South Carolina Water Planning….
Planning for Which Drought?

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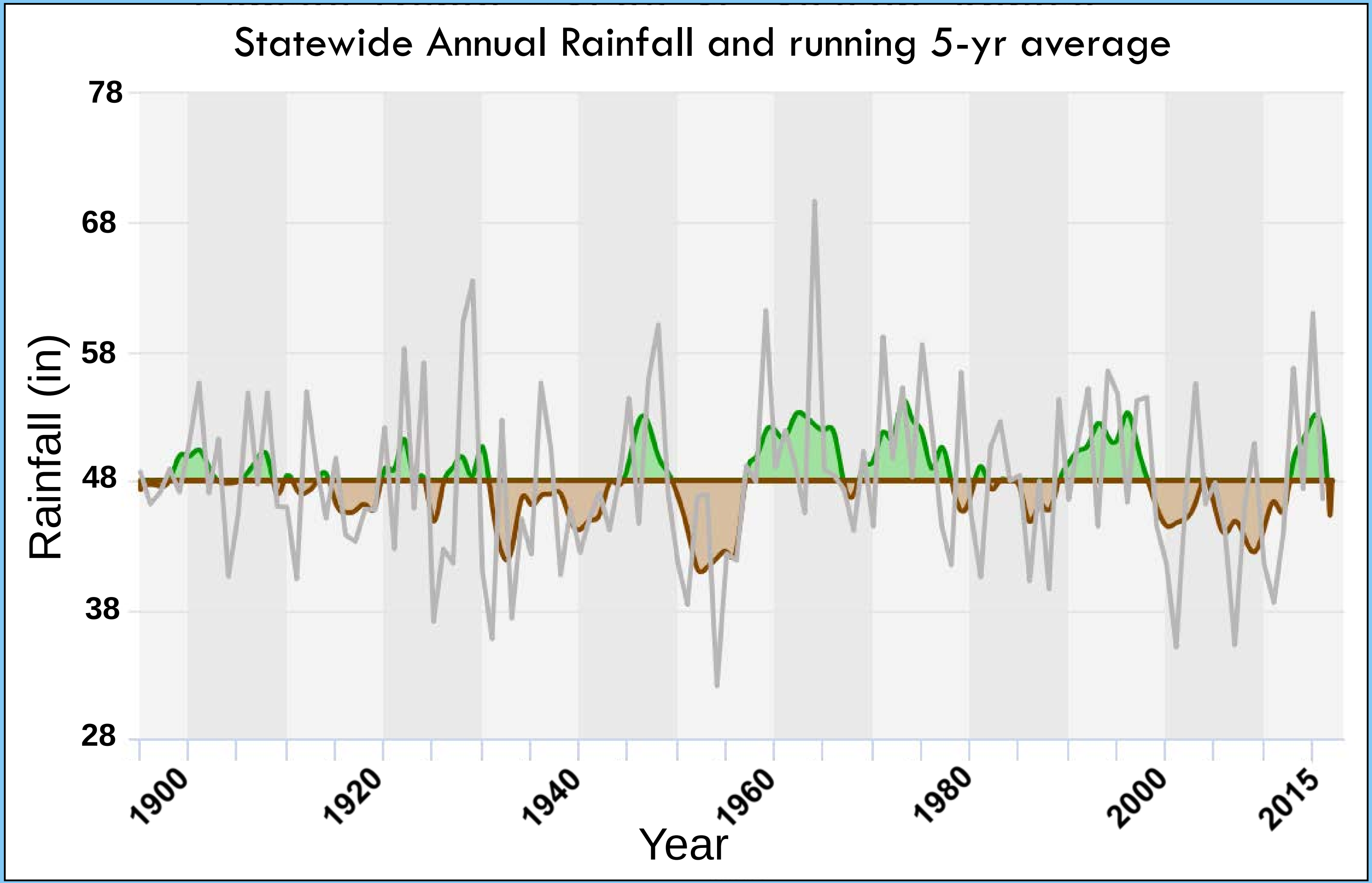
S.C. Department of Natural Resources

Climate Connections Workshop
Greenville, South Carolina
December 12, 2017

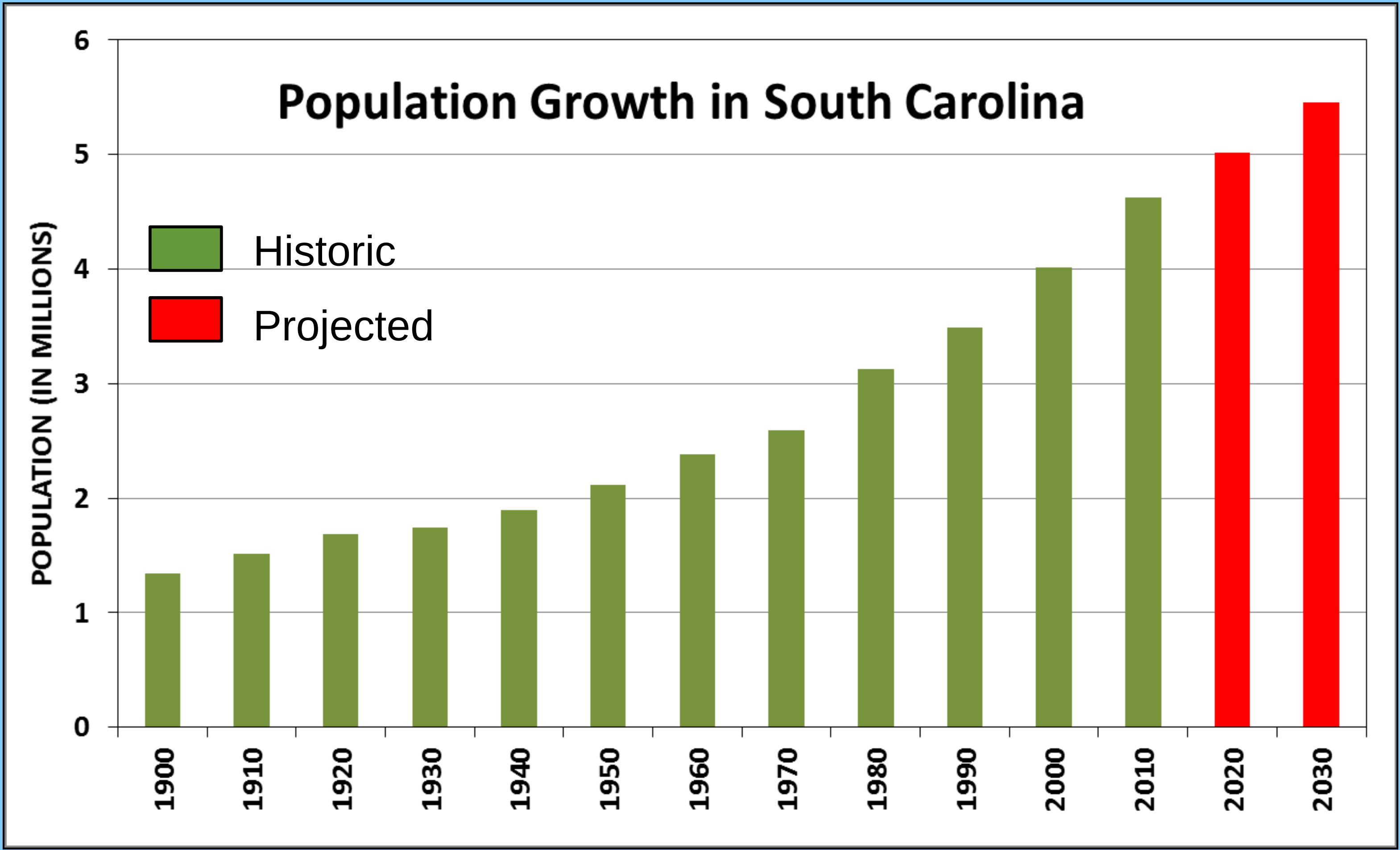
Recent droughts: (1998-2002, 2007-2008, 2011-2012) have stressed water resources and have highlighted the importance of planning



*Plot created by the Southern Climate Impacts Planning Program (SCIPP) – www.southernclimate.org

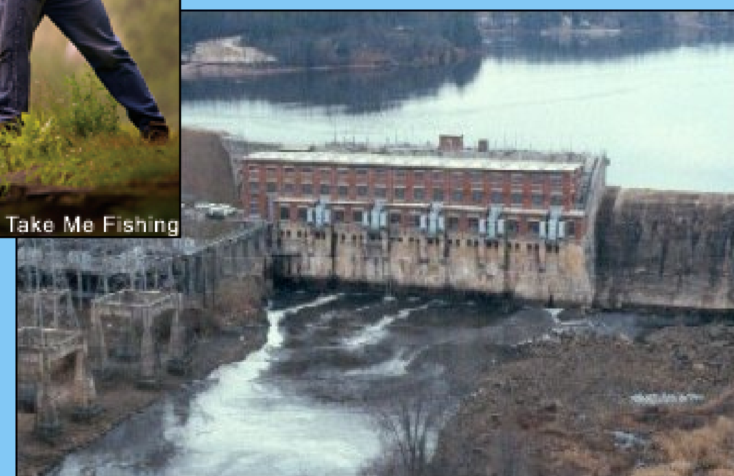
Why Water Planning?

