BUREAU OF RECLAMATION

CVP Water Temperature Modeling Platform

Modeling Technical Committee (MTC) Meeting #4

April 7, 2022; 1:00 p.m. – 4:00 p.m.

Welcome!!

- We are looking forward to a productive meeting, please consider – remote meeting. Remote collaboration meetings can be challenging and frustrating, especially with larger groups – please be patient and flexible. If you are having technical difficulties, please chat with Sarah Hamilton.
- Chat Panel will be used for participants to provide comments and queue up questions. Use Raise Hand functions in Q&A session.
- Agenda includes presentation and Q&A sessions.
- Handouts were distributed this morning.
- Feedbacks on meeting logistic and suggestions: Yung-Hsin Sun, PhD, PE @ yung-hsin.sun@stantec.com

MTC #4: Objectives

- Establish common understanding of project status and upcoming topics of MTC discussion
- Provide opportunities for input on interim products and collaboration
- Report the first subgroup activities and outcome

MTC #4: Agenda

1:00 p.m.	Meeting Logistics, Welcome Remark, and Announcements
1:15 p.m.	Discussion Topic: Sacramento/Trinity River Water Temperature Model
2:15 p.m.	Break (5 min)
2:20 p.m.	Closure Topics: Data Acquisition and Database Management
2:35 p.m.	Reporting Out: Habitat Data Subgroup – Discussion and Outcome
2:45 p.m.	Break (5 min)
2:50 p.m.	Introductory Topic: American River Water Temperature Model Development
3:50 p.m.	Next Steps
4:00 p.m.	Adjourn

Note that the Agenda contains the links to register future MTC meetings for convenience.

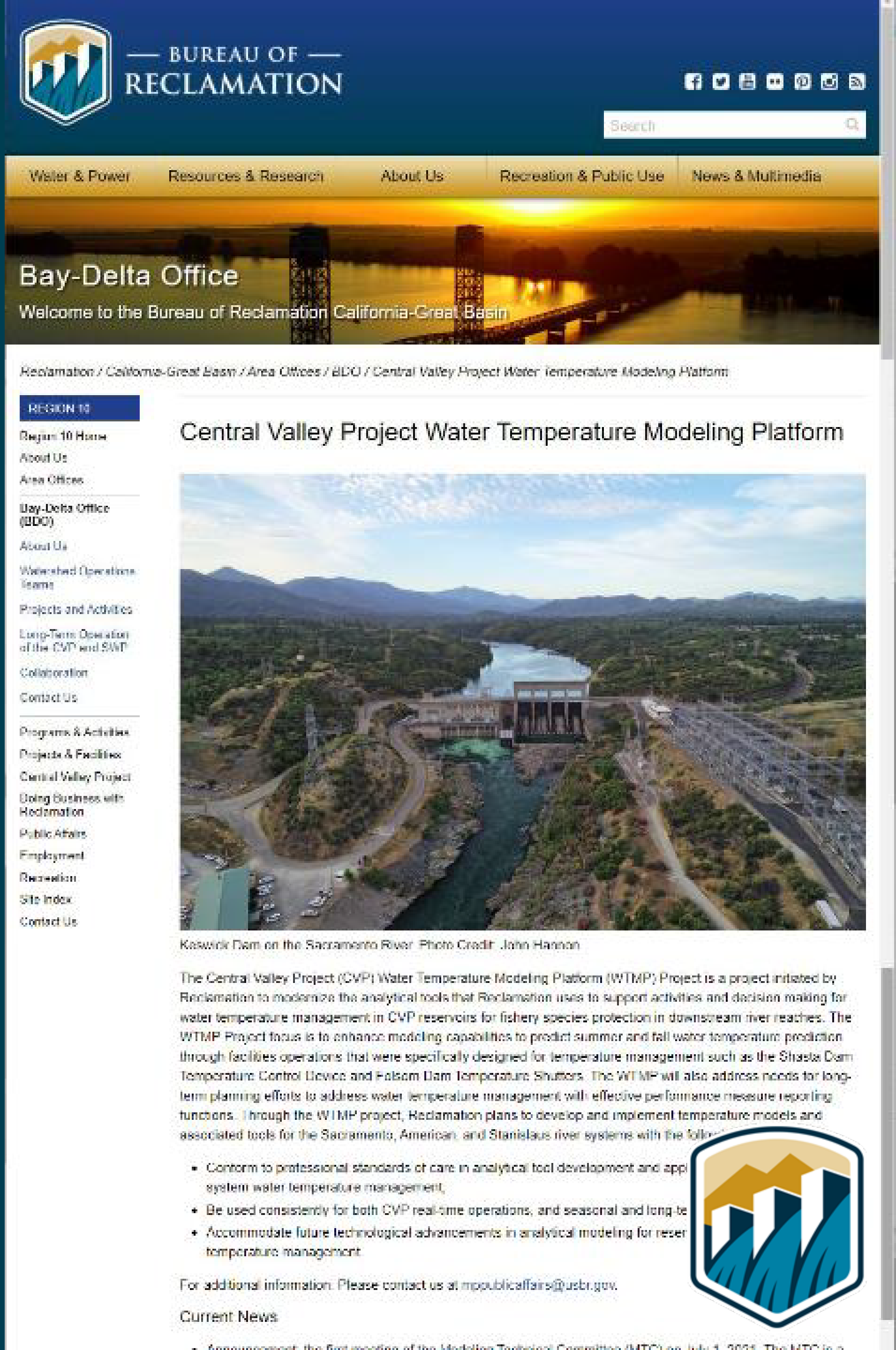
Agenda Topics for the 2022 MTC meetings (Subject to Change)

Topic	7/1/2021	10/7/2021	1/6/2022	4/7/2022	7/7/2022	10/6/2022	2023
MTC Orientation	1/2/3	-	-	-	-	-	-
Project Purposes, Goals, Anticipated Outcomes	1/2/3	3	-	-	-	-	-
Modeling Framework Selection	1	2	3	-	-	-	-
Water Temperature Model Selection	1	2	3	-	-	-	-
Consistency between System Model and Detailed Models	-	1	2	3	-	-	-
Common Model Preparation and Considerations	-	1	2/3	-	-	-	-
Sacramento/Trinity River Water Temperature Model	-	-	1	2	2/3	3	-
American River Water Temperature Model	-	-	-	1	2	2/3	-
Stanislaus River Water Temperature Model	-	-	-	-	1	2	-
Modeling Framework Implementation	1	-	2	-	-	3	-
Phase II Activities	-	-	-	-	TBD	TBD	TBD
Peer Review Outcomes	-	-	-	-	1/2/3	-	TBD

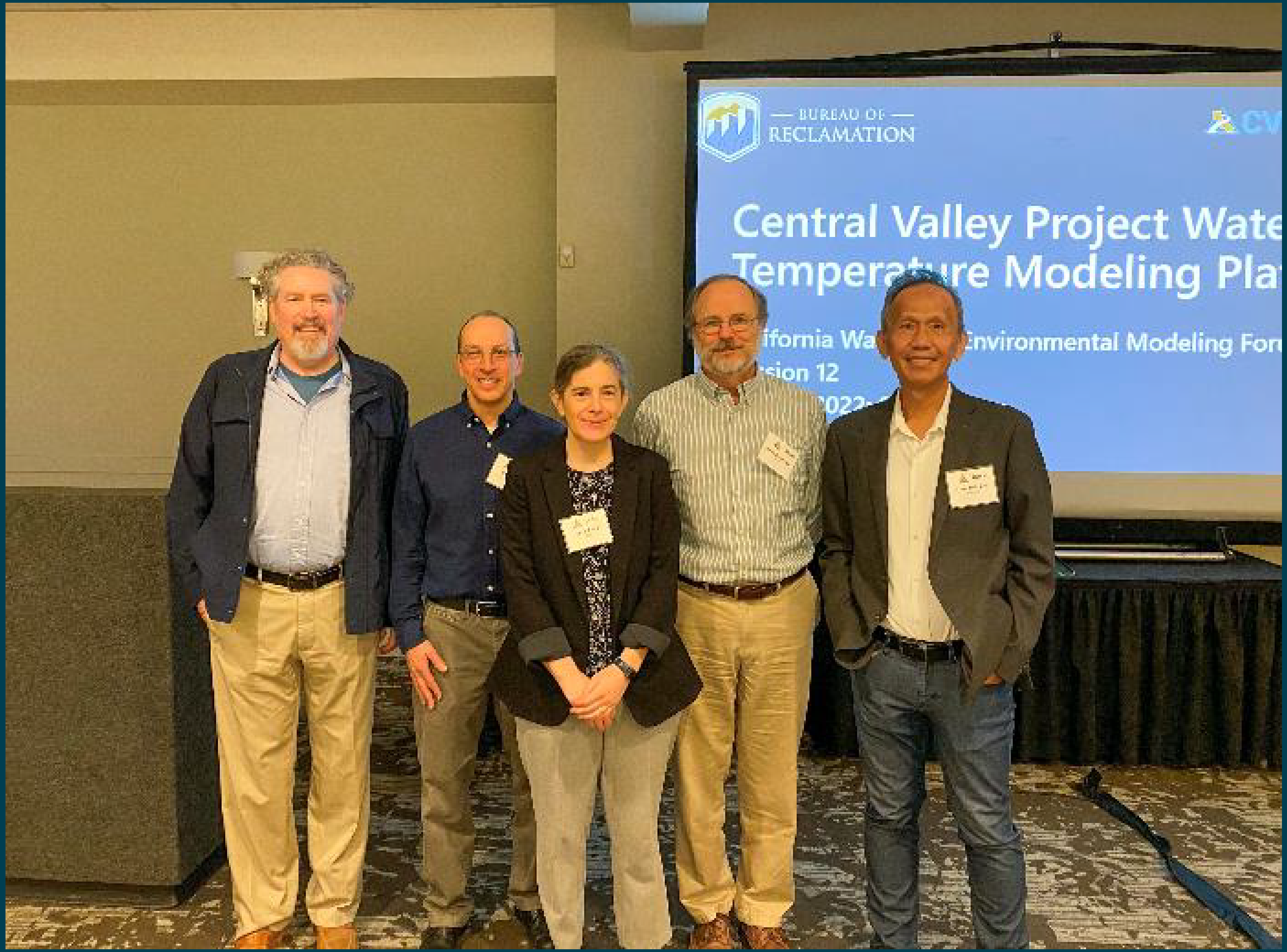
Key: 1 – Introductory Presentation; 2 – Comments and Discussion; 3 – Closure Discussion; TBD – To be determined. The agenda topics and schedule are also available in the handout.

Communication Channels

- Website's Major Update: https://www.usbr.gov/mp/bdo/cvp-wtmp.html
  - Meeting information/Fact sheets/Deliverables
- Project contact: mppublicaffairs@usbr.gov
- Interim deliverable comments and other suggestions: RField@usbr.gov
- MTC: yung-hsin.sun@stantec.com



California Water and Environmental Modeling Forum (April 5, 2022)



Welcome Remark and Announcements

Randi Field, Hydrologic Engineer, CVO

Vision for WTMP Project

- Goal: Deliver quality products to support Reclamation's mission – predict water temperature to support CVP operations
  - Modernize Systemwide Water Temperature Modeling and Analytics
  - Develop to Professional Standards and Foster Transparency
  - Consistent Use: Real-time, Seasonal, and Long-term Planning
  - Accommodate Continued Technological Advancements

Welcome Back, MTC Members

- Community-based collaborative WTMP development
  - Thank you for your feedback
  - Thank you for sharing your data
  - Remember to register for all future meetings
- Request your continued support and collaboration, leveraging your technical expertise:
  - Consistent engagement in quarterly MTC meetings
  - Project product review
  - Constructive input and comments
  - Potential future user group on water temperature modeling
  - Envision opportunities for your use in the future and further collaboration

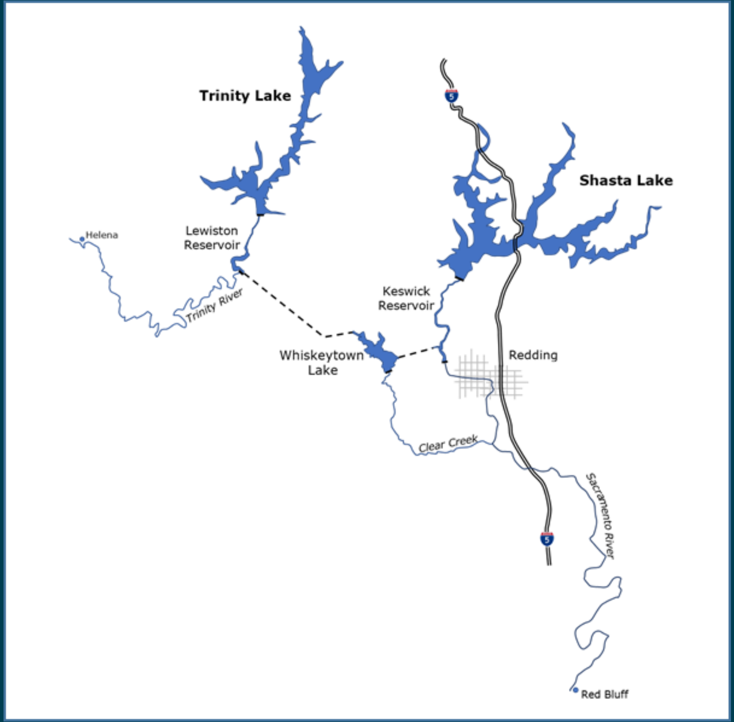
Reminder: Defer extending WTMP model domain after initial implementation

Sacramento/Trinity River System

Trinity Lake to Helena

Whiskeytown to Clear Creek confluence

Lake Shasta to Red Bluff

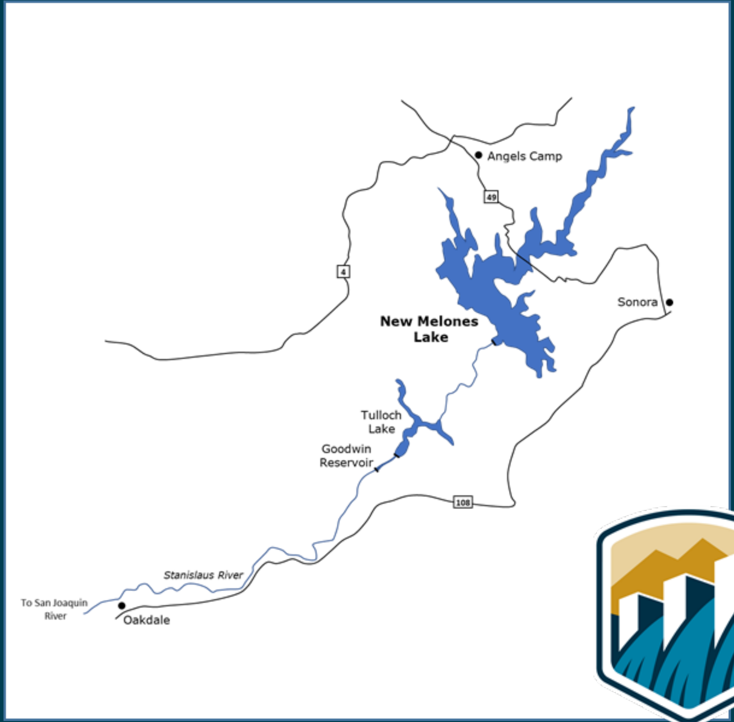


American River System

Folsom Reservoir to American River confluence

Stanislaus River System

New Melones Reservoir to San Joaquin River confluence



Announcement: Reclamation's Science and Technology

- Grant Program Research Opportunity with NCAR
- Proposal: Evaluating Water Temperature Modeling and Prediction in the Sacramento River Basin: Meteorology forcing datasets/inflow temperature
  - October 2021 Proposal accepted
  - Mid-March 2022 – Project kickoff
  - 2-year effort

Announcement: Reclamation's Science and Technology (continued)

- Major tasks for Sacramento River Basin Meteorological Temperature Data Development
  - Evaluate existing forecasting methods and skill
  - Question: Can we improve current forecasting capabilities using new meteorological inputs?
  - Investigate methods to develop inflow temperature
- Reclamation will provide periodic updates to MTC

Announcement: Independent Scientific Peer Review

- Goal: Provide an external, independent review of the critical assumptions, technical approach and resulting products of the WTMP Project
- Reclamation is partnering with Delta Stewardship Council and hosting public reviews:
  - Mid-Term Review: Summer 2022
  - Final Review: Summer 2023
- Link to be posted on WTMP web site

Announcement: Independent Scientific Peer Review (continued)

- The Mid-Term Peer Review:
  - Evaluate the development, methods, and performance of the Shasta-Keswick-Sacramento River temperature models
  - Feedback from the Mid-Term review will guide the continued WTMP development
- The Final Peer Review:
  - Evaluate all model representations, applications, framework design, uncertainty, and testing
- Anticipated outcome: Improved robustness and transparency

Photo credit: John Hannon, Reclamation

Discussion Topic: Sacramento/Trinity Water Temperature Models

Mike Deas, PhD, PE, Watercourse Engineering, Inc.

John DeGeorge, PhD, PE, RMA

Sacramento/Trinity Water Temperature Models Outline

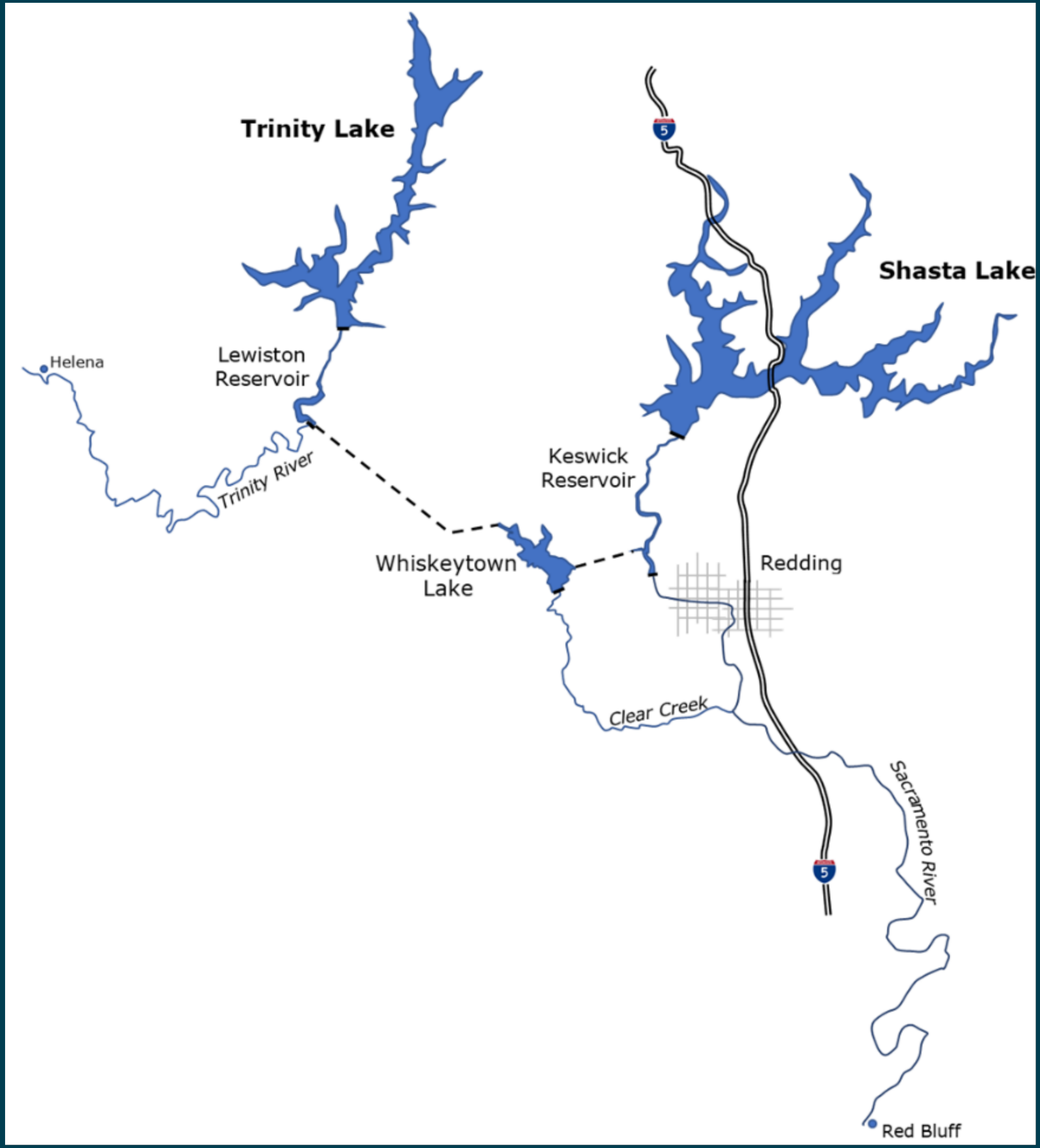
- Recap
  - Selected Models and Domain
  - Shasta/Trinity System – WTMP Representations
- Data Development
- Model Performance Metrics
- CE-QUAL-W2
  - Model Development
  - Model Calibration (preliminary)
- HEC-ResSim
  - Model Development
  - Model Calibration (preliminary)

WTMP Model Representations

- Reservoir Models
  - HEC-ResSim (1-D vertical)
  - CE-QUAL-W2 (2-D vertical and longitudinal)
- River Model
  - HEC-ResSim (1-D longitudinal)
- System Model
  - HEC-ResSim
    - Reservoir (1-D vertical)
    - River (1-D longitudinal)

WTMP Domain

- Sacramento River and Trinity River basins
- Facilities:
  - Sacramento
    - Shasta Lake, Keswick Reservoir
    - Sacramento River (to Red Bluff)
    - Whiskeytown Lake
    - Clear Creek (to Sacramento River)
  - Trinity
    - Trinity Lake
    - Lewiston Lake
    - Trinity River (to North Fork)



WTMP Model Representations Shasta/Trinity System

- Model development data period: 2000 to 2021
- Models
- HEC-ResSim is also applied as a system model

Reservoir/River	CE-QUAL-W2	HEC-ResSim
Shasta Lake	X	X
Keswick Reservoir	X	X
Sacramento River	-	X
Trinity Lake	X	X
Lewiston Lake	X	X
Trinity River	-	X
Whiskeytown Lake	X	X
Clear Creek	-	X

WTMP Modeling Data Development

- Reservoir and River Model Data/Information
  - Geometry
  - Hydrology
  - Temperature
  - Meteorology
- Data Inventory Tables

Geometry

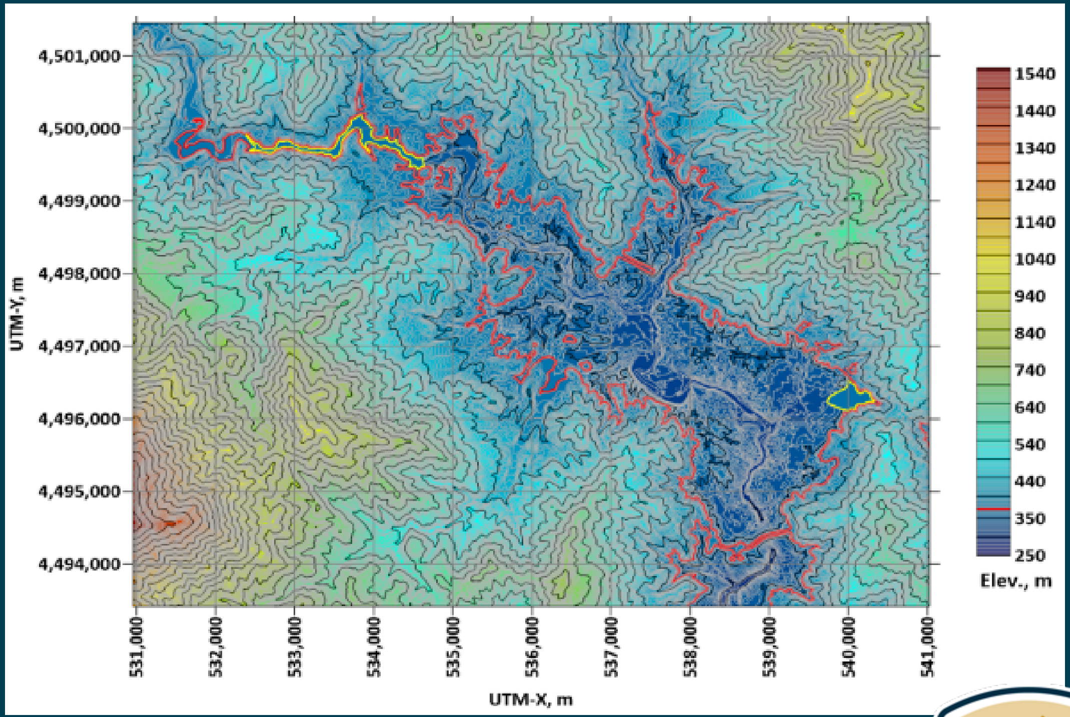
- Reservoirs and River
- Data need: Sacramento River bathymetry/cross section downstream of Clear Creek

Reservoir/River	Bathymetry	Stage-Area-Volume	Cross Section	Plan form (x-y)	Gradient
Shasta Lake	X	X	-	-	-
Keswick Reservoir	X	X	-	-	-
Sacramento River	Partial	-	X	X	X
Trinity Lake	X	X	-	-	-
Lewiston Lake	X	X	X	-	-
Trinity River	X	-	X	X	X
Whiskeytown Lake	X	X	-	-	-
Clear Creek	Limited	-	X	X	X

Whiskeytown Lake Bathymetry

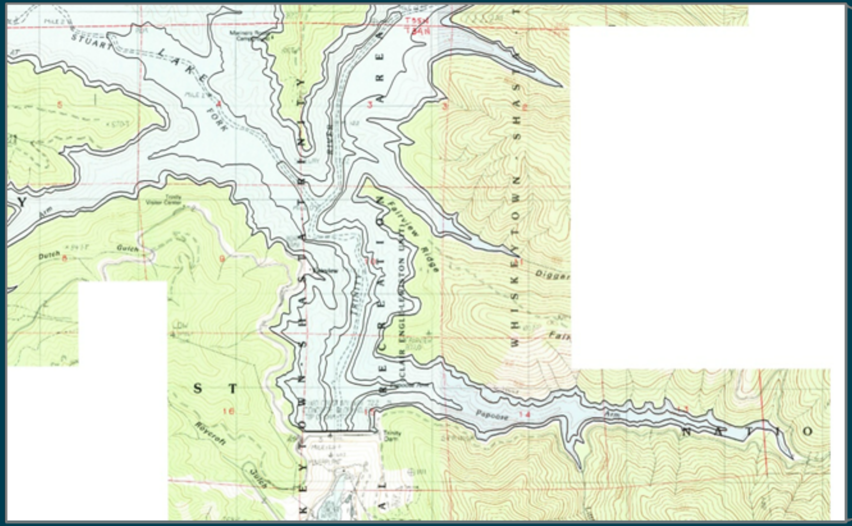
- Data Sources

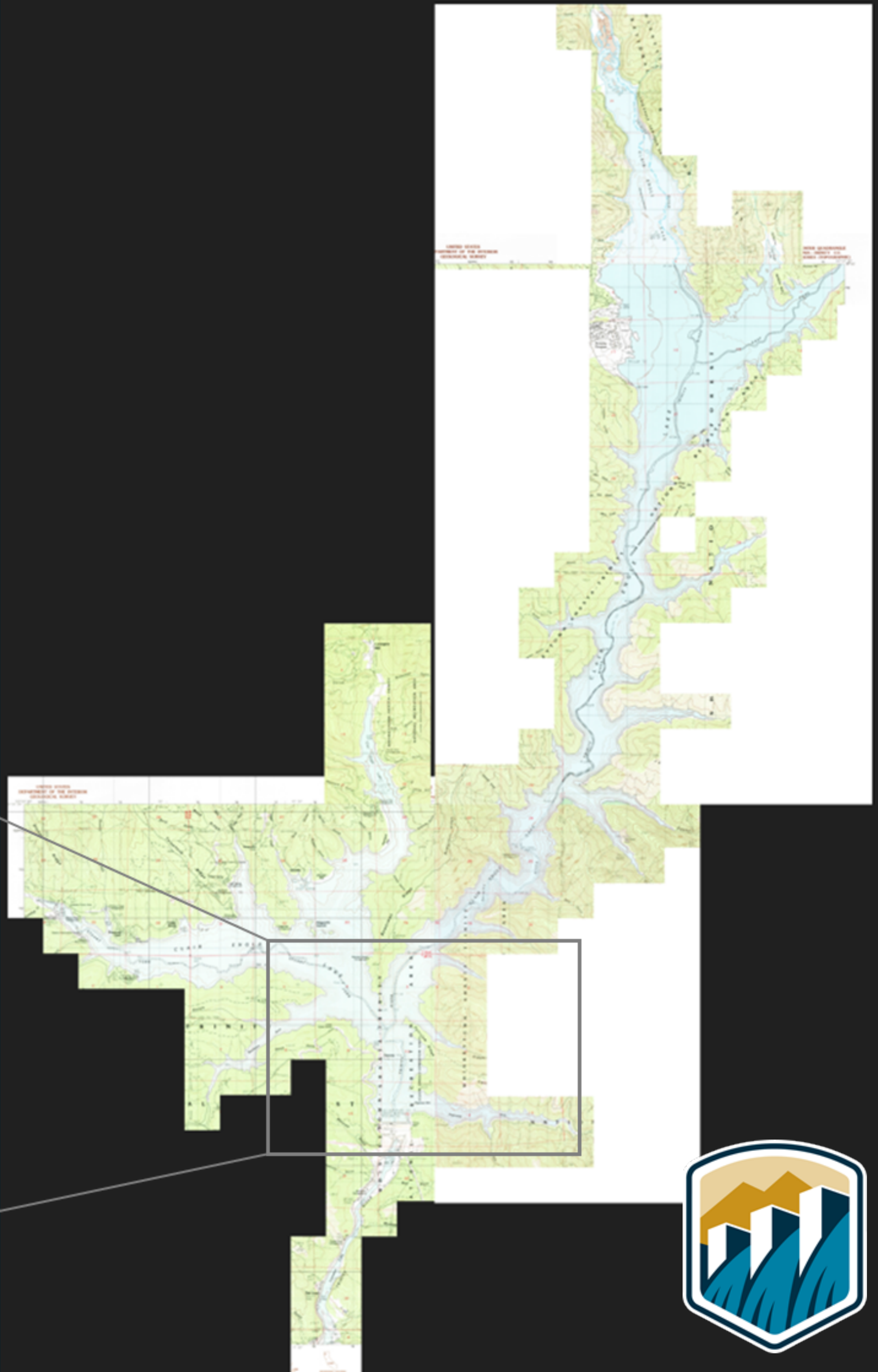
Title	Source	Datum	Units
USGS 1 arc second n41w123 20210624 (data set/map)	USGS 2021	NAD83 NAVD88	Geographic Coordinates: decimal degrees
The U.S. Geological Survey (USGS) Bathymetry, Topography and Orthomosaic imagery for Whiskeytown Lake, northern California	Logan et al. 2020	NAD83 NAVD88	UTM Coordinate (Zone 10): Meter
Historic 1956 US Department of Interior topographic maps of the Whiskeytown Reservoir Area	Alster 1956	NAD27 (Calif. State Plan, zone 0401) NGVD29	UTM Coordinate (Zone 10): Feet



Trinity Lake Bathymetry

- Data Sources
  - USGS Topographic Maps
    - Website link: https://ngmdb.usgs.gov/topoview/
  - Digitize at the 30 m contour





WTMP Modeling Data Development (continued)

- Boundary Conditions
- Initial Conditions
- Calibration/Validation Data
- Draft Table Review (later presentation)
  - Sacramento (complete)
  - Whiskeytown/Clear Creek (in progress)
  - Trinity (in progress)
- Data Gaps (later presentation)
  - Fill – Boundary conditions
  - Not filled – Calibration/Validation data
  - Approaches

Model Progress

- Model Performance Metrics
- Shasta W2
  - Description of model
  - Review of TCD representation
  - Calibration
  - Additional validation years (show graphical presentation – no model metrics)
- Keswick W2
  - Brief description of model
  - Calibration
  - Additional validation years (show graphical presentation – no model metrics)
- ResSim Work

Model Performance Metrics

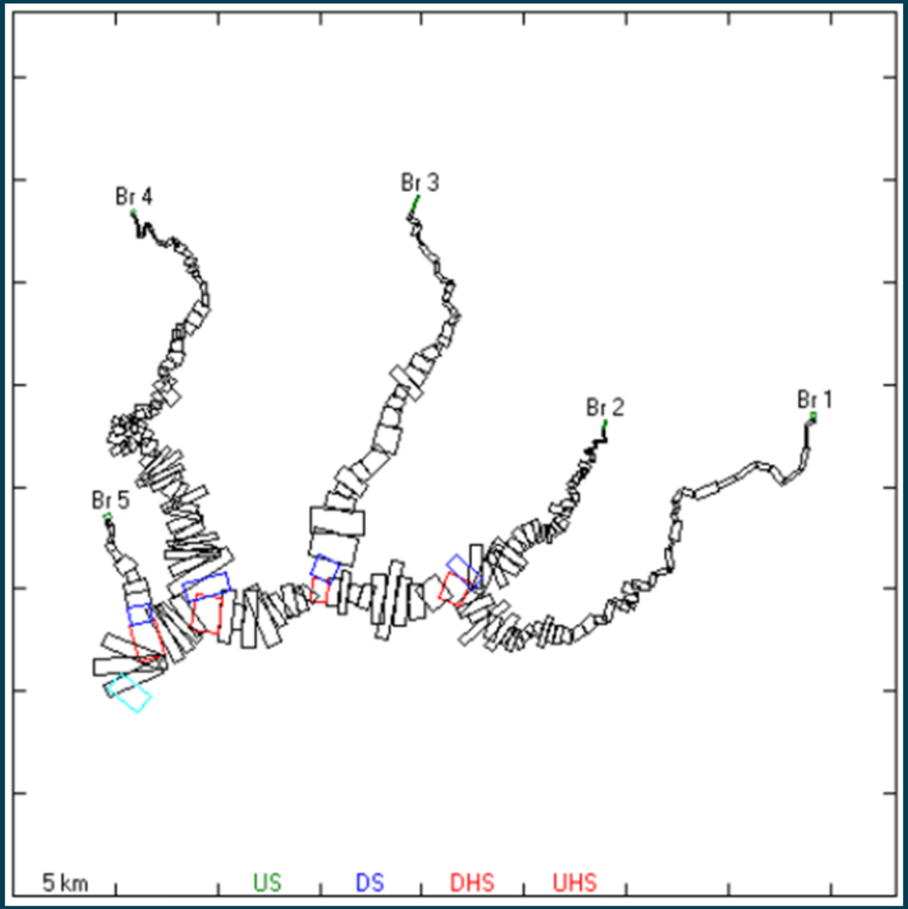
- Graphical (qualitative) and Statistical (quantitative)
- Statistical Metrics
  - Mean bias: systematic model over- or under-prediction
  - Mean absolute error (MAE): estimate of overall model error
  - Root-mean squared error (RMSE): large values indicate that there are periods where differences are appreciable (e.g., outliers)
  - Nash-Sutcliffe Efficiency (NSE): an indication of how well the plot of observed versus simulated data fits the 1:1 line, and is sensitive to differences in the observed and modeled means as well as variances

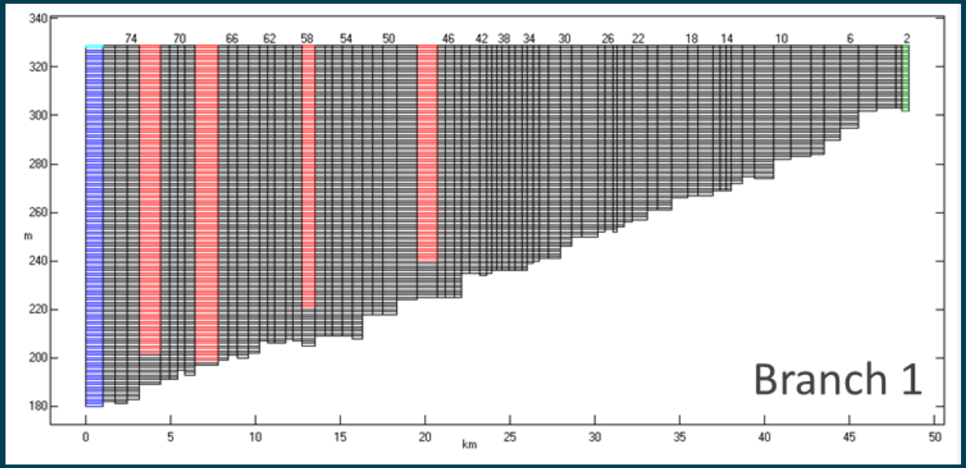
WTMP Model Performance Metrics for Water Temperature (Time Series and Profiles), Flow, and Reservoir Stage

