



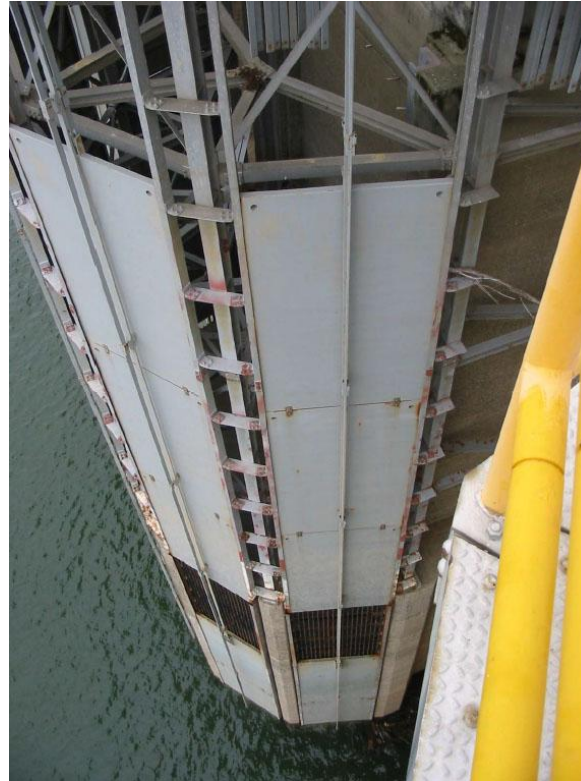
— BUREAU OF —
RECLAMATION

Folsom Temperature Control Shutter (TCS) Hydrology & Operations

CWEMF 2026

Applied Hydrology
Technical Service Center
Bureau of Reclamation

Motivation



- TCS at Folsom dam needs to be redesigned/refurbished
- Structural concerns with the existing system
 - In service since ~1955
- Concerns with useability
- Concerns with ongoing performance



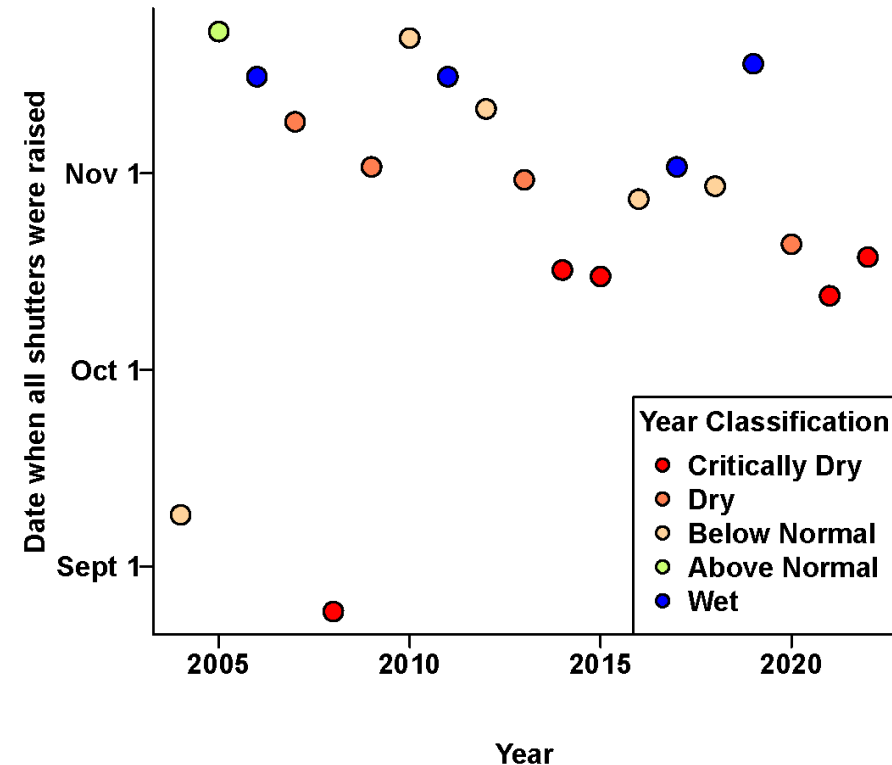
More Motivation

CalMatters, 2021



Multiple endangered and threatened species
require downstream temperature management

Improvements in environmental compliance
allow greater water deliveries



Performance has been worsening
with warming temperatures





Three Hydrologic Phases

- Hydrology guides operational requirements
- Hydrology is providing information as early as possible to the design
- Focusing on producing information to reduce design uncertainty

