Forecast Informed Reservoir Operations Using Ensemble Streamflow Predictions for a Multipurpose Reservoir in Northern California

Delaney, et. al 2020

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Background on FIRO

Forecast Informed Reservoir Operations (FIRO)

- Why? Because operations established with data from 1900-1950's
- Climate change is expected to increase magnitude of extreme precipitation events
- Climate change is expected to reduce snowmelt runoff in the spring
- How to better balance water supply and flood risk?

Study location

- Lake Mendocino, California
- 111,000-acre-foot reservoir
- Headwaters of Russian River
- Multi-purpose reservoir
  - Flood Control
  - Agriculture
  - Resident and municipal
  - Ecological

Key players

Army Corps of Engineers (USACE)

- Flood pool must be empty seasonally
- Ramping rates

NOAA National Weather Service (NWS)

- Maximum down stream flow of 8,000 cfs

California State Water Board

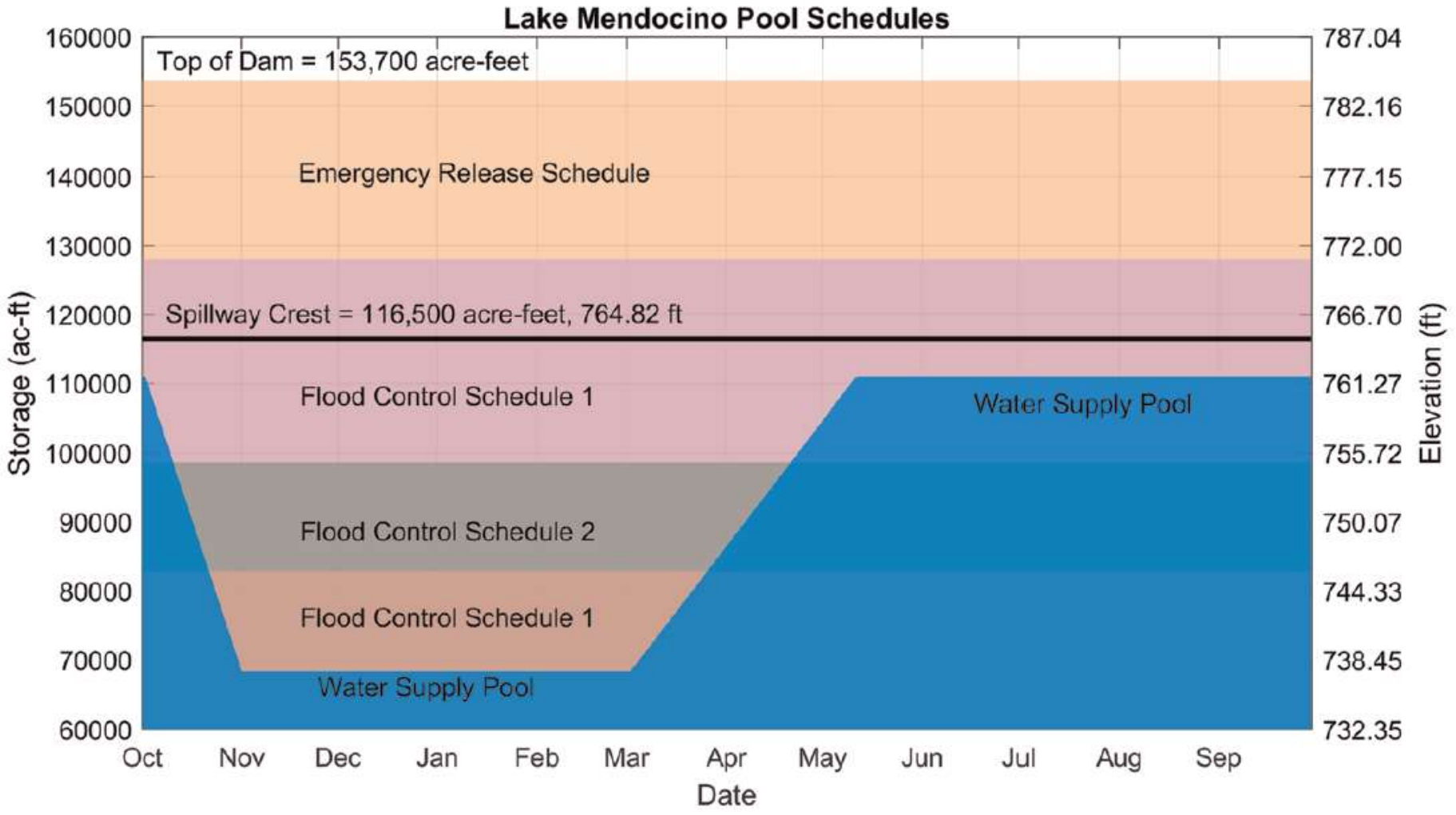
- Water rights allocated to **Sonoma Water**
- Meet down stream demands (ag, residential, municipal) while maintaining minimum flow requirements all year

US Geological Survey (USGS)

