

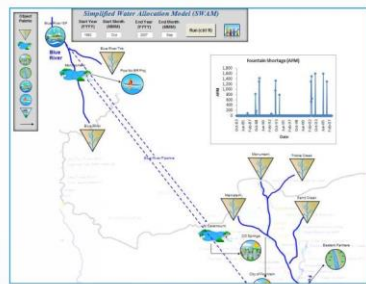
South Carolina Surface Water Quantity Modeling Project

Savannah River Basin Meeting No. 1 – Model Framework

John Boyer, PE, BCEE
Nina Caraway

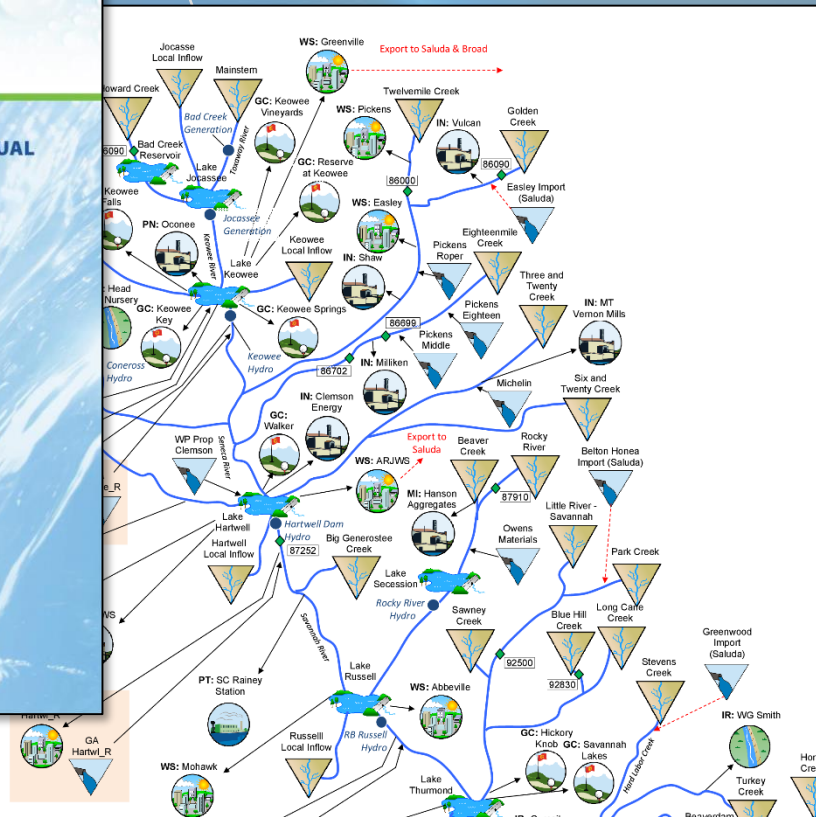
August 10, 2016

Simplified Water Allocation Model (SWAM)



VERSION 3.0
USER'S MANUAL

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CDM Smith
555 17th Street, Suite 1100
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Presentation Outline

- Project purpose and status
- Introduction to SWAM
- Data requirements
- Unimpaired flows
- Overview of proposed Savannah River model framework
- Model setup
- Model calibration/validation

Project Purpose

- Build eight surface water quantity models capable of:
 - Accurately simulating streamflows and reservoir levels over the historical inflow record
 - Conducting “What if” scenarios to evaluate future water demands, management strategies and system performance.
 - Supporting future phases of the State Water Plan Update
 - Being used by regulators, water utilities, basin planning organizations and others.



Modeling Report and Other Documents

- <http://www.dnr.sc.gov/water/waterplan/surfacewater.html>

The screenshot shows the website for the South Carolina Department of Natural Resources (DNR). The header includes the DNR logo and the slogan "Life's Better Outdoors". A navigation menu lists various topics: Buy, Boating, Education, Fishing, Hunting, Land, Maps, Regulations, Water, and Wildlife. The main content area is titled "Surface Water Modeling and Assessments" and contains several paragraphs of text, a "Project Documents" section with a list of links (Monthly Progress Reports, Legislative Quarterly Reports, Technical Reports, Technical Memorandums, Meeting Notes, Presentations, Videos, River Basins), and social media icons for Facebook, RSS Feed, Twitter, and YouTube. The footer contains contact information and copyright details for 2014.

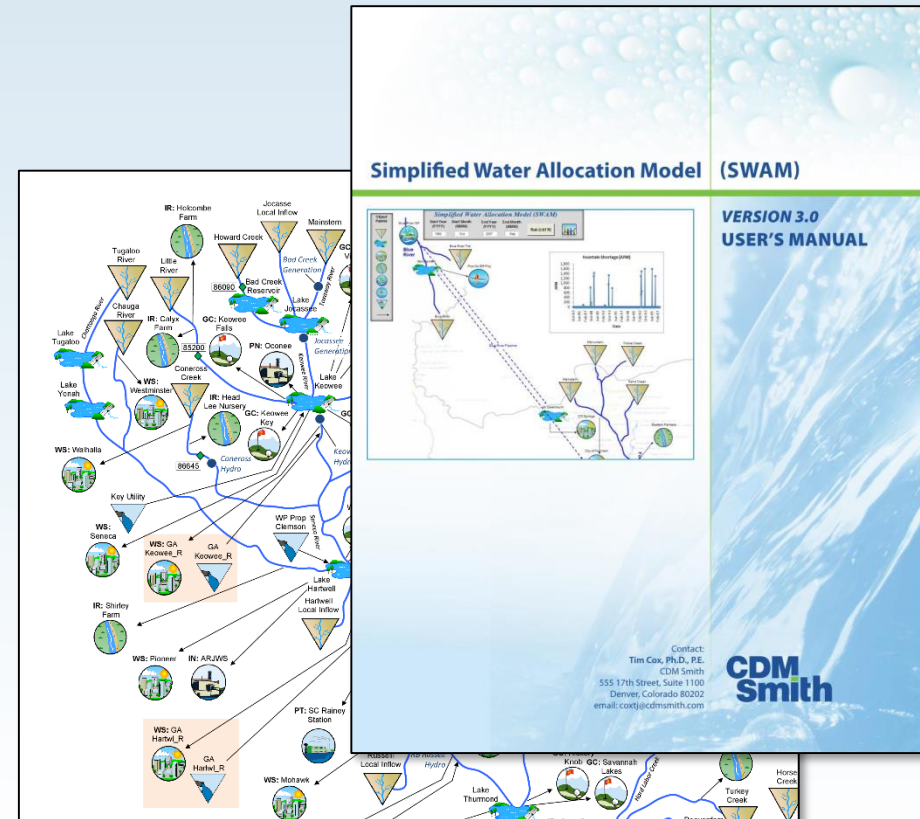
The image shows the cover of a report titled "SOUTH CAROLINA SURFACE WATER QUANTITY MODELS BROAD RIVER BASIN MODEL". The cover features a large, detailed map of the Broad River Basin with various water bodies and flow paths. The report is submitted to the South Carolina Department of Natural Resources and the South Carolina Department of Health & Environmental Control. It is dated May 2016 and prepared by CDM Smith. The word "DRAFT" is prominently displayed at the bottom left of the cover.

Savannah River Basin

INTRODUCTION TO SWAM

Simplified Water Allocation Model (SWAM)

- Developed in response to an increasing need for a desktop tool to facilitate regional and statewide water allocation analysis
- Calculates physically and legally available water, diversions, storage consumption and return flows at user-defined nodes
- Used to support large-scale planning studies in Colorado, Oklahoma, Arkansas and Texas



The Simplified Water Allocation Model is...

- a water accounting tool
- a WHAT-IF simulation model
- a network flow model that traces water through a natural stream network, simulating withdrawals, discharges, storage, and hydroelectric operations
- not precipitation-runoff model (e.g., HEC-HMS)
- not a hydraulic model (e.g. HEC-RAS)
- not a water quality model (e.g., QUAL2K)
- not an optimization model
- not a groundwater flow model (e.g., MODFLOW)

The Models Can Be Used To...

- Determine surface-water availability
- Predict where and when future water shortages would occur
- Test alternative water management strategies, new operating rules, and “what-if” scenarios
- Consolidate hydrologic data
- Evaluate the impacts of future withdrawals on instream flow needs
- Evaluate interbasin transfers
- Support development of Drought Management Plans
- Compare managed flows to natural flows

River Basin Flow and Operations Models

Similarities between **SWAM**, **OASIS**, **CHEOPS**, and **RiverWare**:

- Used in major river basin studies and/or statewide water plans
- Operating Rules of varying complexity
- Monthly and Daily Timesteps
- Visual Depiction of the River Network

Unique Features:

SWAM

- Familiar and adaptable environment: Visual Basic and Spreadsheets
- Built in functions for reservoirs, river operations, discharges, irrigation, return flows, etc.

OASIS

- Built in Probability Analysis for Real-Time Ops
- Optimization toward objectives in each timestep

CHEOPS

- Tailored specifically for hydropower
 - Energy Calculations
 - Reservoir Tracking
- Familiar Visual Basic programming

RiverWare

- Fully linked graphical network development
- 3 modes:
 - Pure simulation
 - Rules-based simulation
 - Optimization

Simplified Water Allocation Model (SWAM)

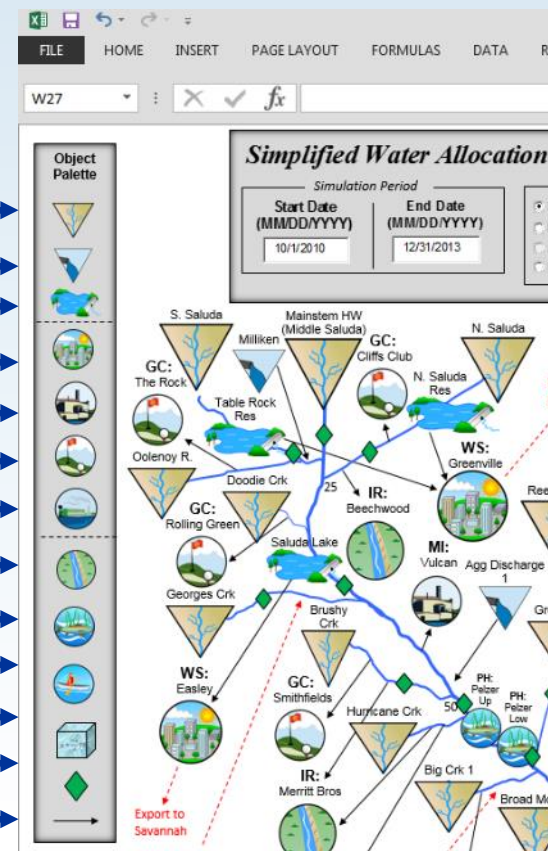
- Object-oriented tool in which a river basin and all of its influences can be linked into a network with user defined priorities
- Resides within Microsoft Excel
- Point and click setup and output access

Input Forms

Water
User
Objects

Objects

- Tributaries →
- Discharges →
- Reservoirs →
- Municipal →
- Industrial →
- Golf Courses →
- Power Plants →
- Agriculture →
- Instream Flow →
- Recreational Pool →
- Aquifer →
- USGS Gage →
- Interbasin Transfer →



Simplified Water Allocation Model (SWAM)

- Supports multiple layers of complexity for development of a range of systems, for example...

A Reservoir Object can include:

1. Basic hydrology dependent calculations
2. Operational rules of varying complexity such as prescribed releases, conditional releases, or hydrology dependent releases.

Reservoir

A screenshot of the 'Reservoir' configuration window in the SWAM software. The window has a title bar 'Reservoir' and a 'Main' tab. It contains several input fields and tables for configuring a reservoir object.

Reservoir Name: [dropdown] **Delete Node** Storage Capacity (AF) [input] Initial Storage (AF) [input] Offline Online

Evaporation: Inches/day % Volume Input Timeseries

Monthly Rates

Month	Evap. Rates (in./day)
Jan	
Feb	
Mar	
Apr	
May	
Jun	
Jul	
Aug	
Sep	

Area-Capacity Table

Simple Detailed

Volume (AF)	Area (ac)

Reservoir Releases

Receiving Stream: [dropdown] Simple Advanced

Release Location (mi) [input]

User Defined Releases

Month	Min. Release (AFM)	(CFS)
Jan		
Feb		
Mar		
Apr		
May		
Jun		
Jul		
Aug		
Sep		

SWAM Model Main Screen

Simplified Water Allocation Model (SWAM)

