Synopsis Report - Surface Water Availability Resource Assessment

Georgia's
State Water Plan

Georgia Environmental
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SURFACE WATER RESOURCE ASSESSMENT

Georgia Statewide Water Planning

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ACRONYMS AND ABBREVIATIONS

7Q10	1- in 10-year 7-day low flow
A	agricultural water-use category
ACF	Apalachicola – Chattahoochee – Flint Study Basin
ACT	Alabama – Coosa – Tallapoosa Study Basin
cfs	cubic feet per second
cfsd	cubic feet per second for one day
CUA	consumptive use assessment, or resource assessment
CUIF	cumulative unimpaired flow
EPD	Georgia Environmental Protection Division
FERC	Federal Energy Regulatory Commission
GWE	groundwater effects water-use category
HEC	Hydrologic Engineering Center
HEC-5	Hydrologic Engineering Center Simulation of Flood Control and Conservation Systems model
HEC-DSS	Hydrologic Engineering Center Data Storage System
HEC-ResSim	Hydrologic Engineering Center Reservoir System Simulation model
I	industrial water-use category
LDA	local drainage area
LUIF	local unimpaired flow
M	municipal water-use category
M7Q10	monthly 1- in 10-year 7-day low flow
OOA	Oconee – Ocmulgee – Altamaha Study Basin

OSSS	Ochlocknee – Satilla – St. Marys – Suwanee Study Basin
ROS	Reservoir Operations Study
Round 1	Georgia statewide surface-water resource assessments completed in 2010
Round 2	Georgia statewide surface water resource assessments documented in this report
SO	Savannah – Ogeechee Study Basin
T	thermal water-use category
TN	Tennessee Study Basin
TVA	Tennessee Valley Authority
UIF	unimpaired flow
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

EXECUTIVE SUMMARY

Background and purpose

In 2010, to support regional water planning, the Georgia Environmental Protection Division (EPD) completed three resource assessments to obtain technical information on the capacity of water resources to meet demand for water supply and wastewater discharge. Assessments were undertaken as directed by Georgia's 2008 State Water Plan and pursuant to the 2004 Georgia Comprehensive Statewide Water Management Planning Act (O.C.G.A. §§ 12-5-520 et seq.). Surface water availability, groundwater availability, and the ability of surface waters to process treated wastewater were assessed.

Because the state's waters support a range of uses and provide a variety of benefits, these assessments were undertaken to give the Water Planning Councils information on the long-term capacity of individual resources to support multiple uses. EPD used models to simulate responses of streams and water bodies to current and projected demands, and compared results with thresholds that indicate the potential for local or regional impacts to be addressed in the regional planning process.

The resource assessments were not intended to be a comprehensive or definitive analysis of how much water can be withdrawn from or discharged to an individual waterbody − those quantities will vary with watersheds and other specifics, e.g., location of withdrawals or discharges or wastewater treatment levels. Rather, the assessments were designed to assist regional Water Planning Councils to identify areas for which management actions might be needed to ensure that a region's resources can sustainably meet long-term demands for water supply and wastewater discharge.

Each assessment used different types of thresholds to indicate the potential for impacts. Thresholds used for resource assessment purposes measure conditions strongly related to resource use, but they do not address all possible impacts. The assessments are model simulations that have elements intentionally built in to produce a conservative analysis. These assessments were undertaken for the first time in 2010, and they are expected to be refined through ongoing five-year review and revision cycles for regional water plans. Resource assessment updates conducted since 2010 are intended to support the current (2016-2017) round of regional Water Planning Council plan review and revisions. For convenience, the 2010 resource assessments are subsequently identified in this report as the "Round 1" assessments, and the current 2016-2017 assessments are identified as the "Round 2" assessments.

This report presents the assessment of surface water availability relative to the quantity and timing of municipal, industrial, agricultural, and thermal power consumptive water uses throughout Georgia. While the focus is on surface water availability, groundwater pumping is also considered to the extent that groundwater withdrawals affect flow in surface streams. Water availability is defined as the "natural"[1] hydrologic capacity to meet water demands without depletion of instream flows below the low-flow thresholds as provided in current state policy, or regulated minimum flow requirements incorporated in the

[1] "Natural" hydrology for purposes of this study is assumed to be characterized by unimpaired flows, or historical flows with effects of reservoir releases, reservoir surface precipitation and evaporation, and water withdrawals and returns removed. Because effects of some human activities, included those associated with land use and waterway improvements, are not readily quantifiable and cannot be entirely removed from historical flows, unimpaired flows are not necessarily 100% natural.

operating rules for federal and non-federal reservoirs in Georgia. These instream low-flow thresholds are also referred to in this report as the *flow regime*. For unregulated streams (i.e., streams not significantly affected by reservoir operations), this study compares available water (natural or unimpaired flow) and water demand (water uses listed above) as the basis for assessment of the amount of water that can be consumed without substantially altering the flow regime, and subsequent opportunities for instream and downstream uses supported by that flow regime. Water availability for regulated streams is based on the physical availability of conservation storage in upstream reservoirs to meet minimum flow requirements imposed by the operating rules with reservoir and river water uses in effect, regardless of whether storage in these lakes has been reserved for water supply use.

The essential impact of offstream water use is its consumptive component, and assessment of surface water consequently was structured as analysis of consumptive use. Consumption is defined as withdrawals from a water body or reach of stream that are not returned to that water body or reach. Modeled consumptive use assessments (CUAs) for current and future water uses were conducted statewide based on sequential simulation of daily flows in unregulated and regulated streams. The period of analysis for the resource assessments for the Apalachicola–Chattahoochee–Flint (ACF) and the Alabama–Coosa–Tallapoosa (ACT) Study Basins is 1939 through 2011, due to the concurrent availability of (1) water use data developed by EPD, (2) daily unimpaired flows (UIFs) developed by the U.S. Army Corps of Engineers (USACE), and (3) USACE-created reservoir system operational models reflecting updated water control manuals for both basins for this period. The period of analysis for the Oconee–Ocmulgee–Altamaha (OOA), Ochlocknee–Suwannee–Satilla–St. Marys (OSSS), Savannah–Ogeechee (SO), and Tennessee (TN) Study Basins is 1939 through 2013. Both periods of analysis include five to six severe and multi-year regional or statewide droughts. Because droughts define limits of water availability, determination of water shortages relative to consumptive water uses and instream flow requirements is based primarily on low-flow as opposed to normal, wet, or flood conditions.

Round 2 surface water availability assessments documented in this report build upon the methods, assumptions, data, and results of the 2010 Round 1 resource assessments, which include an inventory of historical water uses, derived 1939–2007 UIFs, and results of CUA models applied statewide. The Round 1 resource assessment results are documented in the *Synopsis Report – Surface Water Availability Assessment*, Review Draft published by EPD in March 2010 and subsequent addenda. Terms pertinent to surface water availability analysis are defined in Section 7 of this report and described in detail as needed in subsequent sections of this report. For convenience, some of the basic terminology is briefly defined as follows:

- *Unimpaired flows* are historically observed or reconstituted flows with effects of reservoir releases, reservoir surface precipitation and evaporation, and water withdrawals and returns by municipal, industrial, thermal power, and agricultural water users removed.
- *Basic nodes* represent stream gages or locations of interest on rivers or tributary streams where UIFs were derived.
- *Planning nodes* are basic nodes where surface water availability is assessed; one or more basic nodes may be interspersed between planning nodes. Planning nodes are located to avoid separation of major utility withdrawals and returns, and to avoid separation of planning regions and municipalities served by multiple water utilities.
- *Reaches* are streams connecting nodes (basic or planning).

- *Regulated nodes* are located at or downstream of federal or non-federal storage reservoirs; nodes downstream of small run-of-river projects are generally not considered to be regulated.
- *Unregulated nodes* are nodes with no federal or non-federal storage reservoirs located upstream. Off-channel water supply reservoirs are generally not required to make releases for downstream flow augmentation and consequently are not considered to be storage reservoirs for purposes of resource assessment.
- *Study basins* are the six major composite river basins defined above (ACT, ACF, OOA, OSSS, SO, and TN) designated by EPD for consumptive-use assessment and delineated based on hydrologic, topographic, water resource development, water uses, or other considerations important to regional planning.
- *Sub-basins* are intervening watersheds between planning nodes, or total drainage area above the most upstream planning node.
- *Local drainage areas (LDAs)* are intervening watersheds between adjacent nodes (planning or basic), or total drainage area above the most upstream basic node.
- *Net (consumptive) water use* is aggregated withdrawals less returns upstream of or between planning nodes (reaches).
- *Flow regime* (also referred to as the *required flow* regime or *adjusted flow* regime) is the flow threshold at planning nodes used for resource assessment.

This report summarizes the results of Round 2 surface water availability assessments for current and future water use scenarios for all of Georgia's study basins. Methods, assumptions, data, and criteria described in this report pertain to consumptive water uses, UIFs, flow regimes, and resource assessment models. Current water uses reflect historically observed water uses statewide in 2011; future water uses are those projected water demands for 2050 as determined by the updated water demand forecasts. Both current and future water uses are superimposed on historical unimpaired flows (1939–2011 or 1939–2013, depending on study basin) in the resource assessment models, assuming present-day water management practices and reservoir operating rules remain uniformly in effect.

Updates incorporated in the Round 2 resource assessments

As in Round 1, resource assessment models were applied to simulate and compare the responses of rivers and reservoirs to water management, water use, and water supply infrastructure alternatives to historical hydrology and current reservoir system operational policies. In addition, derivation of unimpaired flows for Round 2 resource assessments generally applied methods, procedures, and assumptions used in Round 1. However, significant improvements were made in Round 2 to the data and models used for resource assessment, and to the tools for communication of model results used to inform development and evaluation of water management alternatives by the Water Planning Councils. In addition to improved models and tools, the Round 2 resource assessments extend hydrologic time-series and incorporate greater physical system and operational detail than the Round 1 assessments, specifically in the following ways:

- As previously described, Round 1 daily local unimpaired flows (LUIFs) were extended from 1939–2007 to 1939–2011 for the ACT and ACF Study Basins, and to 1939–2013 for all other study basins (SO, OOA, OSSS, TN) in Round 2.

- No modifications were made to Round 1 1939–2007 daily LUIFs; 1939–2011 ACF and ACT LUIFs developed by USACE Hydrologic Engineering Center (HEC) as input to its Water Control Manual HEC-ResSim (Reservoir System Simulation) models were applied without modification in the Round 2 resource assessment.
- Carsonville (CARSONVL) was added as a planning node in the Flint River Basin (ACF Study Basin). Macon 2 (MACON2) and Lumber City 2 (LUMBER2) were added at the MACON and LUMBER node locations on the Ocmulgee River (OOA Study Basin) for simulation of alternate water withdrawal and return reach locations. These additional nodes now have the necessary input data and simulation results to serve as planning nodes.
- Irrigation meter data as well as mapped irrigated acreage were used for estimation of agricultural water use in Round 2; Round 1 relied on mapped irrigated acreage but estimated application rates.
- Samples of farm ponds were bathymetrically surveyed. Twenty ponds in the Flint (ACF), ten in the Ogeechee (SO), and ten in the Suwannee (OSSS) River Basins were selected for field surveying. Based on the surveys, farm pond storage was incorporated into Round 2 assessments for these basins. Farm ponds simulated in the models were limited to those refilled by natural runoff, i.e., well-to-pond and off-channel pumped-storage ponds were not analyzed. Composite farm ponds were developed for modeling purposes using field-based estimates of farm pond storage for selected basins.
- New and more detailed HEC-ResSim and HEC-5 (Simulation of Flood Control and Conservation Systems) models were used in place of the River Basin Planning Tool (RBPT) developed in Round 1 for resource assessments. The models reflect the most recent USACE Water Control Manual updates for the ACT, ACF, and Savannah River Basins, and Tennessee Valley Authority (TVA) operation of its reservoirs in Georgia in the Tennessee River Basin. The HEC-ResSim models incorporate hydrologic channel routing and were also used to derive cumulative unimpaired flow regimes for planning nodes on unregulated streams. The new models provide the flexibility for resource assessments for any node – planning or basic – assuming water use data can be disaggregated.
- Operational simulation of TVA reservoirs in the Tennessee River Basin in Georgia was performed in Round 2, whereas run-of-river operation of these reservoirs was assumed in Round 1.
- Off-channel water supply pumped-storage reservoirs were included for the Oconee (OOA), Flint and Chattahoochee (ACF), and Etowah (ACT) Study Basins.

Models, data, assumptions, and results pertinent to each study basin are discussed in detail in subsequent sections of this report.

Unimpaired flows

Unimpaired flows are observed or reconstituted flows with human influences removed. Human influences considered in derivation of UIFs include flow regulation by and net evaporation from large reservoirs; water withdrawals and wastewater returns by municipal, industrial, and thermal power users; and agricultural irrigation. Groundwater pumping in areas where groundwater withdrawals affect surface water flows were also considered in derivation of UIFs. The use of UIFs, as opposed to historical observed flows, allows resource assessments to be founded on the “natural” hydrology of the stream network. This approach enables consistent, unbiased evaluation of impacts of past, present, and future water consumption, reservoir regulation, and other water management activities on instream flows and reservoir levels. Daily unimpaired stream flow, evaporation, and precipitation time-series constitute the hydrologic inputs to the HEC-ResSim and HEC-5 models applied in this study to surface water resource assessment.

Some human influences on stream flows take place over long periods of time and may be largely irreversible or difficult to quantify with the degree of certainty needed for resource assessment. Consequently, their influences on observed flows were not considered in derivation of UIFs for resource assessment purposes. In addition, hydrologic and climatological time-series used in this study incorporate variations of hydrology and climate only to the extent that they are captured in the historically observed data. These data reflect a variety of hydrologic conditions with which water use and reservoir operational scenarios can be evaluated.

Unimpaired flows rather than observed flows were applied in this study because of the need for a common benchmark (i.e., with effects of water withdrawals and other water management activities removed). Methods, procedures, and assumptions for UIF development are described in Section 4 of this report.

Water uses

Water use categories include municipal (M), industrial (I), thermal (T), agricultural (A), and groundwater effects (GWEs), representing the depletion of surface water flow by groundwater withdrawals. Historical water withdrawals and returns were used for derivation of UIFs. Water uses for “current” resource assessments are represented by metered surface water withdrawal and groundwater pumping data reported to EPD for the year 2011. Net reach water use includes direct withdrawals and returns to surface waters and GWEs. Groundwater effects in this study are confined primarily to southwestern Georgia portions of the ACF Study Basin, described in more detail in Section 3 of this report.

Water uses for “current” resource assessment demands reflect recorded 2011 monthly historical surface water withdrawals and returns statewide. Water uses for “future” resource assessments are forecasted annual demands for the year 2050 in each water use category, as described in technical memoranda authored by the planning contractors (Black & Veatch, CH2M, and CDM Smith) for each of the 10 Water Planning Councils and EPD. Annual demands were disaggregated into monthly values for future resource assessment modeling based on monthly patterns considered to be typical by EPD.

Flow regimes

Flow thresholds at planning nodes for water availability assessment are determined by the type of planning node assessed, i.e., unregulated or regulated. The flow threshold for unregulated nodes – also referred to in surface water resource assessment as the adjusted flow regime (AFR) – is the lesser of the cumulative unimpaired monthly 7Q10 (1- in 10-year, 7-day low flow for each month of the year) or cumulative unimpaired daily flow. For regulated nodes, the required flow regime is defined by minimum releases or minimum instream flow requirements imposed by the operating rules for upstream storage reservoirs. Operating rules are outlined in the water control plans for federal reservoirs and Federal Energy Regulatory Commission (FERC) license requirements for private power reservoirs. In the absence of such requirements for regulated nodes, there is no required flow regime.

Flow regime definitions and criteria for the Round 2 resource assessments are the same as those applied in Round 1.

Farm ponds

Based on requests by Water Planning Councils to investigate how use of farm pond storage to meet irrigation demands might affect potential gaps at downstream nodes, farm pond storage – estimated by field surveys and extrapolation of survey data – was incorporated into the Round 2 resource assessments for the Flint (ACF), Ogeechee (SO), and Suwannee (OSSS) Study Basins. Farm ponds considered in the current round of resource assessments were limited to those refilled by natural runoff, and consequently well-to-pond and off-channel pumped-storage ponds were not analyzed.

A study was initiated and completed in 2016 to estimate the volume of surface water stored in selected runoff-filled farm ponds used for agricultural irrigation within selected LDAs in the basins. Bathymetric features of these ponds were surveyed to determine available storage as a function of elevation in these ponds. The study used existing geographic information system (GIS) data sets showing farm pond locations and sizes, irrigation metering data reported by agricultural land users of the Flint River Basin, and field topographic surveys. From these data, virtual composite farm ponds, representing aggregations of individual ponds in contributing LDAs, were synthesized and inserted in the appropriate river reaches in the HEC-ResSim and HEC-5 models applied to resource assessment of the ACF, SO, and OSSS Study Basins. Detailed discussion of farm pond model data and assumptions pertinent to the analysis are provided in Section 5 of this report.

The assumption for operational simulation of farm ponds is that releases will be made only when full or overfull due to natural inflow. Farm ponds are not required to make flow-augmentation releases, and consequently nodes downstream of the ponds were considered unregulated rather than regulated.

Water supply reservoirs

Resource assessment models incorporated off-channel pumped-storage water supply reservoirs in several river basins. These reservoirs supply water to municipal and industrial uses either by direct withdrawals or by releases from storage to maintain downstream flows to support river withdrawals. Because natural inflow to off-channel reservoirs is typically insufficient to support water demand, their yield is augmented by diversion of excess flow, i.e., pumping (up to installed pump capacity) above the required flow regime from the river to refill the reservoir.

The following off-channel water supply reservoirs were incorporated in the resource assessment models:

- Bear Creek Regional Reservoir upstream of the Penfield node in the Oconee Basin (OOA Study Basin) HEC-ResSim model.
- Multiple water supply reservoirs represented as a composite reservoir upstream of the Montezuma node in the Flint Basin (ACF Study Basin) HEC-5 model.
- Glades Reservoir upstream of Lake Lanier in the Chattahoochee Basin (ACF Study Basin) HEC-ResSim model.
- Hickory Log Creek Reservoir in the Etowah Basin upstream of Lake Allatoona in the ACT Study Basin HEC-ResSim model.

The assumption for operational simulation of the water supply reservoirs is that flow regimes will be protected by limitations on pumping rather than by flow-augmentation releases, and consequently nodes downstream of the reservoirs were considered unregulated rather than regulated.

Water availability measures

During low-flow periods, the methodology employed in this study curtails water demand only when total stream flow is insufficient, irrespective of flow regime violations. The rationale for this approach is simplicity and consistency of accounting of potential resource gaps under low-flow conditions. Surface water availability model simulation results show that, by design, surface water demand was fully met except when total stream flow was insufficient. All water use categories were assumed to be fully met with sufficient stream flow, and curtailed equally otherwise.

For unregulated planning nodes, water availability is characterized by potential gaps between flow thresholds and simulated flows remaining after water diversions and returns. Potential gaps are characterized based on (1) gap event duration category (1 to 30 days or more), (2) number of gap events by category, (3) total gap days by category, (4) average daily flow deficit per gap event by category, and (5) average cumulative flow deficit (gap volume) per gap event by category. Statistics were also developed showing the percentage of time with potential gaps, average gap, and average flow for the period of analysis (1939–2011 or 1939–2013).

For regulated nodes, water availability is determined by compliance with selected criteria that include potential demand shortages, minimum instream flow requirements prescribed by reservoir operating rules, minimum usable storage remaining in reservoirs, and average basin-wide flow requirement (if applicable) shortfall potentially resulting from water uses throughout the period of analysis. When the amount of water physically in storage in upstream reservoirs is sufficient to meet both prescribed flow regimes and consumptive water uses, potential gaps are assumed to be zero, regardless of whether storage in these reservoirs has been allocated for water supply use. Storage represents aggregate total conservation storage within the reach (i.e., the sum of federal and non-federal reservoir storage between planning nodes).

Summary of findings

Most of the planning nodes distributed among the state's six study basins are regulated, and current and future scenario model simulation results show storage remaining in upstream federal or non-federal reservoirs at all times, indicating no potential gaps for these nodes. However, model simulation results for most of the unregulated planning nodes show potential gaps for both current and future conditions. Tables ES-1 and ES-2 summarize selected gap statistics for all study basins for current (historical 2011 water use) and future (projected 2050 water use) scenarios, with and without consideration of farm ponds. Terminology used in these tables is defined as follows:

Nodes – planning nodes

Number of planning nodes – number of planning nodes in a river or study basin

Nodes with potential shortfalls – number of planning nodes with potential gaps (only planning nodes are examined for shortfalls); potential gaps occur when simulated stream flow after water withdrawals falls below the identified flow thresholds

Nodes with farm ponds – number of planning nodes in a river or study basin with composite farm ponds located upstream

Potential gap duration – length of time of model-simulated potential gaps (simulated flow below threshold) at planning nodes as a percentage of total simulation time (1939–2011 or 1939–2013)

Average potential gap – average potential gap simulated at planning nodes over the total simulation time (1939–2011 or 1939–2013), in cubic feet per second (cfs)

More detailed statistics and charts are subsequently presented in this report for individual planning nodes within each study basin, with potential gap events for each categorized by event duration, and with the number of potential gap days, average flow deficit per potential gap event, and average cumulative flow deficit per potential gap event quantified by category. These more detailed data are intended to assist Water Planning Councils in the formulation, analysis and assessment, comparison, selection, and implementation of water management practices.

Table ES-1 Summary of potential gaps under current conditions

River/ Study Basin	Total number of planning nodes	Current (historical 2011 water use) scenario without farm ponds			Current (historical 2011 water use) scenario with farm ponds			
		Nodes with potential gaps	Gap duration (percent of time)	Average gap (cfs)	Nodes with potential gaps	Nodes with farm ponds	Gap duration (percent of time)	Average gap (cfs)
OSSS	8	8	2-17	<1-45	7	4	1-13	<1-33
TN	6	3	5-6	2-6	3	0	-	-
OOA	8	1	6	21	1	0	-	-
OG (SO)	3	3	6-21	6-35	3	3	5-17	5-25
SAV (SO)	5	0			0	0	-	-
ACT	5	3	2-6	3-6	3	0	-	-
ACF	7	1	12	372	1	3	12	350

Table ES-2 Summary of potential gaps under future conditions

River/ Study Basin	Total number of planning nodes	Future (projected 2050 water use) scenario without farm ponds			Future (projected 2050 water use) scenario with farm ponds			
		Nodes with potential gaps	Gap duration (percent of time)	Average gap (cfs)	Nodes with potential gaps	Nodes with farm ponds	Gap duration (percent of time)	Average gap (cfs)
OSSS	8	7	2-12	<1-46	7	4	2-10	<1-33
TN	6	3	5-6	<1-12	3	0	-	-
OOA	8	1	6	23	1	0	-	-
OG	3	3	3-15	5-37	3	3	3-12	4-21
SAV	5	0			0	0	-	-
ACT	5	3	3-7	4-12	3	0	-	-
ACF	7	1	9	290	1	3	9	286

1 RESOURCE ASSESSMENTS

1.1 Study Objectives and Process

The primary objective of this study is the assessment of surface water availability relative to the quantity and timing of municipal, industrial, agricultural, and thermal power consumptive water uses throughout Georgia. Surface water availability is defined by the natural hydrologic capacity to meet water demands without depletion of instream flows below the flow thresholds mandated by current state policy, or regulated flow requirements incorporated in the operating rules for federal and non-federal reservoirs in Georgia. These instream flow requirements are subsequently referred to in this report as the *flow regime*. This study evaluates the effects of current (historical 2011) and future (projected 2050) water demands on flow regimes and reservoir levels selected as indicators of potential local or regional impacts to be addressed through the regional water planning process.

Assessments were conducted statewide on a sub-basin scale for the major study basin catchments delineated as described in Section 2 of this report. The period of analysis for the Alabama–Coosa–Tallapoosa (ACT) and Apalachicola–Chattahoochee–Flint (ACF) Study Basins resource assessments is 1939 through 2011, and the period of analysis for the Savannah–Ogeechee (SO), Oconee–Ocmulgee–Altamaha (OOA), Ochlocknee–Satilla–St. Marys–Suwanee (OSSS), and Tennessee (TN) Study Basins is 1939 through 2013. These 73- and 75-year periods include seven or more significant multi-year regional droughts. Droughts constitute critical periods for water availability analysis.

