MODELING THE NECHAKO RESERVOIR USING 2D HYDRODYNAMIC MODEL

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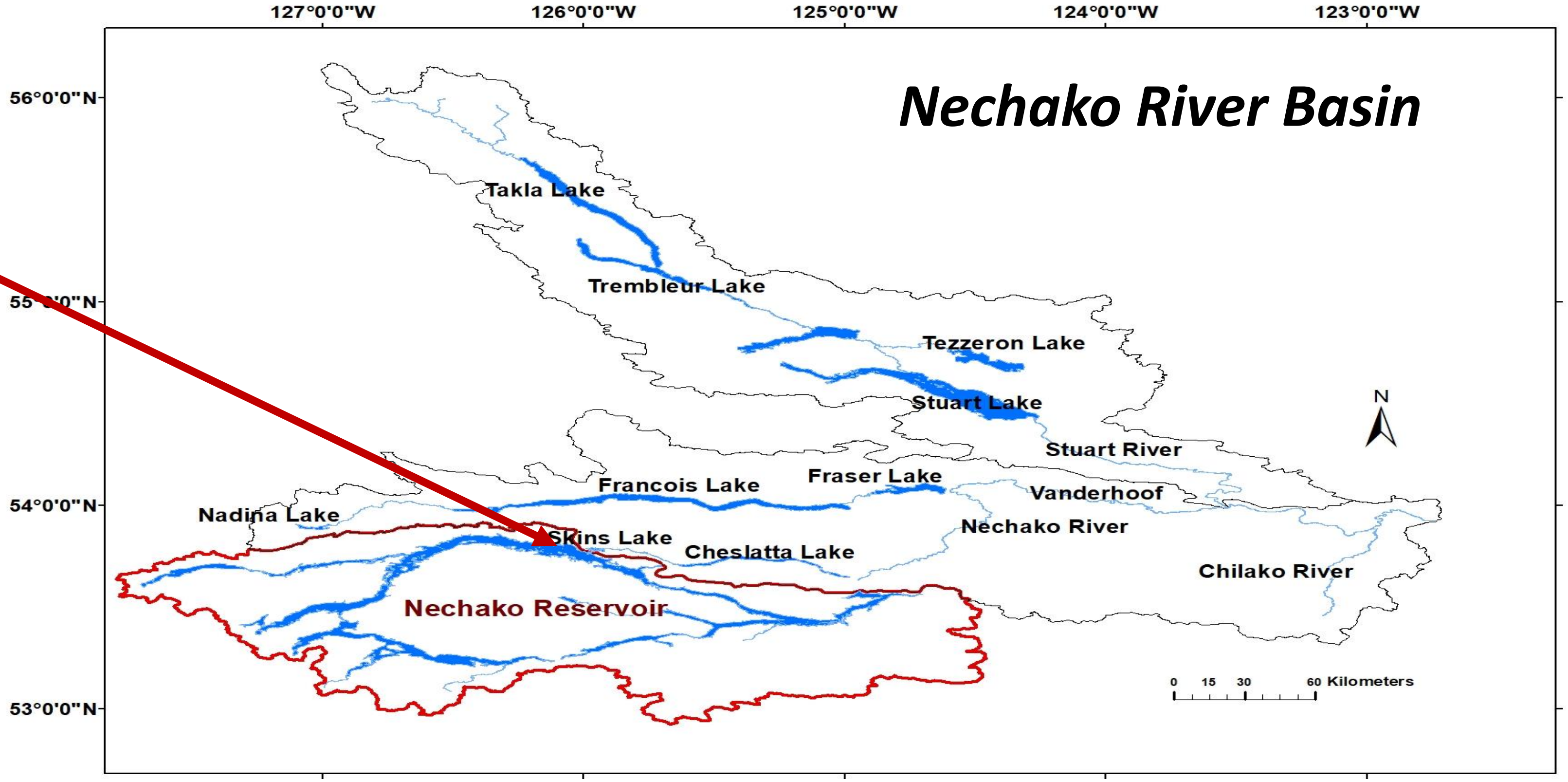
CONTEXT /OBJECTIVES

- Implementing a hydrodynamic model for the Nechako Reservoir.
- Producing future scenarios for water level and temperature within the Nechako Reservoir.
- Assessing the climate change impact on the Reservoir storage and water temperature.

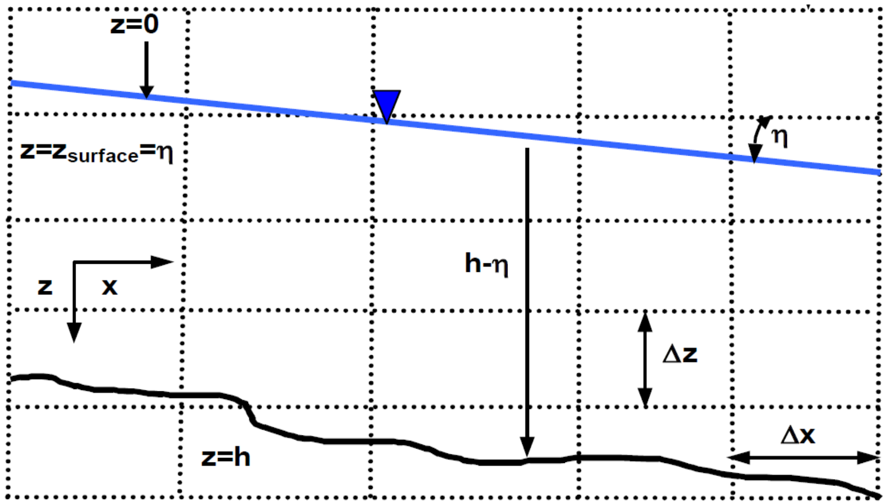
Futures scenarios of water temperature at Skins lake spillway



CE-QUAL-W2 HYDRODYNAMIC MODEL

- 2-D laterally averaged, longitudinal/Vertical Hydrodynamic and water quality model.
- Can be applied for rivers, lakes, reservoirs or entire systems of reservoirs and river segments.
- It supports:
  - Multiple inflows and outflows
  - Ice cover calculations
  - Multiple hydraulic structures (dams, spillways, gates, pipes,….)
  - Dynamic shading
  - Reservoir Automatic vertical port selection
  - Selective withdrawal calculations
  - ….
- Required forcing inputs and boundary conditions:
  - **Bathymetry**
  - **Met data**: Tair, Tdew, Wind speed, Wind direction, Cloud Cover, Solar radiation (optional)
  - **Flow data** : inflows, inflows temperature, outflows
- Model is open source and supported by the Water Quality Research group, Department of Civil and Environmental Engineering, Portland State University (Cole and Wells, 2018)

CE-QUAL-W2 Coordinate System



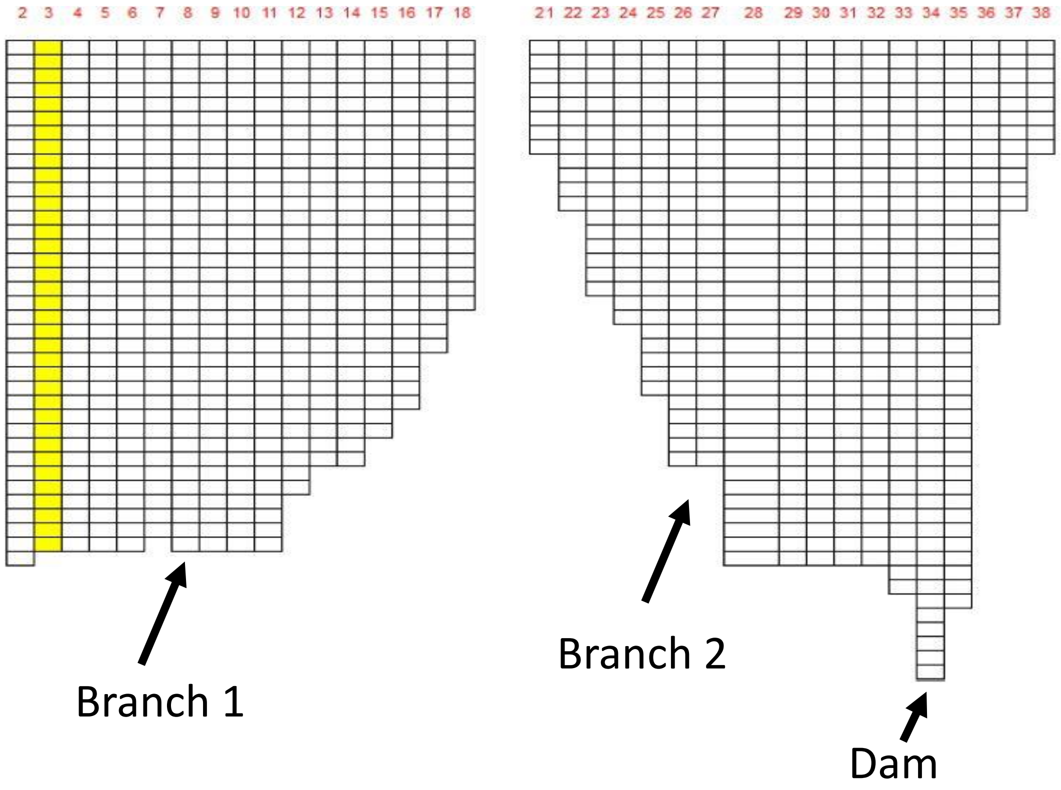
Source Cole, T.M., and Wells, S. A.(2018)