Parameter	Mean Bias	MEA	RMSE	NSE
Stage	±0.5 feet (0.15 meters)	≤1.0 feet (0.3 meters)	≤1.5 feet (0.45 meters)	≥0.65
Flow	±50 cubic feet per second (cfs) (1.4 cubic meters per second (cms))	≤150 cfs (4.2 cms)	≤500 cfs (14.2 cms)	≥0.65
Water Temperature	±0.75°C	≤1.0°C	≤1.5°C	≥0.65

Shasta Lake: CE-QUAL-W2 Geometry

- Shasta Lake Model
  - Five branches
  - Layer thickness: 1 meter
  - Maximum number of layers: 149
  - Shasta Lake bathymetry (historic)
  - 2000-2021 calendar year simulations



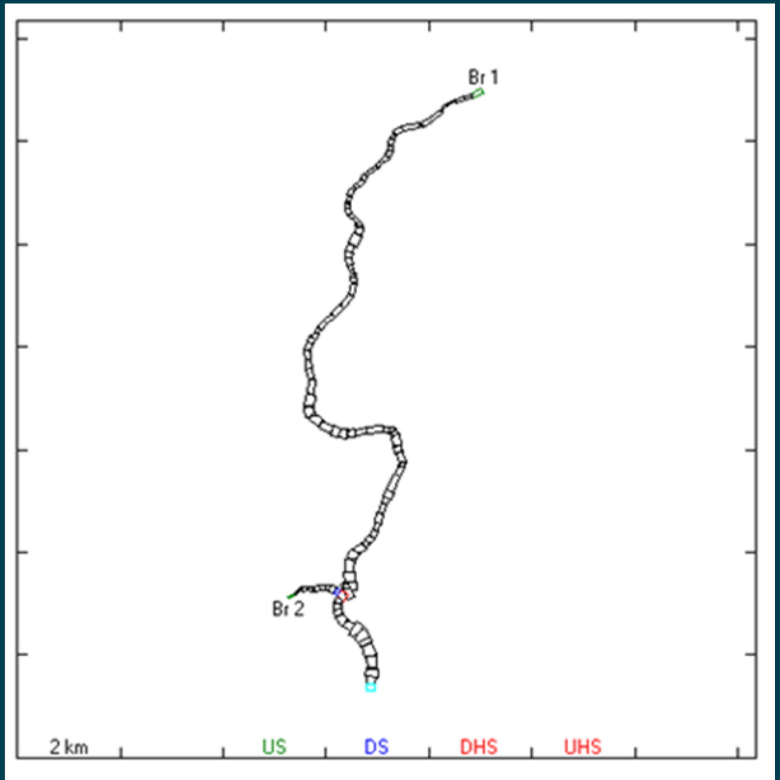


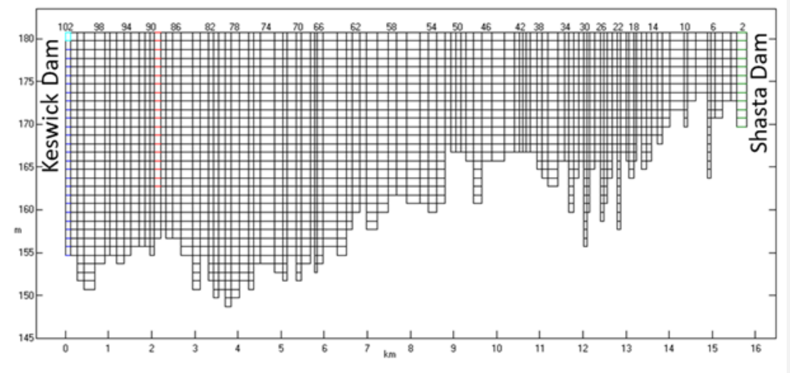
Shasta Lake: CE-QUAL-W2 Geometry

Branch Name [number]	Total Number of Segments in Branch	Total Length of Arm [feet (meters)]	Average Segment Length [feet (meters)]	Minimum Segment Length [feet (meters)]	Maximum Segment Length [feet (meters)]
Pit River arm (1)	76	156,988 (47,850.0)	2,066 (629.6)	820 (250.0)	4,429 (1,350.0)
Squaw Creek arm (2)	33	46,014 (14,025.2)	1,394 (425.0)	656 (200.0)	2,461 (750.2)
McCloud River arm (3)	34	74,020 (22,561.2)	2,177 (663.6)	1,066 (325.0)	4,429 (1,350.0)
Sacramento River arm (4)	70	96,441 (29,395.1)	1,378 (419.9)	492 (150.0)	2,937 (895.1)
Big Backbone Creek arm (5)	12	19,324 (5,890.1)	1,610 (490.8)	689 (210.0)	2,740 (835.1)
Pit River arm (1)	76	156,988 (47,850.0)	2,066 (629.6)	820 (250.0)	4,429 (1,350.0)

Keswick Reservoir: CE-QUAL-W2 Geometry

- Keswick Reservoir Model
  - Two branches
  - Layer thickness: 1 meter
  - Maximum number of layers: 31
  - Keswick Reservoir bathymetry (historic)
  - 2000 – 2021 calendar year simulations

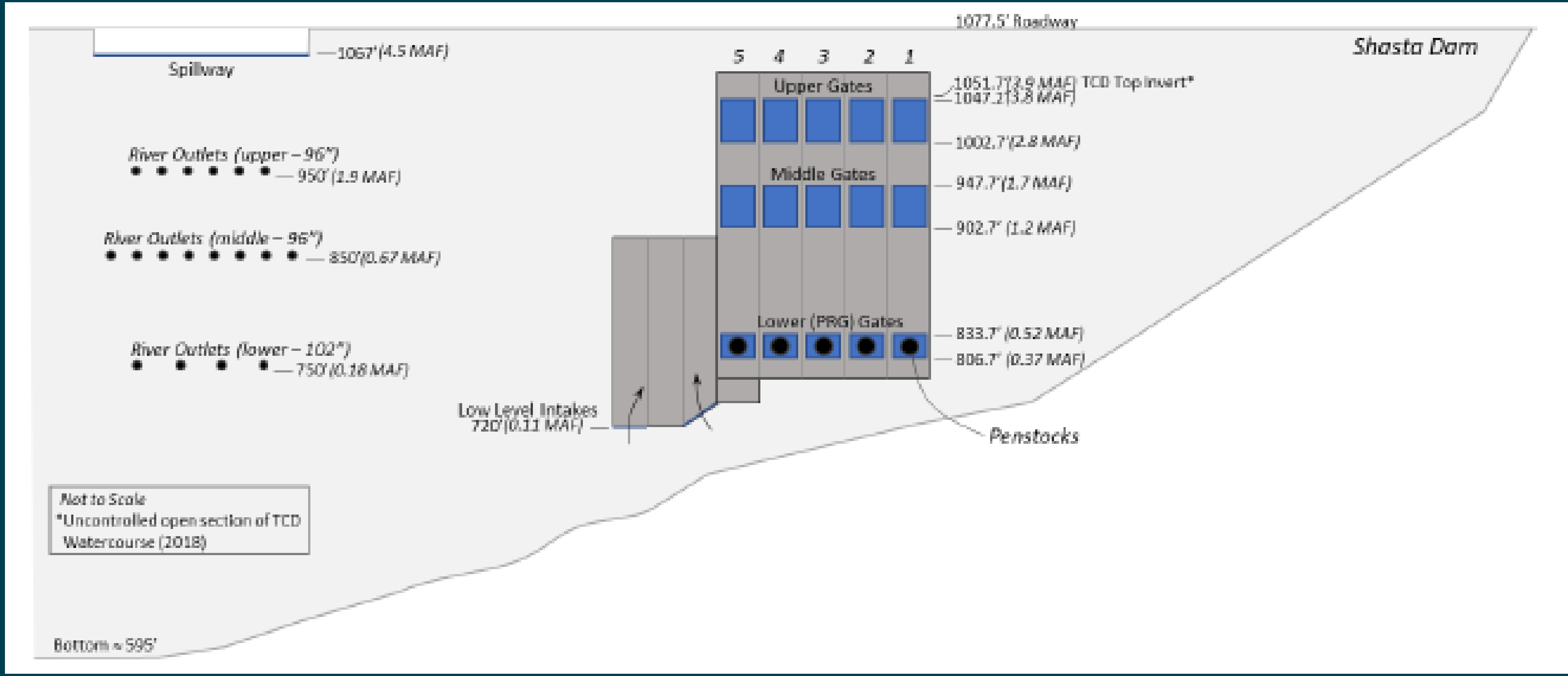




Branch Name [number]	Total Number of Segments in Branch	Total Length of Arm [feet (meters)]	Average Segment Length [feet (meters)]	Minimum Segment Length [feet (meters)]	Maximum Segment Length [feet (meters)]
Main Reservoir (1)	101	51,823 (15,796)	513 (156)	163 (50)	1,132 (345)
Spring Creek arm (2)	12	3,512 (1,071)	293 (89)	137 (42)	492 (150)

Shasta Lake Model: CE-QUAL-W2 Representations

- Shasta Dam River Outlets and Spill
- Shasta Dam Temperature Control Device (TCD)

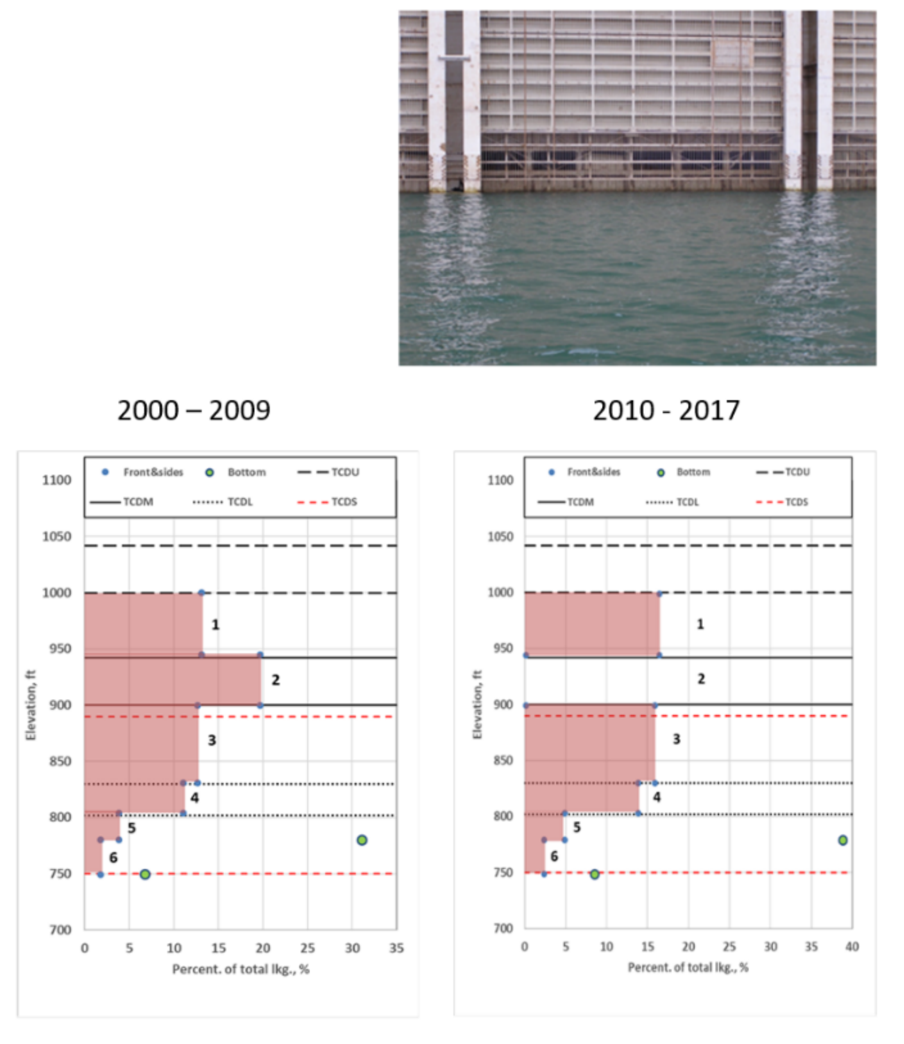


Shasta Lake: CE-QUAL-W2

- TCD Considerations
  - Leakage
  - Temperature Control Device (TCD)
  - Sidegate Operations

TCD Leakage

- Total “theoretical” leakage: 20%
    - Maximum total leakage at full pool and all gates closed except at upper gate level
- Leakage repairs: January 2010
- Repairs reduce leakage area identified by USBR (1999) to about 16.1%
- Test sensitivity of leakage to
    - Total leakage
    - Leakage distribution



TCD Leakage (continued)

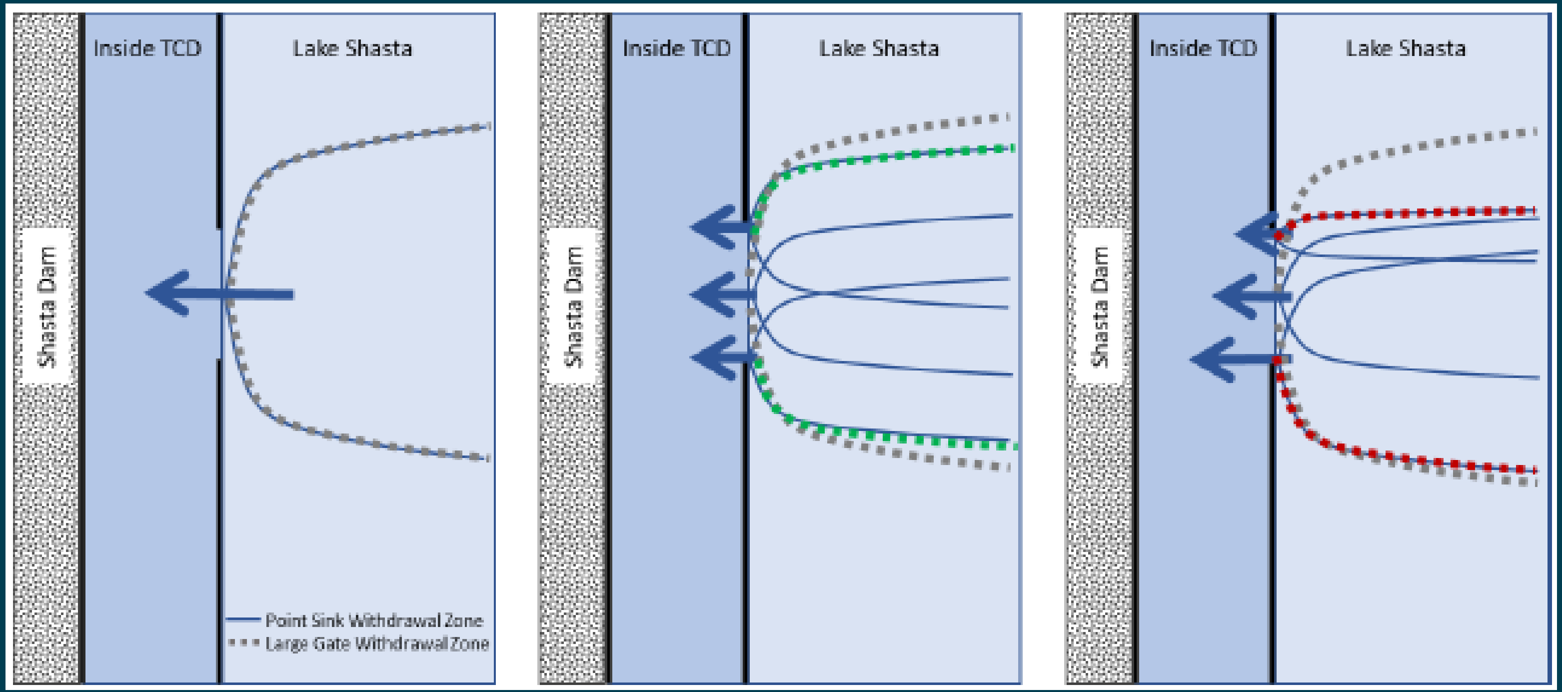
- Results relatively insensitive to:
  - Total leakage
  - Leakage distribution
- Explanation
  - Leakage only makes up a fraction of total TCD outflow
  - When a gate is open, leakage is zero from that vertical “zone”
  - Selective withdrawal targets TCD gate operations to meet outflow temperature target (leakage is always present)

TCD: Large Gate Representation

- Large gate representation
  - Upper and Middle: 45 feet high; Lower: 27 feet high
  - Outflow temperatures are at times cooler than all available water temperatures across a gate level
  - Extended duration releases at a single gate level
  - Potential considerations
    - Point sink representation
    - Minimum flow fractions
    - Density gradient considerations for point/line sinks (superposition)
    - CE-QUAL-W2 representation/limitations
      - Lateral averaging
      - TCD
      - Reservoir boundaries

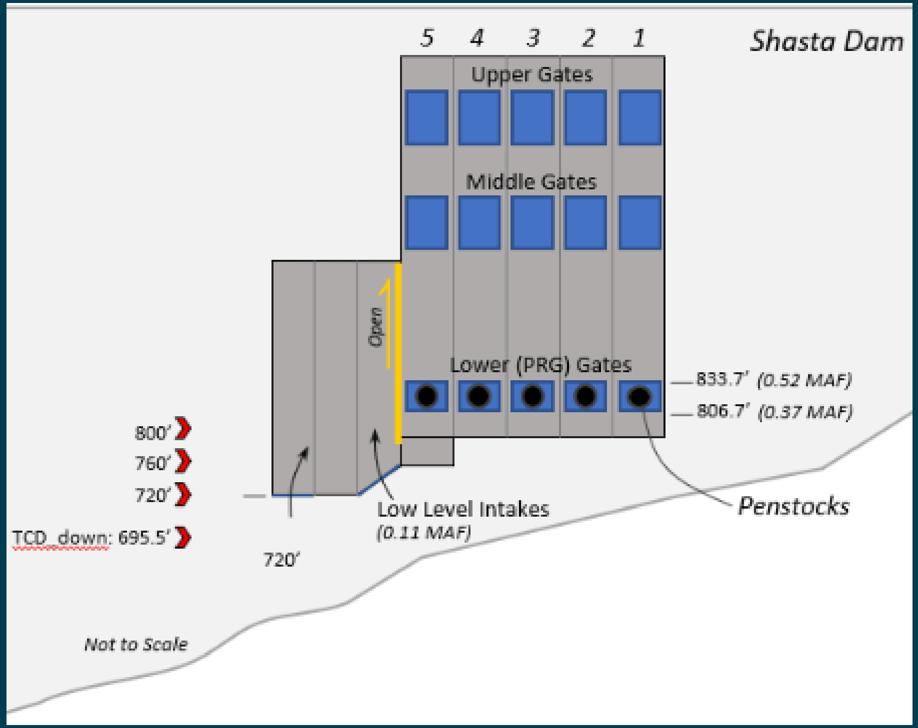
TCD: Large Gate Representation (continued)

- One individual versus three individual point sinks
- Three individual point sinks
  - Uniform distribution
  - Varying distribution (with minimum flow fractions)



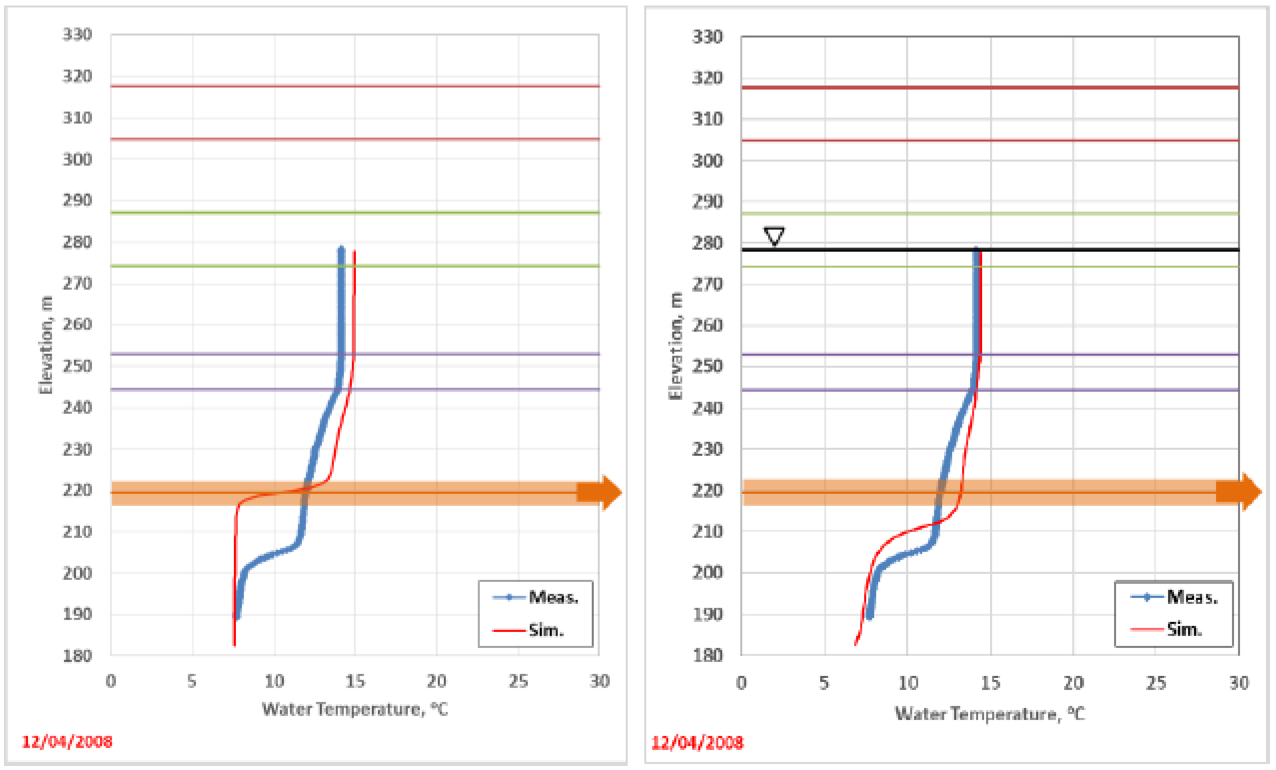
TCD: Side Gate Representation

- Side Gate located on spillway side of dam
  - Vertical flow pattern induced by side gate structure
  - Reservoir boundaries
  - High thermal gradient challenge
  - CE-QUAL-W2 representation (previous slide)
- Representation
  - Three individual point sinks (matching outflow temperatures under side gate only
  - TCD_down to capture low storage conditions and high temperature gradient conditions



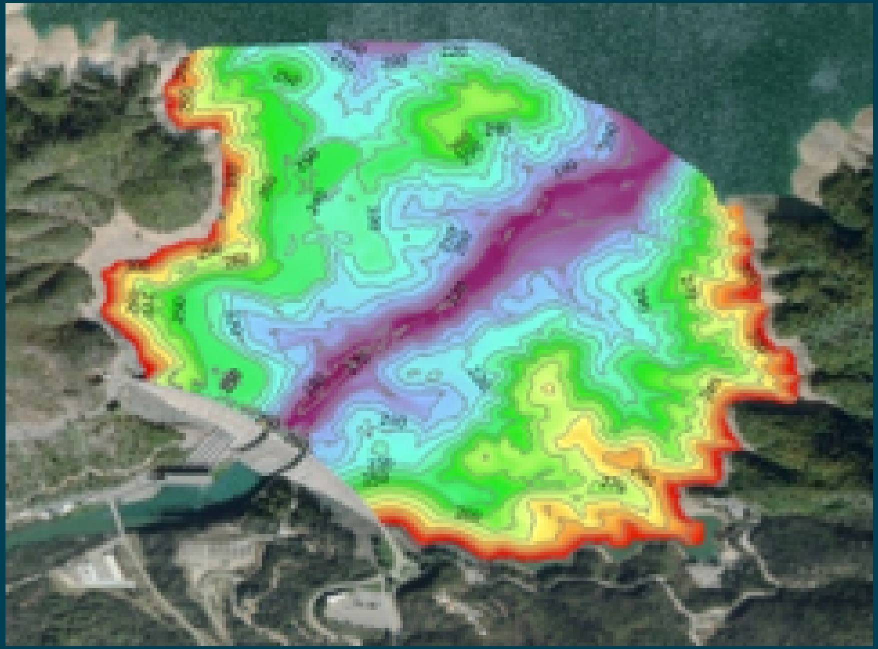
TCD: Side Gate Representation, Model Results

- Model results with and without TCD_down representation
- Tested over a range of years and representations



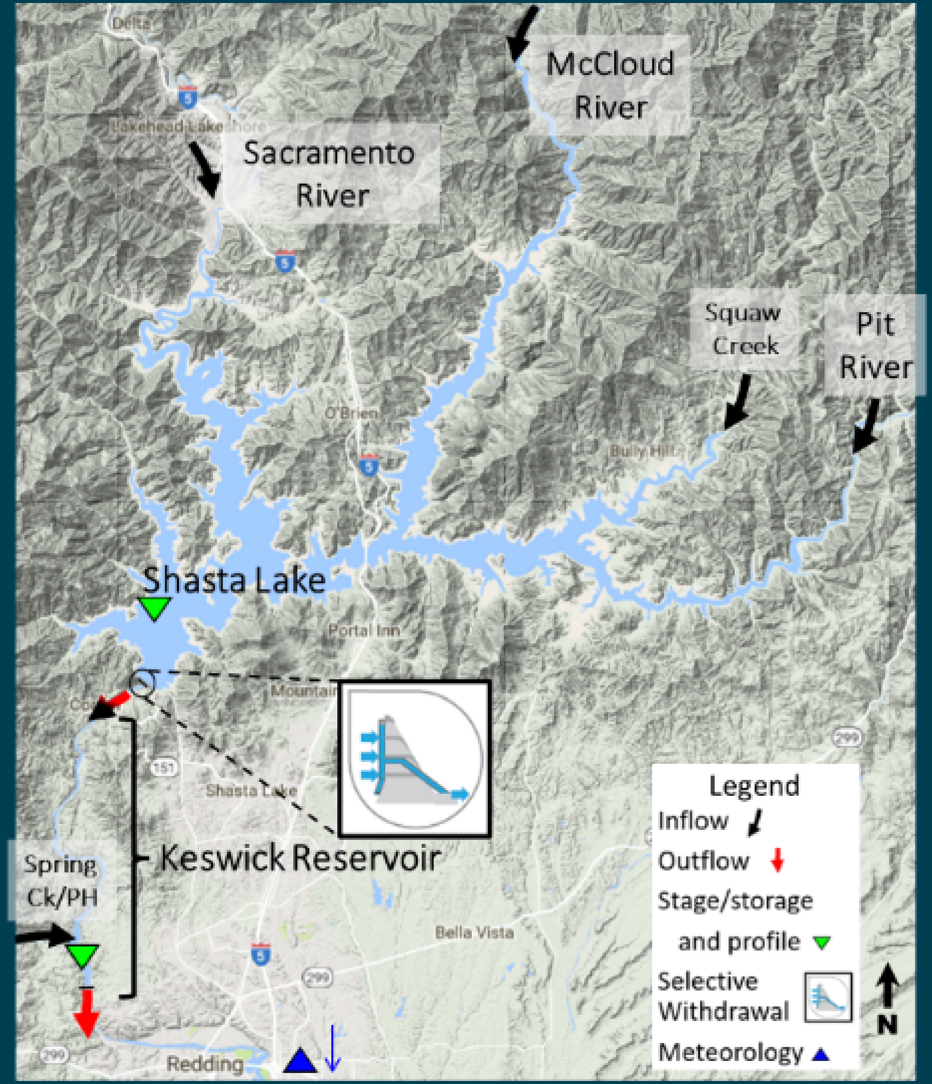
TCD: Side Gate Representation, Status and Studies

- Status: “working” solution
  - Degrees of freedom
    - Number of outlets
    - Elevation of outlets
    - TCD_down elevation and flow fraction
- Field Studies: U.C. Davis
  - Bathymetry, sonar, exploratory ADCP (2019)
  - Additional ADCP exploration (2021)
  - Delta Science Council Project (Pending)
  - Objective: identify local flow patterns upstream of TCD and determine flow through individual gates to improve model representations.



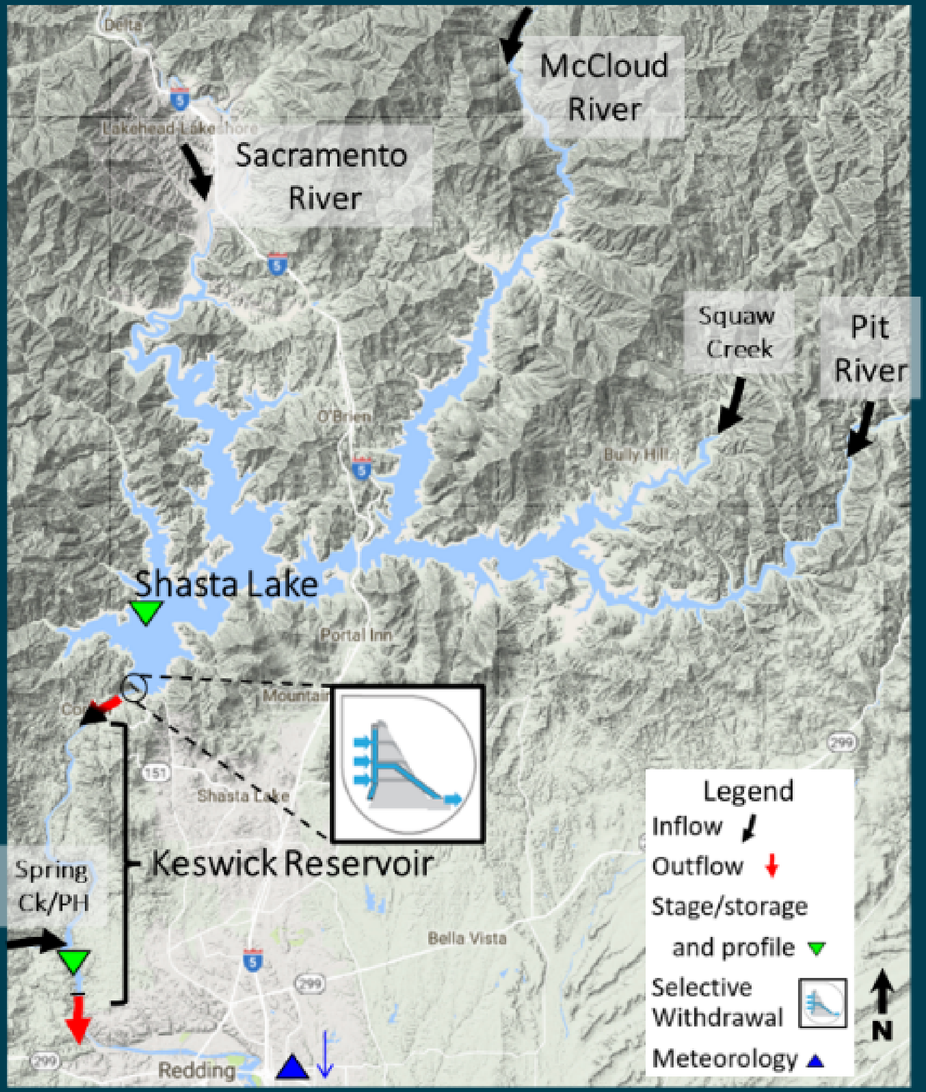
Hydrology, Temperature, Meteorology Data

- Flow
  - Inflow (hourly, daily) USGS
  - Outflow/operations (hourly) USBR
  - Storage (hourly, daily) USBR
  - Selective withdrawal operations (daily, weekly) USBR
- Water Temperature
  - Inflow (hourly, daily) USGS
  - Outflow (hourly, daily) USBR
  - Temperature profiles (weekly, monthly) USBR



Hydrology, Temperature, Meteorology Data (continued)

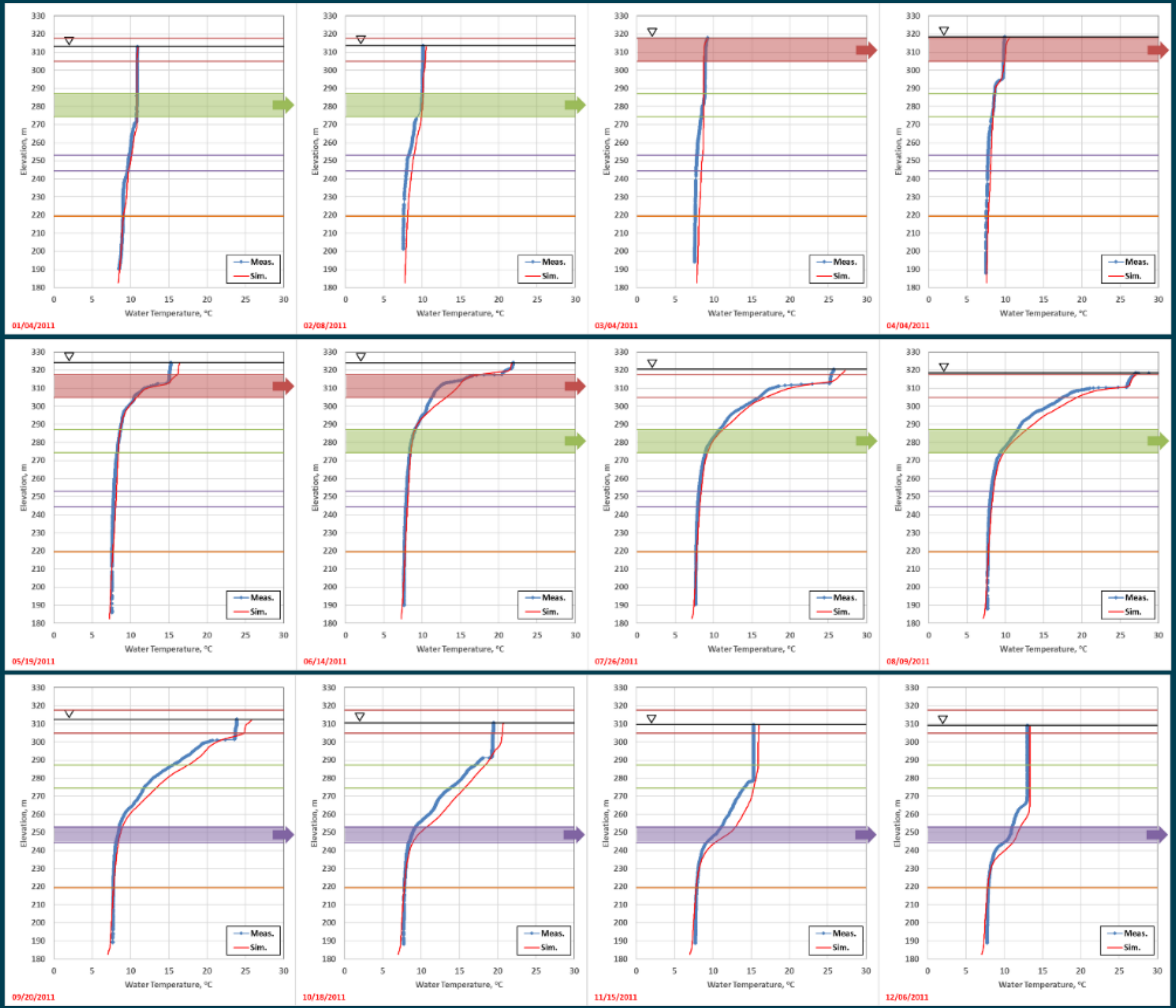
- Meteorology
  - Solar, air temperature, dew point, wind speed/direction, cloud cover, barometric pressure (hourly) NWS
- Geometry
  - Dam outlet structures USBR
  - Bathymetry (and tributary/diversion locations) USGS/Other
  - Topographic shading (minor) USGS



