Hydrological Alterations in Eagle Lake and Pine Creek, CA and Potential Implications on Rainbow Trout

SWATplus Hydrological modelling




Wubneh B Abebe (PhD)

Postdoc researcher at the University of Nevada, Reno (UNR)

Prof. Sudeep Chandra, Prof. Erin Hanan

Global Water Center (GWC) and Lake Tahoe Institute for Global Sustainability

SWAT Conference 2025

CSU, Fort Collins

October 20-24, 2025

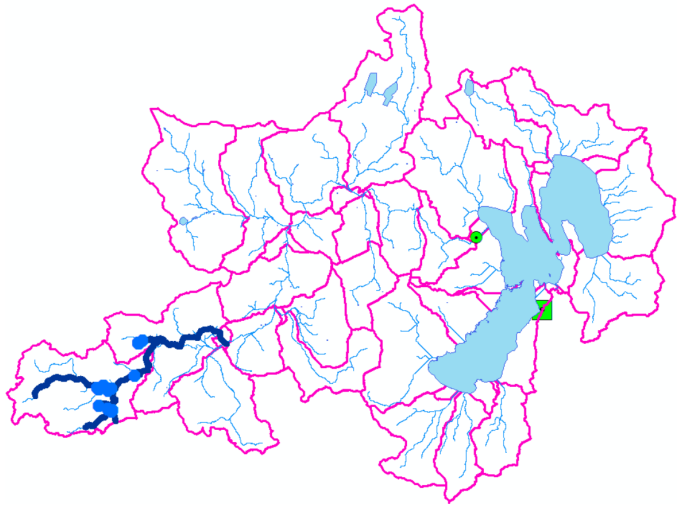
Content

- Background + Objective
- Modeling framework
- Data collected
- Modeling result
- Conclusions

Background

- Eagle Lake rainbow trout (*Oncorhynchus mykiss aquilarum*) are endemic to Eagle Lake and Pine Creek, CA, but are endangered due to habitat degradation and water diversions.
- Habitat issues stem from logging, grazing, water diversions, railroads, and roads, compounded by climate change affecting lake levels and flow conditions.
- Historically, Pine Creek was the primary spawning ground, but extremely low lake levels in the 1930s and 1940s led to fears of extinction.
- A weir was installed on Pine Creek in the 1950s to collect eggs and milt for hatchery rearing, and to replant trout into Eagle Lake and other waters

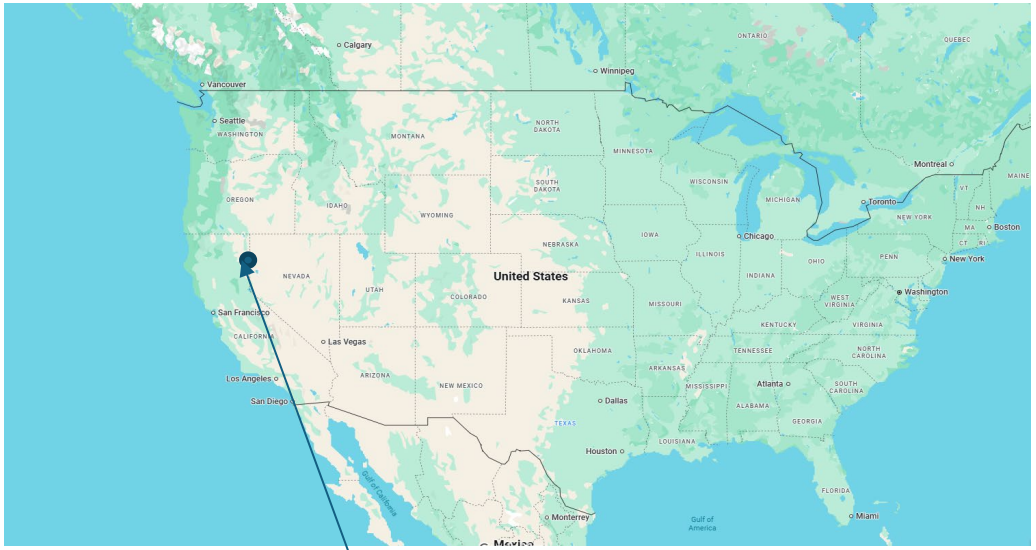
- **Natural reproduction is hindered by a fish weir and intermittent Pine Creek flows**
- **Modifications to the fish weir in 2012 aimed to improve trout access to Pine Creek, but hydrological issues like disconnected flow and watershed degradation still threaten natural breeding.**
- **Objective: to investigate the hydrological alterations in Pine Creek and Eagle Lake** due to water diversion, increased evapotranspiration (dense vegetation), and watershed degradation**.**
  - **Model the historical flow of Pine Creek at different locations of the watershed**
  - **Look at flow trends and water balances of the watershed**
  - **Potential impacts on Eagle Lake Rainbow Trout**

