Russian River DWRAT

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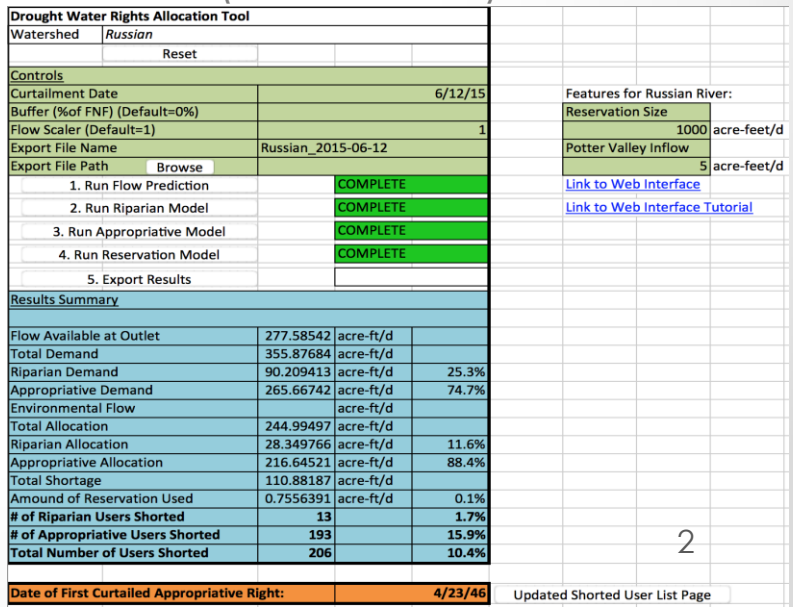
California's Limited Water Supply

- 2014 – SWRCB curtails junior water rights for the first time since 1977
- More curtailments likely to occur
- Need better way to allocate water shortages
  - Must satisfy dual doctrine system
    - Riparian
    - Appropriative

Drought Water Right Allocation Tool (DWRAT)

- Makes optimal water right curtailment decisions based on:
  - Water right priority
  - Local water availability
  - Water demand
- Compiled in Excel workbook
  - Linear programs solved using open source software (SolverSutdio)
- Online web interface
- Developed for:
  - Eel River
  - Russian River
  - Sacramento River
  - San Joaquin River
-

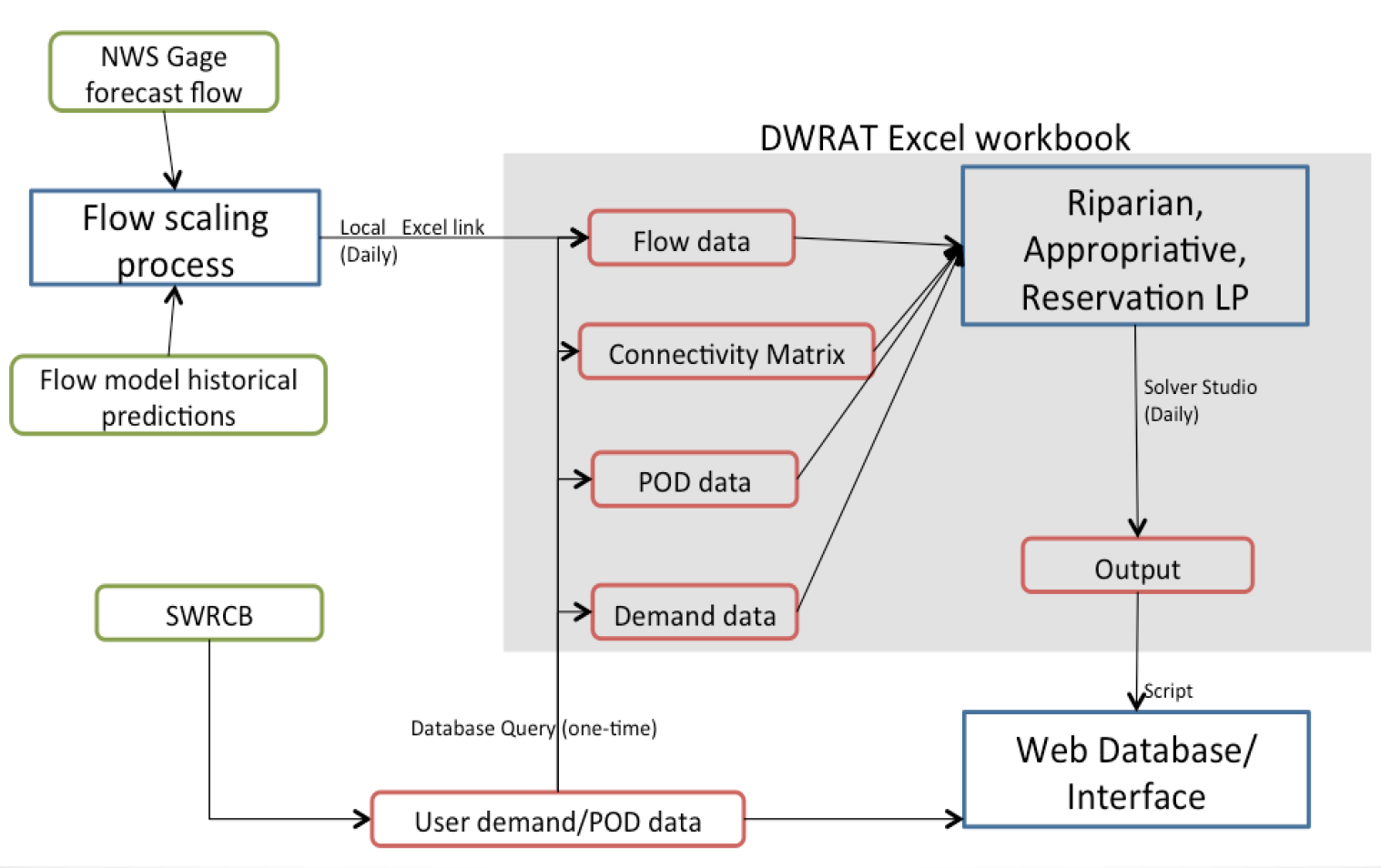


Drought Water Rights Allocation Tool			
Watershed	*Russian*		
Reset			
Controls			
Curtailment Date		6/12/15	
Buffer (%of FNF) (Default=0%)			
Flow Scaler (Default=1)		1	
Export File Name	Russian_2015-06-12		
Export File Path Browse			
1. Run Flow Prediction		COMPLETE	
2. Run Riparian Model		COMPLETE	
3. Run Appropriative Model		COMPLETE	
4. Run Reservation Model		COMPLETE	
5. Export Results			
Results Summary			
Flow Available at Outlet	277.58542	acre-ft/d	
Total Demand	355.87684	acre-ft/d	
Riparian Demand	90.209413	acre-ft/d	25.3%
Appropriative Demand	265.66742	acre-ft/d	74.7%
Environmental Flow		acre-ft/d	
Total Allocation	244.99497	acre-ft/d	
Riparian Allocation	28.349766	acre-ft/d	11.6%
Appropriative Allocation	216.64521	acre-ft/d	88.4%
Total Shortage	110.88187	acre-ft/d	
Amound of Reservation Used	0.7556391	acre-ft/d	0.1%
# of Riparian Users Shorted	**13**		**1.7%**
# of Appropriative Users Shorted	**193**		**15.9%**
Total Number of Users Shorted	**206**		**10.4%**
Date of First Curtailed Appropriative Right:		**4/23/46**	