Unimpaired flows (UIFs) form the basic hydrologic input to the surface water availability modeling component of the resource assessment. Unimpaired flows are reconstructed flows that are intended to resemble natural historical stream flows, or flows that would have naturally occurred absent human activities. Unimpaired flows are developed based on observed flows, but with removal of human influences that are recorded or estimated. Removal of all human influences is not practical because some (e.g., effects of changing land use on evaporation, runoff, and stream flow over time) cannot be directly measured, or reconstituted from indirect measurements with sufficient accuracy that they can be separated from background effects of long-term climate cycles or climate change. Human influences that are measurable and consequently addressed in this study include (1) reservoir regulation (holdouts and releases of reservoir inflows from reservoir storage), (2) net evaporation (evaporation less precipitation) on reservoir surface area, and (3) water withdrawals and returns by municipal, industrial, agricultural, and thermal power uses. In some reaches, groundwater pumping reduces surface water flows. Surface water depletions due to groundwater pumping are designated as groundwater effects in this study, and have been considered in the development of UIFs. Thus, while flows developed in this study are not entirely unimpaired in the literal sense, they do capture the most measurable and changeable human influences, with other more permanent human influences (e.g., land uses and dams) assumed to be part of the hydrologic background. The process for determining UIFs is described in further detail in Section 4 of this report. Incremental daily UIFs were developed for locations designated as planning or basic nodes in all study basins statewide. Surface water resource assessments were performed statewide using the process shown in Figure 1-1.

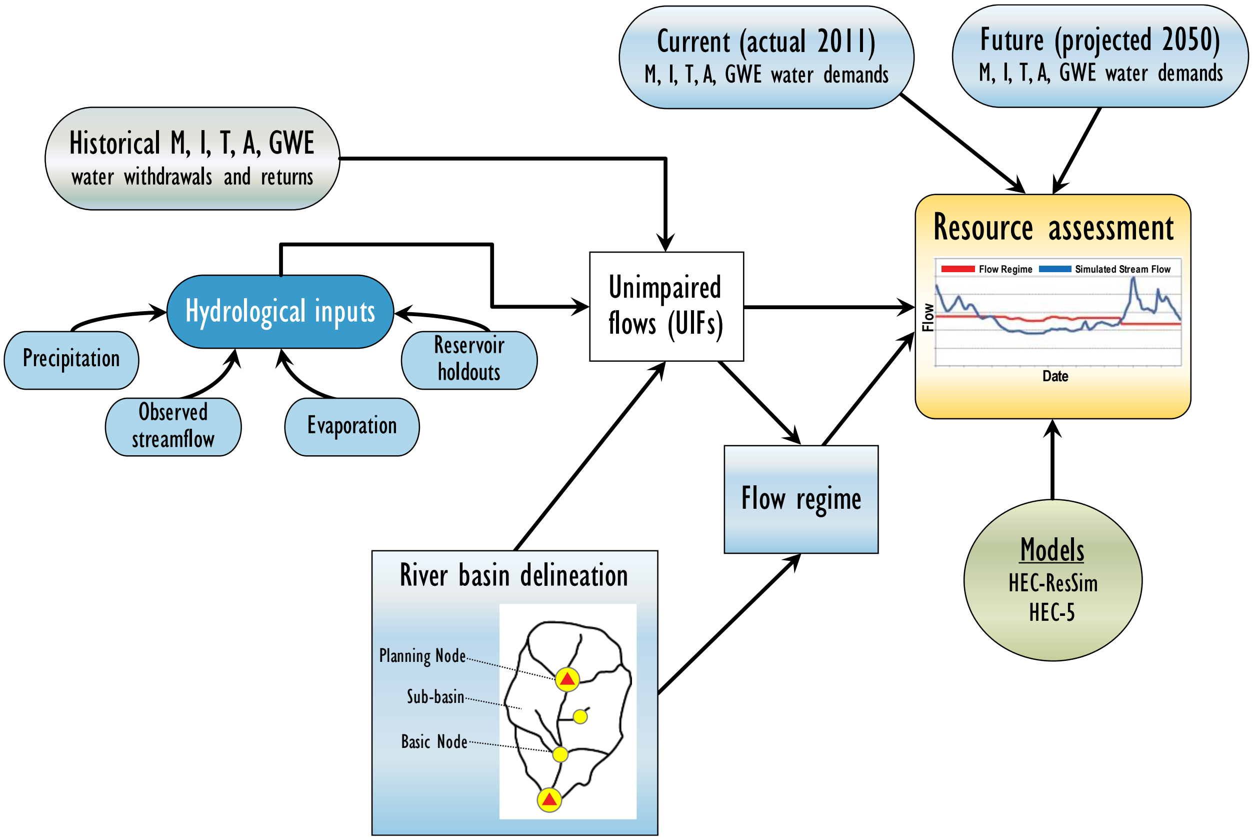


Figure 1-1 **Surface water availability resource assessment process components**

The Georgia Environmental Protection Division (EPD) has directly responded to requests from the Water Planning Councils for improvements in the Round 1 resource assessments completed in 2010. The Round 2 resource assessments benefitted from the following improvements to the methods, assumptions, data, and models applied in Round 1:

- Extension of daily UIFs from 1939–2007 for all study basins in Round 1 to 1939–2011 for the ACT and ACF Study Basins and to 1939–2013 for all other study basins (SO, OOA, OSSS, TN).
- Application of updated current (2011 historical) and future (2050) forecasted water demands.
- Addition of Carsonville (CARSONVL) planning node in the Flint River Basin (ACF Study Basin), and addition of the Macon 2 (MACON2) and Lumber City 2 (LUMBER2) nodes in the Ocmulgee River Basin (OOA Study Basin) used for accounting of alternate locations of return flows.
- Incorporation of agricultural irrigation metering data for estimation of agricultural water use (Round 1 agricultural water use was based on mapped irrigated acreage and estimated water application rate).
- Incorporation of estimated farm pond storage into Round 2 resource assessments for the Flint (ACF), Ogeechee (SO), and Suwannee (OSSS) River Basins; farm ponds considered in the models were limited to those refilled by natural runoff, i.e., well-to-pond and off-channel pumped-storage ponds

were not analyzed; composite farm ponds were developed for modeling purposes using field-based estimates of farm pond storage in selected basins.

- Development and application of advanced and more detailed U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC) HEC-ResSim (Reservoir System Simulation*)* and HEC-5 (Simulation of Flood Control and Conservation Systems) models in place of the River Basin Planning Tool (RBPT) applied in Round 1 for resource assessments; Round 2 models reflect the most recent USACE Water Control Manual updates for the ACT, ACF, and Savannah River Basins, and Tennessee Valley Authority (TVA) operation of its reservoirs in Georgia in the TN Study Basin.
- Development of flow regimes for planning nodes on unregulated streams using hydrologic channel routing incorporated in the resource assessment models in Round 2; the new models provide the flexibility for analysis of water availability at any node – planning or basic – assuming water use data can be disaggregated accordingly.
- Incorporation of off-channel water supply pumped-storage reservoirs in the Oconee (OOA), Flint and Chattahoochee (ACF), and Etowah (ACT) Study Basins.

The resource assessment process is not intended to define absolute limits on withdrawals or discharges to any specific river reach or waterbody. Rather, it was designed to assist regional Water Planning Councils in identifying management strategies that may be needed to reliably meet current and future consumptive water demands while maintaining flows for instream uses.

1.2 Gap Analysis

With unimpaired flow time-series as hydrologic inputs, the resource assessment (HEC-ResSim and HEC-5) models were applied to simulate effects of current (2011 historical) and future (projected 2050) consumptive water uses on prescribed flow regimes and reservoir levels throughout Georgia. Comparison of model-simulated flows with unimpaired flows identified periods when simulated flows fell below the specified flow regime, which for unregulated nodes is the lesser of the cumulative unimpaired monthly 7Q10 (1- in 10-year 7-day low flow for each month of the year) or cumulative unimpaired daily flow. Unregulated nodes are nodes with no federal or federally licensed storage reservoirs upstream.

Potential gaps are defined in this study as periods of potential flow regime deficit, and in some instances periods of potential water supply shortfall, i.e., when water withdrawals exceed total available stream flow. For the Round 2 resource assessments, potential gap events were characterized by frequency (number of gap events in the 73- or 75-year period of record), duration (average length of gap events), and volume (cumulative flow deficit per gap event). Example gap characterization charts for a planning node on an unregulated stream (Bainbridge on the Flint River in the ACF Study Basin) are displayed in Figure 1-2.

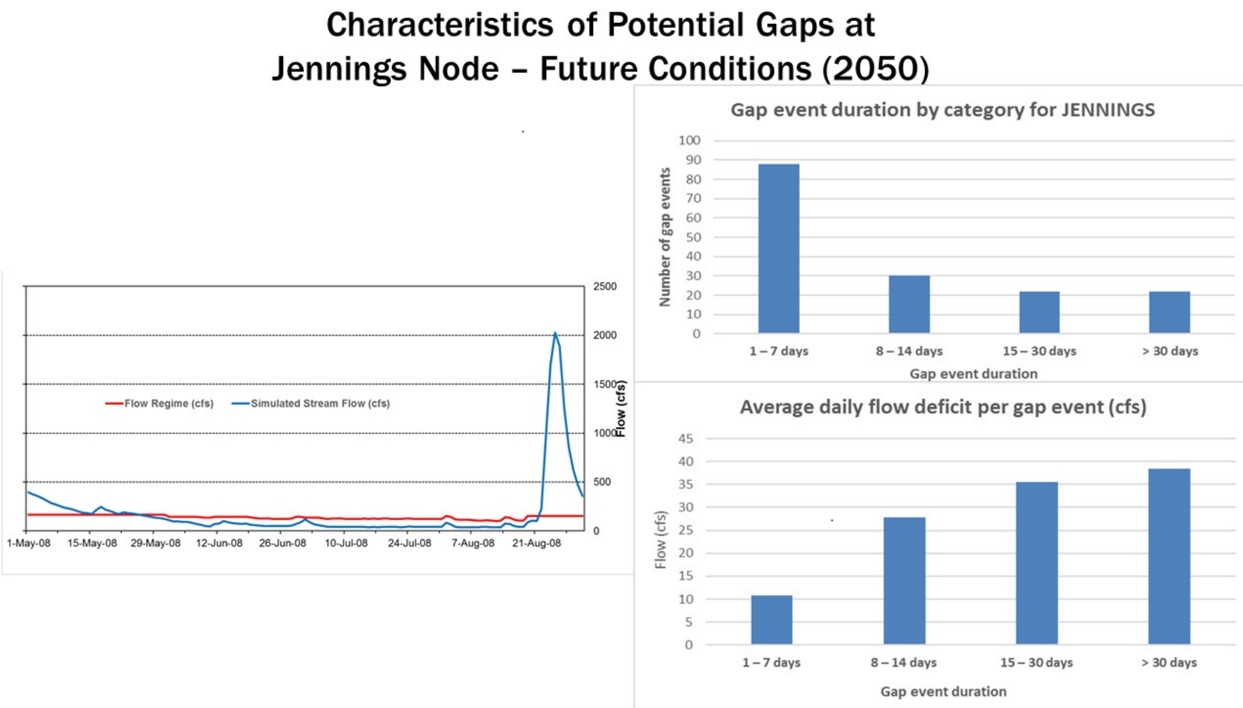
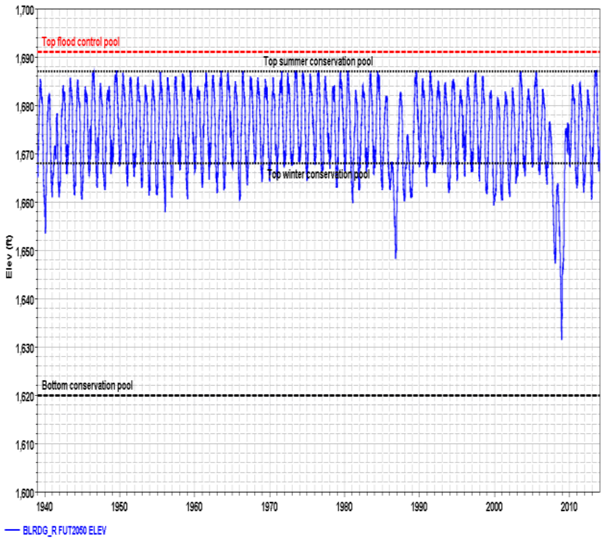


Figure 1-2 **Example potential gap characteristics for planning node on unregulated stream**

Regulated nodes are located at or downstream of federal or federally licensed storage reservoirs. Flow regimes for regulated nodes are defined by required releases or instream flow requirements imposed by reservoir operating rules – water control plans for federal reservoirs and Federal Energy Regulatory Commission (FERC) license requirements for private power reservoirs. In the absence of such requirements for regulated nodes, there is no required flow regime. As long as model simulation results show conservation storage physically remaining in upstream reservoirs, gaps at regulated nodes are assumed to be zero, regardless of whether storage in these lakes has been reserved for water supply. Figure 1-3 provides an example of resource assessment model results for a regulated planning node (Copperhill, downstream of TVA Blue Ridge Reservoir) in the TN Study Basin.

Copperhill and Blue Ridge Reservoir
(1939 – 2013) Future Conditions (2050)



	Demand shortage (cfs)	At-site flow requirement shortage (cfs)	Minimum conservation storage remaining (acre-feet)	Minimum percentage of conservation storage remaining (%)	Basin-wide flow requirement shortage
Current (2011)	0	0	15,453	11	N/A
Future (2050)	0	0	15,453	11	N/A

Figure 1-3 Example resource assessment results for a regulated node

1.3 Key Assumptions

The following key assumptions apply to Round 2 resource assessments summarized in this report:

- Current demands reflect recorded 2011 monthly historical surface water withdrawals and returns statewide.
- Future demands are forecasted annual demands for the year 2050 for all water use categories (municipal [M], industrial [I], thermal [T], agricultural [A], and groundwater effects [GWEs]), as described in technical memoranda authored by the planning contractors (Black & Veatch, CH2M, and CDM Smith) for each of the 10 Water Planning Councils and EPD in 2017. Annual demands were disaggregated into monthly values for future resource assessment modeling based on monthly patterns considered to be typical by EPD.
- Projected 2050 agricultural water demand was assumed to correspond to the 75th percentile non-exceedance level of irrigation needs, i.e., a typical once in every four-year dry condition. Because 2011 was an “extreme” to “exceptional” drought year (as defined by the U.S. Drought Monitor[2]), in most instances future (2050) agricultural irrigation demand was projected to be less than current (2011) agricultural irrigation water use as a result of this assumption.

[2] http://droughtmonitor.unl.edu/

- Flow thresholds for water remaining in streams or conservation storage remaining reservoirs were selected as indicators of potential impacts on water resources.
- For unregulated nodes, the low-flow threshold (adjusted flow regime, or the lesser of cumulative unimpaired monthly 7Q10 or cumulative unimpaired daily flow) was assumed to apply.
- For regulated nodes, the flow regime was assumed to be based on upstream reservoir release requirements of permits, licenses, or water control plans; in the absence of such requirements, no flow regime was assumed to apply for resource assessment purposes. When resource assessment model simulation results showed water physically remaining in upstream reservoir conservation storage when managed in accordance with prescribed operating rules and with water demands imposed, potential gaps were assumed to be zero, regardless of whether water supply storage is allocated for these reservoirs.
- Consumptive water demands were prioritized over flow thresholds, meaning that water withdrawals are curtailed only when total stream flow is insufficient. Gaps were measured as the difference between flow thresholds and water remaining in the stream or the lack of conservation storage remaining in a reservoir after consumptive demands are met. For those periods when consumptive water demand exceeds the required flow regime, water supply shortages can also occur, which adds to the extent of potential gaps as expressed by shortages to flow thresholds.

Local unimpaired flows (LUIFs) and historical water demands used in the 1939–2007 Round 1 resource assessments were extended through 2013 but were not altered prior to 2008 for the SO, OOA, OSSS, and TN Study Basins. Unimpaired flows for 1939–2011 input to the USACE ACT and ACF Water Control Plan HEC-ResSim models were used for Round 2 resource assessment modeling of these study basins. However, the addition of the Carsonville (CARSONVL) planning node upstream of Montezuma (MONTEZMA) on the Flint River (ACF Study Basin) necessitated derivation of complete 1939–2011 reach water uses and LUIFs for these reaches, while preserving the original USACE cumulative unimpaired flows (CUIFs) at Montezuma.

2 BASIN DELINEATION

2.1 Study Basins

The study basins are the six major composite river basins shown in Figure 2-1 (ACT, ACF, OOA, OSSS, SO, and TN) designated by EPD for resource assessment and delineated based on hydrologic, topographic, water resource development, water uses, or other considerations important to regional planning. Study basins are composed of one or more adjacent or connecting river basins and major tributaries.

2.2 Basic Nodes

Basic nodes are locations of interest on rivers or major tributary streams for which UIFs were derived. In most instances, basic nodes are located at or near U.S. Geological Survey (USGS) stream gages or at dams, ideally at gages with records of suitable length for direct determination or filling of the 1939–2011 or 1939–2013 periods of record needed for derivation of daily UIFs. When available, USGS gages immediately downstream of dams are often preferred for flow measurement than reservoir release records due to greater accuracy. As an example, the Chattahoochee Gage on the Apalachicola River just downstream of Jim Woodruff Dam more accurately measures total releases through the dam that include seepage than rated turbine and spillway releases alone.

Local drainage areas (LDAs) are watersheds between adjacent nodes or the total drainage area above the most upstream node. Reaches are river or tributary segments with their contributing local drainage areas that lie between adjacent nodes (basic or planning) or above the most upstream node (basic or planning). Reaches are designated by the name of the downstream node.

Basic node locations are designated by yellow circles in Figure 2-1.

2.3 Planning Nodes

Planning nodes are a selected subset of basic nodes for which assessments of surface water availability are performed. One or more basic nodes may be interspersed between planning nodes. An exception to the planning-basic node correspondence is the virtual planning node, which is a planning node located at or near the most downstream Georgia location (in some cases outside of Georgia) on rivers for which no observed stream flow data are available. Planning nodes are located where possible to avoid separation of major utility withdrawals and returns and to avoid separation of planning regions and municipalities served by multiple water utilities (e.g., North Georgia Metropolitan Water District upstream of Whitesburg, the Chattahoochee River).

Sub-basins are intervening watersheds between planning nodes or total drainage area above the most upstream planning node.

For the Round 2 resource assessments, a new planning node – Carsonville (CARSONVL) – was added to the Flint River (ACF Study Basin) upstream of Montezuma (MONTEZMA).

The HEC-ResSim and HEC-5 models applied in Round 2 in theory allow resource assessments to be performed for any node (planning or basic), assuming upstream reach water use data are available for this purpose.

Planning node locations are designated by red triangles within yellow circles in Figure 2-1.

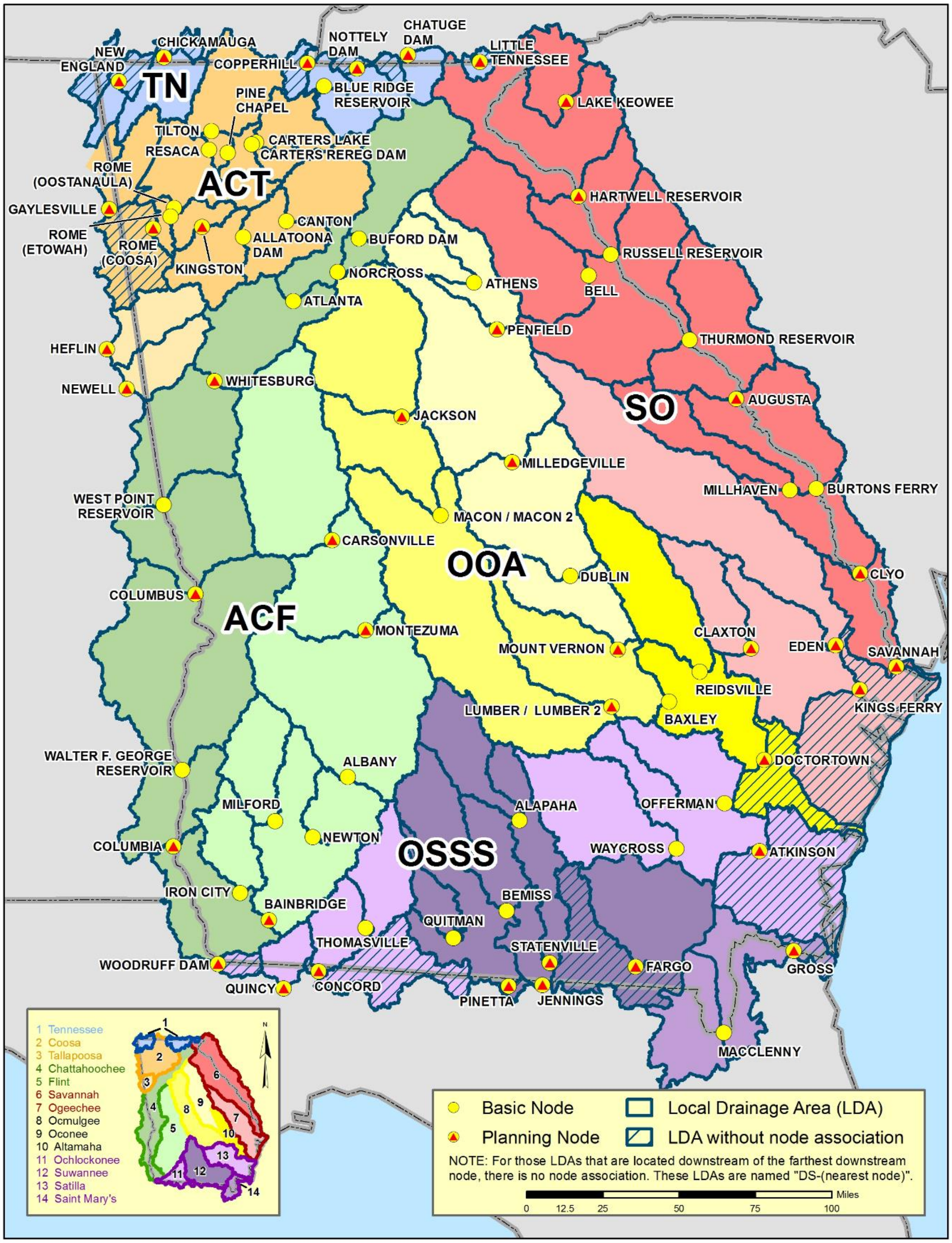


Figure 2-1 **Georgia study basins, planning and basic nodes**

3 WATER USE DATA

3.1 Categories

Computation of UIFs requires removal of the effects of human uses of water – withdrawals and returns – from the historical stream flow record. Water uses considered in this study include municipal (M), industrial (I), thermal power (T), and agricultural irrigation (A), and include an estimation of effective stream flow reductions due to groundwater pumping (groundwater effects or GWEs). Removal of effects of water use was accomplished by the addition of withdrawals to and subtraction of returns from historical stream flow records using the following procedures:

- Municipal withdrawals and returns were aggregated by reach rather than by individual utilities because utilities may withdraw from and return to different reaches of the same river, or return to different rivers or river basins from which withdrawals were made (i.e., interbasin transfers).
- Thermal power water use data were used that typically reflect consumptive use to the extent that it exists in a facility with cooling tower operations. There are, however, thermal power facilities with once-through cooling operations; these do not have consumptive water use.
- Agricultural water use data were used to aggregate direct surface water withdrawals and effective surface stream flow reduction due to groundwater pumping.
- For purposes of UIF derivation and resource assessment, net reach water uses (historical and projected future) were aggregated for all users in each water use category within each reach.

3.2 Water Use Scenarios for Resource Assessment Modeling

Round 2 surface water availability resource assessments were performed for current and future water use scenarios. The current scenario was analyzed using the HEC-ResSim and HEC-5 resource assessment models with daily UIFs and 2011 historical monthly water demands (withdrawals and returns for all categories) repeated throughout the 1939–2011 or 1939–2013 period of analysis applicable to each study basin. Agricultural water use in 2011 was determined based on updated mapped irrigated acreage and metered irrigation data.

Future resource assessment scenarios utilized the updated statewide 2050 water need forecasts for the municipal, industrial, and energy sectors, as documented in water and wastewater forecasting technical memoranda prepared by the planning contractors (Black & Veatch, CH2M, and CDM Smith) for each of the 10 water planning regions in 2017. Demand forecasts were made on an average annual basis and distributed monthly by reach for resource assessment purposes based primarily on historical 2011 monthly withdrawals, returns, and thermal power consumptive uses. Agricultural demand forecasts were made by the Georgia Water Planning and Policy Center at Albany State University (GWPPC), with support from the University of Georgia College of Agricultural and Environmental Sciences.

Forecasting of 2050 demands by EPD for Alabama-permitted facilities on the Chattahoochee River assumed 15 percent growth in reported Alabama 2007 water use. The projected 2050 South Carolina water demand in the Savannah River Basin developed in Round 1 was again used in Round 2. The 2050 annual agricultural demand forecasts assumed a 75-percentile dry-year condition and no “throw” (extra irrigation range provided by impact-rotor sprinklers on the ends of center-pivot lines, also called end guns). Monthly proration of agricultural water use was accomplished using estimates prepared by GWPPC. Forecasted 2050 groundwater effects for Flint Basin reaches and certain Chattahoochee reaches within Subarea 4 were provided by EPD.