- Maintains gages and provides data

Rule Curve

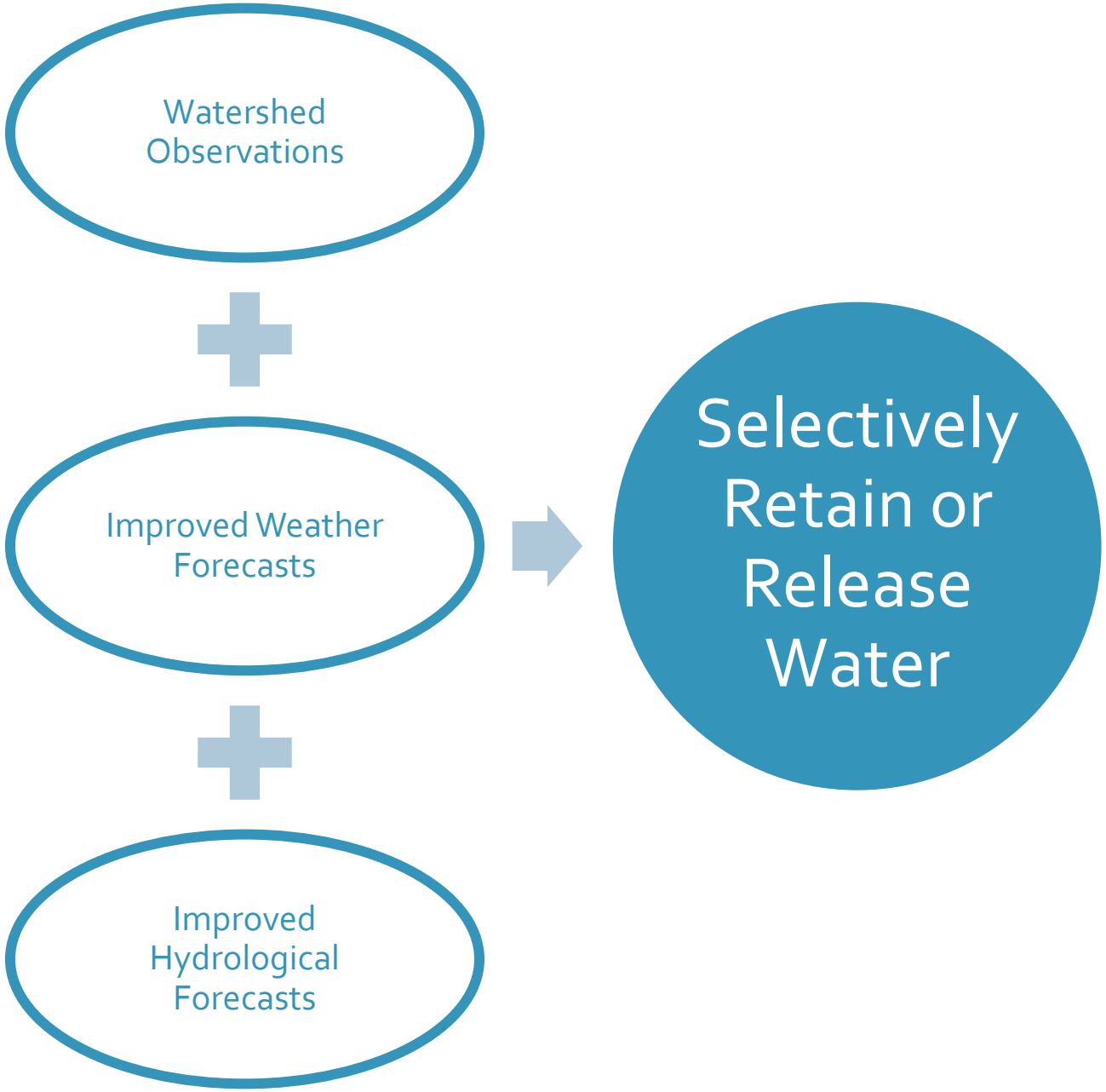
- Must receive significant inflow past March 1 to meet demand
- Dec 2012
  - several storms and water had to be released
  - next 12 months were the driest on record and beginning of multi-year drought



Lake Mendocino FIRO

Steering Committee

- US Army Corps of Engineers
- Sonoma Water
- Scripps Center for Western Weather and Water Extremes
- NOAA
- USGS
- US Bureau of Reclamation
- California Department of Water Resources



Methods

1. **Reservoir System Operational Model**
2. **Data Inputs**
3. **Flood Control Operations Comparison**

Lake Mendocino Model (LMO)

Lake Mendocino storage mass balance:

$$S_T = S_{T-1} - E_T + 1.9835 \times \left(Q_T^{Lm} - L_T^{Lm} - Rel_T^{Flood} - Rel_T^{Emgc} - Rel_T^{WS} - Rel_T^{Spill} \right)$$

(inflow – diversions – flood – emergency – water supply – spillway)

Down stream flow mass balance:

$$Q_T = Q_T^{US} + Q_T^{UI} - L_T$$

upstream + unimpaired – loss

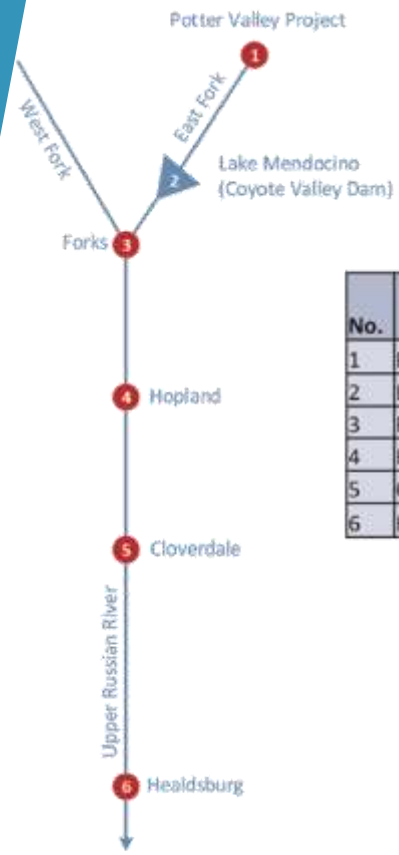
S = storage
E =evaporation
Q = flow
L = loss
Rel = release

Methods

Data Input to the LMO

Ensemble Streamflow Prediction (ESP)
Prepared by the NWS California Nevada River Forecast Center

- Operational since 2012 on Russian River
- Retrospective ensemble (hindcast) forecasts made from 1985-2010
- 61-member flow forecast with 15-day horizon
- Input at 3 junctions: Lake Mendocino, West Fork, and Hopland



No.	Model Junction Name	Junction Type
1	Potter Valley Project	Flow
2	Lake Mendocino	Reservoir
3	Forks	Flow
4	Hopland	Flow
5	Cloverdale	Flow
6	Healdsburg	Flow

Methods

Flood Control Operations Comparison

EO – Existing Operations

- As defined by the water control manual
- Above pool then it must release based on ramping rates and minimizing flooding downstream

PFO – Perfect Forecast Operations

- Designed to simulate perfect forecast skill
- Use observations vs hindcast
- zero risk tolerance