CE-QUAL-W2 HYDRODYNAMIC MODEL

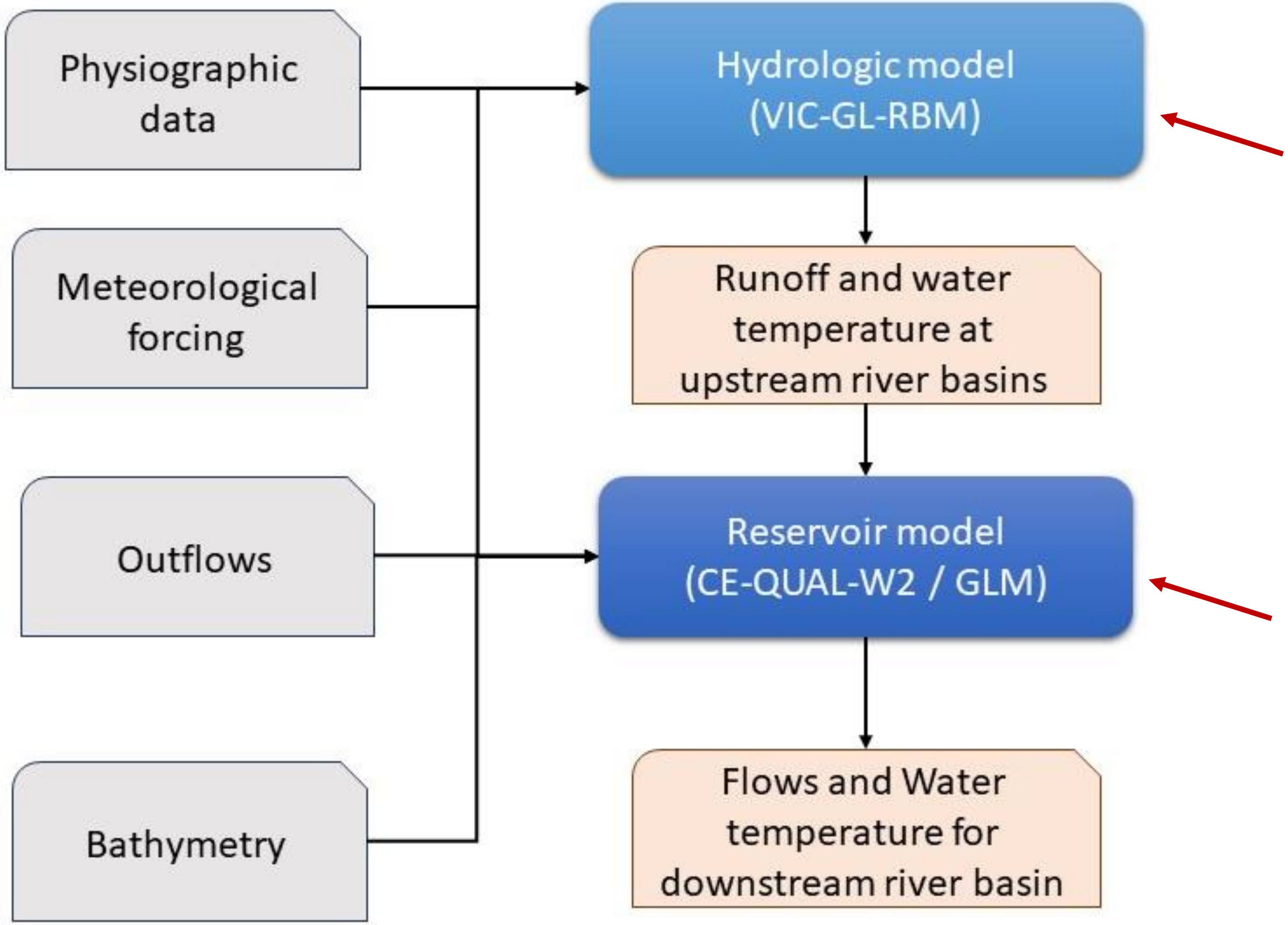
Bathymetry

- Computational grid is function of :
  - Longitudinal spacing Δx (segment length)
  - Vertical spacing Δz (i.e. Layer height)
  - Average cross-sectional width (i.e. cell width)
  - Water body slope
- Model discretizes the waterbody into branches which is an ensemble of model segments.