Phase I Hydrology

Sensitivity

Constructability

Preliminary
Design

Post Raise Operations

Current &
Future
Hydrology

ESRD
Finalization

Operations
Scenarios

Phase II Hydrology

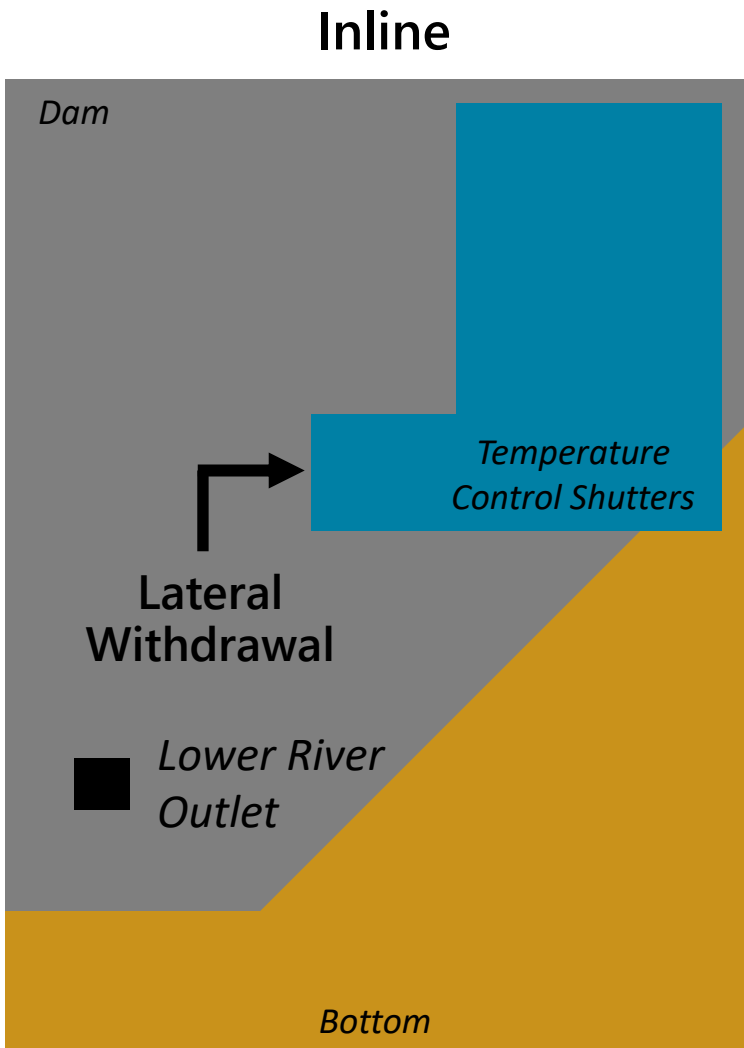
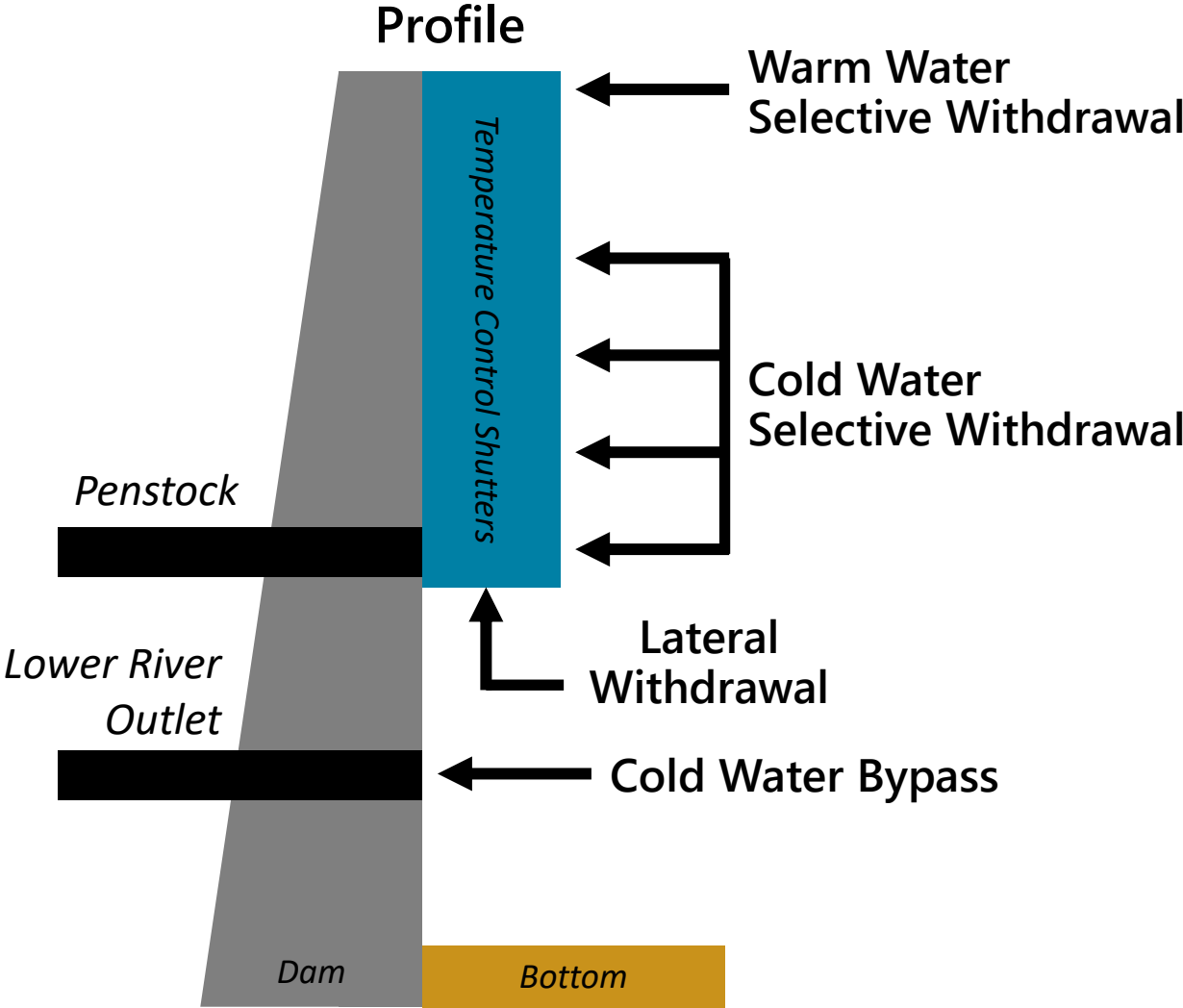
Future
Hydrology
Assessment

