Water Quantity Models

…and an Update on what's Happening in South Carolina

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September 11, 2015

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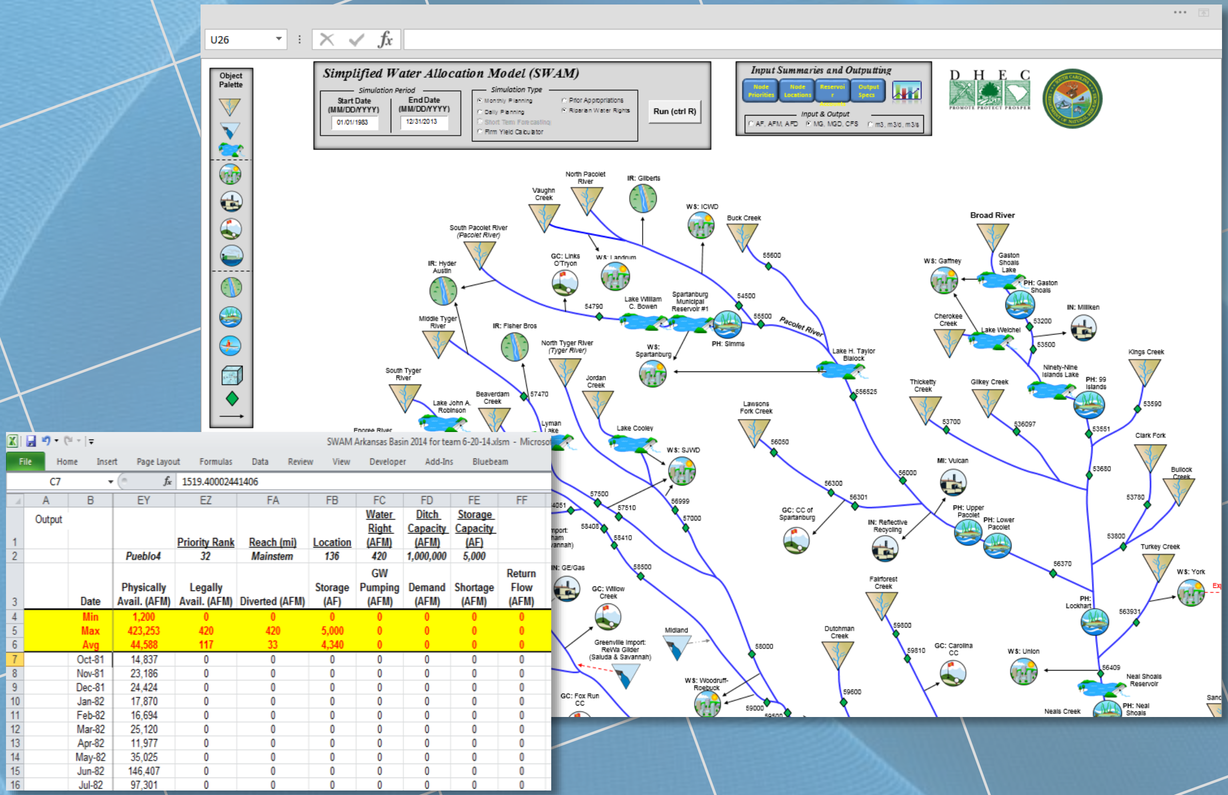

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Outline

- Preface – Types of Water Quantity Models
- Why Model?
- What Models are Being Used?
- Water Quantity Modeling to Support South Carolina's Surface Water Availability Assessment

Types of Water Quantity Models

Precipitation-Runoff Models

Convert rainfall volume into runoff

- Example: HEC-HMS

Hydraulic Models

Characterize the flow and routing of water in the river system

- Example: HEC-RAS

Water Allocation Models

Calculate legally and/or physically available water in a river system

- Examples: OASIS, CHEOPS, RiverWare and SWAM

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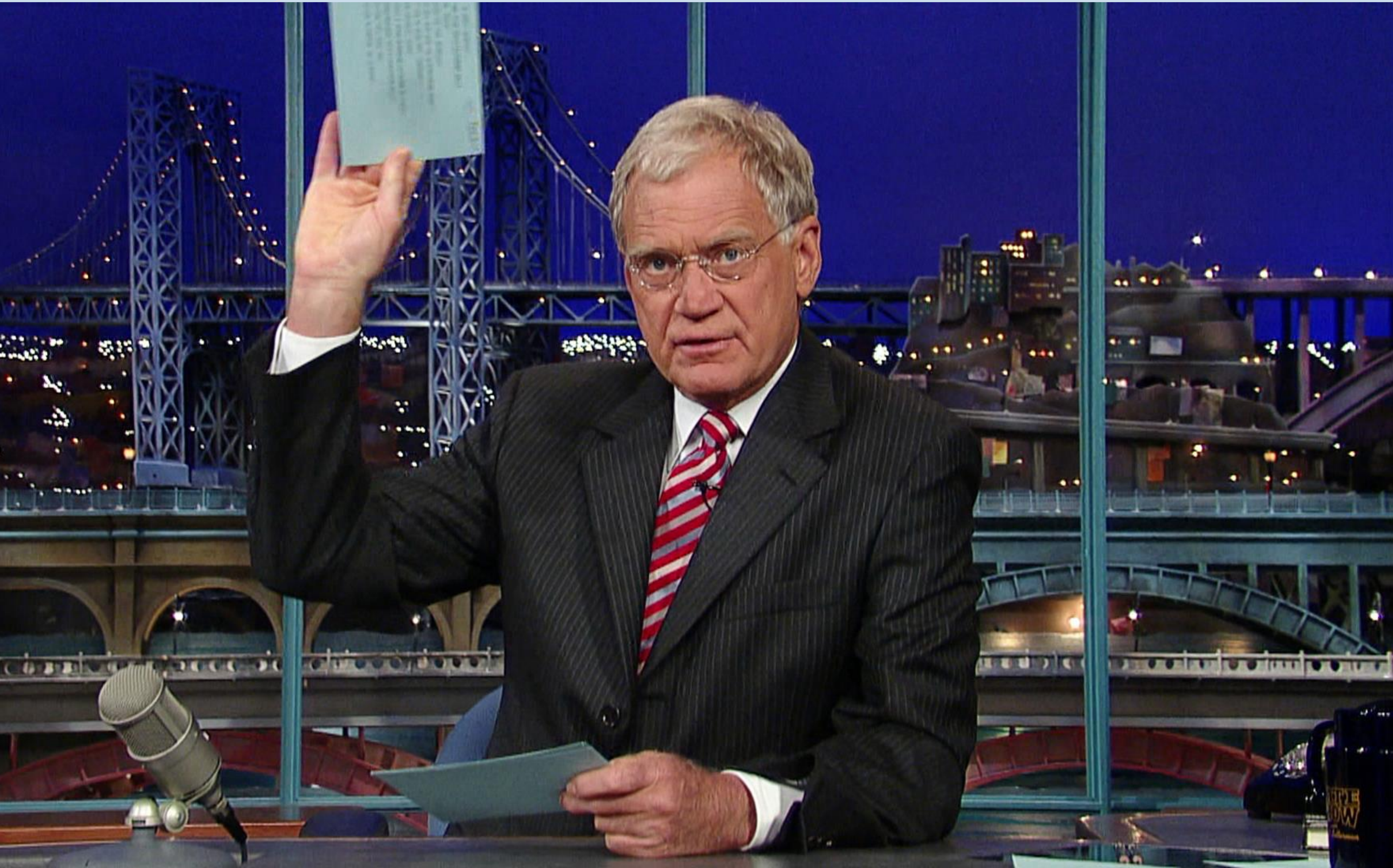
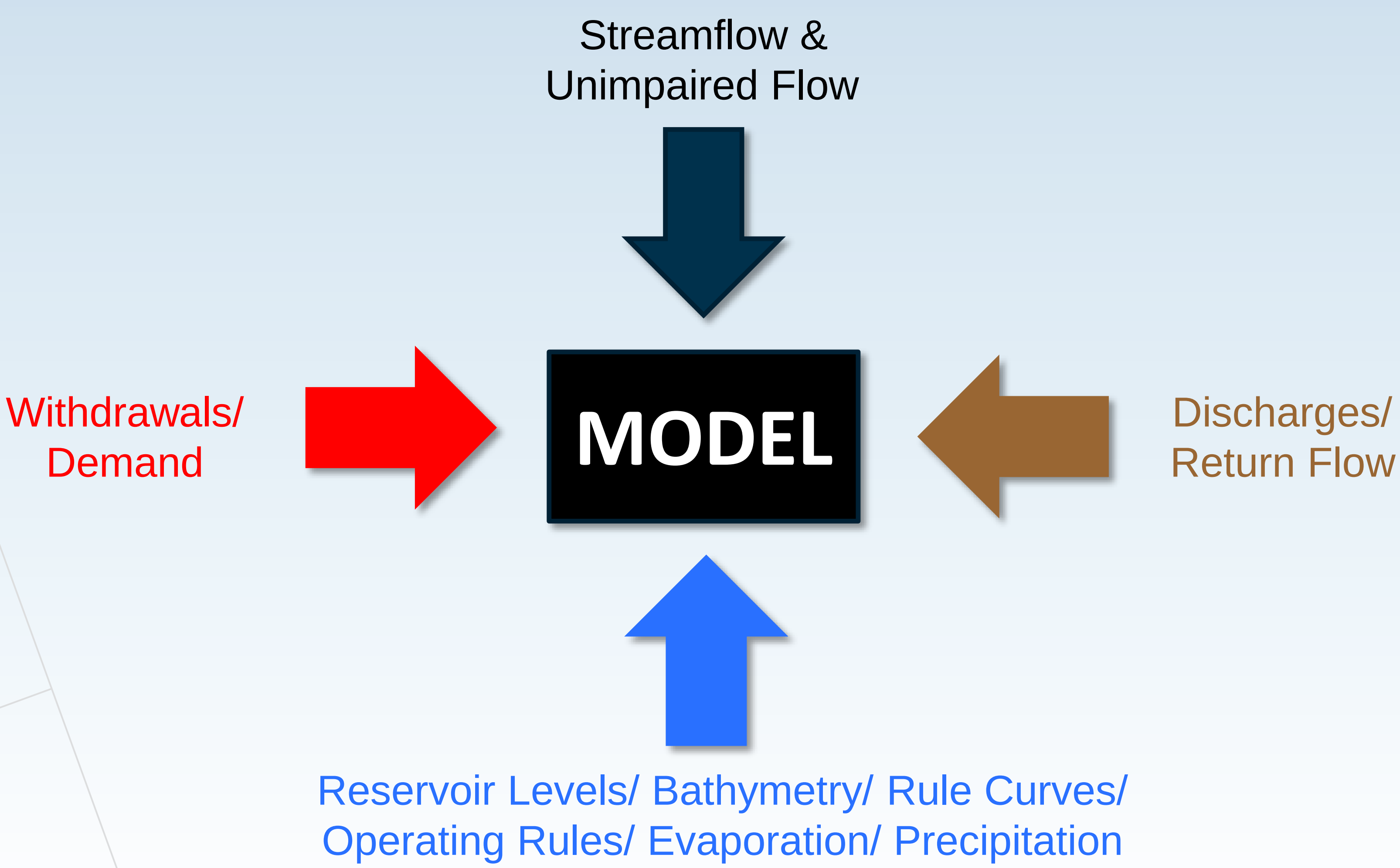
WHY MODEL?

