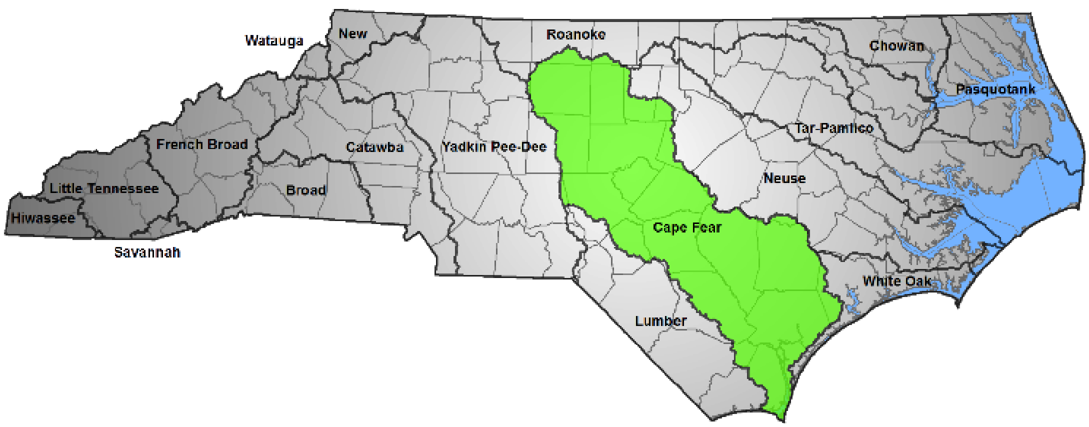
Cape Fear River
Surface Water Supply Evaluation



Prepared for the
North Carolina
Environmental Management Commission
by the
N. C. Department of Environmental Quality
Division of Water Resources
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1 Executive Summary

The Cape Fear River Water Supply Evaluation assesses the ability of public water systems and other self-supplied users that depend on surface water from the Deep River, Haw River and Cape Fear River subbasins to meet their estimated 2060 water withdrawal needs. The evaluation is based on source and demand information submitted to the Division of Water Resources under the local water supply planning and water withdrawal registration programs, information contained in applications for allocations of water supply storage from B. Everett Jordan Lake and comments received in response to the December 2015 draft of this document.

This evaluation considers the demands and water sharing arrangements of surface water users in the Deep River, Haw River, Cape Fear River, Neuse River and Contentnea Creek subbasins, with an emphasis on the effects on surface water availability in the Cape Fear River Basin upstream of Lock Dam # 1 in Bladen County. The analysis considers expected future water needs for 102 public water systems.

The purpose of this evaluation is to determine the long-term resilience of Jordan Lake and the Cape Fear River watershed to meet anticipated water supply needs. The primary purpose of Jordan Lake reservoir is to store water during high flow events to provide flood damage reductions downstream. The project also includes storage to augment flows in the Cape Fear River downstream of the reservoir to protect water quality. During the design of Jordan Lake, the state of North Carolina requested the inclusion of water supply storage with the capacity to provide 100 million gallons per day. Water supply storage is allocated by the North Carolina Environmental Management Commission to units of local government based on needs over a thirty-year planning horizon. Applications for water supply allocations submitted to DWR in November 2014, which necessitated this evaluation, are based on water needs through 2045.This document presents the results of an analysis of withdrawing the amount of water needed to meet expected water demands in 2060.
The analysis focuses on the quantity of water available from sources at the locations where water is withdrawn by communities, electric generating facilities and other industries. It does not consider water quality limitations to water use or the effects of withdrawals on instream water quality.

The evaluation for this analysis was done using a computer- based hydrologic model designed to simulate surface water availability in the Cape Fear and Neuse river basins. The hydrologic model is constructed using a program called OASIS with OCL™ developed by HydroLogics, Inc. to model water resource systems. A reconstructed naturalized flow record is used to determine the effects of management protocols, surface water withdrawals and wastewater returns as water flows downstream from headwater areas to the model's terminal nodes where flows become affected by tidal actions.

The Cape Fear - Neuse River Basins Hydrologic Model (CFNRBHM) uses the historic streamflow records from 1930 through 2011. It was calibrated on water use and management condtions in 2010. It captures water quantity fluctuations throughout the historic record produced by withdrawing the volumes of water needed to meet 2010 water demands. The 2010 scenario provides the basecase against which several different withdrawal scenarios are compared.

Currently, 63 percent of the water supply pool in Jordan Lake is allocated. The Division of Water Resources is recommending the EMC increase the overall allocations to 95.9 percent. The allocation applications and DWR's proposal are discussed in the *Round 4 Jordan Lake Water Supply Allocation Recommendations*. The modeling analysis of the potential yield of the water supply pool indicates that the water supply pool in Jordan Lake is able to reliably supply the expected 100 mgd of water.

As water supply withdrawals from Jordan Lake increase, the percentage of time that water levels in Jordan Lake are anticipated to be below the normal operating level of 216 feet mean sea level may increase slightly and the water levels will be lower. Recreational opportunities, especially boat launching facilities may be affected by the lower water levels. In the extreme, meeting 2060 water demand levels may result in minimum water levels about 2.4feet lower than meeting the 2010 demands. At these levels of water withdrawals, the amount time water levels are below 214 feet may increase from about 10 percent to about 15 percent of the time covered in the historical flow record.

Using the hydrologic model to investigate impacts of increasing water withdrawals throughout the Cape Fear River Basin suggests that the minimum flows in the river at Lillington, N.C. may decline. However, the model also indicates that the flow augmentation pool is not depleted -- even during a reoccurrence of the extreme droughts in the historic flow record. Appendix E shows how the distribution of streamflows vary at 13 locations in the basin under the various model scenarios analyzed.

The interpretations presented in this document are conditioned on the information and assumptions in the hydrologic model. Changes in water management protocols, water demand estimates or assumptions concerning water sharing and wastewater return flows will produce different results. This characteristic means the hydrologic model can be a useful tool for alternatives analysis to support water resources planning.

This analysis focuses on evaluating variations in water availability strictly from the perspective of water quantity. Water quality is not evaluated. The study looks at answering the following question: Is it likely there will be a sufficient quantity of water available at specific water supply intakes to cover the expected withdrawals needed to meet specific water demand levels, whenever they occur? For each model scenario, the specified withdrawals are analyzed for each of the 29,858 days in the historic flow record.

The results of this analysis show that, based on the assumptions in the model, including some increases in water allocations from Jordan Lake reservoir, a few water utilities in the Cape Fear River Basin may face potential flow-related supply shortages during repeats of the drought conditions in the historic record. Some impacts could be addressed by planned water treatment plant expansions and others mitigated by the implementation of effective water shortage response plans along with the use of supplemental water sources.

2 Summary Discussion

The Cape Fear River Water Supply Evaluation reviews the long-term water needs of public water systems that depend on surface water from the Deep River, Haw River and Cape Fear River subbasins and their ability to meet those needs through 2060. The scope of this analysis is limited to public water systems and self-supplied industrial facilities that use surface water and the neighboring water systems that depend on them. The evaluation is based on information submitted to the Division of Water Resources from community water systems and self-supplied industrial water withdrawers under the local water supply planning and water withdrawal registration programs. Additional details were provided by local governments that submitted applications for allocations of water supply storage from B. Everett Jordan Lake and comments in response to the December 2015 draft of this document.

In response to the information in the Draft Cape Fear River Water Supply Evaluation, Duke Energy asked that additional withdrawals for potential expansions of electricity generating capacity be added to the model in the Cape Fear River and Neuse River subbasins.Also, the Lower Cape Fear Water and Sewer Authority requested revisions to their future withdrawals in the model to more accurately reflect Pender County's dependency on their intake for water supply.

Additional water withdrawals for possible expansion at the Harris Nuclear Facility were added to the model, including a withdrawal from the Cape Fear River to supplement inflows to Harris Lake. The maximum elevation of Harris Lake was increased from its current 220 feet to 240 feet above mean sea level. A previous review of the proposed expansion of Harris Lake produced recommendations for minimum flows from the reservoir. The results of the minimum releases on the flows in Buckhorn Creek are shown in the flow duration graph for Buckhorn Creek on page 144.

Withdrawals from the Cape Fear River were added in Chatham County and Cumberland County for potential future combined cycle generating facilities. On the Neuse River, withdrawals were increased in the model scenarios for the potential siting of a combined cycle generating facility at the site of the H. F. Lee facility upstream of Goldsboro in Wayne County.

To address the Lower Cape Fear Water and Sewer Authority's request, their demand projections were revised based on 2014 data presented in the local water supply plans. Future surface water demands for other public water systems were updated as needed to reflect expectations in the 2014 local water supply plans.

While the driving force for this evaluation is to determine the long-term resilience of the Cape Fear River to meet water supply demands and the need for and the effects from allocations of water from the water supply pool in Jordan Lake, defensible allocation decisions require consideration of the adequacy of other regional water supply sources. Communities in several portions of the basin depend on water from the Neuse River Basin. Likewise, communities in the Neuse River Basin depend on water from the Haw River and Cape Fear River subbasins. Therefore, this evaluation looks at the dependency of communities on surface water withdrawals from the Deep River, Haw River, Cape Fear River, Neuse River and Contentnea Creek subbasins, with an emphasis on the effects on surface water availability upstream of Lock Dam # 1 on the Cape Fear River in Bladen County.

Since the early 1990's, North Carolina has required entities that withdraw large quantities of water to register their withdrawals.[1] Units of local government and other large community water systems meet this requirement by preparing and updating a local water supply plan.[2] The Water Withdrawal Registration and Local Water Supply Planning programs are managed by the state Division of Water Resources, or DWR. Both programs require annual reporting of data on current water sources and use. In addition, local water supply plans include anticipated future water demands through 2060. These two programs provide the foundation of water use data used to evaluate water needs from a basin perspective.

The Cape Fear - Neuse River Basins Hydrologic Model (CFNRBHM), the schematic of which is shown in Figure S-2, was developed to characterize current use of surface waters from these five subbasins. Comparisons of the results of model scenarios, based on the anticipated future water demands of surface water withdrawers, provide a glimpse of how surface water availability might change in the future.

The CFNRBHM was calibrated to reproduce known water resource conditions in 2010 providing a representation of current conditions and a point of comparison for changes predicted by modeling various levels of water withdrawals expected to be needed to meet future demands. Each model scenario evaluates a specific set of withdrawals and management options over the range of surface water flows that occurred in the Deep River, Haw River, Cape Fear River, Neuse River and Contentnea Creek river subbasins from January 1930 to September 2011.

The ability of surface water sources to provide enough water to meet water demands at specific intake locations is evaluated using the hydrologic model to look at conditions for each of the 29,858 days in the historic flow data. The results are contingent on the specific data and assumptions used in each model scenario. Local governments that submitted applications for allocations of water from the Jordan Lake water supply pool submitted additional details on demand projections and water supply options.

The analysis focuses on the amount of water available from sources used by communities, industry and agricultural operations. While the analysis may show that water is available from a particular source, some water withdrawers may have to increase the pumping or

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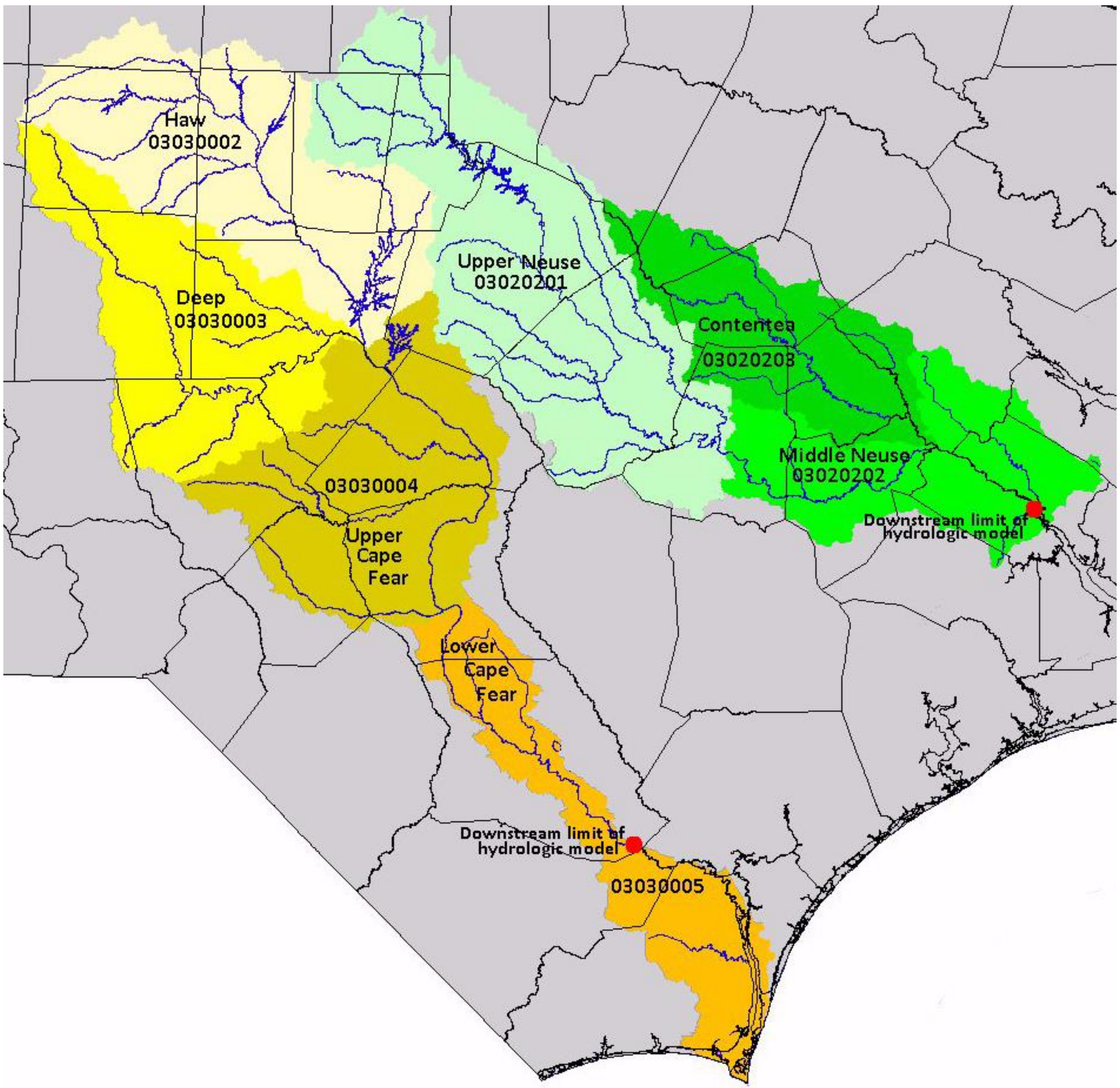
[1] NC GS § 143-215.22H
[2] NC GS § 143-355 (l)

treatment capacity to deliver sufficient amounts of water to meet customer demands in 2060. The Cape Fear – Neuse River Basins Hydrologic Model used for this analysis does not reserve water to protect ecological integrity and it does not include water quality data.

Figure S-1 Geographic scope of Cape Fear - Neuse River Basin Hydrologic Model

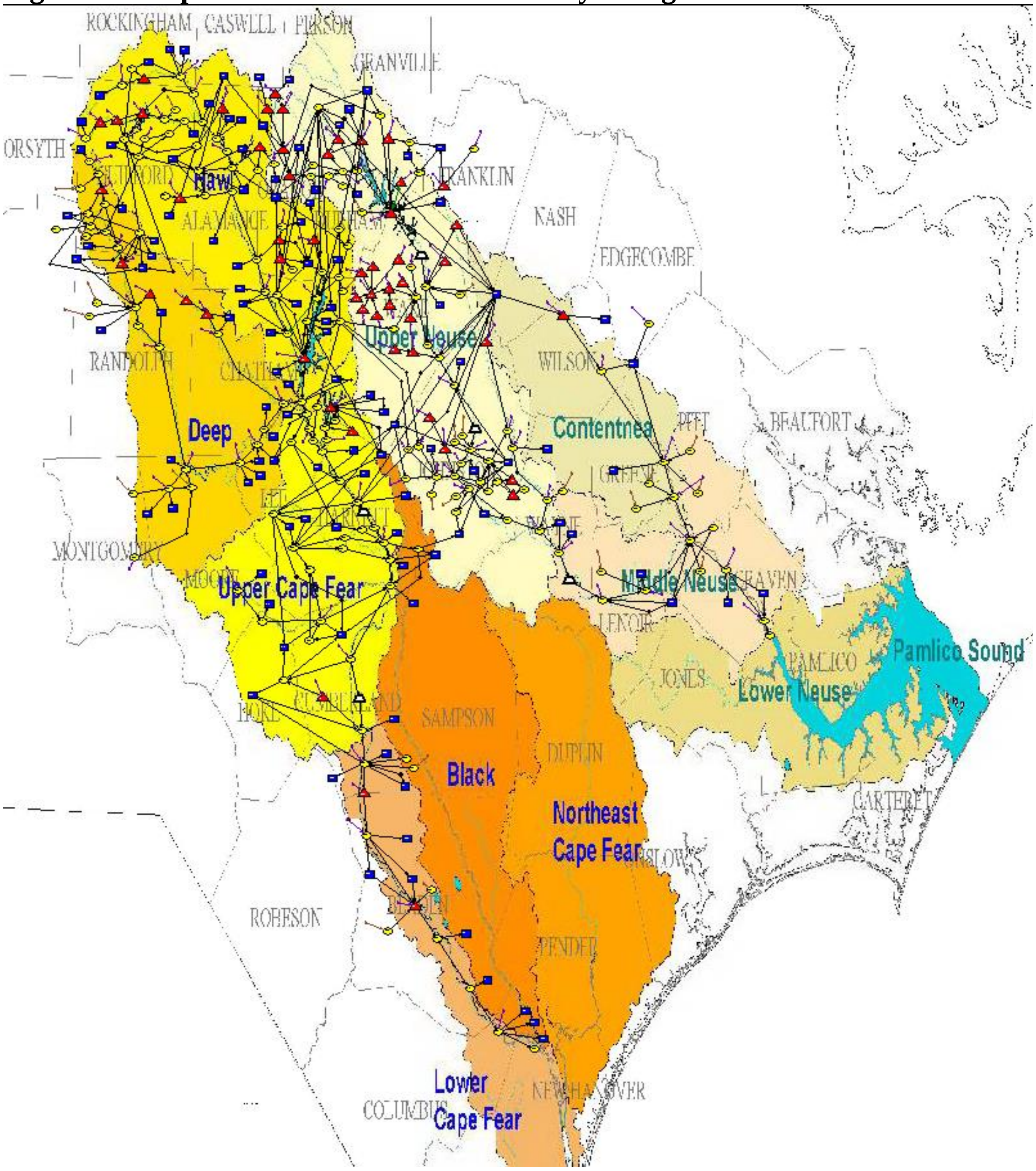


The hydrologic model characterizes surface water quantity conditions over the range of flows represented by the 81-year historic record. It characterizes water quantity conditions by evaluating the effects of withdrawals and inflows as water flows downstream from the headwaters to the model's terminal node where streamflows become tidally influenced. Figure S-1 shows the geographic boundaries and the subbasin designations used in this analysis. The red dots in each basin show the downstream limits of the Cape Fear – Neuse River Basins Hydrologic Model.

The water utilities included in this analysis are listed in Table 1 in the body of this report, along with estimates of the number of people currently served and projected to be served in the future. The specific sources and estimated available supply amounts for each utility evaluated in this study are shown in Table 2 and water demand estimates are shown in Table 3. Table 4 presents estimates of future water demands prepared by DWR using service population estimates from the local plans and the calculated gallons per person per day based on usage in 2010, the basecase year of the hydrologic model.

The Cape Fear – Neuse River Basins Hydrologic Model is a computer - based tool that evaluates changes in surface water quantities at specific locations based on processing water withdrawal estimates and associated wastewater returns in the context of streamflows that occurred between 1930 and 2011. The schematic presentation of the model structure in Figure S-2 shows the complexity of water sharing among water utilities in these basins.

Figure S-2 Cape Fear - Neuse River Basins Hydrologic Model Schematic



3 B. Everett Jordan Dam and Lake

B. Everett Jordan Dam was constructed in response to flooding of the Cape Fear River. The Cape Fear River experienced several significant flooding events prior to the devastating flood of September 1945, which produced an estimated $4.7 million dollars of damage[3] in Fayetteville. The Deep River Subbasin and Haw River Subbasin received about six inches of

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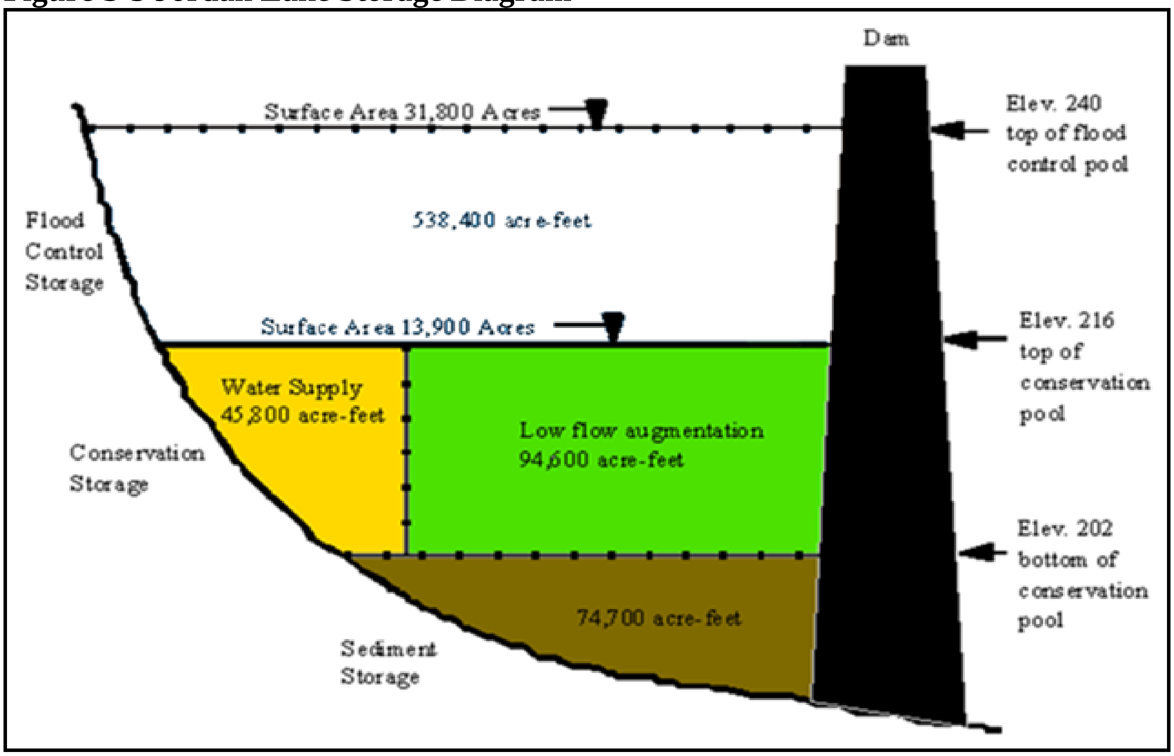
[3] 2007; Carolina Public Health; "The Lake That Almost Wasn't"; Spivey, Angela; Fall 2007

precipitation during the first week of September that year producing river flows at Lillington of 140,000 cubic feet per second, upstream of Fayetteville. The citizens of Fayetteville saw the Cape Fear River rise to 68.9 feet above mean sea level, more than 33 feet above flood stage. Shortly after this event, the U.S. Congress commissioned the U.S. Army Corps of Engineers, or USACE, to study water resource needs in the basin.

In 1963, based on the results of this study, the U.S. Congress authorized the construction of New Hope Reservoir on the Haw River to address issues identified by the USACE. Four years later, construction began. In 1973, the project was renamed in honor of U.S. Senator B. Everett Jordan. According to the USACE, "The purposes of B. Everett Jordan Dam and Lake are to provide flood damage reduction, water supply, water quality control, fish and wildlife conservation and outdoor recreation."[4] The reservoir water levels first reached normal operating levels in February 1982.

Figure S-3 Jordan Lake Storage Diagram



B. Everett Jordan Dam can retain the runoff from a six-inch rainfall on the reservoir watershed in the 538,400 acre-feet[5] dedicated to flood storage. Water in the flood control pool can be released in a controlled manner to manage flooding impacts downstream. The upper level of controllable flood storage is at 240 feet mean sea level. Above this elevation, water flows freely over the spillway.

[4] http://www.saw.usace.army.mil/Locations/DistrictLakesandDams/BEverettJordan.aspx
[5] 538,400 acre-feet can hold 175.4 billion gallons of water

The project also includes 94,600 acre-feet of storage to provide water for flow augmentation to address water quality downstream. During the USACE study, the State of North Carolina agreed to assume financial responsibility for expanding the storage capacity to provide 100 million gallons per day of water to address future water supply needs. Therefore, the project includes 45,800 acre-feet of storage for water supply needs. In addition, 74,700 acre-feet of storage are included to provide the ability to compensate for space lost to the water supply and flow-augmentation pools due to sediment accumulation over the life of the project.

When not in flood control mode, the reservoir water level is maintained at 216 feet above mean sea level, except during times of low inflows. The conservation storage between 202 feet mean sea level and 216 feet mean sea level is dedicated to flow augmentation and water supply. Storage below 202 feet mean sea level is reserved to compensate for sediment accumulation in the reservoir.

Withdrawals from the flow augmentation account and the water supply accounts are tracked separately and deducted from the volumes stored for each purpose. Therefore, it is helpful to think of them as two separate reservoirs. Water in the flow augmentation account is not used for water supply, and water in the water supply account is not used to augment streamflow below the dam.

Flood Risk Management

Prior to Hurricane Mathew in October 2016, the highest water levels in the Cape Fear River at Fayetteville were generated by Hurricane Fran in 1996 when the water level reached 44 feet mean sea level. This was above the minor flooding elevation of 35 feet, but well below the 1945 flood elevation of 68.9 feet. Precipitation from Hurricane Fran pushed the water level in Jordan Lake to 233.25 feet mean sea level, storing about 341,409 acre-feet (over 111 billion gallons) of water in the flood control pool and moderating water levels in Fayetteville.[6] Hurricane Mathew produced water levels of 58.9 feet mean sea level in the Cape Fear River at Fayetteville on October 9, 2016 when the flow in the river at the Lillington streamflow gage reach 53,400 cubic feet per second. Much of the precipitation that generated this flow level did not fall on the Jordan Lake watershed. Jordan Lake reached an elevation of 227 feet mean sea level on October 14, 2016.

The Cumberland County Multi-Jurisdictional Hazard Mitigation Plan Update of 2010 states: "Although the Jordan Dam and Lake serve multiple purposes, such as water supply, recreation, and flood-control, it is the flood-control purpose that is most important in Fayetteville. For example, it is estimated that this project provided an 8-foot reduction in the

[6] The National Oceanographic and Atmospheric Administration and the U.S. Geological Survey designate an elevation of 58 feet mean sea level in the Cape Fear River at Fayetteville as the indicator of a major flooding event. This water level would be produced by stream flows in the range of 85,000 cubic feet per second. If the 58,000 cubic feet per second of water flow down the Haw River continued downstream rather than being retained in Jordan Lake flows at the Lillington stream gage could have reached over 99,000 cubic feet per second, a level sufficient to push water levels in Fayetteville into the major flood classification.

100-year flood stage at the U.S. Geological Survey's streamflow gage on the Cape Fear River at Fayetteville."[7]

Flow Augmentation for Water Quality

During the water resources study, the U.S. Army Corps of Engineers consulted with the U.S. Public Health Service and received the recommendation that a flow in the range of 600 cubic feet per second would be needed to meet water quality targets given the standards of treatment at the time and volumes of wastewater received by the Cape Fear River.[8] The flow augmentation pool of the project was designed to provide enough water to augment river flows to provide flows of 600 cubic feet per second at the U.S. Geological Survey's stream gage on the Cape Fear River at Lillington. This level of flow is equivalent to 388 million gallons per day. Prior to the completion of Jordan Lake, the low flow of record at Lillington was 11 cubic feet per second in October 1954. Since completion of Jordan Lake Dam and initiation of flow augmentations, the lowest daily average flow at Lillington was 155 cubic feet per second during drought conditions in August 2002.

Inflows to the reservoir not needed to maintain normal water levels are passed downstream. Since completion of Jordan Lake Dam, flows at Lillington have been above the target more than 80 percent of the time. Flows have exceeded 1000 cubic feet per second more than 50 percent of the time. Therefore, water does not need to be released from the flow-augmentation pool to meet the target flows downstream the majority of the time. However, the ability to use water stored for this purpose is critical to maintaining streamflows downstream when flows decline between precipitation events, especially during droughts.

During the drought of 1986, the target flow was temporarily reduced to 450 cubic feet per second to preserve the water remaining in the flow augmentation pool.[9] A follow-up study recommended adjusting the target flow to 600 ± 50 cubic feet per second to provide more management flexibility. Flows in this range are equivalent to 355 to 421 million gallons per day.

Severe drought conditions from 1998 through 2002, again, required temporarily reducing flow targets at Lillington to preserve storage in the flow augmentation pool. In 2008, the USACE adopted a revised drought management plan that prescribes a progressive reduction in the flow target as the flow augmentation pool is depleted. Stepped reductions begin when

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[7] 2010; Cumberland County Multi-Jurisdictional Hazard Mitigation Plan Update; prepared by: Comprehensive Planning Section of the Cumberland County Planning & Inspections Department and The Fayetteville Planning Department; March 2011

[8] 1990; Testimony of John N. Morris, Director, Division of Water Resources: Transcript of Fayetteville Area Chamber of Commerce; The Lower Cape Fear Water and Sewer Authority; the Counties of Bladen, Brunswick, Columbus, New Hanover, Pender and the City of Wilmington; Mike Pleasant, President and the Fayetteville Area Economic Development Corporation; City of Fayetteville, a North Carolina Corporation; and the County of Cumberland v. North Carolina Department of Environment, Health and Natural Resources and the Environmental Management Commission: August 16, 1990: Raleigh, NC: before Beecher R. Gray, Senior Administrative Law Judge.

[9] 1987; NC Department of Natural Resources and Community Development; Draft Report, Jordan Lake Hydrology and Downstream Water Quality Considerations.

storage in the flow-augmentation pool drops below 80 percent. This protocol is now implemented automatically as storage declines in the flow-augmentation account. The drought response protocol is described in detail in Appendix A.

Water Supply

The State of North Carolina oversees the allocation of 32.62 percent of the conservation pool dedicated to water supply that was designed to provide 100 million gallons per day of water. Under General Statute § 143-354 (a) (11), the General Assembly authorized the N.C. Environmental Management Commission, or EMC, to allocate water supply storage in Jordan Lake to local governments upon proof of need and the commitment to pay the capital, interest, administrative and operating costs based on the volume allocated. The allocation rules allow the EMC to make allocations sufficient to meet applicants' water supply needs over a 30-year planning horizon. For allocation requests where the withdrawal or return flows would be a transfer of surface water requiring an interbasin transfer certificate, the review of the application for an interbasin transfer certificate must be coordinated with the review of the allocation request. [10]

Due to the uncertainty of whether the desired water supply demands and flow augmentation requirements could be met as water supply withdrawals increased, the allocation rules limited diversions out of the Jordan Lake watershed to 50 percent of the water supply pool yield. This rule did give the EMC the authority to "review and revise this limit based on experience in managing the lake and on the effects of changes in the lake's watershed that will affect its yield."[11] Since 1988, there have been changes on the watersheds above Lillington that have enhanced the reliability of the water supply and flow-augmentation pools in Jordan Lake. Table S-1 shows the current and requested allocations from the Jordan Lake water supply pool.

4 The Cape Fear - Neuse River Basins Hydrologic Model

The Division of Water Resources uses a hydrologic model designed to simulate water resource systems to evaluate surface water availability under various water withdrawal and management scenarios. The hydrologic model creates a hypothetical representation of

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[10] http://www.ncwater.org/?page=297 15A NCAC 02G .0504 (h)

[11] 15A NCAC 02G .0504 (h) To protect the yield of Jordan Lake for water supply and water quality purposes, the Commission will limit water supply allocations that will result in diversions out of the lake's watershed to 50 percent of the total water supply yield. The Commission may review and revise this limit based on experience in managing the lake and on the effects of changes in the lake's watershed that will affect its yield.

surface water conditions based on available data and inferences from known data to characterize the relationships between water withdrawals, return flows and management protocols. The basecase model scenario produces a mathematical characterization of surface water volumes and streamflows based on conditions in 2010. Each model scenario evaluates water usage, infrastructure and management protocols over the range of stream flows experienced from January 1930 through September 2011. The model does not project future streamflow conditions. Outputs from the basecase scenario provide information on the magnitude and duration of water shortages that might have occurred during historic flow conditions or that may occur if similar flow conditions occur in the future with water withdrawals to meet the 2010 water demands.

Scenarios based on alternative water withdrawal volumes and management options are compared to the basecase scenario to identify how conditions could vary compared to current conditions represented by the basecase scenario. The alternative scenarios that are the focus of this document are constructed around the water withdrawals expected to be needed to meet customer demands in 2060. This planning period is consistent with requests from the Environmental Management Commission in previous Jordan Lake Water Supply Allocation processes to look at long-term impacts of allocation decisions.

The geographic scope of the Cape Fear – Neuse River Basins Hydrologic Model is shown in Figure S-2. For surface water users included in the model, estimates of future water demands are derived from local water supply plans and other available data. Corresponding wastewater return flows are estimated as the same percentage of water withdrawals used in the basecase model scenario, unless more specific information is available. The annual average amounts are adjusted to estimate monthly average water and wastewater amounts to capture seasonal variability of water demands. Local government water systems provide data on available water sources, including expected future sources, in their local water supply plans.

The amount of water available at each surface water withdrawal location is determined within the model based on the historic flow data. For water supply reservoirs, water availability is based on reservoir physical characteristics, management protocols, inflows and change in storage. Table 6 in this document lists the annual average withdrawal and wastewater return amounts used in the model scenarios used for this evaluation.

Modeling B. Everett Jordan Reservoir

B. Everett Jordan Reservoir is a multipurpose reservoir built and managed by the U.S. Army Corps of Engineers. It was authorized for flood control, water supply, water quality, recreation, and fish and wildlife conservation. Modeling of Jordan Lake in this evaluation is targeted at identifying the potential impacts to water supply storage, flow augmentation storage, reservoir water levels and streamflows downstream of Jordan Dam as more of the water supply pool is used in the future. The conditions resulting from increased usage of the water supply storage are compared to the model generated conditions produced to meet the withdrawals needed to meet 2010 demands over an 81-year hydrologic record. Effects on the water supply pool are directly related to water withdrawals by units of local government.

Currently, 63 percent of the water supply storage is allocated to communities in Chatham, Durham, Orange and Wake counties.

In 2014, the Division of Water Resources received requests for new or increased allocations totaling 105.9 percent of the water supply pool. Allocation requests are based on anticipated water needs to meet customer demands in 2045. Several model scenarios were constructed to evaluate the ability of surface water withdrawers throughout the Cape Fear River Basin to meet anticipated 2060 demands from existing and planned sources. The scenario labels and descriptions are summarized in Table S-2. Each model scenario evaluates a set of withdrawals needed to meet customer demands based on the current and expected future infrastructure configurations described in the local water supply plans and the Jordan Lake Allocation applications.

Table S- 1 Current and Requested Water Supply Allocations

Allocation of Jordan Lake Water Supply Pool			
Applicant	Current Allocation	Requested Allocation	Draft Recommendation
	Allocation Percent	Allocation Percent	Allocation Percent
Cary Apex Morrisville RTP	39	46.2	46.2
Chatham County-North*	6	13	13
Durham*	10	16.5	16.5
Fayetteville PWC	0	10	0
Hillsborough	0	1	1
Holly Springs	2	2	2
Orange County	1	1.5	1.5
Orange Water&Sewer Authorit	5	5	5
Pittsboro*	0	6	6
Raleigh	0	4.7	4.7
Total Percent	63	105.9	95.9
* Western Intake Partners			

Table S-2 Cape Fear River Water Supply Evaluation Model Scenarios

Model Scenario Descriptions	
_Simbase_Current	This scenario models the baseline current conditons in 2010 based on available water supplies, infrastructure and customer demands at that time
01_JLA_2060	**JLA** indicates this scenario uses the allocations proposed in the draft recommendations for the Jordan Lake Water Supply Allocations **2060** indicates this scenario is modeling the ability to meet the estimated water withdrawals needed to meet 2060 demands. It includes the Jordan Lake allocations recommended in the December 2015 draft document. Demands for water systems not requesting an allocation from Jordan Lake are based on data provided in 2014 local water supply plans and data supplied as comments to the draft documents.
01_JLA_Full_2060_Max	**JLA** indicates this scenario uses the allocations proposed in the draft recommendations for the Jordan Lake Water Supply Allocations **Full** An artificial allocation is added to the recommended 2045 allocations to raise total allocations from the Jordan Lake water supply pool to 100 percent. **2060** indicates this scenario is modeling the ability to meet the estimated water withdrawals needed to meet 2060 demands. Demands for water systems not requesting an allocation from Jordan Lake are based on data provided in 2014 local water supply plans as well as data supplied as comments to the draft documents. **Max** indicates this scenario includes adjustments to the withdrawals for the Cape Fear Water and Sewer Authority and the Cape Fear Public Utility Authority to generate peak monthly average withdrawals that require usage of their estimated available supply limit behind L&D#1 of 106 million gallons per day.

The hydrologic model calculates a solution for each of the 29,858 days in the historic flow record based on daily average values. Using daily calculations means each day constitutes a time step in the model's calculation process. Modeling indicates that for almost 70 percent of the days represented in the historic flow record the water supply and flow augmentation pools are at or above 100 percent full and the water elevation in Jordan Lake is at or above the normal operating elevation. Figures S-4, S-5 and S-6 focus on the percentage of time when modeling shows storage is less than full and when reservoir water levels drop below the normal operating elevation of 216 feet above sea level.

The blue, top line in Figures S-4, S-5 and S-6 represents conditions produced by withdrawals to meet withdrawals and management conditions in 2010 labeled as Simbase_Current. The green line, labeled 01_JLA_2060 characterizes the effects of meeting 2060 estimated demands from available water sources, including the recommended Jordan Lake water supply allocations. The magenta line, labeled 01_JLA_Full_2060_Max, characterizes the effects of meeting 2060 estimated demands with 100 percent allocation of water storage in Jordan Lake and the maximum use of the estimated 106 million gallons per day above Lock and Dam 1 on the Cape Fear River.

All model scenarios are evaluated over the range of flow conditions for the 29,858 days from January 1, 1930 to September 30, 2011. Each day in the inflow record constitutes a time step. Hydrologic conditions are evaluated sequentially thru the daily time steps, using daily average values, through the entire historic record. The Simbase_Current scenario is used to provide a set of conditions that are likely to be familiar to readers. This set of conditions provides a baseline against which the effects of future withdrawal levels can be compared. Figure S-4 shows that as use of the water supply pool increases, the percent of storage will be lower for longer periods of time.

Figure S-4 Jordan Lake Water Supply Storage Duration Graph

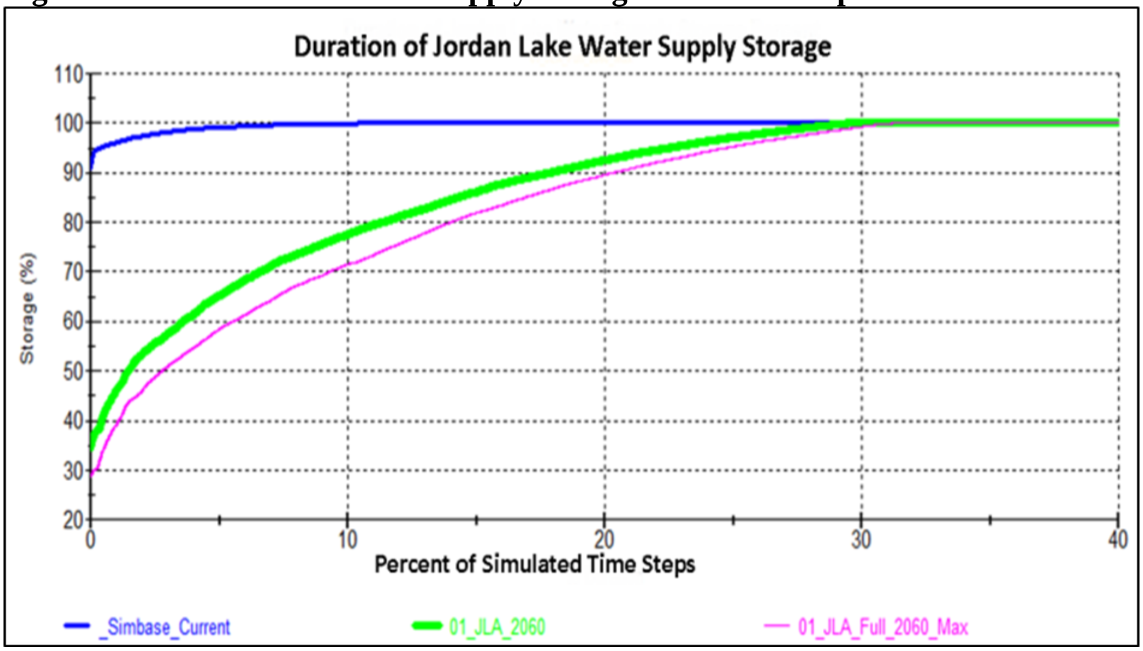


Figure S-5 Jordan Lake Flow Augmentation Storage Duration Plot

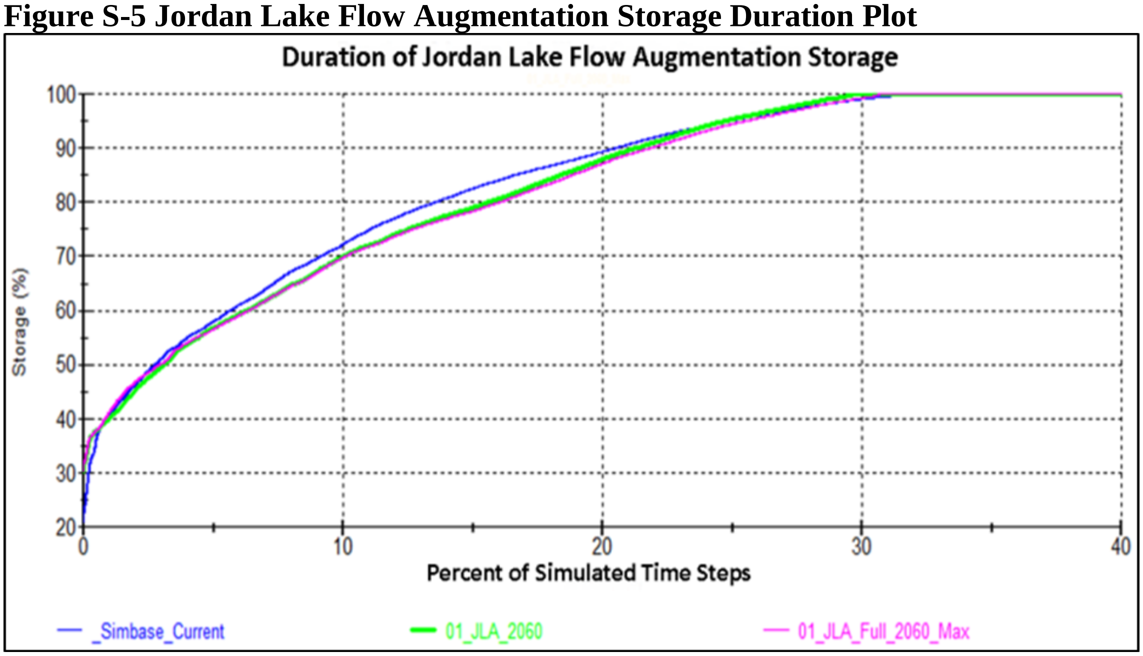


Figure S-5 shows that the model predicts that storage in the flow augmentation pool may be a bit less when trying to satisfy the water withdrawals expected to be needed to meet 2060 customer demands. However, the minimum percent of storage in the flow augmentation pool is higher in both of the future demand scenarios than in the simbase scenario due to required releases from Randleman Reservoir, which eventually flow past the Lillington stream gage, as well as increased wastewater return flows on the Jordan Lake watershed. The increases in both of these inflows to the system have the effects of reducing the need for releases from the flow augmentation pool to meet target flows at the Lillington streamgage.

Figure S-6 Jordan Lake Water Level Duration Graph

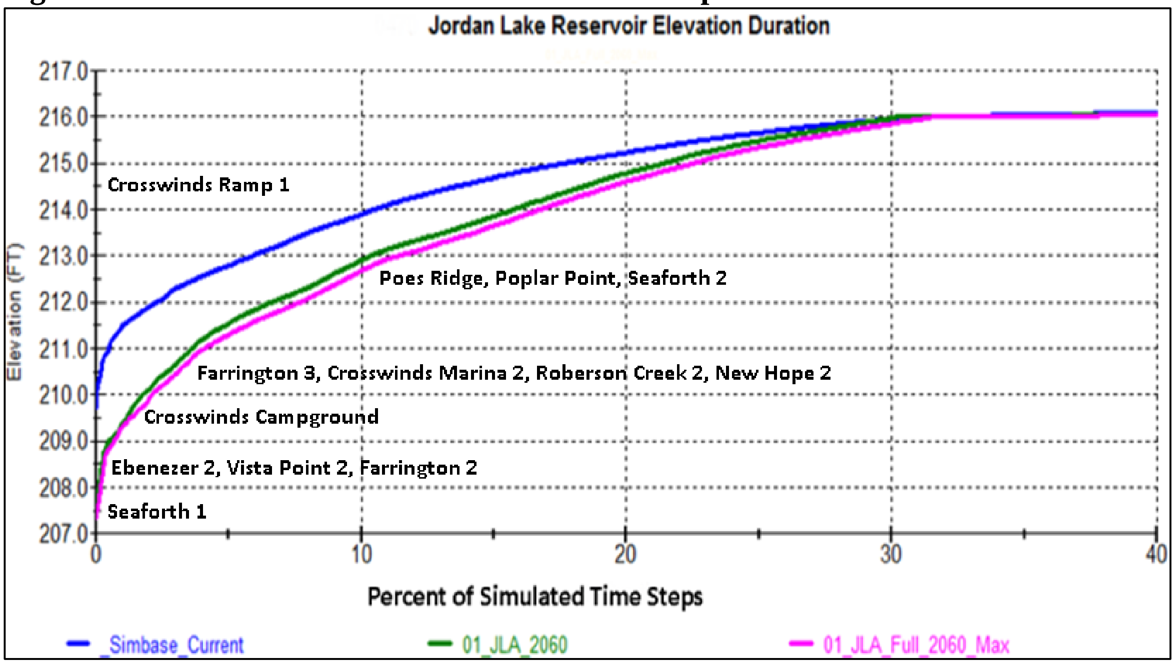


Figure S-6 shows the combined effects of changes in water supply and flow augmentation storage on water levels in Jordan Lake. It also indicates the elevations of the bottoms of public boat ramps where access may be limited due to water levels. As use of water from Jordan Lake increases, boat launching facilities will be impacted more.

Tables S-4 and S-5 show the minimum values reached and when they occurred for the reservoir water levels, water supply storage and flow augmentation storage as well as streamflows in the Cape Fear River at Lillington for each of the model scenarios used to support the Jordan Lake Water Supply Allocation Recommendations and the Cape Fear River Water Supply Evaluation.

The values in Tables S-4 and S-5 show the results of the evaluation of changes in hypothetical

Table S-4 Jordan Lake Minimum Values

Minimum Jordan Lake Elevations and Water Supply Storage							
	Jordan Lake Water Level		Jordan Lake Water Supply Pool				
Model Scenario	Minimum Level, ft	Date	Minimum Water Supply Storage %	Dates Minimum Water Supply %	Number Days @ Minimum Storage %	Longest Period Water Supply Storage <100%	Days In Longest Period
Simbase-current	209.72	8/30/2002	90.91	7/9/1953 - 12/9/1953	154	7/9/1953 - 12/9/1953	154
0_Simbase_2045	209.11	10/23/2007	63.46	5/2/2002-10/10/2002	162	5/17/1933 -2/26/1954	287
01_JLA_2045	207.86	12/1/1953	39.62	7/9/1953 - 1/16/1954	192	5/17/1933 - 3/7/1934	293
01_JLA_2045_Climate	207.48	10/23/2007	36.67	5/19/1933 - 3/19/1934	305	5/19/1933 - 3/19/1934	305
01_JLA_2060	207.62	10/23/2007	34.68	7/6/1953 - 1/15/1954	194	5/17/1933 - 3/5/1934	293
01_JLA_Full_2060_Max	207.32	10/23/2007	28.49	5/19/1933 - 3/5/1934	292	5/19/1933 - 3/5/1934	292

Table S-5 Minimum Values Jordan Lake Flow Augmentation Pool and Cape Fear River Flow at Lillington

Minimum Jordan Lake Flow Augmentation Storage and Target Flow Conditions							
	Jordan Lake Flow Augmentation Pool			Cape Fear River Flow at Lilington, NC			
Model Scenario	Minimum Flow Aug. Storage, %	Date of Minimum Flow Aug. Storage	Days Flow Aug. Storage = 0	Lowest Daily Flow, cfs	Date of Lowest Daily Flow	Years when 1 or more days flows <600 cfs	Days out of 29,858 with estimated Lillington Flow <600cfs
Simbase-current	20.82	8/30/2002	0	284.55	10/1/2007	61	4274 (14.3%)
0_Simbase_2045	25.98	10/23/2007	0	126.18	7/22/2002	65	5191 (17.4%)
01_JLA_2045	30.33	10/23/2007	0	168.87	8/19/2002	60	4485 (15%)
01_JLA_2045_Climate	27.72	10/23/2007	0	153.97	9/29/1968	64	5123 (17.2%)
01_JLA_2060	30.27	10/23/2007	0	152.59	8/19/2002	60	4559 (15.3%)
01_JLA_Full_2060_Max	30.27	10/23/2007	0	152.59	8/19/2002	61	4680 (15.7%)
*When not in drought protocol the target flow at Lillington stream gage is 600 ± 50 cubic feet per second. When the drouth protocol for Jordan Lake is implemented the flow targets are reduced to preserve flow augmentation storage in the reservoir.							

Table S-6 Jordan Lake Water Supply Yield Analysis Results

Estimated Jordan Lake Water Supply Yield									
	Return Flow Assumption			2010 Basecase Scenario			2060 Demand Scenario		
Model Set Up	Percent of Withdrawal Returned to Jordan Lake Watershed	Percent of Withdrawl Returned Below Jordan Lake Dam	Percent of Withdrawal Out of Basin	Estimated Water Supply Yield (MGD)	Jordan Lake Minimum Elevation (ft-msl)	Minimum Water Supply Storage 2/24/1934 (%)	Estimated Water Supply Yield (MGD)	Jordan Lake Minimum Elevation (ft-msl)	Minimum Water Supply Storage 2/24/1934 (%)
1	0	0	100	104.06	202.65	0.65	112.92	203.03	0.79
2	100	0	0	156.94	204.30	1.07	169.66	204.06	1.18
3	0	100	0	104.98	203.55	0.74	113.84	203.36	1.60
4	50	50	0	125.44	203.88	2.69	136.69	203.67	0.96
5	50	0	50	124.19	202.69	0.86	134.86	203.07	0.87
6	0	50	50	104.00	202.65	0.71	112.92	203.03	0.73
7	25	75	0	114.63	203.70	1.17	124.81	203.50	0.81
8	25	0	75	113.25	202.67	0.73	122.91	203.05	0.85
9	75	25	0	140.31	204.07	0.95	151.45	203.86	0.97
10	0	25	75	103.99	202.65	0.75	112.92	203.03	0.77
11	75	0	25	137.56	202.71	0.89	149.55	203.04	1.02
12	0	75	25	104.00	202.65	0.70	112.92	203.03	0.71

Table S-6 shows the results of an analysis of the potential yield of the water supply storage pool in Jordan Lake based on where withdrawn water is discharged back to the waters of the state. The 2010 Basecase Scenario values reflect current management protocols. The 2060 Demand Scenario values take into consideration changes to sources, discharge volumes and management protocols upstream of Jordan Lake that are expected to occur by 2060 based on information submitted to DWR. The theoretical yield estimates range from 104 million gallons per day if all the withdrawn water was removed from the Cape Fear River Basin to 157 million gallons per day if all the withdrawn water was returned to the Jordan Lake watershed.

As noted earlier, the Cape Fear – Neuse River Basins Hydrologic Model includes surface water dependent utilities in the Deep River, Haw River, Cape Fear River, Neuse River and Contentnea Creek subbasins. It includes 43 surface water withdrawals that provide water for 118 community and industrial water systems. This evaluation looks at the ability of the modeled withdrawers in the Deep River, Haw River and Cape Fear River subbasins to meet estimated withdrawals needed to meet 2060 customer demands given the range of streamflows that occurred between 1931 and 2011. Demand numbers came from data submitted to support Jordan Lake water supply allocation requests and from local water supply plans and water withdrawal registrations submitted to DWR for non-applicants. Many, but not all water withdrawers have a water shortage response plan included in the model. These plans are designed to reduce demands during drought conditions.

This analysis assumes some increased use of water from the water supply pool in Jordan Lake, development of additional supplies and interconnections reported in local water supply plans, and expansion of water treatment facilities for some communities. The analysis depends on key assumptions built into the hydrologic model of water quantity availability, the following

- Enough water available at specific locations to satisfy estimated future water demands,
- Water is not reserved in rivers and streams to protect aquatic habitat and ecological integrity except to the extent that minimum releases are required,
- Population and demand projections in local water supply plans and Jordan Lake allocation application are the best informed estimates,
- Future water withdrawals will be from the same locations as current withdrawals with the addition of new withdrawal locations specified in the source data,
- Water systems that depend on purchasing water from another water system will continue being supplied by the current seller during the planning horizon of this study (2010-2060),
- Wastewater return flows will continue at the current locations unless additional information is provide,
- Future wastewater return flows will be the same percentage of water use as in the 2010 basecase model scenario unless additional information was provided,
- The model does not predict the future flow conditions, it indicates the effects of withdrawing various volumes of water over the range of streamflow conditions that occurred between 1930 and 2011,
- Agricultural water use is based on estimates developed for previous river basin models and is assumed to be consistent over the planning horizon,
- Water quality is not evaluated,
- Does not evaluate flooding conditions, and
- Does not extend into tidally influenced sections of the Cape Fear River or Neuse River.

5 Conclusions

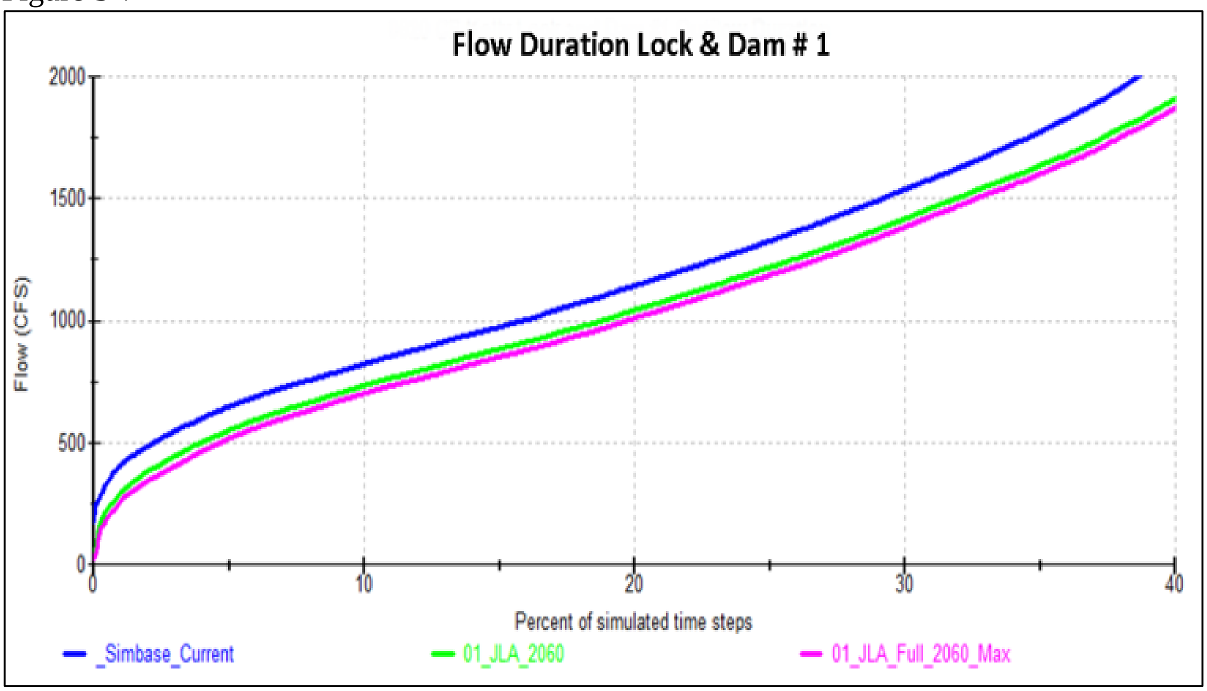
Given the assumptions and data used in the Cape Fear – Neuse River Basins Model, the surface water dependent public water systems in the Deep River, Haw River, and Cape Fear River subbasins are not expected to face flow-related shortages assuming their modeled water shortage response plans are implemented as specified.

Modeling results for Graham, Mebane and Carthage show potential flow- related shortages from their existing water sources. However, their local water supply plans indicate the intention for each of these system to upgrade their connections to neighboring water systems in the future to provide additional water. Modeling for Greensboro shows potential supply shortages at demand levels above those shown for 2045. Currently, Greensboro's supply from the Piedmont Triad Regional Water Authority is limited in the model by the existing capacity of the water treatment plant. If water demand grows as predicted in the local water supply plans, there is enough water available from Randleman Reservoir and enough time to increase treatment capacity to address the estimated shortfall.

While the modeling does not indicate any significant flow limitations to meeting expected water demands through 2060, increased withdrawals behind Lock and Dam 1 may increase the occurances of low flows below Lock and Dam 1 over the range of historic flows in the model flow record.

Lock and Dam 1 is the next to the last node in the Cape Fear River portion of the hydrologic model and the water utilities that withdraw water at that location do not return any treated wastewater above the dam to ameliorate the effects of withdrawals on flows immediately below the dam. Figure S-7 shows the variation in the percent of simulated time steps when flows are predicted to be below 2,000 cubic feet per second for the three model scenarios used for this evaluation.

Figure S-7



6 Discussion

The Cape Fear River Water Supply Evaluation reviews the long-term water needs of public water systems that depend on surface water from the Cape Fear River Basin and the quantity of water available to meet those needs through 2060. The scope of this analysis is limited to public water systems and self-supplied industrial facilities that use surface water and the neighboring water systems that depend on them. While the driving force for this evaluation is to determine the need for and the effects from allocations of water from the water supply pool in B. Everett Jordan Lake, defensible allocation decisions require consideration of the adequacy of regional water supply sources. Communities in several portions of the basin depend on water from the Neuse River Basin. Likewise, communities in the Neuse River Basin depend on water from the Cape Fear River Basin. Therefore, this study evaluates surface water withdrawals from both basins with an emphasis on the effects on surface water availability in the Cape Fear River Basin.

The evaluation is based on information submitted to the Division of Water Resources (DWR) from community water systems and self-supplied industrial water withdrawers. Since the early 1990's North Carolina has required persons that withdraw large quantities of water to register their withdrawals.[12] Units of local government and other large community water systems meet this requirement by preparing and updating a local water supply plan. [13] The DWR receives and manages the data submitted under these programs. The local water supply plans include data on current water use and water sources as well as information on estimated water demands through 2060. Other registrations focus on water use and water sources for a particular year and do not include projections of future needs. Data under both of these programs are submitted annually to DWR. These two programs provide the foundation of water use data used to evaluate water needs from a basin perspective.

The analysis used for this evaluation focuses on the amount of water available from the source used by each community. While the analysis may show that water is available from a particular source, some communities may have to increase the pumping or treatment capacity to be able to deliver enough water to meet customer demands. The model used for this analysis, which will be described in more detail later in this document, does not reserve water to protect aquatic habitat. If the evaluation indicates a shortage of supply while trying to meet the volume of water needed to meet a given level of demand, it is because the model indicates there is an insufficient amount of water available from the source. The results of analyzing the potential shortages based on modeling results will be discussed in this document.

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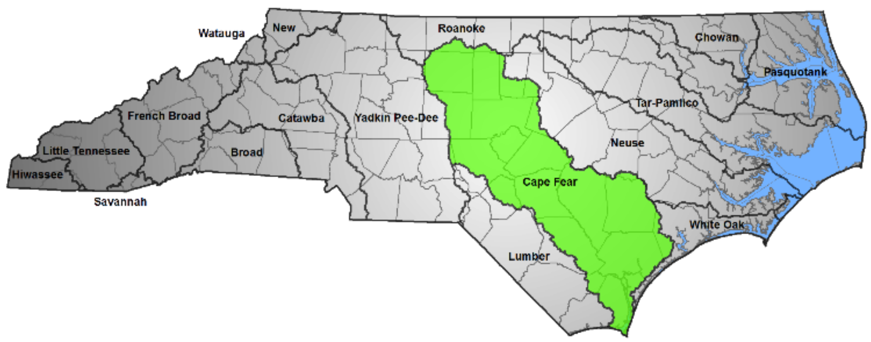
[12] NC GS § 143-215.22H
[13] NC GS § 143-355 (l)

The Cape Fear – Neuse River Basins Hydrologic Model is discussed in detail and the various modeling scenarios used for this evaluation are described. The adequacy of water supply sources is discussed. The applications for water supply storage from Jordan Lake will be summarized and the results of modeling several allocation options are discussed.

Cape Fear River Basin

Figure 1 Cape Fear River Basin



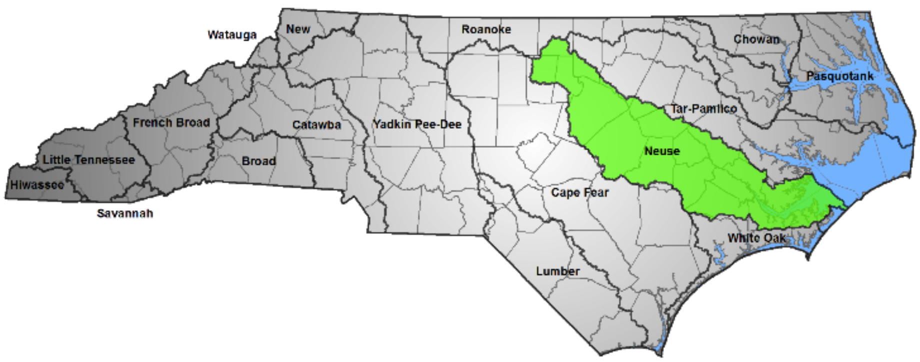
The Cape Fear River Basin is the largest river basin located entirely within North Carolina encompassing 9,200 square miles. Its 1,600 miles of rivers and streams begin in the southern parts of Rockingham and Caswell counties and converge to form the Cape Fear River in Chatham County on its way to flow into the Atlantic Ocean south of Wilmington. The basin contains all or part of twenty-six counties that include the hilly terrain of the Piedmont, as well as the relatively flat Coastal Plain. The Haw and Deep river subbasins, with the hilly terrain characteristic of the Piedmont physiographic region, have most of the water supply reservoirs in the basin. B. Everett Jordan Dam, on the Haw River, creates Jordan Lake, the largest reservoir in the basin, which is capable of holding four million acre-feet of water. At the normal operating water level of 216 feet above mean sea level, the reservoir stores water for public water supply and downstream flow augmentation for water quality. Above this elevation, there are twenty-four vertical feet of flood storage capable of retaining 538,400 acre-feet of runoff during high-flow events for controlled release to minimize downstream flooding.

Downstream of Jordan Dam, the Haw River and the Deep River converge to form the Cape Fear River. The flow of the river is constrained at four locations below Jordan Lake by dams that do not regulate flow, but create pools in the river with water levels determined by the elevations of the tops of the dams. Moving downstream from Jordan Lake, Buckhorn Dam, south of State Route 42 near Corinth, creates the first such backwater. Below the City of Fayetteville, there are three sets of locks and dams in the Cape Fear River that are operated by the U.S. Army Corps of Engineers to support navigation on the river between Fayetteville and the Port of Wilmington. Lock and Dam 1, near the community of Kelly in Bladen County, is the downstream limit of the evaluation of the effects of surface water withdrawals from Cape Fear River Basin.

Effectively evaluating water supply resources and options in the Cape Fear River Basin also requires evaluating water supply conditions in the Neuse River Basin. Regional water sharing and interconnections between public water utilities are critical to reliably meeting community water needs in both river basins.

Neuse River Basin

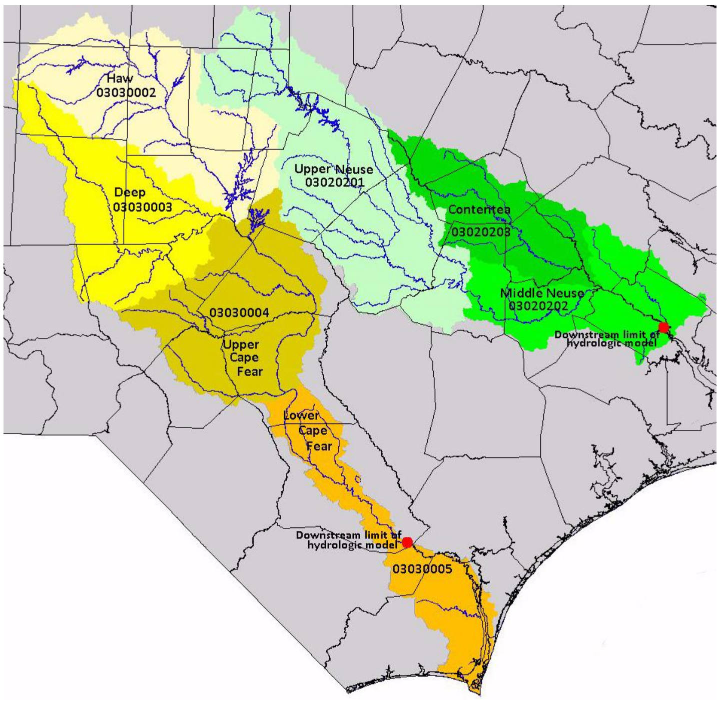
Figure 2 Neuse River Basin



The Neuse River Basin lies entirely within the state, draining an area of 6,235 square miles in eighteen counties. It is the third largest river basin in North Carolina. The Eno, Flat and Little rivers merge to form the Neuse River in eastern Durham County in an area now inundated by Falls Lake. Falls Lake, built and operated by the U.S. Army Corps of Engineers, is the largest reservoir in the Neuse River Basin. It is a multipurpose reservoir that provides storage for water supply and flow augmentation as well as storing runoff during high-flow events to mitigate downstream flooding. Below Falls Lake the Neuse River regains its riverine character as it flows southeasterly through the broad flat terrain of the Coastal Plain to empty into Pamlico Sound.

The Town of Hillsborough and the City of Durham rely on reservoirs on the Eno River watershed and the Flat River and Little River watersheds, respectively, to supply water to their water treatment plants. Downstream of these reservoirs, Falls Lake is the primary source of water for the City of Raleigh and the surrounding communities that have partnered with the Raleigh Public Utilities Department. Raleigh also has a water supply source available from the Swift Creek watershed that supplements the available supply from Falls Lake.

Figure 3 Geographic Scope of the Hydrologic Modeling



The quantitative analysis used for evaluating the adequacy of surface water resources is derived from the outputs of a computer-based hydrologic model. The model characterizes surface water quantity conditions, based on historic flow data, by evaluating the effects of withdrawals and inflows as water flows downstream from the headwaters to the model's terminal node; where streamflows become tidally influenced. Figure 1 shows the geographic boundaries and the hydrologic unit designations within the Cape Fear River Basin and Neuse River Basin used in this analysis. The red dots in each basin show the downstream limits of the Cape Fear – Neuse River Basins Hydrologic Model.

This document presents the current and projected service population estimates submitted by water systems in the Cape Fear and Neuse river basins in their local water supply plans. Population estimates are followed by a review of the water utilities' reported available water supplies and projections of future water demands from 2020 through 2060.

7 Water Sources

Many factors influence how and when a community grows including transportation infrastructure, water and sewer infrastructure, local ordinances, land use controls and development patterns and the availability of jobs. For the purposes of this analysis, we assume that local officials have the best perspective on their community's growth. This analysis accepts the population projections based on currently available data supplied in the local water supply plans submitted by local officials. Population growth is a key determinant of the future water demands on the public water systems. Table 1 shows the estimated service populations for the water supply systems included in the computer modeling and analysis for this evaluation of water supply conditions. The data provide an insight into the number of people each water system is expecting to serve from its drinking water distribution system in the future.

Table 1 shows the service population projections for the water systems included in the modeling for this analysis. The data came from local water supply plans for 2010 and 2014. Future projections were taken from the 2014 plans.

This analysis focuses on the quantity of surface water present at various locations throughout the Cape Fear and Neuse river basins and how the quantity may change as a result of the withdrawals needed to meet future water demands. The amount of water a public water system can provide to meet customer needs is an important factor in assessing the possibility of water shortages. How much water a public water system can provide is a function of the amount available from the source and how much can be pumped and treated to produce potable water. This evaluation looks at how much water is available at the location of water supply intakes. It is important to remember that the analysis for this report only looks at the quantity of water available. There may be treatment capacity or water quality concerns associated with a particular source that limit the ability to produce potable water. The amount of water that can be withdrawn at a particular location may be limited because of potential impacts to instream water quality. The amount of water available may also be limited by contractual arrangements, resource management regulations or habitat protection needs.

Ground Water Supply

Some public water systems included in this analysis get their water from ground water and surface water sources. Their surface water demands for this analysis are determined by subtracting the yield of ground water sources from future demand projections based on information in their local water supply plans.

A practical definition of "yield" for a ground water well is the long-term rate at which water can be withdrawn without exceeding the natural recharge capability of the aquifer. In coastal areas withdrawals may be limited to the amount that can be pumped without causing saltwater intrusion into an aquifer. Systems using ground water conduct a drawdown test, at least at initial well construction. The drawdown test determines how much water can be withdrawn from a well without exceeding the natural recharge capability of the associated aquifers. The results of the drawdown test are used to determine a sustainable pumping rate, or yield, for the well. North Carolina requires at least a 24-hour drawdown test to determine well yield for public water supply wells.[14]

The rules governing public water systems require that the combined yield of all wells of a water supply system be adequate to meet the average daily demand in 12 hours pumping time.[15] This requirement ensures that the system can reliably provide adequate water to its customers. The combined 12-hour supply for the wells supplying

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[14] 15A NCAC 18C .0402(g)(1)
[15] 15A NCAC 18C .0402(g)(3)

a water system reported in the local water supply plans is used to determine the adequacy of the existing supplies. If the system needs to pump more than 12 hours a day to meet average system demands, the system administrators face the question of whether to encourage customers to use water more efficiently or to develop additional sources of supply or both.

We used the data on existing 12-hour yields from the Local Water Supply Plans as the available supply from ground water sources for the systems included in this analysis.

Surface Water Supply

Surface water can be withdrawn from a stream or river as it flows past an intake, a run-of-river intake, or it can be withdrawn from an impoundment where flowing water is retained behind a structure that retards its movement downstream. Such an impoundment can be a managed reservoir which can control releases downstream or it can simply be a structure in the channel that creates a pool of water at the height of the structure and allows water to flow unrestricted over the top of the structure. The lock and dam facilities in the Cape Fear River are examples of the latter arrangement.

Managed reservoirs impound water during high flow periods for later use when stream flows would otherwise be insufficient to meet withdrawal demands and management goals. Run-of-river intakes simply withdraw a portion of the water in a stream as it flows past the intake. The amount of water flowing in the channel and limits established to meet environmental management goals can limit the amount of water that can be withdrawn.

For planning purposes, the potential yield or available supply can be estimated for reservoirs and run-of-river intake locations, but the methods for determining the yields are different. The estimate of potential yield of surface water sources is limited by the amount of water that can be withdrawn during low flow or drought conditions. The potential yield is determined from data on the amount of water that is likely to be available based on the water that was available during a defined period in the recent past.

Run-of-River Intake

Run-of-river intake systems differ from reservoirs in that they are typically limited by the water flowing in the source stream with no ability to augment water supply during extended dry weather periods. During moderate to high flows this is not a problem. However, during low flow periods, the inability to augment flows using stored water can result in water supply shortages. In some cases, even short-term low flow events can result in water shortages if alternative sources are not available to augment water supplies. Planning for a run-of-river intake requires developing an understanding of what low flows could be.

