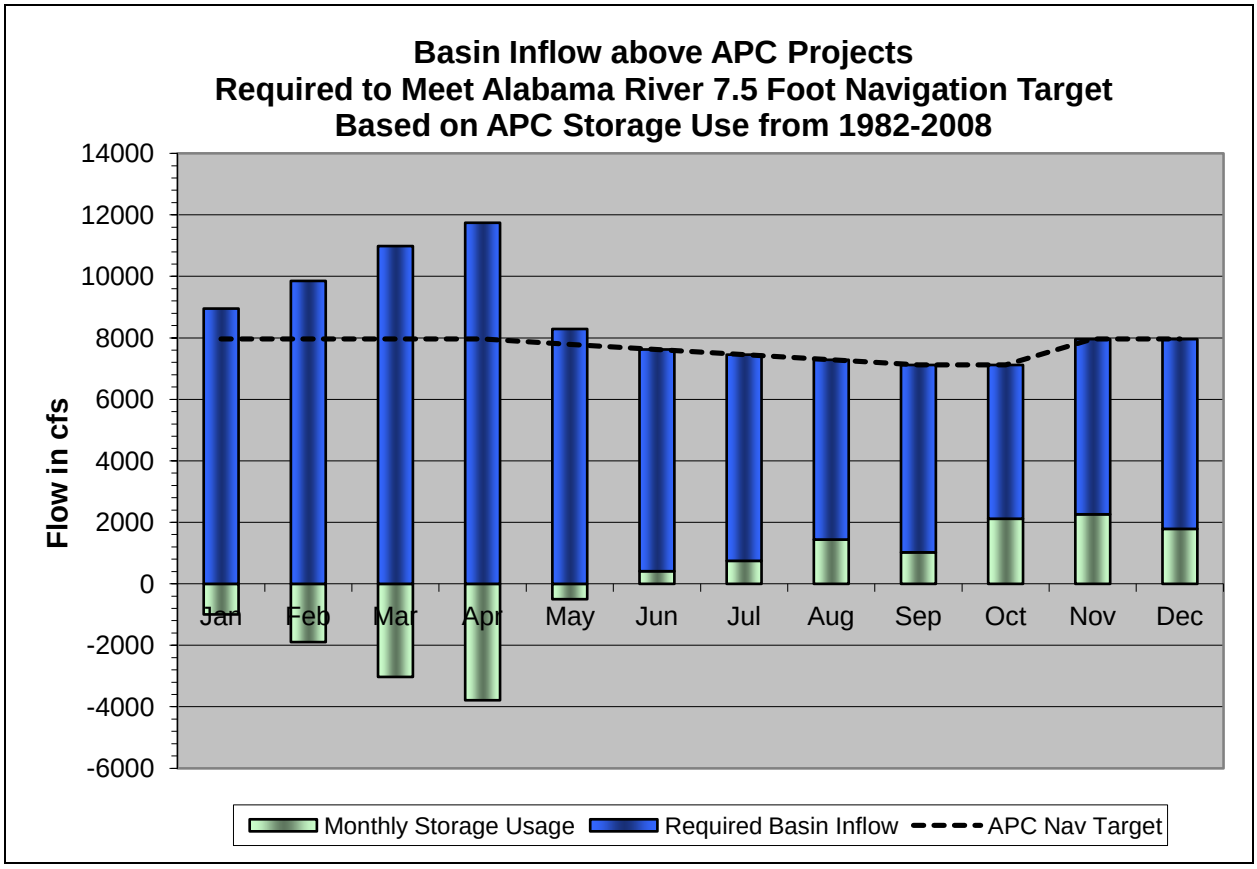


Figure 22. Basin Inflow above APC Projects Required to Meet 7.5-ft Navigation Channel

The Basin Inflow trigger for navigation operation is the sum of regulated local flows above each APC project. Figure 23 is a map indicating the local flow above the APC projects. For Weiss, the net inflow is used, which, unlike the Basin Inflow calculated for determining the Drought Intensity Level, includes regulated flows from Carters and Allatoona. These observed local flows include the effects of depletions and lake evaporative losses. The basic equation is:

$$\text{Basin Inflow}_{\text{Navigation}} = \text{Sum of Weiss Inflow} + \text{APC Unimpaired Local flows (below Weiss)}$$

The same calculation, as implemented in ResSim, using ResSim variables is as follows:

$$\text{Basin Inflow}_{\text{Navigation}} = \text{Jordan UNREG} + \text{Thurlow UNREG} - \text{Weiss UNREG} + \text{Weiss Net Inflow} - \text{APC lake evaporation (below Weiss)}$$

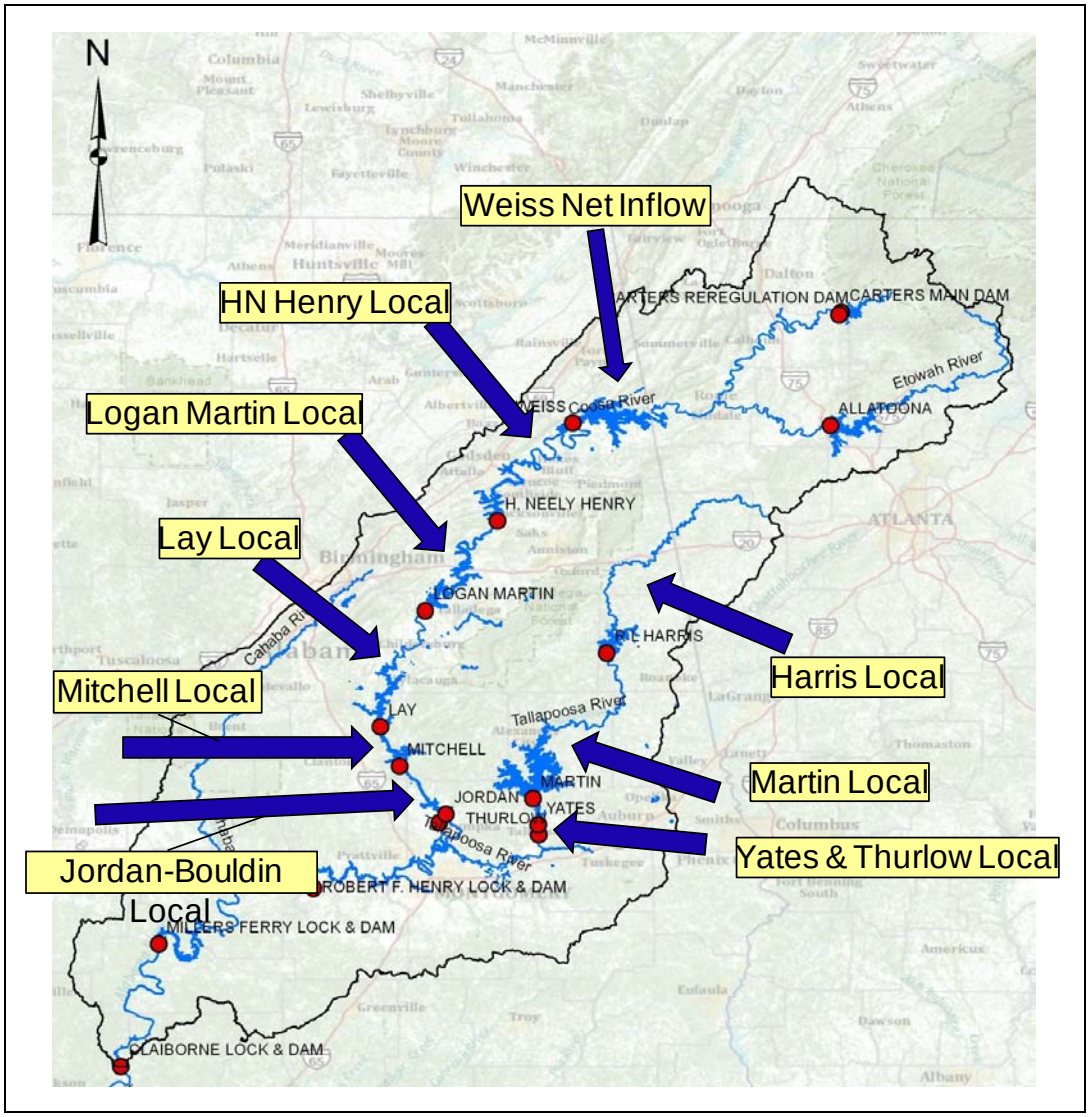


Figure 23. Local Flows above APC Projects

5. Carters Dam Measures

a. Seasonally Varying Flow

The Corps considered changing minimum flow releases from the Carters Reregulation (ReReg) dam, which were a constant 240 cfs, to a seasonally variable requirement. For example, see the Figure 24 plot of monthly flow values considered, which were based on a 2003 study of impacts of revised ReReg minimum flows. Coordination with US Fish and Wildlife Service (FWS) in 2003 indicated a USFWS desire that releases from the Carters Reregulation Dam be revised to mimic a more natural flow regime to benefit the aquatic ecosystem in the Coosawattee River downstream of the Carters Reregulation Dam.

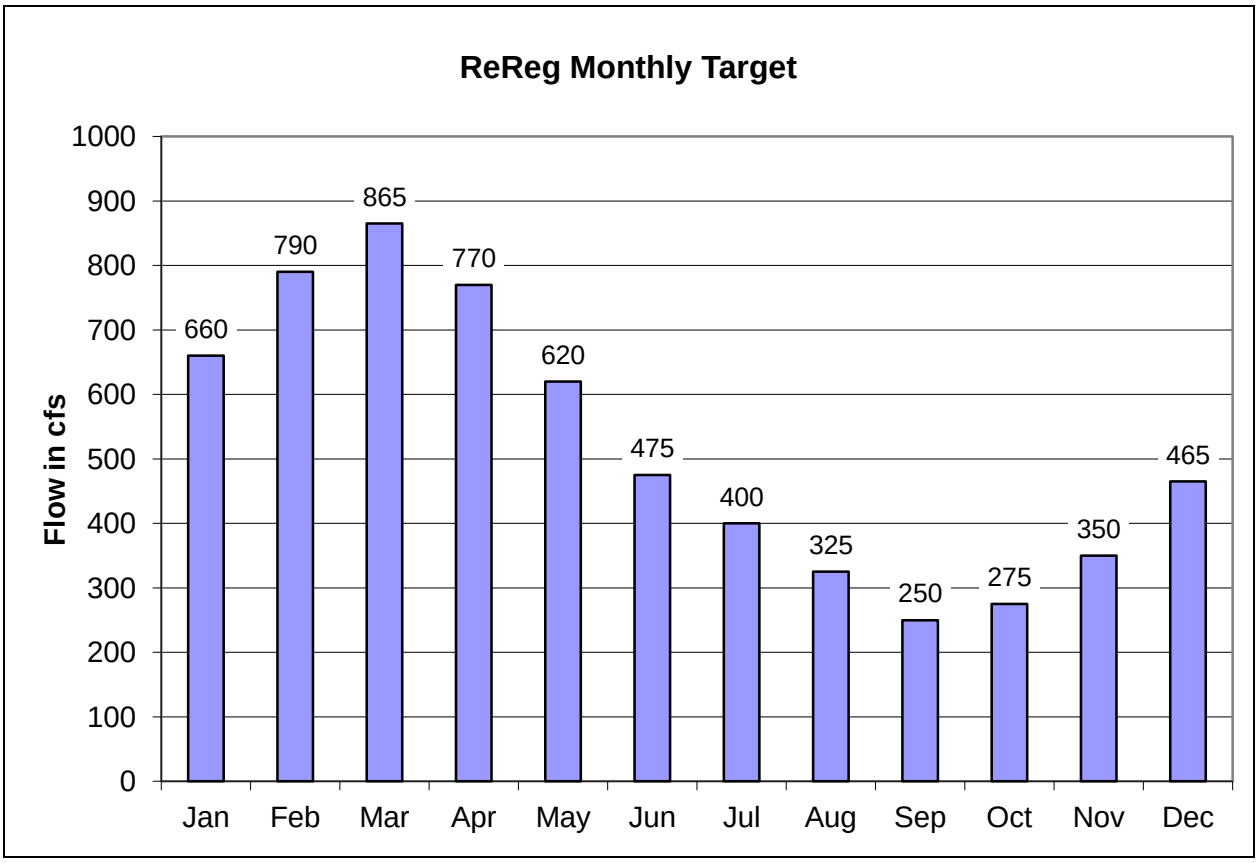


Figure 24. Carters Reregulation Dam Monthly Flow Target

b. Action Zones

The conservation pool of Carters was divided into two different zones - Zone 1 and below it, Zone 2. Once Zone 2 is entered, the seasonally-varying minimum flow is changed to the constant (and lesser) 7Q10 flow of 240 cfs. These zones are used to manage the lakes at the highest level possible for project purposes that benefit from high lake levels. The actions zones also provide guidance on meeting minimum hydropower

needs at the project, as well as to determine the amount of storage available for water quality and environmental flows. The Zone1 / Zone 2 boundary represents a change in monthly minimum flow requirement from the Carters/Carters Reregulation Dam System. The seasonal varied flow is reduced to the constant 7Q10 flow. Zone 2 guide curve follows the pattern of the computed 20th percentile pool elevation (for period 1975-2010). Flow and stage that are less than the 20th percentile are typically classified as low flow or dry conditions for hydrological analysis. Refinements were made so that Zone1 would represent the need for flow augmentation. In other words, the volume of Zone 1 increased during periods of greatest demand in the fall (Sep-Oct) period. Zone 2 represents an operational response to drought conditions and guide curve shaped by historic low flow conditions at the lake. Zone1 guide curve is the original top of conservation guide curve with fixed dates to raise pool during spring and lower pool during fall.

c. Guide Curve Definition

The Corps considered formalizing the guide curve transitions that delineate winter and summer reservoir levels. The existing Carters manual describes a specific summer and winter level, but no exact date to transition from winter to summer or summer to winter. The transition date is selected based on many years of operational experience.

6. Allatoona Dam Measures

a. Action Zones

The 2007-2009 drought period revealed a need to further refine the reservoir operation to reduce the depletion of storage in drought period. Baseline operations include two action zones at Allatoona. The action zones are used to manage the lake levels at the highest level possible and provide guidance on meeting minimum project purposes as the storage is utilized.

Three variations of the actions zones at Allatoona Dam were developed. The first, called “Burkett,” adds two additional action zones, for a total of four (Figure 25). These action zones were derived by evaluating the historic demand for hydropower. There is a distinctive seasonal demand for the hydropower, with highest demand occurring June through August. The top of Zone 2 is revised to have a similar shape to the average pool elevation. This allows for greater generation when storage is above Zone 2 during above normal conditions. The storage in Zone 3 is used to provide reliable hydropower without depleting storage. Zone 4 represents a drought level zone where only minimum flow requirements are released.