Simulation Period

Start Date (MM/DD/YYYY) **End Date (MM/DD/YYYY)**

01/01/1929 12/31/2010

Simulation Type

Monthly Planning Prior Appropriations

Daily Planning Riparian Water Rights

Short Term Forecasting

Firm Yield Calculator

Input Summaries and Outputting

Node Priorities

Node Locations

Reservoir Accounts

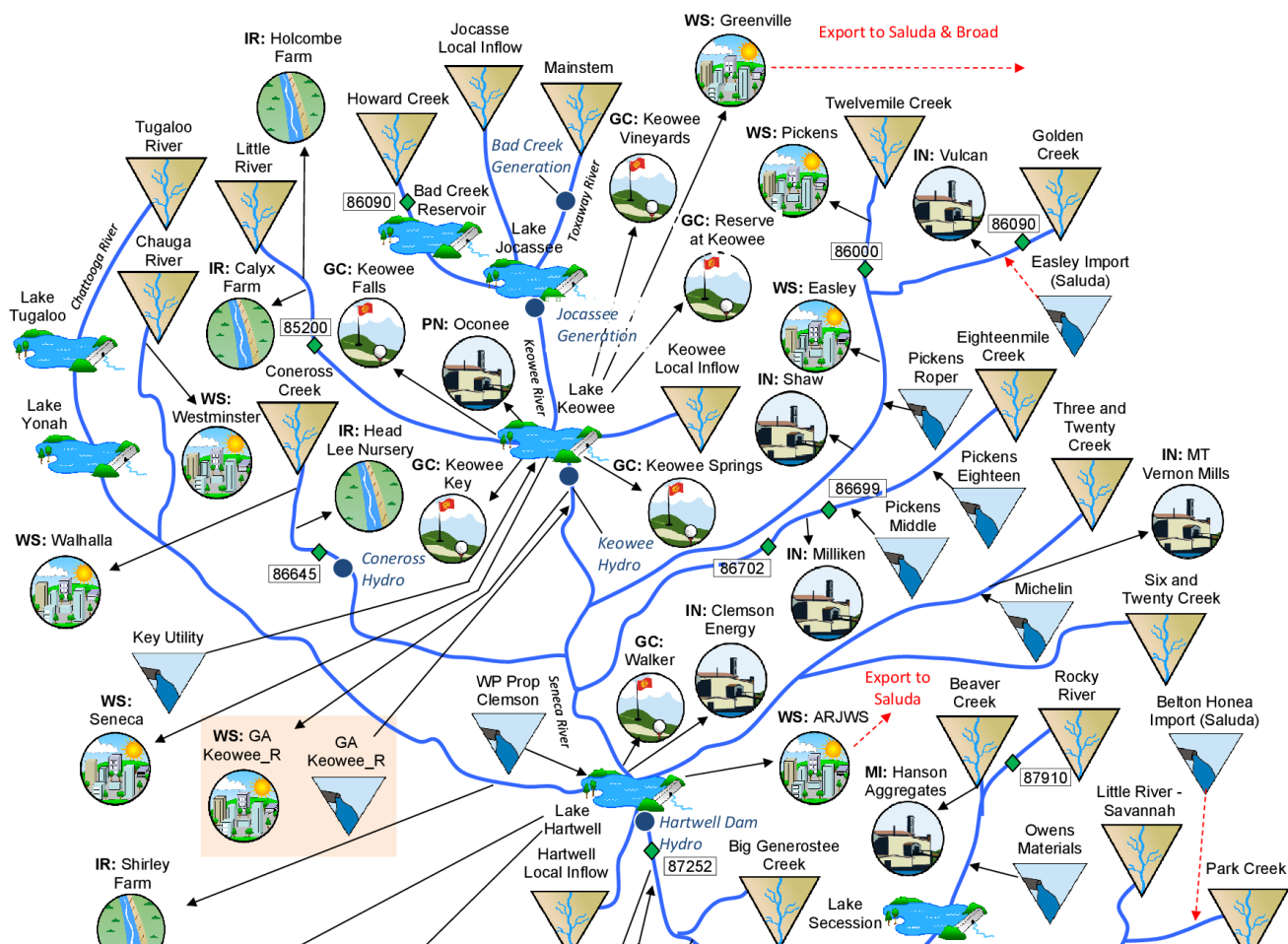
Output Specs

Input & Output Units

AF, AFM, AFD MG, MGD, CFS

Object Palette

-
-
-
-
-
-
-
-
-
-
-
-



Savannah River Basin

MODELING DATA REQUIREMENTS

Data Collected for Model Development

- USGS daily flow records
- Historical daily rainfall and evaporation rates
- Historical Operational Data
 - Withdrawals (municipal, industrial, agricultural, golf courses)
 - Discharges
 - Reservoir elevation
- Reservoir bathymetry and operating rules
- Subbasin characteristics (GIS)
 - Drainage area
 - Land use
- **Other data, studies, and models already developed**

Savannah River Basin

UNIMPAIRED FLOWS (UIF)

UIF Definition and Uses

- **Definition:** Estimate of natural historic streamflow in the absence of human intervention in the river channel:
 - Storage
 - Withdrawals
 - Discharges and Return Flow
- ***Unimpaired Flow*** =
Measured Gage Flow + River Withdrawals + Reservoir Withdrawals – Discharge to Reservoirs – Return Flow + Reservoir Surface Evaporation – Reservoir Surface Precipitation + Upstream change in Reservoir Storage + Runoff from Previously Unsubmerged Area
- **Fundamental input** to the model at headwater nodes and tributary nodes
- **Comparative basis** for model results

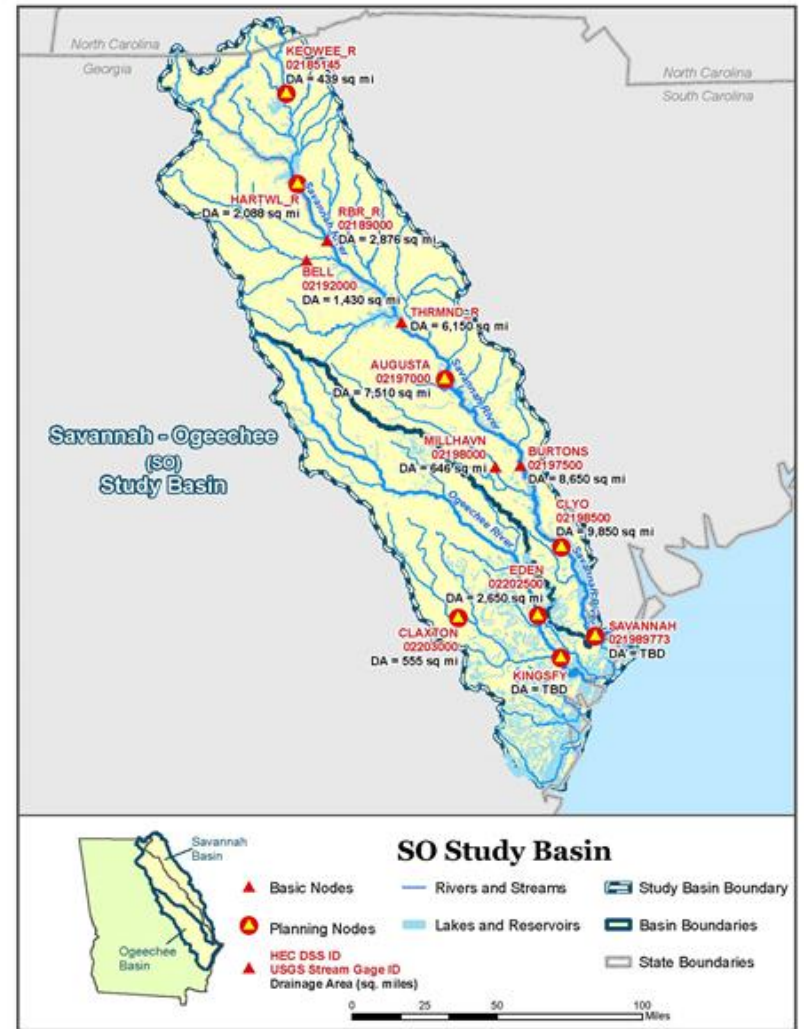
UIFs in the Savannah River Basin

Existing UIFs

- Originally developed for 1939-2007
- Extended through 2008 and added nodes
- Most recently extended through 2013 by GA EPD

UIFs to be Developed

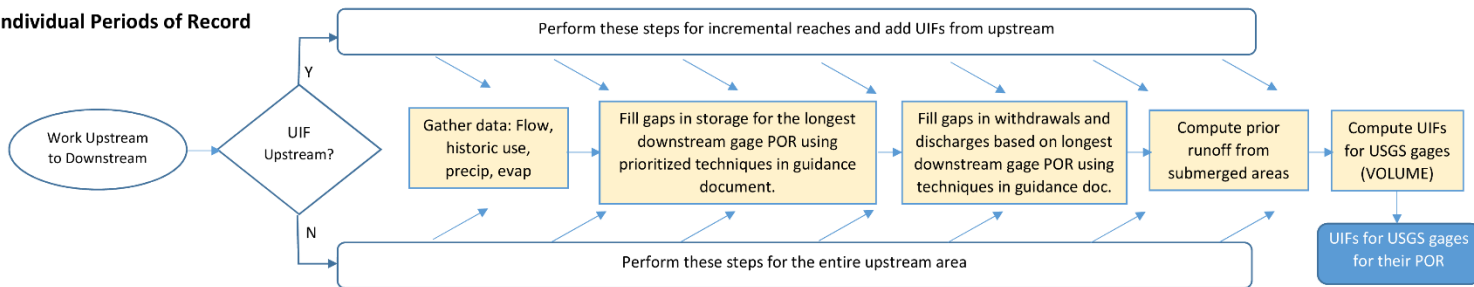
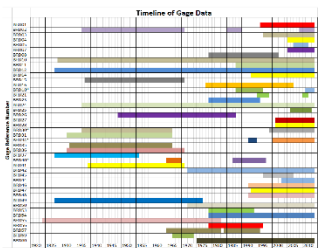
- Modeled SC tributaries to the Savannah River



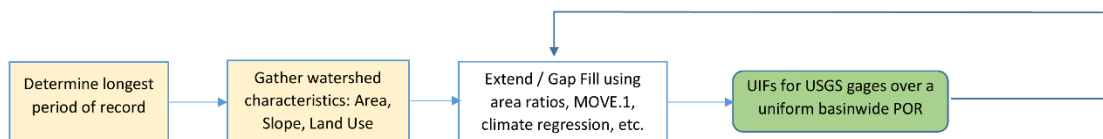
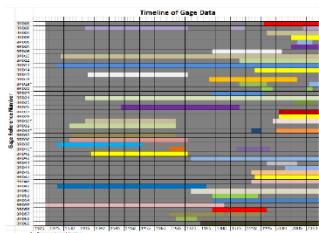
Source: GA EPD's Savannah River Basin Comprehensive Study II: 2009 – 2013 Unimpaired Flow Data Extension (Draft Report)

Basinwide UIF Calculation Process

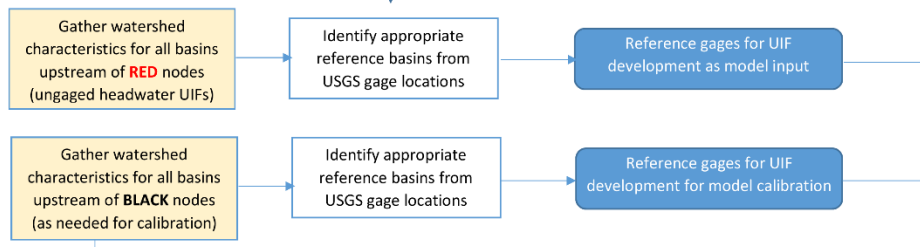
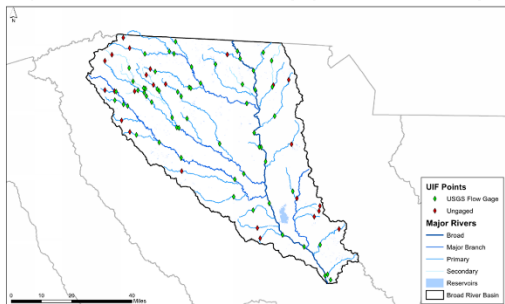
Step 1: UIFs for USGS Gages for their Individual Periods of Record



Step 2: Extension of UIFs for USGS Gages throughout the LONGEST Period of Record



Step 3: Correlation between Ungaged Basins and Gaged Basins

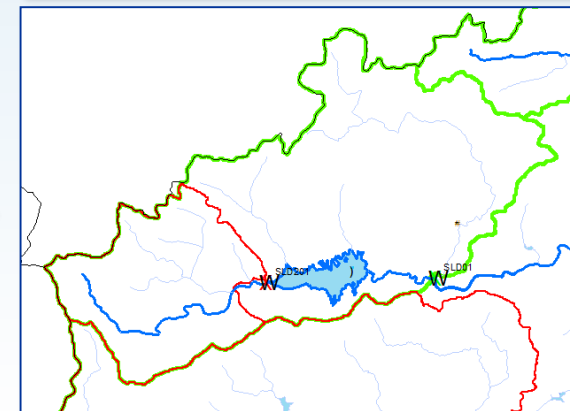
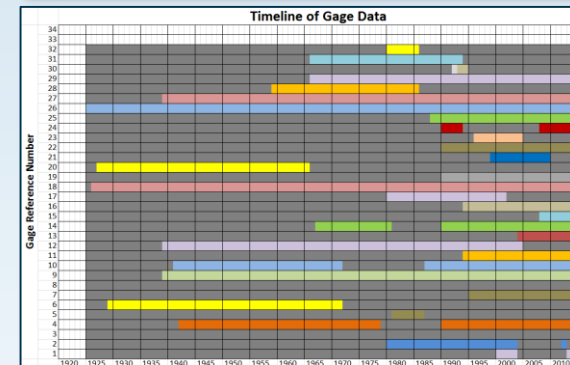
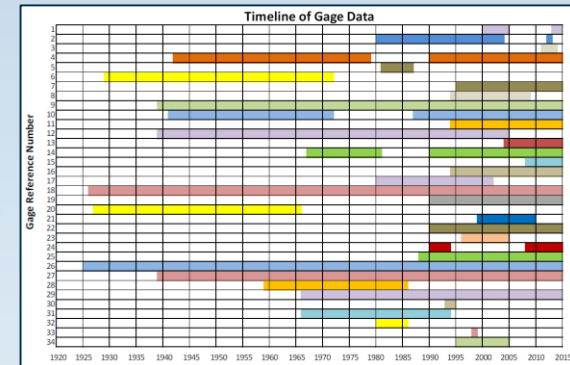


