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BROAD RIVER BASIN PLAN 2023

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Name and Organization

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Justin McGrady, The SC River Guide
Paul Pruitt, Milliken & Company
Bill Stangler, Congaree Riverkeeper
Ken Tuck, Spartanburg Water
Jeff Walker, Inman-Campobello Water District

Chip Few (representing At-Large interests), Steve Hilbert (Water-Based Recreation), Brison Taylor (Water and Sewer Utilities), Jason Wright (Agriculture, Forestry, and Irrigation), and Jim Cook (Industry and Economic Development) also participated on the RBC during some of the planning process but were not active members when the River Basin Plan was finalized.

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Henry Mellor   Dr. Amy Shaw   Camren Shea   Quentin Smith   Kirk Westphal

The Broad RBC

Acronyms

Acronym

ACP	Atlantic Coastal Plain
AFTS	American Tree Farm System
BG	billion gallons
bgy	billion gallons per year
BLS	Bureau of Labor Statistics
BMP	Best Management Practice
BPW	Board of Public Works
BRRWC	Blue Ridge Rural Water Company
cfs	cubic feet per second
CMOR	Condition Monitoring Observer Reports
CPW	Commission of Public Works
CUA	Capacity Use Area
DMA	Drought Management Area
DRC	Drought Response Committee
EDA	Economic Development Administration
EIA	Energy Information Agency
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FSA	Farm Service Agency
GIS	geographic information system
GDP	gross domestic product
gpf	gallons per flush
gpm	gallons per minute
Greer CPW	Greer Commission of Public Works
HD	High Demand
IRA	Inflation Reduction Act
ICWD	Inman Campobello Water District
LEED	Leadership in Energy and Environmental Design
MG	million gallons
MGD	million gallons per day
MGM	million gallons per month
MIF	Minimum Instream Flow
mph	miles per hour
MRLC	Multi-Resolution Land Characteristics Consortium
MSL	mean sea level

NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PPAC	Planning Process Advisory Committee
P&R	Permitted and Registered
RBC	River Basin Council
SCDA	South Carolina Department of Agriculture
SCDHEC	South Carolina Department of Health and Environmental Control
SCDNR	South Carolina Department of Natural Resources
SCE&G	South Carolina Electric & Gas Company
SCO	State Climatology Office
SC ORFA	South Carolina Office of Revenue and Fiscal Affairs
SEPA	Southeastern Power Administration
SPI	Standard Precipitation Index
SJWD	Startex-Jackson-Wellford-Duncan Water District
sq mi	square miles
SWAM	Simplified Water Allocation Model
TMDL	Total Maximum Daily Load
UIF	unimpaired flows
USACE	United States Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
WRWD	Woodruff-Roebuck Water District
WWQA	Watershed Water Quality Assessment

Chapter 1 Introduction

1.1 Background

The South Carolina Water Resources Planning and Coordination Act mandates that the South Carolina Department of Natural Resources (SCDNR) develop a comprehensive water resources policy for the state of South Carolina. SCDNR developed the first state water plan—the *South Carolina Water Plan*—in 1998. In 2004, the plan was updated following what is recognized as one of the worst multi-year droughts on record, which ended in 2002. One of the recommendations from the *South Carolina Water Plan, Second Edition* was forming advisory committees to develop comprehensive water resource plans for each of the state's four major river basins: Ashepoo-Combahee-Edisto (ACE), Pee Dee, Santee, and Savannah. In 2014, when the development of surface water quantity models to support the planning process began, SCDNR and the South Carolina Department of Health and Environmental Control (SCDHEC) decided to further subdivide the basins based on SCDHEC's delineations used for the Water Quality Assessments. The eight planning basins were the Broad, Catawba, Edisto, Pee Dee, Salkehatchie, Saluda, Santee, and Savannah. In 2022, SCDNR made two adjustments to the planning basins. In the Saluda basin, the drainage area just below the confluence of the Broad and Saluda Rivers, which is generally below the Fall Line, was added to the Santee basin. The Savannah basin was subdivided into two planning basins and the portion below Lake Thurmond was combined with the Salkehatchie basin to form the Lower Savannah-Salkehatchie basin, as shown in Figure 1-1.

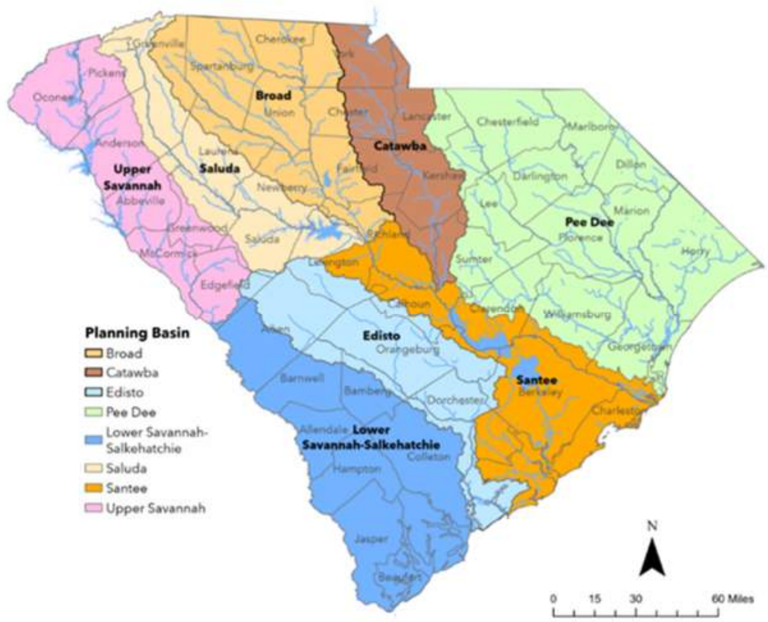


Figure 1-1. Planning basins of South Carolina.

Each of these water resource plans is called a River Basin Plan, which is defined in the *South Carolina State Water Planning Framework* (SCDNR 2019; referred to hereafter as the Planning Framework) as "a collection of water management strategies supported by a summary of data and analyses designed to ensure the surface water and groundwater resources of a river basin will be available for all uses for years to come, even under drought conditions." The next update to the State Water Plan will build on the analyses and recommendations developed in the eight River Basin Plans.

River basins are seen as a natural planning unit for water resources since surface water in each basin is relatively isolated from water in other basins by natural boundaries. Each River Basin Plan will include data, analysis, and water management strategies to guide water resource development in the basin for a planning horizon of 50 years. Specifically, a River Basin Plan answers four questions:

1. What is the basin's current available water supply and demand?
2. What are the current permitted and registered water uses within the basin?
3. What will be the water demand in the basin throughout the planning horizon, and will the available water supply be adequate to meet that demand?
4. What water management strategies will be employed in the basin to ensure the available supply meets or exceeds the projected demand throughout the planning horizon?

In each river basin, a River Basin Council (RBC) is established and tasked with developing a plan that fairly and adequately addresses the needs and concerns of all water users following a cooperative, consensus-driven approach. The Broad River basin is the second of the eight river basins to begin and complete the process that culminated in developing this plan. River basin planning is expected to be an ongoing, long-term process, and this plan will be updated every 5 years.

1.2 Planning Process

The river basin planning process in South Carolina formally began with the development of the eight surface water quantity models starting in 2014 and the update of the Coastal Plain Groundwater Model in 2016. In March 2018, SCDNR convened the Planning Process Advisory Committee (PPAC). Over the next year and a half, SCDNR and the PPAC collaboratively developed the Planning Framework, which defines river basin planning as the collective effort of the numerous organizations and agencies performing various essential responsibilities, as described in the bullets that follow. A more complete description of the duties of each entity are provided in Chapter 3 of the Planning Framework.

- RBC: A group of approximately 25 members representing diverse stakeholder interests in the basin. Each RBC includes at least one representative from each of the eight broadly defined stakeholder interest categories shown in Figure 1-2. The RBC is responsible for developing and implementing the River Basin Plan; communicating with stakeholders; and identifying recommendations for policy, legislative, regulatory, or process changes.

- PPAC: The PPAC is a diverse group of water resource experts established to develop and help implement the Planning Framework for state and river basin water planning. The PPAC will amend the Planning Framework as needed, review draft and final River Basin Plans, ensure consistency between the eight River Basin Plans, and advise SCDNR on developing the new State Water Plan.

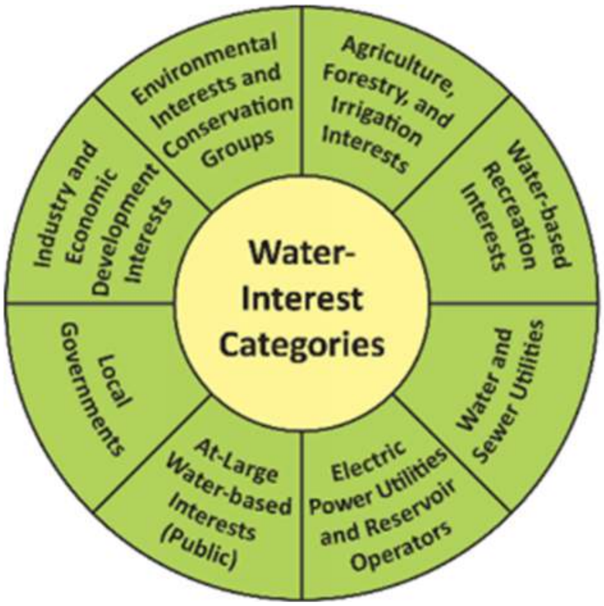


Figure 1-2. RBC water-interest categories.

- State and Federal Agencies:
  - SCDNR is the primary oversight agency for the river basin planning processes. Key duties of SCDNR include appointing members to the PPAC and RBCs; educating RBC members on critical background information; providing RBCs and contractors with data, surface water models, and groundwater models; hiring contractors; and reviewing and approving the final River Basin Plans.
  - SCDHEC is the regulatory agency that administers laws regarding water quality and use within the state. Key duties of SCDHEC include ensuring recommendations are consistent with existing laws and regulations, and serving as an advisor for recommended changes to existing laws and regulations.
  - Other State Agencies: Representatives from other state agencies, such as the Department of Agriculture, Department of Commerce, Forestry Commission, Rural Infrastructure Authority, and the Energy Office, may be asked to attend RBC meetings in an advisory role.
  - Federal Agencies: Representatives from federal agencies, such as the U.S. Geological Survey (USGS), U.S. Army Corps of Engineers (USACE), and Southeastern Power Administration (SEPA), may be asked to attend RBC meetings as formal advisors. Representatives from other federal agencies may be asked to attend RBC meetings in an advisory role.
- Contractors: SCDNR will hire contractors to perform administrative, facilitative, technical, authorship, and public outreach functions. Specific roles include:
  - Coordinator: Performs administrative functions. Coordination of RBC meetings and other activities has been shared by representatives from CDM Smith and Clemson University, with assistance from SCDNR and SCDHEC (collectively, the Planning Team). The Planning Team met at least monthly in between RBC meetings.
  - Facilitator and Author: Guides RBC meetings in a neutral manner to encourage participation, and provides River Basin Plan authorship services. CDM Smith served in these roles for the Broad RBC.
  - Public Outreach Coordinator: Engages stakeholders and the public in the planning process. Clemson University served in this role for the Broad RBC.
- Groundwater and Surface Water Technical Advisory Committees: SCDNR-appointed groups with specific technical expertise intended to enhance the scientific and engineering aspects of the planning process.
- Subcommittees and Ad Hoc Groups: The Broad RBC elected not to form any subcommittees during the initial, 2-year process of developing this plan.
- The Public and Stakeholders: The public was invited to attend and provide comments at RBC meetings and designated public meetings. Additional detail on public participation is described in Chapter 1.4.

The creation of the Broad RBC began with two public meetings organized by SCDNR on November 8 and 9, 2021, in Columbia and Spartanburg, respectively. The goal of these meetings was to describe the need and process for river basin planning to stakeholders and solicit applications to join the Broad RBC. SCDNR accepted applications through early 2022 and selected RBC appointees in February 2022, based on their credentials, knowledge of their interest category, and their connection to the basin (i.e., RBC members must live, work, or represent a significant interest in the water resources of the basin). The diverse membership of the RBC is intended to allow for a variety of perspectives during development of the River Basin Plan. Table 1-1 lists the Broad RBC members (at the time the Final River Basin Plan was issued) and their affiliations, appointment dates, and term lengths. Term lengths are staggered to ensure continuity in the planning process.

Table 1-1. Broad RBC members and affiliations.

Name	Organization	Position	Interest Category	Appointment Date and Term Length (Years)
John Alexander	Slater Properties	Representative	Agriculture, Forestry, and Irrigation	February 2022 (4)
Kristen Austin	The Nature Conservancy	Upstate Conservation Director	Environmental	February 2022 (4)
Mark Boland	York County	Stormwater Administrator	Local Governments	February 2022 (4)
Amy Bresnahan	Dominion Energy SC, Inc.	Engineer II	Electric Power Utilities	February 2022 (2)
Frank Eskridge	City of Columbia	Director of Utility Operations	Water and Sewer Utilities	February 2022 (4)
Bryant Fleming	Cherokee County Board of Public Works	Water Treatment Plant (WTP) Superintendent	Water and Sewer Utilities	February 2022 (3)
Dr. Daniel Hanks (RBC Vice-Chair)	Weyerhaeuser Company	Aquatic Landscape Ecologist	Agriculture, Forestry, and Irrigation	February 2022 (3)
Erika Hollis	Upstate Forever	Clean Water Director	Environmental	February 2022 (2)
James Kilgo	South Carolina Rural Water Association	Source Water Protection Specialist	At-Large	February 2022 (2)
Karen Kustafik	City of Columbia Parks	Assistant Superintendent	Water-Based Recreation	February 2022 (2)
Angus Lafaye	Milliken Forestry Co., Inc.	Chairman Emeritus	At-Large	February 2022 (3)
Jeff Lineberger	Duke Energy	Director, Water Strategy and Relicensing	Electric Power Utilities	February 2022 (3)
Justin McGrady	The SC River Guide	Committee Member	Water-Based Recreation	February 2022 (2)
Paul Pruitt	Milliken & Company	Senior Director, Corp. EHSE	Industry and Economic Development	February 2022 (4)
Bill Stangler	Congaree Riverkeeper	Riverkeeper	Environmental	February 2022 (2)
Ken Tuck (RBC Chair)	Spartanburg Water	Director of Drinking Water Services	Water and Sewer Utilities	February 2022 (3)
Jeff Walker	Inman-Campobello Water District	General Manager	Water and Sewer Utilities	February 2022 (3)

Chip Few (representing At-Large interests), Steve Hilbert (Water-Based Recreation), Brison Taylor (Water and Sewer Utilities), Jason Wright (Agriculture, Forestry, and Irrigation), and Jim Cook (Industry and Economic Development) also participated on the RBC during some of the planning process but were not active members when the River Basin Plan was finalized.

The Broad RBC began meeting in March 2022, and continued meeting monthly using a hybrid format that allowed for virtual participation when needed. Meetings were held at different locations in the basin near or in Spartanburg, Clinton, and Columbia.

The planning process was completed in four phases, as specified in the Planning Framework. During the mostly informational phase (Phase 1), RBC members heard presentations from subject matter experts representing SCDNR, SCDHEC, USGS, Clemson University, The Nature Conservancy, and CDM Smith. Presentation topics included water legislation and permitting; hydrology, monitoring, and low-flow characteristics; climatology; the South Carolina Drought Response Act; freshwater aquatic resources; State Scenic Rivers; Federal Energy Regulatory Commission (FERC) licensing; and the relationships between streamflow and ecologic health.

Phase 2 of the planning process focused on assessing past, current, and future surface water availability. The RBC reviewed historical and current water use, and 50-year planning scenario results from the surface water quantity model (referred to as the Simplified Water Allocation Model or SWAM). Potential water shortages and issues were identified and discussed.

During Phase 3, water management strategies to address water availability issues were identified, evaluated, selected, and prioritized by the RBC based on their effectiveness, as determined by modeling and feasibility criteria such as cost, environmental impact, and socioeconomic impact.

Legislative, policy, technical, and planning process recommendations were considered during Phase 4 of the planning process, which culminated in developing this River Basin Plan.

Broad RBC members participated in two field trips in spring and fall 2022 to better understand the water resources of the basin, how water is withdrawn and used to support agriculture and public water supply needs, and its importance in energy production. In May 2022, the RBC toured the Columbia Canal WTP; visited the diversion dam, fish passage, and minimum flow gate at the entrance of the Broad River Canal; observed and learned about the Rocky Shoals Spider Lily, a threatened species; and visited Dominion Energy's Fairfield Pumped Storage Facility and the Parr Shoals Hydroelectric Facility (Figure 1-3). In October, the RBC paddled and boated on Lake Blalock to Lake Blalock Dam; learned about the RB Simms WTP's new advanced oxidation process; and toured Cooley Farms/Strawberry Hill (Figure 1-4).

1.3 Vision and Goals

During Phase 1 of the planning process, the Broad RBC developed a vision statement establishing the desired outcome of the planning process, and actionable goals supporting their vision for the Broad River basin. The vision statement and goals are listed in Table 1-2.

Figure 1-3. May 2022 field trip. Clockwise from top left: Columbia WTP, Parr Shoals Hydroelectric Facility, Fairfield Pumped Storage Facility, and Columbia WTP.

Figure 1-4. October 2022 field trip. Clockwise from top left: Cooley Farms/Strawberry Hill, kayaking Lake Blalock, RB Simms Advanced Oxidation building, and Lake Blalock Dam.

Table 1-2. Broad RBC Vision Statement and Goals.

Vision Statement	
Empowered stakeholders taking coordinated actions to conserve and enhance the resilience of the Broad River Basin to provide water resources for quality of life, while accounting for the ecological integrity of our shared water resources.	
Goals	
1	**Enhance the understanding of regional water issues and the need for support of policies and behaviors to protect resources through promotion and education.**
2	**Use sound science and data-driven practices to support collaboration for all entities to effectively and efficiently manage the basin.**
3	**Provide policy and legislative recommendations.**

1.4 Public Participation

Public participation is a vital component of the river basin planning process. All RBC meetings are open to the public. To promote visibility and encourage participation, meeting notices are posted on the SCDNR Water Planning web page (https://hydrology.dnr.sc.gov/water-planning.html) and are distributed to an email list. Meeting agendas, minutes, summaries, presentations, and recordings are posted on the SCDNR website and are available to the public.

In addition to the RBC meetings, dedicated public meetings were also held to distribute information and solicit feedback.

- The first two public meetings were held on November 8 and 9, 2019, in Columbia and Spartanburg, respectively. At these meetings, the public was informed of the basin planning process and the plan for public participation. RBC membership applications were solicited at this meeting. There were 44 attendees at the November 8 meeting in Columbia, and 36 attendees at the November 9 meeting in Spartanburg.

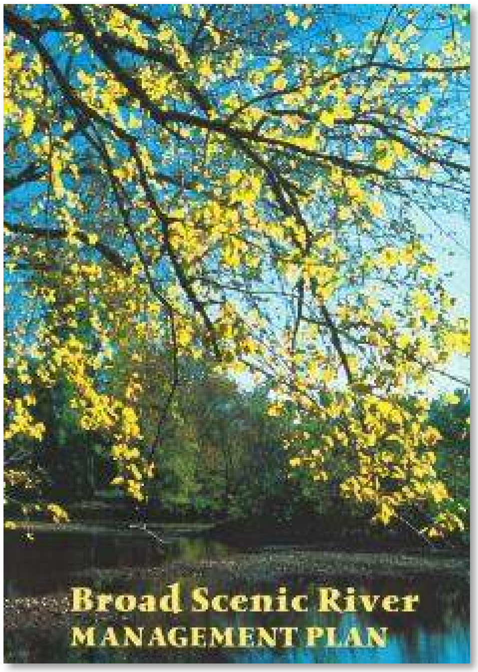
- The third public meeting was held on November 29, 2023, in Spartanburg. A summary of the plan was provided to attendees and a public comment period was opened, which included a verbal comment period at the meeting followed by a 30-day written comment period. Written comments received from the public and the RBC's responses to those comments are included in Appendix F.

- The fourth public meeting was held after the River Basin Plan was finalized and released on ____________, 2023. The fourth public meeting was held on __________, 2023, in ___________. At this meeting, the public was apprised of any changes made to the draft plan.

1.5 Previous Water Planning Efforts

1.5.1 Broad Scenic River Management Plan

The South Carolina Scenic Rivers Act of 1989 enabled and directed SCDNR to inventory and study rivers with unique and outstanding values. The Act was intended to protect the unique and outstanding resource values of South Carolina rivers based on their scenic, recreational, geologic, botanical, fish, wildlife, historic, and cultural characteristics. Statewide, 10 river reaches were formally designated as Scenic Rivers, including a 15.3-mile stretch of the Broad River from Ninety-Nine Islands Dam to its confluence with the Pacolet River. In 1991, the Broad River Scenic Advisory Council was formed to assist and advise SCDNR in the protection and management of the scenic river corridor. The advisory council prepared and published the Broad Scenic River Management Plan in 1993, which served as the guide for ongoing program activities from 1993 through 2003. In 2003, The Broad Scenic Management Plan Update was developed to reflect public values, concerns, and desires for the river. A suite of recommendations was developed focusing on management of land use, natural resources, water quality, recreation, public safety, cultural and historic resources, and education and community stewardship. Specific project-level actions and outcomes were identified, including corridor plans to enhance public recreational access, water trails and trail guides, voluntary monitoring of water quality, and others. The Broad Scenic River Project is currently inactive owing to loss of staffing and funding to implement projects and other recommendations from the plan.



1.5.2 Groundwater Management Plans

The Groundwater Use and Reporting Act (SC Code of Laws §49-5-10 et seq.) establishes conditions for the designation of capacity use areas (CUAs). These are areas where excessive groundwater withdrawal may have adverse effects on natural resources; may pose a threat to public health, safety, or economic welfare; or may pose a threat to the long-term integrity of the groundwater source. Once a CUA is designated, a Groundwater Management Plan must be developed to study the area's groundwater availability and demand and offer strategies to promote the sustainability of the resource. The plan must balance the competing needs and interests of the area, including those of future generations. Additionally, all users within the CUA withdrawing more than 3 million gallons of groundwater in any month must obtain a groundwater permit. The southern end of the Broad River basin contains a small portion of the Santee-Lynches CUA, which includes Richland County, and an even smaller portion of the Western CUA, which includes Lexington County. South Carolina CUAs are shown in Figure 1-5.

The Western CUA was designated in 2018 and the Groundwater Management Plan was completed in November 2019. The Santee-Lynches CUA was designated in 2021 and the Groundwater Management

Plan was completed in August 2022. In preparing the initial plans, SCDHEC convened stakeholder workgroups and solicited public comments. The plans outline current best practices for groundwater management. They are intended to be updated as more data are collected and following the application of the USGS Coastal Plain Groundwater Model of South Carolina.

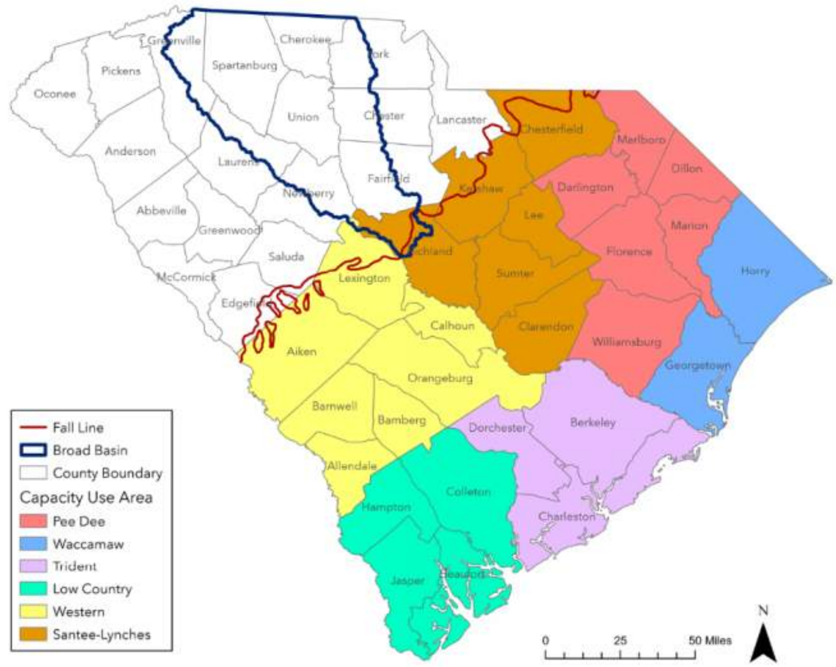


Figure 1-5. Capacity Use Areas.

1.5.3 Drought Planning

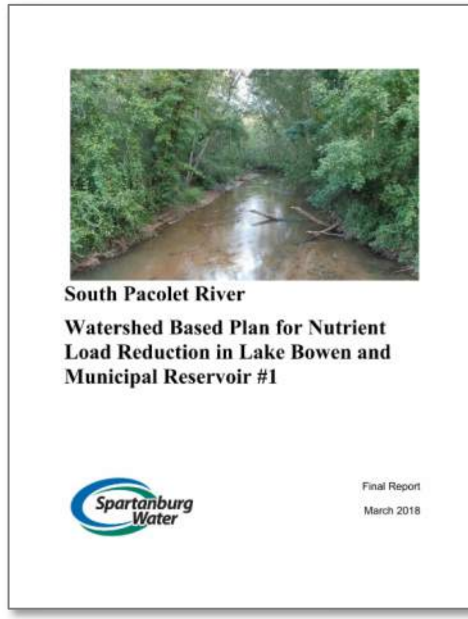
The South Carolina State Climatology Office is responsible for drought planning in the state. The South Carolina Drought Response Act and supporting regulations establish the South Carolina Drought Response Committee (DRC) as the drought decision-making entity in the state. The DRC is composed of state agencies and local members representing various stakeholder interests. To help prevent overly broad response to drought, SCDNR split the state into four drought management areas (DMAs). The Broad River basin is within the Central DMA. The DRC monitors drought indicators, issues drought status updates, determines nonessential water use, and issues declarations for water curtailment as needed. In addition to establishing the DRC, the South Carolina Drought Response Act also requires all public water suppliers to develop and implement their own drought plans and ordinances. Drought Management Plans developed by the public water suppliers in the Broad River basin are further discussed in Chapter 8.

1.5.4 Watershed-Based Plans

Watershed-based plans have been developed for various watersheds throughout South Carolina to document sources of pollution and present a course of action to protect and improve water quality within a watershed. While this first iteration of the Broad River Basin Plan focuses on water quantity issues, previous planning efforts with the Broad River basin that addressed water quality are worth noting. Water quality considerations may be more fully developed in future updates to the Broad River Basin Plan.

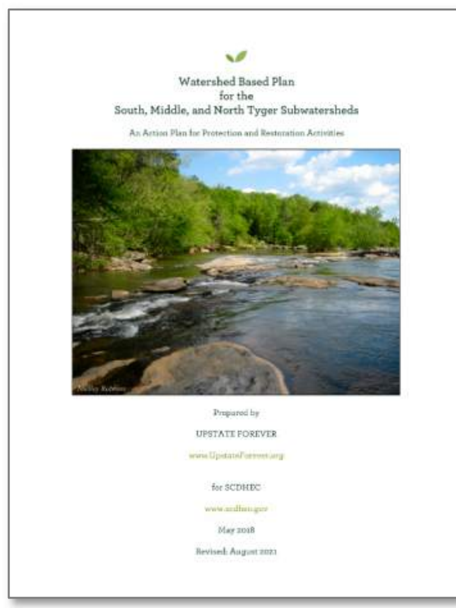
In 1992, SCDHEC initiated its Watershed Water Quality Management program to better coordinate river basin planning and water quality management. Watershed-based management allows SCDHEC to address congressional and legislative mandates and improve communication with stakeholders on existing and future water quality issues. In the Broad River basin, Watershed Water Quality Assessments (WWQAs) were completed in 1998, 2001, and 2007. The WWQAs of the Broad River basin describe, at the watershed level, water-quality-related activities that may potentially have an adverse impact on water quality. As of 2016, the WWQAs have been replaced by the SC Watershed Atlas (https://gis.dhec.sc.gov/watersheds/), which allows users to view watershed information and even add data, create layers from selected features, and export data for use outside of the application. Chapter 3 presents more information on current water quality impairments in the basin.

South Pacolet River Watershed-Based Plan for Nutrient Load Reduction in Lake Bowen and Municipal Reservoir #1



In 2018, a watershed-based plan was developed for the 91.5-square-mile South Pacolet River watershed. The plan focuses on strategies to reduce nutrient loadings in the watershed of Lake Bowen and Municipal Reservoir #1, which are owned and operated by Spartanburg Water and serve as drinking water supplies to a population of over 180,000 (Spartanburg Water 2018). Monitoring and modeling suggested that the likely cause of recent algal blooms to be nitrogen and phosphorus, attributed to pastureland and urban and septic sources. The plan identifies numerous best management practices (BMPs), including vegetated buffer programs, conservation programs, septic tank repair programs, constructed wetlands, green infrastructure, stream restoration, and residential lawn management, to reduce nitrogen and phosphorus loads in the watershed and lower concentrations of these nutrients in the two lakes. Many of the BMPs are expected to assist in meeting bacterial standards in the watershed, which is subject to a bacteria total maximum daily load (TMDL).

Watershed-Based Plan for the South, Middle, and North Tyger Subwatersheds



In 2018, a watershed-based plan was developed for three subwatersheds in the Tyger River Basin (totaling 345.1 square miles) to reduce bacteria levels and sediment pollution. The South, Middle, and North Tyger subwatersheds include source water intakes and protection areas for the Greer Commission of Public Works (Greer CPW), Startex-Jackson-Wellford-Duncan Water District (SJWD), and Woodruff-Roebuck Water District (WRWD). Together, Greer CPW, SJWD, and WRWD provide drinking water to roughly 127,000 residents living in Greenville and Spartanburg Counties (Upstate Forever 2018). The plan provides a comprehensive overview of the sources of bacteria and sediment pollution in the three subwatersheds, identifies critical areas for protection and restoration, recommends BMPs to reduce or eliminate pollution loads, suggests potential funding opportunities and technical resources for pollution mitigation practices, and outlines a public outreach strategy to increase public awareness about water quality issues.

1.6 Organization of this Plan

The Planning Framework outlines a standard format that all river basin plans are intended to follow, providing consistency in the organization and content. Consistency between River Basin Plans will facilitate the eventual update of the State Water Plan. Following the format outlined in the Planning Framework, the Broad River Basin Plan is divided into 10 chapters, described as follows:

- **Chapter 1: Introduction** – Chapter 1 provides an overview of the river basin planning purpose and process. Background on the basin-specific history and vision for the future is presented. The planning process is described, including the appointment of RBC members and the roles of the RBC, technical advisory committees, subcommittees, ad hoc groups, state and federal agencies, and contractors.

- **Chapter 2: Description of the Basin** – Chapter 2 presents a physical and socioeconomic description of the basin. The physical description includes a discussion of the basin's land cover, geography, geology, climate, natural resources, and agricultural resources. The socioeconomic section describes the basin's population, demographics, land use, and economic activity, as these factors influence the use and development of water resources in the basin.

- **Chapter 3: Water Resources of the Basin** – Chapter 3 describes the surface and groundwater resources of the basin and the modeling tools used to evaluate their availability. Monitoring programs, current projects, issues of concern, and trends are noted.

- **Chapter 4: Current and Projected Water Demand** – Chapter 4 summarizes the current and projected water demands within the basin. Demands for public water supply, thermoelectric power, industry, agriculture, and other uses are presented along with their permitted and registered withdrawals. The chapter outlines the methodology used to develop demand projections and the results of those projections.

- **Chapter 5: Comparison of Water Resource Availability** – Chapter 5 describes the methodology and results of the basin's surface water availability analysis. This chapter presents planning scenarios that were developed, and the performance measures used to evaluate them. Any water shortages or reaches of interest identified through this analysis are described. The projected water shortages identified in this chapter serve as the basis for the water management strategies presented in Chapter 6.

- **Chapter 6: Water Management Strategies** – Chapter 6 presents the water management strategies developed as potential solutions to the water shortages presented in Chapter 5. For each water management strategy considered, Chapter 6 includes a description of the measure, results from a technical evaluation (as simulated in the surface water quantity model, if applicable), feasibility for implementation, and a cost-benefit analysis.

- **Chapter 7: Water Management Strategy Recommendations** – Chapter 7 presents the final recommendations for water management strategies based on the analysis and results presented in Chapter 6. The chapter discusses the selection, prioritization, and justification for each of the recommended strategies. Any remaining shortages or concerns are also discussed in this chapter.

- **Chapter 8: Drought Response** – This chapter presents existing and proposed Drought Management Plans. The first part of the chapter discusses existing Drought Management Plans, ordinances, and drought management advisory groups. The second part presents drought response initiatives developed by the RBC.

- **Chapter 9: Policy, Legislative, Regulatory, Technical, and Planning Process Recommendations** – Chapter 9 presents overall recommendations intended to improve the planning process and/or the results of the planning process. Recommendations to address data gaps encountered during the planning process are presented along with recommendations for revisions to the state's water resources policies, legislation, and agency structure.

- **Chapter 10: River Basin Plan Implementation** – Chapter 10 presents a 5-year implementation plan and long-term planning objectives. The 5-year plan includes specific objectives, action items to reach those objectives, detailed budgets, and funding sources. The long-term planning objectives include other recommendations from the RBC that are less urgent than those in the implementation plan. There will be a chapter in future iterations of this plan that details progress made on planning objectives outlined in previous plan iterations.

Columbia Canal Diversion Dam at the entrance to the Columbia Canal

Chapter 2
Description of the Basin

2.1 Physical Environment

2.1.1 Geography

The Broad River basin covers approximately 3,800 square miles (sq mi) in South Carolina making up 12 percent of South Carolina's total area. The basin extends from the eastern edge of the Blue Ridge Mountains in North Carolina to the confluence of the Broad and Saluda Rivers near the City of Columbia (Figure 2-1). All of Spartanburg, Cherokee, and Union Counties, as well as significant portions of Newberry, Richland, York, Greenville, Laurens, Chester, and Fairfield Counties and a small sliver of Lexington County, are within the basin boundary (Table 2-1). The portion of the basin in South Carolina stretches approximately 100 miles in length and is approximately 60 miles in width at its northern extent. The Broad River basin is the third largest of the state's eight water planning basins.

The Broad River basin consists of four major subbasins: the Upper Broad River, which includes the Pacolet River, the Lower Broad River, the Tyger River, and the Enoree River. The headwaters of the Upper Broad River originate in the Blue Ridge Mountains near Chimney Rock, North Carolina. The small mountain stream flows southeast, incorporating multiple tributaries until it reaches South Carolina. The Upper Broad River subbasin transitions to the Lower Broad River subbasin at the confluence of the Pacolet and Broad Rivers on the

Figure 2-1. The Broad River basin and surrounding counties.

Southern edge of Cherokee County. The Lower Broad River serves as the boundary line for multiple counties as it flows south. The Tyger and Enoree Rivers both flow into the Broad River in the Sumter National Forest. The Lower Broad River subbasin ends at the point where the Broad and Saluda Rivers combine to form the Congaree River.

The character of the major rivers changes as they flow the length of the basin. The South Carolina portion of the Broad River is a wide, sandy-bottom river interspersed with rock outcrops, shoals, and sandbars. It is considered to have mostly well-defined channel banks with occasional backwater areas in some of the pools (USACE 1977). Twelve dammed reservoirs can be found on the Broad, Pacolet, and Tyger Rivers. The Broad River basin is known for its recreational fishing, wildlife habitat, and historical-cultural significance. From Ninety-Nine Islands Dam to the confluence with the Pacolet River, the Broad River's natural, cultural, and scenic qualities were considered valuable enough to be designated as a State Scenic River in 1991 (SCDNR 2003).

Table 2-1. Counties of the Broad River basin.

County	Percentage of Broad River Basin in County	Percentage of County in Broad River Basin
Spartanburg	21.6%	100.0%
Union	13.6%	100.0%
Fairfield	11.2%	59.6%
Cherokee	10.5%	100.0%
Newberry	8.7%	50.7%
Greenville	8.1%	38.7%
Laurens	7.1%	37.2%
York	6.8%	37.3%
Chester	6.7%	43.3%
Richland	5.6%	27.4%
Lexington	0.2%	1.1%

2.1.2 Land Cover

Land use and land cover in the Broad River basin varies from rural farmland and state forests to sprawling urban areas. The cities of Spartanburg, Gaffney, and Union as well as significant portions of Greenville and Columbia are located within the basin. Land used for agriculture tends to be in the northern half of the basin. The basin completely contains the 170,000-acre Enoree Ranger District of the Sumter National Forest. As a result, woodland is the dominant landcover in the basin, as shown in Figure 2-2 (Multi-Resolution Land Characteristics Consortium [MRLC] 2019).

Table 2-2, derived from the MRLCs National Land Cover Database (NLCD), provides a more detailed summary of land cover types in the basin, and includes changes in land cover area from 2001 to 2019. Developed land has increased by approximately 72 sq mi, while agricultural land (composed of hay/pasture, cultivated crops, and barren land) decreased by almost the same amount. The area of woodlands (deciduous, evergreen, and mixed forest) stayed fairly constant; however, the composition of woodland changed significantly, with over 100 sq mi of deciduous forest being lost and roughly the same amount of evergreen and mixed forest being gained. A significant composition change can also be seen in shrubland (composed of shrub and herbaceous grassland), where a 90-square-mile decrease in herbaceous grassland cover is countered with nearly the same increase in shrub cover.

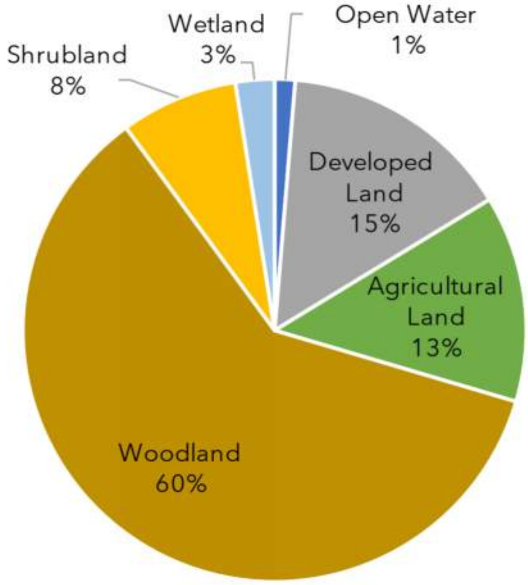


Figure 2-2. Broad River basin land cover (MRLC 2019).

Table 2-2. Broad River basin land cover and trends.

NLCD Land Cover Class	2001 Area (sq mi)	2019 Area (sq mi)	Change from 2001 to 2019 (sq mi)	Percentage Change from 2001 to 2019	Percentage of Total Land (2019)
Open Water	49.4	49.9	0.5	1%	1%
Developed, Open Space	269.3	288.7	19.4	7%	8%
Developed, Low Intensity	153.2	174.6	21.4	14%	5%
Developed, Medium Intensity	50.7	74.0	23.3	46%	2%
Developed, High Intensity	22.2	30.4	8.3	37%	1%
Barren Land	7.8	5.5	-2.3	-29%	<1%
Deciduous Forest	867.2	761.4	-105.8	-12%	20%
Evergreen Forest	965.4	1,038.3	72.9	8%	27%
Mixed Forest	460.7	490.7	30.0	7%	3%
Shrub/Scrub	82.1	172.9	90.7	110%	5%
Herbaceous	202.8	113.7	-89.1	-44%	3%
Hay/Pasture	561.4	488.4	-73.0	-13%	13%
Cultivated Crops	7.1	10.4	3.2	46%	<1%
Woody Wetlands	91.2	90.9	-0.3	0%	2%
Emergent Herbaceous Wetlands	3.6	4.1	0.5	14%	<1%
Total Land Area	3,794	3,794	0.0		100%

2.1.3 Geology

South Carolina is divided into three major physiographic provinces based on geologic characteristics: the Blue Ridge, the Piedmont, and the Coastal Plain. The Broad River basin lies almost completely within the Piedmont province. However, the headwaters to the Pacolet and Tyger Rivers start in the Blue Ridge province and the southeastern edge of the basin crosses over the Fall Line into the Coastal Plain. As the basin flows from the headwaters, high hills in the north give way to rolling hills in the south (SCDNR 2009).

The Piedmont province mostly consists of saprolite, weathered bedrock, and underlying crystalline rock. The saprolite layer can range from 10 to 150 feet in thickness. Figure 2-3 depicts the generalized geologic units of the Broad River basin. Saprolite has a high porosity but low permeability. It absorbs rainwater and slowly releases it to fractures in the underlying rock, which can be tapped by wells. However, these fractures are small and the underlying bedrock is not able to form aquifers in this province. Wells typically yield less than 50 gallons per minute (gpm) (SCDNR 2009). Because of the relatively low well yields, groundwater is not a significant source of water in the basin. Total reported groundwater withdraws, which are around 0.5 million gallons per day (MGD), account for just 0.2 percent of the state's entire groundwater withdraws (Gellici 2022). Groundwater discharges into surface water are more common in the upper portions of the basin where rainfall is higher (Harder 2022). Such discharges are vital to maintaining baseflow in the streams.

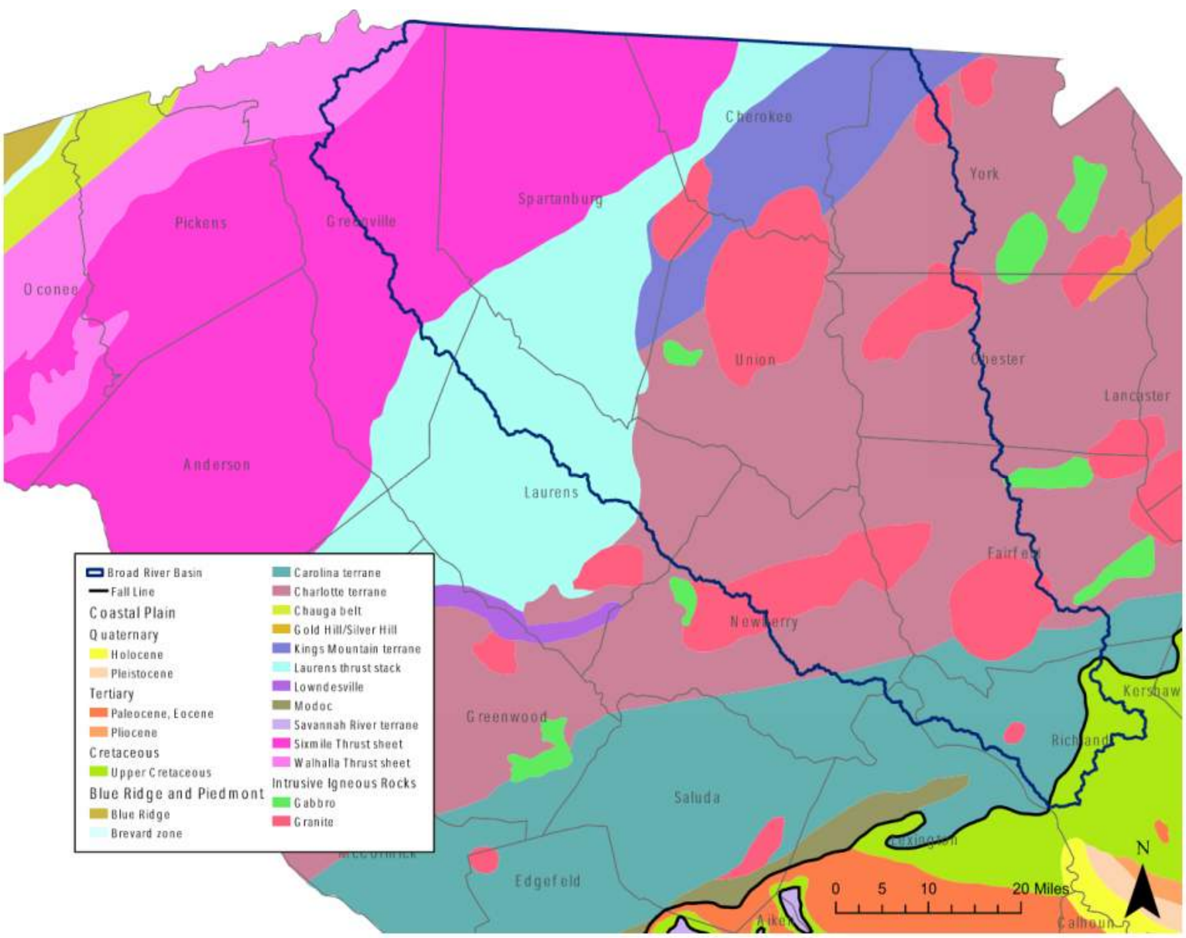


Figure 2-3. Generalized geologic map of the Broad River basin (SCDNR).

2.2 Climate

2.2.1 General Climate

The climate of the Broad River basin, much like the rest of the Carolinas, is described as humid subtropical, with hot summers and mild winters. Figure 2-4 shows the average annual temperature and the annual average precipitation for the Broad River basin based on the current climate normals (1991 to 2020). The current climate normals maps for the entire state for the parameters of temperature (average maximum, and minimum) and precipitation at annual, seasonal, and monthly time steps are available on the South Carolina State Climatology Office's (SCO) "Climate" webpage.

The average annual temperature throughout the basin ranges from 54 to 65 degrees Fahrenheit (F), with temperature increasing from the upper basin to the lower basin. The annual average precipitation ranges throughout the basin from 42 to over 63 inches (in), with rainfall decreasing from the upper basin to the lower basin. Higher precipitation totals occur in the upper basin from orographically enhanced rain due to the mountains and higher elevations.

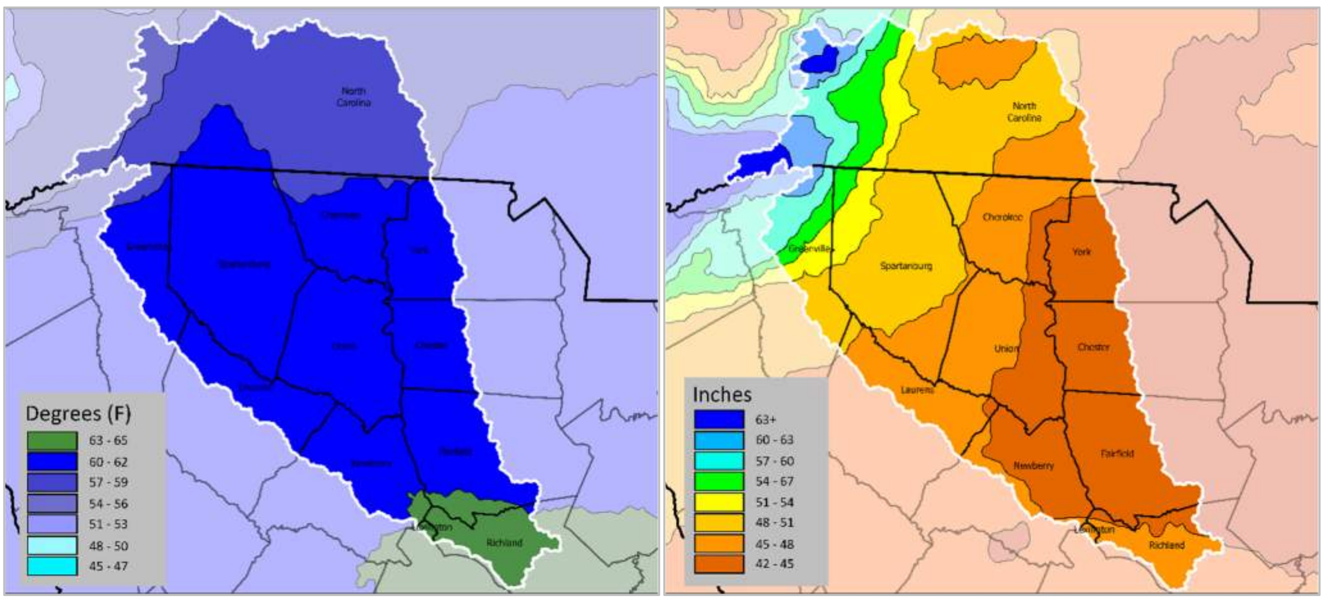


Figure 2-4. Normal annual average temperature and precipitation (1991 to 2020) for the Broad River basin.

Temperature and precipitation values are not constant throughout the basin, and they are not consistent for a given location throughout the year. Figures 2-5 and 2-6 show the monthly variation in temperature and precipitation at the meteorological stations "Tryon" in Polk County, NC, and "Santuck" in Union County, SC, respectively. Both these stations show that temperature oscillates throughout the year, with July generally being the warmest month (average monthly temperature of 77.5 degrees F at Tryon and 78.9 degrees F at Santuck) and January being the coldest month (average monthly temperature of 42.4 degrees F at Tryon and 43.4 degrees F at Santuck). At both stations, precipitation varies throughout the year. Tryon's climatologically wettest month is March (6.17 in), and the driest month is November (4.51 in). At Santuck, the wettest month is also March (4.32 in), and the driest is October (3.15 in) (SCDNR State Climatology Office 2023).

Notes about climate data: The two stations were selected because of their long-term records (Tryon: 1917 to present; Santuck: 1895 to present), and they display the climatological differences in the upper and lower portions of the basin. The Tryon station is near the top of the watershed, while the Santuck station is in the lower-middle portion of the basin. The period of record for the analysis was designated from 1931 to 2022, because both stations have missing data between their start and 1930, while 1931 to present has limited missing data (SCDNR SCO 2023). Both stations have 1 year missing from the time series (1938 for Tryon and 1946 for Santuck) because of missing data affecting the annual averages for temperature and precipitation. Also, the annual averages for each station may not match their locations on the basin climatology images of Figure 2-4 because of differences in the period of records of the data. The long-term station data ranges from 1931 to 2022, while the data used for Figure 2-4 is based on the current climate normals (1991 to 2020).

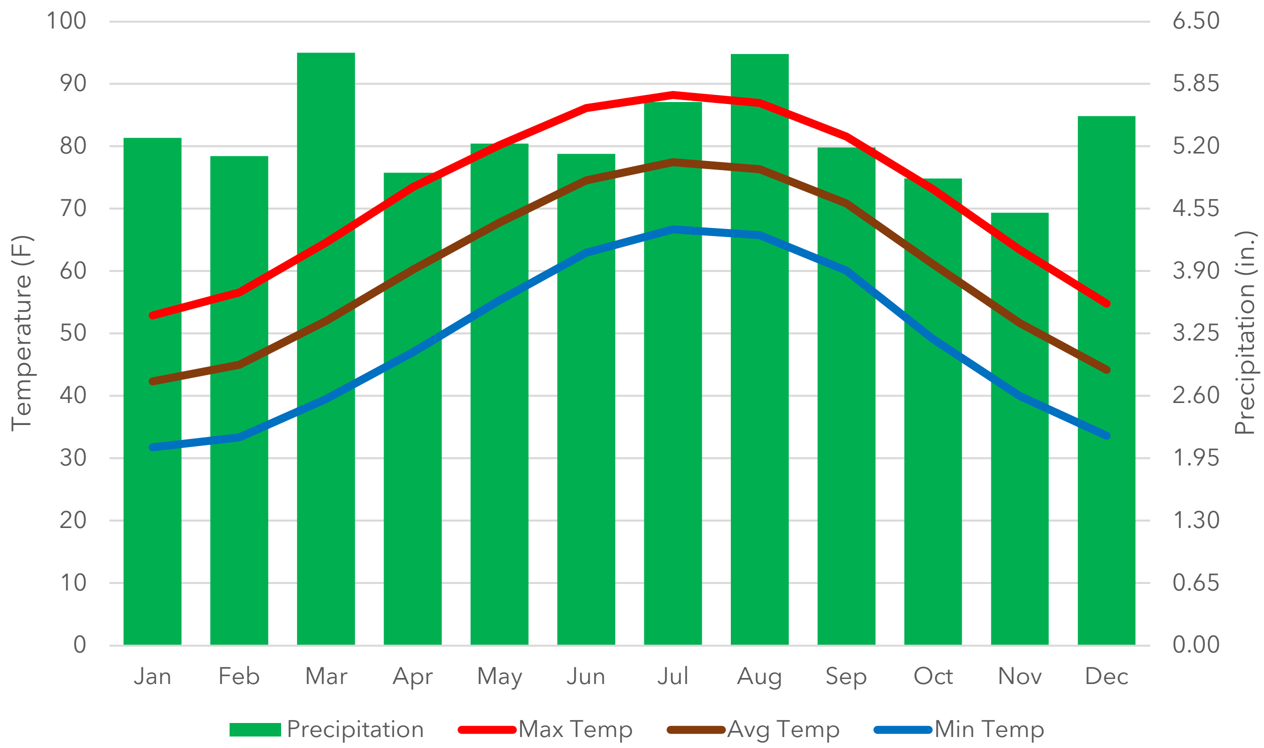


Figure 2-5. Tryon (NC) monthly climate averages, 1931 to 2022 (SCDNR SCO 2023a).

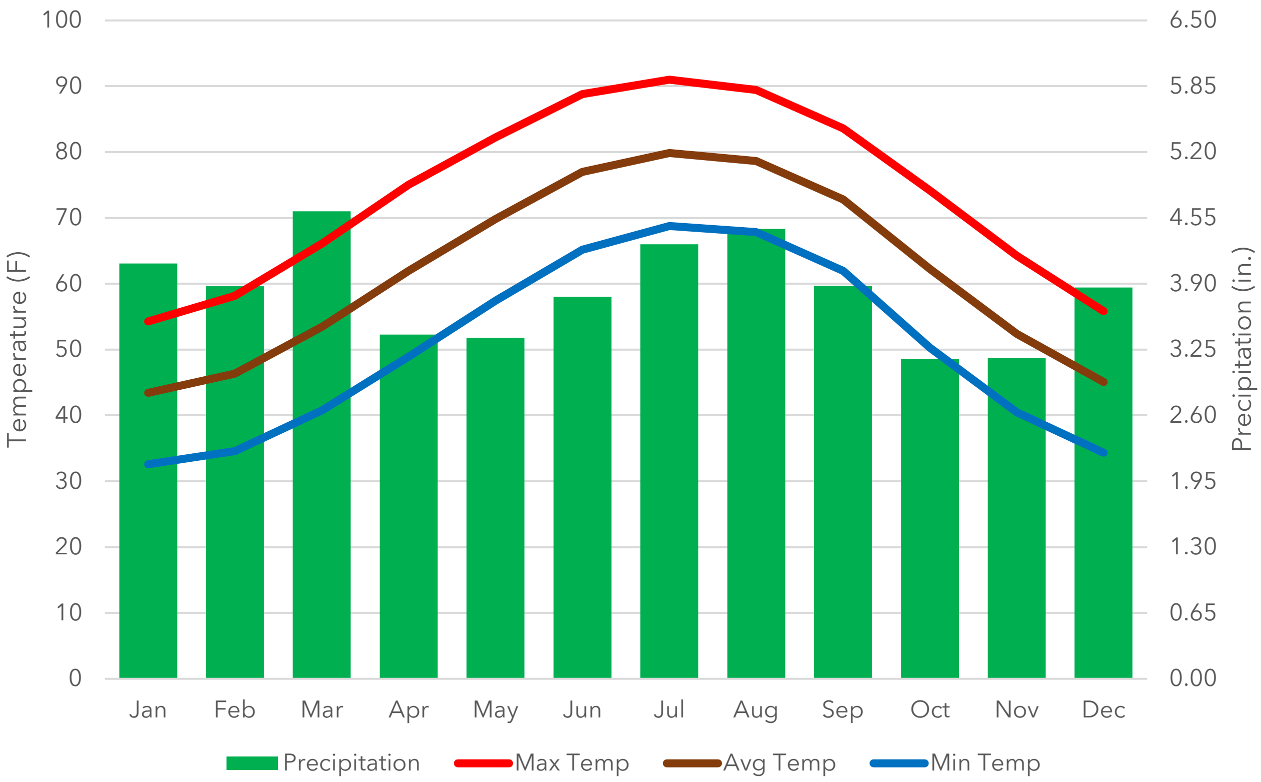


Figure 2-6. Santuck (SC) monthly climate averages, 1931 to 2022 (SCDNR SCO 2023a).

Through time, the annual average temperature and precipitation for Carolinas and the Broad River basin has varied (National Oceanic and Atmospheric Administration [NOAA] 2022; SCDNR SCO 2023). Figures 2-7 and 2-8 show the 1931 to 2022 temperature timeseries for the Tryon and Santuck stations, showing both years of above and below average annual temperature. For this period, the annual average temperature of the Tryon station is 60 degrees F and 63 degrees F for the Santuck station. Table 2-3 shows the stations' warmest and coldest 5 years, with four of the warmest years in common (1990, 2012, 2016, and 2017). 2016 was the warmest year for Tryon and 2012 was the warmest for Santuck. All top five of the warmest years for both stations have occurred since 1990. The coldest year for both stations occurred in 1940, and both stations generally experienced some of their coldest years in the 1960s through the 1980s.

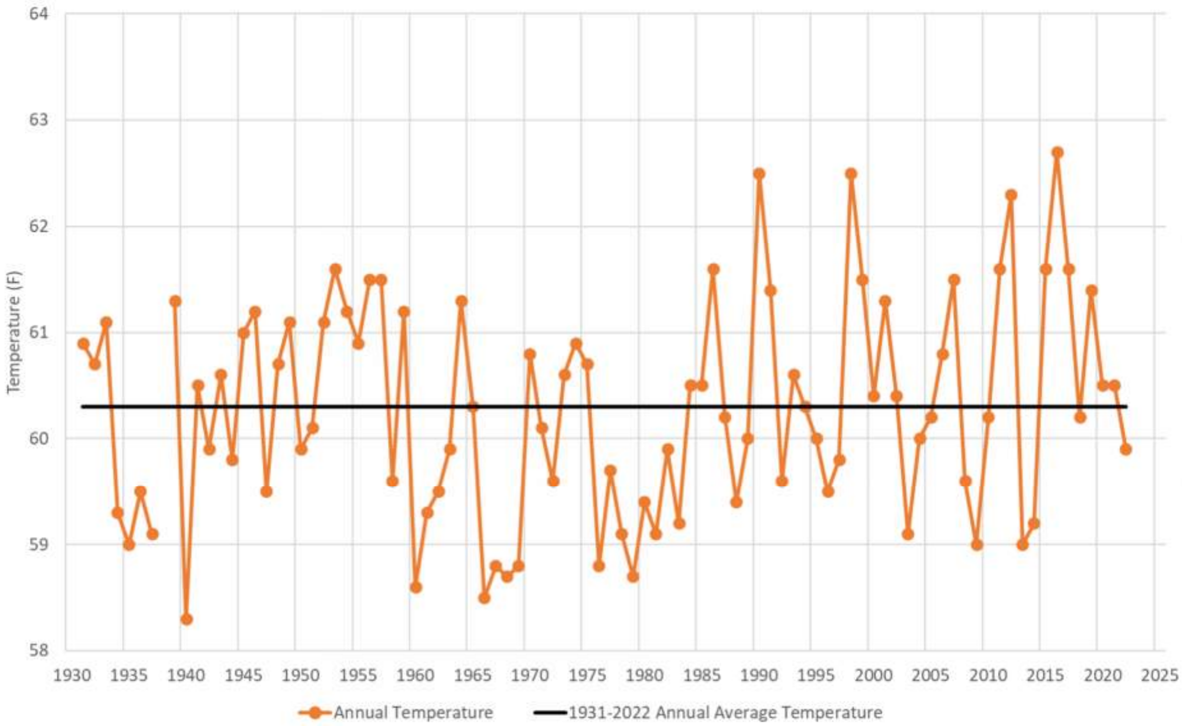


Figure 2-7. Annual average temperature for Tryon, 1931 to 2022 (SCDNR SCO 2023a).

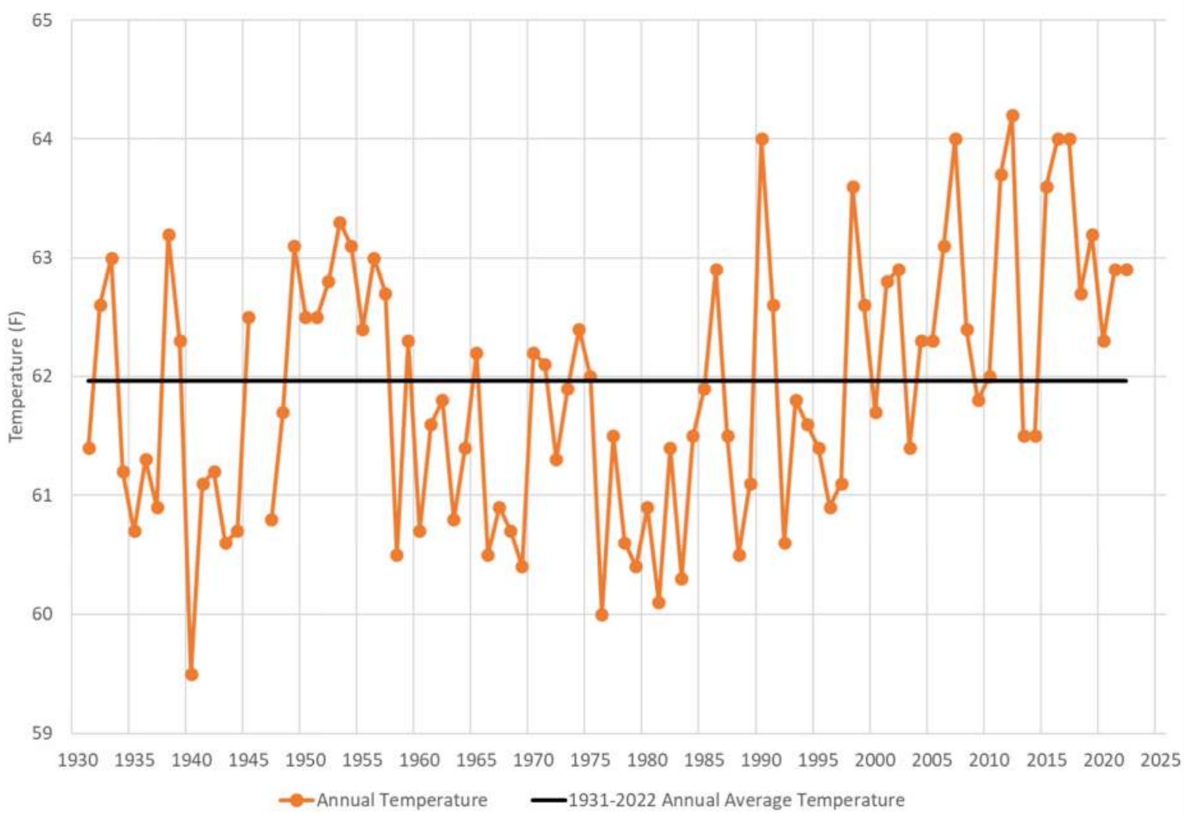


Figure 2-8. Annual average temperature for Santuck, 1931 to 2022 (SCDNR SCO 2023a).

Table 2-3. Comparison of five warmest and coldest years for Tryon and Santuck stations from 1931 to 2022 (SCDNR SCO 2023a).

Year Rank	Warmest		Coldest	
	Tryon	Santuck	Tryon	Santuck
1	2016 (62.7 F)	2012 (64.2 F)	1940 (58.3 F)	1940 (59.5 F)
2	1998 (62.5 F)	2017 (64.0 F)	1966 (59.5 F)	1976 (60.0 F)
3	1990 (62.5 F)	2016 (64.0 F)	1960 (58.6 F)	1981 (60.1 F)
4	2012 (62.3 F)	2007 (64.0 F)	1979 (58.7 F)	1983 (60.3 F)
5	2017 (61.6 F)	1990 (64.0 F)	1968 (58.7 F)	1969 (60.4 F)

Figures 2-9 and 2-10 show the stations' 1931 to 2022 precipitation timeseries. Tryon's annual average precipitation is 64 inches and 46 inches for the Santuck station.

Table 2-4 shows the driest and wettest 5 years for each station. Due to the variability in precipitation and differing climates between the two stations, there are fewer years in common between the dry and wet years. The driest year for Tryon is 1988; for Santuck, 2007. The wettest year for Tryon is 1979; for Santuck, 1964. While specific years for record precipitation may vary between these stations, they share similar wet and dry periods: dry periods in the 1950s, late 1980s, early 2000s, 2005 to 2008, and wet periods in the 1960s and 1970s.

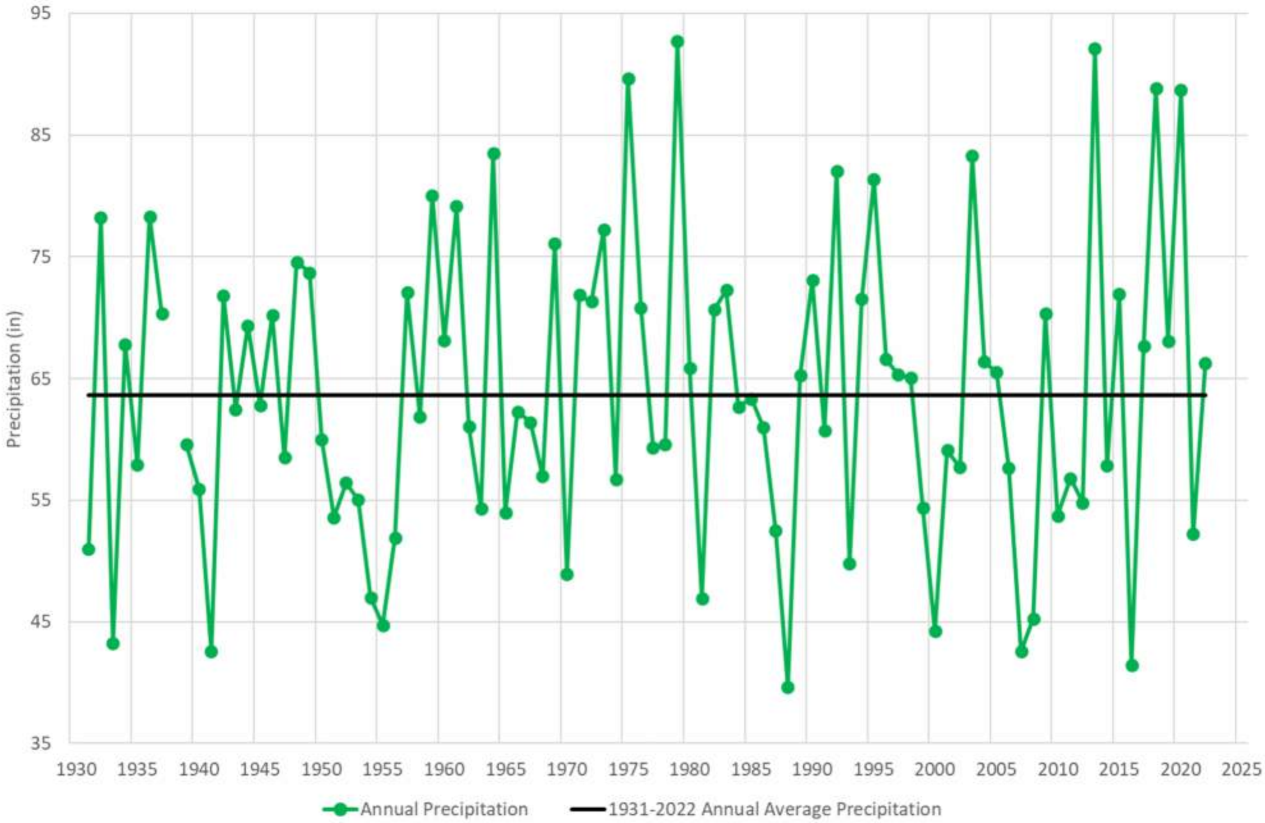


Figure 2-9. Annual average precipitation for Tryon, 1931 to 2022 (SCDNR SCO 2023a).

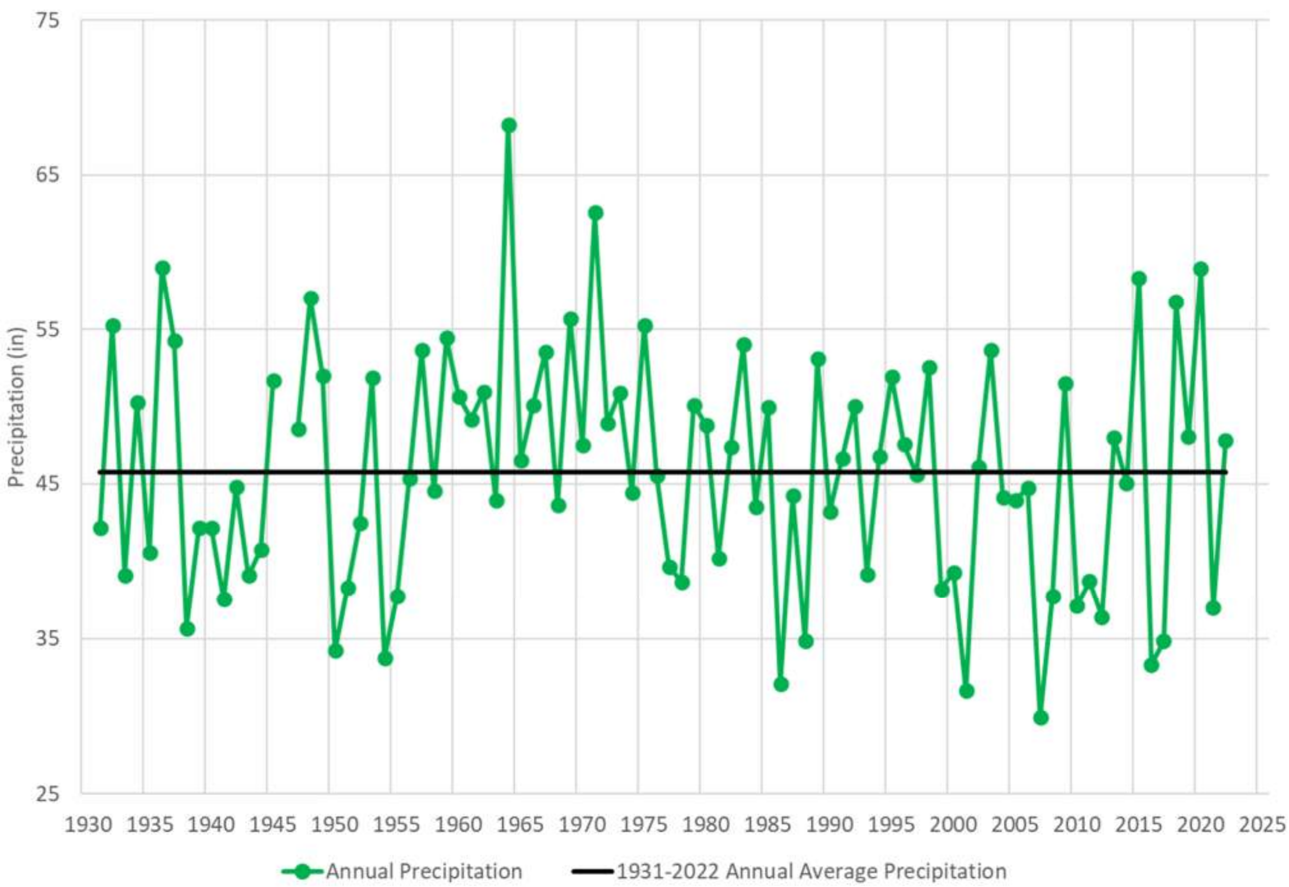


Figure 2-10. Annual average precipitation for Santuck, 1931 to 2022 (SCDNR SCO 2023a).

Table 2-4. Comparison of five driest and wettest years for Tryon and Santuck stations from 1931 to 2022 (SCDNR SCO 2023a).

Year Rank	Driest		Wettest	
	Tryon	Santuck	Tryon	Santuck
1	1988 (39.66 in)	2007 (29.93 in)	1979 (92.76 in)	1964 (68.26 in)
2	2016 (41.45 in)	2001 (31.65 in)	2013 (92.12 in)	1971 (62.56 in)
3	1941 (42.55 in)	1986 (32.09 in)	1975 (89.66 in)	1936 (59.05 in)
4	2007 (42.56 in)	2016 (33.33 in)	2018 (88.89 in)	2020 (58.95 in)
5	1933 (43.25 in)	1954 (33.78 in)	2020 (88.70 in)	2015 (58.37 in)

2.2.2 Severe Weather

Severe weather, including thunderstorms, tornadoes, and tropical cyclones, can impact some or all portions of the Broad River Basin.

2.2.2.1 Severe Thunderstorms and Tornadoes

There are between 45 and 55 thunderstorm days across the Broad River basin annually. While thunderstorms occur throughout the year, severe thunderstorms are more common during climatological spring (March, April, May) and summer (June, July, and August) (SCDNR 2022a). For a thunderstorm to be considered severe, it must produce wind gusts of at least 58 mph, hailstones of 1 in diameter or larger, or a tornado. Tornadoes are violently rotating columns of air that descend from thunderstorms and come in contact with the ground. Most of South Carolina's tornadoes are short-lived EF-0 and EF-1 tornadoes, the lowest strengths on the Enhanced Fujita (EF) Scale, with winds between 65 and 110 miles per hour. However, even a tornado with the lowest intensity rating is dangerous and poses a significant risk to lives and property. A tornado occurs in the basin about once every 7 months on average. Table 2-5 shows the number of tornadoes by intensity ranking, confirmed within the basin between 1950 – 2022. Most of the basin's tornadoes rated E/F-0 and E/F-1. For reference, the EF-Scale became operational in 2007 and replaced the original Fujita scale (F-scale) used since 1971.

Table 2-5. Count of tornadoes in the basin by intensity ranking 1950-2022 (SCDNR SCO 2023b).

Enhanced Fujita Scale	Count
E/F 0 and E/F 1	144
E/F 2	27
E/F 3	8
E/F 4	4
E/F 5	0

2.2.2.2 Tropical Cyclones

South Carolina has an 80 percent chance of being affected by a tropical cyclone (meaning tropical depression, tropical storm, or hurricane) each year, and the chances for a major hurricane (a Category 3 storm with winds of 115 mph or higher) to affect the state is about 3 percent each year. (SCDNR 2022b)

With an average size of approximately 300 miles in diameter, tropical cyclones can have far-reaching hazards, including storm surge, damaging wind, precipitation-induced flooding (flash flooding and riverine flooding), and tornadoes. Impacts from these hazards are not limited to those living along the coast.

Since most of the basin is over 100 miles from the coast, storm surge has no impact. However, damaging winds, while less likely to occur in the basin, are not unprecedented. One of the most well-known instances of damaging winds is Hurricane Hugo of 1989, which produced 90 mph wind gusts as far inland as Charlotte, North Carolina.

While storm surge is not a concern for the basin, flash flooding, riverine flooding, and tornadoes are more typical impacts. Tropical Storm Jerry made landfall along the Florida coast in 1995, before slowly moving into the Upstate. Heavy rains were reported statewide, with amounts varying from 5 in to over a foot in some locations. In parts of the Upstate, most of the rain fell in about eight hours. Figure 2-11 shows the amount and spatial extent of rainfall from Tropical Storm Jerry in 1995.

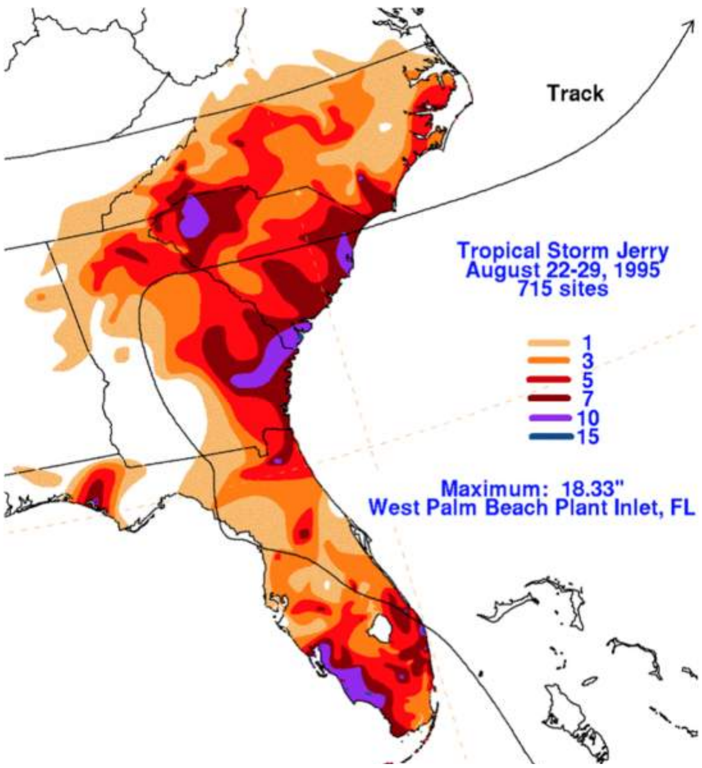


Figure 2-11. Amount and extent of rainfall from Tropical Storm Jerry in 1995.

Courtesty of NOAA's Weather Prediction Center.

Tornadoes produced by tropical cyclones form in the outer rainbands, which can be hundreds of miles from the storm's center. The remnants of Hurricane Nate (2017) produced seven tornadoes across the basin as it moved across Tennessee and the Ohio River Valley.

2.2.2.3 Winter Storms

Winter precipitation events are usually high-impact situations because of their rarity. Two or three winter precipitation events typically occur each year in the upper portions of the basin, while the lower basin averages one winter precipitation event per year. Winter precipitation events include snow, ice accumulation, or freezing rain accretion. While the average snowfall for the entire basin is 4 in or less, these totals are higher in the upper part of the basin and less in the lower section. The average annual snowfall in the highest elevations in the basin ranges from 15 to 20 in.

Winter storms mainly impact travel and transportation. However, heavy snow accumulations or ice accretions have caused impacts to trees, power lines, and built structures. These impacts typically occur with ice accretions that measure 0.5 in or more. A recent example of widespread snow and ice in the basin is the statewide winter storm in February 2014.

2.2.2.4 Flooding

The general definition of a flood is the temporary condition of a partial or complete inundation of typically dry land. There are three common types of flooding; fluvial, pluvial, and coastal. Fluvial flooding, also known as riverine flooding, is the flooding of typically dry areas caused by an increased water level of an established lake, river, or stream when the water overflows its banks. This is the most common type of flooding in the Broad River Basin The damage from fluvial flooding can be widespread, extending miles away from the original body of water. This type of flooding is caused by excessive freshwater from a severe or prolonged rain event.

Figure 2-12 shows the afternmath of flooding in October 2015 in the Columbia Canal at Columbia. An upper-level low-pressure system over the Southeast combined with moisture from Hurricane Joaquin off the Atlantic coast to create historic rainfall across South Carolina. More information on historical riverine flooding events across the state can be found in the Keystone Riverine Flooding Events in South Carolina report produced by the SCO.

Figure 2-12. Columbia Canal flooding following the record-setting rainfall event in October 2015. Photo courtesy Frank Eskridge, Columbia Water.

2.2.3 Drought

Drought is a normal part of climate variability that occurs in every climate. Drought results from a lack of precipitation over an extended period, often resulting in a water shortage for some activity, sector, or the environment. In contrast to other environmental hazards, droughts develop slowly over weeks, months, or years. Three main categories physically define drought: meteorological, agricultural, and hydrological. These categories help determine the economic, ecological, and societal impacts of droughts in communities.

Figures 2-13 and 2-14 show the annual Standard Precipitation Index (SPI) value for Tryon and Santuck, respectively, from 1931 to 2021 (the latest SPI data available for these stations). The SPI is a drought index that compares accumulated rainfall over a given period (here, 12 months) to the historical average, where the index values are standard deviations from the mean. Anything equal to or less than -1.0 is considered a drought. The lower the index value, the more severe the drought. The lowest SPI value was -2.0 for Tryon in 1988 and -1.7 for Santuck in 2007. These stations' lowest SPI values match their respective driest years on record. In the last decade (2012 to 2021), both stations have had SPI values below -1.0 and above 1.0, indicating both drought and excessively wet years. At the Tryon station, 2016 was the last year to have an annual SPI value in drought status (-1.0). At the Santuck station, 2016 and 2017 were consecutive years of annual SPI values in drought status (-1.0), showing that the 2016 drought affected portions of the Broad River basin differently. However, annual SPI values do not show short-term conditions, such as monthly or seasonal conditions. During a year with a negative annual SPI value, there can be months or seasons with positive SPI values, and vice versa. While the annual SPI time series is provided here for reference, it is not the only method for looking at wet and dry periods over time. Furthermore, the SPI only accounts for precipitation accumulation and does not consider wetness or dryness in terms of evapotranspiration, soil moisture, streamflow, or groundwater.

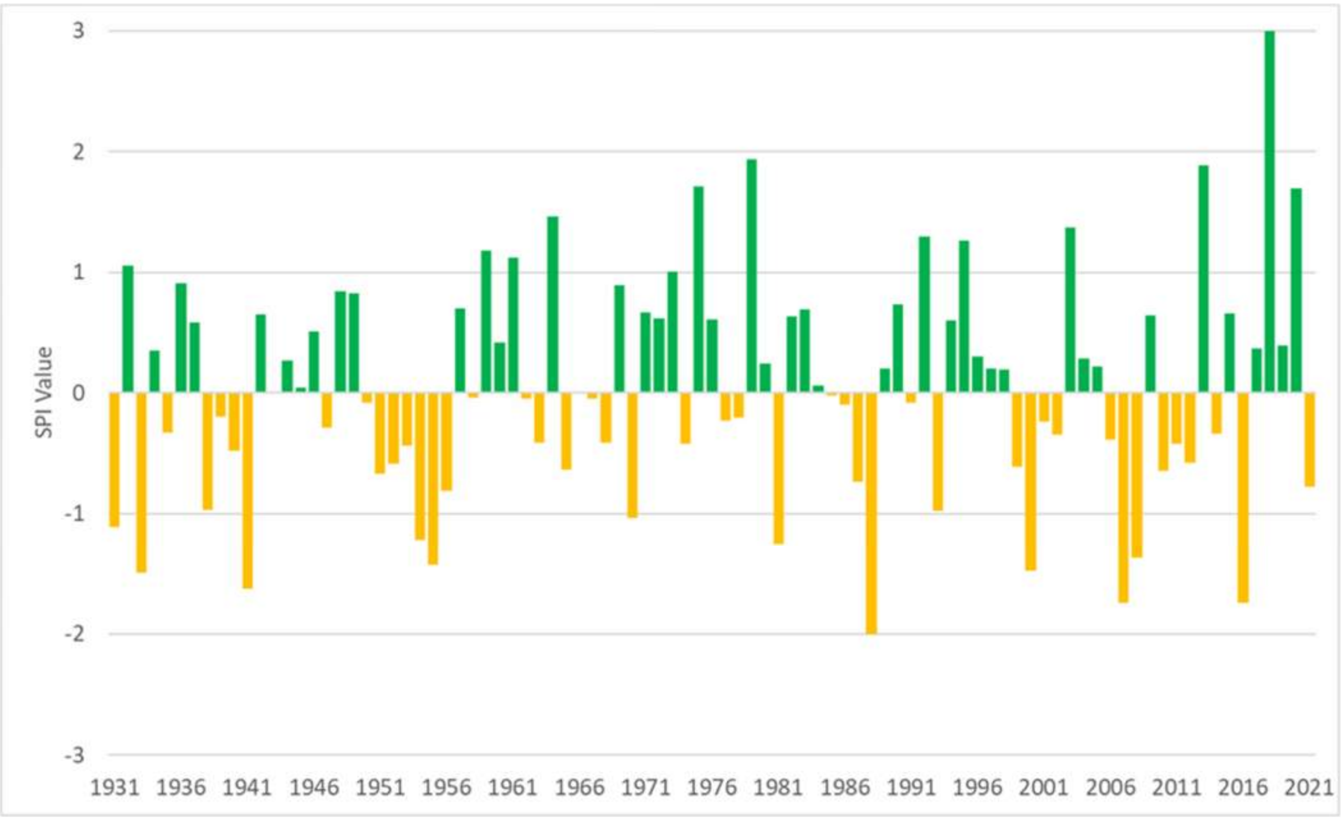


Figure 2-13. Annual SPI values for Tryon 1931 to 2021 (SCDNR SCO 2023c).

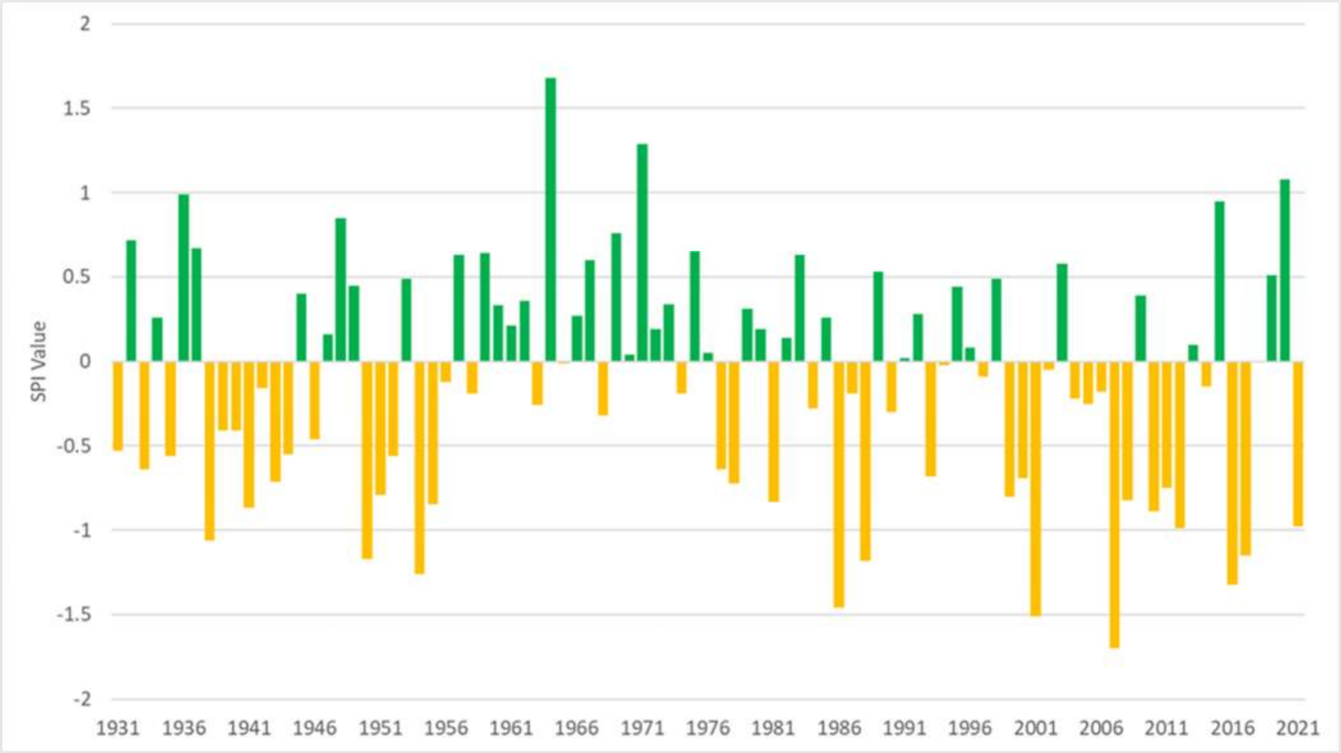


Figure 2-14. Annual SPI values for Santuck 1931 to 2021 (SCDNR SCO 2023c).

The impact of drought on streamflow in the basin was analyzed using four USGS streamflow gaging stations, one in each of the four sub-watersheds. The four stations are Broad River near Boiling Springs (NC) in the Upper Broad subbasin, Broad River near Alston (SC) in the Lower Broad subbasin, the Tyger River near Delta (SC) in the Tyger subbasin, and the Enoree River near Whitmire (SC) in the Enoree subbasin. Beyond the spatial component, these four stations were used because of their consistent long-term record from 1974 to 2021. The monthly data through 2022 is only partially available at publication. Table 2-6 shows the year of the lowest flow, the value of the lowest flow, and the average flow value for each of the four stations. Flow values are provided in cubic feet per second (cfs). These four stations share strong similarities regarding which years had the lowest flows. The two gauges on the Broad River (near Boiling Springs, NC, and at Alston, SC) recorded their record lowest monthly flow during August 2002 (175 cfs and 564 cfs, respectively). The Tyger River near Delta recorded its lowest monthly flow in October 2007 (74 cfs), while the Enoree River at Whitmire recorded its lowest monthly flow in June 2008 (93 cfs). Although there are differences between the four gauges for the record lowest monthly flows, they all had the same record lowest annual flow, which occurred in 2008.

Figures 2-13, 2-14, and Table 2-6 show that drought is a normal part of climate and hydrology in the Broad River basin (and the rest of South Carolina). The drought of 2007 to 2009 is a recent, notable drought for the Broad River basin, with 2007 ranging from one of the driest to the driest climatological year on record for the basin (depending on location) as well as 2008 being the driest hydrological year on record. The 2007 to 2009 drought started in spring 2007 with drier-than-normal conditions, which elevated to drought conditions in early summer. In June of 2007, the South Carolina Drought Response Committee (DRC) declared all 46 counties in moderate drought status. The following September (2007), the DRC placed 44 counties in severe drought status, with Jasper and Beaufort counties staying in

Table 2-6. Year of record minimum flow, record low flow, and average monthly flow for each of the four streamflow gaging stations from 1974 to 2021.

Broad River near Boiling Springs (USGS 2151500)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Year of Minimum Flow	2001	2009	2017	1986	2001	2008	2008	2002	2007	2007	2007	2007	2008
Record Minimum Flow (cfs)	553	574	604	821	505	262	234	175	334	309	345	548	6,902
Average Flow (cfs)	1,815	1,894	2,064	1,926	1,674	1,313	1,079	1,049	1,048	1,167	1,299	1,577	17,772
Broad River at Alston (USGS 2162000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Year of Minimum Flow	2011	2009	2017	2012	2001	2008	2008	2002	2007	2007	2007	2007	2008
Record Minimum Flow (cfs)	2,106	1,985	2,430	2,821	1,783	763	600	546	624	638	725	1,251	25,350
Average Flow (cfs)	7,510	9,090	9,400	7,500	5,380	4,670	3,540	4,510	3,360	3,760	4,440	6,630	70,158
Tyger River near Delta (USGS 2160105)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Year of Minimum Flow	2011	2009	2017	2012	2001	2008	2008	2002	2007	2007	2007	2007	2008
Record Minimum Flow (cfs)	304	332	428	415	277	104	89	78	80	74	96	274	3,990
Average Flow (cfs)	1,300	1,320	1,500	1,120	882	628	523	529	429	637	754	1,010	10,679
Enoree River near Whitmire (USGS 2160700)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Year of Minimum Flow	2011	2009	2017	2012	2001	2008	2008	1988	2008	2007	2007	2007	2008
Record Minimum Flow (cfs)	219	233	317	254	190	93	66	76	87	73	89	202	2,810
Average Flow (cfs)	744	778	878	667	512	372	319	324	261	382	438	592	6,285

moderate drought status. The DRC kept the drought status the same in January 2008. In April 2008, the DRC made improvements, with 20 counties in incipient, 14 counties in moderate, and 12 counties in severe status. Although conditions improved in April 2008, much of the Broad River basin was still in severe drought. Of the 10 counties that are in the basin, one county was in incipient, two were in moderate, and seven were in severe status. Although conditions deteriorated in June 2008, the peak of the drought occurred in August of 2008. At this point, one county in the basin was in moderate, three were in severe, and six were in extreme status. While conditions improved from this point on, parts of the state and the basin were still in severe or extreme drought until February 2009. The state and the basin would not return to normal status until June 2009, two years after the entire state was put into incipient drought status.

This drought caused severe impacts across multiple sectors over two years, including agriculture, recreation, forestry, and public water supply. Agricultural impacts included reduction of crop yields or yield loss and decreases in pasture ability to adequately feed livestock. During the 2007 to 2009 drought, 2007 was the hardest year for corn and soybean production within the basin, with some counties reporting yields 30 percent below normal. Hay production was impacted more severely. Basin-wide, 2007 yields were 20 percent to 40 percent below normal, with many producers worrying about hay supplies not lasting through the winter into 2008. While the basin did see less than normal yields in 2008 and 2009 for these three crops, they were far less severe than the losses of 2007 (Carolinas Integrated Sciences & Assessments 2023).

