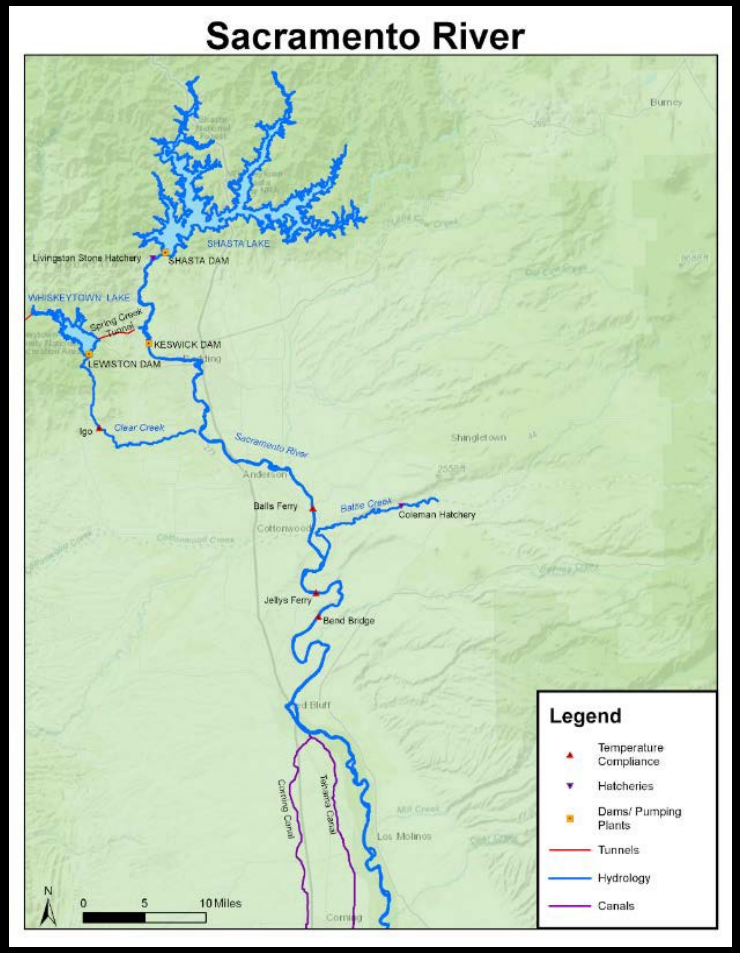
BUREAU OF RECLAMATION

# Shasta Cold Water Pool Management: Description of the Action, Objectives, Metrics, Monthly Operations

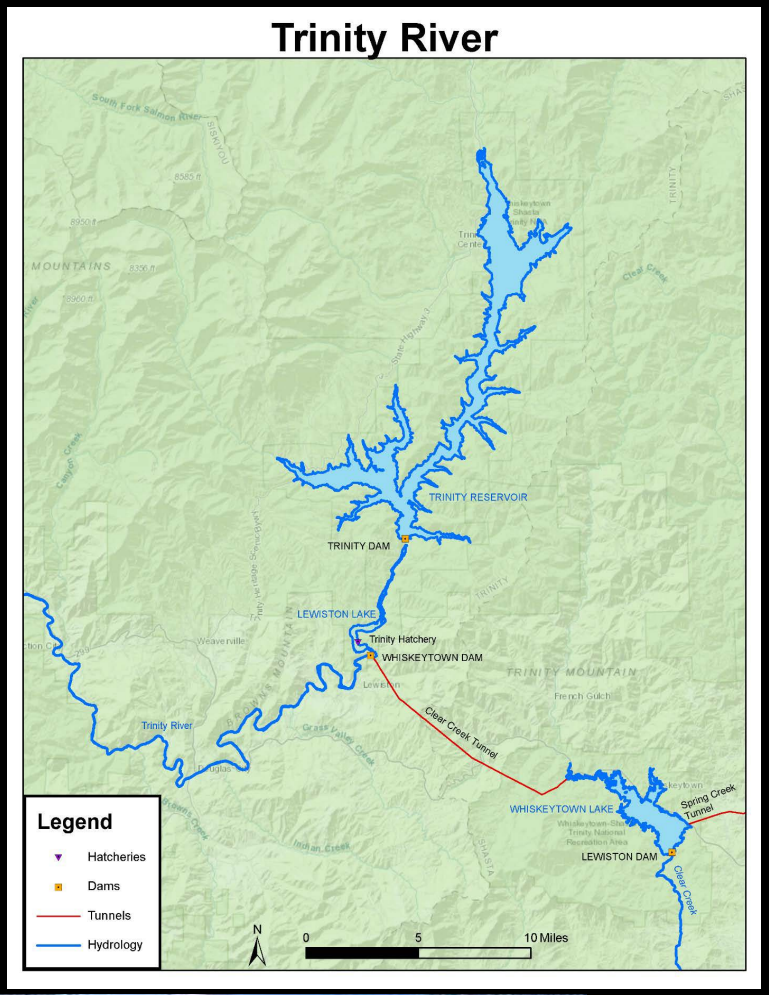
# Shasta Dam

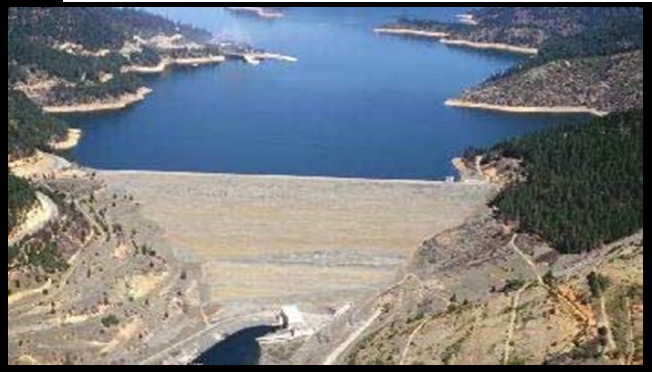
- Sacramento River
- 11 miles north of Redding
- Stands among the world's largest dams
- Flood control, water supply, temperature management, power generation...
- Capacity: 4.5 MAF




# Trinity Dam

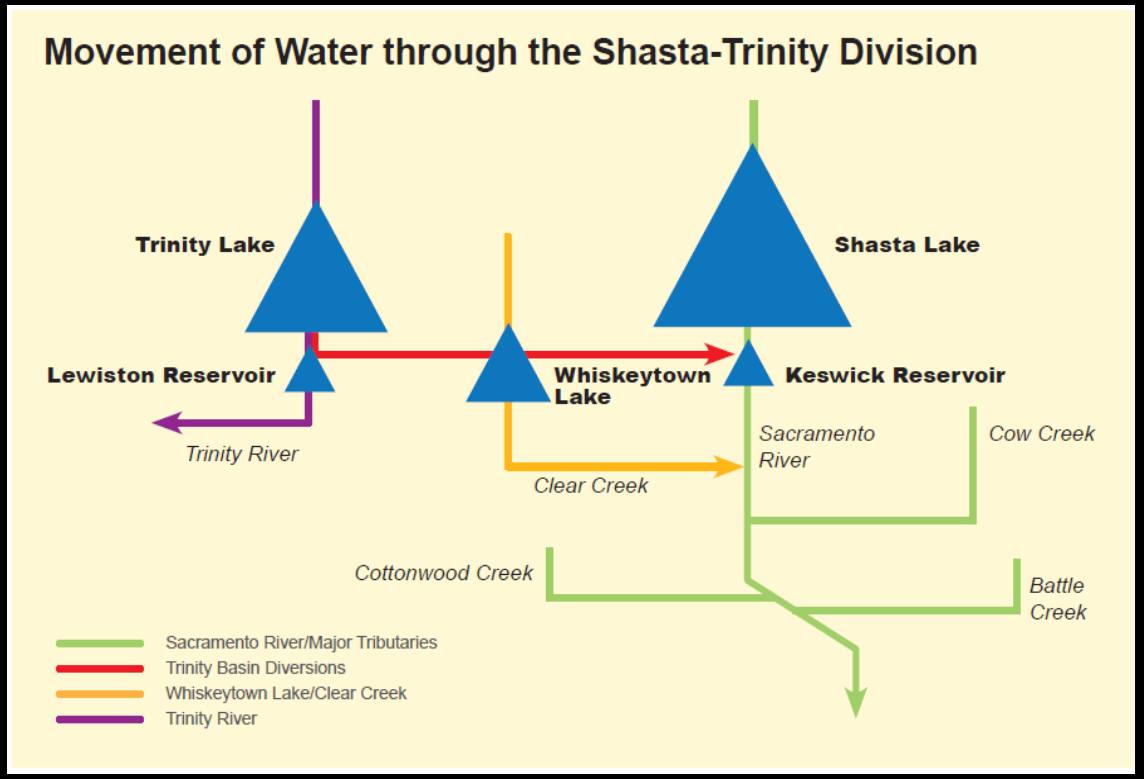
- Trinity River
- 7 miles northeast of Weaverville
- Stores water on the Trinity River which flows into the Klamath River
- Water supply in the Sacramento system via interbasin diversion
- Regulatory requirements both in the Sacramento and Trinity/Klamath systems
- Hydropower
- Capacity: 2.4 MAF