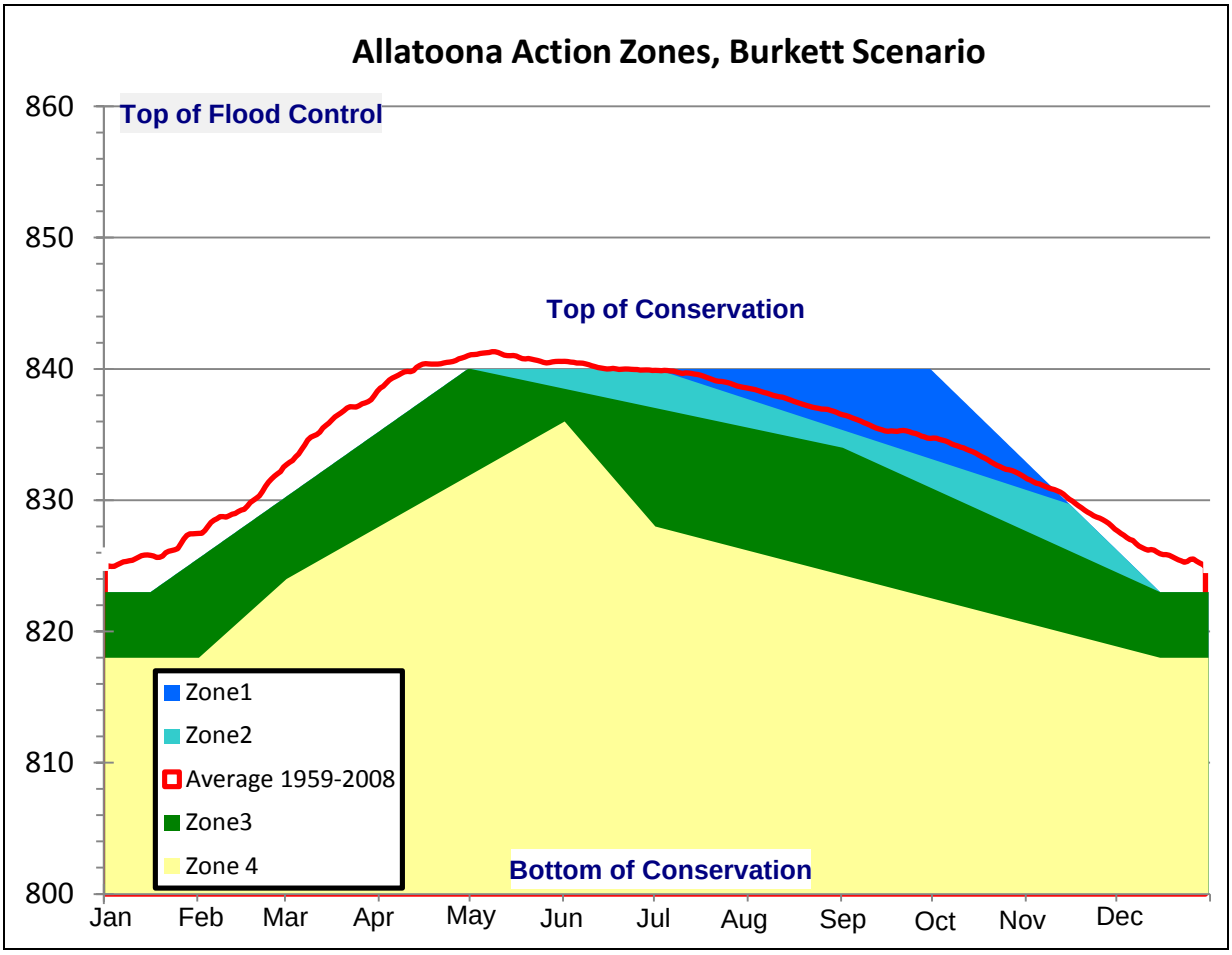


Figure 25. Burkett Allatoona Action Zone Scenario

An alternative operating scenario, "Drago A," adds only one additional action zone for a total of three (Figure 26). Action zones 1 and 2 are not changed. New Zone 3 is a drought level zone wherein only minimum flow requirements are released. The shape of Zone 3 is based on the reservoir operation during the recent 2007 drought period.

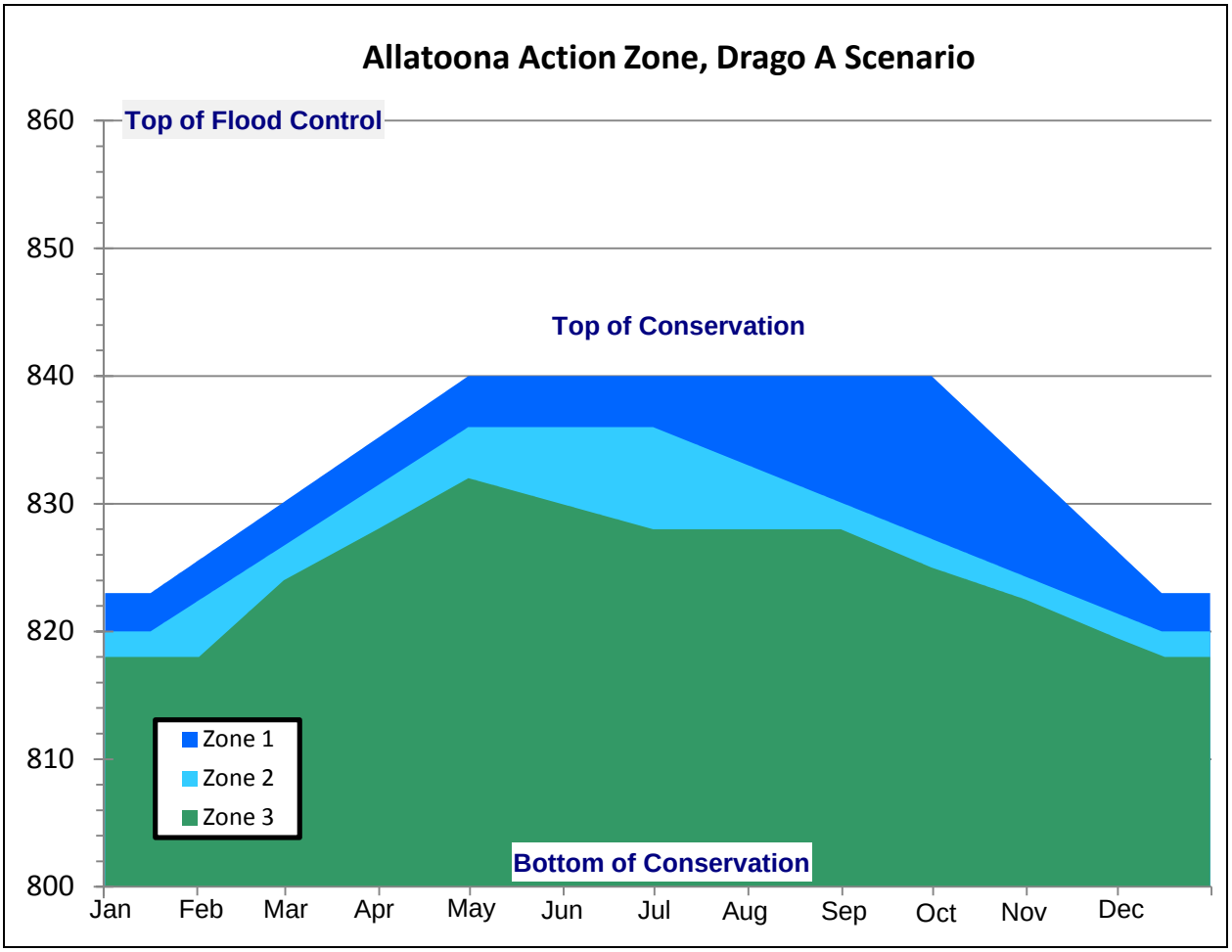


Figure 26. Drago A Allatoona Action Zone Scenario

A third operating scenario, “DragoB," is like DragoA in that it also adds one additional action zone for a total of three (Figure 27). Action Zones 1 and 2 are not changed. New Zone 3 is a drought level zone wherein only minimum flow requirements are released. The shape of Drago B’s Zone 3 is similar to Zone 2.

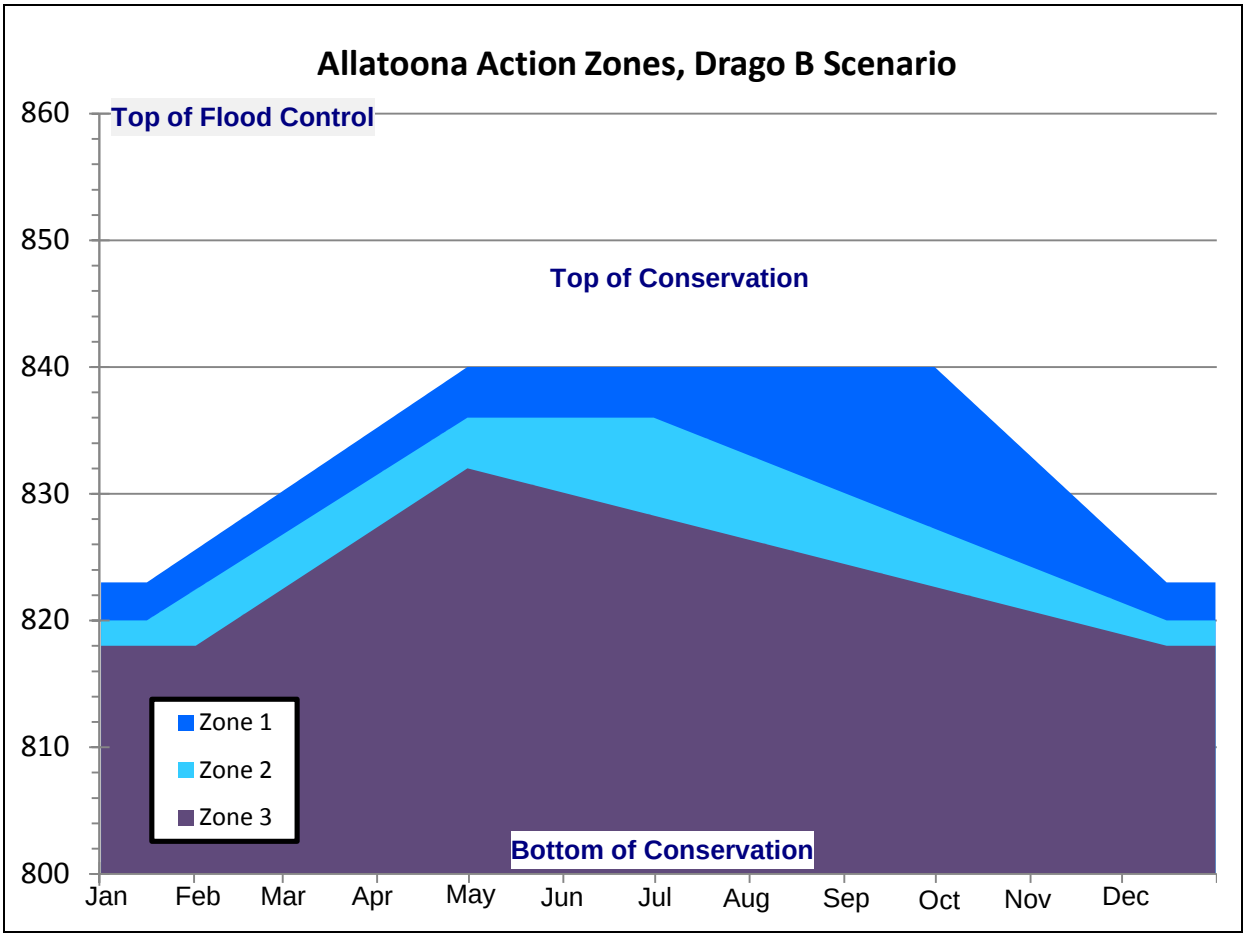


Figure 27. Drago B Allatoona Action Zone Scenario

b. Hydropower Requirement

The Corps also uses the action zones to provide guidance on meeting minimum hydropower needs at Allatoona. The minimum hydropower is represented by a range of peaking hours, depending on the hydrologic condition of the basin. Consistent with Corps conservative reservoir operation, the lower value of the hydropower range is used during low flow drought condition and recovery from droughts. When storage enters lowest zone, peaking hydropower operation is suspended and releases are made to meet the minimum 7Q10 flow release of 240 cfs. There are a total of four hydropower scenarios considered, three for the Burkett Action Zone scenarios and one for the Drago Action Zone scenarios (Table 9 through Table 12). The highest number of hours in each zone is used in the model to simulate the hydropower requirement. The range of hydropower peaking hours allows for flexibility in actual reservoir operation and is not captured in the modeling effort for the manual update.

Table 9. Burkett Hydropower Scenario

Zone	Hours	Minimum Q (cfs)
Zone 1	0-6	240
Zone 2	0-4	240
Zone 3	0-2	240
Zone 4	0	240

Table 10. Burkett B and Burkett C Hydropower Scenario

Zone	Hours	Minimum Q (cfs)
Zone 1	0-4	240
Zone 2	0-3	240
Zone 3	0-2	240
Zone 4	0	240

Table 11. Burkett D Hydropower Scenario**

Zone	Hours	Minimum Q (cfs)
Zone 1	0-4	240
Zone 2	0-3	240
Zone 3	0-2	240
Zone 4	0	240

**Reduced hydropower demand during Sep-Nov period

Table 12. DragoA and DragoB Hydropower Scenario

Zone	Hours	Minimum Q (cfs)
Zone 1	2-6	240
Zone 2	0-2	240
Zone 3	0	240

Fixed hydropower requirements were used in each zone. These requirements represent the most likely hydropower demand during normal conditions. Hydropower power reduction occurs primarily during predicted or actual prolonged low flow conditions. Allatoona is one of several hydropower projects in the ACT/ACF system that contributes to meeting the system demand. There are numerous factors that water managers consider when determining the available hydropower generation hours. These factors don't lend themselves to a model algorithm; as a result they were omitted. The fixed number of hydropower hours per zone is sufficient to capture typical reductions.

c. Guide Curve Fall Drawdown

Responding to comments from stakeholders, there was an attempt to modify the summer pool duration at Allatoona. This was accomplished by adjusting the timing of drawdown periods between summer and winter pool (guide curve fall shoulder).

One scenario included extending the summer level through October and drawing down to the winter level through January. Allatoona does not remain full for the entire summer period, May through September (as shown by historic average pool in Figure 28). Consequently, two early drawdown scenarios were considered; one, a continuous drawdown from September (after Labor Day) through December, and the other, a step-down that remains above the initial recreation impact level until mid November. Three different scenarios were modeled for the Allatoona drawdown (Figure 29):