Step 4: UIFs for Ungaged Basins

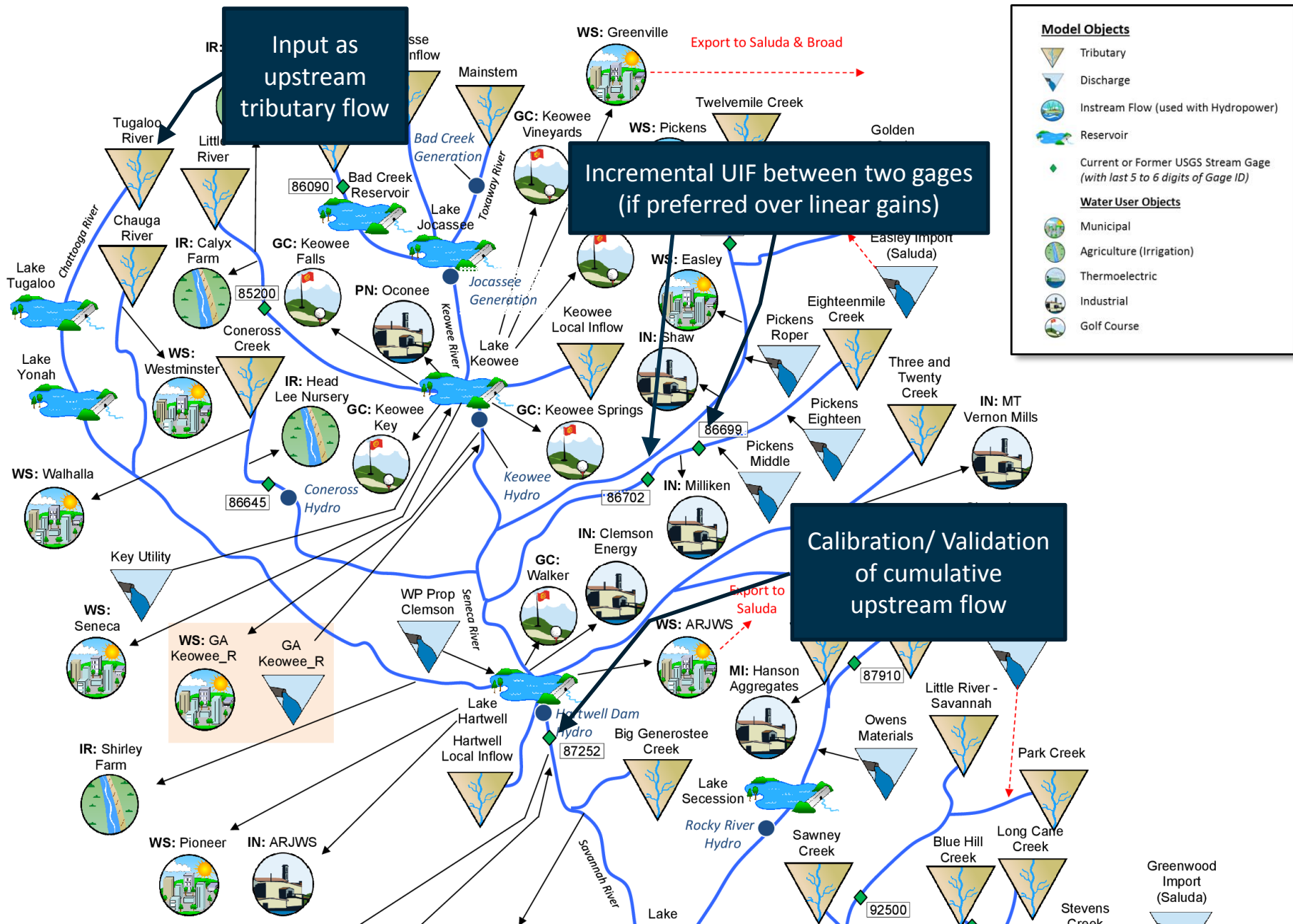


Four Steps in UIF Calculation Process

- **Step 1:** UIFs for USGS Gages for individual periods of record
 - Involves extension of operational data
- **Step 2:** Extension of UIFs for USGS Gages through the LONGEST period of record
- **Step 3:** Correlation between ungaged basins and gaged basins
- **Step 4:** UIFs for ungaged basins



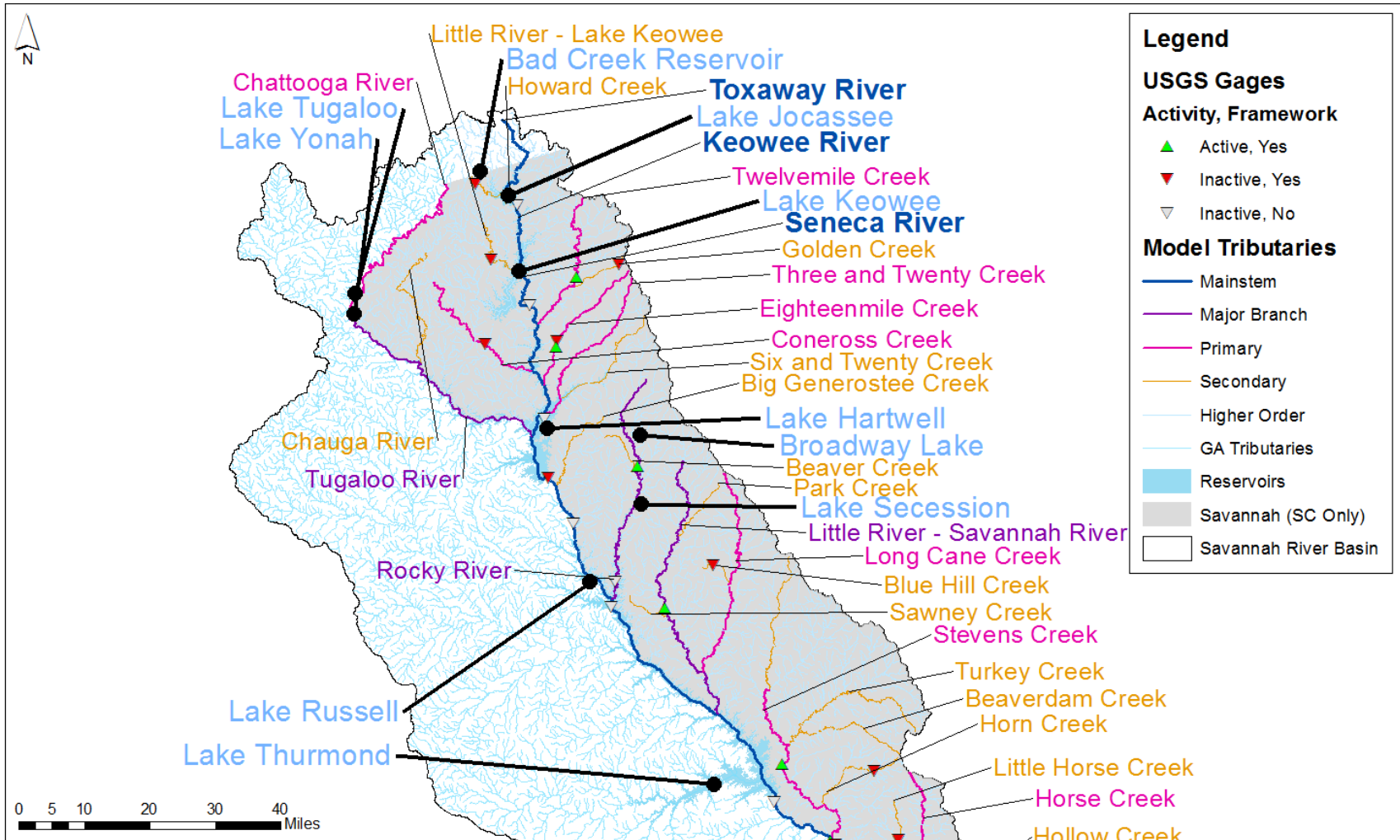
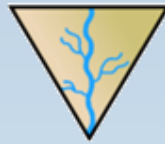
How UIFs are Used in SWAM



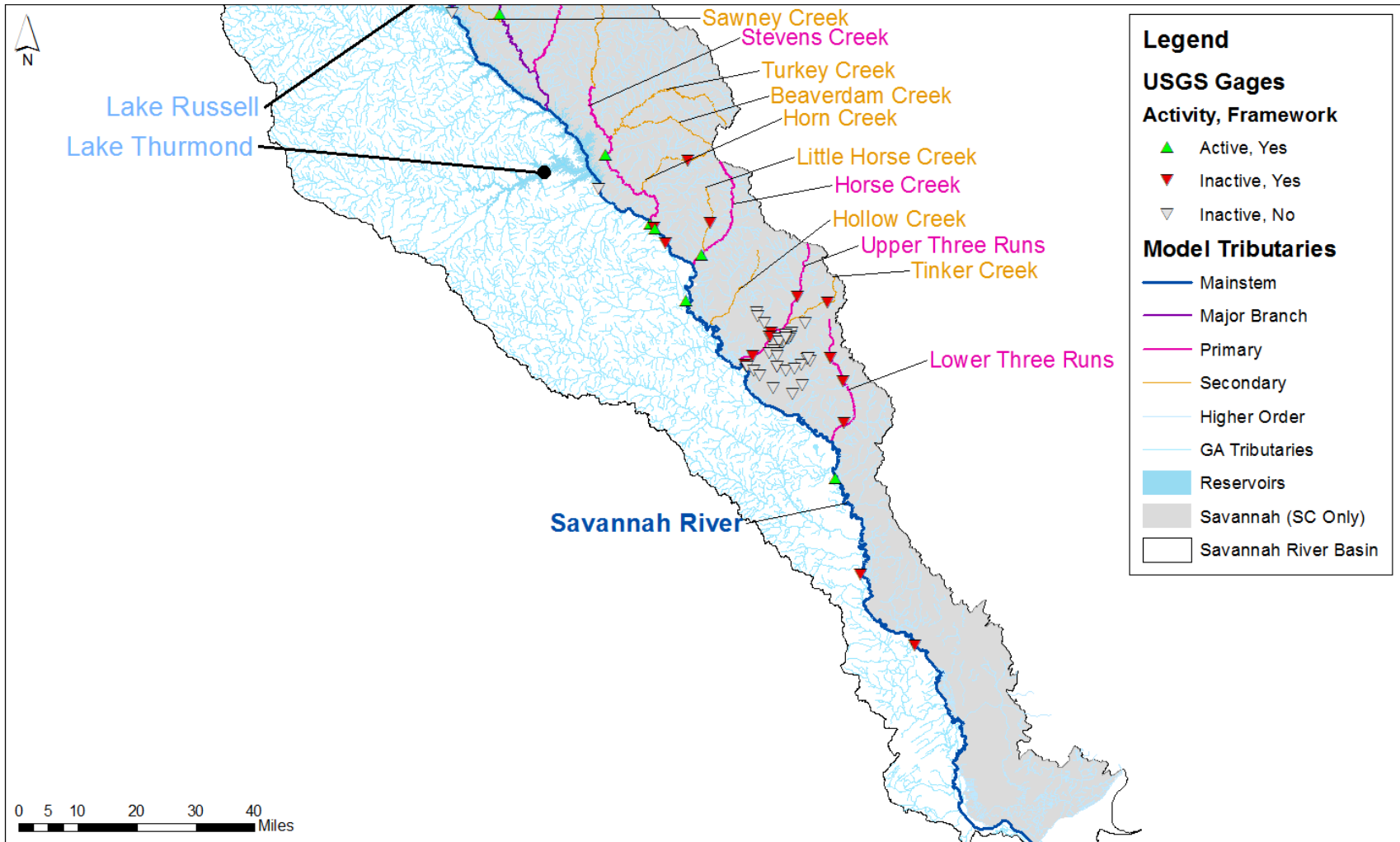
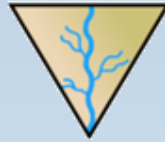
Savannah River Basin

OVERVIEW OF MODEL FRAMEWORK

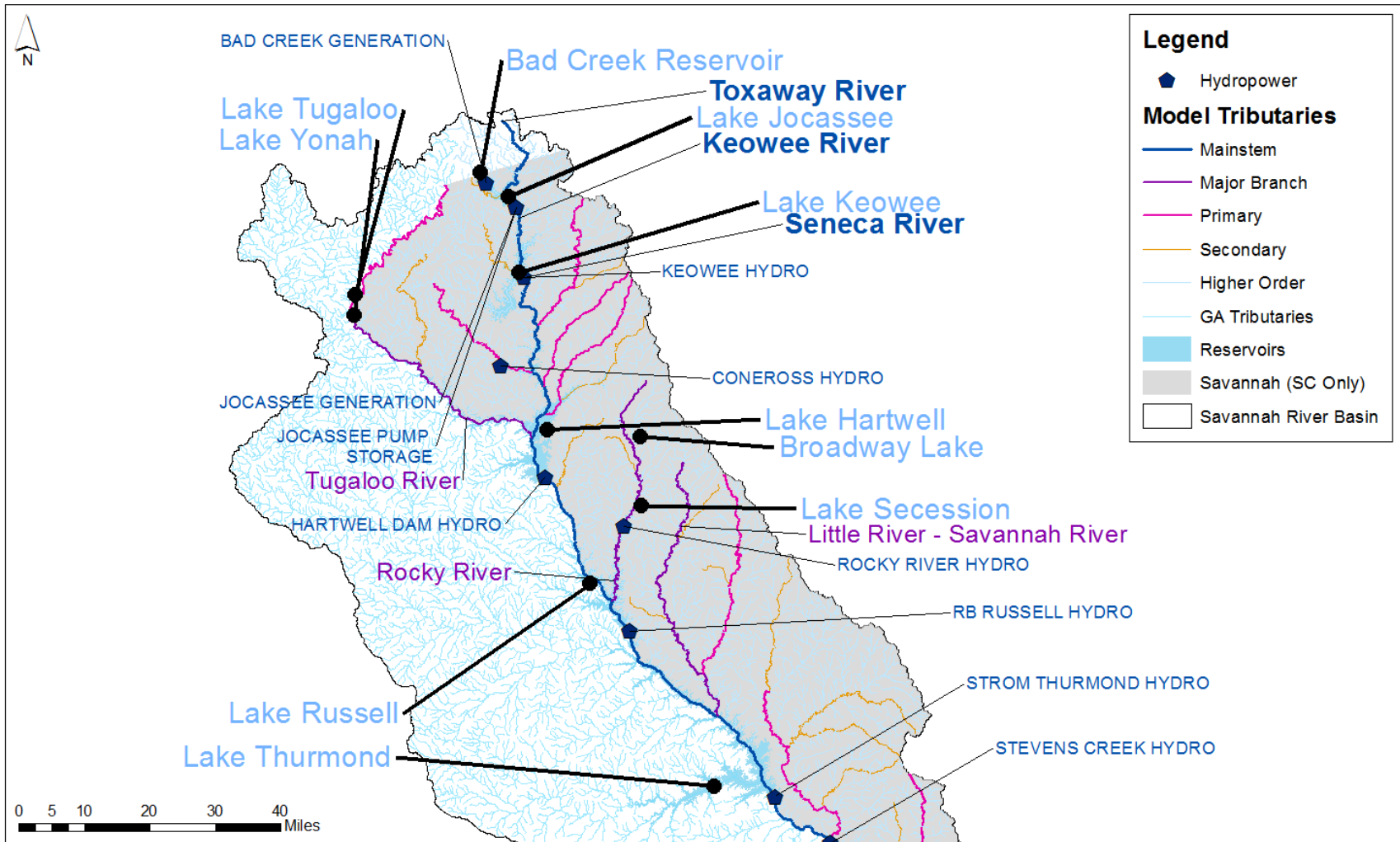
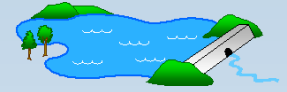
Upper Savannah Basin Model Tributaries



