tx H2O

*A Publication of the Texas Water Resources Institute*

Fall 2023

# READY OR NOT

## HERE COME NEW CHALLENGES TO TEXAS WATER

Inside: Meet the research teams dismantling forever chemicals, helping cities adapt with green infrastructure, managing reservoirs strategically and more

Texas A&M AgriLife Research | Texas A&M AgriLife Extension Service | Texas A&M University College of Agriculture and Life Sciences

# Working to make every drop count

Do you want the good news or the bad news first?

The bad news is, Texas water supplies are facing problems from numerous and interconnected factors that we haven't seen to this extent before — population growth, aging infrastructure, land use changes impacting water quality, emerging water quality concerns such as PFAS, climate change impacts, extreme weather events and more.

But the good news is, solutions to these problems are pouring in from every direction across Texas.

In this issue of tx$H_2O$, we shine a light on some of the exciting solutions that scientists are developing for major Texas water problems: researchers in the Texas A&M University System developing practical mitigation technologies to remove PFAS chemicals from water, U.S. Army Corps of Engineers reservoir managers using modern forecasting to strategically plan water storages in Texas lakes, regional stakeholders and Texas Water Resources Institute (TWRI) researchers using a basin-wide approach to help Matagorda Bay water quality, graduate students across Texas training to be the next generation of water and environmental leaders, Texas A&M AgriLife researchers using green infrastructure to manage cities' flooding issues and more.

At TWRI, we have always brought together teams of experts to find and apply solutions to Texas water problems, and 2023 is no different.

Today we are forging interdisciplinary teams of scientists, outreach specialists, practitioners and students to tackle everything from watershed-level water quality impairments to climate-smart regenerative agriculture science and strategies.

Why? Because we know that the future of Texas water requires both innovation and collaboration.

As always, please join us in making every drop count.

Allen Berthold, Ph.D.
Interim Director, Texas Water Resources Institute

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In the Texas panhandle, a windmill in the foreground with a storm rolling in. Photo by Adobe Stock.

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Texas Water Resources Institute
*make every drop count*

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Somerville Lake. Photo by U.S. Army Corps of Engineers – Fort Worth.



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# RESEARCH NEWS

*Texas scientists work to uncover water solutions the state needs*

Barton Creek. Photo courtesy of the Meadows Center for Water and the Environment at Texas State University.

## Measuring the importance of Barton and Onion creek watersheds to the Colorado River

Barton Creek and Onion Creek contribute significant flows to the Colorado River, according to a study led by researchers at the Meadows Center for Water and the Environment at Texas State University.

The study compared streamflow contributions of the Pedernales River and Barton and Onion creeks to the Colorado River using daily discharge data from Sept. 24, 1998, to Aug. 31, 2022.

The research found that an average acre of land conserved in the watersheds of Barton and Onion creeks produced more than twice as much water to the Colorado River than an average acre of land in the Pedernales River watershed. Furthermore, daily flow into the Colorado River from Barton and Onion creeks surpassed that of the Pedernales River nearly half the time. **Read more ⇨ tx.ag/water23**

## Daylong wastewater samples show limits of 'snapshot' samples

Research by Rice University scientists compared simple, "snapshot" samples of wastewater to daylong composite samples and found that snapshot samples were more likely to result in bias in testing for the presence of antibiotic-resistant genes (ARGs).

Their study showed that composite samples taken over 24 hours at an urban wastewater plant give a much more accurate representation of the level of ARGs in the water. The results could lead to better protocols for treating wastewater to lower the prevalence of ARGs in bacteria that propagate in treatment plants and can transfer ARGs to other organisms in the environment.
**Read more ⇨ tx.ag/water23**

## UT geoscientists using climate models to inform Austin's long-term water plan

The city of Austin is funding a project led by University of Texas at Austin Jackson School of Geosciences researchers analyzing global climate models and downscaling them to inform regional water planning. The research is part of the city's 100-year *Water Forward* plan.

The team has evaluated 35 global models from major modeling centers around the world to determine which best represent the Colorado River basin's climatology and hydrology. These extremely complex models integrate the Earth's oceans, atmosphere, land and ice sheets, and account for greenhouse gas concentrations, aerosol pollution, changes in land cover, urbanization and natural variations.

The models are so large that the resolution becomes fuzzy when trying to zero-in on local areas, due to few data points, researchers explained. To improve the resolution, researchers downscale the models by using statistical relationships between what the models have shown on a broad global level and local climate data, such as data collected by the Texas Water Development Board (TWDB) and other agencies — precipitation, lake evaporation, stream flow, soil moisture and more. The interdisciplinary team is using a supercomputer at UT's Texas Advanced Computing Center.

After downscaling the global models to better reflect local conditions, the results will be plugged into the Water Availability Model provided by the Texas Commission on Environmental Quality for the Colorado River basin and then used to inform the city's planning. **Read more ⇨ tx.ag/water23**

Srinivasulu Ale, Ph.D., Steven Dowhower, Ph.D., and Casey Wade, Dixon Water Foundation president, on the Dixon Ranch. Photo by Jungjin Kim, Texas A&M AgriLife.

## Adaptive multi-paddock grazing improves carbon sequestration, soil health

A Texas A&M AgriLife Research team used the Soil and Water Assessment Tool-Carbon (SWAT-C) model to evaluate the impacts of alternative grazing management practices on soil carbon sequestration and soil health indicators.

They simulated the impacts of three grazing management practices — heavy continuous, light continuous and adaptive multi-paddock grazing (or AMP, a form of rotational grazing) — on soil organic carbon, soil health indicators and hydrological parameters at the ranch- and watershed-scale in Northwest Texas.

Study results indicated that by adaptively maintaining moderate growing-season defoliation with adequate plant recovery time, AMP grazing can minimize the negative effects of area selective overgrazing under continuous grazing. AMP grazing can also enhance soil organic carbon, soil health and hydrological parameters.

Results also showed that prolonged high stocking rates and overgrazing by livestock can result in significantly less soil organic carbon and soil fertility on rangeland. **Read more ⇨ tx.ag/water23**

Keep reading about these important research advances at tx.ag/water23

Story by **Leslie Lee**

# Water

## and the 88th Regular Session of the Texas Legislature

The Texas Capitol. Photo by Laura McKenzie, Texas A&M AgriLife.

This year the Texas Legislature passed legislation related to water and natural resources, including:

- **Senate Bill 28** and **Senate Joint Resolution 75**, which would create two new funding mechanisms at the Texas Water Development Board — the Texas Water Fund and the New Water Supply for Texas Fund. These funds potentially create $1 billion in funding for developing future water supplies and repairing and upgrading water infrastructure. The Texas Water Fund would be a constitutionally dedicated fund, and it will be on the ballot as a constitutional amendment during the fall statewide elections.
- **Senate Bill 1648** and **Senate Joint Resolution 74**, which would create the Centennial Parks Fund, a new fund for acquiring private lands for state parks. Voters will also vote on this fund as a constitutional amendment during the fall statewide elections.

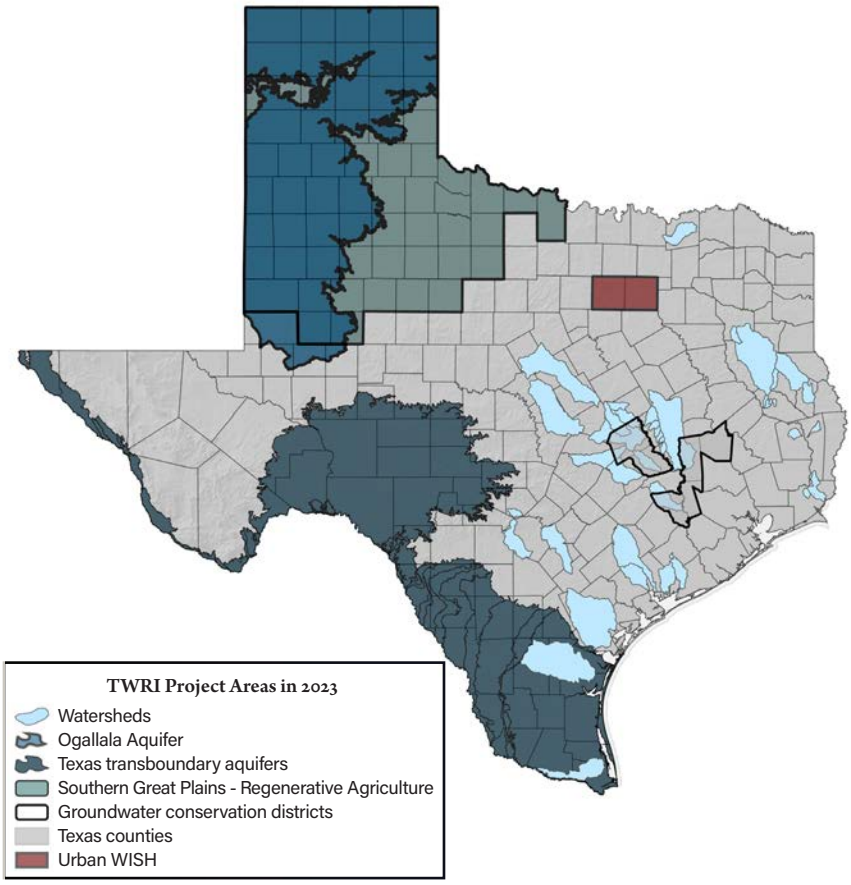
**Read more ⇨ tx.ag/water23**

# TWRI News

*Catch up on TWRI's water research and outreach impacts*

## TWRI project impacts grow, evolve

Texas Water Resources Institute (TWRI) staff and scientists continue to make an impact on water quality, research, conservation and education throughout the state. TWRI currently manages 65 projects serving Texas and received $3,760,962 in new external grant funding in 2022. **Read more ⇨ tx.ag/TWRI23**




**Keep reading about these important research advances at tx.ag/TWRI23**

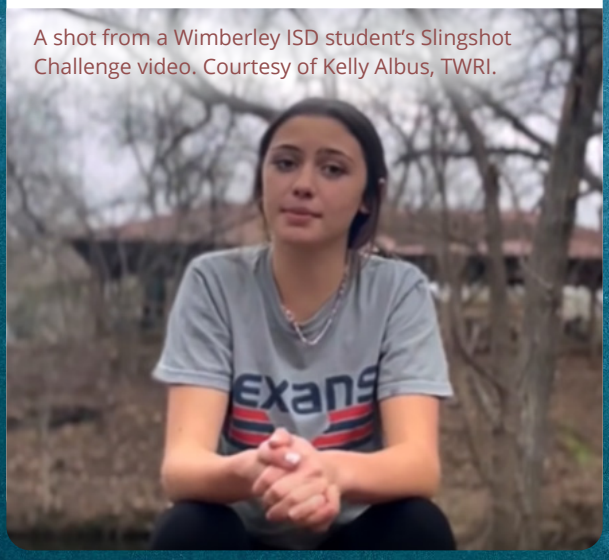
## Hundreds of Texas students compete in National Geographic challenge

Thanks to tireless schoolteachers, students' hard work and support from TWRI and Texas A&M AgriLife, this spring hundreds of middle and high school students in Texas produced educational videos about environmental science for the National Geographic Slingshot Challenge.

Kelly Albus, Ph.D., TWRI research scientist, received National Geographic funding support to serve as the Slingshot Challenge Supporter for the entire state. She helped teachers use the challenge to complement and fulfill course requirements.

"Place-based learning and citizen science are fantastic ways to really teach students and facilitate open-ended learning," Albus said. "They learn how to follow research to its end, and students get to do their own projects and find their own voice, which makes a higher impact on learning. This also impacts students' life behaviors, which in turn can impact environmental quality."

Lindsay O'Gan, a middle school teacher in Wimberley Independent School District, successfully helped all 115 of her 8th-grade science students create videos for the challenge. As a result, many of the students learned about local water quality impairment issues and got involved in restoration efforts.
**Read more ⇨ tx.ag/TWRI23**



A shot from a Wimberley ISD student's Slingshot Challenge video. Courtesy of Kelly Albus, TWRI.

Underwater background image by Freepik.com.

## Faculty Fellows Program

TWRI's Faculty Fellows Program leverages U.S. Geological Survey funding to support recipients as they develop and submit further project proposals seeking external funding.


Katie Lewis

The inaugural class of Faculty Fellows was named in 2021:

- Saurav Kumar, Ph.D., formerly with Texas A&M AgriLife Research Center at El Paso, Texas A&M Biological and Agricultural Engineering.
- Katie Lewis, Ph.D., associate professor of soil chemistry and fertility at the Texas A&M AgriLife Research and Extension Center at Lubbock.
- Itza Mendoza, Ph.D., assistant professor, Texas A&M School of Public Health.

From the first round of fellows' proposal submissions, a $10 million proposal to the U.S. Department of Agriculture's National Institute of Food and Agriculture was awarded to Lewis, who serves as principal investigator of the resulting Southern Great Plains Regenerative Agriculture project.

The 2022 Faculty Fellows both research PFAS in the environment and remediation methods:

- Yina Liu, Ph.D., assistant professor, Texas A&M Department of Oceanography.
- Xingmao 'Samuel' Ma, Ph.D., associate professor, Zachry Department of Civil and Environmental Engineering, Texas A&M.

The 2023 Faculty Fellows are:

- Pao-Tai Lin, Ph.D., associate professor, Texas A&M Department of Electrical and Computer Engineering.
- Ying Li, Ph.D., professor, Texas A&M Department of Mechanical Engineering. **Read more ⇨ tx.ag/TWRI23**


A dry Texas Panhandle field. Photo by Kay Ledbetter, Texas A&M AgriLife.

## Ogallala Aquifer and rangeland management

Spanning from South Dakota to Texas, the Ogallala Aquifer is the largest freshwater aquifer in North America. But, for decades research has shown that much of the Ogallala in Texas could be depleted as soon as 2100 if recharge and use continue at current rates.

