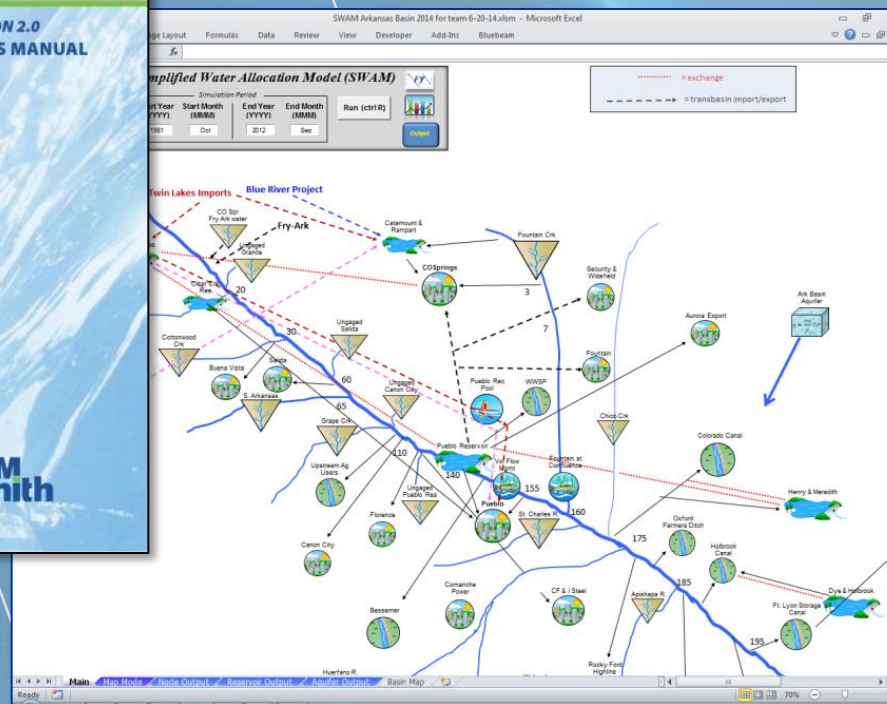
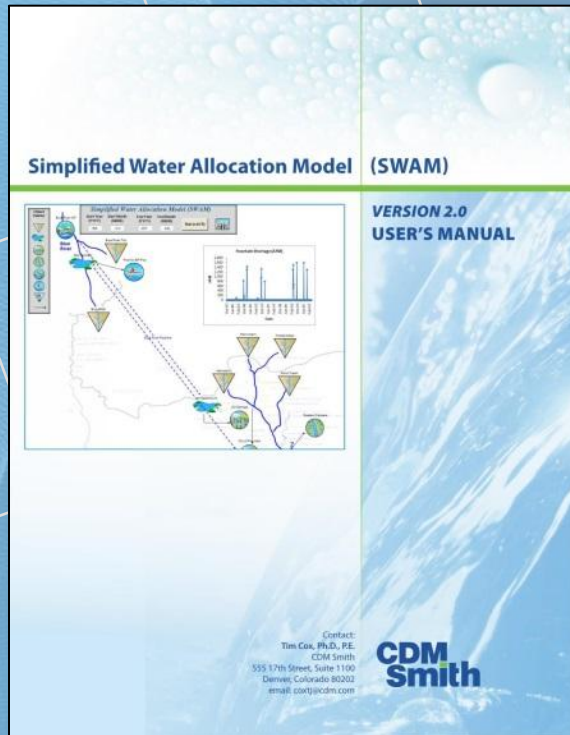


