BUREAU OF RECLAMATION

CVP Water Temperature Modeling Platform

Modeling Technical Committee (MTC) Shasta TCD Modeling Subgroup Meeting #1

July 27, 2022; 12:00 p.m. – 2:00 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 Shasta TCD Modeling Subgroup #1: Objectives

- Provide an effective venue for topic-specific discussions under the MTC framework
- Establish common understanding of the functions of Shasta TCD
- Developed shared knowledge for how Shasta TCD is modeled in the WTMP element model and receive input from subject matter experts

MTC Shasta TCD Modeling Subgroup #1: Agenda

12:00 p.m.	Meeting Logistics, Welcome Remark, and Announcements
12:07 p.m.	Significance of the Shasta TCD for temperature management in the Sacramento River
12:20 p.m.	Review of Shasta TCD Modeling and group Discussion – Part 1 • Specifications of the TCD that are important for modeling • Modeling approximation to TCD specifications
1:00 p.m.	Break (5 min)
1:05 p.m.	Review of Shasta TCD Modeling and group Discussion – Part 2 • Modeling conceptual approximation for simulating selective withdrawal strategy and actions • Verification of hypothesis for modeling conceptual approximation • Ongoing and planned activities for future improvements
1:50 p.m.	Next Steps
2:00 p.m.	Adjourn

Additional Information

- Some references for consideration in the Agenda
- A description of the purpose and charge for this subgroup in handout
- MTC: yung-hsin.sun@stantec.com

Photo credit: John Hannon, Reclamation

Welcome Remark and Announcements

Randi Field, Hydrologic Engineer, CVO

Photo credit: John Hannon, Reclamation

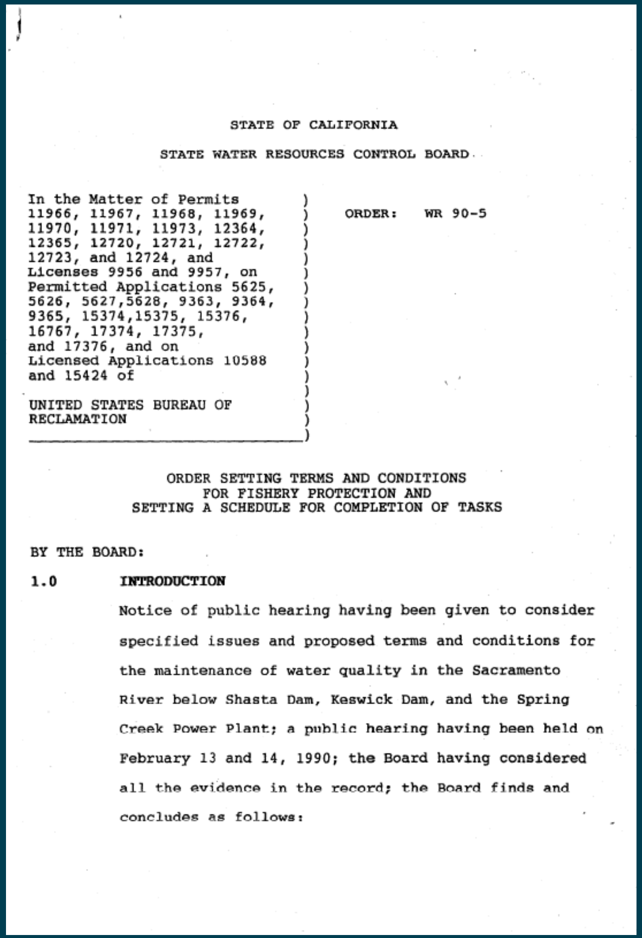
Shasta TCD Background

Randi Field, Hydrologic Engineer, CVO

Reclamation, Central Valley Operations Office

SWRCB Water Right Order 90-5

- Order setting terms and conditions for fishery protection and setting a schedule for completion of tasks
- "maintenance of water quality in the Sacramento River below Shasta Dam, Keswick Dam, and the Spring Creek Power Plant"
- Meet a 56°F in the Sacramento River at Red Bluff Diversion Dam, or consultation to designate an upstream location



STATE OF CALIFORNIA

STATE WATER RESOURCES CONTROL BOARD

In the Matter of Permits 11966, 11967, 11968, 11969, 11970, 11971, 11973, 12364, 12365, 12720, 12721, 12722, 12723, and 12724, and Licenses 9956 and 9957, on Permitted Applications 5625, 5626, 5627,5628, 9363, 9364, 9365, 15374,15375, 15376, 16767, 17374, 17375, and 17376, and on Licensed Applications 10588 and 15424 of UNITED STATES BUREAU OF RECLAMATION	ORDER: WR 90-5

ORDER SETTING TERMS AND CONDITIONS FOR FISHERY PROTECTION AND SETTING A SCHEDULE FOR COMPLETION OF TASKS

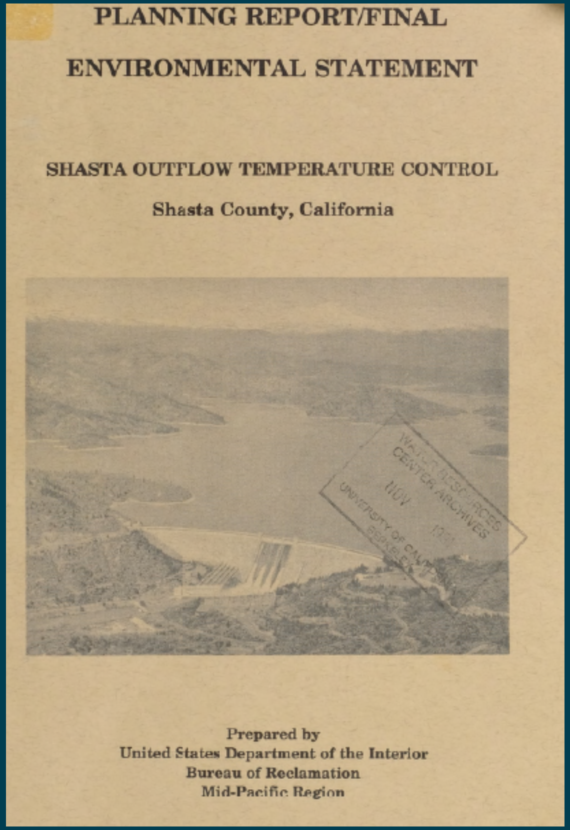
BY THE BOARD:

1.0 **INTRODUCTION**

Notice of public hearing having been given to consider specified issues and proposed terms and conditions for the maintenance of water quality in the Sacramento River below Shasta Dam, Keswick Dam, and the Spring Creek Power Plant; a public hearing having been held on February 13 and 14, 1990; the Board having considered all the evidence in the record; the Board finds and concludes as follows:

1991 Planning Report

- Shasta Outflow Temperature Control
- Design Concepts
  - Optimize available water supplies
  - Improve temperature for winter run Chinook salmon
  - Maintain existing water and hydropower capability


PLANNING REPORT/FINAL

ENVIRONMENTAL STATEMENT

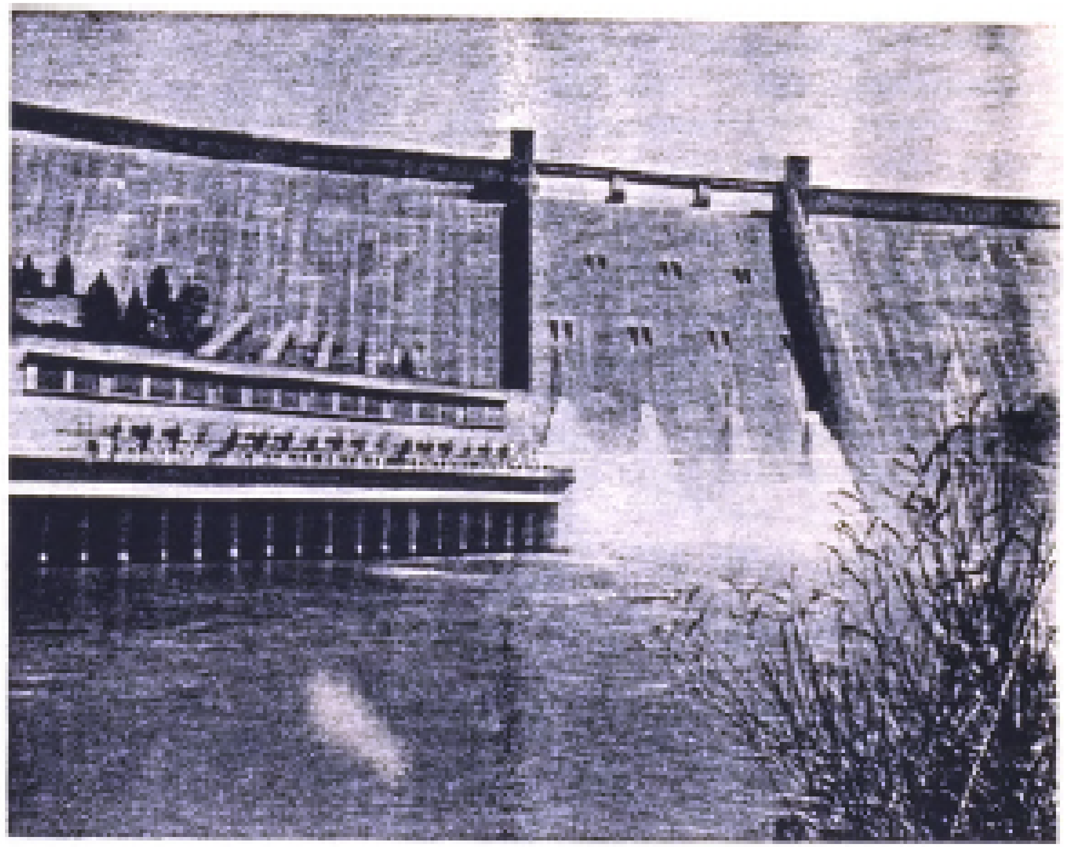
SHASTA OUTFLOW TEMPERATURE CONTROL

Shasta County, California

Prepared by
United States Department of the Interior
Bureau of Reclamation
Mid-Pacific Region

Power Bypass

- Planning Report/Final Environmental Statement 1991

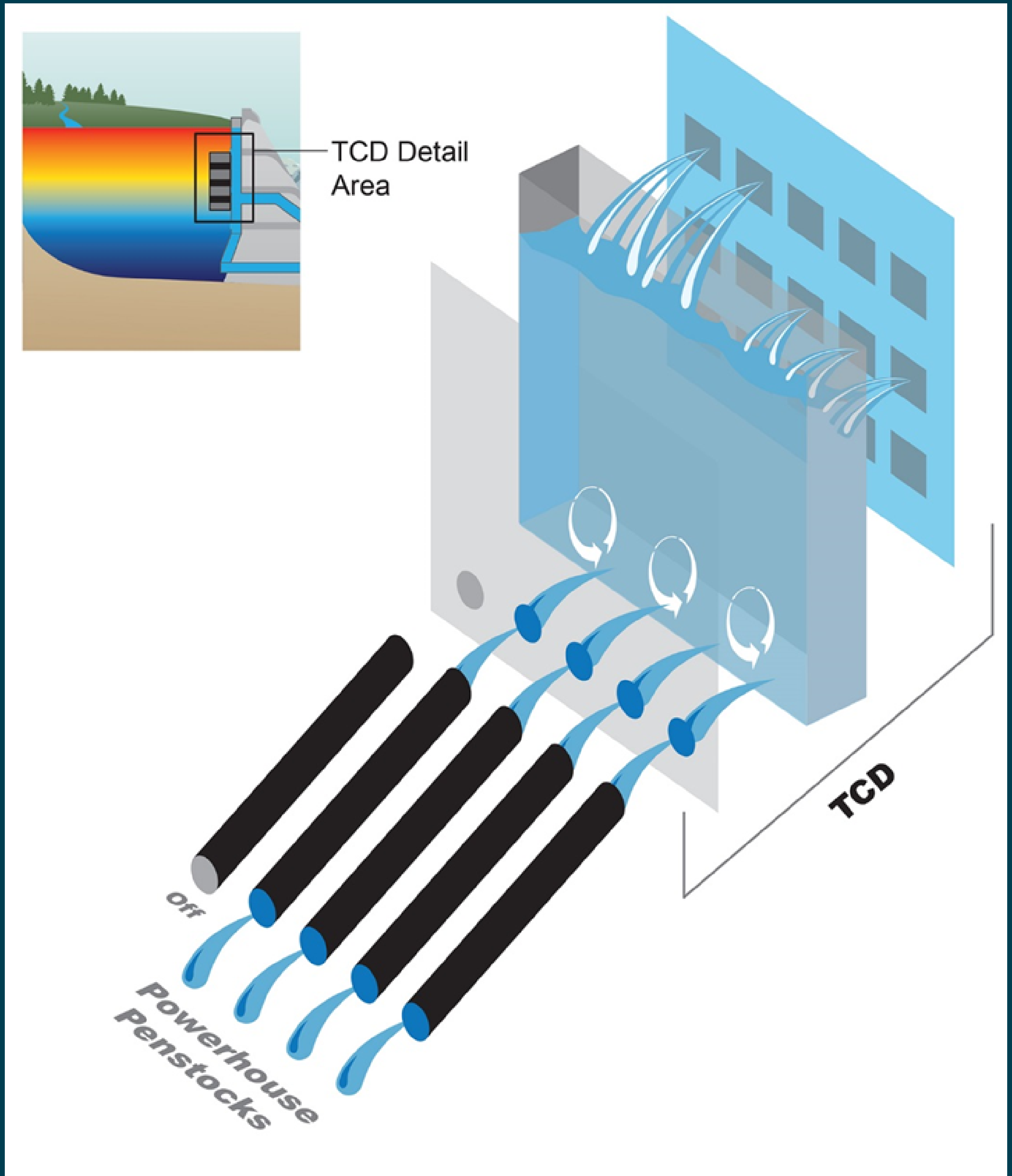


Shasta Dam bypass through low level outlet valves to meet temperature objectives.

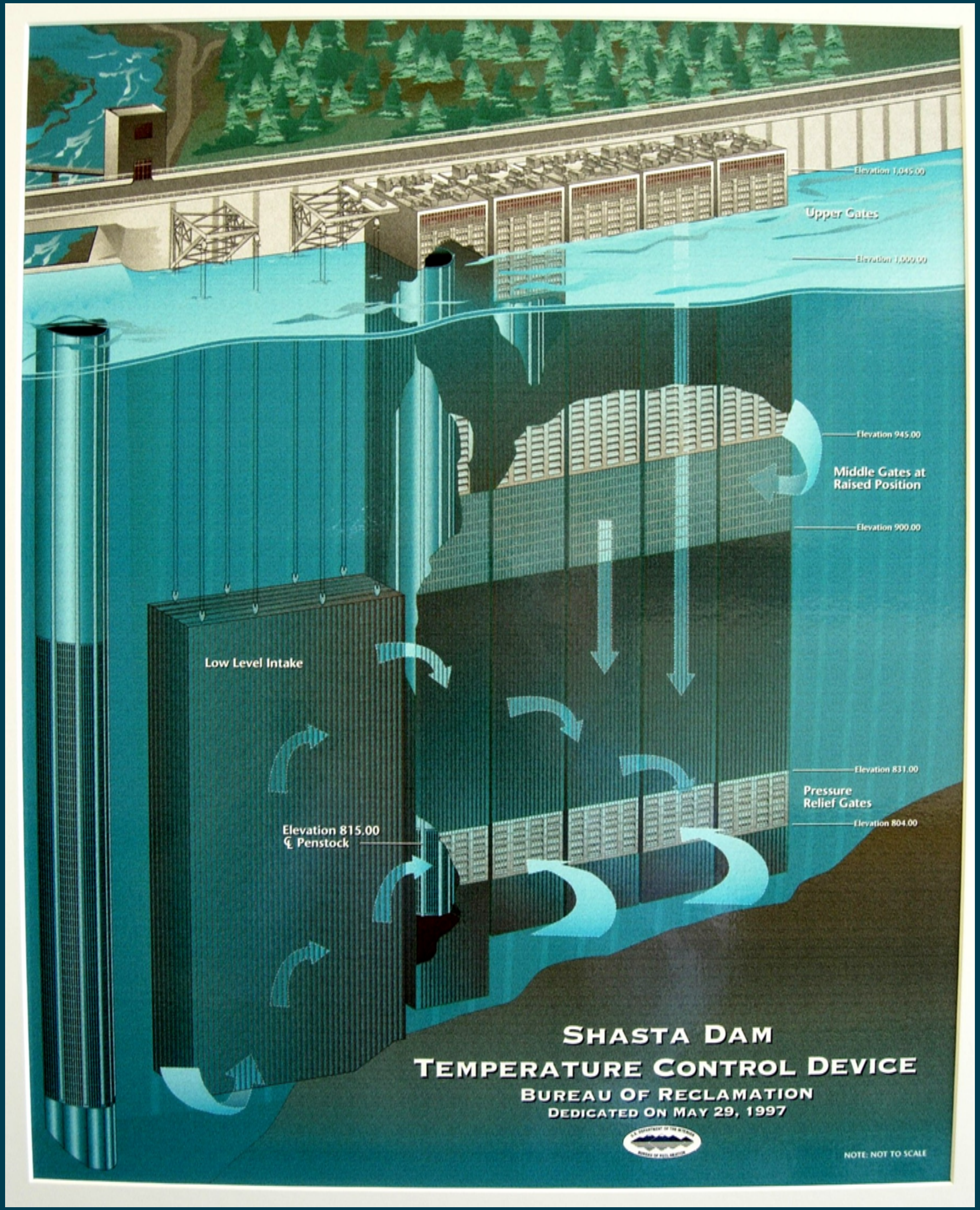
(Replacement power costs of the bypass totaled $8.8 million in 1987-90. The bypass is expected to continue until permanent temperature control measures are implemented at Shasta Dam).

