

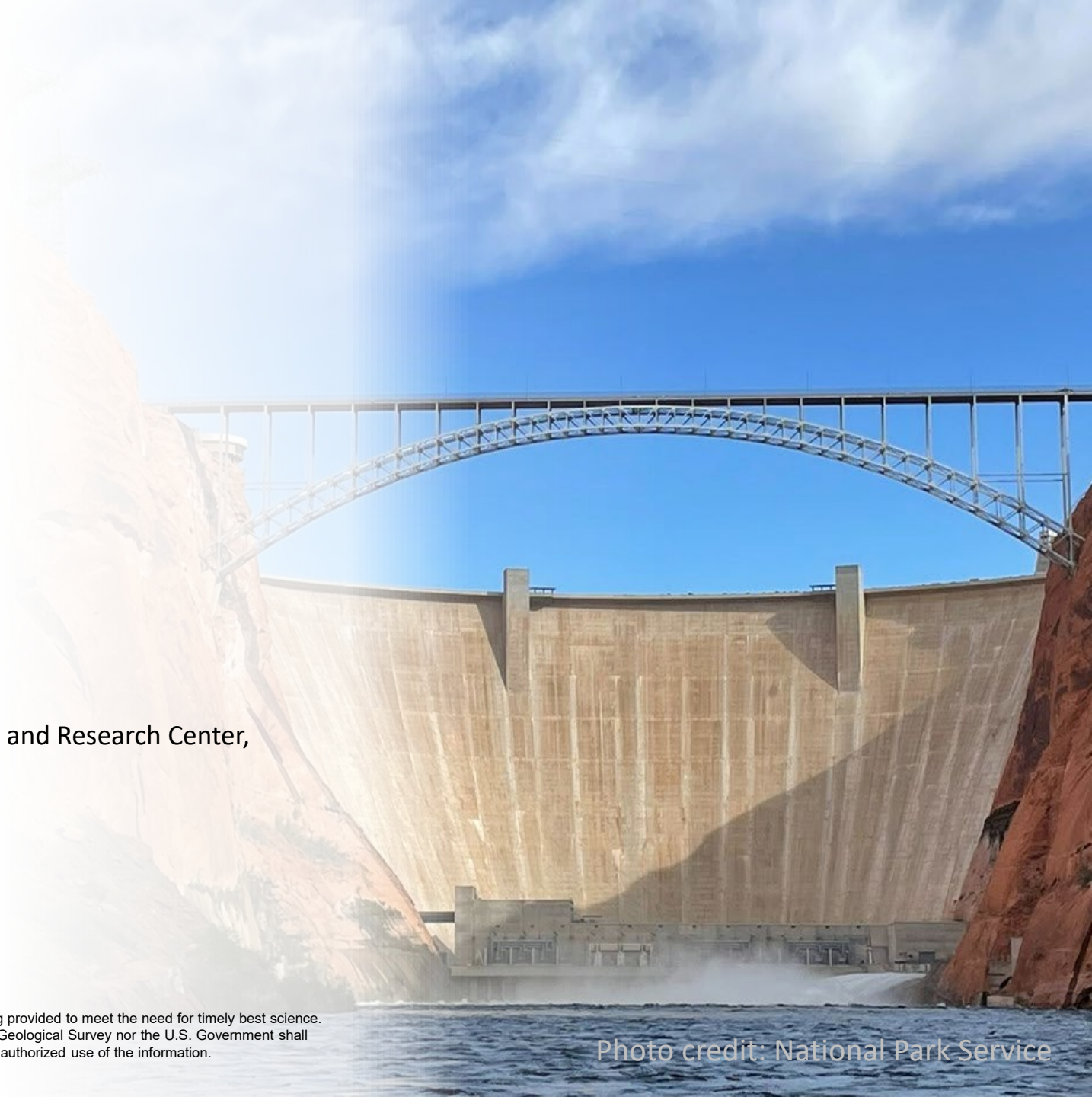


GCMRC Models and Screening Tool

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Predictive models for adaptive management

- Problem: Balancing dam operations between hydropower and humpback chub goals.
- Objective: Maintain a viable population of a humpback chub at the lowest cost.
- Trade-off: Ensure humpback chub viability while accounting for lost hydropower value from experimental management flows.

Example 1: Bioeconomic model

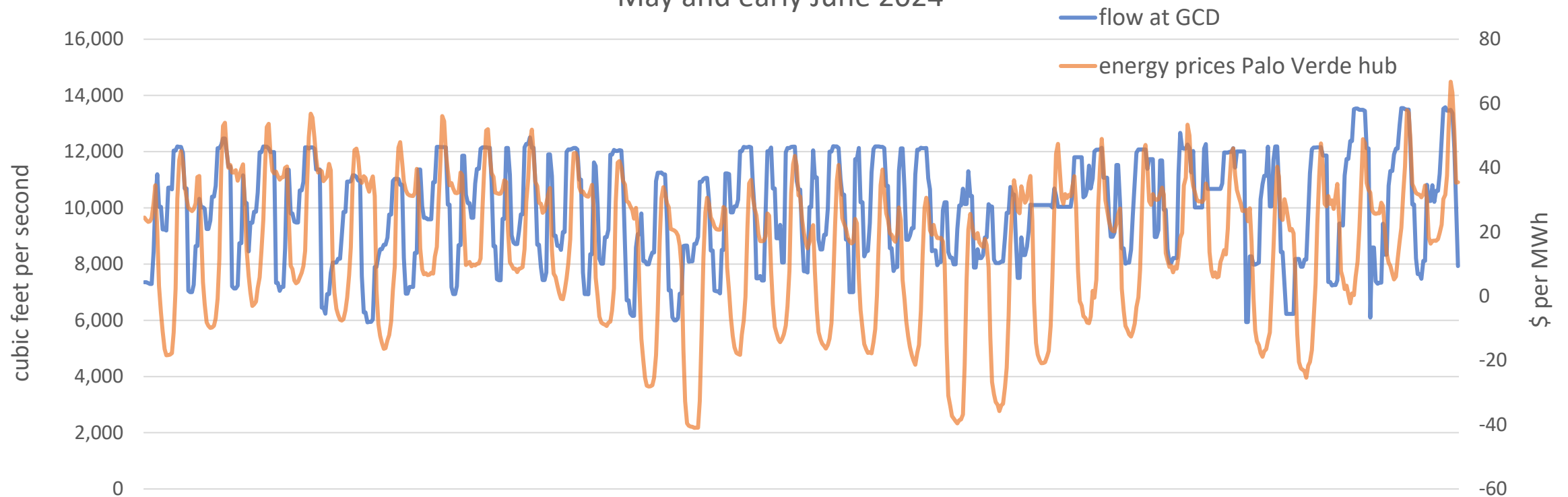
- Population Dynamics: Focus on rainbow (brown) trout and humpback chub.
- Management Actions:
 - Trout Management Flows
 - Mechanical Removal
- Objective function: Implement cost-effective strategies to reduce trout competition and predation on juvenile chub that maintain a viable adult chub population within a defined time horizon and confidence level.

