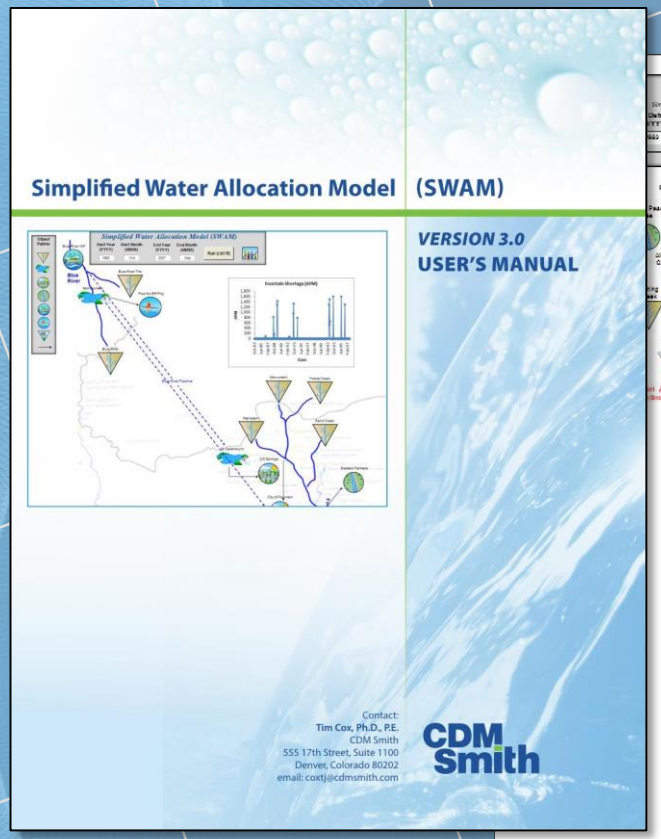
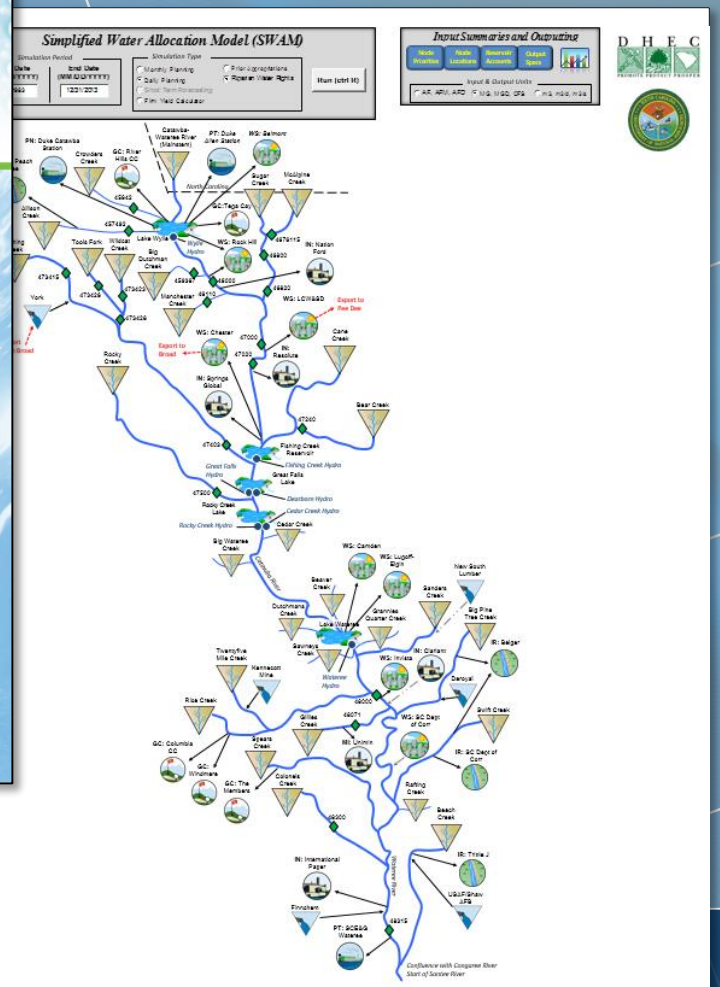
South Carolina Surface Water Quantity Modeling Project

Catawba-Wateree River Basin Meeting No. 1 – Model Framework

Kirk Westphal, PE
John Boyer, PE, BCEE

November 4, 2015





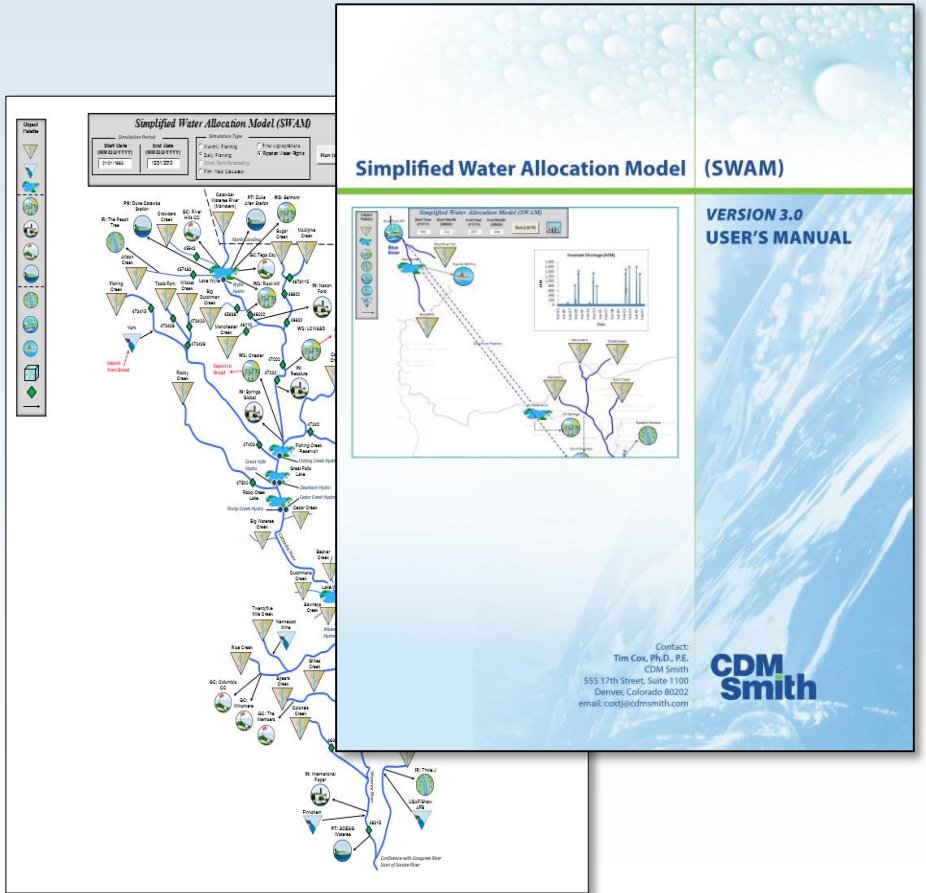
CDM Smith

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

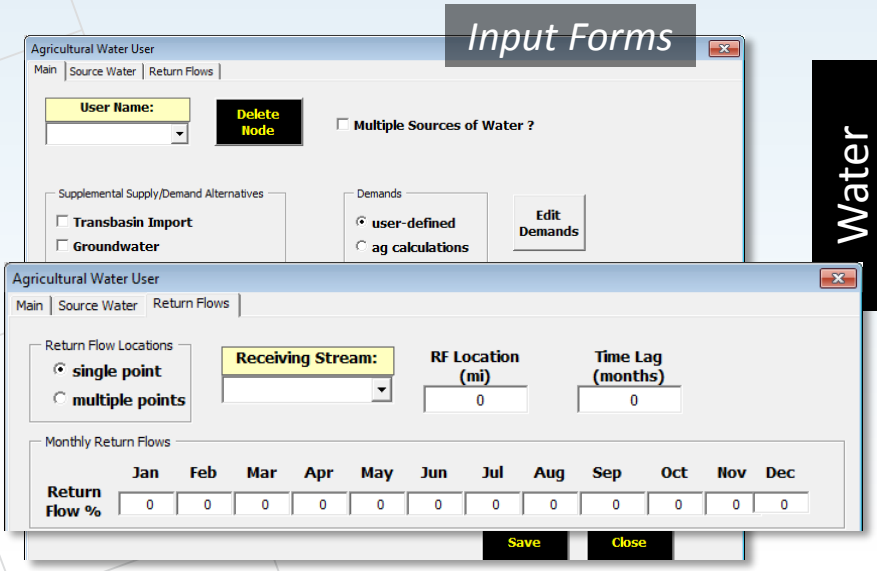
- Tailored specifically for hydropower
  - Energy Calculations
  - Reservoir Tracking
- Familiar Visual Basic programming

RiverWare

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

Simplified Water Allocation Model (SWAM)

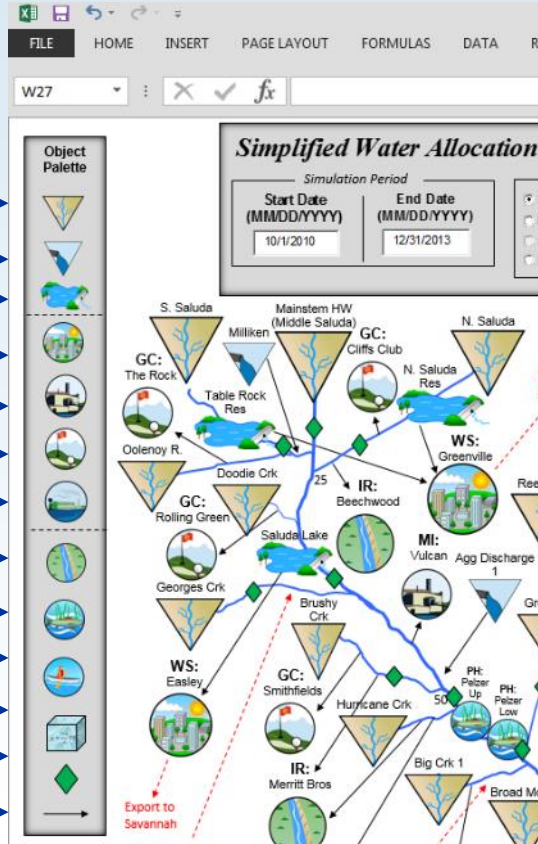
- Object-oriented tool in which a river basin and all of its influences can be linked into a network with user defined priorities
- Resides within Microsoft Excel
- Point and click setup and output access



Objects

Water User Objects

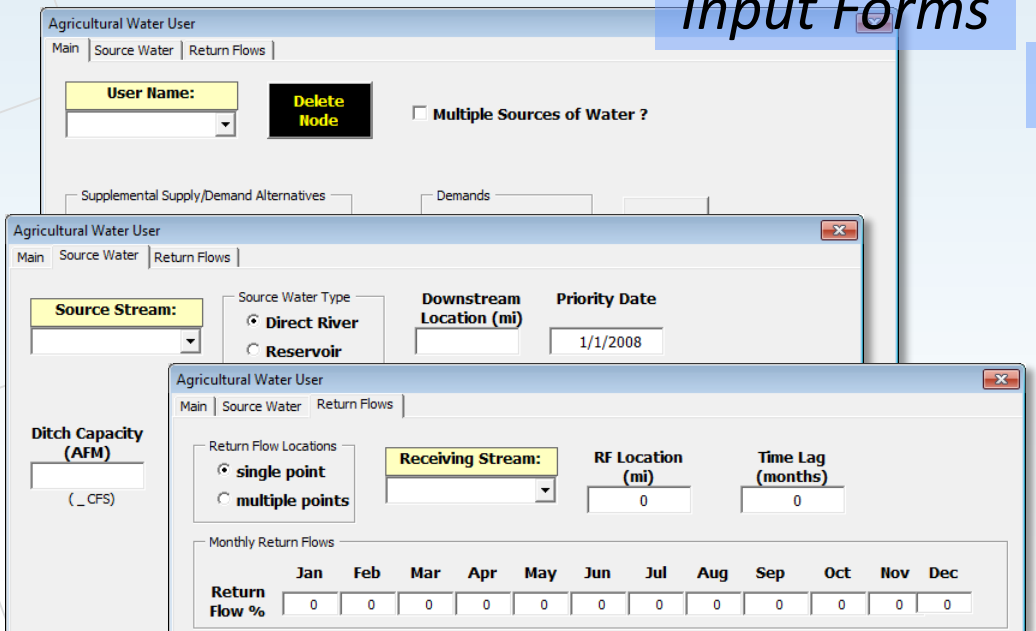
- Tributaries
- Discharges
- Reservoirs
- Municipal
- Industrial
- Golf Courses
- Power Plants
- Agriculture
- Instream Flow
- Recreational Pool
- Aquifer
- USGS Gage
- Interbasin Transfer