The recreation industry experienced impacts from low flows that exposed hazards to boats and negatively affected businesses that rely on river recreation for income. Statewide, forestry felt the impacts as well, due to increased fires due to low soil moisture content and stress from reduced water availability. Early in the drought, in July and August 2007, wildfire numbers were above normal, with 518 fires and 2,730 acres burned. By April 2008, wildfire numbers were above the annual average, with 2,800 fires and 17,000 acres burned. By September 2008, the state had a 66 percent increase in the number of acres burned compared to the five-year average. It was not until April 2009 that the risk of wildfires started to wane due to an improvement in conditions.

The intensity and duration of this drought impacted public water supplies as well. By June of 2007, six water systems across the state had implemented voluntary restrictions, while two systems reported mandatory restrictions. By September, 10 water systems implemented voluntary restrictions and five had mandatory restrictions. By January 2008, 191 water systems across the state had some level of water conservation, with 146 systems implementing voluntary restrictions and 45 systems implementing mandatory restrictions (SCDNR SCO 2023d). Of the 14 water systems within the basin discussed later in this plan (Chapter 8), 10 reported voluntary restrictions, and three reported mandatory restrictions. One system did not provide information. The three systems that reported mandatory restrictions were Jenkinsville Water Company, Mid-County Water Company II, and the Town of Winnsboro.

In July 2008, the Governor, along with the SCDNR, released a statement encouraging conserving water. Although this was targeted for counties in severe and extreme drought status, specifically the Upstate, it was a message for everyone across the state. This statement provided readers with ways to conserve water both inside and outside the house (SCDNR SCO 2023e). While this message only encouraged water conservation, it should be noted that the Governor has seldom needed to use his executive authority to encourage water conservation, indicating how severe the situation had become across the Upstate. The encouragement of water conservation across the state was due to reduced hydrologic conditions. In the Broad River basin, monthly annual flows were below normal (less than the 25th percentile) from May 2007 to November 2008, a 19-month period. During this period, 10 of the months experienced monthly flows that were well below normal (less than the 10th percentile). In December 2008, monthly flows returned to the normal range (25th to the 75th percentile) (USGS 2023).

Although the 2007 to 2009 drought was not the most intense drought for South Carolina, it was a significant drought for the state, and was the most intense drought for the Broad River basin in recent history. More information on historical drought events across the state, some of which have affected the Broad River basin, can be found in the following document produced by the SCO: (https://www.dnr.sc.gov/climate/sco/Publications/SCKeystoneDroughtEvents.pdf.

Although South Carolina typically receives adequate precipitation, droughts can occur at any time of the year and last for several months to several years. While precipitation is the main driver for water availability in the Broad River basin, multiple factors such as temperature, evapotranspiration, and water demands, to name a few, also need to be considered when evaluating how drought periods will impact stream and river flows in the basin. Severe drought conditions can contribute to diminished water and air quality, increased public health and safety risks, and reduced quality of life and social well-being. Because drought causes a lack of expected water across multiple sectors at different time frames, it is essential to plan for drought so water demands can be adequately met and managed before and during a severe drought period.

2.3 Natural Resources

2.3.1 Soils, Minerals, and Vegetation

The Natural Resources Conservation Service (NRCS) divided South Carolina into six land resource areas based on soil conditions, climate, and land use, as shown in Figure 2-15. These areas generally follow the boundaries of the physiographic provinces but are defined based on soil characteristics and their supported land use types. The Broad River basin is located primarily in the Southern Piedmont major land resource area, with small portions of the basin extending to the Blue Ridge Mountains and Carolina-Georgia Sandhills Piedmont land resource areas. The land resource area descriptions below were originally presented in the South Carolina State Water Assessment (SCDNR 2009).

- The Blue Ridge Mountains land resource area consists of dissected, rugged mountains with narrow valleys. Most soils are moderately deep to deep on sloping-to-steep ridges and side slopes. The underlying material consists mainly of weathered schist, gneiss, and phyllite. The area is predominantly forested with a mixture of oak, hickory, and pine. Small farms of the area produce truck crops, hay, and corn.

- The Southern Piedmont land resource area is an area of gentle to moderately steep slopes with broad-to-narrow ridge tops and narrow stream valleys. The region is covered with strongly acid, firm clayey soils formed mainly from gneiss, schist, phyllite, and Carolina slate. Large areas of land centered near Chester and York Counties have moderately acidic to moderately alkaline soils that were formed mainly from diorite, gabbro, and hornblende schist. The area is forested with mixed hardwoods and various pines. Cotton, corn, and soybeans are the major crops grown in the area.

- The Carolina-Georgia Sandhills land resource area consists of strongly sloping, sandy soils underlain by sandy and loamy sediments. With well-drained to excessively drained soils, the region supports cotton, corn, and soybean growth. Approximately two-thirds of the region is covered by forest types dominated by mixed pine and scrub oaks.

As of February 2023, there were 65 active mines in the Broad River basin, most of which are in Spartanburg (16), Laurens (12), and Cherokee (12) Counties. There are a wide variety of mines in the basin, but the most common mined material is granite (17), sand (15), and vermiculite (14) (SCDHEC 2023a). According to the most recently published USGS Minerals Yearbook, South Carolina produced $1.03 billion in nonfuel minerals in 2018 (USGS 2022a). Because 65 of the state's 494 active mines, or approximately 13 percent, are in the Broad River basin, a rough estimate of the annual value of minerals produced from the basin is $133 million. Principal commodities in South Carolina include cement (masonry and Portland), clay (kaolin), sand and gravel (construction), and stone (crushed) (USGS 2022a).

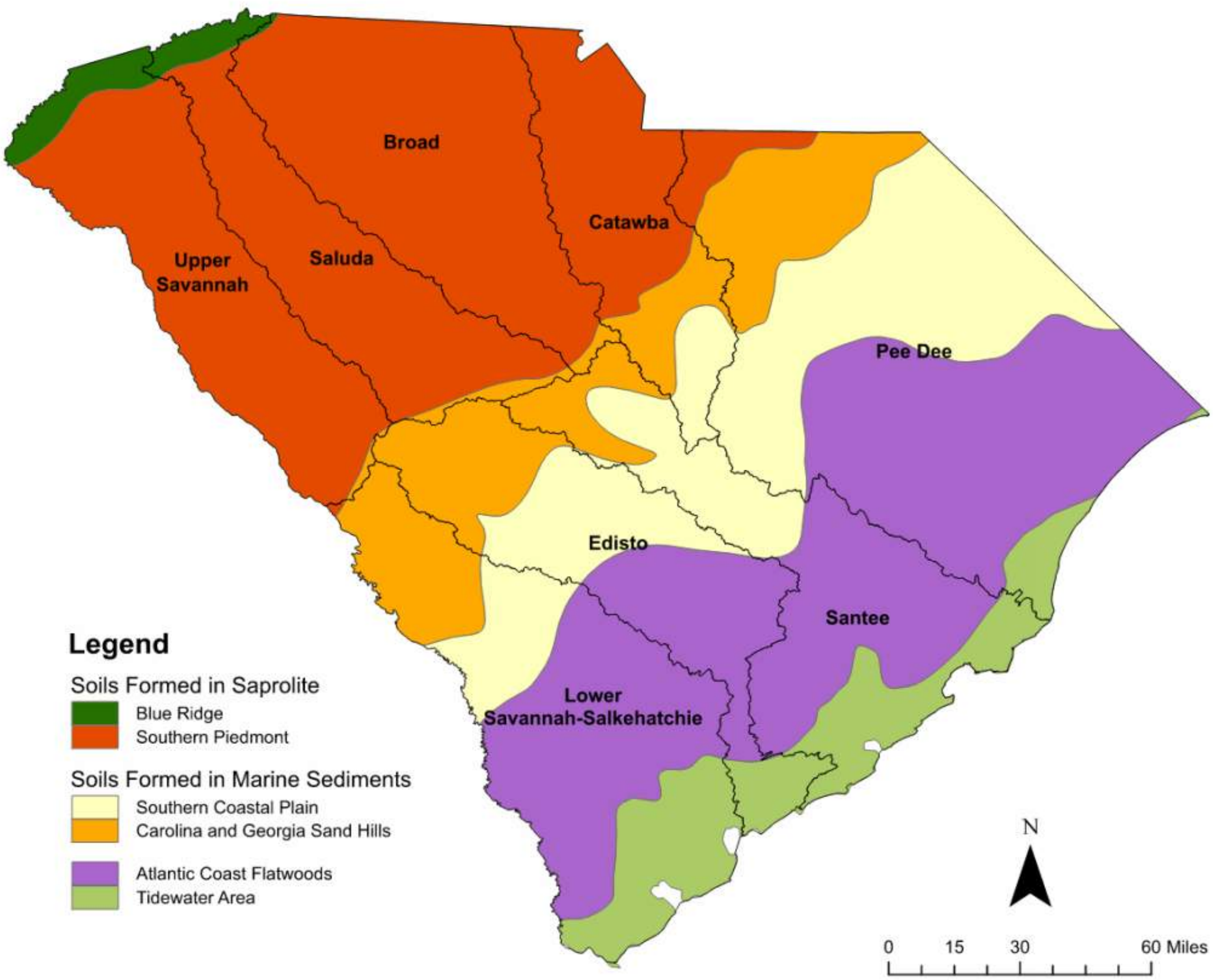


Figure 2-15. Generalized land resource and soils map of South Carolina.

2.3.2 Fish and Wildlife

The rivers and tributaries of the Broad River basin are home to 86 species of freshwater fish, with 69 species being native to the area. Fish commonly found in the basin include the redbreast sunfish, whitefin shiner, and notchlip redhorse. Some introduced species, such as the flathead catfish, prey on or outcompete native fishes. A few fish species have been successfully reintroduced to the Broad River, such as the robust redhorse, as shown in Figure 2-16. Between 2004 and 2013, SCDNR, in a cooperative effort with U.S. Fish and Wildlife Service, South Carolina Electric & Gas (now known as Dominion Energy), and Duke Power (now known as Duke Energy), stocked 72,000 5-inch fingerlings to reestablish populations in the Broad River basin (Bettinger 2022). Since 2015, eight juvenile robust redhorse have been collected that were determined to be wild-spawned individuals (SCDNR 2023a).

Figure 2-16. Representative aquatic species in the Broad River basin (Bettinger 2022).

Mussels are abundant in the Lower Broad River; however, they are rare in the upper reaches of the river because of poor substrate conditions. A recent mussel inventory conducted by SCDNR identified seven different mussel shell forms in the basin (Bettinger 2022).

The Broad River basin is recognized as an excellent destination for recreational fishing of smallmouth bass. Smallmouth bass were stocked in the early 1980s and nonnative species were successfully established shortly after. Other sportfish in the basin include largemouth bass, panfish, and river bullhead (Bettinger 2022).

The Broad River basin provides habitat to numerous rare, threatened, and endangered species. In the counties with at least a portion of their areas in the basin, there are 11 federally endangered species, 7 federally threatened species, and 15 at-risk spices (SCDNR 2023b). Additionally, there are 36 species protected by the Migratory Bird Treaty Act. The bald eagle, protected by the Bald and Golden Eagle Protection Act, has been noted in 10 counties in the basin. The basin is home to six state-listed endangered species, eight state-listed threatened species, and six state-listed regulated species. State and federal endangered and threatened species in the counties covering the basin are listed in Table 2-7.

Table 2-7. Federal- and state-listed endangered and threatened species in Broad River basin counties (SCDNR 2023b).

Federal Endangered	Federal Threatened	State Endangered	State Threatened
Shortnose Sturgeon	Wood Stork	Wood Stork	Bald Eagle
Schweinitz's Sunflower	Smooth Purple Coneflower	Shortnose Sturgeon	Spotted Turtle
Rusty-Patched Bumble Bee	Dwarf-Flower Heartleaf	Bewick's Wren	American Peregrine Falcon
Carolina Heelsplitter	Pool-sprite, Snorkelwort	Rafinesque's Big-Eared Bat	Pine Barrens Treefrog
Red-Cockaded Woodpecker	Swamp Pink	Red-Cockaded Woodpecker	Bog Turtle
Rock Gnome Lichen	Small Whorled Pogonia, Little Five-Leaves	Carolina Gopher Frog	Carolina Pygmy Sunfish
Pocosin Loosestrife, Rough-Leaf Loosestrife	Northern Long-Eared Bat	-	Eastern Small-Footed Bat
Bunched Arrowhead	Monkey-Face Orchid, White Fringeless Orchid	-	Southern Hog-Nosed Snake
Canby's Cowbane	-	-	-
Mountain Sweet Pitcherplant	-	-	-
White Irisette, Isothermal Irisette	-	-	-

2.3.3 Natural and Cultural Preserves

The Broad River basin is well known for its natural and cultural resources. The South Carolina Heritage Trust program was founded in 1974 to protect 1) critical natural habitats that tracked species depend on, and 2) significant cultural sites. There are 9 natural and cultural preserves designated by the South Carolina Heritage Trust program within the Broad River basin (SCDNR 2019b):

- Chestnut Ridge Heritage Preserve / Wildlife Management Area – Owned and managed by SCDNR, the 2,000-acre Chestnut Ridge Heritage Preserve bears the name of a prominent mountain within its boundaries. The natural preserve harbors the white irisette, *Sisyrinchium dichotomum*, a perennial designated as federally endangered.

- Clear Creek Heritage Preserve – The natural preserve comprises 19 acres and contains the state's second-most important population of the rare plant species, bunched arrowhead. Known to occur in less than a dozen populations worldwide, bunched arrowhead is listed as endangered under the U.S. Endangered Species Act. Dense populations of these plants are found in three seepage areas on the property. Besides bunched arrowhead, the preserve harbors two species of state concern: green adder's mouth and kidneyleaf twayblade.

- Blackwell Heritage Preserve – The 72-acre Blackwell Heritage Preserve is located within an intricate network of springs and small streams that drain hilly topography bordering the narrow floodplain of the Enoree River. This produces constant groundwater seepage and extensive saturated soil conditions, which are quite rare in the Upstate and are classified as Piedmont seepage forests. The natural preserve is home to the endangered bunched arrowhead flower.

- Bunched Arrowhead Heritage Preserve – The natural preserve covers 178.7 acres of grassy fields, brushy fields, upland pine-hardwoods, and bottomland hardwoods. This preserve was purchased for the protection of the federally listed as endangered bunched arrowhead plant and two other rare plants, the climbing fern and dwarf-flowered heartleaf.

- Belvue Springs Heritage Preserve – The 28-acre natural preserve is entirely wooded. More than 70 percent of the land is wetlands that include Piedmont seepage forest and beaver impoundments. The preserve exemplifies an upland Piedmont seepage forest, which contains a unique assemblage of rare, peripheral, and disjunct species.

- Peter's Creek Heritage Preserve – The 160-acre natural preserve in Spartanburg County comprises Piedmont cove forest, with rolling topography; an old mill dam; two creeks; and walking trails. The preserve includes hardwood bluffs and slopes along Peters Creek, Mineral Springs, and an unnamed stream. These hardwoods provide stream and bluff-side conditions suitable for the second-largest-known population of dwarf-flowered heartleaf, *Hexastylis naniflora*, a species federally listed as threatened.

- Pacolet River Heritage Preserve – Composed of 278 acres in Spartanburg County, SC, the cultural preserve protects two Native American soapstone quarries. Early residents of the state came here between 3000 and 1100 BC to obtain material from which they made bowls, pipes, and other necessities. The preserve also protects two uncommon plant species, a moss and a leafy liverwort.

- Fish Dam Ford Heritage Preserve – The 143-acre cultural preserve was designated to protect the Fishdam Ford battle site at the border of Chester and Union Counties. The Indian fish dam from which the name is derived can be seen during low water upriver from the highway bridge.

- Nipper Creek Heritage Preserve – Located in Richland County, SC, this 90-acre archaeological preserve was occupied by Paleo-Indian occupants most heavily during the Archaic period, 8000 BCE to 2000 BCE. It is listed on the National Register of Historic Places. The cultural preserve's value lies in the stratified "layer cake" deposits, which produce information on past human lifestyles such as diet, technology, mobility, and social organization.

There are six state parks in the Broad River basin: Battle of Musgrove Mill State Historic Site, Chester State Park, Croft State Park, Kings Mountain State Park, Paris Mountain State Park, and Rose Hill Plantation State Historic Site. National historic Revolutionary War sites, such as the Cowpens National Battlefield and Kings Mountain National Military Park, are also located in the basin. The Enoree Ranger District of the Sumter National Forest is completely contained by the basin.

As previously mentioned, a segment of the Broad River between the Ninety-Nine Islands Dam to the confluence with the Pacolet River was designated a State Scenic River in May 1991. Like other stretches of the river, this 15-mile section is noted for its diverse plant and animal life spotted with human-made structures on the National Register of Historic Places. Major environments in the scenic river area include levee and bottomland forests, upland pine forests, needle-leafed evergreen forests, hardwood forests, and pine-mixed hardwood forests (SCDNR 2003).

2.4 Agricultural Resources

2.4.1 Agriculture and Livestock

Historically, farming, including the production of both crops and livestock, has had a strong presence in the basin. While agricultural land has been gradually replaced with urban development along the I-85 corridor, a significant agricultural economy is present elsewhere in the basin. Farms in the Broad River basin are nationally known for their peach production. Other important agricultural commodities in the area include berries and turkey/poultry (U.S. Department of Agriculture [USDA] NASS 2017). USDA's NRCS, which inventories land that can be used to produce the nation's food supply, has categorized 43.5 percent of the basin as prime farmland or farmland of statewide importance, as shown in Table 2-8 (USDA NRCS n.d.). Prime farmland is defined by the USDA as the land with the best combinations of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is available for these uses. It has an adequate and dependable supply of moisture from precipitation or irrigation, a favorable temperature and growing season, and a water supply that is dependable and of adequate quality. It also is not excessively erodible or saturated with water for long periods and has slopes mainly ranging from 0 to 6 percent. Farmland of statewide importance is land that nearly meets the requirements of prime farmland and that can economically produce high-yield crops when treated and managed with acceptable farming methods. The distribution of the farmland types across the basin are shown in Figure 2-17. The prime farmland and farmland of statewide importance can be found throughout the basin.

As of March 2023, there were 921 permitted livestock operations in the Broad River basin (SCDHEC 2023b). Turkey accounts for over 62 percent of the total operations, followed by other poultry. Figure 2-18 shows that the highest concentrations of livestock operations in the Broad River basin are along the perimeter of the basin, with the type of livestock operation varying by county.

Table 2-8. Area of NRCS-categorized farmland in the Broad River basin.

Farmland Type	Acres	Square Miles	Percent of Basin
Prime farmland	585,511	915	24.0%
Prime farmland if drained	6	0	0.0%
Prime farmland if drained, and either protected from flooding or not frequently flooded during the growing season	87,307	136	3.6%
Prime farmland if protected from flooding or not frequently flooded during the growing season	67,846	106	2.8%
Farmland of statewide importance	475,612	743	19.5%
Farmland of local importance	0	0	0.0%
Not prime farmland	1,378,766	2,154	56.5%
Total	2,439,889	3,812	100.0%

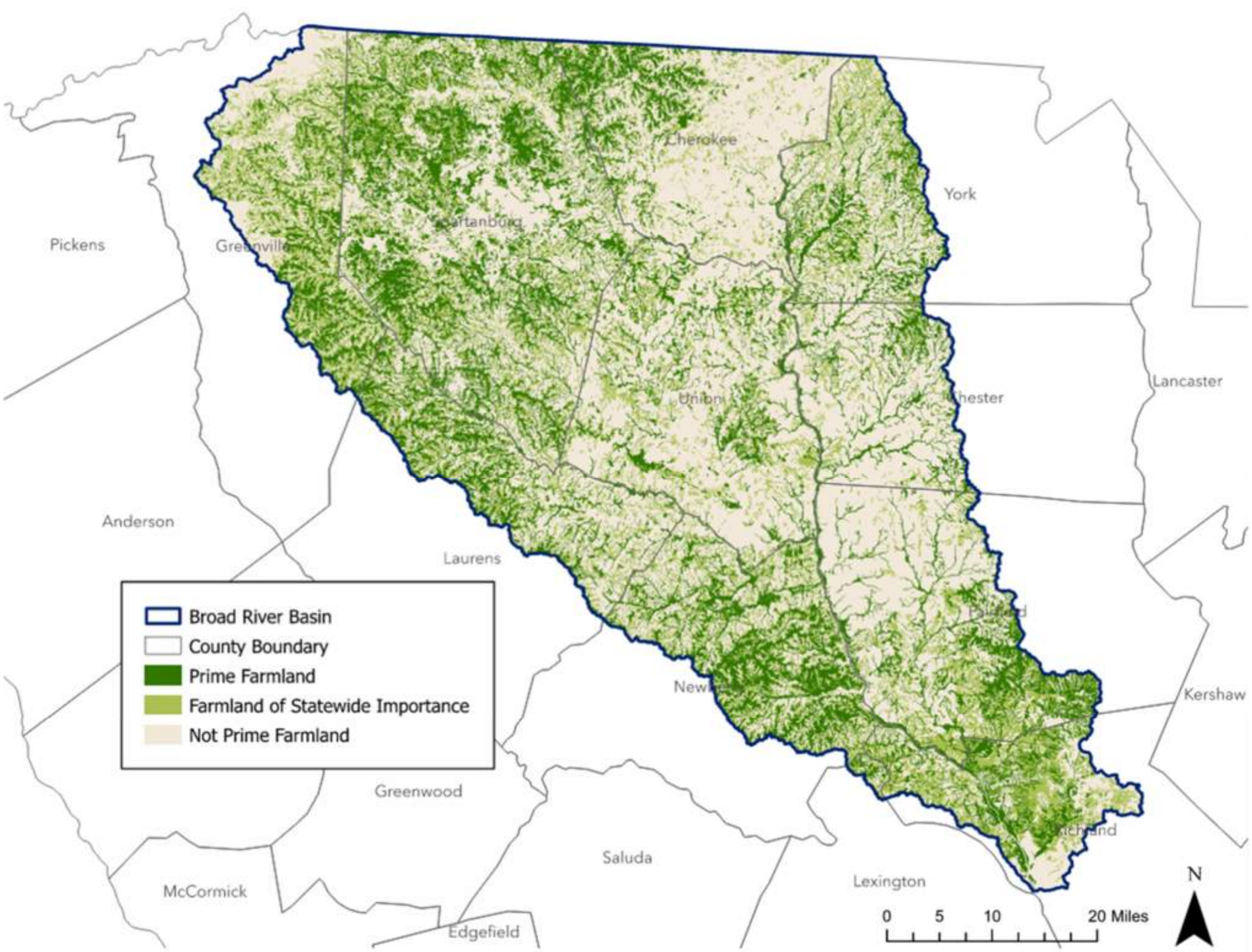


Figure 2-17. Location of NRCS-categorized farmland in the Broad River basin.

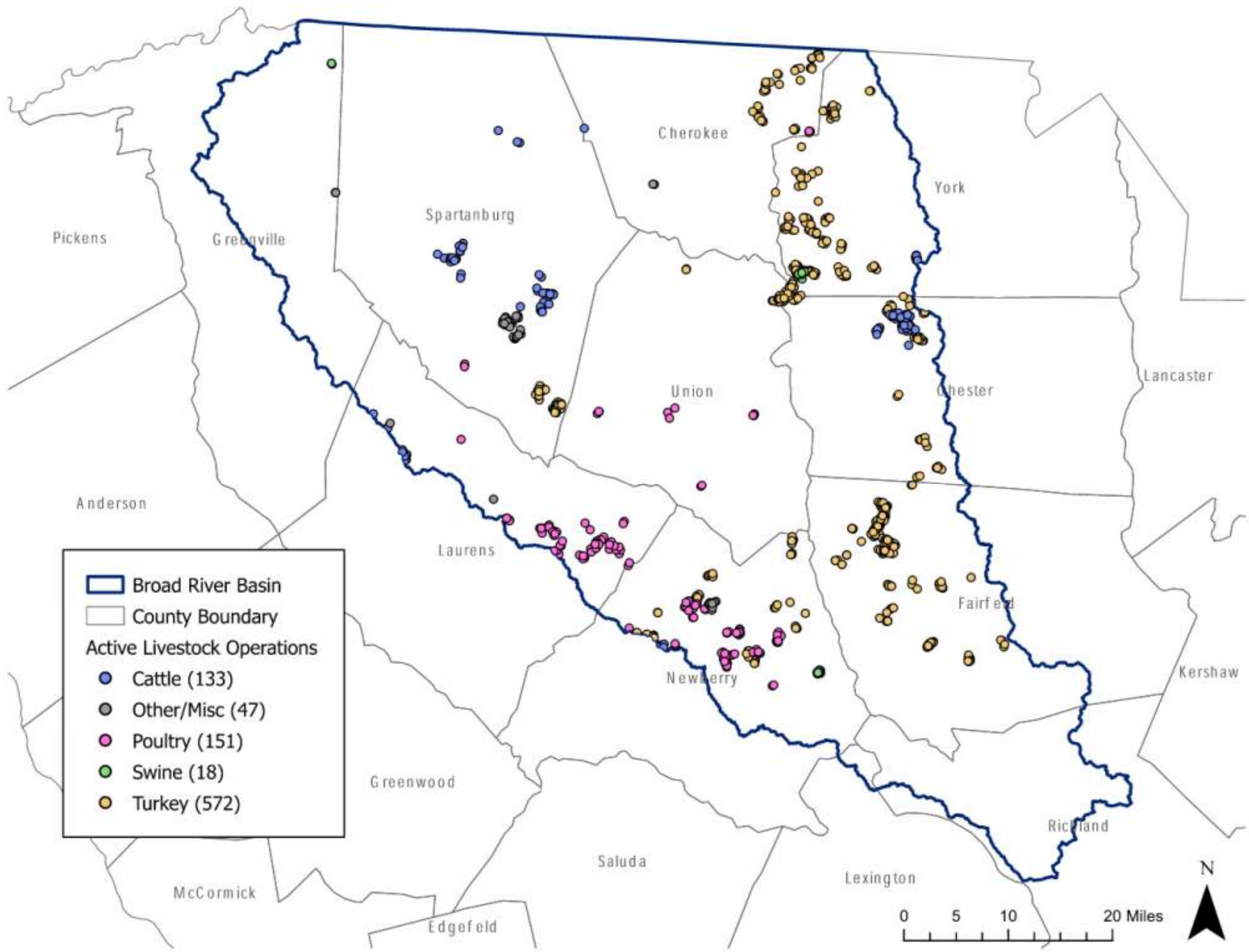


Figure 2-18. Active livestock operations in the Broad River basin.

Data from the Census of Agriculture suggest that while the number of farm operations in South Carolina has increased only slightly since 2002, irrigated acreage has increased by about 30 percent, as shown in Figure 2-19. The number of irrigated farms and irrigated acreage in the Broad River basin has increased over the years, though to a much lesser extent than the rest of the state. The reported number of irrigated farm operations and irrigated acreage for counties that intersect the Broad River basin are also summarized in Figure 2-19. In 2017 there were 481 farms and 8,516 irrigated acres in counties that intersect the Broad River basin, up from 303 farms and 7,956 irrigated acres in 1992. While counties in the basin only account for 4 percent of the state's total irrigated land, the same counties make up 23 percent of the state's total produced commodities value (USDA NASS 2017).

Additional 2017 Census of Agriculture data for Fairfield, Spartanburg, Union, and York Counties is provided in Table 2-9. These counties are included in the table because Fairfield, Spartanburg, and Union Counties make up the largest percentage of the basin, and York has the largest amount of operating farmland in the basin. The commodities with the largest harvested acreage for counties within the basin include forage hay, soybeans, corn, and cotton.

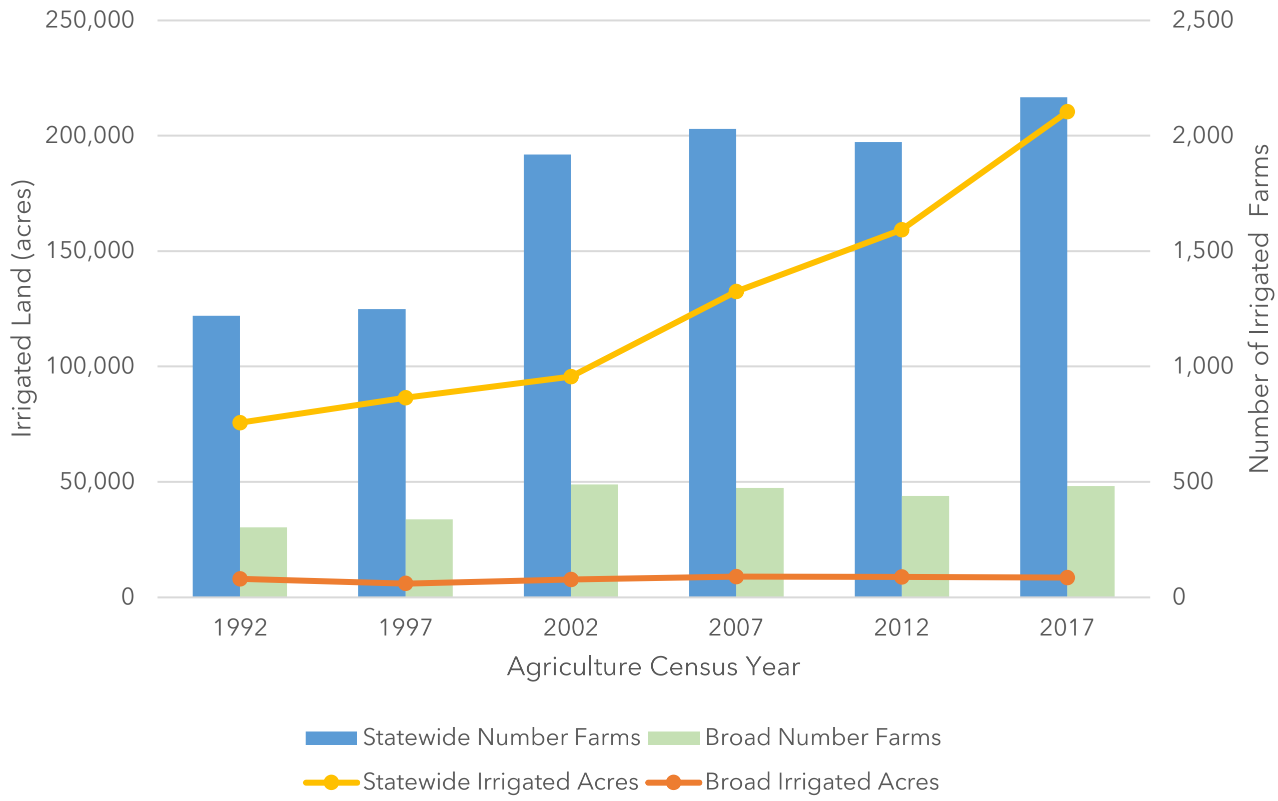


Figure 2-19. Number of farm operations and irrigated acreage for counties containing the Broad River basin and statewide, 1992 to 2017. (USDA NASS 1997, 2007, and 2017)

An agricultural water use survey conducted by Clemson in 2018 found that micro-irrigation is the most used irrigation technique in the Broad River basin, followed by solid set irrigation. Center pivot systems and other types of irrigation techniques are not commonly used in the basin (Sawyer et al. 2018). The water use survey represented a limited sample of South Carolina irrigation practices as it was based on responses from 167 participants representing practices used on 75,000 acres of irrigated land in the state. Most of respondents noted groundwater as their source of irrigation water (141), with other sources being lake/pond (29), river/stream (14), municipal (7), and recycled (2). Table 2-10 lists the irrigation techniques used by survey respondents with farming operations in the Broad River basin.

Table 2-9. Summary of 2017 Census of Agriculture for counties in the Broad River basin (USDA NASS 2017).

	Spartanburg	Union	Fairfield	York
Percentage of County Area in Broad River Basin	100.0%	100.0%	59.6%	37.3%
Total Farm Operation (acres)	95,806	43,765	73,082	120,164
Total Cropland (acres)	34,338	7,268	10,767	37,882
Total Harvested Cropland (acres)	26,045	4,586	5,363	27,934
Total Irrigated Land (acres)	1,830	40	222	1,160
Total Corn (Grain) Harvested (acres)	452	D	230	185
Total Corn (Silage) Harvest (acres)	200	–	–	–
Total Wheat Harvested (acres)	1,375	–	240	1,775
Total Soybeans Harvested (acres)	3,454	D	–	618
Total Cotton Harvested (acres)	–	–	–	5,818
Total Hay and Haylage Harvested (acres)	16,731	3,747	4,328	18,291
Total Vegetables Harvested (acres)	395	D	227	259
Total Orchards Harvested (acres)	2,516	241	5	149
Total Peaches (acres)	2,069	D	–	36
Total Berries (acres)	317	D	D	43
Total Cattle Operations (#)	460	132	81	403
Total Turkey Operations (#)	29	4	6	9
Total Hogs Operations (#)	67	9	7	34
Total Sheep Operations (#)	24	4	7	32
Total Chicken Layers (egg) Operations (#)	250	30	19	141
Total Chicken Broilers (meat) Operations (#)	14	2	1	8
Total Commodity Sales ($ million)	31	10	17	101
Total Crop Sales ($ million)	21	1	2	63
Total Animal Sales ($ million)	9	9	15	37

D = Not shown to avoid disclosure of confidential information; estimates are included in higher-level totals

Table 2-10. Irrigation techniques used in the Broad River basin (Sawyer 2018).[1]

General	Precision	High Efficiency
Center Pivot – Fixed Rate	Center Pivot – Variable Rate	Drip – Surface
Traveling Gun		Drip – Subsurface
Solid Set		Micro-irrigation
Portable Pipe		
Other (not specified)		

[1] Center Pivot – Fixed Rate with best nozzle technology (a high-efficiency type) may also be used; however, this category was not included in the survey.

2.4.2 Silviculture

While not as prominent as other industries, silviculture plays a significant role in the Broad River basin. Timber production values for 2019 are summarized in Table 2-11 (South Carolina Forestry Commission 2022). Harvested timber values are categorized as stumpage, which is the value of standing trees "on the stump," or delivered, which is the value of trees when they are delivered to the mill and considers all costs associated with cutting, preparing, and hauling timber to the plant. Of the 46 counties in South Carolina, Fairfield County is ranked eighth for delivered timber value.

Table 2-11. Value of timber for counties in the Broad River basin and state total.

County	Acres of Forestland	Percent Forest	Harvest Timber Value (in Millions)		Delivered Value Rank
			Stumpage	Delivered	
Cherokee	182,798	75%	1.4	3.2	44
Chester	307,422	85%	9.3	19.2	18
Fairfield	401,239	88%	11.6	28.2	8
Greenville	218,555	46%	1.7	4.1	42
Laurens	335,129	74%	6.0	13.9	30
Newberry	341,564	80%	10.7	24.0	12
Richland	304,311	66%	5.7	13.6	32
Spartanburg	214,059	41%	3.2	7.3	40
Union	258,988	82%	6.3	14.7	27
York	264,181	59%	4.3	9.3	39
Statewide	12,849,182	66%	446.0	881.0	–

Based on 2020 estimates from the South Carolina Forestry Commission (2022).

2.4.3 Aquaculture

Limited data are available on aquaculture in the basin; however, the 2017 Census of Agriculture lists Richland County (27 percent of county in the Broad River basin) as having four aquaculture farms for catfish, ornamental fish, other food fish, and sport or game fish. Newberry County (51 percent of county in the Broad River basin) also has two aquaculture farms, both of which grow sport or game fish (USDA NASS 2017).

2.5 Socioeconomic Environment

2.5.1 Population and Demographics

Overall, the Broad River basin is the third-most populated basin in South Carolina. The Broad basin covers 12 percent of the state's land area and contains 17 percent of its population. The basin's estimated 2020 population of 890,000 increased by about 11 percent since 2010.

The Broad River basin comprises a diverse mix of rural and urban areas. Major urban areas are typically found along the I-85 corridor in the northern half of the basin and the area outlying the state capital in the basin's southern extremity. This development pattern is illustrated in Figure 2-20, which shows the basin's population density by census block group. Urban areas include Spartanburg (population of 38,401, with 330,000 in the metropolitan area), Greer (38,865), Gaffney (12,424), Taylors (23,107), and other portions of the Greenville and Columbia metropolitan areas (U.S. Census Bureau 2020).

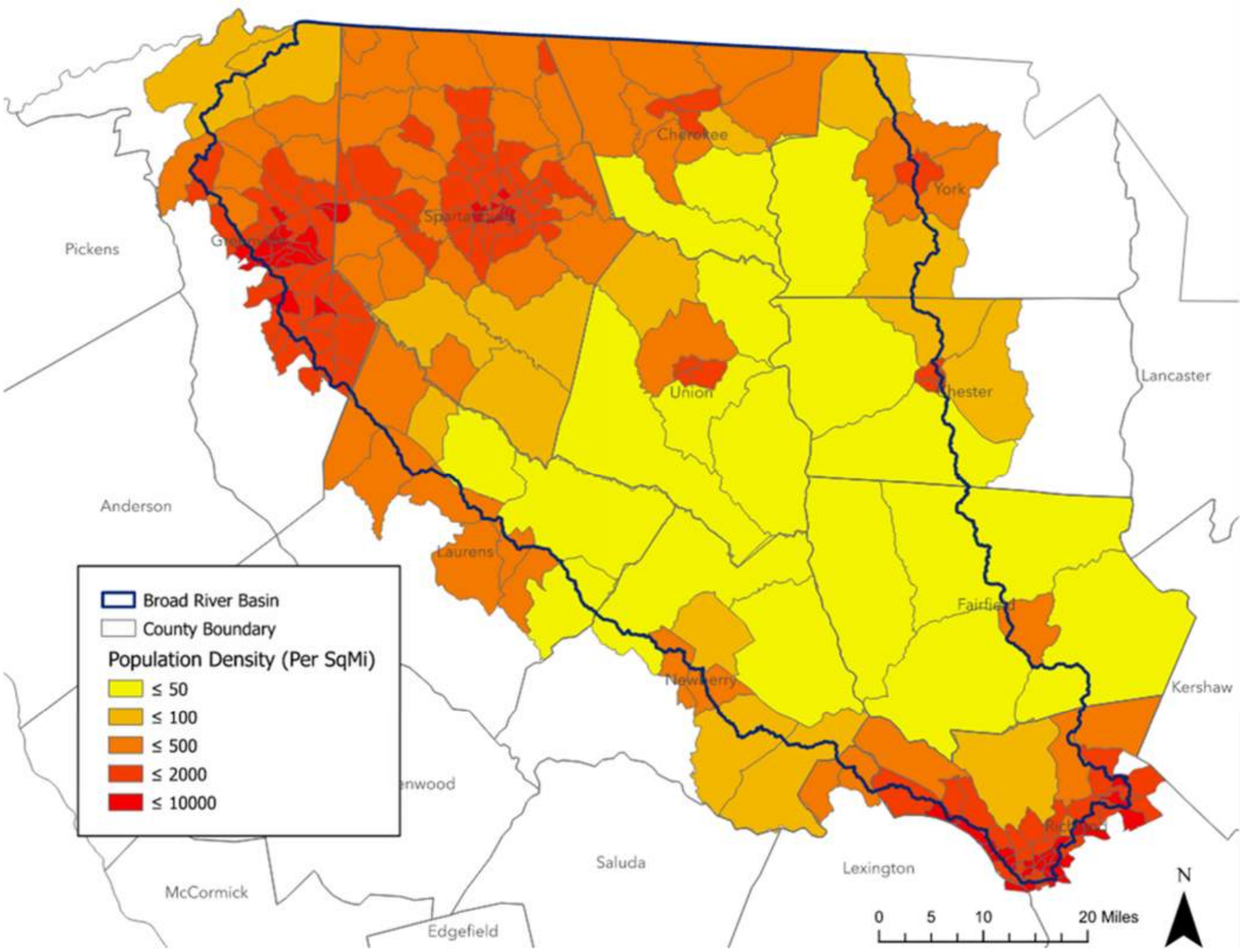


Figure 2-20. Population density of the Broad River basin by census block group (U.S. Census Bureau 2020).

Most of the recent population growth in the Broad River basin has occurred along the I-85 corridor between Greenville and Spartanburg and the outlying areas of Columbia. Elsewhere, population growth in the basin has been modest or negative. Figure 2-21 shows the 10-year population change by census block group (U.S. Census Bureau 2020).

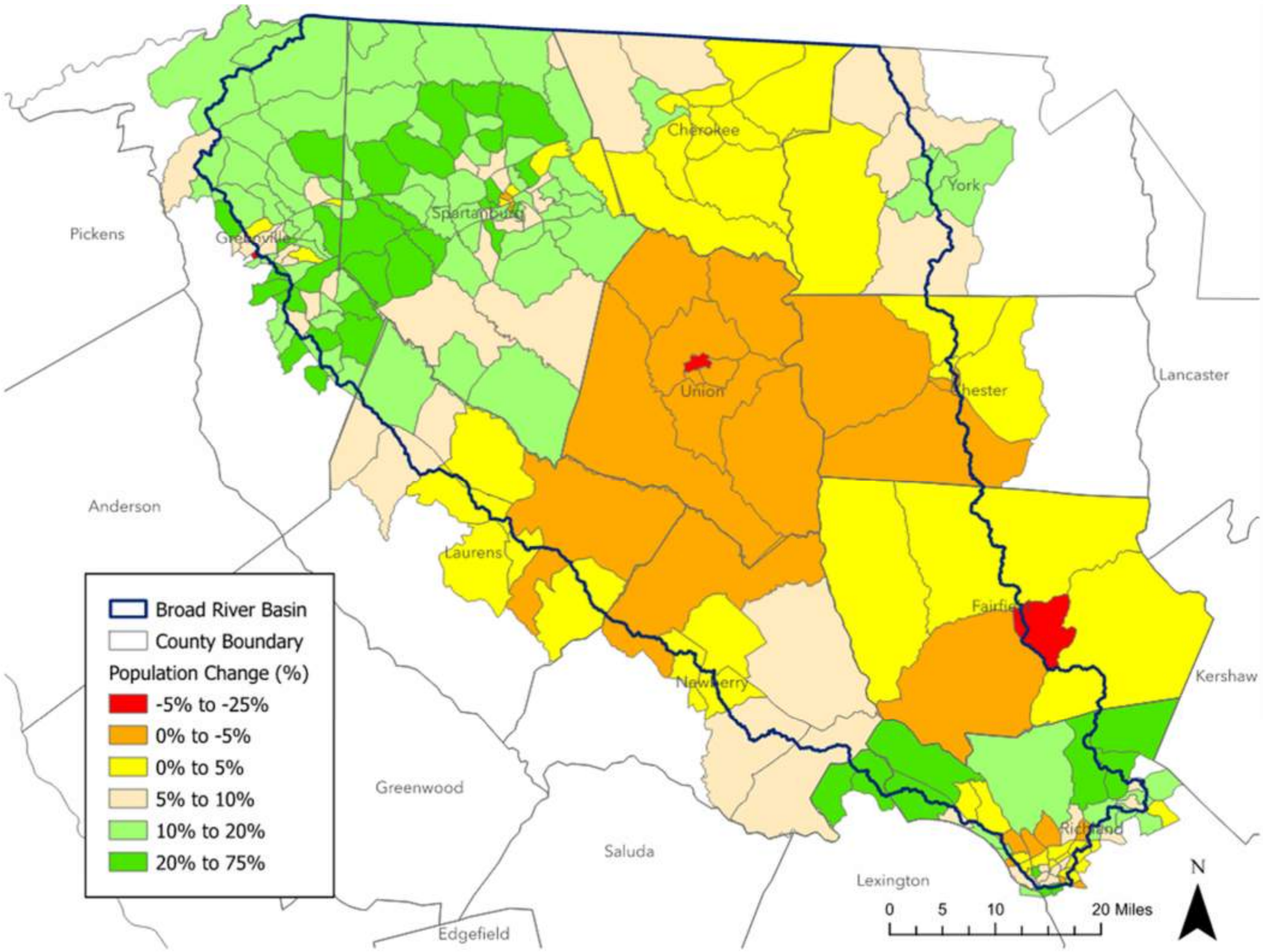


Figure 2-21. Population change from 2010 to 2020 by census block group (U.S. Census Bureau 2020).

The 2020 per capita income of counties that are partially or fully within the basin ranges from $36,567 for Cherokee (43rd highest out of 46 counties in the state) to $52,213 for Greenville (fourth highest in the state) (U.S. Bureau of Labor Statistics [BLS] 2021). The average per capita income of all counties that are partially or fully in the basin is $43,506, which is slightly below the statewide 2020 per capita income of $48,021 (BLS 2021). The percentage of population below the poverty line for counties that intersect the basin ranges from 18.4 percent for Laurens (15th highest out of 46 counties) to 8.8 percent for York (the lowest in the state) (SC Revenue and Fiscal Affairs Office 2020). The average percentage of population below the poverty line for all counties that intersect the basin is 21 percent, which is approximately 50 percent higher than the state average of 13.8 percent.

2.5.2 Economic Activity

The 2021 gross domestic product (GDP) associated with the variety of industries present in Spartanburg, Union, and Fairfield Counties is shown in Table 2-12. Data is shown for these three counties because they cover the largest percentages of Broad River basin. The combined GDP for all counties that intersect the basin is also included in Table 2-12, but there are many cases where an industry subtype cannot be calculated because at least one county does not disclose a GDP estimate. The GDP for all 11 counties that intersect the basin are provided in Appendix A. Intermediate goods, which are goods or services used in the production of final goods or services, are not included in the GDP. Several industries, such as agriculture and manufacturing, rely heavily on the water resources of the Broad River basin. The distribution of employment by industry sector for counties that intersect the basin is shown in Table 2-13 (U.S. Bureau of Economic Analysis 2018).

Table 2-12. 2021 GDP of select counties in the Broad River basin (in millions of dollars).

Industry Type	Combined Counties[1]	Spartanburg	Union	Fairfield
All industry total	110,000	18,000	850	1,200
Private industries	93,000	15,000	690	1,100
Agriculture, forestry, fishing, and hunting	260	17	9	7
Mining, quarrying, and oil and gas extraction	100 [2]	36	0	4
Utilities	1,700 [2]	35	13	410
Construction	4,700	930	16	12
Manufacturing	17,000	4,500	230	97
Durable goods manufacturing	10,000	3,200	160	65
Nondurable goods manufacturing	6,900	1,300	71	32
Wholesale trade	10,000 [2]	1,700	13	170
Retail trade	7,000	1,300	52	35
Transportation and warehousing	2,500 [2]	900	78	(D)
Information	3,700	250	7	10
Finance, insurance, real estate, rental, and leasing	19,000	2,300	190	190
Finance and insurance	6,100	590	13	9
Real estate and rental and leasing	13,000	1,700	170	180
Professional and business services	13,000 [2]	1,500	23	86
Professional, scientific, and technical services	10,000 [2]	610	7	(D)
Management of companies and enterprises	1,900 [2]	270	2	(D)
Administrative and support and waste management and remediation services	4,800 [2]	610	14	43
Educational services, health care, and social assistance	8,100	940	17	37
Educational services	1,000 [2]	180	(D)	4
Health care and social assistance	7,100 [2]	760	(D)	33
Arts, entertainment, recreation, accommodation, and food services	3,600 [2]	580	24	(D)
Arts, entertainment, and recreation	500 [2]	46	(D)	(D)
Accommodation and food services	3,100 [2]	540	(D)	(D)
Other services (except government and government enterprises)	2,200	390	19	13
Government and government enterprises	15,000	2,500	160	110

[1] Total does not include Lexington County.
[2] Between 1 and 5 counties did not report values for industry type, combined data only includes reported data.
D = Not shown to avoid disclosure of confidential information; estimates are included in higher-level totals

Table 2-13. Percentage of employment by sector for all counties in the Broad River basin combined, 2021.

Industry Sector	Percent of Employment
Health Care and Social Assistance	13%
Manufacturing	13%
Retail Trade	11%
Accommodation and Food Services	9%
Administrative and Waste Services	9%
Educational Services	8%
Public Administration	6%
Transportation and Warehousing	5%
Professional and Technical Services	5%
Finance and Insurance	5%
Construction	4%
Wholesale Trade	4%
Other Services, Except Public Administration	2%
Management of Companies and Enterprises	2%
Information	1%
Real Estate and Rental and Leasing	1%
Arts, Entertainment, and Recreation	1%
Utilities	1%
Agriculture, Forestry, Fishing, and Hunting	<1%
Mining, Quarrying, and Oil and Gas Extraction	<1%

Chapter 3
Water Resources of the Broad River Basin

3.1 Surface Water Resources

3.1.1 Major Rivers and Lakes

The Broad River is the main stem of the Broad River basin. The Broad River headwaters originate in North Carolina, and the river joins with the Saluda River to form the Congaree River in the city of Columbia. The major tributaries of the Broad River are the Pacolet, Tyger, and Enoree Rivers. The Tyger and Enoree Rivers originate in South Carolina, while the headwaters of the Pacolet River originate in North Carolina. No other river basins flow into the Broad River basin. The Broad basin has a 3,800-sq mi drainage area in South Carolina, and an additional 1,500 sq mi of drainage area in North Carolina (SCDNR 2022e).

The three largest reservoirs in the basin in terms of surface area and storage capacity are Lake Monticello (on Frees Creek), Parr Shoals Reservoir (on the Broad River), and Lake William C. Bowen (on the South Pacolet River). Several small water supply and hydropower reservoirs are on the Broad, Pacolet, and Tyger Rivers. Most of the smaller reservoirs were built prior to streamflow monitoring and have little effect on streamflow outside of low-flow conditions (SCDNR 2009). Surface water development in the subbasin is discussed in Section 3.1.3.

Figure 3-1 shows the location of the four major subbasins, the major riverine wetland types, reservoirs, and small lakes and ponds. Freshwater forested/shrub wetlands and freshwater emergent wetlands are scattered throughout the basin.

3.1.2 Surface Water Monitoring

There are 31 active gaging stations operated by the USGS in the Broad River basin in South Carolina that report daily data: 27 of the active stations report daily mean discharge (flow) data, and the remaining 4 report daily mean stage data.

An additional 34 gaging stations are no longer active but previously collected streamflow and/or stage data. Tables 3-1 through 3-4 list the streamflow gaging stations and provide the first and last years in their periods of record, drainage areas, and select streamflow statistics through December 31, 2022 (where available). The Boiling Springs, North Carolina station on the Broad River, immediately upstream of the river entering South Carolina, is also included in Table 3-1. Gaging stations that do not report daily mean discharge data are included but do not have streamflow statistics. The locations of all the active and inactive gaging stations are shown in Figure 3-2.

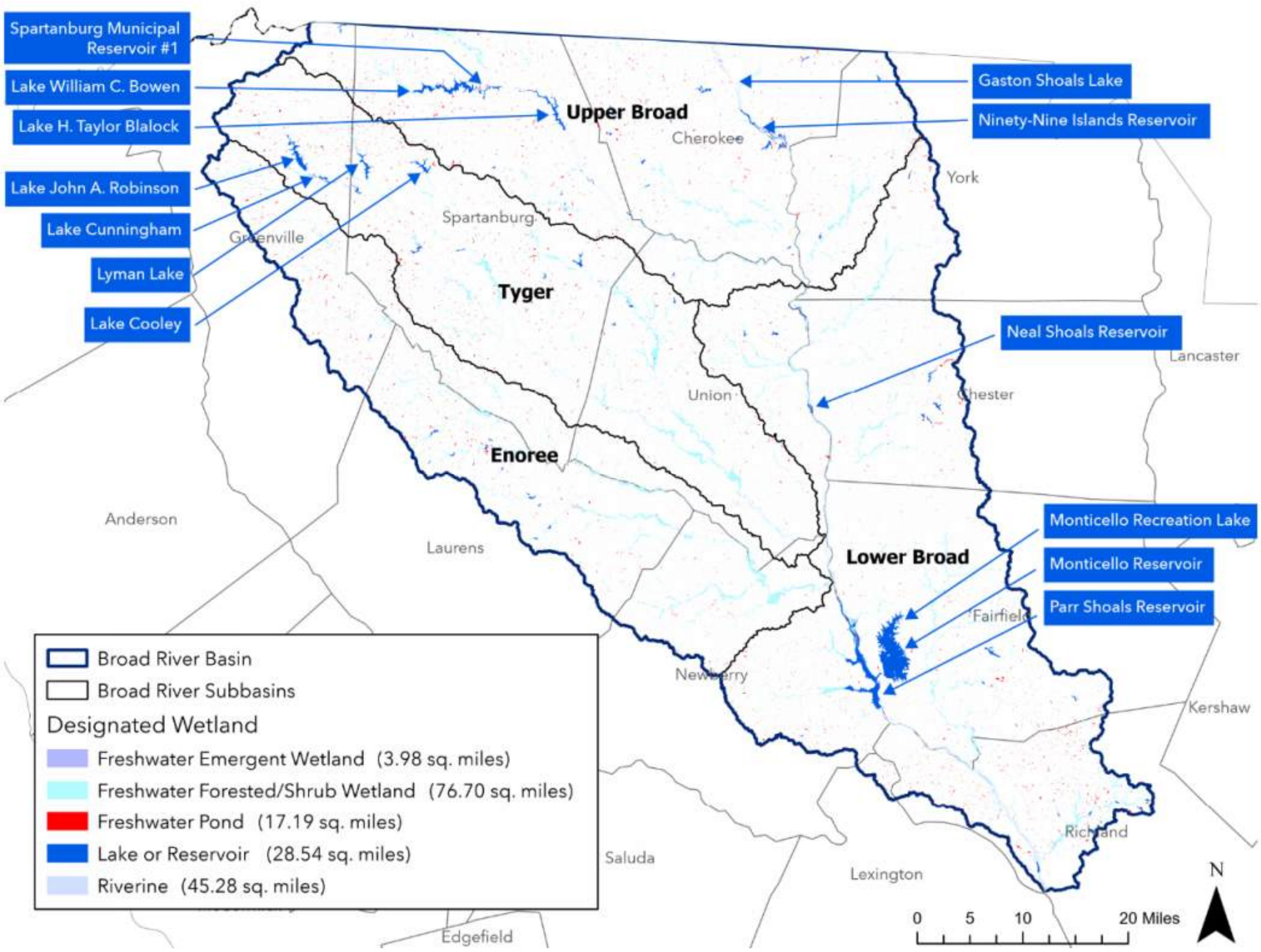


Figure 3-1. Wetland types of the Broad River basin (USFWS 2022).

Table 3-1. Streamflow characteristics at USGS gaging stations in the Upper Broad River subbasin.

Map ID	Gaging Station Name	Station Number	Period of Record	Drainage (sq mi)	Average Daily Flow (cfs)	90% Exceeds Flow[1] (cfs)	Minimum Daily Flow (cfs) and Year	Maximum Daily Flow (cfs) and Year
Upper Broad River Subbasin – HUC 03050105								
1	Broad River near Boiling Springs, NC	02151500	1925-present	875	1,465.2	526	82.8 (2002)	63,900 (1928)
2	Broad River near Blacksburg	02153200	1997-present	1,320	1,864.5	534	40.6 (2002)	51,100 (2020)
3	Broad River below Ninety-Nine Islands Reservoir	02153551	1998-present	1,550	2,069.3	567	42 (2008)	67,000 (2020)

Table 3-1. Streamflow characteristics at USGS gaging stations in the Upper Broad River subbasin (Continued).

Map ID	Gaging Station Name	Station Number	Period of Record	Drainage (sq mi)	Average Daily Flow (cfs)	90% Exceeds Flow[1] (cfs)	Minimum Daily Flow (cfs) and Year	Maximum Daily Flow (cfs) and Year
4	Kings Creek at Blacksburg	02153590	2006-2021	27.9	21.7	4.02	0.04 (2008)	1,290 (2020)
5	Gilkey Creek near Wilkinsville	021536097	2008-2013	20.4	15.8	1.01	0 (2008, 2011)	1,010 (2009) [2]
6	Broad River near Hickory Grove	02153680	2001-2003	1,650	2,089.7	380	145 (2002)	42,200 (2003)
7	Thicketty Creek at County Road 42 near Gaffney	02153700	2006-present	24.3	23.8	4.91	0.03 (2008)	550 (2020)
8	Clarks Fork Creek near Smyrna	02153780	1980-2002	24.1	20.0	2.8	0 (2002)	1,000 (1985)
9	Bullock Creek near Sharon	02153800	2000-2003	84.3	69.8	0.39	0 (2001, 2002)	2,820 (2003)
10	North Pacolet River at Fingerville	02154500	1930-present	116	200.9	75	14 (2002)	8,110 (1964)
11	South Pacolet River near Campobello	02154790	1989-present	55.4	92.1	29	5 (2008)	3,520 (2020)
12	Pacolet River near Fingerville	02155500	1929-present	212	325.3	98.5	21.6 (2008)	13,500 (1940)
13	Buck Creek near Fingerville	02155600	1966-1969	10	18.7	8	5.3 (1968, 1969)	2,500 (1698)
14	Pacolet River below Lake Blalock near Cowpens	021556525	1993-present	273	356.7	82.5	27.6 (2008)	16,100 (2020)
15	Pacolet River near Clifton	02156000	1939-1971	320	487.7	178	17 (1941)	18,200 (1940)
16	Lawsons Fork Creek at Dewey Plant near Inman	02156050	1979-2007	6.46	9.3	3.3	0.37 (2002)	420 (2003)

Table 3-1. Streamflow characteristics at USGS gaging stations in the Upper Broad River subbasin (Continued).

Map ID	Gaging Station Name	Station Number	Period of Record	Drainage (sq mi)	Average Daily Flow (cfs)	90% Exceeds Flow[1] (cfs)	Minimum Daily Flow (cfs) and Year	Maximum Daily Flow (cfs) and Year
17	Lawsons Fork Creek at Spartanburg	02156300	2012-present	74.7	118.8	34.2	15.4 (2012)	3,070 (2020)
18	Lawson Fork Creek at Treatment Plant at Spartanburg	02156301	1989-1997	75.6	136.9	57	31 (1997)	2,000 (1995)
19	Pacolet River at Pacolet	02156350	2021-present	Not reported by USGS	NA	NA	NA	NA
20	Pacolet River near Saratt	02156370	2012-present	503	791.7	194.5	96.2 (2022)	14,400 (2020)

[1] "90% exceeds flow" is the flow for which 90% of daily flows are higher and 10% are lower.

[2] The streamflow record for the Gilkey Creek near Wilkinsville gage contains estimated values on August 26 and 27, 2008, and February 5 and 6, 2010, that are considerably larger than the preceding and following streamflows. These streamflow values were not included in the calculated statistics shown here.

Table 3-2. Streamflow characteristics at USGS gaging stations in the Lower Broad River subbasin.

Map ID	Gaging Station Name	Station Number	Period of Record	Drainage (sq mi)	Average Daily Flow (cfs)	90% Exceeds Flow (cfs)	Minimum Daily Flow (cfs) and Year	Maximum Daily Flow (cfs) and Year
Lower Broad River Subbasin – HUC 03050106								
21	Turkey Creek near Lowrys	021563931	2000-2022	81.5	47.5	1.521	0 (2002)	3,930 (2003)
22	Broad River near Lockhart	02156409	1992-2012	2,720	3,335.3	1,190	158 (2011)	57,600 (1995)
23	Broad River below Neal Shoals Reservoir near Carlisle	021564493	2012-present	2,790	3,409.1	963.2	326 (2015)	56,500 (2013)
24	Neals Creek near Carlisle	02156450	1980-1996	12.3	11.5	1.5	0.27 (1987)	345 (1987)
25	Broad River near Carlisle	02156500	1938-present	2,790	3,741.3	1,140	44 (1956)	114,000 (1976)
26	Broad River at Blair	02160750	2010-2013	4,570	2,341.4	609.3	-211 (2011) [1]	17,400 (2012)

Table 3-2. Streamflow characteristics at USGS gaging stations in the Lower Broad River subbasin (Continued).

Map ID	Gaging Station Name	Station Number	Period of Record	Drainage (sq mi)	Average Daily Flow (cfs)	90% Exceeds Flow (cfs)	Minimum Daily Flow (cfs) and Year	Maximum Daily Flow (cfs) and Year
27	Hellers Creek near Pomaria	02160775	1980-1994	8.16	7.1	1.4	0.42 (1988)	360 (1992)
28	Second Creek near Pomaria[2]	02160800	1966-1975	1.87	NA	NA	NA	NA
29	Broad River near Jenkinsville	02160991	1973-present	4,750	NA	NA	NA	NA
30	Broad River at Alston	02161000	1896-present	4,790	5,790.3	1,340	48.3 (2002)	130,000 (1903)
31	Broad River at Richtex	02161500	1925-1983	4,850	6,154.7	1,880	149 (1935, 1957)	211,000 (1929)
32	West Fork Little River near Salem Crossroads	02161700	1980-1997	25.5	25.8	1.4	0 (1982, 1983)	1,810 (1991)
33	Cedar Creek near Blythewood	02162010	1966-1996	48.9	42.3	3.3	0.07 (1986)	2,910 (1994)
34	Broad River near Columbia	02162035	2011-present	5,230	5,551.6	1,410	351 (2011)	103,000 (2020)
35	Crane Creek at Columbia	02162080	1968-1974	66.5	64.5	4.9	0.1 (1970)	1,500 (1968)
36	Smith Branch at North Main Street at Columbia	02162093	1976-present	5.67	8.8	1.65	0.67 (1985)	1,710 (2015)
37	Broad River at Div. Dam at Columbia	02162100	1987-2012	Not reported by USGS	NA	NA	NA	NA

[1] The Broad River at Blair gage is on the headwaters of Parr Shoals Reservoir, approximately 7 miles upstream of Frees Creek, where the Fairfield Pumped Storage facility is located. Depending on pumped storage operation and the cooling water needs at the V.C. Summer nuclear facility on Monticello Lake, the Broad River has been observed to reverse flow at this gage location. Negative flow measurements indicate reverse flow.

[2] The Second Creek near Pomaria gage reports peak streamflow and daily precipitation.

Table 3-3. Streamflow characteristics at USGS gaging stations in the Tyger River subbasin.

Map ID	Gaging Station Name	Station Number	Period of Record	Drainage (sq mi)	Average Daily Flow (cfs)	90% Exceeds Flow (cfs)	Minimum Daily Flow (cfs) and Year	Maximum Daily Flow (cfs) and Year
Tyger River Subbasin – HUC 03050107								
38	North Tyger River below Wellford	02156999	2007-present	34.1	28.1	5.3	0.16 (2011)	813 (2013)
39	North Tyger River near Fairmont	02157000	1950-present	44.4	65.1	22	4.6 (1988)	2,630 (2020)
40	Middle Tyger River near Gramling	02157470	2002-present	32.6	50.0	13.2	2.26 (2002)	1,780 (2020)
41	Middle Tyger River below Lyman Lake, near Greer	02157475	2022-present	45.6	NA	NA	NA	NA
42	Beaverdam Creek above Greer	02157490	2002-present	15.9	21.2	5.4	0.14 (2002)	656 (2003)
43	Middle Tyger River at Lyman	02157500	1938-1967	68.3	102.6	36	5 (1955)	3,110 (1940)
44	Middle Tyger River near Lyman	02157510	2000-present	69	84.2	13	0.45 (2011)	3,390 (2020)
45	North Tyger River near Moore	02158000	1933-1967	162	233.3	76	16 (1954)	9,340 (1940)
46	Maple Creek near Duncan	021584051	1993-1994	10.2	13.4	7.1	5.5(1993)	235 (1994)
47	South Tyger River below Duncan	02158408	2001-present	94.4	123.9	25.2	8.93 (2008)	2,620 (2014)
48	South Tyger River below Lyman	02158410	1993-1995	96.3	150.4	59	15 (1993)	1,020 (1994)
49	South Tyger River near Reidville	02158500	1934-1967	106	159.8	20	5.5 (1941)	3,850 (1949)
50	South Tyger River near Woodruff	02159000	1933-1971	174	235.5	69	12 (1955)	7,480 (1936)
51	Tyger River near Woodruff	02159500	1929-present	351	465.5	146	29 (1954)	18,000 (1929)
52	Dutchman Creek near Pauline	02159600	1966-1969	8.97	11.3	5.5	3.8 (1966)	242 (1968)
53	Fairforest Creek at Spartanburg[1]	02159800	1966-1970	17	28.9	10	6.3 (1966)	567 (1967)
54	Fairforest Creek below Spartanburg	02159810	1988-1998	23.6	39.1	11	6 (1988)	1,730 (1995)

Table 3-3. Streamflow characteristics at USGS gaging stations in the Tyger River subbasin (Continued).

Map ID	Gaging Station Name	Station Number	Period of Record	Drainage (sq mi)	Average Daily Flow (cfs)	90% Exceeds Flow (cfs)	Minimum Daily Flow (cfs) and Year	Maximum Daily Flow (cfs) and Year
55	Fairforest Creek near Union	02160000	1940-1971	187	211.7	50	5 (1954)	6,740 (1964)
56	Tyger River near Delta	02160105	1973-present	759	883.2	200.8	18.4 (2008)	26,000 (1976)

[1] The Fairforest Creek at Spartanburg gage reports a streamflow of 0 cfs for the first 2 weeks of record, then increases to flows on the order of 20 to 30 cfs. The first 2 weeks of streamflow records are not included in the calculated statistics shown here.

Table 3-4. Streamflow characteristics at USGS gaging stations in the Enoree River subbasin.

Map ID	Gaging Station Name	Station Number	Period of Record	Drainage (sq mi)	Average Daily Flow (cfs)	90% Exceeds Flow (cfs)	Minimum Daily Flow (cfs) and Year	Maximum Daily Flow (cfs) and Year
Enoree River Subbasin – HUC 03050108								
57	Enoree River at Taylors	02160200	1998-2007	49.7	72.5	18	2.28 (2002)	2,000 (2003)
58	Brushy Creek near Greenville	02160325	2004-present	9.05	16.4	4.297	1.31 (2008)	735 (2020)
59	Brushy Creek near Pelham	021603257	1995-1997	13.8	26.4	10	3.9 (1997)	414 (1996)
60	Enoree River at Pelham	02160326	1993-present	84.2	152.6	49.0	16 (1999)	8,500 (1995)
61	Rocky Creek near Wade Hampton	021603273	2016-present	Not reported by USGS	NA	NA	NA	NA
62	Durbin Creek above Fountain Inn	02160381	1994-present	12.9	15.4	3.5	0.09 (2011)	800 (1995)
63	Enoree River near Woodruff	02160390	1993-present	249	357.2	105	33.7 (2002)	20,000 (1995)
64	Enoree River near Enoree	02160500	1929-1977	307	435.4	137	20 (1954)	18,300 (1929)
65	Enoree River at Whitmire	02160700	1973-present	444	520.6	143	28.4 (2008)	22,700 (1995)
66	Indian Creek above Newberry	021607224	1995-1998	62.7	64.9	6.7	2.3 (1997)	2,120 (1998)

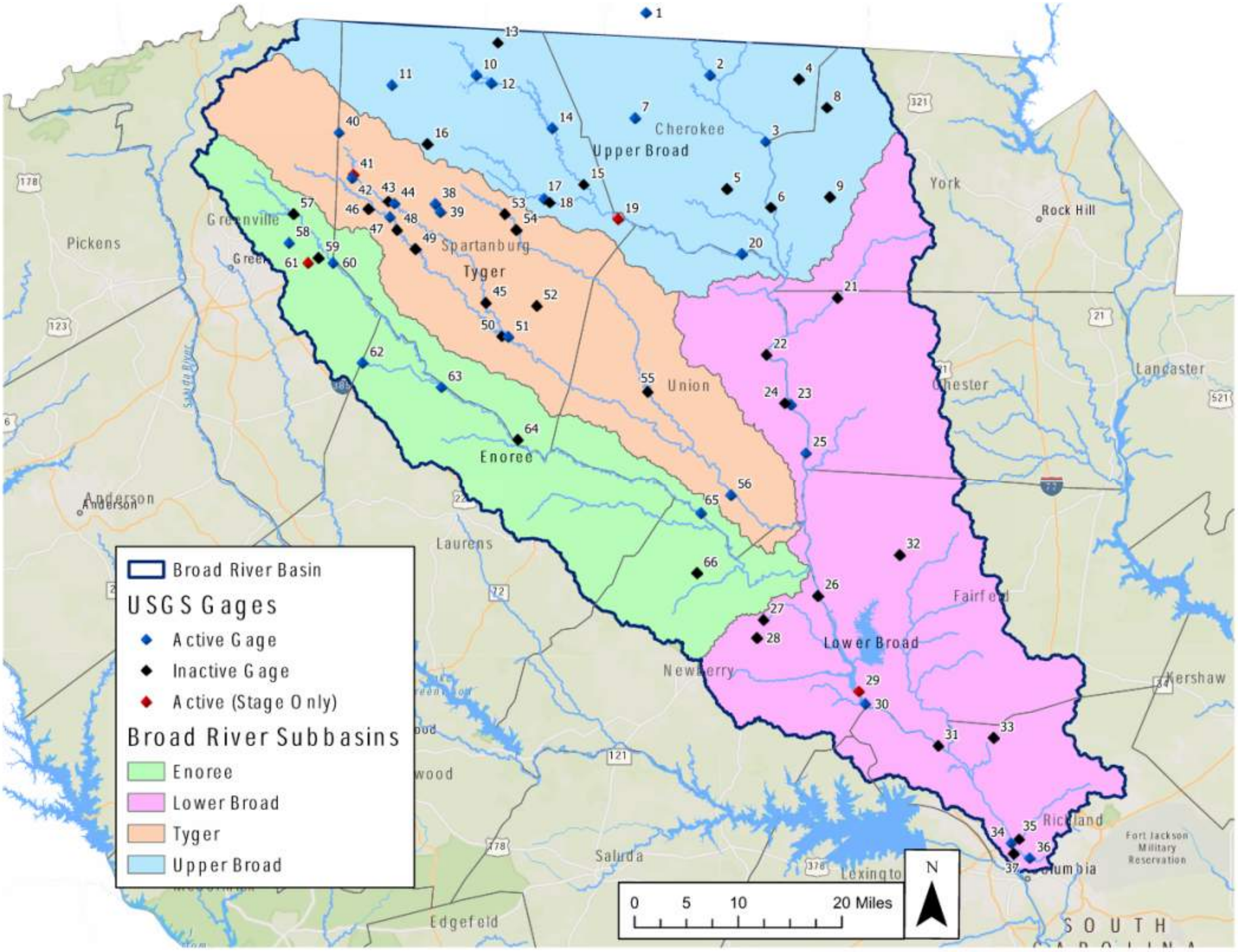


Figure 3-2. USGS streamflow gaging stations.

Duration hydrographs showing average daily streamflow throughout the year at select gaging stations in the Pacolet, Tyger, Enoree, and Broad River subbasins are shown in Figure 3-3. Mean daily flows at the selected gages exhibit similar seasonal patterns and are at their highest in March and April and lowest in August, September, and October. Mean daily flows have similar seasonal differences at three selected gages on the Pacolet, North Tyger, and Enoree Rivers. The seasonal difference in mean daily flow along the Broad River increases with distance traveled downstream. At all stations, median flows are lower than mean flows owing to the influence of occasional short-duration flood events, which can exceed 10 times the mean daily flows.

Mean monthly flows at select Pacolet and Broad Rivers gaging stations over the previous 30 years (1992 to 2022) are plotted in Figure 3-4. The fifth percentile of the mean monthly flows over the 93-year period beginning in 1929 is 90 cfs at the Pacolet River near Fingerville station. The fifth percentile of the mean monthly flows over the 84-year period beginning in 1938 is 1,071 cfs at the Broad River near Carlisle station. Mean monthly flows at both stations exhibit similar patterns, with higher flows at the Broad River station, which is farther downstream in the basin. The fifth percentile flows at the Pacolet River station are used in the graph to distinguish the periods of drought, most of which occurred during from 2007 to 2012. The period from 1999 to 2003 also experienced flows below the fifth percentile at both stations.

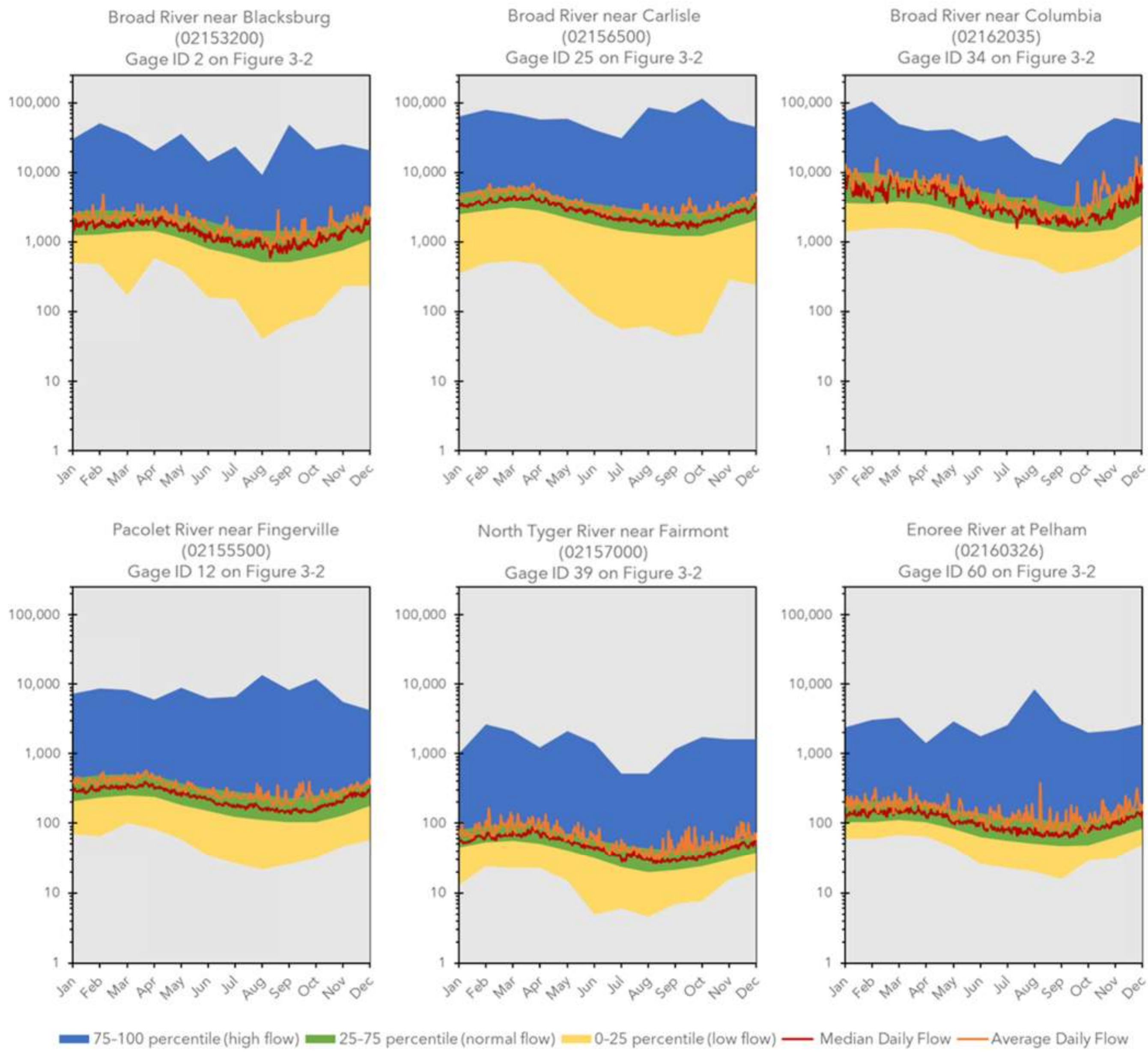


Figure 3-3. Duration hydrographs for select gaging stations on the Broad, Pacolet, North Tyger, and Enoree Rivers.

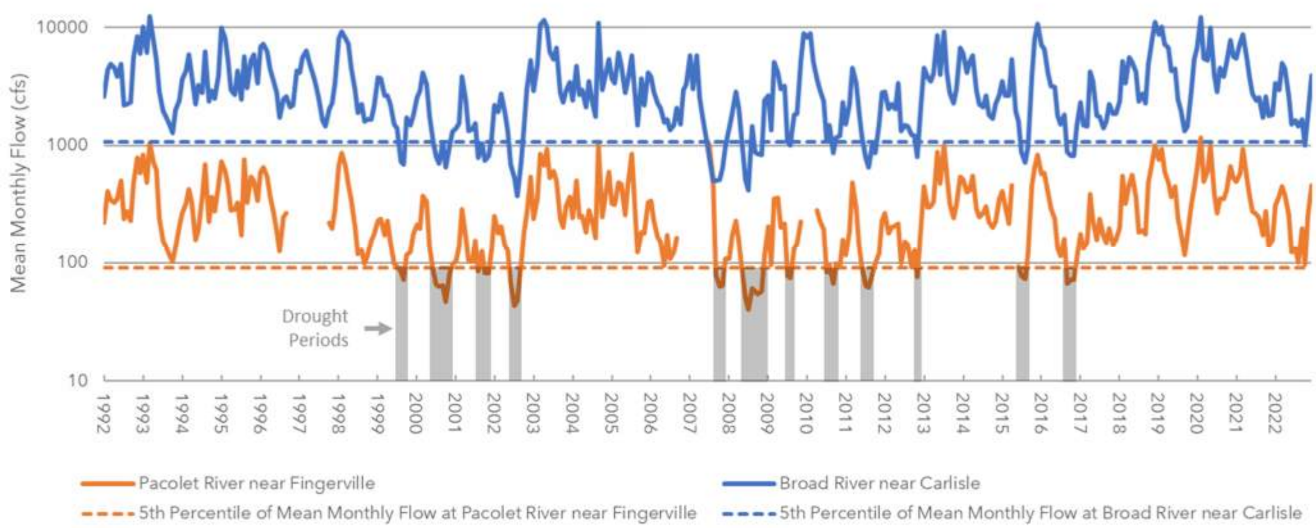


Figure 3-4. Mean monthly flows at select gaging stations on the Pacolet and Broad Rivers.

Apart from the USGS gaging stations that measure stage and flow, there are numerous sites throughout the basin where SCDHEC collects water quality data as part of their ongoing Ambient Surface Water Physical and Chemical Monitoring program to assess water suitability for aquatic life and recreational use. The program includes ongoing fixed-location monitoring and statewide statistical survey monitoring. The fixed-location monitoring includes standardized monthly collection and analysis of water from base sites for the purpose of providing solid baseline water quality data. The statistical survey sites are sampled once per month for 1 year and are moved from year to year (SCDHEC 2022c).

3.1.3 Surface Water Development

The Broad River basin has experienced surface water development primarily for hydroelectric power production, to provide municipal water supplies, and for recreational purposes. Lakes in the Broad River basin that are larger than 200 acres are described in Table 3-5 and shown in Figure 3-1. The reservoirs listed in Table 3-5 are included in the analysis presented in later chapters. The two largest lakes in the basin, Lake Monticello and Parr Shoals Reservoir (also called Parr Reservoir), are 26 miles northwest of Columbia and were initially constructed in 1914 and 1977, respectively (SCDNR 2009). In addition to the purposes listed in Table 3-5, Parr Shoals Reservoir provides cooling water for steam electric generating facilities and previously provided cooling water for an experimental nuclear power facility in the 1960s. Monticello Lake was built to supply cooling water to the V.C. Summer nuclear power plant. The dam at Parr Shoals Reservoir was heightened in 1976 to allow for conjunctive use with Lake Monticello and to provide water for the Fairfield Pumped Storage facility. When electrical demand peaks, electricity is generated by releasing water from Lake Monticello into Parr Shoals Reservoir. When electrical demand is low, water is pumped back into Lake Monticello. The third largest lake in the basin, Lake William C. Bowen, is northwest of Spartanburg and is one of three reservoirs that supplies water to the city of Spartanburg.

Table 3-5. Characteristics of lakes 200 acres or larger in the Broad River basin.

Name	Stream	Surface Area (acres)	Gross Storage Capacity (acre-feet)	Purpose
Monticello Reservoir	Frees Creek	6,800	431,000	Power and recreation
Parr Shoals Reservoir	Broad River	4,400	32,500	Power and recreation
Lake William C. Bowen	South Pacolet River	1,534	22,700	Recreation and water supply
Lake H. Taylor Blalock	Pacolet River	1,100	16,000	Recreation and water supply
Lake John A. Robinson	Barton Creek	800	14,000	Recreation and water supply
Neal Shoals Reservoir	Broad River	575	1,492	Power
Lyman Lake	Middle Tyger River	500	6,200	Industry, recreation, and water supply
Ninety-Nine Islands Reservoir	Broad River	433	1,684	Power and recreation
Lake Cooley	Jordan Creek	330	1,320	Recreation and flood control
Monticello Recreation Lake	Frees Creek	300	6,000	Power and recreation
Spartanburg Municipal Reservoir #1	South Pacolet River	271	3,388	Recreation and water supply
Gaston Shoals Lake	Broad River	251	2,500	Power, recreation, and water supply
Lake Cunningham	South Tyger River	250	2,200	Recreation and water supply

Source: Adapted from Table 6-2 in SCDNR (2009) and from SCDNR (2022e).

One navigation project exists in the Broad River basin (SCDNR 2009). The Columbia Canal receives water from the Broad River and discharges into the Congaree River. The canal was initially constructed in 1824 and was used by barge traffic into the mid-1800s. The canal is now inactive for navigation. A hydroelectric power station was constructed on the canal in 1891 and was active until the canal and hydroelectric plant were damaged by flooding in 2015 (Columbia Water 2023). Repairs are ongoing. The canal is also used as a water supply source for the city of Columbia.

Additionally, numerous regulated and unregulated small dams create small impoundments on many of the Broad River tributaries. These are largely privately owned and are in the upper reaches of the subbasin (SCDNR 2009). Dams that are less than 25 feet high or impound less than 50 acre-feet are generally exempt from regulation in South Carolina. There are 384 SCDHEC-regulated dams in the Broad River basin, most of which are classified as Low Hazard, Class 3 dams (Table 3-6). Regulated dams are primarily clustered in the upper half of the basin and at the southeastern end of the basin near Columbia as shown in Figure 3-5.

Table 3-6. Regulated dams in the Broad River basin.

Dam Type	Number of Dams	Description
High Hazard, Class 1	110	Structure where failure will likely cause loss of life and/or serious damage to infrastructure
Significant Hazard, Class 2	53	Structure where failure will not likely cause loss of life but infrastructure may be damaged
Low Hazard, Class 3	221	Structure where failure may cause limited property damage
Total	**384**	

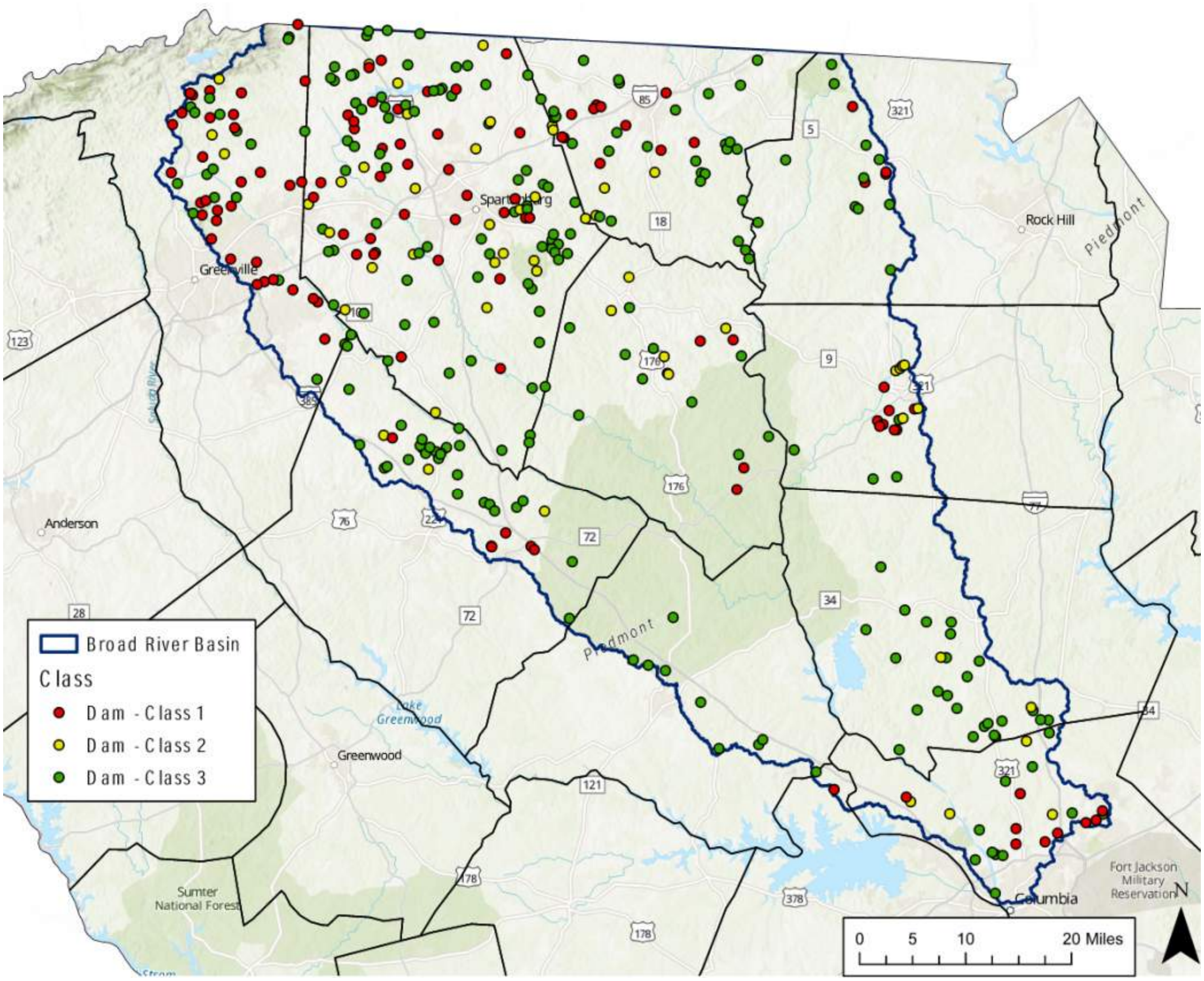


Figure 3-5. Regulated dams in the Broad River basin.

The major hydroelectric power generating facilities are listed in Table 3-7. Except for the Fairfield Pumped Storage facility on Frees Creek (adjacent to the Broad River) and the Pacolet facility on the Pacolet River, all other major facilities are located on the Broad River. Hydroelectric facilities in the basin use either a run-of-river or peaking operational pattern with defined required minimum flows (SCDNR 2022f). Minimum flows are defined seasonally for some facilities, including the Columbia, Parr Shoals, Lockhart, Ninety-Nine Islands, and Gaston Shoals hydroelectric facilities (SCDNR 2022f).

Table 3-7. Major hydroelectric power generating facilities in the Broad River subbasin.

Facility Name and Operator	Impounded stream	Reservoir	Generating Capacity (megawatts)	Water use in 2019 (million gallons)[1]
Gaston Shoals Northbrook Carolina Hydro (previously Duke Energy)[2]	Broad River	Gaston Shoals Lake	6.7	116,224
Ninety-Nine Islands Duke Energy	Broad River	Ninety-Nine Islands Reservoir	14 (authorized capacity)	395,265
Lockhart Lockhart Power Co.	Broad River	Lockhart Canal	18	692,379
Pacolet (Upper and Lower) Lockhart Power Co.	Pacolet River	Pacolet Reservoir	1.9 (authorized capacity)	155,332 (combined)
Neal Shoals Dominion Energy South Carolina (previously SCE&G)[3]	Broad River	Neal Shoals Reservoir	4.4	254,939
Fairfield Pumped Storage Dominion Energy South Carolina (previously SCE&G)[3]	Frees Creek	Monticello Reservoir	511.2	1,098,819
Parr Shoals Dominion Energy South Carolina (previously SCE&G)[3]	Broad River	Parr Shoals	14.88	516,373
Cherokee Falls Cherokee Falls Hydro Project, LLC	Broad River	No reservoir	4.14 (authorized capacity)	Not reported
Columbia City of Columbia, SC	Broad River	No reservoir	10.6 (authorized capacity)	Not reported

Source: Adapted from Table 6-3 in SCDNR (2009) and SCDNR (2022e).

[1] This water use is nonconsumptive.

[2] The Gaston Shoals facility was sold by Duke Energy to Northbrook Carolina Hydro, LLC in 2019 (Boraks 2019).

[3] The South Carolina Electric and Gas Company (SCE&G) was acquired by Dominion Energy in 2019 and now operates under the name Dominion Energy South Carolina (Columbia Business Monthly 2023).

NRCS has assisted in the planning and installation of nine flood-control projects in the basin since 1962. An additional three projects were terminated since their authorizations. Projects completed through 2005 have included 45 flood-retarding structures, 13 miles of channel improvements, erosion-control developments, and sediment-damage reduction (SCDNR 2009).

More than 99 percent of the total water withdrawals in the Broad basin in 2020 were surface water withdrawals (SCDNR 2022e). By far the greatest user of surface water that year was the thermoelectric power industry, which reported withdrawals totaling 87 percent of surface water withdrawals that year. Public water suppliers made up 12.4 percent of the surface water withdrawals and agricultural irrigation, golf courses, mining, and other industry each accounted for less than 1 percent of surface water usage.

3.1.4 Surface Water Concerns

The headwater of the Broad River and several tributaries of the Pacolet River originate in the neighboring state of North Carolina. Consequently, out-of-state withdrawals on the upper portion of the river have the potential to impact water availability in the Broad River in South Carolina. Known surface water users in the North Carolina portion of the Broad River basin include 10 public water suppliers, 5 golf courses, 3 mining sites, 3 hydroelectric power facilities, and 1 thermoelectric power facility (SCDNR 2022e).

Streamflow in the Broad River depends primarily on precipitation and surface runoff (SCDNR 2009). The upper portion of the river, near Gaffney, experiences higher annual rainfall and more significant groundwater discharges, resulting in moderately variable and well-sustained flows. Downstream flows are more variable, because of less rainfall and less groundwater discharge (SCDNR 2009). Consequently, supplies from these streams may be less reliable during periods of low rainfall. This characteristic becomes more pronounced with increased distance downstream. Streamflow characteristics of the tributaries resemble those of the main stem, with streams draining the upper portion of the basin showing the least variability and streams draining the lower portion of the basin showing the greatest variability (SCDNR 2009).

Most of the tributaries in the Broad River basin are designated as Freshwater (Class FW) streams, meaning they are suitable for aquatic life, primary- and secondary-contact recreation, drinking-water supply, fishing, and industrial and agricultural uses. Vaughn Creek, a tributary of the Pacolet River near Tryon, North Carolina, is designated as Outstanding Resource Water (Class ORW), which indicates an outstanding recreational or ecological resource that is suitable as a drinking-water source with minimal treatment (SCDNR 2009).

Water quality in the basin is generally characterized as good and has improved since the mid-1990s (SCDNR 2009). Water quality concerns have been associated with stream and river reaches in the basin that do not meet water quality standards and do not support designated uses.

Water quality monitoring conducted by SCDHEC from 2000 to 2004 demonstrated that aquatic-life uses were fully supported at 69 percent of sites (142 out of 206 sites) sampled in the basin (SCDHEC 2007). Roughly half of the sites that were not fully supporting of aquatic-life uses were impaired by macroinvertebrate community assessments. Recreational use was fully supported at 47 percent of sampled sites (96 out of 206). Sites not supportive of recreational use were all impaired by high levels of fecal coliform bacteria. More recently, the 2020-2022 Section §303(d) Clean Water Act list of impaired waters documented impairments at 95 sampling stations impacting 65 different streams and lakes in the basin, including the Broad, Enoree, Tyger, and South Pacolet Rivers (SCDHEC 2022b). A summary of the causes of impairments and the associated nonsupported designated uses is provided in Table 3-8.