Shasta Dam

Temperature Control Device System



Shasta Temperature Control Device



Construction 1990’s

- Completed 1997

Shasta TCD Gate Operations

- Modeling results suggest the date of gate changes and location of thermocline
- Monitor real-time conditions, forecasts, and previous experience
- Issue change order to Shasta Dam operators
- Shasta Dam operators use controls on top of TCD to move gates up/down
  - Upper Gates – 22.5 min.
  - Middle Gates – 23 min.
  - Lower Gates/PRGs – 13.5 min.
  - Side Gate – 70 min
- Approximately 2-3 days for gate change to reach Keswick Dam


Photo credit: John Hannon, Reclamation

Shasta TCD Modeling Considerations

Mike Deas

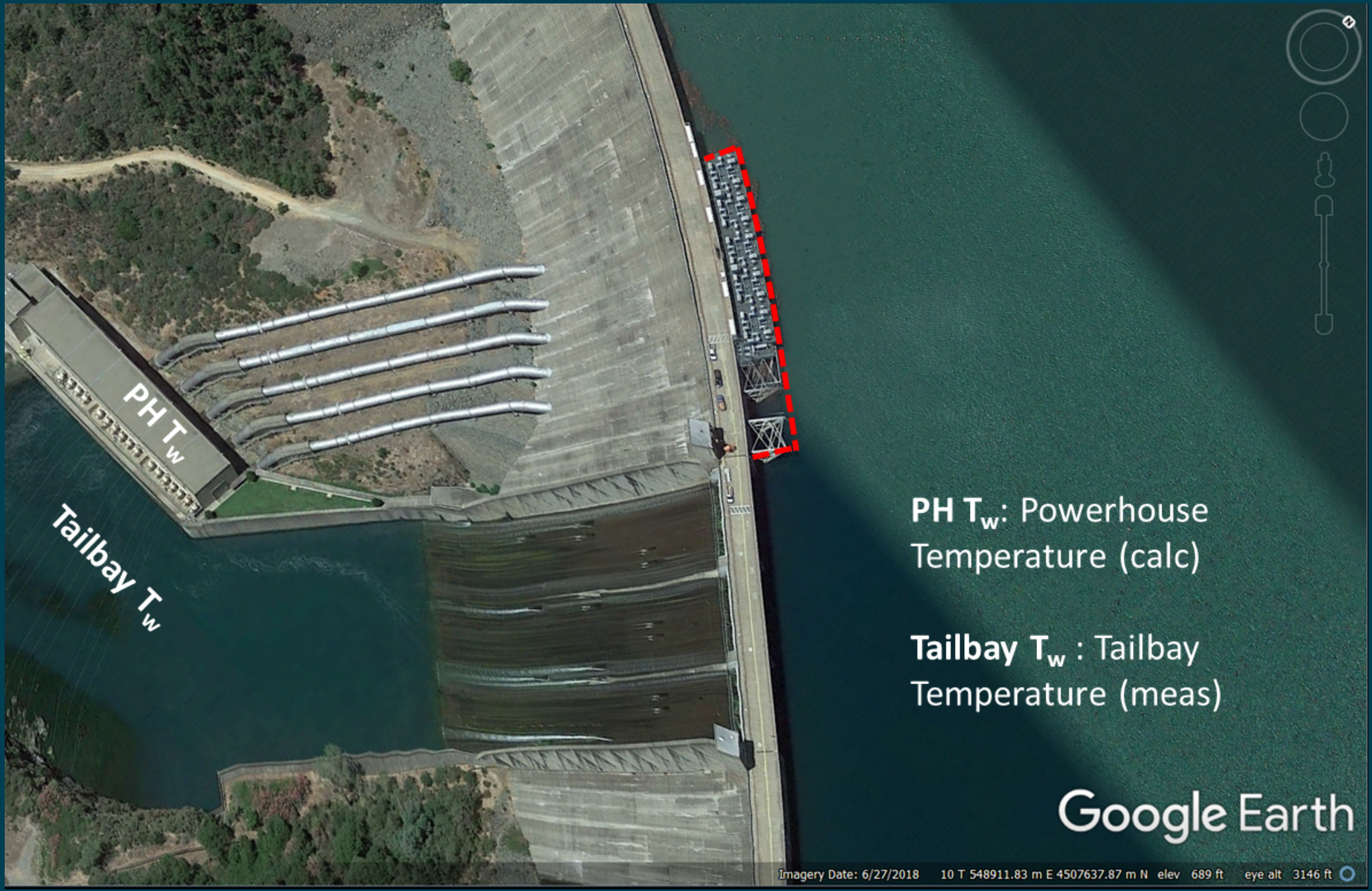
Watercourse Engineering, Inc

Outline

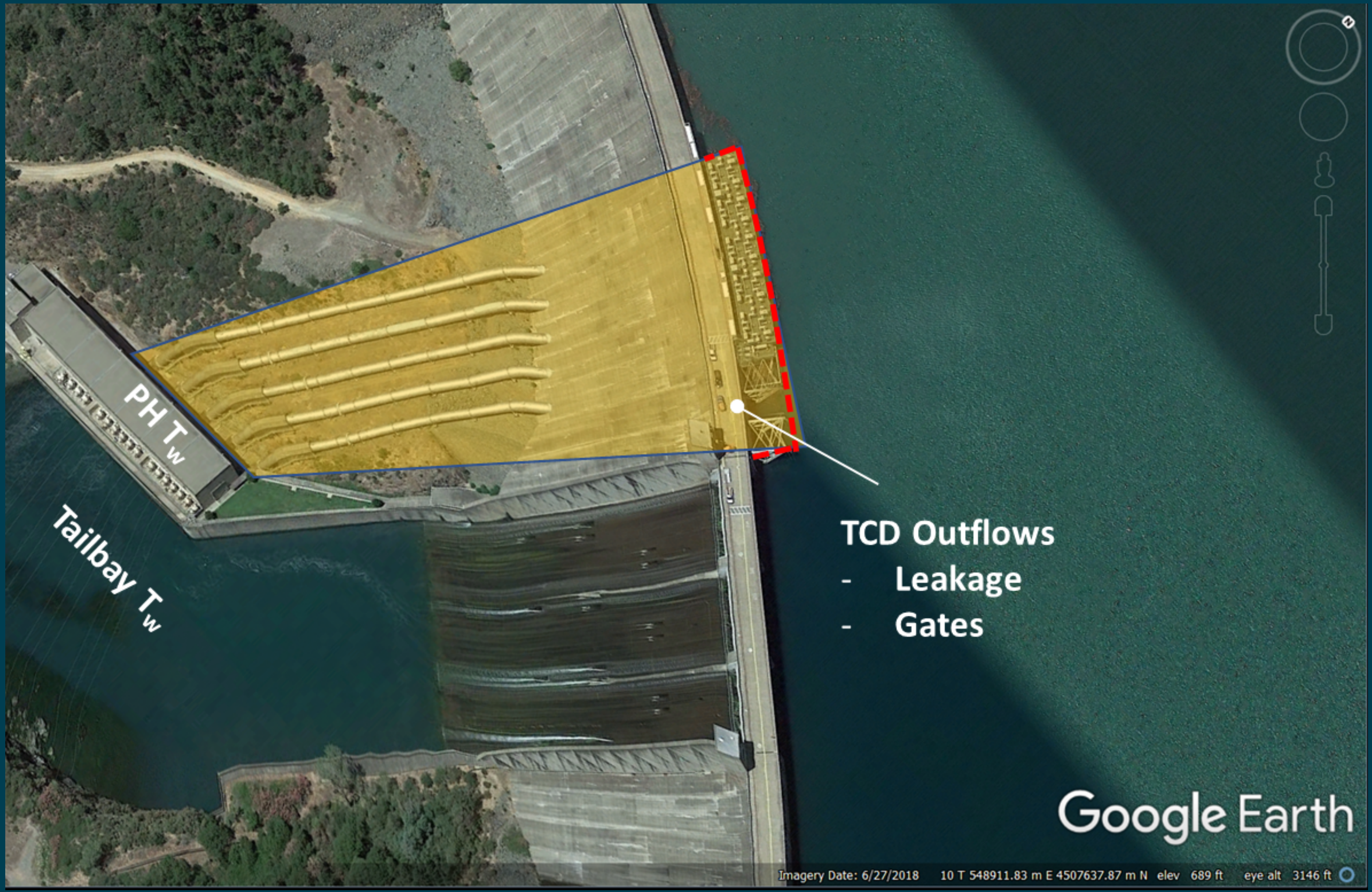
- Shasta TCD Basics
- Key TCD Attributes
- Model Features and Domain
- Model Representation
  - Leakage
  - Large gate openings
  - Low-level intake
  - Selective withdrawal
- Forecasting
- Discussion

Shasta TCD Basics (part 1)

Shasta TCD Basics (part 2)

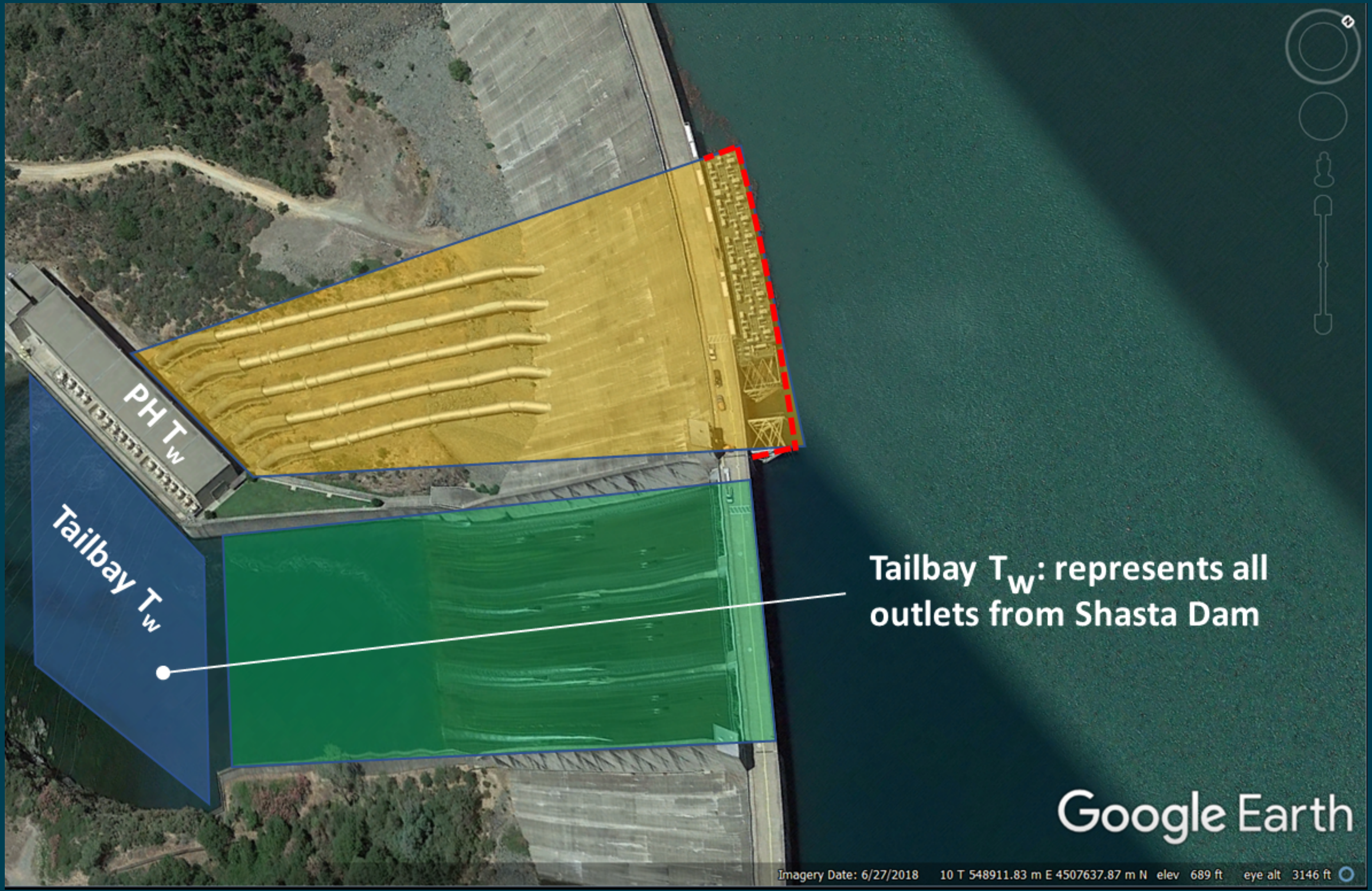


Shasta TCD Basics (part 3)

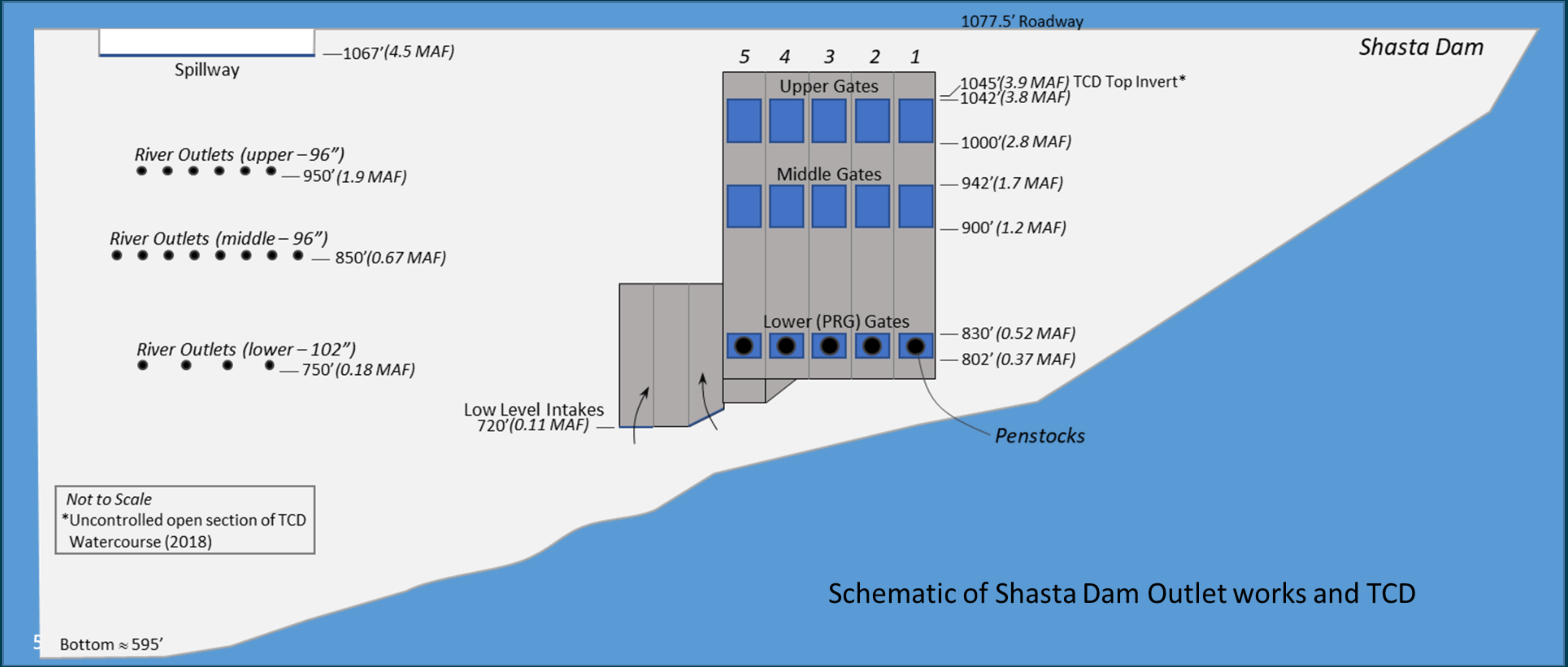


Shasta TCD Basics (part 4)

