

Klamath River Basin **Revised Natural Flow Study**

November 2 – 3, 2022 Stakeholder Workshop **Reservoir Evaporation Modeling**

Outline

- Model Purpose
- Model Selection
- Input Data
- Methodology
- Natural Flow Representation
- Sensitivity & Uncertainty Analysis

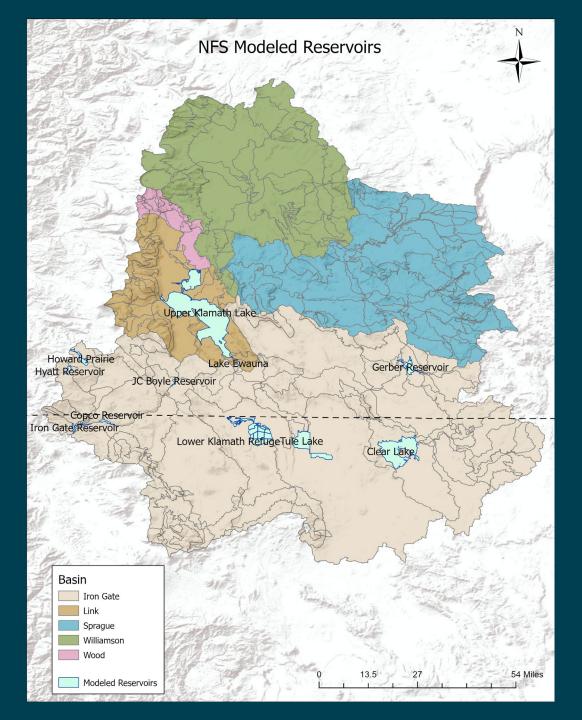




Model Purpose

 To quantify how open water evaporation rates have changed from current to preproject conditions.

Open Water Evaporation Primary Data Model/Data Export = Model = Products **Gridded Climate** Data Daily gridMET alfalfa gridMET: avg temp, Spatially averaged reference ET used to relative humidity & across waterbody disagaregate from Subtract out surface & monthly precipitation solar radiation monthly \rightarrow daily averages Average Depth: Daily **Daily Net** CRLE Mass Balance Water surface elevation Evaporation Evaporation Modeling Monthly (1981-2020) estimate Evaporation Rates Volumes (Riverware) 5", 25", 50", 75", 95[°] percentile Rates Held constant CAP [water surface elevation] throughout volume & area simulation duration Depth = Volume/Area **Hydraulics ACAPs Depth Exceptions** & water elevation Held constant (no water elev. Data): throughout timeseries LK NWR: Objective water levels & month/timestep staff gage heights observed Tule: range in avg. depths 0.5 -4 feet **Google Earth Imagery** Pre-development Conditions (Fish & Wildlife Service - Tule Remove Gerber, Copco, Iron Gate, NWR) & ESA max/min water surface (landsat/Copernicus) elevation guidelines JC Boyle, Hyatt, Howard Prairie, Monthly waterbody area [1984 Historical maps/ hydraulics modeling = - 2020] when no ACAPs/ outlining extent of clear lake, UKL, LKL elevation timeseries available Salinity (model is not sensitive Tule NWR: new avg. depth to this value until above 5000 ppm) All waterbodies set to 150 ppm (WWCRA 2015).



Model Extent

- Upper Klamath Lake
- Lower Klamath National Wildlife Refuge
- Tule Lake National Wildlife Refuge
- Clear Lake
- Gerber Reservoir
- Howard Prairie
- Hyatt Reservoir
- Lake Ewauna
- JC Boyle Reservoir
- Copco Reservoir
- Iron Gate Reservoir



Complementary Relationship Lake Evaporation (CRLE) model

• The CRLE model accounts for water temperature, albedo, emissivity, and heat storage effects to estimate monthly surface water evaporation.