Table 3-8. 2020-2022 303d Broad River basin impairment summary (SCDHEC 2022b).

Designated Use	Number of Stations with Impairments	Causes of Impairments and Number of Impairments
Aquatic Life	95	Macroinvertebrate (47) Cadmium (2) Chlorophyll A (4) Chromium (2) Copper (2) Dissolved Oxygen (4) Nickel (1) Lead (5) pH (19) Total Phosphorus (4) Turbidity (27) Zinc (2)
Recreational Use	3	*Escherichia coli* (4)

Other surface-water-related concerns have been raised by RBC members during the planning process. At the initial (March 3, 2022) RBC meeting, RBC members participated in a small group breakout session where they identified basin concerns and priorities and reported back to the full RBC. Some of the concerns identified during the initial meeting included:

- Rapid population growth and land development are a concern for the sustainability of surface water supplies to support both human and ecosystem needs.
- Droughts of increasing severity may make it difficult or impossible to continue to balance the needs of all users.
- The loss of riparian buffers and increasing development in source water areas will continue to impact water quality, erode streams, and increase sedimentation resulting in loss of reservoir storage.
- Too much surface water that is withdrawn from streams and reservoirs is lost to leaks in conveyance systems or is used inefficiently.

Near the end of the planning process, after surface water availability had been assessed and water management strategies had been identified, the RBC began discussing potential recommendations spanning technical, policy, regulatory, and legislative topics, among others. Additional surface water-related concerns were raised during the debate and discussion leading up to the recommendations. These concerns, which were not held unanimously by all RBC members, included:

- Changing climate conditions may impact water availability. Higher temperatures may cause increased evaporation from surface water. The frequency and severity of both droughts and heavy rain events causing flooding may increase.
- Increased sedimentation may reduce storage in reservoirs that are vital to public water supplies. Sedimentation may also impact water quality and lead to increased water treatment cost.

- Low flows combined with increasing wastewater discharges may result in higher nutrient loading leading to water quality impairments. This is especially a concern in the Enoree River, which has multiple wastewater discharges.
- The existing surface water laws grandfather most surface water users and are therefore not protective of the resource.
- Water law and implementing regulations distinguish between registrations and permits, resulting in different standards based on the water source used and the use category. This limits the ability to effectively manage surface water resources.

These issues are further discussed in Chapter 9, Policy, Legislative, Regulatory, Technical, and Planning Process Recommendations.

3.2 Surface Water Assessment Tools

3.2.1 SWAM Model

The SWAM model was used to assess current and future surface water availability and to evaluate the effectiveness of proposed water management strategies. From 2014 to 2017, all eight South Carolina surface water quantity models were built in the SWAM platform, including the Broad River basin model. The Broad River basin SWAM model was updated in 2021. Updates included extending the period of record to 2019, adding new permits and registrations, and removing inactive users.

SWAM uses a framework composed of a network of river reaches, impoundments, withdrawals, and returns, in which water is routed hydrologically between nodes. The model focuses principally on mainstem rivers along with primary and secondary tributaries, and often does not include smaller-order tributaries (whose flows are aggregated into flow estimates for primary and secondary tributaries). The model simulates basin hydrology at a daily or monthly timestep.

Inputs to the model include:

- Calculated and estimated unimpaired flows for the headwaters of the mainstem and tributary included in the model. Unimpaired flows were calculated by mathematically removing the historical influence of storage, withdrawals, and return flows from measured flow at USGS streamflow gaging stations. This allows the model to simulate either historical or hypothetical water use patterns for evaluating future conditions. Many of the unimpaired flow records were synthesized using standard statistical techniques where measured data were not explicitly available for river reaches or periods.
- Reach gain/loss factors, which are calibrated values used to increase flow as it moves downstream based on additional drainage area or decreased flow for losing river reaches.
- Locations of all withdrawals, return flows, and interbasin transfers (values of which are discussed below as user-adjusted variables).
- Reservoir characteristics such as capacity, bathymetry, constraints, and flexible operating rules.
- USGS daily flow records are embedded in the model for comparative purposes (simulation results can be compared with historical records).

Model variables, which can be modified by users to explore future conditions, include:

- Withdrawal targets (municipal, industrial, thermoelectric, agricultural, golf courses, hatcheries)
- Consumptive use, wastewater discharge, and other return flows (which can be estimated automatically)
- Interbasin transfers
- Reservoir operating rules and storage characteristics, if applicable
- Environmental flow targets

Using this information, the SWAM model calculates available water (physically available based on full simulated flows, and legally available based on permit conditions and other uses), withdrawals, storage, consumption, and return flows at user-defined nodes. The flow from the main river stem and major branches and tributaries are discretely quantified. Figure 3-6 shows the Broad River basin SWAM model framework. The model can be used to simulate current and future demands based on defined scenarios and identify potential shortages in water availability when compared to demands for withdrawals or instream flow targets. The scenarios that were evaluated specifically for the Broad River basin are discussed in further detail in Chapter 4, Current and Projected Water Demand, and Chapter 5, Comparison of Water Resource Availability and Water Demand.

As with all eight of the SWAM models for South Carolina, the Broad model was calibrated and then tested to demonstrate reasonable ability to recreate historical hydrology and operational conditions. Historic water uses were added into the model to alter the estimated unimpaired flows, and simulated versus gaged flows were compared at key locations throughout the basin. An example verification test result is shown in Figure 3-7. Full verification results and methods are discussed in the South Carolina Surface Water Quantity Models: Broad Basin Model report (CDM Smith 2017a).

While the SWAM model is capable of quantifying water balance calculations for free-flowing streams and reservoirs based on a number of inputs, it does have limitations. The model is not capable of performing rainfall runoff or hydraulic routing calculations and cannot be used (by itself) to calculate natural flow in tidally influenced reaches. Groundwater and its impacts are not explicitly modeled by the SWAM model; however, groundwater inputs and losses to streams and rivers are implicitly accounted for through incorporation of gage records and model calibration and verification. Water quality metrics also cannot be modeled by SWAM. Future climate scenarios can be explored with SWAM by adjusting the tributary input flows.

The model, its users guide, and the full report on model development and calibration are publicly available for download at SCDNR's website (https://hydrology.dnr.sc.gov/surface-water-models.html).

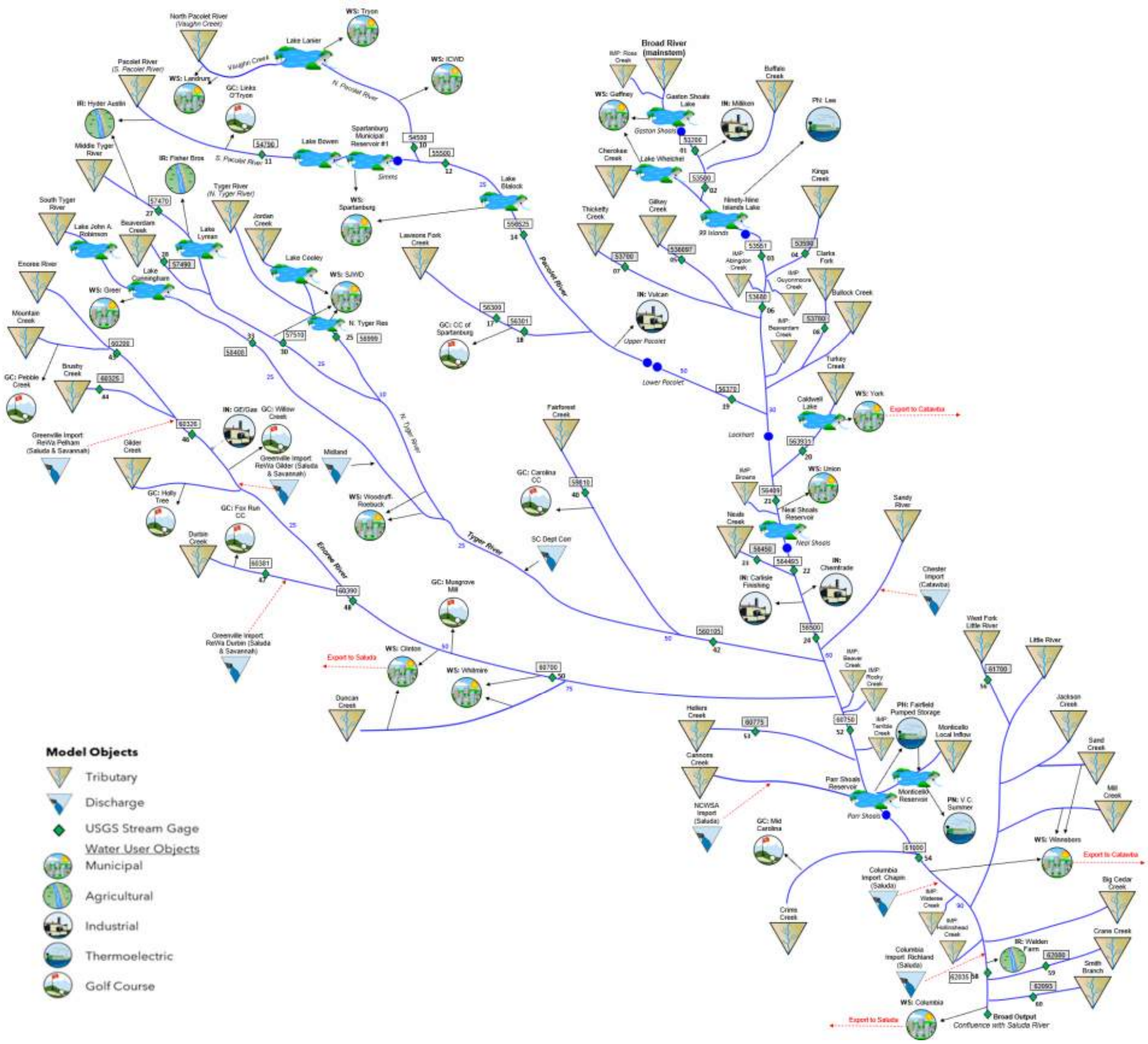


Figure 3-6. SWAM model interface for the Broad River basin.

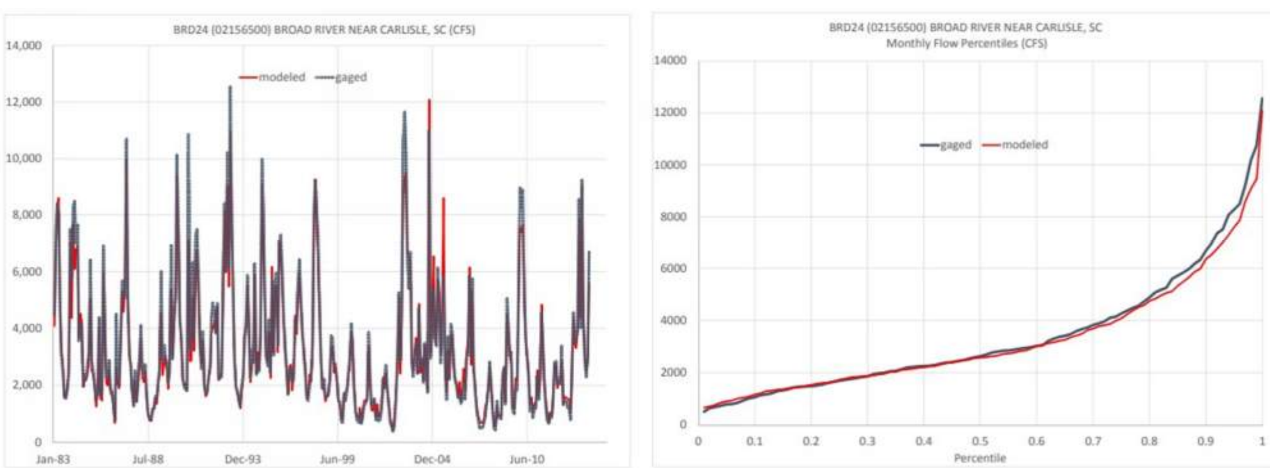


Figure 3-7. Representative Broad River basin SWAM model verification graphs (CDM Smith 2017).

3.2.2 Other Surface Water Analyses

While the SWAM models focus on the hydrology of larger mainstem rivers and primary tributaries in the Broad River basin and other South Carolina basins, other work has focused on the hydrology and flow characteristics in smaller headwater streams, specifically those that are classified as wadeable. As part of an effort to formulate relationships between hydrologic metrics (flow patterns, statistics, and variability in these streams for both pulses and long-term averages) with ecological suitability metrics, daily rainfall runoff modeling of small headwater streams throughout the state was accomplished with the WaterFALL model (Watershed Flow ALLocation model), as described in Eddy et al. (2022) and Bower et al. (2022). Separately, as discussed in Bower et al. (2022), biological response metrics were developed and combined with the hydrologic metrics from WaterFALL to identify statistically significant correlations between flow characteristics and ecological suitability for fish and macroinvertebrates. The results are intended to help guide scientific decisions on maintaining natural hydrologic variations while also supporting consumptive water withdrawals. As a component in the analysis, the WaterFALL hydrologic modeling results augment the SWAM modeling results by providing similar hydrologic understanding of the smaller headwater streams not simulated explicitly or individually in SWAM. The use of the ecological flow metrics as performance measures in the Broad RBC planning process is further discussed in Chapter 5, Comparison of Water Resources Availability and Water Demand.

3.3 Groundwater Resources

3.3.1 Groundwater Aquifers

Groundwater in the Broad River basin is primarily stored in crystalline bedrock fractures and saprolite rock, which underlie the Piedmont physiographic province (SCDNR 2009). The exception to this is the presence of Coastal Plain sediments, which constitute a shallow, sandy aquifer at the extreme southern end of the basin.

Rainfall is collected in a saprolite layer that is as thick as 150 feet, and subsequently recharges fractures in the underlying crystalline rock aquifer (SCDNR 2009). While the size and number of fractures generally diminish with depth, this appears to minimally impact well yields, which are usually less than 50 gpm; however, topography does impact well yields (SCDNR 2009). Recharge water is captured in valleys, which commonly are areas with numerous fractures in weaker rock. Consequently, wells in low-lying areas have higher yields than those on hilltops and hillsides. Higher yields in the Piedmont also occur at wells where saprolite is thick; where wells penetrate certain geologic structures like quartz veins; and where wells are placed in highly textured rock (SCDNR 2022d).

Average well yields in the Broad River basin are about 18 gpm. Groundwater availability in the basin is somewhat limited but generally adequate for domestic use and some small irrigation and industrial use (SCDNR 2009, SCDNR 2022d). Wells that are in ideal locations in terms of topography and geology can produce more than the basinwide average, with an optimum depth for maximum yields being 100 to 250 feet (SCDNR 2009). Wells drilled in crystalline rock fracture zones have higher yields than those along the fracture zone fringes, but there is generally little difference in the depths required for drilled bedrock wells when modest well yields are required. Much larger well yields of more than 1,100 gpm and about 600 gpm were observed at two geologic-core holes in Fairfield County, which were drilled to 3,500 feet and 3,900 feet, respectively (SCDNR 2009). Bored wells make up about 11 percent of the water-producing wells in the basin; these are generally shallow, do not penetrate bedrock, and draw water from the saprolite layer.

3.3.2 Groundwater Monitoring

Groundwater monitoring is performed by SCDNR, SCDHEC, and USGS. Groundwater monitoring wells are used to identify short- and long-term trends in groundwater levels and aquifer storage, and to monitor drought conditions. Statewide, the groundwater monitoring network operated by SCDNR has more than 180 wells as of 2022 (SCDNR 2022c). Most wells have hourly data automatically recorded; some are measured manually four to six times per year (SCDNR 2022c). Most of the wells have water level records dating to the 1990s, with the earliest well dating back to 1955 (SCDNR 2022c). Only 15 SCDNR wells are in the Piedmont and Blue Ridge physiographic provinces, with most in the Coastal Plain province (SCDNR 2022c). Four SCDNR monitoring wells are in the Broad basin, and all are in the northwestern portion of the basin (SCDNR 2023). Two SCDNR wells are at the same location with depths to both the shallow and crystalline rock aquifers. USGS maintains a groundwater-level monitoring network of an additional 21 wells in South Carolina (USGS 2023). Two USGS wells are in the Broad basin: SP-1581 in Spartanburg County and CTR-21 in Chester County. SCDNR and USGS groundwater monitoring wells in and near the Broad River basin are shown in Figure 3-8.

The SCDNR monitoring well in Cherokee County and near the northeastern corner of the basin, CRK-0074, has limited influence from area pumping making it suitable for use in examining the relationship between precipitation, recharge, and groundwater levels. Figure 3-9 shows groundwater levels in this well with precipitation trends recorded at the nearby Gaston Shoals, SC weather station (NOAA 2023). The bottom graph compares precipitation trends to the average annual precipitation from 1999 to 2022. The figure illustrates how the lower-than-average precipitation from 1999 to 2001 correlates to declining water levels over this same period. Levels increased sharply in response to greater-than-average rainfall in 2003. Similarly, the normal to above average precipitation from 2018 through 2021 corresponds to an increase in water levels.

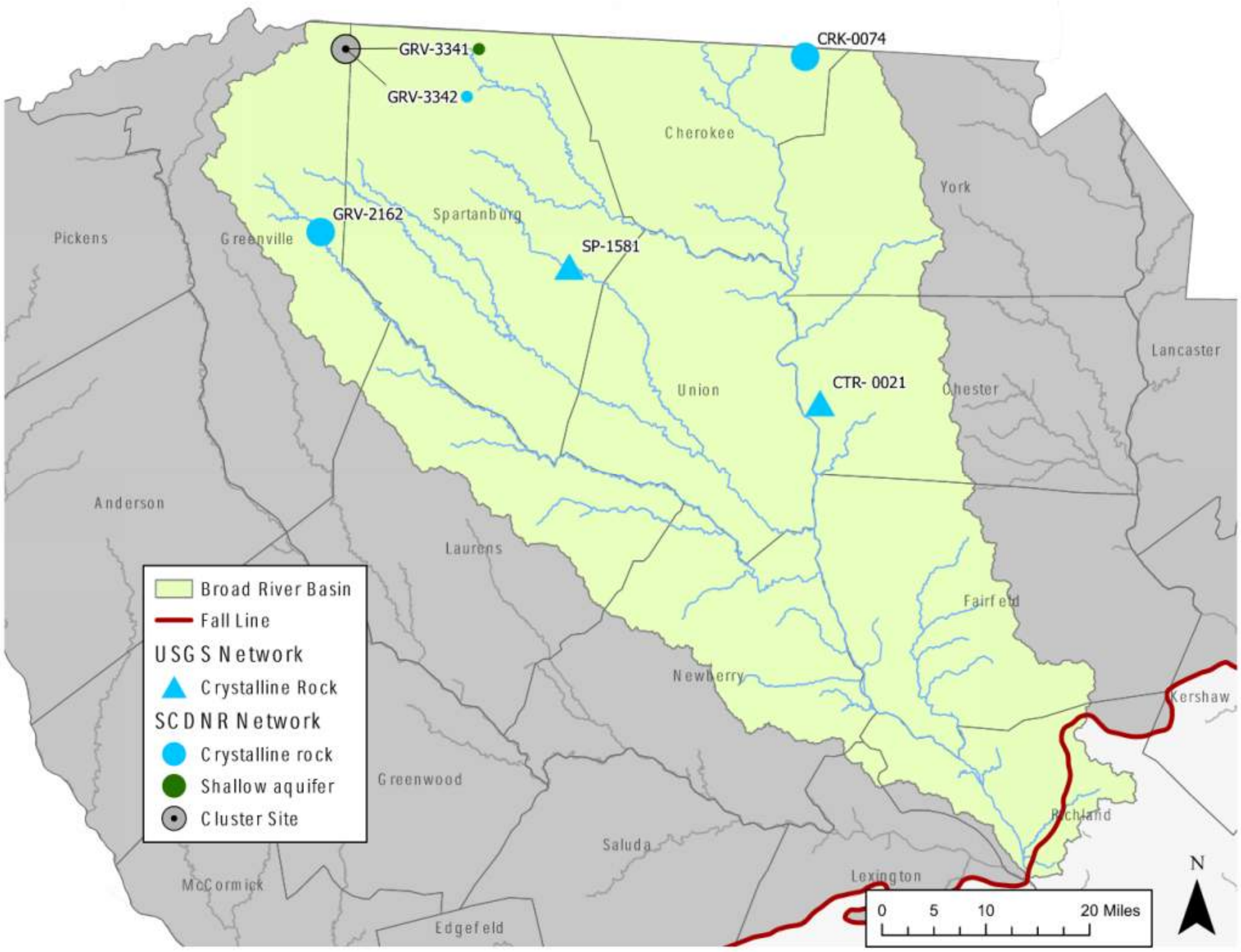


Figure 3-8. Representative Broad River basin SWAM model verification graphs (CDM Smith 2017).

Groundwater levels recorded at the SCDNR monitoring well near Taylors in Greenville County, GRV-2162, exhibit seasonal variations (Figure 3-10). Seasonal drawdowns of approximately 3 feet were observed, with water levels typically peaking around June and at their lowest in November/December. This can be attributed to increased winter recharge.

Potentiometric maps that illustrate the levels to which groundwater will rise in wells have not been drawn for areas northwest of the Fall Line, including the Broad River basin. Unlike the Coastal Plain region, where water levels slope toward the coast, groundwater levels in the Broad basin generally follow topographic patterns.

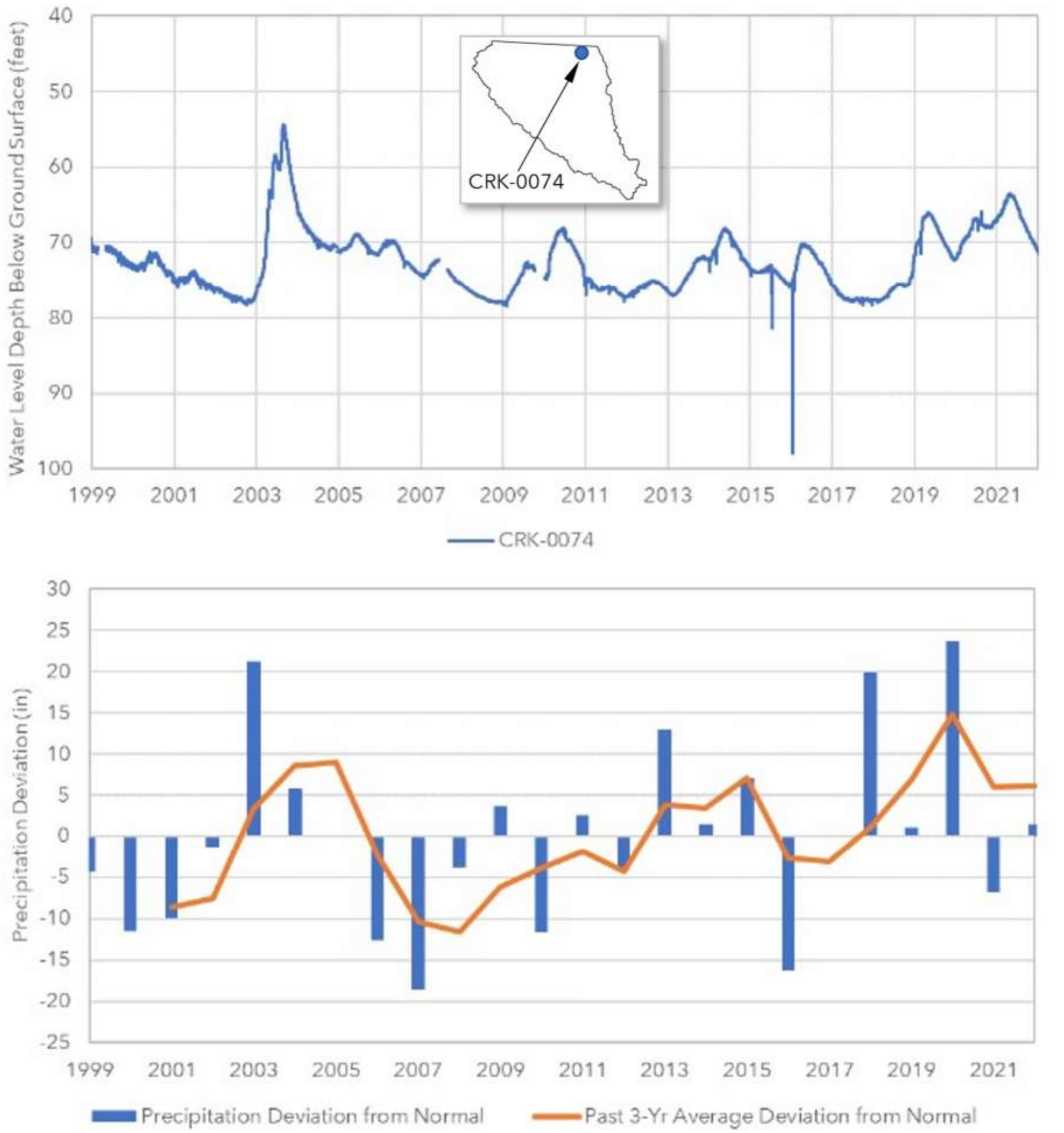


Figure 3-9. Groundwater levels in crystalline rock aquifer and precipitation deviation from normal (bottom graph) in Cherokee County.

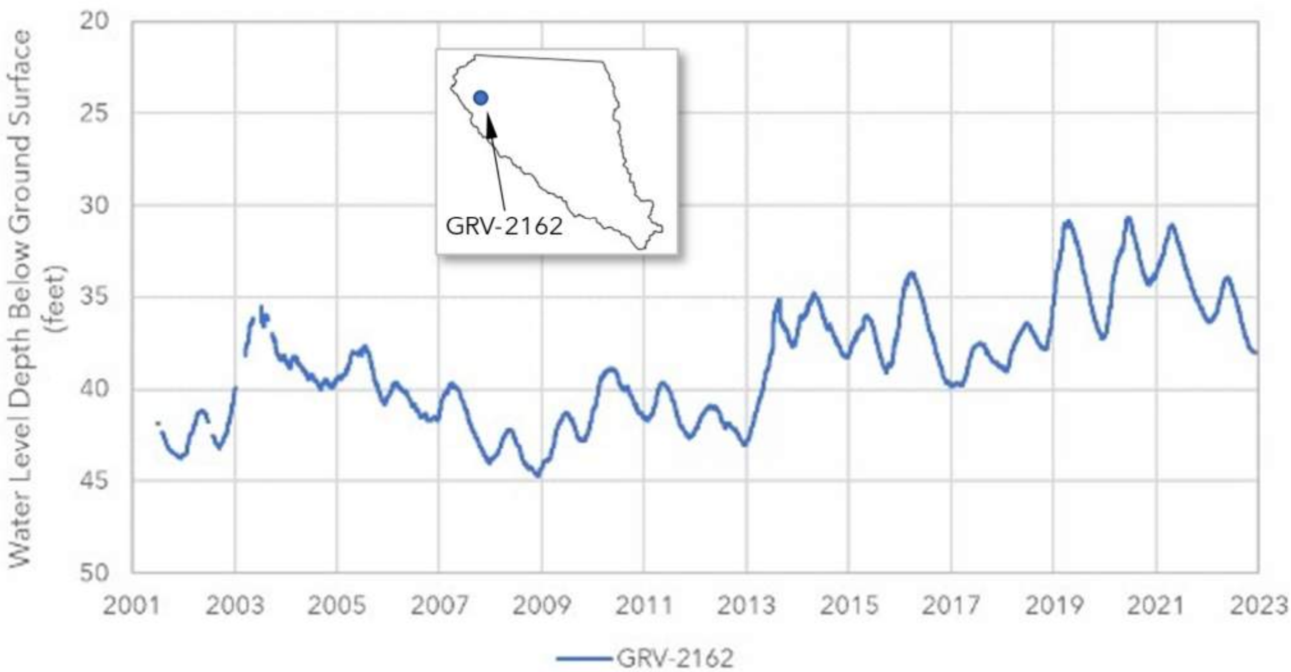


Figure 3-10. Groundwater levels in crystalline rock aquifer in Greenville County.

3.3.3 Groundwater Development

The Broad River basin has the lowest volume of groundwater withdrawals of the eight basins in the state. Reported groundwater withdrawals in the Broad River basin are typically less than 0.2 MGD (SCDNR 2022e), and withdrawals were reported to total 0.5 MGD in 2021 (SCDNR 2022d). That year, 53.7 percent of the reported withdrawals were for water supply, 45.3 percent of withdrawals were for industry, and 1.0 percent of withdrawals were for golf courses (SCDNR 2022d).

The largest user of groundwater in the basin in 2021 was Greenville Gas Turbines, LLC, which withdrew 0.2 MGD from 22 wells (SCDNR 2022d). The next largest user was Blue Ridge Water Company, a water supplier who withdrew 0.1 MGD from nine wells. All other permitted groundwater withdrawers in the basin reported uses of less than 0.1 MGD in 2021. A thermoelectric facility, Cherokee Cogeneration Partners LLC, has a groundwater well in the basin but did not report any groundwater use in 2021.

Many of the groundwater withdrawals in the basin are near interbasin divides, as these locations have fewer surface water options. Additionally, groundwater is used heavily for residential water supply in the basin. While the domestic self-supplied groundwater withdrawals in the basin are not reported, these average 5.34 MGD in Spartanburg County (SCDNR 2022d).

3.3.4 Capacity Use Areas

Groundwater in South Carolina is regulated by SCDHEC in areas designated as CUAs. Under South Carolina's Groundwater Use and Reporting Act (Chapter 5, Section 49-5-60), a CUA is designated where excessive groundwater withdrawals present potential adverse effects to natural resources, public health, safety, or economic welfare. SCDHEC then coordinates with affected governing bodies and groundwater withdrawers to develop a groundwater management plan for the CUA.

Groundwater withdrawals in the Broad River basin are minimal. Even so, and as discussed in Chapter 1, the southern end of the Broad River basin contains a small portion of the Santee-Lynches CUA, which includes Richland County, and an even smaller portion of the Western CUA, which includes Lexington County (see Figure 1-5 in Chapter 1). The Western CUA was designated in 2018 and the Santee-Lynches CUA was designated in 2021.

3.3.5 Groundwater Concerns

Groundwater use within the basin is limited; consequently, there are no areas experiencing significant water level declines as a result of overpumping within the Broad River basin (SCDNR 2009). Groundwater quality in the Broad basin is generally good. Some areas within the basin experience high water hardness. SCDHEC has found radioactive isotopes of radium and lead in two wells in Jenkinsville in concentrations exceeding acceptable drinking-water standards (SCDNR 2009).

Parr Shoals Hydroelectric Facility on the Broad River.

Chapter 4
Current and Projected Water Demand

This chapter summarizes current and projected water demands over the 50-year planning horizon from 2020 to 2070 in the Broad River basin. Demand projections are based on historical demands and published projection datasets for variables that influence water demand including population, economic development, and irrigated acreage. A statistical model was built to project demands for each major water use category using the current demands and driver variables. Two demand projections were developed: a Moderate Demand Scenario using median rates of water use and moderate growth, and a High Demand Scenario using high rates of water use and high growth. The demand projections were used in the surface water model to assess future water availability as summarized in Chapters 5 and 6.

4.1 Current Water Demand

Current water demands reflect the most recent withdrawal data, as reported to SCDHEC, that were available at the time of the analysis. Current surface water demands are based on data available through 2020 and were developed to reflect average withdrawals over the last 10 years (in most cases). Current groundwater demands are based on withdrawals reported for 2010 to 2019 and were developed to reflect average withdrawals over that 10-year period.

The withdrawals used for this demand characterization were reported to SCDHEC by permitted and registered water users in the Broad River basin as required by state regulation. All users withdrawing more than 3 million gallons of surface water or groundwater in any month must either obtain a permit or register their use and report withdrawals to SCDHEC annually. Users withdrawing less than this threshold are not required to report their withdrawals; however, they may choose to report voluntarily. For surface water withdrawals over the threshold, agricultural water users must register their use while all other users must permit their use in accordance with SCDHEC's Regulation 61-119, Surface Water Withdrawal, Permitting, Use and Reporting. For groundwater withdrawals over the threshold, users withdrawing within a CUA must permit their use, while those withdrawing outside of a CUA must only register their use. Most groundwater users in the Broad River basin are outside of CUAs and therefore register their use. One groundwater user in Richland County (a golf course) is in the recently established Santee-Lynches CUA and is in the process of obtaining a groundwater withdrawal permit.

The total current permitted and registered water withdrawals in the Broad River basin are approximately 809 MGD on average. Of this total withdrawal, almost 809 MGD is from surface water and just under 1 MGD is from groundwater. The thermoelectric and water supply sectors account for 87.9 percent and 11.5 percent of total withdrawals, respectively. Manufacturing sector withdrawals are about 0.4 percent of the total. Minimal water withdrawals are associated with agriculture, golf course irrigation, and mining. The distribution by sector is summarized in Table 4-1 and shown in Figure 4-1. Although thermoelectric represents the largest withdrawal category in the basin, these withdrawals represent a once-through cooling use where approximately 84 percent of the water withdrawn is returned to the system, with only 16 percent of the total withdrawal consumed. To better illustrate water use distribution for other categories, water withdrawals for thermoelectric are excluded in Figure 4-2. Appendix B includes a table of all water users along with the user's source (surface water or groundwater), withdrawals, and discharges. For surface water modeling purposes, consumptive use percentages (i.e., the amount of water withdrawn that is not returned to surface water or groundwater) for each water user were calculated by comparing withdrawal and discharge amounts as reported to SCDHEC. It is assumed that all groundwater is used consumptively or returned to the groundwater system through septic tanks.

Table 4-1. Current water demand in the Broad River basin.

Water Use Category	Groundwater (MGD)	Surface Water (MGD)	Total (MGD)
Thermoelectric	0.0	711.1	711.1
Public Supply	0.5	93.0	93.5
Manufacturing	0.2	3.1	3.3
Golf Course	0.1	1.0	1.1
Agriculture	0.0	0.3	0.3
Mining	0.0	0.1	0.1
Total	**0.8**	**808.6**	**809.4**

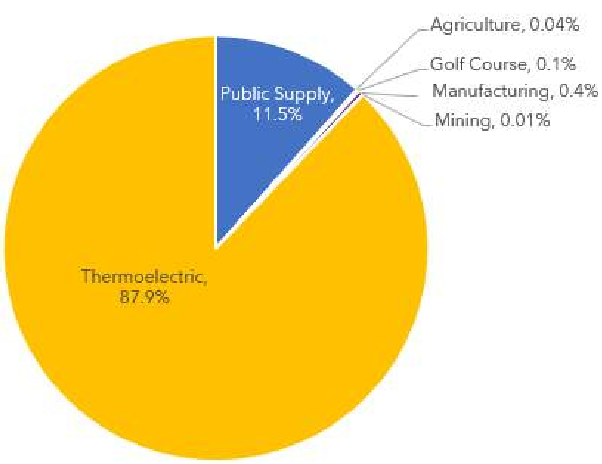


Figure 4-1. Current water use category percentages of total demand.

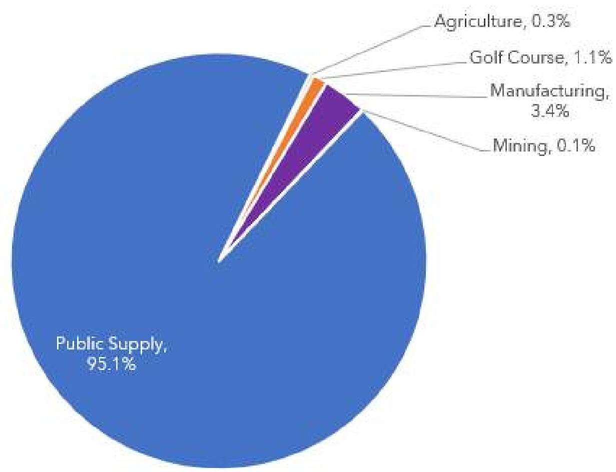


Figure 4-2. Current water use categories percentages of total demand without thermoelectric.

To evaluate surface water availability in the Broad River basin in South Carolina, it was necessary to include withdrawals and discharges in the upper Broad River basin for North Carolina users. In North Carolina, public water supplier current demands and discharges are published annually in Local Water Supply Plans (LWSPs). The OASIS surface water availability model for the North Carolina portion if the Broad River basin was used as the source of agricultural and hydroelectric demands (Hydrologics 2012). Demands for thermoelectric, golf courses, mining, and other recreation were based on information provided by SCDNR. Current North Carolina demands are summarized in Table 4-2.

Table 4-2. North Carolina surface water demands in the upper Broad River basin.

User Type	Withdrawal (MGD)	Consumptive Use (MGD)	Return (MGD)	Information Source
Public Water Suppliers	24.0	7.5	16.5	North Carolina LWSPs
Thermoelectric Energy	6.0	6.0	0.0	Cliffside: Note from Duke Energy to SCDNR
Hydroelectric Energy	13.9	13.9	0.0	OASIS model documentation
Golf Courses	0.52	0.52	0.0	SCDNR
Other Recreation	0.11	0.11	0.0	SCDNR
Agriculture	1.57	1.57	0.0	OASIS model documentation
Mining	3.14	3.14	0.0	SCDNR
Total	**49.3**	**32.8**	**16.5**	

4.2 Permitted and Registered Water Use

As of the development of this River Basin Plan, 1,542.1 MGD of surface water has been permitted or registered in the South Carolina portion of the Broad River basin. Of this total, 8.8 MGD has been registered for agricultural use and 1,533.3 MGD has been permitted for other use. Currently, only 52 percent (809.3 MGD) of the total permitted and registered surface water amount is withdrawn, and only 12 percent (178.8 MGD) is used consumptively within the basin.

Since nearly all groundwater users in the Broad River basin are outside of CUAs, there are currently no permits for groundwater use; however, one golf course in the Richland County portion of the Santee-Lynches CUA is in the process of applying for a groundwater withdrawal permit. All groundwater use in the basin is registered without a registration amount assigned. Current, registered groundwater withdrawals in the basin total 0.8 MGD.

Figure 4-3 shows the location of all permitted and registered surface water intakes and groundwater wells in the basin. Table 4-3 summarizes permitted and registered surface water withdrawals by water use category. Appendix B includes a table of all permitted or registered withdrawals for each user.

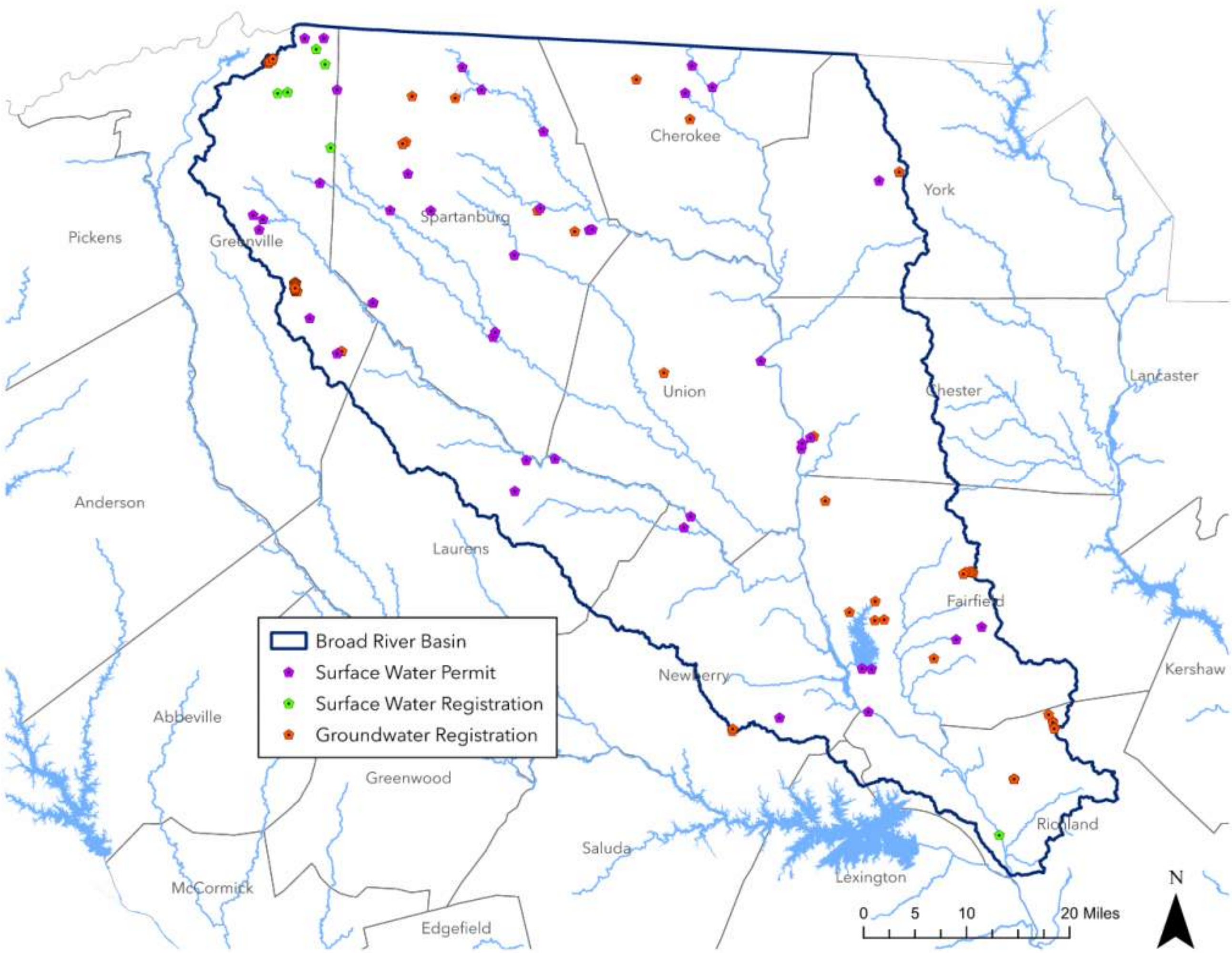


Figure 4-3. Locations of permitted and registered water intakes and groundwater wells with registrations in the Broad River basin.

Table 4-3. Permitted and registered surface water totals by category in the Broad River basin.

Water Use Category	Permitted Amount (MGD)	Registered Amount (MGD)	Total (MGD)	Percent of and Total Permitted and Registered Surface Water Currently Withdrawn
Thermoelectric	862.8	NA	862.8	82.4% (711.1 MGD)
Public Supply	640.1	NA	640.1	14.5% (93.0 MGD)
Manufacturing	14.2	NA	14.2	22.1% (3.1 MGD)
Golf Course	12.3	NA	12.3	8.4% (1.0 MGD)
Agriculture	NA	8.8	8.8	1.7% (0.3 MGD)
Mining	3.9	NA	3.9	3.3% (0.1 MGD)
Total	**1,533.3**	**8.8**	**1,542.1**	**52.4% (808.6 MGD)**

NA – not applicable

4.3 Projection Methodology

The methodology to calculate demand projections followed the guidance in *Projection Methods for Off-Stream Water Demand in South Carolina* (SCDNR 2019). SCDNR developed this document over several years in collaboration with the South Carolina Water Resources Center at Clemson University and the U.S. Army Corps of Engineers, with additional input from stakeholders including:

- South Carolina Water Works Association Water Utility Council
- South Carolina Farm Bureau Water Committee
- South Carolina Chamber of Commerce Environmental Committee
- South Carolina Water Quality Association
- PPAC

Following the guidance in the statewide projections report, SCDNR developed demands for the Broad River basin with only minor deviations from the framework, as presented in a 2023 report, *Water-Demand Projections for the Broad River Basin, 2022–2070* (Pellett and More 2023). In the Broad River basin, demand projections were developed for the thermoelectric power, public water supply, and manufacturing sectors. Nearly all water used for hydroelectric power generation is returned directly to the river and was omitted from the projection analysis. Water use for agriculture, golf course irrigation, and mining account for less than 0.1 percent of total withdrawals and were projected to remain stable over the planning horizon. Groundwater withdrawals, which account for less than 1 percent of total withdrawals, were also assumed to remain at current levels over the planning horizon.

For the three water use categories with projected increases in demands, the projection methodology varies by water use category. Each water use category has an associated driver variable that influences demand growth, as shown in Table 4-4. Projections for these driver variables come from a variety of published sources. Published values were extrapolated to 2070 to match the planning horizon of the River Basin Plan.

Two demand projections were developed: (1) the Moderate Water Demand Scenario (Moderate Scenario) and (2) the High Water Demand Scenario (High Demand Scenario). The Moderate Scenario was originally referred to as the Business-as-Usual Scenario in the Planning Framework. The Moderate Demand Scenario is based on median rates of water use and moderate growth projections, while the High Demand Scenario is based on the maximum monthly rates of water use in recent reporting and high growth projections. While it is unlikely that the conditions of the High Demand Scenario would occur for an extended time or universally across the basin, the scenario is useful for establishing an upper bound for the projected demand. The following subchapters present additional details on the calculation of demand for each water use category.

Table 4-4. Driver variables for each water use category.

Water Use Category	Driver Variable	Driver Variable Data Source	Moderate Scenario	High Demand Scenario
Public Supply	Population	South Carolina Office of Revenue and Fiscal Affairs	Extend straight-line growth or assume constant population if the population projection is negative	Project using statewide or countywide growth rate, increased by 10%
Manufacturing	Economic production	Subsector growth rates from the U.S. Energy Information Agency (EIA)	Manufacturing subsector growth with the minimum adjusted to 0%	Manufacturing subsector growth with the minimum adjusted to 2.1%[1]
Thermoelectric	Electricity demand	Information provided by electric utilities	Extend straight-line demand growth of "base forecast" from report	Extend straight-line demand growth of "high scenario" from report
Agriculture	NA	NA	Assumed constant	Assumed constant
Other (golf courses and mining)	NA	NA	Assumed constant	Assumed constant

NA – not applicable

[1] 2.1% is the total overall EIA economic growth projection increased by 10% (1.9% + 10% x 1.9% = 2.1%)

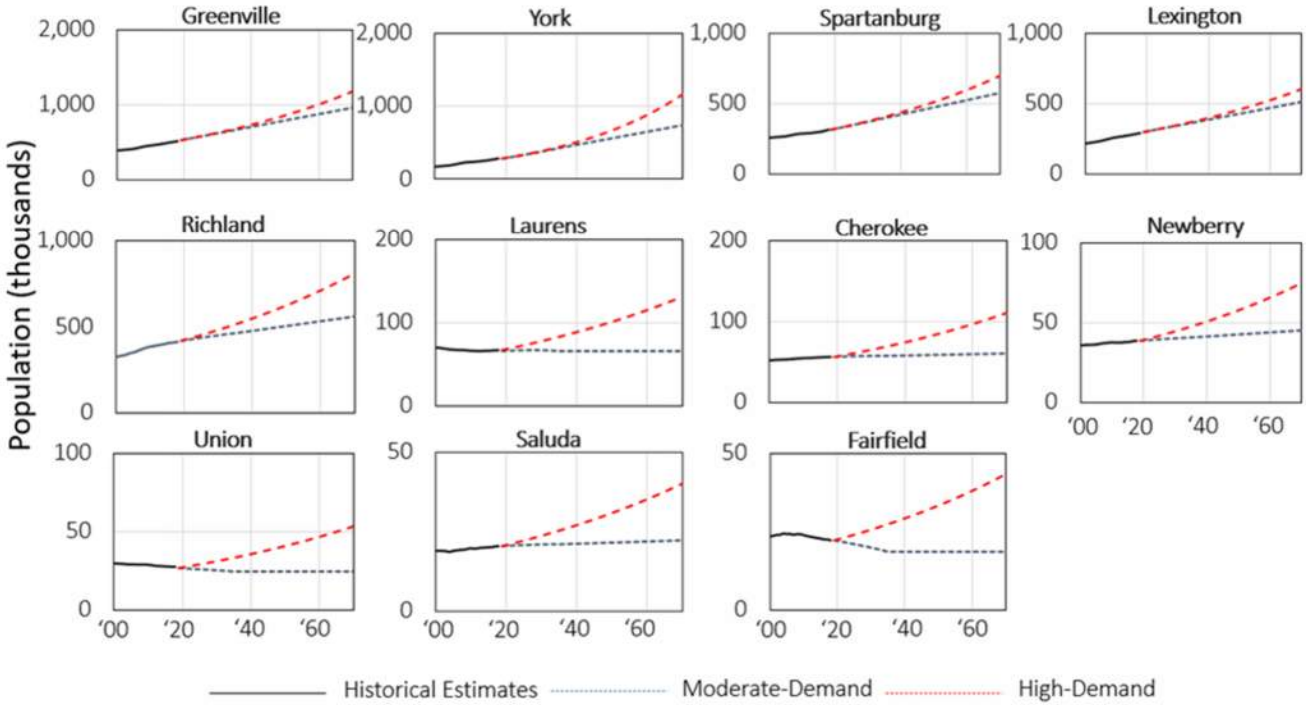
4.3.1 Thermoelectric Demand Projections Methodology

Water is used for thermoelectric power plants to generate steam and cool power-producing equipment. In the Broad River basin, all thermoelectric water use is met with surface water. Most of the surface water withdrawn is returned to the system and only a small percent of the total withdrawal is consumed via evaporation. The V.C. Summer Nuclear Station, owned by Dominion Energy, is the only thermoelectric power plant in the South Carolina portion of the basin. V.C. Summer is a once-through cooling operation where 84 percent of water withdrawn is returned to the river. Dominion Energy has reported that water demand at this station is not projected to change over the planning horizon so was held constant in these projections. Duke Energy has indicated in their long-term planning that they may construct a new nuclear station, the William States Lee III Station (Lee Nuclear Station), on Ninety-Nine Islands Reservoir. Projected withdrawals for the proposed station were provided by Duke Energy and are not projected to begin until 2035. Withdrawals for Lee Nuclear Station will be for cooling tower make-up and will be largely consumptive.

4.3.2 Public Supply Demand Projections Methodology

Public supply is the second largest water use sector in the Broad River basin. Approximately 99 percent of public supply withdrawals are met with surface water. Demand projections for public supply were developed based on county-level population and water use projections. Population projections for the Moderate Scenario were taken from the South Carolina Office of Revenue and Fiscal Affairs (SC ORFA). These projections, which end in 2035, were extended to 2070. For the Moderate Demand Scenario, projections are extended linearly. If SC ORFA projections indicate a decline in population, then the extension to 2070 is flatlined at 2035 levels. For the High Demand Scenario, populations are projected to grow exponentially. If SC ORFA projected growth, then the exponential growth rate was increased by 10 percent. If the SC ORFA projection for a county was less than the state average, then the high scenario population projection is set at the state average plus 10 percent. As shown in Figure 4-4, some counties are projected to experience population declines while others may experience substantial growth in both the Moderate and High Demand Scenarios. Columbia Water, Spartanburg Water System, and the Greer Commission of Public Works are the largest public supply withdrawers in the basin and primarily serve major portions of Richland, Spartanburg, and Greenville Counties.

Figure 4-4. Population projections for counties withdrawing water from the Broad River basin (Pellett and More 2023).



4.3.3 Manufacturing Demand Projections Methodology

Water is used for manufacturing in the Broad River basin to produce textiles (Carlisle Finishing LLC), organic chemicals (Milliken and Company at the Magnolia Plant), and inorganic chemicals (Chemtrade Performance Chemicals at the US LLP Leeds Plant). Manufacturing demand projections were based on projected subsector growth rates from the U.S. Energy Information Agency (EIA), which ranged from 0.3 to 1.3 percent for the sectors present in the Broad River basin (EIA 2020). The Moderate Demand Scenario used the EIA projected growth rates while the High Demand Scenario increased growth rates 10 percent over their projected values. Ninety-four percent of the manufacturing water use in the Broad River basin is from surface water.

4.3.4 Other Demand Projections Methodology

Other water withdrawals in the Broad River basin support agriculture, golf course irrigation, and mining. Water use for these categories is low (approximately 1.5 MGD) and assumed constant into the future (Pellett and More 2023).

Demand growth for North Carolina users in the upper Broad River basin was also considered. Projected water demands for public suppliers withdrawing from the Broad River basin in North Carolina were based on decadal estimates published in each public supplier's 2021 LWSP. Demands for all other demand categories were held constant.

4.4 Projected Water Demand

From 2025 to 2070, total withdrawals are projected to increase by 10 percent to 932.5 MGD under the Moderate Scenario and by 17 percent to 1,113.1 MGD under the High Demand Scenario. Included in these projections is 0.8 MGD of groundwater withdrawals, which are projected to remain constant over the planning horizon. Surface water demand is expected to reach 60 to 72 percent of currently permitted and registered surface water withdrawals by 2070 for the Moderate and High Demand Scenarios, respectively.

Table 4-5 and Figure 4-5 summarize projected surface water and groundwater demands over the planning horizon. Figure 4-5 represents a stacked area graph where total demand is shown as a thick black line and shaded areas show which portion of that demand comes from groundwater or surface water. For example, in 2025, the Moderate Scenario total demand is 845.3 MGD. Of that, 0.8 MGD is from groundwater and 844.5 MGD is from surface water. Projected demands by water use category are summarized in Figure 4-6 and further described in the subchapters that follow. Figure 4-6 does not show thermoelectric withdrawals, which account for 83 and 76 percent of projected 2070 Moderate and High Demand Scenario withdrawals, respectively.

Table 4-5. Projected surface water and groundwater demands.

Year	Moderate Scenario (MGD)			High Demand Scenario (MGD)		
	Surface Water	Groundwater	Total	Surface Water	Groundwater	Total
2025	844.5	0.8	845.3	951.9	0.8	952.6
2030	850.0	0.8	850.7	962.1	0.8	962.9
2035	873.2	0.8	874.0	991.0	0.8	991.8
2040	876.9	0.8	877.7	1,000.6	0.8	1,001.4
2050	899.2	0.8	900.0	1,038.0	0.8	1,038.8
2060	918.0	0.8	918.7	1,075.0	0.8	1,075.8
2070	931.7	0.8	932.5	1,112.3	0.8	1,113.1
Percent Increase 2025-2070	**10%**	**0%**	**10%**	**17%**	**0%**	**17%**

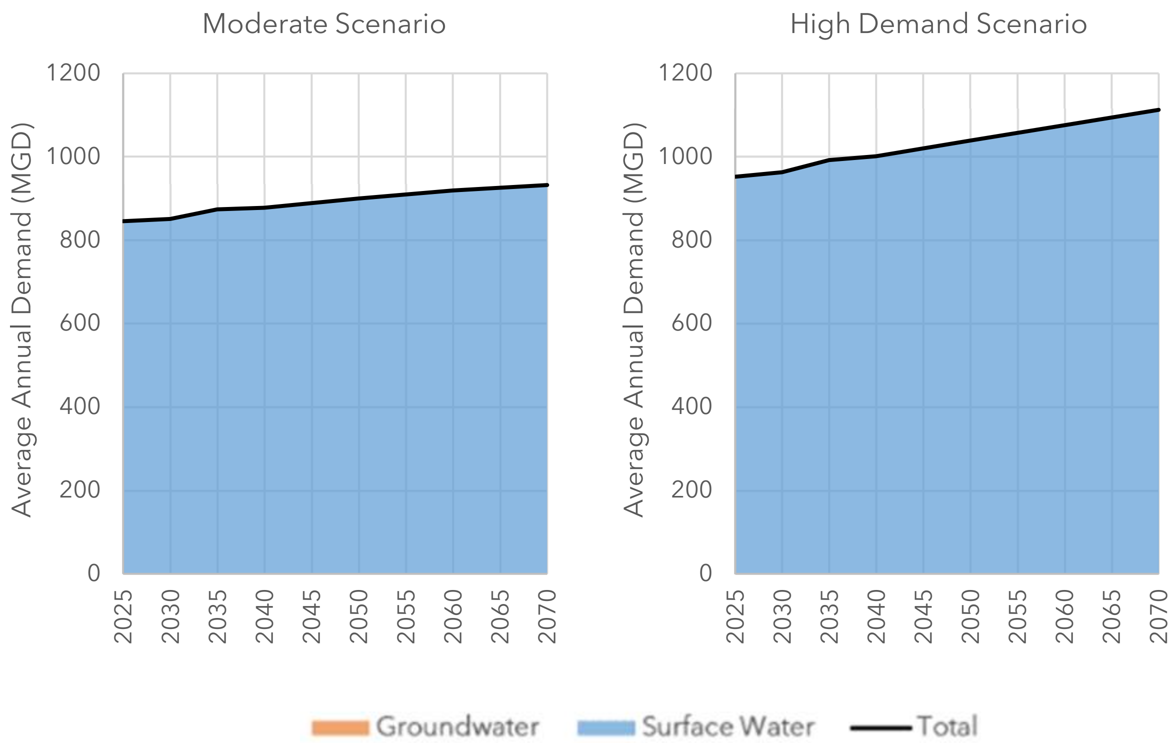


Figure 4-5. Demand projections by water source. (Groundwater demands, projected at a constant average annual demand of 0.8 MGD are too small to be seen on this chart)

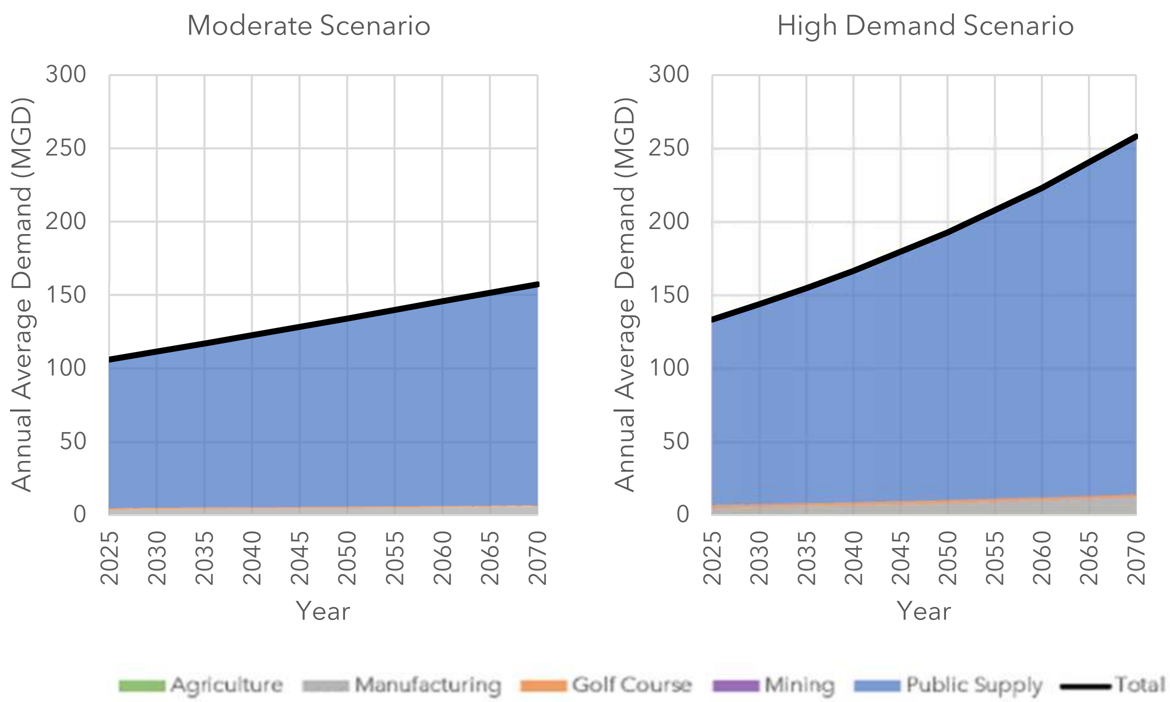


Figure 4-6. Demand projections by water use category without thermoelectric. (Agriculture, golf course, and mining demands make up less than 1 percent of the total 2070 demands and may be too small to be seen on this chart)

4.4.1 Thermoelectric Demand Projections

Thermoelectric demands are projected to increase 5 and 4 percent between 2025 (739.2 to 819.2 MGD) and 2070 (775.0 to 855.0 MGD) in the Moderate and High Demand Scenarios, respectively. Different starting use rates were assumed for each scenario based on variation in past use rates. Demand for the existing V.C. Summer Nuclear Station does not increase over the planning horizon. Duke Energy's proposed Lee Nuclear Station is expected to come online in 2035, with its demand growing from approximately 18 MGD in 2035 to 36 MGD in 2070. Projected 2070 thermoelectric surface water withdrawals for the Moderate and High Demand Scenarios are approximately 90 and 99 percent of currently permitted thermoelectric surface water withdrawals, respectively. The current permitted amounts do not include the proposed Lee Nuclear Station. Thermoelectric demand projections by water source are shown in Figure 4-7 and summarized in Table 4-6.

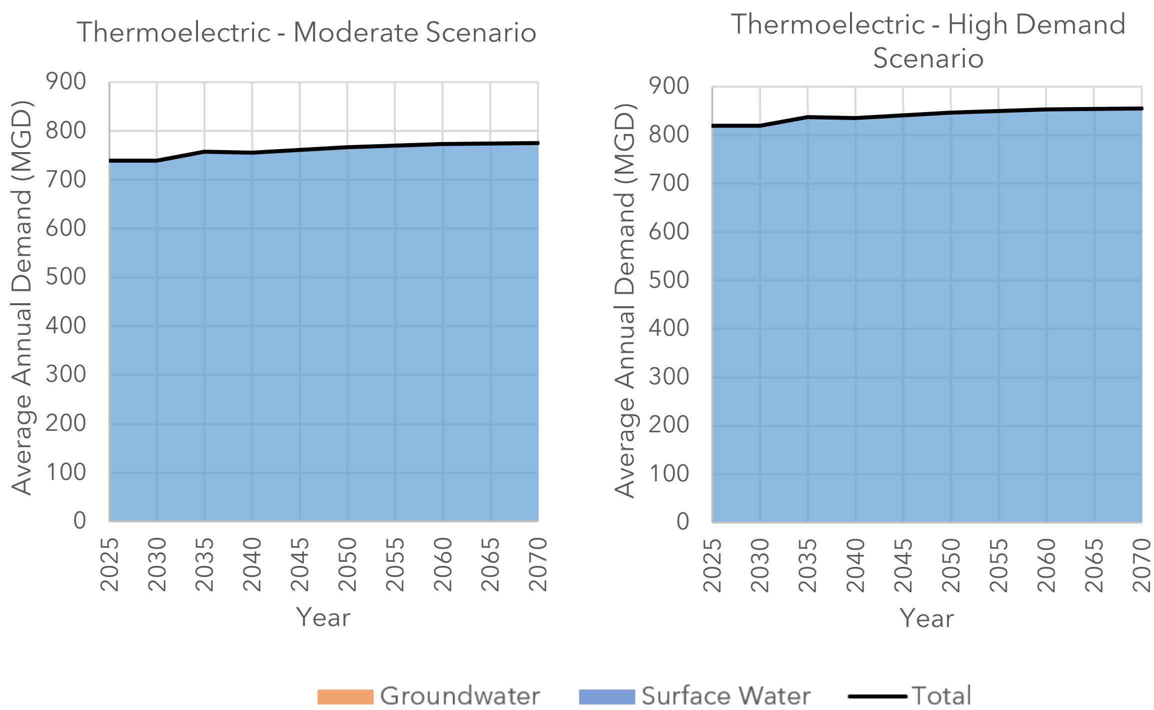


Figure 4-7. Projected thermoelectric water demands. (Groundwater demands, projected at a constant average annual demand of 0.1 MGD are too small to be seen on this chart)

Table 4-6. Projected thermoelectric water demands.

Year	Moderate Scenario (MGD)			High Demand Scenario (MGD)		
	Surface Water	Groundwater	Total	Surface Water	Groundwater	Total
2025	739.1	0.1	739.2	819.1	0.1	819.2
2030	739.1	0.1	739.2	819.1	0.1	819.2
2035	757.0	0.1	757.1	837.0	0.1	837.1
2040	755.1	0.1	755.2	834.8	0.1	834.9
2050	766.0	0.1	766.1	845.9	0.1	846.0
2060	773.0	0.1	773.1	852.7	0.1	852.8
2070	774.9	0.1	775.0	854.9	0.1	855.0
Percent Increase 2025-2070	**5%**	**0%**	**5%**	**4%**	**0%**	**4%**

4.4.2 Public Supply Demand Projections

Most of the water demand growth in the Broad River basin is expected to come from increasing demand for public water supply. Projected population increases are presented in Table 4-7. Public supply demands are projected to increase 49 and 93 percent between 2025 (101.1 to 126.5 MGD) and 2070 (150.5 to 243.7 MGD) in the Moderate and High Demand Scenarios, respectively. Most of this increase will be met by surface water, which will serve over 99 percent of demand. Projected 2070 public supply surface water withdrawals for the Moderate and High Demand Scenarios are approximately 23 and 38 percent of the total permitted amount for public supplies from surface water, respectively. Public supply demand projections by water source are shown in Figure 4-8 and summarized in Table 4-8.

Table 4-7. Projected population increases (in thousands) (Pellett and More 2023).

	County	2020	2025	2030	2035	2040	2050	2060	2070
Moderate Demand Scenario	Greenville	530.9	573.1	616.1	659.3	701.9	787.4	872.9	958.3
	York	289.6	329.9	374.4	423.1	467.2	555.4	643.7	731.9
	Spartanburg	323.5	348.1	373.5	399.4	424.6	475.1	525.5	575.9
	Richland	420.8	436.4	451.0	463.5	477.8	506.5	535.1	563.7
	Lexington	303.6	324.9	345.6	365.6	386.3	427.6	469.1	510.5
	Laurens	67.1	67.4	67.4	67.0	67.0	67.0	67.0	67.0
	Cherokee	57.4	57.9	58.3	58.3	58.7	59.4	60.1	60.8
	Newberry	38.8	39.6	40.3	40.8	41.5	42.9	44.2	45.6
	Union	27.1	26.4	25.6	24.7	24.7	24.7	24.7	24.7
	Saluda	20.7	20.9	21.0	21.1	21.3	21.6	21.9	22.2
	Fairfield	22.0	21.0	19.9	18.6	18.6	18.6	18.6	18.6
High Demand Scenario	Greenville	530.9	575.1	622.9	674.6	730.7	857.2	1005.6	1179.7
	York	289.8	333.2	383.0	440.3	506.2	669.0	884.2	1168.5
	Spartanburg	323.7	349.8	377.9	408.5	441.4	515.4	601.8	702.8
	Richland	423.2	451.7	482.0	514.5	549.1	625.5	712.4	811.5
	Lexington	303.5	325.0	348.1	372.9	399.4	458.3	525.8	603.2
	Laurens	67.9	72.5	77.4	82.6	88.2	100.4	114.4	130.3
	Cherokee	57.9	61.8	66.0	70.5	75.2	86.7	97.6	111.1
	Newberry	39.2	41.8	44.6	47.6	50.8	57.9	65.9	75.2
	Union	27.6	29.5	31.5	33.6	35.8	40.8	46.5	52.9
	Saluda	20.9	22.3	23.7	25.4	27.1	30.8	35.1	40.0
	Fairfield	22.5	24.0	25.6	27.4	29.2	33.3	37.9	43.2

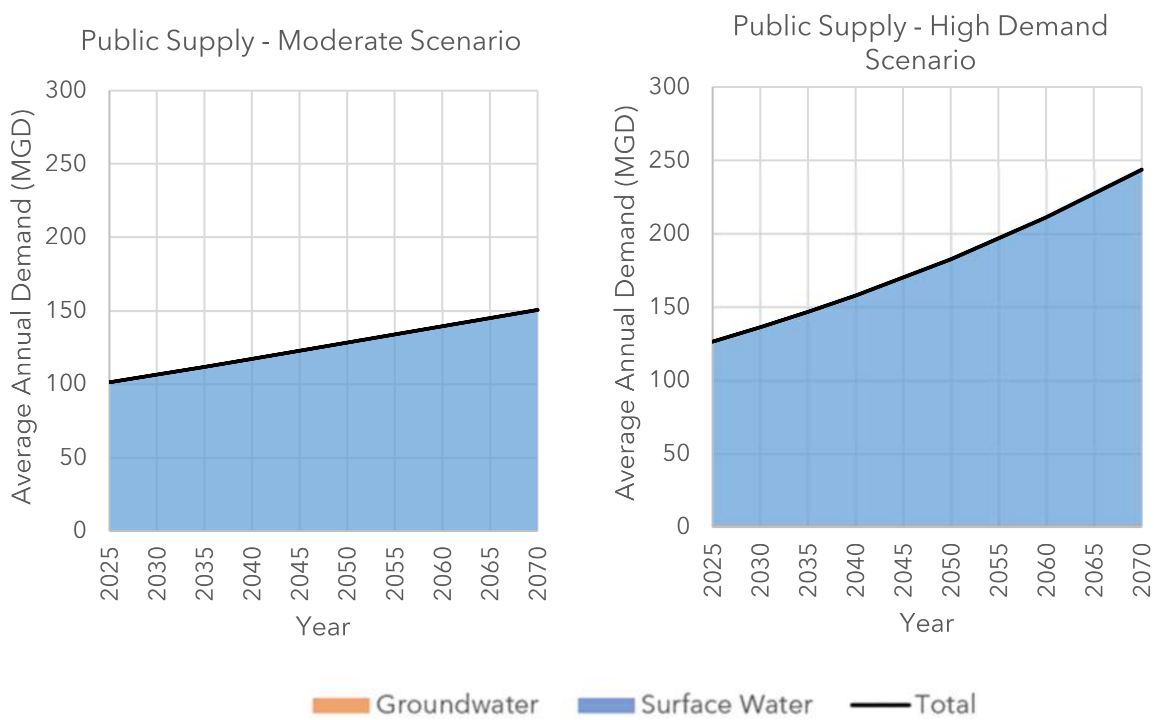


Figure 4-8. Projected public supply water demands. (Groundwater demands, projected at a constant average annual demand of 0.6 MGD are too small to be seen on this chart)

Table 4-8. Projected public supply water demands.

Year	Moderate Scenario (MGD)			High Demand Scenario (MGD)		
	Surface Water	Groundwater	Total	Surface Water	Groundwater	Total
2025	100.5	0.6	101.1	125.9	0.6	126.5
2030	105.7	0.6	106.3	135.6	0.6	136.2
2035	110.9	0.6	111.5	146.0	0.6	146.6
2040	116.3	0.6	117.0	157.1	0.6	157.8
2050	127.5	0.6	128.1	181.9	0.6	182.5
2060	138.7	0.6	139.3	210.3	0.6	210.9
2070	149.8	0.6	150.5	243.1	0.6	243.7
Percent Increase 2025-2070	**49%**	**0%**	**49%**	**93%**	**0%**	**93%**

4.4.3 Manufacturing Demand Projections

Manufacturing demands are projected to increase 58 and 155 percent between 2025 (3.6 to 4.8 MGD) and 2070 (5.7 to 12.2 MGD) in the Moderate and High Demand Scenarios, respectively. No manufacturing demand is from groundwater. Projected 2070 manufacturing surface water withdrawals for the Moderate and High Demand Scenarios are approximately 40 and 85 percent of currently permitted manufacturing surface water withdrawals, respectively. Manufacturing demand projections are shown in Figure 4-9 and summarized in Table 4-9.

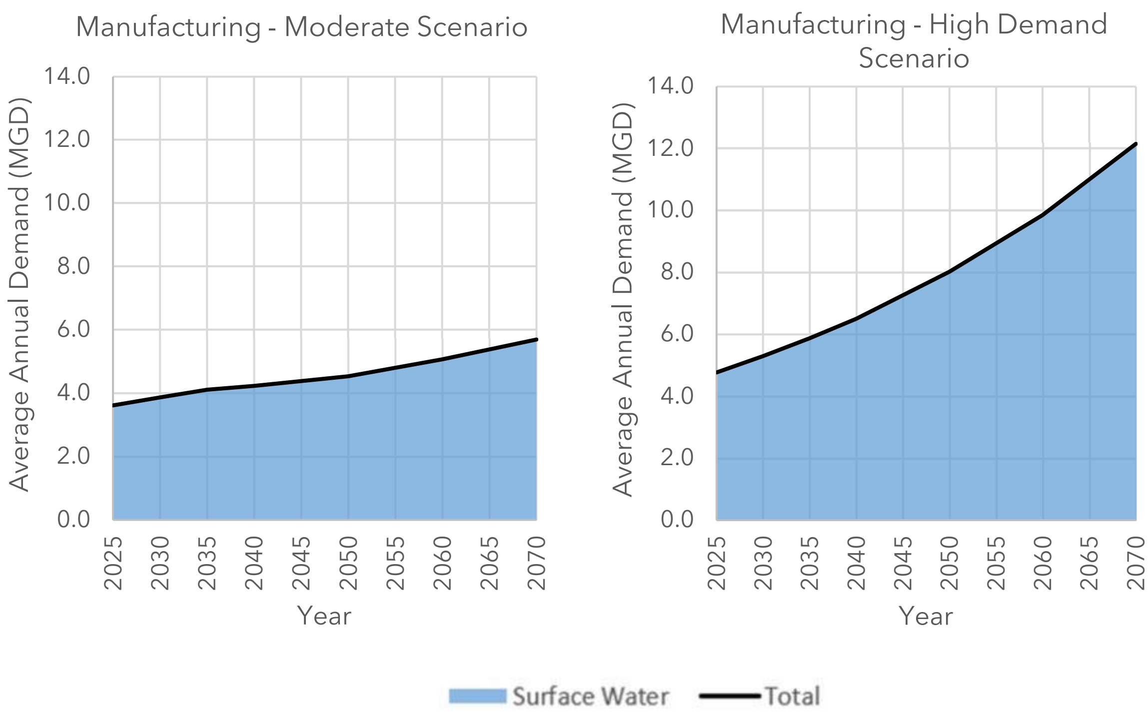


Figure 4-9. Projected manufacturing water demands.

Table 4-9. Projected manufacturing water demands.

Year	Moderate Scenario (MGD)			High Demand Scenario (MGD)		
	Surface Water	Groundwater	Total	Surface Water	Groundwater	Total
2025	3.6	0.0	3.6	4.8	0.0	4.8
2030	3.9	0.0	3.9	5.3	0.0	5.3
2035	4.1	0.0	4.1	5.9	0.0	5.9
2040	4.2	0.0	4.2	6.5	0.0	6.5
2050	4.5	0.0	4.5	8.0	0.0	8.0
2060	5.1	0.0	5.1	9.8	0.0	9.8
2070	5.7	0.0	5.7	12.2	0.0	12.2
Percent Increase 2025-2070	**58%**	**0%**	**58%**	**155%**	**0%**	**155%**

4.4.4 Other Demand Projections

Other demands are held constant into the future. Golf course demands were assumed to be 1.0 MGD and 1.8 MGD in the Moderate and High Demand Scenarios, respectively, over the planning horizon. Of this demand, approximately 1 percent is from groundwater. Mining demands were assumed to be 0.04 MGD and 0.14 MGD from surface water in the Moderate and High Demand Scenarios, respectively. Agriculture demands were assumed to be 0.3 MGD from surface water for both the Moderate and High Demand Scenarios.

Projected water demands for public suppliers withdrawing from the portion of the Broad River basin in North Carolina are expected to increase 61 percent by 2070, with net withdrawals (accounting for returns) expected to increase 65 percent by 2070. The same demand growth was assumed for both the Moderate and High Demand Scenarios. Demands for all other demand categories for North Carolina water users were held constant.

Table 4-10. North Carolina projected public supply water demands.

Surface Water	Withdrawal (MGD)	Discharge (MGD)	Net Withdrawal (MGD)
Current	24.1	7.5	16.6
2030	34.7	10.0	24.7
2040	35.7	10.4	25.4
2050	36.8	10.7	26.1
2060	37.9	11.1	26.8
2070	38.9	11.5	27.4
Percent Increase Current-2070	**61%**	**53%**	**65%**

Chapter 5
Comparison of Water Resource Availability and Water Demand

This chapter describes the methods used to assess surface water availability in the Broad River basin. A surface water quantity model was used to evaluate water availability using current and projected water demands. Water availability was also assessed assuming surface water withdrawals at permitted and registered amounts. The results of these assessments are presented and compared, and potential water shortages and issues are identified.

5.1 Methodology

5.1.1 Surface Water

Surface water planning scenarios were constructed and simulated using the previously developed Broad River basin surface water quantity model (CDM Smith 2017). This model was developed with CDM Smith's SWAM software. It simulates river basin hydrology, water availability, and water use across a dendritic network and over an extended timeseries.

SWAM was designed to provide efficient planning-level analyses of Surface Water Supply systems. Beginning with naturally occurring water flowing in the river reaches, it calculates physically and permitted or allowable water, diversions, storage, consumption, and return flows at user-defined nodes in a networked river system. A range of water user types can be represented in the model, including municipal water suppliers, agricultural irrigators, and industrial water users, with time-variable demands either prescribed by the user or, in some cases, calculated internally. Multiple layers of complexity are available as options in SWAM to allow for easy development of a range of systems, from the very simple to the more complex. As an example, SWAM's reservoir object can include only basic hydrology-dependent calculations (storage as a function of inflow, outflow, and evaporation) or can include operational rules of varying complexity: prescribed monthly releases, a set of prioritized monthly releases or storage targets, or a set of conditional release rules (dependent on hydrology). Municipal water conservation programs can similarly be simulated with sets of rules of varying complexity. The model user chooses the appropriate level of complexity given the modeling objectives and data availability.

The Broad River basin SWAM model simulates almost 90 years of variable historic hydrology (October 1929 through December 2019) with either a monthly or daily user-specified calculation timestep (the surface water scenarios presented in this chapter represent monthly analyses, unless noted otherwise). It is designed for three primary purposes:

- Accounting of current and past basin inflows, outflows, and consumptive uses
- Simulating streamflow and lake storage across a range of observed historical climate and hydrologic conditions, given current water use and operations

- Simulating future "what if" scenarios associated with changes in basin water use, management, and/or operations

The Broad River basin model includes 14 municipal, four industrial, one mining, nine golf course, two thermoelectric, and three discrete agricultural (irrigation) water users. Hydroelectric projects, which are not operated as strictly run-of-river model, are represented through a separate water user object, or through operating rules incorporated into reservoir objects. All water users with permitted withdrawals greater than 0.1 MGD are represented, either explicitly or implicitly. In the model version that represents current conditions, monthly water use is set equal to the average of a recent 10-year period (2010 through 2019) of reported use, with several exceptions. Exceptions include new surface water users and surface water users with recent demands that are significantly different from demands in the early part of the 10-year period. Model users also can adjust water use patterns to explore future water management scenarios, as discussed in this chapter.

A total of 48 "tributary objects" (rivers and streams) are represented discretely in the model, including the mainstem Broad River. Boundary condition (headwater) flows for each tributary object are prescribed in the model based on external analyses (see CDM Smith 2017a), which estimated naturally-occurring historical flows "unimpaired" by human uses. Historic, current, and/or future uses then can be simulated against the same natural hydrology of the basin. Hydrologic flow gains (or losses) for each tributary are simulated in SWAM using lumped gain (or loss) factors, which are set based on a model calibration exercise, using gaged flow data, and/or guided by changes in reach drainage area. SWAM implicitly accounts for interaction between groundwater and surface water through the assignment of the gain/loss factors.

The Broad River basin SWAM model was used to simulate current and potential future scenarios to evaluate surface water availability. Chapter 5.3 provides detailed descriptions of the surface water scenarios and their results.

Following are several key terms of the surface water modeling, introduced in the Planning Framework, used throughout this chapter.

- **Physically Available Surface Water Supply** – The maximum amount of water that occurs 100 percent of the time at a location on a surface water body with no defined Surface Water Conditions applied on the surface water body.

- **Reach of Interest** – A stream reach defined by the RBC that experiences undesired impacts, environmental or otherwise, determined from current or future water demand scenarios or proposed water management strategies. Such reaches may or may not have identified Surface Water Shortages. The Broad RBC did not identify any Reaches of Interest in the Broad River basin.

- **Reservoir Safe Yield** – The Surface Water Supply for a reservoir or system of reservoirs over the simulated hydrologic period of record.

- **Strategic Node** – A location on a surface water body or aquifer designated to evaluate the cumulative impacts of water management strategies for a given model scenario and that serves as a primary point of interest from which to evaluate a model scenario's performance measures. The RBC selected the Strategic Nodes.

- **Surface Water Condition** – A limitation, defined by the RBC, on the amount of water that can be withdrawn from a surface water source and that can be applied to evaluate Surface Water Supply for planning purposes. The Broad RBC did not establish a Surface Water Condition for any location in the Broad River basin.

- **Surface Water Shortage** – A situation in which water demand exceeds the Surface Water Supply for any water user in the basin.

- **Surface Water Supply** – The maximum amount of water available for withdrawal 100 percent of the time at a location on a surface water body without violating any applied Surface Water Conditions on the surface water source and considering upstream demands.

5.1.2 Groundwater

The Broad River basin is almost entirely in the Piedmont physiographic province where groundwater occurs in bedrock fractures and in the overlying saprolite. Groundwater use is limited in the basin, and as such, no modeling or other analysis was performed to assess groundwater availability. In South Carolina, groundwater modeling is being used to assess current and future availability in the river basins that extend into the Coastal Plain. These include the Pee Dee, Santee, Edisto, and Lower Savannah-Salkehatchie.

5.2 Performance Measures

Performance measures were developed as a means for comparing water resource impacts (negative and positive) of each scenario. A performance measure is a quantitative measure of change in a user-defined condition from an established baseline, used to assess the performance of a proposed water management strategy or combination of strategies. Performance measures establish an objective means with which to compare scenarios. Performance measures were selected in collaboration with the RBC.

5.2.1 Hydrologic-based Performance Measures

Table 5-1 presents the hydrologic surface water performance measures used to evaluate and compare simulation results. For each simulated scenario, performance measures were calculated as a post-processing step in the modeling. All metrics were calculated for the entire simulation period. Changes in performance measures between scenarios were particularly useful for the planning process. The first set of performance metrics were calculated for model output nodes that were identified by the RBC as Strategic Nodes. These Strategic Nodes are distributed throughout the river basin. Strategic Nodes are defined at 10 of the USGS streamflow gaging stations in the basin and at the Broad River Outlet at the terminus of the model. Figure 5-1 shows all Strategic Node locations.

Table 5-1. Surface water performance measures.

Strategic Node Metrics (generated for each Strategic Node)
Mean flow (cfs)
Median flow (cfs)
25th percentile flow (cfs)
10th percentile flow (cfs)
5th percentile flow (cfs)
Comparison to minimum instream flows (MIFs)[1]
Basinwide Metrics (generated in aggregate for the entire modeled river basin)
Total basin annual mean shortage (MGD) - Sum of the average shortage for all users over the simulation period
Maximum water user shortage (MGD) - Maximum monthly shortage experienced by any single user over the simulation period
Total basin annual mean shortage (% of demand) - Sum of the average shortage for all users over the simulation period divided by the sum of the average demand for all users over the simulation period
Average frequency of shortage (%) - Average frequency of shortage of all users who experience a shortage, where each user's frequency of shortage is calculated as the number of months with a shortage divided by the total months in the simulation (for a monthly timestep simulation)

[1] Chapter 6, Water Management Strategies, provides discussion of MIFs as performance measures.

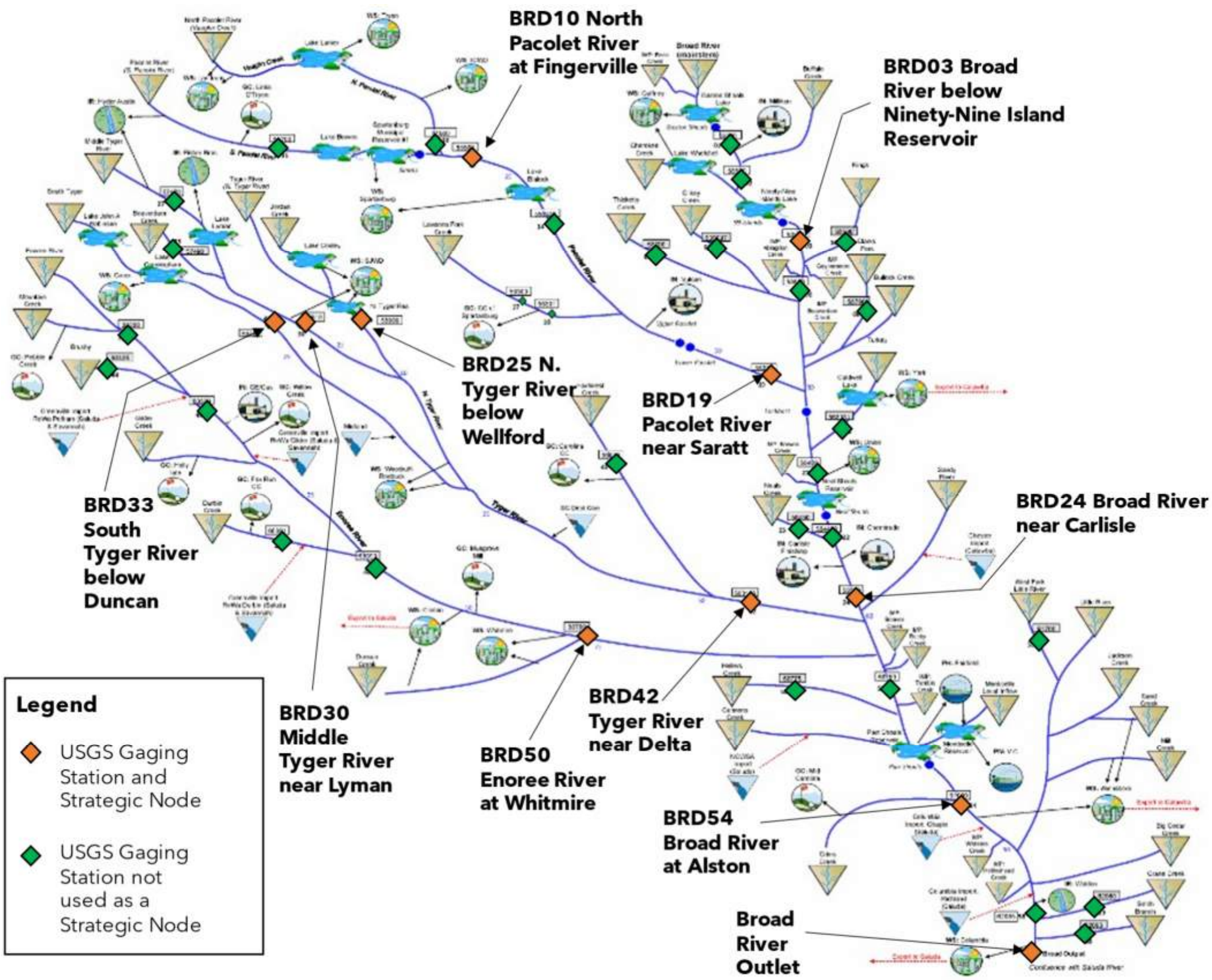


Figure 5-1. Strategic node locations.

5.2.2 Biological Response Metrics

As referenced in Chapter 3.2.2 and discussed in Bower et al. (2022) and The Nature Conservancy et al. (2022), biological response metrics were developed and combined with hydrologic metrics to identify statistically significant correlations between flow characteristics and ecological suitability for fish and macroinvertebrates. Select flow-ecology metrics (hydrologic metrics found to be most correlated to biological diversity) were used then as performance measures to help guide RBC discussions and recommendations for the Broad River basin. This section provides discussion of the relevant, selected biological response metrics and related hydrologic metrics (sometimes referred to as the “flow-ecology metrics”), and Chapter 5.3.7 presents their values and interpretation in the context of the Broad River basin.

The metrics were calculated at key downstream nodes in four of the primary subbasins of the Broad River basin (Lower Broad, Tyger, Enoree, and Pacolet) and represent a general assessment of how aquatic life will be impacted by changes in flow based on SWAM scenarios. Additional metrics were computed in select secondary tributaries. Results should not be considered as necessarily uniform throughout each subbasin. Local conditions may vary along the length of streams. Metrics were based on flow-ecology relationships calculated using data from streams and small rivers with watershed areas ≤ 2,715 mile^2. Because streams of this size comprise 86 percent of all surface water in South Carolina, results are broadly applicable across the basin. However, the results should not be extrapolated to large rivers or reservoirs.

Of the 14 biological response metrics identified in Bower et al. (2022), the following five biological response metrics were used in the Broad River basin because of the relevance and strong correlation to hydrologic statistics that could be readily extracted from the SWAM model (descriptions from The Nature Conservancy et al. 2022):

- Species richness: the number of species found at a given site
- Shannon diversity: an index of biodiversity that accounts for both species richness and proportional representation of each species
- Brood hiders: the proportional representation of fish individuals in the brood hiding breeding strategy
- Nest spawners: the proportional representation of fish individuals in the nest spawning breeding strategy
- Tolerant species: the average tolerance index for aquatic insect taxa

Hydrologic statistics that correlated well to these biological metrics included four metrics that could be easily extracted from SWAM model results (The Nature Conservancy et al. 2022). These flow metrics, intended to support flow-ecology relationships, expand on the hydrologic metrics discussed in Chapter 5.2.1, which were used specifically for hydrologic comparisons. The four flow metrics are:

- **Mean daily flow** is the mean (average) daily flow of the stream in cfs over the period of record.
- **Duration of high flow** is the annual average number of days of flow above the 75th percentile of all daily values over the period of record.
- **Frequency of high flow** is the annual average of the number of flow events above the 75th percentile of all daily values over the period of record.
- **Timing of lowest observed flow** is the (Julian) date of the annual minimum flow, converted to Julian date (a number from 1 to 365).

Mapped together, these hydrologic metrics were used to estimate changes in the biological response metrics, which characterized the ecological integrity of the subbasins. Table 5-2 helps illustrate the flow-ecology relationships for Piedmont Perennial Runoff (P1) and Piedmont Perennial Flashy (P4) stream types, which are the dominant stream types in the Broad River basin (The Nature Conservancy et al. 2022); however, this table is not exhaustive. Chapter 5.3.7 presents and provides discussion of the application of the biological response metrics for the Broad River basin.

Table 5-2. Relationship of hydrologic and biological response metrics.

Hydrologic Metric (Output from SWAM Scenarios)	Biological Response Metrics with High Conditional Importance (Bower et al. 2022)	Type of Evaluation
Mean Daily Flow	Brood Hiders, Shannon Diversity, Species Richness	Ecological Integrity
Duration of High Flow	Nest Spawners, Shannon Diversity, Tolerant Species	Ecological Integrity and Tolerance
Frequency of High Flow	Nest Spawners, Species Richness, Shannon Diversity	Ecological Integrity
Timing of Low Flow	Shannon Diversity, Nest Spawners, Tolerant Species	Ecological Integrity and Tolerance

5.3 Scenario Descriptions and Surface Water Simulation Results

Four scenarios were used to evaluate surface water availability and to identify any anticipated Surface Water Shortages: the Current Surface Water Use Scenario (Current Scenario); the Permitted and Registered Surface Water Use Scenario (P&R Scenario); the Moderate Water Demand Scenario (Moderate Scenario); and the High Water Demand Scenario (High Demand Scenario). The Moderate Scenario was originally referred to as the Business-as-Usual Scenario in the Framework. The RBC requested a fifth scenario, the Unimpaired Flow Scenario (UIF Scenario), and a model simulation was completed. The UIF Scenario removes all surface water withdrawals and discharges and simulates conditions before any surface water development. The following scenarios were simulated over the approximately 90-year period of variable climate and hydrology spanning October 1929 to December 2019. All simulation results, except where noted, are based on model simulations using a monthly timestep.

5.3.1 Current Surface Water Use Scenario

The Current Scenario represents current operations, infrastructure, and water use in the Broad River basin. Water demands were generally set based on reported water usage in the 10-year period spanning 2010 to 2019, with several minor exceptions. This simulation provides information on the potential for Surface Water Shortages that could immediately result under a repeat of historic drought conditions in the basin and highlights the need for short-term planning initiatives, including the development of strategies to mitigate shortages and/or increase Surface Water Supply.

Tables 5-3 and 5-4 summarize simulation results (using a monthly timestep) for the Current Scenario. Only one surface water user has a calculated Surface Water Shortage for one or more months over the 90-year (1,083-month) simulation. This water user is Dominion Energy's Fairfield Pumped Storage Hydroelectric Facility. The simulated shortage, which should be ignored, occurs because of the limitations of modeling a pumped storage facility, which moves large quantities of water to and from Lake Monticello on a sub-daily basis. Consequently, this does not reflect a true shortage. For this reason, subsequent scenarios do not present calculated shortages at the Fairfield Pumped Storage Facility. No other surface water users in the basin have a simulated shortage for the Current Scenario.