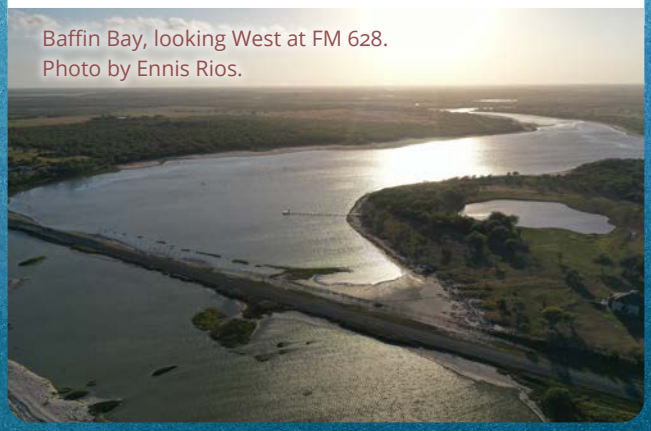
Recent research co-authored by Ed Rhodes, TWRI research specialist and Ph.D. student at the Caesar Kleberg Wildlife Research Institute at Texas A&M University at Kingsville, presented rangeland management strategies as key to the region's future.

"We posit that the art and science of rangeland management stands uniquely poised to tackle this challenge directly through creative integration, where appropriate, of native rangeland restoration, improved pasture management, integrated crop-livestock systems, and regenerative agricultural practices aimed at preserving soil and rangeland health," Rhodes said. **Read more ⇨ tx.ag/TWRI23**

## EPA accepts two new watershed protection plans

In 2023 two watershed protection plans developed by TWRI and local stakeholders have been accepted by the U.S. Environmental Protection Agency (EPA): the San Fernando and Petronila Creeks Watershed Protection Plan and the La Nana Bayou Watershed Protection Plan.

Plan acceptance is dependent on meeting EPA's guidelines for watershed-based plans, and it is a major accomplishment for the coalition of local stakeholders and state officials who collaboratively create the science-based plans.
**Read more ⇨ tx.ag/TWRI23**


Baffin Bay, looking West at FM 628.
Photo by Ennis Rios.

# COULD FOREVER CHEMICALS NOT BE FOREVER?

*Scientists and agencies work to dismantle forever chemicals*

The idea of something lasting forever can be an unnerving thought, especially when little is known about it. This unease is common when people talk about per- and polyfluoroalkyl substances, or PFAS, which cover a large category of thousands of man-made chemicals. These chemicals can be found in virtually every facet of life: air, water, soil and food.

PFAS chemicals' longevity is due to their bonds between carbon and fluorine molecules, one of the strongest chemical bonds possible, which makes removal and breakdown of PFAS very difficult.

Scientists have known about these manufactured chemicals since the 1940s, though it has only been in more recent years that the rest of the world has taken notice of PFAS and their potential risks to human health.

As PFAS become more widely discussed, scientists and policymakers are studying what can be done to remove the "forever" from forever chemicals.

## A complicated environmental problem

PFAS have two classifications: short-chain and long-chain, depending on their chemical make-up. While there is a little overlap, short-chain PFAS are typically defined as having less than six to eight carbon atoms, while long-chain PFAS have more than six to eight carbons.

Long-chain compounds have different rates of solubility, transport and toxicity than short-chain compounds.

While it was previously thought that short-chain PFAS posed less of a human health risk than long-chain and moved through the body faster, Center for Disease Control and Prevention studies have shown that short-chain PFAS actually build up in the body more rapidly and stay there longer.

As more information becomes available about these forever chemicals, agencies have made new efforts to protect human and environmental health from PFAS impacts. In March, the U.S. Environmental Protection Agency (EPA) proposed a national standard for PFAS in drinking water.

"EPA's proposal to establish a national standard for PFAS in drinking water is informed by the best available science and would help provide states with the guidance they need to make decisions that best protect their communities," EPA Administrator Michael Regan said in a news release. "This action has the potential to prevent tens of thousands of PFAS-related illnesses."

Such announcements have brought attention to the possible health impacts of long-term PFAS exposure. While research is still ongoing to understand how different types of PFAS and different levels of exposure can affect humans, EPA noted that there are possible health issues related to low-level, long-term exposure to harmful PFAS. Some of these possible issues, EPA said, include decreased fertility, an increased risk of some cancers, a reduced immune system, interference with natural hormones in the human body and potentially other unknown risks.

The true effects of PFAS are also hard to determine due to the sheer number of different PFAS, all with unique makeups and potential toxicities.

Background images by Freepik.com.

## Testing PFAS removal technologies

Scientists like Xingmao 'Samuel' Ma, Ph.D., have taken a head-on approach to these questions. An associate professor in Texas A&M University's Zachry Department of Civil and Environmental Engineering and at the Texas A&M Engineering Experiment Station (TEES), Ma currently has three funded projects tackling different angles of breaking down PFAS in the environment.

One of his research projects, funded through the Texas Water Resources Institute (TWRI) Faculty Fellows program, examines new ways to break down short-chain PFAS more effectively. Producing a single atom iron catalyst on a biochar support, Ma uses this carbon material to remove PFAS.

Through tests, Ma has found that while the reactions do not necessarily degrade or breakdown the PFAS alone, rapid adsorption occurs by the carbon iron material, which is typically the first step leading to eventual degradation of chemicals. Ma theorizes that iron's positive electron charge might be one of the reasons why it works so well as a remover of negatively charged PFAS anions. He hopes to understand how other metals might work in the role too.

"The main question we're trying to answer is whether incorporating metal atoms in a carbon support can generally improve PFAS removal and whether more redox active elements such as iron work better than other, more stable ones," Ma said.

His second PFAS-related research effort is funded through the Water Exceptional Item, administered by TWRI, and looks to evaluate two light-sensitive photocatalysts. Ma is the principal investigator of the project, working with Anish Jantrania, Ph.D., and June Wolfe, Ph.D., Texas A&M AgriLife; Virender K. Sharma, Ph.D., Texas A&M School of Public Health; and Hongcai (Joe) Zhou, Ph.D., Texas A&M College of Arts and Sciences.

Using light exposure, Ma and his team have seen that their tests on certain PFAS produce hydrated electrons and prove effective for the removal or breakdown of them in smaller samples.

"Our first system that we've tested in a lab seems to work well in part," Ma said. "We already published one paper, and we're working on the second one, and an exciting part is we're also moving towards field tests."

While the tests will be small, he said, being in the field will be much bigger when compared to the 20-milliliter tubes they currently test on.

Ma's third PFAS research effort is funded through the U.S. Army Corps of Engineers Engineer Research and Development Center (ERDC) and builds upon his other research, trying to lower the cost of PFAS removal. Ma also works with Sharma on this project.

His team hopes that by using different removal systems, they can test their efficiency and see which ones have the highest potential of being deployed in the field.

"We know the math works, but the model is expensive," Ma said. "So, what we want to do is try a set of different systems and compare their efficiency for different types of PFAS to see which one really has the potential to work well in removal and also economically in natural water."

Susie Dai, Ph.D., is another Texas A&M researcher studying the use of preexisting materials in the environment for PFAS removal.

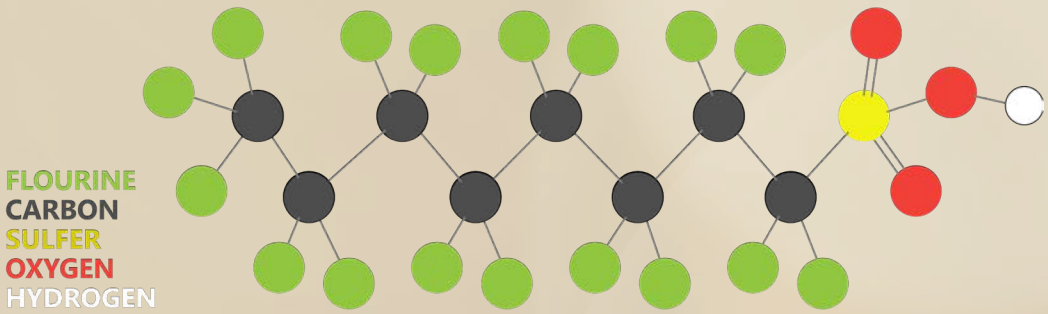
As an associate professor of plant pathology and microbiology in Texas A&M's College of Agriculture and Life Sciences, Dai and collaborators developed a technique of using a plant-derived material to adsorb the PFAS, and then disposing of them with microbial fungi that literally eat the forever chemicals.

"The fungus consumes plants," Dai said. "What I hope to do is use plant biomass to enrich the PFAS and then give that resulting stuff to the fungus to eat."

She explains that certain types of fungi consume lignin, complex polymers found in wood and bark that are resistant to breaking down, as their natural food. Understanding the interactions between fungi

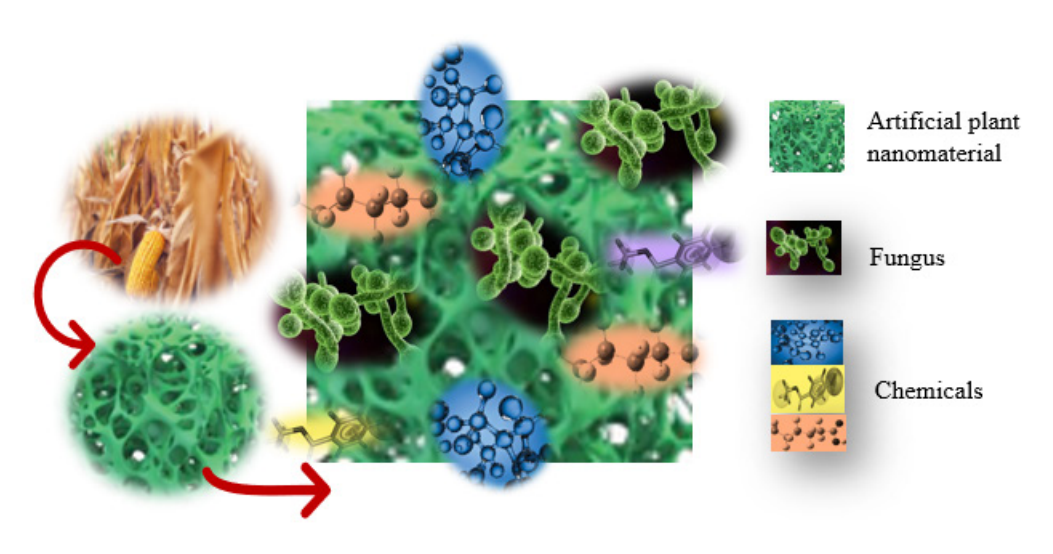
⇨

**PFOS (perfluorooctane sulfonate)**




The bond between carbon and fluorine molecules, one of the strongest chemical bonds possible, makes removal and breakdown of PFOS and other PFAS chemicals very difficult. Illustration by Sarah Richardson, TWRI.

Background image by Freepik.com.




PFAS are adsorbed into the cell wall of the plant material. When the fungus consumes the plant, it also eats the chemical that was adsorbed. Graphic courtesy of Susie Dai.

and PFAS and how they can be applied to PFAS removal is crucial, she said.

"Humans have different personalities, and fungi are the same," she said. "There are so many different fungi in the environment. Some are more robust, some die easier, some like PFAs, some don't."

As the researchers continue to study and refine this remediation technique, Dai sees this method as a sustainable treatment system with the potential to remove harmful chemicals, protecting both human health and ecosystems in a non-toxic, cost-effective way.

## Science informs policy

As researchers like Ma and Dai look to remove PFAS from the natural environment, government agencies want to educate the public about PFAS.

"Identifying the risk a chemical may pose to human health is a scientific process," the EPA website reads. "There are likely thousands of PFAS that are currently present in the United States. Robust information about PFAS is needed to better understand the risks they pose and to be able to take effective actions."

The U.S. Department of Defense (DoD) Strategic Environmental Research and Development Program (SERDP) also sponsors studies on PFAS treatment options. DoD used aqueous film-forming foam (AFFF) from the 1970s until production ceased in 2002.

"The DoD used AFFF mixtures containing significant quantities of the PFAS perfluorooctane sulfonate (PFOS) and perfluoroalkyl sulfonates such as perfluorohexane sulfonate (PFHxS)," the SERDP website reads. "The potential magnitude of the DoD's PFAS liabilities will require a sustained effort to identify the best technologies to characterize, treat and manage PFAS-impacted sites."

AFFF was used for fire suppression in ships, shore-fixed systems and aircraft hangers, and to extinguish liquid fuel fires, according to DoD.

While the removal of chemicals called "forever" can seem daunting, research is showing that it is not impossible.

"Researchers and partners across the country are working hard to answer critical questions about PFAS," the EPA website reads. "This information will help EPA and state, local and tribal partners make more informed decisions on how best to protect human health and the environment."

As more studies are conducted to better understand and test the limits of PFAS, science will continue to reveal what researchers are up against.

Story by Leslie Lee

# NOT AS IT WAS

## *As stormwater and flood threats change, Texas cities use green infrastructure to adapt*

Extreme rain events are motivating some Texans to consider green infrastructure. Photo by Adobe Stock.

How many storm drains does one residential street need? How much water can a vegetated buffer strip hold? How will new construction and increased impervious surfaces affect stormwater flow into an urban creek? In a flash flood event, how much runoff can a culvert divert, and where should it flow to?

Civil engineers and municipal water planners use data and expertise to calculate the answers to these important public safety questions. They do so by considering their city's soil types, average precipitation, historic flood data, land use, stormwater infrastructure capacities and more.

For decades, factoring together these considerations and following municipal stormwater infrastructure protocols in Texas was a predictable process. However, a perfect storm of rapid change has altered that.

### So much, so fast

When it comes to calculating Texas stormwater infrastructure needs, many of the inputs have changed: climate change impacts have made extreme one-day rainfall events more common, rapid growth in urban and suburban Texas has converted vast pervious surfaces to lengthy patchworks of impervious surfaces, and much of the existing stormwater infrastructure is aging and needs improvement.

All these changes result in stormwater flowing into waterways faster — causing less predictable floods, new infrastructure needs, property damage, expensive challenges for communities and new water quality impairments.

"Stormwater runoff from rain events in urban areas, or in locations with large amounts of impervious surfaces, flows directly into water bodies, taking with it any pollutants that are on the surface, like trash, oils, chemicals and fecal matter," said Lucas Gregory, Ph.D., associate director of the Texas Water Resources Institute (TWRI). "Whereas rain that falls on permeable surfaces like grassy areas in parks, is mostly absorbed into the soil."