Design
Verification

Operations
Planning



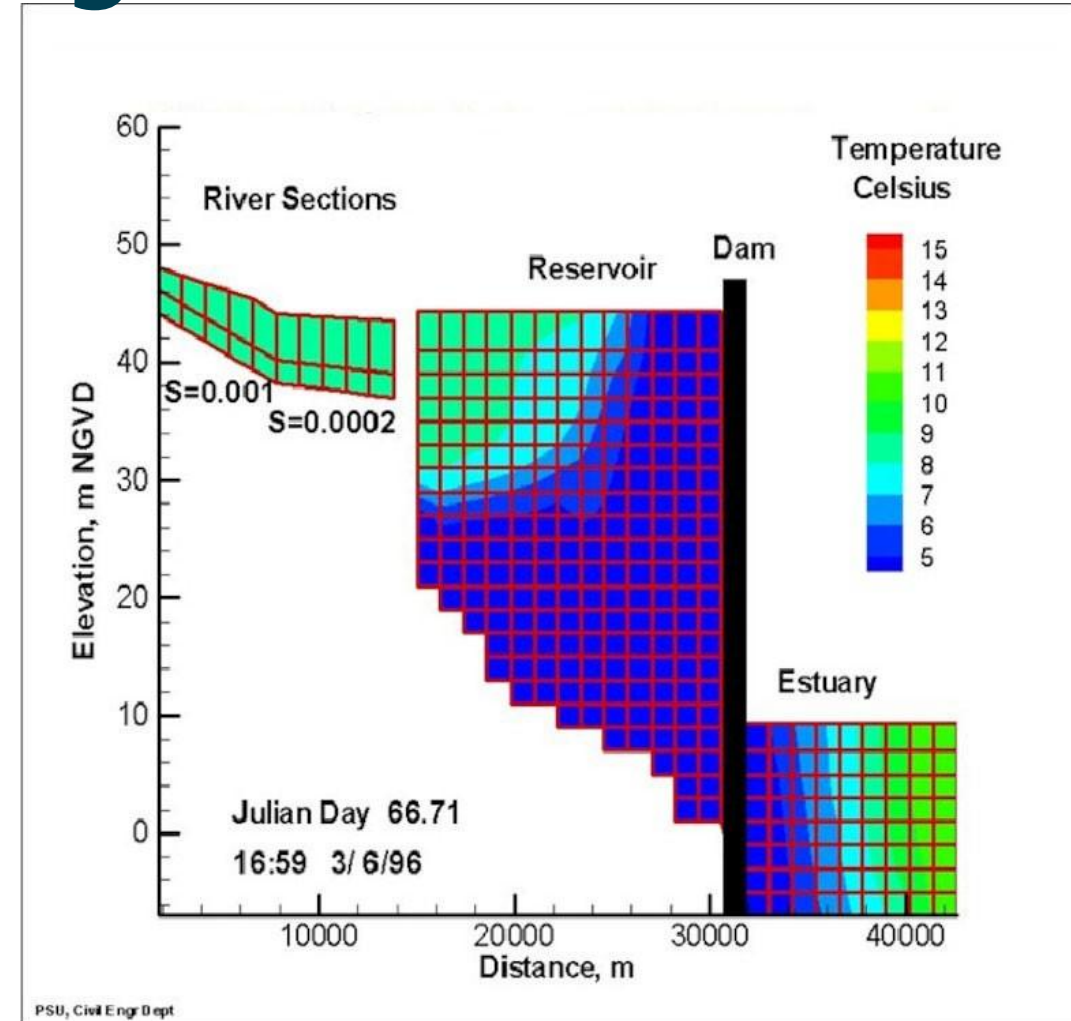
Withdrawal Glossary





CE-QUAL-W2 (W2) Modeling

- CE-QUAL-W2 is a two-dimensional (2D), longitudinal/vertical, hydrodynamics and water quality model.
- A reservoir is “well mixed” laterally with no variation from one side of the channel to the other in a given layer and segment.
- Physics based model of Folsom developed/calibrated by Cardno/KleinSchmidt but used within TSC/BDO
 - Allows confidence with hydrodynamic and structural changes
- TSC has concerns with transparency and flexibility initial modifications
- Need to generalize selective withdrawal and blend timing logics