Top Ten Reasons for Water Quantity Modeling



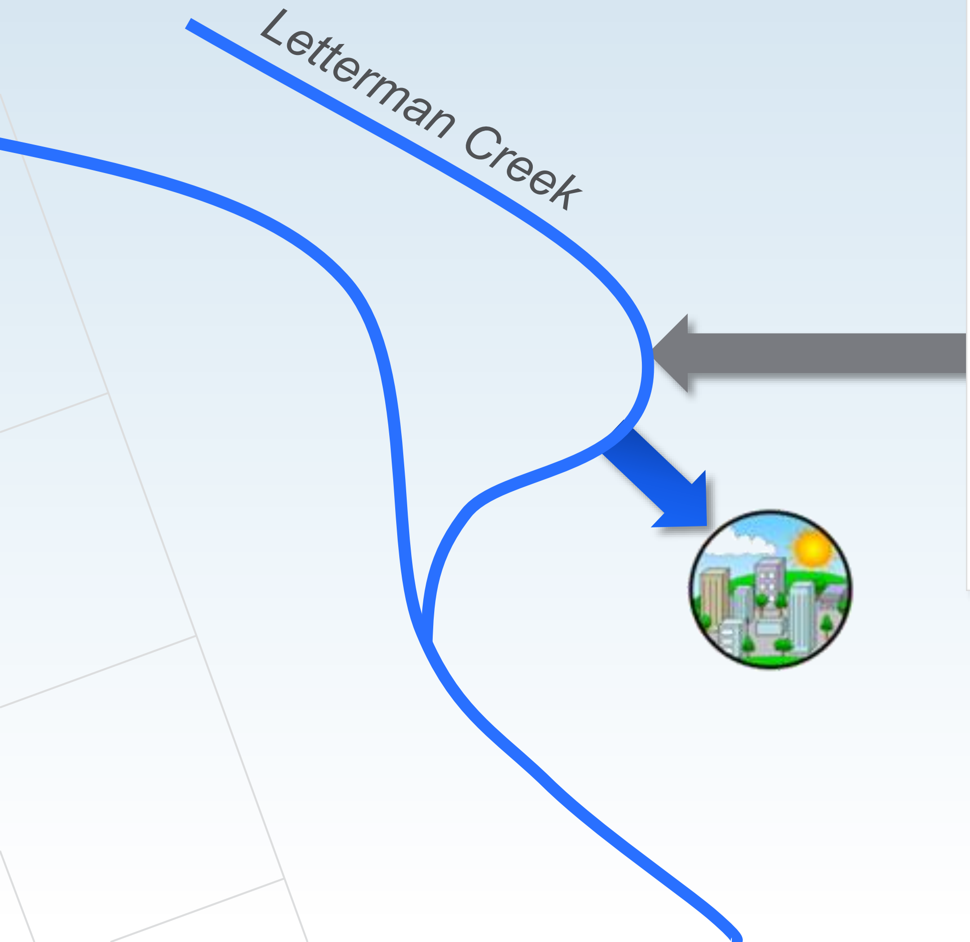
1. Consolidate hydrologic data

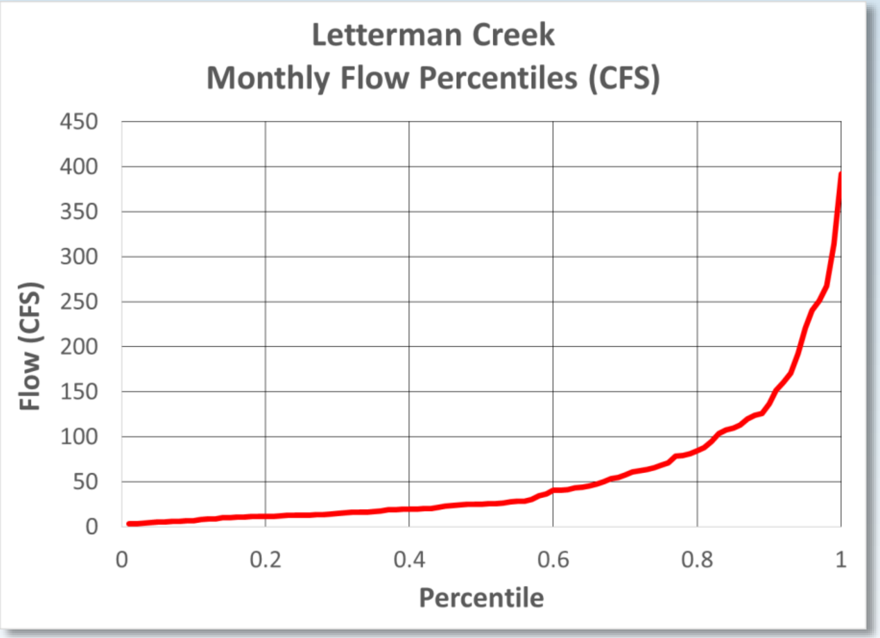


2. Determine surface water availability

- How much water is available for instream uses?
- Is there enough water to support new withdrawals?
- How do withdrawals affect downstream availability?
- How much water is available in the growing season?
- How much water is available during a drought?

3. Predict where and when future water shortages might occur





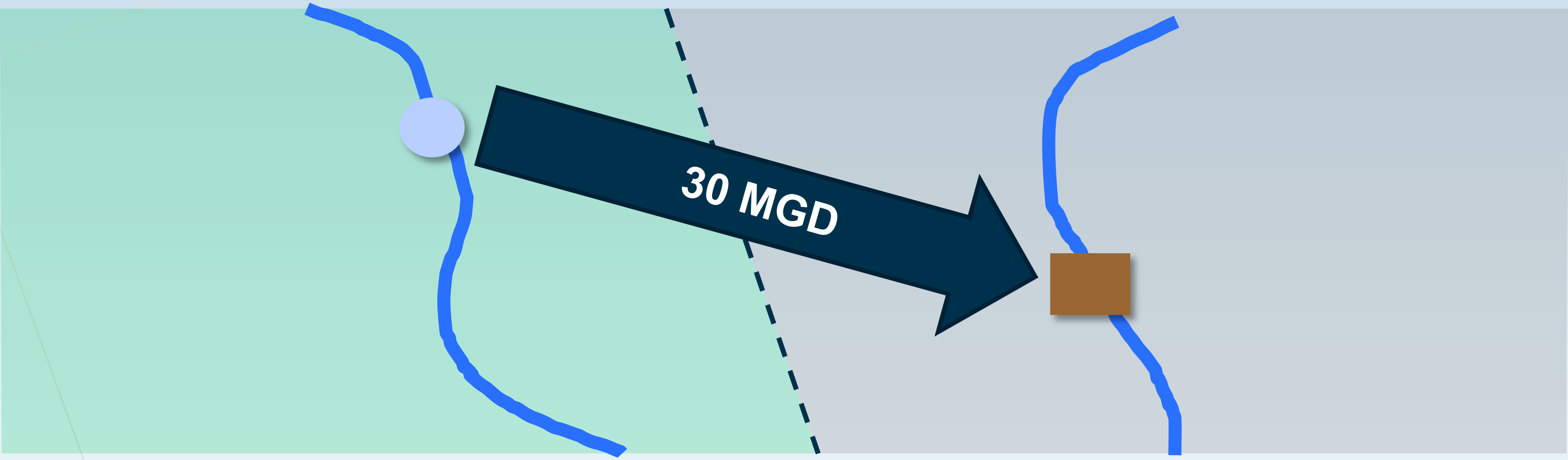
Average Monthly Flows below 10 CFS will occur 15% of the time

4. Test alternative water management strategies, new operating rules, and "what-if" scenarios

- Does intake #1 provide a more reliable supply than intake #2?
- How will an increased minimum flow release impact reservoir levels during the summer?
- What if water supply demand throughout the basin increased by 40% over the next 50 years?

5. Evaluate the impacts of future withdrawals on instream flow needs

6. Evaluate interbasin transfers

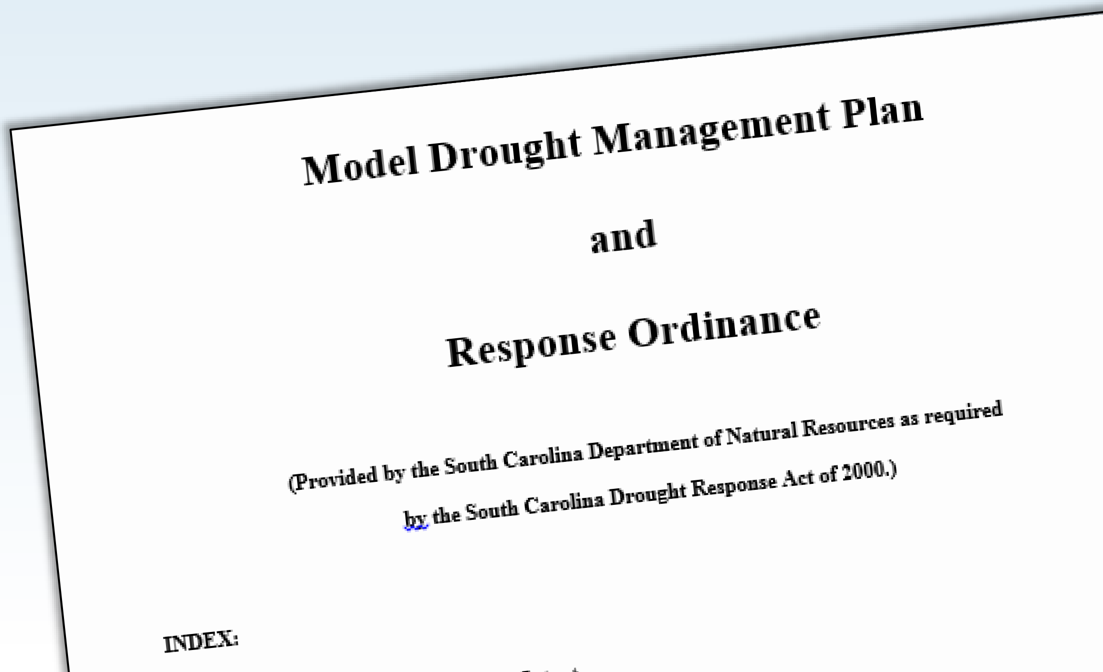


Examples:

- CHEOPS used in NC Catawba Basin
- OASIS used in NC Yadkin Basin

7. Support development of Drought Management Plans and evaluate the effectiveness of drought mitigation measures

- What are appropriate reductions in water use given moderate, severe, and extreme drought conditions?
- What is the cumulative response in the river system if water use reduction goals are achieved by all users?


Model Drought Management Plan

and

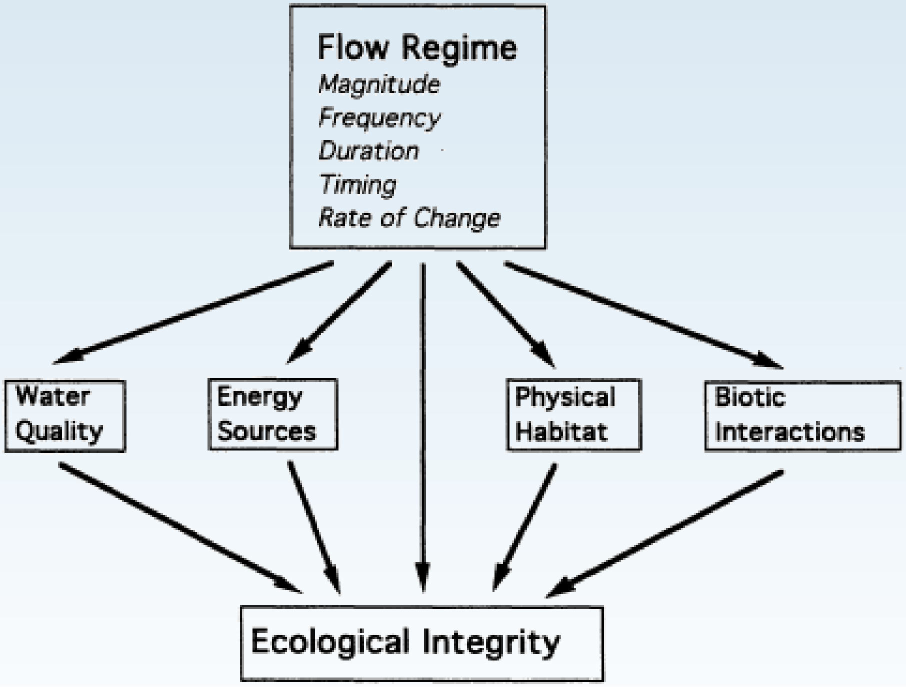
Response Ordinance

(Provided by the South Carolina Department of Natural Resources as required by the South Carolina Drought Response Act of 2000.)