Shasta TCD Basics (part 5)



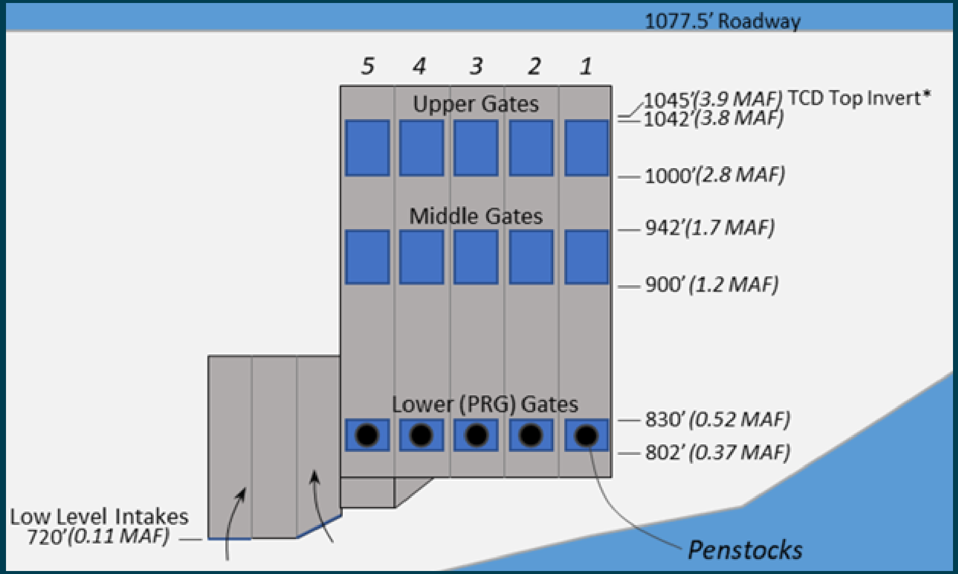
Shasta TCD Basics (part 6)



Schematic of Shasta Dam Outlet works and TCD

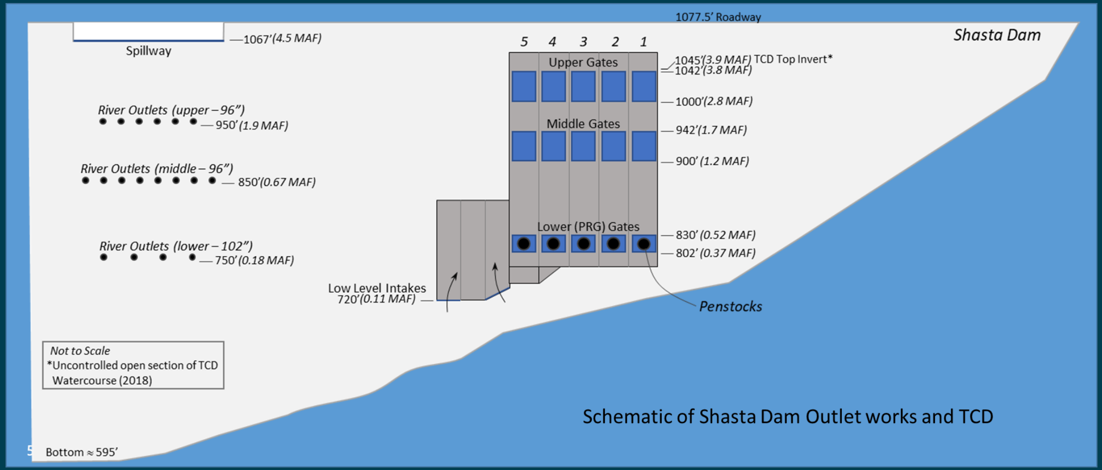
Shasta TCD Basics: Operations

- TCD levels and gates
  - Operation is top down – gate progression from highest to lowest. This preserves the deeper, colder water for late season use
  - Typically, one or two levels at a time (e.g., two level pairs: upper-middle, middle-lower, lower-side gates)
  - No fewer than five gates open at a time
  - 35 ft freeboard for solo level operation
  - The open levels and open gates at each level can have an impact on downstream water temperatures
  - Selective withdrawal
  - Side gate



Key Attributes of the TCD, Overview

- Leakage
- Large gate size
- Low level intake (side gate structure)
- Selective withdrawal
- Other Considerations
  - Multiple (5) gates per level
  - Role of powerhouse operations
  - TCD asymmetrically located on dam
  - Proximity to reservoir bed/boundary
  - Vertical side gate entry point



Schematic of Shasta Dam Outlet works and TCD

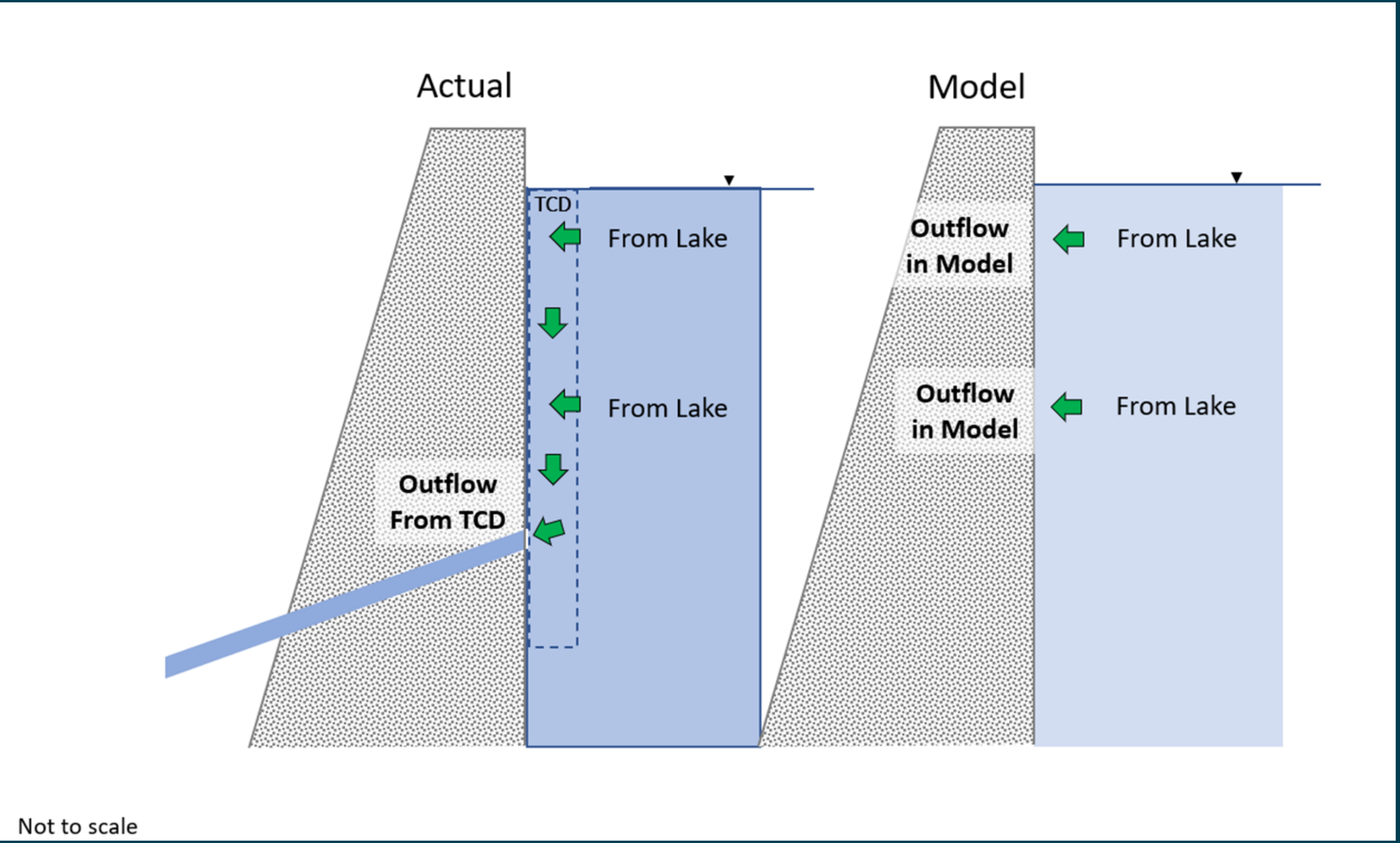
Model Features and Domain (part 1)

- CE-QUAL-W2
  - Laterally averaged
  - Point sink outlet works representation
  - Selective withdrawal logic
- HEC ResSim
  - Laterally and longitudinally averaged
  - Point sink outlet works representation
  - Selective withdrawal logic
- Calibration objective: simulate both dam release temperature and lake profile temperature

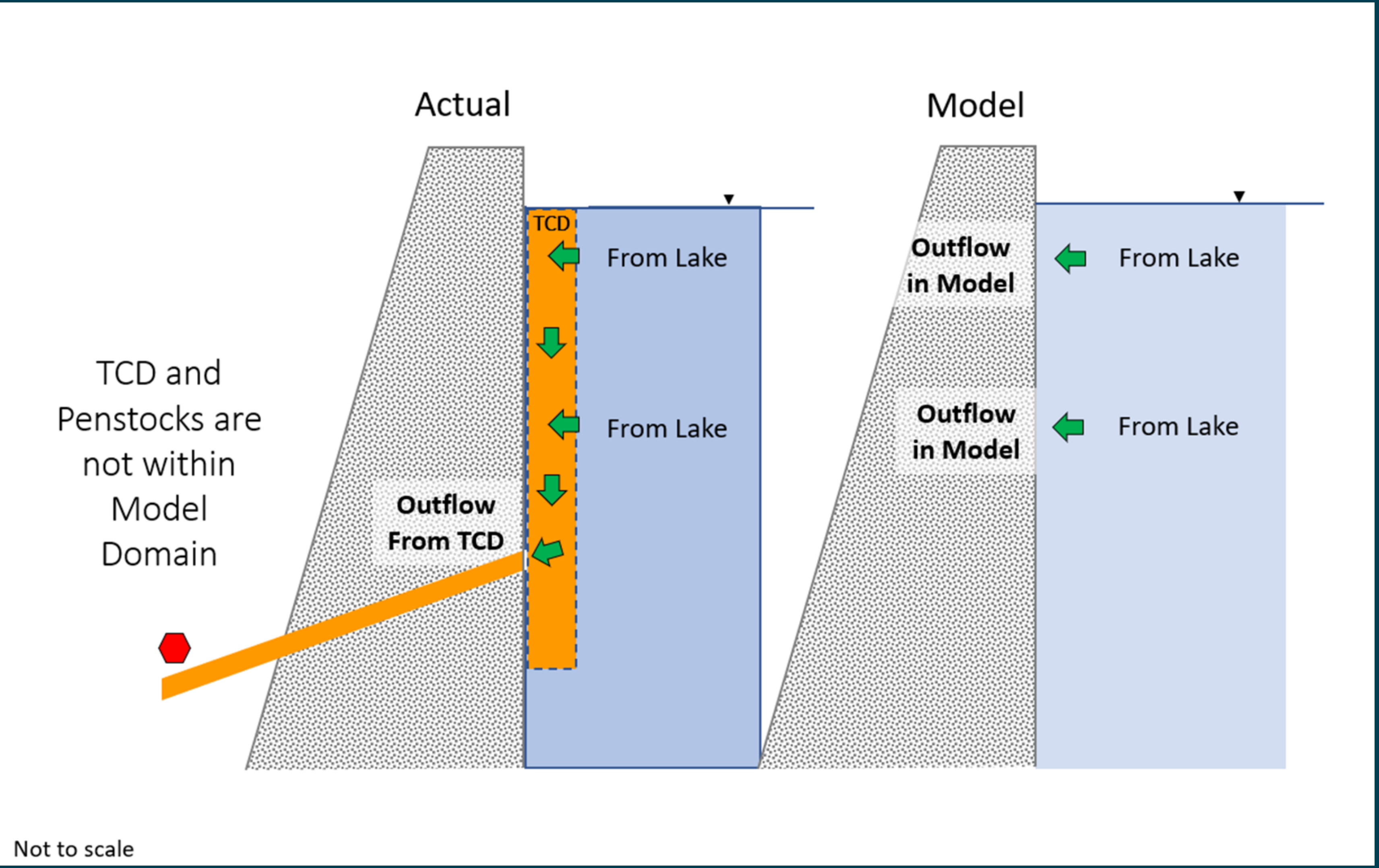
Model Features and Domain (part 2)

- CE-QUAL-W2
  - Indicated with the white outline in photo
- HEC ResSim
  - Indicated with the yellow outline in photo.
- Dam outlets “look” similar in both models
  - One-dimensional (laterally averaged)
  - Vertical

Model Features and Domain (part 3)

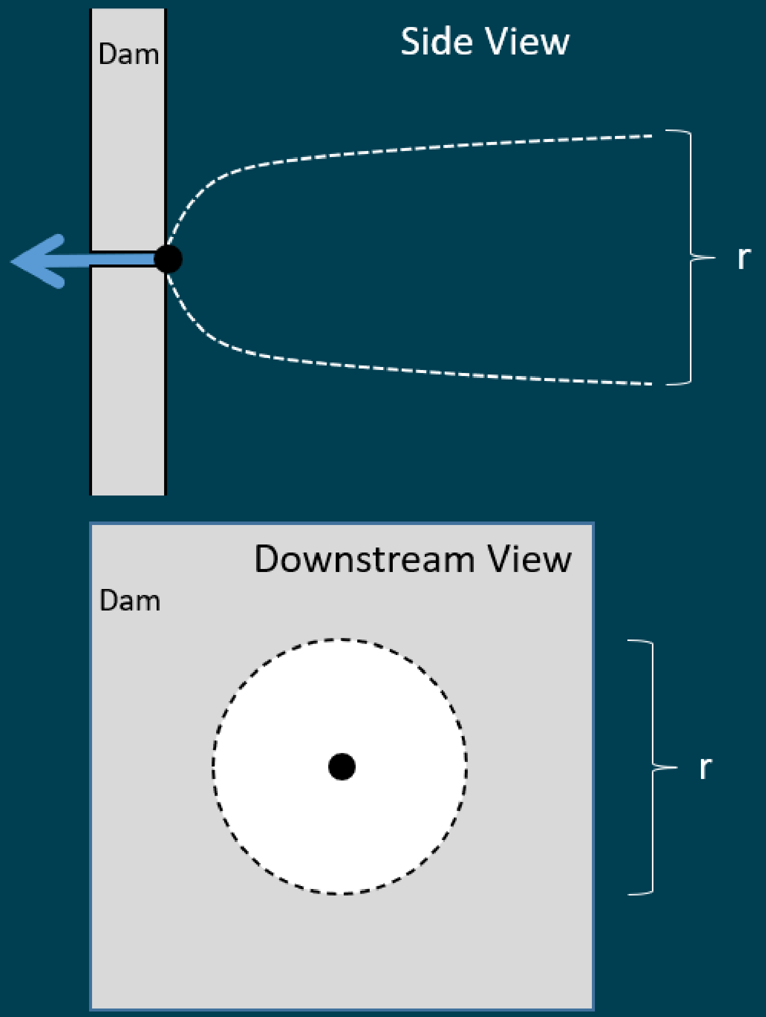


Model Features and Domain (part 4)



