

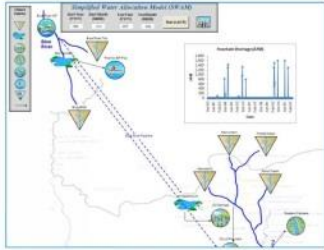
South Carolina Surface Water Quantity Modeling Project

Saluda Basin Meeting No. 1 – Model Framework

Kirk Westphal, PE
John Boyer, PE, BCEE
Tim Cox, PE
April 21, 2015

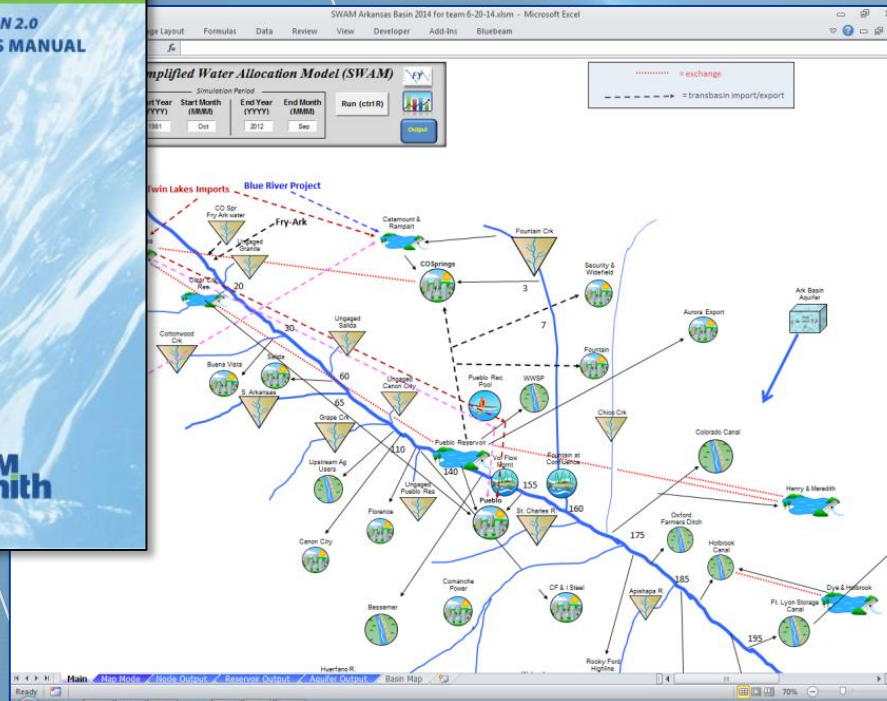
Simplified Water Allocation Model (SWAM)

VERSION 2.0
USER'S MANUAL



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**CDM
Smith**



**CDM
Smith**

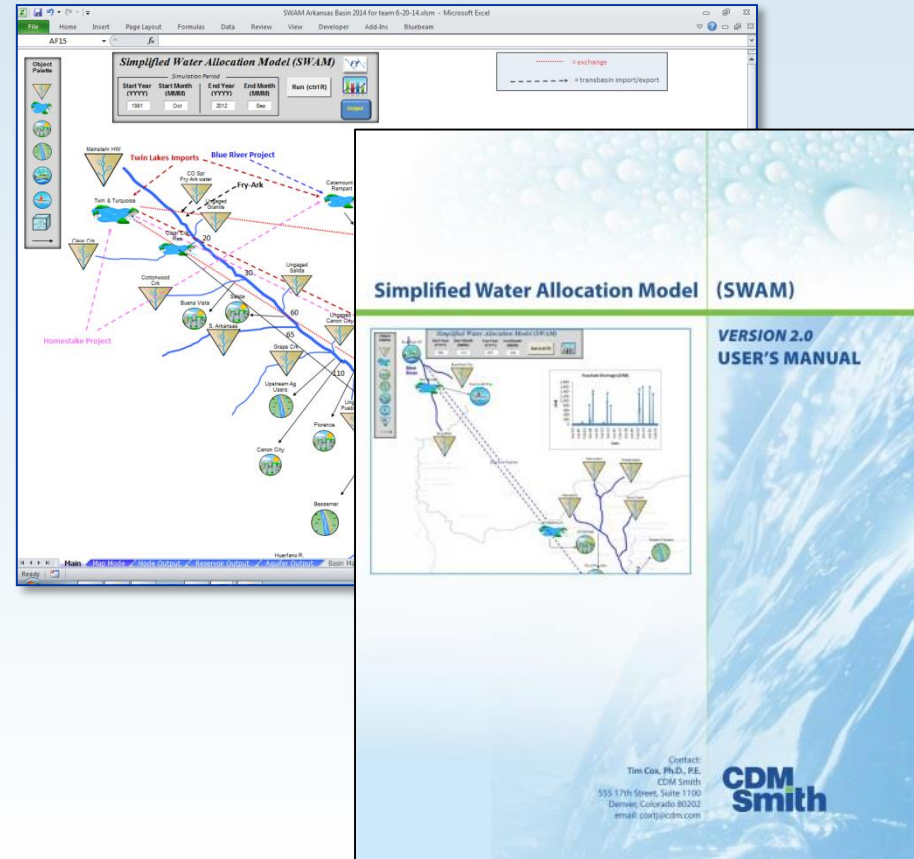
Project Purpose

- 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 a 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

Agricultural Water User - Input Form 1

Main | Source Water | Return Flows

User Name: [] [Delete Node] Multiple Sources of Water?

Supplemental Supply/Demand Alternatives

Transbasin Import Groundwater

Demands

user-defined ag calculations [Edit Demands]

Agricultural Water User - Input Form 2

Main | Source Water | Return Flows

Return Flow Locations

single point multiple points

Receiving Stream: [] RF Location (mi): [0] Time Lag (months): [0]

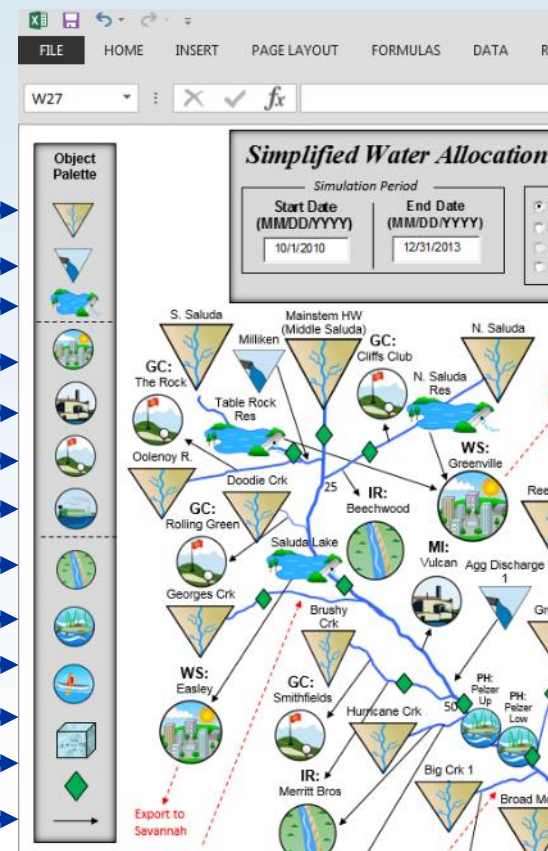
Monthly Return Flows

Return Flow %	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	0	0	0	0	0

[Save] [Close]

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)

- **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

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft

	A	B	EY	EZ	FA	FB	FC	FD	FE	FF
Output							Water Right (AFM)	Ditch Capacity (AFM)	Storage Capacity (AE)	
1			Priority Rank	Reach (mi)	Location					
2			Pueblo4	32	Mainstem	136	420	1,000,000	5,000	
3		Date	Physically Avail. (AFM)	Legally Avail. (AFM)	Diverted (AFM)	Storage (AF)	GW Pumping (AFM)	Demand (AFM)	Shortage (AFM)	Return Flow (AFM)
4		Min	1,200	0	0	0	0	0	0	0
5		Max	423,253	420	420	5,000	0	0	0	0
6		Avg	44,588	117	33	4,340	0	0	0	0
7		Oct-81	14,837	0	0	0	0	0	0	0
8		Nov-81	23,186	0	0	0	0	0	0	0
9		Dec-81	24,424	0	0	0	0	0	0	0
10		Jan-82	17,870	0	0	0	0	0	0	0
11		Feb-82	16,694	0	0	0	0	0	0	0
12		Mar-82	25,120	0	0	0	0	0	0	0
13		Apr-82	11,977	0	0	0	0	0	0	0
14		May-82	35,025	0	0	0	0	0	0	0
15		Jun-82	146,407	0	0	0	0	0	0	0
16		Jul-82	97,301	0	0	0	0	0	0	0

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' software interface. The window title is 'Reservoir' and it has a 'Main' tab. The interface includes several input fields and controls:

- Reservoir Name:** A text input field with a dropdown arrow.
- Delete Node:** A black button with yellow text.
- Storage Capacity (AF):** A text input field.
- Initial Storage (AF):** A text input field.
- Offline/Online:** Radio buttons for 'Offline' (selected) and 'Online'.
- Evaporation:** Radio buttons for 'Inches/day' (selected), '% Volume', and 'Input Timeseries'.
- Reservoir Releases:** Radio buttons for 'Simple' (selected) and 'Advanced'.
- Receiving Stream:** A dropdown menu.
- Release Location (mi):** A text input field with the value '0'.
- User Defined Releases:** A section with a table for defining releases.