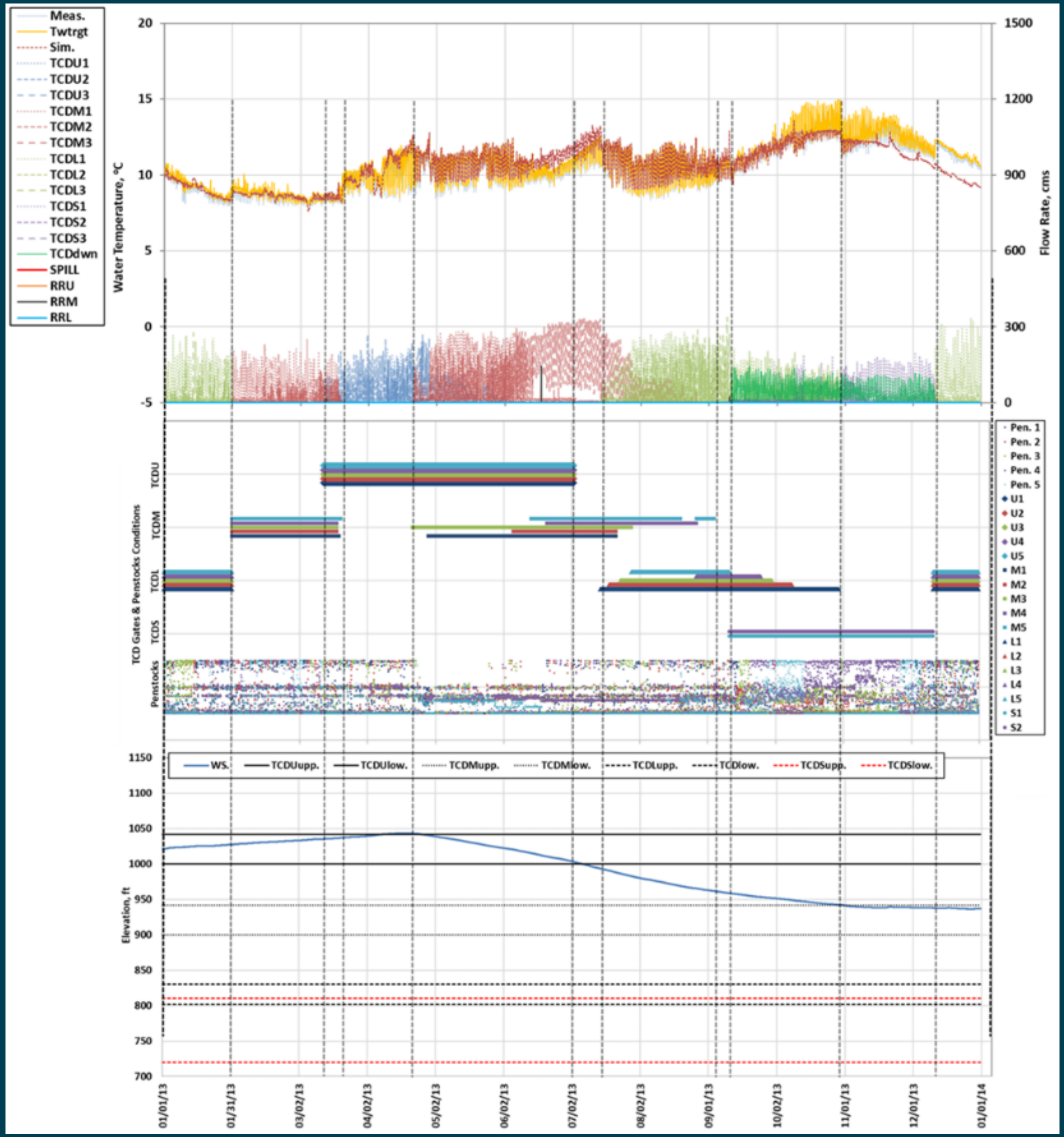
Shasta Lake: CE-QUAL-W2 – Model Results

- Calibration period (2000 – 2017)
- Validation period (2018 – 2021) in progress
- Time Series (hourly)
  - Temperature (simulated, measured)
  - Flow (TCD, River outlets, spill)
  - Active TCD gates (and gate changes)
  - Powerhouse operations
  - Reservoir Elevation and TCD gate elevations
- Profiles (Monthly)
  - Temperature (simulated, measured)
  - Active Gates
  - Reservoir Elevation and TCD gate elevations
- Calendar years completed, with graphical and statistical info

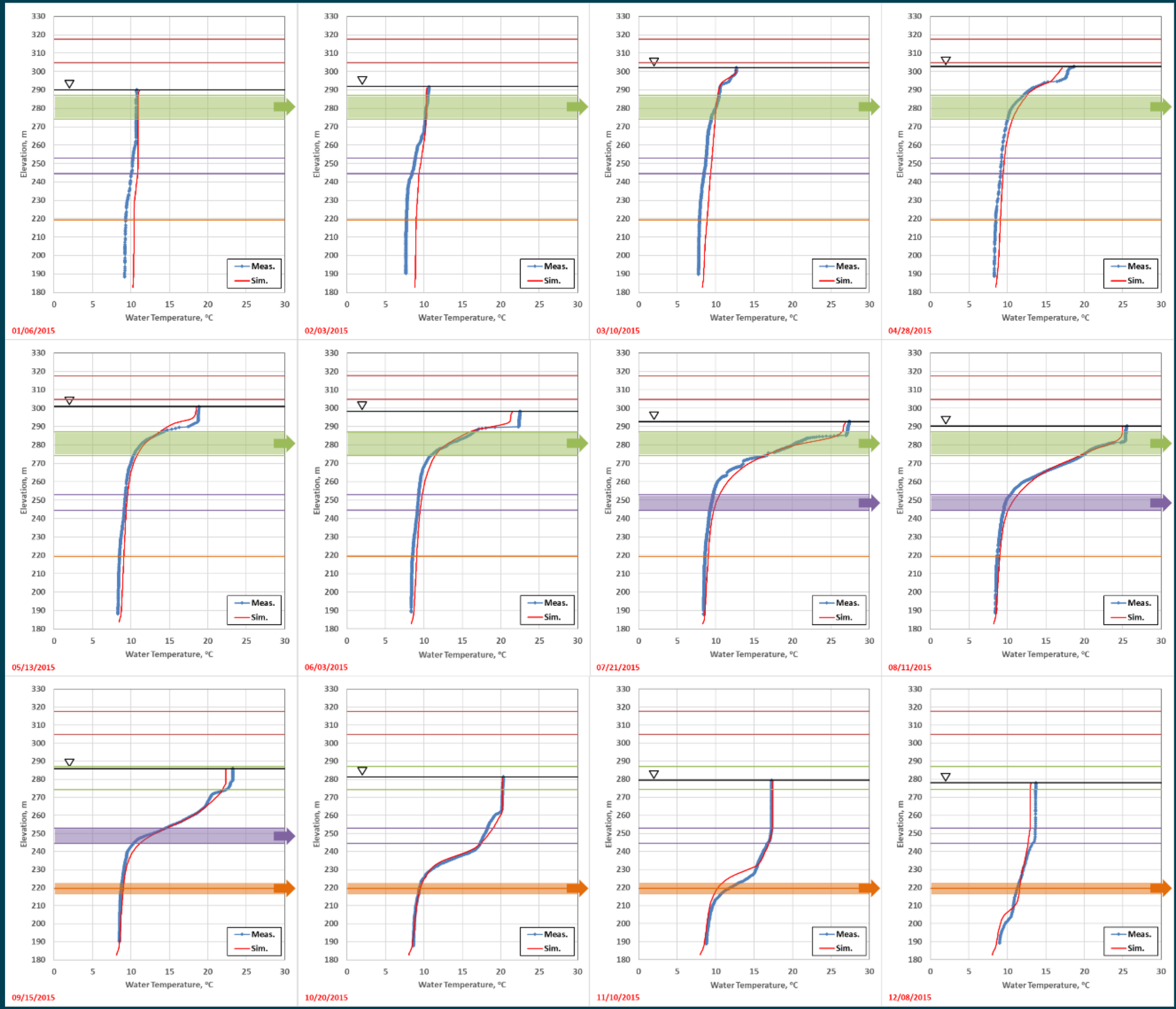
Shasta Lake monthly vertical temperature profiles for 2011



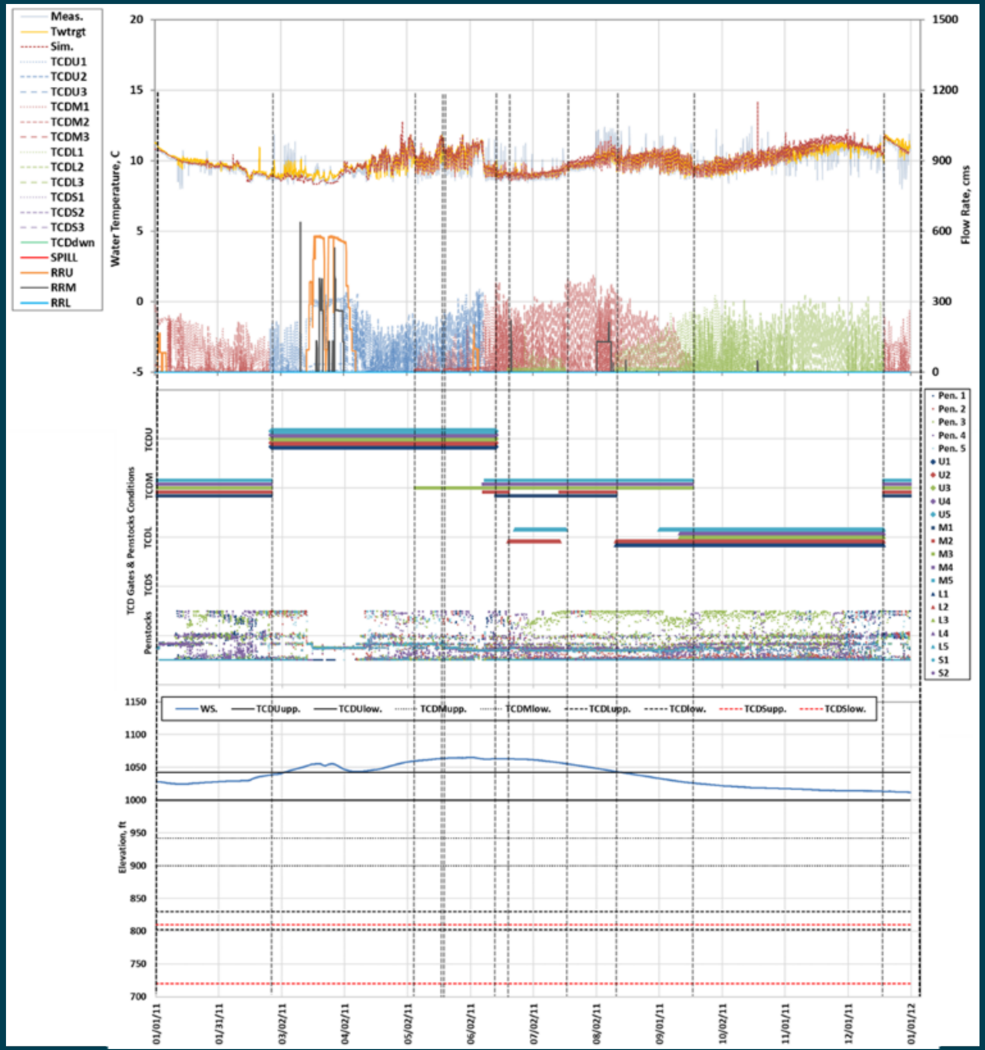
Shasta Lake state, powerhouse operations, TCD gates in 2011



Shasta Lake monthly vertical temperature profiles for 2015



Shasta Lake state, powerhouse operations, TCD gates in 2015



Shasta Lake above Shasta Dam: Mean bias for monthly temperature profiles (degree Celsius) for 2000 – 2017 (DRAFT)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	0.11	0.21	-0.29	-0.23	-0.07	-0.13	-0.07	-0.08	-0.13	0.23	0.02	-0.38
2001	0.03	0.01	-0.01	0.21	0.48	0.40	0.52	0.74	1.19	1.57	1.30	-0.16
2002	-0.15	0.08	0.24	0.38	0.36	0.45	0.39	0.56	0.56	0.84	0.80	-
2003	0.33	-0.04	0.02	0.27	0.43	0.25	0.11	0.16	0.12	0.07	-0.03	0.07
2004	0.32	0.13	0.19	0.09	0.09	0.01	-0.09	-0.16	-0.31	-0.44	-0.59	-0.74
2005	0.04	0.13	0.09	0.39	0.36	0.52	0.33	0.51	0.64	0.69	0.52	0.42
2006	-0.15	-0.17	-0.28	0.03	0.00	0.19	0.10	0.00	0.06	-0.19	-0.06	-0.22
2007	0.37	0.12	0.38	0.19	0.13	0.12	0.08	-0.08	0.00	-0.78	-0.68	-0.50
2008	0.20	-0.02	0.32	0.45	0.29	0.08	0.27	0.14	0.13	-0.70	-0.31	-0.10
2009	0.56	0.90	0.26	0.57	0.71	0.82	0.71	0.75	0.72	0.41	0.47	0.54
2010	0.25	-0.45	-0.45	-	0.08	0.43	0.35	0.20	0.26	0.07	0.04	-0.11
2011	0.13	0.34	0.21	0.12	0.06	0.18	0.19	0.26	0.43	0.48	0.34	0.08
2012	0.18	0.28	0.40	-	0.55	0.43	0.37	0.22	0.27	0.08	0.26	-
2013	0.35	0.35	0.54	0.58	0.87	-	-	0.30	0.72	0.27	-0.05	-0.38
2014	0.39	0.56	1.09	1.21	1.26	1.10	1.24	1.37	0.94	0.71	0.54	0.53
2015	0.75	0.82	0.62	0.39	0.22	0.23	0.49	0.25	0.17	0.06	-0.29	-0.38
2016	0.36	-0.12	0.56	0.48	0.56	0.68	0.59	0.71	0.69	0.57	0.36	-
2017	0.41	0.25	-	0.20	0.46	0.54	0.63	0.54	0.60	0.57	0.50	0.37

Shasta Lake above Shasta Dam: Mean Absolute Error for monthly temperature profiles (degree Celsius) for 2000–2017 (DRAFT)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	0.28	0.41	0.30	0.26	0.15	0.37	0.29	0.37	0.43	0.52	0.38	0.41
2001	0.24	0.44	0.41	0.61	0.62	0.54	0.55	0.79	1.19	1.57	1.30	0.60
2002	0.17	0.29	0.44	0.51	0.66	0.73	0.63	0.66	0.67	0.84	1.00	-
2003	0.36	0.23	0.23	0.50	0.62	0.40	0.37	0.31	0.39	0.32	0.30	0.28
2004	0.42	0.44	0.52	0.33	0.25	0.29	0.22	0.33	0.56	0.48	0.63	0.74
2005	0.43	0.46	0.35	0.66	0.59	0.66	0.54	0.64	0.68	0.80	0.67	0.58
2006	0.27	0.80	0.28	0.29	0.36	0.42	0.24	0.22	0.26	0.25	0.37	0.28
2007	0.37	0.40	0.66	0.50	0.41	0.34	0.42	0.31	0.32	0.80	0.74	0.55
2008	0.22	0.50	0.66	0.58	0.68	0.54	0.47	0.45	0.40	0.91	0.59	0.55
2009	0.62	1.02	0.49	0.72	0.74	0.85	0.82	0.76	0.76	0.47	0.47	0.54
2010	0.26	0.45	0.45	-	0.37	0.54	0.42	0.40	0.43	0.34	0.48	0.47
2011	0.14	0.39	0.39	0.20	0.16	0.36	0.32	0.44	0.57	0.64	0.50	0.26
2012	0.19	0.30	0.59	-	0.93	0.68	0.58	0.54	0.47	0.52	0.37	-
2013	0.35	0.44	0.67	0.64	1.08	-	-	0.50	0.75	0.59	0.43	0.76
2014	0.39	0.61	1.31	1.32	1.32	1.24	1.34	1.37	0.95	0.88	0.73	0.60
2015	0.75	0.86	0.68	0.56	0.51	0.58	0.59	0.42	0.38	0.23	0.47	0.49
2016	0.75	0.27	0.81	0.58	0.71	0.83	0.78	0.88	0.88	0.87	0.77	-
2017	0.61	0.54	-	0.42	0.48	0.71	0.70	0.61	0.66	0.75	0.74	0.44

Shasta Lake above Shasta Dam: Root Mean Squared Error for monthly temperature profiles (degree Celsius) for 2000 – 2017 (DRAFT)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	0.31	0.43	0.39	0.52	0.20	0.61	0.37	0.44	0.48	0.64	0.46	0.50
2001	0.26	0.47	0.56	0.75	0.69	0.59	0.62	0.95	1.48	1.86	1.70	0.67
2002	0.20	0.32	0.49	0.60	0.81	0.84	0.74	0.84	0.85	1.20	1.36	-
2003	0.48	0.30	0.28	0.53	0.66	0.59	0.50	0.40	0.48	0.40	0.35	0.33
2004	0.52	0.46	0.56	0.47	0.41	0.57	0.35	0.39	0.73	0.58	0.76	0.95
2005	0.48	0.52	0.39	0.68	0.66	0.81	0.70	0.73	0.78	0.91	0.81	0.83
2006	0.29	0.41	0.40	0.33	0.61	0.69	0.38	0.32	0.36	0.30	0.45	0.36
2007	0.46	0.42	0.76	0.68	0.69	0.54	0.50	0.43	0.45	1.29	1.14	0.68
2008	0.26	0.52	0.69	0.63	1.01	0.64	0.50	0.62	0.60	1.54	1.03	0.73
2009	0.82	1.16	0.52	0.76	0.96	0.98	0.91	0.82	0.84	0.68	0.66	0.80
2010	0.34	0.51	0.47	-	0.60	0.76	0.54	0.62	0.52	0.41	0.61	0.54
2011	0.21	0.45	0.41	0.22	0.20	0.68	0.52	0.66	0.80	0.84	0.71	0.42
2012	0.21	0.34	0.65	-	1.12	0.76	0.70	0.60	0.53	0.59	0.43	-
2013	0.42	0.50	0.73	0.71	1.16	-	-	0.56	0.94	0.65	0.48	0.86
2014	0.49	0.73	1.41	1.43	1.37	1.35	1.39	1.43	1.08	0.94	0.85	0.74
2015	0.83	0.99	0.75	0.60	0.64	0.70	0.73	0.50	0.47	0.35	0.79	0.56
2016	0.82	0.35	0.89	0.67	0.93	1.00	1.00	1.10	1.15	1.11	0.93	-
2017	0.69	0.58	-	0.47	0.58	0.96	0.90	0.75	0.83	0.99	0.94	0.71

Shasta Lake above Shasta Dam: Nash Sutcliffe Efficiency for monthly temperature profiles for 2000 – 2017 (DRAFT)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	0.93	0.74	0.48	0.91	0.99	0.98	0.99	0.99	0.99	0.97	0.97	0.90
2001	0.90	0.26	0.83	0.88	0.96	0.98	0.99	0.98	0.94	0.85	0.71	0.74
2002	0.88	0.87	0.71	0.94	0.92	0.96	0.98	0.98	0.98	0.93	0.83	-
2003	0.79	0.82	0.91	0.83	0.90	0.98	0.99	0.99	0.99	0.99	0.99	0.97
2004	0.56	0.68	0.41	0.95	0.98	0.99	1.00	1.00	0.98	0.98	0.92	0.50
2005	0.74	0.70	0.91	0.75	0.91	0.95	0.98	0.98	0.97	0.94	0.90	0.75
2006	0.91	0.80	0.60	0.84	0.93	0.97	0.99	1.00	1.00	1.00	0.98	0.98
2007	0.81	0.82	0.35	0.87	0.96	0.99	0.99	0.99	0.99	0.88	0.81	0.90
2008	0.92	0.21	0.55	0.78	0.90	0.98	0.99	0.99	0.99	0.88	0.86	0.88
2009	0.60	-0.44	0.01	0.77	0.90	0.95	0.97	0.98	0.98	0.97	0.95	0.85
2010	0.88	0.36	0.50	-	0.91	0.94	0.99	0.99	0.99	0.99	0.97	0.90
2011	0.94	0.81	0.43	0.93	0.99	0.96	0.99	0.98	0.98	0.96	0.95	0.97
2012	0.97	0.81	0.48	-	0.79	0.95	0.98	0.99	0.99	0.99	0.99	-
2013	0.84	0.77	0.64	0.82	0.84	-	-	0.99	0.97	0.98	0.97	0.63
2014	0.84	0.37	-0.14	0.37	0.83	0.91	0.95	0.95	0.96	0.95	0.93	0.76
2015	-0.93	0.17	0.64	0.94	0.96	0.97	0.98	0.99	0.99	0.99	0.95	0.87
2016	0.03	0.84	-0.18	0.90	0.85	0.93	0.96	0.96	0.95	0.95	0.88	-
2017	0.43	0.53	-	0.90	0.96	0.96	0.97	0.98	0.98	0.95	0.89	0.91

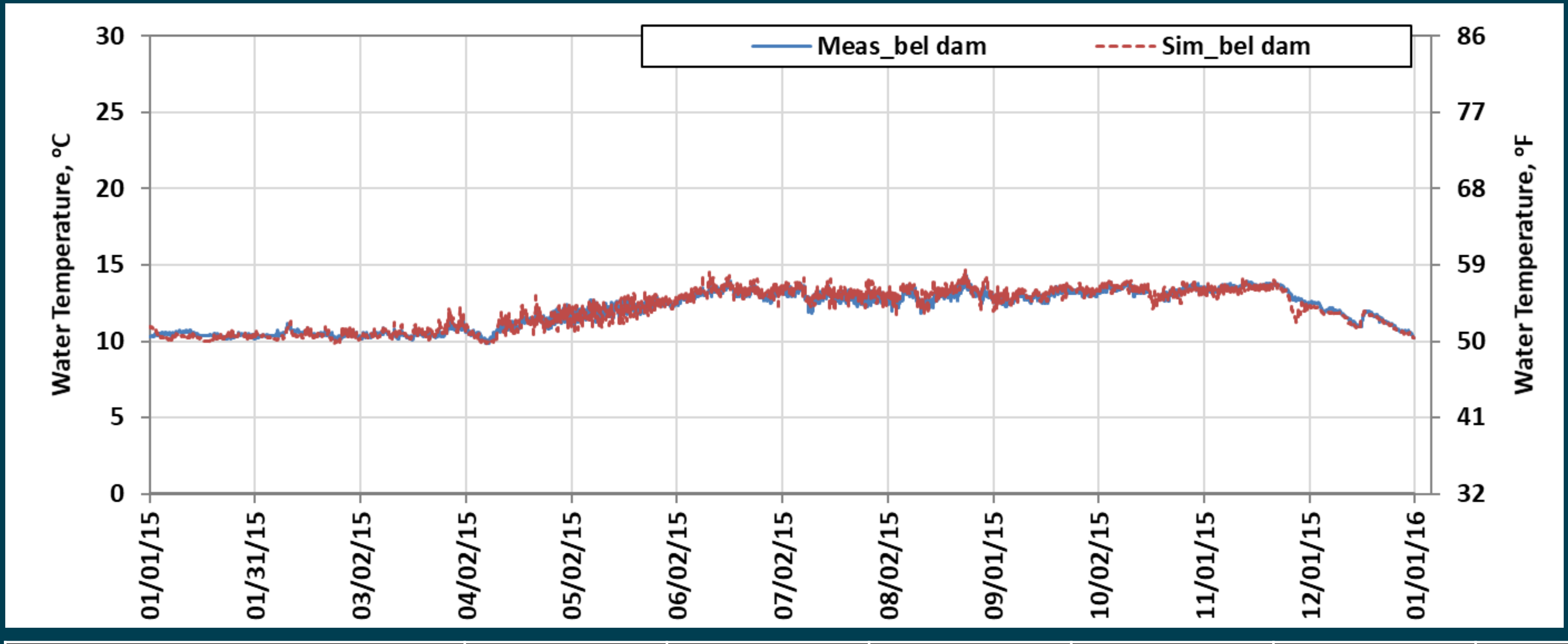
Shasta Dam Release Temperature: Model performance metrics 2000 – 2017 (DRAFT)

Year	Mean Bias (degree Celsius)	MEA (degree Celsius)	RMSE (degree Celsius)	Nash-Sutcliffe (NSE)	Count
2000	-0.08	0.60	0.74	0.54	8,472
2001	0.09	0.36	0.59	0.85	8,760
2002	-0.01	0.31	0.45	0.88	8,760
2003	-0.11	0.20	0.31	0.88	8,760
2004	-0.42	0.47	0.73	0.85	8,784
2005	-0.06	0.15	0.25	0.97	8,760
2006	-0.31	0.33	0.47	0.78	8,760
2007	-0.29	0.38	0.64	0.82	8,760
2008	-0.24	0.38	0.69	0.92	8,784
2009	0.23	0.41	0.60	0.90	8,760
2010	-0.19	0.30	0.49	0.64	8,760
2011	-0.12	0.19	0.32	0.82	8,760
2012	-0.04	0.24	0.36	0.88	8,784
2013	-0.06	0.45	0.66	0.80	8,760
2014	-0.03	0.43	0.66	0.93	8,760
2015	0.07	0.39	0.58	0.52	8,760
2016	0.20	0.38	0.59	0.83	8,784
2017	0.07	0.30	0.39	0.84	8,760

Keswick Reservoir: CE-QUAL-W2 – Model Results

- Calibration period (2000 – 2017)
- Validation period (2018 – 2021) in progress
- Time Series (hourly)
  - Temperature (simulated, measured)
  - Flow (release)
  - Reservoir Elevation
- Profiles (Monthly)
  - Temperature (simulated, measured) profiles are limited pre-2018
- Calendar years completed, with graphical and statistical info

Results



Year	Above Spring Creek 1/21/2010	Below Spring Creek 1/21/2010	Above Spring Creek 3/30/2010	Below Spring Creek 3/30/2010	Above Spring Creek 4/14/2010	Below Spring Creek 4/14/2010	Above Spring Creek 5/18/2010	Below Spring Creek 5/18/2010
Mean Bias (degree Celsius)	-0.47	-0.24	0.57	0.37	0.09	0.02	0.16	-0.01
MAE (degree Celsius)	0.47	0.24	0.57	0.37	0.13	0.06	0.20	0.18
RMSE (degree Celsius)	0.48	0.25	0.58	0.42	0.16	0.07	0.21	0.21
Nash-Sutcliffe (NSE)	-14.0	-6.6	-14.9	-1.73	0.53	0.88	-23.1	-1.35
Count	20	23	21	20	19	22	21	23

Keswick Dam Release Temperature: Model performance metrics 2000 – 2017 (DRAFT)

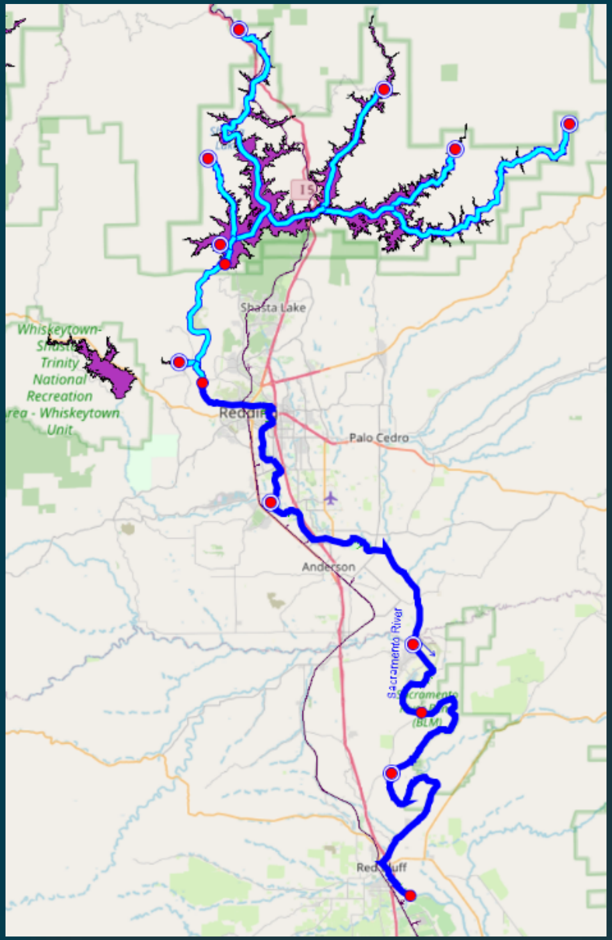
Year	Mean Bias (degree Celsius)	MEA (degree Celsius)	RMSE (degree Celsius)	Nash-Sutcliffe (NSE)	Count
2000	0.01	0.15	0.19	0.96	8,268
2001	0.01	0.18	0.24	0.97	8,568
2002	0.07	0.21	0.28	0.94	8,239
2003	0.00	0.15	0.19	0.94	8,365
2004	-0.01	0.16	0.21	0.98	8,018
2005	-0.03	0.19	0.24	0.96	8,665
2006	0.01	0.14	0.20	0.96	8,717
2007	0.00	0.19	0.26	0.96	8,619
2008	0.00	0.21	0.29	0.98	8,465
2009	0.01	0.21	0.29	0.97	8,739
2010	-0.01	0.24	0.32	0.82	8,668
2011	0.08	0.24	0.32	0.82	8,735
2012	-0.01	0.17	0.23	0.94	8,739
2013	0.04	0.22	0.33	0.93	8,639
2014	0.03	0.22	0.29	0.98	8,731
2015	0.03	0.26	0.34	0.92	8,642
2016	-0.03	0.18	0.23	0.93	8,762
2017	0.00	0.15	0.21	0.96	8,745

Shasta Lake and Keswick Reservoir CE-QUAL-W2 Modeling: Next Steps

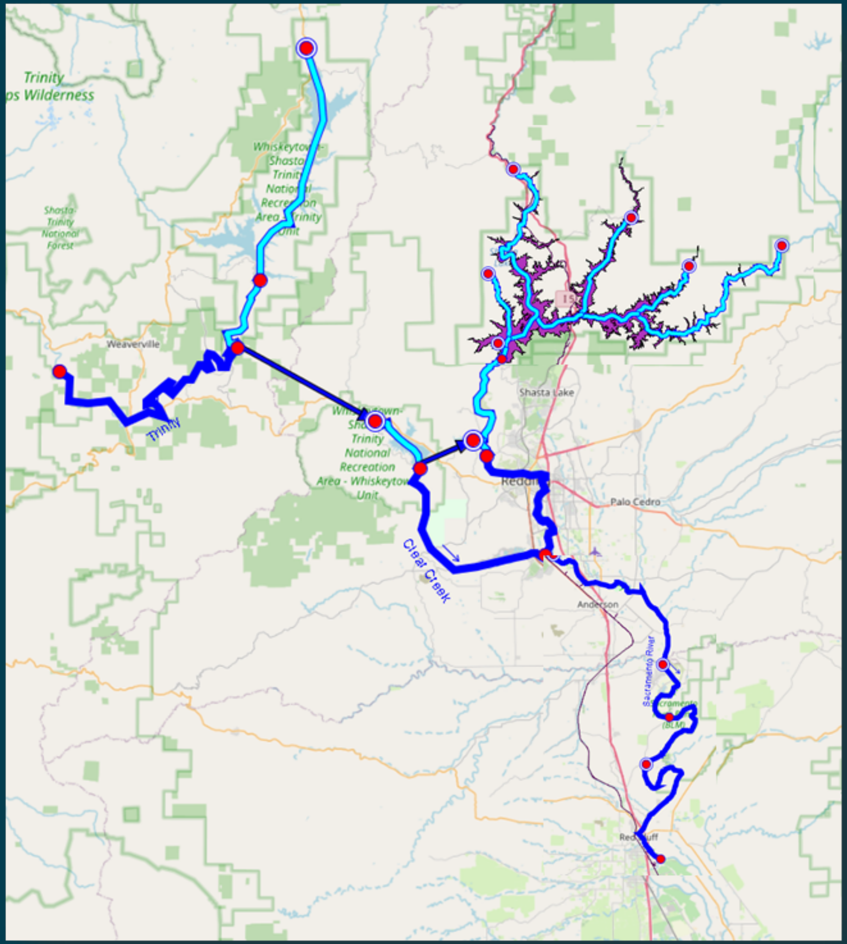
- Model Validation
- Model Calibration/Validation Refinement
- Model Framework Testing
  - Model comparisons (e.g., common boundary conditions)
  - Model linkage performance
  - Reporting
- Documentation

Upper Sacramento ResSim Model

Shasta to Red Bluff

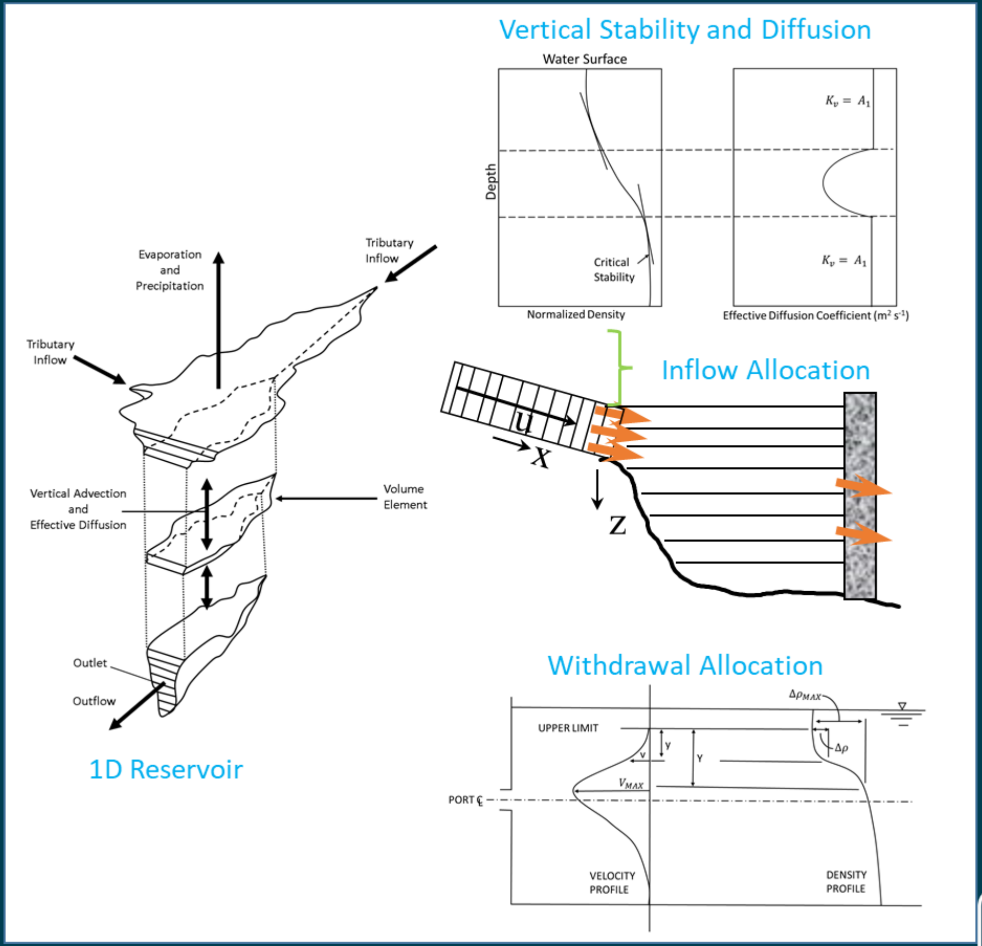


ResSim Upper Sacramento System



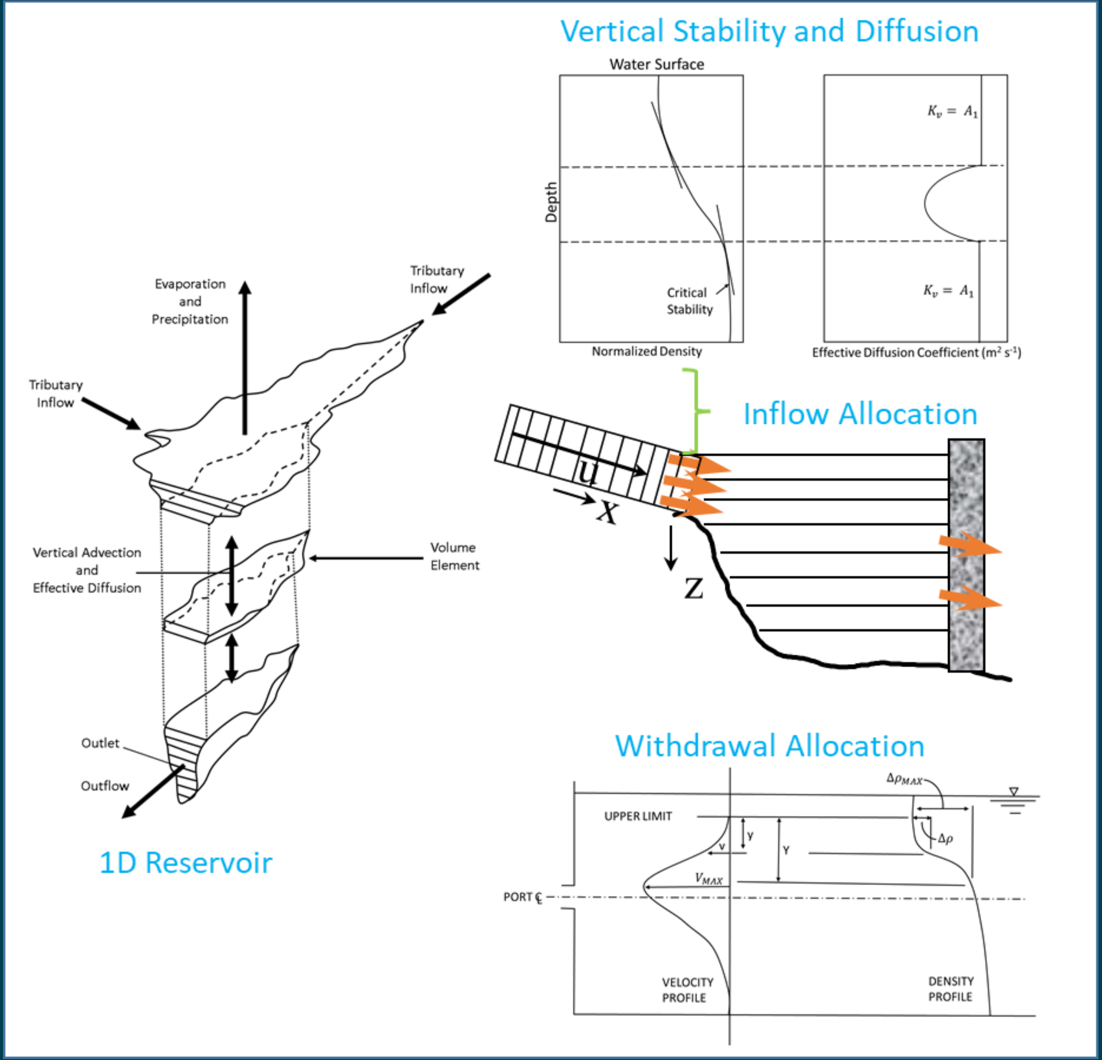
HEC Water Quality Transport Engine Density Stratified Reservoirs