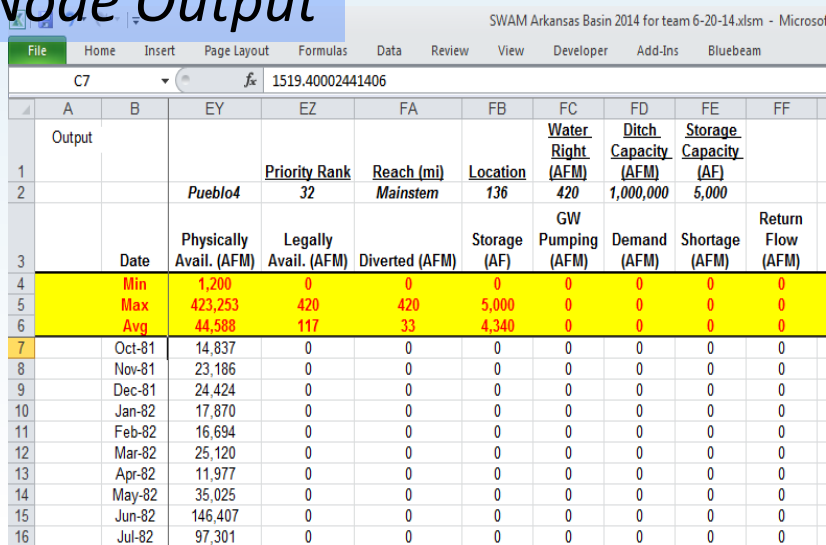
Simplified Water Allocation Model (SWAM)

- **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



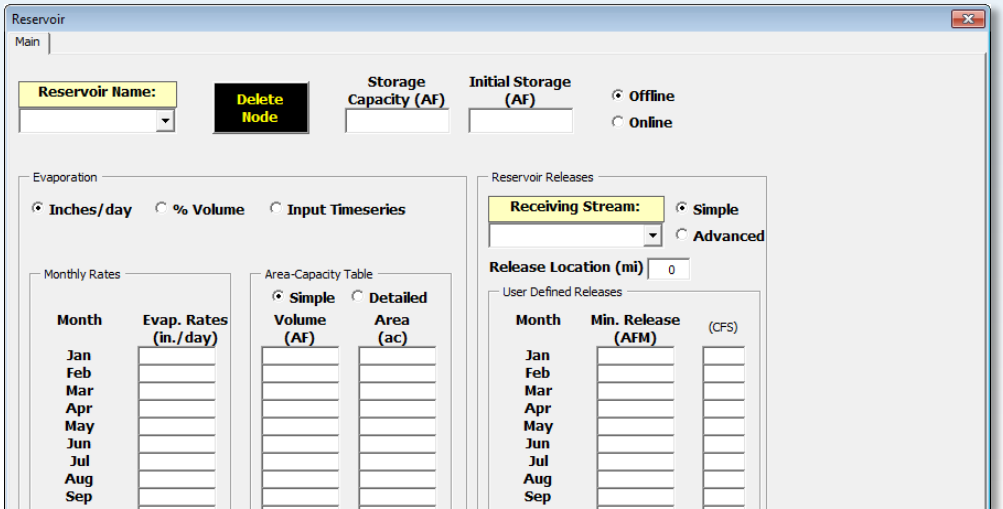
Simplified Water Allocation Model (SWAM)

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

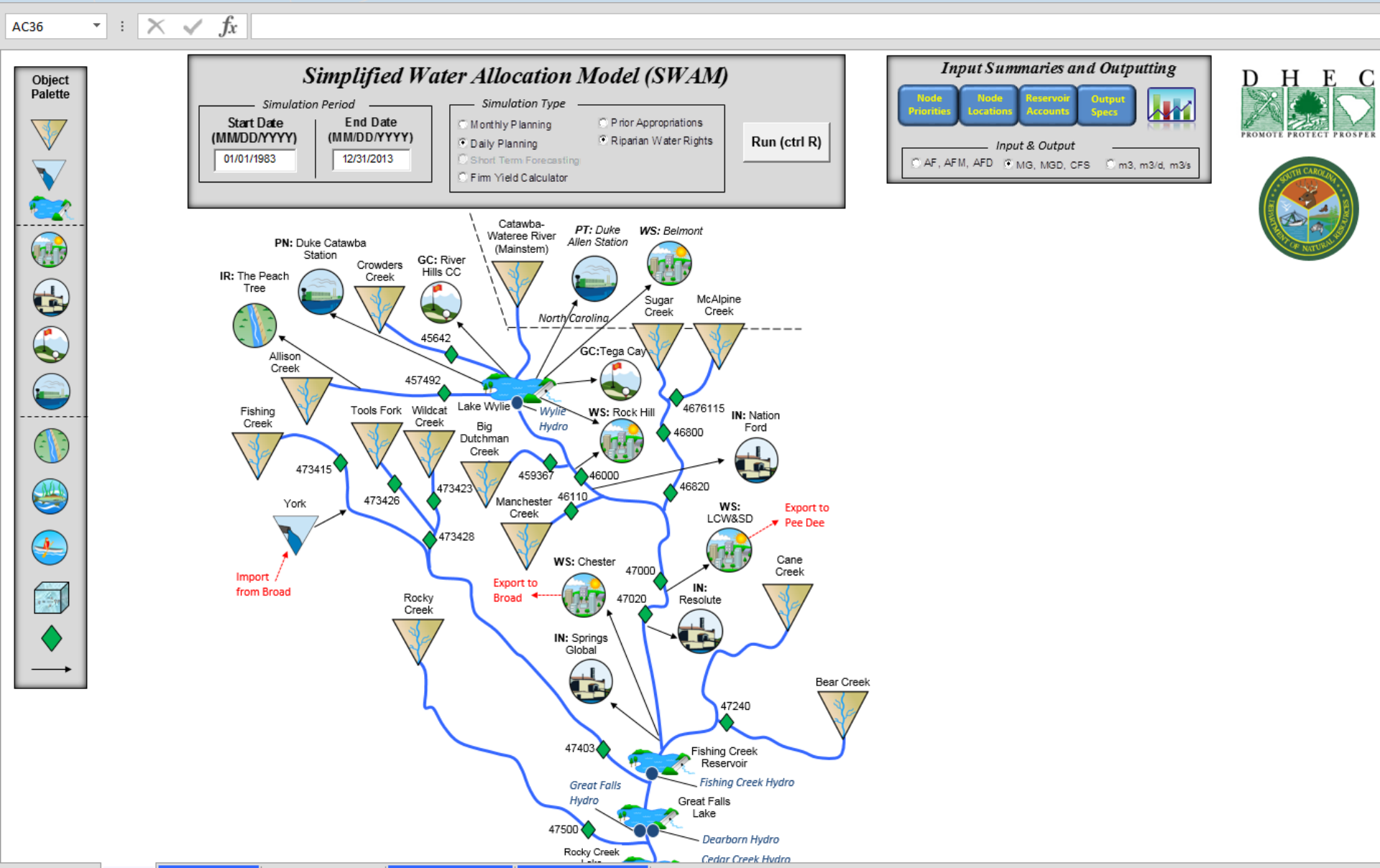
  A Reservoir Object can include:

  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



Catawba-Wateree 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
- CWWMG data, studies, and model

Catawba-Wateree 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
- CWWMG Inflow Dataset

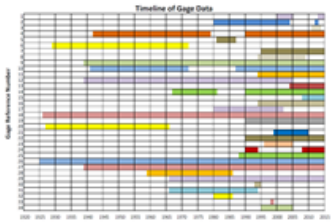
Estimated

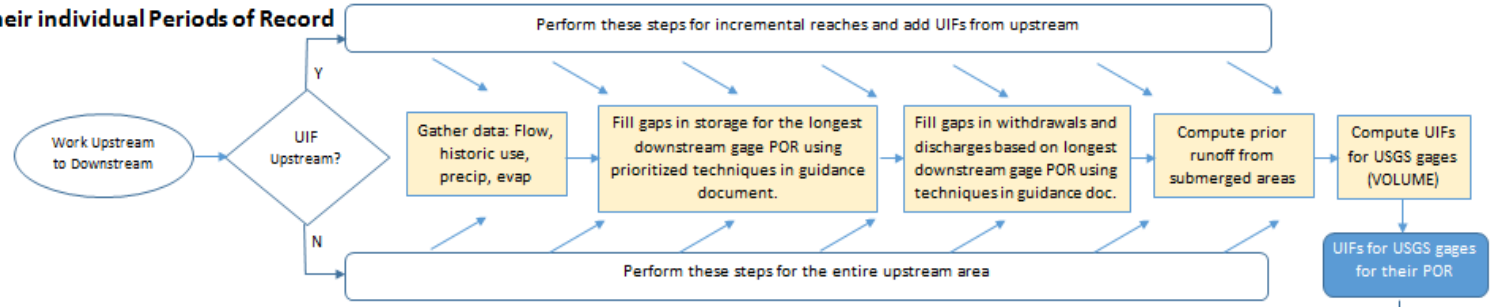
- Direct contact with users regarding historic use patterns
- Operational hindcasting
- Agricultural water use modeling

Basinwide UIF Calculation Process

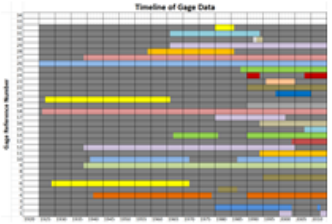
Stepwise Procedure for UIF Calculation – Saluda Basin

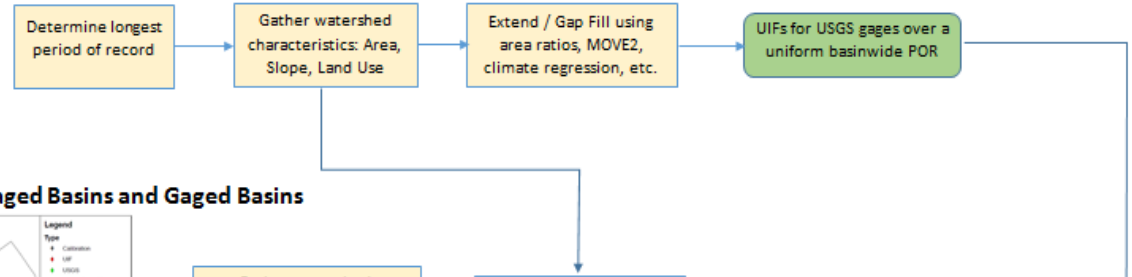
Step 1: UIFs for USGS Gages for their individual Periods of Record



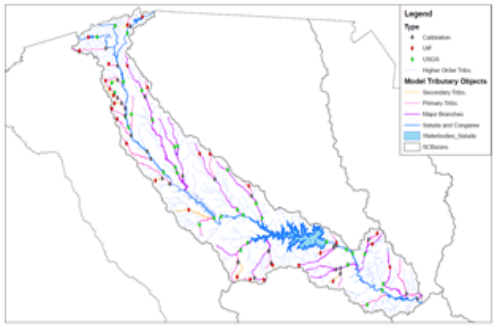


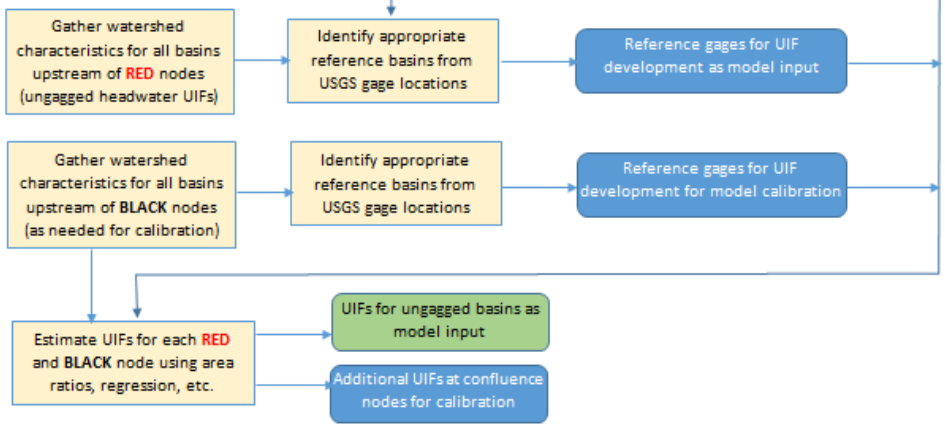
Step 2: Extension of UIFs for USGS Gages throughout the LONGEST Period of Record





