Bedrock groundwater recharge, dynamics, and ages of headwater catchments, western Montana

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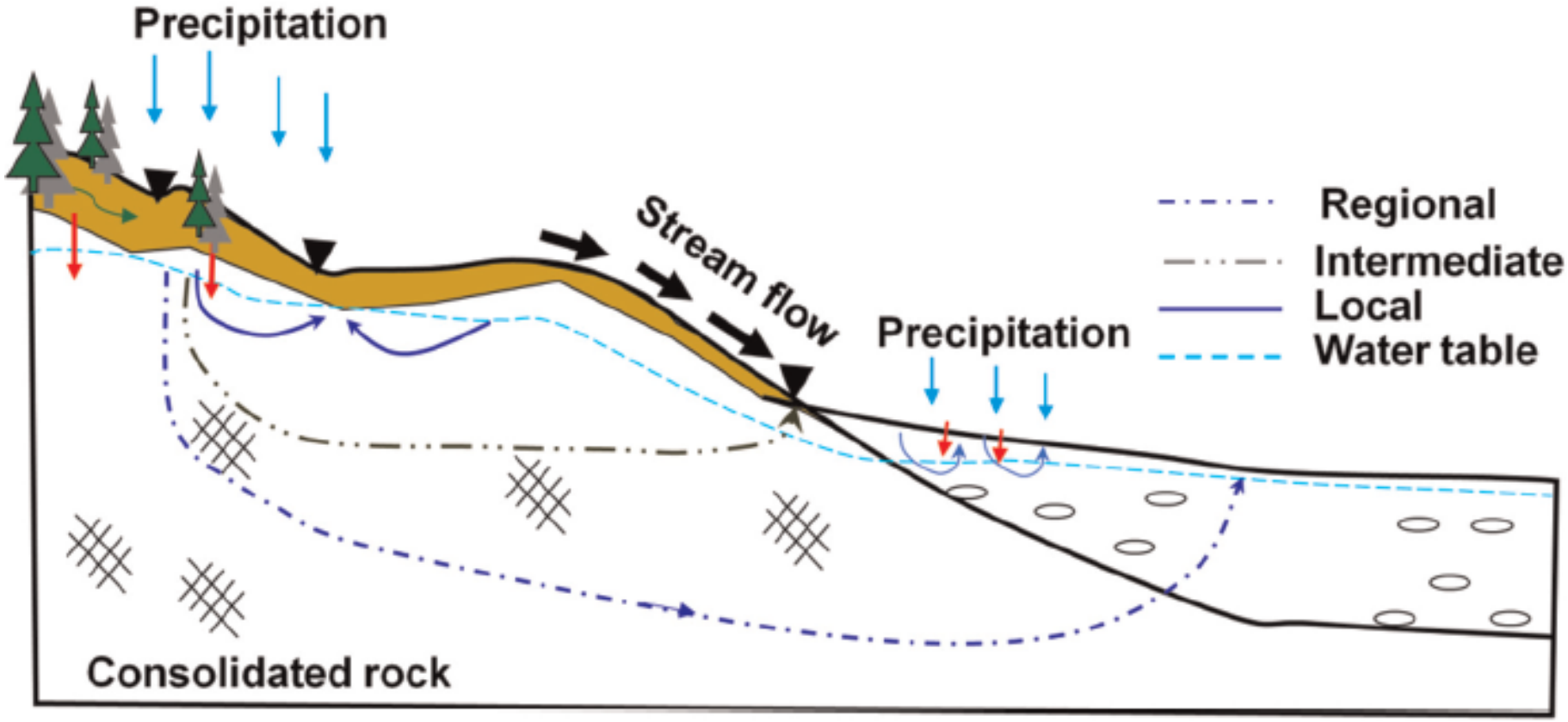
Mountainous headwater catchments



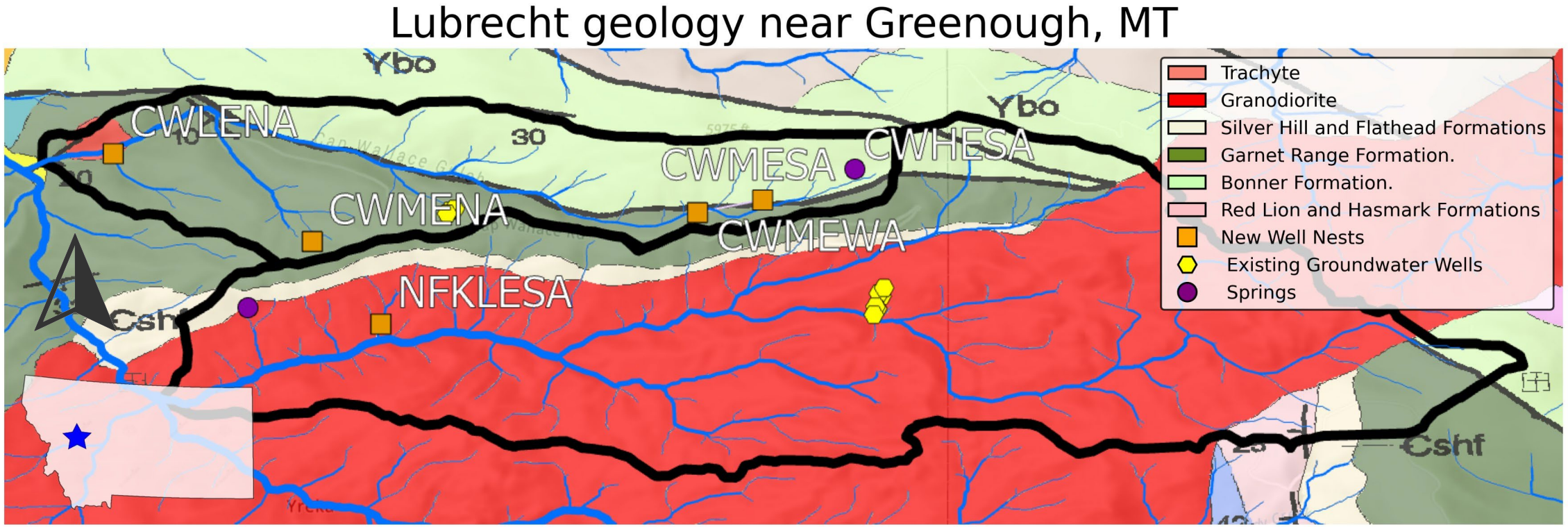
How will a reduced snowpack due to a warming climate affect bedrock groundwater recharge?

