tx H2O

A Publication of the Texas Water Resources Institute

Fall 2017

WATER SECURITY

Inside: Examining the different levels of water security, perfecting the water treatment process and more...

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

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Working to make every drop count

With the impacts of Hurricane Harvey still fresh in our minds and knowing that the long-term efforts needed for the region to recover from this devastating storm are just getting underway, water security is at the forefront of many people's minds. The term water security covers a wide range of subjects, and it can have very different meanings based on what it refers to, who uses it and when it is used. For many, water security conjures up images of protecting our water resources infrastructure (reservoirs, canals, treatment facilities and pipes) from malevolent forces or natural disasters. For others, water security simply means having access to safe, reliable and affordable water supplies.

Ultimately, water security tries to address how confident we feel about the availability, management and control of our water resources at the household, community, state and national level. This includes how threatened we feel by water due to flooding or contamination or as a vector that can spread diseases; how sure we are that we will not run short of water due to drought or failure of our water infrastructure; and how much faith we have that local, state and federal institutions are managing our water resources in a manner that can be sustained for multiple generations.

The impacts of Hurricane Harvey are providing a painful demonstration of the wide range of water security issues that individuals and communities can face. The immediate water security issue was how to get people out of harm's way due to the extensive flooding. As the flood waters receded, there were further security concerns in simply trying to provide safe water and sanitary conditions to people who have been displaced by the flooding. And there was concern about the degree of contamination of the region's water supplies and how this contamination would be remediated. Finally, there will be the long-term question of the damage to the region's water infrastructure, how it will be rebuilt, and what institutional changes need to be made to increase the region's future water security.

This issue of *txH2O* provides an overview of efforts that are ongoing across the state of Texas and within the Texas A&M University System that highlight water security concerns and how we are attempting to develop methods to measure our level of water security and to develop personal, institutional and physical approaches to improving the security of our water resources.

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

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On the cover:
Water security is a local, national and global issue that Texas A&M University researchers are examining.
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Texas Water Resources Institute
make every drop count

Volume 12, number 1, Fall 2017

txH$_2$O *is published two times a year by the Texas Water Resources Institute (TWRI), which is part of Texas A&M AgriLife Research, the Texas A&M AgriLife Extension Service and the Texas A&M University College of Agriculture and Life Sciences. TWRI is funded in part by the U.S. Geological Survey and authorized by the Water Resources Research Act. To subscribe to txH$_2$O or Conservation Matters, TWRI's monthly email newsletter, visit* twri.tamu.edu.

Understanding water security

Finding solutions for accessible, adequate and acceptable water for the future

The term "water security" means different things to different people.

For some, water security means simply having enough clean water to drink when they turn on the faucet; for others, water security involves having existing infrastructure to deliver the water, and still for others, it means guarding a nation's water resources against bioterrorism.

Hurricane Harvey and the resulting flooding exposed some of these different meanings and levels of water security. It also illustrated the importance of water security to the well-being of communities, states and the nation.

Texas A&M University geography professor Dr. Wendy Jepson, who leads Texas A&M's new Water Security Initiative, works on multiple levels of water security.

In most of her work Jepson studies water security at the household scale, relating water security to individuals' water needs. She is involved in finding what she calls "fair and equitable" solutions for human development and human health at the household level.

"That level links with sanitation issues and that links with clean water access and the complex, social and political reasons that either contribute to water security or contribute to water insecurity," said Jepson, who has been studying household water security along the Texas–Mexico border as well as in South and Central America.

Dr. Mary Hilderbrand, senior lecturer in The Bush School of Government and Public Service at Texas A&M, said in developing countries, access to water is a huge issue, not just in rural areas but in urban communities as well.

She said some cities in developing countries are experiencing rapid growth because of rural to urban migration. The countries' urban populations are increasing, and these cities are trying to find ways to meet their water needs.

Examining water security from an institutional scale involves understanding the laws and institutional actors and organizations that are in charge of water allocation, management and protection — and whether they ultimately support or undermine water security.

"We know some geographic areas are experiencing water shortages, which means some people are going to get their water and some people aren't," said Dr. Kent Portney, director of the Institute for Science, Technology and Public Policy at the Bush School. "Every day that water becomes scarcer, somebody is going to be increasingly deprived. That then turns the attention to issues of who is deciding who gets what water. And that is water governance."