The 'Monthly Rates' and 'Area-Capacity Table' sections contain tables with columns for months and various parameters.

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

Area-Capacity Table	
Simple	Detailed
Volume (AF)	Area (ac)

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

SWAM Model Main Screen

AK1

Simplified Water Allocation Model (SWAM)

Simulation Period
Start Date (MM/DD/YYYY): 10/1/2010
End Date (MM/DD/YYYY): 12/31/2013

Simulation Type
 Monthly Planning
 Daily Planning
 Short Term Forecasting
 Firm Yield Calculator

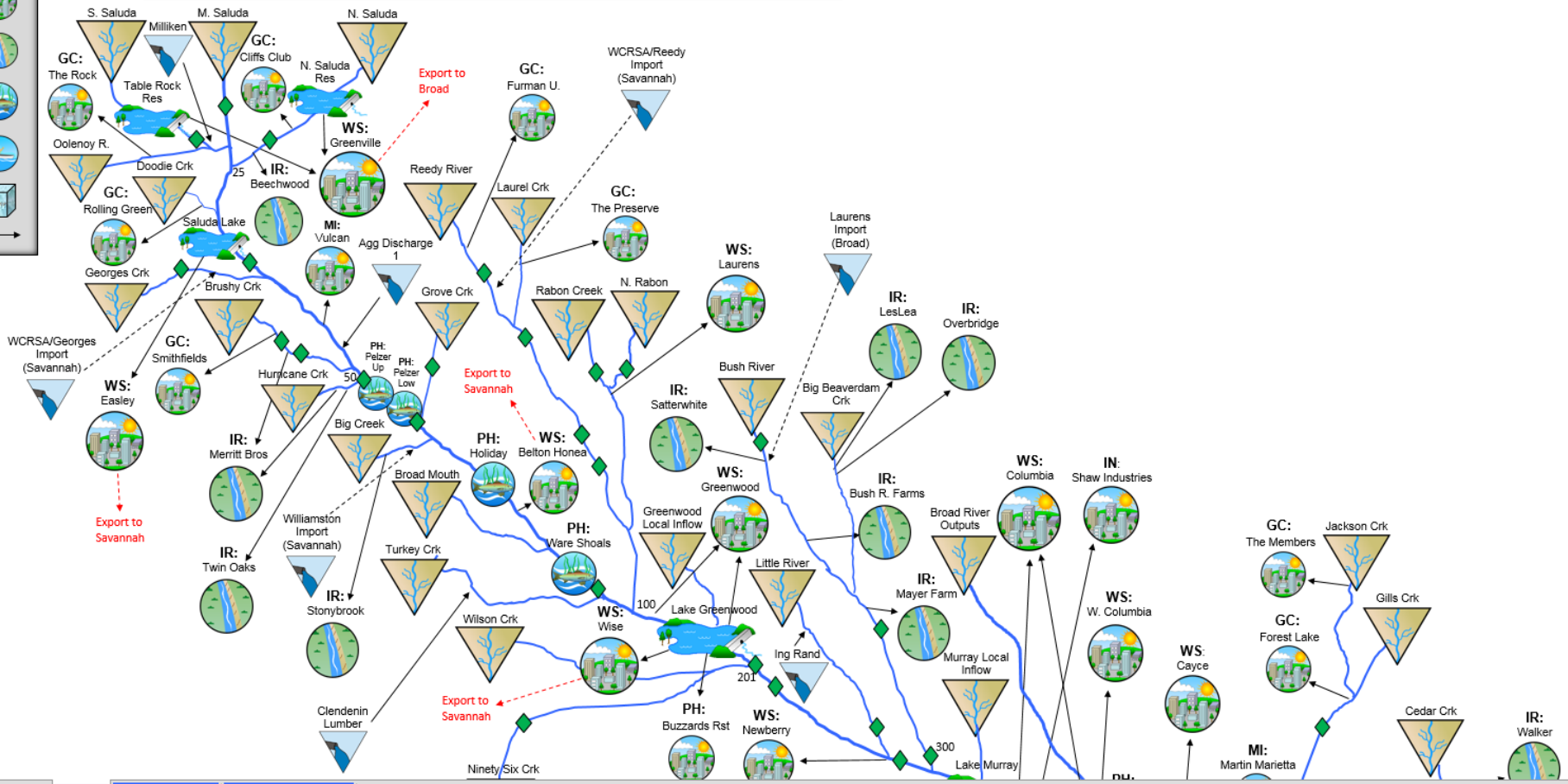
Input & Output
 AF, AFM, AFD
 MG, MGD, CFS
 m3, m3/d, m3/s

Run (ctrl R)

Input Tables and Outputting

Node Priorities **Node Locations** **Output Format**

Object Palette



Main Node Output Reservoir Output

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 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.

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

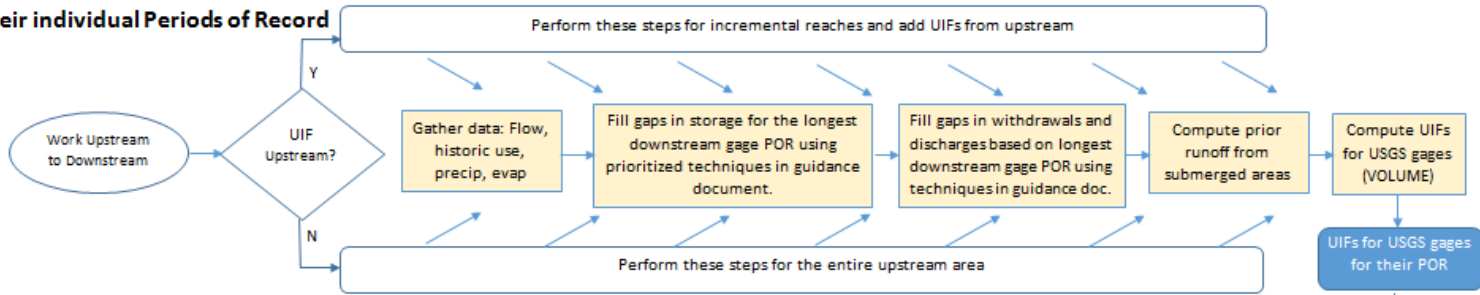
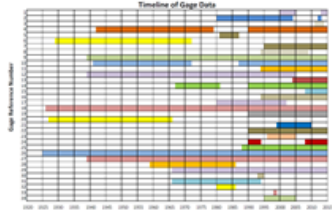
Estimated

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

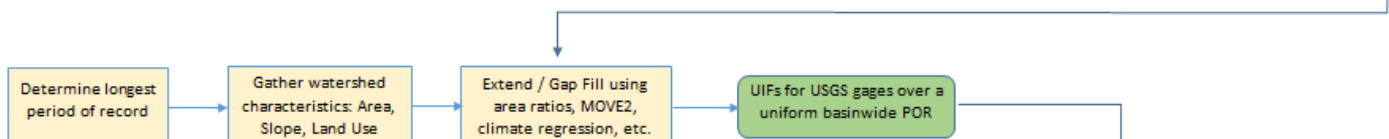
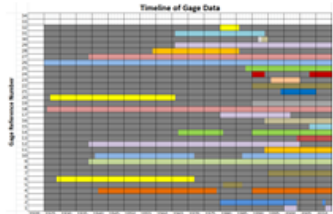
Basinwide UIF Calculation Process

Stepwise Procedure for UIF Calculation – Saluda Basin

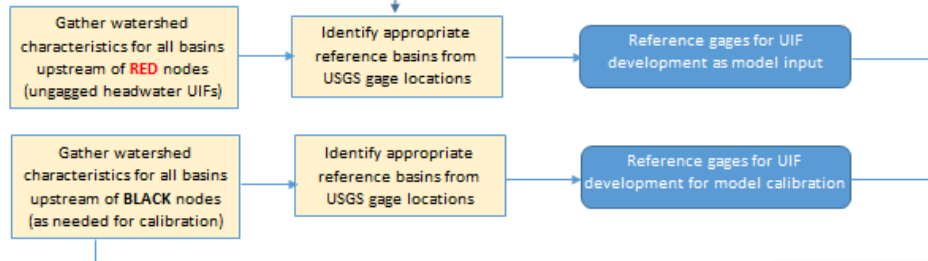
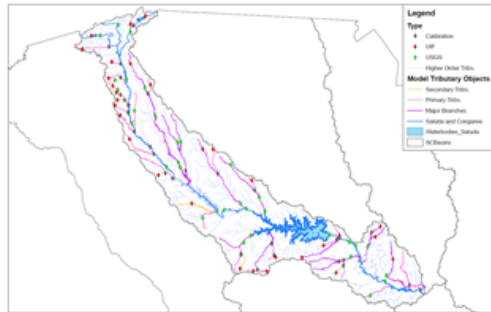
Step 1: UIFs for USGS Gages for their individual Periods of Record



