Credit: USACE

Developing CE-QUAL-W2 Models of Koocanusa Reservoir and the Kootenai River, Montana and Idaho

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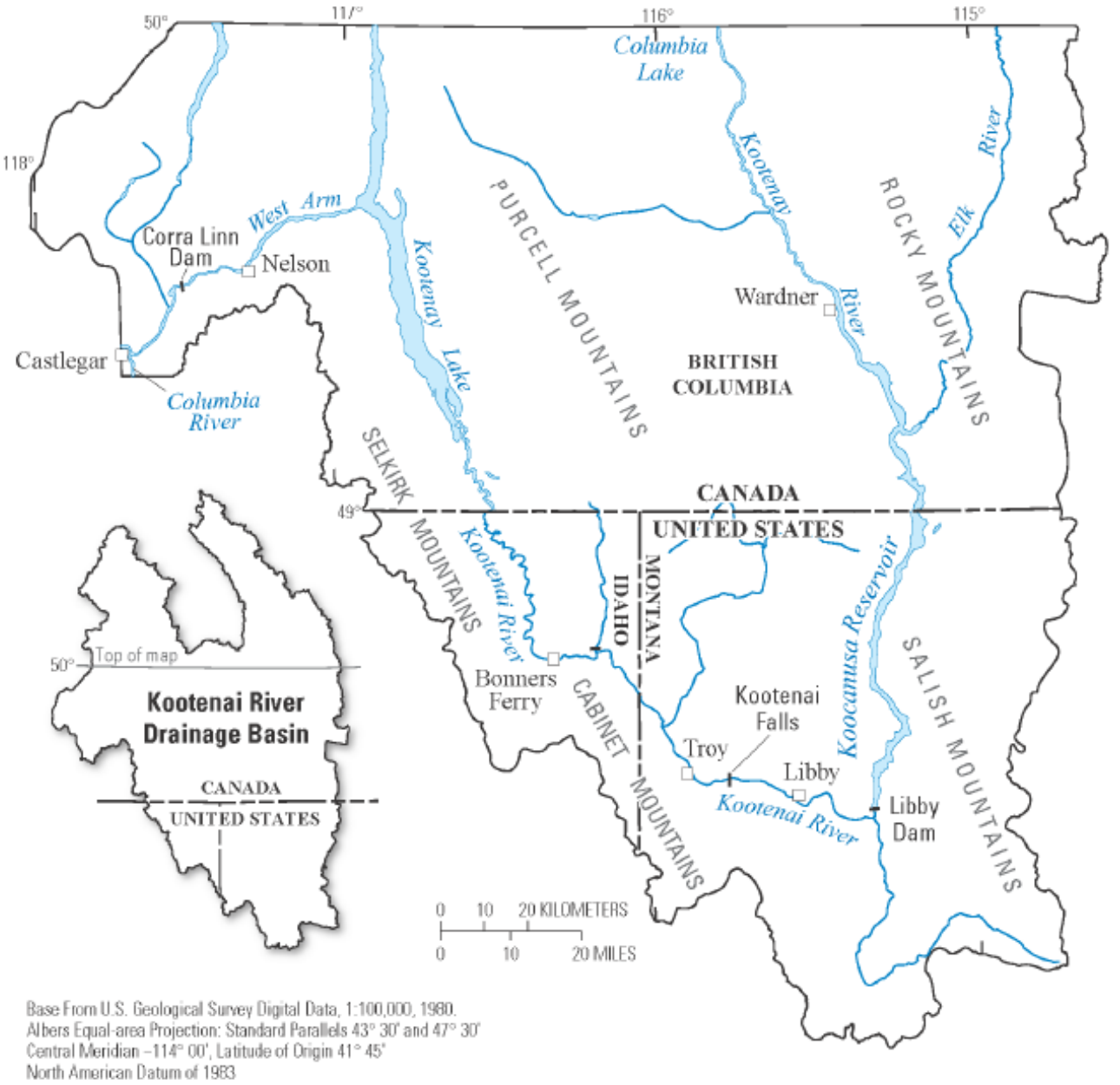
USGS science for a changing world

Project Overview

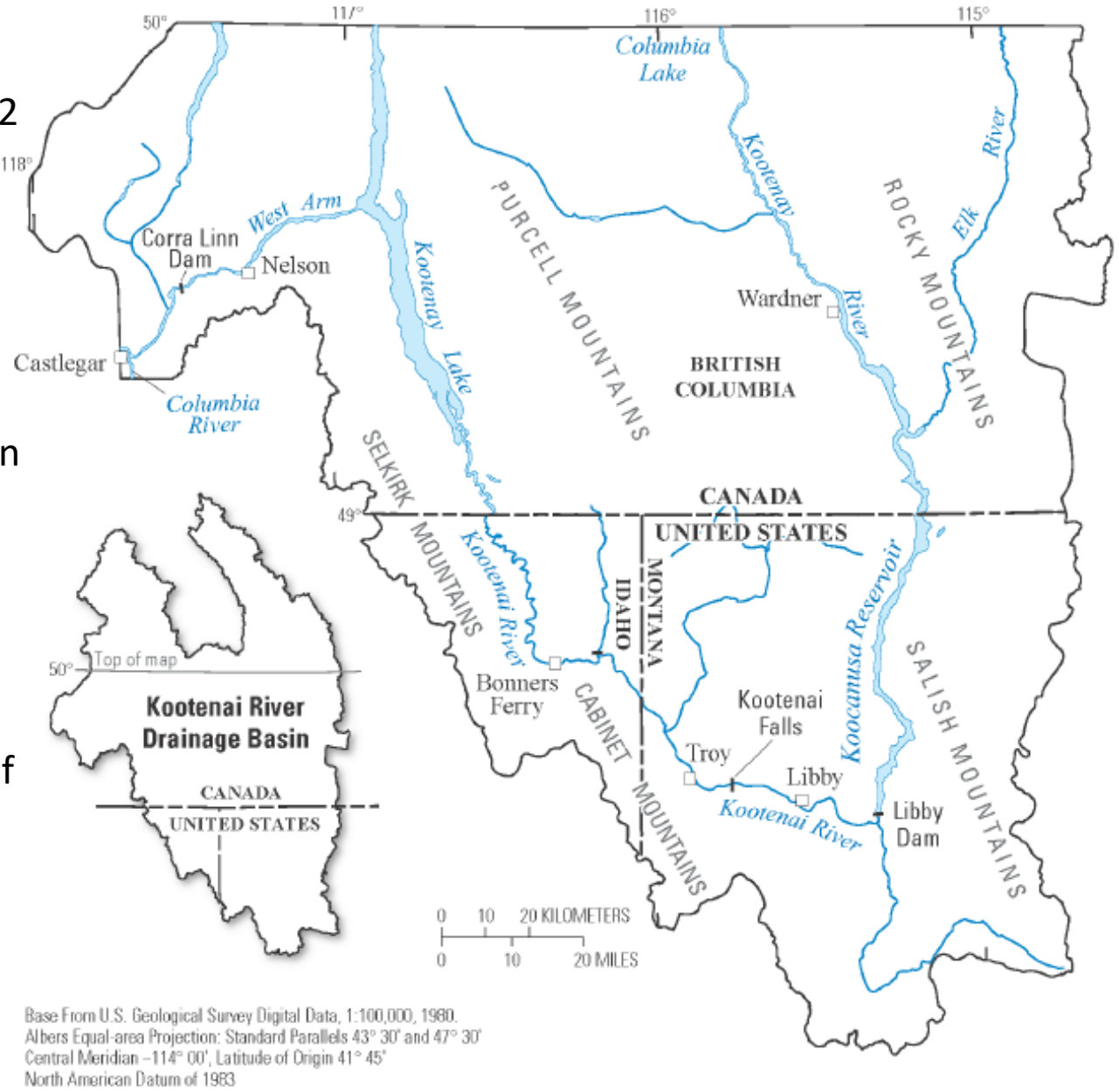
- Goal to develop CE-QUAL-W2 model of Koocanusa Reservoir and Kootenai River from Libby Dam to the International Boundary
- USACE wants to evaluate water quality impacts of future operational changes on reservoir thermal properties, constituent transport, and productivity and trophic state, which will impact downstream temperature and nutrient loadings in the Kootenai River
- Joint study between USGS Oregon, Idaho, and Wyoming-Montana Water Science Centers in cooperation with US Army Corps of Engineers