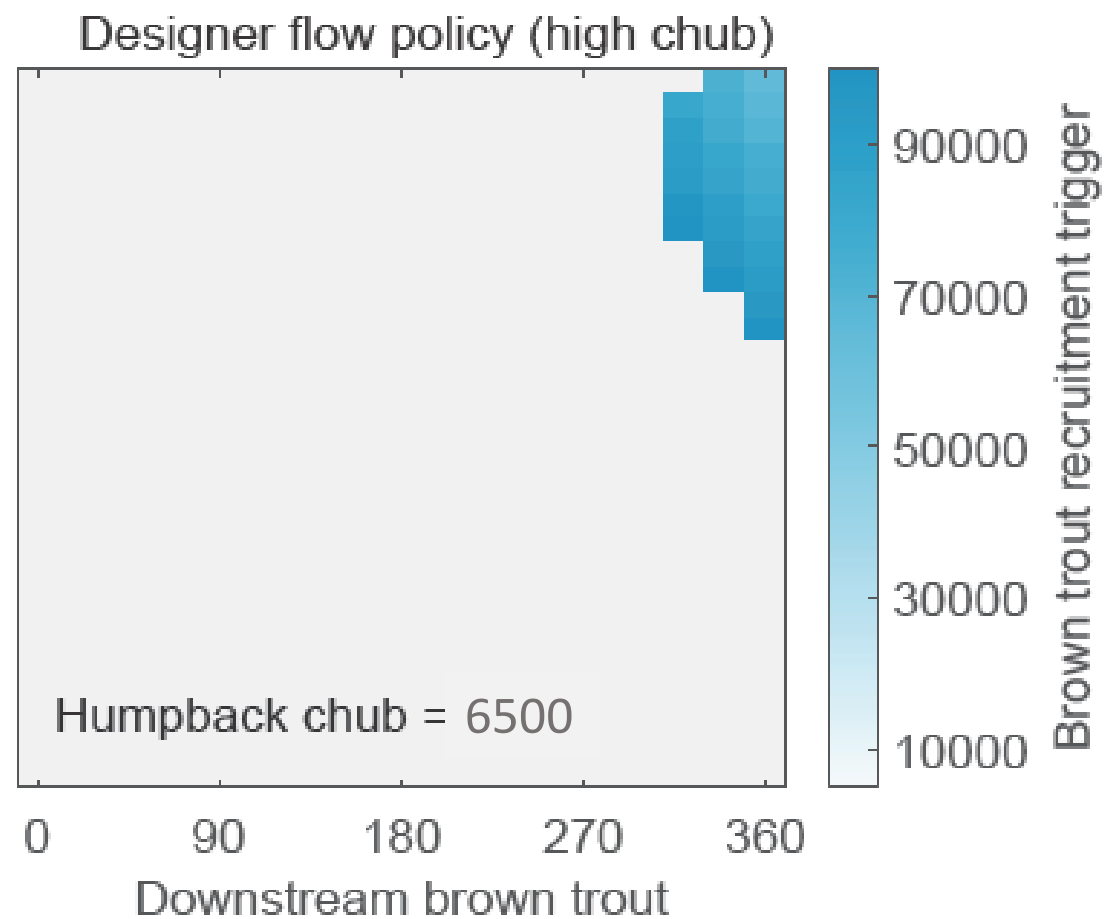
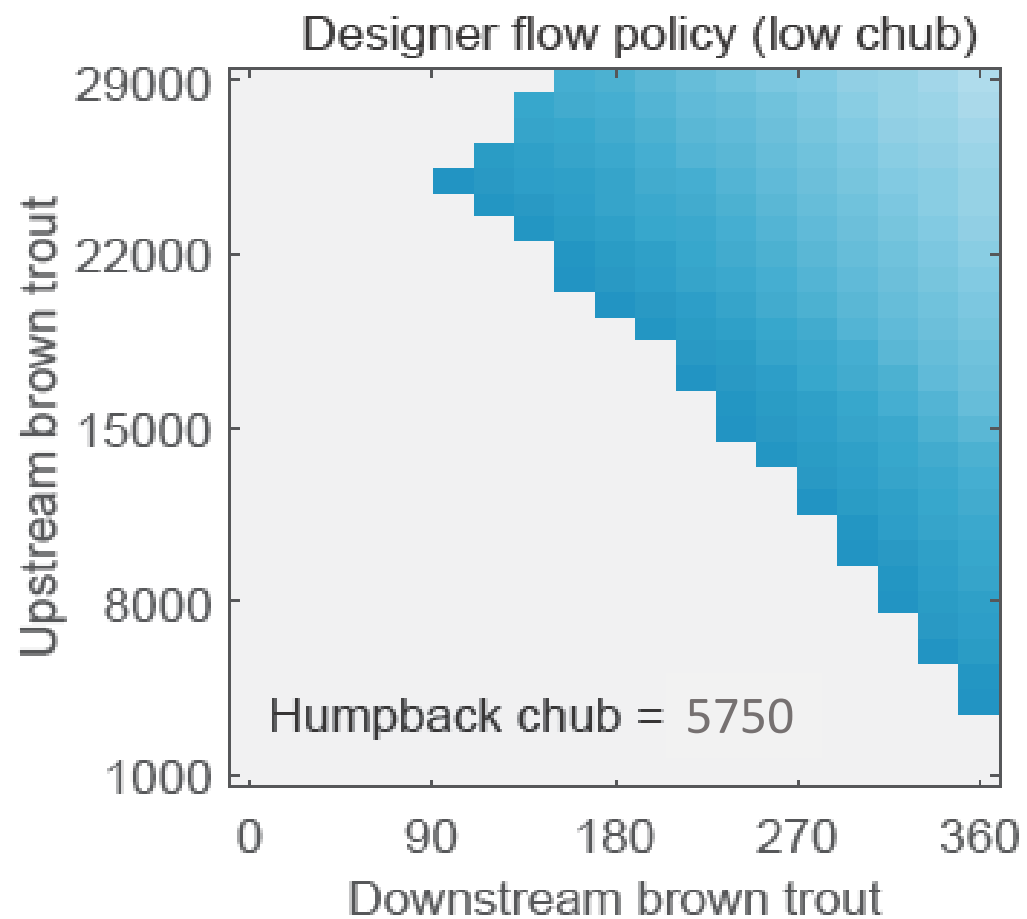