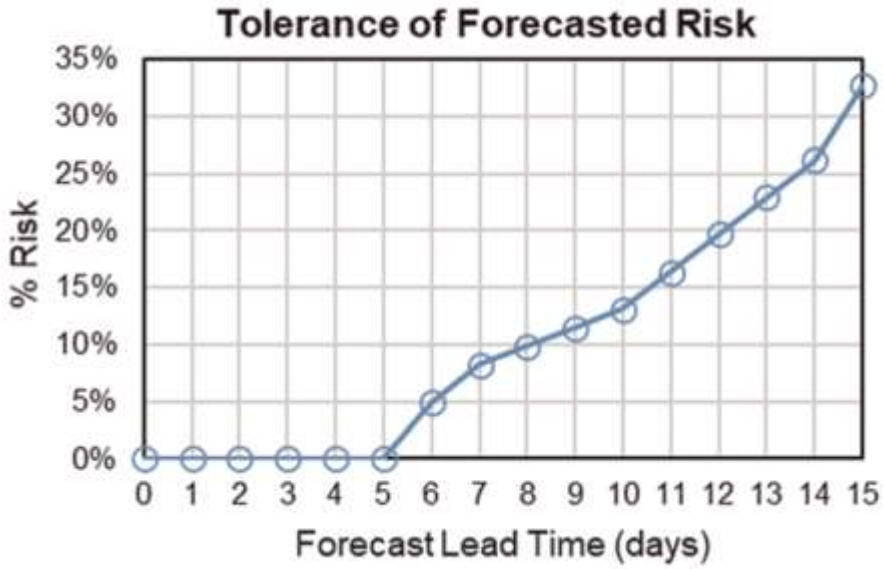
EFO – Ensemble Forecast Operations (proposed approach)

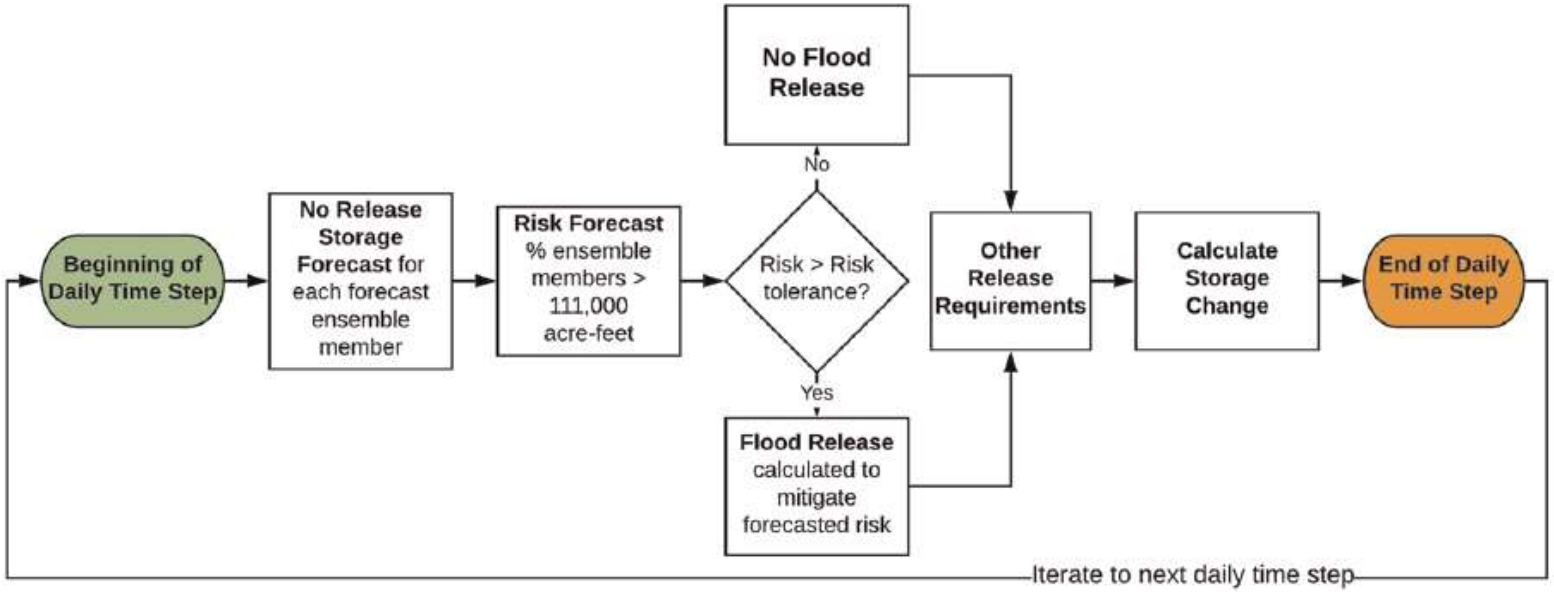
- ESP Forecast from NWS to assess and mitigate risk