A commonly used estimate of expected low flow levels is a measure called the "7Q10." The 7Q10 flow is the lowest average flow for seven consecutive days expected to occur once in 10 years on average based on the historic record. The 7Q10 is not the lowest flow of record, but rather the lowest 7-day average flow with a 10-year recurrence interval. It is also the flow rate used for calculations for wasteload allocations for pollution discharge permits. Low flow conditions with a 10-year recurrence interval have a 10 percent chance of occurring in any year, a high enough probability to warrant advanced planning.

Based on possible impacts to water quality, aquatic organisms and habitat as well as other users, run-of-river intakes may be restricted to withdraw only a portion of the 7Q10 flow. Limits on run-of-river withdrawals may be established after examining the potential impacts of a proposed withdrawal on streamflows and aquatic habitat based on a site-specific study. These studies are time consuming and can be expensive. But, they provide a site-specific evaluation of the effects of potential withdrawals and help in designing intakes for conditions at a particular location. An alternative is to use a planning guideline to determine a withdrawal amount that is unlikely to have serious effects on water quality and aquatic habitat during low flow conditions.

If a proposed project has to meet the requirements of the North Carolina Environmental Policy Act, then the guideline differentiating between a minor and a major project provides one criteria to determine the depth of environment review needed. If a proposed instantaneous surface water withdrawal, in combination with other withdrawals in the stream reach, will not result in cumulative withdrawals that take more than 20 percent of the 7Q10 flow, it may not be considered a major project and may only require an Environmental Assessment -- not the in-depth analysis needed to produce an Environmental Impact Statement. The 20 percent of the 7Q10 flow is not a limit on withdrawals, but rather a general planning guideline. If 20 percent of the 7Q10 does not provide enough water to meet the expected need, a site-specific study may then help to determine if more water can be withdrawn. If there are specific concerns at the proposed site, such as potential impacts on an endangered species, in-depth environmental studies can be required at any level of withdrawal.

For water supply systems that withdraw water from streams in the Cape Fear River Basin, results from the Cape Fear-Neuse River Basin Hydrologic Model provide, for planning purposes, indications of how water availability may change with changes in withdrawals and return flows. Model generated data cannot be directly compared to real world stream gage data. However, the variations in flow statistics between the current conditions model scenario and future conditions scenarios may provide useful information on the potential changes to streamflows that may be observed as withdrawals change to meet future supply demands.

Reservoir Intakes

Water supply reservoirs impound water during high flow periods for later use when stream flows are not sufficient to meet demands. Stream flows and reservoir storage will determine how much water is available, or how many days of supply are available given a particular daily rate of use. Water can be stored by damming a stream channel or by developing an off-stream storage facility. In either case, the historical occurrence of low inflow conditions provides essential data for estimating the potential yield. For any given impoundment, the estimated yield is conditioned by the length of the data record used in the calculations.

Reservoir yields are estimated based on the reliability desired for the intended use. A 20-year yield estimates the allowable withdrawal rate based on an expected reliability of 19 out of 20 years. This estimate implies that in any given year there would be a 5 percent risk that the estimated amount of withdrawal could not be sustained. Similarly, a 50-year yield estimate defines a withdrawal rate with an expected reliability of 49 out of 50 years having a 2 percent risk that the estimated amount of withdrawal could not be sustained in any year.

Public water systems that rely on surface water may not be able to use the entire amount of their available supply because of treatment and distribution system limitations. In this analysis, we assumed that if water were available from the current source, then systems would invest in the facilities necessary to produce and distribute more potable water when demand approached the limits of existing capacity.

Non-reservoir Impoundments

At several locations on the Cape Fear River, water is retained behind an impoundment that creates a pool of water with a surface elevation determined by the height of the impounding structure. Water flowing into the impoundment flows freely over the impounding structure. Water releases from the impoundment are not managed or regulated. These structures provide a relatively constant water depth that provide some of the advantages of a reservoir over a run-of-river intake by maintaining a reliable depth of water behind the impounding structure. As streamflows into the impoundment vary, the water levels above the elevation of the top of the dam. If net withdrawals from the impoundment are less than the inflow, then water will continue to flow downstream. The effect of withdrawals from the impoundment can be evaluated by examining the changes to flow below the impounding structure due to an existing or proposed withdrawal.

Purchased Supply

Many water systems buy water from neighboring systems. The DWR encourages systems that buy or sell water to develop contracts for the transactions. Contracts make clear to all parties the amount of water to be available and the length of time it will be available. Systems that buy water need to know how much water they can get and for how long, while sellers need to plan to have the committed amount of water available when needed.

Local water supply plans provide the DWR with information on water sales and purchases as well as contract amounts. Purchase arrangements are assumed to continue over the fifty-year planning horizon of this analysis. For water systems for which purchasing water is their only supply, we assumed that their estimated future demands will be met by the current suppliers, regardless of reported contract limits.

Water Utilities Available Supplies

Table 1 shows the amount of water available to each of the water utilities analyzed for this report based on the information reported in their local water supply plans. It indicates the sources available to each utility and the estimated amount of water available from each source in millions of gallons per day. The streams that provide surface water sources are identified and, if applicable, water supply reservoirs are identified. The available supply amounts shown represent the estimated amount of water that is expected to be available from a particular source. Communities may or may not have existing infrastructure sufficient to fully use the listed amount of water.

For water systems that depend on water from another system, the selling system is identified and the contract amounts reported in the local water supply plans are shown as the available supplies. The contracts listed in the local plans are of varying lengths and may or may not be capable of being increased if the current contracts prove to be insufficient to meet future demands. These contracts are negotiated directly by the participating utilities.

Local water supply plans are available for review on the DWR website at http://www.ncwater.org/Water_Supply_Planning/Local_Water_Supply_Plan/. Water demand projections are discussed in the next section.

Table 1 Available Water Supply in Million Gallons per Day

Water System's Estimated Available Supplies reported in Local Water Supply Plans					
County	**System ID#**	**Water System**	**Source**	**Available Supply (mgd)**	**Basin**
Alamance					
	02-01-035	Alamance	from Burlington	0.50	
	02-01-010	Burlington	Stoney Creek Reservoir	14.60	Haw River (02-1)
		Burlington	Great Alamance Creek/Lake Mackintosh	35.60	Haw River (02-1)
	02-01-025	Elon	from Burlington	1.60	
	02-01-015	Graham	Back Creek/Graham-Mebane Lake	12.00	Haw River (02-1)
	02-01-030	Green Level	from Graham	0.22	
	02-01-020	Haw River	from Burlington	1.50	
	02-01-018	Mebane	from Graham	4.00	
	30-01-005	Swepsonville	from Graham	0.50	
Bladen					
	03-09-010	Elizabethtown	groundwater	0.98	
	50-09-013	LCFWSA - Kings Bluff (Industrial Use)	Cape Fear River	53.00	Cape Fear River (02-3)
	50-09-012	LCFWSA_Bladen Bluffs (Industrial Use)	Cape Fear River	6.00	Cape Fear River (02-3)
Brunswick					
	04-10-130	Bald Head Island Utilities Dept.	from Brunswick County	0.50	
	04-10-045	Brunswick County	from LCFWSA - Kings Bluff	24.00	Cape Fear River (02-3)
		Brunswick County	groundwater	8.88	
	04-10-070	Brunswick Regional (H2GO)	from Brunswick County	1.00	
	04-10-055	Caswell Beach	from Brunswick County	0.30	
	70-10-058	Leland	from Brunswick County	0.50	
	04-10-065	Navassa	from Brunswick County	0.20	
	70-10-045	Northwest	from Brunswick County	0.21	
	04-10-020	Oak Island	from Brunswick County	2.00	
	04-10-035	Ocean Isle Beach	from Brunswick County	1.06	
	04-10-025	Shallotte	from Brunswick County	0.75	
	04-10-010	Southport	from Brunswick County	1.42	
Chatham					
	40-19-010	Chatham County Asbury Water System	from Sanford	0.40	
	03-19-126	Chatham County North Water System	Haw River/B. Everett Jordan Lake	3.00	Haw River (02-1)
	03-19-050	Chatham County Southwest Water System	from Siler City	0.50	
	03-19-025	Goldston Gulf SD	from Sanford	0.25	
	03-19-015	Pittsboro	Haw River	2.00	Haw River (02-1)
	03-19-010	Siler City	Rocky River/ Upper & Lower Reservoirs	4.00	Deep River (02-2)
Columbus					
	04-24-035	Riegelwood SD	CAPE FEAR RIVER	1.00	Cape Fear River (02-3)
Cumberland					
	50-26-027	Eastover Sanitary District	from Dunn	1.00	
	03-26-035	Falcon	from Dunn	0.20	
	03-26-010	Fayetteville	Cape Fear River - 1	42.90	Cape Fear River (02-3)
		Fayetteville	Cape Fear - 2	42.90	Cape Fear River (02-3)
		Fayetteville	Little Cross Creek/Glenville Lake	4.50	Cape Fear River (02-3)
		Fayetteville	Big Cross Creek	0.90	Cape Fear River (02-3)
	03-26-050	Godwin	from Falcon	0.04	
	03-26-045	Linden	from Harnett County RWS	0.25	
	50-26-019	Old North Utility Services, Inc.	from Fayetteville PWC	8.00	
		Old North Utility Services, Inc.	from Harnett County RWS	8.00	
	03-26-020	Spring Lake	from Fayetteville PWC	1.56	
		Spring Lake	from Harnett County RWS	0.50	
	03-26-030	Stedman	from Fayetteville PWC	0.16	

Table 1 Available Water Supply in Million Gallons per Day (cont.)

Water System's Estimated Available Supplies reported in Local Water Supply Plans					
County	System ID#	Water System	Source	Available Supply (mgd)	Basin
Durham					
	03-32-010	Durham	Eno River	5.00	Neuse River (10-1)
		Durham	Haw River/B. Everett Jordan Lake	10.00	Haw River (02-1)
		Durham	Flat River/Lake Michie	10.50	Neuse River (10-1)
		Durham	Little River Lake	17.40	Neuse River (10-1)
		Durham	Eno River/Teer-Hanson Quarry	5.20	Neuse River (10-1)
Granville					
	02-39-015	Creedmoor	from SGWASA	0.55	
	02-39-107	South Granville Water and Sewer Authority	Knapp of Reed's Creek/RD Holt Reservoir	11.00	Neuse River (10-1)
	40-39-004	Wilton Water and Sewer	from Creedmoor	0.08	
Guilford					
	02-41-025	Gibsonville	from Burlington	2.50	
	02-41-010	Greensboro	Reedy Fork Cr./Lake Townsend	24.00	Haw River (02-1)
		Greensboro	Reedy Fork Cr.Horsepen Cr./Lake Brandt	12.00	Haw River (02-1)
		Greensboro	Brush Creek/Lake Higgins	0.00	Haw River (02-1)
		Greensboro	from PTRWA	6.37	
	02-41-020	High Point	Deep River/Oak Hollow	12.84	Deep River (02-2)
		High Point	Deep River/City Lake	8.60	Deep River (02-2)
		High Point	from PTRWA	2.68	
	02-41-030	Jamestown	from High Point	1.35	
		Jamestown	from Greensboro	0.05	
Harnett					
	03-43-015	Angier	from Harnett County RWS	2.02	
	50-43-001	Bragg Communities	from Harnett County RWS	0.80	
	03-43-020	Coats	from Harnett County RWS	0.72	
	03-43-010	Dunn	Cape Fear River	12.00	Cape Fear River (02-3)
	03-43-045	Harnett County Regional Water System	Cape Fear River	68.39	Cape Fear River (02-3)
		Harnett County Regional Water System	from Dunn	1.00	
	03-43-025	Lillington	from Harnett County RWS	2.00	
Johnston					
	03-51-025	Benson	from Dunn	0.95	
		Benson	from Johnston County	0.20	
	03-51-020	Clayton	from Johnston County	2.59	
	03-51-195	Aqua NC / Flowers Plantation	from Johnston County	0.38	
	03-51-035	Four Oaks	from Johnston County	0.24	
	03-51-070	Johnston County	Neuse River	12.00	Neuse River (10-1)
		Johnston County	from Harnett County RWS	2.60	
	03-51-030	Kenly	from Johnston County	0.30	
	40-51-008	Micro (County Line)	from Johnston County	0.50	
	03-51-050	Princeton	from Johnston County	0.13	
	03-51-010	Smithfield	Neuse River	6.20	Neuse River (10-1)
Lee					
	03-53-015	Broadway	from Sanford	0.30	
	03-53-101	Carolina Trace WS	from Sanford	0.29	
	03-53-010	Sanford	Cape Fear River/Yarborough Lake	12.60	Deep River (02-2)
Lenoir					
	04-54-030	Deep Run WC	from NRWASA	0.73	
		Deep Run WC	groundwater	2.603 (0.651)	
	04-54-010	Kinston	from NRWASA	3.07	
		Kinston	groundwater	6.217 (1.437)	
	60-54-001	Neuse Regional Water and Sewer Authority	Neuse River	15.00	Neuse River (10-1)
	04-54-025	North Lenoir Water Corp.	from NRWASA	1.19	
		North Lenoir Water Corp.	groundwater	2.938 (0.735)	
	04-54-020	Pink Hill	from NRWASA	0.15	
		Pink Hill	groundwater	0.13	
Moore					
	03-63-025	Carthage	Nicks Creek/Carthage Reservoir	1.00	Cape Fear River (02-3)
	50-63-011	East Moore Water District	from Harnett County RWS	3.00	
	50-63-021	Moore County Public Utilities-High Falls	from Chatham County SW	0.03	
	03-63-103	Moore County Public Utilities-Hyland Hills	from East Moore Water District	0.05	
		Moore County Public Utilities-Hyland Hills	from Chatham County SW	0.03	
	03-63-108	Moore County Public Utilities-Pinehurst	groundwater	1.37	
		Moore County Public Utilities-Pinehurst	from East Moore Water District	1.00	
		Moore County Public Utilities-Pinehurst	from Aberdeen	0.60	
		Moore County Public Utilities-Pinehurst	from Southern Pines	1.00	
	03-63-155	Moore County Public Utilities-Robbins	from Robbins	0.03	
	03-63-117	Moore County Public Utilities-Seven Lakes	groundwater	0.06	
		Moore County Public Utilities-Seven Lakes	from Moore County-Pinehurst	1.00	
	03-63-045	Moore County Public Utilities-Vass	from East Moore Water District	0.20	
	03-63-015	Robbins Water System	Bear Creek/ CB Brooks Reservoir	0.05	Deep River (02-2)
		Robbins Water System	from Montgomery County	0.25	Yadkin River (18-1)

Table 1 Available Water Supply in Million Gallons per Day (cont.)

Water System's Estimated Available Supplies reported in Local Water Supply Plans					
County	System ID#	Water System	Source	Available Supply (mgd)	Basin
New Hanover					
	04-65-010	Cape Fear Public Utility Authority - Wilmington	Cape Fear River	53.00	Cape Fear River (02-3)
		Cape Fear Public Utility Authority - Wilmington	groundwater	8.15	
	04-65-015	Carolina Beach	groundwater	2.01	
Orange					
	03-68-015	Hillsborough	Eno River/Lake Ben Johnston	0.68	Neuse River (10-1)
		Hillsborough	West Fork of the Eno Reservoir	1.80	Neuse River (10-1)
		Hillsborough	East Fork Eno River/Lake Orange Reservoir	0.08	Neuse River (10-1)
	03-68-010	Orange Water and Sewer Authority	Cane Creek Reservoir	8.50	Haw River (02-1)
		Orange Water and Sewer Authority	Morgan Creek/University Lake	2.00	Haw River (02-1)
		Orange Water and Sewer Authority	Haw River/ B Everett Jordan Lake	5.00	Haw River (02-1)
	03-68-020	Orange-Alamance	Eno River/Corporation Lake	0.37	Neuse River (10-1)
Pitt					
	04-74-025	Ayden	from NRWASA	0.39	
		Ayden	groundwater	1.091 (0.196)	
	04-74-045	Bell Arthur WC	from NRWASA	0.60	
		Bell Arthur WC	groundwater	1.933 (0.402)	
	04-74-015	Eastern Pines Water Corporation	from NRWASA	1.19	
		Eastern Pines Water Corporation	groundwater	2.722 (0.824)	
	04-74-035	Grifton	from NRWASA	0.14	
		Grifton	groundwater	0.432 (0.108)	
Randolph					
	02-76-030	Archdale	from PTRWA	1.45	
	02-76-035	Franklinville	from Ramseur	0.25	
	30-76-010	Piedmont Triad Regional Water Authority	Deep River/Randleman Reservoir	48.00	Deep River (02-2)
	02-76-020	Ramseur	Sandy Creek Reservoir	6.60	Deep River (02-2)
	02-76-015	Randleman	from PTRWA	1.00	
Rockingham					
	02-79-020	Reidsville	Troublesome Creek/Lake Reidsville	19.00	Haw River (02-1)
		Reidsville	Troublesome Creek/Lake Hunt	0.00	Haw River (02-1)
	02-79-050	Rockingham Co	from Reidsville	0.55	
		Rockingham Co	from Madison	0.20	Roanoke (14-1)
Wake					
	03-92-045	Apex	Haw River/ B Everett Jordan Lake	8.50	Haw River (02-1)
	03-92-020	Cary	Haw River/ B Everett Jordan Lake	30.50	Haw River (02-1)
	03-92-055	Fuquay-Varina	from Harnett County RWS	2.00	
	03-92-050	Holly Springs*	from Harnett County RWS	10.00	
		Holly Springs*	Haw River/ B Everett Jordan Lake	2.00	
	03-92-010	Raleigh	Neuse River/Falls Lake	66.10	Neuse River (10-1)
		Raleigh	Swift Creek/Lake Benson	11.20	Neuse River (10-1)
Wayne					
	04-96-060	Fork Township SD	from Goldsboro	0.50	
		Fork Township SD	groundwater	1.251 (0.645)	
	04-96-025	Fremont	from Wayne WD	0.17	
	04-96-010	Goldsboro	Neuse River	25.85	Neuse River (10-1)
		Goldsboro	Little River	0.65	Neuse River (10-1)
	04-96-030	Pikeville	from Fremont	0.10	
		Pikeville	from Wayne WD	0.15	
	04-96-065	Wayne WD	from Goldsboro	3.20	
		Wayne WD	groundwater	7.85 (6.376)	
Wilson					
	04-98-020	Elm City	from Wilson	0.30	
		Elm City	groundwater	0.15	
	04-98-010	Wilson	Contentnea Creek/Buckhorn Lake	26.70	Contentnea Creek (10-2)
		Wilson	Contentnea Creek/Wiggins Mill Reservoir	1.00	Contentnea Creek (10-2)
		Wilson	Toisnot Swamp/Toisnot Reservoir	0.20	Contentnea Creek (10-2)
		Wilson	Toisnot Swamp/Lake Wilson	1.00	Contentnea Creek (10-2)

8 Expected Service Populations

Table 2 Estimated Service Populations

Estimated Service Populations base on data from Local Water Supply Plans and Jordan Lake Allocation Requests*									Oct-16
County	System ID#	Water System	2010	2014	2020	2030	2040	2050	2060
Alamance									
	02-01-035	Alamance	750	955	1,100	1,200	1,320	1,450	1,600
	02-01-010	Burlington	52,000	53,000	56,100	62,896	70,500	79,000	88,600
	02-01-025	Elon	9,419	10,800	12252	14671	17090	19509	21928
	02-01-015	Graham	15,043	14,280	15106	15965	17463	18511	19622
	02-01-030	Green Level	2,345	2,540	2647	2832	3030	3242	3469
	02-01-020	Haw River	2,068	2,311	2,643	3,039	3,495	4,019	4,622
	02-01-018	Mebane	11,393	13,000	15,419	19,445	23,471	27,497	31,523
	30-01-005	Swepsonville	1,154	1,190	1365	1706	2132	2665	3331
Brunswick									
	04-10-130	Bald Head Island Utilities Dept.	200	175	205	230	240	250	260
	04-10-045	Brunswick County	80,000	84,474	96,374	117,025	138,790	158,803	182,622
	04-10-070	Brunswick Regional WSD	18,726	21,260	22718	27585	31998	37117	44540
	04-10-055	Caswell Beach	501	422	510	510	510	510	510
	70-10-058	Leland		1,257	921	1,183	1,445	1,707	1,969
	04-10-065	Navassa	1,900	843	845	962	1,006	1,115	1,245
	70-10-045	Northwest	882	859	955	1055	1155	1255	1355
	04-10-020	Oak Island	8,203	8,870	15,700	16,700	17,700	18,700	19,700
	04-10-025	Shallotte	1,998	4,003	4,000	4,078	4,282	4,496	4,721
	04-10-010	Southport	5,250	5,405	5,500	5,700	6,000	6,600	6,800
Chatham									
	40-19-010	Chatham County Asbury Water System	841	1,028	1,181	1,371	1,591	1,846	2,143
	03-19-126	***Chatham County North Water System****	***10,200***	***14,710***	***25,900***	***41,600***	***57,300***	***73,400***	***94,000***
	03-19-050	Chatham County Southwest Water System	2,266	2,073	2,601	3,019	3,503	4,066	4,719
	03-19-025	Goldston Gulf SD	1,443	1,370	1,280	1,290	1,295	1,300	1,305
	03-19-015	***Pittsboro****	***3,700***	***4,033***	***24,000***	***58,600***	***79,900***	***87,100***	***96,800***
	03-19-010	Siler City	7,877	8,140	8,547	8,974	9,423	9,894	10,388
Cumberland									
	50-26-027	Eastover Sanitary District		5,000	6,200	6,300	6,400	6,500	6,600
	03-26-035	Falcon	720	735	760	820	907	957	1,007
	03-26-010	***Fayetteville****	***199,102***	***199,560***	***254,208***	***316,772***	***384,376***	***412,383***	***440,390***
	03-26-050	Godwin	267	257	258	268	278	288	290
	03-26-045	Linden	1,547	1,605	1700	1725	1750	1775	1800
	50-26-019	Old North Utility Services, Inc.	65,000	76,000	78,195	80,150	82,154	84,208	86,313
	03-26-020	Spring Lake	9,000	8,907	9,660	10,670	11,780	13,010	14,370
	03-26-030	Stedman	970	1,073	1,050	1,100	1,150	1,250	1,300
Durham									
	03-32-010	***Durham****	***246,180***	***265,472***	***286,419***	***329,421***	***372,423***	***415,425***	***458,426***
Granville									
	02-39-015	Creedmoor	4,124	4,397	7,475	10,450	13,425	16,400	16,400
	02-39-107	South Granville Water and Sewer Authority	10,467	19,216	20,753	22,828	25,111	27,622	30,385
	40-39-004	Wilton Water and Sewer		900	900	900	900	900	900
Guilford									
	02-41-025	Gibsonville	5,980	6,700	8400	10080	12096	14515	17418
	02-41-010	Greensboro	260,083	277,080	299,941	339,800	391,874	451,928	521,186
	02-41-020	High Point	101,409	109,270	113640	119322	125288	131552	138129
	02-41-030	Jamestown	5,667	5,667	7,000	7,500	8,200	8,500	8,800
	30-76-010	Piedmont Triad Regional Water Authority	0	0	0	0	0	0	0
Harnett									
	03-43-015	Angier	6,545	6,075	8,000	10,000	15,000	20,000	25,000
	50-43-001	Bragg Communities	5,855	5,855	5,855	5,855	5,855	5,855	5,855
	03-43-020	Coats	2,246	2,280	2,302	2,359	2,418	2,479	2,531
	03-43-010	Dunn	9,263	9,263	9,363	9,463	9,563	9,663	9,763
	03-43-045	Harnett County Regional Water System	79,059	90,004	124919	144760	164606	187174	212836
	03-43-025	Lillington	3,300	3,408	4,131	4,338	4,554	4,782	5,260
Hoke Co									
	03-47-025	Hoke RWS	37,745	22,897	30200	45000	62000	70000	80000
	03-47-010	Raeford	4,400	4,887	4,800	5,280	5,800	6,300	6,800

Table 2 (cont.) Estimated Service Populations

Estimated Service Populations base on data from Local Water Supply Plans and Jordan Lake Allocation Requests*									Oct-16
County	System ID#	Water System	2010	2014	2020	2030	2040	2050	2060
Johnston									
	03-51-025	Benson	4,671	3,311	3375	3440	3510	3590	3700
	03-51-020	Clayton	15,780	17,985	21,688	29,127	39,118	52,535	70,555
	03-51-195	Flowers Plantation	3,637	4,156	4654	4887	4900	5000	5100
	03-51-035	Four Oaks	2,570	2,479	2,701	3,001	3,376	3,832	4,388
	03-51-070	Johnston County	59,800	70,540	80605	97000	108933	121248	134835
	03-51-030	Kenly	1,328	1,400	1,407	1,423	1,438	1,451	1,466
	40-51-008	Micro (County Line)	45	40	25	30	40	50	60
	03-51-050	Princeton	1,376	1,203	1241	1301	1361	1421	1481
	03-51-010	Smithfield	11,476	11,560	11,093	11,205	11,317	11,431	11,534
Lee									
	03-53-015	Broadway	1,476	1,654	1,848	2,113	2,430	2,795	3,186
	03-53-101	Carolina Trace WS	4,129	4,406	5,220	5,220	5,220	5,220	5,220
	03-53-010	Sanford	40,900	41,881	56,600	76,000	92,200	111,800	135,700
Lenoir									
	04-54-030	Deep Run WC	12,675	12,915	16,413	19,630	23,478	28,080	28,080
	04-54-010	Kinston	27,588	27,588	28000	28000	28500	29000	29500
	04-54-025	North Lenoir Water Corp.	14,450	14,585	14,700	15,000	15,250	15,500	15,750
	04-54-020	Pink Hill	955	955	965	980	990	1,000	1,010
Moore									
	03-63-025	Carthage	2,414	2,250	2,600	2,800	3,000	3,200	3,300
	50-63-011	East Moore Water District	3,248	6,592	6,320	6,547	6,783	7,027	7,280
	50-63-021	Moore County Public Utilities-High Falls	11	220	289	300	310	321	333
	03-63-103	Moore County Public Utilities-Hyland Hills	335	332	358	383	410	438	469
	03-63-108	Moore County Public Utilities-Pinehurst	12,450	19,625	17,095	19,511	22,268	25,415	29,005
	03-63-155	Moore County Public Utilities-Robbins	56	40	62	68	74	81	88
	03-63-117	Moore County Public Utilities-Seven Lakes	6,365	6,300	6,443	6,675	6,916	7,165	7,423
	03-63-045	Moore County Public Utilities-Vass	834	1,052	1,087	1,162	1,242	1,328	1,419
	03-63-015	Robbins Water System	1,332	1,108	2,008	2,286	2,400	2,500	2,600
New Hanover									
	04-65-010	Cape Fear Public Utility Authority - Wilmington	169,568	188,000	200,000	233,526	298,636	363,570	380,500
	04-65-015	Carolina Beach	11,900	4,300	13,800	13,800	13,800	13,800	13,800
Orange									
	03-68-015	***Hillsborough****	***12,216***	***13,705***	***16,800***	***20,100***	***24,200***	***29,000***	***33,800***
	03-68-010	***Orange Water and Sewer Authority****	***79,400***	***83,000***	***92,700***	***107,000***	***121,200***	***135,500***	***149,700***
	03-68-020	Orange-Alamance	8,282	8,568	9168	10168	11168	12168	13168
Pitt									
	04-74-025	Ayden	4,861	5,022	5302	5773	6100	6590	7090
	04-74-045	Bell Arthur WC	9,000	9,649	9800	9900	10000	10500	10550
	04-74-015	Eastern Pines Water Corporation	19,441	19,543	32,160	45,810	45,810	45,810	45,810
	04-74-035	Grifton	2,500	2,854	2,825	3,079	3,356	3,658	3,681
Randolph									
	02-76-030	Archdale	9,700	11,415	13,000	14,000	15,000	16,000	17,000
	02-76-035	Franklinville	1,380	1,164	1,250	1,300	1,400	1,500	1,600
	02-76-020	Ramseur	3,271	3,228	3517	3780	4064	4369	4696
	02-76-015	Randleman	4,113	4,163	4,700	5,100	5,500	5,900	6,300
Rockingham									
	02-79-020	Reidsville	14,637	14,463	16,033	16,650	17,066	17,492	18,399
	02-79-050	Rockingham Co		958	1,300	1,500	1,700	1,900	2,100
Wake									
	03-92-045	***Apex****	***37,700***	***44,348***	***53,100***	***74,400***	***100,500***	***109,200***	***112,200***
	03-92-020	***Cary****	***144,900***	***172,821***	***176,400***	***208,100***	***230,600***	***247,900***	***248,400***
	03-92-055	Fuquay-Varina	17,937	19,804	27,662	42,162	59,662	77,162	94,662
	03-92-050	***Holly Springs****	***24,700***	***30,071***	***46,710***	***61,920***	***74,821***	***89,041***	***103,261***
	03-92-010	***Raleigh****	***485,219***	***525,000***	***638,500***	***799,100***	***963,200***	***1,134,200***	***1,316,200***
Wayne									
	04-96-060	Fork Township SD	11,100	11,100	12410	14402	16714	19398	22512
	04-96-025	Fremont	1,463	1,258	1,324	1,257	1,195	1,135	1,053
	04-96-010	Goldsboro	33,312	37,051	41,356	47,559	54,698	62,902	72,337
	04-96-030	Pikeville	793	714	793	910	1,025	1,135	1,265
	04-96-065	Wayne WD	47,752	49,321	63,037	73,159	85,042	98,692	114,533
Wilson									
	04-98-020	Elm City	1,375	1,375	1400	1500	1525	1550	1575
	04-98-010	Wilson	51,000	53,000	54,500	59,400	64,700	70,500	76,800

9 Water Demands

This analysis answers the question: is there likely to be enough water available from a particular source to meet the 2060 demands of the public water systems that depend on that source? The results are based on output from the Cape Fear – Neuse River Basins Hydrologic Model, a computer modeling platform designed to characterize water resource systems. The details of the model are discussed in a later section of this document. The model does not limit withdrawals to protect ecological integrity or water quality in the vicinity of the withdrawal. Streamflows and water availability estimates generated by the model depend on the wastewater discharge volumes assumed in the model. If the assumptions about the proportions of withdrawals that are discharged as treated wastewater are changed then the flow estimates, and therefore the water availability estimates, will change.

The results of this analysis show that, based on the assumptions in the model, including some increases in water allocations from Jordan Lake reservoir, there appears to be enough water to meet the estimated withdrawals needed to meet 2060 public water supply demands. Some communities may have to implement their water shortage response plans during droughts to manage demand and some communities may have to develop additional infrastructure to make use of available supplies. The ability to develop efficient distribution systems and the ability to have water available when it is needed depends on additional factors such as funding and regional cooperation demand projections for each water system in this analysis are listed in Table 3, organized by county.

Table 3 shows the demand estimates compiled from independent projections for residential, commercial, institutional and industrial demands submitted by local officials in their local water supply plans. Table 4 shows demand estimates developed by DWR using the estimated service populations from the local water supply plans and the system-wide per capita water use (gallons per capita day, gpcd) from the 2010 local water supply plans.

Projecting demand strictly on increases in the number of residents served provides a general indication of demand growth. However, overall water system demands can be strongly influenced by industrial and commercial development within a utility’s service area. These uses are not necessarily linked directly to the number of residential users.

Table 3 Local Water Supply Plan Water Demand Estimates

Estimated Future Water Demands from 2014 Local Water Supply Plans in Million Gallons per Day							
ID#	Water System	Estimated Demand 2020	Estimated Demand 2030	Estimated Demand 2040	Estimated Demand 2045	Estimated Demand 2050	Estimated Demand 2060
Alamance							
02-01-035	Alamance	0.077	0.083	0.092	0.097	0.102	0.11
02-01-010	Burlington	7.007	7.855	8.807	9.340	9.873	11.07
02-01-025	Elon	0.725	0.857	0.991	1.054	1.117	1.248
02-01-015	Graham	2.294	2.5	2.718	2.833	2.947	3.166
02-01-030	Green Level	0.1	0.106	0.113	0.116	0.119	0.127
02-01-020	Haw River	0.221	0.232	0.267	0.287	0.307	0.353
02-01-018	Mebane	1.575	1.854	2.161	2.334	2.506	2.899
30-01-005	Swepsonville	0.144	0.172	0.206	0.230	0.254	0.307
Bladen							
50-09-012	Lower Cape Fear WSA - Bladen Bluffs	1.483	1.483	1.483	1.483	1.483	1.483
50-09-013	Lower Cape Fear WSA - Kings Bluff	0.06	0.06	0.06	0.06	0.06	0.06
Brunswick							
04-10-045	Brunswick County	10.848	12.46	13.916	14.499	15.082	16.538
04-10-070	Brunswick Regional WSD	2.12	2.58	3.193	3.270	3.347	3.584
04-10-055	Caswell Beach	0.257	0.257	0.257	0.257	0.257	0.375
04-10-060	Holden Beach	0.456	0.456	0.566	0.621	0.676	1.006
70-10-058	Leland	0.243	0.312	0.381	0.416	0.451	0.518
04-10-065	Navassa	0.106	0.113	0.121	0.128	0.134	0.147
70-10-045	Northwest	0.05	0.055	0.062	0.066	0.069	0.075
04-10-035	Ocean Isle Beach	1.075	1.391	1.391	1.391	1.391	1.391
04-10-020	Oak Island	0.975	1.409	1.593	1.699	1.804	2.066
04-10-025	Shallotte	0.396	0.416	0.438	0.449	0.46	0.484
04-10-010	Southport	0.632	0.691	0.921	0.979	1.036	1.139
04-10-130	Village Bald Head Island Utilities	0.213	0.225	0.237	0.243	0.249	0.261
Chatham							
40-19-010	Chatham County Asbury Water System	0.142	0.157	0.171	0.181	0.19	0.208
03-19-126	**Chatham County-North***	**5.290**	**8.330**	**11.920**	**13.035**	**14.150**	**18.120**
03-19-050	Chatham County Southwest Water System	0.297	0.34	0.387	0.416	0.445	0.497
03-19-025	Goldston Gulf SD	0.084	0.088	0.09	0.092	0.093	0.097
03-19-015	**Pittsboro***	**3.335**	**7.768**	**10.087**	**10.444**	**10.801**	**11.761**
03-19-010	Siler City	1.522	1.598	1.677	1.719	1.76	1.849
Cumberland							
50-26-027	Eastover Sanitary District	0.405	0.419	0.433	0.441	0.448	0.462
03-26-035	Falcon	0.062	0.065	0.068	0.070	0.071	0.076
03-26-010	Fayetteville	32.491	42.205	52.06	54.337	56.614	67.155
03-26-050	Godwin	0.012	0.012	0.012	0.013	0.014	0.014
03-26-045	Linden	0.123	0.123	0.126	0.126	0.126	0.126
50-26-019	Old North Utility Services, Inc.	4.301	4.408	4.518	4.575	4.631	4.746
03-26-020	Spring Lake	1.079	1.147	1.301	1.384	1.466	1.621
03-26-030	Stedman	0.088	0.097	0.113	0.115	0.117	0.121
Duplin							
04-31-044	Teachey	0.03	0.03	0.03	0.03	0.03	0.237
04-31-010	Wallace	1.221	1.452	1.651	1.753	1.855	2.047
Durham							
03-32-010	**Durham***	**30.660**	**34.140**	**38.100**	**39.975**	**41.850**	**44.370**
Granville							
02-39-015	Creedmoor	0.363	0.417	0.474	0.510	0.546	0.613
02-39-107	South Granville Water and Sewer Authority	2.568	2.826	3.11	3.265	3.419	3.76
40-39-004	Wilton Water and Sewer	0.016	0.016	0.016	0.016	0.016	0.016

Table 3 Local Water Supply Plan Water Demand Estimates (cont.)

Estimated Future Water Demands from 2014 Local Water Supply Plans in Million Gallons per Day							
ID#	Water System	Estimated Demand 2020	Estimated Demand 2030	Estimated Demand 2040	Estimated Demand 2045	Estimated Demand 2050	Estimated Demand 2060
Guilford							
02-41-025	Gibsonville	0.575	0.655	0.751	0.808	0.865	1.001
02-41-010	Greensboro	39.204	44.183	50.69	54.441	58.191	66.843
02-41-020	High Point	13.648	14.9	15.69	16.213	16.736	17.87
02-41-030	Jamestown	0.57	0.601	0.642	0.652	0.662	0.681
Harnett							
03-43-015	Angier	0.556	0.72	1.013	1.192	1.37	1.638
50-43-001	Bragg Communities	0.800	0.800	0.800	0.800	0.800	0.800
03-43-020	Coats	0.152	0.16	0.167	0.170	0.173	0.179
03-43-010	Dunn	2.013	2.049	2.087	2.107	2.126	2.165
03-43-045	Harnett County Regional Water System	9.649	11.259	12.944	13.918	14.891	17.143
03-43-025	Lillington	0.846	0.889	0.933	0.958	0.982	1.028
Hoke							
03-47-025	Hoke County Regional Water System	2.553	3.218	3.925	4.523	5.121	5.885
03-47-010	Raeford	2.488	2.535	2.594	2.630	2.665	2.735
Johnston							
03-51-025	Benson	0.854	0.875	0.886	0.902	0.918	0.939
03-51-020	Clayton	2.702	3.295	4.017	4.457	4.896	5.968
03-51-195	Flowers Plantation	0.339	0.355	0.385	0.389	0.393	0.402
03-51-035	Four Oaks	0.281	0.315	0.357	0.383	0.408	0.469
03-51-070	Johnston County	6.379	7.549	8.207	8.559	8.911	9.667
03-51-030	Kenly	0.231	0.243	0.271	0.285	0.298	0.313
40-51-008	Micro (County Line)	0.014	0.016	0.019	0.020	0.021	0.031
03-51-050	Princeton	0.174	0.218	0.272	0.307	0.341	0.427
03-51-010	Smithfield	2.005	2.165	2.526	2.712	2.897	4.308
Lee							
03-53-015	Broadway	0.118	0.141	0.161	0.172	0.183	0.209
03-53-101	Carolina Trace WS	0.231	0.231	0.231	0.231	0.231	0.231
03-53-010	Sanford	7.458	10.563	14.184	16.710	19.236	23.349
Lenoir							
04-54-030	Deep Run Water Corp	1.218	1.457	1.742	1.914	2.085	2.085
04-54-010	Kinston	5.12	5.545	5.97	6.195	6.42	6.87
60-54-001	Neuse Regional Water and Sewer Authority	1.63	1.63	1.63	1.630	1.63	1.63
04-54-025	North Lenoir Water Corp.	1.249	1.271	1.291	1.299	1.307	1.326
04-54-020	Pink Hill	0.07	0.071	0.072	0.072	0.072	0.072
Moore							
03-63-025	Carthage	0.531	0.567	0.588	0.589	0.589	1.353
50-63-011	East Moore Water District	0.332	0.359	0.416	0.455	0.493	0.556
50-63-021	Moore County Public Utilities-High Falls	0.005	0.005	0.005	0.005	0.005	0.005
03-63-103	Moore County Public Utilities-Hyland Hills	0.024	0.026	0.028	0.029	0.03	0.032
03-63-108	Moore County Public Utilities-Pinehurst	2.031	2.317	2.644	2.831	3.018	3.445
03-63-155	Moore County Public Utilities-Robbins	0.009	0.009	0.012	0.012	0.012	0.015
03-63-117	Moore County Public Utilities-Seven Lakes	0.401	0.415	0.431	0.440	0.448	0.463
03-63-045	Moore County Public Utilities-Vass	0.084	0.09	0.096	0.100	0.103	0.111
03-63-015	Robbins Water System	0.213	0.231	0.236	0.242	0.248	0.261

Table 3 Local Water Supply Plan Water Demand Estimates (cont.)

Estimated Future Water Demands from 2014 Local Water Supply Plans in Million Gallons per Day							
ID#	Water System	Estimated Demand 2020	Estimated Demand 2030	Estimated Demand 2040	Estimated Demand 2045	Estimated Demand 2050	Estimated Demand 2060
New Hanover							
04-65-010	Cape Fear Public Utility Authority - Wilmington	21.509	24.583	28.102	30.116	32.13	38.247
04-65-015	Carolina Beach	2.934	4.214	4.214	4.214	4.214	4.214
Orange							
03-68-015	**Hillsborough***	**2.318**	**2.701**	**3.037**	**3.207**	**3.377**	**3.697**
03-68-010	**Orange Water and Sewer Authority***	**8.320**	**9.680**	**10.790**	**11.325**	**11.860**	**12.910**
03-68-020	Orange-Alamance	0.704	0.725	0.744	0.755	0.765	0.784
Pender							
04-71-010	Burgaw	0.713	1.146	2.123	1.967	1.811	1.955
70-71-011	Pender County Utilities (Rocky Point-Topsail)	1.427	1.903	2.493	3.895	5.296	6.512
04-71-015	Surf City	0.565	0.671	0.793	0.865	0.937	1.112
04-71-020	Topsail Beach	0.340	0.340	0.340	0.340	0.340	0.340
Pitt							
04-74-025	Ayden	0.495	0.517	0.552	0.578	0.603	0.637
04-74-045	Bell Arthur WC	0.703	0.757	0.869	0.955	1.041	1.101
04-74-015	Eastern Pines Water Corporation	2.82	4.02	4.02	4.020	4.02	4.02
04-74-035	Grifton	0.197	0.208	0.214	0.217	0.219	0.232
Randolph							
02-76-030	Archdale	1.107	1.128	1.146	1.157	1.167	1.182
02-76-035	Franklinville	0.12	0.125	0.13	0.132	0.134	0.137
30-76-010	Piedmont Triad Regional Water Authority	0.77	1.11	1.44	1.830	2.22	2.22
02-76-020	Ramseur	0.349	0.375	0.404	0.418	0.432	0.461
02-76-015	Randleman	0.8	0.893	1.015	1.083	1.15	1.191
Rockingham							
02-79-020	Reidsville	3.545	3.683	3.792	3.840	3.887	4.032
02-79-050	Rockingham Co	0.184	0.202	0.221	0.230	0.239	0.257
Wake							
03-92-045	**Apex***	**4.791**	**6.92**	**9.369**	**9.848**	**10.327**	**10.54**
03-92-020	**Cary***	**23**	**29.2**	**33.4**	**34.700**	**36**	**36.2**
03-92-055	Fuquay-Varina	2.554	3.866	5.388	6.150	6.911	8.456
03-92-050	**Holly Springs***	**4.43**	**5.72**	**6.74**	**7.240**	**7.74**	**8.78**
03-92-010	**Raleigh***	**65.679**	**80.518**	**94.011**	**99.862**	**105.713**	**118.366**
Wayne							
04-96-060	Fork Township SD	0.916	1.063	1.234	1.333	1.431	1.661
04-96-025	Fremont	0.126	0.122	0.116	0.114	0.112	0.106
04-96-010	Goldsboro	5.331	6.015	6.775	7.204	7.632	8.601
04-96-030	Pikeville	0.059	0.067	0.077	0.082	0.086	0.091
04-96-065	Wayne WD	4.786	5.555	6.456	6.974	7.492	8.693
Wilson							
04-98-020	Elm City	0.144	0.154	0.164	0.169	0.174	0.184
04-98-010	Wilson	8.832	9.971	10.903	11.415	11.927	12.93

Table 4 Population Based Water Demand Estimates

(Estimated service population from Local Water Supply Plans multiplied by 2010 gallons per capita day water use)

Estimated Water Demands Based on 2010 Per Capita Use, 2014 LWSP Population Projections and Jordan Lake Allocation Requests* October 2016								
County	**System ID#**	**Water System**	***2010 gpcd***	**2020**	**2030**	**2040**	**2050**	**2060**
Alamance								
	02-01-035	Alamance	*128.00*	0.141	0.154	0.169	0.186	0.205
	02-01-010	Burlington	*173.42*	9.729	10.908	12.226	13.700	15.365
	02-01-025	Elon	*64.87*	0.795	0.952	1.109	1.266	1.422
	02-01-015	Graham	*128.83*	1.946	2.057	2.250	2.385	2.528
	02-01-030	Green Level	*34.12*	0.090	0.097	0.103	0.111	0.118
	02-01-020	Haw River	*90.91*	0.240	0.276	0.318	0.365	0.420
	02-01-018	Mebane	*109.72*	1.692	2.133	2.575	3.017	3.459
	30-01-005	Swepsonville	*103.12*	0.141	0.176	0.220	0.275	0.343
Brunswick								
	04-10-130	Bald Head Island Utilities Dept.	*1030.00*	0.211	0.237	0.247	0.258	0.268
	04-10-045	Brunswick County	*119.83*	11.548	14.023	16.631	19.029	21.883
	04-10-070	Brunswick Regional WSD	*88.65*	2.014	2.445	2.837	3.290	3.948
	04-10-055	Caswell Beach	*289.42*	0.148	0.148	0.148	0.148	0.148
	70-10-058	Leland	*100.00*	0.091	0.117	0.143	0.168	0.194
	04-10-065	Navassa	*43.68*	0.037	0.042	0.044	0.049	0.054
	70-10-045	Northwest	*119.05*	0.114	0.126	0.138	0.149	0.161
	04-10-020	Oak Island	*107.77*	1.692	1.800	1.907	2.015	2.123
	04-10-025	Shallotte	*205.71*	0.823	0.839	0.881	0.925	0.971
	04-10-010	Southport	*81.14*	0.446	0.463	0.487	0.536	0.552
Chatham								
	40-19-010	Chatham County Asbury Water System	*230.68*	0.272	0.316	0.367	0.426	0.494
	03-19-126	***Chatham County North Water System****	***190.10***	***4.924***	***7.908***	***10.893***	***13.953***	***17.869***
	03-19-050	Chatham County Southwest Water System	*144.75*	0.376	0.437	0.507	0.589	0.683
	03-19-025	Goldston Gulf SD	*36.73*	0.047	0.047	0.048	0.048	0.048
	03-19-015	***Pittsboro****	***168.38***	***4.041***	***9.867***	***13.453***	***14.666***	***16.299***
	03-19-010	Siler City	*240.83*	2.058	2.161	2.269	2.383	2.502
Cumberland								
	50-26-027	Eastover Sanitary District	*64.59*	0.494	0.501	0.509	0.517	0.525
	03-26-035	Falcon	*152.78*	0.116	0.125	0.139	0.146	0.154
	03-26-010	***Fayetteville****	***126.79***	***32.231***	***40.163***	***48.735***	***52.286***	***55.837***
	03-26-050	Godwin	*56.18*	0.014	0.015	0.016	0.016	0.016
	03-26-045	Linden	*93.73*	0.159	0.162	0.164	0.166	0.169
	50-26-019	Old North Utility Services, Inc.	*73.82*	5.772	5.916	6.064	6.216	6.371
	03-26-020	Spring Lake	*90.22*	0.872	0.963	1.063	1.174	1.296
	03-26-030	Stedman	*91.75*	0.096	0.101	0.106	0.115	0.119
Durham								
	03-32-010	***Durham****	***102.71***	***29.417***	***33.833***	***38.250***	***42.666***	***47.083***
Granville				0.000	0.000	0.000	0.000	0.000
	02-39-015	Creedmoor	*90.69*	0.678	0.948	1.217	1.487	1.487
	02-39-107	South Granville Water and Sewer Authority	*299.32*	6.212	6.833	7.516	8.268	9.095
	40-39-004	Wilton Water and Sewer	*22.22*	0.020	0.020	0.020	0.020	0.020
Guilford								
	02-41-025	Gibsonville	*96.32*	0.809	0.971	1.165	1.398	1.678
	02-41-010	Greensboro	*148.16*	44.441	50.346	58.062	66.960	77.221
	02-41-020	High Point	*120.17*	13.656	14.339	15.055	15.808	16.599
	02-41-030	Jamestown	*88.23*	0.618	0.662	0.723	0.750	0.776
	30-76-010	Piedmont Triad Regional Water Authority		0.000	0.000	0.000	0.000	0.000
Harnett								
	03-43-015	Angier	*63.41*	0.507	0.634	0.951	1.268	1.585
	50-43-001	Bragg Communities	*46.63*	0.273	0.273	0.273	0.273	0.273
	03-43-020	Coats	*64.56*	0.149	0.152	0.156	0.160	0.163
	03-43-010	Dunn	*205.87*	1.928	1.948	1.969	1.989	2.010
	03-43-045	Harnett County Regional Water System	*101.04*	12.622	14.626	16.632	18.912	21.505
	03-43-025	Lillington	*110.91*	0.458	0.481	0.505	0.530	0.583
Hoke Co								
	03-47-025	Hoke RWS	*58.68*	1.772	2.641	3.638	4.108	4.695
	03-47-010	Raeford	*403.64*	1.937	2.131	2.341	2.543	2.745

Table 4 Population Based Water Demand Estimates (cont.)

Estimated Water Demands Based on 2010 Per Capita Use, 2014 LWSP Population Projections and Jordan Lake Allocation Requests* October 2016								
County	System ID#	Water System	*2010 gpcd*	2020	2030	2040	2050	2060
Johnston								
	03-51-025	Benson	*161.21*	0.544	0.555	0.566	0.579	0.596
	03-51-020	Clayton	*142.21*	3.084	4.142	5.563	7.471	10.033
	03-51-195	Flowers Plantation	*200.44*	0.933	0.980	0.982	1.002	1.022
	03-51-035	Four Oaks	*86.77*	0.234	0.260	0.293	0.333	0.381
	03-51-070	Johnston County	*82.34*	6.637	7.987	8.970	9.984	11.102
	03-51-030	Kenly	*173.19*	0.244	0.246	0.249	0.251	0.254
	40-51-008	Micro (County Line)	*66.67*	0.002	0.002	0.003	0.003	0.004
	03-51-050	Princeton	*82.12*	0.102	0.107	0.112	0.117	0.122
	03-51-010	Smithfield	*180.72*	2.005	2.025	2.045	2.066	2.084
Lee								
	03-53-015	Broadway	*64.36*	0.119	0.136	0.156	0.180	0.205
	03-53-101	Carolina Trace WS	*51.83*	0.271	0.271	0.271	0.271	0.271
	03-53-010	Sanford	*143.01*	8.094	10.869	13.185	15.988	19.406
Lenoir								
	04-54-030	Deep Run WC	*72.27*	1.186	1.419	1.697	2.029	2.029
	04-54-010	Kinston	*125.34*	3.510	3.510	3.572	3.635	3.698
	04-54-025	North Lenoir Water Corp.	*68.10*	1.001	1.021	1.038	1.056	1.073
	04-54-020	Pink Hill	*63.87*	0.062	0.063	0.063	0.064	0.065
Moore								
	03-63-025	Carthage	*124.28*	0.323	0.348	0.373	0.398	0.410
	50-63-011	East Moore Water District	*72.97*	0.461	0.478	0.495	0.513	0.531
	50-63-021	Moore County Public Utilities-High Falls	*272.73*	0.079	0.082	0.085	0.088	0.091
	03-63-103	Moore County Public Utilities-Hyland Hills	*86.57*	0.031	0.033	0.035	0.038	0.041
	03-63-108	Moore County Public Utilities-Pinehurst	*156.39*	2.673	3.051	3.482	3.975	4.536
	03-63-155	Moore County Public Utilities-Robbins	*178.57*	0.011	0.012	0.013	0.014	0.016
	03-63-117	Moore County Public Utilities-Seven Lakes	*71.80*	0.463	0.479	0.497	0.514	0.533
	03-63-045	Moore County Public Utilities-Vass	*112.71*	0.123	0.131	0.140	0.150	0.160
	03-63-015	Robbins Water System	*124.62*	0.250	0.285	0.299	0.312	0.324
New Hanover								
	04-65-010	Cape Fear Public Utility Authority - Wilmington	*115.56*	23.112	26.986	34.510	42.014	43.970
	04-65-015	Carolina Beach	*121.85*	1.682	1.682	1.682	1.682	1.682
Orange								
	03-68-015	***Hillsborough****	***94.71***	***1.591***	***1.904***	***2.292***	***2.747***	***3.201***
	03-68-010	***Orange Water and Sewer Authority****	***96.94***	***8.986***	***10.373***	***11.749***	***13.135***	***14.512***
	03-68-020	Orange-Alamance	*78.24*	0.717	0.796	0.874	0.952	1.030
Pitt								
	04-74-025	Ayden	*91.75*	0.486	0.530	0.560	0.605	0.651
	04-74-045	Bell Arthur WC	*72.78*	0.713	0.721	0.728	0.764	0.768
	04-74-015	Eastern Pines Water Corporation	*78.75*	2.533	3.608	3.608	3.608	3.608
	04-74-035	Grifton	*67.20*	0.190	0.207	0.226	0.246	0.247
Randolph								
	02-76-030	Archdale	*116.80*	1.518	1.635	1.752	1.869	1.986
	02-76-035	Franklinville	*63.77*	0.080	0.083	0.089	0.096	0.102
	02-76-020	Ramseur	*121.98*	0.429	0.461	0.496	0.533	0.573
	02-76-015	Randleman	*235.59*	1.107	1.202	1.296	1.390	1.484
Rockingham								
	02-79-020	Reidsville	*249.50*	4.000	4.154	4.258	4.364	4.591
	02-79-050	Rockingham Co	*96.58*	0.107	0.124	0.140	0.157	0.173
Wake								
	03-92-045	***Apex****	***78.17***	***4.151***	***5.816***	***7.856***	***8.536***	***8.771***
	03-92-020	***Cary****	***119.43***	***21.068***	***24.854***	***27.542***	***29.608***	***29.667***
	03-92-055	Fuquay-Varina	*102.92*	2.847	4.339	6.140	7.941	9.742
	03-92-050	***Holly Springs****	***64.82***	***3.028***	***4.014***	***4.850***	***5.771***	***6.693***
	03-92-010	***Raleigh****	***105.11***	***67.110***	***83.989***	***101.237***	***119.210***	***138.339***
Wayne								
	04-96-060	Fork Township SD	*82.79*	1.027	1.192	1.384	1.606	1.864
	04-96-025	Fremont	*81.34*	0.108	0.102	0.097	0.092	0.086
	04-96-010	Goldsboro	*143.61*	5.939	6.830	7.855	9.033	10.388
	04-96-030	Pikeville	*138.71*	0.110	0.126	0.142	0.157	0.175
	04-96-065	Wayne WD	*78.26*	4.933	5.725	6.655	7.723	8.963
Wilson								
	04-98-020	Elm City	*114.18*	0.160	0.171	0.174	0.177	0.180
	04-98-010	Wilson	*133.88*	7.297	7.953	8.662	9.439	10.282

(Estimated service population from Local Water Supply Plans multiplied by 2010 gallons per capita day water use)

Table 4 Population Based Water Demand Estmates (cont.)

Estimated Water Demands Based on 2010 Per Capita Use, 2014 LWSP Population Projections and Jordan Lake Allocation Requests* October 2016								
County	**System ID#**	**Water System**	***2010 gpcd***	**2020**	**2030**	**2040**	**2050**	**2060**
Johnston								
	03-51-025	Benson	*161.21*	0.544	0.555	0.566	0.579	0.596
	03-51-020	Clayton	*142.21*	3.084	4.142	5.563	7.471	10.033
	03-51-195	Flowers Plantation	*200.44*	0.933	0.980	0.982	1.002	1.022
	03-51-035	Four Oaks	*86.77*	0.234	0.260	0.293	0.333	0.381
	03-51-070	Johnston County	*82.34*	6.637	7.987	8.970	9.984	11.102
	03-51-030	Kenly	*173.19*	0.244	0.246	0.249	0.251	0.254
	40-51-008	Micro (County Line)	*66.67*	0.002	0.002	0.003	0.003	0.004
	03-51-050	Princeton	*82.12*	0.102	0.107	0.112	0.117	0.122
	03-51-010	Smithfield	*180.72*	2.005	2.025	2.045	2.066	2.084
Lee								
	03-53-015	Broadway	*64.36*	0.119	0.136	0.156	0.180	0.205
	03-53-101	Carolina Trace WS	*51.83*	0.271	0.271	0.271	0.271	0.271
	03-53-010	Sanford	*143.01*	8.094	10.869	13.185	15.988	19.406
Lenoir								
	04-54-030	Deep Run WC	*72.27*	1.186	1.419	1.697	2.029	2.029
	04-54-010	Kinston	*125.34*	3.510	3.510	3.572	3.635	3.698
	04-54-025	North Lenoir Water Corp.	*68.10*	1.001	1.021	1.038	1.056	1.073
	04-54-020	Pink Hill	*63.87*	0.062	0.063	0.063	0.064	0.065
Moore								
	03-63-025	Carthage	*124.28*	0.323	0.348	0.373	0.398	0.410
	50-63-011	East Moore Water District	*72.97*	0.461	0.478	0.495	0.513	0.531
	50-63-021	Moore County Public Utilities-High Falls	*272.73*	0.079	0.082	0.085	0.088	0.091
	03-63-103	Moore County Public Utilities-Hyland Hills	*86.57*	0.031	0.033	0.035	0.038	0.041
	03-63-108	Moore County Public Utilities-Pinehurst	*156.39*	2.673	3.051	3.482	3.975	4.536
	03-63-155	Moore County Public Utilities-Robbins	*178.57*	0.011	0.012	0.013	0.014	0.016
	03-63-117	Moore County Public Utilities-Seven Lakes	*71.80*	0.463	0.479	0.497	0.514	0.533
	03-63-045	Moore County Public Utilities-Vass	*112.71*	0.123	0.131	0.140	0.150	0.160
	03-63-015	Robbins Water System	*124.62*	0.250	0.285	0.299	0.312	0.324
New Hanover								
	04-65-010	Cape Fear Public Utility Authority - Wilmington	*115.56*	23.112	26.986	34.510	42.014	43.970
	04-65-015	Carolina Beach	*121.85*	1.682	1.682	1.682	1.682	1.682
Orange								
	03-68-015	***Hillsborough****	***94.71***	***1.591***	***1.904***	***2.292***	***2.747***	***3.201***
	03-68-010	***Orange Water and Sewer Authority****	***96.94***	***8.986***	***10.373***	***11.749***	***13.135***	***14.512***
	03-68-020	Orange-Alamance	*78.24*	0.717	0.796	0.874	0.952	1.030
Pitt								
	04-74-025	Ayden	*91.75*	0.486	0.530	0.560	0.605	0.651
	04-74-045	Bell Arthur WC	*72.78*	0.713	0.721	0.728	0.764	0.768
	04-74-015	Eastern Pines Water Corporation	*78.75*	2.533	3.608	3.608	3.608	3.608
	04-74-035	Grifton	*67.20*	0.190	0.207	0.226	0.246	0.247
Randolph								
	02-76-030	Archdale	*116.80*	1.518	1.635	1.752	1.869	1.986
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	04-96-025	Fremont	*81.34*	0.108	0.102	0.097	0.092	0.086
	04-96-010	Goldsboro	*143.61*	5.939	6.830	7.855	9.033	10.388
	04-96-030	Pikeville	*138.71*	0.110	0.126	0.142	0.157	0.175
	04-96-065	Wayne WD	*78.26*	4.933	5.725	6.655	7.723	8.963
Wilson								
	04-98-020	Elm City	*114.18*	0.160	0.171	0.174	0.177	0.180
	04-98-010	Wilson	*133.88*	7.297	7.953	8.662	9.439	10.282

10 Cape Fear - Neuse River Basins Hydrologic Model Details

The modeling results are dependent on data availability and the accuracy of assumptions made about the future conditions.

The analysis presented in this report is based on combining water use data submitted by water users with that compiled by the DWR staff and consultants. The data are evaluated using a computer based hydrologic model designed to simulate the effects of water withdrawals on surface water availability. The results of the modeling give a hypothetical representation of changes in water quantity that may occur as surface water withdrawals vary. The results are dependent on data availability and the accuracy of presumptions made about future conditions. Changes in the data used or changes in the presumptions will produce different results.

An initial version of a Cape Fear River Basin Model was developed for analyzing the potential impacts of water supply allocations from B. Everett Jordan Lake that were approved in 2002. In 2007, the data compiled for the initial model were transferred to a different program platform called OASIS with OCL ™ developed by HydroLogics, Inc. OASIS is a generalized simulation program designed to characterize water resource systems. OCL, Operations Control Language, is a proprietary program that facilitates the customization of OASIS for specific applications. The resulting Cape Fear River Basin Hydrologic Model was developed in consultation with the major surface water withdrawers in the basin along with representatives of state and federal resource management agencies. During the updating process, the historic inflow data were updated to extend streamflow data used in the model through 2005.

For the analysis of this fourth round of allocations of water supply storage in Jordan Lake, the Cape Fear River Basin Hydrologic Model was combined with the existing Neuse River Basin Hydrologic Model. The combined Cape Fear – Neuse River Basins Hydrologic Model characterizes the effects of surface water withdrawals and water sharing among public utilities in both basins. During the process of merging the two models, inflow data were updated to capture flow conditions through September 2011. The basecase of the model processes the range of historical flows through the existing infrastructure and management protocols. Scenarios using expected future water withdrawals are processed to evaluate how resource conditions could vary in the future. The modeling for this analysis evaluates the surface water withdrawals needed to meet estimated 2060 water demands over the range of streamflows that occurred in these two basins between January 1930 and September 2011.

The DWR uses hydrologic modeling to evaluate surface water availability under various water withdrawal and management scenarios. A hydrologic model creates a hypothetical representation of surface water conditions based on available data and inferences based on known data to characterize the relationships between water withdrawals, return flows and management protocols. Each model produces a mathematical characterization of surface water volumes and streamflows based on conditions defined for a point in time when water withdrawals, wastewater discharges, and water management protocols are fixed and data describing the resultant surface water conditions are available. The model coding is adjusted to closely approximate the known conditions. This primary model scenario captures current conditions at the time of model development, based on conditions up to that time and provides the "basecase" for the model. The basecase scenario provides the benchmark against which the impacts from changes in management regimes and water withdrawals can be compared.

While future demand scenarios are typically designed using withdrawal levels thought to be needed to meet demands some year in the future, the model does not project future surface water flows. It evaluates various water demand quantities against the range of streamflows that have occurred in the historic record. Comparing model scenarios provides information to describe how surface water conditions may differ under the alternative scenarios from those of the basecase scenario, over the range of flow conditions that historically occurred in the basins.

The basecase scenario is a point in time with which people living and working in the basin are likely to have had direct experience. In the model used for this analysis, the basecase represents conditions in 2010. Looking at the outputs from the basecase of the model provides information on the magnitude and duration of water shortages that might have occurred with the 2010 levels of water demands during historic flow conditions or that may occur if similar flow conditions occur in the future. For instance, what might water resource conditions be like if water withdrawers were trying to meet 2010 water demands during the water availability conditions that existed during the 1954-55 drought?

Modeling the increased withdrawals needed to meet estimated future water demands provides information on how water resource conditions could be affected over the range of historic flow conditions used in the model. Of particular concern are the potential impacts to the ability to meet public water system demands and changes to the magnitude and duration of water shortages as demands increase.

The Cape Fear-Neuse River Basins Hydrologic Model analyzes changes in surface water quantity as water flows downstream. The model includes a sequential set of evaluation locations, referred to as model nodes, representing locations along the waterways in the Cape Fear and Neuse river basins. The model evaluates the effects of inflows, withdrawals and return flows over the range of flow conditions in these basins from 1930 to 2011. The model balances water coming into the surface water network with water going out of the network at all nodes, subject to the goals and constraints established at each node. Priority among multiple withdrawals at a particular node is regulated by a series of weighting coefficients used to set priority among multiple withdrawals at a node. For example, at reservoir nodes, water is stored and released subject to reservoir operating rules. If the reservoir has a required minimum downstream release of water, then that goal is given a higher priority and water is subtracted for that use before water is subtracted for other withdrawals. The model operates on a daily time step. Each model run makes one set of calculations based on daily average values for each of the 29,850 days of flow data in the model.

Future demand projections and the magnitude of water withdrawals needed to meet those demands were derived from data submitted to the division by local officials and water withdrawal managers. Future water demand projections for water systems not applying for a Jordan Lake allocation were taken from local water supply plans. Public water systems included in the model were asked to review the data included in the model basecase before finalization. Water systems that have reservoirs or multiple sources of water were specifically asked to review the data in the model describing reservoir capacity and how water demands are distributed between multiple sources. Revisions to the data submitted by the water utilities were incorporated into the model before this analysis was completed. Model scenarios were revised from the December 2015 draft document by updating future demands from 2014 local water supply plans for local governments not applying for an allocation from Jordan Lake. Also, withdrawals were added to account for potential expansions of electric generating facilities within the areas covered by the model.

Scope of the Model

The geographic scope of the model is limited by the fact that the model can only handle streamflow moving downstream. Therefore, the downstream limits of the model are set at a point upstream of where water begins to be tidally influenced and moves upstream in response to tidal actions. The Cape Fear portion of the model includes 5260 square miles of the basin above Lock and Dam #1 in Bladen County, including the drainage areas of the Deep River, the Haw River and the Cape Fear River. The Neuse River portion of the model includes 4060 square miles of the basin including the drainage areas of Contentnea Creek and the Neuse River upstream of New Bern.

The model schematic in Figure 6 shows the geographic coverage of the model and shows the relative location of the various model nodes. The nodes on the schematic are not geographically linked to the underlying map. The schematic shows the relative positions where water is withdrawn or added to the streams as it flows downstream. Each of the polygons in the schematic represents a node where the model performs a calculation to sum the effects of inflows and outflows of water.
Figure 7 provides a more detailed image of the model schematic in the vicinity of Jordan Lake.

Figure 6 Cape Fear – Neuse River Basins Hydrologic Model Schematic

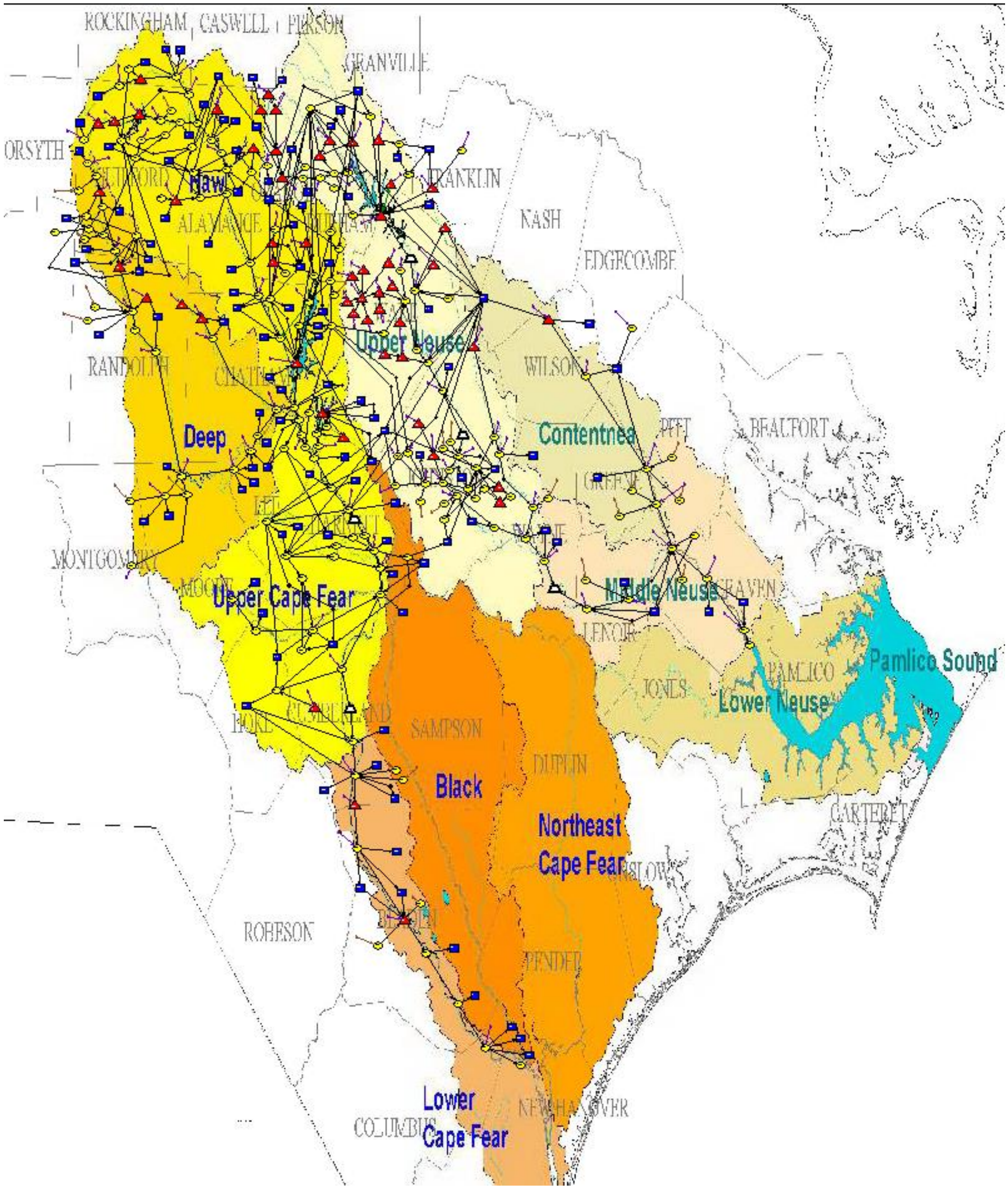
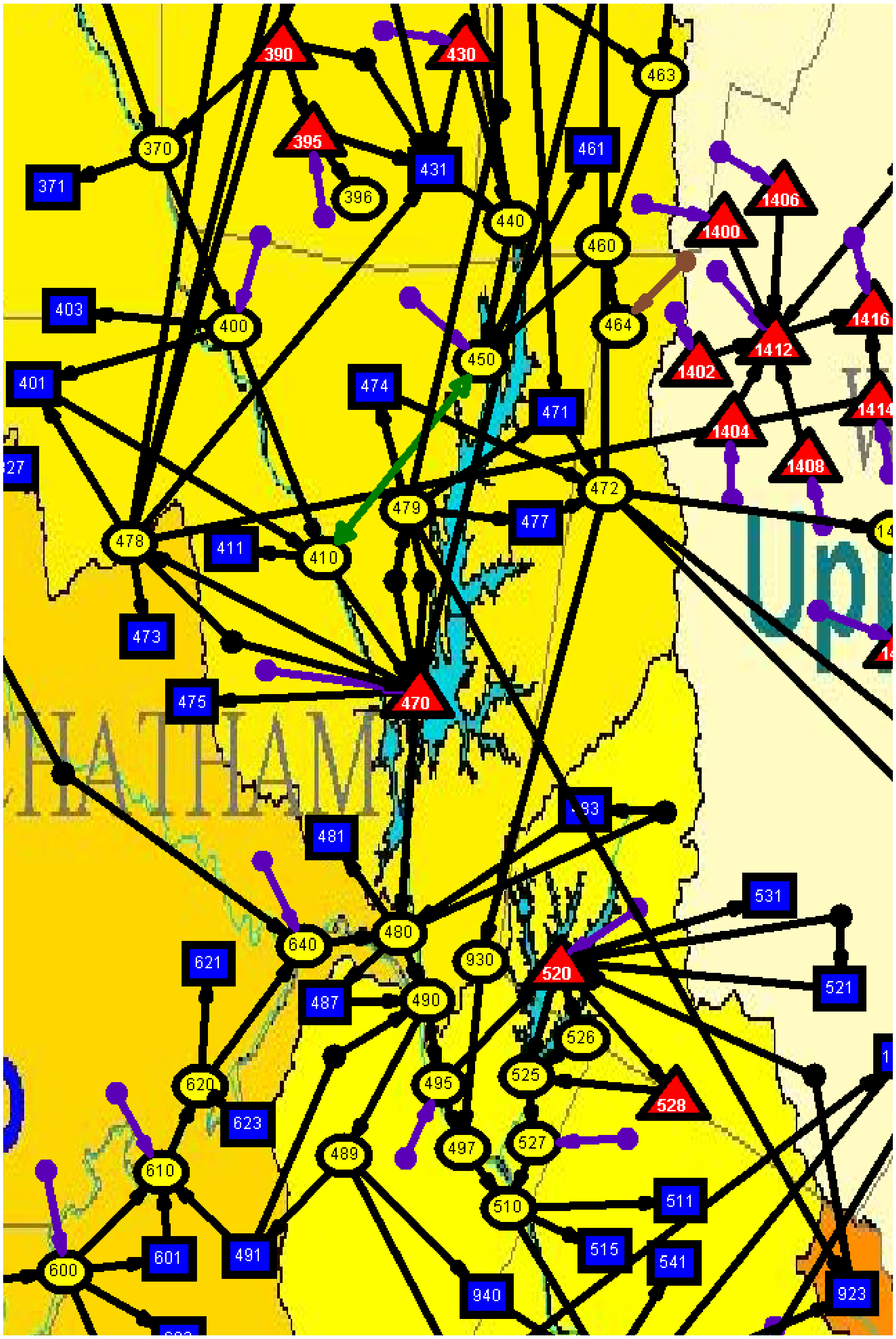


Figure 7 Cape Fear - Neuse River Basins Hydrologic Model Schematic Detail



Modeling the Cape Fear and Neuse River Basins

During each model run, the Cape Fear-Neuse River Basins Hydrologic Model balances surface water coming into and going out of the modeled streams at all nodes, subject to goals, constraints and management protocols defined for the scenario. Each type of water use is given a priority at each node during scenario development so that water is apportioned between competing uses to emulate real world conditions. At the reservoir nodes, water is stored and released subject to operating rules established in consultation with reservoir managers and users. For each scenario, the model calculates daily average values for the characteristics being considered at each node for each of the 29,850 days in the historic flow dataset.