# South Carolina Surface Water Quantity Modeling Project

## And Overview of the Simplified Water Allocation Model (SWAM)

Kirk Westphal, PE  
John Boyer, PE, BCEE  
February 13, 2015



**CDM  
Smith**

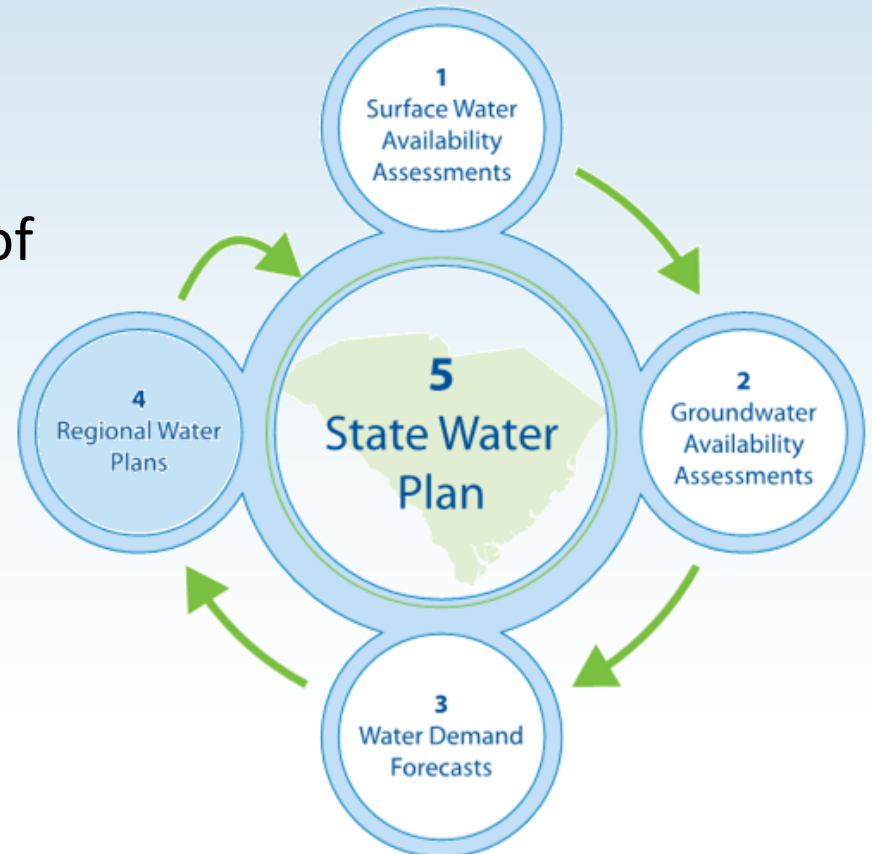
# Project Purpose

- 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.
- CDM Smith’s contract ends after the models are built and training is conducted

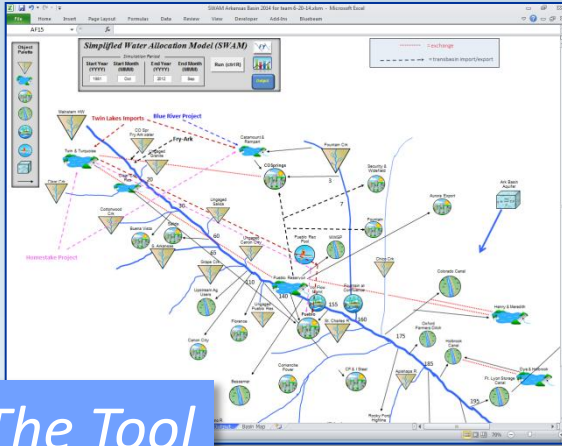


# Project Purpose

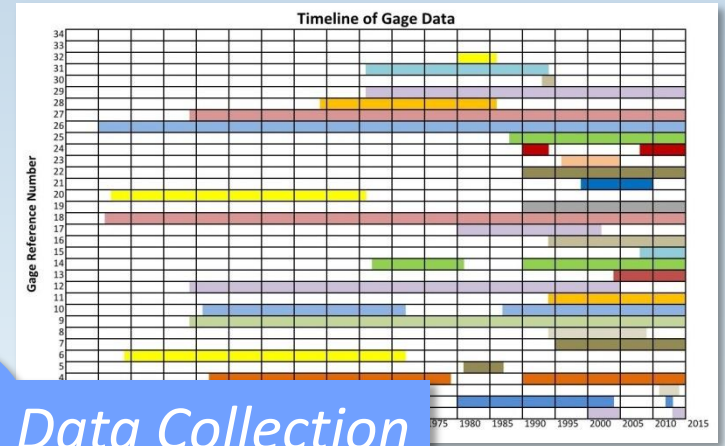
- Once they are built and accepted by DNR/DHEC, the models will be made available for use by water utilities, energy producers, river basin organizations, and other stakeholders.
- The surface water models, and other available tools, can be used to support development of regional water plans



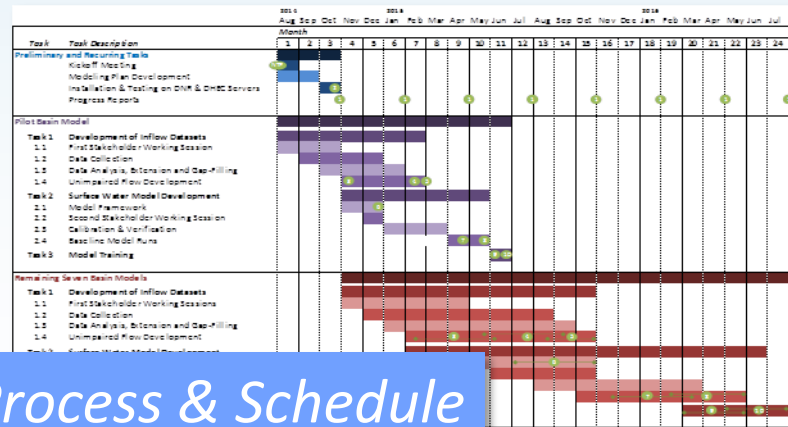
# Development of Surface Water Quantity Models