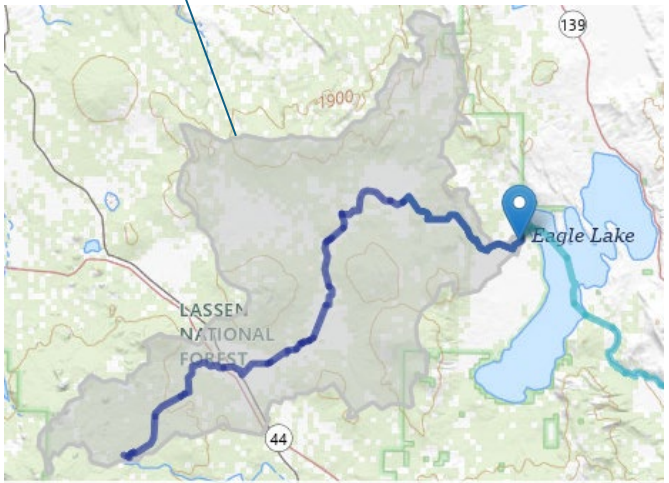


SWAT+ Model

Study area description

- Eagle Lake: Endorheic lake in Lassen County CA
  = 38 sq.mile (99 sq.Km)
- Major tributary: Pine Creek watershed = 226 sq.m. (585 sq.Km.)
- The whole Lake wsd = 424 sqm (1098 sqkm)
- 2 Gage stations – at Spaulding (mouth) and Bogard (upstream)
- And, 6 proposed gage stations – under establishment





SWAT+ Model

SWAT+ Modeling approaches

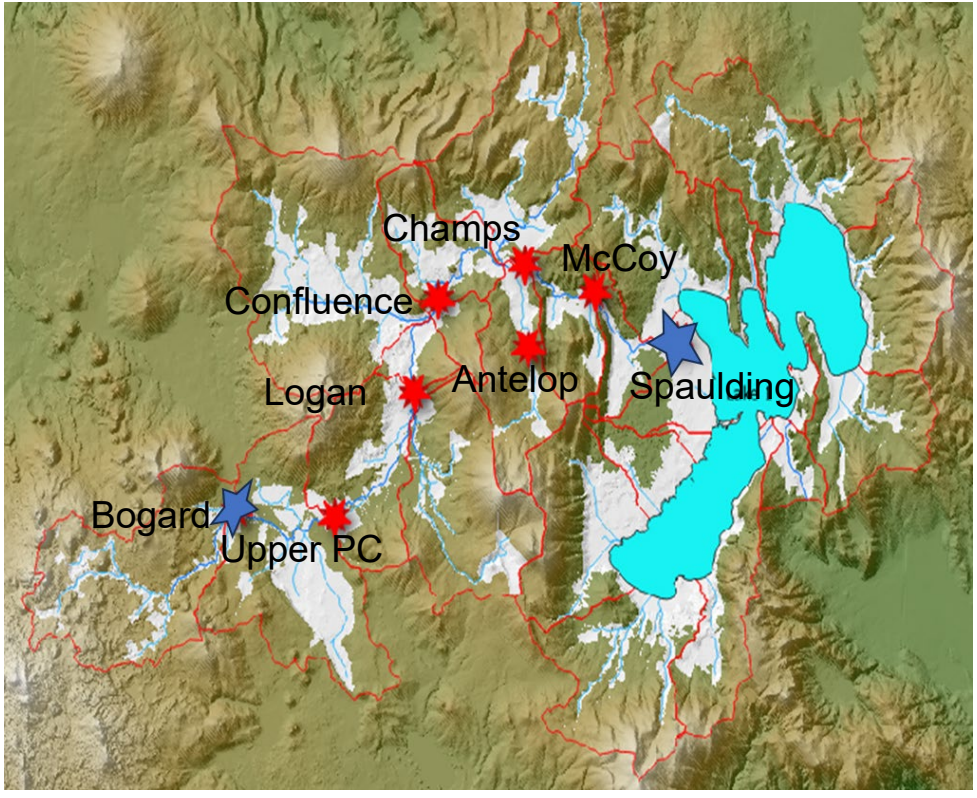
- **Data collection and preparation –**

✓ DEM, land use/land cover maps, soil maps, climate data and historical streamflow data of Pine Creek