When the concept of green stormwater infrastructure (GSI) gained popularity in the early 2000s, addressing these water quality problems was paramount, said Fouad Jaber, Ph.D., professor in the Department of Biological and Agricultural Engineering at Texas A&M University and Texas A&M AgriLife Extension Service specialist.

In recent years, however, water quantity and flooding problems have motivated much of the increasing interest in GSI, he said.

"When I joined Texas A&M AgriLife in 2007, the main reason for GSI was water quality," Jaber said. "But, after Hurricane Harvey and multiple extreme flooding events, I found myself getting more questions about — could GSI be used as a flood management practice?"

### What is GSI?

Designed to mimic nature's ability to absorb and filter water, GSI helps prevent stormwater pollution using systems of plants and soil.

Sometimes called blue-green infrastructure, or BGI, GSI includes bioretention cells, vegetative strips, rain gardens, green roofs, rainwater ⇨

GSI practices in action at the Texas A&M AgriLife Research and Extension Center at Dallas: permeable pavement (left) and a bioswale depressed parking lot median (right). Photos by Leslie Lee, TWRI.

harvesting systems, permeable pavements and constructed wetlands.

Traditional stormwater infrastructure includes storm drains and gutters, concrete detention and retention ponds, culverts and piped drainage.

"Traditionally the idea of stormwater management was: get the rainwater out as soon as possible," said Bardia Heidari, Ph.D., TWRI research scientist who works closely with Jaber. "But with GSI, the philosophy is: help the landscape absorb and naturally filter the water in-place, as close to where it falls as possible, to slow runoff and protect water quality watershed-wide."

## Dallas case study shows GSI benefits

In 2016, with funding from the Nature Conservancy, the city of Dallas began partnering with Jaber to research this question: could GSI effectively enhance urban flood management within Dallas, considering capacity, cost and climate change impacts?

Jaber and Heidari began working with the city of Dallas, collected data and maps, and then ran data and scenarios through hydrological models.

Climate change is predicted to increase the number and the overall impacts of stormwater "system hotspots" — locations where the drainage network is undersized and likely to contribute to inlet overflows and flooding during rain events. Jaber said that for the storms modeled in this study, climate change resulted in an average increase of 26% in the number of drainage system hotpots compared to current conditions.

"We saw that a lot of these systems are going to be experiencing increased flooding with these increased storms caused by climate change, and we asked, 'what if we installed green infrastructure everywhere possible?'" Jaber said. "The result was more than we had imagined — we were able to reduce flooding by 20% for the 100-year storm, which would save a lot of money."

GSI was found to reduce overflows for all storms modeled by 17-31% and to delay peak flows, which potentially reduces areal flooding, creek flows and overbank flooding. The research also found that GSI would cost 77% less than upgrading to gray infrastructure alone to meet modeled overflows; a combination of green and gray provided the maximum cost-effective benefits.

"The results that we got were so positive, that the city was very happy with the results," Jaber said.

Today, Heidari and Jaber continue researching GSI and educating more professionals about its potential benefits.

"Most cities' staff don't need convincing — they know about water quality issues, they know that the erosion is a problem — most municipal staff are well-aware, although they might have misgivings on maintenance needs and implementation costs," Jaber said.

Indeed, some cities are codifying GSI best practices into policies. In November 2022, the city of Austin enacted several environmental protection-related updates to Austin's Land Development Code, including requiring GSI as the primary

method of stormwater pollution prevention for most site plans and subdivisions. It also requires stormwater within parking lots to drain to parking lot islands and medians where feasible.

"I spend a lot of time educating and presenting to city staff, decision-makers, consultants and engineers, and we talk about the devastating impacts of urbanization — runoff, pollution, higher bank erosion, *E.coli* in streams, etc., due to the conversion of pervious land to impervious land," Jaber said. "Then I tell them there is a simple solution — you can integrate these components into parts of your development that you already have — a depressed parking lot median, instead of a high median, use a permeable parking material instead of impermeable concrete."

## Helping coastal communities adapt

Meanwhile, in the Gulf Coast region of Texas, another team of Texas A&M AgriLife experts is working to help communities adapt to changing flood and stormwater realities.

AgriLife Extension's Green Infrastructure for Texas (GIFT) team shows leaders and communities the benefits of green infrastructure, how it can help them meet their land use goals, and how it's working for nearby cities. Working mainly in the Houston and Gulf Coast region, GIFT leads workshops, provides technical assistance, completes large on-the-ground wetland and green infrastructure projects, organizes stakeholder groups, collects data, leads volunteers and provides hands-on learning for students through the GIFT High School Internship Program in Green Infrastructure Career Development, funded by a grant from the U.S. Environmental Protection Agency.

"I like to tell people that we are the blue-sky part of disaster recovery — we try to help communities before a disaster strikes," said Christie Taylor, GIFT wetland program specialist. "Our work takes us up and down the Texas Coast and inland whenever partnerships allow."

GIFT is a part of the Disaster Assessment and Recovery (DAR) group in AgriLife Extension and is headquartered in the Texas Community Watershed Partners office in the Clear Lake region of Houston. GIFT is a grant-funded program funded in part by the Texas General Land Office.

Unfortunately, rapid growth and extreme flooding make green infrastructure badly needed there.

Fortunately, regional results have proven that green infrastructure works. Residents of Houston's Bay Area experienced this in 2017 when a major green infrastructure project called Exploration Green had just begun — but Hurricane Harvey hit first. ⇨


Volunteers work at the stormwater wetland at the Houston Botanic Garden. Photo by Texas A&M AgriLife GIFT.

## Green infrastructure saves property

Exploration Green is a stormwater wetland park complex on land that was formerly the defunct Clear Lake City Golf Course. The Clear Lake City Water Authority now owns and manages the facility in partnership with the Exploration Green Conservancy group, and it is supported by AgriLife Extension and numerous community partners.

However, as Hurricane Harvey approached the Houston area in August 2017, only the first phase of the project had been completed.

"The first wetland section was about halfway done at that point, and that one section prevented about 150 homes from flooding," Taylor said. "In previous, smaller storms, those homes had flooded.

"After that, the community said yes, we want to support this project, we want more of this," she recalled.

Exploration Green originally had a 15-year implementation timeline. After Harvey, the timeline was sped up to 10 years. The project was funded through a bond election, and it is also now supported by a nonprofit, the Exploration Green Conservancy.

"It has proven its value for flood control, that is clear and visible," Taylor said. "Now we are in the middle of a research project measuring its effect on water quality; we're conducting regular water quality monitoring and will be analyzing that data in 2024."

## Building and sustaining wetlands

Today, Exploration Green is completing its fifth and final phase of excavation and construction. It includes vibrant wetlands in five detention ponds that hold up to 500 million gallons of stormwater, and it provides public recreation space and a nature reserve.

Taylor knows its ecosystem extremely well: not only did she and the GIFT team train and supervise the numerous teams of volunteers who planted native plants in all of the wetlands — GIFT grew the plants in their special-built stormwater wetland plant nursery.

"We planted 15,000 wetland plants in each of the five sections — that's a lot of volunteer hours, and we couldn't have done it without so much community support," Taylor said.

GIFT has successfully implemented green infrastructure in numerous spots around the Houston area, including:

- Houston Botanic Garden: constructed a 2.5-acre stormwater wetland
- Anahuac National Wildlife Refuge: restored a 300+ acre freshwater prairie-wetland complex
- Sheldon Lake State Park: restored more than 500 acres of prairie-wetland complex
- Ghirardi WaterSmart Park: helped build a 3.75-acre park in League City showcasing several small-scale green infrastructure practices.

These nature-based solutions are intended to work in conjunction with gray infrastructure to meet the needs of communities, reduce stormwater runoff, protect and improve water quality, provide community green space and support local growth, the GIFT team said.

Based on these successful projects and with help from their partners, Taylor and the GIFT team have recently completed a manual for public education and outreach entitled Texas Regional Stormwater Wetland Manual Gulf Coast Region. This manual is a tool for coastal communities to use to outline future stormwater wetland projects.

Looking forward, both Jaber and Taylor were optimistic.

"I think we have reached the point where major cities are aware that they need to use these practices from the beginning of planning," Jaber said.

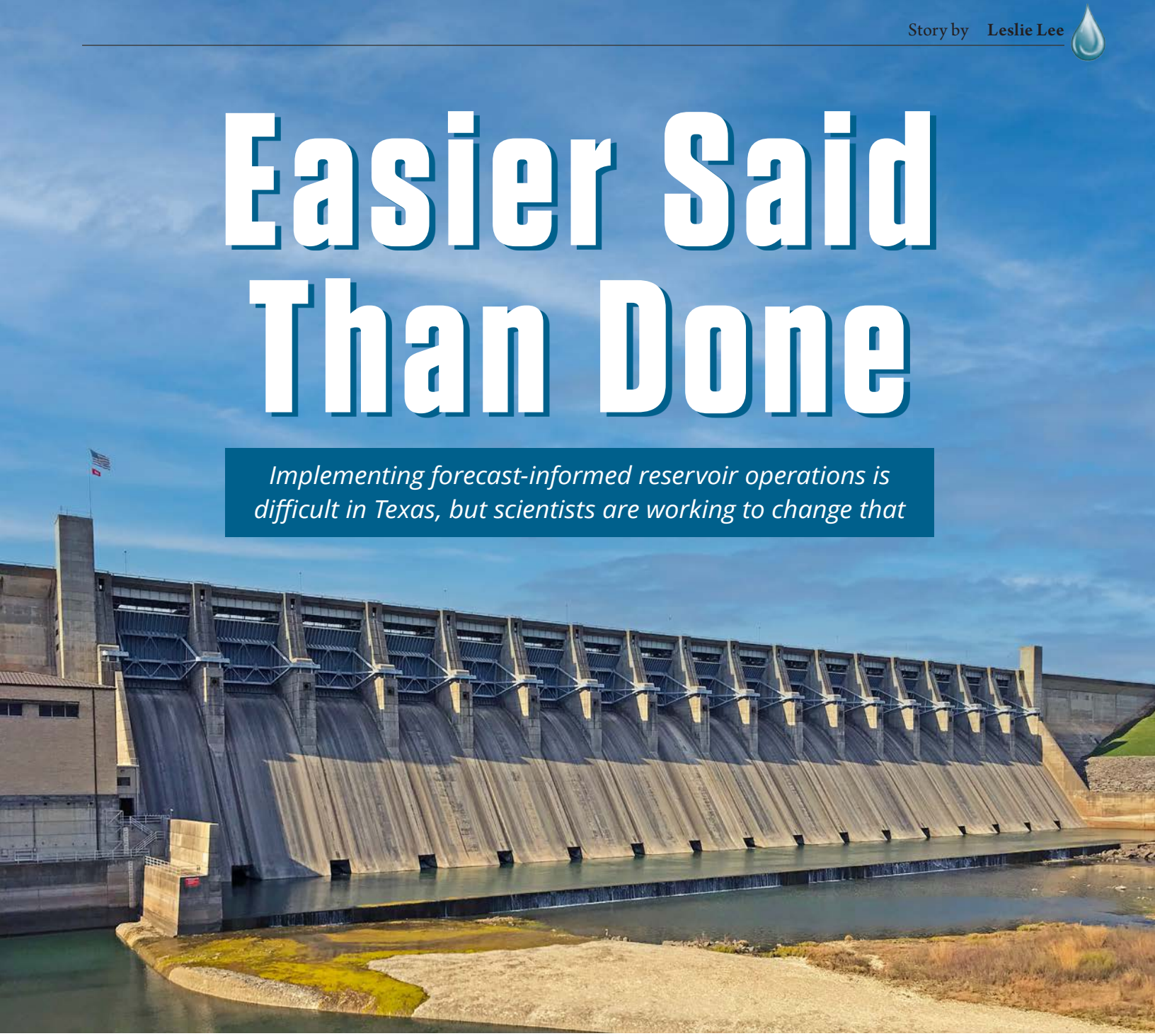
"Here in Texas we can't slow development down, but we can put these green infrastructure practices in from the beginning of a new development project and make a real difference."

Exploration Green, a stormwater wetland park where a golf course once operated, in Clear Lake, Texas. Photo courtesy of Texas A&M AgriLife GIFT.

Story by **Leslie Lee**

# Easier Said Than Done

*Implementing forecast-informed reservoir operations is difficult in Texas, but scientists are working to change that*



Whitney Lake Dam Gates (south side). Photo by Trevor Welsh, U.S. Army Corps of Engineers.

Operating a reservoir in Texas requires managing an extensive list of fluctuating variables: stream flows, scheduled withdrawals, rainfall, evaporation rates, stormwater runoff, municipal water demand, fisheries, recreational needs, water quality, flooding, invasive species and more. Operators all over the state use various forecast models to juggle surface water management amid these sometimes difficult-to-predict variables.

Forecast-informed reservoir operations, or FIRO, is a water supply management strategy recently adopted in the western U.S.

Using FIRO, reservoir operators look to robust, reliable forecast models and manage reservoir releases differently than traditional protocols. For example, if a drought is approaching, they may save more water in the lake's flood pool than usual, and if a major flood event is coming, they may release water preemptively.

But, those operations involve numerous factors, including fulfilling all obligations to downstream customers and water users. Reservoir operators would work closely with water supply entities to implement the most efficient and low-risk operations.

FIRO management strategies could greatly benefit Texas water supplies, but implementing them is not as simple in Texas. ⇨

Whitney Lake Dam Gates (north side). Photo by Trevor Welsh, USACE.

## Understanding Texas' reservoirs

Max Strickler has managed federal reservoirs in Texas for over 10 years and knows many of those lakes inside and out. As a water management lead engineer for the U.S. Army Corps of Engineers (USACE) – Fort Worth District, he supervises reservoir operations for 25 reservoirs across Texas, and each is a balancing act.

"These are multipurpose reservoirs, primarily built for flood risk management, but they also have other purposes such as water supply, fish and wildlife, environmental and recreation," he said.

Strickler explained that the philosophy of the flood pool, which is where operators capture flood waters, is that it should be as empty as possible to always be prepared for the next flood (see diagram on page 15). "That is in competition with the philosophy behind the conservation pool or water supply pool, which says that it should always be as full as possible to prepare for the next drought," he said.

"If you can safely increase the amount of water being held temporarily in the flood control pool, you are able to increase supply temporarily," stated Nelun Fernando, Ph.D., manager of the water availability program at the Texas Water Development Board (TWDB) in a news release. "FIRO offers the potential to help ensure water availability during periods of drought in a cost-effective way."