Adapted from Fosness and Williams 2009

Project Overview

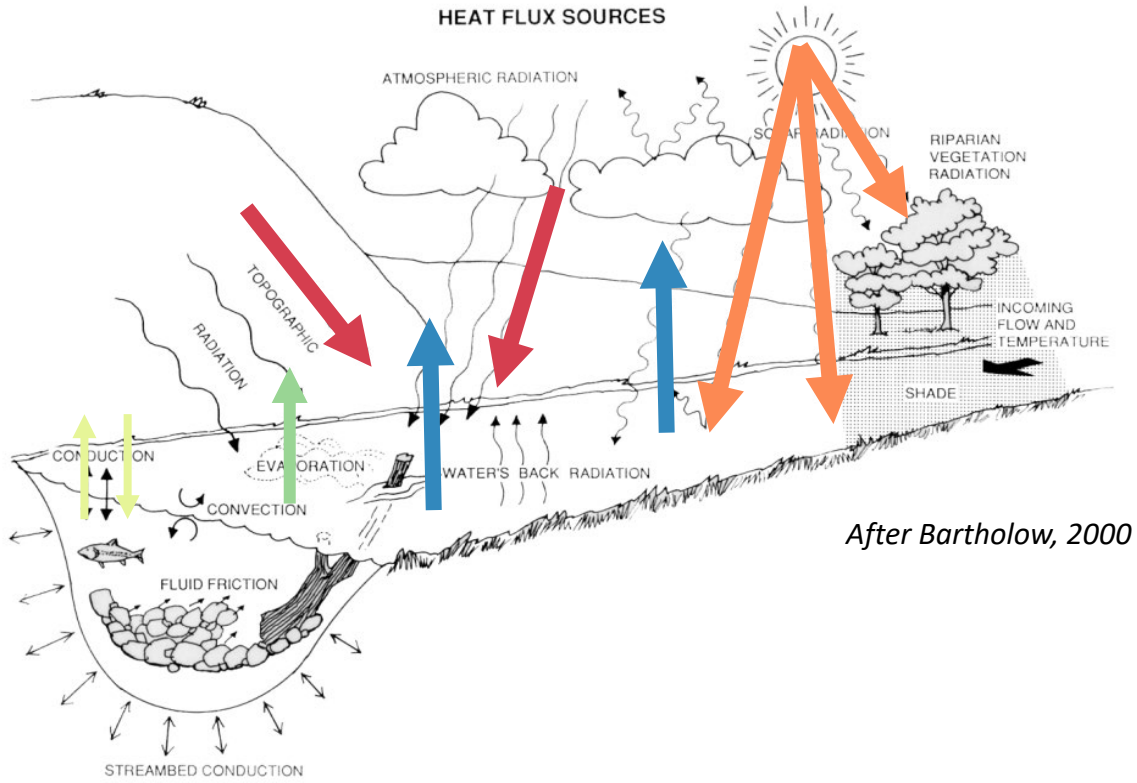
- Model domain includes multiple, independent CE-QUAL-W2 sub-models:
  - Koocanusa Reservoir model
  - Kootenai River model
- Scope will be fulfilled in phased approach:
  - First phase is initial model development and calibration of hydrodynamics and water temperature
  - Second phase *may* address a range of water quality parameters including algal communities and nitrate loading
  - Third phase *may* address selenium transport/fate
- 5 modeled time periods selected to address a wide range of hydrometeorological and operational conditions



Adapted from Fosness and Williams 2009

CE-QUAL-W2

- CE-QUAL-W2 is a reach-scale 2D mechanistic hydrodynamic and water quality model with full heat budget
- Developed by US Army Corps of Engineers and Portland State University with additional USGS modifications; long history of river and reservoir applications
    - See PSU website for list of projects: www.ce.pdx.edu/w2/
- Model capabilities include flow, temperature, water quality:



After Bartholow, 2000

TDS	Phosphorus	Organic matter	Macrophytes
Susp. sediments	Sedimentary OM	CBOD	Mercury
Generic tracers	Silica	DO	Ice cover
Age tracers	Iron	Alkalinity	Dynamic shading
Heat tracers	TDG	Inorganic carbon	
Ammonia	Phytoplankton	pH	
Nitrate	Epiphyton	Zooplankton	

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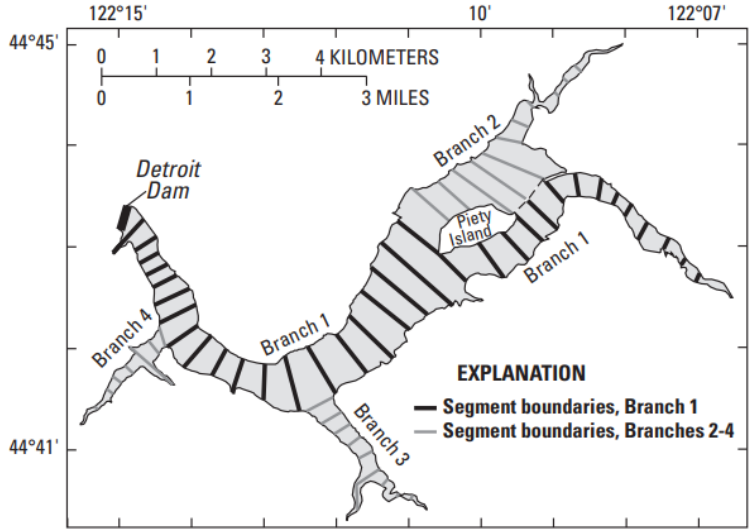
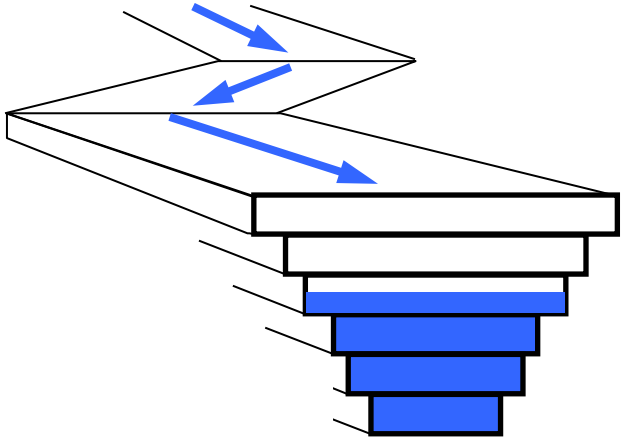
CE-QUAL-W2

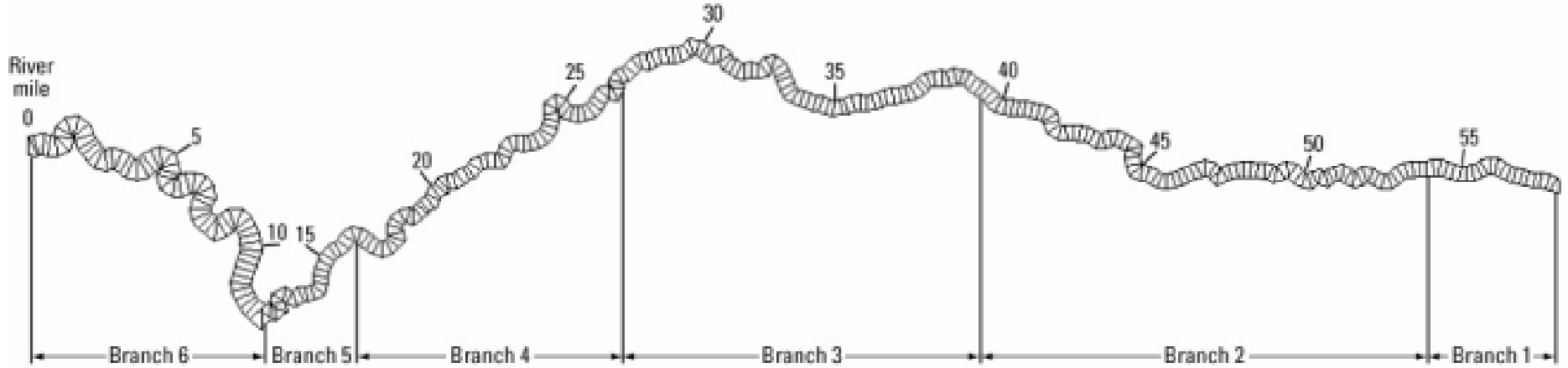
- Designed for long, narrow water bodies that stratify
  - Depth- and longitudinally-discrete:
    - Longitudinal scale typically 10s to 100s of meters
    - Vertical scale typically on order of 1 meter

Detroit Lake model grid (Sullivan and others, 2007)



Base map modified from U.S. Geological Survey digital data (1:24,000). Projection: UTM, Zone 10, North American Datum of 1927.