- **Model sensitivity, calibration and validation –**

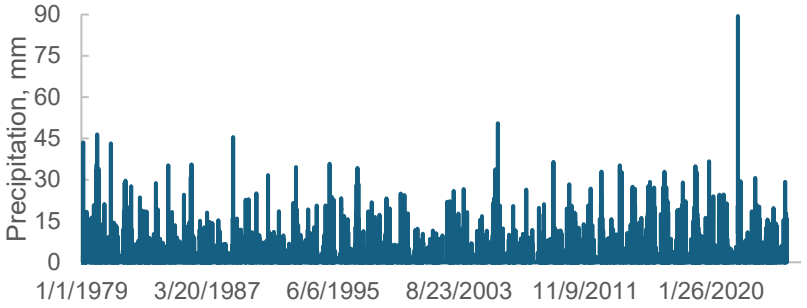
✓ QGIS3.34.13 environment and QSWAT+ 3.0.8 software
✓ SWAT+ rev61.0.1., SWAT+ Toolbox 2.4
✓ define hydrological response units (HRUs) based on 10m resolution DEM/slope, soil, LULC
✓ Penman-Monteith for ET and a variable storage method for routing
✓ 19 parameters, 1080 samples for sensitivity, 100-500-500 samples for calibration
✓ performance metrics - Nash-Sutcliffe Efficiency (NSE), RMSE, and Percent Bias (PBIAS)

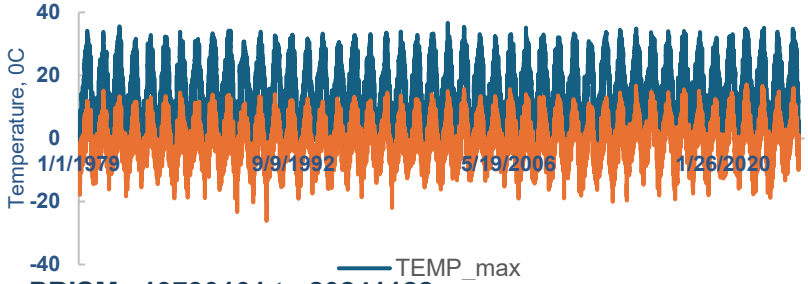
- **IHA software for ecologically relevant flow statistics – low/high flow**