- *Population Growth* – State population forecasted to increase by approximately ***18%*** by 2030
    - *Increased water demand*



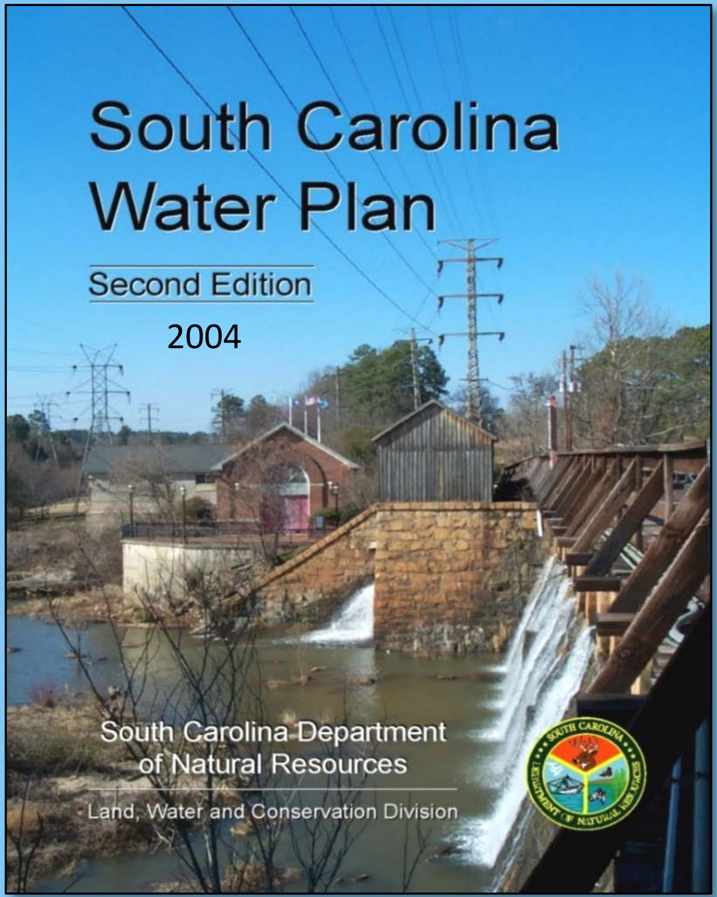
Source: U.S. Census Data, SC Department of Revenue and Fiscal Affairs

South Carolina’s Water Resources



The goal of regional water planning is to develop a water-resources management plan that ensures that an adequate and reliable supply of clean water will be available to sustain all future uses, both instream and offstream.

A Brief History of Water Planning…

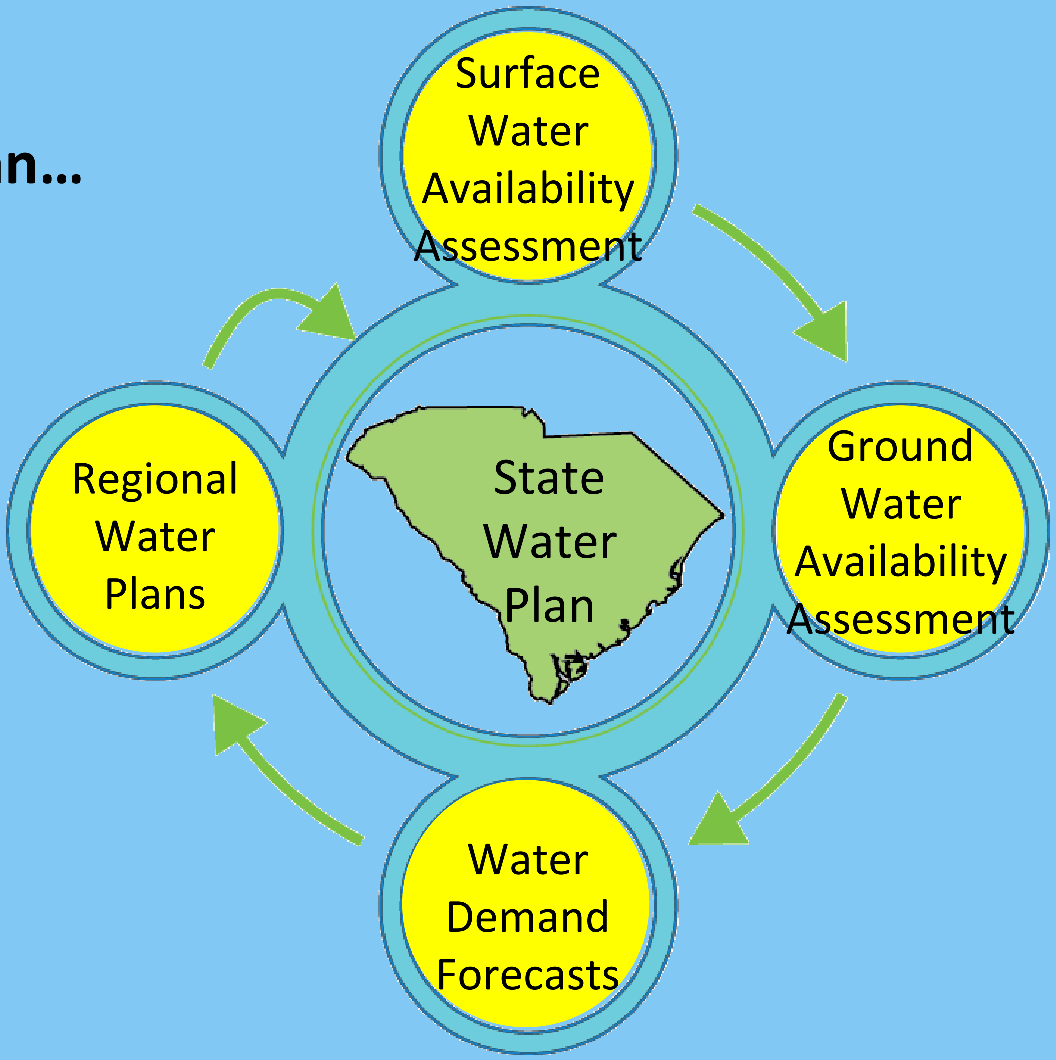


- First Edition published in 1998
- In 2004, DNR published the second edition of the South Carolina Water Plan incorporating lessons learned from the drought of 1998-2002.
- One recommendation was for the development of regional water plans for each major river basin in the State.
- 10 years later – SCDNR and SCDHEC initiated the first step towards these regional water plans.

Regional Planning for South Carolina's eight major river basins…

Models will be developed for each of these basins, the same basins used by DHEC for water-quality assessments and for managing interbasin transfers of water.

Steps involved in developing regional water plans and updating the State Water Plan…



"The effective management of South Carolina's water resources is beyond the scope of any one agency or organization and will require cooperation and shared responsibility among federal, state, and local agencies, as well as public and private parties."

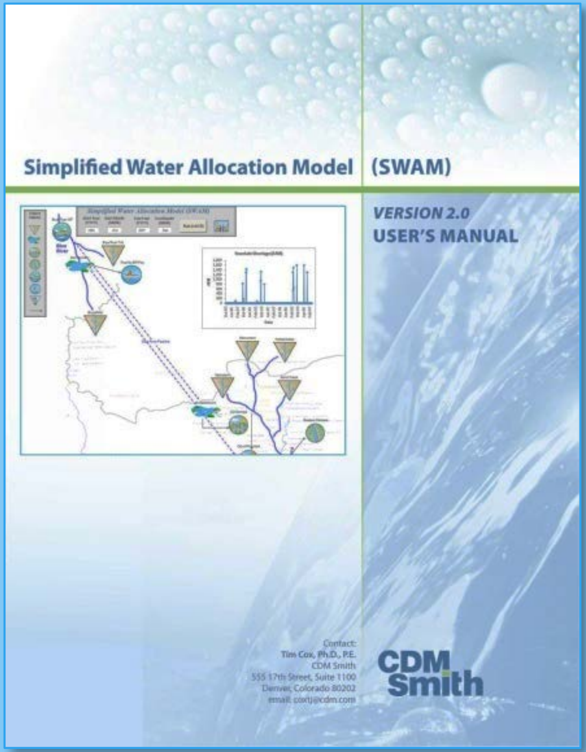
South Carolina Water Plan (2004)

Step 1. Surface-Water Availability Assessment

<u>Purpose</u>: Develop surface water quantity models for each basin.

(Two and a half-year project with the CDM Smith, Inc., Clemson, and DHEC.)

- In August 2014, CDM Smith, Inc. was awarded a contract to develop surface-water quantity models for each basin using its *Simplified Water Allocation Model* (SWAM) modeling tool.
- Stakeholder meetings for the project were facilitated by Clemson University with support from CDM Smith, DNR, and DHEC.
- Final models submitted to SCDNR in June 2017



CDM Smith

John Boyer (lead)
Kirk Westphal
Tim Cox
Nina Caraway

Jeff Allen (lead)
Lori Dickes
Katie Buckley

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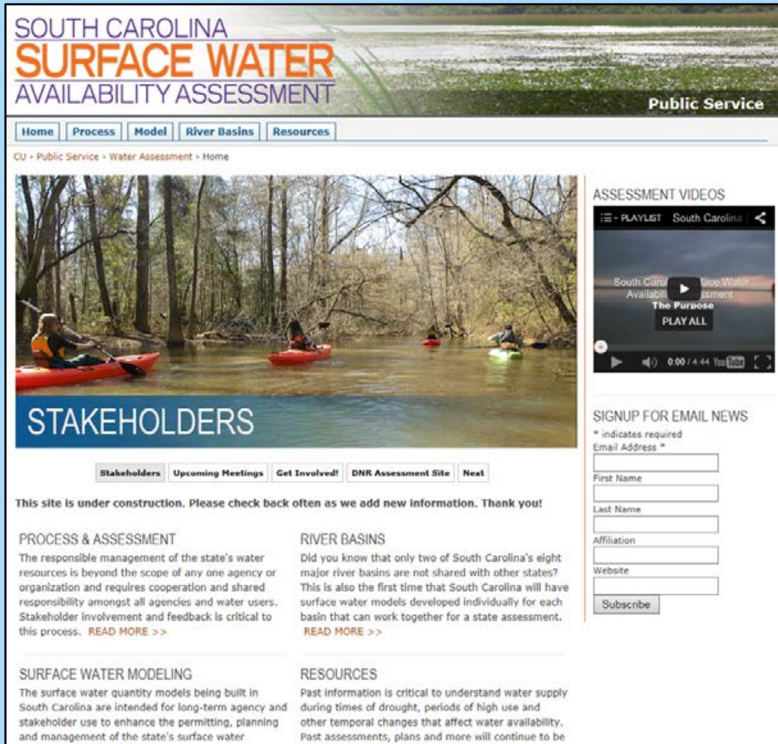
Stakeholder Meetings