Example of CE-QUAL-W2 model Grid



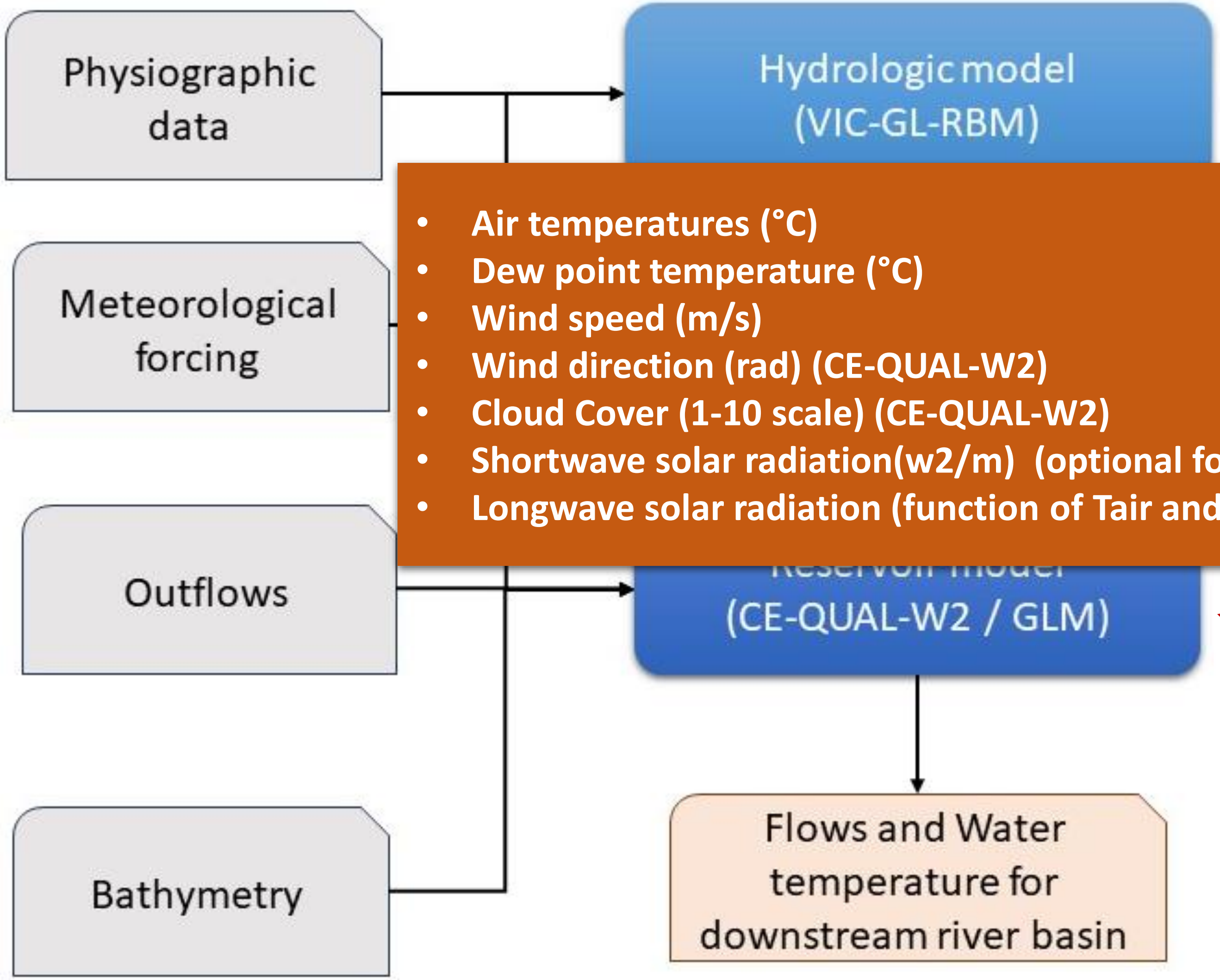
HYDROLOGIC-HYDRODYNAMIC PLATFORM



Provides boundary conditions in the regulated area

Provides boundary conditions at the spillway

HYDROLOGIC-HYDRODYNAMIC PLATFORM

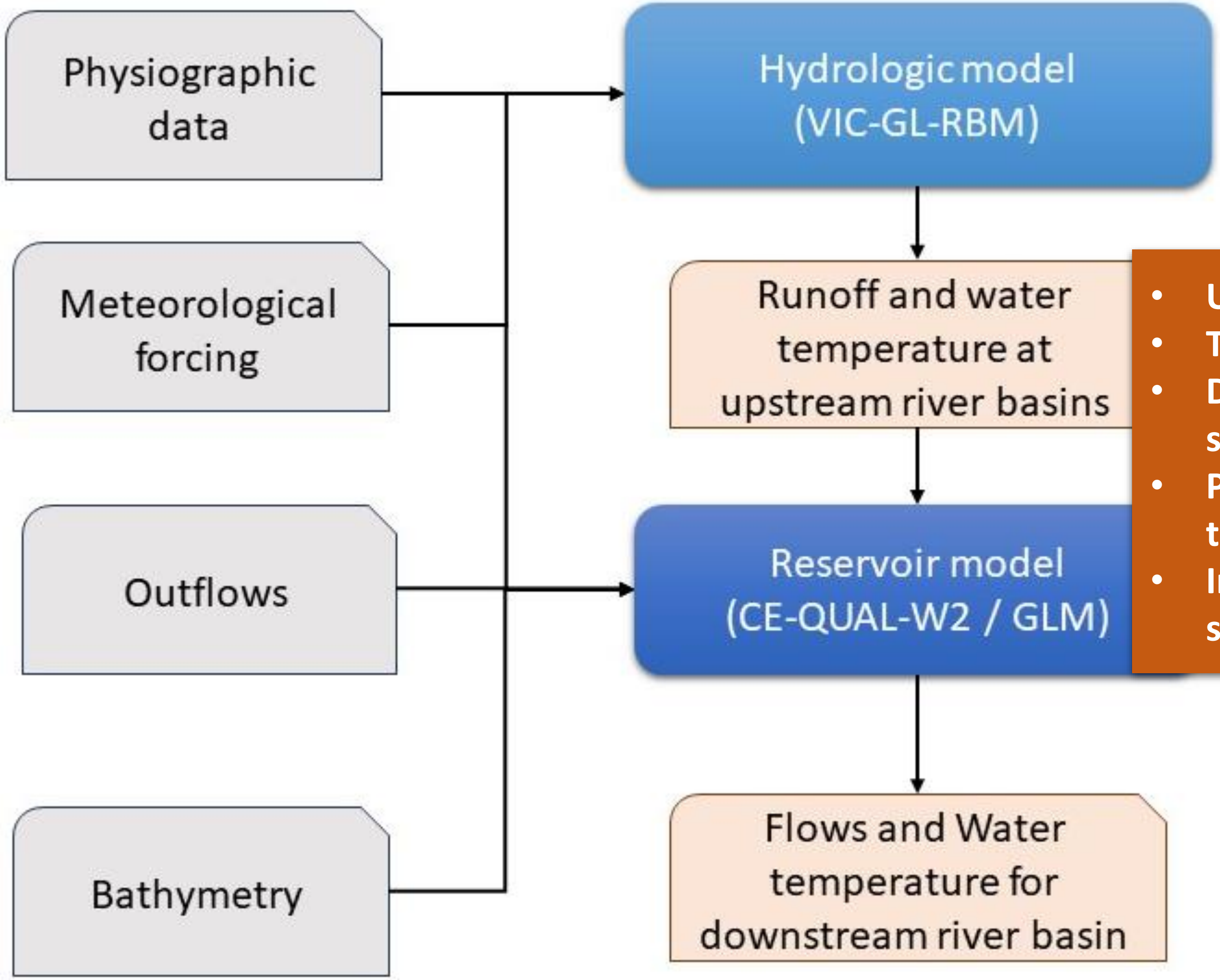


- Air temperatures (°C)
- Dew point temperature (°C)
- Wind speed (m/s)
- Wind direction (rad) (CE-QUAL-W2)
- Cloud Cover (1-10 scale) (CE-QUAL-W2)
- Shortwave solar radiation(w2/m) (optional for CE-QUAL-W2)
- Longwave solar radiation (function of Tair and cloud cover in CE-QUAL-W2)

Provides boundary conditions in

Provides boundary conditions at the spillway

HYDROLOGIC-HYDRODYNAMIC PLATFORM

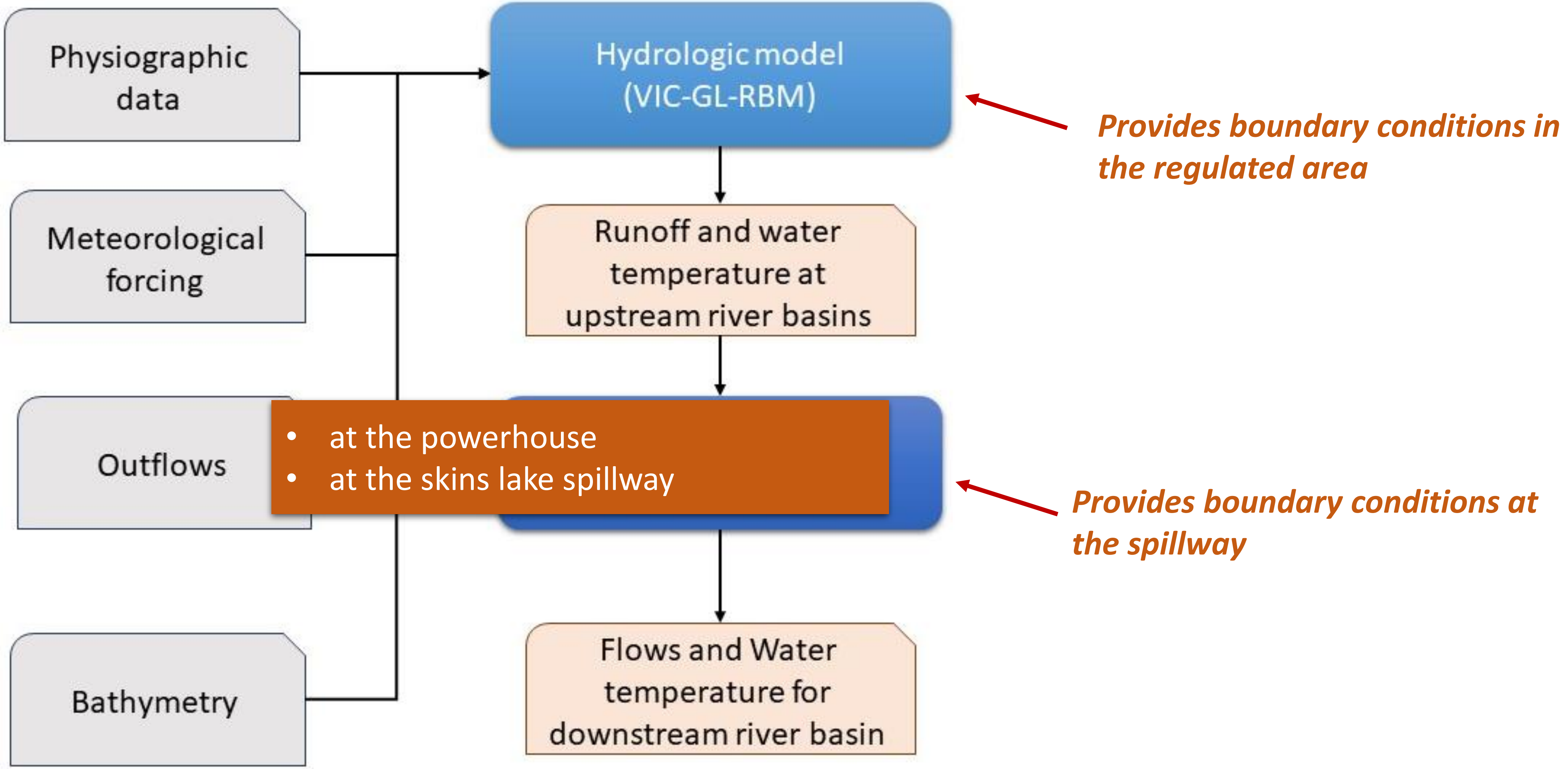


Provides boundary conditions in the regulated area

- **Upstream Inflows**
- **Tributary Inflows**
- **Distributed tributary inflows according to the surface area of segment**
- **Precipitation considered as distributed tributary inflow**
- **Internal inflows (flows from hydraulic structures)**

the spillway

HYDROLOGIC-HYDRODYNAMIC PLATFORM



METEROLOGICAL FORCING

- Met forcing are a combination of PNWNAmet data and reanalysis ERA5 data.
- PNWNAmet is gridded observed data of daily Tmin, Tmax, Precip at a resolution of 0.0625° and wind speed from 20CR reanalysis (Werner et al. (2019)).