1 The Tool



3 Data Collection

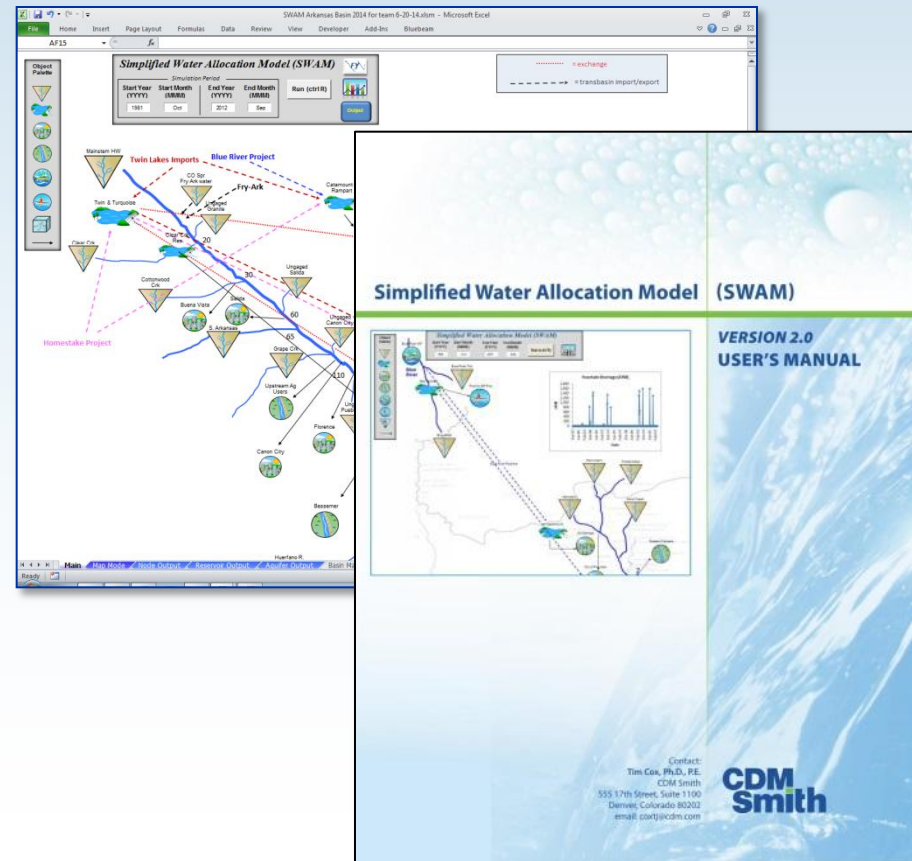


2 Process & Schedule



# 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 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**

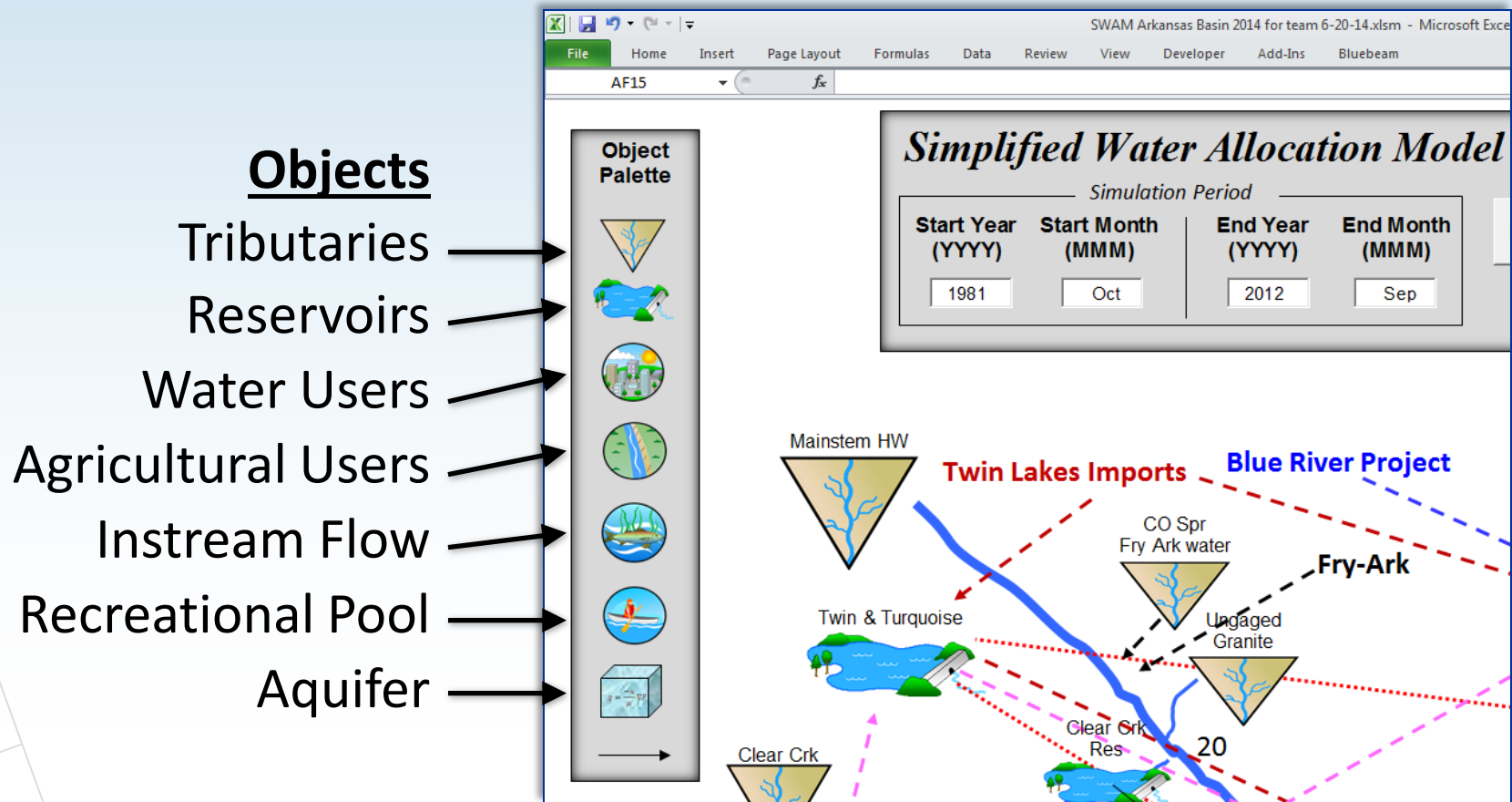
- Tailored specifically for hydropower
  - Energy Calculations
  - Reservoir Tracking
- Familiar Visual Basic programming