North Santiam-Santiam model grid (Sullivan and Rounds, 2004b)

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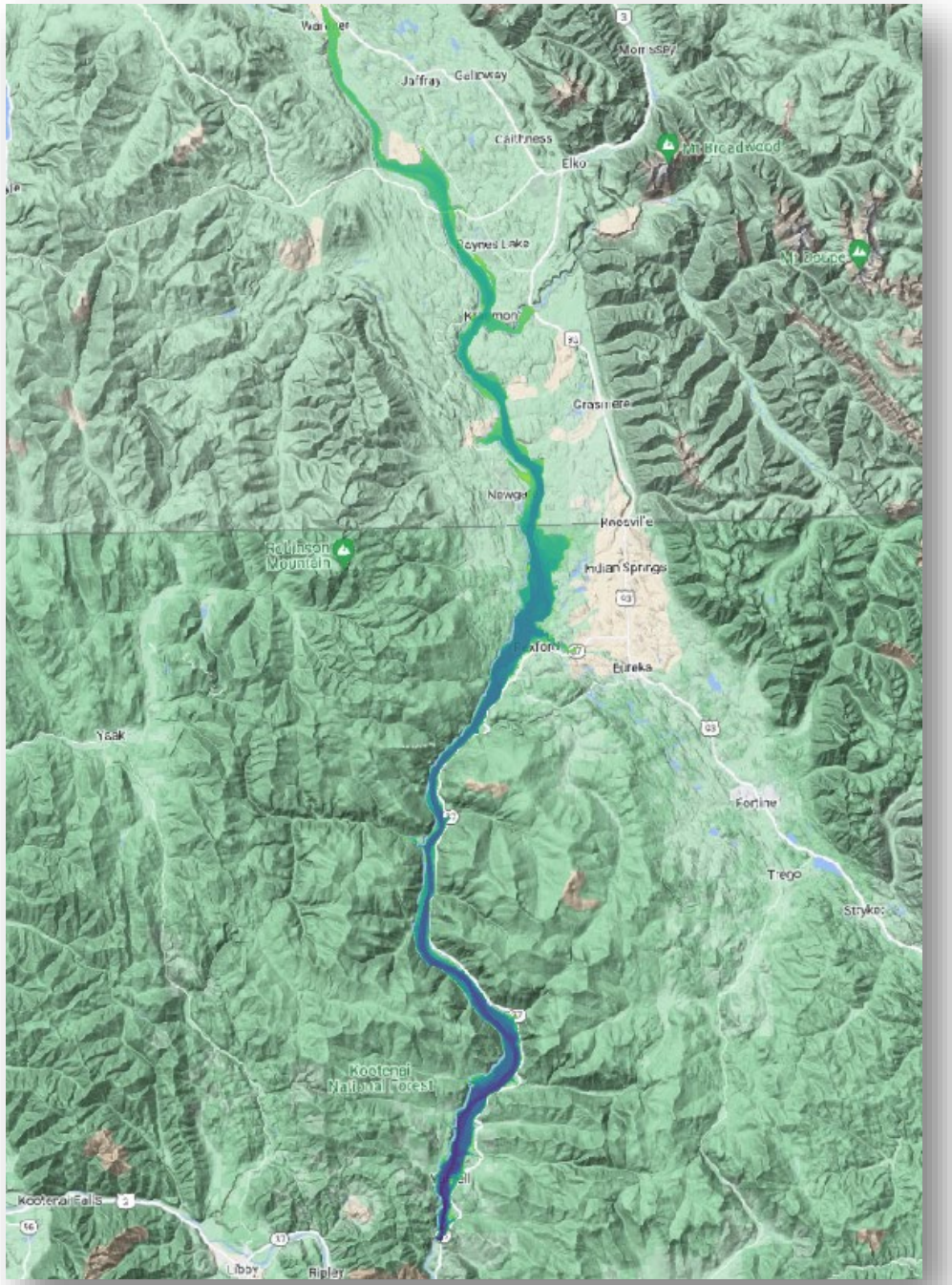
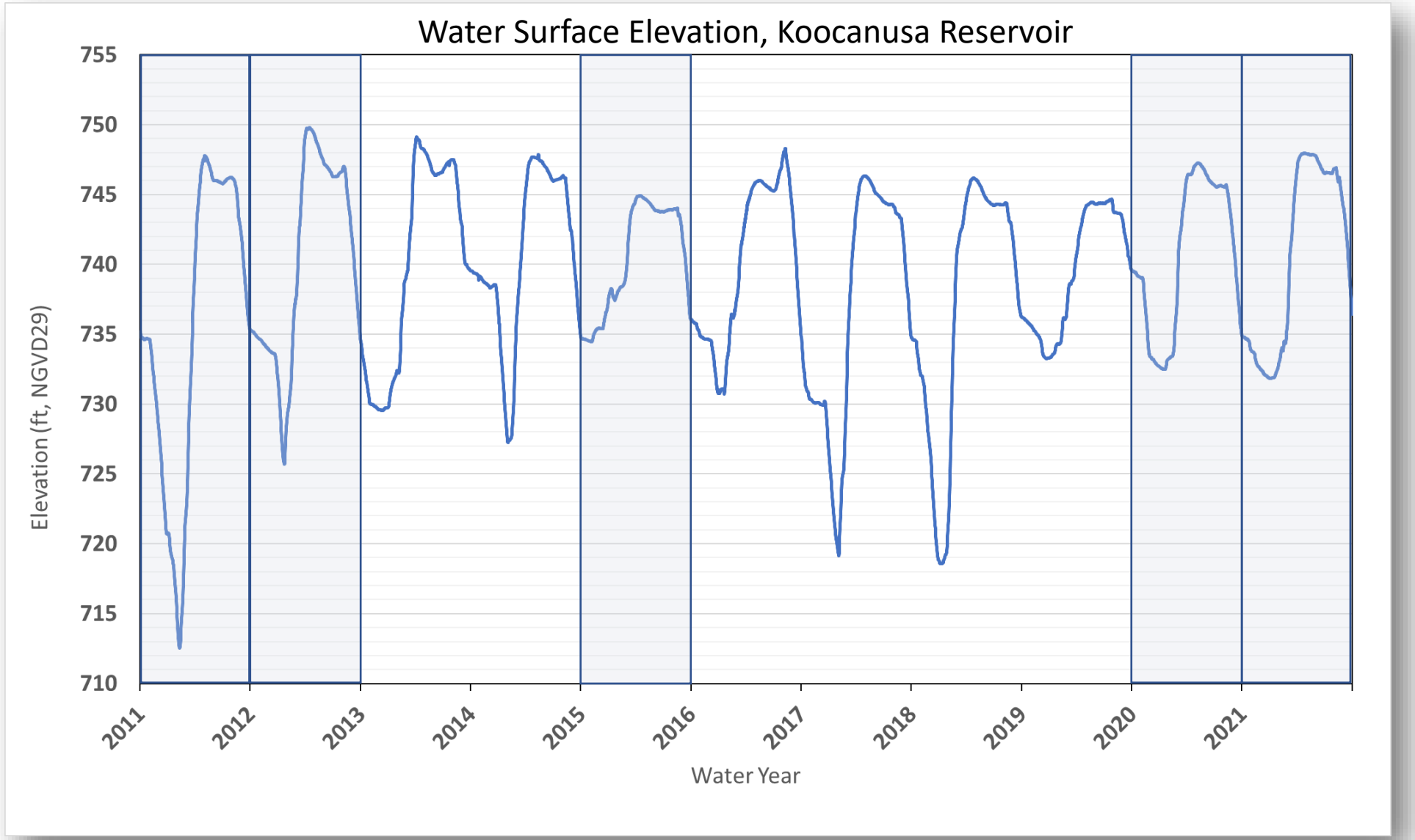
Koocanusa Model

- Model Domain: ~130 km
- Full coverage bathymetry:
  International Boundary → Libby Dam
- Interpolated bathymetry:
  Wardner, BC→ International Boundary
- 1 Waterbody, 9 Branches,
  310 segments



Fosness and Dudunake, 2022

Koocanusa Model – Calibration Years



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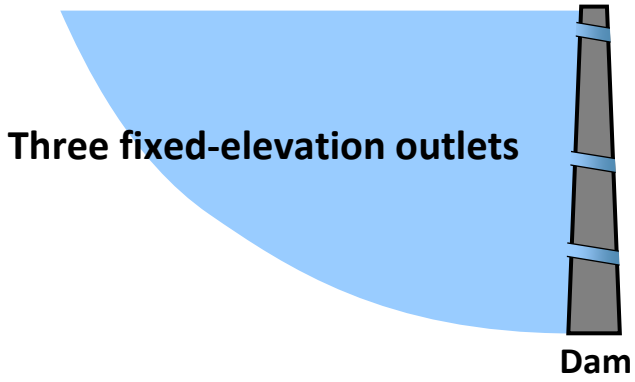
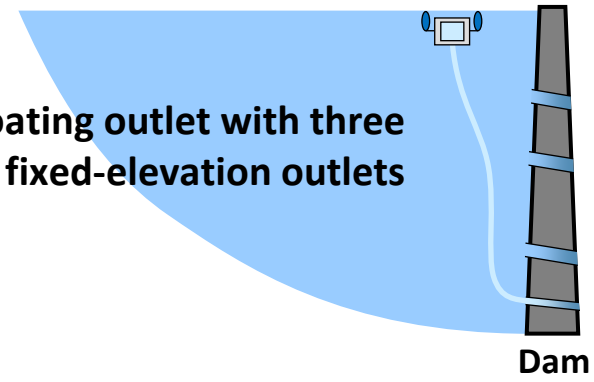
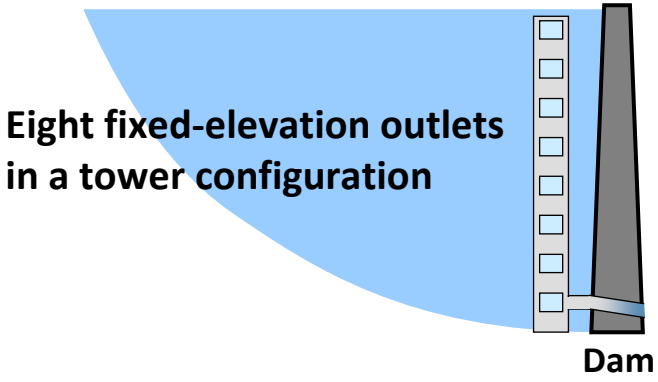
Kootenai River Model – Bathymetry