> "The link between water and security is undeniable. Where freshwater is plentiful, accessible and well-managed, economies can grow, communities can thrive and nature can flourish."

Portney and Hilderbrand, along with Gabriel Eckstein, professor in the Texas A&M School of Law, and Dr. Rosario Sanchez, research scientist with the Texas Water Resources Institute, are working on understanding the governance of shared water across the United States-Mexico border.

Another perspective of water security, Jepson said, includes studying how water security is challenged by global environmental changes, such as climate change, and how existing water systems will need to adapt to these changes. ⇨

"For example, coastal areas have the largest concentrations of human settlements, but yet they are facing increased sea water temperatures, sea-level rise and salt water intrusion that threaten coastal aquifers," she said.

Is water insecurity an issue in the United States?

While some might believe that having sufficient and clean water is limited to developing countries, that is simply not the case, according to the researchers.

"Living in College Station or the Dallas-Fort Worth area, we are confident that when we turn on the tap, water will come out and be clean," Eckstein said, "but there are a couple of million people in the United States who don't have that security. They live along the Mexican border, in the Appalachians and the Ozarks, as well as other areas of the country."

Jepson agreed that these challenges are not restricted to the poorest nations.

"Although access to piped and improved water sources has increased over the past decades, domestic water security remains a difficult goal to achieve in economically distressed communities in both developed countries and across the developing world," she said.

"It is quite clear that while the majority of Americans do have water security, it is not as secure as we maybe thought in the past," Jepson said, citing the example of lead-contaminated drinking water in Flint, Michigan, caused by inadequate water treatment and aging infrastructure. Other U.S. cities, including Detroit, Chicago and Washington, D.C., are facing some of the same issues, she said.

"There is this idea or myth of universal provision of water in the United States…and when something like Flint happens we are surprised about it," she said. "I was not surprised about it."

In Texas, Corpus Christi had four water contamination-related alerts in 2015 and 2016, according to news reports. Many other Texas cities have also issued boil water notices because of breaks in their water infrastructure or problems with water treatment.

"I don't want to overplay the notion of water insecurity, but I think it is a lot more significant than we have been talking about in the past in the United States," Jepson said. "We just have not been asking the right questions. We are assuming that everything is taken care of, and we haven't thought critically about what questions to ask."

Some of the most water insecure and vulnerable areas in the country are along the Texas-Mexico border. Jepson said certain populations, particularly low-income Mexican American communities, have been historically and politically marginalized from water systems in the Rio Grande Valley.

Although economic factors such as poverty and urban development affect this lack of water security, she said the complex and highly fragmented water governance in Texas also contributes to it.

"The districts that organize the allocation and monitoring of water provision are highly fragmented," Jepson said.

The Inuits in Alaska are another example of U.S. populations struggling with water insecurity. Not only are they poor and live in rural areas, but their water resources are changing because of climate change, she said.

Looking ahead

Even geographical areas not normally considered insecure can become susceptible.

The droughts that California experienced in 2016 and Texas in 2011 illustrate how vulnerable some areas are to becoming water insecure, Eckstein said.

With Texas' population expected to double by 2070 but its water supplies predicted to decrease, he said, the state could find itself experiencing water insecurity.

For Eckstein, he sees Texas A&M's emerging focus and research on water security as beneficial.

Although water quantity and water quality research have traditionally been divided into sectors, such as agriculture use, industrial use and municipal use, tackling water research in terms of water security allows scientists and others to look at water from another perspective, he said.

"The security approach gives us a different view of how to look at water as a resource," Eckstein said. "I don't know if it will get us to any different outcomes or conclusions, but we have to go down this road to see because the approaches we currently take don't always give us definitive answers and quite often don't give us helpful answers."

"The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being and socio-economic development; for ensuring protection against water-borne pollution and water-related disasters; and for preserving ecosystems in a climate of peace and political stability."

Working definition of water security, United Nations-Water, 2013

Story by Kathy Wythe

SECURING WATER GLOBALLY

Aggie experts team up to research water security

Photo by Pixabay

Texas A&M University researchers from several disciplines are joining forces to study water security and all its implications through a universitywide Water Security Initiative.