4 UNIMPAIRED FLOW DEVELOPMENT

4.1 Definition and Uses of Unimpaired Flows

Unimpaired or naturalized flows are historically observed or reconstituted flows with effects of reservoir releases, reservoir surface net evaporation, and water withdrawals and returns by municipal, industrial, thermal power, and agricultural water users removed. Groundwater pumping is also considered to the extent surface water flows may be reduced. Unimpaired flows are commonly applied in analysis of water resource systems because they provide the "natural" hydrologic background upon which human water uses, management practices, and reservoir operating rules can be superimposed. Unimpaired flows are also useful for comparison of instream flows affected by reservoir regulation or depleted by consumptive water uses with natural, unregulated flows. The use of UIFs for resource assessment provides the basis for consistent and unbiased evaluation of the impact of past, present, and future water regulation and water consumption on stream networks, reservoir levels, and other performance measures of interest associated with economic and environmental uses of water.

4.2 Unimpaired Flow Derivation Process

Development of UIFs for Round 2 resource assessments generally followed the reconstitution process employed in Round 1. However, because the Round 2 UIFs only extended Round 1 UIFs after 2007, some simplifications were possible in Round 2 for the following reasons:

- Hindcasting of pre-2008 water uses was not necessary for Round 2 resource assessments. For newly created nodes such as Carsonville in the Flint River Basin, and the Lumber2 and Macon2 nodes in the Ocmulgee River Basin, hindcast water use data developed in Round 1 were used in the development of LUIF time series in Round 2.
- Filling of missing historical stream gage records post-2007 was much less complex and in many cases unnecessary, in contrast to the 1939–2007 record-filling required in Round 1.

Development of UIF time-series by reconstitution proceeded along four tracks, described as follows:

Track 1: Filling and routing of cumulative historical flow records for development of unregulated incremental flows

- Statistical methods (Maintenance of Variance Extension Type 2, multiple linear regression, ordinary least-squares regression).
- Hydrologic routing and back-routing (Lag-K, variable Lag-K, coefficient method).
- Removal (addition) of reservoir effects (holdouts and releases from storage), where applicable, for calculation of reservoir inflow.

- Calculation and removal of effects of post-reservoir net evaporation (evaporation minus precipitation), less pre-reservoir surface area runoff.
- Scaling (flow and drainage area ratios).
- Unregulated incremental flow calculation (subtraction of routed upstream observed flow from downstream observed flow).

Track 2: Water use inventory and hindcasting

- Compilation, aggregation, and hindcasting of current monthly municipal and industrial water withdrawals, wastewater returns, and net water consumption from 1939 to the beginning of continuous records (in most cases from the mid-1990s to 2000). Because historical water use data were available for the 2008–2013 extension of the Round 1 water use inventory, in general no hindcasting was required in Round 2.
- Compilation and aggregation of historical thermal power water withdrawals, returns, and net water consumption.
- Compilation and aggregation of historical agricultural surface water withdrawals (assumed to be equivalent to net water consumption for purposes of this study).
- Compilation and aggregation of municipal, industrial, and agricultural groundwater withdrawals and resulting surface water flow depletions (GWEs).

Track 3: Aggregation of effects, calculation of local unimpaired flows, and flow adjustments

- Removal (addition) of reach net water use (all categories).
- Removal (addition) of remaining reservoir effects (holdouts and/or net evaporation flows) where applicable.
- Removal of negative local incremental unimpaired flows (TSTool Adjust Extremes, average annual flow volume adjustment, period of record flow volume adjustment).
- Quality control (manual data adjustments, mass balance, double-mass balance).

Track 4: Routing of local unimpaired flows for calculation of cumulative unimpaired flows and adjusted flow regimes

- Development of CUIFs by combining and routing of LUIFs (performed external to resource assessment models in Round 1, performed using routing parameters incorporated in HEC-ResSim and HEC-5 resource assessment models in Round 2).
- Modification of a USGS spreadsheet by Paul Lamarre (EPD) and Dong Ha Kim (EPD) for determination of monthly 10-year 7-day low flow (M7Q10) using model-routed CUIFs; application of HEC-DSS (Data Storage System) macros for calculation of adjusted flow regime (AFR) as lesser of M7Q10 or CUIF.

The unimpaired flow derivation process will be documented in a forthcoming Unimpaired Flow Data Report.

5 FARM POND ANALYSIS

Some of the Water Planning Councils requested that the Round 2 resource assessments account for use of farm ponds to supplement agricultural irrigation, and the impacts of farm pond storage utilization on potential gaps (i.e., potential flow threshold shortfalls). This study examined characteristics of a subset of farm ponds – those that are surface runoff-supplied – within selected study basins, and, based on this information, incorporated farm pond storage utilization in resource assessment model simulations for current and future water demand conditions. Characterization and parameterization of farm ponds for resource assessment modeling were collaboratively performed by EPD, Arcadis, and Albany State University based on the following:

- Interviews with farm pond owners.
- Bathymetric surveys of active surface runoff-supplied farm ponds in the Flint (ACF), Suwannee (OSSS), and Ogeechee (SO) River Basins. Well-to-pond and pumped-storage ponds (pumping from surface streams) were not considered in the analysis.
- Extrapolation of composite farm pond storage based on surveyed farm pond elevation, area and storage volume, and placement into appropriate stream reaches of resource assessment models.
- Assumption of composite farm pond inflow as a proportion of reach (local) unimpaired inflow (LUIF).
- Placement of current and future reach agricultural water demands on composite farm ponds.

Locations of active and likely farm ponds, and areas where farm ponds were surveyed, are shown in Figure 5-1 for the Flint River Basin (ACF Study Basin), Figure 5-2 for the Suwannee River Basin (OSSS Study Basin), and Figure 5-3 for the Ogeechee River Basin (SO Study Basin). Active farm ponds are those that pond owners have confirmed are in use for irrigation, likely farm ponds are those for which EPD has issued permits and aerial imagery indicates are in use, and possible farm ponds are those for which EPD has issued a permit for irrigation use but no other information is available. Farm pond storage-surface area relationships were computed and pond storage at full pool calculated based on digital elevation models developed for surveyed farm ponds. Regressed surface area to storage volume relationships were developed for each sub-basin for which farm ponds were included in the resource assessment models, and used to develop storage-area tables for composite farm ponds inserted upstream of the appropriate planning nodes within the resource assessment models. Figures 5-4 through 5-6 illustrate the process of composite farm pond extrapolation. Composite runoff-supplied farm ponds were schematically configured in the resource assessment models as shown in Figure 5-7.

Node Name	Number of Active and Likely Ponds Modeled	% of Ponds per Local Drainage Area
Griffin	0	0.0
Carsonville	0	0.0
Montezuma	8	2.2
Albany	110	30.8
Milford	131	36.7
Newton	7	2.0
Iron City	32	9.0
Bainbridge	55	15.4

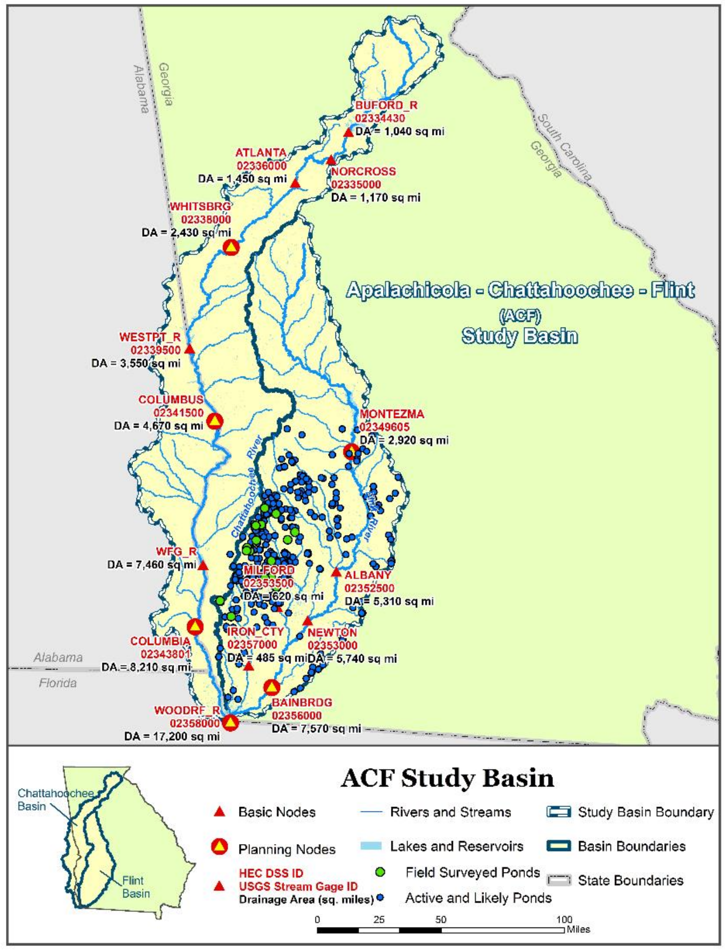


Figure 5-1 Flint River (ACF Study Basin) showing active and likely farm pond locations (dark blue dots) and field surveyed farm ponds (20 – green dots)

Node Name	Number of Active and Likely Ponds Modeled	% of Ponds per Local Drainage Area
Alapaha	157	26.0
Pinetta	224	37.0
Statvl	86	14.2
Bemiss	114	18.8
Quitman	16	2.6
Jennings	8	1.3
Fargo	0	0.0

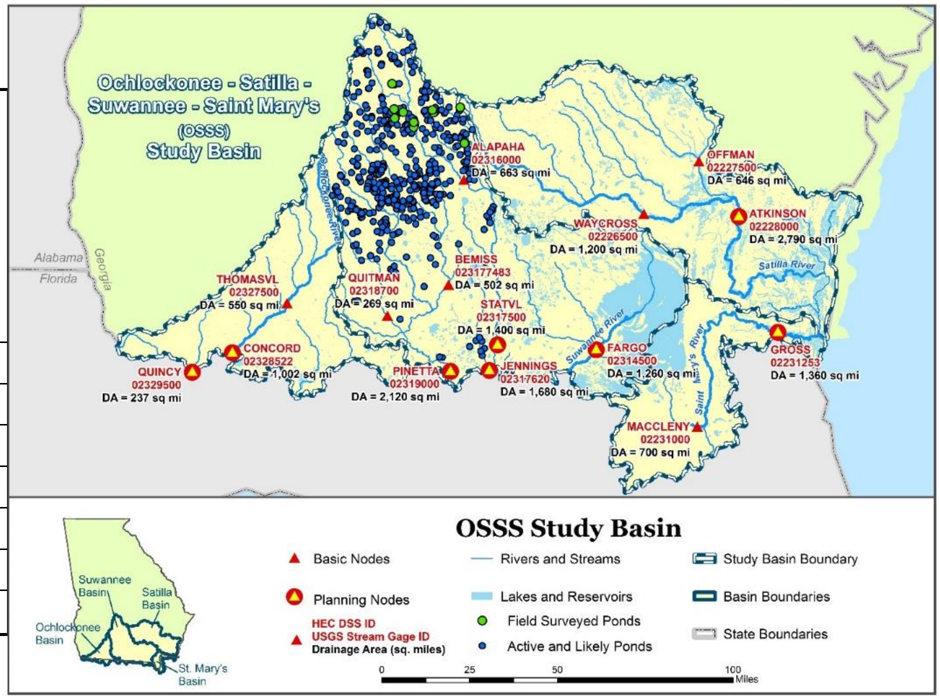


Figure 5-2 Suwannee River Basin (OSSS Study Basin) showing active and likely farm pond locations (dark blue dots) and field surveyed farm ponds (10 – green dots)

Node Name	Number of Active and Likely Ponds Modeled	% of Ponds per Local Drainage Area
Eden	32	18.7
Claxton	86	50.3
Kingsfy	53	31.0
DS-Kingsfy	0	0.0

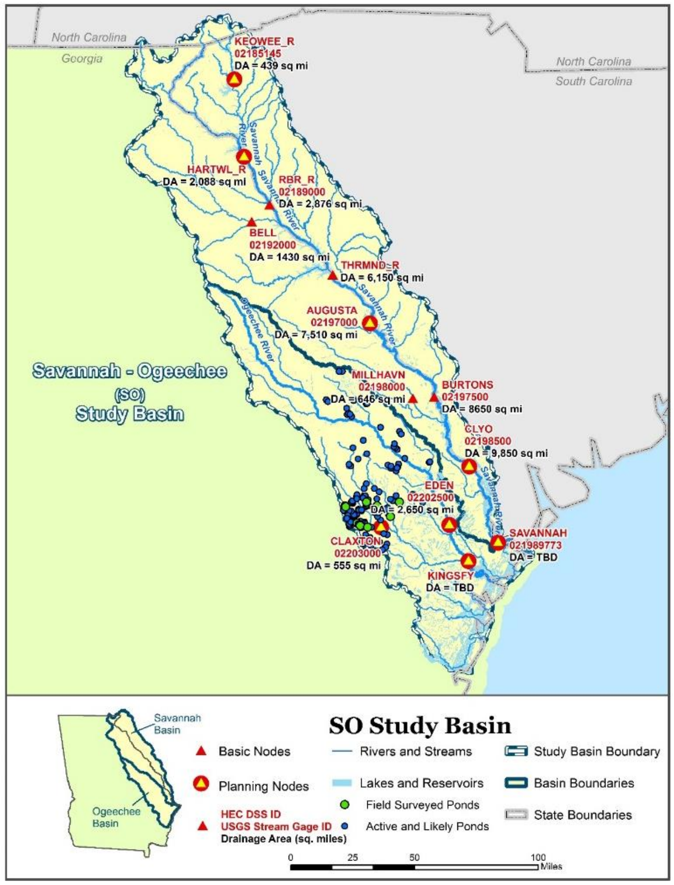


Figure 5-3 Ogeechee River Basin (SO Study Basin) showing active and likely farm pond locations (dark blue dots) and field surveyed farm ponds (10 – green dots)

Figure 5-4 Aerial view of active surface runoff-supplied farm pond

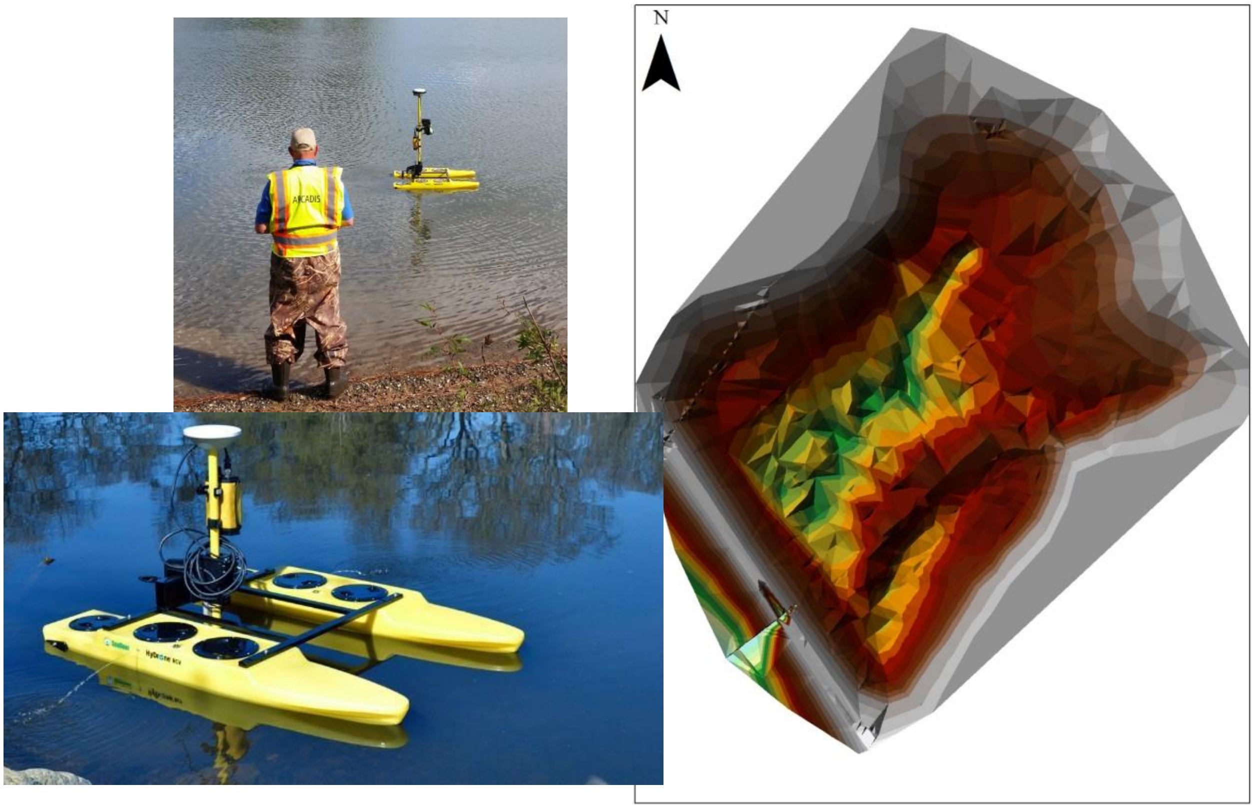


Figure 5-5 Bathymetric survey equipment and resulting farm pond digital elevation model

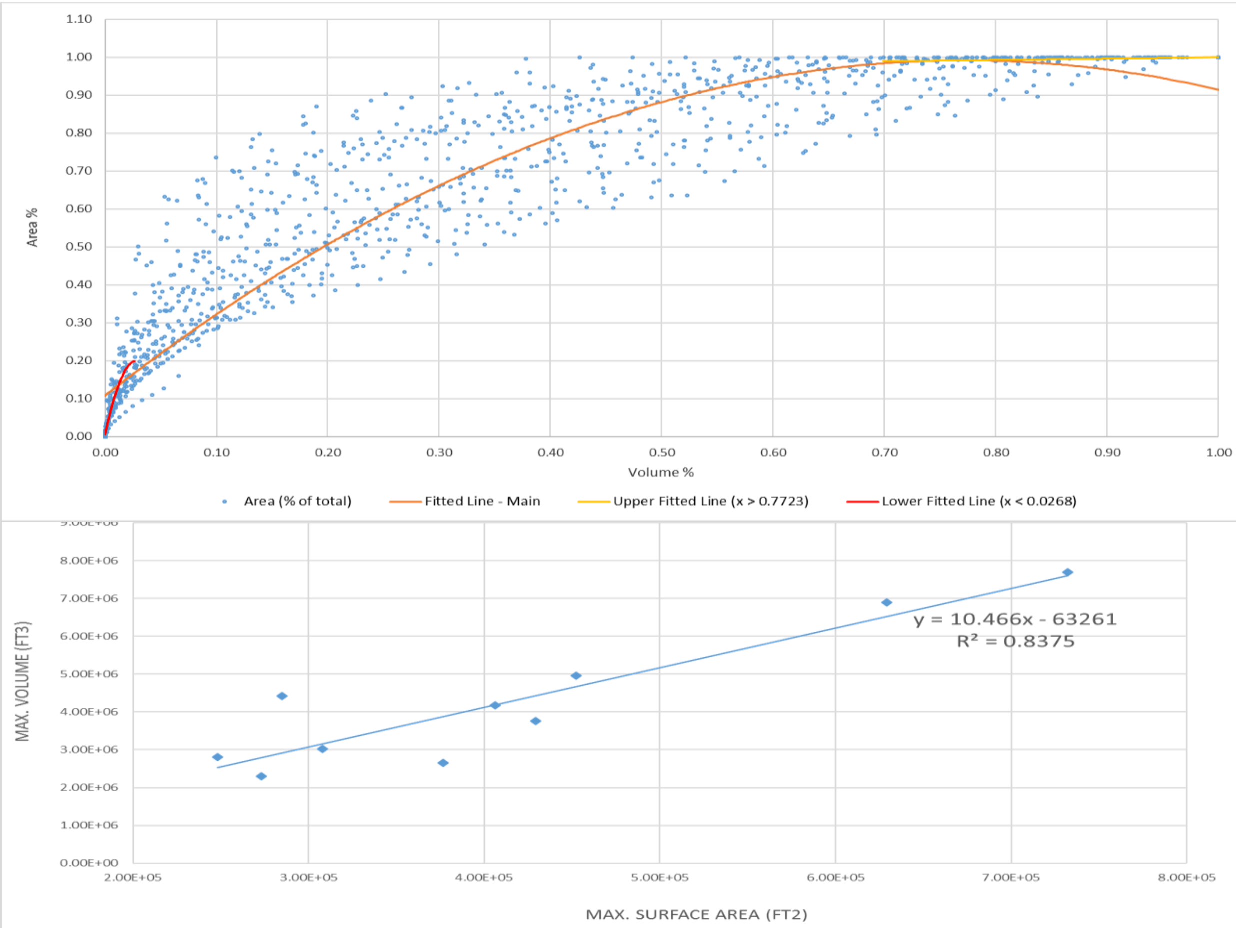


Figure 5-6 Best-fit dimensionless storage-area and maximum storage-area relationships for surveyed farm ponds in the Ogeechee River Basin

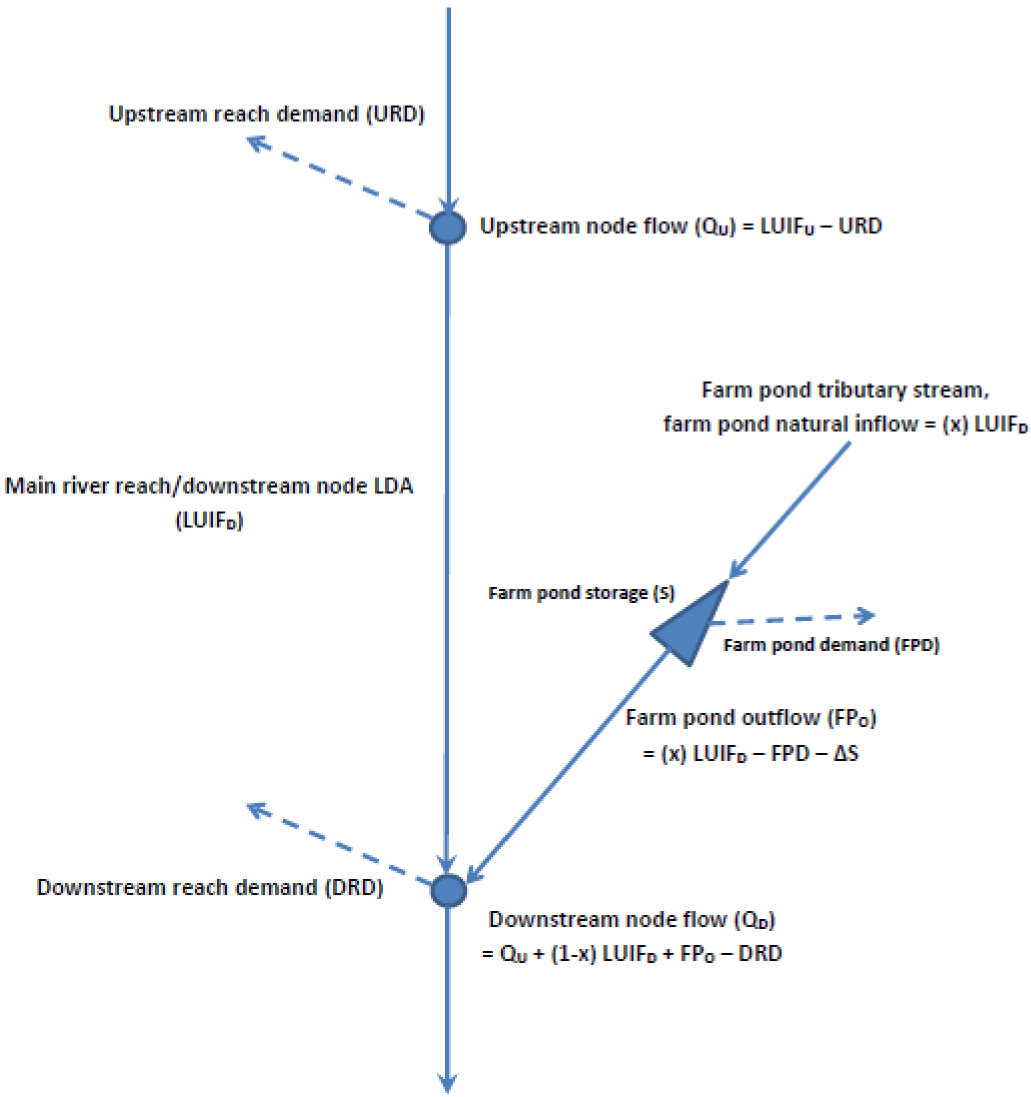


Figure 5-7 **Conceptual surface runoff-supplied farm pond resource assessment model schematic**

Agricultural water demand on farm ponds was estimated based on the total volume of surface water withdrawals for agricultural irrigation in reaches with farm ponds in 2011. For current-condition resource assessments, annual agricultural demand was allocated to composite farm ponds in each reach by the ratio of composite farm pond usable storage to total 2011 agricultural water use in the reach. The same procedure was applied for future resource assessments except that projected 2050 annual agricultural demand volume was used in place of 2011 demand. Monthly distribution of farm pond demand followed 2011 historical agricultural water use patterns for both current and future resource assessments.