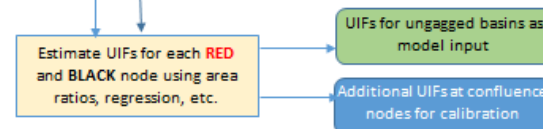
Step 2: Extension of UIFs for USGS Gages throughout the LONGEST Period of Record



Step 3: Correlation between Ungaged Basins and Gaged Basins

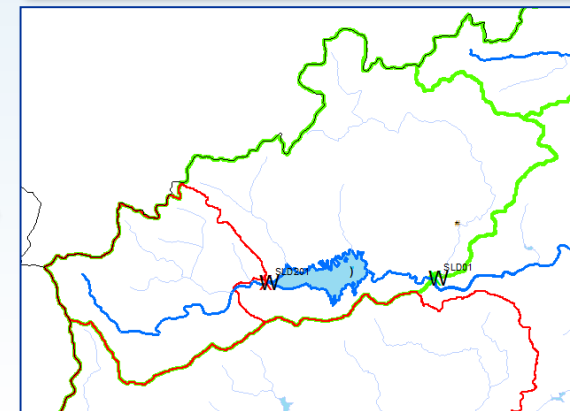
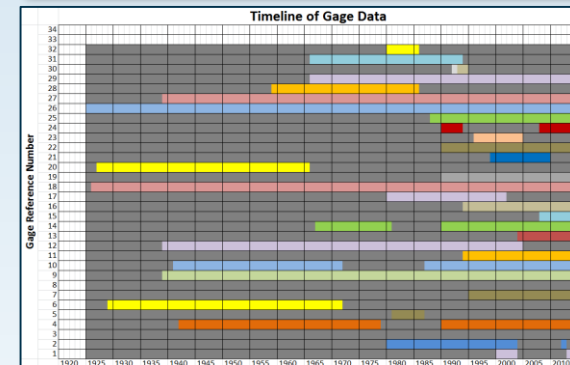
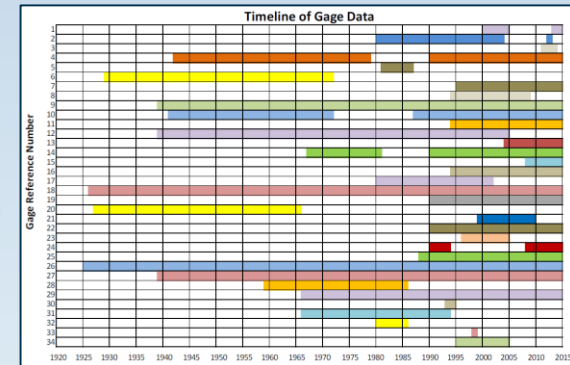


Step 4: UIFs for Ungaged Basins



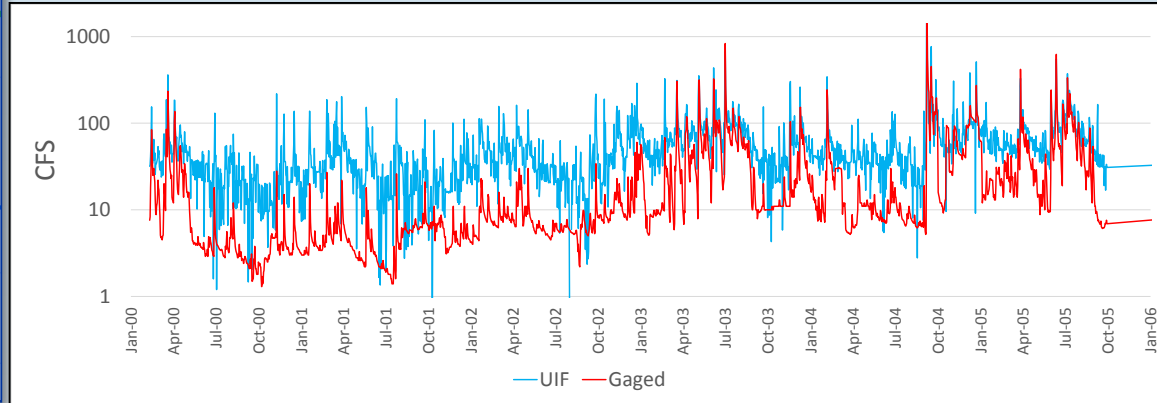
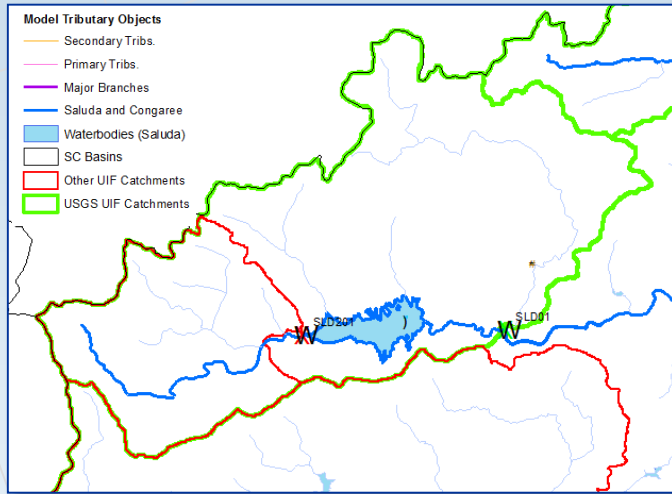
Four Steps in UIF Calculation Process

- **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

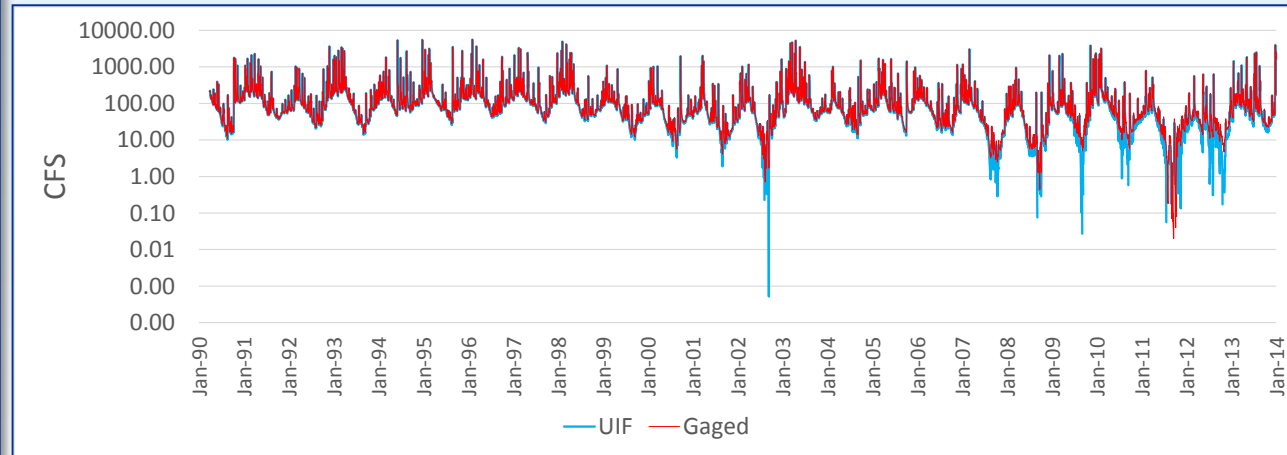
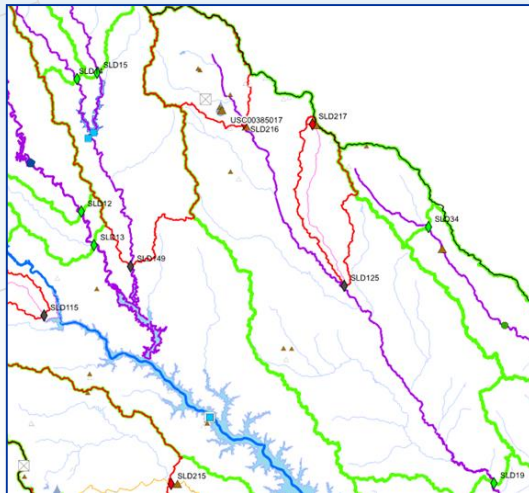


Sample UIF Results (Draft)