Conceptual model of groundwater recharge in a mountain block with permeable bedrock that allows for deep groundwater flow paths. From Ajami et al., 2011.

Research Question: How does bedrock groundwater characteristics vary across hillslope topographic positions?

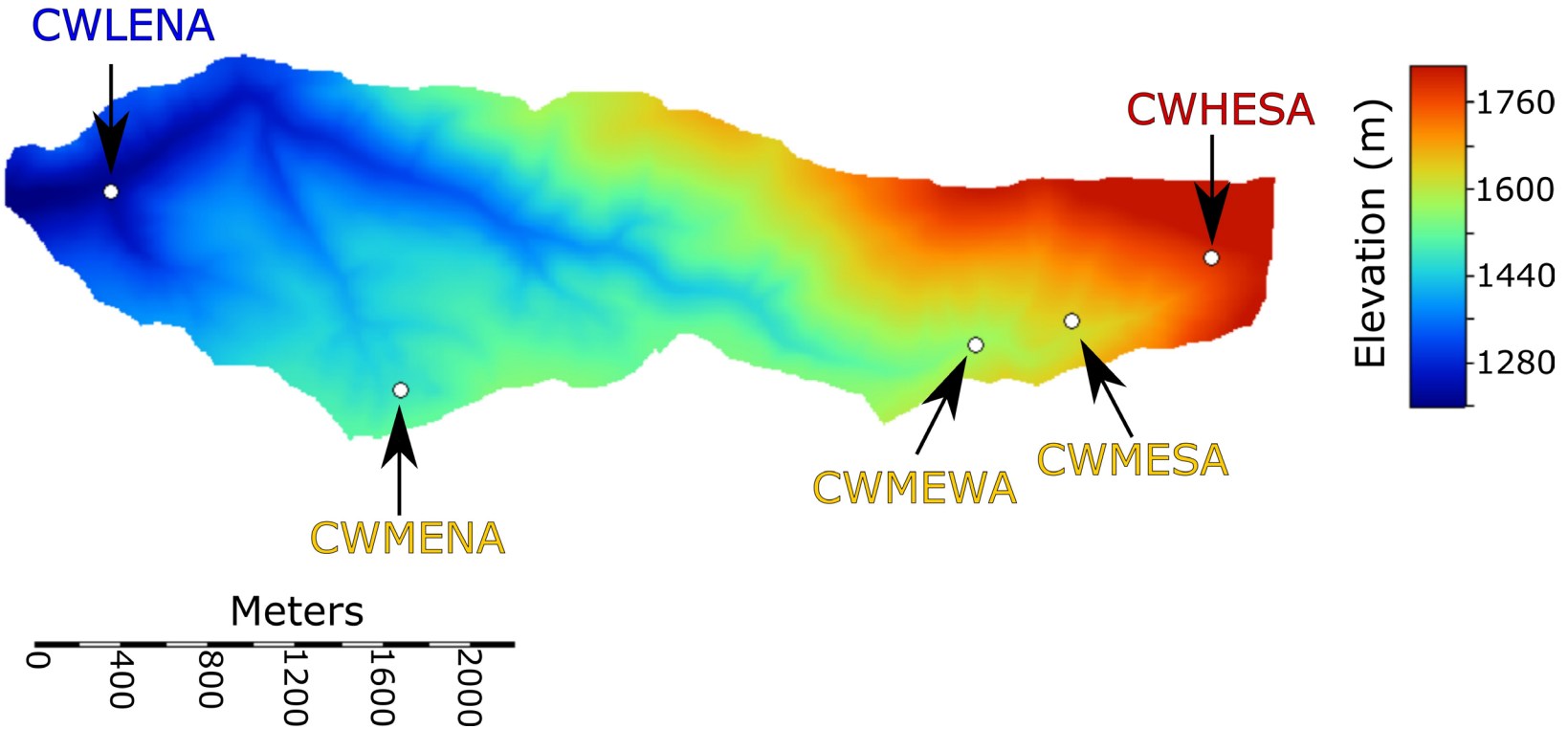
Hypothesis: Bedrock groundwater recharge, dynamics, and age mirrors the hillslope groundwater flow system.

