Drought Water Right Curtailment

Wesley Walker, Chad Whittington, Andy Tweet,

Bonnie Magnuson-Skeels, Brad Arnold, & Jay Lund

Bay-Delta Science Conference

November 17, 2016

UCDAVIS

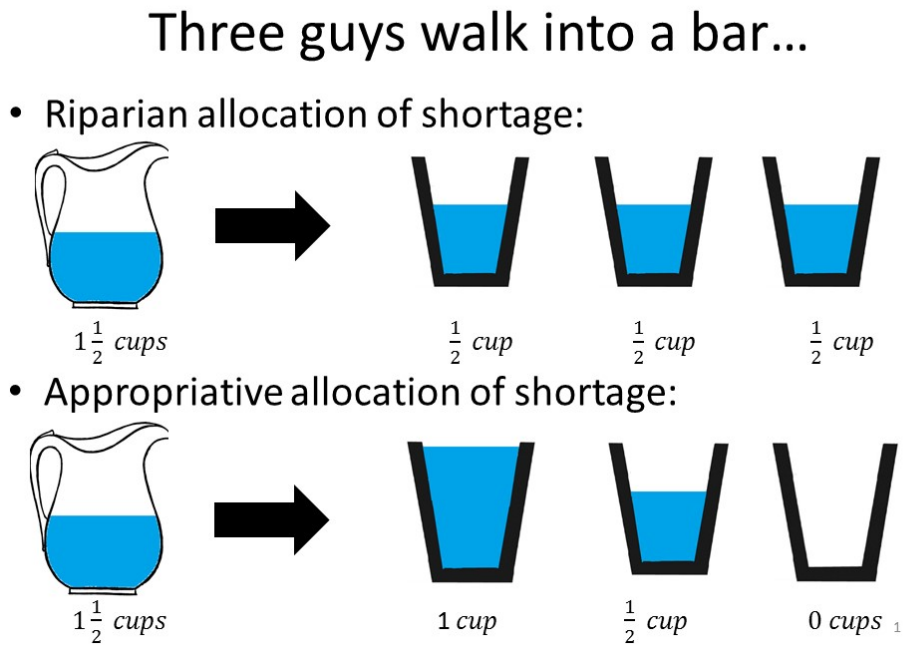
CENTER FOR WATERSHED SCIENCES

Outline

- The Problem
- DWRAT Components
- DWRAT Methods
- San Joaquin DWRAT
- Future Work

The Problem

- Current Drought (2012 -)
- California's Surface Water Rights System
  - Administered by the State Water Resources Control Board (SWRCB)
- Riparian Rights
  - Shared Shortage
- Appropriative Rights
  - First in Time, First in Right
- Very few historical curtailments



The Problem

- Water Shortage Notices
  - 2014: Eel, Russian, Scott, Sacramento, and San Joaquin basins
  - 2015: Scott, Sacramento, and San Joaquin basins