SLD01: South Saluda River downstream of Table Rock Reservoir



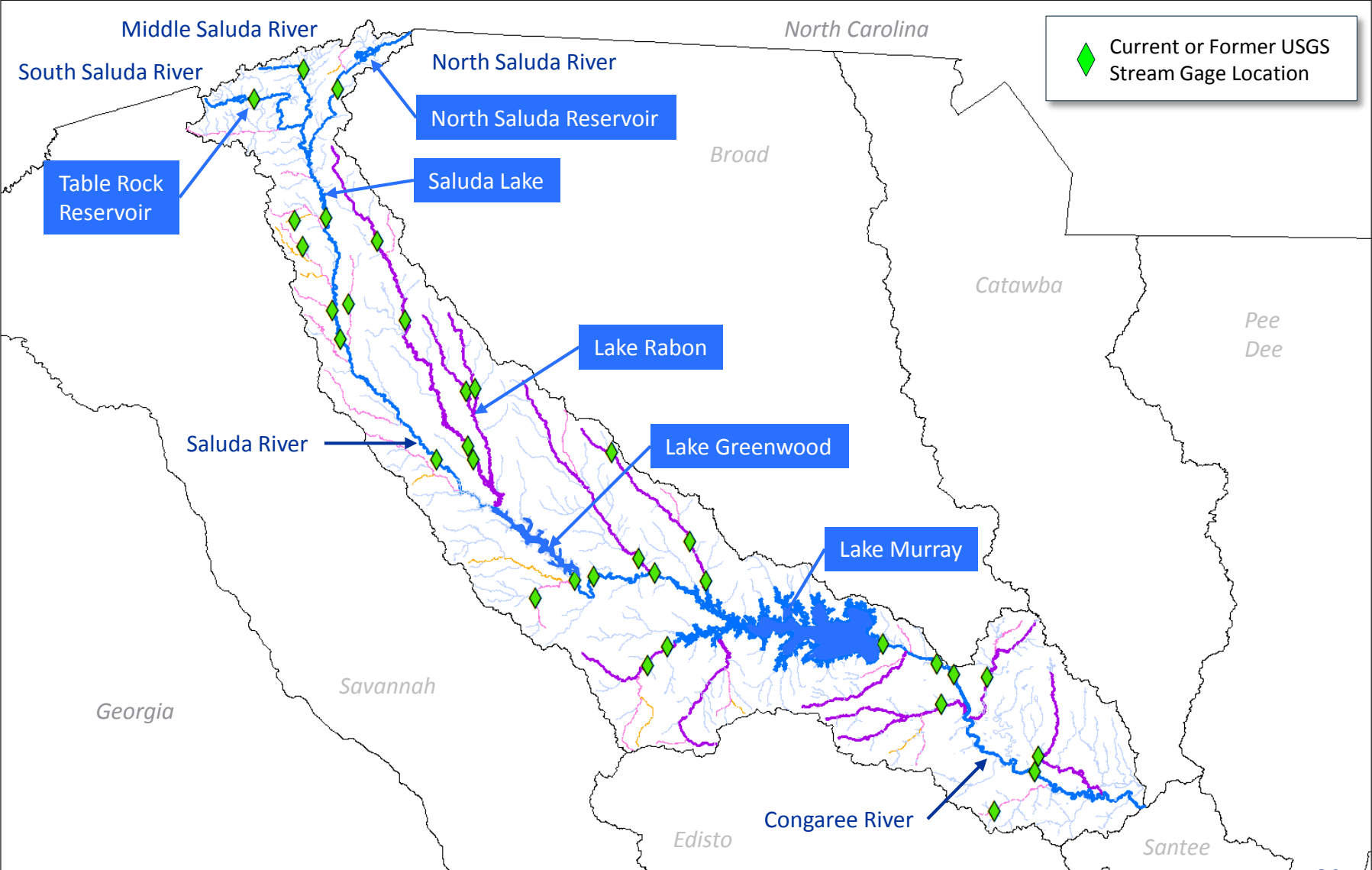
SLD19: Little River near Silverstreet



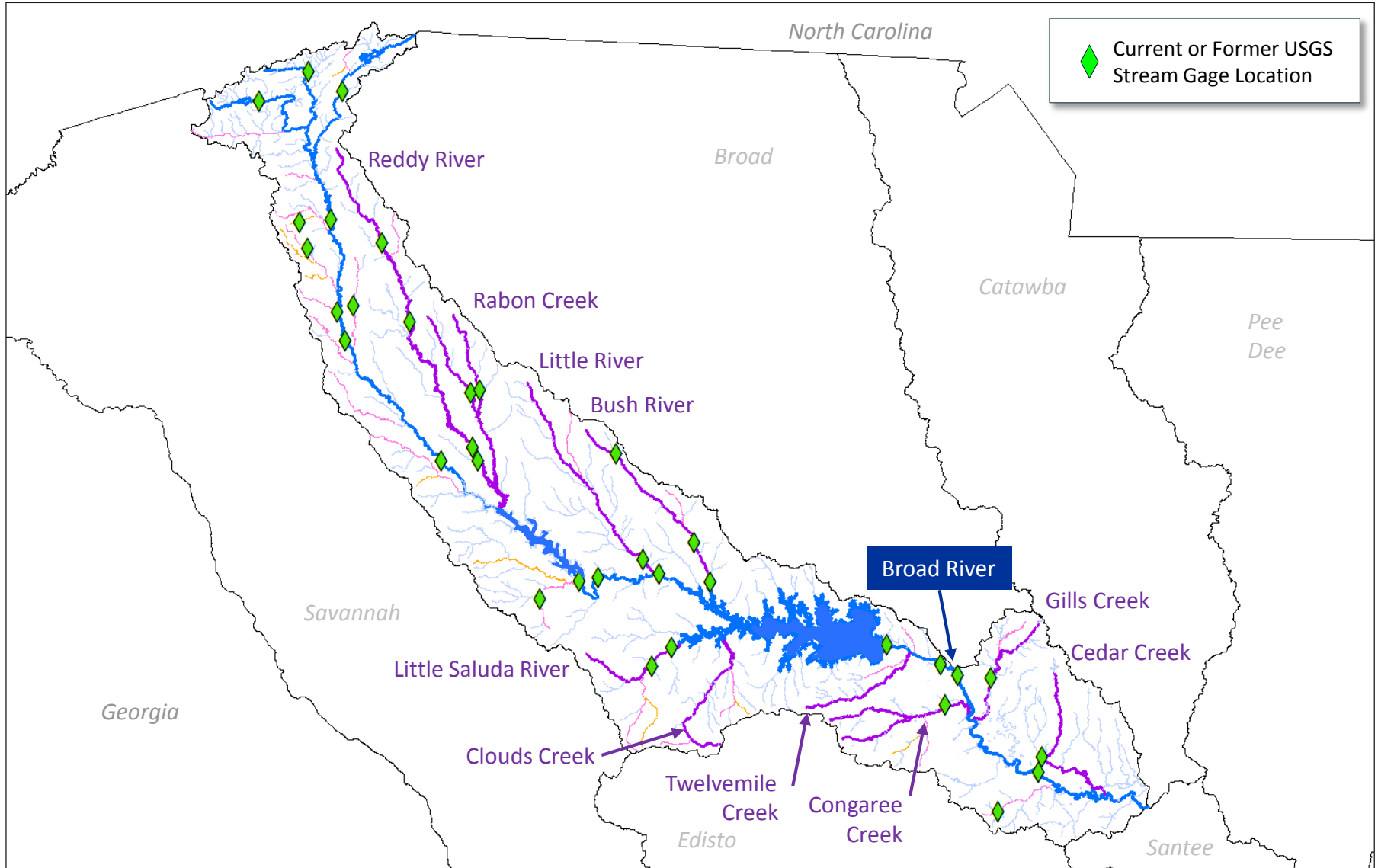
Saluda River Basin

OVERVIEW OF MODEL FRAMEWORK

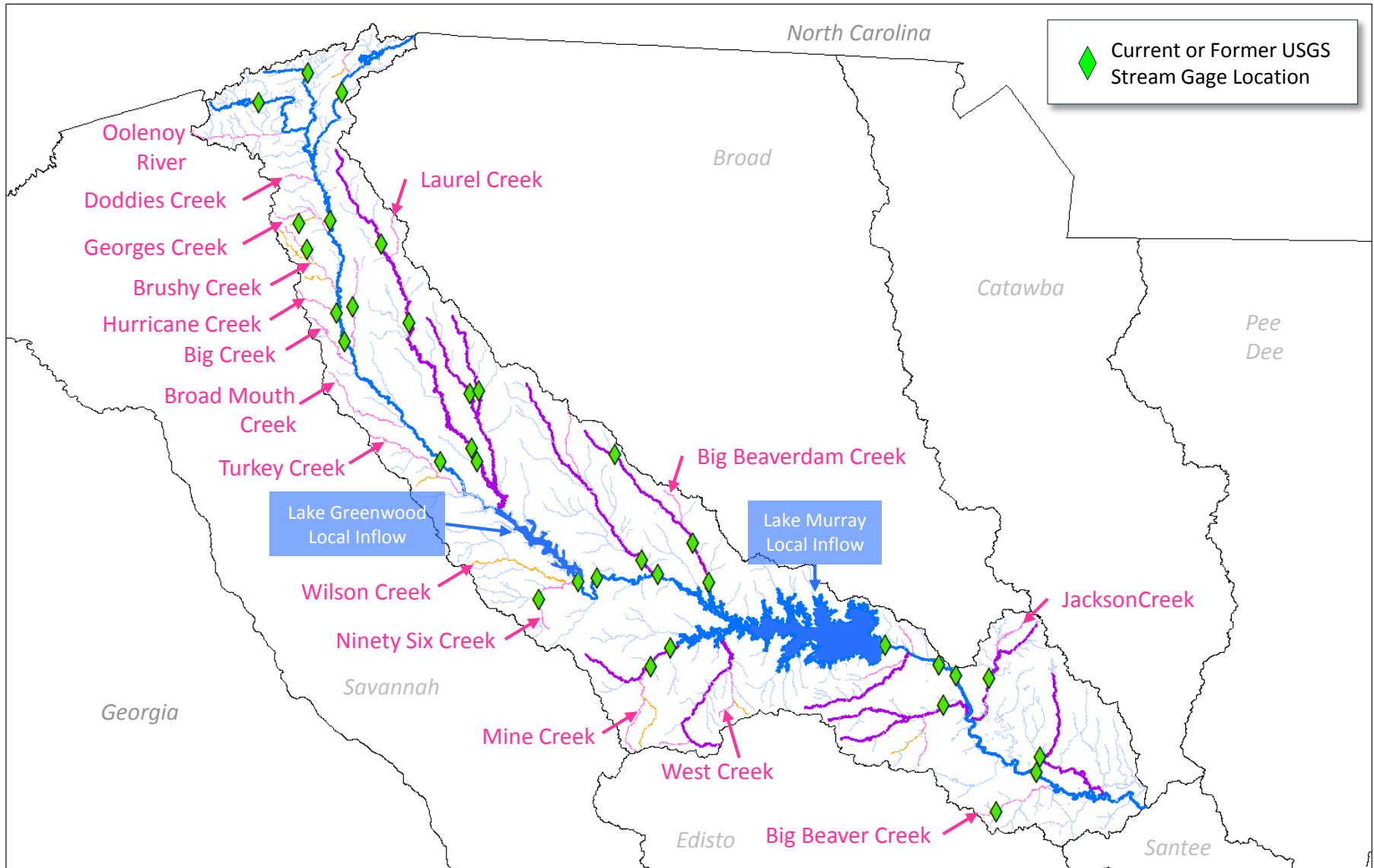
Saluda Basin – Major Streams & Reservoirs