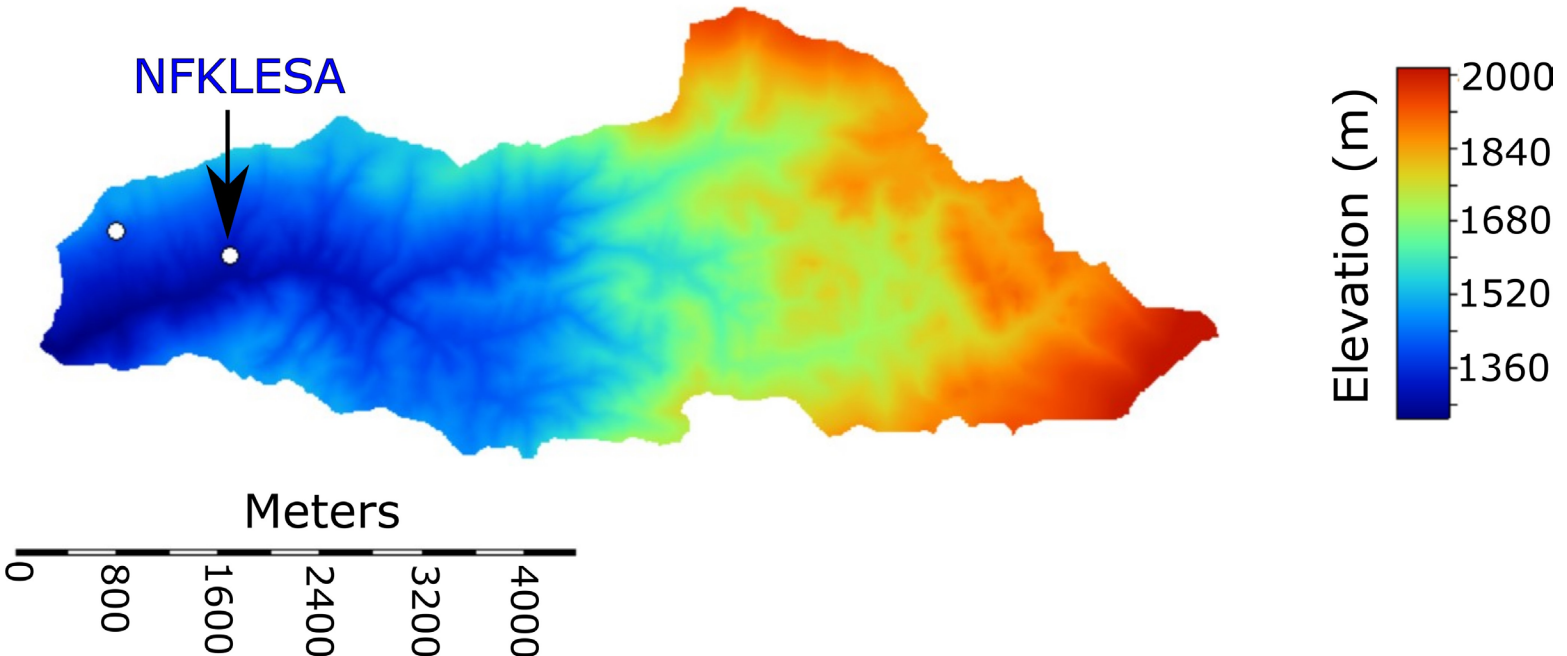
Study area



Geologic map of catchment areas, Cap Wallace (CW) and North Fork Elk Creek (NFK), with locations of well nests installed in May and June of 2022. Adapted from Lonn et al., 2010.

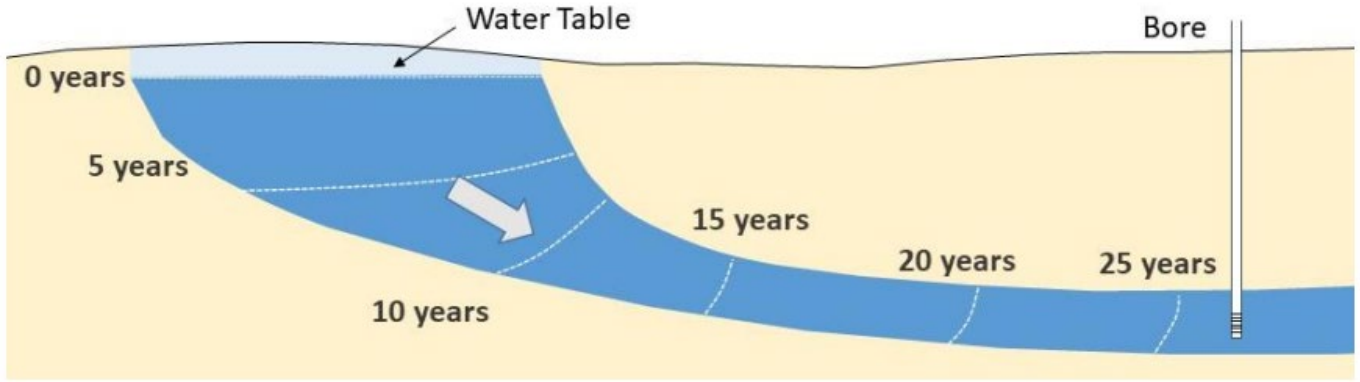
Study area



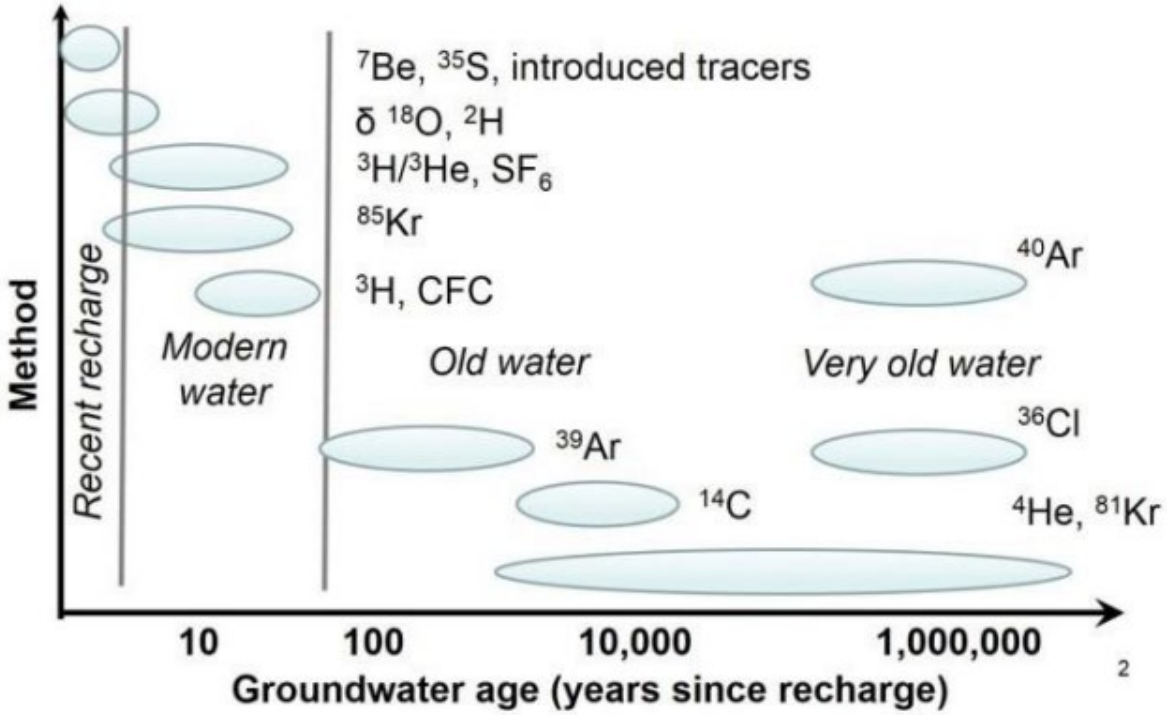


Elevation of catchment areas and well nests.