INDEX:

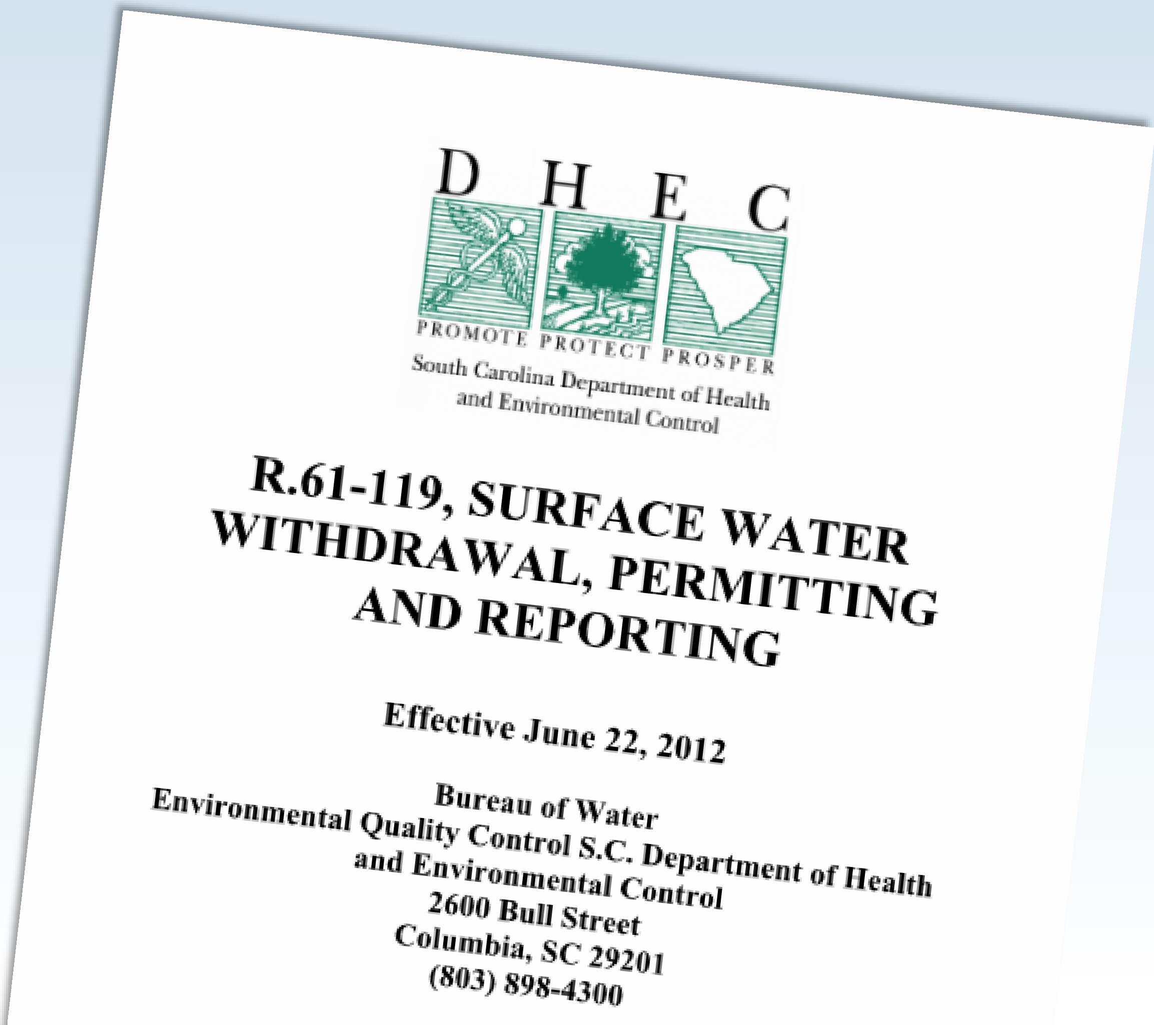
8. Compare managed flows to natural flows

- Help understand cumulative impact of withdrawals, discharges, impoundments, and flow regulation
- Help understand the natural variability in flow within the system, which can be important in maintaining healthy aquatic ecosystems



Source: The Natural Flow Regime. N. Leroy Poff et al. Bioscience, Vol 47, No. 11

9. Provide a scientific basis to make permitting decisions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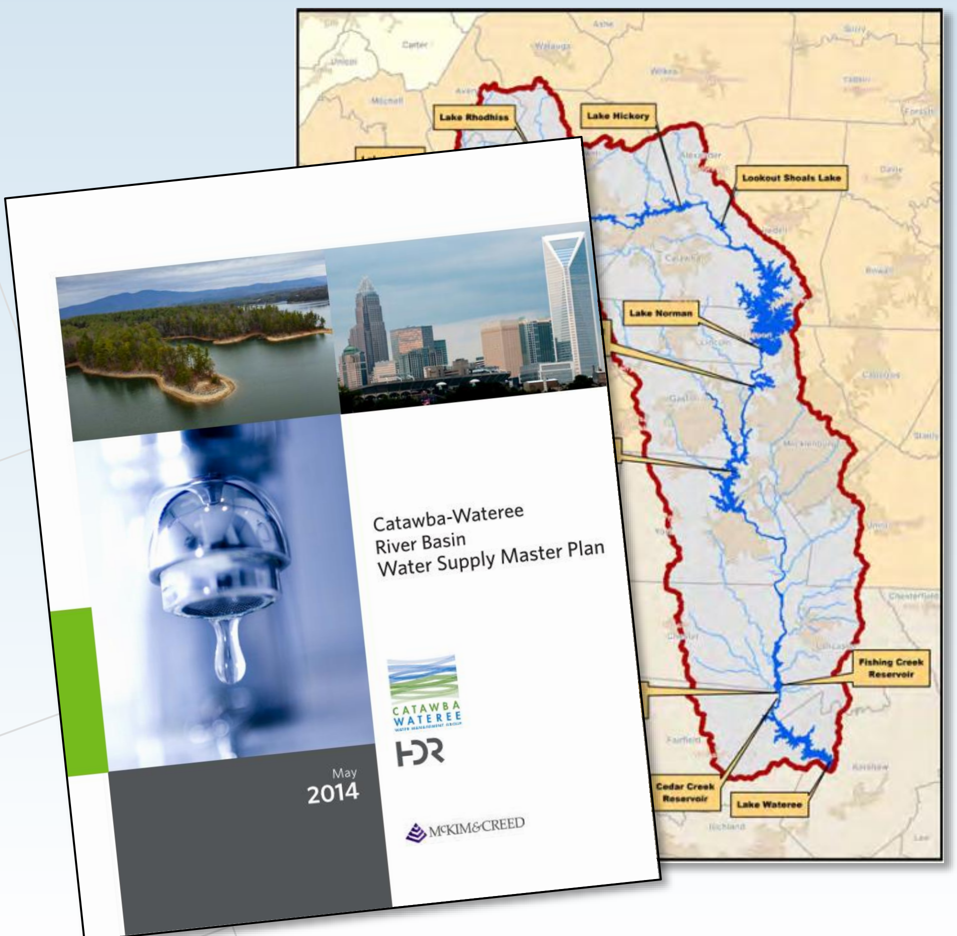
South Carolina Department of Health and Environmental Control

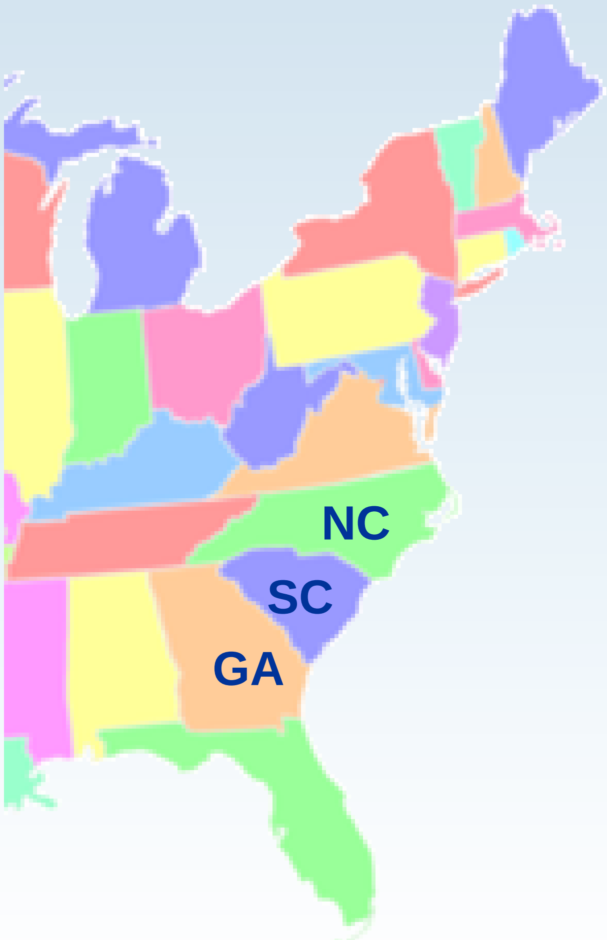
R.61-119, SURFACE WATER WITHDRAWAL, PERMITTING AND REPORTING

Effective June 22, 2012

Bureau of Water
Environmental Quality Control S.C. Department of Health and Environmental Control
2600 Bull Street
Columbia, SC 29201
(803) 898-4300

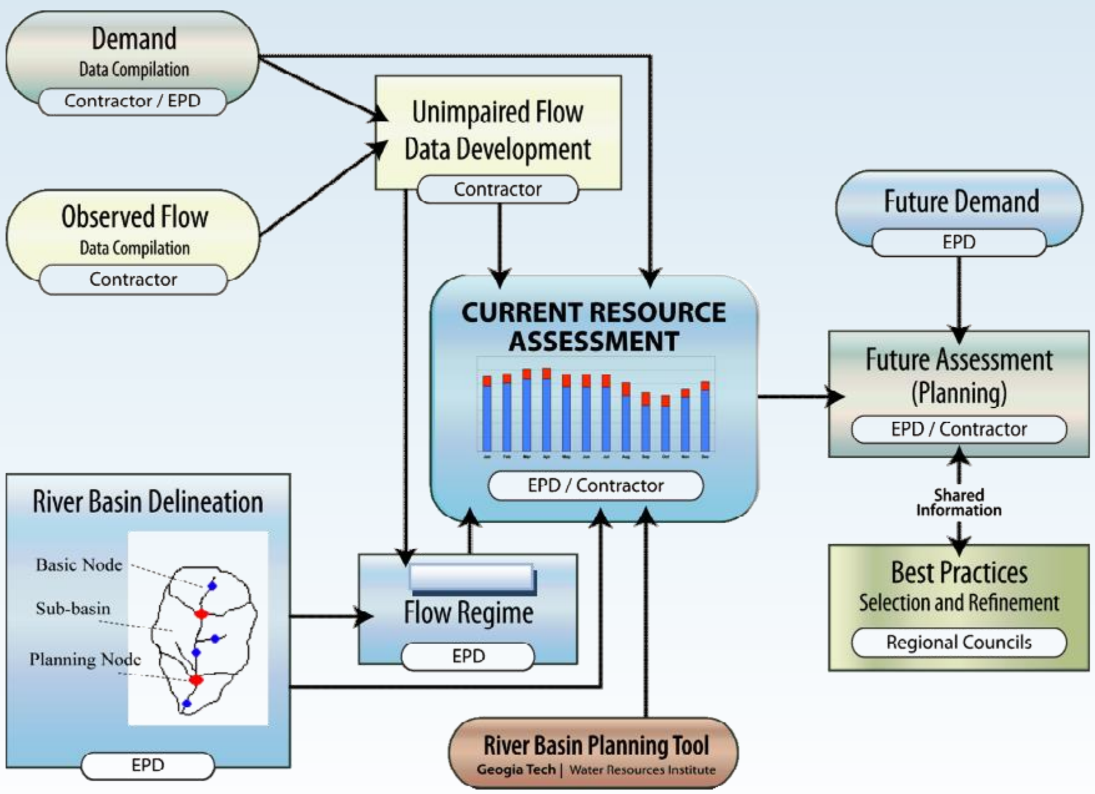
10. Support Basin, Regional and State Water Planning





Water Quantity Models in Georgia Were Used to Answer Three Fundamental Questions…

- How much water are we using?
- How much water do we have?
- How much water can we reliably use without compromising instream flows?