- Vertical Diffusion and Mixing Layers
  - Vertical diffusion and layer stability related to surface wind and density gradient, which is in turn a function of temperature, salinity, or suspended solids
- Inflow Allocation
  - Determine reservoir layer with density equal to inflow density
  - If in upper or lower mixed zones (epilimnion or hypolimnion), distribute over zone
  - If in stratified zone, determine thickness of inflow zone



HEC Water Quality Transport Engine Density Stratified Reservoirs (continued)

- Withdrawal Allocation
  - Layers from which water is withdrawn is a function of the outlet elevation and size, density distribution, and flow rate
- Methodologies adapted from HEC-RAS WQ beta, ERDC CE-QUAL-R1, CE-QUAL-W2, and HEC5Q



Entrainment of Inflow

- Theoretically, when negatively buoyant inflows enter a reservoir, they flow along the submerged river valley until they reach the reservoir level with matching density
- However, as these flows pass through the upper layers of the reservoir, they entrain some fraction of the warmer water, increasing the magnitude of the inflow intrusion and decreasing the density
- This acts to transport some heat from shallower layers of the reservoir to deeper layers
- Inflow density and in-reservoir entrainment determine the density of the inflow intrusion to determine the elevation of matching density within the reservoir
- The physical process is modeled explicitly in 2D models (W2) but needs to be parameterized in 1D models (ResSim)

Entrainment of Inflow (continued)

- From the top layer until either the point of neutral buoyancy or the reservoir bottom is reached:
  - Update the inflow depth
  - Update the inflow flow
  - Update the inflow density
  - At neutral density, flow is inserted using half-flow thickness calculations

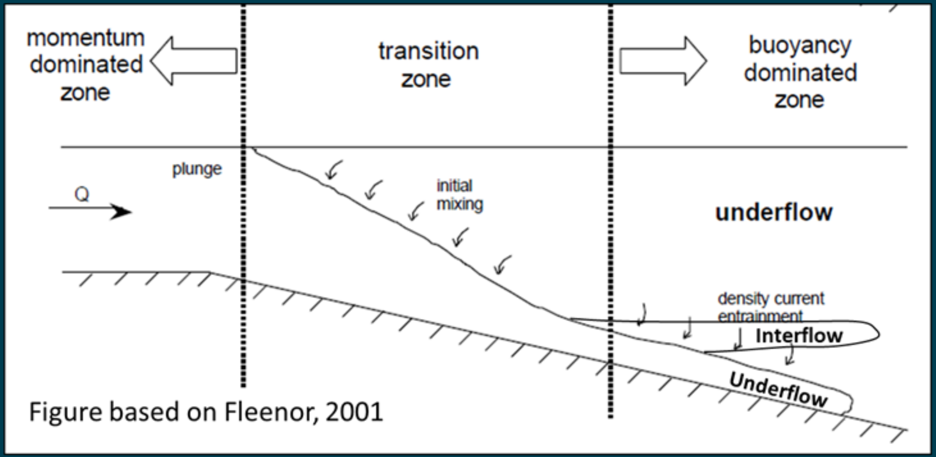
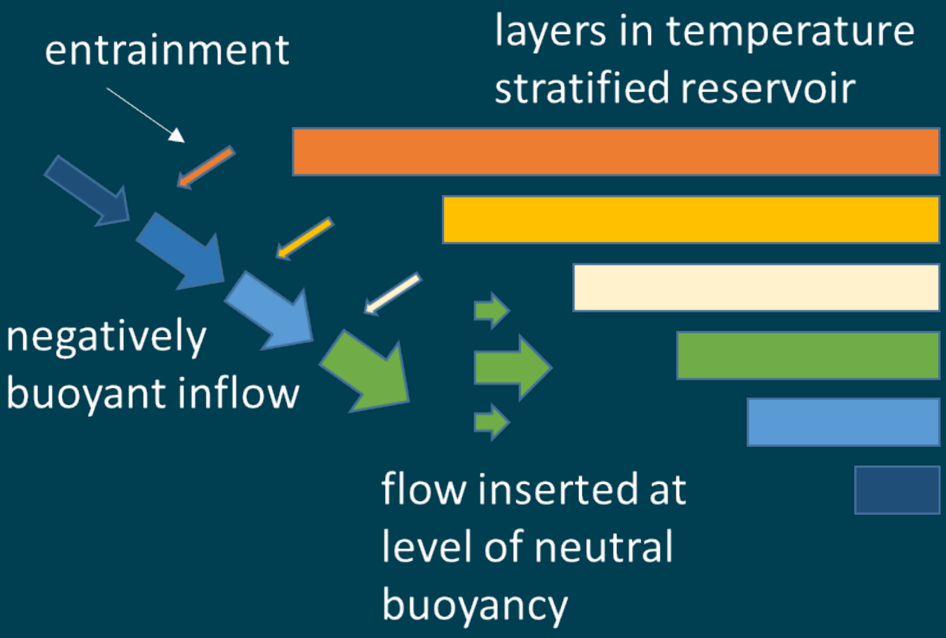
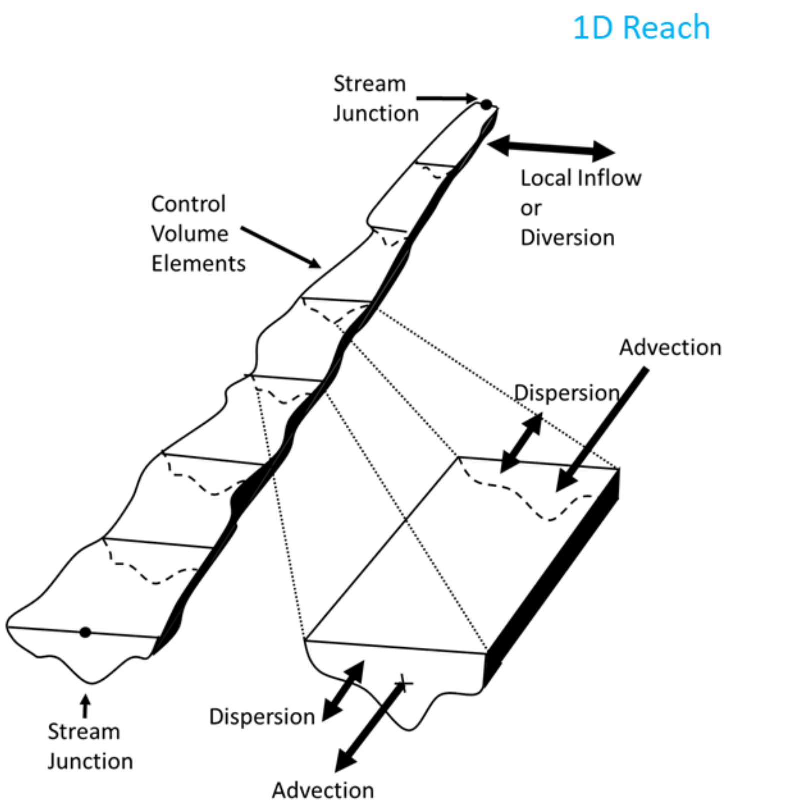


Figure based on Fleenor, 2001



HEC Water Quality Transport Engine River Segments

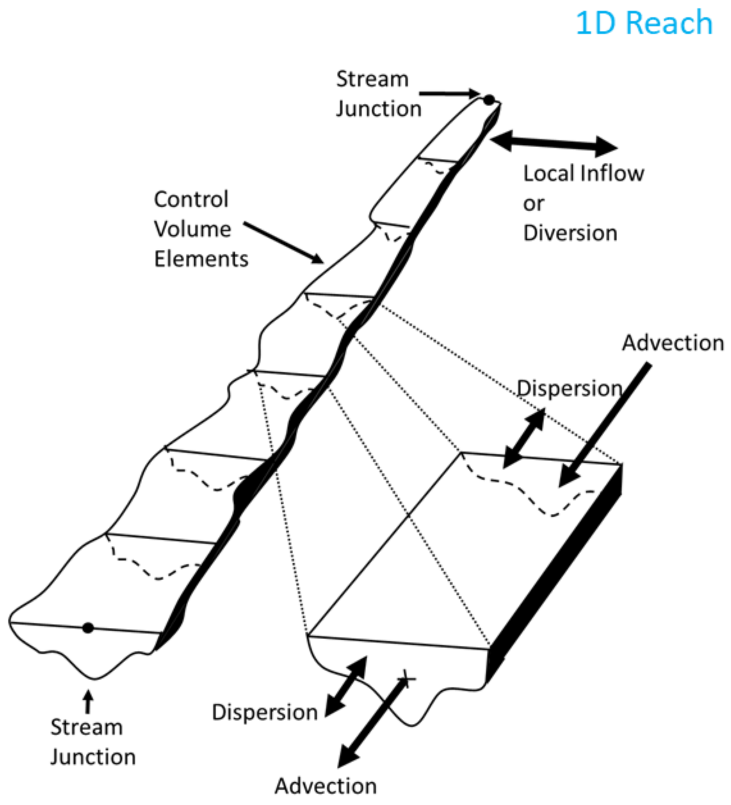
- Unsteady 1D Finite Volume Numerical Scheme
- Explicit solution scheme with sub-stepping
- Cell face concentrations determined with 1st order upwind method, 2nd order flux-limiting method in testing.
- Accept flows computed by hydraulic or hydrologic routing



$$\underbrace{\frac{\partial C}{\partial t}}_{\text{time derivative}} + \underbrace{\frac{\partial (vC)}{\partial x}}_{\text{advection}} = \underbrace{\frac{\partial}{\partial x}\left(K\frac{\partial c}{dx}\right)}_{\text{diffusion}} + \text{sources/sinks}$$

HEC Water Quality Transport Engine River Segments (continued)

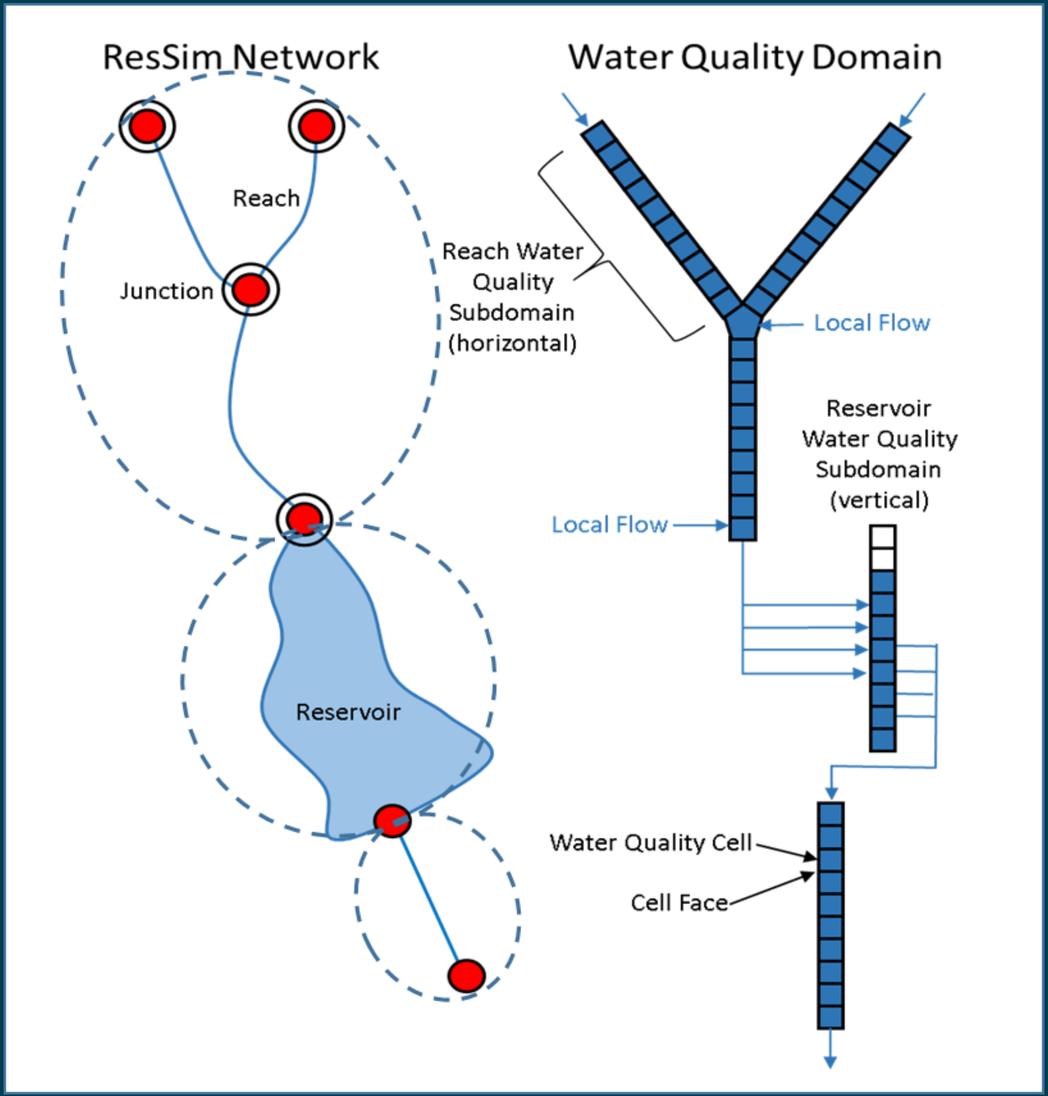
- Cell geometry imported from HEC-RAS cross-sections
- Hydraulic parameter lookup tables derived from HEC-RAS flow simulations
- Technical Documentation - "Generalized One-Dimensional Reservoir and River Water Quality Engine Prototype", USACE Hydrologic Engineering Center, November 2017



$$\underbrace{\frac{\partial C}{\partial t}}_{\text{time derivative}} + \underbrace{\frac{\partial (vC)}{\partial x}}_{\text{advection}} = \underbrace{\frac{\partial}{\partial x}\left(K\frac{\partial c}{dx}\right)}_{\text{diffusion}} + \textbf{sources/sinks}$$

Model Subdomains

- An example ResSim network composed of stream reaches and a reservoir, and its corresponding discretized water quality domain



ResSim Reservoir Outlet Geometry

- Outlet Types
  - Uncontrolled Outlet
  - Controlled Outlet
  - Power Plant
  - Pump
- Hierarchical release structure
  - Total Reservoir Release
  - Dam Release
  - Diverted Outlets
  - Outlet Groups
- Multi-port Water Control Device (WCD) can be placed over any outlet or outlet group
- Intake or WCD Port specifications
  - Shape and size – circular or rectangular
  - Invert Elevation
  - Opens from – top, bottom, center

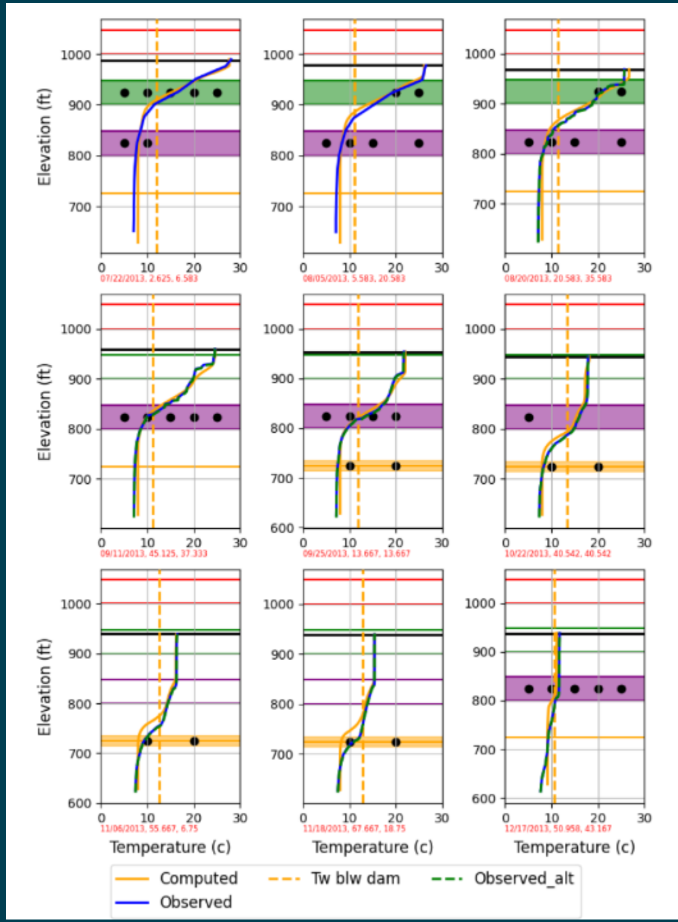
Example

Shasta Reservoir Outlet Structure

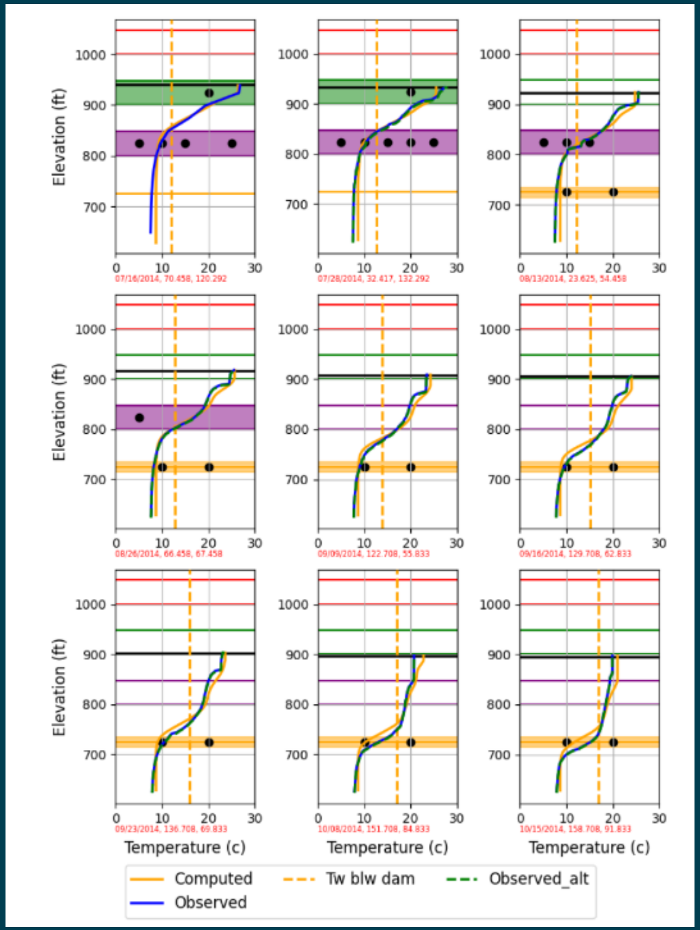
- Dam at Sacramento River
  - Spillway
  - River Outlets-Upper
  - River Outlets-Middle
  - River Outlets-Lower
  - Power Penstocks
    - TCD
      - Upper Gates
      - Middle Gates
      - Lower Gates
      - Low Level Intakes

Preliminary ResSim Calibration Shasta Reservoir Profiles

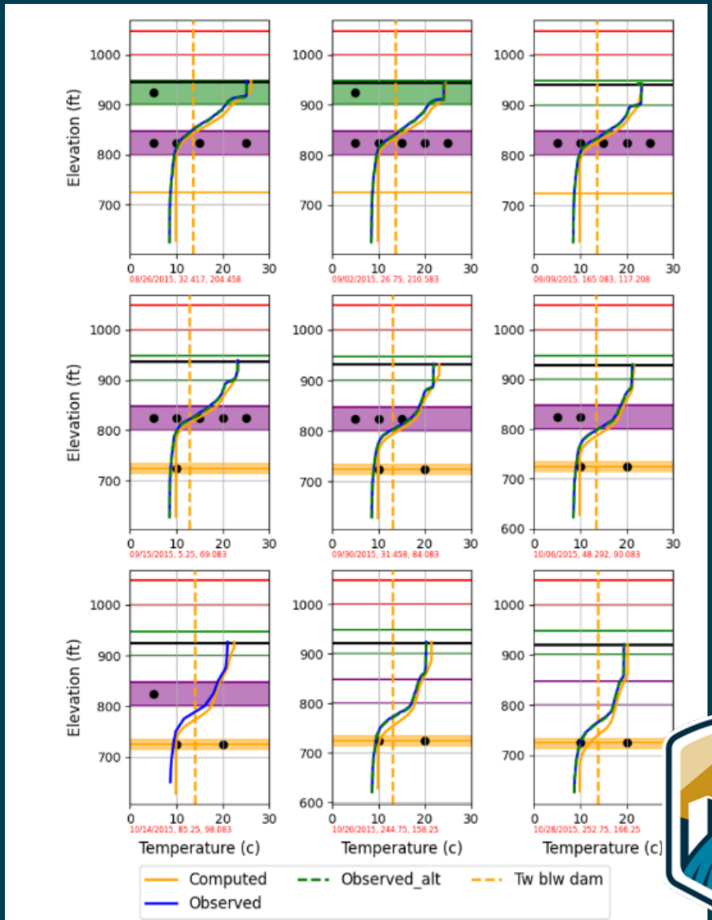
July 22, 2013, to December 17, 2013



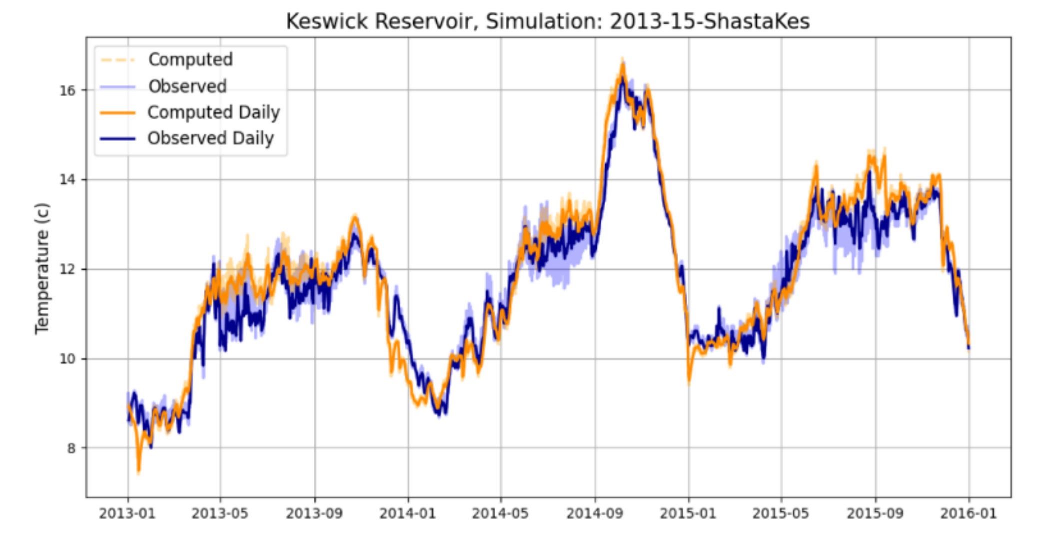
July 16, 2014, to October 15, 2014



July 26, 2015, to October 28, 2015



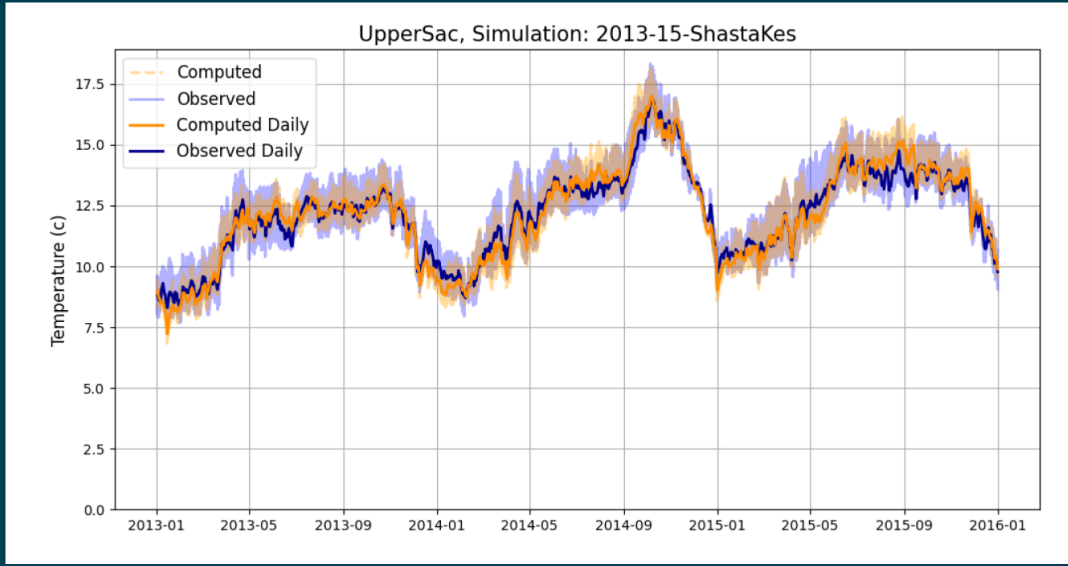
Preliminary ResSim Calibration Keswick Outflow Temperature



Year	Computed Mean 2013	Observed Mean 2013	Computed Mean 2014	Observed Mean 2014	Computed Mean 2015	Observed Mean 2015
Jan	8.3	8.73	9.18	9.66	10.14	10.42
Feb	8.62	8.71	9.39	9.14	10.3	10.47
Mar	9.46	9.13	10.04	10.32	10.69	10.47
Apr	11.35	11.07	10.57	10.75	11.04	10.96
May	11.6	11.18	11.54	11.68	11.92	12.12
Jun	11.72	11.16	12.65	12.51	13.41	13.12
Jul	11.92	11.97	12.99	12.35	13.36	12.98
Aug	11.87	11.6	13.08	12.65	13.97	12.99
Sep	11.89	11.57	14.83	14.12	13.8	12.97
Oct	12.7	12.4	15.84	15.81	13.52	13.33
Nov	12.1	12.11	15.04	14.88	13.57	13.43
Dec	10.18	10.93	12.1	12.21	11.77	11.55

Statistics	2013	2014	2015	All Years
Mean Bias (degree Celsius)	0.18	0.1	0.18	0.15
MEA (degree Celsius)	0.43	0.32	0.34	0.37
RMSE (degree Celsius)	0.53	0.41	0.46	0.47
Nash-Sutcliffe (NSE)	0.83	0.96	0.87	0.92
Count	364	365	365	1095

Preliminary ResSim Calibration Sacramento River above Clear Creek



Year	Computed Mean 2013	Observed Mean 2013	Computed Mean 2014	Observed Mean 2014	Computed Mean 2015	Observed Mean 2015
Jan	8.22	8.73	9.18	9.65	10.1	10.46
Feb	8.73	9.01	9.5	9.41	10.51	10.76
Mar	9.75	9.68	10.42	10.89	11.22	11.21
Apr	11.73	11.76	11.31	11.71	11.66	11.82
May	11.96	11.78	12.12	12.42	12.46	12.9
Jun	12.14	11.59	13.23	13.27	14.19	14.06
Jul	12.39	12.42	13.58	13.09	14.13	13.95
Aug	12.35	12.31	13.68	13.41	14.58	13.84
Sep	12.33	12.34	15.3	14.7	14.22	13.71
Oct	12.87	12.83	16.02	16.1	13.8	13.76
Nov	12.02	12.04	14.9	14.73	13.38	13.07
Dec	9.98	10.46	11.92	12.19	11.52	11.19

Statistics	2013	2014	2015	All Years
Mean Bias (degree Celsius)	-0.04	-0.03	0.09	0.01
MEA (degree Celsius)	0.42	0.43	0.46	0.44
RMSE (degree Celsius)	0.54	0.56	0.59	0.56
Nash-Sutcliffe (NSE)	0.87	0.93	0.85	0.91
Count	8,736	8,760	8,760	26,256

MTC Feedback

- Calibration results
- Shasta TCD Subgroup diving into the detail of modeling, interested?

First Break

- 5-min Break (2:33 p.m. – 2:38 p.m.)

Photo credit: John Hannon, Reclamation

Closure Topic: Data Acquisition and Database Management

Mike Deas, PhD, PE, Watercourse Engineering, Inc.

Jeff Schuyler, Eyasco, Inc.

Data Acquisition and Database Management Outline

- Data Inventory Table Review
- Data Gap Discussion
- DMS Updates

Review of Draft Data Tables

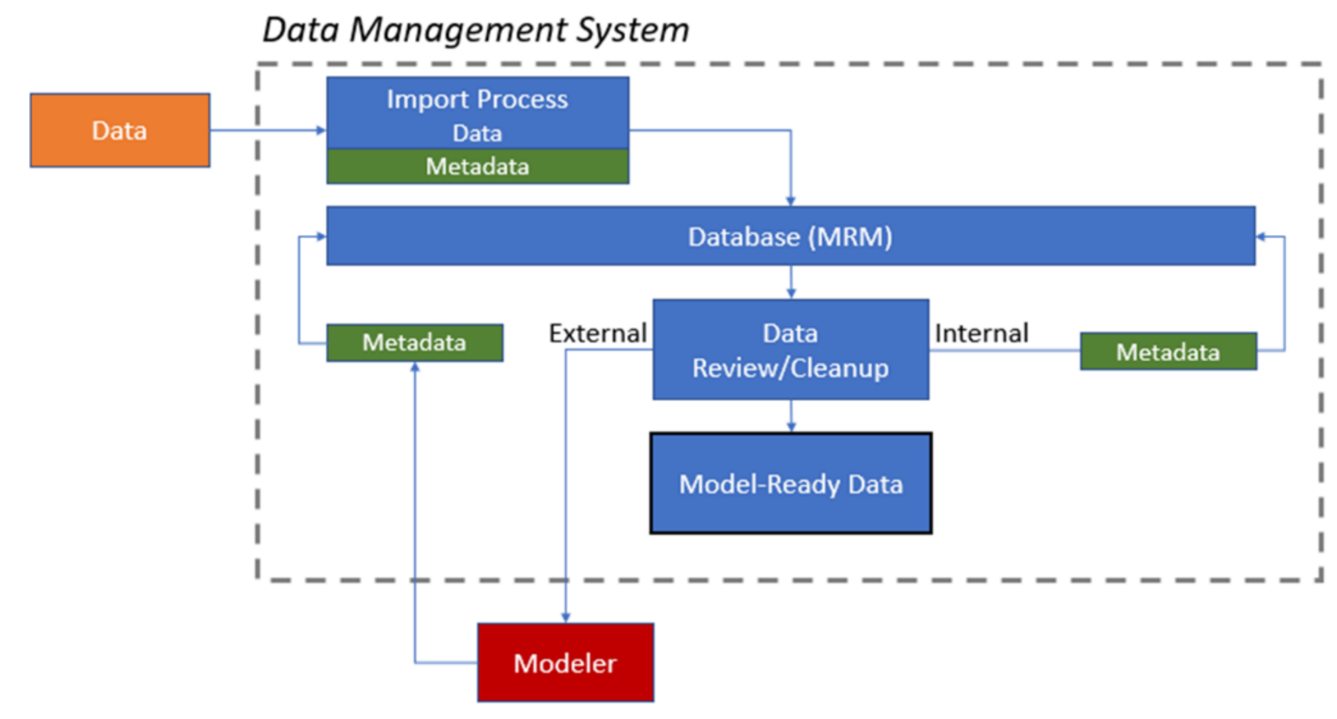
- MTC Feedback
  - Missing any data critical to model development? (We can leave discussion of the American River data for later in the American River Model session.)
  - Additional relevant data to support the model development and future platform expansion use? (Recall Randi's early comments on modeling domains in the current effort.)