In years past, precisely measuring evaporation rates and accurately forecasting floods and droughts in Texas has been extremely difficult. While government agencies publish improved forecast products all the time, verifying their accuracy to make real-world operational decisions is a challenge, Strickler said. Texas operators also face infrastructure constraints, rapid population growth, environmental concerns and real estate development in floodplains.

## Could FIRO work in Texas?

"California in particular has had recent success with FIRO because of the high accuracy of the precipitation forecasts in that region," Strickler said. "Significant investments in meteorological research likely need to happen in Texas before the widespread adoption of FIRO by reservoir operators. Amounts, location and intensity of precipitation are all critical aspects of FIRO that need to see improvement in Texas over the coming years."

The unpredictability of Texas' weather makes FIRO simultaneously difficult and badly needed. "We always have to be prepared for floods or drought," he said.

Experts tout the benefits of FIRO, such as: making more water available without costly infrastructure investment, storing flood water in late spring and early summer, reducing the need for pumping by utilizing natural flows instead and storing runoff during consecutive drought years.

And now, as forecasts and technology improve, Texas operators are beginning to trial-run FIRO.

Since the summer of 2022, TWDB has partnered with the University of Texas at Arlington, USACE Fort Worth, the National Weather Service West Gulf River Forecast Center and the Brazos River Authority on a FIRO pilot project in the Little River watershed in the Brazos River basin.

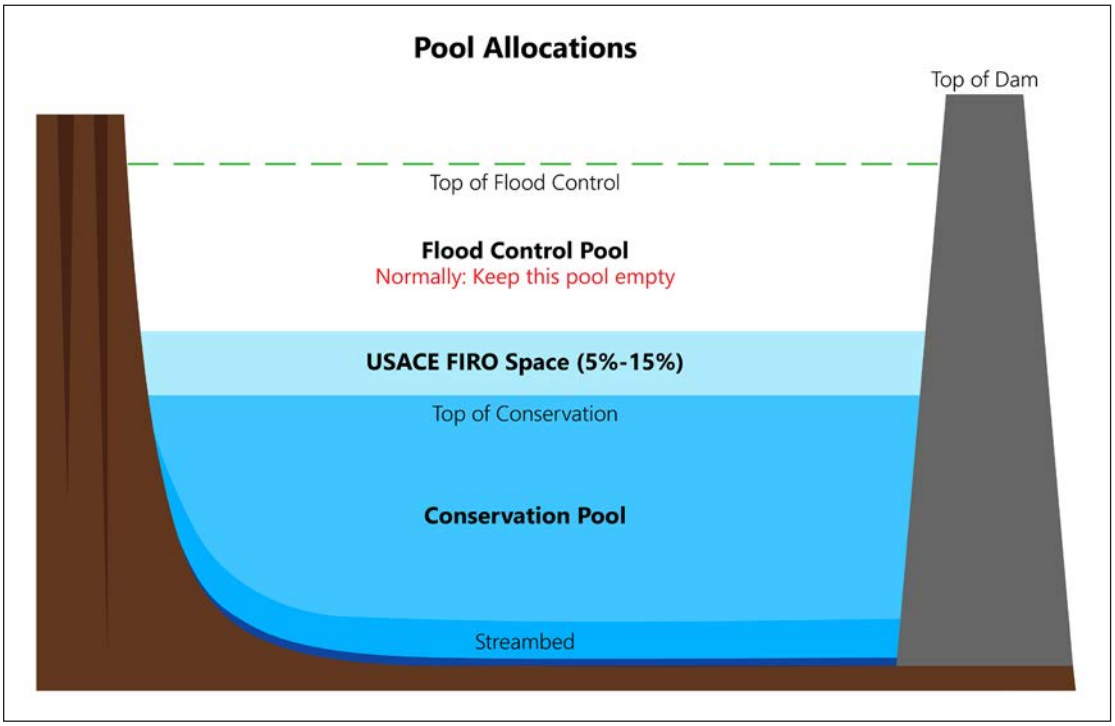
Funded by the U.S. Bureau of Reclamation, the project is studying how short-term operational changes to Lake Georgetown's flood pool can be implemented using improved rainfall forecasts.

## Getting the evaporation variable correct

One key piece of the FIRO puzzle is evaporation rates.

Evaporation loss from reservoirs is a major variable for Texas water planners to incorporate into strategic reservoir operations and models. Using reservoir system simulation models will be one of the first steps that Strickler and other water managers will take toward FIRO. Utilizing the models, they can run hundreds of different hypothetical lake operation plans to find which work best in Texas and then hopefully implement them in the real world.

An expert in reservoir evaporation, Huilin Gao, Ph.D., is an associate professor in the Zachry Department of Civil and Environmental Engineering at Texas A&M University who researches hydrological modeling, remote sensing, water resources management and evaporation rate modeling for informing FIRO.




Reservoir pool allocation explanation by Max Strickler. Diagram by Sarah Richardson.

Remarkably, reservoir water lost via evaporation is substantial — not just in Texas but around the world.

"A recent research study showed that over the last few decades, globally, reservoir evaporation losses actually exceed the total industrial and domestic water consumption together," Gao said.

"I think people would be shocked at how much evaporates," Strickler said. "In Texas, daily evaporation is about the same as daily water supply use."

Gao and collaborators published their research in March laying out just how much evaporation may tax U.S. reservoirs in the future, exacerbated by climate change impacts.

What they discovered was significant.

"Reservoir evaporation losses in the United States are projected to increase by $2.5\times10^7$ $m^3$ per year under the highest future warming scenario," she said.

The research team projected the future evaporation rate and losses with the Lake Evaporation Model, developed by Gao's lab, under a commonly adopted representative future climate scenario. For 678 major reservoirs across the United States, both evaporation rates and losses are projected to increase. She said that future exacerbation of evaporation will be much more substantial in the southwestern United States and is expected to be more severe in the fall.

"Water planners need to consider accelerated water loss through open water evaporation in long-term water resources planning across various spatiotemporal scales," Gao said.

To help water planners do just that, her research team, in collaboration with the Desert Research Institute, also recently produced a critically needed new product — the Reservoir Evaporation Tool website, which will be in TWDB's suite of online tools.

Previous evaporation tools in Texas used monthly data interpolated from the A-pan observations. A-pans are physical evaporation measurement tools, usually located in small metal tanks near a reservoir, but sometimes miles away. A-pans cannot accurately represent all reservoir characteristics, such as location, area and depth.

In contrast, Gao's new site provides both daily and monthly evaporation for each of Texas' 188 large reservoirs, from 1980 to the present. And, it offers the option of monitoring smaller lakes by inputting a custom reservoir scenario. It was co-funded by TWDB, USACE Fort Worth and the Lower Colorado River Authority.

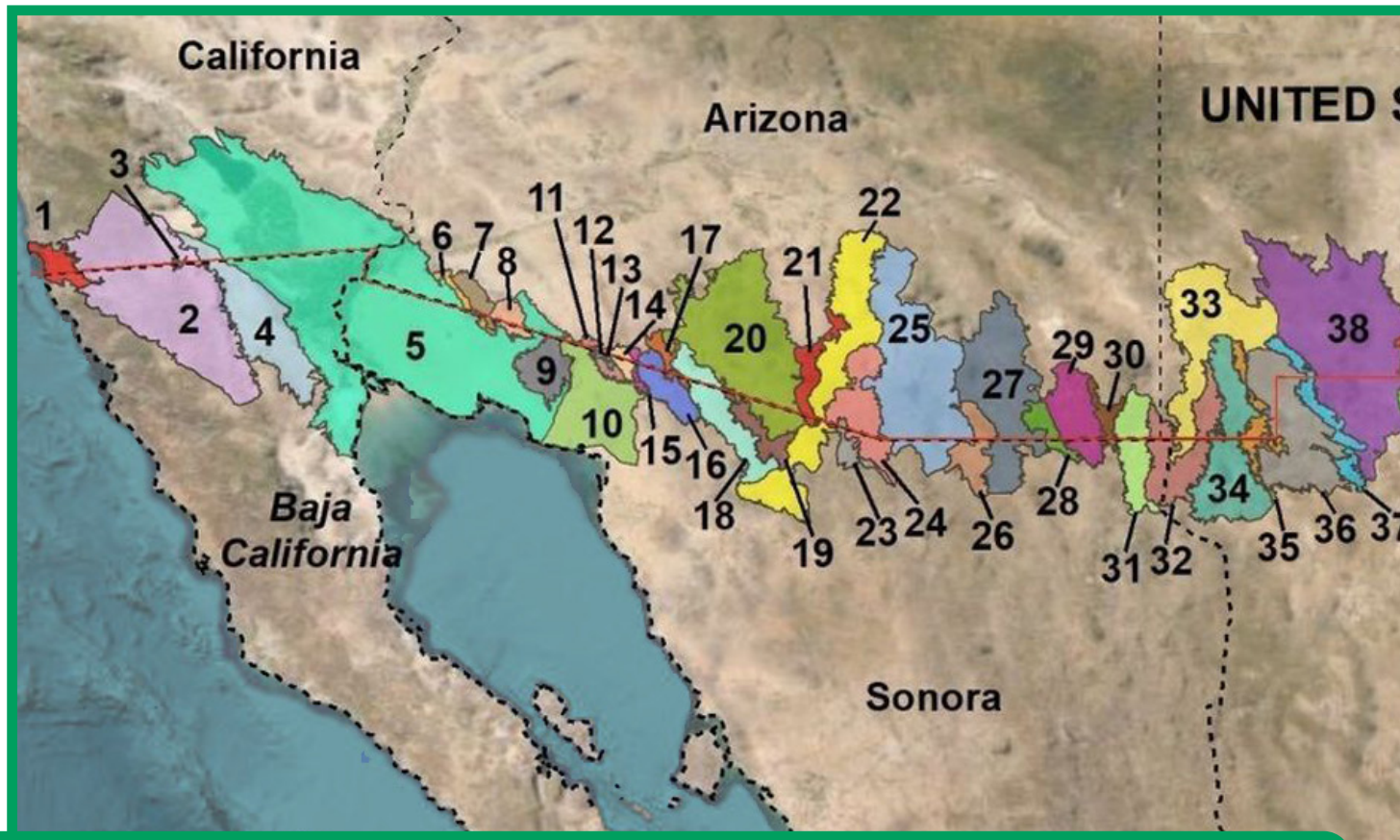
Strickler said that this new evaporation data is going to be critical to FIRO pilot projects in Texas. Using this modern data, FIRO strategies can help Texans save water and money.

"It's billions of dollars to build new lakes and dams," he said. "In contrast, the great thing about FIRO is, it uses the expensive dams and lakes we already have, but uses technology to make them more efficient and beneficial.

"FIRO will be much cheaper per acre-foot of water than doing more dam building."

# FIRST EVER BORDERLANDS

*TWRI's Rosario Sanchez reflects on leading the development of the first complete U.S.-*



