South Carolina Surface Water Quantity Modeling Project

Saluda Basin Meeting No. 1 – Model Framework

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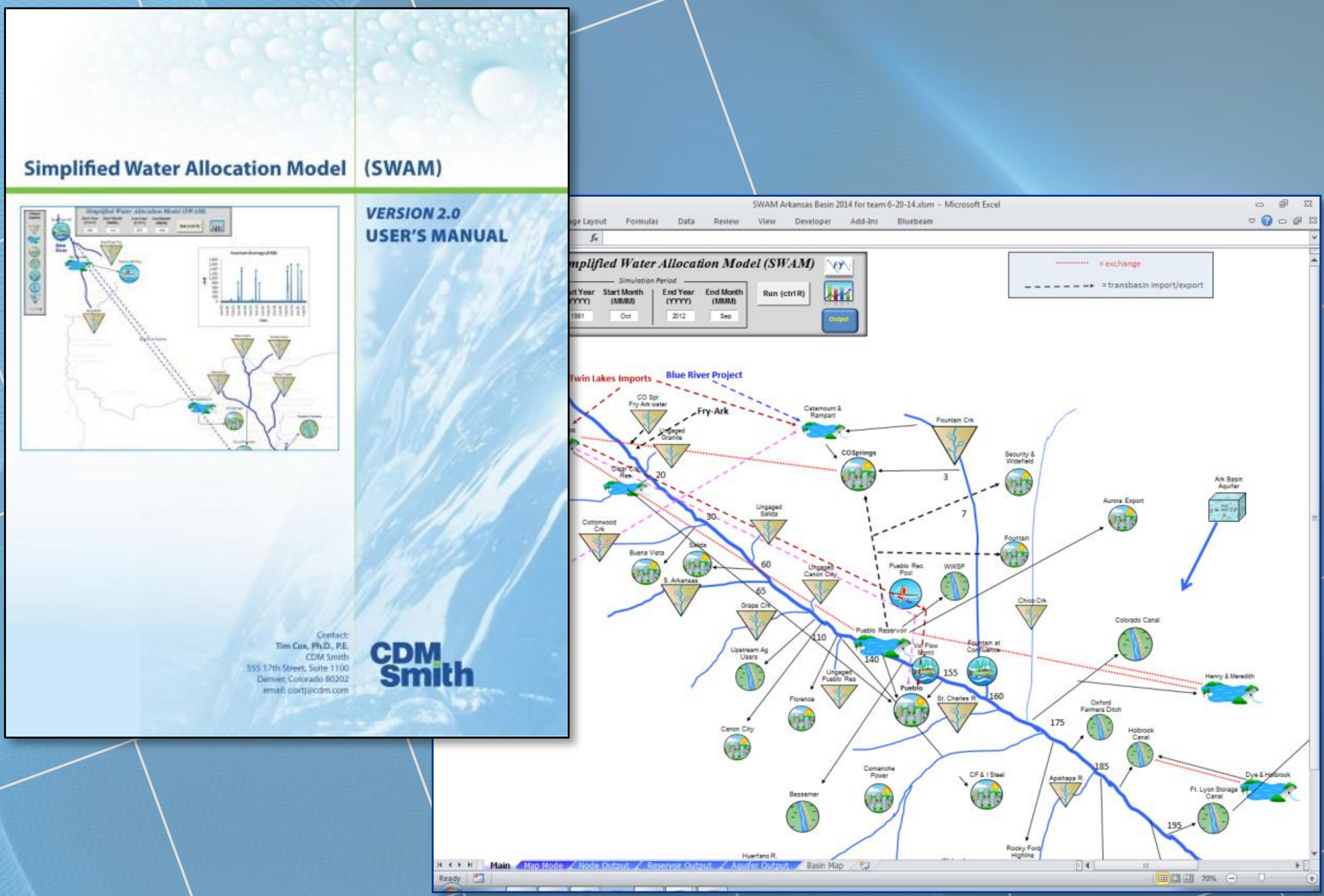


CDM Smith

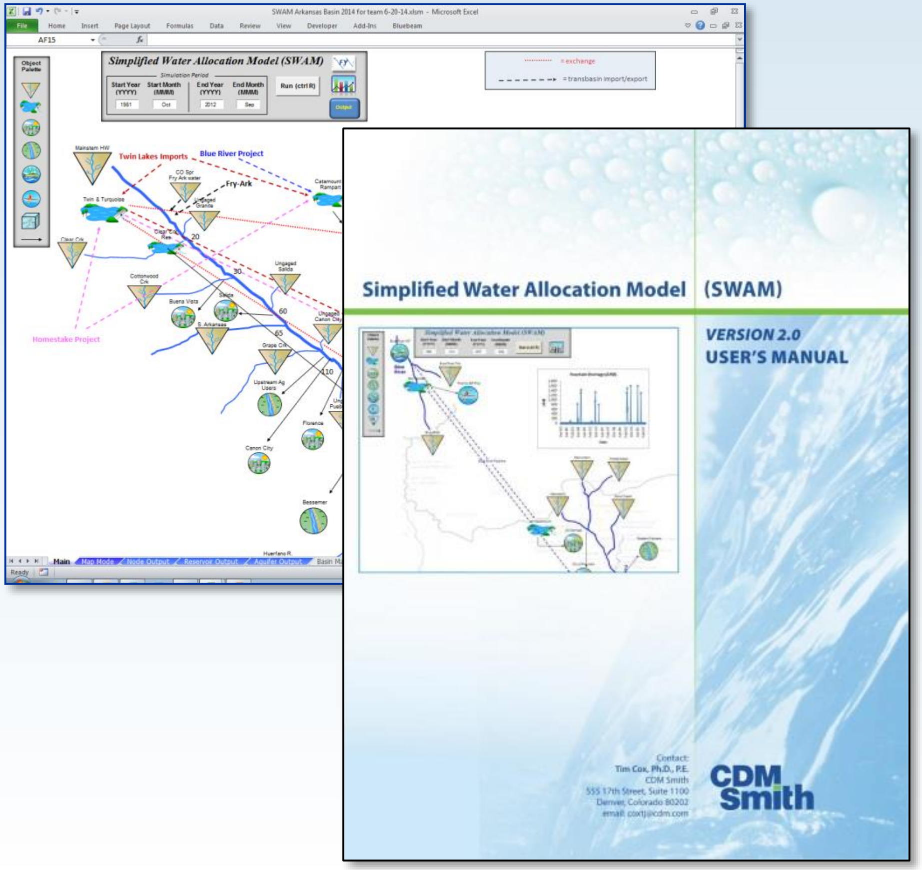
Project Purpose

- Build surface water quantity models capable of:
  - Accounting for inflows and outflows from a basin
  - 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.



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

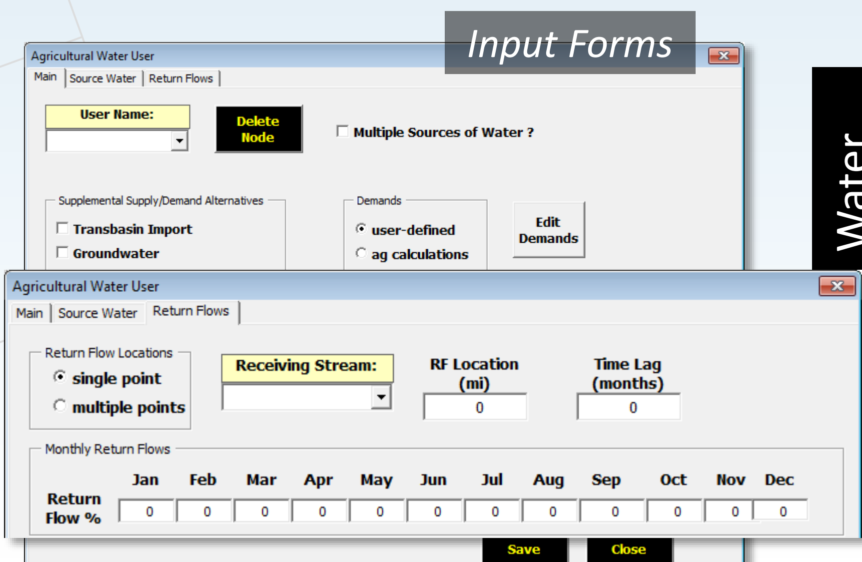
- Tailored specifically for hydropower
  - Energy Calculations
  - Reservoir Tracking
- Familiar Visual Basic programming

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

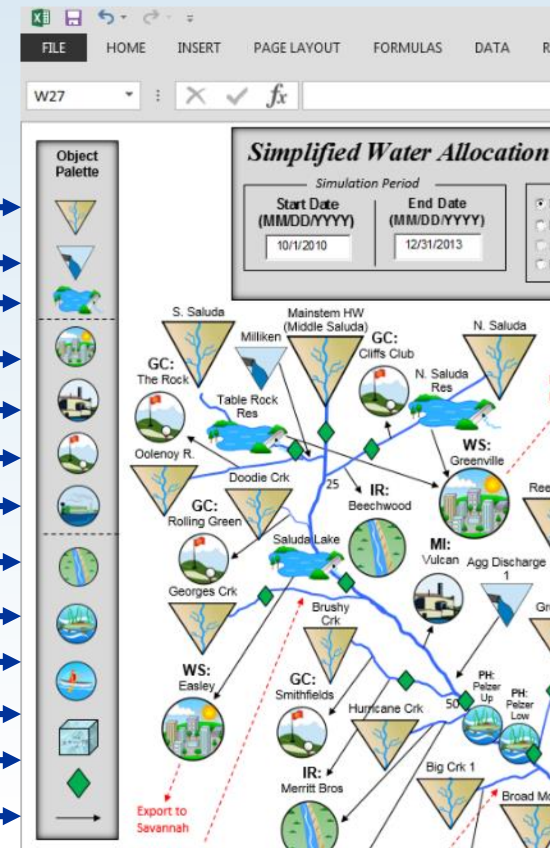


Objects

Tributaries
Discharges
Reservoirs

Water User Objects:
Municipal
Industrial
Golf Courses
Power Plants
Agriculture

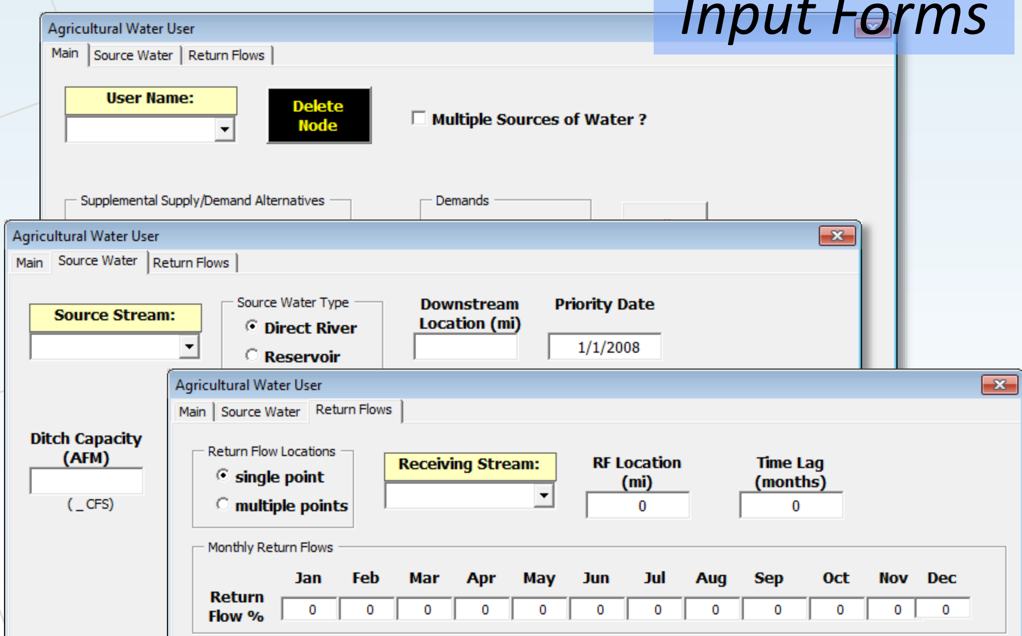
Instream Flow
Recreational Pool
Aquifer
USGS Gage
Interbasin Transfer