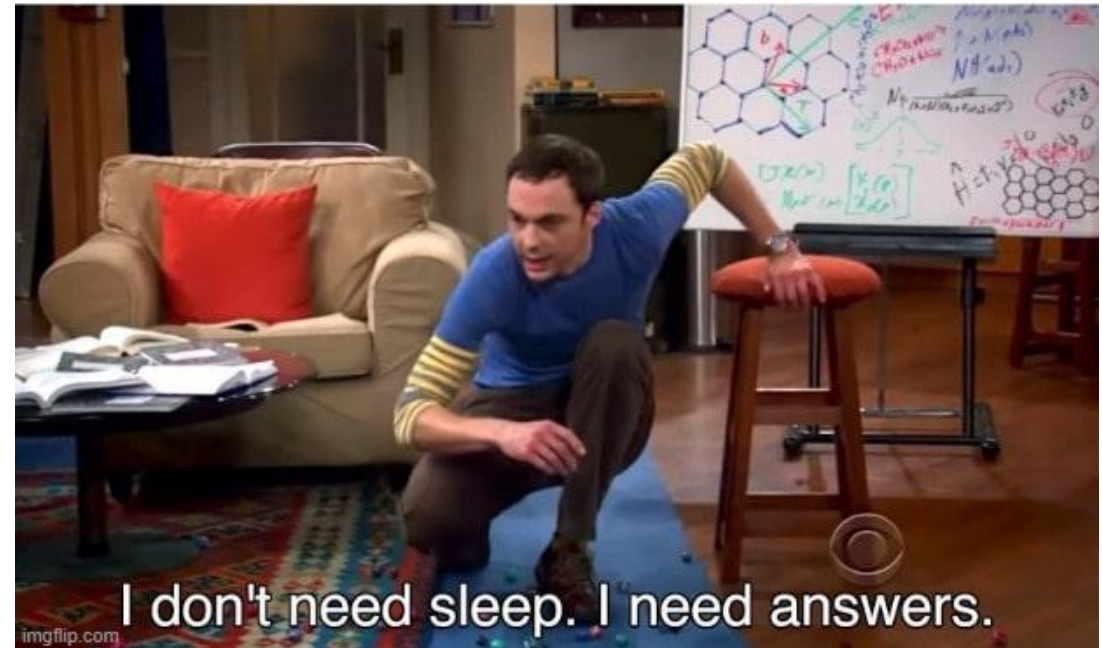
W2 - Modifications

- Initial rebuild of the cold temperature target logic in W2 source code to depreciate previous model
 - *Pending additional development, finalization, and merge into PSU codebase*
- Updating contractor inputs from v3.7 to v4.5 of the model
- Restructure of the inputs for bypass logic generalization
- Added TCS reblend time offset to better mimic CVO operations
- Built Python control wrapper

Assumptions

- Power generation will not be lost at any time
- Cold water bypass allowed from October 15 – November 15