1. Extended November drawdown
2. Early September drawdown
3. October stepped drawdown (Phased Drawdown).

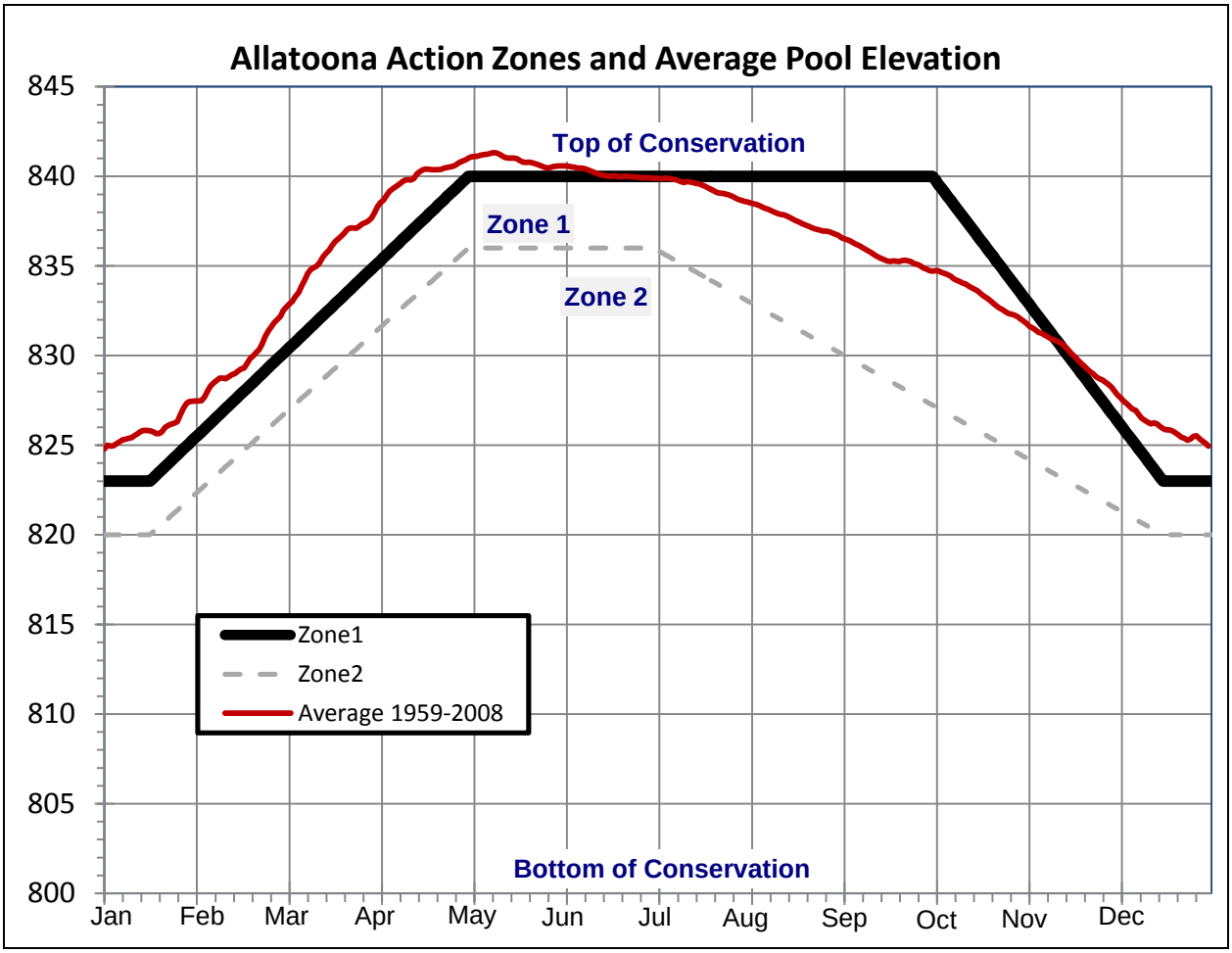


Figure 28. Allatoona Action Zones and Average Pool Elevation

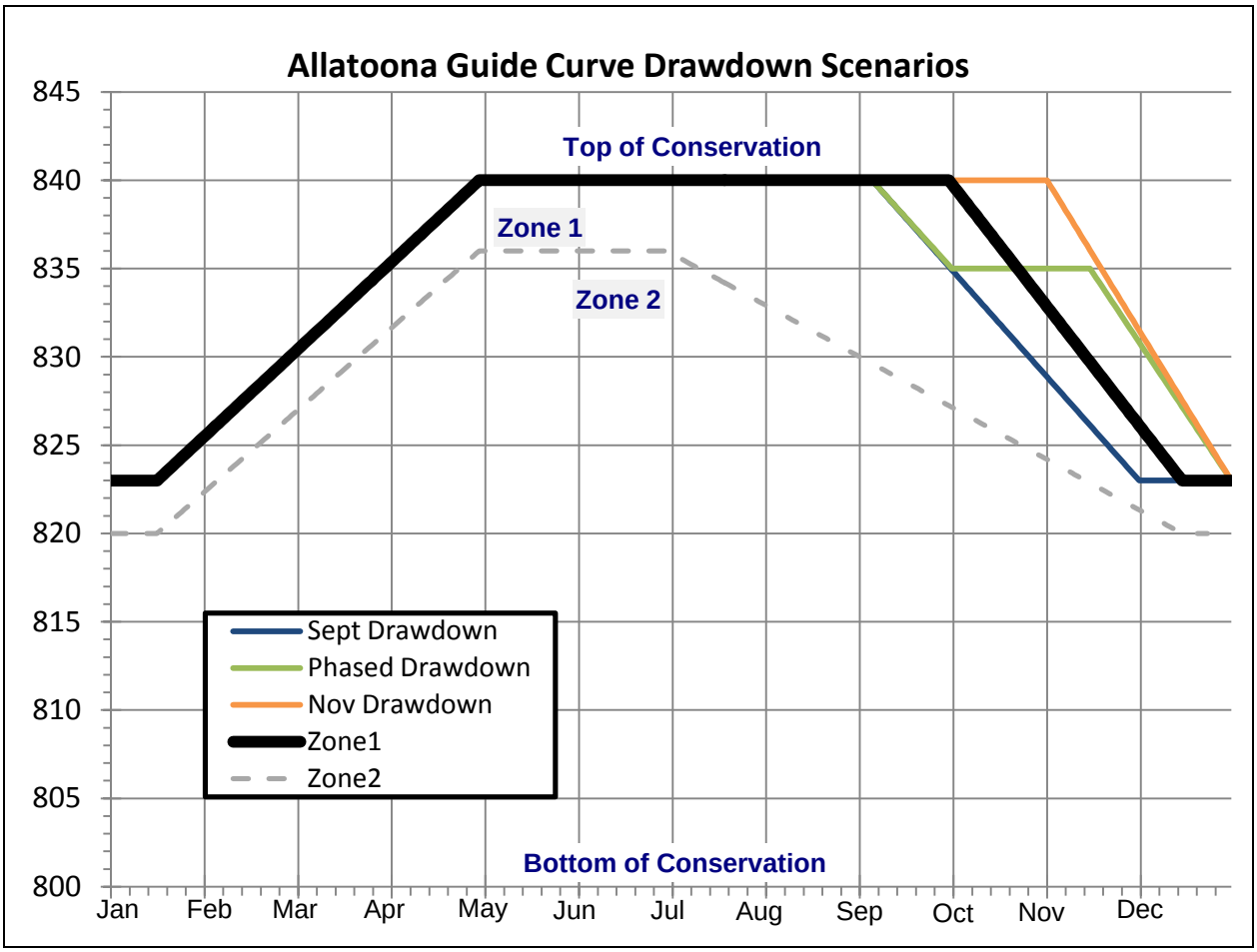


Figure 29. Allatoona Guide Curve Drawdown Scenarios

An hourly flood study model (as discussed in Appendix M) from the headwaters of Allatoona and Carters to Rome, Georgia was developed to evaluate any downstream flooding impact from proposed modifications to flood operations at Allatoona Dam.

The objectives of the flood modeling are as follows:

- Capture the current Flood Reduction operation of Carters and Allatoona,
- Simulate the current guide curve and three additional scenarios of the fall reservoir drawdown (Figure 29),
- Compare the resultant regulated frequency flow at Rome-Coosa and Kingston, and
- Identify improvements in the Carters and Allatoona flood operation.

The Step-Down, or Phased Drawdown, alternative was selected because of the benefit to flood protection, hydropower and recreation. Consequently, alternatives will be considered using the Phased Drawdown as the guide curve or Top of Zone 1. Figure 30 depicts the Burkett scenario with the Phased Drawdown.

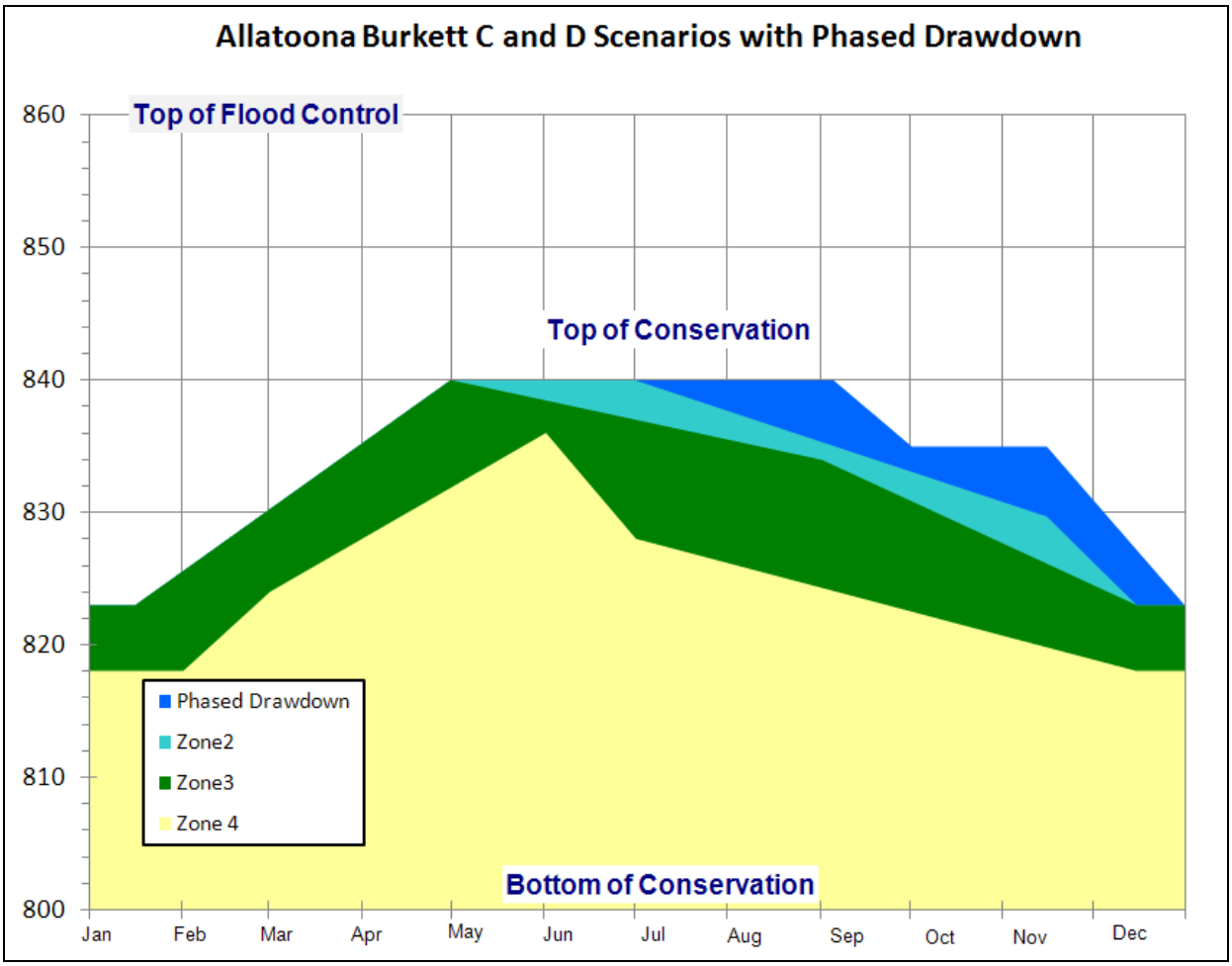


Figure 30. Allatoona Burkett Scenario with Phased Drawdown

7. Drought Plan

The ACT Basin experienced severe drought conditions during the 2007-2009 period. The Corps and APC do not currently have an agreed-upon methodology for defining drought conditions and corresponding reservoir operations. Therefore, while developing the navigation concept, the Corps, in coordination with APC, developed a drought plan to meet minimum flows from the Coosa and Tallapoosa Basins.

The Drought Level Response matrix is shown in Table 13. This matrix provides the operational guidelines for the Coosa, Tallapoosa, and Alabama Rivers, based on the Drought Intensity Level (DIL). The DIL is a drought indicator, ranging from zero to three, that is determined based on three different basin drought criteria. A DIL=0 indicates normal operations, while a DIL from 1 to 3 indicates some level of drought conditions. The DIL increases as the number of drought level criteria that have been triggered increases. The matrix defines monthly minimum flow requirements for the Coosa, Tallapoosa and into the Alabama River, as function of DIL and time of year. These flow requirements are modeled as daily averages.

Table 13. Alternative Drought Level Response Matrix

Alternative Drought Level Response Matrix****

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Drought Intensity Level Triggers	DL 0 - Normal Operations											
	DL 1: Low Basin Inflows or Low Composite or Low State Line Flow											
	DL 2: DL 1 criteria + (Low Basin Inflows or Low Composite or Low State Line Flow)											
	DL 3: Low Basin Inflows + Low Composite + Low State Line Flow											
Coosa River Flow*	Normal Operation: 2000 cfs			4000 (8000)		4000 - 2000	Normal Operation: 2000 cfs					
	Jordan 2000 +/-cfs			4000 +/- cfs		6/15 Linear Ramp down	Jordan 2000 +/-cfs			Jordan 2000 +/-cfs		
	Jordan 1800 +/-cfs			**2500 +/- cfs**		6/15 Linear Ramp down	Jordan 2000 +/-cfs			Jordan 1800 +/-cfs		
	Jordan 1600 +/-cfs			Jordan 1800 +/-cfs			Jordan 2000 +/-cfs			**Jordan 1800 +/-cfs**		Jordan 1600 +/-cfs
Tallapoosa River Flow**	Normal Operations: 1200 cfs											
	Greater of: 1/2 Yates Inflow or 2 x Heflin Gage(Thurlow releases > 350 cfs)				1/2 Yates Inflow					1/2 Yates Inflow		
	Thurlow 350 cfs				1/2 Yates Inflow					Thurlow 350 cfs		
	Maintain 400 cfs at Montgomery WTP (Thurlow release 350 cfs)						Thurlow 350 cfs			Maintain 400 cfs at Montgomery WTP (Thurlow release 350 cfs)		
Alabama River Flow***	Normal Operation: Navigation or 7Q10 flow											
	4200 cfs (10% 7Q10 Cut) - Montgomery				7Q10 - Montgomery (4640 cfs)					Reduce: Full - 4200 cfs		
	3700 cfs (20% 7Q10 Cut) - Montgomery					4200 cfs (10% 7Q10 Cut) - Montgomery				Reduce: 4200 cfs-> 3700 cfs Montgomery (1 week ramp)		
	2000 cfs Montgomery				3700 cfs Montgomery		4200 cfs (10% 7Q10 Cut) - Montgomery			Reduce: 4200 cfs -> 2000 cfs Montgomery (1month ramp)		
Rule Curve Elevation	Normal Operations: Elevations follow Rule Curves as prescribed in License (Measured in Feet)											
	USACE Variances: As Needed; FERC Variance for Martin											
	USACE Variances: As Needed; FERC Variance for Martin											
	USACE Variances: As Needed; FERC Variance for Martin											

*Jordan flows are based on a continuous +/- 5% of target flow.

**Thurlow flows are based on continuous +/- 5% of target flow: flows are reset on noon each Tuesday based on the prior day's daily average at Heflin or Yates.

***Alabama River flows are 7-Day Average Flow.

****Note these are based flows that will be exceeded when possible.

The drought triggers or indicators were selected to capture representative conditions throughout the basin. The combined occurrences of the drought triggers determine the DIL. There are four intensity levels determined using three drought intensity triggers in the ACT system.

Drought Intensity Levels (DIL):

- DL0 – no trigger, normal operation
- DL1 – (moderate drought) 1 of 3 triggers exceeded
- DL2 – (severe drought) 2 of 3 triggers exceeded
- DL3 – (exceptional drought) All 3 triggers exceeded

Drought Intensity Indicators (i.e., DIL Triggers):

a.) low Basin Inflow
b.) low Composite Storage
c.) low State Line Flow

If none of these indicators are triggered, the Drought Intensity Level (DIL) is set to zero. As each of these indicators are triggered, the DIL increases by one, meaning that the DIL will be between one and three if drought conditions are occurring, with three being the most severe DIL with all three indicators being triggered.

The DIL is computed on the 1st and 15th of each month. Once drought operation is triggered, the DIL trigger can only recover from drought condition at a rate of one level per period. For example as the system begins to recover from an exceptional drought with DIL=3, the DIL must be stepped incrementally back to zero to resume normal operations. In this case, even if the system triggers return to normal quickly, it will still take at least a month before normal operations may resume - conditions can only improve to DIL=2 for the next computation period, then DIL=1 for the next period, before finally returning to DIL=0.

For DIL=0, the matrix shows a Coosa River flow between 2,000 cfs and 4,000 cfs with peaking periods up to 8,000 cfs occurring. The required flow on the Tallapoosa River is a constant 1,200 cfs throughout the entire year. The navigation flows on the Alabama River are applied to the APC projects. The required navigation depth on the Alabama River is subject to the basin inflow.

For DIL=1, the Coosa River flow varies from 2,000 cfs to 4,000 cfs. On the Tallapoosa River, part of the year, the required flow is the greater of one-half of the inflow into Yates and twice the Heflin gage. For the remainder of the year, the required flow is one-half of Yates inflow. The required flows on the Alabama River are reduced from the amounts when DIL=0.

For DIL=2, the Coosa River flow varies from 1,800 cfs to 2,500 cfs. On the Tallapoosa River, the minimum is 350 cfs for part of the year and one-half of

Yates inflow for the remainder of the year. The requirement on the Alabama River is between 3,700 cfs and 4,200 cfs.

For DIL=3, the flows on the Coosa River range from 1,600 cfs to 2,000 cfs. A constant flow of 350 cfs on the Tallapoosa River is required. It is assumed an addition 50 cfs will occur between Thurlow Dam the City of Montgomery water supply intake. Required flows on the Alabama River range from 2,000 cfs to 4,200 cfs

In addition to the Drought Plan operations shown in the matrices, the DIL affects the navigation operations. When the DIL is equal to zero, APC projects are operated to meet navigation flow target or the 7Q10 flow as defined in the navigation measure section. Once DIL is greater than zero, drought operations will occur and navigation operations are suspended.

a. Low Basin Inflow Trigger

The Total Basin Inflow needed is sum of Total Filling Volume + 7Q10 flow (4,640 cfs). Table 14 lists the monthly Low Basin Inflow criteria. All numbers are in cfs-days. The Basin Inflow value is computed each daily time step and checked on the 1st and 15th of the month. If computed Basin Inflow is less than the value required, then the Low Basin Inflow Indicator is triggered.

