



# URGSiM Analysis of Climate Risk in the Upper Rio Grande Basin

SAND#2011-8745C

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# The SECURE Water Act

- The SECURE Water Act:

Authorizes the Bureau of Reclamation to assess the risks to water supplies and demands posed by climate change in the eight major river basins in the Western United States in studies referred to as West Wide Climate Risk Assessments (WWCRA).

- West Wide Climate Risk Assessments (WWCRA):

Include (among other things) analysis of

- Changes in timing of runoff
- Changes in quantity of runoff
- Changes in demands
- Changes to consumptive use

And potential impacts to (among other things)

- Water deliveries
- Power
- Fish and wildlife

- For additional info, attend Dagmar Llewellyn's talk in session 31 (4:10 pm this afternoon Fiesta 1-2)

# The Rio Grande WWCRA Approach:

112 runs  
1950-2099

General Circulation  
Model (GCM)

112 Statistically  
Downscaled  
Regional Projections  
of  $\Delta P$  and  $\Delta T$

Variable  
Infiltration  
Capacity  
(VIC)  
Model

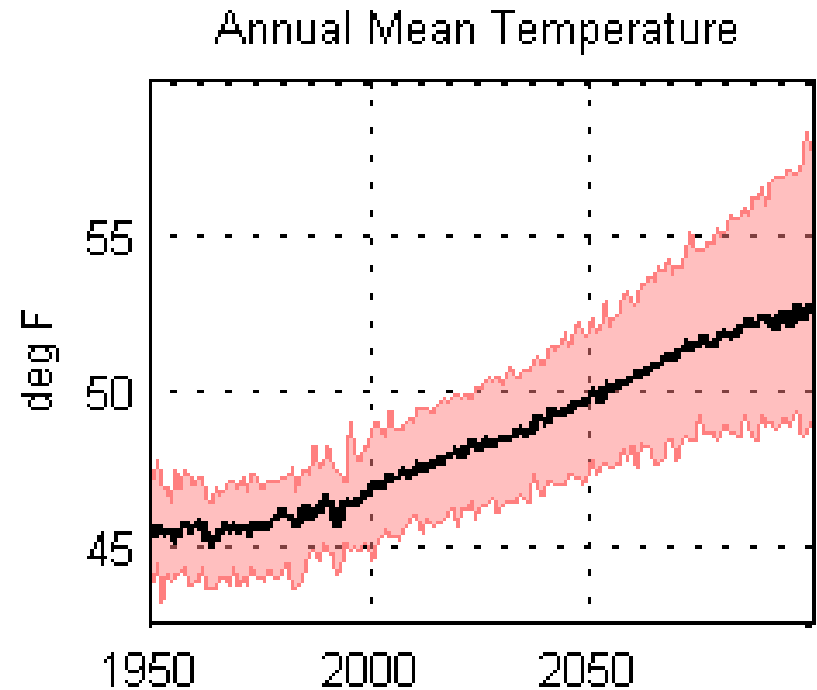
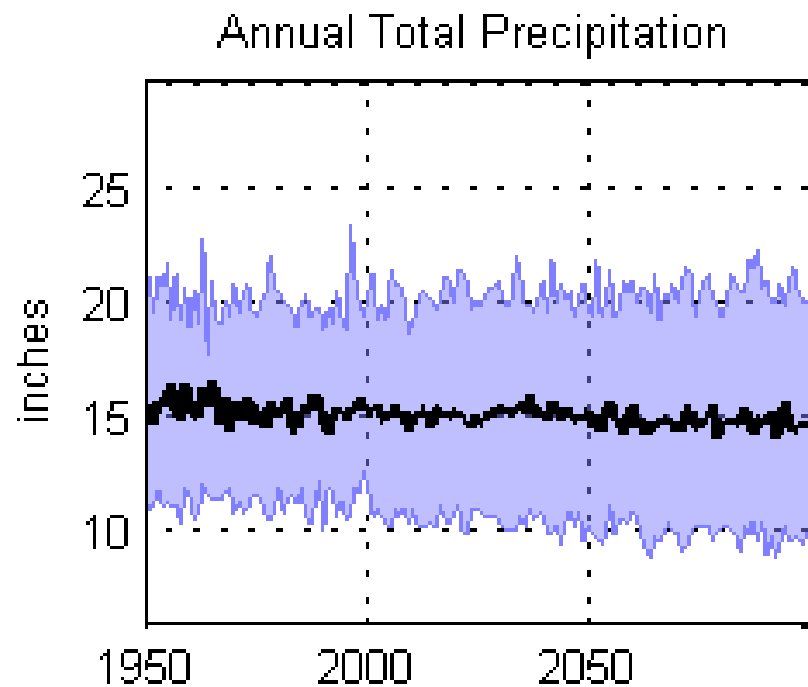
112 Runoff  
Projections Using  
Rainfall Runoff  
Model

Post processing bias  
correction of flows  
(224 hydrographs)

Operations model  
(URGSiM)

Impacts to water  
deliveries, flows, and  
reservoir levels.

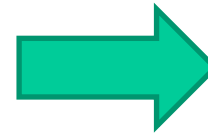
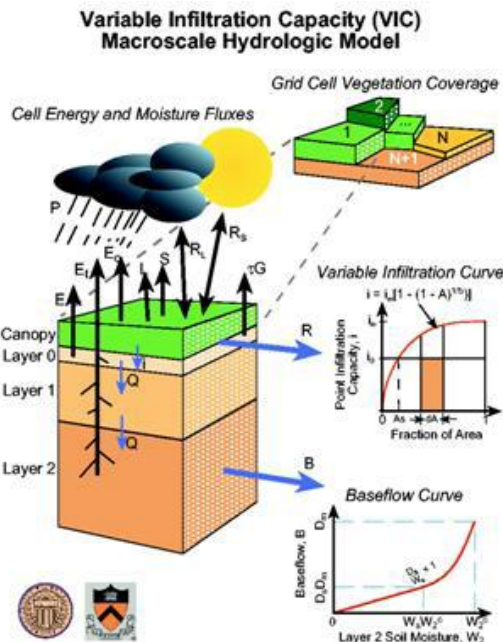
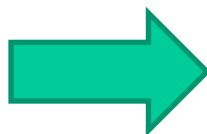
# GCM Runs – Rio Grande



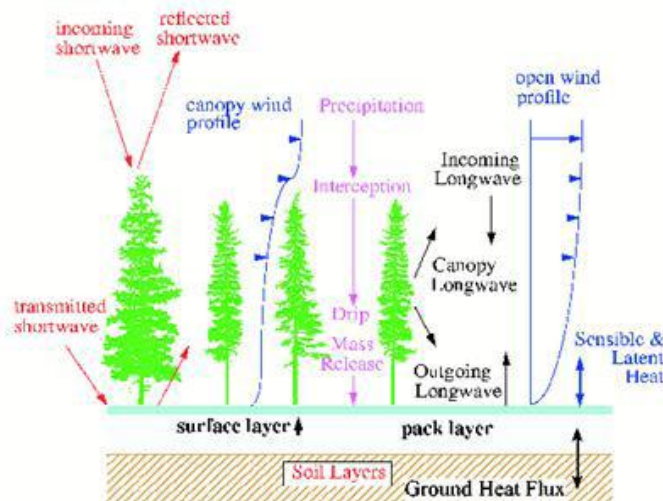
From Figure 46 of Reclamation Technical Memorandum No. 86-68210-2011-01  
“West-Wide Climate Risk Assessments: Bias Corrected and Spatially Downscaled Surface  
Water Projections” March 2011. Subhrendu Gangopadhyay and Tom Pruitt

# VIC Runs

Downscaled  
GCM  
Output  
(T and P)



Hydrographs





# URGSiM

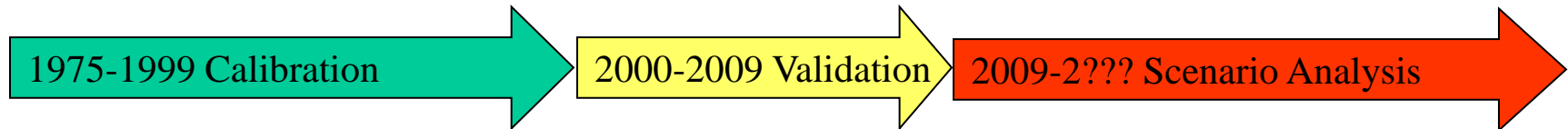
Fast, user friendly model of the Upper Rio Grande hydrologic system capable of running multi-year simulations in a matter of seconds.

URGSiM uses available surface water (URGWOM), groundwater, evapotranspiration, and human use models and data to build a monthly timestep systems level model of water use through the Upper Rio Grande basin.

