Water Intelligence

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Connecting the Dots between Snowpack and Streamflow in Mountainous Watersheds

In mountain regions around the world, seasonal snowmelt replenishes groundwater that accumulates in caverns, caves and conduits located deep inside layers of rock. Northern Utah's Bear River Mountains contain these so-called Karst groundwater stores, which can hold and transmit water for months or even decades at a time. Karst storage plays an important role in river hydrology. However, only recently have we begun untangling the complex story about how this storage translates to rushing water in mountain rivers and streams.

USU Professor Bethany Neilson, left, works with graduate student Jihad Othman to collect water samples from the Logan River. Neilson is leading a major research study to better understand how varying snowpack levels influence water supplies.

"Karst structures are buried deep inside the mountain, making it nearly impossible for us to measure how much water is stored there," says USU's Dr. Bethany Neilson, a professor of civil and environmental engineering and a leading expert on cold-weather watersheds. "Snowmelt-driven, karst-fed watersheds are not well understood because conventional groundwater modeling techniques do not work in mountainous, karst terrain."

The Logan River, like many waterways in the mountains, is fed by a combination of surface water and karst storage. In the spring, snowmelt runs over the land and feeds the river. But for the rest of the year, it is primarily fed by groundwater that enters the river channel via karst conduits or fractures. Neilson says the dilemma for water resource managers is that there is no clear understanding about how varying snowpack levels affect karst storage and how that storage influences streamflow volume. With climate variability and growing demand on water supplies, experts agree that we need a better understanding of how karst watersheds feed the rivers and streams that provide our drinking water and irrigation supply. For Neilson and her colleagues, understanding karst hydrology is the missing piece of the puzzle.

ASU Assistant Professor Tianfang Xu, left, works alongside Patrick Strong of the Utah Water Research Lab to measure flow in the Logan River. They are part of a team collecting several years' of streamflow data.

"In a karst watershed, we're filling up underground reservoirs with snowmelt," she explains. "If snowpack levels change significantly—which we have seen in recent years—and snowmelt isn't replenishing the karst storage, how quickly will it drain out? How long of a drought can we sustain and still meet our water needs?"

To find answers, Neilson is teaming up with a team of researchers, including Dennis Newell of USU's Department of Geosciences; Tianfang Xu at Arizona State University; and Jim McNamara at Boise State University. Collectively, they have received more than $700,000 from the National Science Foundation to build on data collected as part of the Logan River Observatory and further understand Logan River's karst groundwater system.

USU graduate student Devon Hill collects a water sample for chemical analysis as part of a multiyear research study funded by the National Science Foundation.

Measuring how much of the river's total flow originates as karst storage is not a simple task. Neilson and her team are working to change that. For nearly a decade, the observatory has been collecting streamflow data throughout the Logan River watershed. But streamflow only tells part of the story. So in the fall of 2022, they began collecting additional data derived from chemically analyzing water samples from the Logan River and its headwaters. By identifying chemical tracers in the samples, it's possible to predict where the water comes from and get a rough estimate of how long it has been in storage.

"Over the years, we have collected chemical samples that tell us part of a story about where the water has been and potentially where it is going," Neilson added. "And with additional analysis, we are getting a more complete picture of how the water flows and a good estimate of how long the water has been there. It's not precise, but it gives us a clear pattern we can use to build new modeling tools."

By combining historical snowpack data and streamflow data with the new hydro-geological data from the chemical analyses, the research team can develop a new modeling tool that establishes connections between snowpack variability and the amount of groundwater and streamflow available for use in the Logan River.

"We want to know if we can connect physics-based snowmelt models to machine learning or artificial intelligence to understand how water inflow into the karst system translates to streamflow in the Logan River and other karst watersheds," says Neilson.

These new modeling tools will be a first-of-its-kind technology. They will help bridge the gap between the known and unknown aspects of karst watersheds and give water managers tools to make data-informed decisions.

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