For future demand scenarios, water systems that depend on neighboring water systems for their current water supplies are assumed to continue having their demands met by the same suppliers in the future, unless information is available describing planned changes.

Public water systems that submit a local water supply plan provide estimates of future water demands. The plans do not include estimates of future wastewater return flows. Therefore, for model scenarios other than the basecase scenario, wastewater return flows are estimated at the same percentage of water withdrawal or water use as that used in the 2010 basecase scenario, unless additional information is available. The actual amount of treated wastewater returned to the surface waters in these basins will be determined by the utilities' desire and ability to construct the necessary collection systems and treatment facilities as well as the ability to secure the necessary permits.

The results of the various modeling scenarios used for this analysis are inextricably linked to the assumptions about how much treated wastewater is returned to the surface waters of the basins. Changes in modeling assumptions will change the model outputs.

The model schematic above shows the relative position of features in the model as a series of lines, or arcs, leading into, out of, or connecting a variety of polygons called nodes. The color codes are explained below. The arrows on the arcs show how the model moves water. The nodes show points in the process where a mathematical evaluation is done to determine the cumulative effects of water withdrawals, water return flows and management protocols at that point in the flow sequence. The result of that calculation determines the volume of water that is passed downstream to the next node.

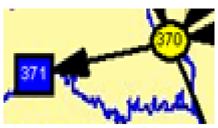
Estimated Inflows:

In the schematic watershed, inflows are shown as purple arcs. The model uses a set of historic flow data that was adjusted to approximate natural inflows to streams produced by surface water runoff and groundwater discharges. These inflow data were reconstructed using streamflow gage data to create 81 years of flow records that were adjusted for historic withdrawals, wastewater discharges, and reservoir operations. The inflows are introduced into the modeling sequence at discrete points throughout the watershed to reflect where the flow enters the river system relative to other model nodes.

Flows between nodes:

Water movement between model nodes is indicated by black arcs in the schematic. The direction of the arrows indicates the direction of flow through the arcs. The yellow oval nodes are junction nodes and indicate where a calculation has to be made to adjust for an addition or subtraction of water to the surface water system or a location where a calculation is needed to conduct the analysis for which the model is being used.

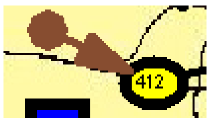
Water Withdrawals:



Arcs leading to a demand node, represented by blue boxes in the schematic, give the location of the withdrawal made to satisfy that demand relative to the locations of other withdrawals and return flows. Water withdrawals are made at discrete nodes to meet demands requested for the associated demand nodes. Withdrawals can be for water supply systems, industrial water users, or agricultural water uses. Public water supply withdrawals are based on local water supply plan data including projections of future demands. Self-supplied industrial water withdrawals were derived from data submitted to the Division under the water withdrawal registration program and comments to the December 2015 draft document. Demands for self-supplied industrial users are assumed to remain the same as in the 2010 basecase scenario through 2060 unless additional information is available to justify changes in projections. Agricultural withdrawals represent the estimated agricultural use on the watershed above the point of withdrawal. Agricultural withdrawals are not linked to specific agricultural operations.

Agricultural demands are the same as those used in previous versions of the individual basin models. Agricultural uses for livestock and irrigation were estimated with the help of county agricultural extension agents and an agricultural irrigation specialist. Water use estimates were developed for crops, taking into consideration variations in planting times in the upper, middle and lower regions of the basins. Irrigation water is withdrawn to make up for precipitation shortfalls to provide optimum crop needs. Livestock water needs are based on animal head counts in each county and the water needs of various animal types. Percentages of irrigated crops and livestock in a basin were developed for counties or drainage areas in consultation with county agricultural extension agents. Agricultural water withdrawals are distributed in the model based on the lands where the water is used.

Wastewater Inflows:



Black arcs leading out of a demand node give the relative location where wastewater from that user is returned to the surface waters of the basin. Return flows from wastewater discharges that are not linked to a water withdrawal in the model are represented in the schematic as brown arcs and are handled similar to natural inflows, as water inputs at discrete nodes. The sources of this water may be from users that get water from a neighboring subbasin or from groundwater sources. Inflows from wastewater discharges come from industrial operations and municipal water reclamation facilities.

Local water supply plans include estimates of expected future water withdrawals but do not include estimates of the expected portions of used water that may be collected for treatment and discharged to the surface waters being modeled. Assumptions about the magnitude of wastewater return flows are key factors in the hydrologic model. Wastewater discharges linked to a modeled withdrawal are estimated based on the percentage of a facility's water withdrawal that was directly returned to the surface waters of the basin in the basecase scenario. This percentage was then applied to estimated future withdrawals to estimate future wastewater return flows. For example, if a town withdrew 10 million gallons per day on average and returned 6 million gallons per day of treated wastewater in the basecase conditions, then 60 percent of the withdrawal was returned directly to the surface waters of the basin. In other scenarios, the assumed wastewater discharge, for this specific user, is assumed to be 60 percent of the withdrawal. This relationship is used for all wastewater discharges linked to a surface water withdrawal unless more specific information is available.

Wastewater return flows are included in the model to reflect reality. Without wastewater returns, the cumulative withdrawals in model scenarios would deplete the water resource system. The assumed volumes of wastewater returns are critical assumptions in the model. If communities choose not to develop wastewater treatment capacities at these levels or their ability to get permits to discharge the estimated volumes of wastewater modeled are limited by policy or funding then future surface water conditions could be significantly different from those shown in the current modeling.

The results of the various modeling scenarios used for this analysis are inextricably linked to the assumptions about how much treated wastewater is returned to the surface waters of the basins.

Reservoir Operations:

Reservoirs are represented by red triangles in the schematic. The model balances inflows and outflows at each node for each time step in a model run. For reservoirs, the change in storage is included in the balancing equation. Each reservoir in the model has a set of operating guidelines that set the maximum and minimum water levels during normal and extraordinary operating conditions. The largest reservoirs in the model, Jordan Lake and Falls Lake, are multipurpose reservoirs managed by the US Army Corps of Engineers. Both are required to make water releases established to minimize violations of water quality standards downstream. Jordan Lake and Falls Lake have storage dedicated for flow augmentation releases that is managed separately from the storage dedicated to water supply. The management plans for Jordan Lake and Falls Lake can be found at the Corp of Engineer's Wilmington District's website at epec.saw.usace.army.mil.

With the exception of the series of flood control impoundments in the Crabtree Creek watershed in the Neuse Basin, the other reservoirs in the model were primarily developed as water supply reservoirs. Some of the water supply reservoirs in the basins have minimum release requirements to maintain streamflows.

For instance, under normal conditions the managers of Randleman Lake maintain a minimum release of 30 cubic feet per second downstream of the reservoir. During times when inflows are not adequate to maintain 60 percent or more of usable storage the release requirements are reduced to more closely mimic the downstream flow conditions that would be typical of flow conditions during droughts. When usable storage drops below 60 percent, the required minimum release drops to 20 cubic feet per second. If storage drops below 30 percent of usable storage, the required release drops to 10 cubic feet per second. For reservoirs that have minimum release requirements, the stipulations of the release schedules are built into the model.

Model Scenarios:

Several levels of water demands were evaluated for this exercise. The 2010 base case scenario reflecting current conditions provides the point of comparison for all other model scenarios. Water demands and return flows were estimated using local water supply plan data, additional information received from water systems including Jordan Lake water supply allocation applications and data from other registered water users. The results of the alternative scenarios are compared to the basecase scenario to identify changes to surface water resources due to the variations in withdrawals, return flows and management protocols included in each alternative scenario.

The 2060 demand scenarios discussed in the report are based on the water withdrawals expected to be needed to meet 2060 demands as presented in the local water supply plans and information included in the applications submitted for water supply allocations from Jordan Lake. The model scenarios used include the levels of water supply allocations included in the December 2015 *Draft Jordan Lake Water*

Supply Allocation Recommendations. It provides a long-range picture of water resource conditions including the effects of the recommended water supply allocations. In previous rounds of Jordan Lake water supply allocations, members of the Environmental Management Commission asked DWR to provide an analysis over a 50-year planning horizon to identify potential water supply issues beyond the 30-year planning horizon used for allocation decisions.

Withdrawals and Discharges:

Table 6 lists the water supply nodes for the Cape Fear-Neuse River Basin Hydrologic Model and the average annual values used for water withdrawals and the estimated amounts of wastewater that was assumed to be collected, treated and discharged back to the surface waters at the current discharge locations. Some of these withdrawals represent the cumulative demands for multiple water purveyors that depend on water from that source to meet customer demands. Table 6 includes revisions to the version that was in the December 2015 draft document.

Table 6 Annual Average Surface Water Withdrawals and Wastewater Discharges

Modeled Annual Average Surface Water Withdrawals and Return Flows in Million Gallons per Day (MGD)						
Model Node	Surface Water Withdrawer	Wastewater Proportion	2010 Current Conditions	2045 Estimated Demand	2060 Estimated Demand	Estimate Type
31	Reidsville Demand_02-79-020		3.530	5.314	5.836	Demand
	Reidsville nc0046345 and nc0024881	0.594	2.097	3.156	3.466	WW Return
123	Greensboro Total Demand_02-41-010		35.240	54.4405	66.843	Demand
	Lake Townsend nc0081671	0.132	4.652	7.186	8.823	WW Return
	North Buffalo Creek nc0024325	0.283	9.973	15.407	18.917	WW Return
	Ozborne nc0047384	0.737	25.972	40.123	49.263	WW Return
	Mitchell nc0081426	0.02	0.705	1.089	1.337	WW Return
223	High Point Service Area Demand_02-41-020		12.640	16.213	17.87	Demand
	High Point nc0081256 and nc0024210	1.085	13.714	17.591	19.389	WW Return
261	City of Randleman Demand_02-76-015		0.400	1.083	1.191	Demand
	Randleman nc0025445	1	0.400	1.083	1.191	WW Return
271	PTRWA Total Withdrawal(supplied to others)		0.000	20.954	24.743	WW Return
	PTRWA WTP nc0087866	0.107	0.000	2.242	2.647	WW Return
301	Ramseur Demand_02-76-020		0.490	0.55	0.598	Demand
	Ramseur nc0026565	0.343	0.168	0.189	0.205	WW Return
321	Graham-Mebane Demand_02-01-015		3.500	6.912	8.449	Demand
	G-M nc0045292,nc0021211,nc0021474	0.773	2.706	5.343	6.531	WW Return
327	Siler City Demand_03-19-010		2.380	2.1395	2.351	Demand
	Siler City nc0026441	0.909	2.163	1.945	2.137	WW Return
341	Burlington Demand_02-01-010		15.030	14.114	16.331	Demand
	Mackintosh nc0023828	0.033	0.496	0.466	0.539	WW Return
	East nc0023868	0.335	5.035	4.728	5.471	WW Return
	Southside nc0023876	0.483	7.259	6.817	7.888	WW Return
401	Pittsboro Demand_03-19-015		0.600	10.440	11.760	Demand
	Pittsboro nc0020354	0.317	0.190	3.309	3.728	WW Return
431	OWASA Demand_03-68-010		7.700	11.320	12.910	Demand
	OWASA nc0025241	0.955	7.354	10.811	12.329	WW Return
471	Cary Apex water supply		18.400	39.150	41.400	Demand
	Cary Apex return	0.813	14.958	31.826	33.655	WW Return
	CarySystem WW (Cary,Apex,Morrisville,RTP)		16.953	37.090	39.133	WW Return
	Cary North WRF nc0048879	0.370	6.951	13.723	14.479	WW Return
	Cary South WRF nc0065102	0.230	5.255	8.531	9.001	WW Return
	Apex WRF nc0064050	0.050	2.543	1.854	1.957	WW Return
	Western Wake WRF nc0088846	0.35	0.000	12.981	13.697	WW Return
	Durham County Triangle WRF nc0026051		2.204	0.000	0.000	
473	Chatham Co. North Demand		2.200	13.030	18.120	Demand
	Chatham County - North nc0084093	0.139	0.306	1.811	2.519	WW Return
474	RTP Demand		0.600	3.200	3.300	Demand
	RTP return	0.603	0.362	1.930	1.990	WW Return
477	Morrisville demand		1.700	3.470	3.630	Demand
	Morrisville return	0.961	1.634	3.335	3.488	WW Return
483	Performance Fibers Demand		0.200	0.168	0.168	Demand
	Performance Fibers nc0001899	0.972	0.194	0.163	0.163	WW Return
487	Cape Fear Steam Station Demand		218.300	0.000	0.000	Demand
	Cape Fear Steam Station nc0003433	0.989	215.899	0.000	0.000	WW Return

Table 6 Annual Average Surface Water Withdrawals and Wastewater Discharges

Modeled Annual Average Surface Water Withdrawals and Return Flows in Million Gallons per Day (MGD)						
Model Node	Surface Water Withdrawer	Wastewater Proportion	2010 Current Conditions	2045 Estimated Demand	2060 Estimated Demand	Estimate Type
491	Sanford Water Supply Demand		6.231	17.39	24.09	Demand
	Sanford nc0002861 and nc0059242	0.103	0.642	1.791	2.482	WW Return
	Sanford nc0024147	0.623	3.882	10.831	15.011	WW Return
515	Duke Energy Future Electric Generation (net withdrawal)			8.000	8.000	Net Withdrawal
521	Duke Energy Harris Nuclear Station (2045, 2060 net withdrawal)		20.000	48.000	48.000	Demand
	Harris Nuclear Station nc0039586	0.518	12.320			WW Return
551	Harnett County RWS Demand		10.137	34.624	42.644	Demand
	Harnett Co WW nc0007684, nc0021636,nc0088366	0.575	5.829	19.909	24.520	WW Return
601	Pilgrims Pride Demand		0.970	0.741	0.741	Demand
	Pilgrims Pride nc0083852	0.053	0.051	0.039	0.039	WW Return
605	Goldston-Gulf WS PWS 03-19-025		0.000	0.000	0	Demand
654	Angier Demand		0.415	1.192	1.638	Demand
	Angier WW to Harnett Co RWS	0.883	0.366	1.052	1.446	WW Return
663	Dunn Demand		3.410	3.475	3.597	Demand
	Dunn nc0078955 and nc0043176	0.683	2.329	2.373	2.457	WW Return
674	Carolina Trace WS_03-53-101		0.215	0.231	0.231	Demand
	Carolina Trace nc0038831	1	0.215	0.231	0.231	WW Return
695	Duke Energy Future Electric Generation (net withdrawal)			4.000	4.000	Net Withdrawal
701	Carthage Demand_03-63-025		0.300	0.589	1.353	Demand
	WW sent out of model boundary		0.000	0.000	0.000	WW Return
719	Spring Lake WS_03-26-020		0.909	1.384	1.621	Demand
	Spring Lake nc0030970	0.833	0.757	1.152	1.350	WW Return
721	Old North Ut. FBragg Demand_50-26-019		4.800	4.575	4.746	Demand
	Old North Utilities WW to Harnett Co. RWS	1	4.800	4.575	4.746	WW Return
733	FayettevillePWC Demand_03-26-010		26.228	60.582	73.464	Demand
	Fayetteville PWC nc0076783 and nc 0023957	0.487	12.773	29.503	35.777	WW Return
	Fayetteville PWC nc0050105	0.517	13.560	31.321	37.981	WW Return
735	Duke Energy Future Electric Generation (net withdrawal)			8.000	8.000	Net Withdrawal
771	Monsanto WS Net Withdrawal		0.000	0.000	0.000	Demand
781	Dupont WS		11.170	11.170	11.170	Demand
	Dupont nc0003573	1	11.170	11.170	11.170	WW Return
785	LCFWSA_BladenBluff Demand_50-09-012			1.483	1.483	Demand
	Smithfield Packing-Tarheel Plant nc0078344	1	0.000	1.483	1.483	WW Return
823	Cape Fear PUA-Wilmington Demand_04-65-010		4.670	24.0928	30.5976	Demand
825	LCFWSA_KingsBluff Demand_50-09-013		25.540	27.274	32.915	Demand
903	Jamestown Demand_02-41-030		0.450	0.652	0.681	Demand
904	Archdale Demand Randleman_02-76-030		0.700	1.1565	1.182	Demand
	Archdale WW to High Point	1	0.700	1.157	1.182	WW Return
906	Randolph Co Demand Randleman		0.000	0.000	0.000	Demand
921	Orange Co Demand		0.000	2.810	3.920	Demand
	Orange Co WW to Mebane	0.493	0.000	1.385	1.933	WW Return
	Orange Co WW to Durham	0.22	0.000	0.618	0.862	WW Return
	Orange Co WW to Hillsborough	0.287	0.000	0.806	1.125	WW Return

Table 6 Annual Average Surface Water Withdrawals and Wastewater Discharges

Modeled Annual Average Surface Water Withdrawals and Return Flows in Million Gallons per Day (MGD)						
Model Node	Surface Water Withdrawer	Wastewater Proportion	2010 Current Conditions	2045 Estimated Demand	2060 Estimated Demand	Estimate Type
923	Holly Springs Demand_03-92-050		1.600	7.240	8.780	Demand
	Holly Springs nc0063098	0.789	1.262	5.712	6.927	WW Return
940	Broadway WS_03-53-015		0.095	0.172	0.209	Demand
	Broadway nc0059242	0.66	0.063	0.114	0.138	WW Return
1046	Orange_Alamance Demand_03-68-020		0.180	0.226	0.235	Demand
	Orange-Alamance nc0082759	0.092	0.017	0.021	0.022	WW Return
1106	Hillsborough Demand_03-68-015		1.160	3.220	3.700	Demand
	Hillsborough nc0026433	0.644	0.747	2.074	2.383	WW Return
1116	Piedmont Minerals Demand		0.000	0.000	0.000	Demand
			0.000	0.000	0.000	WW Return
1162	Durham Service Area Demand		28.230	40.000	44.370	Demand
	Durham Ellerbe Creek nc0023841	0.329	9.288	13.160	14.598	WW Return
	South Durham WRF nc0047967	0.375	10.586	15.000	16.639	WW Return
	Durham County Triangle WRF nc0026051	0.13	3.670	5.200	5.768	WW Return
1256	SGWASA Demand_02-39-107		2.990	3.7855	4.384	Demand
	SGWASA nc0026824	0.624	1.866	2.362	2.736	WW Return
1258	Creedmor Demand_02-39-015		0.320	0.521	0.624	Demand
	Included in SGWASA					WW Return
1306	Raleigh Demand_03-92-010		52.000	97.000	115.010	Demand
	Raleigh nc0029033	0.853	44.356	82.741	98.104	WW Return
	Raleigh nc0079316	0.014	0.728	1.358	1.610	WW Return
	Raleigh nc0030759	0.0244	1.269	2.367	2.806	WW Return
Raleigh future return for presumptive JLA allocation		0.7626	3.584	3.584	3.584	WW Return
1506	Wilson Demand_04-98-010		8.960	11.584	13.114	Demand
	Wilson nc0023906	0.866	7.759	10.032	11.357	WW Return
1646	Johnston County Demand_03-51-070		8.560	14.404	17.453	Demand
	Johnston County nc0030716	0.257	2.200	3.702	4.485	WW Return
	Johnston County to Benson	0.015	0.128	0.216	0.262	WW Return
	Kenly nc0064891	0.048	0.411	0.691	0.838	WW Return
	Clayton nc0064564 and nc0025453	0.263	2.251	3.788	4.590	WW Return
1666	Smithfield Demand_03-51-010		2.960	3.879	5.723	Demand
	Smithfield to Johnston County	0.785	2.324	3.045	4.493	WW Return
1706	Fuquay-Varina Demand_03-92-055		1.870	6.150	8.456	Demand
	Fuquay-Varina to Harnett Co RWS	0.483	0.903	2.970	4.084	WW Return
	Fuquay-Varina nc0066516 and nc0066150	0.336	0.628	2.066	2.841	WW Return
1756	Benson Demand_03-51-025		0.775	0.912	0.949	Demand
	Benson nc0020389	0.333	0.258	0.304	0.316	WW Return
1766	Progress Lee Steam Plant Demand_CUR0001 (Net) (Includes additional Combined Cycle Plant after 2045)		8.910	8.360	8.360	Demand
1786	Goldsboro Demand_04-96-010		4.780	8.1925	11.312	Demand
	Goldsboro nc0023949	1.408	6.730	11.535	15.927	WW Return
1806	Neuse Regional WASA_60-54-001		7.820	12.7635	13.858	Demand
	NRWASA nc0088111	0.068	0.532	0.868	0.942	WW Return
	Kinston nc0024236	0.629	4.919	8.028	8.717	WW Return
	Ayden-Grifton WW	0.173	1.353	2.208	2.397	WW Return
1906	Weyerhauser Demand_CUR0052		14.470	14.9	14.9	Demand
	Weyerhauser nc0003191	0.973	14.079	14.498	14.498	WW Return

11 B. Everett Jordan Dam and Reservoir Management

The Cape Fear River experienced several significant flooding events prior to the devastating flood of September 1945 which produced $4.7 million dollars of damage[16] in Fayetteville. The Deep River Subbasin and Haw River Subbasin received about six inches of precipitation during the first week of September that year producing river flows at Lillington, upstream of Fayetteville, of 140,000 cubic feet per second. The citizens of Fayetteville saw the Cape Fear River rise to 68.9 feet above mean sea level, more than 33 feet above flood stage. Shortly after this event, the U.S. Congress commissioned the U.S. Army Corps of Engineers to study water resource needs in the basin.

In 1963, based on the results of the study, the U.S. Congress authorized the construction of "New Hope Reservoir" on the Haw River to address issues identified by the USACE. The project was later renamed in honor of U.S. Senator B. Everett Jordan. "The purposes of B. Everett Jordan Dam and Lake are to provide flood damage reduction, water supply, water quality control, fish and wildlife conservation and outdoor recreation."[17]

B. Everett Jordan Dam created 538,400 acre-feet[18] of storage to reduce flooding damages downstream. The project provides controlled releases of stored water produced by high flow events in the Haw River Subbasin. The project also includes 94,600 acre-feet of storage to provide water for flow augmentation to address water quality issues downstream. During the study, the State of North Carolina agreed to assume financial responsibility for expanding the storage capacity with the goal of providing 100 million gallons per day of water to address future water supply needs. Therefore, the project includes 45,800 acre-feet of storage for water supply needs. In addition, 74,700 acre-feet of storage are included to provide the ability to compensate for space lost to the water supply and flow augmentation pools due to sediment accumulation over the life of the project

During normal operations, the management goal for the reservoir is to maintain water level at 216 feet above mean sea level. At this level, the conservation pool is full. Water in the conservation pool, storage between 202 feet mean sea level and 216 feet mean sea level, is dedicated to flow augmentation and water supply. The storage below 202

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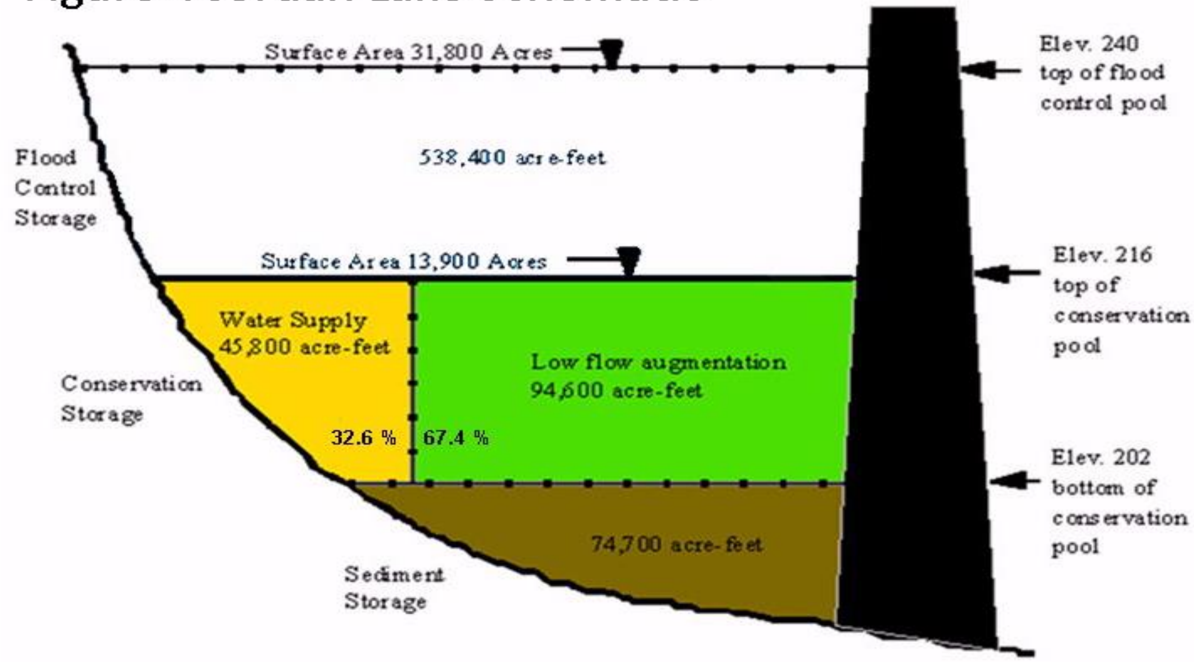
[16] 2007; Carolina Public Health; "The Lake That Almost Wasn't"; Spivey, Angela; Fall 2007
[17] http://www.saw.usace.army.mil/Locations/DistrictLakesandDams/BEverettJordan.aspx
[18] 538,400 acre-feet can hold 175.4 billion gallons of water

feet mean sea level is reserved to compensate for sediment accumulation in the reservoir. Withdrawals from the flow augmentation account and the water supply accounts are tracked separately and deducted from the volumes stored for each purpose. It is helpful to think of the two water storage accounts as two separate reservoirs. Water in the flow augmentation account is not used for water supply and water in the water supply account is not used to augment streamflow below the dam. The upper level of controllable flood storage is at 240 feet mean sea level. Above this elevation water flows freely over the spillway.

Figure 4 Jordan Lake Schematic



The tropical storm that generated flooding in Fayetteville in 1945 deposited about six inches of rain across the Cape Fear River Basin. The headwaters of the Cape Fear River basin are composed of the Deep River Subbasin and the Haw River Subbasin. B. Everett Jordan Dam is located on the Haw River upstream of where it joins the Deep River to form the Cape Fear River. Although usually empty, the flood control storage component of Jordan Lake is designed to retain the runoff from six inches of rainfall on the reservoir's watershed. Water in the flood storage pool can be released from the dam in a controlled manner to manage water levels downstream.

Prior to October 2016, the highest flows in Fayetteville since the completion of Jordan Lake were generated by Hurricane Fran. On September 8,1996, the Cape Fear River elevation at Fayetteville reached 44 feet mean sea level. This was above the minor flooding elevation of 35 feet but below the moderate flooding elevation of 48 feet and well below the 1945 flood elevation of 68.9 feet. The previous day, flows in the Deep River near the confluence with the Haw River reached 33,600 cubic feet per second producing flows of 41,400 cubic feet per second at the Lillington stream gage. At the same time, Jordan Lake was storing about 58,000 cubic feet per second of water that was flowing down the Haw River above the dam. The water level in Jordan Lake eventually reached 233.25 feet mean sea level storing about 341,409 acre-feet (over 111 billion gallons) of water in the flood control pool and moderating water levels in Fayetteville.[19] The intended flood control benefits of Jordan Lake were demonstrated during this event.

In October 2016, Hurricane Mathew brought significant rainfall to Eastern North Carolina. In the Cape Fear River Basin, more precipitation fell downstream of Jordan Lake than upstream producing water levels in Fayetteville of 58.9 feet above mean sea level. This was a new post-Jordan Lake high.

The Cumberland County Multi-Jurisdictional Hazard Mitigation Plan Update of 2010 includes the following statement. “Although the Jordan Dam and Lake serve multiple purposes, such as water supply, recreation, and flood-control, it is the flood-control purpose that is most important in Fayetteville. For example, it is estimated that this project provided an 8-foot reduction in the 100-year flood stage at the U.S. Geological Survey’s streamflow gage on the Cape Fear River at Fayetteville.”[20]

Flow Augmentation for Water Quality

While flood control was the primary purpose for initiating the study of water resource needs in the Cape Fear River Basin, the issue of water quality arose during the study. The U.S. Army Corps of Engineers consulted with the U.S. Public Health Service for guidance on how much streamflow may be needed to meet water quality targets. The USPHS estimated that a flow of 600 cubic feet per second would be needed to meet water quality targets, given the standards of treatment at the time and volumes of wastewater received by the Cape Fear River.[21] The flow augmentation pool, 67.38 percent of the conservation pool, was designed to provide enough water to augment river flows to ensure flows of 600 cubic feet per second at the U.S. Geological Survey’s

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[19] The National Oceanographic and Atmospheric Administration and the U.S. Geological Survey designate an elevation of 58 feet mean sea level in the Cape Fear River at Fayetteville as the indicator of a major flooding event. This water level would be produced by stream flows in the range of 85,000 cubic feet per second. If the 58,000 cubic feet per second of water flow down the Haw River continued downstream rather than being retained in Jordan Lake flows at the Lillington stream gage could have reached over 99,000 cubic feet per second, a level sufficient to push water levels in Fayetteville into the major flood classification.

[20] 2010; Cumberland County Multi-Jurisdictional Hazard Mitigation Plan Update; prepared by: Comprehensive Planning Section of the Cumberland County Planning & Inspections Department and The Fayetteville Planning Department; March 2011

[21] 1990; Testimony of John N. Morris, Director, Division of Water Resources: Transcript of Fayetteville Area Chamber of Commerce; The Lower Cape Fear Water and Sewer Authority; the Counties of Bladen, Brunswick, Columbus, New Hanover, Pender and the City of Wilmington; Mike Pleasant, President and the Fayetteville Area Economic Development Corporation; City of Fayetteville, a North Carolina Corporation; and the County of Cumberland v. North Carolina Department of Environment, Health and Natural Resources and the Environmental Management Commission: August 16, 1990: Raleigh, NC: before Beecher R. Gray, Senior Administrative Law Judge.

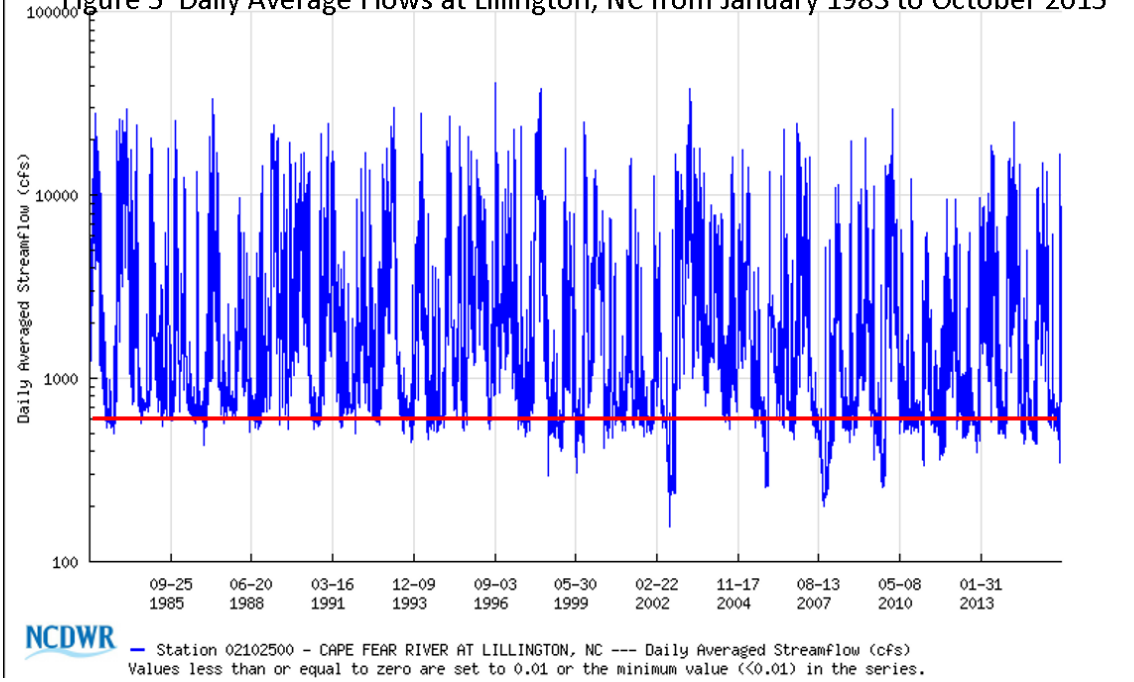
stream gage on the Cape Fear River at Lillington. This level of flow is equivalent to 388 million gallons per day. Prior to the completion of Jordan Lake, the low flow of record at Lillington was 11 cubic feet per second in October 1954. Since completion of Jordan Lake Dam and initiation of flow augmentations, the lowest daily average flow at Lillington reported by the U.S. Geological Survey is 155 cubic feet per second in August 2002.

River flows at Lillington are comprised mainly of the combined flows of the Deep River and Haw River supplemented by the contributions of runoff between the confluence of these rivers and the stream gage. The steam gage at Lillington was set as the compliance point for monitoring flow augmentation releases from Jordan Lake. Jordan Lake is managed to maintain water levels at 216 feet above mean sea level. Inflows that raise the water above this elevation are released downstream, except during flooding conditions. Releases from the flow augmentation account are made, when needed, to supplement flows from other sources with the goal of meeting streamflow targets at the Lillington stream gage.

Flows from the Deep River are influenced by the effects of several small hydropower operations on the river. Prior to the drought of 1986, the Army Corps of Engineers was managing downstream releases from Jordan Lake to prevent flows at Lillington from dropping below 600 cubic feet per second. Because of the unpredictable nature of flows from the Deep River, releases from Jordan Lake were frequently more than what was needed to meet the target flow at Lillington. During the drought of 1986, water levels in Jordan Lake were drawn down eight feet below the normal pool elevation of 216 feet mean sea level, with no withdrawals for water supply. In order to preserve the water remaining in the flow augmentation pool, the target flow was temporarily reduced to 450 cubic feet per second.[22] A follow-up study recommended creating a 50 cubic feet per second buffer on either side of the 600 cubic feet per second flow target to provide more leeway meeting the target and to improve the reliability of the flow augmentation pool. The current flow target is 600 ± 50 cubic feet per second representing a range of flows between 355 and 421 million gallons per day at Lillington.

[22] 1987; NC Department of Natural Resources and Community Development; Draft Report, Jordan Lake Hydrology and Downstream Water Quality Considerations.

Figure 5 Daily Average Flows at Lillington, NC from January 1983 to October 2015



If inflows to the reservoir are greater than water withdrawals and losses from evaporation, the remainder will be released downstream. Therefore, much of the time water does not need to be released from the flow augmentation pool to meet the target flows downstream. Figure 5 shows the daily average streamflows at Lillington since January 1983 with a reference line at 600 cubic feet per second. During this period, flows have been above the target more than 80 percent of the time. More than 50 percent of the time flows have exceeded 1000 cubic feet per second. The ability to use water from the flow augmentation pool is critical to maintaining downstream flows when inflows the river system decline between precipitation events and during droughts. Augmenting streamflows helps protect downstream water quality and increases the reliability of water sources for communities that rely on the Cape Fear River for their public water supply.

Severe drought conditions from 1998 through 2002 again required temporarily reducing flow targets at Lillington to preserve storage in the flow augmentation pool. In 2008, the USACE adopted a revised drought management plan that prescribes a progressive reduction in the flow target as the flow augmentation pool is depleted during periods of low inflows to the reservoir. Stepped reductions begin when storage in the flow augmentation pool drops below 80 percent. This protocol is now implemented automatically as storage declines in the flow-augmentation pool.

Water Supply

The State of North Carolina oversees the allocation of the dedicated water supply pool in Jordan Lake, 32.62 percent of the conservation pool, designed to provide 100 million gallons per day of water. Under General Statute § 143-354 (a) (11) the General Assembly authorized the Environmental Management Commission to allocate water supply storage in Jordan Lake to local governments upon proof of need and the commitment to pay the capital, interest, administrative and operating costs based on the volume allocated.

The rules allow the EMC to make allocations sufficient to meet applicants' water supply needs over a 30 -year planning horizon designating two levels of allocations based on how soon the allocation will be used. For allocation requests where the withdrawal or return flows would be a transfer of surface water requiring an interbasin transfer certificate, the review of the application for an interbasin transfer certificate must be coordinated with the review of the allocation request. [23]

At the time the rules were being formulated, Jordan Lake was relatively new and no water was being withdrawn for water supply purposes. Due to the uncertainty of whether the desired water supply demands and flow augmentation requirements could be met as water supply withdrawals increased, the rules limited diversions out of the Jordan Lake watershed. Allocations that would result in a diversion out of the watershed were limited to 50 percent of the water supply pool yield, assumed to be 100 mgd. This rule did give the EMC the authority to "review and revise this limit based on experience in managing the lake and on the effects of changes in the lake's watershed that will affect its yield".[24] Since 1988 there have been changes on the watersheds above Lillington that have enhanced the reliability of the water supply and flow augmentation pools in Jordan Lake. Table 5 shows the current status of allocations from the Jordan Lake water supply pool. Estimations of the potential yield of the water supply pool under various configurations of the ultimate fate of the withdrawn water are presented in Table 11.

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[23] http://www.ncwater.org/?page=297 15A NCAC 02G .0504 (h)

[24] 15A NCAC 02G .0504 (h) To protect the yield of Jordan Lake for water supply and water quality purposes, the Commission will limit water supply allocations that will result in diversions out of the lake's watershed to 50 percent of the total water supply yield. The Commission may review and revise this limit based on experience in managing the lake and on the effects of changes in the lake's watershed that will affect its yield.

Table 5 Current allocations from the Jordan Lake Water Supply Pool

Current Jordan Lake Water Supply Allocations	
Allocation Holder	Percent of Water Supply Pool
Cary Apex Morrisville RTP	39
Chatham County-North	6
Durham	10
Holly Springs	2
Orange Water & Sewer Authority	5
Orange County	1
Total Allocated	63

12 Modeling Details for B. Everett Jordan Reservoir

Jordan Lake Operations:

B. Everett Jordan Reservoir is a multipurpose reservoir built and managed by the US Army Corps of Engineers. It was authorized for flood control, water supply, water quality, recreation, and fish and wildlife conservation. The storage volume of the impoundment is subdivided based on elevation above sea level. The normally empty space between 216 feet and 240 feet above mean sea level, designated as the flood control pool, can retain the runoff from about six inches of rainfall on the watershed in its 538,000 acre feet of controlled flood storage.

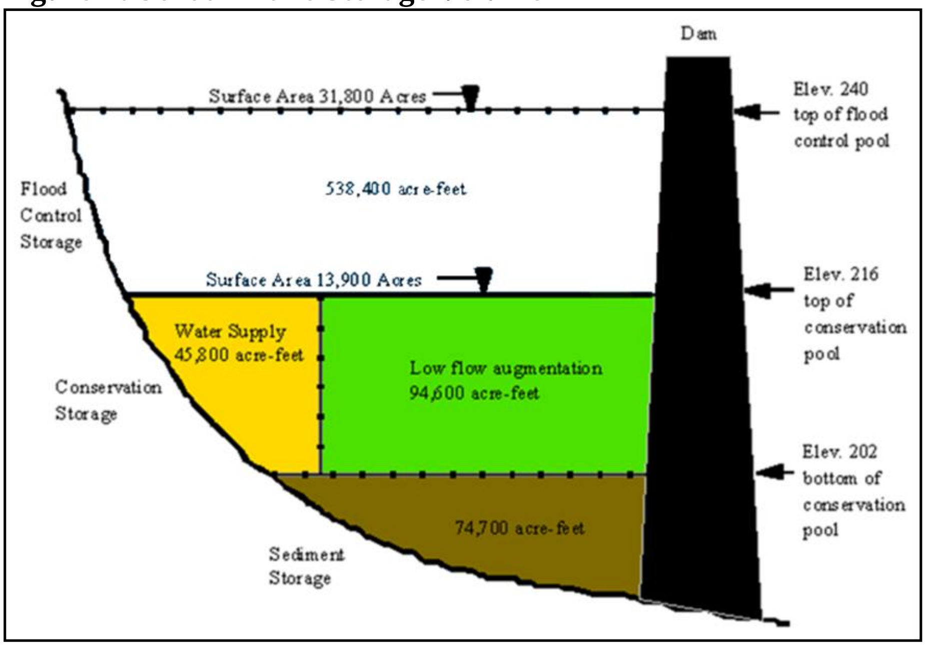
The conservation pool, between 202 and 216 feet above mean sea level, provides storage for water supply and storage for flow augmentation releases to protect water quality downstream. Under normal conditions, water level in the reservoir is maintained at the top of the conservation pool. At this elevation, the reservoir covers 13,900 acres. The conservation pool includes approximately 140,400 acre-feet of storage. The conservation pool is managed as two separate pools of water, separate accounting for each pool. The 74,700 acre-feet of storage below 202 feet mean sea level is reserved to compensate for lost storage volume in the conservation pool due to sediment accumulation.

The 45,800 acre-feet in the water supply pool, reserved for water supply and allocated by the State of North Carolina, contains about 15 billion gallons of water that can reliably supply 100 million gallons per day for local government water systems. The 94,600 acre-feet in the flow augmentation pool is used to supplement downstream river flows. When the releases to maintain water levels at 216 feet mean sea level in combination with tributary inflows below the dam are not sufficient to meet the flow target at Lillington, water is released from this pool to augment downstream flows.

When the project was being designed, the flow target of 600 cubic feet per second was the level of flow thought to be needed to meet water quality targets based on treatment protocols, discharge volumes and water quality standards in place.. The target flow at Lillington was recommended by the Federal Water Quality Agency which was part of the U.S. Public Health Service. The recommended target flow provides a significant increase in the amount of water available during low-flow conditions compared to the estimated seven-day average low flow prior to dam construction of 94 cubic feet per second and the historic minimum flow of 11 cubic feet per second prior to operations of Jordan Lake.

Figure 10 shows a generalized representation of the delineation of storage space in Jordan Lake.

Figure 10 Jordan Lake Storage Volume



The original flow target was redefined to a range of flows centered on 600 cubic feet per second based on the difficulty of meeting a specific flow rate during drought conditions in the 1980's, The current flow target is 600 ± 50 cubic feet per second. Drought conditions from 1998-2002 required reductions in downstream releases in order to extend the storage in the flow augmentation pool resulting in a minimum daily average flow of 155 cubic feet per second at Lillington during the first week of August 2002. Further studies led to the adoption of a revised drought protocol for the reservoir in 2008. A copy of the "Drought Contingency Plan, Updated May 2008" can be found in Appendix A.

Under the revised drought protocol, the Army Corps of Engineers manages the withdrawals from the augmentation pool based on the percent of storage available. Under normal operations, there is a minimum release requirement of 40 cubic feet per second from the dam along with maintaining a streamflow of 600 ± 50 cubic feet per second at the Lillington streamflow gage while maintaining water levels at 216 feet mean sea level. The flow requirements are typically met by releasing inflow to the reservoir to maintain water levels in the reservoir.

When inflows to the reservoir decline during low-flow conditions, and releases to maintain water levels are not adequate to meet the downstream flow target, water is released from the flow augmentation pool to supplement flows below the dam. If the storage in the flow augmentation pool continues to decline, downstream releases are adjusted to meet the adjusted targets outlined in Table 7. The goal of these staged reductions is to extend the usefulness of the water remaining in storage to supplement streamflow as long as possible; protecting water quality and downstream users while at the same time approximating flow reductions that would naturally occur during droughts.

Table 7 Jordan Lake Reservoir Operating Rules during Drought
(Releases and Target values in cubic feet per second)

Drought Stage	% Remaining in Flow Augmentation Pool	Minimum Release (cfs)	Lillington Target (cfs)
0	80-100	40	600 ±50
1	60-80	40	450-600
2	40-60	40	300-450
3	20-40	200	None
4	0-20	100	None

Modeling Results:

The analysis for the Cape Fear River Water Supply Evaluation is based on comparing different levels of estimated future water withdrawals and water supply allocations to current conditions represented by the 2010 basecase model scenario. Data from the local water supply plans, that include estimates of expected water demands through 2060, were used to develop model scenarios.

Future demand estimates were developed by local government water systems and the applicants for allocations of water supply storage in Jordan Lake based on expected customer demands at specific points in the future. Water supply allocations from Jordan Lake are limited by rule to the amount needed within a 30-year planning period. The final decisions on Jordan Lake allocations were expected to be made by the

Environmental Management Commission in late 2015, based on a thirty-year planning horizon. Therefore, some model scenarios evaluate estimated withdrawals expected to be needed to meet 2045 demands. Current river basin planning protocols evaluate water supply conditions for fifty years into the future making 2060, fifty years from the 2010 model simulation basecase, a useful scenario to investigate potential long-range withdrawal needs. This evaluation focuses on the ability of water withdrawers to meet the level of withdrawals anticipate to meet 2060 demands. The allocation requests shown in Table 8 are based on the amount of water needed to meet expected 2045 customer demands.

On each of the following graphs and plots, a line representing current conditions, labeled as "Simbase_current", provides reference conditions against which alternative scenarios can be compared. In addition to the "Simbase_current" line, two additional plots are included showing the results of alternative scenarios for meeting estimated future demands.

The plot labeled "01_JLA_2060", shown in green, shows the results from the scenario that include project withdrawals needed to meet 2060 water demands. Available water supplies include the allocation recommendations presented in the December 2015, *Draft Jordan Lake Water Supply Allocation Recommendations*.

The plot labeled "01_JLA_Full_2060_Max", shown in magenta, shows the results from a scenario designed to show the results of full allocation of the Jordan Lake water supply pool and the maximum use of the estimated available supply behind Lock and Dam #1 on the Cape Fear River. The unallocated percentage of the water supply pool was withdrawn from the reservoir for use out of the river basin with no return flow to the basin. In addition, the annual average day demands for the Lower Cape Fear Water and Sewer Authority and the Cape Fear Public Utilities Authority were increased so the maximum combined withdrawals at Lock and Dam #1 are 106 million gallons per day, the estimated available supply at that location.

Jordan Lake allocation requests were based on the amount of water needed to meet demands in 2045 by each applicant. DWR received applications from the following local governments: Cary-Apex-Morrisville-Wake County for RTP, Chatham County-North, Durham, Fayetteville Public Works Commission, Hillsborough, Holly Springs, Orange County, Orange Water and Sewer Authority, Pittsboro and Raleigh. The total requests for water supply allocations amounted to 105.9% of the water supply pool. The allocation recommendations released in December 2015 include all the requested allocations except for Fayetteville Public Works Commission. The reliability of Fayetteville PWC's supply from the Cape Fear River benefits from the flow augmentation releases from Jordan Lake. Modeling did not indicate any potential flow-related supply shortage limiting Fayetteville's ability to meet its estimated 2060 water demands.

Table 8 Current and Requested Jordan Lake Water Supply Allocations

Allocation of Jordan Lake Water Supply Pool			
Applicant	Current Allocation	Requested Allocation	Draft Recommendation
	Allocation Percent	Allocation Percent	Allocation Percent
Cary Apex Morrisville RTP	39	46.2	46.2
Chatham County-North*	6	13	13
Durham*	10	16.5	16.5
Fayetteville PWC	0	10	0
Hillsborough	0	1	1
Holly Springs	2	2	2
Orange County	1	1.5	1.5
Orange Water&Sewer Authorit	5	5	5
Pittsboro*	0	6	6
Raleigh	0	4.7	4.7
Total Percent	63	105.9	95.9
* Western Intake Partners			

In this analysis, all of the requested allocations are withdrawn directly from Jordan Lake. To avoid potential complication of the resulting surface water transfer, Raleigh proposed the possibility of withdrawing their allocation and returning treated wastewater at a site on the Cape Fear River in the vicinity of Lillington.

Withdrawals in the model for public water suppliers not submitting an application for an allocation from Jordan Lake are based on information in their local water supply plans for each model scenario. The withdrawals are set to the levels needed to meet the estimated volumes necessary to meet demands in 2060 for all modeled water utilities. In response to the December 2015 Draft Cape Fear River Water Supply Evaluation, Duke Energy suggested the inclusion of additional withdrawals to accommodate potential expansion in electric generating capacity within the geographic scope of the model. The model scenarios used for this analysis include the suggested volumes and the suggested locations provide by Duke Energy.

Jordan Lake Water Storage Evaluation:

The discussions of impacts to water resource conditions that follow rely on a series of graphs and tables to present the variations that occur under different water withdrawal arrangements. This evaluation focuses on the variations in water resource conditions between the volumes of water withdrawals in 2010 and the level of withdrawals expected to be needed to meet demands in 2060. Table 9 provides brief descriptions of the conditions in each of the model scenarios presented in the following graphs. The "Simbase_Current" scenario represents the effects of meeting 2010 water demands over the range of hydrologic conditions experienced from 1930 to 2011. The plots for this scenario are shown in blue on each graph. The plots for the other scenarios show how conditions may change given the withdrawal levels and management protocols in each scenario.

Table 9 2016 Cape Fear River Water Supply Evaluation Model Scenarios

Model Scenario Descriptions	
_Simbase_Current	This scenario models the baseline current conditons in 2010 based on available water supplies, infrastructure and customer demands at that time
01_JLA_2060	**JLA** indicates this scenario uses the allocations proposed in the draft recommendations for the Jordan Lake Water Supply Allocations **2060** indicates this scenario is modeling the ability to meet the estimated water withdrawals needed to meet 2060 demands. It includes the Jordan Lake allocations recommended in the December 2015 draft document. Demands for water systems not requesting an allocation from Jordan Lake are based on data provided in 2014 local water supply plans and data supplied as comments to the draft documents.
01_JLA_Full_2060_Max	**JLA** indicates this scenario uses the allocations proposed in the draft recommendations for the Jordan Lake Water Supply Allocations **Full** An artificial allocation is added to the recommended 2045 allocations to raise total allocations from the Jordan Lake water supply pool to 100 percent. **2060** indicates this scenario is modeling the ability to meet the estimated water withdrawals needed to meet 2060 demands. Demands for water systems not requesting an allocation from Jordan Lake are based on data provided in 2014 local water supply plans as well as data supplied as comments to the draft documents. **Max** indicates this scenario includes adjustments to the withdrawals for the Cape Fear Water and Sewer Authority and the Cape Fear Public Utility Authority to generate peak monthly average withdrawals that require usage of their estimated available supply limit behind L&D#1 of 106 million gallons per day.

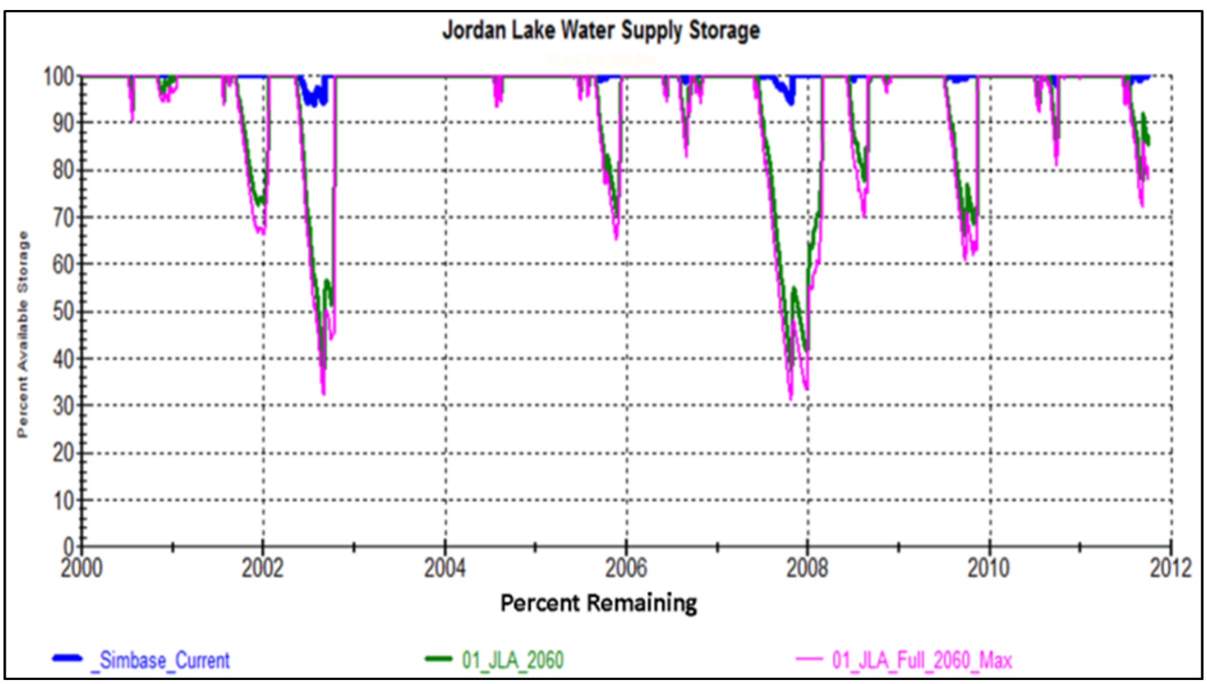
If requested allocations from the water supply pool are granted, the water withdrawals from Jordan Lake will increase dramatically over the coming decades. Larger withdrawals will produce more fluctuations in the storage in the water supply pool as demands and inflows vary seasonally and from year to year. From a water supply perspective low flow conditions and droughts are critical periods since water shortages can threaten the ability to meet drinking water needs. The period from 2000 to 2011 includes two of the driest periods in the Cape Fear River Basin. The two graphs that follow show the storage conditions for the water supply and flow augmentation pools for the flow conditions experienced during these years.

Before looking closely at these plots, it may be helpful to remember that reservoirs are intended to retain water when streamflows are high so that it can be used when flows are low. During low inflow periods, when water is used from storage, water levels are expected to decline. The availability of water stored in a reservoir improves the reliability of the source to meet the desired levels of withdrawals needed to satisfy customer demands. With the larger withdrawals expected in the future the water supply pool in Jordan Lake will be drawn down deeper and longer when the basin experiences low flow conditions. The modeling used for this analysis shows the possible effects of increased withdrawals over the range of hydrologic conditions that have occurred between 1930 and 2011. The graphs below show the effects of each model scenario on the storage pools in Jordan Lake focusing on conditions during recent serious droughts. The blue lines on the graphs show the effects on the water supply pool and the flow augmentation pool from withdrawing water to meet the demands in 2010 during the hydrologic conditions experienced from 2000 to 2011.

Figure 5 shows that the model predicts that during the conditions experienced in 2002 and 2007, the water supply pool would likely have been drawn down to about 95 percent of full pool given the withdrawals needed to meet the 2010 demands. With larger withdrawals in the future more of the water supply storage will be required to meet customer demands. As expected, the graph indicates that during a recurrence of the 2002 or 2007 low inflow conditions meeting the expected water demands for 2060 could reduce water supply storage to about 30 percent of full storage.

One interpretation of this graph is that even at the significantly higher levels of withdrawals anticipated in the future, the water supply pool appears to be able to meet those demands over the range of drought conditions that have occurred in the Cape Fear River Basin since 1930, with a reserve.

Figure 5 Jordan Lake Water Supply Storage 2000-2011 (2060 Demands)



Under future water demand scenarios, the model indicates that conditions of the flow augmentation pool in Jordan Lake will not be drawn down as much as it would be in the 2010 basecase scenario for the period 2000-2011. This is due to at least two factors: Implementation of minimum release requirements from Randleman Reservoir after 2010 and the supplemental input to the Deep River, especially in times of naturally low flows. Both of these factors raise the contribution from the Deep River to the flows in the Cape Fear River at Lillington, which reduces the amount of water required from Jordan Lake to meet flow targets. Also, increased wastewater discharges between Jordan Dam and Lillington reduce the flow augmentation releases needed from Jordan Lake.

The effects of these changes in the future scenarios can be seen in Figure 6 where it is most noticeable during the drought conditions in 2002. In the 2010 basecase scenario, the model indicates the water quality pool would be drawn down to about 20 percent of available storage while in the future 2060 demand scenarios the model predicts it may only be drawn down to about 35 percent of available storage. The effects are less dramatic in other low-flow periods. In a repeat of the October 2007 hydrologic conditions the difference is less than 5 percent, from about 27 percent remaining storage in the 2010 basecase scenario to about 30 percent in the 2060 demand scenarios. The minimum value variations among the 2060 demand scenarios are in the range of a half of one percent.

According to the modeling done for this evaluation, changes in management and wastewater return volumes projected to occur in the future will likely increase the reliability of the flow augmentation pool in Jordan Lake. While this analysis is limited to the range of flows that occurred from 1930-2011, the results suggest that the flow augmentation storage in Jordan Lake is likely to be capable of meeting its management goals if flows are outside of this range in the future.

Figure 6 Jordan Lake Flow Augmentation Storage 2000-2011(2060 Demands)

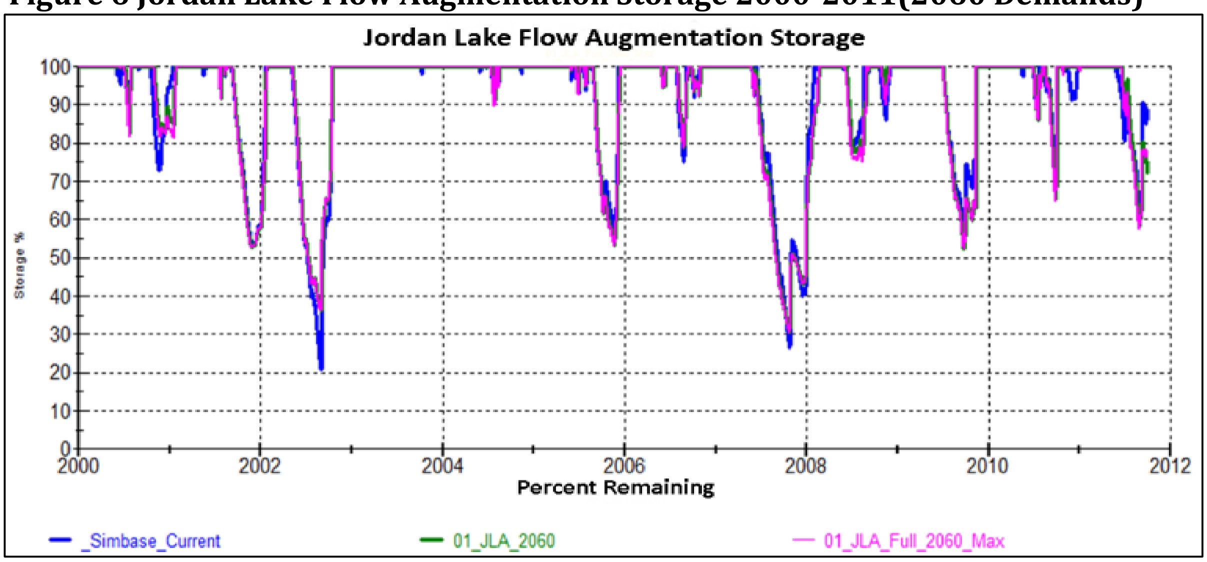
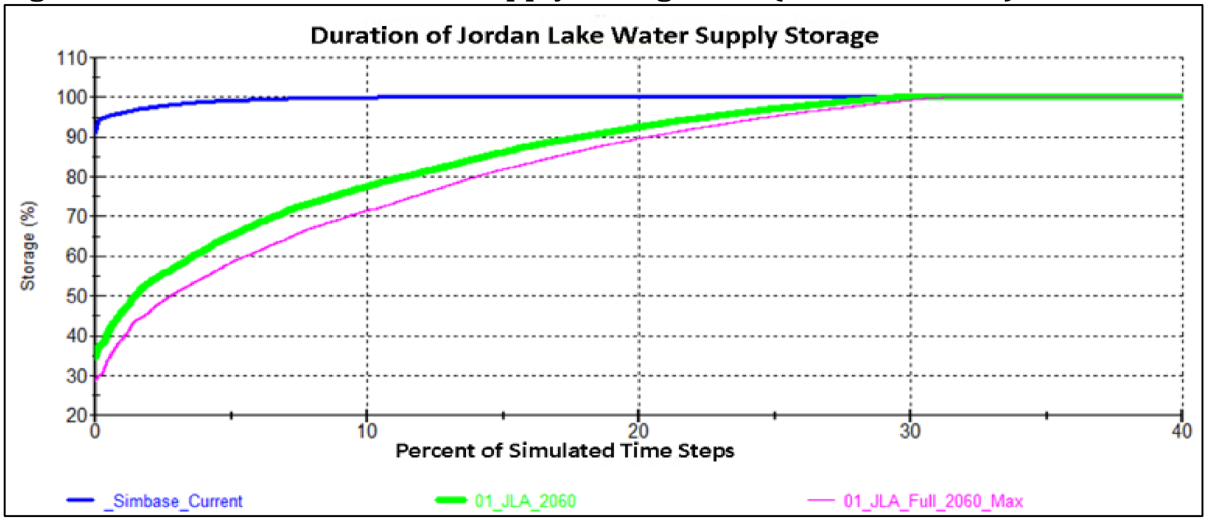


Figure 7 Duration Plot of Water Supply Storage Pool (2060 Demands)



Figures 7 and 8 show the percentage of time the water supply and flow augmentation storage pools are at or below a certain percent of available storage. Note that both graphs show only 40 percent of the entire period of record. For the remaining 60 percent both storage pools are at or above 100 percent full. For water supply storage shown in Figure 7 modeling indicates that the water supply pool is less than 100 percent full about 5 percent of the 29,859 days in the historic flow record for the 2010 basecase demand scenario. The periods when the water supply pool in less than full increases as withdrawals increase in the future. For the 2060 demand scenarios, the model indicates that water supply storage is likely to be less than full about 30 percent of the time, over the range of inflows in the 81-year flow record. The 2060 demand scenarios indicate that for 5 percent of the time, water supply storage could be about 65 percent of full or less.

Figure 8 indicates that the time when storage is less than 100 percent in the flow augmentation pool is about 30 percent for all three model scenarios. Consistent with the information present in Figure 6, the maximum drawdown is less in the 2060 demand scenarios than the basecase scenario. In the 2010 basecase demand scenario, the minimum storage in the flow augmentation pool over the range of flows in the historic record is 21 percent of full storage. Under the 2060 demand scenarios, the minimum flow augmentation storage is about 29 percent of full storage.

Figure 9 shows the magnitude and duration of drought stages that would be triggered under the 2008 Drought Contingency Plan during the flow conditions experienced from 2000 to 2011. Drought responses enter Stage 1 when storage in the flow augmentation pool drops below 80 percent. If storage drops below 60 percent Stage 2 operations are triggered, and if storage drops below 40 percent, Stage 3 operations are implemented. The effects of the flow augmentation storage declines shown in Figure 6 are reflected in the drought stage designations shown in Figure 9.

Figure 8 Duration Plot of Flow Augmentation Storage Pool (2060 Demands)

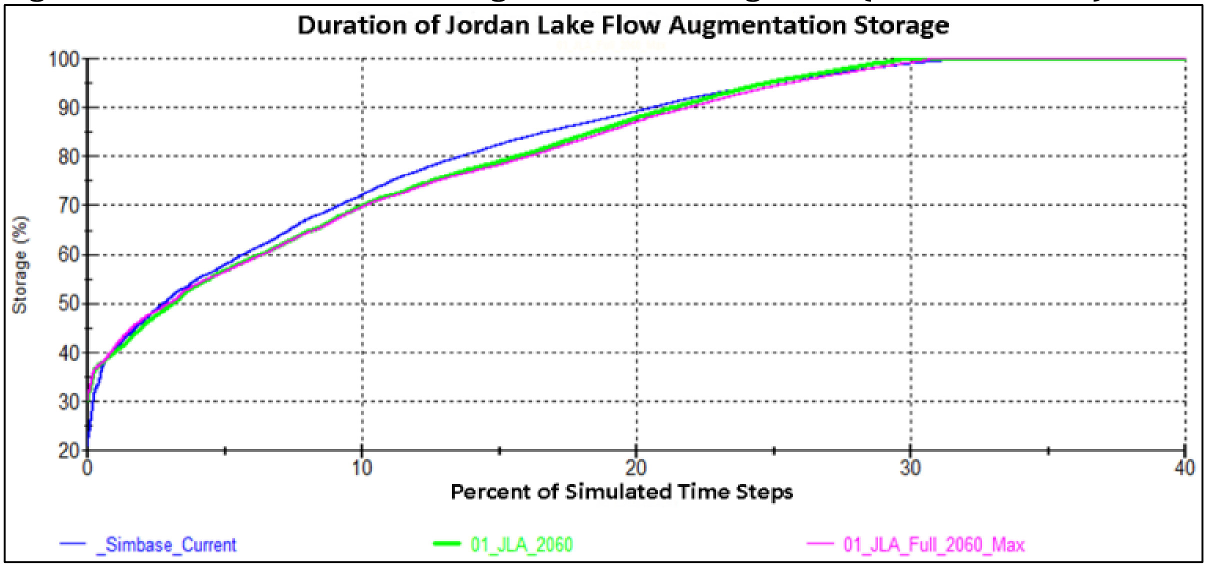
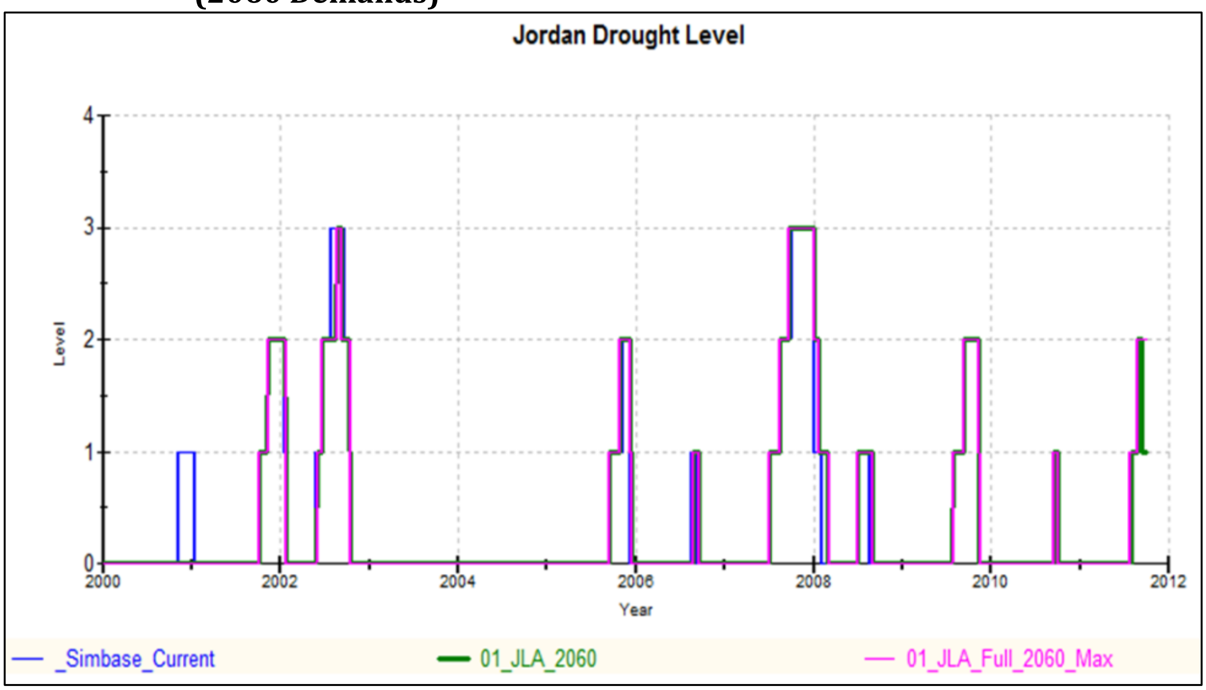


Figure 9 Jordan Lake Estimated Drought Stages for flows in 2000-2011 (2060 Demands)



Jordan Lake Water Level Evaluations:

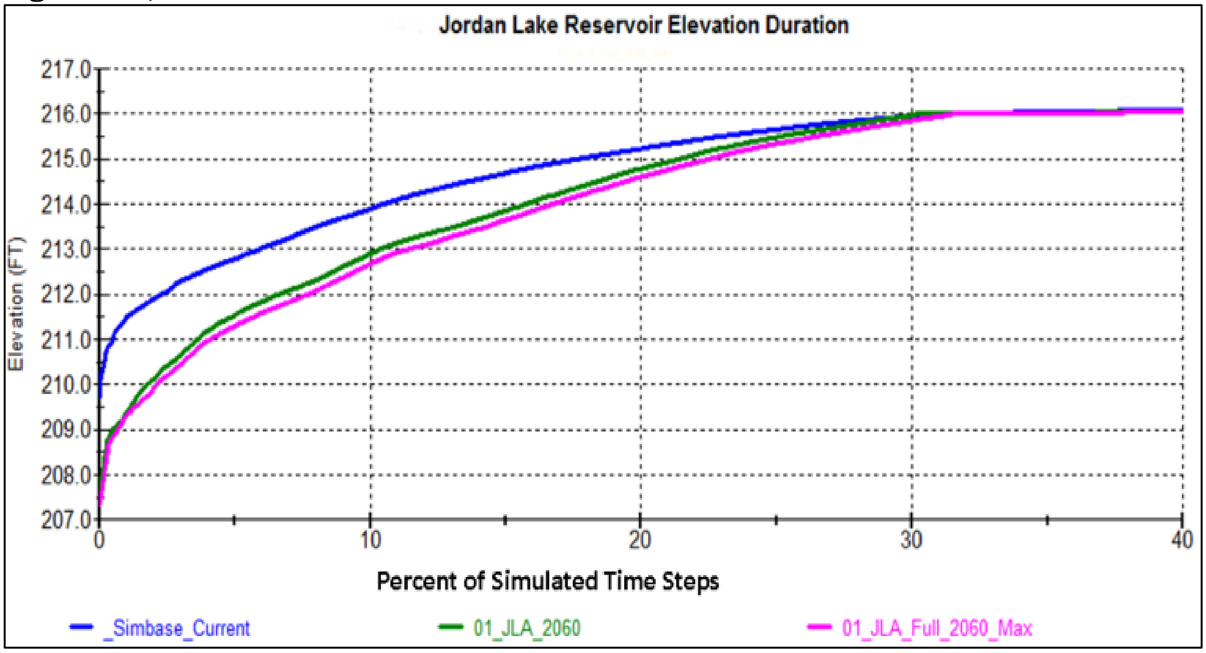
The combined effects of the declines in water storage shown in Figures 5 and 6 are reflected in the duration plot of water levels in Jordan Lake shown in Figure 10. As in Figures 5 and 6, Figure 10 shows the 40 percent of time when water levels are below the normal operating water level for Jordan Lake of 216 feet above mean sea level. At the normal operating level, and above, the water supply and flow augmentation pools are full. During high flow events, the water level rises as runoff from the watershed upstream of the reservoir is retained to mitigate flooding impacts to downstream communities. As inflows to the reservoir and downstream high flows decline, the water in the flood storage pool is released under controlled conditions until the normal operating elevation of 216 feet mean sea level is regained.

When inflows are sufficient to compensate for evaporation and water supply withdrawals and streamflows are above the flow target at the Lillington stream gage, the water level will not drop below 216 feet mean sea level. When not in flood control mode, water flowing into the reservoir is credited to the water supply account and flow augmentation account based on the percentage of the conservation pool designated for each, 32.6 percent for water supply and 67.4 percent for flow augmentation. If both of these accounts are full water is released downstream.

When inflows are not sufficient to maintain water levels at 216 feet mean sea level, the level of water declines as withdrawals are made for public water supplies and water is released downstream to augment streamflows. The combined effects of the declines in the water supply and flow augmentation pools shown in the graphs above are reflected in Figure 10. Figure 10 shows the model derived water levels during the 40 percent of the time when the water level is predicted to be below the normal operating level over the 81-year flow record. These model results imply that 60 percent of the time the water level is predicted to be at or above the normal operating elevation of 216 feet mean sea level.

With withdrawals sufficient to meet the estimated 2060 demands, the hydrologic modeling shows the water level in Jordan Lake will likely be lower for longer than under the 2010 current conditions scenario. The vertical scale on the graphs represents feet above mean sea level. The horizontal scale shows the percent of time of the over 29,000 days in the historic record that the water level may be below specific elevations under each model scenario.

