The De-Aging of Water Resources in the Northern Sierra Nevada

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Abstract
As climate change continues to exacerbate the severity of weather patterns, the majority of the state of California has come to suffer from longer periods of drought and shorter, but more intense rainy seasons. With multi-year droughts comes a decrease in snowpack in the mountains. Alpine watersheds within the Sierra Nevada mountain range are a vital source and storage of water for California and Nevada. Snow water equivalent from snowpack feeds riparian systems that function as California’s primary sources of water, which in the northern region of the state predominantly come from local resources. Baseline conditions are seen earlier in the season and last longer than they used to due to decreased snowpack as a result of climate change. Sagehen Creek, a montane watershed just north of Truckee, CA, follows this behavior.

Background
Sagehen Creek is a perennial stream that is part of a montane watershed in the Northern Sierra Nevada mountain range. The creek, after flowing through both Stampede and Boca reservoirs, feeds into the Truckee River. The Truckee is used as water source for the Reno-Sparks metropolitan area before it reaches its final destination at Pyramid Lake.

Using Radon to Locate Points of Groundwater Discharge to Sagehen Creek
Radon is used as a groundwater tracer. This is because it is produced as part of the radioactive decay series of uranium, which is found in old geologic formations such as the underlying volcanics and is primarily released from the glacial till and alluvium thereof throughout much of the Sierra Nevada mountain range. Radon is produced and contained within the water in an aquifer as a dissolved gas which is lost quickly when the water is introduced to the atmosphere. It also has a short half life of about 4 days, so younger groundwater sources typically have higher radon activity than older groundwater sources where the has decayed.

The Process of De-Aging
There is a now 26 year record of best-estimate ages of water from groundwater sources throughout the Sagehen Creek watershed which began in August 1997. The most consistent data is from August 1997 to August 2010. By using a combination of age data gathered from SF6 and CFC analysis and through the determination of piston flow and bimodal modeling, best-estimate mean ages were produced for groundwater from chosen selected springs.

Conclusion
Groundwater supports the base flow of Sagehen Creek. Throughout years of drought, which has caused the melt of snowpack to occur earlier in the year and the snow season to begin later, base flow conditions persist for longer portions of the year. At the same time, the water contained within aquifers is becomes more modern after snowmelt, and if evaporation is introduced. This suggests that the old fraction of water is being depleted as the groundwater is being discharged consistently while younger water is only added to aquifers during snowmelt and sporadic precipitation events that are heavy enough to produce enough water to infiltrate into aquifers and is not lost to evaporation.

The unpredictability that comes with climate change also presents an uncertainty for the future of alpine creeks. More frequent analysis of the age groundwater sources throughout the basin in different seasons will help provide better insight to the resilience of water resources throughout the watershed. Monitoring when base flow conditions occur each year will also help determine the effects of climate change upon Sagehen Creek. Using age data from both the beginning and end of base flow each year will provide better information about the overall age of groundwater based on estimated quantities of old and new water.

Determining Age of Groundwater Using Chlorofluorocarbons (CFCs) and Sulfur Hexafluoride (SF6)
Dissolved gases are useful tools for determining the age of groundwater. CFC is used as an age tracer for groundwater because it is a stable gas that was introduced to the atmosphere by the use of refrigerants and aerosol sprays. Older groundwater will have lower concentrations of CFCs because CFCs were used heavily between 1950 through 1990. SF6 was used in conjunction with radon to determine the age of groundwater based on estimated gas velocities and the geometries of different parts of the stream (Gleeson et al. 2017).

Both gases were analyzed with different groundwater flow models to determine accuracy.

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