Methods

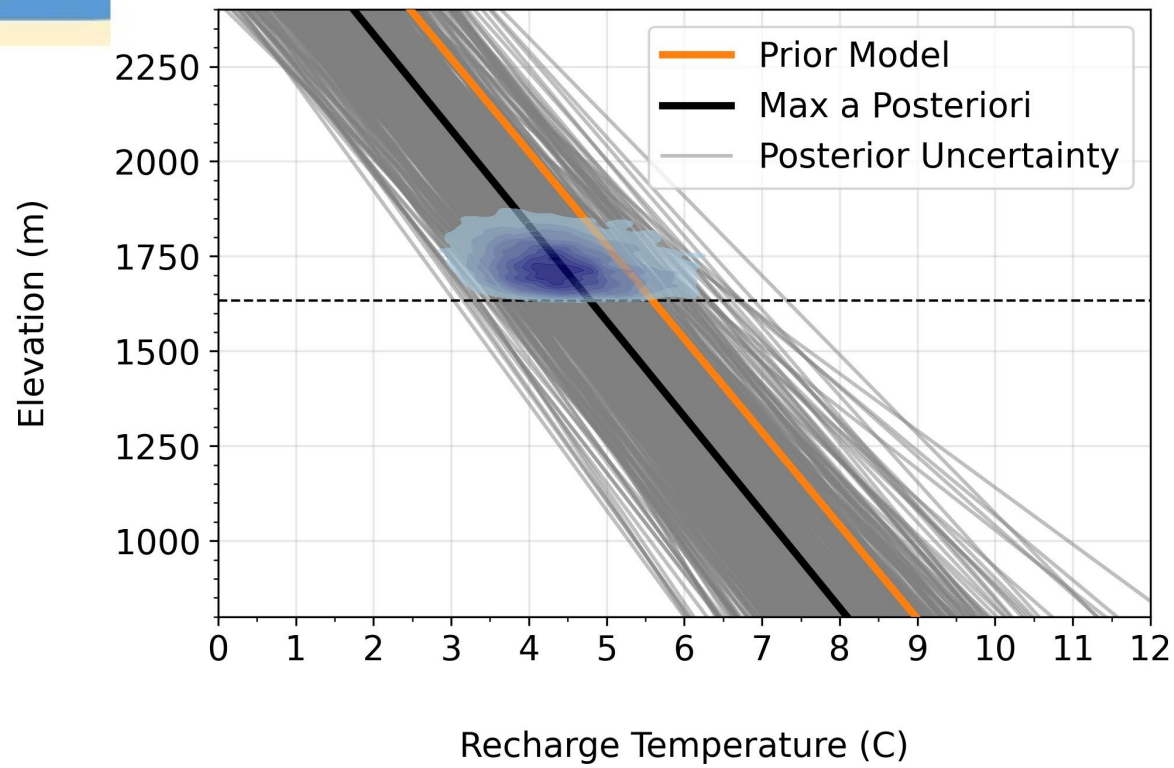


Simple aquifer schematic depicting groundwater age increasing with depth and distance from the recharge area to the point of sampling at a borehole. From Cook 2020.



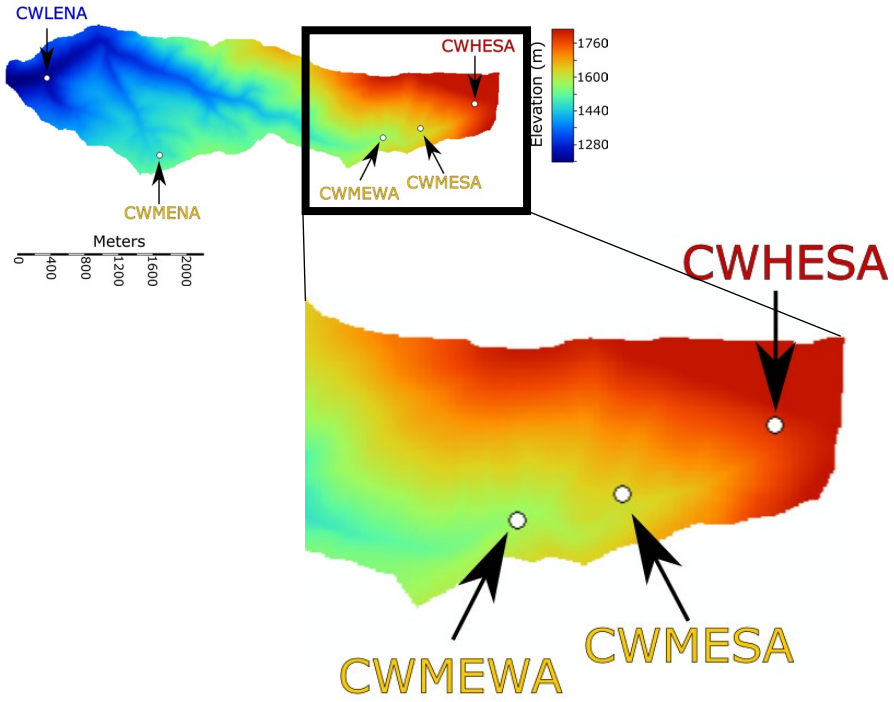
Environmental tracers used to estimate varying groundwater ages from Kralik, 2015.

CWMESAGW2



Recharge temperature versus elevation lapse rates for CWMESAGW2 from the sampled joint posterior distributions.