<https://www.flyfisherman.com/editorial/all-about-brown-trout/454242>

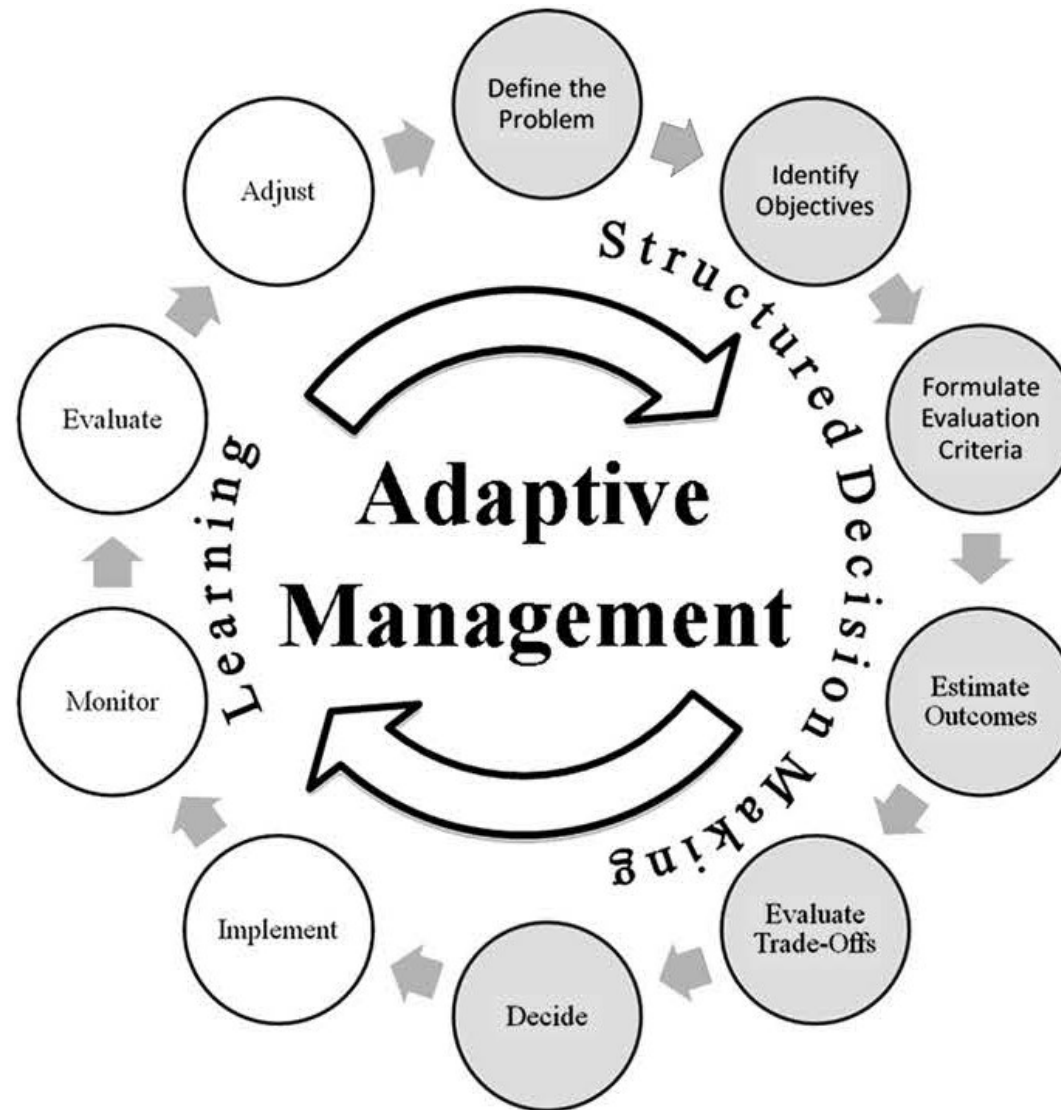
Energy Generation at Glen Canyon Dam

May and early June 2024





Adaptive Management

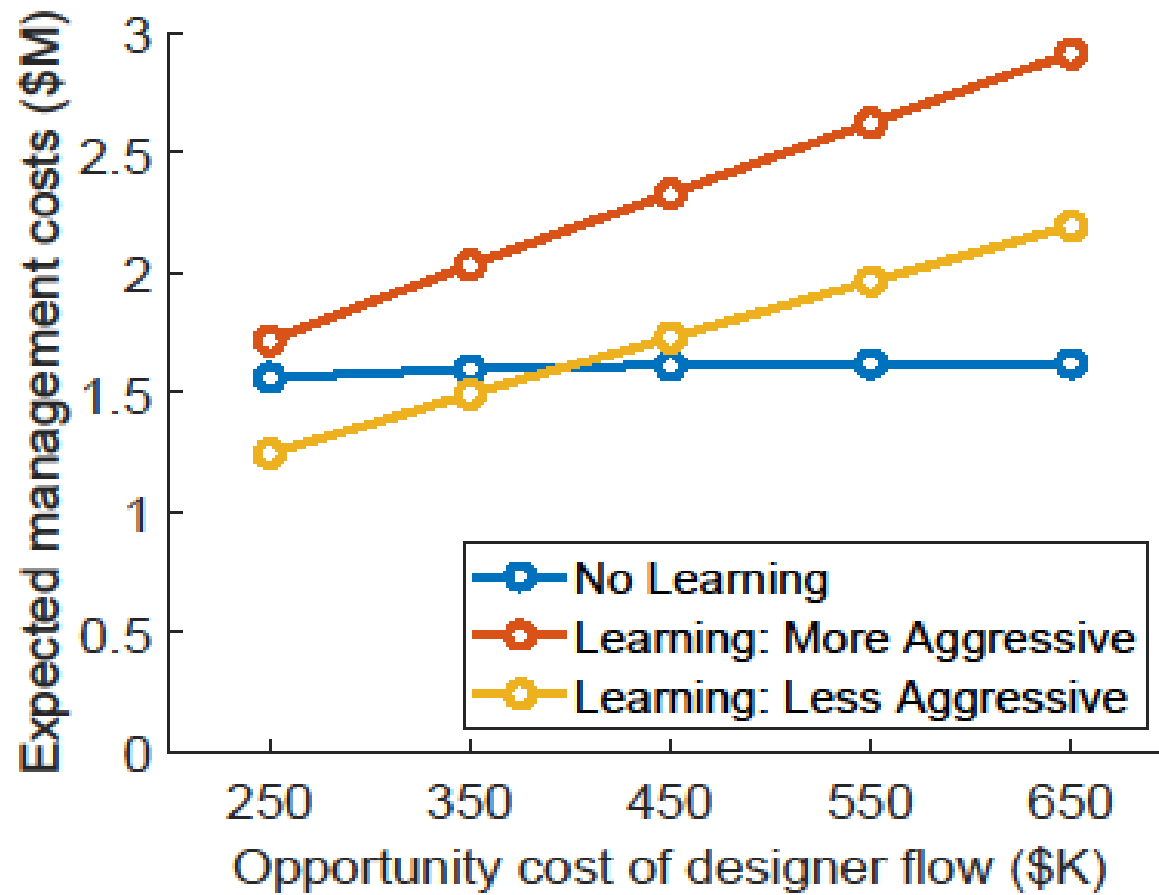


Value of Information

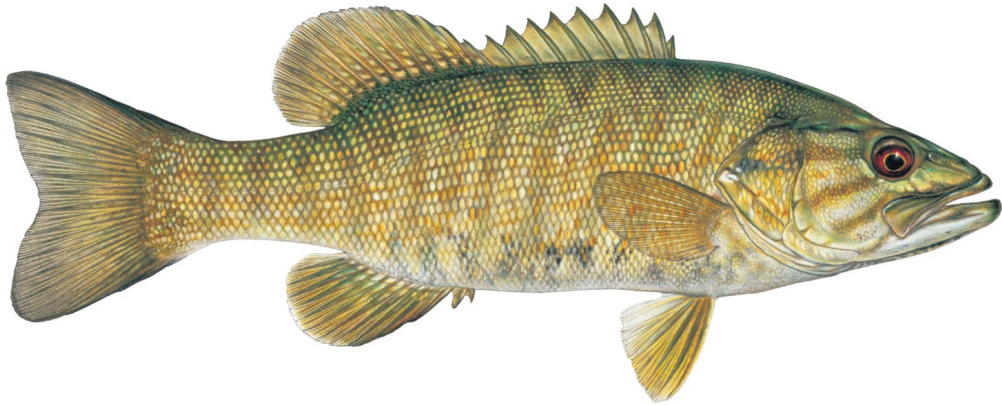
- In adaptive management, value of information (VOI) refers to the benefit derived from reducing uncertainty through learning and using that information to make better decisions over time.
- VOI quantifies how obtaining additional information can improve decision-making outcomes by enhancing the effectiveness and efficiency of management actions.



Adaptive Management



Example 2: Flow Screening Tool



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USGS GCMRC

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Glen Canyon Dam Adaptive Management Program



— BUREAU OF —
RECLAMATION



Western Area
Power Administration

Overview:

Hydrology:

30 traces, April 2025 CRMMS

Most, Min, Max probable, May 2025 24-month study

Alternatives:

No Action

Cool Mix: full temperature period, Oct 20, Oct 1, Sept 15

Non-bypass: full temperature period, Oct 20, Oct 1, Sept 15

Target locations:

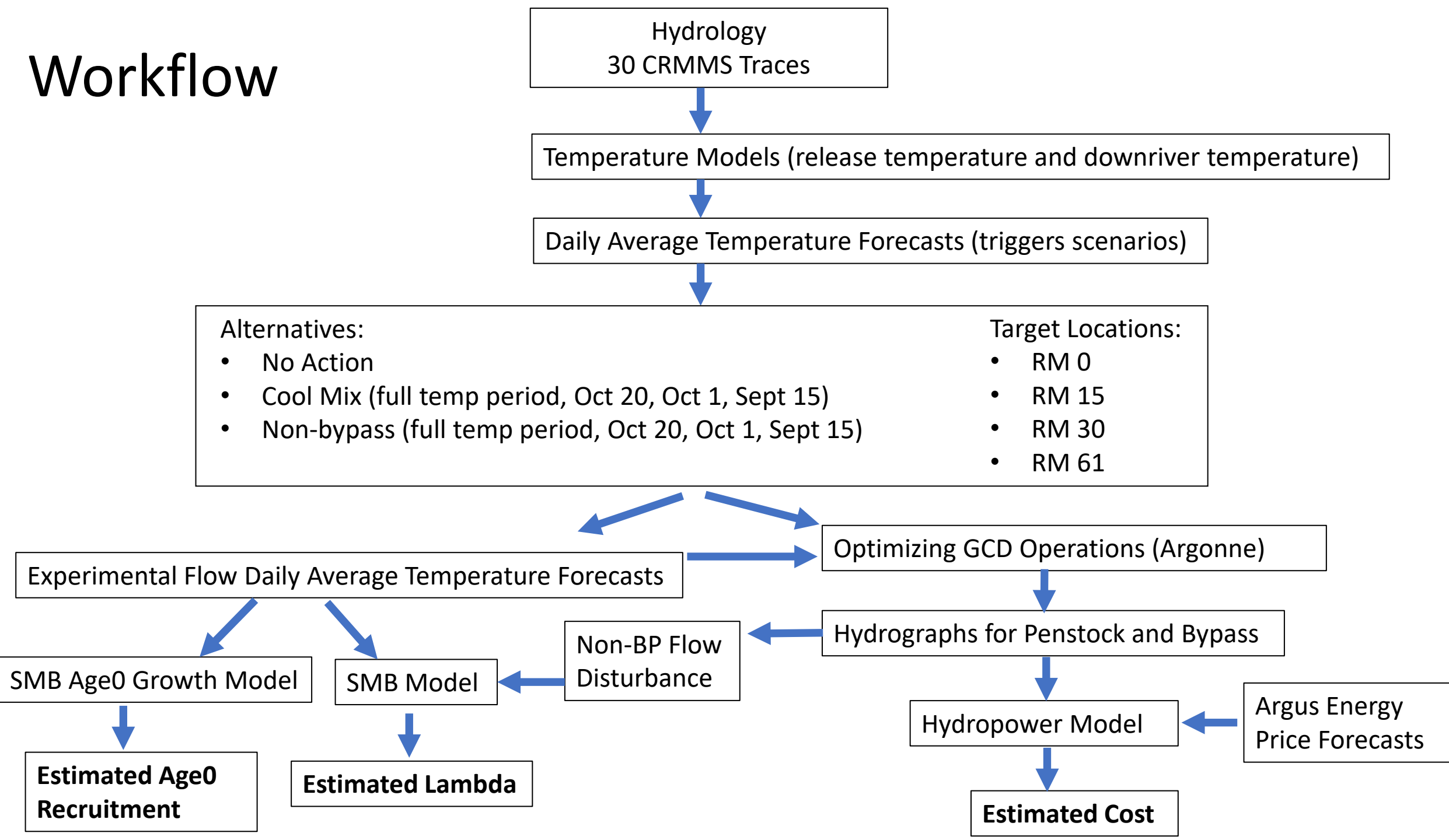
RM 0 (Lees Ferry)