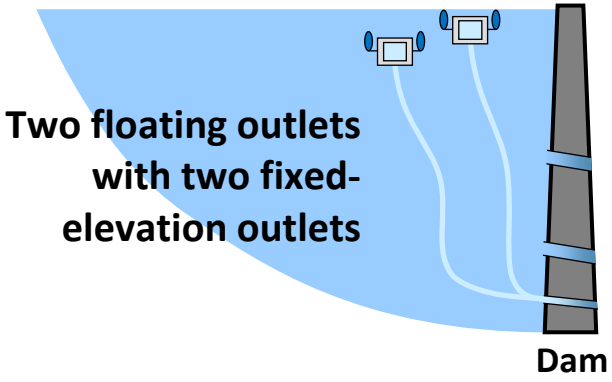
CE-QUAL-W2

Complex structure capabilities and selective withdrawal algorithms









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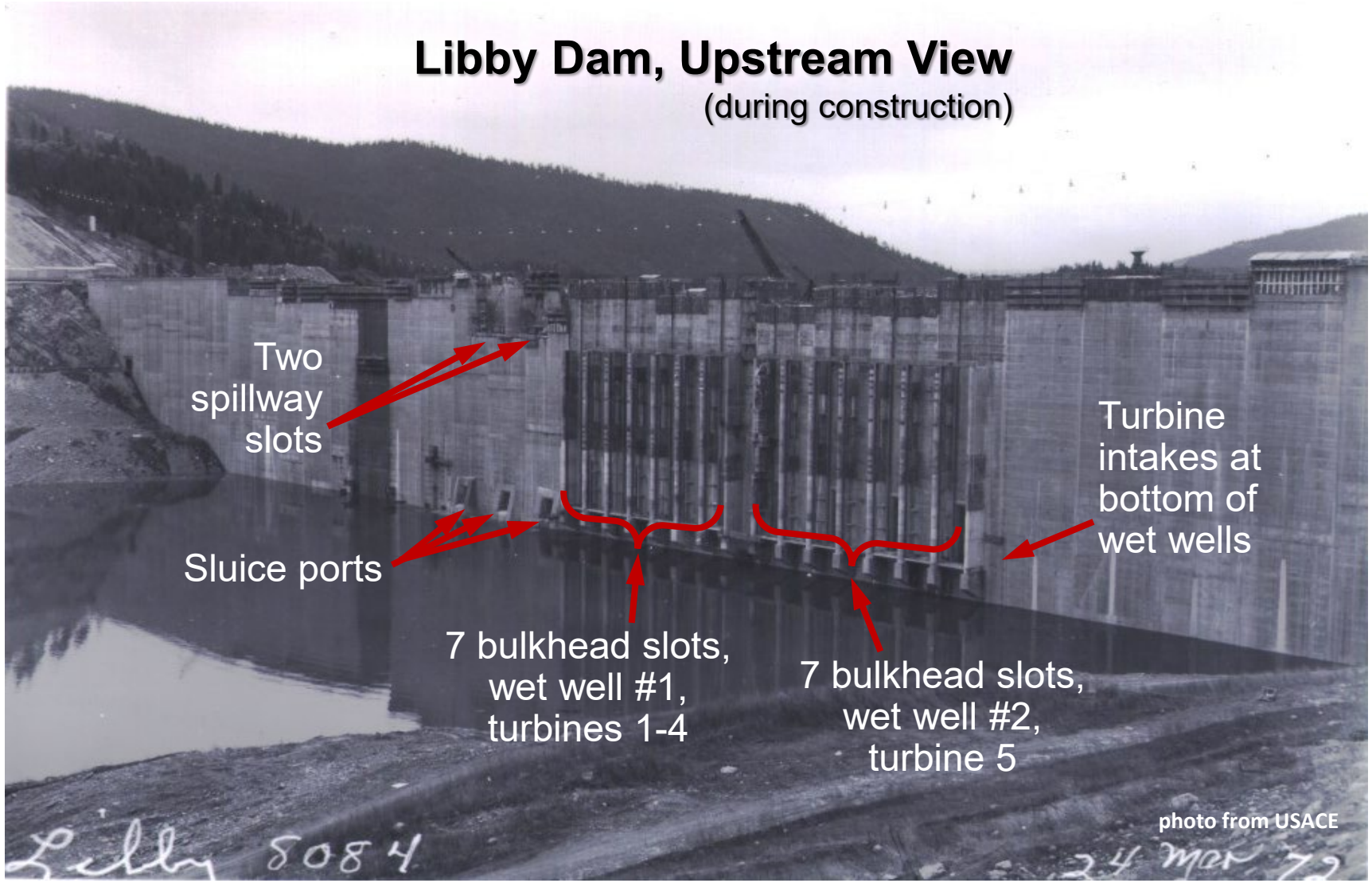
Rounds and Buccola, 2015

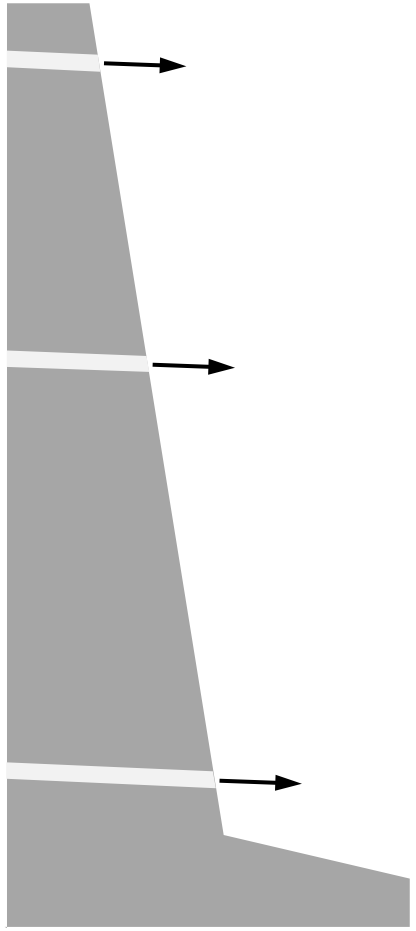
Libby Dam Temperature Management System

- Most releases from Libby Dam are through the power turbines. Water enters turbine intakes through two wet wells, each fronted by an array of removable bulkheads.
- Each bulkhead array has 7 columns (slots) of up to 18 stacked bulkheads.
- Water is released from higher in the reservoir by installing more bulkheads, and vice versa.
- Sluice ports typically are not used.



Selective Withdrawal at Libby Dam

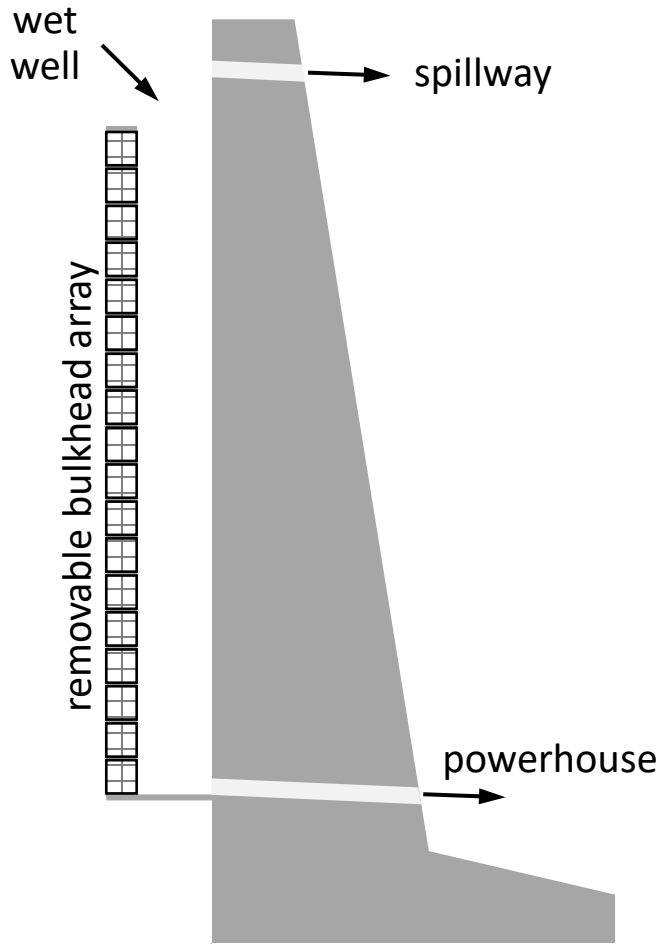
Dam with several discrete outlets



Bulkhead arrays at Libby Dam do not conform to standard selective withdrawal routines in W2:

- Configuration changes over time.
- Openings occur at different elevations.
- Multiple openings at same elevation essentially change the width of a line sink.
- If virtual outlets could be assigned to different elevations with changing line widths, how would the flows to each outlet be assigned?