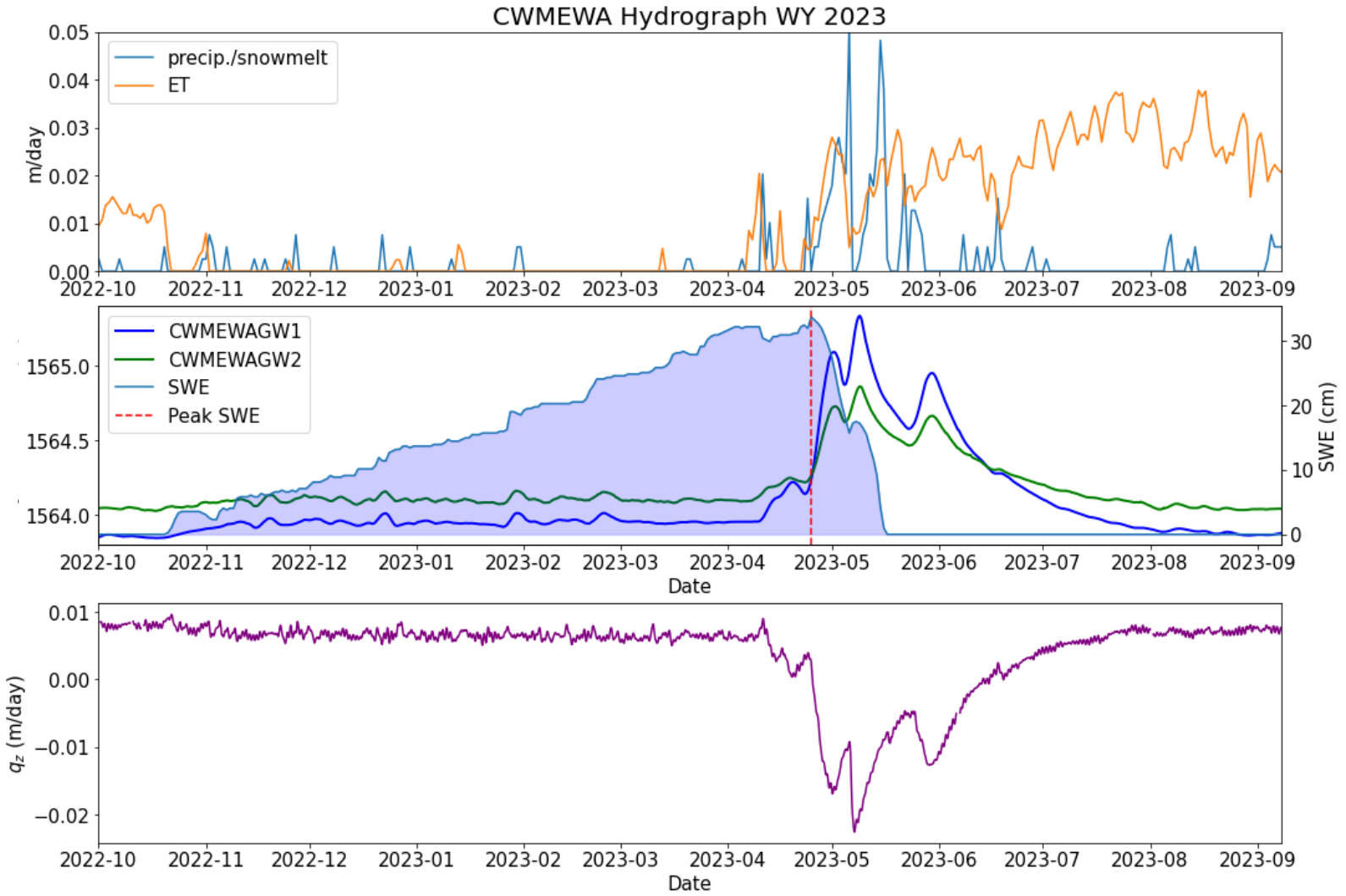
CWMEWA



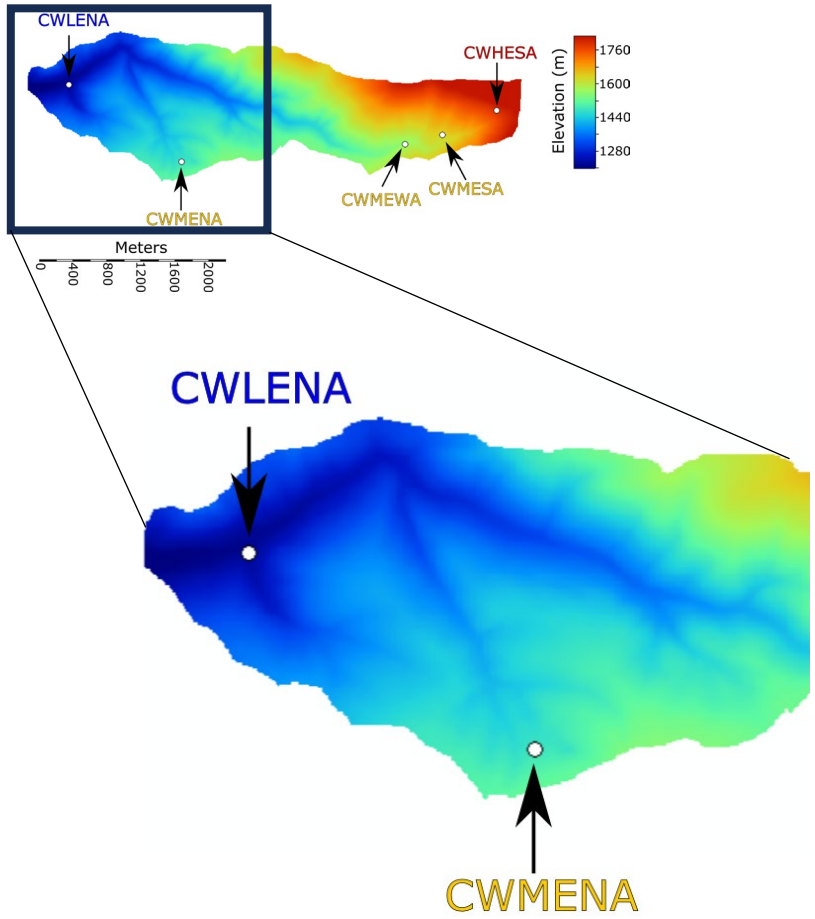
Groundwater dynamics during baseflow and freshet conditions at CWMEWA.

Upward head gradient during baseflow and downward head gradient during freshet.

Hydraulic head and specific discharge quickly responds and increases following peak SWE and during snowmelt.