### **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





# 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

Agricultural Water User  
Main | Source Water | Return Flows |

User Name:  **Delete Node**  Multiple Sources of Water ?

Supplemental Supply/Demand Alternatives | Demands

Agricultural Water User  
Main | Source Water | Return Flows |

Source Stream:  Source Water Type:  Direct River  Reservoir

Downstream Location (mi)  Priority Date 1/1/2008

Agricultural Water User  
Main | Source Water | Return Flows |

Return Flow Locations:  single point  multiple points

Receiving Stream:  RF Location (mi)  Time Lag (months)

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

## Node Output

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
C7 1519.40002441406										
	A	B	EY	EZ	FA	FB	FC	FD	FE	FF
				Priority Rank	Reach (mi)	Location	Water Right (AFM)	Ditch Capacity (AFM)	Storage Capacity (AF)	
1										
2			Pueblo4	32	Mainstem	136	420	1,000,000	5,000	
3							GW Pumping (AFM)	Demand (AFM)	Shortage (AFM)	Return Flow (AFM)
4		Date	Physically Avail. (AFM)	Legally Avail. (AFM)	Diverted (AFM)	Storage (AF)				
5		Min	1,200	0	0	0	0	0	0	0
6		Max	423,253	420	420	5,000	0	0	0	0
7		Avg	44,588	117	33	4,340	0	0	0	0
8		Oct-81	14,837	0	0	0	0	0	0	0
9		Nov-81	23,186	0	0	0	0	0	0	0
10		Dec-81	24,424	0	0	0	0	0	0	0
11		Jan-82	17,870	0	0	0	0	0	0	0
12		Feb-82	16,694	0	0	0	0	0	0	0
13		Mar-82	25,120	0	0	0	0	0	0	0
14		Apr-82	11,977	0	0	0	0	0	0	0
15		May-82	35,025	0	0	0	0	0	0	0
16		Jun-82	146,407	0	0	0	0	0	0	0
17		Jul-82	97,301	0	0	0	0	0	0	0

# 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

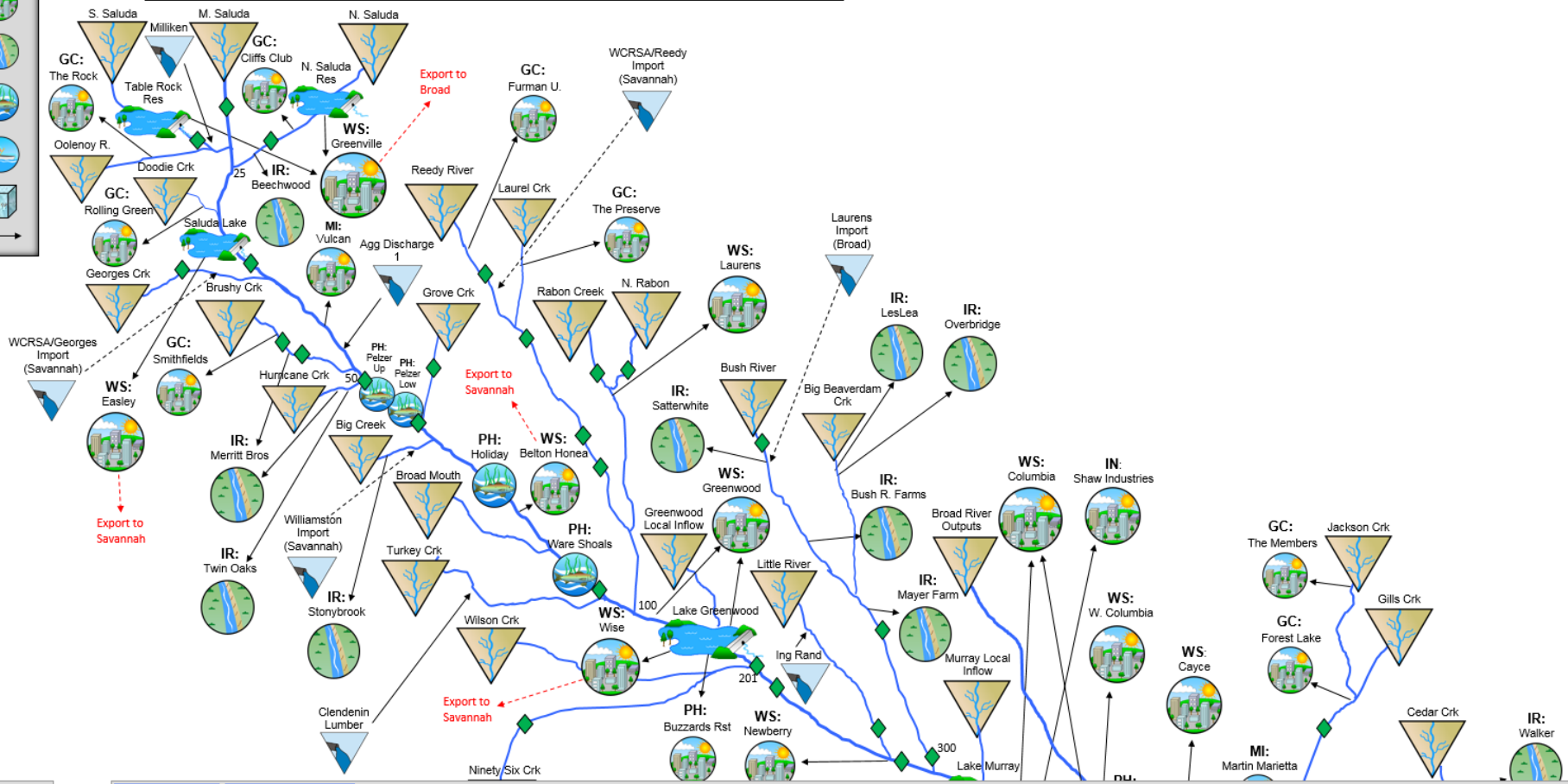
**Simulation Type**  
 Monthly Planning  
 Daily Planning  
 Short Term Forecasting  
 Firm Yield Calculator