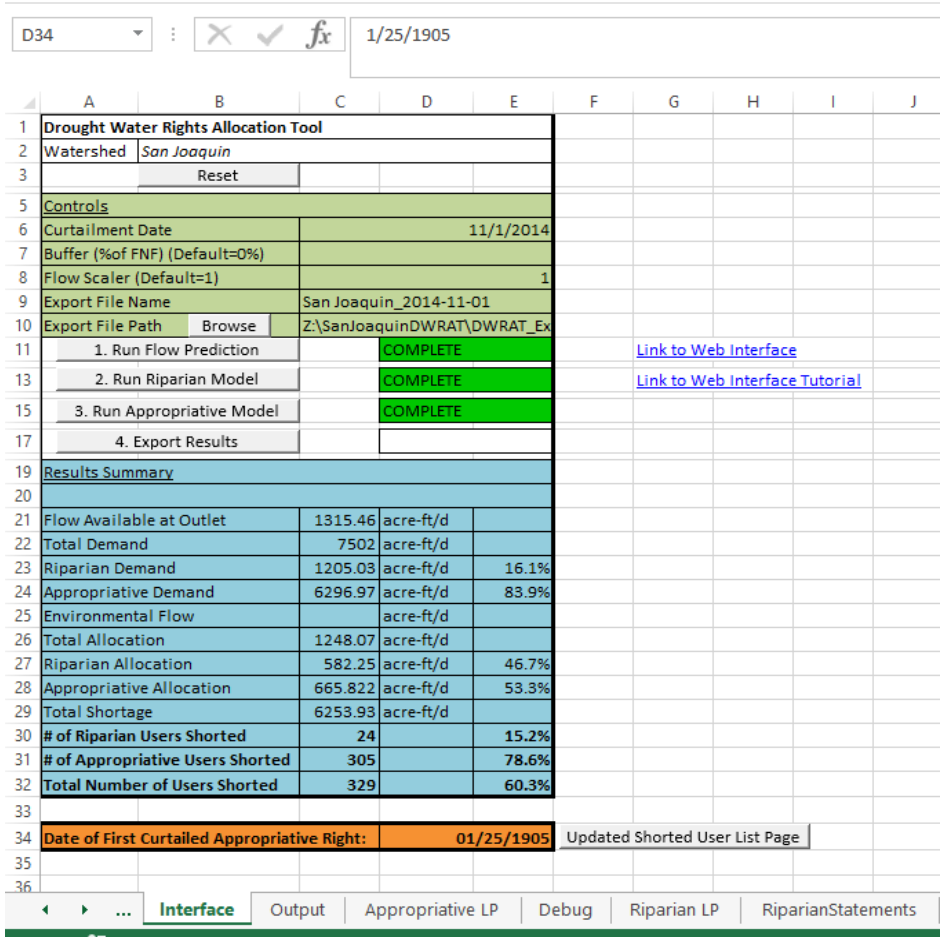
Discussing Water Rights, A Western Pastime

The Task: Develop a Model

- Account for spatial variability in demand, supply, and priority
- Use publicly available data
- Provide an explicit, transparent, and rigorous method for calculating water right curtailments
- This model so far reflects only the work of the authors
  - Not yet peer-reviewed; not yet submitted to the Division
  - Not tasked with reviewing or critiquing the Division 2014 or 2015 methodology

Drought Water Rights Allocation Tool (DWRAT)

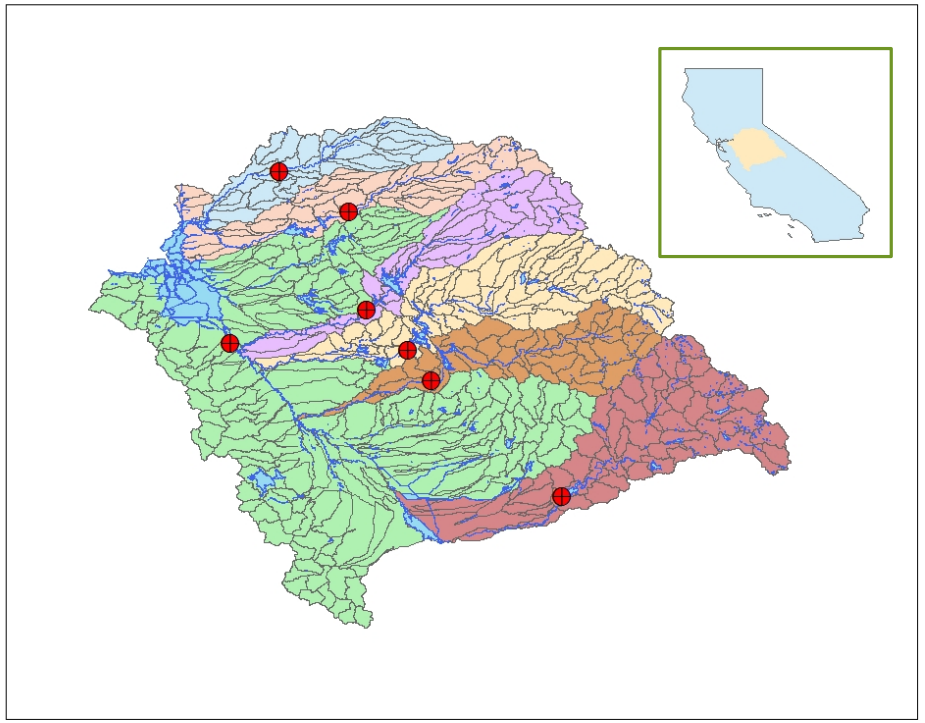
- Excel Workbook, User Interface
- Statistical Hydrologic Model
- Unimpaired Flow Data
  - CDEC
  - CNRFC
- Water Right User Data
  - SWRCB Database
  - Monthly reported demand for 2010-2013 (averaged)
- Riparian and Appropriative Linear Programs
  - Solver Studio: Free, open-source solver
  - "Making water law into an algorithm"