**WHEN YOUR CODE IS
GOOD BUT IT DOESN'T WORK**

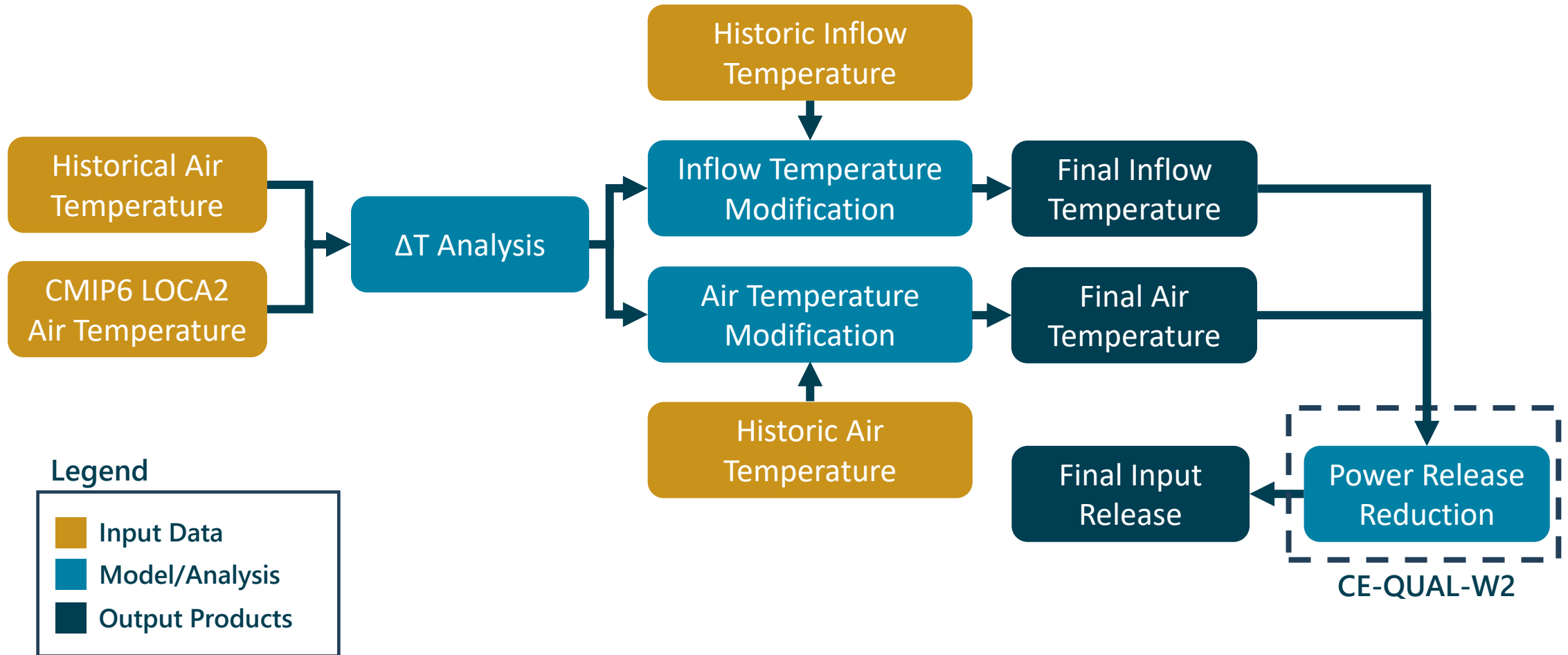


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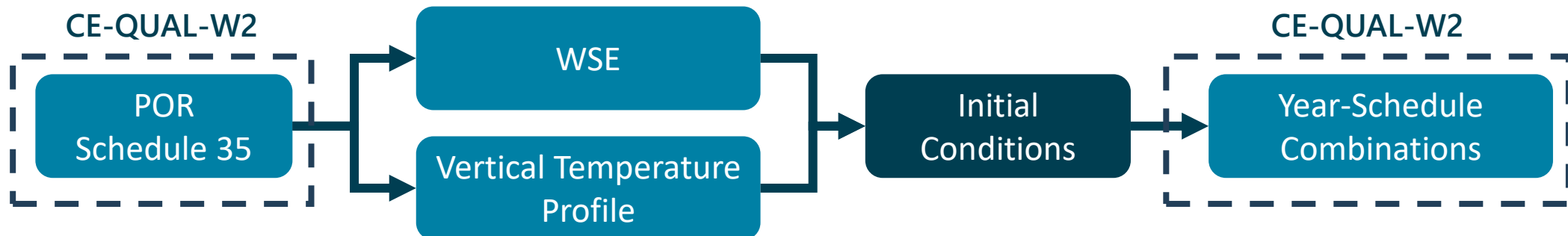


Future Hydrology Modeling Workflow



Data Expansion

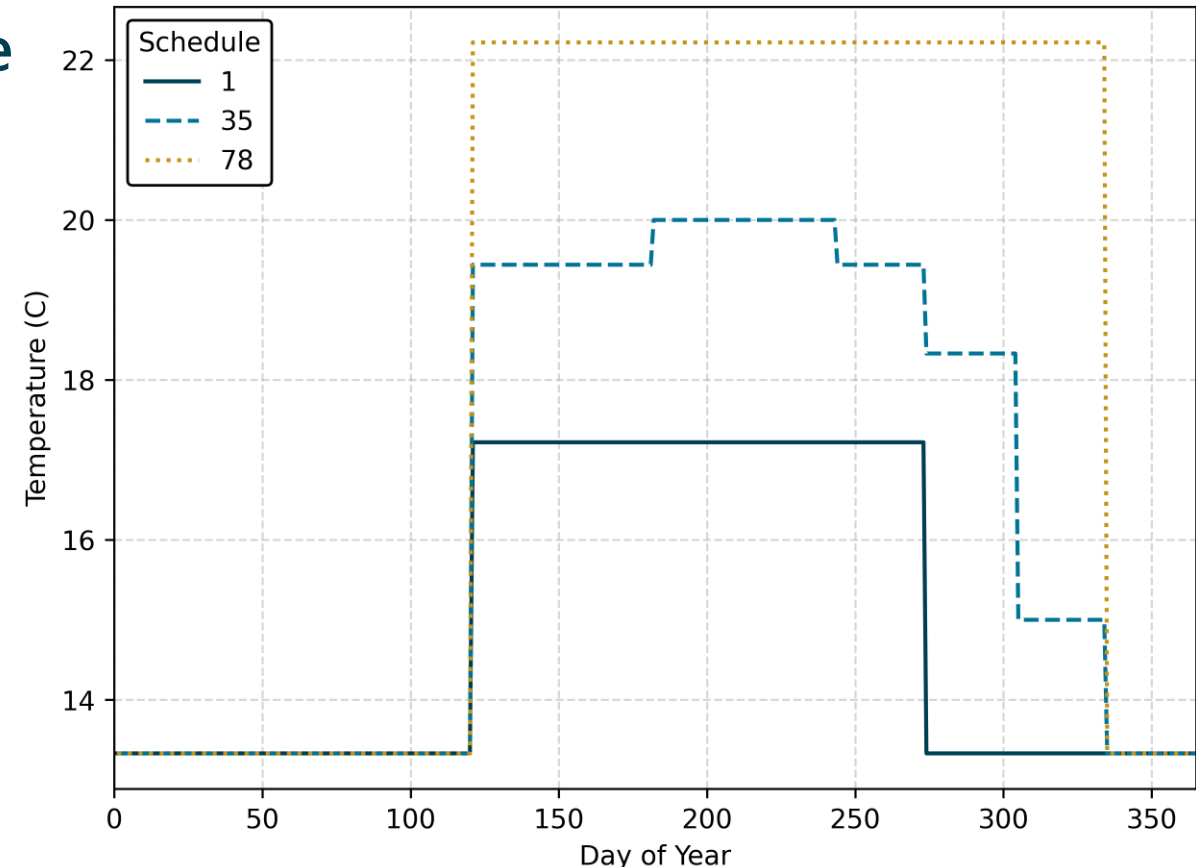
- W2 has a record from 01/01/2001 – 12/31/2020
 - Limited amount of data to understand system performance
- Used an AI/ML technique of data expansion to provide more information
 - Utilize infeasible conditions to build confidence in final solution
 - Utilized all schedules for every year within the period of record