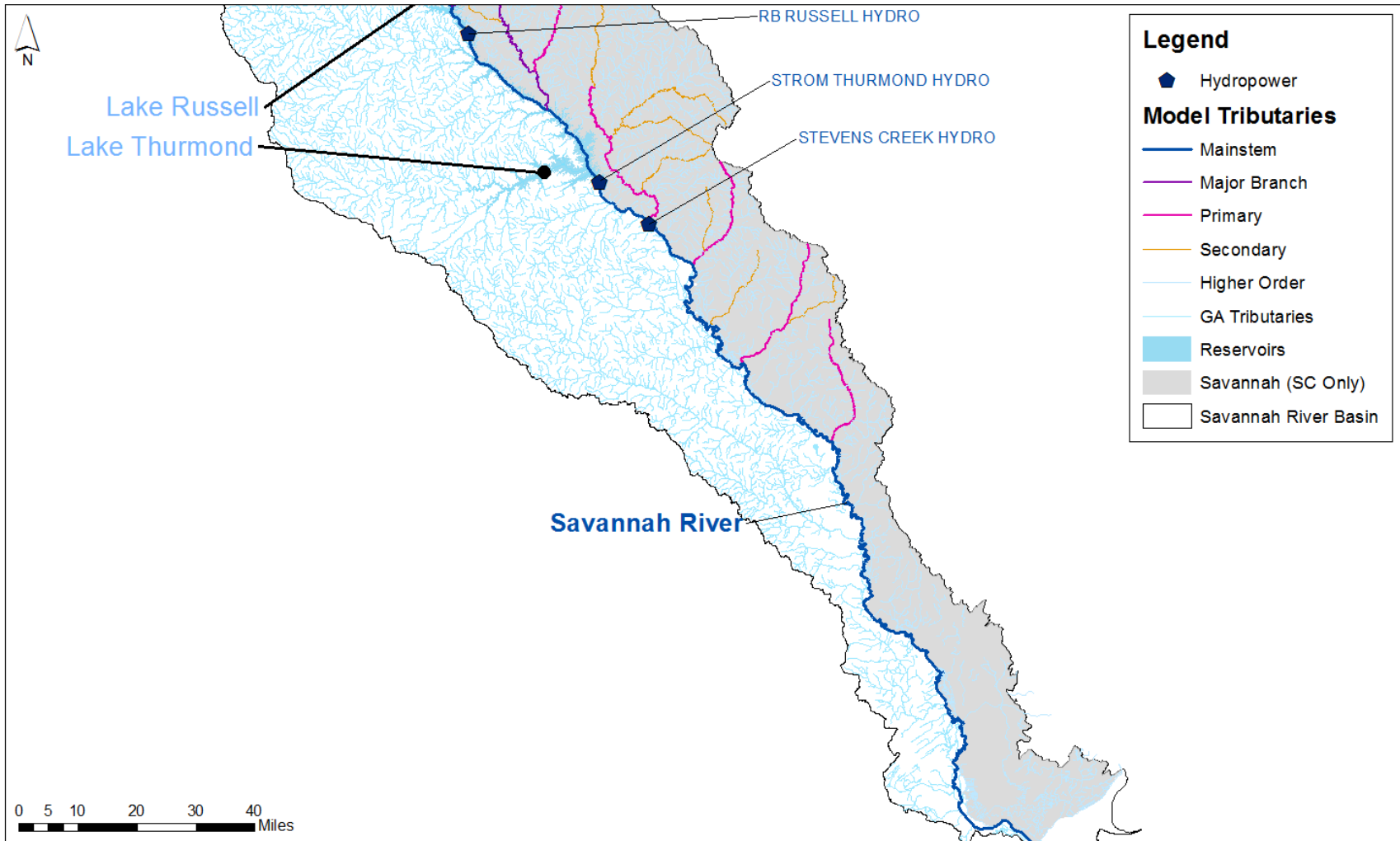
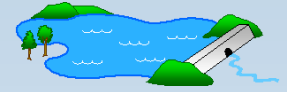
Lower Savannah Basin Model Tributaries



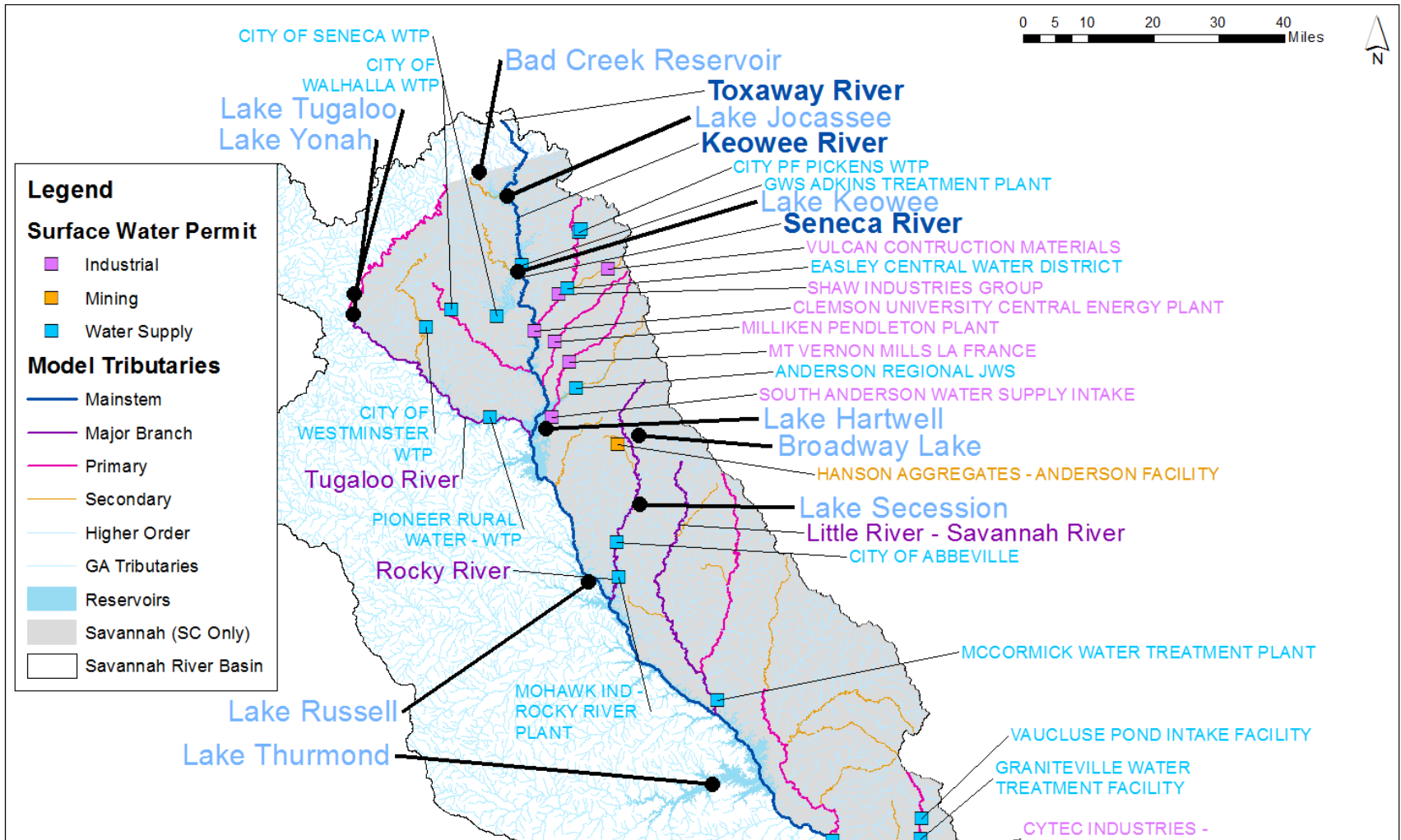
Upper Savannah Reservoirs and Hydroelectric



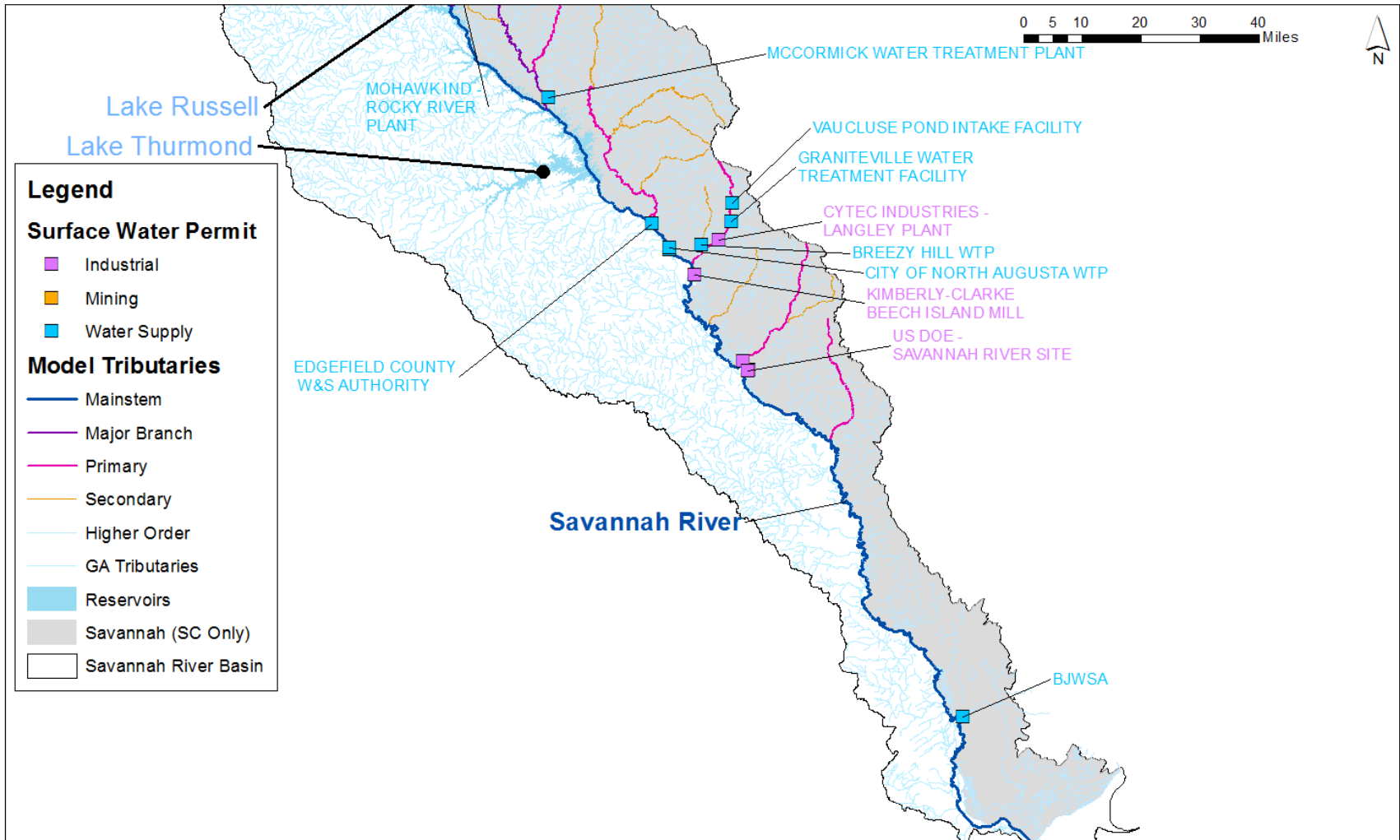
Lower Savannah Reservoirs and Hydroelectric