DMS Draft Data Table Review

- Draft data inventory table

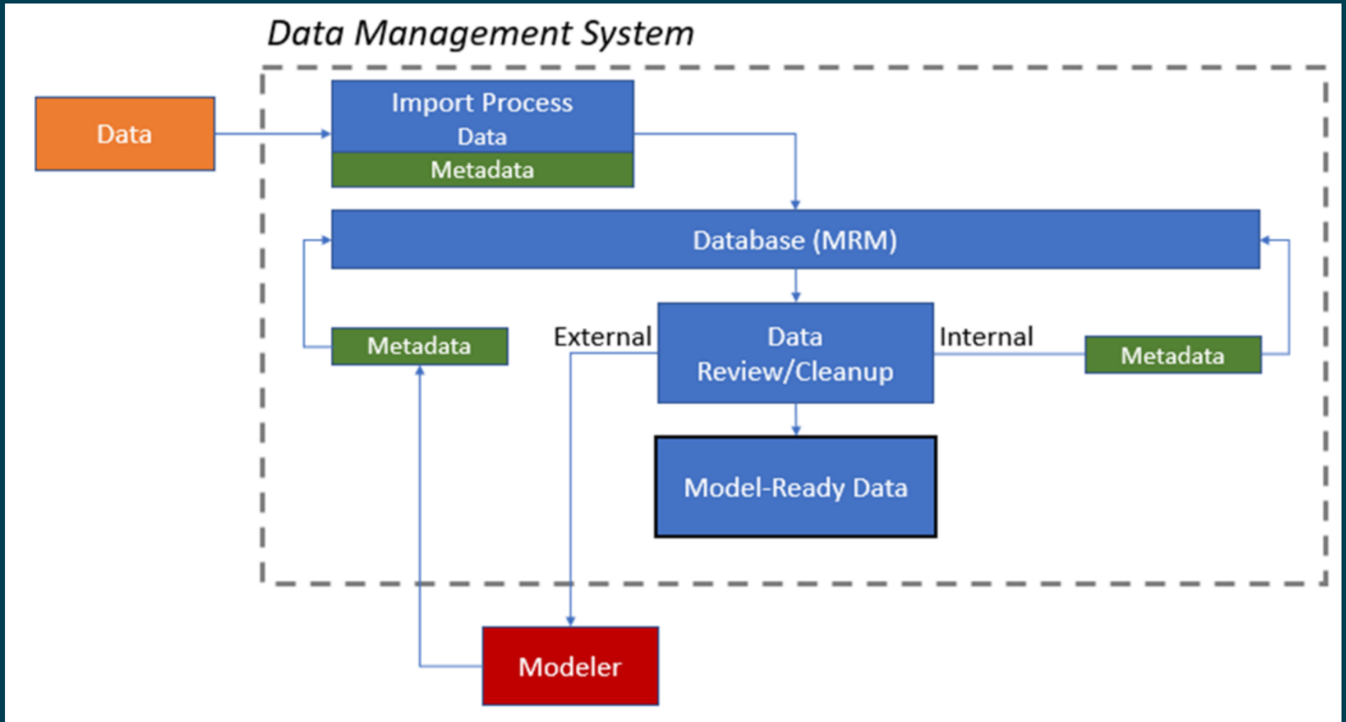
Data Gap Filling

- Geometry
  - Case-by-case
- Time Series
  - Hourly, daily, weekly, monthly, longer
  - Short or stable data – automatic
  - Longer or complex data – “modeler”
- Short
  - Linear interpolation
  - Previous day(s)
  - Neighboring station
  - Constant



Data Gap Filling (continued)

- Long
  - Linear interpolation
  - Statistical assessment
  - Neighboring station
  - Long-Term average
  - Modeled value
    - Regression
    - Equilibrium Temperature Model
    - Other (e.g., SSA)
  - Documentation/metadata
- Completed by technician or modeler



Examples

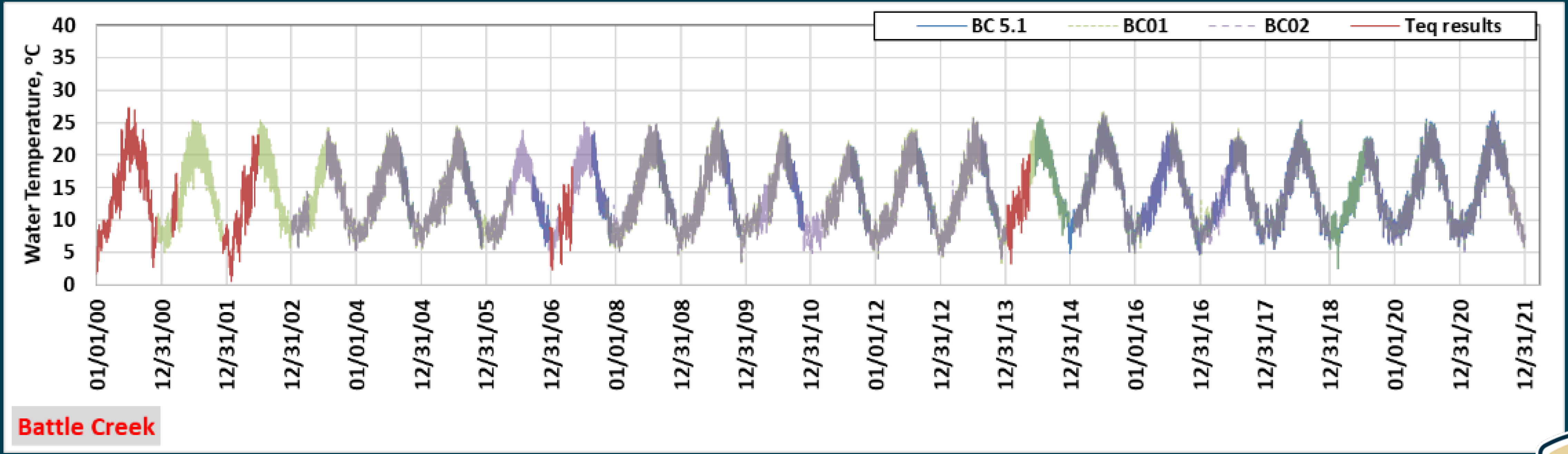
- Linear Interpolation
- Statistical Analysis
- Neighboring station
  - Directly, offset/factor, regression, other
- Long Term Average

Modeled Value, Flow and Temperature

- Flow
  - Linear Regression
    - Squaw Creek inflow to Shasta Lake (daily regression with Sacramento)
  - Multiple linear regression
  - Other statistical relationship
- Temperature
  - Regression
    - Tair (daily)
    - Other locations

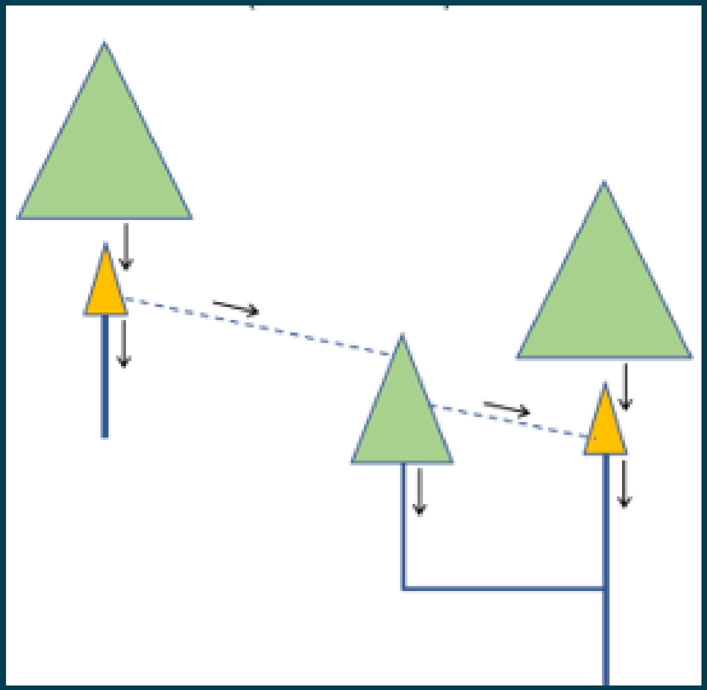
Modeled Value, Water Temperature

- Water Temperatures: Equilibrium Temperature (flow and meteorology)



Modeled Value

- Modeled Value
  - Upstream model (Trinity outflow)
  - Other
    - Singular spectrum analysis
    - Other
- Pros and cons
  - Testing to assess as appropriate



DMS Updates

- American River 70% complete
- Sacramento 20% complete
- Most of the time spent correcting PST/PDT transition (8 different ways) and dealing with different Excel file formats.
- Some files had inconsistent or incorrect dates which usually are not discovered until after import
- Currently working on consistency in naming and application of quality flags
- Cannot import points modified outside the DMS until revision tracking is in place – which requires database version upgrade

Reporting Out: Habitat Data Subgroup Discussions and Outcomes

Yung-Hsin Sun, PhD, PE, Stantec Consulting Services Inc.
Randi Field, CVO, Dept. of the Interior, Bureau of Reclamation

Background

- Regulatory requirements can be specific and location-driven based on many resource management considerations. However, the final rules are often cut and dry for operators or other practitioners that may not be well-versed in all the background derivation and consideration.

Habitat Data

- Broad scan to establish the status of understanding for biological importance and data collection needs
  - All life stages and areas
  - The information can be used for future WTMP development and broader discussions regarding additional data collection
  - Not compiling "critical habitat" information as pertain to any regulatory framework
- For WTMP:
  - To determine the extent and detail of the temperature modeling in river reach downstream of the last CVP facility (e.g., dam) for temperature management purposes and why.

Habitat Data (continued)

- Tabulate and Identify by River Reach:
  - Species/Life-stage
  - Biological Importance
  - Status of Data
    - Desired/Available
    - Type
    - Source

Habitat Data Subgroup Meetings

- Meeting #1 February 9, 2022:
  - Clear Creek
  - American
  - Stanislaus
- Meeting #2 March 8, 2022:
  - Trinity
  - Sacramento
- Participants: NMFS, USFWS, CDFW, Reclamation, and WTMP Team

Outcome

- Positive contribution to data compilation – beneficial format to replicate
- Opportunity to understand perspectives and invitations for data sharing
- Additional feedback:
  - Multiple requests for model reporting locations
    - Reporting locations can be accommodated, and formats are under development
  - Desire to extend model domain
    - The current model domain covers furthest extent of spawning in Sacramento, American and Stanislaus Rivers. Trinity extension is beyond current capabilities.
    - After the initial implementation, further extension of modeling domain will be considered.

Next Steps

- Fill in life-stage details
- Distribute final draft to Subgroup members for review
- Share with the MTC and provide to WTMP Team for reference

Introductory Topic: American River Water Temperature Model Development

Craig Addley, Ph.D., Cardno, now part of Stantec

Vanessa Martinez, M.S., P.E., Cardno, now part of Stantec

John DeGeorge, Ph.D., P.E., RMA

Tom Evans, Ph.D., P.E., D.WRE, RMA

American River Water Temperature Models, Future Meeting Topics

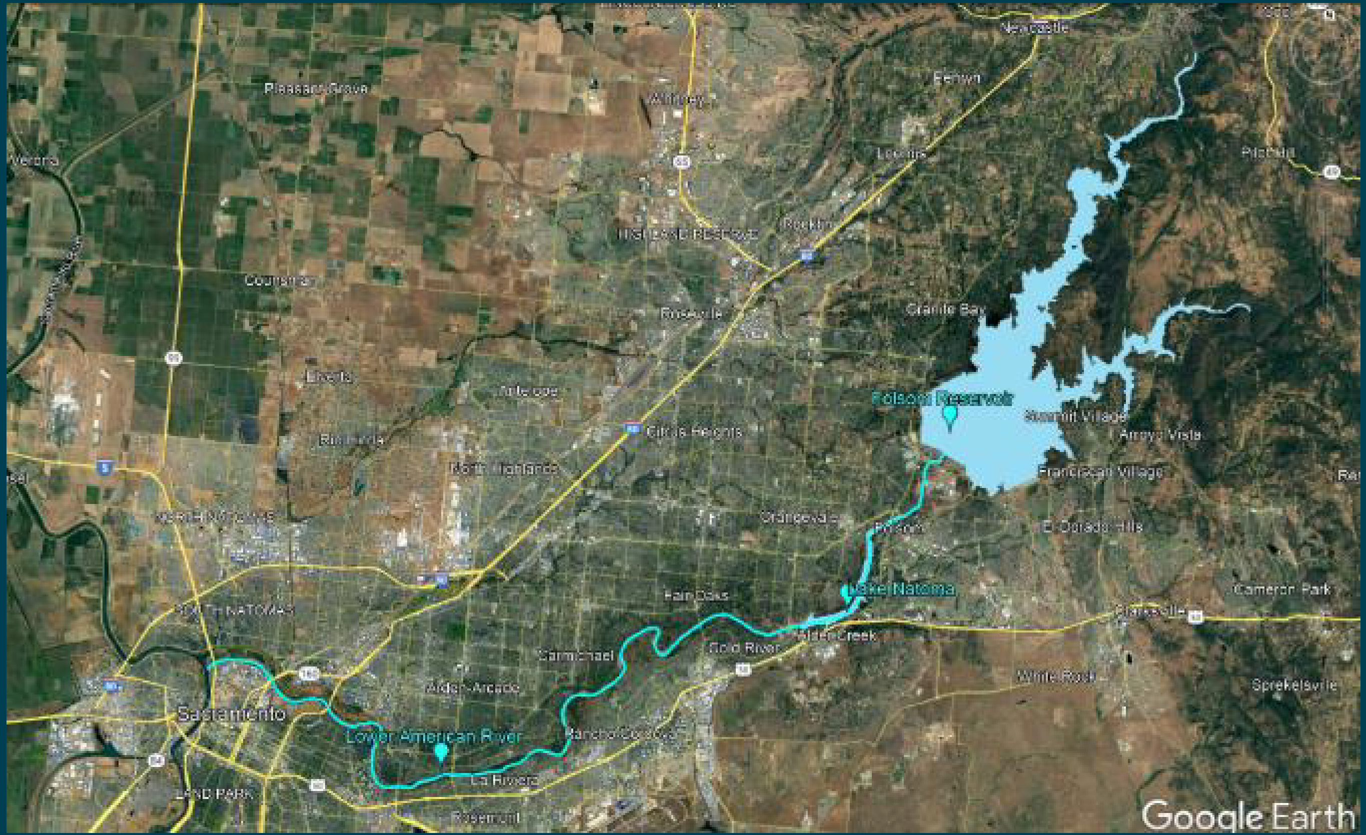
- Anticipated topics for the next three/four meetings
  - MTC 4: Introduction and initial model setup
  - MTC 5: Model calibration/validation
  - MTC 6: Model sensitivity and documentation
- Details for future MTC meetings will be adjusted according to the model development progress.

American River Water Temperature Models, Representation and Input

- WTMP Representation
  - System overview
    - Folsom Reservoir and Folsom Dam
    - Lake Natoma
    - American River below Nimbus Dam to the confluence with the Sacramento River
    - Inflow and outflow water temperature / discharge and meteorological data
  - WTMP representation / boundary conditions
  - WTMP calibration data / preliminary calibration
  - WTMP forecast model components / visualization
- MTC Input

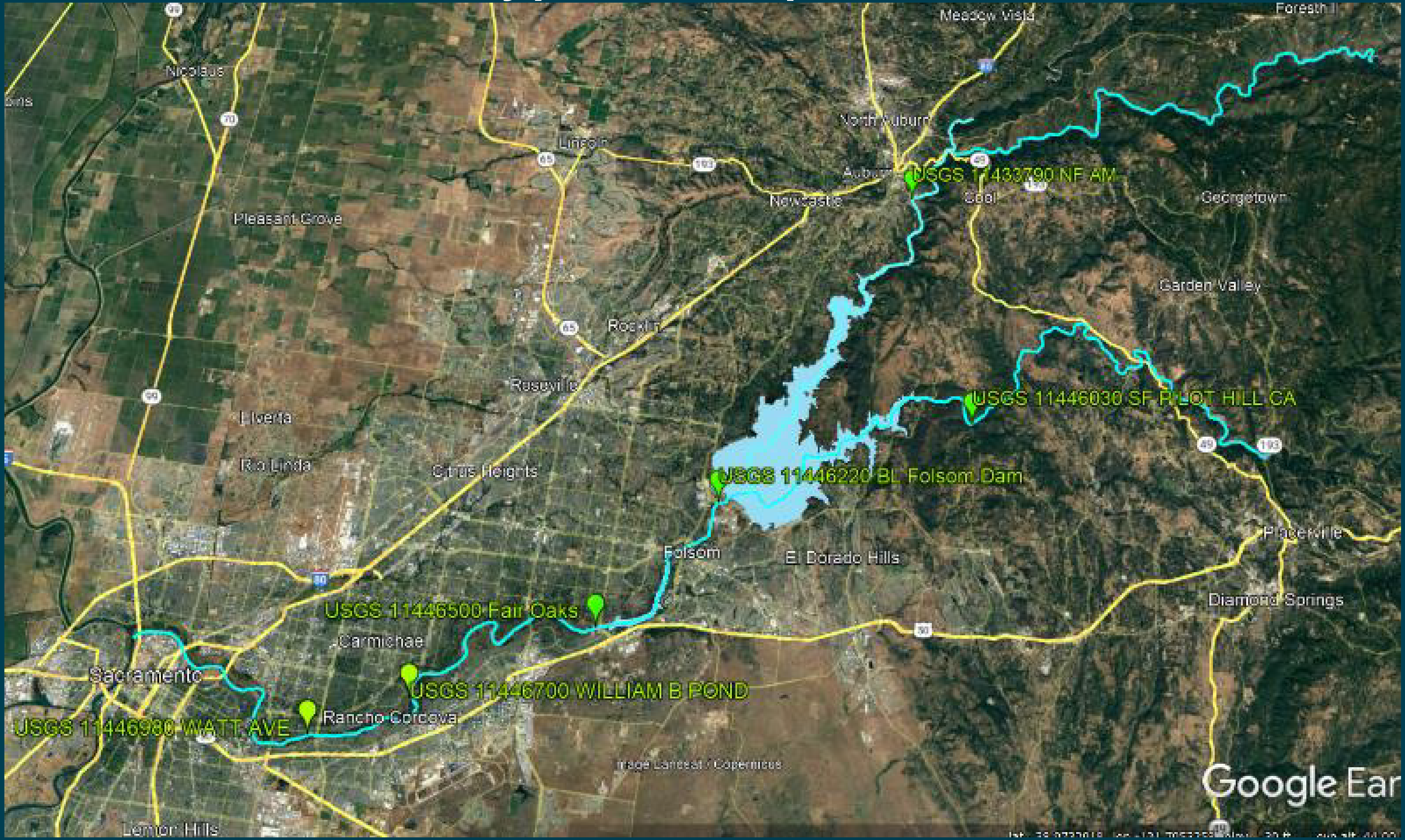
System Overview

- Folsom Reservoir and Folsom Dam
- Lake Natoma
- Lower American River

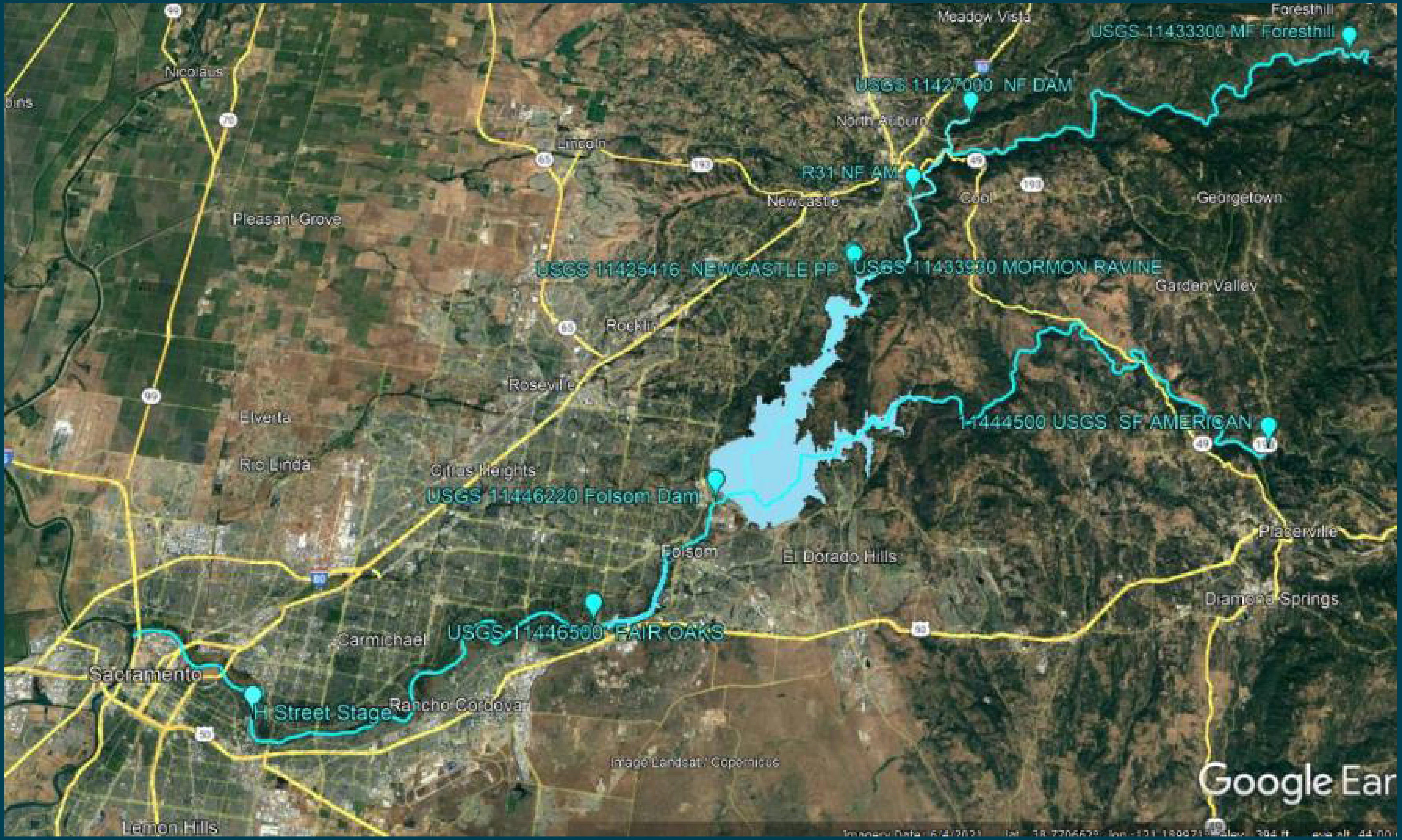


System Overview, Water Temperature Gages

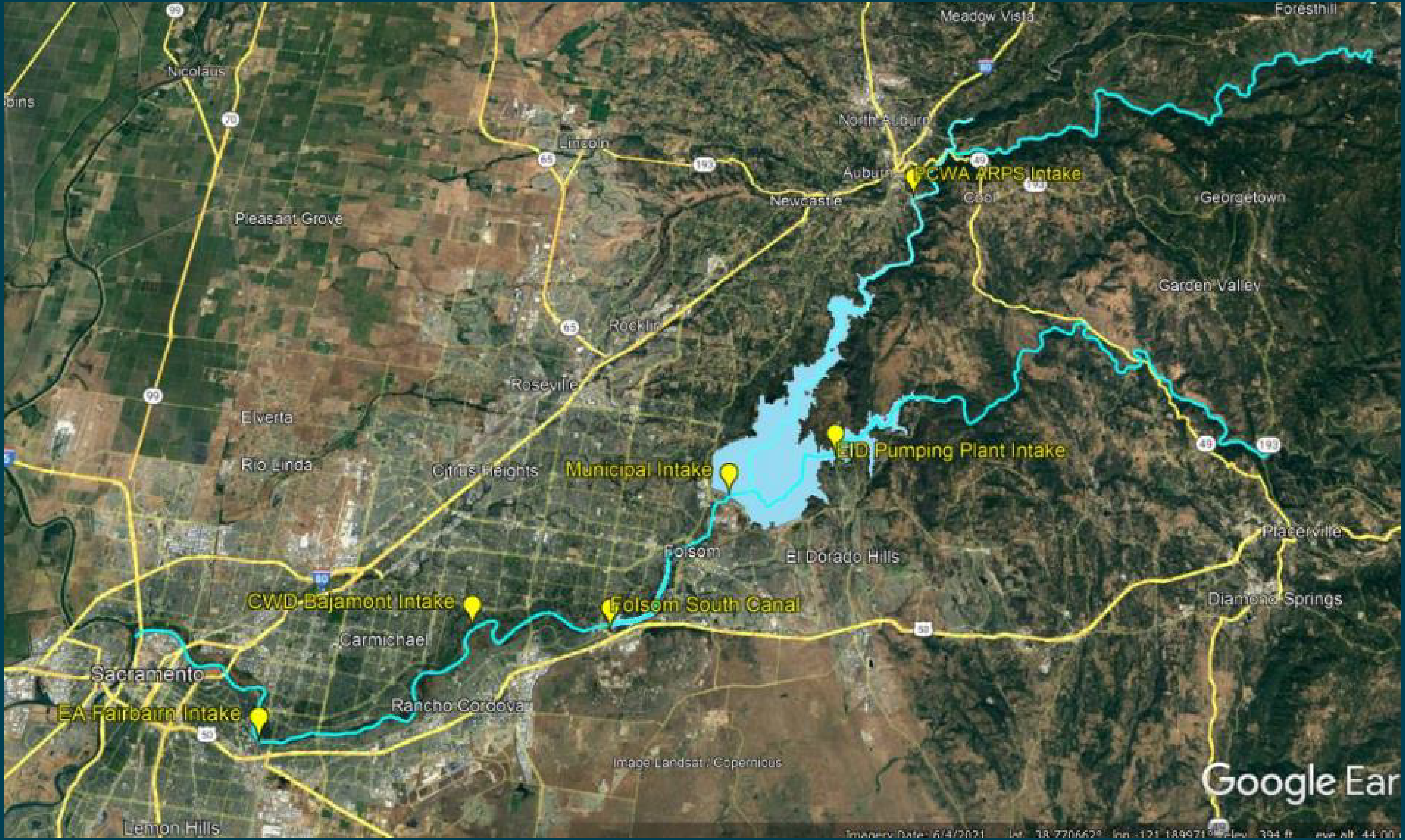
- Water temperature gages
  - Watt Avenue Typical Compliance Location



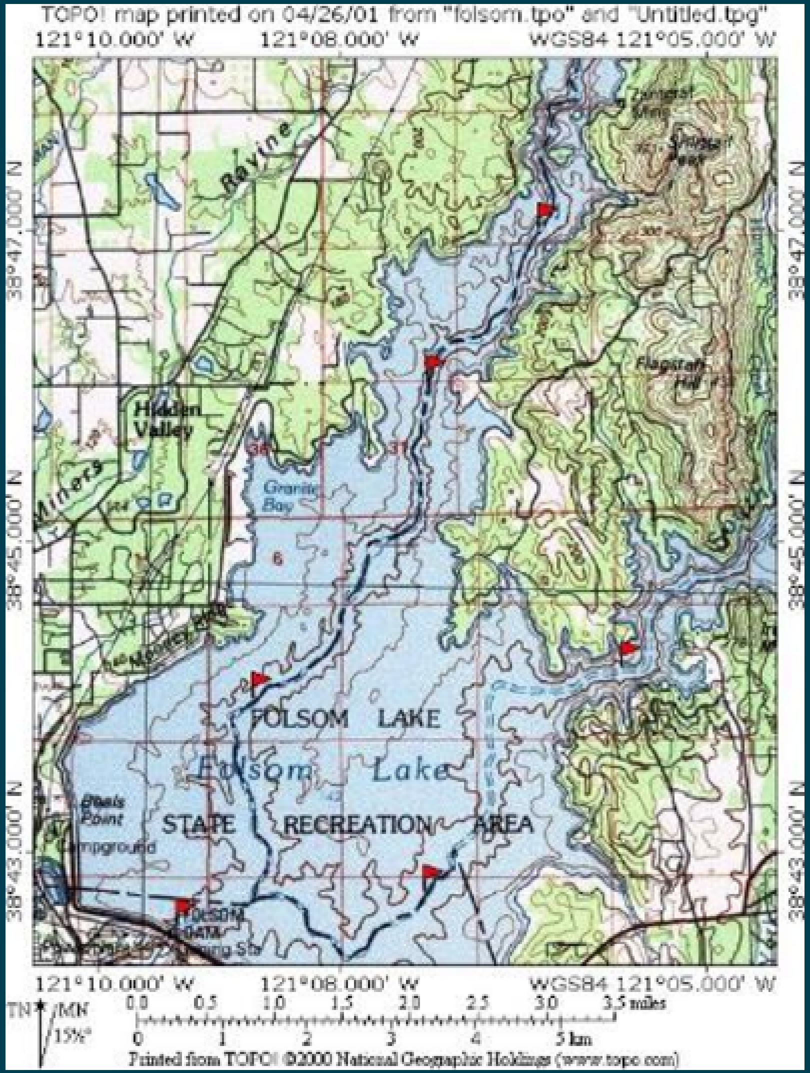
System Overview, Inflow and General Discharge Gages

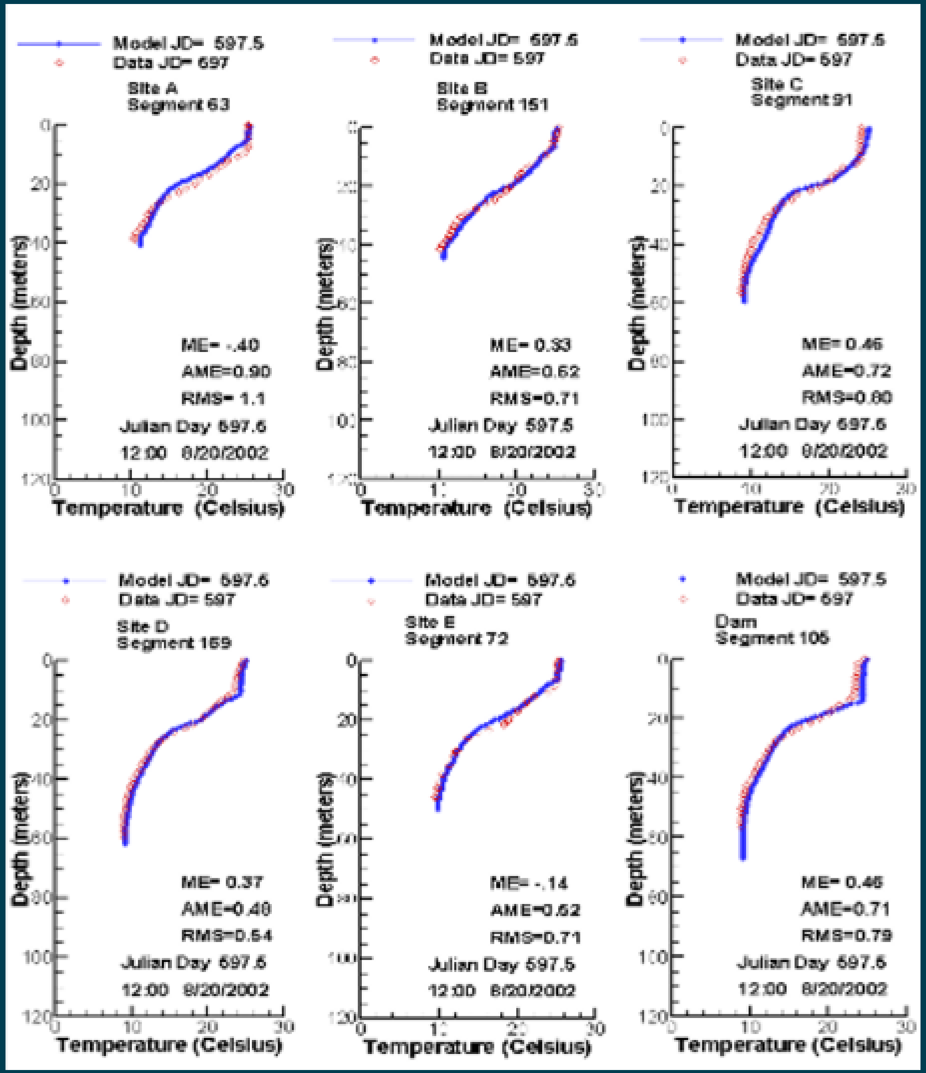


System Overview, Outflow Gages



System Overview, Folsom Reservoir Water Temperature Profiles





System Overview, Meteorological Data

The picture can't be displayed.