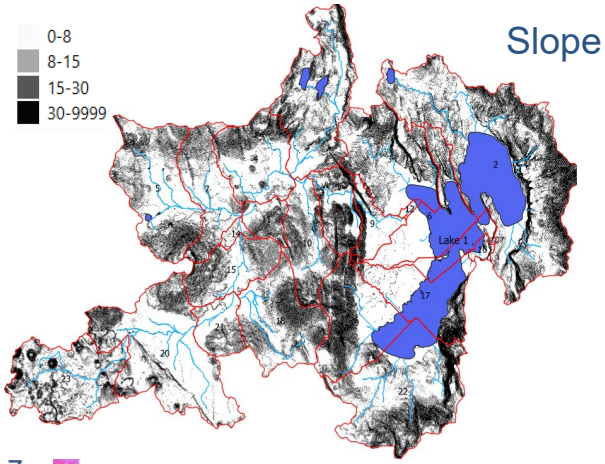


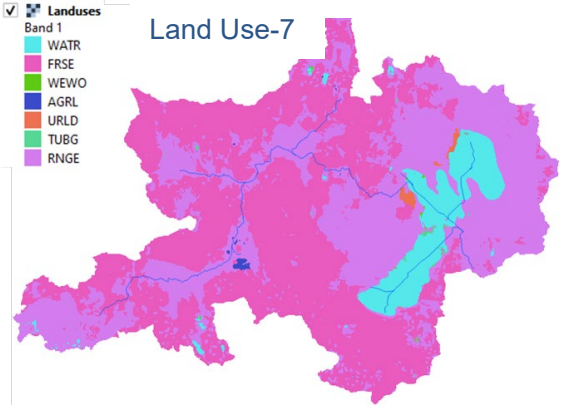
SWAT+ Model

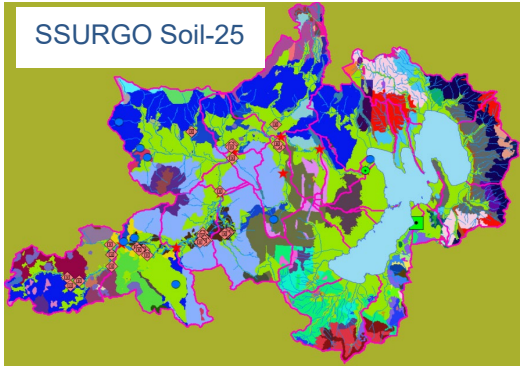
Input Data: Weather, Topography, Land Use and Soil







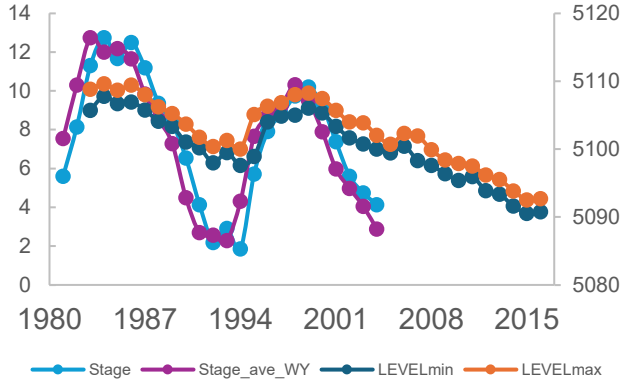


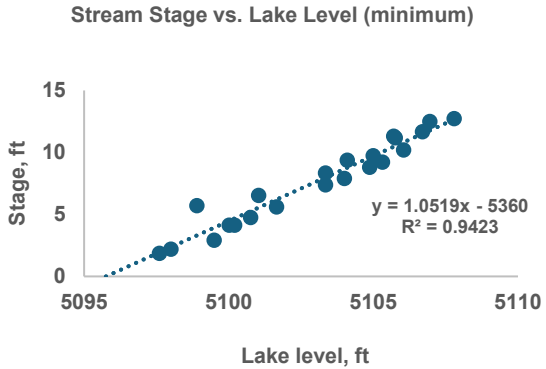


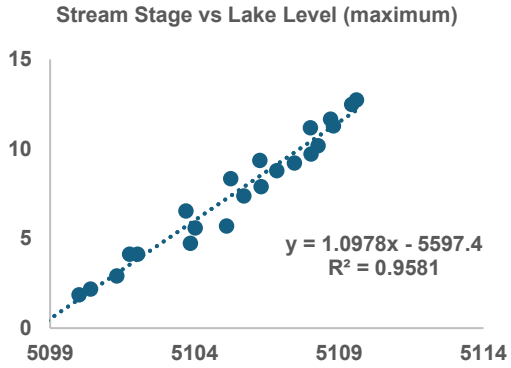
- **PRISM– 19790101 to 20241122**
- **Historical maximum daily PCP 89 mm; ann$_{max}$ 1119mm**
- **Annual average PCP 650mm**
- **Historical maximum daily T^0 36 ^{0}C**
- **Historical minimum daily T^0 -26 ^{0}C**

SWAT+ Model

Evaluating the connection between streamflow (stage) and lake le dynamics given uncertainty between surface and groundwater inflows