Methods

Risk Tolerance

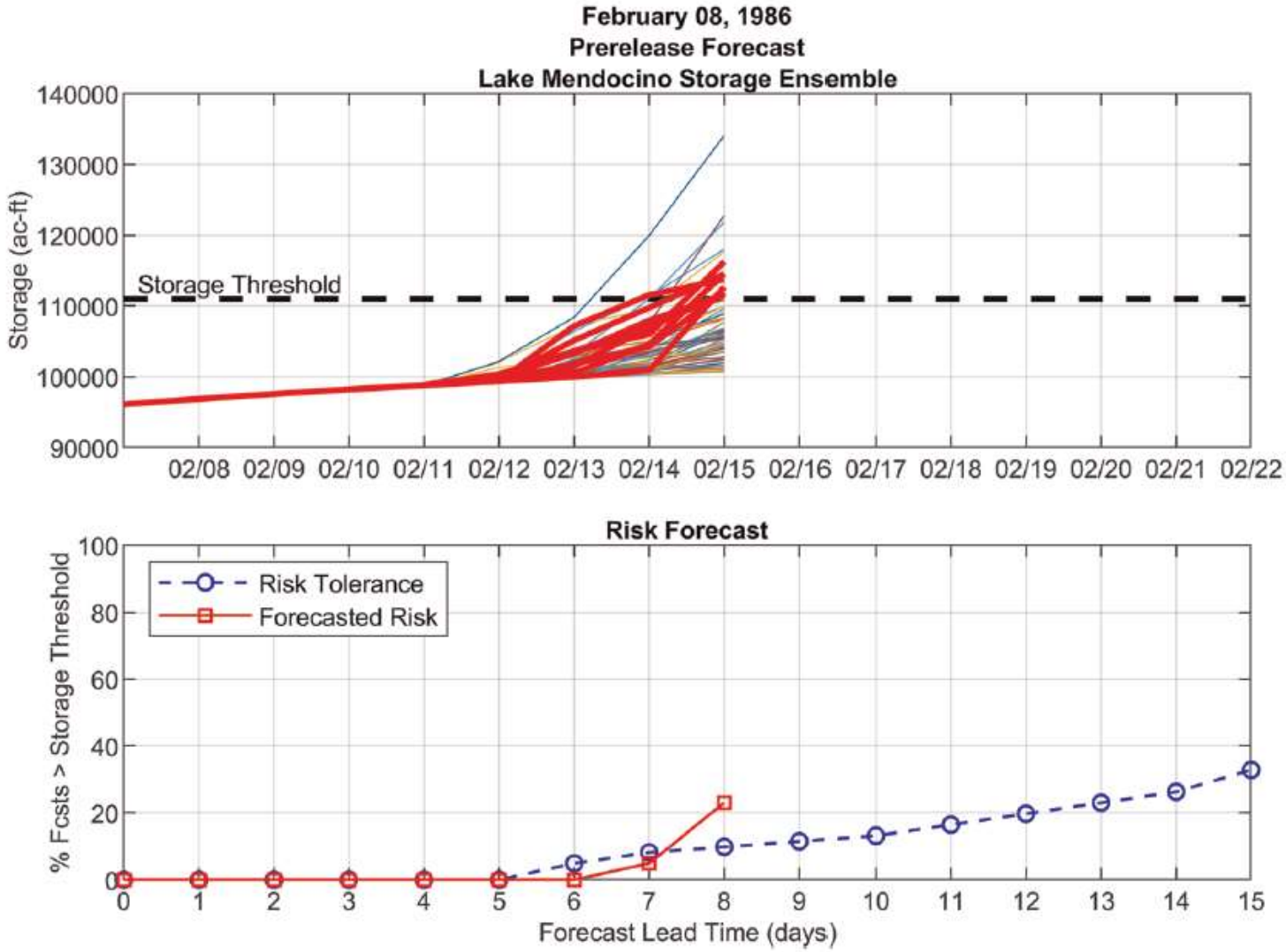
How much risk is acceptable?





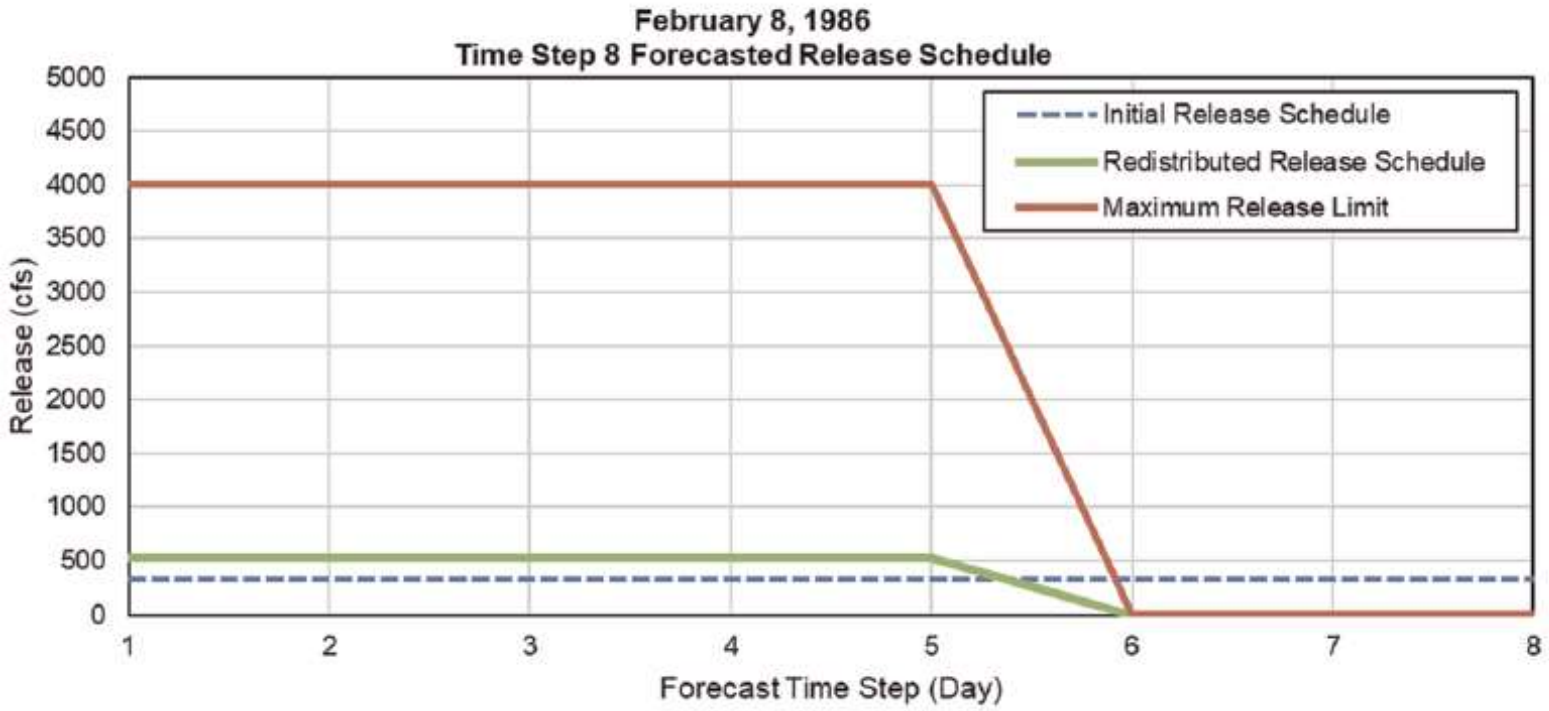
Risky Members

- Top panel shows risky ensemble members for forecast time step 8 highlighted in red
- Forecasted risk vs tolerated risk in bottom panel