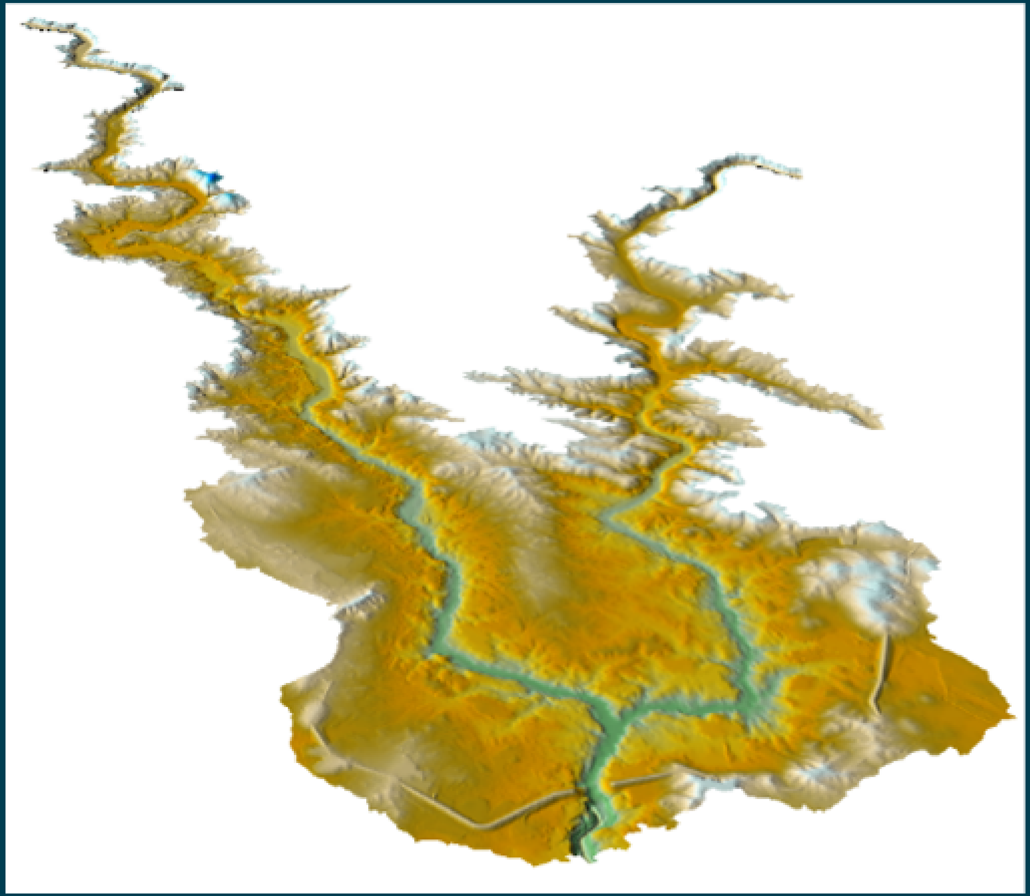
System Overview, Meteorological data (continued)

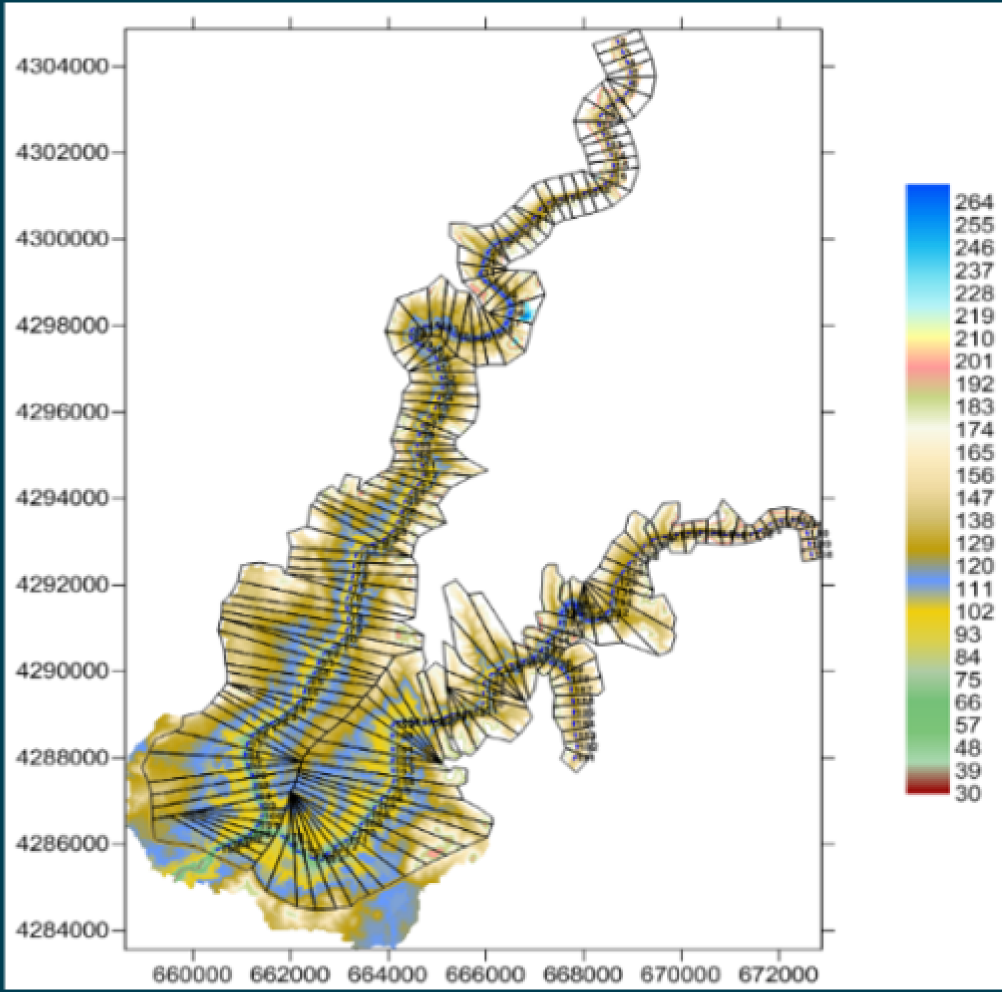
- X – Calibration / Validation Period (2000 – 2021)
- O – Historical Years Model Run (1922 – 2000)

Location	Air Temperature	Dew Point Temperature	Wind Speed	Wind Direction	Cloud Cover	Solar Radiation
Dyke 8 / Folsom Dam	-	-	X	X	-	-
Fair Oaks	X	X	(X)	(X)	-	X
Mather AFB	O	O	O	O	X, O	-
McClellan AFB	O	O	O	O	O	-
Sac Executive Airport	O	O	O	O	O	-
Downtown Sac	O	O	O	O	O	-

WTMP Representation / Boundary Conditions, Folsom Reservoir bathymetry

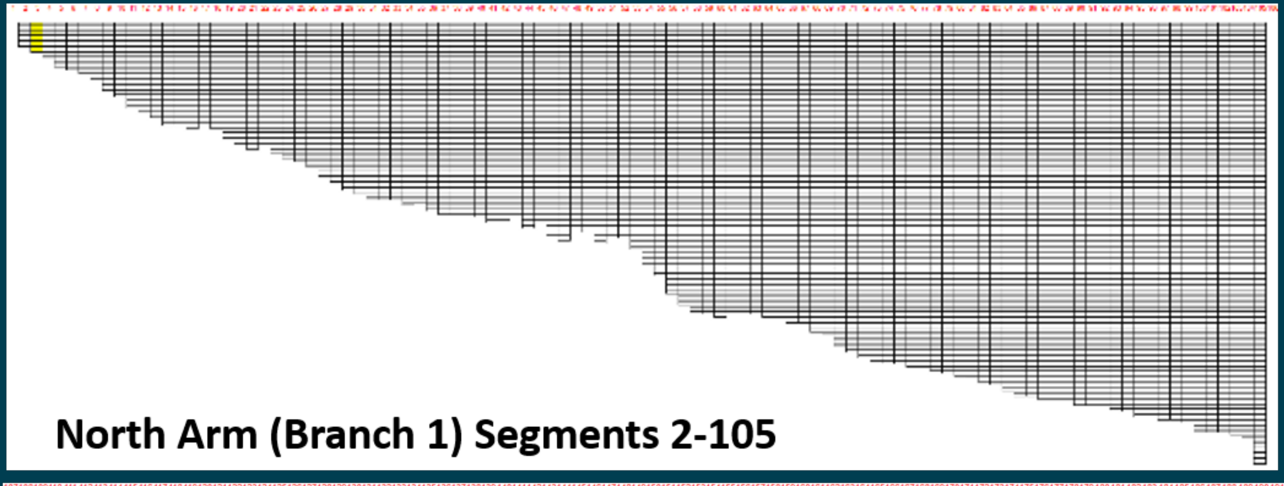
- Folsom Reservoir bathymetry (2005 USBR Sedimentation Survey)
- CE-QUAL-W2 representation

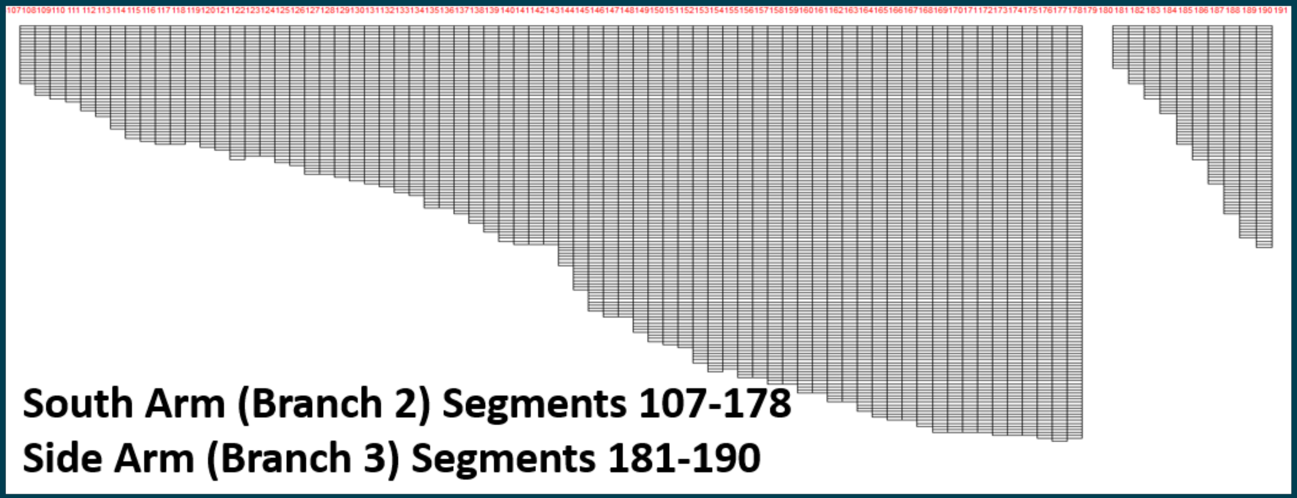


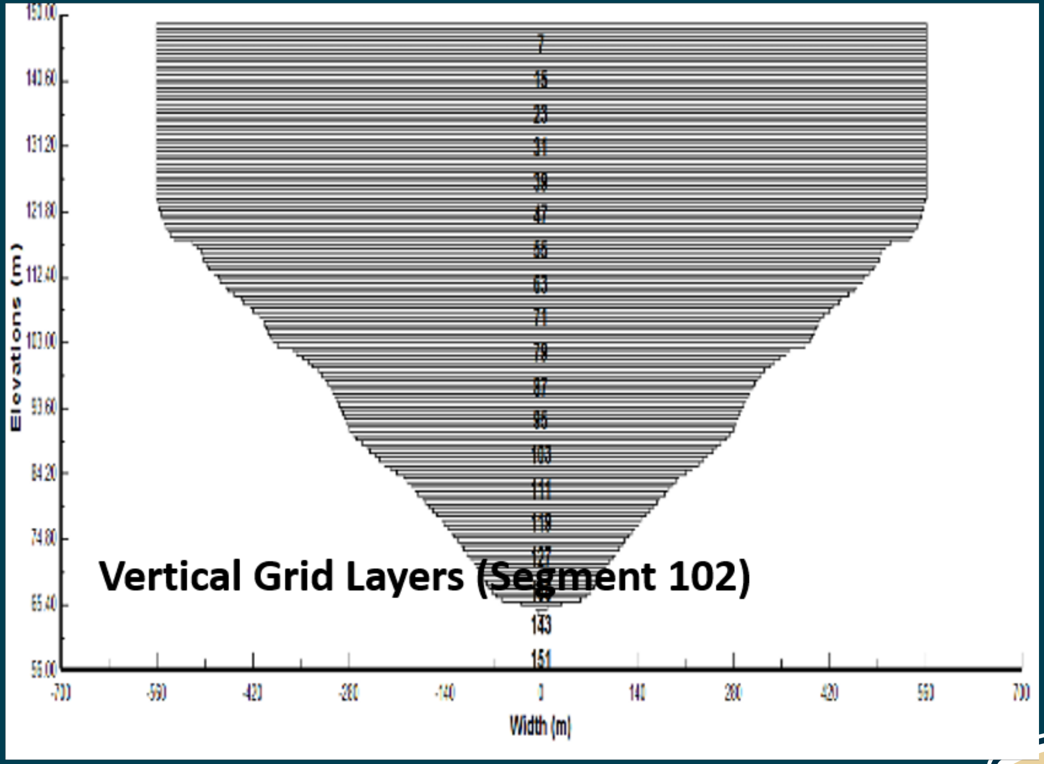


WTMP Representation / Boundary Conditions, Folsom Reservoir bathymetry (continued)

- CE-QUAL-W2 Folsom Reservoir representation

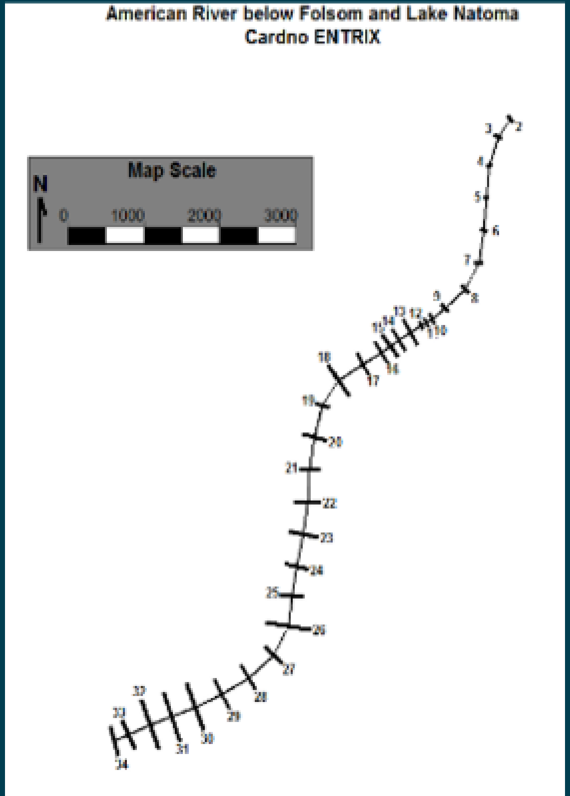


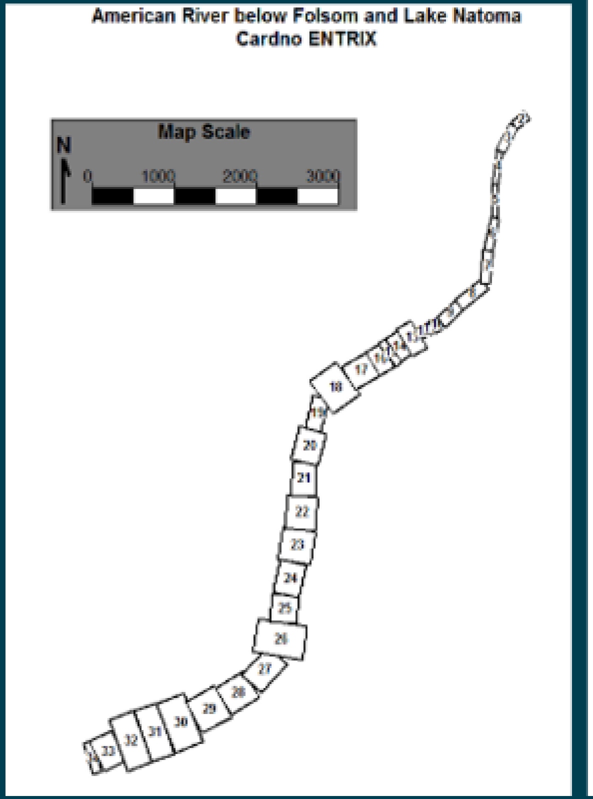


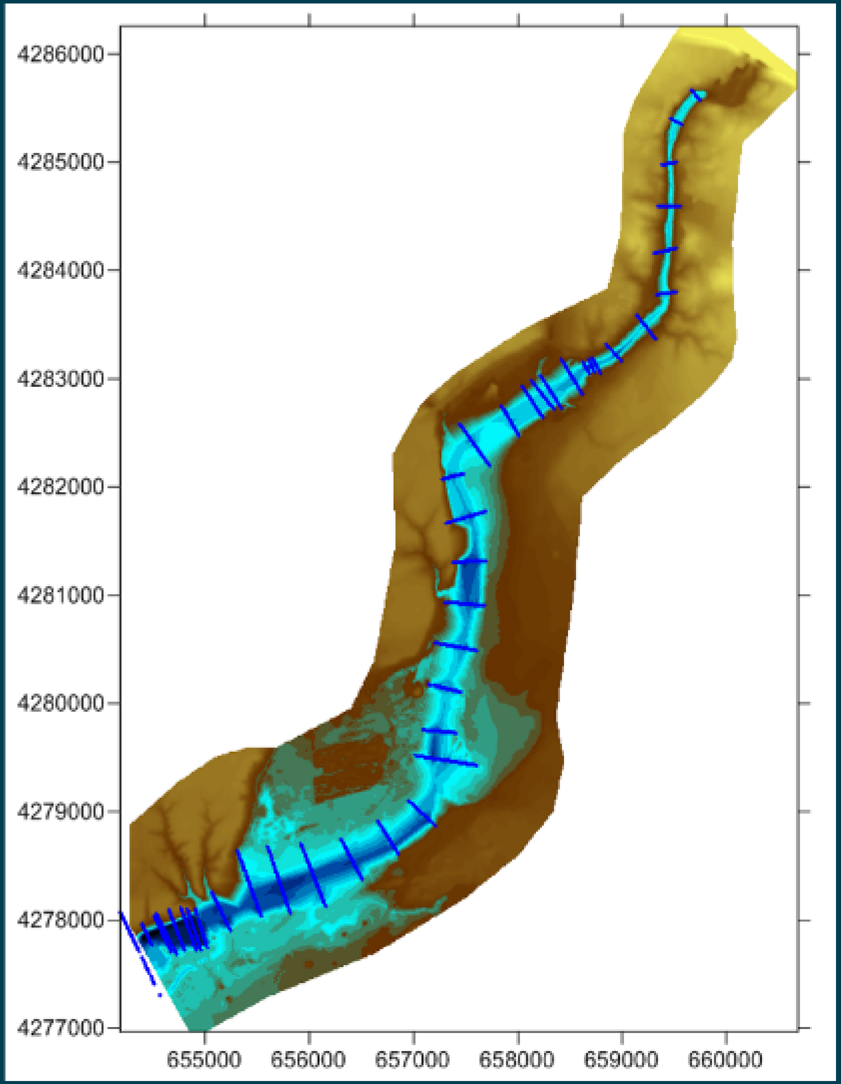


WTMP Representation / Boundary Conditions, Lake Natoma bathymetry

- Lake Natoma bathymetry
- CE-QUAL-W2 representation

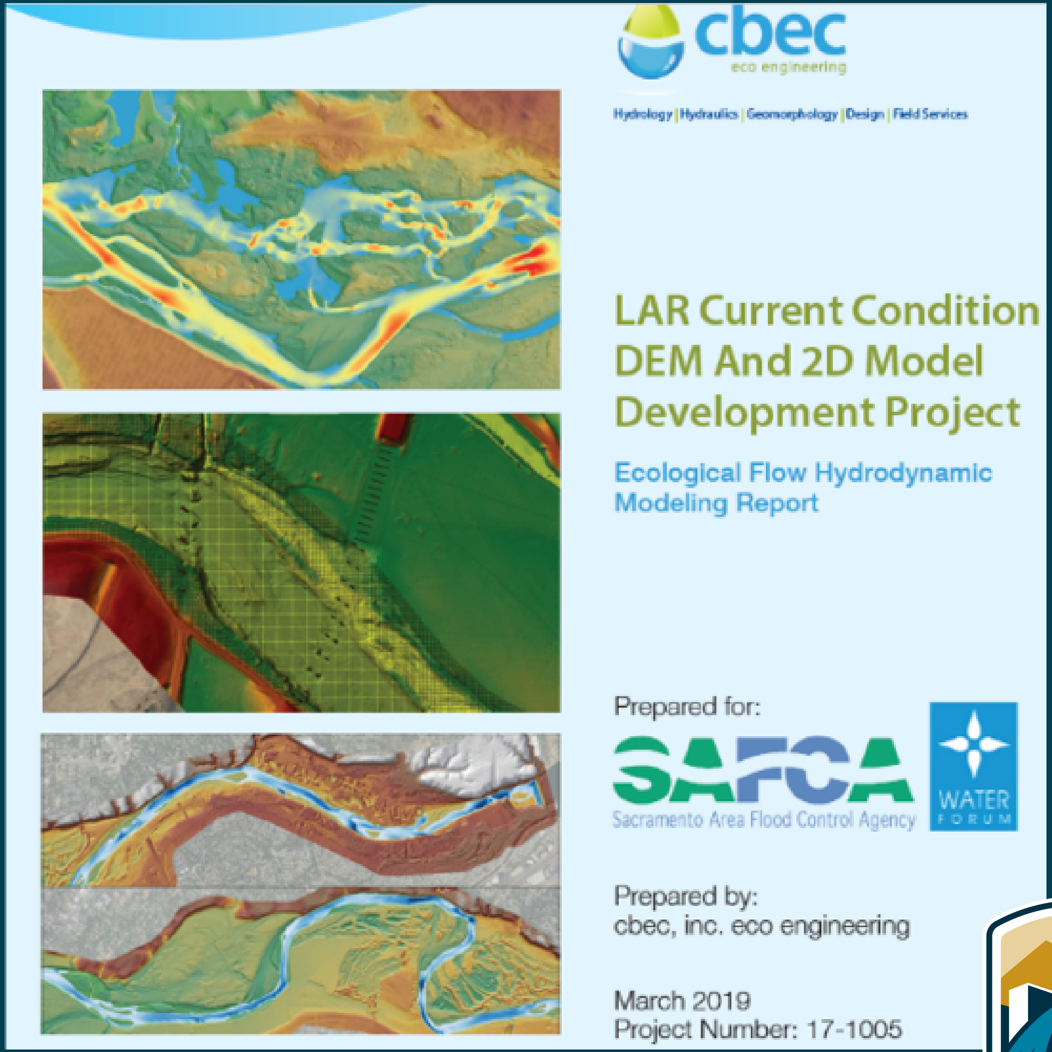






WTMP Representation / Boundary Conditions, Lower American River

- Lower American River
  - River miles
  - Topography (cross-sections)
  - Hydraulics (Q vs width, depth, velocity)


cbec
eco engineering
Hydrology | Hydraulics | Geomorphology | Design | Field Services

LAR Current Condition DEM And 2D Model Development Project

Ecological Flow Hydrodynamic Modeling Report

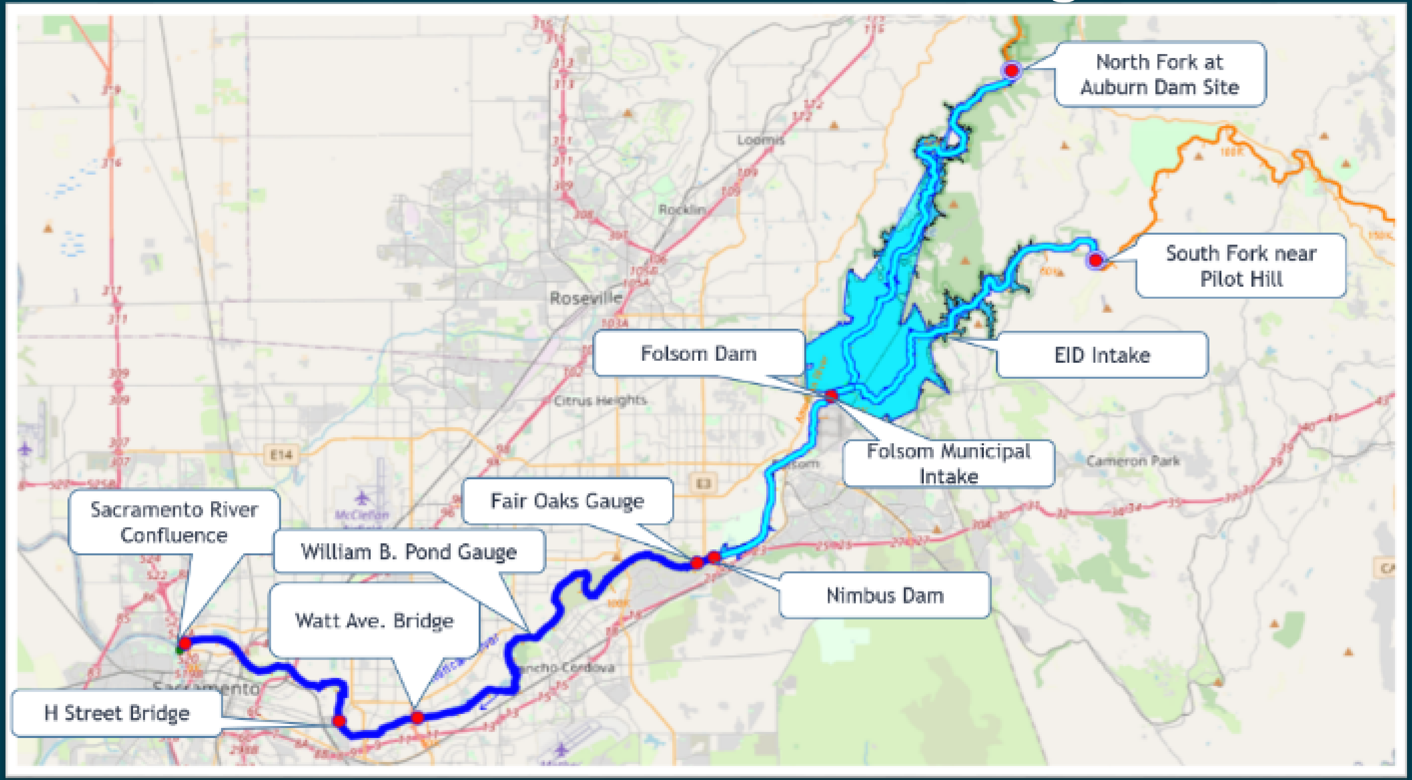
Prepared for:
SAFCA
Sacramento Area Flood Control Agency
WATER FORUM

Prepared by:
cbec, inc. eco engineering

March 2019
Project Number: 17-1005

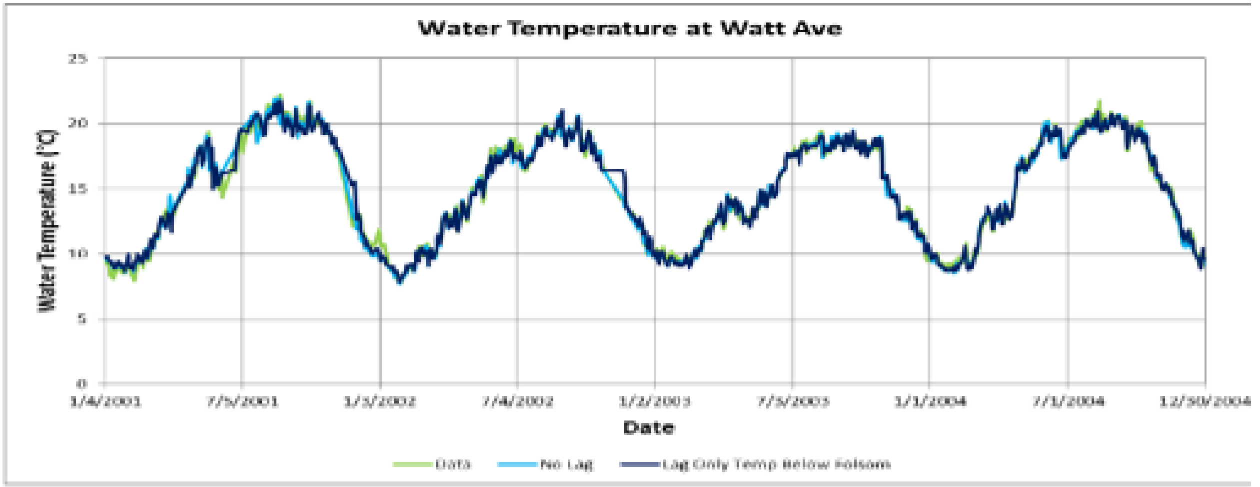
WTMP Representation / Boundary Conditions, HEC-ResSim Model

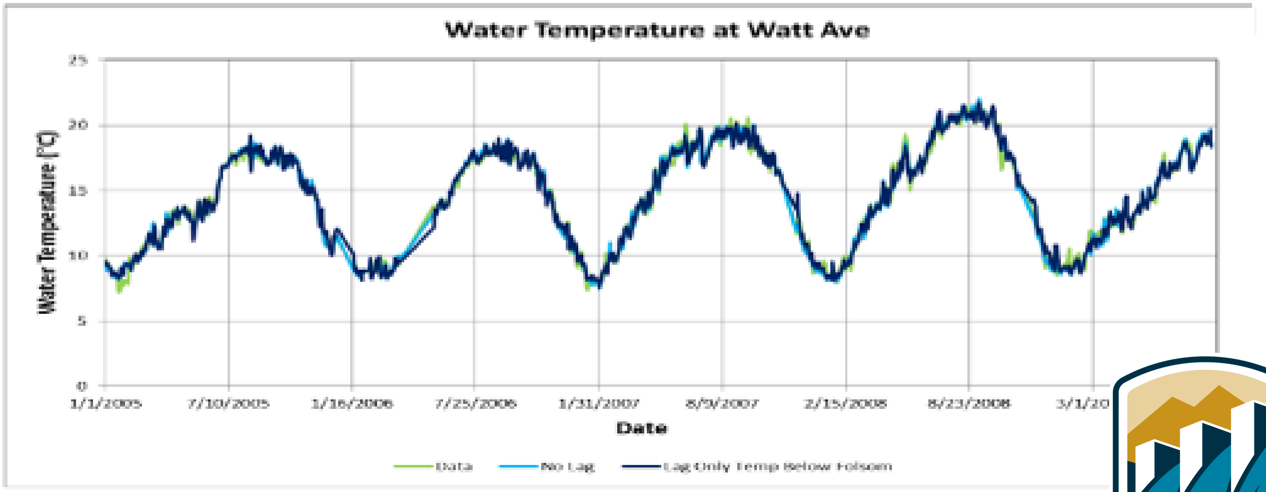
- HEC-ResSim Model
  - Folsom Reservoir (1D vertical cells)
  - Lake Natoma (1D vertical cells)
  - Lower American River (1D longitudinal cells)



WTMP Representation / Boundary Conditions, Water Temperature Regressions

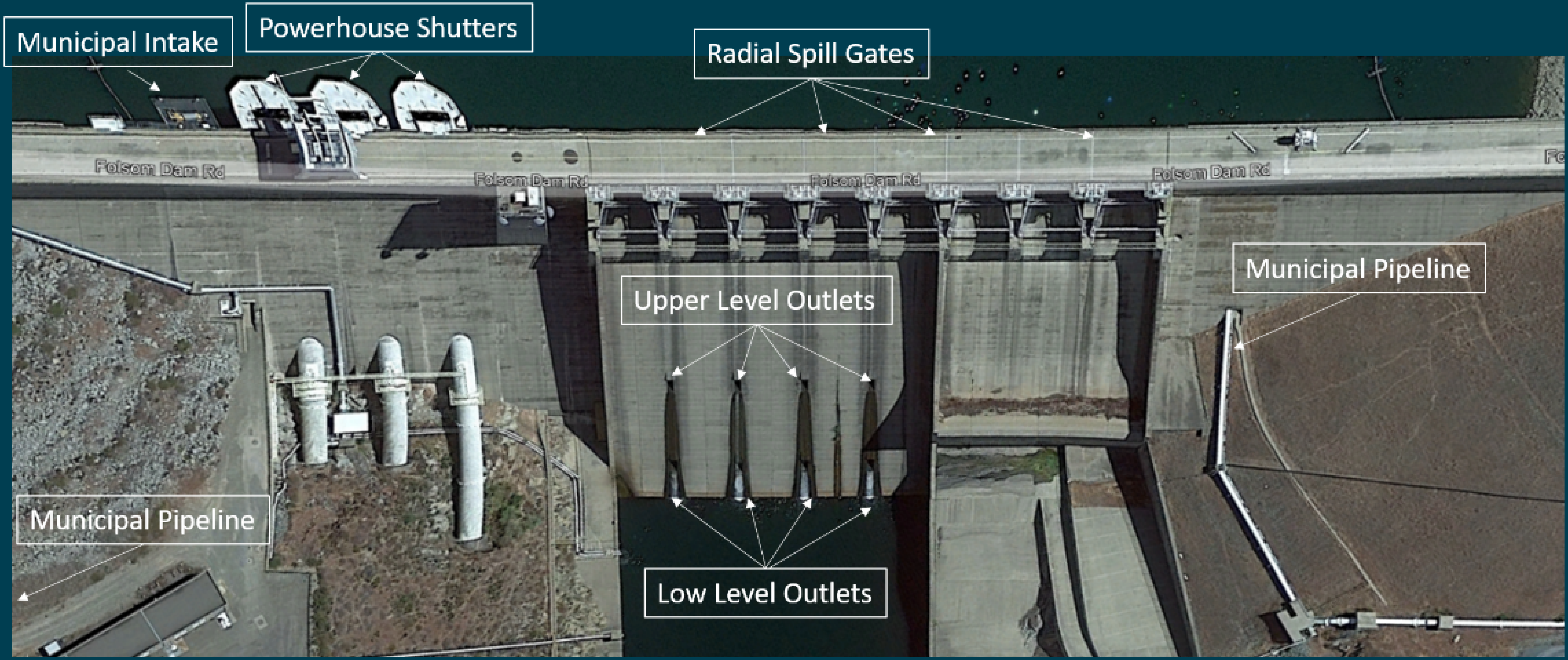
- Water Temperature Regressions (daily average)
  - North Fork American River
    - Flow (NF Am, MF Am)
    - Air temperature
  - South Fork American River
    - Flow
    - Air temperature
  - Lower American River (Watt Ave, Hazel Ave)
    - Water temperature below Folsom Dam
    - Flow
    - Air temperature
    - Solar radiation
    - Water travel time





WTMP Representation / Boundary Conditions, Folsom Dam

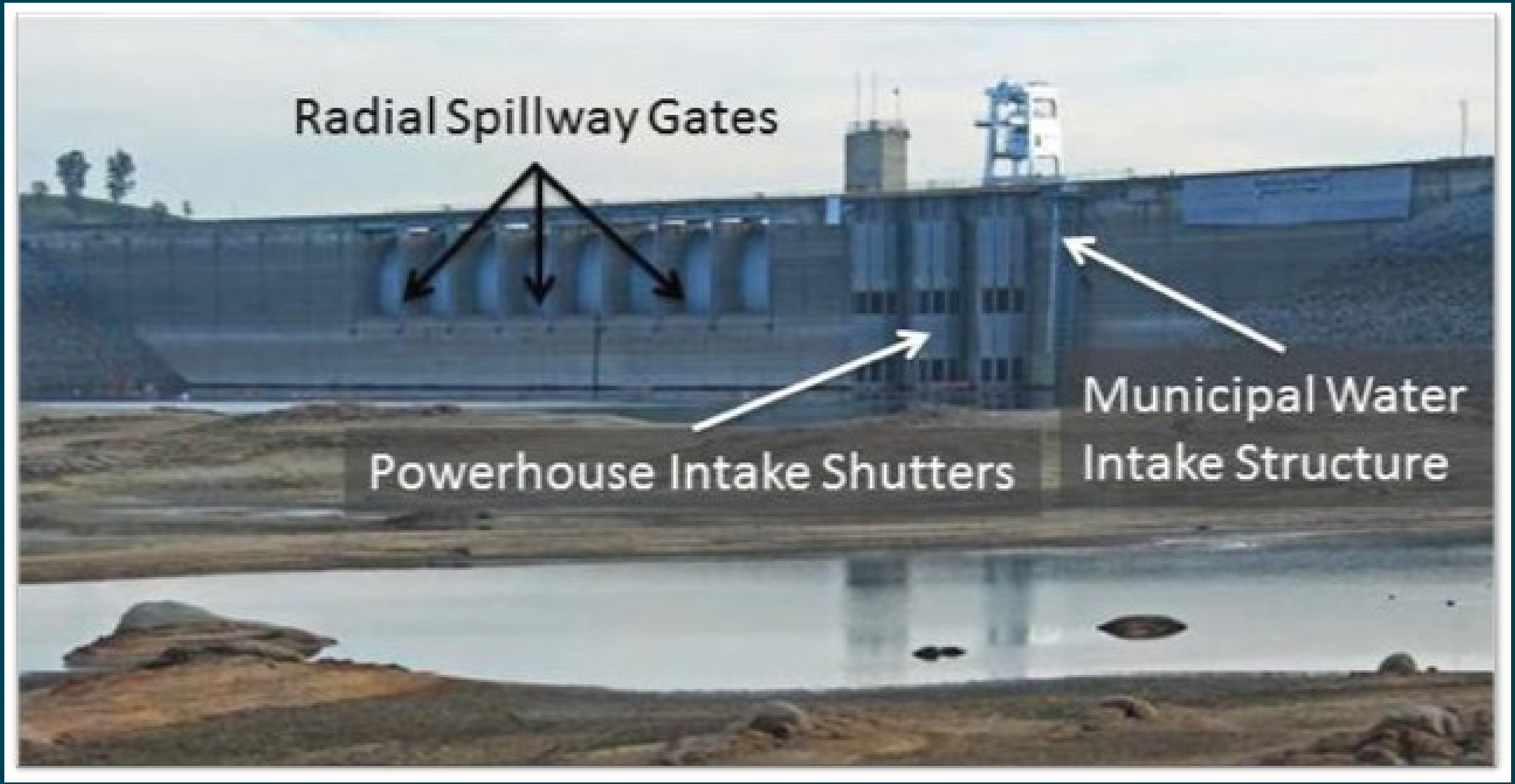
WTMP Representation / Boundary Conditions, Folsom Dam Facilities



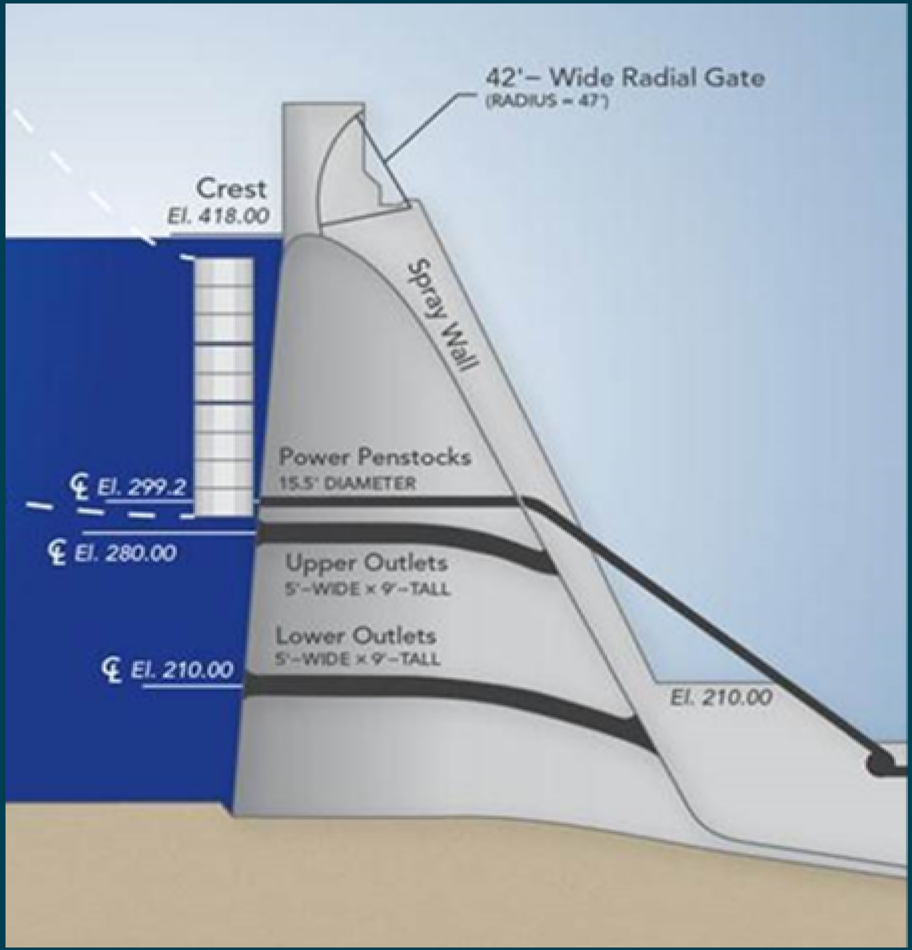
WTMP Representation / Boundary Conditions, Folsom Dam Outlets