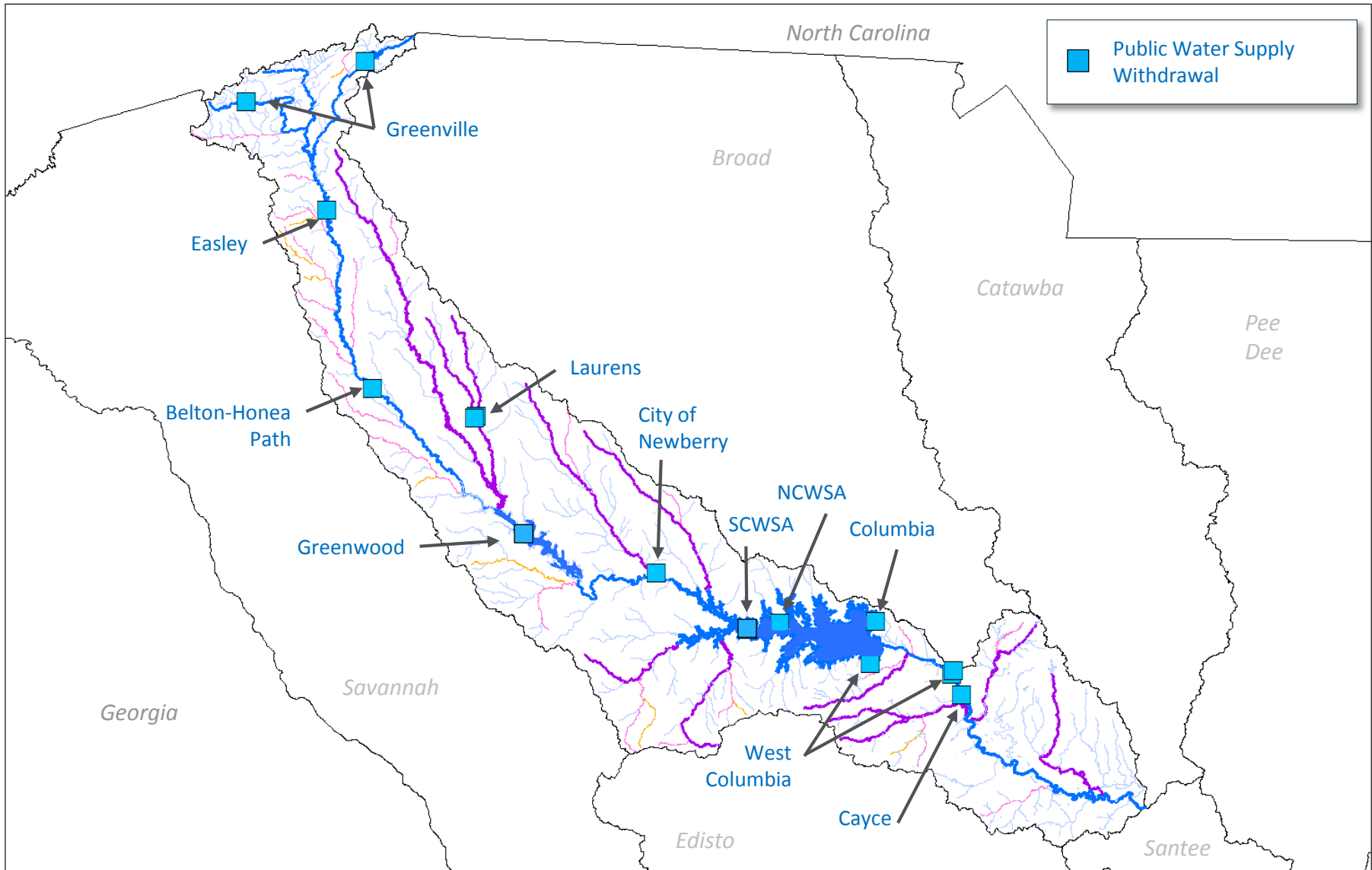
Saluda Basin – Major Branches



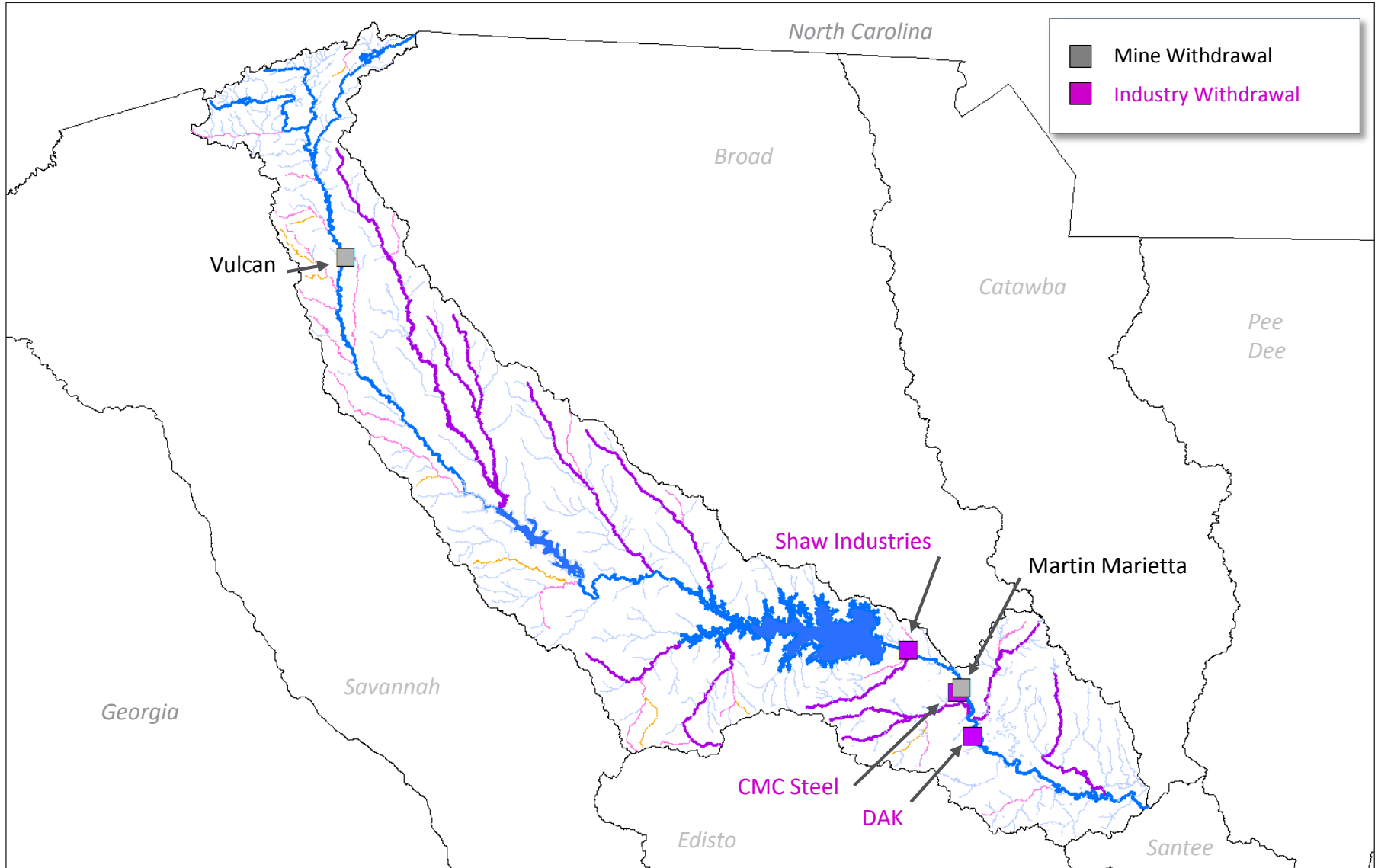
Saluda Basin – Primary Tributaries