$Corr_{min}$ = 0.97

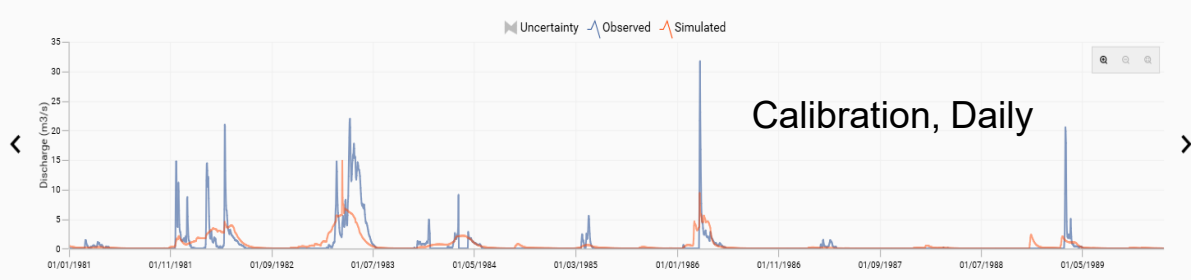
$Corr_{min}$ = 0.98

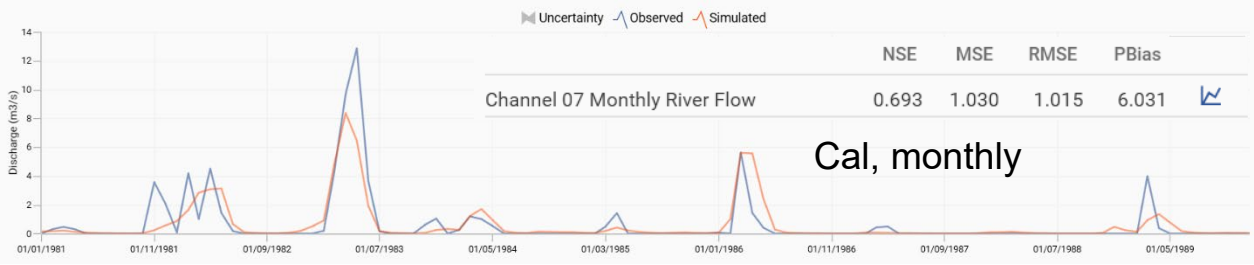
- **Streamflow: oct 1981 – Jun 2004**
- **Lake level: 1983 - 2016**

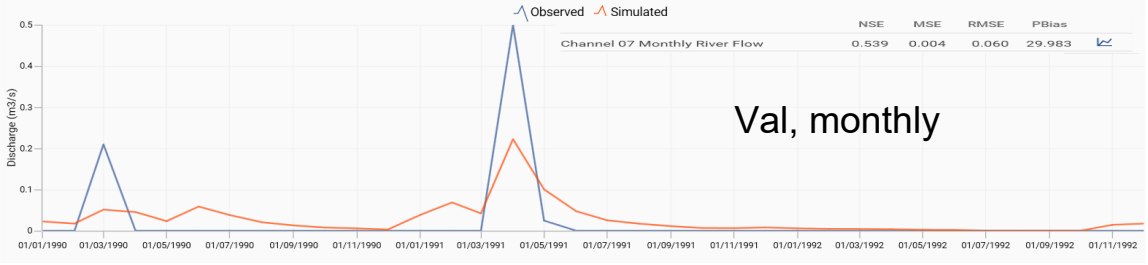
SWAT+ Model

Model Outputs: Sensitivity, Calibration and Validation

- **Only three of the 19 parameters are not found sensitive**
- **Calibration: NSE 0.4 for a daily time step and Monthly NSE 0.70, RMSE 1.015 and PBias 6.031**
- **Validation: NSE 0.54, RMSE 0.06 and PBias 29.983**





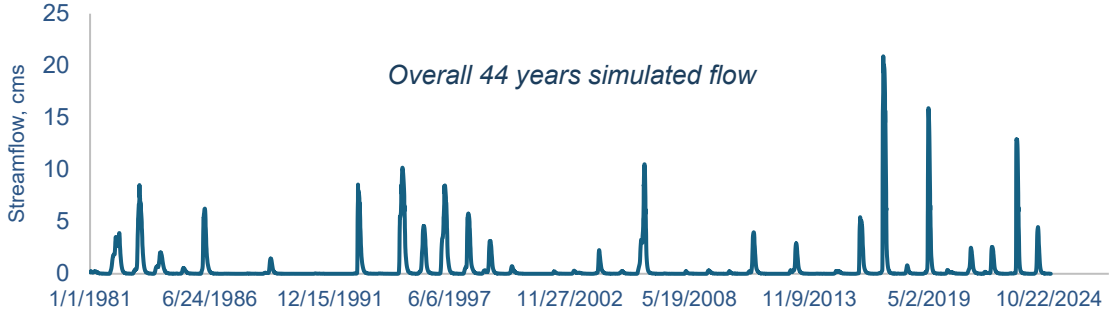


SWAT+ Model

Model OutputsSimulated Streamflow

- **Historical maximum flow found 21 m^3/sec in 2017**
- **Historical Ave. flow is 0.54 m^3/sec**
- **Median flow 0.02 m^3/sec**

➢ **Very small overland flow in the Pine Creek; having about 600 sqkm watershed**