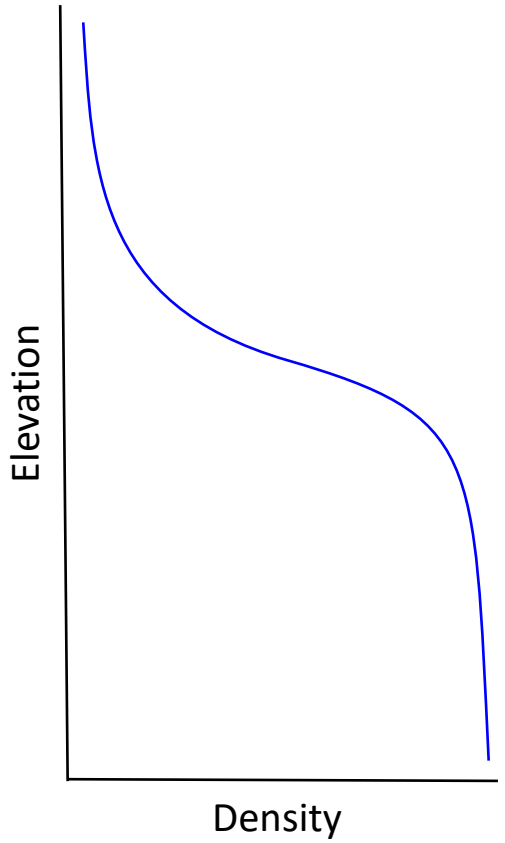
Libby Dam

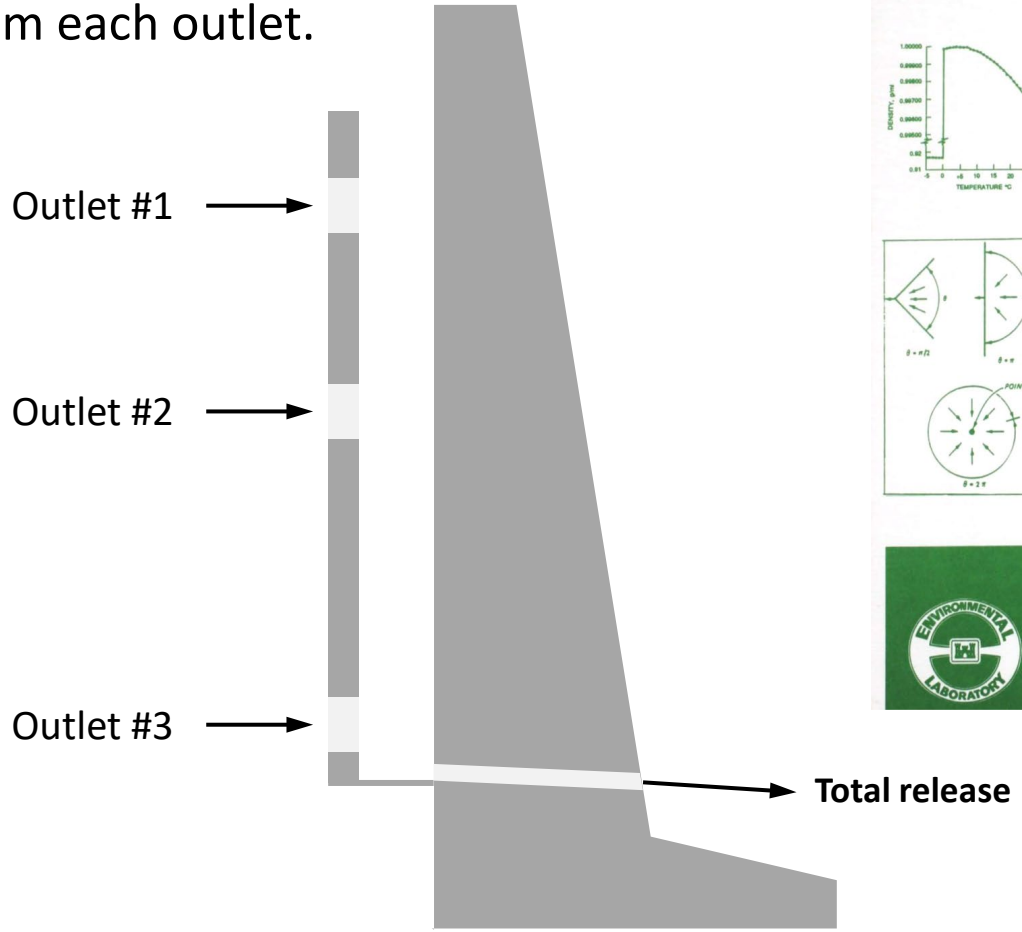


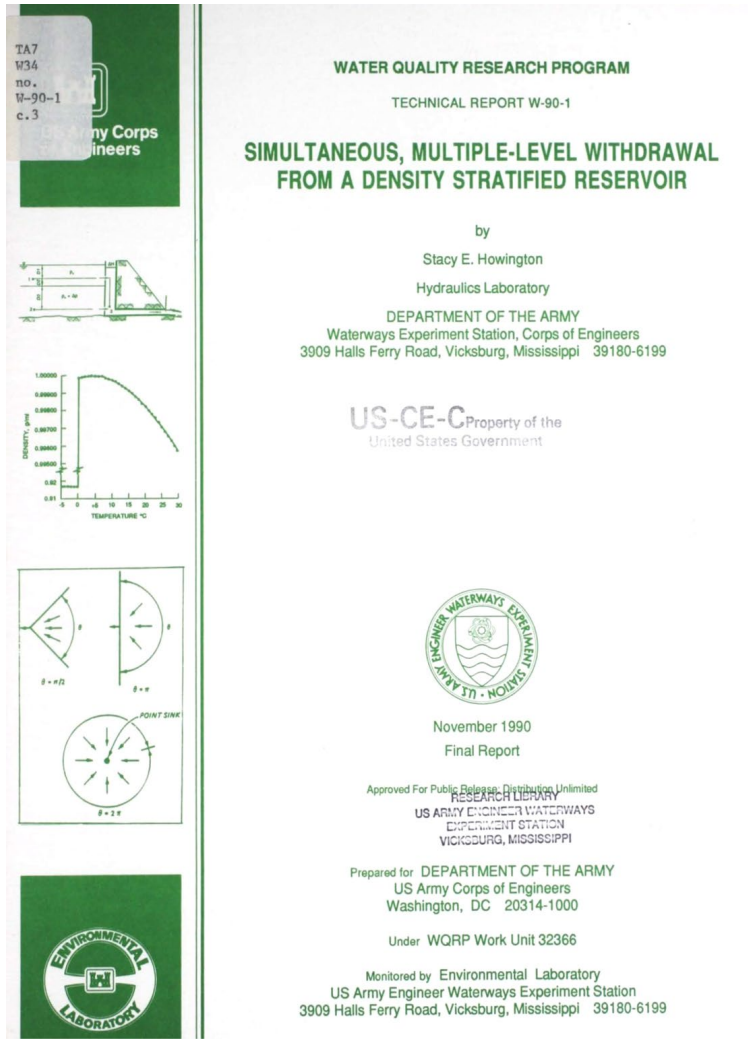
Solution: Use Howington's Algorithm

In 1990, Stacey Howington (USACE) addressed the problem of *simultaneous flows from a density-stratified reservoir to multiple-level outlets connected to a common wet well*. His equations include:

- Critical discharges for outlets 2 through n, below which a density blockage can occur in the wet well, and
- Flow rates entering the wet well from each outlet.