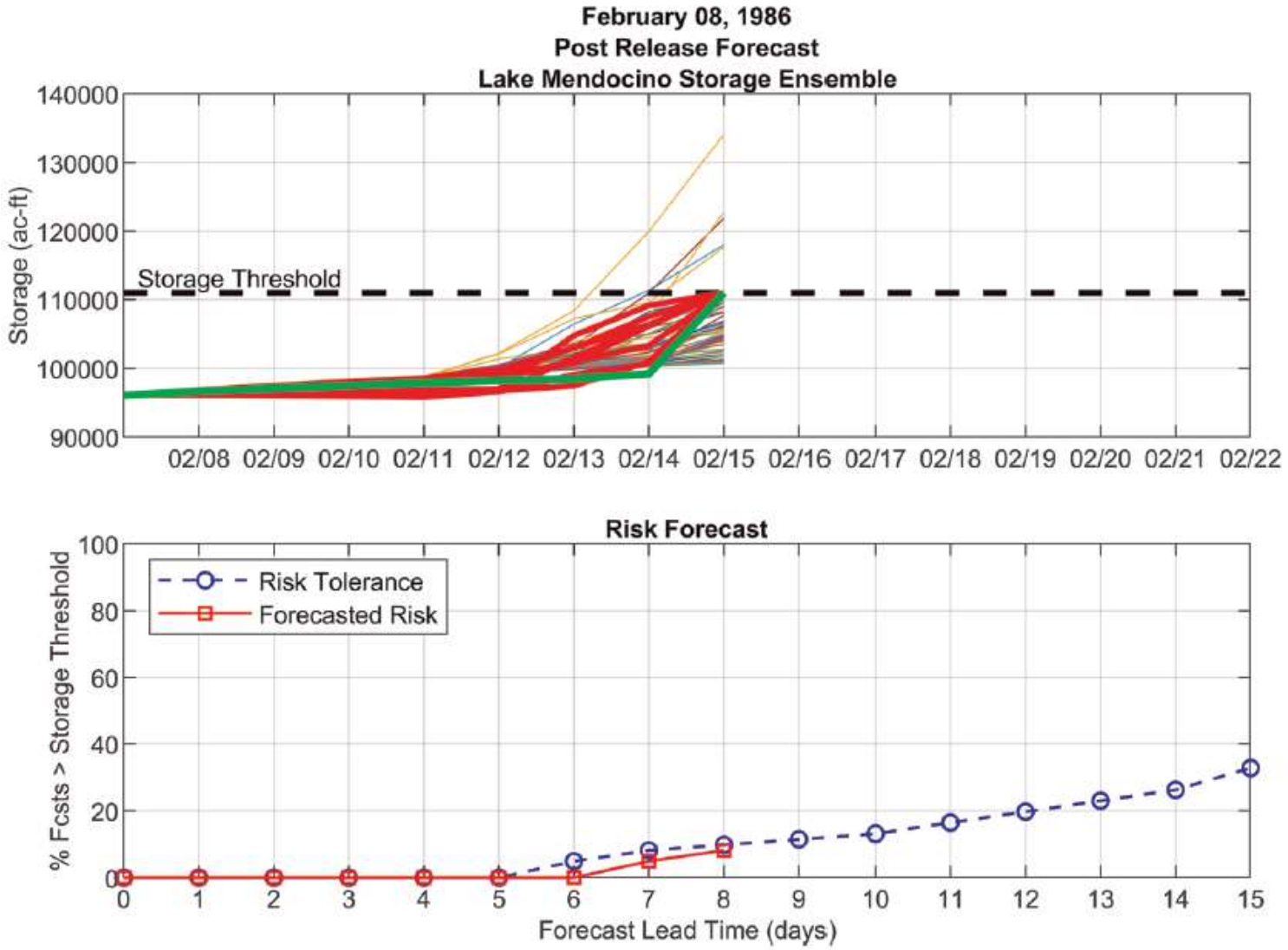
Reduce Risky Member

- Redistribute so that it is below maximum release (days 6-8)
- Redistributed to release days 1 through 5,
  - Release 529 cfs for days 1 through 5 and 0 cfs for days 6 through 8