Figure 10 Jordan Lake Water Elevation



Recreational opportunities at Jordan Lake are impacted by reservoir water levels. One way to characterize this impact is by looking at how boat launching facilities are affected at various reservoir water levels. Figure 11 includes the elevations at which the use of boat ramps at Jordan Lake may become limited due to water levels. The levels noted on the graph are generally a few feet above the bottom of the boat ramp structure. The elevations of the bottoms of the boat ramps on Jordan Lake are listed in Table 3 of the Appendix A, the Drought Contingency Plan. Figure 11 shows that as more of the water supply pool is used in the future, boating access will be restricted at more facilities and for longer periods over the historic range of flows than have been experienced in the past.

Figure 11 Jordan Lake Boat Ramp Impacts

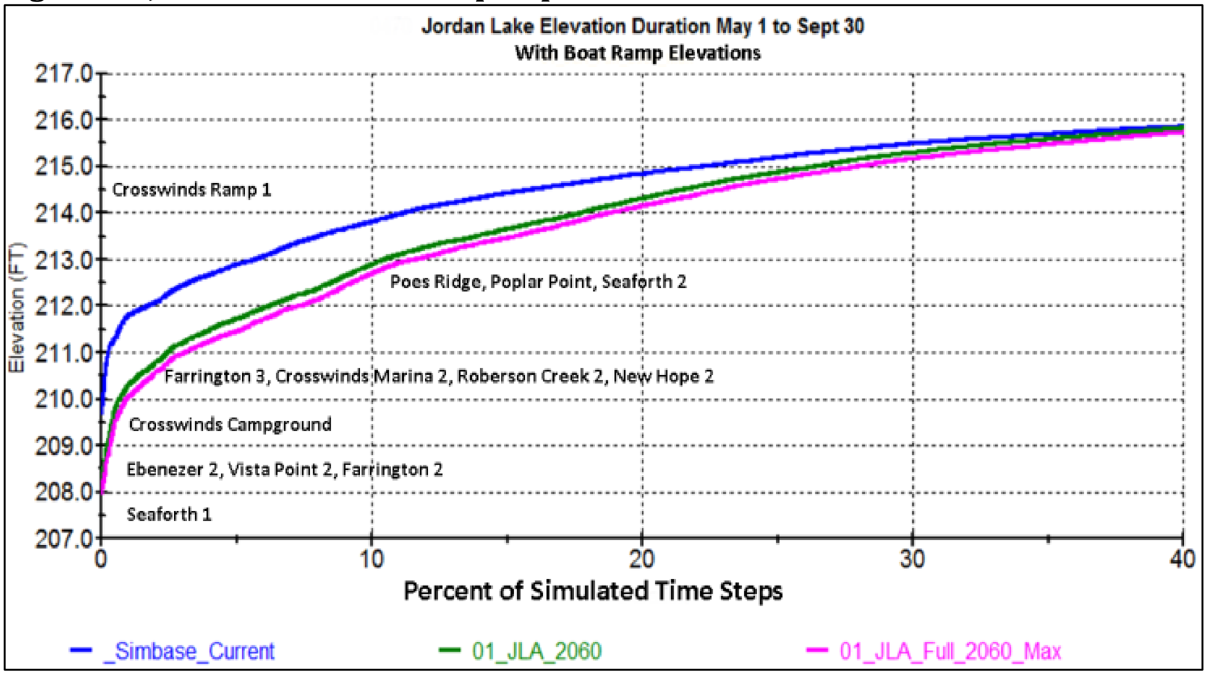


Figure 11a presents a summary of the percentage of days in the flow record when water levels vary by the specified feet during the period from April 1st to June 30th. The variations noted in this graph include times when water is being released from the flood control pool as well as times when water levels are declining due to low inflows to the reservoir.

Figure 11a Jordan Lake Water Level Fluctuations April 1to June 30

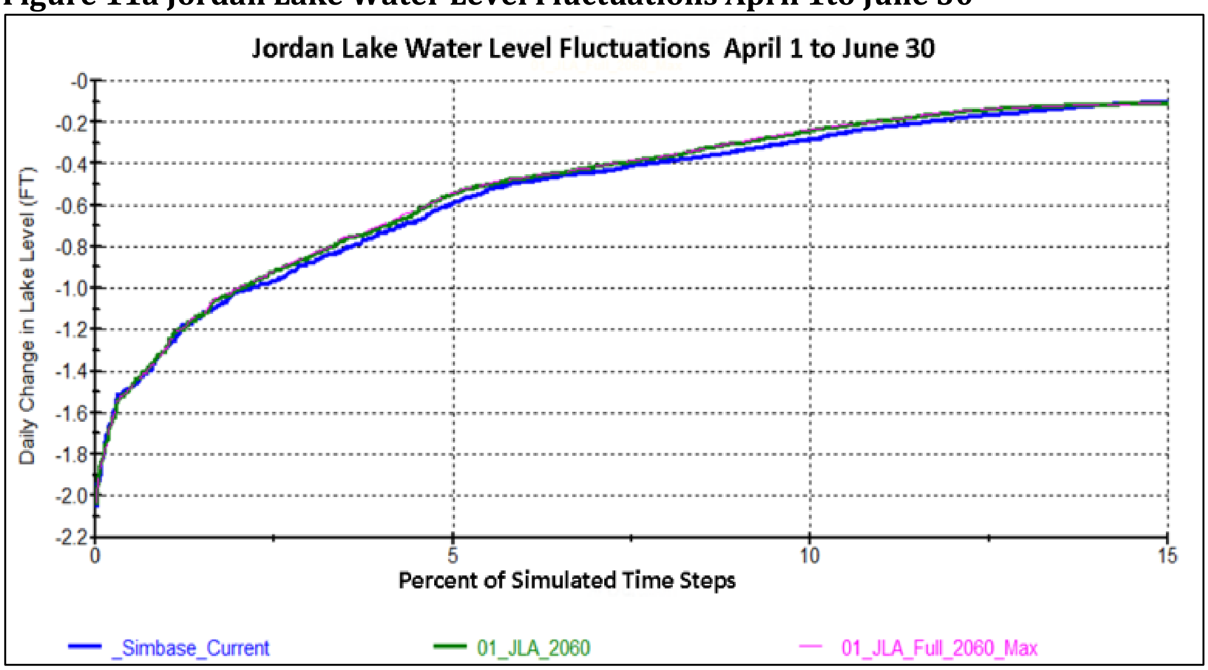


Table 10 shows the model generated minimum values for water level in Jordan Lake, water supply storage, flow augmentation storage, and the minimum average streamflow at the Lillington streamflow gage for the demand scenarios modeled for this analysis. The model scenarios based on 2060 demands show the values if the recommended allocation from the Jordan Lake water supply pool are granted. The dates in the historic flow record when flow conditions produced each of the minimum values are also shown for each scenario.

Table 10 Minimum Value Summary

Minimum Jordan Lake Storage and Target Flow Conditions using 2060 Estimated Demands							
Model Scenario	Jordan Lake Water Level		Jordan Lake Water Supply Pool				
	Minimum Level, ft	Date	Minimum Water Supply Storage %	Dates Minimum Water Supply %	Number Days @ Minimum Storage %	Dates of Longest Period Water Supply Storage <100%	Days In Longest Period
Simbase-current	209.72	8/30/2002	90.91	7/9/1953 - 12/9/1953	154	7/9/1953 - 12/9/1953	154
01_JLA_2060	207.62	10/23/2007	34.68	7/6/1953 - 1/15/1954	194	5/17/1933 - 3/5/1934	293
01_JLA_Full_2060_Max	207.32	10/23/2007	28.49	5/19/1933 - 3/5/1934	292	5/19/1933 - 3/5/1934	292

Minimum Jordan Lake Storage and Target Flow Conditions using 2060 Estimated Demands							
Model Scenario	Jordan Lake Flow Augmentation Pool			Cape Fear River Flow at Lilington, NC			
	Minimum Flow Aug. Storage, %	Date of Minimum Flow Aug. Storage	Days Flow Aug. Storage = 0	Lowest Daily Flow, cfs	Date of Lowest Daily Flow	Years with 1 or more daily flows <600 cfs*	Days out of 29,858 with Estimated Flow <600cfs*
Simbase-current	20.82	8/30/2002	0	284.55	10/1/2007	61	4274 (14.3%)
01_JLA_2060	30.27	10/23/2007	0	152.59	8/19/2002	60	4559 (15.3%)
01_JLA_Full_2060_Max	30.27	10/23/2007	0	152.59	8/19/2002	61	4680 (15.7%)

*When not in drought protocol the target flow at Lillington stream gage is 600 ± 50 cubic feet per second. When the droutht protocol for Jordan Lake is implemented the flow targets are reduced to preserve flow augmentation storage in the reservoir.

The modeling results indicate that Jordan Lake storage appears to be resilient enough to meet the intended water supply and flow augmentation purposes if more extreme drought conditions occur in the future.

The modeling for this evaluation indicates that even as withdrawals increase in the future, there remains significant storage for water supply and flow-augmentation during the worst droughts represented in the historic flow data. With the expected withdrawals needed to meet demands over the next 50 years neither the water supply pool nor the flow augmentation pool are depleted. Both have supply remaining during the driest conditions that have occurred over the 81 years of the historic record. The modeling results indicate that Jordan Lake storage appears to be resilient enough to meet its intended purposes if more extreme drought conditions occur in the future.

13 Jordan Lake Water Supply Pool Potential Yield

The water supply pool of Jordan Lake was designed to reliably supply 100 million gallons per day. The rules governing allocation of water supply storage required the Environmental Management Commission to limit allocations that would result in *"diversions out of the lake's watershed to 50 percent of the total water supply yield."* This limitation was included to protect the yield of Jordan Lake for water supply and water quality purposes. The allocation rules allow for revising the 50 percent diversion limit *"based on experience in managing the lake and on the effects of changes in the lake's watershed that will affect its yield."*

Water supply purposes are met by local government water systems that hold an allocation and withdraw water from the water supply pool. The water quality purposes are met by releasing water from the dam to augment flows in the river downstream. The magnitude of downstream releases is set to maintain a target flow at the USGS stream gage at Lillington.

The reliability of the volume of water available to water withdrawers that use surface water sources is limited by the amount of water available during low-flow conditions. Withdrawers taking water directly from a stream face seasonal variations in streamflows that limit their reliable supply. The purpose of a water supply reservoir is to store water so there is a pool of water available to buffer the effects of seasonal flow variations and thereby increase the reliability of supply. The amount of water available to be withdrawn from a reservoir is determined by the storage volume and the amount of inflow available from the watershed contributing drainage to the reservoir. While the drainage area and the physical storage volume are fixed for a specific reservoir the amount of water available is dependent on the water that flows off the watershed into the reservoir, which varies seasonally and from year-to-year.

The yield of a water supply reservoir is determined by estimating how much could be reliably withdrawn over a given record of inflows. The period of record used for this type of analysis is typically 25 years, 50 years or the entire available record of streamflows, depending on the level of risk that is acceptable to the users. The risk of not being able to reliably withdraw the estimated yield during droughts typically decreases as the period of record increases and a broader range of historic flows are used in the analysis.

The Cape Fear-Neuse River Basins Hydrologic Model provides a tool to evaluate the amount of water available to meet the water supply purposes from Jordan Lake. This computer-based mathematical model tracks changes in water volume in the reservoirs and rivers of the basins in response to variations in flows and water withdrawals. To evaluate the potential water supply yield, 12 different hypothetical scenarios were constructed to bookend the range of potential yields. The magnitude and location of used water return flows were varied to estimate the reliably of the water supply pool over the range of flows in the 81-year hydrologic record and the assumptions used in the model. Various percentages of water withdrawals are assigned to be returned to three different geographic areas: on the Jordan Lake watershed, in the Cape Fear River between the dam and the Lillington streamflow gage, or completely out of the watershed above the Lillington streamflow gage. The yield analysis tool in the model iteratively raises withdrawals from the water supply pool up to the level when the next increase would reduce storage to zero.

The lowest water supply yield estimate occurs when none of the withdrawn water is returned to the reservoir's watershed. The resulting estimated water supply yield is 104 million gallons per day using 2010 water withdrawals for systems not using water from Jordan Lake. Using the 2060 scenario of estimated withdrawals the lowest estimated water supply yield is 113 million gallons per day. This increase is attributed to changes in water use and wastewater returns upstream of Jordan Lake.

Twelve scenarios of return flow possibilities are summarized in Table 11. Reviewing the data in Table 11, it appears that even if none of the water withdrawn from Jordan Lake is returned to the reservoir's watershed the water supply pool can reliably supply the intended 100 million gallons per day.

Table 11 Jordan Lake Water Supply Pool Yields

Estimated Jordan Lake Water Supply Yield									
	Return Flow Assumption			2010 Basecase Scenario			2060 Demand Scenario		
Model Set Up	Percent of Withdrawal Returned to Jordan Lake Watershed	Percent of Withdrawl Returned Below Jordan Lake Dam	Percent of Withdrawal Out of Basin	Estimated Water Supply Yield (MGD)	Jordan Lake Minimum Elevation (ft-msl)	Minimum Water Supply Storage 2/24/1934 (%)	Estimated Water Supply Yield (MGD)	Jordan Lake Minimum Elevation (ft-msl)	Minimum Water Supply Storage 2/24/1934 (%)
1	0	0	100	104.06	202.65	0.65	112.92	203.03	0.79
2	100	0	0	156.94	204.30	1.07	169.66	204.06	1.18
3	0	100	0	104.98	203.55	0.74	113.84	203.36	1.60
4	50	50	0	125.44	203.88	2.69	136.69	203.67	0.96
5	50	0	50	124.19	202.69	0.86	134.86	203.07	0.87
6	0	50	50	104.00	202.65	0.71	112.92	203.03	0.73
7	25	75	0	114.63	203.70	1.17	124.81	203.50	0.81
8	25	0	75	113.25	202.67	0.73	122.91	203.05	0.85
9	75	25	0	140.31	204.07	0.95	151.45	203.86	0.97
10	0	25	75	103.99	202.65	0.75	112.92	203.03	0.77
11	75	0	25	137.56	202.71	0.89	149.55	203.04	1.02
12	0	75	25	104.00	202.65	0.70	112.92	203.03	0.71

The model provides the ability for evaluating the effects of releasing water from the low flow augmentation pool in Jordan Lake to enhance river flows down steam by tracking the volume of storage remaining during drought conditions. All model scenarios include the drought management protocol for adjusting flow targets based on the percentage of water quality storage remaining in the reservoir. Table 12 shows the minimum storage amounts for each of the 12 scenarios evaluated using 2010 and 2060 model scenarios. With the withdrawal levels in the 2010 basecase scenario modeling does not indicate that the water quality pool will be depleted under any of the return flow options. Modeling suggests that as water withdrawals increase in the future, during recurrences of some of the hydrologic conditions that have occurred since 1930, there may be times when the flow augmentation pool may be depleted

Table 12 Jordan Lake Minimum Flow Augmentation Pool Storage

Estimated Minimum Water Quality Pool Storage														
	Return Flow Assumption			2010 Basecase Scenario					2060 Demand Scenario					
Model Set Up	Percent of Withdrawal Returned to Jordan Lake Watershed	Percent of Withdrawl Returned Below Jordan Lake Dam	Percent of Withdrawal Out of Basin	Minimum Water Quality Storage (%)	Date of Minimum Water Quality Storage	Number Days Water Quality = 0	Number Events Water Quality = 0	Max Duration days Water Quality = 0	Minimum Water Quality Storage (%)	Date of Minimum Water Quality Storage	Number Days Water Quality = 0	Number Events Water Quality = 0	Max Duration days Water Quality = 0
1	0	0	100	0.02	8/22/2002	0	0	0	0.00	8/9/2002	10	4	4
2	100	0	0	14.04	11/30/1953	0	0	0	9.94	2/24/1934	0	0	0
3	0	100	0	9.15	2/24/1934	0	0	0	4.08	2/24/1934	0	0	0
4	50	50	0	11.94	2/24/1934	0	0	0	7.03	2/24/1934	0	0	0
5	50	0	50	0.21	10/20/2007	0	0	0	0.11	8/22/2002	0	0	0
6	0	50	50	0.08	10/23/2007	0	0	0	0.00	8/21/2002	4	1	4
7	25	75	0	10.75	2/24/1934	0	0	0	5.99	2/24/1934	0	0	0
8	25	0	75	0.08	8/22/2002	0	0	0	0.03	8/22/2002	0	0	0
9	75	25	0	13.63	11/30/1953	0	0	0	8.43	2/24/1934	0	0	0
10	0	25	75	0.02	8/24/2002	0	0	0	0.00	8/14/2002	7	3	4
11	75	0	25	0.35	12/11/2007	0	0	0	0.26	8/29/2002	0	0	0
12	0	75	25	0.12	12/13/2007	0	0	0	0.08	12/11/2007	0	0	0

Table 13 presents the lowest daily average flows at the Lillington streamflow gage for each of the return flow configurations. The chart uses the flow value of 600 cubic feet per second as the measure for the flow target. The flow target is currently defined as 600 ±50 cubic feet per second. When storage in the water quality pool declines during droughts, the flow target at Lillington is reduced based on the steps defined in the Drought Contingency Plan. Table 13 shows the number of years out of 81 years in the flow record and the number of days out of 29,858 days in the flow record when the model estimates the flows at Lillington to be less than 600 cubic feet per second. The table also shows the date when the flow conditions produced the minimum flow rate given the return flow configurations used for the analysis of the water supply yield.

Table 13 Cape Fear River Minimum Flows @ Lillington

Estimated Minimum Flows at Lillington Streamflow Gage											
	Return Flow Assumption			2010 Basecase Scenario				2060 Demand Scenario			
Model Set Up	Percent of Withdrawal Returned to Jordan Lake Watershed	Percent of Withdrawl Returned Below Jordan Lake Dam	Percent of Withdrawal Out of Basin	Lillington Lowest daily flow, (cfs)	Date of Minimum	Years with Flow <600 cfs	Days with Flow <600 cfs	Lillington Lowest daily flow, (cfs)	Date of Minimum	Years with Flow <600 cfs	Days with Flow <600 cfs
1	0	0	100	43.36	8/23/2002	23	620	0.00	10/25/1953	14	504
2	100	0	0	600.00	5/2/1930	0	0	600.00	5/2/1930	0	0
3	0	100	0	600.00	5/2/1930	0	0	600.00	5/2/1930	0	0
4	50	50	0	284.56	10/2/1986	7	175	600.00	5/2/1930	0	0
5	50	0	50	119.71	10/21/2007	20	364	0.00	8/22/2002	10	226
6	0	50	50	140.74	10/23/2007	12	214	18.06	8/22/2002	7	169
7	25	75	0	284.56	10/2/1986	6	164	600.00	5/2/1930	0	0
8	25	0	75	71.44	8/23/2002	21	427	0.00	8/12/2002	13	394
9	75	25	0	284.56	10/2/1986	7	182	600.00	5/2/1930	0	0
10	0	25	75	95.47	10/21/2007	11	268	0.00	8/14/2002	12	355
11	75	0	25	233.51	12/12/2007	11	285	105.32	8/28/2002	5	103
12	0	75	25	247.90	12/14/2007	9	172	183.43	12/14/2007	4	84

14 Water Supply Evaluations

Responsibility for water supply and water infrastructure development are assumed by local governments or non-governmental entities based on specific goals and needs. The primary focus of this exercise is to evaluate the long term water needs of water systems that depend on surface water sources in the Deep River, Haw River and Cape Fear River Subbasins to evaluate allocation requests of water supply storage in Jordan Lake. Because of mutual water sharing relationships, an effective analysis also requires consideration of the use of surface water sources and water demands in the Neuse River Basin. Cumulative water demands and water sharing arrangements in the Cape Fear and Neuse River Basins were evaluated over a fifty-year planning horizon using data submitted to the Division of Water Resources. Local water supply plans, prepared by units of local government and other large community water systems, provide water use and water source information as well as estimates of future water demands. The effects of the expected water withdrawals were evaluated using the Cape Fear – Neuse River Basins Hydrologic Model that simulates changes in surface water quantity induced by changes in surface water withdrawals and management protocols in the Cape Fear and Neuse River Basins.

The Cape Fear – Neuse River Basin Hydrologic Model provides DWR staff the ability to evaluate changes to surface water availability that could occur from increases in withdrawals to meet demands at levels expected to be needed over the next fifty years. The hydrologic model is used to establish a baseline set of conditions by comparing a given year's known withdrawals and management protocols, in this case 2010, to the amount of water available to meet that level of demand in each of 81 years of a reconstructed hydrologic record.

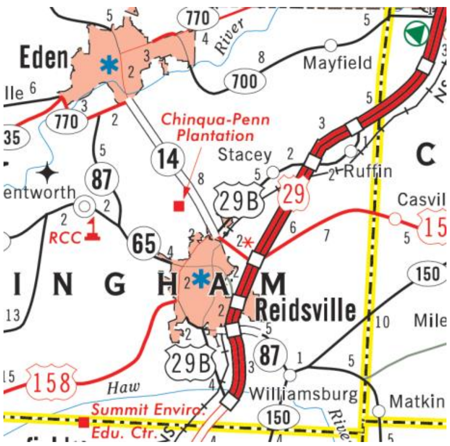
The 81 years of flow records for this model contains several extreme droughts, a couple of which may be familiar to the readers of this report. The 2010 basecase scenario gives an indication of the magnitude and duration of supply shortages that could be expected during a repeat of flow conditions that have occurred in the past when trying to satisfy the 2010 levels of water withdrawals given the current management protocols.

In the analysis for this report, DWR staff compiled projections from local water supply plans and created model scenarios based on several levels of water withdrawals expected to be needed to meet customer demands in the future. Comparing the model results of the future demand scenarios with the basecase scenario gives an indication of how the frequency, magnitude and duration of supply shortages may be different during a reoccurrence of conditions similar to historic low flow periods. The goal of these evaluations is to provide water utility managers and local decision makers with data to inform water source and demand management planning and fine tuning of local water shortage response plans.

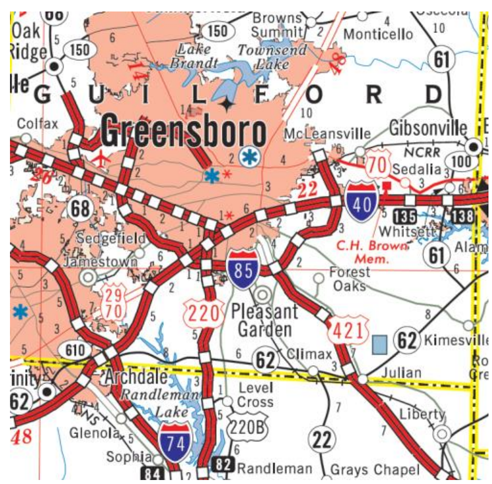
The Cape Fear Basin portion of the model includes the 31 surface water withdrawals in the Cape Fear River and its tributaries above Lock and Dam 1 in Bladen County.

These withdrawals support 82 community and industrial water systems in the Cape Fear and the Neuse River Basin. The Neuse River Basin portion of the model includes the 13 surface water withdrawals in the Neuse River and its tributaries above New Bern. These withdrawals support 36 community and industrial water systems in the Neuse and the Cape Fear River Basin. A schematic of the model is shown in Figure 6.

This section will summarize the potential of flow-related supply shortages for surface water withdrawals in the Haw River, Deep River and Cape Fear River Subbasins based on the Cape Fear-Neuse River Basins Hydrologic Model results. More detail of each of the water system's local water supply plan is available on the division's website at www.ncwater.org/Water_Supply_Planning/Local_Water_Supply_Plan/ .

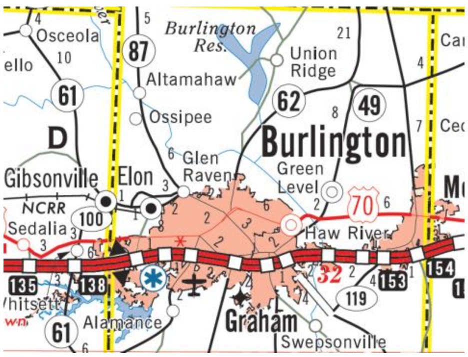


Beginning in the headwaters of the Haw River Subbasin, the Town of Reidsville withdraws water from Lake Reidsville on Troublesome Creek supplying water to Greensboro and Rockingham County as well as the town's service customers. Based on modeling results Reidsville is expected to be able to reliably meet its projected 2060 annual average demand of 5.8 million gallons per day from its current sources without supply shortages.

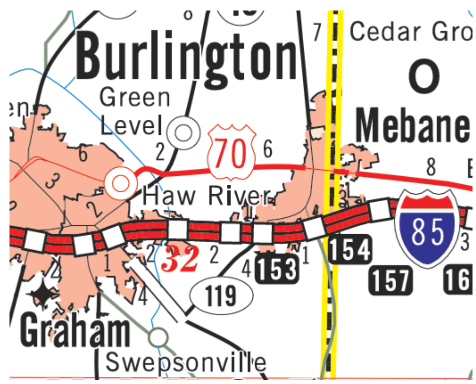


The City of Greensboro has three reservoirs that it manages for water supply: Lake Higgins, Lake Townsend, and Lake Brandt. The supply from these sources is supplemented by finished water purchases from Burlington, Reidsville and the Piedmont Triad Regional Water Authority. The PTRWA recently completed construction of the Randleman Reservoir on the Deep River, a regional water supply source. PTRWA operates a water treatment facility distributing drinking water to surrounding communities. Greensboro's multiple sources of water, from different watersheds, provides source redundancy and resilience to low flow conditions. The available capacity in Randleman Reservoir has the ability to cover regional water supply needs for some time to come. The current water treatment plant with a permitted capacity of 12 million gallons per day is not able to fully utilize the estimated available supply of 48 million gallons per day. PTRWA's local water supply plan indicates an intention to expand treatment capacity as to meet their members water needs.

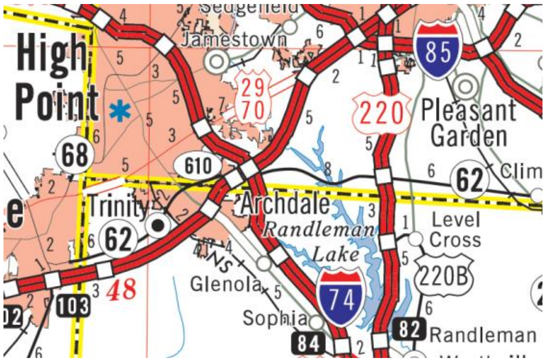
Modeling for this analysis indicates Greensboro could face short periods of supply shortages trying to meet the estimated 2060 demand levels of 66.8 million gallons per day given the initial treatment capacity of PTRWA. As demand increases, it will become more practical to invest in water treatment plant expansions to access more water from Randleman Reservoir. In the meantime, modeling does not show any flow-related supply shortages from current sources over the range of flows that occurred from 1930 to 2011 while meeting the 2045 estimated annual average demand of about 54 million gallons per day.



The City of Burlington manages two water supply reservoirs in the Haw River Subbasin: Lake Mackintosh on Great Alamance Creek and Stoney Creek Reservoir on Stoney Creek. From these sources, Burlington supplies their service customers' demands and regularly provides water to the communities of Greensboro, Elon, Gibsonville, Alamance and Haw River. In turn, Haw River passes some of that water on to the Orange-Alamance Water System. The modeling for this report indicates the expected demand needed to meet 2060 customer demands, 26.8 million gallons per day, is likely to be available without any flow-related shortages over the range of historic hydrologic conditions experienced on the watersheds of these reservoirs from 1930 to 2011.

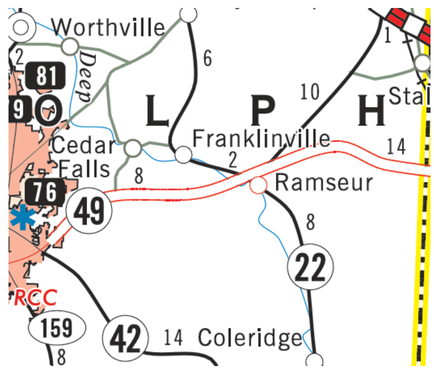


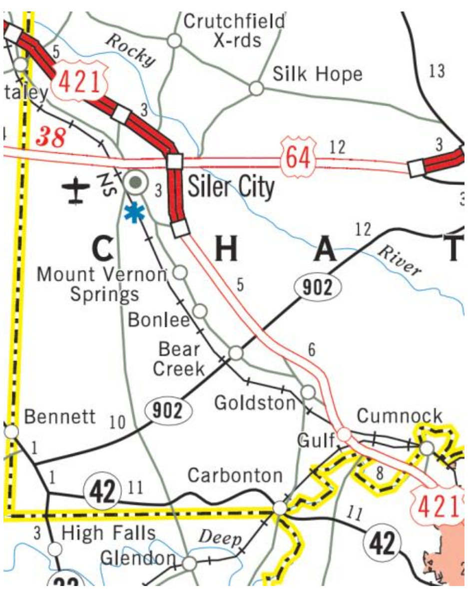
The cities of Graham and Mebane share a reservoir, the Graham-Mebane Lake on Back Creek in Alamance County, and a water treatment plant. Besides the residents of Graham and Mebane the water treatment plant regularly supplies water to customers of the Swepsonville and Green Level water utilities. In the modeling done for this analysis, the total demand on this reservoir is estimated to increase from a 2010 level of 3.5 million gallons per day to an estimated 8.5 million gallons per day to meet customer demands in 2060. Based on current modeling, these public water systems are not expected to face flow-related water supply shortages over the range of streamflows from 1930-2011.



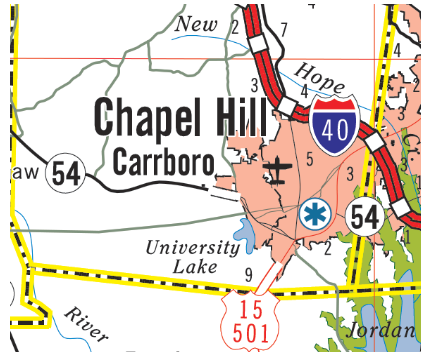
In addition to Greensboro, the communities of High Point, Jamestown, Archdale and Randleman receive water from PTRWA as a sole source or to supplement existing sources. According to the modeling for this analysis flow-related shortages are not an issue for these systems as water demands increase to the amounts expected to be needed to meet 2060 customer demands.

The Town of Ramseur manages the Sandy Creek Reservoir on a tributary of the Deep River and operates a water treatment plant supplying water to its service customers and providing the sole source of potable water to the Franklinville water system. According to information in these towns' local water supply plans, they are expecting only a modest growth in water demand from now to 2060. Modeling indicates they should be able to withdraw the amount of water expected to be needed to meet 2060 without flow-related shortages.

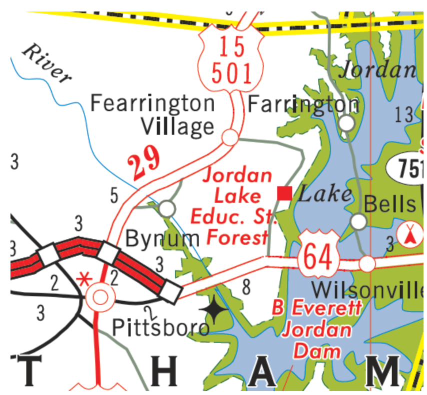




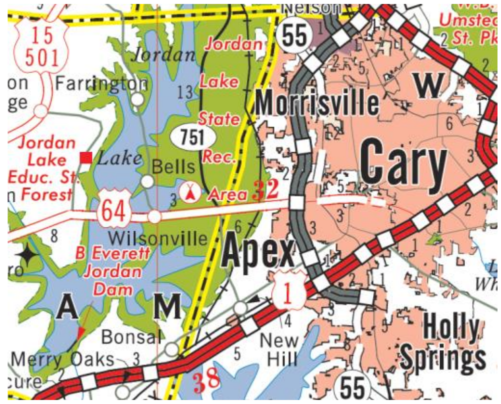
Siler City manages the Rocky River Upper and Lower Reservoirs as a combined system to supply water to its water treatment plant and deliver potable water to the residents and industries in its service area. In addition to its service customers, the Siler City water system supplies water to the Moore County Public UtilitiS-High Falls system and is the sole supplier of potable water to the Chatham County Southwest Water System. The estimated water withdrawal needed to meet 2060 demand in this analysis is 2.4 million gallons per day. The hydrologic model does not indicate any flow-related shortages likely to limit meeting this level of demand from these sources over the range of flows that have occurred on this watershed from 1930 to 2011.



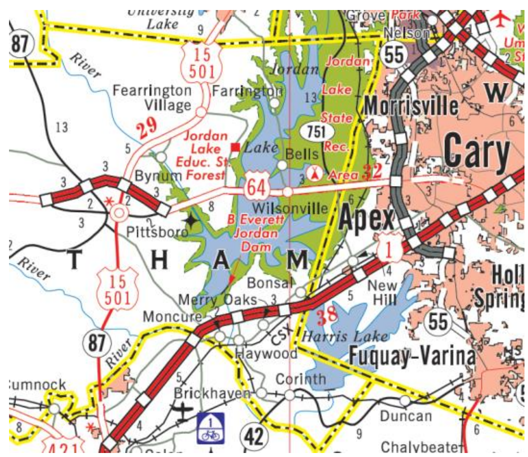
The Orange Water and Sewer Authority provides water and sewer services to residents of Chapel Hill, Carrboro and surrounding portions of Orange County. OWASA manages two reservoirs: University Lake on Morgan Creek and Cane Creek Reservoir, which currently holds a five percent allocation of the Jordan Lake water supply pool. Water from Jordan Lake provides an emergency source that can be accessed by receiving finished water treated by the Cary-Apex WTP and delivered to OWASA through the Durham distribution system. OWASA's long-term plan includes development of increase supply storage in the quarry, currently operated by American Stone, located on the same watershed as the Cane Creek Reservoir. OWASA has submitted an application to retain a five percent allocation of the water supply pool in Jordan Lake. OWASA is a member of the Jordan Lake Partnership and the consortium working to develop the western Jordan Lake intake and water treatment plant. Modeling indicates the OWASA's current sources including the Jordan Lake allocation is expected to be capable of reliably meeting the expected 2060 demand of 12.9 million gallons per day. The resilience of OWASA's water supplies is enhanced by having a source from the larger watershed and reservoir storage provided by Jordan Lake.



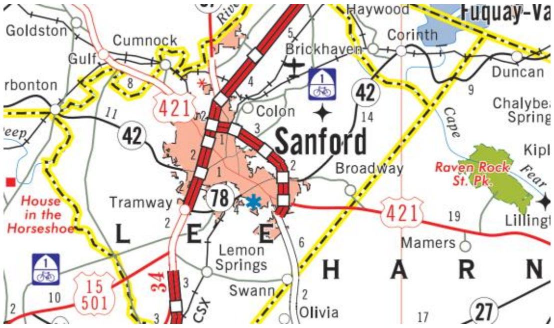
The Town of Pittsboro has an intake in the Haw River upstream of the hydropower dam at Bynum. Currently, the town operates a two million gallons per day water treatment plant. With the proposal to develop Chatham Park east of Pittsboro, the water utility is expecting to see its customer base grow from 3,700 in 2010 to about 96,800 by 2060 with accompanying growth in water demands. Pittsboro has submitted an application for a six percent allocation of water supply storage in Jordan Lake to supplement an eventual six million gallons per day supply from the Haw River. Pittsboro is a member of the Jordan Lake Partnership and is a member of the consortium of local governments working together to develop an intake and water treatment plant on the western shore of Jordan Lake to allow full utilization of the water supply storage in the reservoir. Modeling indicates that if Pittsboro receives the requested allocation and completes the intended expansions of their withdrawal and treatment capacity from the Haw River, there will be enough water available to meet the projected demand of 11.8 million gallons per day.



Currently, the only water intake available to access the water supply storage in Jordan Lake is jointly owned and maintained by the towns of Cary and Apex. There are a group of utilities currently holding allocations of water supply storage in Jordan Lake that depend on the Cary-Apex raw water pump station to access their allocations. The Chatham County – North water system has an arrangement with Cary and Apex that allows it to supply water to its water treatment plant from water withdrawn at the Cary-Apex raw water pump station. The Cary-Apex WTP regularly supplies water to RDU Airport, Morrisville and the Wake County portion of Research Triangle Park. The Town of Holly Springs has an interconnection with Apex that can provide access to its current two percent allocation of water supply storage in Jordan Lake. If these local governments receive their requested allocations their demands will be covered through the allocation planning horizon. Cary has interconnections with OWASA and Durham through which those utilities can access their current Jordan Lake water supply allocations. Modeling shows that if the Cary-Apex, Morrisville and Holly Springs allocation requests are granted, these communities will reliably be able to meet currently expected customer demands through 2060.

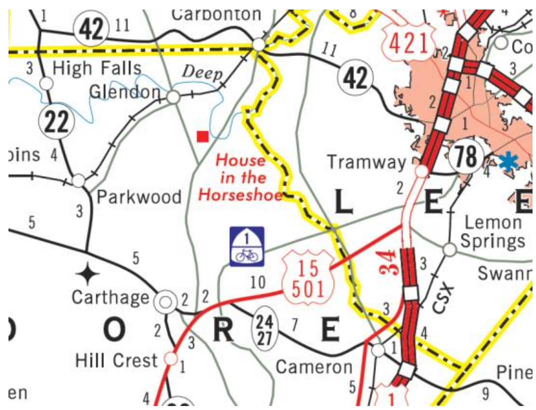


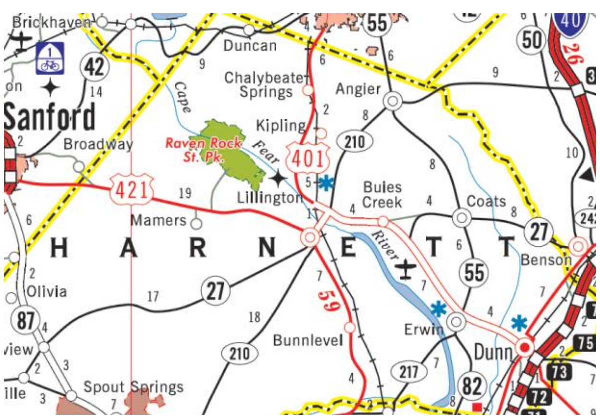
Chatham County provides public water service to areas in the county east of the Haw and Cape Fear rivers not served by Cary or Pittsboro through its Chatham County-North system. The development of Chatham Park, east of Pittsboro, is expected to bring increased development to the surrounding county areas. The Chatham County-North water system is preparing for service population growth from the 2010 level of 10,200, using 2.16 million gallons per day, to 94,000 using 18.1 million gallons per day by 2060. Chatham County currently holds a 6 percent allocation from the Jordan Lake water supply pool and a 3 million gallons per day water treatment plant supplied by the Cary-Apex raw water pump station. Chatham County has requested a 13 percent water supply allocation that will cover there expected demands through 2045. Chatham County is a member of the coalition of systems pursuing the development of the western intake and treatment plant through which its allocation, if granted, will be accessed. If Chatham County receives the anticipated growth associated with Chatham Park, it will likely need to find additional sources of water to meet the projected 2060 demand of over 18 million gallons per day.



Below Jordan Lake, the City of Sanford withdraws water from an unmanaged impoundment behind Buckhorn Dam on the Cape Fear River known as Yarborough Lake and Buckhorn Dam Lake. In addition to its own customers, Sanford also provides water to the Chatham County – East Water System, the Goldston-Gulf Sanitary District, the Town of Broadway and the Utilities, Inc. - Carolina Trace Water System. Sanford discharges about two-thirds of the water it delivers to its service area customers as treated wastewater to the Deep River, upstream of its water supply intake. With this arrangement, the effects of Sanford's withdrawals on streamflows becomes the difference between the quantity of the system's water withdrawal and the amount of its wastewater return flow. Modeling results indicate that the water available at Sanford's current intake location is sufficient to meet the cumulative demands of 24 million gallons per day estimated to be needed to meet 2060 water demands for the public water systems that depend on Sanford's water withdrawals.

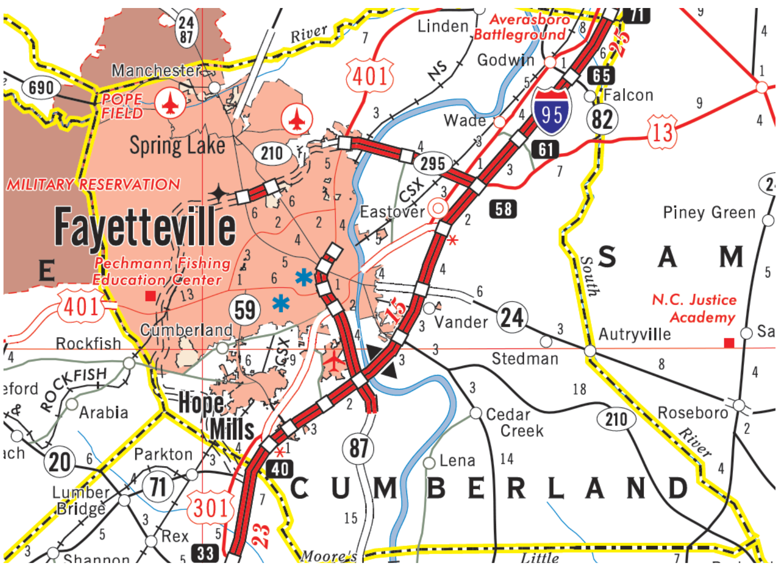
Southwest of Sanford, the Town of Carthage withdraws water from Nicks Creek in the headwaters of the Little River watershed, a tributary of the Cape Fear River. The estimated 2060 water demand for this utility is 1.4 million gallons per day. The model does predict the possibility of short-term flow-related shortages from their current surface water source at this level of demand. Carthage's has an emergency connection with the Town of Southern Pines that can supplement supplies as needed. The additional water source has the potential to alleviate potential flow related shortages at their current source.



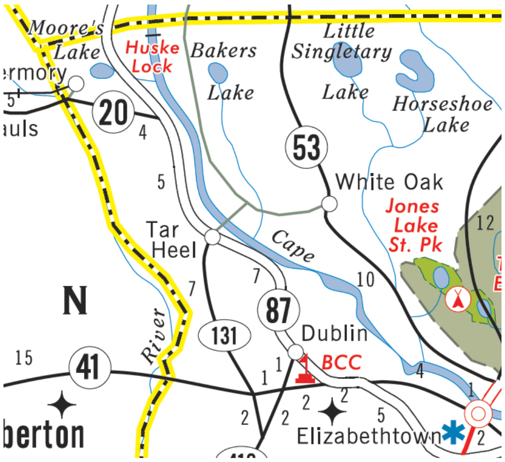


Moving downstream on the Cape Fear River, the next surface water intake is the Harnett County Regional Water System facility near the USGS streamflow gage at Lillington. Over the last few decades, this utility has become a regional water supplier meeting the needs of communities in Harnett, Moore, Cumberland, Wake and Johnston Counties. Its location downstream of Jordan Lake gives this utility an advantageous position to enjoy the increased reliability of the water supply due to the flow augmentation releases from the reservoir. Modeling results do not indicate any flow-related water supply shortages associated with meeting the projected annual average demand of 42.6million gallons per day estimated to be needed to meet the cumulative demands on this intake in 2060.

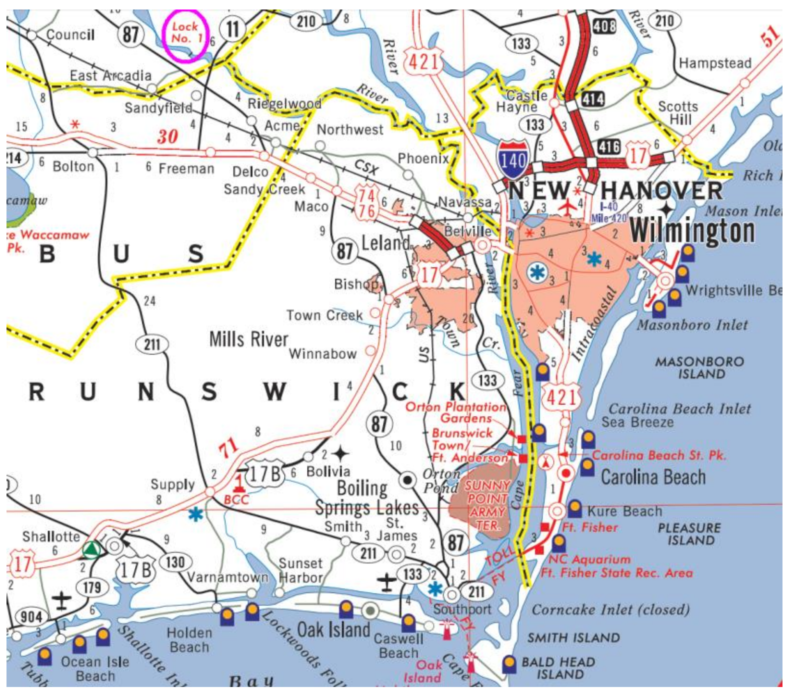
Downstream from the Lillington streamflow gage, the City of Dunn (shown on the map above) withdraws water from the Cape Fear River to supply its residents as well as supplying water to the Town of Benson. The estimated 2060 demand for this intake is 3.6 million gallons per day. The model shows potential flow- related shortages for this volume of withdrawal at this location. The shortage from the model analysis is the result of the levels of flow chosen as the triggers in Dunn's water shortage response plans combined with a 14-day waiting period to activate demand reductions when the triggers are met. This combination forces the model to predict several periods of shortages lasting 14 days or less. Given the location of Dunn's intake on the mainstem of the Cape Fear River, and the level of demand expected, actual flow-related shortages are unlikely.



Further downstream, the City of Fayetteville's Public Works Commission withdraws surface water from the Cape Fear River providing potable water to customers in its own service area as well as several surrounding communities. Fayetteville PWC maintains two surface water intakes on the Cape Fear River in the backwater of William O. Huske Lock and Dam (Lock and Dam 3) operated by the US Army Corps of Engineers. It also has access to water from Little Cross Creek and Big Cross Creek, tributaries of the Cape Fear River. The lock and dam structure maintains a relatively stable water level in the river above the elevation of the top of the dam for approximately 29 miles upstream as long as there is more water flowing downstream than the net withdrawals and evaporation from the impoundment. Fayetteville PWC's withdrawals are approximately 20 miles upstream of the lock and dam structure and the utility discharges treated wastewater downstream of the water supply intakes and upstream of the dam. The wastewater discharges are generally at a volume near 90 percent or more of water withdrawals. Similar to Sanford's arrangement discussed above, the magnitude of the effect of Fayetteville's water withdrawals on the flow in the Cape Fear River is best characterized as the difference between the amount of withdrawal and the amount of wastewater return flow. At the current intake location, modeling does not indicate any flow-related supply shortages limiting Fayetteville PWC ability to meet its estimated annual average 2060 demand of 78.3 million gallons per day. This analysis assumes the range of flow conditions experienced in the basin from 1930-2011 and the current management and drought protocols for Jordan Lake.



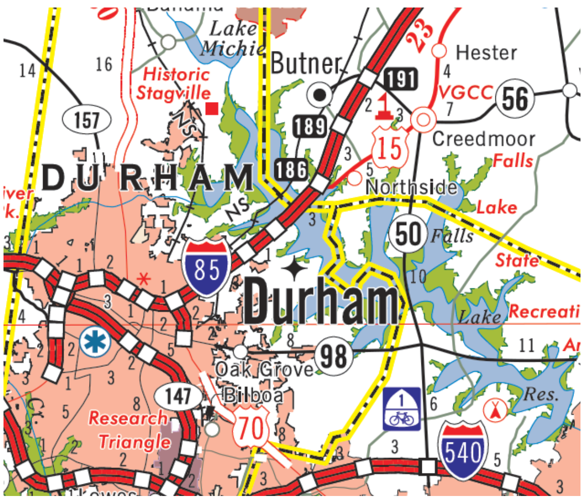
Below Fayetteville, the Lower Cape Fear Water and Sewer Authority withdraws water from the Cape Fear River at its Bladen Bluffs facility near Tarheel and supplies finished water to The Smithfield Packing Company facility in Tarheel. Based on available information, the estimated annual average day demand from this withdrawal in 2060 is 1.5 million gallons per day with approximately the same volume of water returned to the river nearby as treated wastewater. Modeling results do not indicate any flow-related shortages from this volume of withdrawal at this location.



The Cape Fear Public Utility Authority-Wilmington and the Lower Cape Fear Water and Sewer Authority's Kings Bluff facility withdraw water from the Cape Fear River in the back water of Lock and Dam #1 near Kelly, N.C. The CFPUA supplies water to Wilmington and surrounding areas of New Hanover County. The LCFWSA Kings Bluff facility supplies raw water to several industrial customers as well as the water treatment plants operated by Brunswick County, Pender County and CFPUA. The estimated combined 2060 surface water demand for CFPUA and LCFWSA is 63.5 million gallons per day. Hydrologic modeling of the Cape Fear River does not indicate the likelihood of flow-related shortages from withdrawing this amount of water at this location. Lock and Dam #1 is the most downstream point on the Cape Fear River where the hydrologic model estimates effects of water withdrawals. Since none of the water withdrawn above the dam is returned to the backwater of the dam, this withdrawal reduces the streamflow below Lock and Dam 1 by the amount of the withdrawal.

Brunswick County's surface water treatment plant, in combination with water from a groundwater treatment plant, provides water to residents and industries throughout the county including those serviced by the following community water systems: Bald Head Utilities, Brunswick Regional (H2GO), Caswell Beach, Holden Beach, Leland, Navassa, Northwest, Oak Island, Ocean Isle Beach, Shallotte and Southport. In addition, the LCFWSA also provides raw water to the Rocky Point – Topsail Water and Sewer District in Pender County.

As noted in the introduction to this section, consideration of the water needs and the available supplies of communities in the upper Neuse River Basin are crucial to an accurate understanding and optimum utilization of water supply storage in Jordan Lake. Hillsborough, Durham and Raleigh submitted applications for allocations of water supply storage in Jordan Lake and all depend on water sources in the Neuse River Subbasin.

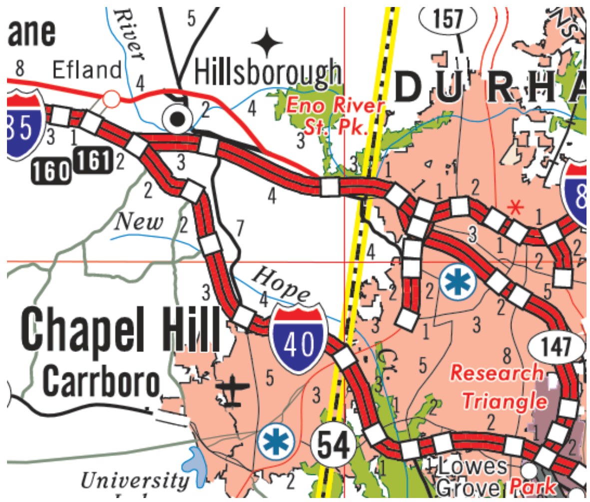


Durham currently has a 10 percent allocation of the Jordan Lake water supply pool, which it can receive as finished water through interconnections with Cary's water system. Durham's primary water supply sources are Lake Michie and the Little River Reservoir upstream of Falls Lake in the Neuse River Subbasin. To date, Durham has only used its Jordan Lake allocation during drought conditions. Durham's ability to access water from Jordan Lake is likely to become less dependable as the Cary-Apex system requires more of their plant capacity to meet their own demands. Except for its Jordan Lake allocation, all of Durham's water supply comes from sources upstream of Falls Lake, which is Raleigh's primary water supply source. Durham has some provisions to pump water from the Eno River, a tributary of Falls Lake, under certain conditions. Durham has investigated the possibility of expanding Lake Michie to increase the amount of water the reservoir can provide. Without a reliable source of water outside of the Neuse River Basin, all of Durham's options for increasing supply to meet future water demands will impact inflows to Falls Lake.

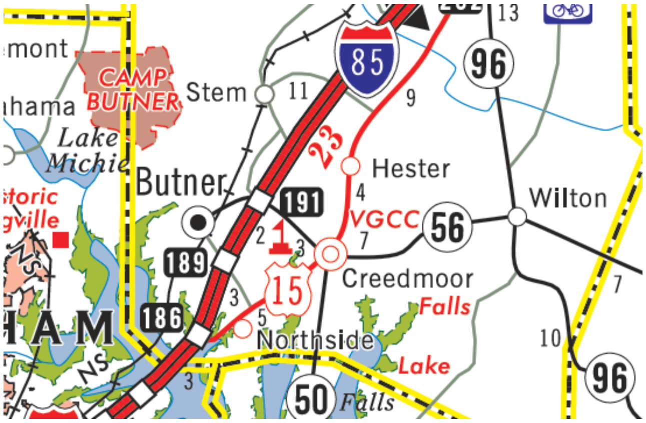
Durham is a partner with the utilities collaborating on the development of a western intake and treatment plant on Jordan Lake. Durham has indicated on its application that when the water treatment plant comes online, it expects to use the full amount of its anticipated 16.5 million gallons a day on a daily basis, which will reduce its withdrawal from the Neuse River Subbasin. Durham currently has mutual aid agreements and emergency connections with Cary, Chatham County – North, Raleigh, Hillsborough, Orange-Alamance Water System and Orange Water and Sewer

Authority. Historically, about 50 percent of Durham's average daily water use is discharged to the Jordan Lake watershed as treated wastewater.

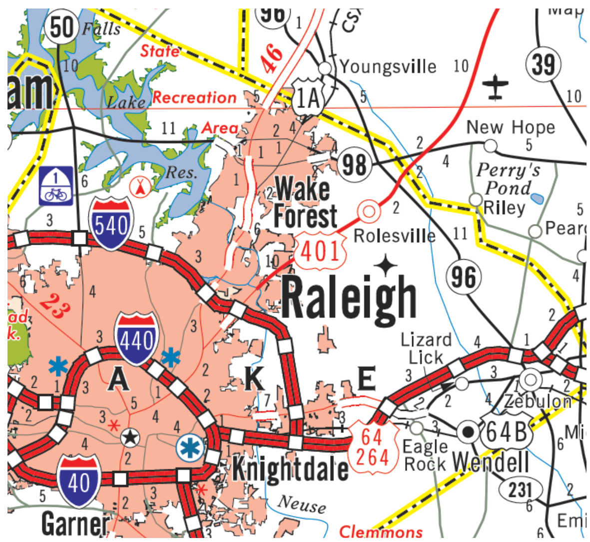
Durham applied for and DWR staff recommended a 16.5 percent allocation from the Jordan Lake water supply pool, which is a 6.5 percent increase over their current allocation. Durham's estimated average daily demand in 2060 is 44.37 million gallons per day. Durham's available supply from Lake Michie and the Little River Reservoir is estimated at 34.4 million gallons per day. The modeling done for this analysis does not indicate any flow-related shortages limiting Durham's ability to meet its customer's demands as modified by the utilities water shortage response plans if it receives the requested allocation from Jordan Lake.



Hillsborough pumps water to its water treatment plant from Lake Ben Johnston, a run-of-river impoundment on the Eno River which receives water from the town's two primary water supplies: Lake Orange, on the East Fork of the Eno River, and the West Fork Eno Reservoir. Hillsborough's primary reservoirs have relatively small drainage areas of nine square miles. In addition, during drought conditions when flows in the Eno River are low, releases must be made from Lake Orange to maintain flows downstream in the Eno River. Hillsborough will soon begin an expansion of the West Fork Eno Reservoir which will increase its water supply storage. The town can receive water from Durham, Orange Water and Sewer Authority and the Orange-Alamance Water System through existing emergency connections. The town can supply water to the Orange-Alamance Water System. Orange County anticipates having the town supply water to economic development zones in the county bordering Hillsborough's current utility service area. Hillsborough applied for, and DWR staff recommended, a one percent allocation from the Jordan Lake water supply pool to meet its long term water supply needs. An allocation from Jordan Lake will provide Hillsborough with a water source from a separate and larger watershed than its existing reservoirs. Hillsborough's estimated average daily demand in 2060 is 3.7 million gallons per day. The modeling done for this evaluation does not indicate any flow-related shortages limiting Hillsborough's ability to meet their customer's demands as modified by the utilities water shortage response plan.



Also upstream of Falls Lake, the South Granville Water and Sewer Authority withdraws water out of R.D. Holt Reservoir on Knapp of Reed's Creek to supply their customers and the Town of Creedmoor. The reservoir has an estimated yield of eleven million gallons per day and the system has an estimated 2060 demand of five million gallons per day. Modeling does not show any flow related shortages meeting the predicted water demands. SGWASA did not apply for a Jordan Lake water supply allocation.

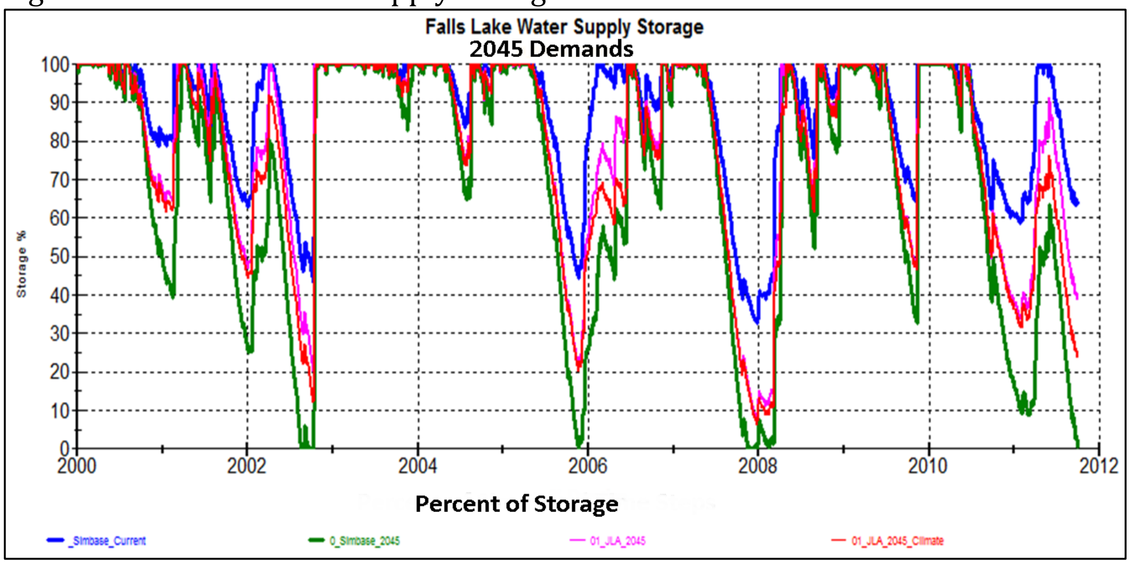


Raleigh depends on the Neuse River Subbasin to supply water to meet its customer's demands. Raleigh's water utility customer base includes the residents of Raleigh, Garner, Knightdale, Rolesville, Wake Forest, Wendell and Zebulon. Raleigh's largest source of water is Falls Lake with an estimated available supply of 66.1 million gallons per day. In addition, Lake Wheeler and Lake Benson on the Swift Creek watershed can provide an estimated 11.2 million gallons per day. The combined yield of 77.3 million gallons per day represents an estimate of the reliable supply available during dry conditions. Most of the time, inflows to the reservoirs are sufficient to support larger withdrawals. Raleigh's 2035, 2045 and 2060 average daily water demands are estimated to be 85, 97 and 115 million gallons per day, respectively. As water withdrawals increase the stress on water supply sources during dry periods will also increase.

The estimated 2045 demand of 97 million gallons per day represents a range of demands from 83 to114 million gallons per day depending on the month of the year. Figure 8 shows the model predictions of the remaining water supply storage for 2010 and 2045 demand levels during the flow conditions experienced from 2000 to 2011. This analysis reflects the restricted demands expected from the water shortage response protocols that Raleigh specified for this modeling effort. Of particular note in Figure 8 is the green plot showing the effect on water storage in Falls Lake when trying to meet anticipated 2045 customer demands without additional sources of water. If Raleigh faced water availability conditions similar to recent droughts, the water supply storage in Falls Lake could be depleted.

Raleigh has been exploring several options to expand the utility's water supply by increments of 14 to 24 million gallons per day. Each option requires extensive environmental and regulatory review and approval resulting in multi-year permitting periods prior to construction and completion. Raleigh will need additional water supplies to meet the anticipated future customer demands.

Figure 8 Falls Lake Water Supply Storage



According to the modeling scenarios run for this analysis, no flow related supply shortages were noted in the modeling results for other surface water withdrawers downstream of Raleigh on the Neuse River or in the Contentnea Creek subbasin. Appendix C contains tables showing the results of the shortage evaluations for the various model scenarios run for this report.

Appendix D shows variations in water resource conditions. Data are presented as percent of days or simulated time steps in the 81-year flow record used in the hydrologic model. Graphs showing reservoir conditions show water levels in terms of feet above sea level or percent of storage. Graphs showing streamflow conditions do so with flow measured in cubic feet per second. The graphs compare conditions that may occur when withdrawing surface water sufficient to meet 2060 water demands with current conditions reflected in the "Simbase_Current" model scenario. Some graphs show 100 percent of the flow record from January 1, 1930 to September 30, 2011. Other graphs focus of critical periods such as when storage or streamflows are low.

Comments to the draft of this document submitted by the NC Wildlife Resources Commission expressed concern about the potential impacts to the distributions of streamflows as withdrawals increase. To address this question Appendix E presents variations in the patterns of flows at 13 locations under the various model scenarios. Flows are subdivided into nine groups ranging from less than 10 percent of mean annual flow to greater than 200 percent of mean annual flow. The graphs show percent of time in the historic record when modeling indicates that flows may be in each percentage grouping for each model scenario. The left-most bar in each group shows the current conditions scenario percentage of mean annual flow for that group. There are four graphs presented for each location. Calendar year values are shown in the first graph for each site. The other three graphs present evaluations based on conditions for the months of March-May, June-November and December-February.

Summary

With the exceptions noted above, modeling shows that for most public water systems that rely on surface water from the Deep River, Haw River, Cape Fear River, Neuse River and the Contentnea Creek subbasins, over the range of flows that have occurred from 1930 to 2011, there will likely be adequate quantities of water available to meet anticipated water needs through 2060. Some communities may have to implement their water shortage response plans in order to reduce customer demands during recurrences of historic drought. Some communities may be able to cover unrestricted demands even during droughts. This group includes communities that get water from the Cape Fear River below Jordan Lake and the Neuse River downstream of Falls Lake. The flow augmentation releases from these reservoirs improve the reliability of water supplies for downstream communities compared to what would be available without the additional flow releases. The completion of Randleman Reservoir and the Piedmont Triad Regional Water Treatment Facility has significantly improved the reliability of water supplies for communities in the Triad Region by reducing the risk of water shortages. Also, Lake Mackintosh continues to provide reliable water supplies for Burlington and the interconnected surrounding communities.

Water supply reliability is less certain for communities in the Research Triangle Region. Thirteen local government entities in this region formed the Jordan Lake Partnership to investigate options to make optimum use of existing water supplies and to cooperatively plan for meeting anticipated future needs. The resulting Triangle Regional Water Supply Plan presents the results of the group's work. The TRWSP recommendations included increased allocations from Jordan Lake for several communities to be withdrawn through a newly constructed intake and water treatment plant on the western shore of Jordan Lake. Optimum utilization of the water supply storage in Jordan Lake will require an additional intake facility. The existing raw water intake does not have the capacity to withdraw the 100 million gallons a day of water assumed to be available from the water supply storage.

Model scenarios were constructed to characterize options presented in the local water supply plans submitted by communities in the Cape Fear and Neuse River Basins as well as alternative water supply options derived from the applications for allocations from the water supply pool in Jordan Lake received by DWR.

15 Surface Water Supply Evaluation Conclusions

The Cape Fear River Water Supply Evaluation is based on the water demand, population estimates, and water supply options data available at the time of the study. The cumulative effects of individual surface water withdrawers' expected future water needs from the Deep River, Haw River, Cape Fear River, Neuse River and Contentnea Creek river subbasins are evaluated using a computer-based hydrologic model. The Cape Fear – Neuse River Basins Hydrologic Model is a platform to evaluate the effects of various levels of water withdrawals on water availability in the context of current and known future management protocols over the range of streamflow variability that occurred between 1930 and 2011 in these basins.

The model results and subsequent interpretation depends on the following key assumptions and limitations:

- The evaluation focuses on the question, will the quantity of water available at specific locations be sufficient to satisfy estimated future water demands,
- Modeling does not include water intended to protect aquatic habitat and ecological integrity except to the extent that required minimum releases are included,
- Population and demand projections in local water supply plans and Jordan Lake allocation application are the best informed estimates,
- Future water withdrawals will be from the same locations as current withdrawals and any new withdrawal locations specified in the source data,
- Water systems that depend on purchasing water from another water system will continue being supplied by the current seller during the planning horizon of this study,
- Wastewater return flows will continue at the current locations unless additional information is provide,
- Wastewater return flows will be the same percentage of water use as in the 2010 basecase model scenario unless additional information was provided,
- The model does not predict future flow conditions, it indicates the effects of withdrawing various volumes of water over the range of streamflow conditions that occurred between 1930 and 2011,
- Agricultural water use is based on estimates developed for previous river basin models and is assumed to be consistent over the planning horizon,
- Water quality is not evaluated,
- The model does not evaluate flooding conditions, and
- The model does not extend into tidally influenced sections of the Cape Fear River or Neuse River.

Given these caveats, the water quantity modeling done for this evaluation suggests that, with several exceptions, the public utilities and other surface water withdrawers in these basins are unlikely to face flow related shortages in the foreseeable future with an increased use of water supply in Jordan Lake. Some communities will have to make use of their water shortage response plans to protect essential water uses during droughts. The modeling indicates potential shortages for several water withdrawers, most of which have plans in place to address these concerns as customer demands increase.

Greensboro's currently available supply will need to be increased to meet projected 2060 demands. However, the currently available supply is limited by the existing water treatment capacity of the Piedmont Triad Regional Water Authority. PTRWA's water source, Randleman Regional Reservoir, reportedly has the capacity to support a three-fold increase in the current 12 million gallons per day treatment plant. Prudent expansions of treatment facilities will be able to cover the expected growth in demand.

The Town of Carthage relies on Nicks Creek for water to meet customer demands. The system also has a long-term contract to purchase water on an emergency basis from the Town of Southern Pines. Modeling of Carthage's 2060 estimated water demands indicate the potential of short-term flow-related shortages during low-flow periods if this demand level becomes reality. The Town's connection with Southern Pines provides a way to address the potential shortages from Nicks Creek.

The Chatham County-North water system anticipates the need to meet annual average day demands of 18 million gallons per days in 2060. Chatham County currently holds a six percent allocation from the water supply pool in Jordan Lake. They have submitted an application request to increase the allocation by seven percent to 13 percent. Under the allocation options modeled, Chatham County-North could face challenges meeting the 2060 estimated demands.

There is no indication this system will face supply shortages over the planning horizon for Jordan Lake water supply allocation decision making, if they receive the requested allocation increase. Chatham County is a member of the consortium of entities proposing to develop a raw water intake and water treatment plant on the western side of Jordan Lake. Their ability to access the requested volume of water is dependent on the construction of these facilities, which is dependent on all members be assured they will have access to Jordan Lake water by receiving their requested allocations.

The City of Raleigh currently depends on water sources in the Neuse River basin to meet water customer needs. It is included in this evaluation because of the water sharing arrangements among public utilities in Haw River, Cape Fear River and Neuse River subbasins. Also, the City of Raleigh Public Utilities Department submitted a request for a 4.7 percent allocation from the water supply pool in Jordan Lake. Currently, Raleigh does not have an allocation from Jordan Lake. With the water supply pool designed to supply 100 million gallons per day, each percent of the pool is generally thought to represent one million gallons per day. The modeling done for this evaluation shows Raleigh having a potential supply shortage to meet the estimated 2045 demands from their existing water sources in the Neuse River Subbasin. Raleigh's primary water supply source is Falls Lake where the city has access to 42.3 percent of the conservation pool. This source is supplemented by water from the Swift Creek Watershed south of the city. The current available supply from both sources is estimated to be 77.3 million gallons per day.

The model scenarios based on local water supply plan data on current and future available supplies supplements existing supplies with 13.7 million gallons per day from a proposed reservoir on Little River in Wake County. The other modeling scenarios do not include water from the Little River Reservoir in Raleigh's available supply. They do, however, include a 4.7 million gallon per day supplement to the existing supplies from a source outside of the Neuse River Basin. The City of Raleigh has a very aggressive water shortage response plan included in the model that is triggered by the percent of storage in the water supply pool of Falls Lake. When supply storage declines during low-flow periods, implementation of the water shortage response plan reduces customer demands.

Modeling for this evaluation that included the additional supplies discussed above and the water shortage response plan did not indicate potential flow-related shortages related to meeting 2060 demand estimates.

This evaluation indicates that, with the water supply sharing arrangements detailed in the Triangle Regional Water Supply Plan and the local water supply plans submitted by surface water dependent water systems in the Deep River, Haw River, Cape Fear River, Neuse River and Contentnea Creek basins, strictly from a quantity perspective, surface water resources are likely to be sufficient to meet expected 2060 demand levels. given the assumptions and limitations of the hydrologic model. The modeling results are dependent on the wastewater return flow assumptions and the limitation that the model does not reserve streamflow to protect aquatic habitats and ecological integrity.

The water elevation variations under the model scenarios discussed above for the reservoirs other than Jordan Lake can be found in the graphs in Appendix D, which also has graphic representations of the flow variations at locations in the Cape Fear River and Neuse River basins.

16 Appendix A Drought Contingency Plan

APPENDIX A
B. Everett Jordan Dam and Lake
Cape Fear River Basin, NC

DROUGHT CONTINGENCY PLAN
Updated May 2008

B. EVERETT JORDAN LAKE
CAPE FEAR RIVER BASIN, NORTH CAROLINA
DROUGHT CONTINGENCY PLAN
Updated May 2008

INTRODUCTION

The purpose of this report is to (1) provide a platform from which to make decisions on implementation of water conservation measures during future droughts, (2) review the operational flexibility of the Jordan Water Control Plan in a drought, and (3) address the potential problems associated with an extreme drought. A severe drought in the Cape Fear River basin develops over a fairly long period of time and may have a typical duration of 6-12 months. However, the severe drought which climaxed in 2002 may have begun as early as 1996. Adequate time will be available to plan specific details of a drought operation. Therefore, this plan is an outline of water management measures and coordination actions to be considered when a severe drought occurs. Details of particular water management measures and the timing of their application will be determined as the drought progresses. This plan is part of the Water Control Manual for B. Everett Jordan Dam and Lake.

BACKGROUND

Usually, the demand for water is the greatest when the natural supply is the least. Jordan Lake has been drawn below elevation 210 feet, MSL on four separate occasions since completion of permanent impoundment on February 4, 1982. (Normal level is 216 ft, MSL). During this time period, no water supply withdrawals were made. The only releases were for water quality needs downstream. Table 1 shows the minimum lake elevation for each year since inception of the project.

These elevations indicate that the 1980's decade was a dry period. The potential for a serious drought did exist in 1983, 1986, and 1988 due to the time of year and the minimum elevation that occurred

TABLE 1

Minimum Elevation at Jordan Lake since Permanent Impoundment

Calendar Year	Date	Elevation (ft. MSL)
1982	September 28	213.95
1983	October 23	208.85
1984	November 28	212.55
1985	November 3	213.25
1986	November 12	207.85
1987	November 26	210.60
1988	August 29	210.23
1989	September 16	215.63
1990	October 10	209.59
1991	December 26	212.69
1992	October 29	213.80
1993	November 26	210.80
1994	October 13	214.75
1995	August 26	214.87
1996	July 23	215.18
1997	October 18	213.65
1998	December 8	210.31
1999	August 24	212.56
2000	December 15	212.95
2001	December 31	210.89
2002	August 24	209.87
2003	September 14	215.88
2004	March 22	215.76
2005	November 20	212.13
2006	August 30	215.34
2007	October 24	210.19

Historical surface water use (in 1987) by municipalities and industries downstream of Jordan Dam as tabulated by the U. S. Geological Survey is provided in Table 2. This table illustrates that the required water supply is significant and will likely continue to increase

Cape Fear River Basin Water Supply Users below Jordan Dam

Municipality	Source of Supply	Amount of Withdrawal MGD	Population (1987) Served
Vass	Little River	0.14	900
Carthage	Nicks Creek	0.26	1,500
Sanford	Cape Fear River	3.34	18,000
Northeast Metro Water District (Harnett Co.)	Cape Fear River	0.75	5,000
Dunn	Cape Fear River	2.35	9,450
Fayetteville	Cape Fear River	16.25	118,604
Fort Bragg	Little River	7.94	121,828
Wilmington	Cape Fear River	9.72	52,000

Industry	Source of Supply	Average Annual Withdrawal in MGD(1987)
Chembond Corp.	Haw River	0.22
Honeywell	Haw River	0.32
Moncure Fiberboard Plant	Shaddox Creek	0.34
Sanford Group	Several Ponds	0.08
Elliott Gravel Pit	Several Ponds	0.20
Burlington Industries Erwin Plant	Cape Fear River	2.0
Dupont (Cumberland Co.)	Cape Fear River	9.0
Monsanto (Cumberland Co.)	Cape Fear River	1.3
Cape Fear Feed Products	Cape Fear River	0.05
Federal Paper Board Co.	Cape Fear River	43.25
Wright Chemical Corp	Livingston Creek	0.2
Dupont (Brunswick Co.)	Cape Fear River	7.3
Occidental Chemical Corp.	Cape Fear River	0.29
Dixie Cement	Cape Fear River (2 intakes)	1.2

Lake access is available during periods of low lake levels. This is illustrated in Table 3 which gives the bottom elevation of boat ramps at current and future access areas. The top elevation of boat ramps at Jordan Lake is approximately 227 feet MSL. However, operational experience during this period showed that recreational use of the lake began to suffer once the elevation fell below 212-213 feet MSL. Numerous complaints were received at both the Resource Manager's Office and Crosswinds Marina during low elevation periods primarily regarding shoals and navigational hazards within the lake. While the facilities at Crosswinds Marina were designed to function at elevations lower than what occurred, there was very little recreational use observed when Jordan Lake fell below elevation 212 feet MSL. While recreational use of the lake is significantly impacted at elevation 212 feet MSL and below, serious problems are also encountered at Crosswinds Marina once the elevation drops to 205.0 MSL. The problem at Crosswinds Marina is the bracings on the finger pier system which require approximately 6 feet of water to remain in place.

