Quantifying Uncertainty through Position Analysis in Drought Water Supply Planning: Examples from California

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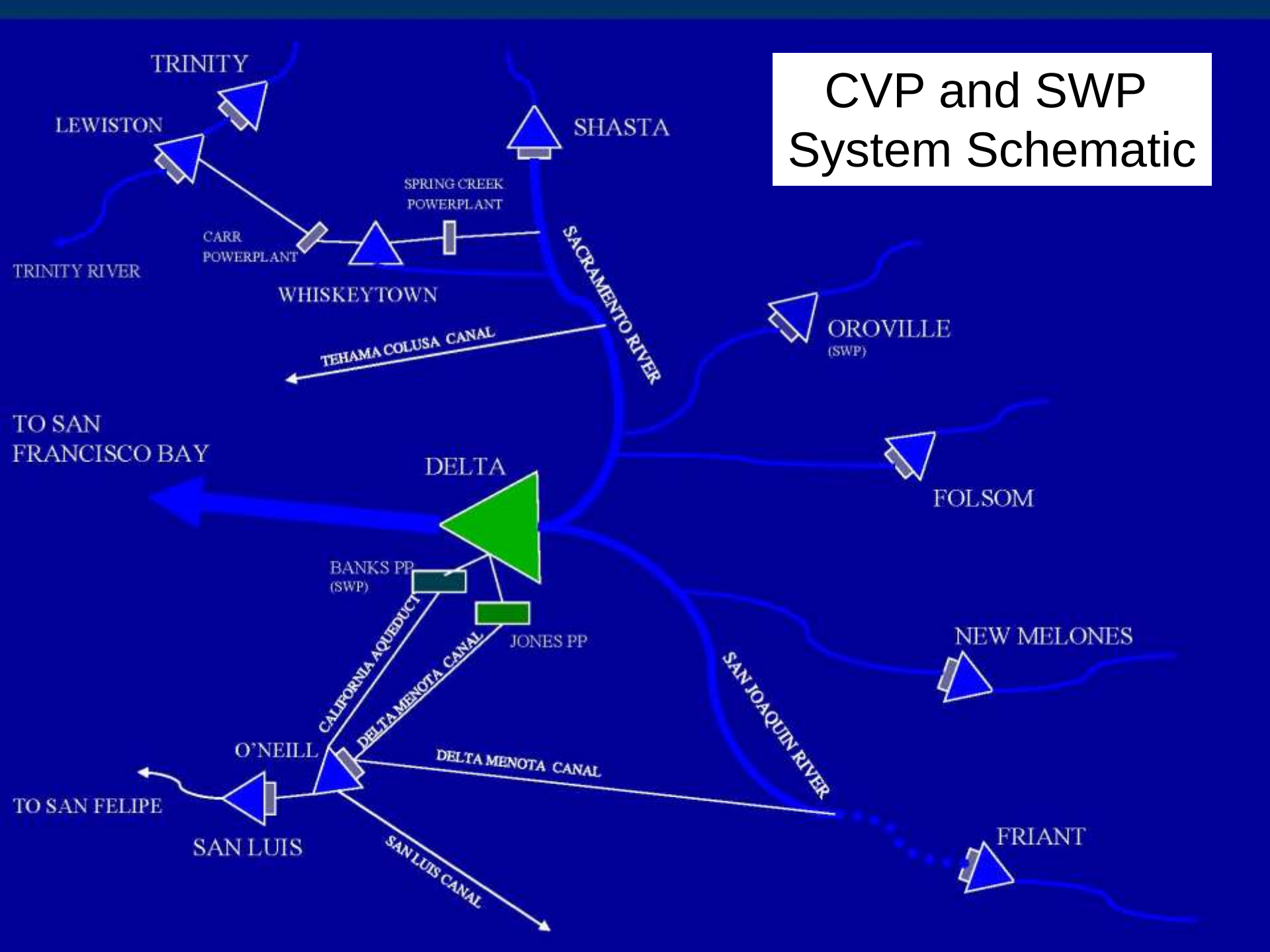
Presentation Outline

- Background on Central Valley Water Supply Operations
- CalSim 2 Model
- Use of Position Analysis in Water Supply Planning
- Example: San Joaquin Flow Objectives Position Analysis
- Forecast-Based Modeling for Water Supply Planning
- Conclusion

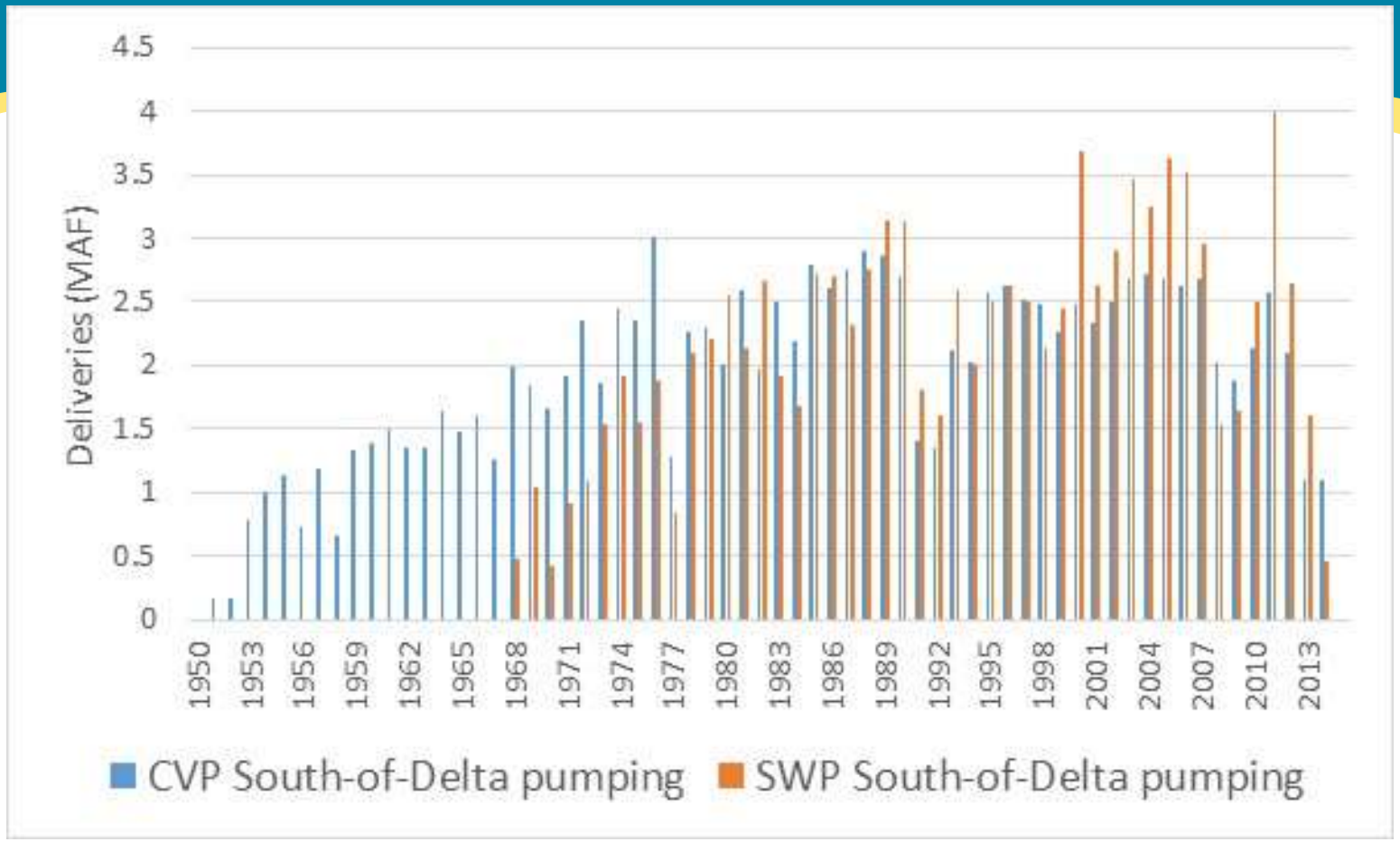
Central Valley Project & State Water Project Features

Description	Central Valley Project	State Water Project
Storage Facilities		
Number	20	20
Storage (TAF)	11,000	5,800
Hydropower Facilities		
Number	11	8
Generation Capacity (Megawatts)	2,100	1,380
Land Use Irrigable Lands (million acres)	2.6	0.75
Direct Beneficiaries		
Water Contractors	>250	29
Power Contractors	60	-