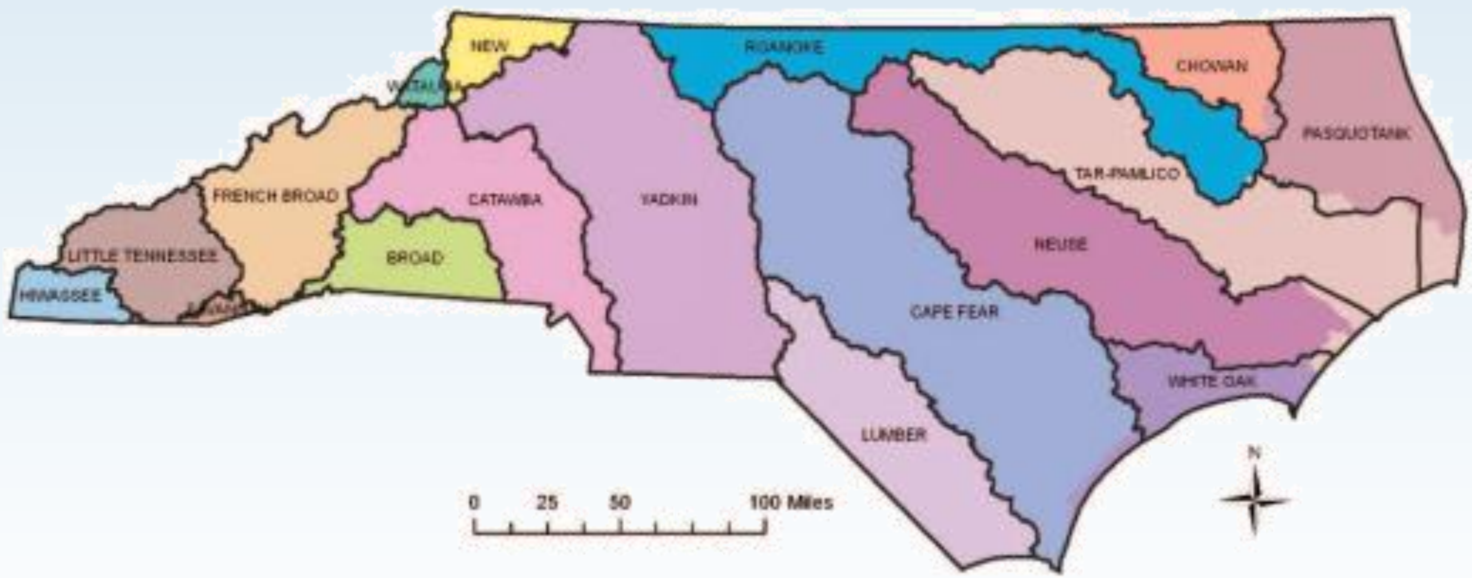
Source: Synopsis Report Surface Water Availability Assessment – Georgia's State Water Plan, Georgia EPD, March 2010

South Carolina Drivers for Water Quantity Modeling

- Limited information about the availability of water supplies
- Need for a tool to support new surface water permitting program
- Need for a tool to evaluate availability given future demand, and support the update of the State Water Plan

North Carolina Has Been Using Water Quantity Modeling as a Tool to:

- Provide a reliable, quantitative method to plan for sustainable water use
- Provide an objective basis for management and regulatory decisions



Source: Discover North Carolina's River Basins, NCDENR, 2013

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WHAT MODELS ARE BEING USED?

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 and/or Important 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
- Flexibility in simulating reservoir ops

CHEOPS

- Tailored for hydropower
  - Energy calculations
  - Reservoir tracking
- Hydraulic routing

RiverWare

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

Models Will Always Have Limitations

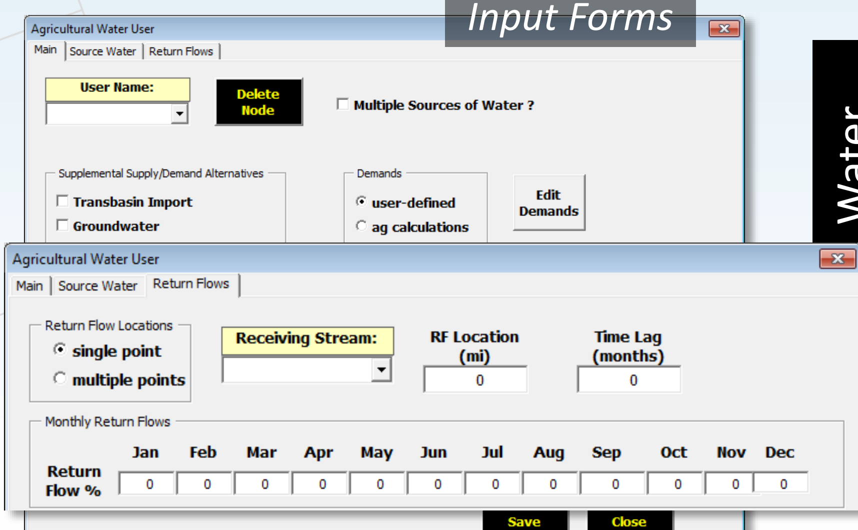
- Models can't incorporate all of the details of a river system
- Models must use approximations
- Water allocation models assume stationarity - the past is statistically the same as the future
- Models can be made more accurate, but at the expense of simplicity

A good model is both as accurate as possible and as simple as possible

Simplified Water Allocation Model (SWAM)

- Developed in response to an increasing need for a desktop tool to facilitate regional and statewide water allocation analysis
- Resides in Microsoft Excel
- Object Oriented / Point and Click

Input Forms



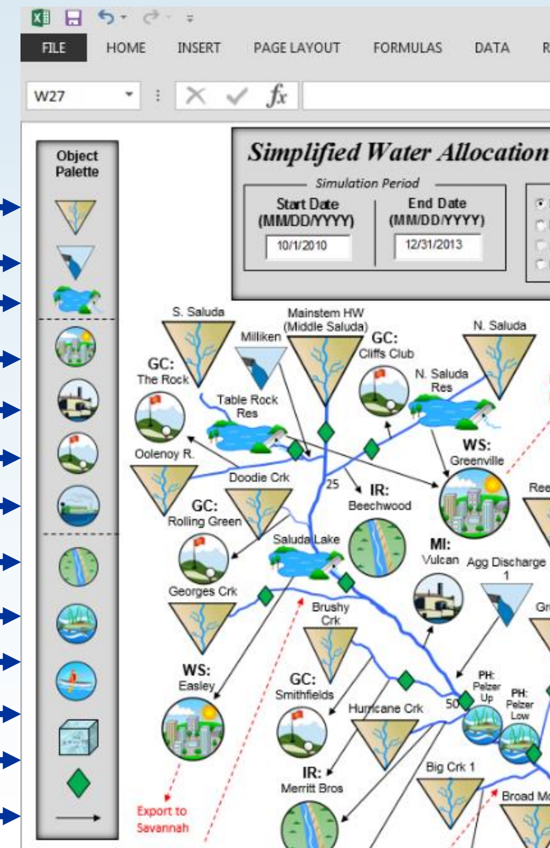
Objects

- Tributaries
- Discharges
- Reservoirs

Water User Objects

- Municipal
- Industrial
- Golf Courses
- Power Plants
- Agriculture

- Instream Flow
- Recreational Pool
- Aquifer
- USGS Gage
- Interbasin Transfer



Other Features of SWAM

- Multi-source water supply portfolios available for each water user
- Groundwater as a source of supply, with returns to surface
- Transbasin imports as a source of supply
- Conservation and reuse demand management options
- Blaney Criddle calculations of ET-based crop demands for Ag objects
- Lagged return flows (e.g. irrigation)
- Simple aquifer water balance
- Instream flow object for prioritized seasonal environmental flows

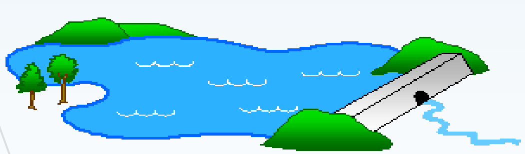
Simple to Complex

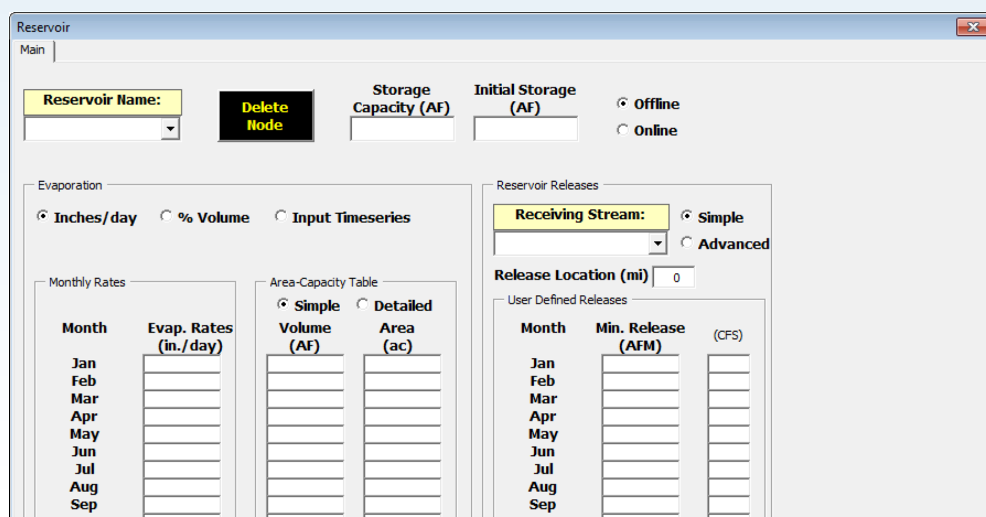
- Supports multiple layers of complexity for development of a range of systems, for example…

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

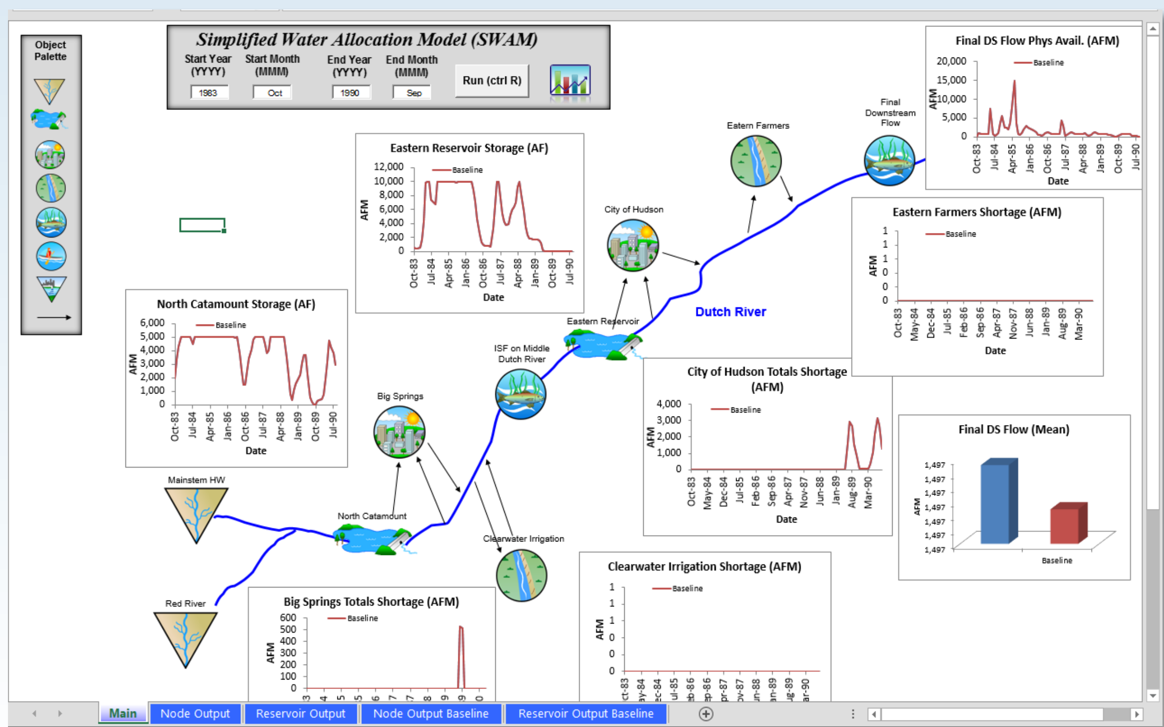




Proof of Concept Modeling for State of Colorado

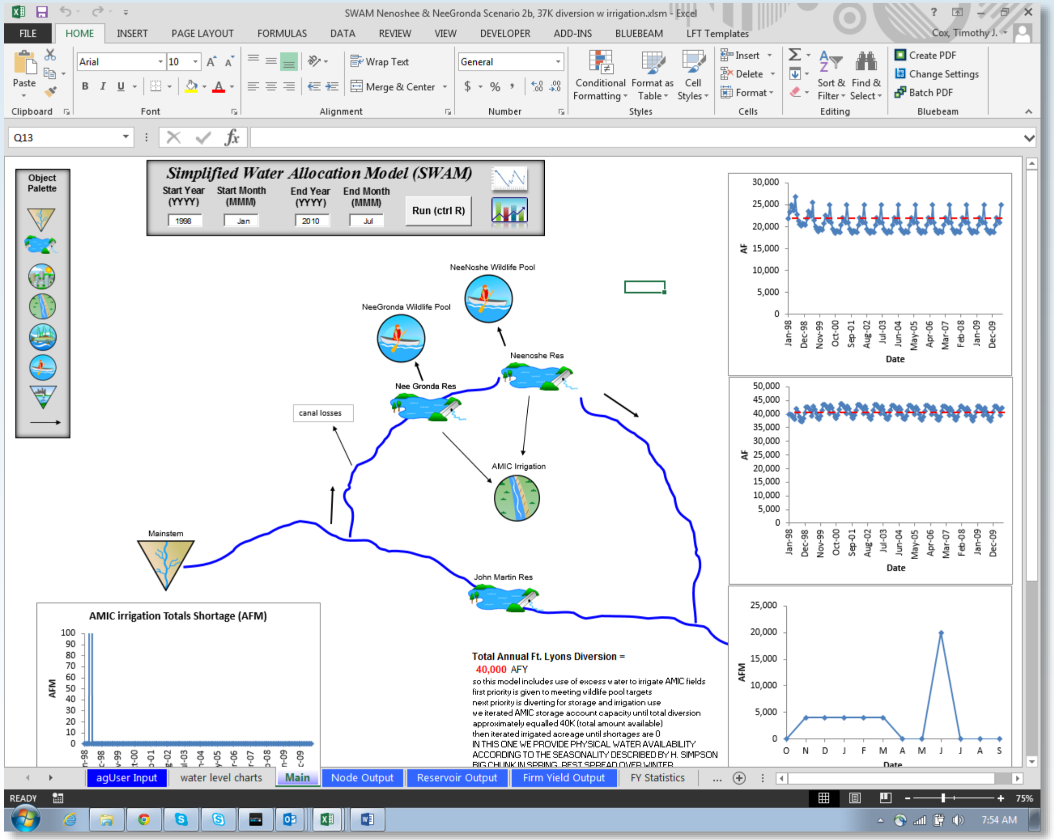
- Investigate impacts of demand management on downstream water users

- Illustrate general concepts associated with conservation, reuse, storage, and return flows.