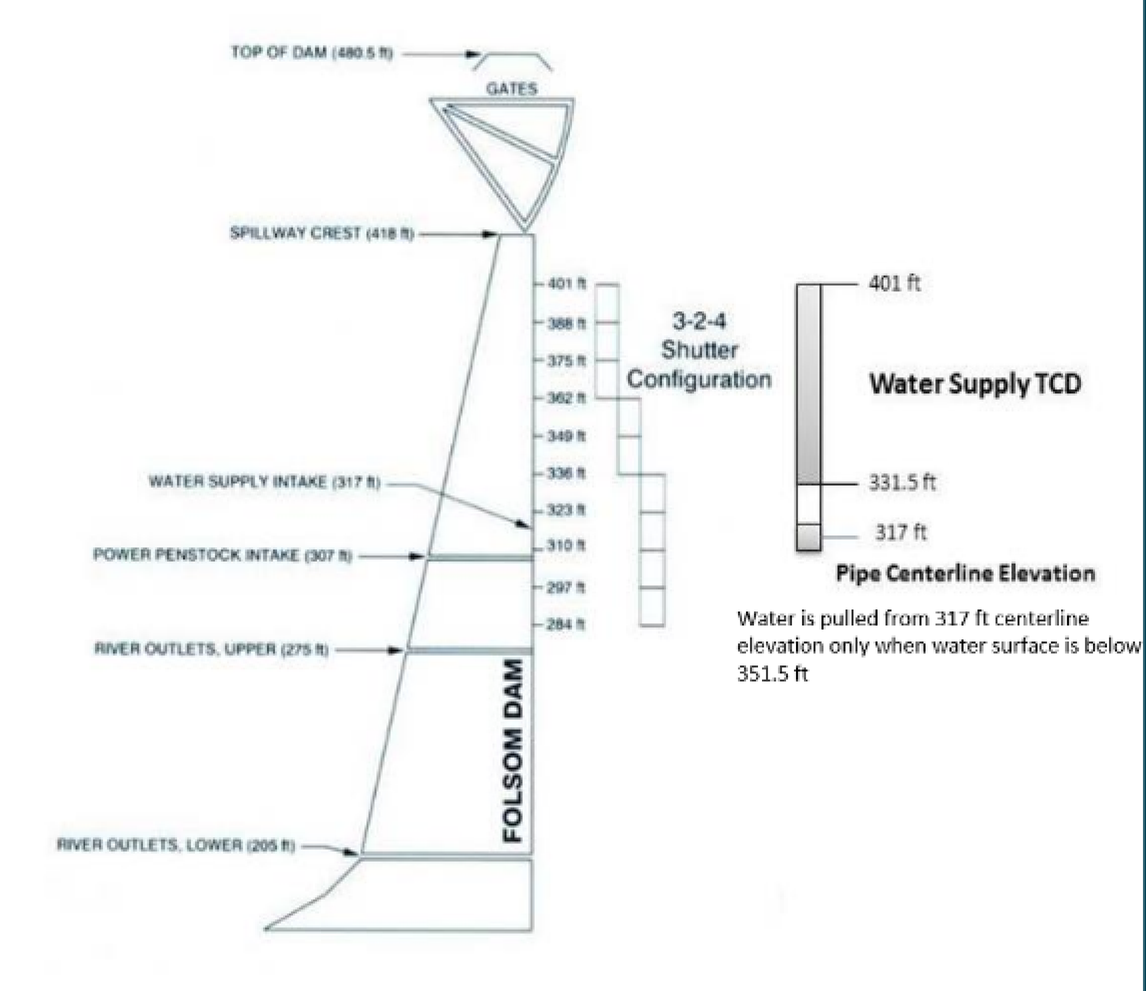
Outlet Description	Shape	Dimension (feet)	Monolith	Horizontal Centerline Coordinates (meters) (X/Y)	Unshuttered – Centerline Elevation (feet)	Unshuttered – Invert Elevation (feet)	Shuttered Configurations, A (All Lowered)	Shuttered Configurations, U (Upper Raised)	Shuttered Configurations, M (Middle Raised)	Shuttered Configurations, L (Lower Raised)
Municipal	Circle	d = 7.0	7	660264/4285826	317	313.5	Max 401 ft - Min 331.5 ft (Gate can be anywhere within this range)	Max 401 ft - Min 331.5 ft (Gate can be anywhere within this range)	Max 401 ft - Min 331.5 ft (Gate can be anywhere within this range)	Max 401 ft - Min 331.5 ft (Gate can be anywhere within this range)
Power Penstock #1	Circle	d = 15.5	8	660290/4285811	307	299.25	401.0	362.0	336.0	284.0
Power Penstock #2	Circle	d = 15.5	9	660304/4285804	307	299.25	401.0	362.0	336.0	284.0
Power Penstock #3	Circle	d = 15.5	10	660317/4285796	307	299.25	401.0	362.0	336.0	284.0
Rectangular River #1-4 (Upper)	Rectangle	w = 5.0 h = 9.0	13-16	660358/4285771	280	275.5	N/A	N/A	N/A	N/A
Rectangular River #1-4 (Lower)	Rectangle	w = 5.0 h = 9.0	13-16	660358/4285771	210	205.5	N/A	N/A	N/A	N/A
Spillway Gates 1-8	Radial Gate	w = 42.0 h = 50.0	12-20	660351/4285774	N/A	418.0	N/A	N/A	N/A	N/A
EID Pump	N/A	N/A	N/A	N/A	N/A	320.0	N/A	N/A	N/A	N/A

WTMP Representation / Boundary Conditions, Folsom Dam Temperature Control Devices (TCDs)

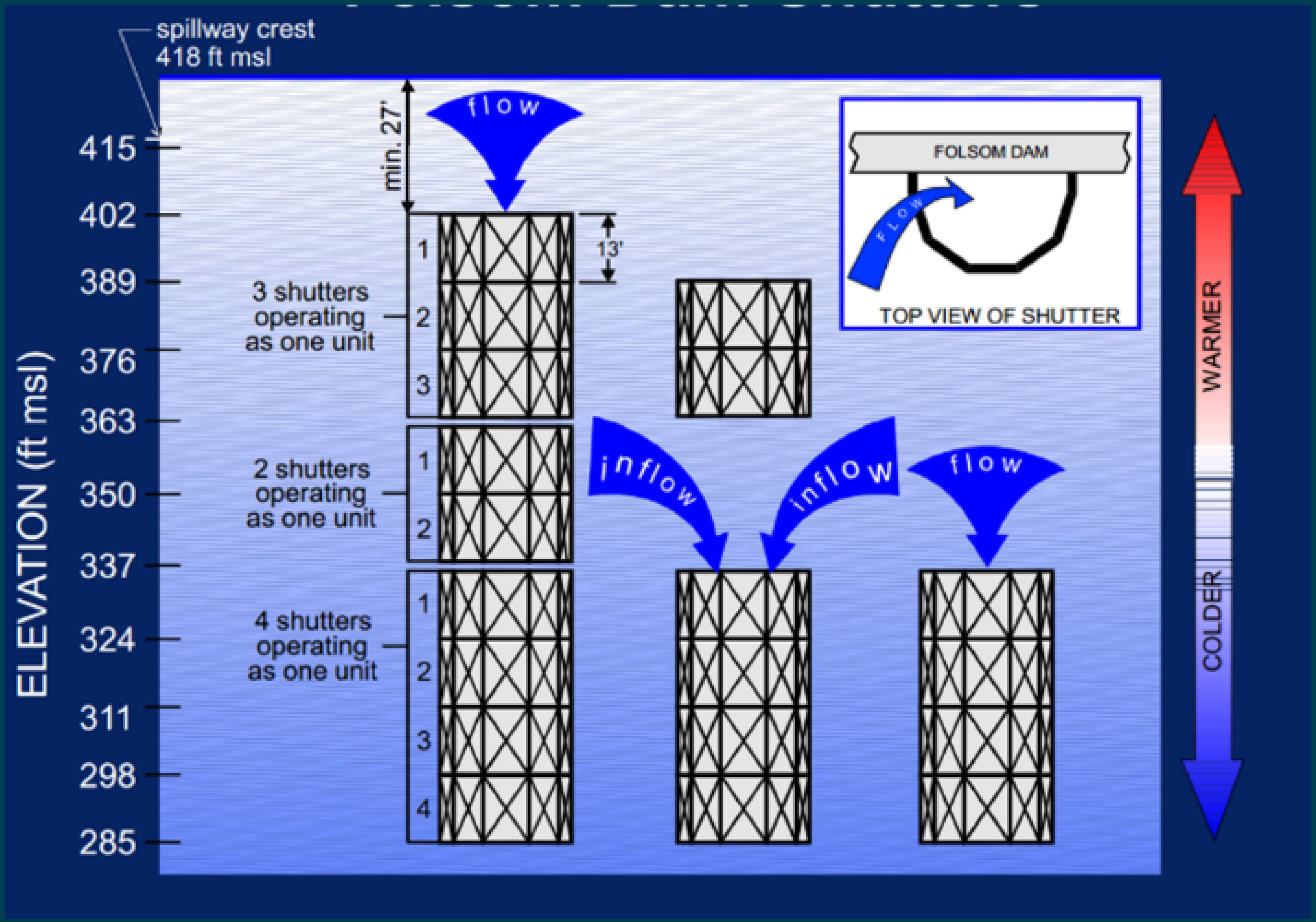


WTMP Representation / Boundary Conditions, Folsom Dam TCD and Outlet Elevations

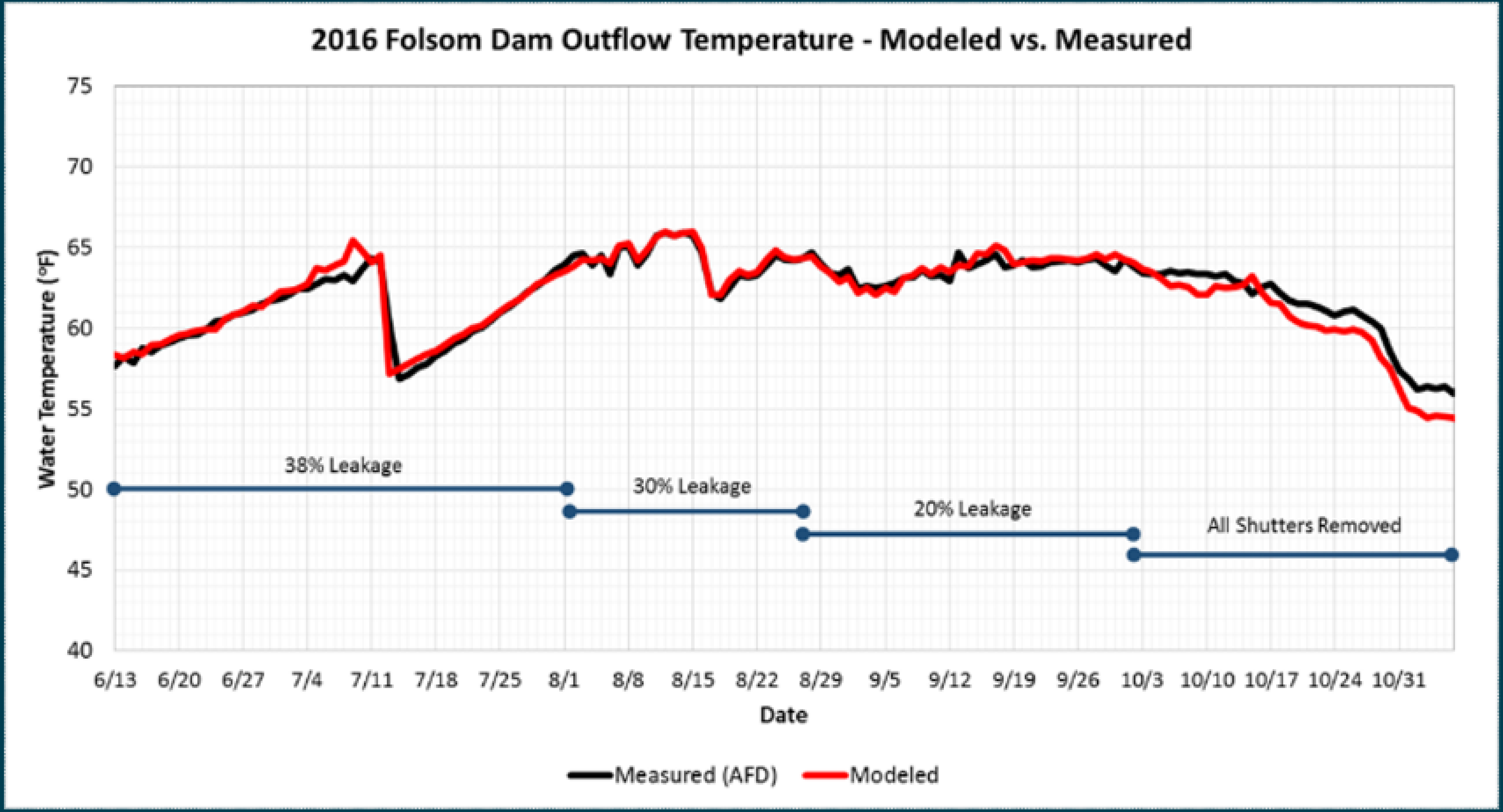




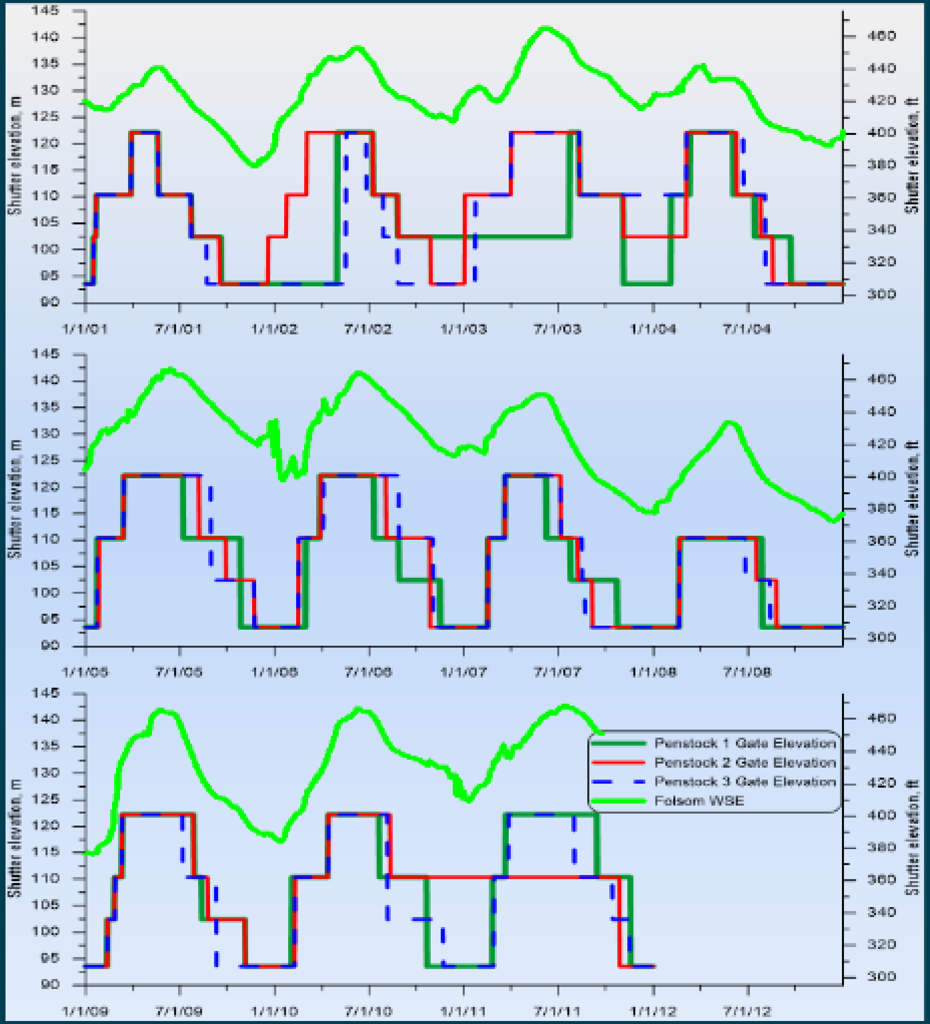
WTMP Representation / Boundary Conditions, TCD shutters and leakage

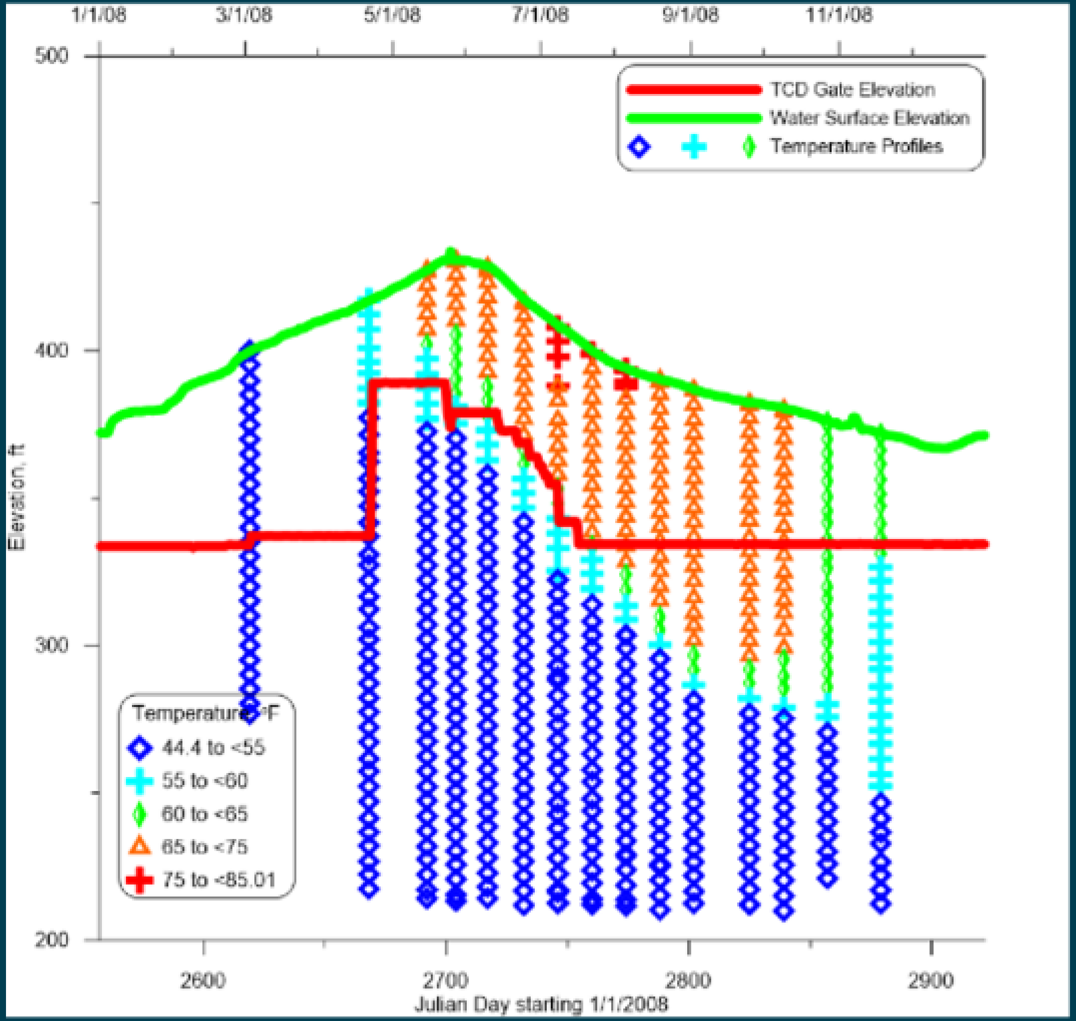


WTMP Representation / Boundary Conditions, Leakage ≈35%, but varies depending shutter configuration



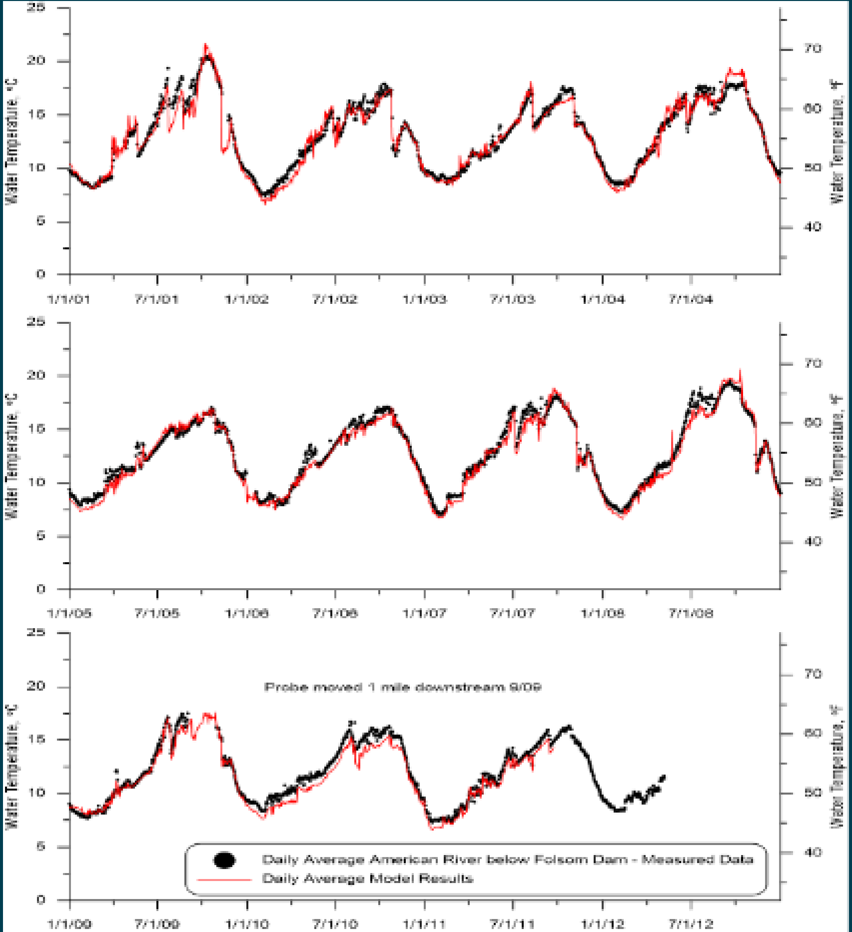
WTMP Representation / Boundary Conditions, Shutter and Municipal Intake Boundary Conditions

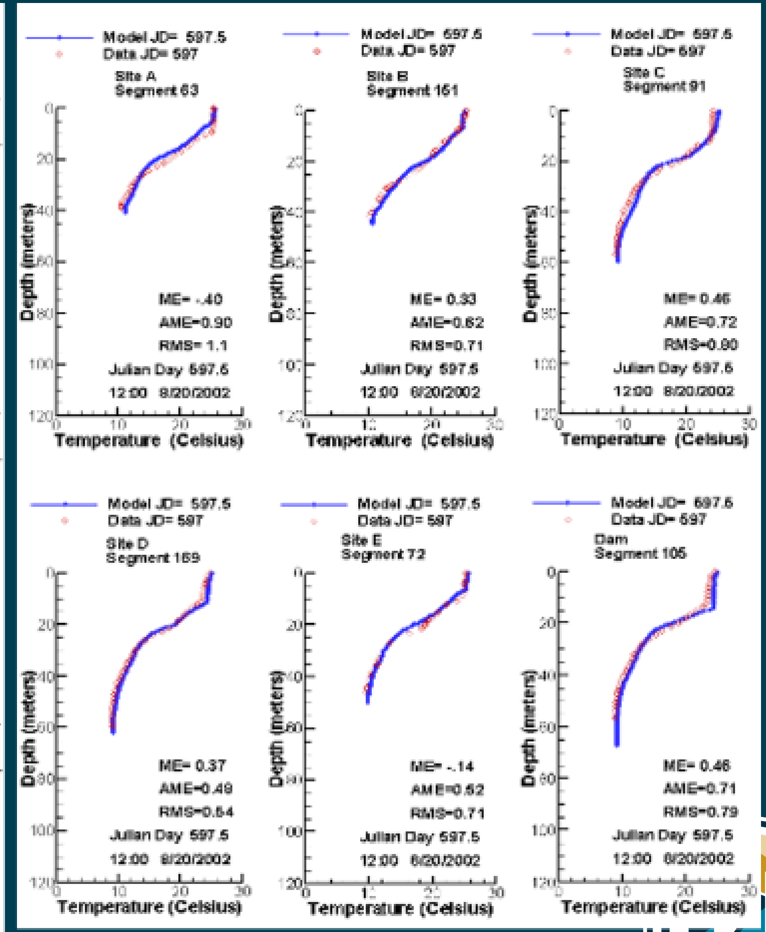




WTMP Calibration, Preliminary 2001 – 2011
Folsom Reservoir CE-QUAL-W2 Calibration

Location	Mean Error (°C/ °F)	Absolute Mean Error (AME)	Flow Weighted AME
Downstream time-series All Years	0.31 °C (0.56 °F)	0.65 °C (1.17 °F)	0.58 °C (1.04 °F)
In-lake temperature profiles	0.027 °C (0.015 °F)	0.569 °C (1.02 °F)	-





WTMP Representation / Boundary Conditions, Nimbus Dam

Structure Name	Structure Type	Elevation (feet/meter)	Width/Diameter (feet/meter)
Power Generation Intakes (2)	Weir	1,007 feet (32.61 meters)	82 feet (25 meters)
Spillways	Weir	103.4 feet (31.52 meters)	656 feet (200 meters)
Hatchery Withdrawal	Pipe	109.5 feet (33.38 meters)	5 feet (1.52 meters)

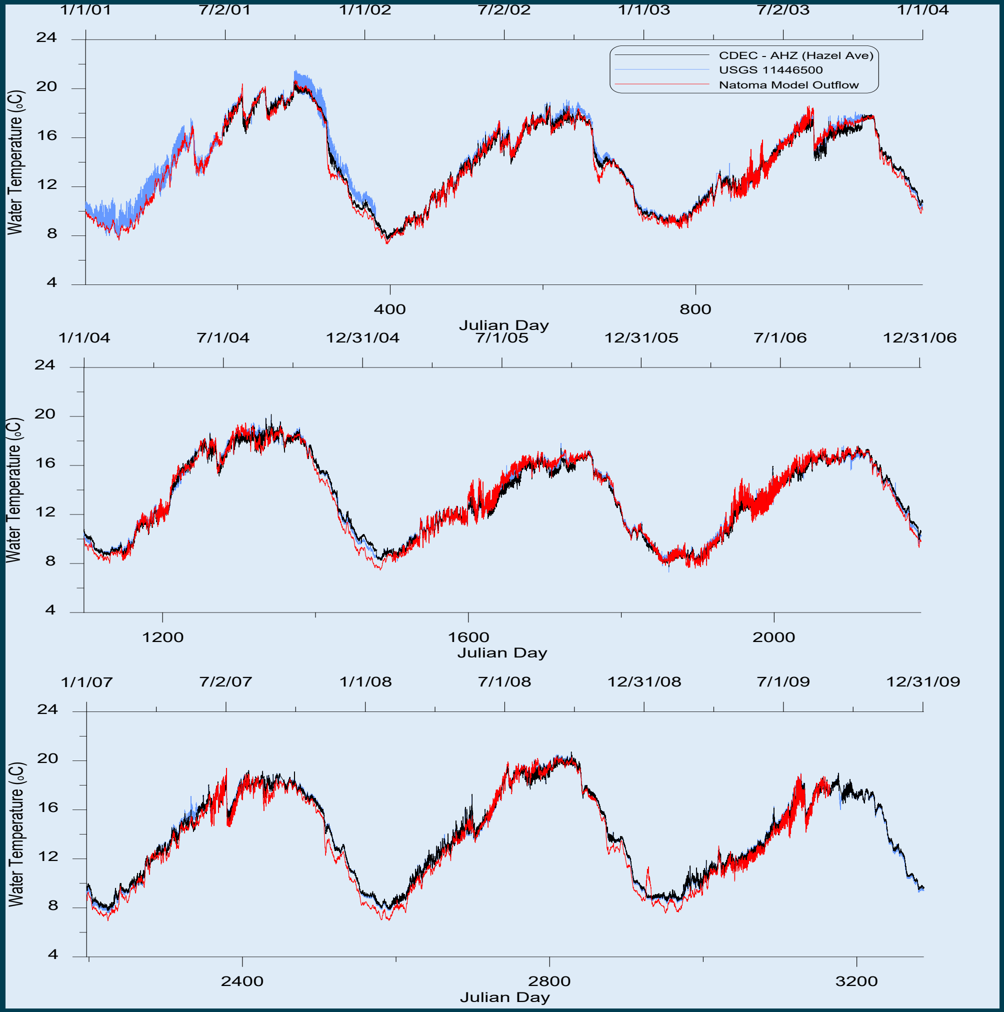
WTMP Calibration, Preliminary 2001 – 2011
Lake Natoma CE-QUAL-W2 Calibration

- Temperature Profile Error Statistics

Location	Mean Error	Absolute Mean Error	Root Mean Squared Error	Number of Profiles	Number of Measurements
Segment 34	0.34 °C (0.61 °F)	0.54 °C (0.97 °F)	0.58 °C (1.04 °F)	308	1,820

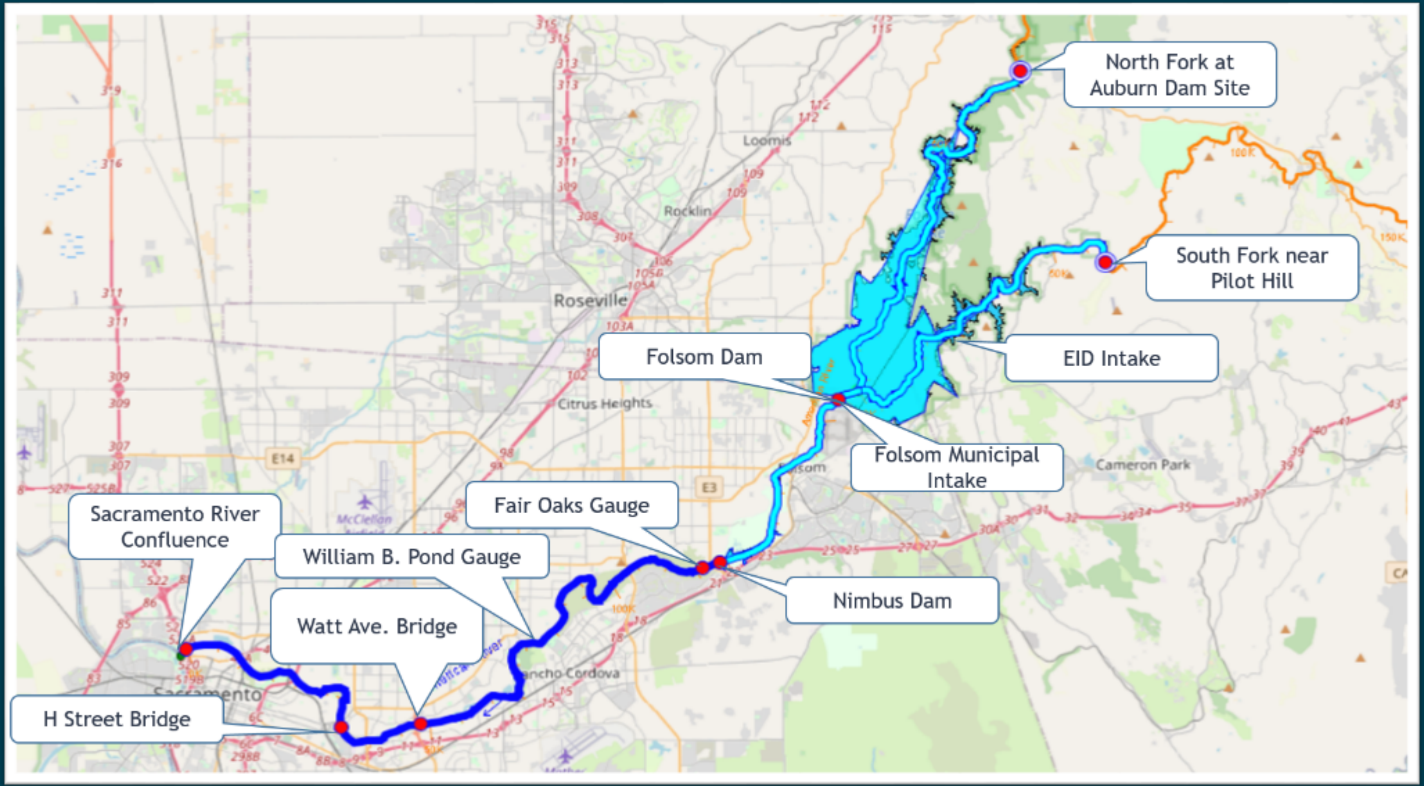
- Temperature Time Series Error Statistics

Location	Mean Error	Absolute Mean Error	Root Mean Squared Error	Number of Measurements
Hazel Ave (AHZ)	-0.16 °C (-0.30 °F)	0.40 °C (0.73 °F)	0.51 °C (0.93 °F)	324,138
Fair Oaks (AFO)	-0.22 °C (-0.41°F)	0.39 °C (0.69 °F)	0.48 °C (0.87 °F)	268,457



WTMP Calibration, HEC-ResSim (In Progress)

- HEC-ResSim (in progress)
  - Model Structure (done)
  - Boundary Conditions (nearly complete)
  - Model Operations (in progress)
    - TCDs (powerhouses, M&I Intake)
    - Inflow Entrainment



WTMP Forecast Model Components, Target temperature at Watt Avenue

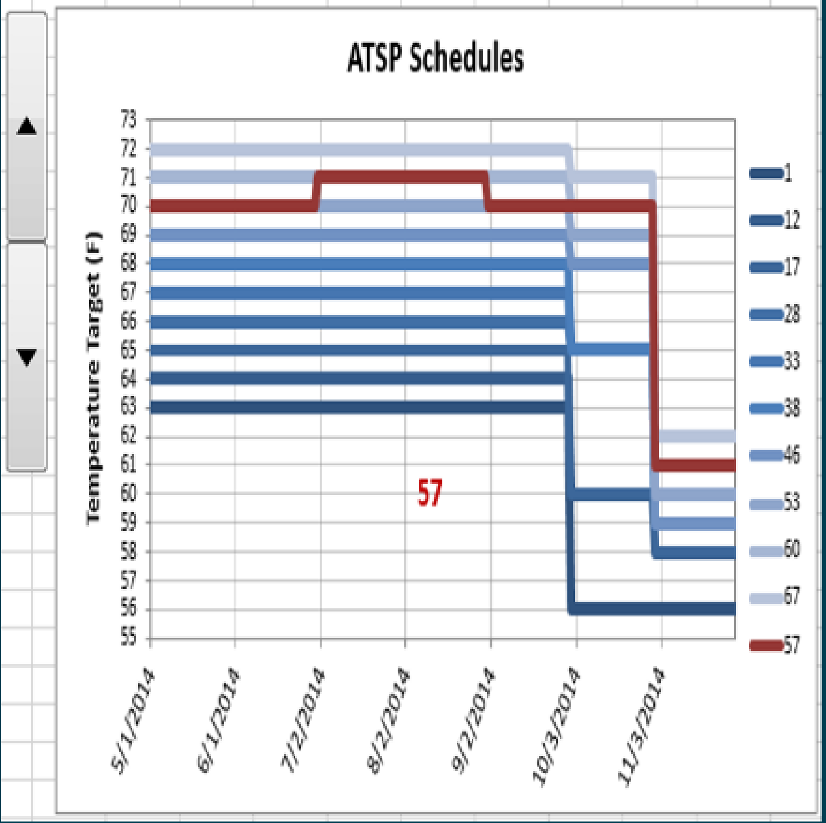
- Target temperature at Watt Avenue
  - Automated or manually specified
  - Requires iterations
  - Requires fast/accurate prediction of Watt Avenue or Hazel Avenue temperature
- Operation of Folsom Reservoir Powerhouse TCDs and low-level outlet bypass operations
  - Automated or manually specified
- Operation of Folsom Reservoir Municipal Intake TCD
  - Automated or manually specified
- Inflow water discharge / temperature and MET data
  - Predicted Q, historical MET data, inflow temperature regression

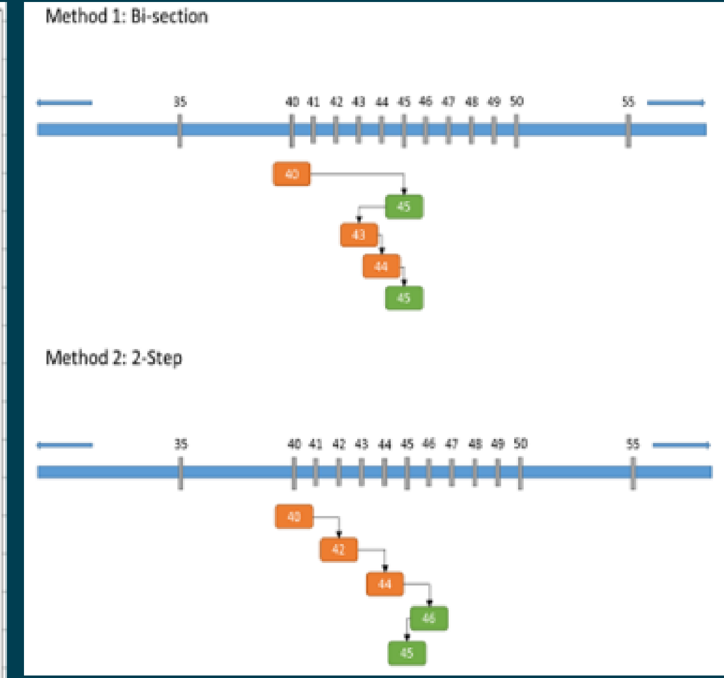
WTMP Forecast Model Components, Target Temperature at Watt Ave (Hazel very dry years)

- Target Temperature at Watt Ave (Hazel very dry years)
  - Automated Temperature Selection Procedure (1 – 78)

Table 1. Automated Temperature Selection Procedure Schedules.