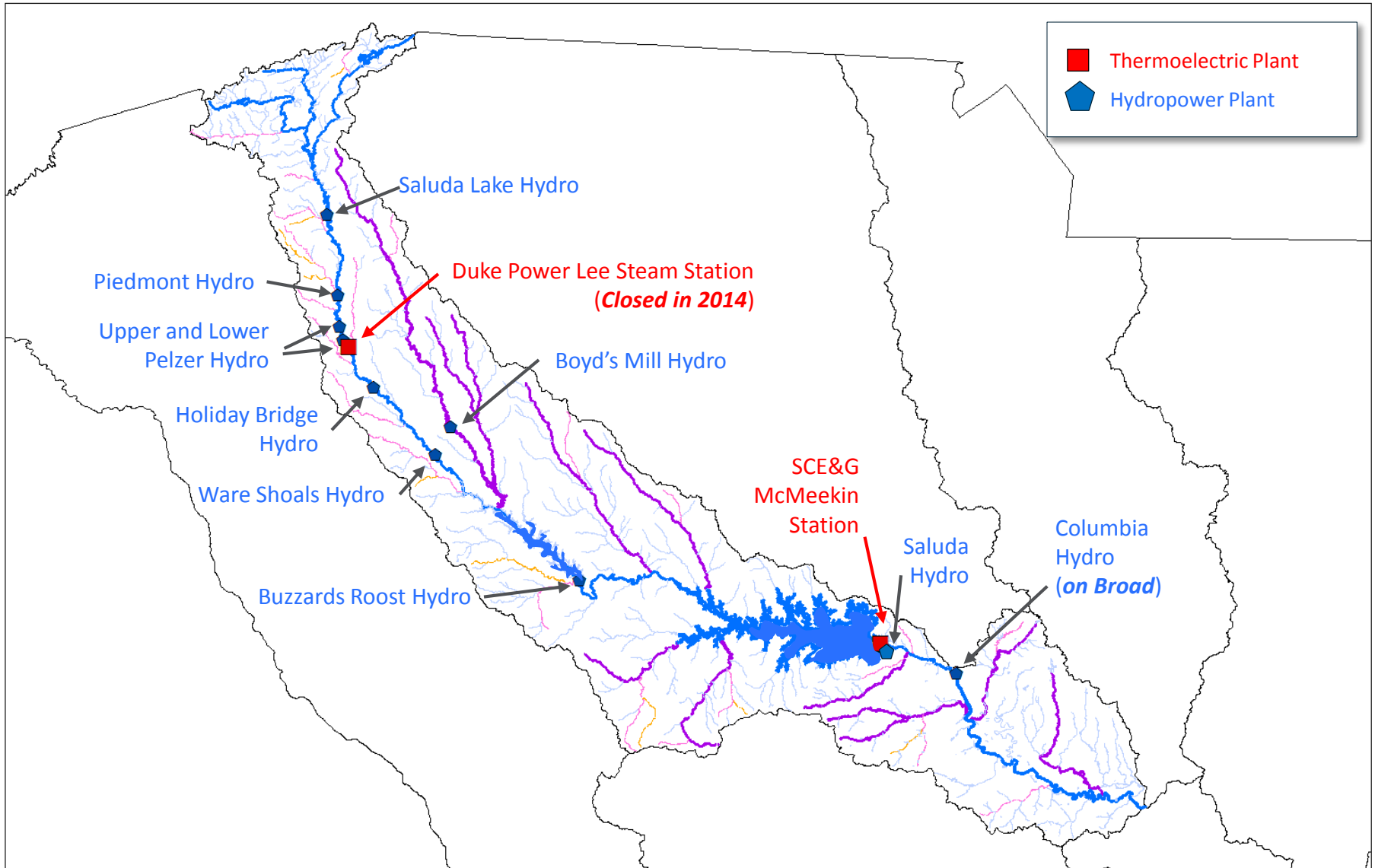
Saluda Basin Withdrawals – Public Water Supply



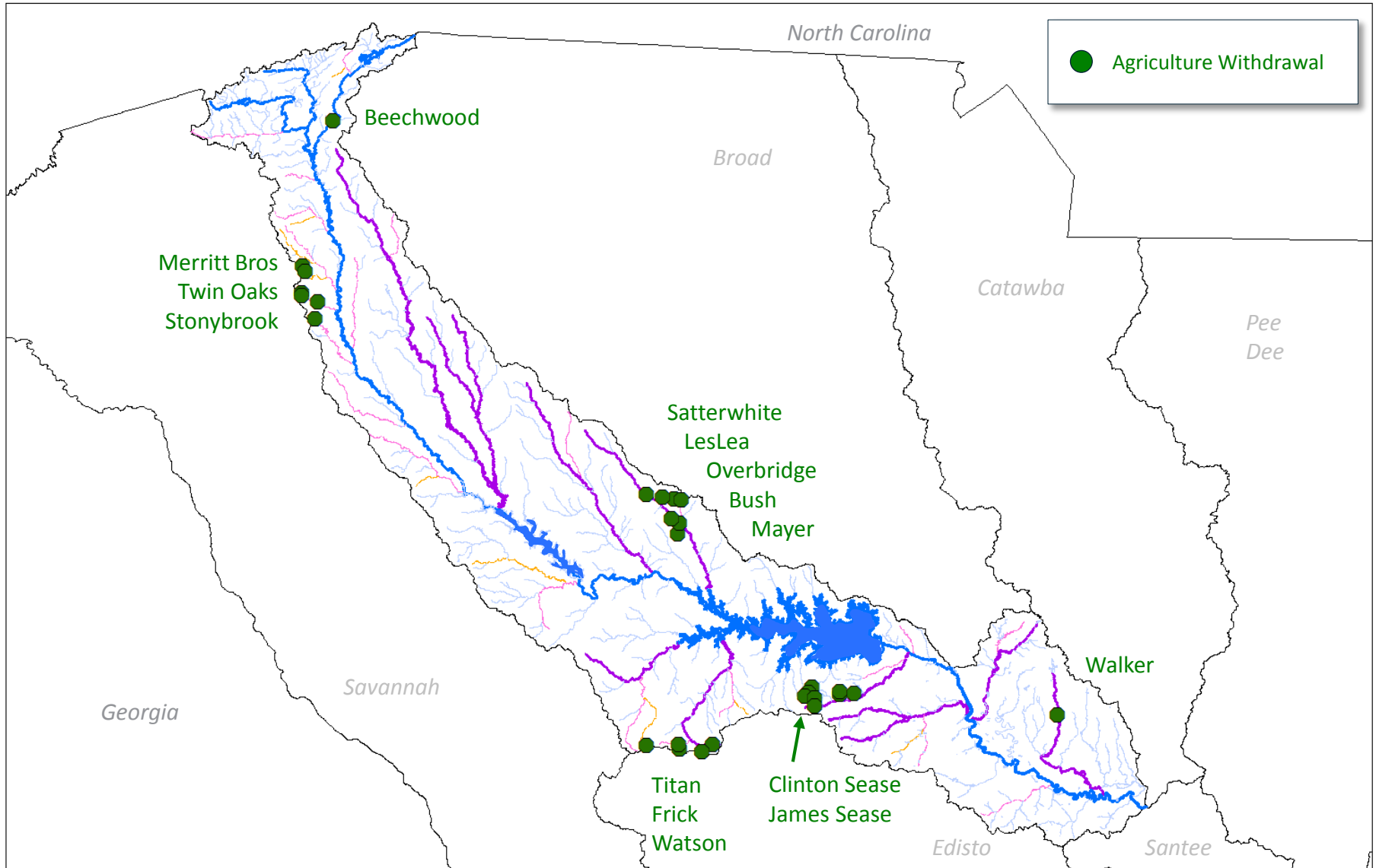
Saluda Basin Withdrawals– Industrial & Mining



