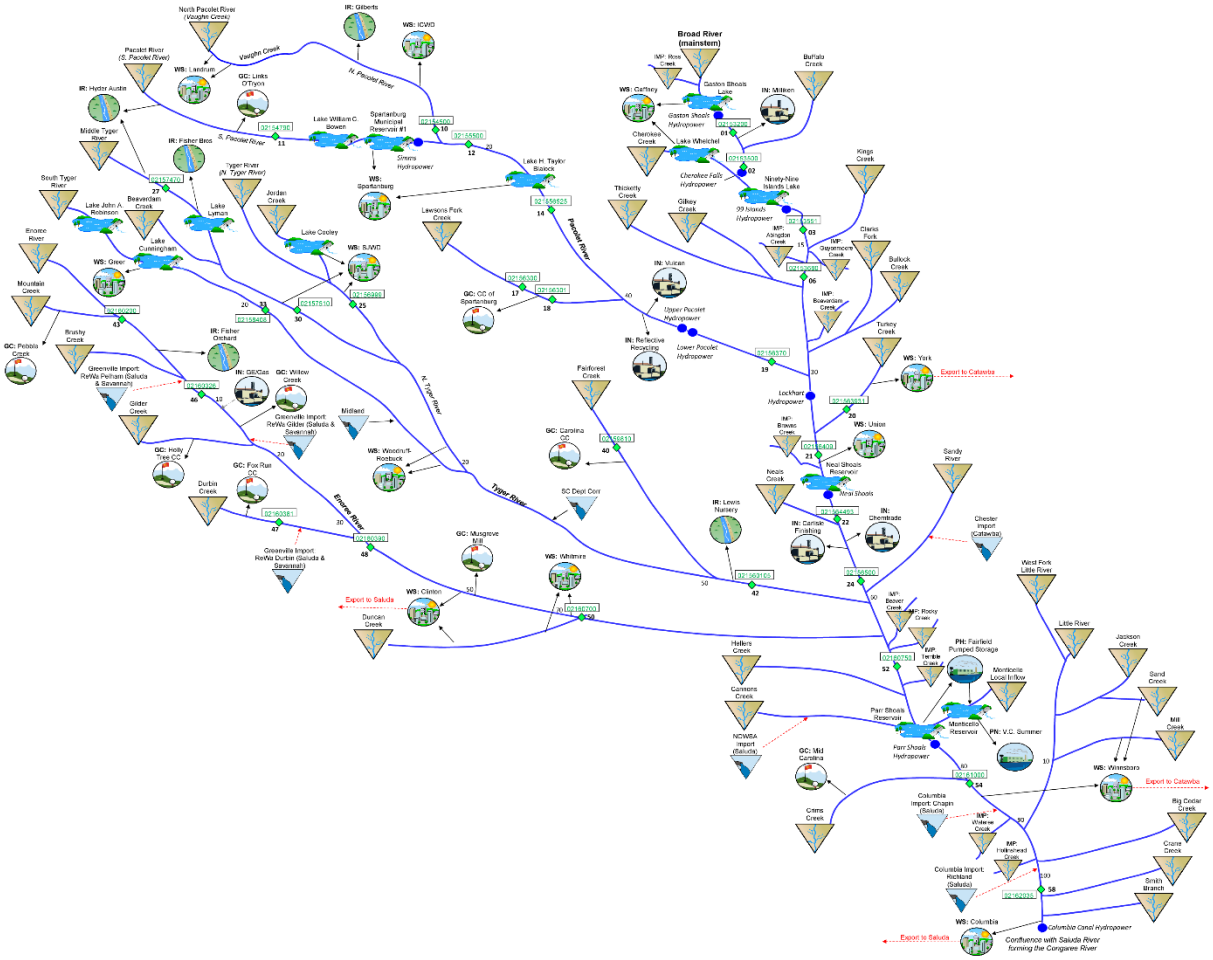
South Carolina Surface Water Quantity Modeling Project

Broad Basin Meeting No. 2 – Introduction to the Draft Model

Kirk Westphal, PE
John Boyer, PE, BCEE

May 18, 2016



CDM Smith

Presentation Outline

- Project Background and Status
- Model Calibration/Verification
  - Calibration/Verification Philosophy and Approach
  - Calibration Results and Discussion
- Overview and Demonstration of Broad Basin Model

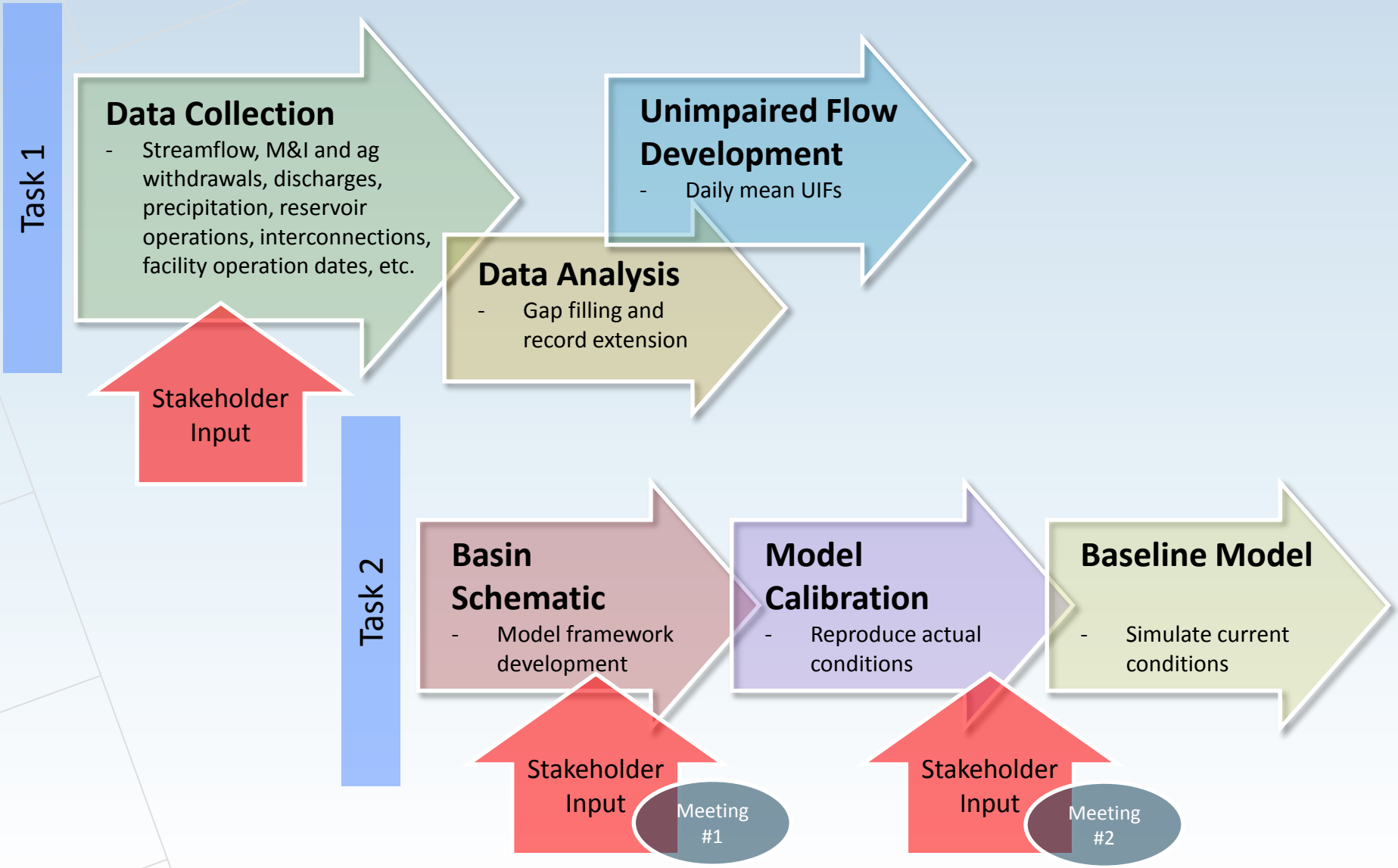
Project Purpose

- 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.

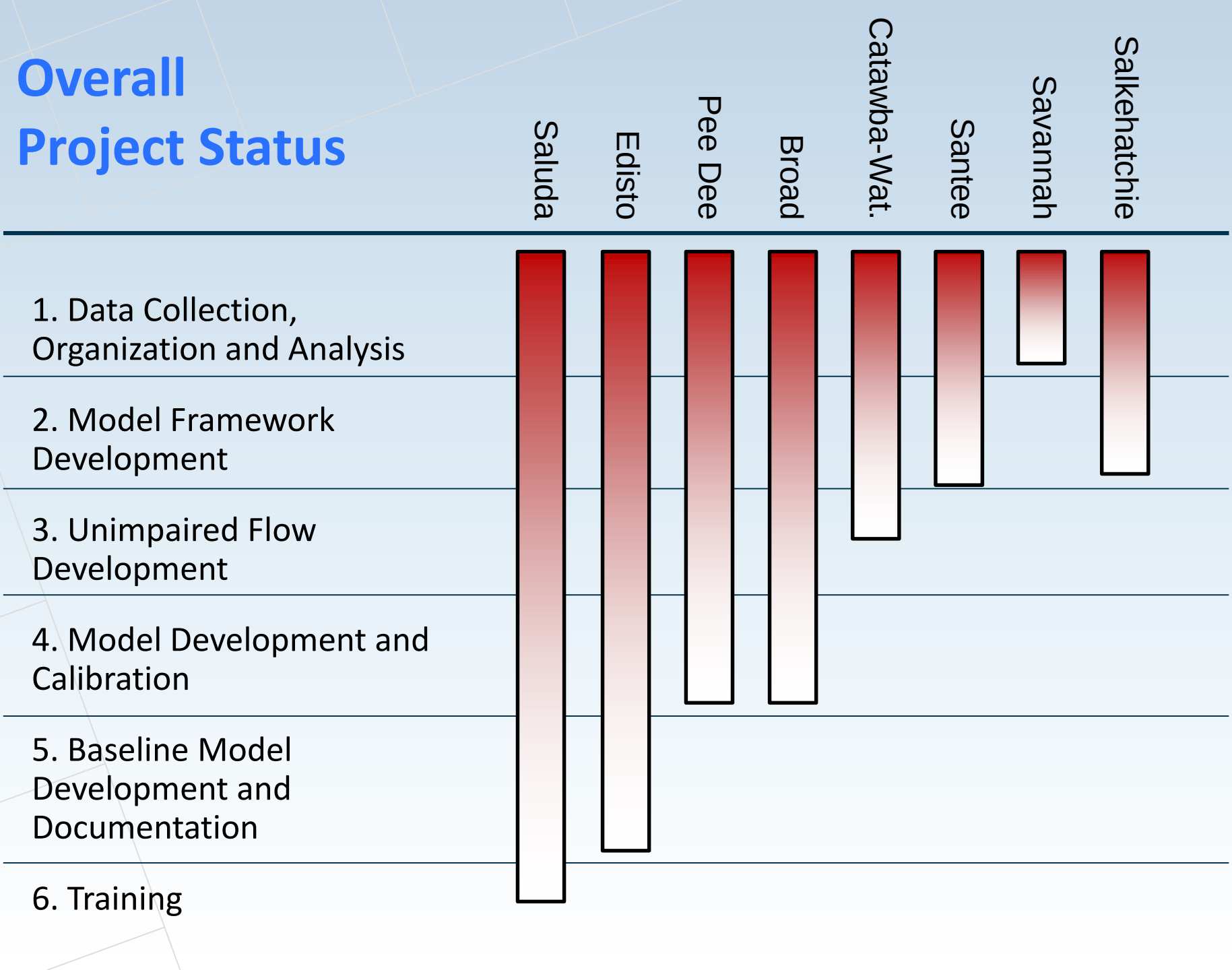
The Simplified Water Allocation Model is…

- A water accounting tool
  - *Calculates physically and legally available water*
  - *Traces water through a natural stream network, simulating withdrawals, discharges, storage, and hydroelectric operations*
- Not a 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)

Project Status – Broad Basin



Overall Project Status



Calibration vs. Baseline Model

- **Calibration Model**
  - Purpose: Confirm models ability to accurately simulate river basin flows and storage amounts
  - Uses recent withdrawal, discharge and flow records

- **Baseline Model**
  - Purpose: Evaluate water availability under future conditions
  - Uses entire record of flow and most current withdrawals and discharges

Broad Basin – SWAM Framework

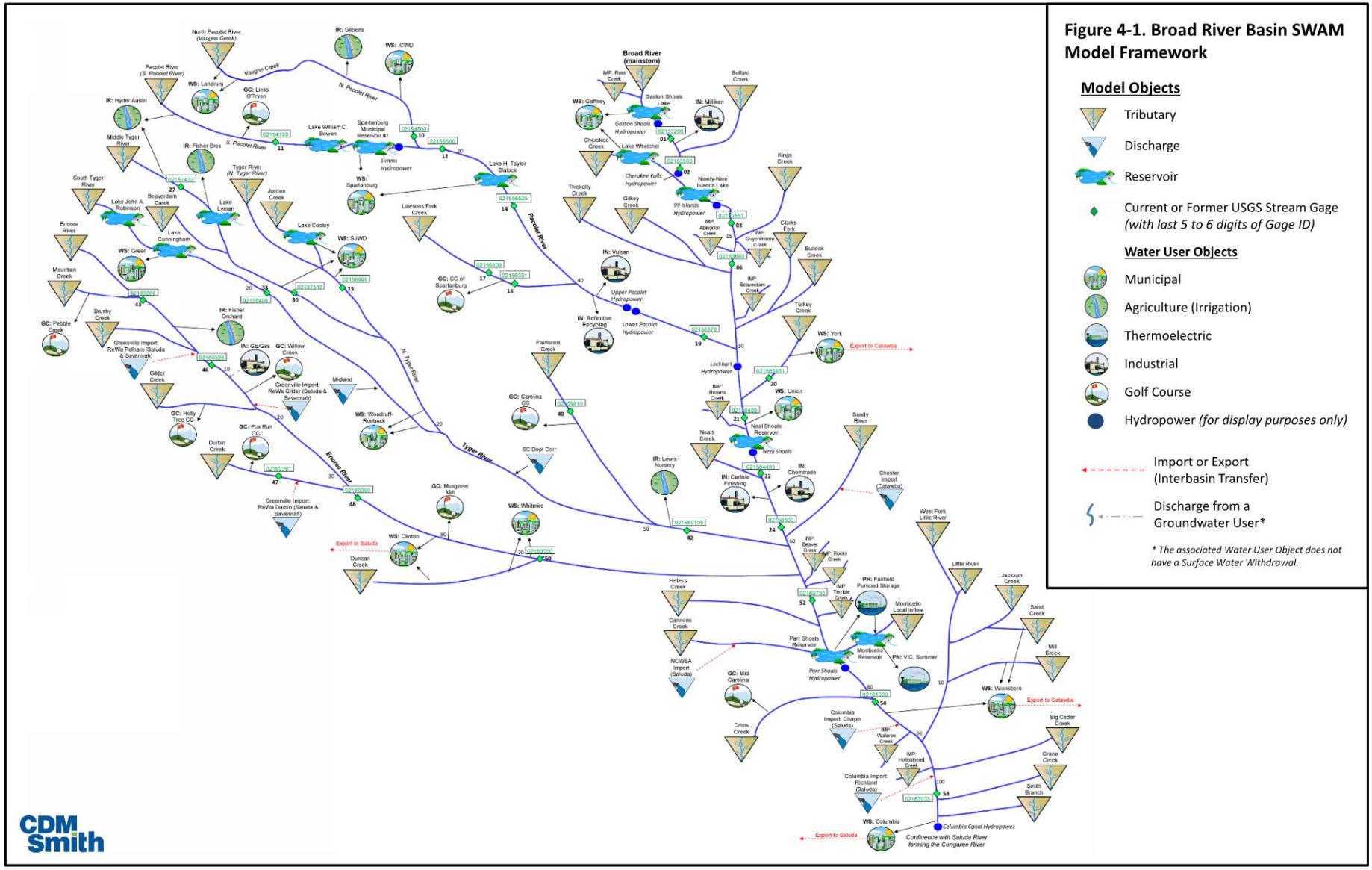


Figure 4-1. Broad River Basin SWAM Model Framework

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
- Industrial
- Golf Course
- Hydropower *(for display purposes only)*