American River Temperature Schedules

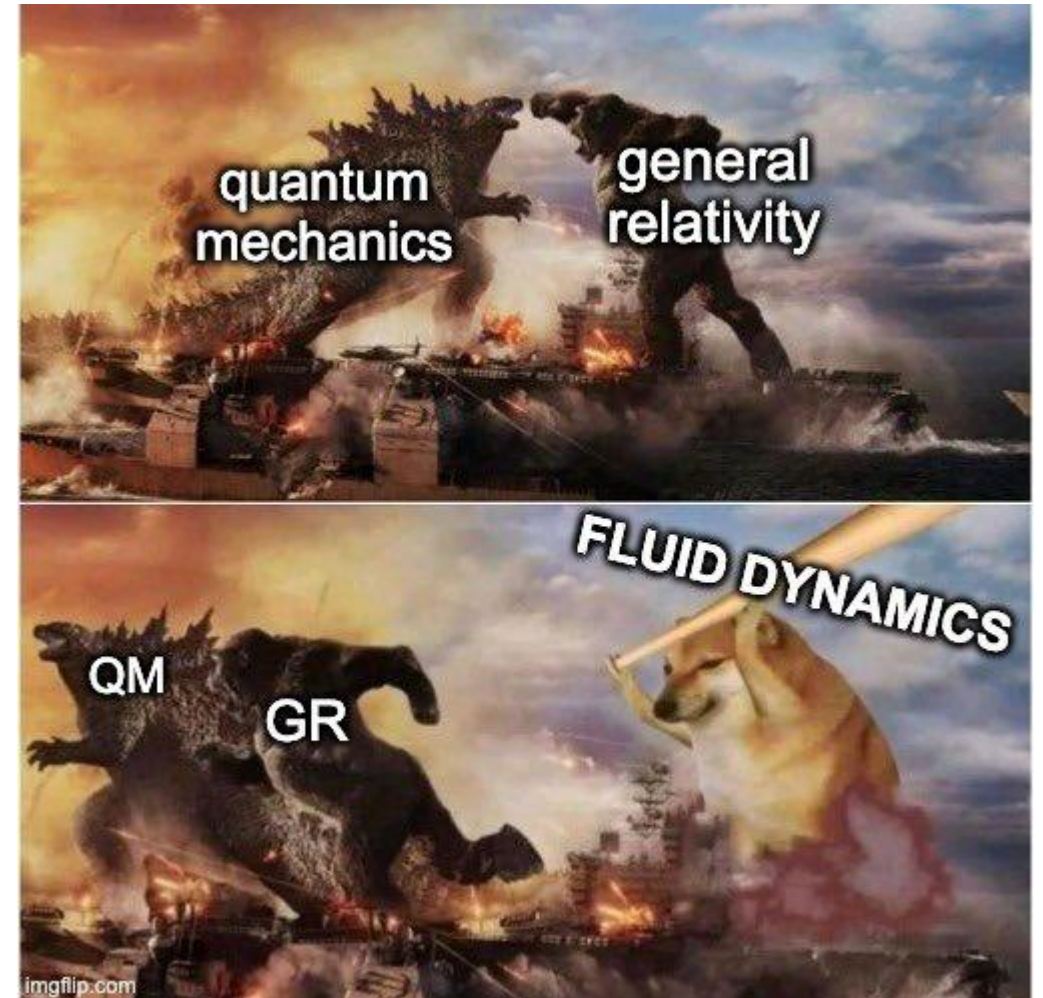
- Predefined temperature targets that incorporate when temperatures should be increased given limited cold water
- Developed by the Water Forum as a common reference language
- 78 Schedules defined to Watt Avenue, with lower values being generally colder
- Real-time operations are informed by the schedules but are not confined by it
 - Adaptive management performed in consultation with the American River Group
 - Potential to change both targets and compliance location