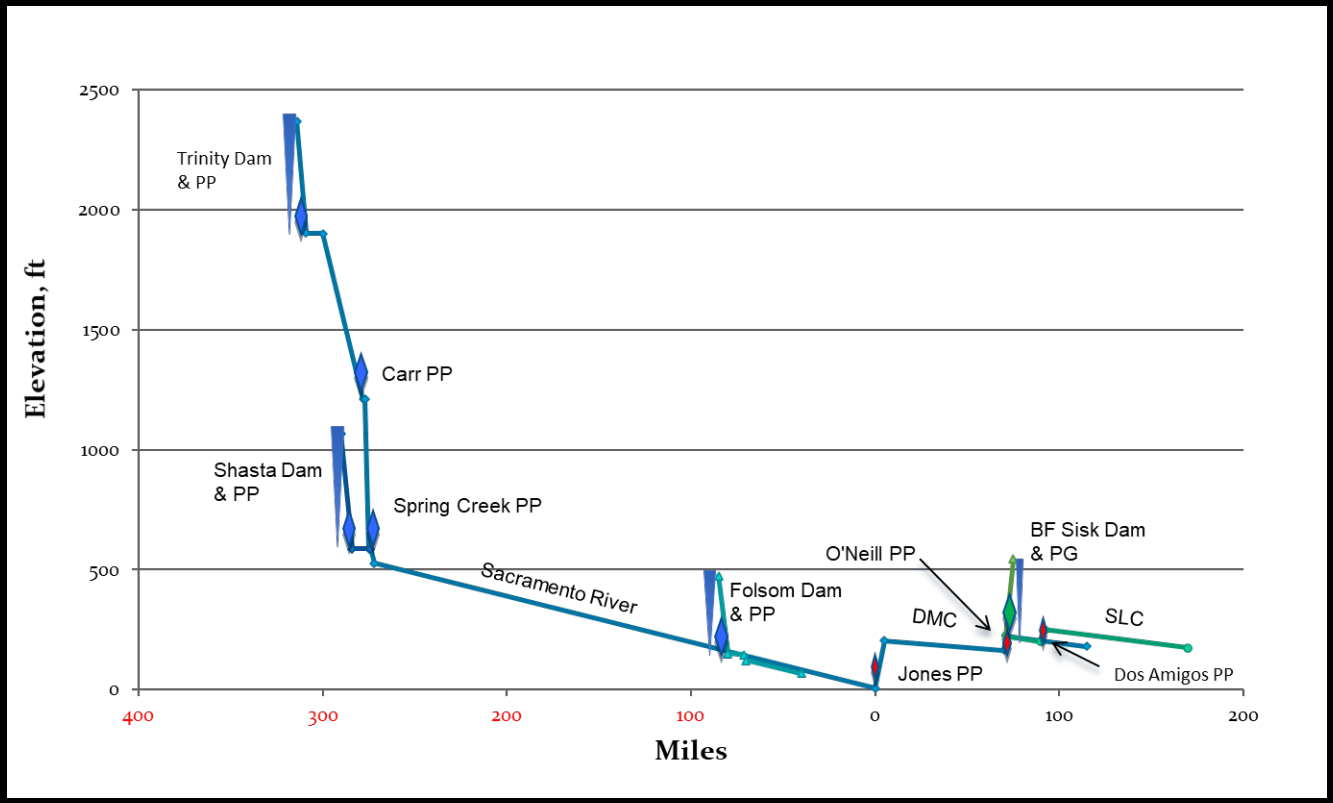



# Whiskeytown Dam and Lake

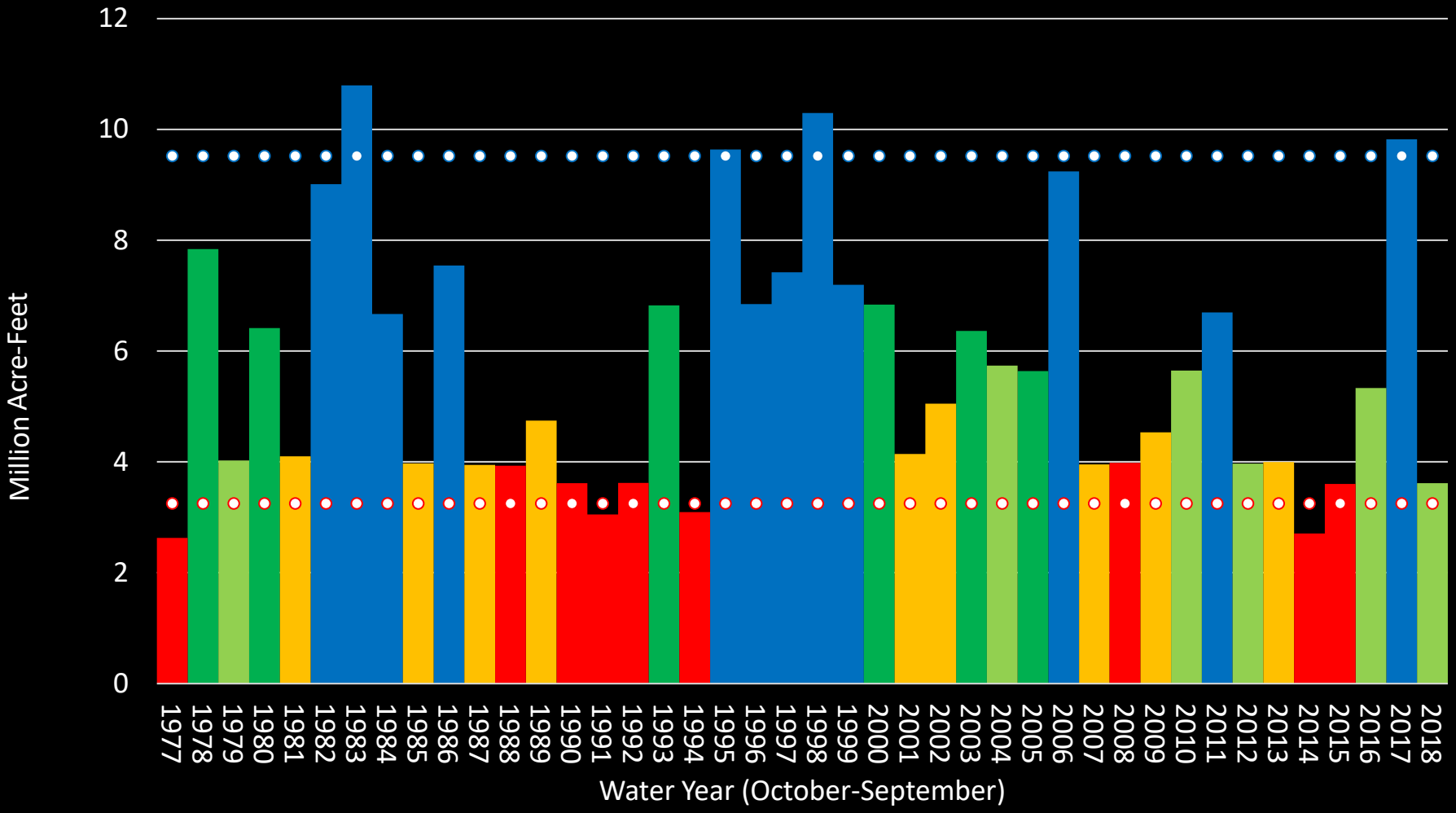
Photo: Reclamation



# CVP Hydropower Profile

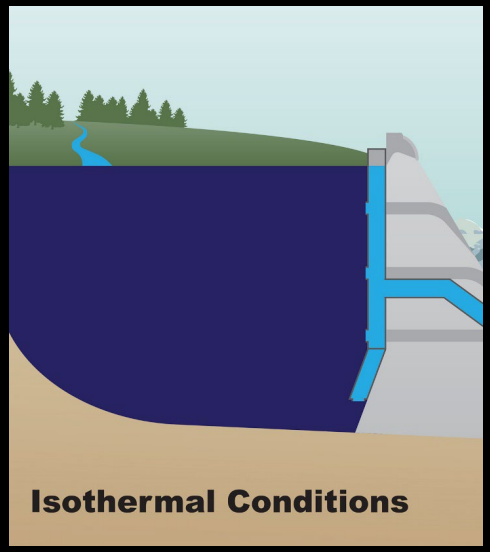


# Historical Inflow to Shasta with 90% and 10% Intervals

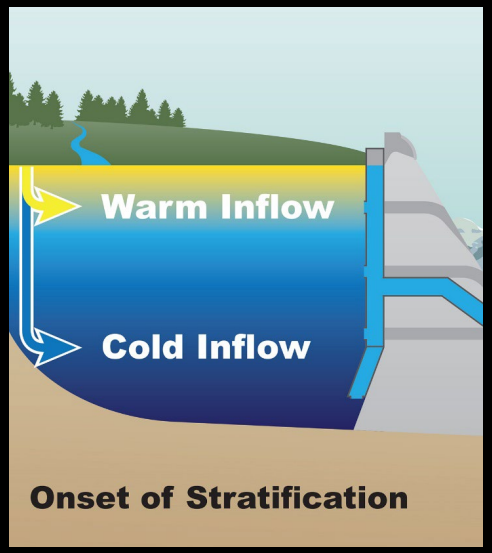


# Seasonal Lake Characteristics

**Winter**

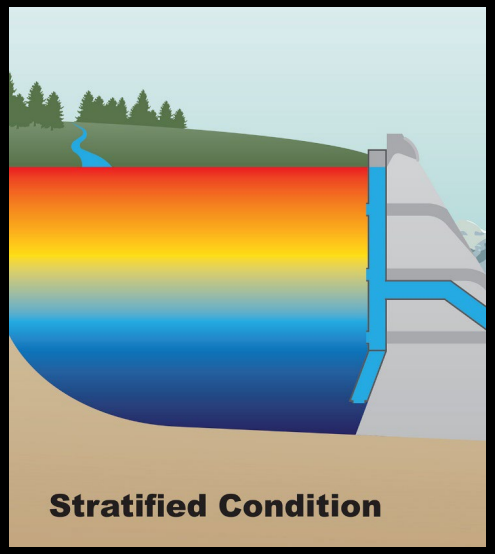



**Spring**

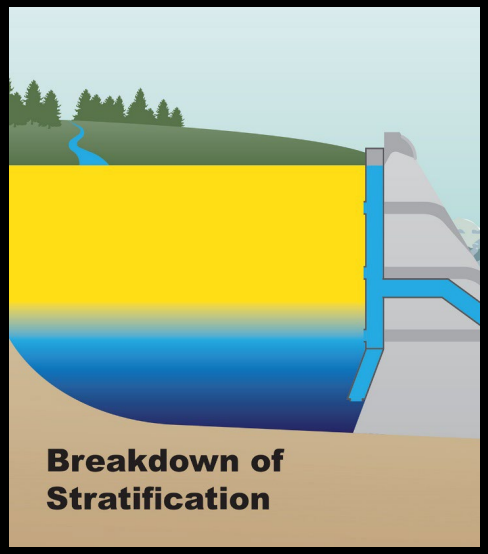


# Seasonal Lake Characteristics

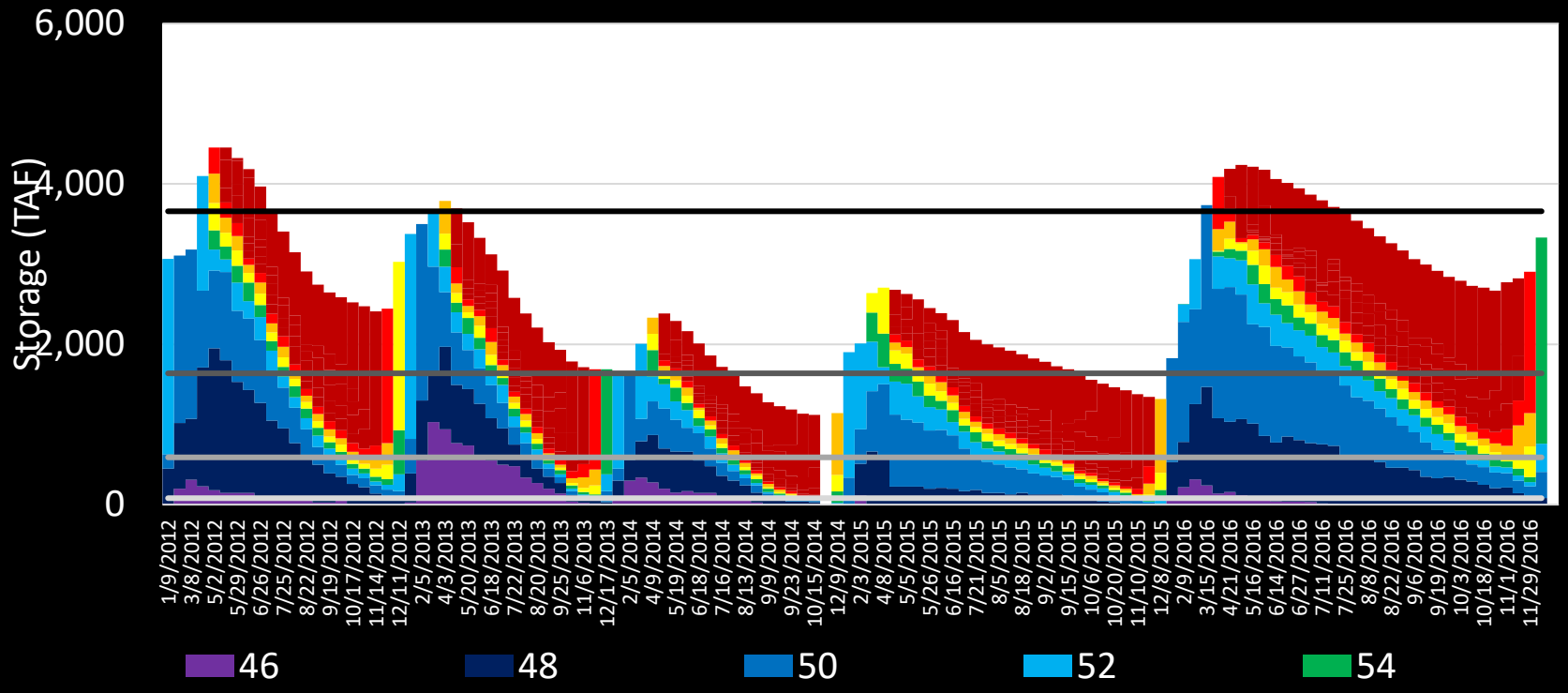
**Summer**



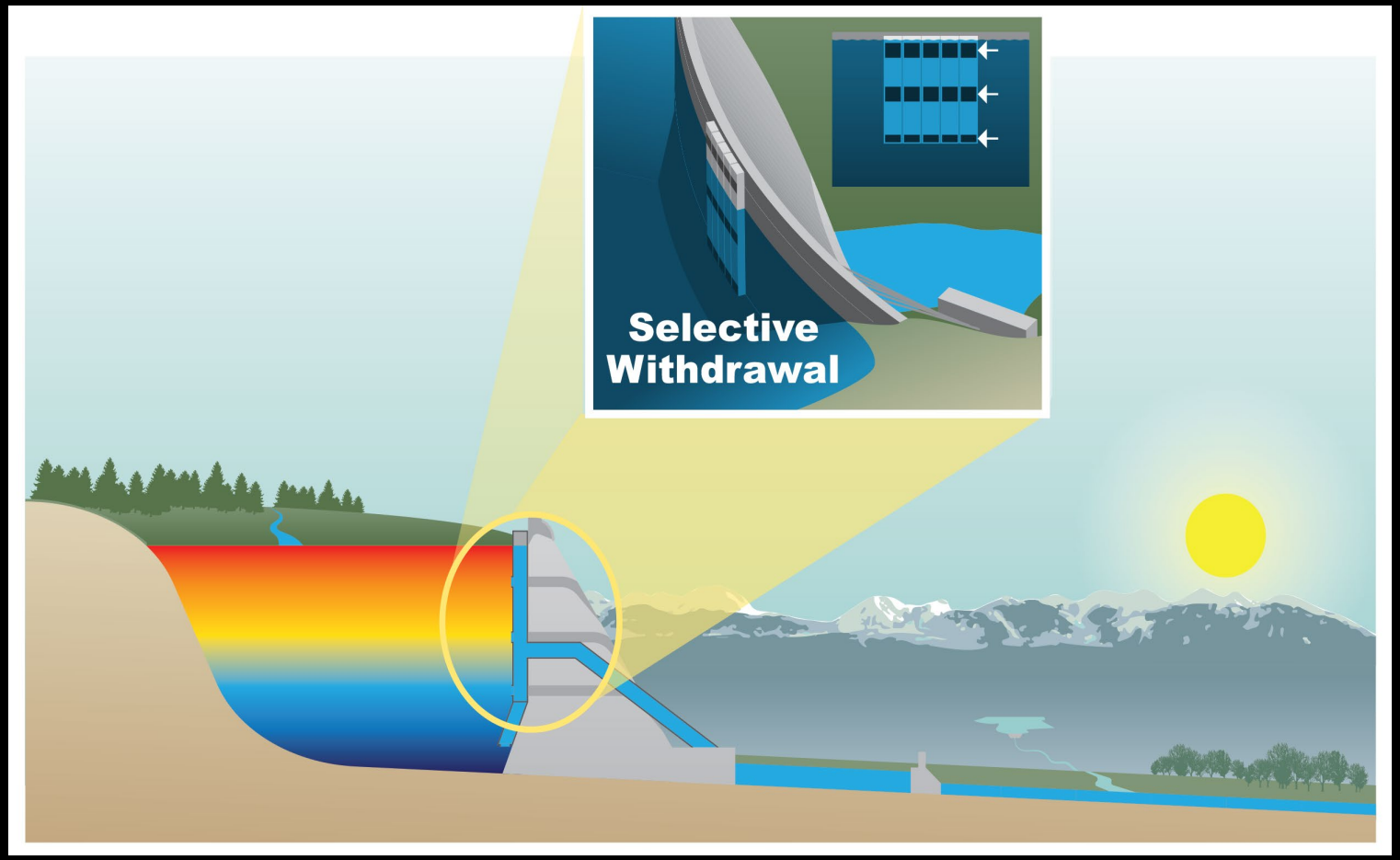

**Fall**



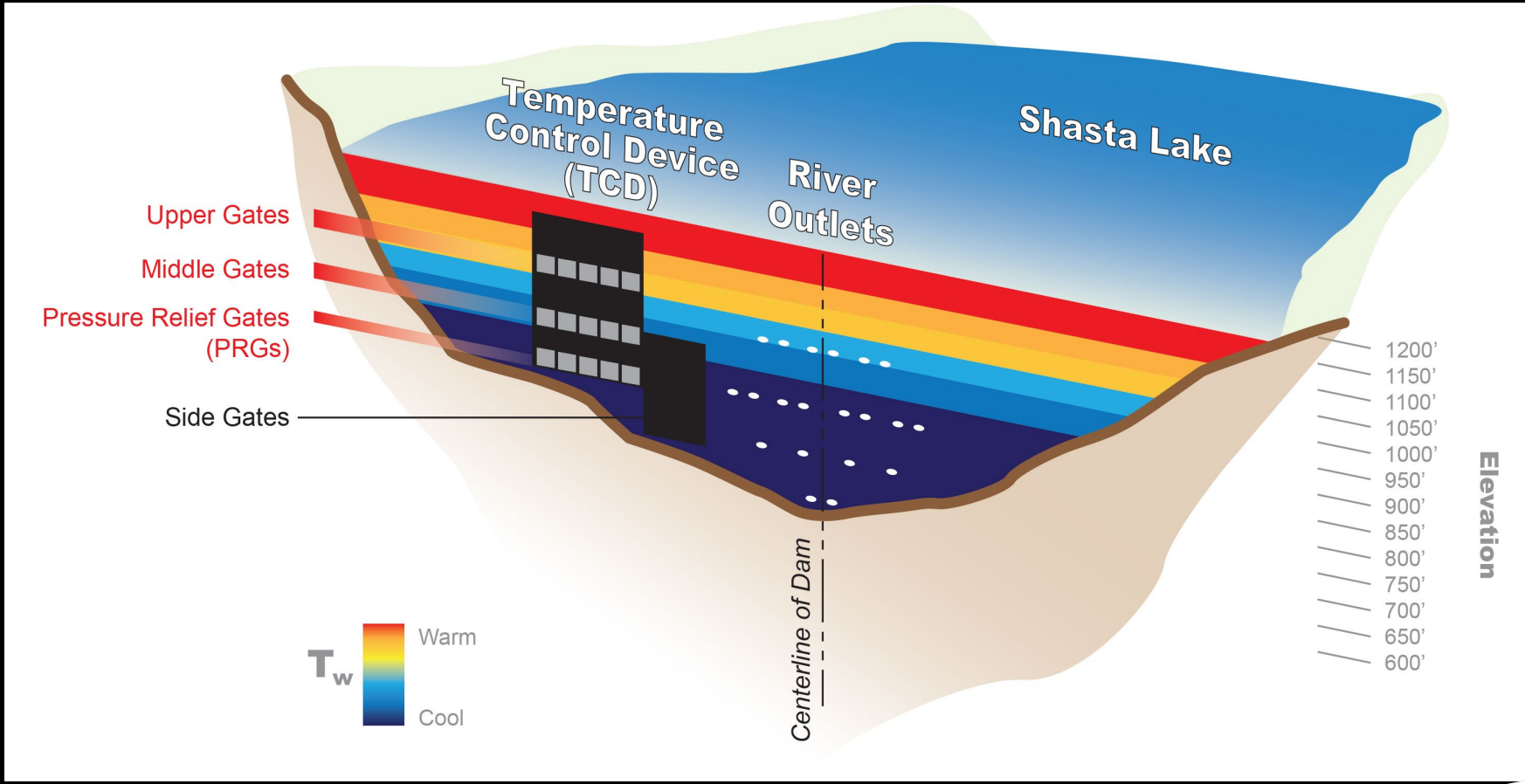
# Use of the cold water depends upon stratification which may not occur until about after April.



# Selective Withdrawal



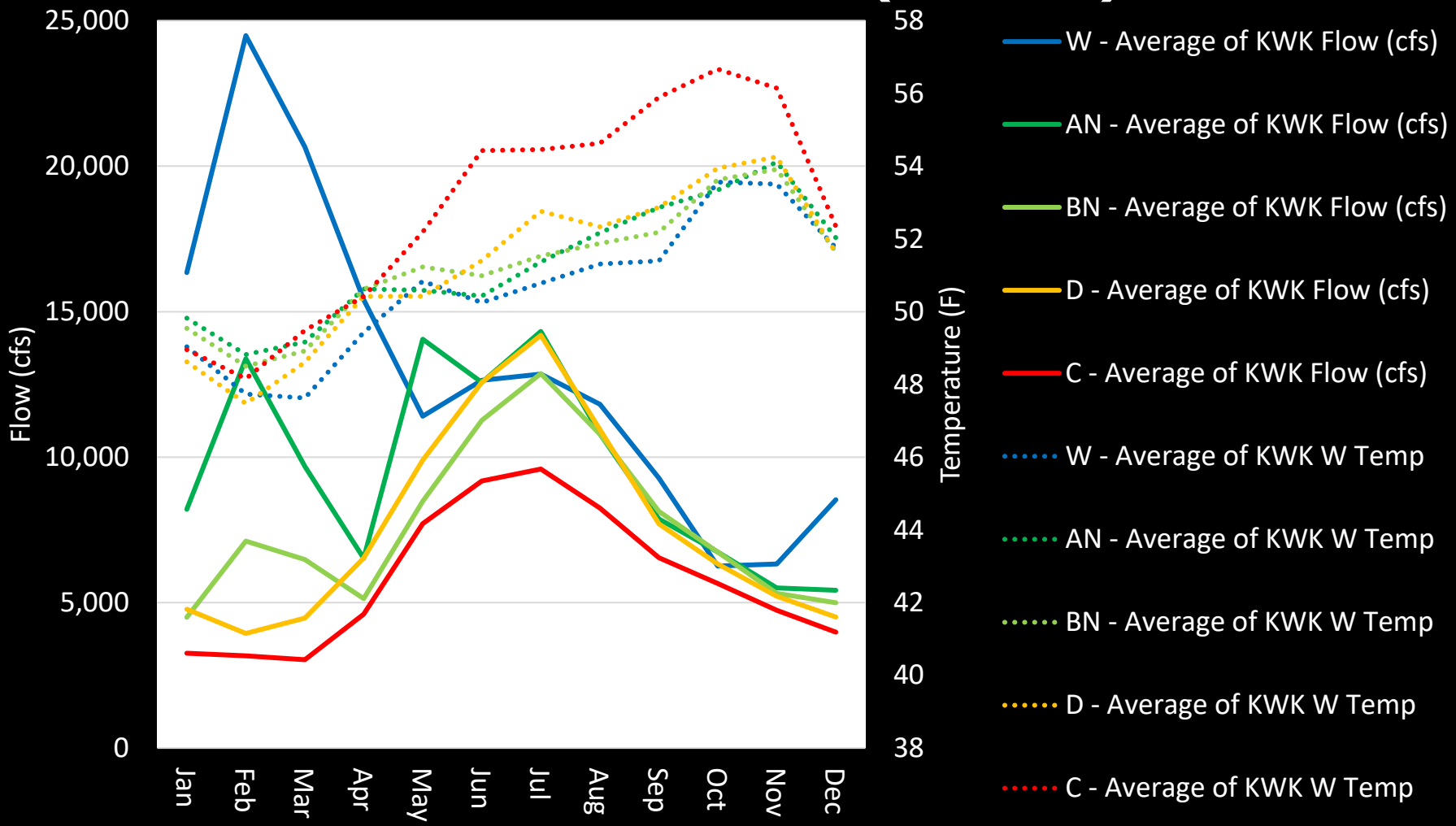
# Selective Withdrawal



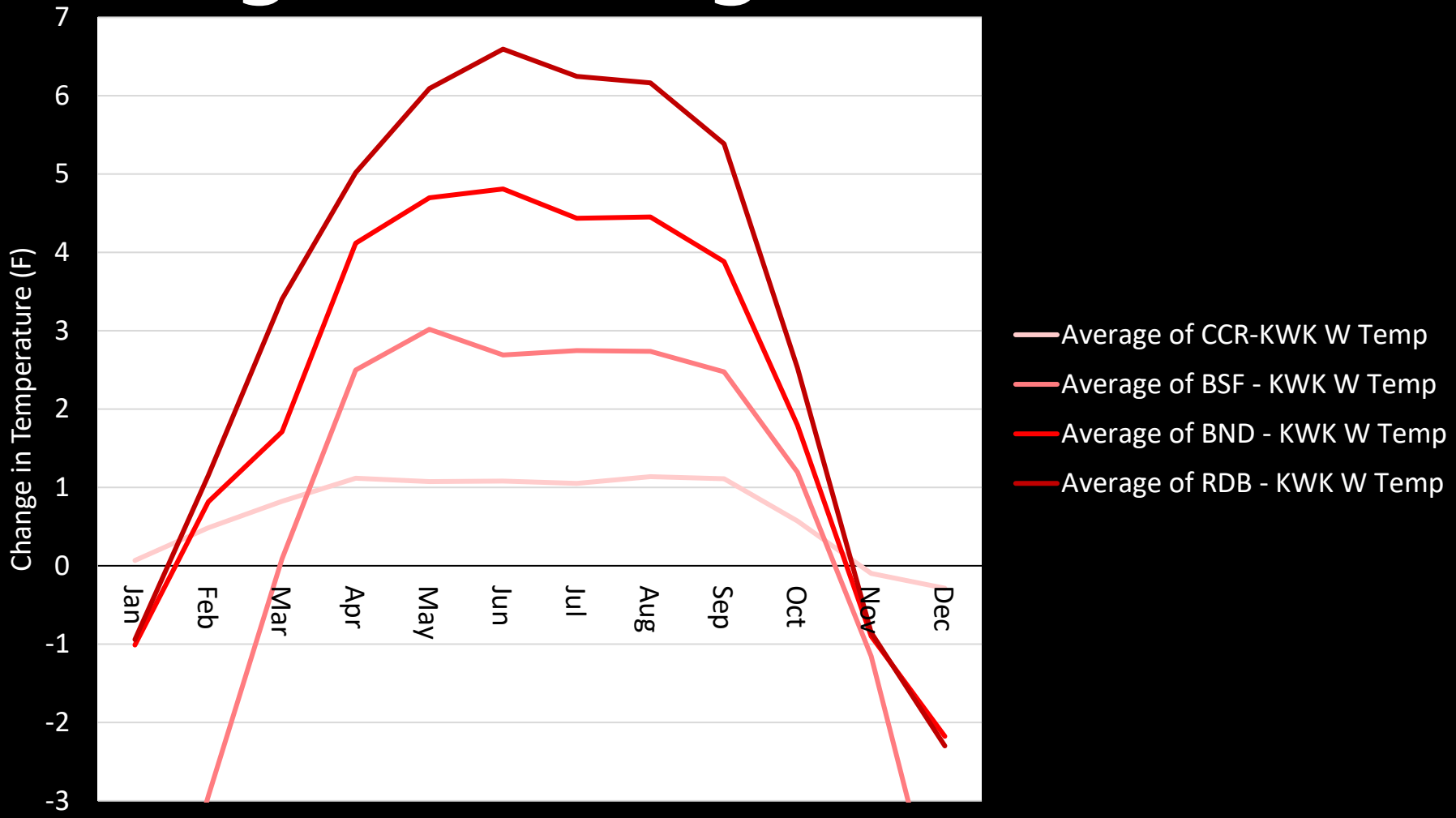
# Shasta Dam outlets

# Shasta Dam TCD

# Releases at Keswick (KWK)



# Average Warming below KWK

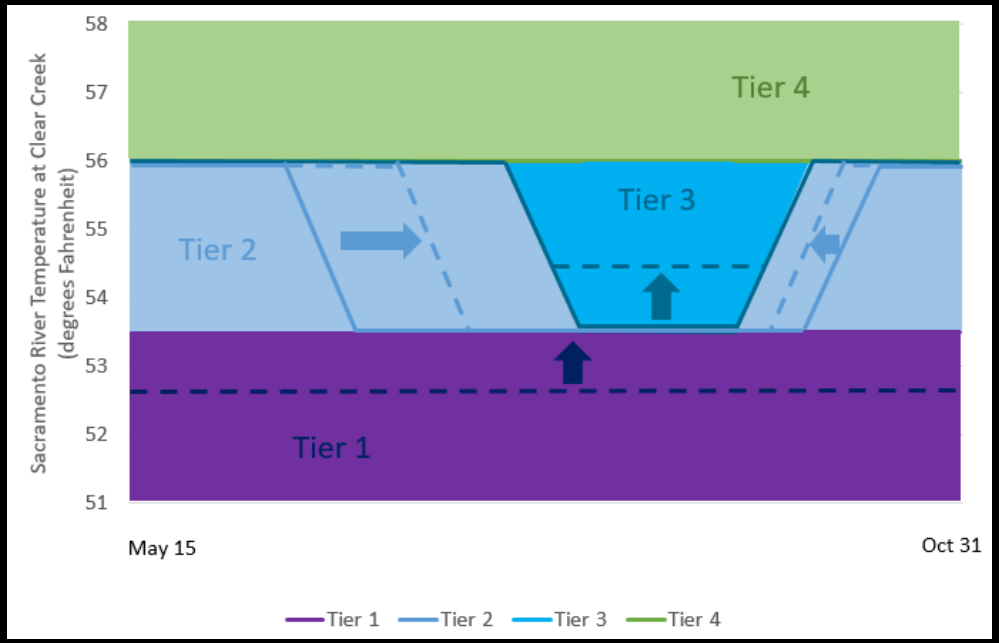


# Key Operating Agreements and Standards related to CWP

- SWRCB Permits and Conditions - Water Rights Order 90-5, 91-1
  - Water Rights Orders that modified Reclamation water rights to incorporate temperature control objectives in Upper Sacramento River and Trinity River
  - Formation of SRTTG
- Central Valley Project Improvement Act – 1992
  - Mandated changes in management of the CVP, particularly for the protection, restoration, and enhancement of fish and wildlife.
- 2000 Trinity River Record of Decision
  - Defined minimum flow regime per year type (370 taf to 815 taf)
- 2019 ROC on LTO
  - NOAA Fisheries (NMFS) Biological Opinion (2019)

# LTO Action for Shasta Cold Water Pool Management

- Summer Cold Water Pool Management
- Commitment to Cold Water Pool Tiers
- Upper Sacramento River Performance Metrics
- Fall and Winter Refill and Redd Maintenance