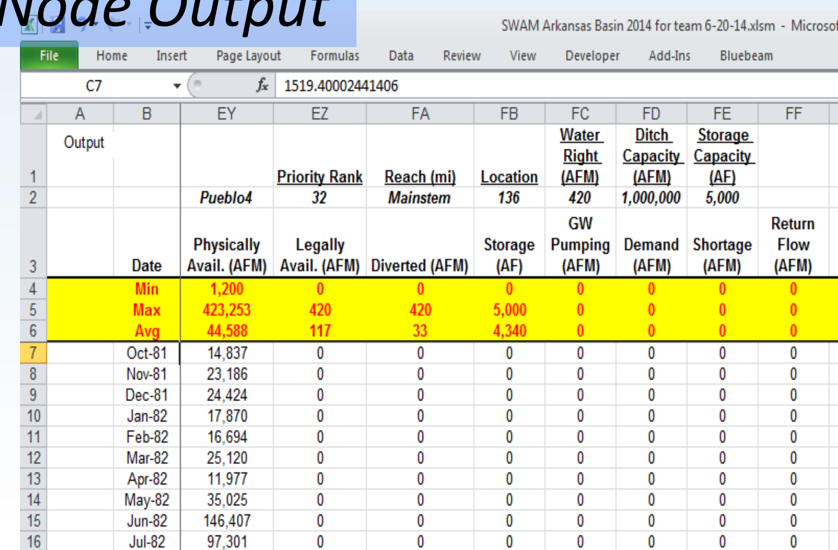
Simplified Water Allocation Model (SWAM)

- **Intuitive & Transparent** — Resides within and interfaces directly with Microsoft Excel
- **Ease-of-Use** — Point-and-click setup and output access
- **Simple & Robust** — Mass balance calculations, but handles operating rules, use priorities, etc.

Input Forms



Node Output



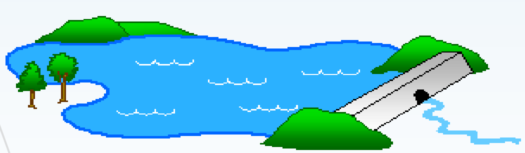
Simplified Water Allocation Model (SWAM)

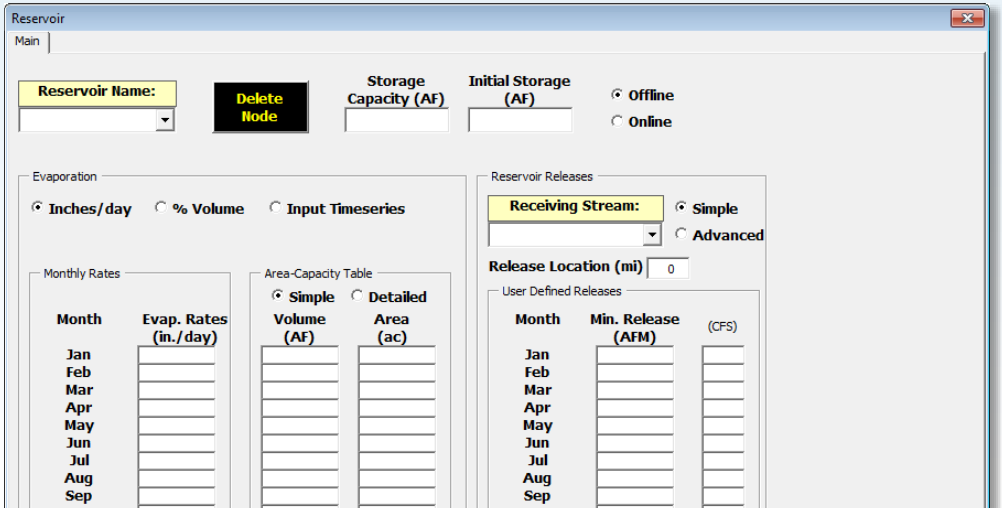
- Supports multiple layers of complexity for development of a range of systems, for example…

A Reservoir Object can include:

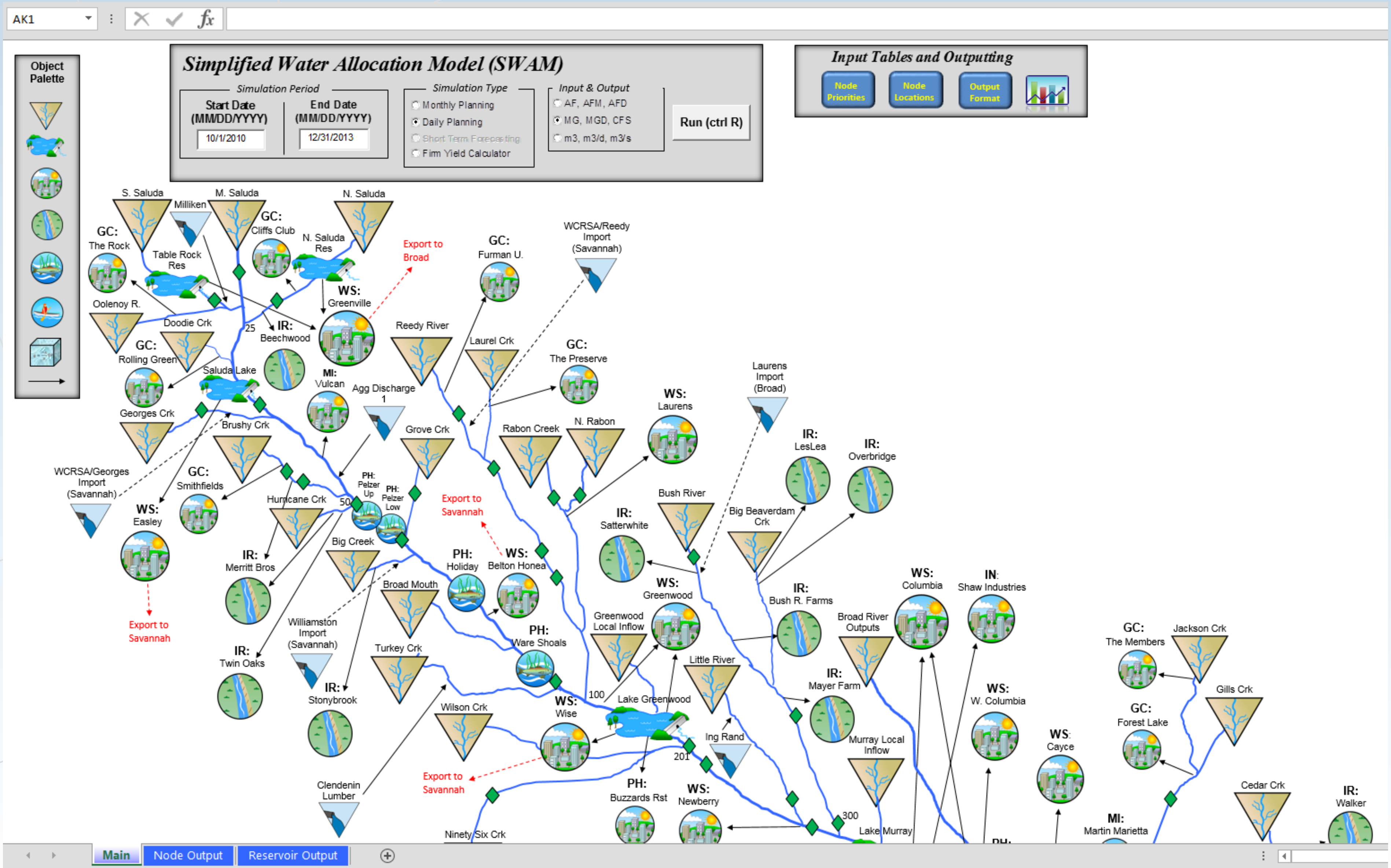
1. Basic hydrology dependent calculations
2. Operational rules of varying complexity such as prescribed releases, conditional releases, or hydrology dependent releases.

Reservoir





SWAM Model Main Screen



Saluda 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
  - Basin slope

Saluda River Basin

UNIMPAIRED FLOWS (UIF)

UIF Definition and Uses

- **Definition:** Estimate of natural <u>historic</u> 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.

Primary UIF Data Sources

Documented

- USGS Gage flows
- DHEC records of M&I withdrawals and discharges
- Reservoir operator records of water levels
- Reported agricultural withdrawals
- GIS Data layers

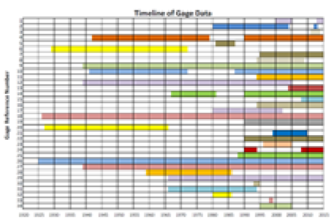
Estimated

- Direct contact with users regarding historic use patterns
- Operational hindcasting
- Agricultural water use modeling

Basinwide UIF Calculation Process

Stepwise Procedure for UIF Calculation – Saluda Basin

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



Work Upstream to Downstream

UIF Upstream?

Y

Perform these steps for incremental reaches and add UIFs from upstream

N

Perform these steps for the entire upstream area

Gather data: Flow, historic use, precip, evap

Fill gaps in storage for the longest downstream gage POR using prioritized techniques in guidance document.

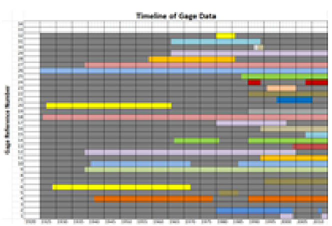
Fill gaps in withdrawals and discharges based on longest downstream gage POR using techniques in guidance doc.

Compute prior runoff from submerged areas

Compute UIFs for USGS gages (VOLUME)

UIFs for USGS gages for their POR

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



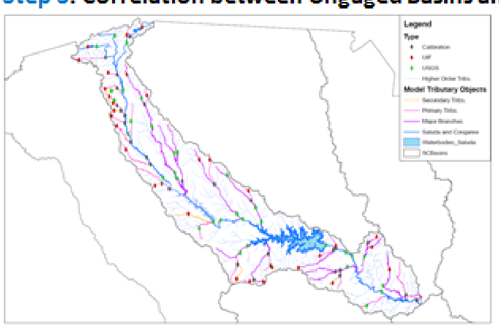
Determine longest period of record

Gather watershed characteristics: Area, Slope, Land Use

Extend / Gap Fill using area ratios, MOVE2, climate regression, etc.

UIFs for USGS gages over a uniform basinwide POR

Step 3: Correlation between Ungaged Basins and Gaged Basins



Gather watershed characteristics for all basins upstream of RED nodes (ungagged headwater UIFs)

Identify appropriate reference basins from USGS gage locations

Reference gages for UIF development as model input

Gather watershed characteristics for all basins upstream of **BLACK** nodes (as needed for calibration)

Identify appropriate reference basins from USGS gage locations

Reference gages for UIF development for model calibration

Step 4: UIFs for Ungaged Basins

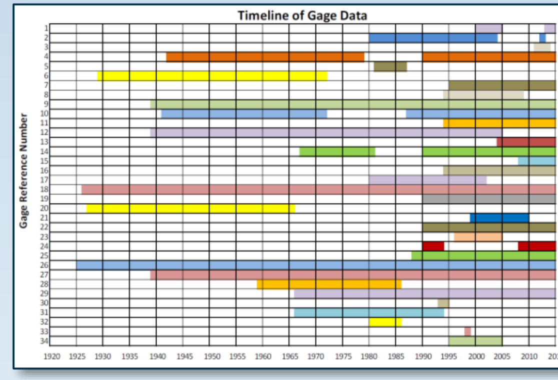
Estimate UIFs for each RED and **BLACK** node using area ratios, regression, etc.