- Two stakeholder meetings per basin
- Facilitated by Clemson University



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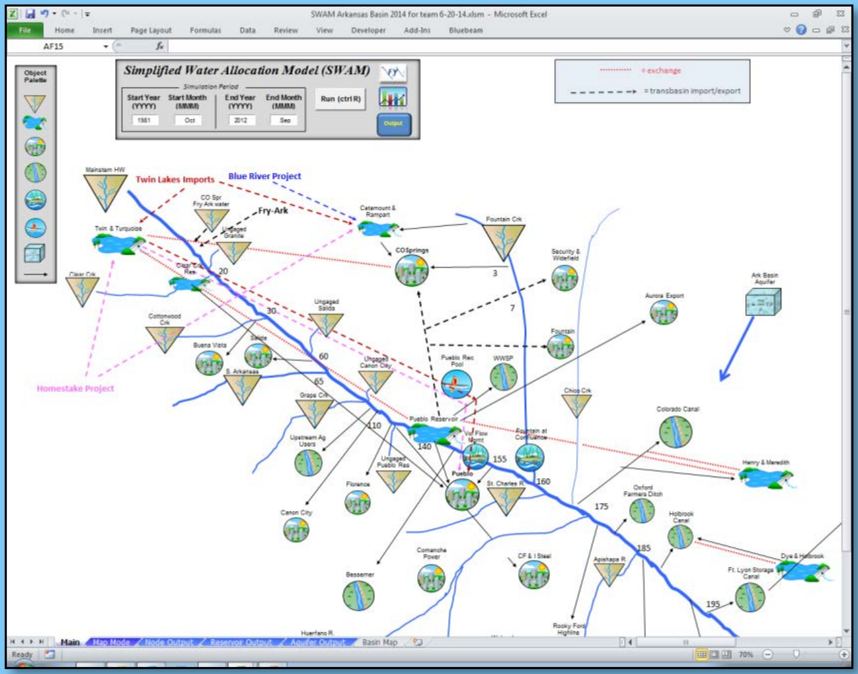
CDM Smith's Simplified Water Allocation Model (SWAM)

- Developed to facilitate regional/statewide water allocation analysis
- Resides in Microsoft Excel, Object Oriented / Point and Click

- Features:
  - Daily or monthly time step
  - Multi-source water supply portfolios
  - Reservoir modeling and associated operating rules
  - Water discharge objects
  - Instream flow object for prioritized seasonal environmental flows
  - Conservation and reuse demand management options



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

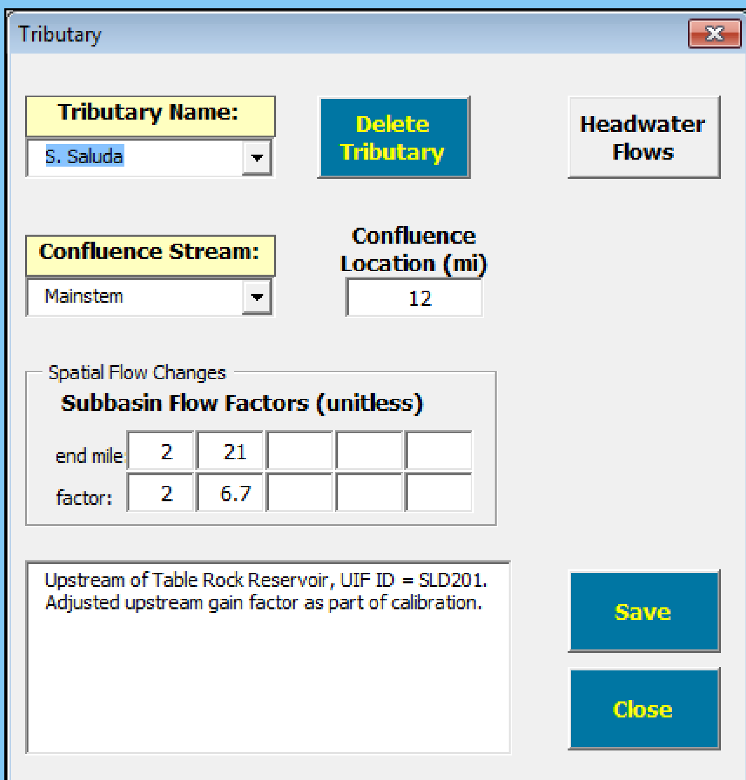
Water Allocation Models

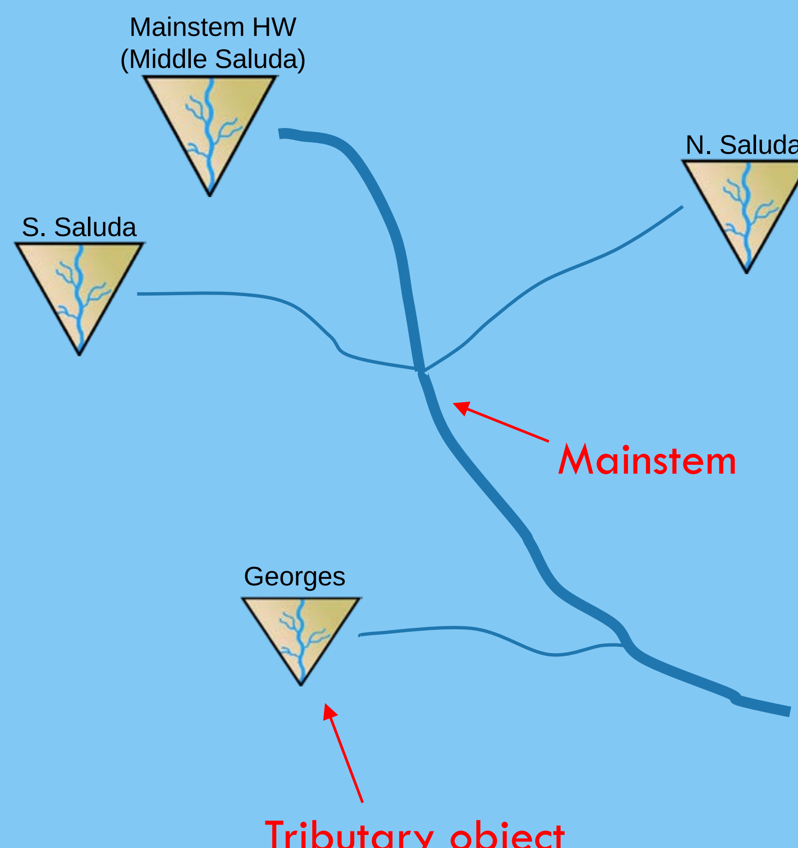
Calculate legally and/or physically available water in a river system

- Examples: OASIS, CHEOPS, RiverWare and SWAM

Building a SWAM Model…

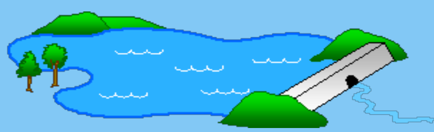
- Define mainstem and add appropriate tributaries
  - Headwater flows defined for each mainstem and tributary object
    - Estimated from unimpaired USGS streamflow records
  - Headwater flows – fundamental model input