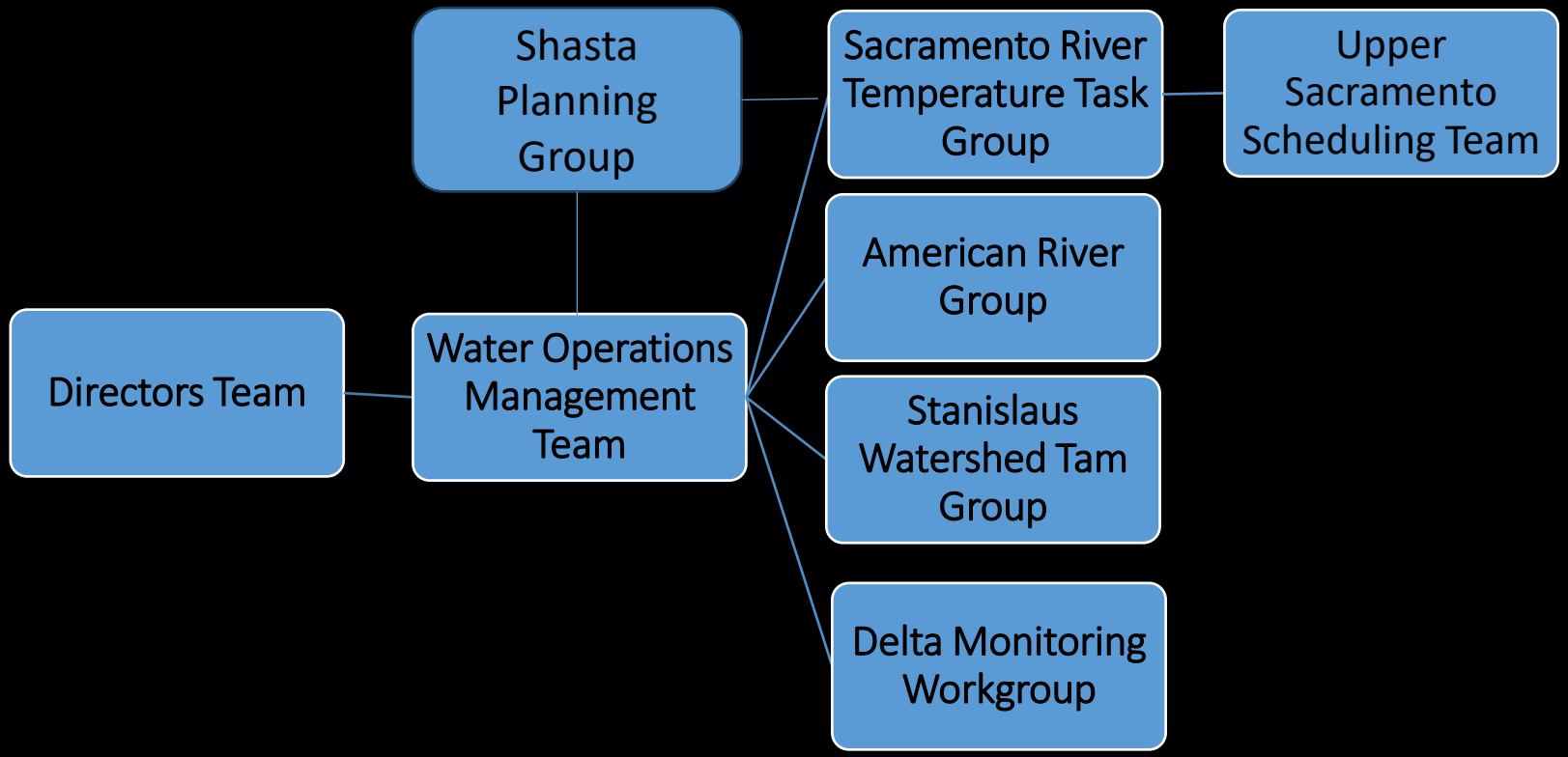
# Operational considerations for temperature management

- Spring pulse operations
- Fall Flow management
- Drought operations
  - Warm water bypass
  - Temporary urgency change petition
  - Diversion shifting
  - Senior water right coordination

# Coordination

- Department of Water Resources : Project Operator
- State Water Resources Control Board : Regulator
- U. S. Fish and Wildlife Service : Regulator
- State Department of Fish and Wildlife: Regulator
- National Marine Fisheries Service : Regulator
- U. S. Army Corps of Engineers : Project Operator/Regulator
- Western Area Power Administration : Transmission and Power Marketing
- Local System Operators: Project Operators
- Various Stakeholders

# Decision-Making Organizational Chart



# Sacramento River Temperature Task Group

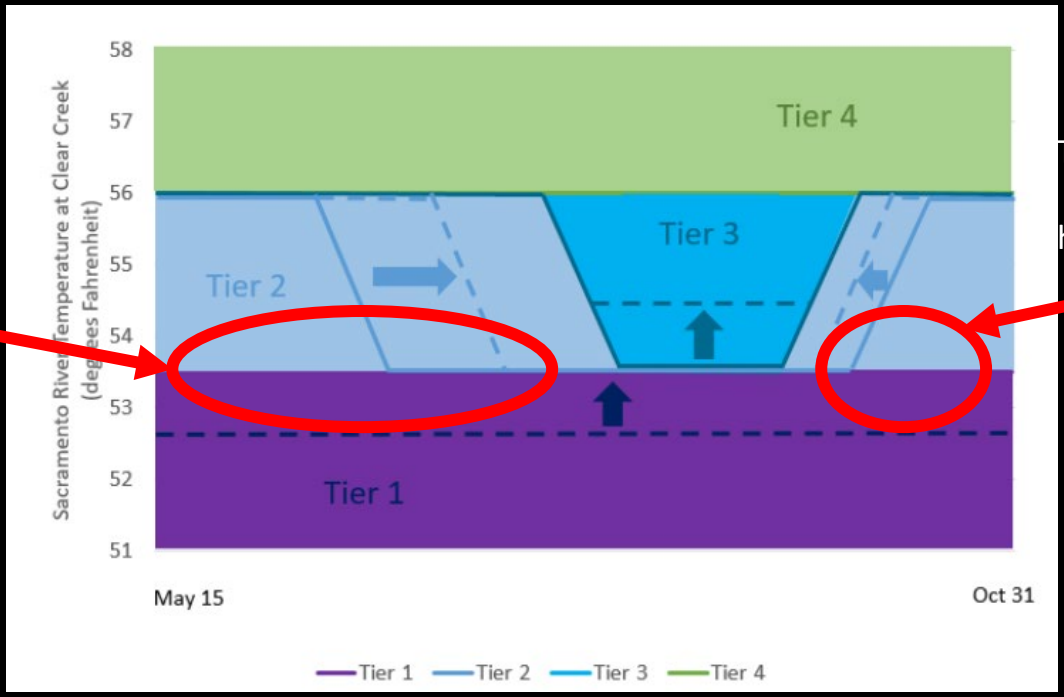
- Coordinates temperature management operations
- Develops seasonal temperature management plan
- USST subgroup
  - Spring pulse
  - Fall rampdown

# Current Risk-Informed Analysis

- SRTTG considers risk:
  - Temperature thresholds at various locations
  - Uncertainty using different runoff and meteorological exceedances
  - Alternatives/tradeoff analysis
  - Performance measures
    - Dates/duration of lowest selective withdrawal configuration
    - Cold water pool volume at select months
    - Biological considerations

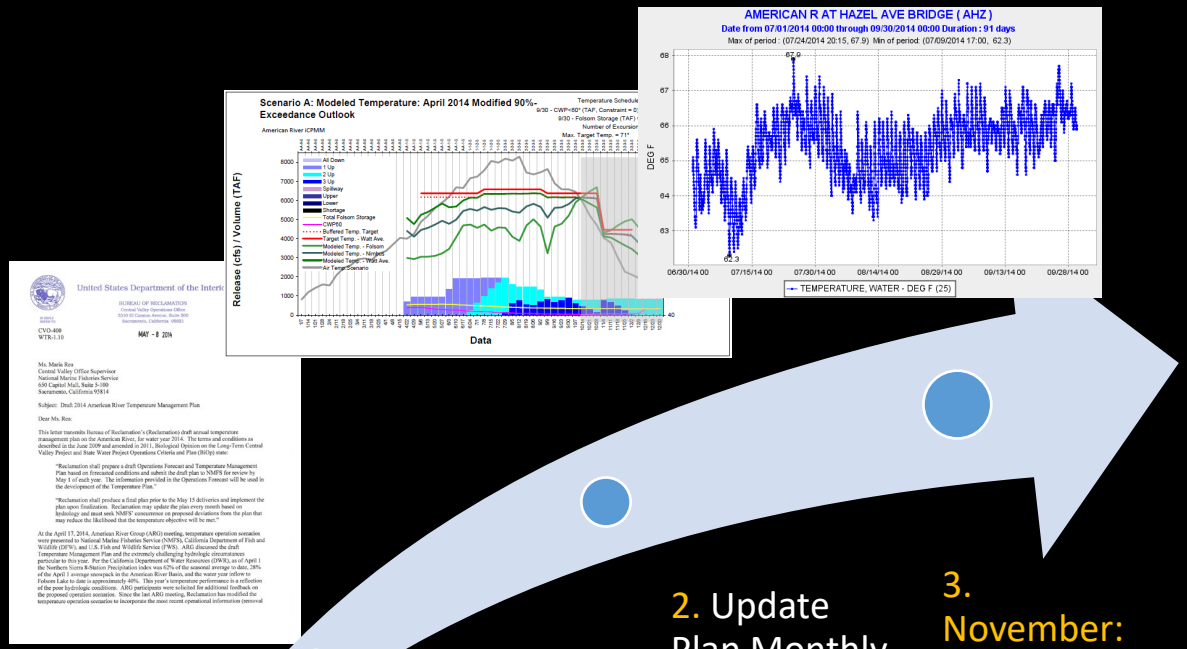
# A tiered approach when cold water is scarce improves egg incubation by focusing protections on critical egg stages.

Smaller egg masses have a lower dissolved oxygen demand.




The development of gills reduces the need for higher dissolved oxygen.

# Temperature Management Process




1. May: Temperature Management Plan

2. Update Plan Monthly

3. November: Complete Season

# Developing the temperature management plan usually begins with a forecast of operations

- TMP reflects storage, releases, diversions…

**Estimated CVP Operations 50% Exceedance**

### Storages

**Federal End of the Month Storage/Elevation (TAF/Feet)**

| Facility | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Trinity** | 1958 | 1987 | 2031 | 2008 | 1913 | 1802 | 1683 | 1633 | 1620 | 1635 | 1698 | 1804 | 1878 |
| Elevation | | 2340 | 2343 | 2341 | 2335 | 2327 | 2318 | 2314 | 2313 | 2314 | 2319 | 2327 | 2332 |
| **Whiskeytown** | 219 | 238 | 238 | 238 | 238 | 238 | 238 | 206 | 206 | 206 | 206 | 206 | 206 |
| Elevation | | 1209 | 1209 | 1209 | 1209 | 1209 | 1209 | 1199 | 1199 | 1199 | 1199 | 1199 | 1199 |
| **Shasta** | 4194 | 4425 | 4300 | 4088 | 3629 | 3268 | 3044 | 2968 | 3002 | 3131 | 3463 | 3786 | 4046 |
| Elevation | | 1063 | 1058 | 1051 | 1034 | 1019 | 1010 | 1006 | 1008 | 1013 | 1027 | 1040 | 1049 |
| **Folsom** | 708 | 830 | 948 | 950 | 767 | 614 | 552 | 510 | 483 | 474 | 503 | 544 | 733 |
| Elevation | | 452 | 463 | 464 | 446 | 430 | 423 | 418 | 414 | 413 | 417 | 422 | 443 |
| **New Melones** | 2008 | 1958 | 2005 | 2027 | 1970 | 1915 | 1872 | 1822 | 1833 | 1851 | 1886 | 1943 | 2023 |
| Elevation | | 1048 | 1053 | 1055 | 1050 | 1045 | 1040 | 1036 | 1037 | 1038 | 1042 | 1047 | 1054 |
| **Federal San Luis** | 783 | 655 | 485 | 338 | 193 | 126 | 165 | 236 | 391 | 533 | 725 | 874 | 881 |
| Elevation | | | | | | | | | | | | | |
| **Total** | 9870 | 10093 | 10007 | 9650 | 8712 | 7963 | 7555 | 7374 | 7536 | 7829 | 8481 | 9156 | 9766 |

**State End of the Month Reservoir Storage (TAF/Feet)**

| Facility | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Oroville** | 3109 | 3315 | 3536 | 3407 | 2894 | 2416 | 2005 | 1791 | 1725 | 1740 | 1897 | 2248 | 2631 |
| Elevation | | 886 | 900 | 892 | 857 | 819 | 783 | 762 | 755 | 757 | 773 | 805 | 837 |
| **State San Luis** | 522 | 475 | 366 | 316 | 478 | 637 | 863 | 980 | 1062 | 1062 | 1063 | 1063 | 1062 |
| Elevation | | | | | | | | | | | | | |
| **Total San Luis (TAF)** | 1305 | 1130 | 851 | 655 | 671 | 763 | 1028 | 1216 | 1453 | 1596 | 1788 | 1937 | 1943 |
| Elevation | | 465 | 437 | 416 | 418 | 428 | 456 | 473 | 495 | 508 | 524 | 536 | 536 |

**Monthly River Releases (TAF/cfs)**

| Facility | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Trinity** | | 161 | 215 | 107 | 45 | 53 | 52 | 23 | 18 | 18 | 18 | 17 | 18 |
| cfs | | 2,700 | 3,500 | 1,800 | 735 | 857 | 870 | 373 | 300 | 300 | 300 | 300 | 300 |
| **Clear Creek** | | 12 | 18 | 14 | 9 | 9 | 9 | 12 | 12 | 12 | 12 | 11 | 22 |
| cfs | | 200 | 291 | 242 | 150 | 150 | 150 | 200 | 200 | 200 | 200 | 200 | 363 |
| **Sacramento** | | 428 | 615 | 535 | 738 | 615 | 476 | 369 | 283 | 277 | 277 | 444 | 615 |
| cfs | | 7200 | 10000 | 9000 | 12000 | 10000 | 8000 | 6000 | 4750 | 4500 | 4500 | 8000 | 10000 |
| **American** | | 238 | 277 | 226 | 282 | 251 | 149 | 123 | 119 | 123 | 123 | 222 | 123 |
| cfs | | 4000 | 4500 | 3800 | 4586 | 4088 | 2507 | 2000 | 2000 | 2000 | 2000 | 4000 | 2000 |
| **Stanislaus** | | 91 | 76 | 54 | 15 | 15 | 15 | 39 | 12 | 12 | 13 | 13 | 12 |
| cfs | | 1537 | 1242 | 900 | 250 | 250 | 250 | 635 | 200 | 200 | 219 | 229 | 200 |
| **Feather** | | 295 | 108 | 190 | 486 | 486 | 497 | 242 | 104 | 108 | 108 | 97 | 65 |
| cfs | | 4960 | 1750 | 3200 | 7900 | 7900 | 8350 | 3930 | 1750 | 1750 | 1750 | 1750 | 1065 |

**Trinity Diversions (TAF)**

| Facility | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Carr PP** | | 0 | 14 | 28 | 69 | 70 | 69 | 38 | 25 | 24 | 1 | 7 | 55 |
| **Spring Crk. PP** | | 0 | 10 | 20 | 60 | 60 | 60 | 60 | 20 | 27 | 23 | 40 | 70 |

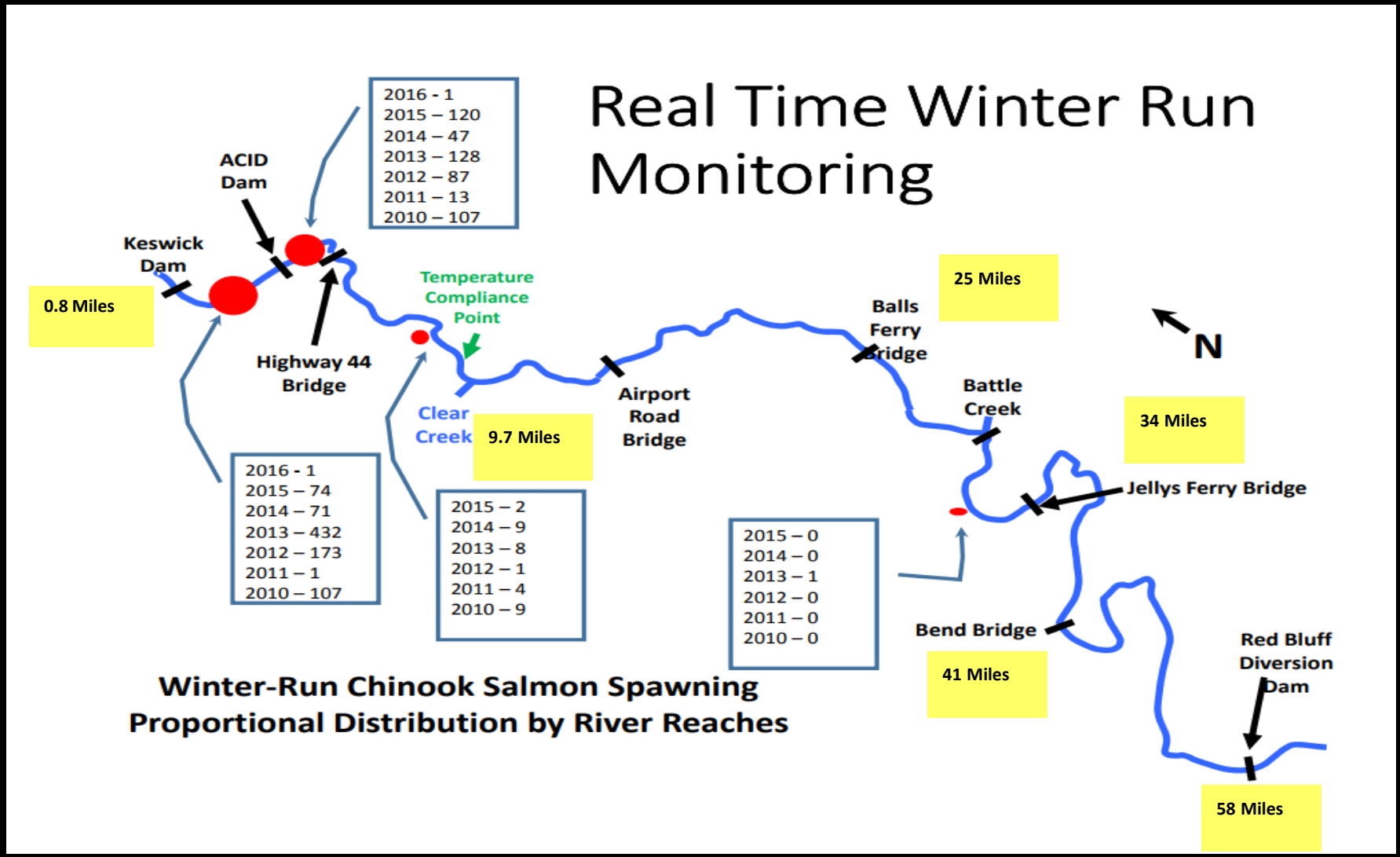
**Delta Summary (TAF)**

| Facility/Location/Metric | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tracy** | | 57 | 138 | 252 | 269 | 260 | 260 | 213 | 243 | 200 | 245 | 240 | 112 |
| **USBR Banks** | | 0 | 0 | 0 | 20 | 20 | 20 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Contra Costa** | | 12.7 | 12.7 | 9.8 | 11.1 | 12.7 | 14.0 | 14.0 | 16.0 | 18.0 | 14.0 | 14.0 | 12.7 |
| **Total USBR** | | 70 | 151 | 262 | 300 | 293 | 294 | 227 | 259 | 218 | 259 | 254 | 125 |

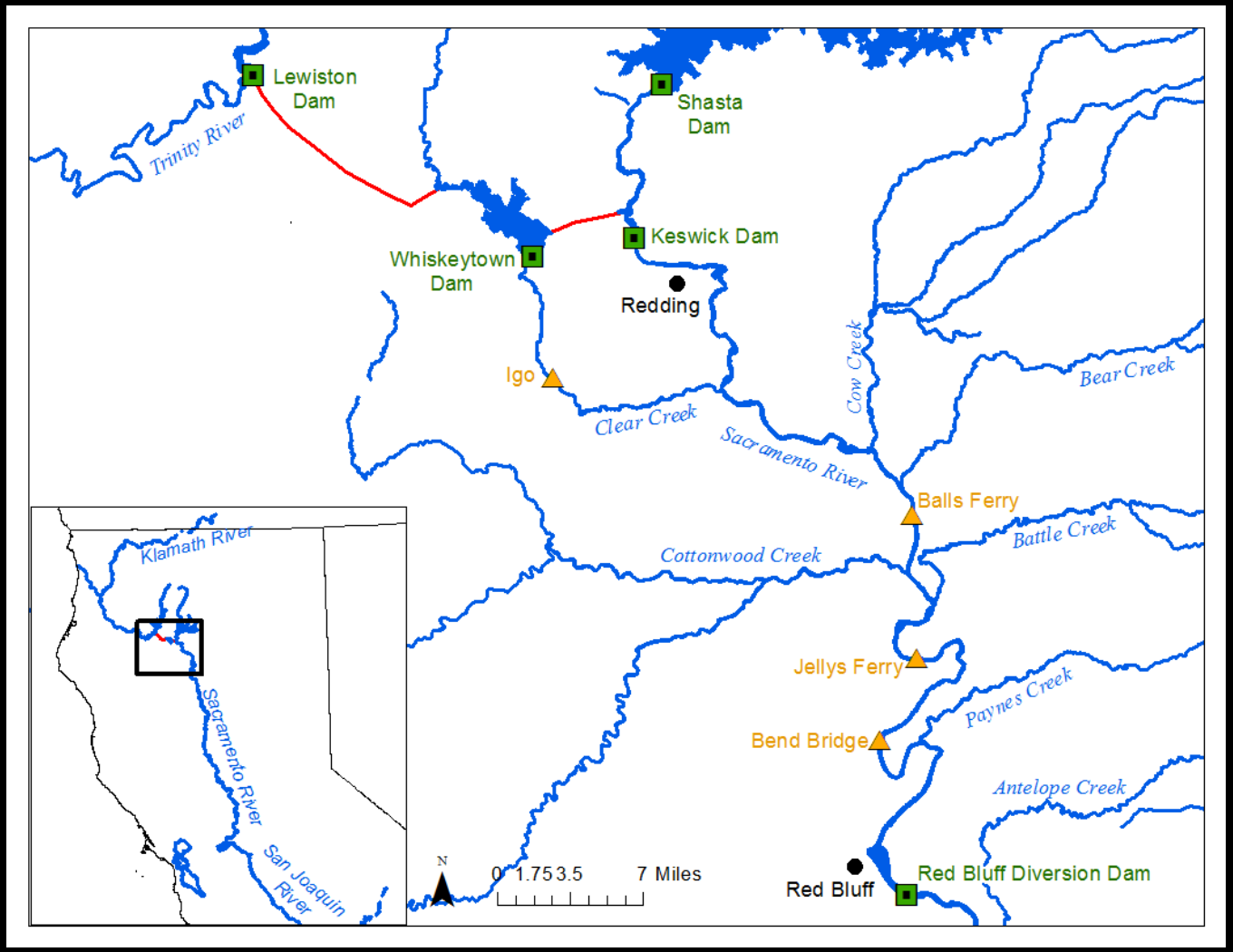
# Uncertainties

- Forecasts
  - Inflows (90% exceedance)
  - Accretions and depletions
  - Delta water quality
- Meteorology (25% exceedance)
- Reservoir stratification
- Facility capabilities/outages
- Modeling

# Sacramento River Temperature Compliance



# Trinity & Shasta temp. stations




CDEC Stations

KWK - 0.8 mi.