Step 3: Correlation between Ungaged Basins and Gaged Basins

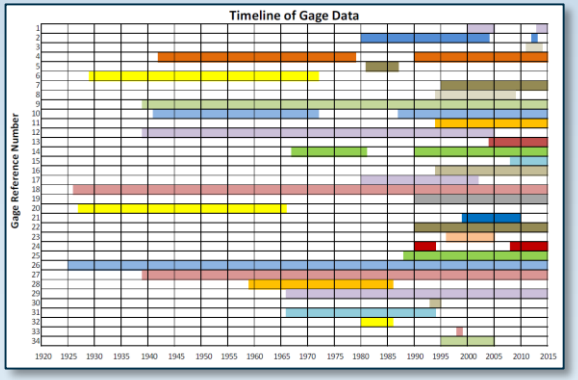


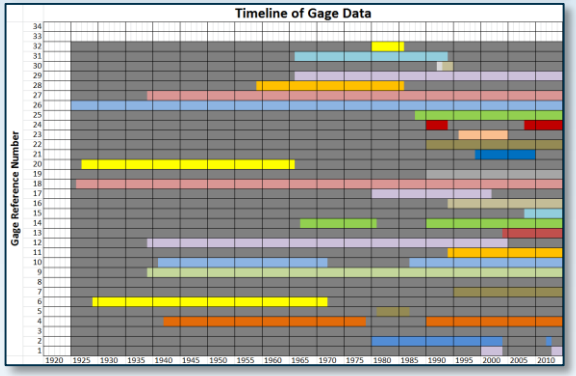


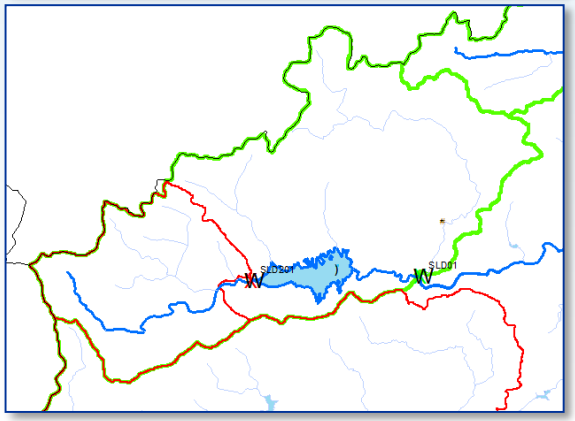
Step 4: UIFs for Ungaged Basins

Four Steps in UIF Calculation Process

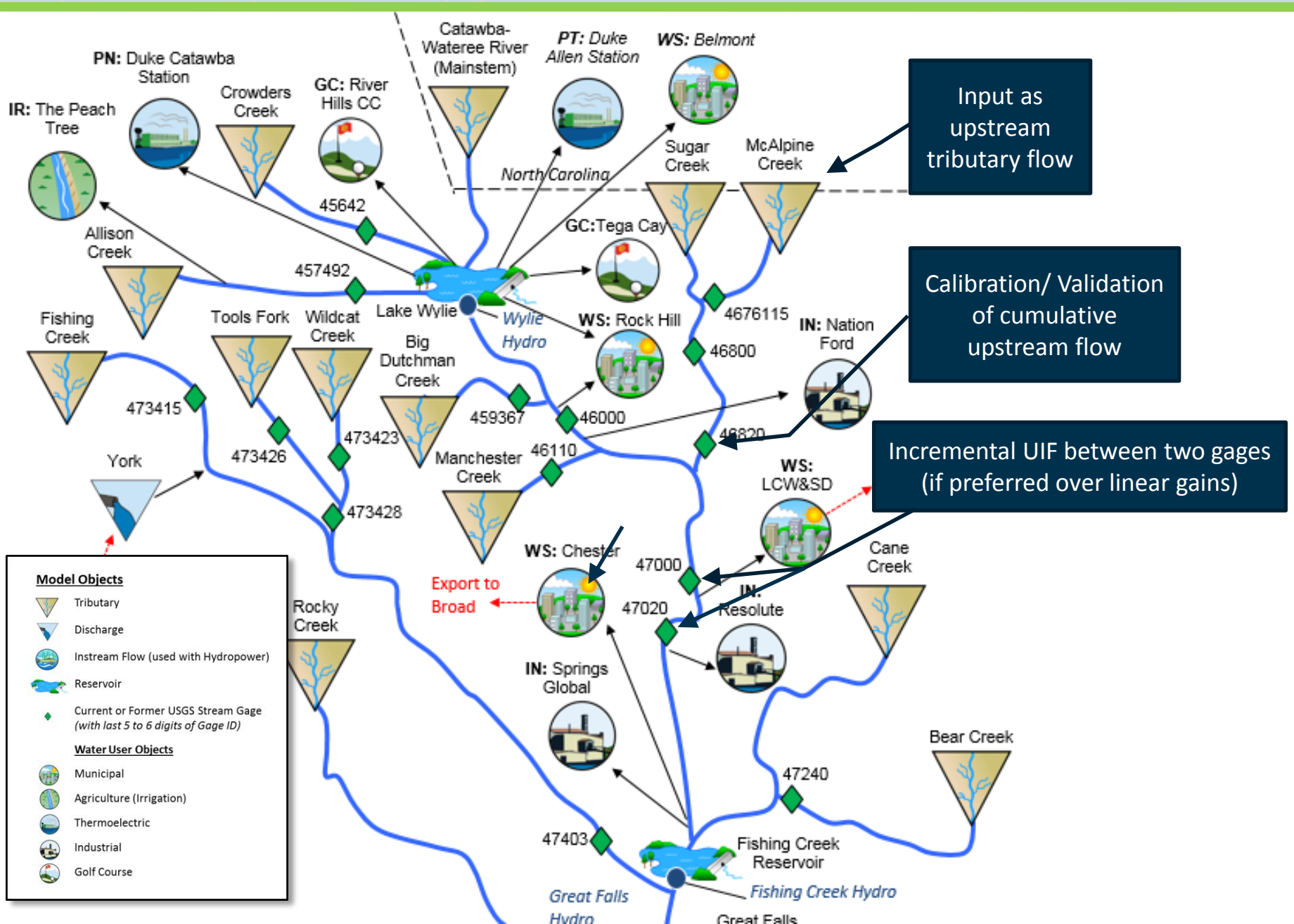
- **Step 1**: UIFs for USGS Gages for individual periods of record
  - Involves extension of operational data
- **Step 2**: Extension of UIFs for USGS Gages through the LONGEST period of record
- **Step 3**: Correlation between ungaged basins and gaged basins
- **Step 4**: UIFs for ungaged basins