Data sources, availability and processing steps by period

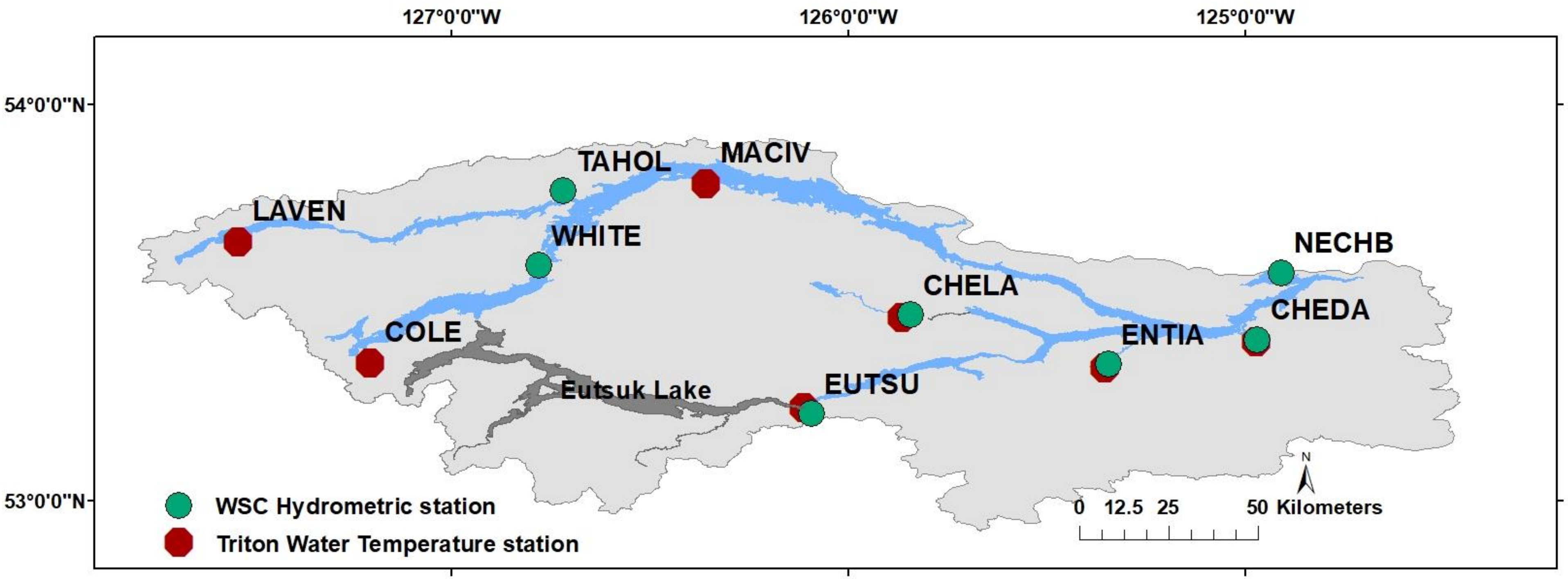
Variable	Periods		
	1945-1979	1980-2012	2013-2018
Primary Variables			
AIR_TEMP		quantile-map	bias-corrected
PREC		quantile-map	bias-corrected
SHORTWAVE	bias-corrected	quantile-map	
LONGWAVE	bias-corrected	quantile-map	
PRESSURE	bias-corrected	quantile-map	
DENSITY	bias-corrected	quantile-map	
VP	bias-corrected	quantile-map	
WIND	bias-corrected	quantile-map	
WIND_DIR			
Additional Variables (estimated from primary variables)			
REL_HUMID			
TDEW			

PNWNAmet-MTCLIM
ERA5
both

Hydrologic model set up

- Variable infiltration Model (VIC-GL) coupled to the River Basin stream temperature Model (RBM).
- Calibration of the VIC-GL- RBM on the major tributaries of the Nechako.
- Flows data available from 1992 to 1995 except TAHOL and WHITE stations (available up to 1952).
- Inflow water temperature is available from late June to mid October 1994 (Triton, 1994).

VIC-GL- RBM calibration stations

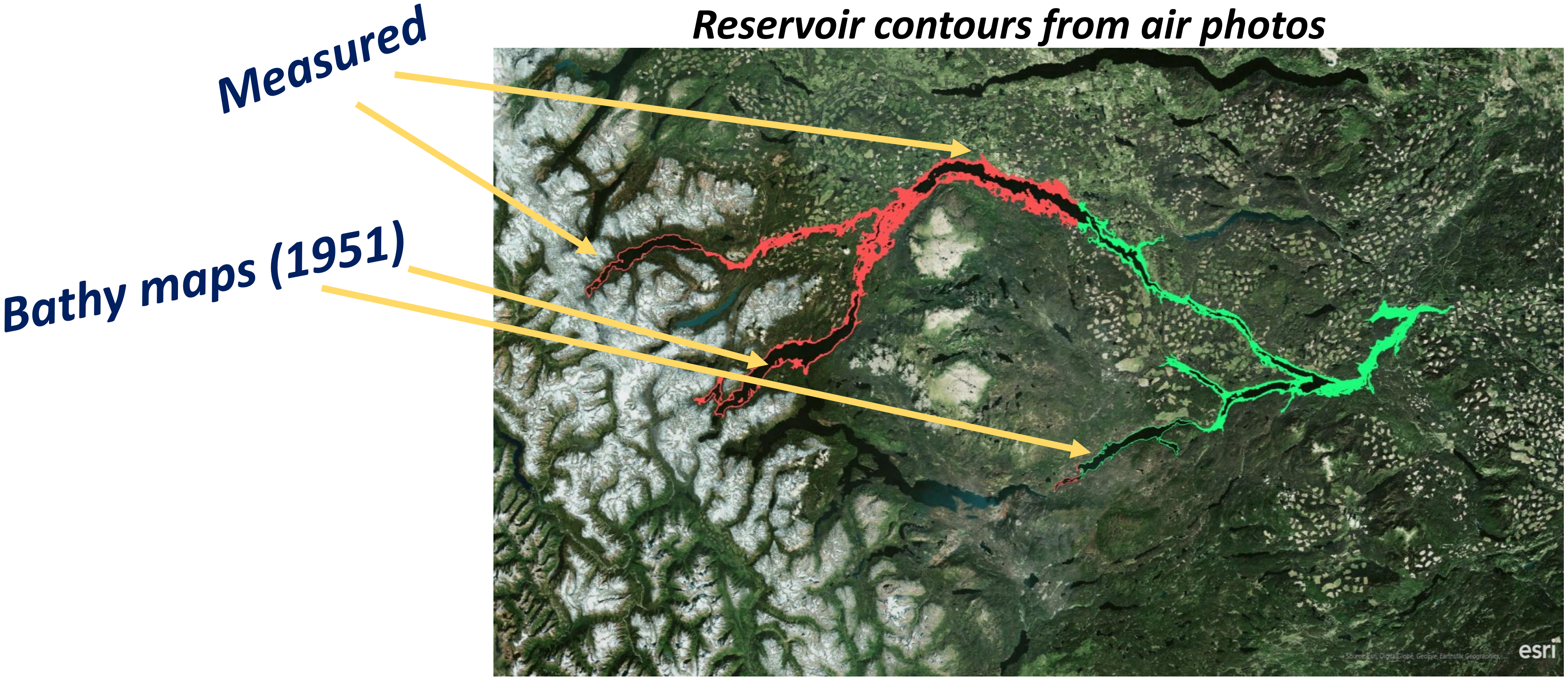


BATHYMETRY DATA

Bathymetry is estimated from :

- Contours produced from a DTM created using air photos taken between 1946 and 1947.
- Bathymetry map surveyed in 1951 .
- Measured bathymetry.

Reservoir contours from air photos



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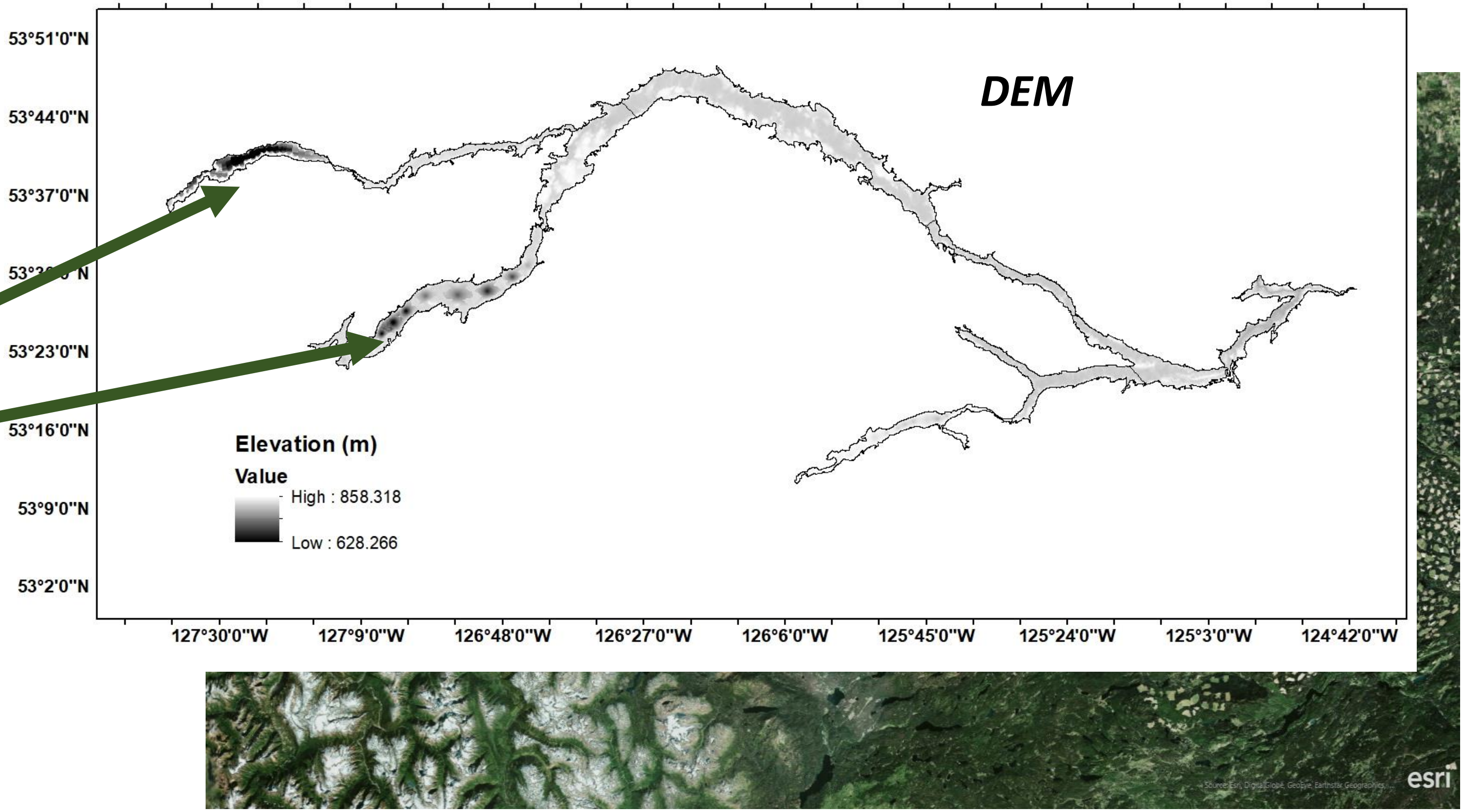
Deepest Lakes