Table 14. Low Basin Inflow Guide (in cfs-days)

Month	Coosa Filling Volume	Tallapoosa Filling Volume	Total Filling Volume	Navigation	Required Basin Inflow
Jan	629	0	629	4640	5269
Feb	647	1968	2615	4640	7255
Mar	603	2900	3503	4640	8143
Apr	1683	2585	4268	4640	8908
May	242	0	242	4640	4882
Jun			0	4640	4640
Jul			0	4640	4640
Aug			0	4640	4640
Sep	-602	-1304	-1906	4640	2734
Oct	-1331	-2073	-3404	4640	1236
Nov	-888	-2659	-3547	4640	1093
Dec	-810	-1053	-1863	4640	2777

The Basin Inflow is total flow above the APC projects including Allatoona and Carters. This is the sum of local flows, minus lake evaporation, minus diversions. Figure 31 is a map indicating the local inflows to the Coosa and Tallapoosa Basin projects. This Basin Inflow computation differs from the Navigation Basin Inflow, because it does not include inflows to Carters and Allatoona. The intent is to capture the hydrologic condition across the Coosa and Tallapoosa Basins. The basic equation is:

Basin Inflow Drought = APC Unimpaired Local flows

The same calculation, as implemented in ResSim, using ResSim variables is as follows:

$$\text{Basin Inflow}_{\text{Drought}} = \text{Jordan UNREG} + \text{Thurlow UNREG} - \text{Carters UNREG} - \text{Allatoona UNREG} - \text{APC lake evaporation}$$

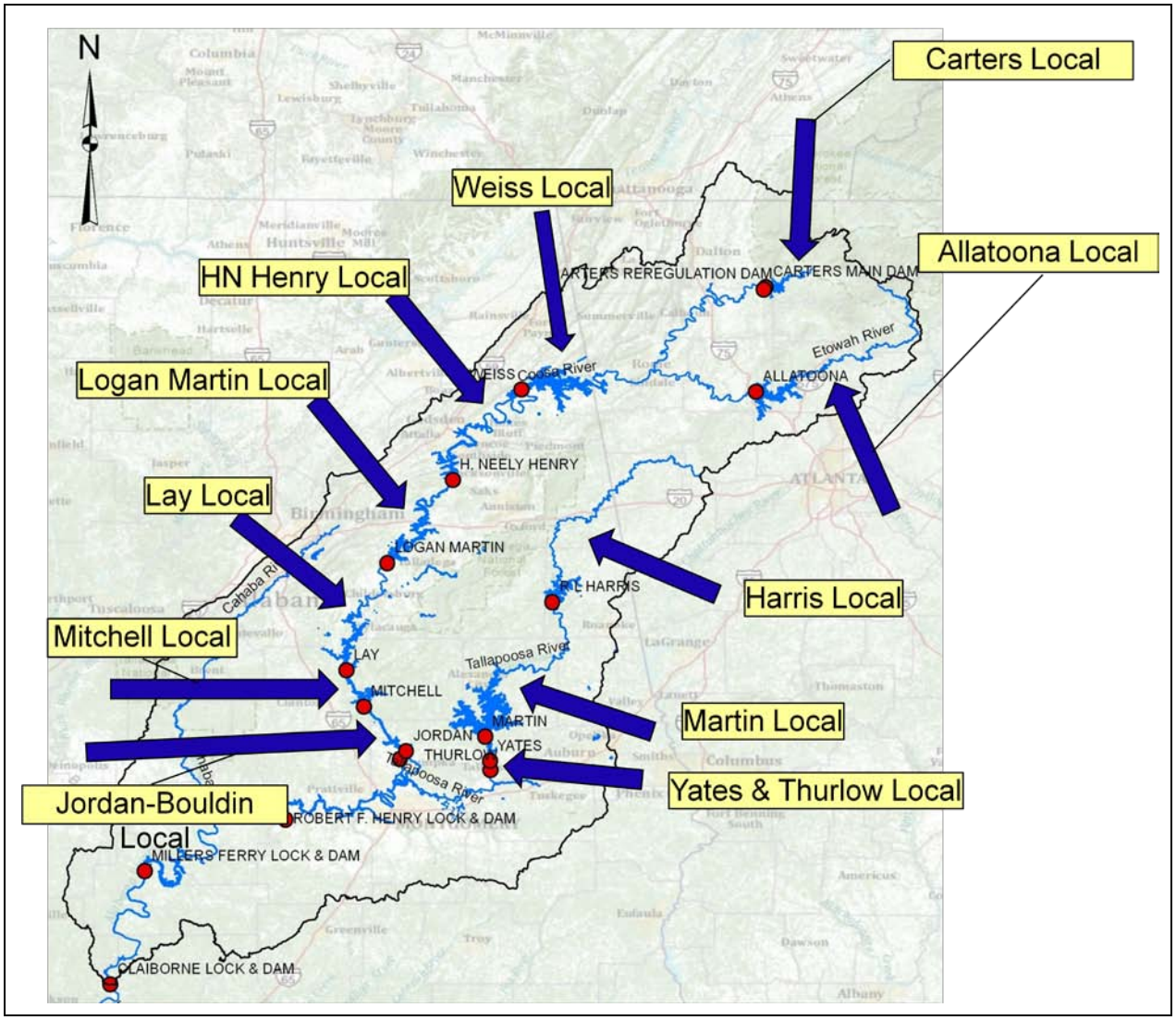


Figure 31. Local Flow above Coosa and Tallapoosa Basin Projects

b. State Line Flow Trigger

A Low State Line Flow trigger occurs when the Mayo's Bar USGS gage measures a flow below the monthly historical 7Q10 flow. The 7Q10 flow is defined as the lowest flow over a 7 day period that would occur once in 10 years. Table 15 list the Mayo's Bar 7Q10 value for each month. The lowest 7-day average flow over the last 14 days is computed and checked at the 1st and 15th of the Month. If the lowest 7-day average value is less Mayo's Bar 7Q10 value, then the State Line Flow Indicator is triggered. If the result is greater than or equal to the trigger value from Table 15, then the flow state is considered normal and the state line flow indicator is not triggered.

Table 15. State Line Flow Trigger

Month	Mayo's Bar (7Q10 in cfs)
Jan	2544
Feb	2982
Mar	3258
Apr	2911
May	2497
Jun	2153
Jul	1693
Aug	1601
Sep	1406
Oct	1325
Nov	1608
Dec	2043

Based on USGS Coosa River at Rome Gage (Mayo's Bar, site 02397000) observed flow from 1949-2006.

c. Low Composite Storage

Low Composite Storage occurs when the APC projects' composite storage is less than or equal to the storage available within the drought contingency curves for the APC reservoirs. Composite storage is the sum of the amounts of storage available at the current elevation for each reservoir down to the drought contingency curve at each APC major storage project. The reservoirs considered for this trigger are Harris, HN Henry, Logan Martin, Martin, and Weiss. Figure 32 plots the APC composite zones. Figure 33 plots the APC low composite storage trigger.

If the actual active composite storage is less than or equal to the active composite drought zone storage, the Low Composite Storage state variable is then assigned a value of one, indicating that one level of drought severity has been triggered. This computation is performed on the 1st and 15th of each month, and is compared to the Low State Line flow trigger and basin inflow trigger.

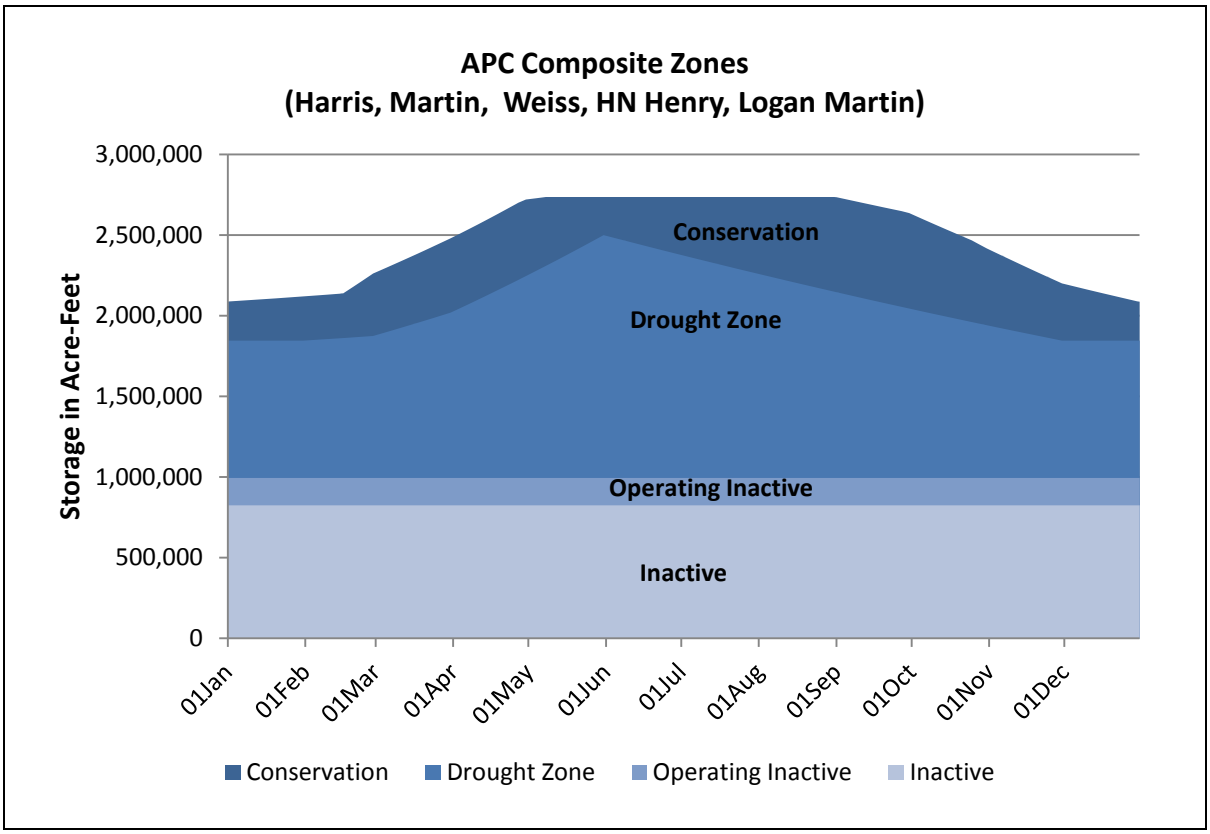


Figure 32. APC Composite Zones

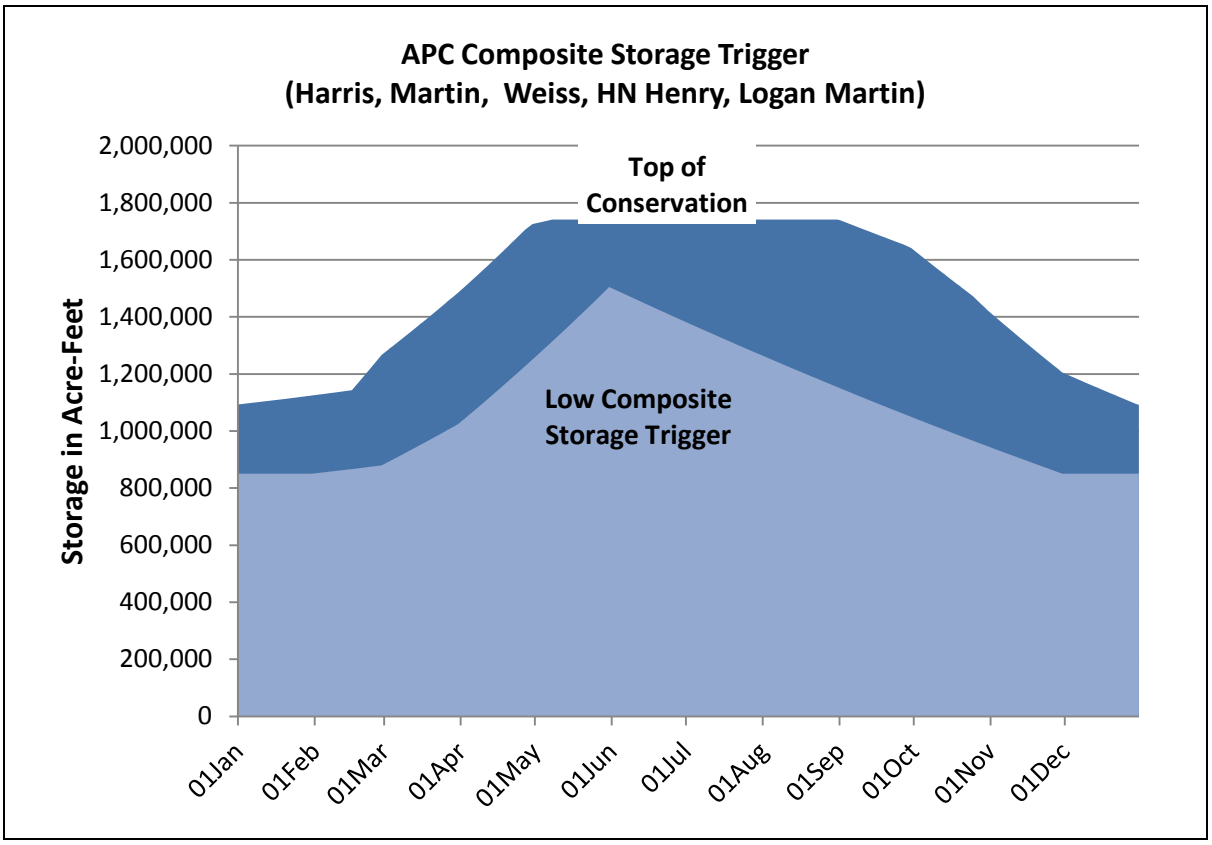


Figure 33. APC Low Composite Storage Trigger

There are three additional variations of the Drought Plan matrix that were considered in the alternative formulation and modeled in ResSim. The four different Drought Plan options modeled were:

- Original Drought Plan
- Revised Drought Plan
- Original Drought Plan with USFWS Enhancement
- Revised Drought Plan with USFWS Enhancement – aka Alternative Drought Plan

Table 16 shows the original Drought Plan matrix, which contained a typo in the 20% reduction of the 7Q10 flow (3900 cfs should be 3700 cfs). Table 17 shows the Revised Drought Plan matrix, which differs from the original plan by using the correct 20% 7Q10 flow reduction, and it includes the "actual revision" to the original drought plan related to the frequency and timing with which the DIL is calculated. The Original Drought Plan calculates the DIL once a month, but the Revised Drought Plan calculates the DIL twice per month. Table 18 shows the Original Drought Plan with a USFWS Enhancement that responds to a concern related to water temperatures below Jordan Dam. USFWS recommended increasing the minimum flow from the Jordan project from 1,600 to 1,800 cfs during the October-November period. To help offset the potential additional use of storage that may occur to meet the higher minimum flow, USFWS recommended lowering the spring Jordan minimum flow from 3,000 cfs to 2,500 cfs April through mid June. The final Drought Plan tested was the Revised (DIL calculated twice per month) Drought Plan with the USFWS Enhancement (previously shown in Table 13).