- URGWOM
- Hargreaves reference ET equation
- MODFLOW models of Espanola, Albuquerque, Socorro gw basins(USGS, NMOSE)

Temporal resolution and extent:

- Monthly timestep, 1975 on



# URGSiM Spatial Resolution

Spatial resolution and extent based on URGWOM model:

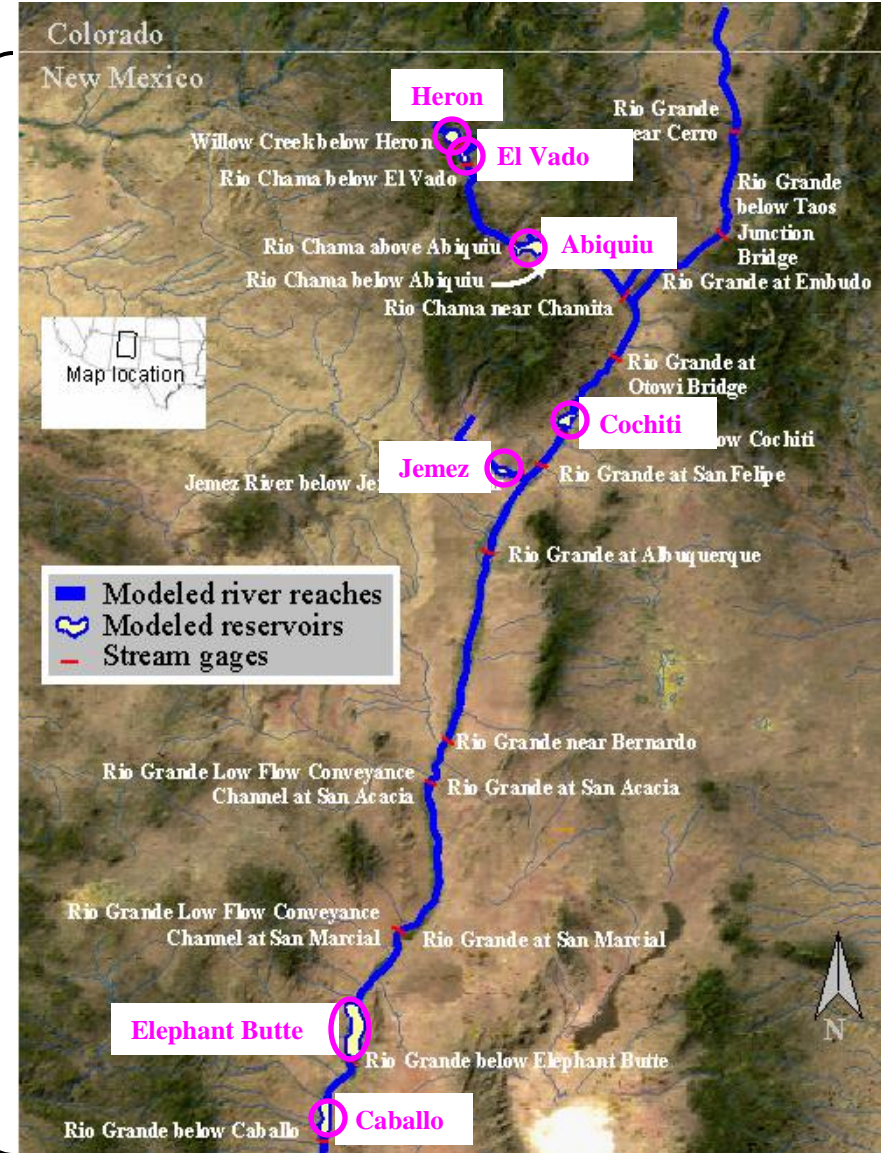
- Dominant historical data set is from USGS stream flow gages:

➔ "River reach": gage location based spatial unit of mass balance.

17 river reaches

- 12 Rio Grande
- 4 Rio Chama
- 1 Jemez River

In addition to river reaches, there are 7 spatial mass balance units representing major reservoirs



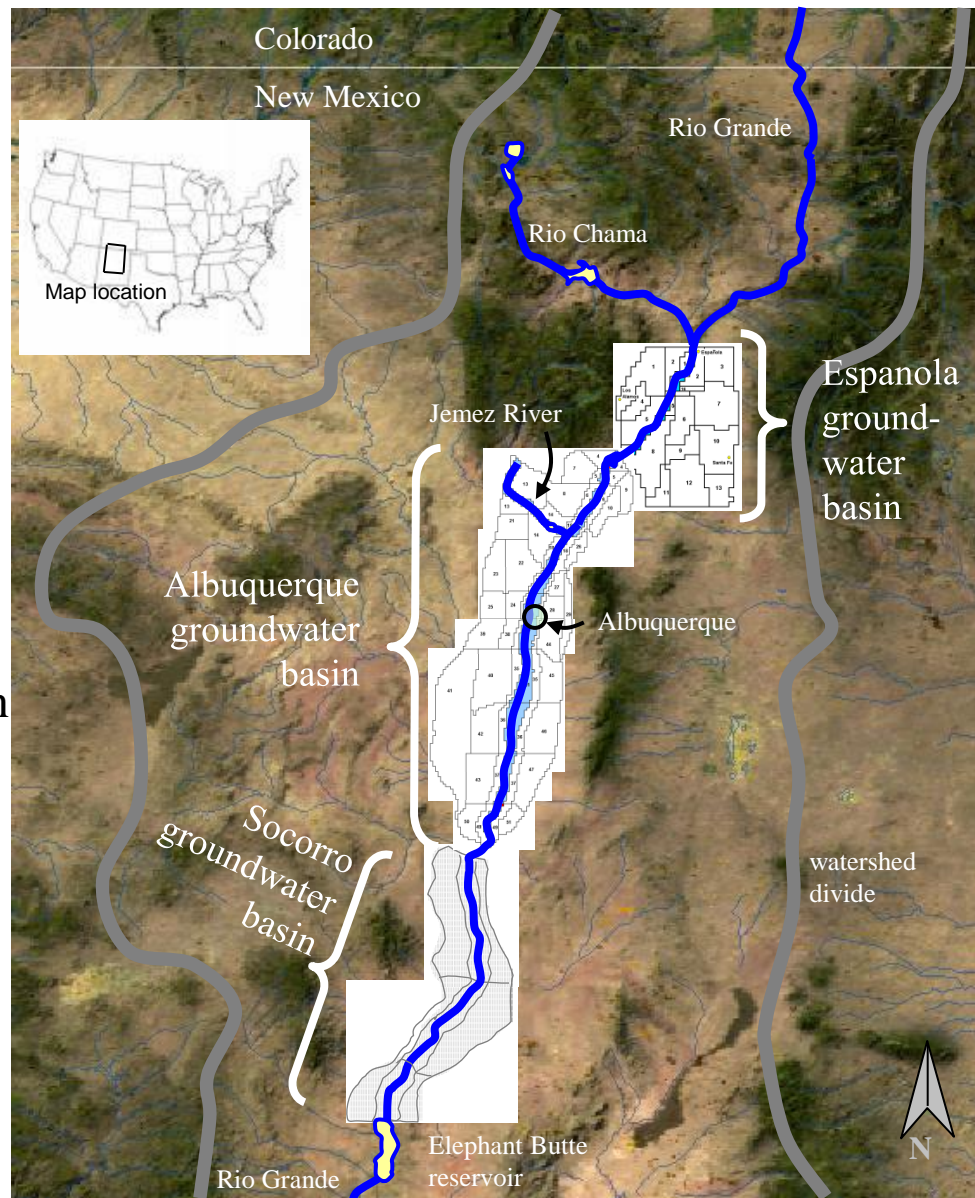
# URGSiM GW Modules

## Goal:

- A rapid and physically based, dynamic representation of sw-gw interactions in Rio Grande river system coupled directly to dynamic surface water model.

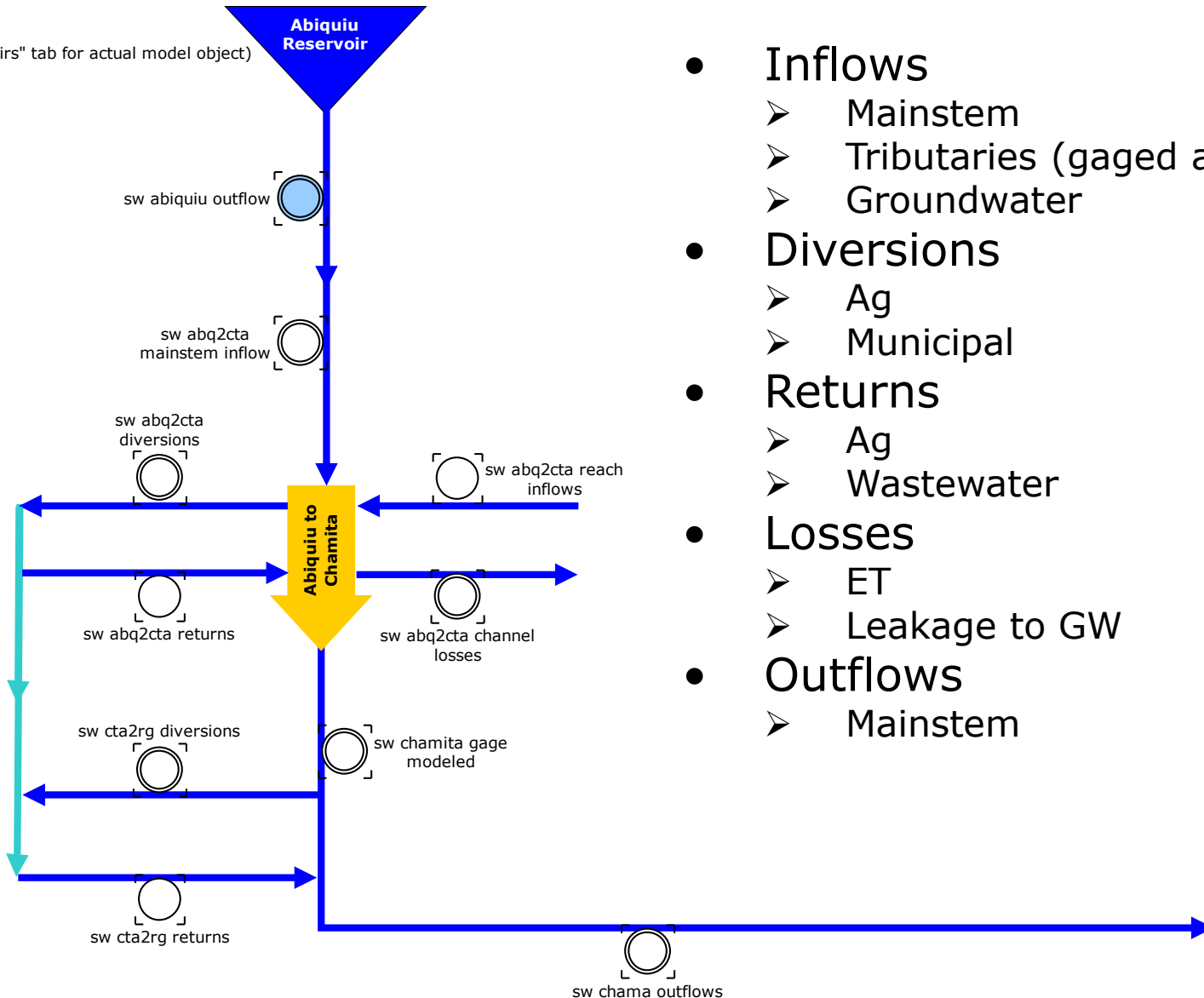
## Strategy:

- Use spatially explicit groundwater models to calibrate spatially aggregated versions in Powersim (system dynamics software).
- Three spatially explicit models of interest:
  - Espanola Basin (Frenzel 1995)
  - Albuquerque Basin (McAda et al 2002)
  - Socorro Basin (Shafike 2005)



# URGSiM reach mass balance

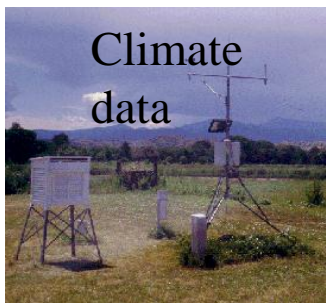
(See "Reservoirs" tab for actual model object)



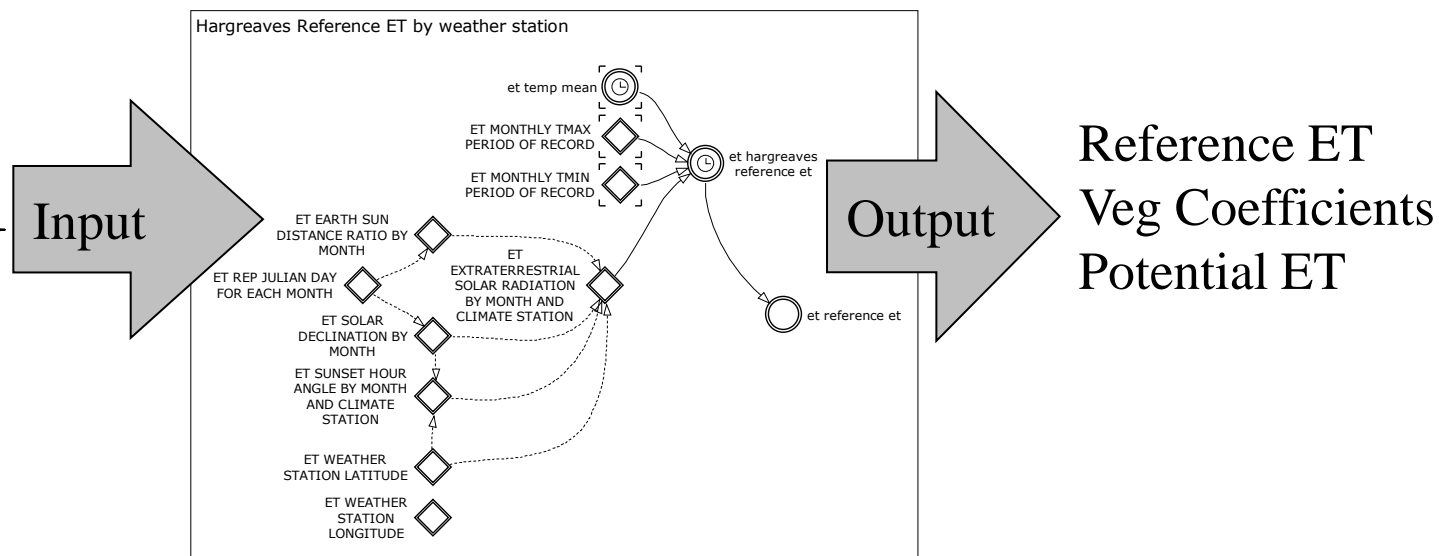
- Inflows
  - Mainstem
  - Tributaries (gaged and ungaged)
  - Groundwater
- Diversions
  - Ag
  - Municipal
- Returns
  - Ag
  - Wastewater
- Losses
  - ET
  - Leakage to GW
- Outflows
  - Mainstem

# Evaporative Demand

- Reference ET ( $ET_0$ ) calculated with climate data using Hargreaves equation:  $ET_0 = f(\text{latitude, date, monthly tmax, tmin, tmean})$
- Vegetation coefficients calculated for riparian and ag plant species



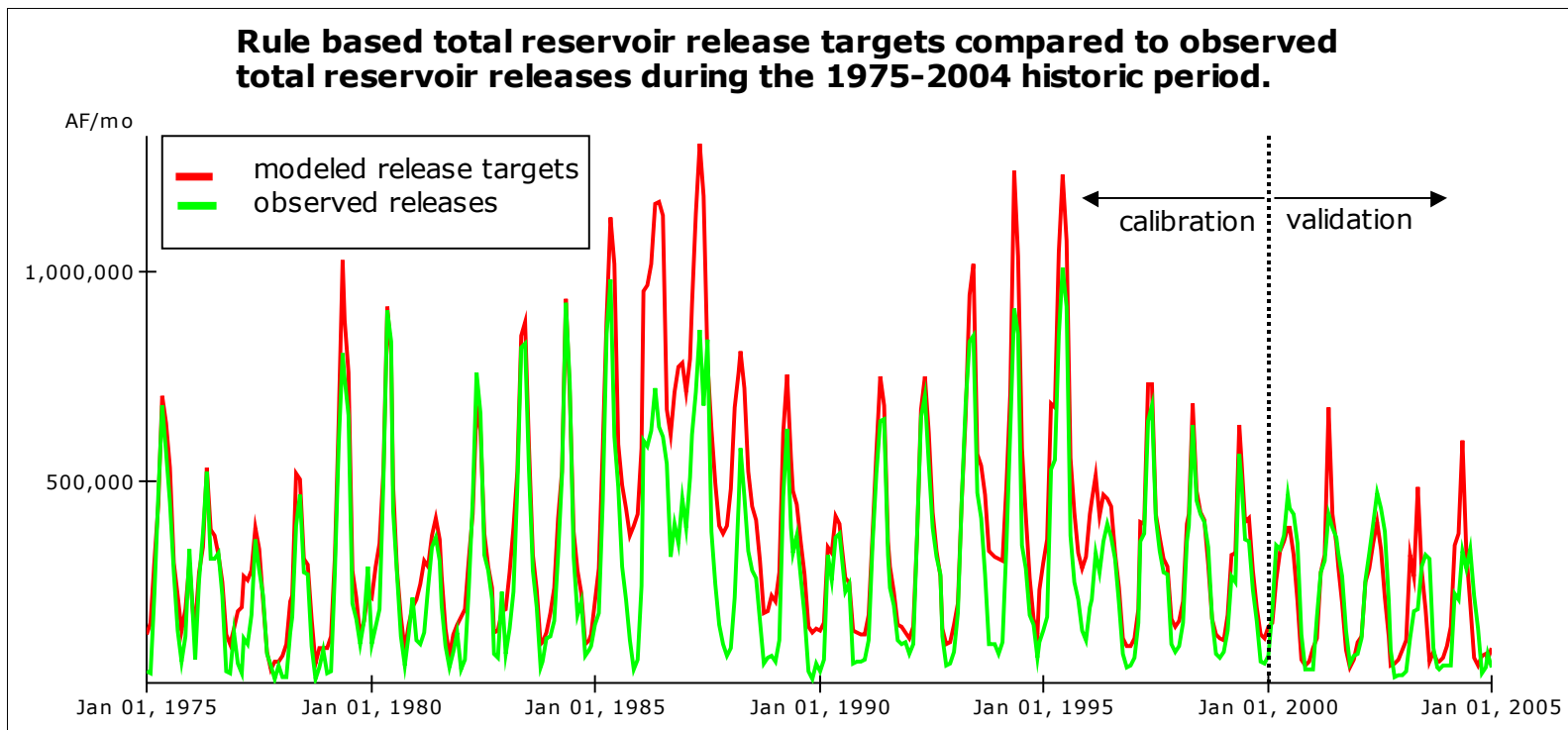
## ET Module



- Actual ET used by model is smaller of potential ET and water available to riparian vegetation or irrigated crop

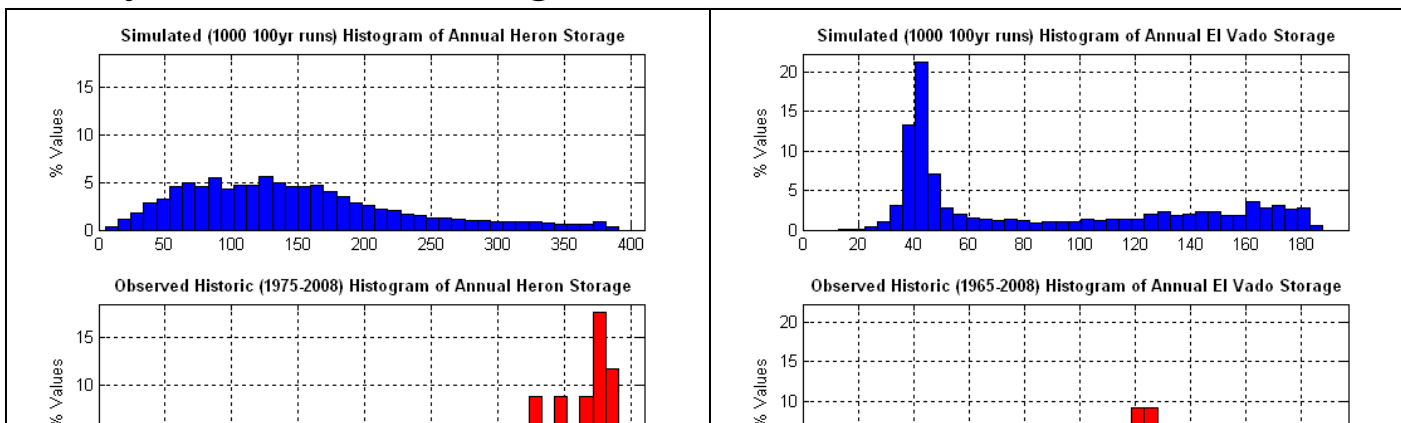
# Reservoir Release Rules

- Reservoirs in upper Rio Grande are managed for a variety of objectives including flood control, storage, minimum flows, and interstate compacts that have been incorporated into the model following URGWOM methods.
- These rules can explain most, of 1975-2004 reservoir releases.
- Discrepancies are due to operations changes and subjective flexibility built into the system that can be exercised by water managers.