RM 15

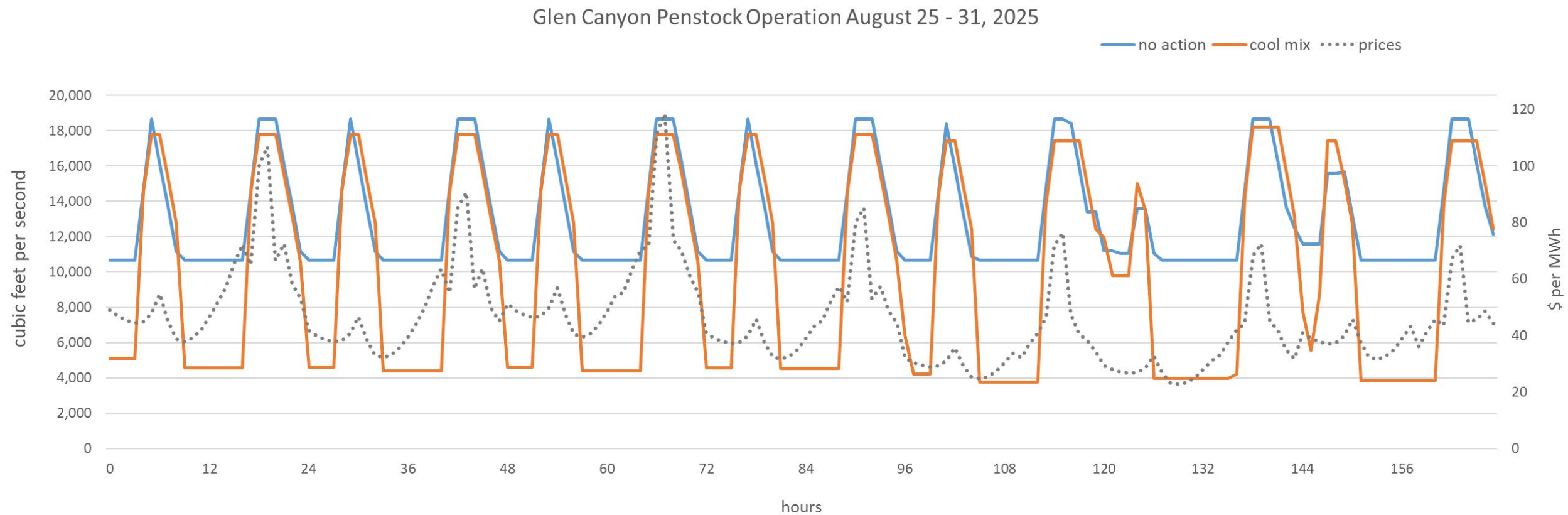
RM 30

RM 61 (LCR confluence)

Workflow



Optimization of Glen Canyon Dam Operations



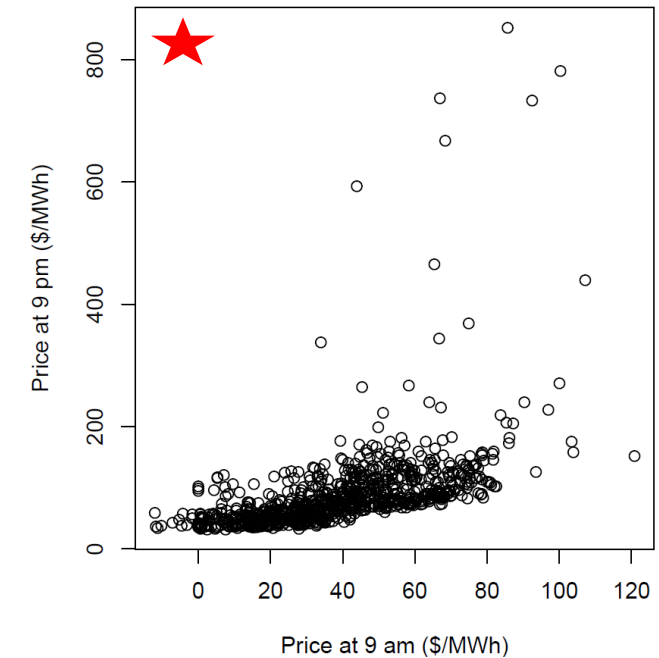
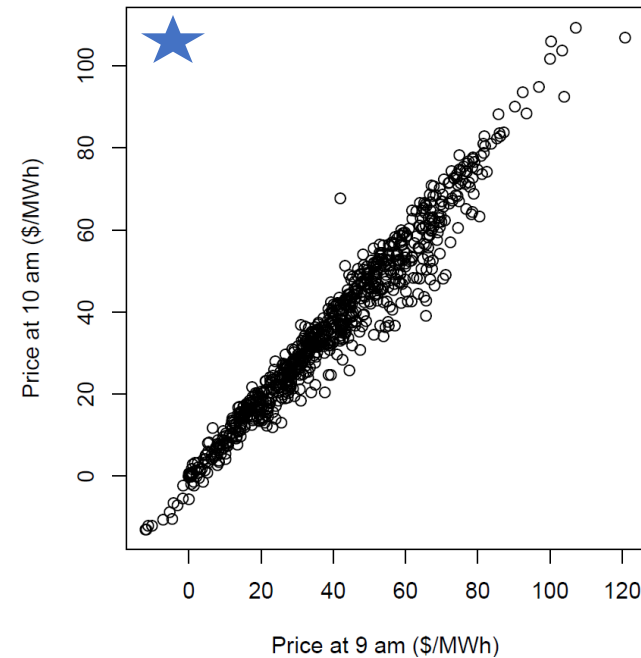
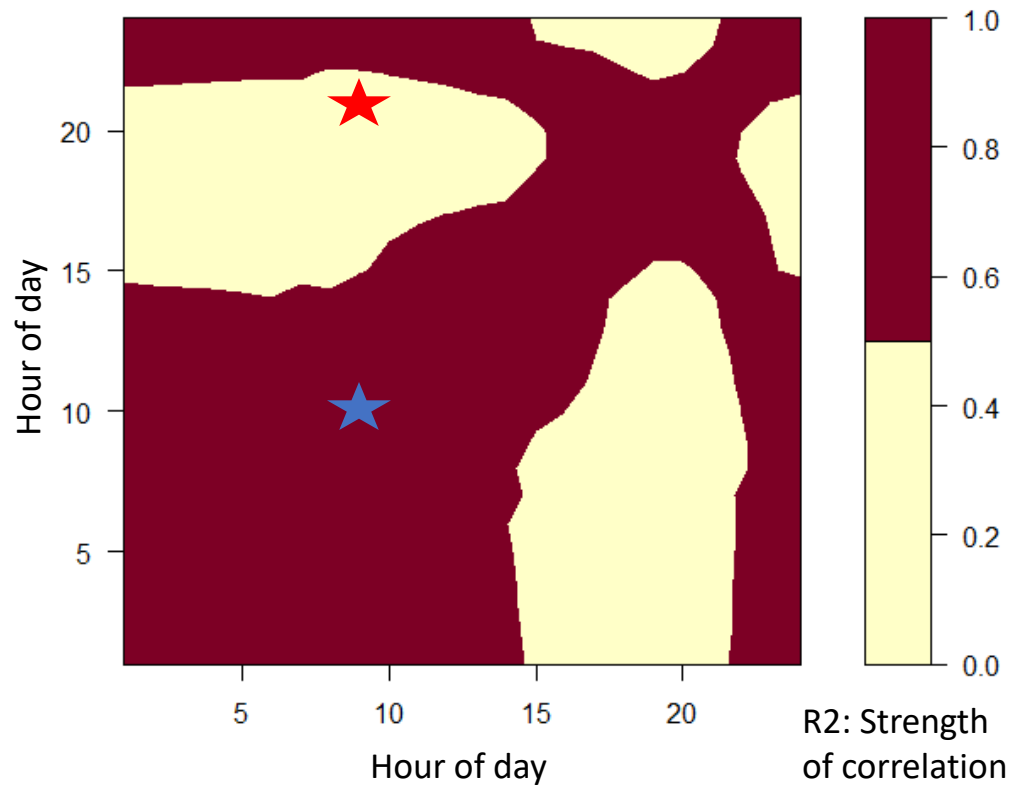
- For cool mix, optimization prioritized bypass use during low-price hours to keep daily average water temperatures below 15.5°C and was only applied during the period when temperature management was triggered.
- Non-bypass followed the LTEMP sEIS operational rules, low flows late on Sunday evening (2,400 cfs) followed by high flows early Monday (penstock capacity) during weeks when temperature management was triggered.
- Outside of when temperature management was triggered, standard operations were assumed.