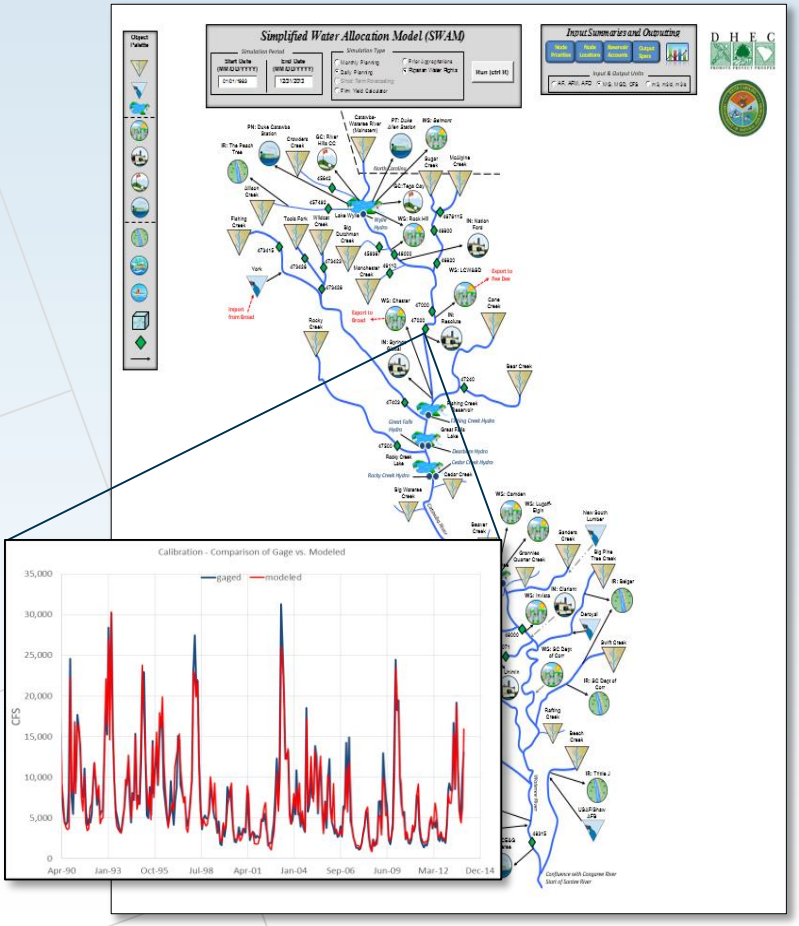


How UIFs are Used in SWAM

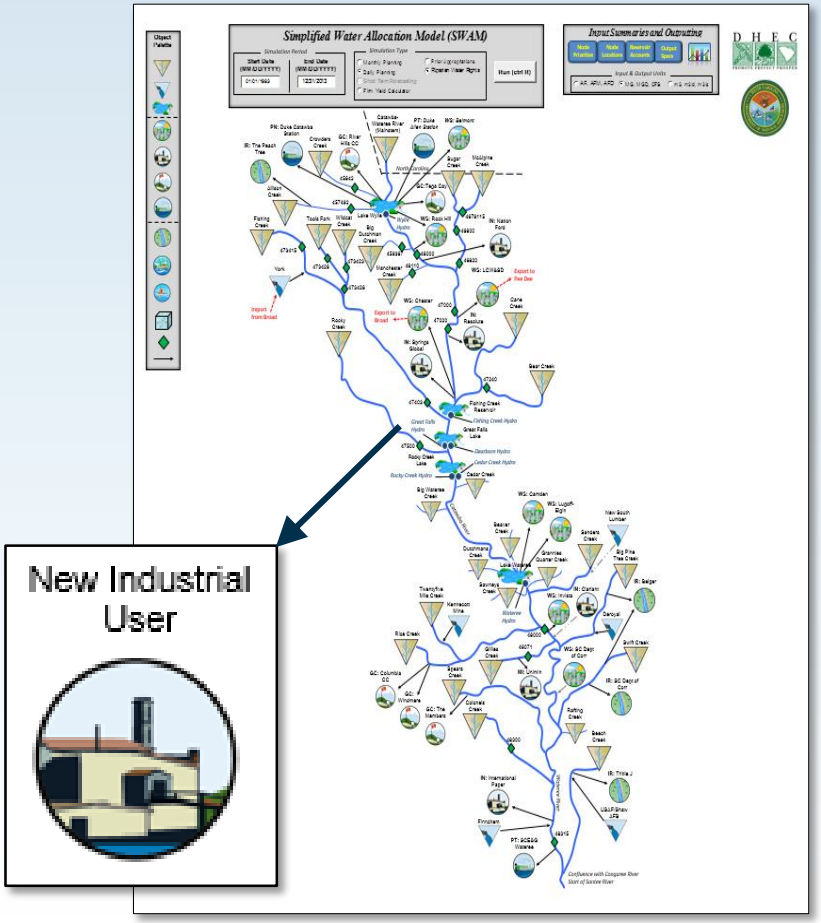


Two Versions of Every Model

Calibration with UIFs and Historic Use Records



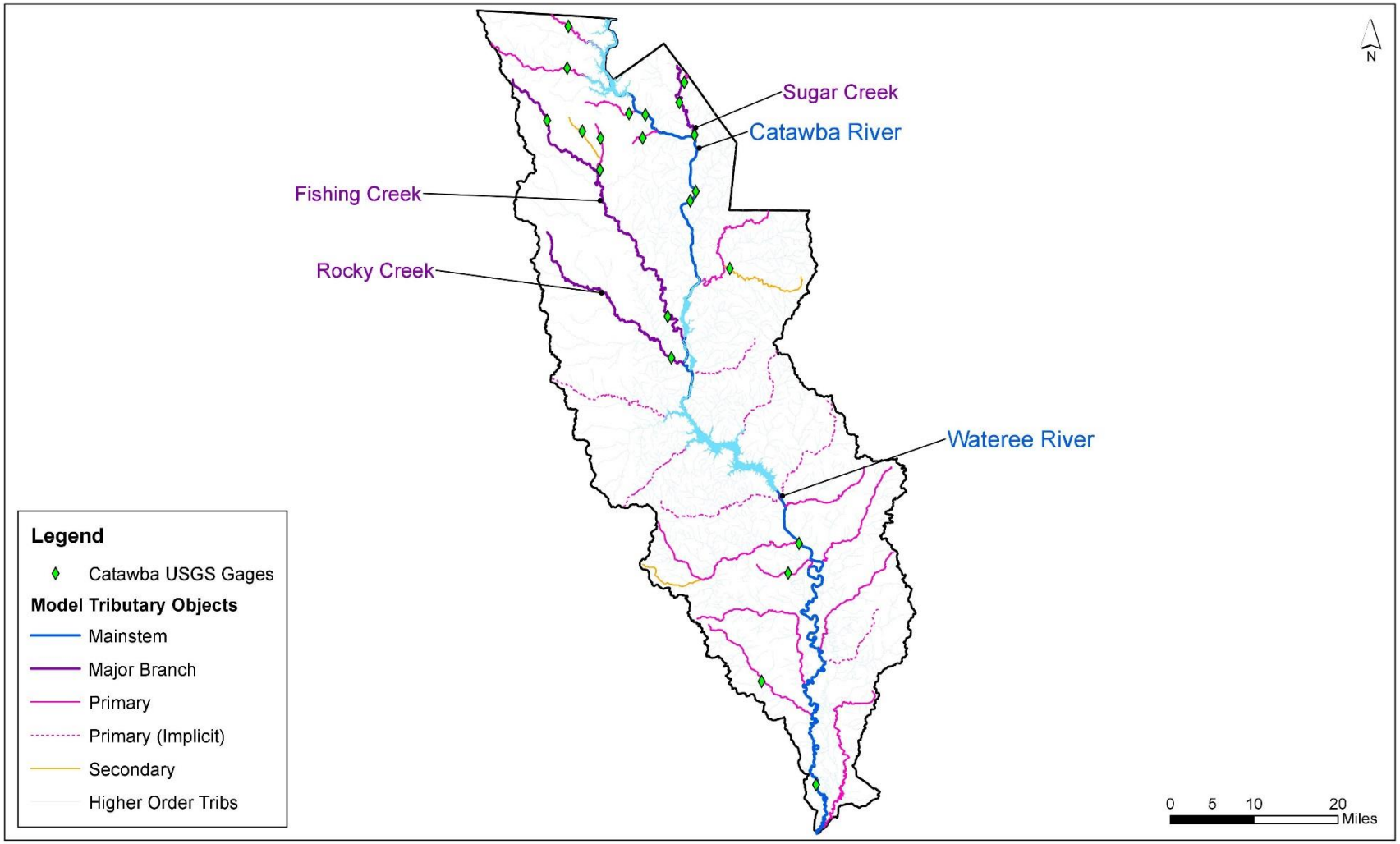
Planning with UIFs, Current Uses, and User-Defined Future Uses