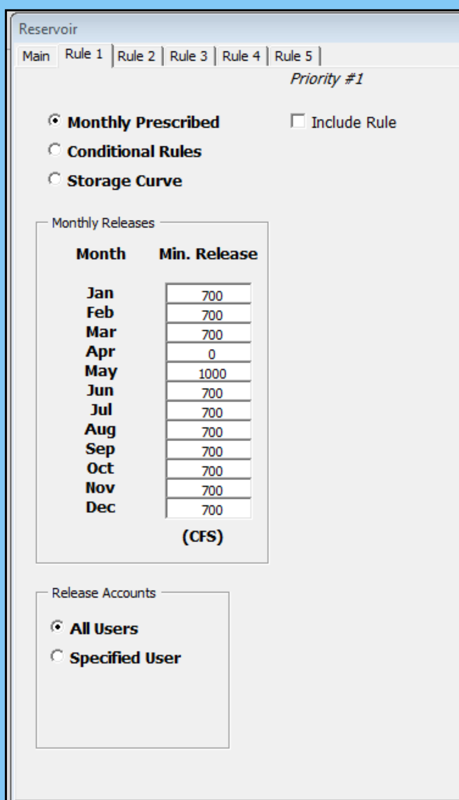


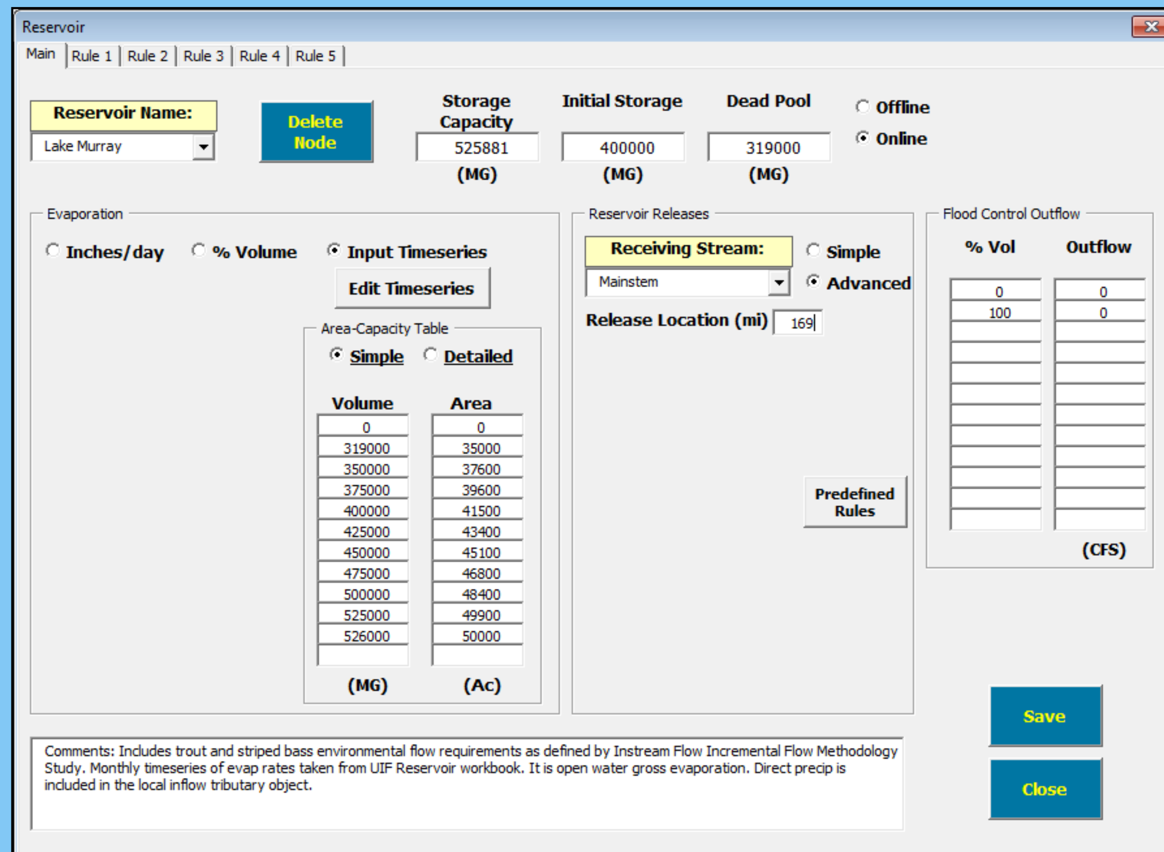


Reservoir Objects

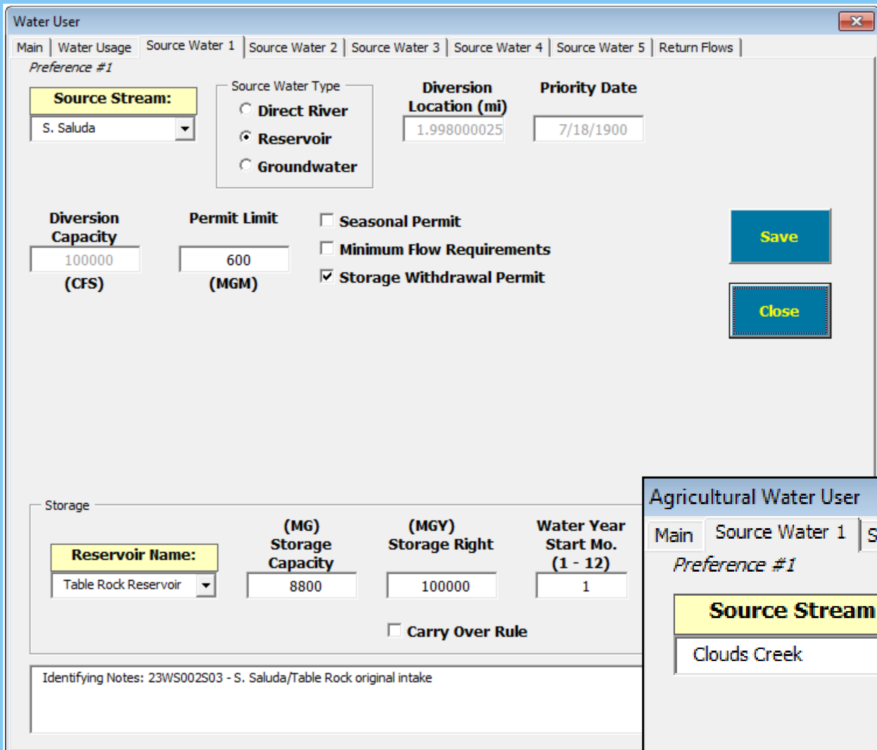
Reservoir







Water Use Objects – Water Supply, Industry, Irrigation, Golf Course, and Energy



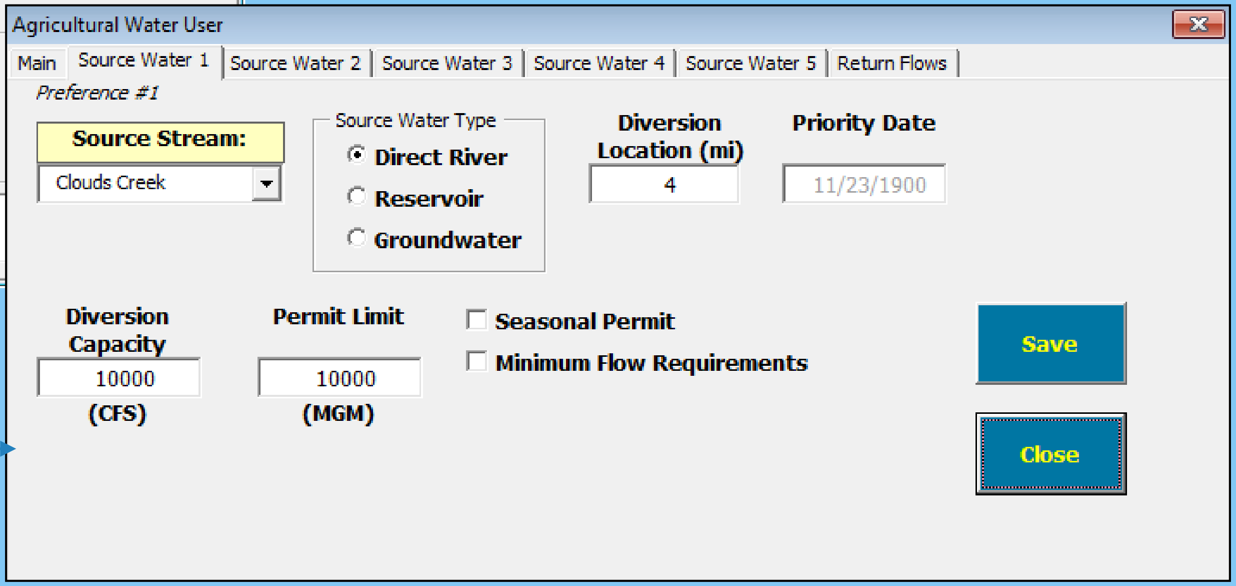
WS: Greenville

PT: SCE&G

GC: Cliffs Club

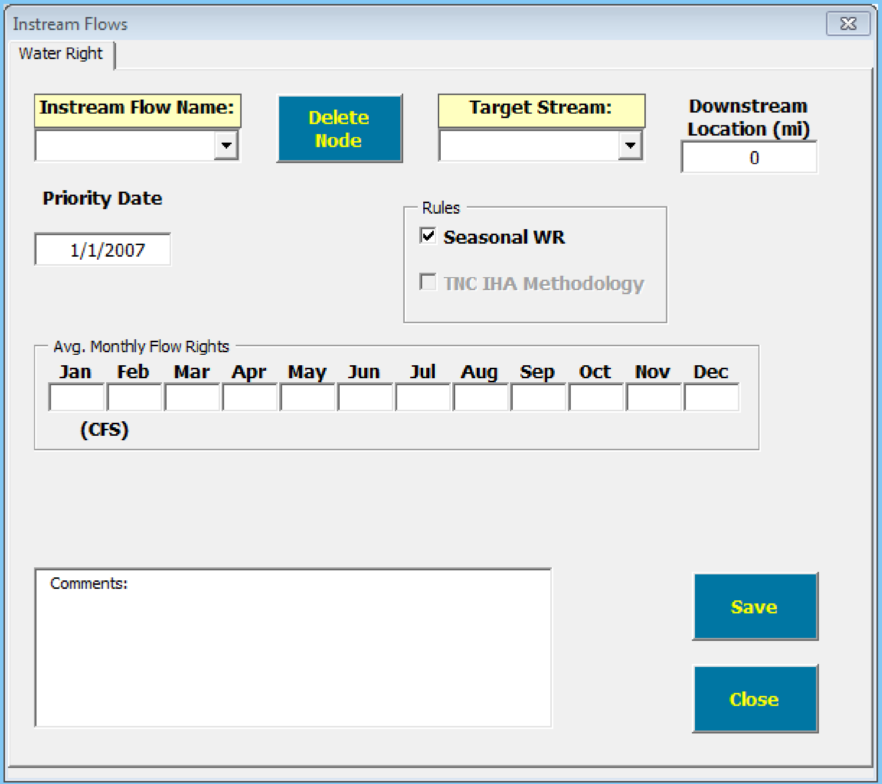
MI: Vulcan

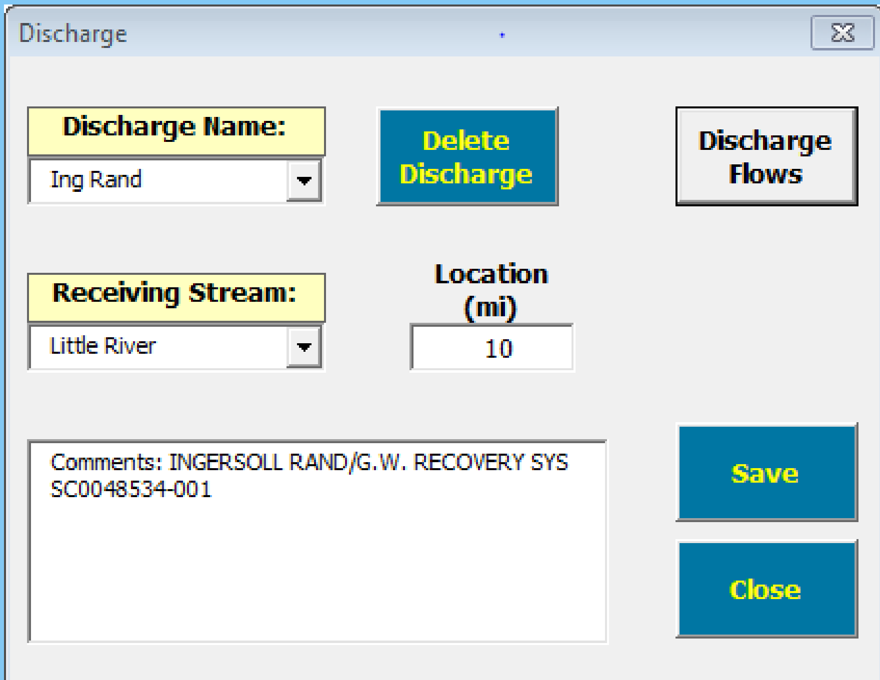
IR: Titan



Instream Flow Objects

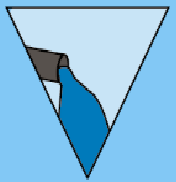
Instream Flow



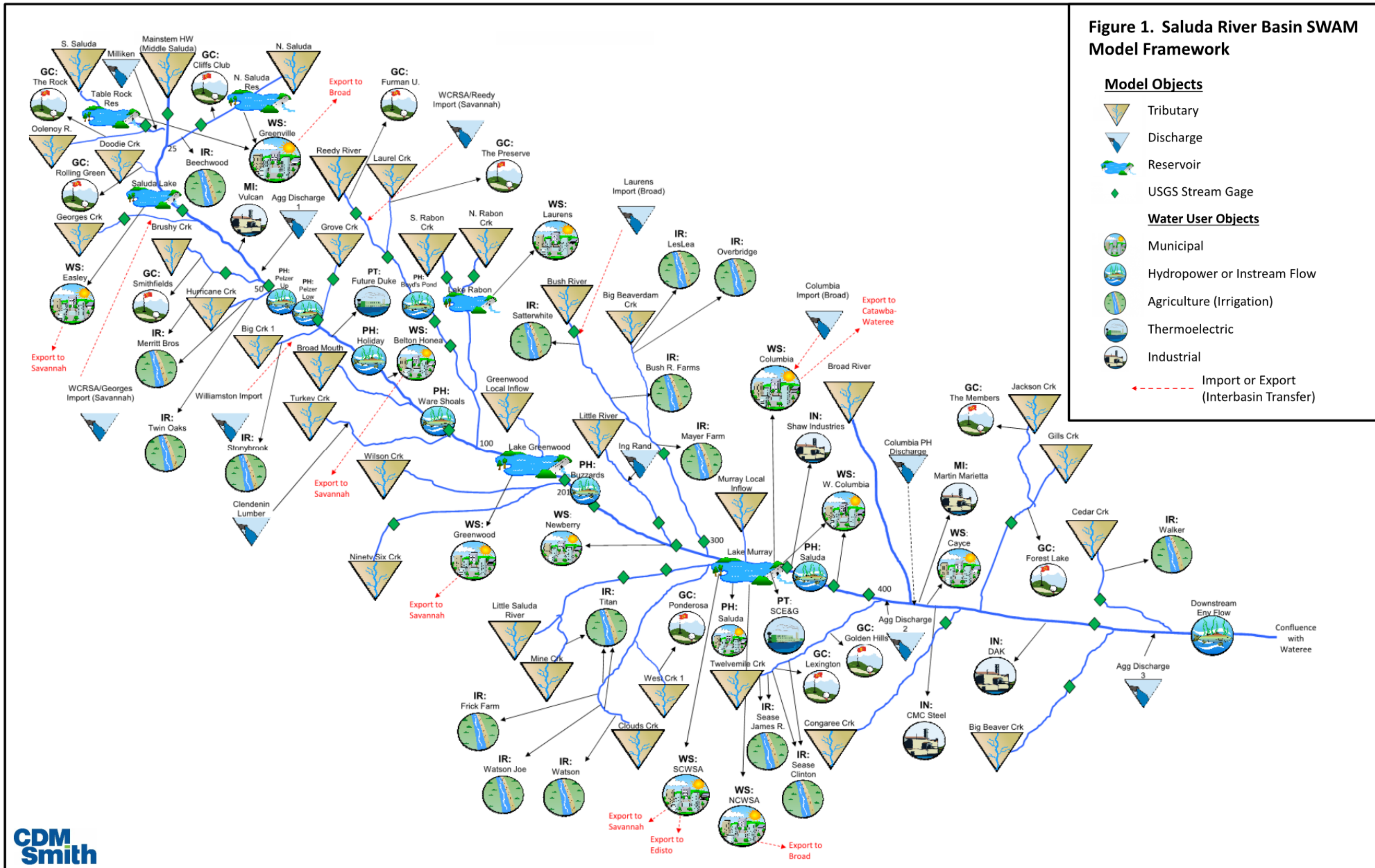


Discharge Objects

Ing Rand