CVP and SWP System Schematic



Historical CVP and SWP Deliveries



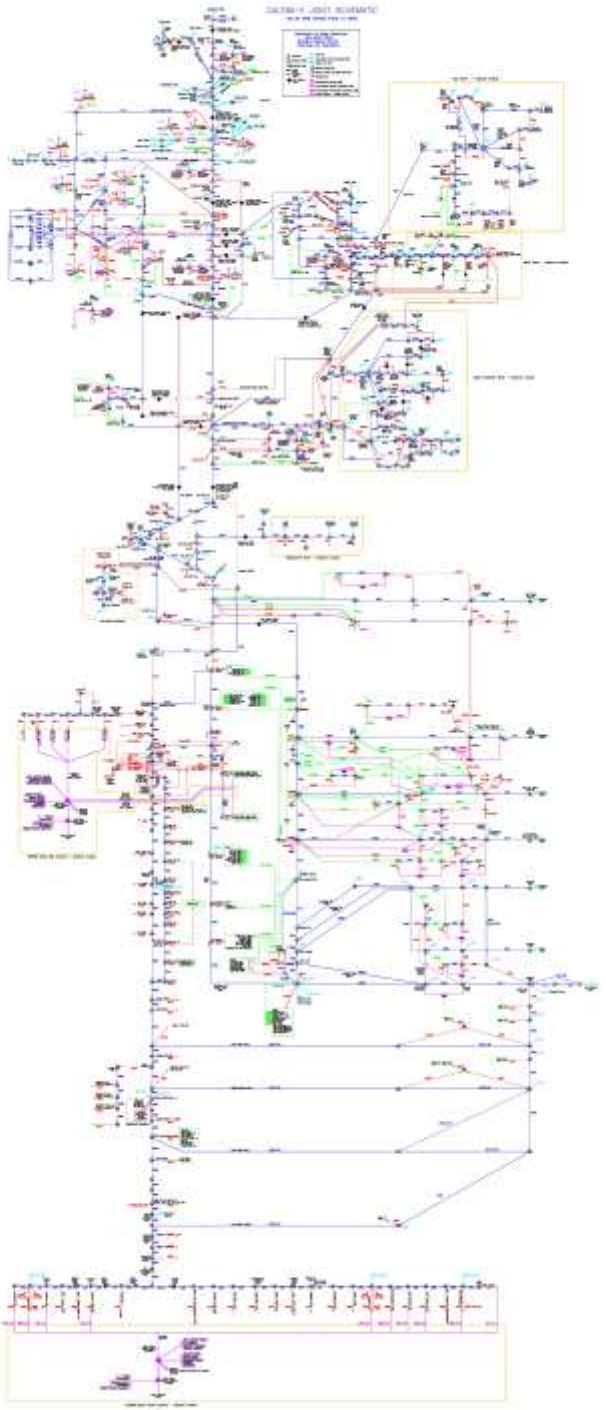
- **Decline in health of Delta and riverine ecosystems has led to increasing environmental regulations, most recently the 2008-2009 Biological Opinions**

Water Supply Allocations

- **Growth of snowpack and storage throughout winter allows for prediction of water supply availability**
- **Midway through water year initial water supply allocation is developed, then refined through May**
  - SWP – January through May
  - CVP – February through May
- **Exceedance probabilities used for inflow forecasts**
  - CVP – Feb 99%, Mar 90%, Apr 75%, May 50%
  - SWP – Jan-Mar 99%, Apr-May 90%
- **Allocation accounts for water to be delivered while retaining carryover storage for future years**

CalSim 2

- CalSim 2 model evaluates the water supply reliability of the CVP/SWP
- Developed by California DWR and U.S. Bureau of Reclamation in early 2000s as a replacement for agencies separate models
- Designed for planning analyses, not day-to-day operations, as it does simplify many aspects of the system as compared to actual operations
- Used for all major planning studies in the Central Valley



CalSim 2

- **CalSim 2 is a specific application generated using a generic modeling system developed by California DWR (WRIMS)**
- **Simulates all major features of system in Valley:**
  - reservoirs and water supply facilities
  - river flows and Delta flows and salinity
  - environmental regulations
  - deliveries under contracts and water rights.
- **Monthly model: Period of record 1922-2003**
- **Operated at a fixed level of development under a consistent regulatory regime**
- **Hydrologic inputs represent flows that historical climate conditions would have produced under current or future levels of development**

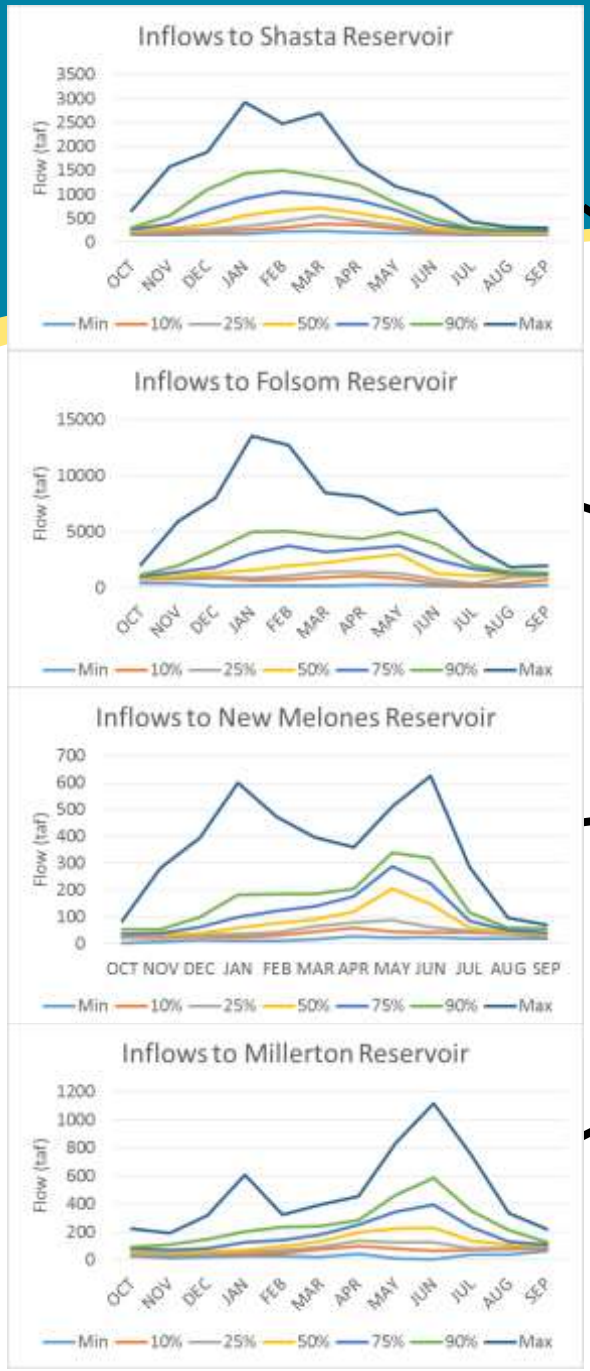
CalSim 2

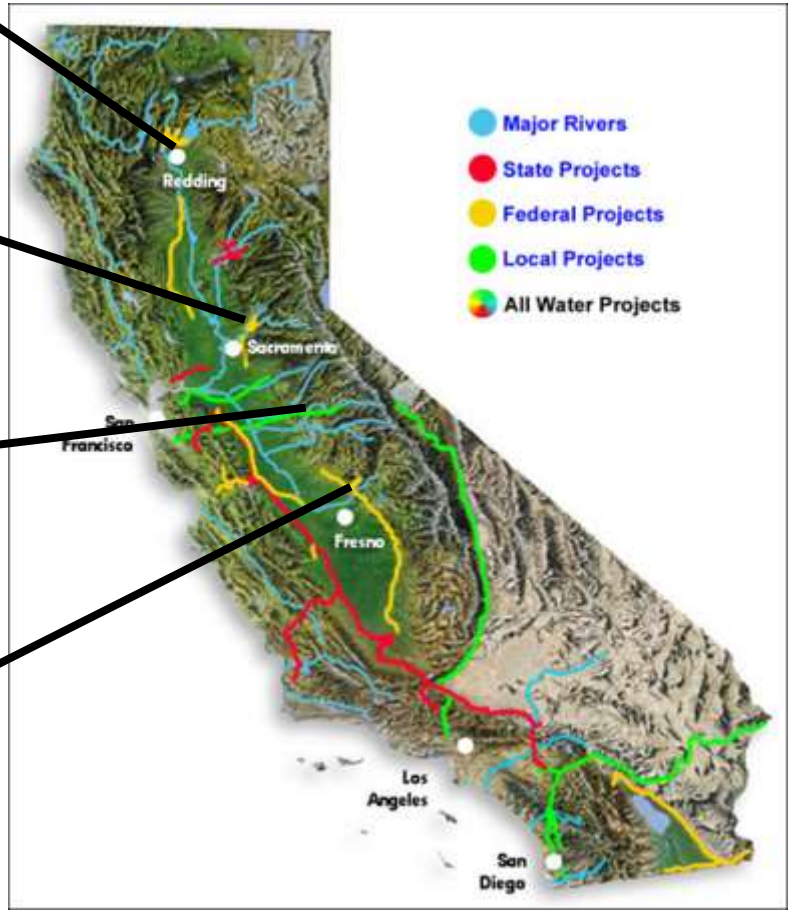
- **Example applications**
  - Storage projects (EISs and Feasibility Reports)
  - Water Control Manual updates
  - SWP Delivery Capability Report
  - Studies of climate change impacts
  - Reclamation long-term operations studies
  - Environmental and water supply permitting
- **Often used to provide inputs/boundary conditions for other models (temperature, economics, water quality)**
- **Versions do exist that are used for annual water supply planning**

Quantifying Uncertainty: Position Analysis

- 82 one year model runs using each annual year of inflows from 1922-2003
- Conducted early in water year (October) when ability to forecast flows is very low
- Model initialized with conditions at end of September (i.e reservoir storages, prior month flows, etc.)
- Results capture the range of possible future operations and deliveries that would occur under the historical range of hydrologic conditions