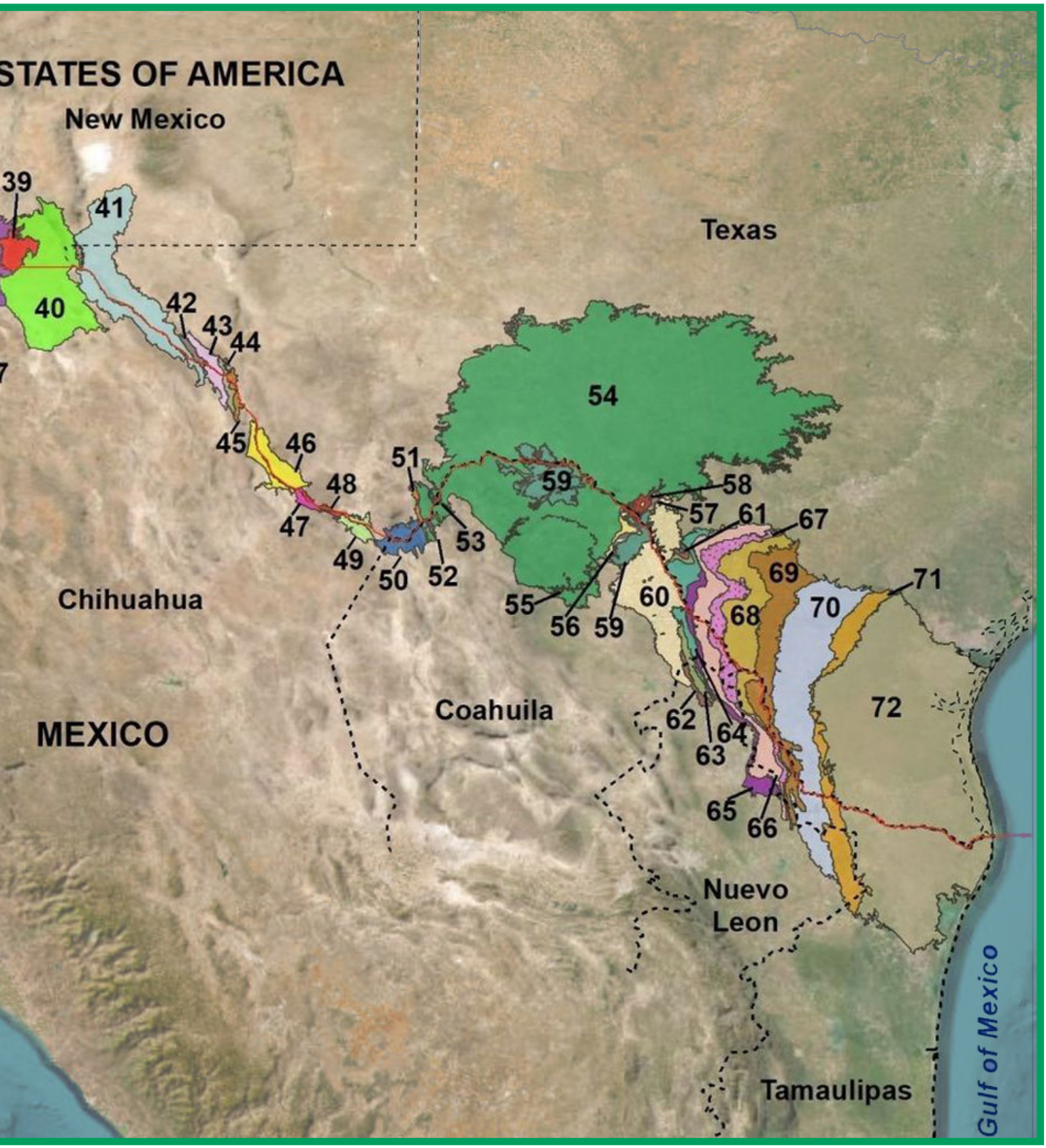

**Hydrogeological Unit**

1 Tijuana - San Diego Aq.
2 Tecate Aq./Potrero Valley
3 La Rumorosa - Tecate Aq./Jacumba Valley
4 Laguna Salada Aq./Coyote Wells Valley
5 Valle de Mexicali - San Luis Rio Colorado Aq./ Yuma - Imperial Valley
6 Tinajas Altas Mountains
7 Puente Cuates Valley/Lechuguilla Desert
8 Cabeza Prieta Mountains
9 Los Vidrios Aq.
10 Sonoyta-Puerto Peñasco Aq.
11 Agua Dulce Mountains
12 Cerro Colorado Numero 3 Valley
13 Quitobaquito Hills
14 La Abra Plain
15 Senita Basin
16 Lukeville - Sonoyta Valley
17 Sierra de Santa Rosa - La Nariz
18 The Great Plain
19 Los Chirriones Aq.
20 San Simon Wash
21 Baboquivari Mountains
22 Arroyo Seco Aq.
23 Rio Altar Aq.
24 Pajarito Mountains
25 Nogales-Rio Santa Cruz Aq./Upper Santa Cruz Basin
26 Cienega Creek Basin
27 Rio San Pedro Aq./Upper San Pedro Basin
28 Mule Mountains
29 Rio Agua Prieta Aq./Douglas Basin
30 Perilla Mountains
31 Arroyo San Bernardino Aq./San Bernardino Valley
32 Guadalupe Mountains
33 Animas Basin
34 Janos Aq./Playas Basin
35 Alamo Hueco Mountains
36 Ascension Aq./Hachita Moscos Basin
37 Josefa Ortiz de Dominguez Aq.
38 Las Palmas Aq./Mimbres Basin
39 Potrillo Mountains
40 Conejos Medanos Aq./Mesilla Bolson
41 Valle de Juarez Aq./Hueco-Tularosa Bolson
42 Quitman Mountains
43 Red Light Draw Bolson
44 Eagle Mountains
45 Green River Valley Bolson
46 Presidio Bolson
47 Redford Bolson
48 Tertiary Igneous Rocks
49 Cretaceous-Terlingua Aq.
50 Mariscal
51 Boquillas Fm/Boquillas Fm
52 Santa Fe del Pino aq.
53 Serrania del Burro Aq.
54 Edwards Aq.
55 Kiamichi Fm/Kiamichi Fm
56 Buda-Del Rio Fm/Buda Limestone-Del Rio Clay
57 Eagle Ford Fm/Eagle Ford Group
58 Presa La Amistad Aq.
59 Austin Fm/Austin Chalk
60 Allende-Piedras Negras Aq.
61 Upson Fm/Upson Clay
62 San Miguel Fm/San Miguel Fm
63 Olmos Fm/Olmos Fm
64 Escondido Fm/Escondido Fm
65 Midway Fm/Kincaid Fm
66 Carrizo-Wilcox Aq.
67 Bigford Fm/Bigford Fm
68 El Pico Clay Fm/El Pico Clay Fm
69 Palma Real-Guayabal Fm/Laredo Fm
70 Yegua-Jackson Aq.
71 Catahoula Confining System
72 BRB/Gulf Coast Aq.

Story by **Madalyn Richards**

# AQUIFER MAP

*Mexico borderlands aquifer map and why it matters*




Hydrogeological units in the borderlands between Mexico and the United States. Map developed by Rosario Sanchez, TWRI.

In 2015, agencies and officials counted the number of shared groundwater aquifers flowing beneath the U.S.-Mexico border to be 11. But after nearly a decade of geological and hydrological research, Rosario Sanchez, Ph.D., revealed a far more complicated picture.

When Sanchez published the first-ever complete map of the U.S.-Mexico transboundary aquifers in January 2023, the map showed that there are actually 72 shared aquifers in the region.

This includes five aquifers between Baja California and the state of California; 26 between Sonora and Arizona; and 33 between Texas and the Mexican states of Chihuahua, Coahuila, Nuevo León and Tamaulipas. Sanchez said 45% of the aquifers were found in "good to moderate" condition.

Sanchez is a senior research scientist for the Texas Water Resources Institute (TWRI). She is also the director of the Permanent Forum of Binational Waters and leads the Transboundary Aquifer Assessment Act program for Texas. Laura Rodriguez, a Ph.D. candidate in Texas A&M University's Water Management and Hydrological Sciences graduate program, co-authored the research and worked as its resident geologist.

## Filling in the blanks

Prior to Sanchez's publication, some groundwater maps and databases run by state and federal agencies had blank regions around the border — incomplete records of groundwater supplies integral to the region's communities and economy, she said.

While the map has helped fill in the blanks, there is currently no formal legal or policy framework at a binational level to address transboundary groundwater management in the border region. These aquifers underlie more than 121,500 square miles of land that is experiencing population growth, drought and climate change impacts. Sanchez said this could put both nations in precarious positions.

"We don't have the luxury to keep ignoring the shared component of these resources," she said. "We have to address this sooner or later, because the less we know, the more vulnerable we are."

To define the aquifers, Sanchez's team first studied the regions' geological formations, spanning both sides of the border, then the type of formations and their porosity. "Every point in that map was a decision we had to make, based on the physical condition and scientific data," she said.

"Our analytical method used geology, topography, lithography, geomorphology and hydrology to identify hydrogeological units (HGUs) and those HGUs that have good aquifer potential at the transboundary level," Sanchez said.

Since the map's publication, they have also been working to assess the aquifers and evaluate priority areas based on the pumping patterns at the transboundary level, and their level of transboundariness, a concept she coined in 2020. Transboundariness is defined as the strategic value that an aquifer acquires by being located at the border, Sanchez said. Economic, social and political conditions also play a role in its level of transboundariness.

Additionally, she continues to quantify and communicate all the unknowns in the region.

"We don't know how much water has been withdrawn," Sanchez said. "We don't know the impact of that on the other side of the border or vice versa. We don't know the quality of that water. We don't know who has been drilling wells or for what use. We don't know what has possibly been pumped into these aquifers. And, we don't know how much water we have left."

## Response to the revolutionary

The map was well received by both countries, Sanchez said, and throughout the 10-year process, the researchers made sure to constantly consider the perspectives of both sides.

"This particular science, that touches two different jurisdictions, political systems and cultures, requires much more than just science to be useful, applicable and recognized," Sanchez said. "We didn't just do this for the sake of science."

Few funding opportunities for continued research existed previously, but the map's impact, the international network of transboundary water researchers and the growing need for efficient groundwater use have all helped the area get more attention from decision-makers, she said. The U.S. Geological Survey recently began pursuing more funding for shared groundwater resources research.

Sanchez's publication is already used by the International Groundwater Resources Assessment Centre (IGRAC), which maps and monitors transboundary aquifers globally. It is also used by the Binational Groundwater Task Force, and both organizations have helped with the map's visualization.

To make progress, leaders must figure out water resources' role in the binational agenda and the implications for future regional water security, she said.

"And, we get to help, we get to participate, we get to collaborate, we get to be part of the decision-making process," Sanchez said. "We are walking with the leaders, which is the most important part of our research. That is my passion."

Story by **Mackenzie Schneider**

# On the Cutting-edge of Climate-smart Farming

*Texas A&M AgriLife's Nithya Rajan leads innovative research aimed at reducing emissions and sustaining agricultural industries*


Nithya Rajan in College Station, Texas. Photo by Sam Craft, Texas A&M AgriLife Marketing and Communications.

In the fall of 2022, Texas A&M AgriLife Research received the largest competitive grant in the organization's history: a $65-million, 5-year, multi-commodity project to work with Texas' agricultural sector on expanding climate-smart agriculture and forestry practices. The Texas Climate-Smart Initiative was part of a massive investment by the U.S. Department of Agriculture, funding 70 research projects with $2.8 billion. Nithya Rajan, Ph.D., agronomist and Texas A&M University soil and crop sciences professor, is one of the scientists involved in this historic investment.

Rajan studies climate-smart farming practices aimed at increasing the sustainability and productivity of row crop production systems while simultaneously increasing carbon capture and reducing greenhouse gas emissions

Her research team of graduate students and post-doctoral scholars is using cutting-edge technologies in their research, including state-of-the-art instrumentation for monitoring greenhouse gas emissions, modeling, and remote sensing.

Rajan obtained her bachelor's degree in agricultural sciences from Kerala Agricultural University, master's in soil science and agricultural chemistry from A.N.G.R. Agricultural University in Hyderabad, India, and Ph.D. in agronomy from Texas Tech University. She then worked as a post-doctoral research associate for two years at Texas Tech, and in 2010 joined the Texas A&M AgriLife Research and Extension Center in Vernon as an assistant professor of cropping systems agronomy.

In December 2014, Rajan moved to College Station and joined the faculty in the Department of Soil and Crop Sciences.

"I would describe myself as a broadly trained agronomist," she said. "My current research goal is to provide evidence that these practices are climate-smart and can reduce emissions."

## Cover crops can help

Rajan's research group is studying and quantifying the impact of cover crops on carbon emissions. Oftentimes, farmers harvest their main crop and then leave the fields fallow until returning the next season to plant and harvest their main crop again, she said.

During that period, high carbon emissions happen if a field is left fallow, she said. This can also lead to a lot of weed pressure and erosion issues. Therefore, Rajan's team is trying to promote cover crops as a climate-smart agricultural practice that increases overall carbon sequestration and reduces emissions.

"Farmers can plant something during their fallow period to capture more carbon dioxide from the atmosphere," she said.

## Big projects, big dreams

In Rajan's lab, they are also studying the climate-smart potential of various irrigation practices, such as center pivot, furrow and subsurface drip. Different irrigation types can differently affect carbon and nitrogen cycling in soil and greenhouse gas emissions.

"We will be comparing climate-smart practices against business-as-usual practices side-by-side, in collaboration with farmers in Texas, and also in other states," Rajan said.

This research is funded by the climate-smart commodities project and will also involve researchers and cotton fields in California, Mississippi and Georgia.

Rajan's lab is asking, when farmers implement these practices in a large operation, what will happen? How much emission reduction can we expect? Is that climate-smart? And is that enough?

Texas is the leading state in greenhouse gas emissions, emitting twice the amount of greenhouse gases as California, the next-highest state.

The state of Texas has an opportunity to reduce its carbon footprint with the help of agriculture, Rajan said. If farmers in Texas can implement climate-smart agricultural practices, that will help reduce the greenhouse gas footprint of Texas.

"If we can encourage and promote the adoption of these climate-smart practices, that is the dream, to eventually make Texas carbon-neutral," she said.

After several years of working in this field, Rajan is optimistic about the momentum science is gaining at all levels.

"I'm incredibly enthusiastic about this opportunity because I currently feel empowered to make meaningful contributions to the climate-smart practices discussion, which is gaining recognition not just at the national level but also on the international stage," she said. "It's truly gratifying to witness the global impact of the research we are engaged in."

## Next steps

Rajan believes that to truly have an impact, it is essential to have a long-term vision.

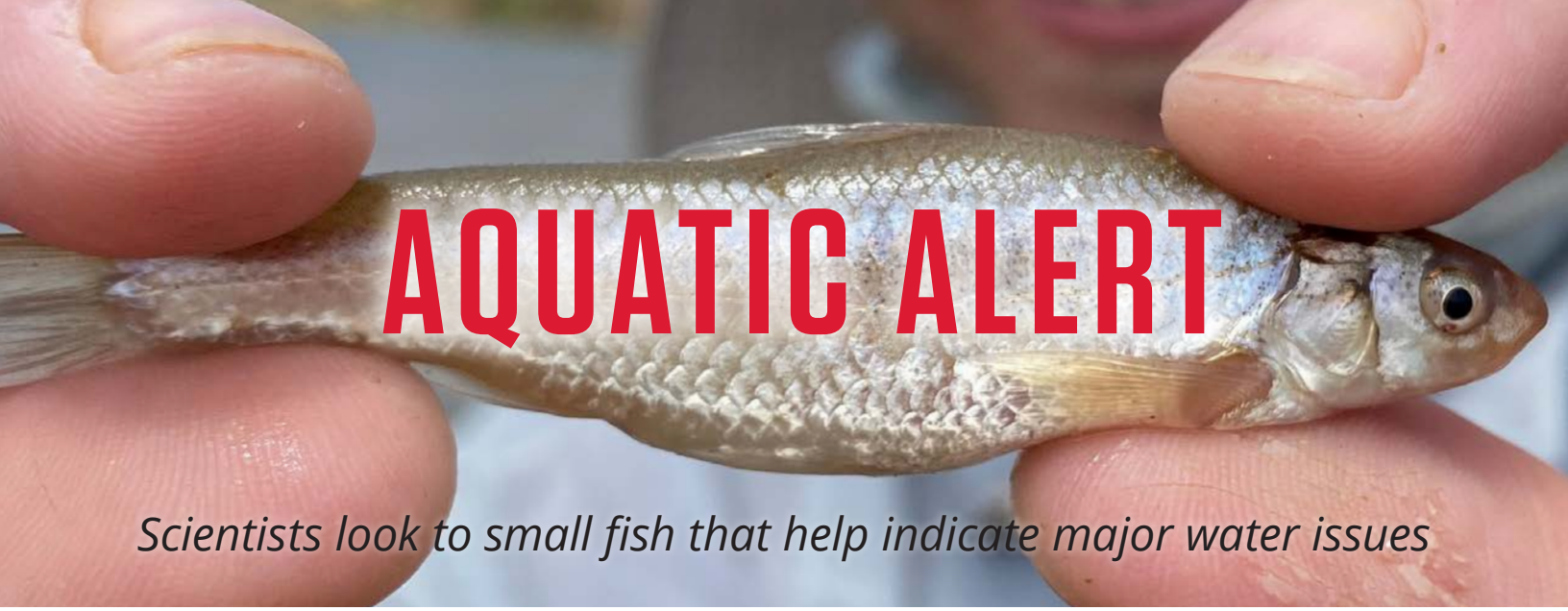
With that in mind, she plans to lead her lab to develop and discover new strategies in the coming years, both during and after the climate-smart project.