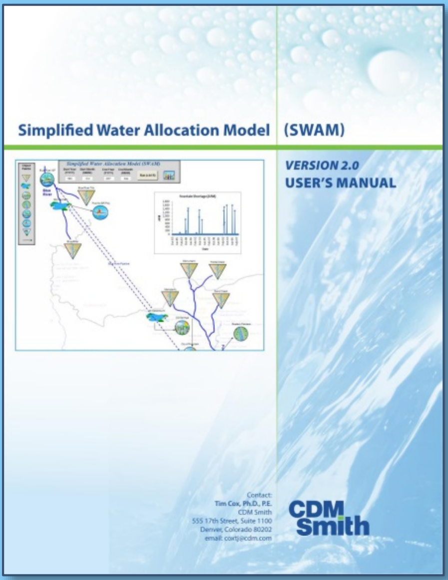
Model Schematic – Saluda Basin

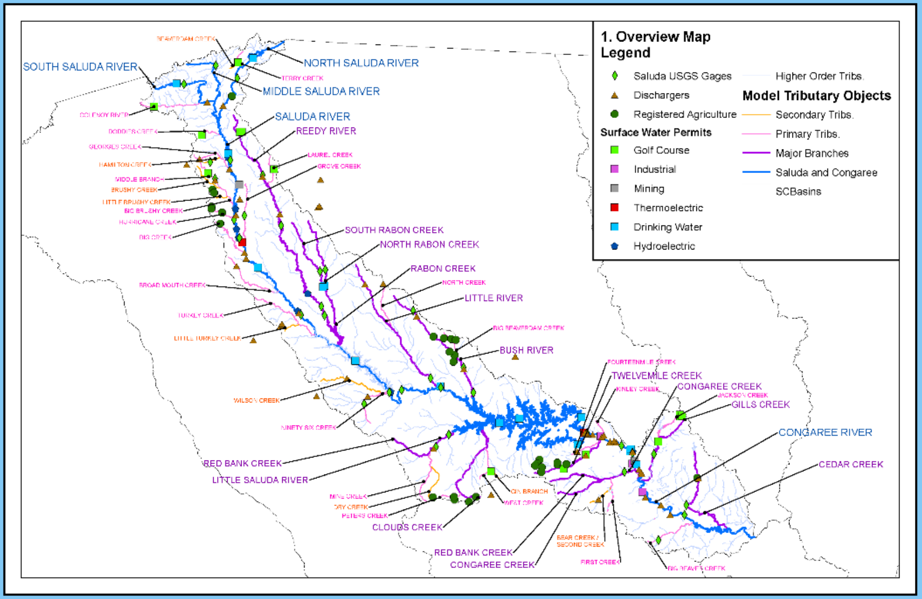


CDM Smith

Surface Water Assessment – SWAM Model

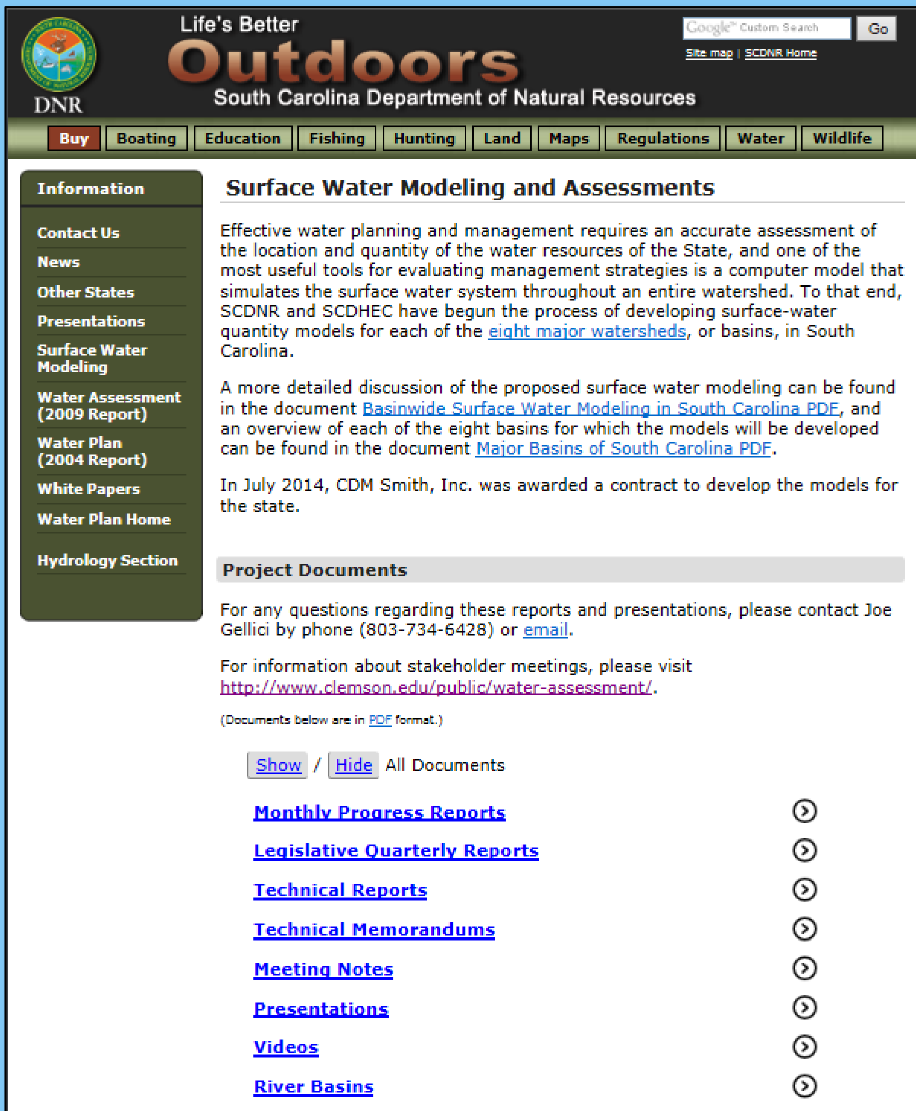
- Models will be used to:
  - Determine surface-water availability
  - Predict where and when water shortages might occur
  - Test alternative water-management strategies
  - Help resolve water disputes
  - Evaluate IBTs and withdrawal permits (DHEC)
  - Support development of drought management plans
- *Ultimately, will support the development of Regional or Basin water plans*