Hydrologic Model

- Developed around USGS Hydrologic Unit (HUC12)
  - Unimpaired flow estimates, WY 1950-2011
- Assumed that users in each HUC have access to flow @ HUC outlet
- Basin Connectivity
- Flow Scaling Ratios
  - Dry-Year Average Flow
  - Unimpaired / FNF gage locations

$$Q_{HUC,i} = Q_{R,i} \times \frac{Q_{HUC,i}}{Q_{HUC,R}} \times \frac{A_{R,HUC,i}}{A_{R,i}}$$



Riparian LP

Objective Function:	$min\ z = \alpha \sum_k w_k P_k - \sum_i A_i$	Allocate as much water to as many users possible
Constraints:	$A_i = P_k u_i, \forall\ i, i \in k_{upstream-most}$	All users in a sub-basin *k* receive the same portion, P_k, of demand
	$P_j \leq P_k, \forall\ k, j \in k$	Upstream portions cannot exceed downstream portions
	$\sum_{i \in k} A_i \leq v_k - e_k, \forall\ k$	Allocations upstream of *k* cannot exceed available water at *k*'s outlet
	$0 \leq P_k \leq 1, \forall k$	Portions must be between 0 and 1
	$A_i \geq 0, \forall\ i$	Allocations must be greater than or equal to 0
	$A_i \geq u_{i,Public\ Health\ and\ Safety}, \forall i$	Allocations must meet public health and safety needs
	$w_k = \frac{n_k}{n_{k,outlet}}$	Unit penalty for *P* increases with downstream basins
	$\alpha < Min\left(\frac{w_{k,i}}{u_{k,i}}\right)\ \forall\ i$	Defines the relative weight for *P* values in the objective function

Where:

A_i = water allocation for user i

α = weight factor in objective function

P_j = proportion of normal usage allowed for all users in basin j

n_k = number of basins upstream of k

w_k = unit penalty for *P*, increases with downstream basins

v_k = flow in basin k

e_k = environmental flow requirement in basin k

u_i = normal usage (demand) for user i

Appropriative LP

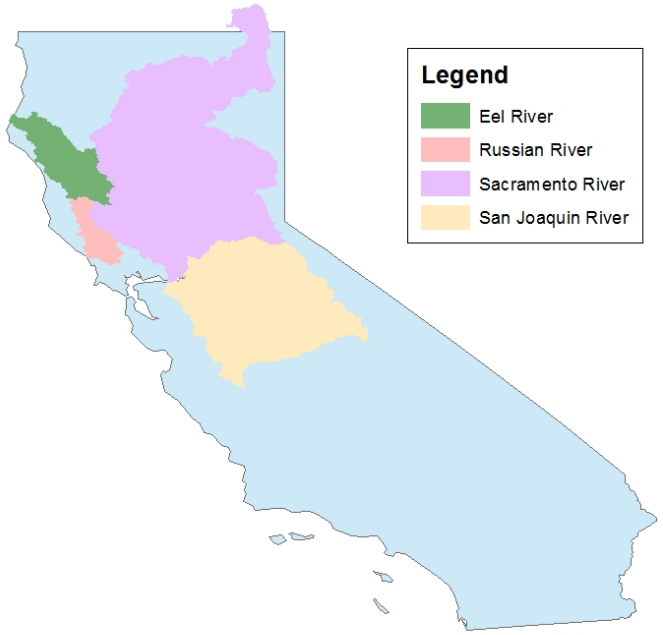
Objective Function	$min\ z = \sum_i p_i(u_i - A_i)$	Minimize total shortage penalty; unit penalties increase with water right seniority
Constraints:	$\sum_{i \in k} A_i \leq v_k - e_k - \sum_{i \in k} A_{upstream\ riparian\ users\ i}, \forall\ k$	Allocations cannot exceed available water remaining after riparian allocations
	$A_i \leq u_i, \forall\ i$	Allocations cannot exceed reported use
	$A_i \geq 0, \forall\ i$	Allocations must be greater than or equal to zero
	$A_i \geq u_{i,Public\ Health\ and\ Safety}, \forall i$	Allocations must meet PHS needs