SAC - 4.8 mi.

CCR - 10 mi.

AND - 18 mi.

BSF - 25 mi.

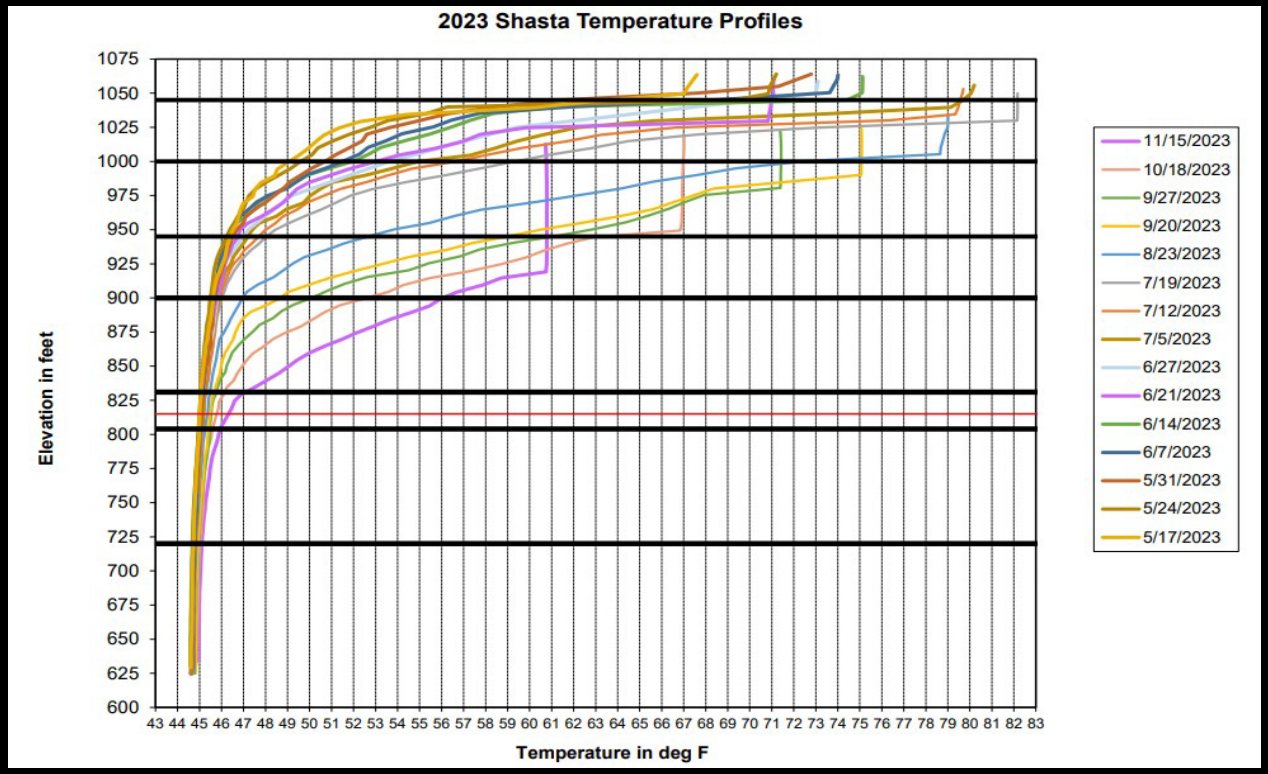
JLF - 34 mi.

SBB (BND) - 41 mi.

RDB - 58 mi.

# Monitoring Lake Profiles

| | Every Month | Every Two Weeks | Every Week |
|---|---|---|---|
| Shasta | Jan, Feb, Dec | Mar, Apr, Nov | May to Mid Nov |



# Metrics to evaluate operations

Table 4. Fish and water performance metrics from biological modeling (Attachment 5)

| Metric | No Pulse Flow Scenario | With Pulse Flow Scenario |
|---|---|---|
| Stage-independent TDM | 3.4% | 9.9% |
| Stage-dependent TDM | 0.4% | 0.8% |
| End of Sept CWP Storage less than 56 deg F (TAF) | 502 TAF | 381 TAF |
| First Side Gate Use | July 31 | July 31 |
| Full Side Gate | August 26 | August 22 |
| End of September Storage (MAF) | 2.69 MAF | 2.55 MAF |

# Metrics to evaluate salmonids

Table 4. Fish and water performance metrics from biological modeling (Attachment 5)

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Questions?
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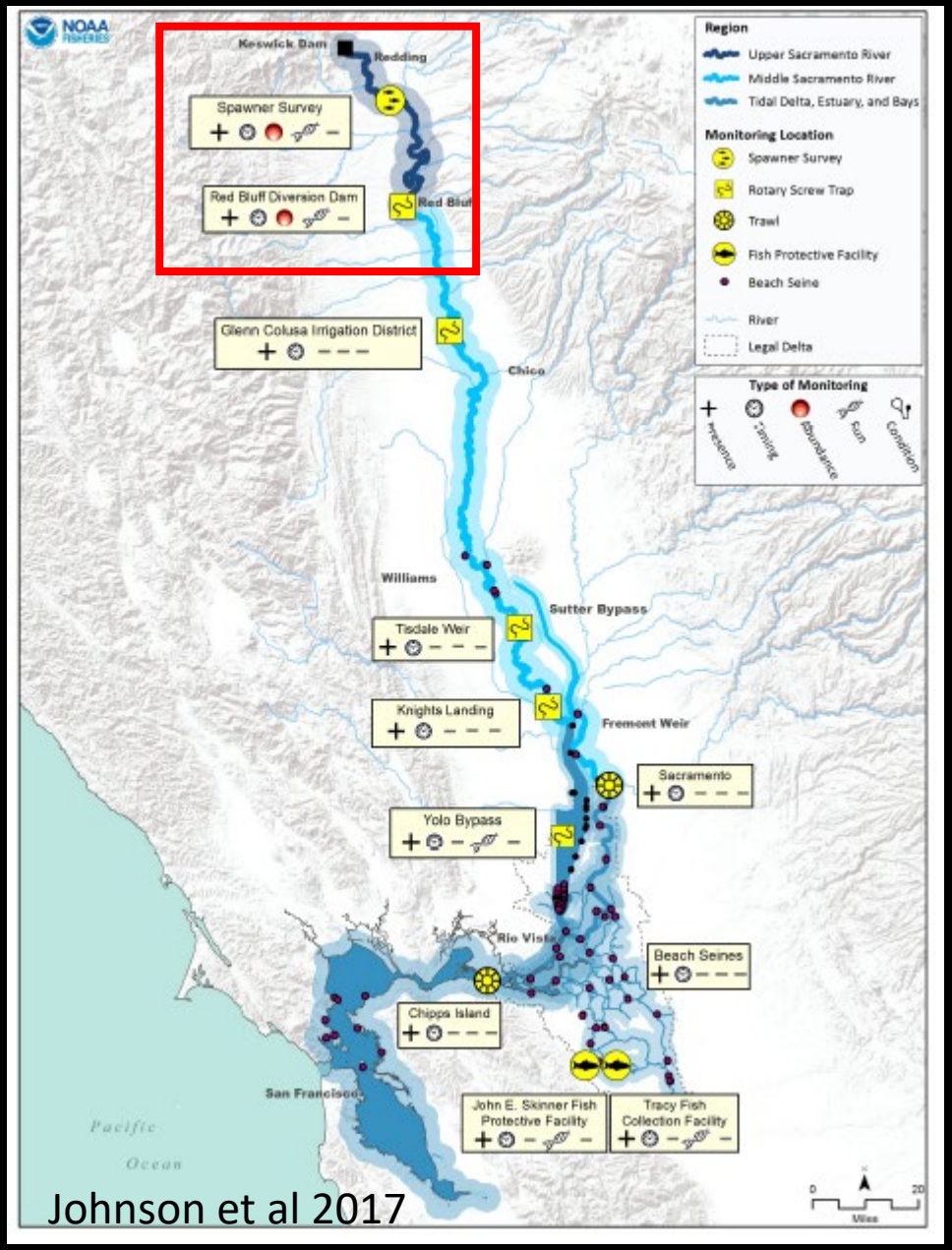
# Monitoring Relevant to Shasta Cold Water Pool Management



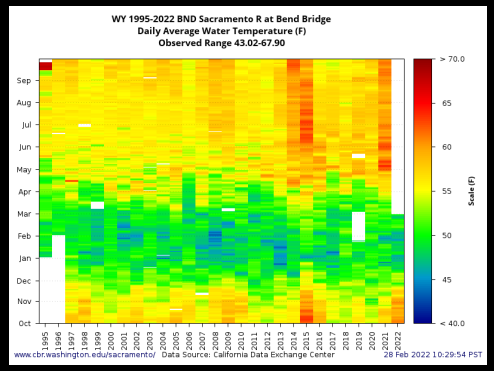

Johnson et al 2017

# Upper Sacramento River Salmon Monitoring

# Real–Time Operation Monitoring

- Flow & temperature in CVP tributaries and mainstem
- Shasta Reservoir temperature profiles
- Redd construction timing and location
- Abundance of juvenile salmonids
- Timing of juvenile outmigration





# Real-time biological monitoring

- Carcass and redd surveys
  - Redd timing and location
    - Used for initiation and location of temperature control point
  - Redd dewatering
  - Used in older versions of the JPE (pre-2015)

- Acoustic telemetry
  - Riverine outmigration timing and survival
  - Used in recent versions of JPE ( post-2015)

# Status and Trend monitoring

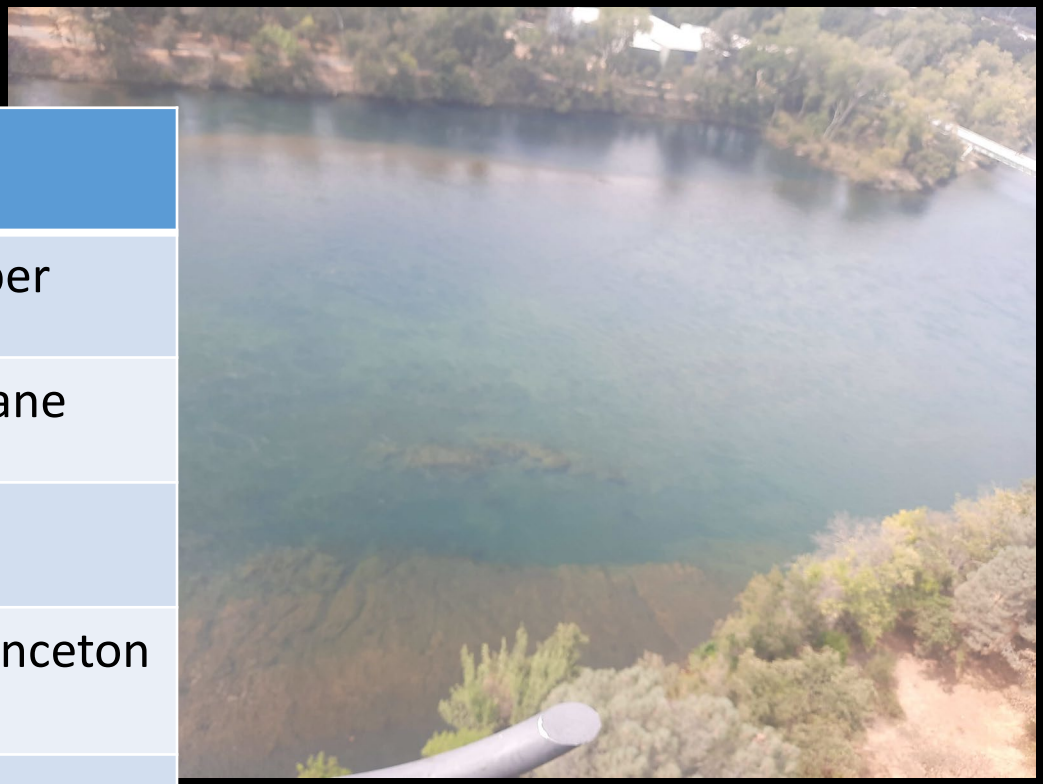
- Carcass and aerial surveys
  - Estimate of adult escapement
- Juvenile stranding surveys
  - Estimate of stranded juveniles
- Juvenile Production Index
  - Used in more recent versions of the JPE.
- Acoustic telemetry
  - Seasonal survival estimates

# U Sacramento adult Chinook salmon monitoring

| Characteristics | Methodology |
|---|---|
| **Season** | year round |
| **Method** | Boat-based Cormack-Jolly-Seber (since 2011) |
| **Freq of survey** | 3-day surveys/ week |
| **Location** | Keswick to Balls Ferry |
| **Collection of biological samples?** | Fin clips subsampled, histo and path samples when special study need. |

Source: Killam 2023

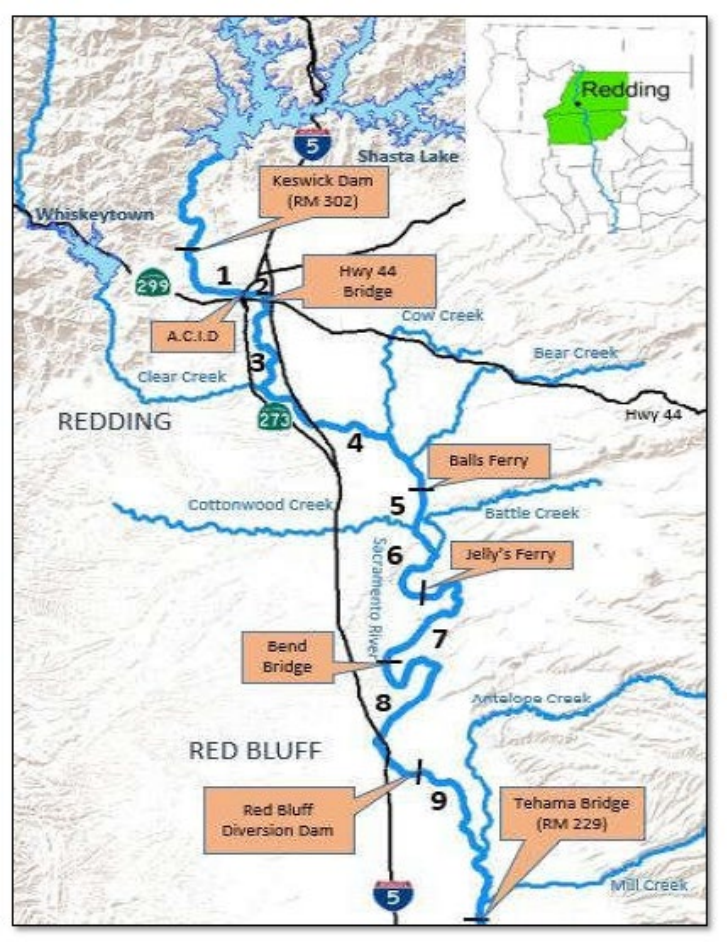

# Aerial redd surveys expand population estimate



| Characteristics | Methodology |
|---|---|
| **Season** | May-September |
| **Method** | Helicopter/plane |
| **Freq of survey** | ~biweekly |
| **Location** | Keswick to Princeton (~140mi) |
| **Collection of biological samples?** | No |

Source: Killam 2023

# Salmon redd dewatering surveys




- Extent = aerial surveys
- Measure “at risk” redds
- Remeasure with flow reductions
- Track redd emergence date
- Post weekly data for estimating number of dewatered redds

# Juvenile stranding surveys

- Extent = downstream to Tehama Bridge
- Rescues attempted
- Depletion method used to estimate number of stranded fish

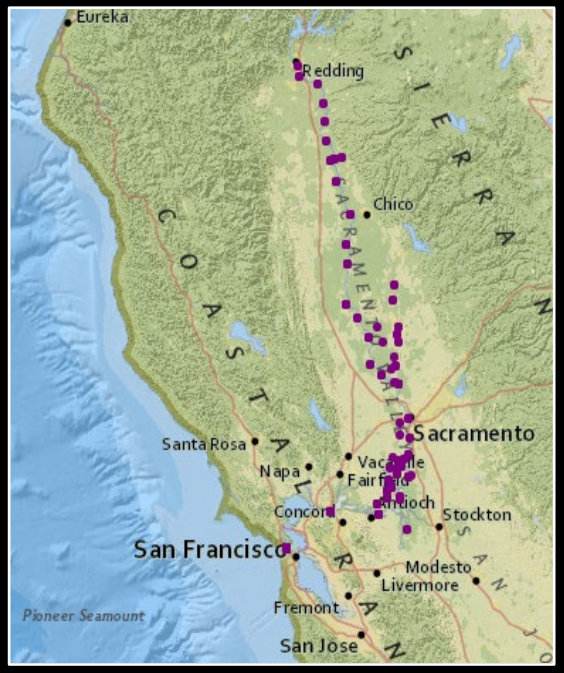
# Red Bluff rotary screw trap Juvenile Production Index

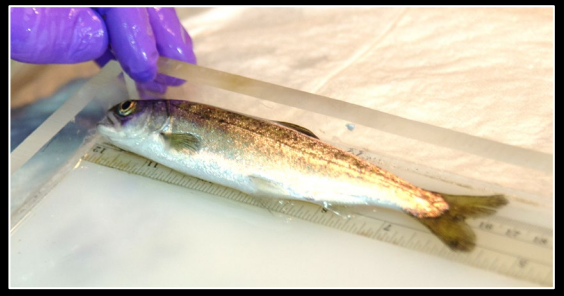
| Characteristics | Methodology |
|---|---|
| **Trapping Season** | January – December |
| **Aver. Trap efficiency** | 3.17% fry, 2.11% larger juveniles |
| **Freq of trials** | 0-15 trial/year |
| **Fish releases per trial** | 800-1200 fish/trial |
| **Multiple size classes used for trials** | No |
| **Sampling gaps?** | Safety stoppage for weather and other challenges (typically less than 3 days) |
| **Collection of biological samples?** | Fin clips subsampled, histo and path samples when special study need. |
| **Precision/accuracy for fall-run Chinook** | +/- 35% |