Table 16. Original Drought Plan Matrix

Drought Level Response Matrix****

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Drought Intensity Level Triggers	DL 0 - Normal Operations											
	DL 1: Low Basin Inflows or Low Composite or Low State Line Flow											
	DL 2: DL 1 criteria + (Low Basin Inflows or Low Composite or Low State Line Flow)											
	DL 3: Low Basin Inflows + Low Composite + Low State Line Flow											
Coosa River Flow*	Normal Operation: 2000 cfs			4000 (8000)		4000 - 2000	Normal Operation: 2000 cfs					
	Jordan 2000 +/-cfs			4000 +/- cfs		**6/15 Linear Ramp down**	Jordan 2000 +/-cfs			Jordan 2000 +/-cfs		
	Jordan 1800 +/-cfs			3000 +/- cfs		**6/15 Linear Ramp down**	Jordan 2000 +/-cfs			Jordan 1800 +/-cfs		
	Jordan 1600 +/-cfs			Jordan 1800 +/-cfs			Jordan 2000 +/-cfs			Jordan 1600 +/-cfs		
Tallapoosa River Flow**	Normal Operations: 1200 cfs											
	Greater of: 1/2 Yates Inflow or 2 x Heflin Gage(Thurlow releases > 350 cfs)				1/2 Yates Inflow					1/2 Yates Inflow		
	Thurlow 350 cfs				1/2 Yates Inflow					Thurlow 350 cfs		
	Maintain 400 cfs at Montgomery WTP (Thurlow release 350 cfs)						Thurlow 350 cfs			Maintain 400 cfs at Montgomery WTP (Thurlow release 350 cfs)		
Alabama River Flow***	Normal Operation: Navigation or 7Q10 flow											
	4200 cfs (10% 7Q10 Cut) - Montgomery				7Q10 - Montgomery (4640 cfs)					Reduce: Full - 4200 cfs		
	3900 cfs (20% 7Q10 Cut) - Montgomery				4200 cfs (10% 7Q10 Cut) - Montgomery					Reduce: 4200 cfs-> 3900 cfs Montgomery		
	2000 cfs Montgomery				3900 cfs Montgomery		4200 cfs (10% 7Q10 Cut) - Montgomery			Reduce: 4200 cfs -> 2000 cfs Montgomery (ramp thru October)		
Rule Curve Elevation	Normal Operations: Elevations follow Rule Curves as prescribed in License (Measured in Feet)											
	USACE Variances: As Needed; FERC Variance for Martin											
	USACE Variances: As Needed; FERC Variance for Martin											
	USACE Variances: As Needed; FERC Variance for Martin											

*Jordan flows are based on a continuous +/- 5% of target flow.

**Thurlow flows are based on continuous +/- 5% of target flow: flows are reset on noon each Tuesday based on the prior day's daily average at Heflin or Yates.

***Alabama River flows are 7-Day Average Flow.

****Note these are based flows that will be exceeded when possible.

Table 17. Revised Drought Plan Matrix

Revised Drought Level Response Matrix****

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Drought Intensity Level Triggers	DL 0 - Normal Operations											
	DL 1: Low Basin Inflows or Low Composite or Low State Line Flow											
	DL 2: DL 1 criteria + (Low Basin Inflows or Low Composite or Low State Line Flow)											
	DL 3: Low Basin Inflows + Low Composite + Low State Line Flow											
Coosa River Flow*	Normal Operation: 2000 cfs			4000 (8000)		4000 - 2000	Normal Operation: 2000 cfs					
	Jordan 2000 +/-cfs			4000 +/- cfs		**6/15 Linear Ramp down**	Jordan 2000 +/-cfs			Jordan 2000 +/-cfs		
	Jordan 1800 +/-cfs			3000 +/- cfs		**6/15 Linear Ramp down**	Jordan 2000 +/-cfs			Jordan 1800 +/-cfs		
	Jordan 1600 +/-cfs			Jordan 1800 +/-cfs			Jordan 2000 +/-cfs			Jordan 1600 +/-cfs		
Tallapoosa River Flow**	Normal Operations: 1200 cfs											
	Greater of: 1/2 Yates Inflow or 2 x Heflin Gage(Thurlow releases > 350 cfs)				1/2 Yates Inflow					1/2 Yates Inflow		
	Thurlow 350 cfs				1/2 Yates Inflow					Thurlow 350 cfs		
	Maintain 400 cfs at Montgomery WTP (Thurlow release 350 cfs)						Thurlow 350 cfs			Maintain 400 cfs at Montgomery WTP (Thurlow release 350 cfs)		
Alabama River Flow***	Normal Operation: Navigation or 7Q10 flow											
	4200 cfs (10% 7Q10 Cut) - Montgomery				7Q10 - Montgomery (4640 cfs)					Reduce: Full - 4200 cfs		
	3700 cfs (20% 7Q10 Cut) - Montgomery				4200 cfs (10% 7Q10 Cut) - Montgomery					Reduce: 4200 cfs-> 3700 cfs Montgomery		
	2000 cfs Montgomery				3700 cfs Montgomery		4200 cfs (10% 7Q10 Cut) - Montgomery			Reduce: 4200 cfs -> 2000 cfs Montgomery (ramp thru October)		
Rule Curve Elevation	Normal Operations: Elevations follow Rule Curves as prescribed in License (Measured in Feet)											
	USACE Variances: As Needed; FERC Variance for Martin											
	USACE Variances: As Needed; FERC Variance for Martin											
	USACE Variances: As Needed; FERC Variance for Martin											

*Jordan flows are based on a continuous +/- 5% of target flow.

**Thurlow flows are based on continuous +/- 5% of target flow: flows are reset on noon each Tuesday based on the prior day's daily average at Heflin or Yates.

***Alabama River flows are 7-Day Average Flow.

****Note these are based flows that will be exceeded when possible.

Table 18. Original Drought Plan Matrix with USFWS Enhancement

Drought Level Response Matrix, FWS Enhancement****

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Drought Intensity Level Triggers	DL 0 - Normal Operations											
	DL 1: Low Basin Inflows or Low Composite or Low State Line Flow											
	DL 2: DL 1 criteria + (Low Basin Inflows or Low Composite or Low State Line Flow)											
	DL 3: Low Basin Inflows + Low Composite + Low State Line Flow											
Coosa River Flow*	Normal Operation: 2000 cfs			4000 (8000)		4000 - 2000	Normal Operation: 2000 cfs					
	Jordan 2000 +/-cfs			4000 +/- cfs		6/15 Linear Ramp down	Jordan 2000 +/-cfs			Jordan 2000 +/-cfs		
	Jordan 1800 +/-cfs			**2500 +/- cfs**		6/15 Linear Ramp down	Jordan 2000 +/-cfs			Jordan 1800 +/-cfs		
	Jordan 1600 +/-cfs			Jordan 1800 +/-cfs			Jordan 2000 +/-cfs			**Jordan 1800 +/-cfs**		Jordan 1600 +/-cfs
Tallapoosa River Flow**	Normal Operations: 1200 cfs											
	Greater of: 1/2 Yates Inflow or 2 x Heflin Gage(Thurlow releases > 350 cfs)				1/2 Yates Inflow					1/2 Yates Inflow		
	Thurlow 350 cfs				1/2 Yates Inflow					Thurlow 350 cfs		
	Maintain 400 cfs at Montgomery WTP (Thurlow release 350 cfs)						Thurlow 350 cfs			Maintain 400 cfs at Montgomery WTP (Thurlow release 350 cfs)		
Alabama River Flow***	Normal Operation: Navigation or 7Q10 flow											
	4200 cfs (10% 7Q10 Cut) - Montgomery				7Q10 - Montgomery (4640 cfs)					Reduce: Full - 4200 cfs		
	3900 cfs (20% 7Q10 Cut) - Montgomery				4200 cfs (10% 7Q10 Cut) - Montgomery					Reduce: 4200 cfs-> 3900 cfs Montgomery		
	2000 cfs Montgomery				3900 cfs Montgomery		4200 cfs (10% 7Q10 Cut) - Montgomery			Reduce: 4200 cfs -> 2000 cfs Montgomery (ramp thru October)		
Rule Curve Elevation	Normal Operations: Elevations follow Rule Curves as prescribed in License (Measured in Feet)											
	USACE Variances: As Needed; FERC Variance for Martin											
	USACE Variances: As Needed; FERC Variance for Martin											
	USACE Variances: As Needed; FERC Variance for Martin											

*Jordan flows are based on a continuous +/- 5% of target flow.

**Thurlow flows are based on continuous +/- 5% of target flow: flows are reset on noon each Tuesday based on the prior day's daily average at Heflin or Yates.

***Alabama River flows are 7-Day Average Flow.

****Note these are based flows that will be exceeded when possible.

C. Study Alternatives/Operational Plans

Eleven alternatives were formulated during the Recommended Plan development for comparison with Baseline. The twelve alternatives are listed below. (While baseline operations are not considered a Plan alternative, the Baseline is considered an Alternative in ResSim terminology.)

1.) Baseline
2.) DroughtPln
3.) Burkett
4.) DragoA
5.) DragoB
6.) RPlanA
7.) RPlanB
8.) RPlanC
9.) RPlanD
10.) RPlanE
11.) RPlanF
12.) RPlanG

Table 19 indicates the measures selected for each alternative.

Table 19. Alternative and Selected Measure

Measure	Alternative											
	Baseline	DroughtPln	Burkett	Drago A	Drago B	RPlan A	RPlan B	RPlan C	RPlan D	RPlan E	RPlan F	RPlan G
Current Operations	XX	XX*										
2006 Water Use	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
Navigation Support: APC & COE		XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
Carters Seasonal Release			XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
Drought Plan		XX	XX	XX	XX	XX						
Drought Plan Revised								XX		XX		
Drought Plan, FWS Enhancement							XX					
Drought Plan Revised, FWS Enhancement									XX		XX	XX
Alltoona, Burkett Scenario			XX									
Alltoona, Drago A Scenario				XX								
Alltoona, Drago B Scenario					XX							
Alltoona, Burkett B Scenario						XX	XX	XX	XX			
Alltoona, Burkett C Scenario										XX	XX	
Alltoona, Burkett D Scenario												XX

* DroughtPln Alternative	uses Current Operations at Allatoona and Carters
Drought Plan, FWS Enhancment	Drought Plan plus Coosa DL2 flow reduction from 3,000 to 2,500 for months Apr-15Jun; Coosa DL3 flow increase from 1,600 to 1,800 for Oct-Nov
Drought Plan Revised	Alabama River flows chaned from 3900 to 3700, State Line 7Q10 values changed to COE values, corrected ramp in Coosa DL2 flows from Jul to Dec; DIL calculated twice/month
Drought Plan Revised, FWS Enhancment	Drought Plan revisions plus Coosa DL2 flow reduction from 3,000 to 2,500 for months Apr-15Jun; Coosa DL3 flow increase from 1,600 to 1,800 for Oct-Nov; reduce Alabama DL2 flow from 4,200 to 3,700 for May

1. Baseline

The Baseline Alternative represents current water control operations at each of the projects in the ACT Basin. The operations selected to represent the "Baseline" Alternative are listed below:

Baseline Measures:

1. Current Operations
2. 2006 Water Use

2. Drought Plan

The Drought Plan alternative includes a navigation operation to support a 9-ft or 7.5-ft channel and drought operations (Figure 34). There is no change from the baseline (current) operations at Allatoona and Carters. The measures selected to represent the "DroughtPln" Alternative are listed below.

Drought Plan Measures:

1. Current Operations at Allatoona and Carters
2. 2006 Water Use (previously shown in Figure 12)
3. Navigation Support: APC projects and COE projects on the Alabama River
4. Drought Plan (previously shown in Table 16)

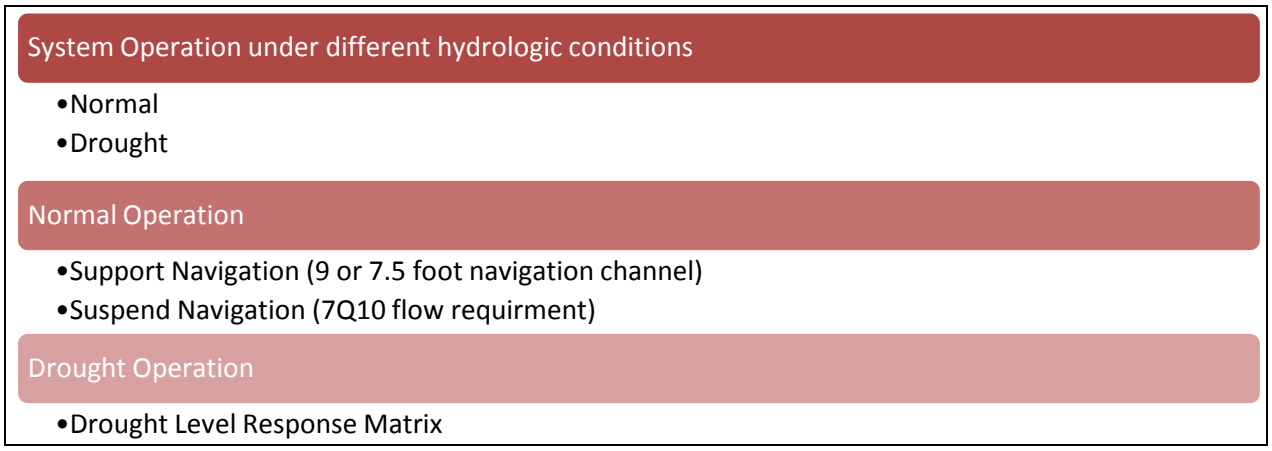


Figure 34. System Operation Includes Navigation Concept and Drought Plan

3. Burkett

The Burkett Alternative includes a navigation operation to support a 9-ft or 7.5-ft channel and drought operations. Carters operations are changed with a seasonally varying minimum flow requirement, the addition of Zone 2, and a defined guide curve (Figure 35). Allatoona operations are changed with the addition of Zones 3 and 4 and the revised peaking hydropower demand that ranges from 0-6 hours (Figure 36). This alternative is the same as the Drought Plan alternative with the changes in operation at Allatoona and Carters. The measures selected to represent the "Burkett" Alternative are listed below.

Burkett Measures:

1. 2006 Water Use
2. Navigation Support: APC projects and COE projects on the Alabama River
3. Drought Plan (previously shown in Table 16)
4. Carters Seasonal Release
5. Allatoona, Burkett Scenario