On the Web at DNR

http://www.dnr.sc.gov/water/waterplan/surfacewater.html



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Surface Water Modeling and Assessments

Effective water planning and management requires an accurate assessment of the location and quantity of the water resources of the State, and one of the most useful tools for evaluating management strategies is a computer model that simulates the surface water system throughout an entire watershed. To that end, SCDNR and SCDHEC have begun the process of developing surface-water quantity models for each of the eight major watersheds, or basins, in South Carolina.

A more detailed discussion of the proposed surface water modeling can be found in the document Basinwide Surface Water Modeling in South Carolina PDF, and an overview of each of the eight basins for which the models will be developed can be found in the document Major Basins of South Carolina PDF.

In July 2014, CDM Smith, Inc. was awarded a contract to develop the models for the state.

Project Documents

For any questions regarding these reports and presentations, please contact Joe Gellici by phone (803-734-6428) or email.

For information about stakeholder meetings, please visit http://www.clemson.edu/public/water-assessment/.

(Documents below are in PDF format.)

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- Monthly Progress Reports
- Legislative Quarterly Reports
- Technical Reports
- Technical Memorandums
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- Presentations
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- River Basins

Monthly Progress Reports

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Technical Reports

Technical Memorandums

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River Basins

Broad

Edisto

Salkehatchie

Santee

Sal

Challenges of SC Basin-Scale Modeling

- Each basin has a unique set of hydrologic characteristics
  - Reservoir dominated (Catawba, Savannah) versus “freely flowing” (Edisto, Salkehatchie)
  - Differences in runoff and baseflow characteristics between basins and within a basin

“One size fits all” modeling approach may not be appropriate for SC – May need to explore other models or tools in some basins to supplement the SWAM model

- Share four basins with other two other States (GA, NC)
- Lack of streamflow gaging stations and/or lack of stations with long periods of record also poses challenges
- Very aggressive schedule for completion of the SWAM models.
  - SCDNR and SCDHEC Hydrologists are reviewing and “fine-tuning” several of the models

Step 2. Groundwater Availability Assessment

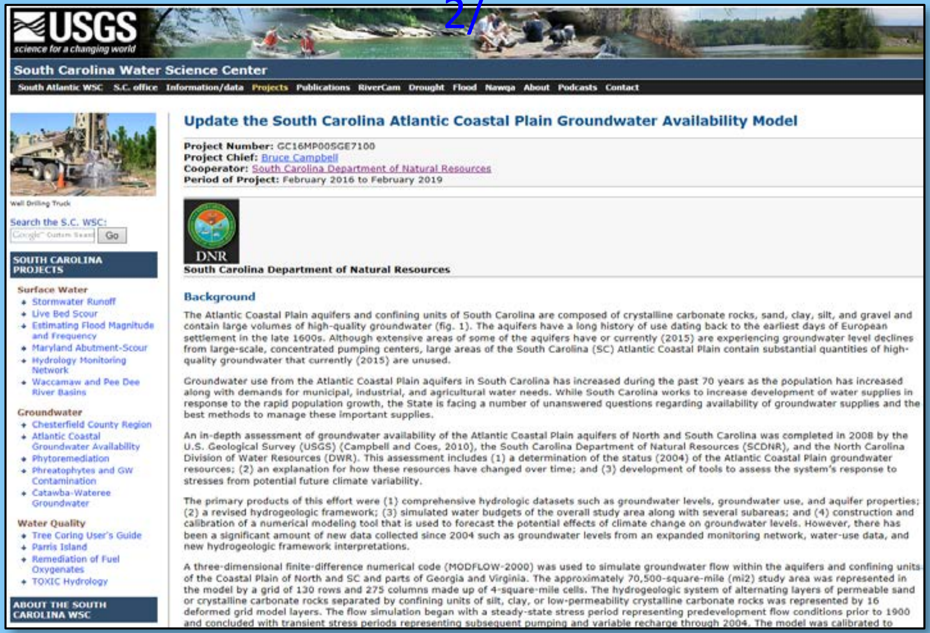
Purpose: Update the 2010 groundwater flow model of the S.C. Coastal Plain.

(Three-year project with the U.S. Geological Survey.)

The model will be used to:

- Determine groundwater availability.
- Evaluate the impacts that pumping has on groundwater and surface water resources and on other groundwater users.
- Evaluate future withdrawal scenarios to maximize groundwater use and minimize undesirable effects of pumping.
  - *Plan is to include climate change scenarios*

USGS webpage for the project:
http://sc.water.usgs.gov/projects/gw_availability2/



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- Hydrology Monitoring Network
- Waccamaw and Pee Dee River Basins

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- Chesterfield County Region
- Atlantic Coastal Groundwater Availability
- Phytoremediation
- Phreatophytes and GW Contamination
- Catawba-Wateree Groundwater

Water Quality
- Tree Coring User's Guide
- Parris Island
- Remediation of Fuel Oxygenates
- TOXIC Hydrology

ABOUT THE SOUTH CAROLINA WSC

Update the South Carolina Atlantic Coastal Plain Groundwater Availability Model

Project Number: GC16MP00SGE7100
Project Chief: Bruce Campbell
Cooperator: South Carolina Department of Natural Resources
Period of Project: February 2016 to February 2019

DNR
South Carolina Department of Natural Resources

Background

The Atlantic Coastal Plain aquifers and confining units of South Carolina are composed of crystalline carbonate rocks, sand, clay, silt, and gravel and contain large volumes of high-quality groundwater (fig. 1). The aquifers have a long history of use dating back to the earliest days of European settlement in the late 1600s. Although extensive areas of some of the aquifers have or currently (2015) are experiencing groundwater level declines from large-scale, concentrated pumping centers, large areas of the South Carolina (SC) Atlantic Coastal Plain contain substantial quantities of high-quality groundwater that currently (2015) are unused.

Groundwater use from the Atlantic Coastal Plain aquifers in South Carolina has increased during the past 70 years as the population has increased along with demands for municipal, industrial, and agricultural water needs. While South Carolina works to increase development of water supplies in response to the rapid population growth, the State is facing a number of unanswered questions regarding availability of groundwater supplies and the best methods to manage these important supplies.

An in-depth assessment of groundwater availability of the Atlantic Coastal Plain aquifers of North and South Carolina was completed in 2008 by the U.S. Geological Survey (USGS) (Campbell and Coes, 2010), the South Carolina Department of Natural Resources (SCDNR), and the North Carolina Division of Water Resources (DWR). This assessment includes (1) a determination of the status (2004) of the Atlantic Coastal Plain groundwater resources; (2) an explanation for how these resources have changed over time; and (3) development of tools to assess the system's response to stresses from potential future climate variability.

The primary products of this effort were (1) comprehensive hydrologic datasets such as groundwater levels, groundwater use, and aquifer properties; (2) a revised hydrogeologic framework; (3) simulated water budgets of the overall study area along with several subareas; and (4) construction and calibration of a numerical modeling tool that is used to forecast the potential effects of climate change on groundwater levels. However, there has been a significant amount of new data collected since 2004 such as groundwater levels from an expanded monitoring network, water-use data, and new hydrogeologic framework interpretations.

A three-dimensional finite-difference numerical code (MODFLOW-2000) was used to simulate groundwater flow within the aquifers and confining units of the Coastal Plain of North and SC and parts of Georgia and Virginia. The approximately 70,500-square-mile (mi2) study area was represented in the model by a grid of 130 rows and 275 columns made up of 4-square-mile cells. The hydrogeologic system of alternating layers of permeable sand or crystalline carbonate rocks separated by confining units of silt, clay, or low-permeability crystalline carbonate rocks was represented by 16 deformed grid model layers. The flow simulation began with a steady-state stress period representing predevelopment flow conditions prior to 1900 and concluded with transient stress periods representing subsequent pumping and variable recharge through 2004. The model was calibrated to

Bruce Campbell (lead)
Greg Cherry
Jason Fine

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Alex Butler (lead)
Joe Gellici
Andrew Wachob

Step 3. Water-Demand Forecasts

Purpose: Develop water-demand forecasts for each of the 8 basins

- Technical Advisory Committee will be developed to oversee the development of the forecasts.
- Pilot study: methodologies and forecasts will first be developed for the Savannah River basin.
- Multi-year project collaboration with the U.S. Army Corps of Engineers and Clemson University.
- Methodologies will be applied to other basins.