Source: Poytress et al 2014, Poytress Pers Comm

# Interagency Telemetry Program

calfishtrack



<u>Interagency Telemetry Advisory Group (started 2017):</u>

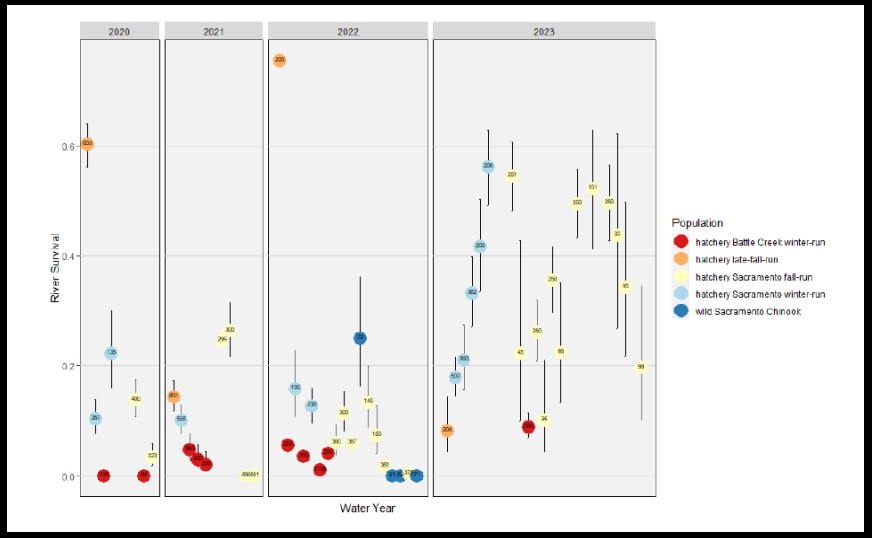
- Multi-agency collaboration
- systemwide telemetry receivers
- Open data platform

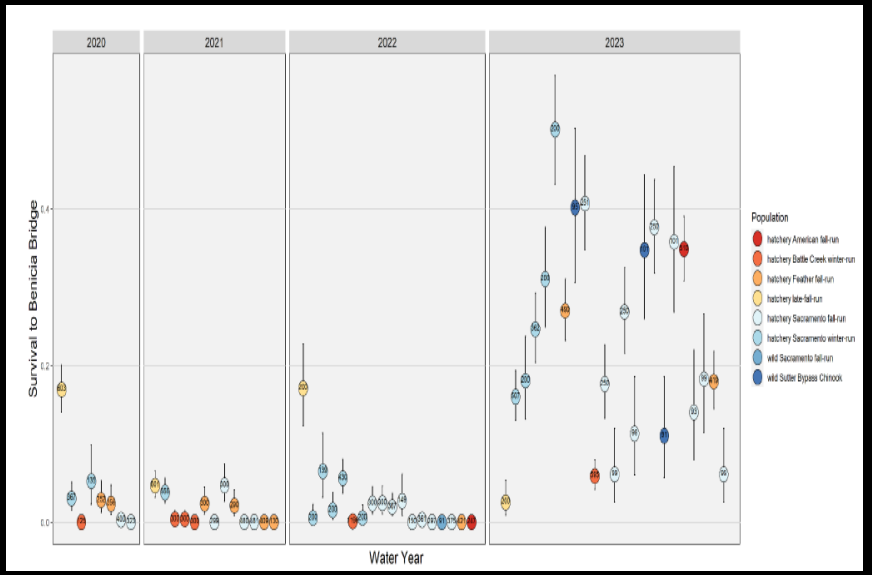
<u>Web-based real-time project reporting</u>:

- Biological summary
- Real-time detections
- Reach-specific survival
- Detection statistics

# WY23 Telemetry studies

| Characteristics | Source: Cordoleani et al 2024 |
|---|---|
| Tagged fish | 8,571 |
| Species | Winter, spring, fall, late fall-run Chinook; steelhead, green sturgeon |
| Real-time receiver deployed | 14 locations |
| Real-time receiver detection rates | 90-99% |
| Autonomous receiver deployment | 675 |
| Autonomous receive detection rates | 71-97% |



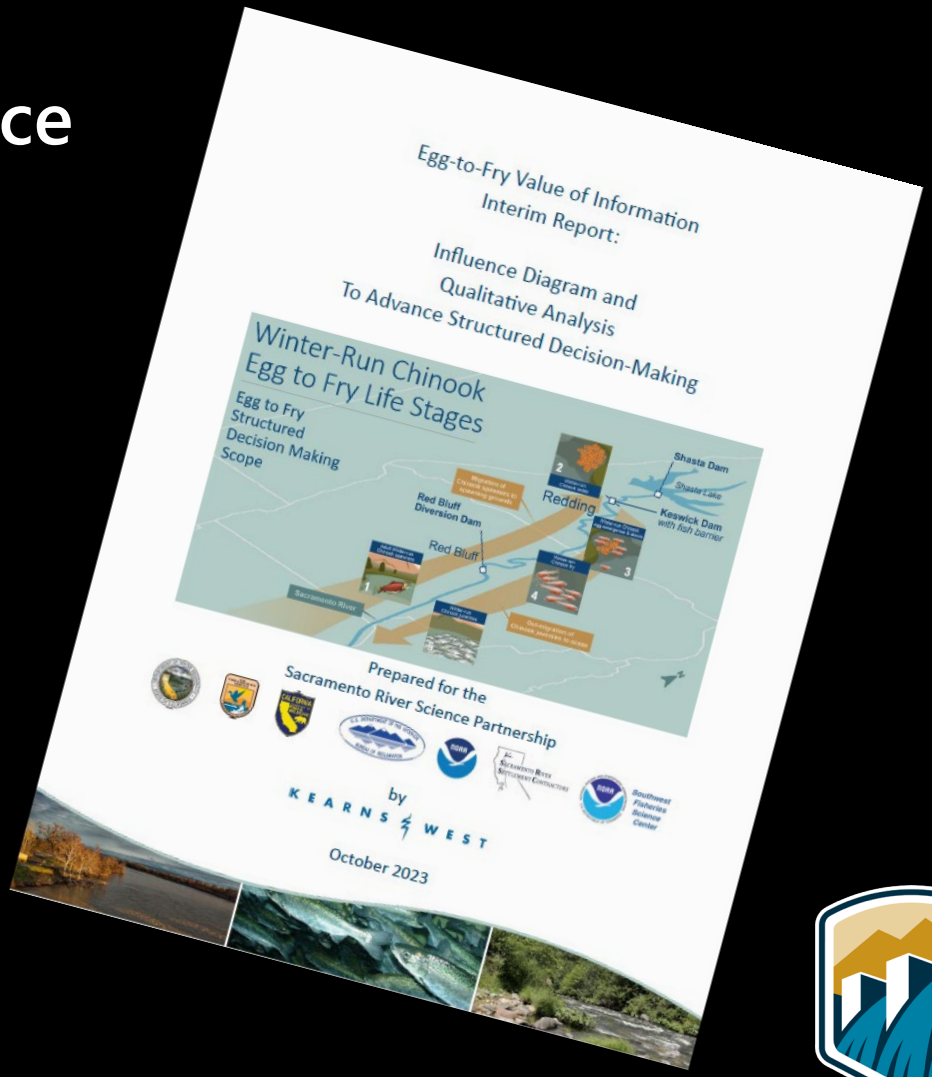
# Special Studies

- Riverine food web investigations
- Habitat restoration effectiveness
- Observational and field study updates to structured decision model
- Sacramento River Science Plan topics



# Advancements for Upper Sac studies

- Sacramento River Science Partnership
  - Egg to fry survival
  - Juvenile production
  - Redd dewatering



# Upper Sacramento River Fish Reporting and References


- Spawning information on CALFISH.org
- SacPAS – Rotary screw trap
- Reported at SRTTG and USST
- [Sacramento River Temperature Task Group | BDO | Area Offices | California-Great Basin | Bureau of Reclamation (usbr.gov)]
- Additional presentations on Sacramento River Science Partnership webpage

# Questions?

Thank you!

ebuttermore@usbr.gov
jaisrael@usbr.gov

BUREAU OF RECLAMATION

BUREAU OF RECLAMATION

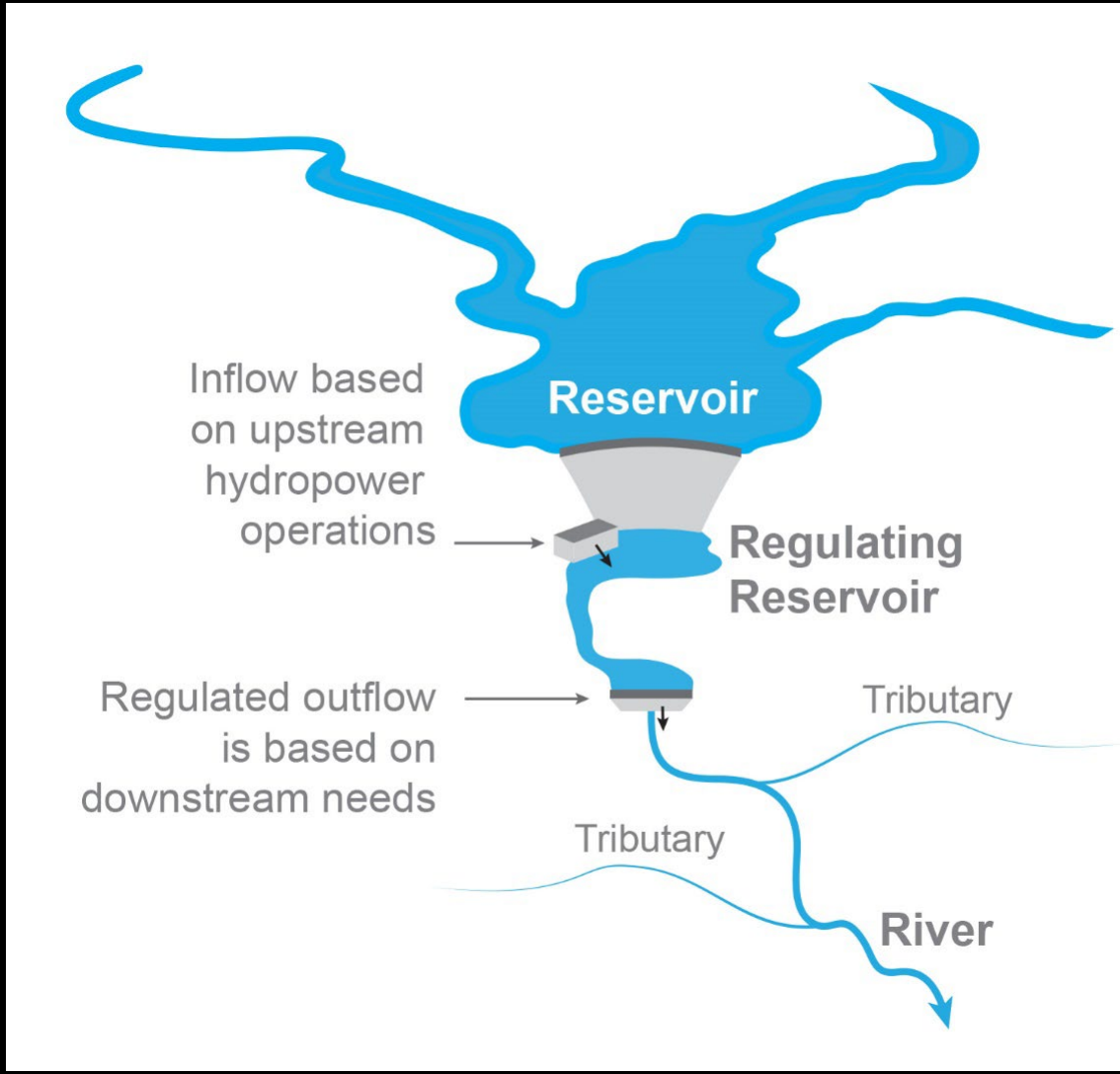
# Modeling relevant to Shasta Cold Water Pool Management

# HEC-5Q

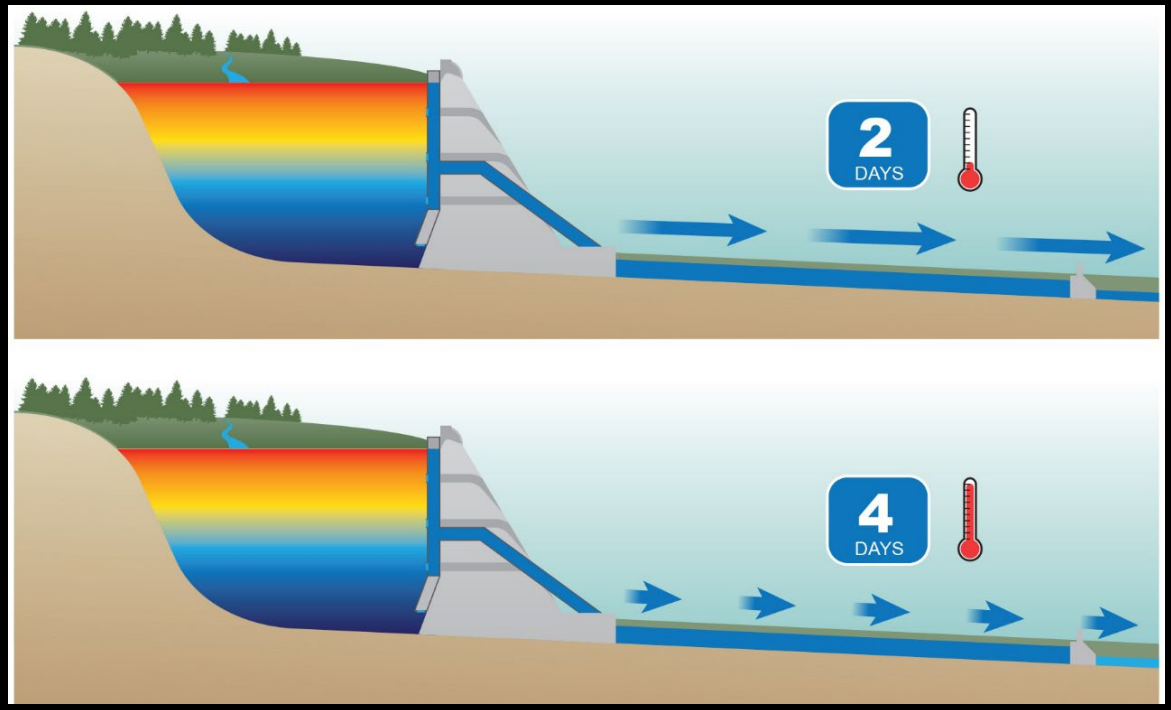
- Input
  - Flows (operations)
  - Initial Profile
  - Forecasted Meteorology
  - Target Shasta release temperature

- Output
  - Temperature at downstream points
  - Lake profiles
  - TCD operations
    - Side gates