Tolerated Risk

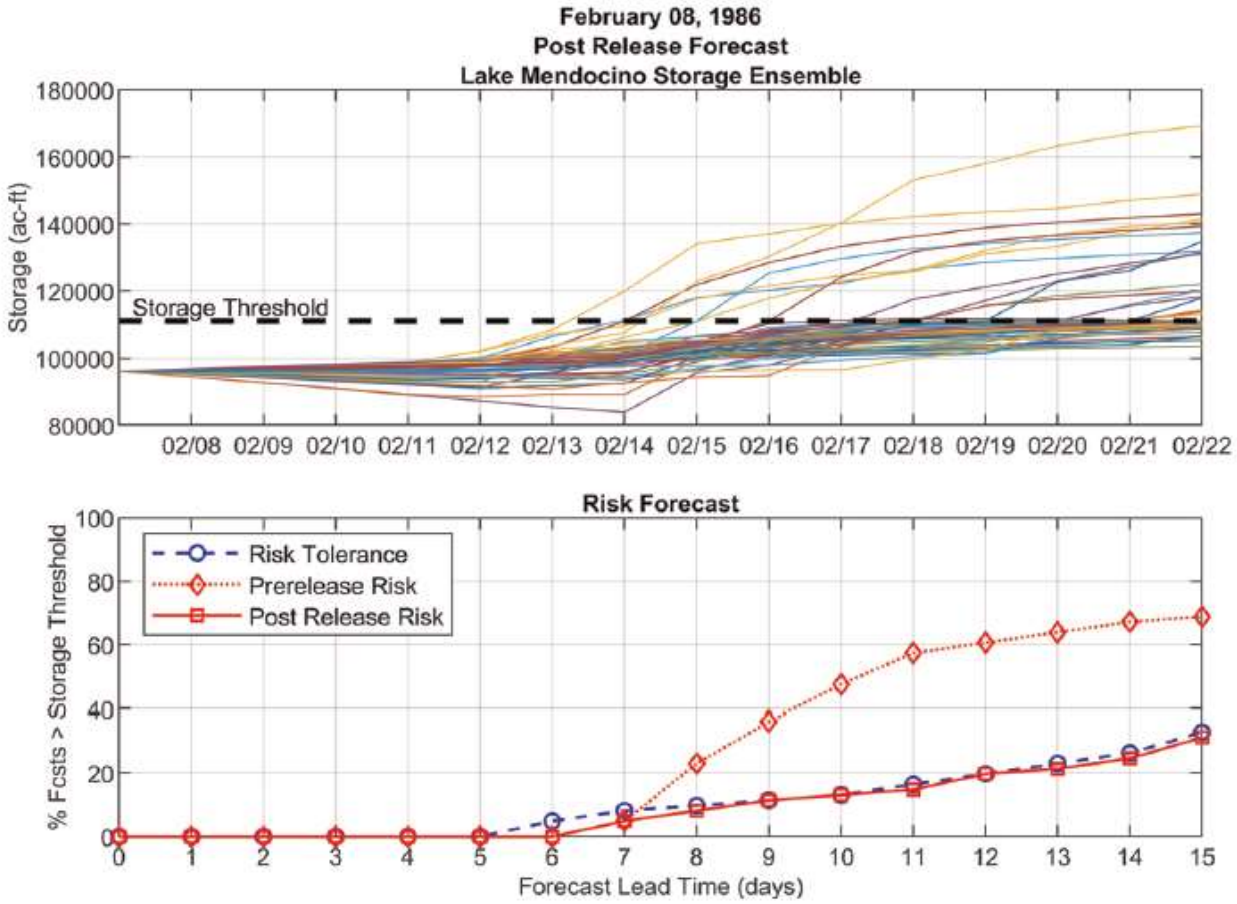
Redistribution of flows (green) reduces risk at an 8-day lead time



Managing Risk

Ensemble forecast used to measure risk

Table on right: scheduled release to reduce risky members



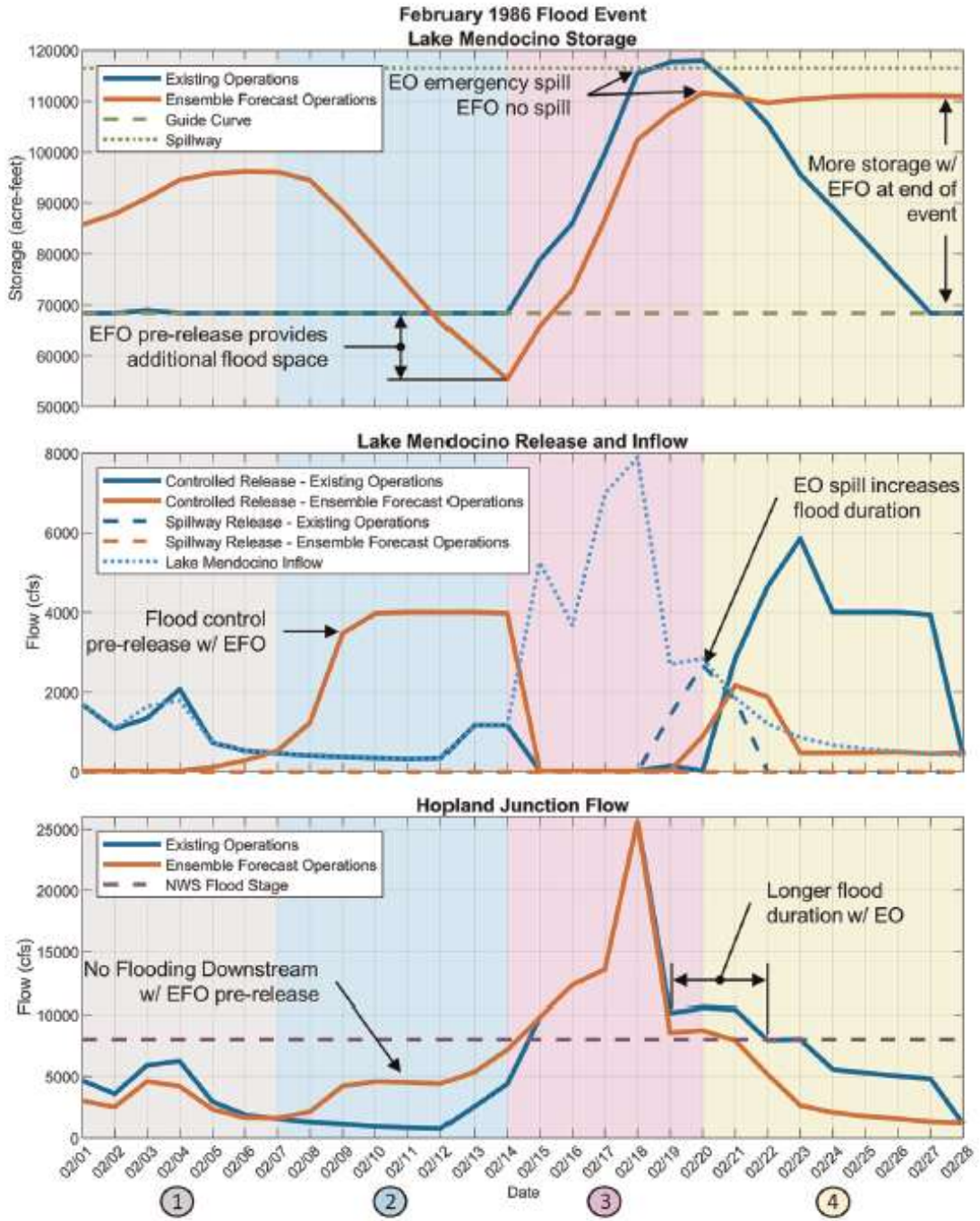
Time Step	Release (cfs)
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	529
9	741
10	882
11	1029
12	1141
13	1172
14	1240
15	1227