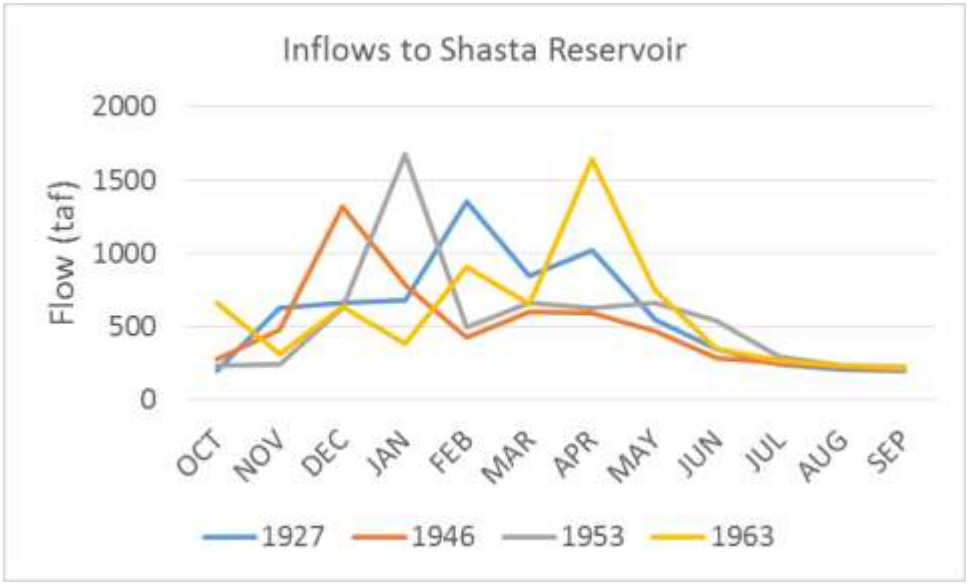
Quantifying Uncertainty: Position Analysis





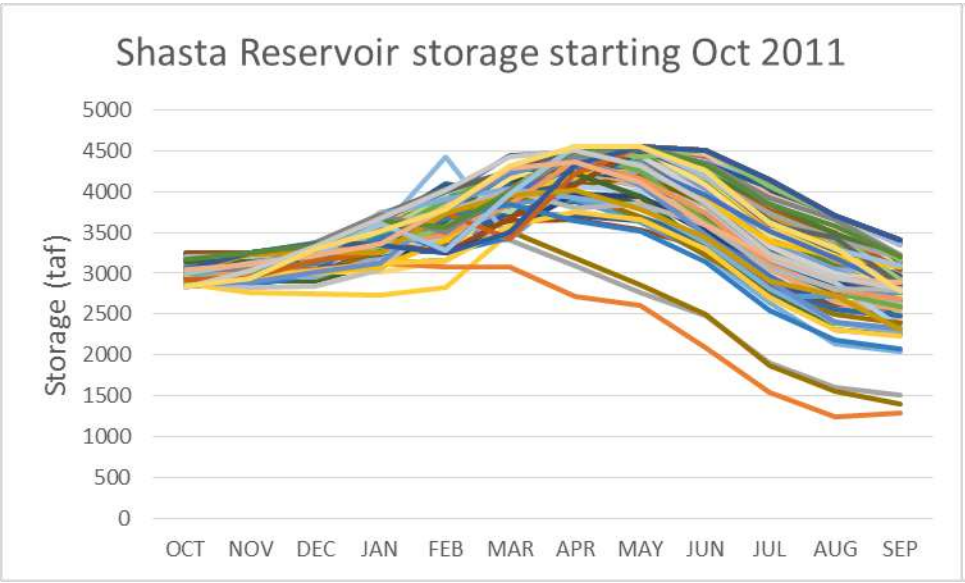
Quantifying Uncertainty: Position Analysis

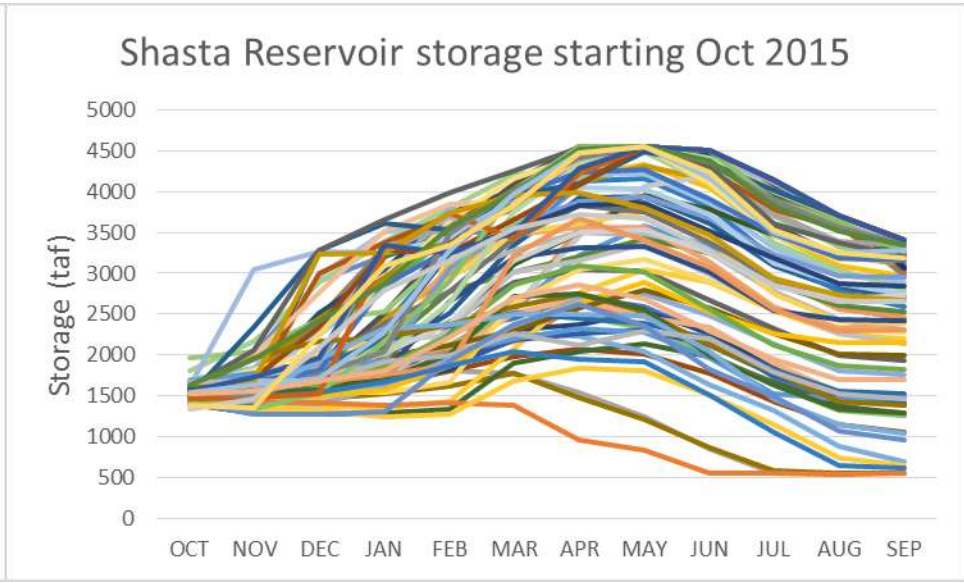
- Seasonal variability of inflows will affect operations
- Snowmelt flows in spring more predictable than rainfall in winter



Quantifying Uncertainty: Position Analysis

- **Examples of operations following:**
  - 2011: Very wet year
  - 2013-2015: 3 consecutive drought years





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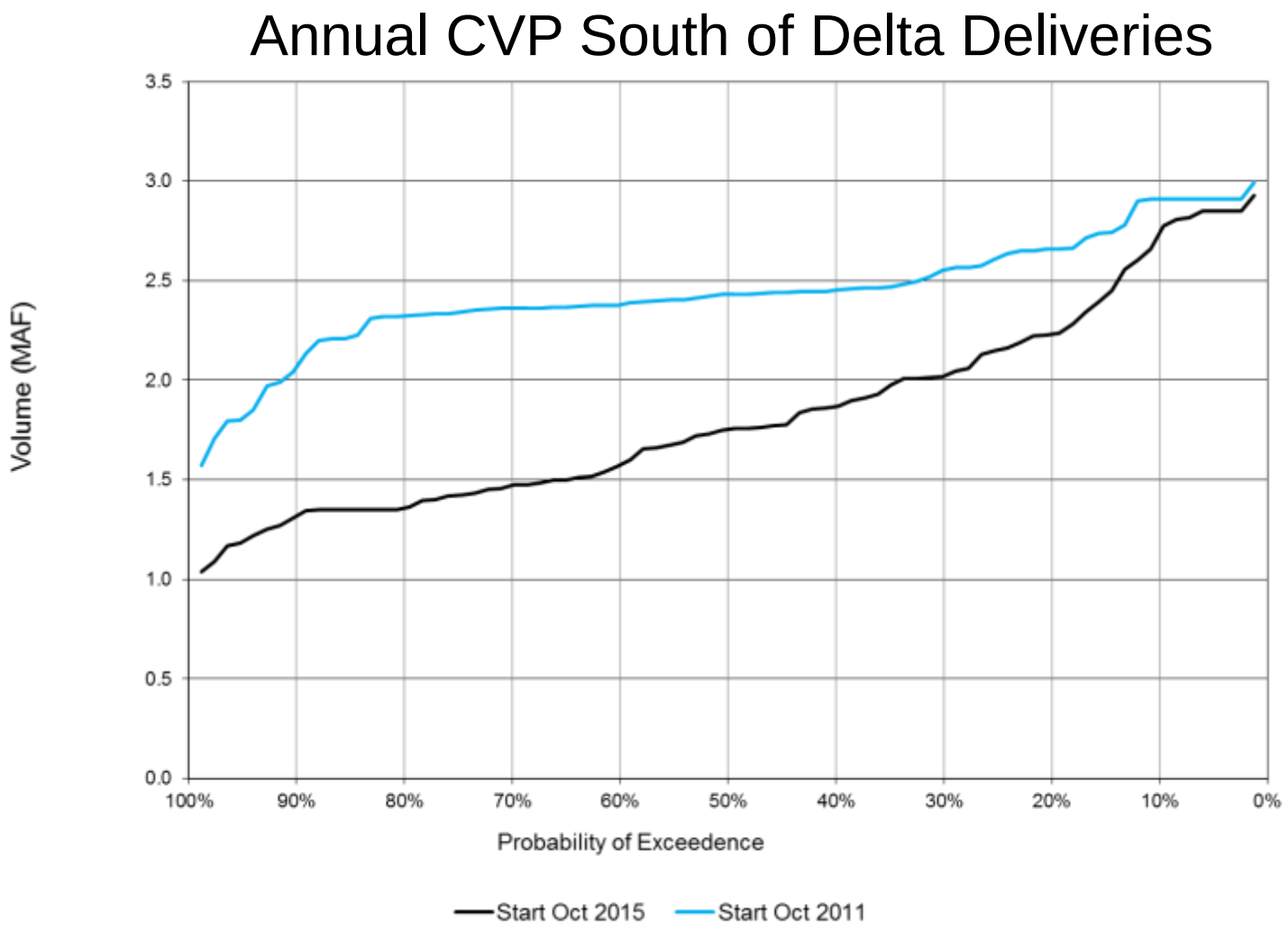

Position Analysis Example: San Joaquin Basin Flow Standards

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- Vernalis Adaptive Management Plan (VAMP), as codified in D-1641, specified flow targets at Vernalis during the Apr 15-May 15 pulse period, to facilitate fall-run Chinook salmon out-migration.

- These targets were met from 1999-2011 through San Joaquin River Agreement, which expired 12/31/11.