Preliminary data, subject to change

Some considerations when forecasting energy prices

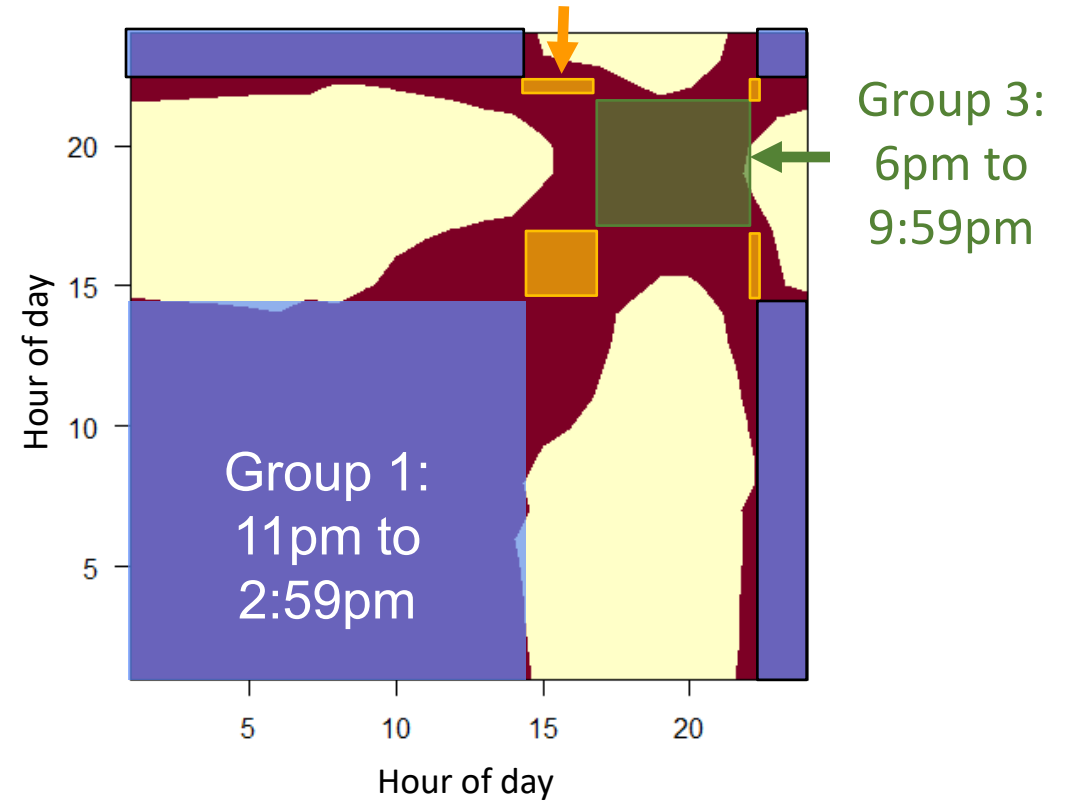
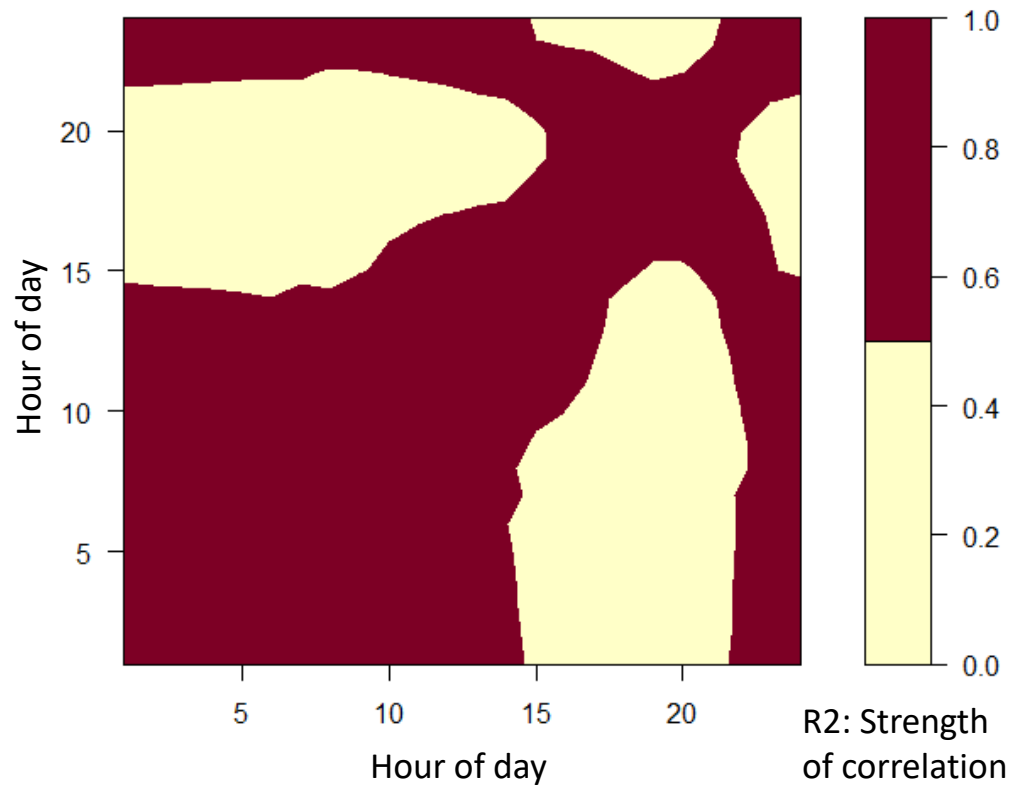
- Forward curves are of moderate accuracy (and sometimes include a risk premium).
- Average prices vary by hour and season.
- Errors within days and across days are highly correlated.
- There are periods of price volatility and volatility effects some hours more than others.
- Causes of volatility likely to be correlated with causes of increased river warming.

Correlations in hourly prices at Palo Verde across May to November from 2020 to 2023