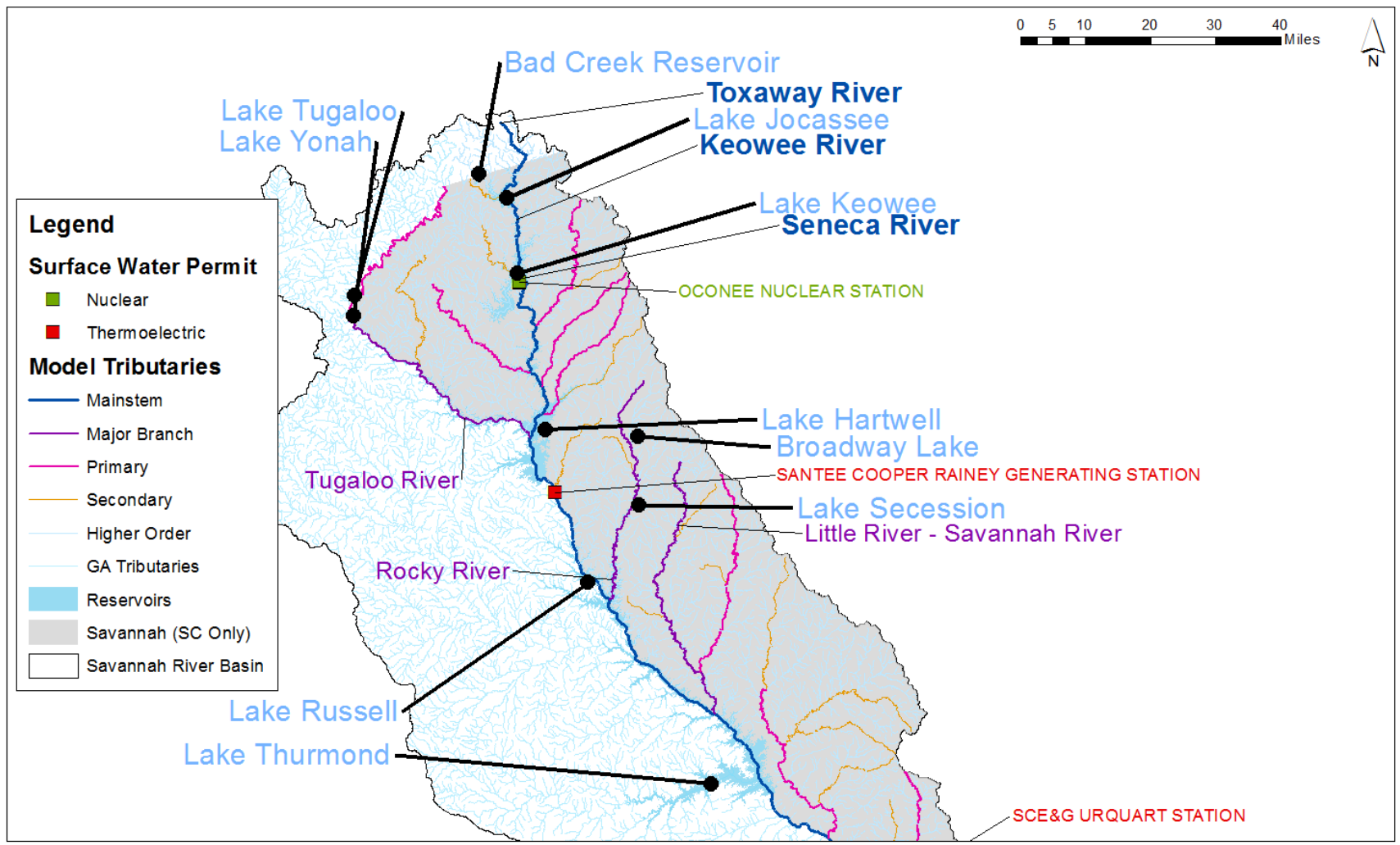
Upper Savannah M&I Water Withdrawals



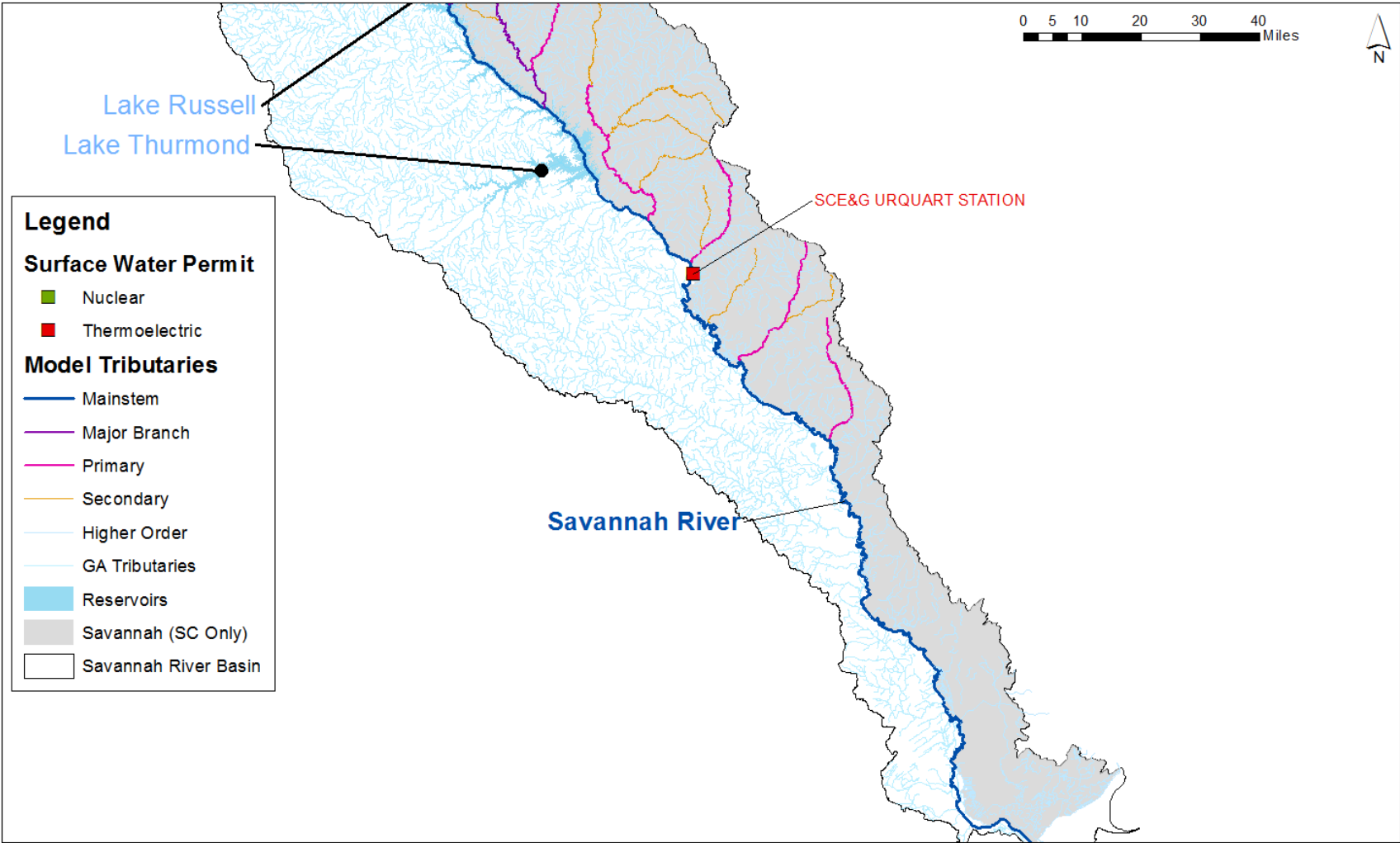
Lower Savannah M&I Water Withdrawals



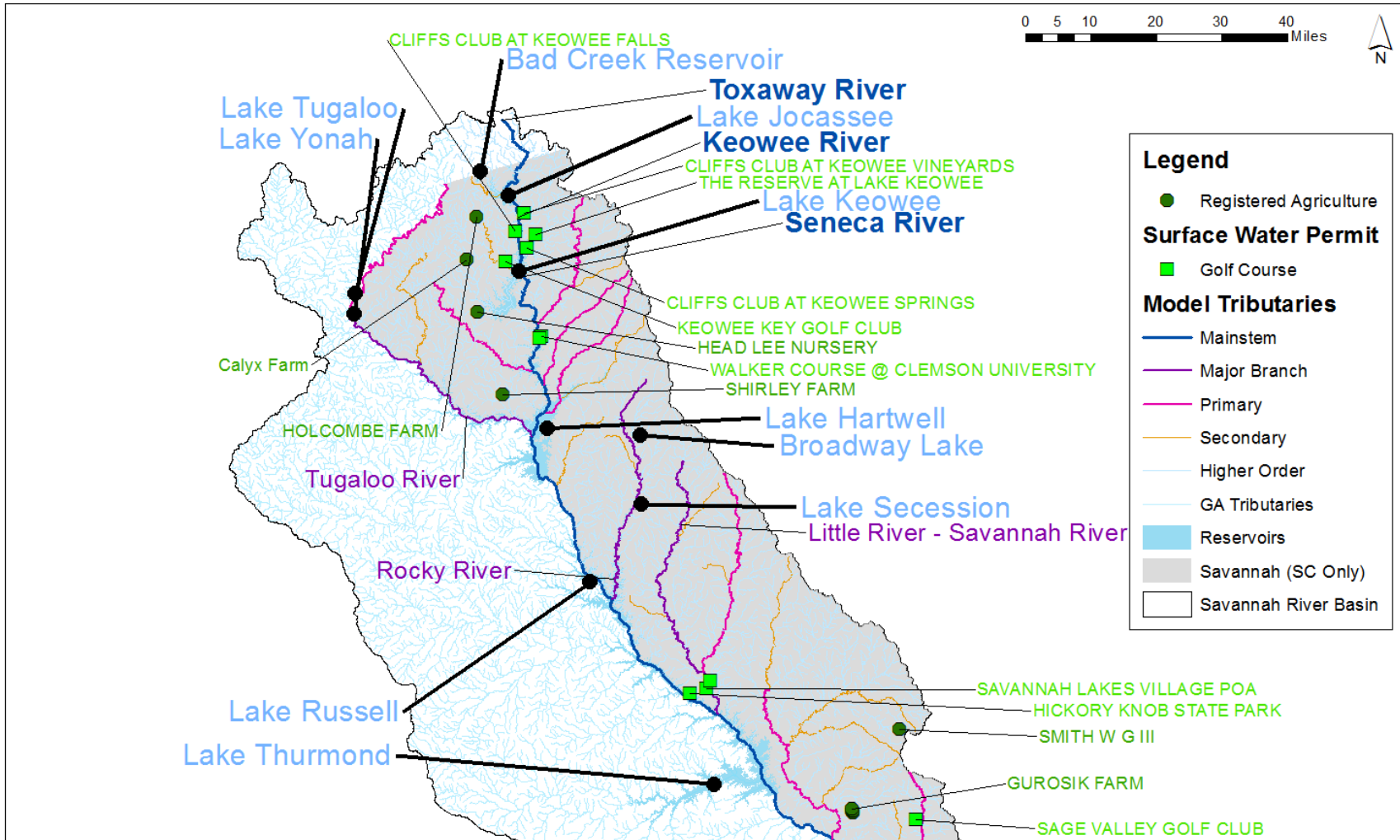
Upper Savannah Energy Surface Water Withdrawals



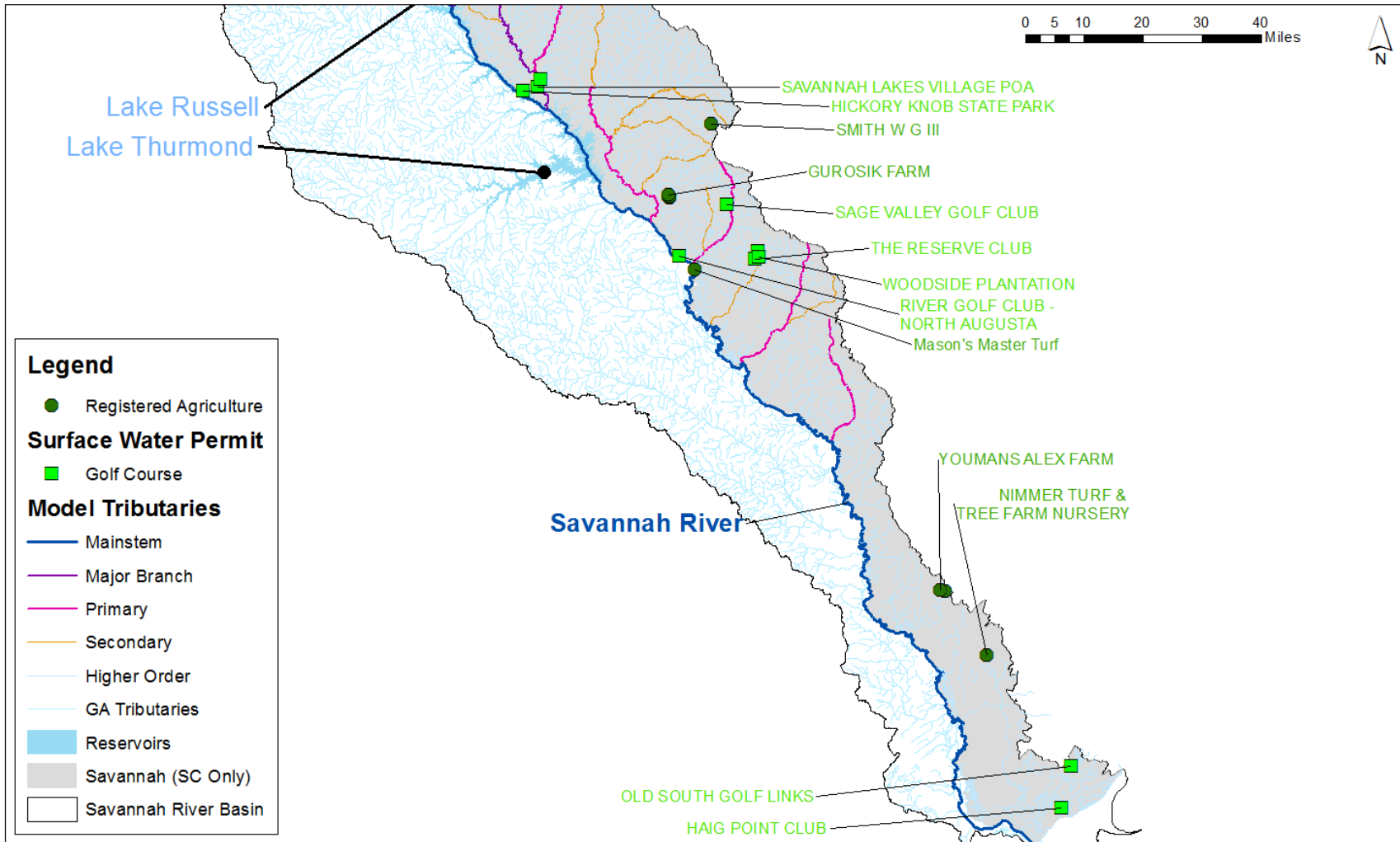
Lower Savannah Energy Surface Water Withdrawals