She hopes that she may be able to use more technology in the upcoming years, as well as new crops that can be potentially engineered to capture more carbon and reduce greenhouse gas emissions.

"We have a new research program now that aims to develop crop varieties that can secrete root exudates with nitrification inhibition potential to reduce nitrous oxide emissions, a highly potent greenhouse gas. I am excited to work with my colleagues on this project, and we are also collaborating with an international team of researchers. Our vision is to release crop varieties that are climate-smart."

"There's so much we can do to help to address some of these global issues," she said. "I hope to inspire more young individuals to take an interest in this kind of research and become aware of the opportunities available for them to make a significant impact."

Nithya Rajan conducting research with graduate students. Photos by Sam Craft, Texas A&M AgriLife Marketing and Communications.



# AQUATIC ALERT

*Scientists look to small fish that help indicate major water issues*

Small fish such as shiners and minnows can have big implications for water quality and quantity in Texas rivers and streams. While these fish might seem inconsequential, they play a key role in ecosystems and for researchers studying the intersections of ecology and water management.

Joshuah Perkin, Ph.D., studies the ecosystem services that these fish provide. He is an assistant professor and fish ecologist in the Department of Ecology and Conservation Biology in the College of Agriculture and Life Sciences at Texas A&M University.

Perkin and others with similar research focuses recognize the value of fish as ecological indicators. Scientists use these fish to understand the long-term consequences of short-term decisions humans make about water.

"As researchers, we think of fishes as providers of goods and services to humans on multiple fronts," he said. "Whether we realize it or not, we benefit from ecosystems in their natural state."

Small fish cannot flourish without sufficient water in streams, so these fish populations tell scientists a lot about the health of an ecosystem and the availability of water in an area, Perkin said. This can help scientists and policymakers develop strategies to manage water resources more effectively in the future.

Tiny fish as indicators function similarly to canaries in coal mines, he said. Canaries are extremely sensitive to carbon dioxide and other toxic gases, so miners kept the birds in cages while they worked. If the birds became sick or died, it would warn the miners and give them time to evacuate.

"Fish can work the same way," Perkin said. "They are much more sensitive to changes in water availability than humans are."

## Fish as indicators

The pelagic broadcast spawning guild of fishes is just one example of how scientists can use these small fish species to detect water scarcity. To an average observer, these fish may seem trivial, but water professionals are watching their every move.

When these fish spawn, or reproduce, they use external fertilization and blast gametes out into the water column to fertilize eggs, Perkin said. After the eggs are fertilized, they swell with water and become larger as they drift downstream.

"When the eggs do not have sufficient water to drift downstream, they will settle to the bottom and suffocate in the sand; they need water pushing them down the stream to live," he said.

If fish like this do not have reproductive success every year, their populations will decline. This can alert researchers to desiccation in certain areas and give leaders the opportunity to address the issues before the water is gone completely.

"There are fish species like this everywhere," Perkin said. "Most people are unaware that they play such an important role."

The Arkansas River Shiner was one of the first major indicator species recognized in the United States.

As agricultural irrigation practices increased in the mid-1900s and the United States started large-scale water extraction for irrigated agriculture, the Arkansas River Shiner's population began declining, he said. By the 1960s, the shiner was gone from the places it naturally occurred, but there were no significant issues with water depletion in the Arkansas River until 20 or 30 years later.

"During this time, humans forced the groundwater levels away from the surface, intercepted melt water and changed river flows, all of which had an immediate effect on the Arkansas River Shiner,"

Perkin holds one of his favorite minnows, the Plains Minnow. Photo courtesy of Josh Perkin.

Perkin said. "If we had paid attention to fish as an indicator, we could have adjusted our management practices."

## Using fish for future flow plans

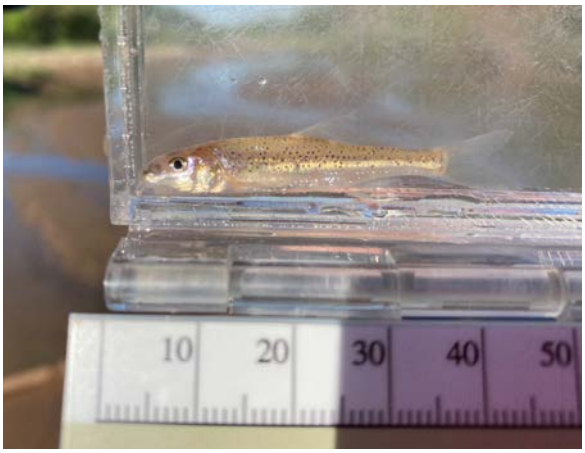
While the information these fish can provide is key, what policymakers do with it is equally important, he said, and his team has shifted to studying the relationship between ecology and water management.

Perkin's current project is funded by the National Science Foundation, in collaboration with researchers at the University of Oklahoma. His team wants to understand water conservation incentives, how water users make decisions about water use and how they can be incentivized to use less water during times of drought.

"Our research guides water management decisions so that we can use water in a more sustainable way," Perkin said. "We are not managing it to the depletion of the resource, and instead making it available for generations to come. Our research is linking ecology to management.

"Reservoirs are very important to human life; understanding how to release water in those reservoirs and manage water levels in the rivers downstream of reservoirs requires a lot of information from ecology and the environment," Perkin said.

Environmental flows and state-regulated flow regimes are included in Perkin's research. The Texas Water Development Board contracts and funds numerous projects surrounding the study of environmental flows.




Graduate student Zach Steffensmier captured this Prairie Chub in the Red River. Photo courtesy of Josh Perkin.

The release of water is referred to as a flow regime. When and where fish spawn depends on the flow and requires management. Understanding this is vital for Perkin's research and the future of ecology, he said, and maintaining the populations of fish in rivers is heavily dependent on flow regimes.

"Water in the state of Texas is a finite resource. We have a growing population and a growing thirst for water. We need to utilize this research so our resources are available for years to come."


Perkin's team conducting field work in the Brazos River. Photo courtesy of Josh Perkin.

# Understanding Matagorda Bay

*Water researchers explain how four watersheds impact a basin*

The Texas coast is known for its seven major bays and five minor estuaries that boast incredibly diverse wildlife and aquatic species and draw tourists from around the country. From popular swim spots like Galveston Bay to world-renowned fishing destinations like Baffin Bay, the variety and beauty of Texas bays have long been known.

Tucked in the middle of the Texas coast is Matagorda Bay. Near Victoria, the bay is a minor estuary, smaller when compared to some of the more well-known bays. Matagorda Bay itself is not highly developed and is fed by various creeks and rivers: Arenosa Creek, Tres Palacios Creek, Garcitas Creek, Carancahua Creek and the Lavaca River.

"The primary industry is agriculture and depending on where you're at, could be rice, could be aquaculture, could be turfgrass, and then obviously row crops," said Texas Water Resources Institute (TWRI) Interim Director Allen Berthold, Ph.D. "Another one is beef cattle. There's a lot of wildlife, so it's a popular hunting area as well as other ecotourism sources of revenue from fishing and beachgoers."

There is also some influence on the bay from oil- and gas-related industries.

Water testing in recent decades has found Matagorda Bay impaired with elevated bacteria levels, and many of the contaminants have come from the river and creeks that feed the bay.

"Bacteria comes from the excrement of everything with hair, fur and feathers," said TWRI Associate Director Lucas Gregory, Ph.D. "So, it's literally everywhere across the watershed. But those in-stream numbers don't meet the state's water quality standards, which are in place to protect human health or at least act as a shield from that level of risk."

## Taking a basin-wide approach

TWRI first became involved with the Matagorda basin in 2014. "Because there were multiple bacteria impairments, we decided to collect and analyze all of the existing data within the entire basin before jumping into a single watershed," Berthold said. "We thought, maybe we can maximize our time this way, especially since everything is in the same area."

Port Lavaca. Photo by Cameron Castilaw, TWRI.

Funded by the Texas Commission on Environmental Quality (TCEQ), the Matagorda Bay Basin project soon began.

The project's first year involved data collection, data analysis and other activities such as developing maps of septic system locations. TWRI also worked with local stakeholders, Texas A&M AgriLife Extension Service county agents, and nearby soil and water conservation districts to form relationships and eventually bring in educational programs.

The team began working with local stakeholders to develop watershed protection plans (WPPs) for watersheds in the Matagorda Bay Basin, and the first was published in 2017: the Tres Palacios Creek WPP.

Water quality monitoring done through the Clean Rivers Program, managed by TCEQ, had found that fecal bacteria levels in Tres Palacios Creek were often exceeding the state's recreational water quality standard. Additionally, dissolved oxygen (DO) monitoring within a 24-hour period found DO levels below the state's standards.

"The goal with a watershed protection plan is to define management recommendations and strategies that can be implemented to reduce some of those bacteria concentrations and other concerns over time," Gregory said.

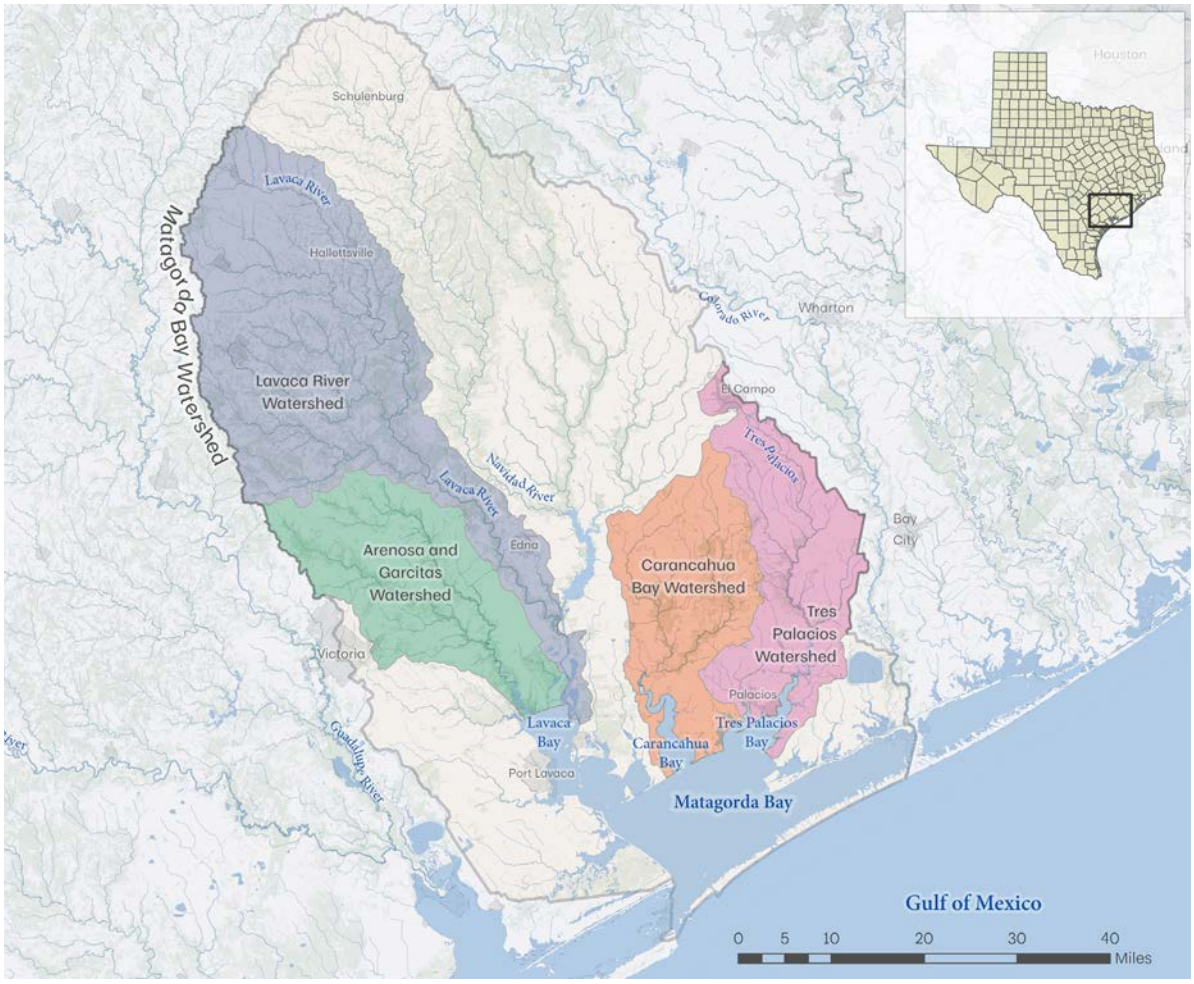
## Helping homeowners shore-up septic systems

TWRI currently works with local communities to develop stormwater management resources that homeowners can implement to ease their impact on the creeks and ultimately, the bay.

Septic systems have been identified as an issue in the area; failing systems near the creek create major health concerns and have been identified as a priority to address potential bacterial load.

"There's a couple of mobile home communities that are right on the shores of the bay," Gregory said. "Based on the results of the project, there was quite a need to address some of those families' septic systems."

This has included both educational outreach efforts to increase awareness about proper septic operation and maintenance, along with septic system repair or replacement programs when necessary. ⇨




The Matagorda Basin includes these watersheds, which all empty into Matagorda Bay: Lavaca River watershed, Arenosa and Garcitas watershed, Carancahua Bay watershed and Tres Palacios watershed. Map by Michael Schramm, TWRI.

## Making progress in more watersheds

The next WPP came in 2018 for the Lavaca River. Citing excessive *E. coli* levels and depressed DO, sections of the river had exceeded TCEQ water quality standards for human contact since 2008.

"Our Lavaca implementation project was pretty similar to the Tres Palacios implementation project: public education, stakeholder meetings and water quality monitoring," Berthold said. "We actually partnered with the Lavaca-Navidad River Authority, and they did the water quality monitoring on that project."

Chad Kinsfather, director of environmental services at Lavaca-Navidad River Authority (LNRA), is involved with work upstream from Matagorda Bay.