The initiative is based out of the Institute for Sustainable Communities, an institute in the College of Geosciences, and is an embodiment of the Environmental Grand Challenge, according to Dr. Wendy Jepson, professor in Texas A&M's Department of Geography and lead for the initiative.

Jepson said the initiative's main objectives are to facilitate research, engagement and teaching around three challenges: water and sanitation security at the household level; water governance and security; and water security, resilience and climate change.

Through the initiative, Jepson said the university hopes to facilitate multidisciplinary research in those water security areas to make key advances in understanding how to ensure adequate, reliable, affordable water across the globe.

"We want to have an impact globally," she said.

Other contributing members of the initiative include:

- Drs. Kathleen O'Reilly, Peter Knappett, Hongbin Zhan, Rodrigo Bombardi and Courtney Thompson and Judy Nunez, College of Geosciences
- Drs. Georgianne Moore and Rosario Sanchez, College of Agriculture and Life Sciences
- Drs. Kent Portney and Mary Hilderbrand, The Bush School of Government and Public Service
- Gabriel Eckstein and Vanessa Casado-Perez, School of Law
- Dr. Manuel Teodoro, College of Liberal Arts
- Dr. Jennifer Horney and Genny Carrillo, School of Public Health
- Dr. Kelly Brumbelow, College of Engineering

As part of the initiative, Jepson is studying household water security in the urban global south, particularly in Brazil and rural communities in Costa Rica.

She spent the 2017 spring semester in Brazil on a Fulbright Fellowship, teaching and conducting research as part of the Urban Water Provision Systems and Household Water Security in Northeast Brazil project, also supported by the National Science Foundation.

The three-year project involves intensive work in neighborhoods to understand households' water access, affordability and reliability, as well as local adaptations for obtaining water.

Another activity under the initiative is a research group of Texas A&M and Texas Water Resources Institute scholars studying the governance of United States-Mexico transboundary groundwater and the related conflicts and cooperation. (See *On the border*, page 8.)

In the fall of 2016, the Water Security Initiative co-hosted a Re-imagining Household Water Security Research workshop in College Station with Arizona State University and Northwestern University, and attendees came from many other universities, including from the United Kingdom and Canada.

Jepson said the workshop was meant to form a collaborative working group of scholars around the area of water security metrics and assessment, a major knowledge gap in the field.

"The current state of knowledge has yet to offer a gold-standard framework for collecting, analyzing and reporting household water security information," she said.

In August the Global Household Water Insecurity workshop was held at Northwestern University and another workshop is planned for June 2018 at Arizona State University.

The initiative also includes educating students through high impact service learning.

One course entails one semester of traditional study with students reading a water-related book and then a second semester of students traveling to Costa Rica to work with a local water provider to learn about water resource challenges in the country's rural areas, Jepson said.

Texas A&M researchers are working on several projects that address the grand challenge of water security:

1. **Texas Transboundary Groundwater Governance Project,** *Dr. Kent Portney and Gabriel Eckstein*
2. **Urban Water Provisioning and Household Water Security in Northeast Brazil,** *Dr. Wendy Jepson*
3. **Water and Sanitation Security in India,** *Dr. Kathleen O'Reilly*
4. **Small Water Systems and Water Security in Greater Houston,** *Dr. Wendy Jepson*
5. **Human Capital and Water Utility Management,** *Dr. Manuel Teodoro*
6. **International Water Law Project,** *Gabriel Eckstein*
7. **Household Water Insecurity Experiences Scale,** *Dr. Wendy Jepson*

The group is developing a study abroad program for water security in Costa Rica that should launch in 2018.

"The students will follow the water all the way from the source to the coast, talking with various stakeholders, water users and water user organizations," Jepson said, "so students have a better sense of thinking through the challenges of water in Costa Rica. Costa Rica is actually a fantastic place for students."

Even though the water security initiative has existed for less than a year, Jepson said the university is well equipped to research and eventually make a difference in this area.

"We have a critical mass of faculty and researchers who are at the cutting edge of some of the key questions that are raised when you talk about water security," she said.

Jepson believes the university is at a crossroads with water security research.