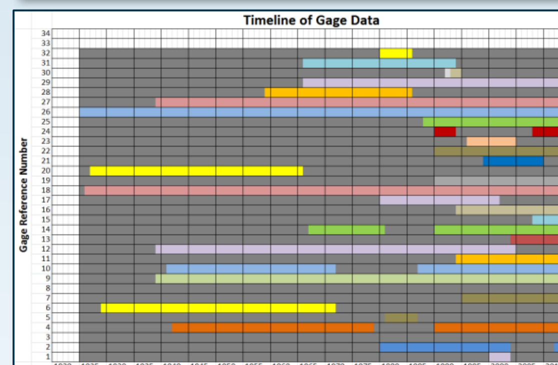
UIFs for ungagged basins as model input

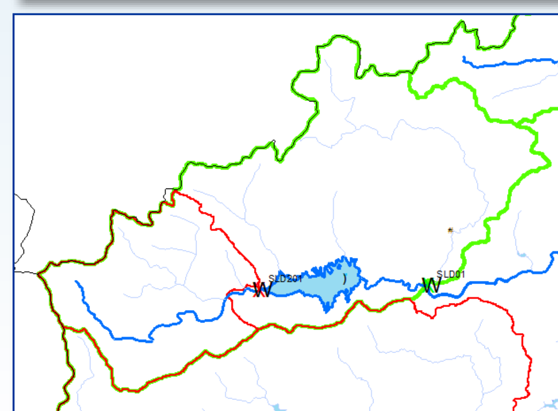
Additional UIFs at confluence nodes for calibration

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

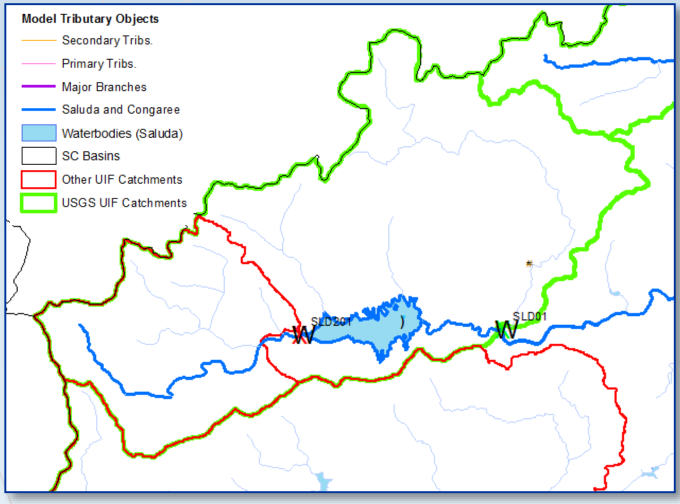


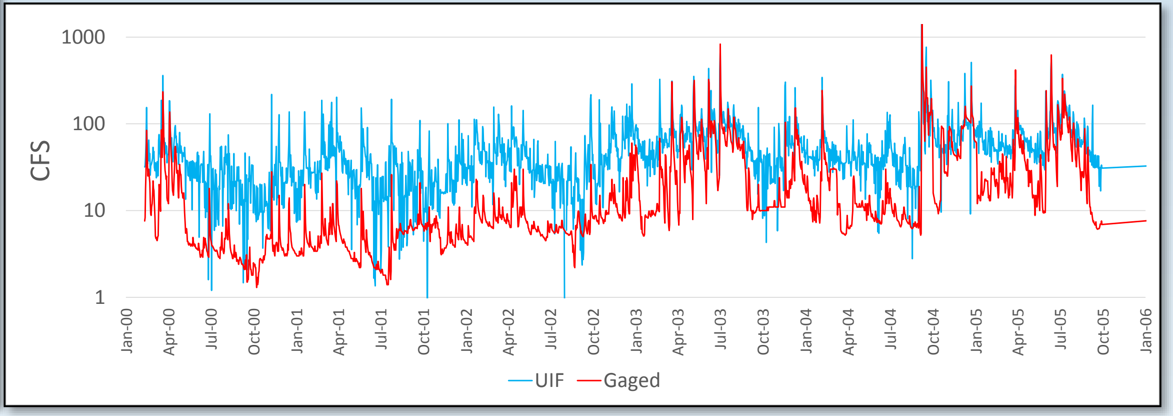




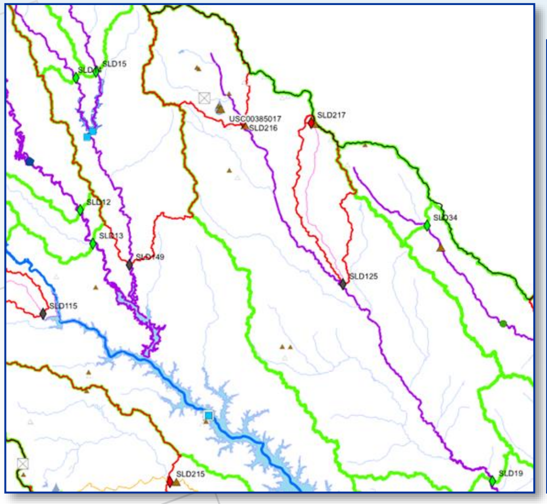
Sample UIF Results (Draft)

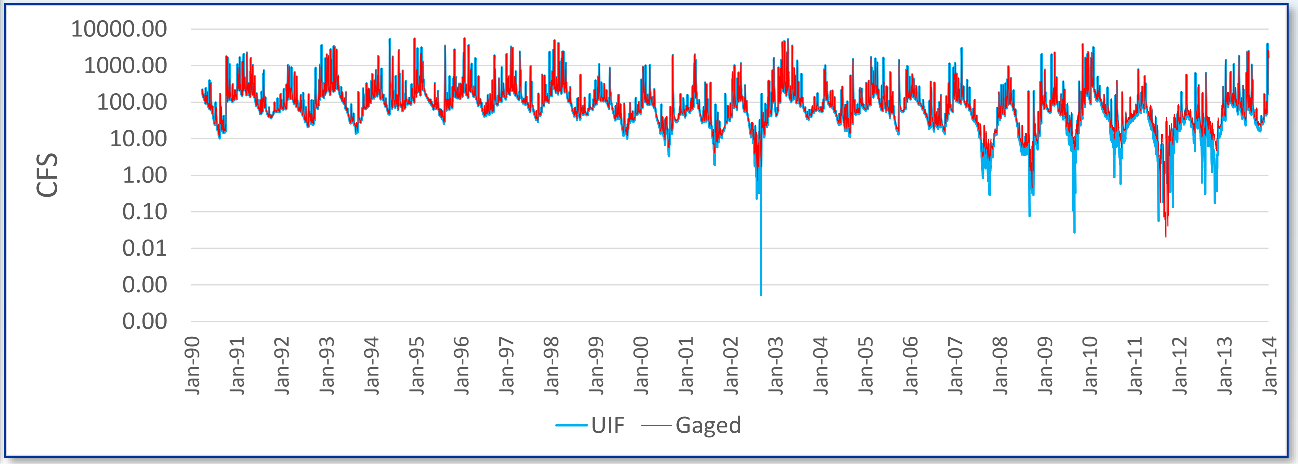
SLD01: South Saluda River downstream of Table Rock Reservoir