Table 5-3 presents the mean flow, median flow, and Surface Water Supply at each Strategic Node. Also presented are the 25th, 10th, and 5th percentile flows, which are useful in characterizing low flows. Table 5-4 presents the basinwide performance metrics. As noted, the model calculated shortage for the Fairfield Pumped Storage Hydroelectric Facility is omitted from the basinwide statistics, since monthly simulations do not accurately represent the pumping and release of water that occurs on a sub-daily basis.

Table 5-3. Surface water model simulation results at Strategic Nodes, Current Scenario.

Strategic Node	Mean Flow (cfs)	Median Flow (cfs)	Surface Water Supply (cfs)	Percentile Flows (cfs)		
				25th	10th	5th
BRD03 Broad River below Ninety-Nine Islands Reservoir	2,344	1,981	278	1,396	952	749
BRD24 Broad River near Carlisle	3,567	2,969	440	2,029	1,369	1,068
BRD54 Broad River at Alston	5,454	4,533	608	2,960	2,012	1,570
Broad River Outlet	5,848	4,748	594	3,080	2,077	1,628
BRD10 North Pacolet River at Fingerville	200	174	31	120	85	66
BRD19 Pacolet River near Saratt	656	548	69	363	235	189
BRD30 Middle Tyger River near Lyman	98	81	1	51	32	22
BRD33 South Tyger River below Duncan	144	122	16	80	51	36
BRD25 North Tyger River below Wellford	47	37	0	22	12	7
BRD42 Tyger River near Delta	776	635	82	413	270	198
BRD50 Enoree River at Whitmire	487	399	75	270	188	153

Table 5-4. Basinwide surface water model simulation results, Current Scenario.

Performance Measure	Result
Total basin annual mean shortage (MGD)	0
Maximum water user shortage (MGD)	0
Total basin annual mean shortage (% of demand)	0
Percentage of water users experiencing shortage	0
Average frequency of shortage (%)	0

Note: Fairfield Pumped Storage modeled shortage results are not included here.

5.3.2 Permitted and Registered Surface Water Use Scenario

In the P&R Scenario, modeled demands were set to permitted or registered values for all water users. In other words, this simulation explored the question of, "What if all water users used the full volume of water allocated through permits and registrations?". The scenario provides information to determine whether surface water is currently over-allocated in the basin.

Tables 5-5 through 5-8 summarize the simulation results for the P&R Scenario (monthly timestep). In this scenario, river flows are predicted to decrease, compared to the Current Scenario, throughout the basin, resulting in Surface Water Shortages for several surface water users. Table 5-5 lists only the surface water users with one or more months of a simulated Surface Water Shortage. Figure 5-2 shows locations of these water users on the SWAM model framework. Also shown are the average annual demand for each water user experiencing a shortage; the minimum physically available (monthly average) flow at the point of withdrawal; the maximum (monthly average) shortage; and the frequency of shortage.

Table 5-5. Identified Surface Water Shortages, P&R Scenario.

Water User Name	Source Water	Average Annual Demand (MGD)	Minimum Physically Available Flow (MGD)	Maximum Shortage (MGD)	Frequency of Shortage (%)
WS: Gaffney	Cherokee Creek	27.40	0	32	6.3
WS: Spartanburg	Pacolet River	278.46	0.6	250	91.2
WS: York[1]	Turkey Creek	3.06	0	3	13.3
IR: Fisher Bros	Middle Tyger River	7.24	4	3	1.8
WS: SJWD	Middle Tyger River	58.14	3	51	94.3
WS: Greer	South Tyger River	55.37	1	45	47.4
WS: Woodruff-Roebuck	South Tyger River	18.36	29	0.8	0.2
GC: Pebble Creek	Mountain Creek	4.11	1	3	9.0
GC: Fox Run CC	Durbin Creek	0.63	0.2	0.4	1.7
WS: Clinton	Enoree River	13.65	46	3	3.5
GC: Mid Carolina	Crims Creek	1.06	0.1	0.9	33.5
WS: Winnsboro	Sand Creek	16.32	275	6	89.2

IR = agricultural (irrigation) water user; WS = water supply water user; GC = golf course water user

[1] WS: York no longer withdraws water from Turkey Creek just below Caldwell Lake and instead purchases all their water from the City of Rock Hill. The simulated shortage in this scenario is based on WS: York withdrawing at their permitted amount from Turkey Creek, and not purchasing any water from Rock Hill.

Table 5-6 presents the mean flow, median flow, and Surface Water Supply at each Strategic Node. Also presented are the 25th, 10th, and 5th percentile flows, which are useful in characterizing low flows. Table 5-7 shows the percent decrease in P&R Scenario flow statistics compared to the Current Scenario. Modeled reductions are most pronounced during low-flow periods. Mean and median flows at the most downstream site of the mainstem (Broad River Outlet) are predicted to decrease by approximately 10 to 12 percent, respectively, if all upstream users withdrew water from the system at their permitted or registered amount. The impact of full allocation withdrawals on downstream water users is evident in the predicted increase in mean annual water shortage and the increase in the number and frequency of water users experiencing a shortage during the simulation period, as shown in Table 5-8. As explained in Chapter 4, the fully permitted and registered withdrawal rates greatly exceed current use rates. Despite the low likelihood of the P&R Scenario, results demonstrate that the surface water resources of the basin are over-allocated based on existing permit and registration amounts. Many users were issued permits prior to implementation of the 2011 Surface Water Withdrawal, Permitting Use, and Reporting Act and have permits based on the maximum volume of their intake rather than safe yield calculations.

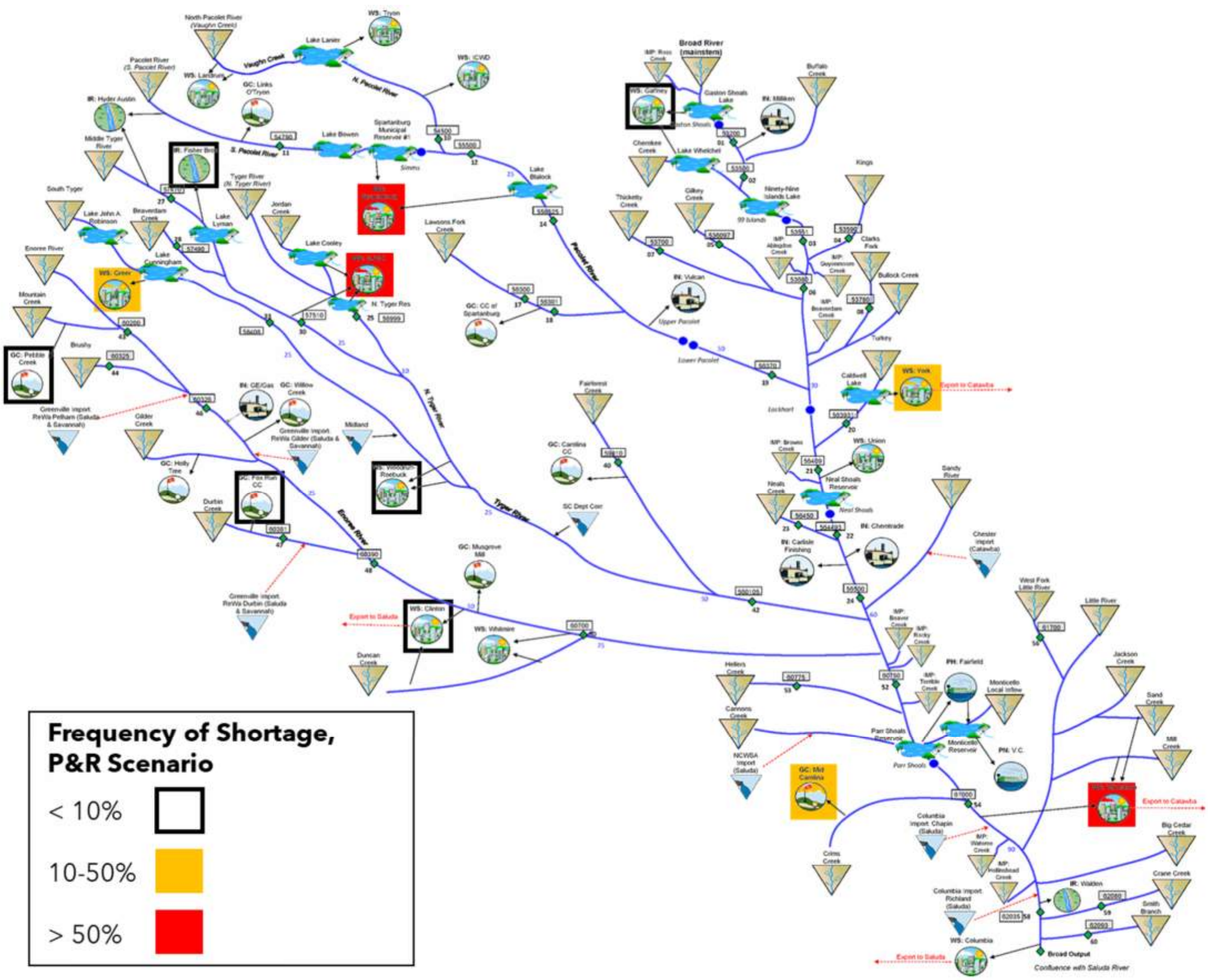


Figure 5-2. Water users with Surface Water Shortages and frequency of shortages, P&R Scenario.

Table 5-6. Surface water model simulation results at Strategic Nodes, P&R Scenario.

Strategic Node	Mean Flow (cfs)	Median Flow (cfs)	Surface Water Supply (cfs)	Percentile Flows (cfs)		
				25th	10th	5th
BRD03 Broad River below Ninety-Nine Islands Reservoir	2,291	1,928	234	1,344	914	714
BRD24 Broad River near Carlisle	3,311	2,703	324	1,851	1,256	966
BRD54 Broad River at Alston	5,044	4,107	426	2,682	1,788	1,363
Broad River Outlet	5,278	4,177	268	2,642	1,667	1,285
BRD10 North Pacolet River at Fingerville	187	161	18	107	73	54
BRD19 Pacolet River near Saratt	473	377	56	251	182	139
BRD30 Middle Tyger River near Lyman	61	42	0	11	0	0
BRD33 South Tyger River below Duncan	103	74	16	51	35	26
BRD25 North Tyger River below Wellford	15	4	0	3	2	1
BRD42 Tyger River near Delta	664	521	49	321	199	144
BRD50 Enoree River at Whitmire	470	382	58	252	170	133

Table 5-7. Percent change in P&R Scenario flows at Strategic Nodes relative to Current Scenario flows.

Strategic Node	Mean Flow	Median Flow	Surface Water Supply	Percentile Flows		
				25th	10th	5th
BRD03 Broad River below Ninety-Nine Islands Reservoir	-2%	-3%	-16%	-4%	-4%	-5%
BRD24 Broad River near Carlisle	-7%	-9%	-26%	-9%	-8%	-10%
BRD54 Broad River at Alston	-8%	-9%	-30%	-9%	-11%	-13%
Broad River Outlet	-10%	-12%	-55%	-14%	-20%	-21%
BRD10 North Pacolet River at Fingerville	-6%	-8%	-40%	-11%	-15%	-19%
BRD19 Pacolet River near Saratt	-28%	-31%	-18%	-31%	-22%	-26%
BRD30 Middle Tyger River near Lyman	-38%	-49%	-99%	-78%	-100%	-100%
BRD33 South Tyger River below Duncan	-28%	-39%	-1%	-37%	-31%	-26%
BRD25 North Tyger River below Wellford	-68%	-89%	0%	-88%	-86%	-82%
BRD42 Tyger River near Delta	-14%	-18%	-41%	-22%	-26%	-28%
BRD50 Enoree River at Whitmire	-4%	-4%	-22%	-7%	-10%	-13%

Table 5-8. Basinwide surface water model simulation results, P&R Scenario.

Performance Measure	Result
Total basin annual mean shortage (MGD)	129
Maximum water user shortage (MGD)	250
Total basin annual mean shortage (% of demand)	8.5
Percentage of water users experiencing shortage	38
Average frequency of shortage (%)	33

Note: Fairfield Pumped Storage modeled shortage results are not included here.

5.3.3 Moderate Water Demand Projection Scenario

For the Moderate Scenario, modeled demands were set to projected future levels based on an assumption of moderate population and economic growth, as described in Chapter 4.3. The year 2070 planning horizon was targeted using the demand projections developed by SCDNR and presented in Chapter 4.4. The Moderate Scenario explores a plausible future where water demands increase with moderate population growth and climate change impacts are negligible, in both the short- and long-term. Existing agricultural users' current demands were kept constant, based on the assumption that agricultural growth in the basin is not expected under any scenario.

Tables 5-9 through 5-12 summarize the Moderate Scenario (monthly timestep) simulation results for the 2070 planning horizon. Calculated water shortages exist for two water users under the Moderate 2070 Scenario, including a shortage at the proposed Lee Nuclear Generating Station. Chapter 6 provides further discussion on the water supply planning for this new user, which includes a proposed off-line storage pond to alleviate projected shortages. The only other water user with a shortage is the Greer CPW municipal water supply. Figure 5-3 shows the locations of these water users on the SWAM model framework. Given current climate conditions and existing basin management and regulatory structure, basin surface water supplies are predicted to be adequate to meet increased demands resulting from moderate economic and population growth.

In the Moderate Scenario, flows are predicted to decrease modestly to moderately, depending on location, compared to the Current Use Scenario. Modeled reductions are most pronounced during low-flow periods. At the most downstream Strategic Node (Broad River Outlet), mean and median flows are predicted to decrease by approximately 3 percent, and low flows by about 5 percent, by 2070 if population and economic growth is moderate and climate change impacts are negligible. Because of a release rule included in the SWAM model for Lake Cooley, Moderate Scenario flows are simulated to increase at Strategic Node BRD25 North Tyger River below Wellford, compared to the Current Use Scenario flows. The release rule causes more water to be released from Lake Cooley, in the Moderate Scenario, because of the higher demands of WS: SJWD. Moderate Scenario flows are also simulated to increase at Strategic Node BRD50 Enoree River at Whitmire because of increased wastewater discharges upstream on the Enoree River.

Table 5-9. Identified Surface Water Shortages, Moderate 2070 Scenario.

Water User Name	Source Water	Average Annual Demand (MGD)	Minimum Physically Available Flow (MGD)	Maximum Shortage (MGD)	Frequency of Shortage (%)
PN: Lee	Mainstem	35.80	0	36	3.0
WS: Greer	South Tyger River	16.40	1	11	2.4

WS = water supply water user; PN = nuclear power water user

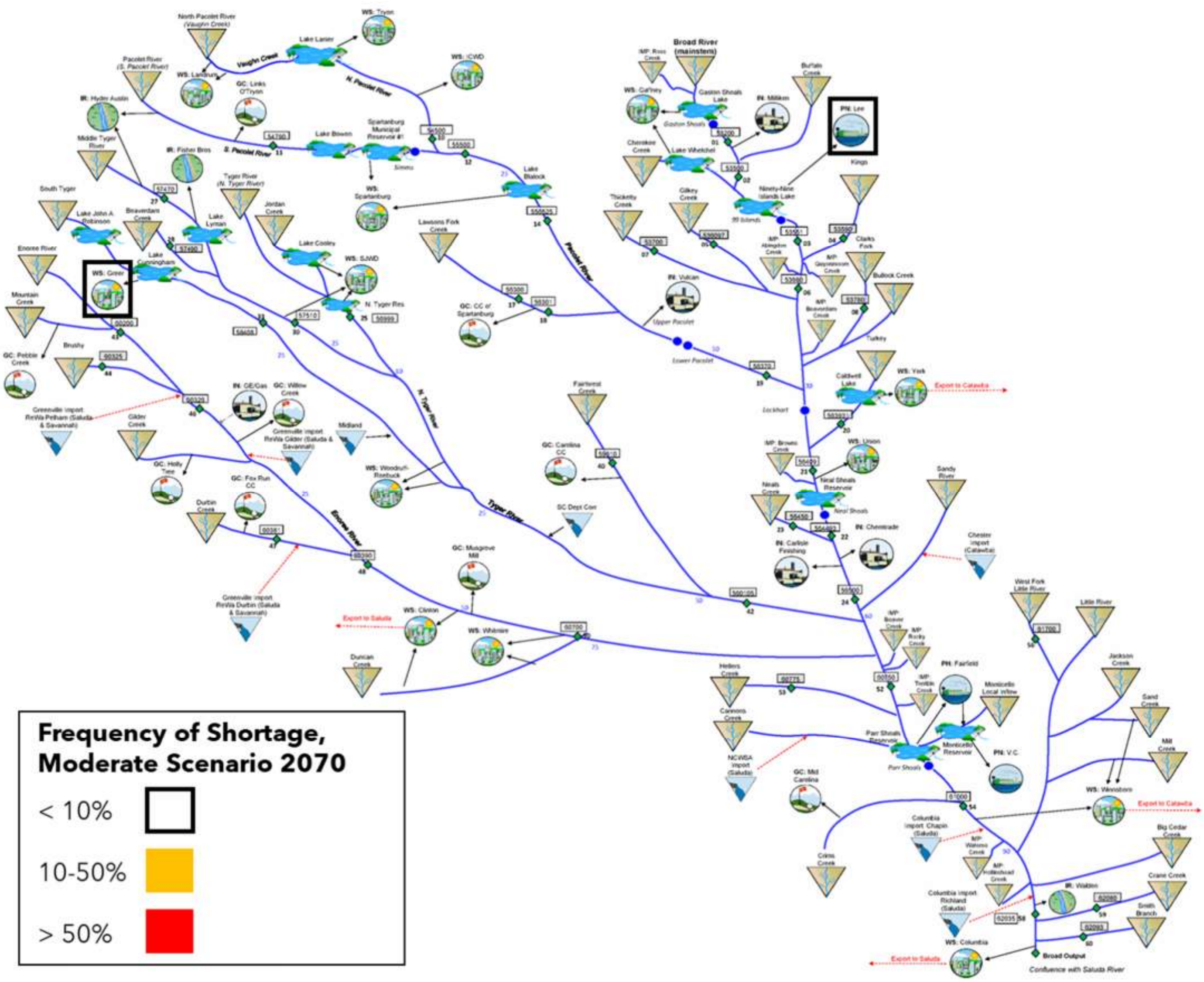


Figure 5-3. Water users with Surface Water Shortages and frequency of shortages, Moderate 2070 Scenario.

Table 5-10. Surface water model simulation results at Strategic Nodes, Moderate 2070 Scenario.

Strategic Node	Mean Flow (cfs)	Median Flow (cfs)	Surface Water Supply (cfs)	Percentile Flows (cfs)		
				25th	10th	5th
BRD03 Broad River below Ninety-Nine Islands Reservoir	2,255	1,893	234	1,314	875	679
BRD24 Broad River near Carlisle	3,456	2,849	354	1,920	1,279	1,010
BRD54 Broad River at Alston	5,334	4,406	503	2,861	1,891	1,506
Broad River Outlet	5,711	4,605	475	2,964	1,937	1,547
BRD10 North Pacolet River at Fingerville	191	164	17	110	74	58
BRD19 Pacolet River near Saratt	633	521	72	334	231	188
BRD30 Middle Tyger River near Lyman	84	67	0	37	15	7
BRD33 South Tyger River below Duncan	136	114	16	70	39	26
BRD25 North Tyger River below Wellford	50	40	0	25	17	11
BRD42 Tyger River near Delta	756	616	72	392	248	179
BRD50 Enoree River at Whitmire	501	412	87	283	200	166

Table 5-11. Percent change in Moderate 2070 Scenario flows at Strategic Nodes relative to Current Scenario flows.

Strategic Node	Mean Flow	Median Flow	Surface Water Supply	Percentile Flows		
				25th	10th	5th
BRD03 Broad River below Ninety-Nine Islands Reservoir	-4%	-4%	-16%	-6%	-8%	-9%
BRD24 Broad River near Carlisle	-3%	-4%	-20%	-5%	-7%	-5%
BRD54 Broad River at Alston	-2%	-3%	-17%	-3%	-6%	-4%
Broad River Outlet	-2%	-3%	-20%	-4%	-7%	-5%
BRD10 North Pacolet River at Fingerville	-5%	-6%	-45%	-8%	-13%	-13%
BRD19 Pacolet River near Saratt	-3%	-5%	5%	-8%	-2%	0%
BRD30 Middle Tyger River near Lyman	-14%	-18%	-99%	-27%	-51%	-69%
BRD33 South Tyger River below Duncan	-6%	-7%	3%	-12%	-23%	-27%
BRD25 North Tyger River below Wellford	6%	8%	0%	17%	34%	56%
BRD42 Tyger River near Delta	-2%	-3%	-13%	-5%	-8%	-10%
BRD50 Enoree River at Whitmire	3%	3%	16%	5%	7%	8%

Table 5-12. Basinwide surface water model simulation results, Moderate 2070 Scenario.

Performance Measure	Result
Total basin annual mean shortage (MGD)	0.8
Maximum water user shortage (MGD)	36
Total basin annual mean shortage (% of demand)	0.1
Percentage of water users experiencing shortage	6
Average frequency of shortage (%)	3

Note: Fairfield Pumped Storage modeled shortage results are not included here.

5.3.4 High Water Demand Projection Scenario

For the High Demand Scenario, modeled demands are set to the 90th percentile of variability in reported withdrawals for each user, and the projections are based on aggressive growth within the range of uncertainty of the referenced driver variable projections, as described in Chapter 4. Like the Moderate Scenario, a year 2070 planning horizon was targeted using the demand projections developed by SCDNR. This set of scenarios represents the combined impacts of all sectors experiencing high growth and all water users experiencing conditions of high water demand. These assumptions are intended to represent an unlikely maximum for total water demand; it is very unlikely these demands would occur month after month and year after year for all water users. The purpose of this scenario is to provide the RBC with information on which to base conservative management strategies. Other methods and assumptions used in constructing the High Demand Scenario were the same as for the Moderate Scenario.

Tables 5-13 through 5-16 summarize the High Demand Scenario (monthly timestep) simulation results for the 2070 planning horizon. The two water users with shortages in the Moderate 2070 Scenario exhibit slightly greater shortages under the High Demand 2070 Scenario. The proposed off-line storage pond to serve Lee Nuclear Generating Station is not included in this scenario and is further discussed in Chapter 6. Four additional municipal water suppliers and three golf courses experience shortages.

In the High Demand Scenario, river flows are predicted to decrease moderately to substantially, compared to the Current Scenario, throughout the basin. Modeled reductions are most pronounced during low-flow periods. Mean and median flows at the most downstream site of the mainstem (Broad River Outlet) are predicted to decrease by approximately 5 percent, and low flows by approximately 10 percent, based on 2070 demands. Calculated water user shortages increase slightly, in terms of both duration and intensity, for the 2070 planning horizon, as compared to the Moderate Scenario results.

Table 5-13. Identified Surface Water Shortages, High Demand 2070 Scenario.

Water User Name	Source Water	Average Annual Demand (MGD)	Minimum Physically Available Flow (MGD)	Maximum Shortage (MGD)	Frequency of Shortage (%)
PN: Lee	Mainstem	35.80	0	36	3.3
WS: Gaffney	Cherokee Creek	25.05	0	28	1.1
WS: Spartanburg	Pacolet River	62.05	0.2	37	0.4
WS: York[1]	Turkey Creek	4.81	0	6	29.4
WS: SJWD	Middle Tyger River	25.05	6	13	0.4
WS: Greer	South Tyger River	22.42	1	17	7.1
GC: Pebble Creek	Mountain Creek	0.58	1	0.1	0.1
GC: Fox Run CC	Durbin Creek	0.12	0.2	0.02	0.1
GC: Mid Carolina	Crims Creek	0.08	0.1	0.03	0.2

WS = water supply water user; PN = nuclear power water user; GC = golf course water user

[1] York recently stopped withdrawing from Turkey Creek below Caldwell Lake in the Broad basin and currently purchases all their water from the City of Rock Hill. For modeling purposes, and because they maintain an active water withdrawal permit, their projected withdrawals were applied to Turkey Creek below Caldwell Lake.

Table 5-14. Surface water model simulation results at Strategic Nodes, High Demand 2070 Scenario.

Strategic Node	Mean Flow (cfs)	Median Flow (cfs)	Surface Water Supply (cfs)	Percentile Flows (cfs)		
				25th	10th	5th
BRD03 Broad River below Ninety-Nine Islands Reservoir	2,239	1,867	232	1,297	870	660
BRD24 Broad River near Carlisle	3,413	2,794	352	1,880	1,267	954
BRD54 Broad River at Alston	5,265	4,332	474	2,782	1,846	1,434
Broad River Outlet	5,605	4,486	402	2,862	1,841	1,443
BRD10 North Pacolet River at Fingerville	183	156	9	102	66	50
BRD19 Pacolet River near Saratt	614	498	70	324	221	178
BRD30 Middle Tyger River near Lyman	70	50	0	16	0	0
BRD33 South Tyger River below Duncan	130	107	17	63	35	27
BRD25 North Tyger River below Wellford	48	40	0	24	5	1
BRD42 Tyger River near Delta	738	596	77	372	224	164
BRD50 Enoree River at Whitmire	503	414	88	286	201	166

Table 5-15. Percent change in High Demand 2070 Scenario flows at Strategic Nodes relative to Current Scenario flows.

Strategic Node	Mean Flow	Median Flow	Surface Water Supply	Percentile Flows		
				25th	10th	5th
BRD03 Broad River below Ninety-Nine Islands Reservoir	-5%	-6%	-17%	-7%	-10%	-12%
BRD24 Broad River near Carlisle	-4%	-6%	-20%	-7%	-7%	-10%
BRD54 Broad River at Alston	-3%	-5%	-22%	-6%	-8%	-8%
Broad River Outlet	-4%	-6%	-32%	-7%	-10%	-11%
BRD10 North Pacolet River at Fingerville	-9%	-10%	-71%	-14%	-22%	-26%
BRD19 Pacolet River near Saratt	-6%	-9%	2%	-11%	-5%	-6%
BRD30 Middle Tyger River near Lyman	-29%	-38%	-99%	-69%	-100%	-100%
BRD33 South Tyger River below Duncan	-10%	-12%	8%	-22%	-33%	-23%
BRD25 North Tyger River below Wellford	2%	7%	0%	13%	-60%	-81%
BRD42 Tyger River near Delta	-5%	-6%	-6%	-10%	-17%	-18%
BRD50 Enoree River at Whitmire	3%	4%	17%	5%	8%	8%

Table 5-16. Basinwide surface water model simulation results, High Demand 2070 Scenario.

Performance Measure	Result
Total basin annual mean shortage (MGD)	3
Maximum water user shortage (MGD)	37
Total basin annual mean shortage (% of demand)	0.2
Percentage of water users experiencing shortage	27
Average frequency of shortage (%)	5

Note: Fairfield Pumped Storage modeled shortage results are not included here.

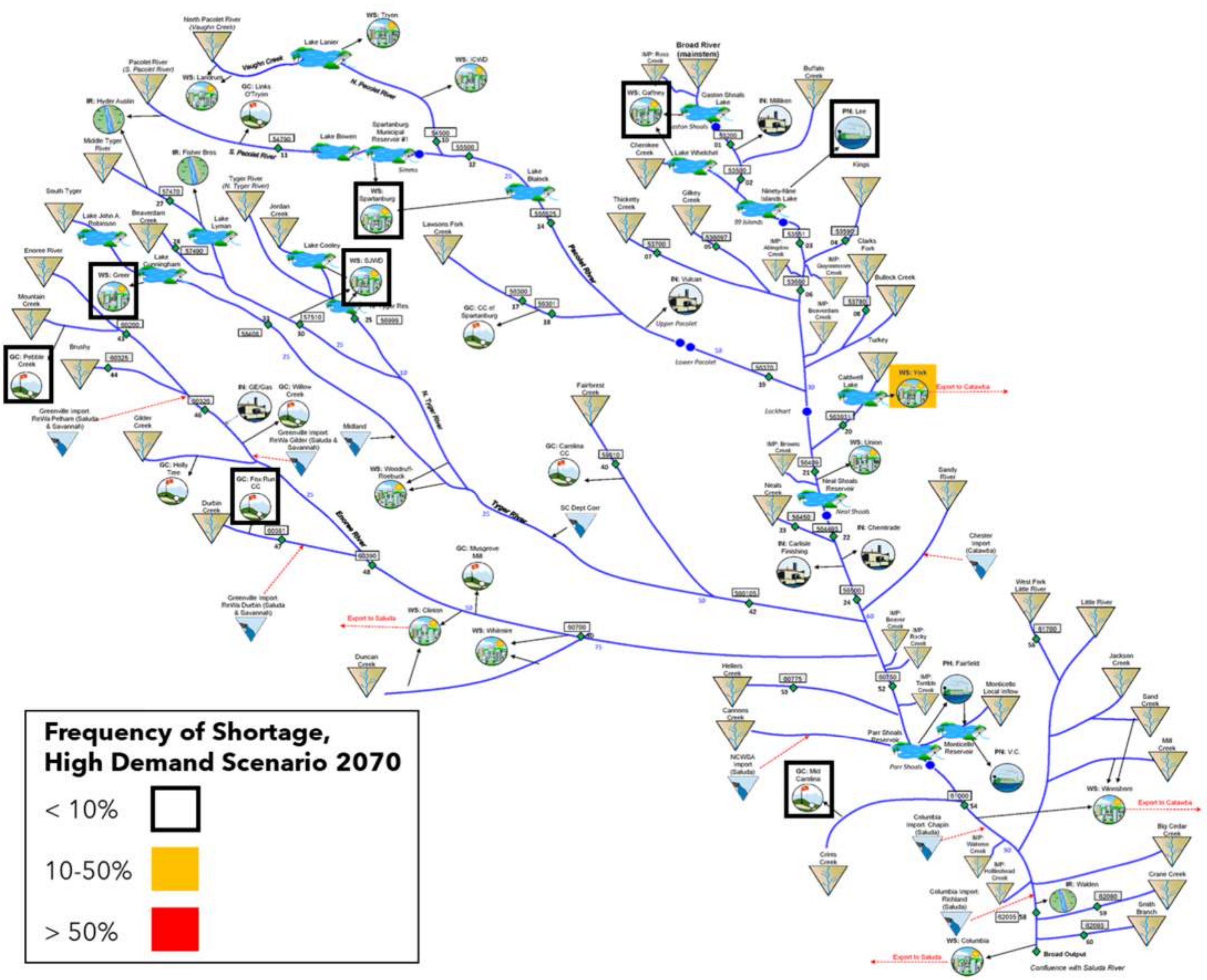


Figure 5-4. Water users with Surface Water Shortages and frequency of shortages, High Demand 2070 Scenario

In addition to the 2070 planning horizon, water supply availability based on interim-year planning horizons ranging from 2025 to 2060 were also assessed, and Surface Water Shortages were identified. Table 5-17 provides a summary of the simulated shortages and frequencies based on these interim-year projections. Several water users are anticipated to have shortages based on growth projections as soon as 2025, while others are not anticipated to experience shortages until 2060 growth levels are reached.

Table 5-17. Identified Surface Water Shortages, High Demand Scenarios for Planning Horizon Years 2025 through 2070.

	Maximum Surface Water Shortage (MGD)					
Water User Name	**2025**	**2030**	**2040**	**2050**	**2060**	**2070**
PN: Lee	Not built, online in 2035		36	36	36	36
WS: Gaffney	6	10	13	19	23	28
WS: Spartanburg	No shortage				15	37
WS: York	0.3	0.8	2	3	4	6
WS: SJWD	No shortage				7	13
WS: Greer	No shortage		4	9	13	17
GC: Pebble Creek	0.1	0.1	0.1	0.1	0.1	0.1
GC: Fox Run CC	0.02	0.02	0.02	0.02	0.02	0.02
GC: Mid Carolina	0.03	0.03	0.03	0.03	0.03	0.03
	Frequency of Surface Water Shortage					
Water User Name	**2025**	**2030**	**2040**	**2050**	**2060**	**2070**
PN: Lee	Not built, online in 2035		2.8%	3.1%	3.2%	3.3%
WS: Gaffney	0.3%	0.3%	0.5%	0.7%	1.0%	1.1%
WS: Spartanburg	No shortage				0.1%	0.4%
WS: York	0.1%	0.9%	4.2%	10.7%	19.9%	29.4%
WS: SJWD	No shortage				0.1%	0.4%
WS: Greer	No shortage		0.8%	2.6%	4.4%	7.1%
GC: Pebble Creek	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
GC: Fox Run CC	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
GC: Mid Carolina	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%

The proposed off-line storage pond to alleviate projected shortages for the Lee Nuclear Generating Station was not included in these simulations. See Chapter 6 for model results with the off-line storage pond included.

The High Demand Scenario for the 2070 planning horizon was also modeled using a daily timestep. Tables 5-18 through 5-20 summarize the results. Not surprisingly, mean modeled flows are similar for the daily and monthly calculation timesteps, but modeled extreme low flows (25th, 10th, and 5th percentiles) are lower for the daily timestep model compared to the monthly timestep model. A greater range of flow variability is simulated with the higher resolution daily model, compared to the monthly model. Because of the higher temporal resolution, the daily model captures a basinwide maximum daily water user shortage that is significantly higher than that quantified by the monthly timestep model.

Table 5-18. Daily timestep surface water model simulation results at Strategic Nodes, High Demand 2070 Scenario.

Strategic Node	Mean Flow (cfs)	Median Flow (cfs)	Surface Water Supply (cfs)	Percentile Flows (cfs)		
				25th	10th	5th
BRD03 Broad River below Ninety-Nine Islands Reservoir	2,236	1,624	0	1,082	725	510
BRD24 Broad River near Carlisle	3,409	2,387	106	1,572	1,070	813
BRD54 Broad River at Alston	5,257	3,646	215	2,341	1,546	1,171
Broad River Outlet	5,596	3,760	114	2,365	1,521	1,128
BRD10 North Pacolet River at Fingerville	182	133	2	86	56	40
BRD19 Pacolet River near Saratt	613	418	49	278	195	164
BRD30 Middle Tyger River near Lyman	71	37	0	7	0	0
BRD33 South Tyger River below Duncan	130	89	6	50	31	25
BRD25 North Tyger River below Wellford	47	34	0	19	2	1
BRD42 Tyger River near Delta	736	510	31	307	190	140
BRD50 Enoree River at Whitmire	502	354	41	241	172	138

Table 5-19. Percent change in High Demand 2070 Scenario daily flows at Strategic Nodes relative to Current Scenario daily flows.

Strategic Node	Mean Flow	Median Flow	Surface Water Supply	Percentile Flows		
				25th	10th	5th
BRD03 Broad River below Ninety-Nine Islands Reservoir	-4%	-6%	-100%	-8%	-10%	-20%
BRD24 Broad River near Carlisle	-4%	-6%	-43%	-7%	-8%	-11%
BRD54 Broad River at Alston	-4%	-5%	-19%	-6%	-8%	-9%
Broad River Outlet	-4%	-6%	-50%	-8%	-11%	-13%
BRD10 North Pacolet River at Fingerville	-9%	-11%	-87%	-17%	-25%	-33%
BRD19 Pacolet River near Saratt	-6%	-10%	63%	-8%	-4%	3%
BRD30 Middle Tyger River near Lyman	-28%	-45%	-10%	-84%	-100%	-100%
BRD33 South Tyger River below Duncan	-10%	-15%	-16%	-26%	-25%	-12%
BRD25 North Tyger River below Wellford	0%	7%	0%	7%	-82%	-78%
BRD42 Tyger River near Delta	-5%	-7%	-6%	-13%	-18%	-17%
BRD50 Enoree River at Whitmire	2%	3%	31%	5%	6%	8%

Table 5-20. Basinwide surface water model daily simulation results, High Demand 2070 Scenario.

Performance Measure	Result
Total basin annual mean shortage (MGD)	3
Maximum water user shortage (MGD)	36
Total basin annual mean shortage (% of demand)	0.3
Percentage of water users experiencing shortage	33
Average frequency of shortage (%)	3

Note: Fairfield Pumped Storage modeled shortage results are not included here.

5.3.5 Unimpaired Flow Scenario

At the request of the RBC, the SWAM model was used to simulate UIFs throughout the Broad River basin. For this simulation, all water demands and discharges in the model were set to zero. Simulation results represent river hydrologic conditions without the impact of surface water users, dischargers, or water imports, as modeled. In other words, results represent "naturalized" surface water conditions in the basin.

Tables 5-21 and 5-22 summarize UIF Scenario monthly simulation results. Simulated UIFs are generally higher than simulated Current Scenario flows, as expected. This reflects the removal of consumptive water use for the UIF Scenario simulation. However, at one Strategic Node location (BRD50 Enoree River at Whitmire) the simulated UIFs are lower than Current Scenario flows. This reflects the removal of wastewater returns in the system for the UIF Scenario. The lack of wastewater returns in the Enoree River more than offsets the lack of consumptive surface water use. At the Broad River Outlet, mean and median UIFs are approximately 5 and 6 percent higher than Current Scenario flows, respectively. At this same location, UIF low flows (25th to 5th percentile) are approximately 12 to 19 percent higher than Current Scenario flows.

Table 5-21. Surface water model simulation results at Strategic Nodes, UIF Scenario.

Strategic Node	Mean Flow (cfs)	Median Flow (cfs)	Surface Water Supply (cfs)	Percentile Flows (cfs)		
				25th	10th	5th
BRD03 Broad River below Ninety-Nine Islands Reservoir	2,387	2,028	303	1,449	1,006	804
BRD24 Broad River near Carlisle	3,672	3,092	499	2,145	1,495	1,193
BRD54 Broad River at Alston	5,696	4,750	783	3,277	2,271	1,809
Broad River Outlet	6,137	5,029	827	3,437	2,362	1,932
BRD10 North Pacolet River at Fingerville	208	183	43	128	95	76
BRD19 Pacolet River near Saratt	706	601	121	416	293	236
BRD30 Middle Tyger River near Lyman	108	91	12	60	42	32
BRD33 South Tyger River below Duncan	158	135	31	94	66	50
BRD25 North Tyger River below Wellford	52	42	5	28	19	14
BRD42 Tyger River near Delta	803	666	115	445	300	235
BRD50 Enoree River at Whitmire	475	387	65	260	178	143

Table 5-22. Percent change in UIF Scenario flows at Strategic Nodes relative to Current Scenario flows.

Strategic Node	Mean Flow	Median Flow	Surface Water Supply	Percentile Flows		
				25th	10th	5th
BRD03 Broad River below Ninety-Nine Islands Reservoir	2%	2%	9%	4%	6%	7%
BRD24 Broad River near Carlisle	3%	4%	13%	6%	9%	12%
BRD54 Broad River at Alston	4%	5%	29%	11%	13%	15%
Broad River Outlet	5%	6%	39%	12%	14%	19%
BRD10 North Pacolet River at Fingerville	4%	5%	40%	7%	12%	14%
BRD19 Pacolet River near Saratt	8%	10%	77%	15%	25%	25%
BRD30 Middle Tyger River near Lyman	10%	12%	695%	18%	32%	45%
BRD33 South Tyger River below Duncan	9%	11%	100%	18%	30%	41%
BRD25 North Tyger River below Wellford	10%	13%	1,101%	28%	53%	93%
BRD42 Tyger River near Delta	4%	5%	40%	8%	11%	18%
BRD50 Enoree River at Whitmire	-2%	-3%	-14%	-4%	-5%	-7%

5.3.6 Comparison to Minimum Instream Flows

At the request of the RBC, model-simulated flows for the UIF, Current Use, 2070 Moderate, 2070 High Demand, and P&R Scenarios were compared to the calculated MIF at a subset of the Strategic Nodes. As defined in R.61-119, Surface Water Withdrawal, Permitting, Use and Reporting regulations, the MIF is the "*flow that provides an adequate supply of water at the surface water withdrawal point to maintain the biological, chemical, and physical integrity of the stream taking into account the needs of downstream users, recreation, and navigation*" (SCDHEC 2012). Under SCDNR's 2009 Minimum Instream Flow Policy, the MIF for the Piedmont region is set at 40 percent of the mean annual daily flow for the months of January, February, March, and April; 30 percent of the mean annual daily flow for the months of May, June, and December; and 20 percent of the mean annual daily flow for the months of July through November for surface water withdrawers. Table 5-23 shows the calculated MIFs at a subset of Strategic Nodes. The MIF regulation applies to new surface water permits only. In the Broad River basin, nearly all permitted surface water users are "grandfathered" and are not subject to the MIFs. Grandfathered water users are those that had surface water withdrawals before January 1, 2011.

For these comparisons, modeled flows from daily timestep simulations were used. Table 5-24 presents and compares the percentage of days for all Scenarios when flows are simulated to drop below the calculated MIF at the Strategic Nodes. The entire simulation period of record covered 90.25 years or 32,964 days. The calculated MIF, which comes from measured flow at each USGS gaging station, is based on a shorter period that coincides with the gaging station's period of record (Table 5-23).

Table 5-23. Calculated MIF at select Strategic Nodes.

Gage Name	Gage ID	Period of Record	Mean Annual Daily Flow (cfs)	MIF (cfs)		
				Jan–Apr	May, Jun, and Dec	Jul–Nov
Broad River below Ninety-Nine Islands	02153551	1998–2003	2,072	829	622	414
Broad River Near Carlisle	02156500	1938–2023	3,887	1,555	1,166	777
Broad River at Alston	02161000	1896–1967; 1980; 2013–2023	5,814	2,325	1,744	1,163
Broad Outlet	N/A	See Note 1	5,718	2,277	1,708	1,138
North Pacolet at Fingerville	02154500	1929–2023	145	58	43	29
Pacolet River near Saratt	02156370	2012–2023	804	321	241	161
North Tyger River below Wellford	02156999	2007–2023	29	11	9	6
Middle Tyger River near Lyman	02157510	2000–2023	86	35	26	17
South Tyger River below Duncan	02158408	2001–2023	124	50	37	25
Tyger River near Delta	02160105	1973–2023	885	354	265	177
Enoree River at Whitmire	02160700	1973–2023	522	209	157	104
Percent of mean annual daily flow for calculating MIF -->				**40%**	**30%**	**20%**

[1] Daily flows and the corresponding MIF at the Broad River Outlet were estimated by scaling from the Broad River near Columbia gaging station.

From Table 5-24, results of the comparison to MIFs suggests the following:

- Under UIF conditions, flows drop below MIFs at all Strategic Nodes. On the major tributaries to the Broad River, this happens most often at the Enoree River at Whitmire, Tyger River near Delta, and Pacolet River near Saratt Strategic Nodes. At the Enoree River at Whitmire and Tyger River near Delta, UIFs drop below MIFs more than 10 percent of the time in late summer and early fall. On the Broad River, UIFs drop below MIFs at all four Strategic Nodes generally between 1 and 7 percent of the time, depending on the month.
- At most Strategic Nodes, there is a modest increase in the percentage of days when flows are below MIFs moving from the Current Use to the 2070 Moderate and 2070 High Demand Scenarios. This is because of the higher surface water withdrawals simulated in the 2070 Moderate and 2070 High Demand Scenarios.
- At most Strategic Nodes, the percentage of days when flows of the 2070 Moderate and 2070 High Demand Scenarios drop below the MIF ranges from 0 to 15 percent. Notable exceptions to this occur at the following Strategic Nodes:
    - North Tyger River below Wellford, where flows drop below the MIF in the 2070 High Demand Scenario between 30 and 44 percent of the days in July through October
    - Middle Tyger River near Lyman, where flows drop below the MIF in the 2070 Moderate Scenario between 28 and 38 percent of the days in June through October, and in the

2070 High Demand Scenario between 30 to 77 percent of the time in May through November

- At the Enoree River Strategic Node, there are fewer days in the Current Use, 2070 Moderate, and 2070 High Demand Scenarios when flows are below MIFs, compared to the UIF Scenario. This is because of wastewater discharges to the Enoree River. Much of the wastewater being discharged to the Enoree River comes from surface water withdrawn in the Saluda and Savannah River basins.
- At the Pacolet River, North Tyger River, Middle Tyger River, South Tyger River, and Tyger River Strategic Nodes, there is a relatively large increase in the percentage of days when P&R Scenario flows are below MIFs, compared to the other Scenarios. At most other Strategic Nodes, the difference between the P&R Scenarios and other Scenarios is much less pronounced.

Table 5-24. Percent of days below MIF at select Strategic Nodes.

Strategic Node	Scenario	Percentage of days below MIF[1]											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Broad River below Ninety-Nine Islands	UIF	2.8	1.3	0.5	0.0	0.2	3.1	1.4	3.2	2.8	1.4	0.2	1.3
	Current Use	1.4	0.6	0.1	0.0	0.0	1.2	0.5	1.9	1.3	0.5	0.0	0.4
	2070 Moderate	1.5	1.0	0.2	0.0	0.0	1.4	0.9	2.2	1.6	0.7	0.0	0.4
	2070 High Demand	1.6	1.3	0.2	0.0	0.0	1.4	1.3	2.8	2.4	1.0	0.0	0.5
	P&R	1.8	0.9	0.3	0.0	0.1	1.6	0.9	2.3	1.8	0.9	0.0	0.6
Broad River Near Carlisle	UIF	6.8	4.6	1.4	0.9	1.3	6.9	3.3	6.6	6.4	4.2	0.8	4.4
	Current Use	8.4	5.7	2.2	1.8	3.0	10.4	6.0	9.6	9.6	7.7	2.8	6.2
	2070 Moderate	9.7	7.3	3.1	2.3	3.7	12.4	7.3	12.1	11.9	10.7	4.8	7.7
	2070 High Demand	10.6	7.6	3.4	2.6	4.0	12.6	8.0	12.7	12.8	11.7	5.5	8.2
	P&R	10.5	8.2	3.7	2.9	4.0	12.9	7.1	11.6	11.9	10.2	4.6	7.8
Broad River at Alston	UIF	5.2	3.6	0.7	0.8	1.3	6.6	3.2	7.2	7.1	5.0	1.4	2.9
	Current Use	6.8	5.2	1.1	1.7	3.5	12.3	7.2	11.8	11.6	9.4	4.5	4.9
	2070 Moderate	7.4	5.7	1.6	2.3	4.7	13.4	8.4	13.0	12.7	11.7	5.5	5.7
	2070 High Demand	8.2	6.1	1.8	2.7	5.1	13.9	9.0	13.5	13.6	12.6	6.2	6.5
	P&R	9.7	7.6	3.2	3.7	6.0	15.5	9.4	13.8	14.4	13.8	6.8	7.7
Broad Outlet	UIF	3.8	2.8	0.4	0.5	0.9	5.6	2.6	5.8	6.1	3.9	0.5	2.0
	Current Use	5.0	3.9	0.7	1.3	2.7	10.9	6.6	11.3	10.7	8.7	4.2	3.7
	2070 Moderate	5.7	4.8	0.8	1.7	4.1	12.4	8.1	12.5	12.4	11.1	5.3	4.8
	2070 High Demand	7.0	5.3	1.1	2.1	4.9	13.8	9.7	13.6	13.9	12.8	6.4	5.8
	P&R	9.7	7.7	3.3	3.9	7.2	17.1	11.4	15.3	17.0	16.6	8.5	8.5
North Pacolet at Fingerville	UIF	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.1	0.0	0.0	0.0	0.0
	Current Use	0.1	0.0	0.0	0.0	0.0	1.0	0.8	1.4	0.4	0.1	0.0	0.0
	2070 Moderate	0.5	0.0	0.0	0.0	0.2	3.4	2.8	6.1	4.9	1.5	0.0	0.0
	2070 High Demand	1.1	0.5	0.1	0.0	1.0	6.1	5.1	10.3	9.2	5.5	0.7	0.2
	P&R	1.3	0.5	0.1	0.0	0.2	3.2	2.4	5.8	5.4	3.0	0.1	0.2

[1] There were 32,964 days in the simulation period.

Table 5-24. Percent of days below MIF at select Strategic Nodes (Continued).

Strategic Node	Scenario	Percentage of days below MIF[1]											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pacolet River near Saratt	UIF	6.8	4.6	1.5	1.3	1.8	8.6	3.8	6.7	7.8	5.6	0.5	3.3
	Current Use	11.7	8.7	3.3	4.7	6.3	17.7	9.6	13.9	16.0	12.6	6.1	8.5
	2070 Moderate	14.2	10.6	4.0	4.1	4.0	13.1	7.8	11.2	13.8	12.0	6.2	10.0
	2070 High Demand	13.3	9.6	4.6	3.3	5.9	14.9	7.0	12.5	14.5	12.1	6.3	12.3
	P&R	28.5	20.0	15.3	17.0	14.7	27.3	11.7	16.2	18.3	16.7	11.0	18.2
North Tyger River below Wellford	UIF	6.8	4.6	1.5	1.3	1.8	8.6	3.8	6.7	7.8	5.6	0.5	3.3
	Current Use	11.7	8.7	3.3	4.7	6.3	17.7	9.6	13.9	16.0	12.6	6.1	8.5
	2070 Moderate	14.2	10.6	4.0	4.1	4.0	13.1	7.8	11.2	13.8	12.0	6.2	10.0
	2070 High Demand	13.3	9.6	4.6	3.3	5.9	14.9	7.0	12.5	14.5	12.1	6.3	12.3
	P&R	28.5	20.0	15.3	17.0	14.7	27.3	11.7	16.2	18.3	16.7	11.0	18.2
Middle Tyger River near Lyman	UIF	1.0	0.2	0.0	0.0	0.1	3.4	2.2	4.2	4.4	2.6	0.0	0.2
	Current Use	3.9	3.4	0.4	1.4	2.4	11.7	9.1	11.5	13.6	11.1	3.2	3.7
	2070 Moderate	12.5	9.2	4.2	6.5	13.5	28.1	32.7	30.9	37.8	33.7	15.7	12.9
	2070 High Demand	17.2	13.3	8.2	12.3	44.0	55.8	62.7	64.2	75.6	62.4	30.6	21.8
	P&R	36.5	33.7	22.5	32.0	39.4	54.3	56.6	61.7	72.4	65.2	52.2	46.5
South Tyger River below Duncan	UIF	1.3	0.0	0.1	0.0	0.3	1.9	0.3	1.2	0.6	0.7	0.1	0.1
	Current Use	2.2	0.4	0.7	1.0	2.5	9.2	8.4	10.9	12.6	8.3	2.0	1.0
	2070 Moderate	2.9	1.5	1.1	2.3	4.5	16.3	11.6	15.6	19.5	17.5	5.9	2.8
	2070 High Demand	3.5	2.6	1.5	3.9	8.0	20.3	8.7	11.9	15.6	13.8	4.3	5.7
	P&R	9.1	7.2	3.7	7.4	7.8	19.8	12.5	15.3	19.0	16.6	4.5	5.3
Tyger River near Delta	UIF	5.4	4.4	0.9	1.6	2.3	10.1	6.7	10.1	10.9	9.3	3.1	4.0
	Current Use	6.8	5.5	1.3	2.9	4.5	15.0	10.8	14.6	15.9	14.4	5.6	5.7
	2070 Moderate	8.2	6.4	1.9	4.0	6.7	18.0	14.1	17.0	19.7	17.3	7.1	7.0
	2070 High Demand	9.6	6.7	2.3	4.9	9.7	21.1	15.9	19.8	24.2	20.3	9.1	8.6
	P&R	14.9	11.5	5.3	10.3	13.6	26.1	20.7	24.9	31.1	25.9	11.8	14.7
Enoree River at Whitmire	UIF	6.9	4.7	0.8	1.9	3.2	11.9	6.2	10.3	12.0	11.5	3.7	5.7
	Current Use	4.7	3.1	0.3	1.1	1.9	9.1	4.2	7.8	8.9	7.8	2.3	3.0
	2070 Moderate	3.6	1.9	0.1	0.7	1.4	7.8	3.2	6.5	7.4	5.8	1.1	2.1
	2070 High Demand	3.4	1.5	0.1	0.6	1.2	7.6	3.2	6.4	7.6	5.6	0.9	2.0
	P&R	6.6	5.1	0.9	2.1	3.5	13.1	6.8	10.9	13.1	12.3	3.7	5.4

[1] There were 32,964 days in the simulation period.

5.3.7 Application of Biological Response Metrics

The biological response metrics developed by Bower et al. (2022) were correlated to model-simulated flows from the various planning scenarios to assess the potential for ecological risk, as described in The Nature Conservancy et al. (2022) report provided in Appendix C. Results of this assessment are not presented in their entirety, but rather illustrated by example for the various biological response metrics used (as discussed in Chapter 5.2.2).

The consistent methodology used is discussed in Bower et al. (2022) and summarized in this plan in Chapter 5.2.2. Fundamentally, the four selected hydrologic metrics (mean daily flow, duration of high flow, frequency of high flow, and timing of low flow) are compared to current conditions and expressed as a percentage change relative to future demand scenarios. This percentage change is converted into a percentage change in the biological response metric using the pre-developed correlation relationships between these factors and plotted on a risk scale. Table 5-25 and Figure 5-5 illustrate how the process works.

Table 5-25. Example of calculating changes in the biological metrics at the Middle Tiger River near Lyman Strategic Node[1]

Demand Scenario	Current Scenario Flow (cfs)	Projected Demand Scenario Flow (cfs)	Percentage Change in Flow Metric	Biometric	Percentage Change in Biometric	95% Confidence Interval[2]
UIF	98.4	107.8	9.6	Richness	7.9	-5.82 to 21.62
Moderate 2070		84.6	-14.0	Richness	-11.5	-25.22 to 2.22
High Demand 2070		69.9	-29.0	Richness	-23.8	-37.52 to -10.08
P&R		61.7	-37.3	Richness	-30.6	-44.32 to -16.88

[1]This table is one example, extracted from the analysis at the BRD30 Strategic Node on the Middle Tyger River near Lyman, and looks at the single hydrologic metric of mean daily flow (MA1) and its correlation with the single biological metric of species richness for fish taxa.
[2] 95 percent confidence interval for the percentage change in biometric estimates.

Once the changes in flow-ecology relationships are quantified via machine learning techniques, they are converted into a risk chart. The three risk categories, high, medium, and low, are determined by sudden and significant changes in biological health, driven by the change in the hydrologic metric, as shown in Figure 5-5.

Biological response metrics were applied at Strategic Nodes in the Lower Broad, Pacolet, Enoree, and Tyger subbasins. Figure 5-6 presents representative results for many of the combinations of hydrologic metrics and biological response metrics in the four subbasins. These results do not constitute the full array of results for all subbasins and all metrics but are offered to help support understanding of the process, the results themselves as shared with the RBC, the consistency of results, and the interpretations that follow.

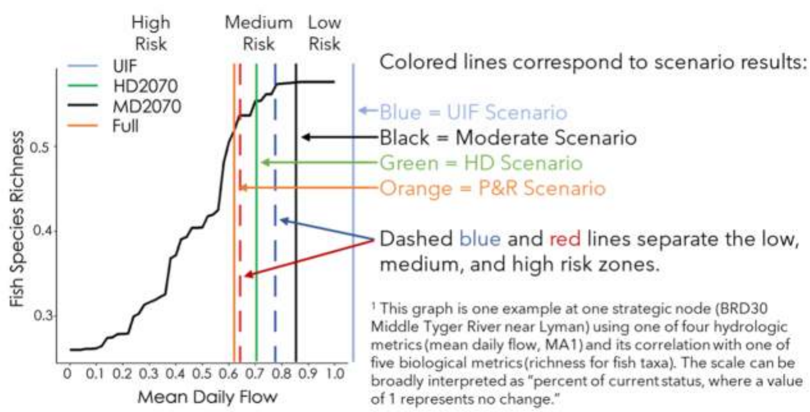
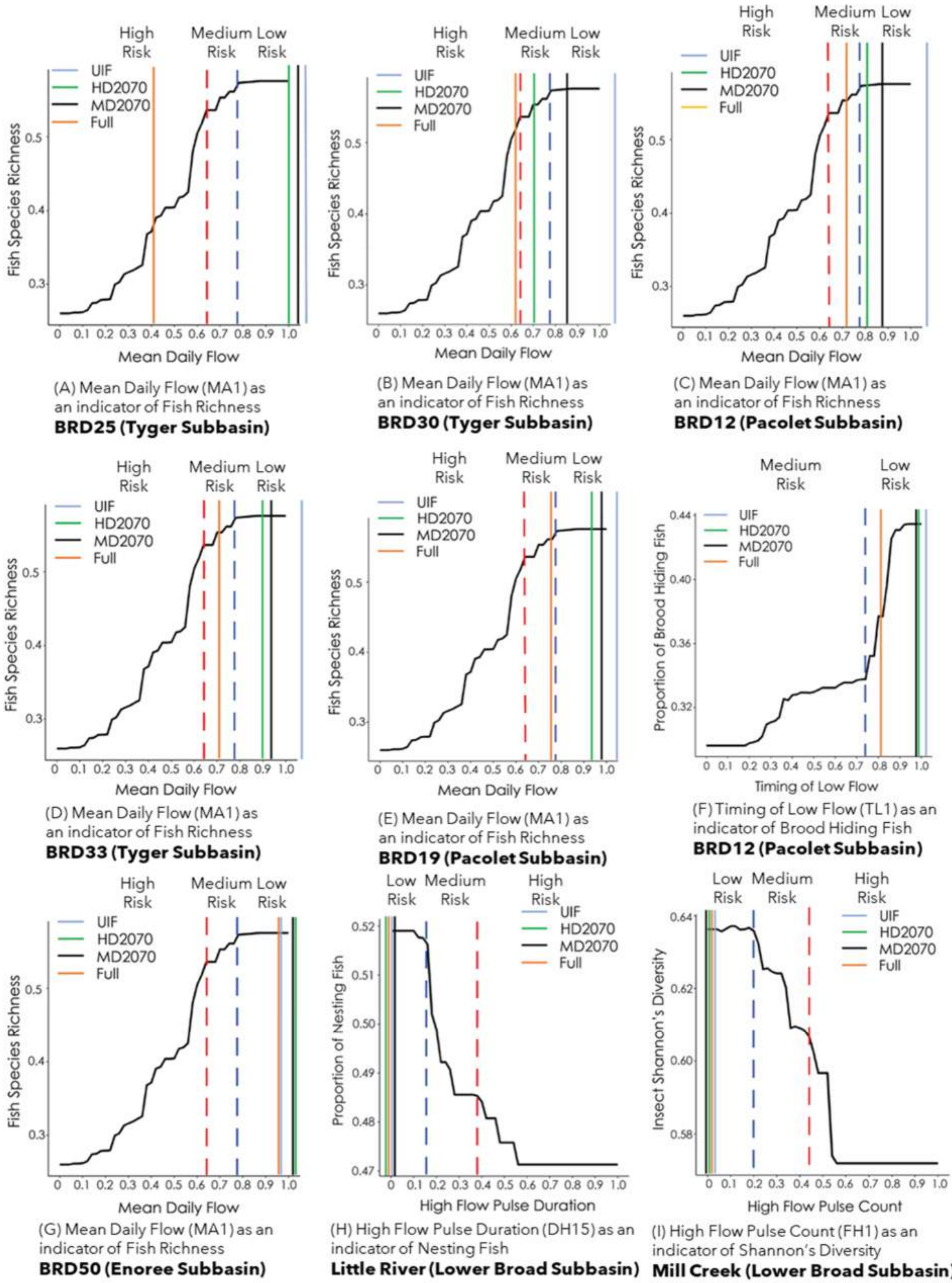


Figure 5-5. Example of the conversion of changes in biological metrics into risk.[1]



(A) Mean Daily Flow (MA1) as an indicator of Fish Richness
BRD25 (Tyger Subbasin)

(B) Mean Daily Flow (MA1) as an indicator of Fish Richness
BRD30 (Tyger Subbasin)

(C) Mean Daily Flow (MA1) as an indicator of Fish Richness
BRD12 (Pacolet Subbasin)

(D) Mean Daily Flow (MA1) as an indicator of Fish Richness
BRD33 (Tyger Subbasin)

(E) Mean Daily Flow (MA1) as an indicator of Fish Richness
BRD19 (Pacolet Subbasin)

(F) Timing of Low Flow (TL1) as an indicator of Brood Hiding Fish
BRD12 (Pacolet Subbasin)

(G) Mean Daily Flow (MA1) as an indicator of Fish Richness
BRD50 (Enoree Subbasin)

(H) High Flow Pulse Duration (DH15) as an indicator of Nesting Fish
Little River (Lower Broad Subbasin)

(I) High Flow Pulse Count (FH1) as an indicator of Shannon's Diversity
Mill Creek (Lower Broad Subbasin)

Figure 5-6. Selected biological risk level results for various biological metrics and Strategic Node locations (The Nature Conservancy et al. 2022).

As illustrated in Figure 5-6, SWAM model–simulated flow metrics for the UIF and Moderate Demand 2070 Scenarios result in low risk for ecological integrity and tolerance (The Nature Conservancy et al. 2022). Large changes in mean daily flow for the P&R Scenario and the High Demand 2070 Scenario are predicted to substantially reduce the number of fish species, with five Strategic Nodes predicted to lose more than 20 percent of fish species in the P&R Scenario, and one Strategic Node predicted to lose up to 45 percent of fish species under the High Demand 2070 Scenario.

The P&R Scenario results in mean daily flows fall in the high-risk zone for species richness at the North Tyger River below Wellford [Figure 5-6 (A)] and the Middle Tyger River near Lyman [Figure 5-6 (B)] Strategic Nodes. The North Pacolet River near Fingerville [Figure 5-6 (C)], South Tyger River below Duncan [Figure 5-6 (D)], and Pacolet River near Saratt [Figure 5-6 (E)] Strategic Nodes fall in the medium-risk zone for species richness based on mean daily flows.

SWAM did not predict substantial changes for timing of low flow. The North Pacolet near Fingerville [Figure 5-6 (F)] Strategic Node was predicted to experience an 18 percent decrease under the P&R Scenario, and all other nodes were predicted to have less than a 2 percent change. All scenarios resulted in low-risk outcomes in terms of timing of low flow, high-flow duration, and high-flow frequency.

In general, the four future management scenarios examined in this study suggest a moderate to high ecological risk to fish species on the Pacolet and Tyger tributaries of the Broad River basin. For proper context, the following are some important limitations of the work:

- Biological response metrics and associated risks were only calculated at select nodes, principally at the downstream end of primary tributaries and at the downstream end of certain secondary tributaries. There may be other locations in the river network that are more susceptible to flow changes, or where flow changes may be higher percentages when compared against current conditions. This could lead to more significant impacts to associated ecological integrity and tolerance in these unexamined locations.

- Processing biological samples from wadeable sampling locations and hydrologic records throughout the Broad River basin via machine learning techniques derived the relationships between hydrologic metrics and biological responses. Wadable access, while more limited downstream and in larger tributaries, is the most widespread form of surface water across the basin.

- The assessment was limited to the hydrologic and biological response metrics selected by the principal investigators, and for which biologically meaningful correlation had been established. This limited the use of these metrics to four hydrologic metrics and five biological metrics. The findings do not rule out potential risks for ecological integrity or tolerance related to other flow metrics or other forms of flow changes.

- Because the SWAM model focuses principally on primary and secondary tributaries, the study did not examine impacts on smaller headwater streams, which may be more vulnerable to flow management changes, but which are also less likely to be affected by large-scale changes in their flow regimes. Since the SWAM model includes all streams where significant flow management occurs (i.e., permitted and registered withdrawals and major discharges), the likelihood of significant flow alteration on non-modeled streams is low.

- The demand scenarios are based solely on potential future changes on withdrawals, and do not consider other human impacts that affect instream flow. Increased development of the landscape from forest or agricultural land cover to suburban/urban development will continue to degrade the flow regime, which will exacerbate the effects of water withdrawals on ecological integrity streams and rivers in the basin. As such, our estimates of potential biodiversity loss are likely underestimated. Additionally, the flow metrics used to estimate flow-ecology relationships were estimated based on precipitation, temperature, land cover, etc. within a recent period of record. Future changes in these factors will affect the shape and magnitude of flow-ecology relationships. Accordingly, incorporating future climate and land use projections would likely alter our estimates of future water withdrawals impact on aquatic biodiversity.

5.4 Safe Yield of Reservoirs

An important factor in estimating the reliability of current water supply systems against future demand forecasts is the ability of reservoir systems to provide anticipated levels of supply without interruption. The safe yield of a reservoir, or system of reservoirs, is a measure of its long-term reliability. The Planning Framework defines Reservoir Safe Yield as *the Surface Water Supply for a reservoir or system of reservoirs over the simulated hydrologic period of record*. Since the Surface Water Supply *is the maximum amount of water available for withdrawal 100 percent of the time*, the safe yield of a reservoir or system of reservoirs can be thought of as *the maximum annual average demand that can be sustained through the period of record without depleting available storage*.

For the Broad River basin, safe yield was computed for each reservoir and system of reservoirs that provide water to four providers: Spartanburg Water System (or SWS), SJWD, Greer CPW, and Cherokee County Board of Public Works (BPW) which serves Gaffney. Standard methods were used, in which the SWAM model was used to gradually increase hypothetical water demand over the entire period of record until a reservoir, or reservoir system, could no longer satisfy that demand with 100 percent reliability. Figure 5-7 shows an example for SWS's reservoirs.

Several important factors in the analysis include:

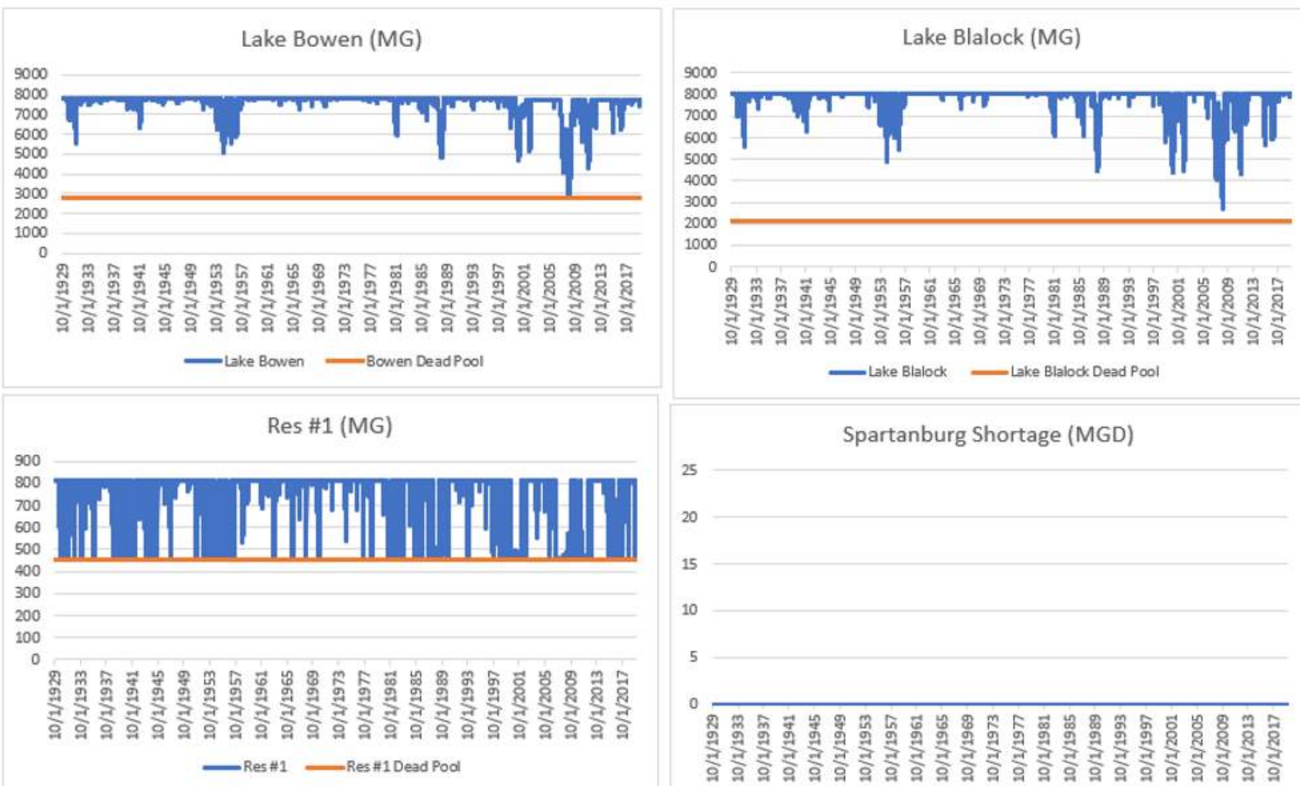
- Future demand assumptions at the point of withdrawal are not relevant to safe yield calculations, since the question is simply "how much can be supplied reliably." However, if there are upstream withdrawals, the demand scenarios used for RBC planning purposes are important. For any demands upstream of the reservoirs being evaluated, the conservative 2070 High Demand assumptions were applied.

- Reservoir systems in the Broad River basin have well-established rules and operating protocols that have proven sufficient for historical operations. However, as demand increases, it may become necessary to adjust these rules so that reservoirs draw down concurrently such that water is not depleted in one while plentiful in another, where it may not be accessible. The example in Figure 5-8 illustrates the process of adjusting operating rules in the SWAM model to help increase the simulated available yield. These results should not be interpreted as suggested modifications in operations without considering environmental, economic, recreational, and other factors. Adjustments were made solely based on accessing available water for simulated withdrawal.

- Safe yield of a reservoir system is not always the linear addition of the yield of individual reservoirs. In some cases, total system yield may be higher because of operational efficiencies and, in other cases, may be lower because of operational constraints.

Table 5-26 provides results of the safe yield analysis. In most cases, the simulated safe yield exceeds the anticipated level of demand in the conservative 2070 High Demand Scenario, but not in all cases. These projections are based solely on historical hydrology, which may or may not exhibit similar dry-period trends in the future. The analysis was also conducted at a monthly timestep, which does not necessarily account for all operational flexibility of reservoirs.

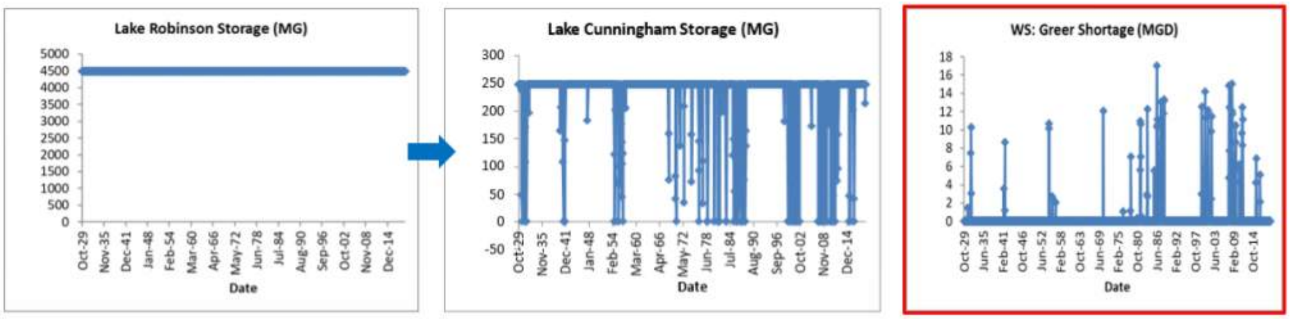
SWS Demands at 62 MGD, 2070 High Demand, Reservoirs Balanced[1]



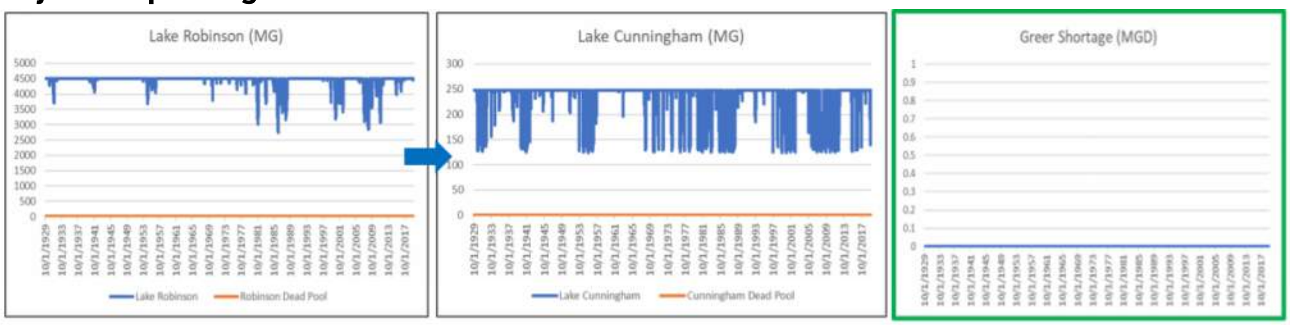
*Notice that storage is used fully in all reservoirs in this simulation. Any additional demand above 62 MGD (considering 2070 High Demand assumptions upstream of SWS) would result in simulated shortage based on 2009 hydrology.

Figure 5-7. Example of safe yield calculation for SWS reservoirs.

Historical Operating Rules:[1]



Adjusted Operating Rules:[2]



[1] Historical rules simulated in SWAM result in frequent depletion of Lake Cunningham when Lake Robinson has plenty of water that is not directly accessible for withdrawal.

[2] Simulated rules adjusted such that Lake Robinson releases 44 cfs to Lake Cunningham when Lake Cunningham drops to 60 percent of its storage. This results in more balanced use of Lake Robinson and avoidance of simulated depletion of Lake Cunningham.

Figure 5-8. Example of simulating adjusted operations, Greer water supply reservoirs.

Table 5-26. Safe yield results for Broad River basin water supply reservoirs.

Water System	Reservoir (Total System)	Safe Yield with SWAM Model[1] (MGD)	Comparative Results from Other Studies (MGD)	Sufficiency for 2070 High Demand Scenarios	Notes
Cherokee County BPW (Gaffney)	Lake Whelchel	6.8	N/A	Not sufficient for 2070 High Demand (approx. 25 MGD annual average)	Yield from Gaston Shoals assumed to be 6 MGD based on agreement with FERC Licensee for Gaston Shoals.
	Gaston Shoals	6.0	N/A		
	Total System	**12.8**	**10.2-11.4** (AECOM)		
Greer	Lake Robinson	26.8	N/A	Sufficient to satisfy 2070 High Demand of 22 MGD (average annual)	12.0 MGD from Lake Cunningham is estimated *without* coordinated releases from Lake Robinson. Also, simulated total system yield is slightly lower than the addition of the individual yields because they rely upon the same runoff to some extent.
	Lake Cunningham	12.0			
	Total System	**<38.8**			
SJWD	Lake Cooley	3.6	N/A	Marginally sufficient to meet 2070 High Demand of 25 MGD (daily analysis suggests that safe yield can provide this reliably). Further analysis may be prudent, given the range of values produced.	Some of the withdrawals are from river reaches and include additional runoff availability beyond reservoir storage alone. Differences between SWAM model and the GMC analysis is based on a variety of different assumptions regarding time periods, timestep, demand patterns, and instream flows
	North Tyger Res	4.6	N/A		
	North Tyger System	10.2	6.7 (GMC 2022)		
	Lake Lyman	11.5	N/A		
	Middle Tyger System	13.7	14.5 (GMC 2022)		
	Total System	**20.5-23.9**	**21.2** (GMC 2022)		
SWS	Lake Bowen / Reservoir #1	32	N/A	Marginally sufficient to meet 2070 High Demand of 62 MGD. Further analysis may be prudent.	Total system yield with current demands upstream = ~72.6 MGD
	Lake Blalock	30			
	Total System	**62**			

[1] Most yield values determined with adjusted rules for high-demand conditions such that reservoirs draw down and recover with synchronicity.

5.5 Summary of Water Availability Assessments

Application of the surface water model using current and projected rates of water withdrawals resulted in the identification of several key observations and conclusions regarding the availability of water resources in the Broad River basin. Following are specific observations and conclusions relative to each planning scenario.

- Surface water availability modeling suggests a low risk of water supply shortages under the Current Use Scenario. No water supply shortages were identified using current, monthly average demands when considered the 90-year period of record covering hydrologic conditions observed from 1929 and 2019.
- The P&R Scenario explored the question of, "What if all water users used the full volume of water allocated through permits and registrations?". The results, which include projected shortages for eight public water suppliers, three golf courses, and one agricultural operation, demonstrate that the surface water resources of the basin are over-allocated based on existing permit and registration amounts. Four of the eight of the public water suppliers with shortages (SWS, SJWD, Greer CPW, and Winnsboro) have a projected frequency of shortage greater than 50 percent. Projected mean, median, and low flows at Strategic Nodes suggests for the P&R Scenario are significantly lower than the same performance measures for the Current Use Scenario, especially in the Pacolet and Tyger River subbasins. At the most downstream Strategic Node (Broad River Outlet), mean and median flows are predicted to decrease by approximately 10 percent, and low flows by about 20 percent.
- For the Moderate Scenario, modeled demands were set to projected future levels based on an assumption of moderate population and economic growth. Given current climate conditions and existing basin management and regulatory structure, basin surface water supplies are predicted to be adequate to meet increased demands, resulting from moderate economic and population growth. Based on 2070 demands, two water users, Greer CPW and the proposed Lee Nuclear Generating Station, were simulated to experience shortages at a frequency of 2.4 and 3.0 percent, respectively. This analysis did not include a proposed storage pond to supplement Lee Nuclear Generating Station's supply. Impacts of this reservoir are discussed in Chapter 6. River flows are predicted to decrease modestly to moderately, depending on location, compared to the Current Use Scenario. Modeled reductions are most pronounced during low-flow periods. At the most downstream Strategic Node (Broad River Outlet), mean and median flows are predicted to decrease by approximately 3 percent, and low flows by about 5 percent, based on 2070 demands.
- For the High Demand Scenario, modeled demands are set to the 90th percentile of variability in reported withdrawals for each user, and the projections are based on aggressive growth assumptions. This scenario represents an unlikely maximum for total water demand because it is very unlikely these demands would occur month after month and year after year for all water users; however, this scenario provides the RBC with information on which to base conservative management strategies. The two water users with shortages in the Moderate Demand 2070 Scenario exhibit slightly greater shortages under the High Demand 2070 Scenario. Four additional municipal water suppliers experience shortages and three golf courses. River flows are predicted to decrease moderately to substantially, compared to the Current Scenario, throughout the basin. Modeled reductions are most pronounced during low-flow periods. Mean and median flows at the most downstream site of the mainstem (Broad River Outlet) are predicted to decrease by approximately 5 percent, and low flows by approximately 10 percent, based on 2070 demands.
- The High Demand Scenario was also evaluated for years 2025, 2030, 2040, 2050, and 2060. The results of these interim-year scenarios demonstrate a shortage for the Cherokee County BPW (serves Gaffney) using 2025 demands, at a frequency of 0.3 percent; a shortage for Greer CPW using 2040 demands, at a frequency of 0.8 percent; and shortages for SWS and SJWD using 2060 demands at a frequency of 0.1 percent.

- The SWAM model was also used to simulate hydrologic conditions without the impact of surface water users, discharges, or water imports. Predicted river flows for the UIF Scenario are generally higher than simulated Current Scenario flows, as expected. However, at one Strategic Node on the Enoree River, the simulated UIFs are lower than Current Scenario flows. This reflects the removal of wastewater returns in the system for the UIF Scenario. The lack of wastewater returns in the Enoree River more than offsets the lack of consumptive surface water use. At the Broad River Outlet, mean and median UIFs are approximately 5 and 6 percent higher than Current Scenario flows, respectively. At this same location, UIF low flows (25th to 5th percentile) are approximately 12 to 19 percent higher than Current Scenario flows.
- SWAM model–simulated flow metrics for the UIF and Moderate Demand 2070 Scenarios result in low risk for ecological integrity and tolerance (The Nature Conservancy et al. 2022). Large changes in mean daily flow for the P&R Scenario are predicted to substantially reduce the number of fish species, with five Strategic Nodes predicted to lose more than 20 percent of fish species. For the High Demand 2070 Scenario, the predicted impact is less pronounced but still significant, with one Strategic Node predicted to lose more than 20 percent of fish species. Low-risk outcomes in terms of timing of low flow, high-flow duration, and high-flow frequency, were identified for all scenarios.

Results and conclusions are based on modeling that assumed historical climate patterns. In subsequent phases of river basin planning, the RBC may decide to evaluate potential impacts to Surface Water supply availability resulting from changing climate conditions such as increasing temperatures and more variable precipitation. Modeling results led to the RBC identifying and evaluating a suite of water management strategies to address projected Surface Water Shortages, and to identify strategies to protect Surface Water Supply and maintain adequate river flows. Chapter 6, Water Management Strategies, presents the evaluation and selection of water management strategies.

Chapter 6
Water Management Strategies

This chapter summarizes the evaluation of potential water management strategies identified by the Broad RBC. The Framework identifies a two-step process to evaluate water management strategies. As a first step, proposed management strategies are simulated using the available models to assess their effectiveness in eliminating or reducing identified shortages or increasing surface water or groundwater supply. For strategies deemed to be effective, their feasibility for implementation is addressed during a second step. The Framework identifies multiple considerations for determining feasibility, including potential cost and benefits, consistency with state regulations, reliability, environmental and socioeconomic impacts, and potential interstate or interbasin impacts.

6.1 Surface Water Management Strategies

Under the Framework, a surface water management strategy is any water management strategy proposed to eliminate a surface water shortage, reduce a surface water shortage, or generally increase surface water supply to reduce the probability of future shortages. Strategies include demand-side management strategies that reduce supply gaps by reducing demands, as well as supply-side strategies that reduce supply gaps by directly increasing supply.

The Broad RBC identified a portfolio of various demand-side strategies consisting of municipal water conservation and efficiency practices and agricultural water efficiency practices as listed in Tables 6-1 and 6-2, respectively. While these demand-side strategies were identified and evaluated for surface water withdrawers, they also apply to the basin's limited groundwater withdrawers. The RBC also identified a variety of strategies that increase the amount of surface water available for withdrawal. Table 6-3 summarizes these supply-side strategies. The first surface water supply-side strategy focuses on public water suppliers adjusting their reservoir operations as demands grow to conserve supply. The remaining surface water supply-side strategies focus on Cherokee County BPW, which serves Gaffney and was the only public supplier with remaining projected shortages in the 2070 High Demand Scenario after reservoir operations were adjusted for public suppliers.

Table 6-1. Municipal water conservation and efficiency practices.

Municipal Practices	
Development, Update, and Implementation of Drought Management Plans	Water Efficiency Standards for New Construction
Public Education of Water Conservation	Leak Detection and Water Loss Control Program
Conservation Pricing Structures	Reclaimed Water Programs
Residential Water Audits	Car Wash Recycling Ordinances
Landscape Irrigation Program and Codes	Time-of-Day Watering Limit

Table 6-2. Agricultural water efficiency practices.

Agricultural Practice
Water Audits and Nozzle Retrofits
Irrigation Scheduling
Soil Management
Crop Variety, Crop Type, and Crop Conversions
Irrigation Equipment Changes

Table 6-3. Municipal supply-side practices evaluated.

Practice	
Adjust Reservoir Operations – Municipalities with Projected Shortages	New Broad River Intake – Cherokee County BPW
Seasonal Distribution of Gaston Shoals Allocation – Cherokee County BPW	Connection to SWS – Cherokee County BPW
Renegotiated Gaston Shoals Allowance with FERC Licensee – Cherokee County BPW	New Reservoir on King's Creek – Cherokee County BPW
Raise Dam Height of Lake Whelchel – Cherokee County BPW	New Regional Reservoir – Cherokee County BPW
Quarry – Cherokee County BPW	–

These strategies do not represent an exhaustive list of possible strategies that could be implemented by water users in the Broad River basin. Similarly, not all these strategies will be applicable to all users in the basin. The most appropriate strategies for a water withdrawer will depend on their location, end use, water source, financial resources, and other constraints or opportunities.

The following sections present details on the surface water management strategies identified by the RBC, a technical evaluation of their potential effectiveness, and an assessment of their feasibility.

6.1.1 Municipal Water Efficiency and Conservation Demand-Side Strategies

This subchapter further describes municipal water efficiency practices considered as part of the toolbox of strategies. These demand-side strategies also apply to groundwater users.

Development, Update, and Implementation of Drought Management Plans

This strategy is already ongoing in the basin, because public suppliers were required to develop drought management plans as part of the Drought Response Act of 2000. Each drought management plan has a set of measurable triggers indicating when conditions have entered one of three phases of drought and corresponding response actions to reduce demand by a target percentage. Chapter 8 provides detailed description of the drought management plans in the Broad River basin. The RBC recognizes the importance of these drought management plans for reducing demand and conserving water during critical low-flow periods. Under this strategy, public suppliers would continue to implement their drought management plans during drought conditions as well as keep their plans up to date to reflect any changes to the system.

Public Education of Water Conservation

This strategy would involve expanding existing public education programs or developing new programs as needed. Water conservation education could occur through public schools, civic associations, or other community groups. Water utilities and local governments could create informational handouts and/or include additional water conservation information on water utility bills. For this strategy to remain effective, public outreach would need to continue on a regular basis to maintain public engagement and motivation. The RBC discussed the possibility of larger water utilities sharing staffing or other conservation resources with smaller utilities.

The Broad RBC could look to the 2014 Water Use Efficiency Plan developed by the Catawba-Wateree Water Management Group (CWWMG) for an example of a basin-wide approach to reduce demand. The Plan includes measures such as a public information campaign, education and outreach, and landscape water management and demonstration gardens. The Broad RBC may request that members of the CWWMG provide an update on actions and results since the 2014 Plan, to guide the Broad RBC's actions.

Conservation Pricing Structures

Conservation pricing structures increase the unit cost of water as consumption increases. Utilities may have pricing structures that have a flat rate for customers, a unit use rate that varies with consumption, or some combination of the two. Conservation pricing sets higher unit price use rates for customers whose usage exceeds set thresholds. This strategy assumes that consumers will curtail their personal use to avoid paying higher prices. The extent of demand reduction depends on the magnitude of the price increase as well as the local price elasticity of demand for water usage.

In the Broad River basin, several utilities including the Inman Campobello Water District (ICWD) and Greer CPW have drought surcharges that may be implemented during severe and/or extreme drought phases. These surcharges are like conservation pricing structures, because the intent is to encourage customers to use less water. If implemented during a drought, ICWD charges the regular water rate for the first 5,000 gallons used in a month, twice the regular water rate for up to 12,000 gallons used, and three times the regular rate for all water used above 12,001 gallons.

Residential Water Audits

Residential water audits allow homeowners to gain a better understanding of their personal water use and identify methods to reduce water use. Homeowners can perform these audits themselves using residential water audit guides, or water utilities may provide free residential water audits to their customers. Residential water audits involve checking both indoor uses, such as toilets, faucets, and showerheads, and outdoor uses, such as lawn sprinklers. Based on the results of the audit, homeowners may invest in low-flow systems, repair leaks, and/or adjust certain personal water–use behaviors.

Landscape Irrigation Program and Codes

Landscape irrigation programs or water-efficient landscaping regulations can encourage or require homeowners to adopt water-efficient landscaping practices. Such practices seek to retain the natural hydrological role of the landscape, promote infiltration into groundwater, preserve existing natural vegetation, and, ultimately, conserve water. Water-efficient landscaping may include the incorporation of native plants or low water–use plants into landscape design (City of Commerce, CA 2021).

Local governments can require the use of these water efficiency measures through municipal codes or encourage them through incentives or educational programs. Potential practices include:

- Smart Irrigation Controller Rebate – Utilities may offer rebates to homeowners who replace their existing irrigation controllers with smart irrigation controllers that adjust irrigation according to soil moisture levels (soil-moisture-based or SMS) and precipitation and/or evapotranspiration rates (weather-based or WBIC). Controllers can be WaterSense-certified by meeting EPA criteria.

- Turf Replacement Rebate – Utilities may offer rebates to homeowners or businesses who replace irrigable turf grass with landscaping that requires minimal or no supplemental irrigation.

- Developer Turf Ordinance – Ordinances can be set that require new developments to have reduced irrigable turf grass area. Such development may be required to have low flow or microirrigation in plant beds, spray or rotor heads in separate zones for turf grass, or smart irrigation controllers to manage remaining turf area.

- Education Programs – Programs could be offered for homeowners to learn about water-efficient landscaping practices. Some examples of landscape irrigation improvements include:
  - Verification of the best irrigation schedule for the climate and soil conditions
  - Verification of the recommended nozzle pressure in sprinklers
  - Adjustments to sprinkler locations to ensure water falls on lawn or garden (not on sidewalk or other impervious surfaces)
  - Use of a water meter to measure water used in landscape irrigation

Water Efficiency Standards for New Construction

Local ordinances can require that all new construction or renovations meet established water efficiency metrics, either set by the local government or by existing water efficiency certifications, such as LEED or EPA's WaterSense. These programs have set water efficiency requirements for all household fixtures, such as a maximum rating of 2.5 gallons per minute flow rate for showers and maximum rating of 1.6 gallons per flush for toilets (Mullen n.d.).

Leak Detection and Water Loss Control Program

A water loss control program identifies and quantifies water uses and losses from a water system through a water audit. Once identified, sources of water loss can be reduced or eliminated through leak detection, pipe repair or replacements, and/or changes to standard program operations or standard maintenance protocols. Following these interventions, the water loss program can evaluate the success of the updates and adjust strategies as needed.

Automated meter reading (AMR) and advanced metering infrastructure (AMI) are technologies that can assist with leak detection. AMR technology allows water utilities to automatically collect water–use data from water meters, either by walking or driving by the property. AMI systems automatically transmit water usage data directly to the utility, without requiring an employee to travel to the property. AMI systems collect data in real time. Both technologies reduce the staff time required to read meters and allow utilities to more frequently analyze actual consumption (as opposed to predicted usage based on less frequent manual meter readings). Higher than expected readings then can be noted and flagged as potential leaks. Because of their ability to collect data more frequently, AMI systems may detect consumption anomalies sooner than AMR. This allows for earlier detection of smaller leaks so that repairs can be made before major pipe breaks. AMI systems are more expensive to install than AMR systems and, therefore, may not be economical for smaller utilities. Hybrid systems on the market allow for future migration from AMR to AMI.

An example of a basin-wide water audit and water loss control program is that of the CWWMG, which is undertaking a significant water audit project to identify real (leaks) and apparent (meter inaccuracy) water losses throughout the basin. This project identified 17 billion gallons of non-revenue water that could be managed to increase utility revenue by $16.8 million (CWWMG no date). Subsequent phases involve conducting economic analyses and identifying water loss goals for each CWWMG member, and the entire group. A similar effort could be pursued within the Broad River Basin.

Georgia is one of the few states that have implemented statewide water loss control requirements. In 2010, the Georgia Water Stewardship Act was signed into law. The Act set water loss control requirements that apply to public water systems serving populations over 3,300, which include:

- Completion of an annual water loss audit using American Water Works Association (AWWA) M36 Methodology
- Development and implementation of a water loss control program
- Development of individual goals to set measures of water supply efficiency
- Demonstration of progress toward improving water supply efficiency

Reclaimed Water Programs

Reclaimed water programs reuse highly treated wastewater for other beneficial purposes, reducing demands on surface water and groundwater. Water can be reclaimed from a variety of sources then treated and reused for beneficial purposes such as irrigation of crops, golf courses, and landscapes; industrial processes including cooling water; cooling associated with thermoelectric plants; and environmental restoration. The quality of reuse water would need to be matched with water quality requirements of the end use, and emerging contaminants of concern (e.g., per- and polyfluoroalkyl substances [PFAS] and microplastics) would need to be considered.

Car Wash Recycling Ordinances

In-bay automatic car wash systems use approximately 35 gallons of water per vehicle. A touch-free car wash (one that relies solely on chemicals and high-pressure spray rather than on the gentle friction of a soft-touch wash) uses approximately 70 gallons per vehicle. Assuming one-bay and 100 customers per day, these two common types of systems use between 3,500 and 7,000 gallons of water per day. To reduce water usage, car wash recycling ordinances require all new car washes to be constructed to include recycled water systems. Recycled water systems allow for water used in washing or rinsing to be captured and reused. Ordinances can set a percentage of recycled water to total water used. Typical ordinances require at least 50 percent use of recycled water.