Features for Russian River:	
Reservation Size	
1000	acre-feet/d
Potter Valley Inflow	
5	acre-feet/d
Link to Web Interface	
Link to Web Interface Tutorial	

Updated Shorted User List Page

Model Composition



HUC-12: USGS's smallest unit for watershed classification

Flow-forecasting Model

- Predicts unimpaired flows for each HUC-12
- Input data
  - Daily FNF estimates from an NWS gage in Healdsburg
- Method
  - FNF estimates from Healdsburg are disaggregated to all ungaged HUC-12s by using ratios of gaged to ungaged flow

Linear Programs

Riparian, Appropriative, Reservation

Riparian LP

$$Min\ z = \propto \sum_{k} w_k P_k - \sum_{i} A_i$$

Constraints

1. $A_i = P_k u_i\ , \forall\ i\ , i \in\ k$
2. $P_j \leq P_k\ , \forall\ k\ , j \in k$
3. $\sum_{i \in k} A_i \leq v_k - e_k - b_k\ , \forall k$
4. $0 \leq P_k \leq 1, \forall k$
5. $A_i \geq 0, \forall\ i$
6. $A_i \geq u_{i,public\ health\ and\ safety}\ , \forall\ i$
7. $w_k = \dfrac{n_k}{n_{k,system\ \ outlet}}$
8. $\propto < Min\left(\dfrac{w_k}{u_{k,}}\right), \forall\ k$

Explanation

1. All users in a sub-basin k receive the same proportion, Pk, of demand
2. Upstream proportions(Pj) cannot exceed downstream proportions(Pk)
3. Allocations upstream of k can not exceed available water at k's outlet
4. Proportions must be between 0 and 1
5. Allocations must be greater than or equal to zero
6. Allocations must meet public health and safety requirements
7. Unit penalty for P increases with downstream basins
8. Defines the relative weight for P values in the objective function

A_i = water allocation for user i
α = weight factor in objective function
P_k = proportion of normal use allocated to all users in basin k
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

$$\boldsymbol{Min\ z = \sum_i p_i(u_i - A_i)}$$

Constraints	Explanation
1. $\boldsymbol{\sum_{i \in k} A_i \leq v_k - e_k - b_k - \sum_{i \in k} A_{UR}\ , \forall\ k}$	Allocations cannot exceed available water remaining after riparian allocations
2. $\boldsymbol{A_i \leq u_i\ , \forall\ i}$	Allocations cannot exceed normal use
3. $\boldsymbol{A_i \geq 0, \forall\ i}$	Allocations must be greater than or equal to zero
4. $\boldsymbol{A_i \geq u_{i,public\ health\ and\ safety}\ , \forall\ i}$	Allocations must meet public health and safety requirements

Where:

A_i = water allocation for user i

A_{UR} = water allocation of riparian users

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

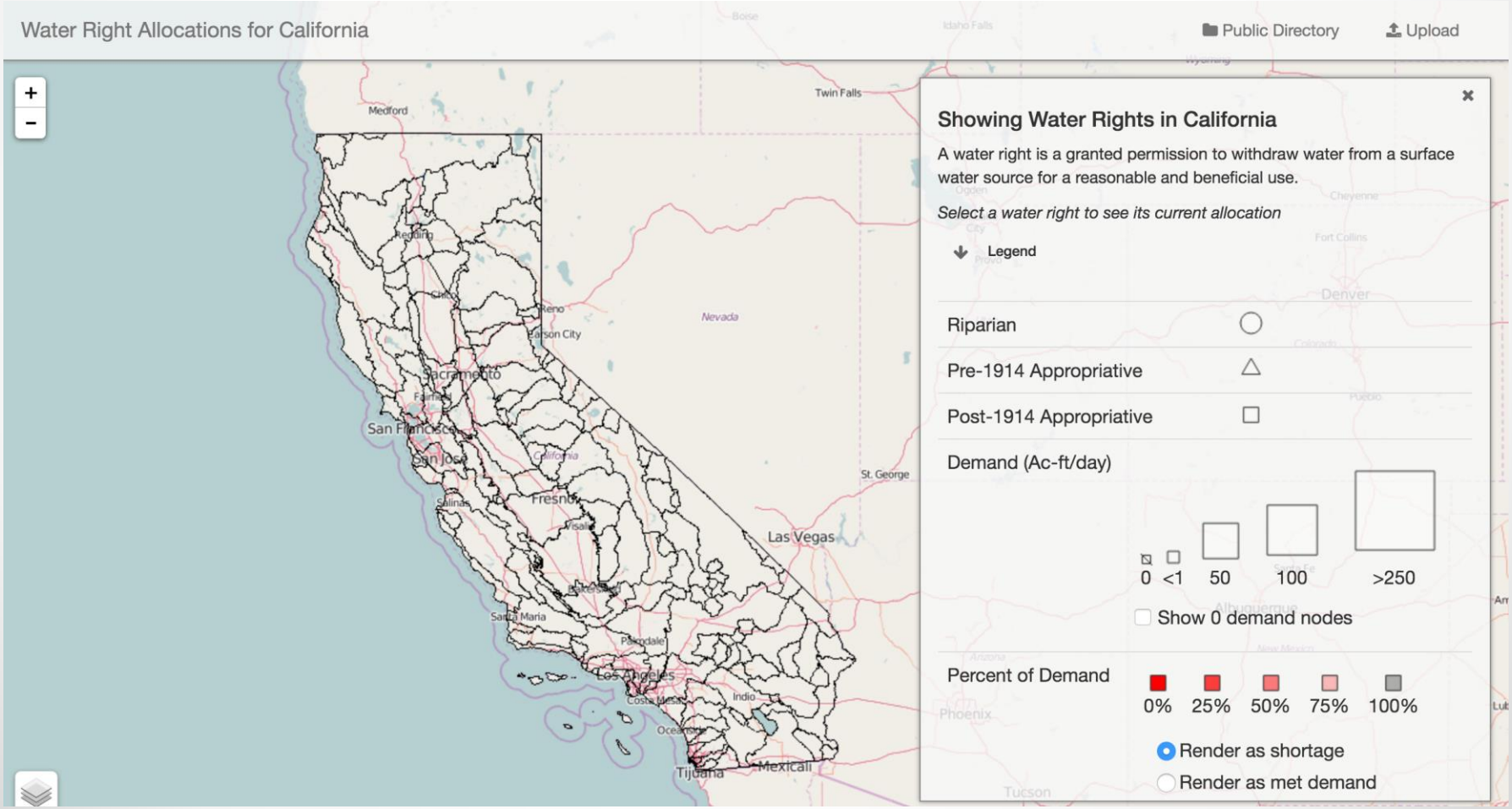
u_i = normal usage (demand) for user i

Reservation LP

- Permit 12947A; Term 23:
  - 10,000 afa available from Lake Mendocino releases
- 74 users
- Insurance for junior appropriators
- Priority given by application filing date (in DWRAT)