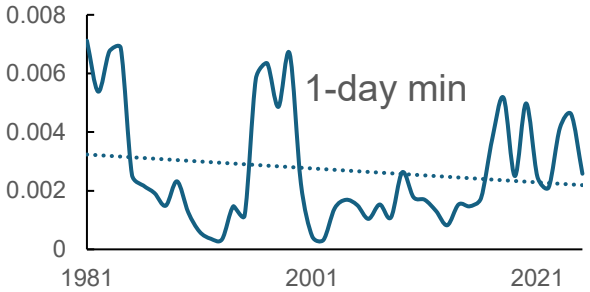


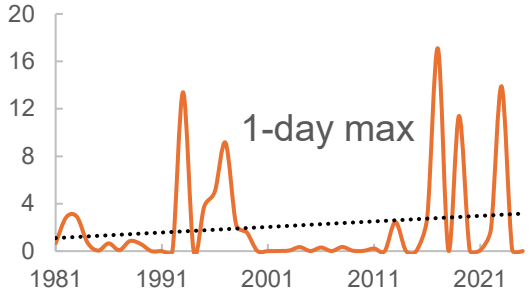
SWAT+ Model

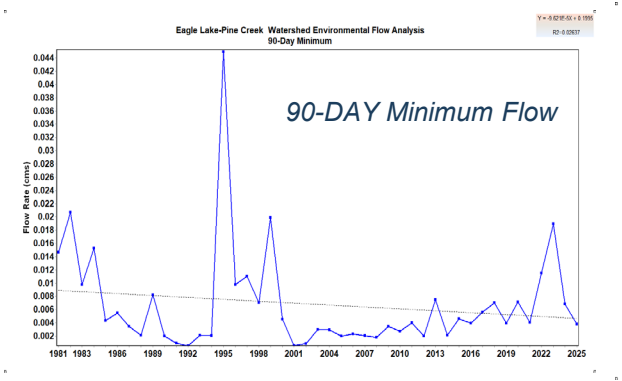
Model OutputsLow and High flows

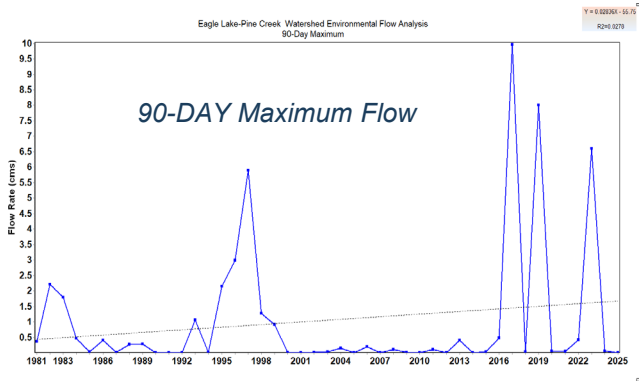
- **Low flows decreased for all durations; whereas, High Flows showed increase**