- Under the Agreement, water to meet flow targets was purchased by Reclamation from water users on the Stanislaus, Tuolumne, Merced, and Upper San Joaquin River.

Position Analysis Example: San Joaquin Basin Flow Standards

- VAMP flow targets are based on the following schedule:

Existing Flow (cfs) (VAMP Baseline)	Target Flow (cfs)
0-1,999	2,000
2,000-3,199	3,200
3,200-4,449	4,450
4,450-5,699	5,700
5,700-6,999	7,000
7,000 or greater	Existing Flow

- Also contained provisions for relaxing the standard during droughts and increasing the standard (Double-Step) during wetter periods.

Position Analysis Example: San Joaquin Basin Flow Standards

- Two-year window (2012-2013) after expiration of VAMP standard but before implementation of a long-term flow standard by the CA State Water Resources Control Board (SWRCB).

- Modeling conducted to support Reclamation's negotiations with water users for purchase of water to meet VAMP-like flow targets over this two-year period.

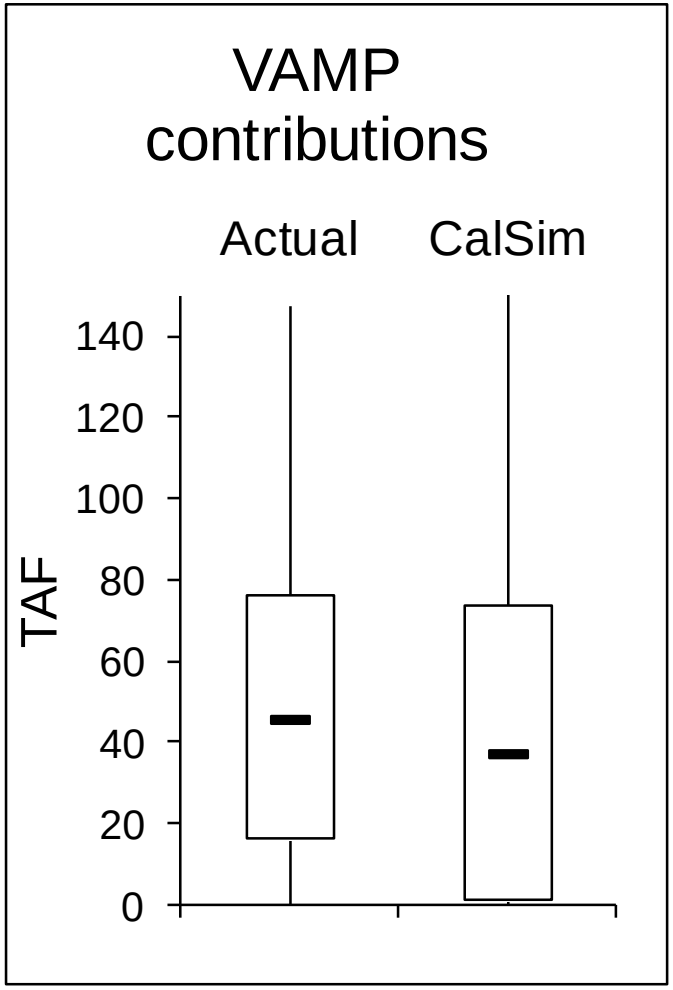
- Led to agreement with Merced Irrigation District for purchase of water to meet single-step VAMP standards

Position Analysis Example: San Joaquin Basin Flow Standards

Position Analysis Example: San Joaquin Basin Flow Standards

Model Validation

- Comparison of actual VAMP contributions during 1999-2010 to CalSim 2 modeled contributions over 82 year model run (with assumptions similar to historical conditions).
- Boxplots very similar. Wilcoxon rank-sum test p-value = 0.76, so no statistically significant difference.



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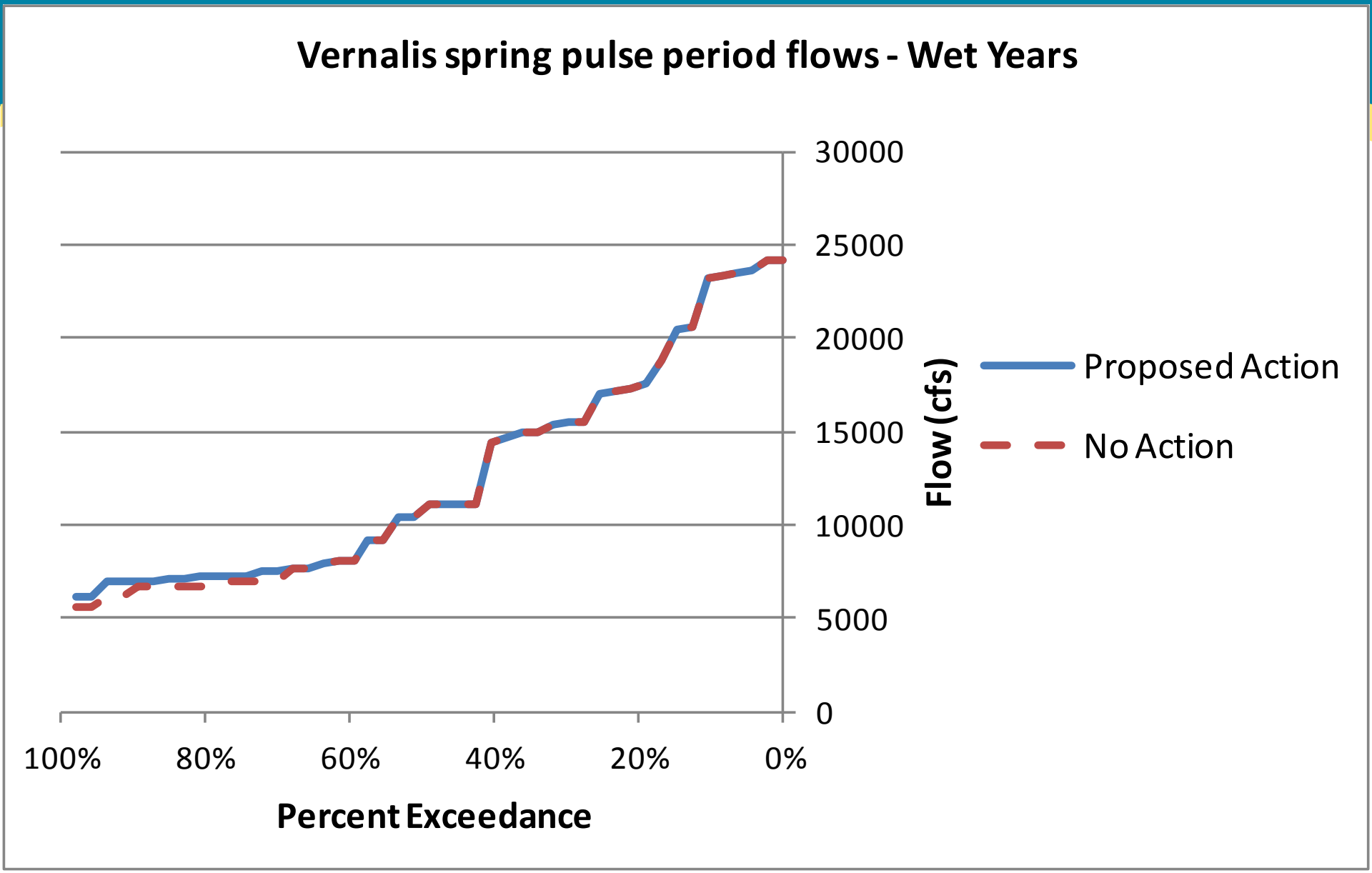

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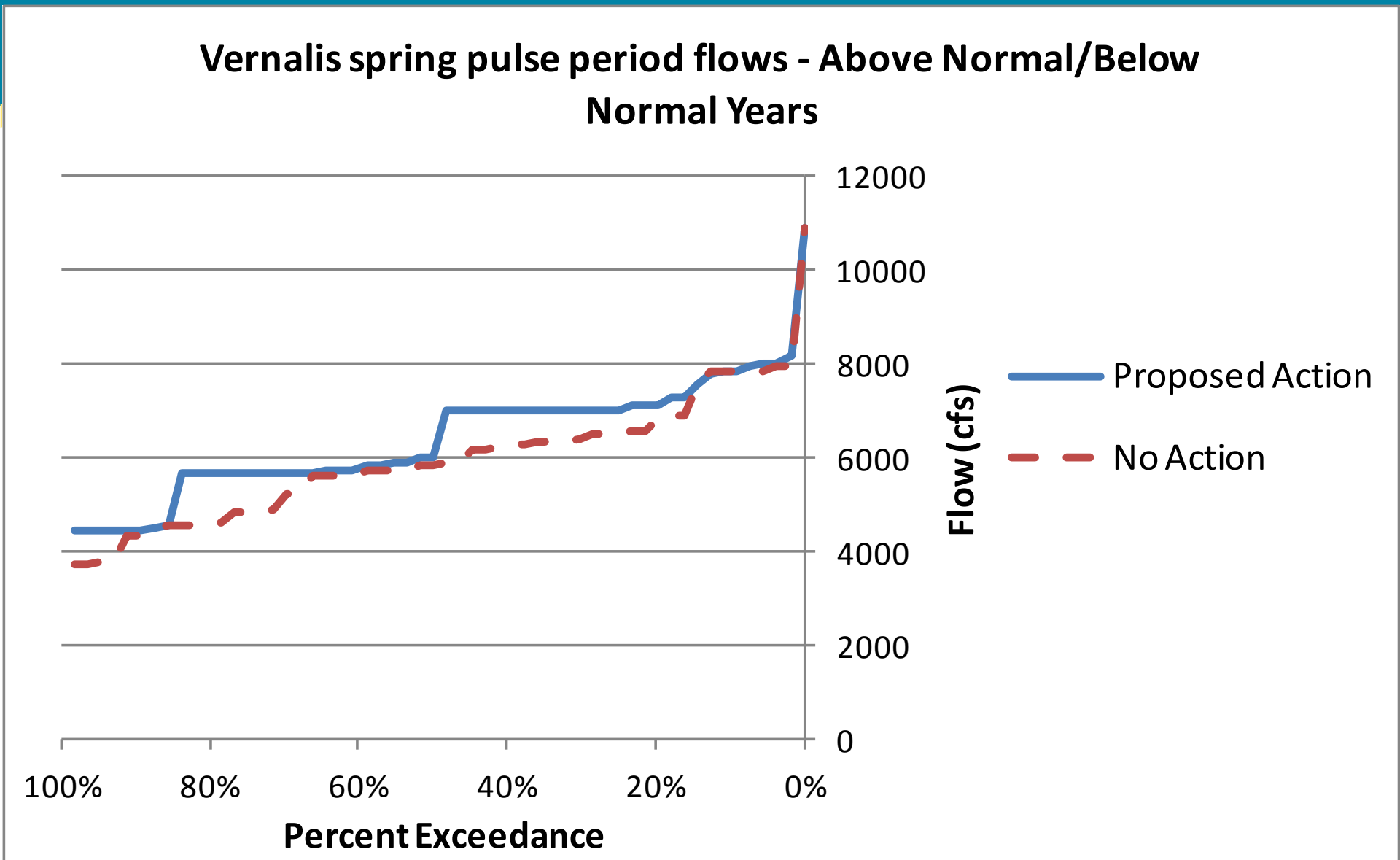