Where:
A_i = water allocation for user i
p_i = unit shortage penalty for user i, increases with seniority of water right
v_k = flow in basin k
e_k = environmental flow requirement in basin k
u_i = normal usage (demand) for user i

Current DWRAT Models

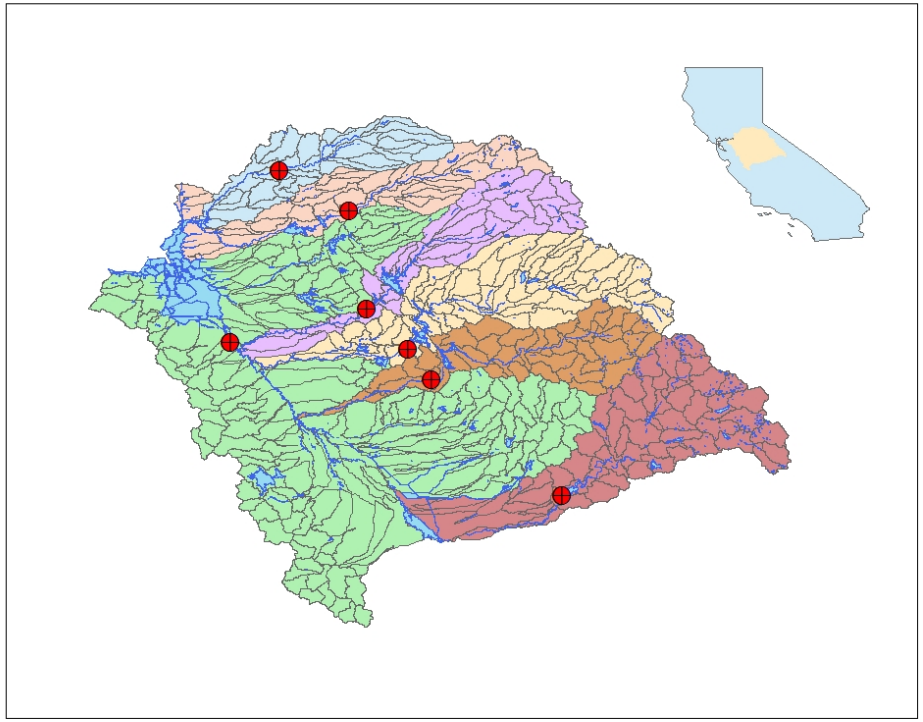
- Eel River
- Russian River
  - SCWA Reservation Water Rights

Basin	Area (mi^2)	HUCs	Rip. Users	Pre14 Users	Post14 Users
Eel	3,684	113	331	47	206
Russian	1,485	44	883	42	1,090
Sacramento	27,000	768	1,293	348	2,641
San Joaquin	15,824	443	1,001	137	1,685