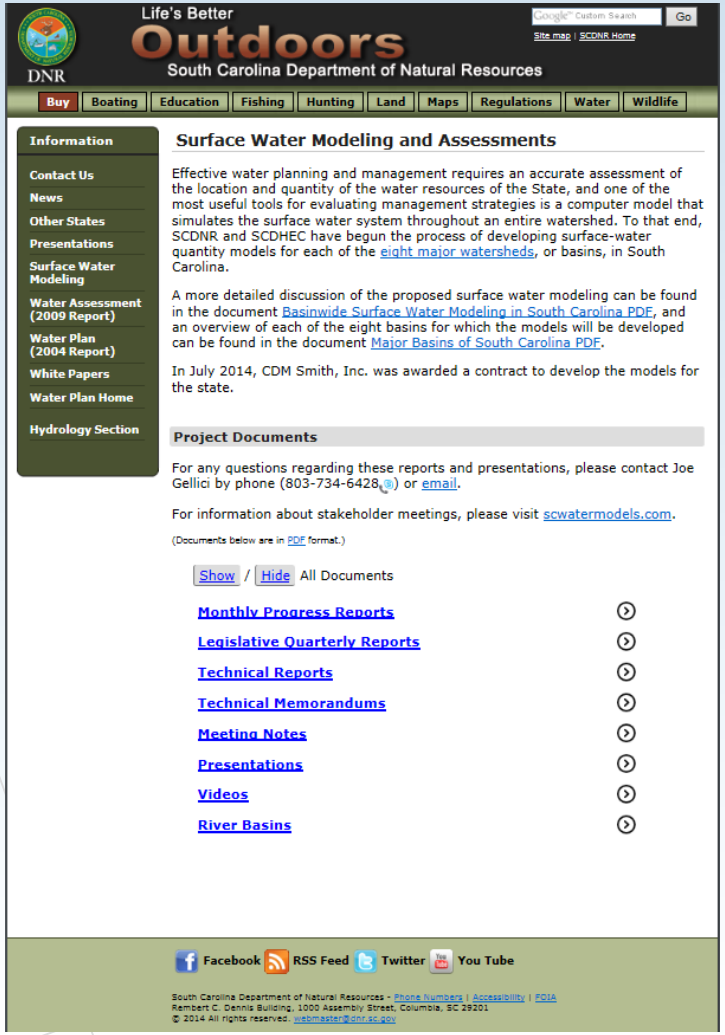
- Import or Export (Interbasin Transfer)
- Discharge from a Groundwater User*

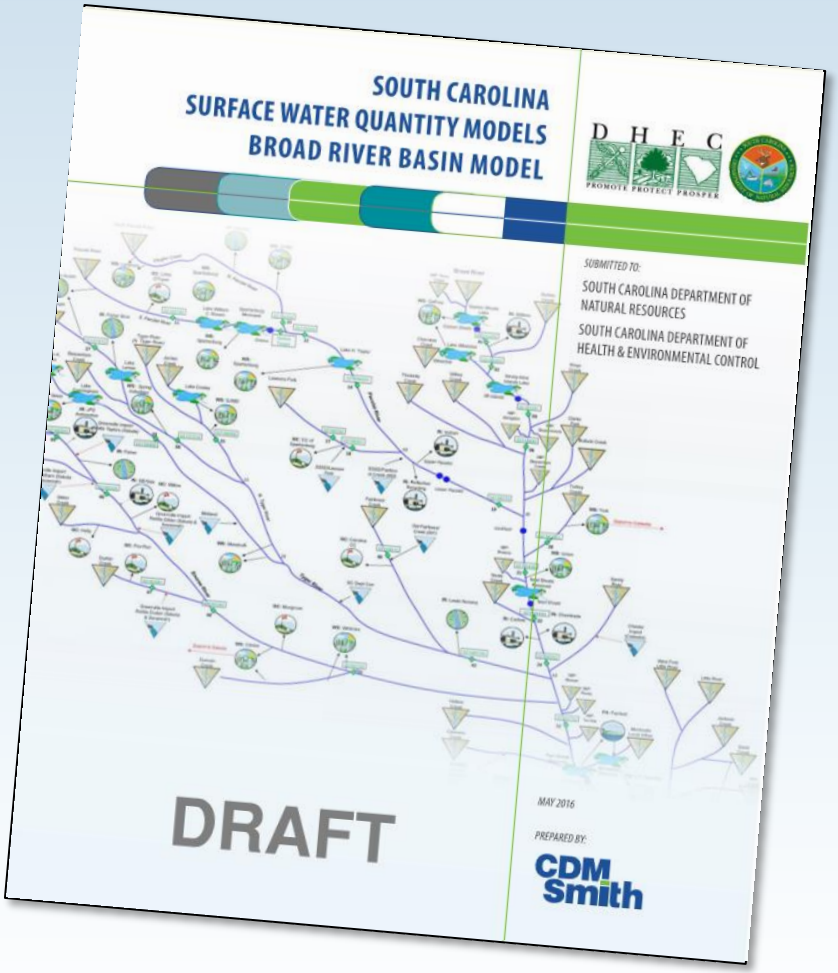
** The associated Water User Object does not have a Surface Water Withdrawal.*

CDM Smith

Modeling Report and Other Documents

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





Broad River Basin

MODEL CALIBRATION/VERIFICATION

Calibration Objectives

1. Extend hydrologic inputs (headwater UIFs) spatially to adequately represent entire basin hydrology by parameterizing reach hydrologic inputs
2. Refine initial parameter estimates, as appropriate
   - E.g. reservoir operating rules, %Consumptive Use assumptions, return flow locations
3. Gain confidence in the model as a predictive tool by demonstrating its ability to adequately replicate past hydrologic conditions, operations, and water use
   - **without being overly prescriptive**

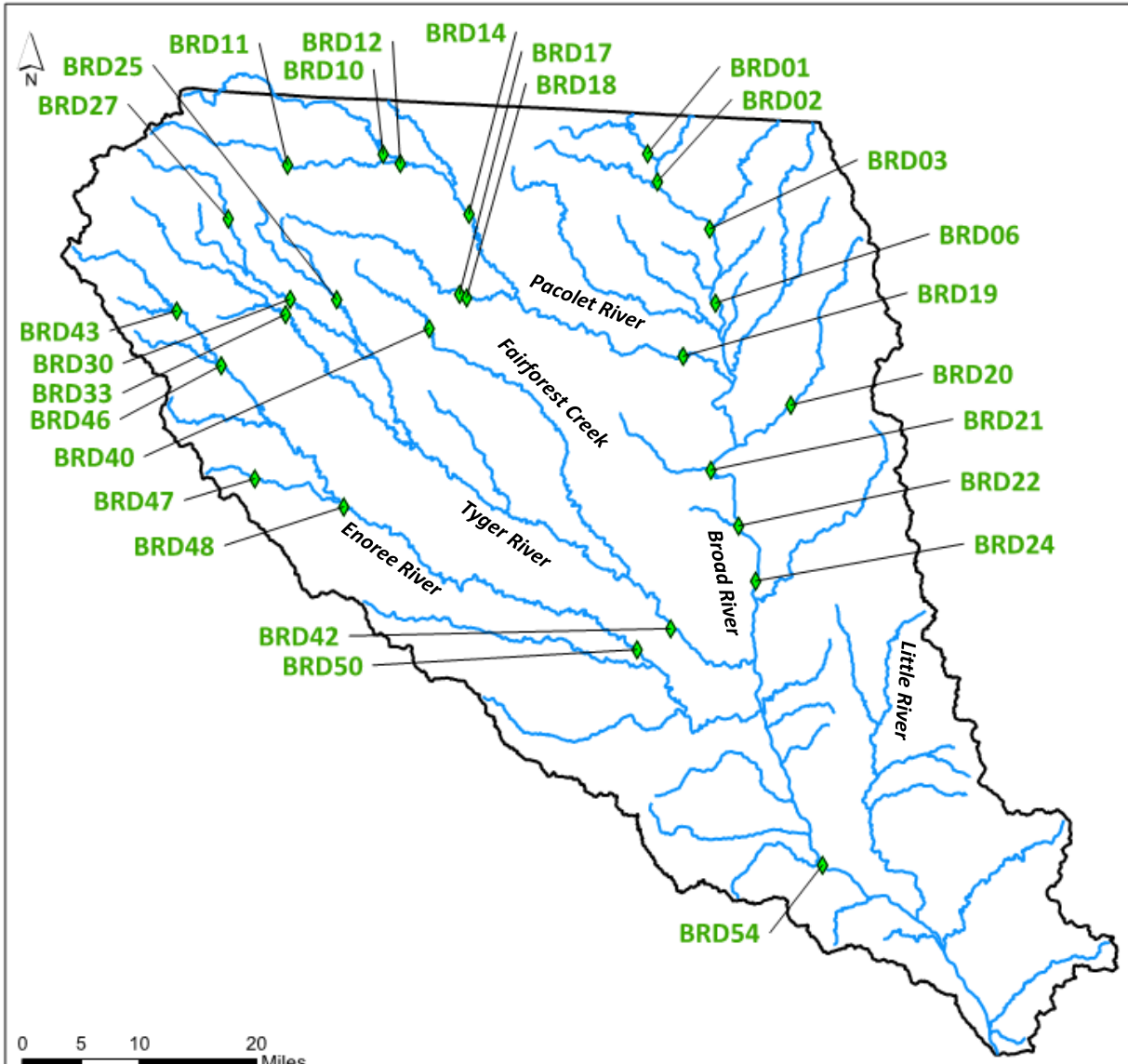
Potential Sources of Model Error and Uncertainty

- Gaged flow data (± 20%)
- Gaged reservoir levels (± ?%)
- Basin climate and hydrologic variability
- Reported withdrawal data
- Consumptive use percentages
- Return flow locations (outdoor use)
- Return flow lag times (if applicable, e.g. outdoor use)
- *Reservoir operations (operator decision making)*
- *Reach hydrology: gains, losses, local runoff and inflow*

Calibration/Validation General Approach

- 1983 – 2013 hindcast period; monthly timestep
  - Includes droughts in both early and late 2000's
- 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 (where levels/storage are available)
- Multiple model performance metrics, including:
  - timeseries plots (monthly and daily variability)
  - annual and monthly means (water balance and seasonality)
  - percentile plots (extremes and frequency)

Calibration/Validation Locations



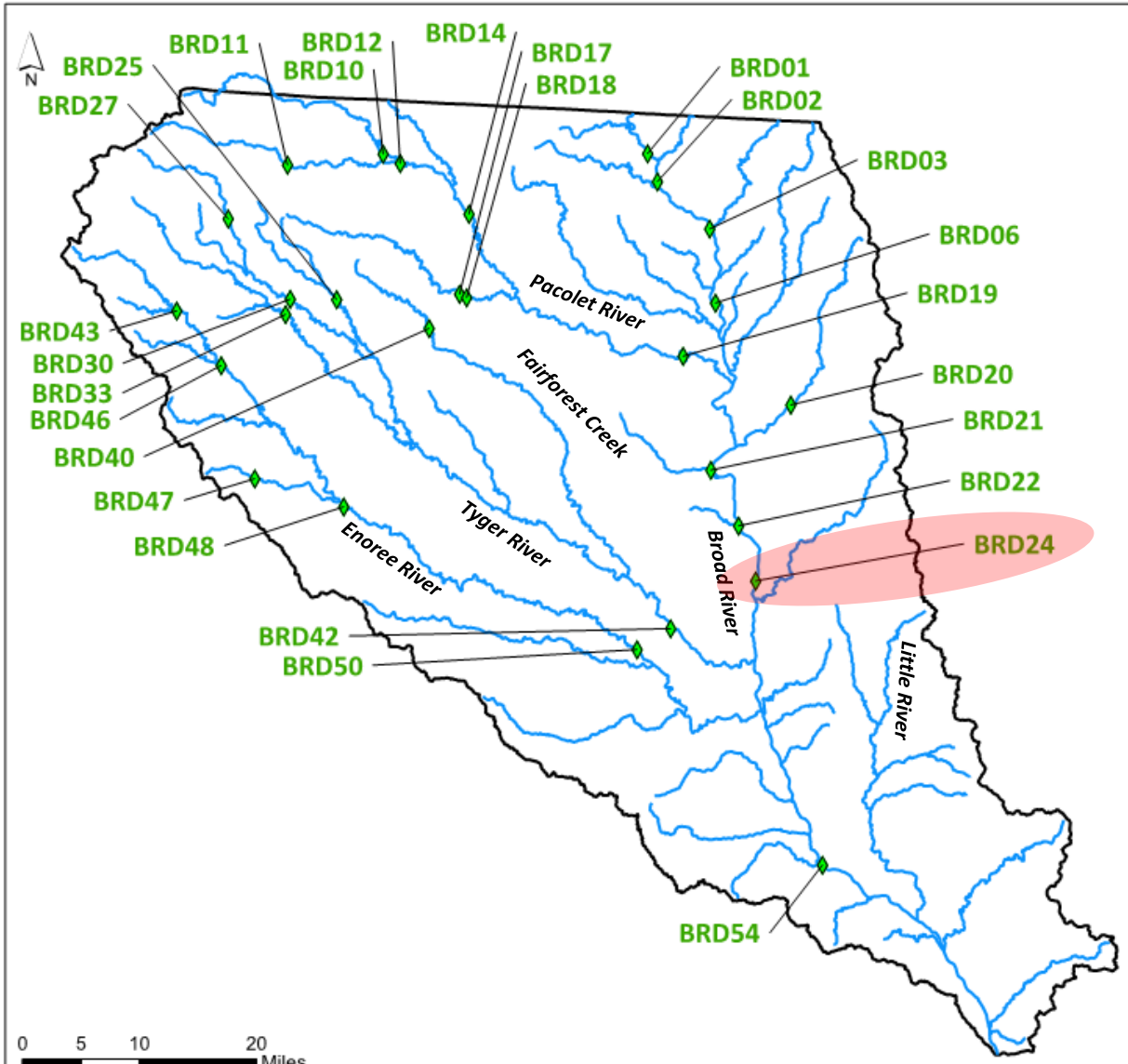
Project Gage ID	USGS Number	Tributary Object	Periods of Record	Basin Area (sq. mi.)	River Mile
BRD01	02153200	Mainstem	9/1997 - current	1,317	5
BRD02	02153500	Mainstem	12/1938 - 9/1971 4/1986 - 9/1990 2/2010 - current	1,501	8
BRD03	02153551	Mainstem	10/1998 - current	1,559	15
BRD06	02153680	Mainstem	6/2001 - 9/2003	1,666	22
BRD10	02154500	North Pacolet	4/1930 - current	114	25
BRD11	02154790	Pacolet River	1/1989 - current	55	6
BRD12	02155500	Pacolet River	12/1929 - 9/1996 10/1997 - 9/2006 6/2007 - 12/2013	209	19
BRD14	021556525	Pacolet River	11/1993 - current	271	28
BRD17	02156300	Lawsons Fork	6/2012 - current	74	21
BRD18	02156301	Lawson Fork	5/1989 - 9/1997	76	21
BRD19	02156370	Pacolet River	8/2012 - current	502	61
BRD20	021563931	Turkey Creek	12/2000 - 8/2003	82	18
BRD21	02156409	Mainstem	10/1996 - 9/1999 4/2011 - 11/2012	2,658	41
BRD22	021564493	Mainstem	3/2012 - current	2,730	48
BRD24	02156500	Mainstem	10/1938 - current	2,781	53
BRD25	02156999	Tyger River	5/2007 - 11/2013	34	2
BRD27	02157470	Middle Tyger River	2/2002 - current	33	10
BRD30	02157510	Middle Tyger River	2/2000 - current	69	22
BRD33	02158408	South Tyger River	2/2001 - current	95	22
BRD40	02159810	Fairforest Creek	5/1988 - 4/1998	23	10
BRD42	02160105	Tyger River	10/1973 - current	756	58
BRD43	02160200	Enoree River	3/1998 - 10/2007	50	1
BRD46	02160326	Enoree River	3/1993 - current	85	9
BRD47	02160381	Durbin Creek	7/1994 - 10/2007 10/2009 - current	13	3
BRD48	02160390	Enoree River	2/1993 - current	249	33
BRD50	02160700	Enoree River	10/1973 - current	443	73
BRD54	02161000	Mainstem	10/1896 - 12/1907 10/1980 - current	4,774	80