Unimpaired inflow to composite farm ponds was calculated as a ratio of LUIF at nodes downstream of reaches and LDAs in which the composite farm ponds were placed in the resource assessment models. The ratio was calibrated by trial and error to produce, when routed through the composite farm pond by the resource assessment models, roughly one period of drawdown and refill per year without completely emptying the pond or failing to meet irrigation water demand in any year. An example simulated storage utilization time series for a composite farm pond located upstream of Claxton on the Canoochee River (SO Study Basin) is shown in Figure 5-8.

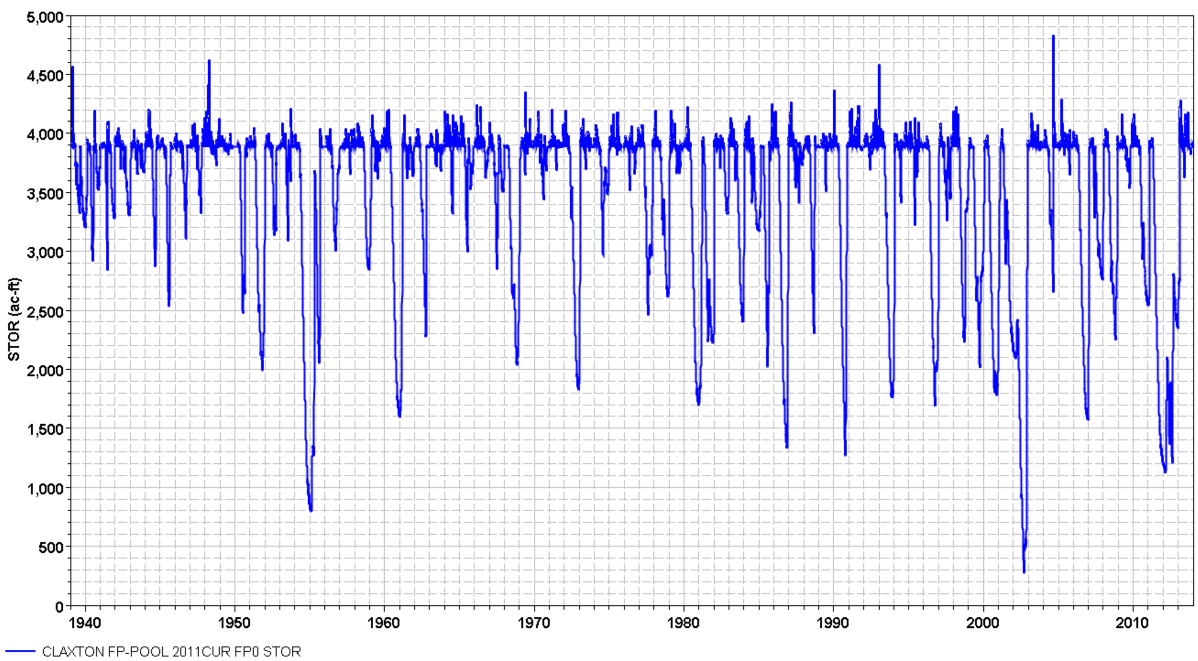


Figure 5-8 Example simulated surface runoff-supplied composite farm pond storage utilization with current (2011) water use, Canoochee River Basin above Claxton (SO Study Basin)

The above-described approach enabled the resource assessment models to (1) estimate the effective yield of surface runoff-supplied farm ponds in each LDA for which farm pond operation was simulated, and (2) simulate and compare gaps at downstream planning nodes with and without farm ponds. As expected and subsequently described in greater detail in this report, use of farm ponds generally reduced flow regime gaps.

6 RESOURCE ASSESSMENTS

Round 2 resource assessments for each study basin were performed in much the same manner as in Round 1 with the following exceptions:

- Different models were applied in Round 2; the RBPT and HEC-5 were the primary models applied in Round 1.
- More detailed operational simulation was performed in Round 2, reflecting the most recent USACE water control plans for the ACF, ACT, and SO Study Basins, and the most recent River Operations Plan for TVA reservoirs operating within the TN Study Basin.
- Potential gaps identified in the resource assessment process were analyzed in a more detailed manner in Round 2, with characteristics and statistics of potential gap events presented.
- Only two (current and future) resource assessment timelines were considered in Round 2 versus multiple future scenarios at 10-year intervals through 2050 in Round 1.

As in Round 1, the resource assessment models were applied to simulate and compare the responses of rivers and reservoirs to water management, water use, and water supply infrastructure alternatives to historical hydrology and current reservoir system operational policies.

6.1 Methodology

6.1.1 Overview

Resource assessments were performed by sequential simulation of daily stream flows, reservoir releases, and consumptive water uses within each of Georgia's six study basins. The models applied to the resource assessments are rule-based operational simulation models, and as such can be applied to both unregulated and regulated streams. As previously described, continuous periods of simulation extended from 1939 through 2013 for the SO, TN, OOA, and OSSS Study Basins, and from 1939 through 2011 for the ACF and ACT Study Basins.

General procedures for surface water resource assessments are summarized as follows:

- Define basin and sub-basin boundaries and river reaches to be assessed. Boundaries are defined based on drainage area, and reaches are defined by basic and planning node locations, reservoirs, water and wastewater utility service areas, political and economic boundaries, and other practical planning considerations.
- Develop resource assessment model data, including net reach and reservoir water diversions (withdrawals minus returns), water transfers into and out of sub-basins, and water supply reservoir and/or composite farm pond storage within reaches.
- Specify flow regime (minimum flow) requirements for unregulated planning nodes based on Georgia interim instream flow policy (cumulative unimpaired M7Q10), and for regulated nodes based on requirements for releases or instream flows incorporated in upstream reservoir operating rules.
- Perform a gap analysis for consumptive water uses based on model-simulated low-flow threshold deficits (or reservoir minimum instream flow target deficits) after meeting current (2011) or future

(projected 2050) consumptive water demands upstream of planning nodes; gap analysis was performed using consumptive use assessment (CUA) spreadsheets (subsequently described) developed to measure and characterize potential low-flow threshold shortfalls.

The following scenarios were analyzed:

- Current (2011) water demands in all study basins.
- Current (2011) water demands with farm ponds in the Ogeechee River Basin (SO Study Basin), Suwannee River Basin (OSSS Study Basin), and Flint River Basin (ACF Study Basin).
- Future (2050) projected water demands in all study basins.
- Future (2050) projected water demands with farm ponds in the Ogeechee River Basin (SO Study Basin), Suwannee River Basin (OSSS Study Basin), and Flint River Basin (ACF Study Basin).

The resource assessment models in Round 2 are capable of hydrologic flow routing using a variety of methods, including those originally used to derive LUIFs. For determination of flow regimes applicable to unregulated planning nodes, the resource assessment models were initially applied with no water demands simply to route and combine LUIFs, producing CUIFs at all nodes. These CUIF time-series were then used to develop flow thresholds, enabling subsequent resource assessments to determine potential resource gaps.

6.1.2 Resource assessment models

Two software packages served as the primary platforms for resource assessment modeling. Both were developed by the USACE HEC: the HEC-ResSim[3] model and the legacy HEC-5 model.[4] Post-processing of model results for characterization of gaps was performed using CUA spreadsheets. These are briefly described as follows:

HEC-ResSim: HEC-ResSim is a sequential simulation model designed to simulate rule-based operation of reservoirs and reservoir systems operating for multiple flood and conservation management objectives. The model is the successor to the HEC-5 model also applied for resource assessment as subsequently described. River systems are represented in ResSim as a georeferenced network of watersheds, rivers, reservoirs, routing reaches, stream junctions, and diversions. Model input is by graphical user interface and includes physical data, operating rules and constraints, and a variety of hydrologic, diversion, and other time-series data as needed. Reservoirs in the model can be operated simultaneously to support both at-site and system requirements. Tandem and parallel system storage balancing, common and unique storage zone-specific operating rules for reservoir flood and conservation pools, prioritization of rules by reservoir and system storage levels, a wide variety of hydrologic channel routing methods, and conditional reservoir releases based on internal, external, and user-scripted state variables, e.g., drought triggers, are also accommodated.

[3] USACE Hydrologic Engineering Center, Institute for Water Resources. (December 2013). *HEC-ResSim, Reservoir System Simulation*. Version 3.2 Dev., Revision 3.1.22.
[4] USACE Hydrologic Engineering Center, Institute for Water Resources. (October 1998). *HEC-5, Simulation of Flood Control and Conservation Systems*.

HEC-ResSim is a continuous simulation model capable of running on time-steps ranging from 5 minutes to 1 day. A daily time-step was applied for all resource assessment modeling statewide.

Built-in model functionality, user-scripted state variables, and integration of HEC-DSS utilities make HEC-ResSim one of the most powerful platforms currently available for operational simulation of large and complex river systems with complex operational requirements. The HEC-ResSim models applied for resource assessment of the Savannah, ACF, and ACT Study Basins incorporate prioritized and conditional at-site and system operating rules prescribed by the most recent USACE water control plans. Because the baseline ResSim models for these river basins were developed and applied by the USACE Savannah and Mobile Districts in the formulation of their respective water control plans, they are assumed to be acceptable to USACE as the most appropriate platforms for resource assessment for these basins. While initial setup can be difficult, ResSim models can be highly useful for planning due to the model's inherent capability for transparent display of operating objectives, constraints, and priorities. In addition, because HEC-ResSim is designed to mimic actual release decision-making processes by river regulators and reservoir operators, the model is especially well-suited to future operational planning and real-time water control management applications.

The HEC-ResSim model was applied for resource assessment in the SO, OOA, OSSS, and ACT Study Basins, and the Chattahoochee River Basin (ACF Study Basin).

HEC-5: The HEC- 5 model is a legacy model with capabilities for operational simulation of complex river and reservoir systems, similar to HEC-ResSim. The program was developed primarily for planning as opposed to real-time application, and continues to be used for determination of flood and conservation storage requirements and evaluation of operating rules relative to reservoir levels and flood control, water supply, hydropower, navigation, water quality, and environmental performance measures. As with HEC-ResSim, HEC-5 is a sequential simulation model designed to mimic actual release decisions made by river regulators and reservoir operators following prescribed operating rules.

Lacking a graphical user interface and georeferenced stream network, stream/reservoir network connectivity, physical and hydraulic data, and operating rules are input to HEC-5 by formatted text file, with time-series data (e.g., reach inflows) input either by formatted text file or HEC-DSS using time-steps ranging from 1 hour to 1 month. HEC-5 can read from and write to either text files or HEC-DSS direct-access files, or both. Hydrologic channel routing can also be performed in HEC-5, although fewer methods are available than in HEC-ResSim. As with HEC-ResSim, all HEC-5 models applied to resource assessment use a daily time-step. While less capable overall, HEC-5 may be more convenient than HEC-ResSim in certain applications due to (1) ease of setup when georeferenced stream/reservoir networks or participatory planning applications are not needed, (2) ease of adding or deleting system components (e.g., reservoirs, streams, and control points), (3) user-controllable output tables and HEC-DSS pathname parts, (4) simplified and hard-wired operating rule and storage-balancing criteria definition, and (5) more user-friendly input data debugging and error diagnosis, especially for river basins without highly complex reservoir operating rules.

The HEC-5 model was applied for resource assessment of the Flint River Basin (ACF Study Basin) and the Tennessee River Basin (TN Study Basin).

Consumptive Use Assessment spreadsheets: Resource assessment model results were input to CUA spreadsheets developed for gap analysis and characterization of unregulated planning nodes. Basic time-series inputs to the CUA spreadsheets included (1) CUIF at the planning node, with upstream local UIFs routed and combined as necessary by the resource assessment models, (2) AFR, calculated as the lesser of M7Q10 or CUIF, and (3) model-simulated daily flow at the planning node. Potential gaps occur where the model-simulated flow is less than the AFR. The following statistics are generated by CUA spreadsheets:

- A basic table of potential gaps displaying percent of simulation period with potential gaps, average shortfall for all potential gap events, and average simulated flow for simulation period.
- Charts displaying potential gap statistics and monthly exceedance curves for potential gaps.
- Categorized statistics including number of potential gap events, total days with potential gaps, average daily flow deficit per gap event, and average cumulative flow deficit per gap event; gap events are categorized by duration (1–7 days, 8–14 days, 15–30 days, and more than 30 days), and gap statistics are displayed in tabular and bar chart form.
- Charts of potential gap characteristics, displaying time-series of simulated flow relative to AFR.

CUA spreadsheets were applied only to unregulated nodes with natural flow regimes determined for resource assessment purposes as subsequently described. Water availability at regulated nodes was assessed by considering model simulated water demands met, explicit flow requirements met, and remaining conservation storage through the most critical hydrologic periods.

6.1.3 Flow regime determination

Georgia's interim instream flow protection policy, articulated in the Water Issues White Paper adopted by the Board of Natural Resources in 2001, outlines three options for minimum flow protection.[5] One of the options was used as the basis for flow thresholds for planning purposes, recognizing that value-specific and site-specific flow thresholds may be developed in the future for individual basins. Depending on planning node type (unregulated or regulated), low-flow thresholds for resource assessment were drawn from either the interim policy or from reservoir release policies applicable to upstream federal reservoirs operated by USACE and TVA, or FERC license provisions applicable to upstream private hydroelectric power projects (also referred to as federally licensed projects). Metrics on flow regimes adopted for this study for determination of water availability are briefly summarized as follows:

Unregulated nodes are nodes with no federal or federally licensed reservoirs upstream. The required flow regime for unregulated nodes applied in this study is the lesser of cumulative unimpaired M7Q10 or cumulative unimpaired daily flow; upstream water supply reservoirs and farm ponds are not considered to be storage projects for purposes of node classification.

Regulated nodes are nodes located at or downstream of federal or federally licensed reservoirs. Required flow regimes at regulated nodes are defined by requirements for releases or instream flows imposed by reservoir operating rules – water control plans for federal reservoirs and FERC license requirements for private power reservoirs. In the absence of such requirements for regulated nodes, there is no specified flow regime at these nodes. The flow regime criteria used for the Round 2 resource assessments are the same as those used in Round 1.

[5] https://epd.georgia.gov/sites/epd.georgia.gov/files/related_files/site_page/GADNR_WaterIssuesWhitePaper_May2001.pdf

6.1.4 Current resource assessment

The current-condition resource assessment models estimate impacts of current consumptive water uses and reservoir operations on stream flows and reservoir levels when superimposed on the 1939–2011 or 1939–2013 unimpaired hydrologic record, depending on study basin. Current resource assessment modeling assumed that historical 2011 monthly water withdrawals and returns in all sectors (M, I, T, A, and GWE) are repeated in each year of the applicable 73- or 75-year simulation period. Because 2011 was a year with extreme and exceptional drought conditions (as indicated by U.S. Drought Monitor data), water use in this year was somewhat higher than non-drought years. For this reason, the approach used in the current resource assessment, i.e., applying a drought year water use to all hydrologic conditions through the entire simulation period, is conservative.

Current-condition model-simulated cumulative flows at unregulated planning nodes were post-processed using the previously described CUA spreadsheets to measure and characterize potential gaps (i.e., periods when simulated flow falls below flow regimes).

For regulated nodes with flow regimes prescribed by reservoir operating rules, current-condition resource assessment model results were examined to determine minimum conservation storage remaining in upstream reservoirs (excluding water supply reservoirs and farm ponds). When the volume of water physically in storage in upstream reservoirs is sufficient to meet both prescribed flow regimes and consumptive water uses without emptying the reservoirs, potential gaps are assumed to be zero. Water supply use and operations that exist under current conditions are modeled according to reported data, regardless of whether such use or operations are currently associated with water supply contracts.

6.1.5 Future resource assessment

Future resource assessment modeling and potential gap analysis were performed in the same manner as for current conditions, except with repeating consumptive water uses forecasted for 2050 input to the models. Water uses for future resource assessments are forecasted annual demands for the year 2050 in each water use category, described in technical memoranda prepared by the planning contractors (Black & Veatch, CH2M, and CDM Smith) for each of the 10 Water Planning Councils in 2017. Annual demands were disaggregated into monthly values for future resource assessment modeling based on historical monthly patterns considered to be typical by EPD. Any increase in water supply from storage reservoirs has been evaluated based on physical availability of water, regardless of whether the extra amounts have been allocated for water supply.

6.2 Resource Assessment Results

The essence of the surface water availability resource assessment is the determination of whether there is sufficient water to simultaneously satisfy both water demands and flow thresholds during the simulation period. At unregulated nodes, any shortfall in meeting both can be expressed as (1) meeting water demand while having a shortage in meeting flow thresholds, (2) meeting flow thresholds while having a shortage in meeting water demand, or (3) having shortages in both. For simplicity, approach (1) was chosen. At regulated planning nodes, potential gaps are assumed to be zero as long as water physically remains in upstream reservoir conservation storage that could potentially be released for augmentation of downstream flows to support water demands and minimum flows prescribed by reservoir operating rules.

6.2.1 Apalachicola-Chattahoochee-Flint (ACF) Study Basin

The ACF Study Basin drains an area of 19,600 square miles in northern and western Georgia, southeastern Alabama, and a portion of northwestern Florida. Most of the Apalachicola River Basin is in the state of Florida, with one major tributary, the Chipola River, extending into Alabama. The Chattahoochee River extends from the headwaters of Lake Lanier to its confluence with the Flint River in Lake Seminole. The Flint River Basin lies entirely within the state of Georgia. Chattahoochee River flows are highly regulated by a series of federal storage reservoirs and several pondage and run-of-river private power reservoirs. Federal reservoirs operate for multiple purposes, including flood control, water supply, hydropower, navigation, water quality, recreation, and fish and wildlife conservation. The Flint River is largely unregulated, with no storage reservoirs. The most downstream ACF planning node for purposes of this study is the Chattahoochee Gage, which is in Florida just downstream of Woodruff Dam. The four federal reservoirs, Lanier, West Point, W.F. George, and Woodruff, comprise basic or planning nodes for surface water availability assessment purposes, whereas the smaller private power reservoirs are not located at basic or planning nodes. An ACF Study Basin map showing node locations and LDAs for each node is provided in Figure 6-1.

The HEC-ResSim model developed for the USACE update of the ACF Water Control Manual was adapted for resource assessment of the Chattahoochee River Basin.[6] The model incorporates five federal reservoirs (Lanier, West Point, W.F. George, George Andrews, and Jim Woodruff), and seven non-federal reservoirs (Glades, Morgan Falls, Bear Creek, Bartletts Ferry, Goat Rock, Oliver, and North Highlands). The USACE-recommended operational alternative, formulated in response to the Georgia 2015 Water Supply Request[7] was adapted for resource assessment. The current conditions assessment used measured water use in 2011 – an extremely dry year with historically high water use – to represent current water demands. This is a conservative approach that supports assessment of resource availability to meet demand when water is needed most. Current water use data input to the model represented observed monthly net water use aggregated across all use categories in 2011. Projected 2050 net water demand, also aggregated across all categories and distributed monthly in accordance with 2011 demand, was applied for future conditions resource assessment modeling. The HEC-ResSim model reservoir network used for current and future resource assessment of the ACF Study Basin is shown in Figure 6-2.

Two standalone HEC-5 models were developed for resource assessment of the Flint Basin, briefly described as follows:

- Model 1 (Bainbridge model) – Extends from Griffin through Bainbridge; incorporates a composite water supply off-channel pumped storage reservoir (representing six smaller projects) upstream of the Montezuma node, and composite farm ponds in the Albany, Newton, and Bainbridge reaches; composite farm pond elevation-area storage relationships were extrapolated from bathymetric surveys of 20 ponds within the Flint Basin and a number of active and likely farm ponds in each reach.

[6] USACE Mobile District. 2015. Draft Environmental Impact Assessment – Update of the Apalachicola-Chattahoochee-Flint River Basin in Alabama, Florida and Georgia and a Water Supply Storage Assessment. Volume 3, Appendix E: HEC-ResSim Modeling Report. October.
[7] Letter from Governor Nathan Deal to Jo-Ellen Darcy, Assistant Secretary of the Army for Civil Works dated January 11, 2013, re: State of Georgia's Water Supply Request.

- Model 2 (Carsonville model) – Extends from Griffin through Carsonville; incorporates a composite water supply off-channel pumped storage reservoir (representing the same six smaller projects incorporated in the Bainbridge model) upstream of the Carsonville node.

The ACF Study Basin consists of seven planning nodes:

- Whitesburg (Chattahoochee Basin, regulated) – Located approximately midway downstream of Atlanta and upstream of West Point Lake. Atlanta was not designated as a planning node in order to prevent Atlanta's withdrawals and returns from being separated into two different planning areas; the planning reach includes municipal, industrial, and agricultural water uses and thermal cooling water use by Plant McDonough.
- Columbus (Chattahoochee Basin, regulated) – Located just downstream of the Georgia Power fall line projects and West Point Lake, and upstream of the city of Columbus; the planning reach includes cooling water demands by the Yates, Wansley, and Franklin thermal power plants, municipal and industrial water uses, but no agricultural usage. A portion of Alabama's net water use was applied to this reach.
- Columbia (Chattahoochee Basin, regulated) – Located at Andrews Dam; has Plant Farley thermal power, municipal and agricultural water uses, but no industrial water use; a portion of Alabama's net water use is applied to this reach.
- Woodruff (Apalachicola Basin, regulated) – Located at the confluence of the Chattahoochee and Flint Rivers, this reach is in Subarea 4, which is located in the Dougherty Plain and in the region where groundwater pumping affects surface water flows, thus exhibiting groundwater effects; the reach has municipal, industrial, and agricultural water uses, and a portion of Alabama's net water use is applied to this reach. The Woodruff sub-basin includes the Iron City basic node in the Spring Creek basin.
- Carsonville (Flint Basin, unregulated) – The most upstream node on the Flint River; has municipal, industrial, and agricultural water uses.
- Montezuma (Flint Basin, unregulated) – Located just downstream of the Carsonville node on the Flint River, this node has municipal, industrial, and agricultural water uses.
- Bainbridge (Flint Basin, unregulated) – Located just upstream of Lake Seminole (Woodruff Dam), this reach is in Subarea 4 and thus exhibits groundwater effects on surface water; this reach has municipal and agricultural water uses but no industrial use, and the Plant Mitchell thermal power plant is in the Bainbridge sub-basin; the Milford basic node on the Ichawaynochaway Creek Basin is also within the Bainbridge sub-basin.

Neither the current nor future conditions HEC-ResSim models show potential gaps at any of the four regulated planning nodes in the ACF Study Basin due to conservation storage remaining in the upstream federal reservoirs at all times, as shown in Tables 6-1 and 6-2. Due to the composite water supply reservoirs located upstream, neither the Carsonville nor Montezuma planning nodes in the Flint River Basin showed potential gaps for either current or future conditions. Potential gaps were shown for both present and future conditions at the Bainbridge planning node, mitigated slightly in both cases by the composite farm ponds placed in the Albany, Newton, and upstream Bainbridge reaches. Statistics for potential gaps at Bainbridge in the Flint River Basin are shown in Tables 6-3 through 6-7.