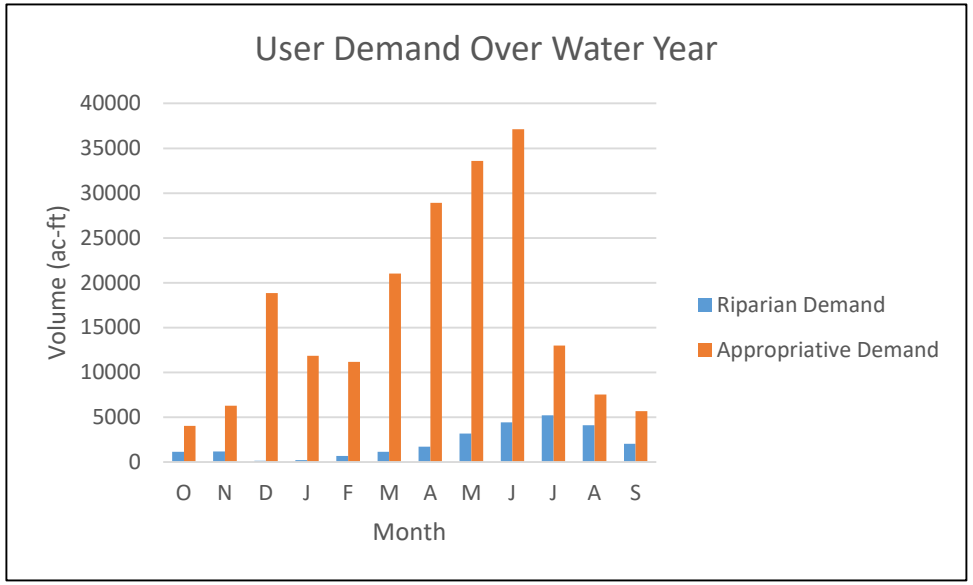
San Joaquin DWRAT

- San Joaquin River
  - Merced River, Tuolumne River, Stanislaus River, Mokelumne River, Cosumnes River
- 15,824 mi^2 area
- 443 Total HUCs
- Current/Historical Gage Data
  - CDEC
- Forecast Gage Data
  - CNRFC (90%, 75%, 50%, 25%, 10% Exceedance)