Catawba-Wateree River Basin

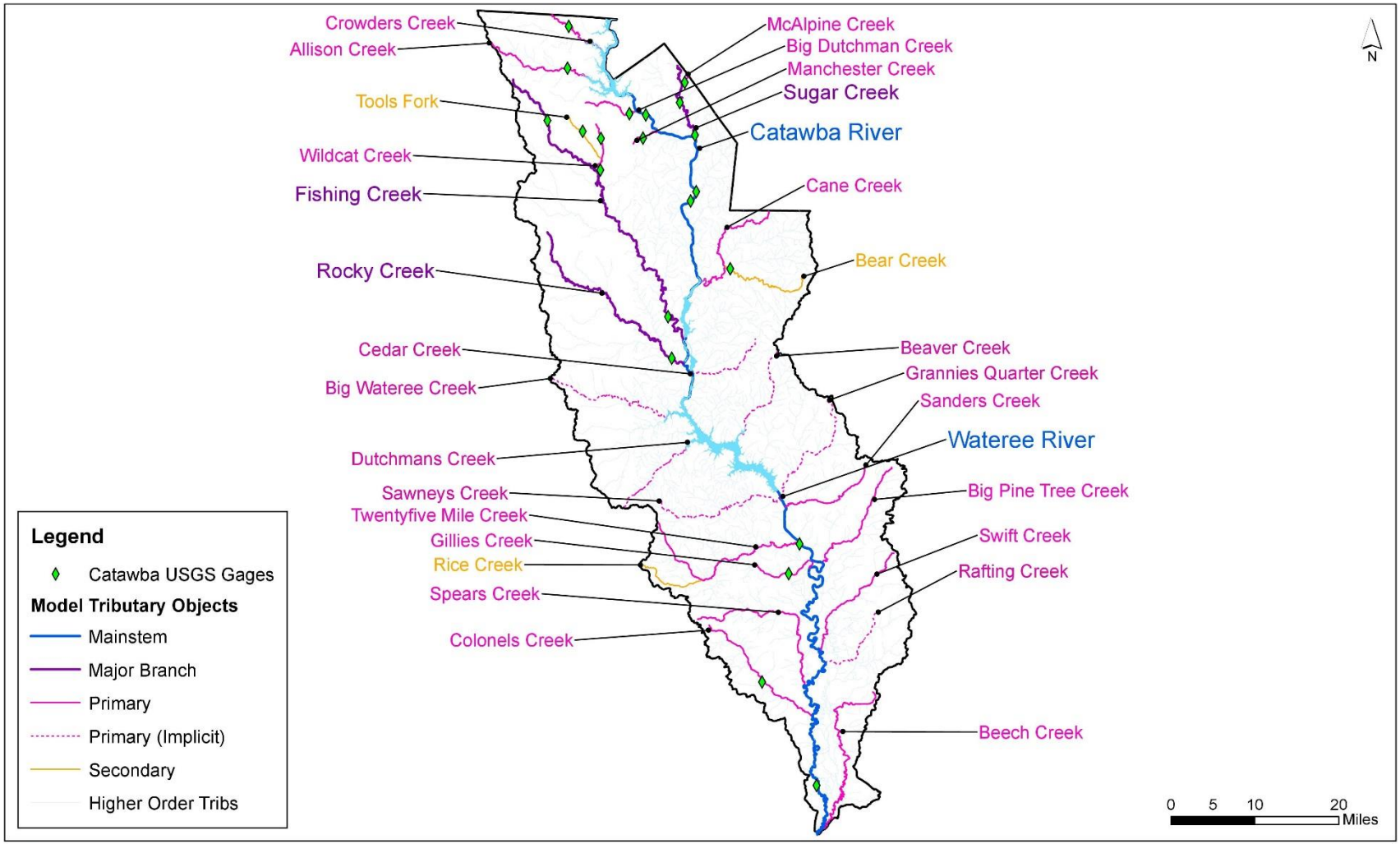
OVERVIEW OF MODEL FRAMEWORK

Catawba-Wateree Basin
Main and Major Branches



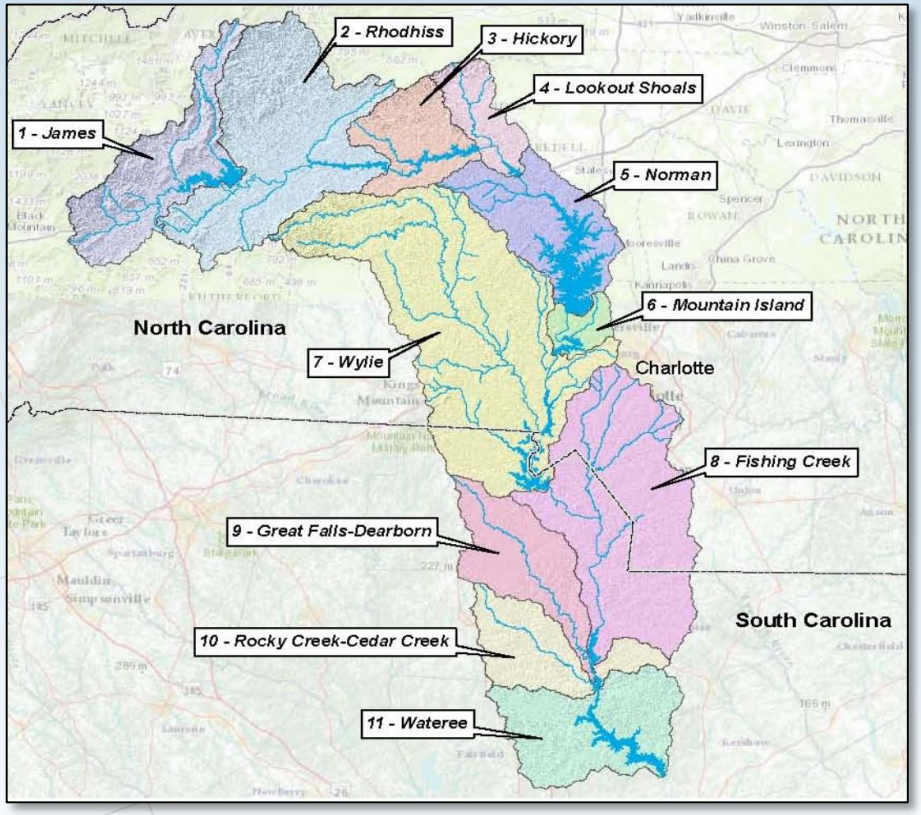
CDM Smith

Primary and Secondary Tributaries



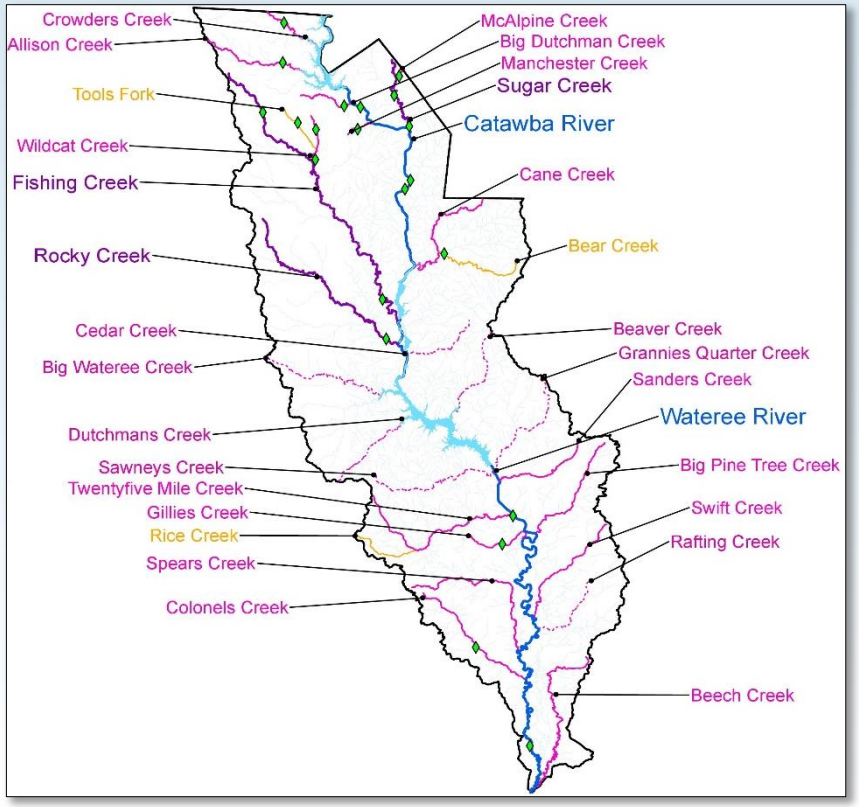
Catawba-Wateree Basin

CHEOPS Model Coverage

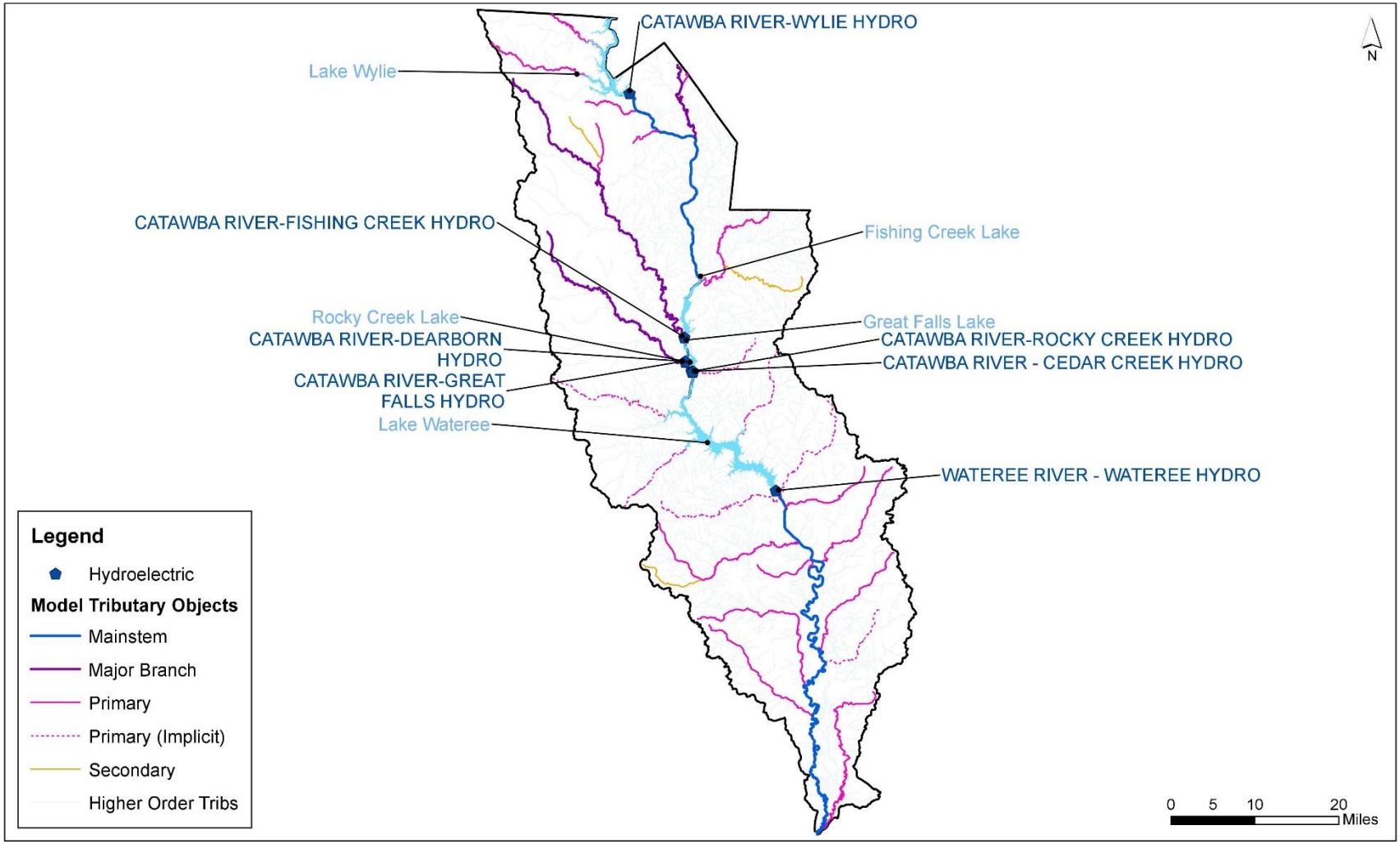


Source: CWWMG Master Plan CHEOPS Model, HDR, Inc.