"I really hope that the idea of water security is flexible enough to provide a space for a diverse set of faculty, researchers and students interested in these issues to come together," she said. "There is something to be said about getting a critical mass of scholars in a room about topics that everyone is passionate about. You can change the world when you do that. We just have to find the right room, and I think we have found it with water security."

More information about the initiative can be found on its website: h2osecurity.net.

Texas A&M University students participate in the Water Security Initiative's work in Costa Rica to learn about water challenges in the country's rural areas.

Story by Kathy Wythe

On the border

Transboundary water initiative looks at shared aquifers, governance

Underneath the border of the United States and Mexico lie shared sources of water. Little is known about these waters or how the two countries manage these waters.

An interdisciplinary group of Texas A&M University System researchers is studying and mapping the quantity, movement and management of these shared waters to ultimately better understand their governance.

Drs. Kent Portney, Mary Hilderbrand and others in The Bush School of Government and Public Service, along with Gabriel Eckstein, a professor at the Texas A&M University School of Law, and Dr. Rosario Sanchez, a research scientist at the Texas Water Resources Institute, are involved in the work through the Bush School's United States–Mexico Transboundary Water Governance Initiative.

Portney, professor and director of the Institute for Science, Technology and Public Policy at the Bush School, said the initiative has two related parallel projects, one focusing on water governance, policy and management specifically on the Texas-Mexico border and the other extending the analysis to the New Mexico and Arizona borders with Mexico.

He said the group wants to understand the laws and water rights regimes that operate on both sides of the border, as well as the governmental institutions and informal organizations involved, so they can better understand management of the competing water demands.

"Amazingly very little work has been done on governance of shared groundwater resources," Portney said. "That is really the new piece we are adding to this."

Dr. Kent Portney and Dr. Mary Hilderbrand are working on understanding the governance of the transboundary aquifers shared by the United States and Mexico. Photo by Leslie Lee.

Hilderbrand, senior lecturer and project director, said one of the group's essential first steps is discovering exactly what aquifers the two countries share and their locations.

Sanchez has been working with Eckstein to map these transboundary aquifers. To date, they have identified potentially 36 different transboundary aquifers.

She said there is very little data quantifying these transboundary aquifers' water and connectivity. Differences in methodology and language complicate the work.

"Mexico uses and recognizes a certain methodology to identify aquifers, and Texas uses another one," Sanchez said. "We know the groundwater is there, but we are not certain of the quantity or quality or who is pumping it."

"The danger is that when water is governed in a really decentralized way, made up of hundreds of individual decisions, it ends up depriving someone of water that they need."

Sanchez, along with Dr. Zhuping Sheng, director of the Texas A&M AgriLife and Extension Center in El Paso, are also continuing their transboundary aquifer work through the U.S. Transboundary Assessment Act Program funded by the U.S. Geological Survey

The researchers' work on identifying the aquifers will eventually result in one comprehensive map showing the location of groundwater on both sides of the border.

Hilderbrand said the group is also identifying the different governance institutions and people who make decisions about the water on both sides of the border to compile a database of decision-makers. Eventually, the group will survey these decision-makers to better understand their perceptions of risk, instances of cooperation and conflicts, and other factors.

Equipped with input from the survey and aquifer maps, the group plans to eventually develop recommendations based on sound science on ways to improve joint management and governance of the shared groundwater resources and promote cooperation between the two countries.