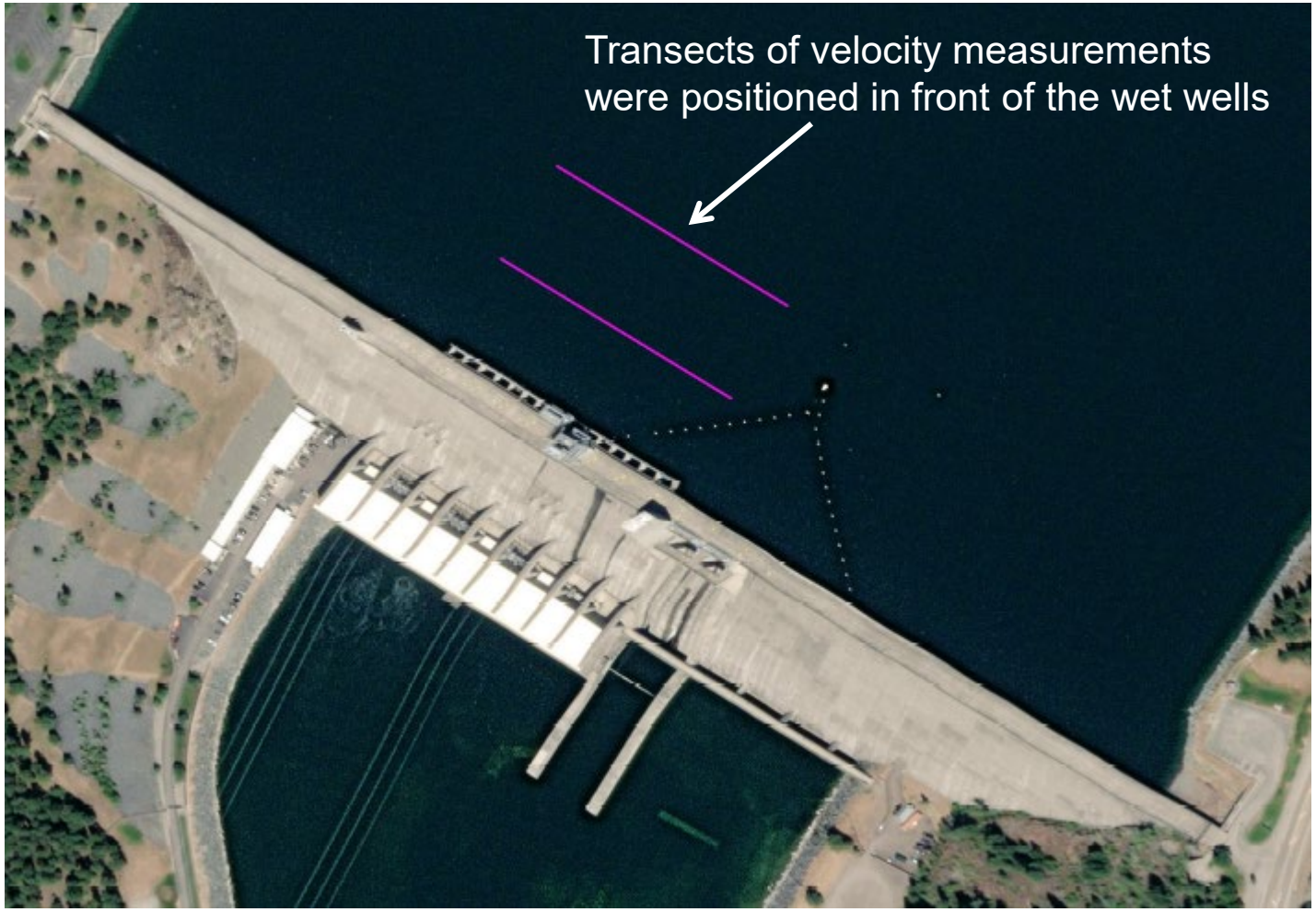
Howington (1990)

Algorithm Verification: Measured Velocity Profiles

Vertical profiles of water velocity were measured on four dates in 2022 to provide verification data for the new selective withdrawal algorithm.

An acoustic doppler unit was used to measure velocity profiles along transects in front of the wet wells.

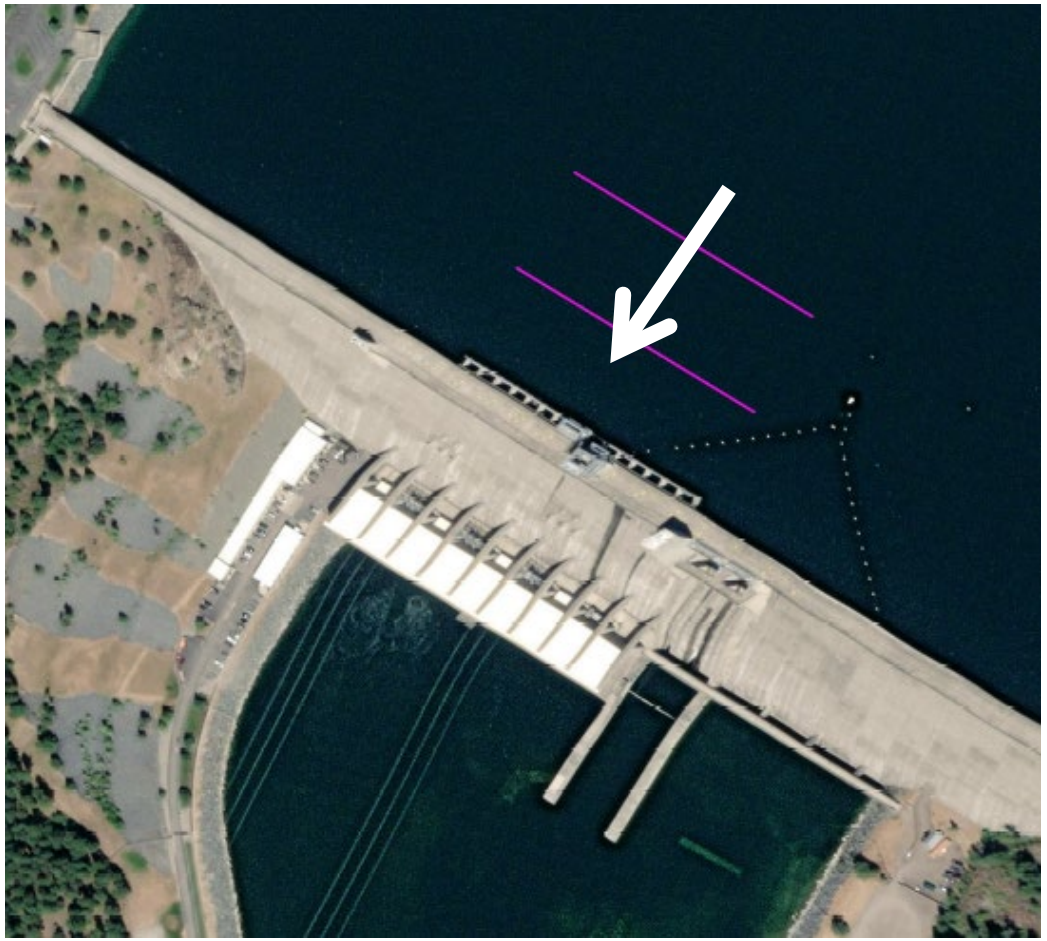
Clear water made for challenging measurement conditions because of diminished signal at greater depth, but sufficient data were collected for the analysis.



Imagery from NAIP; U. S. Department of Agriculture, Farm Service Agency

Measured Velocity Profiles

Only velocities in the direction of the dam were used, and the mean was used to delineate the vertical profile.