➢**Because of: High ET, prolonged dry season, snowmelt shift**





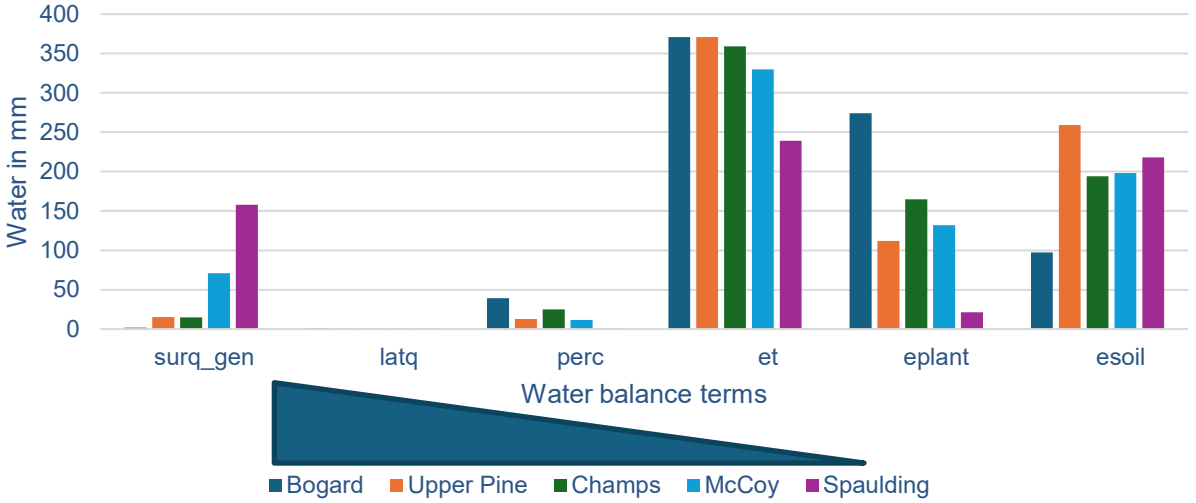




SWAT+ Model

Model Outputs: Water Balance at Subbasins Level

- Surface runoff (SurQ) increased downstream
- Lateral flow (LatQ) decreased downstream
- Percolation(Perc) decreased downstream
- Evapotranspiration (ET) decreased downstream
- Most of the water being lost upstream via ET
- And, although seems small, percolation is also high U/S
- This has contributed to disconnection of flow in the middle reach

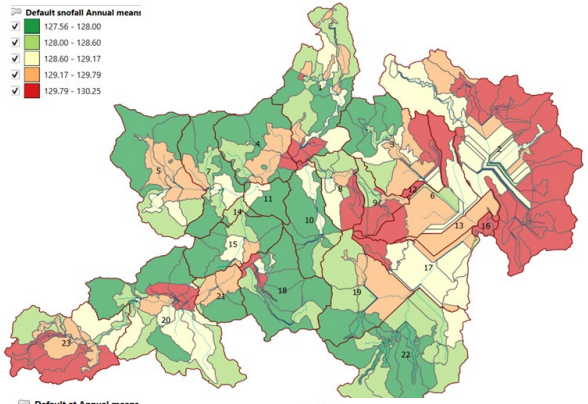


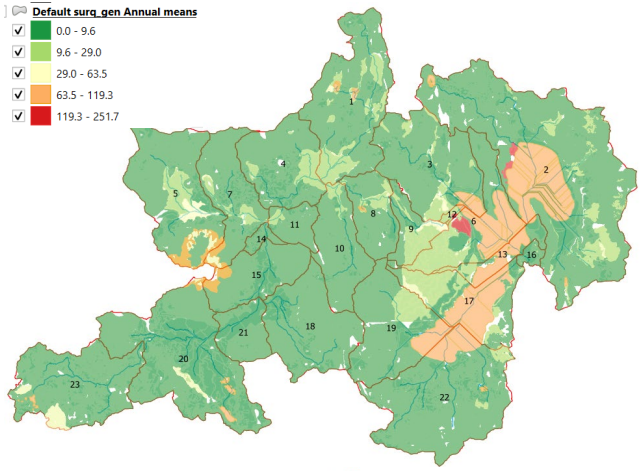
Subbasin	name	precip	snofall	snomlt	surq_gen	latq	wateryld	perc	et	eplant	esoil
Bogard	rtu0531	397	271	270	1.87	1.06	2.93	39.2	371	274	97.2
Upper Pine	rtu0221	397	271	270	15.2	0.201	15.4	12.7	371	112	259
Champs	rtu0151	397	271	270	15	0.482	15.5	24.9	359	165	194
McCoy	rtu0101	397	271	270	70.9	0.343	71.3	11.6	330	132	198
Spaulding	rtu0051	397	271	270	158	0.16	158	0.468	239	21.3	218

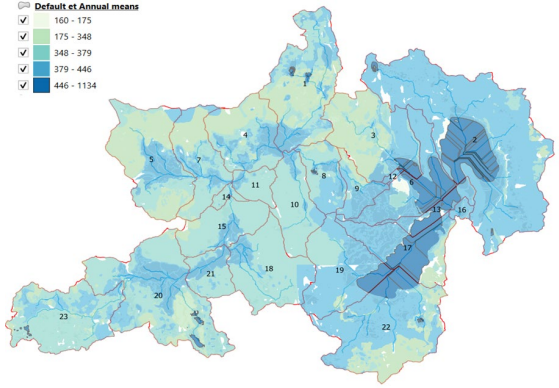
SWAT+ Model

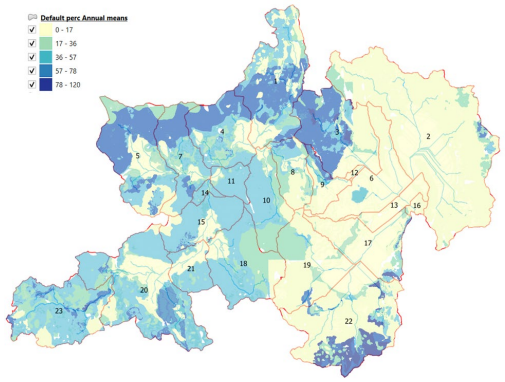
Model Outputs: Spatial Distribution of Water Balance Terms