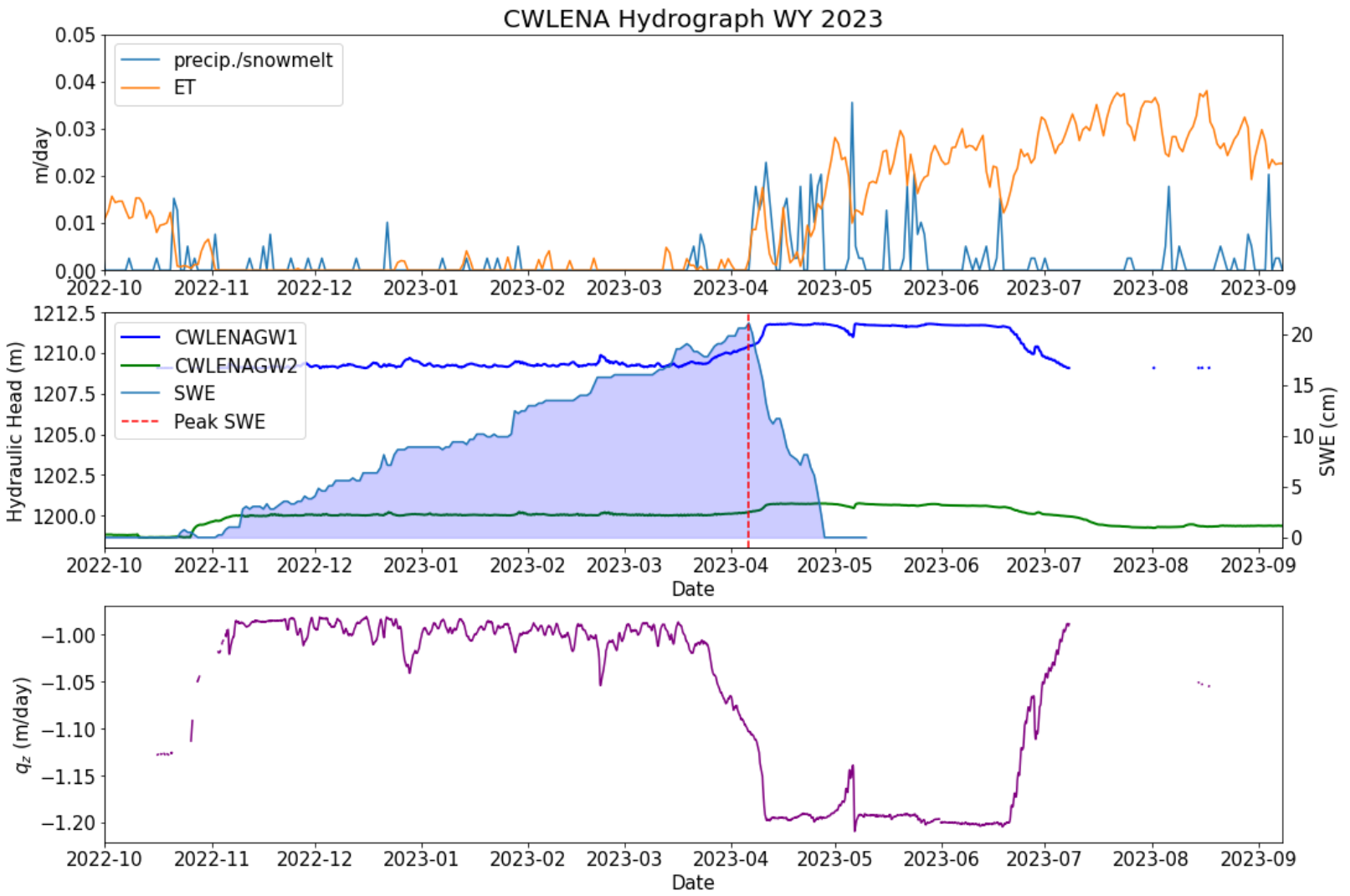
CWLENA



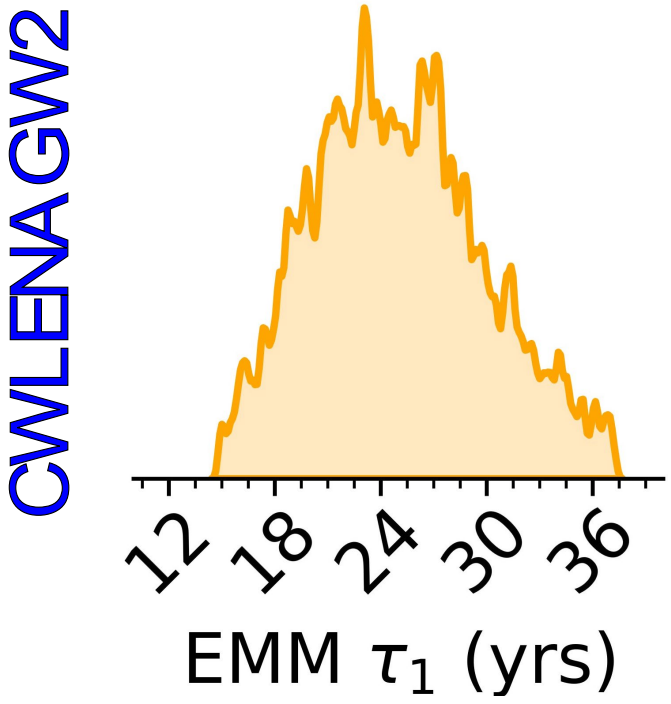
Groundwater dynamics during baseflow and freshet conditions at CWMEWA.

Head gradient and specific discharge increase and become ‘stable’ following peak SWE and snowmelt. Possibly due to high K and fracture zone.

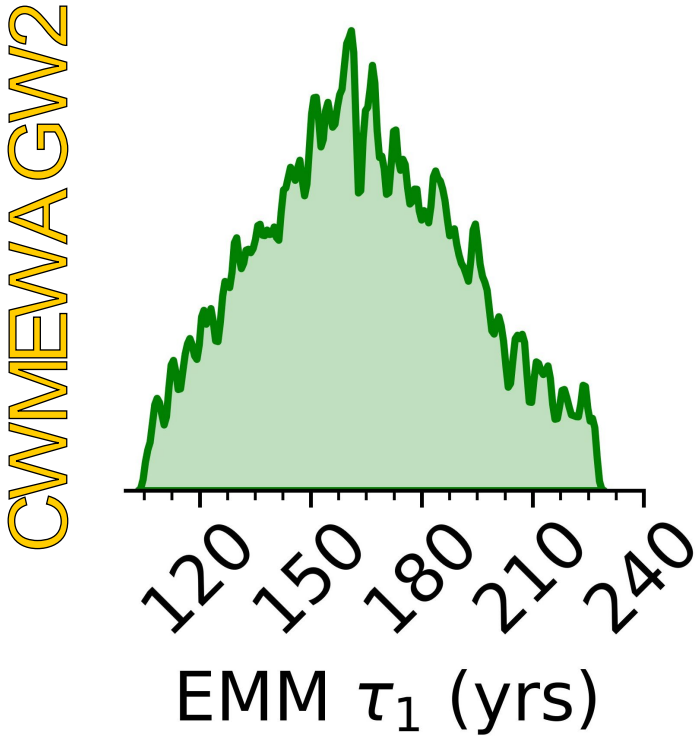
Large downward head gradient throughout the year.