Forecasts from 2015-2065 in 5- and 10-year intervals for:

1. Public supply
2. Domestic supply
3. Agriculture
4. Industry
5. Power
6. Golf Course

DNR

Alex Pellett (lead)

CLEMSON UNIVERSITY

Dr. Jeff Allen
Dr. Thomas Walker III

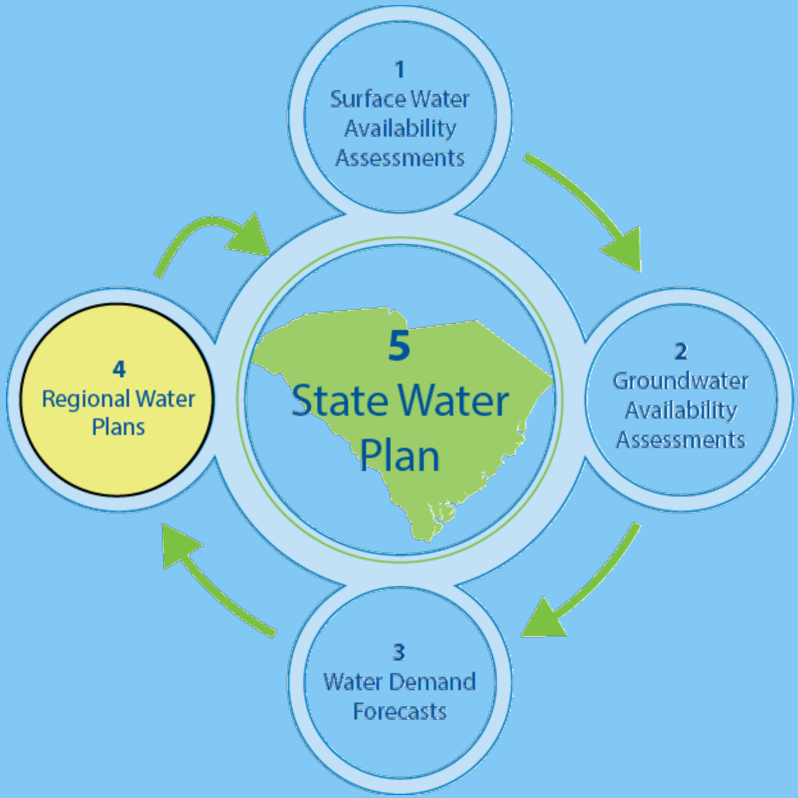
US Army Corps of Engineers

Colt Bowles
Holly Carpenter
Jesse Helton

Step 4. Regional (Basinwide) Water Plans

Using the models and forecasts, and with oversight from State agencies, stakeholders will begin the process of developing regional water plans for each basin. This step includes:

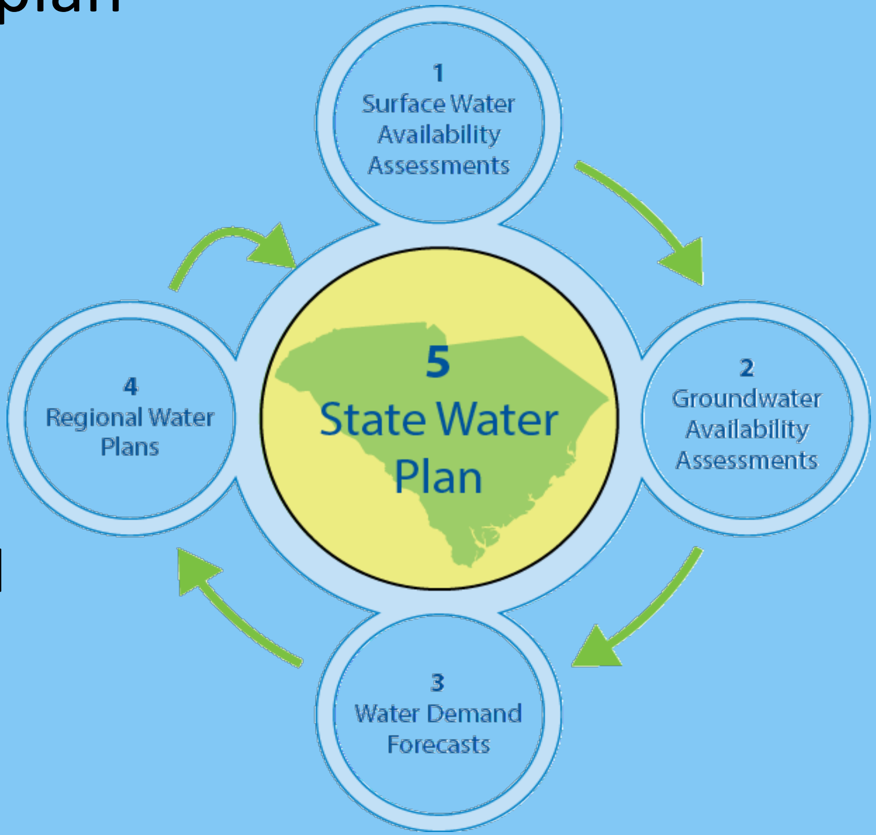
- The formation of basin advisory councils
- *An evaluation of future water availability*
  - *A gap-analysis to determine where and when shortages will occur*
  - *Reservoir safe yield studies*
- An assessment of management strategies to meet the future demands or to plan for potential changes in water availability:
  - Demand Side (Water conservation measures, drought management plans)
  - Supply side (new water sources)



Step 5. Update the *State* Water Plan

Upon completion of the regional water plans, the State water plan will be updated by DNR.

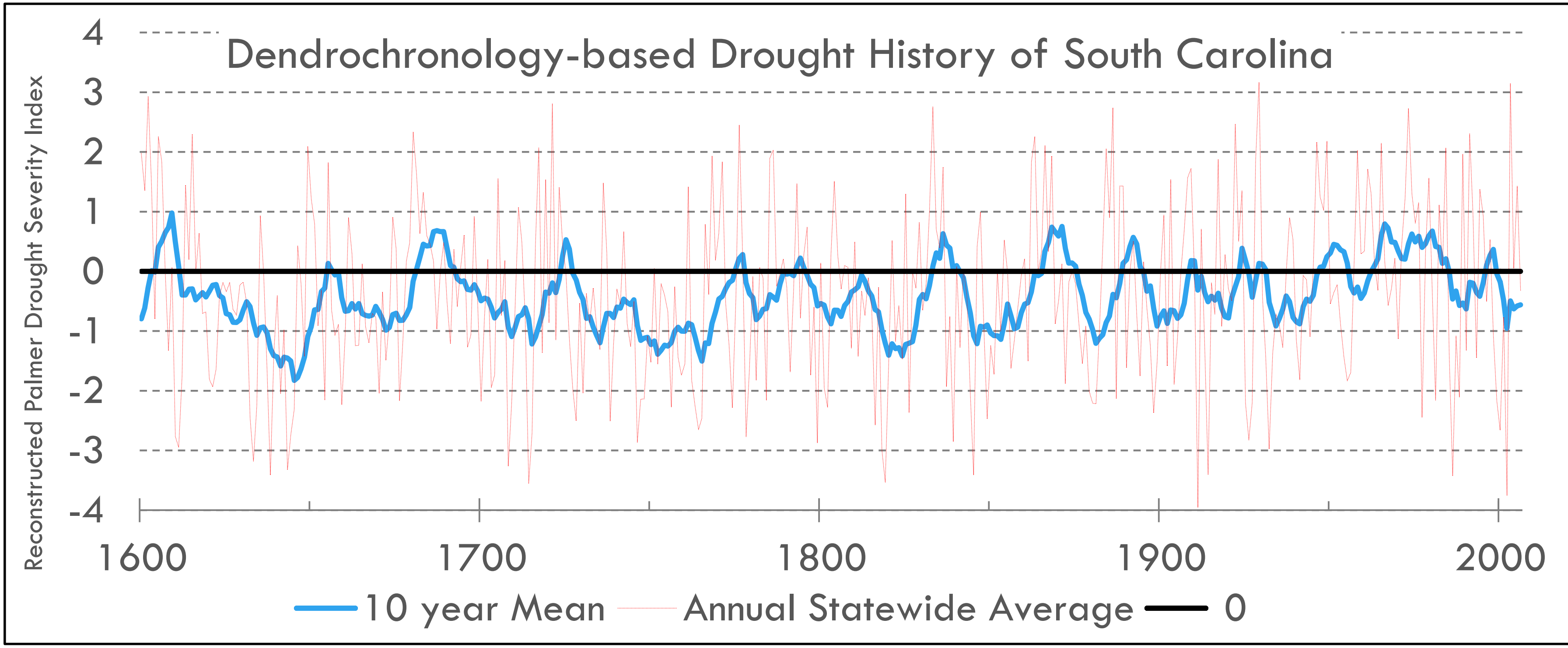
- Assess the overall condition of water resources in the State
- Evaluate statewide trends in water use and availability
- Offer water-resource policy and program recommendations
- Introduce innovative practices

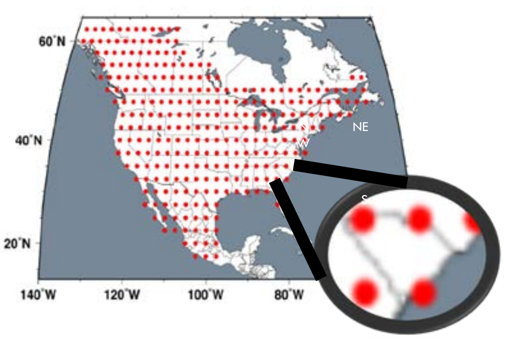


Evaluating Future Water Availability…

- Typically, the determination of water shortages and/or safe yield estimates are based on a basin's drought of record
  - Water allocation models assume stationarity - the past is statistically the same as the future
  - Streamflow records extend back approximately 80 years at most
  - Approach implemented in other states (Texas, for example)
  - Risky assumption!
  - Dendro-climatology studies
    - suggest 20th century may have been relatively wet
    - provide evidence for much more severe drought in preceding centuries

Historic droughts: Dendro-climatology studies show recent droughts may be relatively minor compared to droughts preceding 20^{th} century





Post-1600 estimates based on ~30 trees.