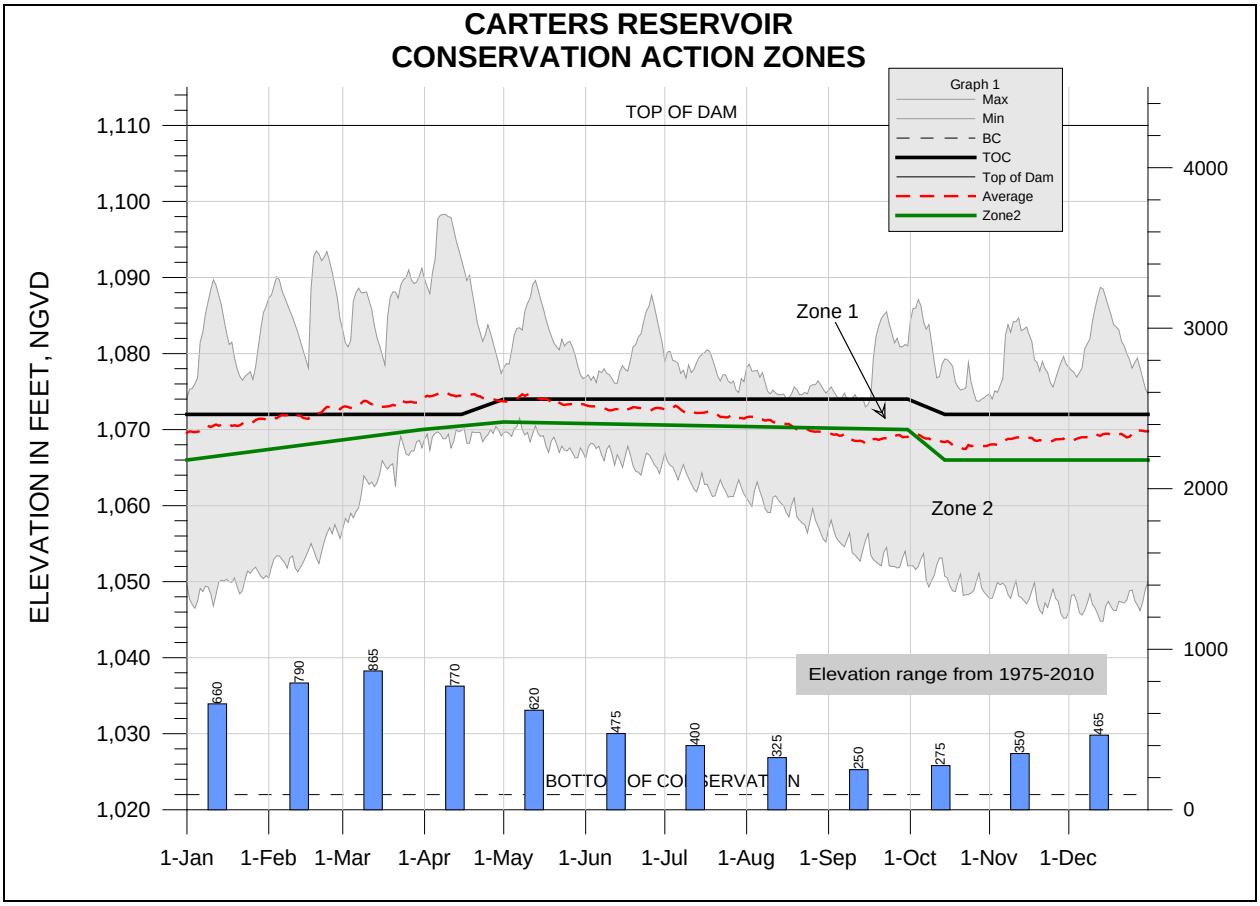


Figure 35. Carters Seasonal Release Scenario

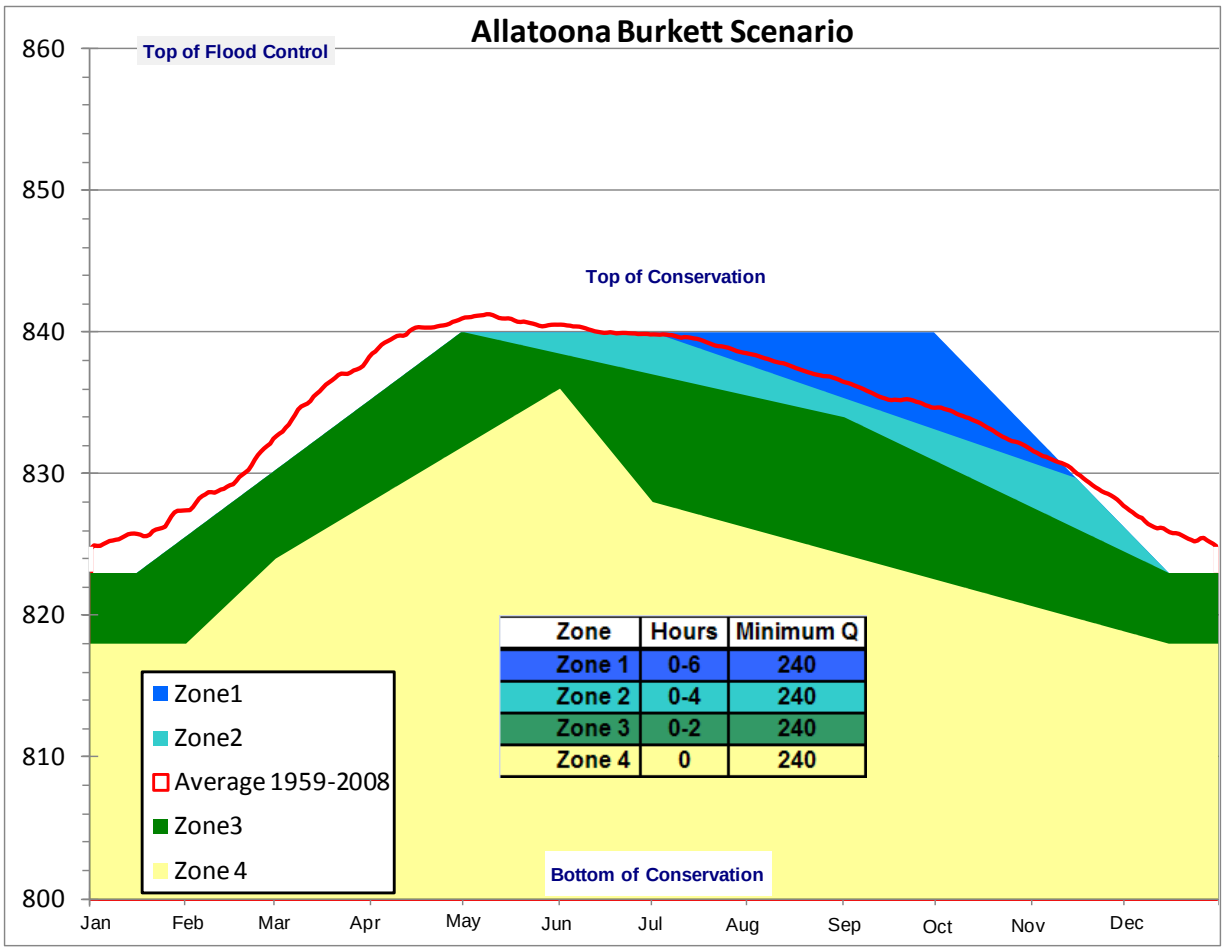


Figure 36. Allatoona Burkett Scenario

4. Drago A

The Drago A alternative includes a navigation operation to support a 9-ft or 7.5-ft channel and drought operations. Carters operations are changed with a seasonally varying minimum flow requirement, the addition of Zone 2, and a defined guide curve. Allatoona operations are changed with the addition of Zone 3 (version A) and the revised peaking hydropower demand that ranges from 0-6 hours (Figure 37). This alternative is the same as the Drought Plan alternative with the changes in operation at Allatoona and Carters. The measures selected to represent the "DragoA" Alternative are listed below.

Drago A Measures:

1. 2006 Water Use
2. Navigation Support: APC projects and COE projects on the Alabama River
3. Drought Plan (previously shown in Table 16)
4. Carters Seasonal Release
5. Allatoona, Drago A

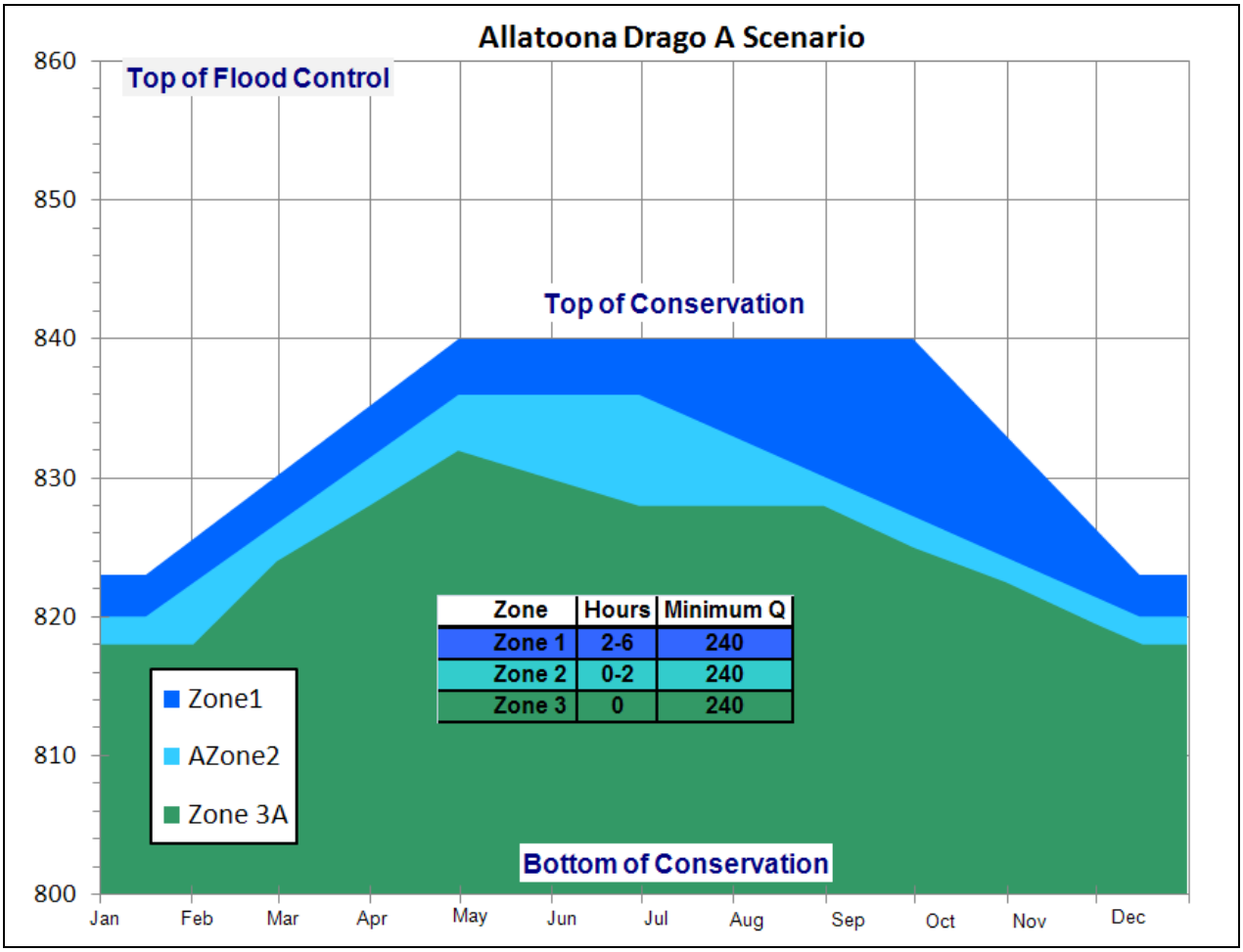


Figure 37. Allatoona Drago A Scenario

5. Drago B

The Drago B alternative includes a navigation operation to support a 9-ft or 7.5-ft channel and drought operations. Carters operations are changed with a seasonally varying minimum flow requirement, the addition of Zone 2, and a defined guide curve. Allatoona operations are changed with the addition of Zone 3 (version B) and the revised peaking hydropower demand that ranges from 0-6 hours (Figure 38). This alternative is the same as the Drought Plan alternative with the changes in operation at Allatoona and Carters. The measures selected to represent the "DragoB" Alternative are listed below.

Drago B Measures:

1. 2006 Water Use
2. Navigation Support: APC projects and COE projects on the Alabama River
3. Drought Plan (previously shown in Table 16)
4. Carters Seasonal Release
5. Allatoona, Drago B

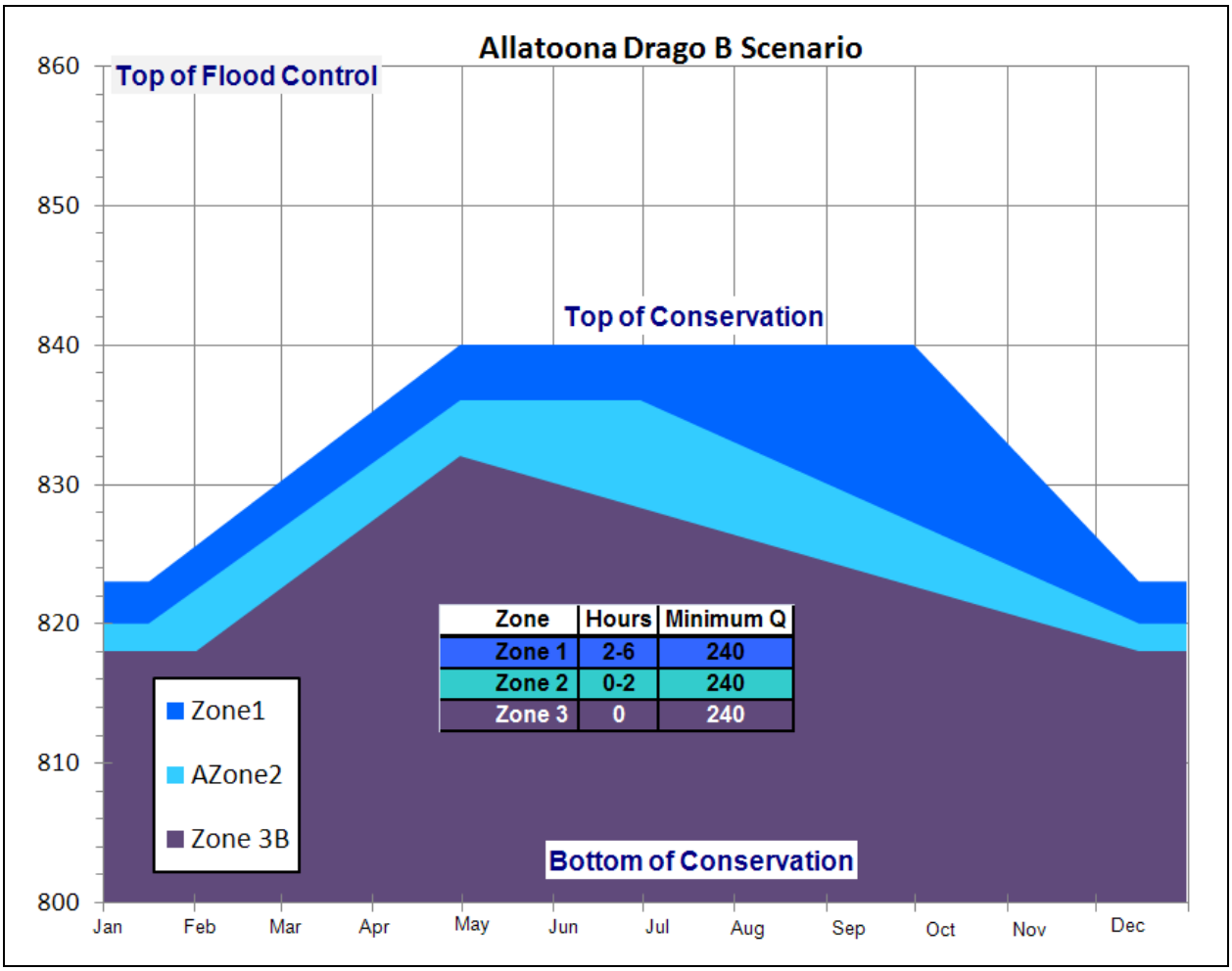


Figure 38. Allatoona Drago B Scenario

6. RPlan A

The RPlan A alternative includes a navigation operation to support a 9-ft or 7.5-ft channel and drought operations. Carters operations are changed with a seasonally varying minimum flow requirement, the addition of Zone 2, and a defined guide curve. Allatoona operations are changed with the addition of Zones 3 and 4 and the revised peaking hydropower demand that ranges from 0-4 hours (Figure 39). This alternative is the same as the Drought Plan alternative with the changes in operation at Allatoona and Carters. The measures selected to represent the "RPlanA" Alternative are listed below.