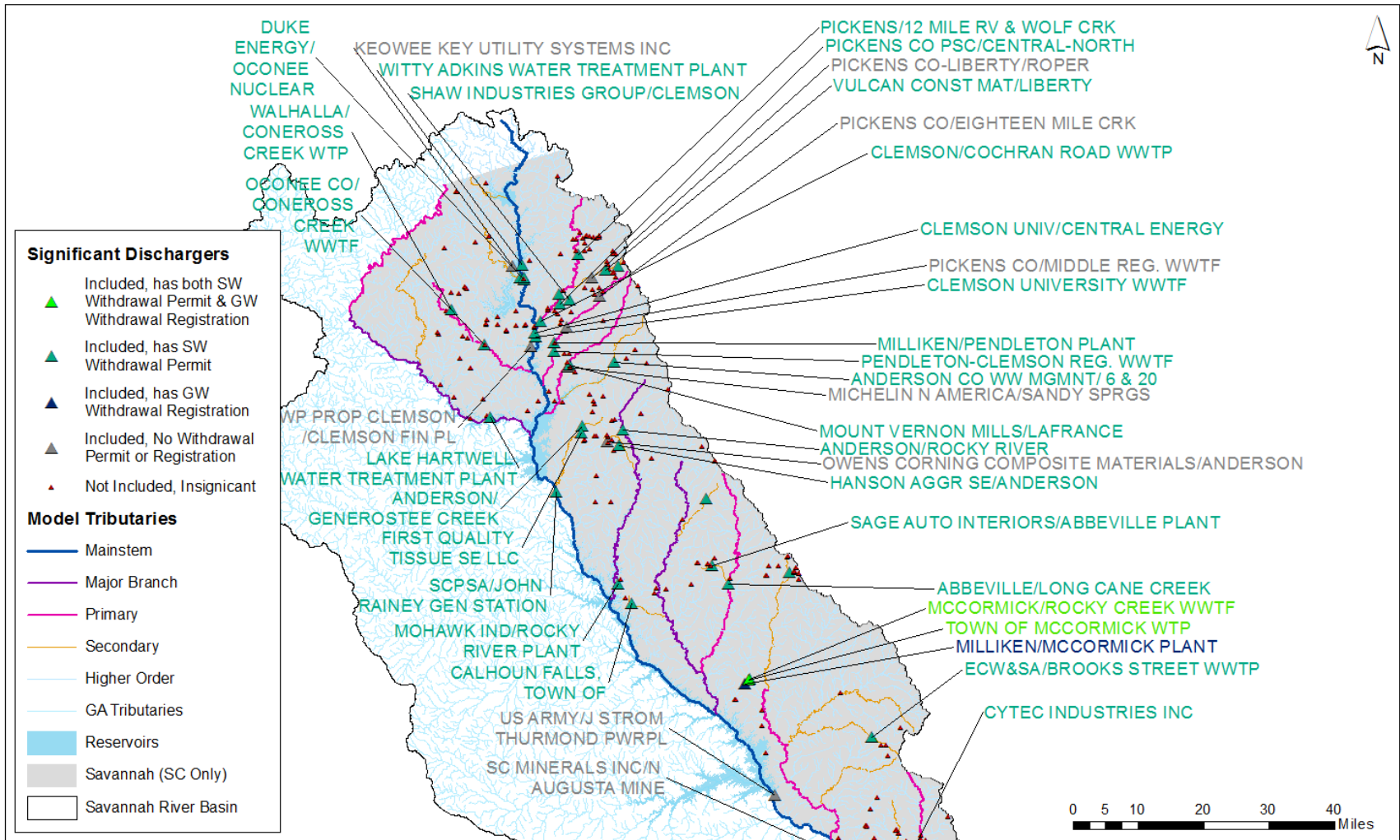
Upper Savannah Surface Water Withdrawals for Irrigation



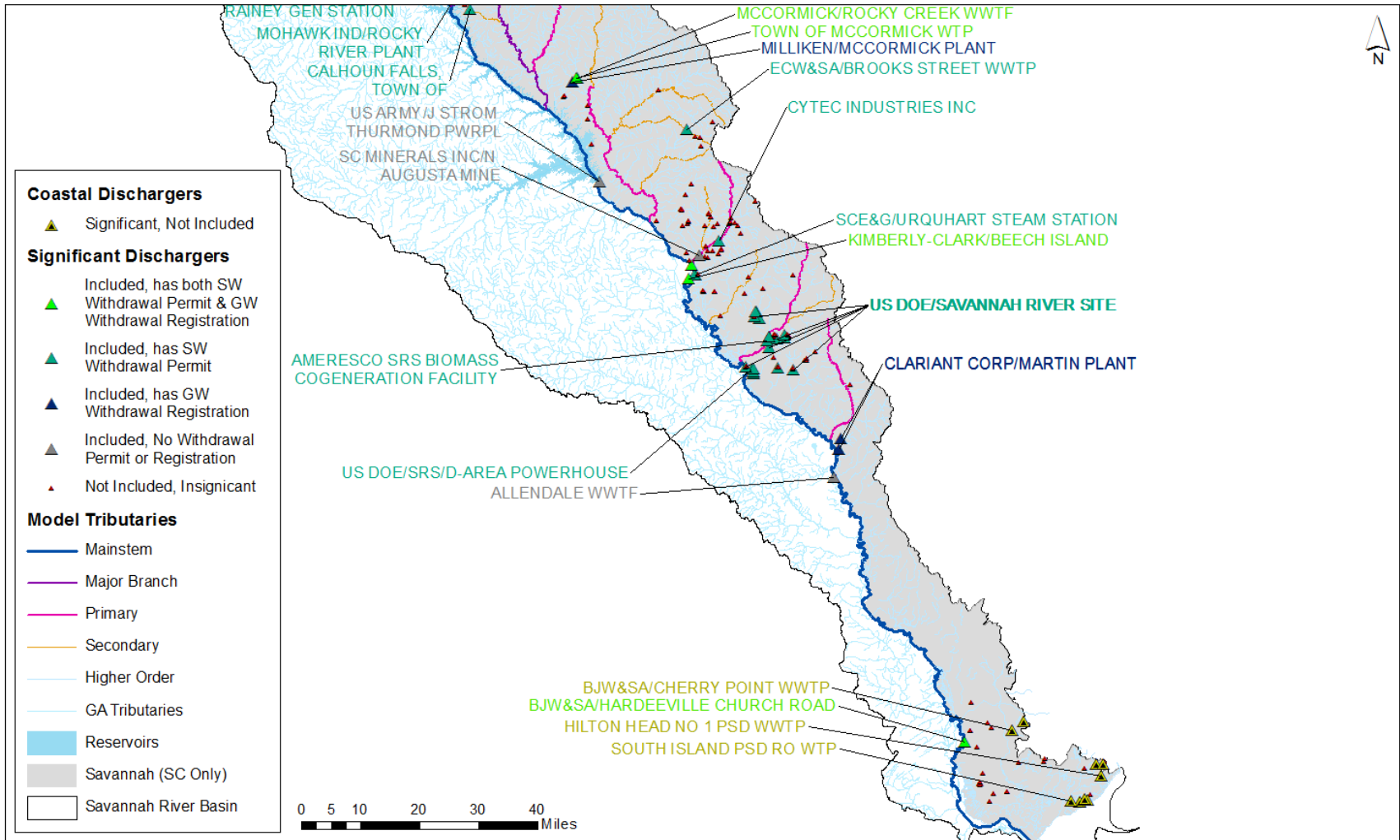
Lower Savannah Surface Water Withdrawals for Irrigation



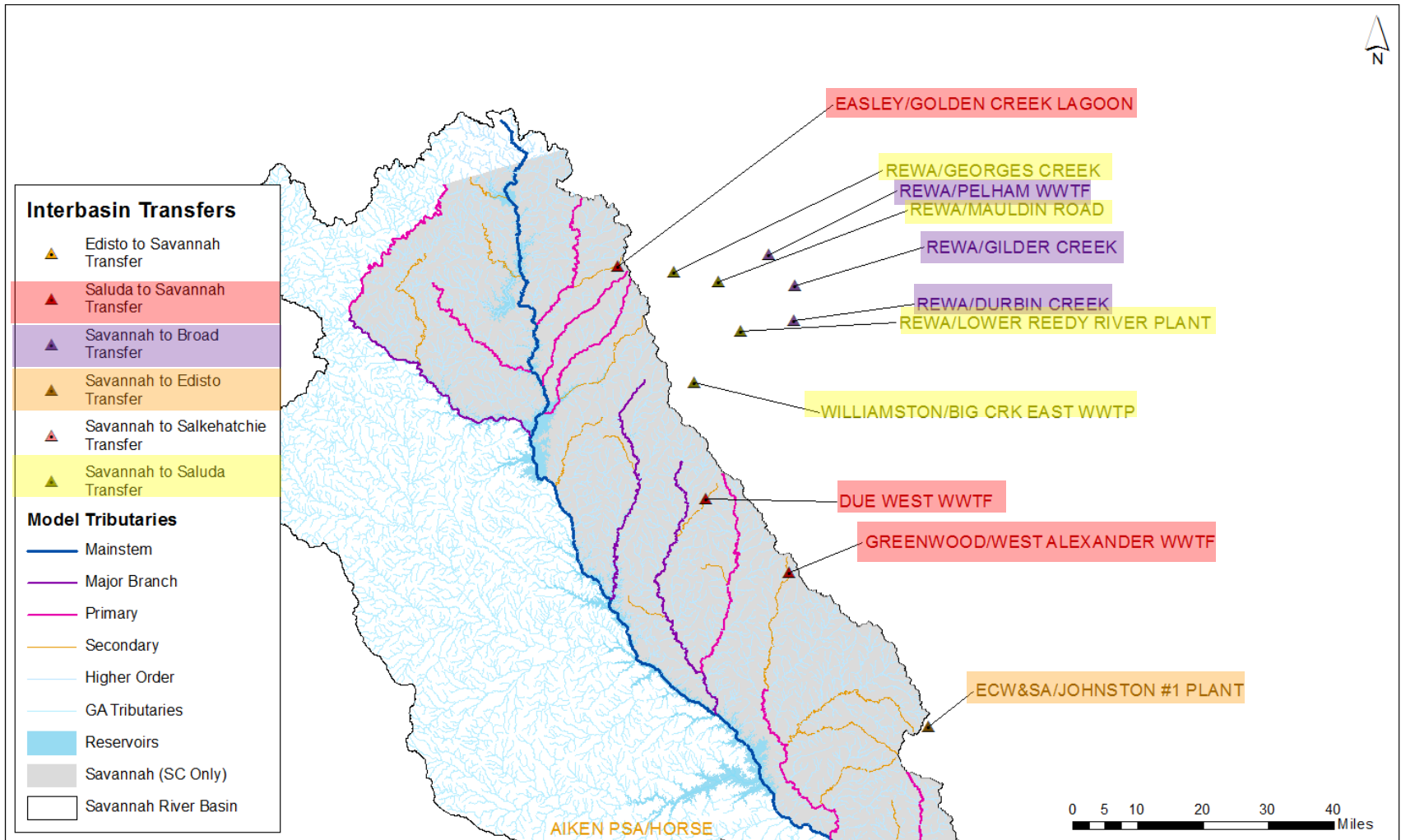
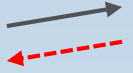
Upper Savannah Discharges to Surface Water