**Input & Output**  
 AF, AFM, AFD  
 M.G, M.GD, CFS  
 m3, m3/d, m3/s

**Run (ctrl R)**

### Input Tables and Outputting

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



# 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

Huerfano R.

Rocky Ford Highline

Bessemer

Comanche Power

CF & I Steel

Homestake Project

Mainstem HW

Twin Lakes Impo

Twin & Turquoise

Clear Crk Res.

Clear Crk

Cottonwood Crk

Bue

Object Palette

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)**

Simulation Period  
Start Year Start Month End Year End Month

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

**Instream Flows**

Water Right

**Instream Flow Name:** [Dropdown] **Delete Node** **Target Stream:** [Dropdown] **Downstream Location (mi)** [Input: 0]

**Priority Date** [Input: 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
[Input]	[Input]	[Input]	[Input]	[Input]	[Input]	[Input]	[Input]	[Input]	[Input]	[Input]	[Input]

(CFS)

Comments: [Text Area]

**Save**  
**Close**

Object Palette  
Mainstem HW  
Twin & Turquoise  
Clear Crk  
Homestake Project

Basin Guifer  
& Meredith  
Dye & Harbrook  
Orange

Main Map Mode

Ready 70%

# Output Tables

## Node Output

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

C7 1519.40002441406

Output	EY	EZ	FA	FB	FC	FD	FE	FF	FG	FH	FI	FJ	FK	FL
	Priority Rank	Reach (mi)	Location	Water Right (AFM)	Ditch Capacity (AFM)	Storage Capacity (AF)							Priority Rank	Reach (mi)
	Pueblo4	32	Mainstem	136	420	1,000,000	5,000					Fountain2	44	Mainstem
Date	Physically Avail. (AFM)	Legally Avail. (AFM)	Diverted (AFM)	Storage (AF)	GW Pumping (AFM)	Demand (AFM)	Shortage (AFM)	Return Flow (AFM)	Release (AFM)	Evap Losses (AFM)	Physically Avail. (AFM)	Legally Avail. (AFM)	Diverted (AFM)	
Min	1,200	0	0	0	0	0	0	0	0	0	1,200	0	0	
Max	423,253	420	420	5,000	0	0	0	0	0	52	423,201	0	0	
Avg	44,588	117	33	4,340	0	0	0	0	0	21	44,555	0	0	
Oct-81	14,837	0	0	0	0	0	0	0	0	0	14,837	0	0	
Nov-81	23,186	0	0	0	0	0	0	0	0	0	23,186	0	0	