Results

Anticipating vs Reacting

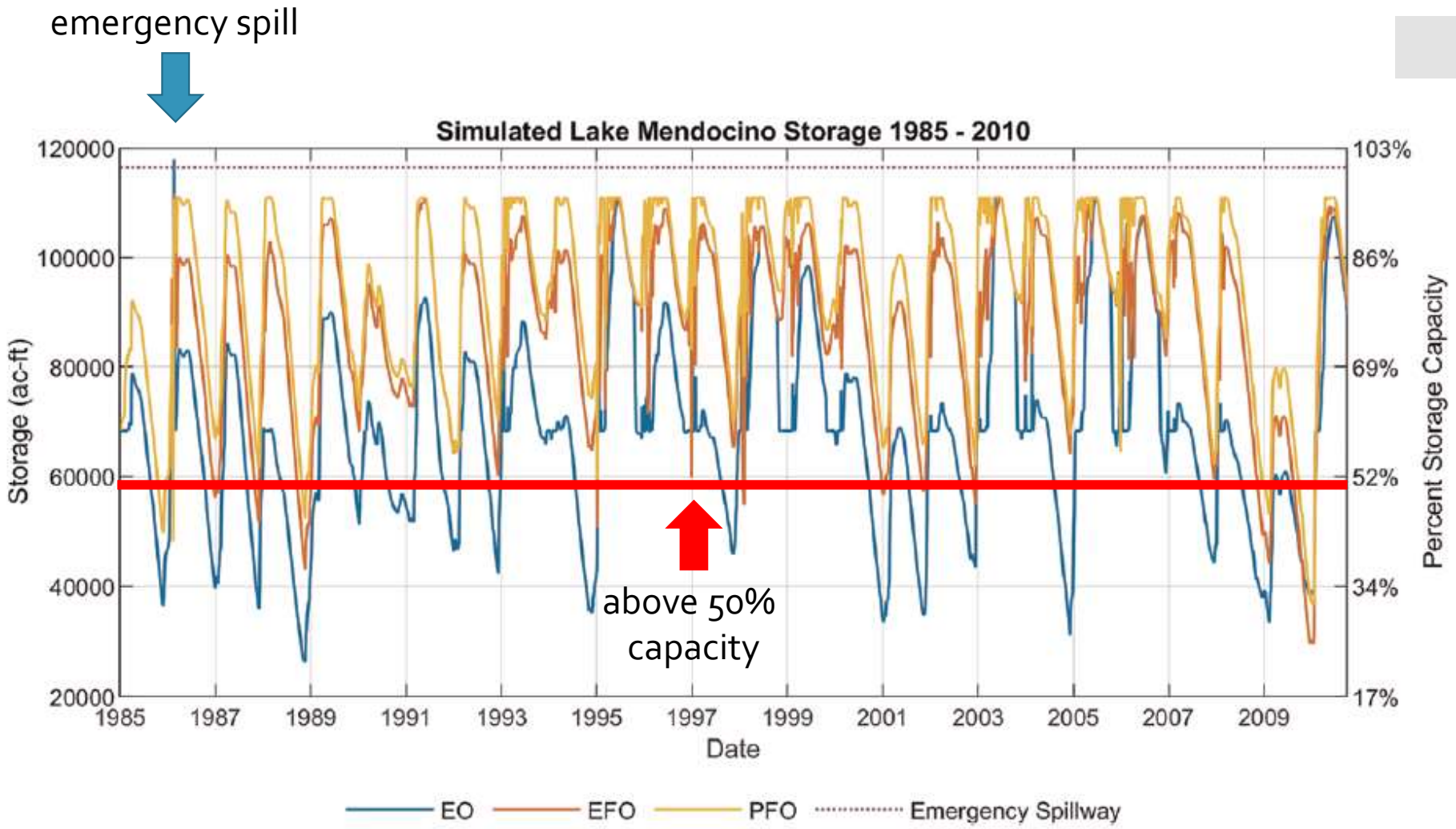
1. Dry Forecast
2. Wet Forecast
3. Flood Event
4. Post Flood

- Existing Operations:
  - 3 days of emergency spill
  - Less stored water
  - Longer flood duration