SWAM Model Intended Coverage

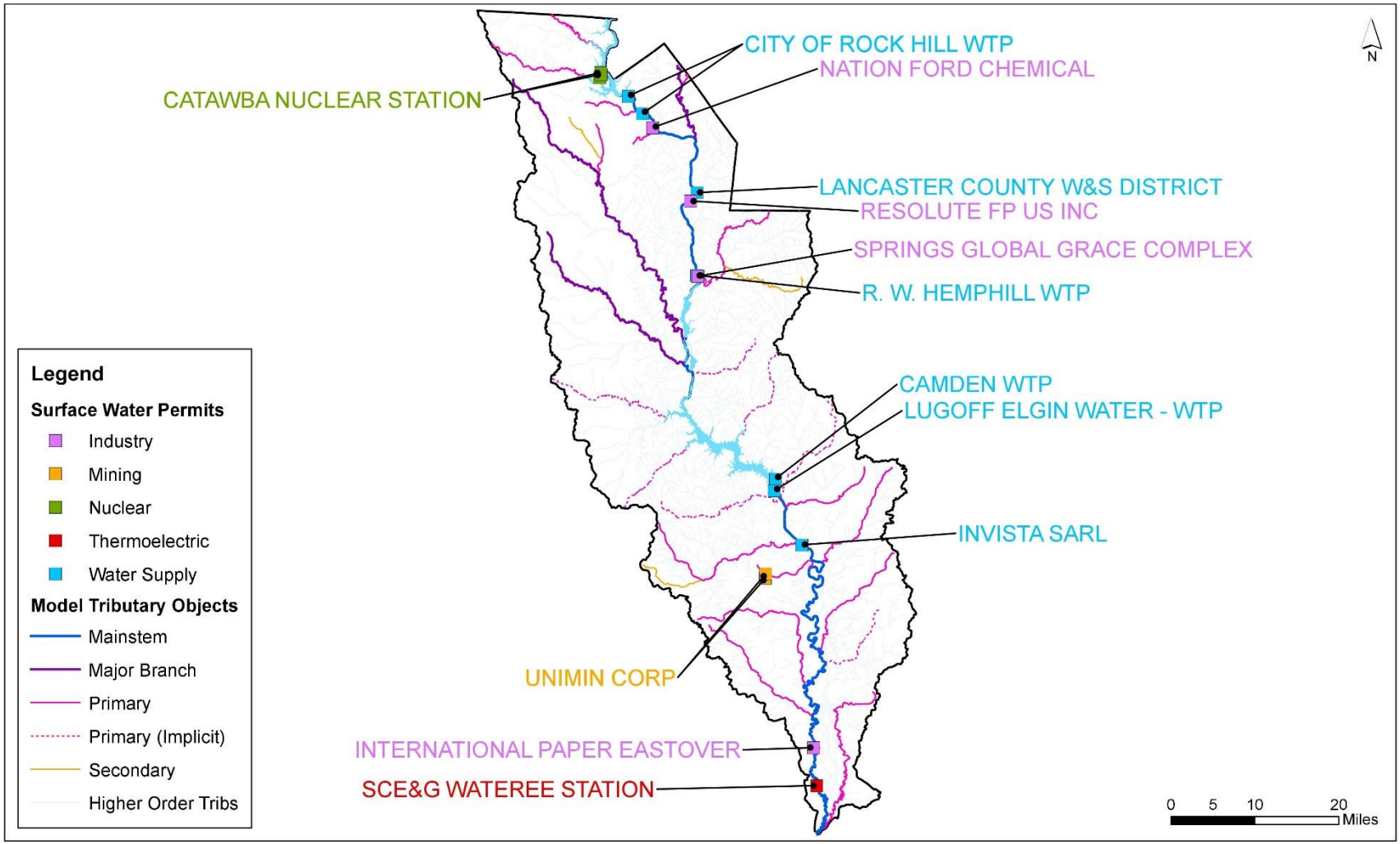


Reservoirs and Hydroelectric



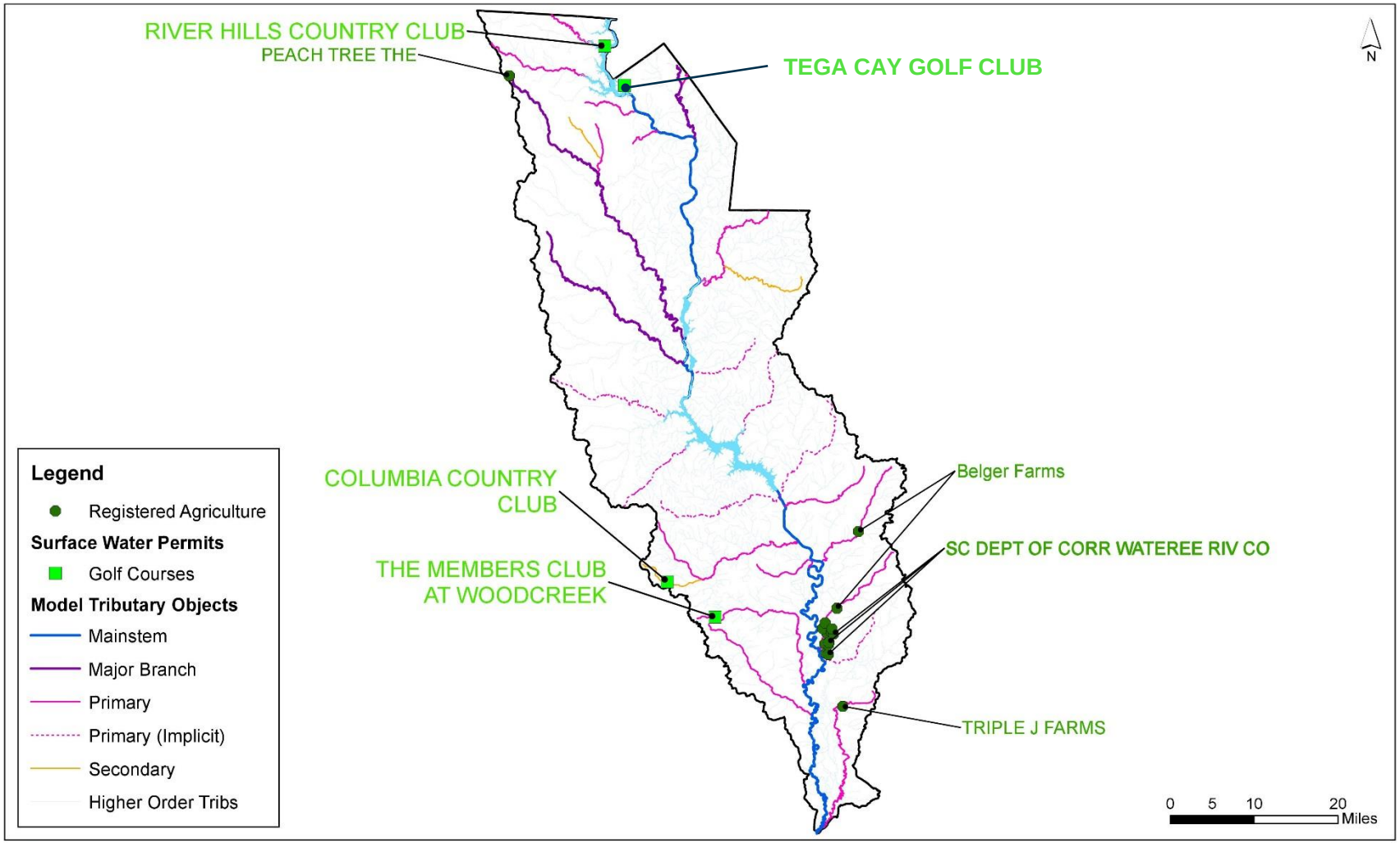
CDM Smith

M&I and Energy Surface Water Withdrawals



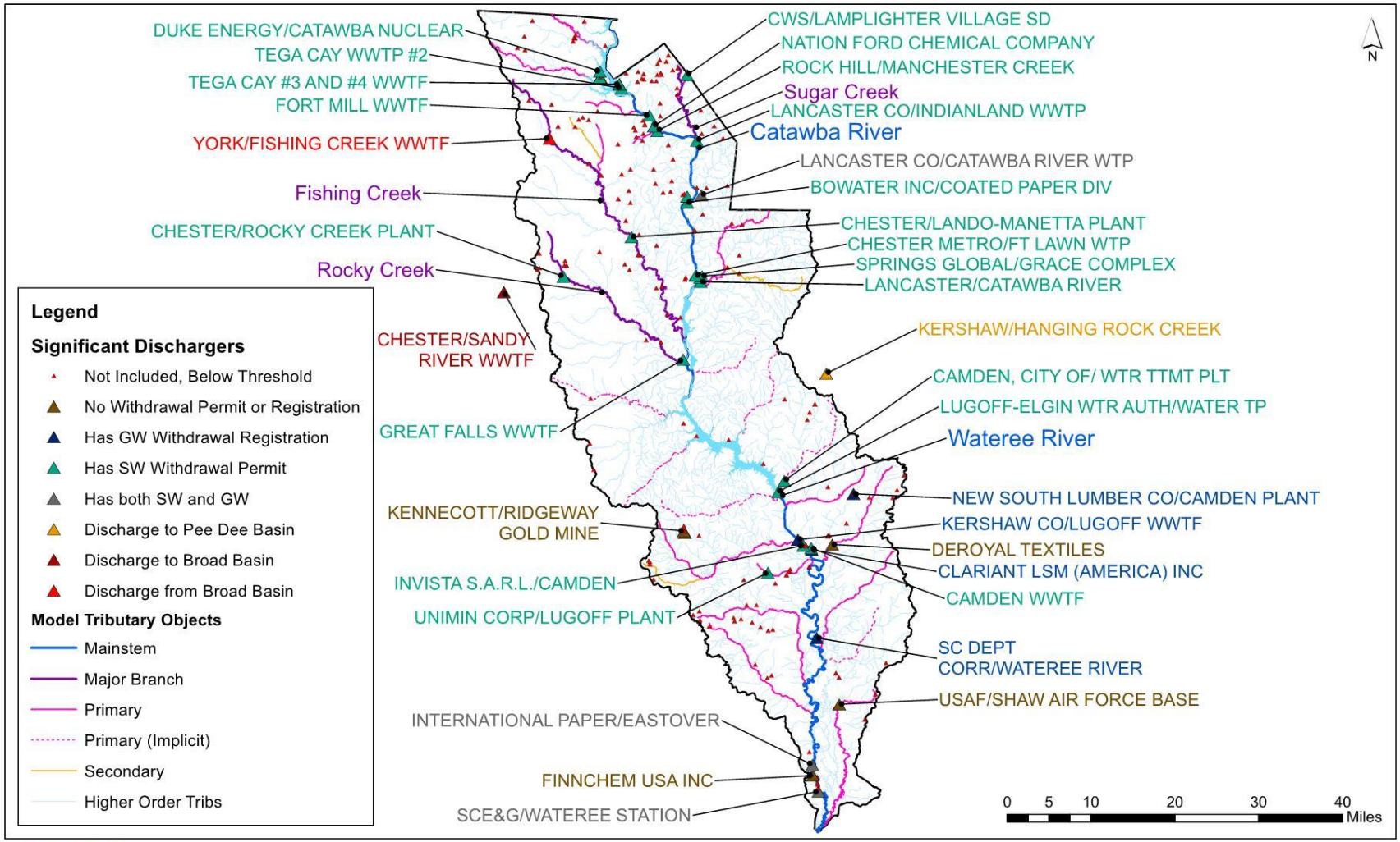
CDM Smith

Surface Water Withdrawals for Irrigation

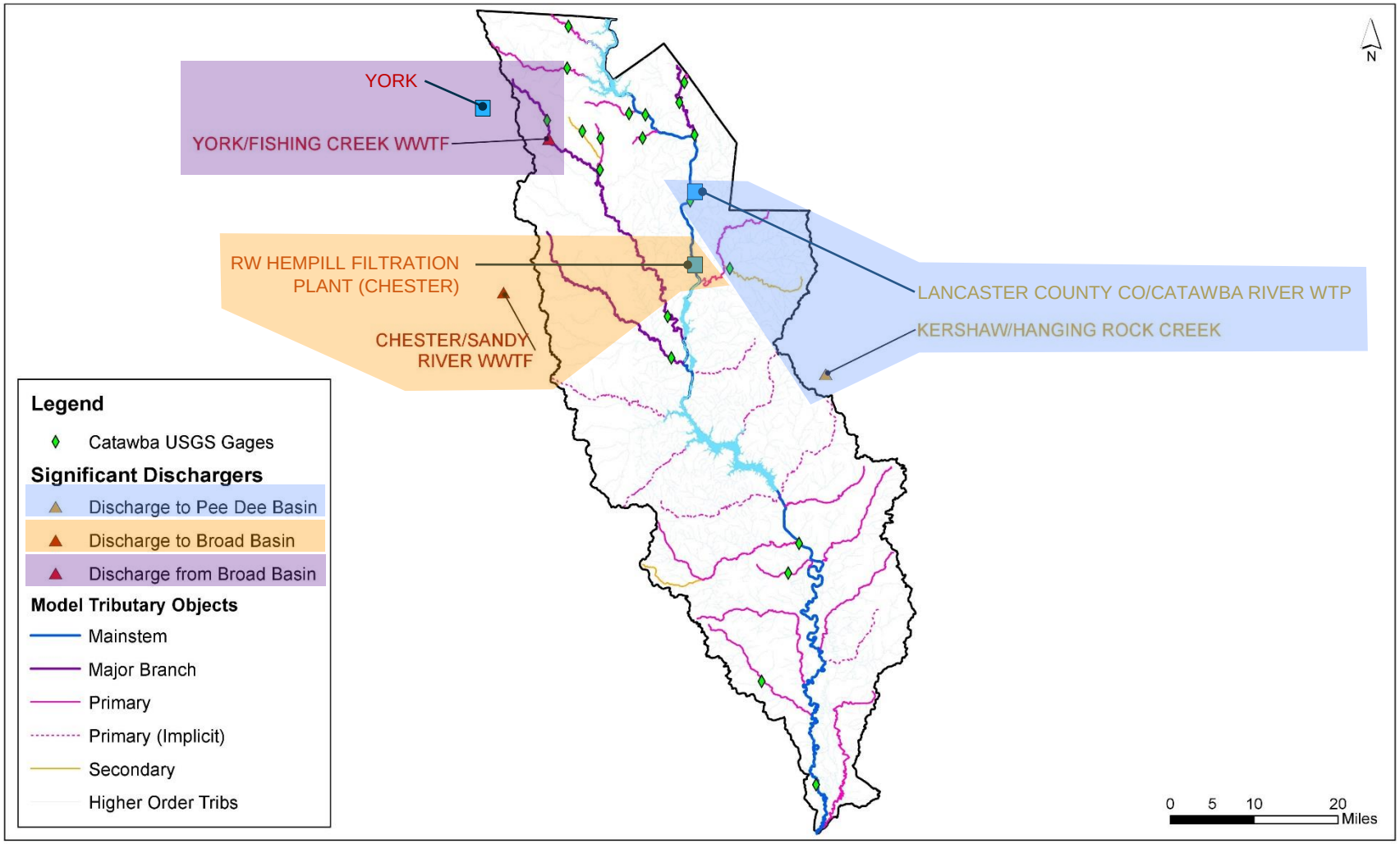