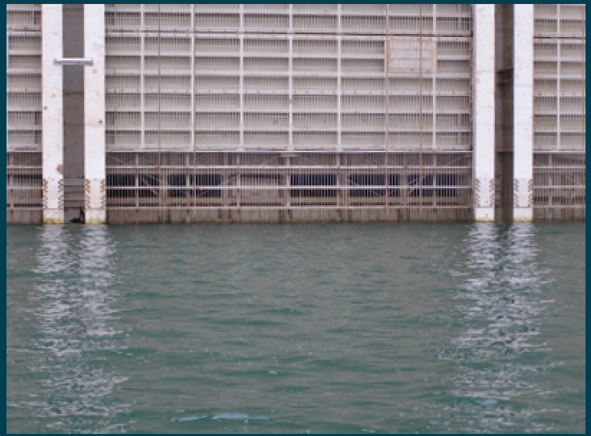
Model Features and Domain (part 5)

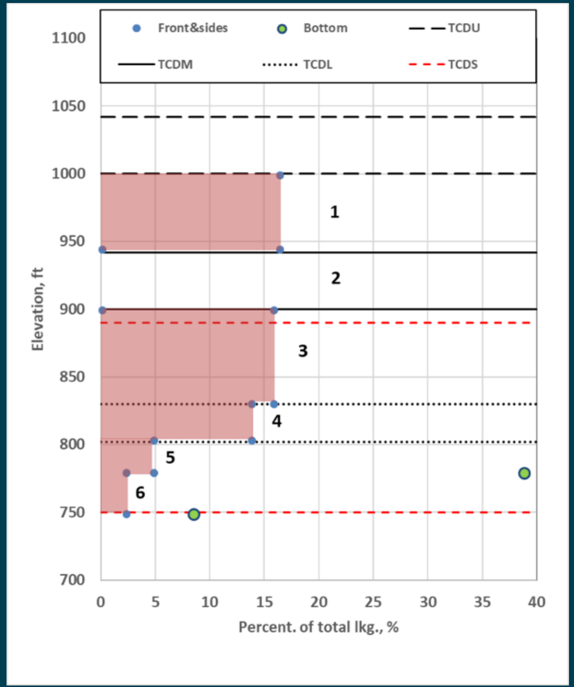
- Outlet representation
- Point sink
  - No vertical dimension
  - No lateral dimension
- Line sink
  - Series of point sinks
  - No vertical dimension
- Optimal
  - Outlet size small relative to water depth



Leakage

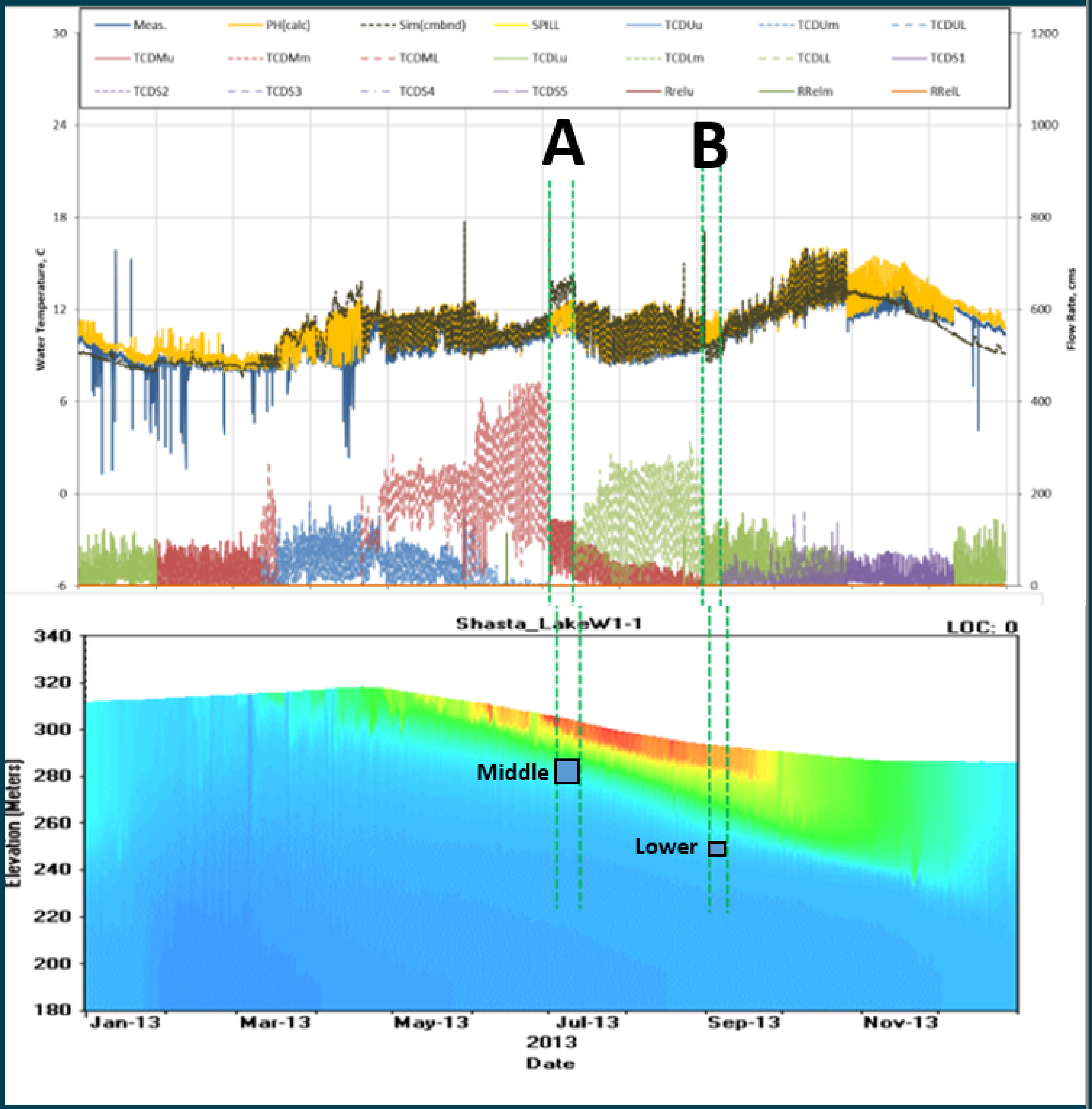
- Total leakage
  - Assumed 20%* of total outflow (full pool, gates closed)
  - As storage falls, percentage reduces
  - Not actively blended with TCD operations/gates
- Leakage zones
- Leakage repairs
  - January 2010
  - *Repairs reduce leakage area identified by USBR (1999) to about 16.1%
- Test model representation
  - Role of leakage
  - Total leakage
  - Leakage distribution





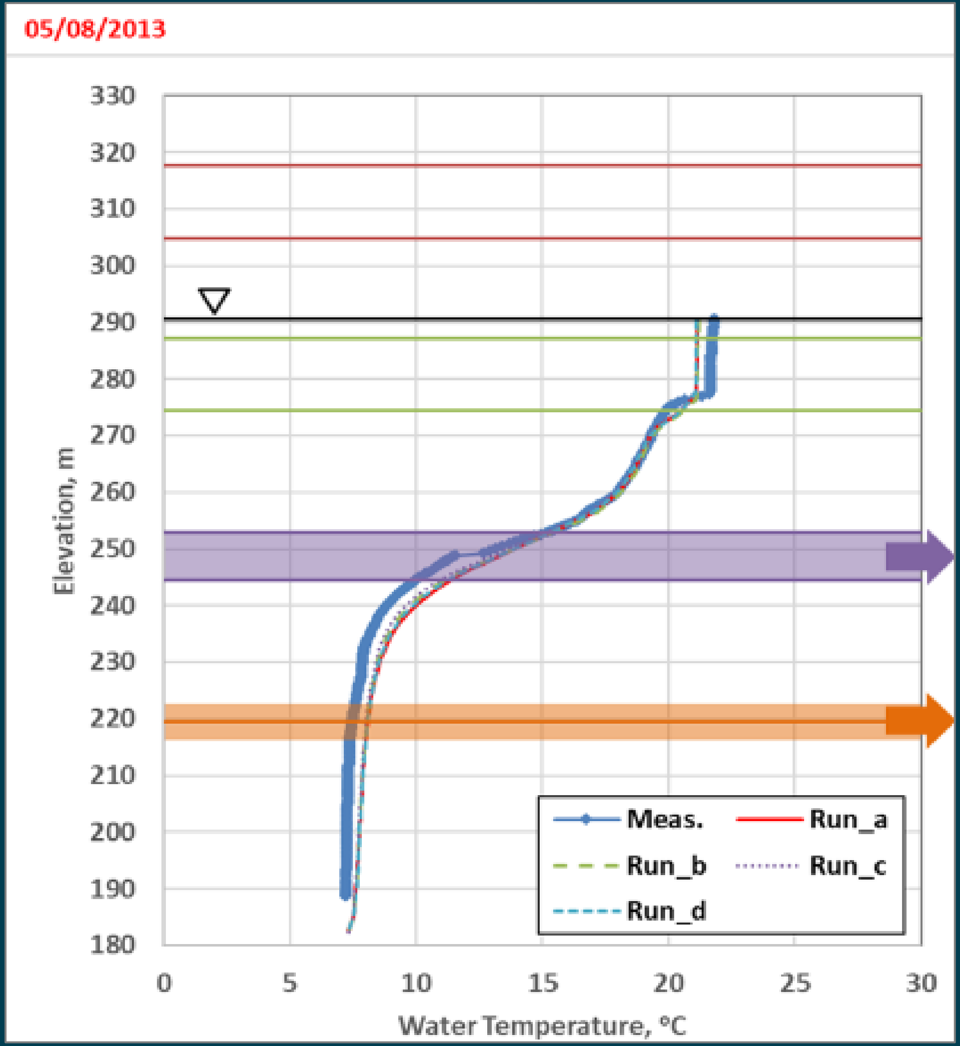
Leakage Sensitivity (part 1)

- Role of Leakage
  - Assume with and without leakage
  - Model overpredicts release temperature when middle gates only are open (“missing” deeper, cooler leakage) “A”
  - Model underpredicts release temperature when lower gates only are open (“missing” shallower, warmer leakage) “B”



Leakage Sensitivity (part 2)

- Maximum total leakage fraction
  - 5% reduction
  - Relatively insensitive
- Leakage distribution
  - Switch lower and upper distributions (zone 1 and 6)
  - Reduced leakage fraction
  - Moderately sensitive
- Result: relatively insensitive
  - Leakage only makes up a fraction of total TCD outflow
  - When a gate is open, leakage is zero from that “zone” (middle gate is used a lot, so sealing those off had less impact that a lower gate)

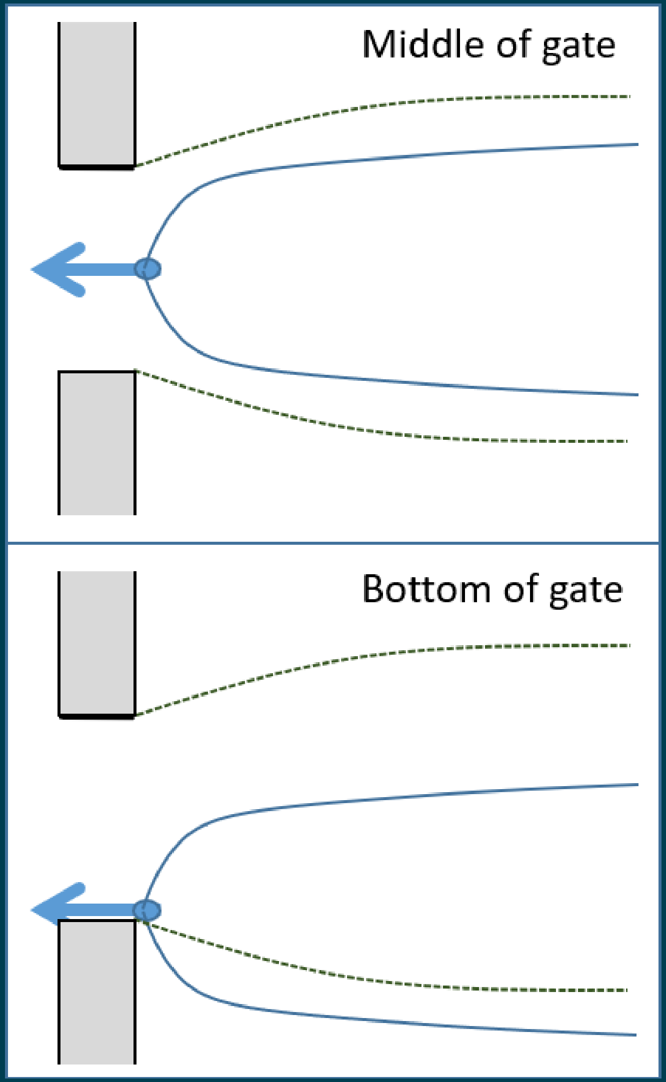


TCD Representation: Large Gates (part 1)

- Large Gates
  - Upper: 46 feet
  - Middle: 46 feet
  - Lower (PRG): 28 feet

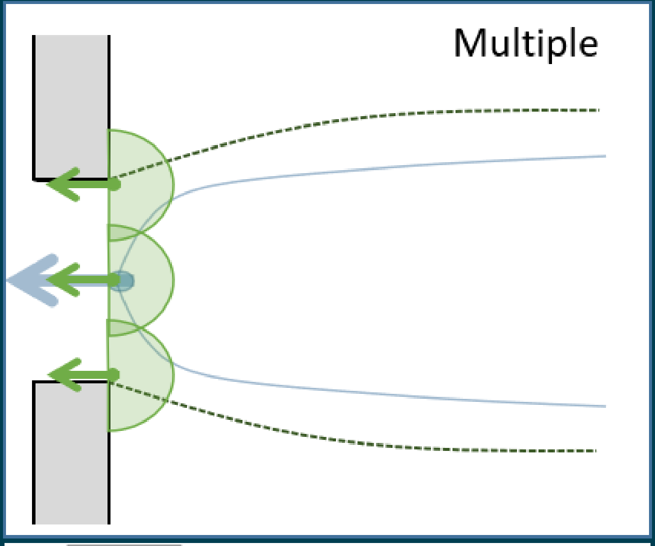
TCD Representation: Large Gates (part 2)

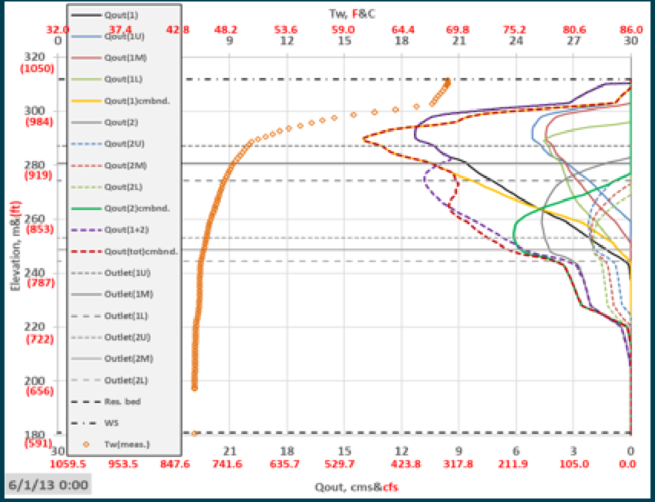
- Large Gates
  - Point sink in middle of gate
    - Simple to implement
    - Challenge:
      - When stage falls below gate, gate unavailable (1/2h)
      - Does not represent large gate opening
  - Point sink at bottom of gate
    - Simple to implement
    - Challenge:
      - Does not represent large gate opening



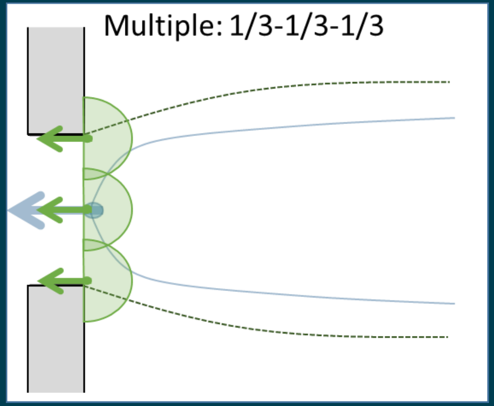
TCD Representation: Large Gates (part 3)