Legend

- USGS Flow Gages
- Streams and Rivers
- Broad River Basin

Broad River near Carlisle

USGS Gage 02156500

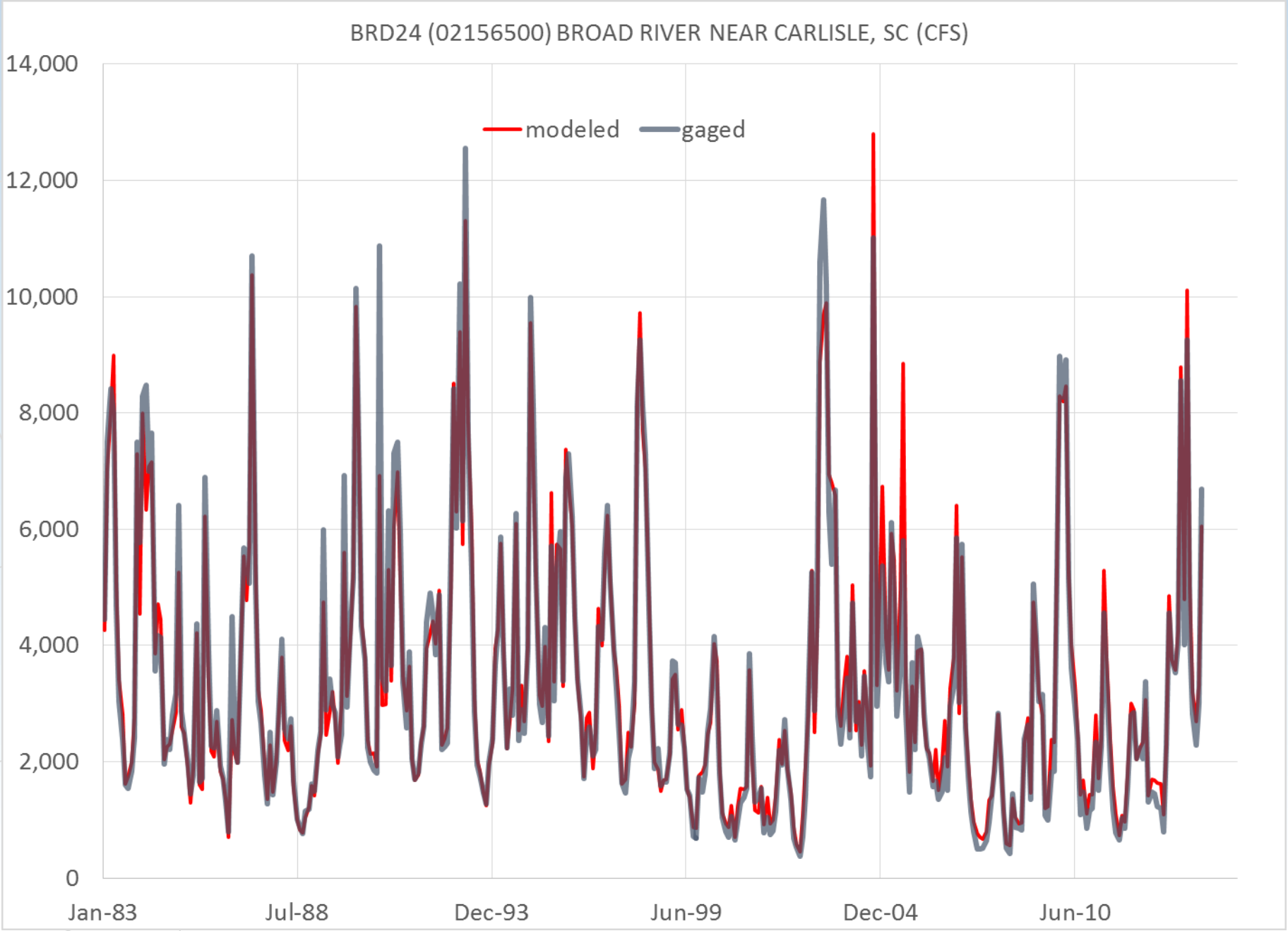


Project Gage ID	USGS Number	Tributary Object	Periods of Record	Basin Area (sq. mi.)	River Mile
BRD01	02153200	Mainstem	9/1997 - current	1,317	5
BRD02	02153500	Mainstem	12/1938 - 9/1971 4/1986 - 9/1990 2/2010 - current	1,501	8
BRD03	02153551	Mainstem	10/1998 - current	1,559	15
BRD06	02153680	Mainstem	6/2001 - 9/2003	1,666	22
BRD10	02154500	North Pacolet	4/1930 - current	114	25
BRD11	02154790	Pacolet River	1/1989 - current	55	6
BRD12	02155500	Pacolet River	12/1929 - 9/1996 10/1997 - 9/2006 6/2007 - 12/2013	209	19
BRD14	021556525	Pacolet River	11/1993 - current	271	28
BRD17	02156300	Lawsons Fork	6/2012 - current	74	21
BRD18	02156301	Lawson Fork	5/1989 - 9/1997	76	21
BRD19	02156370	Pacolet River	8/2012 - current	502	61
BRD20	021563931	Turkey Creek	12/2000 - 8/2003	82	18
BRD21	02156409	Mainstem	10/1996 - 9/1999 4/2011 - 11/2012	2,658	41
BRD22	021564493	Mainstem	3/2012 - current	2,730	48
BRD24	02156500	Mainstem	10/1938 - current	2,781	53
BRD25	02156999	Tyger River	5/2007 - 11/2013	34	2
BRD27	02157470	Middle Tyger River	2/2002 - current	33	10
BRD30	02157510	Middle Tyger River	2/2000 - current	69	22
BRD33	02158408	South Tyger River	2/2001 - current	95	22
BRD40	02159810	Fairforest Creek	5/1988 - 4/1998	23	10
BRD42	02160105	Tyger River	10/1973 - current	756	58
BRD43	02160200	Enoree River	3/1998 - 10/2007	50	1
BRD46	02160326	Enoree River	3/1993 - current	85	9
BRD47	02160381	Durbin Creek	7/1994 - 10/2007 10/2009 - current	13	3
BRD48	02160390	Enoree River	2/1993 - current	249	33
BRD50	02160700	Enoree River	10/1973 - current	443	73
BRD54	02161000	Mainstem	10/1896 - 12/1907 10/1980 - current	4,774	80

