News Release

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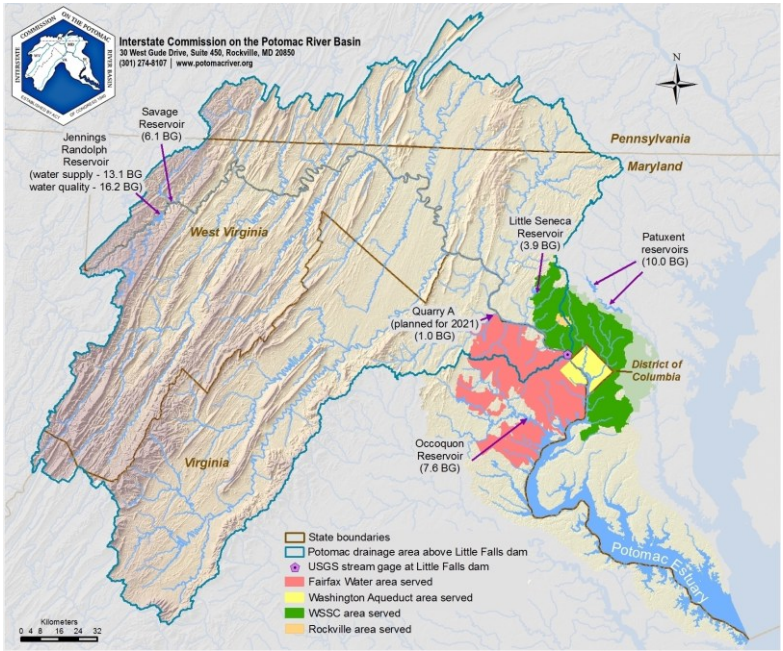
When the milkshake runs low: what groundwater can tell us about future droughts

ROCKVILLE, MD (July 23, 2025) - Imagine you are sharing a chocolate milkshake with ten of your best friends. You all have a straw in the glass. As the milkshake gets lower you want to make sure everyone has enough to go around, so there is a lot of discussion and collaboration to ensure no one person sucks the glass dry. Now, picture the glass is a river and the milkshake is water. That is how water resources management works in the Potomac River basin. There is collaboration and agreements (and a lot of data and science) in place to ensure everyone with a straw in the river has water, even during a drought. After all, this milkshake *ahem* river must satisfy the 5 million people that live in the Washington Metropolitan Area.

To continue that milkshake analogy… the milkshake is so good, everyone wants more. Ideally, deliveries keep coming in to refill the glass; that's rain. But sometimes, the deliveries slow down or stop, and the building gets hotter, making what's left disappear faster. That's a drought. You know there is more milkshake reserved somewhere in the building, but you're not sure if it's right next door or 13 floors down with a slow, rusty elevator. How long will it take to get everyone their milkshake? They're thirsty. In this scenario, the reserve milkshake is groundwater that will help replenish the river, come out of our taps, and support the river's natural ecosystem. How long does it take for groundwater to become surface water? This is another piece of the water resources management puzzle.

Understanding the connection between groundwater and surface water is vital to water resources management. A recent study led by staff from ICPRB's Section for Cooperative Water Supply Operations on the Potomac (CO-OP) and 2024 Yale Conservation Scholar and ICPRB intern AJ Villaruel explored groundwater trends (is the reserve milkshake getting fuller, emptier, or staying the same over time?) and the time-lagged relationship between groundwater and surface water (if our milkshake is low today, how long will that affect our milkshake in the future?).

The authors used a relatively new tool — a groundwater drought index developed by NASA, which combines the Gravity Recovery and Climate Experiment (GRACE) satellite data with land surface models — to assess changes in groundwater storage. According to the authors, this approach is more comprehensive than using *in situ* monitoring equipment alone.



Metropolitan Washington Area water supply service areas and resources in the Potomac River basin (Source: ICPRB).

Unfortunately, in this scenario, the amount of reserved milkshake available appears to be declining. The study looked at sub-basins within the Potomac River above Little Falls. Over more than two decades, all of the sub-basins showed a decreasing trend in groundwater storage and most of the sub-basins showed a decreasing trend in river discharge. Many of the well water levels showed no trend, but some had a decreasing trend. Decreasing groundwater trends have also been seen in the Colorado River basin, another shared milkshake with a bigger, and perhaps thirstier, crowd.

In the study area, the time lag — or how long it takes a change in groundwater conditions to impact surface water conditions — was longer during low flow conditions (i.e. drought). The timing varied from one year to a little under two years. The length of time also varied depending on the geological makeup of the sub-basin.

“Using 22 years of satellite-based data, streamflow, and climate data, we identify clear declines in groundwater and low flows and uncover strong time-lagged relationships between groundwater levels and river discharge,” states Villaruel, the study’s first author.

Understanding how groundwater levels impact river flows can help water resource managers, such as the Interstate Commission on the Potomac River Basin, to better predict drought conditions weeks or months in advance. It also highlights the importance of maintaining monitoring networks across watersheds and jurisdictions. These findings are not only applicable to the Potomac River basin, but across the nation.

“We’ve long known that groundwater contributes to river flow with a delay. That is, the system has memory. This study helps quantify how long that memory might last in our region for shallow groundwater systems,” said Dr. Alimatou Seck, co-author and senior water resources scientist at ICPRB. “What’s valuable here is putting a number on that delay. Knowing how long today’s conditions will continue to influence future streamflows helps us improve low-flow forecasts, which are a core part of CO-OP’s drought preparedness.”

“The findings also reinforce a concerning pattern seen globally: declining groundwater availability,” continues Dr. Seck. “Confirming this trend locally provides critical context for decision-makers focused on long-term water supply resilience. At the same time, the study reflects just one lens — a 22-year satellite-based analysis focused on sub-basins. More work is needed to reconcile these results with longer-term records and basin-wide studies that have shown more mixed trends.”

The study also points to future directions, including better quantifying uncertainty in satellite-derived groundwater drought indices and validating lag times with empirical data and physically based models.

Evaluating time-lagged relationships between groundwater storage and river discharge using GRACE-based data: insights from the Potomac Basin was published in the July issue of Environmental Research Communications. AJ Villaruel joined ICPRB through an internship program with the Yale Conservation Scholars – Early Leadership Initiative program.

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The ICPRB is an interstate compact commission established by Congress in 1940. Its mission is to protect and enhance the waters and related resources of the Potomac River basin through science, regional cooperation, and education. Represented by appointed commissioners, the ICPRB includes the District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia, and the federal government.