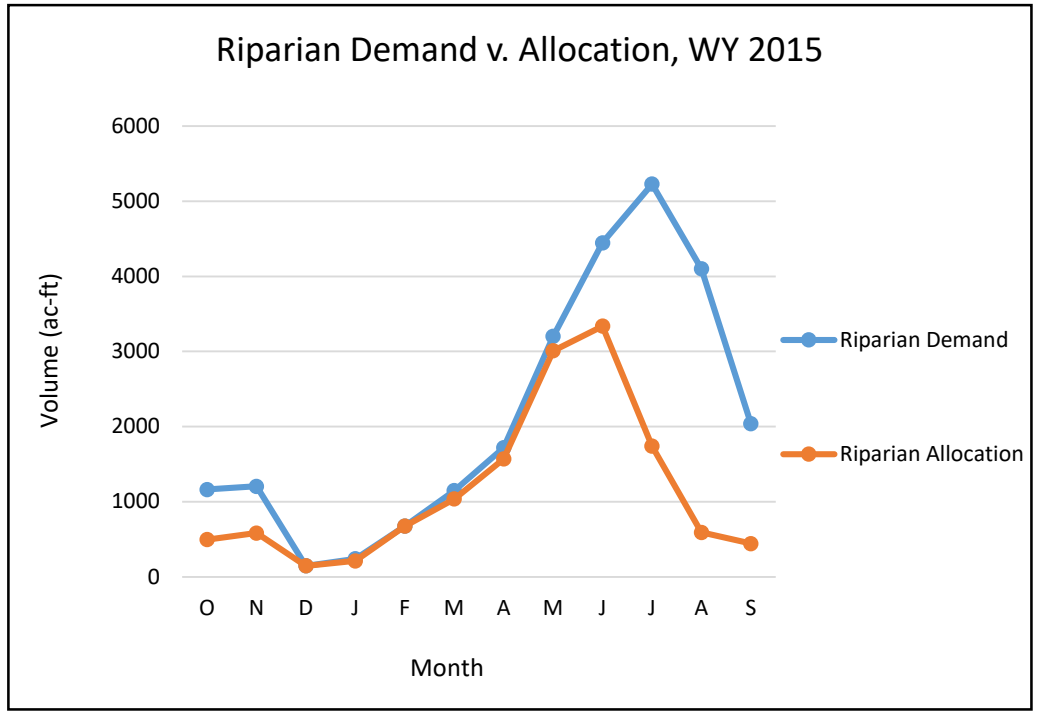
User Demand – San Joaquin

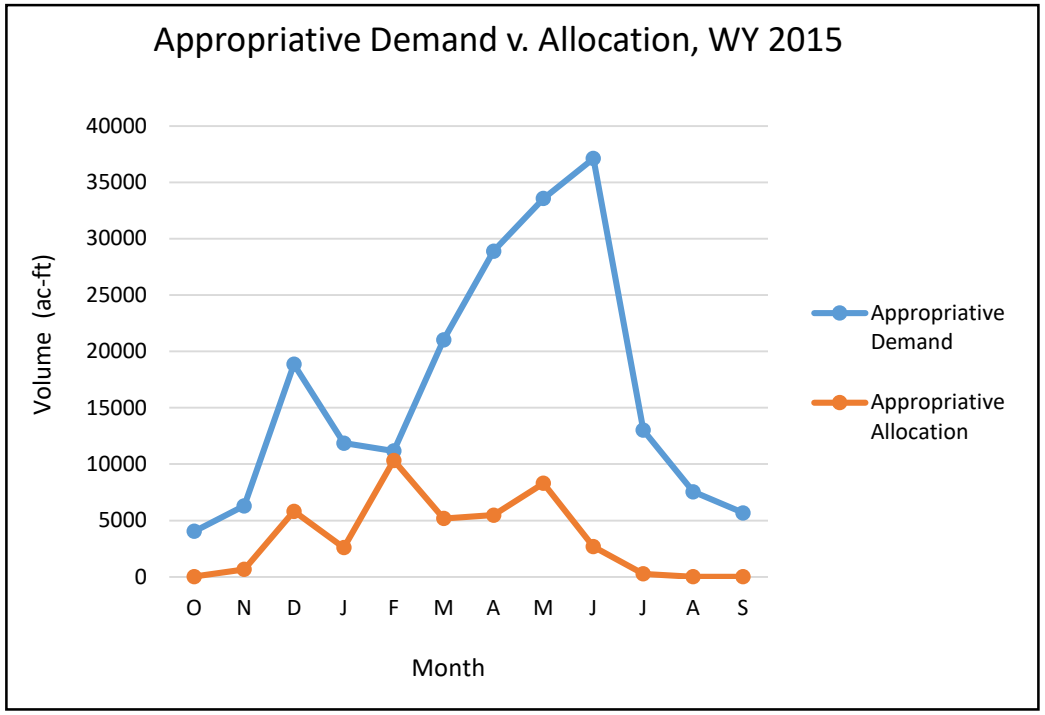
	Total Users	% of Total Users	Active Users*	% of Users Active	% of Total Active
Riparian	1001	35.5%	101	10.1%	10.5%
Pre-1914 Approp.	137	4.9%	90	65.7%	9.4%
Post-1914 Approp.	1685	59.7%	770	45.7%	80.1%
Total Approp.	1822	64.5%	860	47.2%	89.5%
Total Users	2823	100.0%	961	34.0%	100.0%