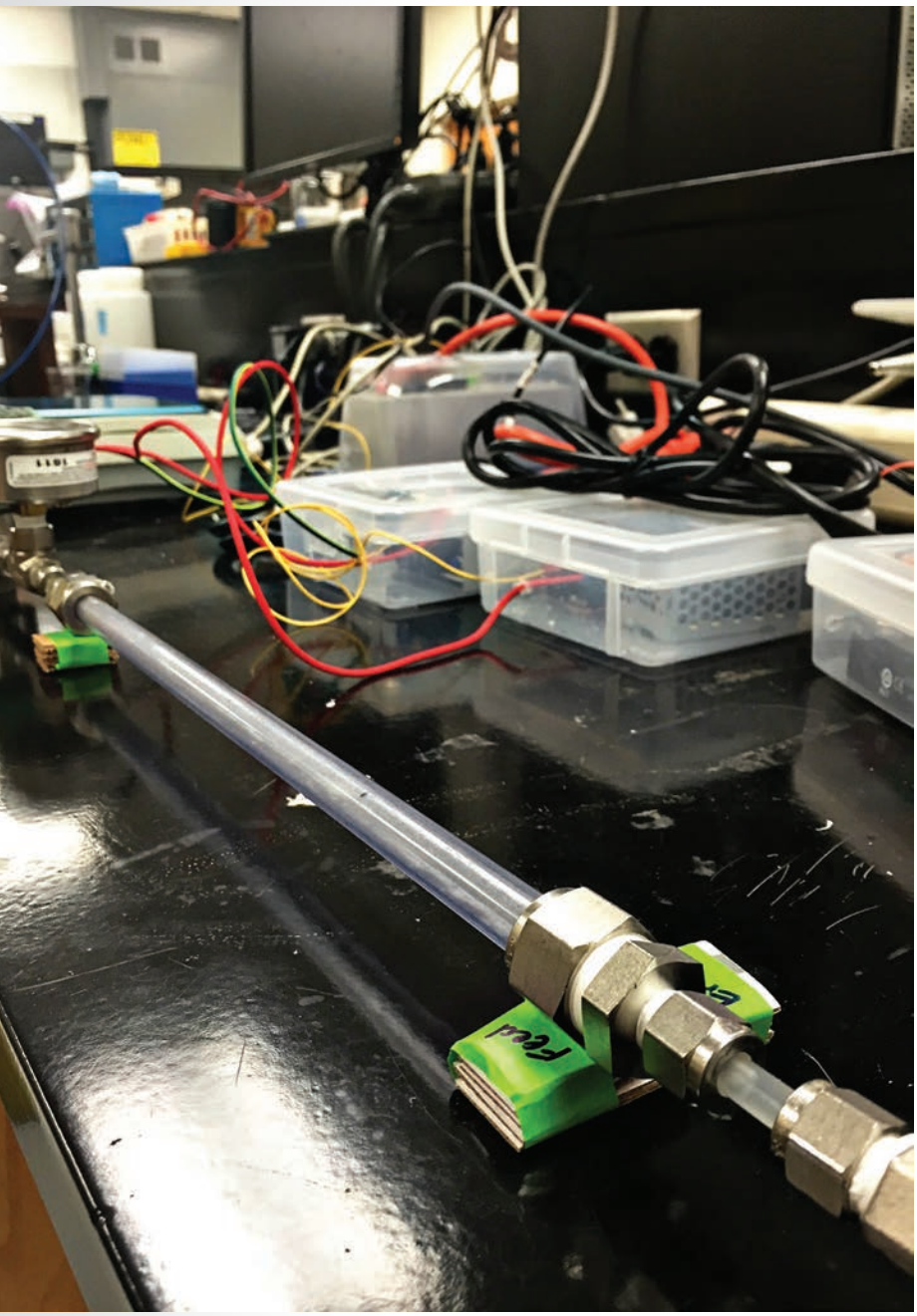
"Maybe we will see even cross-border public participation where people on one side of the border can have a say in decisions being made across the border that affect both sides," Eckstein said.

Portney said this cooperation would reduce the likelihood that some people will get water at the expense of other people.

"The danger is that when water is governed in a really decentralized way, made up of hundreds of individual decisions, it ends up depriving someone of water that they need," he said. "That is what motivates the study of governance — to see if there are better ways of governing to make decisions about water that improve the efficiency of the water usage."

Story by Leslie Lee

MICROFILTERS, MAJOR RESULTS



Doctorate student Kunal Gupta designed and fabricated a backwashable, bench-scale hollow fiber microfiltration module to aid in the membrane filtration research.

Professor helps perfect membrane filtration processes vital to water suppliers

What does a $350 water filter capable of removing microscopic contaminants from 1,300 gallons of water a day look like? To the untrained eye, it looks like a large sheet of paper rolled-up inside a pipe, similar to a classroom craft supply perhaps.

These paper-thin filters, called membrane filters, are actually made of multiple layers of permeable polymers. An average filter module contains about 85 square feet of filter surface. Placed in pipes that water is pushed through at high pressures, these filters are hugely important to Texas water.