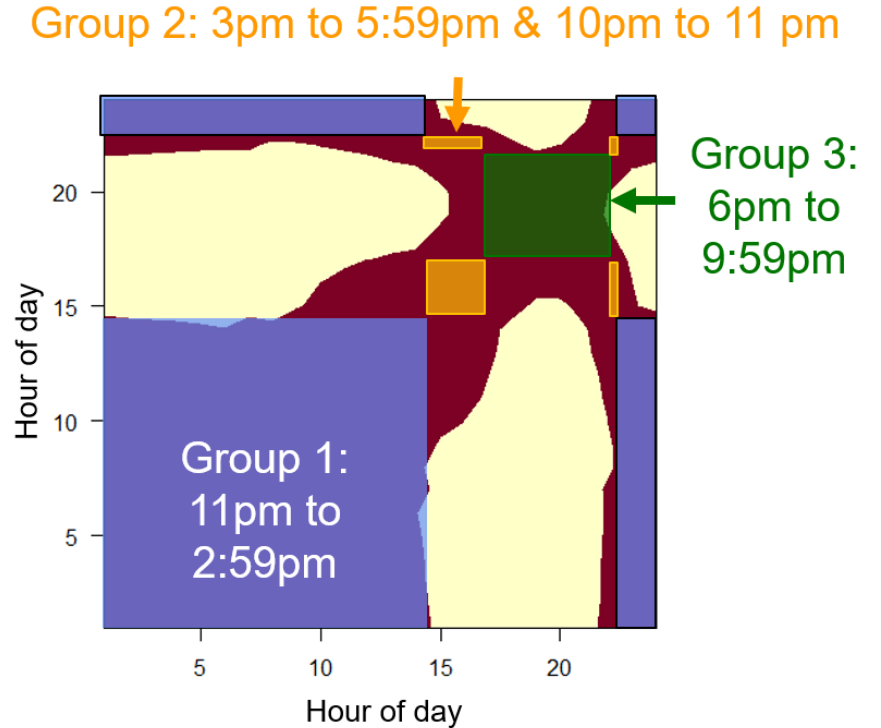
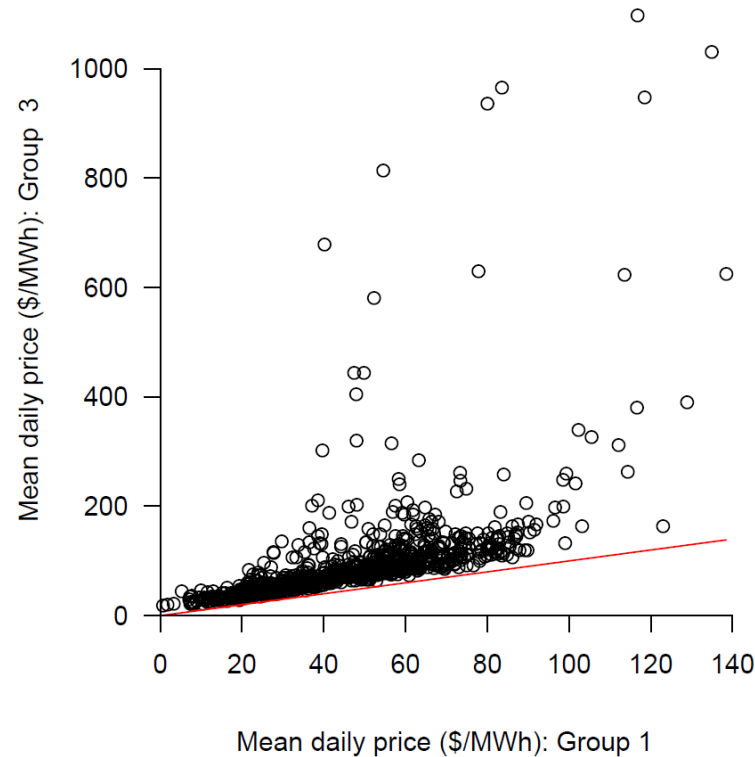
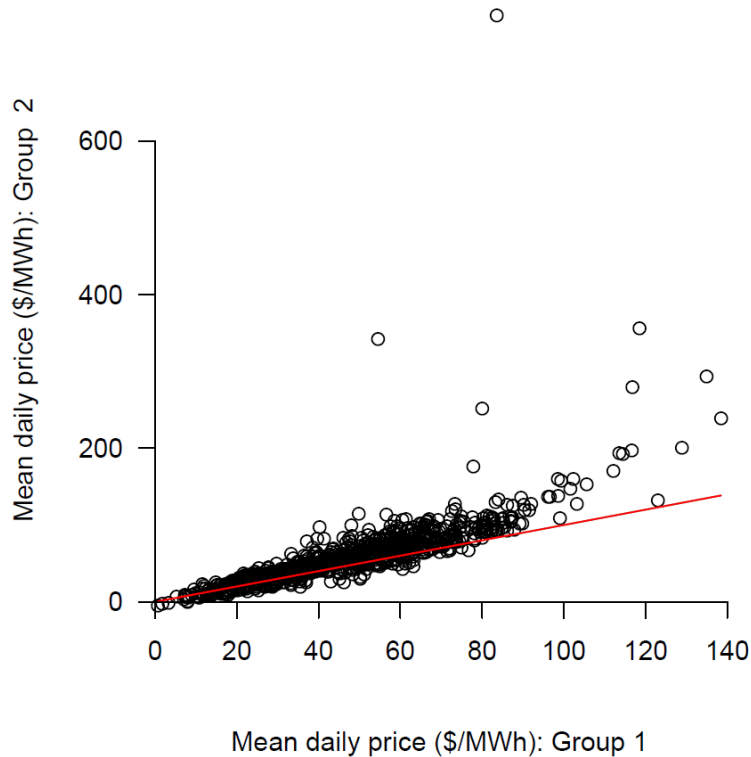


Step 1: Group hours that are highly correlated with each other

Group 2: 3pm to 5:59pm & 10pm to 11 pm

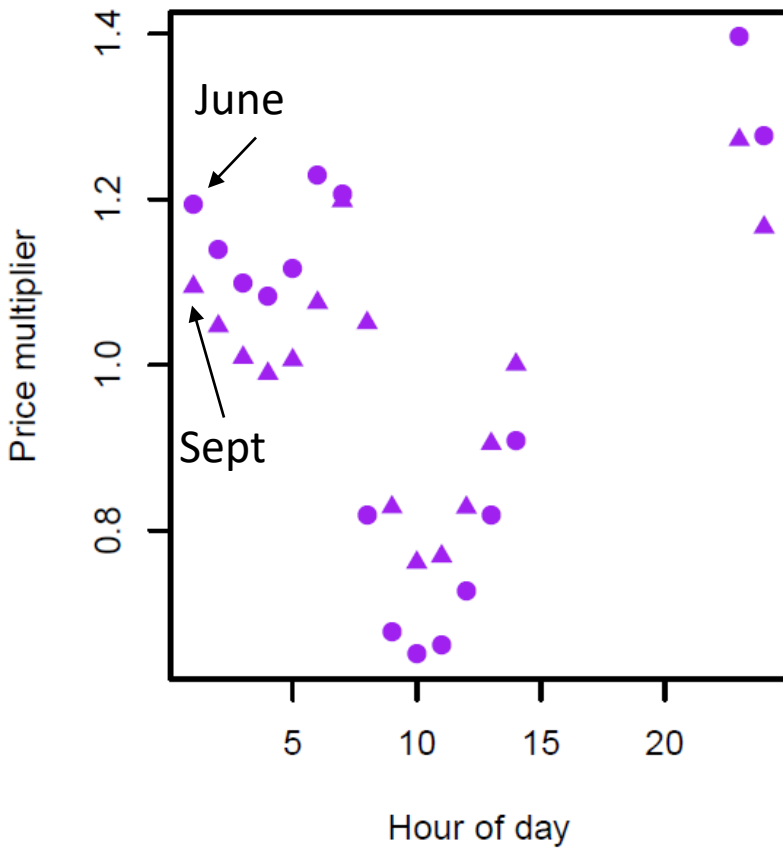


Correlation among group daily mean prices

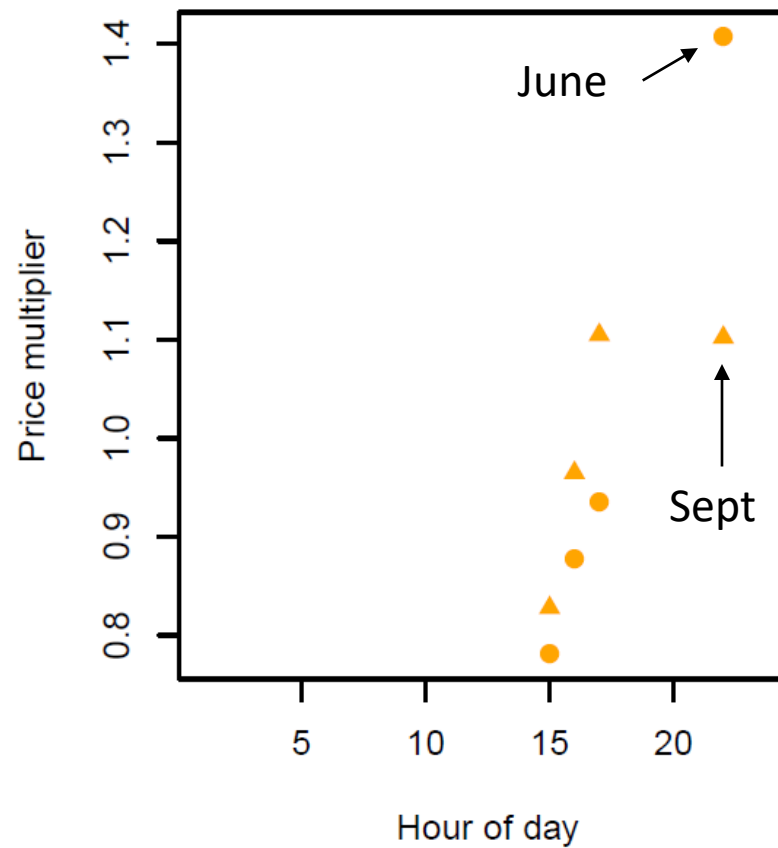


Step 2: Determine relationship between hourly means for each month and Group means