Outputs

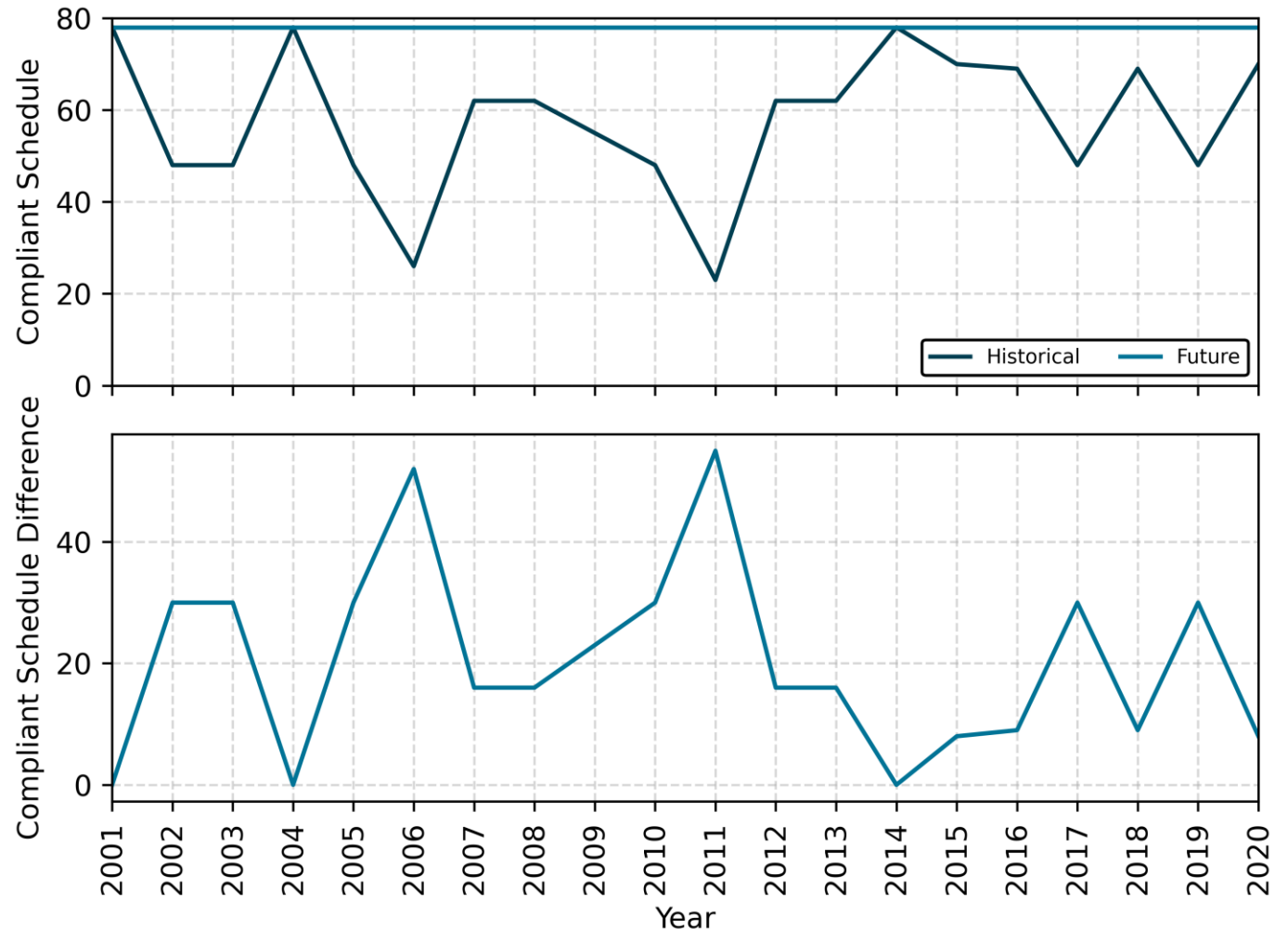
- **Schedule Compliance**
 - A predefined set of temperature targets used to establish compliance
 - Lower schedules indicate better temperature performance
- **Thermal Buffering Capacity**
 - The total thermal potential of the reservoir to absorb heat with respect to a reference temperature
 - Accounts for both temperature and volume changes
- **Cold Water Pool**
 - The volume of water less than a temperature





Historic/Future - Schedules

- Future hydrology reduces benefit from the TCS with current configuration and storages
- Always at the highest schedule even with power bypass



Thermal Buffering Capacity - Defined

- Defined to capture the total change in thermal energy in the reservoir with respect to a baseline
- Accounts for both volume and temperature changes
- Reduces sensitivity to shutter operations
- Upstream reservoir thermal changes translate to different downstream temperature outcomes