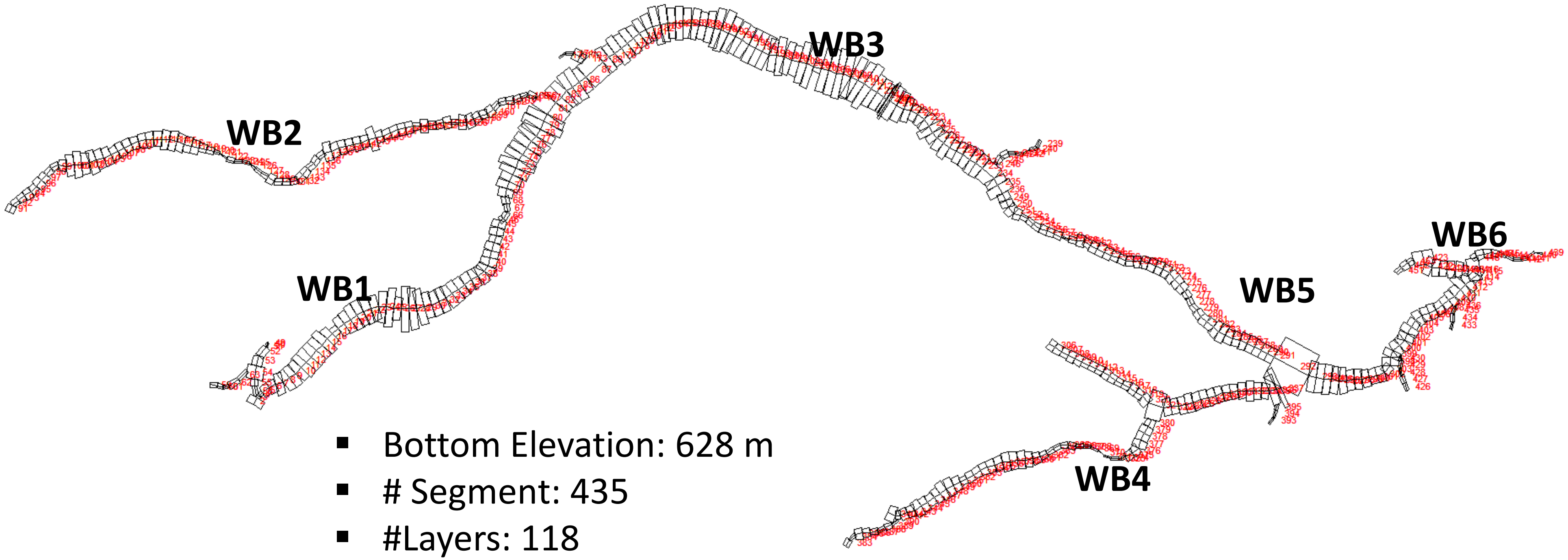


CE-QUAL-W2 set up

CE-QUAL-W2 Computational Grid

- Nechako reservoir is set up as a 6 inter-connected waterbodies with a vertical grid spacing of 2.2m and horizontal grid spacing of approx. 1km
- Each waterbody is a set of model branches driven by the same meteorological forcing

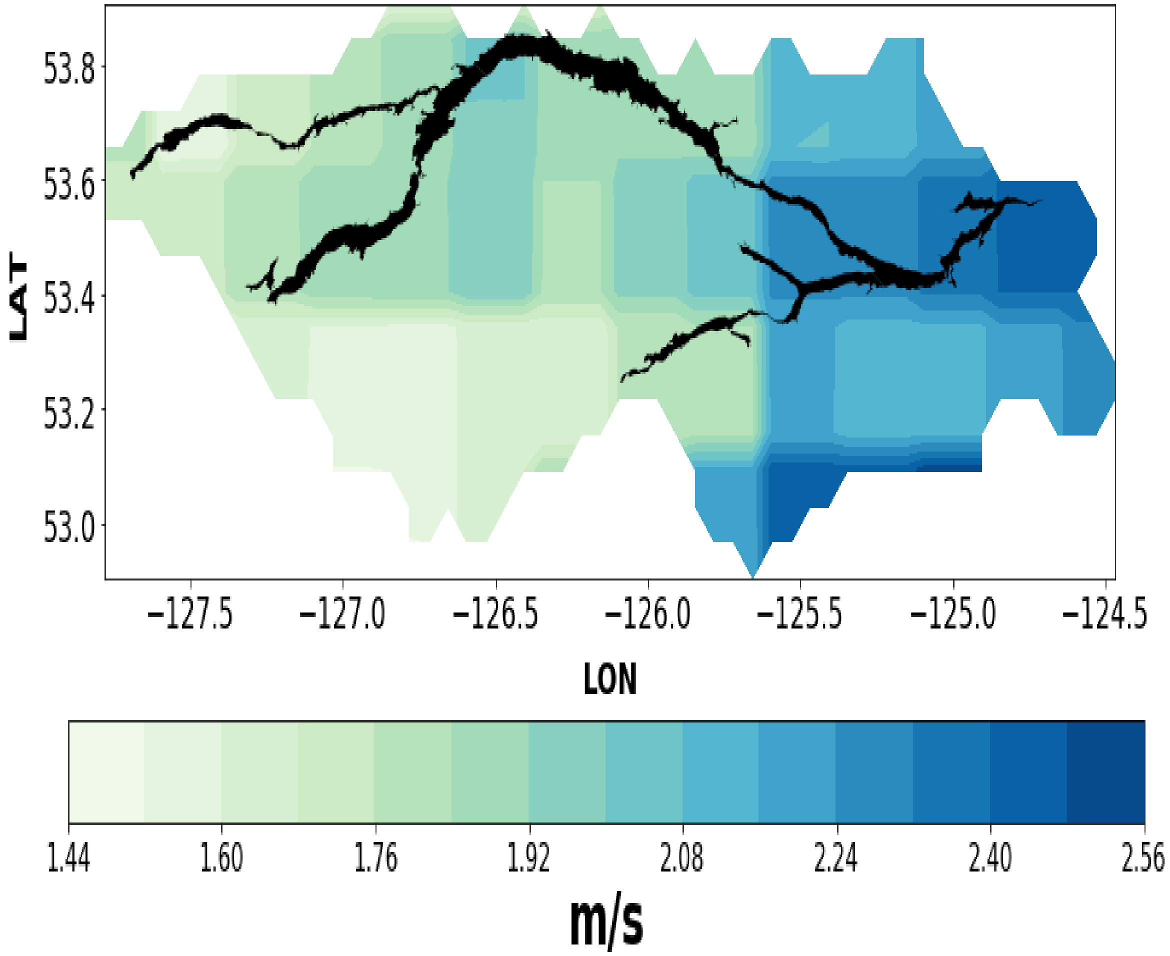
CE-QUAL-W2 model discretization of the Nechako Reservoir