*Number of active users is based off users with a reported demand

2015 Results – San Joaquin





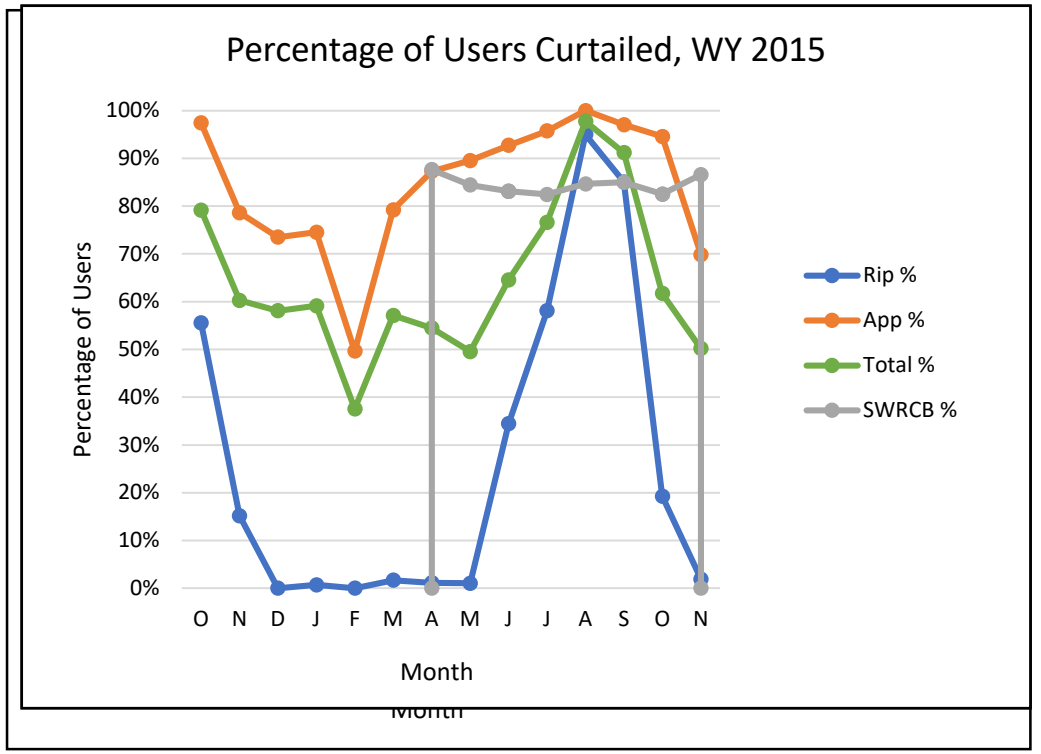
2015 SWRCB Water Shortage Notices

- 5/1/2015: 1914 and junior appropriative rights received water shortage notices*
- 6/12/2015: 1903 and junior appropriative rights received water shortage notices*
- 6/26/2015: Upper-San Joaquin rights, 1858 and junior rights on the Merced, City & County of SF rights: S002637, S014379, S018734, S018735 received water shortage notices
- 10/27/2015: Pre-1914 rights received notice of temporary diversion opportunities
- 11/2/2015: All remaining junior rights received notice of temporary diversion opportunities

*Water shortage notices issued to the Sacramento-San Joaquin Delta, Sacramento River & San Joaquin River watersheds

2015 Results and Conclusions – San Joaquin

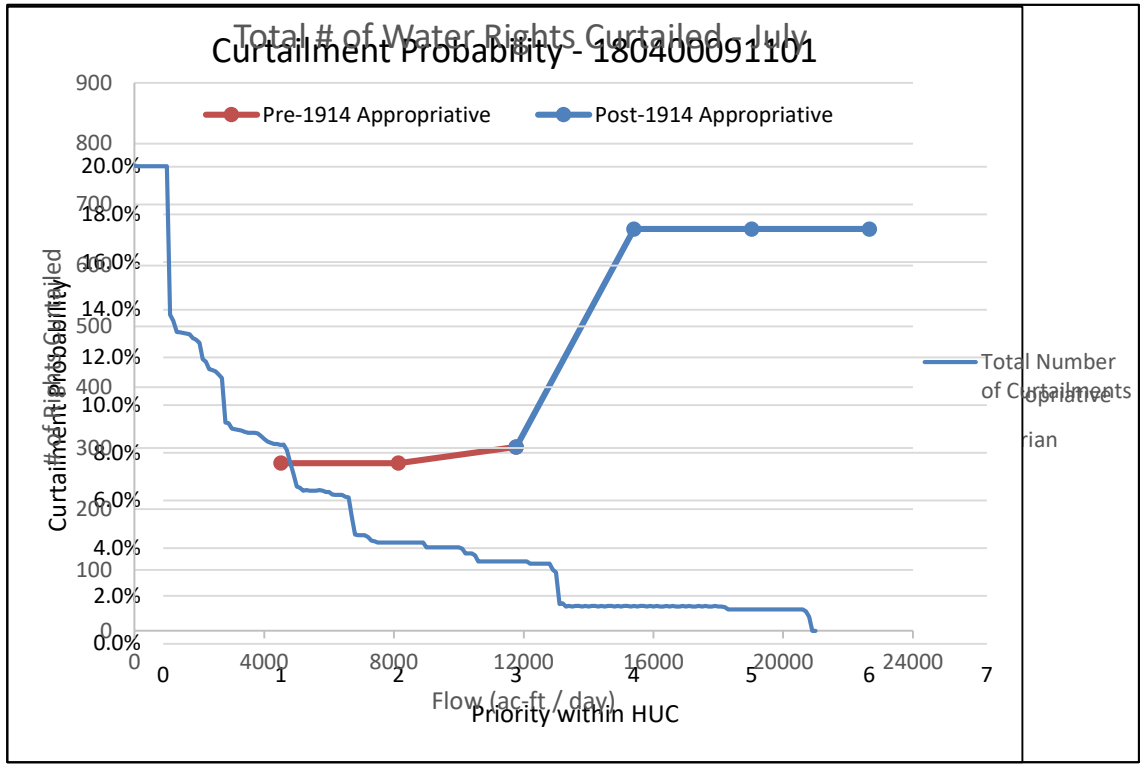
- Fairly good agreement between DWRAT and SWRCB
- Continued dry conditions led to greater shortages in spring/summer(DWRAT & SWRCB)
- DWRAT curtailed riparians in the summer and some appropriative users in the winter