- Snowfall accumulation is a little bit higher in the upper reaches above Bogard and Northern watershed
- Surface runoff (SurQ) low in most areas
- Percolation(Perc) high in the upper reaches
- Evapotranspiration (ET) is high on meadow areas, on and around the lake





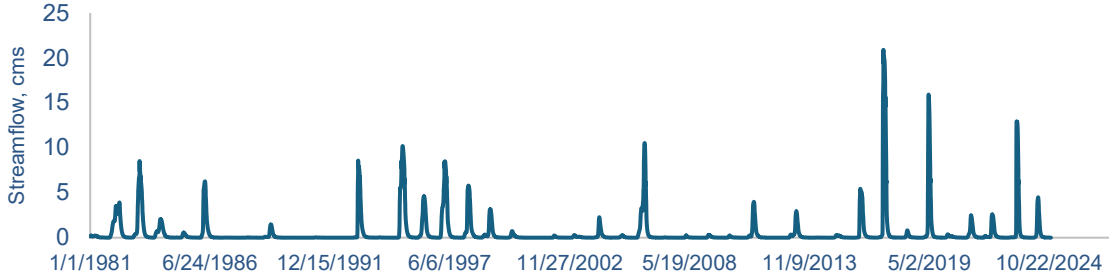




SWAT+ Model

Model OutputsLand Use Change

- 1985 land use was used
- No major fire event in the 1980s
- Most Land conversions were to a few thousands of forest or range land
- Only 188 ha farmland found as a new land use in 2023
- NSE 0.372 for daily, 0.57 for monthly
- There is no significant change in stream flow between 1985 and 2023 land use



		2023							
		Bare land	Built-up Area	Evergreen Forest	Flooded Vegetation	Open Water	Range land	Farm land	Grand Total
1985	Barren Land	4.78	0.19	14.15	0.20	0.56	277.94	0.02	297.8
	Developed/ built-up	2.15	87.15	1981.28	0.00	4.85	727.73	0.67	2803.8
	Forest	2.10	36.37	46571.36	0.49	24.85	13125.9	4.77	59765.8
	Wetlands	0.69	8.74	270.04	30.95	179.95	2135.27	13.37	2639.02
	Open Water	126.1	32.96	2.50	33.37	8443.2	1786.28	0.02	10424.4
	Shrub/Scrub	38.52	207.10	7709.22	0.42	46.33	27825.2	159.56	35986.4
	Grassland	1.20	0.57	304.77	0.23	3.50	852.10	9.81	1172.2
	Grand Total	175.5	373.08	56853.32	65.67	8703.2	46730.4	188.2	113089.4

SWAT+ Model

Summary and Inferences

- **Streamflow: The pattern of decreasing low flows and increasing high flows reflects the compounded effects of climate change, land use alterations, and water management practices; in this case**
  - increasing evapotranspiration under warming conditions
  - prolonged droughts or reduced precipitation during dry months
  - Snowmelt shifts: In snow-dominated regions, earlier or more rapid snowmelt due to warming can cause higher peak flows
- **Water balance across reaches downstream: showed distinct spatial patterns in hydrologic processes across the longitudinal profile**
  - Surface runoff (SURQ) increases progressively in the downstream sub-basins.
  - Lateral flow (LATQ) and percolation (PERC) both decrease with distance from the headwaters.
  - Total evapotranspiration (ET) and plant transpiration show a declining trend downstream.
  - Soil evaporation (Es), however, increases in the lower watershed.
  - The upper watershed—characterized by dense vegetation, shallower soils, and higher precipitation/snow accumulation—experiences greater water loss through ET, mainly via plant transpiration
- **Evapotranspiration (ET) constitutes the dominant component of water loss**
  - high vegetation density, such as upland forests
- **Early disconnection of Pine Creek flow due to water losses by ET and Percolation**
  - Impact on Rainbow Trout due to habitat loss, being the Creek is known to be a spawning ground
- **Land use management is essential**

Thank You!