As water suppliers have built water reuse and inland desalination plants throughout Texas, new treatment infrastructure was needed to continue providing enough high quality water. These plants cannot function without such rigorously tested water filters; many water plants use about 100 of them simultaneously throughout their facilities and daily processes.

According to state water planners, to keep Texas water secure, desalination and reuse will be two of the major technology-dependent tools bridging the gap between future water demands and strained supplies.

"There is a lot of brackish groundwater in Texas," said Dr. Shankar Chellam, who is the J. Walter "Deak" Porter '22 and James W. "Bud" Porter '51 Professor in the Zachry Department of Civil Engineering at Texas A&M University.

"And during the 2011 drought, even a lot of surface waters became more brackish; no rain, lots of sunshine and high evaporation results in increased salinity in surface waters. So, how do you remove the salt content from these waters?"

Reverse osmosis (RO) and nanofiltration are how, and there are currently 47 major inland brackish desalination plants in the state using those technologies to supply high quality water to residents, according to the Texas Water Development Board. Chellam and his team study the filters and processes involved in RO and nanofiltration. ⇨

Dr. Shankar Chellam shows an end "anti-telescoping" cap for a spiral-wound membrane element. Photo by Leslie Lee.

Their research shows that precise, plant-specific protocols using advanced technologies and a series of filters can perfect these filtration processes, protecting consumers from filtration failures and possible resulting water contamination, while also benefiting plants with more cost-effective systems.

"We are examining how to tailor the process to the particular kind of water you need to desalinate at a particular plant," Chellam said.

Basics of modern large-scale water filtration

Chellam's team studies the various water purification uses of polymer membrane filters and their related applications, including desalination, water reuse, disinfection, and removing turbidity, microorganisms and chemicals.

"Polymer filters are the cheaper variety of advanced water filters, and they are the most implemented, so we exclusively work with those," he said.

Because research on the fundamental scientific principles of advanced water filtration is still greatly needed, Chellam said, the National Science Foundation (NSF) and the U.S. Department of the Interior have funded multiple projects conducted by his team.

> "I believe more and more people will use this or similar processes as pressures on water supplies increase and as water quality worsens."

The most common advanced water filtration processes used today are RO, nanofiltration and microfiltration/ultrafiltration, Chellam said.

- RO is used by many seawater desalination plants and is "very expensive and energy-intensive." It involves pushing saline water under high pressure across a dense membrane, i.e. one with no pores. The clean water preferentially flows through the filter, and the salt does not, thereby achieving desalination.
- Nanofiltration involves pushing brackish or surface water across a membrane with tiny pores to remove contaminants as small as 0.002 microns (2 nanometers), he said. This is typically used for removing hardness and organic compounds. It is similar to RO but less expensive because it operates at much lower pressures than RO.
- Microfiltration involves filters with pore sizes larger than about 0.1 microns. It is similar to ultrafiltration, which spans the range between microfiltration and nanofiltration. These processes require much less energy and are relatively widely implemented in Texas for small- to medium-sized drinking water plants. "It is less intensive than RO but sufficient for many plants," Chellam said.

One important factor for water providers' considering these options is that filters with smaller pores require more pressure to push the water through, and therefore bigger pumps and higher energy costs.

"The idea is to use the least pressure possible, so that your energy costs are low," he said.

Perfecting the ideal process

Chellam has found that generally the most efficient way to begin the water filtration process is with coagulation, which clumps together small contaminants, making them bigger.

"We've been looking at a technology called electro-coagulation," he said, most recently in a study funded by the Interior Department, studying the practice for use in inland desalination plants.

Electro-coagulation uses trace amounts of aluminum (or other configurations) to bind many small contaminants together into larger clumps. This water is then treated through a series of filters, beginning with a course filter, meaning it has large pores. This filter is able to catch the contaminants because they have been coagulated together.

Then the process continues with pumps pushing the water through finer filters. The coagulation and pretreatment processes save energy resources and costs by minimizing fine-filter use and high-pressure pumping needs, Chellam said.

The final step is to filter the water through an extremely fine filter. RO is needed for this final step at seawater desalination plants, he said, but the cellular make-up of inland brackish groundwater allows for nanofiltration, to be used.

"Most of the salt content in seawater is from sodium and chloride, and for that you need to use RO," Chellam said. "But in many inland sources, the salinity comes from sulfate and calcium, which don't need RO. So, you can reduce the salinity just by doing nanofiltration, which is more energy-efficient."