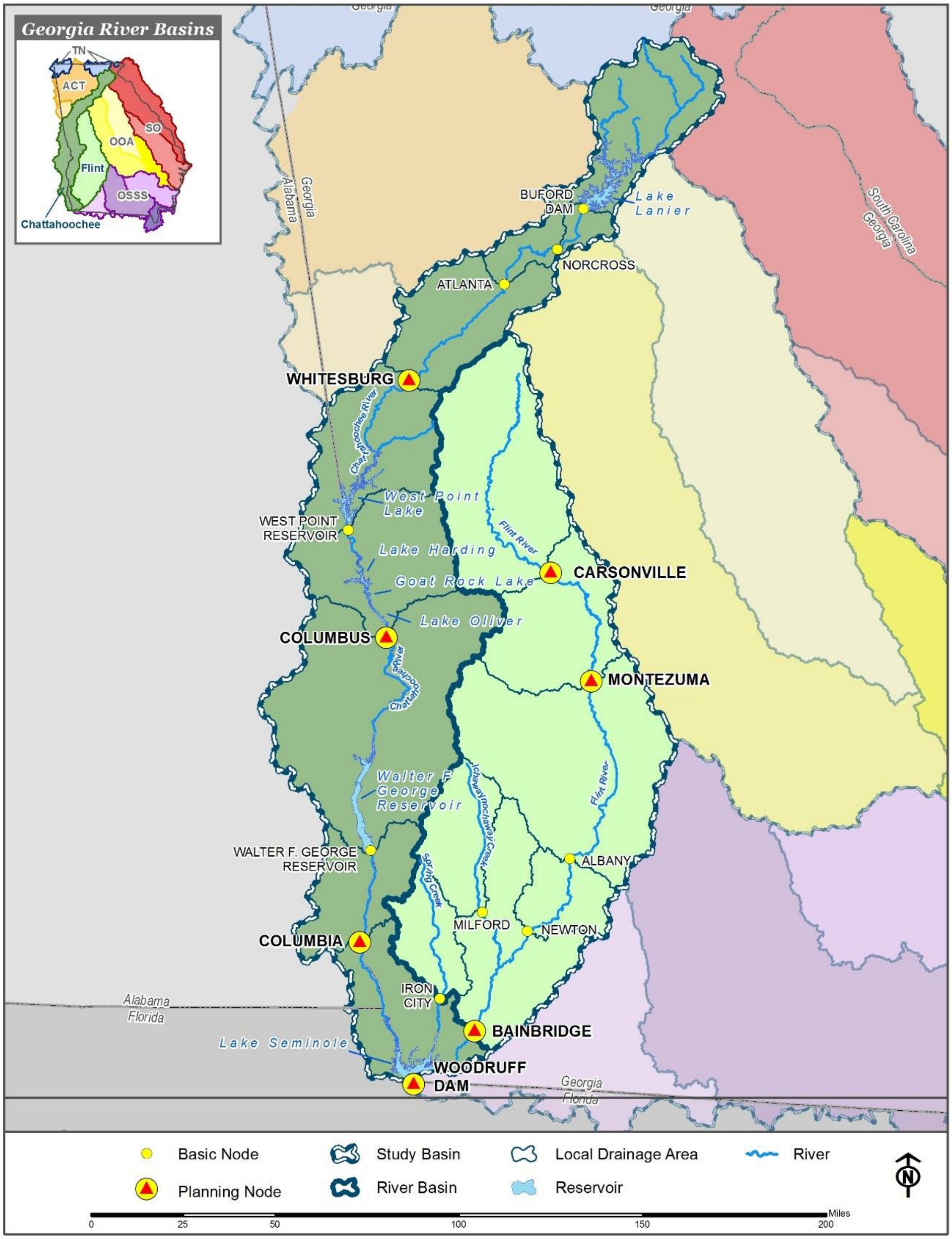


Figure 6-1 Apalachicola-Chattahoochee-Flint (ACF) Study Basin

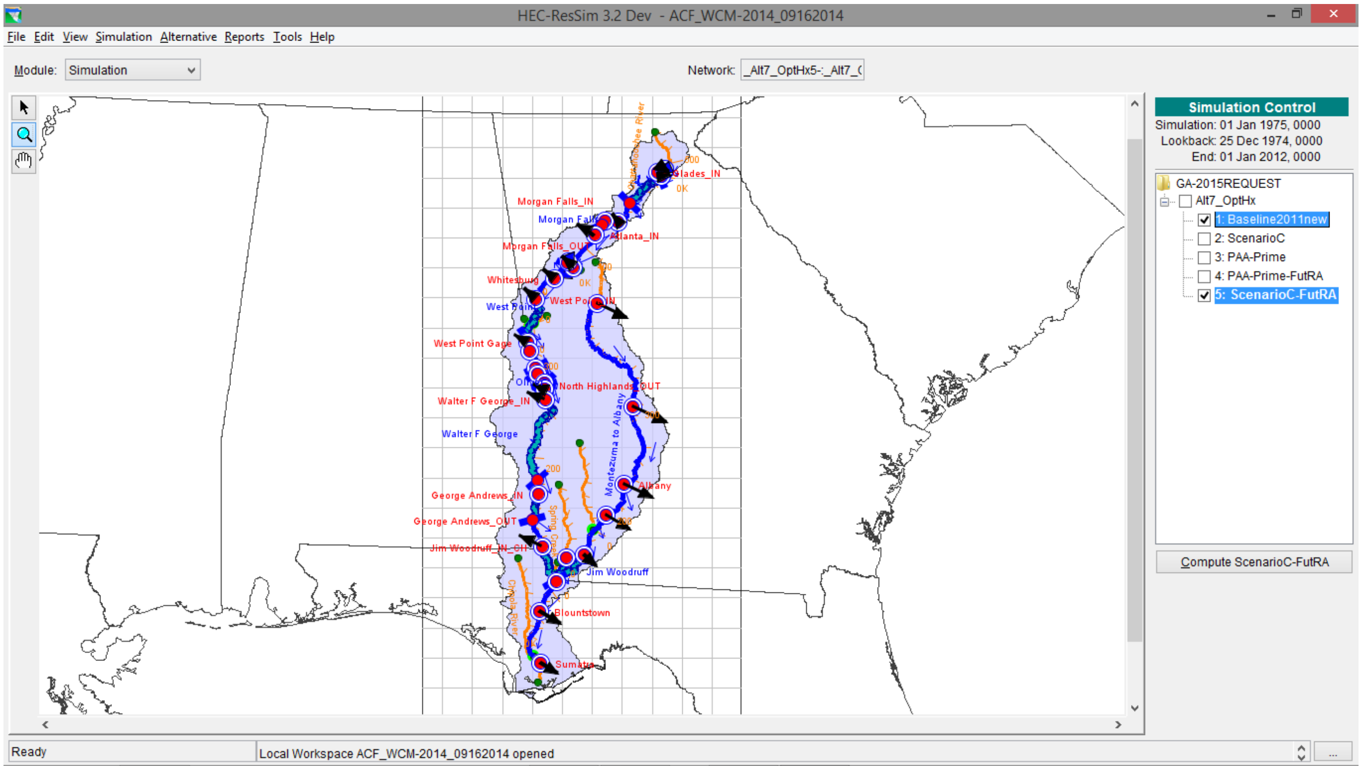


Figure 6-2 **ACF HEC-ResSim resource assessment model reservoir network**

Table 6-1 Summary of current conditions reservoir storage availability for Chattahoochee River Basin regulated nodes

Federal reservoir	Potential demand shortage (cfs)	At-site flow requirement shortage (cfs)	Minimum reservoir conservation storage remaining (acre-feet)	Minimum percentage conservation storage remaining	Basin-wide flow requirement shortage (cfs)
Lake Lanier	0	0	454,119	42%	0 – Note 1
West Point Lake	0	0	15,807	5%	0 – Note 1
Lake Walter F. George	0	0	15,693	6%	0 – Note 1
Composite (Lanier + WP + WFG)	0	0	505,189	31%	0 – Note 1
Note 1: Rule-based flow regime (i.e., seasonal and conditional flow requirements prescribed by system operating rules)					

Table 6-2 Summary of future conditions reservoir storage availability for Chattahoochee River Basin regulated nodes

Federal reservoir	Potential demand shortage (cfs)	At-site flow requirement shortage (cfs)	Minimum reservoir conservation storage remaining (acre-feet)	Minimum percentage conservation storage remaining	Basin-wide flow requirement shortage (cfs)
Lake Lanier	0	0	389,703	36%	0 – Note 1
West Point Lake	0	0	15,807	5%	0 – Note 1
Lake Walter F. George	0	0	18,648	8%	0 – Note 1
Composite (Lanier + WP + WFG)	0	0	509,834	31%	0 – Note 1
Note 1: Rule-based flow regime (i.e., seasonal and conditional flow requirements prescribed by system operating rules)					

Table 6-3 Potential gaps at Bainbridge Planning Node

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2011)	12	372	7,866
Round 2 current with farm ponds (1939–2011)	12	350	7,866
Round 2 future (1939–2011)	9	290	7,993
Round 2 future with farm ponds (1939–2011)	9	286	7,993

Table 6-4 Characteristics of potential gaps at Bainbridge Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2011)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	250	(71.2%)	740	(2.8%)	156	557
8 – 14 days	51	(14.5%)	525	(2.0%)	288	2,976
15 – 30 days	29	(8.3%)	637	(2.4%)	406	9,081
< 30 days	21	(6.0%)	1,216	(4.6%)	492	28,863
Totals	351	(100%)	3,118	(11.7%)		

Table 6-5 Characteristics of potential gaps at Bainbridge Planning Node for current conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2011)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	264	(72.7%)	799	(3.0%)	150	563
8 – 14 days	49	(13.5%)	514	(1.9%)	286	3,067
15 – 30 days	27	(7.4%)	579	(2.2%)	376	8,388
< 30 days	23	(6.3%)	1216	(4.6%)	454	24,489
Totals	363	(100.0%)	3108	(11.7%)		

Table 6-6 Characteristics of potential gaps at Bainbridge Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2011)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	225	(72.1%)	670	(2.5%)	139	518
8 – 14 days	48	(15.4%)	482	(1.8%)	258	2,567
15 – 30 days	21	(6.7%)	464	(1.7%)	324	7,159
< 30 days	18	(5.8%)	850	(3.2%)	387	18,070
Totals	312	(100%)	2,466	(9.2%)	See footnote[8]	

[8] Characteristics of potential gaps at Bainbridge for future conditions (2050) originally provided to the planning councils in December 2016 were based on draft model results. Subsequent resource assessment modeling results presented in the table show minor differences in potential gaps from the draft model results.

Table 6-7 Characteristics of potential gaps at Bainbridge Planning Node for future conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2011)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	225	(72.3%)	665	(2.5%)	135	501
8 – 14 days	48	(15.4%)	480	(1.8%)	262	2,590
15 – 30 days	20	(6.4%)	445	(1.7%)	317	7,066
< 30 days	18	(5.8%)	849	(3.2%)	382	17,764
Totals	311	(100%)	2,439	(9.1%)	See footnote[9]	

6.2.2 Alabama-Coosa-Tallapoosa (ACT) Study Basin

The ACT Basin drains an area of 14,739 square miles in Georgia and Alabama. Approximately 5,299 square miles of the basin are in Georgia, and approximately 9,440 square miles are in Alabama. The confluence of the Coosa and Tallapoosa Rivers forms the Alabama River near Wetumpka, Alabama, and the Alabama and Tombigbee Rivers merge to form the Mobile River near Calvert, Alabama.

The Georgia portion of the Coosa River Basin and its tributary streams occupy a 4,579-square-mile area of the northwestern corner of the state, shown in Figure 6-3. Downstream of Georgia, the Coosa River covers a 5,353-square-mile area of Alabama. North of Georgia, a 127-square-mile area lies in Tennessee.

The Coosa River Basin contains several major rivers, tributary streams, and federal and non-federal storage reservoirs. The Coosa River itself is formed by the confluence of the Oostanaula and Etowah Rivers near Rome, Georgia. The Oostanaula River in turn is formed by the confluence of the Conasauga and Coosawattee Rivers. The basin also contains the Chattooga River, which joins the Coosa River in Alabama.

Three dams are located within the Georgia portion of the Coosa River Basin, while a fourth – Weiss Dam in Alabama – has an impoundment that extends into Georgia. Within Georgia, multipurpose federal projects are currently operated for power generation, water supply, and flood control purposes. Allatoona Dam was constructed by USACE and placed into operation in 1956. Carters Dam, a pumped-storage peaking hydropower project on the Coosawattee River, was completed in 1974, along with a reregulation dam downstream that stores a portion of Carters Dam releases for pump back and reregulation of peaking power releases.

[9] Characteristics of potential gaps at Bainbridge for future conditions (2050) originally provided to the planning councils in December 2016 were based on draft model results. Subsequent resource assessment modeling results presented in the table show minor differences in potential gaps from the draft model results.

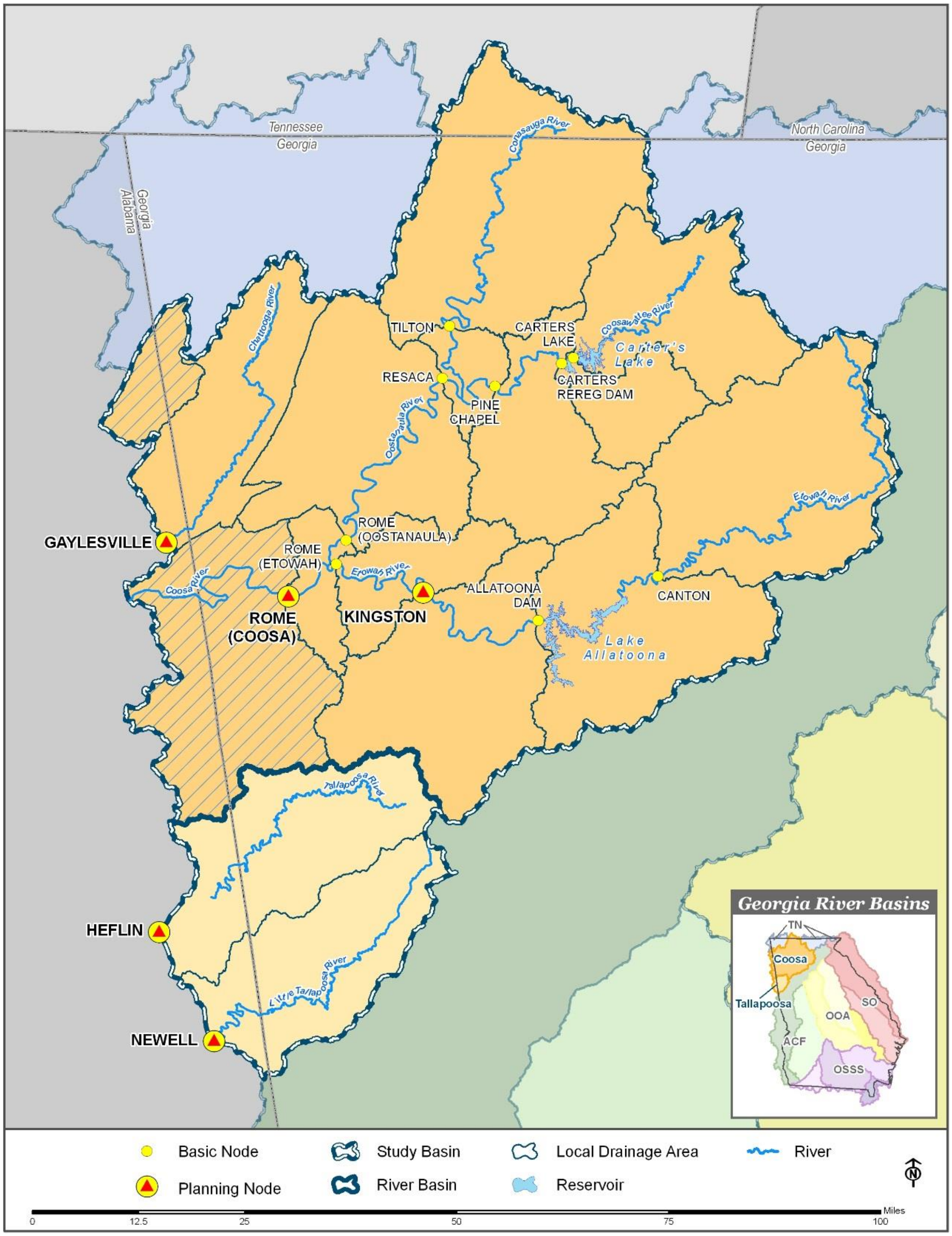


Figure 6-3 **Alabama-Coosa-Tallapoosa (ACT) Study Basin**

The Tallapoosa River Basin within Georgia consists of the Tallapoosa River itself and the Little Tallapoosa River. The basin drains a total area of 4,680 square miles, of which 720 square miles are in Georgia and 3,960 square miles are in Alabama.

The HEC-ResSim model developed for the USACE update of the ACT Water Control Manual[10] was adapted for resource assessment of the portions of the ACT Study Basin within Georgia. The model incorporates the Allatoona, Carters, and Carters Reregulation federal reservoirs. The proposed action alternative was adapted for resource assessment using Georgia historical 2011 water demands for current conditions and projected Georgia 2050 water demands for future conditions.

The most downstream node on the Coosa River in Georgia is located at Rome, which lies upstream of the Alabama Lake Weiss project. Heflin and Newell are planning nodes located within the Tallapoosa River Basin in Alabama just downstream of the Georgia-Alabama state line, with most of their watersheds lying in Georgia. Consequently, no adjustments to the ACT HEC-ResSim model downstream of Georgia planning nodes were made for resource assessment purposes in Georgia, and model time-series outputs for downstream locations were ignored. The ACF HEC-ResSim model reservoir network applied to both current (2011) and future (2050) resource assessments is shown in Figure 6-4.

[10] USACE Mobile District. 2014. Final Environmental Impact Assessment – Update of the Water Control Manual for the Alabama-Coosa-Tallapoosa River Basin in Georgia and Alabama. Volume 4, Appendix C: HEC-ResSim Modeling Report. October.

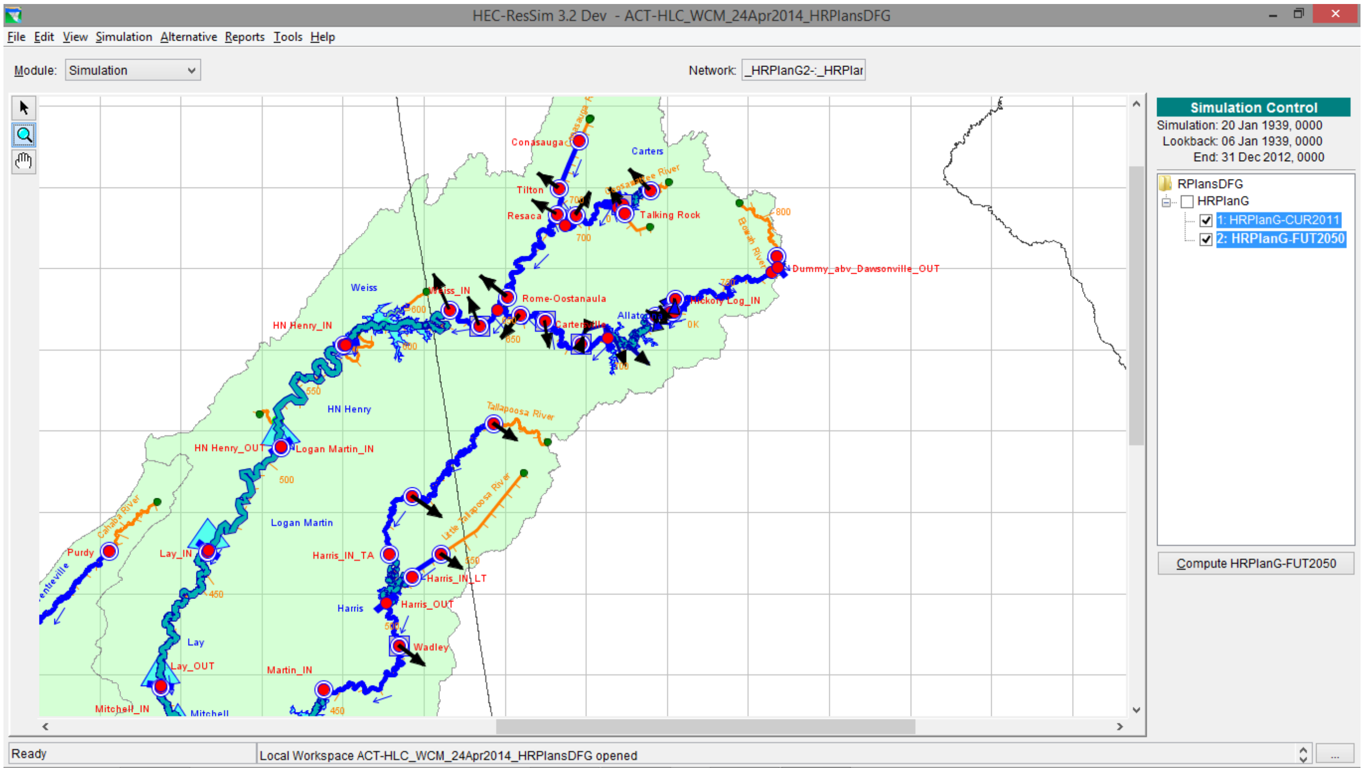


Figure 6-4 **ACT HEC-ResSim resource assessment model reservoir network**

Current and future resource assessments for the Gaylesville planning node were performed using HEC-DSS macros because the node is a headwater node and, while Chattooga Basin inflows into Lake Weiss are accounted for, the Chattooga River itself is not incorporated within the ACT HEC-ResSim model stream network.

The ACT Study Basin consists of five planning nodes, described as follows:

- Kingston (Etowah Basin, regulated) – Located downstream of Lake Allatoona, with Plant Bowen thermal power plant cooling water and municipal, industrial, and agricultural water uses within the sub-basin.
- Rome (Coosa Basin, regulated) – Located at the confluence of the Etowah and Oostanaula Rivers (downstream of both Allatoona and Carters), with municipal and industrial but no agricultural water uses.
- Gaylesville (Chattooga Basin, unregulated node located in Alabama) – Downstream gage on the Chattooga River below the Georgia-Alabama state line, with municipal and industrial but no agricultural water uses.
- Newell (Little Tallapoosa Basin, unregulated node located in Alabama) – Downstream gage on the Little Tallapoosa River below the Georgia-Alabama state line, with municipal and industrial but no agricultural water uses.

- Heflin (Tallapoosa Basin, unregulated node located in Alabama) – Downstream gage on the Tallapoosa River below the Georgia-Alabama state line, with municipal and industrial but no agricultural water uses.

The Kingston and Rome planning nodes are regulated, and resource assessment modeling results show no shortfalls under either current or future conditions based on storage remaining in Lakes Allatoona and Carters, as shown in Table 6-8. For the three unregulated nodes, however, potential shortfalls were simulated for both current and future conditions, with results summarized in Tables 6-9 through 6-17.

Table 6-8 Summary of current and future conditions reservoir storage availability for Kingston and Rome regulated nodes

Federal reservoir	Potential demand shortage (cfs)	At-site flow requirement shortage (cfs)	Minimum reservoir conservation storage remaining (acre-feet)	Minimum percentage conservation storage remaining	Basin-wide flow requirement shortage (cfs)
Allatoona current conditions (Kingston and Rome)	0	0	108,935	38%	0 – Note 1
Carters current conditions[11] (Rome)	0	0	90,436	64%	0 – Note 1
Allatoona future conditions (Kingston and Rome)	0	0	96,530	34%	0 – Note 1
Carters future conditions[11] (Rome)	0	0	91,668	65%	0 – Note 1
Note 1: Rule-based flow regime, i.e., seasonal and conditional flow requirements prescribed by system operating rules					

Table 6-9 Potential gaps at Gaylesville Planning Node

[11] Carters minimum remaining storage and percentage of conservation storage remaining values were originally provided to the planning councils in October 2016. Subsequent resource assessment modeling resulted in modifications to these values shown in the table.

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2011)	2	3	656
Round 2 future (1939–2011)	3	9	656

Table 6-10 Characteristics of potential gaps at Gaylesville Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2011)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	91	(82.0%)	214	(0.8%)	2	6
8 – 14 days	12	(10.8%)	131	(0.5%)	2	6
15 – 30 days	4	(3.6%)	95	(0.3%)	2	6
< 30 days	4	(3.6%)	170	-0.6%	4	131
Totals	111	(100.0%)	610	(2.2%)		

Table 6-11 Characteristics of potential gaps at Gaylesville Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2011)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	111	(78.7%)	268	(1.0%)	7	18
8 – 14 days	15	(10.6%)	153	(0.6%)	6	64
15 – 30 days	10	(7.1%)	193	(0.7%)	11	216
< 30 days	5	(3.5%)	223	(0.8%)	8	421
Totals	141	(100.0%)	837	(3.1%)		

Table 6-12 Potential gaps at Heflin Planning Node

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2011)	5	3	648
Round 2 future (1939–2011)	5	4	647

Table 6-13 Characteristics of potential gaps at Heflin Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2011)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	122	(69.7%)	386	(1.4%)	2	8
8 – 14 days	29	(16.6%)	313	(1.1%)	2	8
15 – 30 days	18	(10.3%)	392	(1.4%)	2	8
< 30 days	6	(3.4%)	321	-1.2%	3	156
Totals	175	(100.0%)	1,412	(5.2%)		

Table 6-14 Characteristics of potential gaps at Heflin Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2011)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	124	(69.3%)	389	(1.5%)	3	11
8 – 14 days	31	(17.3%)	332	(1.2%)	4	38
15 – 30 days	18	(10.1%)	399	(1.5%)	4	85
< 30 days	6	(3.4%)	321	(1.2%)	4	207
Totals	179	(100.0%)	1,441	(5.4%)		

Table 6-15 Potential gaps at Newell Planning Node

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2011)	6	6	587
Round 2 future (1939–2011)	7	12	580

Table 6-16 Characteristics of potential gaps at Newell Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2011)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	130	(69.9%)	430	(1.6%)	5	18
8 – 14 days	29	(15.6%)	305	(1.1%)	6	68
15 – 30 days	20	(10.8%)	410	(1.5%)	7	138
< 30 days	7	(3.8%)	356	(1.3%)	7	366
Totals	186	(100.0%)	1,501	(5.6%)		

Table 6-17 Characteristics of potential gaps at Newell Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2011)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	152	(67.6%)	451	(1.7%)	8	28
8 – 14 days	45	(20.0%)	460	(1.7%)	12	120
15 – 30 days	16	(7.1%)	317	(1.2%)	13	245
< 30 days	12	(5.3%)	596	(2.2%)	15	759
Totals	225	(100.0%)	1,824	(6.8%)		

6.2.3 Ocmulgee-Oconee-Altamaha (OOA) Study Basin

The OOA Study Basin is located entirely within the state of Georgia and drains an area of approximately 14,265 square miles in the central-southeastern part of the state. The Ocmulgee River Basin is the westernmost river basin within the study basin and is located in the Piedmont and Coastal Plain physiographic provinces of central Georgia. The South, Yellow, and Alcovy Rivers join at Lake Jackson south of the Atlanta metropolitan area to form the Ocmulgee River. The Oconee River Basin is located just east of the Ocmulgee River Basin and is formed by the confluence of the Middle and North Oconee Rivers south of Athens, Georgia. Approximately 20 miles south of the confluence of the Middle and North Oconee Rivers, the Oconee River flows into Lake Oconee and then into Lake Sinclair. The Altamaha River begins at the confluence of the Ocmulgee and Oconee Rivers and flows eastward, where it is joined by the Ohoopee River. The Altamaha River flows southeasterly from its confluence with the Ohoopee River to the Atlantic Ocean, south of Savannah, Georgia.