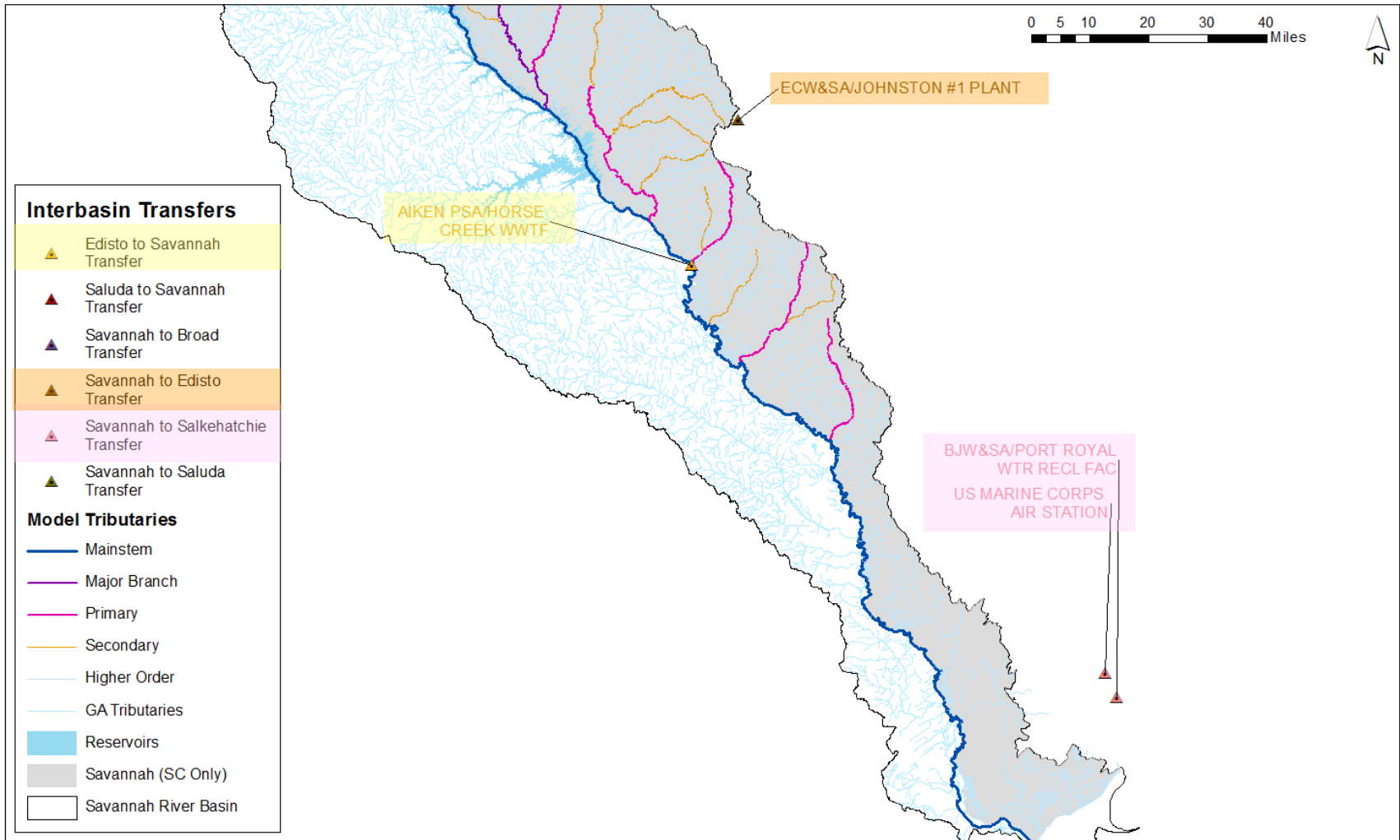
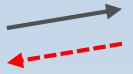
Lower Savannah Discharges to Surface Water



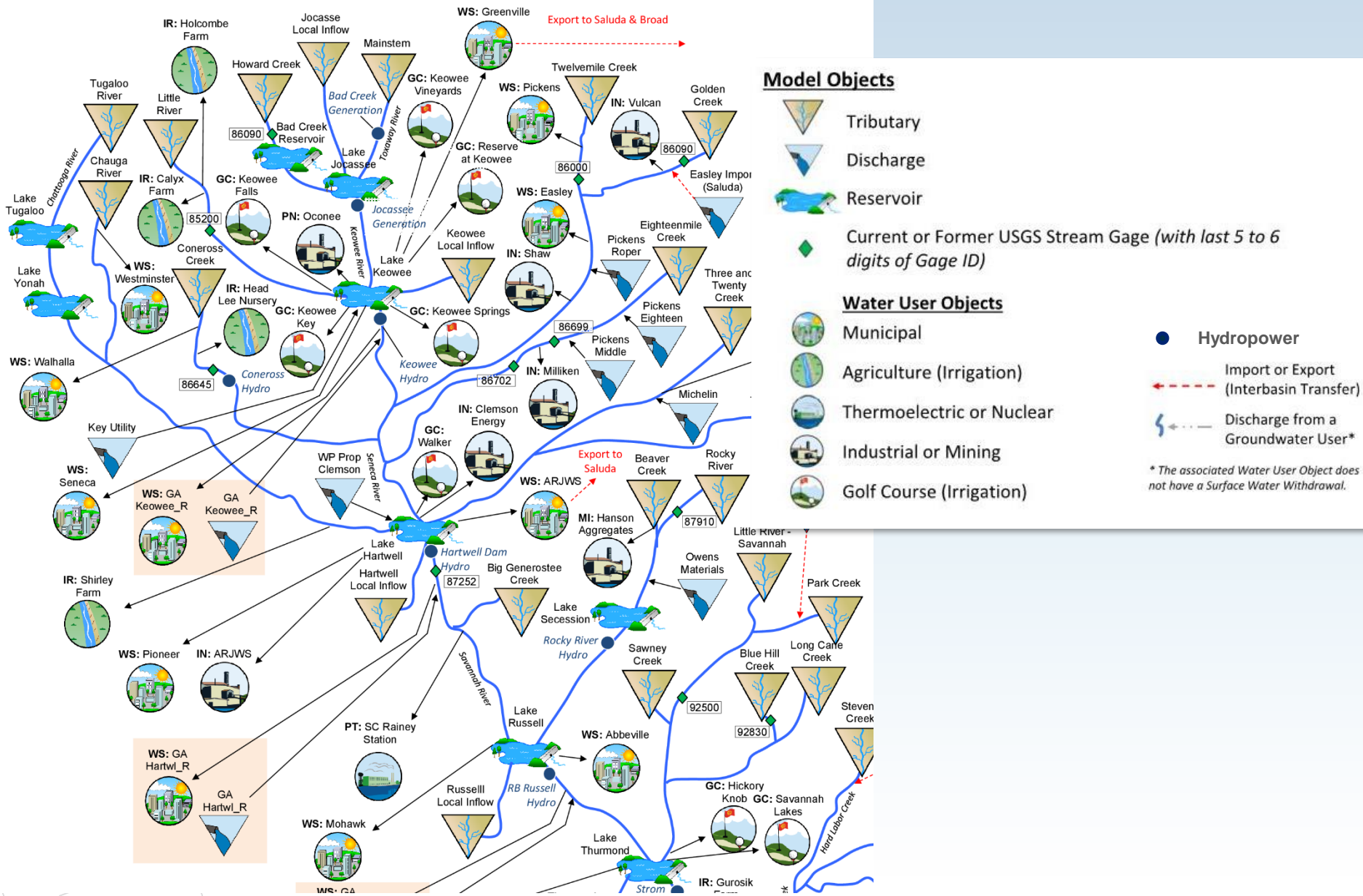
Upper Savannah Interbasin Transfers



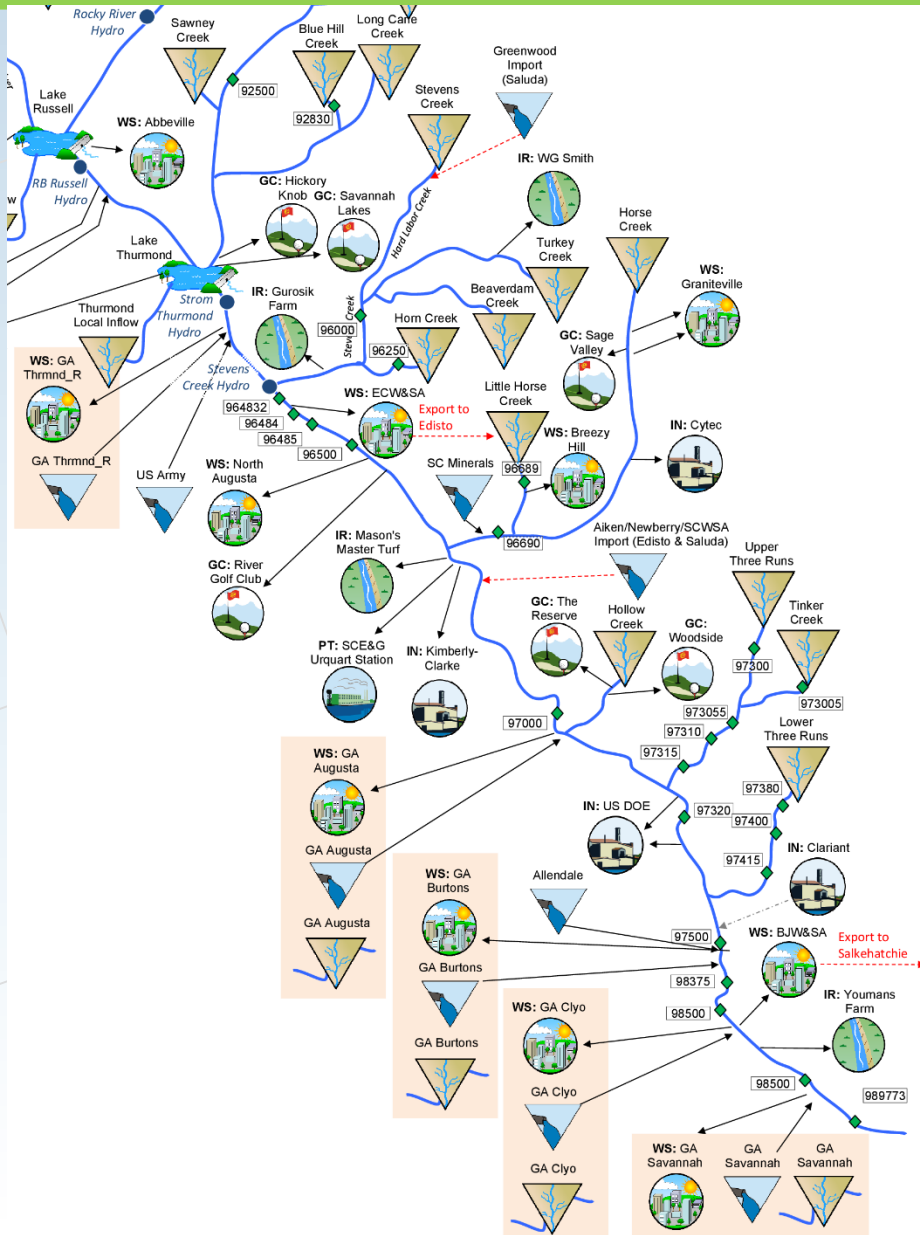
Lower Savannah Interbasin Transfers



Upper Savannah Basin – SWAM Framework











Lower Savannah Basin – SWAM Framework



Model Objects

-  Tributary
-  Discharge
-  Reservoir
-  Current or Former USGS Stream Gage (with last 5 to 6 digits of Gage ID)

Water User Objects

-  Municipal
 -  Agriculture (Irrigation)
 -  Thermoelectric or Nuclear
 -  Industrial or Mining
 -  Golf Course (Irrigation)
-  Hydropower
-  Import or Export (Interbasin Transfer)
-  Discharge from a Groundwater User*

* The associated Water User Object does not have a Surface Water Withdrawal.

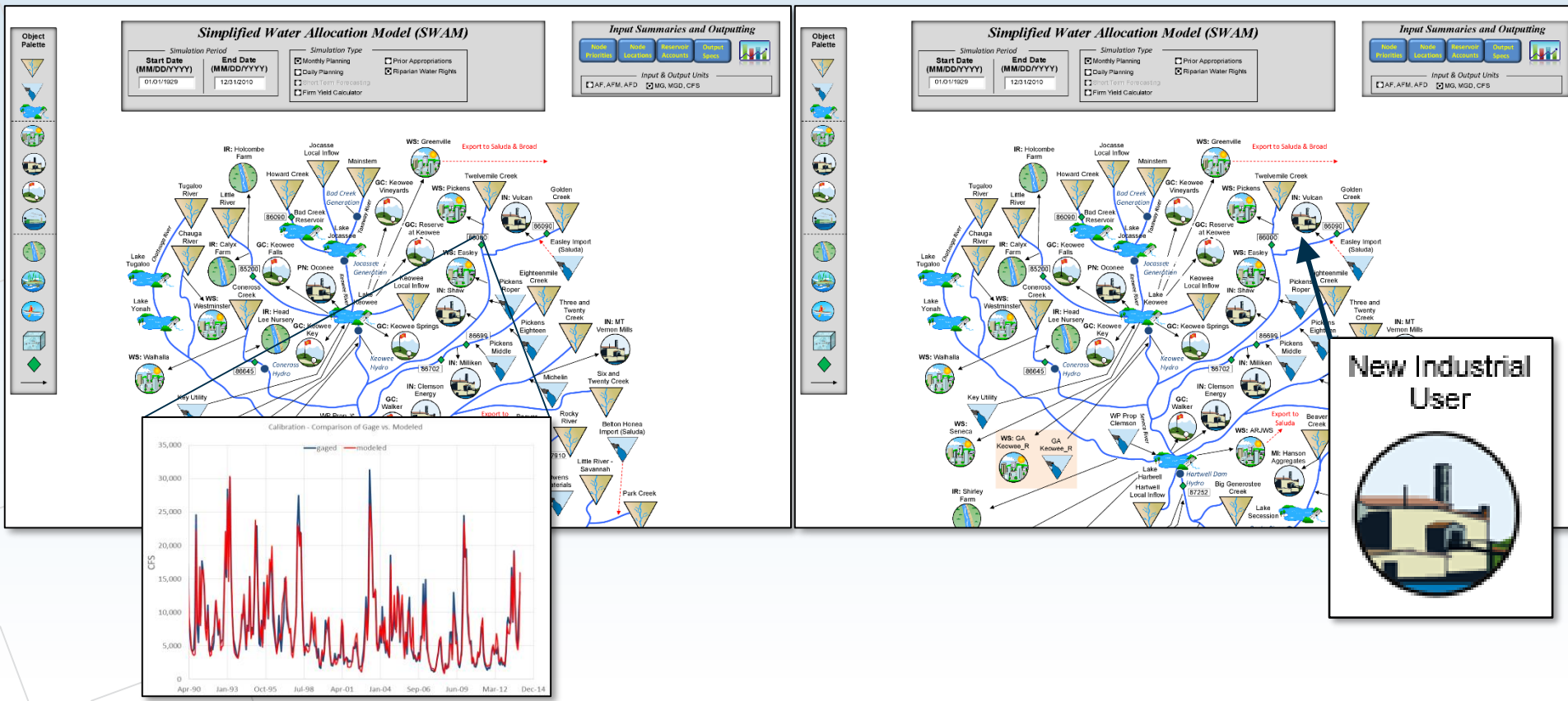
Savannah River Basin

MODEL SETUP

Two Versions of Every Model

Calibration with UIFs and
Historic Use Records

Planning with UIFs, Current Uses,
and User-Defined Future Uses



Tributary Input Form

Simplified Water Allocation Model (SWAM)