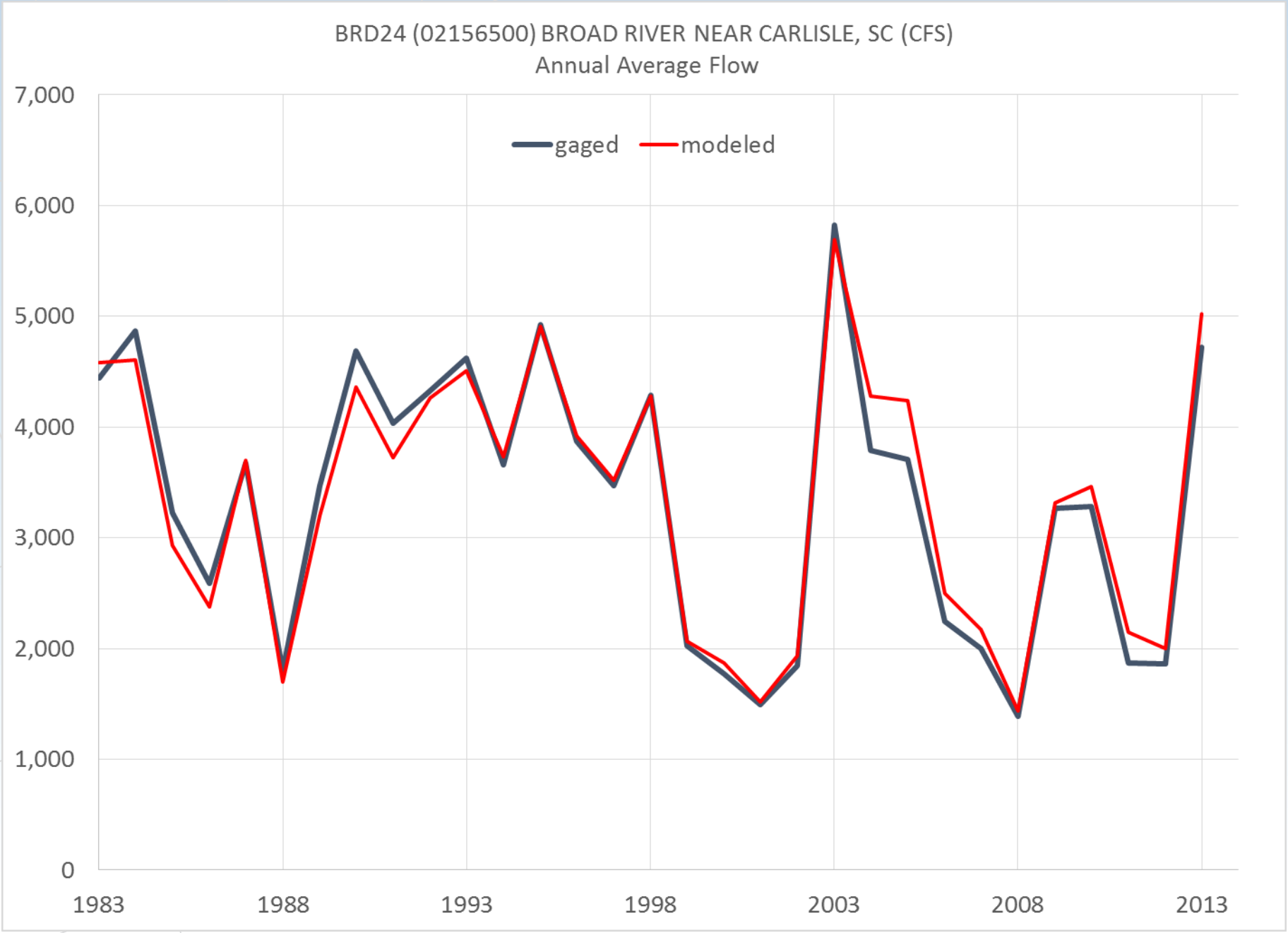
Legend

- USGS Flow Gages
- Streams and Rivers
- Broad River Basin

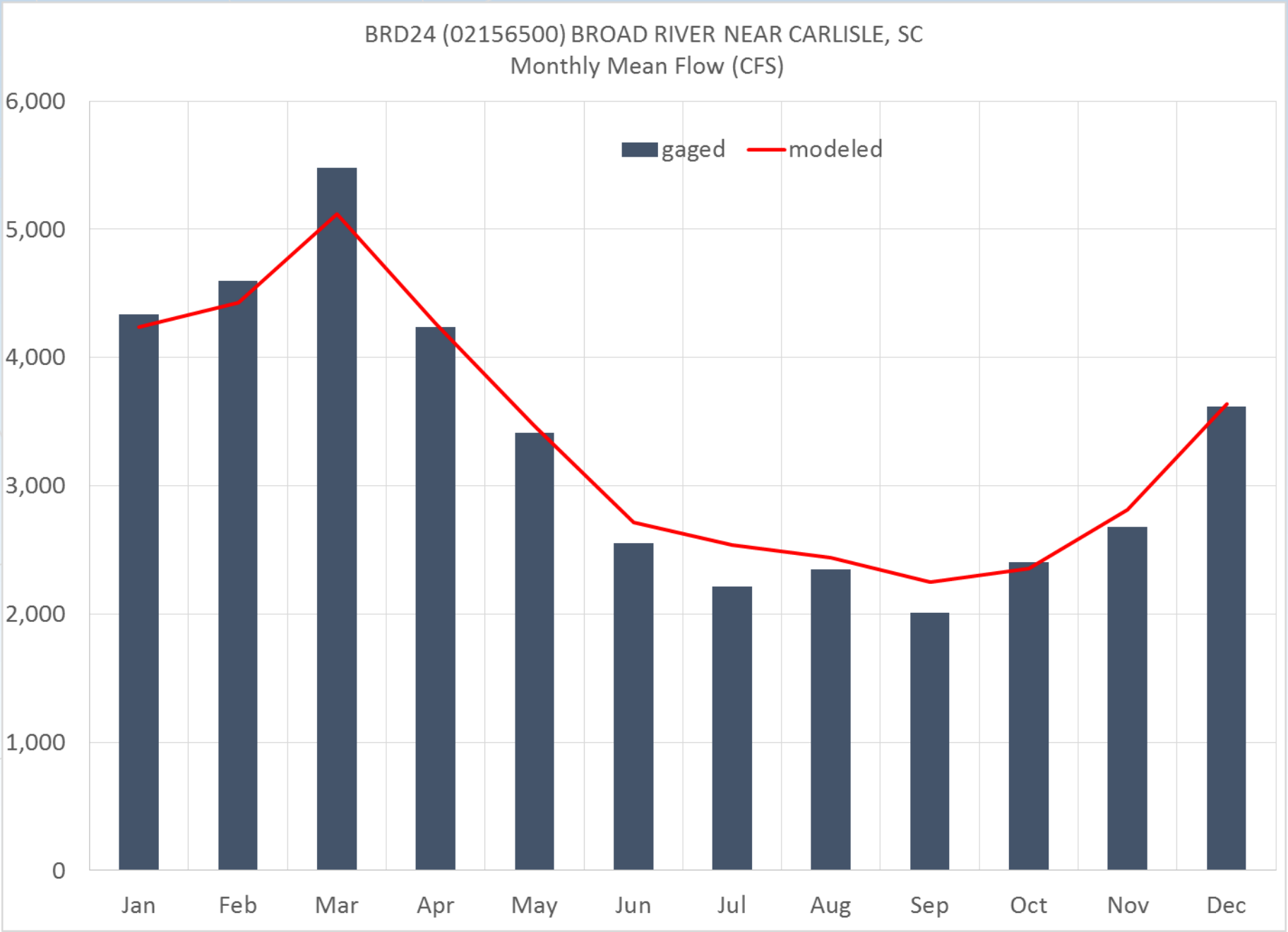
Monthly Flow Comparison



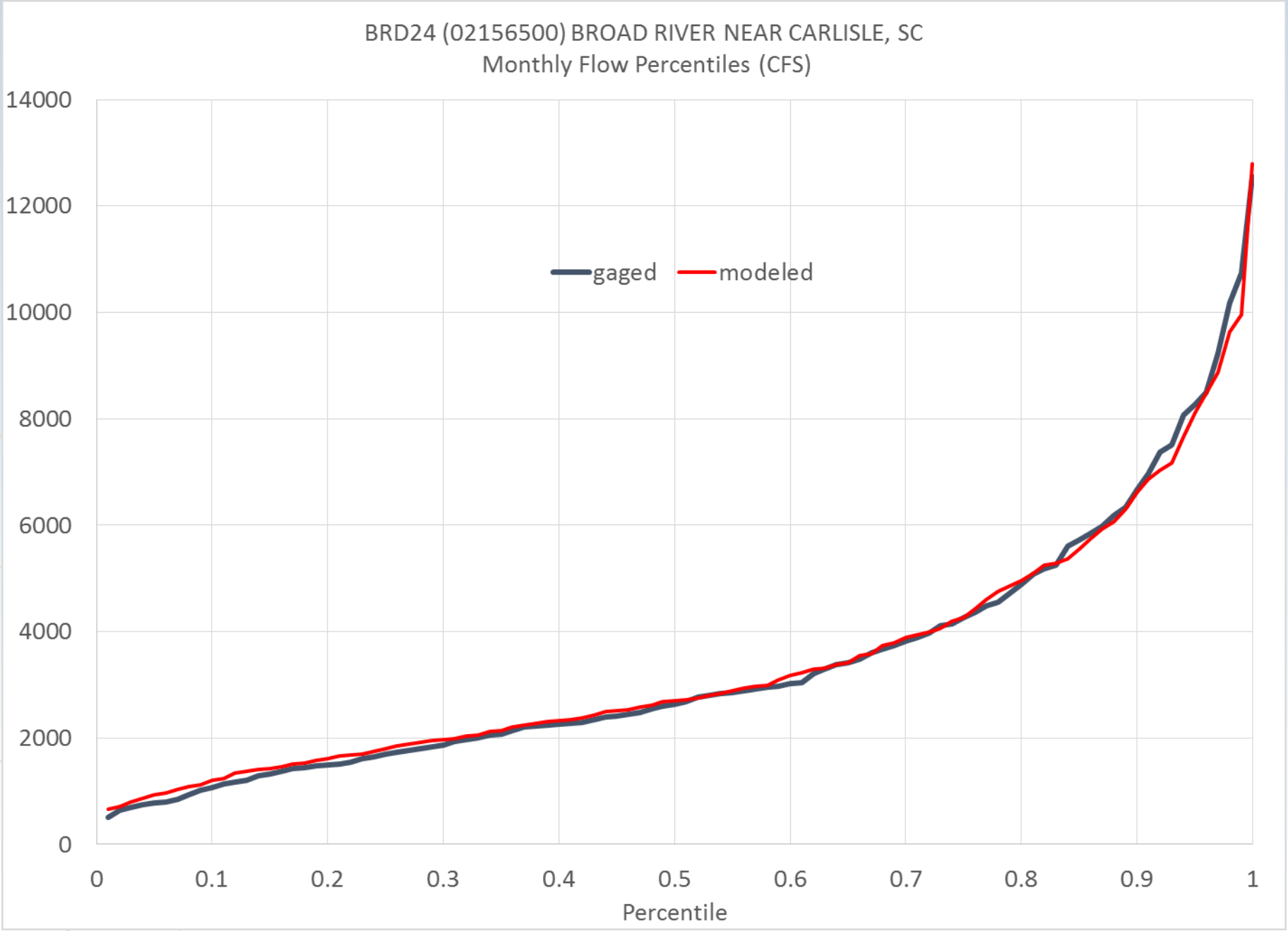
Annual Average Flow Comparison



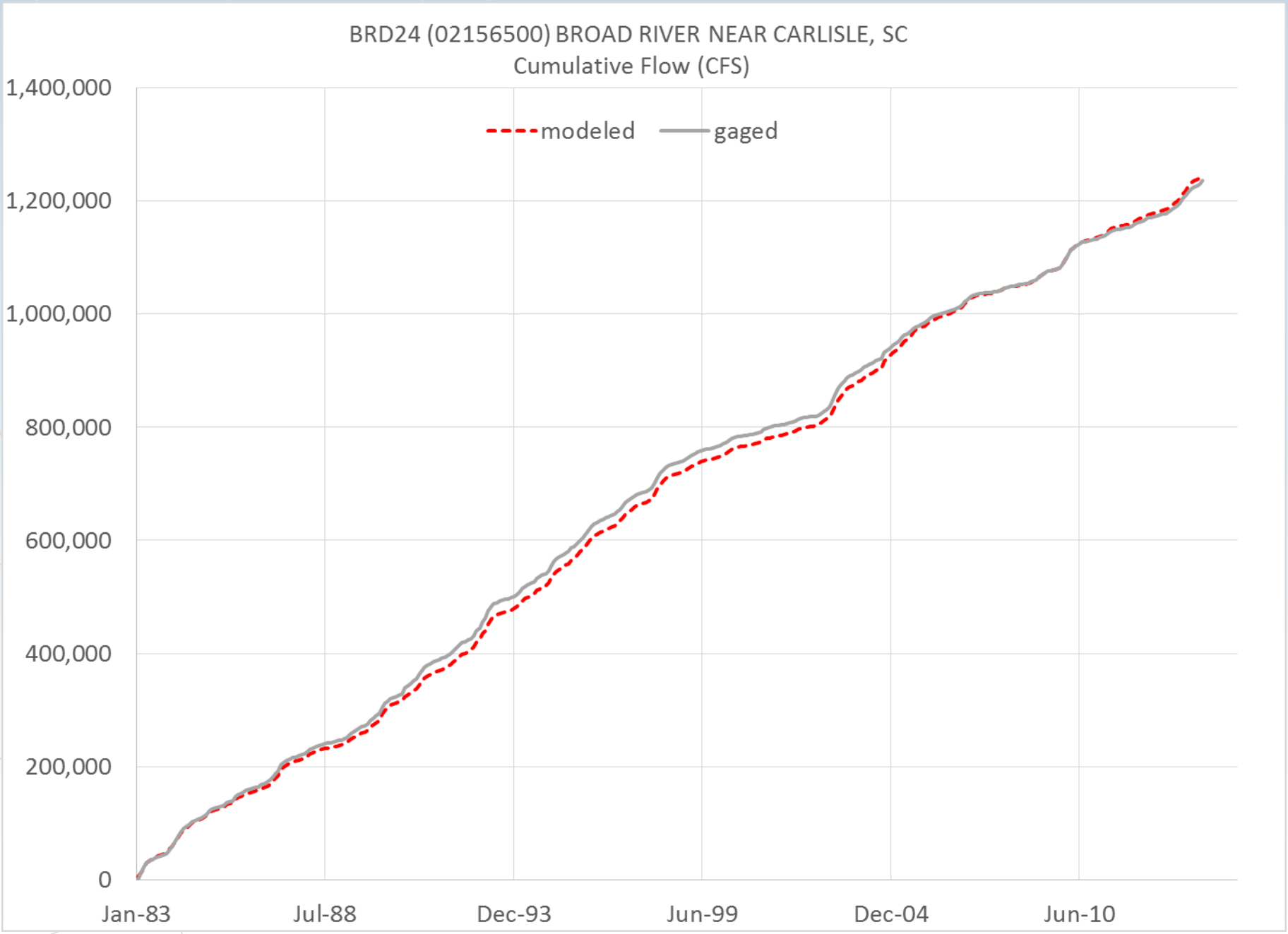
Monthly Mean Flow Comparison



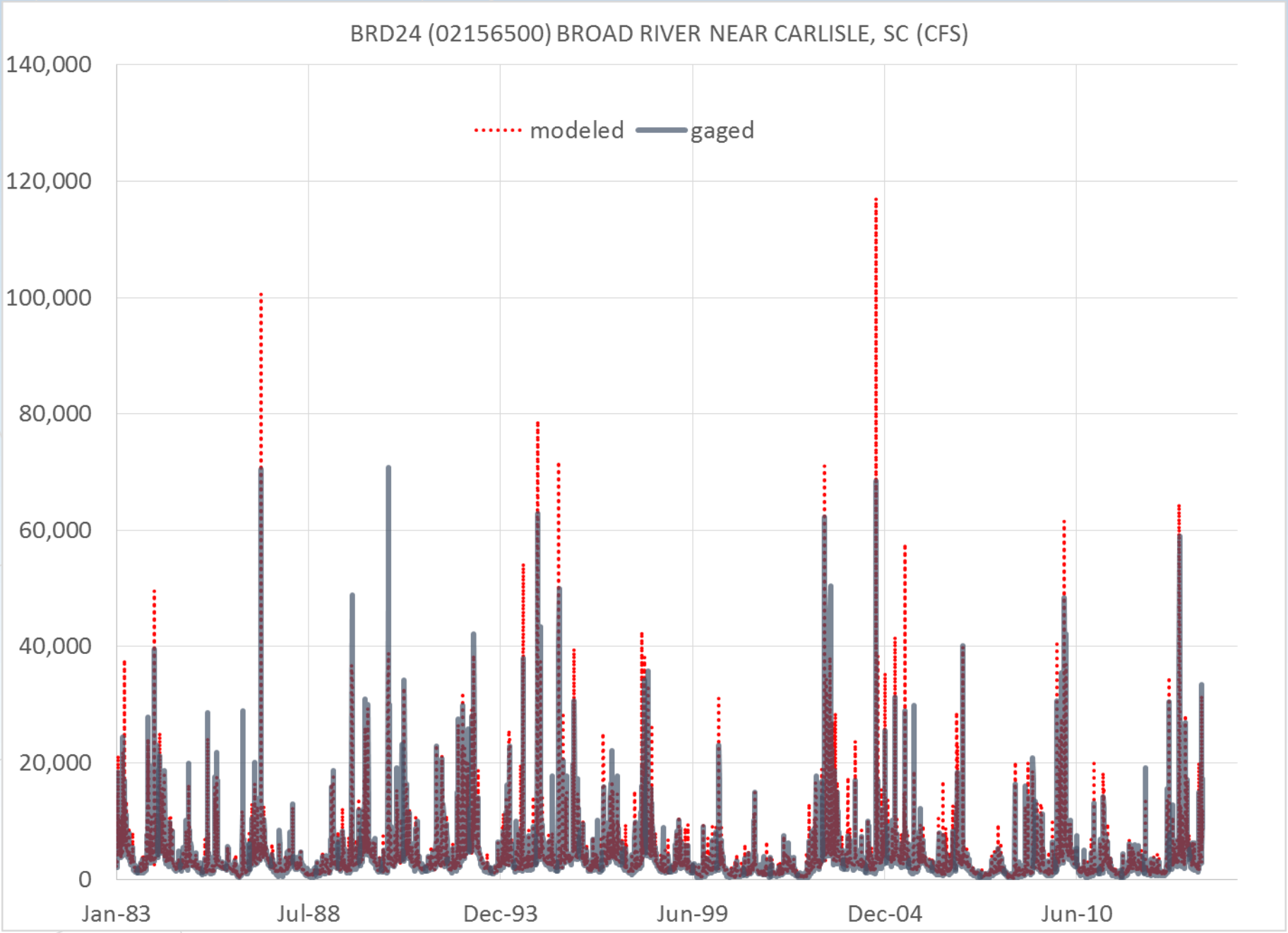
Monthly Flow Percentiles Comparison



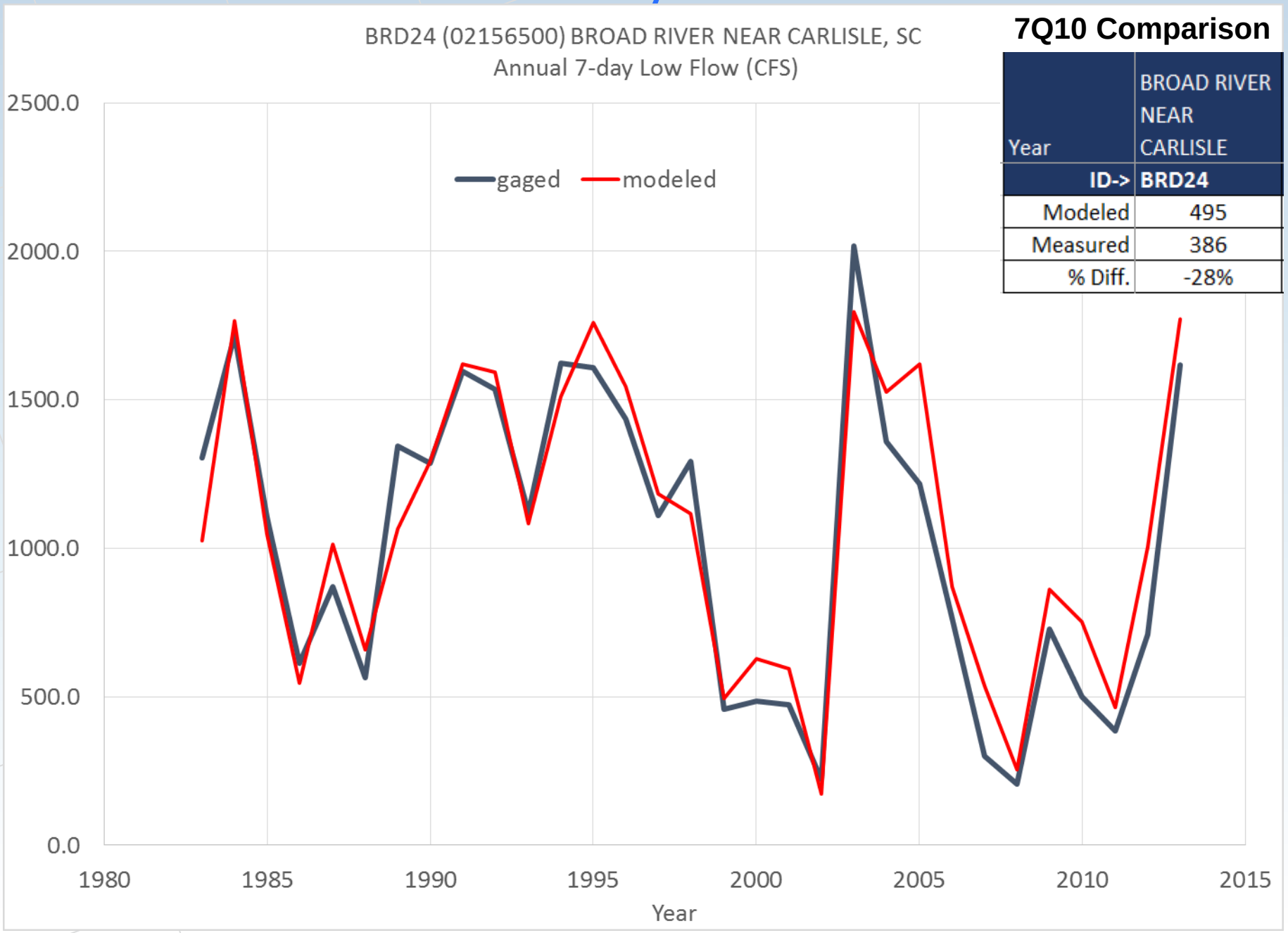
Cumulative Flow Comparison



Daily Flow Comparison



Annual 7 Day Low Flows



7Q10 Comparison

Year	BROAD RIVER NEAR CARLISLE
ID->	BRD24
Modeled	495
Measured	386
% Diff.	-28%

SWAM Calibration/Validation Summary

- For most sites, modeled mean flow values, averaged over the full period of record, are within 5% of measured mean flows