Age modeling

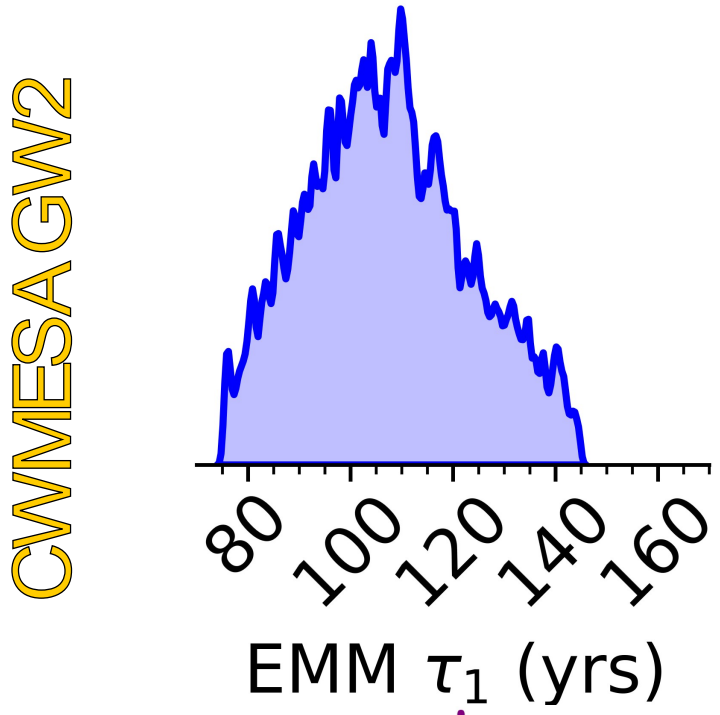


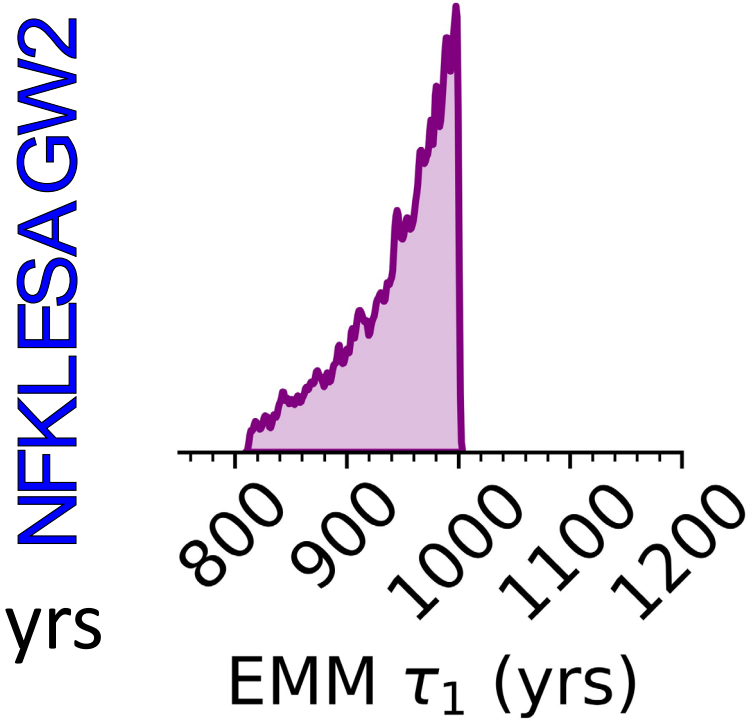
τ = 23 yrs



τ = 159 yrs

τ = 109 yrs

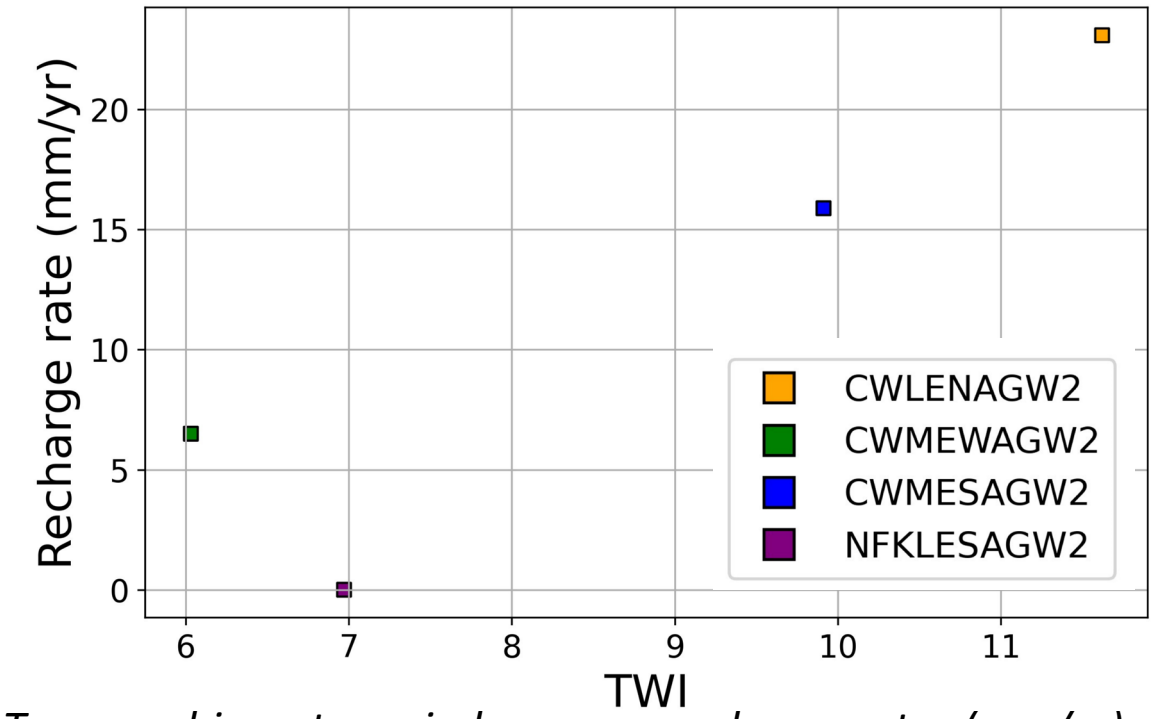




τ = 999 yrs

Groundwater age modeling results

TWI vs recharge rates

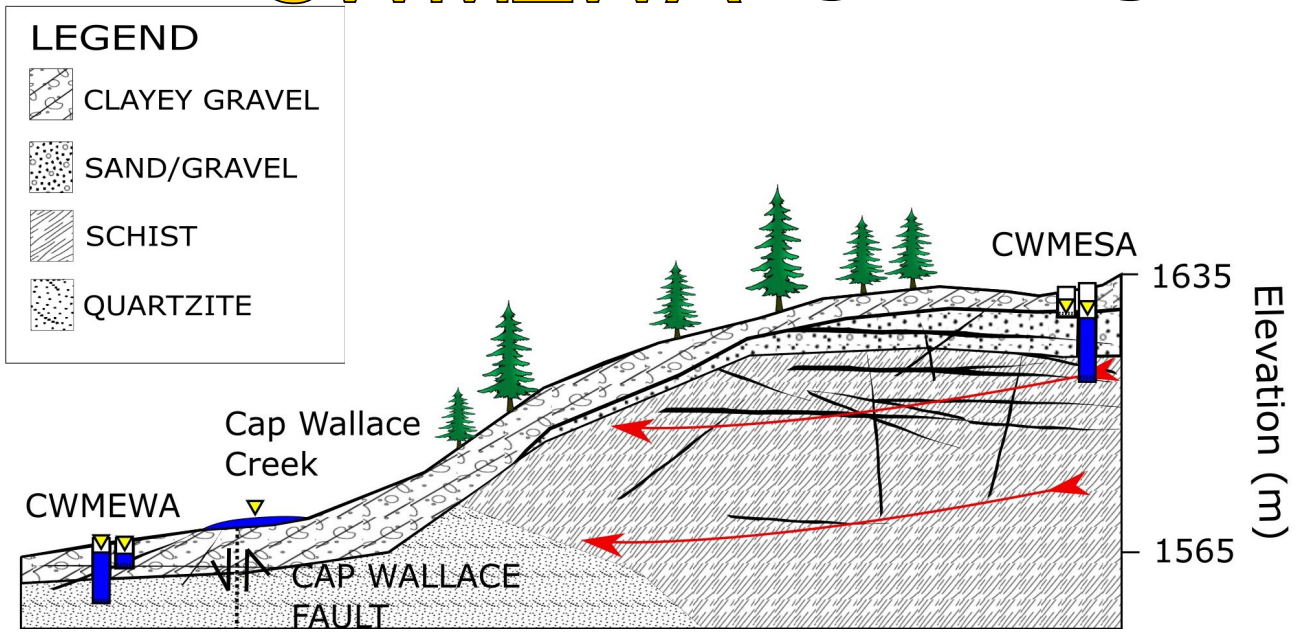


Topographic wetness index versus recharge rates (mm/yr) derived from Vogel, 1967.

Vogel equation:

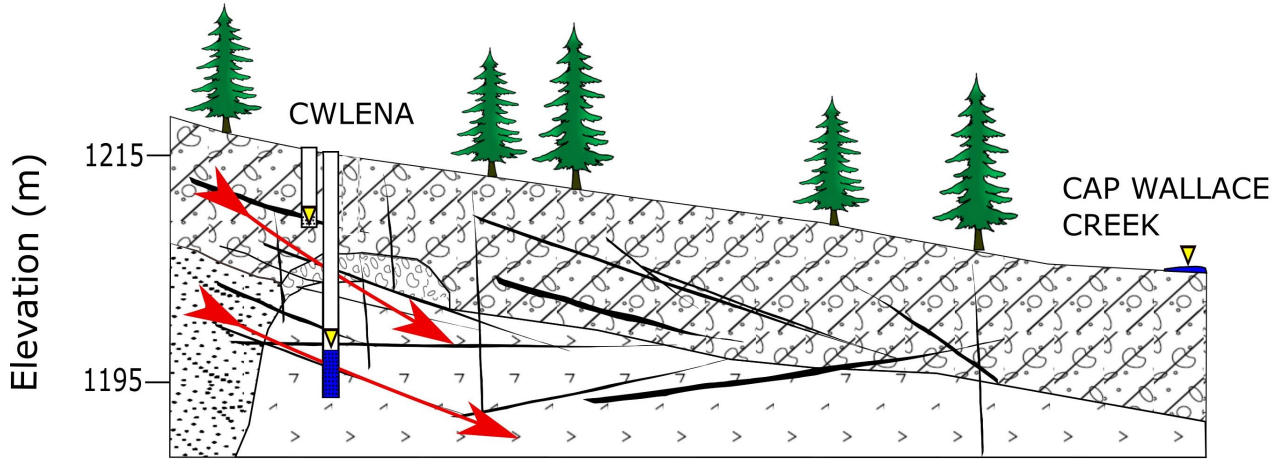
$$R = \frac{H\Theta \ln\left(\frac{H}{H - Z}\right)}{\tau}$$