*The number, percentage, and volume of SWRCB users is determined by applying SWRCB actions to appropriative users in the DWRAT database

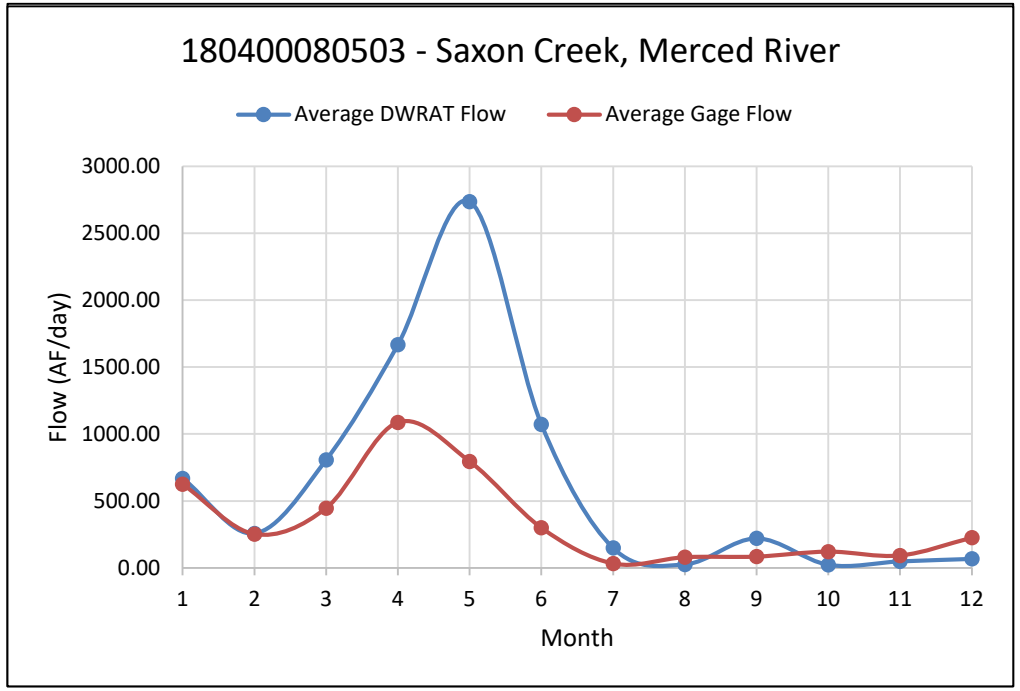
Developing Curtailment Rules

- Is a user curtailed at the specified flow (binary)
- Probability of Curtailment
  - Curtailment Threshold
  - Probability of flow less than curtailment threshold
- Ran with one reference flow point (VNSC0)
  - 0 -21,000 AF/day (by 100)
  - July Demands
- Probability of Curtailment Charts
  - Basinwide
  - By HUC



Flow Error Analysis

- Add in reservoir releases to the system
- Provide full allocation to all users
- Compare DWRAT predicted HUC flow (after allocations) to measured gage flow
- Preliminary Results - 2013
  - DWRAT appears to over predict in wet season
  - Similar patterns
  - Further refinement needed for analysis and hydrology



Model Limitations / Future Work

- Flow Error Analysis
  - Scaling Ratio Analysis
  - FNF Error
- Monte Carlo Analysis for Curtailment Probabilities
- Curtailment/Shortage Error Analysis
  - Buffer flows – False allocation promises / false curtailments

Questions?

Special thanks to the SWRCB for technical and financial support

Wesley Walker

MS Student, UC Davis

wfwalker@ucdavis.edu