ID	Station	Modeled (cfs)	Measured (cfs)	% Difference	Years to compare
BRD18	LAWSON FORK CREEK @ TREATMENT PLANT @ SPARTANBU	37	134	-72.4%	9
BRD20	TURKEY CREEK NEAR LOWRYS, SC	39	77	-48.4%	4
BRD42	TYGER RIVER NEAR DELTA, SC	771	828	-6.9%	31
BRD46	ENOREE RIVER AT PELHAM, SC	144	146	-1.3%	21
BRD12	PACOLET RIVER NEAR FINGERVILLE, SC	278	281	-1.1%	31
BRD17	LAWSONS FORK CREEK AT SPARTANBURG SC	99	100	-0.6%	2
BRD10	NORTH PACOLET RIVER AT FINGERVILLE, SC	179	180	-0.2%	31
BRD47	DURBIN CREEK ABOVE FOUNTAIN INN, SC	16	16	-0.1%	19
BRD27	MIDDLE TYGER RIVER NEAR GRAMLING, SC	46	46	-0.1%	12
BRD25	N. TYGER RIVER BELOW WELLFORD, SC	27	27	-0.1%	7
BRD33	SOUTH TYGER RIVER BELOW DUNCAN, SC	121	121	0.0%	13
BRD48	ENOREE RIVER NEAR WOODRUFF, SC	343	343	0.0%	21
BRD11	SOUTH PACOLET RIVER NR CAMPOBELLO, SC	89	89	0.2%	25
BRD40	FAIRFOREST CREEK BELOW SPARTANBURG, S.C.	40	40	0.7%	11
BRD24	BROAD RIVER NEAR CARLISLE, SC	3355	3325	0.9%	31
BRD19	PACOLET RIVER NEAR SARATT,SC	629	622	1.1%	2
BRD14	PACOLET RIVER BELOW LAKE BLALOCK NEAR COWPENS, SC	324	320	1.1%	21
BRD06	BROAD R NR HICKORY GROVE, SC	2116	2091	1.2%	3
BRD30	MIDDLE TYGER RIVER NEAR LYMAN, SC	76	74	1.8%	14
BRD02	BROAD RIVER NEAR GAFFNEY, SC	2087	2050	1.8%	9
BRD50	ENOREE RIVER AT WHITMIRE, SC	508	498	2.1%	31
BRD43	ENOREE RIVER AT TAYLORS, SC	74	72	2.3%	10
BRD01	BROAD RIVER NEAR BLACKSBURG, SC	1734	1681	3.1%	17
BRD21	BROAD RIVER NEAR LOCKHART, SC	2647	2551	3.8%	6
BRD03	BROAD RIVER BELOW NINETYNINE ISLAND RESERVOIR,SC	1874	1776	5.5%	16
BRD22	BROAD RIVER BELOW NEAL SHOALS RES. NR CARLISLE,SC	3301	3103	6.4%	2
BRD54	BROAD RIVER AT ALSTON, SC	5611	5226	7.4%	31

>5% difference

2% or less difference

5% or less diff.

>5% difference

SWAM Calibration/Validation Summary

- Monthly mean flows percentile deviations are all generally within 10-20% with no clear bias
- Modeled low flow values (as represented by 7Q10 flows) are within:
  - 4% and 35% on the Broad River
  - 0% to 54% on Pacolet River
  - 0% to 150% on the Tyger River
  - 0% to 36% on the Enoree River
- The model adequately hindcasts delivered water supply for each water user in the model (no significant shortfalls).

Broad River Basin

BASELINE MODEL AND USES

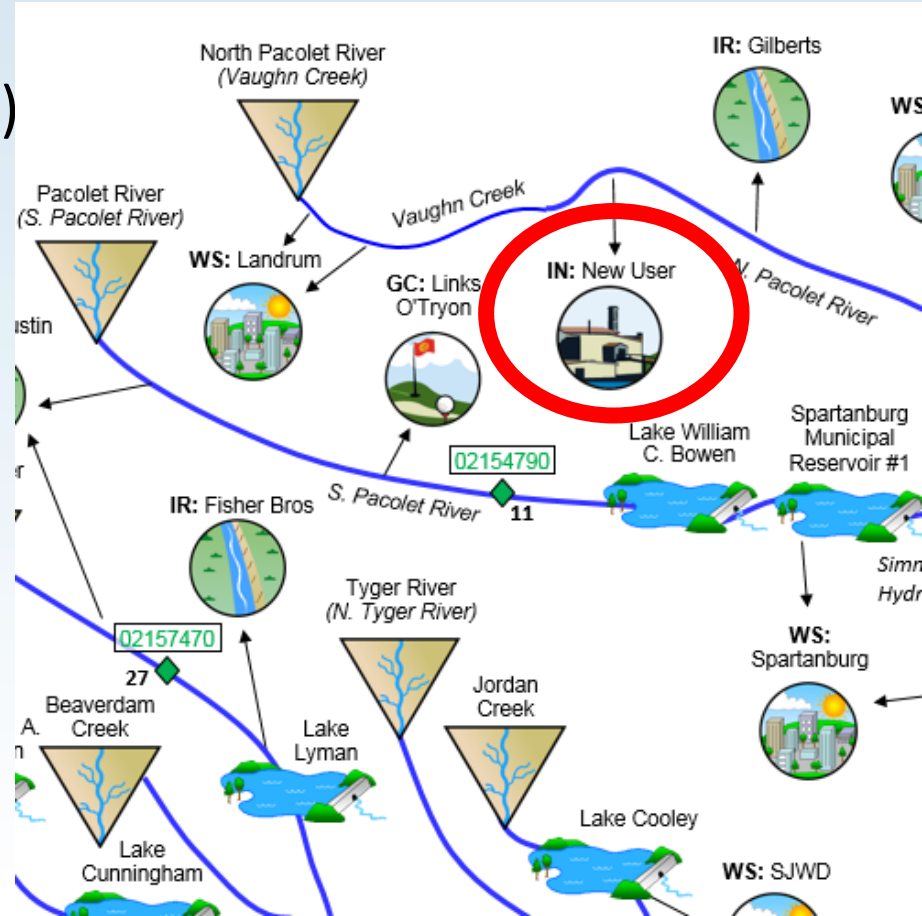
Baseline Model

- Will represent current demands and operations combined with an extended period of estimated hydrology
  - Most demands reflect 2004-2013 averages
  - Estimated hydrology from 1929 to 2013
  - Inactive users are not included
- The baseline model serves as the starting point for future predictive simulations

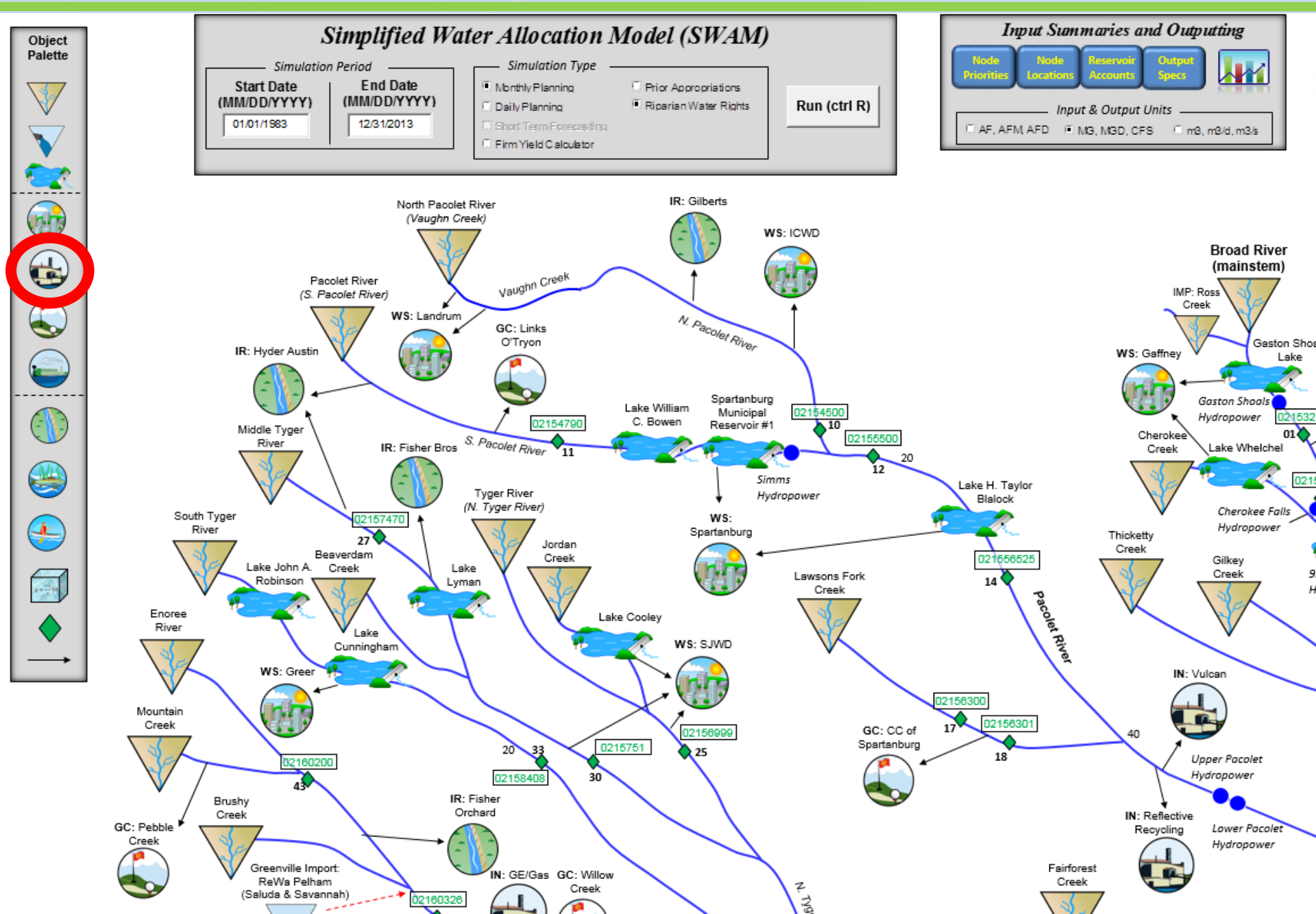
Example Use
Adding a New User

- Add a new M&I permittee on the North Pacolet River
  - Demand = 15 mgd
  - Consumptive Use = 50%
    (return to N. Pacolet River)

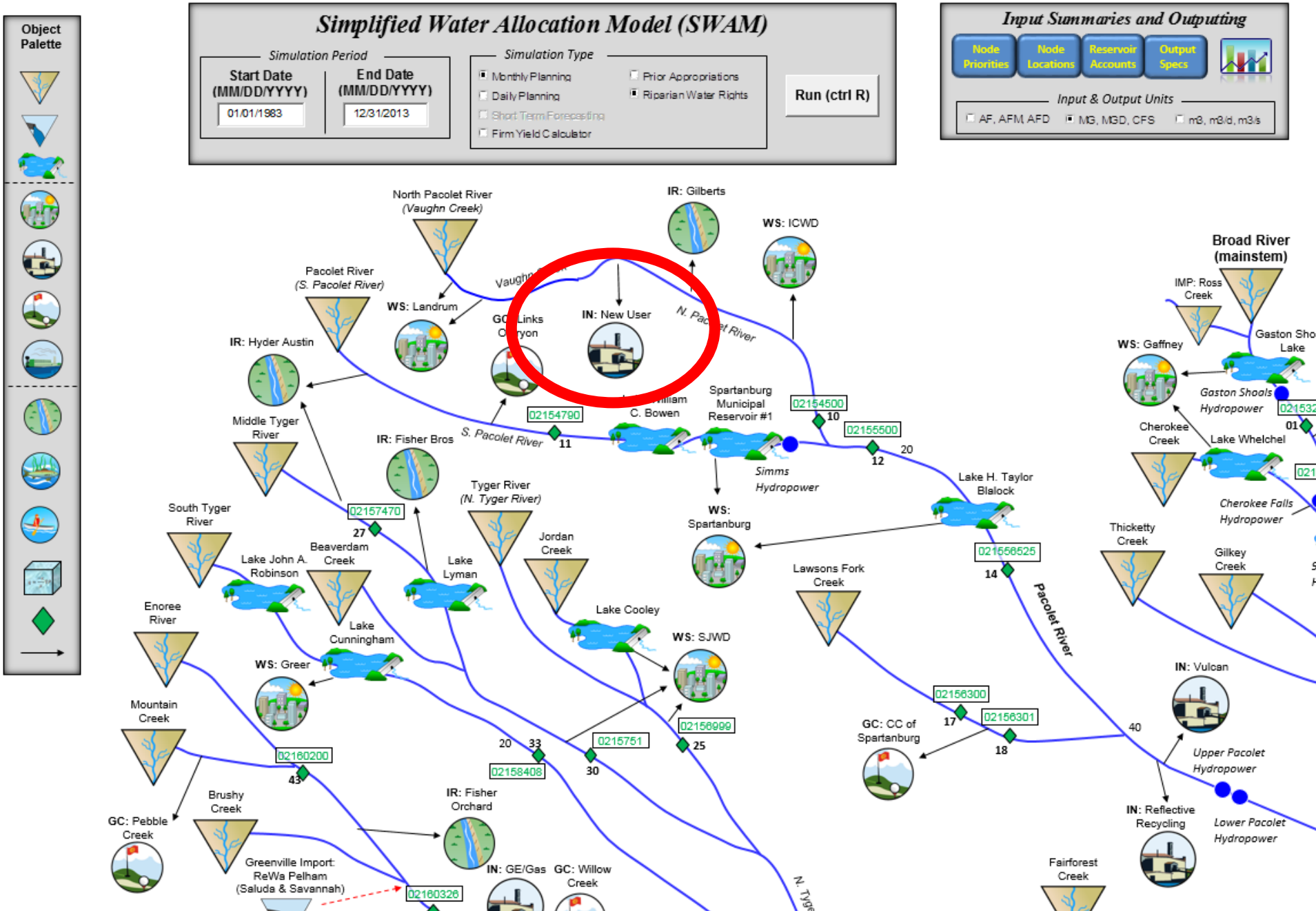
- *Is there enough water to support the new user?*
- *Does the new withdrawal cause shortages for downstream users?*