The Ocmulgee and Oconee Rivers are regulated by hydropower reservoirs operated by Georgia Power. The Altamaha River is downstream of these two regulated rivers, but has no federal or private power storage reservoirs in its own drainage area. The most downstream OOA planning node is Doctortown, located northeast of Jessup, Georgia. Three Georgia Power reservoirs are located within the OOA basin: Lake Jackson on the Ocmulgee River southeast of Atlanta, and Lakes Oconee and Sinclair on the Oconee River between Greensboro and Milledgeville, Georgia. Lake Oconee is a 21,000-acre reservoir formed by Wallace Dam; immediately downstream is Lake Sinclair, a 15,330-acre reservoir formed by Sinclair Dam. Lake Oconee drains approximately 1,830 square miles and began operation in 1979 upon completion of Wallace Dam. Lake Sinclair drains an area of approximately 2,910 square miles, and its construction was completed in 1953. Stream flow gages south of Lake Jackson (Jackson) and Lake Sinclair (Milledgeville) are planning nodes for surface water availability assessment purposes. An OOA Study Basin map showing node locations and LDAs for each is provided in Figure 6-5.

The HEC-ResSim model developed for resource assessment of the OOA Basin uses a schematic (i.e., not georeferenced) stream and reservoir network. The model incorporates the Bear Creek water supply reservoir in the upper Oconee River basin (upstream of the Milledgeville planning node), which provides water to Barrow, Jackson, and Oconee Counties. The OOA HEC-ResSim model reservoir network applied to both current (2011) and future (2050) resource assessments is shown in Figure 6-6.

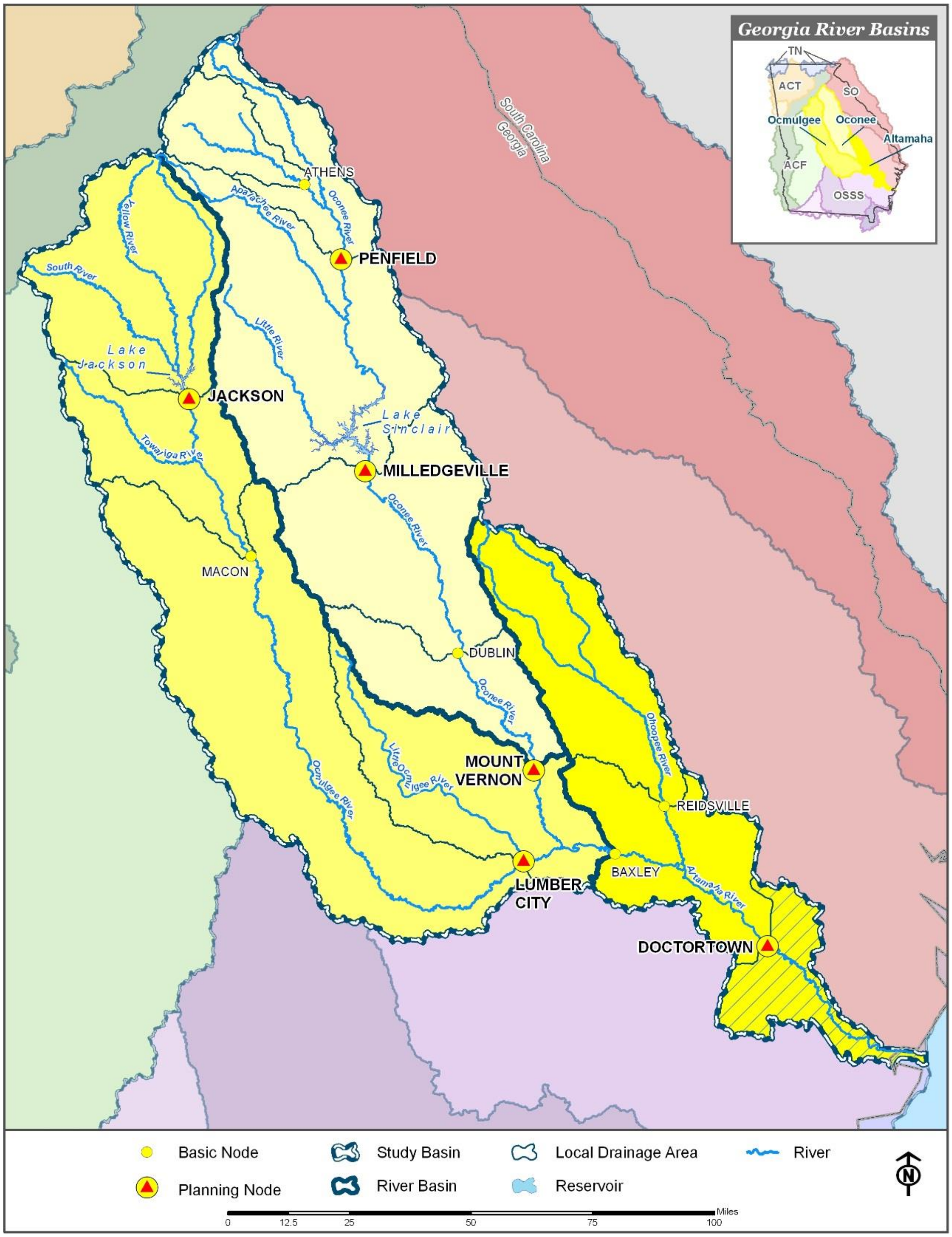


Figure 6-5 Ocmulgee-Oconee-Altamaha (OOA) Study Basin

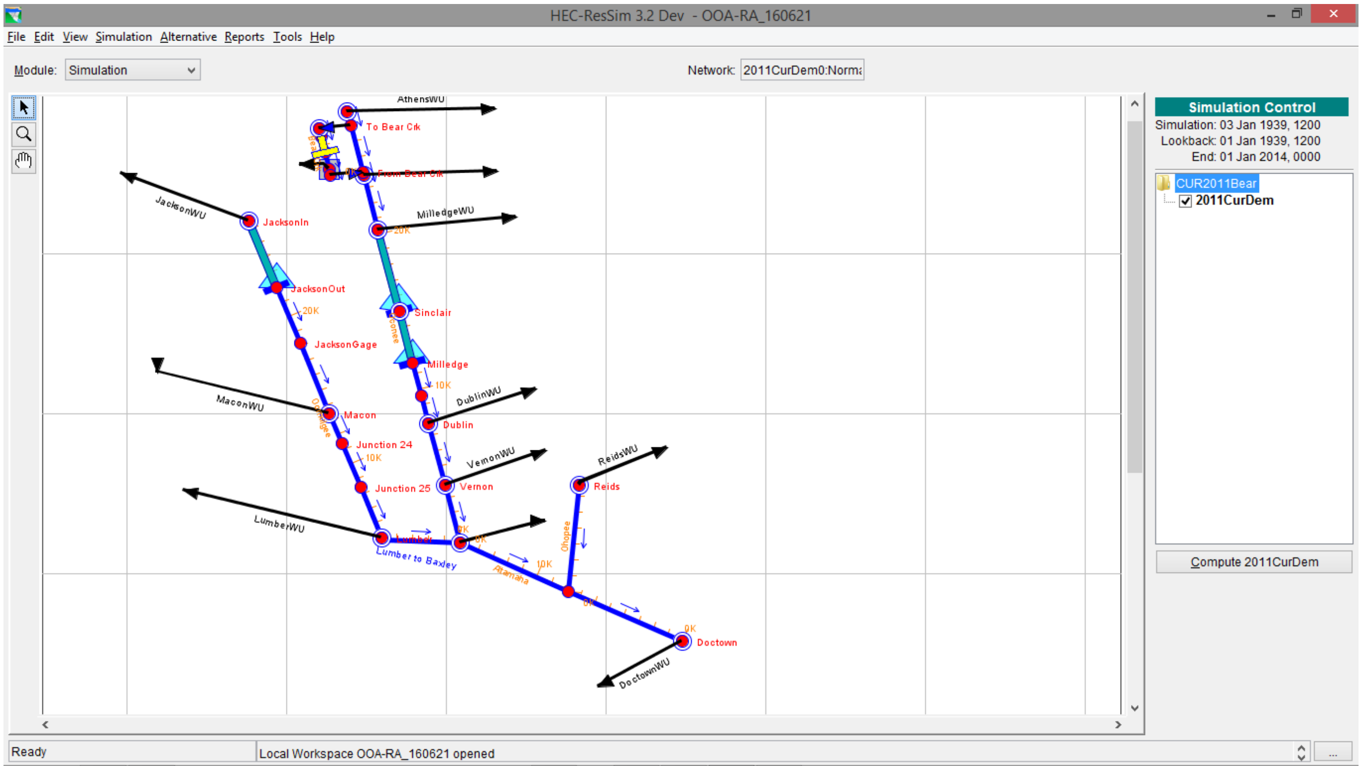


Figure 6-6 **OOA HEC-ResSim resource assessment model reservoir network**

The OOA Study Basin consists of six planning nodes. Planning nodes are listed below with types of water uses at the node. More detailed descriptions of the nodes are provided in the appendix.

- Jackson (Ocmulgee Basin, regulated) – Located on the Ocmulgee River just downstream of Lake Jackson; this node has municipal demands and returns, industrial returns, and agricultural water use.
- Lumber City (Ocmulgee Basin, regulated) – Located on the Ocmulgee River in Lumber City, Georgia, upstream of the Ocmulgee-Altamaha confluence; this node has municipal and industrial withdrawals and returns, and agricultural and thermal power water demands. The Lumber planning node is located downstream of the Macon basic node, and to enable resource assessment with future municipal returns by the City of Macon upstream of the Macon reach (as opposed to downstream in the Lumber reach as they currently occur), the Macon2 and Lumber2 nodes were created to shift returns from the Lumber node upstream to the Macon node. Resource assessment model-simulated flows at Macon are affected by the location of returns, but simulated flows at the downstream Lumber planning node are virtually identical in both cases, differing only slightly due to flow routing of returns made above Macon to Lumber that are otherwise not routed with existing returns to the Lumber reach.
- Penfield (Oconee Basin, unregulated) – Located on the Oconee River near Penfield, Georgia, upstream of Lake Oconee; this node has municipal withdrawals and returns, and agricultural water use. As previously described, the Bear Creek water supply reservoir is located upstream of Penfield.

- Milledgeville (Oconee Basin, regulated) – Located on the Oconee River near Milledgeville, Georgia, just downstream of Lake Sinclair; this node has municipal withdrawals and returns, industrial withdrawals, and agricultural and thermal power water uses.
- Mount Vernon (Oconee Basin, regulated) – Located on the Oconee River near Mount Vernon, Georgia, upstream of the Oconee-Altamaha confluence; this node has municipal and industrial withdrawals and returns, and agricultural water uses.
- Doctortown (Altamaha Basin, regulated) – Located on the Altamaha River in Doctortown, Georgia; this node has municipal and industrial returns, and agricultural and thermal power water uses.

Five of the six planning nodes are regulated, and as shown in Table 6-18, no shortfalls were simulated to occur at any of these nodes for current (2011) or future (2050) conditions.

Table 6-18 Summary of current and future conditions reservoir storage availability for OOA Study Basin regulated nodes

Georgia Power reservoir	Potential demand shortage (cfs)	At-site flow requirement shortage (cfs)	Minimum reservoir conservation storage remaining (acre-feet)	Minimum percentage conservation storage remaining	Basin-wide flow requirement shortage (cfs)
Lake Jackson current conditions	0	0	14,033	28%	N/A
Lake Jackson future conditions	0	0	18,778	37%	N/A
Lake Oconee current conditions	0	0	22,358	28%	N/A
Lake Oconee future conditions	0	0	27,242	35%	N/A
Lake Sinclair current conditions	0	0	44,230	34%	N/A
Lake Sinclair future conditions	0	0	50,063	39%	N/A

The OOA HEC-ResSim model includes a composite water supply reservoir upstream of the Penfield node, with storage equivalent to the combined conservation storage of the Bear Creek, Laurel Lane, Cedar Creek, and Parks Creek water supply reservoirs. With this water supply storage accounted for, no gaps were simulated at Penfield for either current or future conditions.

6.2.4 Ochlockonee-Suwannee-Satilla-St. Marys (OSSS) Study Basin

The OSSS Study Basin drains an area of 10,450 square miles in southern Georgia. The Ochlockonee River Basin is in the southwestern part of the state, flowing from its headwaters approximately 19 miles southeast of Albany southwest through Florida to the Gulf of Mexico. The Suwannee River Basin lies between the Ochlockonee and Satilla Basins, flowing southwest from the Okefenokee Swamp (approximately 9 miles south of Waycross, Georgia) through Florida and into the Gulf of Mexico. Major tributaries of the Suwannee River within Georgia include the Alapaha, Withlacoochee, and Aucilla Rivers. The Satilla Basin extends between the Suwannee River Basin and the Atlantic coast. The Satilla River begins approximately 25 miles east of Tifton, Georgia, and flows southeast to the Atlantic Ocean. A major tributary of the Satilla River is the Little Satilla River. The St. Marys Basin is located in the southeastern corner of Georgia, beginning approximately 14 miles east of Lake City, Florida, and flowing north into Georgia and then east to the Atlantic coast.

The Ochlockonee, Suwannee, Satilla, and St. Marys Rivers are unregulated, having no federal or private power storage reservoirs. The OSSS Study Basin includes the Quincy, Concord, Pinetta, Jennings, Statenville, Fargo, Atkinson, and Gross Planning Nodes. A map showing locations of planning and basic nodes in the OSSS Study Basin is provided in Figure 6-7.

The HEC-ResSim model developed for OSSS Study Basin resource assessment includes composite farm ponds in the Alapaha, Statenville, and Jennings reaches of the Alapaha River Basin, in the Pinetta reach of the Withlacoochee River Basin, and in the Fargo reach of the Suwanee River Basin. The OSSS HEC-ResSim model reservoir network applied to both current (2011) and future (2050) resource assessments is shown in Figure 6-8.

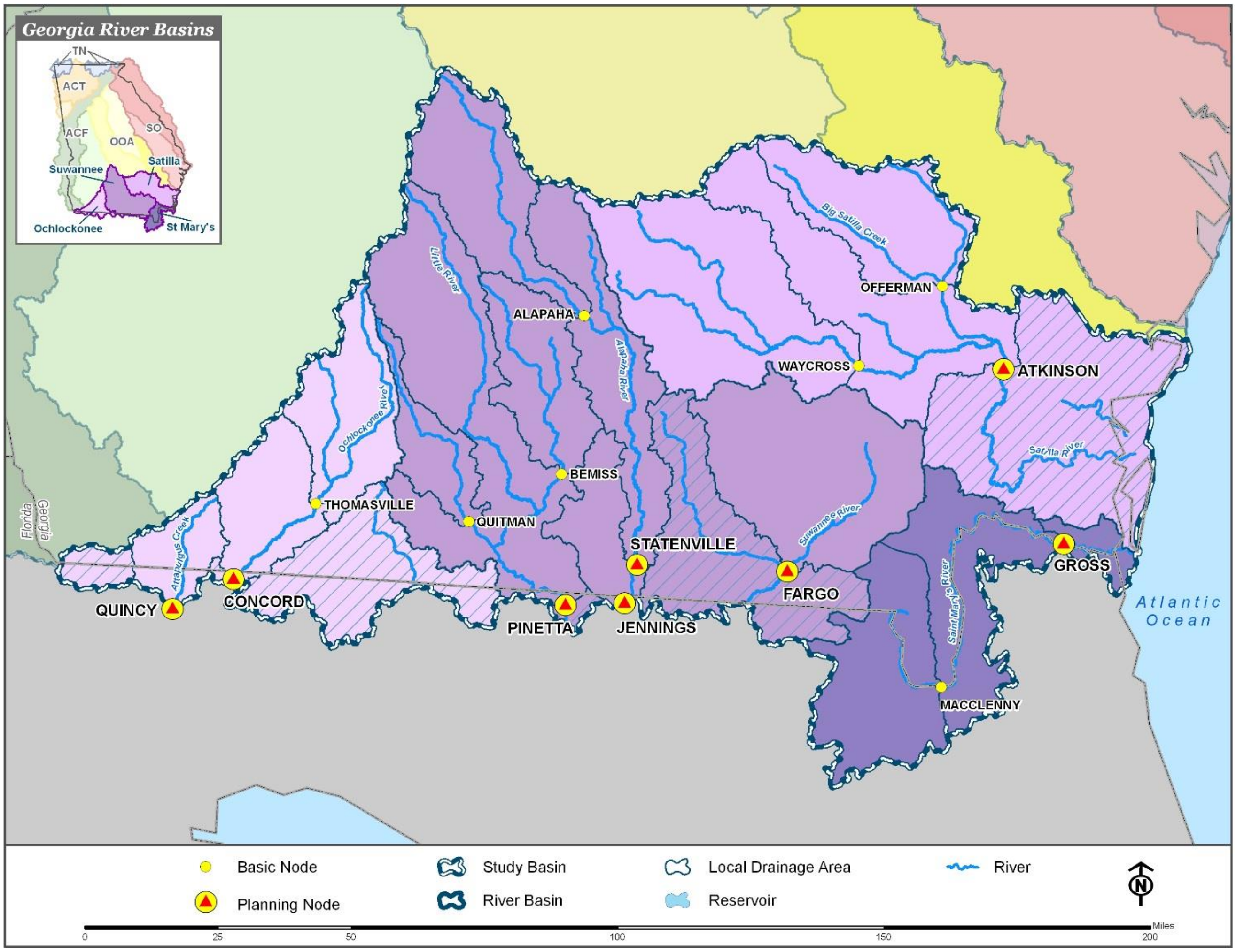


Figure 6-7 Ochlockonee-Suwanee-Satilla-St. Marys (OSSS) Study Basin

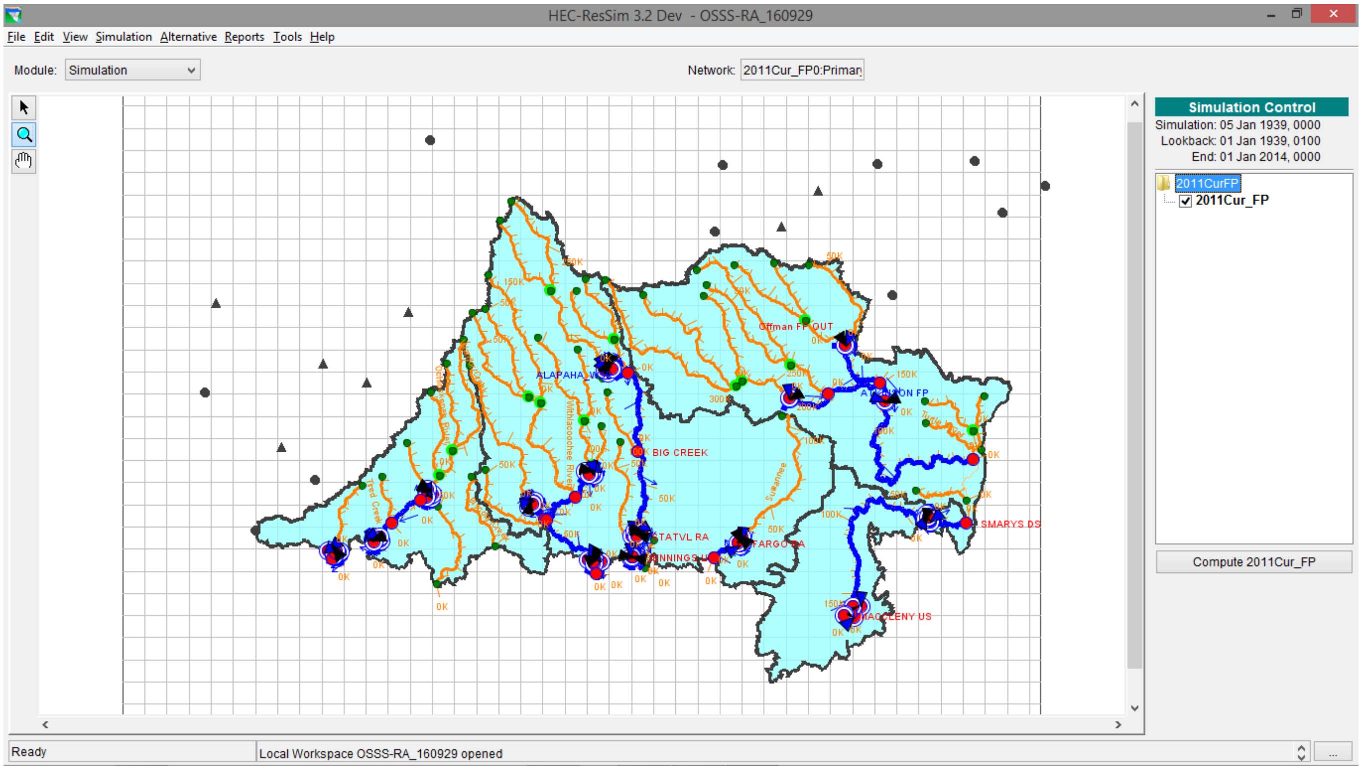


Figure 6-8 OSSS HEC-ResSim resource assessment model reservoir network

Some of the reaches in the OSSS Study Basin have municipal and industrial water use, and most have agricultural water use. Some reaches have no withdrawals but have returns because groundwater withdrawals are returned to surface streams in these reaches. Each planning node is listed below with the type of water uses at the node. More detailed descriptions of the nodes are provided in the appendix.

- Quincy (Little River Basin, unregulated) – Located on the Little River near Quincy, Florida; this node has industrial withdrawals and returns, and agricultural water use.
- Concord (Ochlockonee Basin, unregulated) – Located on the Ochlockonee River near Concord, Florida, this node has industrial returns, municipal returns, and agricultural water use.
- Pinetta (Withlacoochee Basin, unregulated) – Located at the Withlacoochee River near Pinetta, Florida; this node has industrial returns, municipal returns, and agricultural water use.
- Statenville (Alapaha Basin, unregulated) – Located on the Alapaha River at Statenville, Georgia; this node has municipal returns and agricultural water use.
- Jennings (Alapaha Basin, unregulated) – Located on the Alapaha River near Jennings, Florida; this node has agricultural water use.
- Fargo (Suwanee Basin unregulated) – Located on the Suwanee River at U.S. 441 in Fargo, Georgia; this node has municipal returns and agricultural water use.

- Atkinson (Satilla Basin, unregulated) – Located on the Satilla River in Atkinson, Georgia; this node has municipal returns, industrial withdrawals, and agricultural water use.
- Gross (St. Marys Basin, unregulated) – Located on the St. Marys River near Gross, Florida; this node has municipal returns. Because only returns occur upstream, no gaps were simulated at the Gross Planning Node for either current or future conditions.

Potential gaps were identified at all planning nodes except Gross, in general mitigated slightly in reaches with farm ponds. Gap statistics for planning nodes in the OSSS Study Basin are shown in Tables 6-19 through 6-47.