Time-of-Day Watering Limit

A time-of-day watering limit prohibits outdoor watering during the hottest part of the day, usually 10:00 a.m. to 6:00 p.m. This practice reduces water loss from evaporation.

6.1.2 Agriculture Water Efficiency Demand-Side Strategies

Following is a more detailed description of the agricultural water efficiency practices considered as part of the toolbox of strategies. These demand-side strategies also apply to groundwater users.

Water Audits and Nozzle Retrofits

Water audits monitor water use in an agricultural irrigation system to identify potential opportunities for water efficiency improvements. Water audits consider water entering the system, water uses, water costs, and existing water efficiency measures. They gather information on the size, shape, and topography of the agricultural field, depth to groundwater, vulnerability to flooding, pumping equipment, irrigation equipment, and past and present crop use and water use (Texas Water Development Board 2013).

Across the state, Clemson University Cooperative Extension Service specialists and researchers have held meetings to talk with farmers about center pivot irrigation and discuss the Clemson Center Pivot Irrigation Test Program, a type of water audit offered by the Clemson Extension Water Resources, Agronomic Crops, and Horticulture Teams. These audits measure irrigation uniformity—the consistency of irrigation depth across the irrigated area. Without irrigation uniformity, some crops may experience overirrigation and some may experience underirrigation, leading to wasted water and profit losses. The Center Pivot Irrigation Test Program can provide growers with a map of irrigation depths, observed issues such as leaks and clogs, estimated costs of over- or underwatering, estimated costs for nozzle retrofits, and design versus observed flow rates and system pressure (Clemson Cooperative Extension 2022a). After the audit, a report is provided that includes an estimated cost of under- and overirrigation based on crop types. This cost of suboptimal irrigation is compared to the estimated cost of a sprinkler retrofit.

The South Carolina Mobile Irrigation Laboratory pilot project is another example water audit program. This project is the result of a partnership with South Carolina Department of Agriculture (SCDA) and Aiken Soil and Water Conservation District. The audits identify areas of over- and underwatering, suggest energy savings opportunities, and recommend upgrades or operational changes (SCDNR 2019c). The project is providing no-cost water and energy audits on 24 agricultural center pivot irrigation systems throughout South Carolina over 3 years (SCDNR 2020b). Following the 3-year pilot program, the feasibility of expanding the pilot to a statewide project will be assessed (SCDNR 2020b).

Irrigation Scheduling

Irrigation scheduling refers to the process of scheduling when and how much to irrigate crops based on the needs of the crops and the climatic/meteorological conditions. It ensures that crops are receiving the correct amount of water at the right time. The three main types of irrigation scheduling methods include soil water measurement, plant stress sensing, and weather-based methods. To measure soil water, farmers can use soil moisture probes at varying depths. For weather-based methods, farmers can research regional crop evapotranspiration reports to develop an irrigation schedule. Additionally, farmers can use thermal sensors to detect plant stress (Freese and Nichols, Inc. 2020). The use of thermal and/or moisture sensors to automatically schedule irrigation is referred to as *smart irrigation*.

A 2021 Clemson study on Intelligent Water and Nutrient Placement (IWNP) combines smart watering strategies with smart fertilizer applications. IWNP will use smart sensing with model-based decision support systems to determine the irrigation water and nutrient application required by crops at a given time (Clemson College of Agriculture, Forestry and Life Sciences 2021). The IWNP systems would be installed on existing overhead irrigation systems as a retrofit. The program first seeks to develop the system, then develop a training program to teach farmers how to use the system.

Soil Management

Soil management includes land management strategies such as conservation tillage, furrow diking, and the use of cover crops in crop rotations. The USDA defines conservation tillage as “any tillage or planting system that covers 30 percent or more of the soil surface with crop residue, after planting, to reduce soil erosion by water” (USDA 2000). Conservation tillage can conserve soil moisture, increase water–use efficiency, and can decrease costs for machinery, labor, and fuel. Types of conservation tillage include:

- No-Till – The soil is left undisturbed from harvest to planting except for nutrient injection. With this type of practice, planting is done in narrow seedbeds and a press wheel may be used to provide firm soil–seed contact (Janssen and Hill 1994).
- Strip Till – This practice involves tilling only the seed row prior to planting, disturbing less than one-third of the row width (CTIC 1999).
- Ridge Till – This practice involves planting into a seedbed prepared on ridges using sweeps, disk openers, coulters, or row cleaners. Residue is left on the surface between ridges to reduce soil loss (Janssen and Hill 1994).
- Mulch Till – This practice uses chisel flows, field cultivators, disks, sweeps, or blades to till soil in such a way that it does not invert the soil but leaves it rough and cloddy (Janssen and Hill 1994).
- Furrow Diking – The practice of creating small dams or catchments between crop rows to slow or prevent rainfall runoff and increase infiltration. Increased water capture reduces supplemental irrigation needed, resulting in a direct water savings.
- Cover Crops – This practice involves planting cover crops, such as cereal grains or legumes, following the harvest of summer crops. Such cover crops use unused nutrients and protect against nutrient runoff and soil erosion. They can increase infiltration and water-holding capacity of the soil, which may indirectly result in water savings.

Crop Variety, Crop Type, and Crop Conversion

Changing crop type from those that require a relatively large amount of water to crops that require less water use can save significant amounts of irrigation water. In South Carolina, transitioning away from corn and small grains, such as wheat, rye, oats, and barley, and increasing cotton crops can reduce water use. However, because the choice of crops is market-driven and certain machinery, infrastructure, and skills are specific to different crops, changing crop type may not make economic sense for growers. Conversion programs that offer growers incentives may be necessary. Switching the variety of a particular crop may also act as a water conservation strategy. For example, switching from full/mid-season corn to short-season corn could result in a 3.7 acre-inches per acre savings. However, such a change could also result in substantial yield loss, making it an unviable option for some growers (Freese and Nichols, Inc. 2020).

Converting from irrigated crops to dryland crops can have substantial water saving benefits. Exact savings vary by crop but potentially could be on the order of 15.8 acre-inches per acre (Freese and Nichols, Inc. 2020).

Irrigation Equipment Changes

Changing from low-efficiency irrigation equipment to higher-efficiency equipment can reduce water use but requires significant financial investment. Irrigation methodologies may include mid elevation, low elevation, low-elevation precision application, or drip irrigation. These methodologies have application efficiencies of 78, 88, 95, and 97 percent, respectively (Amosson et al. 2011).

6.1.3 Supply-Side Strategies

The Broad RBC identified and considered one supply-side water management strategy that can be widely applied in the basin: adjustment of reservoir operations in the future to help accommodate increased demand. As mentioned in Chapter 5, Duke Energy has plans to develop an offline-storage pond to meet demands of the proposed Lee Nuclear Generating Station. The remaining supply-side strategies focus on Cherokee County BPW, which was the only public supplier with remaining projected shortages in the 2070 High Demand scenario after reservoir operations were adjusted. Following is a more detailed description of these strategies. All of them are evaluated only at the conceptual level in this report.

Adjust Reservoir Operations

Most of the reservoir systems in the Broad River basin have well-defined operating rules that react well to current and historic hydrologic conditions and demand levels. Looking ahead to 2070, some of these rules may need to be adjusted to better balance the drawdown and recovery patterns; that is, to help avoid situations in which one reservoir in a system is depleted while others are much fuller but limited in the access to their water. Modest changes in operating rules for extreme future demand conditions could better balance the reservoirs to consistently provide available water at appropriate points of withdrawal. Any modifications to reservoir operating rules would be subject to more detailed scrutiny, operational evaluation, and regulatory feasibility assessments.

Lee Nuclear Generating Station Offline Storage

Duke Energy proposes to meet the demands of its proposed Lee Nuclear Generating Station by developing an off-line storage pond called Pond C/London Creek Reservoir. The reservoir would be filled by pumping from the Broad River upstream of Ninety-Nine Islands Reservoir into Pond C. During periods of low flow, withdrawals from the river would cease and storage in Pond C would be used until stream flows recover. The proposed reservoir would require approximately 623 acres and have a capacity of 7,079 MG with a dead pool of 1,374 MG.

Seasonal Distribution of Gaston Shoals Allocation – Cherokee County BPW

Through agreement with Northbrook Power Management, who is the FERC licensee for the Gaston Shoals project, Cherokee County BPW is limited to an average annual withdrawal of 6 MGD from Gaston Shoals. How these withdrawals are distributed over the year can affect the overall reliability of the system—not in terms of firm yield but with respect to frequency and magnitude of potential shortages as estimated with the 2070 High Demand Scenario. Cherokee County BPW could explore the option to redistribute their Gaston Shoals withdrawals proportionally to their demand patterns, reducing or eliminating withdrawals during lower demand periods (relying on Lake Whelchel to meet demands) and reserving higher withdrawals for high demand periods.

Renegotiated Gaston Shoals Allowance with FERC Licensee – Cherokee County BPW

Through agreement with Northbrook Power Management, who is the FERC licensee for the Gaston Shoals project, Cherokee County BPW is limited to an average annual withdrawal of 6 MGD from Gaston Shoals. Cherokee County BPW also has a SCDHEC allowable withdrawal of 620 million gallons per month (MGM) (or approximately 20 MGD) from Gaston Shoals. The lower 6 MGD limit with Northbrook Power Management is the limiting control on Cherokee County BPW's Gaston Shoals withdrawals. The RBC chose to explore the impact of renegotiating a higher withdrawal limit from Gaston Shoals with Northbrook Power Management. As an upper threshold, the RBC explored using the 620 MGM SCDHEC (20 MGD) withdrawal limit as the limiting allowance instead of the 6 MGD allowance through agreement with the current FERC licensee.

Raise Dam Height of Lake Whelchel – Cherokee County BPW

Lake Whelchel is the primary water source for Cherokee County BPW. It impounds Cherokee Creek and another unnamed creek, and additional water is pumped from the Broad River to supplement the lake's water supply. This strategy would involve raising the dam height by 3 to 5 feet to provide additional raw water storage capacity. Raising the dam height by 3 feet would increase Lake Whelchel's total storage by approximately 18 percent to 953 million gallons (MG).

Quarry Storage – Cherokee County BPW

A nearby quarry potentially could be converted to a third raw water storage reservoir to augment Cherokee County BPW's water supply when necessary. A previous study looked at developing the Blacksburg quarry in Cherokee County to serve as an additional raw water source for the region (WK Dickson 2002). The quarry previously was the site of limestone mining. This quarry stored 1.69 billion gallons (BG) of water, had a high rate of groundwater inflow, and approximately 100,000 gallons per day were naturally discharged from the quarry into surrounding ponds.

Any selected quarry's geology would need to be assessed to determine whether the quarry walls exhibit characteristics, such as faults or unstable conditions, that might prohibit its use as a water reservoir. The potential amount of groundwater inflow or leakage from the quarry also would need to be investigated. Additionally, water quality would need to be assessed and found to be within normal acceptable ranges for drinking water. Water quality may need to be treated to be compatible with the existing treatment and distribution system infrastructure.

New Broad River Intake – Cherokee County BPW

This conceptual alternative examines a potential new intake and surface water withdrawal permit on the Broad River, downstream of the confluence of Buffalo Creek. In this scenario, it is assumed that the Broad River water would be used to supplement Cherokee County BPW's existing sources (Lake Whelchel and Gaston Shoals) and taken only when needed.

Connection to SWS – Cherokee County BPW

Cherokee County BPW could explore the opportunity to build an interconnection to SWS to supplement their supply sources when SWS has sufficient supply. An interconnection could provide an additional supply as demands continue to grow and could improve Cherokee County BPW's resilience and recovery in an emergency, because Cherokee County BPW does not currently have any interconnections to other systems.

The Broad RBC explored the extent of interconnections between systems throughout the basin. Currently, Union and Clinton, in addition to Cherokee County BPW, also do not have interconnections. The remaining water providers in the basin do have interconnections or are contemplating building them in the future to increase the resilience of their supplies. Figure 6-1 maps interconnections in the basin.

New Reservoir on King's Creek – Cherokee County BPW

The 2002 WK Dickson study, which evaluated the Blacksburg quarry as a new source of supply, conceptually compared the quarry to a similar-sized reservoir. The study identified nearby King's Creek as a potential source to the new reservoir. A total area of 640 acres would be required for the reservoir and buffer zone to match the 1.67 BG usable storage amount provided by the proposed Blacksburg quarry (WK Dickson 2002). Success of this alternative is dependent on further feasibility assessment of the location and sizing as well as permitting considerations. The effectiveness of the strategy will be dependent on the feasible size of the reservoir, future hydrologic conditions impacting inflows to the reservoir, and permitting requirements.

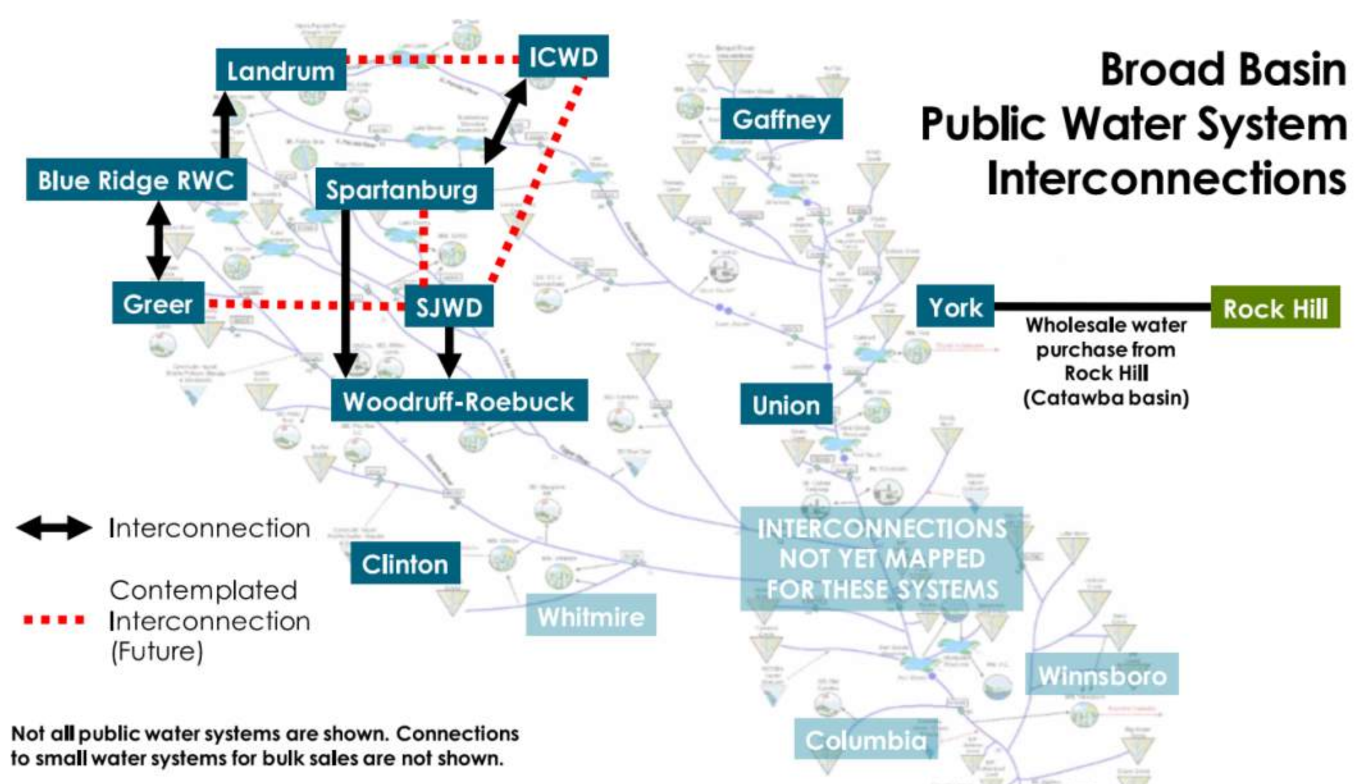


Figure 6-1. Interconnections between public water systems in the Broad River basin.

New Regional Reservoir – Cherokee County BPW

The Broad RBC chose to evaluate the concept of a new regional reservoir that would supply water to alleviate Cherokee County BPW's shortages as well as provide a new supply for other users within the region. Impounding an existing stream and creating a new reservoir would provide additional raw water supply to the region. This would involve constructing an in-channel earthen dam, and the reservoir would be filled directly by the flow of the impounded stream. The RBC explored this strategy as a purely theoretical strategy, recognizing that far more detailed evaluation would be required to consider topography, feasible reservoir sizing, regulatory viability, land ownership, costs, and environmental and social impacts. Like the new reservoir on King's Creek discussed above, the effectiveness of the strategy will be dependent on the feasible size of the reservoir, future hydrologic conditions impacting inflows to the reservoir, and permitting requirements.

6.1.4 Technical Evaluation of Strategies

The effectiveness of surface water management strategies in the Broad River basin were evaluated using the SWAM surface water model. This analysis focused on the impact of strategies on projected shortages and water availability in the 2070 High Demand Scenario.

Demand-Side Strategies

Two demand-side management scenarios were developed using the SWAM model to evaluate a range of potential actions that could be used to reduce water demands and mitigate shortfalls. The first scenario evaluated the effectiveness of municipal drought management plans. The second scenario evaluated the impact of aggregated municipal demand-side management strategies. Although the Broad RBC included agricultural demand-side management strategies in the plan, their effectiveness was not explicitly evaluated in the SWAM model. Agricultural water use accounts for less than 1 percent of current water use in the Broad River basin and is not projected to increase over the planning horizon. Impacts to agricultural demand reduction are expected to have minimal impact on other water users or stream flows in the basin.

Drought Management Plans

The first scenario evaluated the effectiveness of existing municipal water supply drought management plans. Chapter 8, Drought Response, summarizes the municipal drought management plans. To model these plans, each municipal water provider was assumed to fully achieve water–use reduction targets for a given drought condition as specified in their drought management plans. Drought triggers and reduction goals identified in the drought management plans were incorporated into the SWAM model using the software's water user conservation rules. Rules were prescribed for the following surface water withdrawers: Greer CPW, SWS, SJWD, Cherokee County BPW, Clinton, Winnsboro, and Union. For each of these users, water use was curtailed in the model in stages according to the user-specific drought triggers. These triggers were either based on effective system storage (volume or elevation) or river flows at various locations throughout the basin dropping below the trigger levels identified in the drought management plans. In some instances, a user has multiple triggers that were simplified in this SWAM analysis using only the trigger shown in Table 6-4. Other triggers found in these drought management plans and those of other water users in the Broad River basin are based on factors such as drought declarations by the DRC or local entity or daily fluctuations in water demands. For modeling purposes, these triggers were not applied since they could not readily be incorporated into the model. This potentially results in conservative estimates of river flow since the scenarios did not simulate full curtailment.

Table 6-5 summarizes the impact of drought management plan implementation on projected shortages in the 2070 High Demand Scenario. Cherokee County BPW's maximum shortage is reduced by approximately 30 percent and the frequency of shortage is reduced by less than 1 percent because of the reduction in demand preserving storage in Cherokee County BPW's reservoirs. A similar impact of reduced demand is seen for SWS, which has an 86 percent reduction in maximum shortage and a less than 1 percent reduction in frequency of shortage with the implementation of drought management plans. There is no impact on projected shortages of public suppliers Greer CPW and SJWD, where the specified drought trigger thresholds were not crossed during the simulation. Drought management plans applied throughout the basin also did not have an impact on small projected shortages for three golf courses, Mid Carolina, Pebble Creek, and Fox Run. It is expected that the small projected golf course shortages likely can be managed with existing on-site small impoundments for irrigation and a reduction in irrigation demand during periods of low flow. Golf course managers may also consider the installation of a groundwater well to supplement the surface water system during periods of low flow.

Table 6-4. Simulated drought management plans.

Water User	Reduction in Water Use (%)	Drought Flow Trigger
Greer CPW	N/A – incipient phase	System effective storage drops below 4,484 MG
	15	System effective storage drops below 4,248 MG
	20	System effective storage drops below 3,776 MG
	25	System effective storage drops below 3,304 MG
SWS	N/A – incipient phase	Combined streamflow entering the reservoir system from the North and South Pacolet Rivers drops below 60 cfs
	15	Combined streamflow entering the reservoir system from the North and South Pacolet Rivers drops below 40 cfs
	20	Combined streamflow entering the reservoir system from the North and South Pacolet Rivers drops below 30 cfs
	25	Combined streamflow entering the reservoir system from the North and South Pacolet Rivers drops below 25 cfs
SJWD	15	Storage in Lake Lyman drops below 841 feet
	20	Storage in Lake Lyman drops below 840 feet
	25	Storage in Lake Lyman drops below 836 feet
Cherokee County BPW	15	Lake Whelchel elevation at 668 feet
	20	Lake Whelchel elevation at 666 feet
	25	Lake Whelchel elevation at 664 feet
Clinton	15	Flow in Enoree River drops below 60 cfs
	20	Flow in Enoree River drops below 50 cfs
	25	Flow in Enoree River drops below 20 cfs
Winnsboro	15	Flow in Sand Creek drops below 2.8 cfs
	20	Flow in Sand Creek drops below 1.7 cfs
	25	Flow in Sand Creek drops below 1.0 cfs
Union	15	Flow in Broad River drops below 200 cfs
	20	Flow in Broad River drops below 125 cfs
	25	Flow in Broad River drops below 75 cfs

Table 6-5. 2070 High Demand Scenario shortages with and without demand management plans.[1]

	Without Demand Management Plan Reductions		With Demand Management Plan Reductions	
Water User	Frequency of Shortage (%)	Max Shortage (MGD)	Frequency of Shortage (%)	Max Shortage (MGD)
WS: Greer	7.1	17.0	No change	
WS: SJWD	0.6	18.3	No change	
WS: Gaffney	1.1	27.8	0.8	19.2
WS: Spartanburg	0.4	36.9	0.1	5.2
GC: Mid Carolina	0.2	0.03	No change	
GC: Pebble Creek	0.1	0.1	No change	
GC: Fox Run	0.1	0.02	No change	

[1] All other operating rules reflect current practices, which means that reservoirs are not necessarily balanced to provide water for higher future demands and may not draw down in these simulations significantly enough to trigger drought measures (Lake Robinson and Lake Lyman, for example). For suggested resolution, see the "Supply-Side Strategies" section for evaluation of alternative future operating rules.

Municipal Demand-Side Management Strategies

The second demand-side scenario evaluated the aggregated impact of municipal demand-side management strategies. The municipal demand-side strategies were evaluated as a portfolio of strategies by assuming a lumped decrease in projected municipal water demands because of implementing one or more strategies from the toolbox, such as water audits, low-flow appliances, public education, modified pricing structures, water loss control programs, landscape irrigation ordinances, and the use of reclaimed water. There is high uncertainty regarding the effective reduction in demand for individual demand-side management strategies because their effectiveness depends on the extent of implementation and the magnitude of impact for each instance of implementation. For example, water savings associated with a landscaping program such as turf replacement will depend on the number of water users who participate in the program, the area of turf replaced, water demands for the existing turf landscape, water demands for the replaced landscaping, and the individual's adjustment of irrigation habits in response to the increased efficiencies. Because of this uncertainty, the effectiveness of the municipal demand-side strategies was simulated at three levels: 10 percent reduction in demand, 15 percent reduction in demand, and 20 percent reduction in demand. This represents a reasonable expected range of outcomes since many strategies may already be implemented to some extent (low flow appliances, pricing structures, etc.). In the SWAM model, a demand multiplier of 0.9, 0.85, or 0.8 was applied to all municipal surface water supply users.

Table 6-6 summarizes the impact of the municipal demand-side management strategies at three levels of effectiveness on projected 2070 High Demand Scenario shortages. All public suppliers with projected shortages see a reduction in both frequency of shortage and maximum shortages with two users, SWS and SJWD, seeing an elimination of shortages with a 20 percent demand reduction. For Cherokee County BPW and Greer CPW, the municipal demand-side management strategies alone may not be enough to eliminate shortages, but the evaluation shows the strategies can be successful in reducing the frequency and magnitude of shortage.

Table 6-6. 2070 High Demand Scenario shortages with three levels of implementation of municipal demand-side management strategies.

	Frequency of Shortage (%)				Maximum Shortage (MGD)			
Water User	2070 High Demand	10% Demand Reduction	15% Demand Reduction	20% Demand Reduction	2070 High Demand	10% Demand Reduction	15% Demand Reduction	20% Demand Reduction
WS: Gaffney	1.1	1.0	1.0	0.8	27.8	24.6	22.2	20.7
WS: Spartanburg	0.4	0.1	0.1	0.0	36.9	19.8	4.8	0.0
WS: SJWD	0.6	0.4	0.1	0.0	18.3	9.9	5.8	0.0
WS: Greer	7.1	5.4	4.3	3.4	17.0	14.4	13.1	11.8

Supply-Side Strategies

Adjust Reservoir Operations

These strategies were simulated in the SWAM model to assess whether current reservoir operating rules (which have been historically sufficient and effective) could be adjusted for extreme future demand conditions to better balance the reservoirs to consistently provide available water. There are four municipal supply systems with reservoirs that were evaluated using this strategy: SWS, Greer CPW, SJWD, and Cherokee County BPW. Discussion regarding the adjustments made to each system follow separately. A series of graphs are provided for SWS as an example of improvements to drawdown patterns and shortages in the 2070 High Demand Scenario with reservoir operational adjustments.

The specific alterations below, at this point, should not be considered as recommendations. Any revisions to reservoir operations would be subject to more detailed scrutiny, operational evaluation, and regulatory feasibility assessments (if necessary). The purpose of these evaluations was to demonstrate the physical availability of water through improved reservoir balancing. As a preview, the adjusted operations for improved balance in drawdown and recovery for multiple-reservoir systems demonstrate the potential to eliminate shortages for SWS, Greer CPW, and SJWD, but Cherokee County BPW would need further management measures, which are discussed following these sections on adjusted future rules.

SWS Reservoir System

SWS draws water from Municipal Reservoir #1, which is fed principally from Lake Bowen, directly upstream. Another supply source is Lake Blalock, which has not been used much in recent history because of the adequacy of Reservoir #1. When considering the 2070 High Demand Scenario, Lake Blalock becomes more necessary, but to satisfy demand fully, it is essential to balance its drawdown with that of Lake Bowen. Lake Bowen currently has tiered release rates of water that are conditioned on storage levels in Municipal Reservoir #1. For experimental purposes, these rules were adjusted until Lake Bowen and Lake Blalock exhibited balanced drawdown and recovery patterns during periods of hydrologic stress, by adjusting the following:

- When Municipal Reservoir #1 > 800.1 MG, increase release from Lake Bowen from 20 to 30 cfs.
- When Municipal Reservoir #1 > 795.1 MG, increase release from Lake Bowen from 25 to 30 cfs.
- When Municipal Reservoir #1 > 790.1 MG, increase release from Lake Bowen from 30 to 35 cfs.
- When Municipal Reservoir #1 > 790 MG, increase release from Lake Bowen from 45 to 55 cfs.

Additionally, Municipal Reservoir #1 was balanced with Lake Blalock such that withdrawal from Lake Blalock is delayed until Municipal Reservoir #1 has used 1,500 MG within a month.

These experimental adjustments resulted in more balanced drawdown and recovery of Lake Bowen and Lake Blalock (SWS's two largest reservoirs) and SWS's ability to satisfy 2070 High Demand projections. Figure 6-2 illustrates the changes in reservoir drawdown and shortage with the reservoir operational changes described above. The graphs on the left side illustrate the shortages and reservoir levels in the 2070 High Demand Scenario without optimization. There are shortages even though there is ample supply remaining in Lake Bowen. The graphs on the right side show the more balanced drawdown achieved between Lake Bowen and Lake Blalock, with the modification of reservoir operating rules. By better using the supply in Lake Bowen, shortages are eliminated. With improved utilization of Lake Bowen and Lake Blalock, Municipal Reservoir #1 is also drawn down to its dead storage less frequently.

Greer Commission of Public Works Reservoir System

Greer CPW draws water from Lake Cunningham, a small reservoir immediately downstream and in series with Lake Robinson, a much larger reservoir. Greer CPW can release water from Lake Robinson intentionally to Lake Cunningham (there is no direct intake from Lake Robinson), but historically this need has been minimal. In the future, this need may be significantly amplified by much higher demand that could leave water stranded in Robinson. The SWAM model was used to demonstrate current rules with current demand, current rules with future demand, and adjusted rules for future demand. Experimentally, the rules were adjusted such that Lake Robinson releases 44 cfs to Lake Cunningham (approximately the maximum monthly demand for the 2070 High Demand Scenario) whenever Lake Cunningham drops below 150 MG (or approximately 60 percent of its storage capacity). The scenario resulted in Greer CPW's ability to satisfy the 2070 High Demand projections and a more balanced utilization of Lake Robinson.

Startex-Jackson-Wellford-Duncan Reservoir System

SJWD relies on water from three reservoirs on the North and Middle Tyger Rivers, Lake Cooley, Lake Lyman, and North Tyger Reservoir. The three reservoirs are sufficient to provide for current demand, but like the other water suppliers, 2070 High Demand Scenario withdrawals can cause shortages without adjustment of operating rules. The following experimental rules were implemented:

- Lake Cooley will release 5 cfs downstream as needed to maintain minimum streamflow feeding into the downstream intake.
- Lake Lyman will release 25 cfs whenever the downstream flow drops below 35 cfs to help augment water availability at the downstream point of withdrawal.
- The Middle Tyger system can continue to be prioritized, perhaps even more than current practice.

The modifications above result in a more balanced drawdown of SJWD's three reservoirs and SJWD's ability to meet 2070 High Demand Scenario projections.

Cherokee County BPW Reservoir System

Cherokee County BPW has less operational flexibility with its two reservoirs, Lake Whelchel and Gaston Shoals Reservoir. The safe yield of Lake Whelchel is approximately 6.8 MGD, and the safe yield of Gaston Shoals is approximately 6.0 MGD. Combined, these two sources can meet current demand, but represent only about half of the approximately 25 MGD in the 2070 High Demand Scenario projections. The following sections present various surface water supply alternatives for Cherokee County BPW.

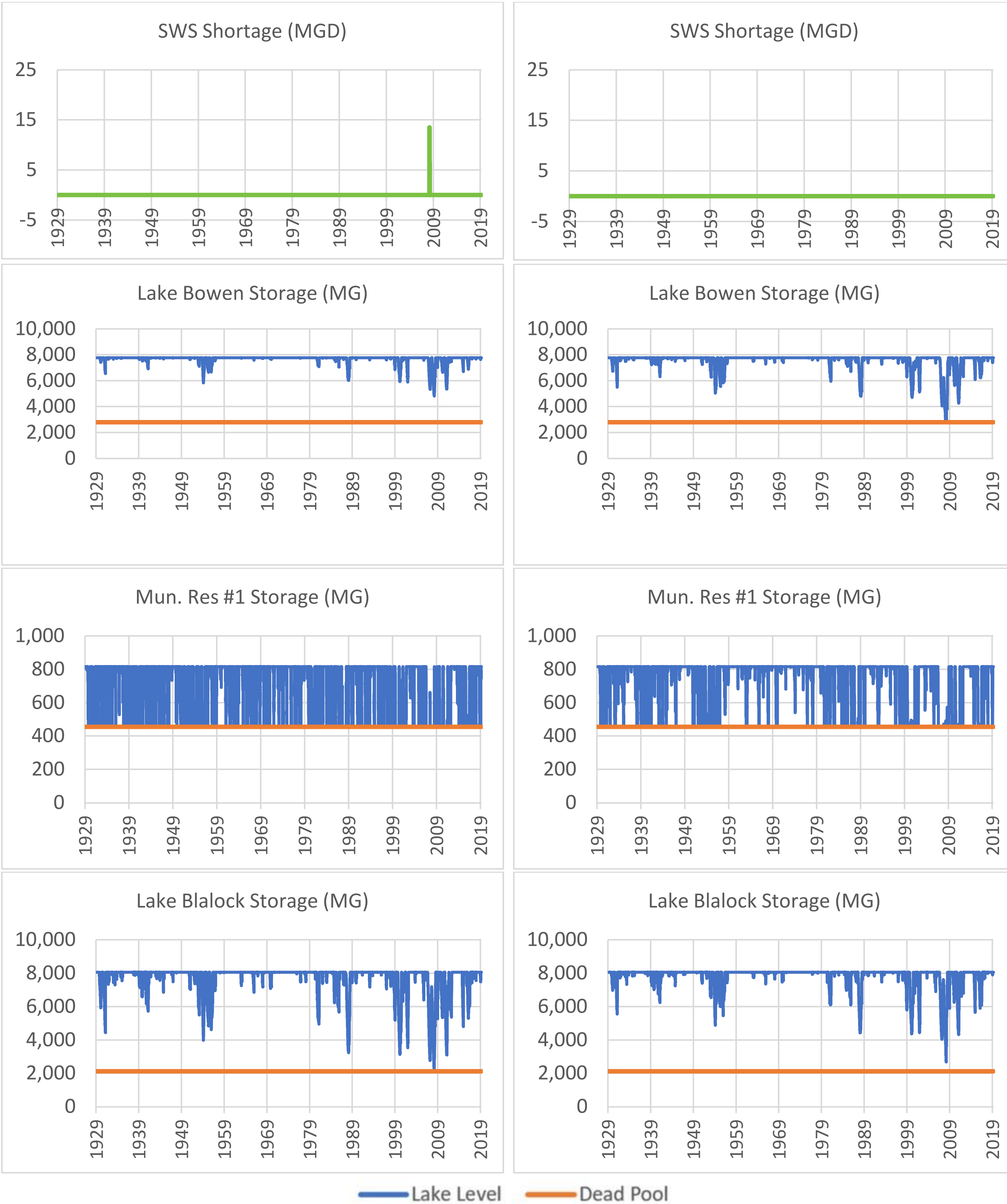


Figure 6-2. SWS storage and reservoir levels in the 2070 High Demand Scenario without (left) and with (right) reservoir optimization.

Lee Nuclear Generating Station Offline Storage

Duke Energy's proposed Pond C/London Creek Reservoir was evaluated using the SWAM model. Lee Nuclear would meet cooling water demand via withdrawals from both Pond C and Ninety-Nine Islands Reservoir. Pond C was configured to leave 20 percent of the mean annual flow at the Broad River withdrawal point. SWAM modeling indicates that the addition of Pond C could provide all of Lee Nuclear Generating Station's projected demand in both the Moderate and High Demand Scenarios, eliminating projected shortages.

Cherokee County BPW Supply-Side Strategies

Several additional supply-side strategies discussed in this section were evaluated using the SWAM model to assess their ability to reduce or eliminate Cherokee County BPW's projected shortages in the 2070 High Demand Scenario. While the 2070 High Demand Scenario presented in Chapter 5 assumed that permit requirements were not limiting and assessed physical water availability, the following evaluations for Cherokee County BPW did apply the limitations of their existing permits for Lake Whelchel and Gaston Shoals withdrawals. The enforcement of their permits increases the projected frequency of shortage and average shortage. There is a slight decrease in the maximum shortage, likely because the higher withdrawals allowed without enforcement of permits results in reservoir levels being drawn down prior to drought periods, leading to larger shortages. Table 6-7 summarizes Cherokee County BPW's baseline projected shortages for the 2070 High Demand Scenario.

Table 6-7. Baseline projected shortages for Cherokee County BPW in the 2070 High Demand Scenario.

	2070 High Demand, Permits Not Enforced	2070 High Demand, Permits Enforced
Average Shortage (MGD)	0.2	1.6
Maximum Shortage (MGD)	27.8	26.7
Frequency of Shortage (%)	1.1	37.4

Seasonal Distribution of Gaston Shoals Allocation – Cherokee County BPW

Cherokee County BPW is currently allocated 6 MGD (annual average) from Gaston Shoals Reservoir. Modeling evaluation found that redistributing the monthly withdrawals from Gaston Shoals proportionally to Cherokee County BPW's demands could reduce the impact of frequent, small shortages. The average shortage of approximately 1.6 MGD 37.4 percent of the time was reduced to an average shortage of approximately 0.4 MGD 5.0 percent of the time. The modification of these operational choices, however, did not impact their projected maximum monthly shortage of up to 26.7 MGD. Table 6-8 summarizes the impact of this alternative on projected shortages in the 2070 High Demand Scenario.

Table 6-8. Projected shortages for Cherokee County BPW using seasonal distribution of Gaston Shoals allocation in the 2070 High Demand Scenario.

	2070 High Demand Baseline	2070 High Demand – Seasonal Distribution of Gaston Shoals Allocation
Average Shortage (MGD)	1.6	0.4
Maximum Shortage (MGD)	26.7	26.7
Frequency of Shortage (%)	37.4	5.0

Renegotiated Gaston Shoals Allowance with FERC Licensee – Cherokee County BPW

The RBC chose to explore the impact of renegotiating a higher withdrawal limit from Gaston Shoals with the current FERC licensee, Northbrook Power Management. According to operations governed by FERC, Cherokee County BPW understands that its allowance from Gaston Shoals is 6 MGD on an annual average basis. Separately, Cherokee County BPW has a 620 MGM (20 MGD) SCDHEC permitted withdrawal from Gaston Shoals. The SWAM model was used to explore the impact of using the 620 MGM permitted withdrawal limit as the limiting allowance instead of the FERC-associated allowance. The higher withdrawal limit reduced the average shortage of approximately 1.6 MGD 37.4 percent of the time to an average shortage of 0.2 MGD 2.2 percent of the time. This strategy did not reduce the maximum monthly shortage of 26.7 MGD. In the month where the maximum shortage occurs, Cherokee County BPW's supply is limited by physical water availability rather than a permitted withdrawal limit. Table 6-9 summarizes the impact of this alternative on projected shortages in the 2070 High Demand Scenario.

Table 6-9. Projected shortages for Cherokee County BPW using a renegotiated FERC allowance in the 2070 High Demand Scenario.

	2070 High Demand Baseline	2070 High Demand – Renegotiated FERC Allowance
Average Shortage (MGD)	1.6	0.2
Maximum Shortage (MGD)	26.7	26.7
Frequency of Shortage (%)	37.4	2.2

Raise Dam Height of Lake Whelchel – Cherokee County BPW

The SWAM model was used to explore the impact of increased storage in Lake Whelchel. Raising the dam height by 3 feet would increase the Lake Whelchel's total storage by approximately 18 percent, to 953 MG. The increase in dam height also would result in an increased safe yield of 7.8 MGD compared to Lake Whelchel's current safe yield of 6.8 MGD. By 2070 in the High Demand Scenario, this results in a slight reduction in the average shortage and frequency of shortage and has no impact on the maximum shortages. Table 6-10 summarizes these results, along with results combining the raised dam with the seasonal distribution of Gaston Shoals allocation described in an earlier strategy. Since Cherokee County BPW likely will revise operating practices to minimize shortage, the results with the seasonal distribution of Gaston Shoals allocations and the raised dam are likely more representative of predicted shortages in 2070.

Table 6-10. Projected shortages for Cherokee County BPW with a raised Lake Whelchel dam height in the 2070 High Demand Scenario.

	2070 High Demand Baseline	2070 High Demand – Raised Dam Lake Whelchel	2070 High Demand – Raised Dam Lake Whelchel with Seasonal Distribution of Gaston Shoals Allocation
Average Shortage (MGD)	1.6	1.57	0.37
Maximum Shortage (MGD)	26.7	26.7	26.7
Frequency of Shortage (%)	37.4	36.5	4

Quarry Storage – Cherokee County BPW

Conceptual analysis with the SWAM model simulating a hypothetical offline quarry supplied with water downstream of Lake Whelchel suggested that a quarry with 2 BG of storage potentially could eliminate projected shortages by 2070.

The previous study of the Blacksburg quarry in Cherokee County indicated the 1.69 BG quarry could provide an additional raw water source to serve 1 MGD for more than 4 years or 5 MGD for 280 days, not considering additional inflow from groundwater (WK Dickson 2002).

New Broad River Intake – Cherokee County BPW

This conceptual alternative examines a potential new intake on the Broad River, downstream of the confluence of Buffalo Creek. The intake location is outside of any FERC project boundaries (Cherokee Falls, Ninety-Nine Islands, or Gaston Shoals); therefore, the intake would not be subject to FERC license limitations. Cherokee County BPW would need to apply for a new surface water withdrawal permit from SCDHEC for the intake. In this scenario, it is assumed that the Broad River water would be used to supplement their existing sources (Lake Whelchel and Gaston Shoals) and taken only when needed.

Analysis with the SWAM model (using a monthly timestep) suggests that a new intake on the Broad River, downstream of the confluence of Buffalo Creek, could provide 100 percent supply reliability to Cherokee County BPW through 2070 using the High Demand Scenario projections, and likely beyond. Simulated shortages are eliminated (see Table 6-11).

Table 6-11. Impacts of new Broad River intake on downstream gage BR02 flows in the 2070 High Demand Scenario.

	2070 High Demand Baseline	2070 High Demand – New Broad River Withdrawal	2070 High Demand – New Broad River Withdrawal with Seasonal Distribution of Gaston Shoals Allocation
Average Shortage (MGD)	1.6	0	0
Maximum Shortage (MGD)	26.7	0	0
Frequency of Shortage (%)	37.4	0	0
Average Cherokee County BPW Broad River Withdrawal (MGD)	0	1.6	0.51
Maximum Cherokee County BPW Broad River Withdrawal (MGD)	0	26.7	26.7
Minimum Gaged BR02 Flow (MGD)	157	134	134
1st Percentile Gaged BR02 Flow (MGD)	318	305	303
2nd Percentile Gaged BR02 Flow (MGD)	359	359	359

It is important to understand the impacts of a new surface water withdrawal on stream flows downstream of the intake. Table 6-11 summarizes impacts to downstream flows in the Broad River at gage BR02 (USGS 02153500). Two variations of the new Broad River withdrawal strategy are shown: one with only the new Broad River withdrawal and one combining the new Broad River withdrawal with the seasonal distribution of Gaston Shoals allocation. The variation without seasonal distribution of Gaston Shoals allocation results in more frequent withdrawals (30 percent of the time) and higher average withdrawal from the Broad River. Combined with the seasonal distribution of Gaston Shoals allocation, the new Broad River intake would be used at a 5 percent frequency. Both variations have the same maximum withdrawal of 26.7 MGD and result in a 15 percent reduction in the minimum downstream flow. The new withdrawal reduces the lowest first percentile downstream flow by 4 to 5 percent while it does not substantively change the second percentile downstream flow. Figure 6-3 illustrates the minimal changes to the flow duration curve with the addition of a new Broad River withdrawal. In this figure, the x-axis indicates the percentage of time that flow at BR02 exceeds the indicated flow on the y-axis. Since there is virtually no change in all but the lowest flows, only the lowest 10 percent flows are plotted. As shown in the figure, only the first (99th) percentile flow is reduced because of the new intake.

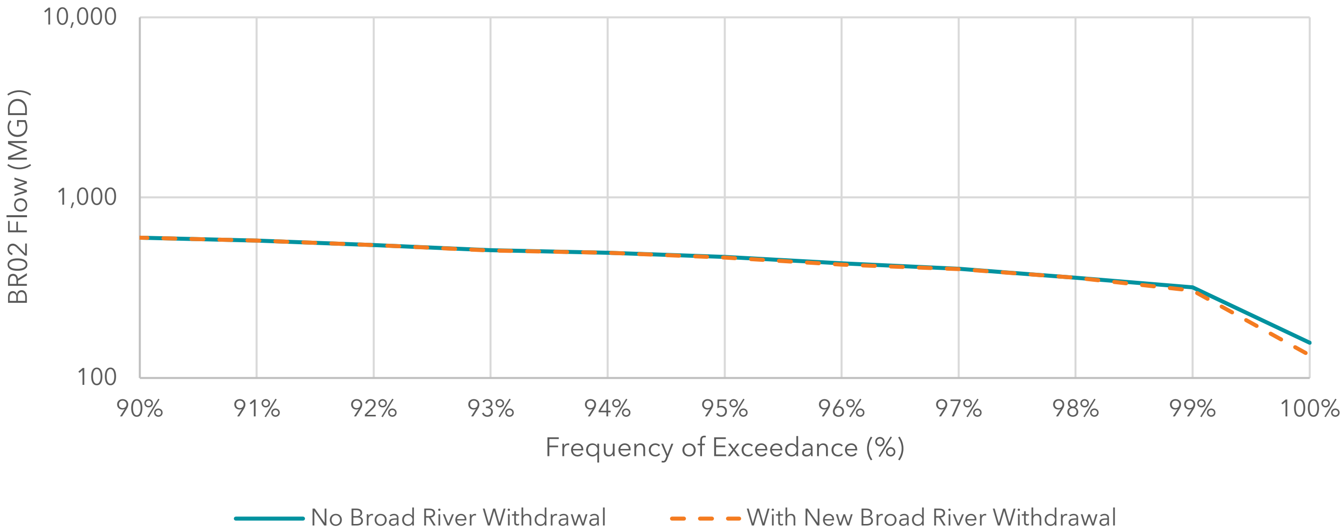


Figure 6-3. Frequency of exceedance of flows at BR02 downstream of a new Broad River withdrawal.

Connection with SWS – Cherokee County BPW

Cherokee County BPW could pursue an interconnection to SWS to purchase water to meet growing demands and provide a redundant supply in case of emergency. To assess the availability of excess water from SWS, the SWAM model was used to simulate a new withdrawal from one of SWS's reservoirs, Lake Blalock, to Cherokee County BPW. Lake Blalock has a capacity of more than 8 BG and currently provides water to SWS when needed, though it has not been heavily used recently.

Two configurations of a possible SWS interconnection were explored via the proxy of withdrawal from Lake Blalock. In the first configuration, Cherokee County BPW relies on SWS as a third source to supplement its existing supplies from Gaston Shoals and Lake Whelchel. In this configuration, Cherokee County BPW may take as much water as it needs to meet demands, provided sufficient water is available in Lake Blalock. In the second configuration, Cherokee County BPW relies on SWS as a primary source at a constant 5 MGD, provided there is enough water available.

Table 6-12 summarizes the results of both configurations. Cherokee County BPW's use of SWS water supply via Lake Blalock results in a lower projected average shortage and frequency of shortage and in a slight reduction in the maximum shortage in the 2070 High Demand Scenario. However, it also results in shortages for SWS that were not present before the addition of Cherokee County BPW's withdrawal from the system. By 2070, under High Demand Scenario conditions, SWS is expected to need its full allocation of water from Lake Blalock, so withdrawal by Cherokee County BPW before drought conditions could reduce water levels and cause shortages to both utilities during droughts. Further development and examination of carefully crafted rules would be needed to guard against such unintended consequences. In the near-term, SWAM modeling suggests SWS may have more water available than needed to meet its own demands and could provide a solution to Cherokee County BPW's projected shortages through 2030.

Table 6-12. Projected shortages for Cherokee County BPW with interconnection to SWS in the 2070 High Demand Scenario.

	2070 High Demand Baseline	2070 High Demand – SWS as Cherokee County BPW's 3rd source with unlimited withdrawal with Seasonal Distribution of Gaston Shoals Allocation	2070 High Demand – SWS as Cherokee County BPW's 1st source at 5 MGD with Seasonal Distribution of Gaston Shoals Allocation
Cherokee County BPW Average Shortage (MGD)	1.6	0.15	0.21
Cherokee County BPW Maximum Shortage (MGD)	26.7	24.3	24.0
Cherokee County BPW Frequency of Shortage (%)	37	1.7	2.5
SWS Average Shortage (MGD)	0	0.21	0.19
SWS Maximum Shortage (MGD)	0	39.6	38.4
SWS Frequency of Shortage (%)	0	1.2	1.1

New Reservoir on King's Creek – Cherokee County BPW

A new 1,670 MG storage reservoir on King's Creek was added to the SWAM model at approximately the location evaluated in the 2002 WK Dickson study. The model assumed approximately 400 MG of the total storage was dead storage. To represent the need for environmental flow maintenance, but also to keep the analysis from becoming too speculative, the model was set up simply to enforce minimum releases of 95 percent of flow upstream of the reservoir. (For screening purposes, this was more conservative than the 20/30/40 rule that affects new withdrawal permits, though it may underestimate reservoir storage in times of extreme low flows). The model evaluations indicate that the addition of the conceptual King's Creek reservoir to Cherokee County BPW's supply portfolio nearly could meet their projected 2070 high demands, reducing the frequency of shortage to 0.3 percent of time and significantly reducing the maximum projected shortage. Table 6-13 summarizes these results along with results combining the new reservoir with the seasonal distribution of Gaston Shoals allocation described in an earlier strategy.

Table 6-13. Projected shortages for Cherokee County BPW with new King's Creek Reservoir in the 2070 High Demand Scenario.

	2070 High Demand Baseline	2070 High Demand – New King's Creek Reservoir	2070 High Demand – New King's Creek Reservoir with Seasonal Distribution of Gaston Shoals Allocation
Average Shortage (MGD)	1.6	0.01	0.02
Maximum Shortage (MGD)	26.7	5.2	11.1
Frequency of Shortage (%)	37.4	0.3	0.3

The original 2002 WK Dickson study sized the Kings Creek reservoir to match the storage provided by the Blacksburg quarry and provide a final yield of 5 MGD to Cherokee County BPW.

New Regional Reservoir – Cherokee County BPW

A large, regional reservoir was simulated in the SWAM model on Fairforest Creek in the Tyger River basin. This location was selected for exploration simply because it is reasonably centralized and there is only one upstream use on this stream. This was a purely conceptual analysis, undertaken to study water availability only. Permitting, land ownership, development plans, storage potential, design, costs and cost sharing, and a full suite of aquatic and terrestrial environmental impacts would all need to be considered in detail to extract this alternative from the conceptual realm. In this analysis, the only regional water management issue that was addressed by this hypothetical reservoir was the projected water shortage in Cherokee County BPW by 2070, assuming the High Demand Scenario. If a regional reservoir were to be constructed, it likely would serve multiple users in the basin. For this conceptual evaluation, a reservoir was simulated in SWAM beginning with available capacity equal to Lake Blalock (for comparative purposes). The model was run iteratively to determine what size reservoir would be needed to meet Cherokee County BPW's projected 2070 demand in the High Demand Scenario. Analysis determined that a reservoir with approximately 4 BG of storage (6 BG total, with a little more than 2 BG reserved as dead storage) could satisfy their demand through 2070, using the projections of the High Demand Scenario.

New Cherokee County BPW Supplies Summary

Table 6-14 summarizes the effectiveness of new surface water management strategies at reducing Cherokee County BPW's projected 2070 High Demand Scenario shortages. Many strategies can reduce their average shortage and frequency of shortage but fail to provide sufficient supply during drought to effectively reduce the maximum shortage. Three strategies, the conceptual offline quarry, the new Broad River withdrawal, and the new regional reservoir, are effective at eliminating their projected shortages in the 2070 High Demand Scenario. These three strategies have large uncertainties regarding feasibility, as further discussed in the next section. It is likely that Cherokee County BPW's preferred strategy will involve a portfolio of supply options and an adaptive management philosophy to explore additional options as demand and hydrologic conditions necessitate.

Table 6-14. Effectiveness of Cherokee County BPW supply-side water management strategies at reducing their projected 2070 High Demand Scenario shortages.

Alternative	Average Shortage (MGD)	Frequency of Shortage (%)	Maximum Shortage (MGD)
Baseline	1.6	37	26.7
Seasonal Distribution of Gaston Shoals Allocation	0.4	5	26.7
Renegotiated Gaston Shoals allowance with FERC licensee	0.2	2.2	26.7
Raise dam height of Lake Whelchel (3 feet)	0.37	4	26.7
2 BG Offline Quarry	0	0	0
New Broad River withdrawal	0	0	0
Interconnection to SWS	0.15	1.7	24.3
New reservoir on Kings Creek	0.02	0.3	11.1
New regional reservoir	0	0	0

Effectiveness
Entirely effective
Highly effective
Somewhat effective
Not effective

6.1.5 Feasibility of Surface Water Management Strategies

The Broad RBC assessed the feasibility of the strategies described above considering consistency with regulations, reliability of water source, environmental impacts, socioeconomic impacts, potential interstate or interbasin impacts, and water quality impacts. Table 6-15 presents this assessment.

Table 6-15. Water management strategy feasibility assessment.

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Potential Moderate/High Adverse Effect	Potential Low Adverse Effect	Likely Neutral Effect (either no effect, or offsetting effects)	Potential Low Positive Effect	Potential Moderate/High Positive Effect

Water Management Strategy	Strategy Type	Consistency with Regulations	Reliability of Water Source	Environmental Impacts and Benefits[1]	Socioeconomic Effects	Potential Interstate or Interbasin Effects	Other Water Quality Considerations
Development, Update, and Implementation of Drought Management Plans	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability during droughts.	**Impacts:** None anticipated	Low anticipated effects – Effects to utility revenue if demand reductions are substantial. Positive effect to residential users from reduced water bills (if billed at unit rate).	No anticipated effects	No anticipated impacts
Public Education of Water Conservation	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** None anticipated	Low anticipated effects – Effects to utility revenue if demand reductions are substantial. Positive effect to residential users from reduced water bills (if billed at unit rate).	No anticipated effects	No anticipated impacts
Conservation Pricing Structures	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** None anticipated	Moderate anticipated effects – Customers that cannot reduce water use may face economic hardship. Reduced billing revenue for utilities may cause financing issues or lead to further rate increases.	No anticipated effects	No anticipated impacts
Residential Water Audits	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** None anticipated	No to low anticipated effects – Revenue effects to utility from reduced demand may be offset by lower delivery costs. Effects to homeowners from repairs may be offset by reduced water bills (if billed at unit rate). The need to hire implementation and compliance staff would contribute to rate increase.	No anticipated effects	No anticipated impacts

Table 6-15. Water management strategy feasibility assessment. (Continued)

Water Management Strategy	Strategy Type	Consistency with Regulations	Reliability of Water Source	Environmental Impacts and Benefits[1]	Socioeconomic Effects	Potential Interstate or Interbasin Effects	Other Water Quality Considerations
Landscape Irrigation Program and Codes	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** None anticipated **Benefits:** Water quality of receiving waters may be improved by reducing runoff from landscaping.	Low anticipated effects – Mandates to meet standards may cause financial hardship for homeowners. No anticipated effects to homeowners from educational programs. The need to hire implementation and compliance staff would contribute to rate increase.	No anticipated effects	See Environmental Benefits
Water Efficiency Standards for New Construction	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** None anticipated	Low anticipated effects – Efficiency standards may make renovations or construction more expensive and limit access to renovate or build. The need to hire implementation and compliance staff would contribute to rate increase.	No anticipated effects	No anticipated impacts
Leak Detection and Water Loss Control	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts**: None anticipated	Cost of program implementation could result in rate increase, no impact, or potential rate decrease, depending on circumstances.	No anticipated effects	No anticipated impacts

Table 6-15. Water management strategy feasibility assessment. (Continued)

Water Management Strategy	Strategy Type	Consistency with Regulations	Reliability of Water Source	Environmental Impacts and Benefits[1]	Socioeconomic Effects	Potential Interstate or Interbasin Effects	Other Water Quality Considerations
Reclaimed Water Programs	Demand-side – Municipal	SCDHEC regulates reclaimed wastewater systems for irrigation use with public contact; there are no laws or regulations pertaining to indirect potable reuse or direct potable reuse.	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** Low to moderate anticipated impacts: Depending on the extent of reclaim demand, reduced discharge from wastewater treatment facilities may reduce low-flow levels. **Benefits:** Depending on the extent of reclaim demand, reduced discharge from wastewater treatment facilities may result in improved receiving water quality.	Moderate anticipated effects – Higher initial water bills to finance a reclaimed water program may be offset by long-term savings from postponing the need for new supplies and raw water treatment facilities. The need to hire operations staff could contribute to rate increase.	No anticipated effects	**Benefits to Natural Waters:** See Environmental Benefits. **Risks to Drinking Water:** Need to match end use with quality of reclaimed water. Consider emerging contaminants of concern (e.g., PFAS and microplastics).
Car Wash Recycling Ordinances	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** Low anticipated impacts – renovation or construction may impact sensitive areas. **Benefits:** Positive environmental benefit of reduced pollutant runoff.	Low anticipated effects – Financial burden to developer or owner of car wash for construction/ renovation. The need to hire implementation and compliance staff would contribute to rate increase.	No anticipated effects	See Environmental Benefits.
Time-of-Day Watering Limit	Demand-side – Municipal	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts**: None anticipated	The need to hire implementation and compliance staff would contribute to rate increase.	No anticipated effects	No anticipated impacts.

Table 6-15. Water management strategy feasibility assessment. (Continued)

Water Management Strategy	Strategy Type	Consistency with Regulations	Reliability of Water Source	Environmental Impacts and Benefits[1]	Socioeconomic Effects	Potential Interstate or Interbasin Effects	Other Water Quality Considerations
Water Audits and Nozzle Retrofits	Demand-side – Agriculture	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** None anticipated. **Benefits:** Prevention of overwatering may limit runoff, erosion, and sedimentation.	No to low anticipated effects – Financial gains from reduced delivery and pumping costs likely outweigh costs of audit and nozzle retrofits.	No anticipated effects	See Environmental Benefits.
Irrigation Scheduling	Demand-side – Agriculture	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** None anticipated. **Benefits**: May reduce over-fertilization and prevention of overwatering may limit runoff, erosion, and sedimentation.	Low to moderate effects – Initial costs of advanced technology may be partially offset by savings from reduced water and nutrient use.	No anticipated effects	See Environmental Benefits.
Soil Management	Demand-side – Agriculture	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** Low anticipated impacts – Increase in herbicides may be required. **Benefits:** May improve soil quality and reduce runoff.	Low to moderate effects – Initial costs of new equipment plus training and O&M costs. Costs may be partially offset by reduction in soil, water, and nutrient loss.	No anticipated effects	No to low anticipated impacts – Conservation tillage may increase potential leaching of nitrogen or pesticide to groundwater. See also Environmental Benefits.
Crop Variety, Crop Type, Crop Conversion	Demand-side – Agriculture	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** Low anticipated impacts – Variation in chemical application for different crops must be considered.	Medium to high anticipated effects – Potential profit loss from switching to lower demand crop or from a full season to short-season crop.	No anticipated effects	No anticipated impacts
Irrigation Equipment Changes	Demand-side – Agriculture	Consistent	Strategy reduces demand and extends supply, increasing water source reliability for other demands.	**Impacts:** Low anticipated impacts – Changing equipment may disturb environmentally sensitive areas.	Low anticipated effects – Initial costs of equipment changes may be partially offset by water-use savings.	No anticipated effects	No anticipated impacts

Table 6-15. Water management strategy feasibility assessment. (Continued)

Water Management Strategy	Strategy Type	Consistency with Regulations	Reliability of Water Source	Environmental Impacts and Benefits[1]	Socioeconomic Effects	Potential Interstate or Interbasin Effects	Other Water Quality Considerations
Adjust Reservoir Operations – Municipalities with Projected 2070 High Demand Shortages	Supply	Consistent with existing permits and storage volumes. Would require additional regulator evaluation.	Eliminates projected shortages through planning period for Greer CPW, SWS, and SJWD (assuming historic hydrology).	**Impacts:** Low anticipated impacts – More significant and frequent drawdown of reservoirs possible.	No to low anticipated effects.	No anticipated effects	Low anticipated impacts – water quality impacts in reservoirs as a result of changes in drawdown should be evaluated.
Lee Nuclear Generating Station Offline Storage	A feasibility analysis was not conducted by the RBC for this alternative. The Generating Station is expected to come online in 2035, and Duke Energy would be responsible for the feasibility analysis of the supplemental storage pond needed to meet the water demands of this facility.						
Seasonal Distribution of Gaston Shoals Allocation – Cherokee County BPW	Supply	Consistent.	Strategy reduces small, frequent shortages but does not significantly reduce risk of shortage by 2070.	**Impacts:** No anticipated impacts. Gaston Shoals still meeting downstream releases.	No to low anticipated effects.	No anticipated effects	No anticipated impacts – reservoirs will be operated within allowable drawdown and subject to required downstream releases.
Renegotiated Gaston Shoals Allowance with FERC Licensee – Cherokee County BPW	Supply	Consistent with SCDHEC regulations but would require renegotiation of FERC license for Gaston Shoals.	Strategy reduces small, frequent shortages but does not significantly reduce risk of shortage by 2070.	**Impacts:** Low anticipated impacts – Downstream flows could be impacted from an increase in withdrawals from Gaston Shoals.	No to low anticipated effects.	No anticipated effects	Low anticipated impacts – water quality impacts in Gaston Shoals as a result of changes in drawdown and in streams as a result of altered flow regimes should be evaluated.
Raise Dam Height of Lake Whelchel – Cherokee County BPW	Supply	Consistent. Would require design to comply with dam safety requirements.	Strategy reduces average shortages and frequency of shortage but does not significantly reduce risk of shortage by 2070.	**Impacts:** Low to moderate anticipated impacts – wetlands, sensitive species, and vegetation bordering the lake could be impacted.	Low to moderate effects – Cherokee County BPW would need to purchase any impacted land it does not already own around the lake. Construction would initially create jobs but operational staffing would be unchanged from current conditions.	No anticipated effects	**Impacts**: Potential increases to residence time, stratification, and sediment nutrient release during anoxic conditions. **Benefit**: Deepening reservoir could reduce algae blooms caused by excessive nutrients and warm water temperatures.

Table 6-15. Water management strategy feasibility assessment. (Continued)

Water Management Strategy	Strategy Type	Consistency with Regulations	Reliability of Water Source	Environmental Impacts and Benefits[1]	Socioeconomic Effects	Potential Interstate or Interbasin Effects	Other Water Quality Considerations
Quarry – Cherokee County BPW	Supply	Would require additional state and federal permits for withdrawal, construction, water quality certification, and disposal permits if a new water treatment facility is built.	Strategy has potential to satisfy Cherokee County BPW's projected demands through 2070 provided there is sufficient diversion flow or groundwater flow before filling the quarry prior to drought.	**Impacts:** Moderate to high anticipated impacts – Impact of reservoir water levels on groundwater flow must be assessed. Potential impacts of associated pipeline construction on environment and species.	No to low anticipated effects – Construction would initially create jobs but operational staffing would be unchanged from current conditions.	No anticipated effects	Low to high anticipated impacts – water quality impacts to streams from diversions to reservoir should be evaluated. Design must consider potential for contamination from surrounding groundwater and soil.
New Broad River Intake – Cherokee County BPW	Supply	Consistent. Would require new surface water withdrawal permit from SCDHEC.	Strategy has potential to satisfy Cherokee County BPW's projected demands through 2070.	**Impacts:** Low anticipated impacts – Downstream flows would be minimally impacted by a new withdrawal. Minimum flows may be reduced by 15%, but impact to 1st and 2nd percentile flows would be practically negligible.	No to low anticipated effects – Construction would initially create jobs but operational staffing would be unchanged from current conditions.	No anticipated effects	Low anticipated impacts – water quality impacts to streams from reduced flow should be evaluated for flows at the 1st percentile level and lower.
Connection to SWS – Cherokee County BPW	Supply	Consistent.	Strategy may increase resilience and reduce average shortage and frequency of shortage but does not significantly reduce risk of shortage by 2070 when SWS has less excess supply.	**Impacts:** Low anticipated impacts – Downstream flows could be impacted from an increase in withdrawals from SWS's reservoirs to meet Cherokee County BPW's additional needs.	Low to moderate anticipated effects – Use of SWS water by Cherokee County BPW has potential to deplete SWS supplies prior to drought. Operating rules must be developed to avoid impacts to SWS, which may decrease benefits.	No anticipated effects	Low anticipated impacts – water quality impacts in SWS's reservoirs as a result of changes in drawdown and in downstream streams as a result of altered flow regimes should be evaluated.

Table 6-15. Water management strategy feasibility assessment. (Continued)

Water Management Strategy	Strategy Type	Consistency with Regulations	Reliability of Water Source	Environmental Impacts and Benefits[1]	Socioeconomic Effects	Potential Interstate or Interbasin Effects	Other Water Quality Considerations
New Reservoir on King's Creek – Cherokee County BPW	Supply	Construction of a new reservoir may require years of permitting, planning, and regulatory coordination.	Strategy reduces average shortages and frequency of shortage but may not entirely reduce risk of shortage by 2070.	**Impacts:** High anticipated impacts – terrestrial habitat is submerged, river flow is impeded, and habitat may be lost.	No to low anticipated effects – Construction would initially create jobs and there may be new operational staffing requirements.	No anticipated effects	High anticipated impacts – water quality impacts due to reduced flows in Buffalo Creek downstream of the new reservoir should be evaluated. Uncertainty in water quality issues in the new water body, such as algae.
New Regional Reservoir – Cherokee County BPW	Supply	Construction of a new reservoir may require years of permitting, planning, and regulatory coordination.	Depending on sizing and downstream flow requirements, this strategy has potential to satisfy Cherokee County BPW's projected demands through 2070.	**Impacts:** High anticipated impacts – terrestrial habitat is submerged, river flow is impeded, and habitat may be lost.	High anticipated effects – A new reservoir has a high level of uncertainty related to land ownership, development plans, potential costs of compensatory environmental projects, etc., which may impact costs to the utility or socioeconomic impacts to the community from lost development opportunity.	No anticipated effects	High anticipated impacts – water quality impacts due to reduced flows downstream of the new reservoir should be evaluated. Uncertainty in water quality issues in the new water body, such as algae.

[1]For this comparison, "impacts" can be understood as potentially adverse consequences, while "benefits" are potential advantageous consequences

6.1.6 Cost-Benefit Analysis

Available information related to costs and benefits in terms of potential savings of water or dollars for each strategy follows. These are generalized values from literature or other locations and should be considered for planning-level assessment only, to help screen and understand the alternatives. Implementation planning would require more specific analysis.

The information provided in this chapter is not intended to rule any of the alternatives into or out of a recommended River Basin plan for the Broad River basin. Rather, the information is for relative comparison purposes, so that the potential benefits, risks, and impacts of the alternatives can be understood more completely and decision-makers can make more informed decisions about priorities.

Demand-Side Municipal Strategies

Public Education of Water Conservation

Building water conservation awareness will not only save water but will save money on operational and production costs. Savings are estimated at 5,000 gallons per household per year for 30 percent of households targeted. Public education and outreach costs more per person in smaller communities than in larger ones ($2.75 per person per year for communities less than 20,000 and $1.80 per person per year for communities with more than 20,000) (Freese and Nichols, Inc. 2020).

Conservation Pricing Structures

The implementation of conservation pricing rate structures, which discourage the inefficient use or waste of water, is a cost-effective option for utilities because there are no direct costs to them to achieve a reduction in demand. However, reduction in billing revenue associated with decreased customer usage must be considered. On average, in the United States, a 10 percent increase in the marginal price of water in the urban residential sector can be expected to diminish demand by about 3 to 4 percent in the short run (Olmstead and Stavins 2009). An example application in the Texas Panhandle assumed 10 percent of households would respond and change their water consumption behavior resulting in 6,000 gallons saved per household per year (Freese and Nichols, Inc. 2020).

Residential Water Audits

Residential water audits may result in the implementation of various strategies, retrofits, and other measures that may save up to 20 to 30 gallons of water per day per household. Costs are associated with the cost of the water audit (if applicable) and the costs of replacements or repairs to the household system.

Landscape Irrigation Program and Codes

If water efficiency measures are required, costs would be associated with enforcement. If not required, costs will be associated with incentives or education programs. If programs include rebate offerings, the cost of the rebate itself and the administration of the program must be considered. Smart irrigation controllers with an EPA WaterSense certification are commercially available for between $120 and $280. These costs assume there is already a compatible irrigation system in place. Costs to the homeowner would be greater if irrigation system installation or renovation is required. Irrigation with a smart irrigation meter rather than a standard irrigation meter may result in a water–use efficiency reduction of 30 percent. An example of a turf replacement rebate is from California's Metropolitan Water District, which offers a $2 per square foot rebate for up to 5,000 square feet. Ultimately, the cost to the utility or municipality would be dependent on the rebate rate and percent uptake by customers.

Water Efficiency Standards for New Construction

High-efficiency toilets can save more than $100 per family per year (Mullen n.d.). EPA estimates that fixtures meeting the WaterSense requirements can save approximately 700 gallons of water per year per household (EPA 2021). The costs associated with implementing local ordinances outlining water efficiency standards is low. There are numerous examples that can be used to guide ordinance development and implementation.

Leak Detection and Water Loss Control Program

EPA estimates that the average water loss in water systems is 16 percent, with up to 75 percent of the water loss potentially recoverable through a water loss control program (EPA 2013). Since 2010, Georgia's public water systems have reported, on average, between 13.5 and 17.4 percent water loss; however, 43 of 263 systems reported over 30 percent average annual water loss since 2010. Costs of a water loss control program would be associated with the time spent conducting the water audit and the costs of needed repairs, which would depend on the system. However, water audits generally have been proven to be cost-effective practices. The AWWA M36 Manual of Water Audits and Loss Control Programs includes an example of a utility with a $79,000 water audit cost, which, in 2022 dollars, translates to a unit cost $310/mile water main (AWWA 2016).

AMI and AMR technologies greatly reduce the labor required for water meter reading. Davie County Public Utilities, a water system in North Carolina, required 50 days (with frequent misreads) to manually read all 11,000 service connections in their network. After using AMR technology, they reduced their meter reading rate to 3,000 meters in two days, with nearly 100 percent accuracy (Atkinson 2016). In Michigan, the Oakland County Water Resources Commission achieved a 99 percent read success rate and reduced their meter reading staff by half after implementing an AMR system (Atkinson 2016).

A cost-benefit analysis for Washington Suburban Sanitary Commission Water concluded that an AMI system would pay for itself in 11 years, and project savings would exceed $286 million over a 20-year period (Arcadis 2020). The project cost was estimated to total $208 million dollars, with the primary driver of cost being the replacement of 492,000 meters. The analysis estimated that 29 of the existing 37 meter reader employee positions would be eliminated, and that the utility would have a revenue gain of more than $580 million over 20 years because of the improved meter accuracy. The improved domestic leak detection would save customers approximately $56 million over 20 years. Intangible benefits include safer working environments for utility employees due to the reduction in meter reading field activities, water and energy conservation by customers, identification of meter tampering and potential water theft, and benefits from more frequent billing cycles.

Reclaimed Water Programs

Benefits include increased water supply, increased reliability, and reduced effluent disposal. Initial costs may be substantial and include construction/retrofit costs to wastewater facilities for full reuse capabilities and construction of distribution lines to end users. Benefits may result by lowering demand on highly treated potable water, thereby extending the source of supply and delaying the need for future upgrades to treatment processes or procuring additional water sources. The overall cost-benefit is dependent on the system, the end user, the cost of treatment, and many other factors. Utilities and others that have implemented reclaimed water programs have typically done so after careful analysis and planning to demonstrate the long-term financial viability of a reclaimed water program.

Car Wash Recycling Ordinances

Costs of this practice are associated with the purchase and installation of a recycled water system by the car wash owner or developer. The initial cost for a water recycling system can range between $20,000 and $40,000 (in 2022 dollars) depending on the car wash size and requirements (Taylor 2013). Operating costs would be higher than a nonrecycled wash water system because of increased energy usage, replacement of filters and membranes, and other factors. Depending on whether the water was obtained from a public water system or (private) well, there would be a reduction in raw water costs since water demand would be reduced. Ordinances can set a percentage of recycled water to total water used. Typical ordinances require at least 50 percent use of recycled water.

Time-of-Day Watering Limit

Setting a time-of-day watering limit may save up to 1,000 gallons of water per household per year, depending on the amount of irrigated landscape. Costs are associated with enforcement and can vary depending on the size of the utility but are expected to be low. Utilities may benefit from reduced water use and a reduction in peak demands if a time-of-day water limit restricts usage before typical morning peak demands.

Demand-Side Agricultural Strategies

Water Audits and Nozzle Retrofits

The cost of a Clemson Center Pivot Irrigation Test Program audit is $125.00 per pivot. Costs of other water audits vary significantly depending on whether they are conducted internally, by a consultant, or by a government entity. While the process of conducting a water audit does not alone provide benefits, if improvements such as nozzle retrofits are made, benefits can include increased water efficiency and energy savings. An approximately 15 percent reduction in water use could be expected from nozzle retrofits made following a center pivot sprinkler audit (Walther, pers. comm. 2021).

A sample audit report provided by Clemson Cooperative Extension estimates the cost of a retrofit sprinkler package at $5 per foot of pivot length (Clemson Cooperative Extension 2022b). In this example, the total cost to retrofit is estimated at $2,982. Using an assumed crop value, irrigation need, and cost of under- or overirrigation, the estimated suboptimal irrigation cost is $4.39/acre. With an irrigated area of 37.4 acres, this comes out to an estimated loss of $164. Over the estimated 23.6-year lifespan of the retrofit, this equates to $3,875 in savings compared to the total cost of $3,107 ($2,982 cost of the retrofit plus the $125 cost of the initial audit).

Irrigation Scheduling

According to the 2021 Texas Panhandle Water Plan, the cost of a typical smart irrigation system ranges from $6.50 to $12.00 per acre and benefits amount to approximately 10 percent of the water used on each crop seasonally (Freese and Nichols, Inc. 2020).

Soil Management

The 2021 Texas Panhandle Water Plan assumed a 1.75 acre-inches per acre of water savings from soil management strategies (Freese and Nichols, Inc. 2020). While conservation tillage may result in savings from reduced machine, fuel, and labor costs, depending on the conservation type implemented, it also has initial costs to transition from conventional to conservation tillage, including the purchase of new equipment and any chemical control costs (herbicides or pesticides). For example, ridge tilling requires specially designed equipment such as a ridge cultivator or ridge planter.

Implementing furrow diking can range from less than $2,000 to several thousand dollars. Per crop per season per acre estimates range from $5 to $30. The Texas Water Development Board estimates water savings of 3 inches per season (0.2 acre-feet per acre), but savings will vary by field and season.

Crop Variety, Crop Type, and Crop Conversion

The cost of implementation and the actual reduction in irrigation water used will depend on numerous local factors including market pricing, cost of seed, cost of harvesting, and the value of crops.

If farmers are encouraged to switch from long season varieties to short-season varieties, they may experience loss in yield and, therefore, revenue. However, they will also see a cost savings from reduced seed, pumping, fertilizer, harvest, and water–use costs.

Irrigation Equipment Changes

Total replacement of a system (assumed 125-acre, 30-inch spacing) with a new 60-inch spacing system is estimated at $151.20 an acre, including labor and new hoses, heads, and weights. Conversion instead of full replacement of the same system is estimated at $44 per acre. Costs assume that the system is converting from low-elevation spray application (LESA) or mid-elevation spray application (MESA) systems to low-elevation precision application (LEPA) systems (Freese and Nichols, Inc. 2020). This transfer in irrigation practice may result in a 7 to 17 percent increase in irrigation efficiency and, consequently, water usage. In most cases, irrigation equipment changes will be a combination of replacement and conversion.

Supply-Side Strategies

Adjust Reservoir Operations

There is no appreciable cost associated with implementing new reservoir operating rules that better balance operations when water demands increase and/or droughts occur. Most water utilities in the Broad River basin have remote sensing equipment in place that provides real-time lake level information, which can be used to manually or automatically increase or decrease releases from an upstream reservoir to a downstream reservoir or prioritize use of an intake on one reservoir or stream fed by an upstream reservoir over another. SWAM modeling indicated that adjustments of reservoir operations may be sufficient to eliminate projected shortages in even the 2070 High Demand Scenario for all water suppliers except Cherokee County BPW making this a low-cost, high-benefit alternative.

Lee Nuclear Generating Station Offline Storage

A cost-benefit analysis was not conducted by the RBC for this alternative. The Lee Nuclear Generating Station is expected to come online in 2035, and Duke Energy would be responsible for the cost-benefit analysis of the supplemental storage pond needed to meet the water demands of this facility.

Seasonal Distribution of Gaston Shoals Allocation – Cherokee County BPW

Costs of these discretionary rule changes are likely minimal because they require no capital expenditures. Pumping cost may vary as the two sources are prioritized and used differently. This alternative offers a low-cost approach for Cherokee County BPW to minimize frequent, small projected shortages as demands grow. Gaston Shoals has lake level limitations associated with Northbrook Energy's hydroelectric plant. Impacts to this requirement from potential changes to Cherokee County BPW's withdrawal patterns were not considered in the modeling analysis but would need to be addressed prior to implementation.

Renegotiated Gaston Shoals Allowance with FERC Licensee – Cherokee County BPW

Costs would include support negotiation meetings with Northbrook Power Management and potential infrastructure capacity upgrades. Pumping cost likely would increase with more withdrawals from Gaston Shoals. This alternative offers a low-cost, though potentially difficult to negotiate, approach for Cherokee County BPW to minimize frequent, small projected shortages as demands grow.

Raise Dam Height – Cherokee County BPW

Estimated costs for the 2019 assessment of three alternatives to raise the dam crest height by 3 and 5 feet are $27 million and $31 to $35 million, respectively (adjusted to 2022 dollars) (AECOM 2019). This estimate included earth excavation and fill, concrete spillway construction, bridge and roadway work, and engineering and permitting. This equates to approximately $182 per 1,000 gallons of additional raw water storage (assuming a 3-foot increase in dam height).

Quarry – Cherokee County BPW

The cost of this type of project is highly variable based on site characteristics. Costs include land acquisition, water treatment, pumping systems, and distribution piping costs.

The Blacksburg quarry assessment determined a safe daily water yield of 3,500 gallons per day based on groundwater inflow and existing water in storage (WK Dickson 2002). Pumping of additional water into the reservoir was not considered. The capital cost estimate for quarry reservoir and water treatment facilities development ranged from $12 million to $17 million (adjusted to 2022 dollars) with 1 and 5 MGD treatment capabilities, respectively. Annual water treatment operating costs were estimated to range from approximately $0.88 / 1,000 gallons for 1 MGD of delivered water during the first 2 years to $0.64 / 1,000 gallons for 5 MGD after 5 years in service, largely driven by power and labor costs.

For a similar proposed project in North Carolina, a preliminary cost estimate for design and construction of a quarry reservoir ranged from $21 million to $35 million (adjusted to 2022 dollars) to construct 1,320 to 1,950 MG of raw water storage (Hazen and Sawyer 2003). This estimate did not include any costs associated with property acquisition and translates to $2.41 /gallon to $2.97/gallon of safe yield raw water supply. This was comparable to the unit costs of other recent reservoir development projects in North Carolina at the time the original cost estimate was developed in 2003 (Hazen and Sawyer 2003).

New Broad River Intake – Cherokee County BPW

This alternative would include the cost of engineering, surveying, permitting, and the construction of the new intake, pumping station, and approximately 2.2 miles of conveyance infrastructure to deliver water to Cherokee County BPW's water treatment facilities on Filter Plant Road. Additional land acquisition, easements, and financing also may be necessary, requiring legal and financing-related services.

In support of Colorado's Statewide Water Supply Initiative Update, a Water Project Cost Estimating Tool was developed to aid in uniform, planning-level development of water-related project costs (CDM Smith 2018). Using this tool and based on assumptions of a 15 MGD pumping facility and 30-inch pipeline, project costs (including engineering, surveying, permitting, and the construction) are approximately $12 million (adjusted for 2022 dollars). This equates to $0.80 per gallon (assuming 15 MGD).

Annual costs would be associated with debt service, operations and maintenance, and power costs. These annual costs are estimated to be $1.3 million, or $0.09 per gallon (assuming 15 MGD).

Connection to Spartanburg Water System – Cherokee County BPW

Cherokee County BPW has multiple options of where to build an interconnection to the SWS system. The closest possible location for an interconnection is 2.3 miles from Cherokee County BPW's system; however, this 10-inch pipeline would have deliveries limited to 2 MGD. Cherokee County BPW could choose to interconnect to a large, 42-inch transmission line, which could convey up to 30 MGD. However, this would require them to build a 42-inch pipeline measuring over 12 miles in length. The choice depends on what rate of water they hope to receive and the level of investment they wish to undertake. Table 6-16 summarizes these interconnection options. Costs were estimated using Colorado's Statewide Water Supply Initiative Update, a Water Project Cost Estimating Tool (CDM Smith 2018). The project costs include the pipeline construction costs and estimates engineering, surveying, legal and financial services, permitting, and interest costs. Costs assume there is no need for pump stations or significant valves or appurtenances.

Table 6-16. Cherokee County BPW options to interconnect with Spartanburg Water System.

Connection	Diameter Pipe (inch)	Approximate Flow Rate Conveyed (MGD)	Distance of Pipeline to Connect (miles)	Approximate Project Cost
Connection on Mt. Olive Rd	10	1-2	2.3	$5.5 million
Cowpens (Battleground) Distribution Area	12	2-3	9+	$15 million
Eastside Transmission Main	42	Up to 30 MGD	12+	$32 million

New Reservoir on King's Creek – Cherokee County BPW

This alternative would include the cost of studies and permitting, as well as the costs of land acquisition, construction, and operation of a new reservoir. The capital cost to develop a surface water reservoir and water treatment facilities with a 5 MGD capacity was estimated to total $37 million (adjusted to 2022 dollars), plus an additional $10 million to $20 million for necessary regulatory permitting (WK Dickson 2002). The following section presents additional cost estimates for reservoir construction and provides discussion of a new regional reservoir.

New Regional Reservoir – Cherokee County BPW

The cost of a project of this scale is highly variable. Costs would include, but are not limited to, construction of an earth-filled dam embankment and spillways, transmission pipelines, and pump stations, as well as roadway and utility relocations, environmental mitigation, permitting, administration and operations, and land acquisition of the reservoir location and any transmission easements. Several regional and state water planning efforts have estimated the cost of new reservoirs. To highlight the range of potential cost for developing a new water supply reservoir, summarized estimates developed in Georgia, Colorado, and Texas follow.

Georgia

A multi-region reservoir was identified as a possible water management strategy to help meet the future water demands of the Coastal Georgia, Savannah-Upper Ogeechee, and Upper Oconee water planning regions. Capital and programmatic costs were broadly identified to range from $0.01 million to $0.15 million per MGD of yield (CDM Smith 2017b).

Colorado

For a new reservoir, the Water Project Cost Estimating Tool (CDM Smith 2018) identifies a baseline cost of $30 million and goes up to $224 million (in 2022 dollars) for a reservoir with approximately 10,000 acre-feet of storage capacity (approximately 3.2 BG), with more storage requiring more development expense. This equates to approximately $70 per additional 1,000 gallons of raw water storage for a reservoir with a capacity of 10,000 acre-feet.

Texas

The Texas Water Development Board has developed Regional Water Plans along with a list of proposed projects throughout the state, including an estimated capital cost for each (TWDB 2020). This list includes 45 projects categorized solely as new major reservoirs, with capital costs ranging from $3.3 million to $4.5 billion, as reported in 2020. Table 6-17 summarizes a selection of new reservoir projects from Region C (Freese and Nichols, Inc. et al. 2020). Normalizing the capital cost to the raw water supply provided by each, the price per 1,000 gallons of raw water supplied is on the order of $1.50 to $3.00 during debt service and reduces to approximately $0.25 to $1.00 after debt service, in 2020 dollars.

Table 6-17. Select Texas Water Development Board, Region C Proposed New Major Reservoirs.

New Major Reservoir	Capital Costs (Millions)	Maximum Supply Available (Acre-Feet/Year)	$ / 1,000 gallons of raw water
Marvin Nichols Reservoir	$4,467	451,500	$2.67 during debt service $0.57 after debt service
Bois D'Arc Lake	$940	120,200	$1.49 during debt service $0.25 after debt service
Lake Ralph Hall	$469	39,220, plus 15,391 reuse supply	With Reuse: $1.40 during debt service $0.25 after debt service Without Reuse: $2.15 during debt service $0.38 after debt service
Tehuacana Reservoir	$325	25,400 (firm yield) 21,070 (safe yield)	$3.28 during debt service $0.96 after debt service
Lake Columbia	$322 (Dallas portion only)	85,507 total, with 56,000 allocated to Dallas	$1.77 during debt service $0.86 after debt service
George Parkhouse Lake (North)	$1,100	106,500	$2.67 during debt service $0.61 after debt service
George Parkhouse Lake (South)	$1,346	116,000	$2.85 during debt service $0.57 after debt service

6.2 Groundwater Management Strategies

In the Broad River basin, less than 1 percent of current demands are met by groundwater and these demands are not projected to significantly increase over the planning horizon (Pellett and More 2023). The Broad RBC, therefore, focused the evaluation and selection of water management strategies on surface water management strategies. The demand-side strategies described in the previous section for surface water withdrawers also apply to the basin's limited groundwater withdrawers.

Chapter 7
Water Management Strategy Recommendations

The Broad RBC recommends that the demand-side strategies and a subset of the supply-side strategies evaluated in Chapter 6 be included in the implementation plan. The recommended water management strategies are categorized as a portfolio of municipal conservation and efficiency practices; a portfolio of agricultural water efficiency practices; and recommended short-, mid-, and long-term supply-side strategies. The feasibility analysis in Chapter 6 illustrated the viability of each strategy. Although the assumed combined reduction in projected demands resulting from the portfolios of water efficiency and conservation strategies is uncertain and dependent on many factors, it is considered reasonable for the Broad River basin and was shown to be effective in increasing water supply availability. Similarly, although the additional water supply provided by the recommended supply-side strategies is uncertain and dependent on additional feasibility assessment and surface water availability under uncertain future hydrologic conditions, the assumptions of effectiveness described in Chapter 6 illustrate that these strategies can eliminate or reduce the risk of water shortages. Combined, the recommended demand-side and supply-side strategies presented in this chapter are projected to eliminate water supply shortages, increase supply availability, and help maintain flows that support instream needs in the Broad River basin. The recommended strategies are also expected to provide some protection against unknown future conditions such as altered hydrologic conditions or demand growth patterns that vary from projections.

The RBC water management strategy recommendations presented in this Chapter align with the RBC vision and goal statements for the basin. By assessing and recommending these specific strategies, the stakeholders comprising the RBC are recommending actions that achieve the RBC's vision statement to "***conserve and enhance the resilience of the Broad River Basin to provide water resources for quality of life, while accounting for the ecological integrity of our shared water resources.***" The development of a feasibility assessment and the evaluation of water management strategies using the SWAM model are in line with goal 1 of "***enhance[ing] the understanding of regional water issues and the need for support of policies and behaviors to protect resources through promotion and education,***" and goal 2 of "***us[ing] sound science and data-driven practice to support collaboration for all entities to effectively and efficiently manage the basin.***"

7.1 Selection, Prioritization, and Justification for each Recommended Water Management Strategy

Demand and supply-side strategies recommended by the Broad RBC to reduce or eliminate projected water shortages, enhance instream flows, and increase water supply availability are identified and discussed below.

Municipal Demand-side Strategies: The recommended municipal demand-side water management strategies are summarized in Table 7-1. The Broad RBC did not prioritize these strategies because of the significance of individual utility circumstances (e.g., current operations and programs, utility size, financial means) in determining which is the most desirable strategy to pursue. The strategies instead represent a "toolbox" of potential approaches to reduce water demands. Utility managers may find the descriptions and feasibility assessment presented in Chapter 6 helpful for determining which strategies to pursue.

Table 7-1. Municipal demand-side water management strategies.

Water Management Strategy	Prioritization
Public Education of Water Conservation	Toolbox of strategies. Priority varies by utility.
Conservation Pricing Structures	
Residential Water Audits	
Landscape Irrigation Program and Codes	
Water Efficiency Standards for New Construction	
Leak Detection and Water Loss Control Program	
Reclaimed Water Programs	
Car Wash Recycling Ordinances	
Time-of-Day Watering Limit	

The RBC identified several additional considerations related to the recommended municipal demand-side water management strategies:

- The RBC noted that while public education is a strategy on its own, it is also an important component of each municipal water management strategy. For the public to accept and support such strategies, they must understand the need and impact of implementation.
- The RBC noted that some strategies can be complimentary, such as implementation of conservation pricing structures with leak detection and water loss control programs to help water users identify opportunities to reduce water use and save money.
- The RBC also noted that some strategies may be cost-prohibitive to smaller utilities. Having a consortium of utilities to help with implementation may be beneficial. System-to-system communication is already happening in parts of the basin where water managers gather monthly to share best practices and lessons learned. This communal knowledge sharing could also be

beneficial to smaller utilities that do not have a dedicated conservation program with staff to assess the financial impacts of demand reduction and coordinate education and outreach programs.

- Establishing a fund supported by fees from new development could help shift the emphasis from system growth toward system maintenance. Effective system maintenance can reduce water loss and help offset increasing system-wide demands resulting from growth.
- For effective implementation of strategies, it may be necessary to engage city councils and local governments.
- Reclaimed water programs may be an option for industrial users in addition to municipal users.

Agricultural Demand-side Strategies: Agricultural water use accounts for less than 1 percent of current water use in the Broad River basin and is not projected to increase over the planning horizon. Although this use category is small, the RBC considered and has recommended several agricultural demand-side water management strategies. Many of these practices are likely already used in the basin. The recommended agricultural water management strategies are summarized in Table 7-2. The RBC chose not to prioritize strategies to recognize that the most appropriate strategy for a given agricultural operation will depend on the size of the operation, crops grown, current irrigation practices, and financial resources of the owner/farmer. The descriptions and feasibility assessment presented in Chapter 6 may be helpful to owners/farmers for determining which strategy to pursue.

Table 7-2. Agricultural water management strategy prioritization.

Water Management Strategy	Prioritization
Water Audits and Nozzle Retrofits	Toolbox of strategies. Priority varies by operation.
Irrigation Scheduling	
Soil Management	
Crop Variety, Crop Type, and Crop Conversion	
Irrigation Equipment Changes	

Supply-side Strategies: As water demands increase over the coming decades, the Broad RBC recommends that Greer, Spartanburg, SJWD, and Cherokee County BPW adjust reservoir operations to optimize their supplies. Chapter 6 illustrated how modifications to reservoir operations can successfully eliminate projected shortages in the 2070 High Demand scenario for all public suppliers, except Cherokee County BPW, with no appreciable associated cost.

The remaining, supply strategies focus on alleviating Cherokee County BPW's projected shortages. Based on the feasibility assessment and results of SWAM modeling presented in Chapter 6, the Broad RBC recommends that Cherokee County BPW continue to evaluate and pursue the following short-, mid-, and long-term strategies:

- *Short-term*:
  - The first strategy involves optimization of existing supplies. Through agreement with Northbrook Power Management who is the FERC licensee for the Gaston Shoals project, Cherokee County BPW is limited to an average annual withdrawal of 6 MGD from Gaston Shoals. By withdrawing larger quantities of water from Gaston Shoals during higher demand periods and less or no water from Gaston Shoals during lower demand periods,

while still maintaining an average annual withdrawal of 6 MGD from the reservoir, they can avoid or reduce potential short-term shortages. This was demonstrated through modeling described in Chapter 6.

- The second short-term strategy is to further evaluate, then design, permit, and install a new Broad River intake downstream of the confluence with Buffalo Creek and upstream of the Cherokee Falls Hydropower project limits. Chapter 6 illustrated the ability of this strategy to eliminate projected shortages in the 2070 High Demand Scenario, and demonstrated that it is a more cost-effective strategy, relative to other strategies noted below. Part of the additional evaluation would include determining the size of intake and pipeline needed to not be over-sized at implementation and not be under-sized for future demands.

- *Mid-term*:
    - Depending on the sizing of the new Broad River intake and its ability to meet demands into the future, Cherokee County BPW may (1) further explore raising the dam height of Lake Whelchel to increase storage capacity and (2) further evaluate the feasibility of converting a quarry to a water supply reservoir. Evaluation of an existing quarry requires detailed geotechnical evaluation, source water consideration and water quality evaluation, consideration of pumping and intake structures, permitting, environmental impacts, and other aspects.
    - Cherokee County BPW may also evaluate the benefit of establishing an interconnection to the Spartanburg water system. An interconnection may provide an additional source of water to Cherokee County BPW, depending on their need after implementation of short-term strategies and availability of excess water from Spartanburg at the time. SWAM modeling indicated that in the 2070 High Demand Scenario Spartanburg will need all its existing supplies to meet projected demands; however, earlier in the planning period, Spartanburg is expected to have sufficient excess supply to sell to Cherokee County BPW. An interconnection could also improve Cherokee County BPW's resilience and recovery from disruption, as they currently do not have any interconnections to other water systems.
- *Long-term:*
    - If demands continue to grow beyond current projections, or changes to hydrology reduce the effectiveness of the short- and mid-term strategies, it is recommended that Cherokee County BPW further explore the option of a new local or regional reservoir. This effort, which can easily take 10-plus years for development, would include siting of a reservoir, land acquisition, exploring partnerships, assessing construction and permitting feasibility, and determining the financial feasibility.