RPlan A Measures:

1. 2006 Water Use
2. Navigation Support: APC projects and COE projects on the Alabama River
3. Drought Plan (previously shown in Table 16)
4. Carters Seasonal Release
5. Allatoona, Burkett B

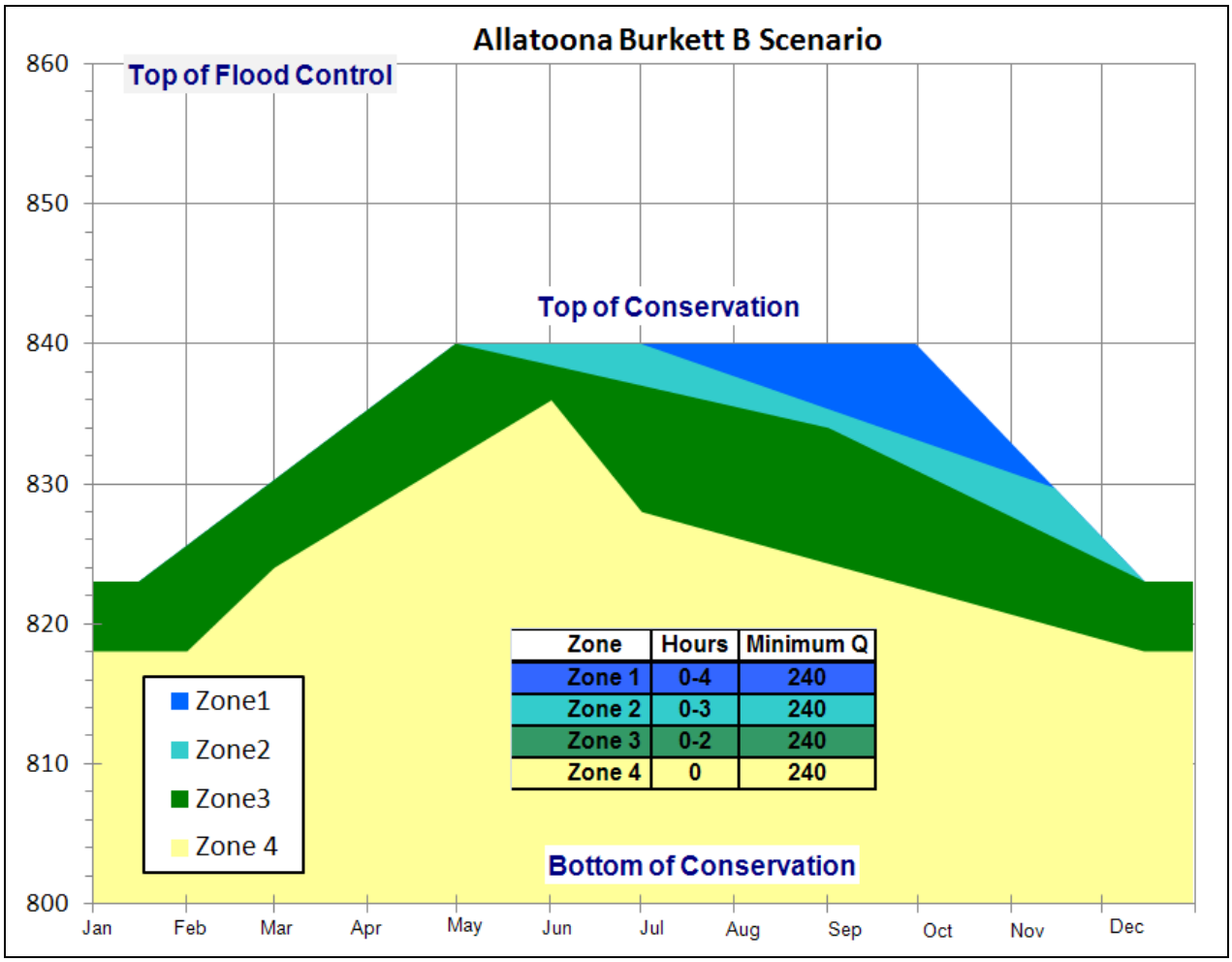


Figure 39. Allatoona Burkett B Scenario

7. RPlan B

The RPlan B alternative includes a navigation operation to support a 9-ft or 7.5-ft channel and drought operations. Carters operations are changed with a seasonally varying minimum flow requirement, the addition of Zone 2, and a defined guide curve. Allatoona operations are changed with the addition of Zones 3 and 4 and the revised peaking hydropower demand that ranges from 0-4 hours. This alternative is the same as the RPlan A alternative, except that the Drought Plan includes the USFWS enhancement. The measures selected to represent the "RPlanB" Alternative are listed below.

RPlan B Measures:

1. 2006 Water Use
2. Navigation Support: APC projects and COE projects on the Alabama River
3. Drought Plan, FWS Enhancement (previously shown in Table 18)
4. Carters Seasonal Release
5. Allatoona, Burkett B

8. RPlan C

The RPlan C alternative includes a navigation operation to support a 9-ft or 7.5-ft channel and drought operations with the revised 20% reduction of 7Q10 flow (4,640 cfs) and DIL calculated semi-monthly. Carters operations are changed with a seasonally varying minimum flow requirement, the addition of Zone 2, and a defined guide curve. Allatoona operations are changed with the addition of Zones 3 and 4 and the revised peaking hydropower demand that ranges from 0-4 hours. This alternative is the same as the RPlan A alternative, except that it uses the Revised Drought Plan. The measures selected to represent the "RPlanC" Alternative are listed below.

RPlan C Measures:

1. 2006 Water Use
2. Navigation Support: APC projects and COE projects on the Alabama River
3. Drought Plan Revised (previously shown in Table 17)
4. Carters Seasonal Release
5. Allatoona, Burkett B

9. RPlan D

The RPlan D alternative includes a navigation operation to support a 9-ft or 7.5-ft channel and drought operations with the revised 20% reduction of 7Q10 flow (4,640 cfs), the DIL calculated semi-monthly, and the USFWS enhancement. Carters operations are changed with a seasonally varying minimum flow requirement, the addition of Zone 2, and a defined guide curve. Allatoona operations are changed with the addition of Zones 3 and 4 and the revised peaking hydropower demand that ranges from 0-4 hours. This alternative is the same as the RPlan A alternative, except that it uses the Revised Drought Plan with the USFWS enhancement. The measures selected to represent the "RPlanD" Alternative are listed below.

RPlan D Measures:

1. 2006 Water Use
2. Navigation Support: APC projects and COE projects on the Alabama River
3. Drought Plan Revised, FWS Enhancement (previously shown in Table 13)
4. Carters Seasonal Release
5. Allatoona, Burkett B

10. RPlan E

The RPlan E alternative includes a navigation operation to support a 9-ft or 7.5-ft channel and drought operations with the revised 20% reduction of 7Q10 flow (4,640 cfs) and the DIL calculated semi-monthly. Carters operations are changed with a seasonally varying minimum flow requirement, the addition of Zone 2, and a defined guide curve. Allatoona operations are changed with the addition of Zones 3 and 4 and the revised peaking hydropower demand that ranges from 0-4 hours and the Phased Drawdown guide curve (Figure 40). This alternative is the same as the RPlan C alternative, except that it uses the Allatoona Phased Drawdown guide curve. The measures selected to represent the "RPlanE" Alternative are listed below.

RPlan E Measures:

1. 2006 Water Use
2. Navigation Support: APC projects and COE projects on the Alabama River
3. Drought Plan Revised (previously shown in Table 17)
4. Carters Seasonal Release
5. Allatoona, Burkett C

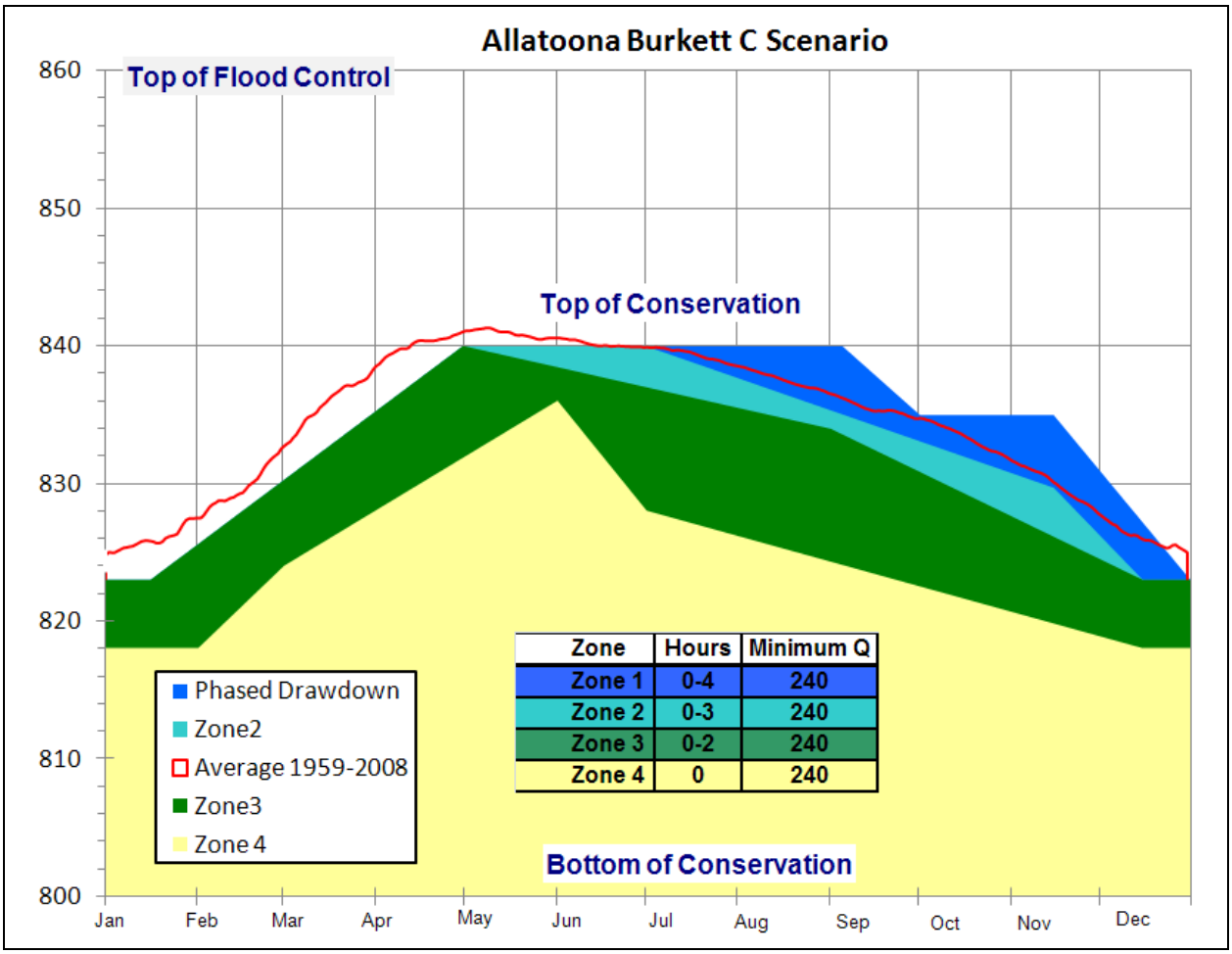


Figure 40. Allatoona Burkett C Scenario

11. RPlan F

The RPlan F alternative includes a navigation operation to support a 9-ft or 7.5-ft channel and drought operations with the revised 20% reduction of 7Q10 flow (4,640 cfs), the DIL calculated semi-monthly, and the USFWS enhancement. Carters operations are changed with a seasonally varying minimum flow requirement, the addition of Zone 2, and a defined guide curve. Allatoona operations are changed with the addition of Zones 3 and 4 and the revised peaking hydropower demand that ranges from 0-4 hours and the Phased Drawdown guide curve. This alternative is the same as the RPlan E alternative, except that it uses the Revised Drought Plan with the USFWS enhancement. The measures selected to represent the "RPlanF" Alternative are listed below.

RPlan F Measures:

1. 2006 Water Use
2. Navigation Support: APC projects and COE projects on the Alabama River
3. Drought Plan Revised, FWS Enhancement (previously shown in Table 13)
4. Carters Seasonal Release
5. Allatoona, Burkett C

12. RPlan G

The RPlan G alternative includes a navigation operation to support a 9-ft or 7.5-ft channel and drought operations with the revised 20% reduction of 7Q10 flow (4,640 cfs), the DIL calculated semi-monthly, and the USFWS enhancement. Carters operations are changed with a seasonally varying minimum flow requirement, the addition of Zone 2, and a defined guide curve. Allatoona operations are changed with the addition of Zones 3 and 4 and the revised peaking hydropower demand that ranges from 0-4 hours, reduced during September-October period, and the Phased Drawdown guide curve (Figure 41). This alternative is the same as the RPlan F alternative, except that it uses the reduction in hydropower from September to October. The measures selected to represent the "RPlanG" Alternative are listed below.

RPlan G Measures:

1. 2006 Water Use
2. Navigation Support: APC projects and COE projects on the Alabama River
3. Drought Plan Revised, FWS Enhancement (previously shown in Table 13)
4. Carters Seasonal Release
5. Allatoona, Burkett D

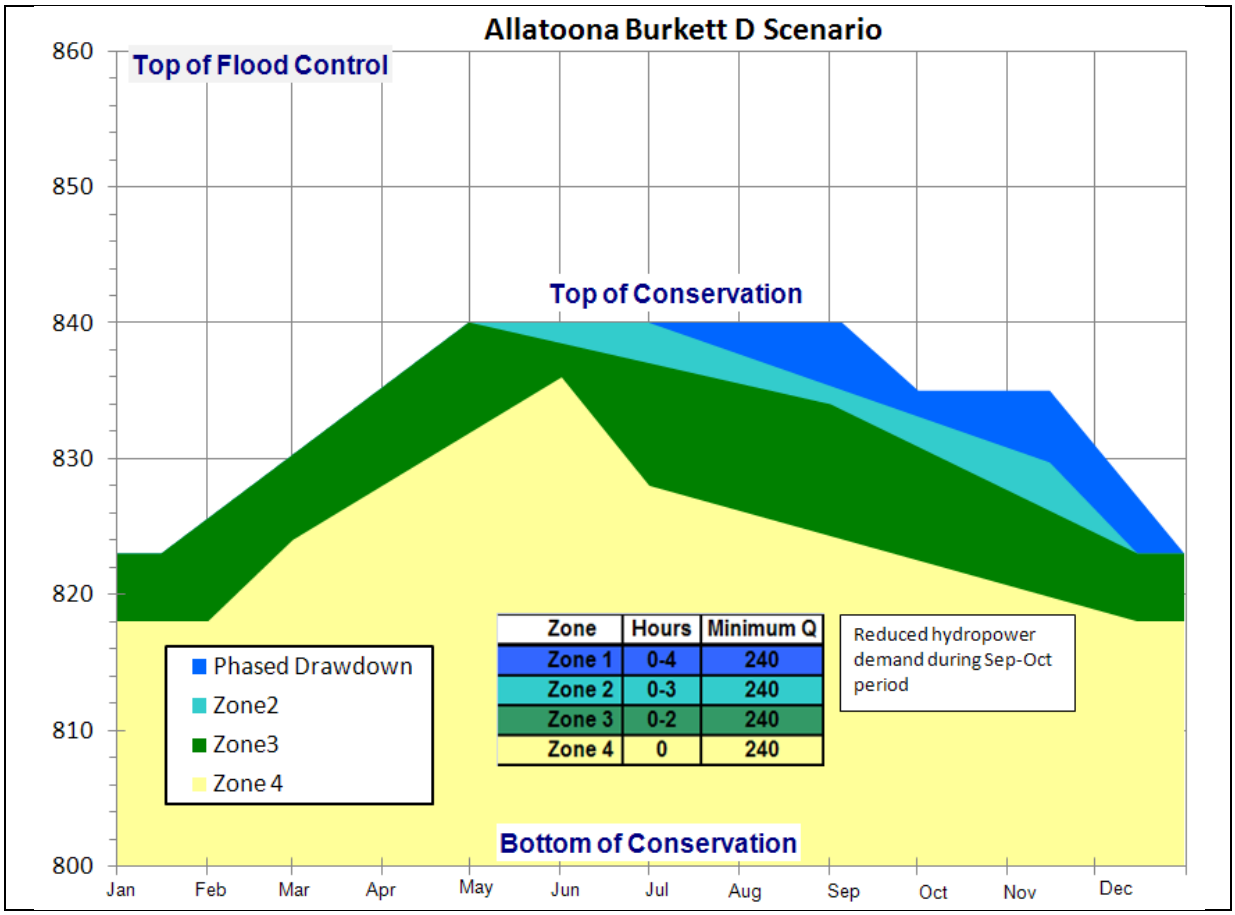


Figure 41. Allatoona Burkett D Scenario

IV. Results of Modeling

Each simulated alternative produces daily results including reservoir release (distributed by outlet) and storage, and streamflow at all locations throughout the model. To assist with the analysis of so many results, scripted plot templates and report generation templates were created to provide on-demand illustrations of the state of various reservoir systems operations. Figure 42 shows the list of custom scripts used for plotting and building reports.