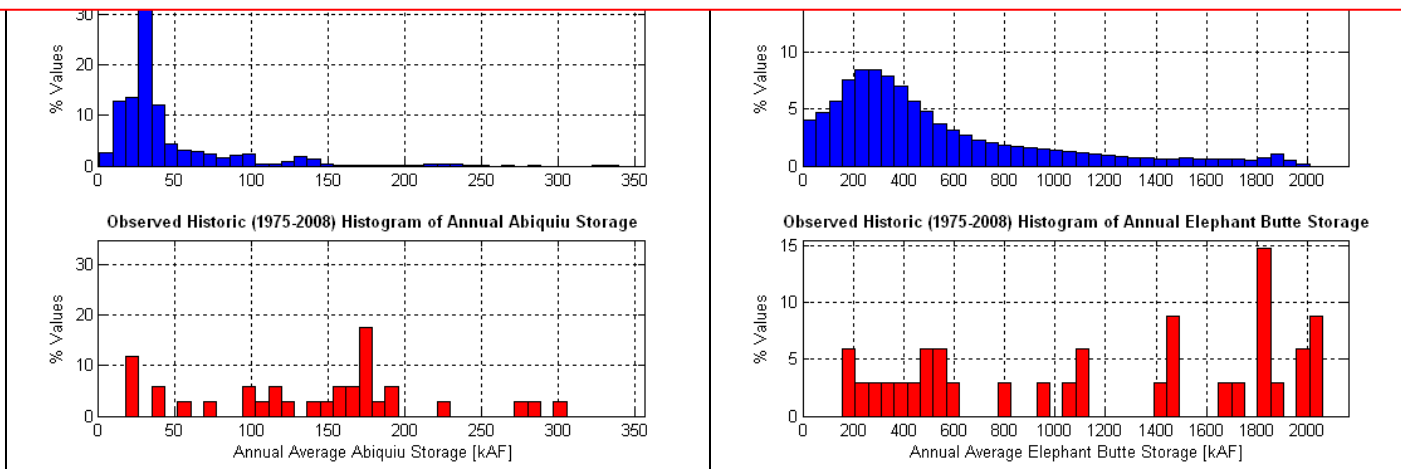


# URGSiM Stochastic Hydrology Results

Ran 1000, 100 year long climate sequences based on 400 years of tree ring data:



For more detailed information on URGSiM, please attend my talk this afternoon (1:50 pm, session 49, Enchantment E-F)



# URGSiM hydrologic inputs:

## • Gaged SW inflows (USGS and CODWR):

- Rio Grande near Lobatos\*
- Conejos near Mogote\*
- San Antonio near Ortiz\*
- Los Pinos near Ortiz\*
- Rio Grande near Del Norte\*
- Costilla Creek near Garcia
- Red River below Fish Hatchery
- Rio Pueblo de Taos below Los Cordovas
- Embudo Creek at Dixon
- Rio Blanco above Blanco Diversion
- Little Navajo River above Little Oso Diversion
- Navajo River above Oso Diversion
- Rio Chama at La Puente
- Rio Ojo Caliente at La Madera
- Rio Nambe below Nambe Falls Dam
- Santa Fe River above Cochiti
- Galisteo Creek below Galisteo Dam
- Jemez River near Jemez
- North Floodway Channel near Alameda
- Tijeras Arroyo near Albuquerque
- South Diversion Channel near Albuquerque
- Rio Puerco near Bernardo

Driven  
by  
VIC  
for  
WWCRA

## • Ungaged SW inflows:

- All reaches above Central at Albuquerque
- Calibration term

Correlated to gaged inflows

## • GW inflows to river:

- All reaches above Rio Grande – Rio Chama confluence
- Based on winter sw gaged flow analysis

No change in this WWCRA

## • GW recharge:

- All reaches from Rio Grande – Rio Chama confluence to Elephant Butte
- Based on regional GW flow model values

## • Reservoir precipitation:

- Heron, El Vado, Abiquiu, Cochiti, Jemez, Elephant Butte, Caballo
- Volume depends on reservoir area

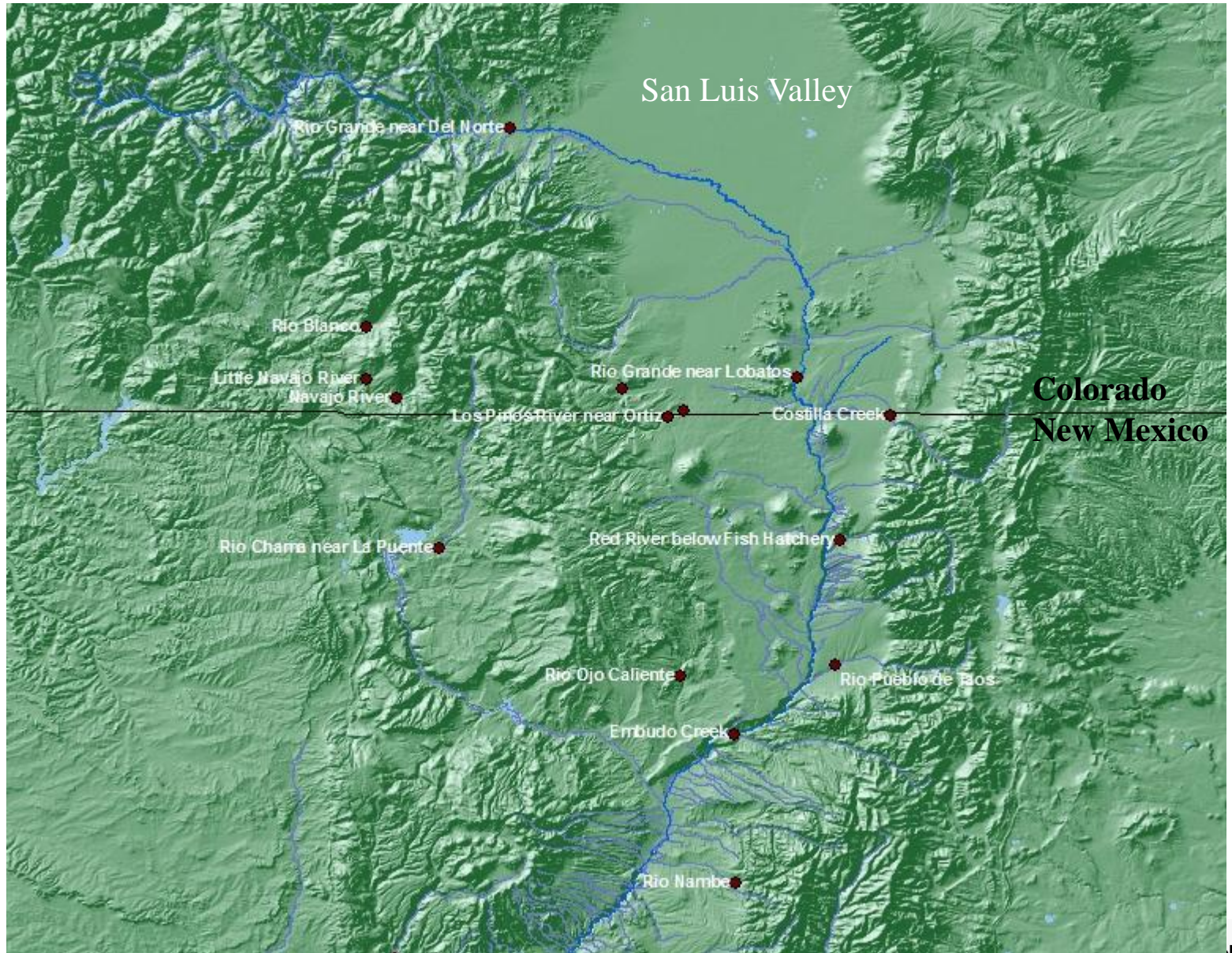
From GCM for WWCRA

\* Lobatos gage used for historic period, but Rio Grande Compact Index gages (Conejos – Mogote, Los Pinos – Ortiz, San Antonio – Ortiz, Rio Grande - Del Norte) for Colorado used to calculate Colorado delivery obligation during scenario period.