The implementation plan included in Chapter 10 outlines an adaptive management approach to further evaluate and implement these short-, mid- and long-term strategies, as the need arises.

7.2 Remaining Shortages

The results of the modeling and analysis summarized in Chapter 5 indicate that under current use patterns, there are no expected shortages based on historical hydrologic conditions. The risks and potential impacts of future water shortages are relatively low with some exceptions, including shortages for public water suppliers Greer, Cherokee County BPW, Spartanburg, and SJWD and small, infrequent shortages for three golf courses in the 2070 High Demand Scenario. Except for the golf courses, the recommended strategies presented in this chapter have been demonstrated as effective in eliminating these remaining shortages. Projected shortages for three of the four public water suppliers with shortages in the 2070 High Demand Scenario were eliminated by optimizing reservoir operations to preserve supply. With implementation of these operational adjustments, the only remaining projected shortages were for Cherokee County BPW. Their shortages in the High Demand Scenario are projected to start in 2025 and grow through 2070 with increasing demands. To extend the time before a new source of supply is needed, and to reduce these potential future shortages, it is recommended that Cherokee County BPW explore appropriate municipal demand-side management strategies from the recommended strategies toolbox. To fully eliminate these shortages, they will likely need to pursue the recommended short-, mid-, and long-term supply strategies.

The recommended demand side management strategies presented in this chapter will result in a general increase in water supply in the basin and higher instream flows. Implementation of these strategies also serves to protect against future climate conditions such as more frequent or severe droughts and water demands that exceed current projections.

7.3 Remaining Issues Regarding Designated Reaches of Interest or Groundwater Areas of Concern

The evaluation presented in Chapter 6 allowed for the Broad RBC to identify any Reaches of Interest or Groundwater Areas of Concern. Reaches of Interest are defined in the Framework as "specific stream reaches that may have no identified Surface Water Shortage but experience undesired impacts, environmental or otherwise, determined from current or future water-demand scenarios or proposed water management strategies" (SCDNR 2019). The Broad RBC did not identify any Reaches of Interest.

A Groundwater Area of Concern is defined in the Framework as "an area in the Coastal Plain, designated by a River Basin Council, where groundwater withdrawals from a specified aquifer are causing or are expected to cause unacceptable impacts to the resource or to the public health and well-being" (SCDNR 2019). The Coastal Plain only intersects the Broad River basin at its extreme southern end. The Broad RBC did not identify any Groundwater Areas of Concern.

Chapter 8
Drought Response

8.1 Existing Drought Management Plans and Drought Management Advisory Groups

8.1.1 Statewide Drought Response

The South Carolina Drought Response Act of 2000 (Code of Laws of South Carolina, 1976, Section 49-23-10, et seq., as amended) was enacted to provide the state with a mechanism to respond to drought conditions (SCDNR 2009). The Act stated that SCDNR will formulate, coordinate, and execute a statewide drought mitigation plan. The Act also created the South Carolina Drought Response Committee (DRC) to be the major drought decision-making entity in the state. The DRC is a statewide committee, chaired and supported by SCDNR's State Climatology Office (SCO) with representatives from local interests.

To help prevent overly broad response to drought, the Act assigned SCDNR the responsibility of developing smaller DMAs within the state. SCDNR split the state into four DMAs that generally follow the boundaries of the four major river basins but are delineated along geopolitical county boundaries rather than basin boundaries. The Broad River basin is entirely within the Central DMA as shown in Figure 8-1. The Governor appoints members from various sectors to represent each DMA within the DRC. The organizational relationship of the DRC, DMAs, SCDNR, and SCO are shown in Figure 8-2.

In accordance with the Drought Response Act, SCDNR developed the South Carolina Drought Response Plan, which is included as Appendix 10 of the South Carolina Emergency Operations Plan. South Carolina has four drought alert phases: incipient, moderate, severe, and extreme. SCDNR and the DRC monitor a variety of drought indicators to determine when drought phases are beginning or ending. Examples of drought indicators include streamflows, groundwater levels, the Palmer

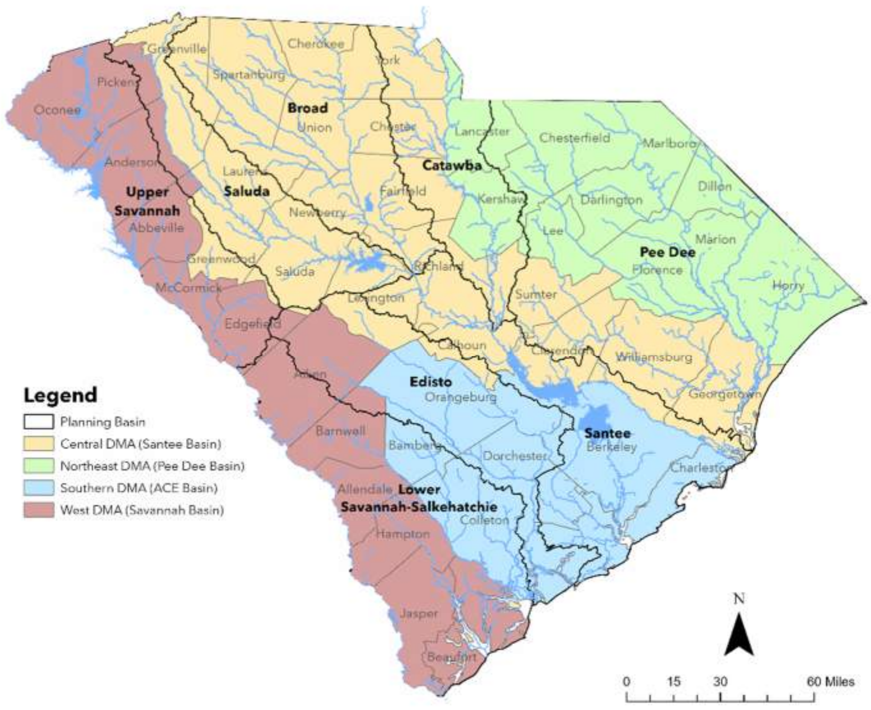

Figure 8-1. The four Drought Management Areas.

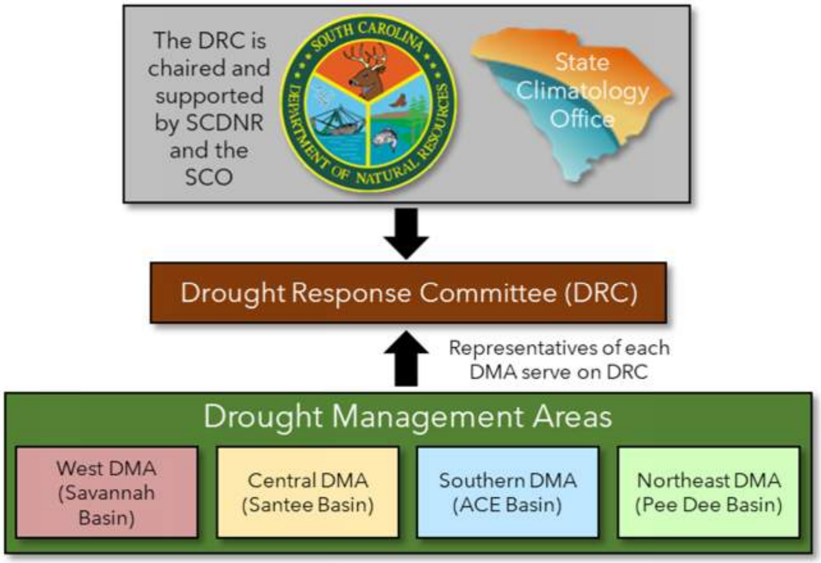

Figure 8-2. Drought Act organizational chart.

Drought Severity Index, the Crop Moisture Index, the Standardized Precipitation Index, and the United States Drought Monitor. The South Carolina Drought Regulations establish thresholds for these drought indicators corresponding to the four drought alert phases. Declaration of a drought alert phase is typically not made based only on one indicator, rather a convergence-of-evidence approach is used. The need for the declaration of a drought alert phase is also informed by additional information including water supply and demand, rainfall records, agricultural and forestry conditions, and climatological data.

Based on their assessment of drought conditions, SCDNR and the DRC coordinate the appropriate response with the affected DMAs or counties. Local drought response is discussed in more detail in the following section. Under Section 49-23-80 of the Drought Response Act, if SCDNR and the DRC determine that drought has reached a level of severity such that the safety and health of citizens are threatened, the DRC shall report such conditions to the Governor. The Governor is then authorized to declare a drought emergency and may require curtailment of water withdrawals.

8.1.2 Local Drought Response

At a local level, Section 49-23-90 of the Drought Response Act states that municipalities, counties, public services districts, and commissions of public works shall develop and implement drought response plans or ordinances. These local plans must be consistent with the State Drought Response Plan. SCDNR developed a sample drought management plan and response ordinance for local governments and water systems to use as templates. In a drought management plan, each phase of drought has a set of responses that are put in motion to reduce demand, bolster supply, or both. The drought plans and ordinances include system-specific drought indicators, trigger levels, and responses. Responses include a variety of actions that would be taken to reduce water demand at the levels indicated in Table 8-1. When drought conditions have reached a level of severity beyond the scope of the DRC and local communities, the State Drought Response Plan, Emergency Management Division, and State Emergency Response Team are activated.

The drought management plans and response ordinances prepared by public water suppliers located in the Broad River basin or who draw water from the basin largely follow the templates prepared by SCDNR. The plans on file for the public water systems in the Broad River basin are listed in Table 8-2. Many of the plans were submitted to SCDNR in 2003, shortly after the Drought Response Act went into effect. As such, they may contain information that is outdated. The Act did not explicitly require drought plans to be updated at a specific interval; however, SCDNR is actively encouraging public water suppliers to update their plans.

Table 8-1. Demand reduction goals of drought response plans in South Carolina.

Drought Phase	Response
Incipient	None specified
Moderate	Seek voluntary reductions with the goal of: ▪ 20% reduction in residential use ▪ 15% reduction in other uses ▪ 15% overall reduction
Severe	Mandatory restrictions for nonessential use and voluntary reductions of all use with the goal of: ▪ 25% reduction in residential use ▪ 20% reduction in other uses ▪ 20% overall reduction
Extreme	Mandatory restrictions of water use for all purposes with the goal of: ▪ 30% reduction in residential use ▪ 25% reduction in other uses ▪ 25% overall reduction

Table 8-2. Drought Management Plans and Response Ordinances for water suppliers withdrawing water from the Broad River basin.

Water Supplier	Year	Water Source	Drought Indicator/Trigger Types[1]	Alternative Water Supply Agreements
Blue Ridge Rural Water Company (BRRWC)	2003	**Purchase** – Greer Commission of Public Works (CPW) water system (surface water from Robinson and Cunningham Lakes) and Greenville water system (surface water from Table Rock and Poinsett Reservoir)	- As declared by either supplier of BRRWC - Storage falls below an average of 30%, 50%, or 80% of capacity for 5 consecutive days - Average daily use greater than 3 MGD for 5, 10, or 20 consecutive days	A 3-inch interconnection between the Startex-Jackson-Wellford-Duncan (SJWD) water system is an alternate source to supply the northwest section of the BRRWC system. A 10-inch interconnection with the City of Landrum could, with a negotiation of an agreement, supply the north end of the BRRWC system with water.
City of Clinton	2003	**Surface Water** – Enoree River and Duncan Creek	- Reservoir is 3/4, 1/2, or 1/4 full - Storage falls below 75%, 50%, or 25% of capacity - Streamflow less than 70, 50, or 20 cubic feet per second	None.
City of Columbia	2003	**Surface Water** – Broad River Canal, Lake Murray	- Average daily use greater than 85 MGD for 7-10 consecutive days, 90 MGD for 7 consecutive days, or 95 MGD for 2-3 consecutive days	None.
Gaffney Board of Public Works (BPW)	2003	**Surface Water** – Unspecified	- Water level in Lake Whelchel is at elevation 668, 666, or 664 feet - Palmer Index reaches the -1.5 to -2.99 range and moderate drought conditions have been declared, -3.0 to -3.99 range and severe drought conditions have been declared, or below -4.0 and extreme drought conditions have been declared for Cherokee County by the State DRC	Cherokee County is in the process of pursuing an alternate water supply for the Town of Blacksburg (a wholesale customer of the Gaffney BPW) through an abandoned rock quarry, reducing the demand placed on the Gaffney BPW.

Table 8-2. Drought Management Plans and Response Ordinances for water suppliers withdrawing water from the Broad River basin (Continued).

Water Supplier	Year	Water Source	Drought Indicator/Trigger Types[1]	Alternative Water Supply Agreements
Grassy Pond Water Company	2008	**Groundwater Purchase** – Broad River Water Authority (BRWA) (Rutherford County, NC), Gaffney BPW (Cherokee County, SC)	- Moderate, severe, or extreme drought phase has been declared by Gaffney BPW or BRWA - Moderate, severe, or extreme drought conditions have been declared by the DRC	Agreements with BRWA, Gaffney BPW, and the Daniel Morgan Water Company.
Greer CPW[2]	2008	**Surface Water** – Lake Robinson, Lake Cunningham	- System effective capacity is 95%, 90%, 80%, or 70% - System effective storage is 4,484 MG, 4,248 MG, 3,776 MG, or 3,304 MG - Approximate water elevation at Lake Robinson is 888.0 feet, 887.0 feet, 885.5 feet, or 883.5 feet - Approximate distance below Lake Robinson Spillway is 1 foot, 2 feet, 3.5 feet, or 5.5 feet	Can interconnect to provide water to the SJWD Water District in emergency situations.
ICWD	2023	**Purchase** – Broad River Water Authority (BRWA in North Carolina) and Spartanburg Water System	- Reduction in Broad River flow at the BRWA raw water intake to 65, 32, or 24 MGD for a period of 7 consecutive days - Moderate, severe, or extreme drought conditions declared by the DRC for Spartanburg County - Declaration of severe or extreme drought conditions by ICWD	ICWD currently has agreements to purchase water from BRWA and Spartanburg Water System and is in the process of developing its own intake on the North Pacolet River and a water treatment plant. ICWD will be pursuing agreements to strengthen conservation measures by its largest water users.
Jenkinsville Water Company	2003	**Groundwater Purchase** – Connection with Mid-County Water Company to purchase wholesale water produced by Winnsboro's surface water treatment plant	- Storage falls below 25%, 50%, or 75% of capacity and is unable to recover - Daily use greater than 0.2 MGD for 5, 7, or 14 consecutive days - Pumping levels in wells deepen by 25%, 50%, or 75% normal pumping levels - Notification that the system's wholesale supplier is requesting conservation measures be implemented	Agreement with Mid-County Water Company to purchase wholesale water as needed (currently limited to 50,000 gallons per day but in the process of being allowed to purchase its entire supply)
Mid-County Water Company II	2003	**Groundwater Purchase** – Winnsboro (master meter connections)	- District #1 (rural, north of Winnsboro): Well daily operating time increases by 10%, 20%, or 30% from normal - District #2 (rural, south of Winnsboro): Master meters reflect 10%, 20%, or 30% increase from normal	Mid-County/ Winnsboro/Jenkinsville contracts encourage timely repair of leaks, daily monitoring of usage, etc.

Table 8-2. Drought Management Plans and Response Ordinances for water suppliers withdrawing water from the Broad River basin (Continued).

Water Supplier	Year	Water Source	Drought Indicator/Trigger Types[1]	Alternative Water Supply Agreements

Spartanburg Water System[3]	2008	**Surface Water** – Lake Bowen, Municipal Reservoir #1, and Lake Blalock	- Water shortage that could (in Spartanburg Water System's opinion) threaten the health/safety of their customers
			- Total usable raw water storage availability for production of drinking water from Lake Bowen, Lake Blalock, and Municipal Reservoir #1 drops below 175, 150, 120, or 90 days
			- Combined stream flow entering the storage reservoir system from the North and South Pacolet Rivers drops below 60, 40, 30, or 25 cfs
			- Daily water demand exceeds 75% or 51 MGD, 80% or 55 MGD, 90% or 62 MGD, or 95% or 65 MGD of the system's reliable capacity
			- The DRC recommends implementation or the Governor mandates implementation of the phase
			- The following apply only to severe, extreme drought phase stage 1, and extreme drought phase stage 2:
			  - Failure to meet the goal of 15% water use reduction as required by the moderate drought phase (voluntary) water restrictions, 20% water use reduction as required by the severe drought phase (mandatory) water restrictions, or 25% water use reduction as required by the extreme drought phase (mandatory) stage 1 water restrictions
			  - Reservoir levels or system demands create undue water quality issues
				Currently discussing the possibility of regionalized water storage reservoirs and shared/interconnecting distribution systems with neighboring counties; some wholesale water districts have interconnections with Greenville Water System and Greer CPW, which could help offset their drought-related shortages

SJWD Water District[4]	2008	**Surface Water** – Lake Lyman, Lake Cooley, North Tyger Reservoir	- Usable volume in Lake Lyman less than or equal to 95% of normal water surface elevation (842.3 feet MSL), 85% of normal water surface elevation (841.1 feet MSL), 75% of normal water surface elevation (839.8 feet MSL), 65% of normal water surface elevation (838.4 feet MSL), or 50% of normal water surface elevation (836.2 feet MSL)	Owns Lake Apalache, Berry's Pond, and Berry's Mill Pond for future water supply needs. Can receive up to 1 MGD from Greer CPW and up to 6 MGD of water from the Spartanburg Water System
City of Union	2012	**Surface Water** – Broad River	- Broad River streamflow less than 200 cubic feet per second, 125 cubic feet per second, or 75 cubic feet per second	None, but negotiating with the Town of Jonesville and Spartanburg Water District to provide emergency alternate water supply
Town of Whitmire	2003	**Surface Water** – Enoree River, Duncan Creek	- Storage falls below 75%, 50%, or 25% capacity	None
Town of Winnsboro	2003	**Surface Water** – Mill Creek Reservoir, Sand Creek	- Reservoir is 80%, 65%, or 50% full Storage falls below 25%, 35%, or 45% of capacity - Streamflow in Mill Creek is less than 2.8 cubic feet per second, 1.7 cubic feet per second, or 1.0 cubic feet per second	Alternative water sources include the old town reservoir, Sand Creek pumping station, and Rion Quarry #1 and #2

Table 8-2. Drought Management Plans and Response Ordinances for water suppliers withdrawing water from the Broad River basin (Continued).

Water Supplier	Year	DMA	Water Source	Drought Indicator/Trigger Types[1]	Alternative Water Supply Agreements
Woodruff-Roebuck Water District	2003	Central	**Purchase** – Spartanburg Water System	- Drought indicator/trigger types are the same as for Spartanburg Water System	Emergency connection with SJWD for 1 MGD, in the process of working on plans for water supply for the next 30–50 years, and present plans call for obtaining its own water source and treatment plant
City of York	NA	Central	**Purchase** – City of Rock Hill	- A current DMP is not on file with the SCO but it is assumed that since the City of York purchases water from Rock Hill, the drought indicator/trigger types are the same as for Rock Hill. As part of the Catawba-Wateree Water Management Group, Rock Hill follows the Low Inflow Protocol (LIP) established for the Catawba-Wateree Project. A variety of triggers specific to the Catawba River basin are detailed in the LIP.	None

[1] When three trigger points are listed, those reflect trigger points for the moderate, severe, and extreme drought phases, respectively. When four trigger points are listed, those reflect trigger points for the moderate; severe; extreme drought phase stage 1; and extreme drought phase stage 2, respectively.

[2] Greer CPW includes drought triggers and responses for the incipient drought alert phase as well as moderate, severe, and extreme drought alert phases. The triggers are listed in the tables in this order.

[3] Spartanburg Water System includes four drought phases of moderate, severe, extreme drought stage 1, and extreme drought stage 2. The triggers are listed in the table in this order.

[4] SJWD Water District includes drought triggers and responses for the incipient drought alert phase as well as moderate, severe phase I, severe phase II, and extreme drought alert phases. The triggers are listed in the tables in this order.

8.2 RBC Drought Response

8.2.1 Roles and Responsibilities

Under the Planning Framework, the RBC will support drought response, collect drought information, and coordinate drought response activities. With support of SCDNR, the RBC will:

- Collect and evaluate local hydrologic information for drought assessment
- Provide local drought information and recommendations to the DRC regarding drought declarations
- Communicate drought conditions and declarations to the rest of the RBC, stakeholders, and the public
- Advocate for a coordinated, basinwide response by entities with drought management responsibilities (e.g., water utilities, reservoir operators, large water users)
- Coordinate with other drought management groups in the basin as needed

8.2.2 Communication Plan

The Broad RBC will communicate drought conditions and responses within the basin through the RBC's elected Chair (or Vice Chair, if the need arises). If any part of the basin is in a declared drought as determined by the DRC, the RBC Chair will solicit input from RBC members and other water managers and users regarding drought conditions and responses in their respective locations or interests. The Chair is then responsible for communicating updates on drought conditions and responses within the basin to the Central DMA representatives on the DRC or the SCO. The DRC has existing mechanisms to communicate and coordinate drought response with stakeholders and the public. Under Section 49-23-70 of the Drought Response Act, SCDNR is responsible for disseminating public information concerning all aspects of the drought.

Further communication channels may exist if a member of the Broad RBC also serves on the DRC as a Central DMA representative. This member may work with the RBC Chair (or Vice Chair) to directly communicate between the Broad RBC and the DRC. At the time of this Plan's development, the RBC Chair, Ken Tuck from Spartanburg Water System, serves as a Central DMA representative on the DRC.

8.2.3 Recommendations

Through consideration and discussion, the Broad RBC developed the following five recommendations related to drought planning and response. The steps to implement these recommendations are detailed in the 5-year and long-range implementation plans in Chapter 10.

1. The RBC recommends that water utilities review and update their drought management plan and response ordinance every 5 years or more frequently if conditions change. Once updated, the plans should be submitted to the SCO for review. Changing conditions that could merit an update might include:

- Change in the source(s) of water
- Significant increase in water demand (such as the addition of a new, large wholesale customer)
- Significant change in the proportion of water used by one sector compared to another (e.g., residential versus commercial use)
- Addition (or loss) of another user relying on the same source of water
- New water supply agreement with a neighboring utility

2. The RBC recommends that water utilities, when updating their drought management plan and response ordinance, look for opportunities to develop response actions that are consistent with those of neighboring utilities. While triggers are likely to be unique to each water utility based on their source(s) of water, coordination of response actions identified in their ordinance, to the extent practical, supports consistent messaging through the basin, and helps avoid confusion between customers. Many water utilities in the Broad River basin already meet monthly to discuss and coordinate on various water issues. This standing meeting offers the opportunity to discuss drought response actions, and improve the consistency of those actions, where feasible.

3. The RBC recommends that water utilities coordinate, to the extent practical, their drought response messaging. Drought messaging refers to both the content and the method or mechanism to deliver the message. During droughts in the early and late 2000s, many water utilities in the Broad River basin collaborated on outreach mechanisms. Billboards and other methods were used to encourage conservation and reduce water demand regardless of the water service area. Since that time, more targeted means to reach water customers have emerged including emails, text messages, automated phone calls, and social media. While the RBC recommends that coordinated messaging continue, the need to coordinate how the message is delivered has largely been eliminated because of the more effective outreach mechanisms. Coordination on the content of the messaging should continue through the standing, monthly meetings, and other means as appropriate.

4. The RBC encourages water utilities in the basin to consider drought surcharges on water use during severe and/or extreme drought phases. Drought surcharges, when used, are typically only implemented if voluntary reductions are not successful in achieving the desired reduction in water use. In the Broad River basin, several water utilities have already built into their response ordinance the ability to implement drought surcharges during the severe and/or extreme drought phases. Two examples are detailed below:

Example 1: The ICWD may, at its option, implement the following excessive use rate schedule for water for its residential customers during severe and extreme drought phases:

Tier	Water Usage (gallons per month)	Rate
I	0–5,000	Regular water rate
II	5,000–12,000	Two times the regular water rate
III	Over 12,001	Three times the regular water rate

Example 2: In the event of an extreme drought, Greer CPW limits domestic water use to 55 gallons per household member per day and may include a surcharge of $0.02 per gallon for use above that limit. Institutional, commercial, industrial, and recreational water users are subject to water use surcharges of $20 per 1,000 gallons of water used if it is deemed that adequate conservation measures were not implemented.

5. When droughts occur, the RBC encourages water users and those with water interests to submit their drought impact observations through the Condition Monitoring Observer Reports (CMOR). The CMOR system, maintained by the National Drought Mitigation Center (NDMC), provides supporting evidence in the form of on-the-ground information to help the authors of the U.S. Drought Monitor better understand local conditions. The U.S. Department of Agriculture (USDA) uses the Drought Monitor to trigger disaster declarations and determine eligibility for low-interest loans and some assistance programs. The SCO also reviews and uses the CMOR system in a variety of ways. CMORs can be submitted by clicking the “Submit a Report” button at the NDMC’s Drought Impacts Toolkit website.

Chapter 9
Policy, Legislative, Regulatory, Technical, and Planning Process Recommendations

During the fourth and final phase of the planning process, the Broad RBC identified and discussed recommendations related to the river basin planning process; technical and program considerations; and policy, legislative, or regulatory considerations. Various recommendations were proposed by RBC members and discussed over the span of several meetings. Although no formal vote was conducted on the recommendations, they received broad RBC support and are to be taken as having consensus as defined by the River Basin Council Bylaws (SCDNR 2019). Under these bylaws, consensus is achieved when all members can "live with" a decision, although some members may strongly endorse a solution while others may only accept it as a workable agreement.

The planning process recommendations are summarized in Chapter 9.1; the technical and program recommendations are summarized in Chapter 9.2; and the policy, legislative, and regulatory recommendations are summarized in Chapter 9.3.

The Broad RBC understands that as of July 1, 2024, the newly formed South Carolina Department of Environmental Services (SCDES) will be the regulatory agency that is primarily responsible for State Water Planning activities and will play a major role in supporting the RBCs with implementation of their river basin plans. Throughout chapters 9 and 10, SCDNR and SCDHEC are identified as responsible or supporting parties, but it is understood that SCDES will likely replace them in that role come July 1, 2024.

9.1 River Basin Planning Process Recommendations

The following planning process recommendations should be taken as considerations for future phases of the river basin planning process. To implement these recommendations, the Broad RBC will need support from SCDNR, SCDHEC, technical experts, and the South Carolina Legislature.

- **RBCs and their Planning Teams should consider regularly polling the RBC members to identify if adjustments to meeting times, locations, and dates would allow for easier and/or more member attendance and/or increased in-person attendance.** As RBC members hail from different parts of the basin and have various conflicting time commitments, adjusting the timing and location of meetings could ease the burden on various members.

- **SCDNR, the RBC Planning Teams, and the RBCs should conduct regular (e.g., annual) reviews of the RBC membership to make sure all interest categories are adequately represented**. The Broad RBC discussed that adequate representation of all water use groups may require intentional, targeted outreach to encourage potential members to apply to the RBC. Membership should also be reviewed when any member resigns from the council to ensure there is still sufficient representation of that member's water interest category. Recognizing that RBC members invest significant time over the planning process in understanding basin background and issues, any appointments of RBC members after the river basin planning process is underway would need to be considered on a case-by-case basis. Appointments would be at the discretion of SCDNR and would consider feedback from the RBC. In such instances, orientation would be necessary to bring new members up to speed.

- **Where appropriate and allowed, experts who present technical information to the RBCs should offer proposed recommendations for RBC consideration.** The Broad RBC noted that it may be challenging to offer recommendations related to more advanced technical topics and a recommendation from a technical expert could be a helpful starting point for RBC discussion and ultimately for developing a recommendation.

Members of the Broad RBC proposed the following recommendations to improve communication among RBCs and other groups:

- **RBCs should consider developing and executing a communication plan early in the initial 2-year planning process, and conducting education and outreach prior to completion of the River Basin Plan.** The Broad RBC plans to conduct outreach to both the public and legislative delegations to inform them of the planning process and progress. The RBC may choose to develop a fact sheet to provide to boards or councils or a list of talking points to assist RBC members in personal outreach. Such fact sheets or talking points may vary depending on if the communication is intended for the public or legislators. The RBC noted that conversations to support continued funding of the water planning process may be best targeted for one-on-one conversations. The Broad RBC recommends that other river basins develop a communication plan at the beginning of the planning process.

- **SCDNR should take lead in organizing an annual state-wide meeting of the RBCs with the Agriculture and Natural Resources Committee of the State Senate and the Agriculture, Natural Resources and Environmental Affairs Committee of the State House to communicate the value of water planning, highlight progress and recommendations, and share ideas among RBCs**.

Members of the Broad RBC proposed the following recommendations for funding needs and sources of funding:

- **The South Carolina Legislature should continue to fund state water planning activities, including river basin planning.** Currently, nearly all the funding for the river basin planning process has come from the legislature.

9.2 Technical and Program Recommendations

The RBC may make technical and program recommendations to address any data gaps or information needs identified during the river basin planning process. The following recommendations should be taken as considerations for future phases of the river basin planning process. To implement these recommendations, the Broad RBC will need support from SCDNR, SCDHEC, and other technical experts.

Members of the Broad RBC developed the following recommendations for model improvement:

- **Consider incorporating future climate projections into modeling analyses (e.g., projected temperature, evapotranspiration, and precipitation trends) to better address potential supply-side changes in hydrology. Consider incorporating historical climate information such as dendroclimatology (tree ring data) to inform drought risk and or drought scenarios.** This iteration of the river basin plan relied upon historical hydrologic data.

Members of the Broad RBC identified the following needs for more data:

- **Recognizing that comprehensive, reliable, and long-term hydrologic data is critical to water planning, funding mechanisms to support continued USGS efforts to maintain and expand streamflow gages should be identified.**

- **The Broad RBC recommends the funding and establishment of a mesoscale network of weather and climate monitoring stations in South Carolina.** Establishing a mesoscale network of weather and climate monitoring stations, known as a Mesonet, provides near real-time data at the local level to improve situational awareness and preparedness and support decision-makers and stakeholders, such as emergency management agencies, water resources managers, agricultural interests, transportation officials, and energy providers. Currently, South Carolina is only one of 12 states in the United States without a Mesonet. A network of 46 weather stations (one per county) will provide an essential public service to the citizens of South Carolina.

Members of the Broad RBC developed the following recommendations for technical studies to improve knowledge of specific issues:

- **The Broad RBC should identify the financial impacts of increased sedimentation on reservoirs and water resources and communicate the results to local governments to demonstrate the value of riparian buffers, sedimentation and erosion control measures, and other policies and controls that reduce sediment generation and transport.** The RBC noted that proper protection of riparian buffers to minimize sedimentation requires both cooperation between jurisdictional governments and enforcement of existing policies.

- **The Broad RBC, with support from technical experts, should evaluate the impact of future land use changes on water resources quantity and quality.**

- **The Broad RBC should continue to consider ecological flow standards, including new and/or improved data, as it becomes available.** Application of ecological flow standards is a relatively new process in South Carolina which will continue to be modified and improved throughout the water planning process.

- **The Broad RBC should identify potential pinch points where current and projected low flows may lower the assimilative capacity of the streams. Strategies may need to be identified to mitigate low flows at these potential pinch points.** Pinch points may occur, for example, where a wastewater treatment plant discharges treated wastewater to a stream. If the stream is experiencing low flow conditions, the discharge will make up a greater percentage of total flow in the stream and it will have greater bearing on the water quality of the stream.

- **While the RBC should maintain its focus on the assessment of water quantity, future planning efforts in the Broad River basin should include evaluation of surface water quality, including nutrient loading and sedimentation, which is important to maintaining affordable public water supplies and the ecological health of the streams, rivers, and lakes.** The RBC could make recommendations to other planning bodies or departments of water quality parameters or stream segments requiring further study and impairment mitigation. Similarly, the RBC should be educated on other on-going water quality efforts such as 303d listing, watershed planning programs, and TMDL development.

- **The RBC supports further investigation and potential piloting of low-tech, process-based approaches to stream restoration.** According to Wheaton et al (2019) healthy streams moderate extreme flows and can reduce sediment transport. In parts of the U.S., low-cost techniques have been shown to address stream degradation at scale. Beaver dams, large woody debris, and other low-tech structural elements create flow pattern changes that produce physically diverse habitats. Large numbers of small, structural elements working in concert can achieve more than a few isolated, large structures that likely come with significant expense. This low-cost, low-tech approach merits further investigation and consideration in South Carolina.

Members of the Broad RBC identified the following needs for technical training for the RBC members:

- **The Facilitator should create an online library of, or a catalog of links to, technical information that will enhance the RBC's technical understanding of water resources concepts and issues.** RBC members noted that having an external resource available could help individual members develop their understanding of technical subjects outside of RBC meetings to prevent the meeting process from being slowed down.

Members of the Broad RBC identified the following opportunity to align the Broad River Basin Plan with other water-related planning efforts in the basin:

- **For river basins with state or federal specially designated streams (e.g., National Wild and Scenic Rivers or State Scenic Rivers), the RBCs should assess alignment between the River Basin Plan and the management plan associated with the special designation.**

9.3 Policy, Legislative, or Regulatory Recommendations

The Broad RBC engaged in discussion about issues and concerns with the existing policies, laws, and regulations governing water withdrawals and water use. Current (as of June 2023) regulations regarding surface water and groundwater withdrawals are summarized in Table 9-1 located at the end of this chapter. The Broad RBC developed the following recommendations for modifications to existing state or local laws, regulations, or ordinances:

- **The South Carolina Surface Water Withdrawal, Permitting, Use, and Reporting Act should allow for reasonable use criteria to be applied to all surface water withdrawals, like those that currently exist for groundwater withdrawals.** For surface water withdrawals, reasonable use criteria varies depending on the water use category and the time of permit application (pre- or post-2011, when SCDHEC's regulation, 61-119 Surface Water Withdrawal, Permitting, Use and Reporting, came into effect).

- Existing (pre-2011) non-agricultural surface water withdrawers do not need to meet reasonable use criteria. The permitted withdrawal is based on the largest volume as determined by previously documented use, current treatment capacity, or designed capacity of the intake structure.
- New (post-2011) or expanding non-agricultural surface water withdrawers must demonstrate that the requested water withdraw amount meets the criteria for reasonable use.
- Agricultural surface water withdrawals, all of which do not require a permit where there is remaining safe yield in a basin, do not need to satisfy reasonableness criteria for the requested withdrawal amount.

Comparatively, under SCDHEC's regulation 61-113 Groundwater Use and Reporting, permittees of any use category seeking to withdraw greater than 3 million gallons in any month from groundwater must demonstrate to SCDHEC's satisfaction that groundwater withdrawal is reasonable and necessary and there are no unreasonable adverse effects on other water users.

- **Laws that allow for regulation of water use need to be enforceable to be effective. The current water law, which grandfathers most water users, can be improved to support effective management of the state's water resources.**

- **Water law and implementing regulations should not distinguish between registrations and permits. All water users that withdraw above the identified threshold should be required to apply for a water withdrawal permit**. Current law allows for agricultural surface water users and all groundwater users withdrawing water outside of CUAs to register their water use rather than apply for permits.

- **The Broad RBC or the PPAC should develop a model riparian buffer ordinance for local jurisdictions to consider.** Such an ordinance would need to consider what size streams the ordinance applies to and how that is determined. A model ordinance is expected to be part of the Catawba-Wateree Integrated Water Resources Plan (IWRP), an update to the 2014 Water Supply Master Plan.

- **The water withdrawal permitting process should specifically assess the permit application's alignment with the current River Basin Plan, particularly regarding proposed withdrawals, returns, resource conservation, and drought response.**

Table 9-1. Summary of regulations related to surface water and groundwater withdrawal.

Water Source	Use Type	User Type	Process	Applicability	Withdrawal Volume	Use Criteria	Low Flow Period Requirements	Review Period	Reporting
Surface Water	Agricultural	Existing (pre Jan 1, 2011)	Registration	Users withdrawing more than 3 MG in a month	Highest previous water usage	No criteria	No MIF obligations	No review, in perpetuity	Annual
		New (post Jan 1, 2011) or Expanding	Registration	Users withdrawing more than 3 MG in a month	Amount of water requested by the proposed withdrawer and availability of water at the point of withdrawal based on Safe Yield calculations.	Subject to safe yield assessment	No MIF obligations	No review, in perpetuity	Annual
	Hydropower	All	Exempt (non-consumptive use)						Annual
	All Other Use Types	Existing (pre Jan 1, 2011)	Permit	Users withdrawing more than 3 MG in a month	Largest volume as determined by previously documented use, current treatment capacity, or designed capacity of the intake structure	No criteria	Must address "appropriate industry standards for water conservation." Not subject to enforcement for MIF.	30 to 50 years[1]	Annual
		New (post Jan 1, 2011) or Expanding	Permit	Users withdrawing more than 3 MG in a month	Based on reasonableness, availability of water at point of withdrawal based on Safe Yield calculations.	Reasonable use criteria	Development of Contingency Plan for low flow periods, enforceable. Public water suppliers not subject to MIF[2]	20 to 50 years[1]	Annual

Table 9-1. Summary of regulations related to surface water and groundwater withdrawal. (Continued)

Water Source	Use Type	User Type	Process	Applicability	Withdrawal Volume	Use Criteria	Low Flow Period Requirements	Review Period	Reporting
Ground water	All Use Types	Withdrawals in Capacity Use Areas	Permit	Users withdrawing more than 3 MG in a month	Permit withdrawals based on reasonable use guidelines, which vary by water use sector.	Reasonable use criteria	Requires development of Best Management Plan that identifies water conservation measures, alternate sources of water, justification of water use, and description of beneficial use	Every 5 years	Annual
	All Use Types	Withdrawals Outside of Capacity Use Areas	Registration	Users withdrawing more than 3 MG in a month	Registrations do not have limits but require reporting.	No criteria	No MIF obligations	No review, in perpetuity	Annual

[1] New surface water permitees may receive permits of 20 years or up to 40 years as determined by department review
Existing surface water permittees may receive permits of 30 years or up to 40 years as determined by department review
Municipal or governmental bodies may receive permits of up to 50 years to retire a bond it issues to finance the construction of waterworks (SECTION 49-4-100)

[2] Public water suppliers not subject to MIF but are required to implement their contingency plan in accordance with drought declarations 49-4-150 6

Chapter 10
River Basin Plan Implementation

10.1 Recommended Five-Year Implementation Plan

10.1.1 Implementation Objectives

The Broad RBC identified five implementation objectives for the Broad River Basin Plan. The objectives are listed in Table 10-1. These five objectives were developed based on themes that emerged from the recommendations made in previous chapters. Objective 1, improve water use efficiency to conserve water resources, corresponds to the demand side management strategies presented in Chapters 6.1.1 and 6.1.2 and recommended in Chapter 7.1. Objective 2, optimize and augment sources of supply, corresponds to the supply strategies presented in Chapter 6.1.3 and recommended in Chapter 7. Objective 3, improve drought management, corresponds to the drought management recommendations made in Chapter 8.2.3. Objectives 4 and 5, regarding RBC communication and technical recommendations, respectively, were developed based on the RBC recommendations presented in Chapter 9. The Planning Framework states that the RBC should prioritize the objectives. The Broad RBC ranked three objectives as high priority and two objectives as medium priority. The justifications for each priority ranking are summarized in Table 10-1.

Table 10-1. Implementation objectives and prioritization.

Objective	Prioritization	Prioritization Justification
Objective 1. Improve water use efficiency to conserve water resources	High	Water conservation is a good practice to implement even if water shortages are not an immediate concern.
Objective 2. Optimize and augment sources of supply	Medium	Surface water modeling indicated most suppliers will not need to adjust their water supplies within the next 5 years.[1]
Objective 3. Improve drought management	High	Maintaining up-to-date drought plans is critical for public water supplier response and to coordinate actions at a basin- and state-level.
Objective 4. Effectively communicate RBC findings and recommendations	High	Communication is essential to ensuring all objectives are pursued by stakeholders. Communication should be on-going.
Objective 5. Improve technical understanding of water resource management issues	Medium	Additional technical information is necessary to inform and continually update the RBC's understanding of basin issues and best practices to manage concerns. However, other high priority actions can be taken based on current understanding.

[1] Modeling indicated that Cherokee County BPW could experience shortages based on 2025 projected water demands under certain drought conditions. Although Objective 2 is medium priority for the Broad RBC, Cherokee County BPW may take actions related to this objective within the five years following publication of this River Basin Plan.

The strategies and corresponding actions to achieve each objective are presented in Table 10-2. Where applicable, each strategy under an objective was listed by its priority for implementation. Table 10-2 also includes an outline of 5-year actions, responsible parties, budget, and potential funding sources to achieve each objective. The funding sources are further described in Chapter 10.1.2.

10.1.2 Funding Opportunities

Existing external funding sources may be leveraged to promote implementation of the objectives outlined in Chapter 10.1.1. For example, EPA's Water Infrastructure Finance and Information Act program offers funding to support eligible water and wastewater infrastructure projects including those related to drought prevention, reduction, and mitigation. Other funding to support drought mitigation efforts may be available through the Federal Emergency Management Agency's Hazard Mitigation Grant Program (HMGP) or Building Resilient Infrastructure and Communities (BRIC) programs. Table 10-3 summarizes existing federal funding sources for public suppliers.

Although agricultural water use in the Broad River basin is limited and expected to already be efficient, funding opportunities related to agricultural programs are also included in this section for reference. The USDA offers numerous programs for farmers and ranchers to reduce risk from drought or to restore land impacted by drought. Table 10-4 summarizes existing USDA funding sources.

In 2022 Congress passed the Inflation Reduction Act (IRA), which may provide additional funding to programs related to agricultural conservation. For example, of the $20 billion allotted to the USDA, Section 21001 of the IRA assigned $8.5 billion in addition to amounts otherwise available to an existing USDA program, the Environmental Quality Incentives Program (EQIP). EQIP pays for ecosystem restoration and emissions reduction projects on farmland and may be used for activities such as the purchase of cover crops (one of the agricultural conservation strategies discussed in this plan). Annual obligations from the EQIP program have been approximately $1.8 to $1.9 billion from 2018 through 2021, with between $36 to $45 million allotted for projects in South Carolina in these years. Additionally, $3.25 billion was allotted to the federal Conservation Stewardship Program, $1.4 million to the Agricultural Conservation Easement Program, and $4.95 billion to the Regional Conservation Partnership Program. The IRA indicates that activities funded by these programs must "directly improve soil carbon, reduce nitrogen losses, or reduce, capture, avoid, or sequester carbon dioxide, methane, or nitrous oxide emissions, associated with agricultural production" (Inflation Reduction Act 2022). Projects that provide water efficiency benefits in addition to these climate benefits may be eligible for funding under these programs. Section 30002 of the IRA also designated $837.5 million in funding to the Secretary of Housing and Urban Affairs for projects that improve energy or water efficiency for affordable housing (Inflation Reduction Act 2022).

In September 2022, $70 million in USDA "Partnerships for Climate-Smart Commodities" funding was invested in South Carolina's two land-grant universities, Clemson University and South Carolina State University, to promote "climate-smart" agricultural practices in South Carolina. The project will utilize a coalition of 27 entities to promote the program to farmers, with a focus on peanuts, leafy greens, beef cattle, and forestry. Most of the funding will go directly to growers to offset the costs of implementing conservation practices. There may be opportunities to leverage this new funding source to implement the agricultural conservation strategies recommended in this plan.

Table 10-2. Implementation plan.

Strategy		Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
Objective 1. Improve water efficiency to conserve water resources						
A. Municipal Conservation	Public Education of Water Conservation Conservation Pricing Structures Residential Water Audits Landscape Irrigation Program and Codes Water Efficiency Standards for New Construction Leak Detection and Water Loss Control Program Reclaimed Water Programs Car Wash Recycling Ordinances Time-of-Day Watering Limit	1 *No priority assigned to toolbox of sub-strategies as priority varies by utility*	1. Identify funding opportunities (yrs 1-5) 2. Establish a baseline of residential per capita water use (yr 1) by system. 3. Implement outreach and education program about recommended water management practices and funding opportunities (yrs 1-5) 4. Individual water users to implement conservation practices (yrs 3-5) 5. Develop survey of practices implemented, funding issues, and funding sources utilized (beginning in yr 5 as part of 5-year Plan update) 6. Review and analyze per capita water usage to improve understanding of water savings of strategies (beginning in yr 5 as part of 5-year Plan update)	*RBC with support of SCDHEC, SCDNR, and contractors* - Identify funding opportunities and develop information to distribute. Conduct surveys and analyze results. *Municipal Withdrawers* - Implement appropriate strategies and seek funding from recommended sources as necessary.	Costs of implementation will vary by municipality according to current program capabilities and financial means. See Chapter 6.1.6 for discussion of cost-benefit of individual strategies. Cost of RBC support activities are included in on-going RBC meeting budgets.	Individual strategies to be funded using outside funding opportunities or by evaluating existing rate structure. Possible outside funding sources include: Fed-1, 2, 5, 6, 7, 8 and USDA-8 and 9
B. Agricultural Conservation	Water Audits and Nozzle Retrofits Irrigation Equipment Changes Soil Management Crop Variety, Crop Type, and Crop Conversion Irrigation Scheduling	2 *No priority assigned to toolbox of sub-strategies as priority varies by operation.*	1. Identify funding opportunities (yrs 1-5) 2. Implement outreach and education program about recommended water management practices and funding opportunities (yrs 1-5) 3. Individual water users to implement conservation practices (yrs 3-5)	*RBC with support of SCDHEC, SCDNR, and contractors* - Identify funding opportunities and develop and implement outreach program. Conduct surveys and analyze results. *Farmers* - Implement appropriate strategies and seek funding from recommended sources as necessary.	Costs of implementation will vary by agricultural operation according to size of operation, crops grown, current irrigation practices, and financial means. See Chapter 6.1.6 for discussion of cost-benefit of individual strategies. Cost of RBC activities are included in on-going RBC meeting budgets.	Possible funding sources include USDA-7

[1] See Tables 10-3 and 10-4 for funding source references.

Table 10-2. Implementation plan. (Continued)

Strategy		Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
Objective 2. Optimize and augment sources of supply						
A. Greer, SWS, SJWD, and Cherokee County BPW to adjust reservoir operations as demands grow to optimize their supplies		1 *(A, B, and C are generally equal priority)*	1. Public suppliers to assess how current operations affect reservoir drawdown and identify what conditions may require changes to operations (yrs 1-5) 2. Public suppliers to adjust reservoir operations as necessary to better balance available supply (yrs 1-5)	Greer, SWS, SJWD, and Cherokee County BPW. Communication with other reservoir users as needed.	There is no appreciable cost associated with implementing new reservoir operating rules. Costs may be incurred if public suppliers require consultants to assist in evaluation of reservoir operations and impacts under future conditions.	NA
B. Cherokee County BPW to pursue recommended strategies	Seasonal redistribution of Gaston Shoals allocation	1 *(A, B, and C are generally equal priority)* Priority 1 within B.	1. Cherokee County BPW to assess seasonal demand patterns and determine what redistribution of Gaston Shoals withdrawals could best extend their existing supplies (yrs 1-5)	Cherokee County BPW	There is no appreciable cost associated with implementing new reservoir operating rules that better balance operations when water demands increase and/or droughts occur.	NA
	Explore feasibility of new intake on the Broad River	1 *(A, B, and C are generally equal priority)* Priority 2 within B.	1. Cherokee County BPW to further explore condition of abandoned intake on the Broad River from the 1950's (yr 1) 2. Cherokee County BPW to further explore permitting requirements and costs for a new intake on the Broad River and associated conveyance and treatment (yrs 1-5) 3. Cherokee County BPW to schedule design and construction of intake (yrs 2-5) 4. Cherokee County BPW to implement design, construction, and start up of intake (yrs 3+)	Cherokee County BPW	Implementation costs vary based on pump facility capacity and pipeline size. Assuming a 15 mgd facility with a 30-in diameter pipeline, project costs including engineering, surveying, permitting, and construction may be $12M. See Chapter 6.1.6 for discussion of cost-benefit.	Fed-1, Fed-2, Fed-8, Fed-9

[1] See Tables 10-3 and 10-4 for funding source references.

Table 10-2. Implementation plan. (Continued)

Strategy		Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
B. Cherokee County BPW to pursue recommended strategies	Develop adaptive management strategy for mid- and long-term strategies	1 *(A, B, and C are generally equal priority)* Priority 3 within B.	1. Cherokee County BPW to explore potential of interconnection with SWS - identify location of connections, capacities, and available supply (yrs 1-5) 2. Cherokee County BPW to further explore supply benefit, cost, and permitting requirements for raising Lake Whelchel dam (yrs 1-5) 3. Cherokee County BPW to monitor demands and hydrologic conditions to determine when timing of future investments may be necessary (yrs 1-5)	Cherokee County BPW to assess feasibility of strategies and determine appropriate timing based on changing demand and hydrologic conditions. Broad RBC to remain engaged in discussions with multiple suppliers in the Broad River basin about the need for and concept of a regional reservoir.	Mid- and long-term strategies may involve significant planning, engineering, construction, and permitting costs. Cherokee County BPW would be responsible for costs for strategies to augment their individual supply. See Chapter 6.1.6 for discussion of cost-benefit.	Fed-1, Fed-2, Fed-8, Fed-9
C. Encourage public suppliers without existing interconnections in the Broad River basin to explore building interconnections to improve resilience of supply		1 *(A, B, and C are generally equal priority)*	1. Identify funding opportunities (yrs 1-5) 2. Broad RBC to identify public suppliers without interconnection and develop an outreach strategy (yr 1) 3. Broad RBC to execute outreach strategy to communicate with public suppliers about benefits of interconnections and funding opportunities (yrs 2-5)	Broad RBC to develop outreach strategy to communicate with public suppliers. This may involve SCRWA or existing, informal meetings of public suppliers.	Implementation costs vary based on location, length, and size (diameter) of interconnection. See Chapter 6.1.6 for discussion of cost-benefit of a Cherokee County BPW and SWS interconnection. Cost of RBC support activities are included in on-going RBC meeting budgets.	Fed-1, Fed-2, Fed-4, Fed-5, Fed-7, Fed-8, Fed-9
D. Conjunctive use and small storage ponds for golf courses		2 *(lowest priority)*	1. Individual entities explore and implement conjunctive use and small storage ponds as an alternative water supply (yrs 1-5)	Golf course operators - Implement strategies as appropriate and seek funding from recommended sources as necessary.	Implementation costs vary based on location, size (diameter) and depth of well and can range from $50,000 to $250,000. Cost estimates for an unlined 100-acre-foot storage pond range from $70,000 to $478,000 (Curtis et al. 2001) Cost of RBC support activities are included in on-going RBC meeting budgets.	NA

[1] See Tables 10-3 and 10-4 for funding source references.

Table 10-2. Implementation plan. (Continued)

Strategy	Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
Objective 3. Improve drought management					
A. Develop materials and outreach strategy to public suppliers in the basin to implement the RBC's drought management recommendations (see Chapter 8.2.3)	2	1. Develop materials on benefits and implementation of RBC drought management recommendations (yr 1) 2. Develop outreach strategy to communicate with public suppliers and distribute materials (yr 2) 3. Execute outreach strategy and update materials as necessary (yrs 3-5) 4. Develop approach to track updates to drought management plans in the basin (yrs 3-5)	RBC with support of SCDNR and contractors.	No direct cost, other than ongoing contractor support, if needed. Cost of RBC activities are included in on-going RBC meeting budgets.	Fed-6
B. Public suppliers on the RBC should review and regularly update their drought management plans , including their supporting water shortage response ordinances and consider other RBC recommendations related to drought planning for their individual operations	1	1. Public suppliers on the RBC to review and update their drought management plans, including their supporting water shortage response ordinances and send them to the SCO (yrs 1-5) 2. Public suppliers on the RBC to consider ways to incorporate RBC drought management recommendations into their drought plans and ordinances (yrs 1-5) 3. Updates to drought management plans and ordinances should be shared with the SCO (e-mailed to drought@dnr.sc.gov)	Public suppliers in the Broad RBC.	Drought planning activities to occur within public suppliers' annual budgets.	Fed-6

[1] See Tables 10-3 and 10-4 for funding source references.

Table 10-2. Implementation plan. (Continued)

Strategy	Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
Objective 4. Effectively communicate RBC findings and recommendations					
A. Conduct Broad RBC meetings to review, initiate, and support implementation actions	1	1. Broad RBC to meet quarterly as needed following publishing of Broad River Basin Plan. Meetings will focus on implementation plan actions and identifying funding (yr 1) 2. Future RBC meetings on less frequent basis, as deemed necessary (minimum 1 per year) (yrs 2-5) 3. SCDNR and/or Contractors to provide new member orientation (yrs 1-5, on-going) 4. Convene existing or form new ad-hoc subcommittees to address time-sensitive matters (yrs 1-5 as needed)	Broad RBC members to attend. SCDNR, SCDHEC, and contractors to organize.	No direct cost, other than ongoing contractor support, if needed. Cost of RBC activities are included in on-going RBC meeting budgets. If contractor led, RBC meetings may range between $5,000 and $15,000 per meeting, depending on effort needed to prepare for, conduct, and document each meeting.	Funded by SC Legislature and Fed-8
B. Develop a communication plan early in the planning process and conduct education and outreach prior to completion of the River Basin Plan	2	1. Develop talking points/script to provide consistent message from RBC. Talking points will vary depending on whether communication is with public or elected officials/decision makers. Engage communication specialists to help with messaging (yrs 1-5) 2. Track which representatives have been spoken to and by whom from the RBC. Note any outcomes of conversation (yrs 1-5)	RBC with the support of contractors to develop talking points and track interactions.	No direct cost, other than ongoing contractor support, if needed. Cost of RBC activities are included in on-going RBC meeting budgets.	No direct cost
C. Conduct an annual state-wide meeting of the RBCs with the Agriculture and Natural Resources Committee of the State Senate and the Agriculture, Natural Resources and Environmental Affairs Committee of the State House to communicate the value of water planning, highlight progress and recommendations, and lobby for continued funding	3	1. SCDNR to gage interest from all active RBCs (yr 1) 2. SCDNR to plan first annual meeting location, agenda, and invitees. Identify costs and identify funding source (yr 1-2) 3. Execute annual meeting (yrs 3-5)	SCDNR to lead effort. RBC members and representatives of invited committees to attend.	No direct cost, other than ongoing contractor support, if needed.	No direct cost

[1] See Tables 10-3 and 10-4 for funding source references.

Table 10-2. Implementation plan. (Continued)

Strategy	Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
Objective 5. Improve technical understanding of water resource management issues					
A. Maintain and expand streamflow gages in the basin	1	1. Develop communication strategy for speaking with USGS and other entities funding stream gages (yr 1-2) 2. Outreach to USGS and current funding entities on the importance of streamflow data to the river basin planning process. RBC to support search for additional funding sources as needed (yr 3-5)	Broad RBC with support from SCDHEC, SCDNR, and contractors	Costs of monitoring and processing data for existing streamflow gages are included in USGS existing budget. Some gages are maintained by other entities. A stream gauge suitable for inclusion in the USGS system costs between $20,000 and $35,000 to install, depending on the site, and $16,000 a year to operate (Gardner-Smith 2021).	USGS, SCDNR, and co-sponsors
B. Research how changes in land-use impact water resources quality and quantity	2	1. Invite RTI to educate the RBC on Catawba Wateree Water Management Group (CWWMG) land conservation modeling. (yr 1-2) 2. Consider performing similar land conservation modeling to identify how land use changes may impact water resources (yrs 3-5).	Broad RBC with support from SCDHEC, SCDNR, and contractors	SCDNR existing budget.	Funded by SCDNR budget as available
C. Research financial impacts of increased sedimentation on reservoirs and water resources and communicate impacts to local governments	2	1. Using estimates of sedimentation, and considering future land use (2070), estimate current and future loss of storage to Broad River basin reservoirs (yrs 1-2) 2. Develop methodology to estimate financial impacts related to loss in storage (dredging, new supplies) (yrs 1-2) 3. Communicate financial impacts of sedimentation on water supply relates to local governments (yrs 3-5)	Broad RBC with support from SCDHEC, SCDNR, and contractors	Costs of performing analysis of financial impacts will vary with the level of detail and could range between $20,000 to $50,000.	Funded by SCDNR budget as available

[1] See Tables 10-3 and 10-4 for funding source references.

Table 10-2. Implementation plan. (Continued)

Strategy	Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
Objective 5. Improve technical understanding of water resource management issues					
D. The Broad RBC should continue to consider ecological flow standards, including new and/or improved data, as it becomes available.	3	1. Continue to update and apply ecological flow relationships as new data is available (yrs 1-5) 2. RBC to consider making recommendations related to ecological flow standards in 5-yr update (yr 5)	Broad RBC with support from USGS, Clemson, TNC, SCDHEC, SCDNR, and contractors.	Aquatic data collection funded through on-going SCDNR and SCDHEC programs. Additional funding may be needed to continue developing ecological flow relationships.	Existing SCDNR and SCDHEC budgets with TNC, USGS, Clemson contributions.
E. While the RBC should maintain its focus on the assessment of water quantity, future planning efforts in the Broad River basin should include evaluation of surface water quality, including nutrient loading and sedimentation, which is important to maintaining affordable public water supplies and the ecological health of the streams, rivers, and lakes.	3	1. RBC to first identify specific water quality issues and concerns in the basin (yrs 3-5) 2. RBC to develop approach to further address those water quality issues and concerns, including the need for development of a watershed plan under SCDHEC's Watershed Program (yrs 4-5)	Broad RBC with support from SCDHEC, SCDNR, and contractors	Cost of RBC activities are included in on-going RBC meeting and support budgets. Development of watershed plans would come from SCDHEC's existing Watershed Program budget.	Fed-9
F. The Broad RBC should identify potential pinch points where current and projected low flows may lower the assimilative capacity of the streams. Strategies may need to be identified to mitigate low flows at these potential "pinch points".	4	1. As part of the 5-yr update, use surface water modeling results to identify pinch-points, develop strategies to mitigate issues, and assess their feasibility using modeling tools as appropriate (yr 5)	Broad RBC with support from SCDHEC, SCDNR, and contractors	No direct cost, other than ongoing contractor support, if needed. Cost of RBC activities are included in on-going RBC meeting budgets. If contractor led, RBC meetings may range between $5,000 and $15,000 per meeting, depending on effort needed to prepare for, conduct, and document each meeting.	Funded by SC Legislature and Fed-8

[1] See Tables 10-3 and 10-4 for funding source references.

Table 10-2. Implementation plan. (Continued)

Strategy	Strategy Priority	5-Year Actions	Responsible Parties	Budget	Funding Sources[1]
Objective 5. Improve technical understanding of water resource management issues					
G. Consider using tree-ring data (dendroclimatology) to assess the severity, frequency, and duration of historical droughts and incorporating future climate projections (e.g., projected temperature, evapotranspiration, and precipitation trends) to better address potential hydrologic variability in the basin.	3	1. RBC receives and considers information on the how tree-ring data and climate projections may be used to better address potential hydrologic variability in the basin. 2. RBC to decide whether to include results of tree-ring evaluation and/or climate change evaluation in surface water quantity modeling performed as part of the five-year update. Contractor to incorporate projections as necessary (Beginning in yr 5 as part of 5-yr Plan update)	Broad RBC with support from SCDHEC, SCDNR, and contractors	Cost for RBC meetings and technical support may range between $40,000 and $70,000	Funded by SC Legislature and Fed-8
H. Investigate the feasibility of low-tech, process-based approaches to stream restoration, and identify potential funding for pilot projects, if deemed feasible	4	1. RBC receives and considers latest research into this technology (yrs 1-2) 2. RBC to investigate opportunities and partners for pilot projects (yrs 3-5) 3. Based on outcome of 1 and 2 above, RBC to consider recommending approach as part of 5-yr Plan update (yr 5)	Broad RBC with support from SCDHEC, SCDNR, and contractors	Cost for RBC meetings and technical support may range between $40,000 and $70,000	Funded by SC Legislature and Fed-8
I. The Facilitator should create an online library of, or a catalog of links to technical information that will enhance the RBC's technical understanding of water resources concepts and issues	1	1. Facilitator will create an online library/catalog of technical information to support RBC (yrs 1-5) 2. Facilitator to add resources based on new topics discussed in RBC meetings and at request of RBC members (yrs 1-5) 3. Assess how often RBC members access and use the resources to determine if the effort should continue (yr 5)	Contractors through contract with SCDNR	No direct cost, other than ongoing contractor support, if needed. Cost of RBC activities are included in on-going RBC meeting and support budgets	Funded by SC Legislature and Fed-8

[1] See Tables 10-3 and 10-4 for funding source references.

Table 10-3. Federal funding sources.

Funding Source Index[1]	Program	Agency	Grant/Loan Funds Available	Description
Fed-1	U.S. Economic Development Administration (EDA) Grants	EDA	No limit (subject to federal appropriation)	EDA's Public Works Program and Economic Adjustment Assistance Program aids distressed communities by providing funding for existing physical infrastructure improvements and expansions.
Fed-2	Water Infrastructure Finance and Information Act	U.S. Environmental Protection Agency (EPA)	Up to 49 percent of eligible project costs (minimum project size is $20 million for large communities and $5 million for small communities)	A federal credit program administered by EPA for eligible water and wastewater infrastructure projects, including drought prevention, reduction, and mitigation.
Fed-3	Section 502 Direct Loan Program	USDA Rural Development	Loans based on individual county mortgage limits	Loans are available for wells and water connections in rural communities. Availability is based on community income.
Fed-4	National Rural Water Association Revolving Loan Fund	USDA Rural Utilities Service	$100,000 or 75% of the total project	Provides loans for predevelopment costs associated with water and wastewater projects and for existing systems in need of small-scale capital improvements.
Fed-5	Emergency Community Water Assistance Grants	USDA Rural Development	Up to $100,000 or $1,000,000 depending on the type of project	Offers grants to rural areas and towns with populations of 10,000 or less to construct waterline extensions; repair breaks or leaks; address maintenance necessary to replenish the water supply; or construct a water source, intake, or treatment facility.
Fed-6	HMGP	Federal Emergency Management Agency (FEMA)	Variable	Provides funds to states, territories, tribal governments, and communities for hazard mitigation planning and the implementation of mitigation projects following a presidentially declared disaster event
Fed-7	Building Resilient Infrastructure and Communities	FEMA	Variable	Building Resilient Infrastructure and Communities will support states, local communities, tribes, and territories as they undertake hazard mitigation projects, reducing the risks they face from disasters and natural hazards
Fed-8	Planning Assistance to States	USACE	Variable – funding is 50% federal and 50% nonfederal	USACE can provide states, local governments, and other nonfederal entities assistance in the development of comprehensive plans for the development, use, and conservation of water resources.

[1] As referenced in the "Funding Sources" column of Table 10-2.

Table 10-3. Federal funding sources. (Continued)

Funding Source Index[1]	Program	Agency	Grant/Loan Funds Available	Description
Fed-9	Drinking Water State Revolving Fund	SCDHEC and SC Rural Infrastructure Authority	Congress appropriates funding for the Drinking Water State Revolving Fund that is then awarded to states by EPA based on results of the most recent Drinking Water Infrastructure Needs Survey and Assessment.	This program is a federal-state partnership aimed at ensuring that communities have safe drinking water by providing low-interest loans and grants to eligible recipients for drinking water infrastructure projects.

[1] As referenced in the "Funding Sources" column of Table 10-2.

Table 10-4. USDA disaster assistance programs.

Funding Source Index[1]	Program	Agency	Description
USDA-1	Crop Insurance	Risk Management Agency	Provides indemnity payments to growers who purchased crop insurance for production and quality losses related to drought, including losses from an inability to plant caused by an insured cause of loss.
USDA-2	Conservation Reserve Program Haying and Grazing	Farm Service Agency (FSA)	Provides for emergency haying and grazing on certain Conservation Reserve Program practices in a county designated as D2 or higher on the United States Drought Monitor, or in a county where there is at least a 40% loss in forage production.
USDA-3	Emergency Assistance for Livestock, Honeybees, and Farm-Raised Fish Program	FSA	Provides assistance to eligible owners of livestock and producers of honeybees and farm-raised fish for losses.
USDA-4	Emergency Conservation Program	FSA	Provides funding and technical assistance for farmers and ranchers to restore farmland damaged by natural disasters and for emergency water conservation measures in severe droughts.
USDA-5	Emergency Forest Restoration Program	FSA	Provides funding to restore privately owned forests damaged by natural disasters. Assistance helps landowners carry out emergency measures to restore forest health on land damaged by drought disasters.
USDA-6	Farm Loans	FSA	Provides emergency and operating loans to help producers recover from production and physical losses due to natural disasters and can pay for farm operating and family living expenses.
USDA-7	Environmental Quality Incentives Program	FSA	Provides agricultural producers with financial resources and assistance to plan and implement improvements on the land in support of disaster recovery and repair and can help mitigate loss from future natural disasters. Assistance may also be available for emergency animal mortality disposal from natural disasters.

[1] As referenced in the "Funding Sources" column of Table 10-2.

Table 10-4. USDA disaster assistance programs. (Continued)

Funding Source Index[1]	Program	Agency	Description
USDA-8	Emergency Watershed Program (Recovery)	Natural Resources Conservation Service	Offers vital recovery options for local communities to help people reduce hazards to life and property caused by droughts.
USDA-9	Emergency Community Water Assistance Grants	Rural Development	Offers grants to rural areas and towns with populations of 10,000 or less to construct waterline extensions; repair breaks or leaks; address maintenance necessary to replenish the water supply; or construct a water source, intake, or treatment facility.

[1] As referenced in the "Funding Sources" column of Table 10-2.

10.1.3 Implementation Considerations

The Broad RBC may encounter challenges in the implementation of the identified strategies. One such challenge is the identification of sufficient funding. For the implementation of Objectives 1–3, water withdrawers may have limited financial capacity to pursue the recommended water management strategies. A municipal water utility's budget is limited by its customer base and rate structure. The increases to water rates necessary to fund implementation of the actions associated with these objectives may not be feasible for some communities. Agricultural water withdrawers may have limited financial resources to invest in new and potentially expensive water conservation or augmentation strategies. Although some outside funding sources exist, applications for such programs may present a technical or resource barrier to many water withdrawers. Any new funding sources pursued by the RBC with SCDNR support may take time to develop, leading to delays in implementation. The identification of immediately available funding opportunities, the provision of support in funding applications, and the investigation of new funding sources are vital to implementation of the recommended strategies under Objectives 1–3.

Another challenge in the implementation of the River Basin Plan is stakeholder acceptance. The RBC itself has no authority to enforce recommendations in the basin. Therefore, implementation of these strategies is dependent upon effective communication of RBC findings and recommendations to stakeholders. For example, stakeholder acceptance is vital for achieving Objectives 1–3, as these strategies rely on individual water withdrawers reducing their demands, developing new supplies, or modifying their drought management plans. To gain acceptance, water withdrawers must understand the need for and goals of the recommended strategies as well as have assurance that they are viable and effective in improving equitable access to the basin's water resources. The RBC must compile sufficient data and develop and execute an outreach plan to meet these stakeholder needs. The RBC included the development and implementation of an education and outreach communication plan as one of the 5-year actions for the water management objectives (Objectives 1–3). During RBC meetings following publication of the River Basin Plan, the RBC will craft outreach plans to both municipal and agricultural water withdrawers within the basin. Outreach may include the development of print or online materials to describe potential water management strategies, benefits, and funding sources and to describe how these strategies relate to findings from the planning process.

Success of the River Basin Plan is dependent upon continued support for the South Carolina river basin planning process. Consequently, the RBC identified a separate objective, Objective 4, focused on effective communication of RBC findings and recommendations. This objective includes actions to develop strategies to communicate not just to water withdrawers (as is necessary to support Objectives 1-3), but to public and elected officials and decision makers who influence the continued funding of the water planning process.

A recommended communication strategy under Objective 4 is to conduct an annual state-wide meeting of the state's multiple RBCs, the Agriculture and Natural Resources Committee of the State Senate and the Agriculture, Natural Resources and Environmental Affairs Committee of the State House to communicate the value of water planning, highlight progress and recommendations, and lobby for continued funding. Although the Broad RBC developed this recommendation from seeing the value in formal communication with legislative bodies, other RBCs have not heard or endorsed this plan. In addition to being dependent on the interest levels of the parties involved, this strategy would also be contingent upon a funding source and availability of participants from the Committees.

To effectively implement the recommended strategies of the River Basin Plan, the RBC must continue to meet as a planning body. The Planning Framework states that the River Basin Plan should not be perceived as a static document and the RBC should not be a stagnant planning body between successive updates. Rather, the RBC is to be "actively engaged in promoting the implementation of the recommendations proposed" and "will continue to meet on a periodic basis to pursue River Basin Plan implementation activities as needed" (SCDNR 2019, p. 90). The Broad RBC has identified quarterly meetings as desirable in the first year after publication of the River Basin Plan to pursue funding and implementation. After the first year, meetings may be held less frequently as needed, but at least once per year.

As the RBC makes decisions related to implementation, the RBC should aim to build consensus where possible and consider documenting alternative points of view when consensus is not possible. Documenting alternative points of view can be equally valuable to officials who have a role implementing water management strategies and/or recommendations made by a portion of the RBC. Full consensus on every issue is an unrealistic goal, but the RBC should continue to discuss, revisit, and document issues from this and later planning phases that are marked by alternative or opposing points of view.

10.2 Long-term Planning Objectives

The Broad RBC's objectives described in Chapter 10.1 represent both short-term and long-term objectives. For each objective, short-term strategies are discussed in Chapter 10.1 and long-term strategies are presented below in Table 10-5.

Table 10-5. Long-term planning objectives.

Objective and Strategy		Long-Term Strategy
Objective 1. Improve water use efficiency to conserve water resources		
A. Municipal Conservation		Continue short term goals. Adjust recommended actions based on water savings realized. Seek additional funding sources.
B. Agricultural Conservation		Continue short term goals. Adjust recommended actions based on water savings realized. Seek additional funding sources. Explore new technologies and incorporate into recommendations as appropriate.
Objective 2. Optimize and augment sources of supply		
A. Greer, SWS, SJWD, and Cherokee County BPW to adjust reservoir operations as demands grow to optimize their supplies		Continue to monitor how operations affect drawdown in reservoirs and enact changes to operations when necessary.
B. Cherokee County BPW to pursue recommended strategies	Seasonal redistribution of Gaston Shoals allocation	Decide on and implement near-term strategies to maintain water supply reliability.
	Explore feasibility of new intake on the Broad River	
	Develop adaptive management strategy for mid- and long-term strategies	Monitor conditions to determine when to further explore mid- and long-term strategies.
C. Encourage public suppliers without existing interconnections in the Broad River basin to explore building interconnections to improve resilience of supply		Continue to monitor the extent of interconnections between public suppliers in the basin and continue outreach strategy as needed.
D. Conjunctive use and small storage ponds for golf courses		Continue short-term goals.
Objective 3. Improve drought management		
A. Develop materials and outreach strategy to public suppliers in the basin to implement the RBC's drought management recommendations (see Chapter 8.2.3)		Continue short-term goals. Monitor progress towards increasing the number of up-to-date (within last 5 years) drought management plans in the basin.
B. Public suppliers on the RBC should review and regularly update their drought management plans and supporting water shortage response ordinances and consider other RBC recommendations related to drought planning for their individual operations		Public suppliers maintain up-to-date drought management plans with aligned ordinances that are consistent (where possible) with the recommendations of the RBC. Incorporate updated drought management plans into modeling, to test effectiveness.
Objective 4. Effectively communicate RBC findings and recommendations		
A. Conduct Broad RBC meetings to review, initiate, and support implementation actions		Maintain regular meeting schedule to encourage continuity between various iterations of RBC membership.
B. Develop a communication plan early in the planning process and conduct education and outreach prior to completion of the River Basin Plan		Continue regular communication to emphasize the on-going work and impacts of the RBC.
C. Conduct an annual state-wide meeting of the RBCs with the Agriculture and Natural Resources Committee of the State Senate and the Agriculture, Natural Resources and Environmental Affairs Committee of the State House to communicate the value of water planning, highlight progress and recommendations, and lobby for continued funding		Continue meetings to communicate the value of water planning, highlight progress and recommendations, and lobby for continued funding.

Table 10-5. Long-term planning objectives. (Continued)

Objective and Strategy	Long-Term Strategy
Objective 5. Improve technical understanding of water resource management issues	
A. Maintain and expand streamflow gages in the basin	Continue short-term goals. Monitor number of active gages in the basin.
B. Research how changes in land-use impact water resources quality and quantity	Incorporate land use projections and recharge impacts into future modeling efforts.
C. Research financial impacts of increased sedimentation on reservoirs and water resources and communicate impacts to local governments	Consider documenting findings of analysis in next 5-yr Plan update. Continue to communicate with local governments to enact appropriate land-use management strategies.
D. The Broad RBC should continue to consider ecological flow standards, including new and/or improved data, as it becomes available	Consider findings of analysis in next 5-yr Plan update.
E. While RBC should maintain its focus on the assessment of water quantity, future planning efforts in the Broad River basin should include evaluation of surface water quality, including nutrient loading and sedimentation, which is important to maintaining affordable public water supplies and the ecological health of the streams, rivers, and lakes	Consider findings of analysis and include recommendations in next 5-yr Plan update.
F. The Broad RBC should identify potential pinch points where current and projected low flows may lower the assimilative capacity of the streams. Strategies may need to be identified to mitigate low flows at these potential "pinch points".	Consider findings of analysis and include recommendations in next 5-yr Plan update.
G. Consider using tree-ring data (dendroclimatology) to assess the severity, frequency, and duration of historical droughts and incorporating future climate projections (e.g., projected temperature, evapotranspiration, and precipitation trends) to better address potential hydrologic variability in the basin.	Consider findings of analysis in next 5-yr Plan update.
H. Investigate the feasibility of low-tech, process-based approaches to stream restoration, and identify potential funding for pilot projects, if deemed feasible	Consider findings of analysis and include recommendations in next 5-yr Plan update.
I. The Facilitator should create an online library of, or a catalog of links to, technical information that will enhance the RBC's technical understanding of water resources concepts and issues	Continue short-term goals.

10.3 Progress on River Basin Plan Implementation

To assess the performance of and quality of actions taken by the RBC, the Framework proposes the development of progress metrics. A progress metric is a "*benchmark used to monitor the success or failure of an action taken by an RBC*" (SCDNR 2009). Noting that the ultimate value and impact of the river basin planning process is the dissemination of its findings and implementation of its recommendations, the Broad RBC developed progress metrics around each of the six implementation objectives defined at the beginning of this chapter. The progress metrics are:

1. Improve water use efficiency to conserve water resources
    a. Metric 1a: Municipal and agricultural water conservation and efficiency strategies are considered, evaluated, and implemented. On the municipal side, a 5-year reduction in residential per capita demand is realized and water utility financial strength is maintained.
    b. Metric 1b: Funding opportunities are identified and used to implement strategies.
2. Optimize and augment sources of supply
    a. Metric 2a: Supply augmentation strategies are implemented before they are needed.
    b. Metric 2b: Funding opportunities are identified and successfully used to implement supply augmentation strategies.
3. Improve drought management
    a. Metric 3: One hundred percent of public water suppliers' drought management plans are updated within the last 5 years and submitted to the SCO for review.
4. Effectively communicate RBC findings and recommendations
    a. Metric 4a: Within 2 years, the RBC has presented the Broad River Basin Plan to all County Councils that are within the basin and requested their feedback and ideas for future study.
    b. Metric 4b: Outreach is effective, prompting legislative actions, decisions, and funding that support implementation strategies and actions.
5. Improve technical understanding of water resource management issues
    a. Metric 5a: Streamflow gages in the basin are maintained.
    b. Metric 5b: The RBC has become familiar with the study in the Catawba River basin that assessed the relative impacts of climate and land use change on water supply resiliency and considered the value of a similar study in the Broad River basin.
    c. Metric 5c: Research into financial impacts of sedimentation on reservoirs and water resources is completed. Results are communicated to local governments.
    d. Metric 5d: New data on ecological flow relationships is presented to the RBC and incorporated in RBC recommendations.
    e. Metric 5e: Potential pinch-points where low flows may lower the assimilative capacity of streams have been identified and incorporated in RBC recommendations.
    f. Metric 5f: Water quality issues and concerns in the basin are identified and a strategy to study approaches to address them is developed.
    g. Metric 5g: Information on how tree-ring data may be used to assess the severity, frequency, and duration of historical droughts and how that and/or climate projections may be used

to better address potential hydrologic variability is presented to the RBC, and the value of performing such studies as part of the next 5-year Plan update is considered by the RBC.

h. Metric 5h: An online library of technical resources is available to and used by RBC members.

This 2023 publication is the first Broad River Basin Plan publication. Future 5-year updates will evaluate the Broad RBC's performance relative to the progress metrics.

As noted throughout this plan, communication and the development of stakeholder buy-in is key to successful plan implementation. To develop stakeholder acceptance, RBC members, who are the ambassadors of the River Basin Plan, must have confidence in the planning process and outcomes. A key responsibility of RBC members, as defined in the Framework, is to regularly communicate with stakeholders to maintain a current understanding of RBC activities, the River Basin Plan, and emerging issues. To assess each RBC member's confidence in the plan, the plan approval process dictates that there will first be a test for consensus on the Draft Broad River Basin Plan. For the test of consensus, each member rates their concurrence with the plan using a five-point scale, as shown below:

1. Full Endorsement (i.e., member likes it).
2. Endorsement but with minor points of contention (i.e., basically member likes it).
3. Endorsement but with major points of contention (i.e., member can live with it).
4. Stand aside with major reservations (i.e., member cannot live with it in its current state and can only support it if changes are made).
5. Withdraw - Member will not support the draft river basin plan. The Planning Framework indicates that if a member votes 5 they will not continue working within the RBC's process and will leave the RBC. In practice, if a member votes 5 but wishes to remain engaged in future work of the RBC, the RBC has the discretion to vote on whether the member may remain on the RBC.

For the Final River Basin Plan, each RBC member votes simply to support or not support the plan. By indicating support, the member would be acknowledging his/her concurrence with the Final River Basin Plan and their commitment to support implementation of the plan. The results of the test for consensus on the Draft River Basin Plan and the RBC's votes on the Final River Basin Plan are shown in Table 10-6. The full results are included in Appendix E.

Table 10-6. Test of consensus results.

Test of Consensus Result	Number of RBC Members
Draft River Basin Plan	
1. Full Endorsement (i.e., Member likes it).	**13**
2. Endorsement but with Minor Points of Contention (i.e., basically Member likes it).	**4**
3. Endorsement but with Major Points of Contention (i.e., Member can live with it).	**0**
4. Stand aside with Major Reservations (i.e., Member cannot live with it in its current state and can only support it if changes are made).	**0**
5. Withdraw – Member will not support the Draft River Basin Plan and will not continue working within the RBC's process. Member has decided to leave the RBC.	**0**
Final River Basin Plan	
Support	*To be added when vote is taken on final plan*
Does Not Support	*To be added when vote is taken on final plan*

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Appendix A
2021 GDP for Counties in the Broad River Basin

2021 GDP of counties in the Broad River basin (in millions of dollars).

	Cherokee	Chester	Fairfield	Greenville
Percentage of County in Broad River basin	100	43.3	59.6	38.7
All industry total	2,000	1,400	1,200	37,000
Private industries	1,800	1,200	1,100	34,000
Agriculture, forestry, fishing and hunting	22	8	7	9
Mining, quarrying, and oil and gas extraction	4	-	4	15
Utilities	(D)	(D)	410	35
Construction	96	53	12	1,900
Manufacturing	620	510	97	5,500
Durable goods manufacturing	260	340	65	2,800
Nondurable goods manufacturing	360	170	32	2,700
Wholesale trade	76	170	170	4,700
Retail trade	170	53	35	2,400
Transportation and warehousing	92	40	(D)	760
Information	10	59	10	1,700
Finance, insurance, real estate, rental, and leasing	360	190	190	5,900
Finance and insurance	29	13	9	1,800
Real estate and rental and leasing	330	180	180	4,100
Professional and business services	(D)	36	86	5,900
Professional, scientific, and technical services	(D)	28	(D)	2,800
Management of companies and enterprises	(D)	(D)	(D)	750
Administrative and support and waste management and remediation services	96	(D)	43	2,300
Educational services, health care, and social assistance	76	27	37	3,200
Educational services	33	2	4	410
Health care and social assistance	44	26	33	2,800
Arts, entertainment, recreation, accommodation, and food services	73	(D)	(D)	1,300
Arts, entertainment, and recreation	11	(D)	(D)	190
Accommodation and food services	63	(D)	(D)	1,100
Other services (except government and government enterprises)	44	24	13	710
Government and government enterprises	210	160	110	3,200

D = Not shown to avoid disclosure of confidential information; estimates are included in higher-level totals

2021 GDP of counties in the Broad River basin (in millions of dollars).

	Laurens	Newberry	Richland	Spartanburg
Percentage of County in Broad River basin	37.2	50.7	27.4	100
All industry total	2,500	1,800	28,000	18,000
Private industries	2,200	1,600	22,000	15,000
Agriculture, forestry, fishing and hunting	28	43	54	17
Mining, quarrying, and oil and gas extraction	7	-	42	36
Utilities	13	4	180	35
Construction	71	68	850	930
Manufacturing	1,100	810	1,800	4,500
Durable goods manufacturing	790	530	920	3,200
Nondurable goods manufacturing	330	280	880	1,300
Wholesale trade	(D)	71	1,800	1,700
Retail trade	130	98	1,800	1,300
Transportation and warehousing	79	(D)	260	900
Information	29	3	890	250
Finance, insurance, real estate, rental, and leasing	310	250	6,100	2,300
Finance and insurance	29	18	3,000	590
Real estate and rental and leasing	280	240	3,100	1,700
Professional and business services	(D)	(D)	3,600	1,500
Professional, scientific, and technical services	(D)	(D)	2,300	610
Management of companies and enterprises	(D)	(D)	200	270
Administrative and support and waste management and remediation services	74	67	1,100	610
Educational services, health care, and social assistance	150	69	2,800	940
Educational services	37	22	260	180
Health care and social assistance	110	47	2,500	760
Arts, entertainment, recreation, accommodation, and food services	57	38	1,000	580
Arts, entertainment, and recreation	13	4	110	46
Accommodation and food services	44	34	910	540
Other services (except government and government enterprises)	55	30	590	390
Government and government enterprises	310	200	6,600	2,500

D = Not shown to avoid disclosure of confidential information; estimates are included in higher-level totals

2021 GDP of counties in the Broad River basin (in millions of dollars).

	Union	York
Percentage of County in Broad River basin	100	37.3
All industry total	850	15,000
Private industries	690	13,000
Agriculture, forestry, fishing and hunting	9	66
Mining, quarrying, and oil and gas extraction	0	12
Utilities	13	1,000
Construction	16	670
Manufacturing	230	1,800
Durable goods manufacturing	160	1,000
Nondurable goods manufacturing	71	770
Wholesale trade	13	1,300
Retail trade	52	1,000
Transportation and warehousing	78	340
Information	7	710
Finance, insurance, real estate, rental, and leasing	190	3,100
Finance and insurance	13	620
Real estate and rental and leasing	170	2,400
Professional and business services	23	1,800
Professional, scientific, and technical services	7	670
Management of companies and enterprises	2	670
Administrative and support and waste management and remediation services	14	460
Educational services, health care, and social assistance	17	810
Educational services	(D)	55
Health care and social assistance	(D)	760
Arts, entertainment, recreation, accommodation, and food services	24	510
Arts, entertainment, and recreation	(D)	85
Accommodation and food services	(D)	430
Other services (except government and government enterprises)	19	310
Government and government enterprises	160	1,200

D = Not shown to avoid disclosure of confidential information; estimates are included in higher-level totals
Lexington County was not included as only 1.1 percent of it is in the Broad River Basin.

Appendix B
Demand Projections for Individual Water Users

Table B-1. Current Water Demands, Consumptive Use, and Returns.

User	Use Category	Source	Withdrawal (MGD)	Consumptive Use (%)	Consumptive Use (MGD)	Return (MGD)	Return to Broad (MGD)
Fisher Bros	Agriculture	Surface Water	0.03	100.0%	0.03	0.0	0.0
Hyder Austin	Agriculture	Surface Water	0.002	100.0%	0.002	0.0	0.0
Walden Farm	Agriculture	Surface Water	0.3	100.0%	0.3	0.0	0.0
Carolina CC	Golf Course	Surface Water	0.1	0.0%	0.0	0.1	0.1
CC of Spartanburg	Golf Course	Surface Water	0.2	0.0%	0.0	0.2	0.2
Fox Run CC	Golf Course	Surface Water	0.03	0.0%	0.0	0.03	0.03
Holly Tree	Golf Course	Surface Water	0.03	0.0%	0.0	0.03	0.03
Links O'Tryon	Golf Course	Surface Water	0.04	0.0%	0.0	0.04	0.04
Mid Carolina	Golf Course	Surface Water	0.04	0.0%	0.0	0.04	0.04
Musgrove Mill	Golf Course	Surface Water	0.03	0.0%	0.0	0.03	0.03
Pebble Creek	Golf Course	Surface Water	0.5	0.0%	0.0	0.5	0.5
Willow Creek	Golf Course	Surface Water	0.1	0.0%	0.0	0.1	0.1
Cobblestone Park Golf Club	Golf Course	Groundwater	0.003	100.0%	0.003	0.0	0.0
Country Club Of Spartanburg	Golf Course	Groundwater	0.04	100.0%	0.04	0.0	0.0
Fox Run Country Club	Golf Course	Groundwater	0.003	100.0%	0.003	0.0	0.0
Heddles Hideaway Country Club	Golf Course	Groundwater	0.003	100.0%	0.003	0.0	0.0
Richland County Rec Comm Linrick GC	Golf Course	Groundwater	0.01	100.0%	0.01	0.0	0.0
Willow Creek GC	Golf Course	Groundwater	0.02	100.0%	0.02	0.0	0.0
Woodfin Ridge Golf Club	Golf Course	Groundwater	0.01	100.0%	0.01	0.0	0.0
York City Of	Golf Course	Groundwater	0.01	100.0%	0.01	0.0	0.0
Fairfield Pumped Storage	Hydroelectric	Surface Water	2000.3	0.0%	0.0	2000.3	2000.3
Carlisle Finishing	Manufacturing	Surface Water	0.7	67.9%	0.5	0.2	0.2

Table B-1. Current Water Demands, Consumptive Use, and Returns.

User	Use Category	Source	Withdrawal (MGD)	Consumptive Use (%)	Consumptive Use (MGD)	Return (MGD)	Return to Broad (MGD)
Chemtrade	Manufacturing	Surface Water	0.1	96.0%	0.1	0.0	0.0
Milliken	Manufacturing	Surface Water	2.3	4.6%	0.1	2.2	2.2
Cherokee Co Cogeneration Partners LLC	Manufacturing	Groundwater	0.0	100.0%	0.0	0.0	0.0
GE (Greenville) Gas Turbines, LLC	Manufacturing	Groundwater	0.2	75.0%	0.1	0.05	0.05
Timken Company/ Tyger River Plant	Manufacturing	Groundwater	0.01	100.0%	0.01	0.0	0.0
Vulcan	Mining	Surface Water	0.1	90.0%	0.1	0.01	0.01
Clinton	Public Supply	Surface Water	2.5	51.4%	1.3	1.2	1.2
Columbia	Public Supply	Surface Water	30.7	75.3%	23.1	7.6	7.6
Gaffney	Public Supply	Surface Water	7.9	48.7%	3.8	4.0	4.0
Greer	Public Supply	Surface Water	8.9	71.7%	6.4	2.5	2.5
ICWD	Public Supply	Surface Water	0.0	0.0%	0.0	0.0	0.0
Landrum	Public Supply	Surface Water	0.4	20.8%	0.1	0.3	0.3
SJWD	Public Supply	Surface Water	7.2	59.4%	4.3	2.9	2.9
Spartanburg	Public Supply	Surface Water	26.2	76.4%	20.0	6.2	6.2
Tryon	Public Supply	Surface Water	0.5	27.1%	0.1	0.4	0.4
Union	Public Supply	Surface Water	3.0	80.1%	2.4	0.6	0.6
Whitmire	Public Supply	Surface Water	0.3	74.6%	0.2	0.1	0.1
Winnsboro	Public Supply	Surface Water	1.7	52.8%	0.9	0.8	0.8
Woodruff-Roebuck	Public Supply	Surface Water	2.9	88.7%	2.6	0.3	0.3
York	Public Supply	Surface Water	0.7	24.1%	0.2	0.5	0.5
Blue Ridge Rural Water Co., Inc./Cliffs At Glassy	Public Supply	Groundwater	0.1	100.0%	0.1	0.0	0.0

Table B-1. Current Water Demands, Consumptive Use, and Returns.

User	Use Category	Source	Withdrawal (MGD)	Consumptive Use (%)	Consumptive Use (MGD)	Return (MGD)	Return to Broad (MGD)
Grassy Pond Water District	Public Supply	Groundwater	0.1	100.0%	0.1	0.0	0.0
Inman Mills Water District SJWD	Public Supply	Groundwater	0.1	100.0%	0.1	0.0	0.0
Jenkinsville Water District	Public Supply	Groundwater	0.1	100.0%	0.1	0.0	0.0
Mid County Water Dist #1	Public Supply	Groundwater	0.1	100.0%	0.1	0.0	0.0
Prosperity Town Of	Public Supply	Groundwater	0.02	100.0%	0.02	0.0	0.0
V.C. Summer	Thermoelectric	Surface Water	711.1	15.7%	111.5	599.5	599.5
Chemtrade Performance Chemicals, Us LLP Leeds Plant	Thermoelectric	Groundwater	0.01	100.0%	0.01	0.0	0.0

Table B-2. Permit and Registration Amounts for Current Water Users.

User	Use Category	Water Source	Permit or Registration	Permit or Registration Amount (MGD)	Permit or Registration Amount (MGM)	Permit or Registration Amount (MGY)
Carolina CC	Golf Course	Surface Water	Permit	1.6	49.1	589.2
CC of Spartanburg	Golf Course	Surface Water	Permit	2.3	71.4	856.8
Fox Run CC	Golf Course	Surface Water	Permit	0.6	19.0	228.0
Holly Tree	Golf Course	Surface Water	Permit	0.2	6.3	75.0
Links O'Tryon	Golf Course	Surface Water	Permit	0.4	11.8	142.0
Mid Carolina	Golf Course	Surface Water	Permit	1.1	32.4	388.4
Musgrove Mill	Golf Course	Surface Water	Permit	0.8	24.6	294.6
Pebble Creek	Golf Course	Surface Water	Permit	4.1	125.0	1,499.6
Willow Creek	Golf Course	Surface Water	Permit	1.1	33.5	401.8
Carlisle Finishing	Manufacturing	Surface Water	Permit	5.9	178.6	2,142.7
Chemtrade	Manufacturing	Surface Water	Permit	0.7	22.3	267.8
Milliken	Manufacturing	Surface Water	Permit	7.6	232.0	2,784.0
Fisher Bros	Agriculture	Surface Water	Registration	7.2	220.0	495.0
Hyder Austin	Agriculture	Surface Water	Registration	0.7	19.9	21.85
Walden Farm	Agriculture	Surface Water	Registration	0.9	27.0	297.0
Vulcan	Mining	Surface Water	Permit	3.9	118.9	1,426.8
V.C. Summer	Thermoelectric	Surface Water	Permit	862.8	26,243.9	314,926.3
Clinton	Public Supply	Surface Water	Permit	13.6	415.0	4,980.0
Columbia	Public Supply	Surface Water	Permit	127.4	3,875.0	46,500.0
Gaffney	Public Supply	Surface Water	Permit	41.8	1,272.0	15,264.6
Greer	Public Supply	Surface Water	Permit	55.3	1,682.9	20,194.3
ICWD	Public Supply	Surface Water	Permit	8.2	248.0	2,976.0
Landrum	Public Supply	Surface Water	Permit	1.3	39.1	468.7
SJWD	Public Supply	Surface Water	Permit	58.1	1,767.0	21,204.0
Spartanburg	Public Supply	Surface Water	Permit	278.2	8,463.0	101,556.0

Table B-2. Permit and Registration Amounts for Current Water Users.