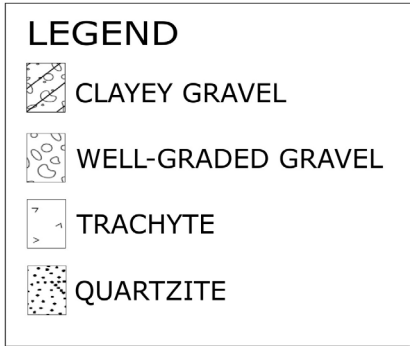
CWMEWA / CWMESA



Conceptual hillslope models

CWLENA

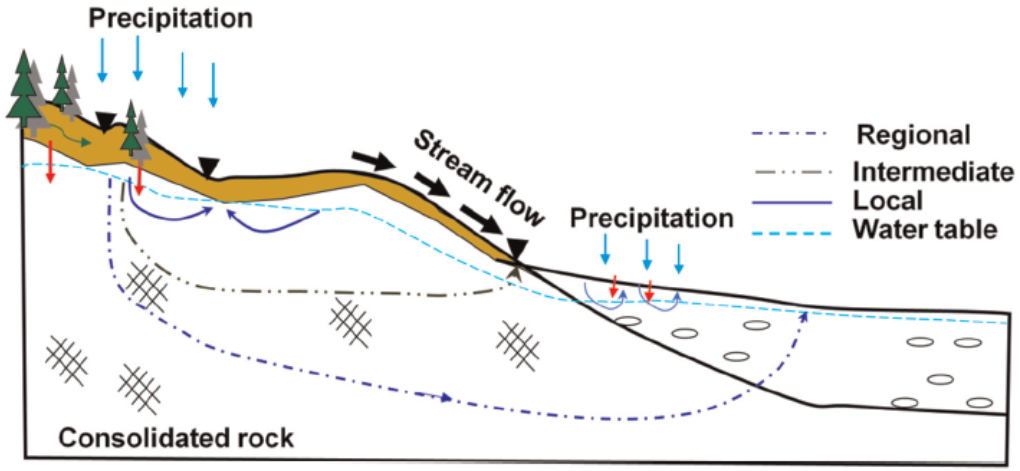




Final thoughts

Groundwater head dynamics are more variable in the upslope positions compared to the downslope hollow locations.

Topographic lows, downslope hollow locations, do not necessarily indicate shallow water tables, groundwater discharge zones, and older groundwater.



From Ajami et al., 2011.

Topographic wetness index (TWI) of catchment areas and well nests