SLD19: Little River near Silverstreet

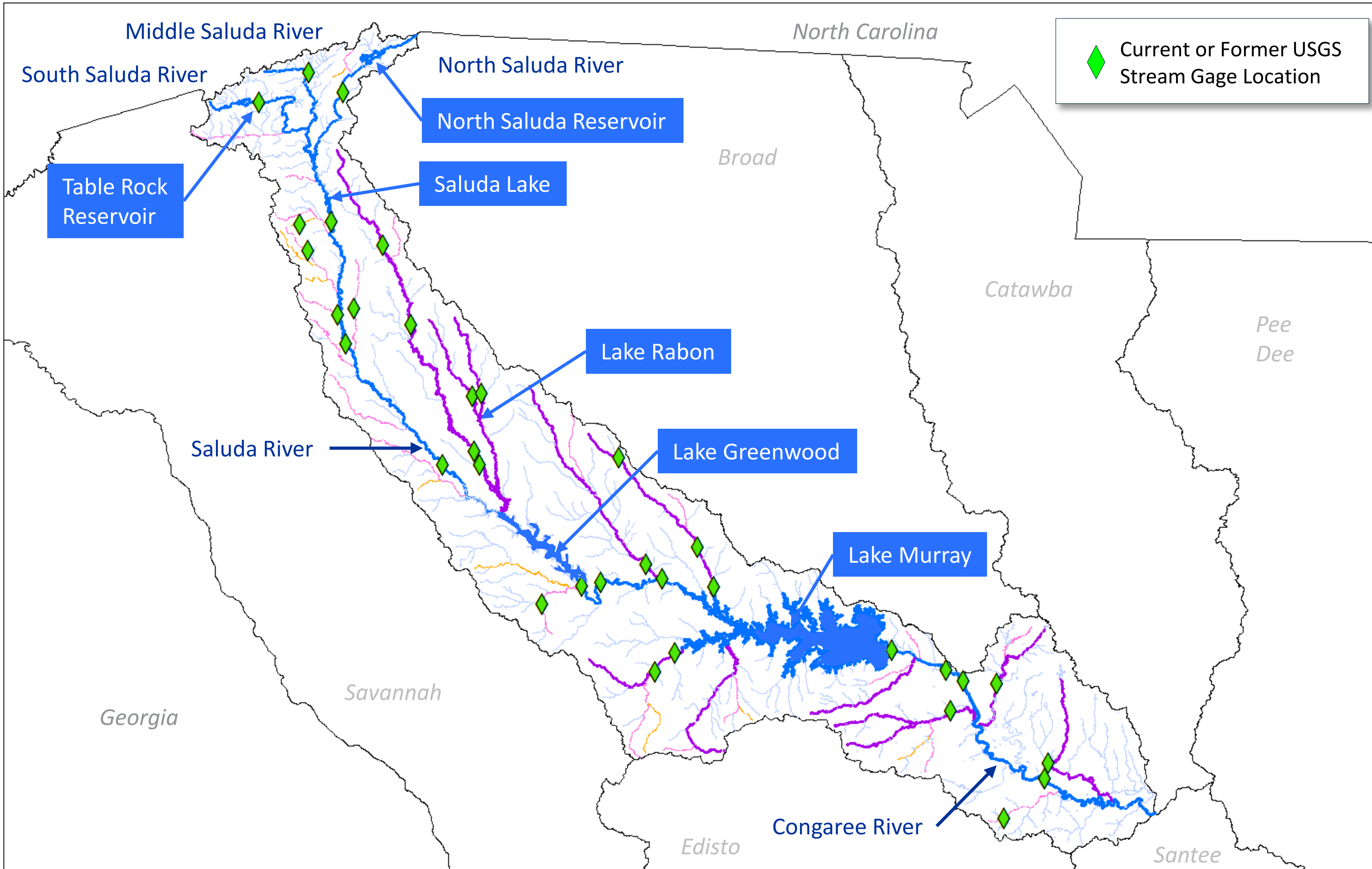




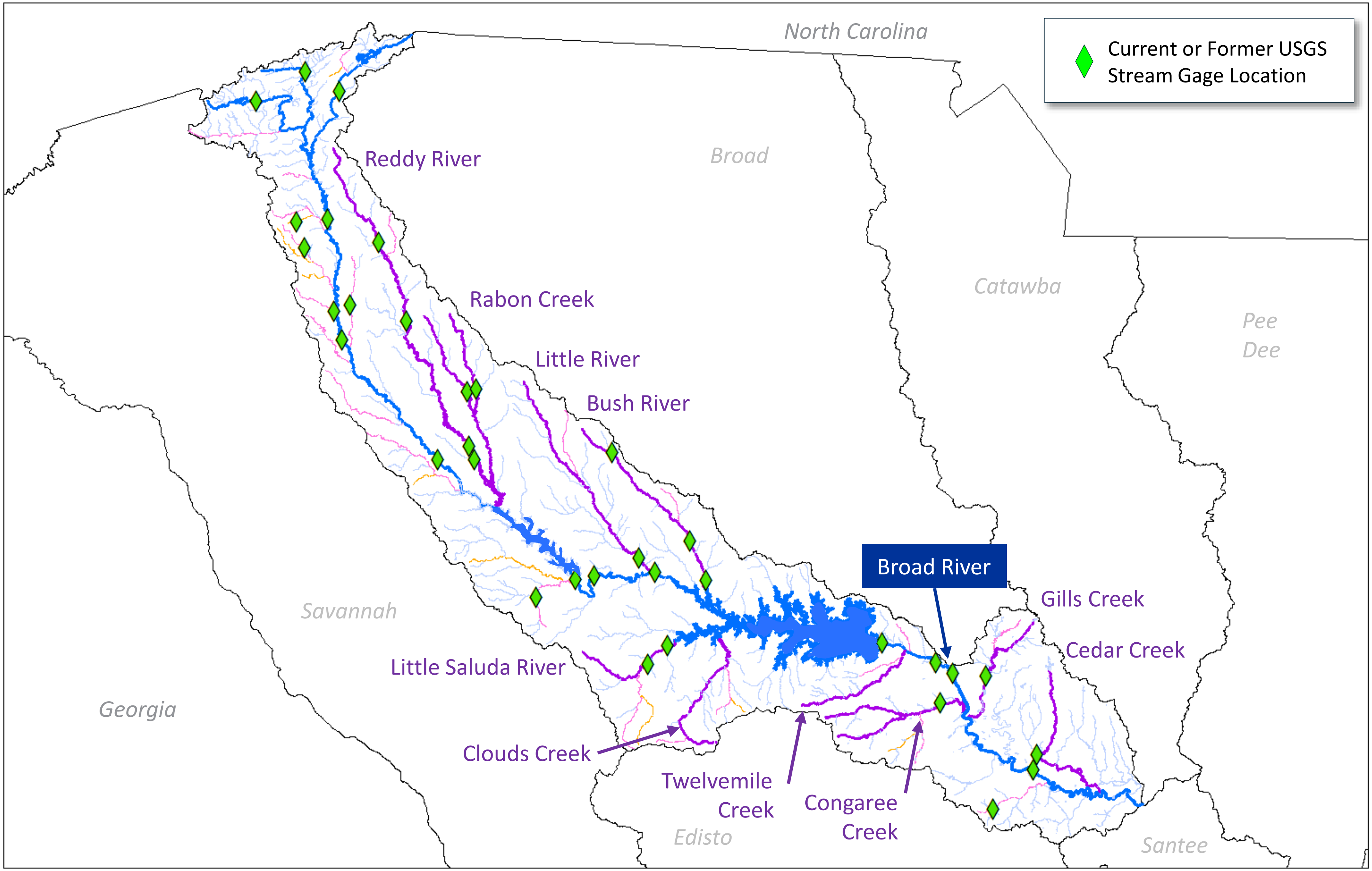
Saluda River Basin

OVERVIEW OF MODEL FRAMEWORK

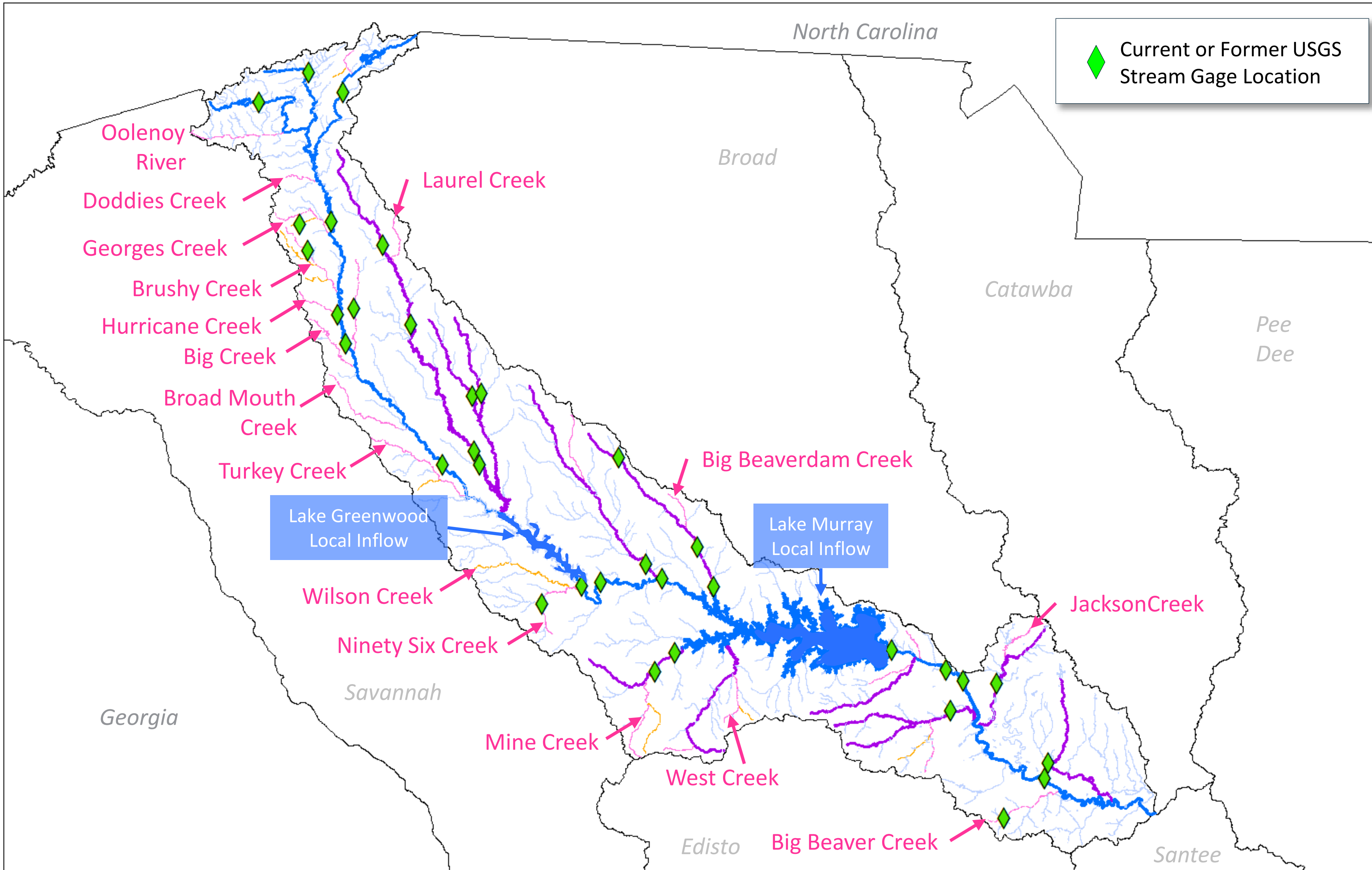
Saluda Basin – Major Streams & Reservoirs