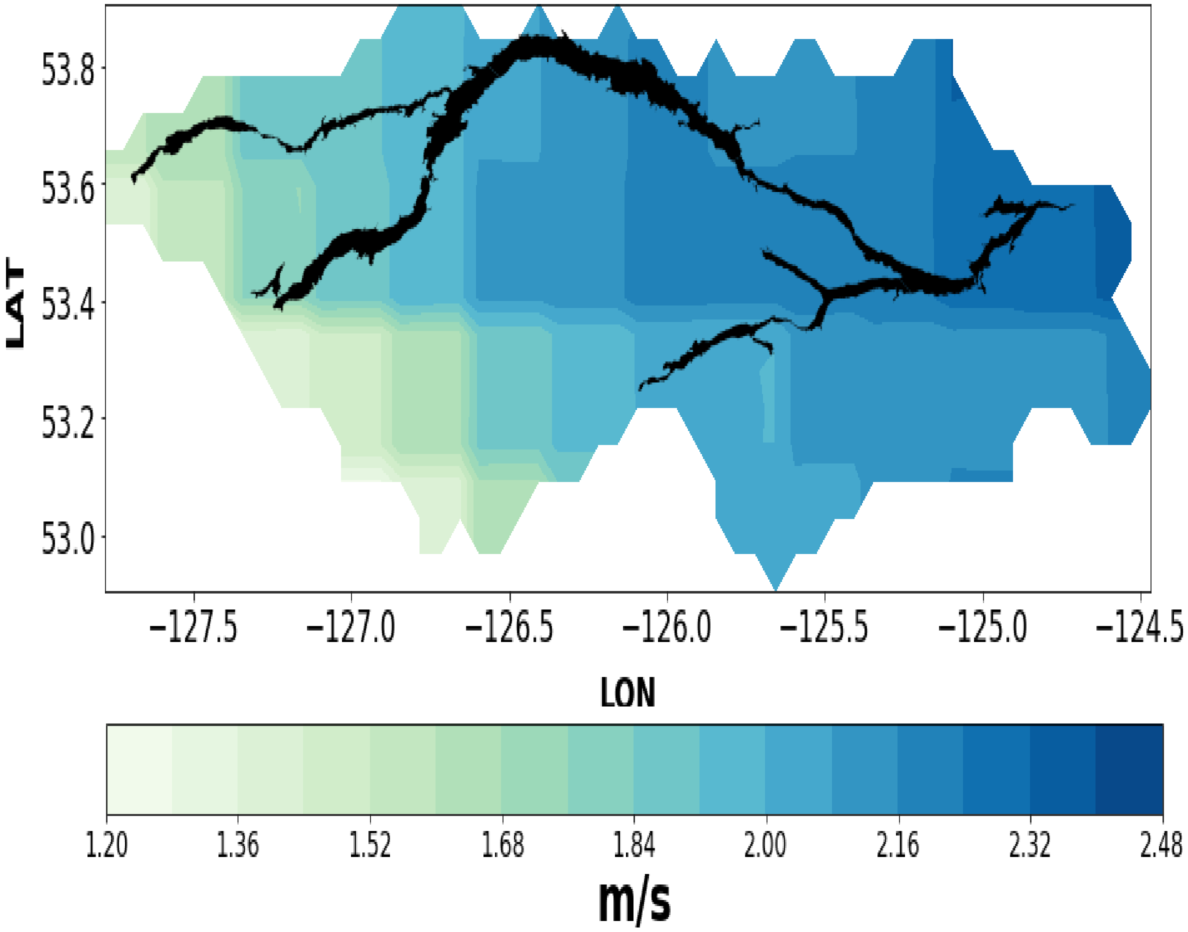
- Bottom Elevation: 628 m
- # Segment: 435
- #Layers: 118

Wind speed variability over the Nechako Reservoir

3-hourly Wind speed Average (January, 1945-2018)



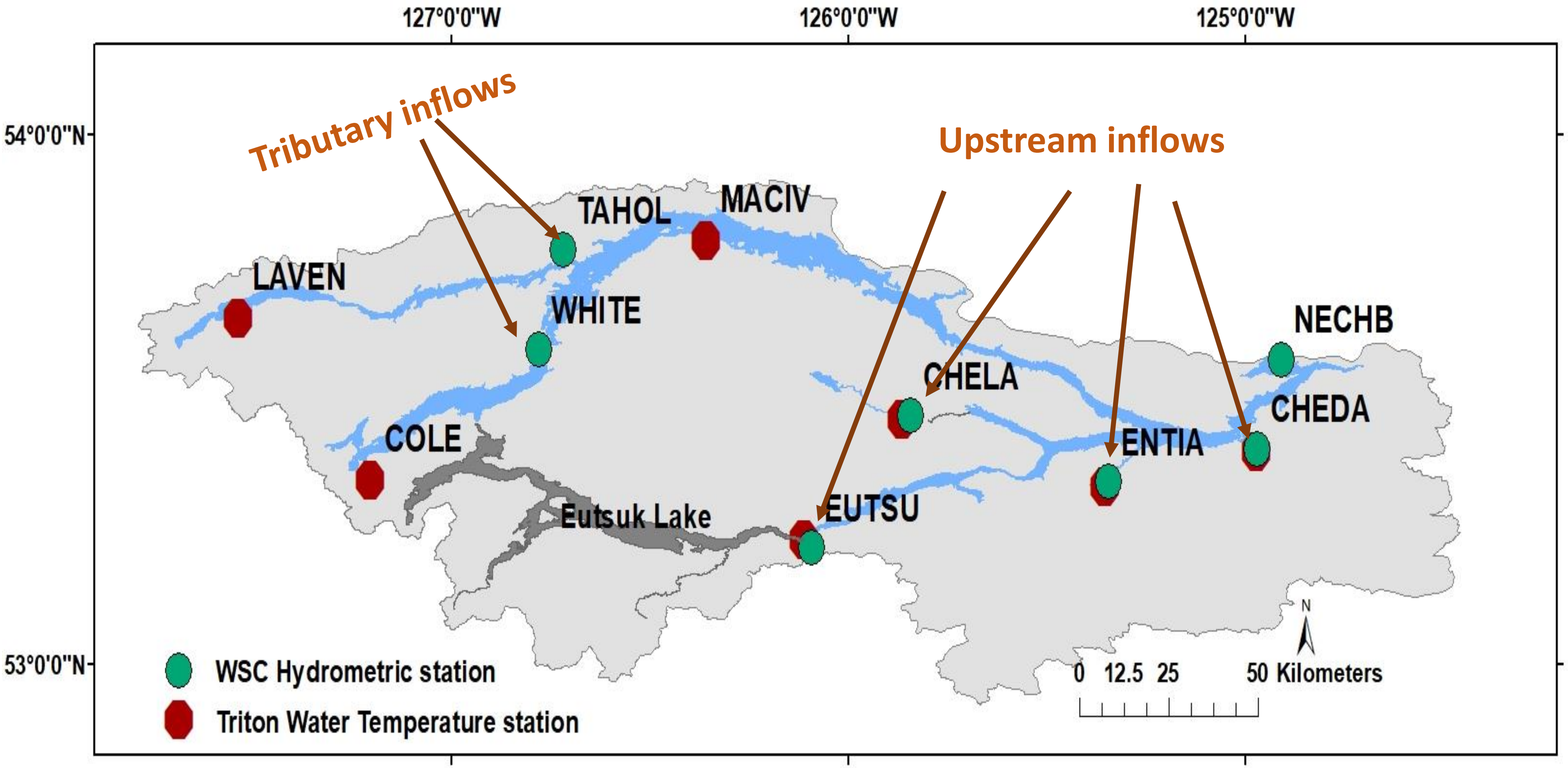
3-hourly Wind speed Average (August, 1945-2018)



CE-QUAL-W2 set up

CE-QUAL-W2 Boundary Conditions

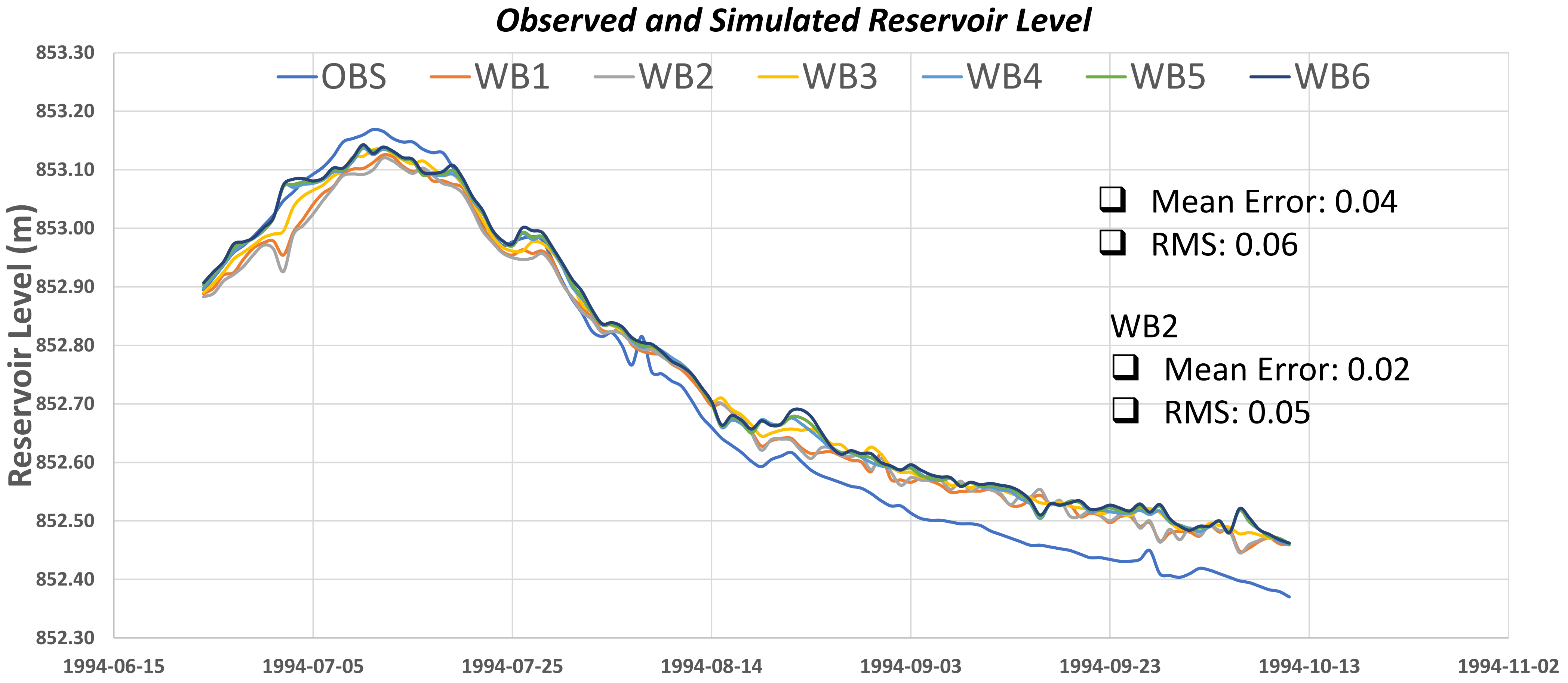
Nechako Reservoir Inflows boundary conditions