Dec-81	24,424	0	0	0	0	0	0	0	0	0	24,424	0	0	
Jan-82	17,870	0	0	0	0	0	0	0	0	0	17,870	0	0	
Feb-82	16,694	0	0	0	0	0	0	0	0	0	16,694	0	0	
Mar-82	25,120	0	0	0	0	0	0	0	0	0	25,120	0	0	
Apr-82	11,977	0	0	0	0	0	0	0	0	0	11,977	0	0	
May-82	35,025	0	0	0	0	0	0	0	0	0	35,025	0	0	
Jun-82	146,407	0	0	0	0	0	0	0	0	0	146,407	0	0	
Jul-82	97,301	0	0	0	0	0	0	0	0	0	97,301	0	0	
Aug-82	75,150	0	0	0	0	0	0	0	0	0	75,150	0	0	
Sep-82	73,884	420	0	0	0	0	0	0	0	0	73,884	420	0	
Oct-82	39,997	420	0	0	0	0	0	0	0	0	39,997	420	0	
Nov-82	4,595	0	0	0	0	0	0	0	0	0	4,595	0	0	
Dec-82	4,215	0	0	0	0	0	0	0	0	0	4,215	0	0	
Jan-83	16,663	420	0	0	0	0	0	0	0	0	16,663	420	0	
Feb-83	15,069	420	0	0	0	0	0	0	0	0	15,069	420	0	
Mar-83	26,208	420	0	0	0	0	0	0	0	0	26,208	420	0	
Apr-83	42,386	420	0	0	0	0	0	0	0	0	42,386	420	0	
May-83	47,647	420	0	0	0	0	0	0	0	0	47,647	420	0	
Jun-83	349,601	420	0	0	0	0	0	0	0	0	349,601	420	0	
Jul-83	178,891	420	0	0	0	0	0	0	0	0	178,891	420	0	
Aug-83	93,139	420	0	0	0	0	0	0	0	0	93,139	420	0	
Sep-83	21,418	0	0	0	0	0	0	0	0	0	21,418	0	0	
Oct-83	13,990	0	0	0	0	0	0	0	0	0	13,990	0	0	
Nov-83	1,200	0	0	0	0	0	0	0	0	0	1,200	0	0	
Dec-83	1,200	0	0	0	0	0	0	0	0	0	1,200	0	0	
Jan-84	18,621	420	0	0	0	0	0	0	0	0	18,621	420	0	
Feb-84	17,647	420	0	0	0	0	0	0	0	0	17,647	420	0	
Mar-84	40,025	420	0	0	0	0	0	0	0	0	40,025	420	0	
Apr-84	61,011	420	0	0	0	0	0	0	0	0	61,011	420	0	
May-84	224,609	420	0	0	0	0	0	0	0	0	224,609	420	0	
Jun-84	261,443	420	0	0	0	0	0	0	0	0	261,443	420	0	
Jul-84	147,595	420	0	0	0	0	0	0	0	0	147,595	420	0	
Aug-84	99,322	420	0	0	0	0	0	0	0	0	99,322	420	0	
Sep-84	30,073	0	0	0	0	0	0	0	0	0	30,073	0	0	
Oct-84	37,219	420	0	0	0	0	0	0	0	0	37,219	420	0	
Nov-84	1,200	0	0	0	0	0	0	0	0	0	1,200	0	0	
Dec-84	4,940	420	0	0	0	0	0	0	0	0	4,940	420	0	
Jan-85	22,847	420	0	0	0	0	0	0	0	0	22,847	420	0	
Feb-85	25,222	420	0	0	0	0	0	0	0	0	25,222	420	0	

## Reservoir Output

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

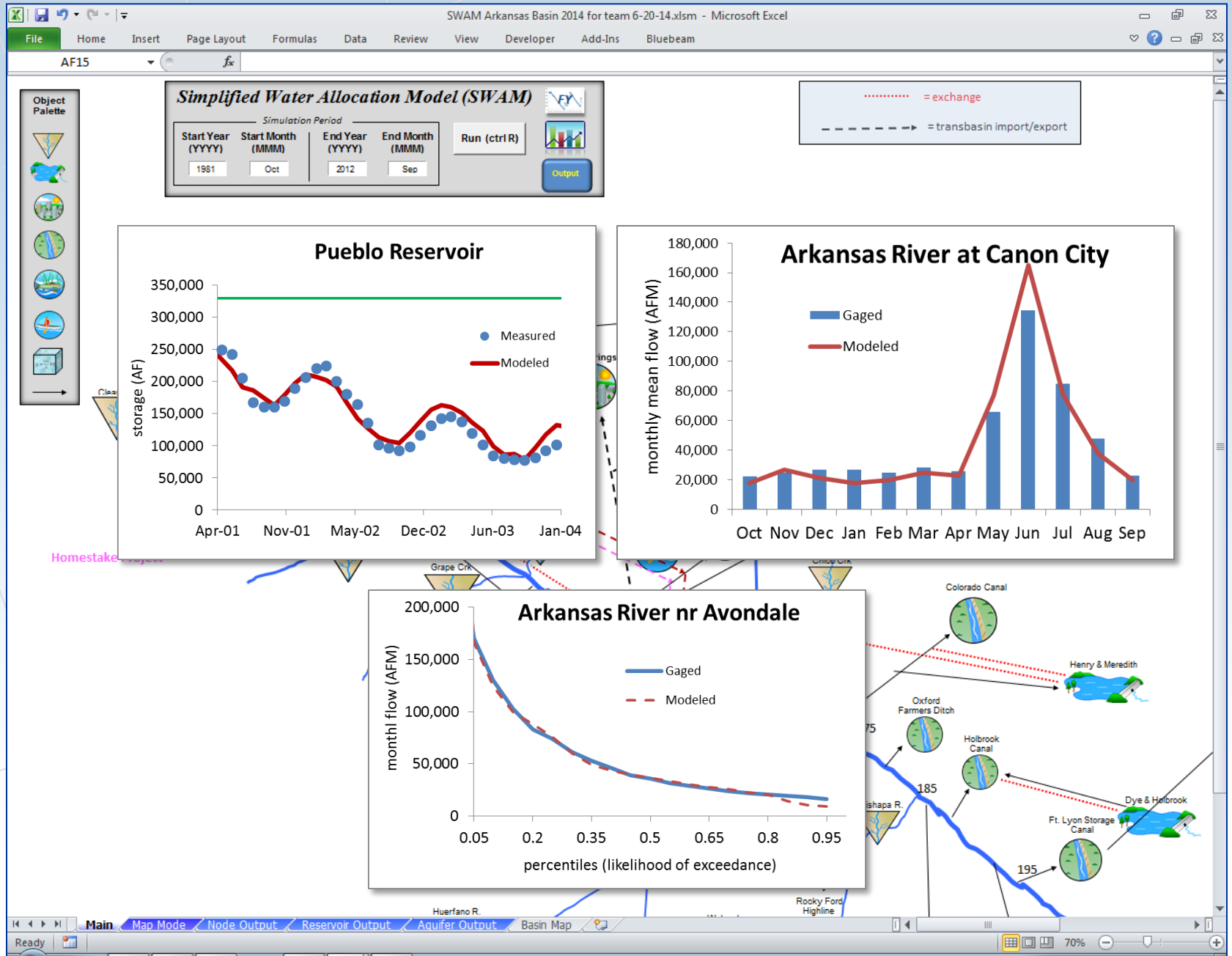
File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