Table 6-19 Potential gaps at Atkinson Planning Node

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2013)	10	24	2,208
Round 2 future (1939–2013)	5	20	2,236

Table 6-20 Characteristics of potential gaps at Atkinson Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	74	(47.7%)	249	(0.9%)	11	42
8 – 14 days	25	(16.1%)	258	(0.9%)	19	188
15 – 30 days	22	(14.2%)	499	(1.8%)	21	466
< 30 days	34	(21.9%)	1,727	(6.3%)	29	1,422
Totals	155	(100.0%)	2,733	(10.0%)		

Table 6-21 Characteristics of potential gaps at Atkinson Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	43	(51.2%)	146	(0.5%)	9	35
8 – 14 days	11	(13.1%)	109	(0.4%)	16	158
15 – 30 days	17	(20.2%)	403	(1.5%)	21	498
< 30 days	13	(15.5%)	608	(2.2%)	22	1,031
Totals	84	(100.0%)	1,266	(4.6%)		

Table 6-22 Potential gaps at Concord Planning Node

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2013)	8	23	1,093
Round 2 future (1939–2013)	6	26	1,110

Table 6-23 Characteristics of potential gaps at Concord Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	109	(55.6%)	352	(1.3%)	10	40
8 – 14 days	42	(21.4%)	438	(1.6%)	16	170
15 – 30 days	25	(12.8%)	517	(1.9%)	22	466
> 30 days	20	(10.2%)	1,007	(3.7%)	29	1,454
Totals	196	(100.0%)	2,314	(8.4%)		

Table 6-24 Characteristics of potential gaps at Concord Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	75	(54.0%)	249	(0.9%)	11	47
8 – 14 days	33	(23.7%)	354	(1.3%)	21	224
15 – 30 days	18	(12.9%)	387	(1.4%)	23	477
> 30 days	13	(9.4%)	706	(2.6%)	33	1,864
Totals	139	(100.0%)	1,696	(6.2%)		

Table 6-25 Potential gaps at Fargo Planning Node

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2013)	2	<1	928
Round 2 current with farm ponds (1939–2013)	1	<1	928
Round 2 future (1939–2013)	2	<1	928
Round 2 future with farm ponds (1939–2013)	2	<1	928

Table 6-26 Characteristics of potential gaps at Fargo Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	12	(38.7%)	39	(0.1%)	<1	1
8 – 14 days	8	(25.8%)	90	(0.3%)	<1	4
15 – 30 days	6	(19.4%)	133	(0.5%)	<1	4
> 30 days	5	(16.1%)	215	(0.8%)	<1	13
Totals	31	(100.0%)	477	(1.7%)		

Table 6-27 Characteristics of potential gaps at Fargo Planning Node for current conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	9	(39.1%)	27	(0.1%)	<1	1
8 – 14 days	6	(26.1%)	68	(0.2%)	<1	4
15 – 30 days	3	(13.0%)	48	(0.2%)	<1	5
> 30 days	5	(21.7%)	215	(0.8%)	<1	12
Totals	23	(100.0%)	358	(1.3%)		

Table 6-28 Characteristics of potential gaps at Fargo Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	20	(48.8%)	73	(0.3%)	1	3
8 – 14 days	8	(19.5%)	88	(0.3%)	1	9
15 – 30 days	8	(19.5%)	181	(0.7%)	1	10
> 30 days	5	(12.2%)	299	(1.1%)	1	61
Totals	41	(100.0%)	641	(2.3%)		

Table 6-29 Characteristics of potential gaps at Fargo Planning Node for future conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	20	(48.8%)	71	(0.3%)	1	3
8 – 14 days	8	(19.5%)	88	(0.3%)	1	9
15 – 30 days	8	(19.5%)	181	(0.7%)	<1	9
> 30 days	5	(12.2%)	298	(1.1%)	1	56
Totals	41	(100.0%)	638	(2.3%)		

Table 6-30 Potential gaps at Jennings Planning Node

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2013)	11	33	1,367
Round 2 current with farm ponds (1939–2013)	8	23	1,365
Round 2 future (1939–2013)	8	36	1,380
Round 2 future with farm ponds (1939–2013)	6	30	1,378

Table 6-31 Characteristics of potential gaps at Jennings Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	136	(59.9%)	447	(1.6%)	9	37
8 – 14 days	33	(14.5%)	353	(1.3%)	24	260
15 – 30 days	32	(14.1%)	676	(2.5%)	29	631
> 30 days	26	(11.5%)	1,456	(5.3%)	39	2,389
Totals	227	(100.0%)	2,932	(10.7%)		

Table 6-32 Characteristics of potential gaps at Jennings Planning Node for current conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	97	(55.4%)	298	(1.1%)	9	36
8 – 14 days	33	(18.9%)	340	(1.2%)	16	166
15 – 30 days	27	(15.4%)	573	(2.1%)	21	456
> 30 days	18	(10.3%)	908	(3.3%)	31	1,542
Totals	175	(100.0%)	2,119	(7.7%)		

Table 6-33 Characteristics of potential gaps at Jennings Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	88	(54.3%)	249	(0.9%)	11	42
8 – 14 days	30	(18.5%)	316	(1.2%)	28	308
15 – 30 days	22	(13.6%)	478	(1.7%)	36	796
> 30 days	22	(13.6%)	1,208	(4.4%)	38	2,255
Totals	162	(100.0%)	2,251	(8.2%)		

Table 6-34 Characteristics of potential gaps at Jennings Planning Node for future conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	64	(50.8%)	194	(0.7%)	10	37
8 – 14 days	25	(19.8%)	280	(1.0%)	26	289
15 – 30 days	24	(19.0%)	506	(1.8%)	24	518
> 30 days	13	(10.3%)	704	(2.6%)	38	2,137
Totals	126	(100.0%)	1,684	(6.1%)		

Table 6-35 Potential gaps at Pinetta Planning Node

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2013)	12	45	1,687
Round 2 current with farm ponds (1939–2013)	11	33	1,687
Round 2 future (1939–2013)	9	46	1,721
Round 2 future with farm ponds (1939–2013)	7	33	1,721

Table 6-36 Characteristics of potential gaps at Pinetta Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	131	(54.6%)	443	(1.6%)	14	57
8 – 14 days	41	(17.1%)	436	(1.6%)	32	356
15 – 30 days	37	(15.4%)	739	(2.7%)	44	898
> 30 days	31	(12.9%)	1,707	(6.2%)	54	3,002
Totals	240	(100.0%)	3,325	(12.1%)		

Table 6-37 Characteristics of potential gaps at Pinetta Planning Node for current conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	147	(58.1%)	427	(1.6%)	10	38
8 – 14 days	45	(17.8%)	472	(1.7%)	25	265
15 – 30 days	31	(12.3%)	651	(2.4%)	34	737
> 30 days	30	(11.9%)	1,453	(5.3%)	40	1,923
Totals	253	(100.0%)	3,003	(11.0%)		

Table 6-38 Characteristics of potential gaps at Pinetta Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	96	(51.3%)	313	(1.1%)	16	63
8 – 14 days	40	(21.4%)	417	(1.5%)	26	274
15 – 30 days	29	(15.5%)	563	(2.1%)	46	920
> 30 days	22	(11.8%)	1,134	(4.1%)	59	3,064
Totals	187	(100.0%)	2,427	(8.9%)		

Table 6-39 Characteristics of potential gaps at Pinetta Planning Node for future conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	91	(54.5%)	302	(1.1%)	12	49
8 – 14 days	31	(18.6%)	315	(1.1%)	24	248
15 – 30 days	30	(18.0%)	609	(2.2%)	34	698
> 30 days	15	(9.0%)	671	(2.4%)	45	2,006
Totals	167	(100.0%)	1,897	(6.9%)		

Table 6-40 Potential gaps at Quincy Planning Node

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2013)	7	4	259
Round 2 future (1939–2013)	7	4	259

Table 6-41 Characteristics of potential gaps at Quincy Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	103	(56.9%)	311	(1.1%)	2	8
8 – 14 days	42	(23.2%)	437	(1.6%)	4	42
15 – 30 days	23	(12.7%)	507	(1.9%)	3	75
> 30 days	13	(7.2%)	666	(2.4%)	5	245
Totals	181	(100.0%)	1,921	(7.0%)		

Table 6-42 Characteristics of potential gaps at Quincy Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	106	(59.6%)	328	(1.2%)	2	9
8 – 14 days	38	(21.3%)	391	(1.4%)	4	42
15 – 30 days	22	(12.4%)	477	(1.7%)	3	64
> 30 days	12	(6.7%)	679	(2.5%)	6	358
Totals	178	(100.0%)	1,875	(6.8%)		

Table 6-43 Potential gaps at Statenville Planning Node

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2013)	17	26	1,047
Round 2 current with farm ponds (1939–2013)	13	15	1,045
Round 2 future (1939–2013)	12	32	1,058
Round 2 future with farm ponds (1939–2013)	10	25	1,056

Table 6-44 Characteristics of potential gaps at Statenville Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	137	(49.8%)	406	(1.5%)	7	24
8 – 14 days	47	(17.1%)	484	(1.8%)	16	171
15 – 30 days	49	(17.8%)	1,039	(3.8%)	20	441
> 30 days	42	(15.3%)	2,787	(10.2%)	28	2,081
Totals	275	(100.0%)	4,716	(17.2%)		

Table 6-45 Characteristics of potential gaps at Statenville Planning Node for current conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	127	(49.2%)	409	(1.5%)	7	29
8 – 14 days	56	(21.7%)	573	(2.1%)	9	96
15 – 30 days	45	(17.4%)	986	(3.6%)	15	326
> 30 days	30	(11.6%)	1,649	(6.0%)	17	971
Totals	258	(100.0%)	3,617	(13.2%)		

Table 6-46 Characteristics of potential gaps at Statenville Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	91	(48.4%)	298	(1.1%)	9	37
8 – 14 days	37	(19.7%)	405	(1.5%)	21	229
15 – 30 days	27	(14.4%)	554	(2.0%)	26	536
> 30 days	33	(17.6%)	2,044	(7.5%)	38	2,444
Totals	188	(100.0%)	3,301	(12.1%)		

Table 6-47 Characteristics of potential gaps at Statenville Planning Node for future conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	88	(49.2%)	262	(1.0%)	8	27
8 – 14 days	32	(17.9%)	357	(1.3%)	18	194
15 – 30 days	39	(21.8%)	835	(3.0%)	20	437
> 30 days	20	(11.2%)	1,316	(4.8%)	32	2,126
Totals	179	(100.0%)	2,770	(10.1%)		

6.2.5 Savannah-Ogeechee (SO) Study Basin

The Savannah River Basin is located in northern and eastern Georgia, originating in the Blue Ridge Mountains at the common border of Georgia, North Carolina, and South Carolina. The basin forms the Georgia-South Carolina border and flows through the Mountain, Piedmont, and Coastal Plains physiographic regions to the Atlantic Ocean. The total drainage area of the Savannah River is 10,577 square miles, of which 5,821 square miles are in Georgia, 175 square miles are in southwestern North Carolina, and 4,581 square miles lie in western South Carolina. The Savannah River Basin is characterized by mild winters and hot summers in the lower portions, and cold winters and mild summers in the mountain area. Mean annual precipitation ranges from 40 inches to 80 inches. Precipitation occurs principally as rainfall, distributed fairly uniformly throughout the year but with a dry season from mid-summer to late fall. Rainfall is usually greatest in March and least in October. Mean annual temperature in the basin is approximately 65 degrees Fahrenheit.

The Savannah River upstream of Augusta is highly regulated by three large multipurpose USACE reservoirs (Hartwell, Richard B. Russell, and Thurmond), and by a number of private power reservoirs, including several small Georgia Power projects (Burton, Nacoochee, Rabun, Tallulah Falls, Tugaloo, and Yonah, assumed to be operated as run-of-river projects), and Duke Energy's Keowee-Jocassee hydroelectric project, which includes the Bad Creek pumped-storage project, the Jocassee pumped-storage project, and the Keowee conventional hydro project. Downstream of Augusta are the USACE New Savannah Bluff Lock and Dam and the South Carolina Electric and Gas Stevens Creek projects, both of which are run-of-river projects.

The Ogeechee Basin lies in southeastern Georgia between the Altamaha and Oconee River Basins to the west, and the Savannah Basin to the north and east. The headwaters are located at the southeastern edge of the Piedmont physiographic region, and the river flows 245 miles in a southeasterly direction to the Atlantic Ocean. The Ogeechee River Basin is located entirely within Georgia and drains approximately 5,540 square miles. There are no storage reservoirs or hydroelectric projects in the Ogeechee Basin, although there are numerous small lakes, reservoirs, and farm ponds.

An SO Study Basin map showing node locations and LDAs for each is provided in Figure 6-9.

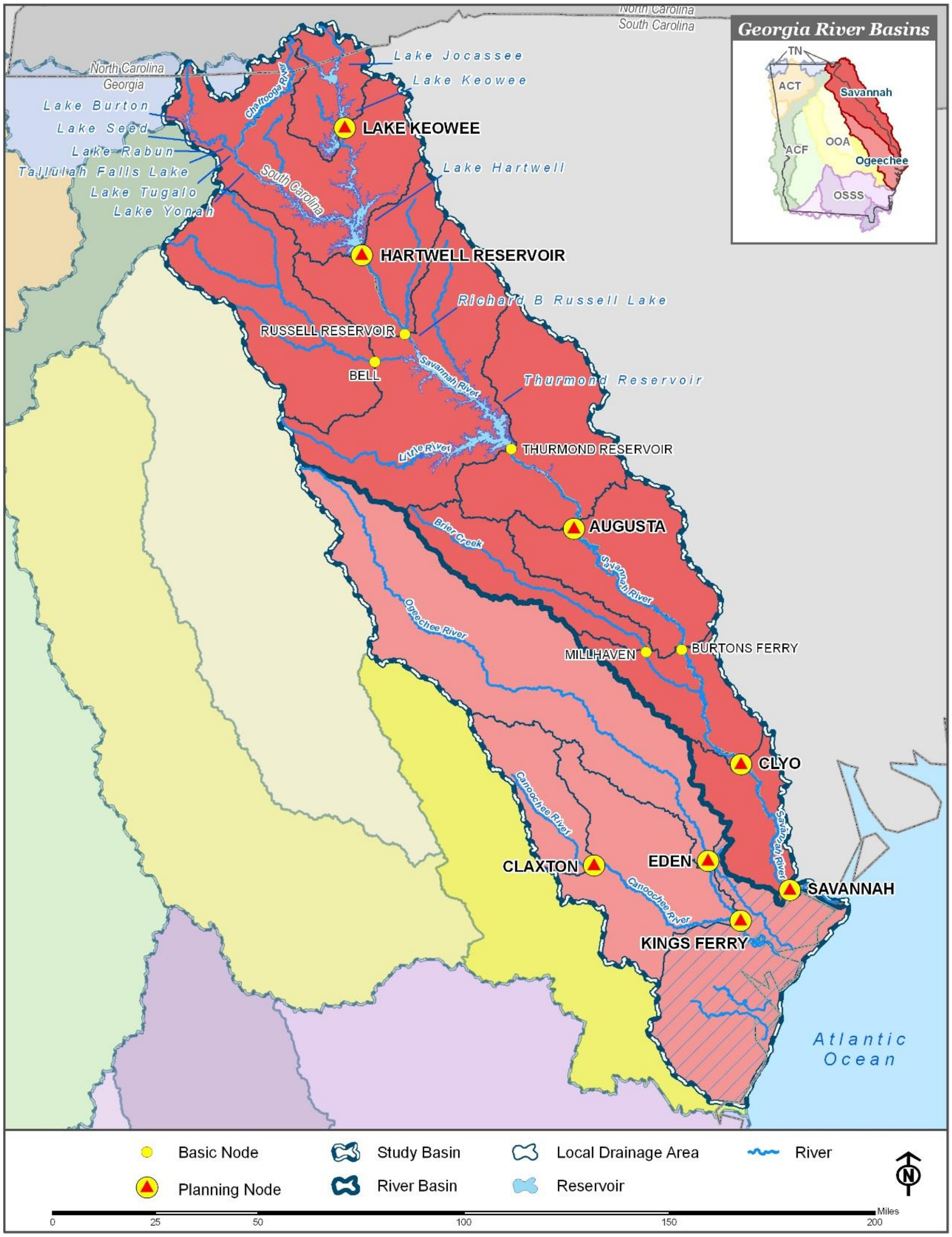


Figure 6-9 **Savannah-Ogeechee (SO) Study Basin**

The HEC-ResSim model applied for resource assessment of the Savannah River Basin is a modified version of the USACE Savannah District daily operations model. The baseline model reflects federal reservoir (Hartwell, Richard B. Russell, Thurmond) operations consistent with the September 2012 Savannah River Basin Drought Management Plan, and the 2014 FERC relicensing agreement with Duke Energy on the operation of its Keowee-Toxaway project. The license was granted by FERC in August 2016. Due to the complexities of analysis of two separate power systems (USACE and Duke Energy) operating under different operating rules (the Savannah River Drought Management Plan and the Keowee-Toxaway license, respectively), and the inclusion of one non-integral (Bad Creek) and two integral pumped-storage hydropower projects in series (Jocassee, Russell) in the model, it was necessary to apply a special, non-public release version of HEC-ResSim (Version 3.3 Dev, September 2015) for resource assessment in the Savannah Basin. The downstream boundary of the model was extended from Clyo (originally) to Savannah. The run-of-river Georgia Power projects were ignored, i.e., considered to be part of the natural watershed and stream network. The Savannah Basin HEC-ResSim model reservoir network applied to both current (2011) and future (2050) resource assessments is shown in Figure 6-10.

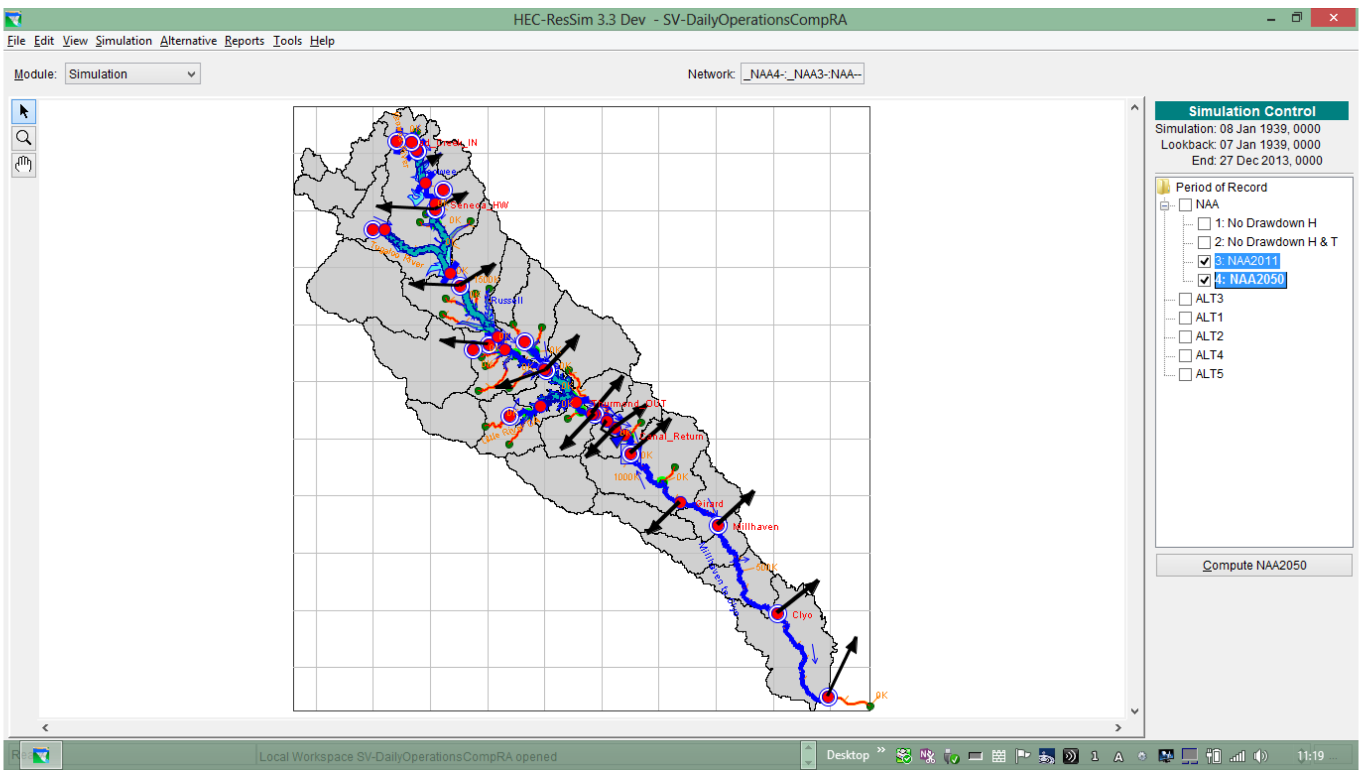


Figure 6-10 **Savannah Basin HEC-ResSim resource assessment model reservoir network**

Due to the complexity of Savanah River Basin operating rules and the fact that the Ogeechee Basin is not connected to the Savannah River, a standalone HEC-ResSim model was developed for Ogeechee River Basin resource assessment, as opposed to adding the Ogeechee network to the Savannah model. Composite farm ponds were placed in the Ogeechee model upstream of the Claxton, Eden, and Kings Ferry Planning Nodes to supplement agricultural irrigation water demand and for estimation of the effects of farm pond use on potential gaps in comparison to without-farm pond conditions. The Ogeechee Basin HEC-ResSim model reservoir network applied to both current (2011) and future (2050) resource assessments is shown in Figure 6-11.

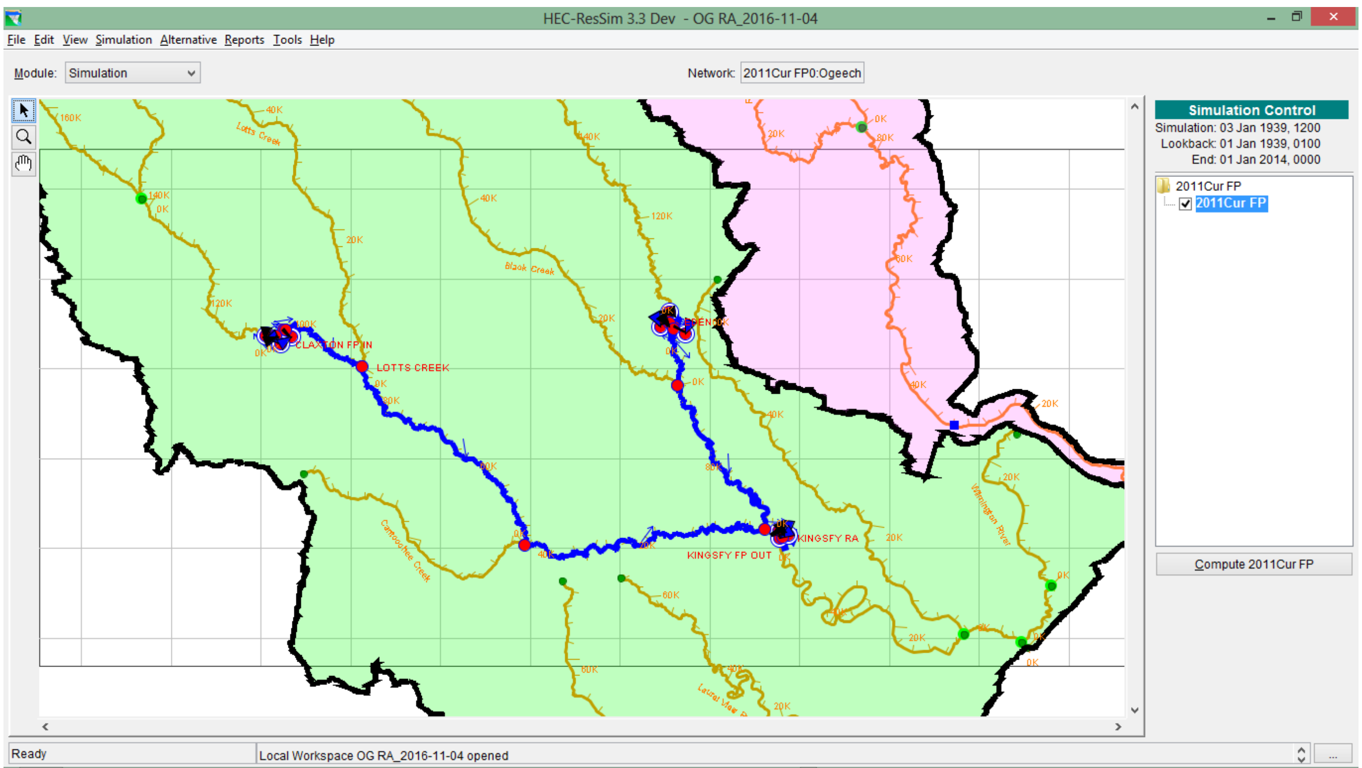


Figure 6-11 **Ogeechee Basin HEC-ResSim resource assessment model reservoir network**

The SO Study Basin consists of eight planning nodes, listed below with types of water use for each:

- Lake Keowee (Savannah Basin, regulated) – Located on Lake Keowee near Six Mile, South Carolina; this node has municipal and industrial withdrawals and returns; because Lake Keowee is a Duke Energy project upstream of all Georgia planning nodes, resource assessment model results are not presented in this report.
- Hartwell Reservoir (Savannah Basin, regulated) – Located at Hartwell Dam; this node has municipal and industrial withdrawals and returns.
- Augusta (Savannah Basin, regulated) – Located on the Savannah River at Augusta, Georgia; this node has municipal and industrial withdrawals and returns, and agricultural water use.
- Clyo (Savannah Basin, regulated) – Located on the Savannah River near Clyo, Georgia; this node has municipal and industrial withdrawals and returns, and agricultural and thermal water uses.
- Savannah (Savannah Basin virtual planning node, regulated) – Located on the Savannah River at the former USACE dock in Savannah Harbor; this node has municipal and industrial withdrawals and returns, and agricultural and thermal water uses.
- Claxton (Ogeechee Basin, unregulated) – Located on the Canoochee River near Claxton, Georgia; this node has municipal returns and agricultural water use.
- Eden (Ogeechee Basin, unregulated) – Located on the Ogeechee River near Eden, Georgia; this node has municipal withdrawals and returns, industrial returns, and agricultural water use.
- Kings Ferry (Ogeechee Basin, unregulated) – Located on the Ogeechee River at U.S. 17 near Richmond Hill, Georgia; this node has municipal returns and agricultural water use.