$$\Delta Q_b = \text{Scenario}_1 - \text{Scenario}_2$$

$$\Delta Q_b = c\rho V_1(T_1 - T_0) - c\rho V_2(T_2 - T_0)$$

$$\Delta Q_b = c\rho(V_1T_1 - V_2T_2) + c\rho T_0(V_2 - V_1)$$

$$\Delta Q_b = \textit{Thermal} + \textit{Volume}$$

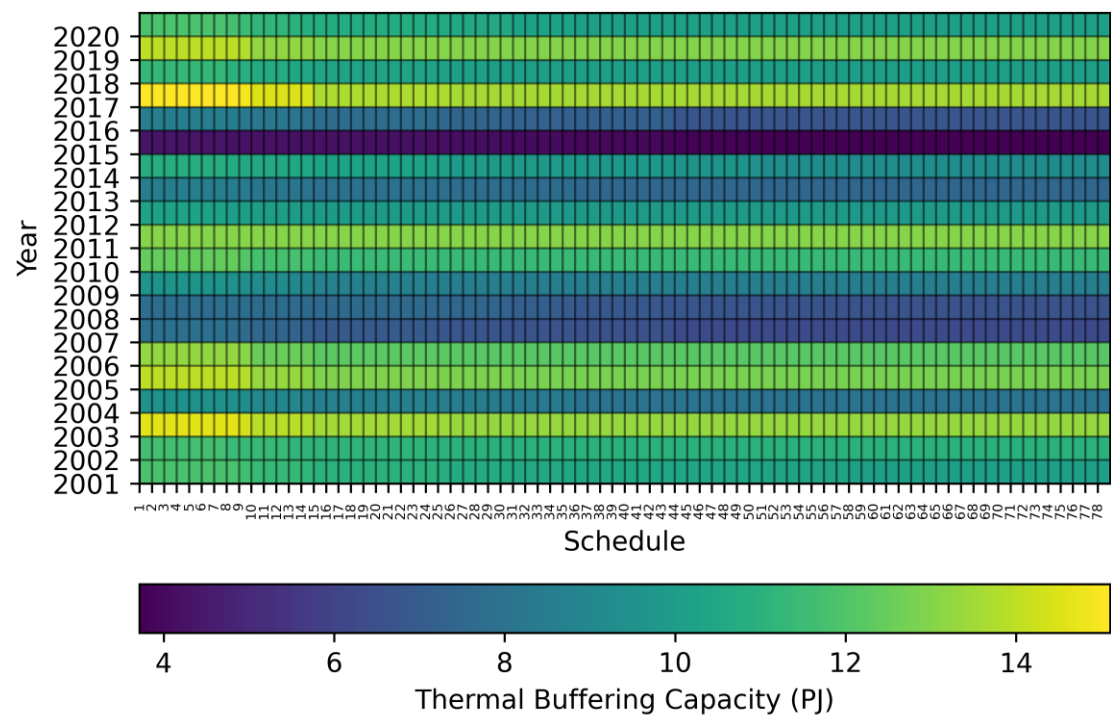
More negative values indicate better performance



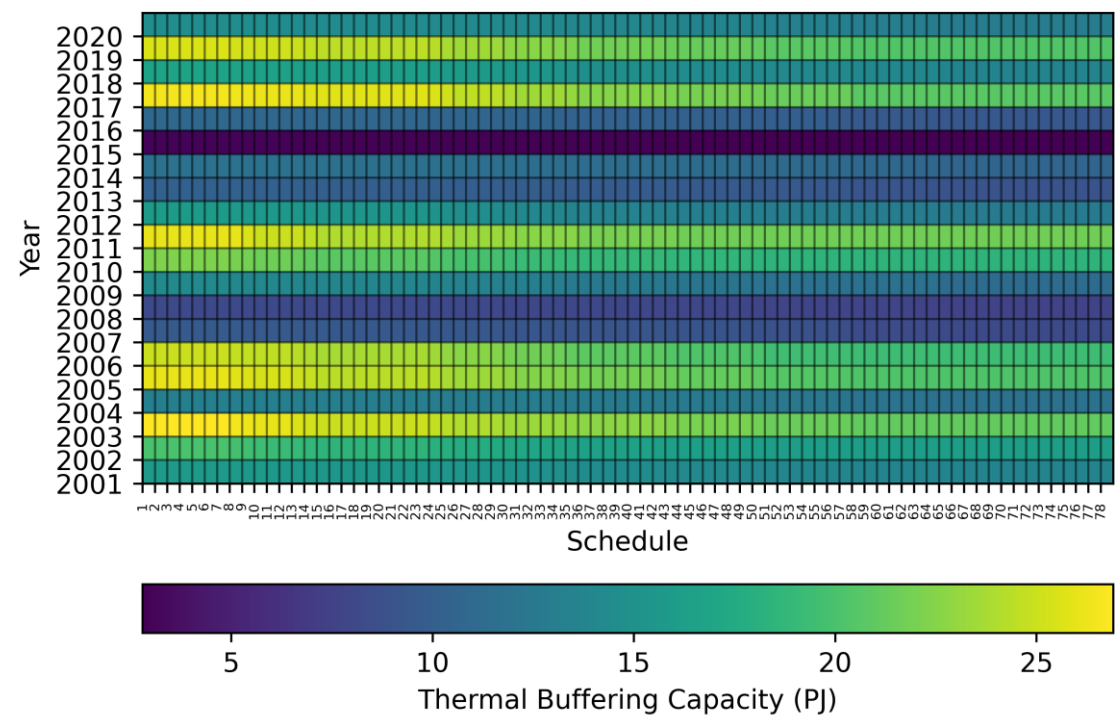


Thermal Buffering Capacity

Historical



Future



1 PJ $\approx$ 239 Tons of TNT
1 PJ $\approx$ 52.5% Folsom Annual Electricity Generation

Planned Work

- Finalize Phase I Sensitivity Documentation
- W2 Modifications
 - Generalizing cold/warm water selective withdrawal
 - Exposing new logic within input files
 - Conversion to Linux to enable HPC deployment
- Constructability Analysis
- Phase I Design Analysis



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