"Everybody's downstream from somewhere, and what happens upstream affects those downstream," Kinsfather said. "If you're a good steward in your area, it helps those further downstream."

LNRA works with local stakeholders to address watershed concerns and create discussions about better management practices that can help lessen pollution downstream. They also create educational programs for youth to help the next generation understand why protecting water quality matters so much.

Kinsfather noted the high levels of bacteria within the watersheds, which is an issue also highlighted in WPPs and research. While that pollution can come from wildlife, which can't be controlled, livestock in the area are also contributors. LNRA works with other agencies to educate farmers and ranchers about these problems and the resources available to them to lessen their environmental impact.

"Each individual landowner has their own, literal watershed that they're responsible for, and it's very important that they understand this from a river authority perspective," Kinsfather said. "I can't tell you what to do and that's a great source for water, but cows are a great source of pollution and bacteria. It's a very real health standard risk."

## Working towards a healthy Matagorda Bay

TWRI is also working on WPPs for other creeks within the bay system; a lack of information and data had been a roadblock for those plans to be accepted. There are ongoing efforts to fill that gap.

One such way is led by Steven Raabe, the trustee for the Matagorda Bay Mitigation Trust. The trust was created from a Consent Decree in 2019 as part of a lawsuit between the San Antonio Bay Estuarine Waterkeeper and Formosa Plastics Corp. Raabe oversees distributing funds from the lawsuit for projects ranging from environmental education to restoration work along Matagorda Bay. Since its creation, the trust has executed 47 different contracts within the bay area, totaling $17.5 million worth of work.

"The bay is a significant economic generator for this area of the coastal band, both from a recreational standpoint and commercial fisheries," Raabe said. "So, the projects that we've been working on support both of those objectives."

The trust recently finished its first major project since its creation three and half years ago, the

Shaky Point Living Shoreline Restoration. Project timelines tend to take longer in sensitive environmental areas such as the bay, Raabe explained, due to environmental permits and the need to get local stakeholders involved.

Studies from Texas A&M University at Corpus Christi and Galveston and the University of Texas Marine Science Institute have also received funding to provide environmental research that can be used for future projects.

"Those studies are bringing a lot more scientific information about the bays that stakeholders can use," Raabe said. "They want to develop projects because this area doesn't have a lot of scientific information available; we're trying to correct that."

One area that the trust focuses on is mitigating environmental harm caused as a side effect of industries operating in or near the bay area, he said. Plastic pollution has been a problem in the past, with funding going towards clean-up efforts and restoration work.

"Matagorda Bay has a very significant industrial economy," Raabe said. "While it's very important to the area, particularly from the standpoint of providing jobs, it's also important that the industries care for the environment."

All parties involved understand people's hesitance to get involved in restoration efforts when they feel that they are being blamed for the issues, Berthold said.

"Ag is going to point at urban and urban is going to point at ag," he said. "However, there's no single problem; it's cumulative, it's an issue that we've got to address as a whole, so everybody's got to do their part."

Another factor to note, Berthold said, is that wildlife and their impact cannot be measured in an accurate way. That is something to keep in mind when understanding all factors impacting the bay area.

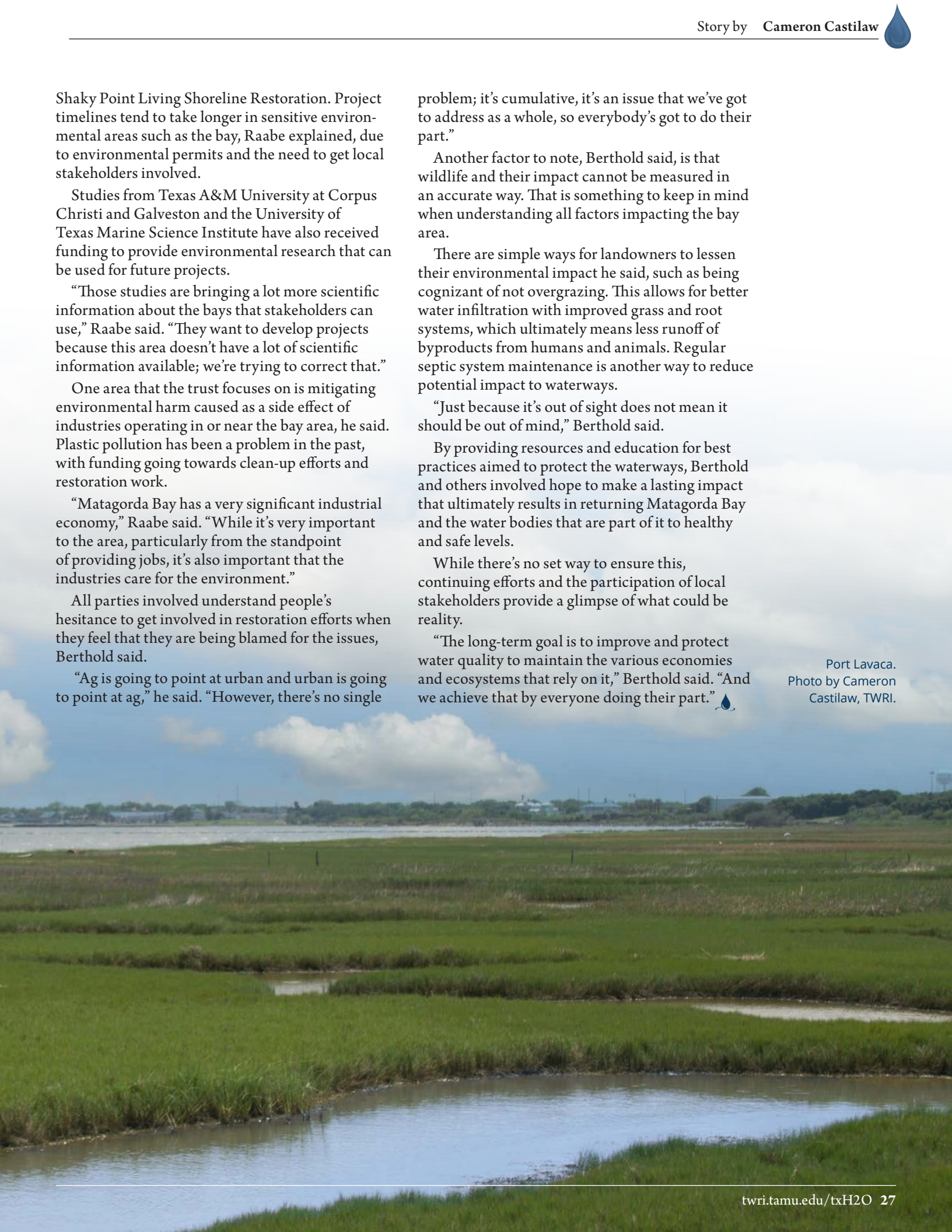
There are simple ways for landowners to lessen their environmental impact he said, such as being cognizant of not overgrazing. This allows for better water infiltration with improved grass and root systems, which ultimately means less runoff of byproducts from humans and animals. Regular septic system maintenance is another way to reduce potential impact to waterways.

"Just because it's out of sight does not mean it should be out of mind," Berthold said.

By providing resources and education for best practices aimed to protect the waterways, Berthold and others involved hope to make a lasting impact that ultimately results in returning Matagorda Bay and the water bodies that are part of it to healthy and safe levels.

While there's no set way to ensure this, continuing efforts and the participation of local stakeholders provide a glimpse of what could be reality.

"The long-term goal is to improve and protect water quality to maintain the various economies and ecosystems that rely on it," Berthold said. "And we achieve that by everyone doing their part."



Port Lavaca. Photo by Cameron Castilaw, TWRI.

# Q&A:

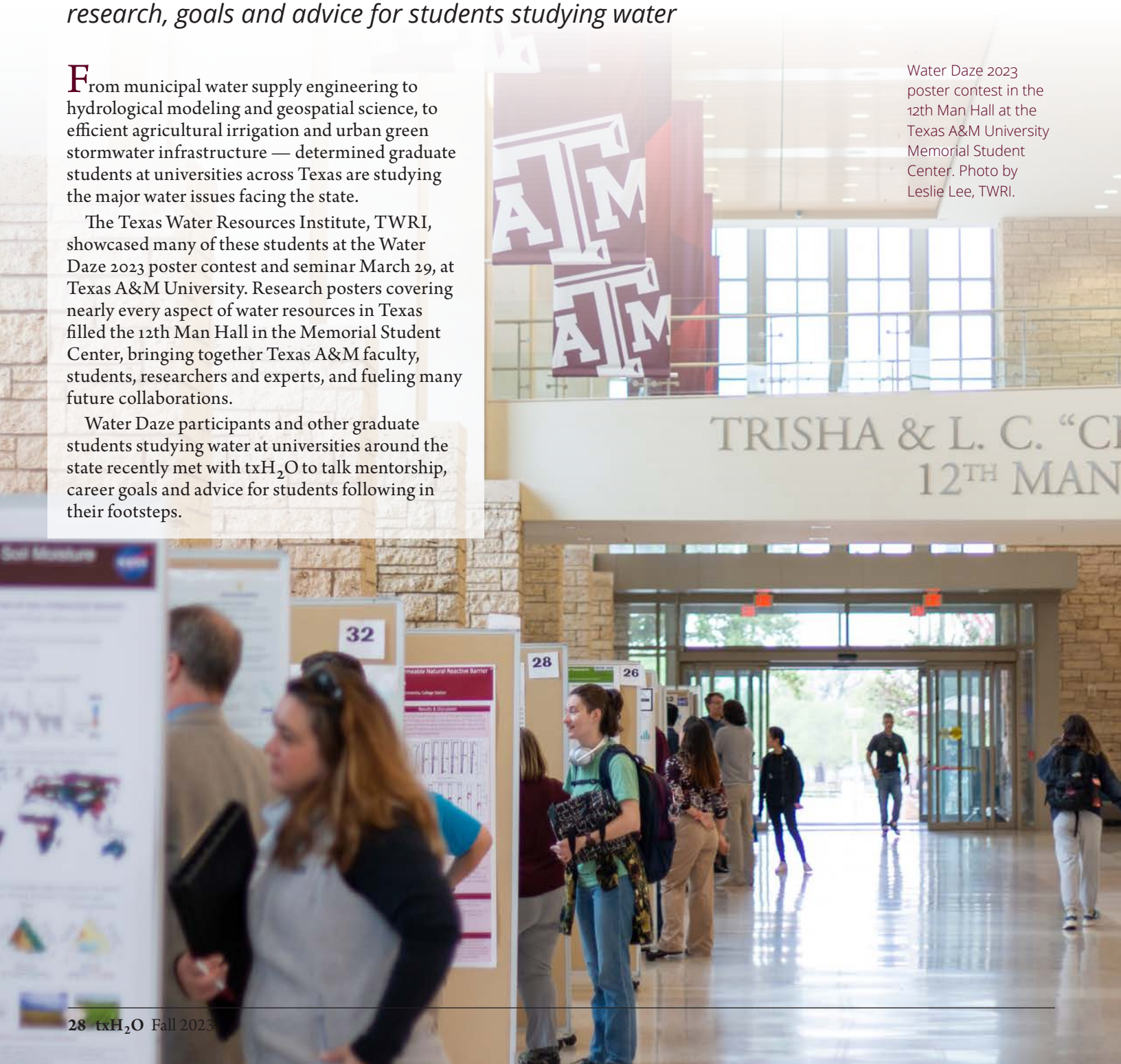
# Meet the Next Generation of Water Professionals

*txH$_2$O sat down with graduate students across the state to discuss research, goals and advice for students studying water*

From municipal water supply engineering to hydrological modeling and geospatial science, to efficient agricultural irrigation and urban green stormwater infrastructure — determined graduate students at universities across Texas are studying the major water issues facing the state.

The Texas Water Resources Institute, TWRI, showcased many of these students at the Water Daze 2023 poster contest and seminar March 29, at Texas A&M University. Research posters covering nearly every aspect of water resources in Texas filled the 12th Man Hall in the Memorial Student Center, bringing together Texas A&M faculty, students, researchers and experts, and fueling many future collaborations.

Water Daze participants and other graduate students studying water at universities around the state recently met with txH$_2$O to talk mentorship, career goals and advice for students following in their footsteps.




Water Daze 2023 poster contest in the 12th Man Hall at the Texas A&M University Memorial Student Center. Photo by Leslie Lee, TWRI.


(Left) Norberto Barragan collecting water sampling data. Photo by Michael Miller, Texas A&M AgriLife Marketing and Communications.

(Right) Melanie Brewer recieved first place for her research poster at Water Daze, presented by Allen Berthold, Ph.D., TWRI's interim director. Photo by Leslie Lee, TWRI.

# Norberto Barragan

## Master's student, Water Management and Hydrological Science program, College of Arts and Sciences, Texas A&M, and TWRI graduate research assistant

**Q :** What is your current research about?

**A :** For my thesis research, I am studying Arctic and non-Arctic rivers, comparing the morphologies and planforms of these rivers in relation to climate and environmental conditions. I'll mainly be using remote sensing to extract satellite imagery data and global river centerlines datasets in ArcGIS and other applications.

**Q :** What accomplishments are you most proud of from your academic career so far?

**A :** My greatest accomplishment is becoming the first one in my family to graduate from any university and obtaining a degree in environmental geosciences from Texas A&M. Also, getting accepted into graduate school to pursue a master's degree.

**Q :** Who is a mentor who has helped or inspired you?

**A :** My current graduate advisor Inci Güneralp, Ph.D., associate professor of geography at Texas A&M, has helped me through funding opportunities and helped me to apply for fellowships. The faculty and staff at TWRI have also led me and encouraged me to become successful by getting involved in research projects.

**Q :** What is your advice for younger students finding their path?

**A :** Don't be afraid to ask questions or for help or guidance. It took me a couple of semesters in college to decide what I wanted to study. If it wasn't for my undergraduate advisor mentioning a major in environmental geosciences, I would probably be studying something else that I do not like.