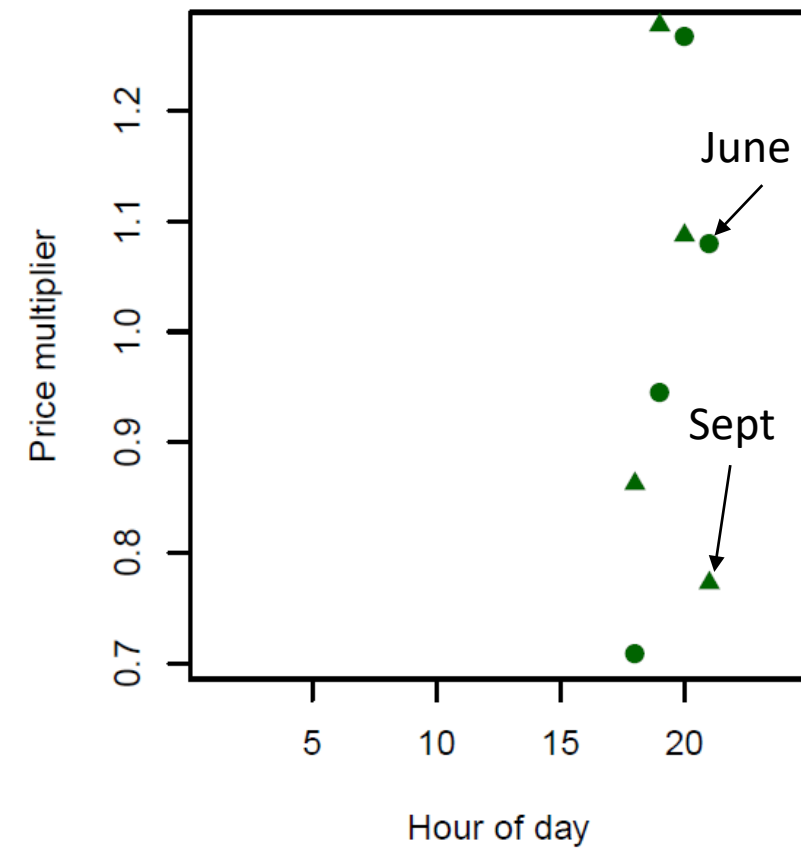
Group 1



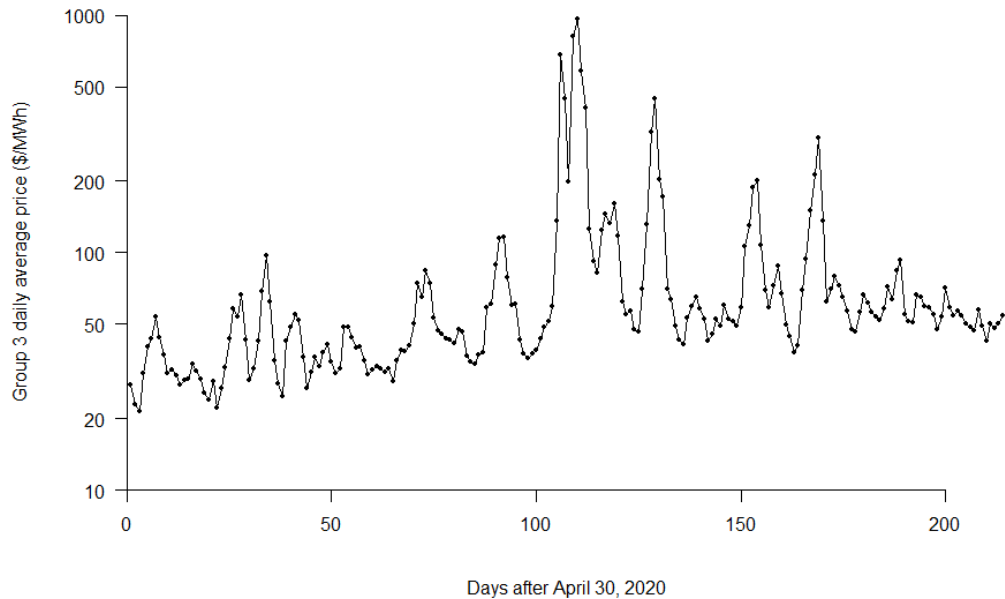
Group 2



Group 3



Specify a model that accounts for observation that variation in prices is nonnormally distributed and autocorrelated



- Suggests need to use GARCH class of models which are common in financial market modeling.
- Our approach includes some elements of GARCH, but is modified to include covariates and to include two discrete states (i.e., baseline and volatile periods).

Generalized Autoregressive Conditional Heteroskedasticity (GARCH)

[ˈje-nə-rə-,lɪzd ˈo-(l)tō-ri-ˈgre-siv kən-ˈdɪʃ-nəl ˈhe-tə-,rō-ˈske-,də-ˈsti-sə-tē]

An approach to estimating the volatility of financial markets.

Investopedia

Step 3: Fit the model

- Price associated with a given state, s , (i.e., baseline or volatile), group, g , (i.e., groups 1-3), and day d are predicted based on the Argus of-peak forward curve(OP) for that month, m , whether it is weekday or weekend (W_d) and a normally distributed random effect for each month (η_m).
- $P_{s,g,d} = \alpha_{s,g} + \beta * OP_{m[d]} + \gamma * W_d + \eta_{m[d]}$

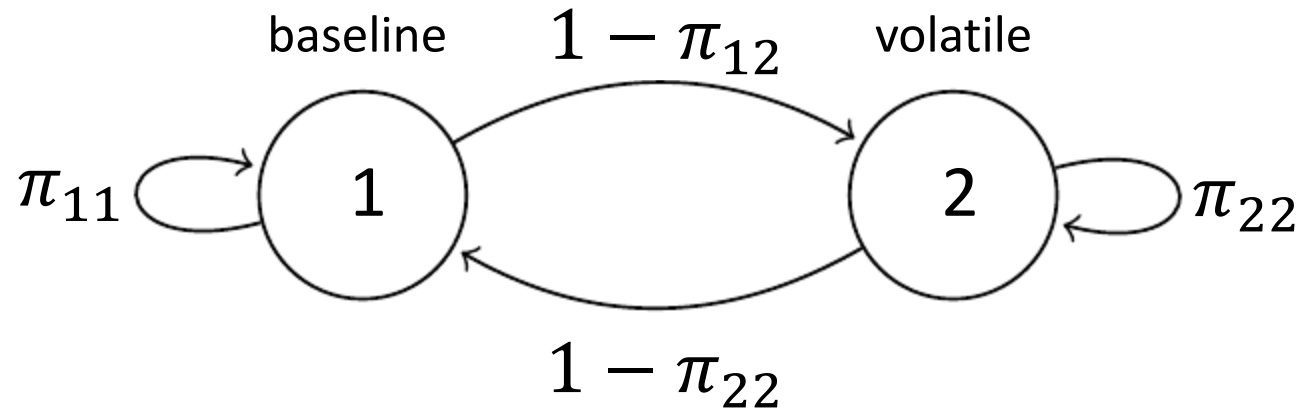
Step 3 (continued)

- Errors are drawn from a state-specific variance covariance matrix.

$$\begin{bmatrix} \text{Var}(X) & \text{Cov}(X, Y) & \text{Cov}(X, Z) \\ \text{Cov}(X, Y) & \text{Var}(Y) & \text{Cov}(Y, Z) \\ \text{Cov}(X, Z) & \text{Cov}(Y, Z) & \text{Var}(Z) \end{bmatrix}$$

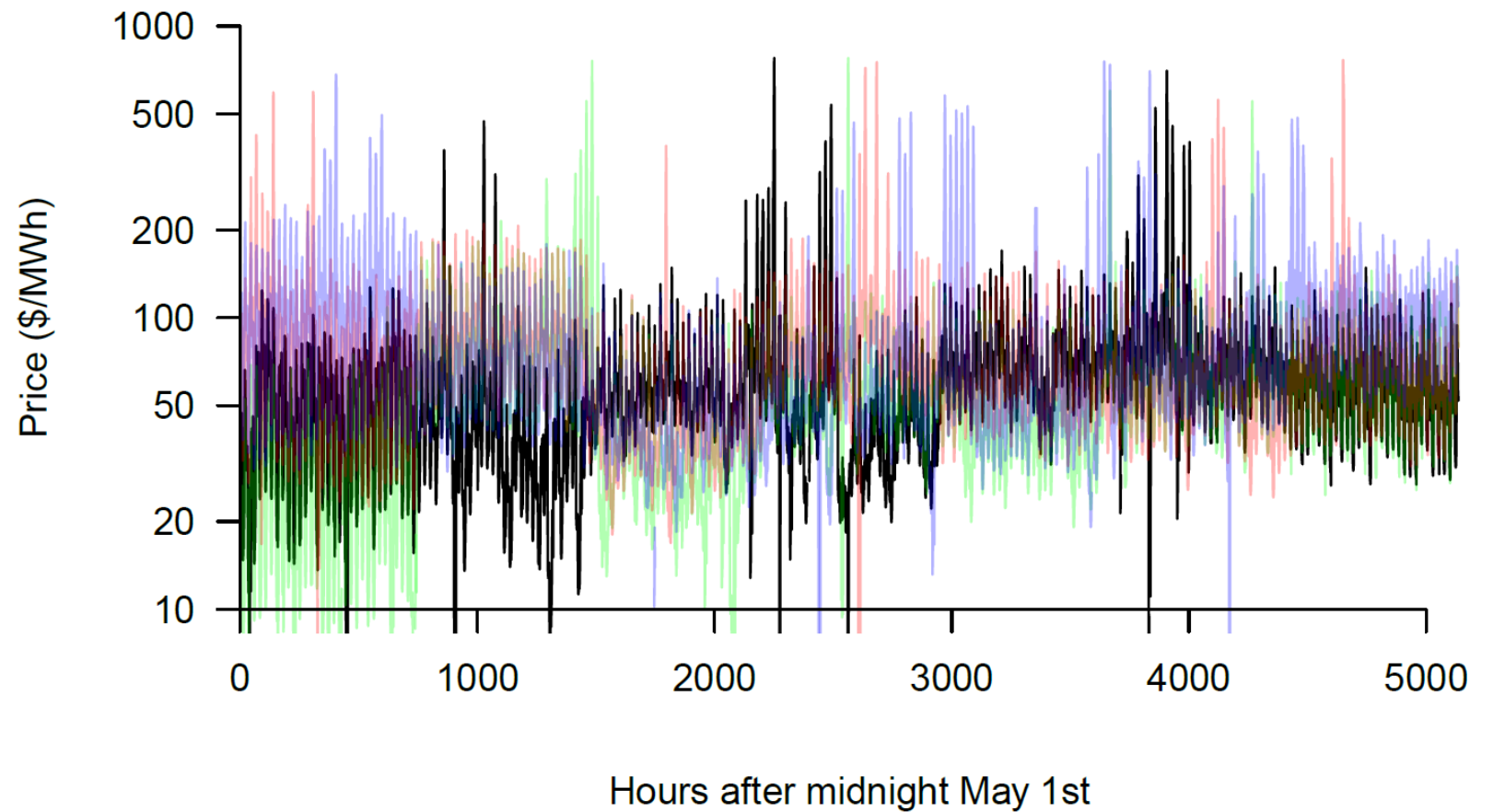
Step 3 (continued)