User	Use Category	Water Source	Permit or Registration	Permit or Registration Amount (MGD)	Permit or Registration Amount (MGM)	Permit or Registration Amount (MGY)
Tryon	Public Supply	Surface Water	Permit	0.5	15.2	182.5
Union	Public Supply	Surface Water	Permit	14.7	446.0	5,352.0
Whitmire	Public Supply	Surface Water	Permit	3.3	99.2	1,190.4
Winnsboro	Public Supply	Surface Water	Permit	16.3	496.0	5,952.0
Woodruff-Roebuck	Public Supply	Surface Water	Permit	18.3	558.0	6,696.0
York	Public Supply	Surface Water	Permit	3.1	93.0	1,116.0

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Carolina CC	Surface Water	GC	Moderate	2025	0.1
Carolina CC	Surface Water	GC	Moderate	2030	0.1
Carolina CC	Surface Water	GC	Moderate	2035	0.1
Carolina CC	Surface Water	GC	Moderate	2040	0.1
Carolina CC	Surface Water	GC	Moderate	2050	0.1
Carolina CC	Surface Water	GC	Moderate	2060	0.1
Carolina CC	Surface Water	GC	Moderate	2070	0.1
CC of Spartanburg	Surface Water	GC	Moderate	2025	0.2
CC of Spartanburg	Surface Water	GC	Moderate	2030	0.2
CC of Spartanburg	Surface Water	GC	Moderate	2035	0.2
CC of Spartanburg	Surface Water	GC	Moderate	2040	0.2
CC of Spartanburg	Surface Water	GC	Moderate	2050	0.2
CC of Spartanburg	Surface Water	GC	Moderate	2060	0.2
CC of Spartanburg	Surface Water	GC	Moderate	2070	0.2
Fox Run CC	Surface Water	GC	Moderate	2025	0.03
Fox Run CC	Surface Water	GC	Moderate	2030	0.03
Fox Run CC	Surface Water	GC	Moderate	2035	0.03
Fox Run CC	Surface Water	GC	Moderate	2040	0.03
Fox Run CC	Surface Water	GC	Moderate	2050	0.03
Fox Run CC	Surface Water	GC	Moderate	2060	0.03
Fox Run CC	Surface Water	GC	Moderate	2070	0.03
Holly Tree	Surface Water	GC	Moderate	2025	0.04
Holly Tree	Surface Water	GC	Moderate	2030	0.04
Holly Tree	Surface Water	GC	Moderate	2035	0.04
Holly Tree	Surface Water	GC	Moderate	2040	0.04
Holly Tree	Surface Water	GC	Moderate	2050	0.04
Holly Tree	Surface Water	GC	Moderate	2060	0.04
Holly Tree	Surface Water	GC	Moderate	2070	0.04
Links O'Tryon	Surface Water	GC	Moderate	2025	0.01
Links O'Tryon	Surface Water	GC	Moderate	2030	0.01
Links O'Tryon	Surface Water	GC	Moderate	2035	0.01
Links O'Tryon	Surface Water	GC	Moderate	2040	0.01
Links O'Tryon	Surface Water	GC	Moderate	2050	0.01

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Links O'Tryon	Surface Water	GC	Moderate	2060	0.01
Links O'Tryon	Surface Water	GC	Moderate	2070	0.01
Mid Carolina	Surface Water	GC	Moderate	2025	0.04
Mid Carolina	Surface Water	GC	Moderate	2030	0.04
Mid Carolina	Surface Water	GC	Moderate	2035	0.04
Mid Carolina	Surface Water	GC	Moderate	2040	0.04
Mid Carolina	Surface Water	GC	Moderate	2050	0.04
Mid Carolina	Surface Water	GC	Moderate	2060	0.04
Mid Carolina	Surface Water	GC	Moderate	2070	0.04
Musgrove Mill	Surface Water	GC	Moderate	2025	0.03
Musgrove Mill	Surface Water	GC	Moderate	2030	0.03
Musgrove Mill	Surface Water	GC	Moderate	2035	0.03
Musgrove Mill	Surface Water	GC	Moderate	2040	0.03
Musgrove Mill	Surface Water	GC	Moderate	2050	0.03
Musgrove Mill	Surface Water	GC	Moderate	2060	0.03
Musgrove Mill	Surface Water	GC	Moderate	2070	0.03
Pebble Creek	Surface Water	GC	Moderate	2025	0.4
Pebble Creek	Surface Water	GC	Moderate	2030	0.4
Pebble Creek	Surface Water	GC	Moderate	2035	0.4
Pebble Creek	Surface Water	GC	Moderate	2040	0.4
Pebble Creek	Surface Water	GC	Moderate	2050	0.4
Pebble Creek	Surface Water	GC	Moderate	2060	0.4
Pebble Creek	Surface Water	GC	Moderate	2070	0.4
Willow Creek	Surface Water	GC	Moderate	2025	0.1
Willow Creek	Surface Water	GC	Moderate	2030	0.1
Willow Creek	Surface Water	GC	Moderate	2035	0.1
Willow Creek	Surface Water	GC	Moderate	2040	0.1
Willow Creek	Surface Water	GC	Moderate	2050	0.1
Willow Creek	Surface Water	GC	Moderate	2060	0.1
Willow Creek	Surface Water	GC	Moderate	2070	0.1
Woodfin Ridge Golf Club	Groundwater	GC	Moderate	2025	0.01
Woodfin Ridge Golf Club	Groundwater	GC	Moderate	2030	0.01
Woodfin Ridge Golf Club	Groundwater	GC	Moderate	2035	0.01

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Woodfin Ridge Golf Club	Groundwater	GC	Moderate	2040	0.01
Woodfin Ridge Golf Club	Groundwater	GC	Moderate	2050	0.01
Woodfin Ridge Golf Club	Groundwater	GC	Moderate	2060	0.01
Woodfin Ridge Golf Club	Groundwater	GC	Moderate	2070	0.01
York City Of	Groundwater	GC	Moderate	2025	0.01
York City Of	Groundwater	GC	Moderate	2030	0.01
York City Of	Groundwater	GC	Moderate	2035	0.01
York City Of	Groundwater	GC	Moderate	2040	0.01
York City Of	Groundwater	GC	Moderate	2050	0.01
York City Of	Groundwater	GC	Moderate	2060	0.01
York City Of	Groundwater	GC	Moderate	2070	0.01
Carlisle Finishing	Surface Water	IN	Moderate	2025	0.6
Carlisle Finishing	Surface Water	IN	Moderate	2030	0.6
Carlisle Finishing	Surface Water	IN	Moderate	2035	0.6
Carlisle Finishing	Surface Water	IN	Moderate	2040	0.6
Carlisle Finishing	Surface Water	IN	Moderate	2050	0.6
Carlisle Finishing	Surface Water	IN	Moderate	2060	0.6
Carlisle Finishing	Surface Water	IN	Moderate	2070	0.7
Chemtrade	Surface Water	IN	Moderate	2025	0.1
Chemtrade	Surface Water	IN	Moderate	2030	0.1
Chemtrade	Surface Water	IN	Moderate	2035	0.1
Chemtrade	Surface Water	IN	Moderate	2040	0.1
Chemtrade	Surface Water	IN	Moderate	2050	0.2
Chemtrade	Surface Water	IN	Moderate	2060	0.2
Chemtrade	Surface Water	IN	Moderate	2070	0.2
Milliken	Surface Water	IN	Moderate	2025	2.9
Milliken	Surface Water	IN	Moderate	2030	3.1
Milliken	Surface Water	IN	Moderate	2035	3.3
Milliken	Surface Water	IN	Moderate	2040	3.5
Milliken	Surface Water	IN	Moderate	2050	3.8
Milliken	Surface Water	IN	Moderate	2060	4.3
Milliken	Surface Water	IN	Moderate	2070	4.9

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Walden Farm	Surface Water	IR	Moderate	2025	0.3
Walden Farm	Surface Water	IR	Moderate	2030	0.3
Walden Farm	Surface Water	IR	Moderate	2035	0.3
Walden Farm	Surface Water	IR	Moderate	2040	0.3
Walden Farm	Surface Water	IR	Moderate	2050	0.3
Walden Farm	Surface Water	IR	Moderate	2060	0.3
Walden Farm	Surface Water	IR	Moderate	2070	0.3
Vulcan	Surface Water	MI	Moderate	2025	0.04
Vulcan	Surface Water	MI	Moderate	2030	0.04
Vulcan	Surface Water	MI	Moderate	2035	0.04
Vulcan	Surface Water	MI	Moderate	2040	0.04
Vulcan	Surface Water	MI	Moderate	2050	0.04
Vulcan	Surface Water	MI	Moderate	2060	0.04
Vulcan	Surface Water	MI	Moderate	2070	0.04
V.C. Summer	Surface Water	PN	Moderate	2025	739.1
V.C. Summer	Surface Water	PN	Moderate	2030	739.1
V.C. Summer	Surface Water	PN	Moderate	2035	739.1
V.C. Summer	Surface Water	PN	Moderate	2040	737.2
V.C. Summer	Surface Water	PN	Moderate	2050	739.1
V.C. Summer	Surface Water	PN	Moderate	2060	737.2
V.C. Summer	Surface Water	PN	Moderate	2070	739.1
Lee	Surface Water	PT	Moderate	2025	0
Lee	Surface Water	PT	Moderate	2030	0
Lee	Surface Water	PT	Moderate	2035	17.9
Lee	Surface Water	PT	Moderate	2040	17.9
Lee	Surface Water	PT	Moderate	2050	26.9
Lee	Surface Water	PT	Moderate	2060	35.8
Lee	Surface Water	PT	Moderate	2070	35.8
Blue Ridge Rural Water Co., Inc./Cliffs at Glassy	Groundwater	PT	Moderate	2025	0.1
Blue Ridge Rural Water Co., Inc./Cliffs at Glassy	Groundwater	PT	Moderate	2030	0.1
Blue Ridge Rural Water Co., Inc./Cliffs at Glassy	Groundwater	PT	Moderate	2035	0.1

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Blue Ridge Rural Water Co., Inc./Cliffs at Glassy	Groundwater	PT	Moderate	2040	0.1
Blue Ridge Rural Water Co., Inc./Cliffs at Glassy	Groundwater	PT	Moderate	2050	0.1
Blue Ridge Rural Water Co., Inc./Cliffs at Glassy	Groundwater	PT	Moderate	2060	0.1
Blue Ridge Rural Water Co., Inc./Cliffs at Glassy	Groundwater	PT	Moderate	2070	0.1
Clinton	Surface Water	WS	Moderate	2025	2.7
Clinton	Surface Water	WS	Moderate	2030	2.7
Clinton	Surface Water	WS	Moderate	2035	2.7
Clinton	Surface Water	WS	Moderate	2040	2.7
Clinton	Surface Water	WS	Moderate	2050	2.7
Clinton	Surface Water	WS	Moderate	2060	2.7
Clinton	Surface Water	WS	Moderate	2070	2.7
Columbia	Surface Water	WS	Moderate	2025	32.6
Columbia	Surface Water	WS	Moderate	2030	33.7
Columbia	Surface Water	WS	Moderate	2035	34.7
Columbia	Surface Water	WS	Moderate	2040	35.8
Columbia	Surface Water	WS	Moderate	2050	37.9
Columbia	Surface Water	WS	Moderate	2060	40.1
Columbia	Surface Water	WS	Moderate	2070	42.2
Gaffney	Surface Water	WS	Moderate	2025	9.2
Gaffney	Surface Water	WS	Moderate	2030	9.3
Gaffney	Surface Water	WS	Moderate	2035	9.4
Gaffney	Surface Water	WS	Moderate	2040	9.5
Gaffney	Surface Water	WS	Moderate	2050	9.7
Gaffney	Surface Water	WS	Moderate	2060	10.0
Gaffney	Surface Water	WS	Moderate	2070	10.2
Greer	Surface Water	WS	Moderate	2025	9.9
Greer	Surface Water	WS	Moderate	2030	10.6
Greer	Surface Water	WS	Moderate	2035	11.4
Greer	Surface Water	WS	Moderate	2040	12.1
Greer	Surface Water	WS	Moderate	2050	13.5

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Greer	Surface Water	WS	Moderate	2060	15.0
Greer	Surface Water	WS	Moderate	2070	16.4
ICWD	Surface Water	WS	Moderate	2025	0.3
ICWD	Surface Water	WS	Moderate	2030	0.8
ICWD	Surface Water	WS	Moderate	2035	1.3
ICWD	Surface Water	WS	Moderate	2040	1.9
ICWD	Surface Water	WS	Moderate	2050	3.3
ICWD	Surface Water	WS	Moderate	2060	4.7
ICWD	Surface Water	WS	Moderate	2070	6.1
Landrum	Surface Water	WS	Moderate	2025	0.5
Landrum	Surface Water	WS	Moderate	2030	0.5
Landrum	Surface Water	WS	Moderate	2035	0.5
Landrum	Surface Water	WS	Moderate	2040	0.6
Landrum	Surface Water	WS	Moderate	2050	0.6
Landrum	Surface Water	WS	Moderate	2060	0.7
Landrum	Surface Water	WS	Moderate	2070	0.8
SJWD	Surface Water	WS	Moderate	2025	8.7
SJWD	Surface Water	WS	Moderate	2030	9.4
SJWD	Surface Water	WS	Moderate	2035	10.0
SJWD	Surface Water	WS	Moderate	2040	10.7
SJWD	Surface Water	WS	Moderate	2050	11.9
SJWD	Surface Water	WS	Moderate	2060	13.2
SJWD	Surface Water	WS	Moderate	2070	14.5
Spartanburg	Surface Water	WS	Moderate	2025	27.8
Spartanburg	Surface Water	WS	Moderate	2030	29.7
Spartanburg	Surface Water	WS	Moderate	2035	31.8
Spartanburg	Surface Water	WS	Moderate	2040	33.8
Spartanburg	Surface Water	WS	Moderate	2050	37.8
Spartanburg	Surface Water	WS	Moderate	2060	41.8
Spartanburg	Surface Water	WS	Moderate	2070	45.7
Union	Surface Water	WS	Moderate	2025	3.0
Union	Surface Water	WS	Moderate	2030	2.9
Union	Surface Water	WS	Moderate	2035	2.8

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Union	Surface Water	WS	Moderate	2040	2.8
Union	Surface Water	WS	Moderate	2050	2.8
Union	Surface Water	WS	Moderate	2060	2.8
Union	Surface Water	WS	Moderate	2070	2.8
Whitmire	Surface Water	WS	Moderate	2025	0.3
Whitmire	Surface Water	WS	Moderate	2030	0.3
Whitmire	Surface Water	WS	Moderate	2035	0.3
Whitmire	Surface Water	WS	Moderate	2040	0.3
Whitmire	Surface Water	WS	Moderate	2050	0.4
Whitmire	Surface Water	WS	Moderate	2060	0.4
Whitmire	Surface Water	WS	Moderate	2070	0.4
Winnsboro	Surface Water	WS	Moderate	2025	1.7
Winnsboro	Surface Water	WS	Moderate	2030	1.6
Winnsboro	Surface Water	WS	Moderate	2035	1.5
Winnsboro	Surface Water	WS	Moderate	2040	1.5
Winnsboro	Surface Water	WS	Moderate	2050	1.5
Winnsboro	Surface Water	WS	Moderate	2060	1.5
Winnsboro	Surface Water	WS	Moderate	2070	1.5
Woodruff-Roebuck	Surface Water	WS	Moderate	2025	3.3
Woodruff-Roebuck	Surface Water	WS	Moderate	2030	3.5
Woodruff-Roebuck	Surface Water	WS	Moderate	2035	3.8
Woodruff-Roebuck	Surface Water	WS	Moderate	2040	4.0
Woodruff-Roebuck	Surface Water	WS	Moderate	2050	4.5
Woodruff-Roebuck	Surface Water	WS	Moderate	2060	5.0
Woodruff-Roebuck	Surface Water	WS	Moderate	2070	5.4
York	Surface Water	WS	Moderate	2025	0.5
York	Surface Water	WS	Moderate	2030	0.6
York	Surface Water	WS	Moderate	2035	0.7
York	Surface Water	WS	Moderate	2040	0.7
York	Surface Water	WS	Moderate	2050	0.9
York	Surface Water	WS	Moderate	2060	1.0
York	Surface Water	WS	Moderate	2070	1.1

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Chemtrade Performance Chemicals, US LLP Leeds Plant	Groundwater	WS	Moderate	2025	0.01
Chemtrade Performance Chemicals, US LLP Leeds Plant	Groundwater	WS	Moderate	2030	0.01
Chemtrade Performance Chemicals, US LLP Leeds Plant	Groundwater	WS	Moderate	2035	0.01
Chemtrade Performance Chemicals, US LLP Leeds Plant	Groundwater	WS	Moderate	2040	0.01
Chemtrade Performance Chemicals, US LLP Leeds Plant	Groundwater	WS	Moderate	2050	0.01
Chemtrade Performance Chemicals, US LLP Leeds Plant	Groundwater	WS	Moderate	2060	0.01
Chemtrade Performance Chemicals, US LLP Leeds Plant	Groundwater	WS	Moderate	2070	0.01
Cobblestone Park Golf Club	Groundwater	WS	Moderate	2025	0.003
Cobblestone Park Golf Club	Groundwater	WS	Moderate	2030	0.003
Cobblestone Park Golf Club	Groundwater	WS	Moderate	2035	0.003
Cobblestone Park Golf Club	Groundwater	WS	Moderate	2040	0.003
Cobblestone Park Golf Club	Groundwater	WS	Moderate	2050	0.003
Cobblestone Park Golf Club	Groundwater	WS	Moderate	2060	0.003
Cobblestone Park Golf Club	Groundwater	WS	Moderate	2070	0.003
Country Club Of Spartanburg	Groundwater	WS	Moderate	2025	0.04
Country Club Of Spartanburg	Groundwater	WS	Moderate	2030	0.04
Country Club Of Spartanburg	Groundwater	WS	Moderate	2035	0.04
Country Club Of Spartanburg	Groundwater	WS	Moderate	2040	0.04
Country Club Of Spartanburg	Groundwater	WS	Moderate	2050	0.04
Country Club Of Spartanburg	Groundwater	WS	Moderate	2060	0.04
Country Club Of Spartanburg	Groundwater	WS	Moderate	2070	0.04
Fox Run Country Club	Groundwater	WS	Moderate	2025	0.00
Fox Run Country Club	Groundwater	WS	Moderate	2030	0.00
Fox Run Country Club	Groundwater	WS	Moderate	2035	0.00

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Fox Run Country Club	Groundwater	WS	Moderate	2040	0.00
Fox Run Country Club	Groundwater	WS	Moderate	2050	0.00
Fox Run Country Club	Groundwater	WS	Moderate	2060	0.00
Fox Run Country Club	Groundwater	WS	Moderate	2070	0.00
GE (Greenville) Gas Turbines, LLC	Groundwater	WS	Moderate	2025	0.2
GE (Greenville) Gas Turbines, LLC	Groundwater	WS	Moderate	2030	0.2
GE (Greenville) Gas Turbines, LLC	Groundwater	WS	Moderate	2035	0.2
GE (Greenville) Gas Turbines, LLC	Groundwater	WS	Moderate	2040	0.2
GE (Greenville) Gas Turbines, LLC	Groundwater	WS	Moderate	2050	0.2
GE (Greenville) Gas Turbines, LLC	Groundwater	WS	Moderate	2060	0.2
GE (Greenville) Gas Turbines, LLC	Groundwater	WS	Moderate	2070	0.2
Grassy Pond Water District	Groundwater	WS	Moderate	2025	0.1
Grassy Pond Water District	Groundwater	WS	Moderate	2030	0.1
Grassy Pond Water District	Groundwater	WS	Moderate	2035	0.1
Grassy Pond Water District	Groundwater	WS	Moderate	2040	0.1
Grassy Pond Water District	Groundwater	WS	Moderate	2050	0.1
Grassy Pond Water District	Groundwater	WS	Moderate	2060	0.1
Grassy Pond Water District	Groundwater	WS	Moderate	2070	0.1
Heddles Hideaway Country Club	Groundwater	WS	Moderate	2025	0.003
Heddles Hideaway Country Club	Groundwater	WS	Moderate	2030	0.003
Heddles Hideaway Country Club	Groundwater	WS	Moderate	2035	0.003
Heddles Hideaway Country Club	Groundwater	WS	Moderate	2040	0.003
Heddles Hideaway Country Club	Groundwater	WS	Moderate	2050	0.003
Heddles Hideaway Country Club	Groundwater	WS	Moderate	2060	0.003
Heddles Hideaway Country Club	Groundwater	WS	Moderate	2070	0.003

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Inman Mills Water District SJWD	Groundwater	WS	Moderate	2025	0.1
Inman Mills Water District SJWD	Groundwater	WS	Moderate	2030	0.1
Inman Mills Water District SJWD	Groundwater	WS	Moderate	2035	0.1
Inman Mills Water District SJWD	Groundwater	WS	Moderate	2040	0.1
Inman Mills Water District SJWD	Groundwater	WS	Moderate	2050	0.1
Inman Mills Water District SJWD	Groundwater	WS	Moderate	2060	0.1
Inman Mills Water District SJWD	Groundwater	WS	Moderate	2070	0.1
Jenkinsville Water District	Groundwater	WS	Moderate	2025	0.1
Jenkinsville Water District	Groundwater	WS	Moderate	2030	0.1
Jenkinsville Water District	Groundwater	WS	Moderate	2035	0.1
Jenkinsville Water District	Groundwater	WS	Moderate	2040	0.1
Jenkinsville Water District	Groundwater	WS	Moderate	2050	0.1
Jenkinsville Water District	Groundwater	WS	Moderate	2060	0.1
Jenkinsville Water District	Groundwater	WS	Moderate	2070	0.1
Mid County Water Dist #1	Groundwater	WS	Moderate	2025	0.1
Mid County Water Dist #1	Groundwater	WS	Moderate	2030	0.1
Mid County Water Dist #1	Groundwater	WS	Moderate	2035	0.1
Mid County Water Dist #1	Groundwater	WS	Moderate	2040	0.1
Mid County Water Dist #1	Groundwater	WS	Moderate	2050	0.1
Mid County Water Dist #1	Groundwater	WS	Moderate	2060	0.1
Mid County Water Dist #1	Groundwater	WS	Moderate	2070	0.1
Prosperity Town Of	Groundwater	WS	Moderate	2025	0.0
Prosperity Town Of	Groundwater	WS	Moderate	2030	0.02
Prosperity Town Of	Groundwater	WS	Moderate	2035	0.02
Prosperity Town Of	Groundwater	WS	Moderate	2040	0.02
Prosperity Town Of	Groundwater	WS	Moderate	2050	0.02
Prosperity Town Of	Groundwater	WS	Moderate	2060	0.02
Prosperity Town Of	Groundwater	WS	Moderate	2070	0.02

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Richland County Rec Comm Linrick GC	Groundwater	WS	Moderate	2025	0.01
Richland County Rec Comm Linrick GC	Groundwater	WS	Moderate	2030	0.01
Richland County Rec Comm Linrick GC	Groundwater	WS	Moderate	2035	0.01
Richland County Rec Comm Linrick GC	Groundwater	WS	Moderate	2040	0.01
Richland County Rec Comm Linrick GC	Groundwater	WS	Moderate	2050	0.01
Richland County Rec Comm Linrick GC	Groundwater	WS	Moderate	2060	0.01
Richland County Rec Comm Linrick GC	Groundwater	WS	Moderate	2070	0.01
Timken Company/Tyger River Plant	Groundwater	WS	Moderate	2025	0.01
Timken Company/Tyger River Plant	Groundwater	WS	Moderate	2030	0.01
Timken Company/Tyger River Plant	Groundwater	WS	Moderate	2035	0.01
Timken Company/Tyger River Plant	Groundwater	WS	Moderate	2040	0.01
Timken Company/Tyger River Plant	Groundwater	WS	Moderate	2050	0.01
Timken Company/Tyger River Plant	Groundwater	WS	Moderate	2060	0.01
Timken Company/Tyger River Plant	Groundwater	WS	Moderate	2070	0.01
Willow Creek GC	Groundwater	WS	Moderate	2025	0.02
Willow Creek GC	Groundwater	WS	Moderate	2030	0.02
Willow Creek GC	Groundwater	WS	Moderate	2035	0.02
Willow Creek GC	Groundwater	WS	Moderate	2040	0.02
Willow Creek GC	Groundwater	WS	Moderate	2050	0.02
Willow Creek GC	Groundwater	WS	Moderate	2060	0.02
Willow Creek GC	Groundwater	WS	Moderate	2070	0.02
Carolina CC	Surface Water	GC	High Demand	2025	0.1
Carolina CC	Surface Water	GC	High Demand	2030	0.1
Carolina CC	Surface Water	GC	High Demand	2035	0.1
Carolina CC	Surface Water	GC	High Demand	2040	0.1

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Carolina CC	Surface Water	GC	High Demand	2050	0.1
Carolina CC	Surface Water	GC	High Demand	2060	0.1
Carolina CC	Surface Water	GC	High Demand	2070	0.1
CC of Spartanburg	Surface Water	GC	High Demand	2025	0.4
CC of Spartanburg	Surface Water	GC	High Demand	2030	0.4
CC of Spartanburg	Surface Water	GC	High Demand	2035	0.4
CC of Spartanburg	Surface Water	GC	High Demand	2040	0.4
CC of Spartanburg	Surface Water	GC	High Demand	2050	0.4
CC of Spartanburg	Surface Water	GC	High Demand	2060	0.4
CC of Spartanburg	Surface Water	GC	High Demand	2070	0.4
Fox Run CC	Surface Water	GC	High Demand	2025	0.1
Fox Run CC	Surface Water	GC	High Demand	2030	0.1
Fox Run CC	Surface Water	GC	High Demand	2035	0.1
Fox Run CC	Surface Water	GC	High Demand	2040	0.1
Fox Run CC	Surface Water	GC	High Demand	2050	0.1
Fox Run CC	Surface Water	GC	High Demand	2060	0.1
Fox Run CC	Surface Water	GC	High Demand	2070	0.1
Holly Tree	Surface Water	GC	High Demand	2025	0.1
Holly Tree	Surface Water	GC	High Demand	2030	0.1
Holly Tree	Surface Water	GC	High Demand	2035	0.1
Holly Tree	Surface Water	GC	High Demand	2040	0.1
Holly Tree	Surface Water	GC	High Demand	2050	0.1
Holly Tree	Surface Water	GC	High Demand	2060	0.1
Holly Tree	Surface Water	GC	High Demand	2070	0.1
Links O'Tryon	Surface Water	GC	High Demand	2025	0.1
Links O'Tryon	Surface Water	GC	High Demand	2030	0.1
Links O'Tryon	Surface Water	GC	High Demand	2035	0.1
Links O'Tryon	Surface Water	GC	High Demand	2040	0.1
Links O'Tryon	Surface Water	GC	High Demand	2050	0.1
Links O'Tryon	Surface Water	GC	High Demand	2060	0.1
Links O'Tryon	Surface Water	GC	High Demand	2070	0.1
Mid Carolina	Surface Water	GC	High Demand	2025	0.1
Mid Carolina	Surface Water	GC	High Demand	2030	0.1

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Mid Carolina	Surface Water	GC	High Demand	2035	0.1
Mid Carolina	Surface Water	GC	High Demand	2040	0.1
Mid Carolina	Surface Water	GC	High Demand	2050	0.1
Mid Carolina	Surface Water	GC	High Demand	2060	0.1
Mid Carolina	Surface Water	GC	High Demand	2070	0.1
Musgrove Mill	Surface Water	GC	High Demand	2025	0.1
Musgrove Mill	Surface Water	GC	High Demand	2030	0.1
Musgrove Mill	Surface Water	GC	High Demand	2035	0.1
Musgrove Mill	Surface Water	GC	High Demand	2040	0.1
Musgrove Mill	Surface Water	GC	High Demand	2050	0.1
Musgrove Mill	Surface Water	GC	High Demand	2060	0.1
Musgrove Mill	Surface Water	GC	High Demand	2070	0.1
Pebble Creek	Surface Water	GC	High Demand	2025	0.6
Pebble Creek	Surface Water	GC	High Demand	2030	0.6
Pebble Creek	Surface Water	GC	High Demand	2035	0.6
Pebble Creek	Surface Water	GC	High Demand	2040	0.6
Pebble Creek	Surface Water	GC	High Demand	2050	0.6
Pebble Creek	Surface Water	GC	High Demand	2060	0.6
Pebble Creek	Surface Water	GC	High Demand	2070	0.6
Willow Creek	Surface Water	GC	High Demand	2025	0.2
Willow Creek	Surface Water	GC	High Demand	2030	0.2
Willow Creek	Surface Water	GC	High Demand	2035	0.2
Willow Creek	Surface Water	GC	High Demand	2040	0.2
Willow Creek	Surface Water	GC	High Demand	2050	0.2
Willow Creek	Surface Water	GC	High Demand	2060	0.2
Willow Creek	Surface Water	GC	High Demand	2070	0.2
Woodfin Ridge Golf Club	Groundwater	GC	High Demand	2025	0.01
Woodfin Ridge Golf Club	Groundwater	GC	High Demand	2030	0.01
Woodfin Ridge Golf Club	Groundwater	GC	High Demand	2035	0.01
Woodfin Ridge Golf Club	Groundwater	GC	High Demand	2040	0.01
Woodfin Ridge Golf Club	Groundwater	GC	High Demand	2050	0.01
Woodfin Ridge Golf Club	Groundwater	GC	High Demand	2060	0.01
Woodfin Ridge Golf Club	Groundwater	GC	High Demand	2070	0.01

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
York City Of	Groundwater	GC	High Demand	2025	0.01
York City Of	Groundwater	GC	High Demand	2030	0.01
York City Of	Groundwater	GC	High Demand	2035	0.01
York City Of	Groundwater	GC	High Demand	2040	0.01
York City Of	Groundwater	GC	High Demand	2050	0.01
York City Of	Groundwater	GC	High Demand	2060	0.01
York City Of	Groundwater	GC	High Demand	2070	0.01
Carlisle Finishing	Surface Water	IN	High Demand	2025	1.0
Carlisle Finishing	Surface Water	IN	High Demand	2030	1.1
Carlisle Finishing	Surface Water	IN	High Demand	2035	1.2
Carlisle Finishing	Surface Water	IN	High Demand	2040	1.3
Carlisle Finishing	Surface Water	IN	High Demand	2050	1.7
Carlisle Finishing	Surface Water	IN	High Demand	2060	2.0
Carlisle Finishing	Surface Water	IN	High Demand	2070	2.5
Chemtrade	Surface Water	IN	High Demand	2025	0.3
Chemtrade	Surface Water	IN	High Demand	2030	0.3
Chemtrade	Surface Water	IN	High Demand	2035	0.4
Chemtrade	Surface Water	IN	High Demand	2040	0.4
Chemtrade	Surface Water	IN	High Demand	2050	0.5
Chemtrade	Surface Water	IN	High Demand	2060	0.6
Chemtrade	Surface Water	IN	High Demand	2070	0.8
Milliken	Surface Water	IN	High Demand	2025	3.5
Milliken	Surface Water	IN	High Demand	2030	3.9
Milliken	Surface Water	IN	High Demand	2035	4.3
Milliken	Surface Water	IN	High Demand	2040	4.7
Milliken	Surface Water	IN	High Demand	2050	5.9
Milliken	Surface Water	IN	High Demand	2060	7.2
Milliken	Surface Water	IN	High Demand	2070	8.9
Fisher Bros	Surface Water	IR	High Demand	2025	0.02
Fisher Bros	Surface Water	IR	High Demand	2030	0.02
Fisher Bros	Surface Water	IR	High Demand	2035	0.02
Fisher Bros	Surface Water	IR	High Demand	2040	0.02
Fisher Bros	Surface Water	IR	High Demand	2050	0.02

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Fisher Bros	Surface Water	IR	High Demand	2060	0.02
Fisher Bros	Surface Water	IR	High Demand	2070	0.02
Hyder Austin	Surface Water	IR	High Demand	2025	0.01
Hyder Austin	Surface Water	IR	High Demand	2030	0.01
Hyder Austin	Surface Water	IR	High Demand	2035	0.01
Hyder Austin	Surface Water	IR	High Demand	2040	0.01
Hyder Austin	Surface Water	IR	High Demand	2050	0.01
Hyder Austin	Surface Water	IR	High Demand	2060	0.01
Hyder Austin	Surface Water	IR	High Demand	2070	0.01
Walden Farm	Surface Water	IR	High Demand	2025	0.3
Walden Farm	Surface Water	IR	High Demand	2030	0.3
Walden Farm	Surface Water	IR	High Demand	2035	0.3
Walden Farm	Surface Water	IR	High Demand	2040	0.3
Walden Farm	Surface Water	IR	High Demand	2050	0.3
Walden Farm	Surface Water	IR	High Demand	2060	0.3
Walden Farm	Surface Water	IR	High Demand	2070	0.3
Vulcan	Surface Water	MI	High Demand	2025	0.1
Vulcan	Surface Water	MI	High Demand	2030	0.1
Vulcan	Surface Water	MI	High Demand	2035	0.1
Vulcan	Surface Water	MI	High Demand	2040	0.1
Vulcan	Surface Water	MI	High Demand	2050	0.1
Vulcan	Surface Water	MI	High Demand	2060	0.1
Vulcan	Surface Water	MI	High Demand	2070	0.1
V.C. Summer	Surface Water	PN	High Demand	2025	819.1
V.C. Summer	Surface Water	PN	High Demand	2030	819.1
V.C. Summer	Surface Water	PN	High Demand	2035	819.1
V.C. Summer	Surface Water	PN	High Demand	2040	816.9
V.C. Summer	Surface Water	PN	High Demand	2050	819.1
V.C. Summer	Surface Water	PN	High Demand	2060	816.9
V.C. Summer	Surface Water	PN	High Demand	2070	819.1
Lee	Surface Water	PT	High Demand	2025	0.0
Lee	Surface Water	PT	High Demand	2030	0.0
Lee	Surface Water	PT	High Demand	2035	17.9

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Lee	Surface Water	PT	High Demand	2040	17.9
Lee	Surface Water	PT	High Demand	2050	26.9
Lee	Surface Water	PT	High Demand	2060	35.8
Lee	Surface Water	PT	High Demand	2070	35.8
Blue Ridge Rural Water Co., Inc./Cliffs at Glassy	Groundwater	PT	High Demand	2025	0.1
Blue Ridge Rural Water Co., Inc./Cliffs at Glassy	Groundwater	PT	High Demand	2030	0.1
Blue Ridge Rural Water Co., Inc./Cliffs at Glassy	Groundwater	PT	High Demand	2035	0.1
Blue Ridge Rural Water Co., Inc./Cliffs at Glassy	Groundwater	PT	High Demand	2040	0.1
Blue Ridge Rural Water Co., Inc./Cliffs at Glassy	Groundwater	PT	High Demand	2050	0.1
Blue Ridge Rural Water Co., Inc./Cliffs at Glassy	Groundwater	PT	High Demand	2060	0.1
Blue Ridge Rural Water Co., Inc./Cliffs at Glassy	Groundwater	PT	High Demand	2070	0.1
Clinton	Surface Water	WS	High Demand	2025	3.2
Clinton	Surface Water	WS	High Demand	2030	3.4
Clinton	Surface Water	WS	High Demand	2035	3.6
Clinton	Surface Water	WS	High Demand	2040	3.8
Clinton	Surface Water	WS	High Demand	2050	4.4
Clinton	Surface Water	WS	High Demand	2060	5.0
Clinton	Surface Water	WS	High Demand	2070	5.7
Columbia	Surface Water	WS	High Demand	2025	36.3
Columbia	Surface Water	WS	High Demand	2030	38.7
Columbia	Surface Water	WS	High Demand	2035	41.3
Columbia	Surface Water	WS	High Demand	2040	44.1
Columbia	Surface Water	WS	High Demand	2050	50.2
Columbia	Surface Water	WS	High Demand	2060	57.2
Columbia	Surface Water	WS	High Demand	2070	65.1
Gaffney	Surface Water	WS	High Demand	2025	13.8
Gaffney	Surface Water	WS	High Demand	2030	14.8
Gaffney	Surface Water	WS	High Demand	2035	15.8
Gaffney	Surface Water	WS	High Demand	2040	16.9

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Gaffney	Surface Water	WS	High Demand	2050	19.3
Gaffney	Surface Water	WS	High Demand	2060	22.0
Gaffney	Surface Water	WS	High Demand	2070	25.1
Greer	Surface Water	WS	High Demand	2025	11.2
Greer	Surface Water	WS	High Demand	2030	12.1
Greer	Surface Water	WS	High Demand	2035	13.1
Greer	Surface Water	WS	High Demand	2040	14.1
Greer	Surface Water	WS	High Demand	2050	16.5
Greer	Surface Water	WS	High Demand	2060	19.2
Greer	Surface Water	WS	High Demand	2070	22.4
ICWD	Surface Water	WS	High Demand	2025	4.8
ICWD	Surface Water	WS	High Demand	2030	5.5
ICWD	Surface Water	WS	High Demand	2035	6.2
ICWD	Surface Water	WS	High Demand	2040	6.9
ICWD	Surface Water	WS	High Demand	2050	8.4
ICWD	Surface Water	WS	High Demand	2060	9.8
ICWD	Surface Water	WS	High Demand	2070	11.2
Landrum	Surface Water	WS	High Demand	2025	0.6
Landrum	Surface Water	WS	High Demand	2030	0.6
Landrum	Surface Water	WS	High Demand	2035	0.7
Landrum	Surface Water	WS	High Demand	2040	0.7
Landrum	Surface Water	WS	High Demand	2050	0.8
Landrum	Surface Water	WS	High Demand	2060	1.0
Landrum	Surface Water	WS	High Demand	2070	1.1
SJWD	Surface Water	WS	High Demand	2025	12.5
SJWD	Surface Water	WS	High Demand	2030	13.5
SJWD	Surface Water	WS	High Demand	2035	14.6
SJWD	Surface Water	WS	High Demand	2040	15.8
SJWD	Surface Water	WS	High Demand	2050	18.4
SJWD	Surface Water	WS	High Demand	2060	21.5
SJWD	Surface Water	WS	High Demand	2070	25.1
Spartanburg	Surface Water	WS	High Demand	2025	31.0
Spartanburg	Surface Water	WS	High Demand	2030	33.5

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Spartanburg	Surface Water	WS	High Demand	2035	36.2
Spartanburg	Surface Water	WS	High Demand	2040	39.1
Spartanburg	Surface Water	WS	High Demand	2050	45.6
Spartanburg	Surface Water	WS	High Demand	2060	53.2
Spartanburg	Surface Water	WS	High Demand	2070	62.1
Union	Surface Water	WS	High Demand	2025	3.7
Union	Surface Water	WS	High Demand	2030	4.0
Union	Surface Water	WS	High Demand	2035	4.2
Union	Surface Water	WS	High Demand	2040	4.5
Union	Surface Water	WS	High Demand	2050	5.2
Union	Surface Water	WS	High Demand	2060	5.9
Union	Surface Water	WS	High Demand	2070	6.7
Whitmire	Surface Water	WS	High Demand	2025	0.4
Whitmire	Surface Water	WS	High Demand	2030	0.5
Whitmire	Surface Water	WS	High Demand	2035	0.5
Whitmire	Surface Water	WS	High Demand	2040	0.5
Whitmire	Surface Water	WS	High Demand	2050	0.6
Whitmire	Surface Water	WS	High Demand	2060	0.7
Whitmire	Surface Water	WS	High Demand	2070	0.8
Winnsboro	Surface Water	WS	High Demand	2025	3.2
Winnsboro	Surface Water	WS	High Demand	2030	3.4
Winnsboro	Surface Water	WS	High Demand	2035	3.7
Winnsboro	Surface Water	WS	High Demand	2040	3.9
Winnsboro	Surface Water	WS	High Demand	2050	4.4
Winnsboro	Surface Water	WS	High Demand	2060	5.1
Winnsboro	Surface Water	WS	High Demand	2070	5.8
Woodruff-Roebuck	Surface Water	WS	High Demand	2025	3.6
Woodruff-Roebuck	Surface Water	WS	High Demand	2030	3.9
Woodruff-Roebuck	Surface Water	WS	High Demand	2035	4.2
Woodruff-Roebuck	Surface Water	WS	High Demand	2040	4.5
Woodruff-Roebuck	Surface Water	WS	High Demand	2050	5.3
Woodruff-Roebuck	Surface Water	WS	High Demand	2060	6.2
Woodruff-Roebuck	Surface Water	WS	High Demand	2070	7.2

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
York	Surface Water	WS	High Demand	2025	1.4
York	Surface Water	WS	High Demand	2030	1.6
York	Surface Water	WS	High Demand	2035	1.8
York	Surface Water	WS	High Demand	2040	2.1
York	Surface Water	WS	High Demand	2050	2.8
York	Surface Water	WS	High Demand	2060	3.6
York	Surface Water	WS	High Demand	2070	4.8
Chemtrade Performance Chemicals, US LLP Leeds Plant	Groundwater	WS	High Demand	2025	0.01
Chemtrade Performance Chemicals, US LLP Leeds Plant	Groundwater	WS	High Demand	2030	0.01
Chemtrade Performance Chemicals, US LLP Leeds Plant	Groundwater	WS	High Demand	2035	0.01
Chemtrade Performance Chemicals, US LLP Leeds Plant	Groundwater	WS	High Demand	2040	0.01
Chemtrade Performance Chemicals, US LLP Leeds Plant	Groundwater	WS	High Demand	2050	0.01
Chemtrade Performance Chemicals, US LLP Leeds Plant	Groundwater	WS	High Demand	2060	0.01
Chemtrade Performance Chemicals, US LLP Leeds Plant	Groundwater	WS	High Demand	2070	0.01
Cobblestone Park Golf Club	Groundwater	WS	High Demand	2025	0.003
Cobblestone Park Golf Club	Groundwater	WS	High Demand	2030	0.003
Cobblestone Park Golf Club	Groundwater	WS	High Demand	2035	0.003
Cobblestone Park Golf Club	Groundwater	WS	High Demand	2040	0.003
Cobblestone Park Golf Club	Groundwater	WS	High Demand	2050	0.003
Cobblestone Park Golf Club	Groundwater	WS	High Demand	2060	0.003
Cobblestone Park Golf Club	Groundwater	WS	High Demand	2070	0.003
Country Club Of Spartanburg	Groundwater	WS	High Demand	2025	0.04
Country Club Of Spartanburg	Groundwater	WS	High Demand	2030	0.04
Country Club Of Spartanburg	Groundwater	WS	High Demand	2035	0.04

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Country Club Of Spartanburg	Groundwater	WS	High Demand	2040	0.04
Country Club Of Spartanburg	Groundwater	WS	High Demand	2050	0.04
Country Club Of Spartanburg	Groundwater	WS	High Demand	2060	0.04
Country Club Of Spartanburg	Groundwater	WS	High Demand	2070	0.04
Fox Run Country Club	Groundwater	WS	High Demand	2025	0.003
Fox Run Country Club	Groundwater	WS	High Demand	2030	0.003
Fox Run Country Club	Groundwater	WS	High Demand	2035	0.003
Fox Run Country Club	Groundwater	WS	High Demand	2040	0.003
Fox Run Country Club	Groundwater	WS	High Demand	2050	0.003
Fox Run Country Club	Groundwater	WS	High Demand	2060	0.003
Fox Run Country Club	Groundwater	WS	High Demand	2070	0.003
GE (Greenville) Gas Turbines, LLC	Groundwater	WS	High Demand	2025	0.2
GE (Greenville) Gas Turbines, LLC	Groundwater	WS	High Demand	2030	0.2
GE (Greenville) Gas Turbines, LLC	Groundwater	WS	High Demand	2035	0.2
GE (Greenville) Gas Turbines, LLC	Groundwater	WS	High Demand	2040	0.2
GE (Greenville) Gas Turbines, LLC	Groundwater	WS	High Demand	2050	0.2
GE (Greenville) Gas Turbines, LLC	Groundwater	WS	High Demand	2060	0.2
GE (Greenville) Gas Turbines, LLC	Groundwater	WS	High Demand	2070	0.2
Grassy Pond Water District	Groundwater	WS	High Demand	2025	0.1
Grassy Pond Water District	Groundwater	WS	High Demand	2030	0.1
Grassy Pond Water District	Groundwater	WS	High Demand	2035	0.1
Grassy Pond Water District	Groundwater	WS	High Demand	2040	0.1
Grassy Pond Water District	Groundwater	WS	High Demand	2050	0.1
Grassy Pond Water District	Groundwater	WS	High Demand	2060	0.1
Grassy Pond Water District	Groundwater	WS	High Demand	2070	0.1
Heddles Hideaway Country Club	Groundwater	WS	High Demand	2025	0.003
Heddles Hideaway Country Club	Groundwater	WS	High Demand	2030	0.003

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Heddles Hideaway Country Club	Groundwater	WS	High Demand	2035	0.003
Heddles Hideaway Country Club	Groundwater	WS	High Demand	2040	0.003
Heddles Hideaway Country Club	Groundwater	WS	High Demand	2050	0.003
Heddles Hideaway Country Club	Groundwater	WS	High Demand	2060	0.003
Heddles Hideaway Country Club	Groundwater	WS	High Demand	2070	0.003
Inman Mills Water District SJWD	Groundwater	WS	High Demand	2025	0.1
Inman Mills Water District SJWD	Groundwater	WS	High Demand	2030	0.1
Inman Mills Water District SJWD	Groundwater	WS	High Demand	2035	0.1
Inman Mills Water District SJWD	Groundwater	WS	High Demand	2040	0.1
Inman Mills Water District SJWD	Groundwater	WS	High Demand	2050	0.1
Inman Mills Water District SJWD	Groundwater	WS	High Demand	2060	0.1
Inman Mills Water District SJWD	Groundwater	WS	High Demand	2070	0.1
Jenkinsville Water District	Groundwater	WS	High Demand	2025	0.1
Jenkinsville Water District	Groundwater	WS	High Demand	2030	0.1
Jenkinsville Water District	Groundwater	WS	High Demand	2035	0.1
Jenkinsville Water District	Groundwater	WS	High Demand	2040	0.1
Jenkinsville Water District	Groundwater	WS	High Demand	2050	0.1
Jenkinsville Water District	Groundwater	WS	High Demand	2060	0.1
Jenkinsville Water District	Groundwater	WS	High Demand	2070	0.1
Mid County Water Dist #1	Groundwater	WS	High Demand	2025	0.1
Mid County Water Dist #1	Groundwater	WS	High Demand	2030	0.1
Mid County Water Dist #1	Groundwater	WS	High Demand	2035	0.1
Mid County Water Dist #1	Groundwater	WS	High Demand	2040	0.1
Mid County Water Dist #1	Groundwater	WS	High Demand	2050	0.1
Mid County Water Dist #1	Groundwater	WS	High Demand	2060	0.1
Mid County Water Dist #1	Groundwater	WS	High Demand	2070	0.1

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Prosperity Town Of	Groundwater	WS	High Demand	2025	0.02
Prosperity Town Of	Groundwater	WS	High Demand	2030	0.02
Prosperity Town Of	Groundwater	WS	High Demand	2035	0.02
Prosperity Town Of	Groundwater	WS	High Demand	2040	0.02
Prosperity Town Of	Groundwater	WS	High Demand	2050	0.02
Prosperity Town Of	Groundwater	WS	High Demand	2060	0.02
Prosperity Town Of	Groundwater	WS	High Demand	2070	0.02
Richland County Rec Comm Linrick GC	Groundwater	WS	High Demand	2025	0.01
Richland County Rec Comm Linrick GC	Groundwater	WS	High Demand	2030	0.01
Richland County Rec Comm Linrick GC	Groundwater	WS	High Demand	2035	0.01
Richland County Rec Comm Linrick GC	Groundwater	WS	High Demand	2040	0.01
Richland County Rec Comm Linrick GC	Groundwater	WS	High Demand	2050	0.01
Richland County Rec Comm Linrick GC	Groundwater	WS	High Demand	2060	0.01
Richland County Rec Comm Linrick GC	Groundwater	WS	High Demand	2070	0.01
Timken Company/Tyger River Plant	Groundwater	WS	High Demand	2025	0.01
Timken Company/Tyger River Plant	Groundwater	WS	High Demand	2030	0.01
Timken Company/Tyger River Plant	Groundwater	WS	High Demand	2035	0.01
Timken Company/Tyger River Plant	Groundwater	WS	High Demand	2040	0.01
Timken Company/Tyger River Plant	Groundwater	WS	High Demand	2050	0.01
Timken Company/Tyger River Plant	Groundwater	WS	High Demand	2060	0.01
Timken Company/Tyger River Plant	Groundwater	WS	High Demand	2070	0.01
Willow Creek GC	Groundwater	WS	High Demand	2025	0.02
Willow Creek GC	Groundwater	WS	High Demand	2030	0.02
Willow Creek GC	Groundwater	WS	High Demand	2035	0.02
Willow Creek GC	Groundwater	WS	High Demand	2040	0.02

Table B-3. Projected Water Demands by Water User.

User	Water Source	Use Category	Projection	Year	Demand (MGD)
Willow Creek GC	Groundwater	WS	High Demand	2050	0.02
Willow Creek GC	Groundwater	WS	High Demand	2060	0.02
Willow Creek GC	Groundwater	WS	High Demand	2070	0.02

Appendix C
Flow-Ecology Relationships in the Broad River Basin

11/2/2022

Flow-Ecology Relationships in the Broad River Basin

With Applications for Flow Performance Measures in SWAM

DISCLAIMER

The following peer-reviewed scientific publications contain detailed information on data sources, flow metric calculations, statistical analyses relating flow to aquatic organisms, etc.:

- Bower, L. M., Peoples, B. K., Eddy, M. C., & Scott, M. C. (2022). Quantifying flow–ecology relationships across flow regime class and ecoregions in South Carolina. Science of the Total Environment, 802, 149721. URL: https://www.sciencedirect.com/science/article/pii/S0048969721047963
- Eddy, M. C., Lord, B., Perrot, D., Bower, L. M., & Peoples, B. K. (2022). Predictability of flow metrics calculated using a distributed hydrologic model across ecoregions and stream classes: Implications for developing flow–ecology relationships. Ecohydrology, 15(2), e2387. URL: https://onlinelibrary.wiley.com/doi/full/10.1002/eco.2387

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RTI International:

Michele Eddy

Benjamin Lord

The Nature Conservancy

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John Boyer

US Forest Service

James Keith Whalen

Weyerhaeuser Corporation

Daniel Hanks

EXECUTIVE SUMMARY

Responses of organisms to stream flow change have long been recognized in the scientific literature. The evolution of methods, large data sets, and statistical improvements over the last 20 years have advanced our ability to characterize these responses. If the necessary data is available, it is now possible to understand these responses to a specificity, making them useful for water resource management.

We identified a wide variety of flow–biological relationships to derive a set of recommended performance measures and predict changes in biological metrics in response to changes in flow for the Broad River basin. These relationships:

1) are highly relevant to drought management and water withdrawal,

2) are the strongest relationships between flow and river health, and

3) capture the greatest number of flow regime components of the streams and rivers of the Broad Basin.

We found statistically significant effects of flow on fish and invertebrates for all attributes of the natural flow regime, including magnitude, duration, frequency, timing, or rate of change. For this recommendation, only measures that are relevant to the Broad River, can be calculated in SWAM, and meet the three principles cited above were used.

Priority Flow Characteristics

Four flow metrics emerged as having the greatest impact on instream health in the Basin. They are:

1. *Mean Daily Flow*: The mean daily flow is the mean of daily flows over the period of record.
2. *Duration of High Flow*: Duration of high flow is defined by the annual average number of days of flow above the 75th percentile of all daily values over the period of record.
3. *Frequency of High Flow*: Frequency of high flow is defined by the annual average of the number of flow events above the 75th percentile of all daily values over the period of record.
4. *Calendar day of lowest observed flow*: This is simply the day of the year when the lowest flow is observed, converted to Julian date (a number from 1-365).

Results Summary:

Mean daily flow is expected to be impacted more by water use than the timing of low flow, high flow duration, and high flow frequency based on the SWAM water use scenarios. The changes in mean daily flow predicted by the full allocation and high demand water use scenarios are expected to substantially reduce the number of fish species at some strategic nodes with reductions in the number of fish species up 50.3% ± 7% . These changes in mean daily flow pose a high to medium risk to fish species at five strategic nodes. The linear relationships and performance measures suggest that the Pacolet River near Fingerville and Middle Tyger near Lyman may be at the highest risk of fish species loss based on the SWAM water use scenarios. All other SWAM scenarios generally indicated little change in the timing of low flow, high flow duration, and high flow frequency for nodes suggesting a low risk to the fish and macroinvertebrates.

INTRODUCTION

South Carolina is home to a rich diversity of freshwater organisms, including a variety of fishes and invertebrates. These organisms have unique traits that make them especially adapted for life in rivers. Many species have traits that make them *sensitive* to environmental change. Some of these traits include spawning or living in gravel habitats, or specialized body shapes for living in high-flow conditions. Likewise, other species have traits that make them *tolerant* to environmental change, such as the ability to spawn in a variety of habitats or to tolerate a wide range of temperatures.

Over 50 years of research supports the fact that aquatic organisms respond readily to changes in their environment. It is well known that key *biological metrics* such as the total number of species in a location and the representation of species with similar traits are directly indicative of *aquatic ecosystem health*. As ecosystems become less healthy, sensitive species are removed and replaced by tolerant species. Scientists use these biological metrics to assess aquatic ecosystem health to (a) identify high quality ecosystems to maintain and (b) identify ecosystems in poor health for remediation.

Aquatic ecosystem health is influenced strongly by instream flow. Sensitive species are especially adapted to the *natural flow regime*. The natural flow regime is described by five aspects of flow events that culminate to describe the overall flow conditions in a stream or river. These include:

-*Magnitude*: The size of high- and low-flow events

-*Frequency*: How often high- and low-flow events occur

-*Duration*: How long high- and low-flow events last when they do occur

-*Timing:* The time of year in which high- and low-flow events occur

-*Rate of change*: How often flows change from increasing to decreasing, or vice versa

Historically, instream flow management recommendations have focused only on maintaining minimum daily flows. However, it is becoming increasingly recognized that management for all five components of the natural flow regime is necessary for maintaining aquatic ecosystem health.

The natural flow regime is different across regions, and changes based on geology, natural vegetation, and precipitation patterns (see **Broad River Stream Types** below). Humans can alter the natural flow regime by withdrawing water directly from surface water or indirectly through groundwater withdrawal. Humans can also affect flow by changing land cover. Converting natural forests, grasslands, and wetlands to intensive agriculture or urban/suburban land cover types changes natural patterns of surface runoff and groundwater recharge. These changes have direct effects on aquatic ecosystem health and are indicated by aquatic organisms.

South Carolina is a state that is rich in water resources. However, the state is experiencing a period of rapid economic growth and population expansion. As such, identifying relationships between key instream flow metrics and biological metrics (hereafter, *flow-ecology relationships*) will provide guidance for developing recommendations for instream flow management that allows for smart development while maintaining the natural flow regime for aquatic ecosystem health.

THIS STUDY

The goal of this study was to estimate flow-ecology relationships for fishes and macroinvertebrates for streams and small rivers in the Broad River basin, South Carolina to provide recommendations for guiding instream flow management in the basin. The best available data sources and statistical modeling tools were used to accomplish this goal. The approach is summarized as follows:

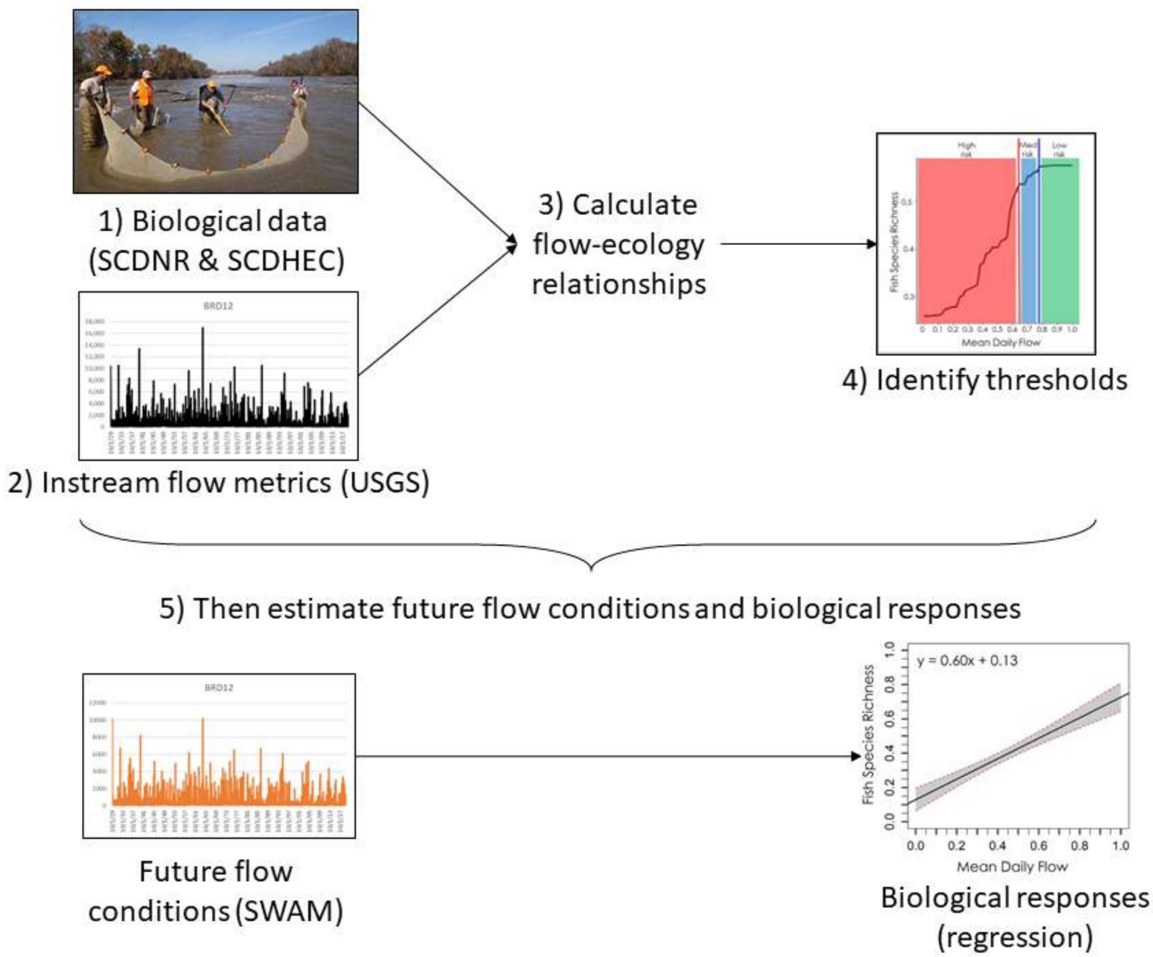

Figure 1: Flow chart of the described methods.

1. *Obtain biological data*: Fish community data is collected by the South Carolina Department of Natural Resources (SCDNR). Aquatic invertebrate community data is collected by the South Carolina Department of Health and Environmental Control (SCDHEC). In total, these include 1,022 sampling locations across the state, and 165 in the Broad River basin (Figure 1). All data are collected using standardized protocols designed to fully characterize the aquatic community for the purpose of quantifying aquatic ecosystem health. Sampling protocols can be found in Scott et al. (2009) and SCDHEC (2017). Raw fish and invertebrate community data were summarized into numerous biological metrics for each sampling site based on the number of species and proportional representation of species with similar traits. These metrics have been shown in previous studies to be directly indicative of aquatic ecosystem health. The full list of biological metrics included in this study is presented in Appendix Table 1.

2. *Estimate instream flow metrics*. The US Geological Survey maintains 7 flow gauges in the Broad River basin. However, biological sampling does not always occur at those locations, and the

number of gauged sites do not present sufficient sample sites for estimating flow ecology relationships. Accordingly, flow metrics were estimated for every stream/river in the Broad River basin using the WaterFALL(™) flow allocation model. This work was accomplished by researchers from RTI International and is reported in full detail in Eddy et al. (2022). The full list of candidate flow metrics used in this study is presented in Appendix Table 2.

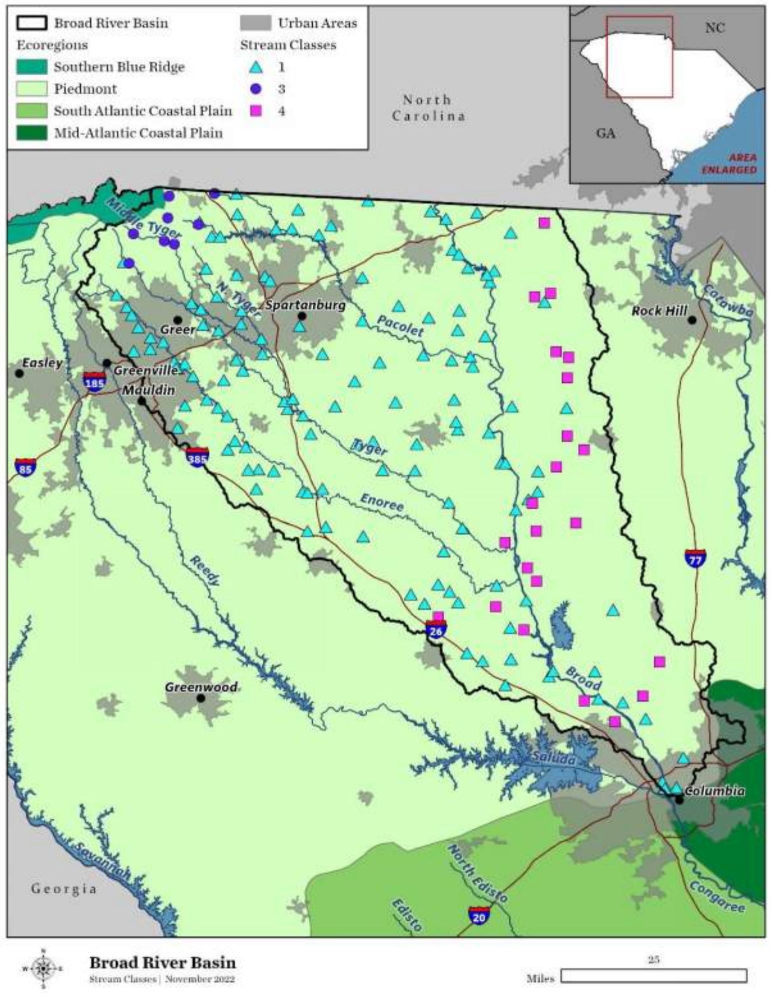

Figure 2: *Map of the Broad River basin overlain with ecoregion boundaries and stream classifications. Each point is also a biological sampling point for either fish, or aquatic invertebrates, or both.*

3. *Identify critical flow-ecology relationships*. The modeling approach started with 24 flow metrics and 14 biological metrics, yielding an untenable number of potential relationships. To reduce this complexity, we only analyzed flow metrics that were (a) shown to be biologically relevant (b) captured all components of the flow regime, and (c) were non-redundant (Appendix Table 2). Because many biological metrics will be weakly correlated with some flow metrics, it was critical to identify the strongest and most informative flow-ecology relationships to develop recommendations. This was accomplished using *random forests*—a type of machine learning statistical model that is ideal for identifying complex ecological relationships.

4. *Use flow-ecology relationships to identify potentially harmful/protective levels of flow change*. The most important relationships can be identified by random forest in two ways: 1) as a performance measure to determine the potential biological impact of water withdrawal, and 2) to estimate predicted change in a biological metric based on estimated change in flow due to water withdrawal. To create the performance measures, the random forest model plots were used as seen below (Figure 2). These plots are scaled to represent the estimated proportional change in the biotic metric that would result from a proportional change in the flow metric. These plots were used to identify potential flow thresholds – a point along a flow metric that corresponds to large shifts in biological health. The thresholds define the best points to set performance measures. Two distinct thresholds were identified in each relationship to produce 3 zones corresponding to high, medium, and low levels of risk to the chosen biotic metric.

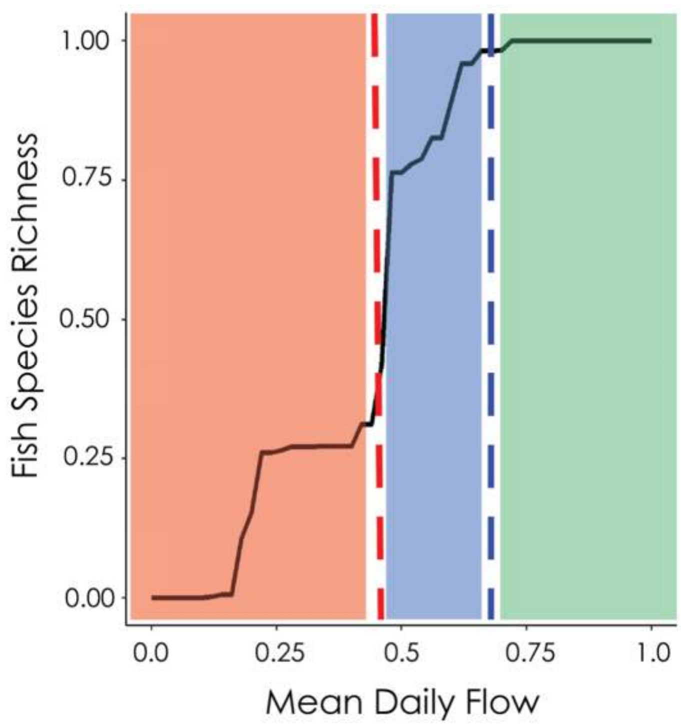

Figure 3: *Model-estimated risk ranges for the selected biota and flow metrics. in Piedmont Flashy Streams. Areas of high risk are shaded red, medium risk in blue, and low risk in green. Changes in the overall flow regime cause mean daily flow to fall between 71 and 49% of current values in Piedmont flashy perennial streams correspond to low and high risk for fish species loss, respectively. Reducing mean daily flow into the zone of 49-71% constitutes medium risk for fish species loss.*

5. *Estimate potential future flow conditions and biological response*. Researchers from CDM Smith used the Surface Water Allocation Model (SWAM) to estimate future flow conditions at *strategic nodes*–key locations in tributaries to the Broad River (Figure 4). Estimates were provided for four potential future water withdrawal scenarios: (1) unimpaired flow (no water withdrawals occur in the system), (2) moderate development by 2070, (3) high development by 2070, and (4) full allocation (all permitted water withdrawals are realized) for each strategic node. Finally, potential future changes in biological metrics were estimated in each of the four future water withdrawal scenarios based on (a) model-predicted responses of biological metrics to instream flow, and (b)

SWAM-based predicted flow metrics. To do this, linear relationships between each flow metric and biological metric were used for the important relationships identified by random forest models. This method provides a more precise estimate of the biological change in response to flow alteration and the error associated with this estimate (Figure 5). This process was conducted for each of three main categories of streams and rivers in the Broad River Basin (see below).

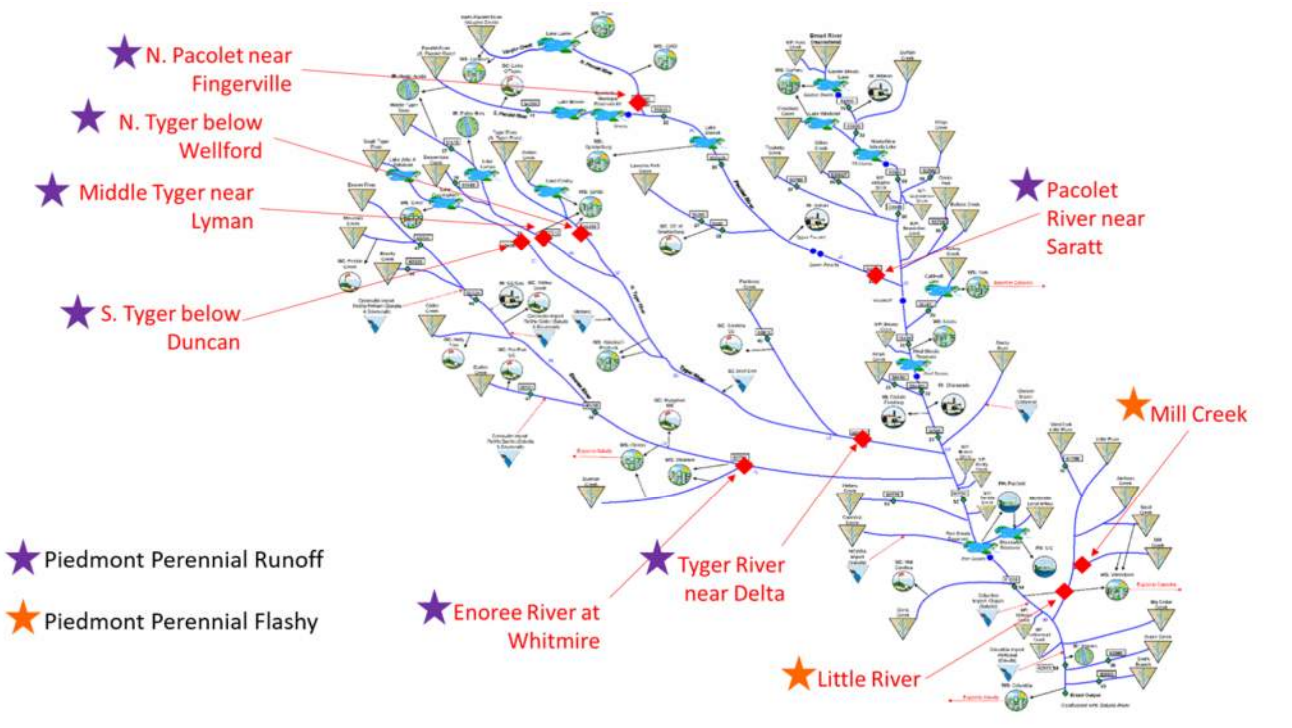

Figure 4: *Location of example strategic nodes from the Broad River*

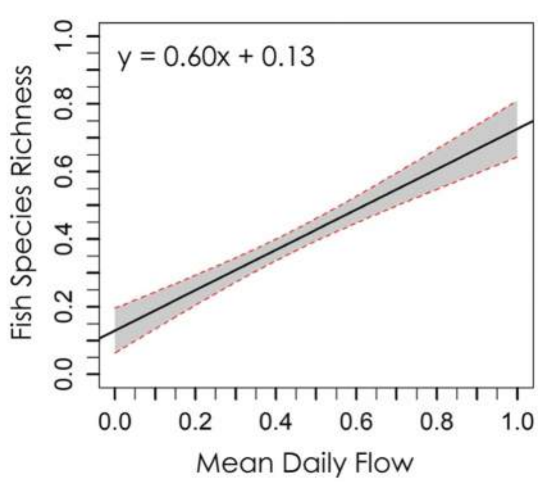

Figure 5*. Example of the linear relationship established between mean daily flow and fish species richness in Piedmont Flashy Streams. The formula,* $Y = 0.60x + 0.13$*, allows us to apply this relationship to the flow projection scenarios by replacing* x *with the predicted mean daily flow in order to derive the predicted change in fish richness, represented by* Y.

BROAD RIVER STREAM TYPES

There are 2 dominant stream types in the Broad River basin (**Figure 1**), determined by ecoregion and water source / behavior (~2478 segments):

1. Piedmont Perennial Runoff (P1): Streams and rivers in the Piedmont ecoregion characterized by moderately stable flow and distinct seasonal extremes; a dominant stream type in the Broad
2. Piedmont Perennial Flashy (P4): Streams in the Piedmont ecoregion with moderately stable flow with high variability; also a dominant stream type in the Broad

There are also 2 stream types in the lower basin which comprise a very small portion of the watershed (~106 streams):

3. Southeastern Plains Perennial Runoff (SE 1): Streams and rivers in the southeastern plains ecoregion characterized by moderately stable flow and distinct seasonal extremes; a minor stream type in the Broad.
4. Southeastern Plains Base Flow (SE 3): Streams and rivers in the southeastern plains ecoregion whose flow is composed of both high stable base flow and rainfall runoff; a minor stream type in the Broad.

No strategic nodes were selected in the Southeastern Plains ecoregion.

ASSUMPTIONS OF THE APPROACH

Like all model-based studies, the approach relies on a few assumptions that should be considered when interpreting the results.

First, the flow-ecology relationship analyses assume that flow metrics were estimated perfectly. This is not the case, and indeed is impossible, as described in detail in Eddy et al. (2022). However, this study relied on the most precisely estimated flow metrics estimated by Eddy et al. (2022), and omitted flow metrics with high levels of uncertainty.

Second, models are only as good as the data on which they are based. The most up-to-date sources to estimate flow metrics and their relationships with biological metrics were used. However, data are continuously being collected by USGS, SCDHEC, and SCDNR. As such, the inclusion of new data into potential future approaches could yield different results. However, the inclusion of new data would be expected to only increase the precision of the estimates.

A third assumption is that future flow-ecology relationships will exist in the same shape and magnitude as they currently do. The future flow scenarios are based solely on changes to instream flow metrics due to known surface water withdrawal demands. These scenarios assume that land cover, temperature, and precipitation, and thus instream flow, will remain the same in the future. While this may not be a reasonable assumption, incorporating these factors into more detailed estimates of future instream flow conditions is beyond the scope of the present work, but will be an important contribution to ongoing flow management efforts.

Finally, this work was developed on streams in rivers with watershed areas of 3 to 1400 km^2. Streams of this size represent 87% of the surface water in South Carolina. This work did not include data from reservoirs or large rivers, and as such is not informative for making recommendations regarding flow management of any waterbody with a watershed greater than XX km^2.

RESULTS: IDENTIFYING FLOW-ECOLOGY RELATIONSHIPS

Biotic metrics: Random forest models allowed us to identify clear flow-ecology relationships. Several biotic metrics were found to be informative of changes in instream flow. These include:

- Species Richness: the number of species found at a given site
- Shannon diversity: an index of biodiversity that accounts for both species richness and proportional representation of each species
- Brood hiders: proportional representation of fish individuals in the brood hiding breeding strategy
- Nest Spawners: proportional representation of fish individuals in the nest spawning breeding strategy
- Tolerant species: average tolerance index for taxa.

Flow metrics: Statistically significant effects of flow on fish and invertebrates were found for all attributes of the natural flow regime, including magnitude, duration, frequency, timing, or rate of change. However, for this recommendation, we are only bringing forward measures that are relevant to the Broad River basin, can be calculated in SWAM, and meet the three principles cited above. Four flow metrics emerged as having the greatest impact on aquatic ecosystem health in the Broad River Basin:

1. *Mean Daily Flow*: The mean of all daily flows over the period of record.
2. *Duration of High Flow*: The annual average number of days with flow above the 75th percentile of all daily values over the period of record.
3. *Frequency of High Flow*: The annual mean of the number of flow events above the 75th percentile of all daily values over the period of record.
4. *Calendar day of lowest observed flow*: This is simply the day of the year when the lowest flow is observed, converted to Julian date (a number from 1-365).

RECOMMENDED PERFORMANCE MEASURES

Based on the flow-ecology relationships identified above, we suggest the following performance measures (Table 1). The recommended measures reflect the variability of biological response in different ecoregions and stream types while producing a manageable set of responses to consider.

Table 1: The risk ranges for the most informative flow and biological metric for each stream class in the Broad River basin. The biological metric is given in the brackets. The risk ranges are colored as green (low risk), yellow (medium risk), and red (high risk).

	Instream Flow Performance Recommendations and Risk Ranges												
Stream Type:	Piedmont Perennial Runoff			Piedmont Flashy			SE Plains Perennial Runoff			SE Plains Stable Baseflow			
	Risk Ranges												
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	
Flow Metric													
Mean Daily Flow (FR)	>0.78	0.64-0.78	<0.64	>0.71	0.49-0.71	<0.49	>0.66	0.42-0.66	<0.42	>0.75	0.52-0.75	<0.52	
Duration of High Flow (NF)				<0.16	0.16-0.39	>0.39							
Frequency of High Flow (MS)				<0.20	0.20-0.43	>0.43							
Low Flow Duration (FR)										<0.13	0.13-0.40	>0.40	
Calendar Day of Lowest Flow (BHF)	>327												
Calendar Day of Lowest Flow (NF)				<278									
Calendar Day of Lowest Flow (MT)				>285									

FR=Fish Species Richness: The number of fish species found in a stream or river reach
NF=Nesting fishes - the group of fish species who build nests for their eggs, and typically guard the site and the young hatchlings.
MS=Shannon diversity of aquatic insects. Shannon diversity accounts for both the number of species at a site, and also how equally their numbers are distributed
BHF=Brood hiding fishes. Brood hiders bury or place their eggs in a concealed location, but do not guard or provide any parental care
MT=Macroinvertebrate Tolerance: Aquatic insects which tolerate stagnant water, low oxygen and pollution. This includes worms, nematodes, gnats, mosquitoes, etc.

APPLICATION: EVALUATING WATER USE SCENARIOS IN SWAM

SWAM was used to create four flow scenarios based on water withdrawals:

1. Unimpaired flow (no water withdrawals occur in the system)
2. Moderate development by 2070
3. High development by 2070
4. Full allocation (all permitted water withdrawals are realized) for each strategic node.

We used the flow–biological relationships in conjunction with SWAM results to estimate the responses of the organisms to these various water withdrawal scenarios at each strategic node. The performance measures can be used in an intuitive graphic approach to quickly compare the scenario performance and identify patterns. The performance measures can be used to

1) analyze the impacts or benefits of flow changes within a SWAM scenario
2) to compare impacts or benefits across multiple SWAM scenarios
3) to compare the benefits of water management strategies to a SWAM scenario(s)

Performance measure plots provide a visual way to compare the water withdrawal scenarios with respect to aquatic ecosystem health. This feature can also be informative when water management strategies are applied to the scenarios, revealing which strategies best protect stream health while still meeting essential water needs. Figure 6 shows an example of the performance measure plots.

Linear relationships were used to estimate the change in a biological metric from current flows for each SWAM scenario, producing color-coded output with the specific percentage change of the biological metric and its associated estimate error. Figure 7 shows an example of the linear relationship output.

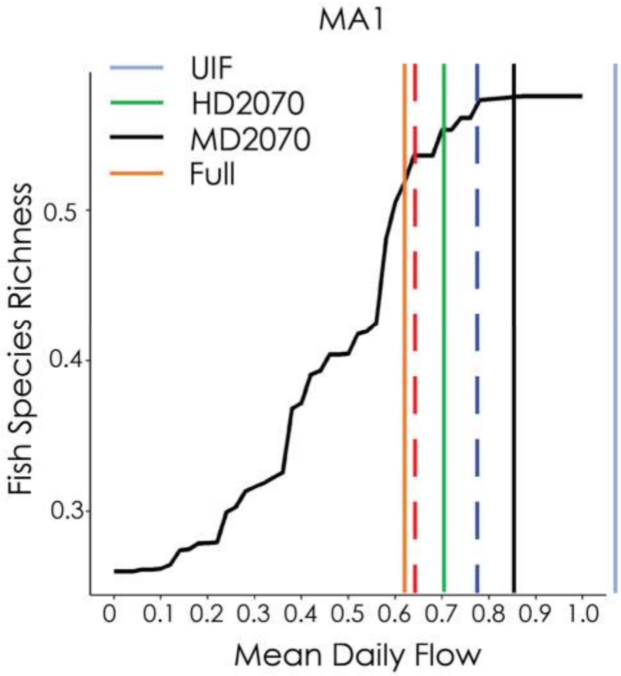

Figure 6: In this example (Mean daily flow at Middle Tyger River near Lyman), the predicted change in mean daily flow was plotted for the four SWAM scenarios along the X axis, allowing for quick determination of risk to the biologic metric. In this example, the full allocation model (orange) had a 37.3% reduction in flow, meaning only 62.7% of current flows remain, which is considered 'high risk' to the biotic metric, fish species richness. Alternatively, the medium development scenario (vertical black line), predicted only a 14% reduction in flow, which was considered 'low risk'.

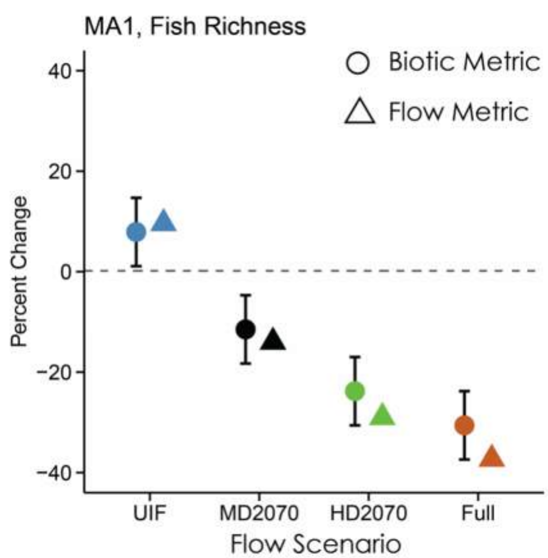

Figure 7: In this figure, the four SWAM scenarios are plotted along the X axis, and percent change for each scenario is plotted along the Y axis. The horizontal dashed line indicates the current conditions. Predicted flow metrics (triangles) were derived from the SWAM model, whereas predicted biotic metrics (circles) were derived from linear regression (figure xx). Error bars on the biotic metrics represent the standard error or the uncertainty in the predictions.

SWAM results summary.

SWAM estimated large changes in mean daily flow (MA1) for the full allocation and high development water use scenarios for several strategic nodes. Six scenarios produced a >20% reduction in mean daily flow (Figures 8-31). This change in mean daily flow was predicted to substantially reduce the number of fish species. The linear relationships predicted losses in the number of species to be between 0.2% and 50.3% for the full allocation water use scenario and between -1.9% and 23.8% for the high development scenario (Figure 8-31), resulting 5 number of strategic nodes predicted to lose >20% of fish species in a full allocation scenario and 1 strategic node for the high development scenario. All other SWAM scenarios predicted lower reductions in mean daily flow (range: 5.8% increase to 14.0% decrease for medium development, and a predicted 3.2% decrease to 12.7% increase for unimpaired flows) and losses in the number of fish species (range: 4.7% increase to 11.5% decrease for medium development and 2.7% loss to 12.7% increase for unimpaired flow). The standard error associated with these estimates is important to consider because it provides a range associated with each prediction. For example, the linear relationships predicted a 23.8% reduction in fish species with a standard error of 7 at Middle Tyger near Lyman for the high development scenario, suggesting reduction in fish species could be as low as 16.8% or as high as 30.8%.

The performance measures based on mean daily flow and species richness showed the full allocation scenario as being in the high-risk zone for the North Tyger River below Wellford and Middle Tyger River near Lyman nodes (Figures 8 and 12) and medium risk zone for the North Pacolet River near Fingerville, South Tyger river below Duncan, and Pacolet River near Saratt nodes.

SWAM generally did not predict large changes in timing of low flow, as with all scenarios predicted less than 2% changes, with the exception of full allocation on the N. Pacolet near Fingerville, which predicted an 18% decrease. This decrease corresponded to a predicted 12.4% decrease in the proportion of brood hiding fish, which was still within the 'low risk' zone (Figures 8-31). All SWAM scenarios remained in the low-risk range for timing of low flow, high flow duration, and high flow frequency (Figures 8-31).

CONCLUSIONS

Mean daily flow is expected to be impacted more by water use than the timing of low flow, high flow duration, and high flow frequency based on the SWAM scenarios. The changes in mean daily flow predicted by the full allocation and high demand water use scenarios are expected to substantially reduce the number of fish species and pose a high-medium risk to fish species at five strategic nodes. The linear relationships and performance measures suggest that the Pacolet River near Fingerville and Middle Tyger near Lyman may be at the highest risk of fish species loss due to water use. These results suggest high water withdrawals, mainly the full allocation and high development water use scenarios, would pose a medium to high risk to fish species and result in large losses in the number of fish species. The findings do not rule out all potential risks to ecological integrity or aquatic biodiversity related to other metrics or flow alterations.

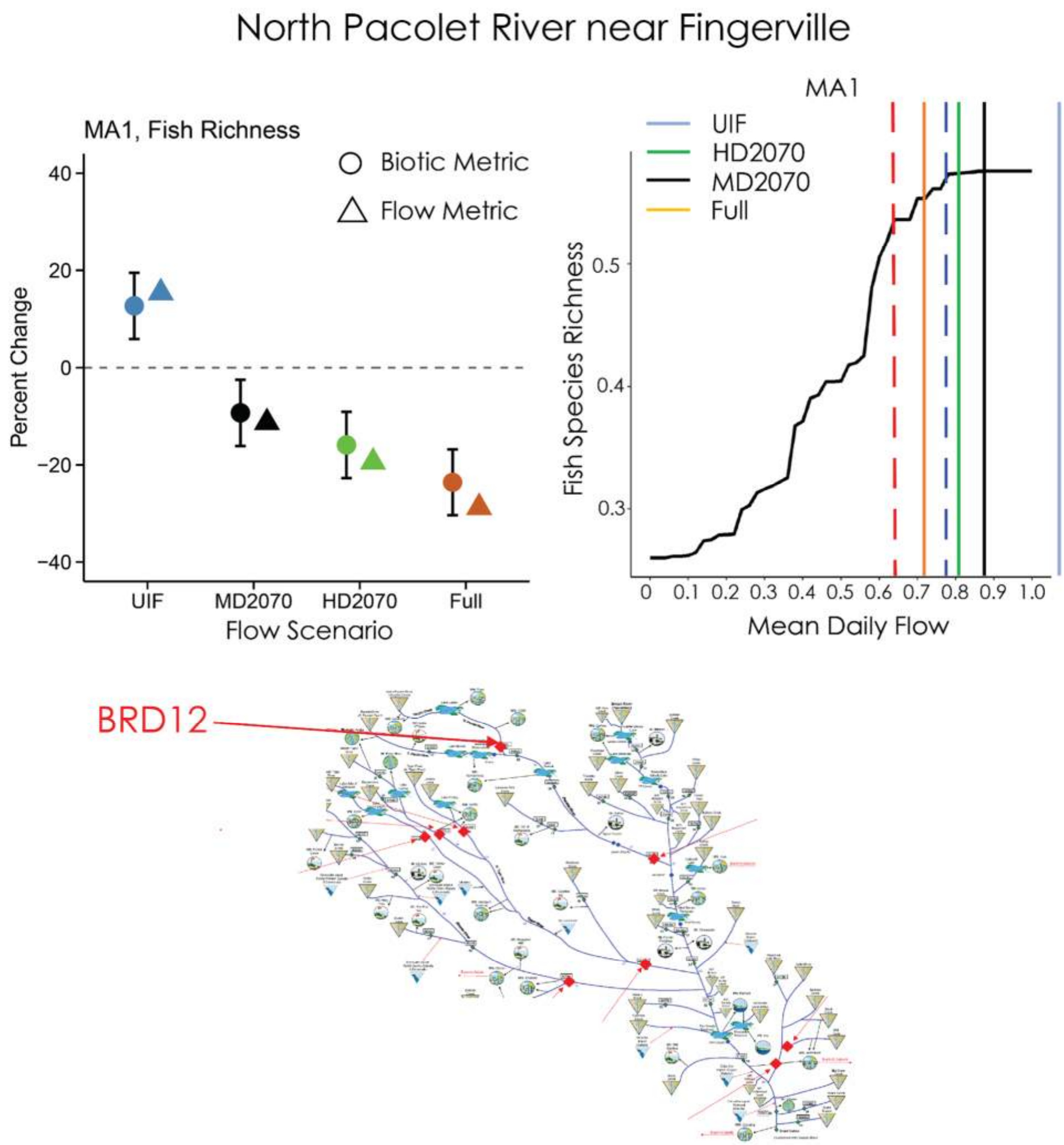

Figure 8: Mean daily flow (MA1) projections for the North Pacolet River near Fingerville (BRD12). The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding only that the full allocation scenario to be 'medium risk' due to a projected loss of 23.6% of fish richness, and all other scenarios were in the low-risk zone.

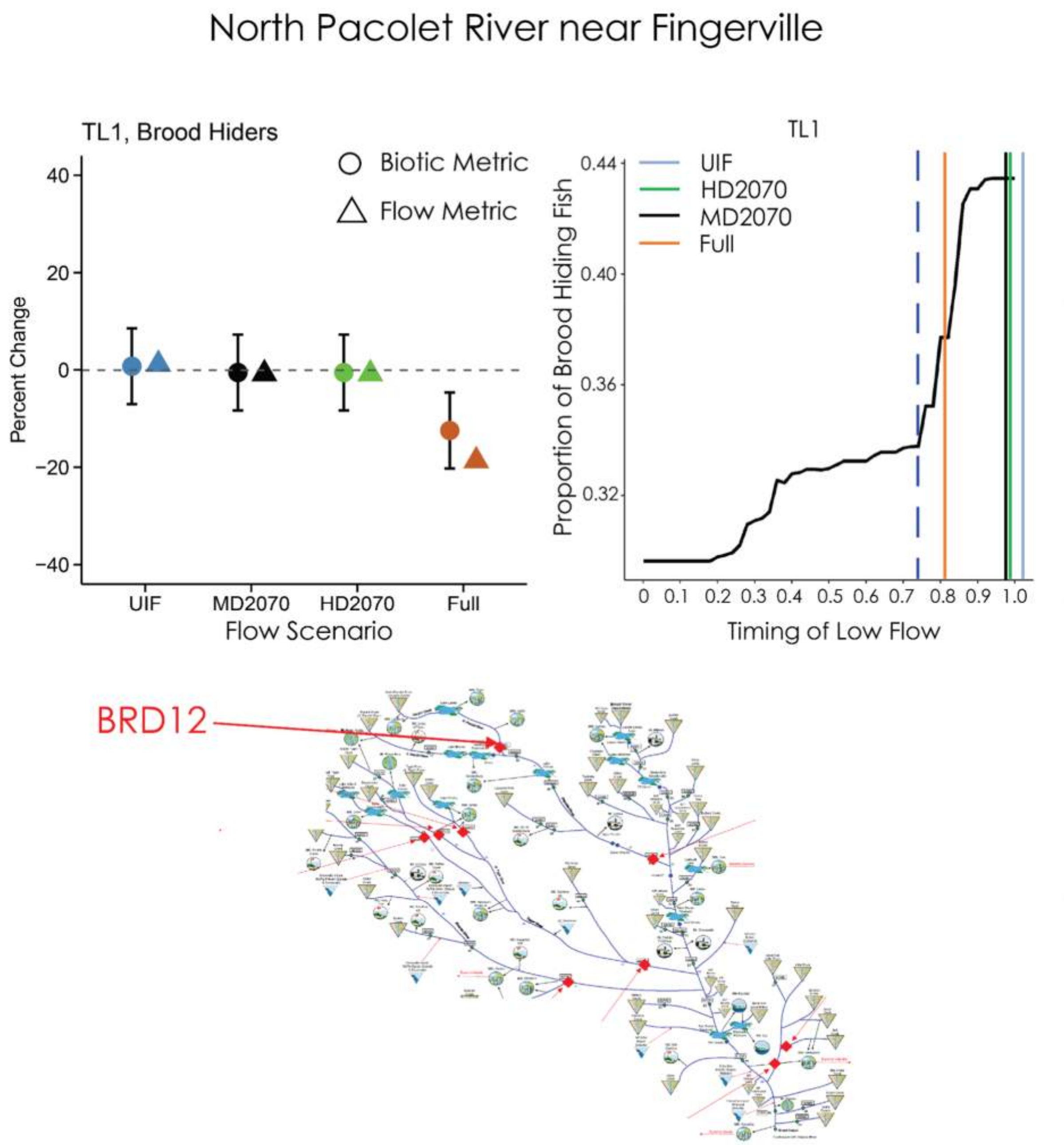

Figure 9: Timing of low flow (TL1) projections for the North Pacolet River near Fingerville (BRD12). The triangles indicate the percent change in timing of low flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in timing of low flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding only that while the full allocation projected a 12.4% change in the proportion of brood hiding fish, it was above the threshold for 'high risk', and all other scenarios were in the low-risk zone.