Web Interface

- http://watershed.ice.ucdavis.edu/dwrat/



Web Interface

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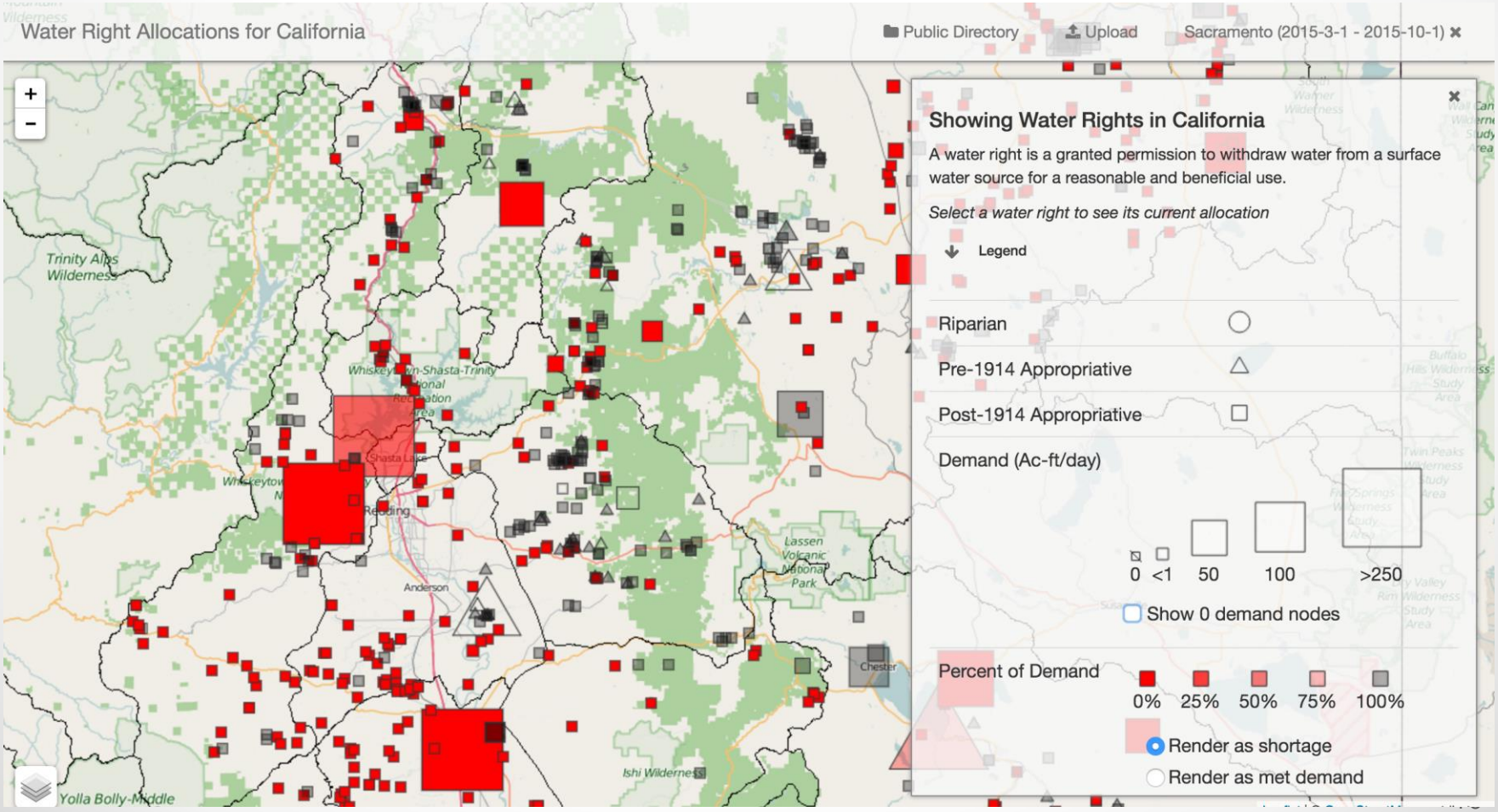
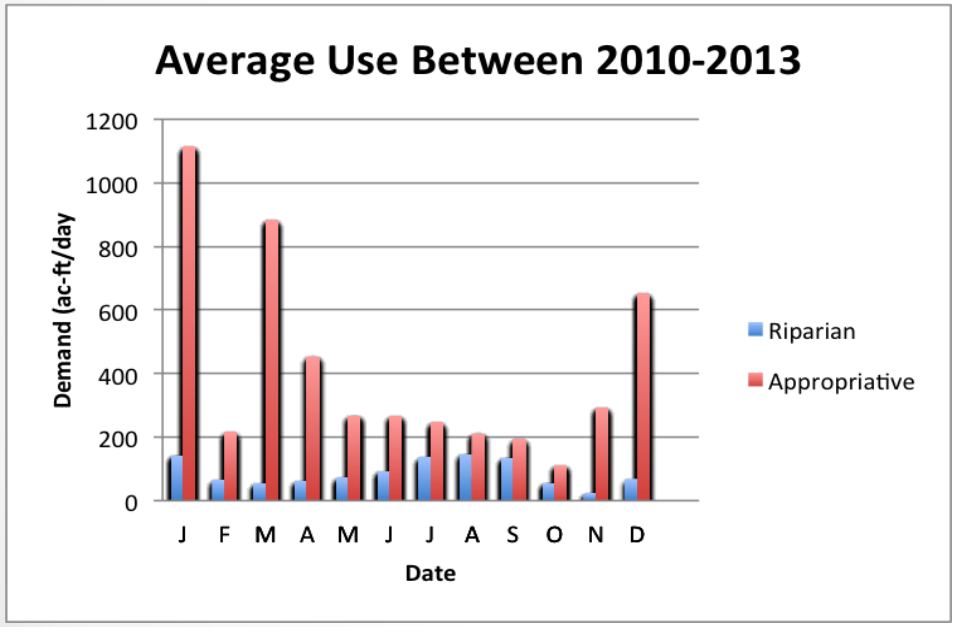
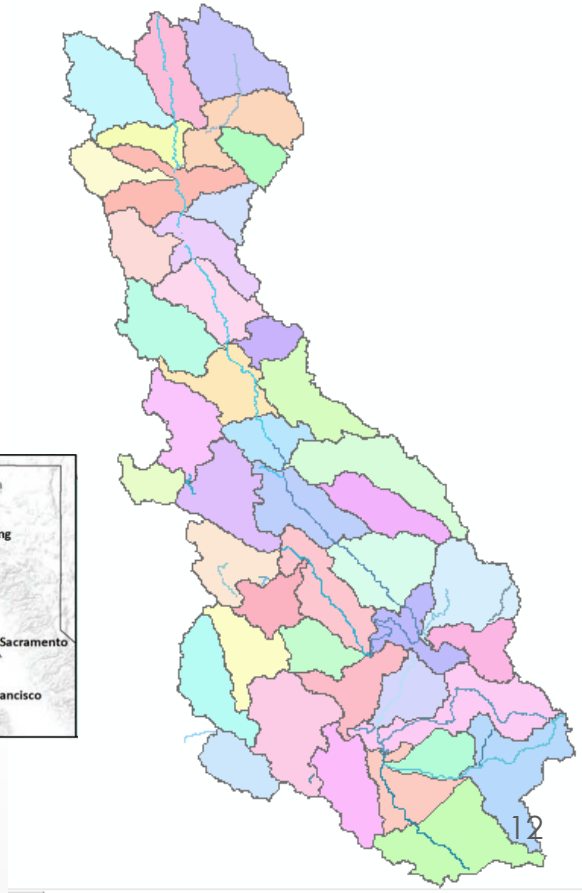