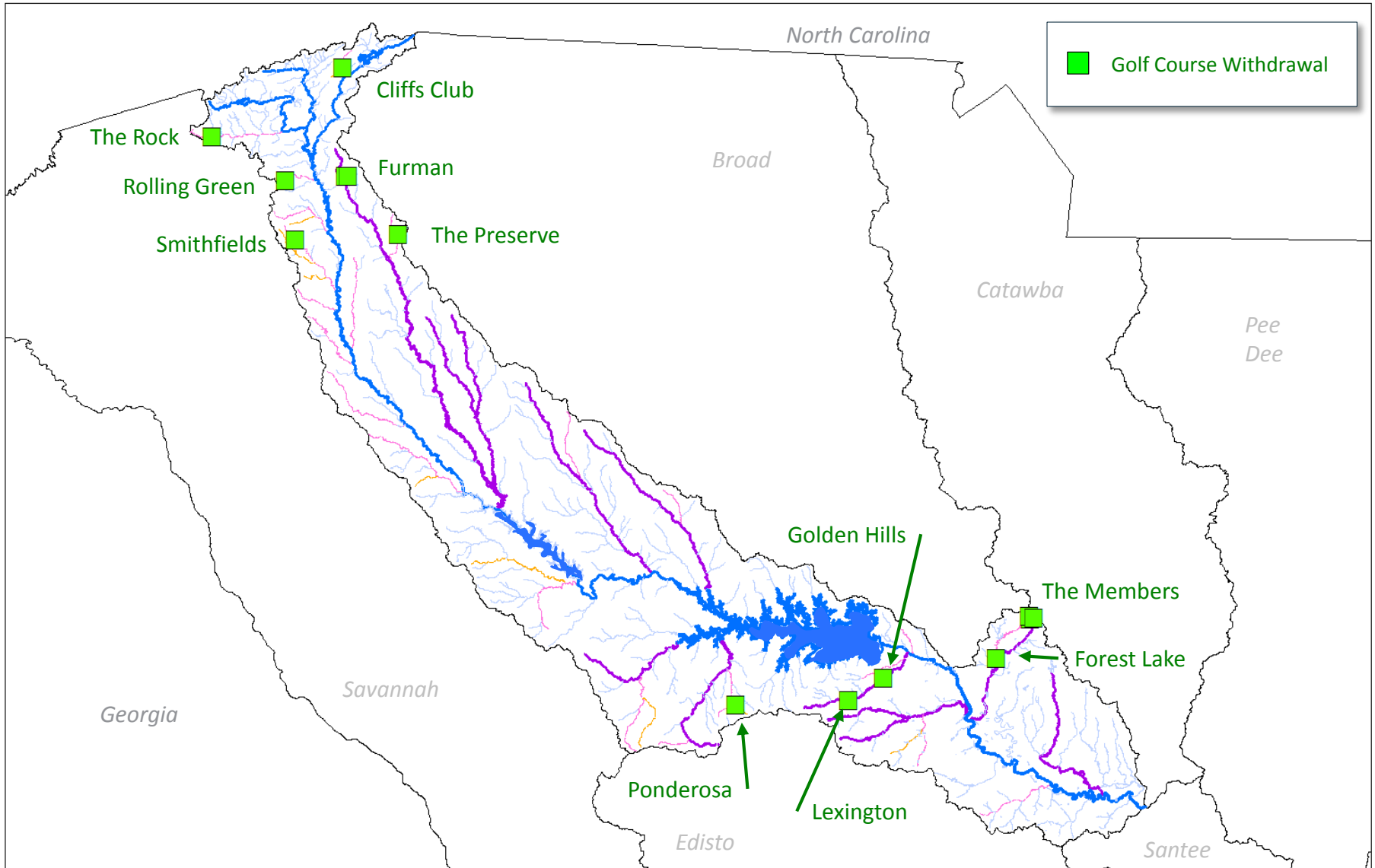
Saluda Basin Withdrawals – Energy



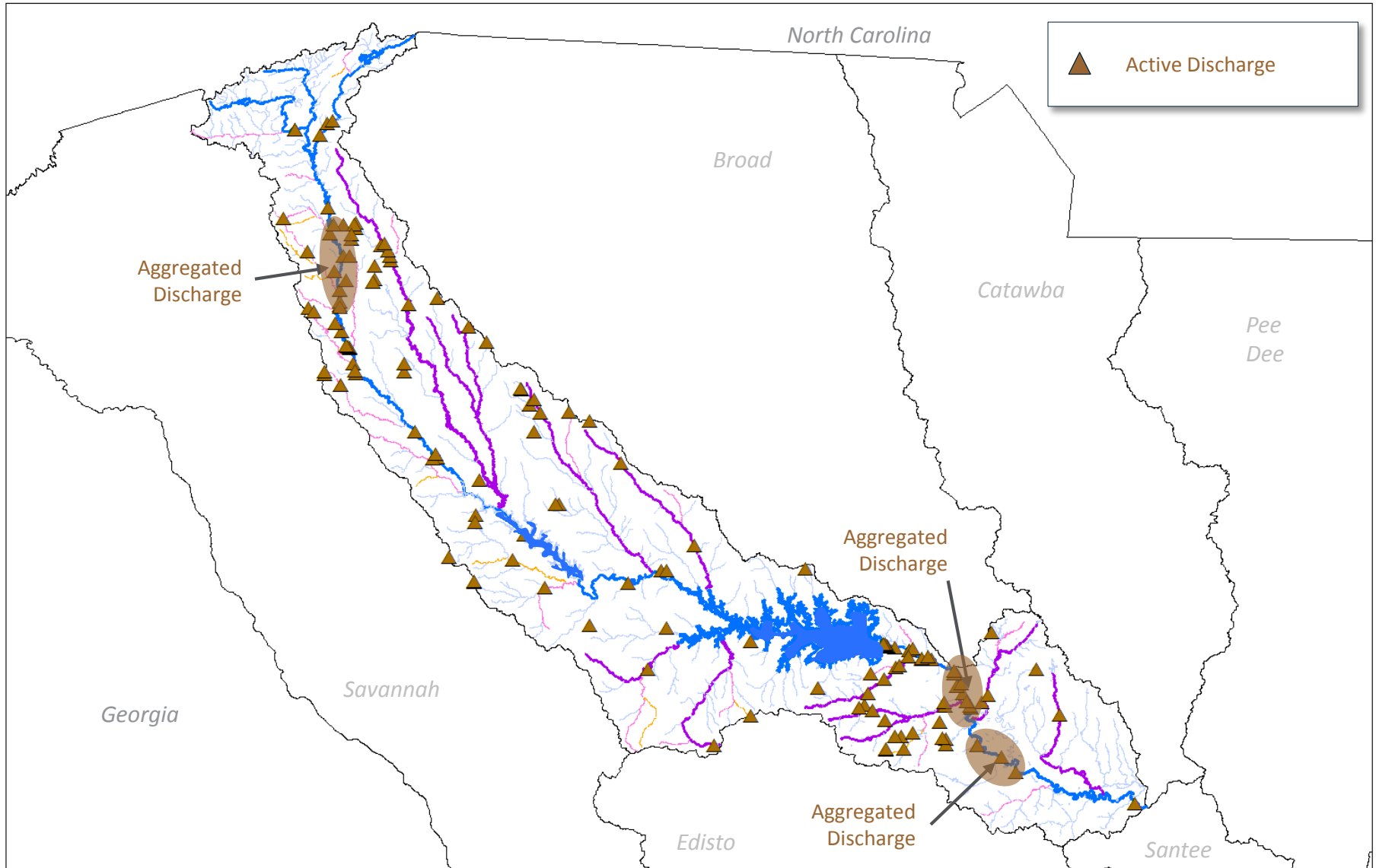
Saluda Basin Withdrawals – Agriculture



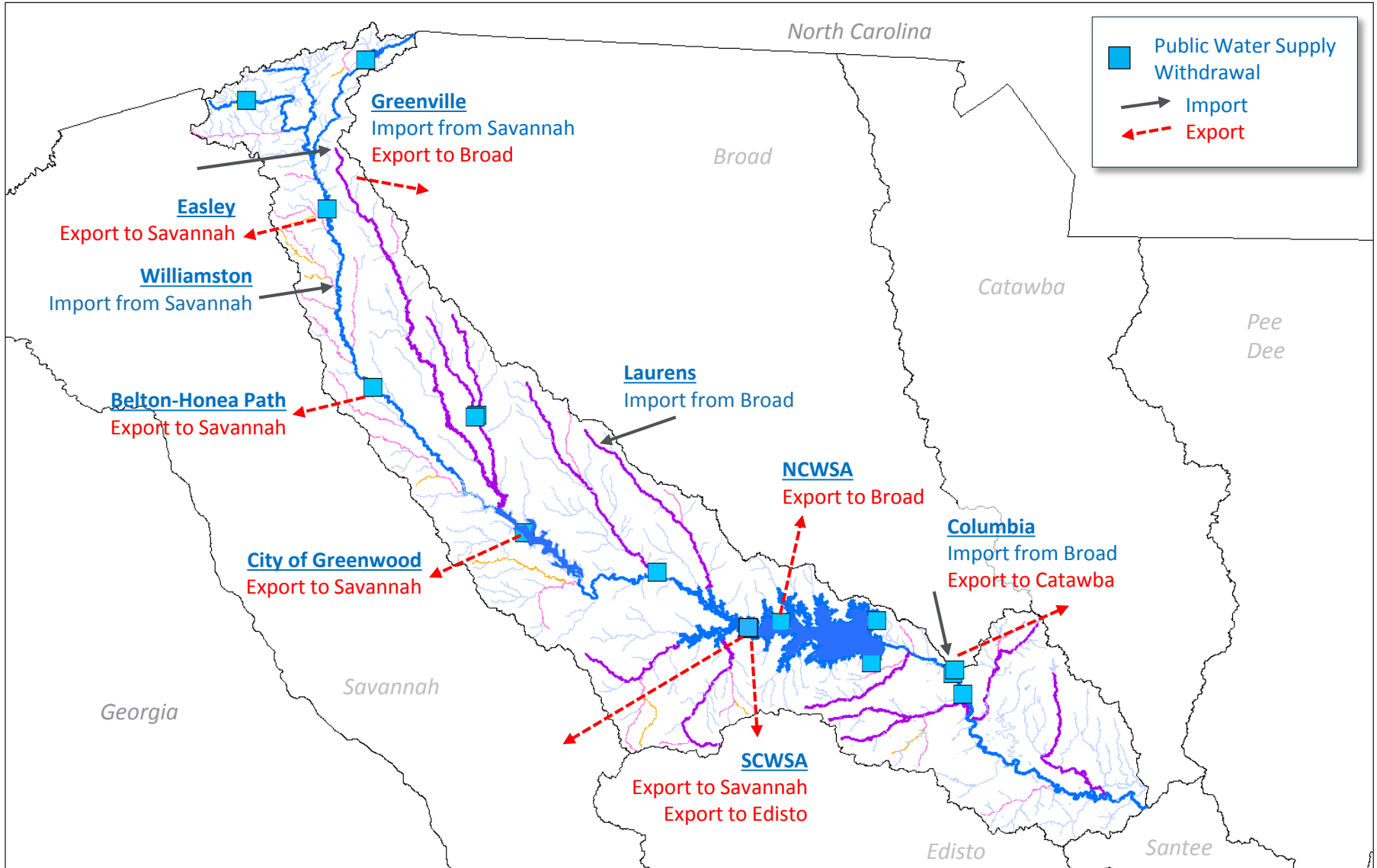
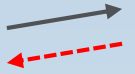
Saluda Basin Withdrawals – Golf Courses