CDM Smith

Discharges to Surface Water

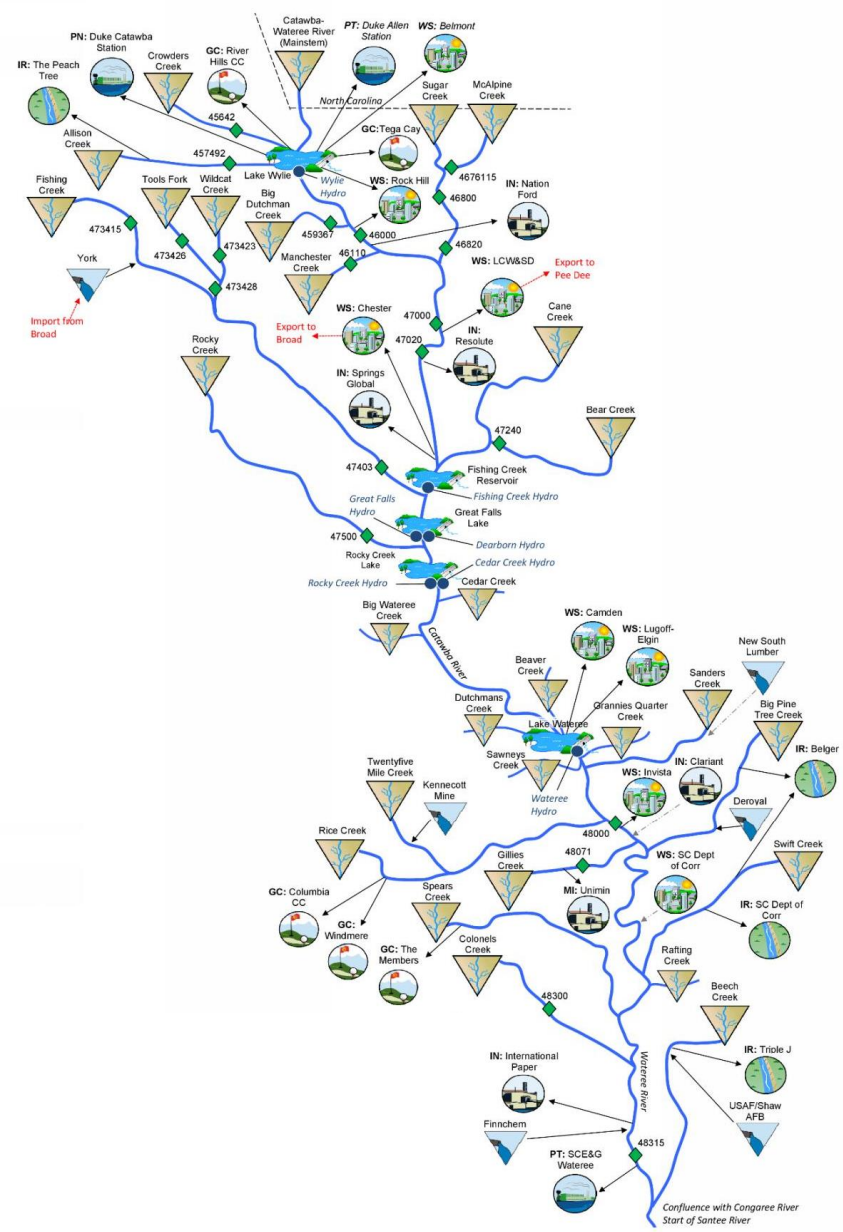


Interbasin Transfers



CDM Smith

Catawba-Wateree 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

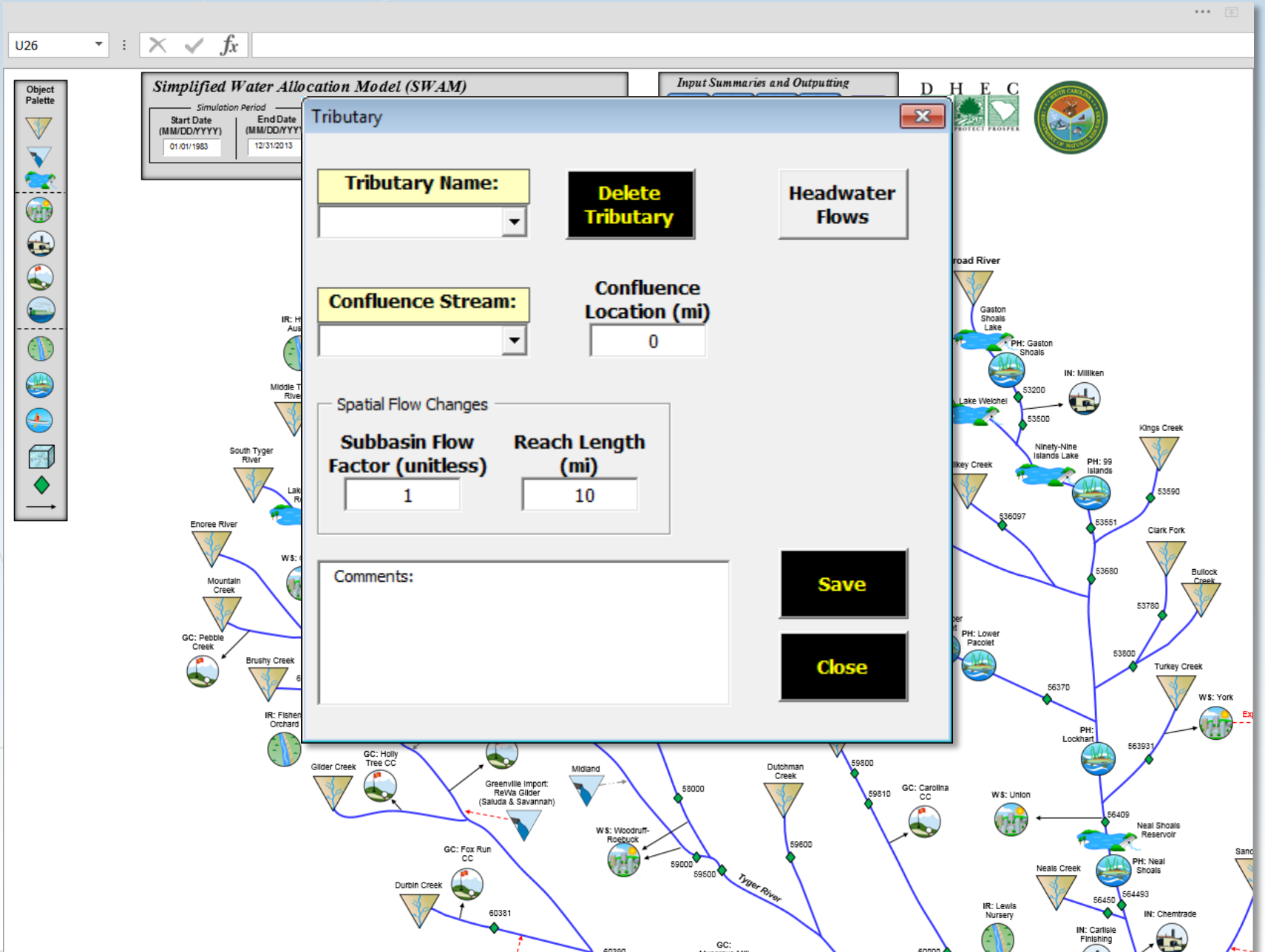
- Import or Export (Interbasin Transfer)
- Discharge from a Groundwater User*