TABLE 3
Bottom Elevation of Public Boat Ramps at Jordan Lake
May 2008

Location	**Lanes**	**Bottom of Ramp Elevation (ft. MSL)**
Access Currently Available:		
Ebenezer	2 Lanes	202.0
	4 Lanes	206.0
Vista Point	2 Lanes	202.0
	2 Lanes	206.0
Parkers Creek	2 Lanes	210.0
Farrington	2 Lanes	202.0
	2 Lanes	206.0
	2 Lanes	208.0
Crosswinds Ramp	4 Lanes	212.0
	2 Lanes	202.0
Crosswinds Marina	2 Lanes	202.0
	2 Lanes	208.0
Poes Ridge	4 Lanes	210.0
Poplar Point	4 Lanes	210.0
Seaforth	3 Lanes	205.0
	3 Lanes	210.0
Crosswinds Campground	2 Lanes	207.0
Robeson Creek	2 Lanes	202.0
New Hope Overlook	2 Lanes	202.0
	4 Lanes	208.0

Note: All boat ramps were constructed prior to impoundment of Jordan Lake. The top elevation of all ramps is approximately 227 feet, MSL.

SUMMARY OF EXISTING WATER CONTROL PLAN

The authorized purposes of Jordan Lake are to provide for flood control, water supply, water quality control, recreation, and fish and wildlife conservation. The top of the conservation pool is at elevation 216.0 feet MSL. At that elevation, the mean depth of the lake is 15 feet and the maximum depth is about 66 feet. Allocated storages for Jordan Lake are shown in table 4.

Storage Allocation

	Elevation (Ft. MSL)	**Area (Ac.)**	**Capacity/Jun85 (Ac-Ft)**
Top of flood control pool	240	31,811	753,560
Flood control storage	216-240		538,430
Top of conservation pool	216	13,942	215,130
Bottom of conservation pool	202	6,658	74,700
Conservation pool storage	202-216		140,430
Water Supply			45,810
Water Quality (Low Flow)			94,620
Sediment storage	155-202		74,700

The plan of operation for Jordan Lake project provides for maintaining a normal pool at elevation 216 feet MSL on a year round basis. This is accomplished during periods of normal flow by releasing inflow. During flood periods, releases are based on a combination of downstream flow conditions and lake levels to minimize flood damages downstream. During normal and low-flow conditions, flows are released to maintain a minimum target flow of 600 cubic feet per second (c.f.s.) at the Lillington gage with an allowable range of 550 to 650 c.f.s.. A minimum instantaneous flow of 40 c.f.s. is maintained immediately below the dam. The conservation pool storage is divided with 67.38 percent allocated for water quality releases downstream and 32.62 percent contracted by the State of North Carolina for water supply.

Regulation flexibility is very limited under existing authority. When the lake elevation is in the conservation pool, the project will be operated to meet water supply requirements and water quality low flow releases. The only available flexibility from a regulation viewpoint in this situation would be that the State of North Carolina water quality release requirements and/or water supply withdrawals.

Storage-use flexibility between the conservation and flood control pools is not a viable option within the guidelines authorizing the project. Flexibility within the conservation pool between water supply and water quality would have to be initiated and addressed by the State of North Carolina.

ANALYSIS OF DROUGHT OPERATION

Dry periods occur randomly during any time period. There is no major indicator to distinguish "normal" dry periods from severe droughts during the early stages. Conditions may vary depending on the time of year, length of time the lake is below elevation 216 feet MSL, and water supply and water quality requirements. However, a water budget (which will be generated and maintained by the Wilmington District) outlining water quality and water supply storage remaining will be used to initiate action.

The Drought Management Committee shall consist of the Wilmington District and other Federal agencies as required. Advisors to the committee will be representatives from the State of North Carolina and local governments. Coordination activities shall include but not be limited to initiation of the Drought Contingency Plan, alerting recreation interests within the lake, issuing forecasts of water supply and water quality storage remaining, implementing conservation measures, and making public information releases.

The Division of Water Resources with the Department of Environment and Natural Resources will act as the point of contact for the State of North Carolina and as the responsible party for notifying all related concerned interests. The Operations Manager for Jordan Lake will be responsible for notifying all related concerned interests within the lake (marina operation, recreation use areas, etc.) of the current status, forecast of drawdown and for performing duties in conjunction with state agencies as described in the "Operational Management Plan" for B. Everett Jordan Lake. Wilmington District Water Management personnel shall prepare a water budget consisting of water supply, water quality storage remaining and a forecast of time remaining at the current usage rate for water quality and water supply. This forecast and water budget shall be updated as needed and furnished to the Operations Manager at Jordan Lake and the Director of Water Resources with the State.

Public press releases shall be made on an "as-needed" basis through the Public Affairs Office (PAO) in the Wilmington District. These statements shall provide the public with a full explanation of drought operations and forecasts of expected conditions in an effort to reduce inquiries from recreation and concerned interests.

A drought situation report for Jordan and other projects within the Wilmington District shall be prepared as appropriate by the Reservoir Regulation Section of the Wilmington District. This report shall provide detailed information on current and forecast situations for informational purposes of District and South Atlantic Division elements.

DROUGHT MANAGEMENT PLAN

This plan may be initiated by the Chief, Coastal, Hydrology and Hydraulics Section of the Wilmington District Corps of Engineers when the elevation at Jordan is below 216 ft., MSL. The Drought Management Plan focuses on waters contained in the conservation pool (202-216 ft, MSL) of Jordan Lake. The said conservation pool contains water to meet congressionally approved water supply and water quality purposes. The Drought Management Plan emphasizes increased coordination and consultation with stakeholders when either water supply or water quality pool storage declines to 80 percent remaining. Due to capacity and outflow requirements, the water quality pool is the controlling entity in management of drought releases.

The Drought Management Committee shall consist of the Wilmington District and other

The drought release schedule from Jordan Dam is listed in table 5 below.

Table 5: Drought Release Schedule

Drought Level	Water Quality Storage Remaining (%)	Jordan Dam Minimum Release* (cfs)	Jordan Dam Maximum Release (cfs)	Lillington Daily Average Flow Target (cfs)
0	>= 80	40+	600	600 +/- 50
1	60 – 80	40+	Lillington target	450 - 600 +/- 50
2	40 – 60	40+	Lillington target	300 - 450 +/- 50
3	20 – 40	40+	200+ *	None**
4	0 – 20	40+	100-200+ *	None**

* Water quality release plus any required downstream water supply releases.
** Lillington flow will be total of Jordan Dam release plus local inflow.

1. A water budget shall be initiated by the Wilmington District (retroactive to the date that the lake first dropped below elevation 216.0 feet MSL). The State of North Carolina shall be updated by the Wilmington District, U.S. Army Corps of Engineers, on a weekly basis regarding water quality and water supply storage remaining. Based on the budget and storage remaining the following operations from BE Jordan Dam and Lake will be taken:

A. Drought level 0: flow target at Lillington remains at 600 +/- 50 cfs
B. Drought level 1: flow target at Lillington ranges from 450 – 600 +/- 50 cfs
C. Drought level 2: flow target at Lillington ranges from 300 – 450 +/- 50 cfs
D. Drought level 3: no flow target set at Lillington. A maximum release rate of 200 cfs from BE Jordan Dam and Lake, plus any required downstream water supply releases.
E. Drought level 4: no flow target set at Lillington. A maximum release rate of 100-200 cfs from BE Jordan Dam and Lake, plus any required downstream water supply releases

Note that for drought levels 0-2, the flow target is a range of flow targets at Lillington. The range of flows result from collaboration and coordination on a variety of parameters such as stakeholder input, short and long term weather outlook, project gate status, influences on stream flows downstream, and local inflows to both Jordan Lake and reaches below the dam. In addition, the minimal flows immediately below B. Everett Jordan Dam and Lake is 40 cfs for all drought levels.

Note that for drought level 3 – 4, no flow target is set for Lillington. The flow rate is a mostly constant release set from B. Everett Jordan Dam and Lake. Level 4 releases between 100-200 c.f.s. will be set based on consultation with the state of NC and other stakeholders. Temporary reductions can be made as long as flows at Lillington can be maintained at 300 c.f.s. or greater.

For all release modes listed, in Table 5 above, the release operation will be made for a minimum of seven (7) days in conjunction with the monitoring of the river system, made by NCDWQ and other agencies.

Conversely, with increasing water quality storage, the sequence of operation will generally be reversed; however, consideration of limited watershed inflows, precipitation forecasts, or other factors with appropriate stakeholder consultation may warrant continued reduced flow targets at Lillington.

2. Once drought level 4 has passed and no water quality storage remains, the plan of action will depend on decisions that must be made by the State of North Carolina, since all storage within the conservation pool at Jordan Lake has been allocated to water supply and water quality. Potential alternatives available to the State of North Carolina once drought level 4 of the management plan has been met include, but are not limited to, the following:

a. Implement restrictive water use measures for personal and emergency use only (no water for lawns, gardens, pools, car washes, etc.)

b. Temporarily relax State standards for water quality requirements in the river below Jordan Lake to permit continued operation of industrial and municipal waste treatment facilities, and conserve remaining water quality storage.

c. Reallocate any surplus water supply storage for the duration of the drought to supplement water quality storage and/or provide relief in those areas of greatest need.

3. Should the elevation of Jordan Lake fall below lake elevation 202 ft, MSL or all water supply or water quality storage become depleted, potential alternatives include but are not limited to:

a. Emergency reallocation(s) by the Corps under PL 78-534 of remaining storage volume within the Sediment Pool.

b. Declaration by the State of North Carolina of a water emergency as authorized by G.S. 143-355.3. After a water emergency has been declared by the Governor, State of North Carolina, the Secretary, Department of Environmental and Natural Resources, can order emergency diversions to meet the essential water uses of water systems experiencing water shortage emergencies. The Division of Water Resources along with other agencies within the Department of Environmental and Natural Resources will assess water supply problems and recommend actions to the Secretary under this statute.

SELECTED FEDERAL EMERGENCY AUTHORITIES PROVIDING DROUGHT ASSISTANCE

The responsibility for providing an adequate supply of water to inhabitants of any area is basically non-Federal. Corps assistance to provide emergency water supplies will only be considered when non-Federal interests have exhausted reasonable means for securing necessary water supplies, including assistance and support from other Federal agencies.

Assistance may be available from the Corps through PL 84-99 as amended by PL 95-51. Before Corps assistance is considered under PL 95-51, the applicability of other Federal assistance authorities should be evaluated. If these programs cannot provide the needed assistance, then maximum coordination should be made with appropriate agencies in implementing Corps assistance. The applicability of programs administered by the following Federal agencies, as a minimum, will be determined prior to consideration of Corps assistance.

1. Small Business Administration (SBA).

2. Farmers Home Administration (FmHA).

3. Economic Development Administration (EDA).

Corps Authority for Drought Assistance

The Corps authority for Drought Assistance is contained in Chapter 6, "Emergency Water Supplies and Drought Assistance" of Engineering Regulation 500-1-1 Natural Disaster Procedures (1983). Under this authority, the Chief of Engineers, acting for the Secretary of the Army, can construct wells and transport water to farmers, ranchers, and political subdivisions within areas he determines to be drought-distressed.

17 Appendix B Water Availability Behind Lock and Dam #3

Cape Fear River Water Availability at Lock and Dam #3

When developing a Local Water Supply Plan DWR has been suggesting to local governments with run-of-river intakes to consider 20% of the ten year seven-day low flow[25] as a guideline of how much water it may be possible to withdraw at a specific location for planning purposes, if no better value is available. This value was chosen because it is one of the benchmark criteria in DENR's rules[26] for conforming to the North Carolina Environmental Policy Act.[27] The rules define minor construction activities that may not require the preparation of an environmental document as outlined in the NCEPA.

Specific criteria that must be met for public water supply system projects to be considered minor are "improvements to water treatment plants that involve less than 1,000,000 gallons per day of added capacity and total design withdrawal less than one-fifth of the 7-day, 10-year low flow of the contributing stream."[28] If a proposed increase in the total design capacity for a potable water treatment plant would equal or exceed this amount at the withdrawal location then the preparation of an environmental document is required to evaluate the impact of the proposed project.[29] Using 20% of the 7Q10 flow for planning suggests the amount of water that may be available from a run-of-river intake location without an extensive environmental impact evaluation, if no other NCEPA criteria are triggered by a proposed project. It is not a fixed limit on the withdrawal capacity that may be possible at a specific location. With the proper environmental impact evaluation the utility may be able to withdraw more water.

Estimates of 7Q10 flows are dependent on the historic flow conditions reflected in the data in the period of record used. Water intakes located in free-flowing stream reaches have the potential to significantly impact the river environment and other water users when flows are low. In free-flowing river reaches the amount of water available for all uses is only the amount flowing in the stream channel. If water is withdrawn from a managed reservoir, stored water is available to meet water withdrawal demands and supplement downstream flows to minimize environmental impacts during low flows. Having stored water available increases the reliability of a public water supply source. Having the ability to manage downstream releases provides the ability to compensate for the potential environmental impacts of a withdrawal during low flow conditions by releasing stored water to supplement downstream river flows.

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[25] 7Q10,
[26] 15A NCAC 01C .0101 et seq.
[27] NC G.S. § 113A-1
[28] 15A NCAC 01C .0408 (2)(b)(i)
[29] The same section of the rule includes the criteria that if the proposed project would increase treatment capacity by 1,000,000 gallons per day or more the preparation of an environmental document would also be required.

In Fayetteville's case basing the quantity of water available at the intake on the 7Q10 value has limited usefulness. Fayetteville PWC has the capacity to withdraw and treat 57.5 mgd of water through an intake on the Cape Fear River in the backwater of Lock and Dam #3. The lock and dam structure maintains water levels sufficient to reliably keep the intake structure covered to a depth sufficient to pump water to the water treatment plants. This arrangement increases the reliability of the source to meet the utility's water needs. L&D#3 is not operated to regulate downstream releases. The water levels behind L&D#3 are typically at or above the top of the spillway creating a pool of water that extends 29 miles upstream. However, unlike a managed water supply reservoir where downstream releases can be tailored to compensate for withdrawals and minimize environmental impacts, L&D#3 does not have the ability to compensate for the cumulative effects of water use from the backwater on downstream river flows. Water flowing into the backwater of L&D#3 flows over the dam with little variation in water levels except during flooding events making it difficult to estimate flow variation within this river reach. The amount of water flowing below L&D#3 is affected by the cumulative use of water from the backwater. Evaluating the potential changes in flows from L&D#3 can be used to consider potential environmental impacts from any proposed increases in water withdrawals in the vicinity of Fayetteville's intake.

The Cape Fear-Neuse River Basins Hydrologic Model can provide flow estimations at L&D#3. Flows downstream from the model node representing L&D#3 can be compared under various withdrawal scenarios to quantify the resulting changes in downstream river flows.
Lock and Dam Number 3 (William O. Huske Lock and Dam) is located at river mile (RM) 95 on the main stem of the Cape Fear River. The estimated upstream limit of the backwater of L&D#3 is RM 124[30]. Within the 29 miles of backwater there are several withdrawals and discharges:

- DuPont intake at RM 96.
- DuPont discharge at RM 95.3.
- City of Fayetteville discharge at RM 109.
- City of Fayetteville discharge at RM 115.5.
- City of Fayetteville intake at RM 117.

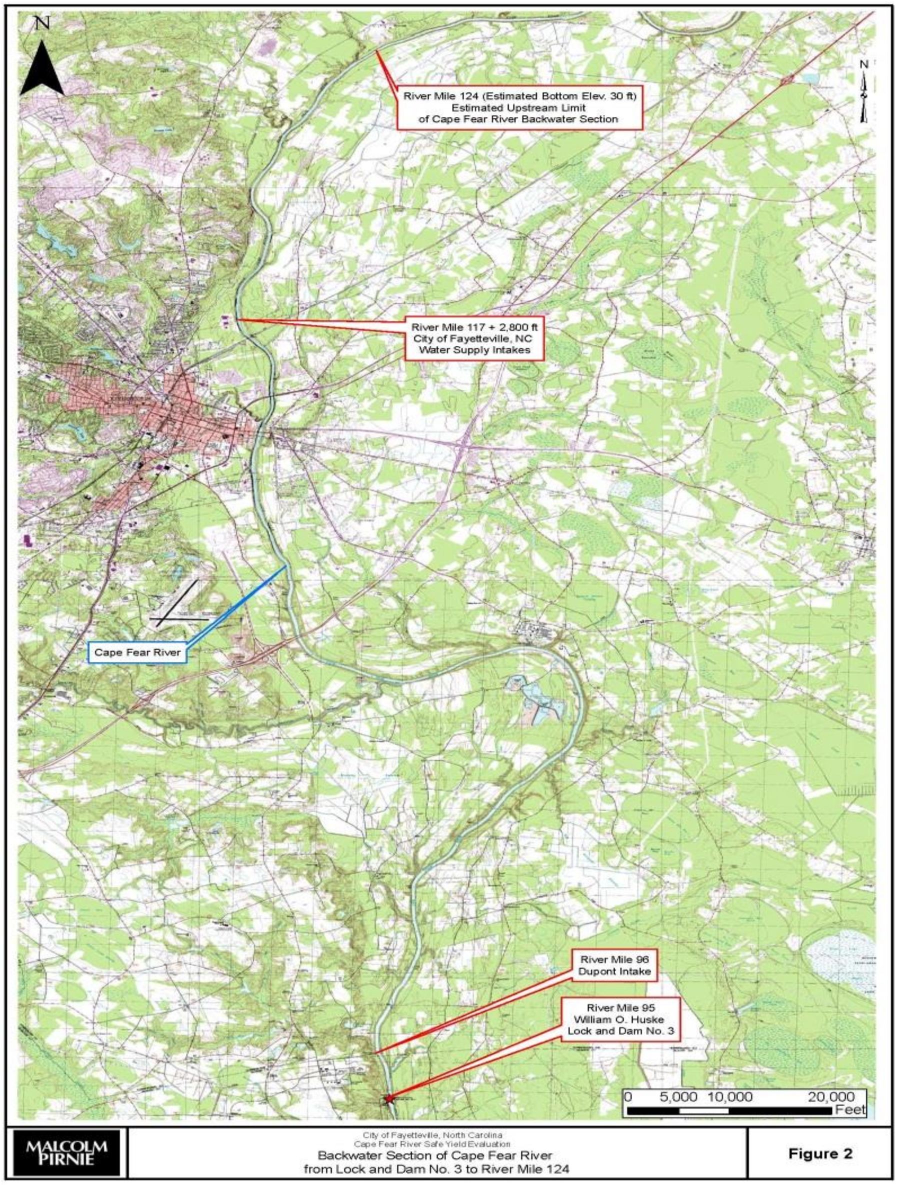
The map below, extracted from a Technical Memorandum prepared for Fayetteville PWC by staff at Malcolm Pirnie, shows the location of the features cited above.

The Cape Fear-Neuse River Basins Hydrologic Model characterizes the cumulative effects on surface water conditions of water withdrawals, wastewater returns and water resource management protocols, in the context of over 80 years of surface water flows. The model covers both basins from the headwaters downstream to where flows are tidally influenced. In the Cape Fear River Basin it goes to Lock and Dam #1 and in the Neuse River downstream to a bit above New Bern. A portion of the model schematic showing the nodes associated with the water users in the backwater of L&D#3 is shown below. The locations of inputs and outflows in the model are shown in their relative location to other features in the model. The nodes in the model schematic are not geographically referenced. The schematic represents a very large mathematical equation tracking surface water conditions as water flows downstream. The nodes show where in

[30] Malcolm Pirnie June 25, 2007 Technical Memorandum – Cape Fear River Safe Yield Evaluation.

the sequence water is added to the system from tributary flows, where water is withdrawn for off-stream uses, where used water is returned, where water is stored in a reservoir and where the model compensates for the time-of-travel of water flowing downstream.

Figure B-1Cape Fear River in Vicinity of Fayetteville, NC

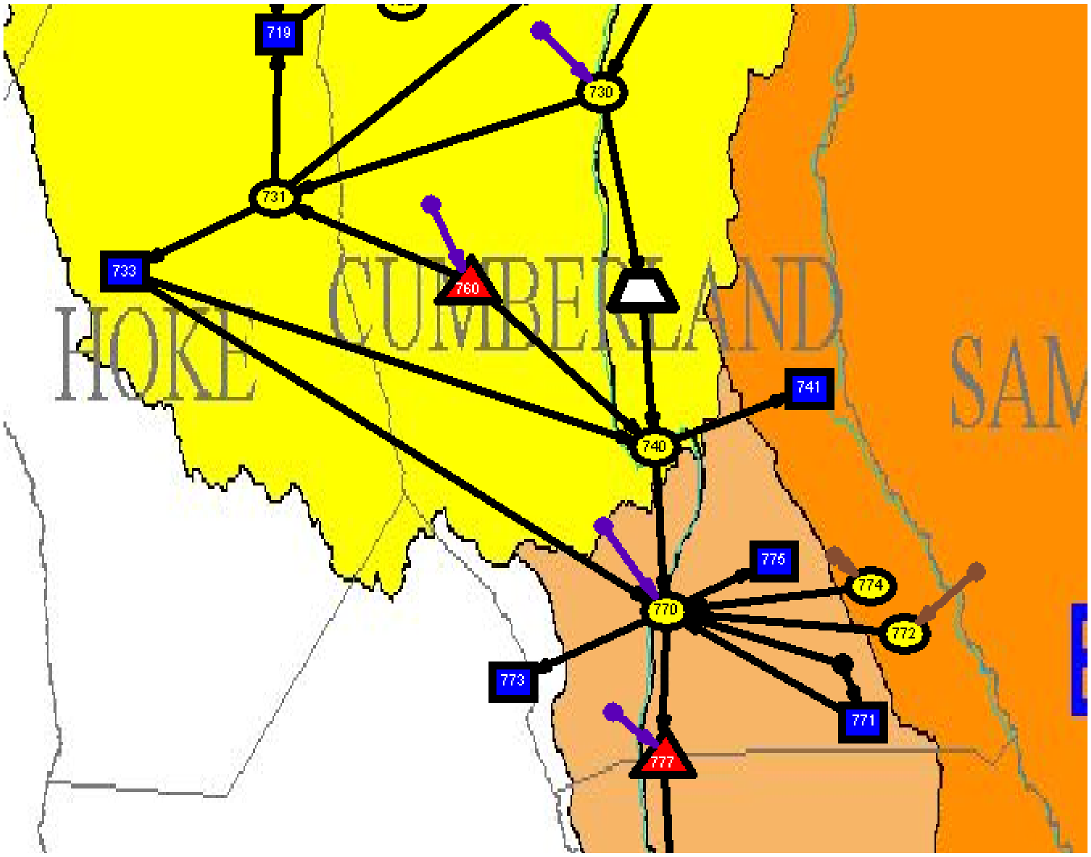


The relevant model nodes in the combined Cape Fear – Neuse Hydrologic Model are shown below. The arcs between polygons show the direction of water movement. The purple arcs indicate where local inflows are added to the river system.

- Node 777 is Lock and Dam Number 3
- Node 730 is Fayetteville's intake on the Cape Fear River
- Node 731 is Fayetteville's total water withdrawal including water for PWC customers and water supplied to Spring Lake and Old North Utilities

- Node 740 adjusts river flows for the cumulative effects of water flow from node 730, inflow from Glenville Lake, return flow from Fayetteville's Cross Creek WWTP, and agricultural withdrawals in Cumberland County
- Node 760 is Glenville Lake
- Node 770 adjusts river flows for the cumulative effects of water flow from node 740, local inflow, return flow from Fayetteville's Rockfish Creek WWTP, withdrawals to and return flow from the Dupont facility, agricultural withdrawals in Cumberland and Hoke counties, and inflows from two wastewater treatment plants that do not withdraw surface water from the basin.

Figure B-2 Cape Fear – Neuse River Basins Hydrologic Model Detail Lock and Dam #3



Data on the elevation, area and volume relationships for the backwater of L&D#3 are not available therefore it is not modeled as a reservoir but as a free-flowing river reach with no accommodations for water storage. The combined basin model was calibrated to sufficiently describe the known surface water conditions experienced in 2010. To evaluate potential changes that may occur due to changes in management, return flows and water withdrawals, various scenarios are developed from the 2010 scenario and modeling results are compared to those from the 2010 scenario. This approach provides a picture of how conditions may change under the alternative scenarios compared to the conditions experienced in 2010, given the assumptions in the model. The hydrologic model produces flow data at river nodes that can be used to estimate various flow statistics, including 7Q10.

There are many factors that will come into play in the evaluation of a proposed expansion of water withdrawal capacity at Fayetteville's intake location. In all likelihood an in-depth environmental impact evaluation will be required regardless of any estimation of the magnitude of the design capacity in relationship to an estimated 7Q10 flow. Potential impacts to river flows due to an increased withdrawal will have to be evaluated. For this analysis DWR staff proposes to use the flow from Lock and Dam #3, as the appropriate measure of impacts to flows from the affected river reach resulting from any increased withdrawal in the backwater of L&D#3. The Cape Fear – Neuse River Basins Hydrologic Model could be used for this analysis by comparing the effects of proposed withdrawal scenarios on outflows from Node 777 representing L&D#3.

Cumulative withdrawals in relation to 7Q10 flow below L&D#3

L&D#3 is not equipped to manage downstream releases. River flows below L&D#3 are the result of spillage over the dam resulting from the cumulative effects of upstream inflows, water withdrawals and return flows in the backwater. The flows coming out of Node 777, representing spillage over the dam, can be used to estimate 7Q10 flows at this location based on the flow record used in the model runs. Changes in outflows from Node 777 under various withdrawal scenarios can be used to evaluate the effects of streamflows that may result from proposed withdrawal increases in the backwater.

Therefore, due to the presence of multiple withdrawals and discharges in the affected reach of Fayetteville's intake, for planning purposes DWR proposes to evaluate the flow impacts of any withdrawal proposals by comparing model outputs at Node 777 to those in the 2010 model scenario that forms the basecase and point of comparison for all modeling scenarios.
The proposed water availability evaluation and flow impact evaluation described above is presented to support water supply planning. Any evaluation associated with a proposed project will be subject to all relevant criteria addressed in the rules[31] guiding conformity with the NC Environmental Policy Act.[32]

In February 2015 DWR staff evaluated the proposed methodology to assess the implications of Fayetteville PWC's 2060 demand projections noted in its Jordan Lake Water Supply Allocation Application. For this evaluation the results of two model scenarios were compared. The 2010 Basecase of the Cape Fear- Neuse River Basins Hydrologic Model and the scenario constructed to evaluate the Jordan Lake allocation requests for 2045 with the estimated water supply withdrawals needed to meet demands in 2060, referred to here as the 2060 scenario. The 2060 scenario did not include Fayetteville PWC's requested allocation from Jordan Lake to see if future demands could be met from the river at the current intake location and to limit the potential effects on flows below L&D#3 to flows in the river and Fayetteville's use of water above L&D#3.

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[31] 15A NCAC 01C .0101

[32] Additional information of compliance with the NCEPA can be found at: http://portal.ncdenr.org/web/deao/sepa

Fayetteville's annual average demand in the 2010 model scenario is 27 mgd with withdrawals ranging from 20 mgd to 35 mgd. For the 2010 scenario the model estimated 7Q10 flow at L&D#3 is 277 mgd. The maximum daily average withdrawal of 35 mgd is about 13% of 277 mgd. The reductions in flows at L&D#3 from Fayetteville's withdrawal is offset by the system's wastewater discharges in the affected reach between the water supply intake and L&D#3. The 2010 model scenario shows the cumulative annual average discharge as 26 mgd with discharges ranging from 25 mgd to 27 mgd. Having the system's wastewater return flows between the withdrawal and first downstream point where flow can be measured suggests that the logical measure of Fayetteville's impact on river flows should be measured as the net withdrawal rather than the water supply withdrawal. Evaluating the annual average withdrawal of 27.3 mgd, in relation to the annual average wastewater discharge of 25.8 mgd, results in a net withdrawal of 1.5 mgd from the Cape Fear River in the backwater of L&D#3. A 1.5 mgd net withdrawal translates into about 0.5% of the estimated 277 mgd 7Q10 flow. Evaluating the maximum withdrawal (35 mgd) in relation to the minimum wastewater discharge (25 mgd) produces a net withdrawal of 10 mgd; or about 4% of the 7Q10 flow.

The other demand scenario evaluated was for Fayetteville's estimated 2060 water demands. According to Fayetteville's Jordan Lake Water Supply Allocation Application the estimated annual average water demand in 2060 is 75 mgd, ranging from 60 mgd to 90 mgd throughout the year. This demand scenario evaluates water quantity conditions using the estimated 2060 demands for all modeled water withdrawals and the same historic flow data as the 2010 scenario. As expected, increasing withdrawals over the same range of flow conditions reduces river flows below L&D#3 below the levels in the 2010 scenario. The estimated 7Q10 flow below L&D#3 in the 2060 scenario is 246 mgd. Fayetteville's daily average withdrawal of 75 mgd represents 30% of the 7Q10 flow at L&D#3. Fayetteville's estimated 2060 wastewater return flows averages 72 mgd which produces a net withdrawal by Fayetteville PWC of 3 mgd or a little over 1% of the model estimated 7Q10 flow. Estimated wastewater discharges in 2060 range from 69 mgd to 76 mgd. Evaluating the maximum withdrawal estimate (90 mgd) in relationship to the minimum estimated wastewater discharge (69 mgd) gives an estimated net withdrawal of 21 mgd or about 9% of the 7Q10 flow at L&D#3.

Using this approach of assessing net withdrawal by Fayetteville compared to the 2060 7Q10 estimate, based on the water demands and assumptions in the Cape Fear – Neuse River Basin Hydrologic Model, we can estimate the level of withdrawal that may be possible without exceeding 20% of the 7Q10.

2060 Lock & Dam # 3 estimated 7Q10 flow	246 mgd
20% of estimated 7Q10 flow	49 mgd
Fayetteville's	
Estimated 2060 Average Day Demand	75 mgd
Maximum Day Withdrawal	90 mgd
Minimum Wastewater Discharge	69 mgd
Maximum Net Withdrawal	90 – 69 = 21 mgd
Maximum Day / Average Day ratio	90 / 75 = 1.2
Minimum Wastewater / Maximum Withdrawal	69 / 90 = 0.766[33]
Net Withdrawal portion of Maximum Withdrawal	1– 0.766 = 0.234
Net Withdrawal as % of 7Q10	21 mgd / 246 mgd = 8.5 %

Potential Withdrawals relative to 20% of 246 mgd 7Q10	
Estimated Maximum Day Withdrawal	49 mgd / 0.234 = 209.4 mgd
Estimated Average Day Withdrawal	209.4 mgd / 1.2 = 174.5 mgd

These calculations, based on model-generated flow statistics, indicate Fayetteville PWC may be able to withdraw 174.5 mgd from behind Lock & Dam # 3, on an average day basis, without reducing the model-generated 7Q10 flow by more than 20 percent. Because this estimate is based on net withdrawals it depends on Fayetteville's ability to maintain a similar ratio of wastewater discharges to water withdrawals in the future. The estimate of potential withdrawal capacity only takes into consideration the water quantity effects of the withdrawal. During the planning and review of a proposed project other factors may be identified that limit the actual withdrawal possible.

When Fayetteville PWC submits a proposal to increase water treatment capacity to supply their customers' estimated future demands, they will in all likelihood be required to prepare an environmental assessment for the project which will be based on real world data not model-generated values. The methodology described above provides a way to estimate the potential impact to river flows associated with any proposed increase in water withdrawals by comparing results from future demand scenarios with the basecase scenario of the Cape Fear – Neuse River Basins Hydrologic Model. Water demand estimates may need to be reassessed and additional model scenarios developed to capture changes in customers' water use patterns when an expansion project is proposed.

[33] 76.6% of the water withdrawn is returned as treated wastewater

18 Appendix C Model Predicted Water Supply Shortages

Summary of Model Predicted Water Supply Shortages

Six model scenarios for the Cape Fear River Water Supply Evaluation and the Jordan Lake Water Supply Allocation Recommendations. This document focuses on evaluating the ability of water utilities to meet the anticipated withdrawals need to satisfy expected customer demands in 2060. The evaluation of Jordan Lake water supply allocation requests, which are based on water needs in 2045, are discussed in a separate document. Water delivery shortages were identified in each of the six scenarios for each surface water withdrawal. The tables in Appendix C summarize the magnitude and duration of delivery shortages documented using output from the model. The magnitudes of delivery shortages are presented in million gallons per day. The durations of shortages are listed as the number of days. For context when reviewing the duration figures if may be helpful to bear in mind that the 81 years of hydrologic data used in the model results in demands and deliveries being evaluated for 29,858 days (time steps) for each model scenario.

The “Simbase_Current” scenario represents current conditions based on conditions in 2010. It describes the starting point against which projected changes produced by future withdrawals can be compared.

The “0_Simbase_2045” scenario models the effects of meeting the levels of withdrawals expected to be needed to meet 2045 customer demands from the water supply sources available to each utility in 2010.

The “01_JLA_2045” scenario models the effects of meeting the levels of withdrawals expected to be needed to meet 2045 customer demands using the recommended Jordan Lake water supply allocations in addition to the estimated available water supplies for users that did not apply for an allocation.

The “01_JLA_2045_Climate” scenario uses the demands and estimated water supplies in the “01_JLA_2045” scenario but it reduces the inflows used in the model by 10 percent for each of the 29,858 days in the flow record. This scenario is intended to provide information on potential conditions if flows in the future are less than those experience in the 81 years between 1930 and 2011.

The “01_JLA_2060” scenario models the effects of meeting the levels of withdrawals expected to be needed to meet 2060 customer demands using the recommended Jordan Lake water supply allocations and estimated available water supplies for users that did not apply for an allocation.

The “01_JLA_Full_2060_Max” scenario models the effects of meeting the levels of withdrawals expected to be needed to meet 2060 customer demands if the percent of storage in the water supply pool in Jordan Lake is withdrawn and not returned to the Cape Fear River watershed. This configuration is intended to capture effects on water withdrawers downstream of Jordan Lake if the water supply pool is fully allocated. The "Max" component of the label indicates this scenario includes increases in the average day demands used for the Lower Cape Fear Water and Sewer Authority and the Cape Fear Public Utility Authority to identify the possible implications on water availability if these utilities use the estimated 106 million gallons per day available at their intakes behind Lock and Dam #1 on the Cape Fear River.

For some systems customer demands are reduced during low flow conditions based on protocols outlined in a water shortage response plan (WSRP). For utilities where the water shortage response plan could be included in the model they are labeled as "with WSRP modeled for system". Some water shortage response plans are triggered by criteria that cannot be captured using the hydrologic model. These systems are designated in the table by the label "without WSRP modeled for system". The shortage evaluation for these systems does not take into consideration the reduced demands induced by implementing demand reduction protocols during supply shortages.

For water systems where the modeling indicates a potential water supply shortage the table entries show the maximum shortage in million gallons per day and the number of days when the maximum shortage is predicted to occur. The longest average shortage and the magnitude of that shortage, in million gallons per day, are also show. The table also includes the model predicted total number of days of supply shortages out of the over 29,000 days in the flow record.

Discussions of shortages noted in the following table.

Greensboro

The shortages shown for Greensboro in the table below appears to be related to the limits on treatment capacity of the Piedmont Triad Regional Water Authority's water treatment plant. The reported available supply from Randleman Regional Reservoir will support an increase in treatment capacity. As water demand among the member communities increases in the future expanding treatment capacity will become more practical. PTRWA's has noted its intension to expand treatment as needed as members' water demands increase.

Carthage

Current modeling limits the amount of water available to meet customer demands to the amounts listed as regular supplies in a water systems local water supply plan. Carthage's regular supply comes from Nicks Creek which historically has been limited during extreme drought conditions. Carthage responded to this situation by establishing a connection to the Southern Pines water system to supplement the amount of water during emergency situations. Water from Southern Pines is likely to be sufficient to cover the shortages noted in this analysis.

Orange Water and Sewer Authority

OWASA's regular water supply sources in both of the Simbase model scenarios include only University Lake and the Cane Creek Reservoir. As noted in the "Simbase_2045" scenario there is the possibility that these sources could be insufficient to avoid supply shortages when trying to satisfy the expected customer demands in 2045. The possible supply shortages do not show up in the other scenarios because these scenarios included anticipated supplies from storage in the Stone Quarry. Also OWASA has the ability to use water from their allocation in Jordan Lake to supplement supplies from the existing reservoirs.

Chatham County – North

Modeling indicates the Chatham County – North water system could face significant limitations meeting the expected withdrawals necessary to meet anticipated 2045 customer demands from its current six percent allocation in the Jordan Lake water supply pool. The requested increase to a 13 percent allocation is expected to remedy this shortfall. Water supply allocations from Jordan Lake are limited to needs over a thirty-year planning horizon. The horizon for the current round of allocation ends in 2045. If demands for this system continue to grow as anticipated in the 2060 demand scenarios Chatham County may have to improve the efficiency of how customers use water or find additional supplies.

Dunn

The supply shortages noted in the table for Dunn are a function of the triggers and timing specified in their water shortage response plan. The location of Dunn' intake on the mainstem of the Cape Fear River in Cumberland County makes it highly unlikely they would experience a flow-related supply shortage meeting the anticipated 3.6 million gallons per day withdrawal expected to be needed to meet 2060 customer demands.

Orange County

Modeling indicates insufficient existing sources for Orange County to satisfy the anticipated customer demands in 2045. It also indicates the addition of the County's requested allocation from Jordan Lake, in combination with other supply arrangements, will remedy this shortfall.

Raleigh

The shortages noted in the table below show the potential limitations of Raleigh Public Utilities Department's ability to supply water sufficient to meet their customers anticipated 2045 water demands from currently available supplies. Raleigh's water utility customer base includes the residents of Raleigh, Garner, Knightdale, Rolesville, Wake Forest, Wendell and Zebulon. Raleigh's largest source of water is Falls Lake with an estimated available supply of 66.1 million gallons per day. In addition, Lake Wheeler and Lake Benson on the Swift Creek watershed can provide an estimated 11.2 million gallons per day. The combined yield of 77.3 million gallons per day represents an estimate of the reliable supply available during dry conditions.

The "01_JLA_2045" and "01_JLA_2045_Climate" model scenarios include the recommended 4.7 percent allocation from the Jordan Lake water supply pool to the system's available supply. Modeling indicates this increase is likely to be sufficient to avoid the predicted shortfall associated with meeting 2045 demand volumes. The shortage indicated by the scenarios modeling 2060 demand volumes suggest that, even with the recommended allocation from Jordan Lake, Raleigh will need to find additional sources of water to meet expected customer demands.

Table C-1 Summary of Modeled Water Supply Shorages Cape Fear River Basin

Appendix C Summary of Modeled Water System Supply Shortages							
Cape Fear River Basin							
		Model Scenario					
Model Node Number	Water System / Shortage Measure	Simbase-current	Simbase_2045	01_JLA_2045	01_JLA_2045_Climate	01_JLA_2060	01_JLA_Full_2060_Max
0031	Reidsville	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0123	Greensboro	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	32.3/16	0	24.3/8	35.5/49	35.5/49
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	20/97	0	13.1/47	21.5/98	21.5/98
	Total Days Short		381		95	421	421
0223	Highpoint	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0301	Ramseur	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0321	Graham Mebane	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0327	Siler City	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0341	Burlington	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0701	Carthage	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0.3/21	0.7/12	0.7/12	0.7/22	1.6/23	1.6/23
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0.3/21	0.7/22	0.7/22	0.7/22	1.5/23	1.5/23
	Total Days Short	66	71	71	81	84	84
0401	Pittsboro	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0

Appendix C Summary of Modeled Water System Supply Shortages							
Cape Fear River Basin							
		Model Scenario					
Model Node Number	Water System / Shortage Measure	Simbase-current	Simbase_2045	01_JLA_2045	01_JLA_2045_Climate	01_JLA_2060	01_JLA_Full_2060_Max
0431	Orange Water & Sewer Authority	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	5.6/22	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	5.2/22	0	0	0	0
	Total Days Short	0	22	0	0	0	0
0473	Chatham County-North	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	12.5/25	0	9.9/1	9.9/1	12.4/8
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	9.96/25	0	9.9/1	9.1/1	2.8/11
	Total Days Short	0	134	0	1	1	28
0471	Cary Apex	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0474	RTP	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0477	Morrisville	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0663	Dunn	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	1.1/14	1.1/7	1.1/14	1.1/7	1.1/7
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0.8/45	0.8/16	1.1/14	0.9/27	0.9/27
	Total Days Short	0	178	72	120	88	95
0075	Haw River	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0077	Green Level	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0261	Randleman	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0

Appendix C Summary of Modeled Water System Supply Shortages							
Cape Fear River Basin							
		Model Scenario					
Model Node Number	Water System / Shortage Measure	Simbase-current	Simbase_2045	01_JLA_2045	01_JLA_2045_Climate	01_JLA_2060	01_JLA_Full_2060_Max
0483	Performance Fiber	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0521	Harris Nuclear Plant	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0491	Sanford	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0940	Broadway	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0674	Carolina Trace	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0923	Holly Springs	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0551	Harnett County RWS	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0719	Spring Lake	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0721	Old North Utilities	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0

Appendix C Summary of Modeled Water System Supply Shortages							
Cape Fear River Basin							
		Model Scenario					
Model Node Number	Water System / Shortage Measure	Simbase-current	Simbase_2045	01_JLA_2045	01_JLA_2045_Climate	01_JLA_2060	01_JLA_Full_2060_Max
0733	Fayetteville PWC	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0771	Monsanto	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0785	LCFWSA_Bladen Bluffs	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0823	Cape Fear Public Utilities	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0825	LCFWSA_Kings Bluff	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0903	Jamestown	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0904	Archdale	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0906	Randolph	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
0921	Orange County	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	3.02/26	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	1.96/36	0	0	0	0
	Total Days Short	0	654	0	0	0	0

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Summary of Modeled Water Supply Shorages Neuse River Basin

Appendix C Summary of Modeled Water System Supply Shortages							
Neuse River Basin							
		Model Scenario					
Model Node Number	Water System / Shortage Measure	Simbase-current	Simbase_2045	01_JLA_2045	01_JLA_2045_Climate	01_JLA_2060	01_JLA_Full_2060_Max
1046	Orange Alamance Water System	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
1106	Hillsborough	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
1116	Piedmont Minerals	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
1162	Durham	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
1256	South Granville WSA	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
1306	Raleigh	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	81.9/10	0	0	82.2/20	82.2/20
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	13.3/184	0	0	41.1/21	41.1/21
1506	Wilson	(with WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
1646	Johnston County	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0

Appendix C Summary of Modeled Water System Supply Shortages							
Neuse River Basin							
		Model Scenario					
Model Node Number	Water System / Shortage Measure	Simbase-current	Simbase_2045	01_JLA_2045	01_JLA_2045_Climate	01_JLA_2060	01_JLA_Full_2060_Max
1666	Smithfield	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
1706	Fuquay-Varina	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
1756	Benson	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
1766	HF Lee Steam Station	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
1786	Goldsboro	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
1806	Neuse Regional WSA	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0
1906	Weyerheauser	(without WSRP modeled for system)					
	Max Shortage, mgd / Max shortage Period, days	0	0	0	0	0	0
	Longest Avg Shortage, mgd / Longest Shortage Period, Days	0	0	0	0	0	0

19 Appendix D Modeled Reservoir Conditions and River Flows

Reservoir and River Flows Status Graphs

The following graphs show the variation in reservoir conditions across the three model scenarios used for this evaluation. The scenario labeled "Simbase_Current" is a characterization of current conditions based on water use and supplies in 2010. This scenario provides a point of comparison to show how meeting 2060 demands may alter conditions over the range of flows used in the model.

The scenario labeled "01_JLA_2060" indicates the effects of meeting 2060 water demands with the recommended Jordan Lake water supply allocations and the available water sources reported in the local water supply plans for water systems not applying for an allocation.

The scenario labeled "01_JLA_Full_ 2060_Max" evaluates the effects of meeting 2060 water demands with the Jordan Lake water supply pool 100 percent allocated and the available supplies reported in local water supply plans. Full allocation is modeled by withdrawing the percent of storage unallocated in the recommendations to node where all the withdrawal is removed from the Cape Fear River watershed. The "Max" portion of the label indicates that the annual average day demands for the Lower Cape Fear Water and Sewer Authority and the Cape Fear Public Utility Authority were increased to fully use the estimated 106 million gallons per day during peak demands.

The reservoir elevation graphs show the percent of simulated time steps in the model that the water levels are at or below the elevations noted in the vertical scales from January to December. The blue plot shows results of modeling the 2010 basecase scenario that provides a point of comparison for the two scenarios modeling the amount of water expected to be needed to meet 2060 customer demands, shown in green and magenta.

For more differentiation, the graphs show the portion of the record when reservoir levels are less than full. The plots of water levels in the Jordan Lake Reservoir Elevation Duration graph show that modeling indicates the water levels are likely to be at or above the normal operating level of 216 feet above mean sea level (ft-msl) over 65 percent of the time in the flow record. As a reminder, the flow record includes 29,858 days from January 1, 1930 to September 30, 2011. For the Simbase_Current scenario the graph shows that the model indicates the water level below 213 ft-msl about 6 percent of the time. For the other scenarios, the model estimates water levels below 213 ft-msl from 11 to about 13 percent of the days in the flow record.

The graph labeled "Jordan Lake Elevation Duration May 1 to Sept 30" shows the water level conditions during the peak recreation season. It also includes indicators of the approximate elevations of the bottoms of public boat ramps.

The graph labeled "Jordan Lake Water Level Fluctuations April 1 to June 30" shows the percent of simulated time steps when daily water levels fluctuate within the ranges specified in the vertical scale during the months of April, May and June. For example, the modeling indicates daily water level fluctuations between 0.5 feet and 0.6 feet for about five percent of the days in those months.

In the following graphs elevations are shown in feet above mean sea level (ft-msl) and storage conditions are shown as percent of storage.

Figure D-1 Jordan Lake Water Levels over POR for January to December (ft-msl)

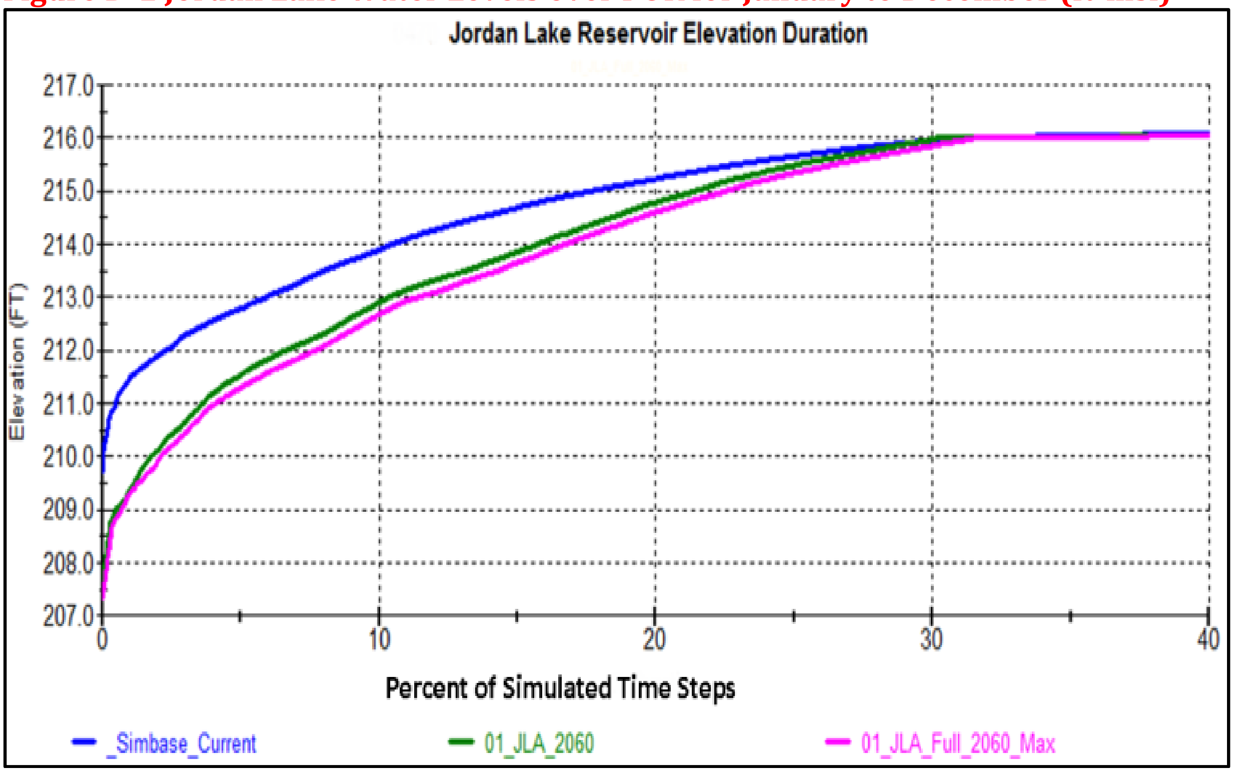


Figure D-2 Jordan Lake Water Levels for May to September (ft-msl)

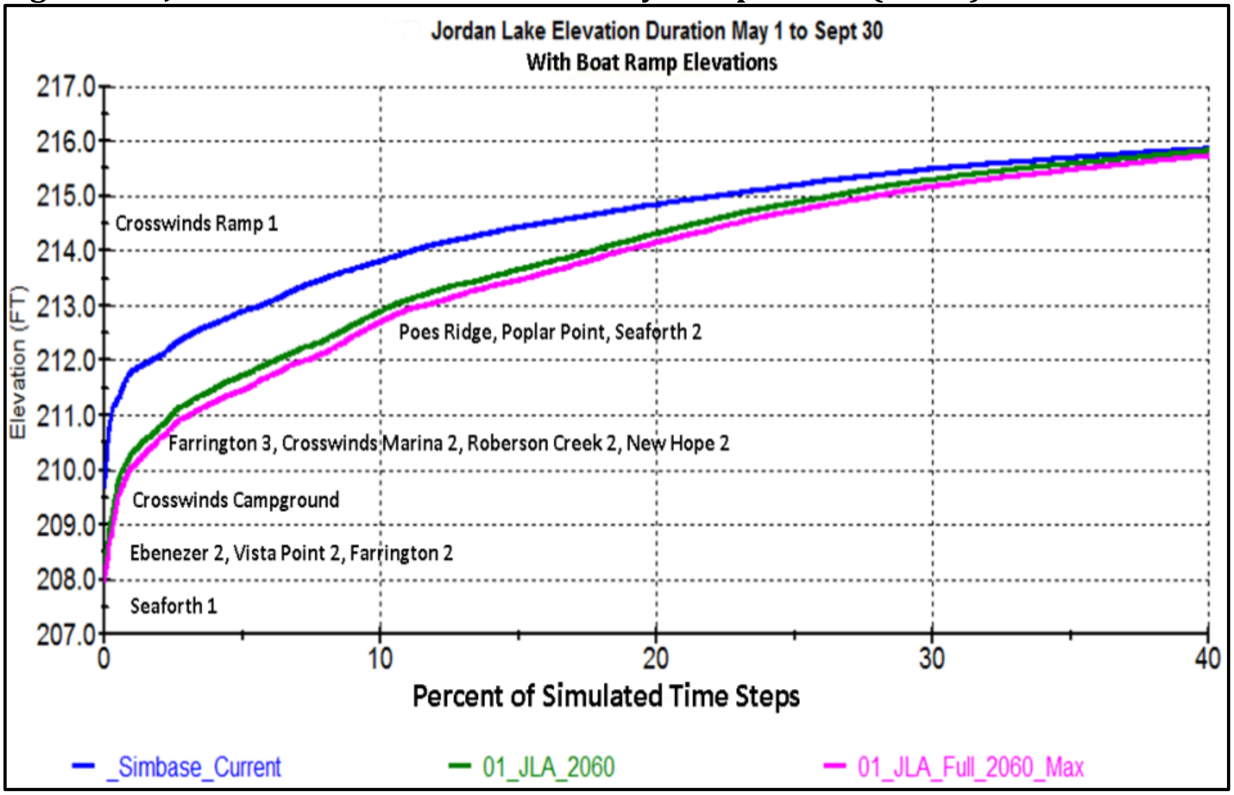


Figure D-3 Jordan Lake Daily Decline in Water Level over POR (feet)

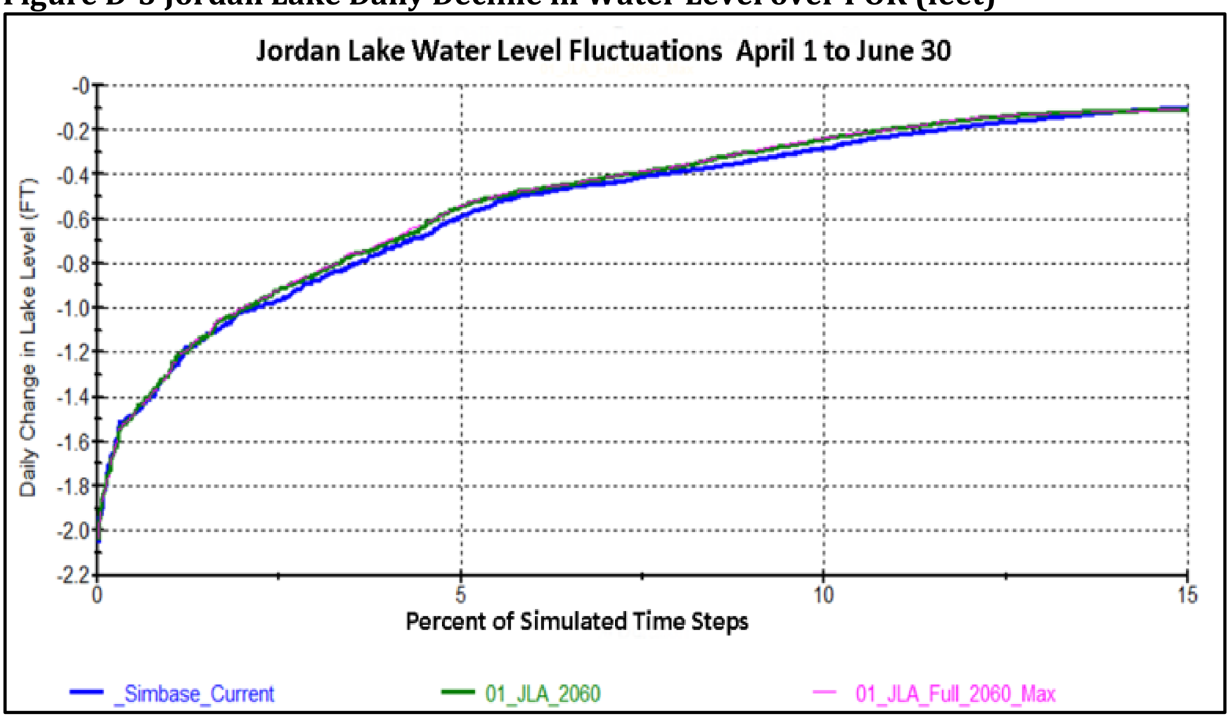


Figure D-4 Jordan Lake Water Supply Storage over POR (percent of storage)

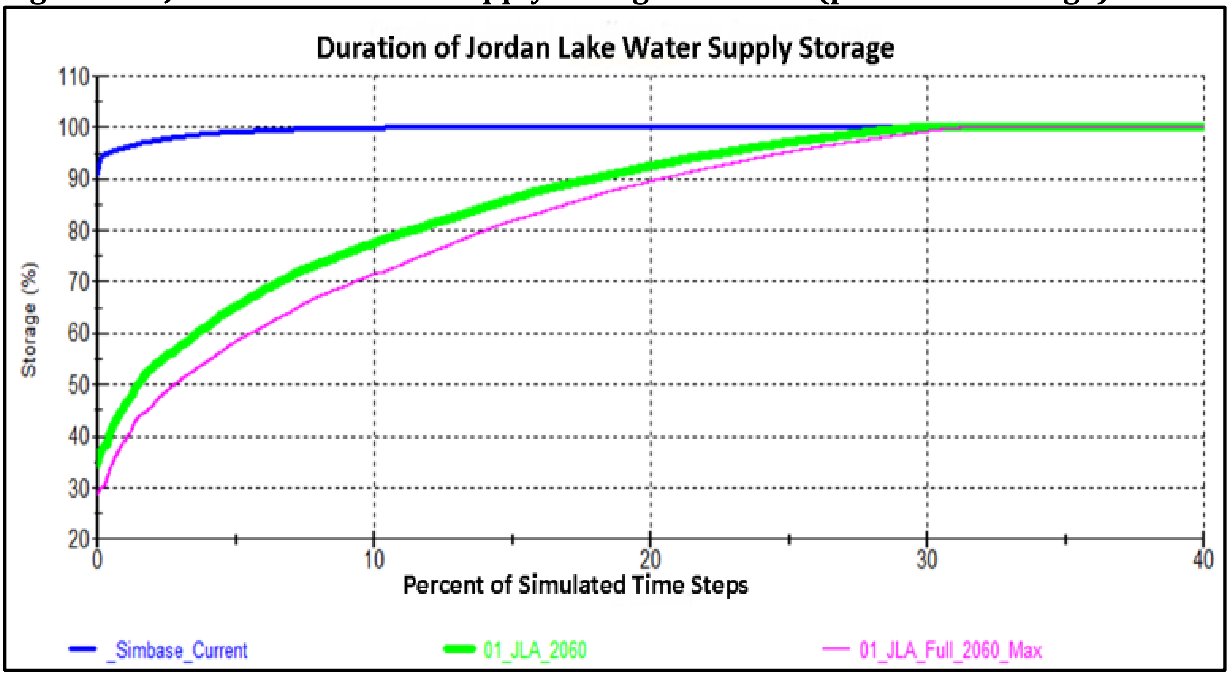


Figure D-5 Jordan Lake Water Supply Storage January 2000 through September 2011 (percent of storage)

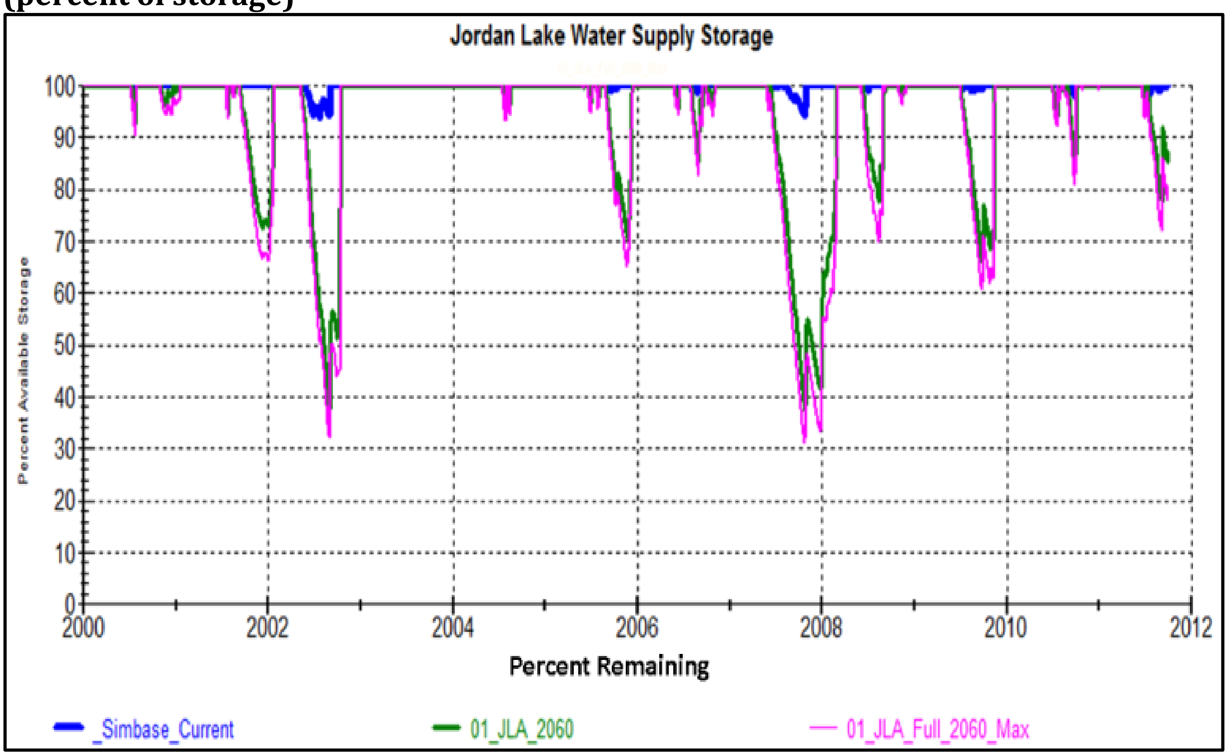


Figure D-6 Jordan Lake Flow Augmentation Storage over POR (percent of storage)

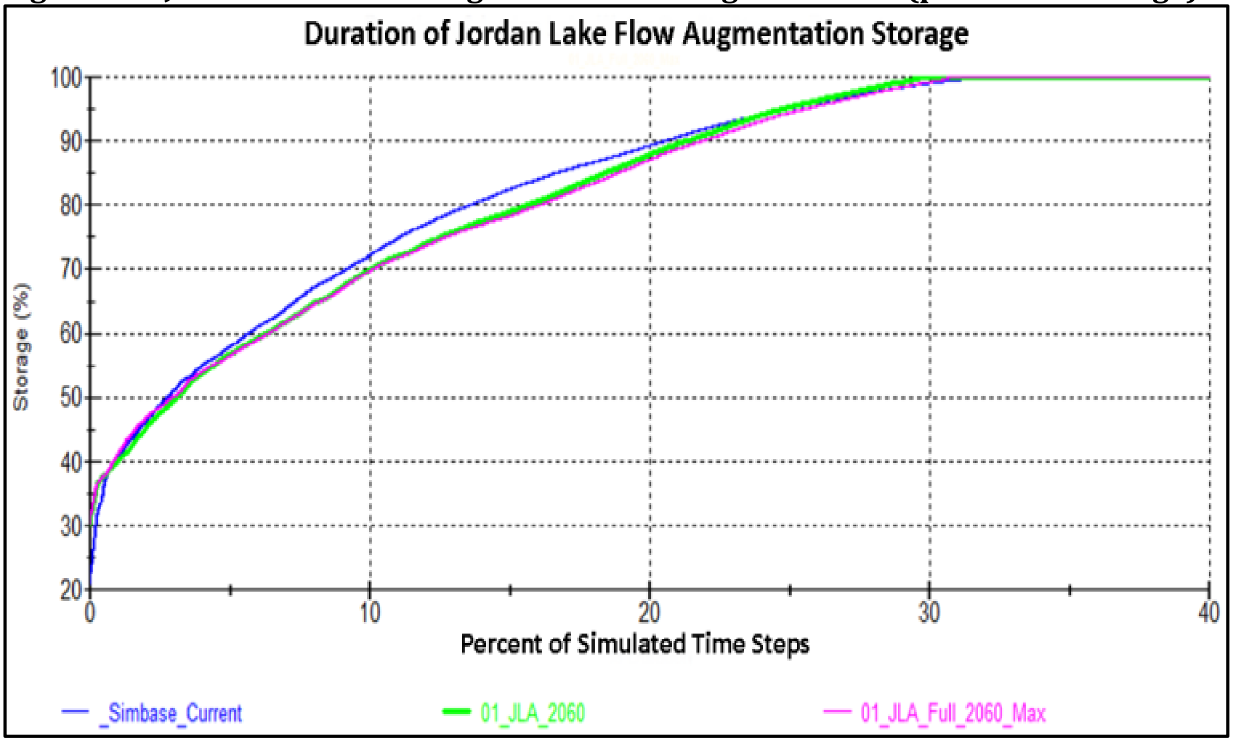


Figure D-7 Jordan Lake Flow Augmentation Storage January 2000 through September 2011 (percent of storage)

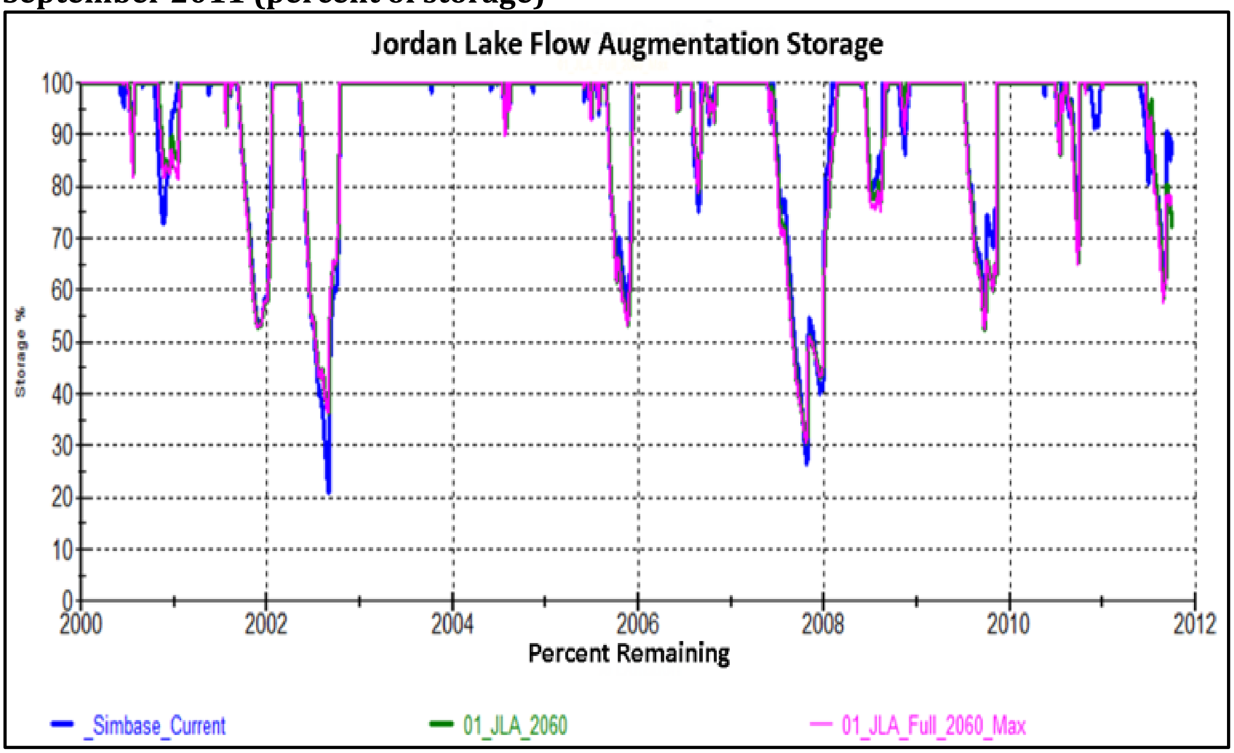


Figure D-8 Jordan Lake Drought Level January 2000 through September 2011

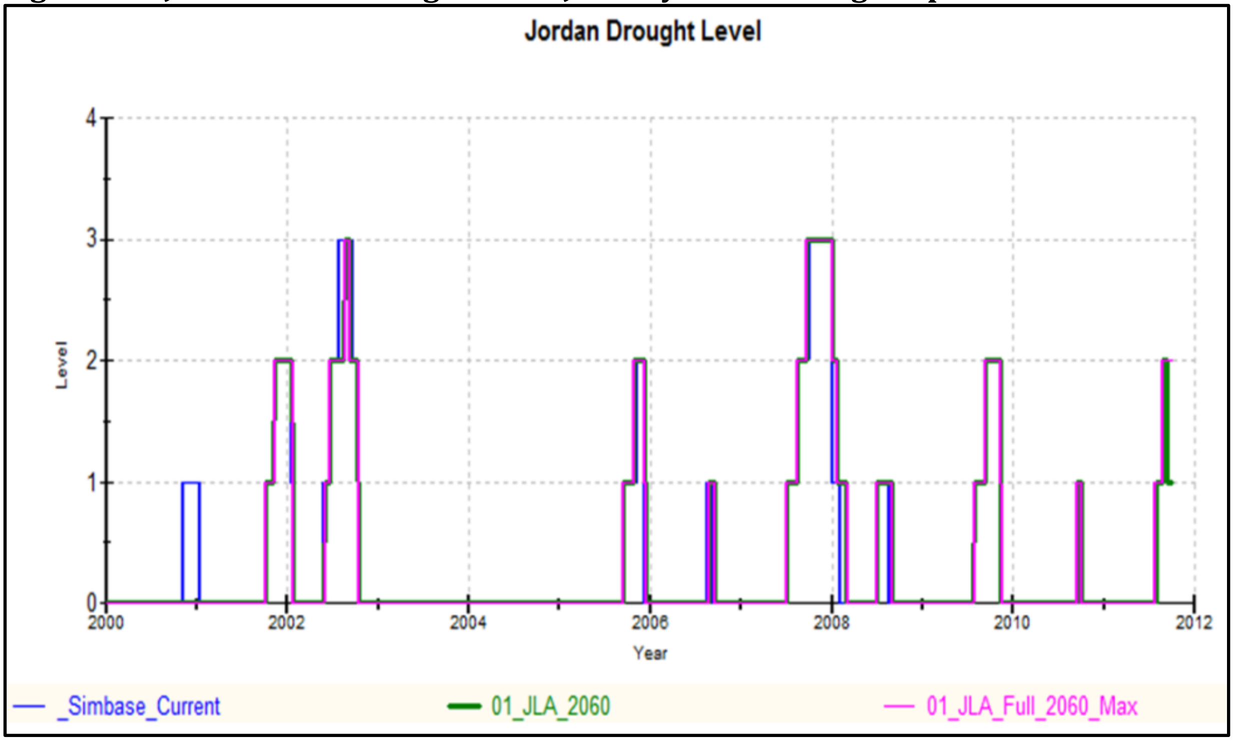


Figure D-8 Lake Reidsville Water Level (ft-msl)