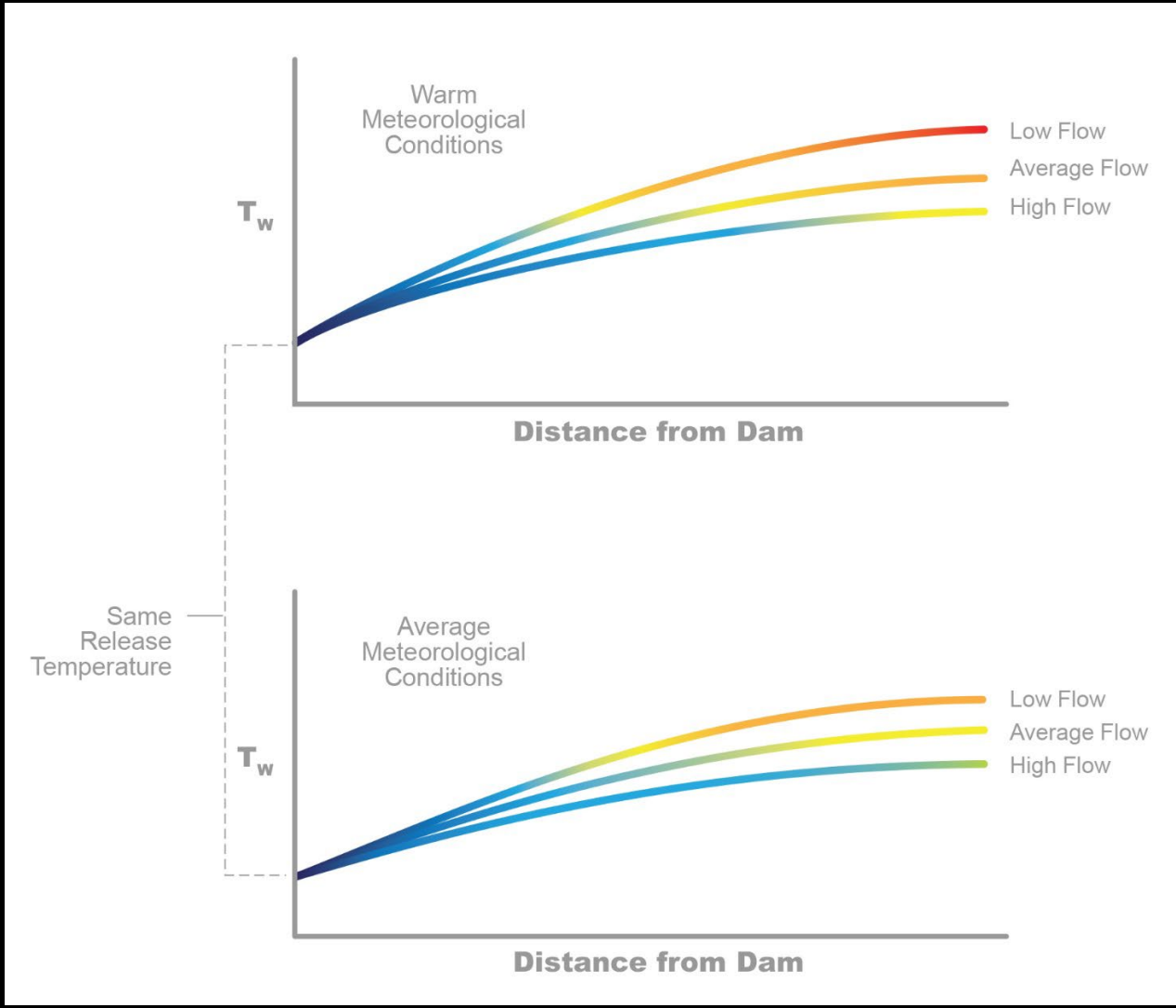
# Reservoir and Regulating Reservoir



# Regulating Reservoir Residence Time

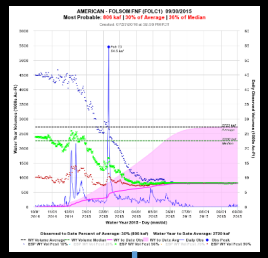


# River Flow Heat Gain

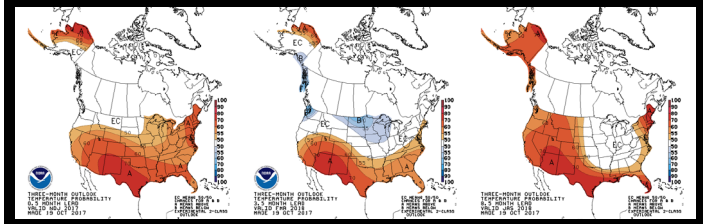


# Temperature Modeling - Seasonal Plan

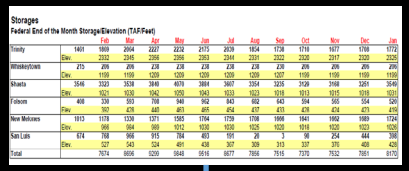
Hydrology Forecasts



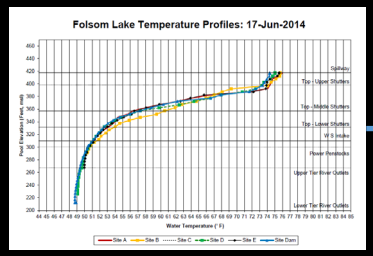
Long-Term Meteorology Forecasts

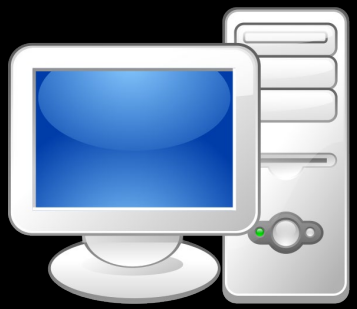


Operation Outlook




Initial Conditions



Temperature Performance

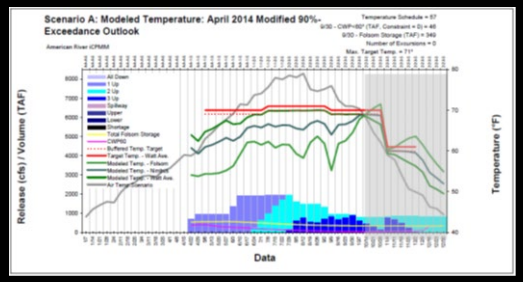


Photo credit: John Hannon, Reclamation

# CVP Water Temperature Modeling Platform (WTMP)

Randi Field, Hydrologic Engineer, CVO, Reclamation

# Vision for WTMP Project

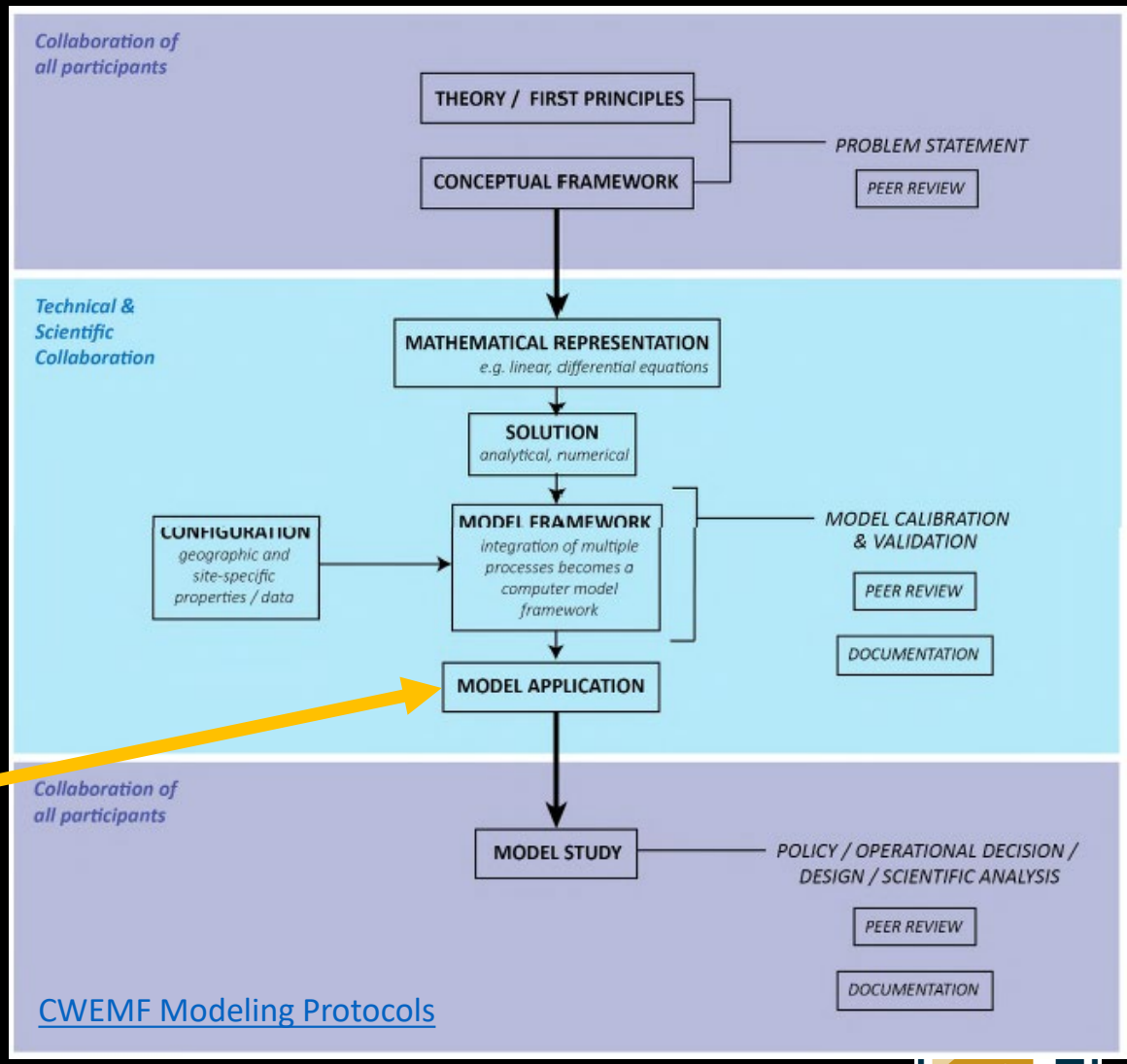
**Goal: Deliver quality products to support Reclamation's mission – predict water temperature to support CVP operations**

- Modernize CVP systemwide water temperature modeling and analytics
- Develop to current professional standards in a transparent fashion
- Consistency: Real-time, seasonal, and long-term planning
- Design for flexibility
- Address uncertainty
- Leverage technological advancements
- Build expertise

# WTMP: Development Effort

(Jan 2022 – Mar 2024)

*WE ARE HERE*

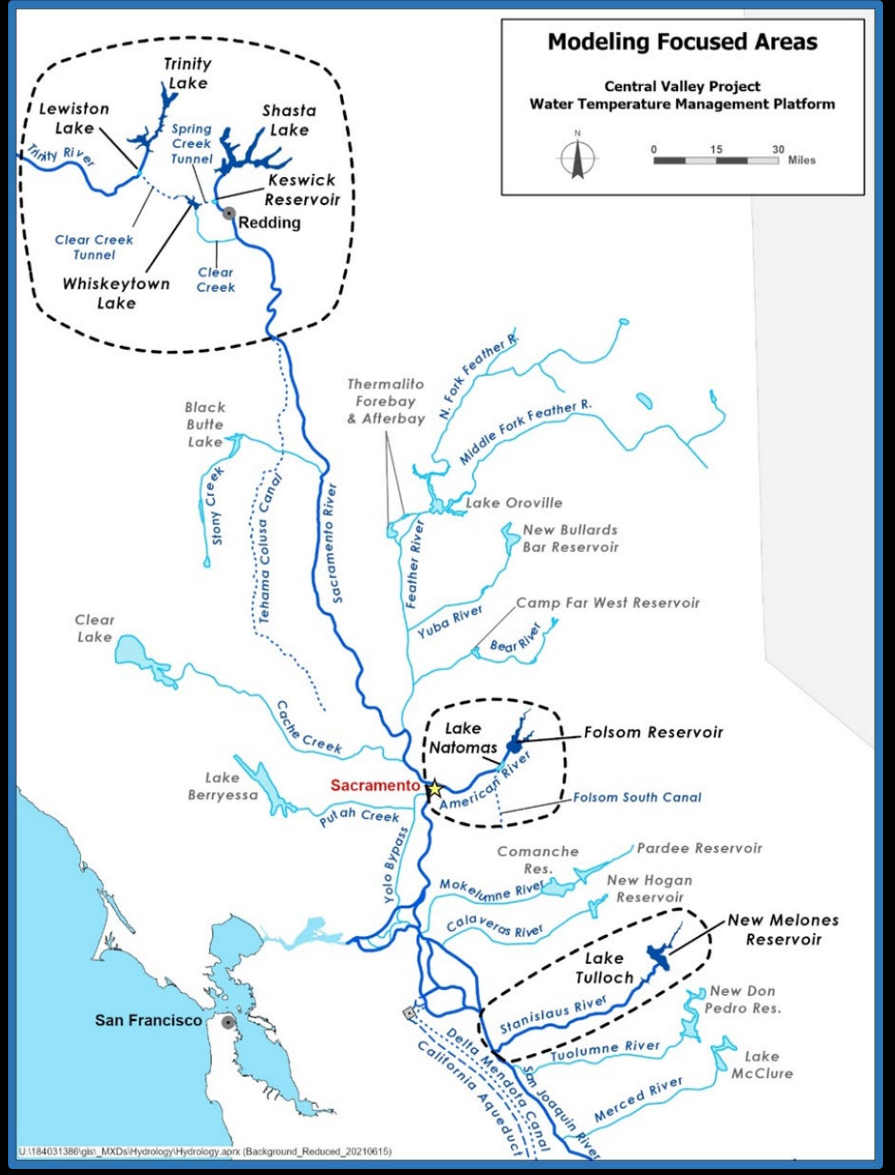


# How does the Development Approach Compare?

| Guidance | WTMP |
| --- | --- |
| Preliminary Analyses | Model and Framework Selections |
| Framing the Modeling Study | Model Configuration, Testing, and Uncertainty |
| Application of the Model | Model Applications (In-Progress) |
| Communicating and Documenting Results | Technical Memoranda |
| Encouraging Collaboration in the Modeling Community | Modeling Technical Committee and Peer Review |

# WTMP Model Domain

- Northern System
- American Basin
- Stanislaus Basin



# Sacramento/ Trinity River System

Trinity Lake to Helena
Whiskeytown to Clear Creek confluence
Lake Shasta to Red Bluff

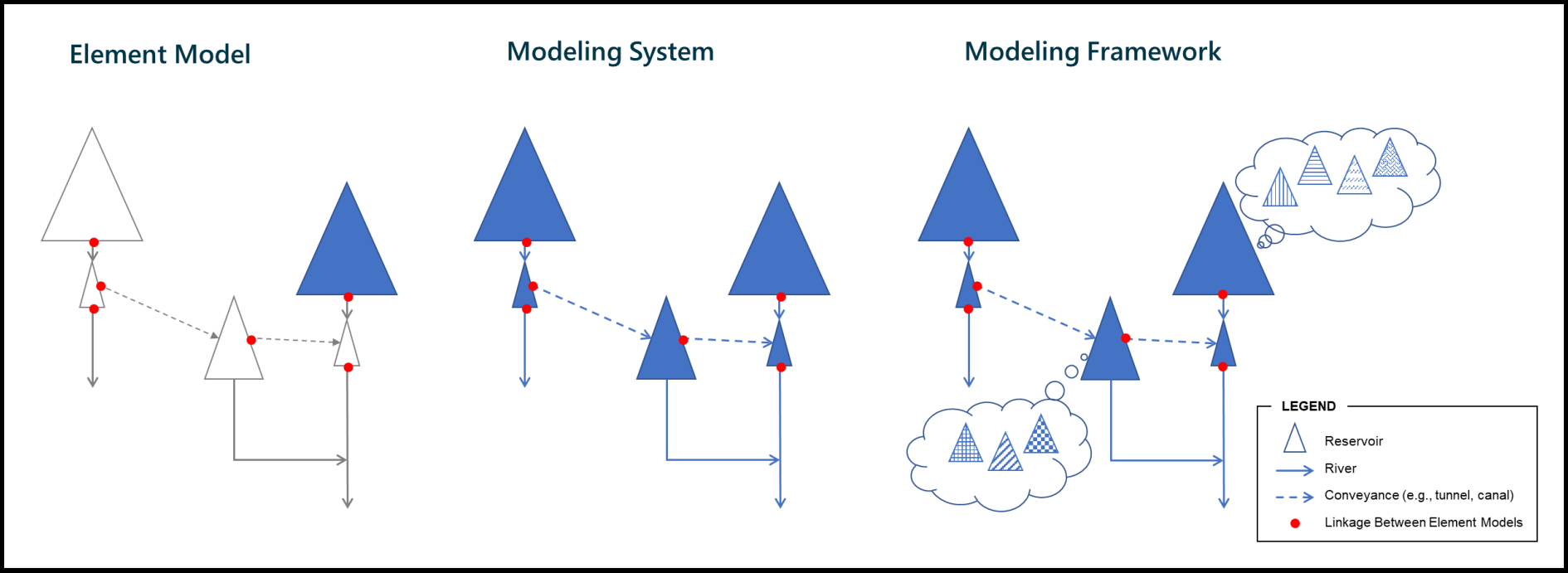
# WTMP Unique Features

| WTMP Items | Highlights of Unique Features |
|---|---|
| Key Code Modifications | Enhanced modeling considerations for unique facility components |
| Model Domain | Consistent with operations which influence downstream water temperature |
| Model Framework | Addresses multi-model simulations/different spatial-temporal scales + uncertainty |
| Data Management System | Improve flexibility for data access and quality of data |
| Communications/Transparency | Quarterly Modeling Technical Committee Meetings/Web access/RISE |

# Collaborative Model Development Approach

- Working hypothesis - Approach fosters:
  - Confidence
  - Transparency and trust
  - Problem solving synergy
  - A better model application
- Modeling Technical Committee (MTC):
  - Consistent engagement
  - Timely project product review as available
  - Constructive input and comments
  - Future user group

# Modeling Flexibility: Element, System, and Framework



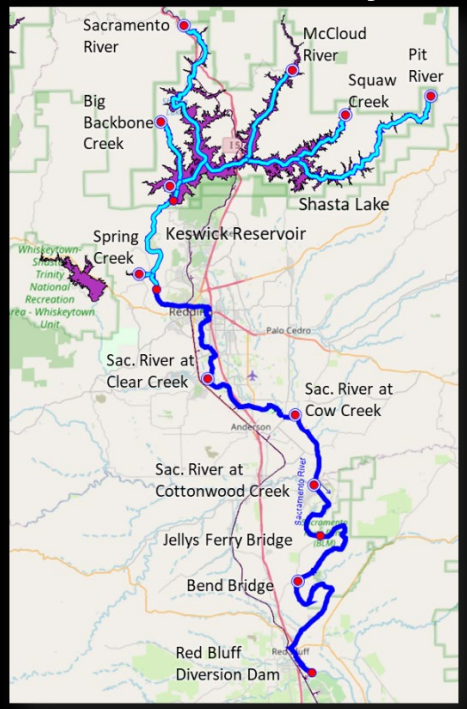

CE-QUAL-W2

HEC-ResSim

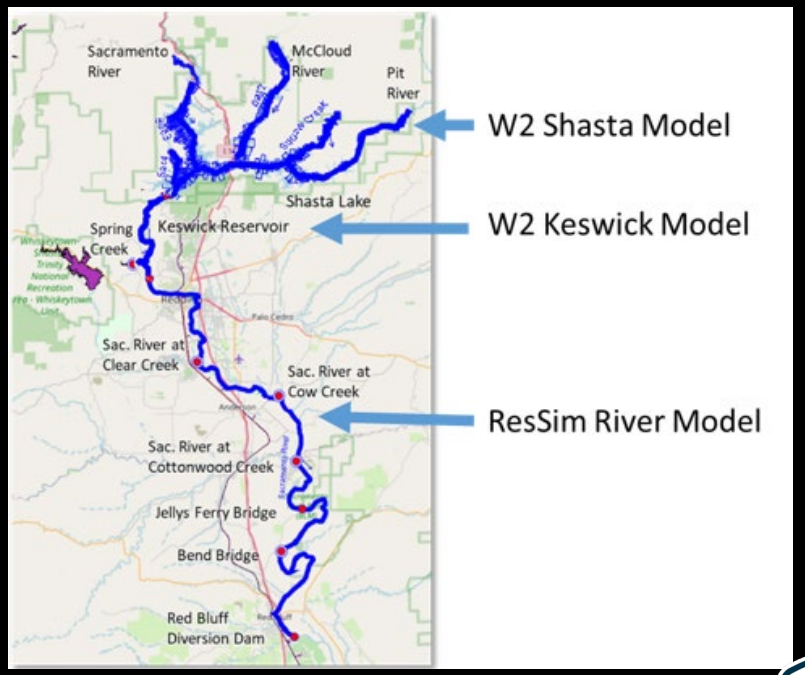
HEC-WAT

# HEC-WAT Framework Using W2 and ResSim

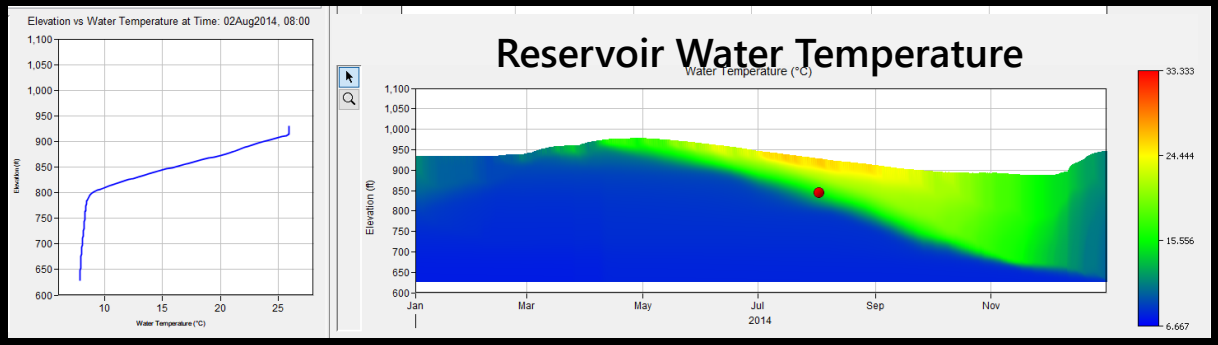
- Shasta-Keswick-Upper Sacramento River
  - ResSim Only

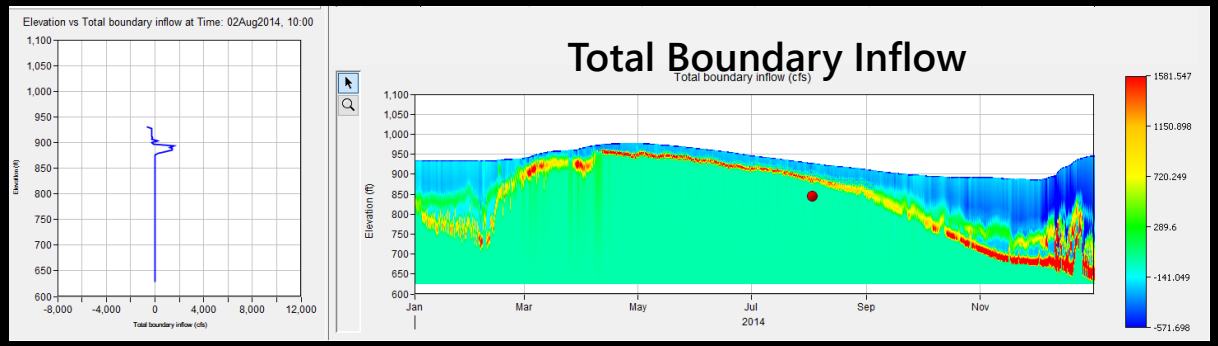


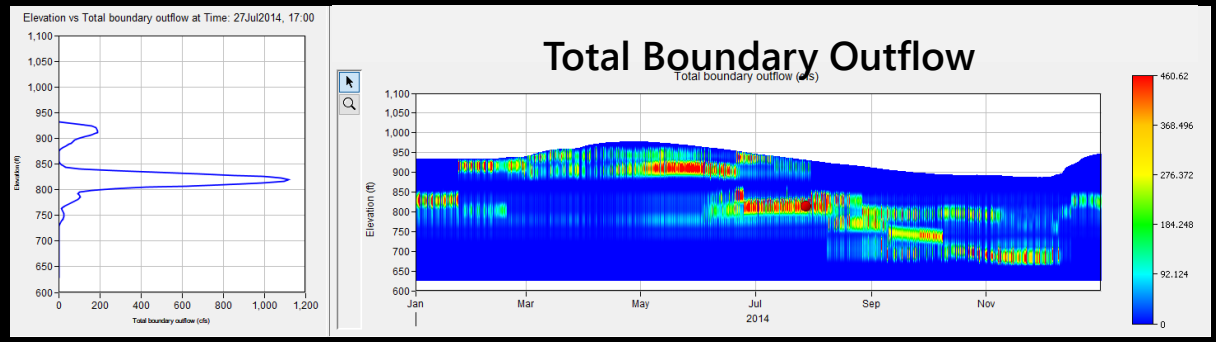

  - Combined W2 and ResSim



# Example Contour Plots for Reservoir Conditions (HEC-ResSim)



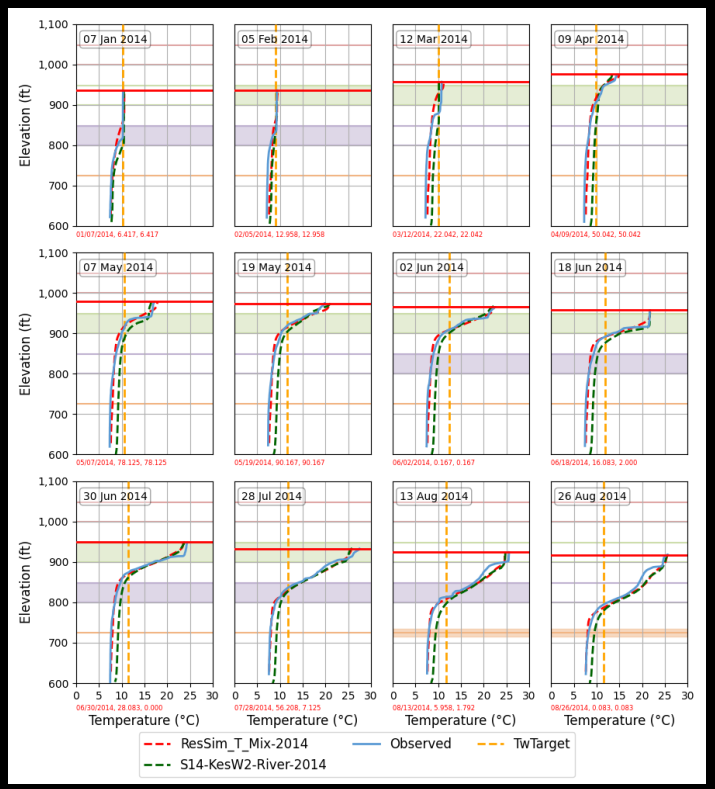



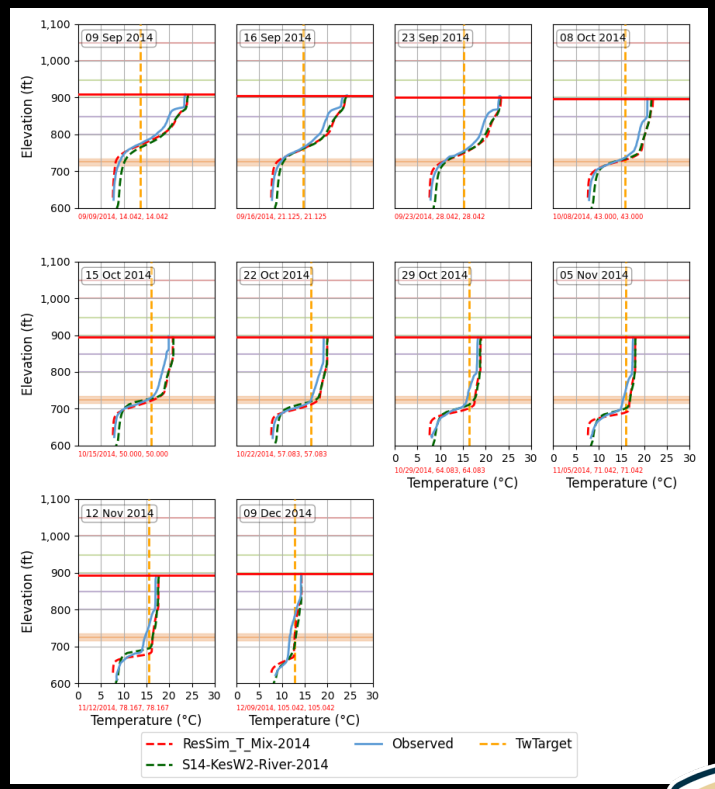



# Automated Plotting and Tabulation of Results

- Rapid creation of key output tables and graphics to facilitate results review by modelers
- Creation of tables and graphics that could be incorporated in other reporting and presentation products

# W2-ResSim Comparison, Shasta Lake Temperature Profiles for 2014

# WTMP - Activities Developing Procedures to Address Uncertainty

- **Identify sources of uncertainty**
  *(e.g., data, models)*
- **Estimate and prioritize uncertainty**
  *(e.g., datasets and models)*
- **Characterize aggregated uncertainty of modeling results**
  *(e.g., forecasts, hindcasts)*
- **Communicate uncertainty**
  *(e.g., forecasts for real-time operational decision-making, hindcasts for learning and strategic investment to improve long-term effectiveness in forecasting)*

# WTMP - Handling Uncertainty in Datasets and Models

Build Models | Test Models

- **Calibration Mode**
  - Quantification of uncertainty associated with the data and parameter estimation was included in calibration (e.g., calibration parameters)
  - Resulting predictive errors were assessed using model performance metrics to determine the fitness and acceptability of the calibrated model.
  - Only calibrated models with acceptable predictive errors are used for applications.