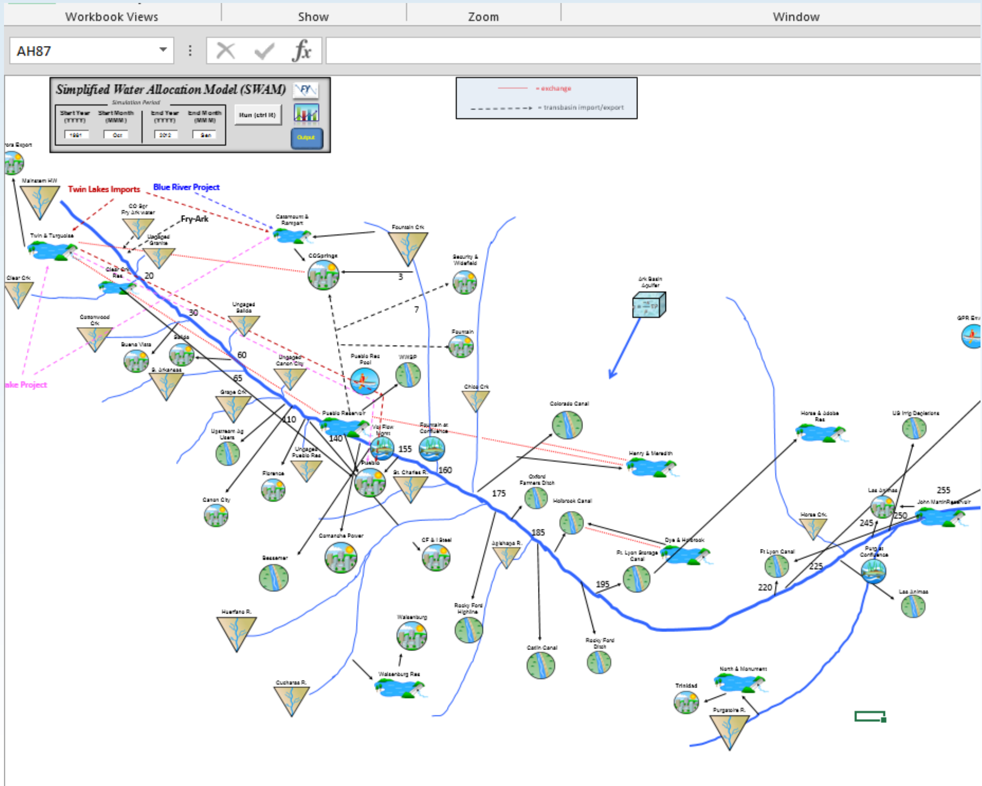
Arkansas River (CO) Non-Consumptive Needs Assessment

- Quantify water needs associated with migratory bird and sport fishery populations in a multi-reservoir system
- Evaluate seasonal dynamics in availability, storage, and losses for various management and growth scenarios



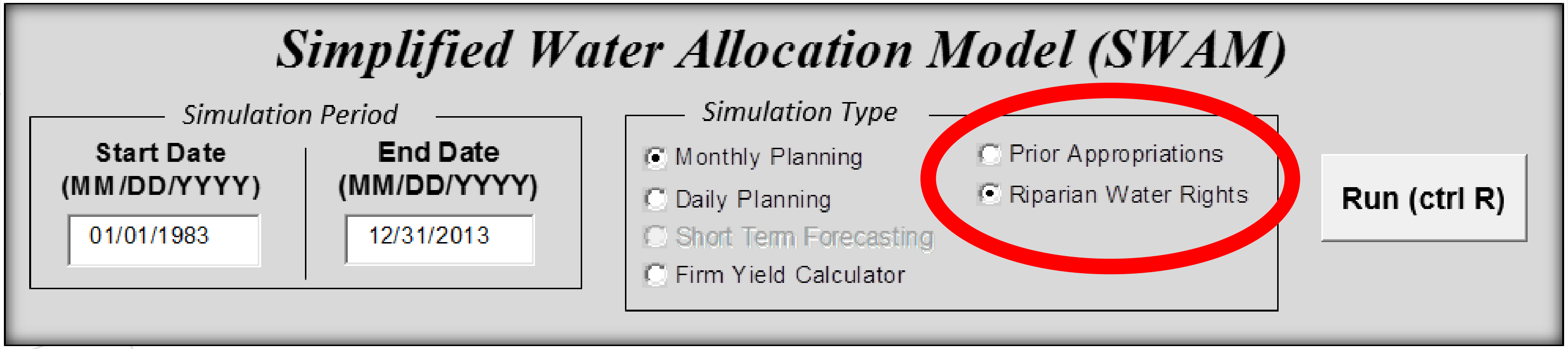
Arkansas River Basin (CO) Implementation Plan

- Detailed water allocation model of basin
- Quantify future water availability and identify shortfalls associated with increasing demands
- Included complex water exchange agreements, transbasin imports, groundwater-surface water interactions, and large reservoir operations



Prior Appropriation and Riparian Rights

- SWAM originally developed to support Prior Appropriations
  - Allows priorities to be set, regardless of location within the basin
  - During times of shortage, key calculation is the consideration of <u>downstream priority water needs</u>
- Modified to support Riparian Rights
  - Priorities turned off (but can be activated)



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WATER QUANTITY MODELING TO SUPPORT SOUTH CAROLINA’S SURFACE WATER AVAILABILITY ASSESSMENT

Overview of Project

1. Data Collection, Organization and Analysis

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2. Model Framework Development

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3. Unimpaired Flow Development

↓

4. Model Development and Calibration

↓

5. Baseline Model Development and Documentation

↓

6. Training

Project Team

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SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES
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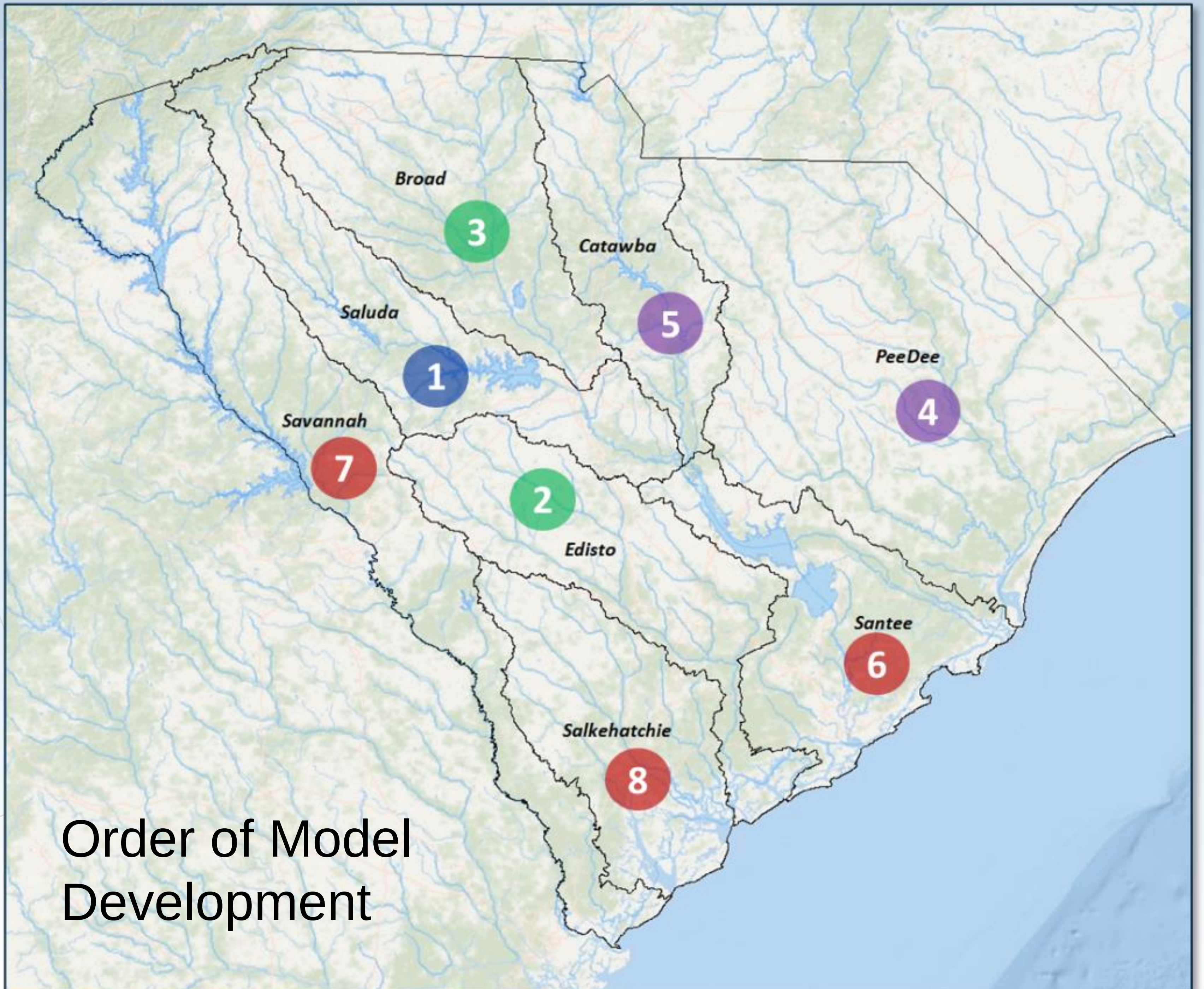
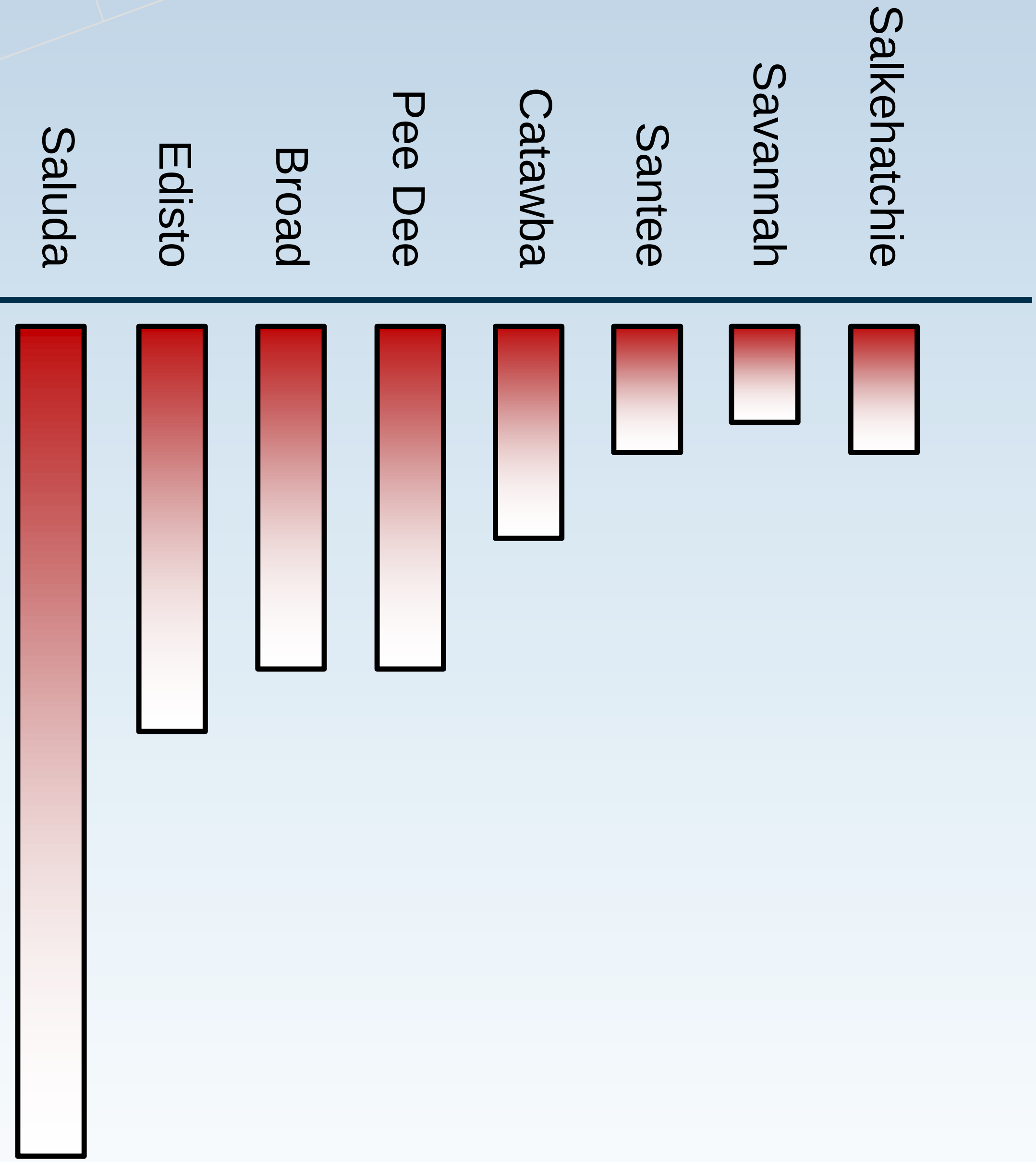
Stakeholder Representation/ Technical Advisory Committee