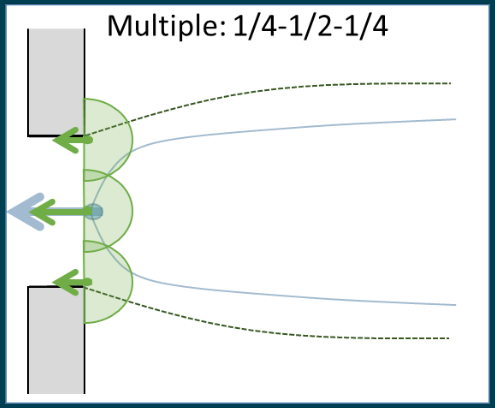
- Large Gates
  - Multiple point sinks in middle of gate
    - Simple to implement
      - Represents large gate
    - Challenge:
      - Flow distribution determination
        (e.g., 1/3-1/3-1/3)
      - Was examined analytically using point sink logic
      - Was tested through range of model applications





TCD Representation: Large Gates (part 4)

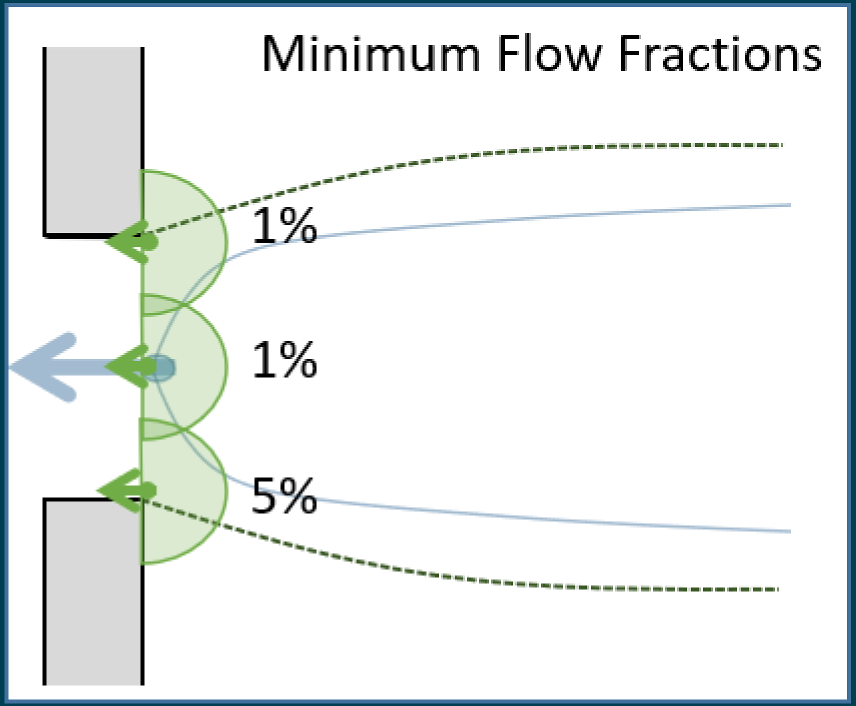




- Large Gate Representation
  - Flow distribution – three outlets
    - 1/3 – 1/3 – 1/3
    - 1/4 – 1/2 – 1/4
    - Others
  - Results did not reproduce historical temperatures (outflow/profile)
  - Dam release temperatures were at times
    - within the range of temperature across the gate opening
    - Warmer or cooler than the range of temperature across the gate opening
    - Function of season, stratification, thermocline position relative to active gates
  - Explored different approach than fixed distributions

TCD Representation: Large Gates (part 5)

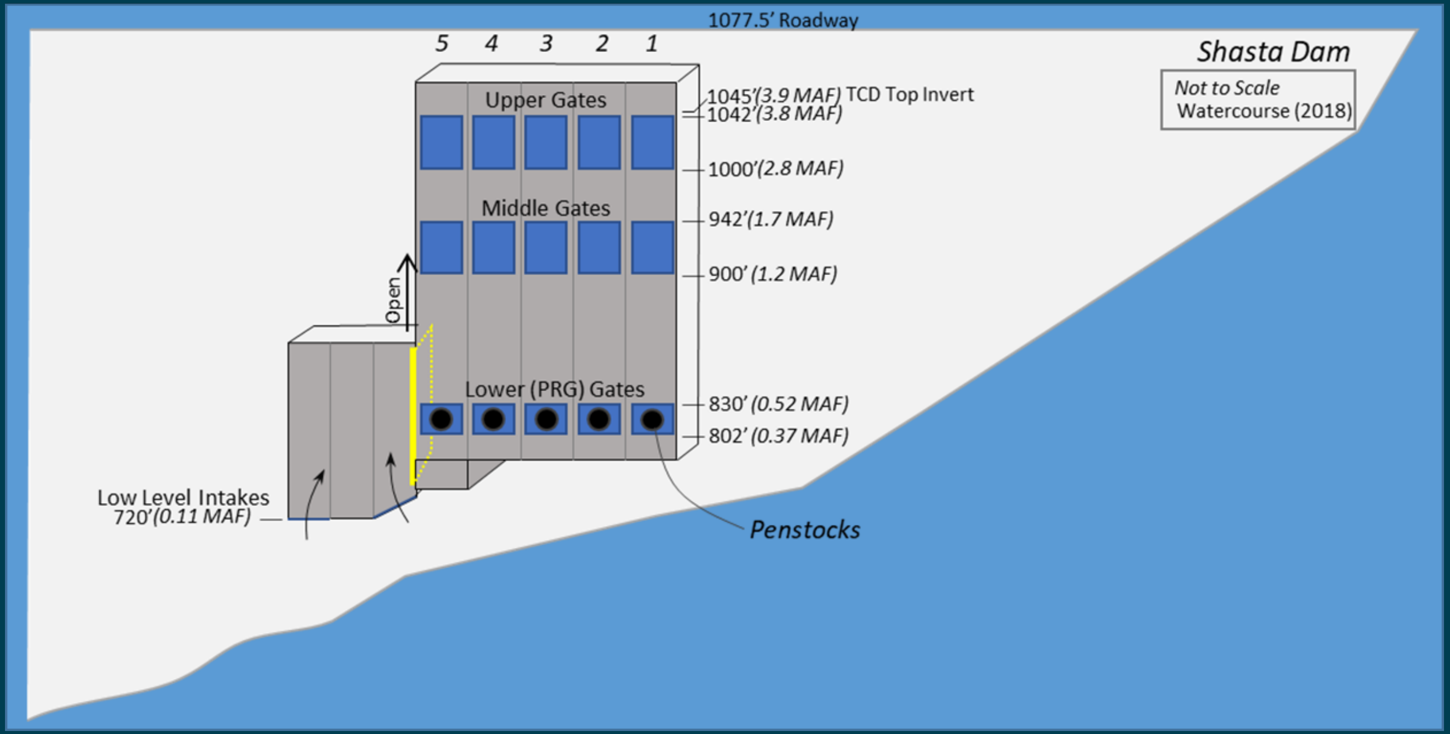
- Minimum Flow Fractions
  - Assign a percentage through each gate
    - Can assign for each point sink
    - Assigned as a non-blending flow
  - Let model select assignment for remaining flow through gate
  - Conserve USGS Rule: all through one or two adjacent gates
- Effectively reproduced profiles and release temperatures*



* With exception of certain conditions under sidegate operations (addressed below)

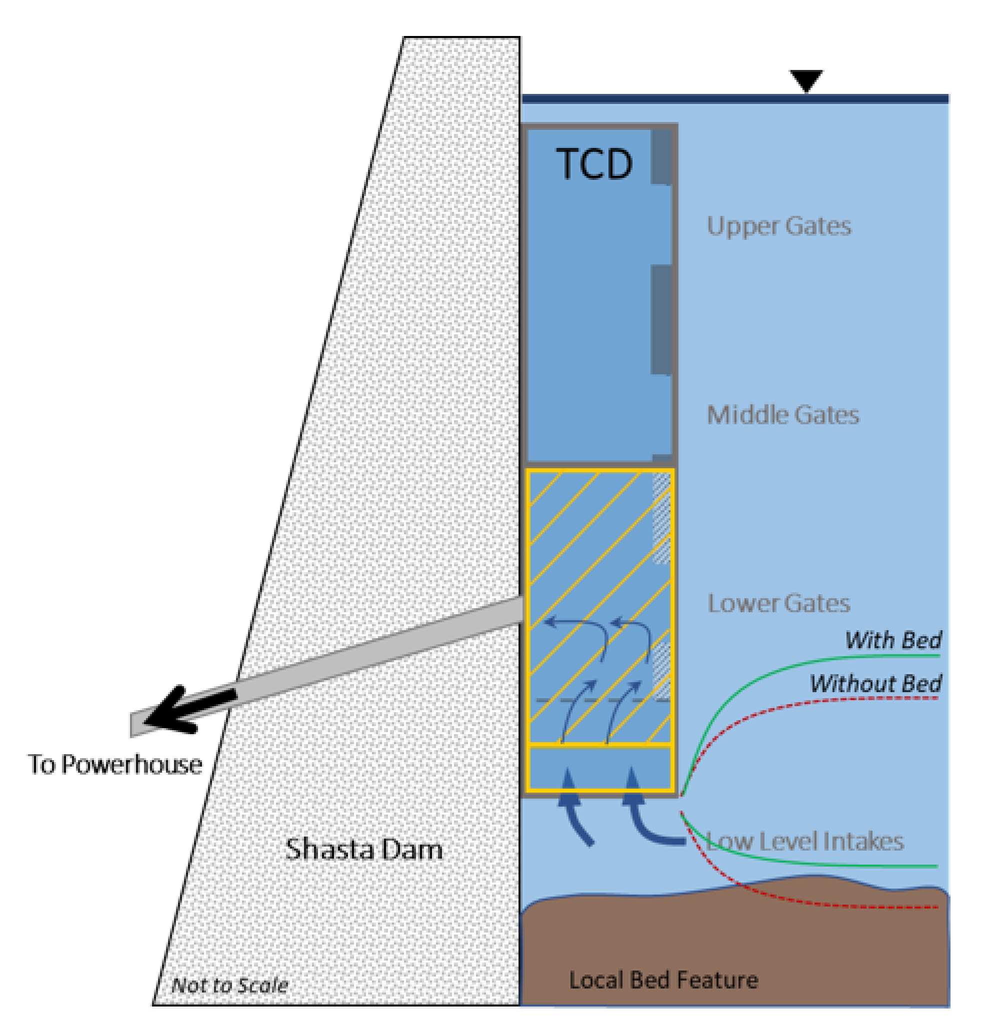
TCD Representation: Side Gate (part 1)

- Low level intakes accessed through side gate (a gate in the side of the TCD that connects the main unit with the low-level intake unit)
- Two gates (side-by-side)
- Vertical flow upwards into TCD
- Invert: 720 ft
- Storage: 110,000 AF
- Proximity of bed is a design consideration



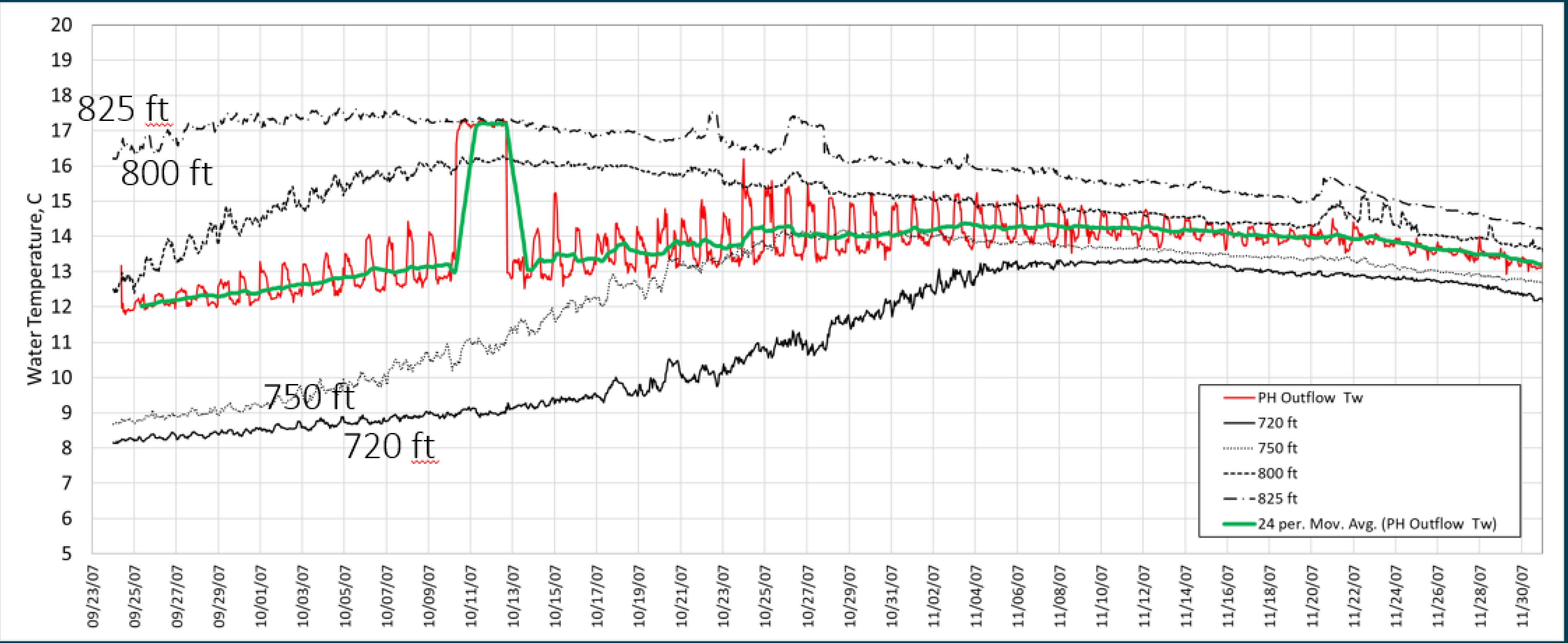
TCD Representation: Side Gate (part 2)

- Field data suggest waters are drawn from above and below the 720 ft invert elevation of the side gate
- Use model to assess performance using:
  - Dam release temperatures
  - In-reservoir profiles



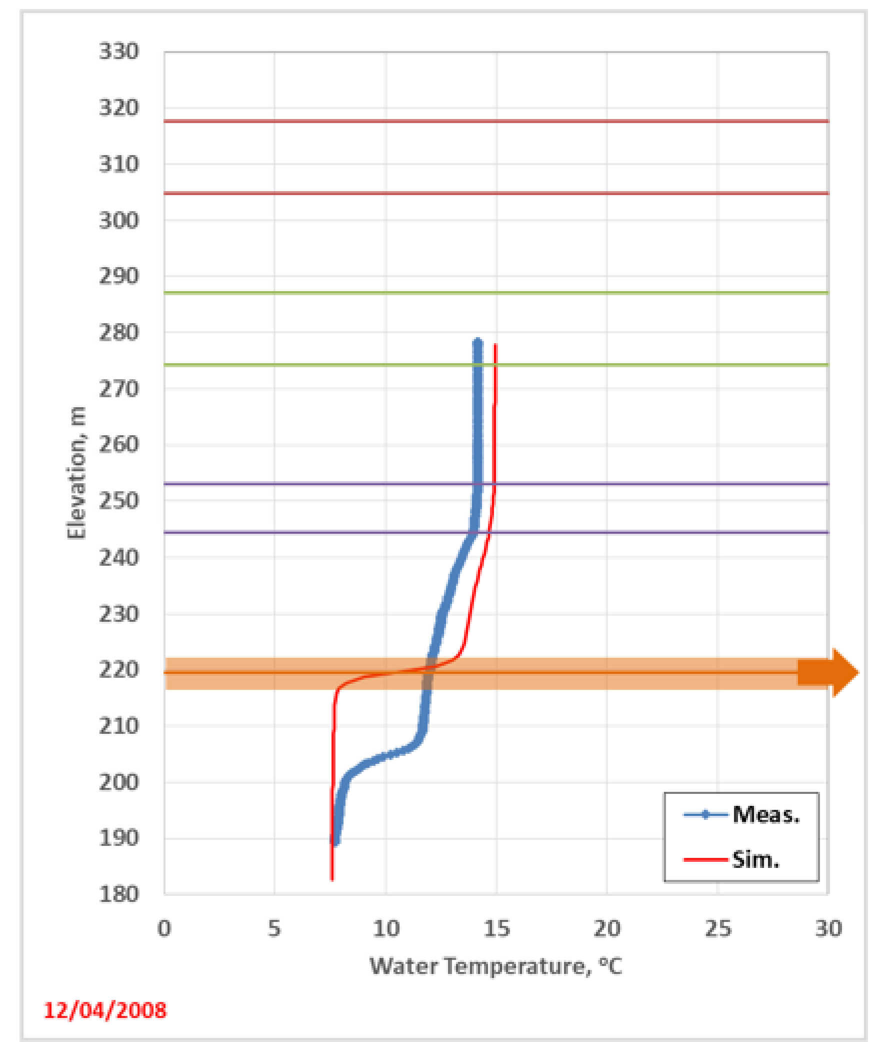
TCD Representation: Side Gate (part 3)