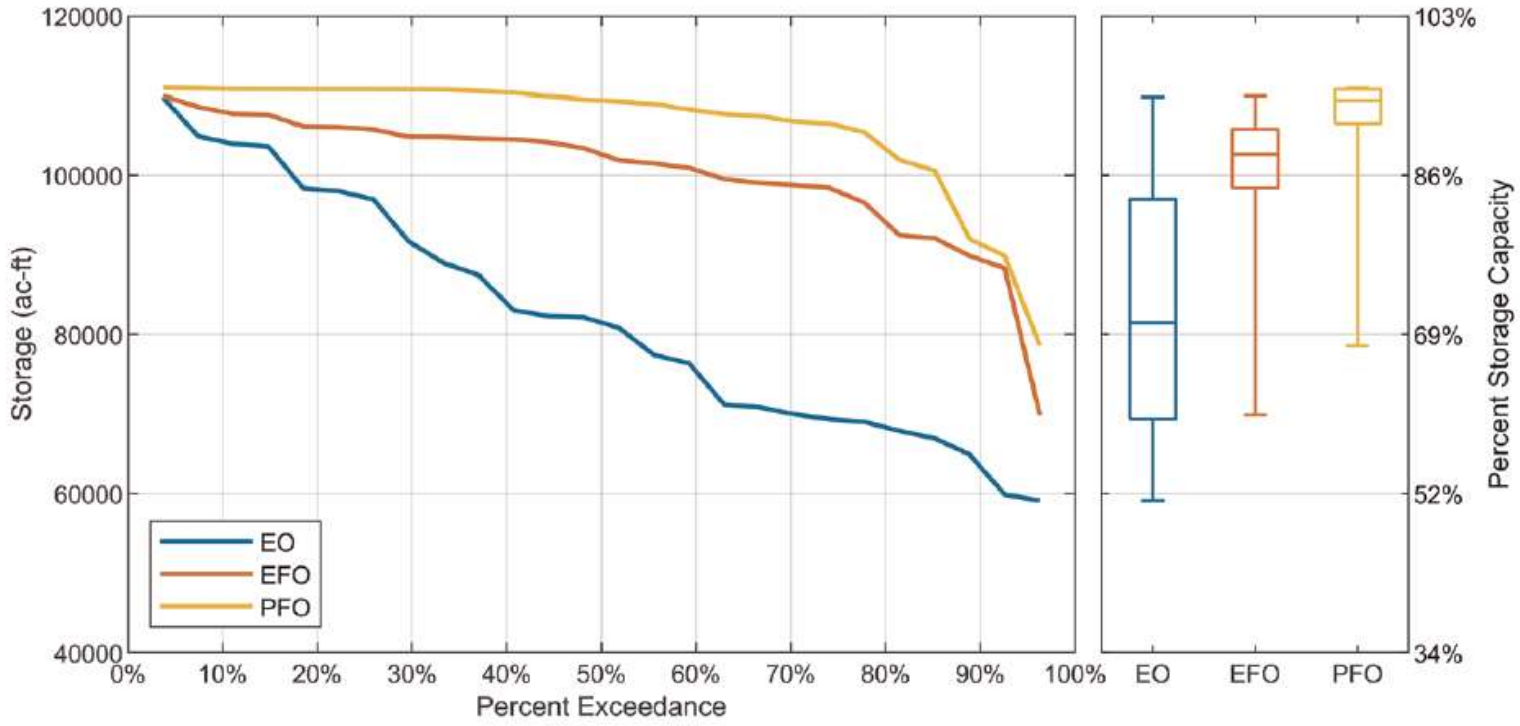
Higher Lows

- Existing operations have lower lows – harder to recover from drought
- Ensemble Forecast is closer to Perfect Forecast
- More water storage



Improved Water Management

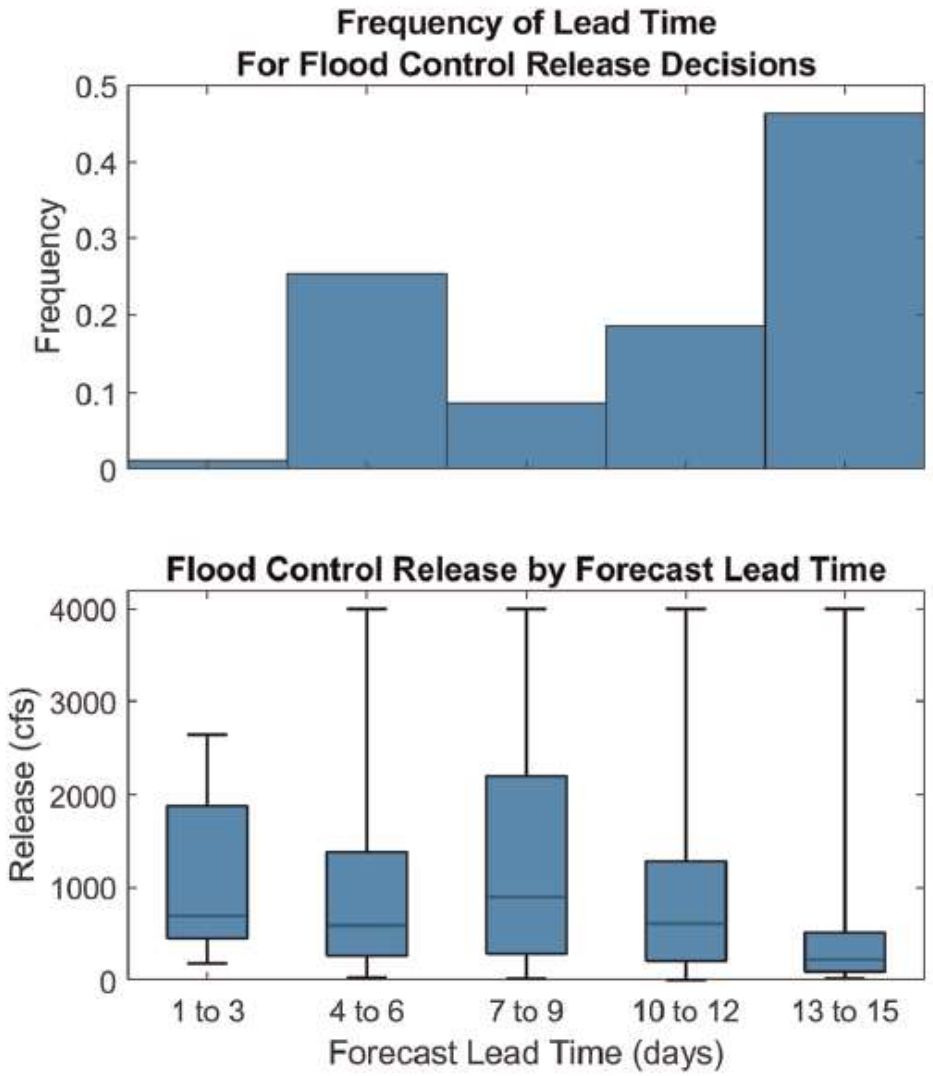
- Anticipated storage on May 1 (end of flood season)
- Inter-quartile range of 27,650, 7,374, and 4,299 (EO, EFO, and PO)
- About 20,000 ac-ft more storage on average



Summary

Hold more water while avoiding increased risk

- Flood control releases decisions made early and scheduled
- 13-15 day: pre-release to reduce risk
- 4-6 day: improved certainties requires adjustment
- Minimal action taken 1-3 days in advance as the system has been anticipating vs reacting



Questions?