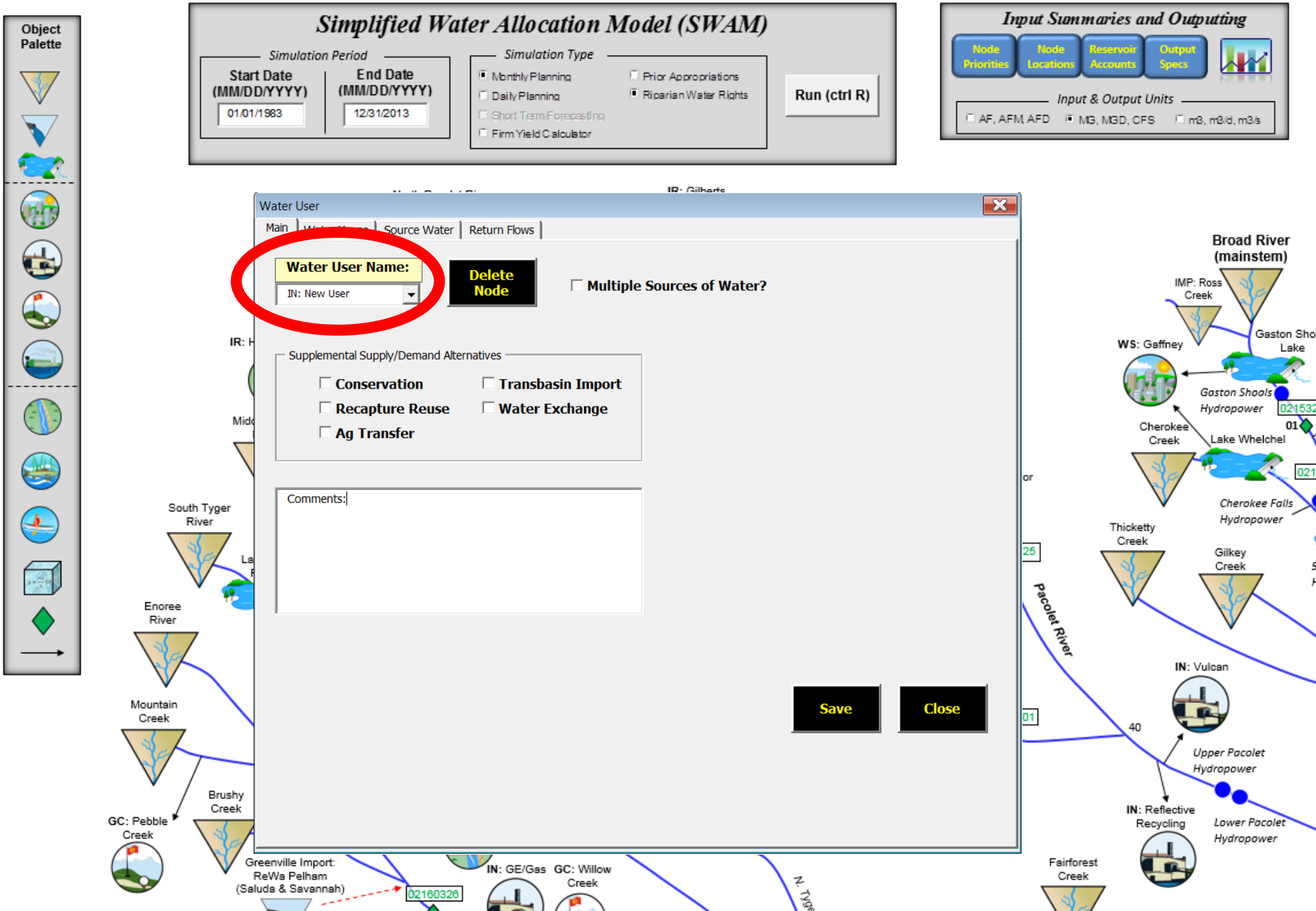
Add an Industrial Water User Object from the Palette



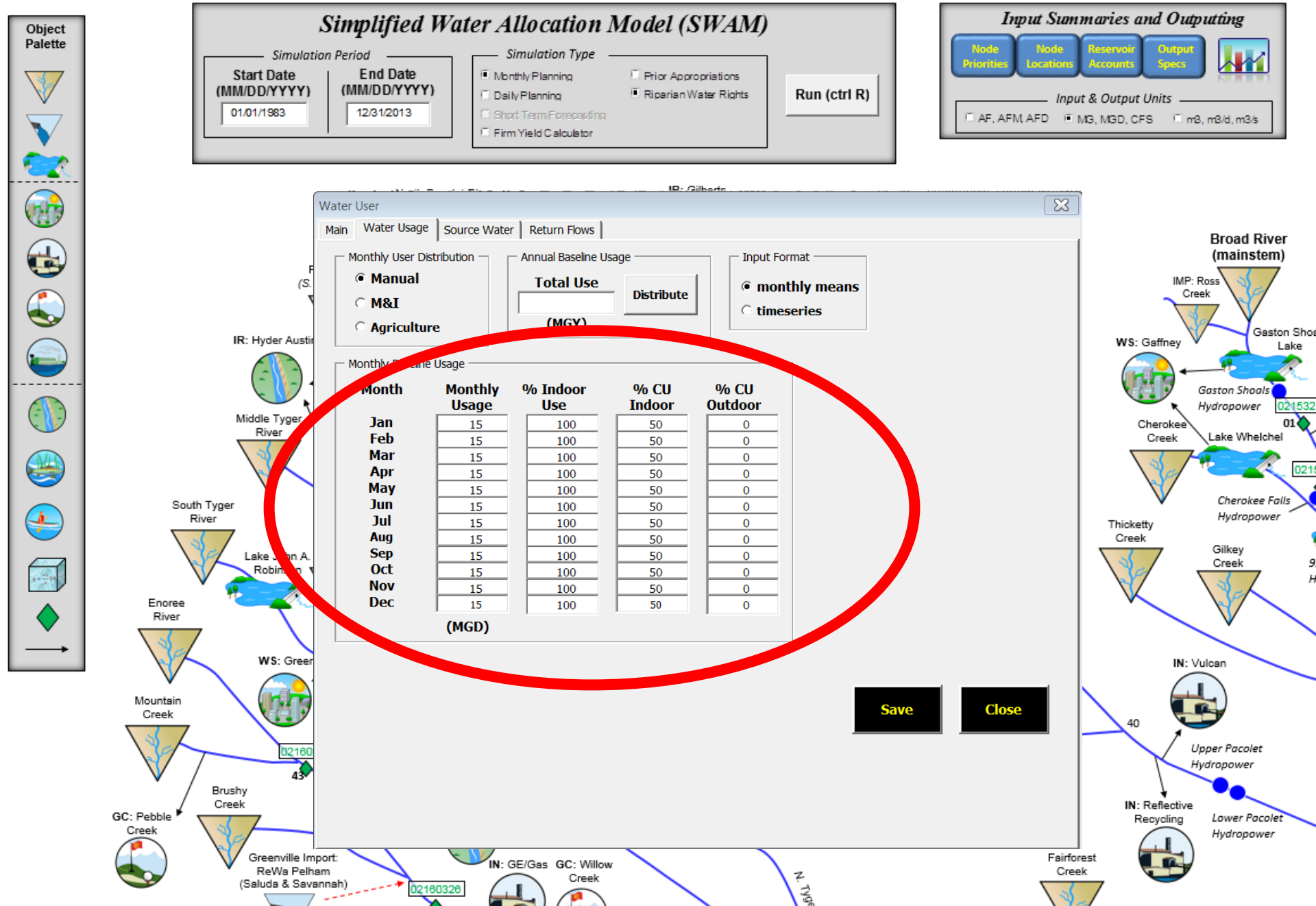
Add an Industrial Water User Object from the Palette



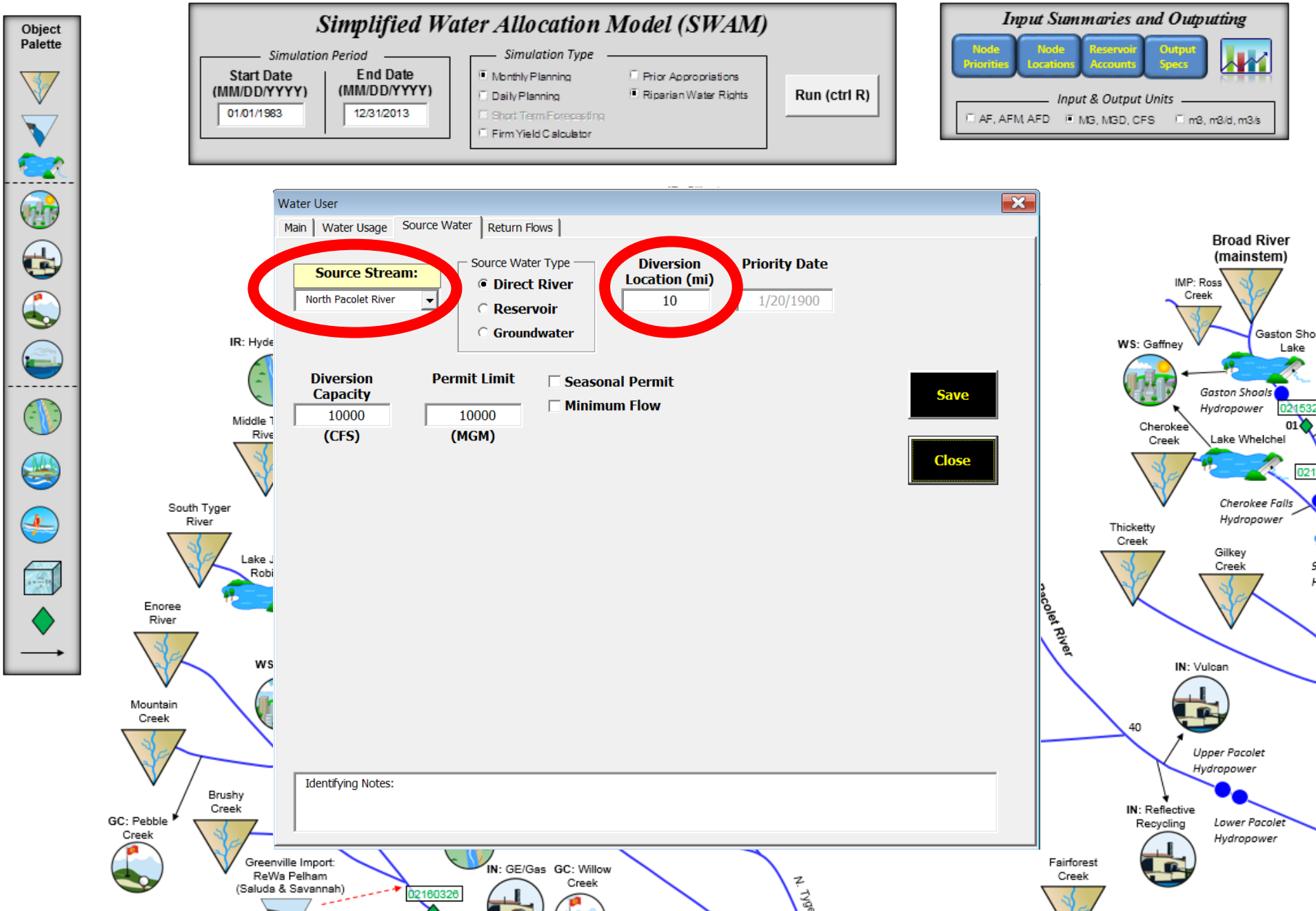
Add the New User in the Water User Dialogue