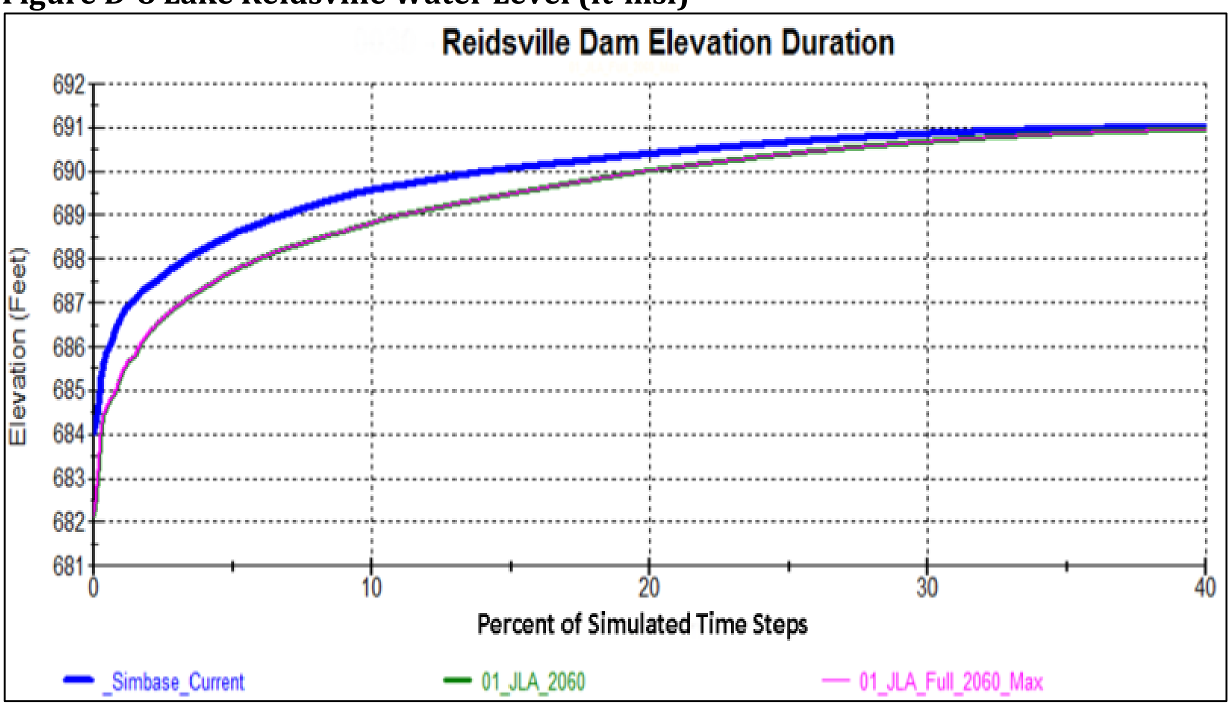


Figure D-9 Lake Higgins Water Level (ft-msl)

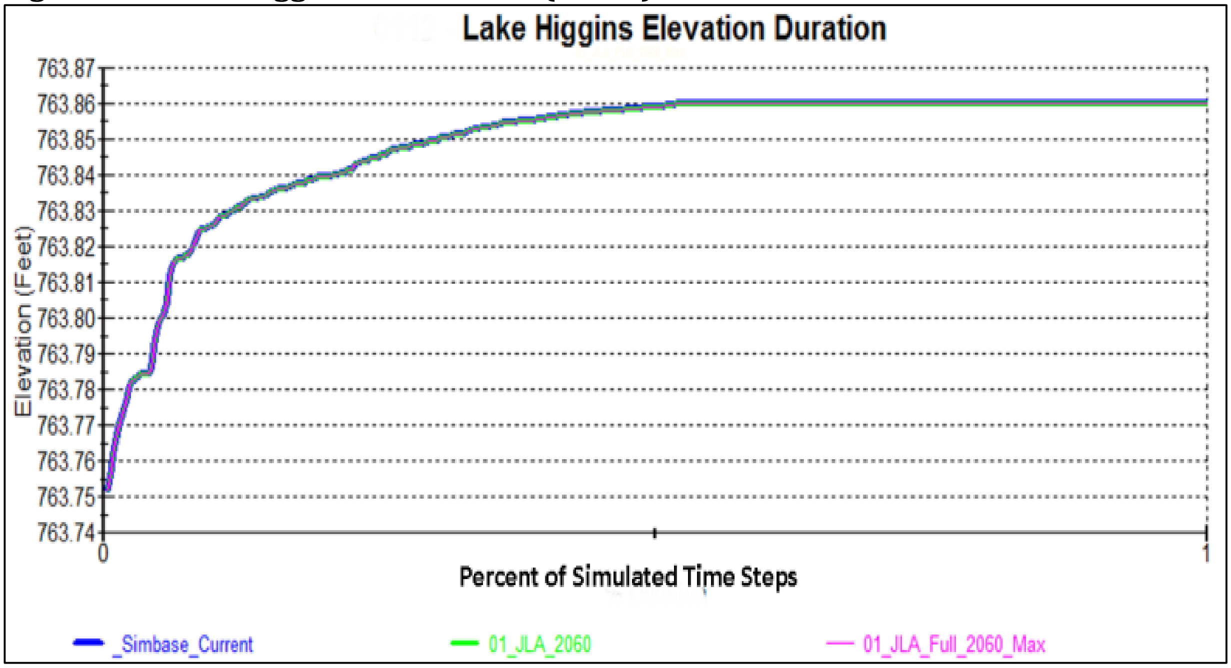


Figure D-10 Lake Brandt Water Level (ft-msl)

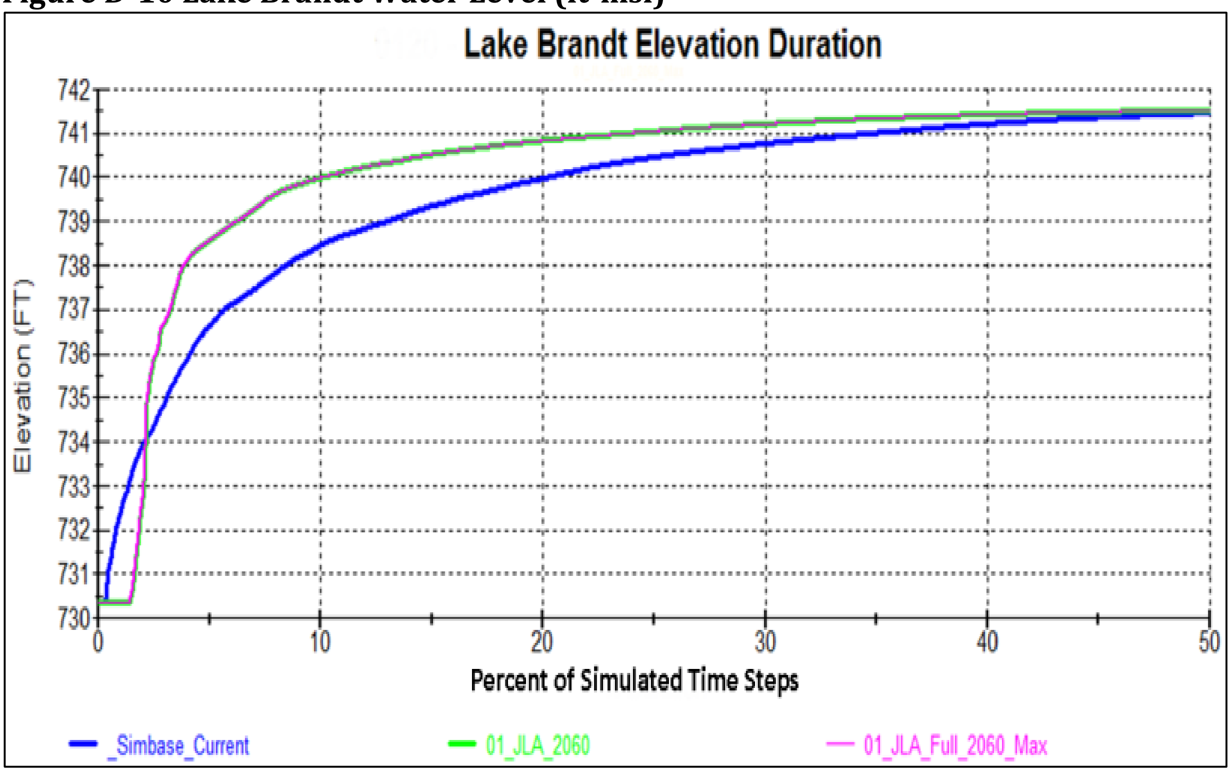


Figure D-11 Lake Townsend Water Level (ft-msl)

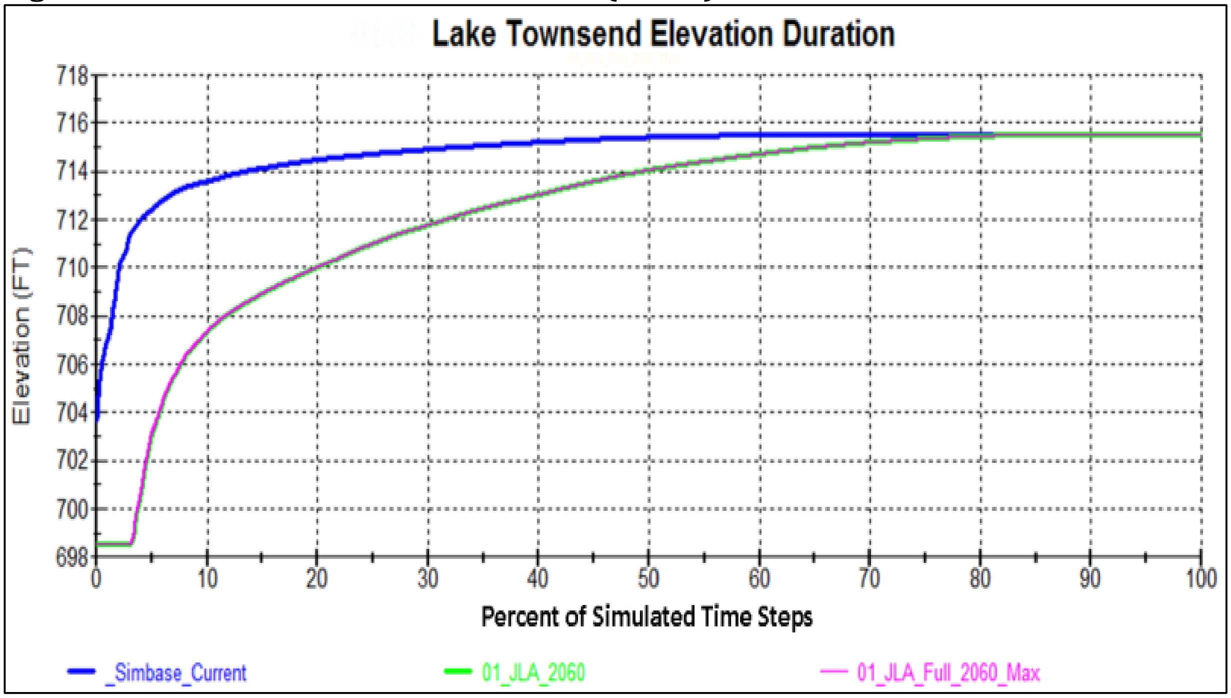


Figure D-12 Randleman Reservoir Water Level (ft-msl)

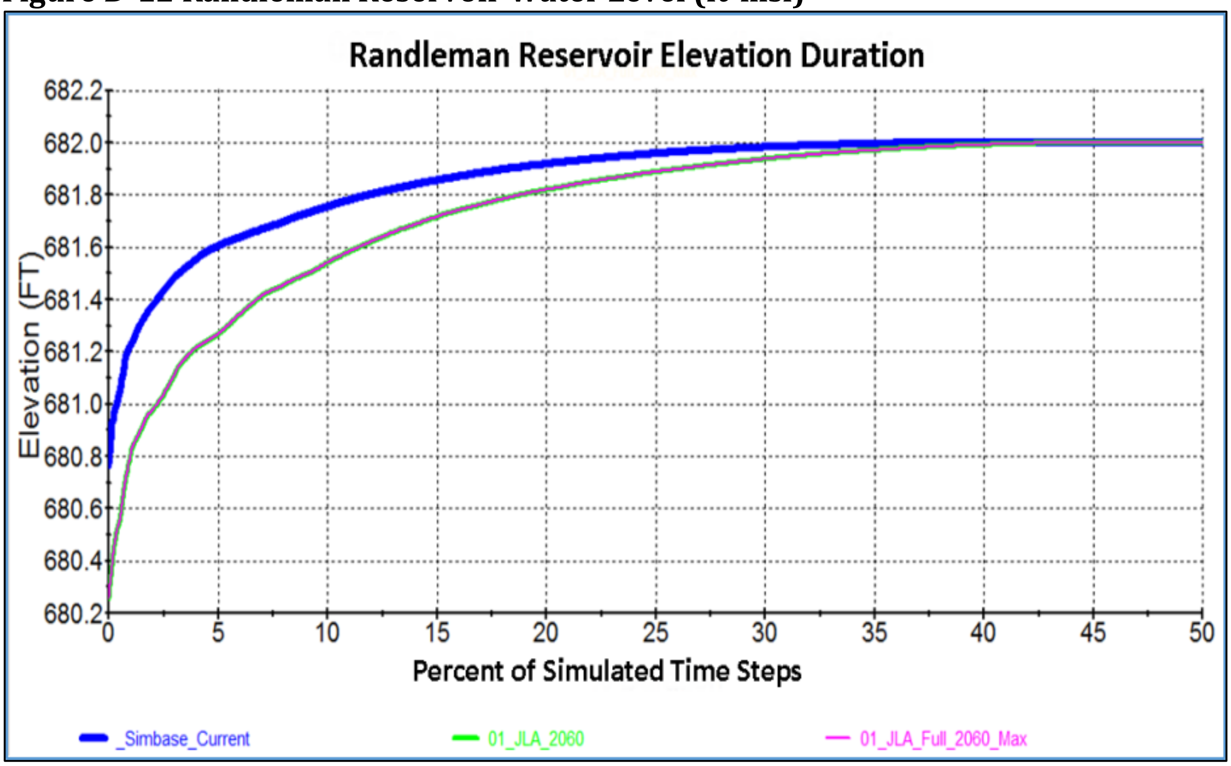


Figure D-13 High Point-City Lake Water Level (ft-msl)

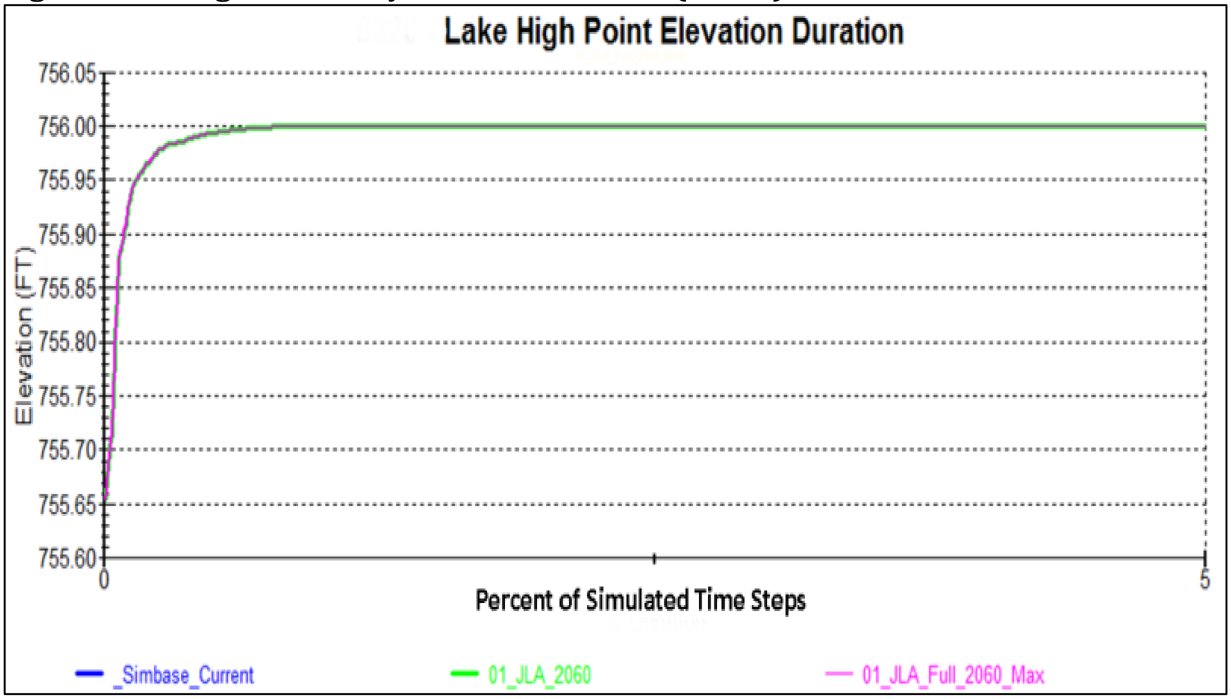


Figure D-14 Sandy Creek Reservoir Water Level (ft-msl)

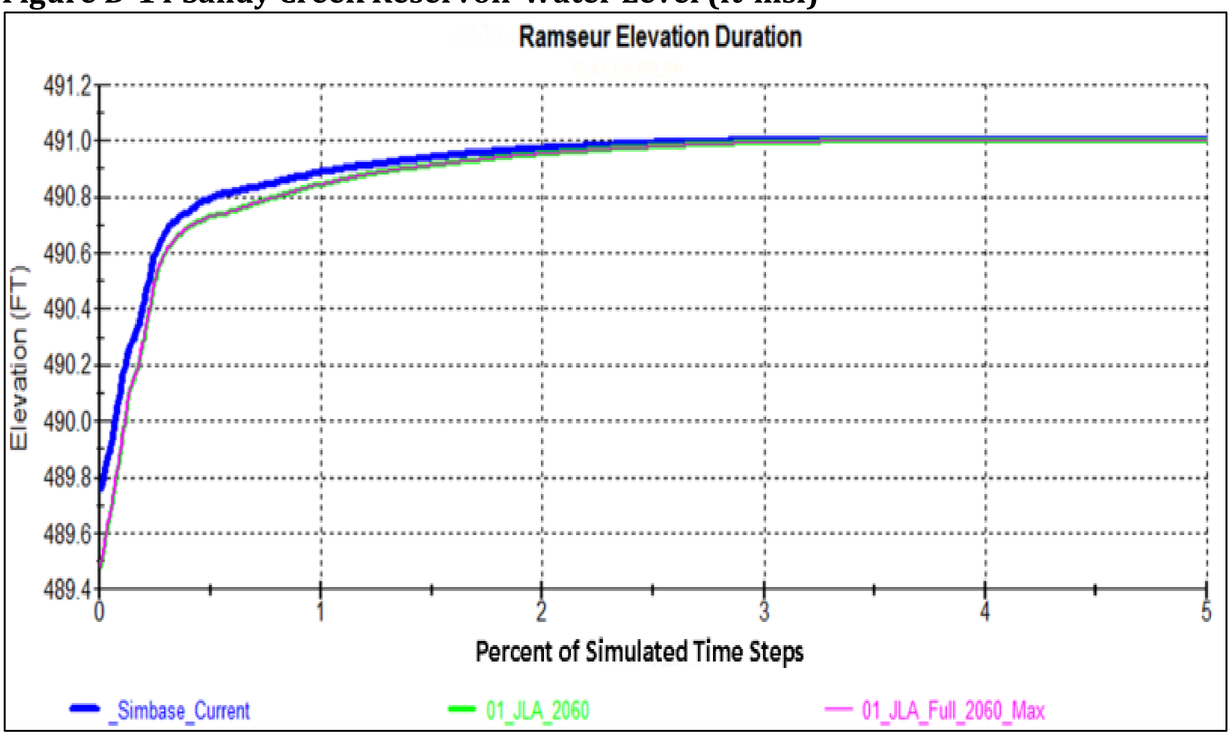


Figure D-15 Lake Mackintosh Water Level (ft-msl)

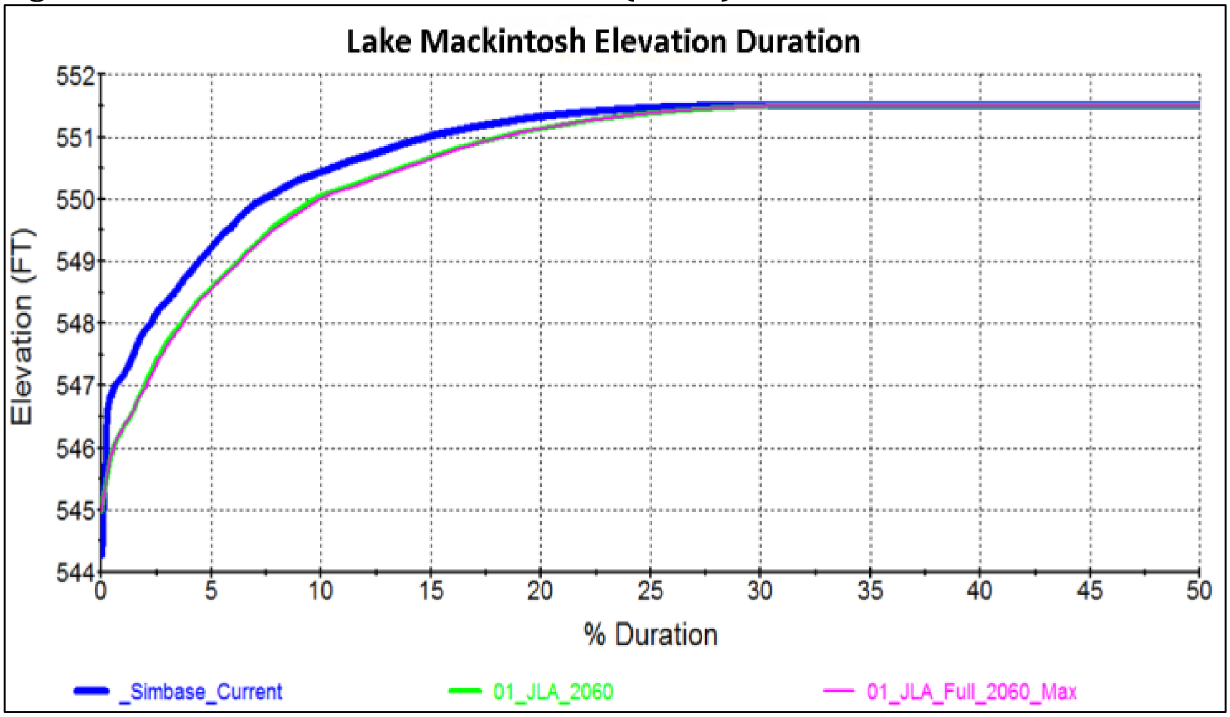


Figure D-16 Old Stoney Creek Reservoir Water Level (ft-msl)

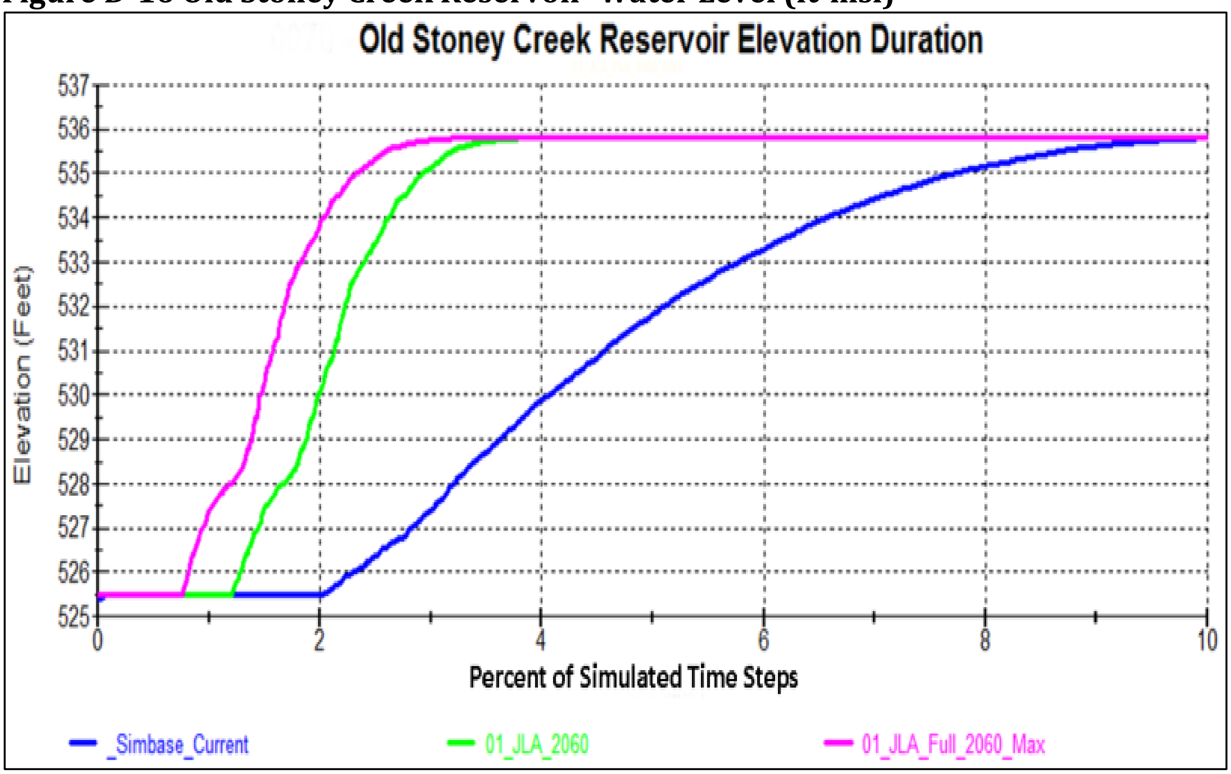


Figure D-17 Graham-Mebane Lake Water Level (ft-msl)

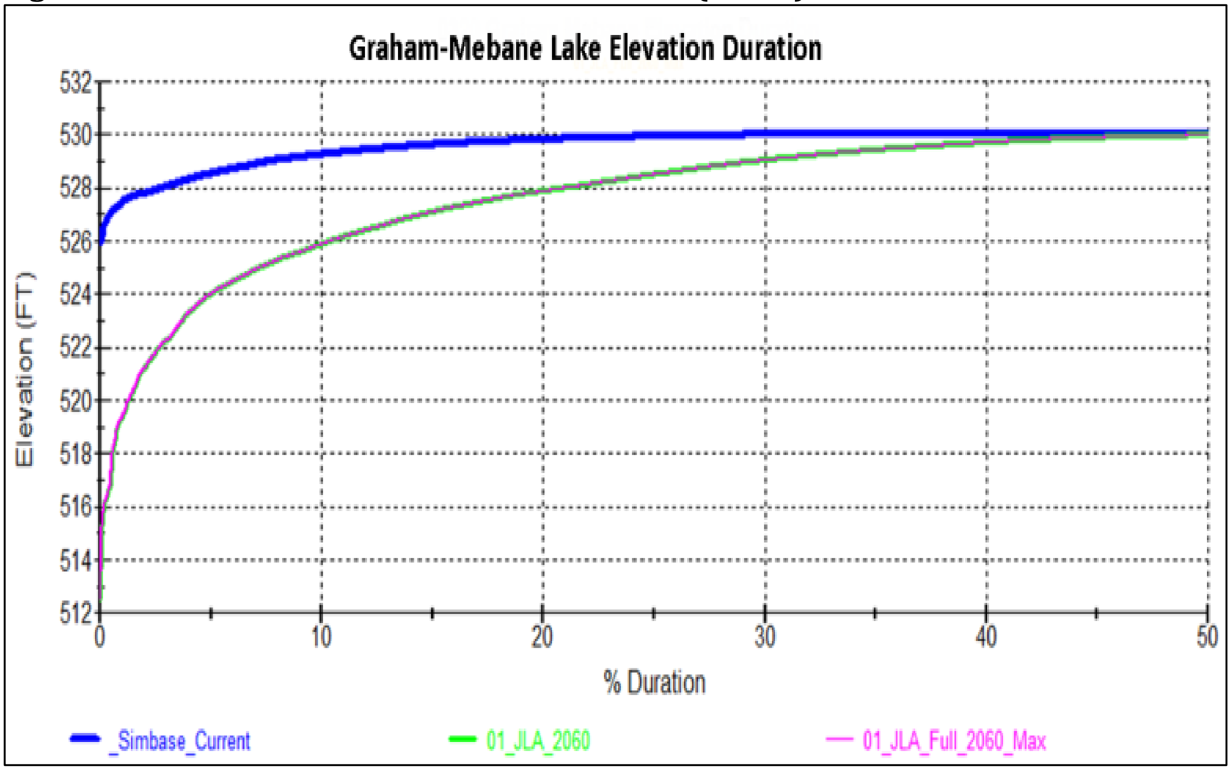


Figure D-18 Cane Creek Reservoir Water Level (ft-msl)

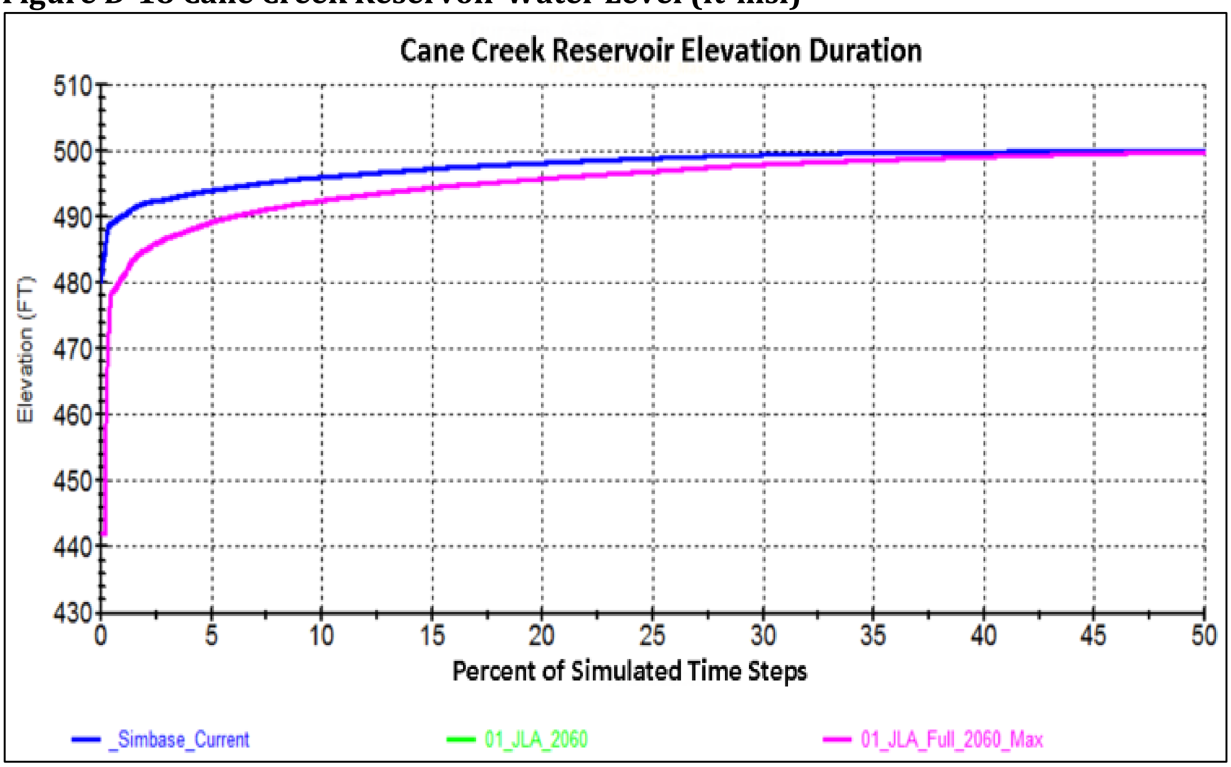


Figure D-19 University Lake Water Level (ft-msl)

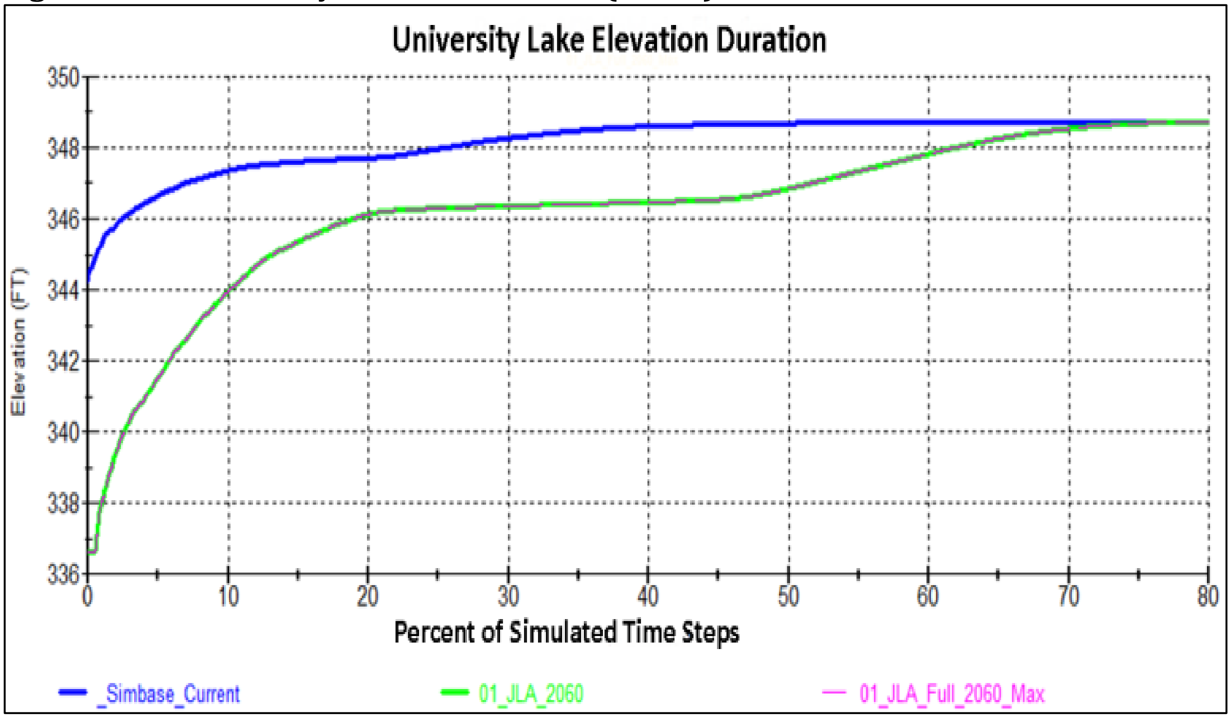


Figure D-20 Siler City-Upper Reservoir Water Level (ft-msl)

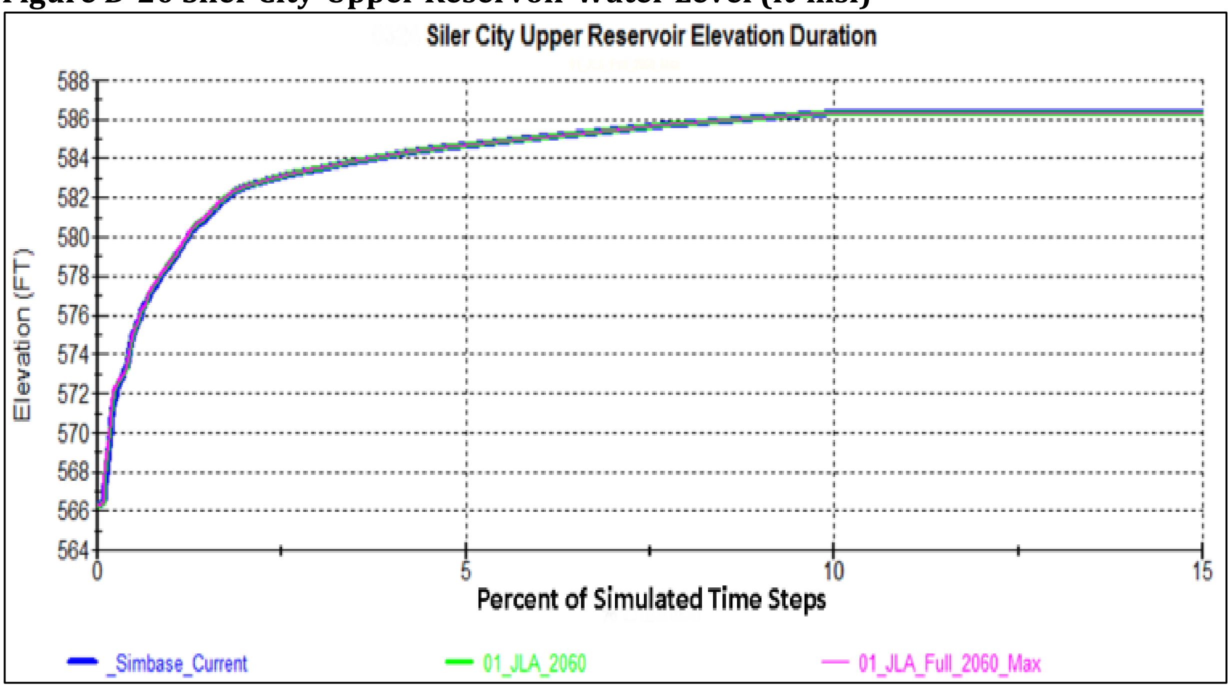


Figure D-21 Siler City-Lower Reservoir Water Level (ft-msl)

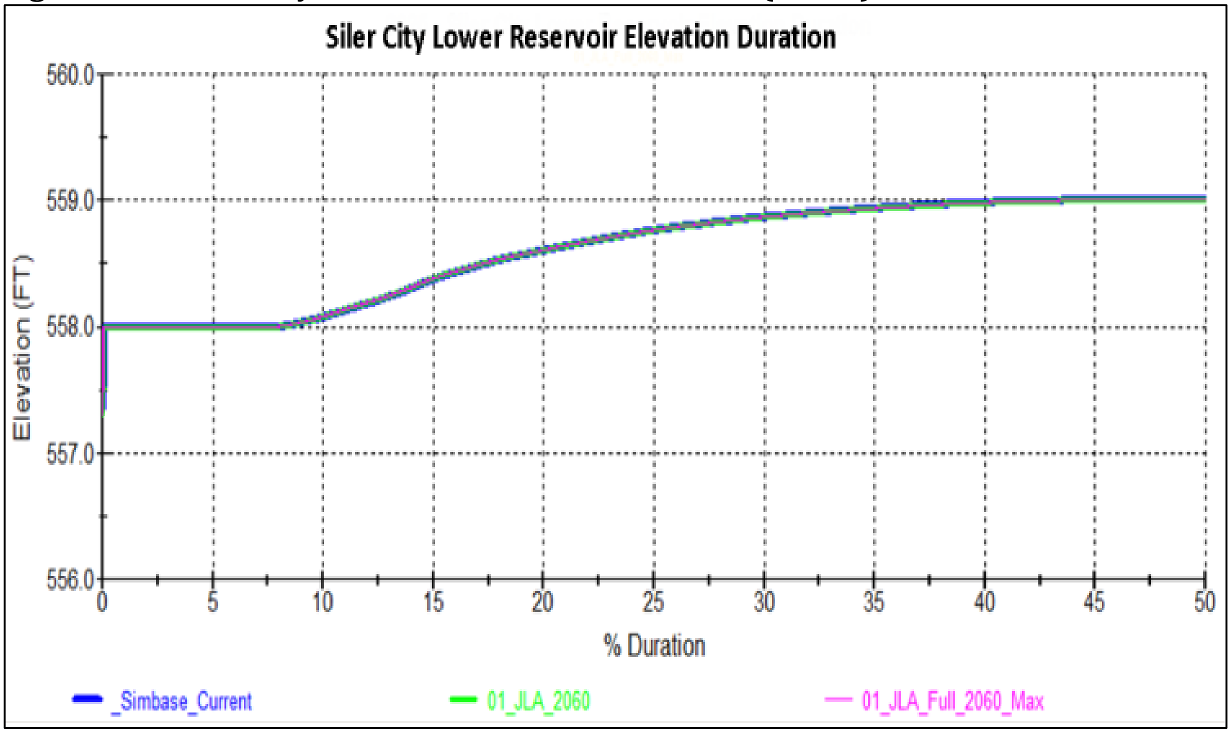
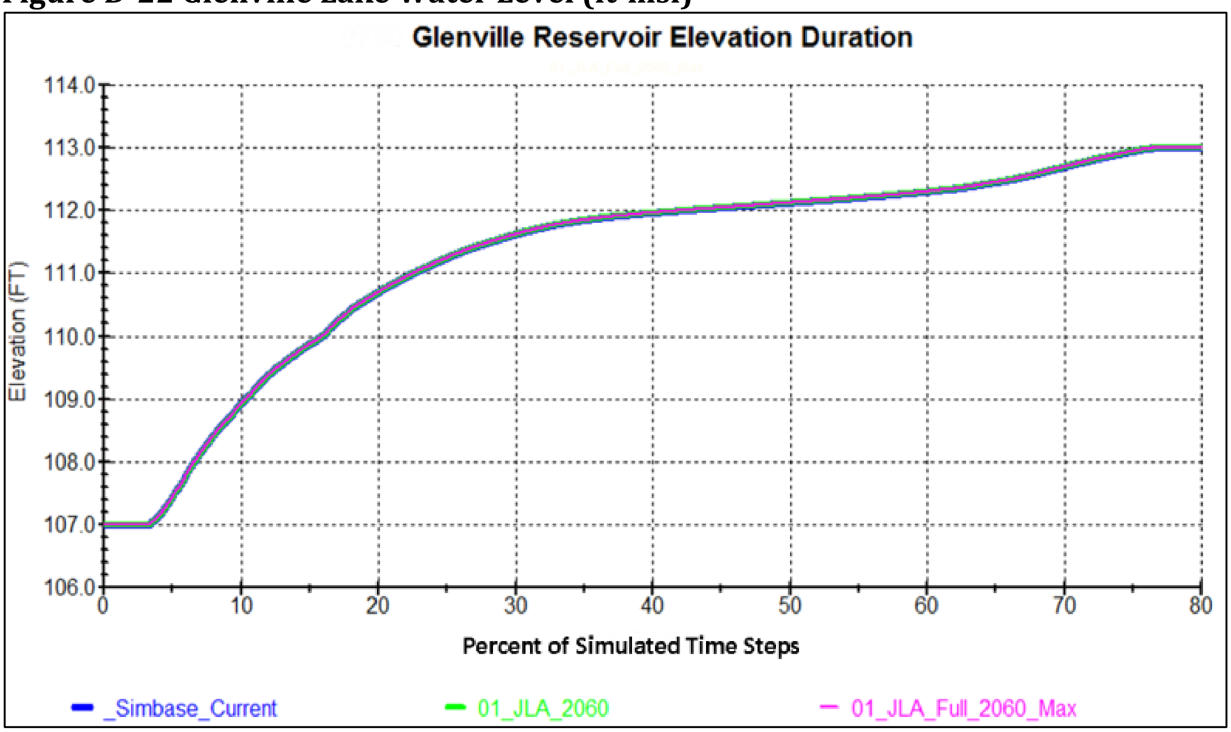


Figure D-22 Glenville Lake Water Level (ft-msl)



Neuse River Basin Plots

Figure D-22 Lake Michie Water Level (ft-msl)

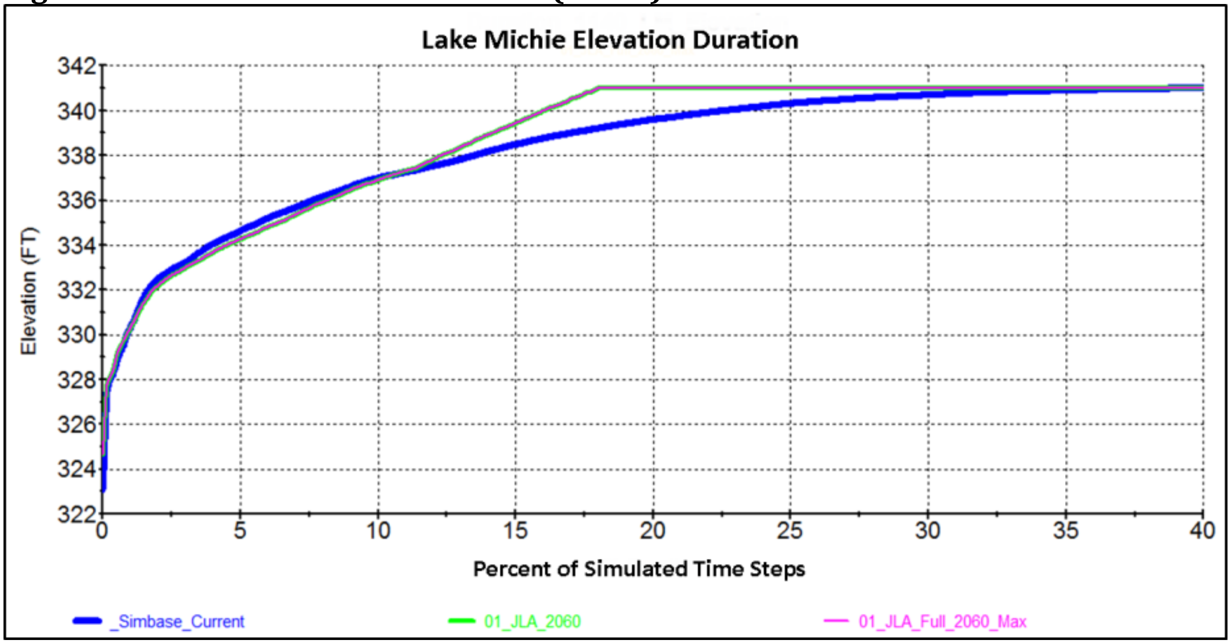


Figure D-23 Little River Reservoir Water Level (ft-msl)

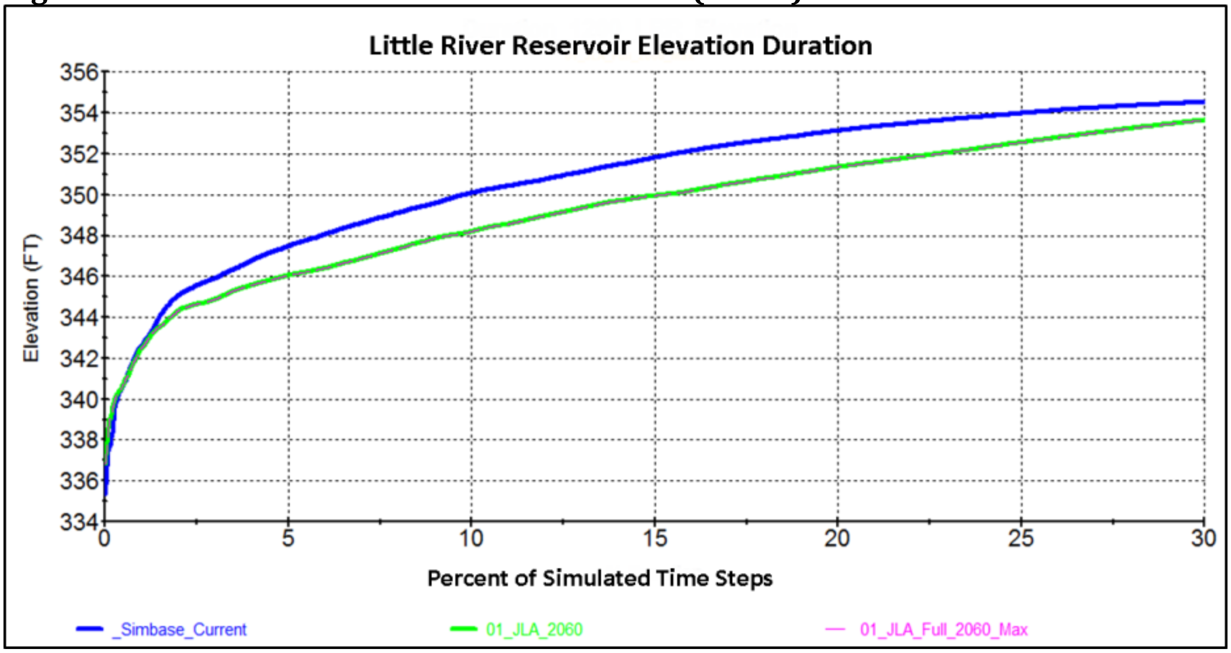


Figure D-24 West Fork Eno Reservoir Water Level (ft-msl)

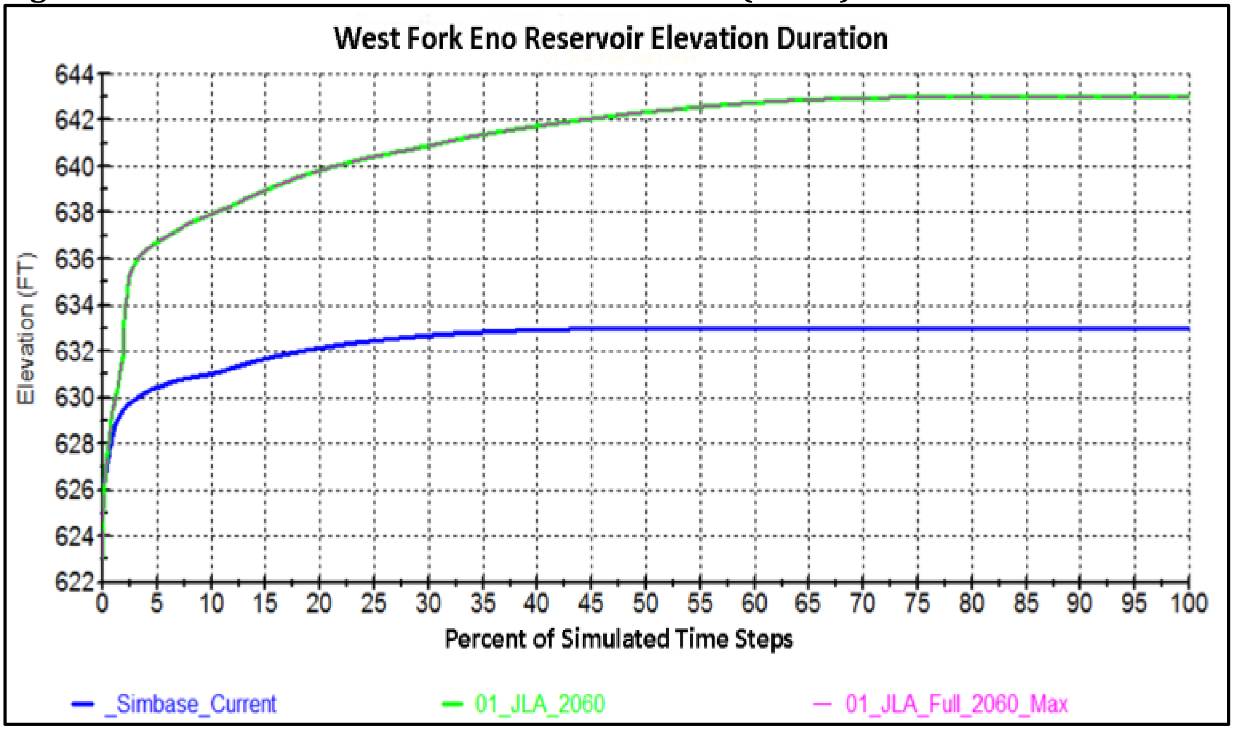


Figure D-25 Falls Lake Water Level (ft-msl)

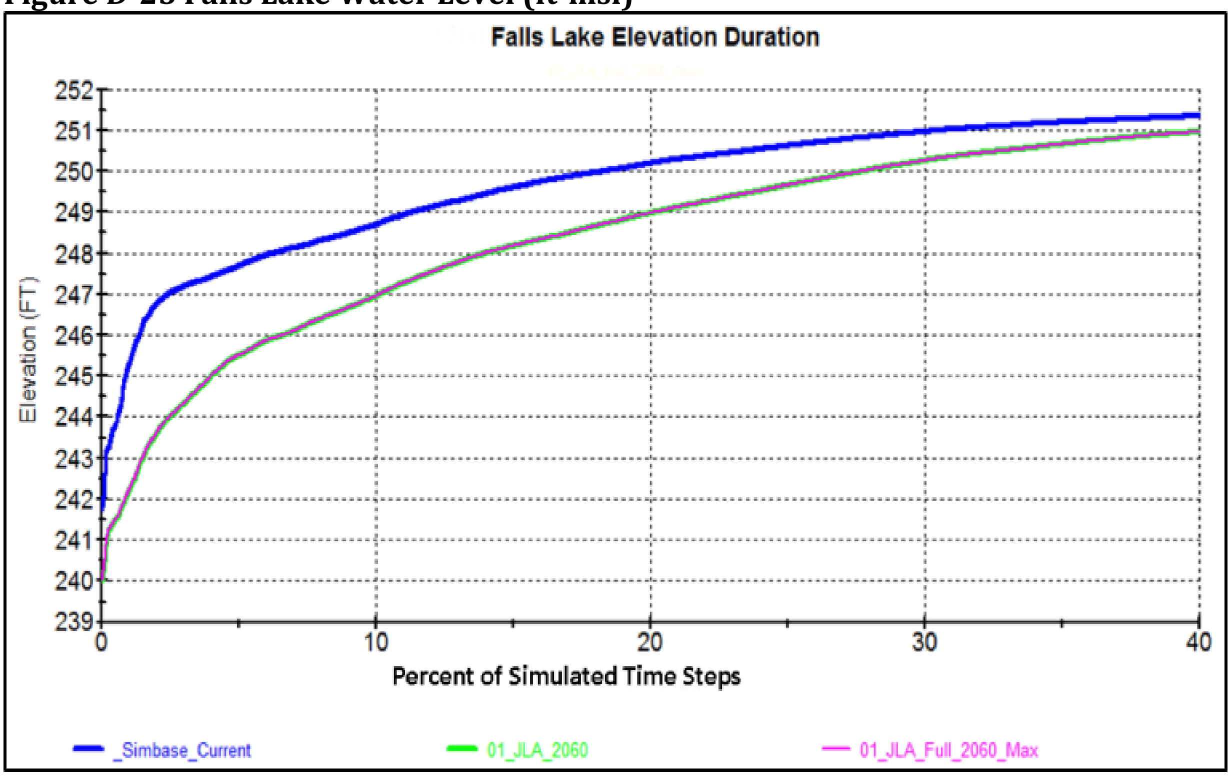


Figure D-26 Falls Lake Water Supply Storage (percent of storage)

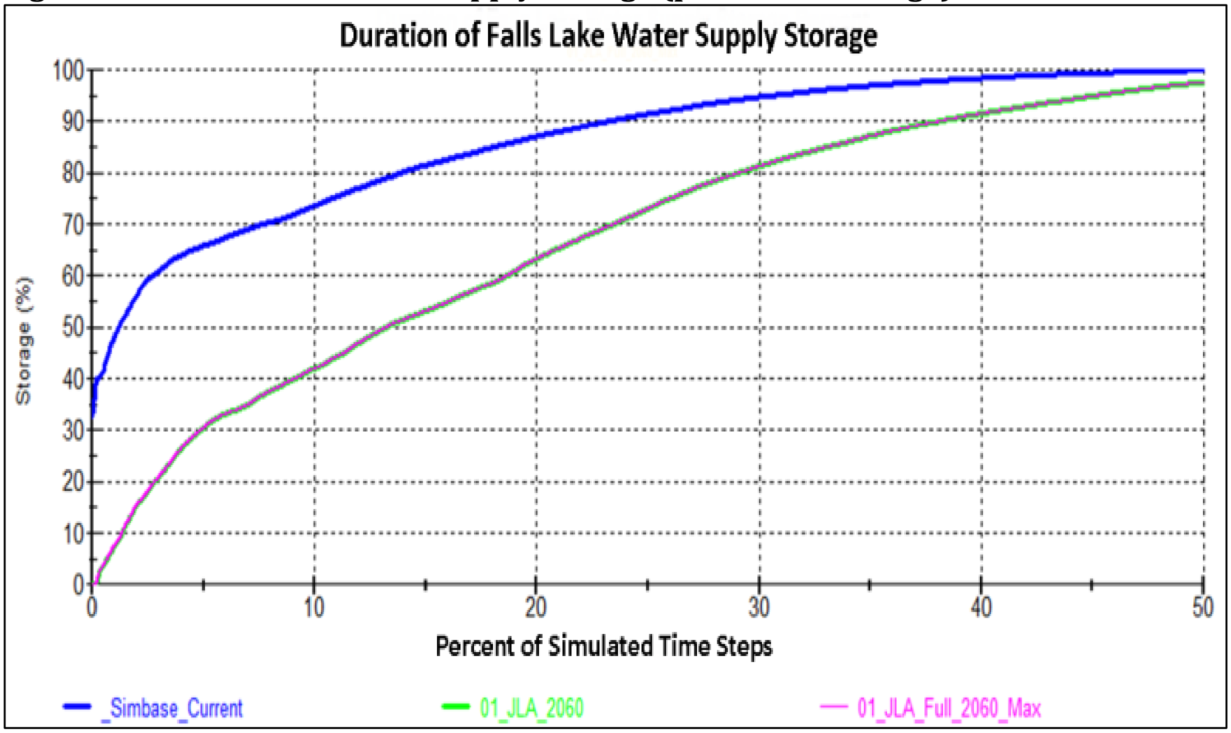


Figure D-27 Falls Lake Water Supply Storage, January 2000 through September 2011

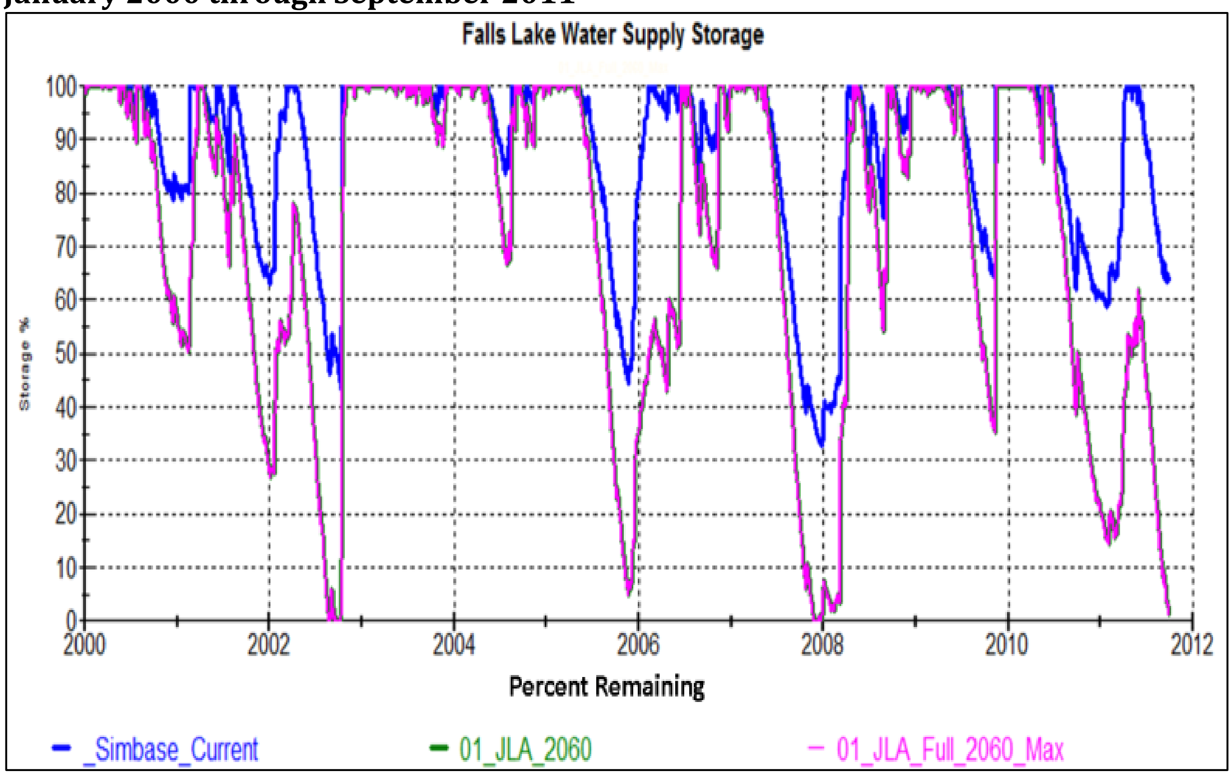


Figure D-28 Falls Lake Flow Augmentation Storage,

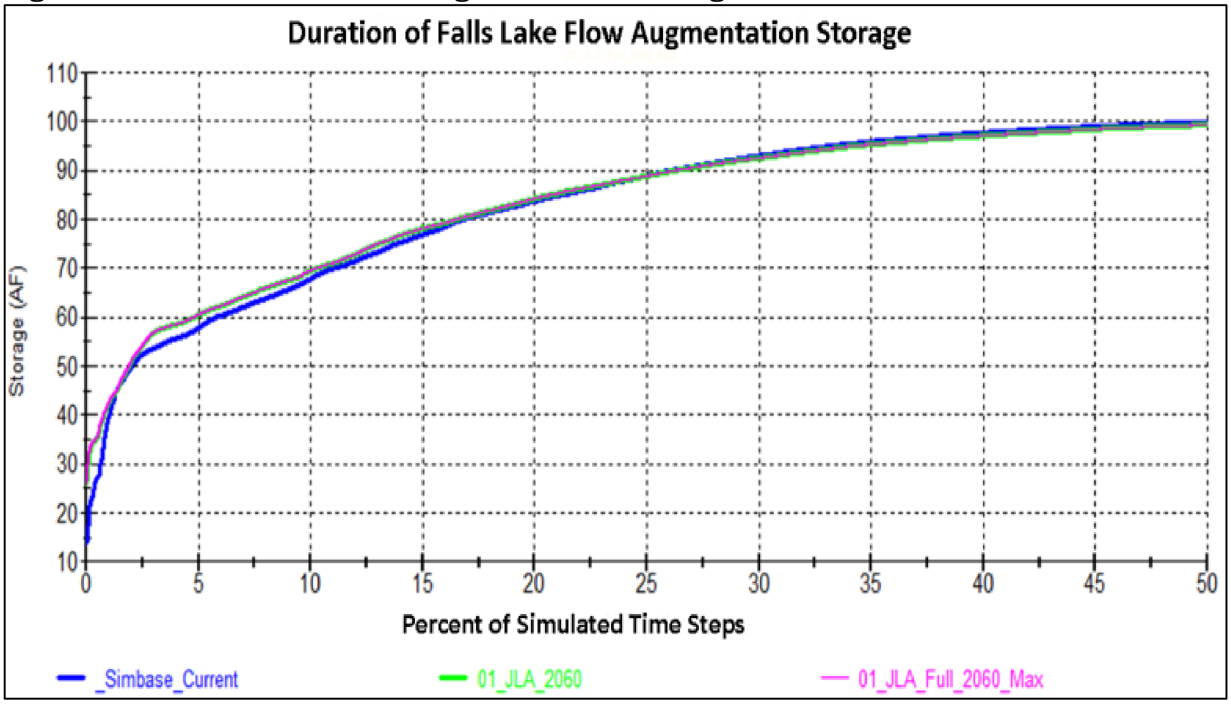


Figure D-29 Falls Lake Flow Augmentation Storage, January 2000 through September 2011

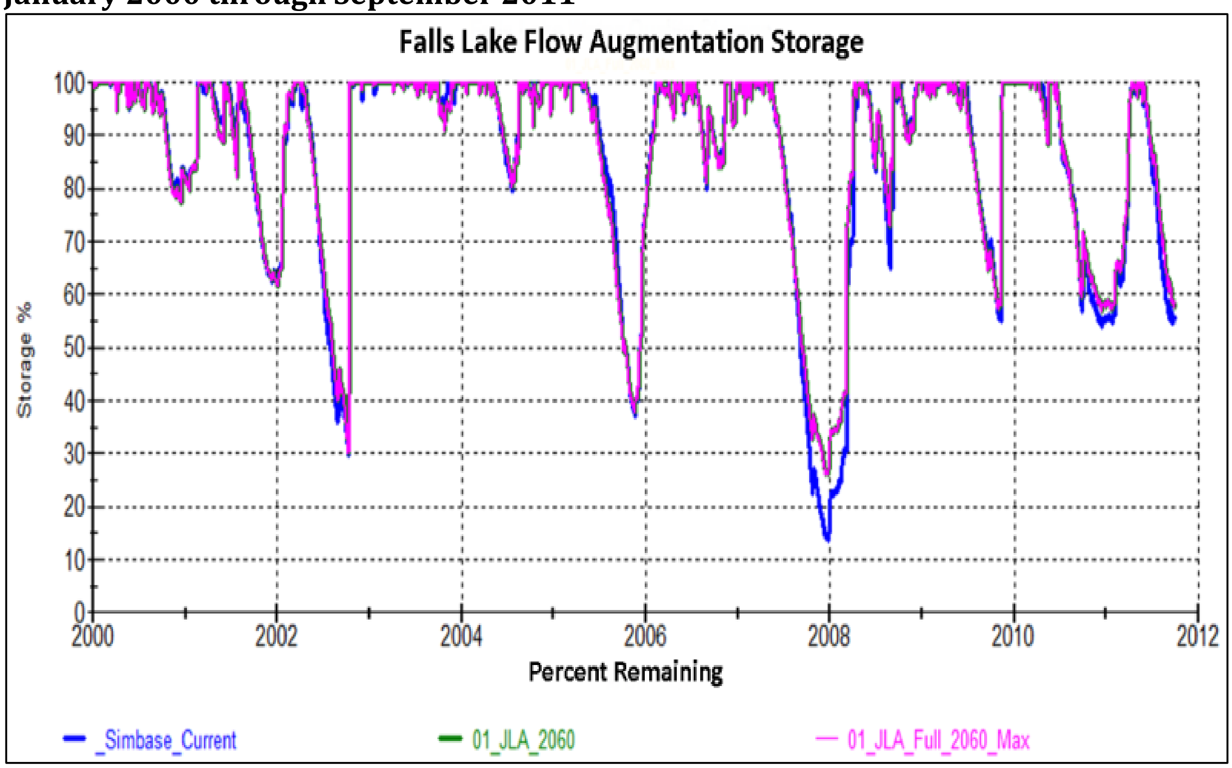


Figure D-30 Lake Wheeler Water Level (ft-msl)

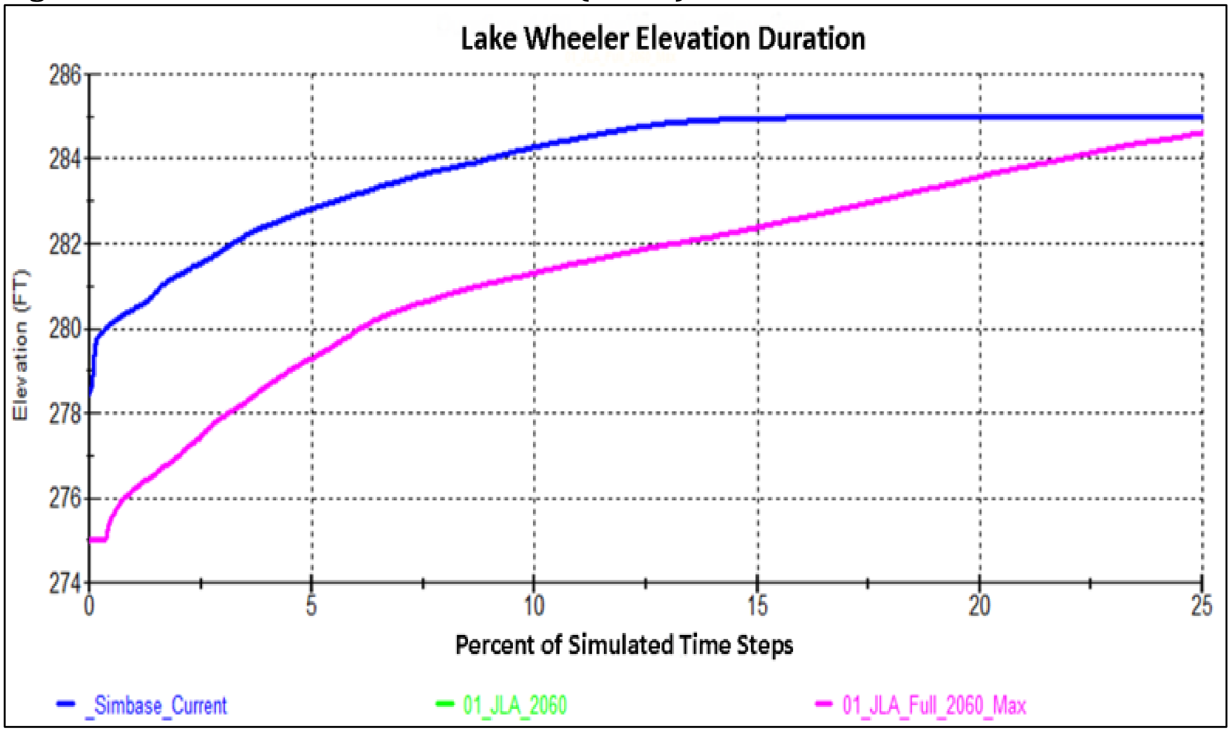
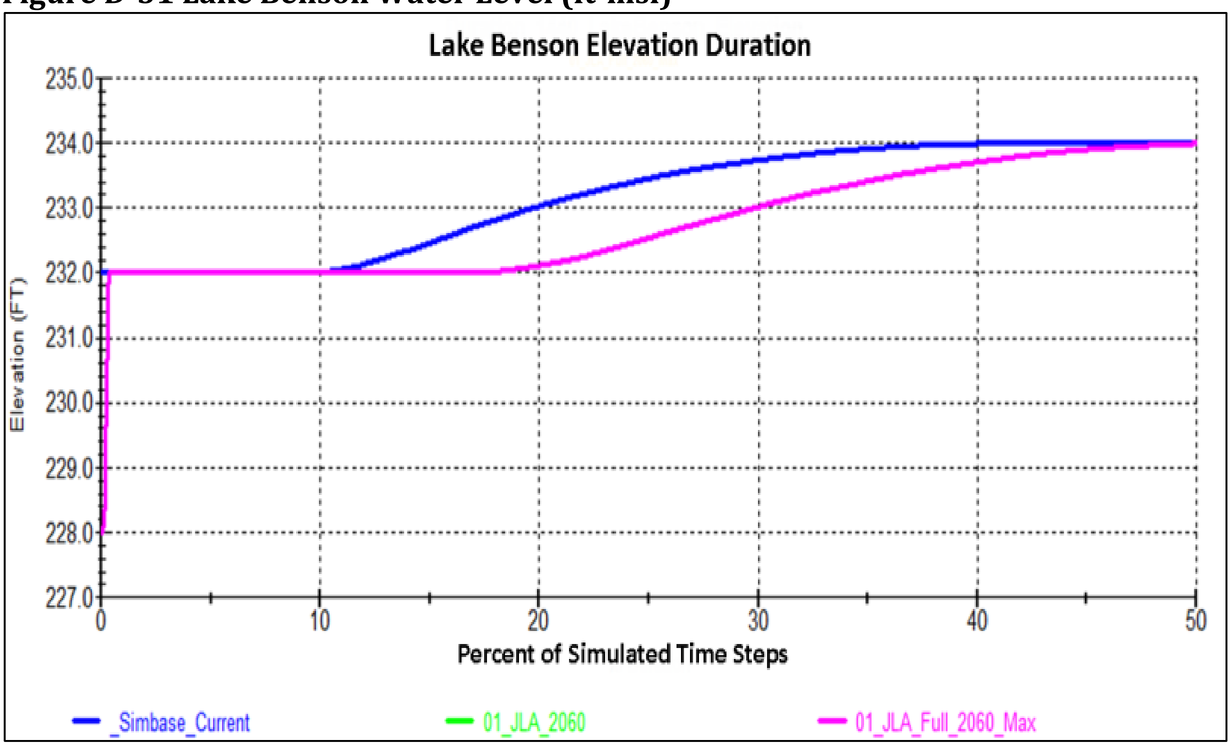


Figure D-31 Lake Benson Water Level (ft-msl)



The following flow duration graphs highlight the variations in low flows at each location presented. The vertical scale shows flow rates in cubic feet per second while the horizontal scale shows the percent of simulated time steps in a model run. Using daily time steps when running a model scenario over the 29,858 days in the flow record means there are 29,858 time steps simulated for each model scenario. The flow record used in the model was reconstructed from historic flow records to capture hydrologic conditions from January 1930 to September 2011.