- Transitions between baseline and volatile states between day d and day $d+1$ are modelled based on a first-order Markov transition matrix, $\boldsymbol{\pi}$.

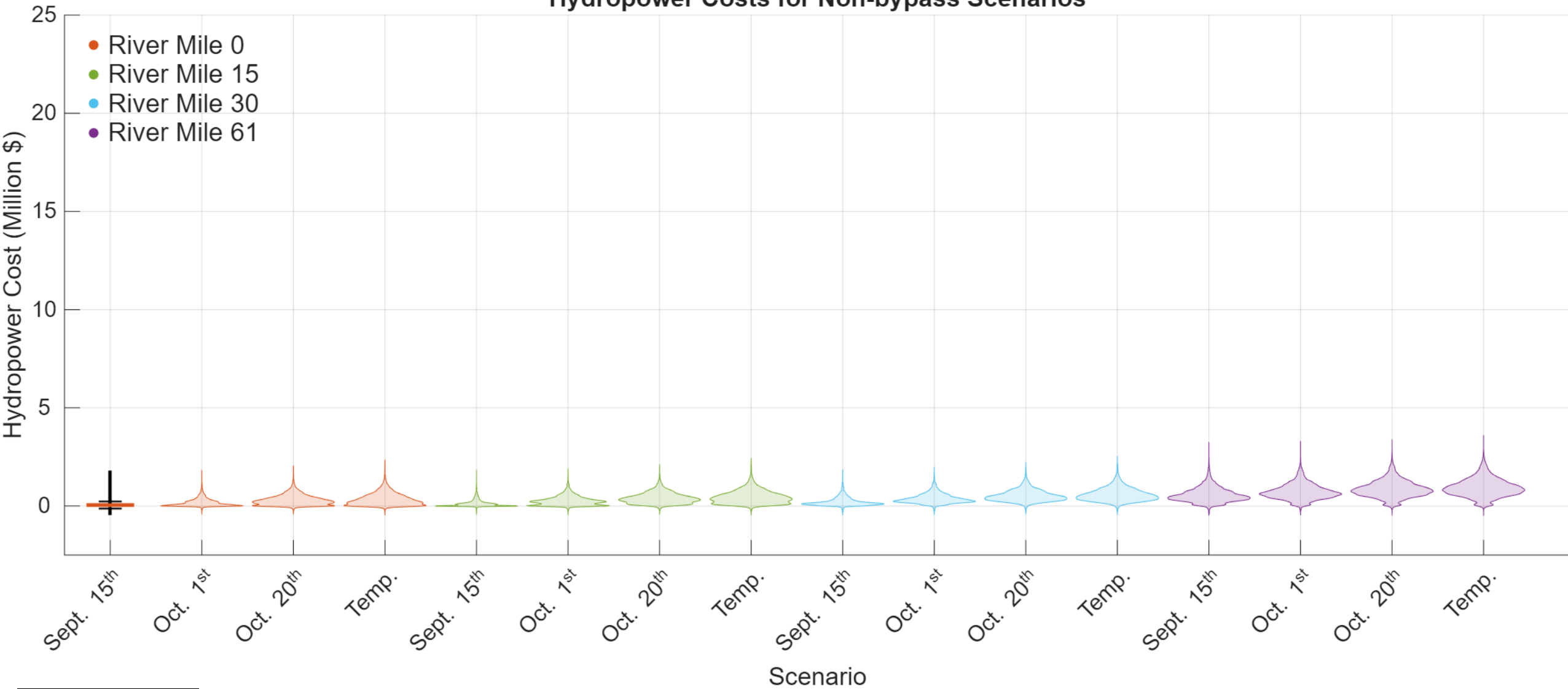


Step 4: Forecasts Group means based on Argus forward curves and reshape to hourly prices using monthly relationships among hourly relative prices

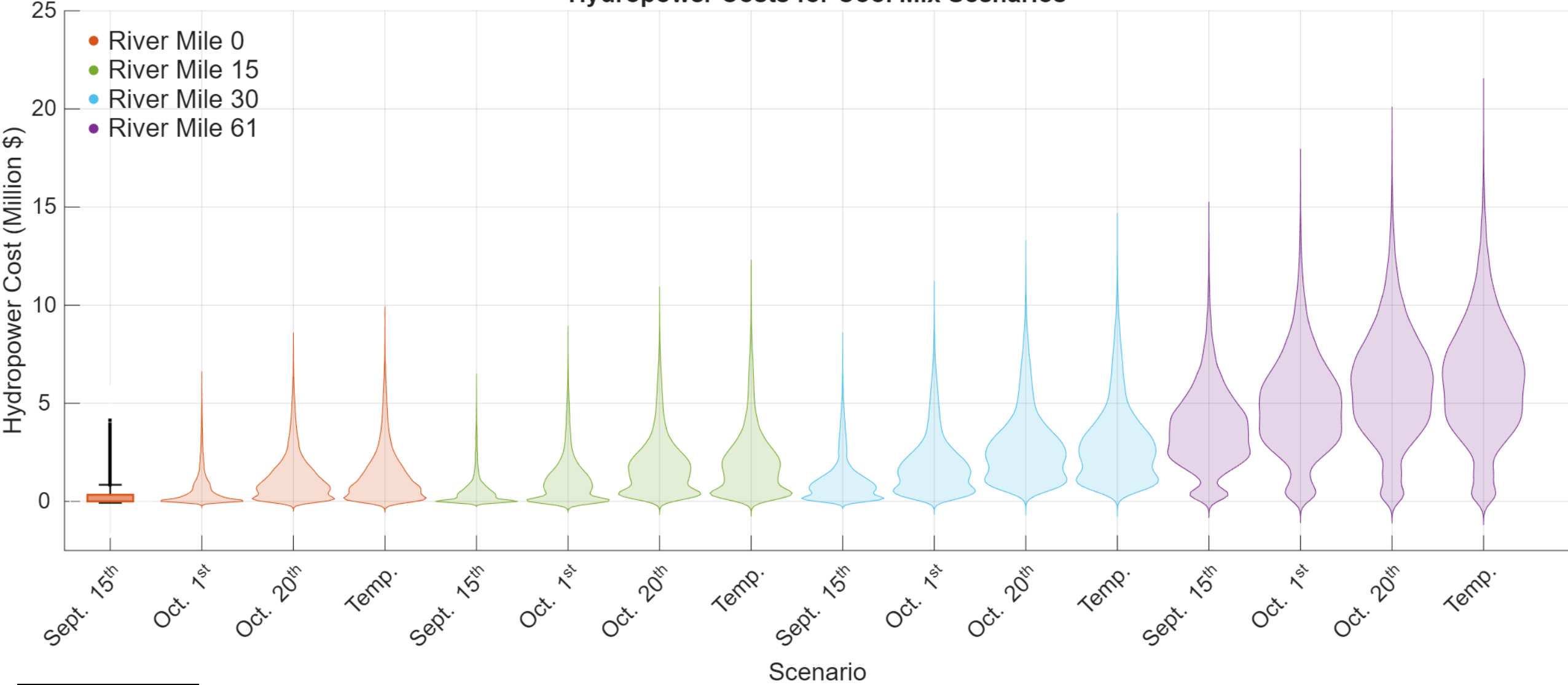
- Simulate 1000 price vectors incorporating various sources of uncertainty.



Hydropower Costs for Non-bypass Scenarios



Hydropower Costs for Cool Mix Scenarios



Questions?

Photo Credit: Richard McLeish

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