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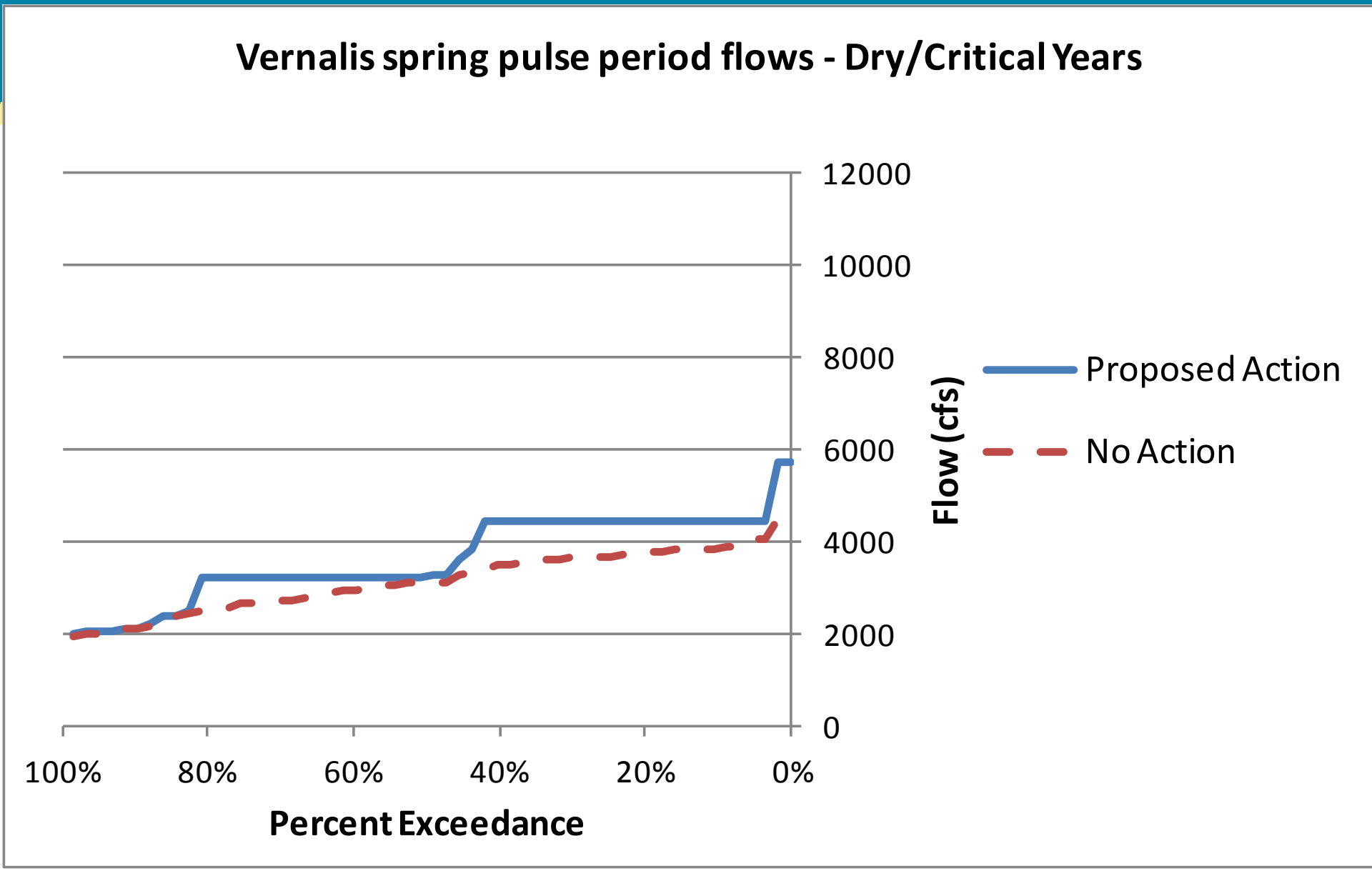

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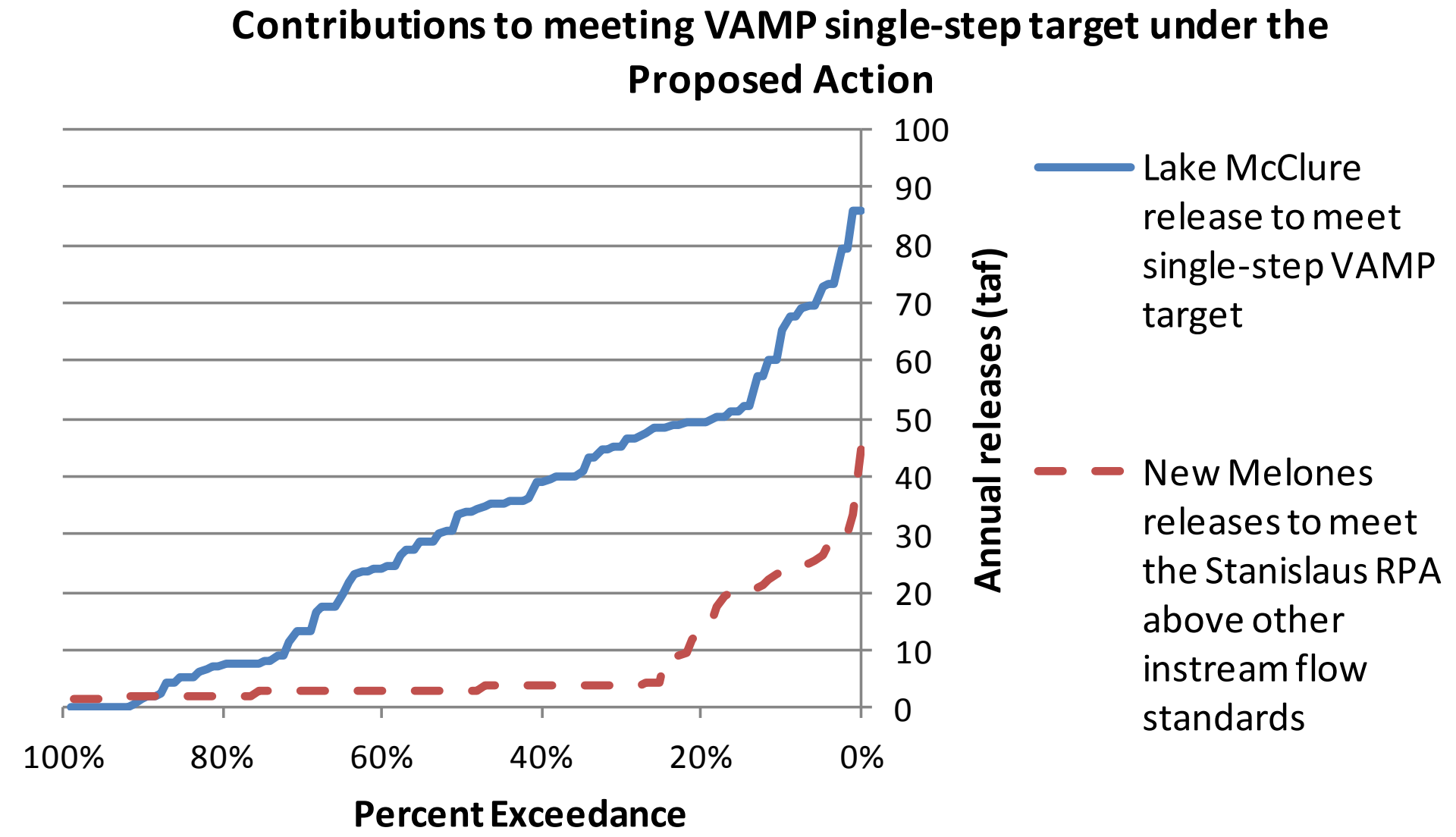