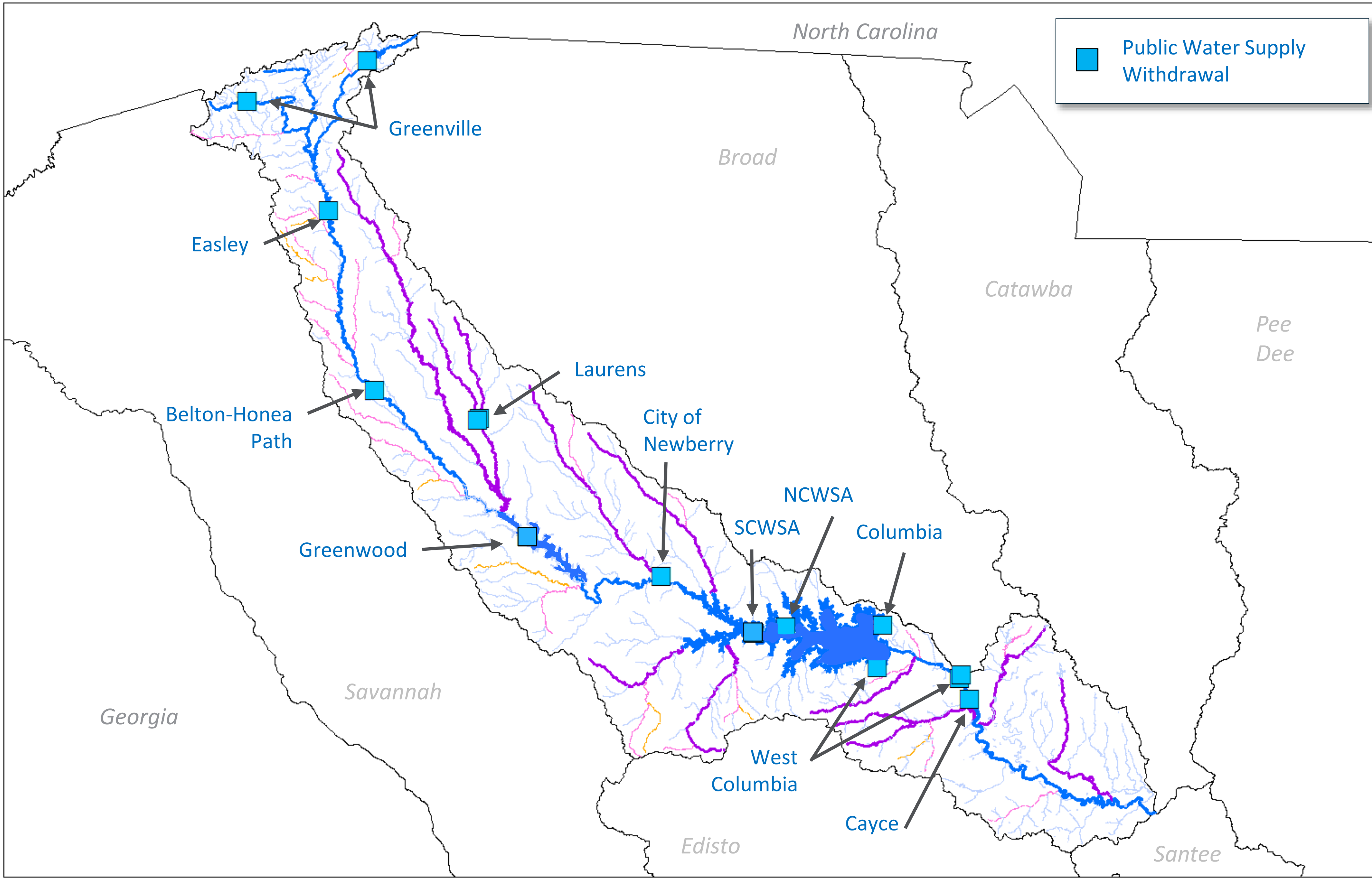
Saluda Basin – Major Branches



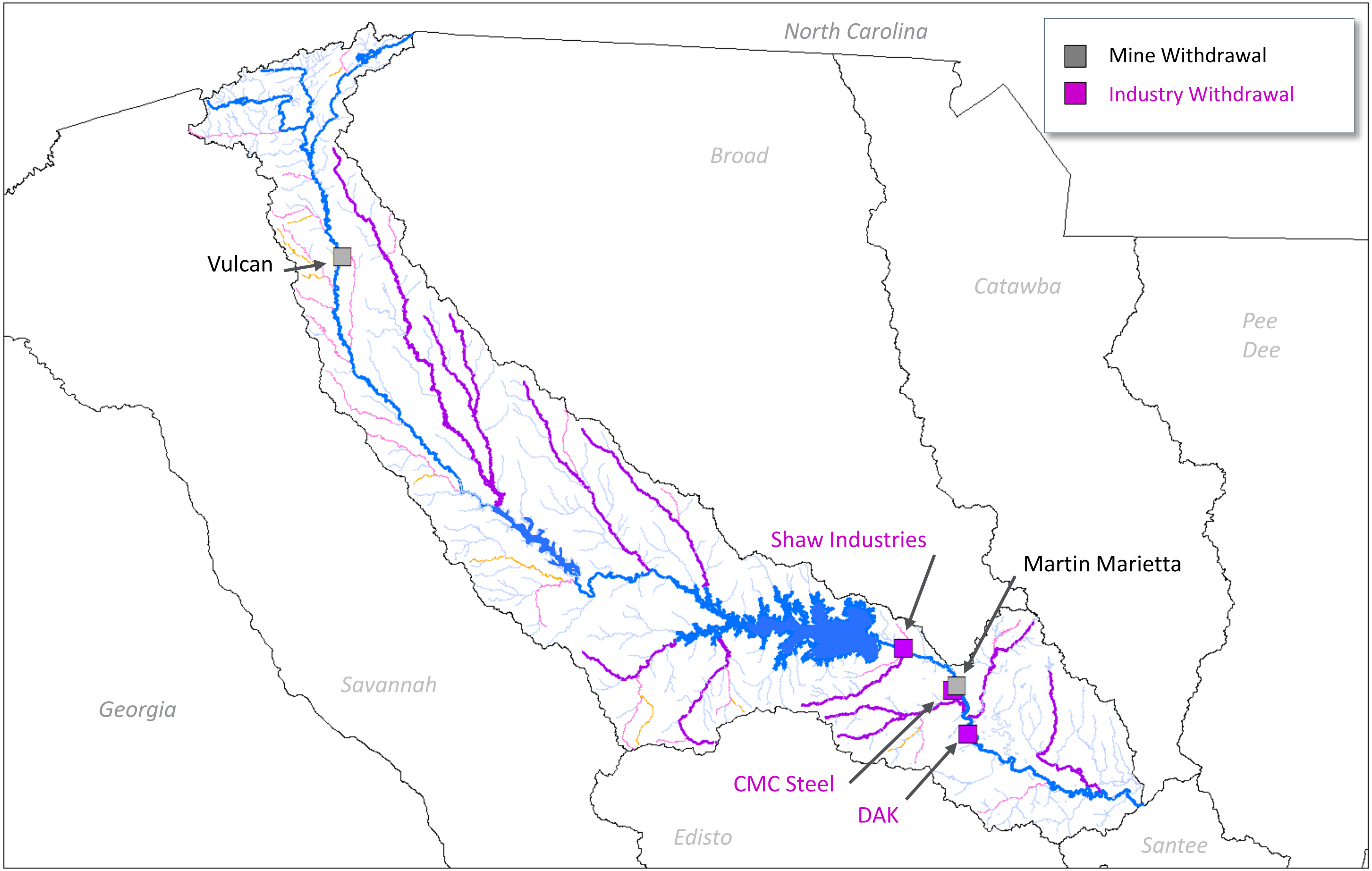
Saluda Basin – Primary Tributaries



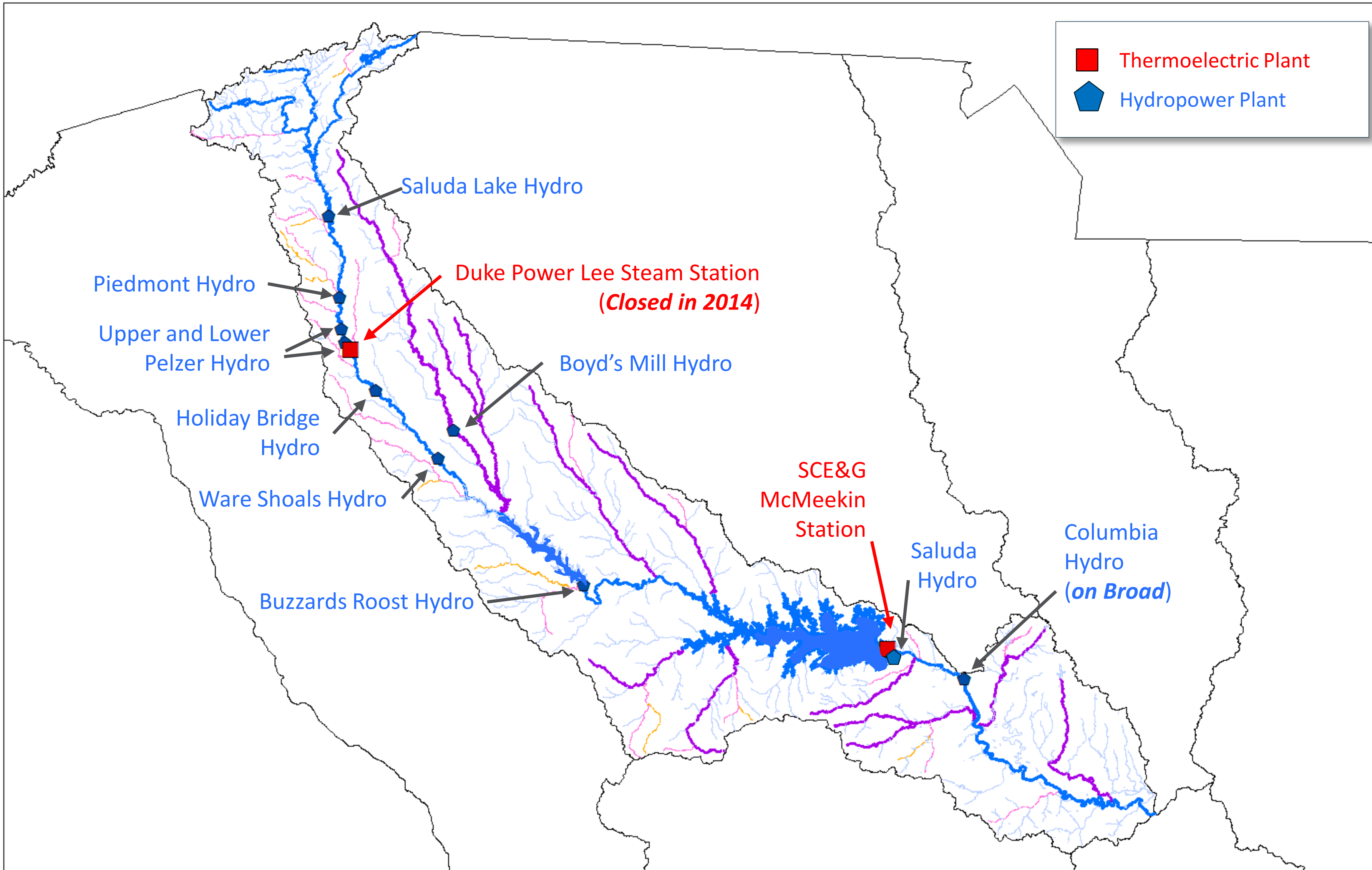
Saluda Basin Withdrawals – Public Water Supply



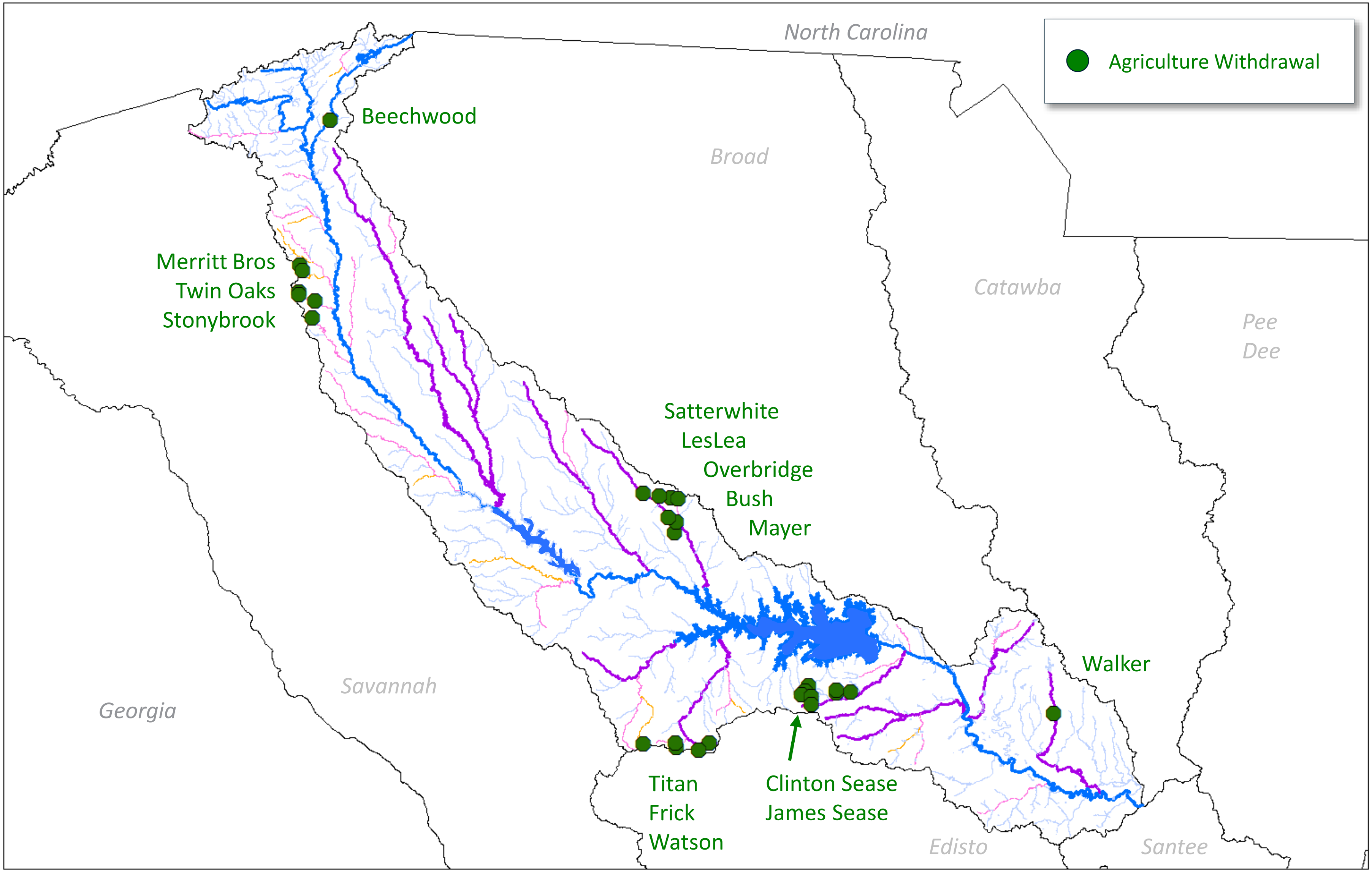
Saluda Basin Withdrawals– Industrial & Mining