Simulation Period: _____ Simulation Type: _____

Start Date (MM/DD/YYYY): 01/01/1929

Input Summaries and Outputting

Node Priorities Node Locations Reservoir Accounts Output Specs

Input & Output Units: AF, AFM, AFD MG, MGD, CFS

Tributary

Tributary Name: _____ **Delete Tributary** **Headwater Flows**

Confluence Stream: _____ Confluence Location (mi): 0

Spatial Flow Changes

Subbasin Flow Factor (unitless): 1 Reach Length (mi): 10

Comments: _____ **Save** **Close**

Reservoir Input Form

Simplified Water Allocation Model (SWAM)

Simulation Period: Start Date: End Date: Simulation Type: Monthly Planning Prior Associations

Input Summaries and Outputting
Node Priorities Node Locations Reservoir Accounts Output Specs

Reservoir Input Form

Main

Reservoir Name: [Dropdown] **Delete Node** **Storage Capacity (AF)** [Input] **Initial Storage (AF)** [Input] Offline Online

Evaporation
 Inches/day % Volume Input Timeseries

Reservoir Releases
Receiving Stream: [Dropdown] Simple Advanced
Release Location (mi) [Input: 0]

Monthly Rates

Month	Evap. Rates (in./day)
Jan	
Feb	
Mar	
Apr	
May	
Jun	
Jul	
Aug	
Sep	
Oct	
Nov	
Dec	

Area-Capacity Table
 Simple Detailed

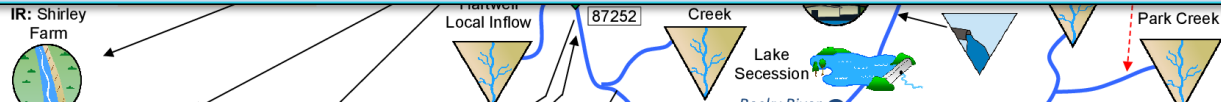
Volume (AF)	Area (ac)

User Defined Releases

Month	Min. Release (AFM)	(CFS)
Jan		
Feb		
Mar		
Apr		
May		
Jun		
Jul		
Aug		
Sep		
Oct		
Nov		
Dec		

Comments:

Save
Close



Water User Input Form – Main

Object Palette

Water User [X]

Main | Water Usage | Source Water | Return Flows

Water User Name: [] Delete

Water User [X]

Main | Water Usage | Source Water | Return Flows

Monthly User Distribution

Manual

M&I

Agriculture

Monthly Baseline Usage

Month	Mont Usa
Jan	
Feb	
Mar	
Apr	
May	
Jun	
Jul	
Aug	
Sep	
Oct	
Nov	
Dec	

(AFM)

Comments:

Water User [X]

Main | Water Usage | Source Water | Return Flows

Source Stream: []

Source Water Type

Direct River

Reservoir

Groundwater

Downstream Location (mi) []

Priority Date [1/1/2008]

Ditch Capacity [] (AFM)

Permit Limit [] (AFM)

Seasonal Permit

Storage Withdrawal Permit

Save

Close

Storage

Reservoir Name: []

(AF) Storage Capacity []

(AFY) Storage Right []

Water Year Start Mo. (1 - 12) [1]

Carry Over Rule

Identifying Notes:

Input Summaries and Outputting

Node Priorities Node Locations Reservoir Accounts Output Specs

Input & Output Units

FD MG, MGD, CFS

IR: Shirley Farm

Agricultural Water User Input Forms

Agricultural Water User

Main | Source Water | Return Flows

User Name: [Dropdown]

Delete Node

Supplemental Supply/Demand Alternatives

Transbasin Import

Groundwater

Comments:

Agricultural Water User

Main | Water Usage | Source Water | Return Flows

Blaney Criddle ET

Original

Modified

Irrigated Acres	Ditch Loss (%)	Irrigation Efficiency (%)	Elevation (ft absl)	Latitude (degr)
0	10	90	0	40

Crops

Edit Coeffs	% of Total Acreage	Start Month
[Dropdown]	0	5
[Dropdown]	0	5
[Dropdown]	0	5
[Dropdown]	0	5
[Dropdown]	0	5
[Dropdown]	0	5

Climate

	Temp. (F)	Precip. (in.)
Jan	30	0.5
Feb	35	0.6
Mar	45	1.2
Apr	55	1.6
May	75	2.3
Jun	80	1.6
Jul	80	1.9
Aug	80	1.4
Sep	65	1.1
Oct	50	1.0
Nov	45	0.8
Dec	40	0.5

Calculated River Headgate Demand

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot.
0	0	0	0	0	0	0	0	0	0	0	0	0

(AFM)

Calculated Potential Consumptive Use of Irrigation Water

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot.
0	0	0	0	0	0	0	0	0	0	0	0	0

(AFM)


Save / Calculate

Close

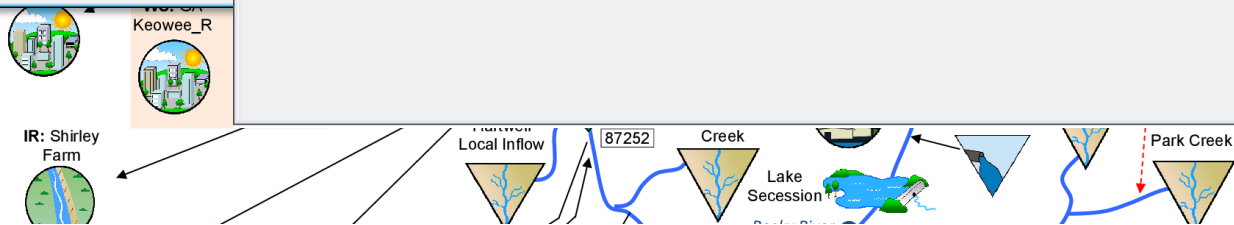
Input Summaries and Outputting

Node Priorities | Node Locations | Reservoir Accounts | Output Specs

Output Units: [Dropdown] CFS



Object Palette

Instream Flow Input Form

Simplified Water Allocation Model (SWAM)

Input Summaries and Outputting

Reservoir Accounts Output Specs

Input & Output Units
 MG, MGD, CFS

Object Palette

Water Right

Instream Flow Name: [Dropdown] **Delete Node** **Target Stream:** [Dropdown] **Downstream Location (mi):** [0]

Priority Date: [1/1/2007]

Rules:
 Seasonal WR
 TNC IHA Methodology

Avg. Monthly Flow Rights (CFS)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Comments: [Text Area]

Save **Close**

IR: Shirley Farm
Hartwell Local Inflow
Hydro 87252
Big Generostee Creek
Lake Secession
Materials
Park Creek

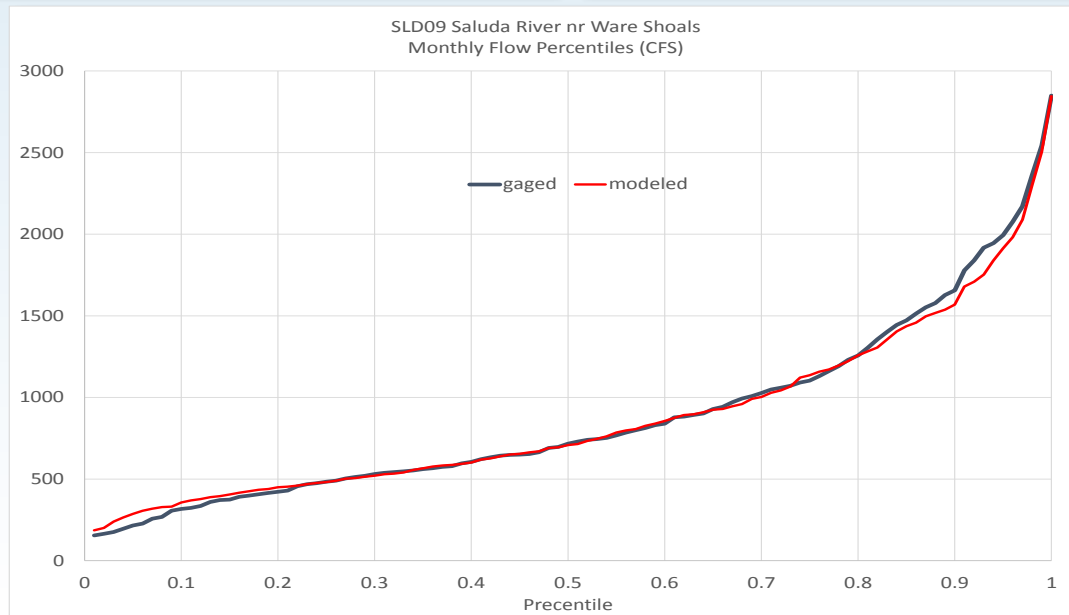
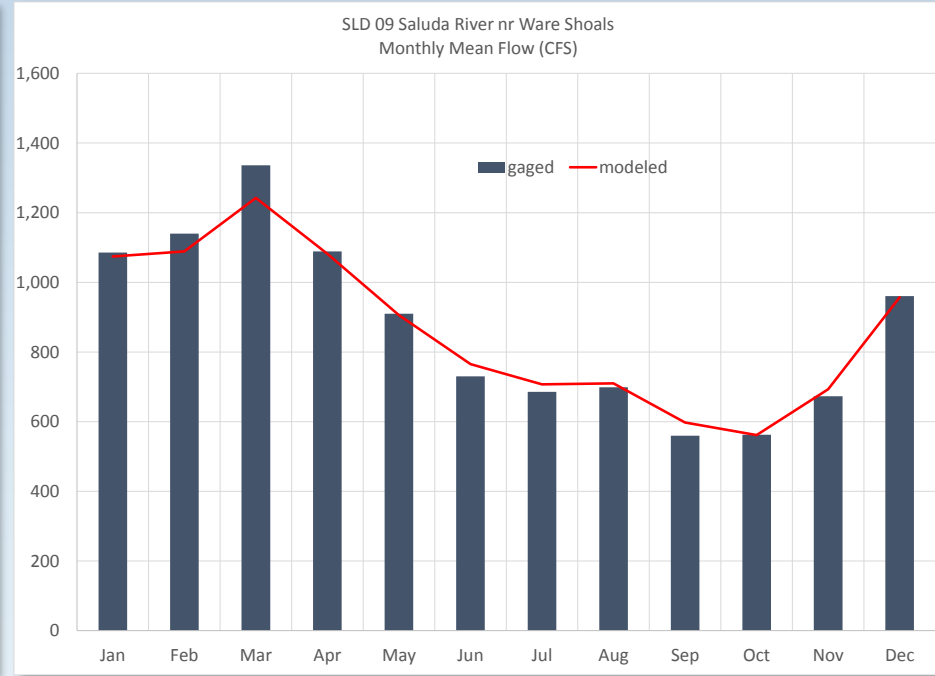
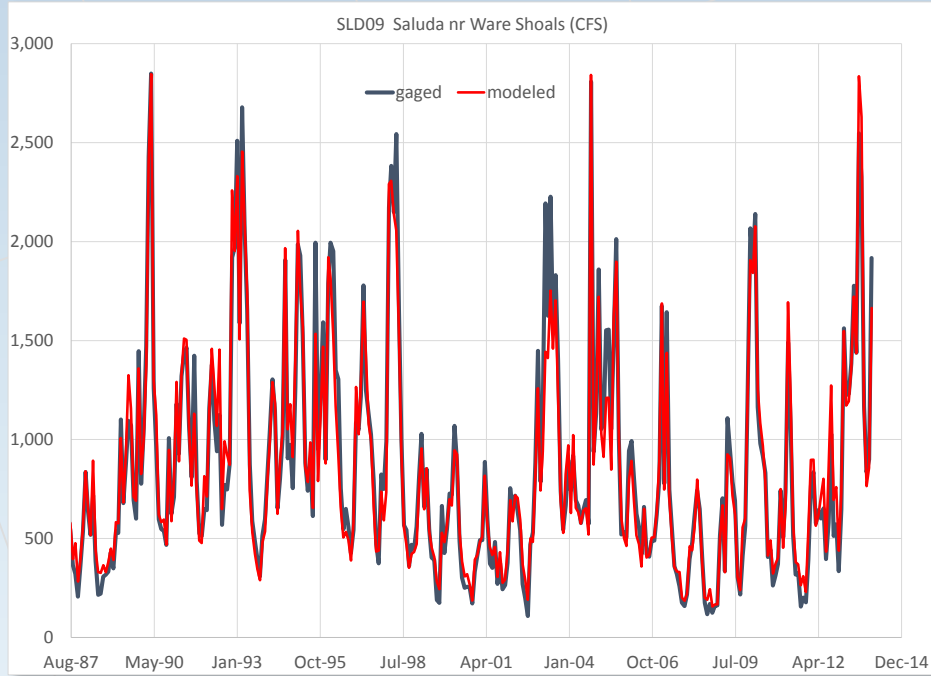
Savannah River Basin

MODEL VALIDATION

SWAM Calibration/Validation

- Calibration targets = downstream flow gage records
- Calibration parameters =
 - reach gains/losses,
 - unaged flow records,
 - reservoir operations
 - ag return flow percentages, locations, lags
- Performance metrics =
 - Annual avg flows (overall water balance)
 - Monthly avg flows (seasonality)
 - Flow percentile distributions (variability, extreme events)
 - Flow timeseries (specific timings, operations)
 - Cumulative flows over entire calibration period
 - Reservoir storage timeseries

Calibration Result Graphs



Examples
from the
Saluda Basin

Savannah River Basin

THANK YOU