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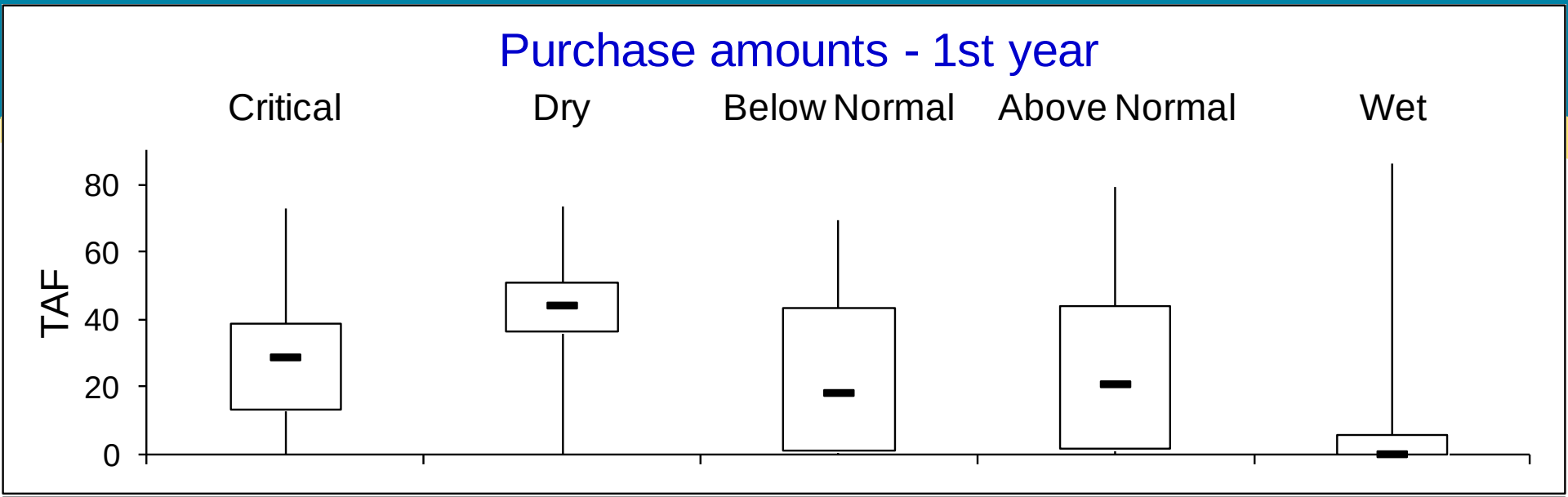
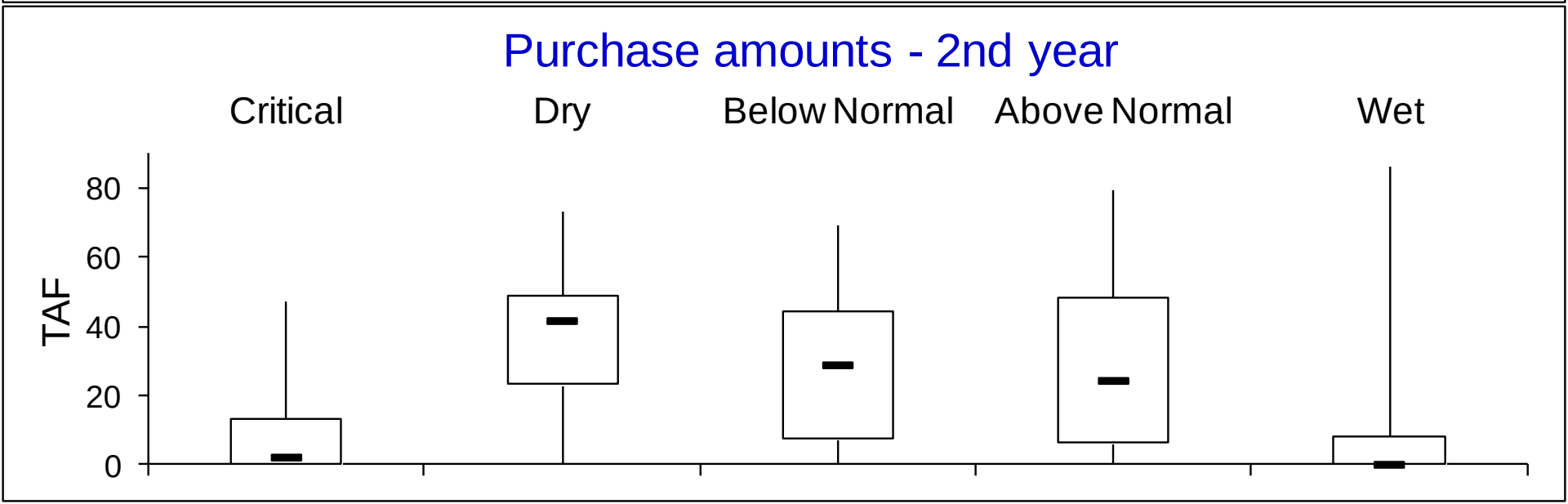




Forecast-Based Modeling for Water Supply Planning

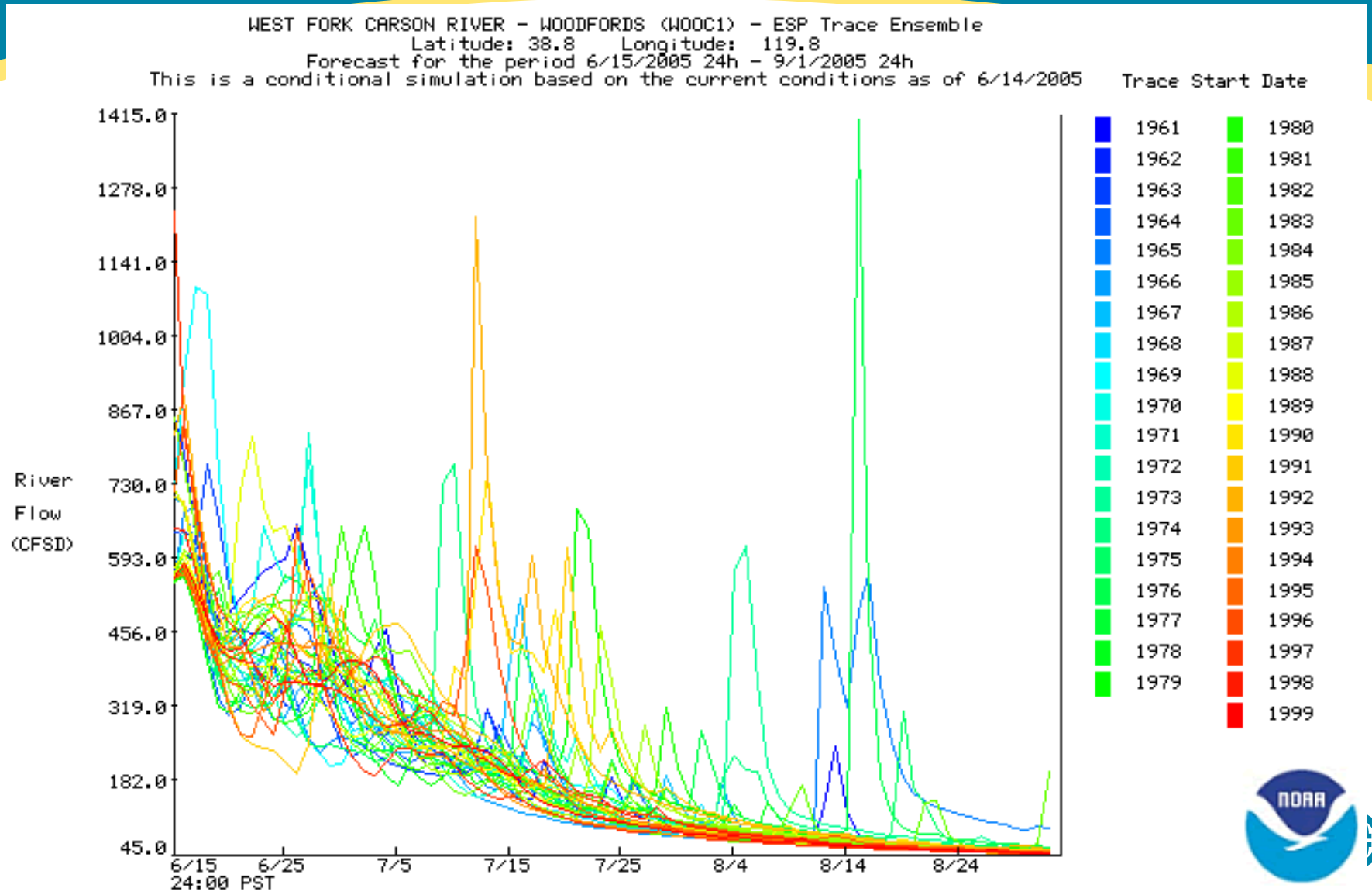
- Limitation of Position Analysis is that it is only useful at the beginning of the water year
- Once there is snowpack in the mountains, all historical runoff patterns are not equally likely
- Alternative approach is to run model using flow forecasts
- Data available to do this from California Nevada River Forecast Center (CNRFC)
- Modified CalSim 2 to replace historically-based inflows with inflows from CNRFC forecasts
- Model can be run starting in any month October-May, for one year, under 5 exceedance forecasts (10%, 25%, 50%, 75%, 90%)

Forecast-Based Modeling for Water Supply Planning

CNRFC Forecasts:

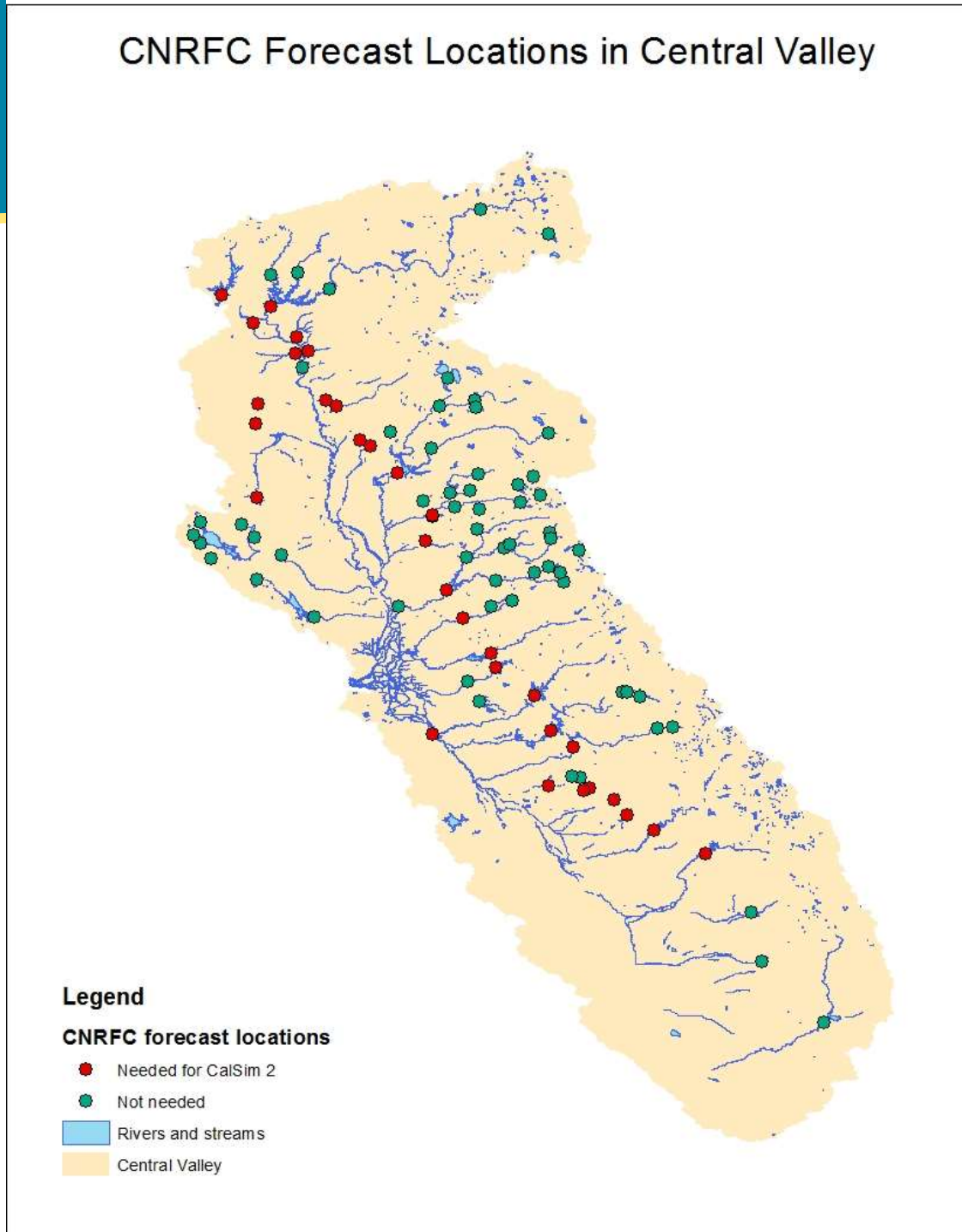
- Generated using National Weather Service River Forecast System, a collection of data processing tools and hydrologic simulation models
- Model is run for one year starting from current date for all calibration datasets (30-40 years), producing a series of traces
- Exceedance values derived from these traces are published daily on the internet
- Forecasts are unimpaired runoff, so in many cases need to be statistically converted to estimates of actual inflows into reservoirs

Forecast-Based Modeling for Water Supply Planning



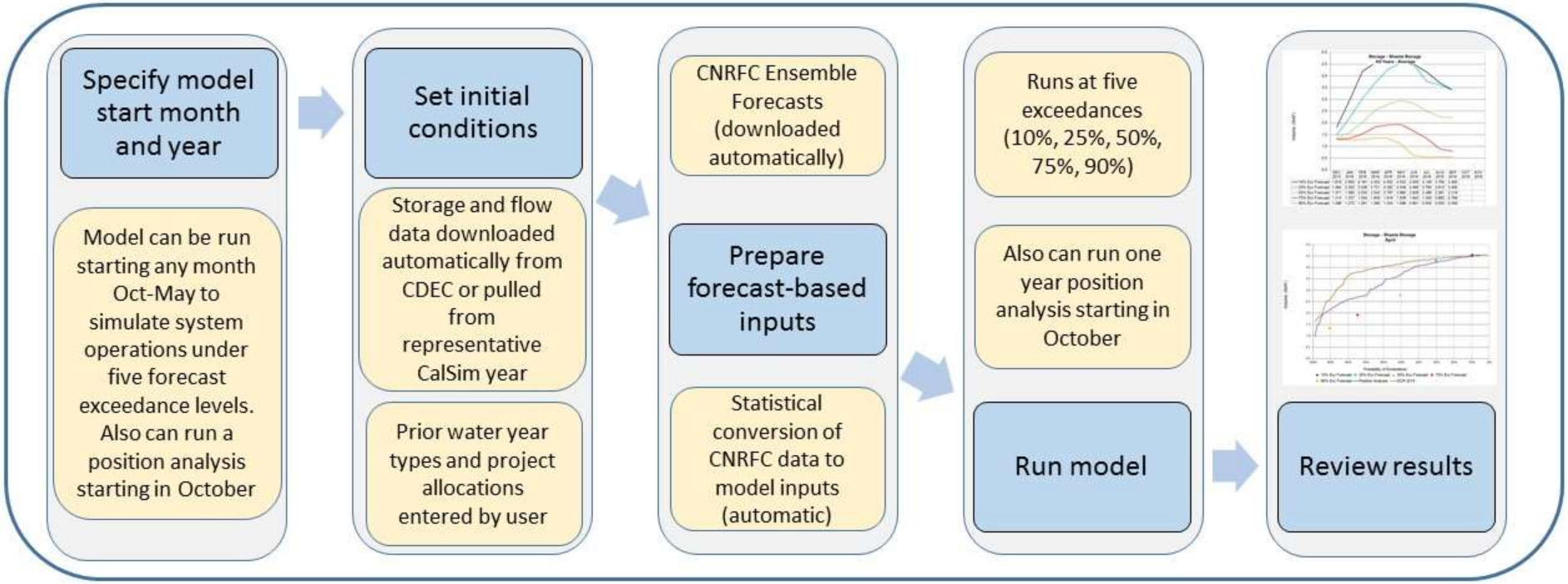
CNRFC Forecast Locations

- Forecast locations needed to run CalSim 2 shown in map
- These mostly are rim inflows to major reservoirs
- Forecasts statistically converted into inflows to reservoirs and also accretion-depletion terms and agricultural demands



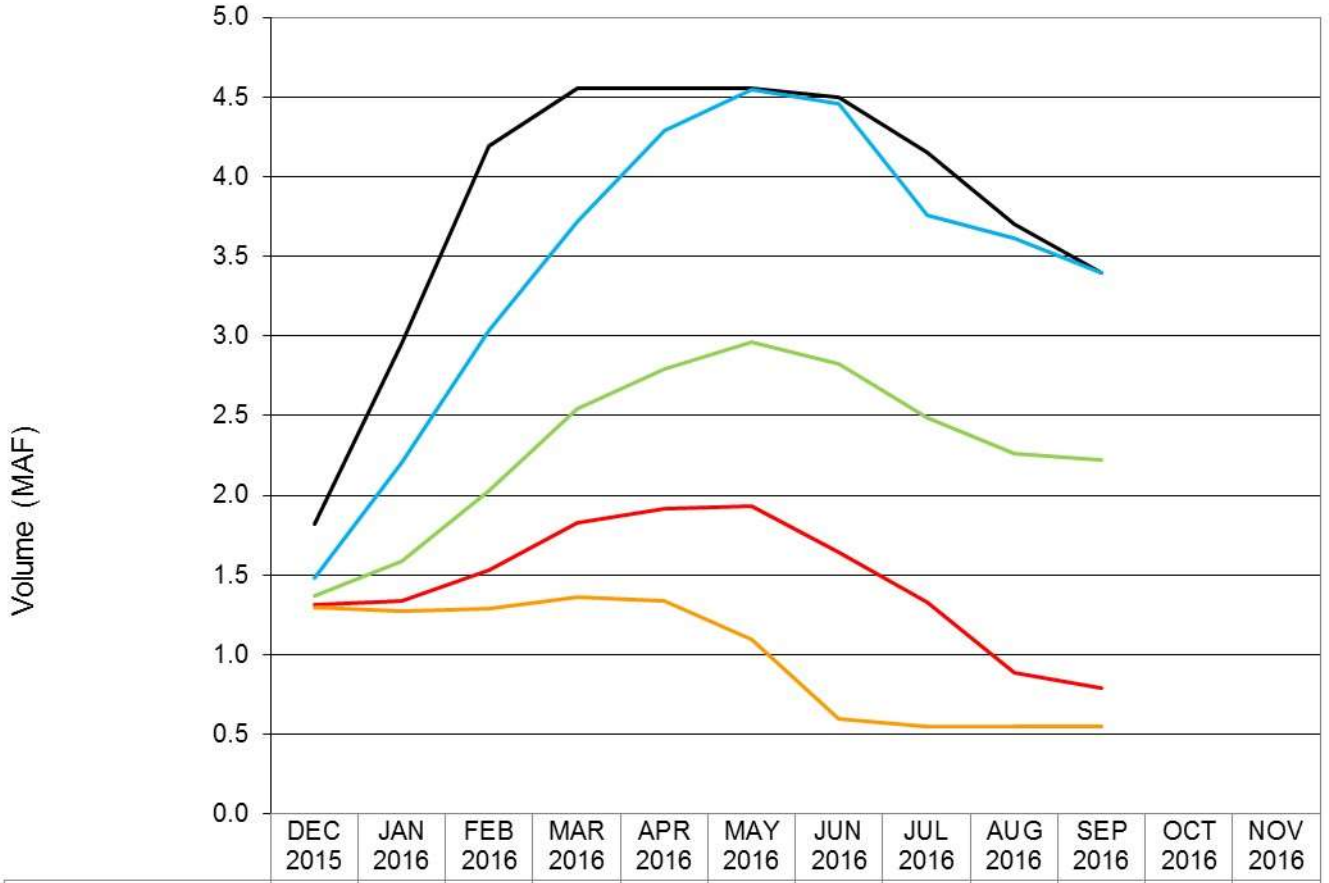
Forecast-Based Modeling for Water Supply Planning