- Dam release temperatures
  - Higher than side gate elevation temperatures



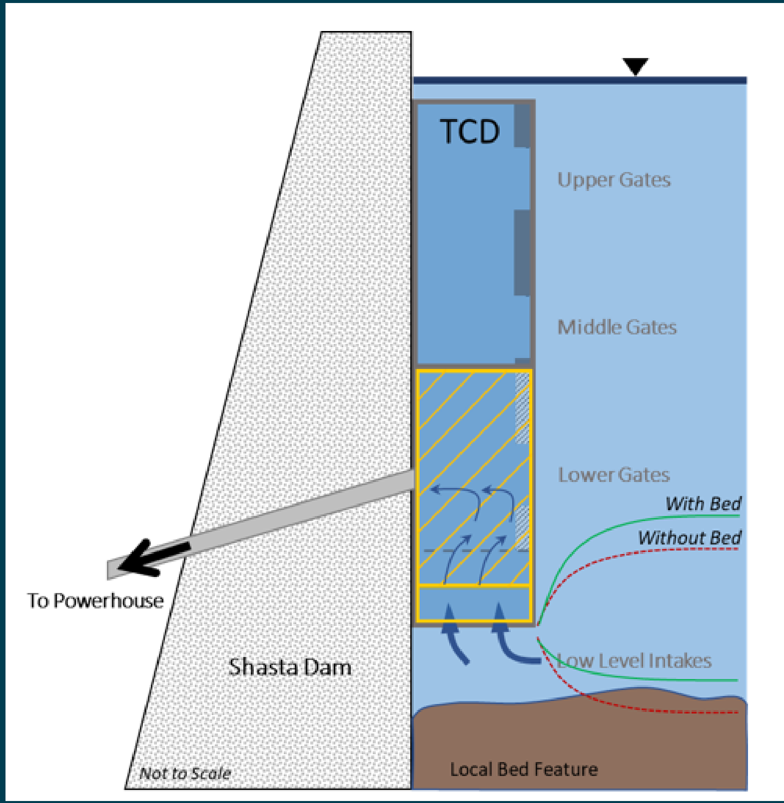
TCD Representation: Side Gate (part 4)

- Simulated profile temperatures
  - Lower than measured temperatures at and below side gate
- Multiple factors impact withdrawal zone for side gate
  - Thermal structure and location and strength of stratification
  - Vertical withdrawal
  - Operations
  - Reservoir morphology and proximity of bed



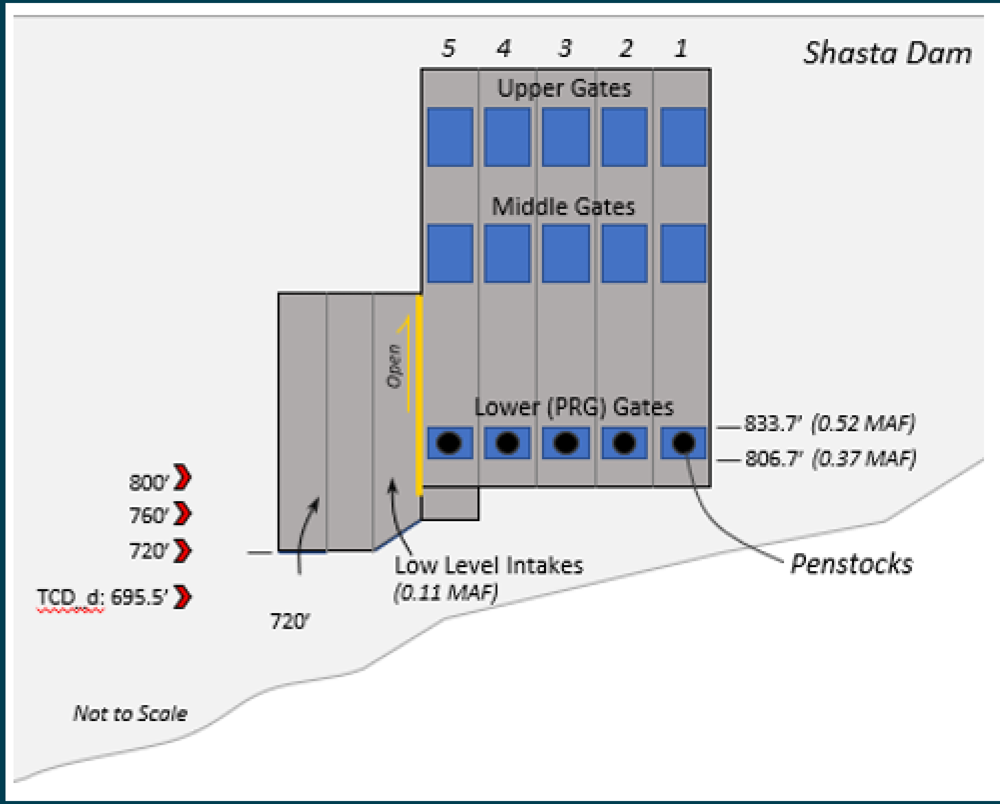
TCD Representation: Side Gate (part 5)

- Examined conditions when TCD is only utilizing low level intake via side gates
- Point sink
  - Challenges
    - Vertical draw at side gate
    - Boundary of reservoir
  - Single point sink (ineffective)
  - Multiple point sink



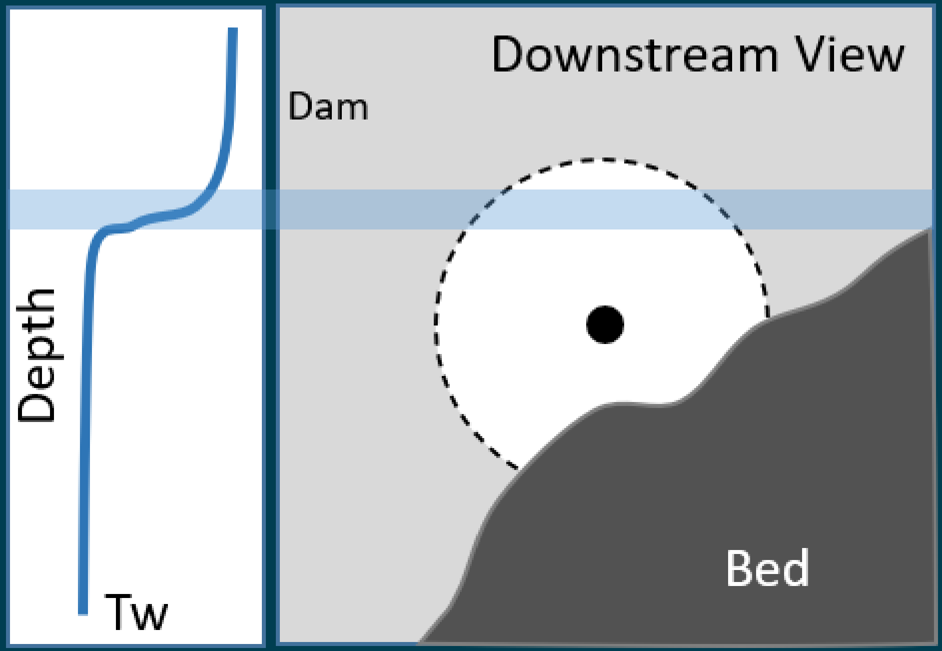
TCD Representation: Side Gate (part 6)

- Multiple point sink
  - 720 ft: to capture water at 720 ft
  - 760 and 800 ft: to capture water above sidegate invert (outflow temperature)
  - 695.5 ft: to capture water below sidegate invert (profile temperature)
- Leakage (TCD main and sidegate structure)



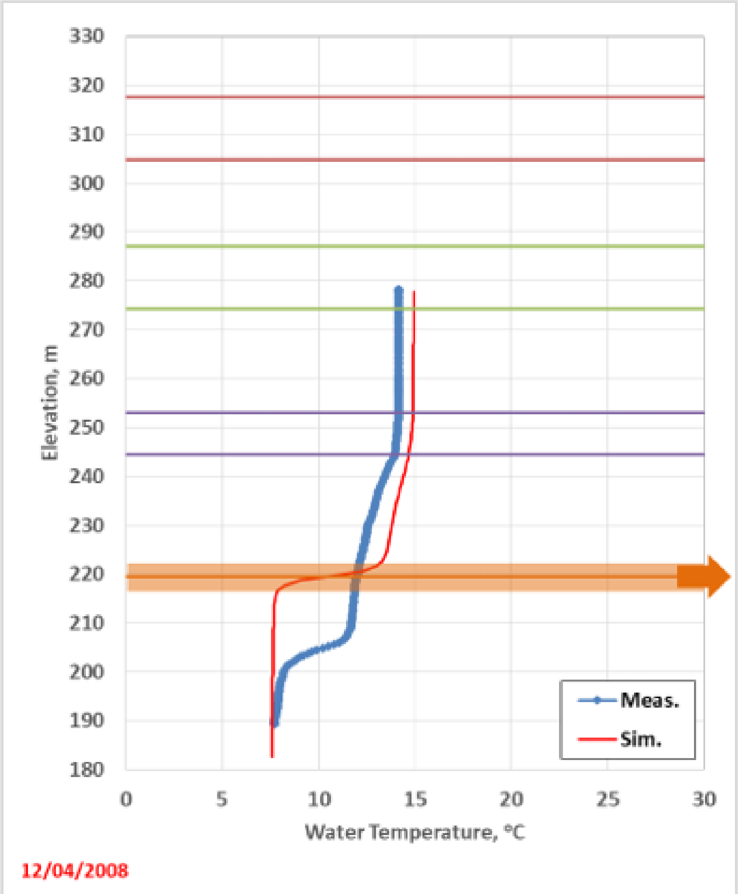
TCD Representation: Side Gate (part 7)

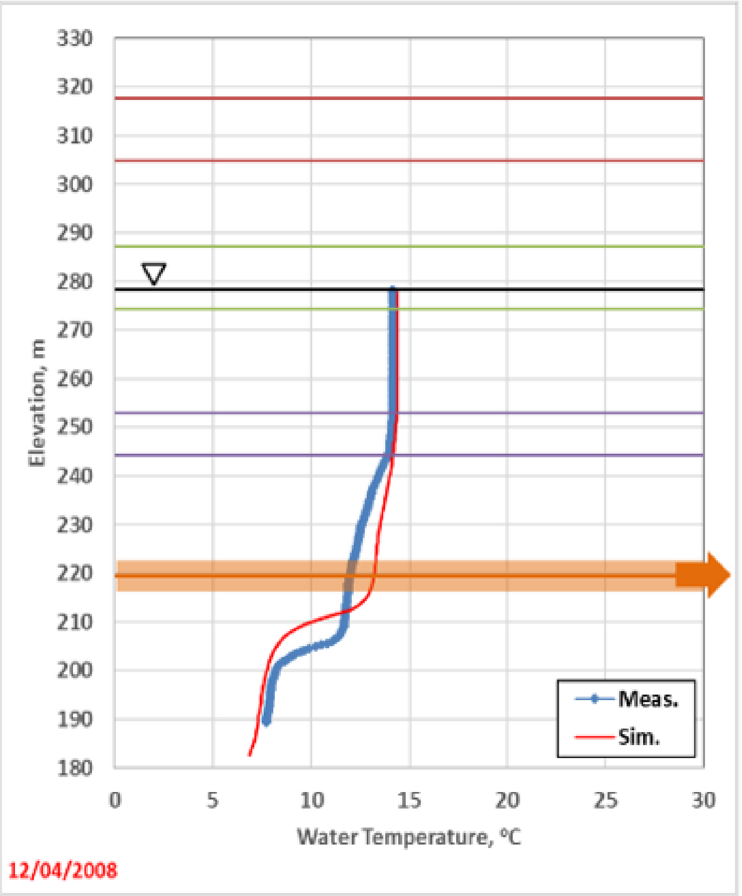
- TCD-down
  - Vertical draw
  - Proximity to bed
  - Stratification
    - Remaining cold water pool
    - High thermal gradient
  - Converging section
- Constrain withdrawal envelop
  - Deviation from theoretical point sink
- Use model to test configurations against field data



TCD Representation: Side Gate (part 8)

- TCD-down
  - Elevation 695.5 ft
  - 35% assigned to outflow TCD_down
  - Alone or in conjunction with another gate
- Effectively reproduces conditions 2000-2021



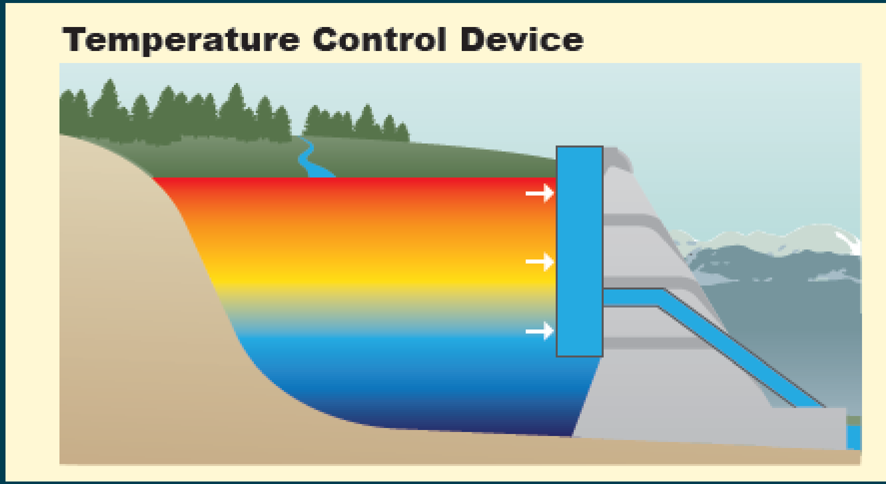


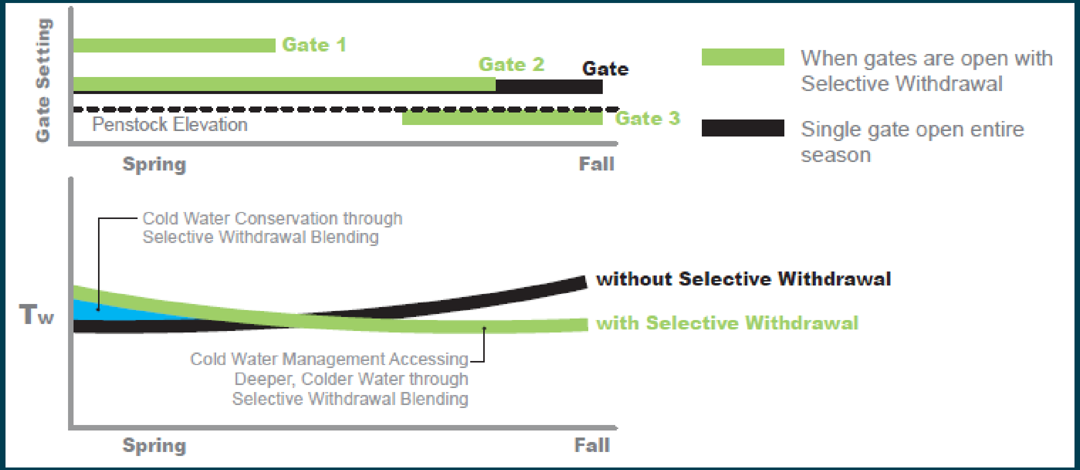
TCD Representation: Side Gate (part 9)

- Ongoing work
  - Recognize limitation of parameterizing model to represent TCD
  - ADCP surveys
    - Proof of concept 2019, 2021
    - Delta Stewardship Council grant 2022-2024
  - Completed bathymetric mapping
  - Ongoing ADCP work to ascertain
    - Side gate dynamics
    - Local hydrodynamics in conjunction with thermal profiles in vicinity of TCD
    - Flow into TCD
    - Potential lateral variability at PRG and other gates (hydropower production, reservoir boundaries)

TCD Representation: Selective Withdrawal (part 1)

- Selective withdrawal
  - Purpose: model tailbay water temperatures to meet downstream temperature management actions throughout the temperature management season (May-Oct)
  - Recall tailbay temperature target (last point of "active" management)
- Select waters from the reservoir to:
  - Meet downstream temperature management actions
  - Manage cold water pool throughout temperature management season
  - Conservation action
  - Adapt





TCD Representation: Selective Withdrawal (part 2)

- Models: Selective withdrawal
  - CE-QUAL-W2
    - Point sink
    - No SW logic (outflow pre-defined by user)
  - CE-QUAL-W2: USGS Modification
    - Point sink
    - SW logic
  - ResSim can replicate W2

TCD Representation: Selective Withdrawal (part 3)

- USGS SW Logic*
- Pros:
  - Effective for re-creating historic or hypothetical withdrawal
  - Blends gate flows during pre-defined blending periods
  - Several blending periods may be defined
  - Gate combinations (groups) are prioritized
  - Any combination of gates may be blended
  - Allows minimum head and flow-fraction criteria
  - Allows maximum head and flow criteria

* Rounds, S.A., and Buccola, N.L., 2015, Improved algorithms in the CE–QUAL–W2 water-quality model for blending dam releases to meet downstream water-temperature targets: U.S. Geological Survey Open-File Report 2015-1027, 40 p., http://dx.doi.org/10.3133/ofr20151027.