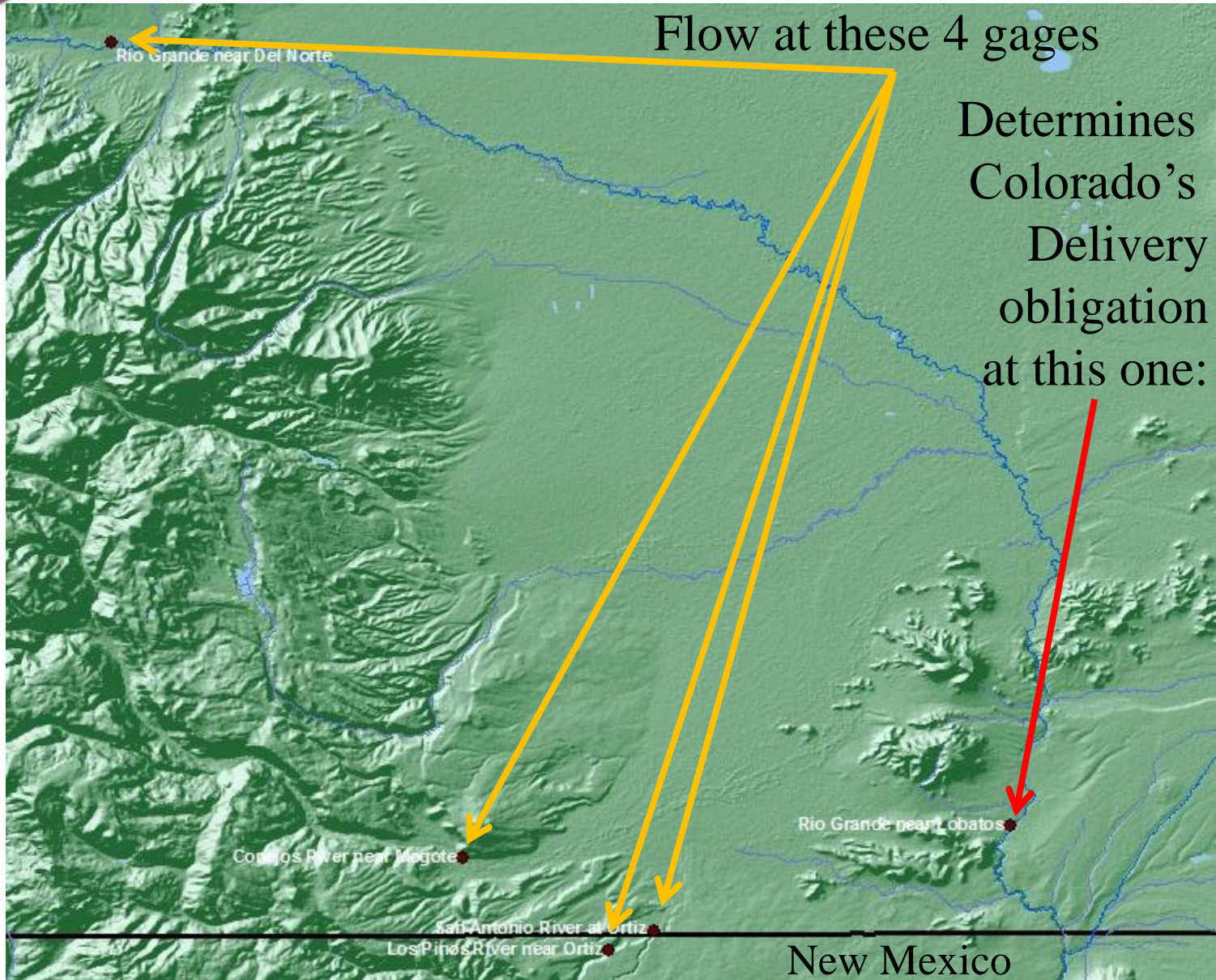
# URGSiM Gaged Inflows

Gage	USGS Gage#	Average Annual Input 1975-99 [af/yr]	% of Gaged Inputs [%]	Contrib Drainage Area [mi <sup>2</sup> ]	Datum Elev [ft amsl]	~Lat [dd]	~Long [dd]
Rio Grande near Lobatos	<a href="#">CDWR</a>	386200	<b>34%</b>				
Rio Chama near La Puente	<a href="#">8284100</a>	295300	<b>26%</b>	480	7083	36.66	106.63
Azotea tunnel outlet	BoR	97100	<b>9%</b>				
Embudo Creek at Dixon	<a href="#">8279000</a>	72500	<b>6%</b>	305	5859	36.21	105.91
Jemez River near Jemez	<a href="#">8324000</a>	65100	6%	470	5622	35.66	106.74
Red River below Fish Hatchery	<a href="#">8266820</a>	58300	<b>5%</b>	185	7105	36.68	105.65
Rio Pueblo de Taos below Los Cordovas	<a href="#">8276300</a>	57900	<b>5%</b>	380	6650	36.38	105.67
Rio Ojo Caliente at La Madera	<a href="#">8289000</a>	56900	<b>5%</b>	419	6359	36.35	106.04
Rio Puerco near Bernardo	<a href="#">8353000</a>	23100	2%	6220	4722	34.41	106.85
Santa Fe River above Cochiti	<a href="#">8317200</a>	8700	1%	231	5505	35.55	106.23
North Floodway Channel near Alameda	<a href="#">8329900</a>	7300	1%	88	5015	35.20	106.60
Costilla Creek near Garcia	<a href="#">8261000</a>	6500	1%	200	7821	36.99	105.53
Galisteo Creek Below Galisteo Dam	<a href="#">8317950</a>	4200	0%	597	5450	35.46	106.21
Tijeras Arroyo near Albuquerque	<a href="#">8330600</a>	300	0%	128	4999	35.00	106.65