CE-QUAL-W2 set up

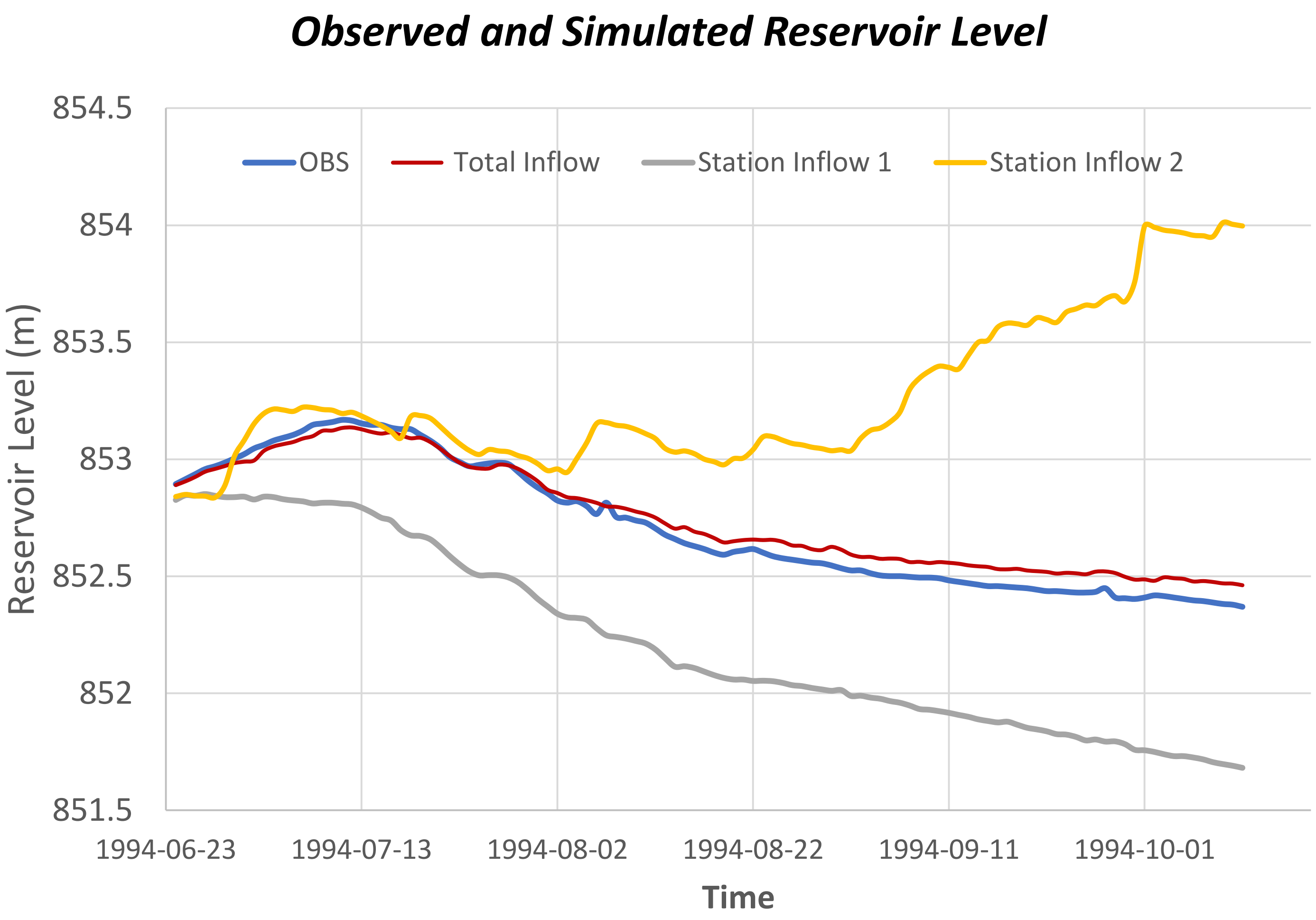
CE-QUAL-W2 Computational Grid Validation

- Evaporation and precipitation are not included in the water balance.
- Average water balance correction is -1.29 m^3/s.



NEXT STEPS

- Understanding the contribution and distribution of precipitation and inflows at identified stations to the Reservoir storage.



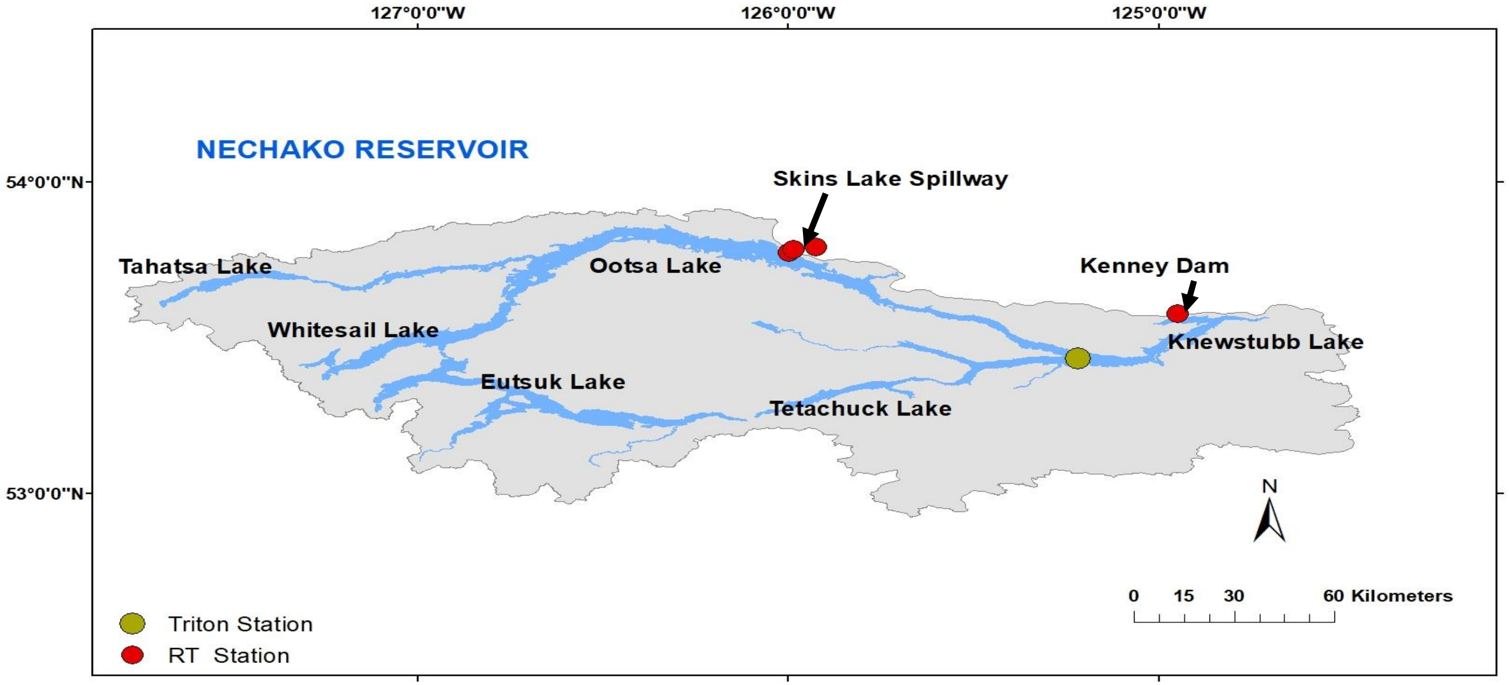
Model is supplied with :