TCD Representation: Selective Withdrawal (part 4)

- USGS SW Logic*
- Cons:
  - No forecasting ability
  - Blending periods must be pre-defined
  - Gates to blend must be pre-defined and prioritized
  - Once 2 groups of gates are selected for blending, they remain selected throughout the blending period unless elevation or head criteria are not met.
  - If target Tw cannot be met by selected gates, this method cannot search for other gate combinations to meet the target.
  - Leakage flows must be pre-calculated.

* Rounds, S.A., and Buccola, N.L., 2015, Improved algorithms in the CE–QUAL–W2 water-quality model for blending dam releases to meet downstream water-temperature targets: U.S. Geological Survey Open-File Report 2015-1027, 40 p., http://dx.doi.org/10.3133/ofr20151027.

TCD Representation: Selective Withdrawal (part 5)

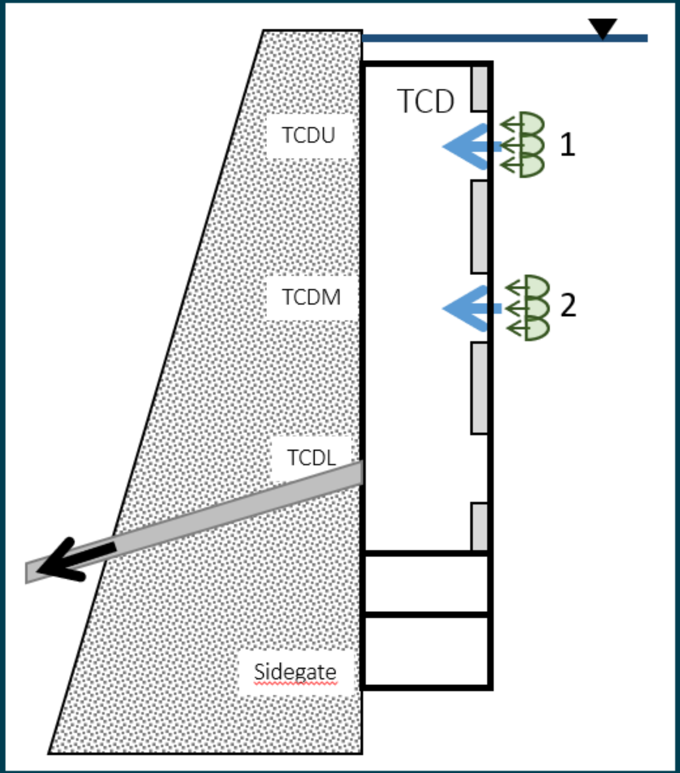
- Modified CE-QUAL-W2 selective withdrawal logic
- Objective
  - Utilize existing W2 framework
  - Take advantage of USGS SW logic approach and existing coding in W2
  - Take advantage of HEC-5Q information (automatic gate selection, forecasting, etc.)
  - Accommodate leakage, large gate representation, sidegate representation
  - Provide more user flexibility (e.g., avoid hard-wired parameters)

TCD Representation: Selective Withdrawal (part 6)

- Use W2 USGS code as basis for new gate selection methods
  - Uses USGS gate setup and blended/non-blended flow logic
  - Gate elevations may be changed in input file
  - Leakage may be specified or calculated by model
- Specifically simulates TCD gate selection
  - Openings are grouped by TCD gates (upper, middle, lower, and side)
  - At each blending time, gates groupings are evaluated from top to bottom (i.e., working from the upper gate to the middle gate, middle gate to the lower gate, etc.)
- Uses a simplified iterative method for selecting gate flows (efficient)

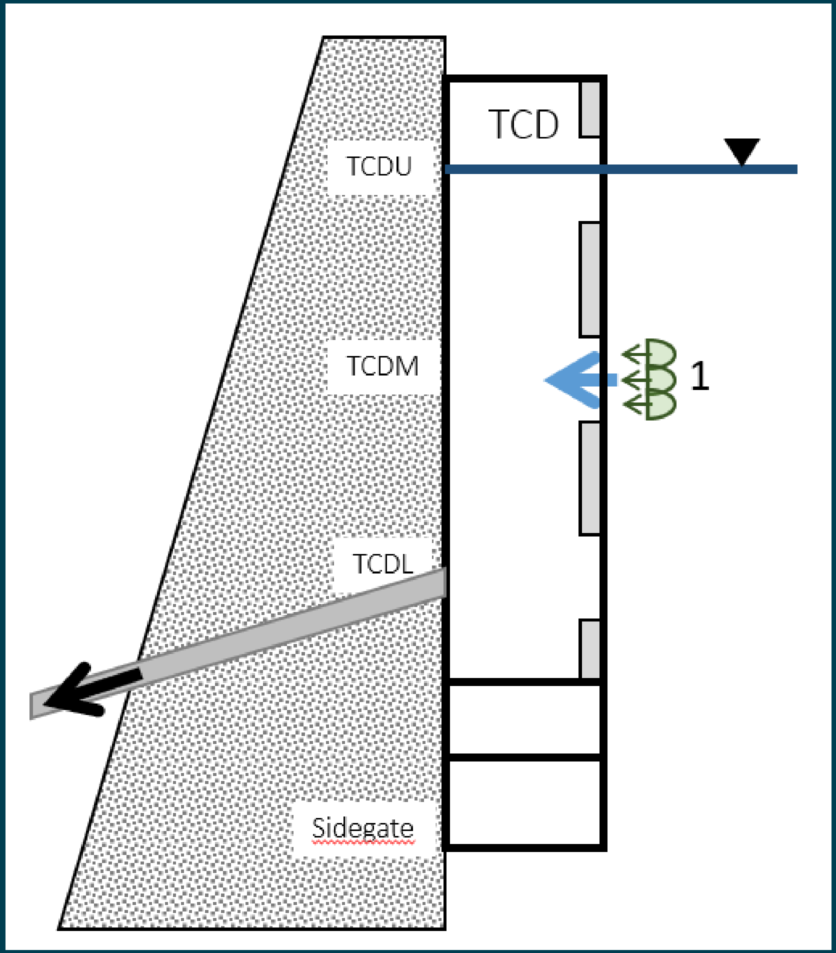
TCD Representation: Selective Withdrawal (part 7)

- Blending Progression: Example
  - Blend at Upper (TCDU) and Middle (TCDM) gate levels



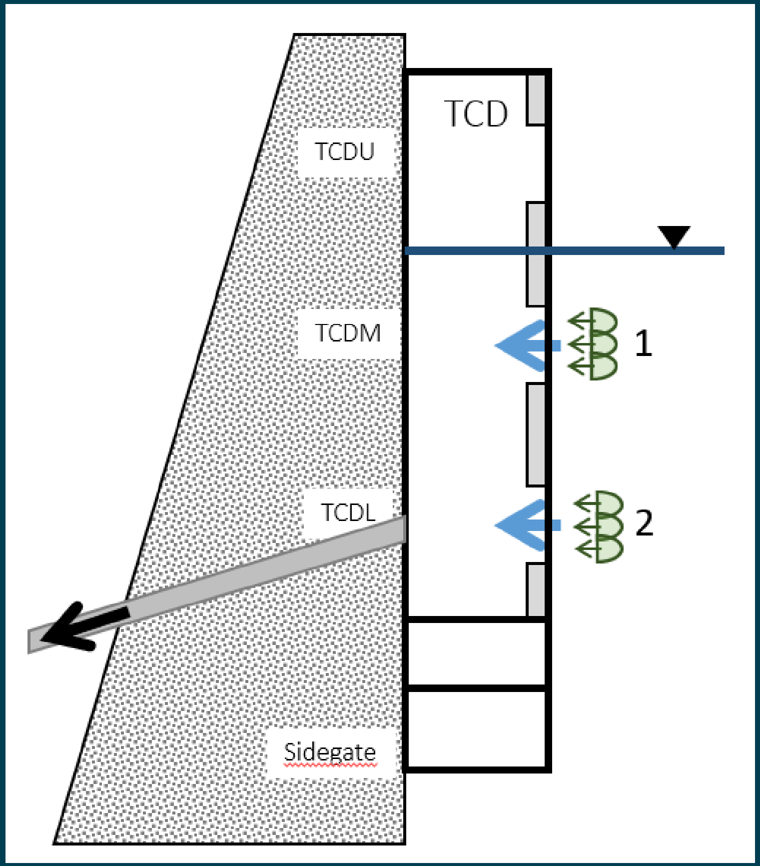
TCD Representation: Selective Withdrawal (part 8)

- Blending Progression: Example
  - TCDM only



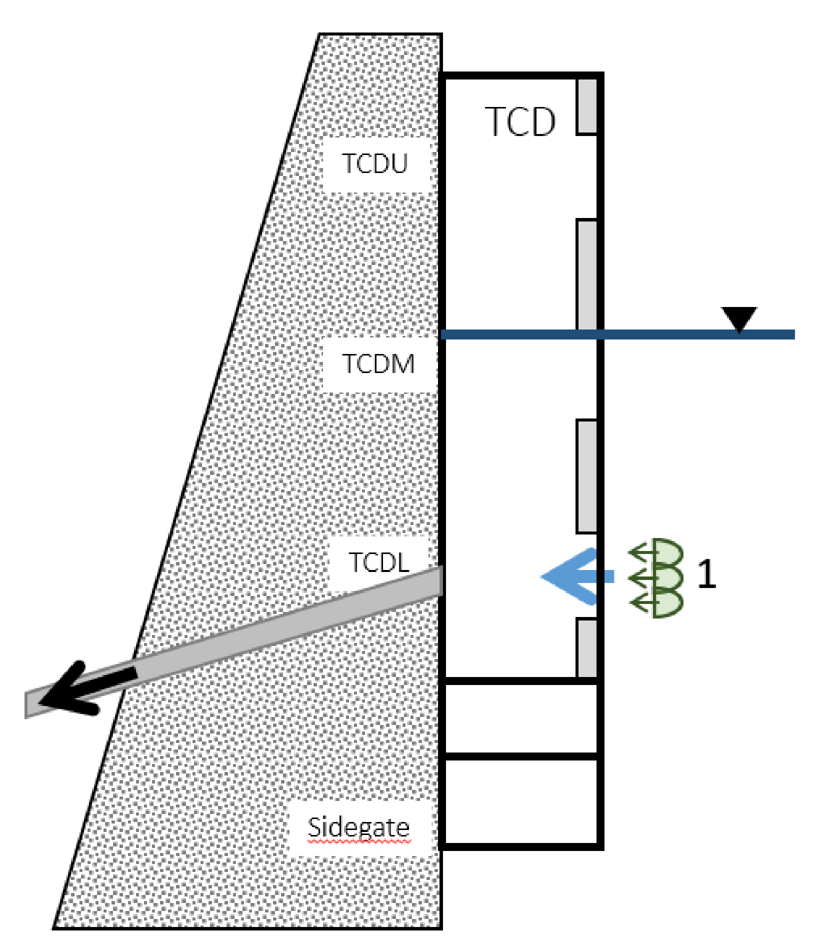
TCD Representation: Selective Withdrawal (part 9)

- Blending Progression: Example
  - Blend at Middle (TCDM) and Lower (TCDL) gate levels



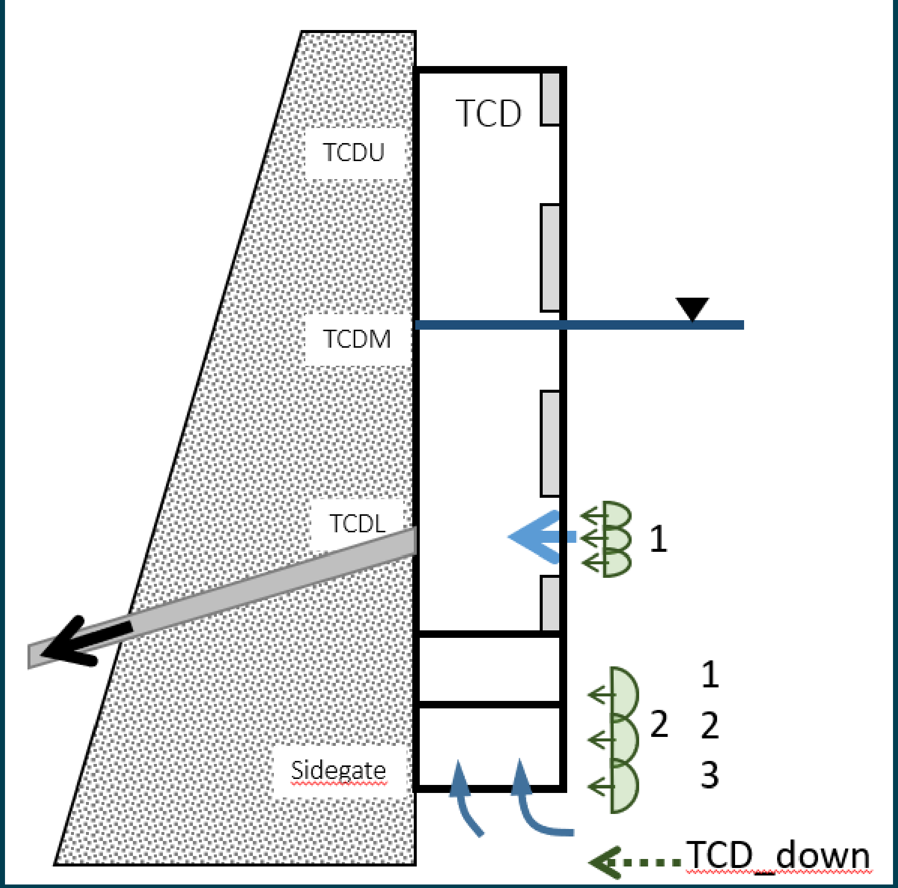
TCD Representation: Selective Withdrawal (part 10)