Russian River Results

Russian River

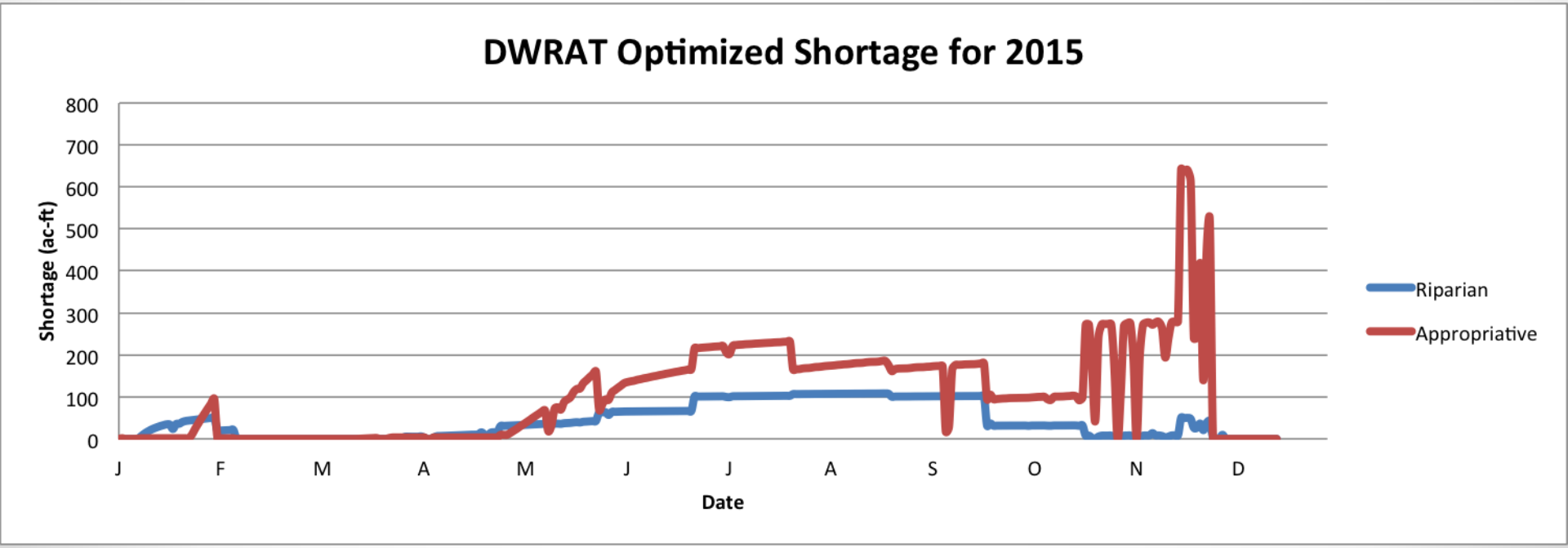
Type of Right	Number
Riparian	883
Pre-1914 Appropriative	42
Post-1914 Appropriative	1,090
Total	2,015





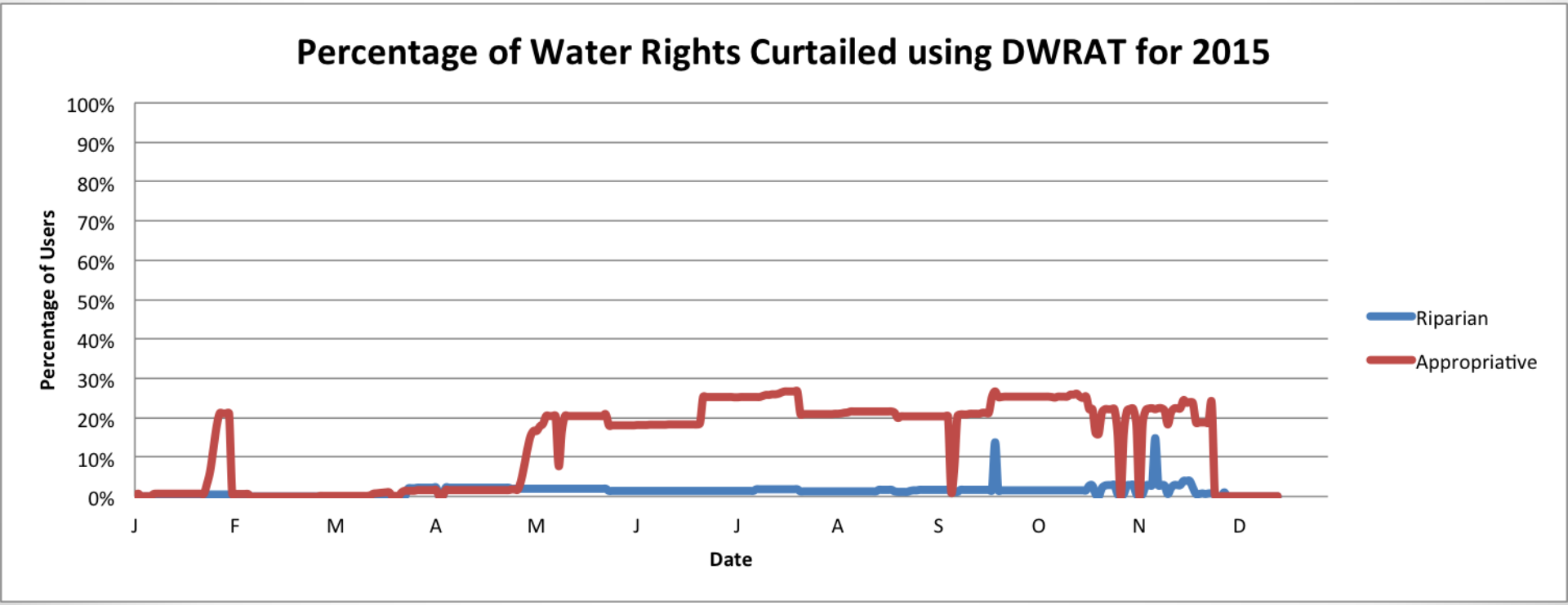
Russian River DWRAT Results

- Shortage
  - Maximum shortage:
    - Appropriative – 675 AF in November
    - Riparian – 103 AF in August



Russian River DWRAT Results

- Percent of Curtailed Water Rights
  - Filing date of earliest curtailed appropriative right:
    - 04/23/1946