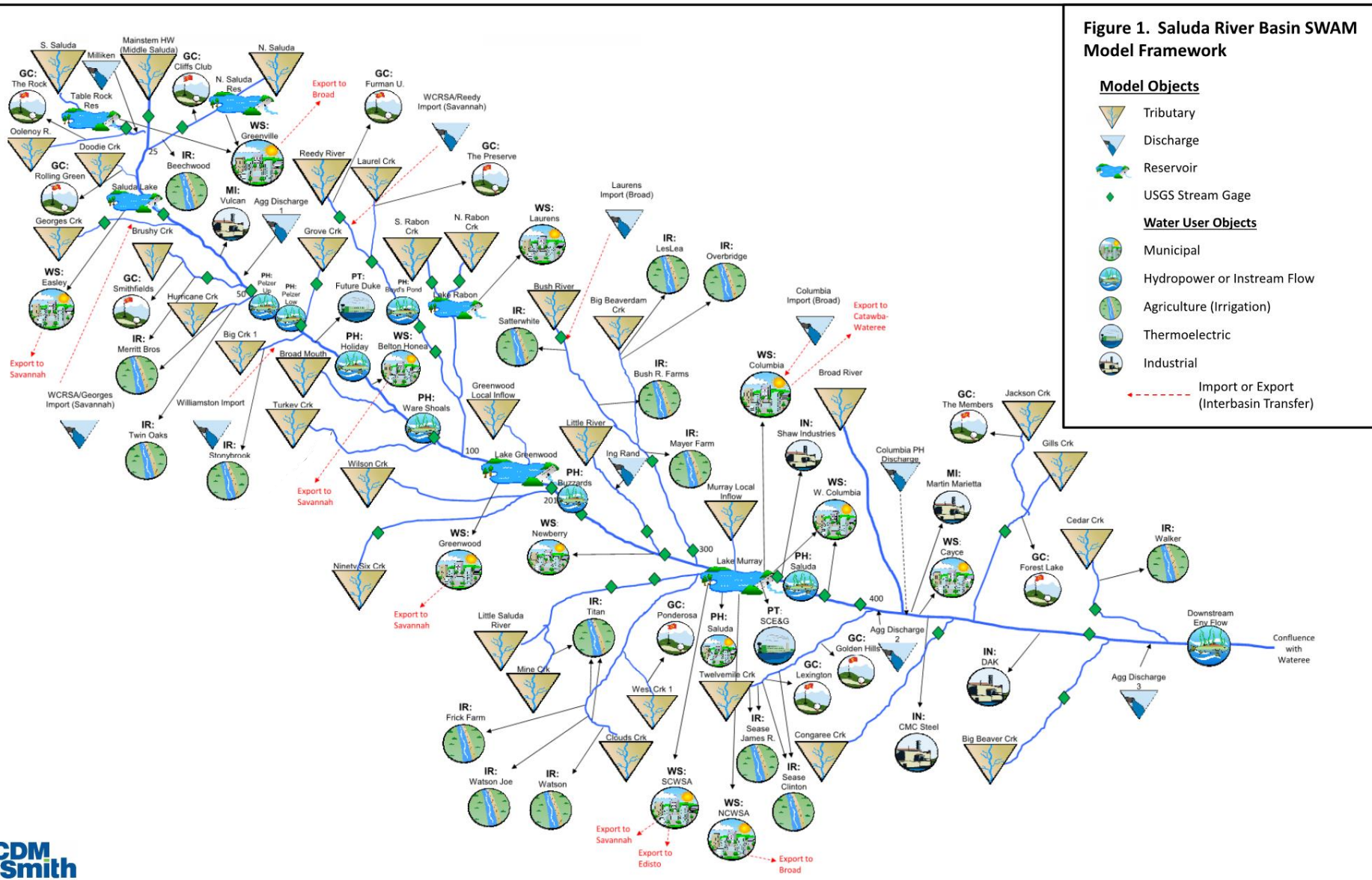
Saluda Basin Discharges



Interbasin Transfers



Saluda Basin – SWAM Framework



Saluda River Basin

MODEL SETUP

Tributary Input Form

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

AF15

Simplified Water Allocation Model (SWAM)

Simulation Period
Start Year (YYYY): 1981 Start Month (MMM): Oct

Tributary

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

Confluence Stream: Confluence Location (mi):

Spatial Flow Changes

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

Comments:

Save
Close

..... = exchange

Transbasin import/export

Ark Basin Aquifer

Colorado Canal

Henry & Meredith

Holbrook Canal

Dye & Holbrook

Ft. Lyon Storage Canal

Apishapa R.

185

195

Rocky Ford Highline

Huerfano R.

Bessemer

Comanche Power

CF & I Steel

Homestake Project

Clear Crk Res.

Clear Crk

Cottonwood Crk

Bue

Twin & Turquoise

Mainstem HW

Twin Lakes Impo

Fry

Object Palette

Main Map Mode Node Output Reservoir Output Aquifer Output Basin Map

Ready 70%

Reservoir Input Form

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

AF15

Simplified Water Allocation Model (SWAM)

Simulation Period: Start Year, Start Month, End Year, End Month

..... = exchange
 -----> = transbasin import/export

Reservoir

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**

Month	Volume (AF)	Area (ac)
Jan		
Feb		
Mar		
Apr		
May		
Jun		
Jul		
Aug		
Sep		
Oct		
Nov		
Dec		

User Defined Releases

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

Comments: [Text Area]

Save **Close**

Homesta

atbrook

Main Map Mode Node Output Reservoir Output Aquifer Output Basin Map

Ready 70%

Water User Input Form – Main

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

Water User

Main | Water Usage | Source Water | Return Flows

Water User Name: **Delete**

Object Palette

Supplemental S...

Cons

Reca

Ag T

Comments:

Home

Water User

Main | Water Usage | Source Water | Return Flows

Monthly User Distribution

Manual

M&I

Agriculture

Monthly Baseline Usage

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

(AFM)

Source Stream:

Source Water Type

Direct River

Reservoir

Groundwater

Downstream Location (mi)

Priority Date

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)

Carry Over Rule

Identifying Notes:

Ready

Main | Map Mode | Node Output | Reservoir Output

70%

... = exchange

--- = transbasin import/export

Agricultural Water User Input Forms

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

Agricultural Water User

Main | Source Water | Return Flows

User Name:

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
<input type="text"/>	0	5
<input type="text"/>	0	5
<input type="text"/>	0	5
<input type="text"/>	0	5
<input type="text"/>	0	5
<input type="text"/>	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

Object Palette

Home

Huerfano R. Highline

Main | Map Mode | Node Output | Reservoir Output | Aquifer Output | Basin Map

Ready 70%

Instream Flow Input Form

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

AF15

Simplified Water Allocation Model (SWAM)

Instream Flows

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

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

(CFS)

Comments: [Text Area]

Save **Close**

Object Palette

Mainstem H
Twin & T
Clear Crk

Homestake Project

Ark Basin Aquifer

Henry & Meredith

Dye & Harbrook

Lyon Storage Canal

Huerfano R. Rocky Ford Highline

Main Map Mode Node Output Reservoir Output Aquifer Output Basin Map

Ready 70%

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