Figure D-32 Jordan Lake Outflow (cfs)

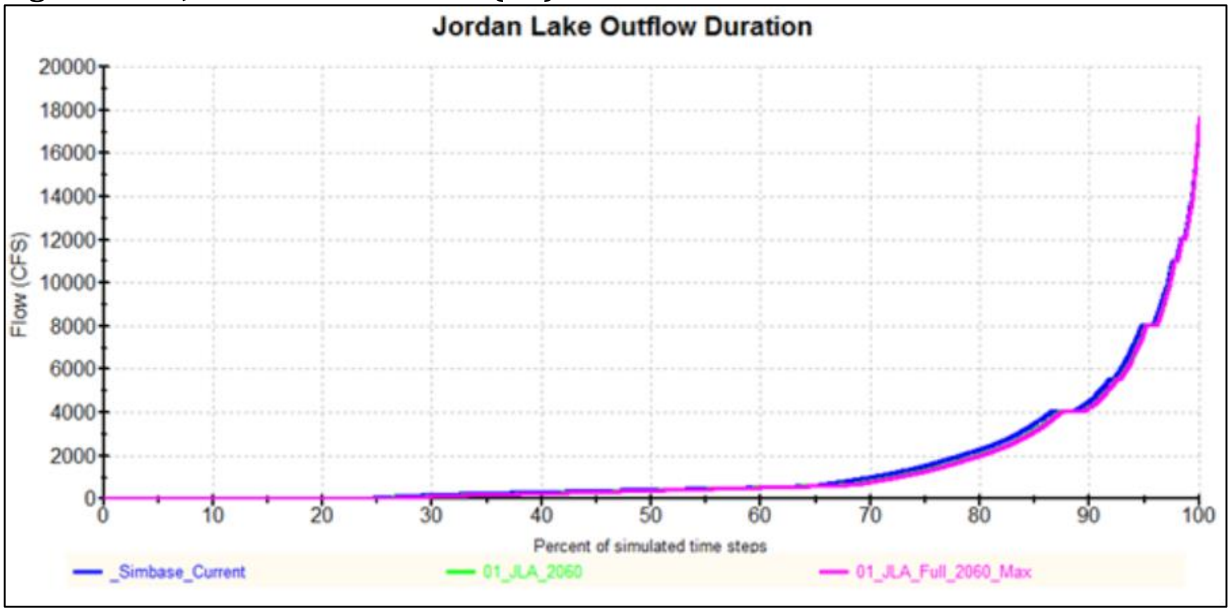


Figure D-33 Jordan Lake Outflow (cfs)

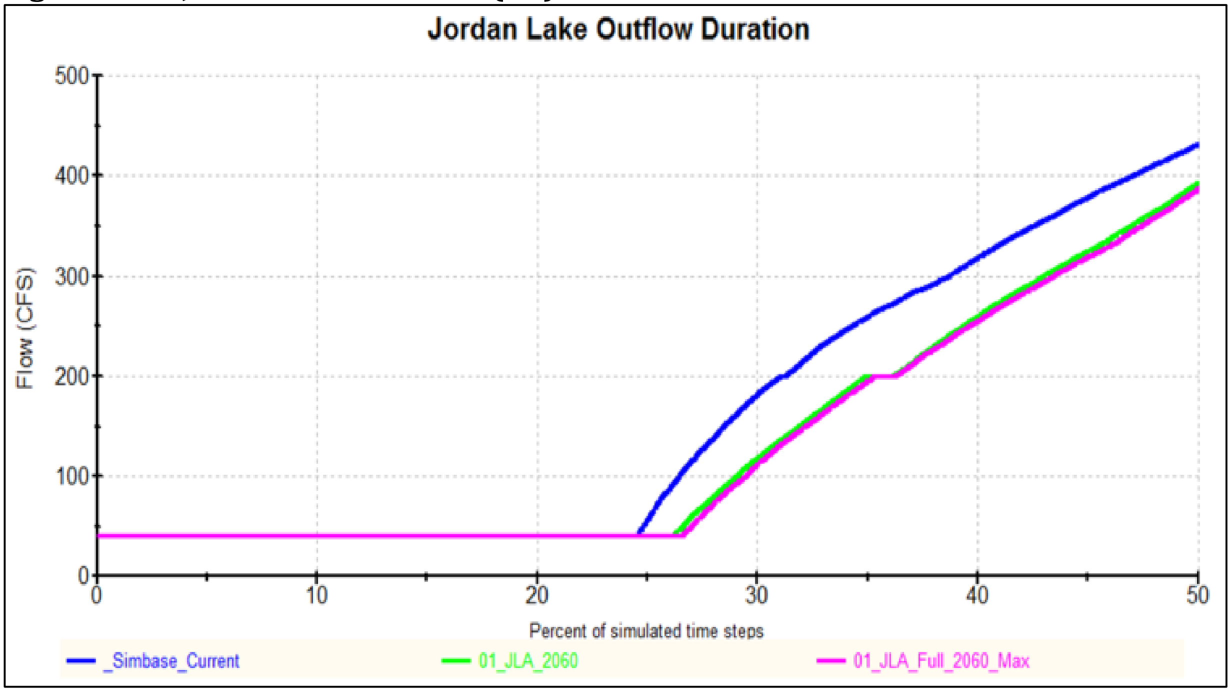


Figure D-34 Harris Lake Outflow (cfs)

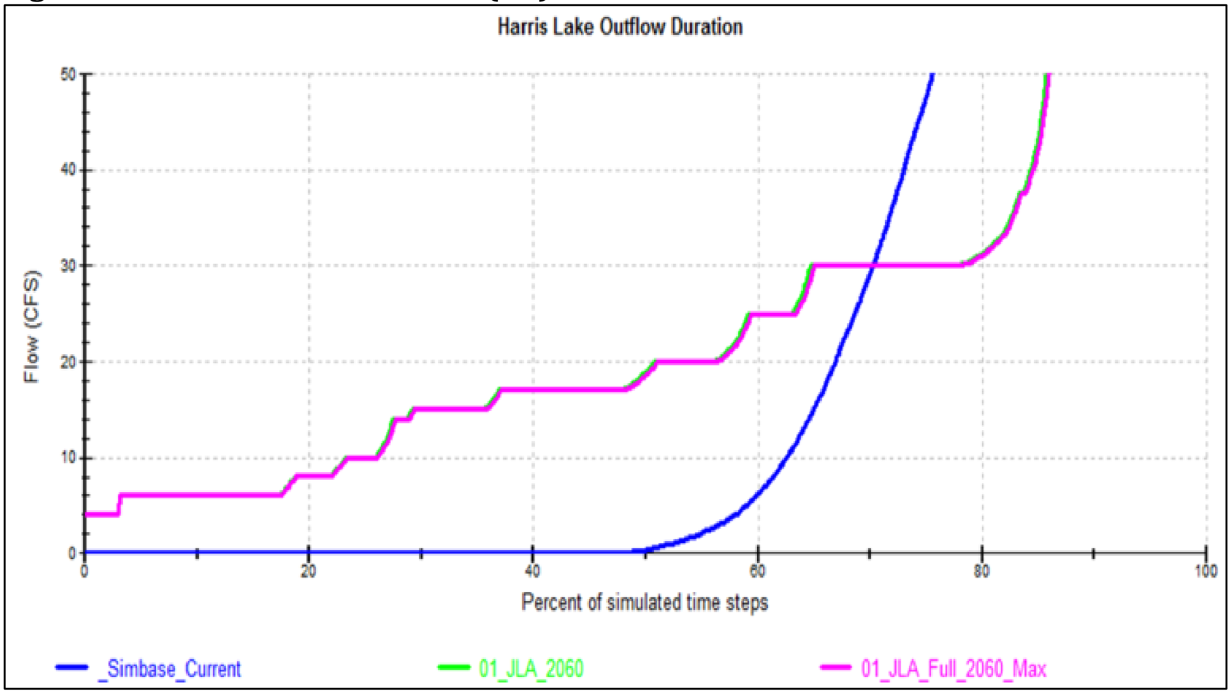


Figure D-35 Buckhorn Creek Flow (cfs)

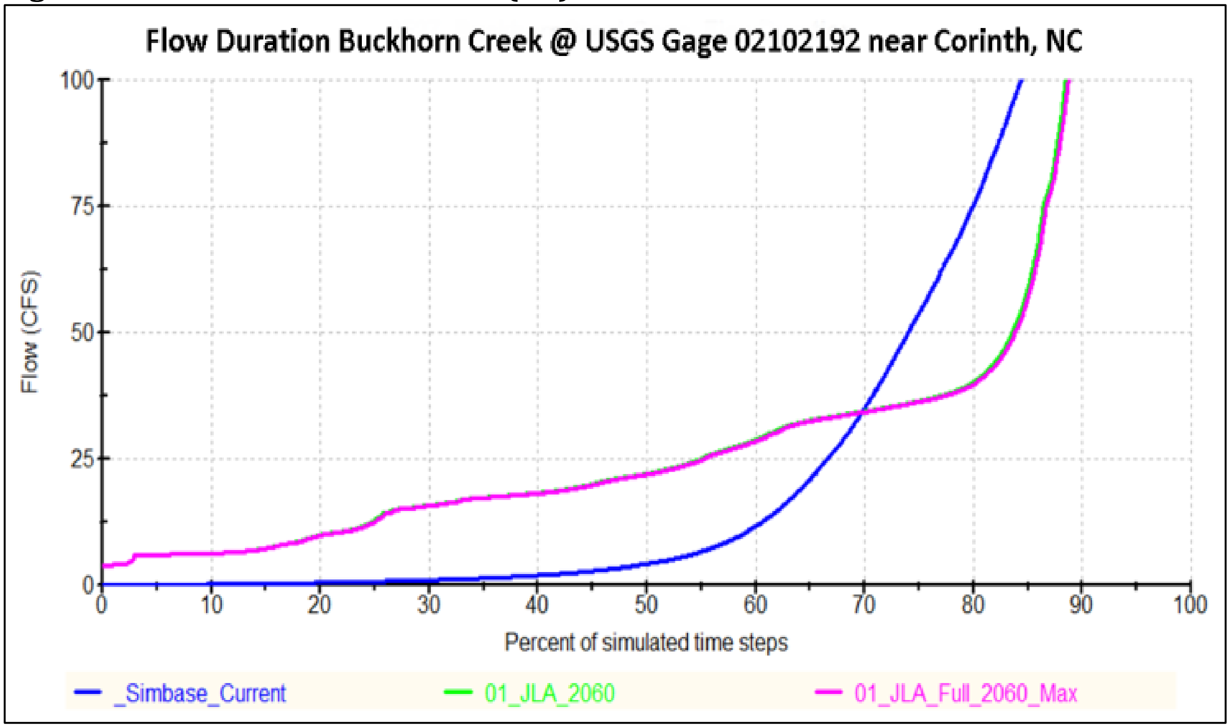


Figure D-36 Cape Fear River Flow at USGS Gage 02102500 at Lillington, NC (cfs)

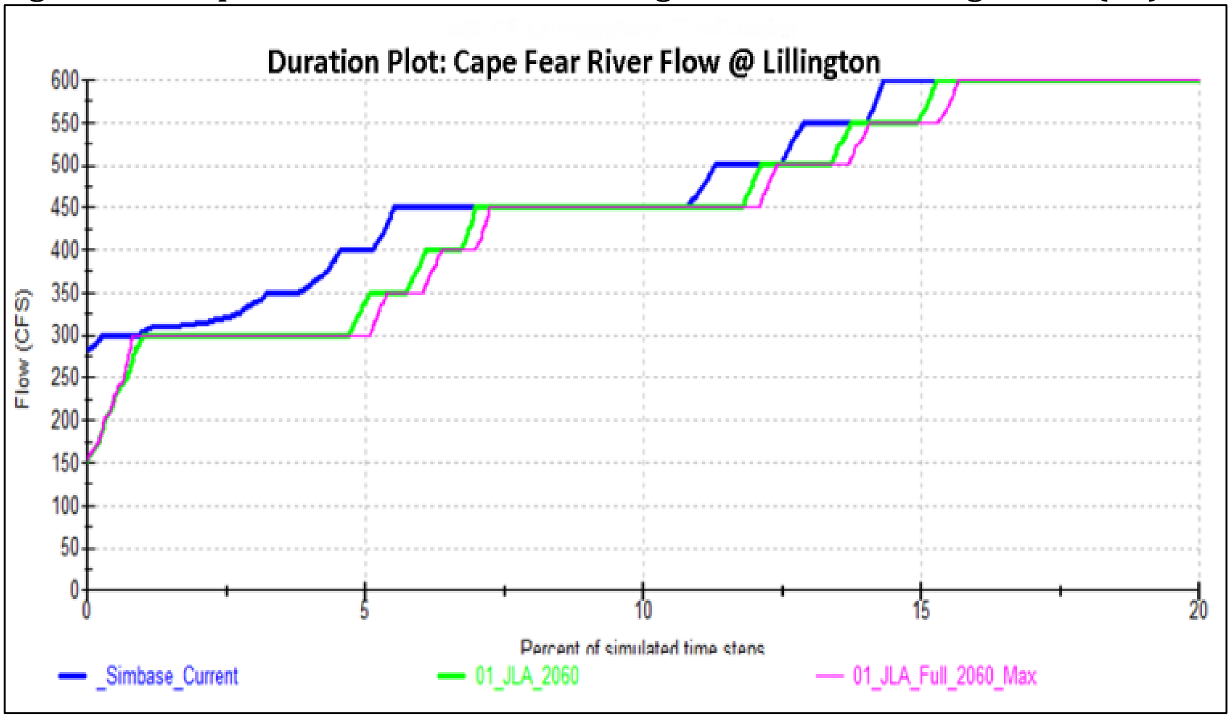


Figure D-37 Cape Fear River Flow at Lock and Dam #3 (cfs)

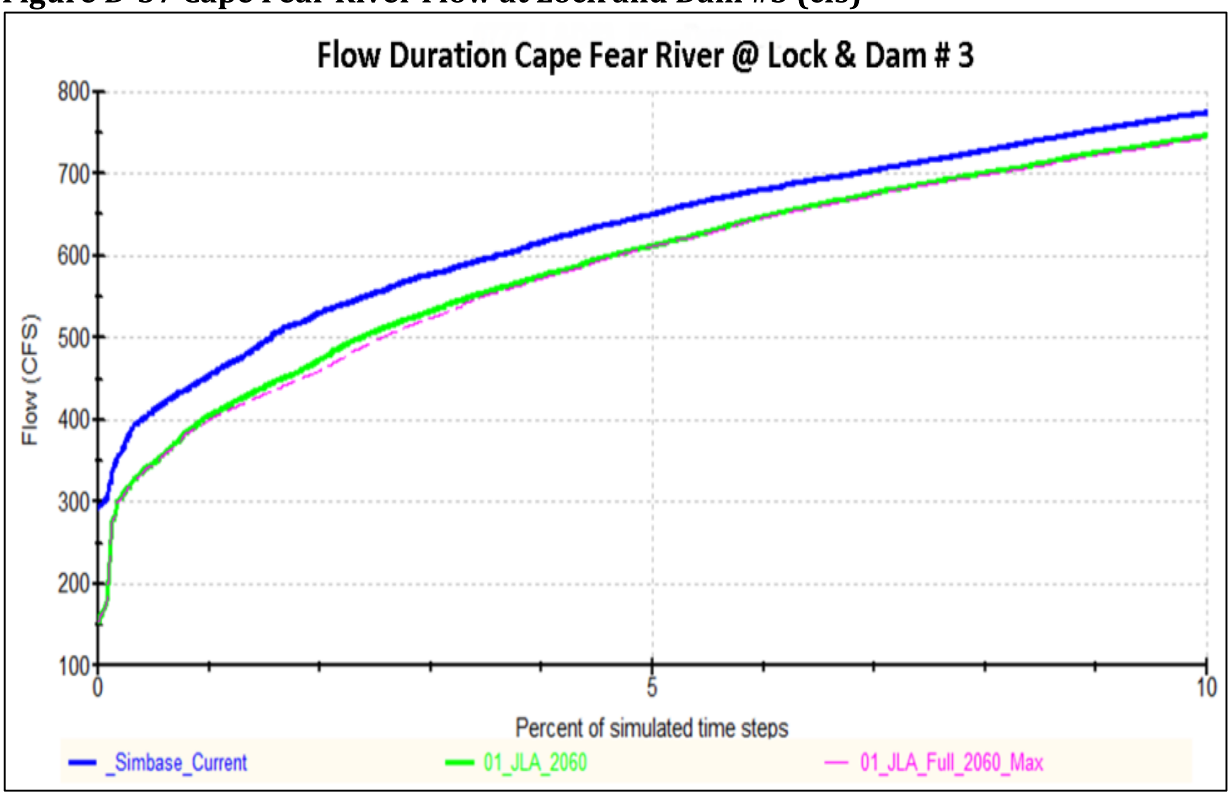


Figure D-38 Cape Fear River Flow at USGS Gage 02105500 near Tarheel, NC (cfs)

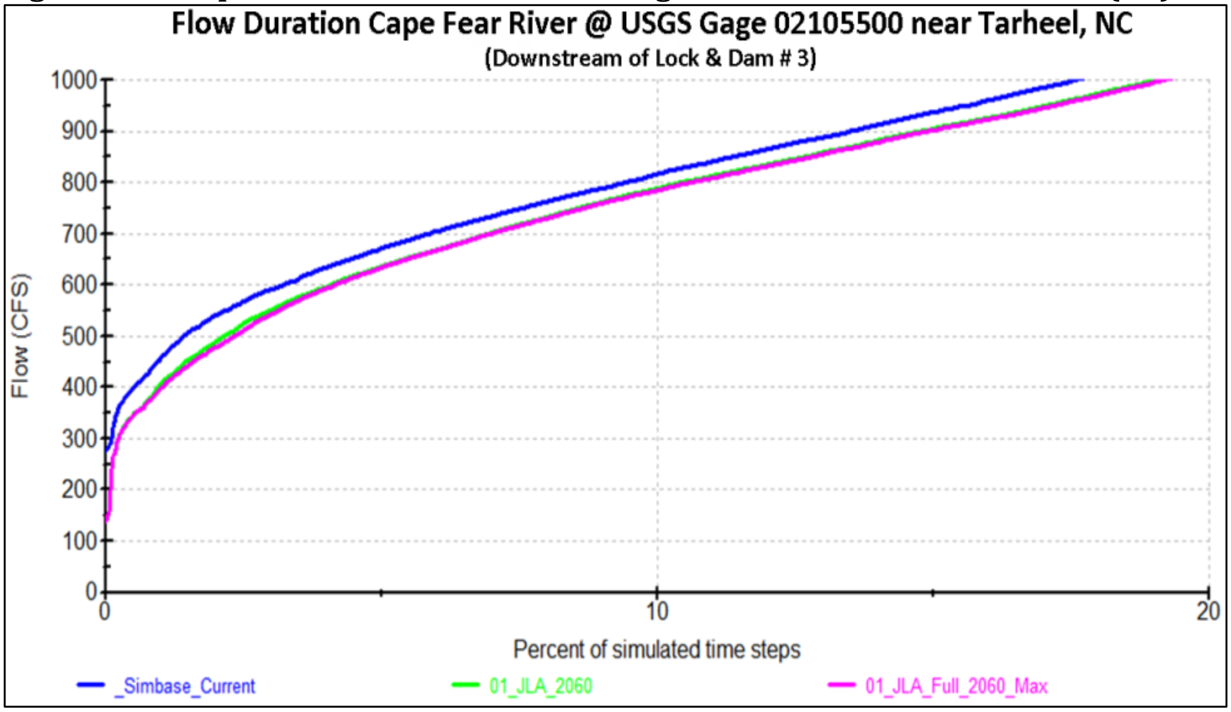


Figure D-39 Cape Fear River Flow below Lock and Dam #1 (cfs)

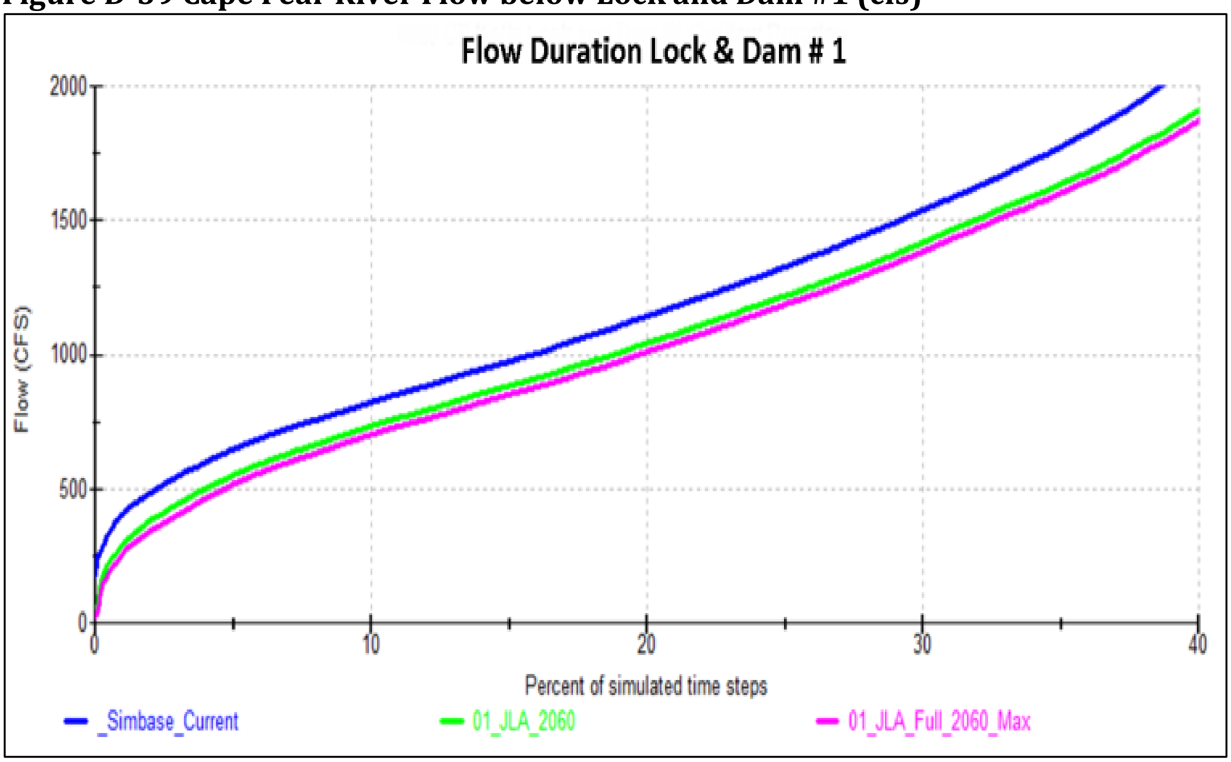
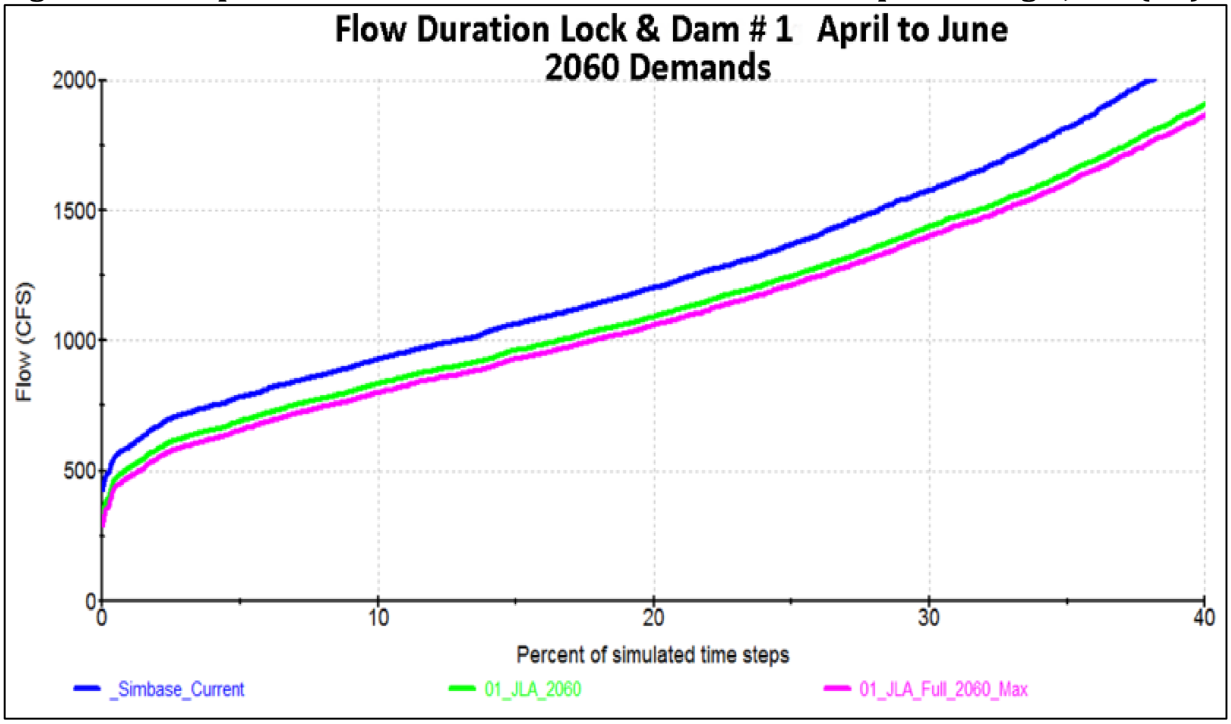


Figure D-40 Cape Fear River Flow below Lock and Dam #1 April through June (cfs)



Flow Duration Plots for Falls Lake and Downstream

Figure D-41 Falls Lake Outflow (cfs)

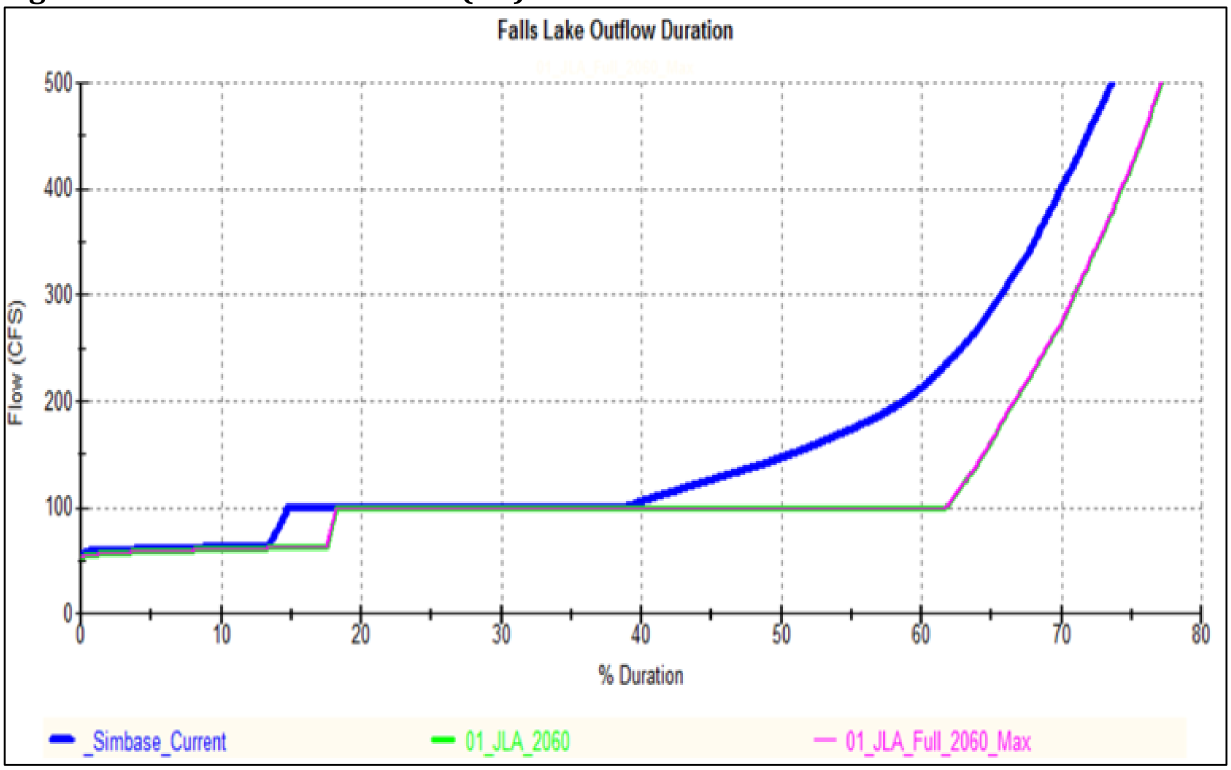


Figure D-42 Middle Creek Flow at USGS Gage 02088000 near Clayton, NC (cfs)

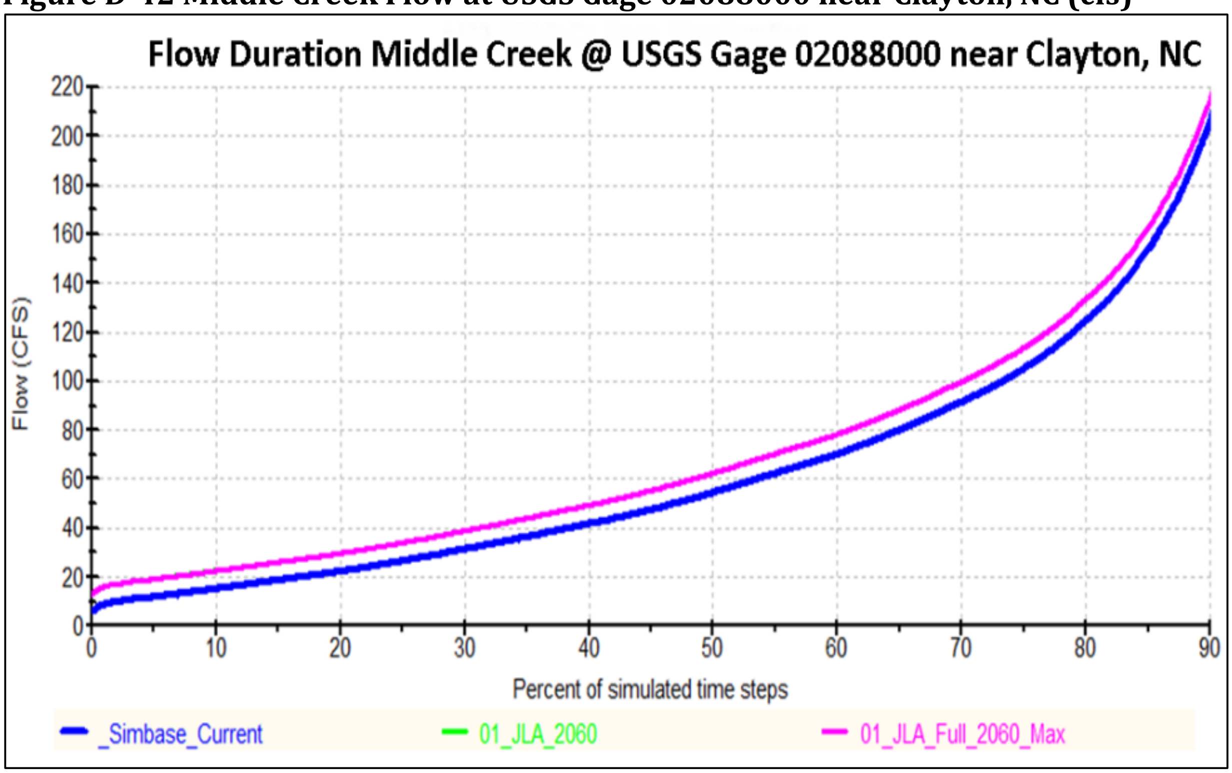


Figure D-43 Neuse River Flow at USGS Gage 02087500 near Clayton, NC (cfs)

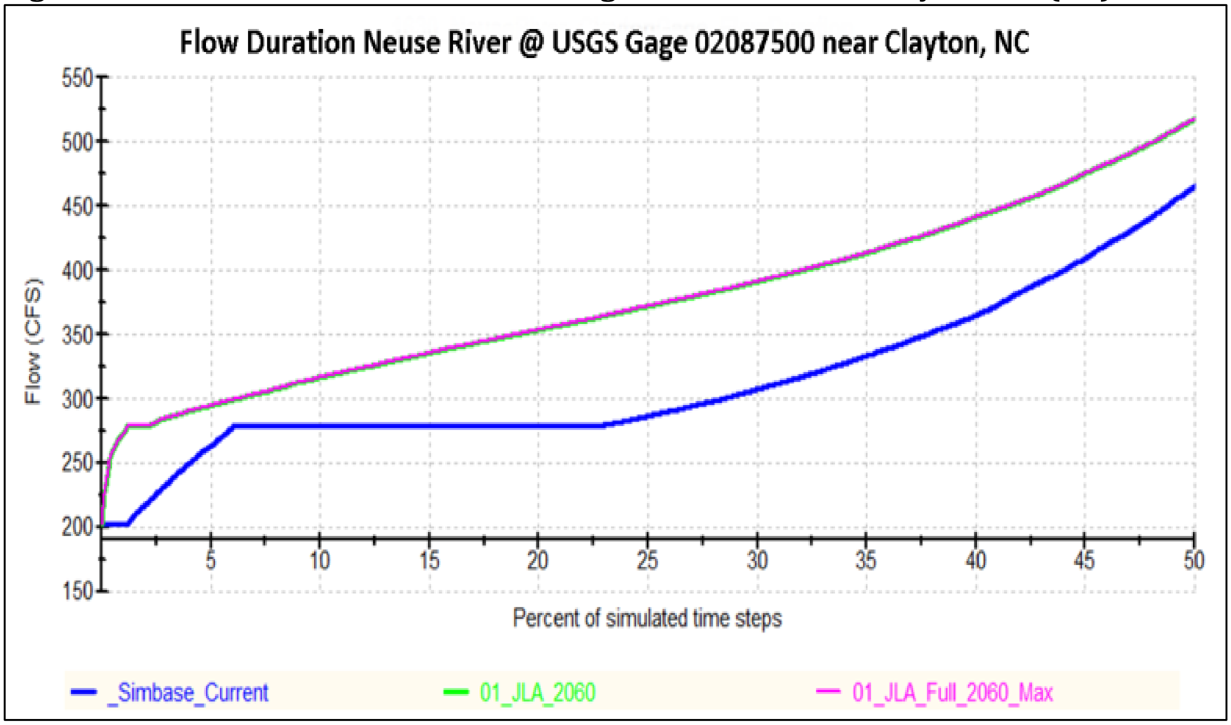


Figure D-44 Neuse River Flow at USGS Gage 02087500 near Clayton, NC (cfs)

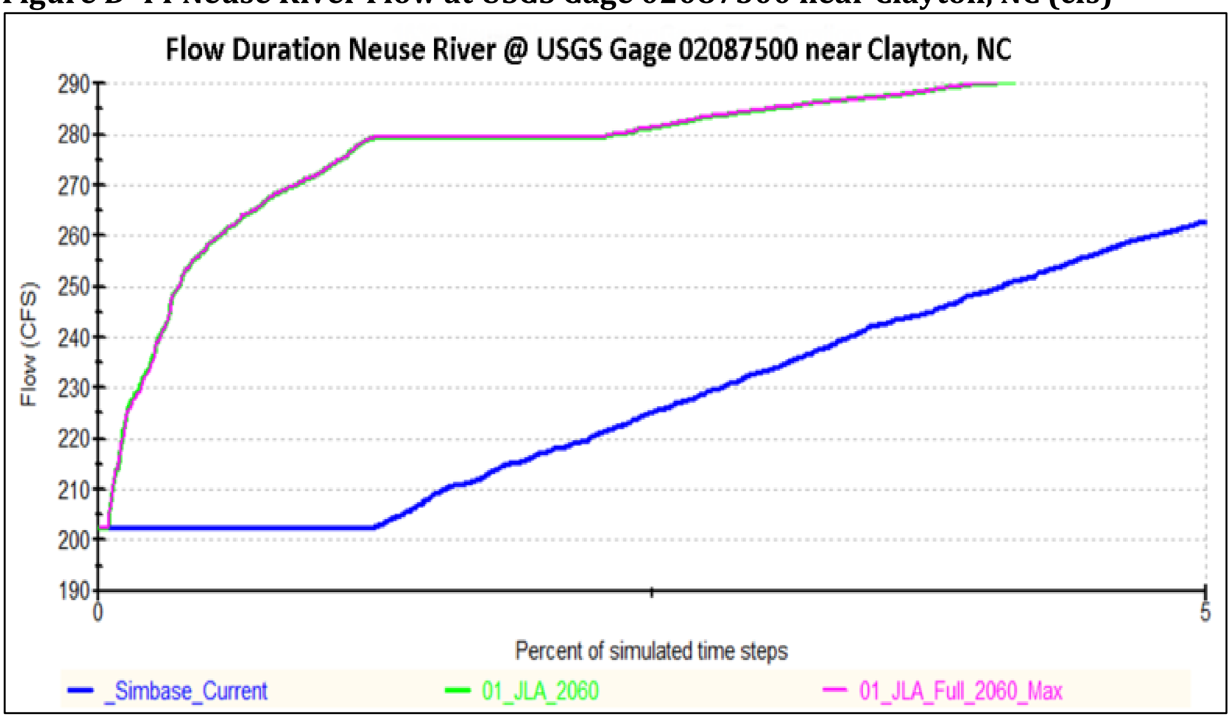


Figure D-45 Neuse River Flow at USGS Gage 02087570 near Smithfield, NC (cfs)

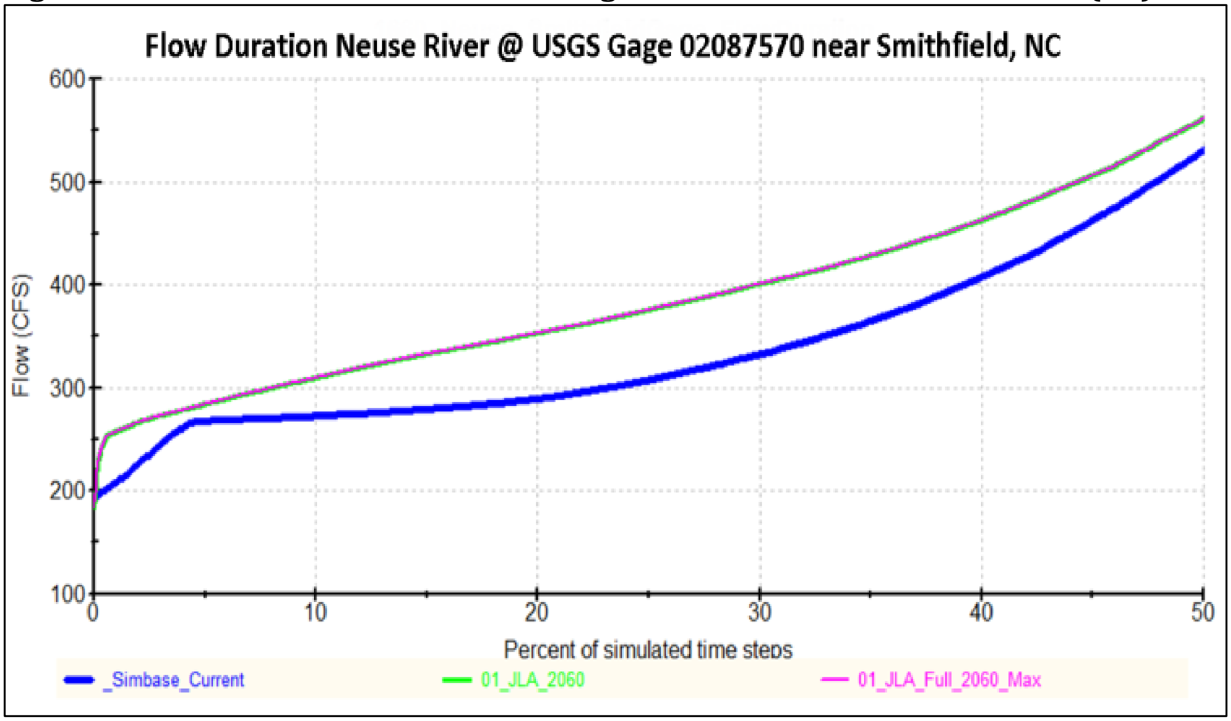


Figure D-46 Neuse River Flow at USGS Gage 02089000 near Goldsboro, NC (cfs)

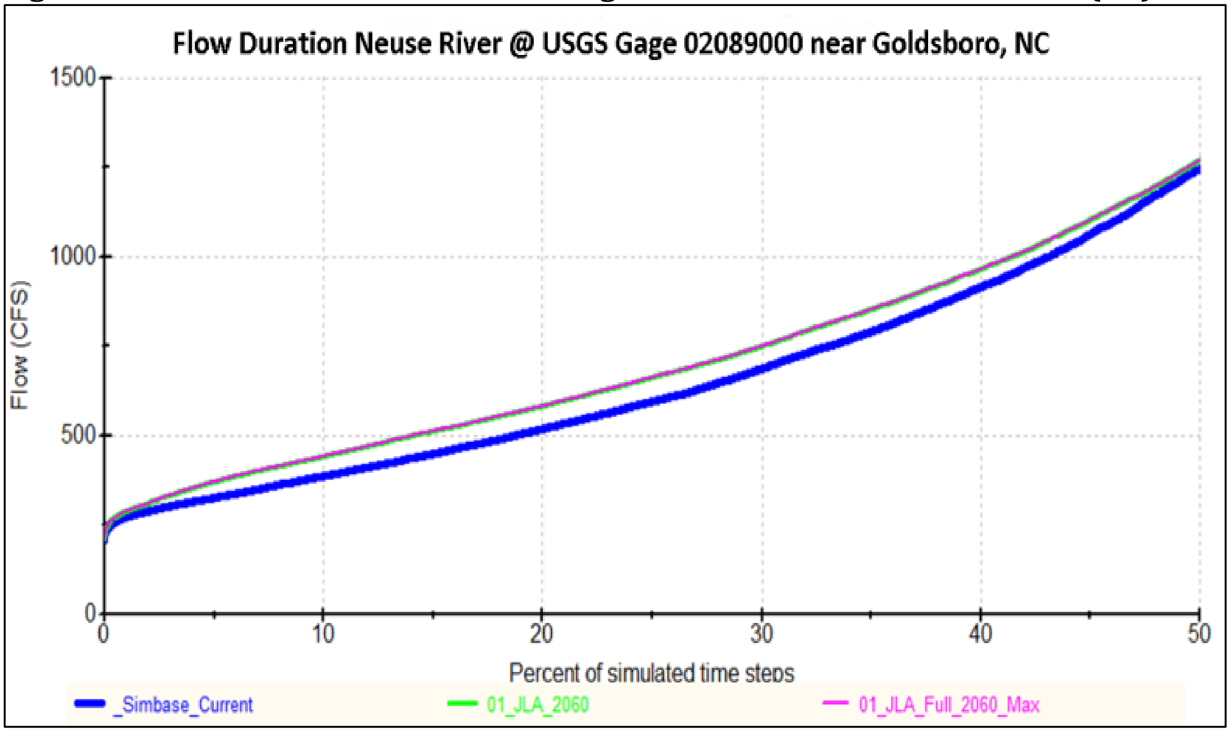


Figure D-47 Neuse River Flow at USGS Gage 02089500 near Kinston, NC (cfs)

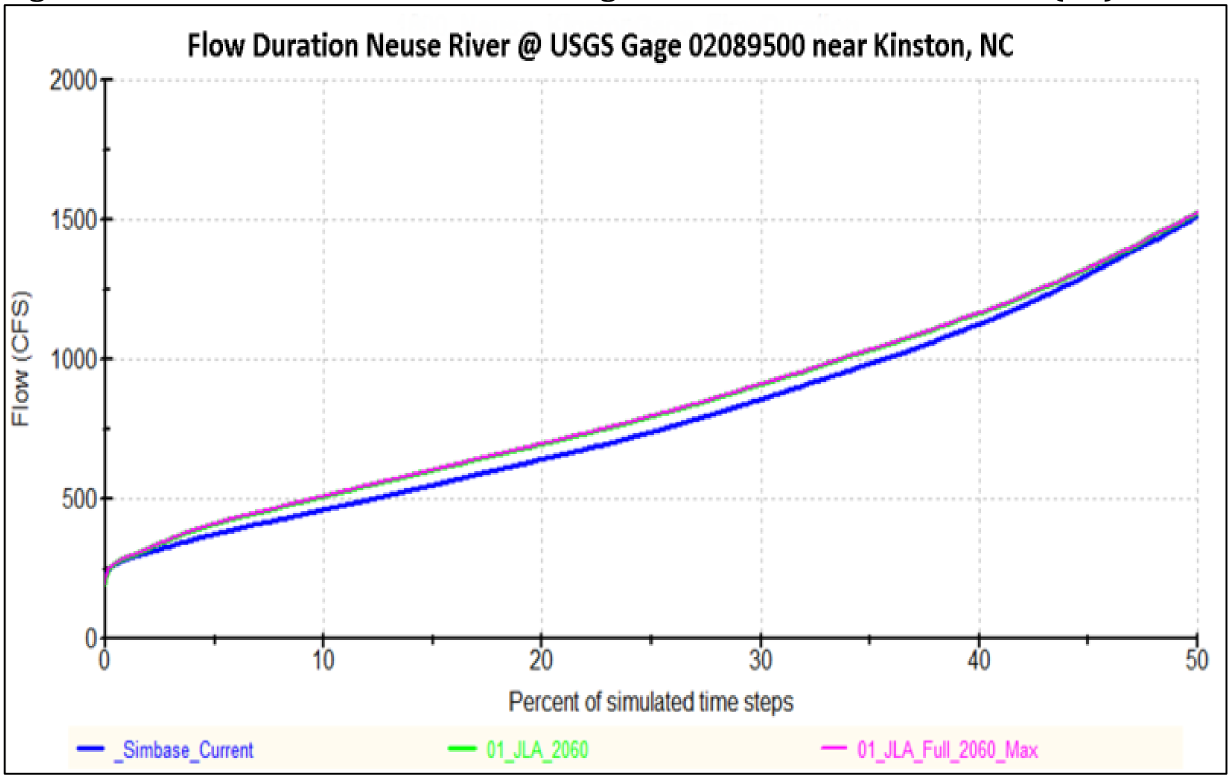
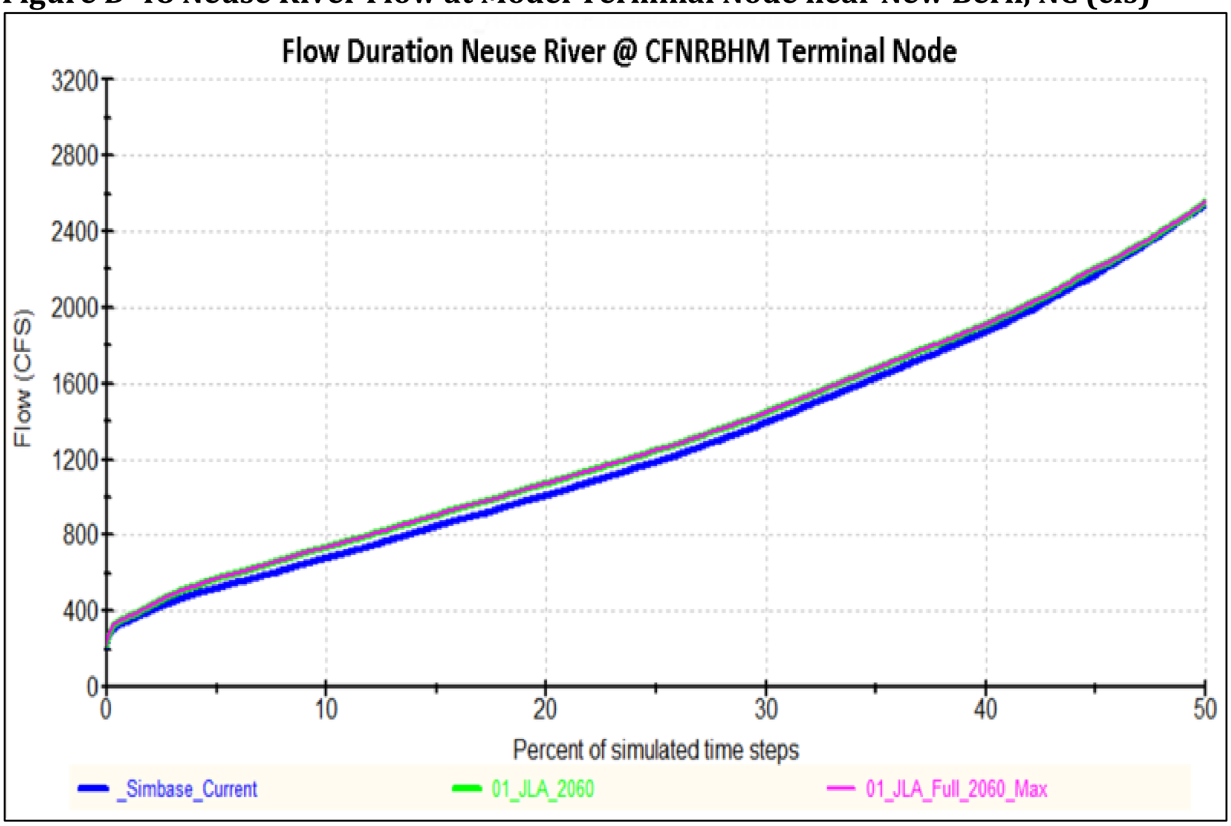


Figure D-48 Neuse River Flow at Model Terminal Node near New Bern, NC (cfs)



20 Appendix E Flow Variations as Percent of Mean Annual Flow

With increasing withdrawals from surface water in the Cape Fear Basin the potential changes to streamflow patterns become a question of concern. Comparing streamflow data from the various model scenarios can provide an indication of the changes in flow regimes that may occur in the future. Changes in flow regimes can affect ecological integrity of water courses.

This review of changes in streamflow patterns provides information for general planning purposes. When comparing the potential impacts of various water withdrawal and reservoir operation options it can be informative to consider how flows of different levels in the Cape River Basin vary between scenarios. The flow record used in the Cape Fear – Neuse River Basins Hydrologic Model is a reconstruction of naturalized flow based on observed hydrologic conditions using stream gage data for the period from January 1, 1930 to September 30, 2011.

Because the streamflow records are incomplete certain assumptions and adjustments must be made to produce a useful set of data to create an historic record. Therefore, the flows and flow statistics produced by the model cannot be directly compared to stream gage data. Details of how the synthetic flow records were produced for the Cape Fear River and Neuse River portions of the model are available on the Division of Water Resources' website by clicking here.[i]

DWR is not advocating the use of this method to establish instream flow requirements. DWR does not have sufficient data to determine optimal conditions to protect ecological integrity. Without site specific information, determining the ability of existing flow regimes to support ecological integrity is not possible. Therefore, the modeling results will not be able to determine if existing instream flows are adequate or not. Like the hydrologic model, this analysis of trends is intended only as a planning tool to inform water withdrawers and resource management agencies if potential future conditions might impact aquatic organism populations structured on 2010 conditions.

The model data presented shows the potential differences between alternative scenarios at thirteen locations in the Cape Fear Basin. This analysis is a desktop application of a variation of the method proposed by D. L. Tennant[ii] that describes a stream flow regime as percentages of the mean annual flow (MAF).

Tennant's original flow classifications and associated habitat descriptions have been modified to better reflect hydrologic and habitat characteristics in North Carolina. Table 1 shows the percentage groupings and a narrative description of habitat quality for three seasons chosen to reflect habitat needs for fish, mussels, other aquatic organisms and channel maintenance in North Carolina.

A table for each location shows model scenario descriptions and the estimated MAF for each. There are four graphs presented for each location. The first in each series shows data for the calendar year, January through December. The other three graphs present data for March through May (Spring), June through November (Summer/Fall) and December through February (Winter).

These graphs show how the distribution of flows during particular times of the year vary under the different model scenarios.

On the graphs, the bars in each grouping indicate how the percent of the 29,858 days in the flow record vary under the different model scenarios. The order and color of the graph bars are consistent for all the graphs. The first bar in each group represents existing conditions based on the "Simbase_Current" model scenario labeled as "1Sim2010" on graphs. This scenario reflects the water sources, management protocols and water withdrawals present in 2010. Comparing the plots for alternative model scenarios to the plots for the 1Sim2010 scenario suggests how conditions may vary between model scenarios.

The eight-digit number in the label of each graph indicates the specific arc in the hydrologic model that was analyzed. Water flows through each arc from an upstream node indicated by the first four digits to a downstream node indicated by the second four digits.

Table 1: Modified Tennant Method Guidelines for Evaluating Flow Deviations by Season.

% Mean Annual Flow	March to May	June to Nov.	Dec. to Feb.
< 10%	Severe Degradation	Severe Degradation	Severe Degradation
10 - 20%	Poor or Minimum	Fair/Degrading	Fair/Degrading
20 - 30%	Fair or Degrading	Good	Good
30 - 40%	Good	Excellent	Excellent
40 - 50%	Excellent	Outstanding	Outstanding
50 - 60%	Outstanding	Outstanding	Outstanding
60 - 100%	Optimum	Optimum	Optimum
100 - 200%	Optimum/Flushing	Optimum/Flushing	Optimum/Flushing
>200%	Flushing/Max. Flow	Flushing/Max. Flow	Flushing/Max. Flow

The following map shows the nodes of interest that were identified for this evaluation.

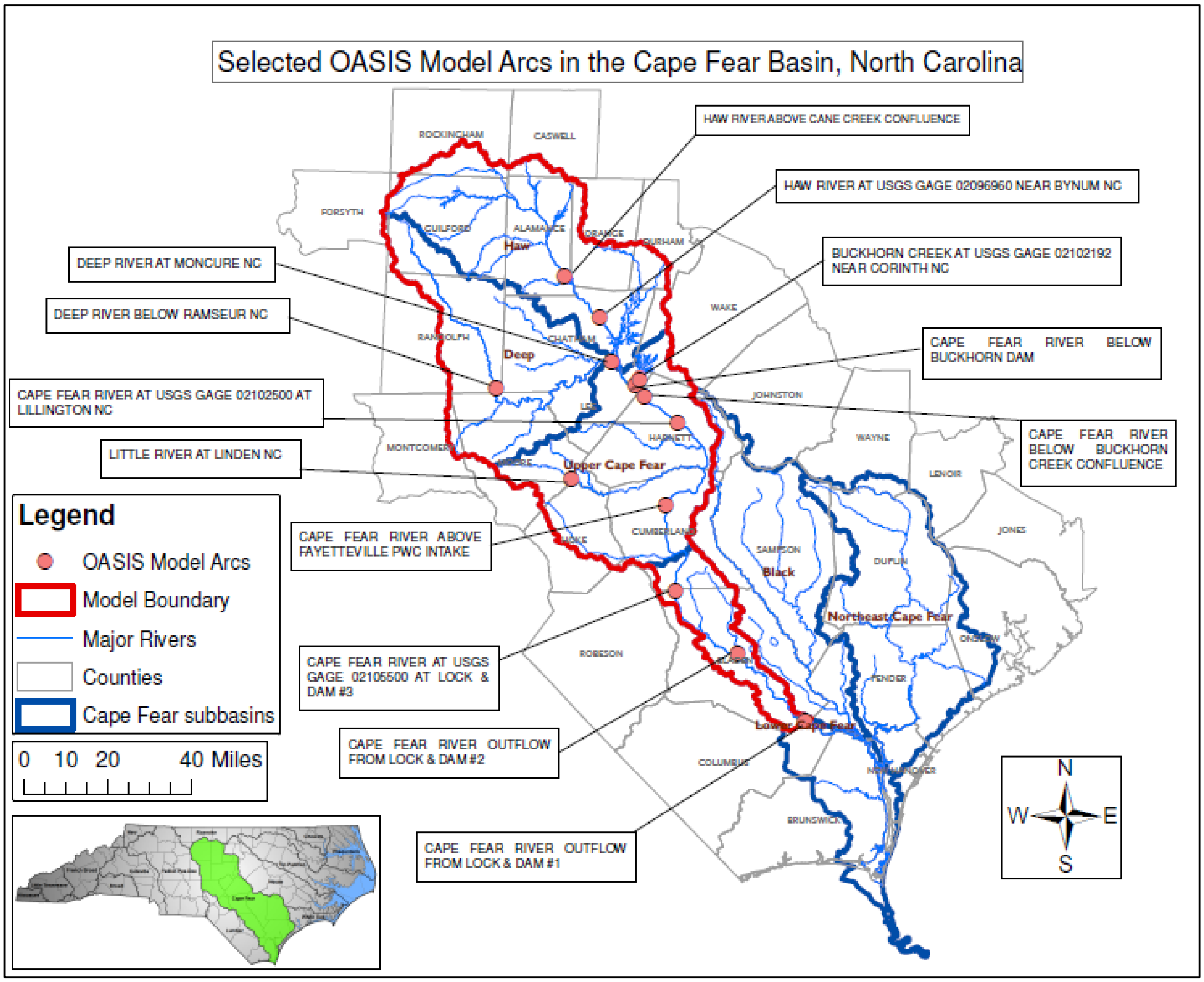

Selected OASIS Model Arcs in the Cape Fear Basin, North Carolina
HAW RIVER ABOVE CANE CREEK CONFLUENCE
HAW RIVER AT USGS GAGE 02096960 NEAR BYNUM NC
BUCKHORN CREEK AT USGS GAGE 02102192 NEAR CORINTH NC
CAPE FEAR RIVER BELOW BUCKHORN DAM
CAPE FEAR RIVER BELOW BUCKHORN CREEK CONFLUENCE
DEEP RIVER AT MONCURE NC
DEEP RIVER BELOW RAMSEUR NC
CAPE FEAR RIVER AT USGS GAGE 02102500 AT LILLINGTON NC
LITTLE RIVER AT LINDEN NC
CAPE FEAR RIVER ABOVE FAYETTEVILLE PWC INTAKE
CAPE FEAR RIVER AT USGS GAGE 02105500 AT LOCK & DAM #3
CAPE FEAR RIVER OUTFLOW FROM LOCK & DAM #2
CAPE FEAR RIVER OUTFLOW FROM LOCK & DAM #1
Legend
OASIS Model Arcs
Model Boundary
Major Rivers
Counties
Cape Fear subbasins
0 10 20 40 Miles
N
W
E
S
Haw
Deep
Upper Cape Fear
Black
Northeast Cape Fear
Lower Cape Fear

Table E-1. Haw River above confluence with Cane Creek.

Model Scenario	Description	MAF (cfs)
1Sim2010	basecase conditions in 2010	754
2Sim2045	2010 available supplies and 2045 demands	753
3JLA2045	recommended Jordan Lake allocations added to 2010 available supplies and 2045 demands	762
4JLA2045_C	same as 3JLA2045 with daily data in the flow record reduced 10%	686
5JLA2060	recommended Jordan Lake allocations and 2060 demands	761
6JLA2060	full allocation of Jordan Lake water supply pool and 106mgd withdrawals during peak month at L&D#1	761

Figure E-1. Haw River above confluence with Cane Creek. Percent of POR by deviation class when compared to MAF, all months (January-December).

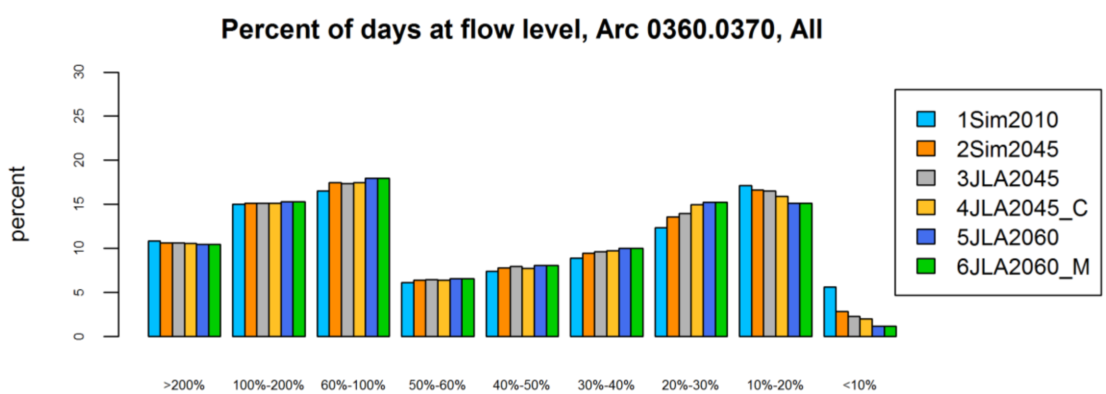


Figure E-2. Haw River above confluence with Cane Creek. Percent of POR by deviation class when compared to MAF, Spring (March-May).

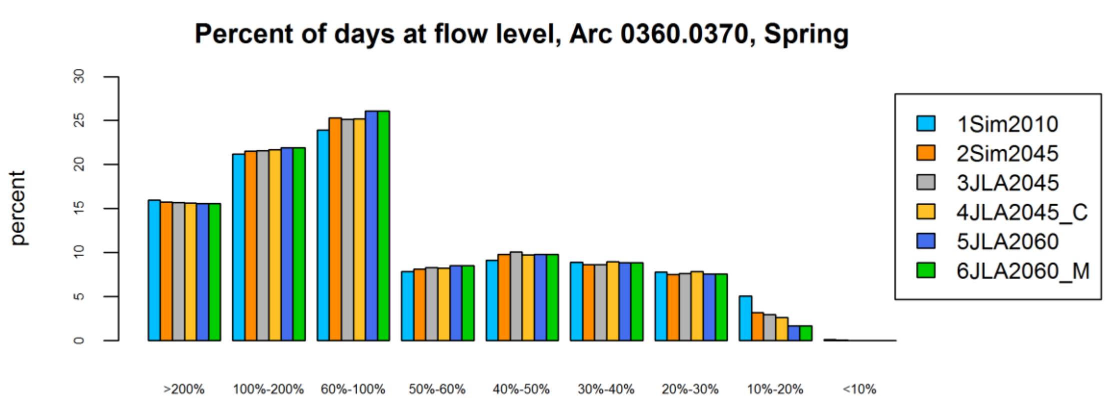


Figure E-3. Haw River above confluence with Cane Creek. Percent of POR by deviation class when compared to MAF, Summer-Fall (June-November).

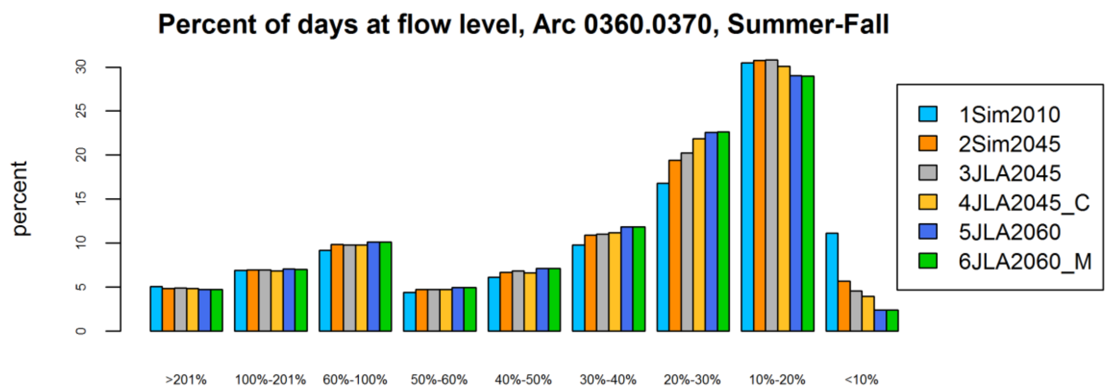


Figure E-4. Haw River above confluence with Cane Creek. Percent of POR by deviation class when compared to MAF, Winter (December-February).

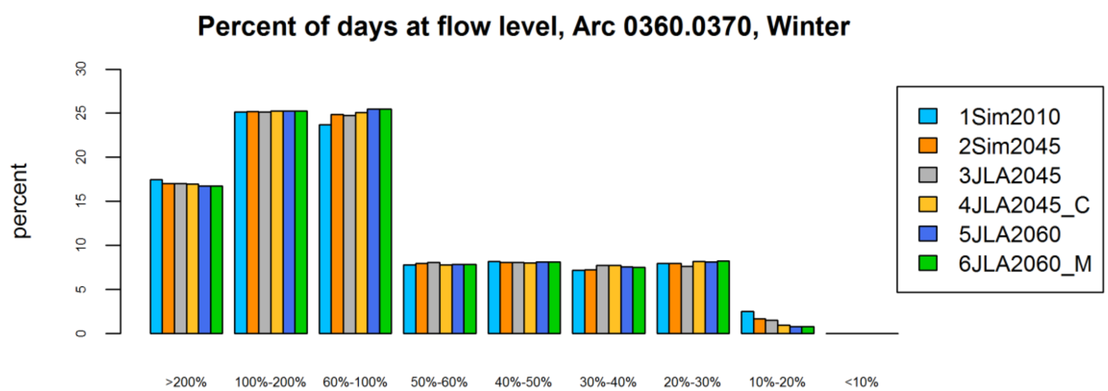


Table E-2. Haw River at USGS Gage 02096960 near Bynum, NC.		
Model Scenario	**Description**	**MAF (cfs)**
1Sim2010	basecase conditions in 2010	1196
2Sim2045	2010 available supplies and 2045 demands	1176
3JLA2045	recommended Jordan Lake allocations added to 2010 available supplies and 2045 demands	1199
4JLA2045_C	same as 3JLA2045 with daily data in the flow record reduced 10%	1077
5JLA2060	recommended Jordan Lake allocations and 2060 demands	1195
6JLA2060	full allocation of Jordan Lake water supply pool and 106mgd withdrawals during peak month at L&D#1	1195

Figure E-5. Haw River at USGS Gage 02096960 near Bynum, NC. Percent of POR by deviation class when compared to MAF, all months (January-December).

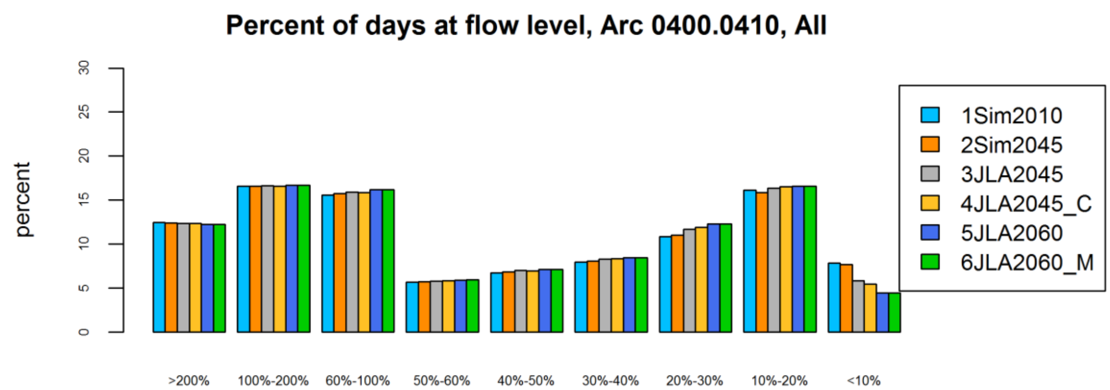


Figure E-6. Haw River at USGS Gage 02096960 near Bynum, NC. Percent of POR by deviation class when compared to MAF, Spring (March-May).

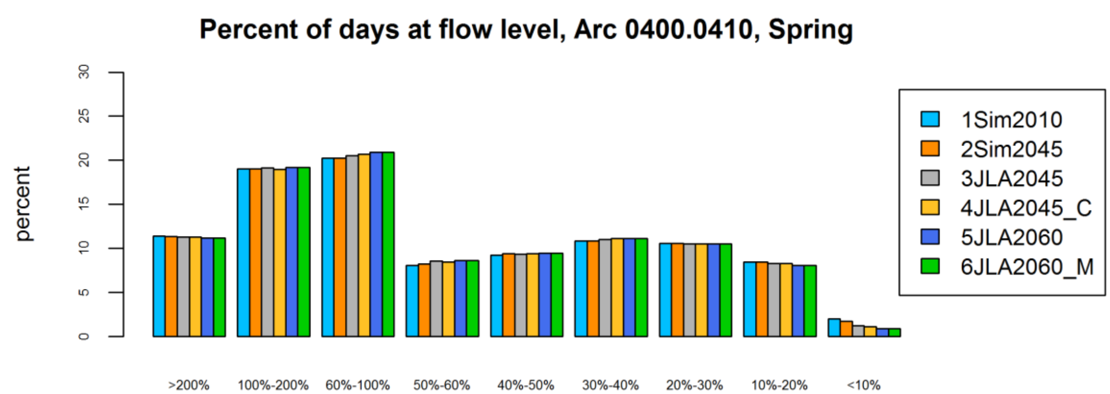


Figure E-7. Haw River at USGS Gage 02096960 near Bynum, NC. Percent of POR by deviation class when compared to MAF, Summer-Fall (June-November).

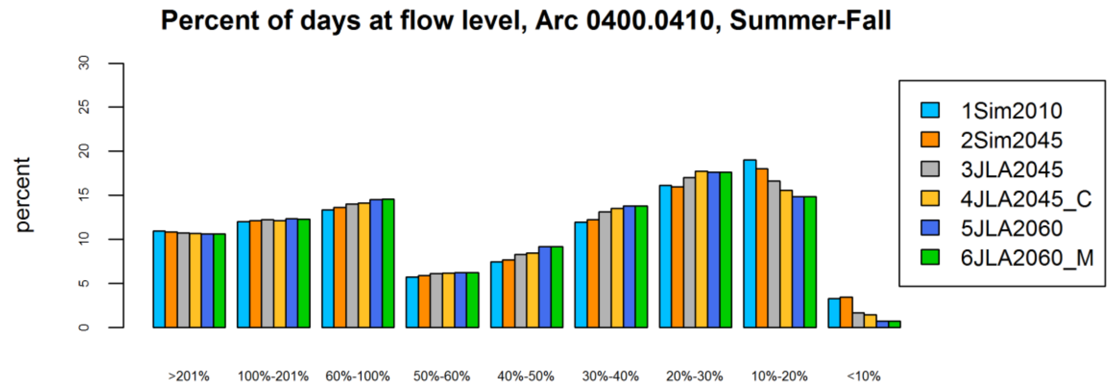


Figure E-8. Haw River at USGS Gage 02096960 near Bynum, NC. Percent of POR by deviation class when compared to MAF, Winter (December-February).

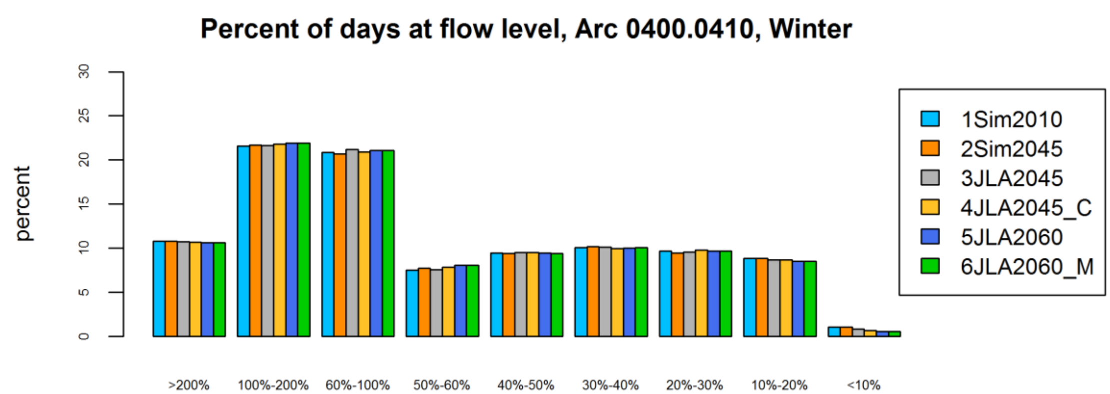


Table E-3. Cape Fear River below Buckhorn Dam.		
Model Scenario	**Description**	**MAF (cfs)**
1Sim2010	basecase conditions in 2010	2901
2Sim2045	2010 available supplies and 2045 demands	2847
3JLA2045	recommended Jordan Lake allocations added to 2010 available supplies and 2045 demands	2812
4JLA2045_C	same as 3JLA2045 with daily data in the flow record reduced 10%	2521
5JLA2060	recommended Jordan Lake allocations and 2060 demands	2798
6JLA2060	full allocation of Jordan Lake water supply pool and 106mgd withdrawals during peak month at L&D#1	2783

Figure E-9. Cape Fear River below Buckhorn Dam. Percent of POR by deviation class when compared to MAF, all months (January-December).

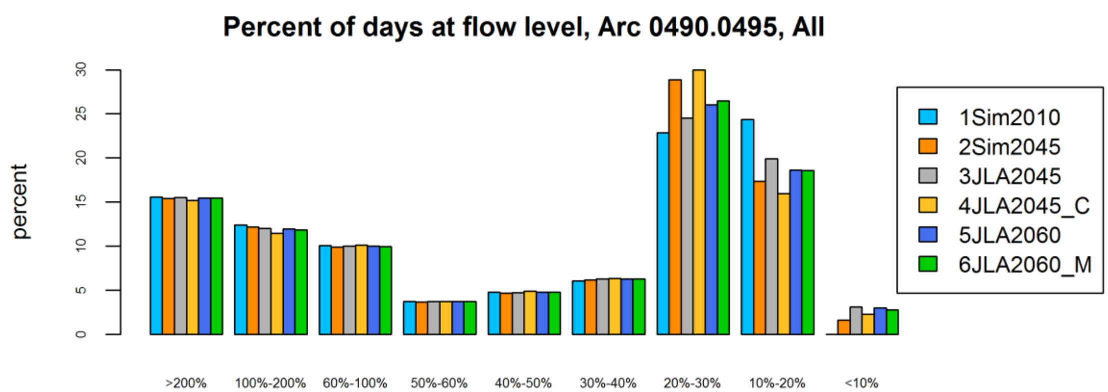


Figure E-10. Cape Fear River below Buckhorn Dam. Percent of POR by deviation class when compared to MAF, Spring (March-May).