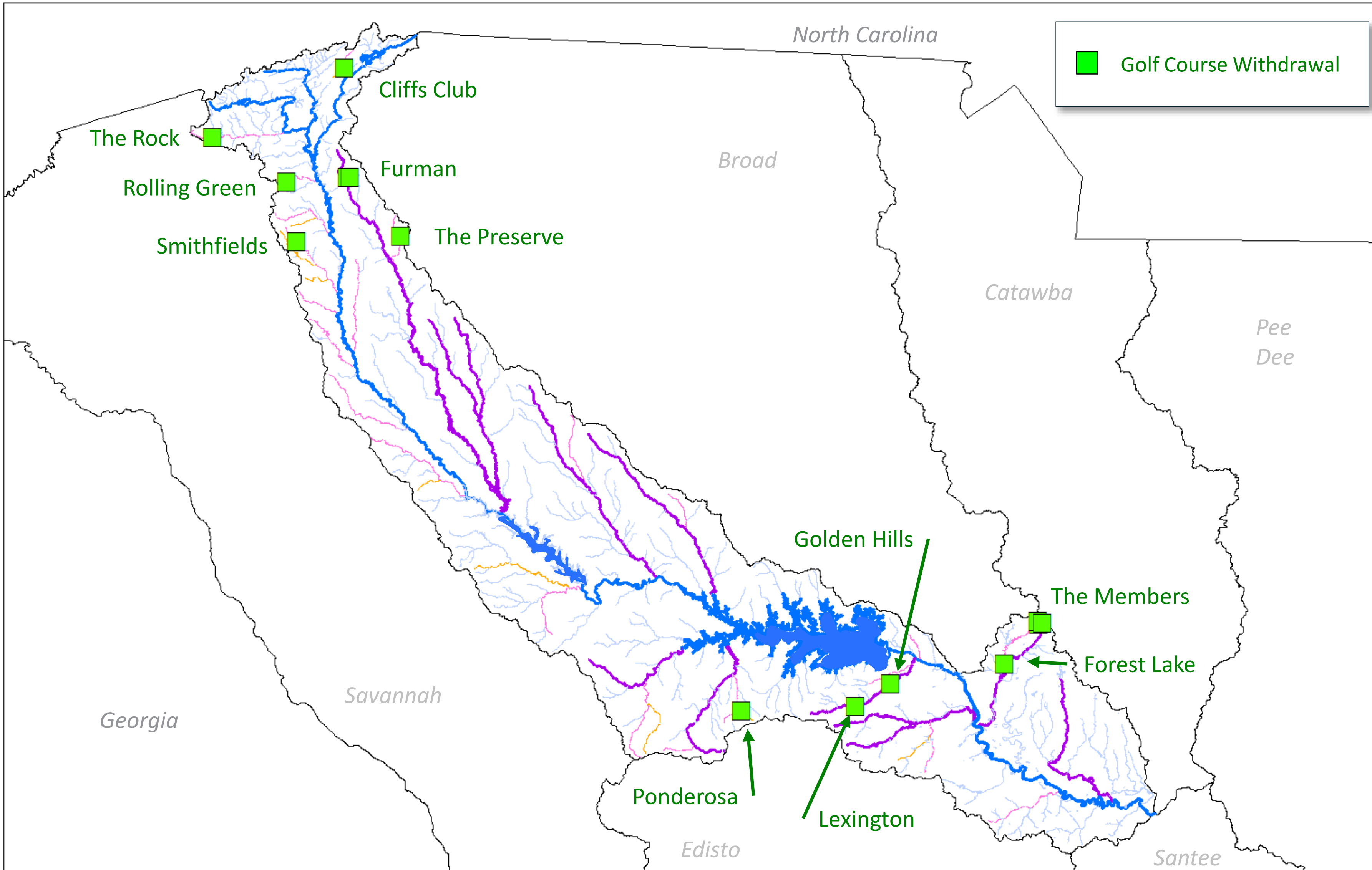
Saluda Basin Withdrawals – Energy



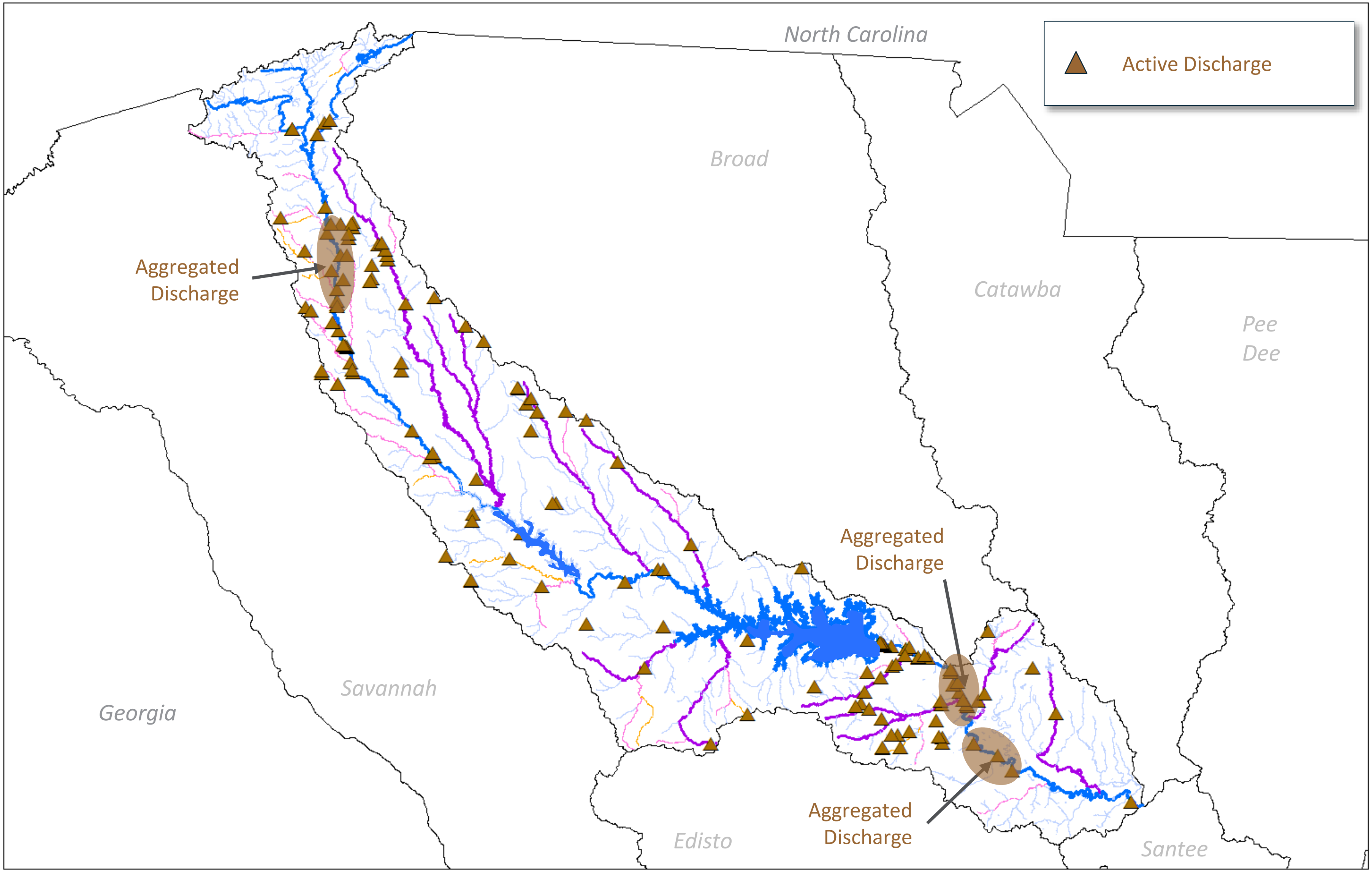
Saluda Basin Withdrawals – Agriculture



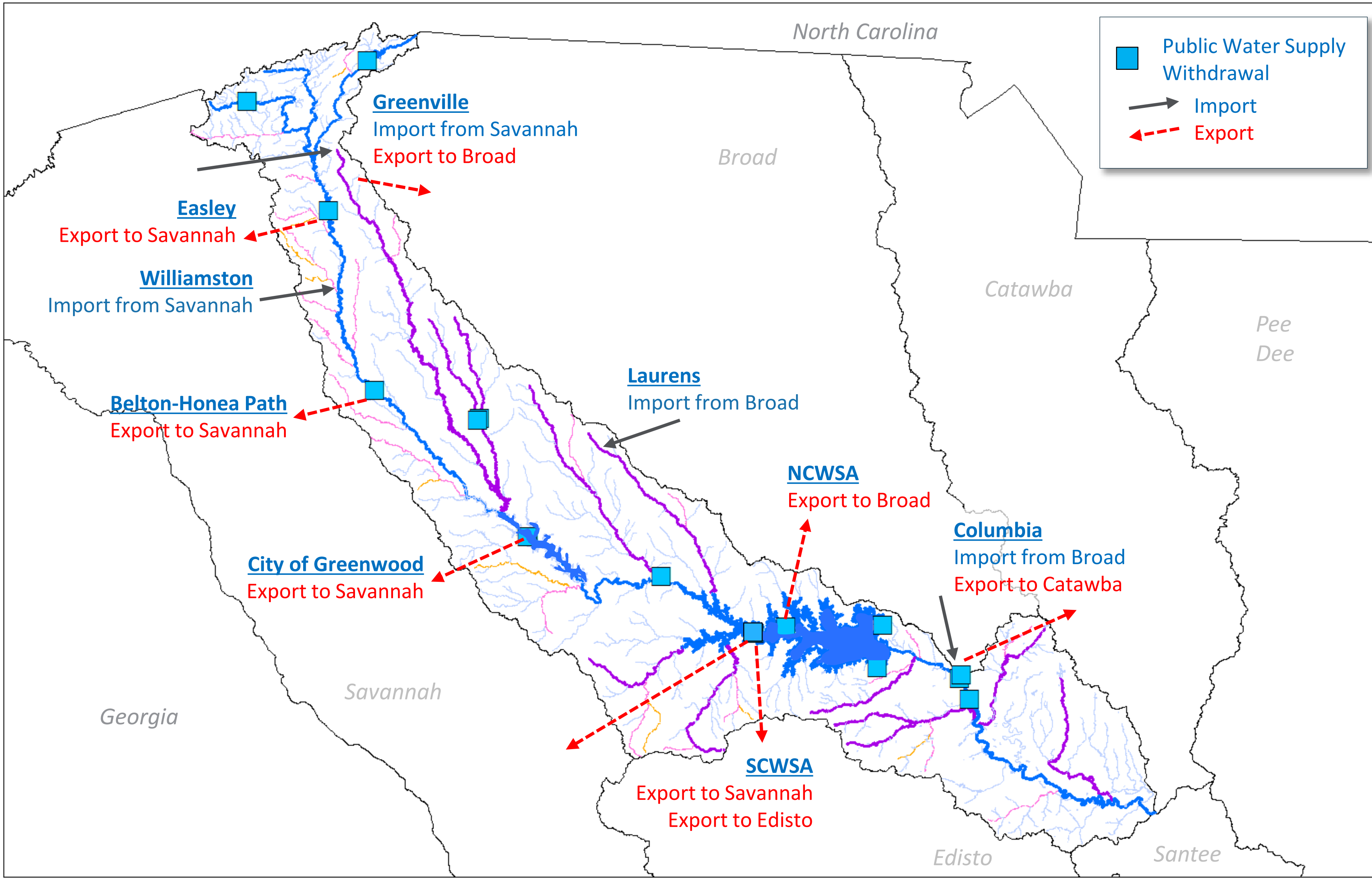
Saluda Basin Withdrawals – Golf Courses



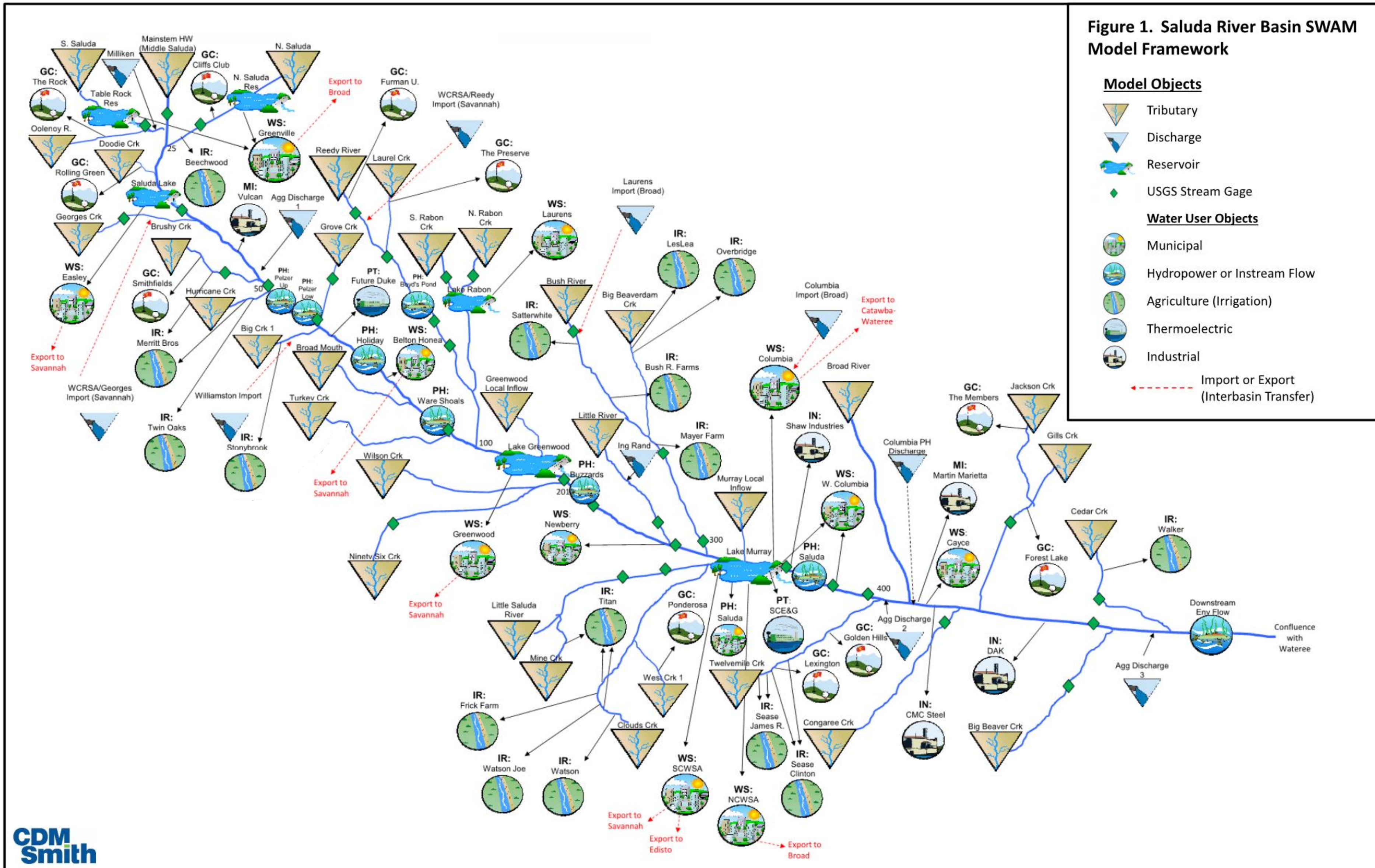
Saluda Basin Discharges



Interbasin Transfers