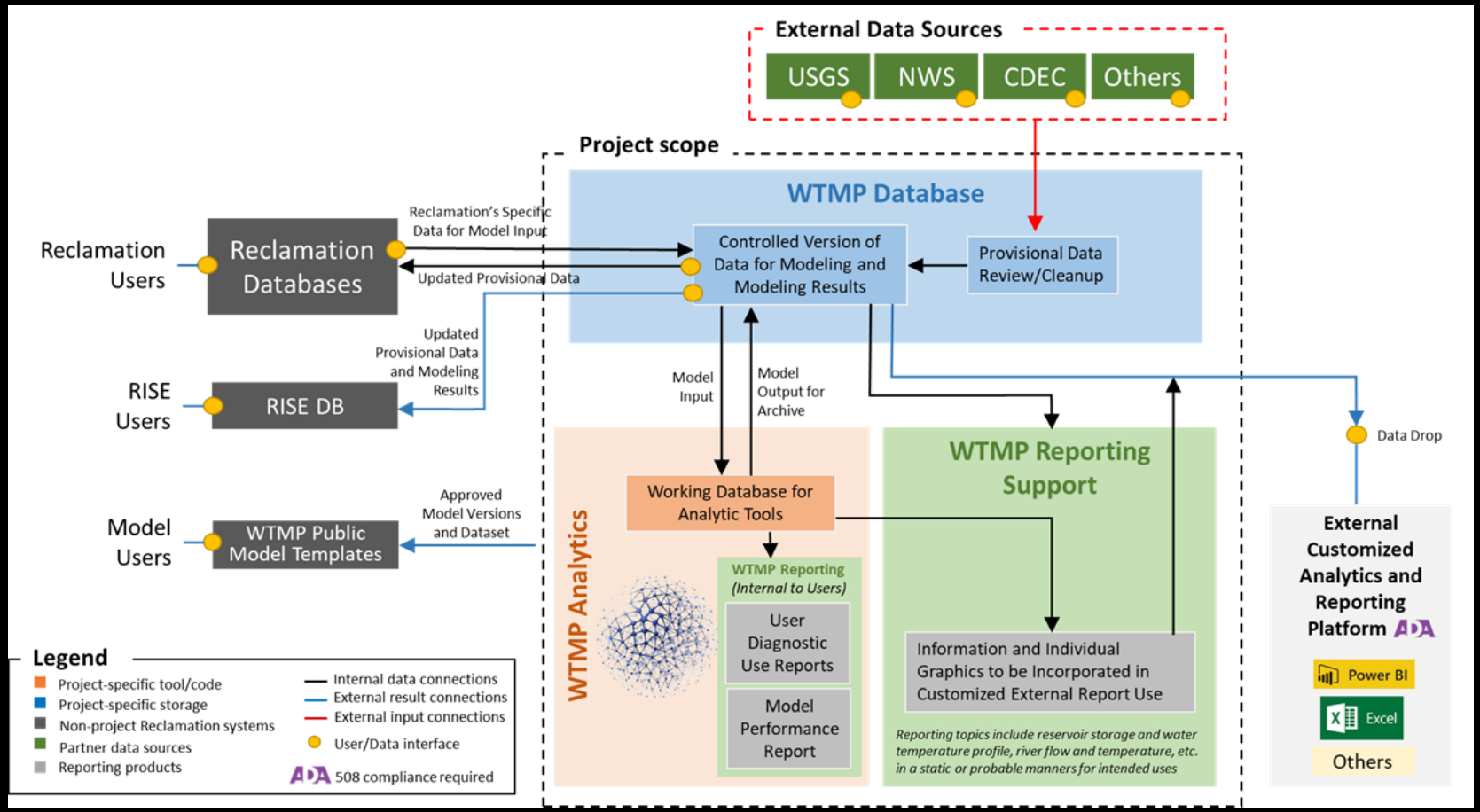
Apply (Calibrated) Models

- **Forecasting Mode**
  - Uncertainty of the calibrated model is accepted as is for contributing the overall uncertainty of model results.
  - Initial and boundary conditions (i.e., data) are the focus for examining uncertainty of the predictive/ forecasting estimates

# WTMP – Integration with Data Management System

- Web-service interface for WTMP data access
- Automated download of
  - "Model Ready" data for boundary conditions
  - Observed data for comparison to model results
- Time series data organized in "templates"
- Elements in models associated with templates

# Water Temperature Modeling Platform Workflow



# Model Development Documentation

- Project Webpage Link:
  - CVP Water Temperature Modeling Platform
- Project Factsheets
- Modeling Tech. Committee Mtgs.
- Technical Memorandums
- Additional References

# WTMP Technical Memorandums

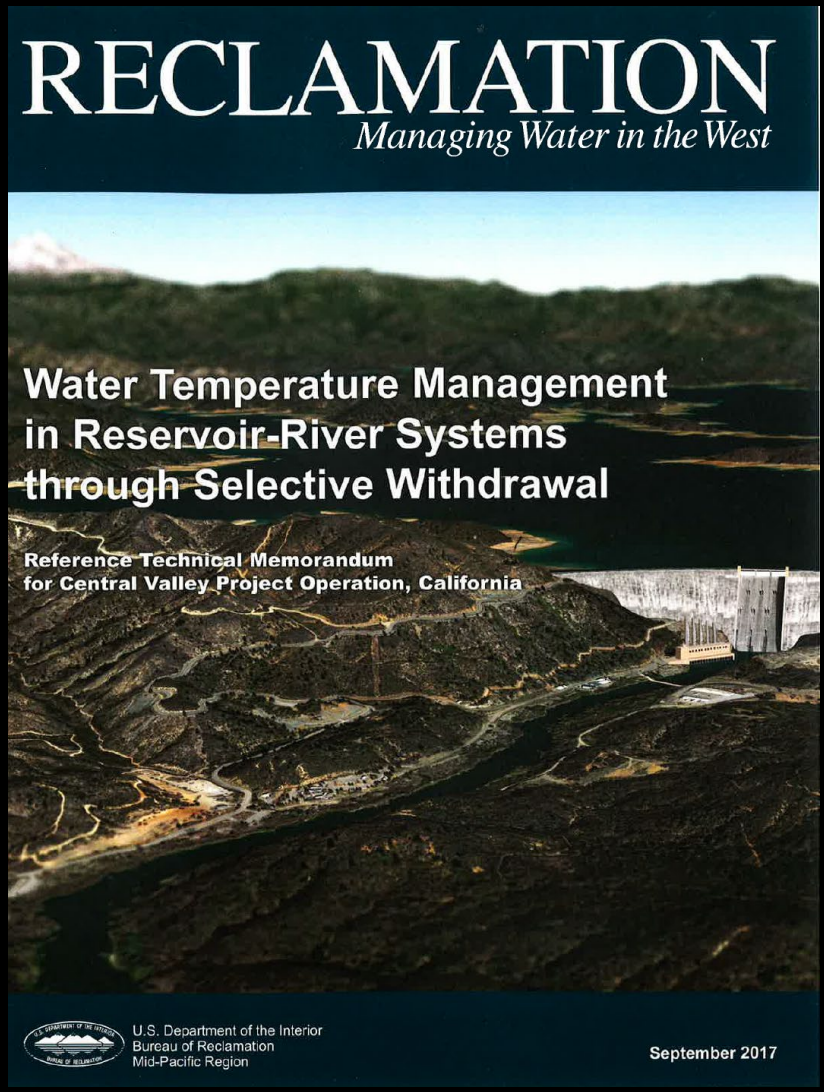
- Model Framework Selection and Design
- Model Selection
- Data Management Plan
- Data Development
- Model Development, Calibration, Validation, and Sensitivity Analysis
- Model Implementation
- Estimation of Uncertainty – Sources
- Estimation of Uncertainty - Protocols

# Additional References

## Reference Technical Memorandum 2017

Web Link - See Additional References:

https://www.usbr.gov/mp/bdo/cvp-wtmp.html



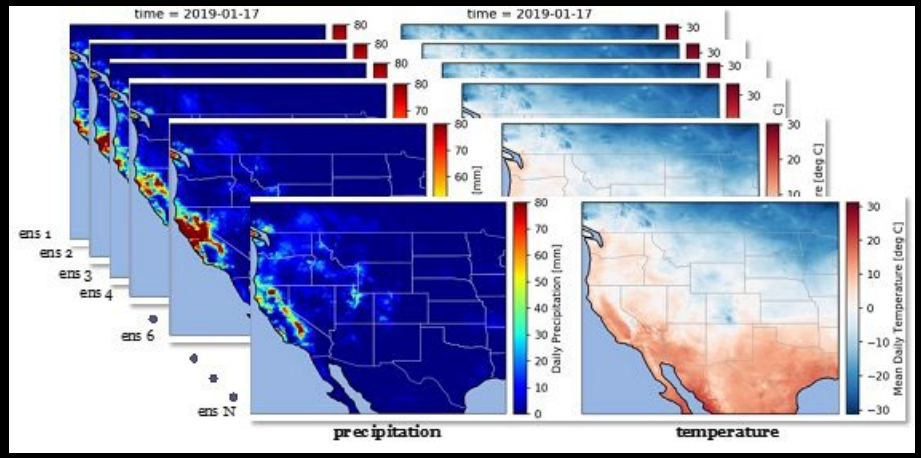
# Midterm & Final Independent Scientific Peer Reviews

- Host: Delta Stewardship Council
- Water Temperature Modeling Platform
- Mid-Term Review 7/19/22-7/20/2
- Final Review 9/12/23 – 9/14/23


- "The WTMP Project Team has taken important and commendable steps to position the modeling framework along an adequate path. These steps include: (1) engagement with scientific community working on climate forecasts and downscaling, (2) engagement with stakeholders, (3) modeling's and data sharing, (4) sharing documentation on modeling approach and performance, (5) system monitoring, (6) hinder approach for continuing model performance evaluation, and (7) building the system framework to operate within a Monte Carlo framework."

# SacMetTemp Project Overview

- Motivation
  - Long lead stream temperature outlooks are central to seasonal operations planning
  - Updates the data and approach for sub-seasonal to seasonal (S2S) climate forecasts are required for water temperature model inputs as the WTMP is under development
- This project centers on research to review the existing datasets and approach to identify and explore potential areas for improvement.

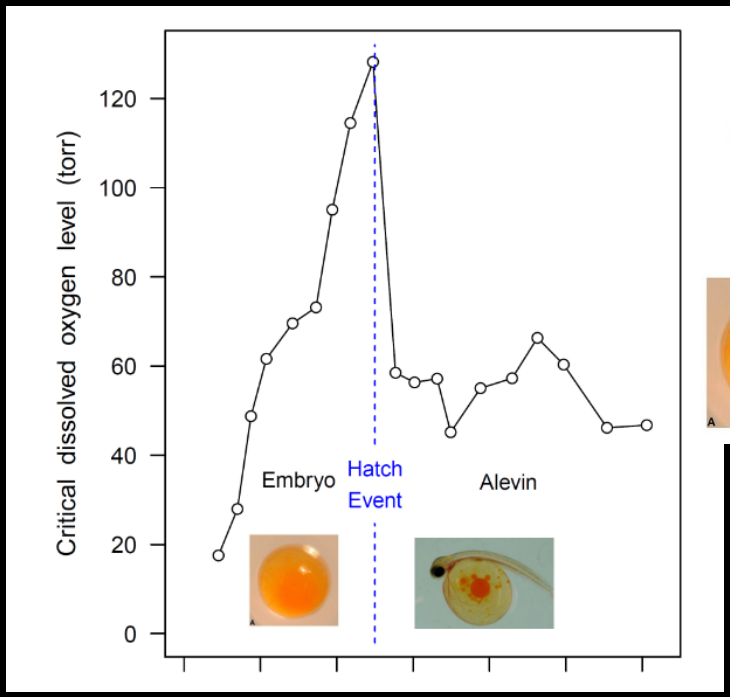


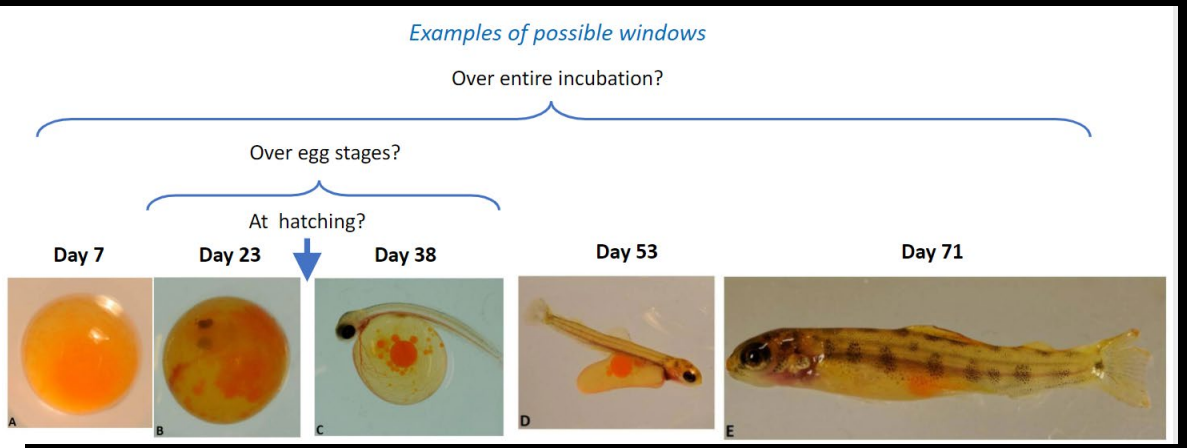
# WTMP Next Steps

- WY2024 internal testing
- DMS standup and testing
- Rollout late 2024
- Facilitated Adoption 2025
- Continued Support Activities:
  - Performance assessments
  - Improving data collection
  - Model refinements
  - Re-assessment of modeling needs
  - Technology refinements
  - User group

# Estimating Temperature Mortality

- Calculated by model, not measured or observed
- Stage Independent (Martin et al 2017))
- Stage Dependent (Anderson et al. 2021)