Q19 26140.1484375

Output	C	D	E	F	G	H	I	J	K	L	M
	Total Capacity (AF)	Release Location									
	Pueblo Reservoir	330000.0	143.0								JMR
Date	Storage (AF)	Excess Volume (AF)	Overflow (AFM)	Total Inflow (AFM)	Total Withdrawal (AFM)	Release (AFM)	Outflow (AFM)	Evap (AFM)	Storage (AF)		
Min	37,367	0	0	2,862	4,373	0	0	0	7,545		
Max	330,000	0	19,692	303,831	101,197	0	7,000	3,451	450,000		
Avg	212,993	0	1,352	46,753	39,940	0	4,281	1,009	132,387		
Oct-81	92,749	0	0	40,265	46,985	0	0	532	200,277		
Nov-81	90,783	0	240	14,646	16,371	0	0	0	176,741		
Dec-81	88,111	0	680	11,817	13,808	0	0	0	154,539		
Jan-82	86,610	0	680	8,105	8,927	0	0	0	134,969		
Feb-82	87,315	0	680	7,549	6,165	0	0	0	119,018		
Mar-82	88,019	0	680	10,218	8,834	0	0	0	107,688		
Apr-82	82,264	0	614	24,650	29,220	0	0	571	98,144		
May-82	64,852	0	624	55,732	71,830	0	0	690	90,661		
Jun-82	62,620	0	728	98,054	98,922	0	0	637	95,890		
Jul-82	52,251	0	525	79,954	89,142	0	0	655	94,416		
Aug-82	42,029	0	600	61,795	70,950	0	0	466	102,863		
Sep-82	38,780	0	810	50,284	52,424	0	0	299	110,282		
Oct-82	53,544	0	1,087	56,442	40,384	0	0	206	107,965		
Nov-82	82,590	0	1,384	44,561	12,995	0	1,136	0	97,376		
Dec-82	100,657	0	1,384	31,635	10,432	0	1,752	0	87,514		
Jan-83	110,347	0	1,384	19,931	6,721	0	2,135	0	90,684		
Feb-83	118,421	0	1,384	17,965	6,165	0	2,341	0	83,248		
Mar-83	127,482	0	1,384	22,397	9,440	0	2,512	0	89,077		
Apr-83	136,429	0	1,213	43,943	30,270	0	2,687	827	97,669		
May-83	132,169	0	936	74,268	73,580	0	2,870	1,144	108,757		
Jun-83	330,000	0	728	303,831	101,197	0	2,776	1,299	258,390		
Jul-83	330,000	0	525	103,845	84,042	0	6,027	3,451	271,590		



# Calibration Result Graphs



# Major Tasks

## Task 1

### Data Collection

- Streamflow, M&I and ag withdrawals, discharges, precipitation, reservoir operations, interconnections, facility operation dates, etc.