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

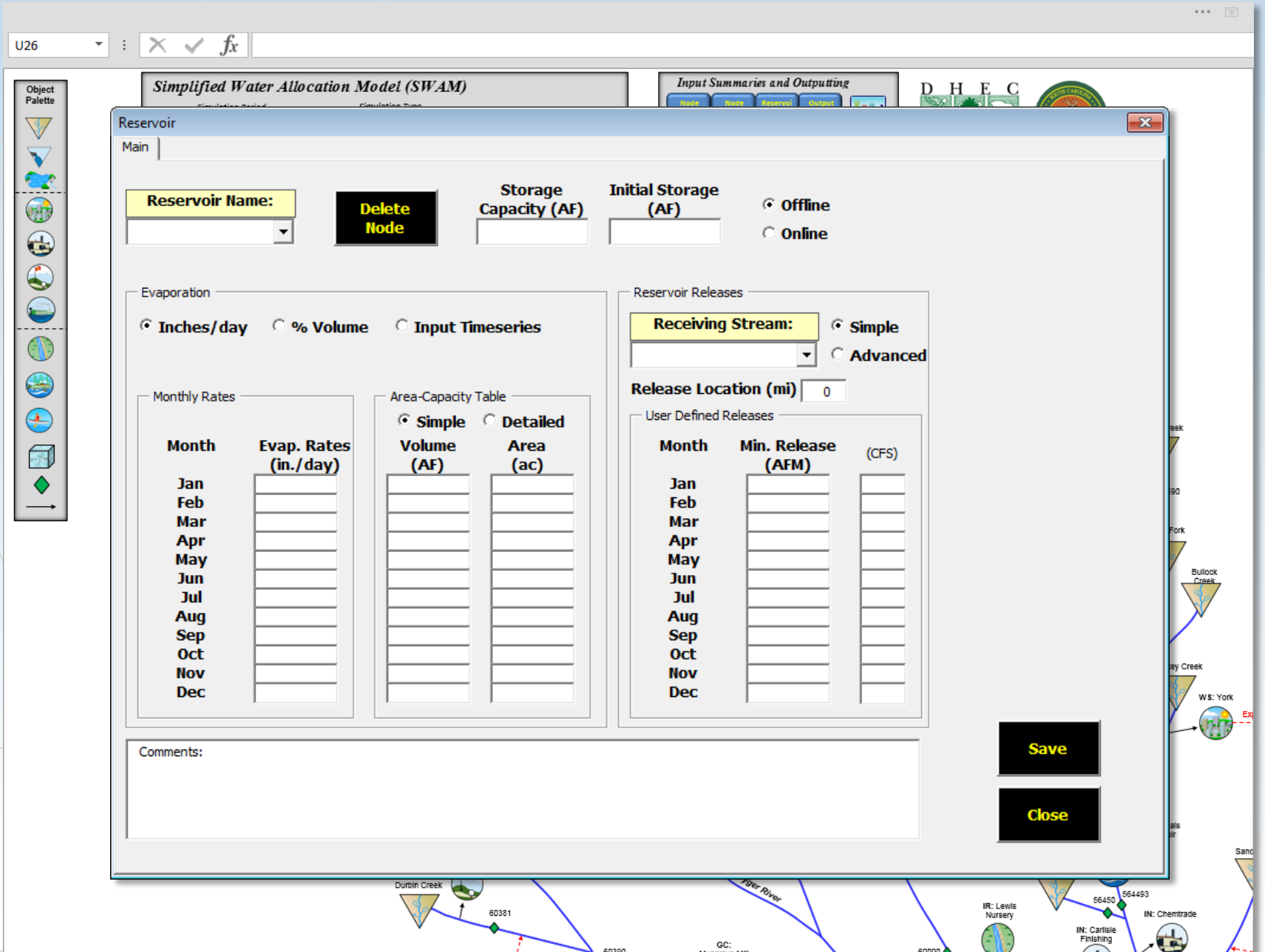
Catawba-Wateree River Basin

MODEL SETUP

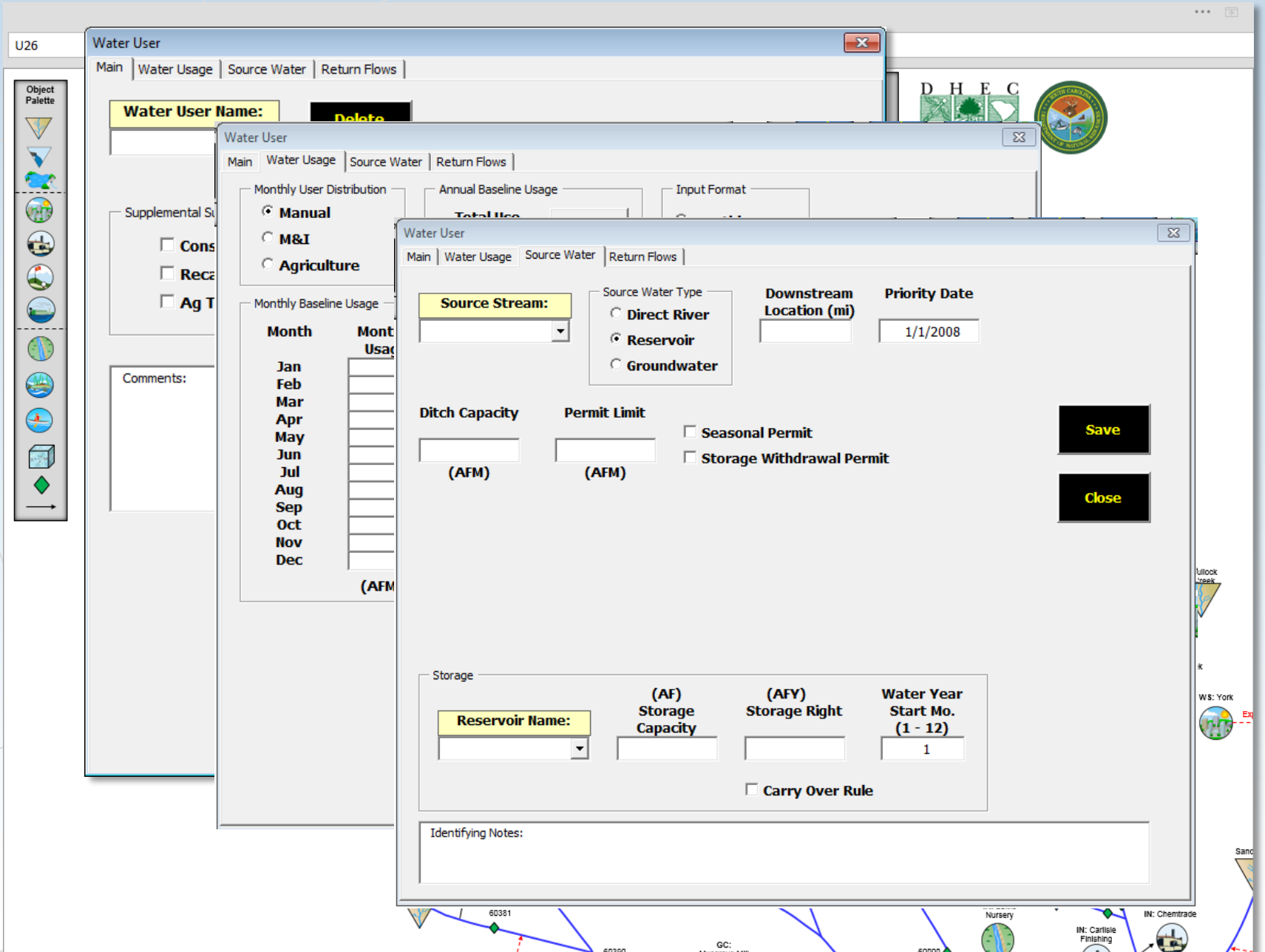
Tributary Input Form



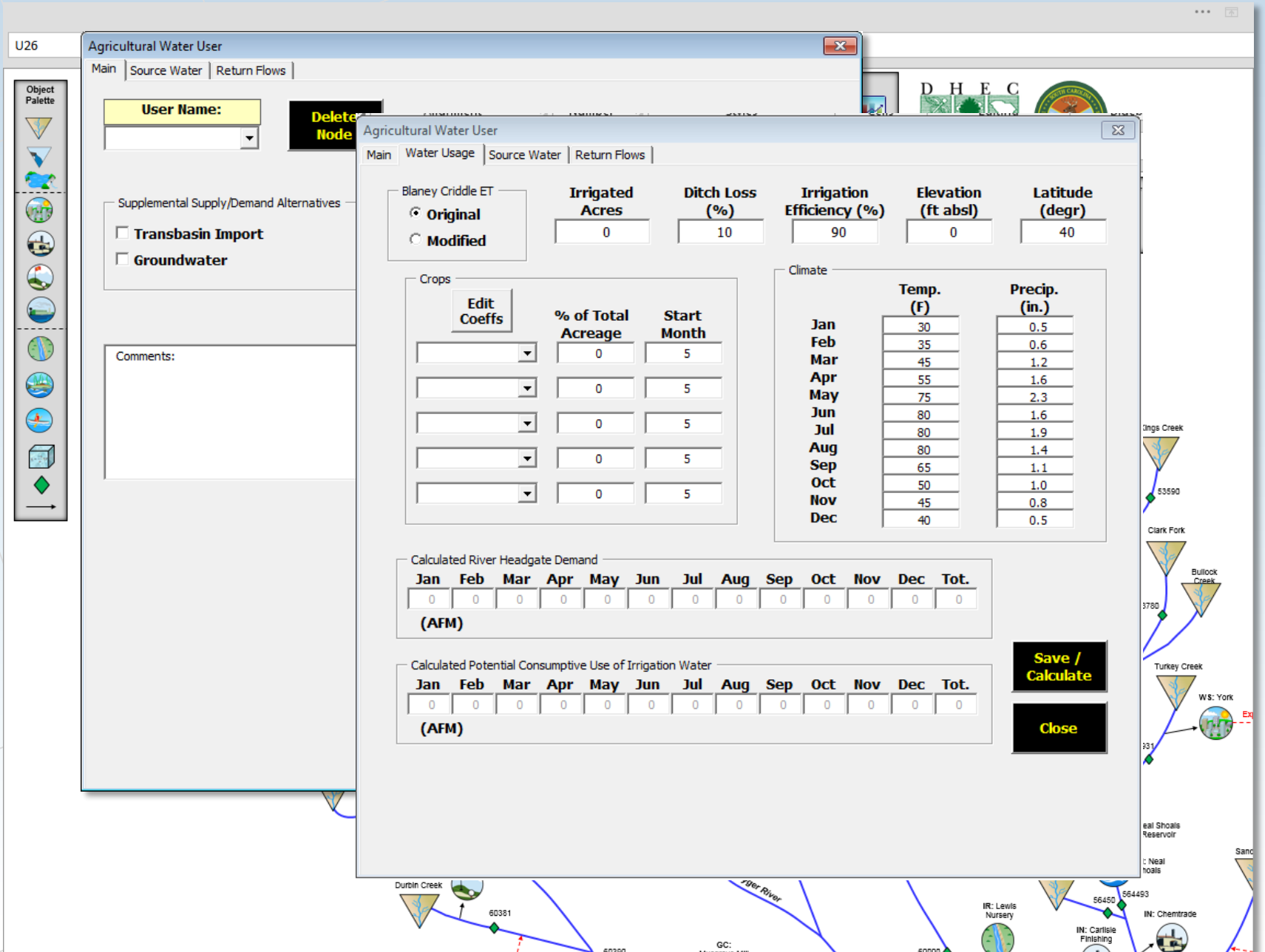
Reservoir Input Form



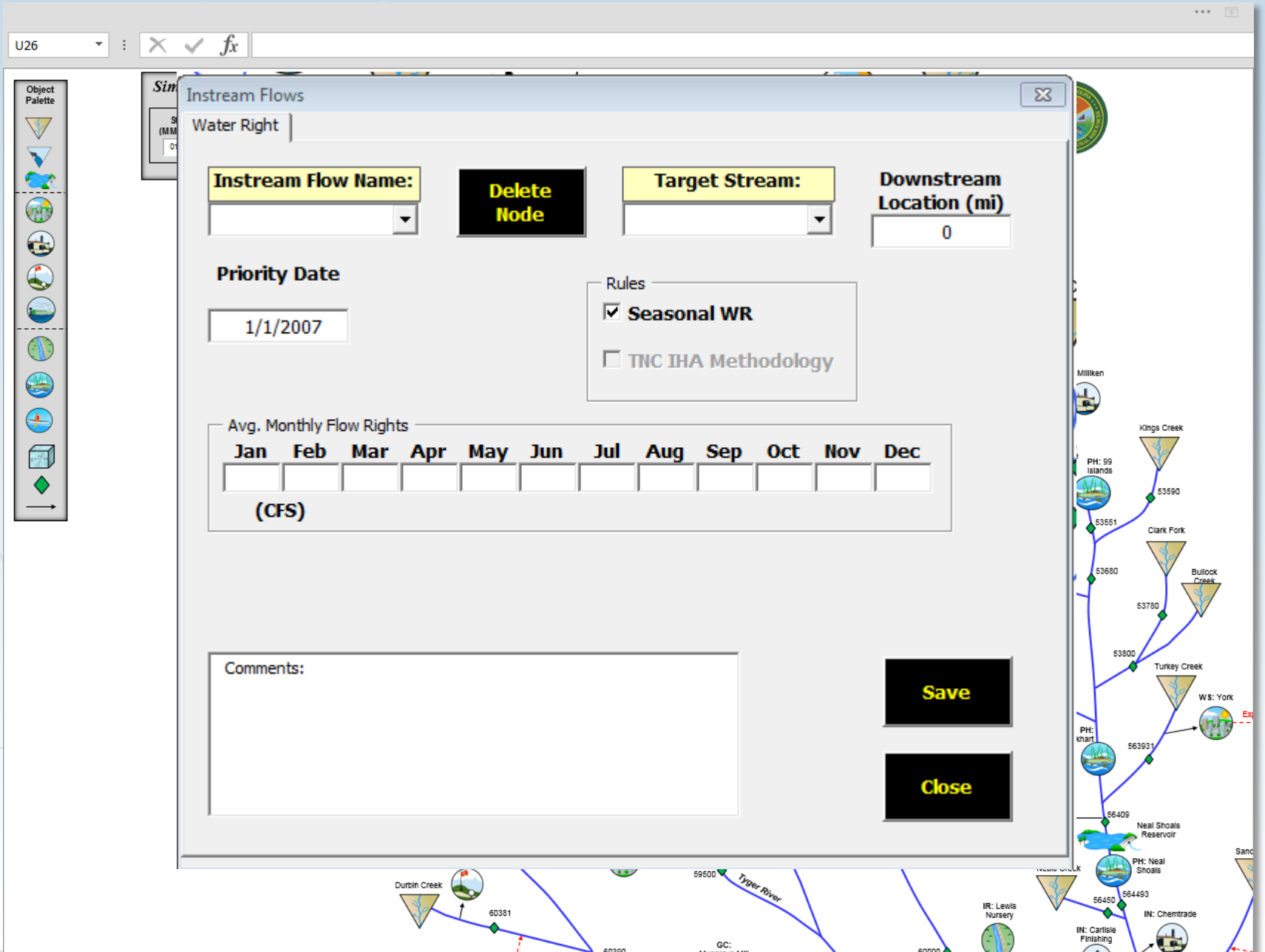
Water User Input Form – Main



Agricultural Water User Input Forms



Instream Flow Input Form



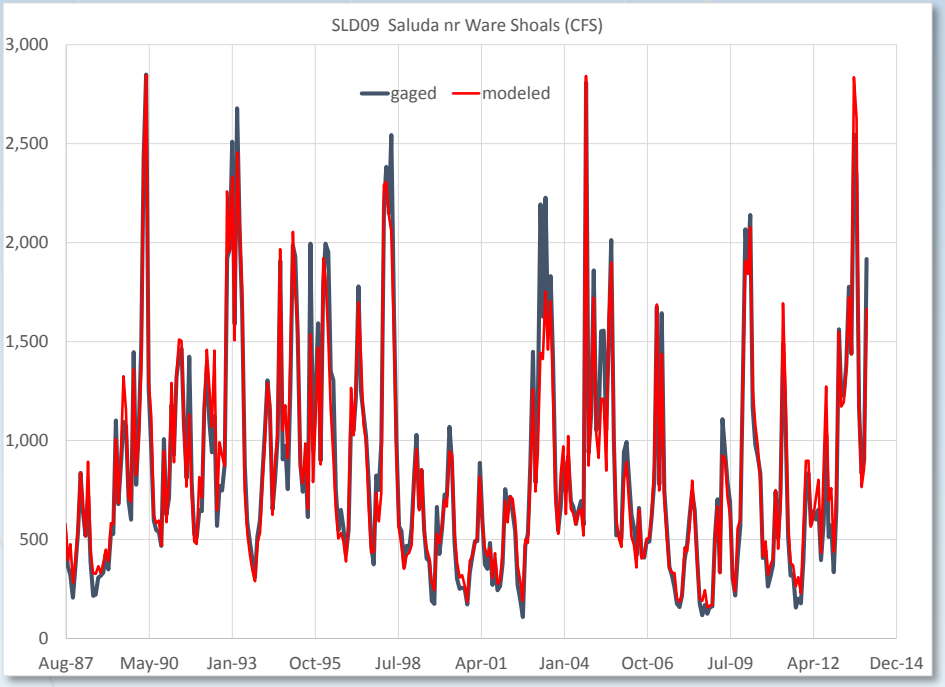
Catawba-Wateree River Basin

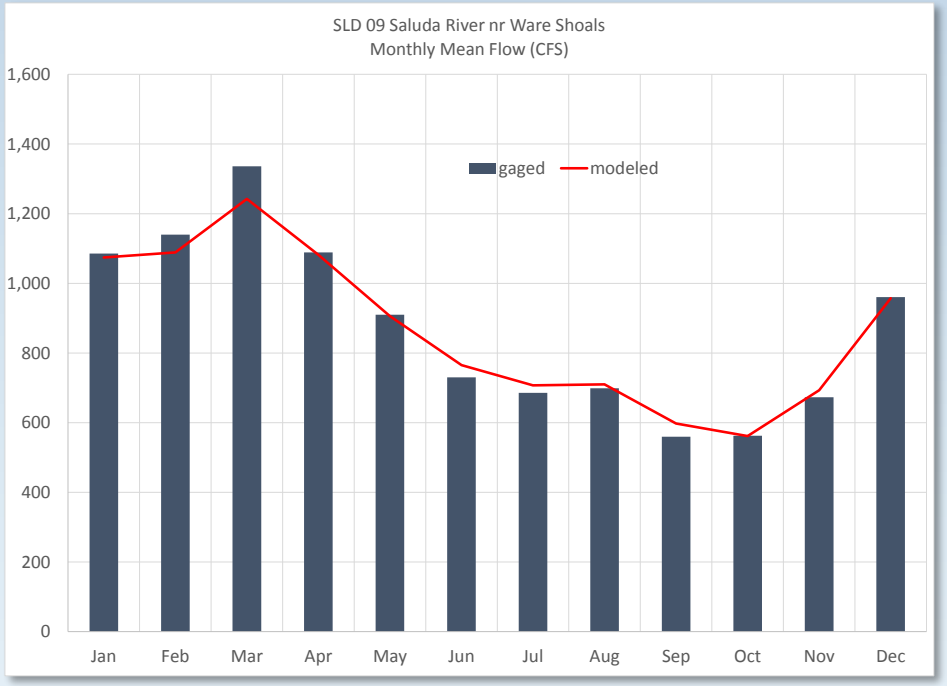
MODEL VALIDATION

SWAM Calibration/Validation

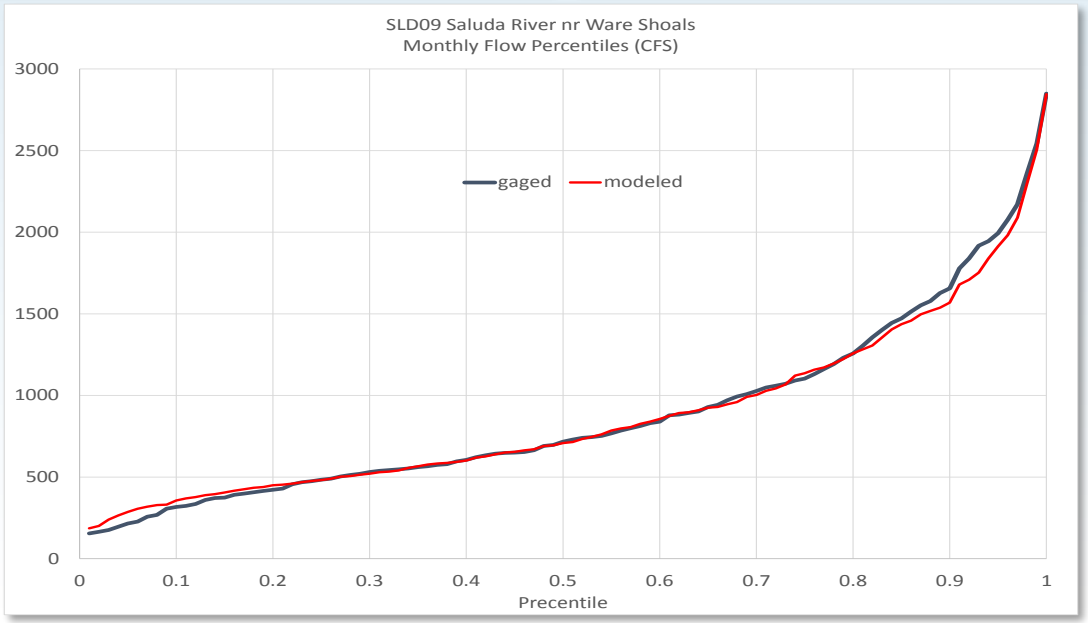
- Calibration targets = downstream flow gage records
- Calibration parameters =
  - reach gains/losses,
  - ungaged flow records,
  - reservoir operations
  - ag return flow percentages, locations, lags
- Performance metrics =
  - Annual avg flows (overall water balance)
  - Monthly avg flows (seasonality)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

Calibration Result Graphs





Preliminary examples from the Saluda Basin



Catawba-Wateree River Basin

THANK YOU