# Melanie Brewer

## Master's student, Department of Geology and Geophysics, College of Arts and Sciences, Texas A&M

*Brewer won first place and a $7,500 scholarship for her research poster, "Reconstructing River Hydrology Using Stable Oxygen, Carbon and Clumped Isotopes in Freshwater Mussels from the Brazos River, TX," at Water Daze 2023.*

**Q :** What is your current research about?

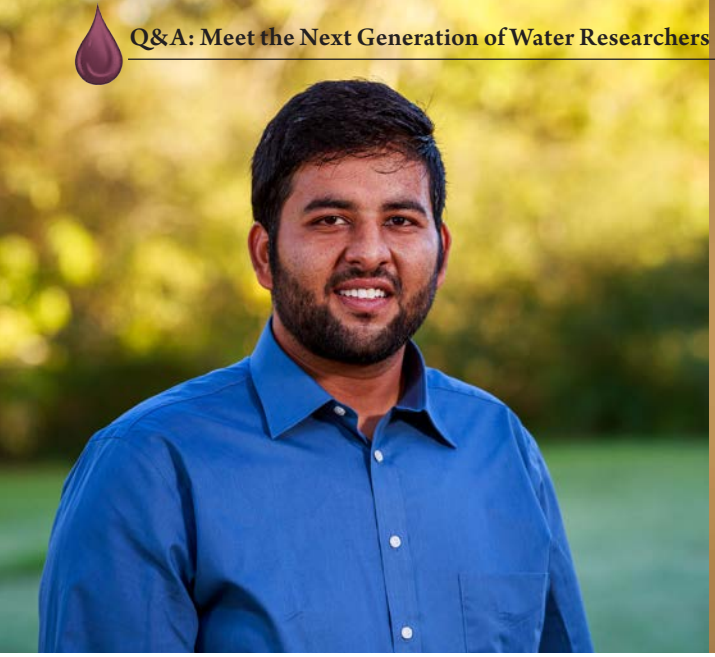
**A :** My current research focuses on stable isotopes and trace element chemistry in freshwater mussels from the Brazos River. The project spans over the past 150 years and investigates chemical proxies to reconstruct paleo hydrology, climate and shell growth rates to see how they are affected by both climate change and the damming of the river.

**Q :** Who is a mentor who has helped or inspired you?

**A :** My advisor, Ethan Grossman, Ph.D., professor in the Department of Geology and Geophysics. I did undergraduate research with him, and he introduced me to the world of isotopes and really just showed me how to do research and what you can do with these isotopes. He was the first professor to encourage me to pursue a graduate degree and has continued to be a mentor and supporter throughout my graduate school journey.

**Q :** What is your advice for younger students finding their path?

**A :** I would encourage them to get involved in research and talk to your professors early on. After you first meet someone, jot down their information and just continue creating contacts, whether that is just talking to professors, other grad students or other people at conferences that you think their work is interesting. I was shy in the beginning; but later, I realized there was absolutely nothing to be scared of. ⇨



(Left) Shubham Jain, Texas A&M Ph.D. student. Photo by Ed Rhodes, TWRI.

(Right) Christopher Cobos recieving second place for his research poster at Water Daze, presented by Allen Berthold, Ph.D., TWRI's interim director. Photo by Leslie Lee, TWRI.

# Shubham Jain

## Ph.D. student, Water Management and Hydrological Science program, College of Arts and Sciences, Texas A&M, and former TWRI graduate research assistant

**Q :** What is your current research about?

**A :** My current research is focused on evaluating the individual and synergistic effects of various climatological and geological characteristics on the hydrologic signatures of U.S. watersheds.

**Q :** What accomplishments are you most proud of from your academic career so far?

**A :** I am most proud to be a part of the Large-scale Data Visualization in R workshops that my colleagues in the department and I have been conducting for the past several years.

**Q :** What are your career goals?

**A :** My goal is to continue working in the field of water resources research, and later focus more on managing water resources in developing regions of the world that have much poorer water quality and insufficient resources to manage them. With the research tools we have at our disposal, we can find ways to manage water resources and improve water quality that are both cost-effective and strategically oriented to be implemented anywhere in the world.

**Q :** Who is a mentor who has helped or inspired you?

**A :** I am very inspired by my advisor Raghavan Srinivasan, Ph.D., who has contributed greatly to the field of hydrological modeling and spatial science.

# Christopher Cobos

## Ph.D. student, Department of Soil and Crop Science, College of Agriculture and Life Sciences, Texas A&M, and senior research associate at the Texas A&M AgriLife Research Center in Lubbock

*Cobos won second place and a $5,000 scholarship for his research poster, "Soil Water Dynamics in Semi-Arid Cotton Conservation Systems" at Water Daze 2023.*

**Q :** What is your current research about?

**A :** My research focuses on soil-water dynamics in agricultural production systems, looking at how we can more efficiently capture and store precipitation and conserve the current water resources that we do have. I'm really focusing on optimizing conservation practices for semi-arid dryland production systems.

**Q :** Who is a mentor who has helped or inspired you?

**A :** My advisor, Katie Lewis, Ph.D., associate professor in the Department of Soil and Crop Sciences at the Texas A&M AgriLife Research Center in Lubbock. Prior to working at Texas A&M AgriLife, I didn't have any agricultural experience or background. I started working with her as a part-time technician, then full-time technician, research associate and then a student. She's given me essentially free rein to research whatever I'm interested in and has given me many opportunities to meet people, and since I'm new to agriculture, has kind of guided me into this world of research. She's definitely someone to look up to.

**Q :** What is your advice for younger students finding their path?

**A :** I would suggest using every opportunity you can to just put yourself in a room full of smart people and sit and listen. Whether that's conferences or meetings or lectures, just listen to what others have to say.

Story by **Mackenzie Schneider**

(Left) Trevor Johnson, Ph.D. student at Texas Tech University. Photo courtesy of Trevor Johnson.

(Right) Charity Kgotlaebonywe, Ph.D. student at the University of Texas at Arlington. Photo courtesy of Charity Kgotlaebonywe.

# Trevor Johnson

## Ph.D. student, Department of Agricultural and Applied Economics, Gordon W. Davis College of Agricultural Sciences and Natural Resources, Texas Tech University

**Q :** What is your current research about?

**A :** My research focuses primarily on the economics of carbon sequestration in agricultural production. During many agricultural production processes, carbon is released into the atmosphere. We're focusing on how to incentivize producers to adopt regenerative agricultural practices that would sequester carbon back into the ground. We also plan to look at how these different sequestering practices and various carbon contracts may be related to water conservation.

**Q :** What accomplishments are you most proud of from your academic career so far?

**A :** Probably successfully defending my master's thesis. It may be a document that will never be read again, but it's the first piece of research that I completed and was able to present. Undoubtedly the process was difficult, but I am very grateful I went through it.

**Q :** Who is a mentor who has helped or inspired you?

**A :** My advisor, Donna McCallister, Ph.D., has been a great mentor since I began my undergraduate education at Texas Tech. She has been a great source of information, support and encouragement throughout all of my undergraduate and graduate education/research.

**Q :** What is your advice for younger students?

**A :** Get involved. If your department or specific major has an association/group, getting involved is a great way to get to know other students, faculty and professors. These connections will benefit you just as much as the degree(s) you acquire. It's also pretty fun and a great distraction when needed.

# Charity Kgotlaebonywe

## Ph.D. student, Department of Earth and Environmental Science, College of Science, University of Texas at Arlington, and 2022-23 TWRI-USGS graduate student research grant recipient

**Q :** What is your current research about?

**A :** My research focuses on understanding water use/availability and implications on urban systems under inter-annual climate variability, climate change and drought on water resources using naturally occurring isotope tracers for the Dallas-Fort Worth metroplex.

**Q :** What accomplishments are you most proud of from your academic career so far?

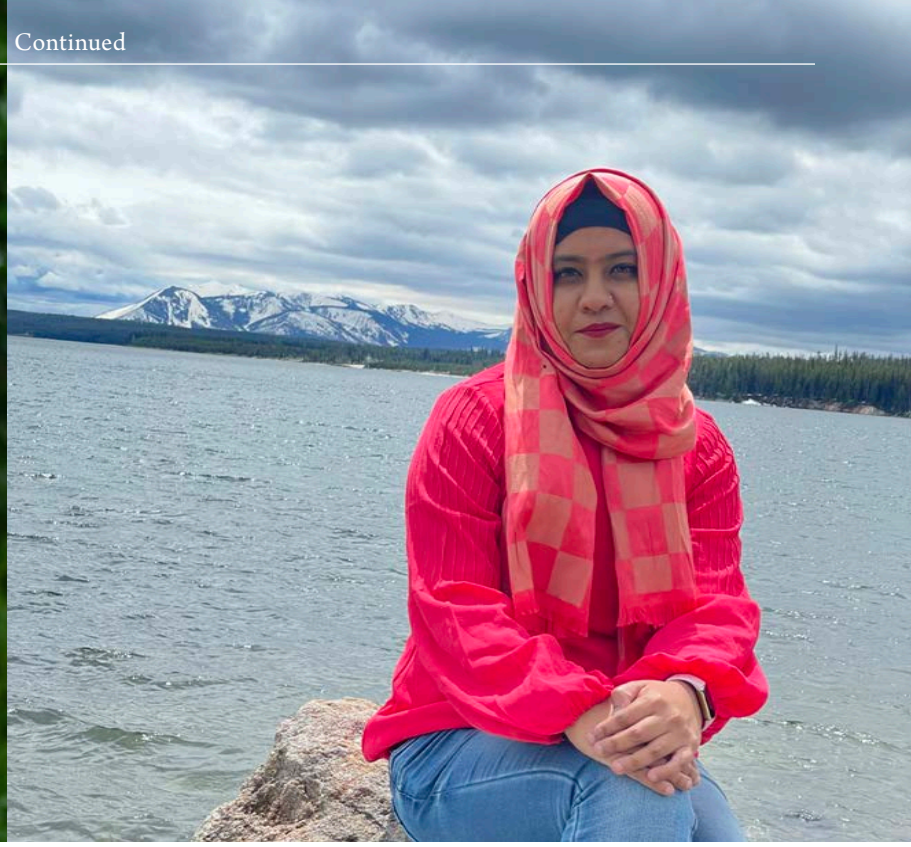
**A :** I recently got a Schlumberger Foundation Faculty for the Future Award for the 2023-2024 year. So, I'm really proud, and I'm really fascinated to have this type of support.

**Q :** Who is a mentor who has helped or inspired you?

**A :** I'm currently working with Ricardo Sanchez Marino, Ph.D. He's really been an inspiration to me, and he studies most water issues from his home country of Costa Rica. So, I'm really fascinated to do the same for my country of Botswana, Africa, as well.

**Q :** What is your advice for younger students?

**A :** I am a young woman, but women are scarce in my field. So, I just wanted to show women that it is possible to do it in a male-dominated field. The sky's the limit. Young women out there, I want to show them — let's do this, we got this, and we can do it. ⇨



(Left) Najibullah Loodin, Texas A&M Ph.D. student. Photo by Leslie Lee, TWRI.

(Right) Sabiha Tabassum Ph.D. student at the University of Texas at Austin. Photo courtesy of Sabiha Tabassum.

# Najibullah Loodin

### Ph.D. student, Water Management and Hydrological Science, College of Arts and Sciences, Texas A&M, and former TWRI graduate research assistant

**Q :** What is your current research about?

**A :** I'm working on transboundary water governance and management. My research specifically centers on the Helmand River and Rio Grande basins. The aim is to see how emotional attachment and mistrust challenge the water cooperation between upstream and downstream states of a shared watercourse.

**Q :** What accomplishments are you most proud of from your academic career so far?

**A :** I am proud of being engaged in academic affairs. I love writing research articles and then sharing and communicating the outcome of my research with scholars in the field. Those accomplishments make me proud of my work.

**Q :** What are your career goals?

**A :** I would like to do postdoctoral studies after completing my Ph.D., if possible, especially at Texas A&M. And my long-term goal is to stay in academia.

**Q :** Who is a mentor who has helped or inspired you?

**A :** Professors Gabriel Eckstein, J.D.; Susanne Schmeier, Ph.D.; Wendy Jepson, Ph.D.; and Aaron Wolf, Ph.D. I'm interested to learn more from them, and I'm inspired by their work and the way they do research in the field of water governance and management.

# Sabiha Tabassum

### Recent Ph.D. graduate, Jackson School of Geosciences, University of Texas at Austin

**Q :** What is your current research about?

**A :** I work on the impact of climate change on hydrological extremes. I look at how climate change might impact extreme rainfall events and the resulting flooding events in Texas using projections of climate models.

**Q :** What accomplishments are you most proud of from your academic career so far?

**A :** Being able to work on the Water Forward 2024 project (with the City of Austin) is a big thing for me because in this project I got a chance to work directly with stakeholders and policymakers and be part of a very important task. This experience is going to help me a lot in the future.

**Q :** What are your career goals?

**A :** I am looking for positions where I can use my knowledge, both as a water resource engineer and a climate scientist who's into mitigating climate risk, and contribute towards developing a climate-resilient society.

**Q :** What is your advice for younger students with these interests?

**A :** With climate change, water-related problems are becoming more severe and our role as water resources professionals and researchers is becoming more important. We need the expertise of these young minds to come up with innovative ideas to tackle these problems. Let's do this.


# Amanda Tague

## Received master's degree August 2023, Water Management and Hydrological Science, College of Arts and Sciences, Texas A&M, and former TWRI graduate research assistant, now a TWRI research associate

**Q :** What was your graduate research about?

**A :** I was a non-thesis student, so I did not have any graduate research, but I was able to gain valuable research experience through the projects I helped with at TWRI.

**Q :** What accomplishments are you most proud of from your academic career so far?

**A :** I gave a presentation last year for cybersecurity in the water sector, and it was a lot of really interesting things that I previously didn't know about. I was able to learn a lot in a very short amount of time.

**Q :** Who is a mentor who has helped or inspired you?

**A :** The water management and hydrological sciences program has some really awesome professors. Hongbin Zhang, Ph.D., a professor in the Department of Soil and Crop Sciences, is a fantastic professor and very, very passionate about the water system and about educating people.

**Q :** What is your advice for younger students?

**A :** Don't be afraid to ask a billion questions; you and your peers will be better off for it. Also don't forget to get connected with other students and professors within your programs.

(Left) Amanda Tague, TWRI research associate. Photo by Leslie Lee, TWRI.

(Right) Water Daze 2023 poster contest in the 12th Man Hall at Texas A&M. Photo by Leslie Lee, TWRI.

Texas A&M AgriLife Extension Service

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