South Carolina Surface Water Quantity Modeling Project
Saluda Basin Meeting No. 1 – Model Framework
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
- 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.
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.
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
UNIMPAIRED FLOWS (UIF)

Saluda River Basin
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 =**
  
  \[
  \text{Measured Gage Flow} + \text{River Withdrawals} + \text{Reservoir Withdrawals} - \text{Discharge to Reservoirs} - \text{Return Flow} + \text{Reservoir Surface Evaporation} - \text{Reservoir Surface Precipitation} + \text{Upstream change in Reservoir Storage} + \text{Runoff from Previously Unsubmerged Area}
  \]

- **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

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

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 ungaged 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

- Lake Greenwood
- Lake Murray
- Table Rock Reservoir
- North Saluda Reservoir
- Saluda Lake
- Lake Rabon

Current or Former USGS Stream Gage Location

Major Streams:
- North Saluda River
- Middle Saluda River
- South Saluda River
- Saluda River
- Congaree River

States:
- Georgia
- North Carolina
- South Carolina
Saluda Basin Withdrawals – Energy

- Saluda Basin
- Withdrawals
- Energy

- Thermolectric Plant
- Hydropower Plant

- Saluda Lake Hydro
- Piedmont Hydro
- Upper and Lower Pelzer Hydro
- Holiday Bridge Hydro
- Ware Shoals Hydro
- Buzzards Roost Hydro
- Boyd’s Mill Hydro
- SCE&G McMeekin Station
- Columbia Hydro (on Broad)
- Saluda Hydro
- Duke Power Lee Steam Station (Closed in 2014)
Saluda Basin Withdrawals – Agriculture

- Beechwood
- Merritt Bros
- Twin Oaks
- Stonybrook
- Satterwhite
- LesLea
- Overbridge
- Bush
- Mayer
- Titan
- Frick
- Watson
- Clinton Sease
- James Sease
Saluda Basin Discharges

- Savannah Broad
- Catawba Pee Dee
- Edisto
- Georgia
- North Carolina
- Santee

Active Discharge
Aggregated Discharge

Map showing the Saluda Basin Discharges with active and aggregated discharges indicated on the map.
Interbasin Transfers

Greenville
- Import from Savannah
- Export to Broad

Easley
- Export to Savannah

Williamston
- Import from Savannah

Belton-Honea Path
- Export to Savannah

City of Greenwood
- Export to Savannah

Laurens
- Import from Broad

NCWSA
- Export to Broad

Columbia
- Import from Broad
- Export to Catawba

SCWSA
- Export to Savannah
- Export to Edisto
Saluda Basin – SWAM Framework

Figure 1. Saluda River Basin SWAM Model Framework

**Model Objects**
- Tributary
- Discharge
- Reservoir
- USGS Stream Gage

**Water User Objects**
- Municipal
- Hydropower or Instream Flow
- Agriculture (Irrigation)
- Thermoelectric
- Industrial

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Import or Export (Interbasin Transfer)
Saluda River Basin

MODEL SETUP
Reservoir Input Form

- Reservoir Name:
- Delete Node
- Storage Capacity (Af)
- Initial Storage (Af)
  - Offline
  - Online

Evaporation
- Inches/day
- % Volume
- Input Timeseries
- Monthly Rates
  - Month
  - Evap. Rates (in./day)
- Area-Capacity Table
  - Simple
  - Detailed
- Area (ac)

Reservoir Releases
- Receiving Stream:
  - Simple
  - Advanced
- Release Location (mi)
- User Defined Releases
- Month
- Min. Release (AFM)
- (CF)
Agricultural Water User Input Forms

- User Name: [Input Field]
- Supplemental Supply/Demand Alternatives:
  - Transbasin Import
  - Groundwater
- Blaney Criddle ET:
  - Original
  - Modified
- Irrigated Acres: 0
- Ditch Loss (%): 10
- Irrigation Efficiency (%): 90
- Elevation (ft abs): 0
- Latitude (deg): 40
- Climate:
  - Temp. (F):
    - Jan: 30
    - Feb: 35
    - Mar: 45
    - Apr: 55
    - May: 75
    - Jun: 80
    - Jul: 80
    - Aug: 80
    - Sep: 65
    - Oct: 50
    - Nov: 45
    - Dec: 40
  - Precip. (in.):
    - Jan: 0.5
    - Feb: 0.5
    - Mar: 0.5
    - Apr: 1.5
    - May: 1.5
    - Jun: 1.5
    - Jul: 1.9
    - Aug: 1.4
    - Sep: 1.1
    - Oct: 1.0
    - Nov: 0.8
    - Dec: 0.5
- Calculated River Headgate Demand
- Calculated Potential Consumptive Use of Irrigation Water

[Save / Calculate]
Instream Flow Input Form

Instream Flows
Water Right

**Instream Flow Name:**

**Delete Node**

**Target Stream:**

**Downstream Location (mi):**

**Priority Date**

1/1/2007

**Rules**

- Seasonal WR
- TNC IHA Methodology

**Avg. Monthly Flow Rights**

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(CFS)

**Comments:**

Save

Close
Saluda 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)
  – Reservoir storage timeseries
Calibration Result Graphs

- Pueblo Reservoir
  - Measured
  - Modeled

- Arkansas River at Canon City
  - Gaged
  - Modeled

- Arkansas River nr Avondale
  - Gaged
  - Modeled
  - Percentiles (likelihood of exceedance)