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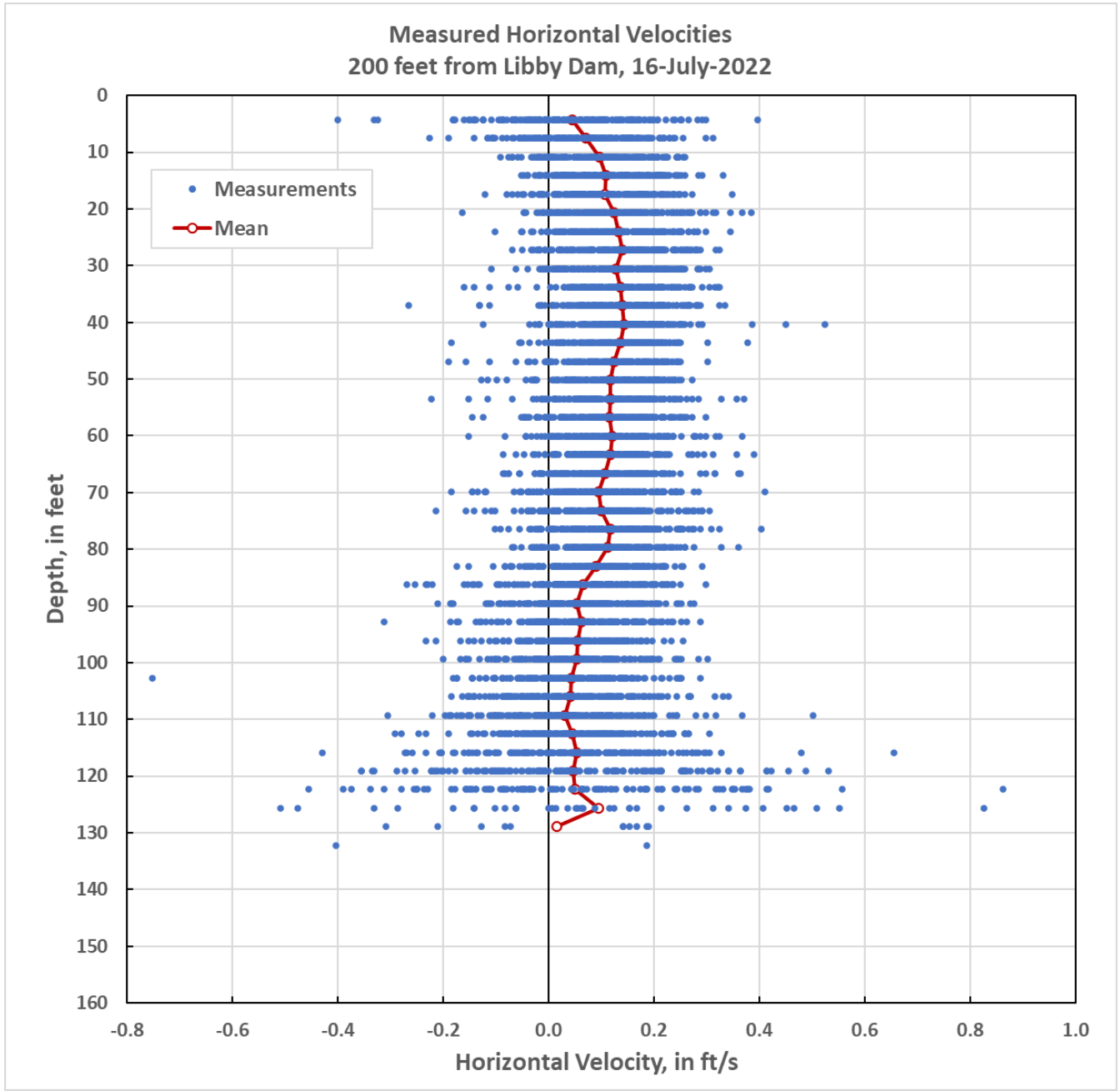
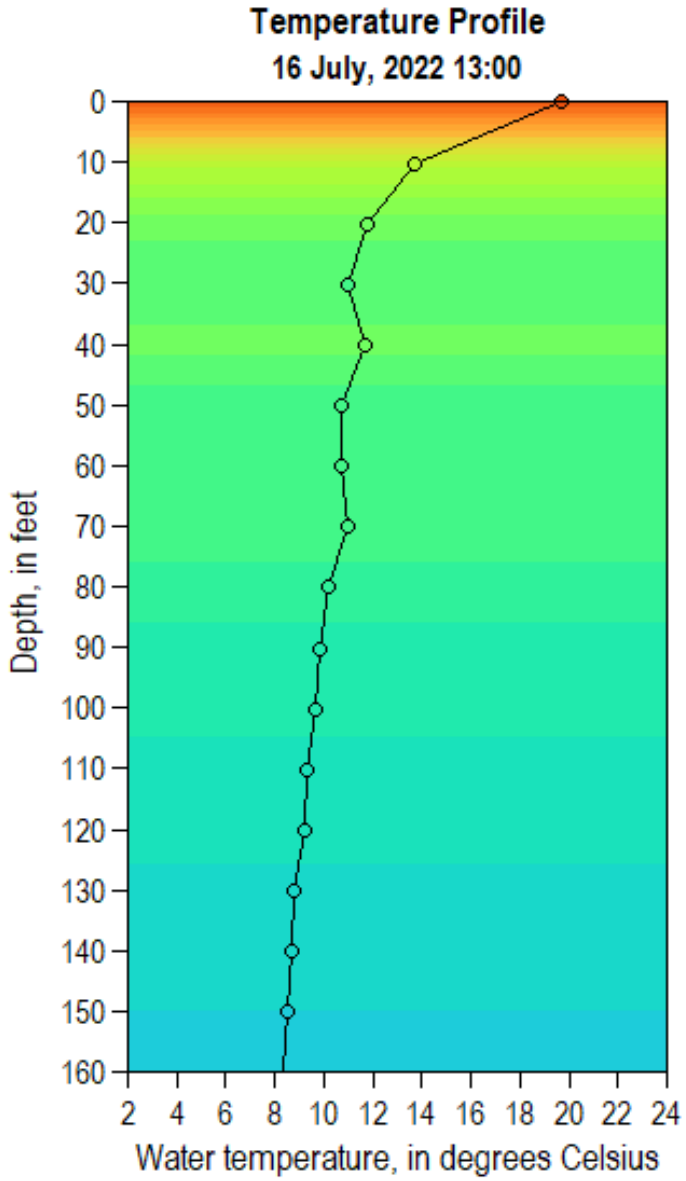
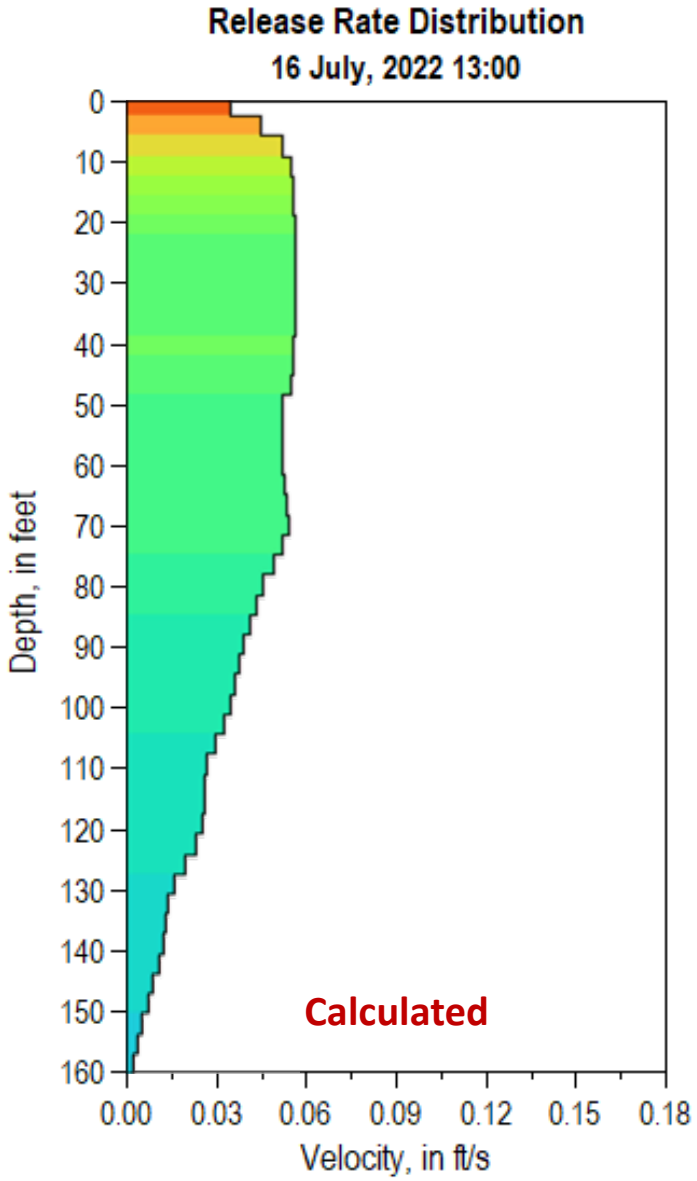
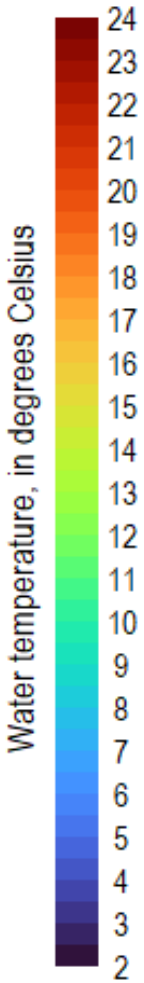