- Water Utilities
- Energy
- Agriculture
- Conservation
- Industry
- Consulting
- Legal



Order of Model Development

Project Status



1. Data Collection, Organization and Analysis
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Data Collected for UIFs and Model Development

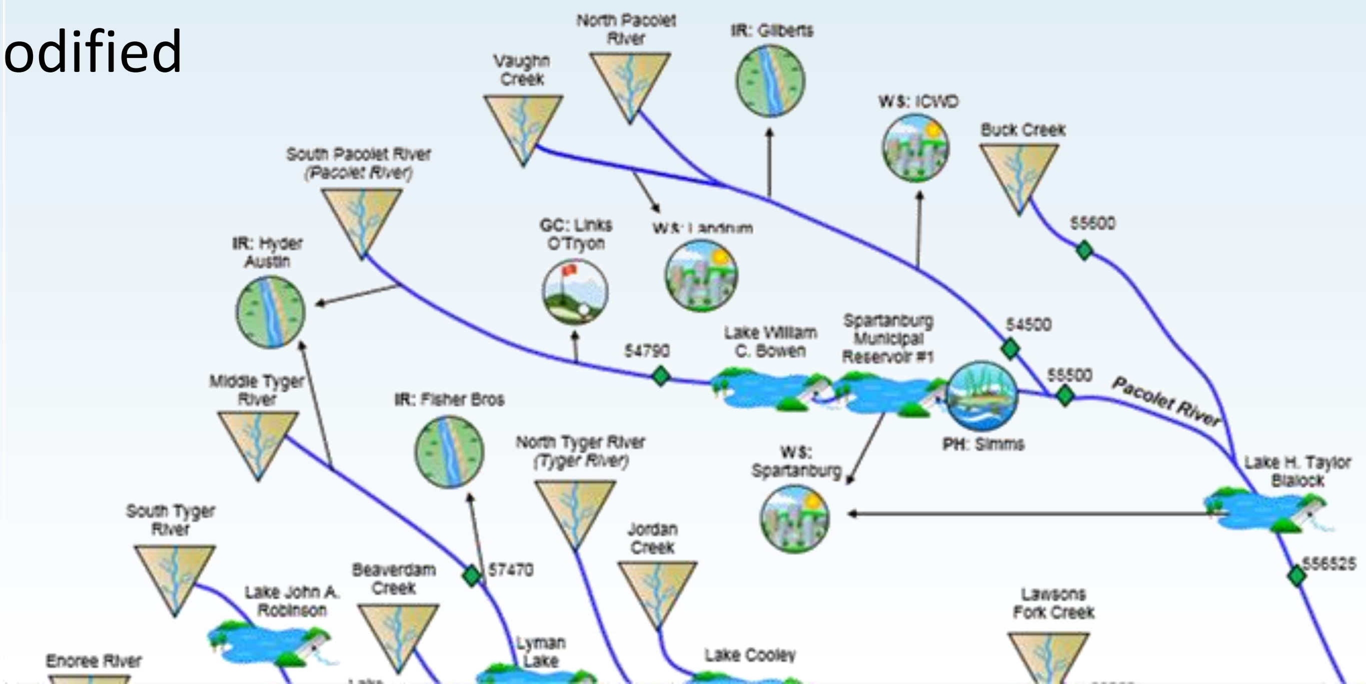
- USGS daily flow records
- Historical daily rainfall and evaporation rates
- Historical Operational Data
  - Withdrawals (municipal, industrial, agricultural, golf courses)
  - Discharges
  - Reservoir elevation
- Reservoir bathymetry and operating rules
- Sub-basin characteristics (GIS)
  - Drainage area
  - Land use
  - Basin slope

Data Collection Observations

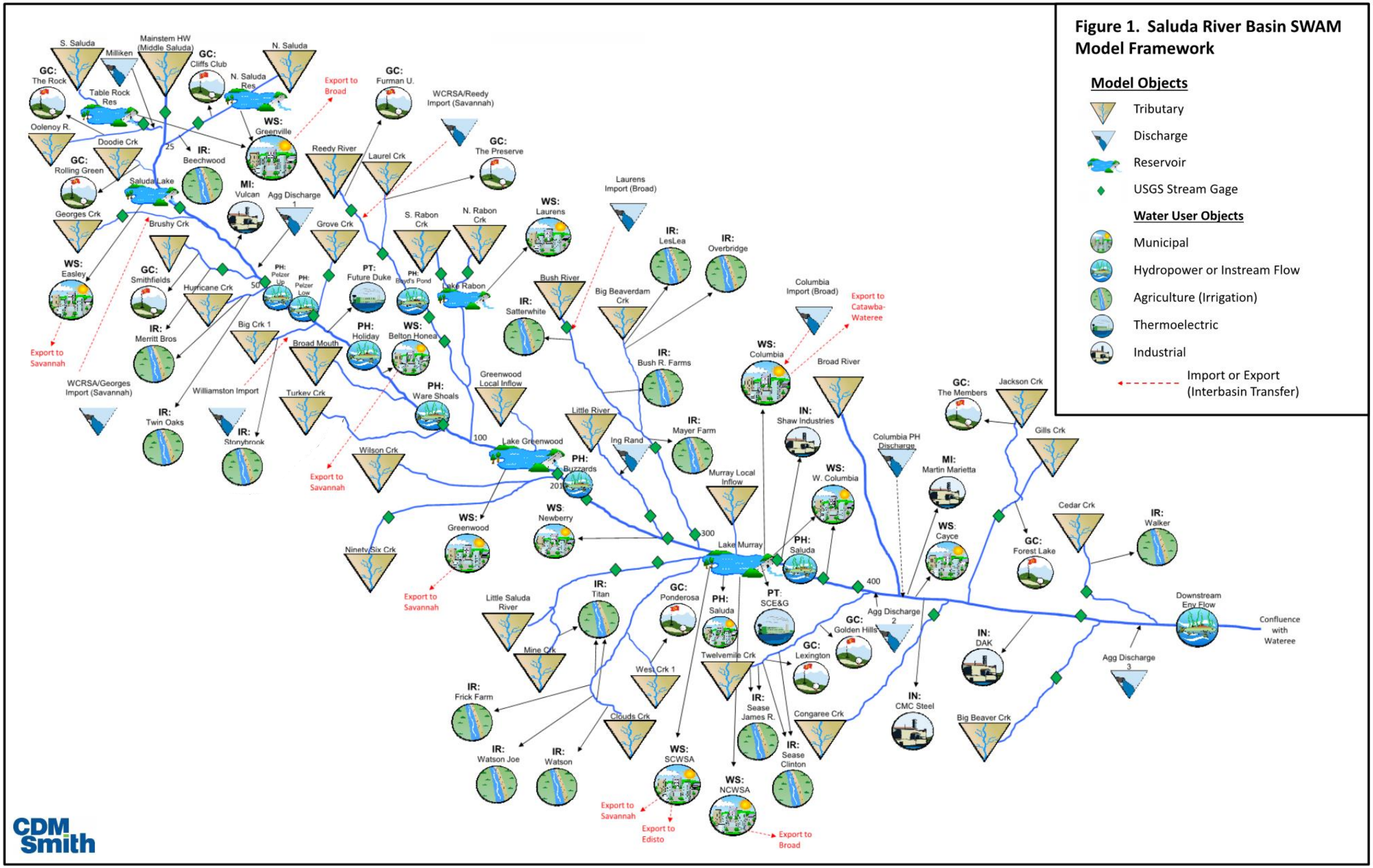
- Except for streamflow, daily data is sparse
  - Monthly values are disaggregated for daily model
- Wide range in quality of data
  - But even anecdotal data is usable, and generally has little to no influence on UIFs or calibration
- Uncertainty in larger (e.g. thermopower) withdrawals has the potential to impact UIFs the most
- Water users have demonstrated excellent cooperation in providing data

Model Framework

- How will the river basin will be represented?
  - Focus on reaches where management occurs
  - Include water users and dischargers > 3 mgal/month
  - Permit-based representation
  - Include significant reservoirs (>200 acres and/or those with withdrawals)
- Can be modified



Saluda Basin – SWAM Framework



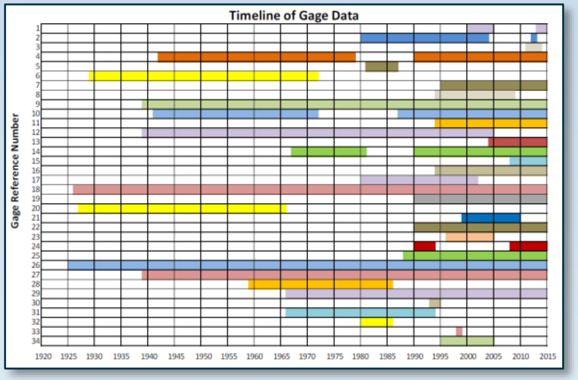
Unimpaired Flow Definition and Uses

- **Definition:** Estimate of natural historic streamflow in the absence of human intervention in the river channel:
  - Storage
  - Withdrawals
  - Discharges and Return Flow
- ***Unimpaired Flow*** *=*

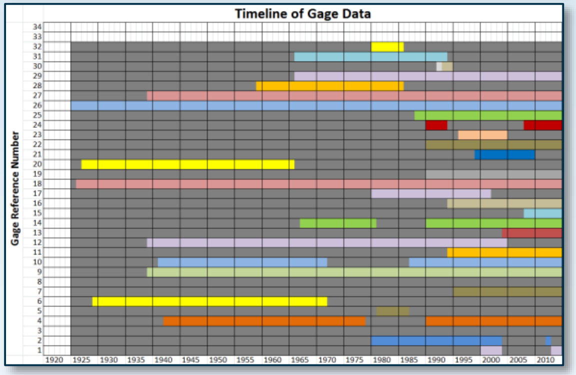
  Measured Gage Flow + River Withdrawals + Reservoir Withdrawals – Discharge to Reservoirs – Return Flow + Reservoir Surface Evaporation – Reservoir Surface Precipitation + Upstream change in Reservoir Storage + Runoff from Previously Unsubmerged Area
- **Fundamental input** to the model at headwater nodes and tributary nodes
- **Comparative basis** for model results

Four Steps in UIF Calculation Process

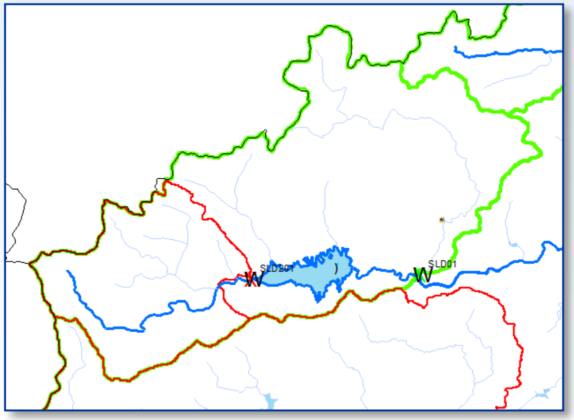
- **Step 1**: UIFs for USGS Gages for individual periods of record
  - Involves extension of operational data