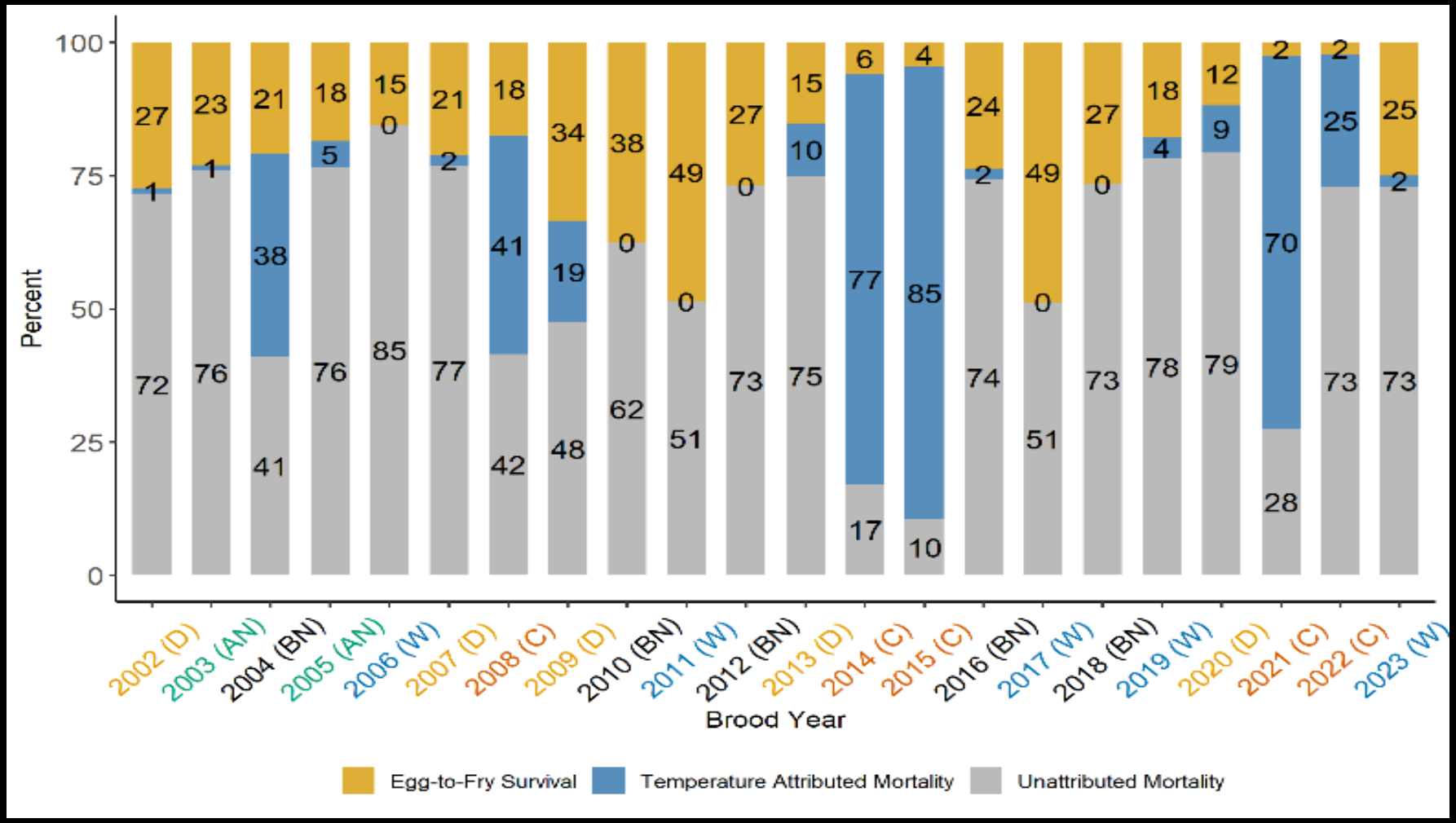


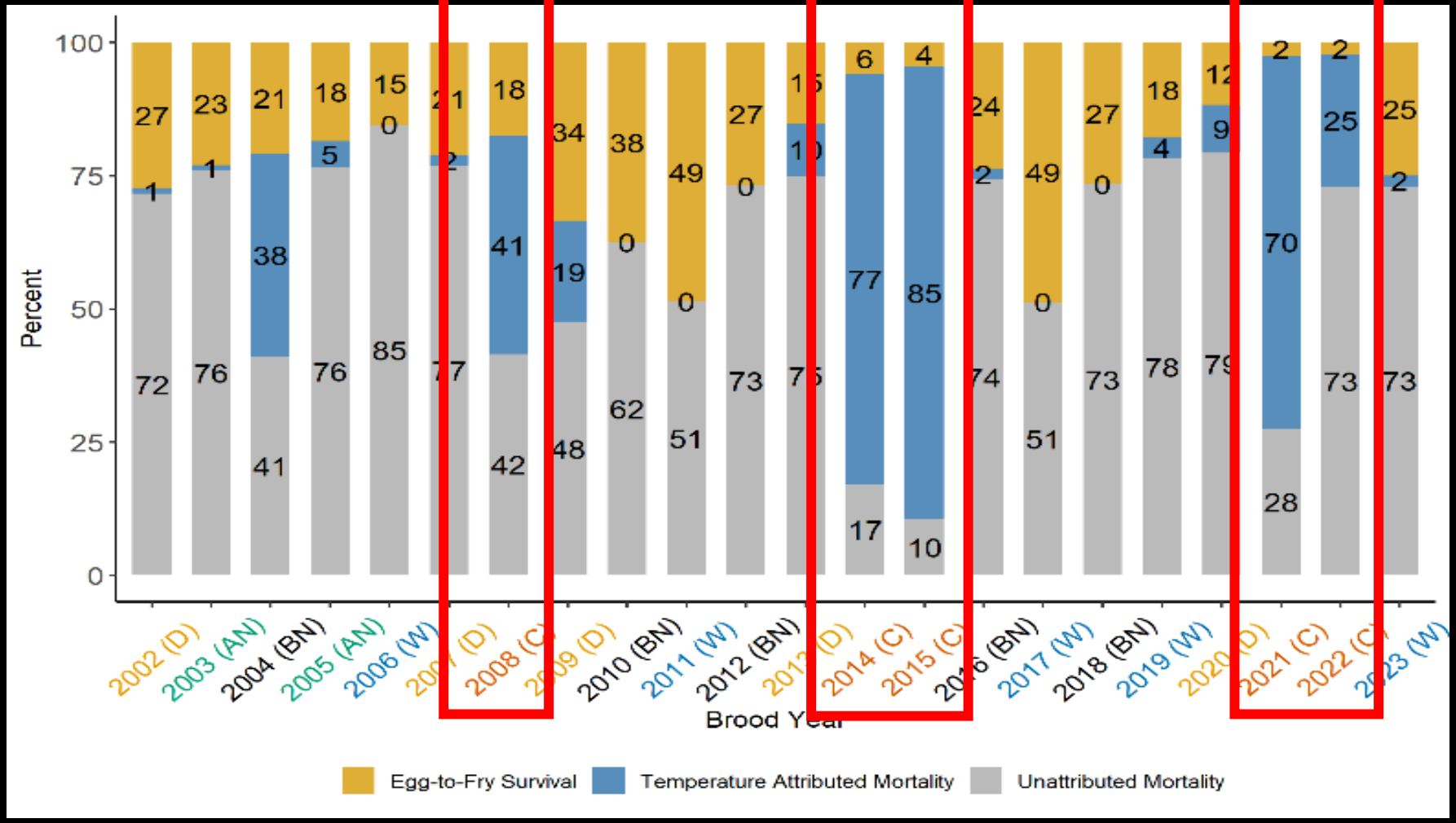
# Estimating Egg to Fry Survival

- Calculated from observed and estimated information

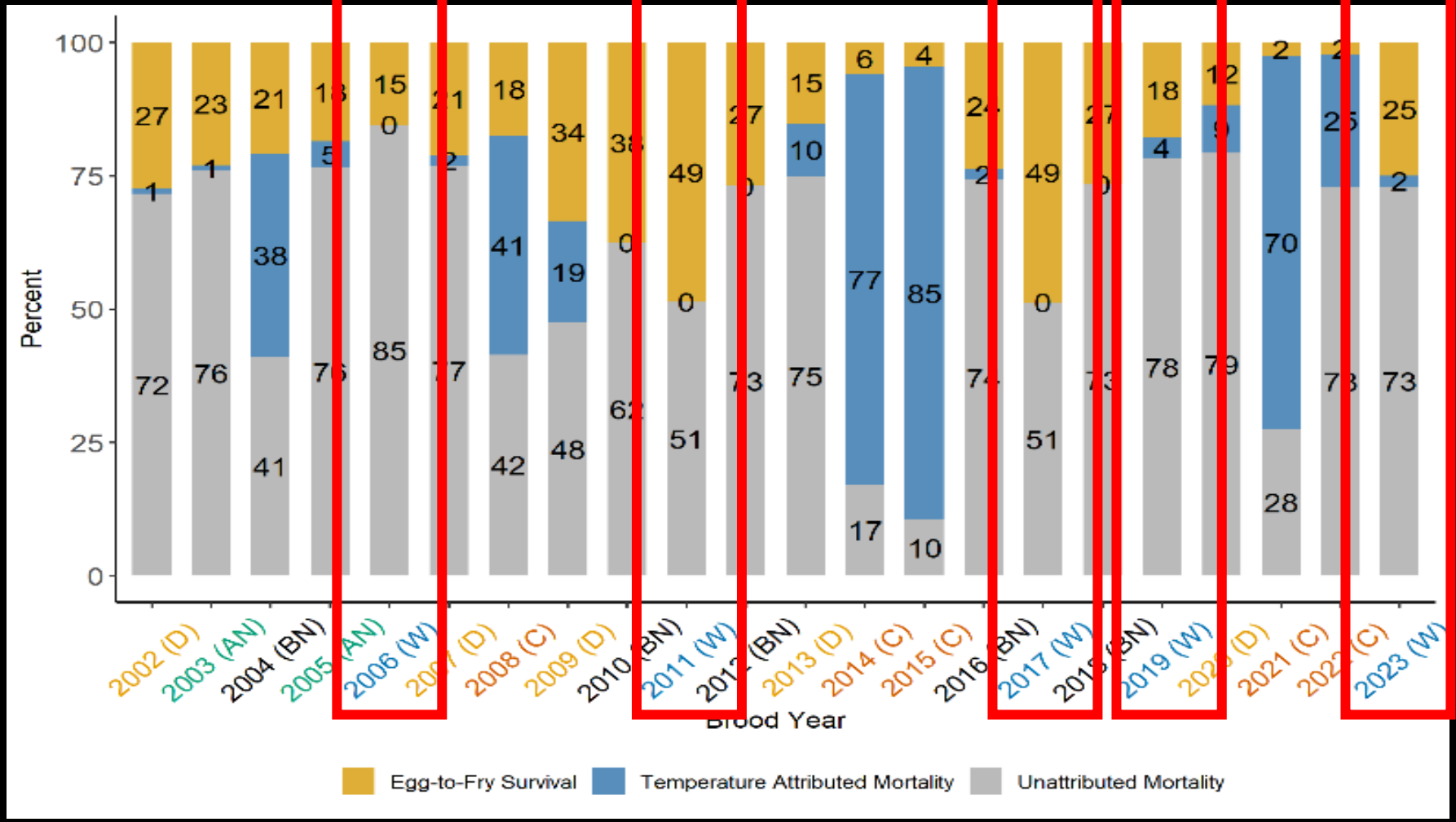
# Egg Mortality by Year



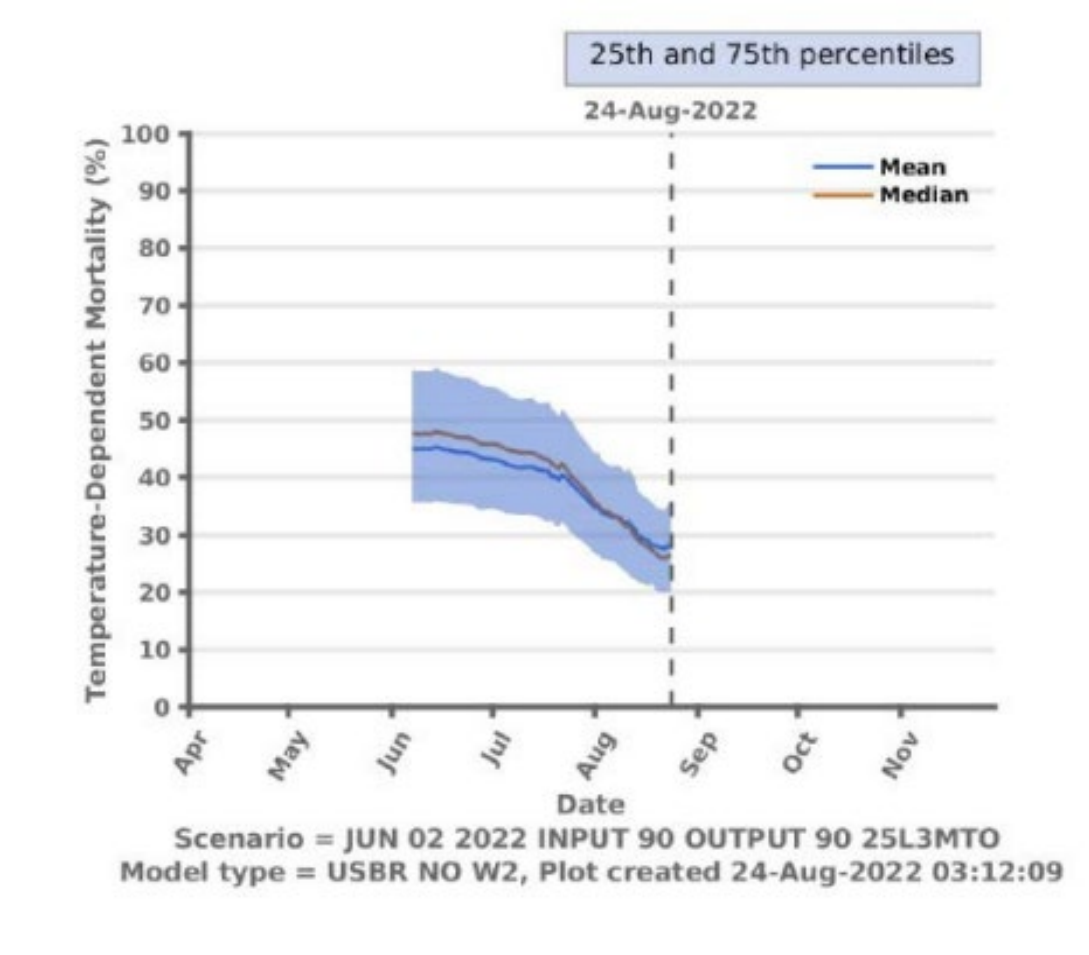
# Egg Mortality by Year



# Egg Mortality by Year



# Estimating Temperature Mortality




| Year | April Forecast (%) | November Hindcast (%) |
|---|---|---|
| 2022 | 36 to 58 | 18 |
| 2023 | 0 to 2 | 0 to 2 |

# Estimating Temperature Mortality

| Year | April Forecast (%) | November Hindcast (%) |
|---|---|---|
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# Estimating Temperature Mortality

| Year | April Forecast (%) | November Hindcast (%) |
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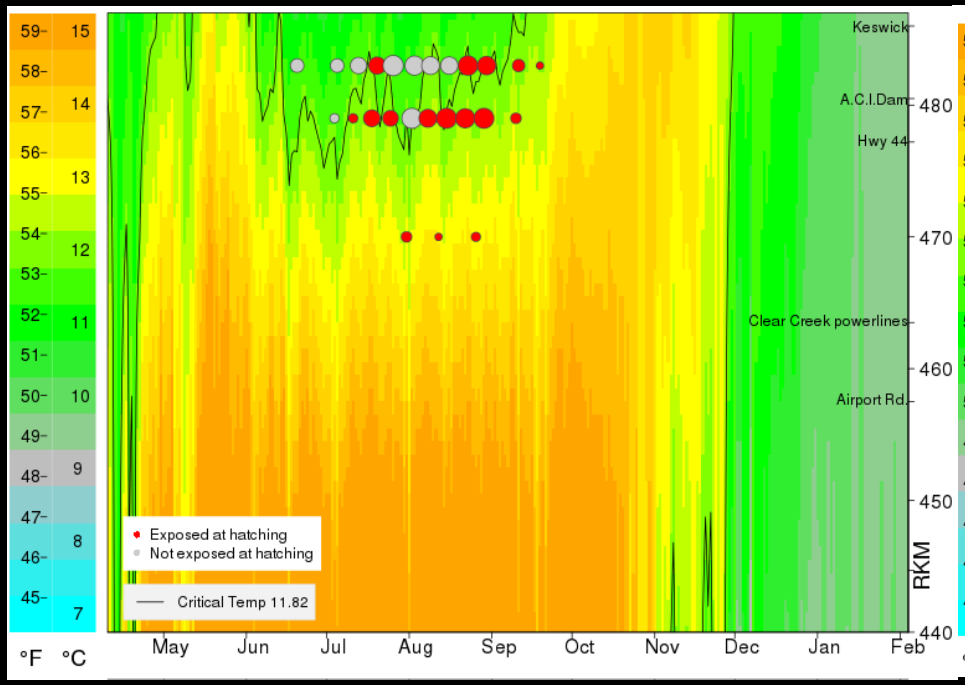
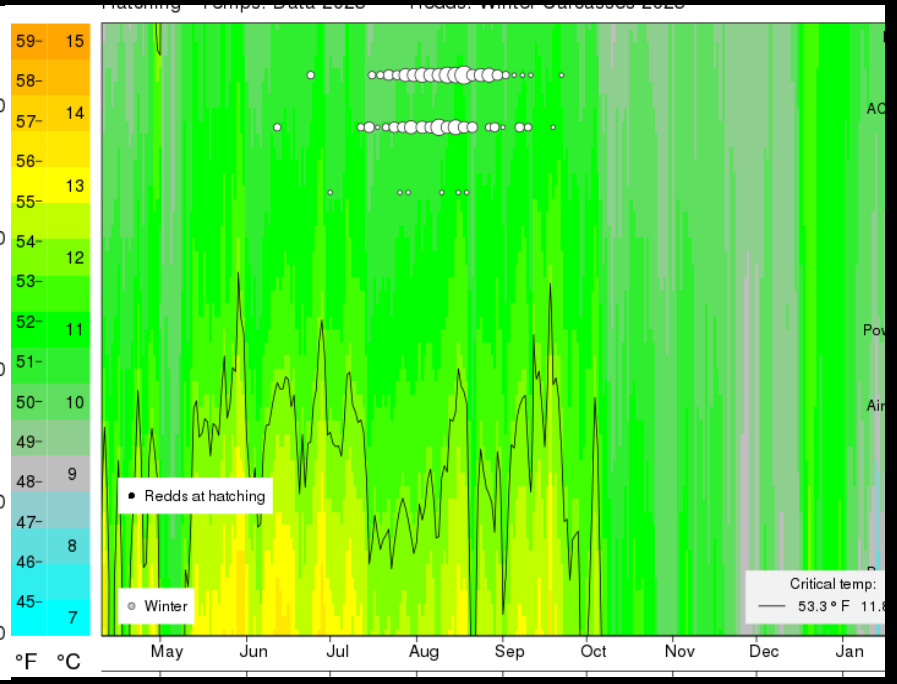
| 2023 | 0 to 2 | 0 to 2 |

# Estimating Temperature Mortality

## 2022




## 2023

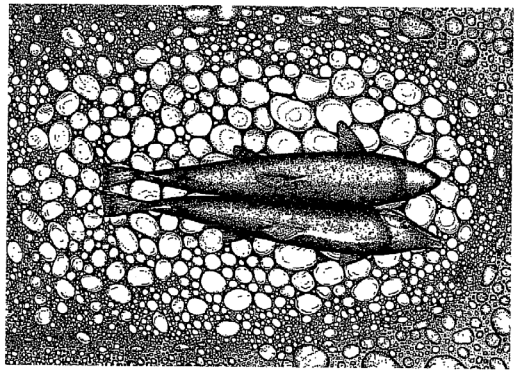


# Redd dewatering models
# FCS v WCS

**Percentage of Fall-run Chinook Salmon Redds Dewatered - ACID Dam Boards In**

| Dewatering flow (cfs) \ Spawning Flow (cfs) | 3500 | 3750 | 4000 | 4250 | 4500 | 4750 | 5000 | 5250 | 5500 | 6000 | 6500 | 7000 | 7500 | 8000 | 9000 | 10000 | 11000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29000 | | | | | | | | | | | | | | | | | |
| 27000 | | | | | | | | | | | | | | | | | |
| 25000 | | | | | | | | | | | | | | | | | |
| 23000 | | | | | | | | | | | | | | | | | |
| 21000 | | | | | | | | | | | | | | | | | |
| 19000 | | | | | | | | | | | | | | | | | |
| 17000 | | | | | | | | | | | | | | | | | |
| 15000 | | | | | | | | | | | | | | | | | |
| 14000 | | | | | | | | | | | | | | | | | |
| 13000 | | | | | | | | | | | | | | | | | |
| 12000 | | | | | | | | | | | | | | | | | |
| 11000 | | | | | | | | | | | | | | | | | |
| 10000 | | | | | | | | | | | | | | | | | 1.2% |
| 9000 | | | | | | | | | | | | | | | | 1.6% | 3.8% |
| 8000 | | | | | | | | | | | | | | | 2.0% | 4.9% | 8.1% |
| 7500 | | | | | | | | | | | | | | 0.6% | 3.4% | 6.7% | 9.9% |
| 7000 | | | | | | | | | | | | | 0.7% | 1.6% | 5.0% | 8.6% | 12.1% |
| 6500 | | | | | | | | | | | | 1.1% | 2.1% | 3.3% | 7.4% | 11.5% | 15.0% |
| 6000 | | | | | | | | | | | 1.0% | 2.3% | 3.7% | 5.1% | 9.8% | 14.5% | 18.3% |
| 5500 | | | | | | | | | | 1.2% | 2.7% | 4.4% | 6.2% | 8.1% | 13.5% | 18.5% | 22.3% |
| 5250 | | | | | | | | | 0.6% | 1.9% | 3.5% | 5.6% | 7.7% | 9.7% | 15.3% | 20.4% | 24.1% |
| 5000 | | | | | | | | 0.7% | 1.3% | 2.9% | 4.9% | 7.2% | 9.6% | 11.9% | 17.7% | 23.1% | 26.9% |
| 4750 | | | | | | | 0.8% | 1.6% | 2.4% | 4.3% | 6.6% | 9.1% | 11.8% | 14.3% | 20.3% | 25.7% | 29.5% |
| 4500 | | | | | | 0.8% | 1.6% | 2.6% | 3.7% | 6.0% | 8.9% | 11.9% | 15.0% | 17.8% | 24.4% | 29.9% | 33.6% |
| 4250 | | | | | 0.8% | 1.5% | 2.5% | 3.7% | 5.0% | 7.8% | 11.1% | 14.4% | 17.8% | 20.9% | 27.5% | 33.1% | 36.6% |
| 4000 | | | | 0.9% | 1.7% | 2.6% | 3.8% | 5.3% | 6.6% | 10.0% | 13.5% | 16.9% | 20.4% | 23.5% | 30.1% | 35.4% | 38.7% |
| 3750 | | | 0.9% | 1.6% | 2.5% | 3.6% | 5.1% | 6.7% | 8.3% | 11.9% | 15.6% | 19.3% | 23.0% | 26.2% | 32.8% | 37.7% | 40.9% |
| 3500 | | 1.0% | 2.0% | 3.1% | 4.4% | 5.7% | 7.4% | 9.2% | 10.9% | 14.8% | 18.8% | 22.8% | 23.9% | 29.8% | 36.2% | 40.8% | 43.6% |
| 3250 | 1.0% | 2.0% | 3.3% | 4.7% | 6.2% | 7.8% | 9.7% | 11.7% | 13.6% | 17.8% | 22.2% | 26.3% | 30.2% | 33.4% | 39.5% | 43.5% | 46.0% |

**RELATIONSHIPS BETWEEN FLOW FLUCTUATIONS AND REDD DEWATERING AND JUVENILE STRANDING FOR CHINOOK SALMON AND STEELHEAD IN THE SACRAMENTO RIVER BETWEEN KESWICK DAM AND BATTLE CREEK**



**Gard, Mark. 2006. Relationships between flow fluctuations and redd dewatering and juvenile stranding for Chinook Salmon and Steelhead in the Sacramento River between Keswick Dam and Battle Creek.**

# Redd Dewatering Estimates

| Year | Model Predictions | Field Observations |
|---|---|---|
| 2013 | 0.09 | 0.03 |
| 2014 | 0.06 | 0.003 |
| 2015 | 0.07 | 0.02 |
| 2016 | 0.08 | 0 |
| 2017 | 0.11 | 0.02 |
| 2018 | 0.07 | 0.06 |
| 2019 | 0.08 | 0.003 |
| 2020 | 0.07 | 0.03 |
| 2021 | 0.09 | 0.02 |
| 2022 | 0.04 | 0 |


Questions?
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BUREAU OF
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