- Calculated total inflows => Total Inflow
- Observed inflows at stations in the south east part of the reservoir with
  - Precip and EVAP not included in the water balance => Station Inflow 1
  - Precip and EVAP included in the water balance =>Station Inflow 2

NEXT STEPS

- Calibrate VIC-GL-RBM and CE-QUAL-W2/GLM simultaneously via a multi-objective approach including reservoir level and water temperature:
  - Calibration period late June to mid October 1994 using Triton stations
  - Validation using RT stations 2016-2017

Water Temperature Profile Stations



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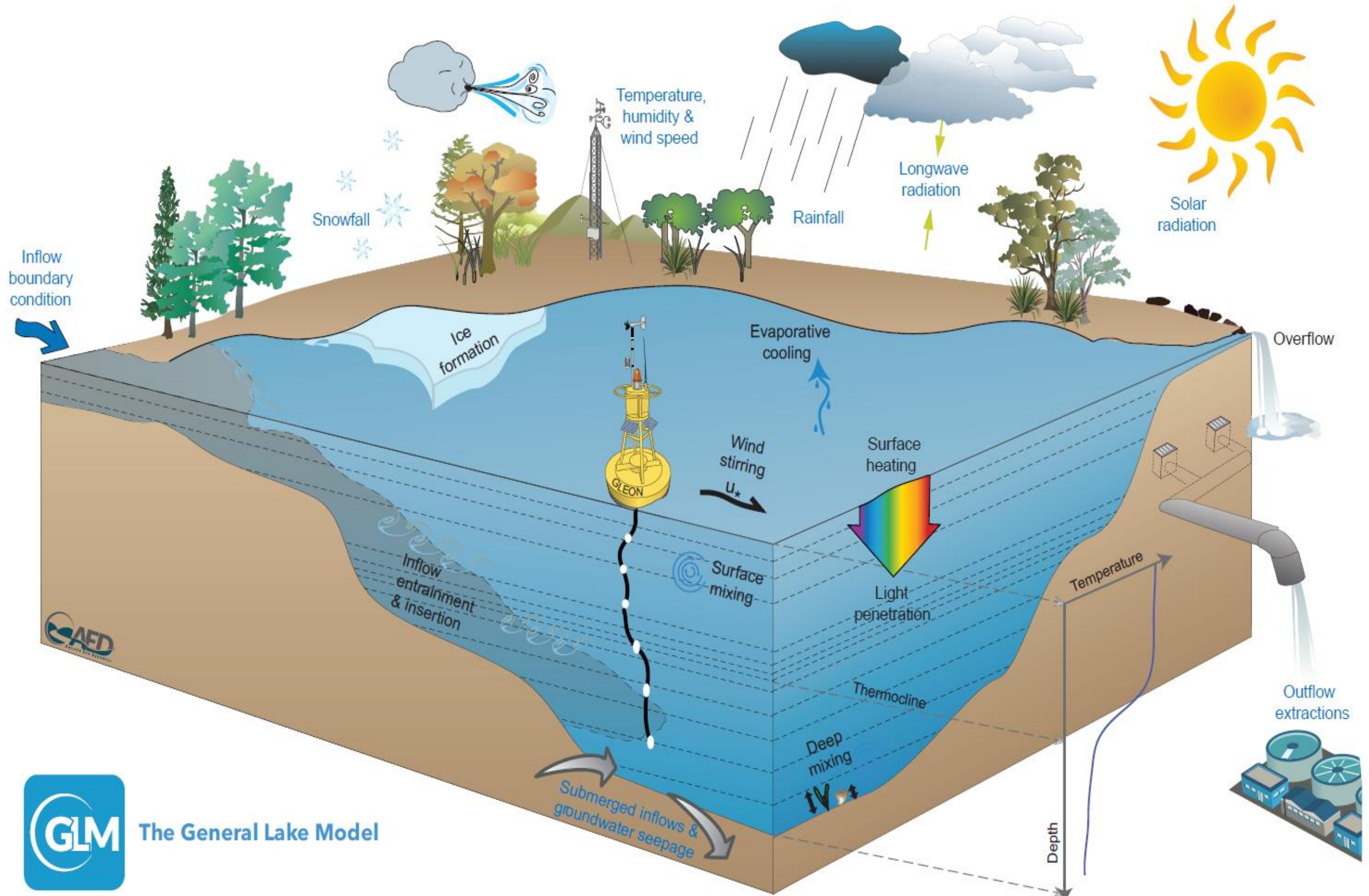
  - Validation using RT stations 2016-2017

- Boundary outflow conditions:
  - Model the gates in CE-QUAL-W2
  - Future scenarios of outflows (powerhouse)

GENERAL LAKE MODEL

- 1D open source Hydrodynamic model resolving vertical series of layers (Hipsey et al. 2019)
- It supports:
  - Multiple inflows and outflows
  - Ice cover calculations
- Required forcing inputs and boundary conditions:
  - **Bathymetry** required as surface elevation relationship
  - **Met data**: Tair, Relative humidity, Wind speed, ,
    Cloud Cover, Shortwave Solar radiation, longwave Solar radiation
  - **Flow data** : inflows, inflows temperature, outflows

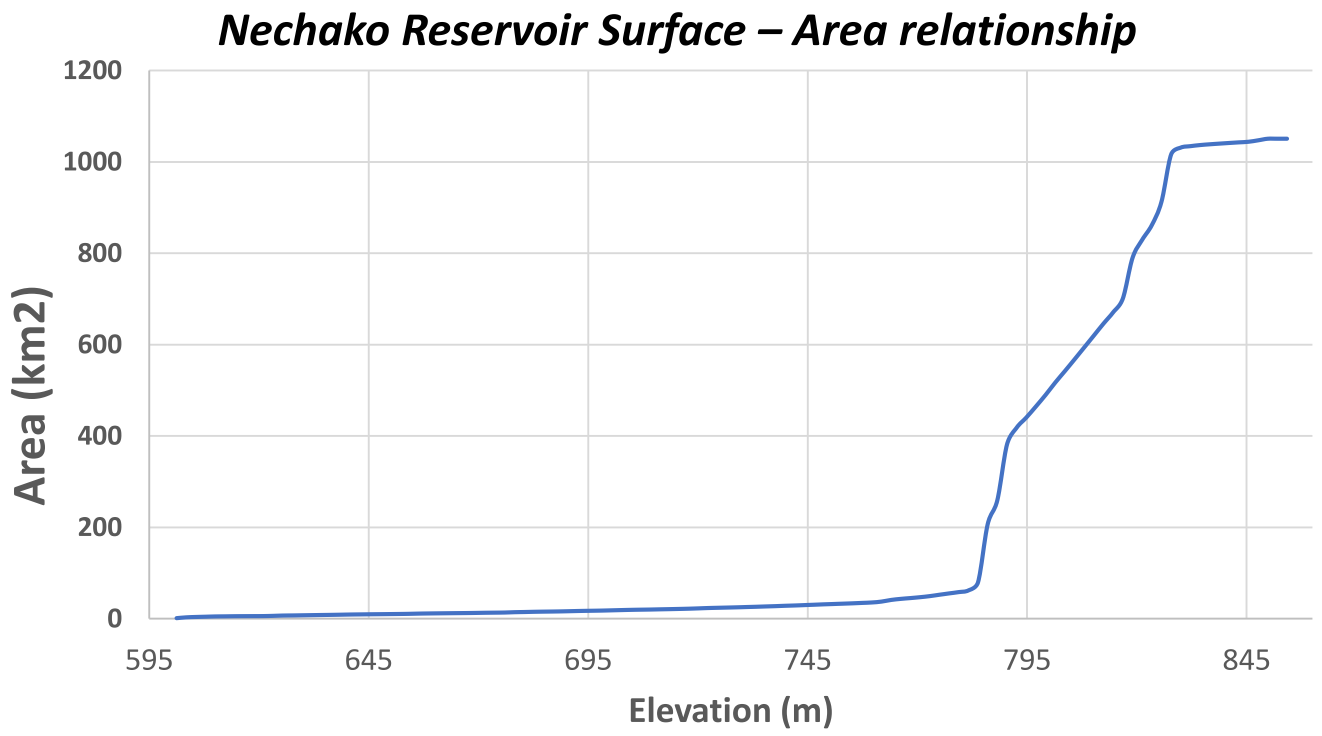
GLM Schematic domain



Source Hipsey et al. (2018)

GLM set up

- Surface-Area relationship is estimated from bathymetry used by CE-QUAL-W2 model.
- Meteorological forcing inputs are extracted at the spillway station.
- Supplied inflows depends on the simulated inflows by VIC-GL compared to total inflows.



References

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- Hipsey, M.R., Bruce, L.C., Boon, C. et al. 2017. A General Lake model (GLM 2.4) for linking with high-frequency sensor data from the Global lake Ecological Observatory Network (GLEON). Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2017-257.
- Hipsey, M.R., Bruce, L.C., Boon, C. et al. 2019. A General Lake model (GLM 3.0) for linking with high-frequency sensor data from the Global lake Ecological Observatory Network (GLEON). Geosci. Model Dev., 12, 473–523, 2019.
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