- Blending Progression: Example
  - TCDL only



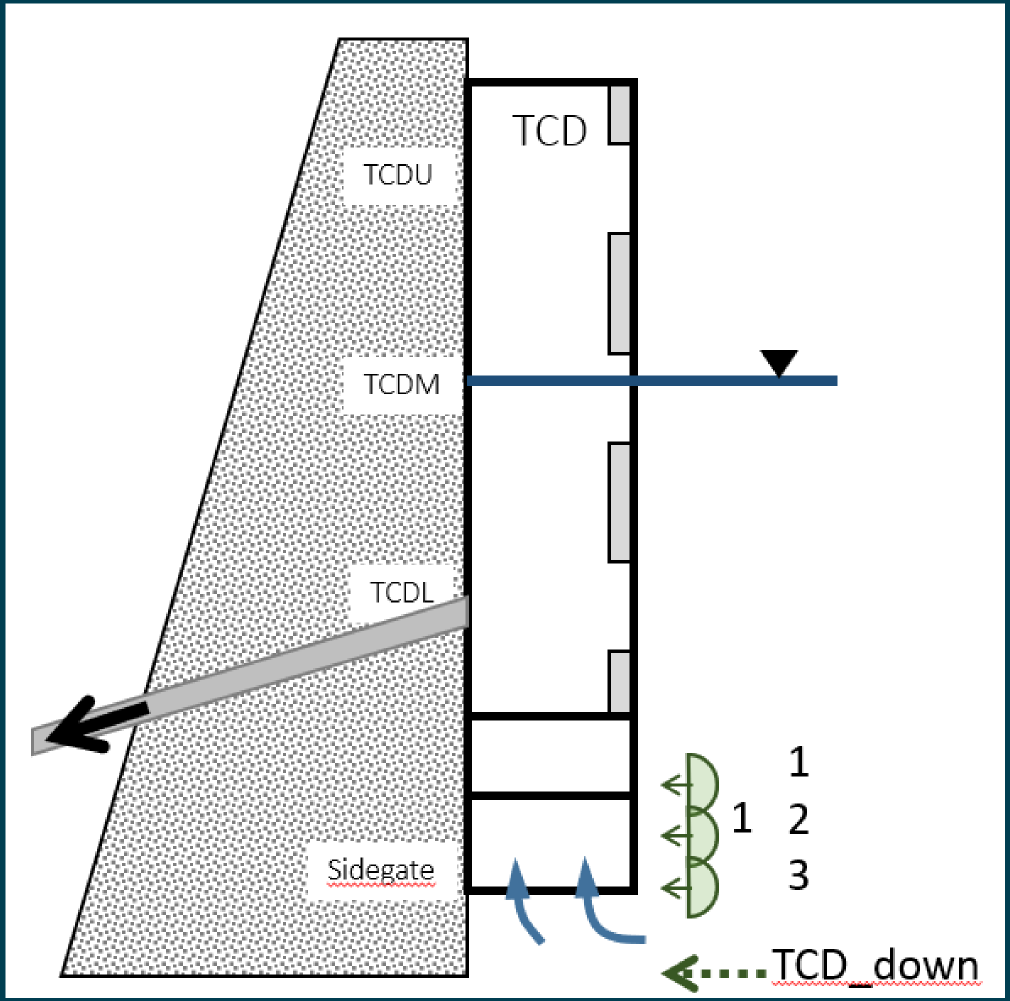
TCD Representation: Selective Withdrawal (part 11)

- Blending Progression: Example
  - Blend at Lower (TCDL) and sidegate levels
  - Include TCD_down



TCD Representation: Selective Withdrawal (part 12)

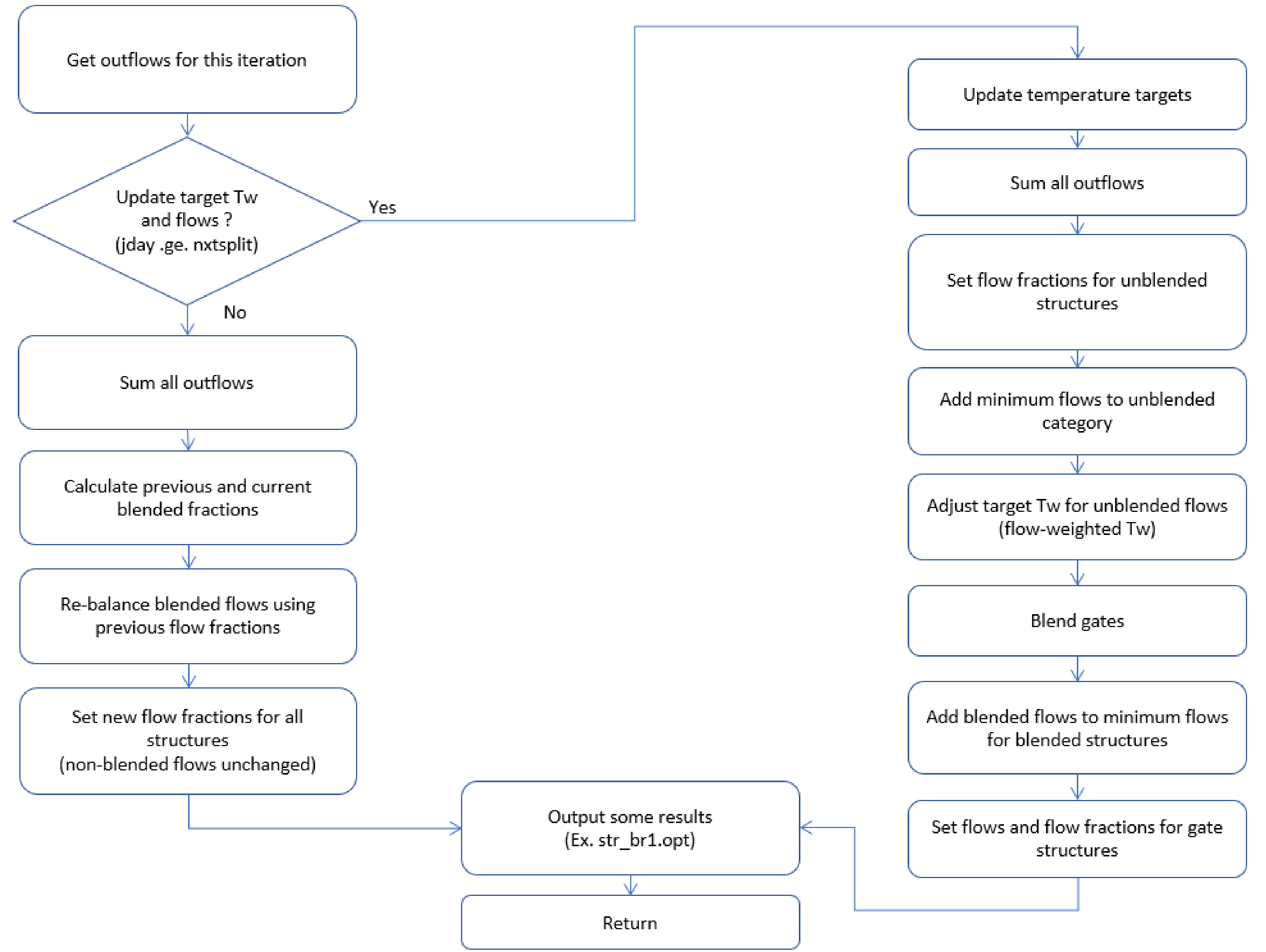
- Blending Progression: Example
  - Sidegate only
  - Include TCD_down



TCD Representation: Selective Withdrawal (part 13)

- Key elements
  - Blends to meet user prescribed tailbay temperature (target)
  - Always maintain minimum flow fractions
  - One point sink can be used
  - If two-point sinks are used; they must be adjacent point sinks
  - Two adjacent point sinks can be
    - Within a single gate level (e.g., top and middle, middle and bottom)
    - Shared among two gate levels (e.g., bottom of higher gate and top of lower gate)
  - When side gate is used TCD_down is automatically used
  - Can use in prescribed or forecast mode

Blending Logic



TCD Representation: Selective Withdrawal (part 14)

- Limitations
  - Field data confirmation
  - Three-point sinks (vs 4, 5, 10 or other representation)
  - Point sink progression (within and between gates) is a proxy and may not always represent in-reservoir thermal progression in response to initial storage, seasonal thermal loading, operations, powerhouse use, other factors

TCD Representation: Selective Withdrawal (part 15)

- Refinements
  - Exploring seasonal gate operational constraints (forecasting)
  - Gate combinations/progression rules (gate switches) (forecasting)
  - User flexibility
  - Ongoing model performance assessment
  - Incorporate UC Davis studies

TCD Representation: Summary

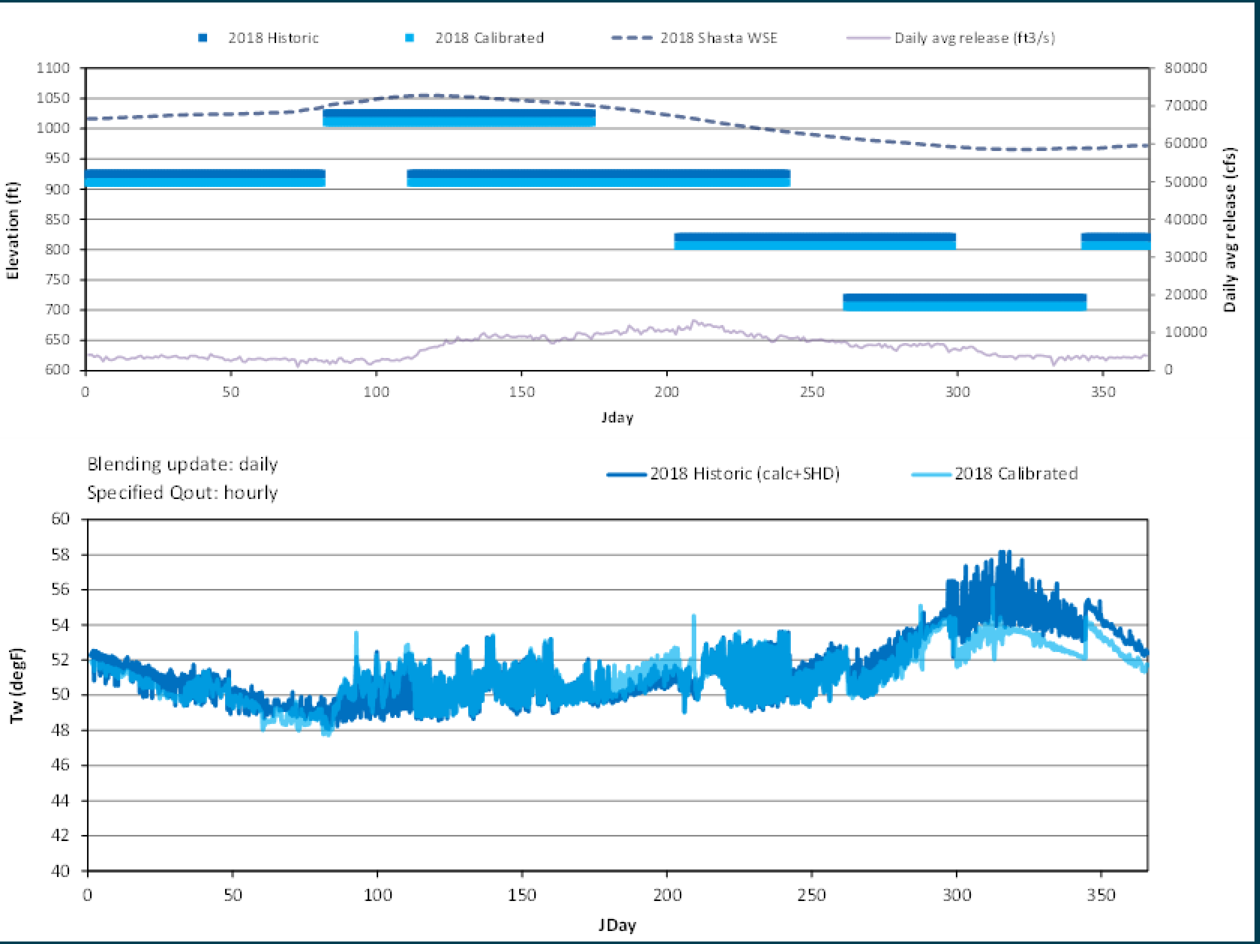
- Leakage
  - Incorporated (not in the management blend)
- Large Gates
  - Three-point sinks
- Side Gate
  - Waters drawn from above and below
  - Accommodate proximity to bed with TCD_down
- Selective withdrawal
  - Develop specific logic to track tailbay temperatures
  - Appendix C (Watercourse 2020)

TCD Representation: Forecasting Overview

- Features
  - Leakage
  - Large gates
  - Side gates
  - Selective withdrawal
    - “Rules” to guide model
      - Basic gate operations
    - Frequency of testing for temperature release
      - Model (any time step, e.g., 1-hour)
      - Actual operation (on the order of days, weeks)

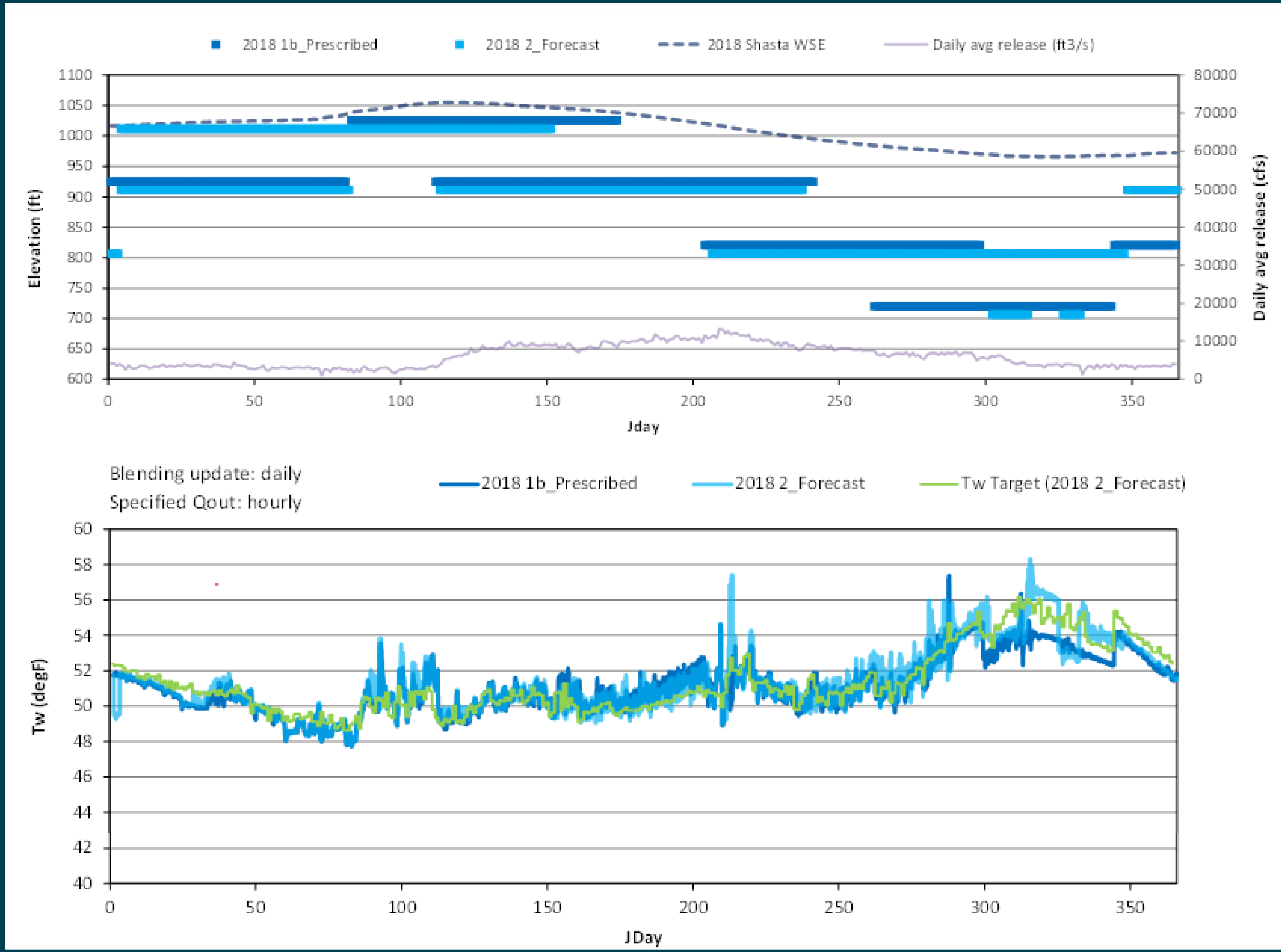
TCD Representation: Forecasting (Historical)

- Historic (Calibration)



TCD Representation: Forecasting

- Forecast



Discussion

Photo credit: John Hannon, Reclamation

Wrap Up and Next Steps

Randi Field, CVO

Yung-Hsin Sun, PhD, PE, Stantec

Next Steps

- Report back to MTC
- Engage this subgroup as needed.
- Complete the modeling development and initiate Phase II activities

Upcoming MTC and Topics

- Next MTC Meeting: October 6, 2022; 1:00 p.m. – 4:00 p.m.
- Upcoming topics:
  - Model development topics
    - Sacramento/Trinity River Water Temperature Model
    - American River Water Temperature Model
    - Stanislaus River Water Temperature Model
- You have the registration links for all remaining meetings already in previous MTC agenda – do it today.

NEXT MTC MEETING: October 6, 2022; 1 p.m.–4 p.m.

BUREAU OF RECLAMATION