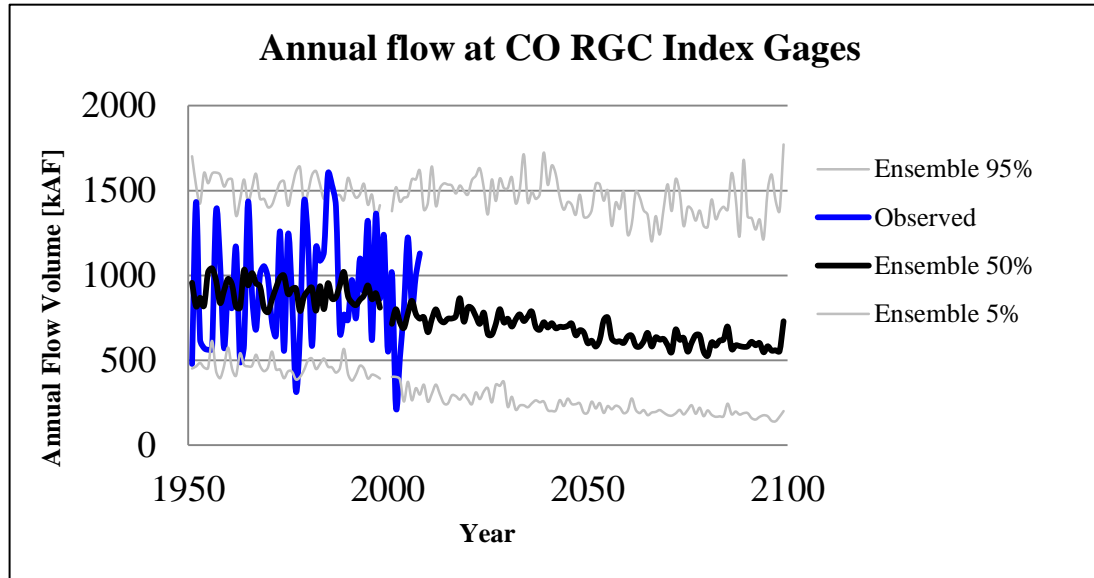
# URGSiM Input Gages above Otowi



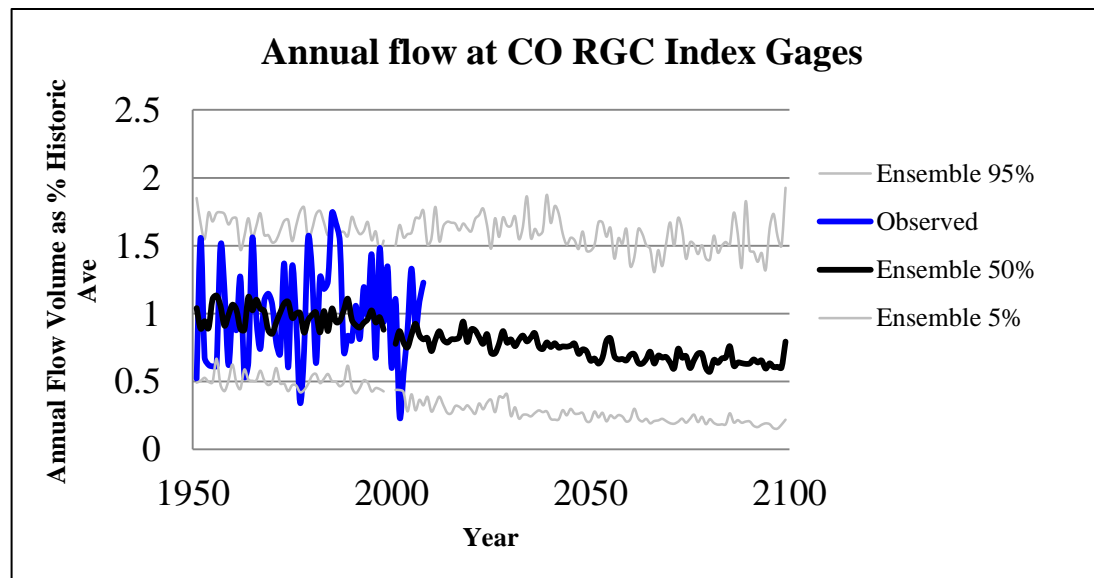
# CO RGC Index Gages



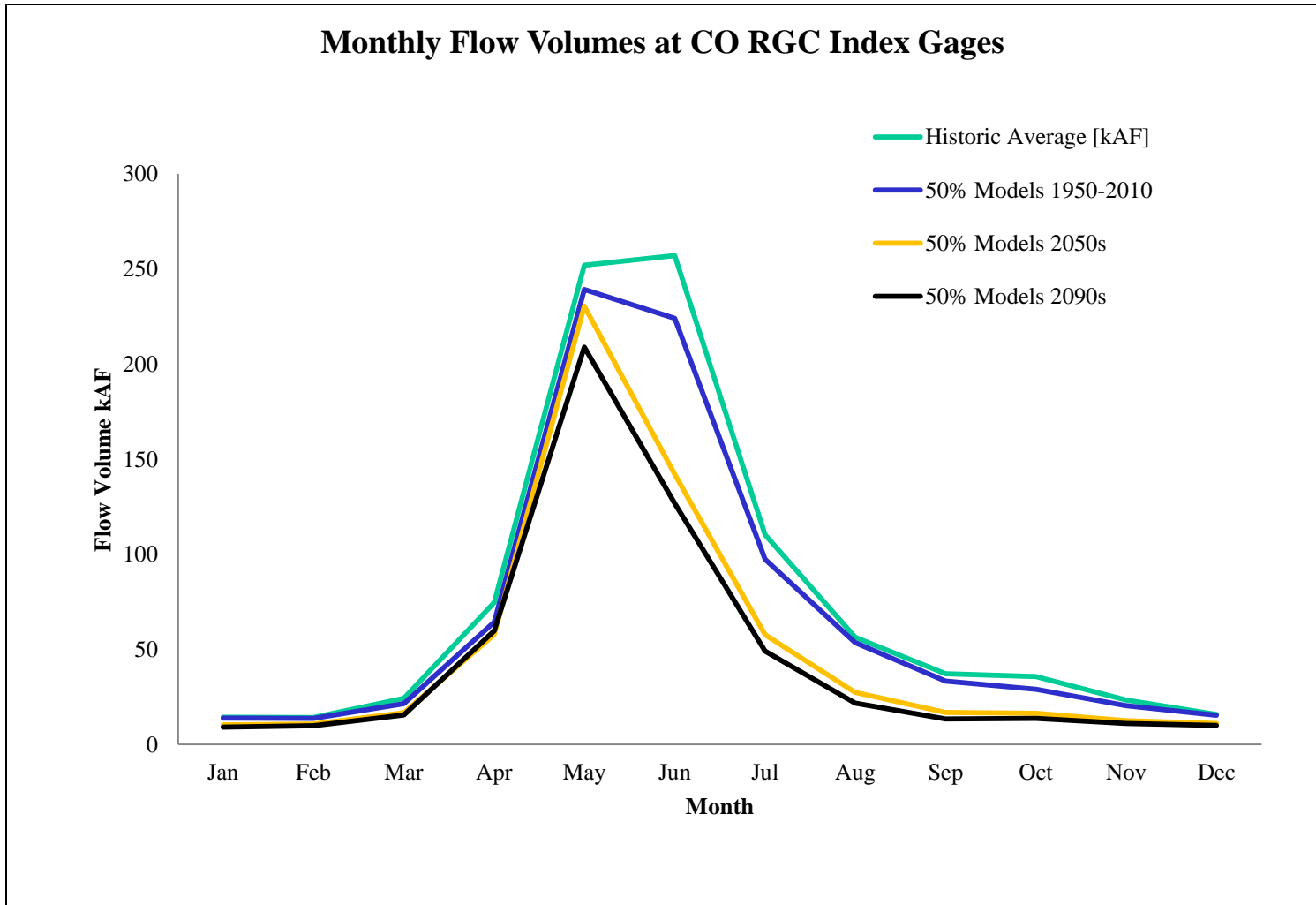
# CO RGC Index Gages



Determine  
~1/3 of gaged  
flows into  
URGSiM



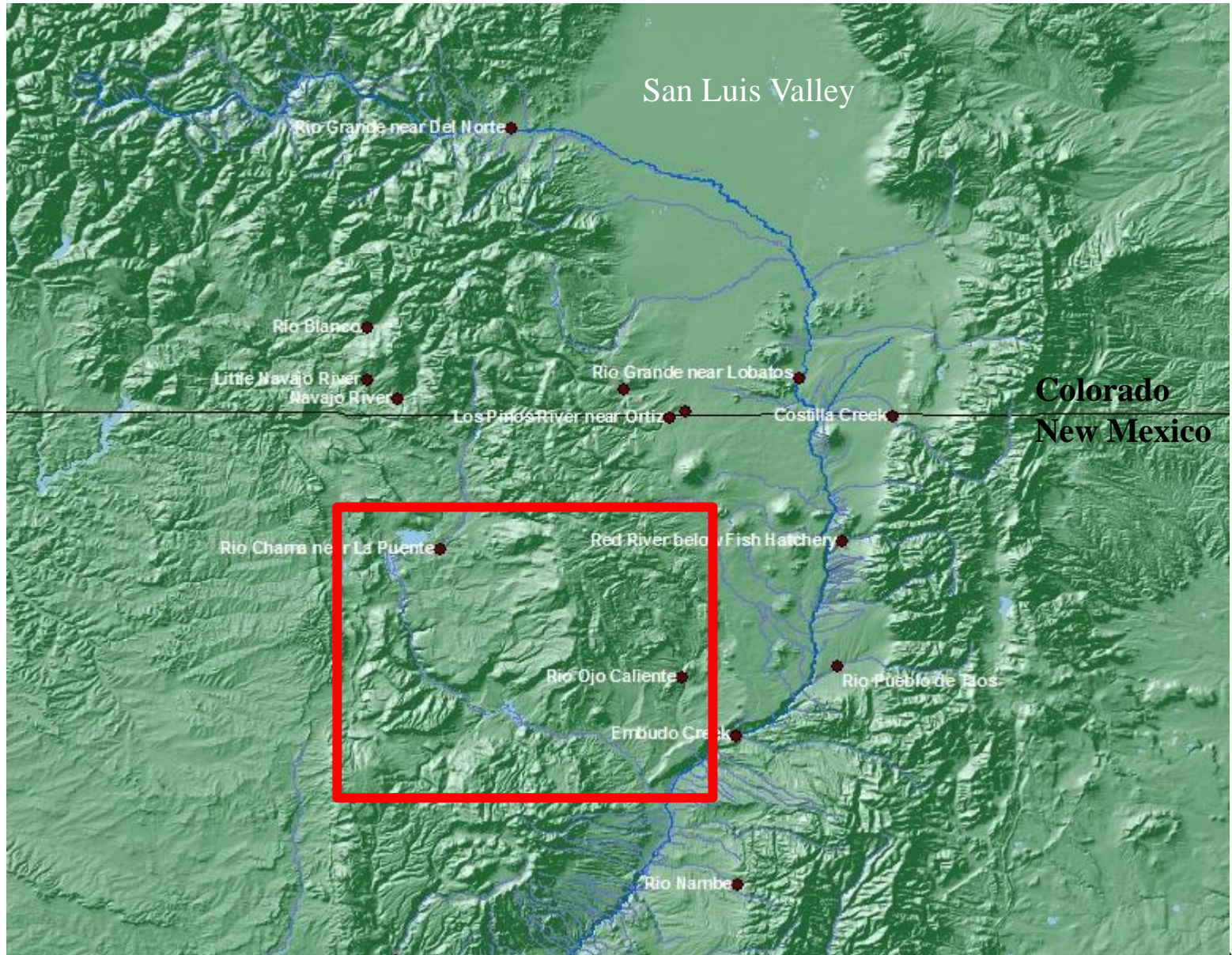
# CO RGC Index Gages Monthly



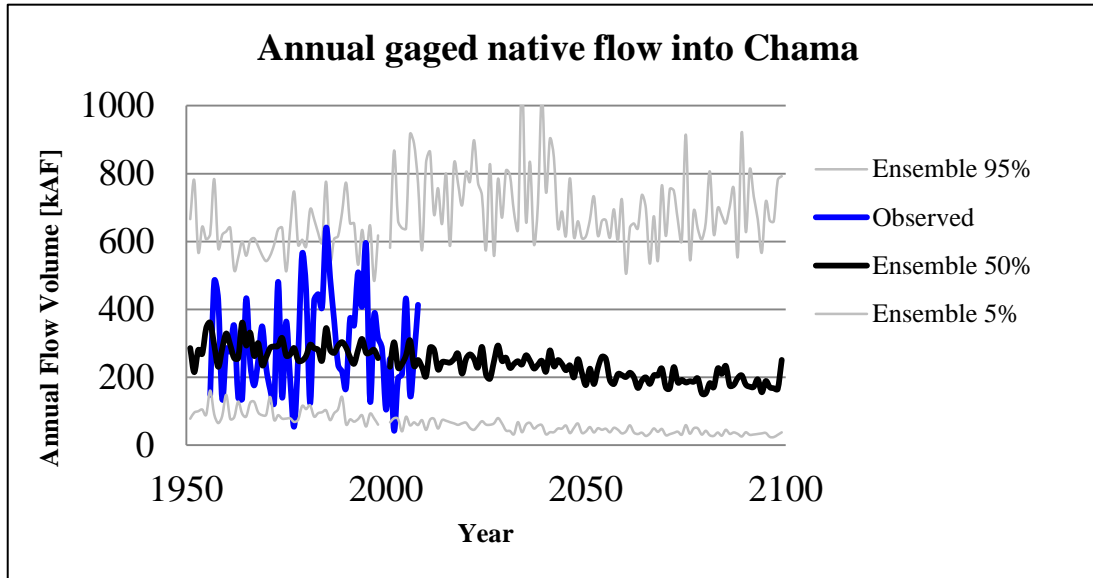
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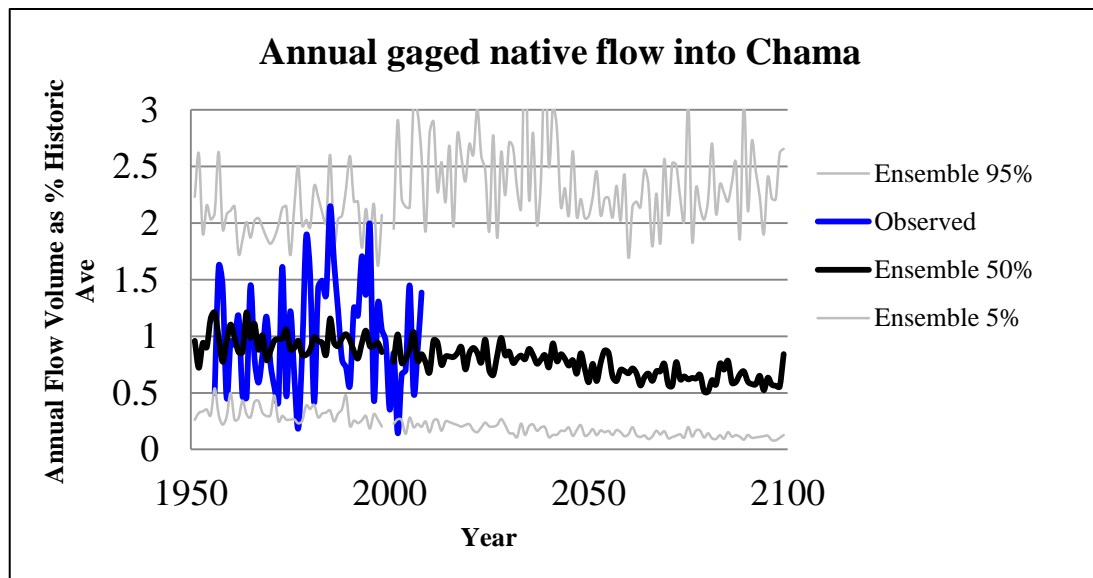
# URGSiM Input Gages above Otowi