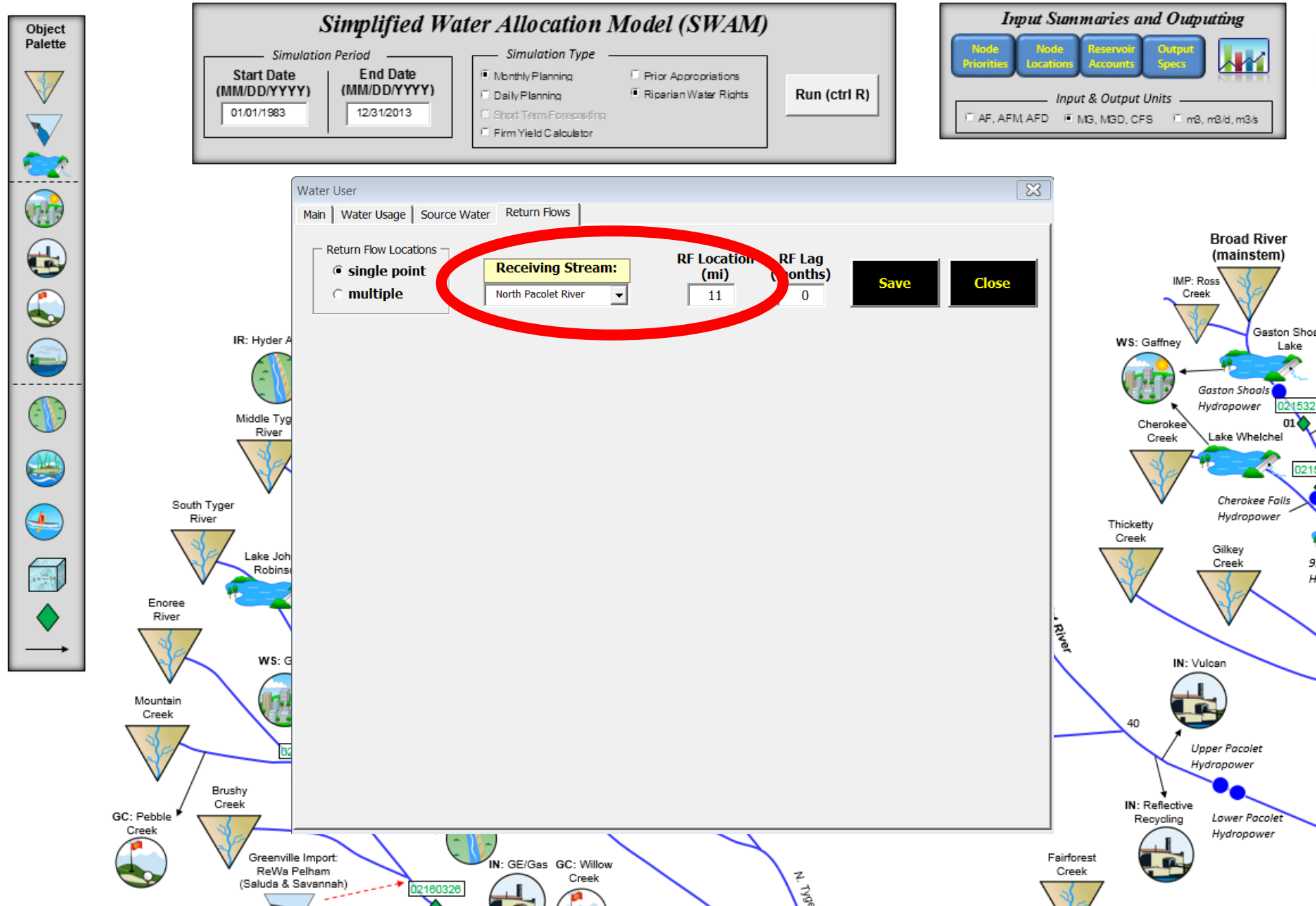
Specify Water Use



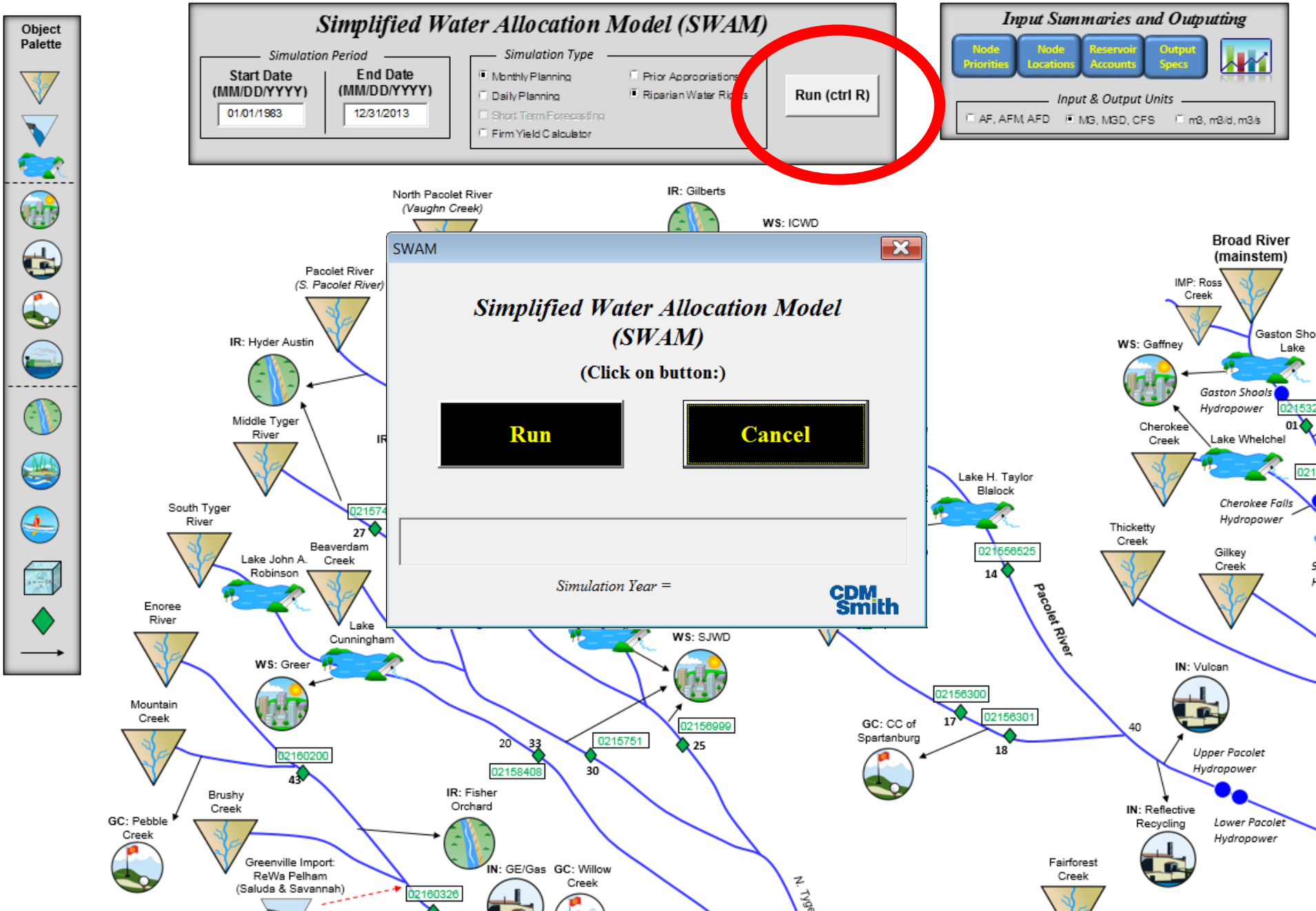
Specify Source and Withdrawal Location



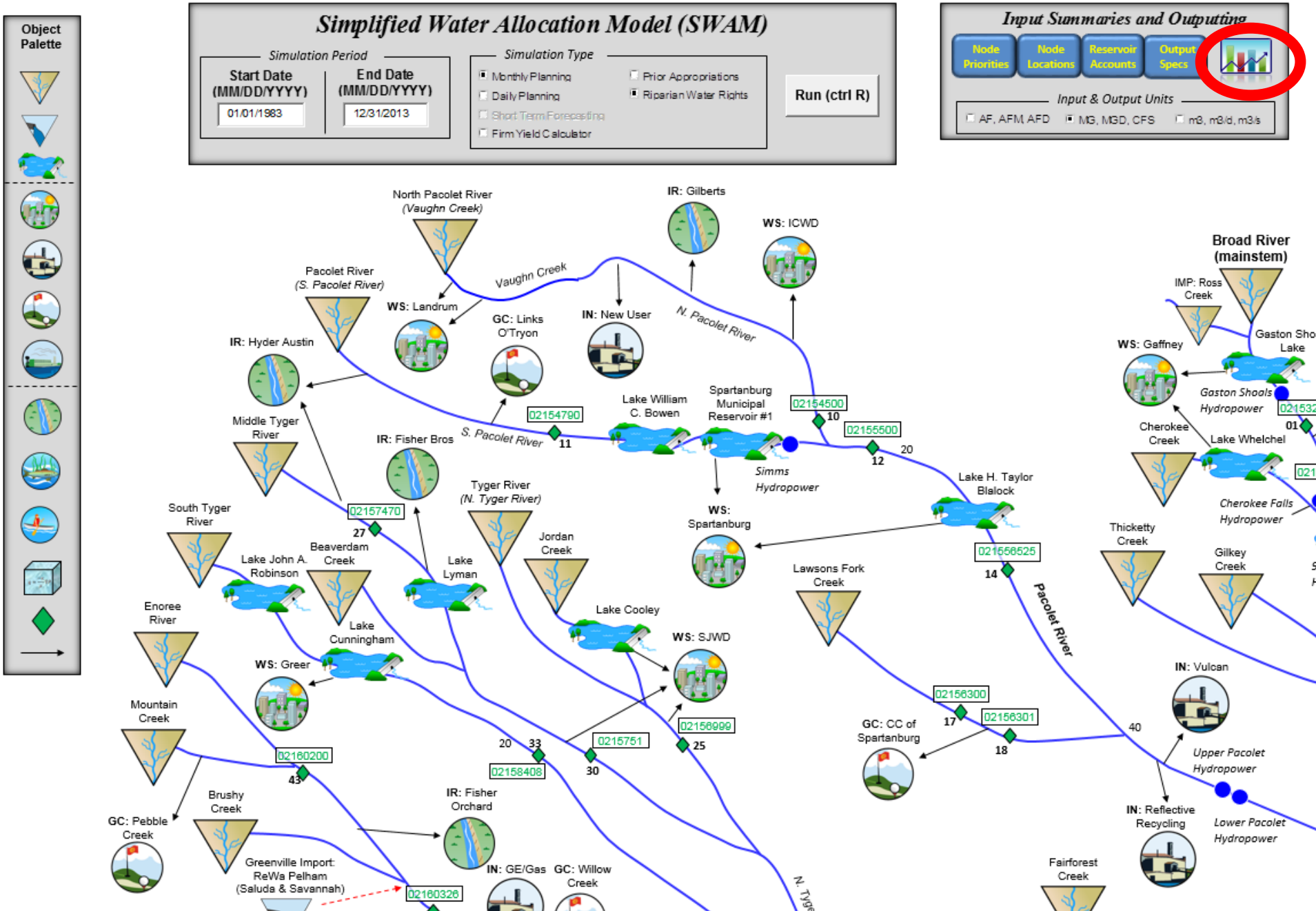
Specify Return Location



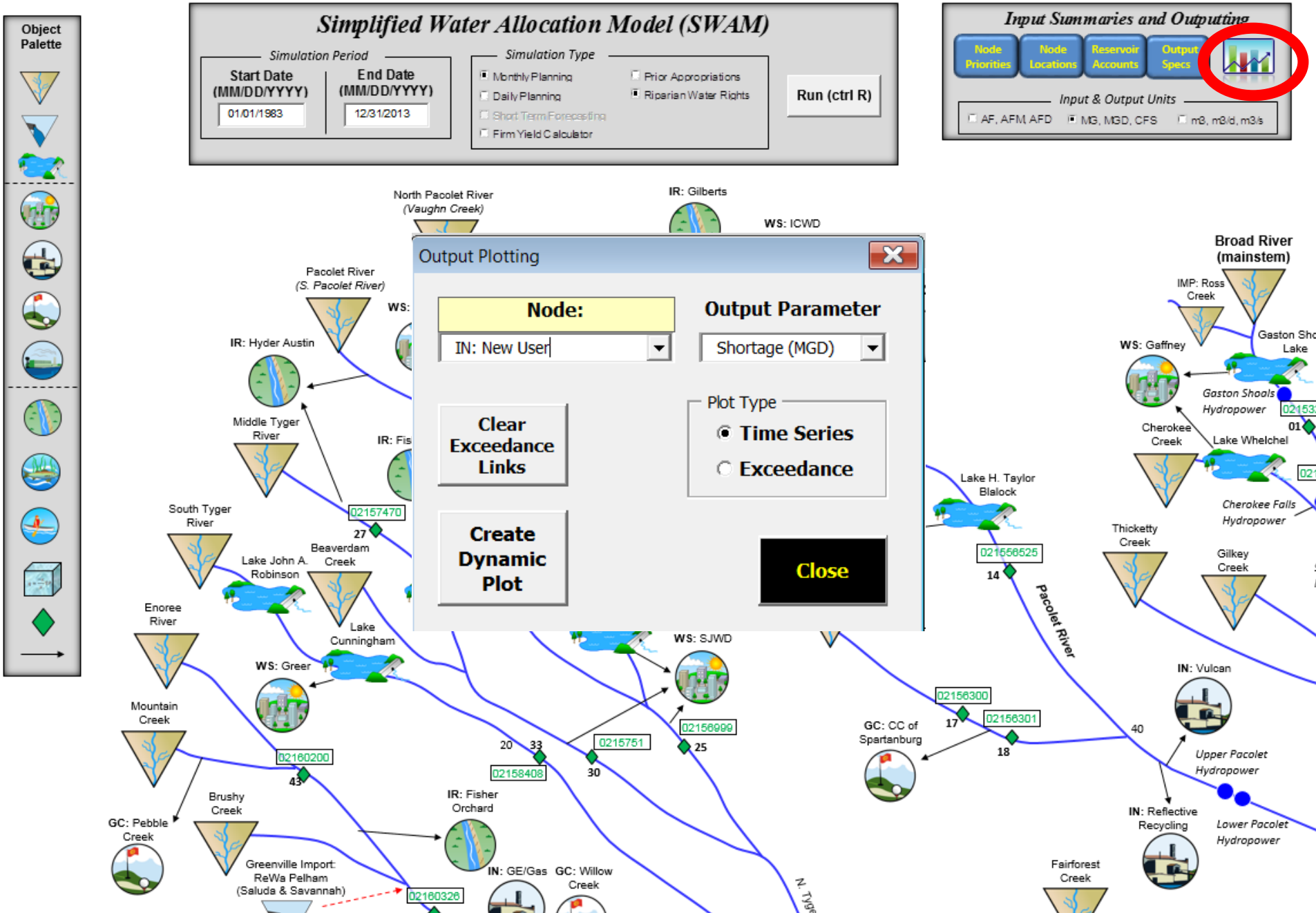
Run Model Scenario



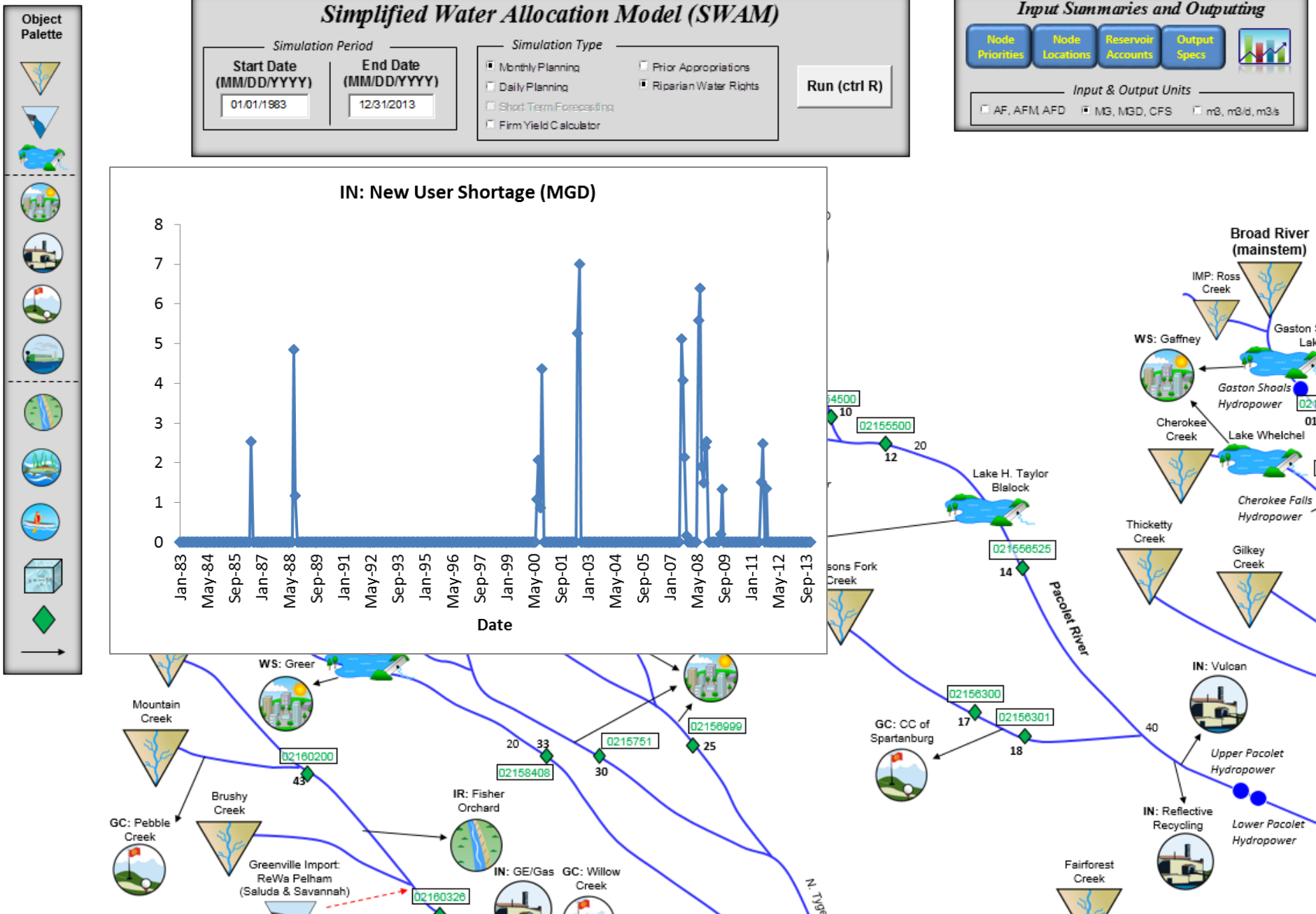
Build a Shortage Plot for the New User



Build a Shortage Plot for the New User



Build a Shortage Plot for the New User

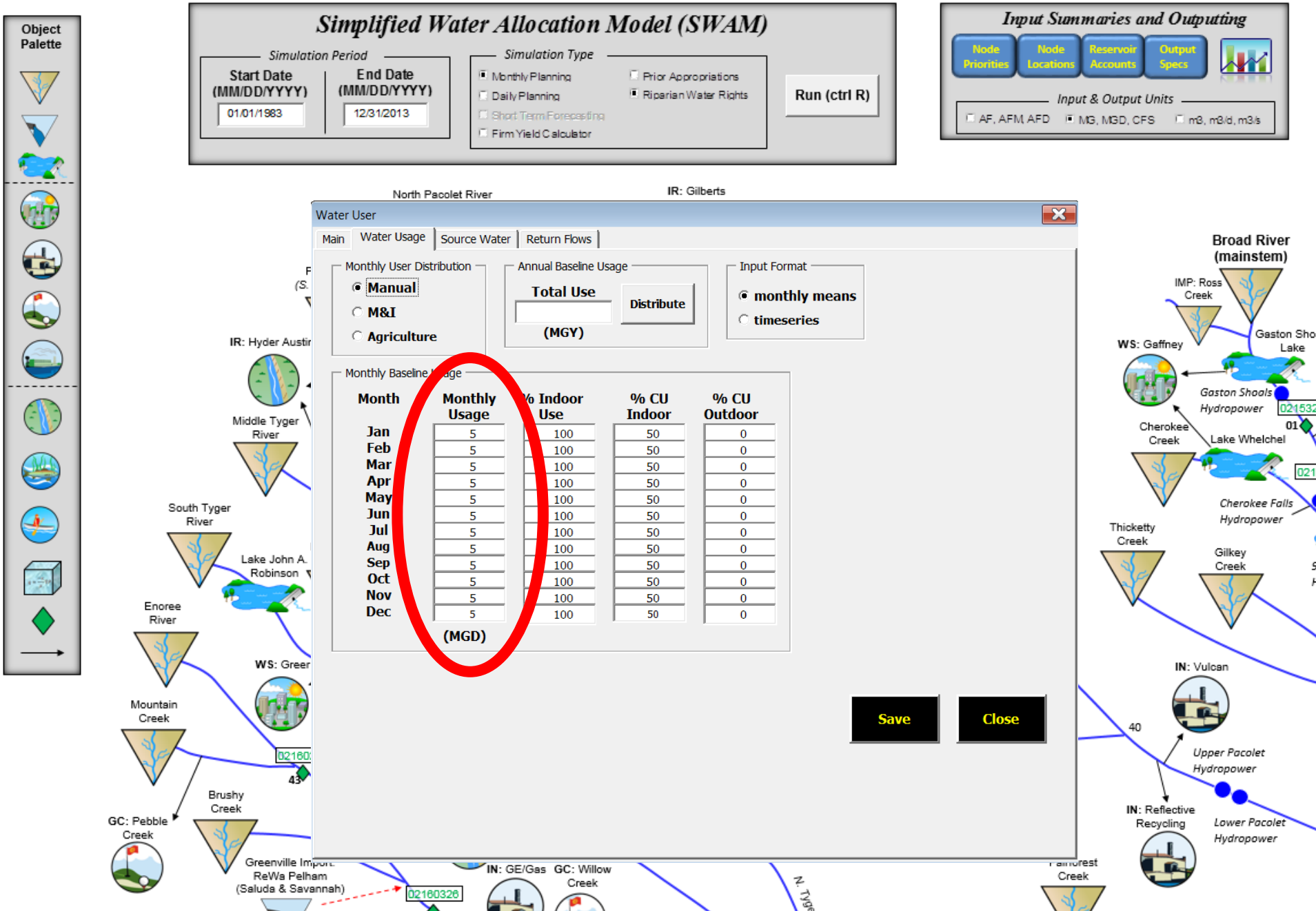


Shortages are Also Listed in the Node Output Table

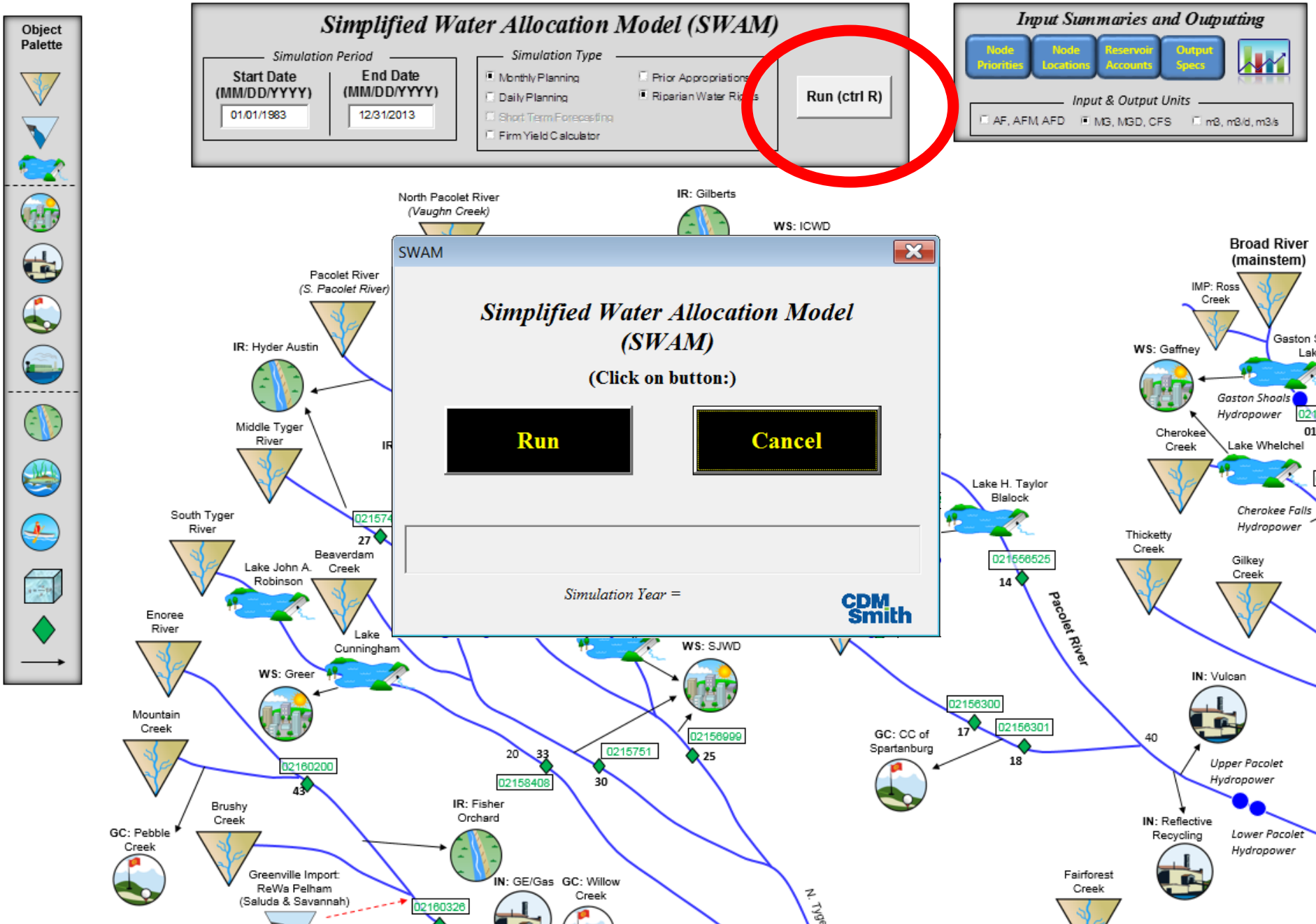
Output

		Priority Rank	Reach	Location	Permit Limit (MGM)	Diversion Capacity (CFS)	Storage Capacity (MG)	Reservoir Withdrawal Permit (MGM)
	IN: New User	*21*	*North Pacolet River*	*10*	*10000*	*10000*	*0*	
Date	Physically Avail. (MGD)	Legally Avail. (MGD)	Demand (MGD)	River Withdrawal (MGD)	Storage (MG)	Groundwater Withdrawal (MGD)	Shortage (MGD)	Return Flow (MGD)
Min	8	8	15	8	0	0	0	4
Max	166	166	15	15	0	0	7	8
Avg	47	47	15	15	0	0	0	7
2/28/08	32	32	15	15	0	0	0	8
3/31/08	44	44	15	15	0	0	0	8
4/30/08	32	32	15	15	0	0	[illegible]	8
5/31/08	19	19	15	15	0	0	0	8