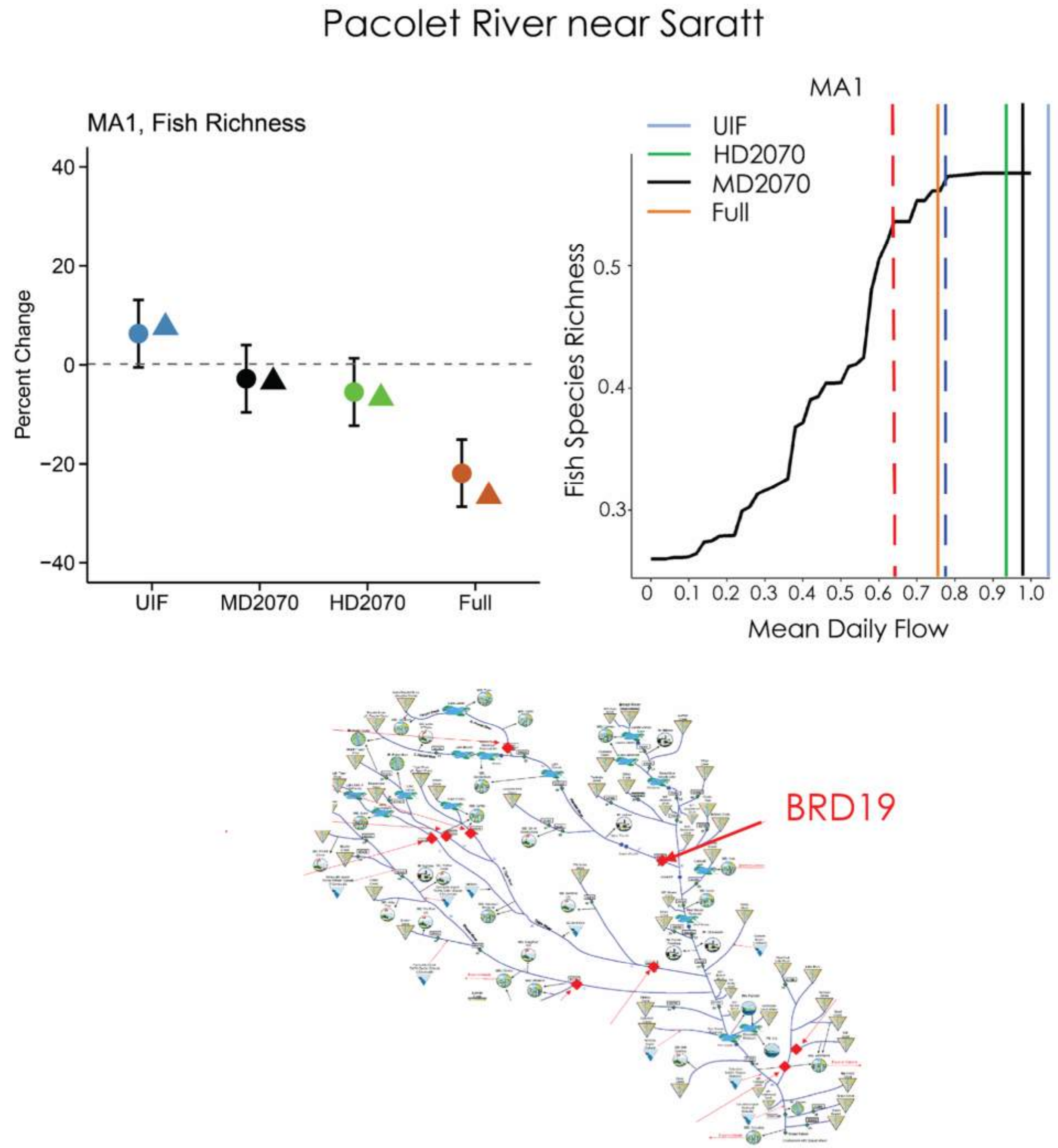

Figure 10: Mean daily flow (MA1) projections for the Pacolet River near Saratt (BRD19). The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding only that the full allocation scenario to be 'medium risk' due to a projected loss of 21.9% of fish richness, and all other scenarios were in the low-risk zone.

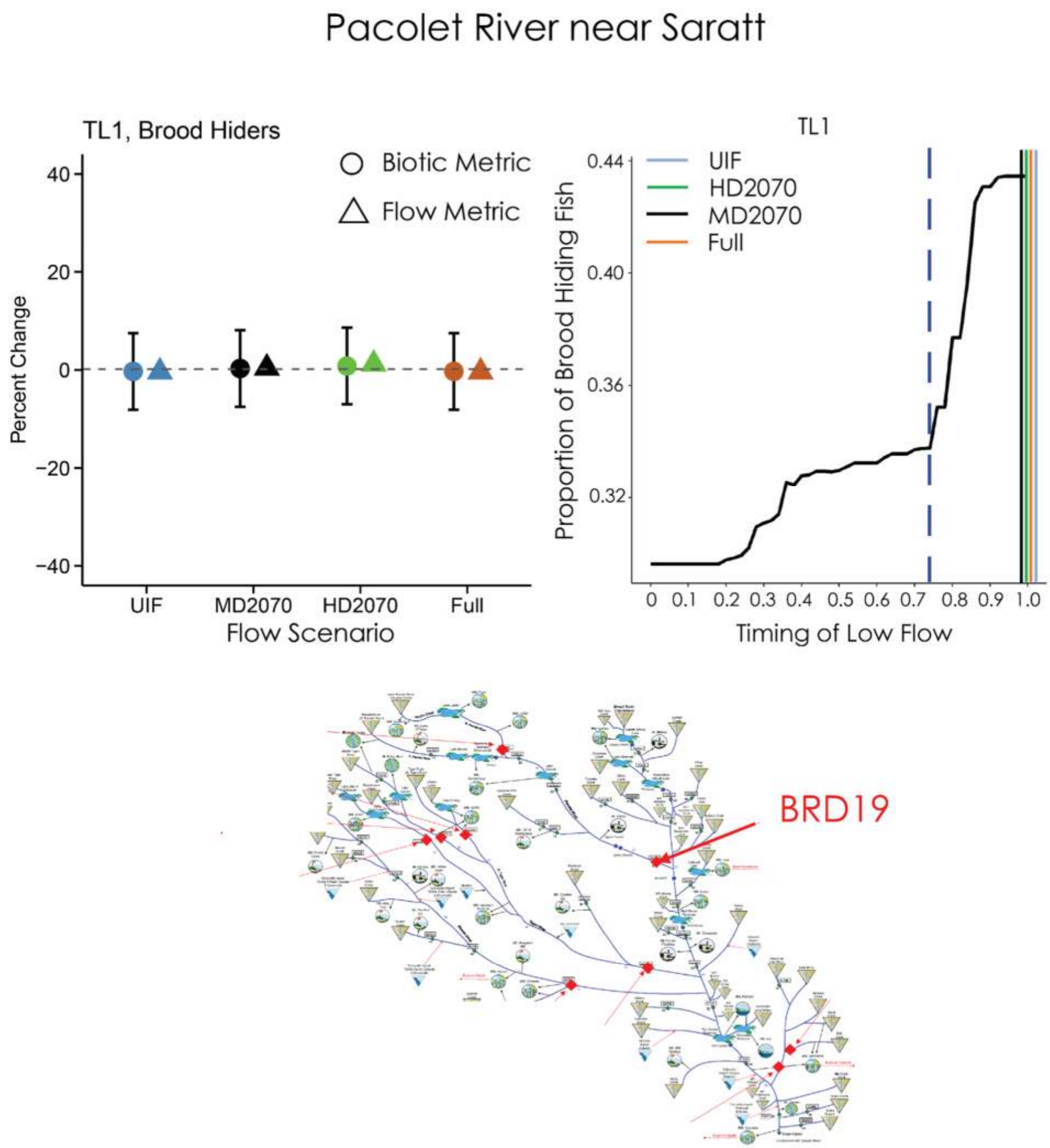

Figure 11: Timing of low flow (TL1) projections for the Pacolet River near Saratt (BRD19). The triangles indicate the percent change in timing of low flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in timing of low flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding that all other scenarios were in the low-risk zone.

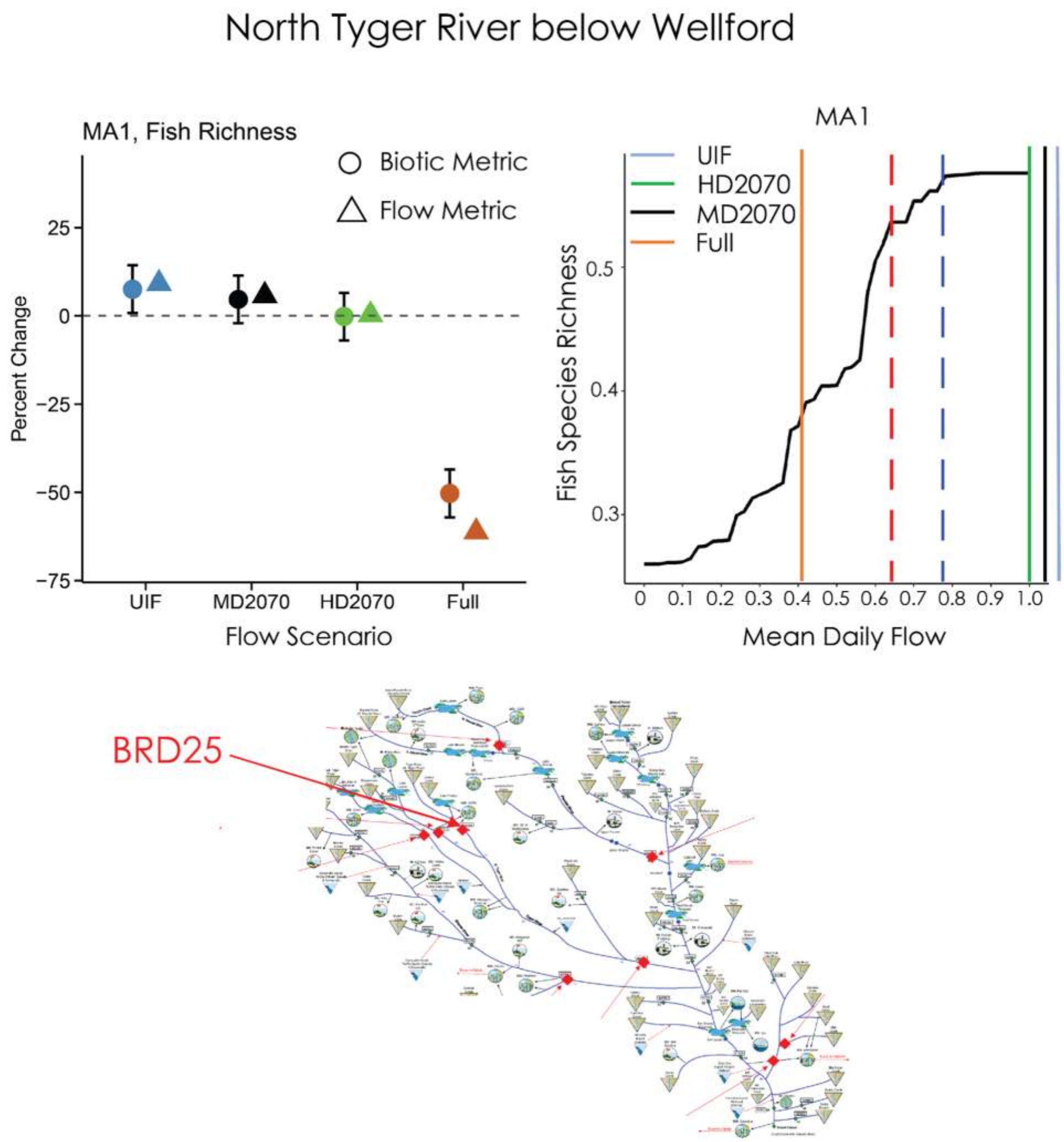

Figure 12: Mean daily flow (MA1) projections for the North Tyger River below Wellford (BRD25). The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding only that the full allocation scenario to be 'medium risk' due to a projected loss of 50.3% of fish richness, and all other scenarios were in the low-risk zone.

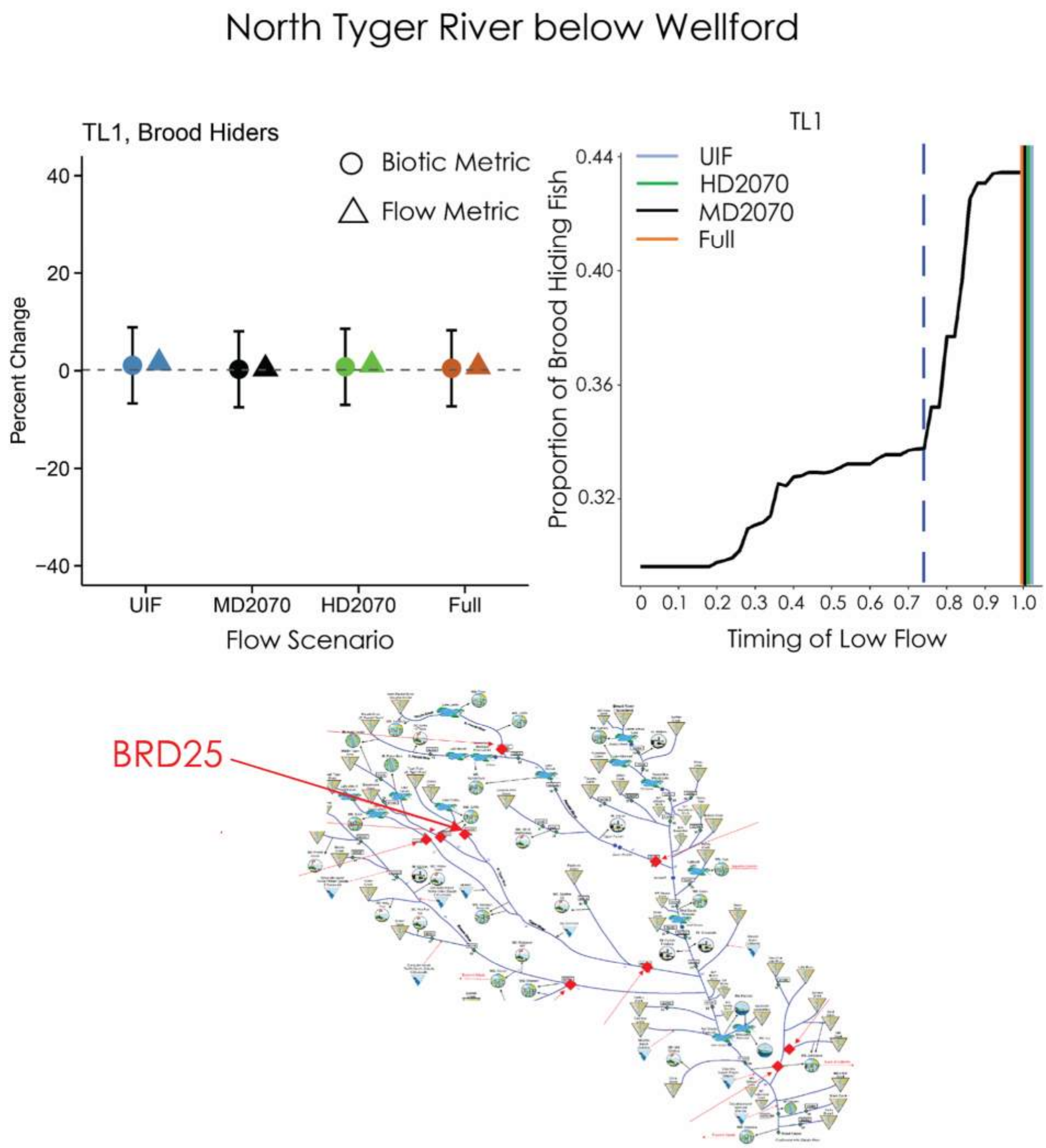

Figure 13: Timing of low flow projections for the North Tyger River below Wellford (BRD25). The triangles indicate the percent change in timing of low flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in timing of low flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding that all other scenarios were in the low-risk zone.

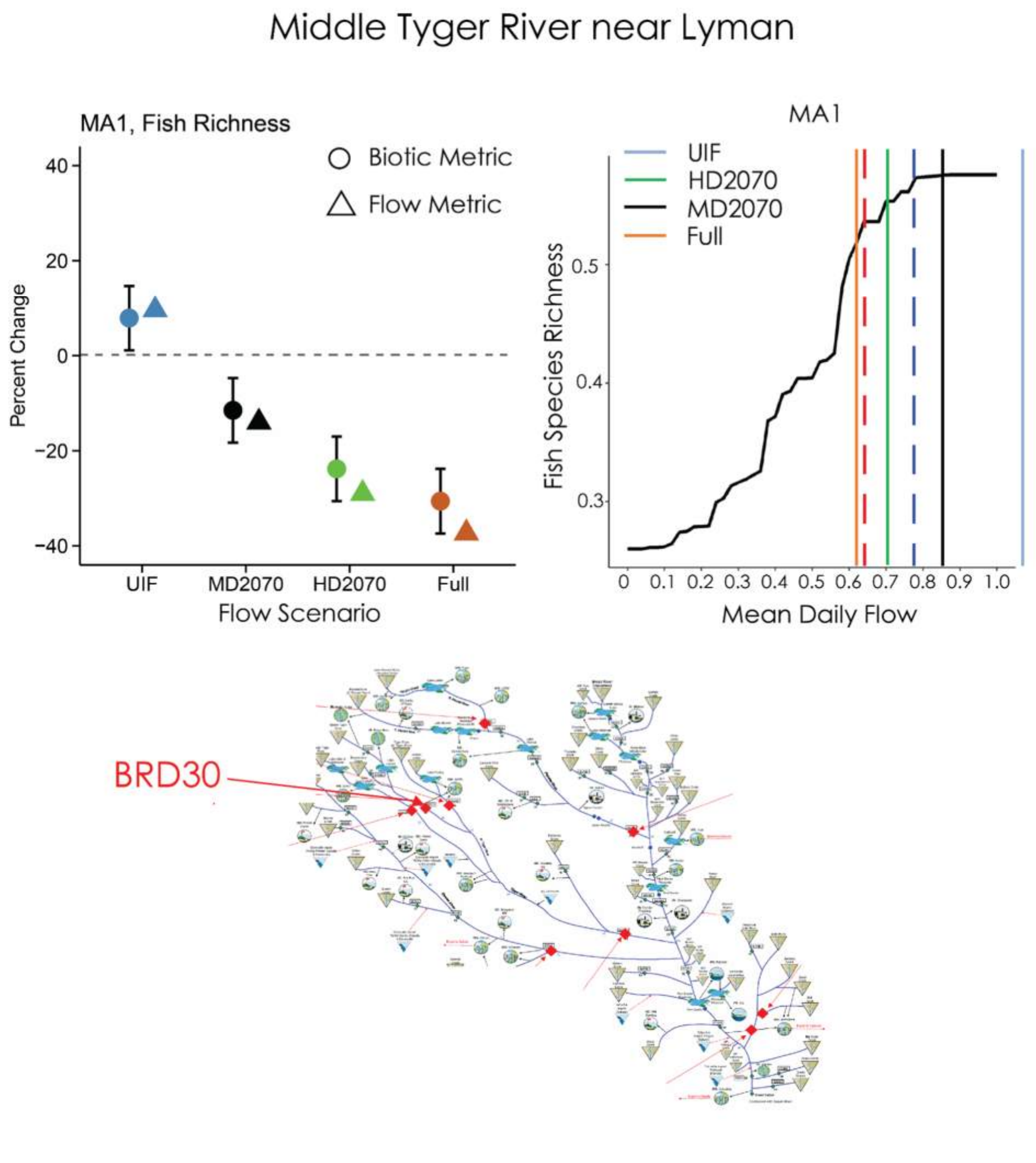

Figure 14: Mean daily flow (MA1) projections for the Middle Tyger River near Lyman (BRD30). The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding the full allocation scenario to be 'high risk' due to a projected loss of 30.6% of fish richness, and the high development to be 'medium risk', due to a 23.8% loss of fish richness. All other scenarios were in the low-risk zone.

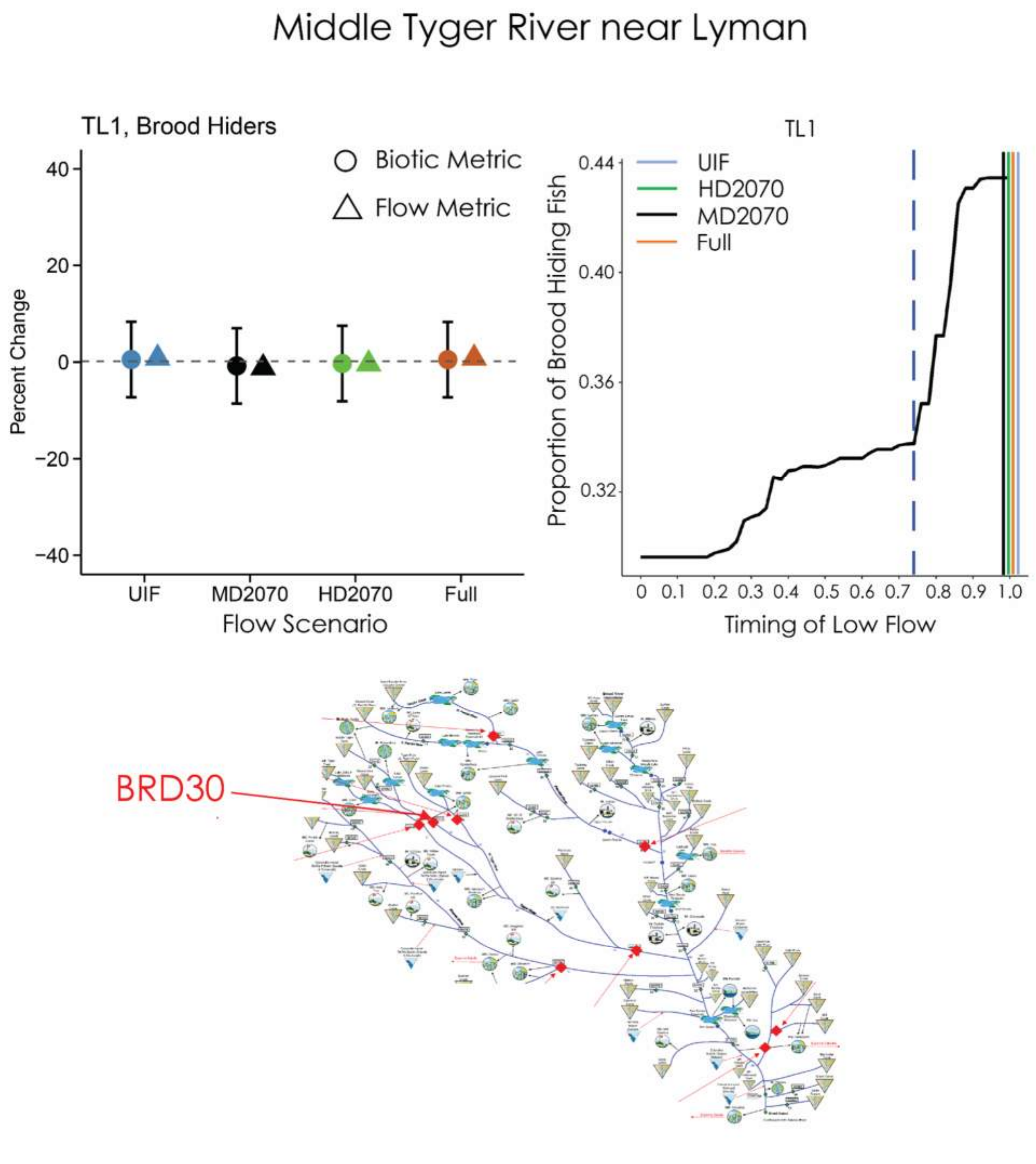

Figure 15: Timing of low flow (TL1) projections for the Middle Tyger River near Lyman (BRD30). The triangles indicate the percent change in timing of low flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in timing of low flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding that all other scenarios were in the low-risk zone.

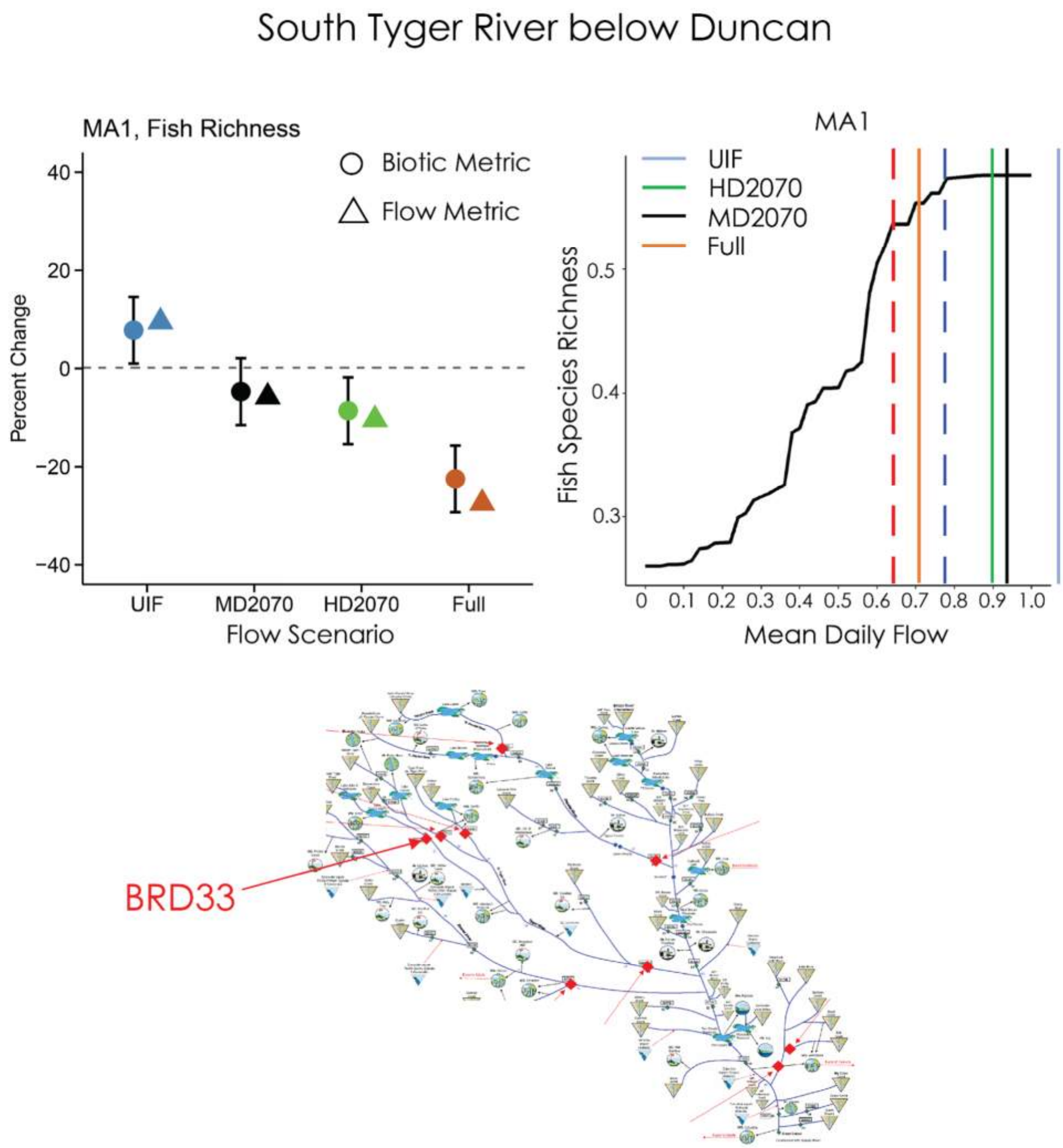

Figure 16: Mean daily flow (MA1) projections for the South Tyger River below Duncan (BRD33). The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, only finding the full allocation scenario to be ‘medium risk’ due to a projected loss of 22.5% of fish richness, and all other scenarios were in the low-risk zone.

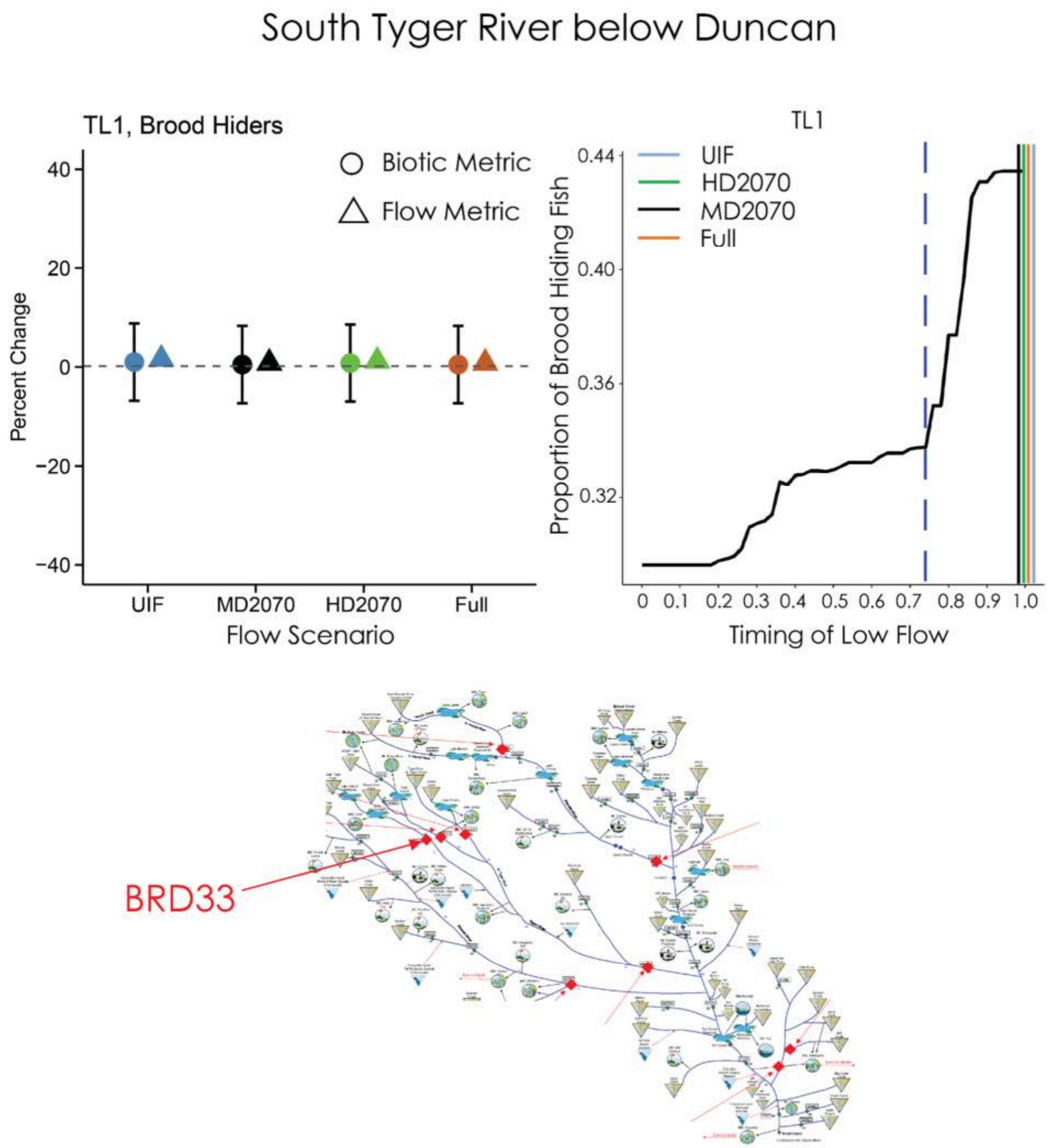

Figure 17: Timing of low flow (TL1) projections for the South Tyger River below Duncan (BRD33).The triangles indicate the percent change in timing of low flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in timing of low flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding that all other scenarios were in the low-risk zone.

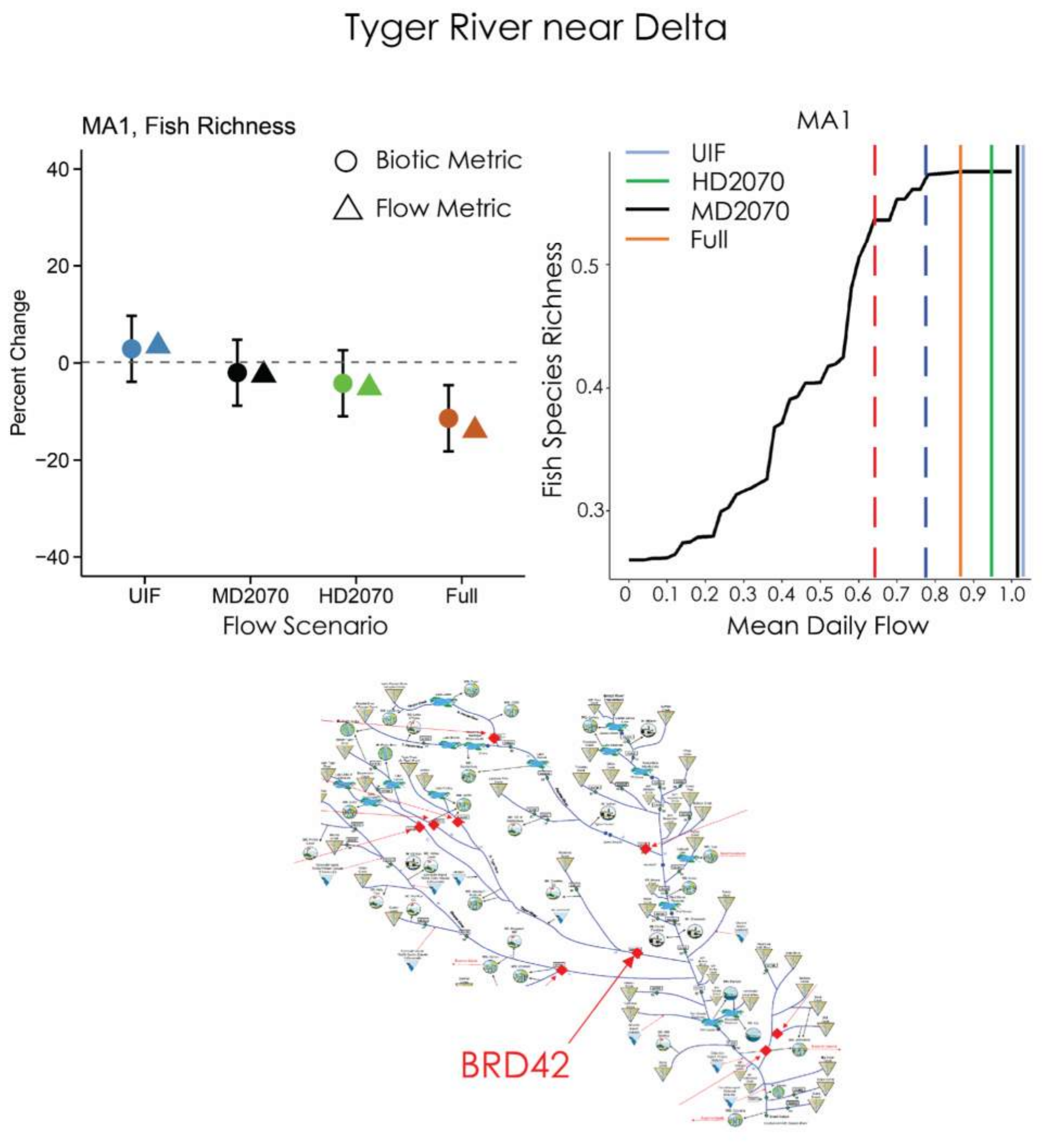

Figure 18: Mean daily flow (MA1) projections for the Tyger River Delta (BRD42). The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, and while finding the full allocation scenario projected a loss of 11.4% of fish species richness, this was below the threshold for medium risk, thus all scenarios were found to be in the low-risk category.

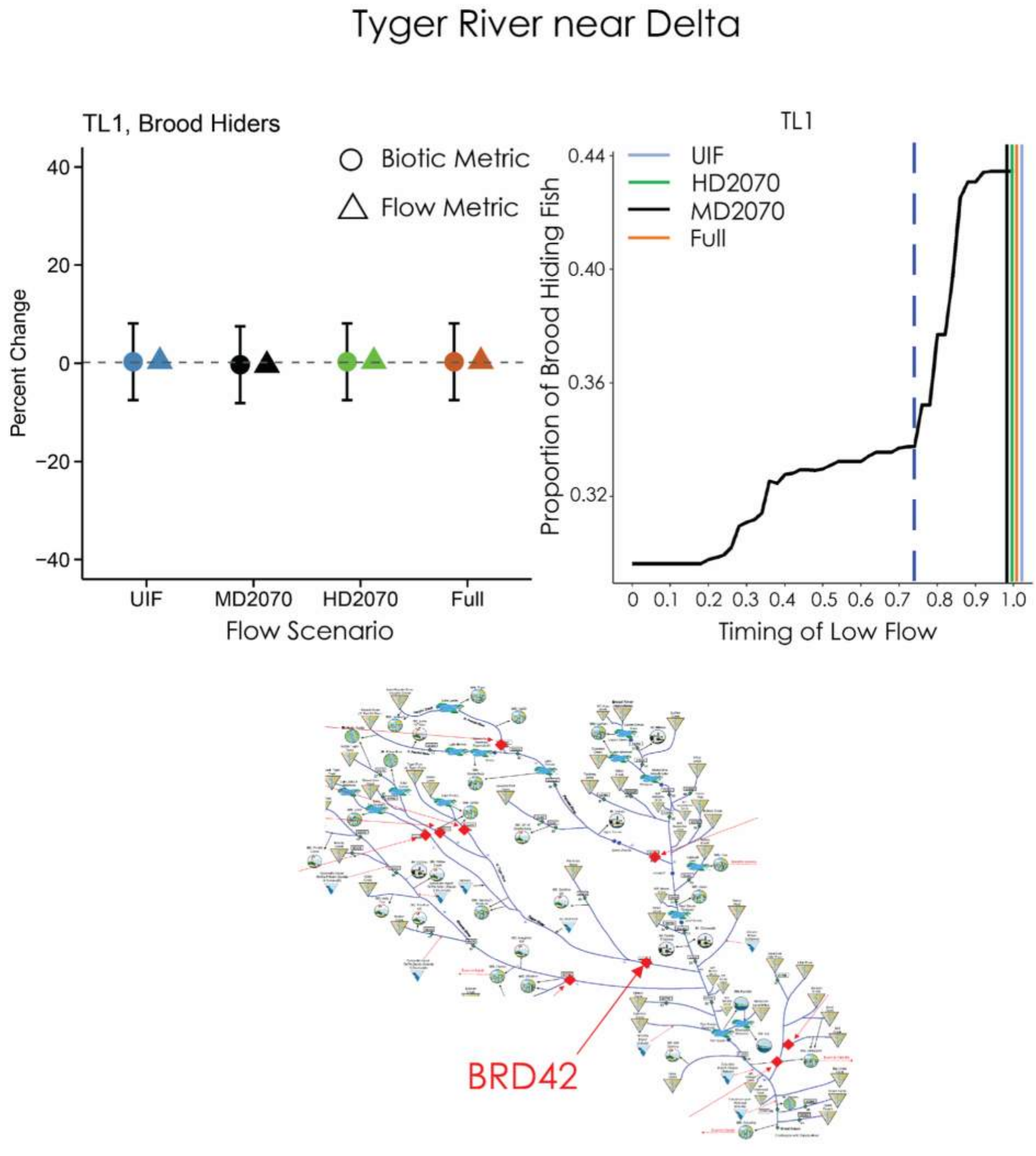

Figure 19: Timing of low flow (TL1) projections for the Tyger River near Delta (BRD42). The triangles indicate the percent change in timing of low flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in timing of low flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding that all other scenarios were in the low-risk zone.

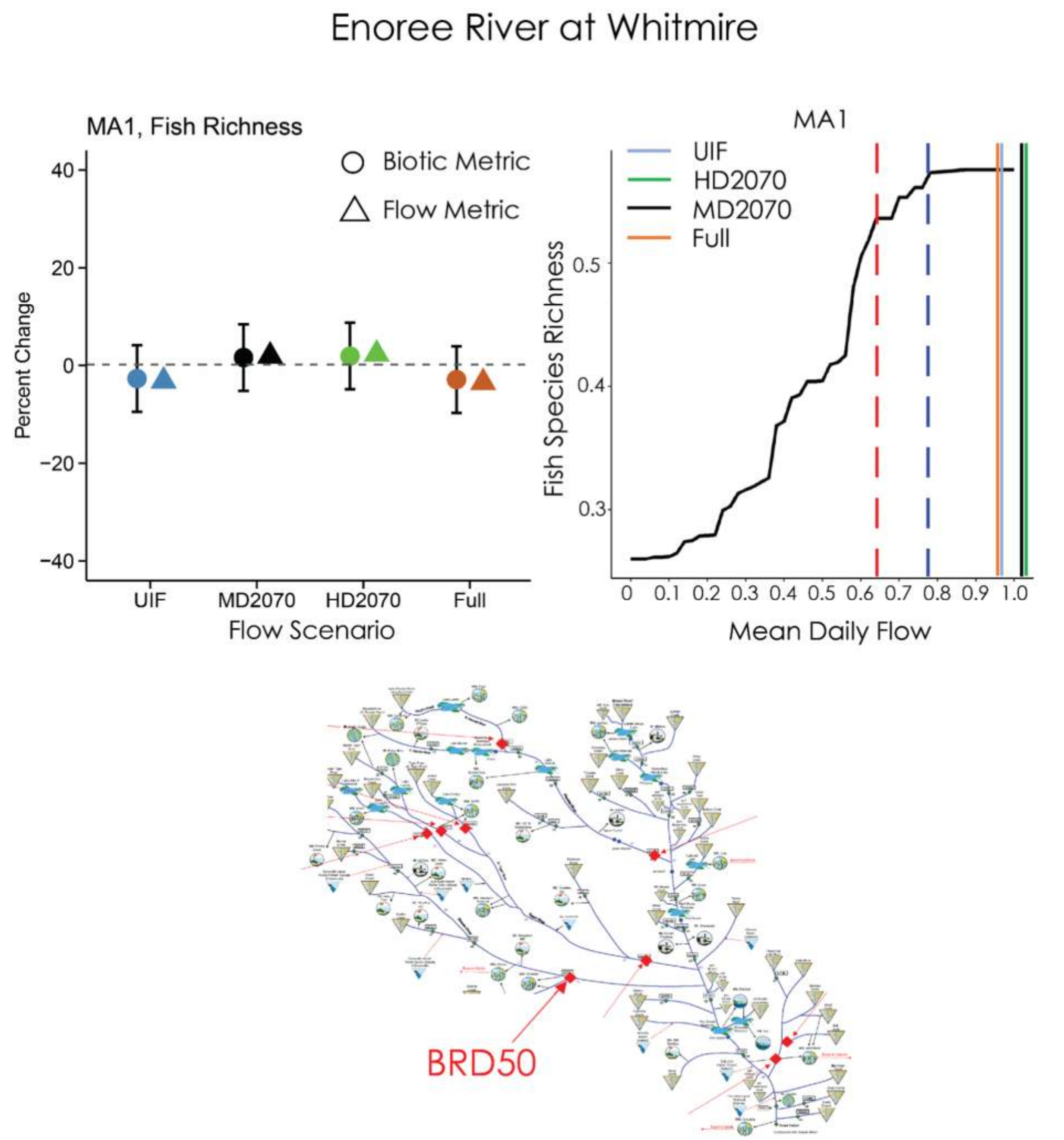

Figure 20: Mean daily flow (MA1) projections for the Enoree River at Whitmire (BRD50). The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios to be in the low-risk category.

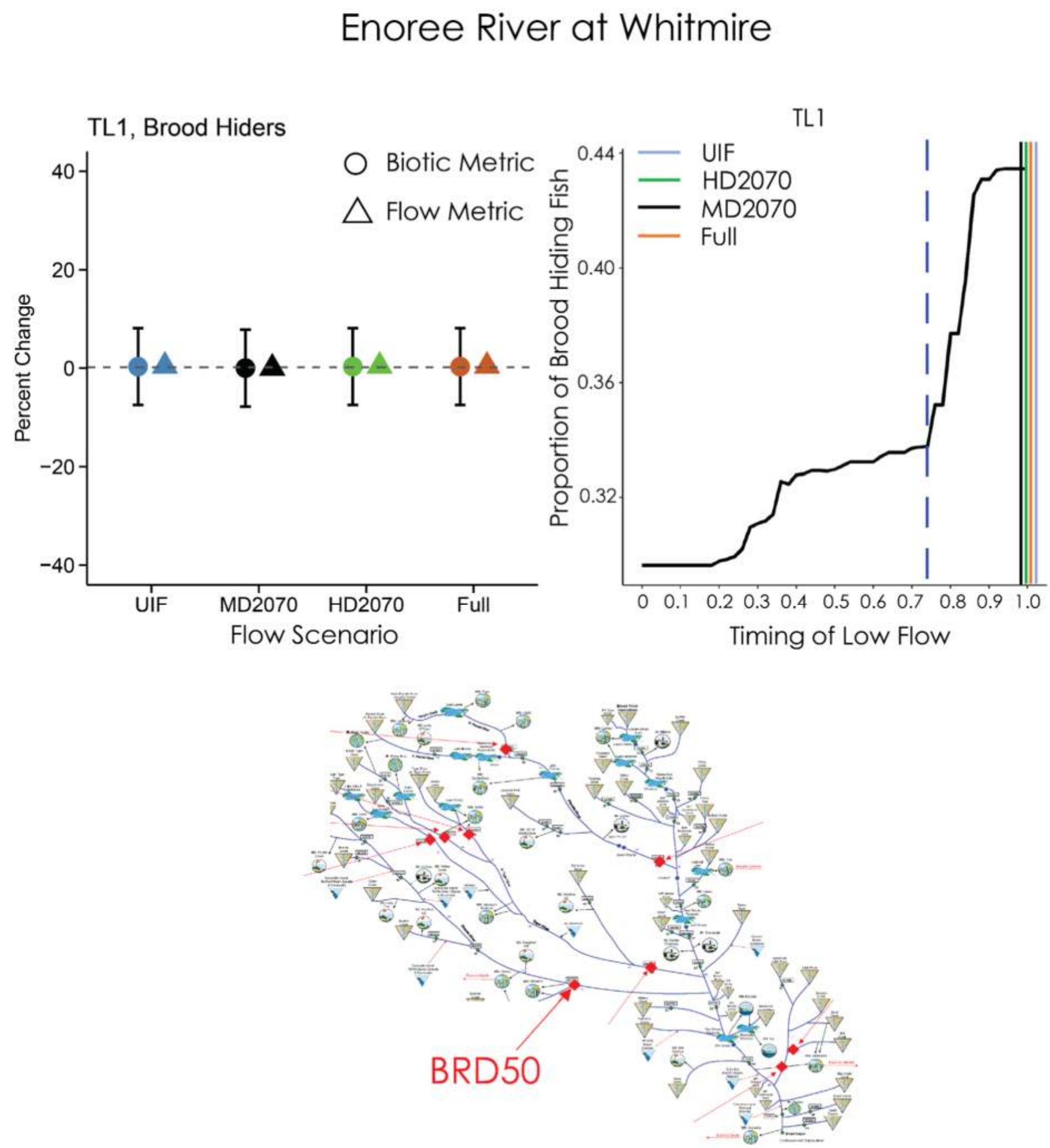

Figure 21: Timing of low flow (TL1) projections for strategic node Enoree River at Whitmire (BRD50). The triangles indicate the percent change in timing of low flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in timing of low flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios to be in the low-risk category.

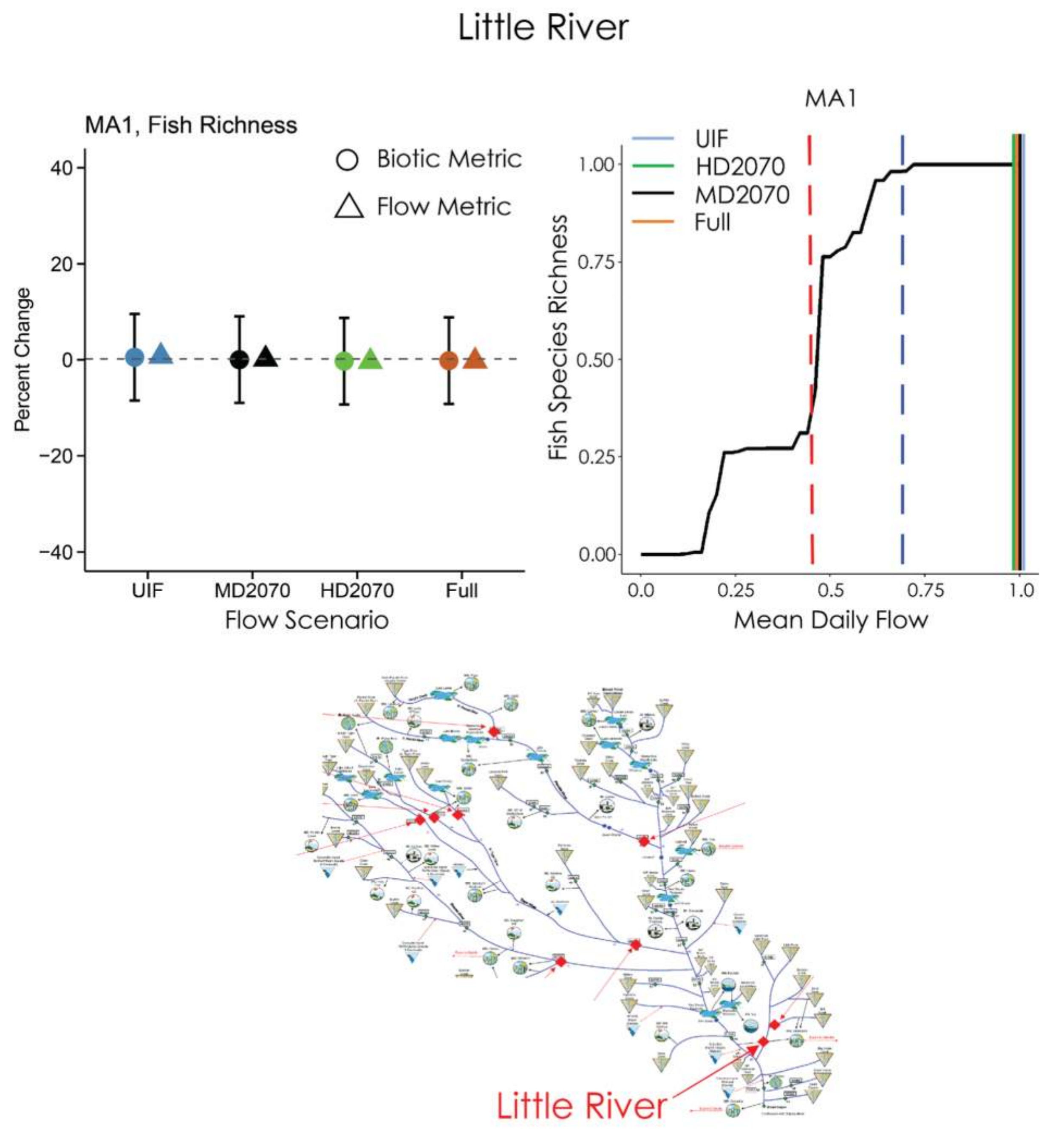

Figure 22: Mean daily flow (MA1) projections for the Little River. The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios to be in the low-risk category.

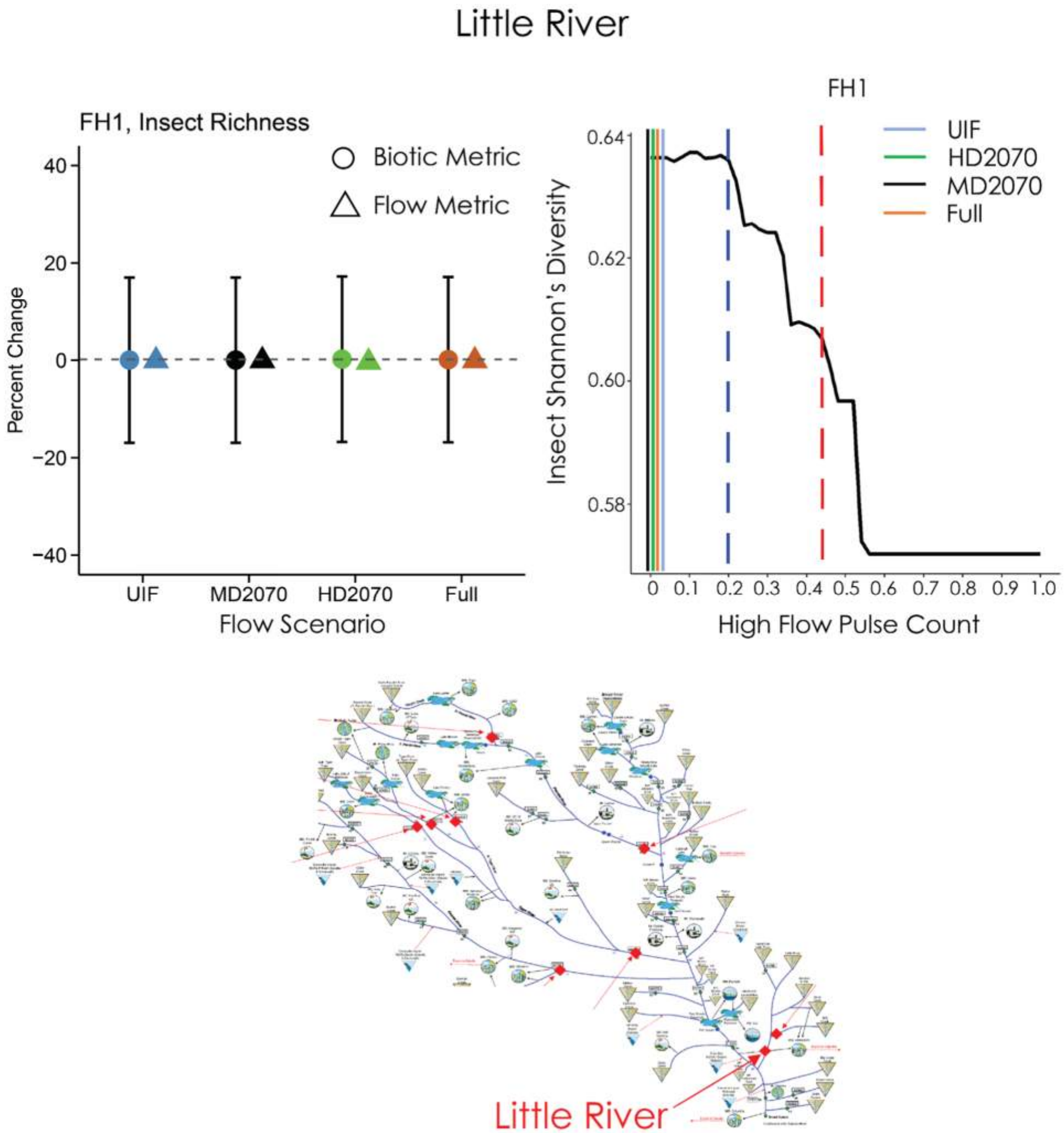

Figure 23: Frequency of high flow (FH1) projections for the Little River. The triangles indicate the percent change in frequency of high flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in frequency of high flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios to be in the low-risk category.

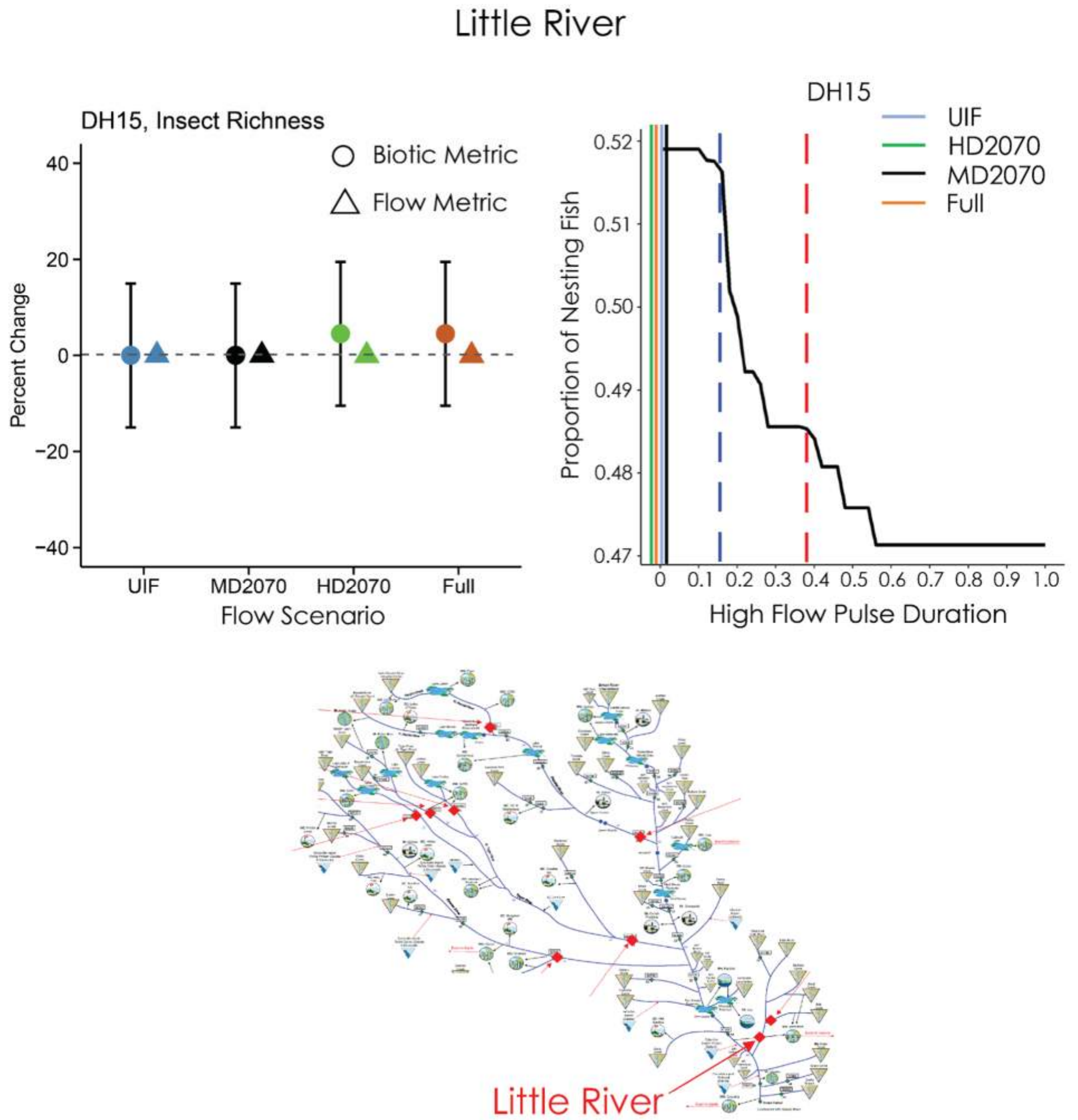

Figure 24: Duration of high flow (DH15) projections for the Little River. The triangles indicate the percent change in duration of high flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in duration of high flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios to be in the low-risk category.

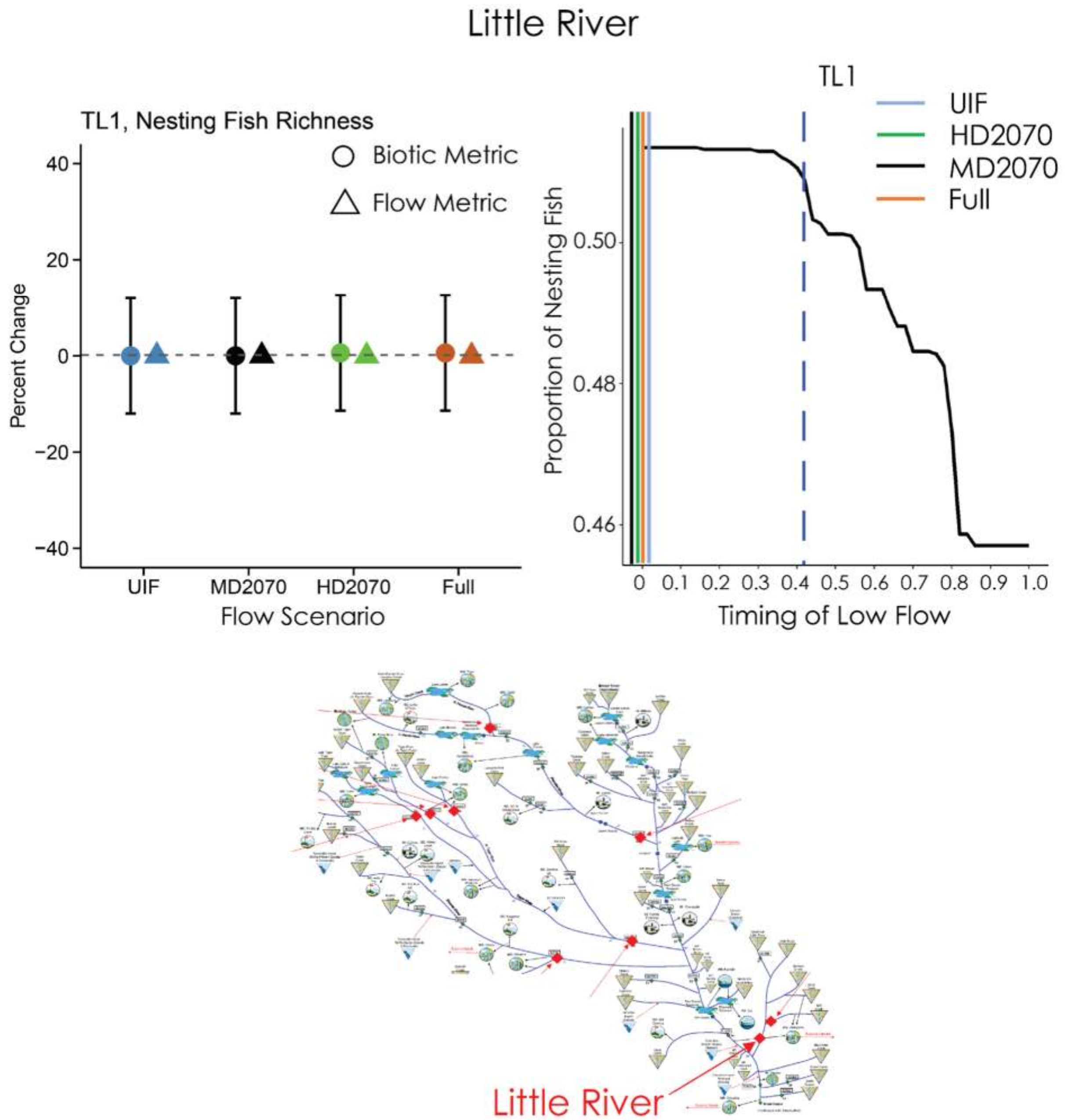

Figure 25: Timing of low flow (TL1) projections for the Little River. The triangles indicate the percent change in timing of low flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in timing of low flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios to be in the low-risk category.

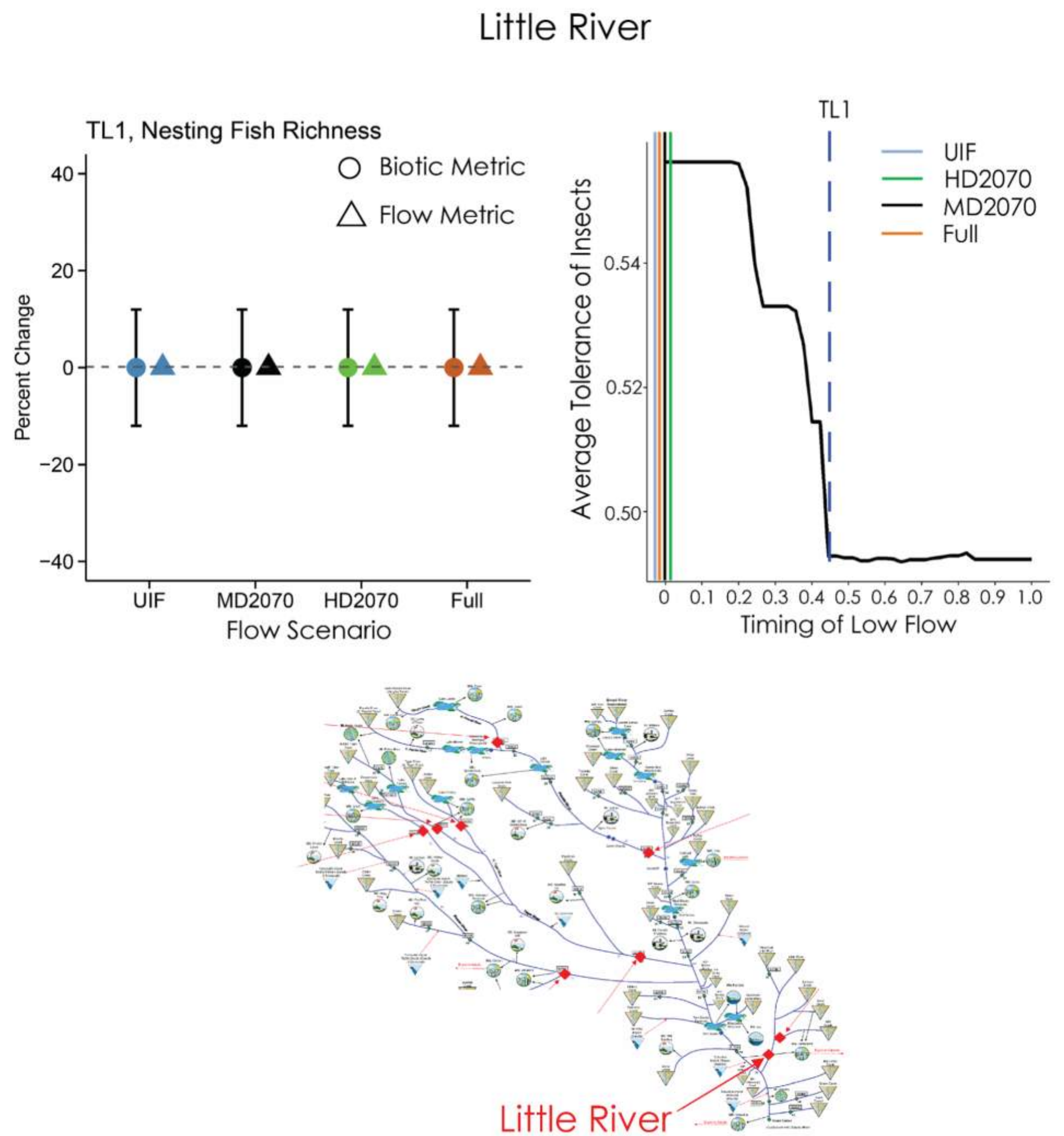

Figure 26: Timing of low flow (TL1) projections for the Little River. The triangles indicate the percent change in timing of low flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in timing of low flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios to be in the low-risk category.

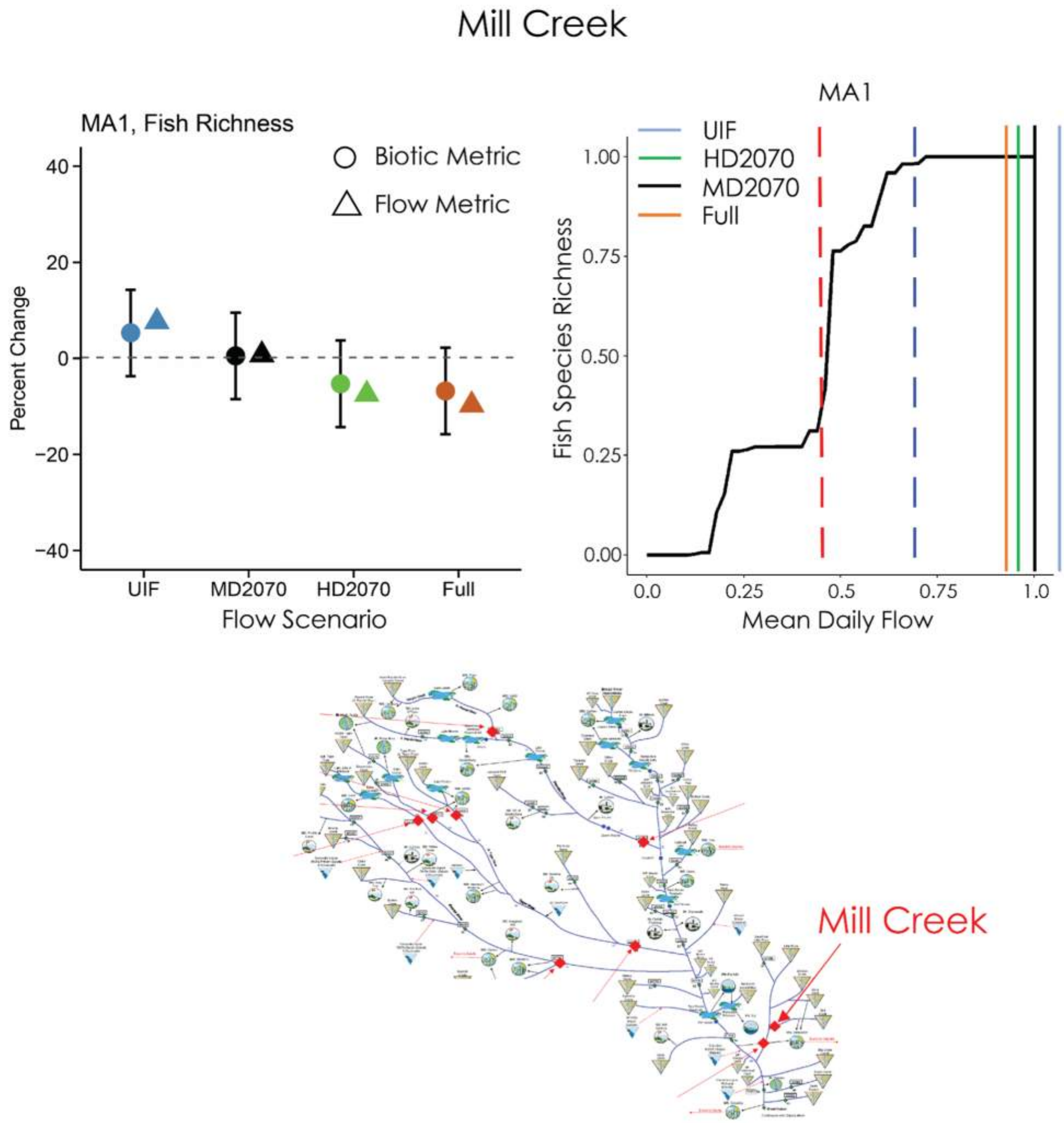

Figure 27: Mean daily flow (MA1) projections for Mill Creek. The triangles indicate the percent change in mean daily flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in mean daily flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios to be in the low-risk category.

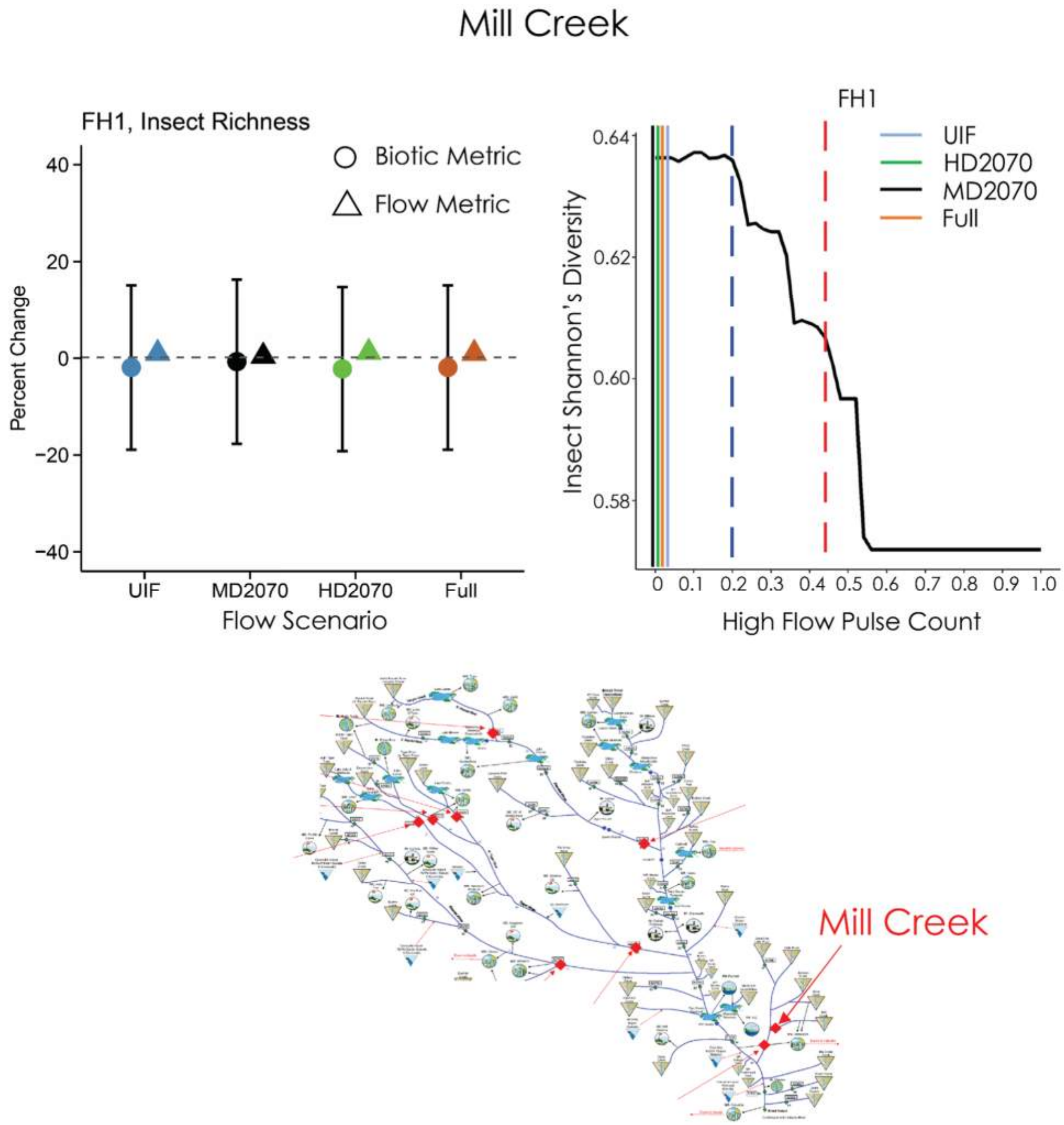

Figure 28: Frequency of high flow (FH1) projections for Mill Creek. The triangles indicate the percent change in frequency of high flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in frequency of high flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios to be in the low-risk category.

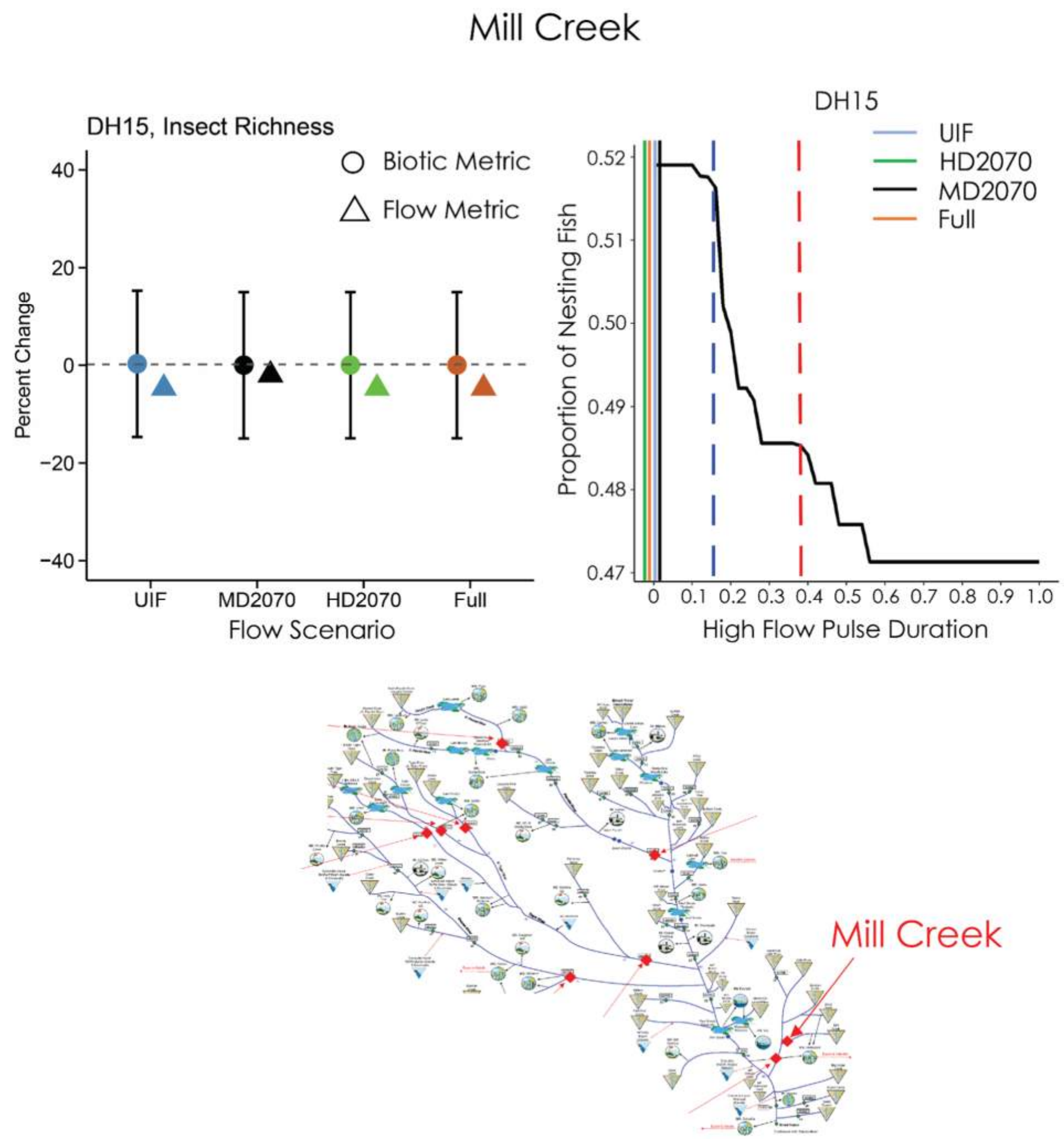

Figure 29: Duration of high flow (DH15) projections for Mill Creek. The triangles indicate the percent change in duration of high flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in duration of high flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios to be in the low-risk category.

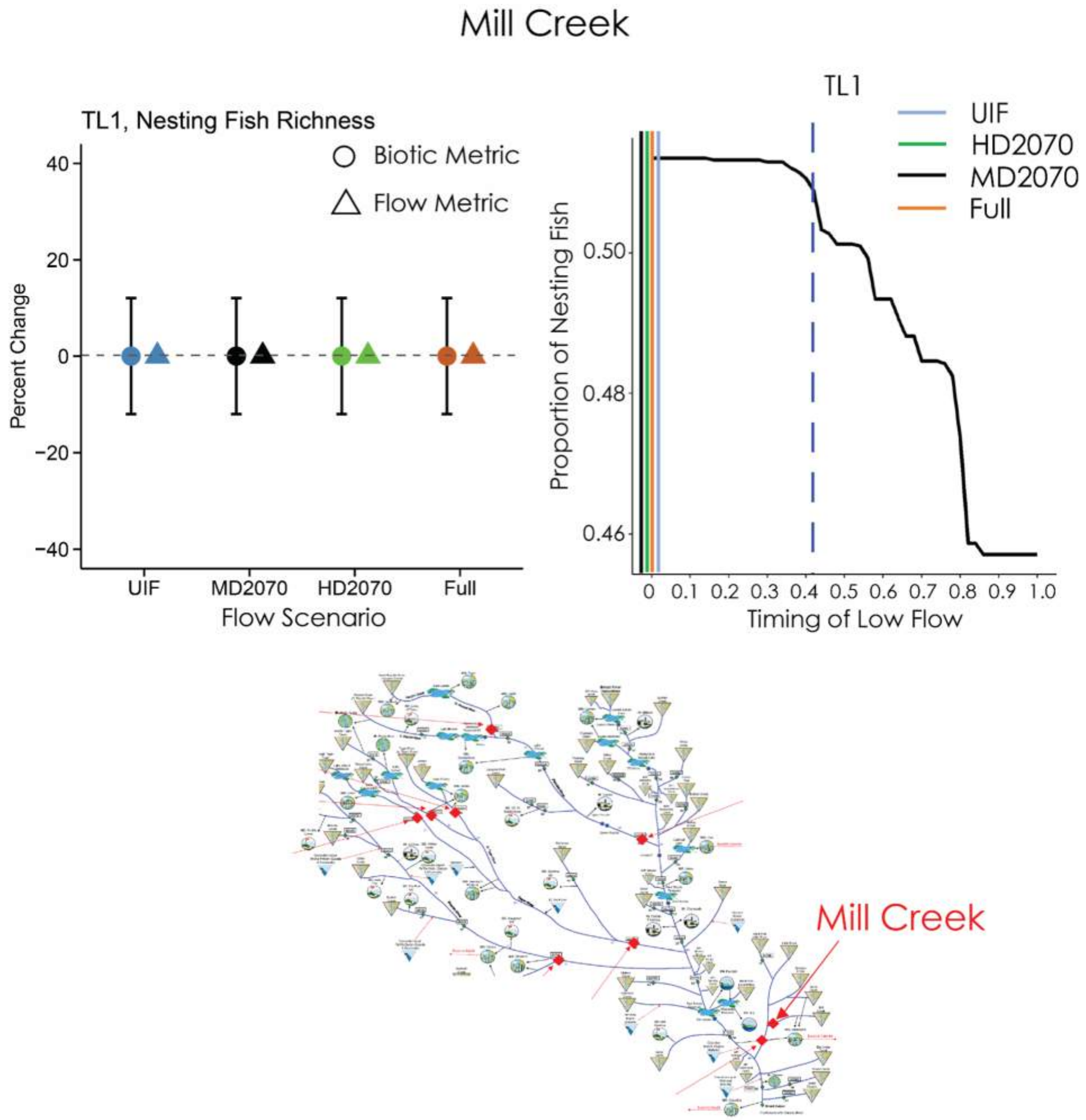

Figure 30: Timing of low flow (TL1) projections for Mill Creek. The triangles indicate the percent change in timing of low flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in timing of low flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios to be in the low-risk category.

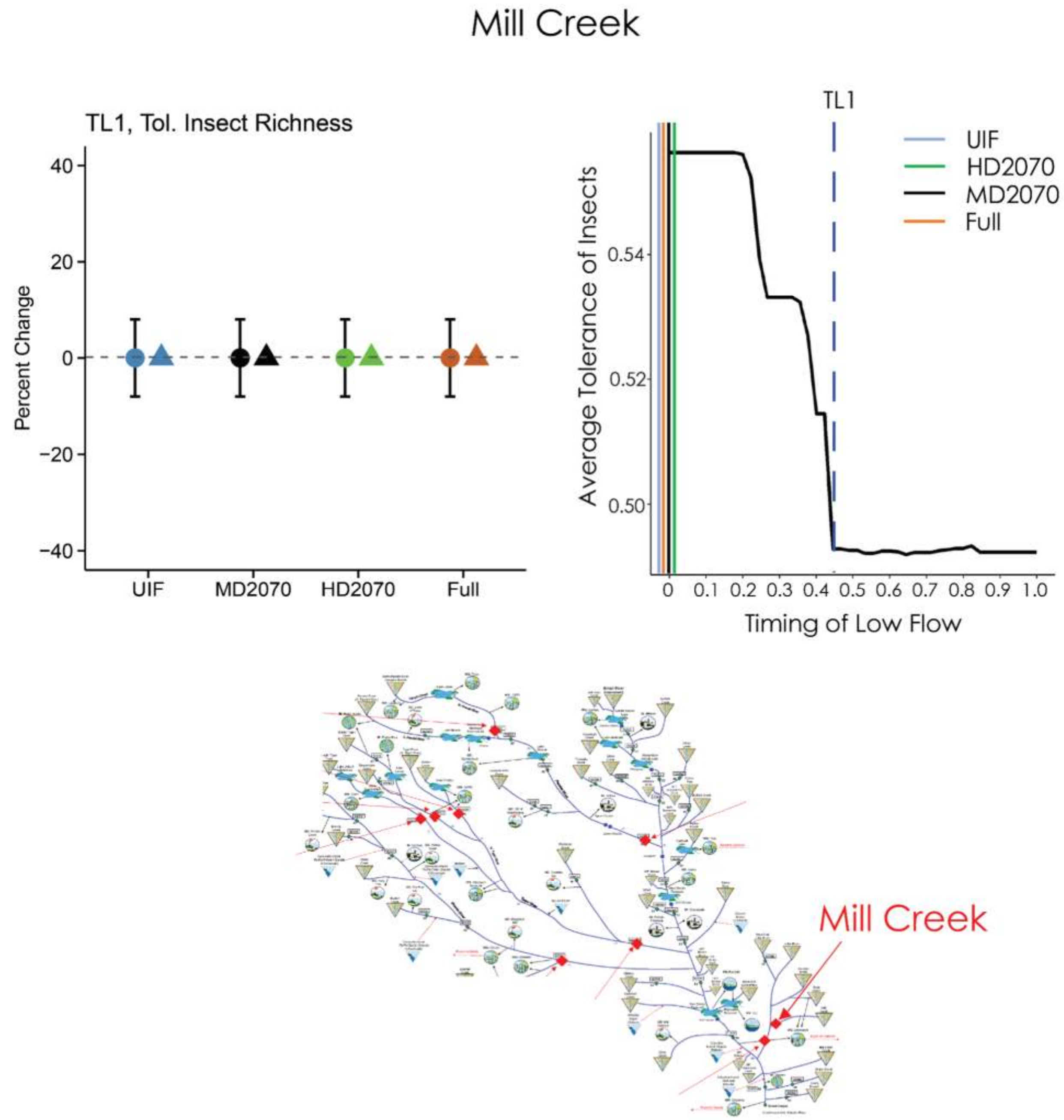

Figure 31: Timing of low flow (TL1) projections for Mill Creek. The triangles indicate the percent change in timing of low flow for the four scenarios predicted by the SWAM model. The circles indicate the percent change in fish species richness based on the SWAM predictions, with the uncertainty of that prediction described by standard error (error bars). The percent change in timing of low flow for each SWAM scenario is shown on performance measure plots to quickly assess risk, finding all scenarios to be in the low-risk category.

Appendix Table 1: *Abbreviation, description, and association with type of biological metrics*

Fish metrics	
Abbreviation	***Description***
Richness	*Taxa richness*
Shannon	*Shannon's diversity index*
Lepomis	*proportional representation of individuals in the genus Lepomis*
Brood Hider	*proportional representation of individuals in the brood hiding breeding strategy (Balon, 1975).*
Nest Spawner	*proportional representation of individuals in the nest spawning breeding strategy (Balon, 1975).*
Open substrate	*proportional representation of individuals an open substrate spawning breeding strategy (Balon, 1975).*
Lotic	*proportional representation of individuals that prefer lotic environments*
Tolerance	*proportional representation of tolerant individuals*
Benthic Macroinvertebrate metrics	

Abbreviation	*Description*
Richness	*Taxa richness*
Shannon	*Shannon's diversity index*
EPT	*proportional representation of individuals in*
Chronomidae	*proportional representation of individuals in Chrionomidae family*
M-O index	*Average of an index indicative of Odonata and Megaloptera taxa preference for lotic or lentic conditions*
Tolerance	*Average tolerance index for macroinvertebrate taxa*

Appendix Table 2: List of hydrologic metrics, their associated flow regime component, and description.

Code	Flow regime	Description
DL16	Duration	Low flow pulse duration. The average pulse for flow events below a threshold equal to the 25th percentile value for the entire flow record.
DL17	Duration	Coefficient of vitiation in DL16
DL18	Duration	Number of zero-flow days
DH15	Duration	High flow pulse duration. The average duration for flow events with flows above a threshold equal to the 75th percentile value for each year in the flow record.
DH16	Duration	Coefficient of vitiation in DH15
FL1	Frequency	Low flow pulse count. Average number of flow events with flows below a threshold equal to the 25th percentile value for the entire flow record
FL2	Frequency	Coefficient of vitiation in FL1
FH1	Frequency	High flow pulse count. Average pulse duration for each year for flow events below a threshold equal to the 25th percentile value for the entire flow record.
FH2	Frequency	Coefficient of vitiation in FH1
MA1	Magnitude	Mean daily flow (cfs)
MA3	Magnitude	Mean of the coefficient of vitiation (standard deviation/mean) for each year of daily flows
MA41	Magnitude	Annual runoff computed as the mean of the annual means divided by the

MA42	Magnitude	Coefficient of vitiation of MA41
ML17	Magnitude	Base flow index. The minimum of a 7-day moving average flow divided by the mean annual flow for each year.
ML18	Magnitude	Coefficient of vitiation in ML17
ML22	Magnitude	Specific mean annual minimum flow. Annual minimum flows divided by the drainage area
MH14	Magnitude	Median of annual maximum flows. The ratio of annual maximum flow to median annual flow for each year
MH20	Magnitude	Specific mean annual maximum flow. The annual maximum flows divided by the drainage area
RA8	Rate	Number of reversals. Number of days in each year when the change in flow from one day to the next changes direction
TA1	Timing	Constancy or stability of flow regime computed via the formulation of Colwell (see example in Colwell, 1974).
TL1	Timing	Julian date of annual minimum
TL2	Timing	Coefficient of vitiation in TL1
TH1	Timing	Julian date of annual maximum starting at day 100
TH2	Timing	Coefficient of vitiation in TH1

Appendix D
Draft Plan Survey Consensus Results

To assess each RBC member's confidence in the plan, the plan approval process dictates that there will be a test for consensus on the Draft River Basin Plan and a vote of support or disagreement on the Final River Basin Plan. For the test of consensus on the Draft Plan, each member rates their concurrence with the plan using a five-point scale, as shown below:

1. Full Endorsement (i.e., member likes it).
2. Endorsement but with minor points of contention (i.e., basically member likes it).
3. Endorsement but with major points of contention (i.e., member can live with it).
4. Stand aside with major reservations (i.e., member cannot live with it in its current state and can only support it if changes are made).
5. Withdraw - Member will not support the draft river basin plan and will not continue working within the RBC's process. Member has decided to leave the RBC.

For the Final River Basin Plan, each RBC member votes simply to support or disagree with the plan. By indicating support, the member would be acknowledging his/her concurrence with the Final River Basin Plan and their commitment to support implementation of the plan. The RBC members vote's on the Draft and Final River Basin Plans are listed below.

Table D-1. Level of consensus for the Draft and Final River Basin Plan.

RBC Member	Draft Plan Level of Endorsement	Final Plan Level of Support[1]
John Alexander	1	
Kristen Austin	2	
Mark Boland	1	
Amy Bresnahan	1	
Frank Eskridge	1	
Bryant Fleming	1	
Daniel Hanks	1	
Erika Hollis	2	
James Kilgo	1	
Karen Kustafik	1	
Angus Lafaye	1	
Jeff Lineberger	1	
Justin McGrady	1	
Paul Pruitt	1	
Bill Stangler	2	
Ken Tuck	1	
Jeff Walker	2	

[1] To be noted once the Final River Basin Plan is prepared, following the public comment period.

Appendix E
Public Comments and Responses


JENKINSVILLE
WATER CO., INC.