- **Step 2**: Extension of UIFs for USGS Gages through the LONGEST period of record



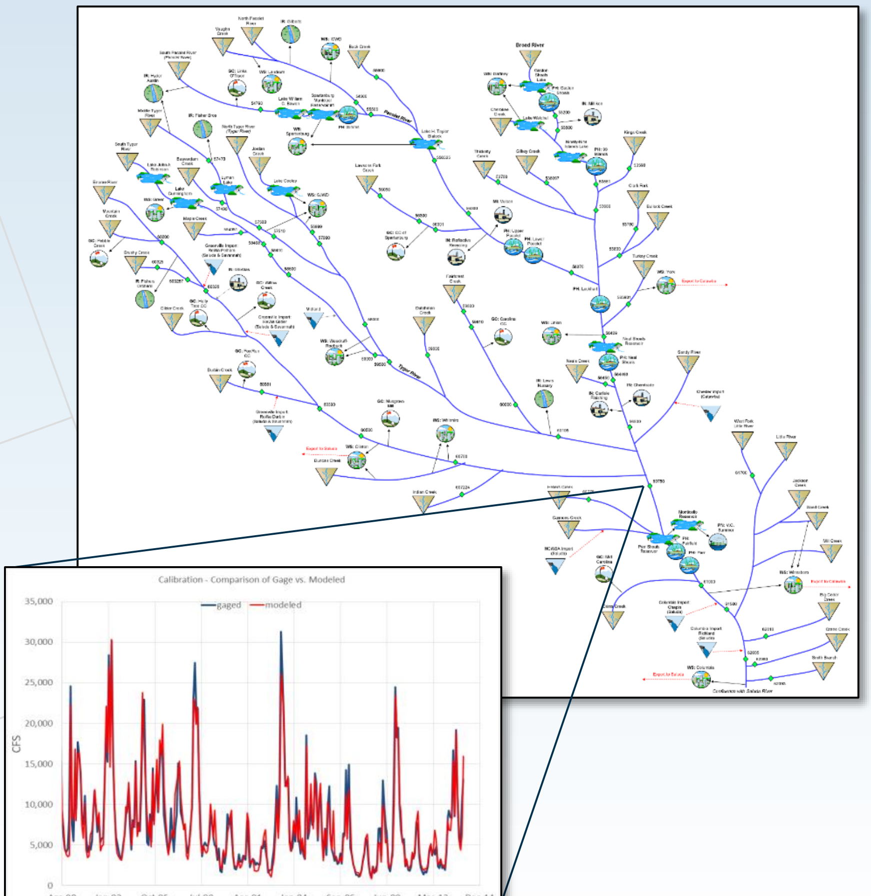
- **Step 3**: Correlation between ungaged basins and gaged basins



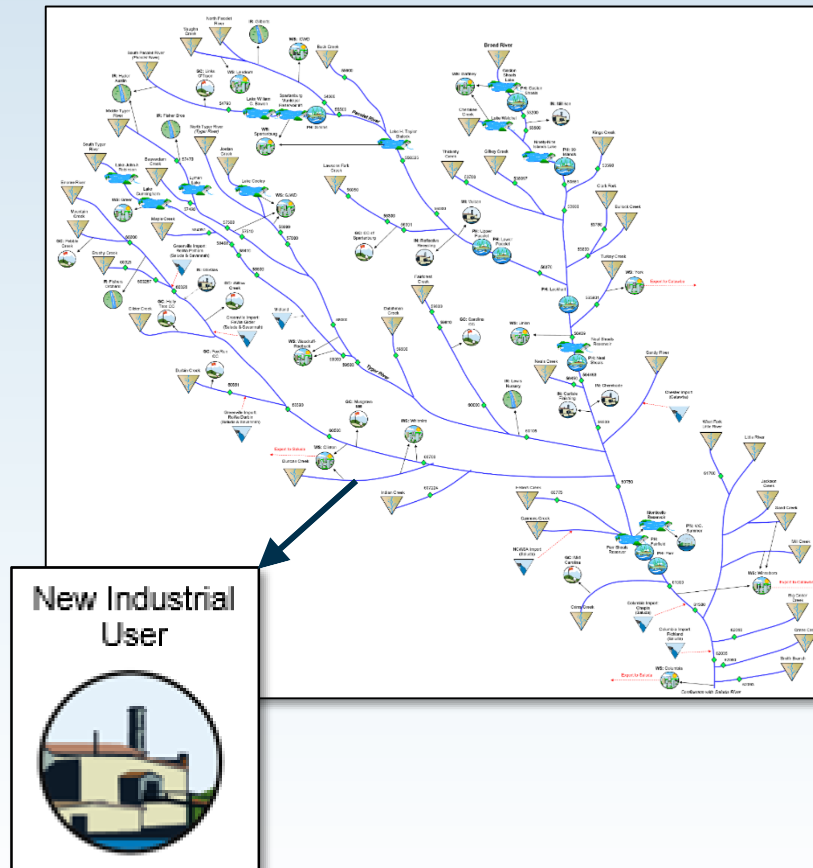
- **Step 4**: UIFs for ungaged basins

Two Versions of Every Model

Calibration with UIFs and Historic Use Records



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

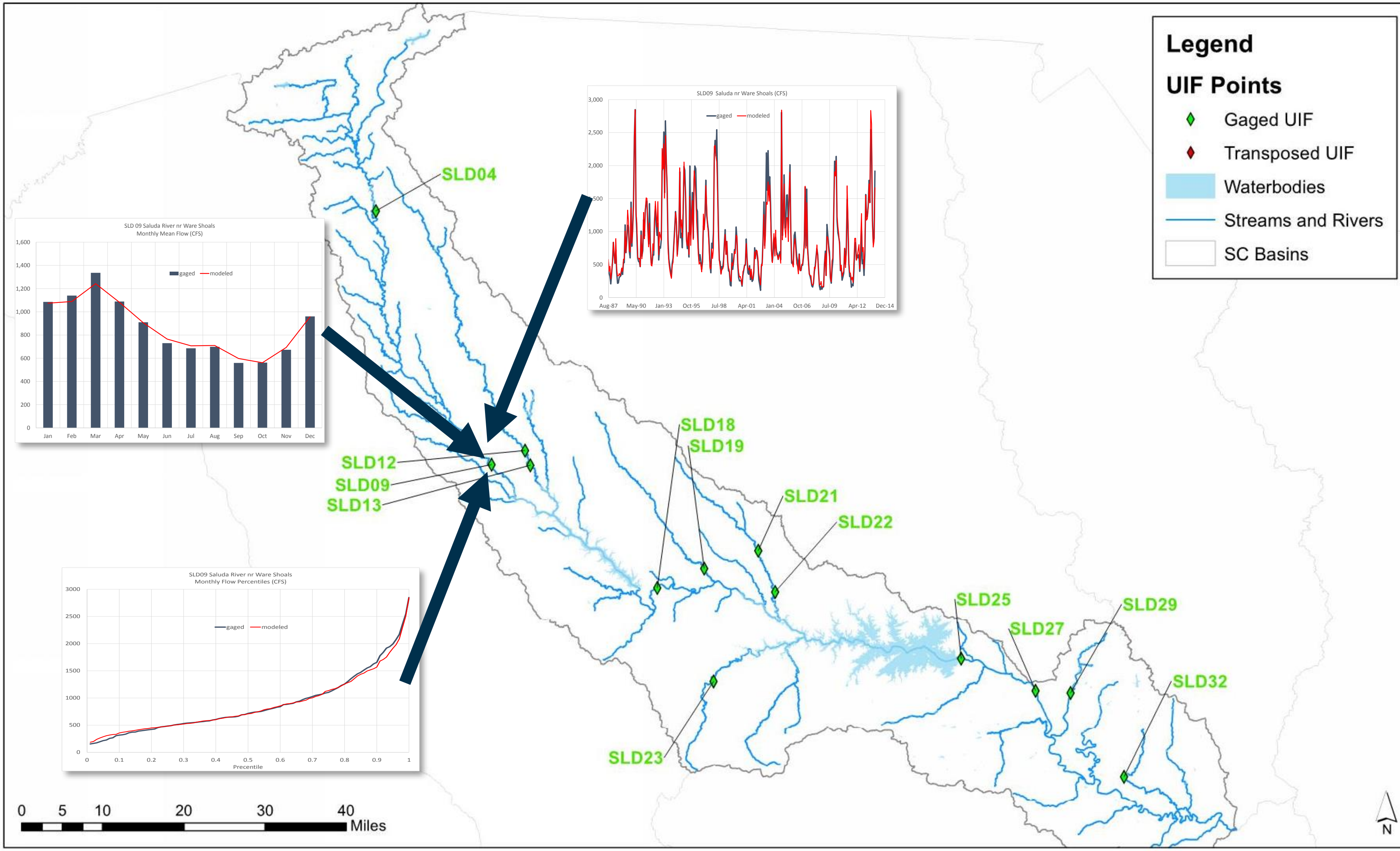


Calibration/Validation Objectives

- Extend hydrologic inputs (headwater UIFs) spatially to adequately represent entire basin hydrology by parameterizing reach hydrologic inputs
- Refine initial parameter estimates, as appropriate
  - E.g. reservoir operating rules, % consumptive use assumptions
- Gain confidence in the model as a predictive tool by demonstrating its ability to adequately replicate past hydrologic conditions, operations, and water use

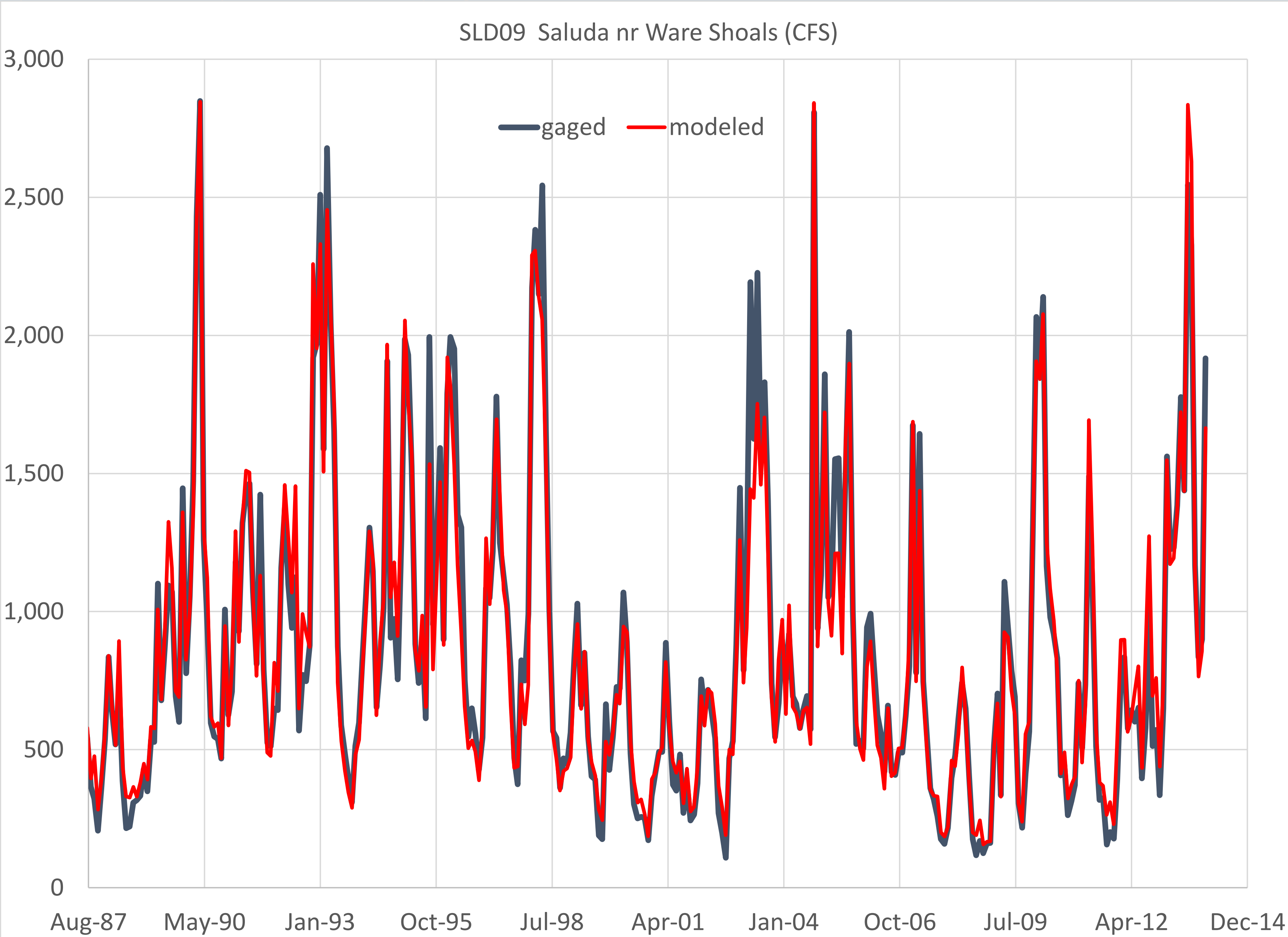
Calibration/Validation Objectives

- 1983 – 2013 hindcast period; monthly and daily timesteps
- Comparison to gaged (measured) flow data - only operations and impairments are implicit in that data
- Assess performance at (subject to gage data availability):
  - Multiple mainstem locations
  - All tributary confluence locations
  - Major reservoirs
- Multiple model performance metrics, including:
  - Timeseries plots (monthly and daily variability)
  - Annual and monthly means (water balance and seasonality)
  - Percentile plots (extremes and frequency)
  - Residuals
  - Correlation coefficients