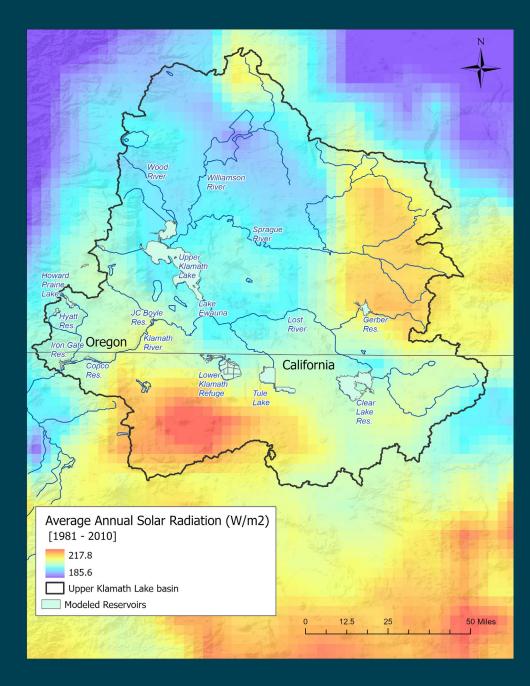
PET ~ estimated from converging solution of energy balance and vapor transfer equations

Lake Evaporation (wet-environment E) ~ estimated using a modified Priestly-Taylor eqn that takes into account heat storage [depends on solar and waterborne energy inputs from previous months – net available energy where delay times are estimated using depth and salinity]



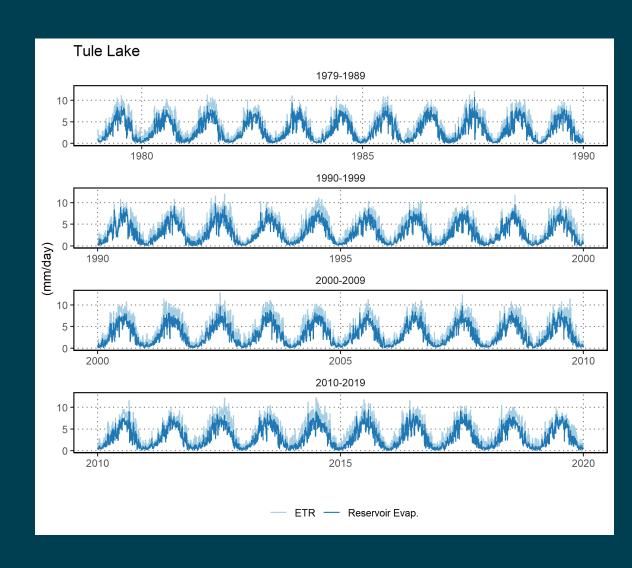
Input Data

- gridMET: monthly avg. temp, solar radiation, & relative humidity
- Salinity
- Average reservoir depth (held constant throughout simulation)
 - Estimated 5th, 25th, 50th, 75th, 95th percentile of water surface elevation timeseries [1980-2020]. ACAP then used to calculate volume at respective water surface elevation. Depth = volume/area.
 - Tule: 0.5ft 4ft avg. depth range for Sump 1A and 1B (CCP Appendix F).
 - Lower Klamath NWR: area-weighted depths were determined based on objective water levels & staff gage heights for each relevant section (seasonal and permanent wetlands only) of the refuge.

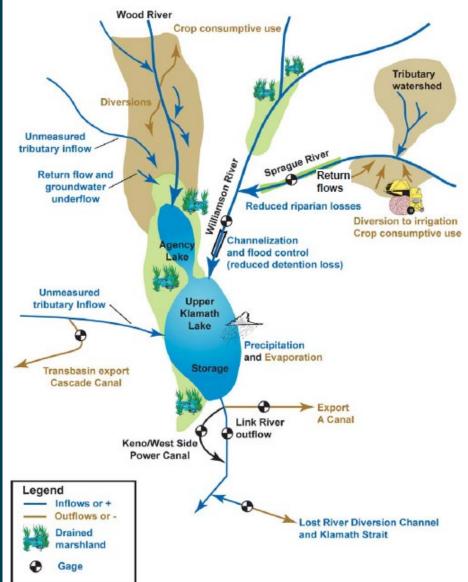


Model Methodology

- No calibration needed two constants in the modified Priestly-Taylor equation were 'once calibrated' using water-budget estimates of lake evaporation from seven lakes situated throughout the United States.
- Dissaggregation from monthly to daily evaporation estimates – using daily gridMET ETr as a training dataset
- Volumetric Evaporation (in RiverWare): areas estimated using ACAP/water elevation timeseries or remotely sensed imagery







2005 Natural Flow Study Conceptual Model Comparison to 2005 Natural Flow Study

2005 study 'Natural Lake Simulations'
Monthly water budget approach for UKL (only) accounting for inflow, storage & outflow.