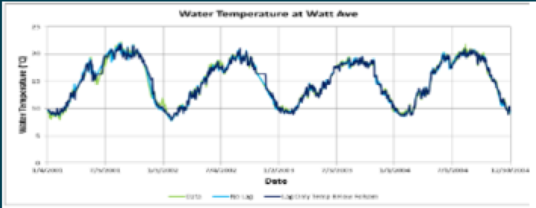
Schedule	Lower American River Water Temperature Targets at Watt Avenue (°F)						
	May	Jun	Jul	Aug	Sep	Oct	Nov
1	63	63	63	63	63	56	56
2	63	63	63	63	63	57	56
3	63	63	63	63	63	58	56
4	63	63	63	63	63	59	56
5	63	63	63	63	63	60	56
6	63	63	63	63	63	60	57
7	63	63	63	63	63	60	58
8	63	63	64	63	63	60	58
9	63	63	64	64	63	60	58
10	63	63	64	64	64	60	58
11	63	64	64	64	64	60	58
12	64	64	64	64	64	60	58
13	64	64	65	64	64	60	58
14	64	64	65	65	64	60	58
15	64	64	65	65	65	60	58
16	64	65	65	65	65	60	58
17	65	65	65	65	65	60	58
18	65	65	65	65	65	61	58

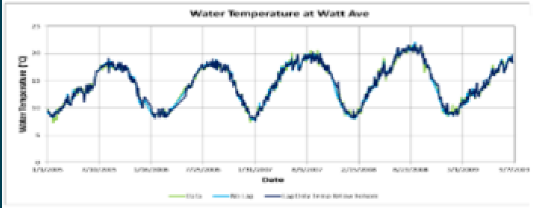


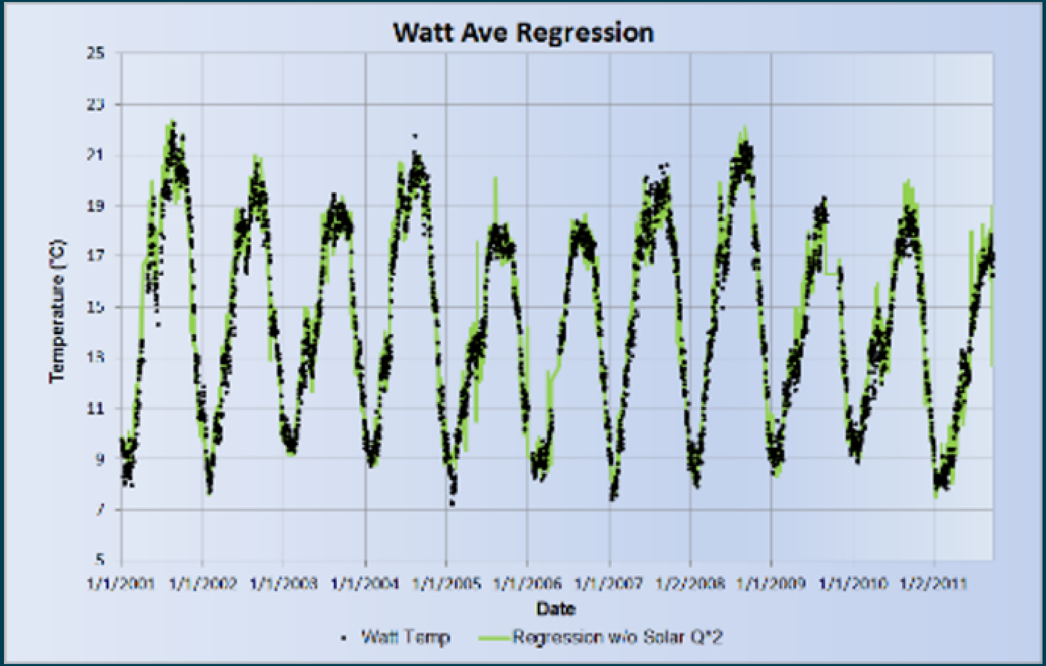


WTMP Forecast Model Components, Target Temperature at Watt Ave (Hazel very dry years) (continued)

- Target temperature at Watt Ave (Hazel very dry years)
  - Lower American Regression
    - Water temperature below Folsom Dam (average daily)
    - Air temp (average daily)
    - Flow (average daily)
    - Solar radiation (average daily)
    - Water travel time (time)

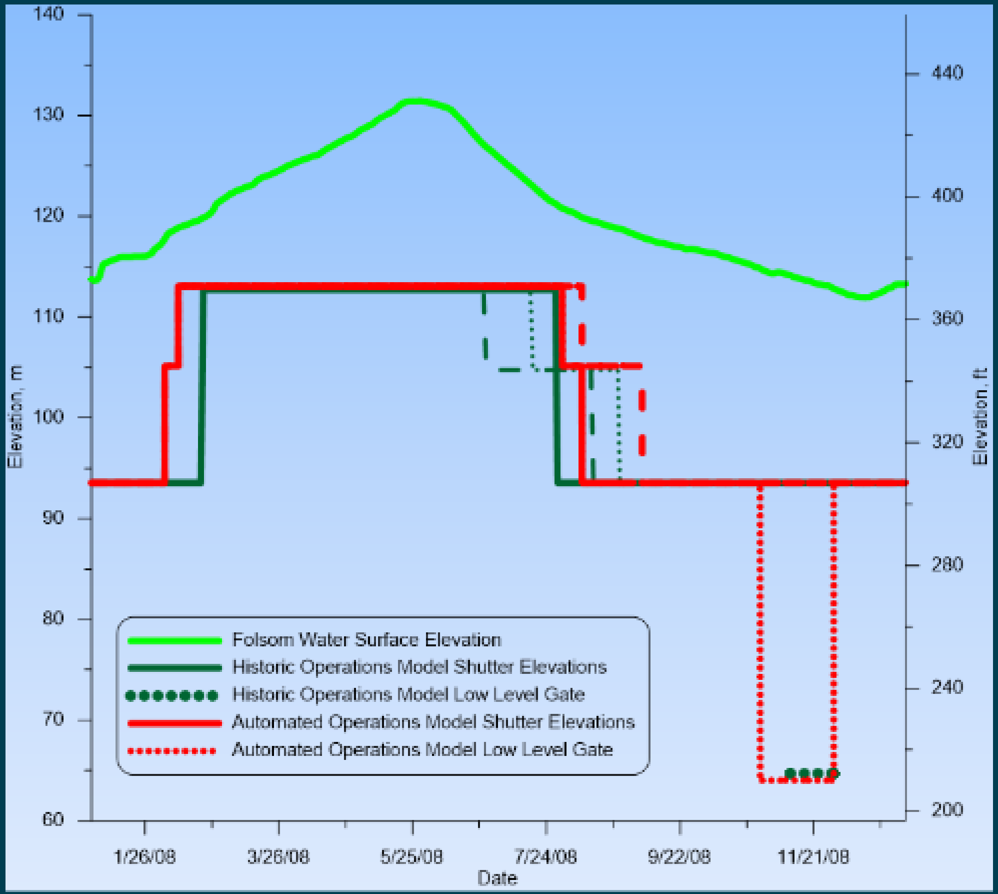


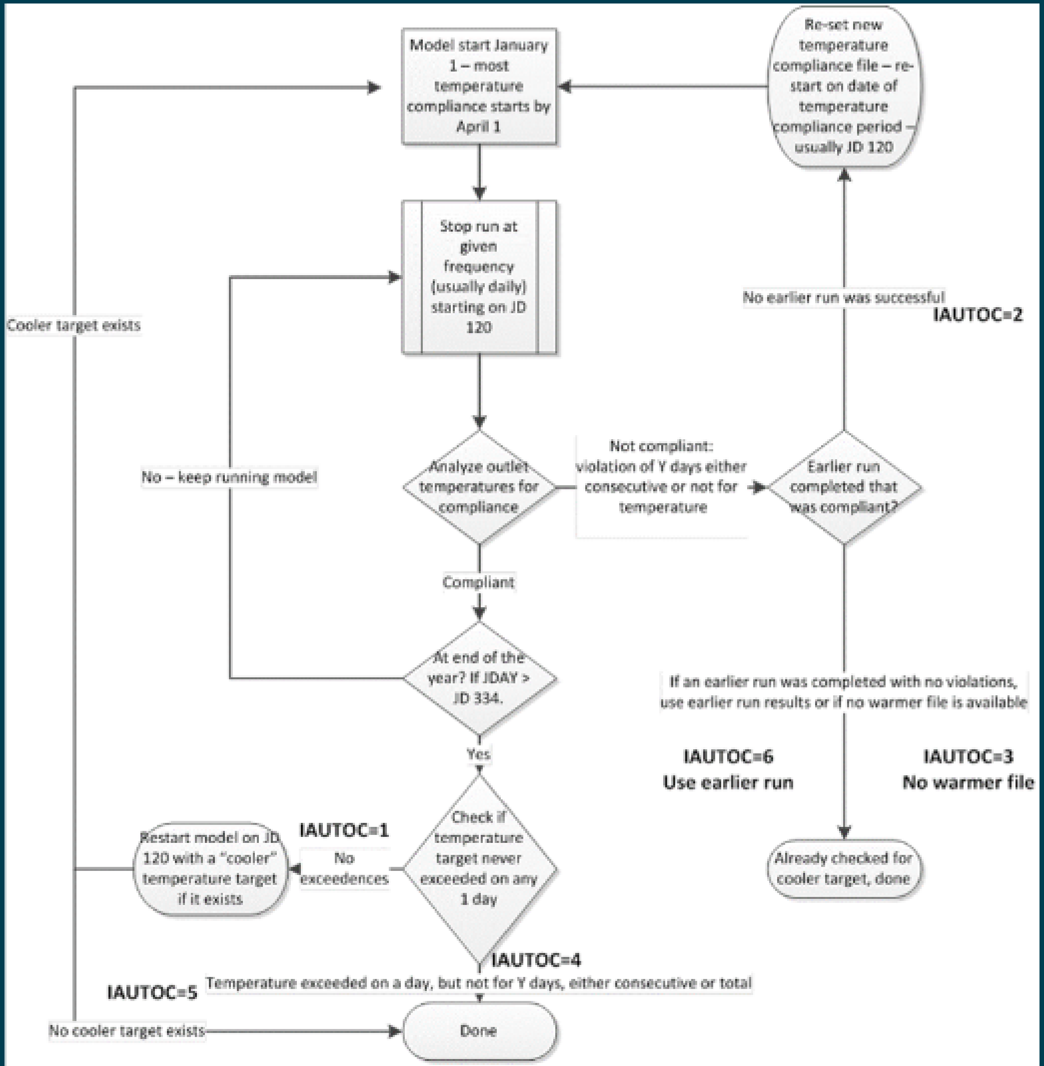




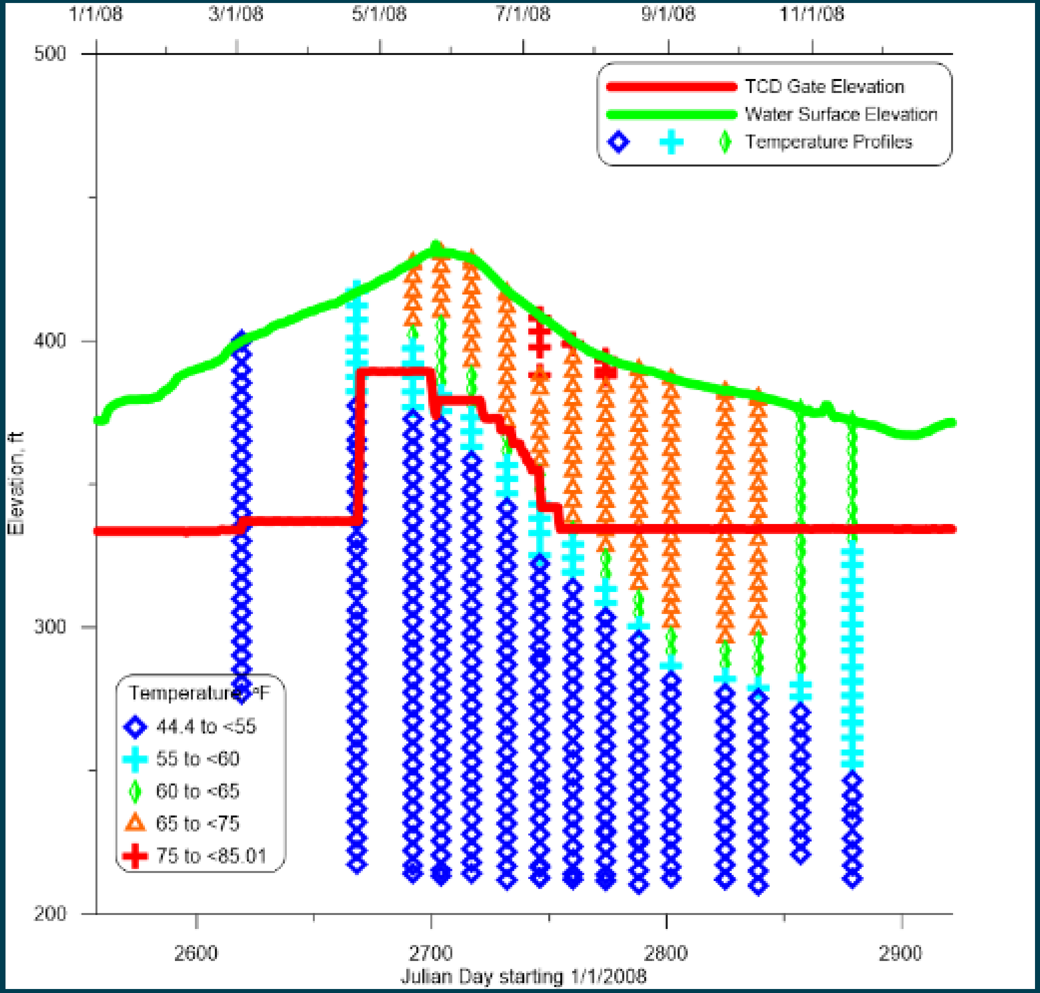
WTMP Forecast Model Components, Automated Folsom Powerhouse TCD Operations

- Mimic actual operations approach





WTMP Forecast Model Components, Automated Municipal Intake TCD



WTMP Forecast Model Components, Forecasts

- Operations inflow forecasts (Reclamation)
- MET data (current practice, historical warm year e.g., 2014)
- Inflow Water temperature (current practice, inflow regression or historical)

DRAFT April 2021

90% Runoff Exceedance Outlook:

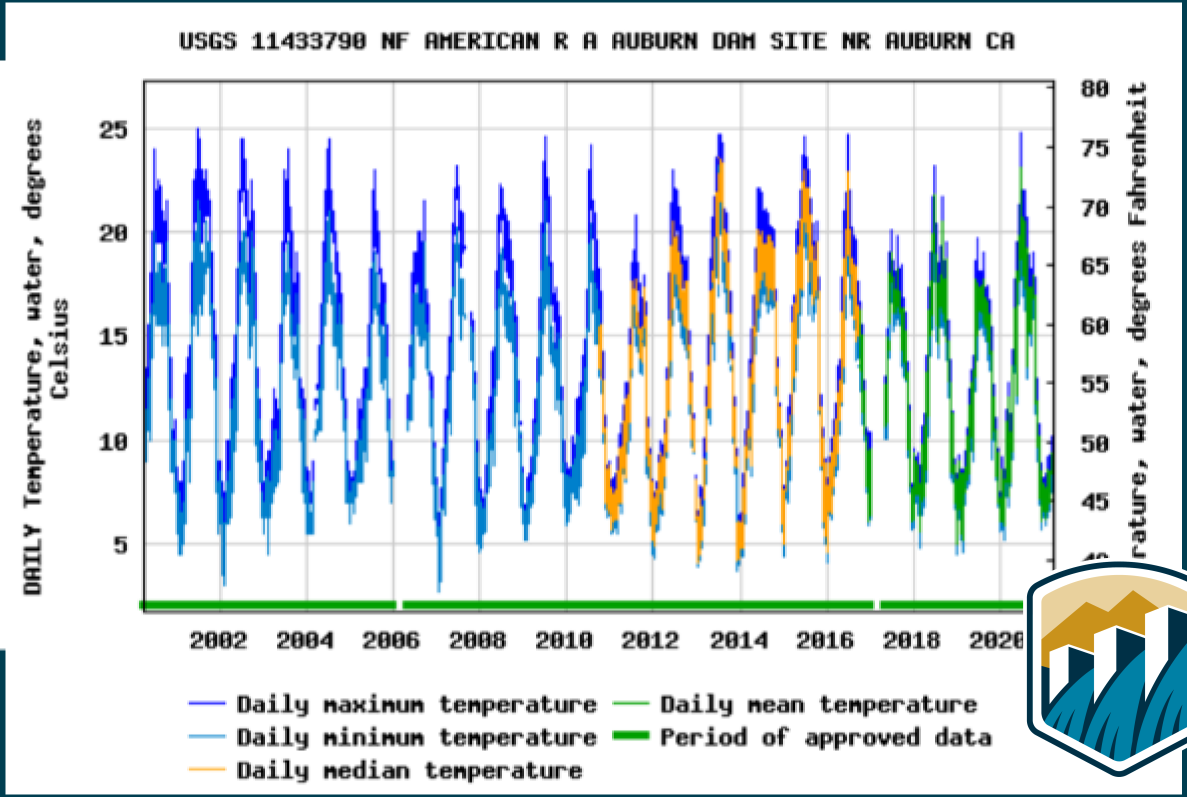
Inflow based on 90% exceedance forecast

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

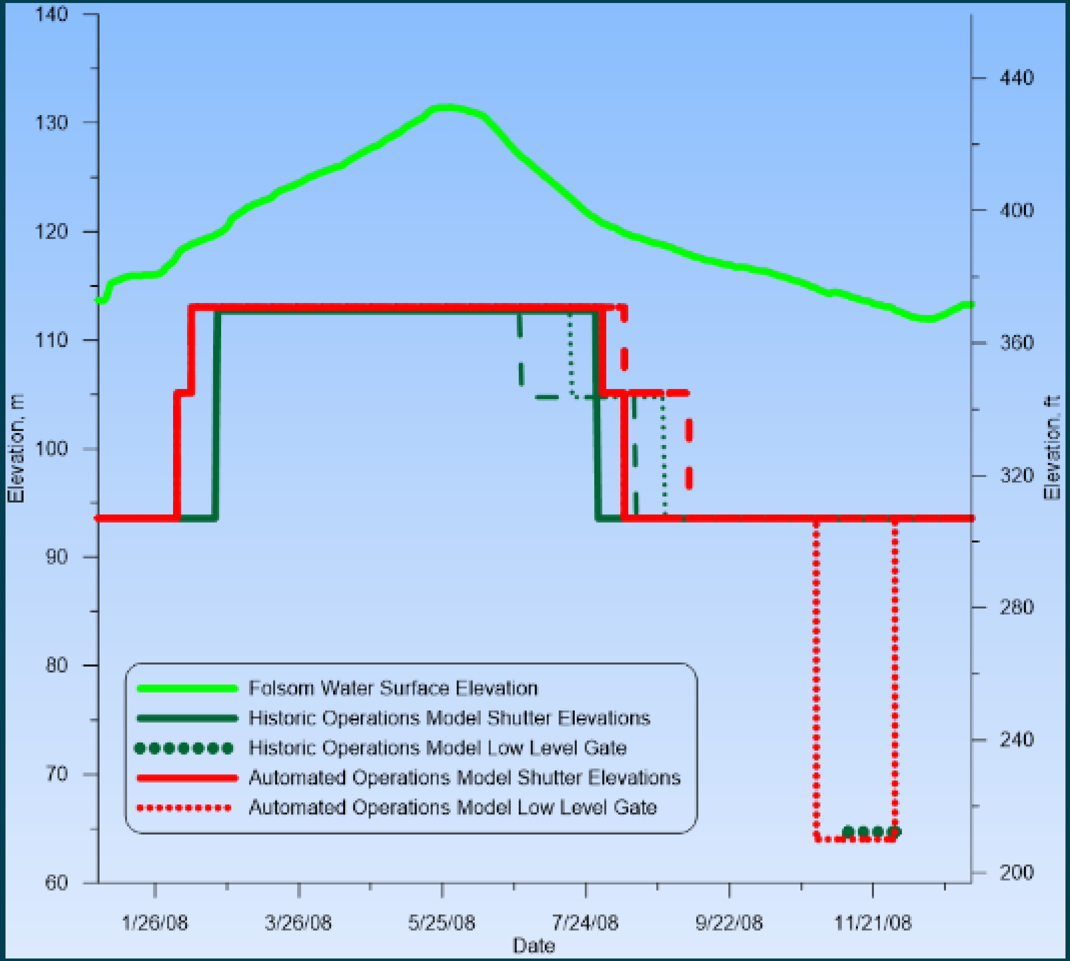
		Apr	May	Jun	Jul	Aug	Sep
Folsom	361	378	417	343	248	250	251
Elev.		400	406	394	378	378	378

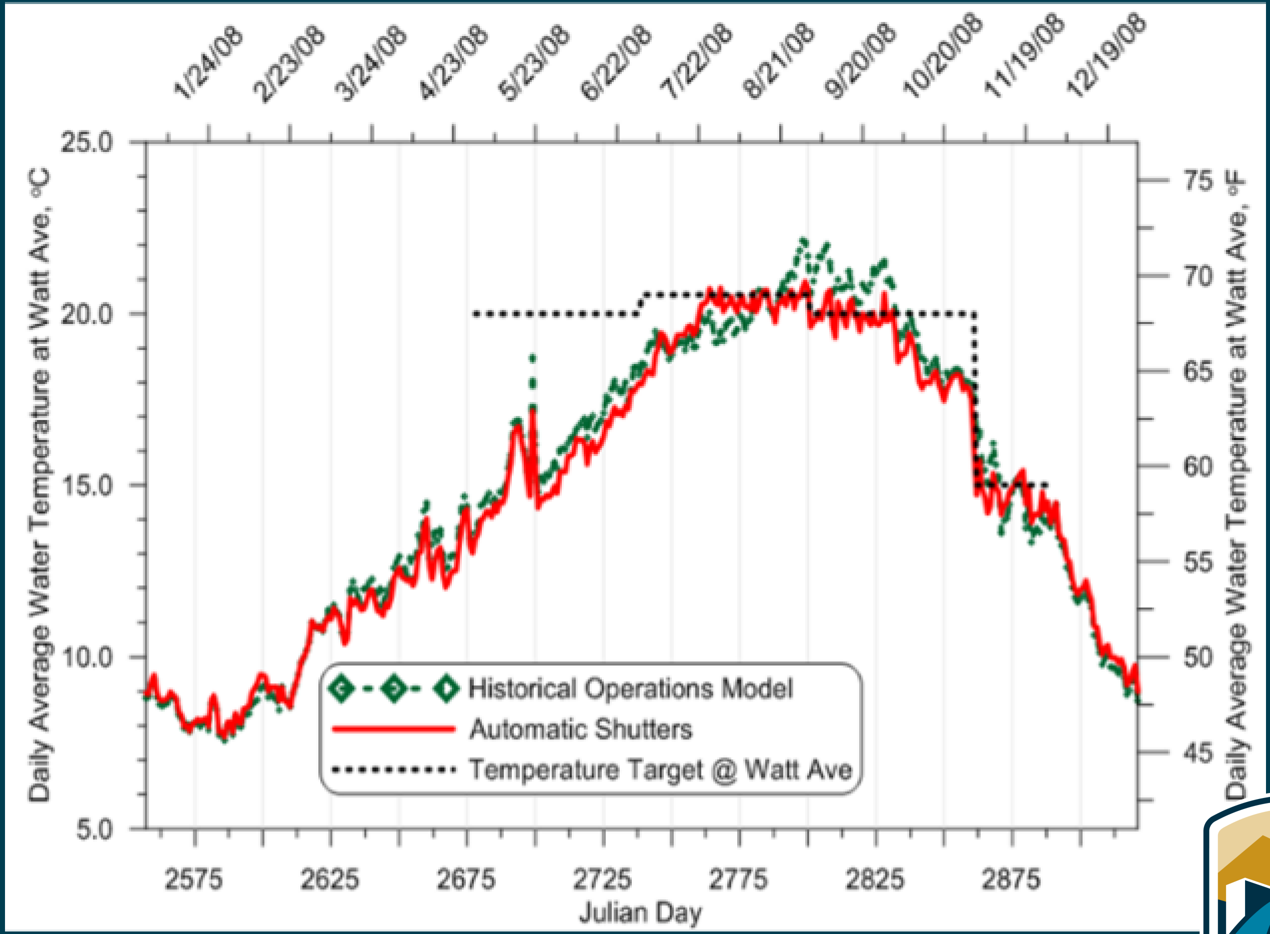
Monthly River Releases (cfs)

	Apr	May	Jun	Jul	Aug	Sep
American	2013	1256	2290	2406	955	804
MRR	858					



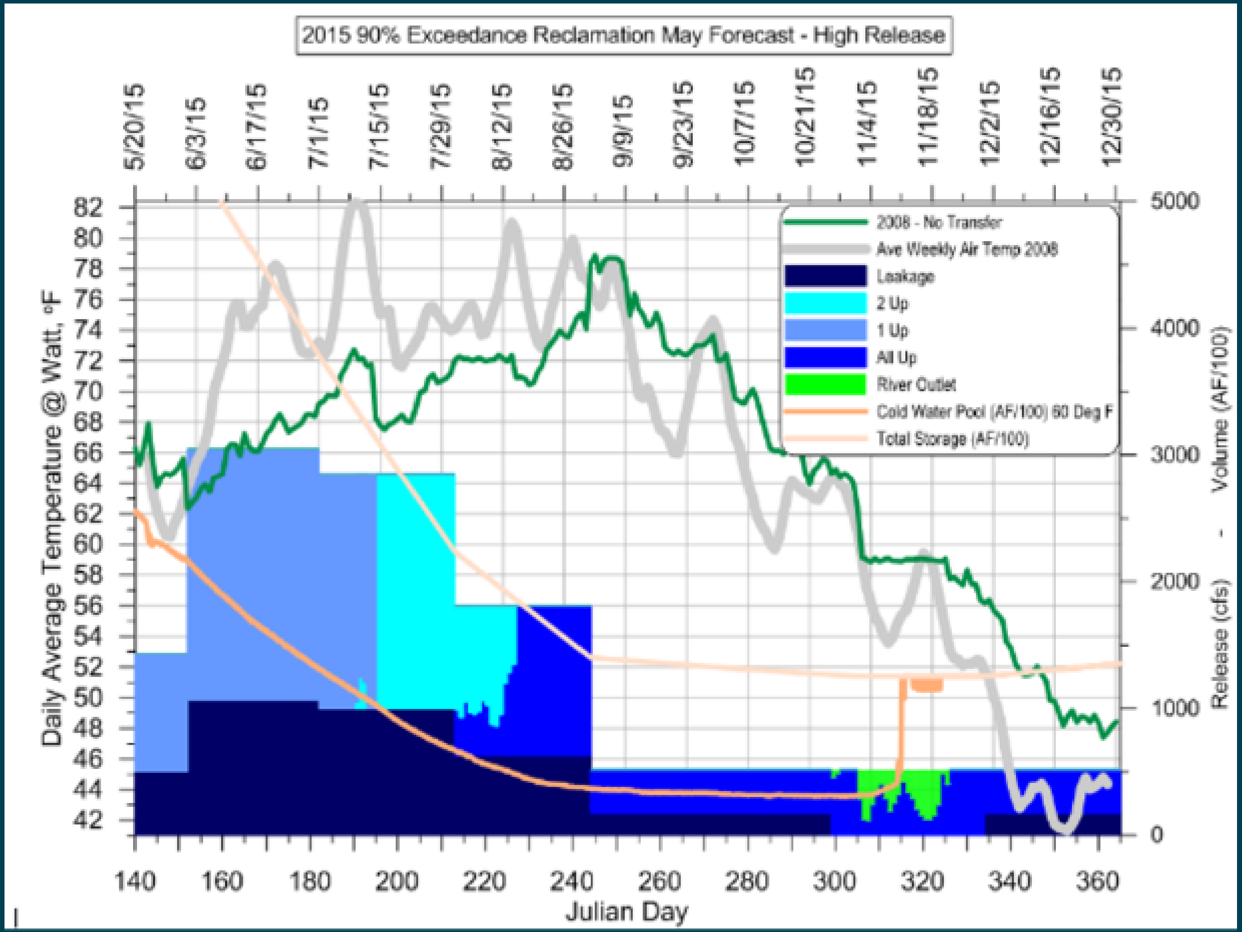
WTMP Forecast Model Components, WTMP Forecast Model Example

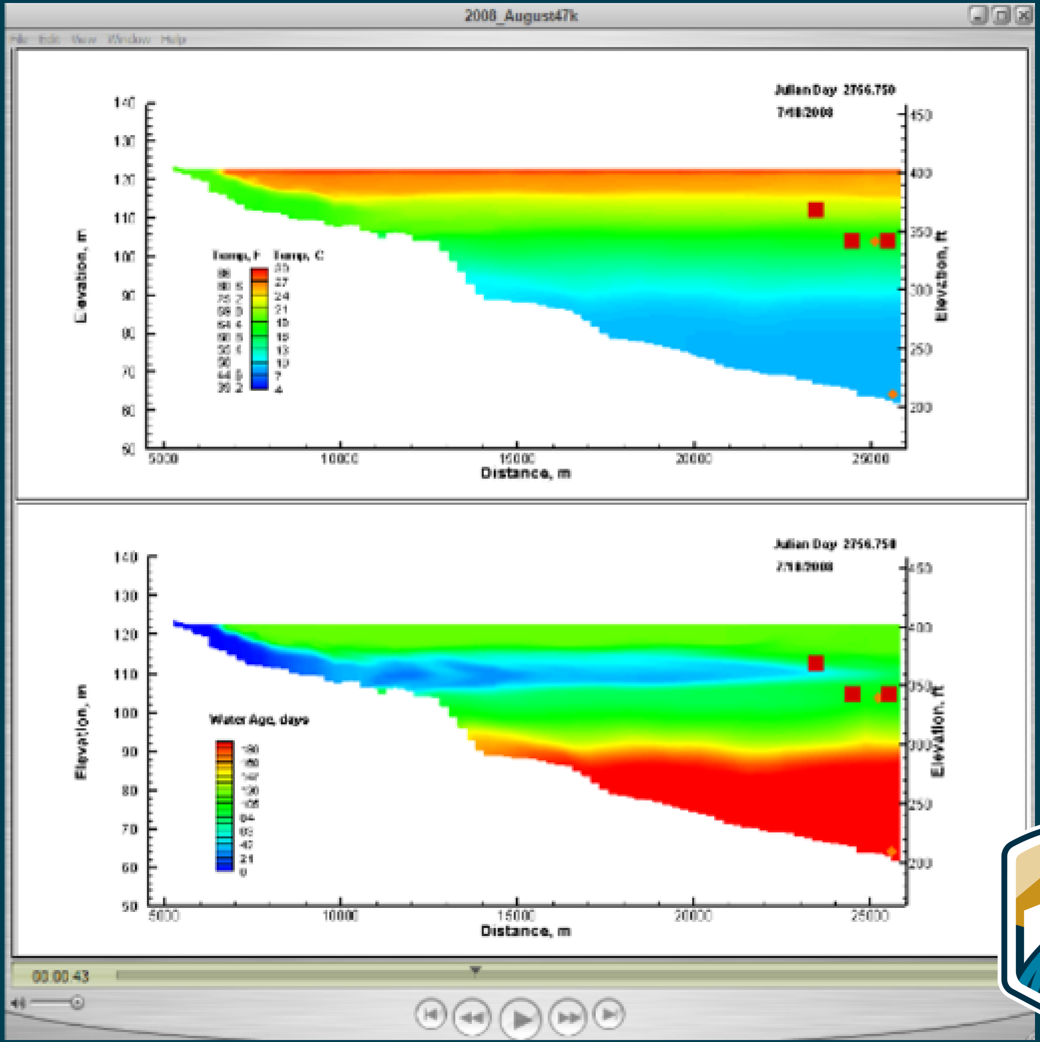




WTMP Visualization

- American River Group plots, etc.





American River Water Temperature Models, Representation

- WTMP Representation
  - System overview
    - Folsom Reservoir and Folsom Dam
    - Lake Natoma
    - American River below Nimbus Dam to the confluence with the Sacramento River
    - Inflow and outflow water temperature / discharge and meteorological data
  - WTMP representation / boundary conditions
  - WTMP calibration data / preliminary calibration
  - WTMP forecast model components / visualization

MTC Feedback

- Do we miss any important elements?
- Do we miss any critical data for model development?

Photo credit: John Hannon, Reclamation

Wrap Up and Next Steps

Randi Field, CVO

Yung-Hsin Sun, Ph.D., P.E., Stantec

WTMP Next Steps

- TM development and distribution for review
  - Data management plan TM
  - Data inventory
- Model development and framework implementation
- Initiation of subgroup discussions

Upcoming MTC and Topics

- Next MTC Meeting: July 7, 2022; 1:00 p.m. – 4:00 p.m.
- Upcoming topics:
  - Model development topics
    - Sacramento/Trinity River Water Temperature Model (continued)
    - American River Water Temperature Model (continued)
    - Stanislaus River Water Temperature Model (introduction)
- You have the registration link already – do it today.
- Reminder: Submit your comments on data inventory to Randi

Information Sharing and Contacts

- Key team members presenting today
  - Randi Field, RField@usbr.gov
  - Mike Deas, Mike.Deas@watercourseinc.com
  - John DeGeorge, jfdegeorge@rmanet.com
  - Craig Addley, Craig.Addley@cardno.com
  - Yung-Hsin Sun, yung-hsin.sun@stantec.com
- Project Information:
  - Contract: mppublicaffairs@usbr.gov
  - Website link - https://www.usbr.gov/mp/bdo/cvp-wtmp.html


Next MTC Meeting:
July 7, 2022; 1:00 p.m. – 4:00 p.m.
BUREAU OF
RECLAMATION