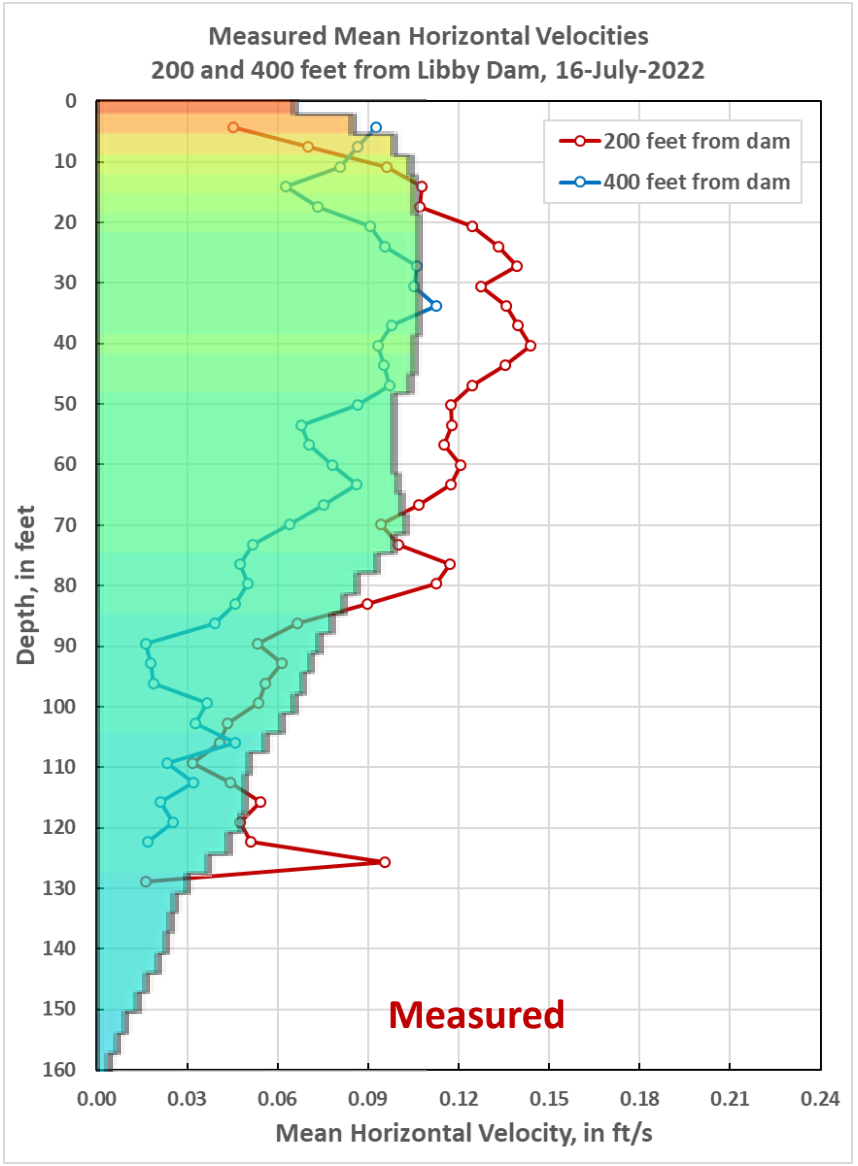
Provisional results; subject to change. Do not cite.

Velocity Profile Comparison: July 16, 2022









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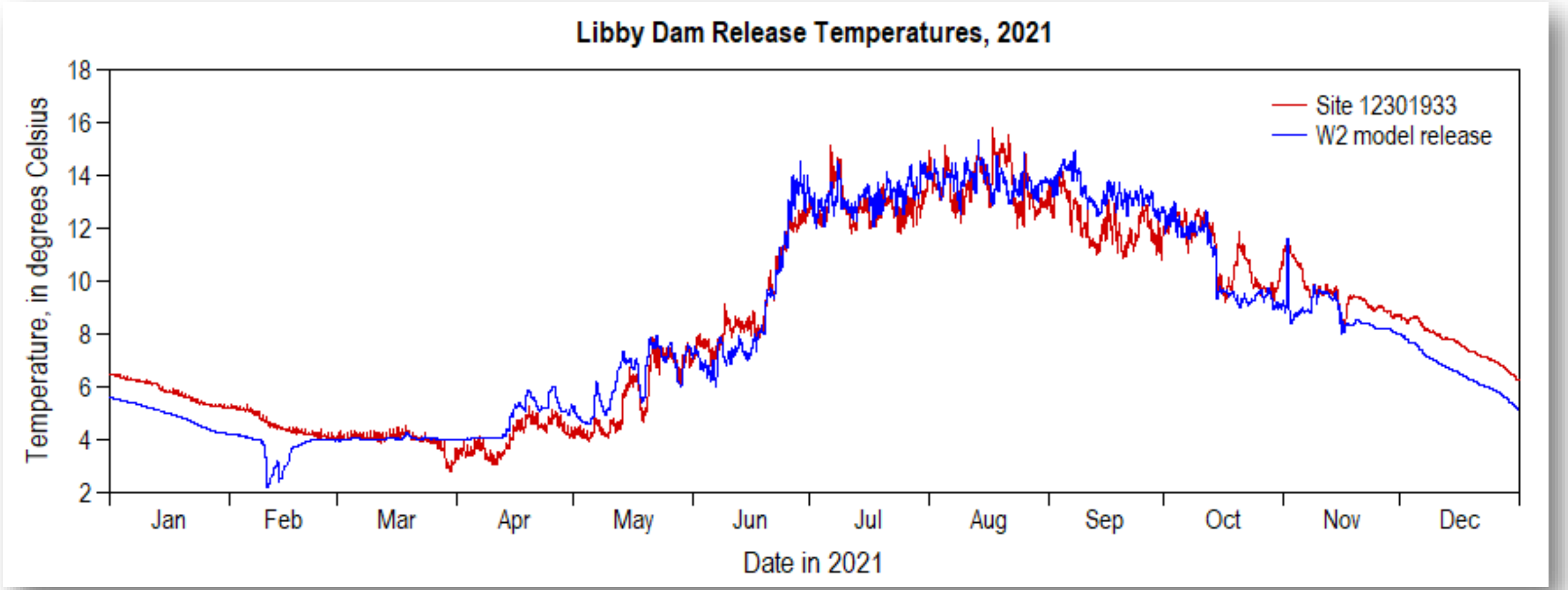
Koocanusa Model – Preliminary Temperature Results



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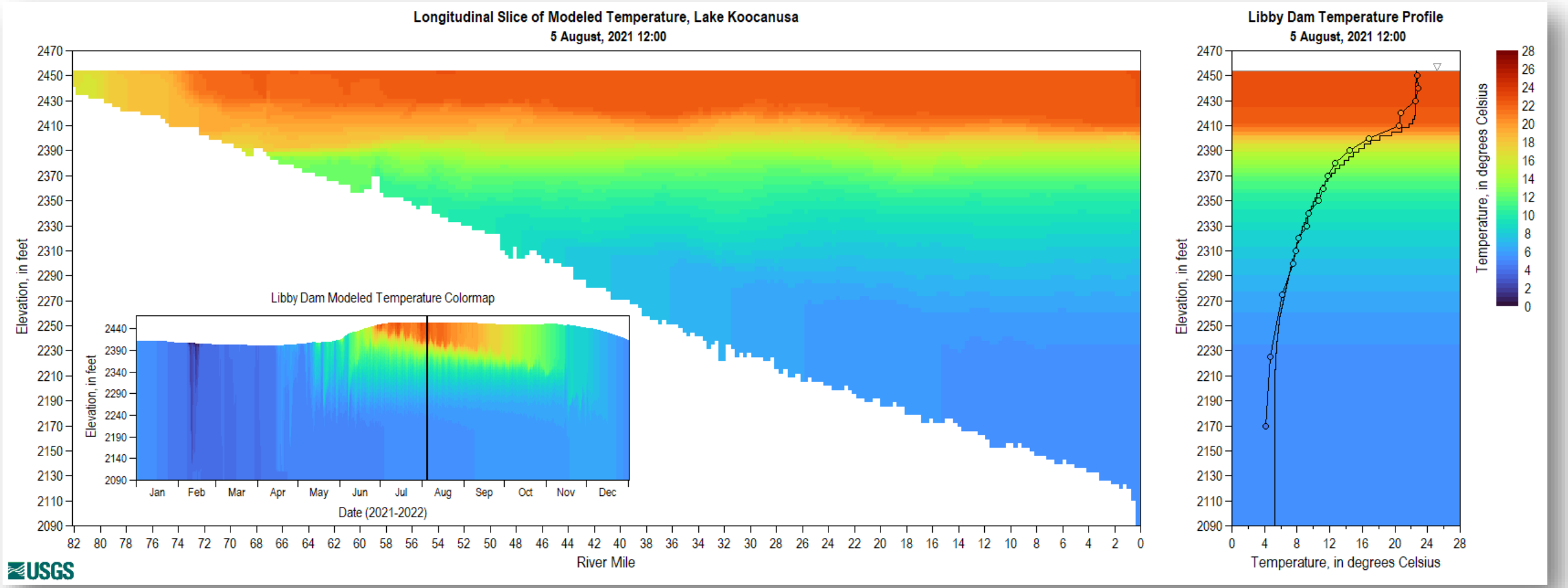
Koocanusa Model – Preliminary Temperature Results



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CE-QUAL-W2 – Purpose and Future Tasks

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