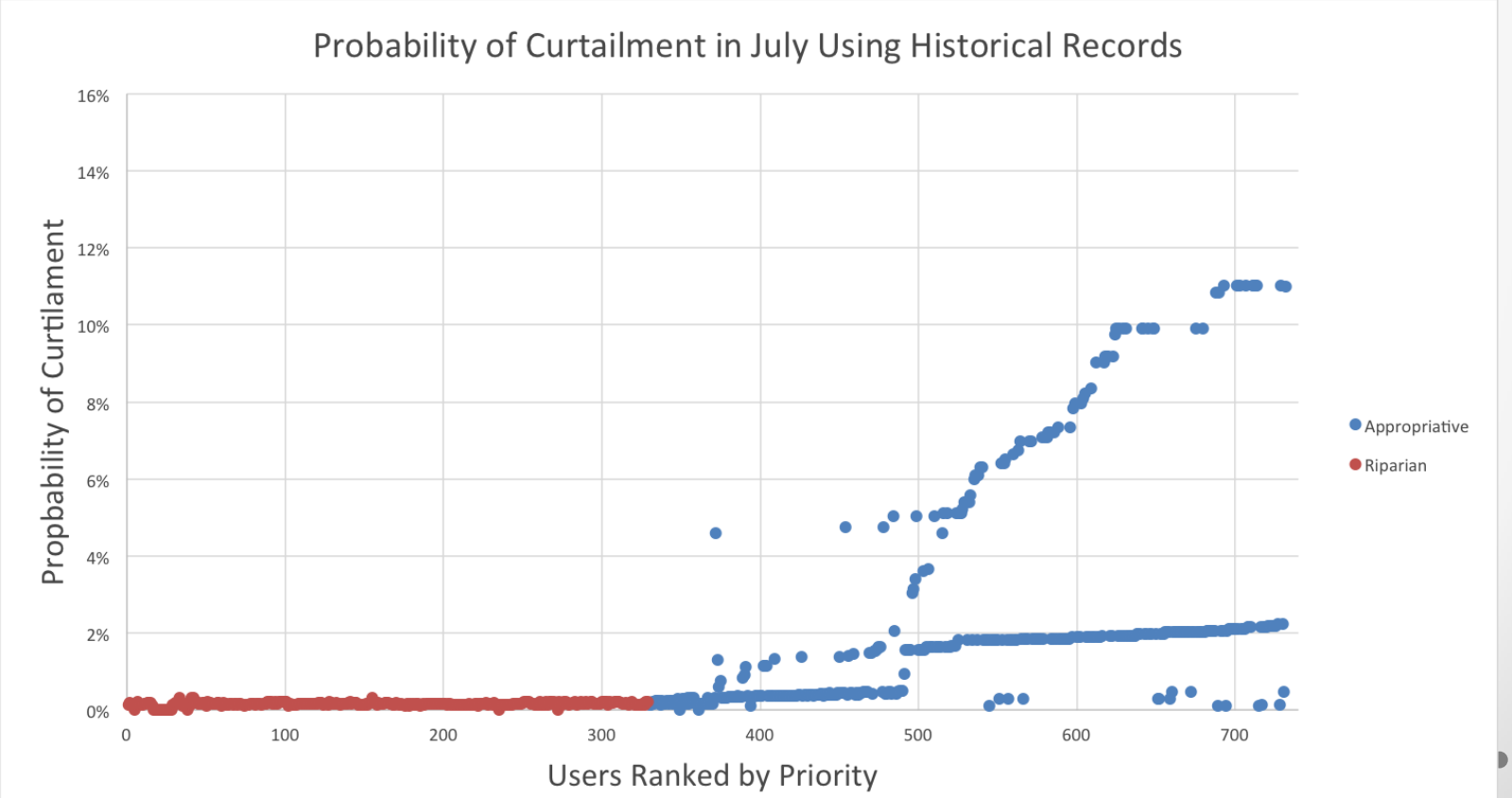


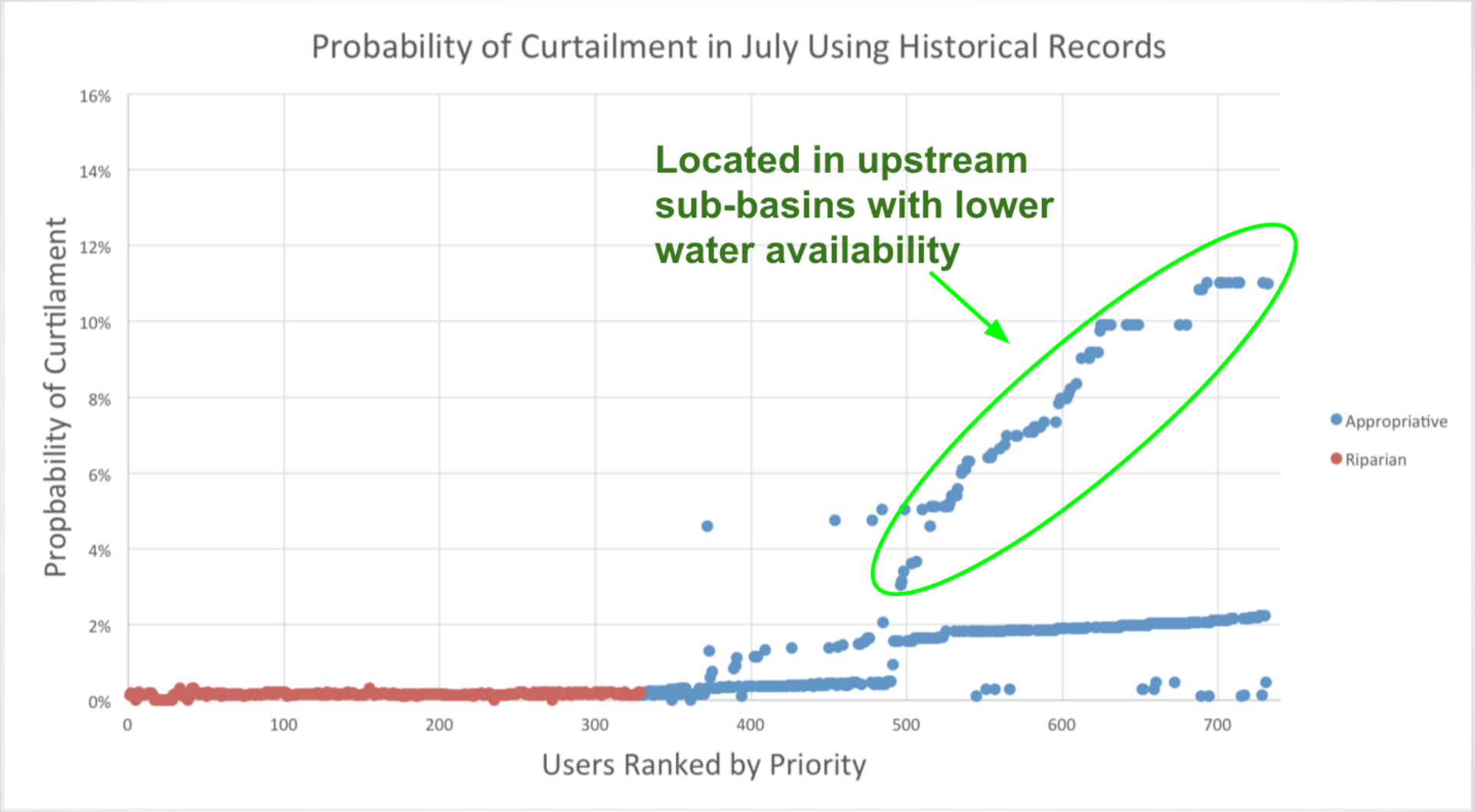
Water Reliability

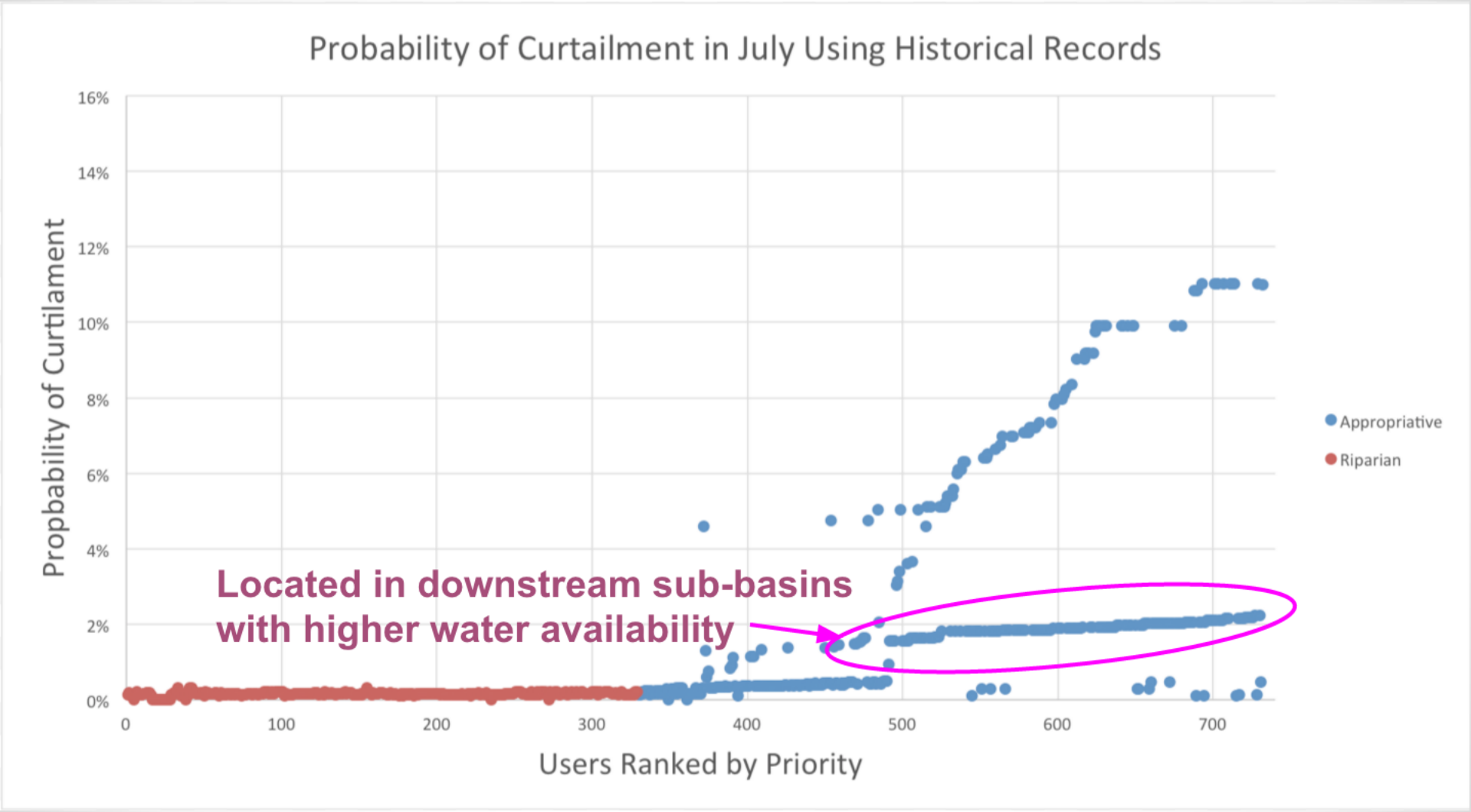
Using July as Example

Water Reliability

- DWRAT can be used to determine the probability of curtailment for water users
- Probability of curtailment using historical records for July:




Probability of Curtailment in July Using Historical Records
Propbability of Curtilament
16%
14%
12%
10%
8%
6%
4%
2%
0%
0
100
200
300
400
500
600
700
Users Ranked by Priority
Located in upstream sub-basins with lower water availability
Appropriative
Riparian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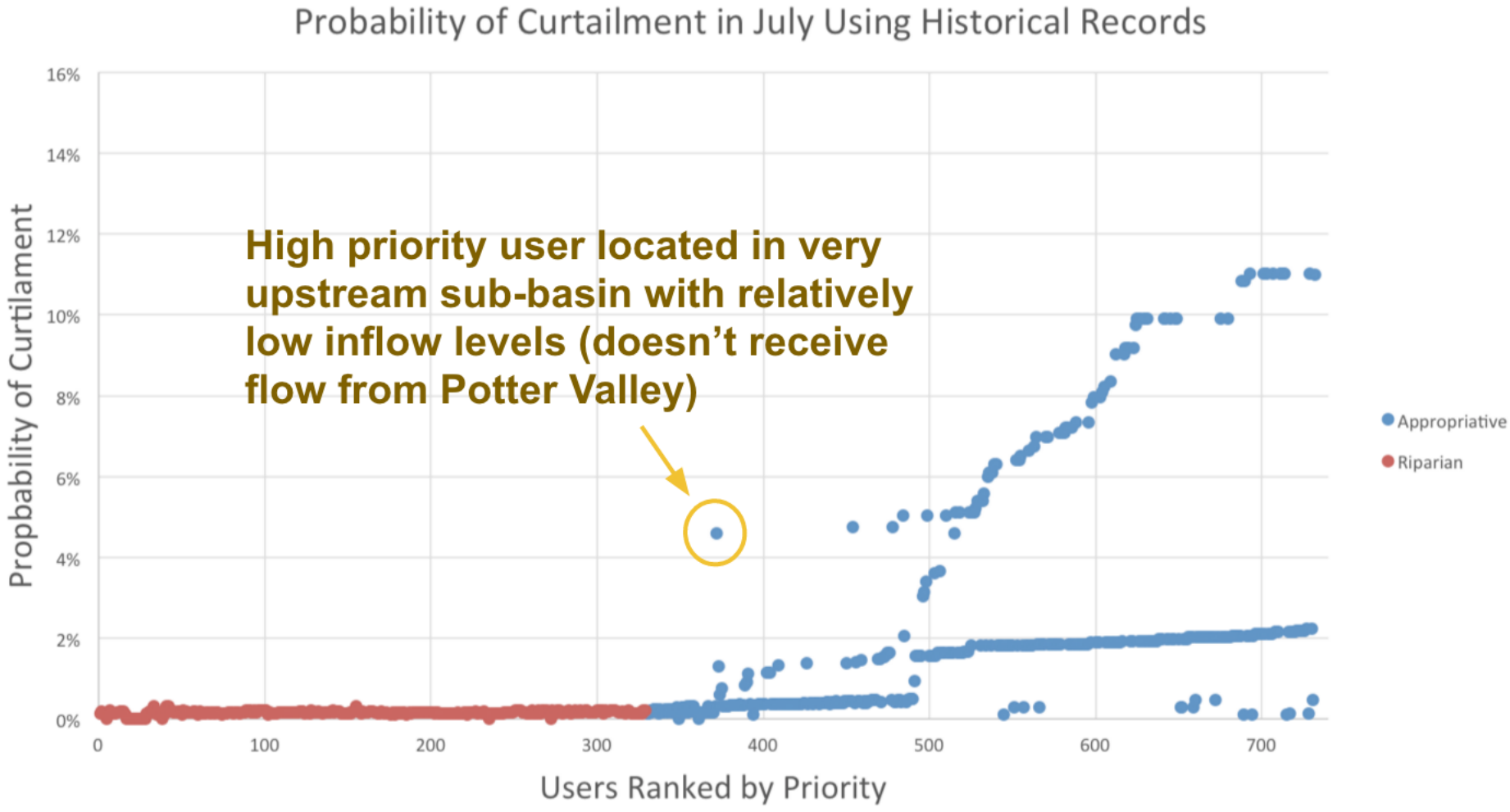
Users Ranked by Priority
Appropriative
Riparian
Located in downstream sub-basins
with higher water availability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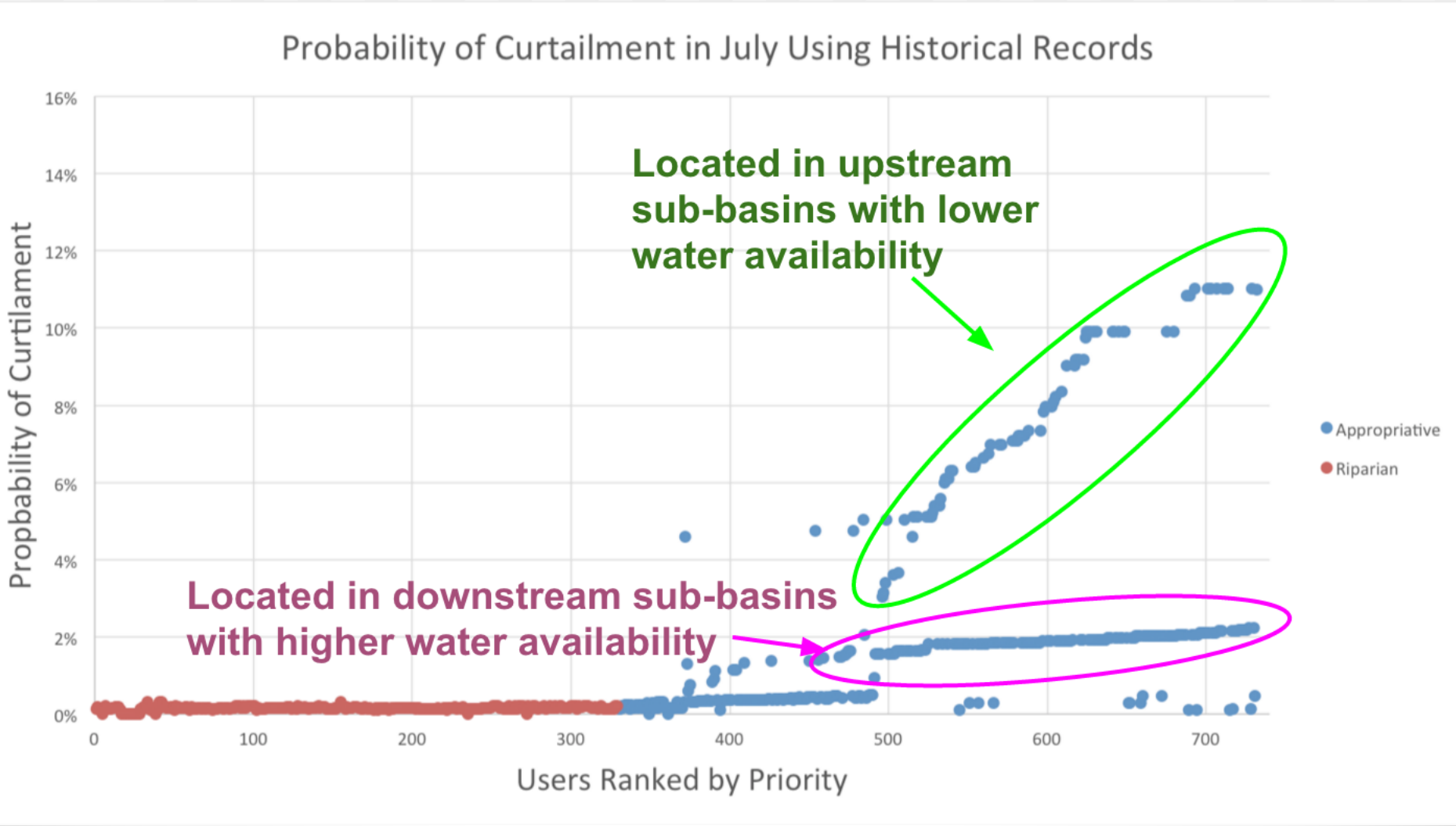
Users Ranked by Priority
High priority user located in very upstream sub-basin with relatively low inflow levels (doesn't receive flow from Potter Valley)
Appropriative
Riparian


User is
located here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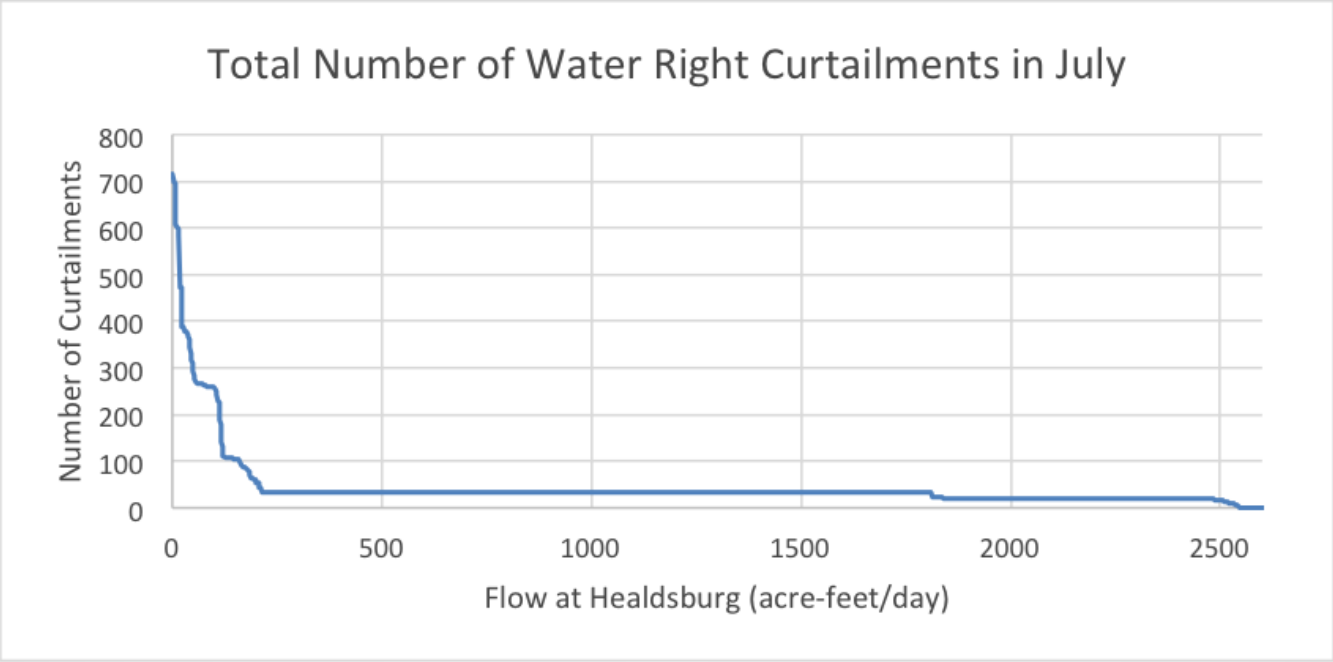
Located in upstream sub-basins with lower water availability
Located in downstream sub-basins with higher water availability
Appropriative
Riparian