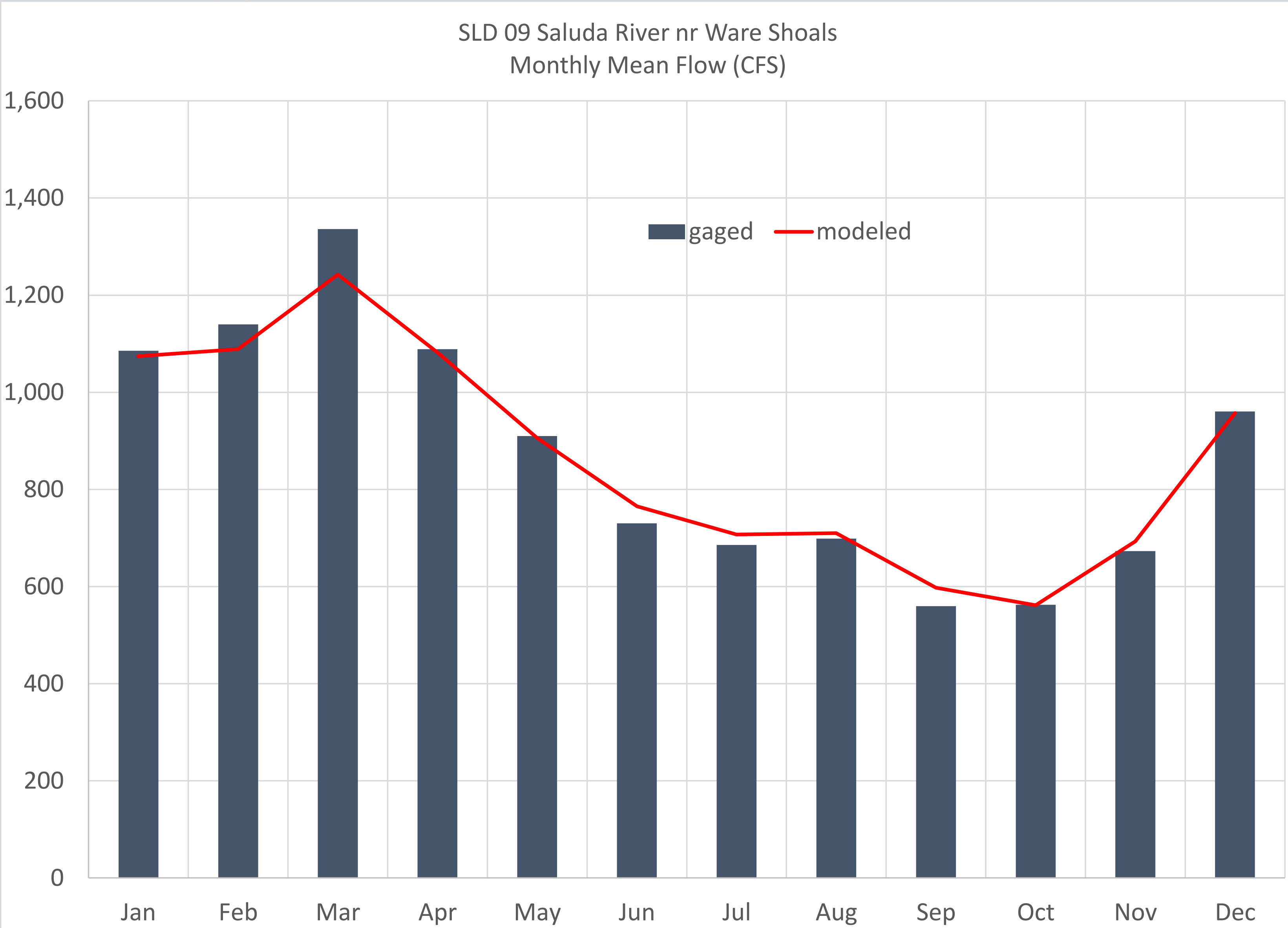


Saluda Basin Calibration/Verification

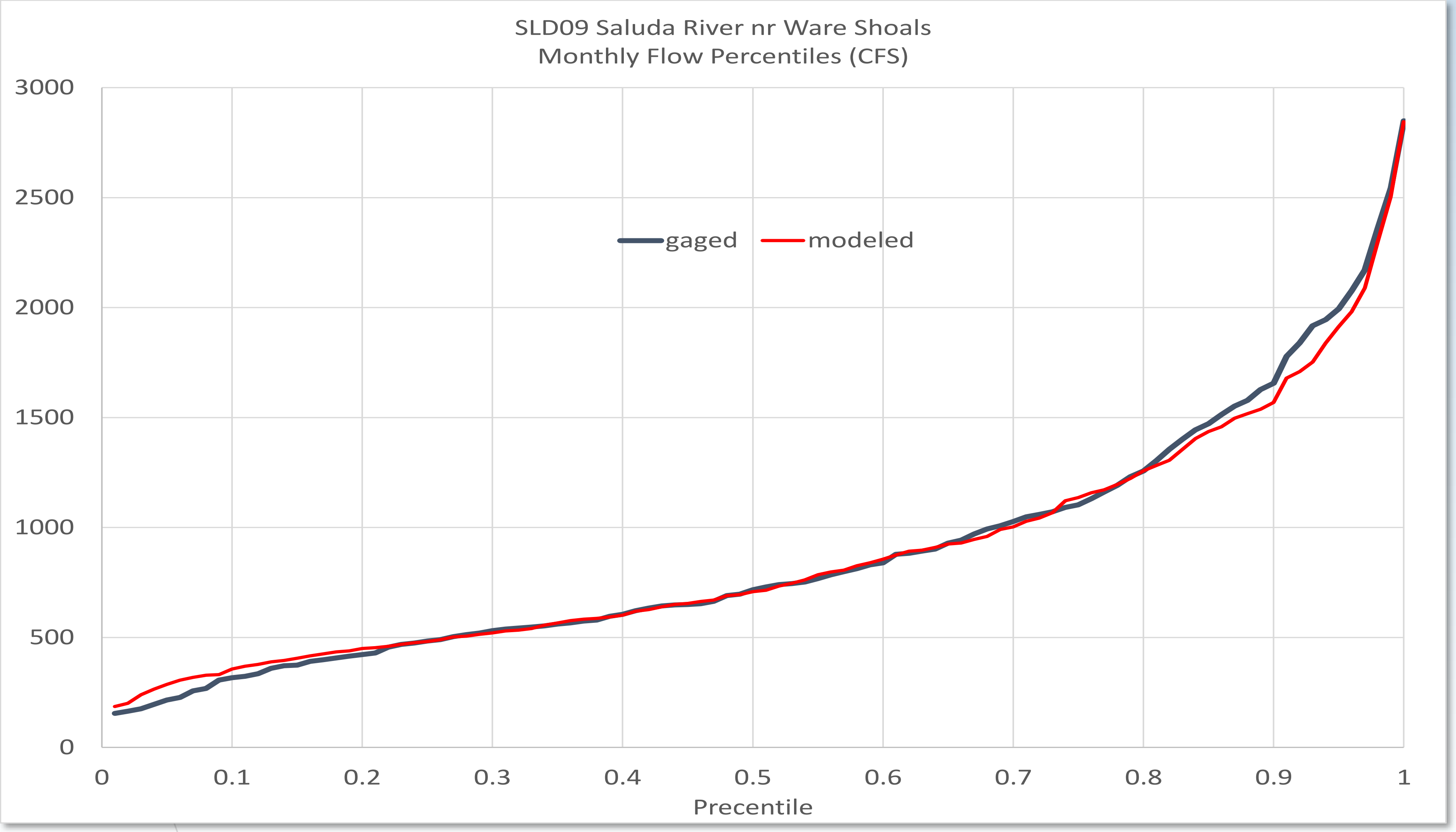
Timeseries Plots (Monthly/Daily Variability)



Annual and Monthly Mean (Seasonality and Water Balance)



Percentile Plots
(Extremes and Frequency)



Baseline Models and Training

- Following calibration, baseline models will be developed to provide basis for planning and management simulations
  - Reflect current withdrawals, discharges and operations

- Training will be offered once all models are complete

- Models will reside in the cloud (hosted virtual desktop)
  - Scalable
  - Consistent user experience
  - Facilitates model improvements and updates
  - Secure

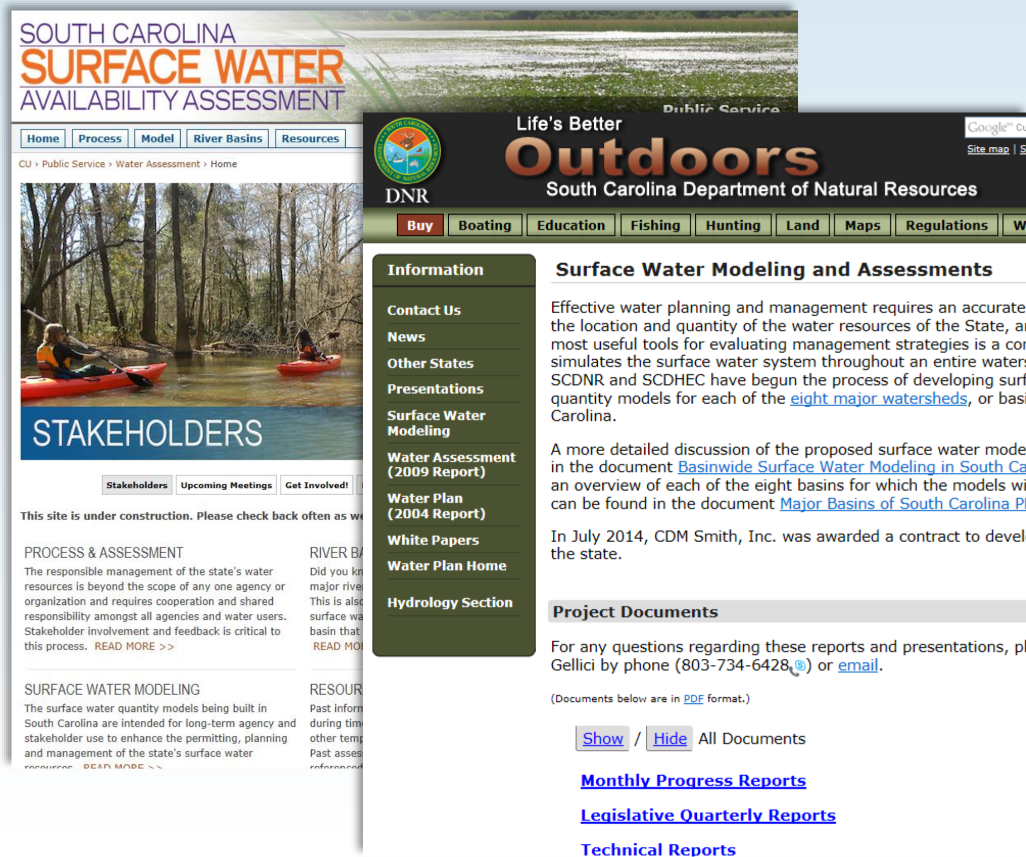
For More Information

On the Web

- www.scwatermodels.com
- DNR: http://www.dnr.sc.gov/water/waterplan/surfacewater.html

Contacts

- Joe Gellici, DNR
  - gellicij@dnr.sc.gov
- David Baize, DHEC
  - baized@dhec.sc.gov
- John Boyer, CDM Smith
  - boyerjd@cdmsmith.com



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