### Unimpaired Flow Development

- Daily mean UIFs

### Data Analysis

- Gap filling and record extension

## Task 2

### Basin Schematic

- Model framework development

### Model Calibration

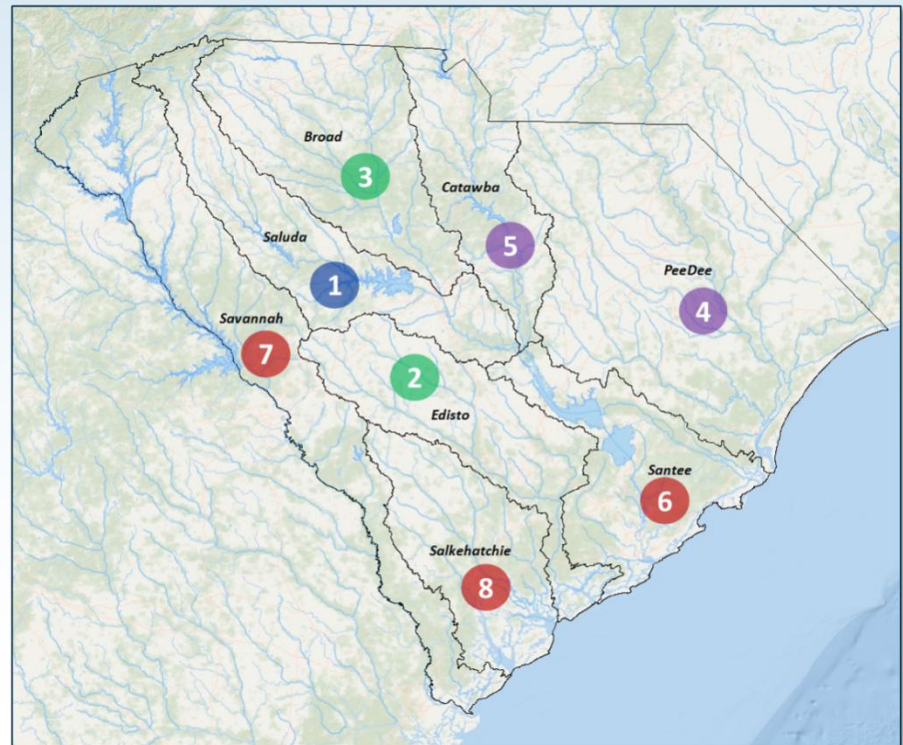
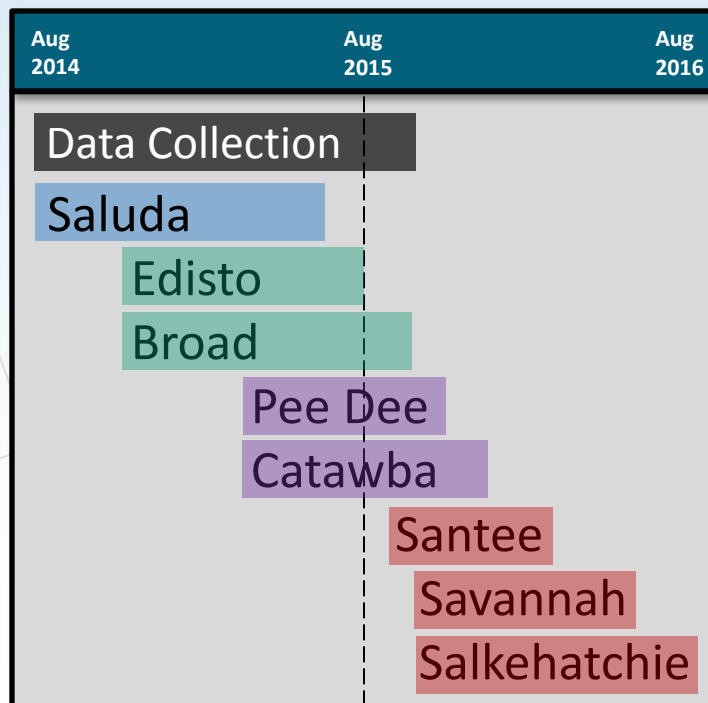
- Reproduce actual conditions

### Baseline Model Runs

- Simulate current conditions

# Schedule for Developing the Models

- ***Pilot Model*** of the Saluda River Basin
- Other models to follow, with order based on data availability
- 2-year schedule requires that groups of models be constructed in parallel



# Data is Needed to Support...

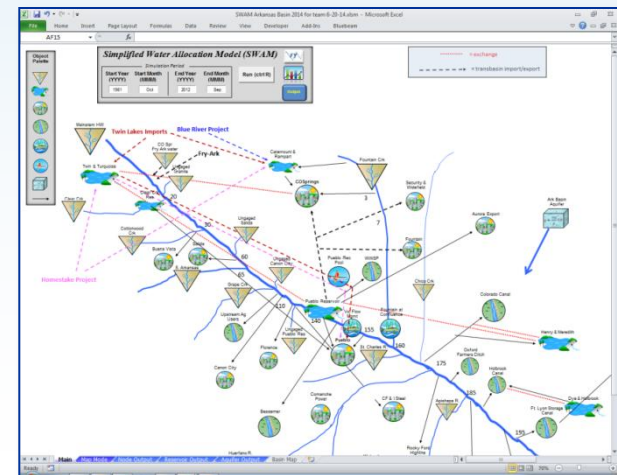
## 1. Development of Unimpaired Flows (UIFs)

UIF Definitions: - Flow in a river as it would be in a completely unaltered state  
- Historically observed flows with human influences removed

UIFs Provide: A baseline for evaluating impacts of human use by allowing analysts to compare altered flows to UIFs

## 2. Development of each baseline model

- A. Withdrawal and return amounts and locations
- B. Current reservoir operating rules
- C. Drought Management Plans and Requirements
- D. Instream flow requirements





# THANK YOU