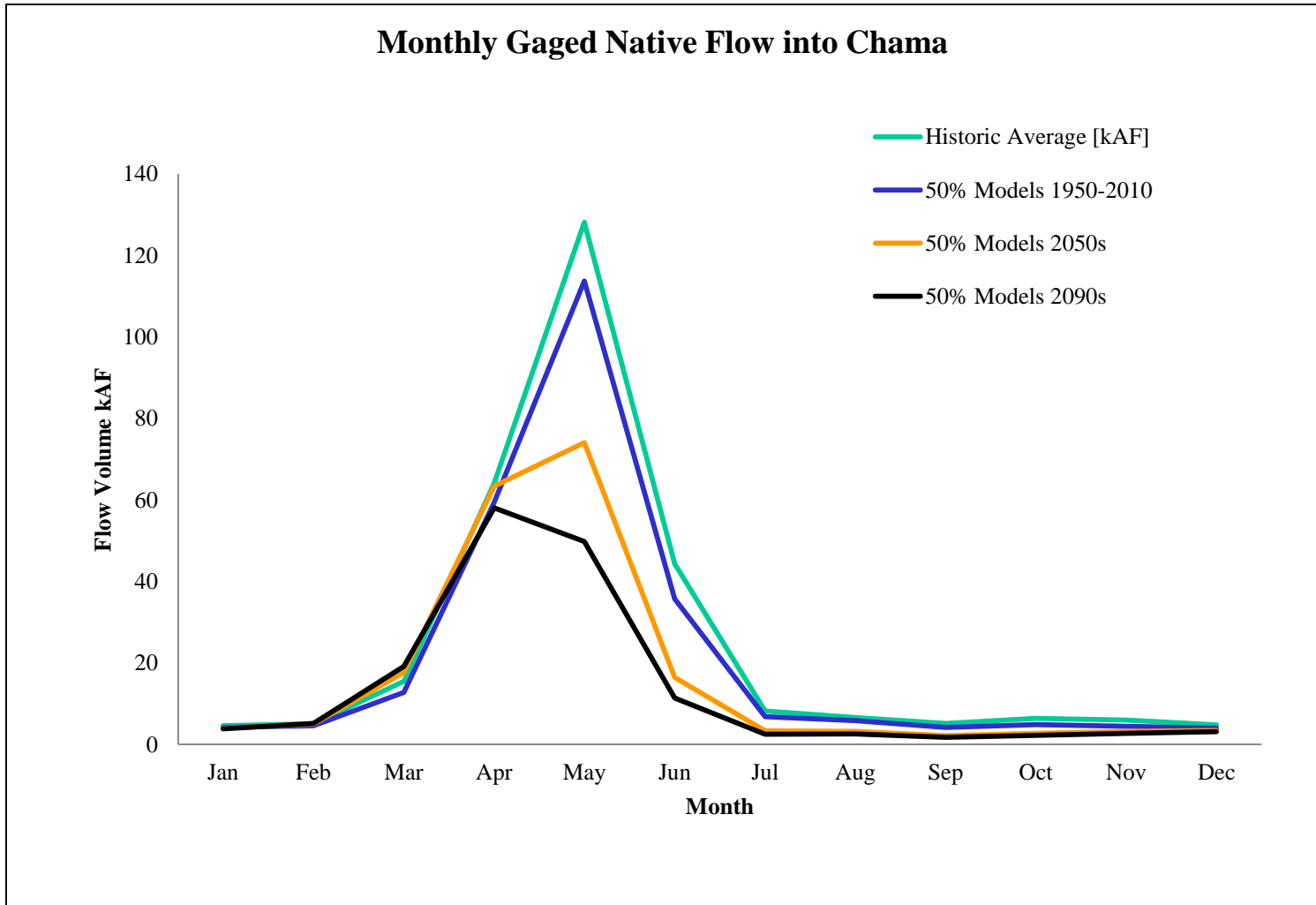
# Native Chama Gages Annual Flow



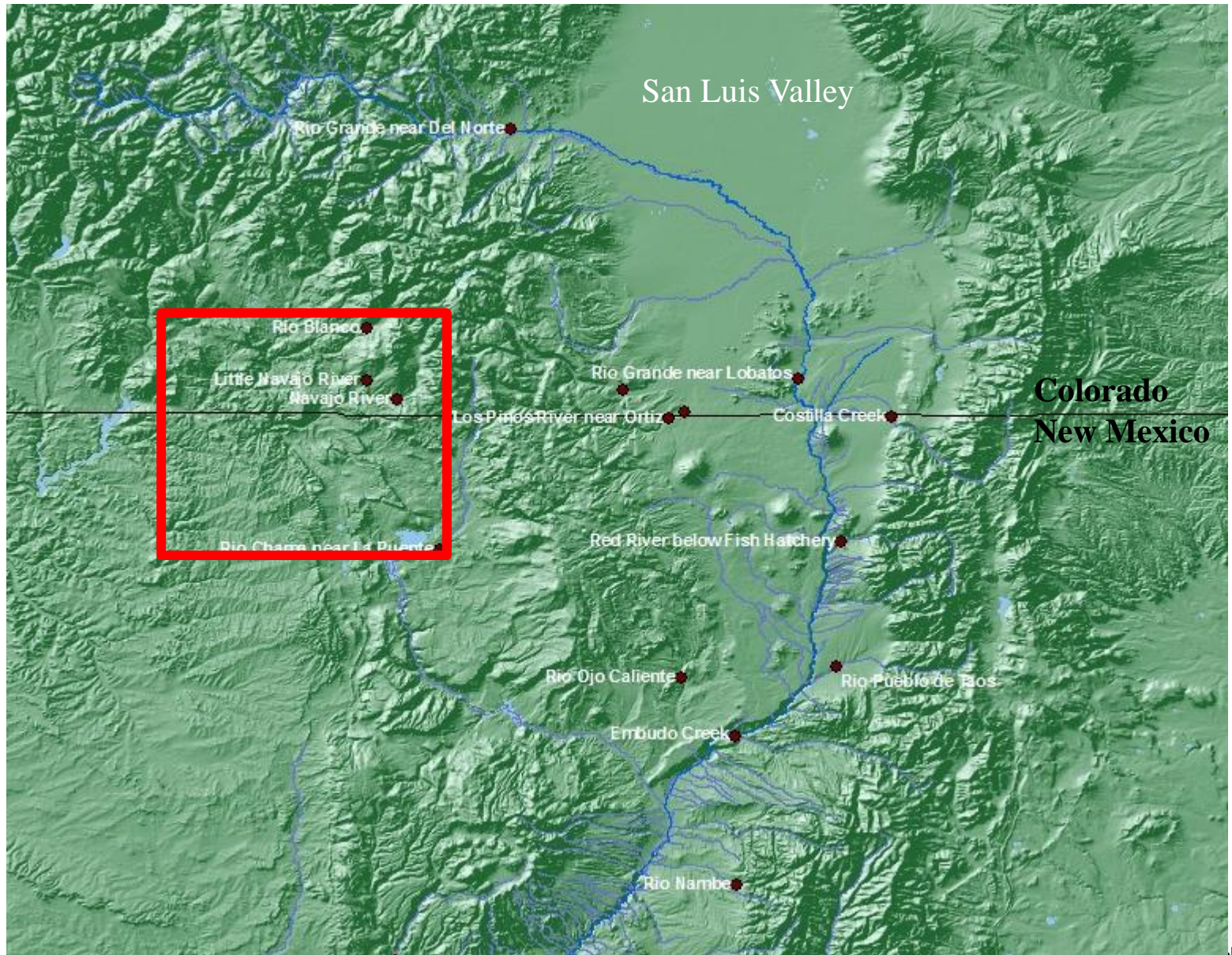
Determine  
another  $\sim 1/3$  of  
gaged flows  
into URGSiM