Monthly Curtailment Rules

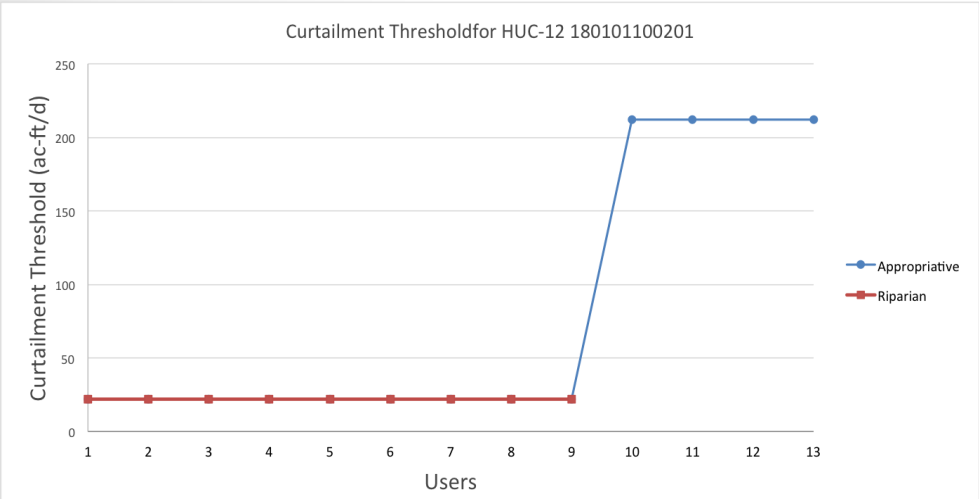
Implicit Stochastic Optimization

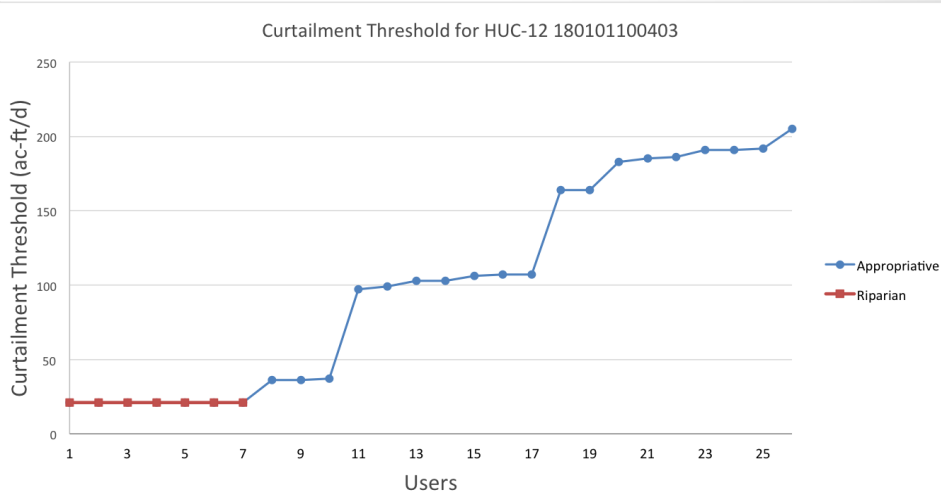
1. Generate multiple synthetic inflow sequences
2. Use DWRAT to find optimal curtailment decisions for each inflow sequence
3. Use the ensemble of optimal curtailment decisions to determine water reliability and construct monthly curtailment rules

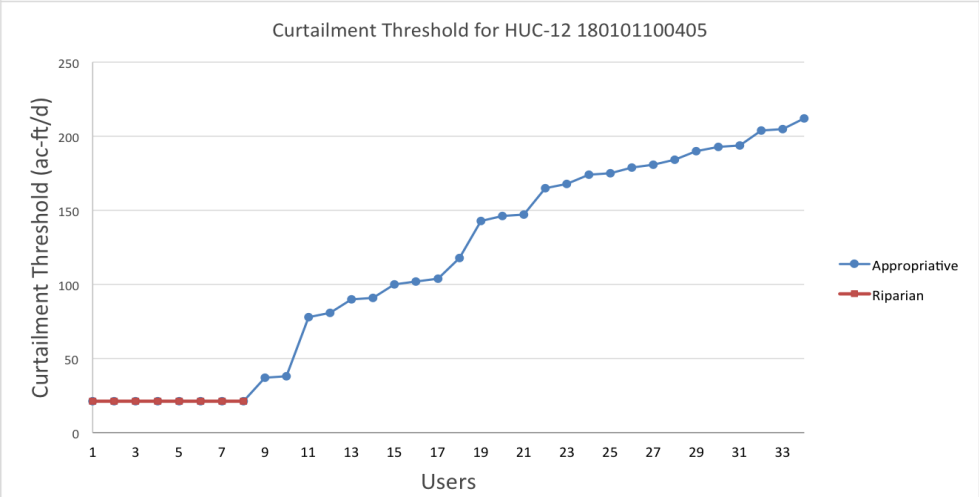


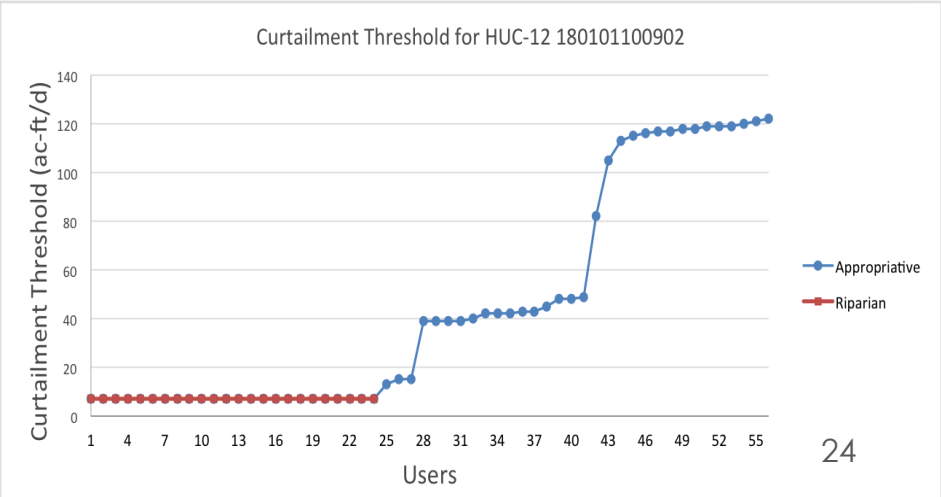
- Curtailment threshold equals the FNF through Healdsburg at which DWRAT releases a right holder from curtailment

- If the expected FNF at Healdsburg is less than a user's curtailment threshold, then he or she should be curtailed









Further Work for DWRAT

- Formation of curtailment rules for other dry months
- Incorporation of return flows
- Development of San Joaquin DWRAT
- Flow error analysis
- Improvement of hydrologic model

References

- Grantham, T. (2014). *California Water Rights Model – Supply Estimation*. Center for Watershed Sciences, University of California Davis.
- Lord, B. (2015). Water Rights Curtailments for Drought in California: Method and Eel River Application. *University of California Davis, Center for Watershed Sciences.*
- National Weather Service. (2016). California Nevada River Forecast Center. *National Oceanic and Atmospheric Administration*.
- SWRCB. (1974). In the Matter of Applications 12947, 12948, 12949, and 12950 to Appropriate Water from East Fork Russian River and Russian River in Mendocino and Sonoma Counties. *State of California Water Rights Board.* (Order WR 74-30).

End

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