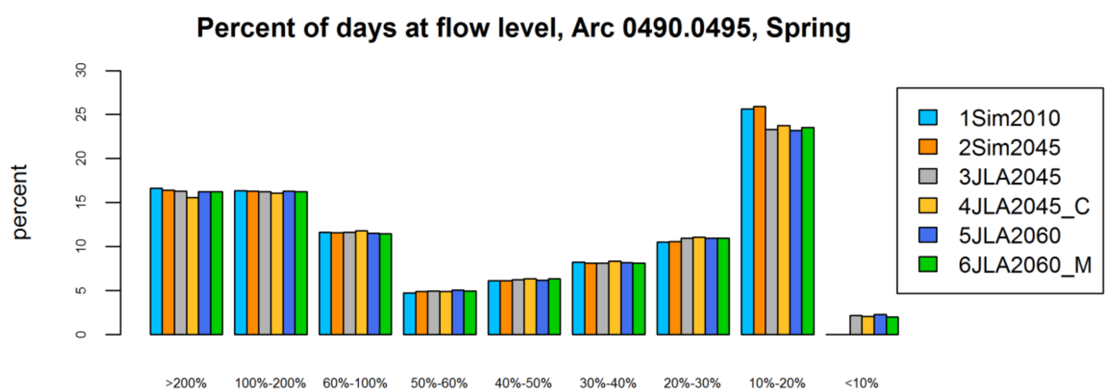


Figure E-11. Cape Fear River below Buckhorn Dam. Percent of POR by deviation class when compared to MAF, Summer-Fall (June-November).

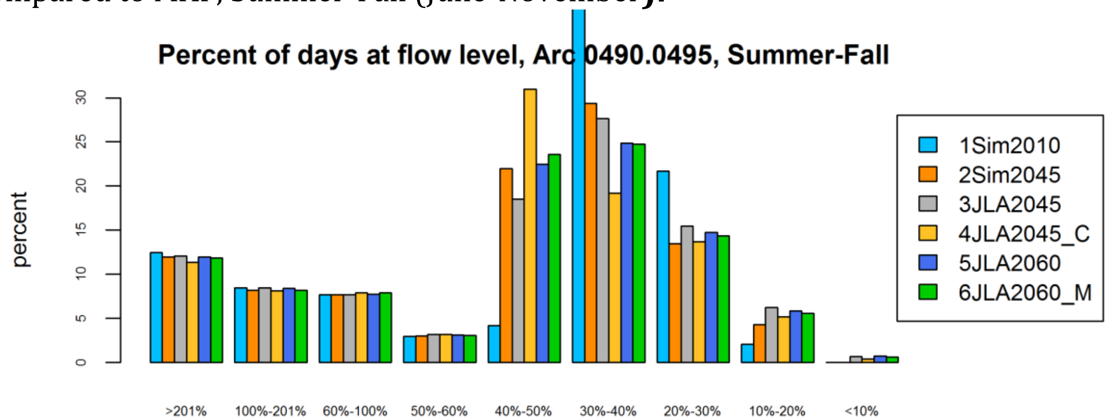


Figure E-12. Cape Fear River below Buckhorn Dam. Percent of POR by deviation class when compared to MAF, Winter (December-February).

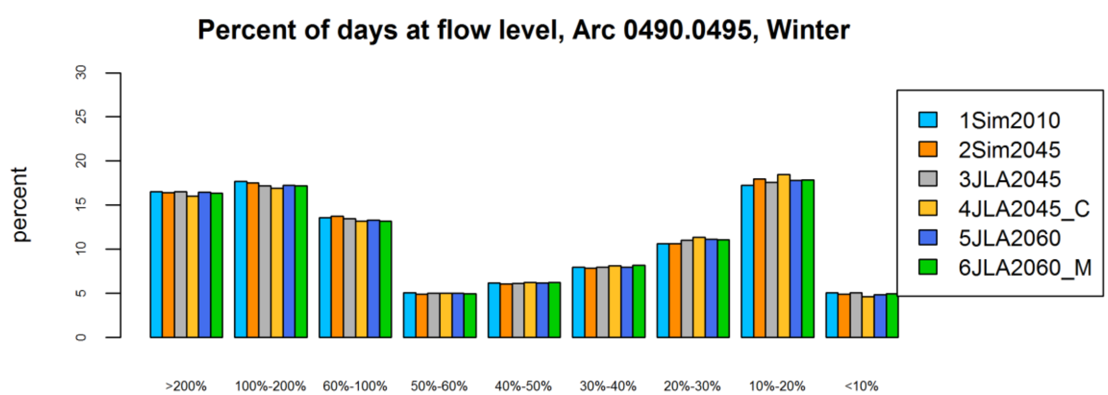


Table E-4. Buckhorn Creek at USGS Gage 02102192 near Corinth, NC.		
Model Scenario	**Description**	**MAF (cfs)**
1Sim2010	basecase conditions in 2010	45
2Sim2045	2010 available supplies and 2045 demands	12
3JLA2045	recommended Jordan Lake allocations added to 2010 available supplies and 2045 demands	61
4JLA2045_C	same as 3JLA2045 with daily data in the flow record reduced 10%	54
5JLA2060	recommended Jordan Lake allocations and 2060 demands	62
6JLA2060	full allocation of Jordan Lake water supply pool and 106mgd withdrawals during peak month at L&D#1	61

Figure E-13. Buckhorn Creek at USGS Gage 02102192 near Corinth, NC. Percent of POR by deviation class when compared to MAF, all months (January-December**).**

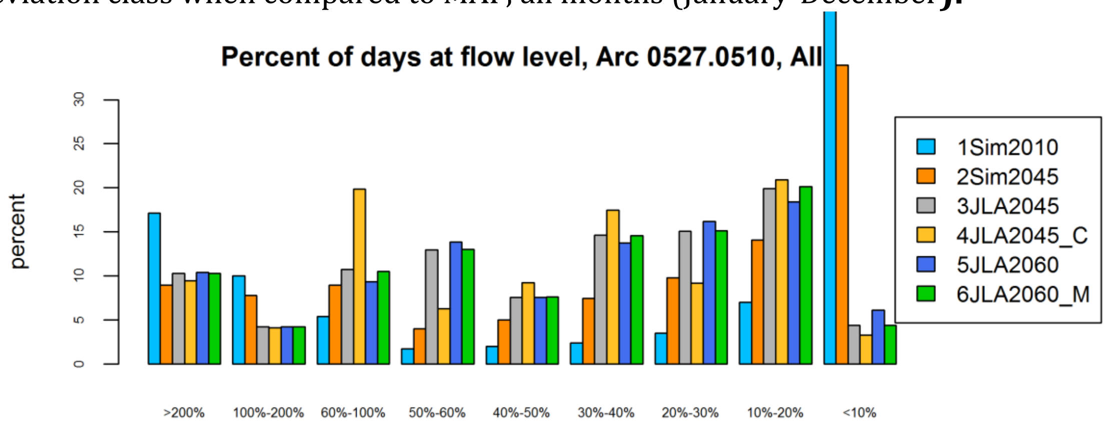


Figure E-14. Buckhorn Creek at USGS Gage 02102192 near Corinth, NC. Percent of POR by deviation class when compared to MAF, Spring (March-May**).**

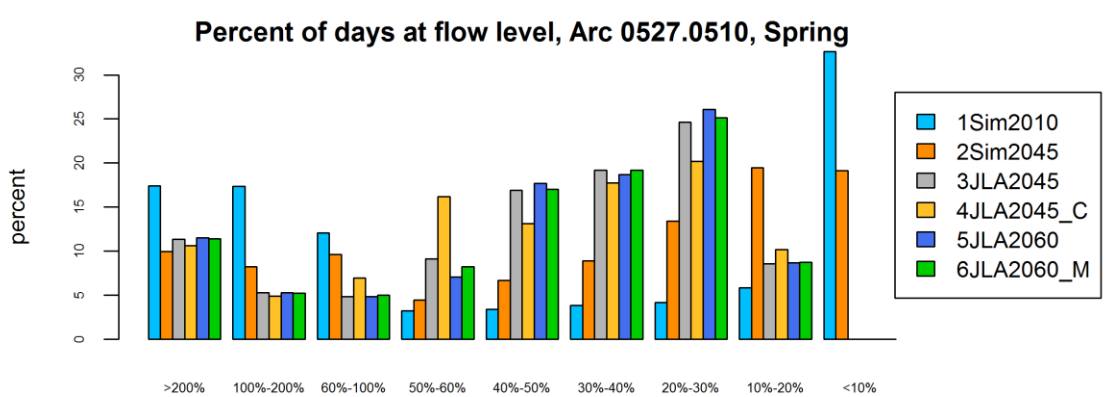


Figure E-15. Buckhorn Creek at USGS Gage 02102192 near Corinth, NC. Percent of POR by deviation class when compared to MAF, Summer-Fall (June-November).

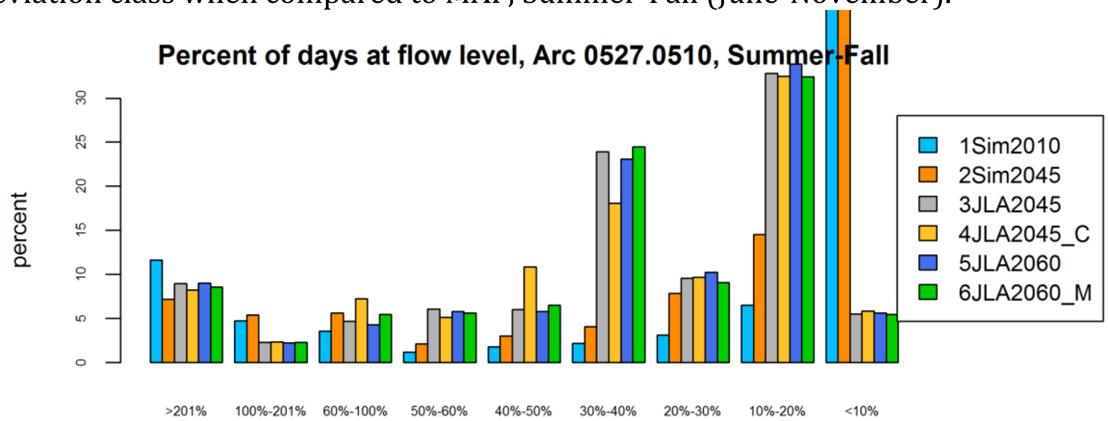


Figure E-16. Buckhorn Creek at USGS Gage 02102192 near Corinth, NC. Percent of POR by deviation class when compared to MAF, Winter (December-February).

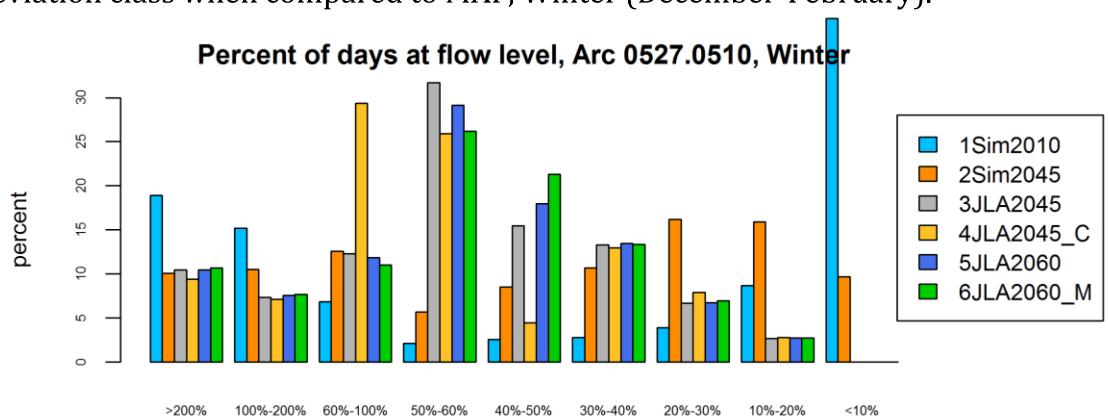


Table E-5. Cape Fear River below confluence with Buckhorn Creek.		
Model Scenario	**Description**	**MAF (cfs)**
1Sim2010	basecase conditions in 2010	3141
2Sim2045	2010 available supplies and 2045 demands	3054
3JLA2045	recommended Jordan Lake allocations added to 2010 available supplies and 2045 demands	3025
4JLA2045_C	same as 3JLA2045 with daily data in the flow record reduced 10%	2707
5JLA2060	recommended Jordan Lake allocations and 2060 demands	3015
6JLA2060	full allocation of Jordan Lake water supply pool and 106mgd withdrawals during peak month at L&D#1	3000

Figure E-17. Cape Fear River below confluence with Buckhorn Creek. Percent of POR by deviation class when compared to MAF, all months (January-December).

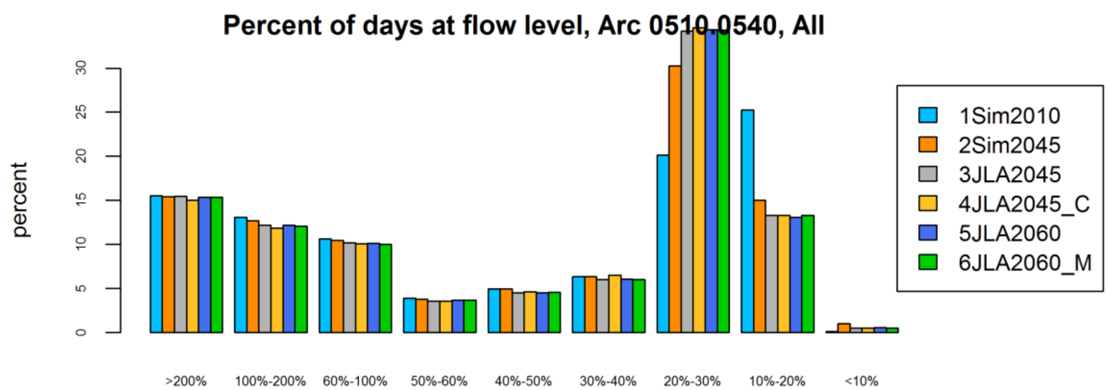


Figure E-18. Cape Fear River below confluence with Buckhorn Creek. Percent of POR by deviation class when compared to MAF, Spring (March-May).

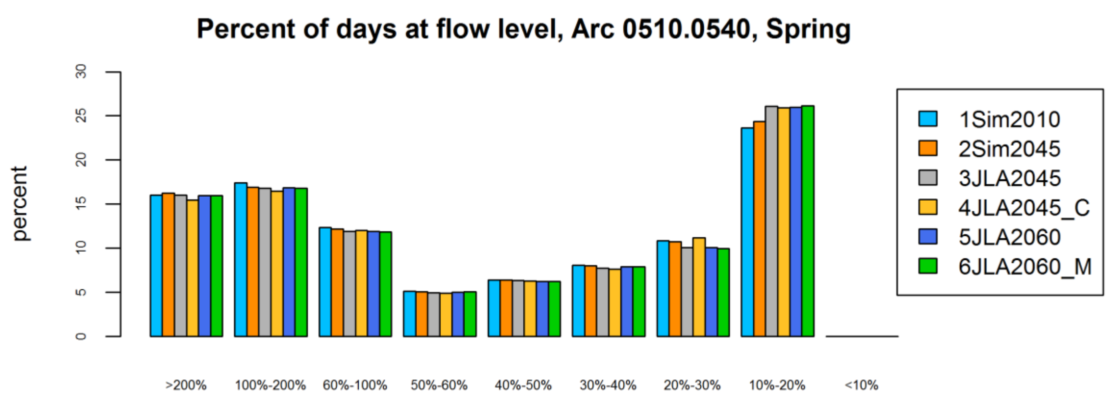


Figure E-19. Cape Fear River below confluence with Buckhorn Creek. Percent of POR by deviation class when compared to MAF, Summer-Fall (June-November).

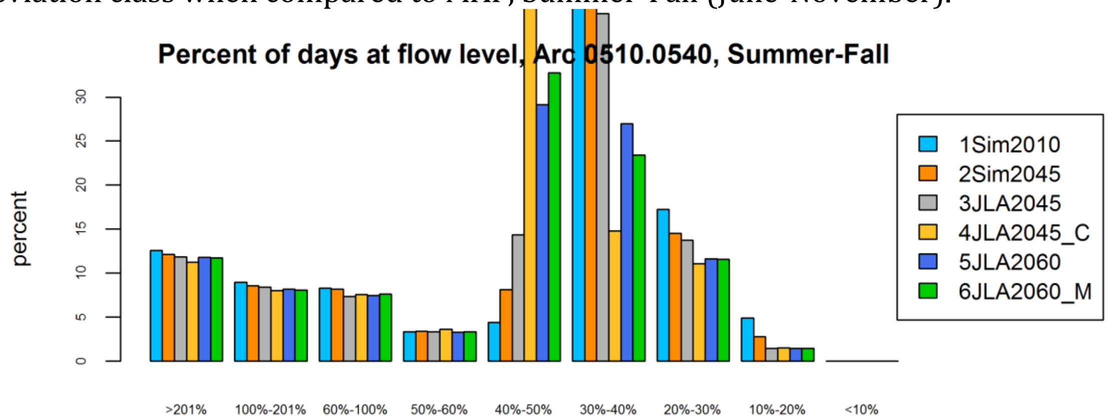


Figure E-20. Cape Fear River below confluence with Buckhorn Creek. Percent of POR by deviation class when compared to MAF, Winter (December-February).

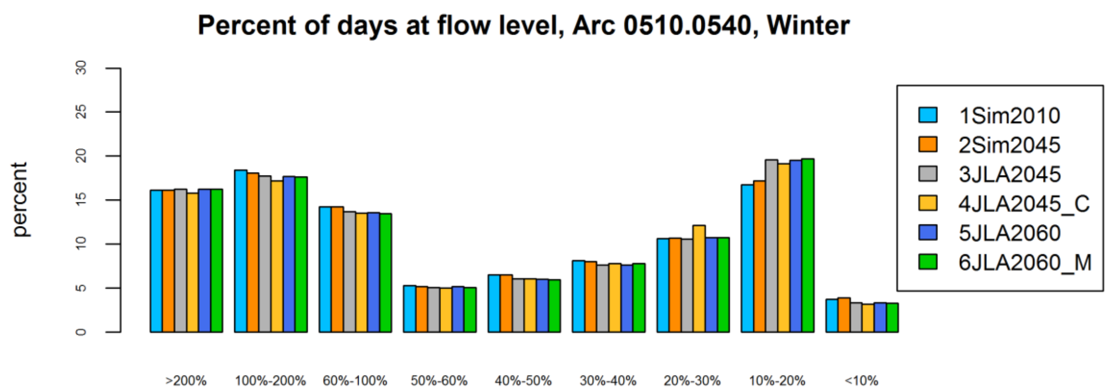


Table E-6. Cape Fear River at USGS Gage 02102500 at Lillington, NC.		
Model Scenario	**Description**	**MAF (cfs)**
1Sim2010	basecase conditions in 2010	3150
2Sim2045	2010 available supplies and 2045 demands	3022
3JLA2045	recommended Jordan Lake allocations added to 2010 available supplies and 2045 demands	2998
4JLA2045_C	same as 3JLA2045 with daily data in the flow record reduced 10%	2676
5JLA2060	recommended Jordan Lake allocations and 2060 demands	2973
6JLA2060	full allocation of Jordan Lake water supply pool and 106mgd withdrawals during peak month at L&D#1	2959

Figure E-21. Cape Fear River at USGS Gage 02102500 at Lillington, NC. Percent of POR by deviation class when compared to MAF, all months (January-December).

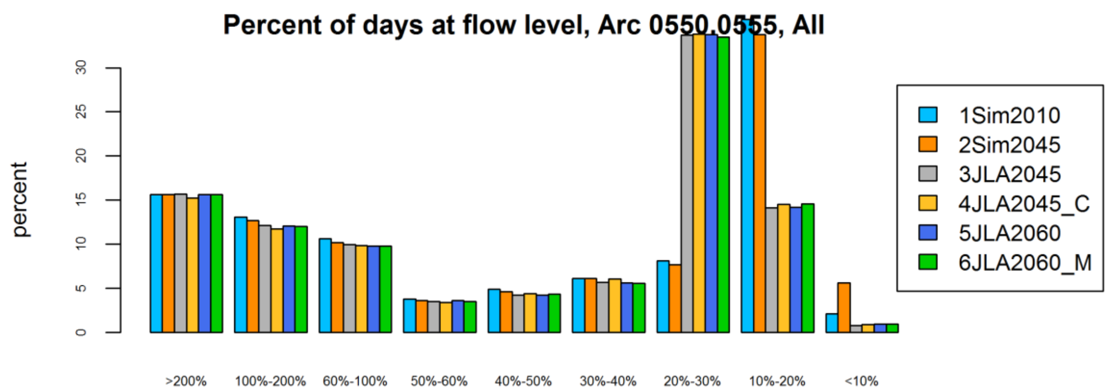


Figure E-22. Cape Fear River at USGS Gage 02102500 at Lillington, NC. Percent of POR by deviation class when compared to MAF, Spring (March-May).

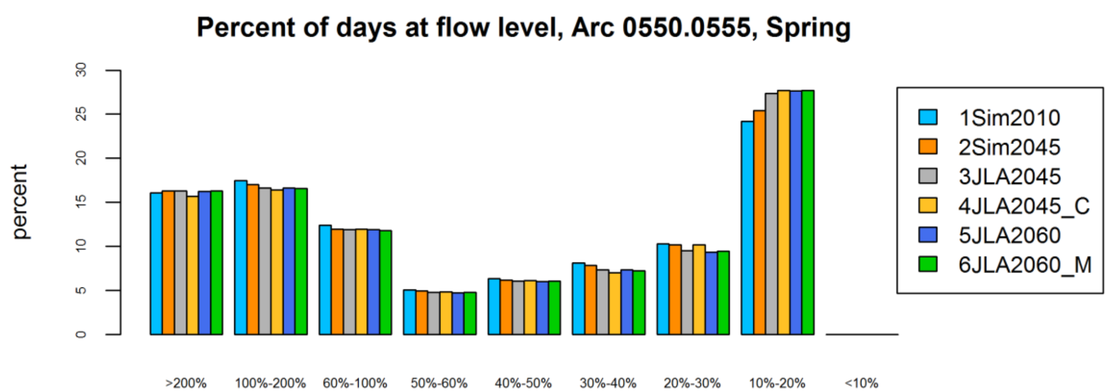


Figure E-23. Cape Fear River at USGS Gage 02102500 at Lillington, NC. Percent of POR by deviation class when compared to MAF, Summer-Fall (June-November).

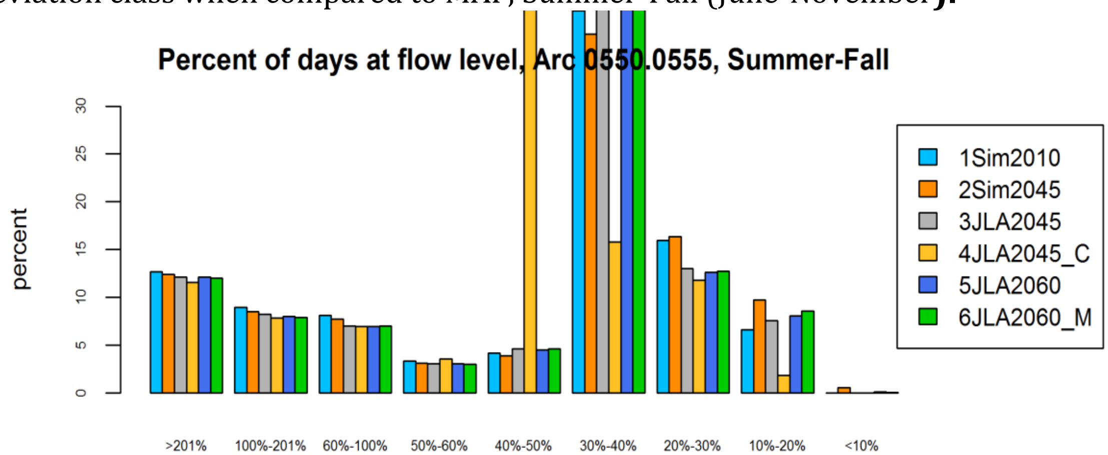


Figure E-24. Cape Fear River at USGS Gage 02102500 at Lillington, NC. Percent of POR by deviation class when compared to MAF, Winter (December-February).

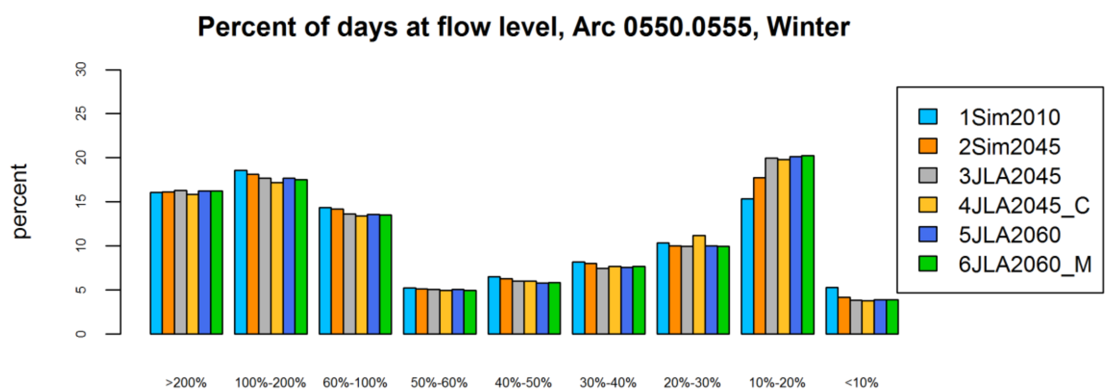


Table E-7. Cape Fear River above Fayetteville PWC Intake		
Model Scenario	**Description**	**MAF (cfs)**
1Sim2010	basecase conditions in 2010	4031
2Sim2045	2010 available supplies and 2045 demands	3911
3JLA2045	recommended Jordan Lake allocations added to 2010 available supplies and 2045 demands	3881
4JLA2045_C	same as 3JLA2045 with daily data in the flow record reduced 10%	3470
5JLA2060	recommended Jordan Lake allocations and 2060 demands	3859
6JLA2060	full allocation of Jordan Lake water supply pool and 106mgd withdrawals during peak month at L&D#1	3844

Figure E-25. Cape Fear River above Fayetteville PWC intake. Percent of POR by deviation class when compared to MAF, all months (January-December).

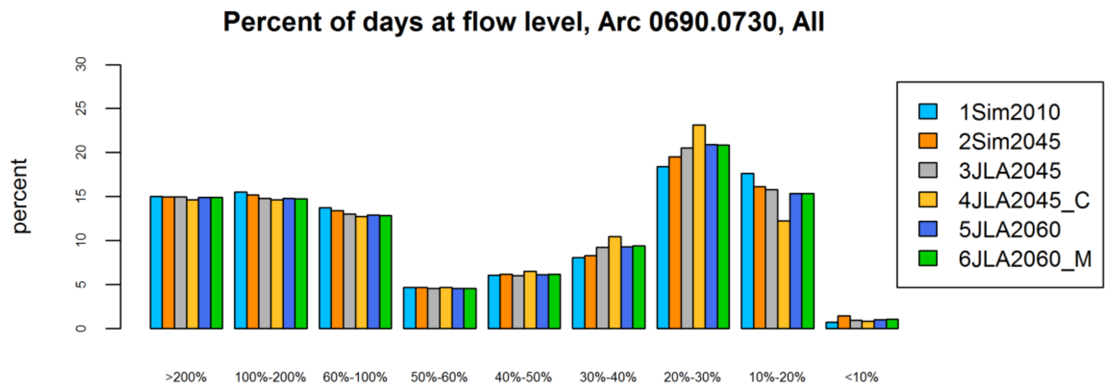


Figure E-26. Cape Fear River above Fayetteville PWC intake. Percent of POR by deviation class when compared to MAF, Spring (March-May).

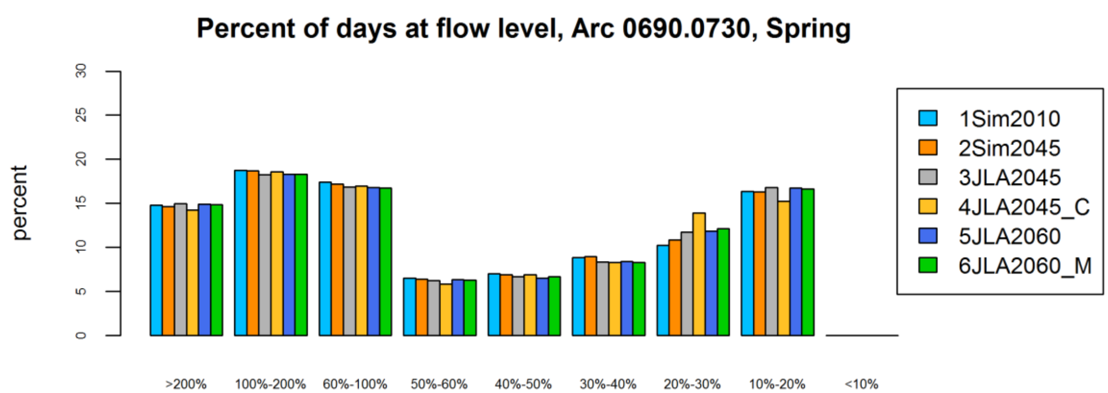


Figure E-27. Cape Fear River above Fayetteville PWC intake. Percent of POR by deviation class when compared to MAF, Summer-Fall (June-November).

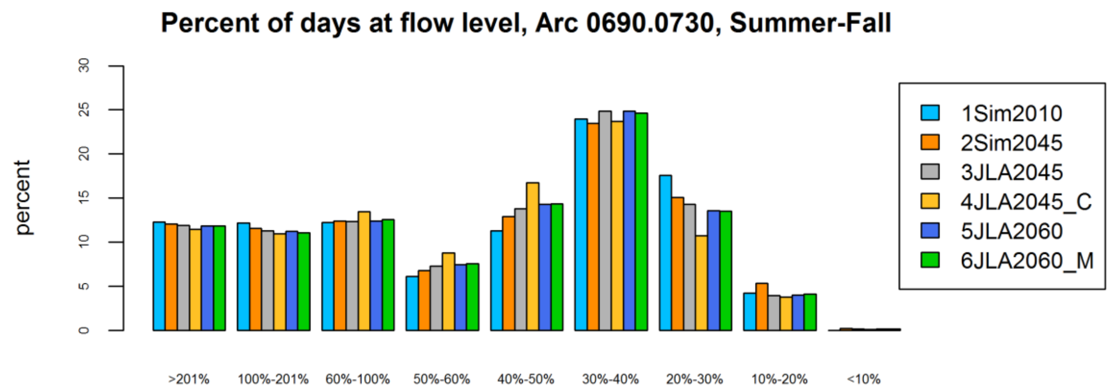


Figure E-28. Cape Fear River above Fayetteville PWC intake. Percent of POR by deviation class when compared to MAF, Winter (December-February).

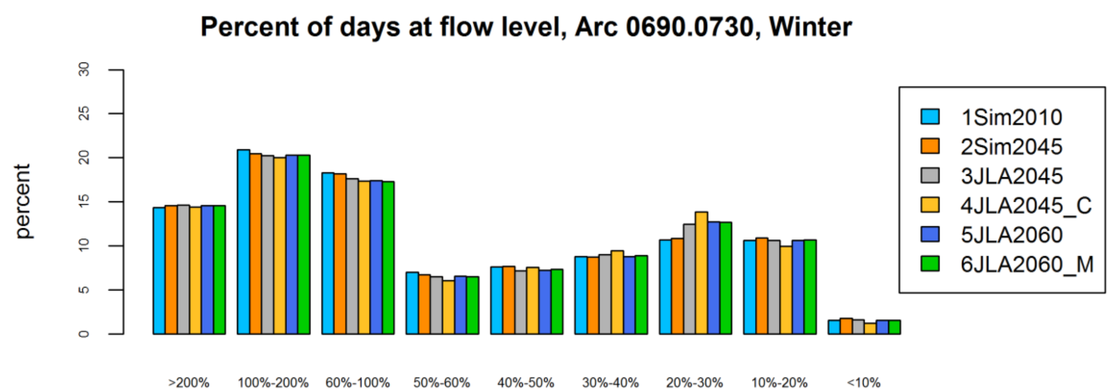


Table E-8. Cape Fear River at USGS Gage 02105500 at Lock and Dam #3.		
Model Scenario	**Description**	**MAF (cfs)**
1Sim2010	basecase conditions in 2010	4488
2Sim2045	2010 available supplies and 2045 demands	4367
3JLA2045	recommended Jordan Lake allocations added to 2010 available supplies and 2045 demands	4322
4JLA2045_C	same as 3JLA2045 with daily data in the flow record reduced 10%	3864
5JLA2060	recommended Jordan Lake allocations and 2060 demands	4299
6JLA2060	full allocation of Jordan Lake water supply pool and 106mgd withdrawals during peak month at L&D#1	4285

Figure E-29. Cape Fear River at USGS Gage 02100500 at Lock and Dam #3. Percent of POR by deviation class when compared to MAF, all months (January-December).

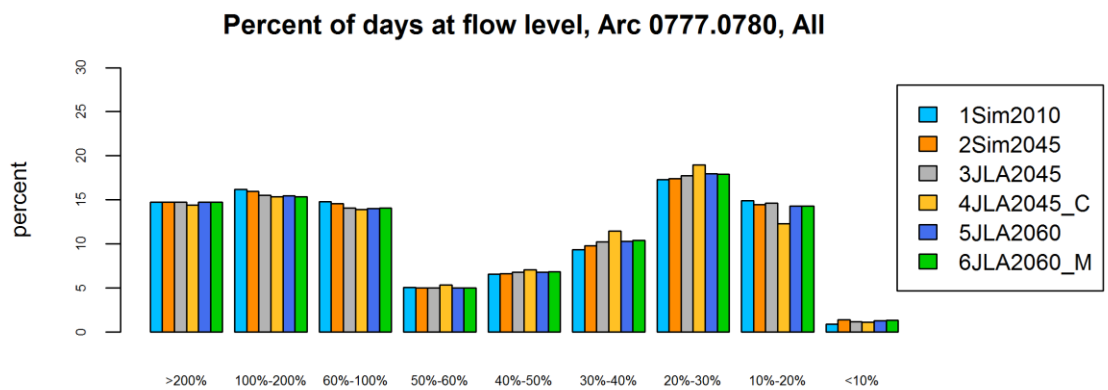


Figure E-30. Cape Fear River at USGS Gage 02100500 at Lock and Dam #3. Percent of POR by deviation class when compared to MAF, Spring (March-May).

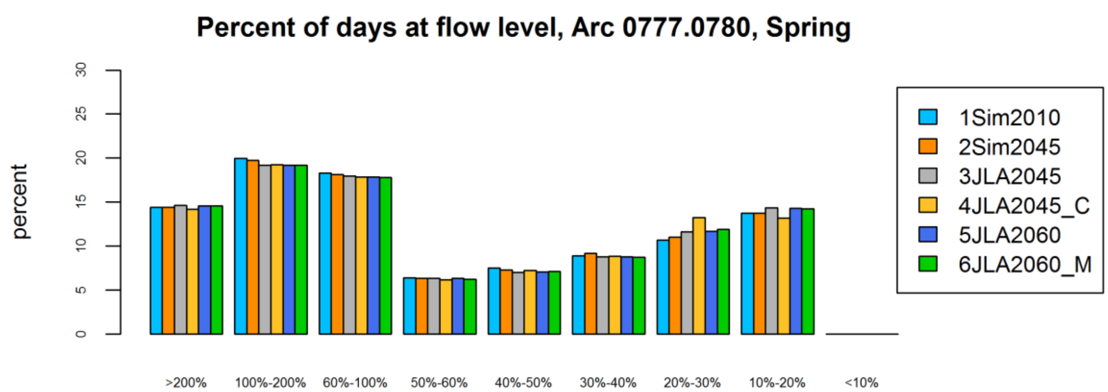


Figure E-31. Cape Fear River at USGS Gage 02100500 at Lock and Dam #3. Percent of POR by deviation class when compared to MAF, Summer-Fall (June-November).

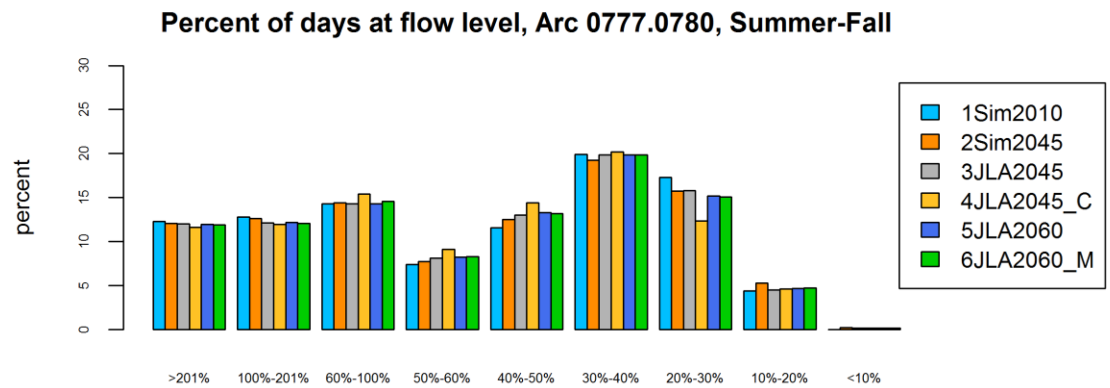


Figure E-32. Cape Fear River at USGS Gage 02100500 at Lock and Dam #3. Percent of POR by deviation class when compared to MAF, Winter (December-February).

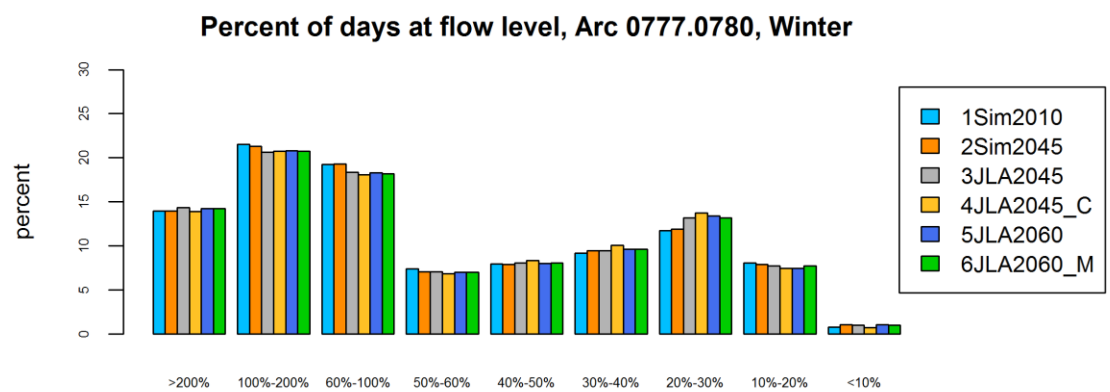


Table E-9. Cape Fear River Outflow from Lock and Dam #2.		
Model Scenario	**Description**	**MAF (cfs)**
1Sim2010	basecase conditions in 2010	5069
2Sim2045	2010 available supplies and 2045 demands	4949
3JLA2045	recommended Jordan Lake allocations added to 2010 available supplies and 2045 demands	4906
4JLA2045_C	same as 3JLA2045 with daily data in the flow record reduced 10%	4389
5JLA2060	recommended Jordan Lake allocations and 2060 demands	4883
6JLA2060	full allocation of Jordan Lake water supply pool and 106mgd withdrawals during peak month at L&D#1	4868

Figure E-33. Cape Fear River outflow from Lock and Dam #2. Percent of POR by deviation class when compared to MAF, all months (January-December).

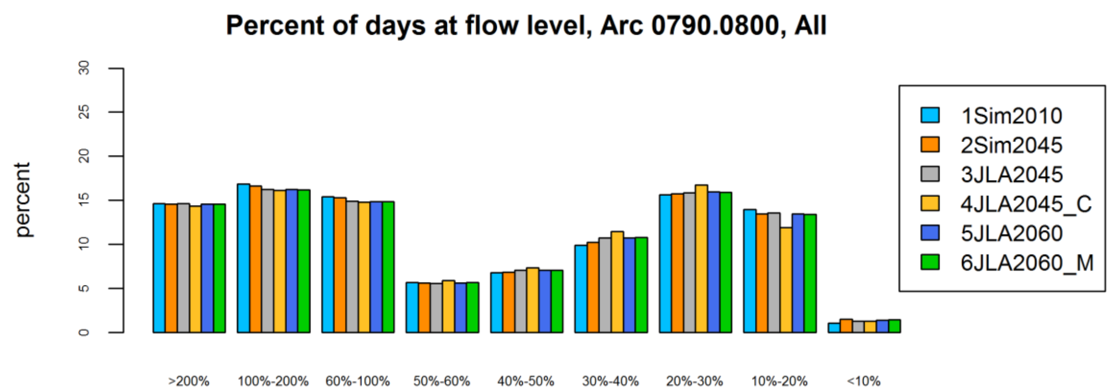


Figure E-34. Cape Fear River outflow from Lock and Dam #2. Percent of POR by deviation class when compared to MAF, Spring (March-May).

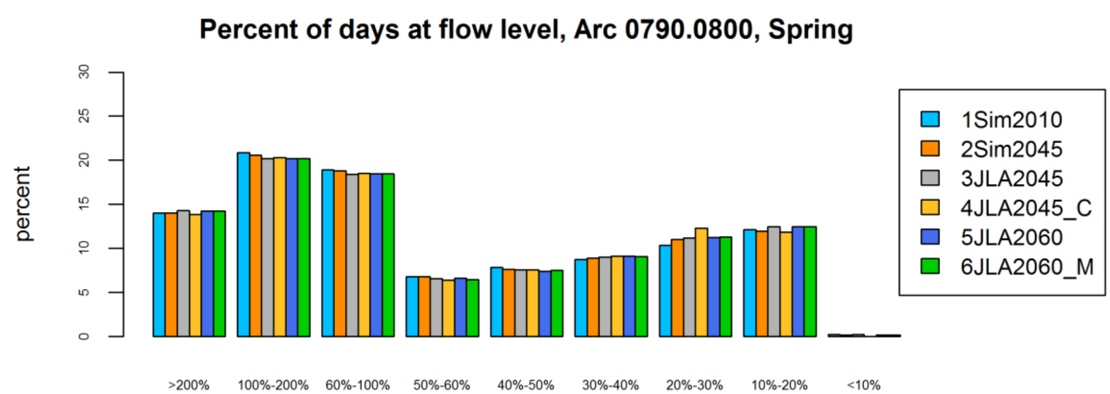


Figure E-35. Cape Fear River outflow from Lock and Dam #2. Percent of POR by deviation class when compared to MAF, Summer-Fall (June-November).

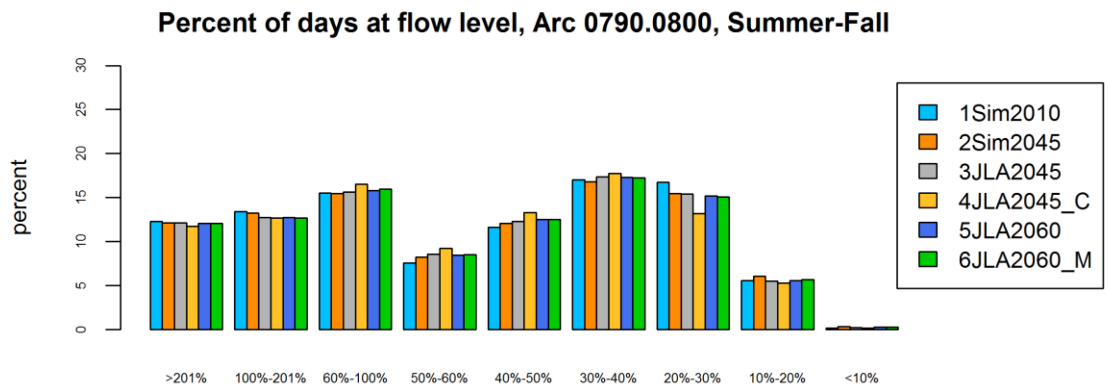


Figure E-36. Cape Fear River outflow from Lock and Dam #2. Percent of POR by deviation class when compared to MAF, Winter (December-February).

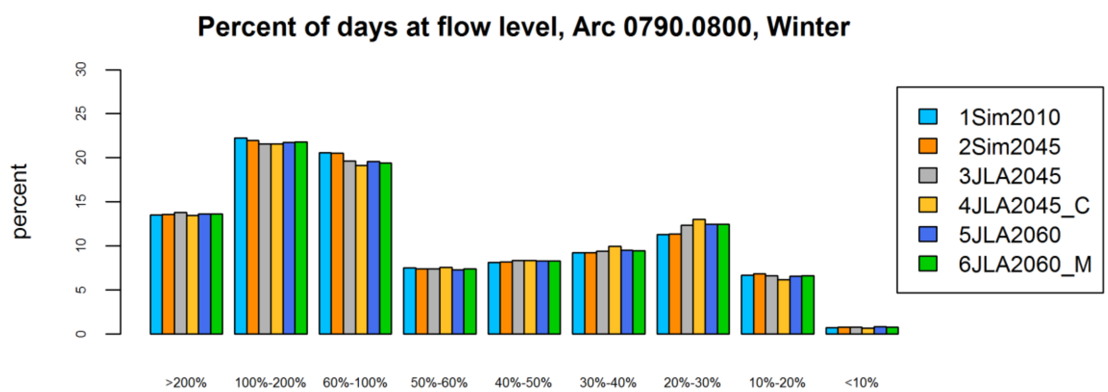


Table E-10. Cape Fear River outflow from Lock and Dam #1.		
Model Scenario	**Description**	**MAF (cfs)**
1Sim2010	basecase conditions in 2010	5367
2Sim2045	2010 available supplies and 2045 demands	5214
3JLA2045	recommended Jordan Lake allocations added to 2010 available supplies and 2045 demands	5170
4JLA2045_C	same as 3JLA2045 with daily data in the flow record reduced 10%	4613
5JLA2060	recommended Jordan Lake allocations and 2060 demands	5129
6JLA2060	full allocation of Jordan Lake water supply pool and 106mgd withdrawals during peak month at L&D#1	5087

Figure E-37. Cape Fear River outflow from Lock and Dam #1. Percent of POR by deviation class when compared to MAF, all months (January-December).

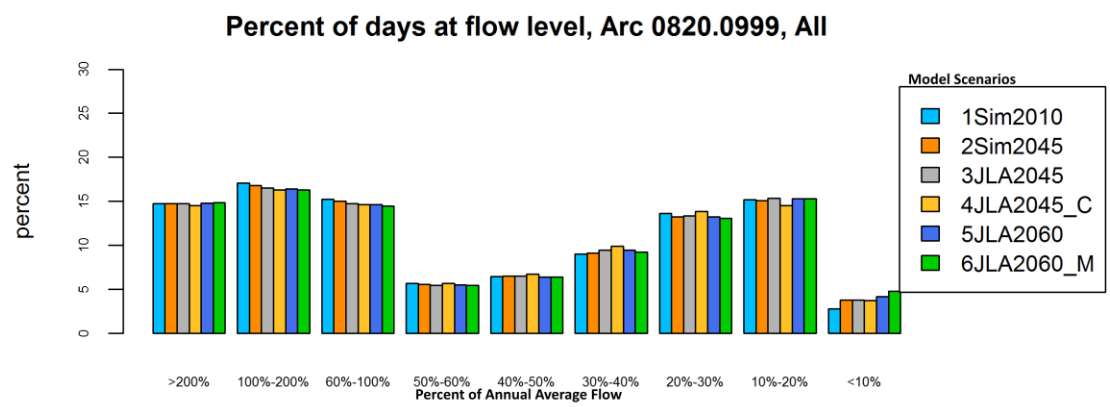


Figure E-38. Cape Fear River outflow from Lock and Dam #1. Percent of POR by deviation class when compared to MAF, Spring (March-May).

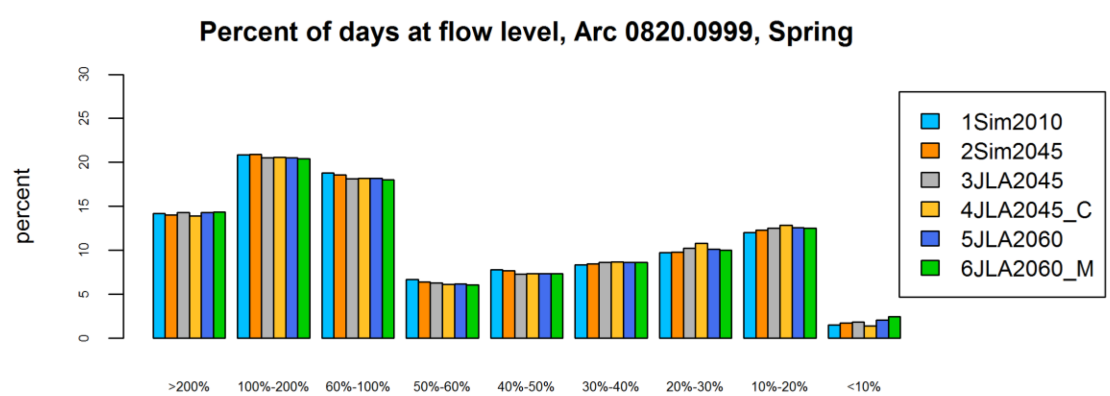


Figure E-39. Cape Fear River outflow from Lock and Dam #1. Percent of POR by deviation class when compared to MAF, Summer-Fall (June-November).

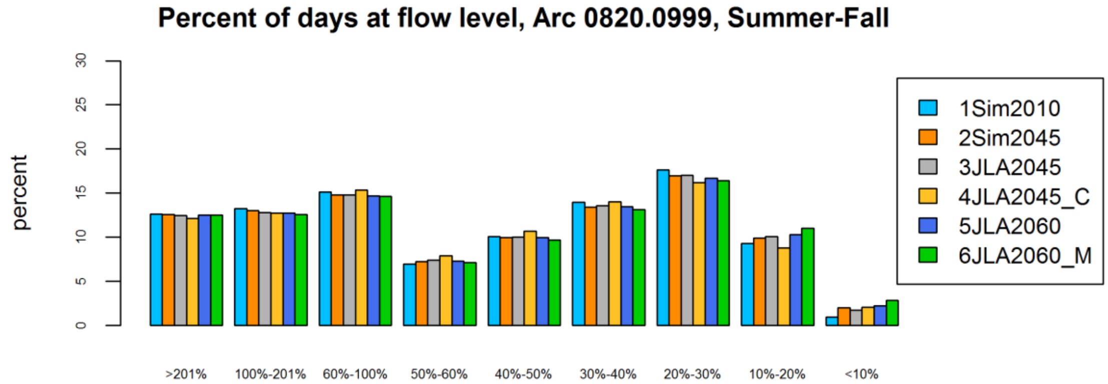


Figure E-40. Cape Fear River outflow from Lock and Dam #1. Percent of POR by deviation class when compared to MAF, Winter (December-February).

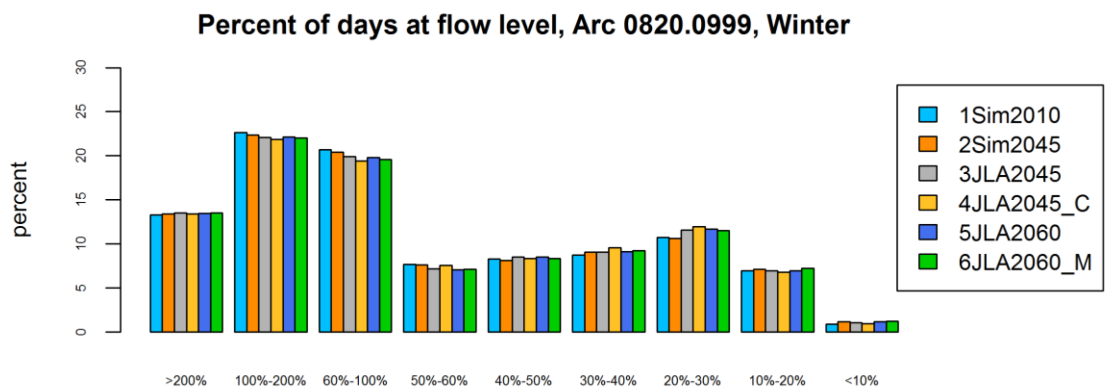


Table E-11. Deep River at USGS Gage 02100500 near Ramseur, NC		
Model Scenario	**Description**	**MAF (cfs)**
1Sim2010	basecase conditions in 2010	335
2Sim2045	2010 available supplies and 2045 demands	334
3JLA2045	recommended Jordan Lake allocations added to 2010 available supplies and 2045 demands	333
4JLA2045_C	same as 3JLA2045 with daily data in the flow record reduced 10%	300
5JLA2060	recommended Jordan Lake allocations and 2060 demands	334
6JLA2060	full allocation of Jordan Lake water supply pool and 106mgd withdrawals during peak month at L&D#1	334

Figure E-41. Deep River below Ramseur, NC. Percent of POR by deviation class when compared to MAF, all months (January-December).

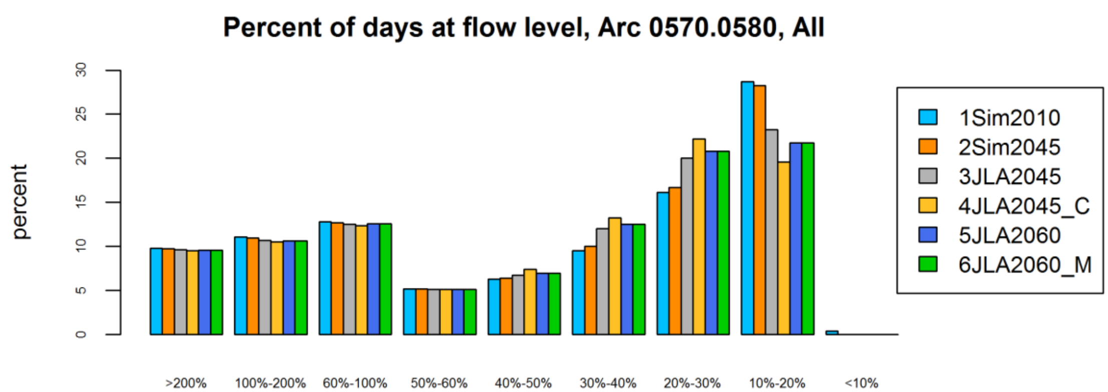


Figure E-42. Deep River below Ramseur, NC. Percent of POR by deviation class when compared to MAF, Spring (March-May).

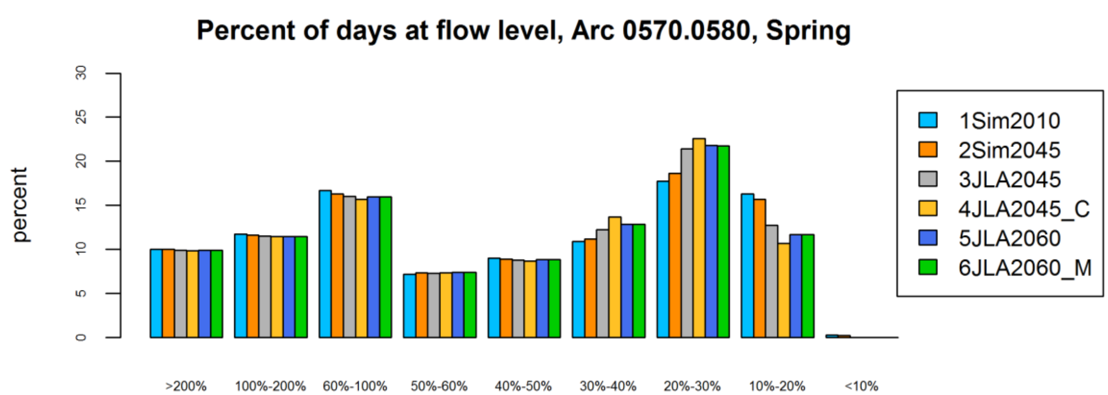


Figure E-43. Deep River below Ramseur, NC. Percent of POR by deviation class when compared to MAF, Summer-Fall (June-November).

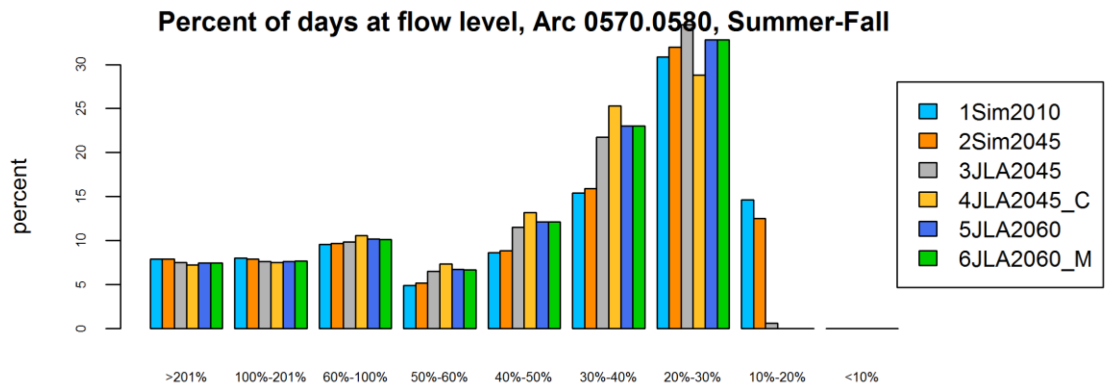


Figure E-44. Deep River below Ramseur, NC. Percent of POR by deviation class when compared to MAF, Winter (December-February).

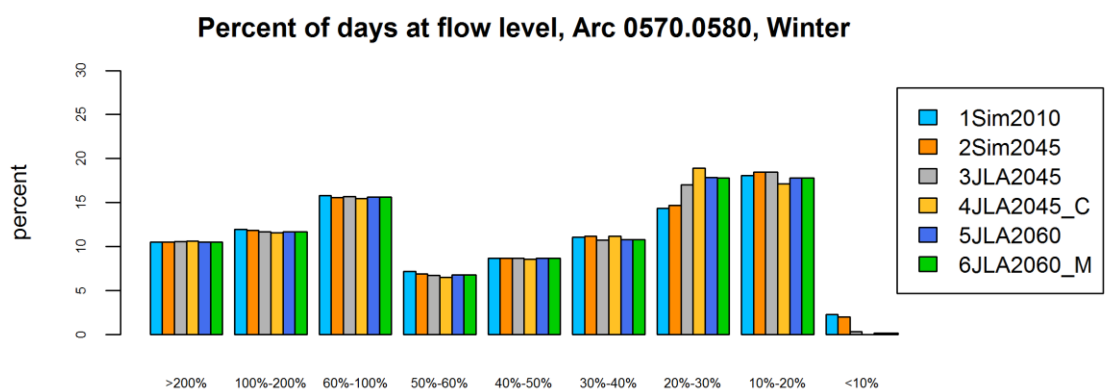


Table E-12. Deep River at USGS Gage 02102000 at Moncure, NC		
Model Scenario	**Description**	**MAF (cfs)**
1Sim2010	basecase conditions in 2010	1371
2Sim2045	2010 available supplies and 2045 demands	1381
3JLA2045	recommended Jordan Lake allocations added to 2010 available supplies and 2045 demands	1380
4JLA2045_C	same as 3JLA2045 with daily data in the flow record reduced 10%	1243
5JLA2060	recommended Jordan Lake allocations and 2060 demands	1387
6JLA2060	full allocation of Jordan Lake water supply pool and 106mgd withdrawals during peak month at L&D#1	1387

Figure E-45. Deep River at Moncure, NC. Percent of POR by deviation class when compared to MAF, all months (January-December).

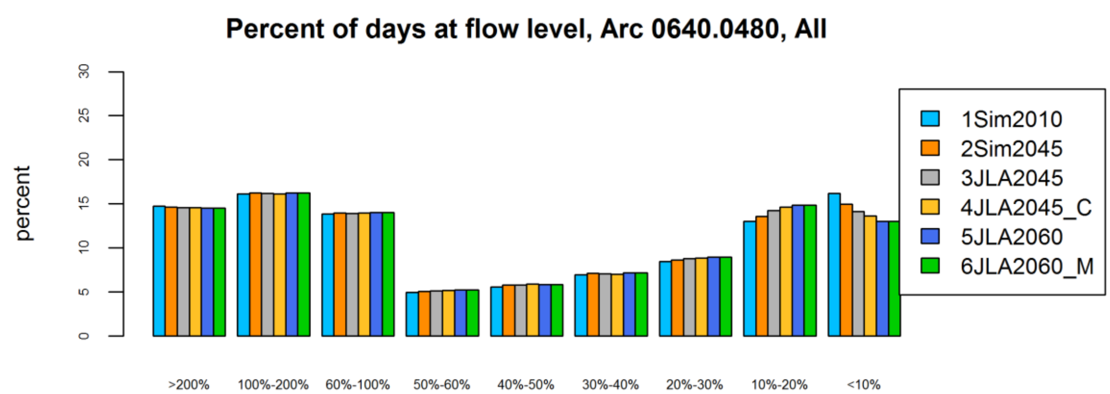


Figure E-46. Deep River at Moncure, NC. Percent of POR by deviation class when compared to MAF, Spring (March-May).

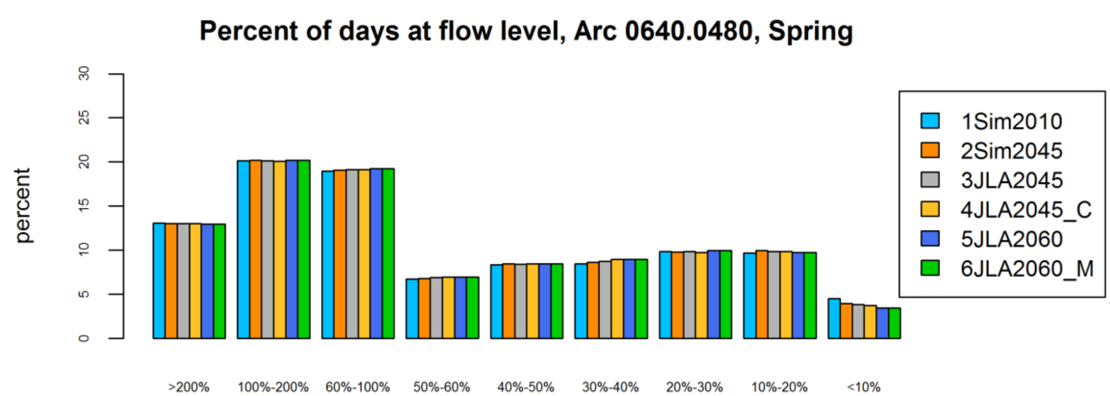


Figure E-47. Deep River at Moncure, NC. Percent of POR by deviation class when compared to MAF, Summer-Fall (June-November).

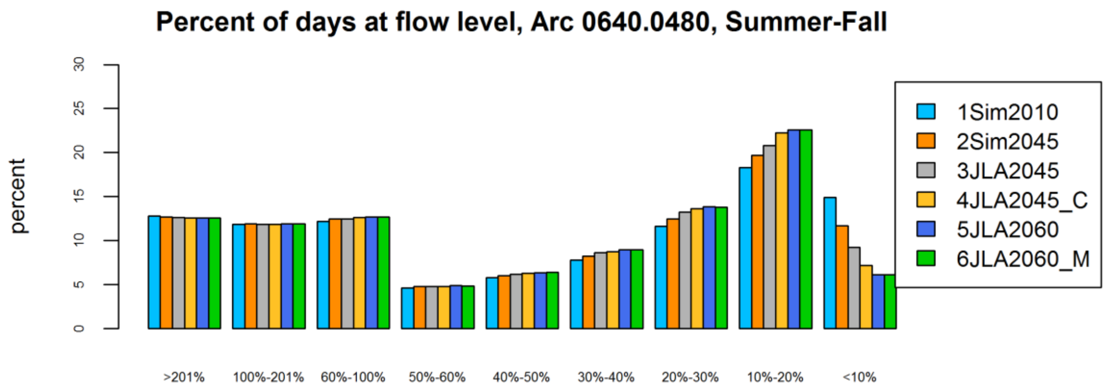


Figure E-48. Deep River at Moncure, NC. Percent of POR by deviation class when compared to MAF, Winter (December-February).

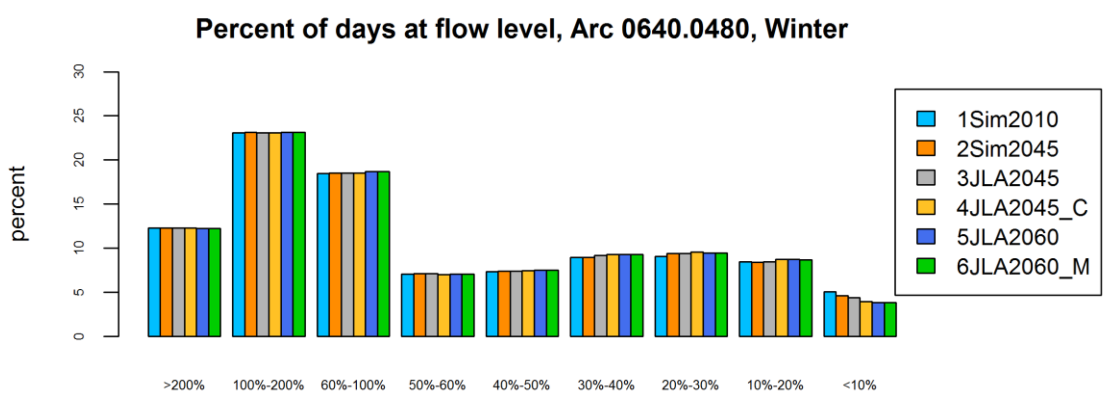


Table E-13. Little River at Linden, NC.		
Model Scenario	**Description**	**MAF (cfs)**
1Sim2010	basecase conditions in 2010	574
2Sim2045	2010 available supplies and 2045 demands	573
3JLA2045	recommended Jordan Lake allocations added to 2010 available supplies and 2045 demands	573
4JLA2045_C	same as 3JLA2045 with daily data in the flow record reduced 10%	516
5JLA2060	recommended Jordan Lake allocations and 2060 demands	572
6JLA2060	full allocation of Jordan Lake water supply pool and 106mgd withdrawals during peak month at L&D#1	572

Figure E-49. Little River at Linden, NC. Percent of POR by deviation class when compared to MAF, all months (January-December).

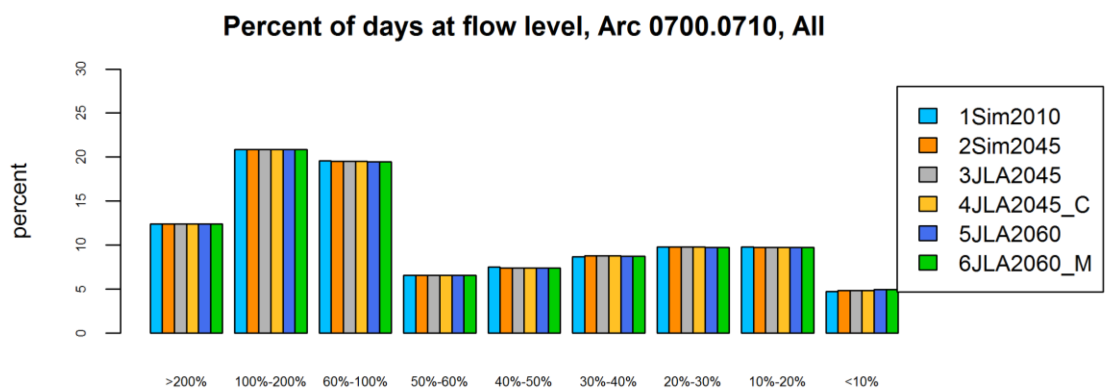


Figure E-50. Little River at Linden, NC. Percent of POR by deviation class when compared to MAF, Spring (March-May).

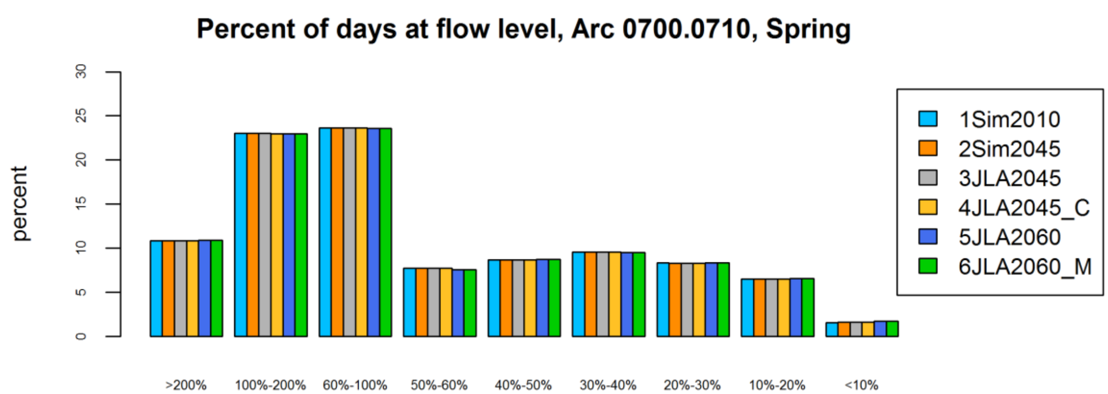


Figure E-51. Little River at Linden, NC. Percent of POR by deviation class when compared to MAF, Summer-Fall (June-November).

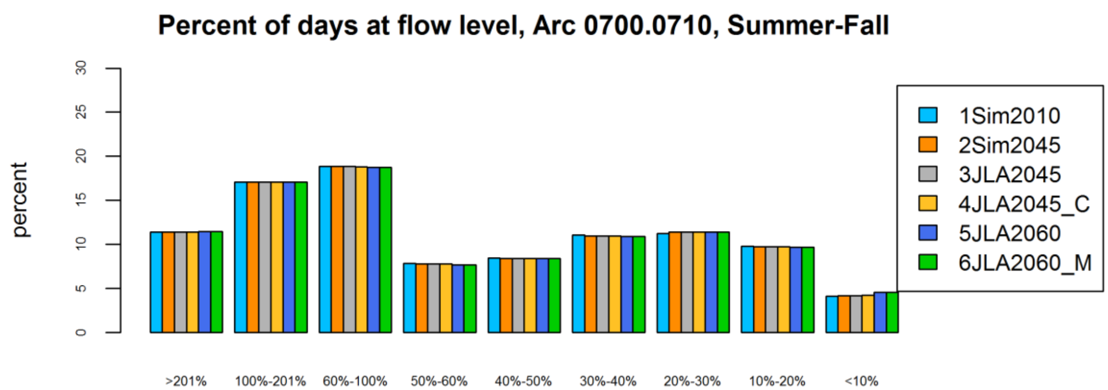
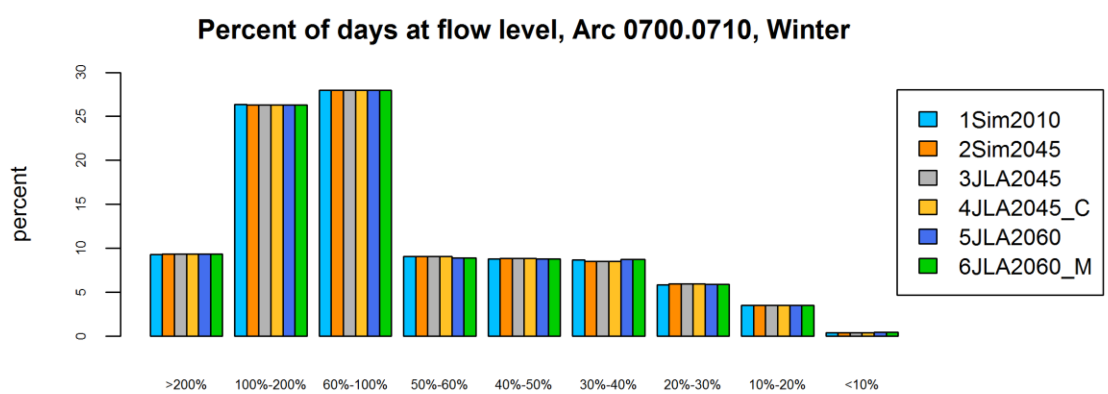


Figure E-52. Little River at Linden, NC. Percent of POR by deviation class when compared to MAF, Winter (December-February).



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[i] https://deq.nc.gov/about/divisions/water-resources/planning/basin-planning/map-page/cape-fear-river-basin-landing/cape-fear-neuse-combined-river-basin-model

[ii] Tennant, D. L. 1976. "Instream flow regimens for fish, wildlife, recreation, and related environmental resources", in Orsborn, J. F. and Allman, C. H. (Eds), *Proceedings of the Symposium and Specialty Conference on Instream Flow Needs II.* American Fisheries Society, Bethesda, Maryland. PP. 359-373.