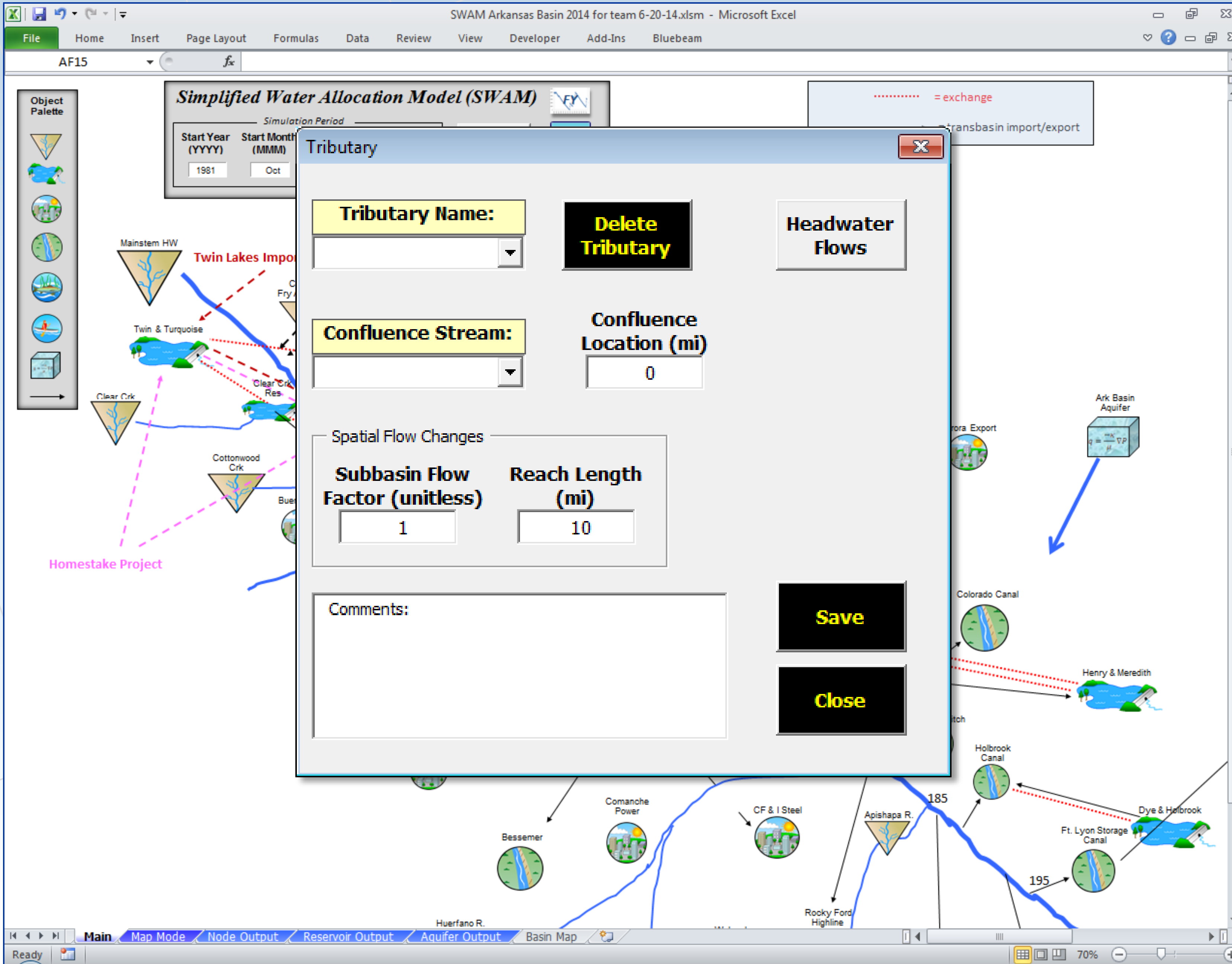
Saluda Basin – SWAM Framework



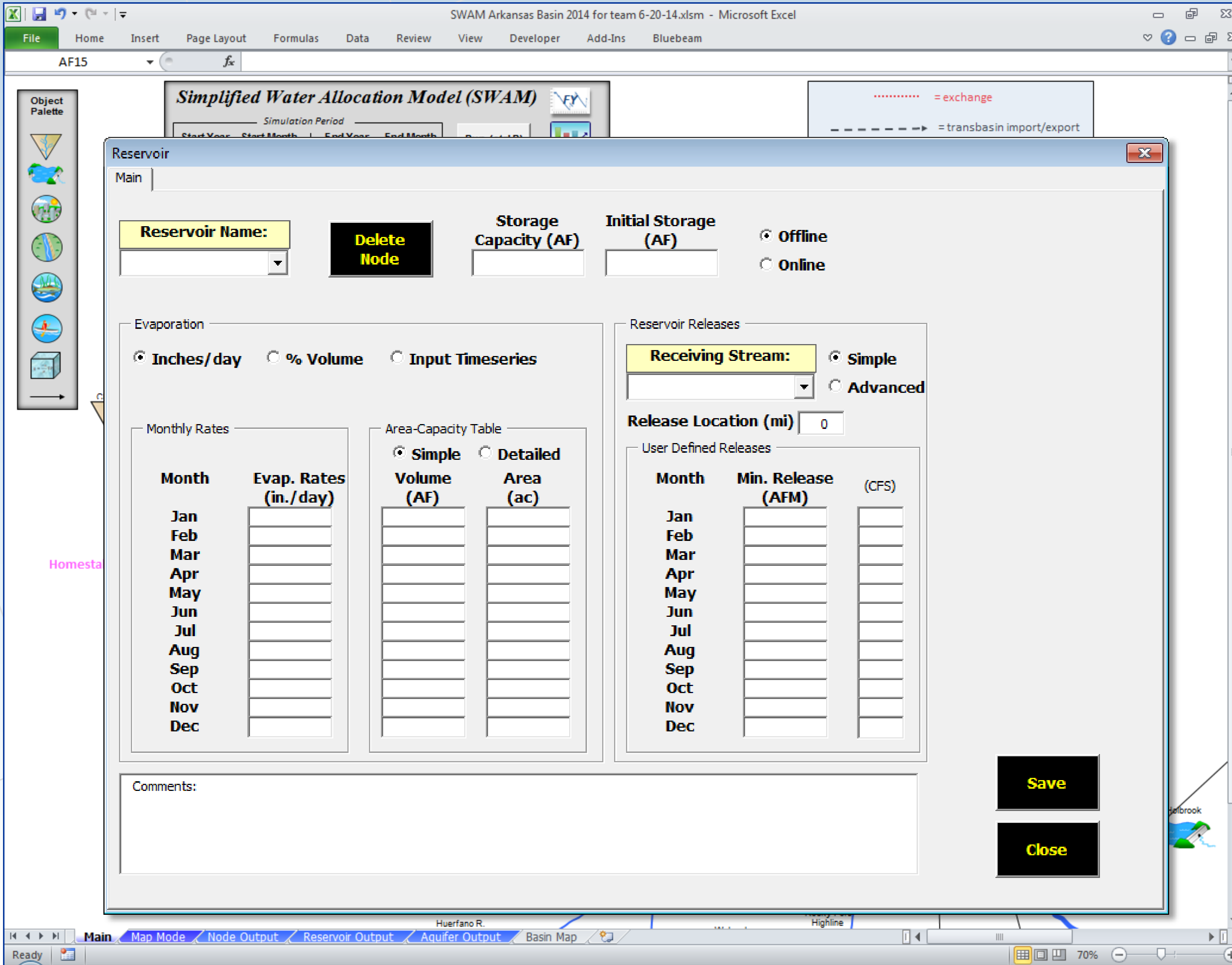
Saluda River Basin

MODEL SETUP

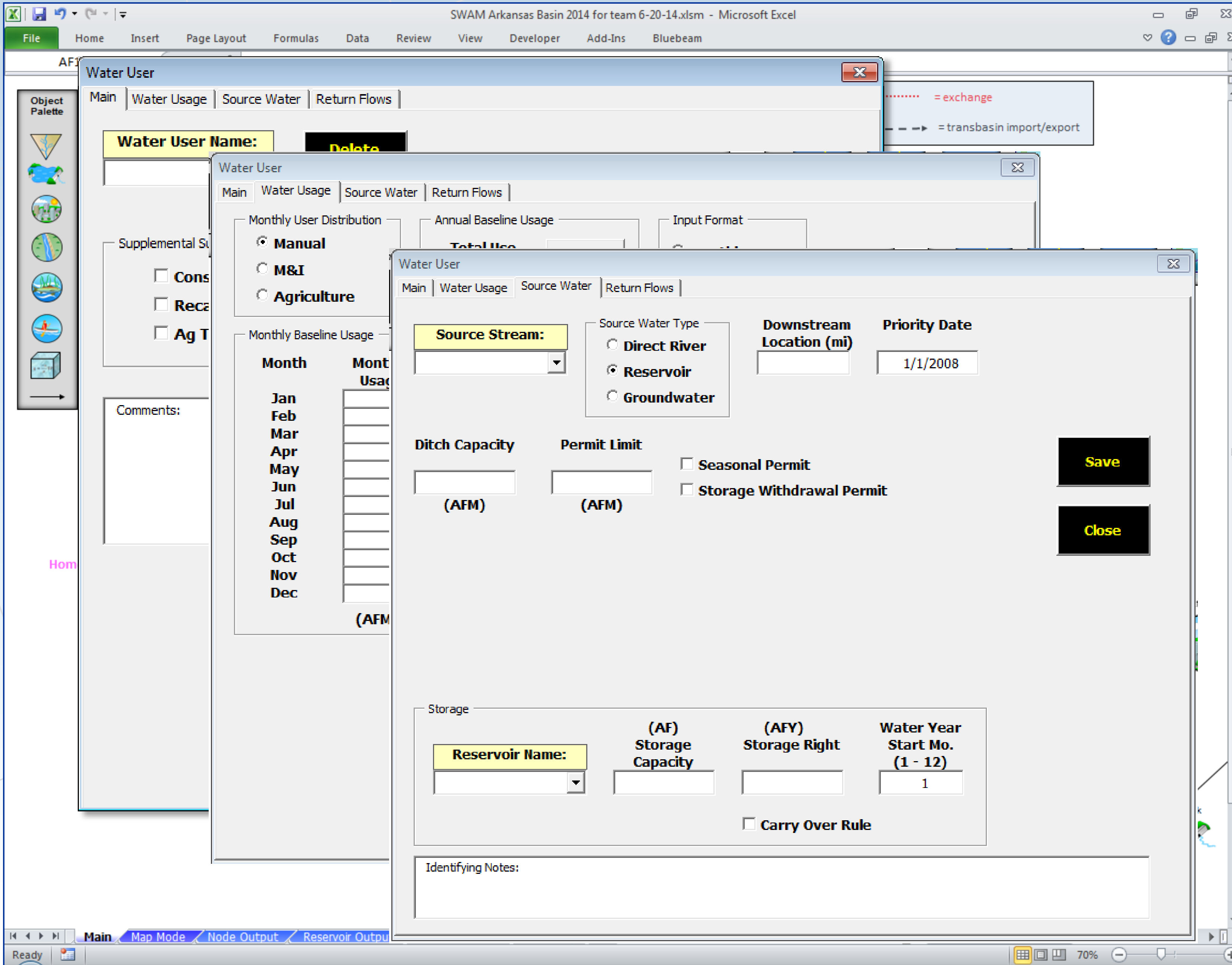
Tributary Input Form



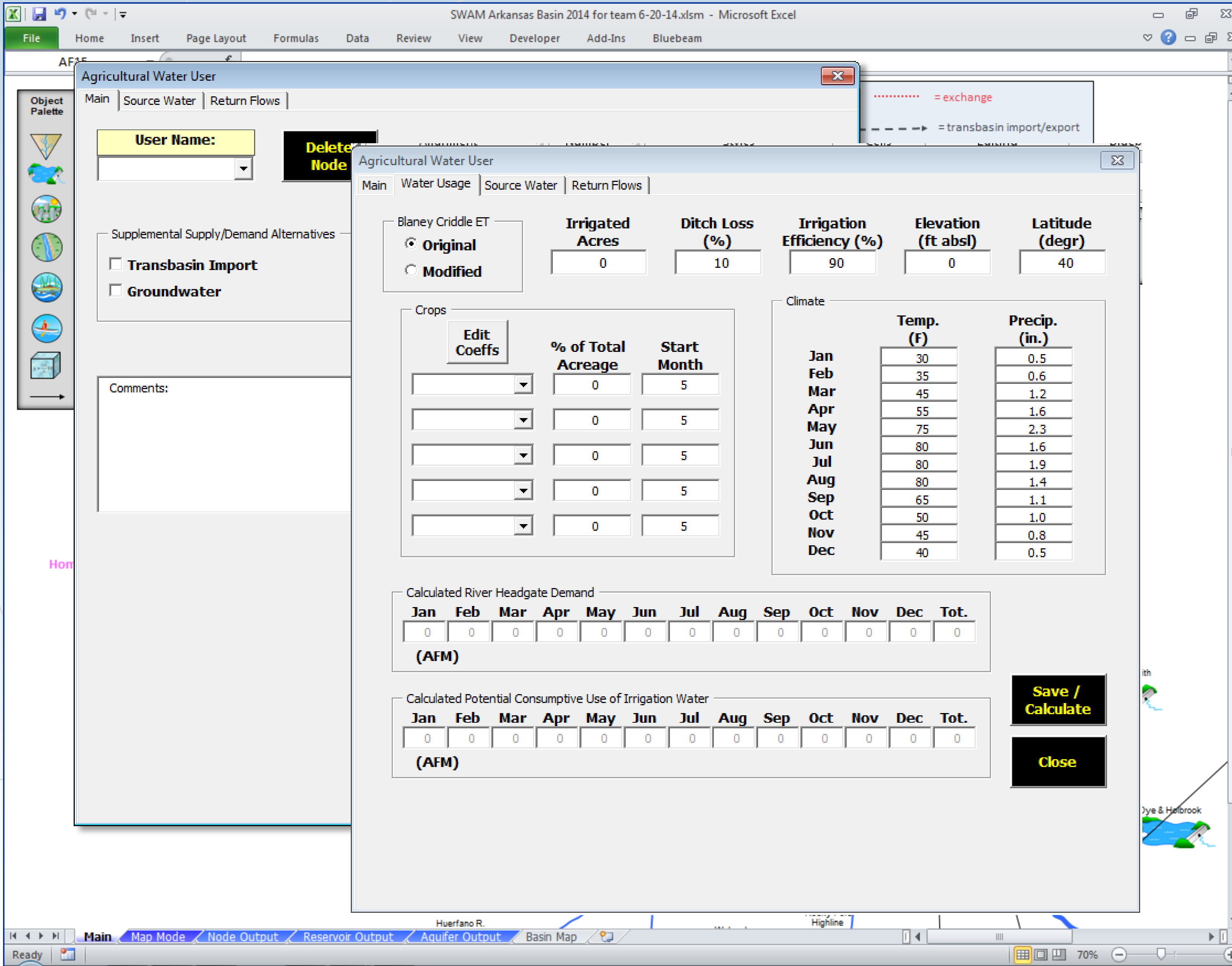
Reservoir Input Form



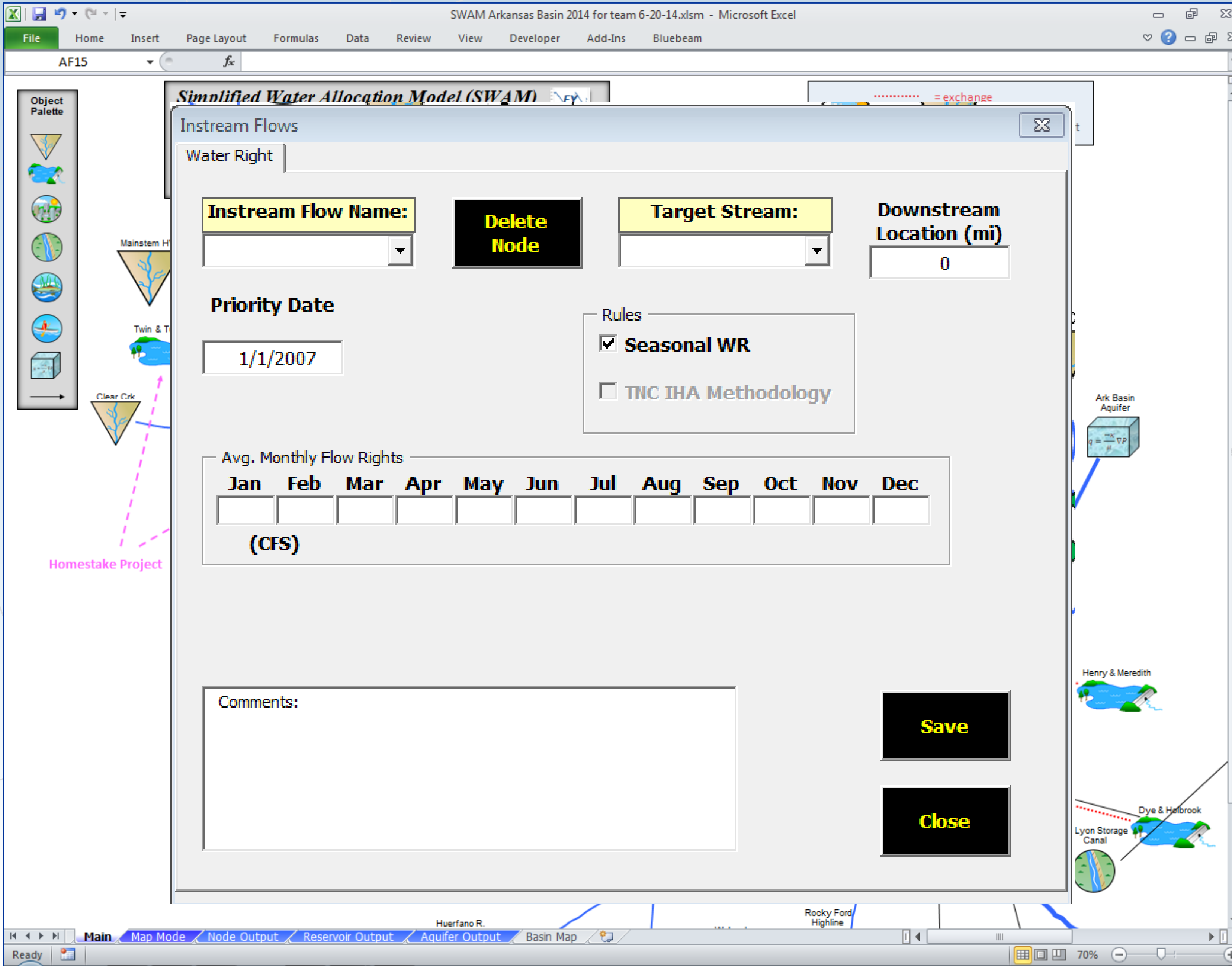
Water User Input Form – Main



Agricultural Water User Input Forms



Instream Flow Input Form



Saluda River Basin

MODEL VALIDATION

SWAM Calibration/Validation

- Calibration targets = downstream flow gage records
- Calibration parameters =
  - reach gains/losses,
  - ungaged 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)
  - Reservoir storage timeseries

Calibration Result Graphs