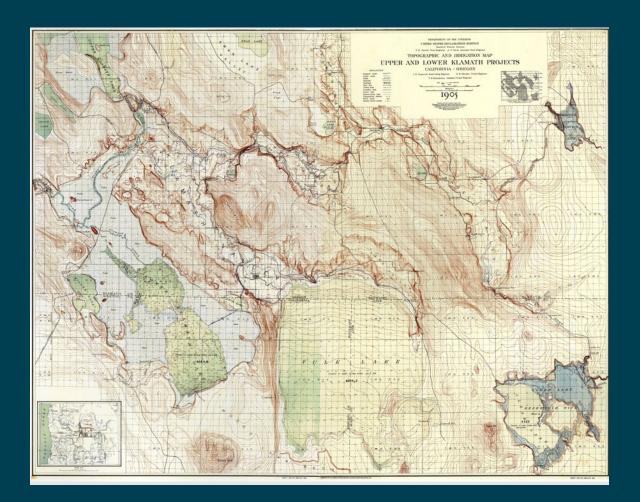
 Open water evaporation estimated using the Hargreaves eqn. (uses air temp. & latitude)



Natural Flow Representation

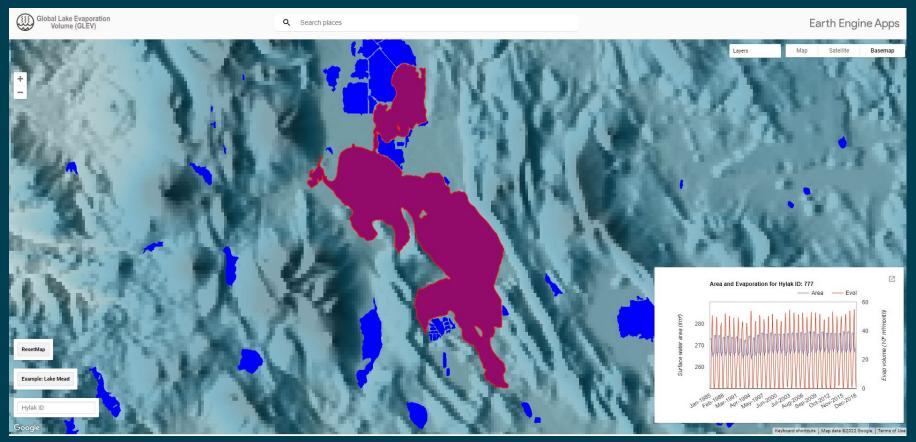


- Remove all reservoirs: Gerber, Copco, Iron Gate, JC Boyle, Hyatt, Howard Prairie
- Re-estimate average depths of natural lakes from hydraulic modeling & historic maps: Clear Lake, UKL, Lower Klamath Lake, Tule Lake.
- (In Riverware) Waterbody areas (for volumetric evap) estimated from historic maps, assume stationary?



Sensitivity & Uncertainty Analysis

- CRLE is most sensitive to average depths. Ran model at 5th, 25th, 50th, 75th, and 95th avg. depth percentiles.
- Will compare to the new 'glev' (global lake evaporation volume) remotely sensed reservoir evaporation dataset.



*Zhao et al. 2022. Evaporative water loss of 1.42 million global lakes. Nature Communications.



Summary

- Used the CRLE model to simulate open-water evaporation rates
 - Datasets include gridMET climate data, ACAP, water elevation timeseries
 - Dissaggregate monthly evaporation rates to daily using gridMET ETr
- Improved upon the 2005 Study by:
 - Using an energy-aerodynamic approach for estimating reservoir evaporation
 - Modeling open-water evaporation at all large bodies of water that have changed between pre-project and current conditions
 - Daily timestep
- Natural flow represented by:
 - Removing all man-made reservoirs
 - Calculating pre-project average depths for all natural lakes



*Upper Klamath Lake (<u>https://www.flickr.com/photos/usbr/</u>)





Questions and Additional Discussion

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