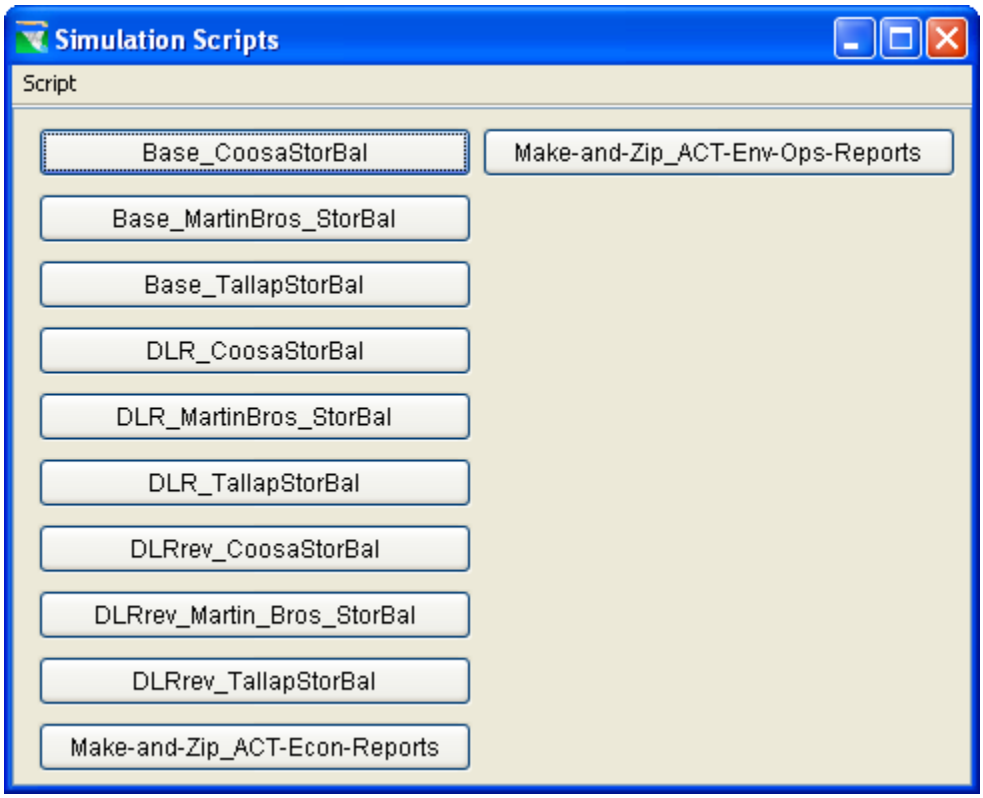


Figure 42. Simulation Scripts for Generating Plots and Reports

Three main custom plot types were designed for viewing system balances. The Coosa Storage Balance script plots the storage as a percentage of zone in Weiss, HN Henry, and Logan Martin, as well as reservoir releases and flow at J.D.Minimum and JBT Goal (Figure 43). Reservoirs on the Coosa River operate to meet a minimum flow at J.D.Minimum and Logan Martin operates to meet a minimum at JBT Goal. The objective flows for J.D.Minimum and JBT Goal are also plotted, as are the computed values of the minimum flow rules (Min@JBT_Goal_4640 and Min@J.D.Minimum). The other two storage balance plot types are similar. The Martin Brothers Storage Balance script plots the storage in Martin and Logan Martin, along with reservoir releases and flow at JBT Goal, for which Martin and Logan Martin operate together (Figure 44). The Tallapoosa Storage Balance script plots storage in Harris and Martin, as well as reservoir releases and flows at Tallassee and JBT Goal (Figure 45). Reservoirs on the Tallapoosa operate to meet a minimum at Tallassee. The pool of each reservoir is shown at 200% of zone when the Conservation Pool is full. The Drought Pool is full at 100% and the Flood Pool is full at 300%.

Separate scripts are used to review the results for the Baseline Alternative (scripts beginning with "Base_": Base_CoosaStorBalance, Base_Martin_Bros_StorBal, and Base_TallapStorBal), all alternatives that use the basic Drought Operations (scripts beginning with "DLR_"), and all alternatives that use the Revised Drought Operations (scripts beginning with "DLRrev_"). The plots that were designed to be used with alternatives that use Drought Operations include a plot area for the Drought Intensity Level. This allows the user to easily view how operations are responding to the changing Drought Levels. Figure 46 shows an example of one of these plots, with the DIL at the top.

In addition to the plotting scripts are report scripts, "Make-and-Zip_ACT-Econ-Reports" and "Make-and-Zip_ACT-Env-Ops-Reports." These scripts build excel data files of results that are useful to the economic, environmental, and operational analysis and assembles them in zip files.

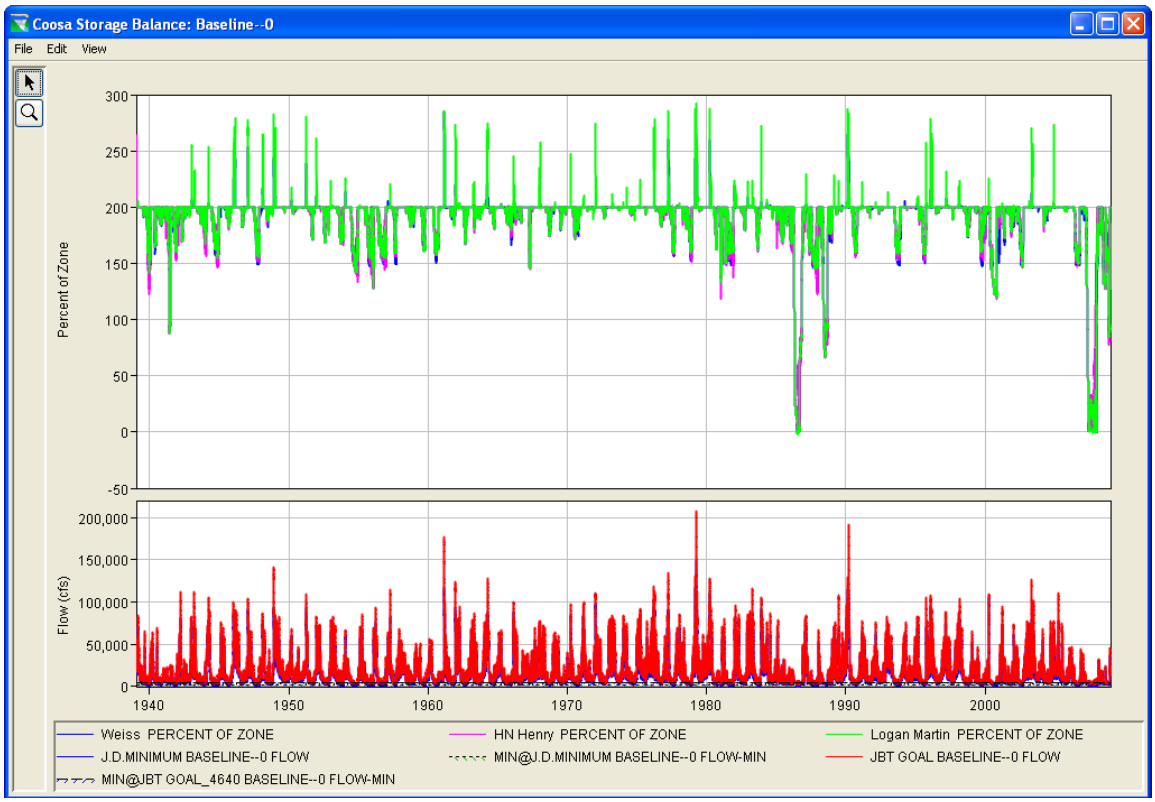


Figure 43. Coosa Storage Balance for Baseline Alternative

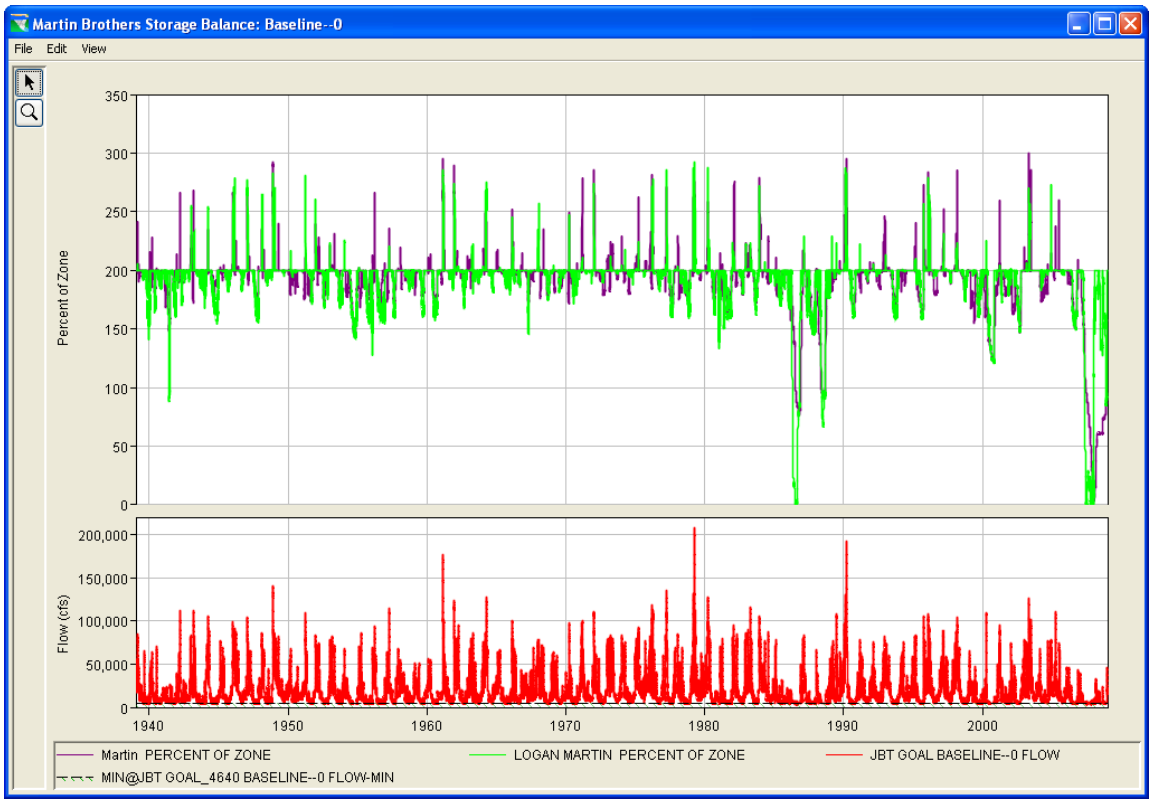


Figure 44. Martin Brothers Storage Balance for Baseline Alternative

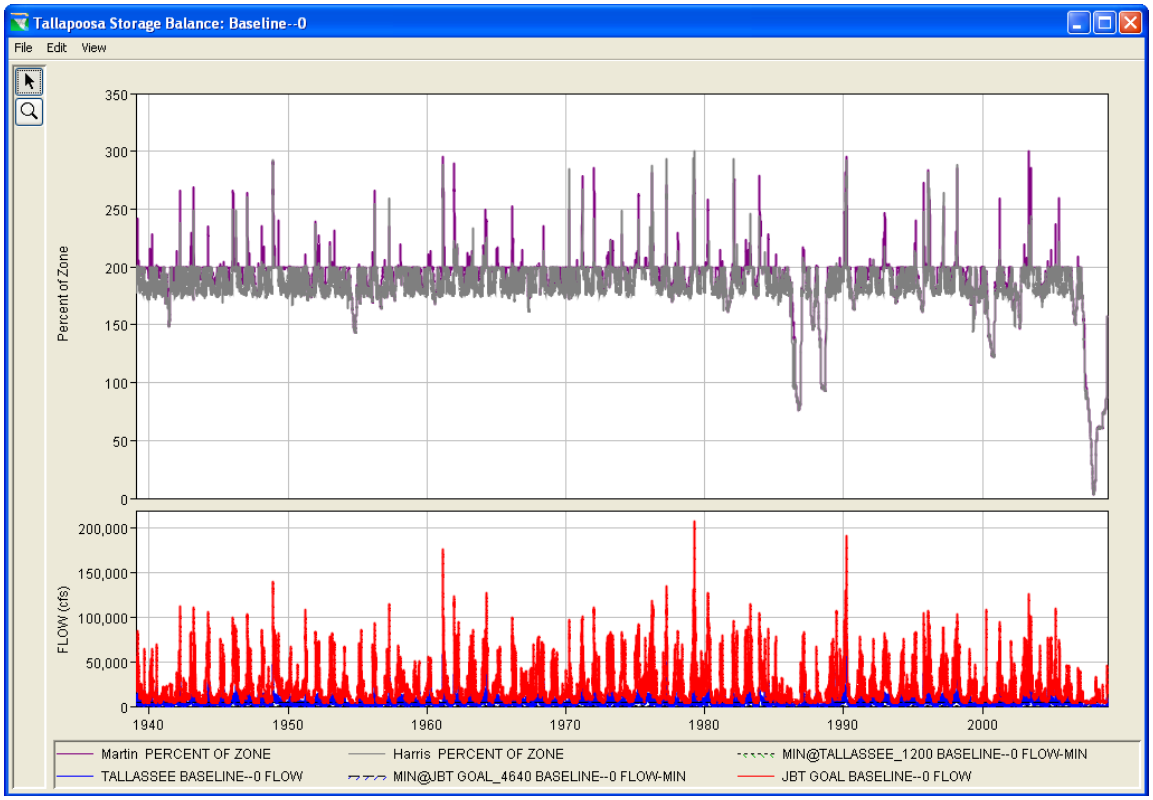


Figure 45. Tallapoosa Storage Balance for Baseline Alternative

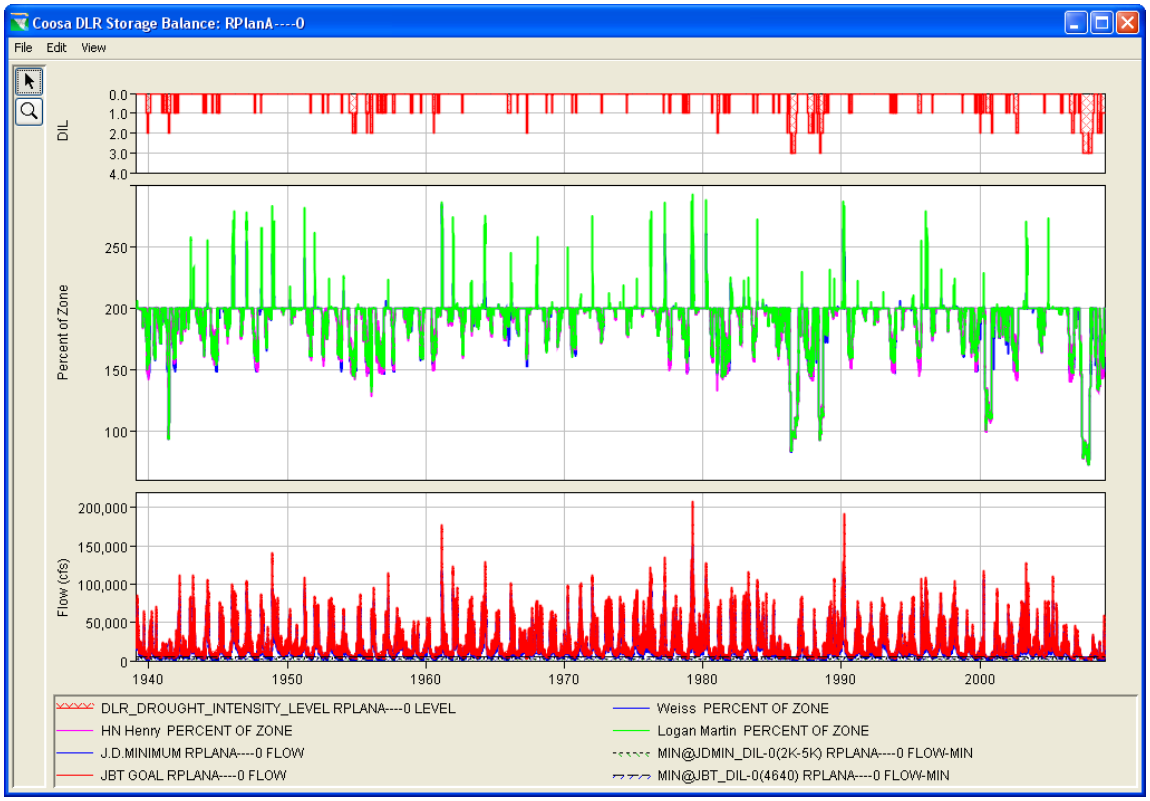


Figure 46. Coosa Storage Balance for RPlan A Alternative (with Drought Operations)

V. References

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Alabama-Coosa-Tallapoosa (ACT) Watershed

HEC-ResSim Modeling of Reservoir
Operations in Support of Water Control
Manual Update

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US Army Corps of Engineers
Mobile District
P.O. Box 2288
Mobile, AL 36628-0001

Prepared by:
US Army Corps of Engineers
Institute for Water Resources
Hydrologic Engineering Center
609 Second Street
Davis, CA 95616

(530) 756-1104
(530) 756-8250 FAX
www.hec.usace.army.mil