Run Process



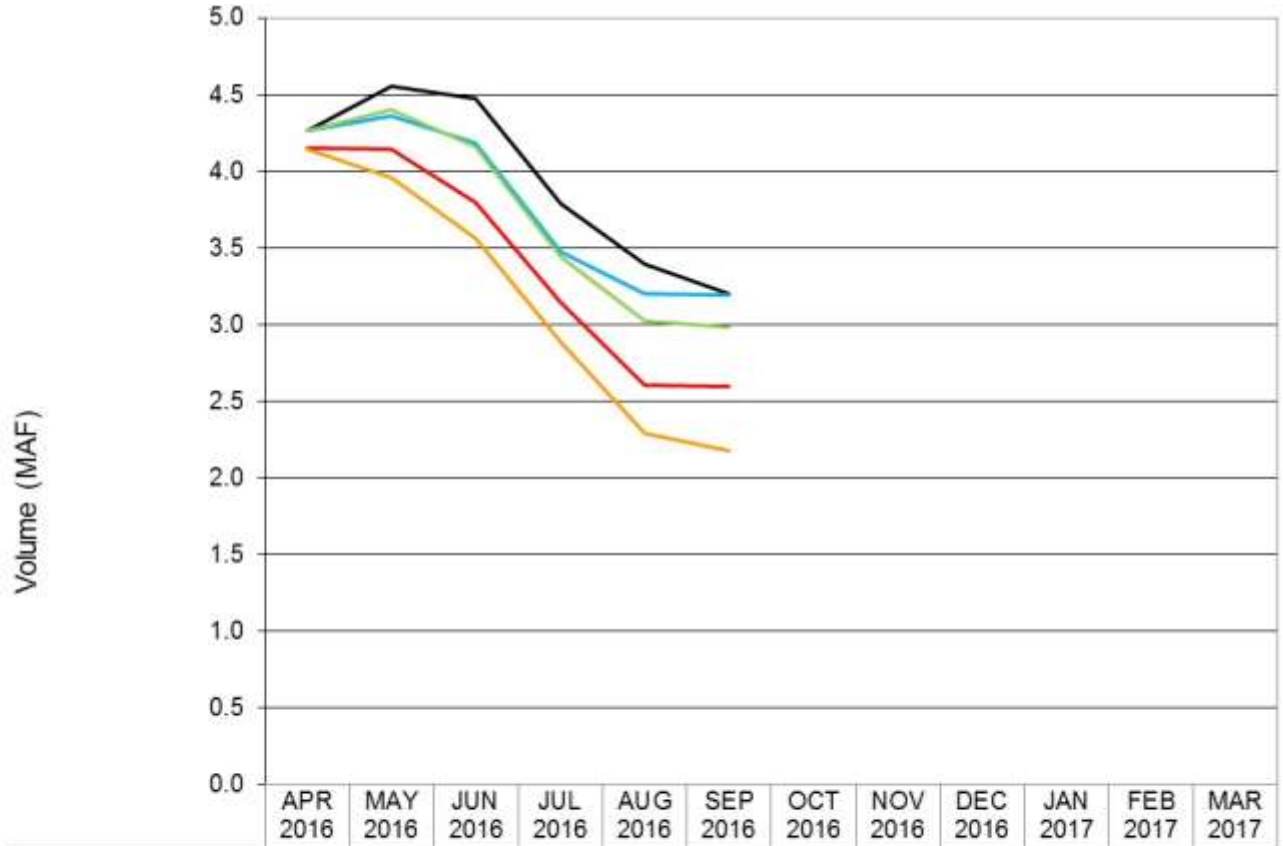
Forecast-Based Modeling for Water Supply Planning

Shasta monthly storage, from forecast-based run conducted in December 2015



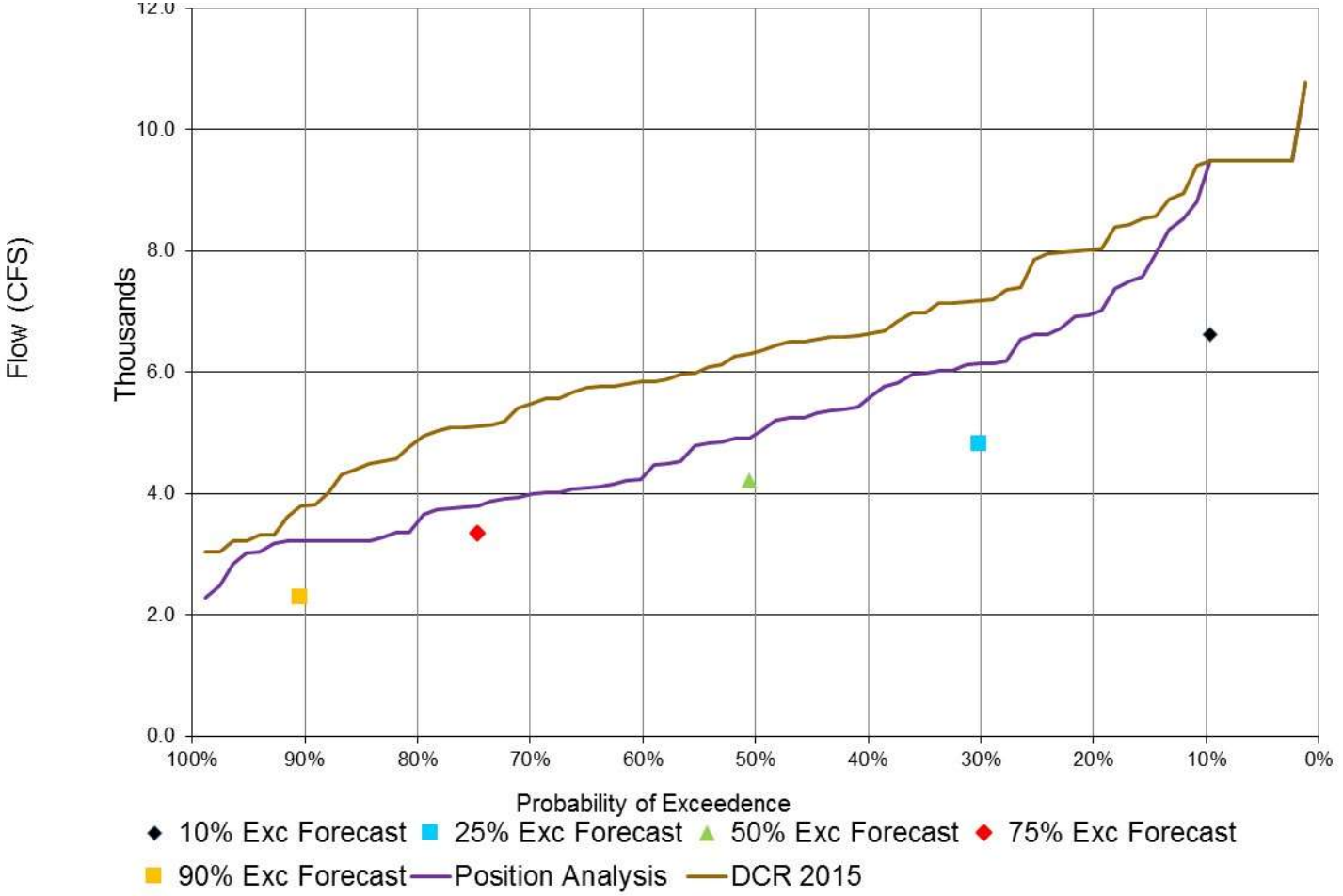
Forecast-Based Modeling for Water Supply Planning

Shasta monthly storage, from forecast-based run conducted in April 2016



Forecast-Based Modeling for Water Supply Planning

CVP South of Delta Deliveries in July, from forecast-based run conducted in December 2015



Summary and Conclusions

- **CalSim 2 model provides multiple methods for analyzing uncertainty in annual water supply planning**
  - Position analysis to simulate range of possible operations from beginning of water year (October)
  - Forecast-based analysis to evaluate changes in operations throughout water year (October – May)

- **Further work to be conducted validating forecast-based CalSim 2 model compared to historical water supply operations**

Questions?

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