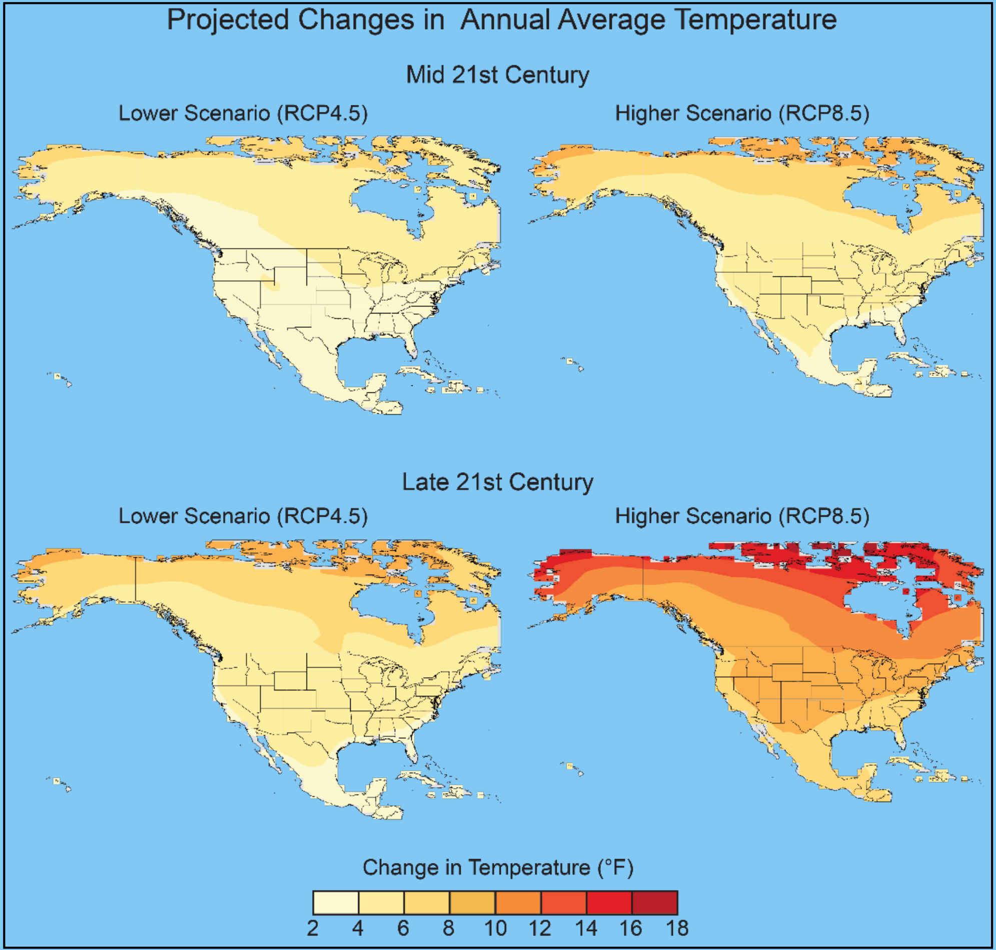
DATA CITATION: Cook, E.R., et al. 2008.
North American Summer PDSI Reconstructions, Version 2a.
IGBP PAGES/World Data Center for Paleoclimatology
Data Contribution Series # 2008-046.
NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.

http://iridl.ldeo.columbia.edu/SOURCES/.LDEO/.TRL/.NADA2004/.pdsi-atlas.html

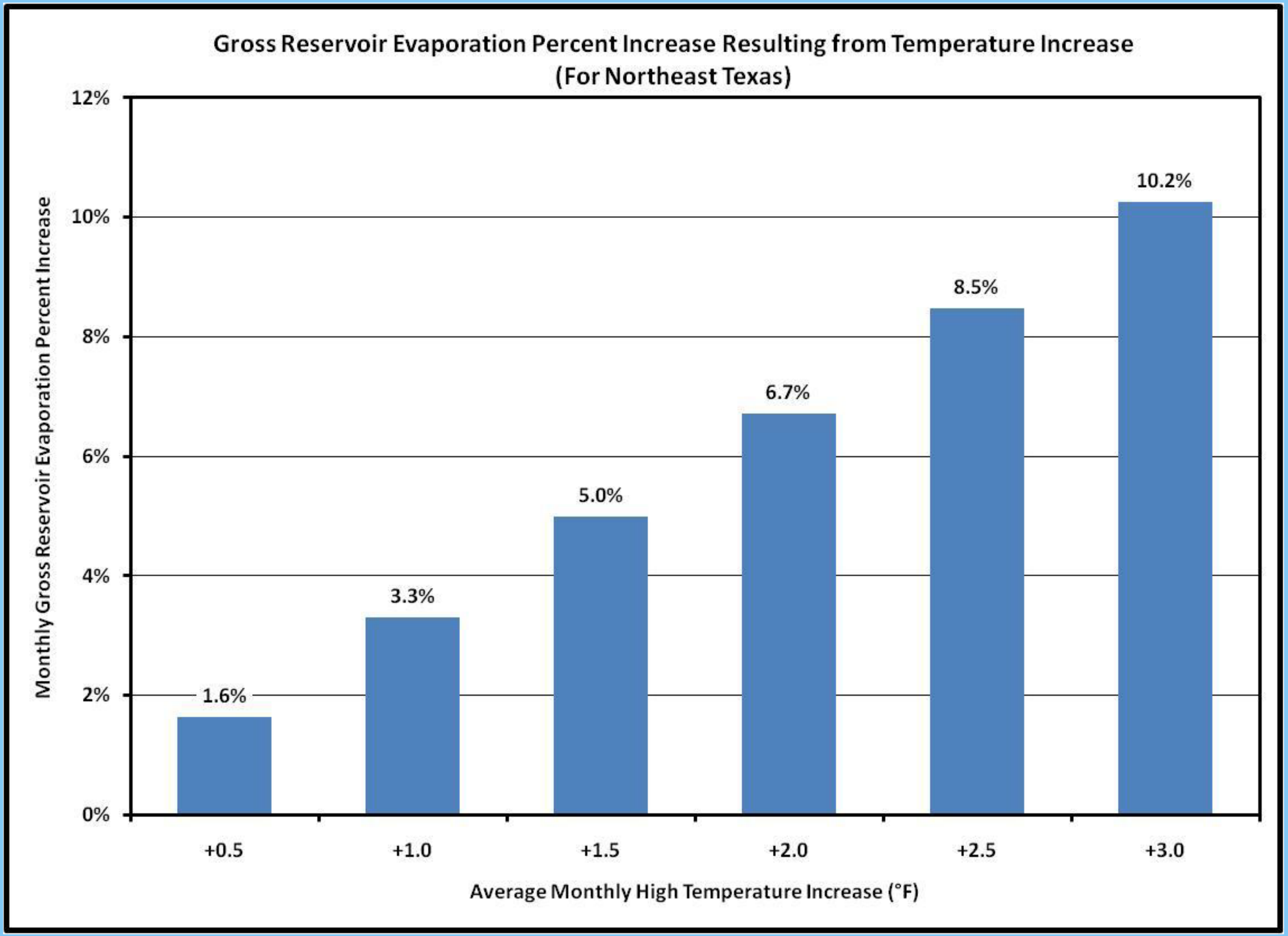
How could climate change affect future drought?

- Potential impacts
  - Changes in the amounts and distribution of rainfall
  - Increases in evapotranspiration
  - Changes in streamflow and/or reservoir inflow
  - Increases in reservoir evaporation
  - Changes in water demand

(adapted from Water Research Foundation Web Report – 4304 in the Catawba-Wateree Basin)



Vose et. al., 2017, Fourth National Climate Assessment, Chapter 6.



Sources: NCDC 2010, TWDB 2010

Figure 4.7 Percent increase in gross reservoir evaporation resulting from potential increases in monthly high temperatures in northeast Texas

(included in Web Report #4304 from the Water Research Foundation)

Considerations for incorporating potential drought scenarios into South Carolina water planning ….

- Should climate change scenarios be included in the water planning process?
- Downscaled global climate models provide temperature and rainfall information:
    - SW Models
        - Require evaporation and streamflow inputs - what are appropriate methods to convert changes in temperature and rainfall into changes in evaporation and streamflows?
        - Application may more applicable to basins with reservoirs
    - GW Models
        - Recharge module uses direct inputs of rainfall and temperature,
        - USGS has plans to incorporate some climate change scenarios
    - Which climate models and emission scenarios are appropriate?

Considerations for incorporating potential drought scenarios into South Carolina Water planning ….

- Alternatively, can dendro-climatology information be used in our existing assessments to simulate historic droughts?
- Are there existing studies in the State that address these questions?
  - Water Research Foundation Web Report #4304, 2013, “Defining and Enhancing the Safe Yield of a Multi-Use , Multi-Reservoir Water Supply” – Catawba-Wateree River Basin
  - Other Studies?

Addressing these questions is beyond the scope of one agency/institution and will require a collaborative effort among multiple organizations!

Thank You

Scott Harder

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References:

Pederson N. et. Al., 2012, *A long-term perspective on a modern drought in the American Southeast*, Environ. Res. Lett. 7 (2012), 8 p.

Cook, E.R., Meko, D.M., Stahle, D.W. and Cleaveland, M.K. 1999. *Drought reconstructions for the continental United States.* Journal of Climate, 12:1145-1162
See also - http://www.ncdc.noaa.gov/paleo/pdsi.html