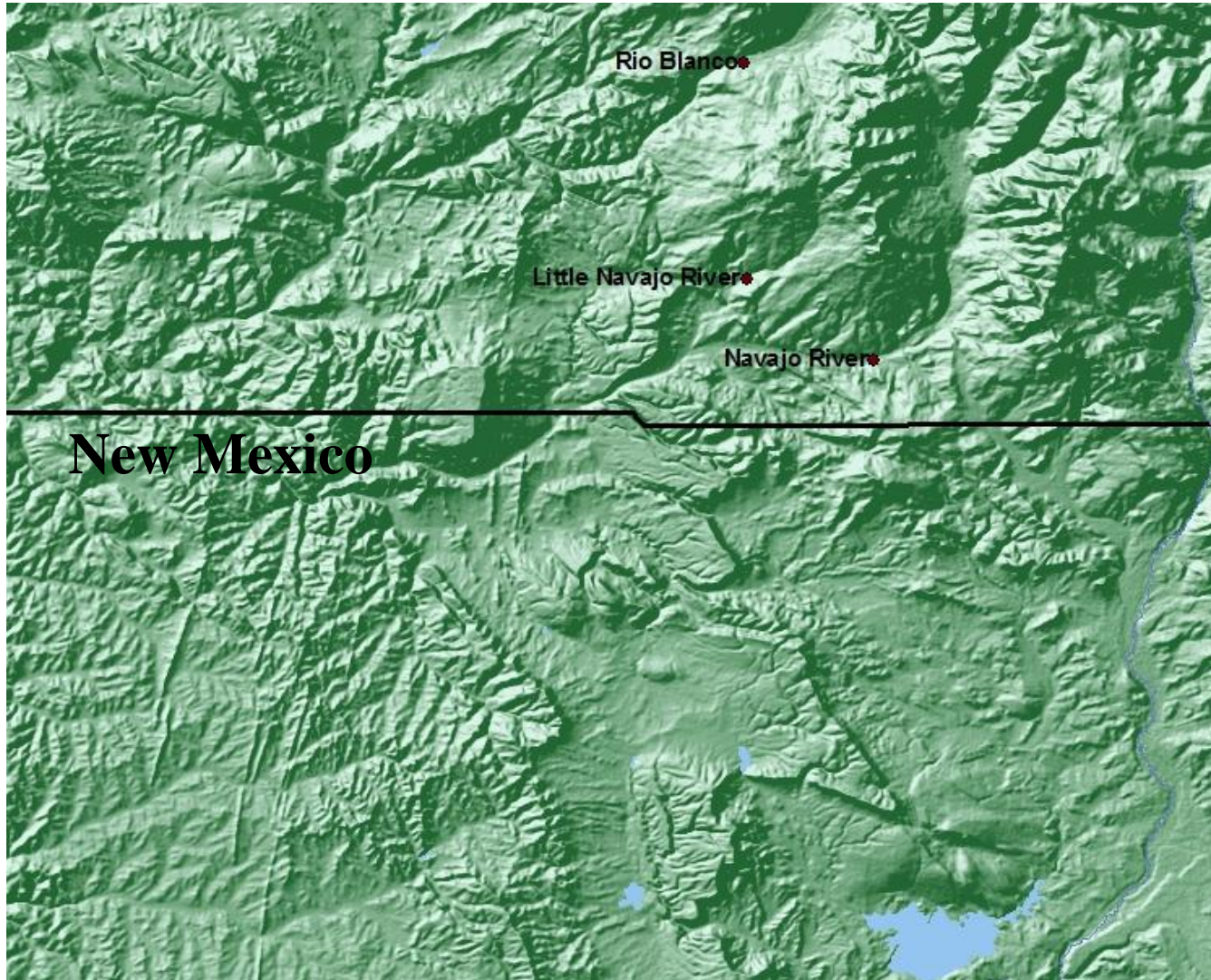
# Native Chama Gages Monthly



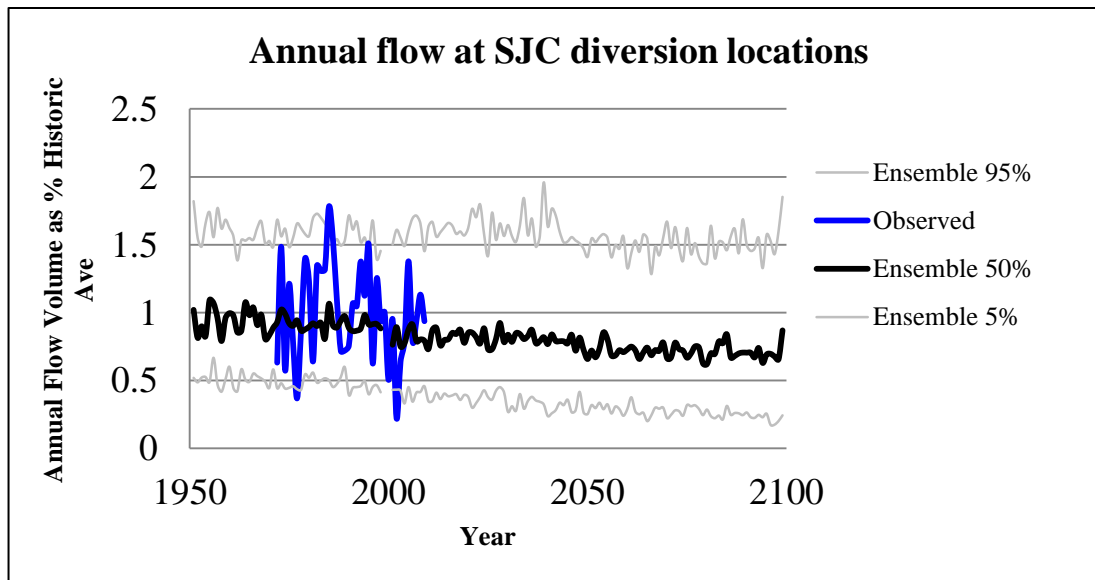
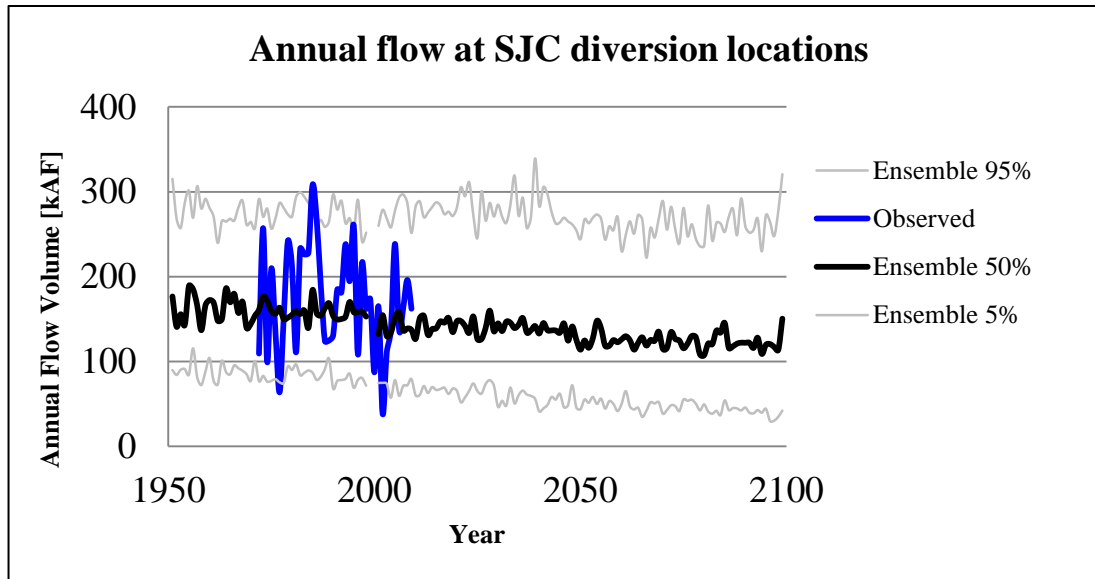
# URGSiM Input Gages above Otowi



# SJC Diversion Points

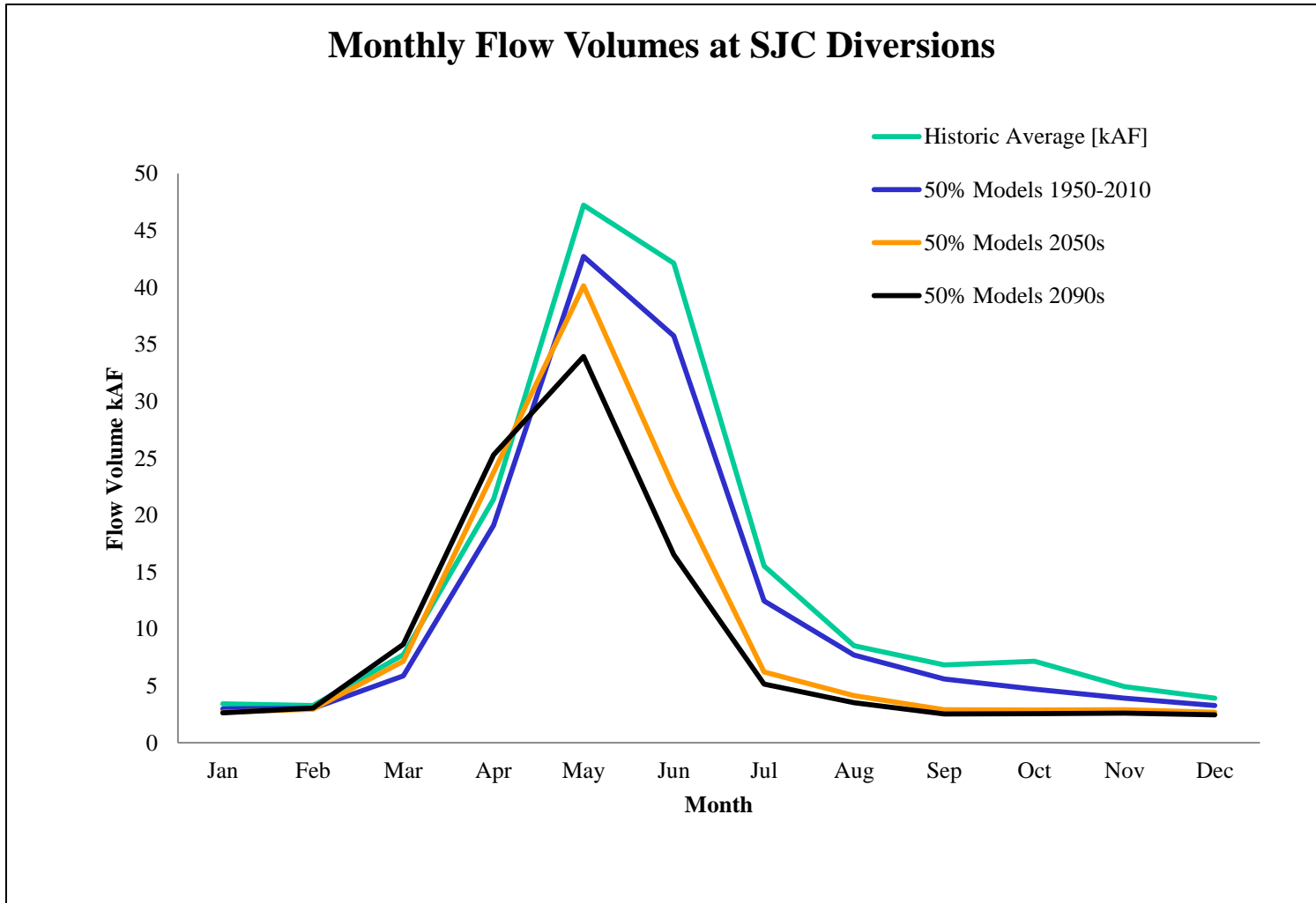


# SJC Diversion Points



Determine 10% of gaged flows into URGSiM, but becoming a key part of Albuquerque and Santa Fe long term drinking water strategies.

# SJC Diversion Points Monthly





# Conclusions

- GCM output suggests temperatures will rise between 4 and 12 degrees F in the Upper Rio Grande Basin by 2099
- GCM output suggests little change to precipitation during the same time period.
- VIC rainfall-runoff model output suggests significant decreases to runoff by 2099 throughout the basin.
- Native RG flows may be more threatened than SJC flows.
- Next step is to drive URGSiM with the VIC hydrographs and GCM temperature fields to see...

# Questions?