Of these eight planning nodes, five are regulated, all of which are in the Savannah Basin. As shown in Tables 6-48 and 6-49, the Savannah resource assessment model indicates no potential gaps for either current (2011) or future (2050) conditions due to conservation storage remaining in upstream reservoirs at all times during the 1939–2013 simulation period. For the three unregulated nodes in the Ogeechee Basin, potential gaps were simulated for both current and future conditions with and without farm ponds, as shown in Tables 6-50 through 6-64.

Table 6-48 Resource assessment results at Hartwell Planning Node

	Demand shortage (cfs)	At-site flow requirement shortage (cfs)	Minimum conservation storage remaining (acre-feet)	Minimum percentage of conservation storage remaining	Basin-wide flow requirement shortage (cfs)
Round 2 current (1939–2013)	0	0	730,964	52%	N/A
Round 2 future (1939–2013)	0	0	705,054	50%	N/A

Table 6-49 Resource assessment results at Augusta, Clyo, and Savannah Planning Nodes

	Demand shortage (cfs)	Minimum flow requirement shortage (cfs)	Minimum conservation storage remaining (acre-feet)	Minimum percentage of conservation storage remaining
Round 2 current (1939–2013)	0	0	730,964 (Hartwell) 252,671 (Thurmond)	52% (Hartwell) 24% (Thurmond)
Round 2 future (1939–2013)	0	0	705,054 (Hartwell) 226,893 (Thurmond)	50% (Hartwell) 22% (Thurmond)

Table 6-50 Potential gaps at Claxton Planning Node

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2013)	21	6	448
Round 2 current with farm ponds (1939–2013)	17	5	447
Round 2 future (1939–2013)	15	5	452
Round 2 future with farm ponds (1939–2013)	12	4	451

Table 6-51 Characteristics of potential gaps at Claxton Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	168	(50.3%)	556	(2.0%)	4	15
8 – 14 days	67	(20.1%)	731	(2.7%)	6	64
15 – 30 days	47	(14.1%)	1,008	(3.7%)	7	139
> 30 days	52	(15.6%)	3,394	(12.4%)	6	365
Totals	334	(100.0%)	5,689	(20.8%)		

Table 6-52 Characteristics of potential gaps at Claxton Planning Node for current conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	174	(54.7%)	518	(1.9%)	3	10
8 – 14 days	61	(19.2%)	627	(2.3%)	5	50
15 – 30 days	43	(13.5%)	869	(3.2%)	5	93
> 30 days	40	(12.6%)	2,519	(9.2%)	5	308
Totals	318	(100.0%)	4,533	(16.5%)		

Table 6-53 Characteristics of potential gaps at Claxton Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	139	(51.7%)	482	(1.8%)	3	13
8 – 14 days	55	(20.4%)	597	(2.2%)	5	56
15 – 30 days	39	(14.5%)	851	(3.1%)	6	123
> 30 days	36	(13.4%)	2,181	(8.0%)	6	335
Totals	269	(100.0%)	4,111	(15.0%)		

Table 6-54 Characteristics of potential gaps at Claxton Planning Node for future conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	159	(56.8%)	463	(1.7%)	2	7
8 – 14 days	62	(22.1%)	660	(2.4%)	4	38
15 – 30 days	29	(10.4%)	608	(2.2%)	4	85
> 30 days	30	(10.7%)	1,530	(5.6%)	4	221
Totals	280	(100.0%)	3,261	(11.9%)		

Table 6-55 Potential gaps at Eden Planning Node

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2013)	6	16	2,207
Round 2 current with farm ponds (1939–2013)	5	11	2,206
Round 2 future (1939–2013)	3	24	2,213
Round 2 future with farm ponds (1939–2013)	4	11	2,212

Table 6-56 Characteristics of potential gaps at Eden Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	53	(51.5s%)	202	(0.7%)	11	49
8 – 14 days	21	(20.4%)	207	(0.8%)	13	132
15 – 30 days	19	(18.4%)	423	(1.5%)	17	377
> 30 days	10	(9.7%)	761	(2.8%)	16	1,249
Totals	103	(100.0%)	1,593	(5.8%)		

Table 6-57 Characteristics of potential gaps at Eden Planning Node for current conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	47	(49.0%)	170	(0.6%)	10	40
8 – 14 days	21	(21.9%)	206	(0.8%)	12	122
15 – 30 days	19	(19.8%)	403	(1.5%)	12	243
> 30 days	9	(9.4%)	691	(2.5%)	11	866
Totals	96	(100.0%)	1,470	(5.4%)		

Table 6-58 Characteristics of potential gaps at Eden Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	44	(61.1%)	178	(0.6%)	11	52
8 – 14 days	12	(16.7%)	114	(0.4%)	15	150
15 – 30 days	10	(13.9%)	222	(0.8%)	29	633
> 30 days	6	(8.3%)	388	(1.4%)	28	1,795
Totals	72	(100.0%)	902	(3.3%)		

Table 6-59 Characteristics of potential gaps at Eden Planning Node for future conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	50	(59.5%)	167	(0.6%)	6	23
8 – 14 days	15	(17.9%)	146	(0.5%)	7	69
15 – 30 days	14	(16.7%)	285	(1.0%)	14	276
> 30 days	5	(6.0%)	371	(1.4%)	11	851
Totals	84	(100.0%)	969	(3.5%)		

Table 6-60: Potential gaps at Kings Ferry Planning Node

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939-2013)	6	35	3,634
Round 2 current with farm ponds (1939-2013)	6	25	3,632
Round 2 future (1939-2013)	3	37	3,658
Round 2 future with farm ponds (1939-2013)	3	21	3,656

Table 6-61 Characteristics of potential gaps at Kings Ferry Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	54	(51.9%)	187	(0.7%)	18	78
8 – 14 days	17	(16.3%)	179	(0.7%)	32	342
15 – 30 days	17	(16.3%)	347	(1.3%)	38	802
> 30 days	16	(15.4%)	902	(3.3%)	36	2,088
Totals	104	(100.0%)	1,615	(5.9%)		

Table 6-62: Characteristics of potential gaps at Kings Ferry Planning Node for current conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	44	(47.3%)	146	(0.5%)	22	92
8 – 14 days	19	(20.4%)	208	(0.8%)	25	270
15 – 30 days	16	(17.2%)	326	(1.2%)	26	544
> 30 days	14	(15.1%)	903	(3.3%)	25	1,537
Totals	93	(100.0%)	1,583	(5.8%)		

Table 6-63 Characteristics of potential gaps at Kings Ferry Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	40	(58.0%)	137	(0.5%)	13	53
8 – 14 days	9	(13.0%)	98	(0.4%)	27	302
15 – 30 days	13	(18.8%)	291	(1.1%)	37	817
> 30 days	7	(10.1%)	413	(1.5%)	49	2,820
Totals	69	(100.0%)	939	(3.4%)		

Table 6-64 Characteristics of potential gaps at Kings Ferry Planning Node for future conditions with farm ponds

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	32	(50.8%)	125	(0.5%)	12	45
8 – 14 days	14	(22.2%)	140	(0.5%)	15	160
15 – 30 days	11	(17.5%)	234	(0.9%)	20	426
> 30 days	6	(9.5%)	317	(1.2%)	27	1,409
Totals	63	(100.0%)	816	(3.0%)		

6.2.6 Tennessee (TN) Study Basin

The TN Study Basin drains an area of 2,100 square miles in northern Georgia and small portions of southwestern North Carolina, southeastern Tennessee, and northeastern Alabama. The Georgia portion of the Tennessee Basin is split between three tributaries along the northern border of Georgia. The Little Tennessee Basin drains an area of 85 square miles beginning in Georgia and flowing north into North Carolina. The Toccoa-Nottely-Hiwassee Basin drains an area of 1,030 square miles beginning in Georgia and flowing northwest into Tennessee and North Carolina. The South Chickamauga-Lookout Creek Basin drains an area of 970 square miles beginning in Georgia and Alabama and draining north into Tennessee.

Stream flow from the Toccoa, Nottely, and Hiwassee Rivers into Tennessee is regulated by TVA reservoirs operated primarily for flood control and hydropower. The three reservoirs in Georgia – Blue Ridge, Nottely, and Chatuge – comprise basic or planning nodes for surface water availability assessment purposes. The Little Tennessee River and the South Chickamauga-Lookout Creek Basins are largely unregulated. A TN Study Basin map showing node locations and LDAs for each is provided in Figure 6-12.

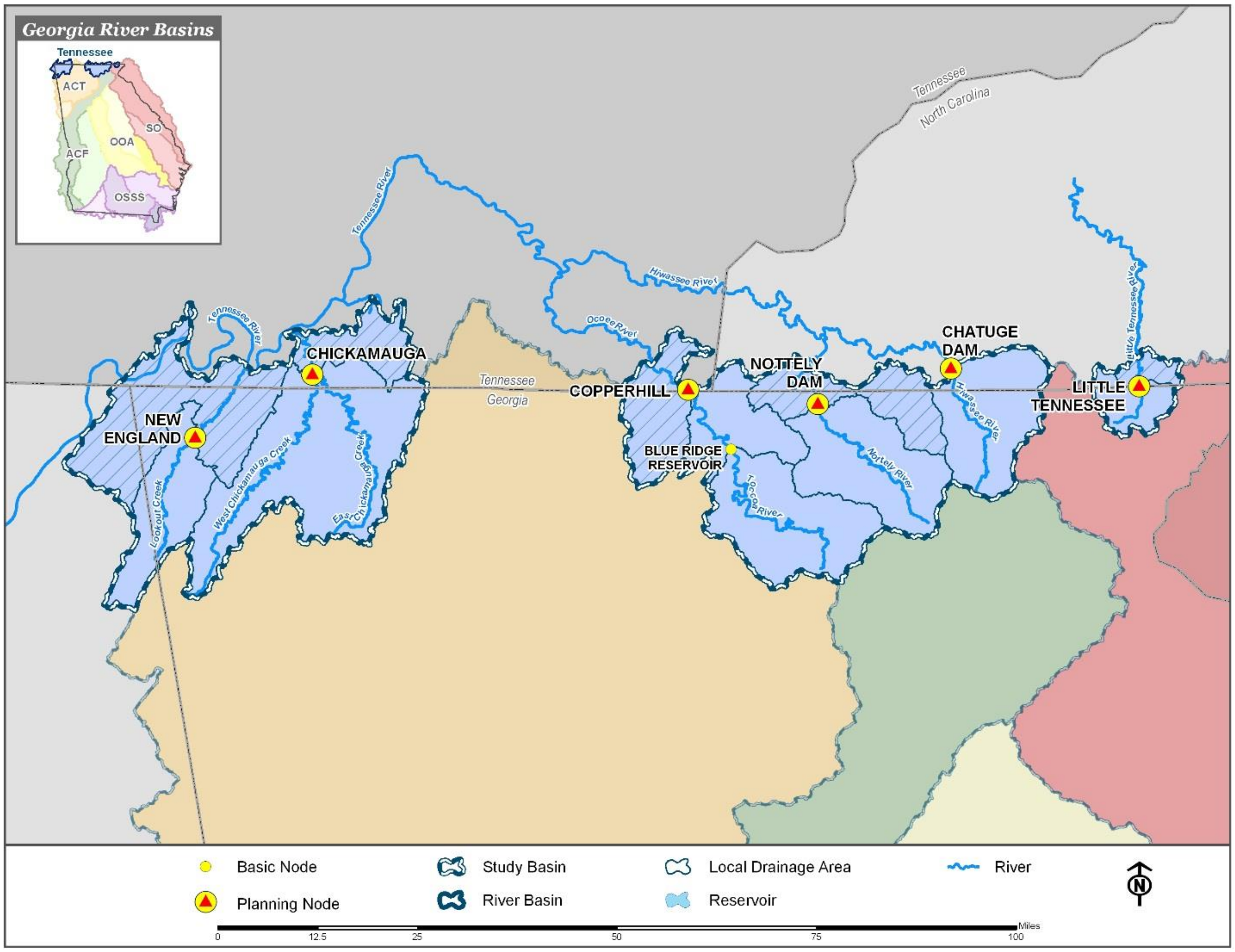


Figure 6-12 **Tennessee (TN) Study Basin**

In 2004, TVA implemented recommendations of its Reservoir Operations Study (ROS) for operation of the Tennessee River system, the fifth-largest in the nation with 49 reservoirs regulating a watershed spanning seven states and more than 40,000 square miles. Water management objectives include flood control, hydropower, navigation, water supply, water quality, and reservoir and river recreation. For Georgia resource assessment purposes, a special-purpose HEC-5 model was developed to simulate system and at-site operations of the Blue Ridge, Nottely, and Chatuge TVA projects separately from the remaining system components. The model was calibrated to simulate historical 2005–2013 reservoir levels with (1) 2011 Georgia consumptive water uses, (2) 2005–2013 unimpaired reservoir inflows, (3) at-site minimum and maximum release requirements imposed by the ROS, and (4) Tennessee River minimum flow augmentation and system storage balancing requirements of the ROS replicated by at-site firm energy requirements adjusted to reproduce historical (2005–2013) reservoir levels reasonably well.

Resource assessment modeling for the TN Study Basin was performed using the calibrated HEC-5 model with 1939–2013 local UIFs, and current (2011) and future projected (2050) consumptive water uses. Unlike HEC-ResSim, HEC-5 can only simulate operation of dendritic river systems (i.e., all tributary streams must converge and ultimately discharge to a single downstream control point; unconnected river segments of the kind previously shown in the OSSS HEC-ResSim network are not allowed). The HEC-5 model does not have a graphical user interface for display of river-reservoir networks, although the model does output a printer diagram of system connectivity as shown in Figure 6-13 for the TN Study Basin.

```
Upstream Reservoirs Operating for Each Location
   99R                                  ENGLAND DUMMY
  100                                   ENGLAND
   |     .---199R                       CHICKMGA DUMMY
   .---200                              CHICKMGA
  910                                   TN-ENG+CHK
   |                       .---300R     BLRDG_R
   |                 .---301            BLRDG_R OUT
   |     .---310                        COPRHILL
   |     |      .---400R                NOTLY_R
   |     .---401                        NOTLY_R OUT
   .---920                              TN-BLR+NOTLYR
  930                                   TN-WEST
   |            .---500R                CHATUG_R
   |     .---501                        CHATUG_R OUT
   |     |      .---599R                LITLE_TN DUMMY
   |     .---600                        LITLE_TN
   .---940                              TN-EAST
  990                                   TN-TOTAL
```

Figure 6-13 TN HEC-5 resource assessment model system connectivity diagram

The TN Study Basin includes one basic and six planning nodes. Each planning node is listed below with the type of water uses at the node:

- Chatuge Dam (Hiwassee Basin, regulated) – Located on the Hiwassee River below Chatuge Dam near Hayesville, North Carolina; this node has municipal withdrawals and returns.
- Chickamauga (Chickamauga Basin, unregulated) – Located on South Chickamauga Creek near Chickamauga, Tennessee; this node has municipal and industrial withdrawals and returns, and agricultural water use.

- Copperhill (Ocoee Basin, regulated) – Located on the Ocoee River downstream of the TVA Blue Ridge reservoir near Copperhill, Tennessee; this node has municipal withdrawals and returns.
- New England (Lookout Creek Basin, unregulated) – Located on Lookout Creek near England, Georgia; this node has municipal withdrawals and returns.
- Little Tennessee (Little Tennessee Basin, unregulated) – Planning node located on the Little River at the Georgia-North Carolina boundary; this node has industrial returns.
- Nottely Dam (Nottely Basin, regulated) – Located on the Nottely River at Nottely Dam near Ivylog, Georgia; this node has municipal withdrawals and returns.

As shown in Table 6-65, for both current and future conditions, resource assessment model simulation results indicate no shortfalls at any of the regulated planning nodes (Copperhill, Nottely, and Chatuge) in the TN Study Basin, due to conservation storage remaining in upstream TVA reservoirs at all times during the 1939–2013 simulation period. Shortfalls were simulated at the unregulated nodes, however, as shown in Tables 6-66 through 6-73.

Table 6-65 Summary of current and future conditions reservoir storage availability for TN Study Basin regulated nodes

TVA reservoir	Potential demand shortage (cfs)	At-site flow requirement shortage (cfs)	Minimum reservoir conservation storage remaining (acre-feet)	Minimum percentage reservoir conservation storage remaining	Basin-wide flow requirement shortage (cfs)
Blue Ridge current conditions	0	0	15,453	11%	N/A
Blue Ridge future conditions	0	0	15,453	11%	N/A
Nottely current conditions	0	0	11,530	9%	N/A
Nottely future conditions	0	0	10,790	9%	N/A
Chatuge current conditions	0	0	21,994	17%	N/A
Chatuge future conditions	0	0	21,180	17%	N/A

Table 6-66 Potential gaps at Chickamauga Planning Node

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2013)	5	6	698
Round 2 future (1939–2013)	5	6	698

Table 6-67 Characteristics of potential gaps at Chickamauga Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	167	(75.9%)	483	(1.8%)	5	14
8 – 14 days	28	(12.7%)	308	(1.1%)	5	14
15 – 30 days	18	(8.2%)	366	(1.3%)	5	14
> 30 days	7	(3.2%)	313	(1.1%)	6	288
Totals	220	(100.0%)	1,470	(5.4%)		

Table 6-68 Characteristics of potential gaps at Chickamauga Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	175	(77.1%)	509	(1.9%)	5	16
8 – 14 days	26	(11.5%)	280	(1.0%)	6	64
15 – 30 days	19	(8.4%)	375	(1.4%)	7	132
> 30 days	7	(3.1%)	328	(1.2%)	7	334
Totals	227	(100.0%)	1492	(5.4%)		

Table 6-69 Potential gaps at England Planning Node

	Length of gaps (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2013)	6	2	250
Round 2 future (1939–2013)	6	2	250

Table 6-70 Characteristics of potential gaps at England Planning Node for current conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	158	(71.2%)	447	(1.6%)	2	5
8 – 14 days	29	(13.1%)	290	(1.1%)	2	5
15 – 30 days	24	(10.8%)	483	(1.8%)	2	5
> 30 days	11	(5.0%)	468	(1.7%	3	115
Totals	222	(100.0%)	1,688	(6.2%)		

Table 6-71 Characteristics of potential gaps at England Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	158	(71.5%)	447	(1.6%)	2	5
8 – 14 days	28	(12.7%)	275	(1.0%)	2	24
15 – 30 days	23	(10.4%)	466	(1.7%)	2	49
> 30 days	12	(5.4%)	502	(1.8%)	3	113
Totals	221	(100.0%)	1,690	(6.2%)		

Table 6-72 Potential gaps at Little Tennessee Planning Node

	Length of gap (% of time)	Average gap (cfs)	Long-term average flow (cfs)
Round 2 current (1939–2013)	0 (no gaps)	0	149
Round 2 future (1939–2013)	5	<1	149

Table 6-73 Characteristics of potential gaps at Little Tennessee Planning Node for future conditions

Gap event duration category	Number of gap events		Total gap days by category (1939–2013)		Average daily flow deficit per gap event (cfs)	Average cumulative flow deficit per gap event (cfsd)
1 – 7 days	152	(75.6%)	432	(1.6%)	<1	1
8 – 14 days	27	(13.4%)	290	(1.1%)	<1	5
15 – 30 days	17	(8.5%)	318	(1.2%)	<1	9
> 30 days	5	(2.5%)	199	(0.7%)	<1	19
Totals	201	(100.0%)	1,239	(4.5%)		

In simulation of future streamflow conditions at the Little Tennessee node, an aggregate consumptive use of 0.47 cfs – the projected consumptive use for the year 2050 – was applied. As previously described in this report, resource assessment modeling assumes that water supply diversions are met so long as total streamflow is sufficient, even when remaining streamflow after diversions is less than the flow protection threshold. For the Little Tennessee node, modeling also assumed that no upstream storage facility was available to augment streamflow or support diversions. These assumptions were conservative in this case, because permitted facilities in the Little Tennessee Basin have various levels of flow protection, meaning that diversions would cease when streamflows are lower than conditions prescribed by permit. At the Little Tennessee node, the lowest median daily historical flow during the summer months is 141 cfs. The lowest low daily historical flow (also in the summer) is 36.7 cfs. By comparison, the projected 2050 consumptive use, even when not mitigated by flow protection requirements prescribed by permit (as assumed in the resource assessment modeling), is less than 1.3% of the lowest historical daily flow. For these reasons, the statistics shown in Tables 6-72 and 6-73, computed based on resource assessment model results, do not represent a true resource concern.

7 GLOSSARY OF KEY TERMS

- *Basic nodes* are locations of interest on rivers or major tributary streams from which unimpaired flows are derived. In most instances, basic nodes are located at or near USGS stream gages or at dams.
- *Basins or river basins* are individual river or major tributary watersheds within study basins, e.g., Chattahoochee River basin and Savannah River basin in the ACF and SO study basins, respectively.
- *Consumptive water use* is net aggregated withdrawals minus returns upstream of basic or planning nodes.
- *Cumulative unimpaired flows (CUIFs)* are upstream incremental unimpaired flows that have been combined and routed to downstream nodes.
- *Holdouts* are changes in storage in upstream reservoirs applied to observed flows in determination of unimpaired flows.
- *Incremental flows* are reach inflows from local drainage areas; incremental flows may be observed or unimpaired, depending on whether effects of human uses of water and reservoir regulation are included.
- *Local drainage areas (LDAs)* are intervening watersheds between basic nodes, or total drainage area above the most upstream basic node.
- *Local unimpaired flows (LUIFs)* are incremental unimpaired flows computed for local drainage areas.
- *Period of record* is the period for which daily LUIFs were derived (1939–2011 for the ACF and ACT Study Basins, and 1939–2013 for the OOA, OSSS, SO, and TN Study Basins); equal to the *period of analysis* for resource assessment modeling performed for each study basin.
- *Planning nodes* are basic nodes for which water availability assessments are performed; one or more basic nodes may be interspersed between planning nodes; planning nodes are located insofar as possible to avoid separation of major utility withdrawals and returns, and to avoid separation of planning regions and municipalities served by multiple water utilities.
- *Reaches* are river or tributary segments and contributing local drainage areas between adjacent nodes (basic or planning), or above the most upstream node (basic or planning); reaches are designated by downstream node.
- *Study basins* are the six major composite river basins designated by Georgia EPD for surface water availability assessment; study basins are delineated based on hydrologic, topographic, water resource development, water use, and other important considerations in regional planning; study basin designations are as follows:

  ACF – Apalachicola-Chattahoochee-Flint River Basins

  ACT – Alabama-Coosa-Tallapoosa River Basins

  OOA –Oconee-Ocmulgee-Altamaha River Basins

  OSSS – Ochlockonee-Suwanee-Satilla-St. Marys River Basins

SO – Savannah and Ogeechee River Basins

TN – Tennessee River Basin

- *Sub-basins* are intervening watersheds between planning nodes, or total drainage area above the most upstream planning node.
- *Unimpaired flows* are historical flows with effects of reservoir holdouts, releases from storage, and surface evaporation, and water withdrawals and returns removed.
- *Virtual planning nodes* are planning nodes located at or near the most downstream Georgia location (in some cases outside of Georgia) on rivers for which no observed stream flow data are available.

APPENDIX

Resource Assessment Model and Consumptive Use Assessment Spreadsheet Archive Filenames

ACF Study Basin

(Chattahoochee) resource assessment model (HEC-ResSim)	*ACF-RA_161221.7z*
(Flint-Carsonville) resource assessment model (HEC-5)	*FLCVLH5120-RA_161208.7z*
(Flint-Bainbridge) resource assessment model (HEC-5)	*FLH5120-RA_161221.7z*
CUA spreadsheets	*ACF-CUA_170131.zip*

ACT Study Basin

Resource assessment model (HEC-ResSim)	*ACT-RA_160926.7z*
(Gaylesville) resource assessment model (HEC-DSS batch/macro procedure)	*CUA-GAYLES.zip*
CUA spreadsheets	*ACT-CUA_170109.zip*

OOA Study Basin

Resource assessment model (HEC-ResSim)	*OOA-RA_161115-2.7z*
CUA spreadsheets	*OOA-CUA_161115-2.zip*

OSSS Study Basin

Resource assessment model (HEC-ResSim)	*OSSS-RA_161021.7z*
CUA spreadsheets	*OSSS-CUA_161020-2.zip*

SO Study Basin

(Savannah) resource assessment model (HEC-ResSim)	*SV-RA_160925.7z*
(Ogeechee) resource assessment model (HEC-ResSim)	*OG-RA_161104.7z*
CUA spreadsheets	*SO-CUA_161102-2.zip*

TN Study Basin

(Current) resource assessment model (HEC-5)	*TN-CurRA_160816.7z*
(Future) resource assessment model (HEC-5)	*TN-FutRA_161017.7z*
(Current) CUA spreadsheets	*TN-CUA-2011CurDem_160816.zip*
(Future) CUA spreadsheets	*TN-CUA-2050FutDem_170117.zip*

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