6/30/08	9	9	15	9	0	0	6	5
7/31/08	9	9	15	9	0	0	6	4
8/31/08	13	13	15	13	0	0	2	7
9/30/08	14	14	15	14	0	0	1	7
10/31/08	13	13	15	13	0	0	2	6
11/30/08	12	12	15	12	0	0	3	6
12/31/08	27	27	15	15	0	0	0	8
1/31/09	35	35	15	15	0	0	0	8
2/28/09	20	20	15	15	0	0	0	8
3/31/09	56	56	15	15	0	0	0	8
4/30/09	56	56	15	15	0	0	0	8
5/31/09	33	33	15	15	0	0	0	8
6/30/09	33	33	15	15	0	0	0	8
7/31/09	15	15	15	15	0	0	0	7
8/31/09	14	14	15	14	0	0	1	7
9/30/09	31	31	15	15	0	0	0	8
10/31/09	31	31	15	15	0	0	0	8
11/30/09	70	70	15	15	0	0	0	8
12/31/09	113	113	15	15	0	0	0	8
1/31/10	107	107	15	15	0	0	0	8

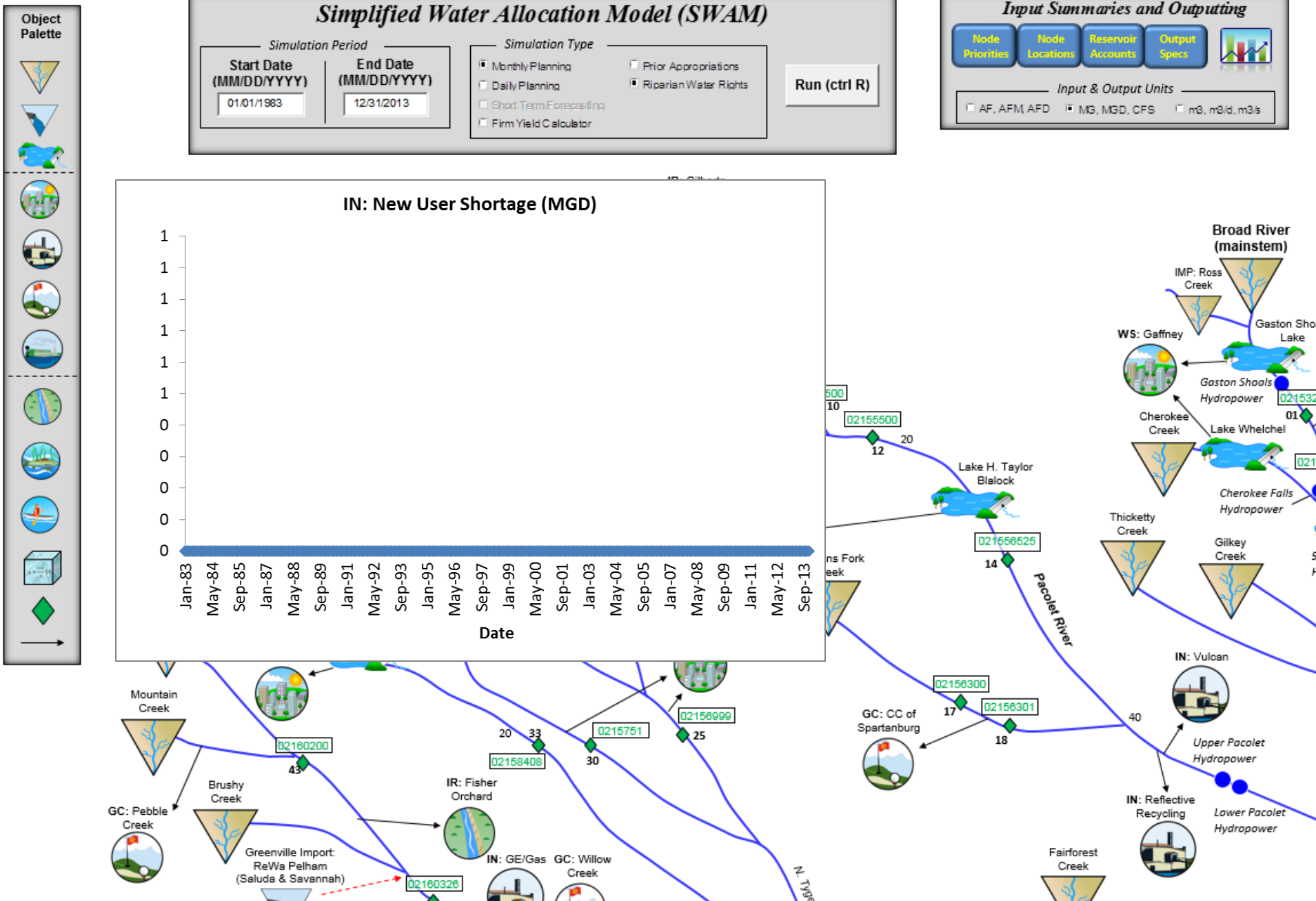
Reduce the New User's Total Water User to 5 mgd



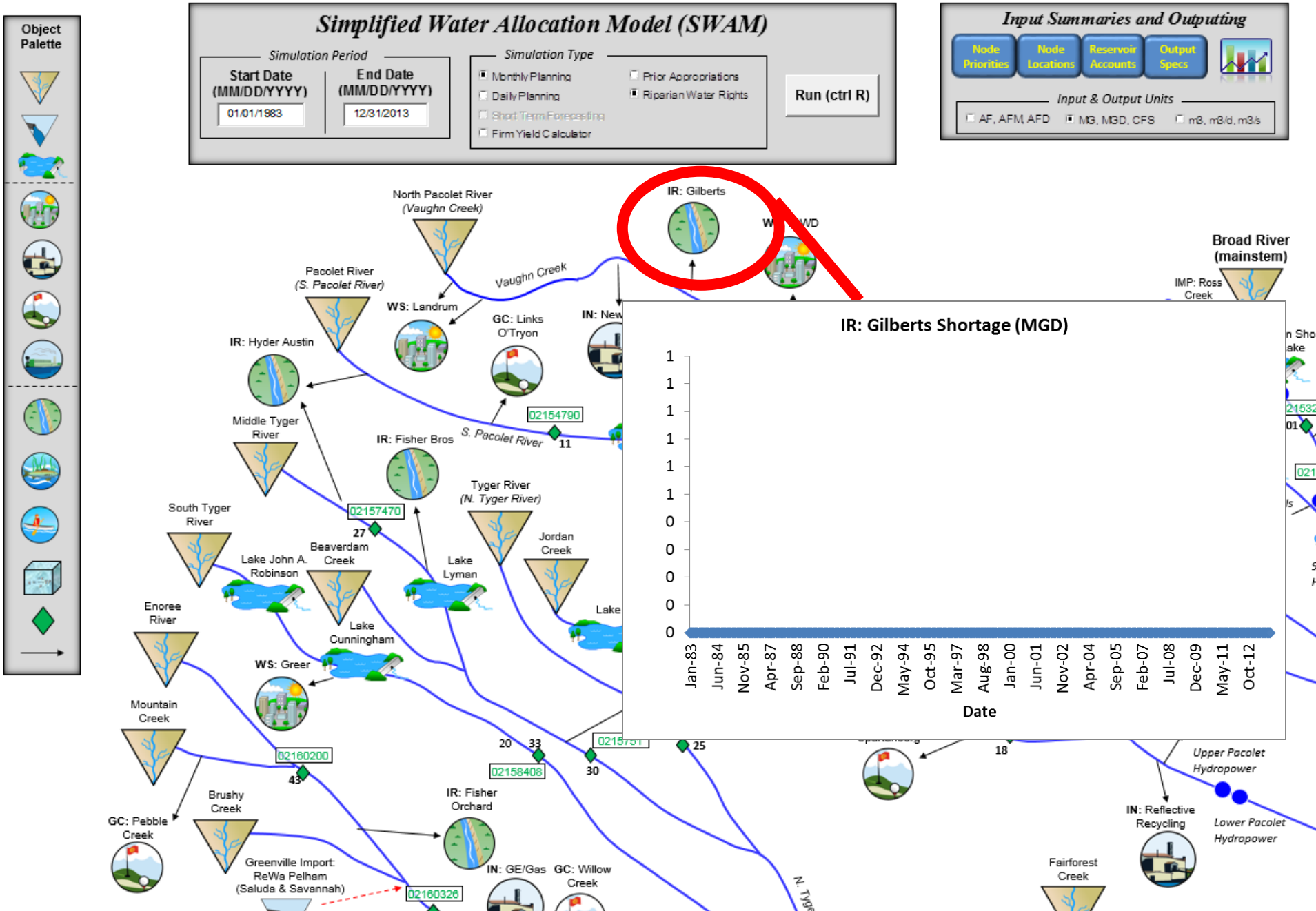
Rerun Model Scenario



Dynamic Shortage Plots Update Automatically



Check for Shortages for Downstream Users



Demonstrations and Q&A

- Station 1 (Nina)

  Evaluate increased withdrawals from a reservoir

- Station 2 (John)

  Evaluate a proposed new municipal water supply withdrawal

- Station 3 (Kirk)

  Evaluate a proposed new industrial user and compare against instream flow requirements

Broad River Basin

THANK YOU