Chellam describes this entire progression as an "integrated, hybrid process," and his team has found it to be ideal for inland brackish water filtration.

"I believe more and more people will use this or similar processes as pressures on water supplies increase and as water quality worsens."

Clogs happen

Researching and perfecting these filtration protocols makes plants more efficient, but Chellam said dealing with clogs and filter failures is also part of his research.

"These filters will clog rapidly if everything is not completely in-sync," he said.

Planning clog prevention and remediation into plants' automated system protocols is part of Chellam's work. Reversing the water flow direction in pipes can de-clog a filter, but that can result in slowing down the process. Analyzing and perfecting this process requires "reducing the clogging rate versus increasing the volume of water filtered," he said.

"The idea of filtration is to remove stuff," he said. "And the more stuff you remove, the faster a filter clogs. So how do you de-clog and regenerate the filter? How do you maximize the water productivity of a filter? We are researching that."

Chellam's team conducts "autopsies" on failed filters that plant operators send in for examination.

"We cut these filters open and find out why they clogged," he said. "You can use spectroscopic methods and microscopic methods; you can do some advanced surface chemistry and surface physics to compare the brand new filter and the clogged filter. And then you can understand what you can do and how you should adjust your process to remove all these items that clogged your filter.

"Once we identify what's clogging it, now the question is, why did the pretreatment process not remove it? Where was your pretreatment not good enough? How can you tweak it or replace a part of it? How can you clean the materials that clog the filter? Maybe you did not have enough safeguards against this particular contaminant that is fouling your filter and you need to implement something else."

The future of filtration

Another question that Chellam has been researching is: how can viruses, the very smallest kind of microbial pathogen, be more effectively removed from water supplies using a filter and low pressures?

Currently, drinking water plants use chlorine or other disinfectants to inactivate viral pathogens. However, chemical disinfectants produce potentially carcinogenic byproducts via side reactions, he said. Using membrane filters to physically remove microorganisms would reduce the need for chemical disinfectants and decrease undesirable toxic byproducts in drinking water.

His team is working on three filtration-related projects, two funded by NSF and one by the Interior Department. One is studying how virus shapes, sizes and surface characteristics/charges affect filtration efficacy. Virus filtration is a relatively new field, and the NSF and Chellam are still seeking full, fundamental understandings of how viruses behave in filtration systems, he said. In another project, Chellam's team is looking at optimal filter regeneration by flow reversal, or backwashing, to remove previously filtered materials that clog the filter. The third grant is for performing autopsies on actual filters from real-world membrane facilities to better understand the clogging process and to propose innovative cleaning models, Chellam said.

He believes that the need for advanced water treatment technologies will only grow in Texas.

"What used to be freshwater isn't as fresh anymore, and many cities are looking to alternative sources, so we will need higher and higher technology levels to purify these strained water supplies."

(Left) Dr. Shankar Chellam holds a disc microfiltration and ultrafiltration membrane used for fundamental investigations of dead end filtration. Photo by Leslie Lee.

(Right) Doctorate students Kyungho Kim and Bilal Abada sacrifice a fouled spiral-wound membrane to conduct its autopsy.

Story by Leslie Lee

Dr. Lucas Gregory carries the water quality monitoring team's kayak to the river bank to begin collecting samples along the Navasota River. Photo by Leslie Lee.

How does water quality monitoring work?

Get a behind the scenes look at TWRI's monitoring process

One way the Texas Water Resources Institute (TWRI) contributes to water security in Texas is by monitoring water quality in rivers and streams that are subjects of watershed restoration processes. Healthy watersheds help keep regional water supplies clean and plentiful.

When a watershed restoration project begins, TWRI professionals typically conduct water quality monitoring at several locations in a watershed approximately once every two weeks for two years. All of this monitoring results in a thorough knowledge of real-time water quality at different spots along a watershed's rivers or streams. Along with input from local stakeholders and state and federal agencies, that data informs the development of a watershed protection plan or total maximum daily load.

TWRI's water quality monitoring process typically involves:

- **Sample Collection:** The team uses a sterile water sampling bag to collect a grab sample from the river or stream for quality testing and analysis at an accredited lab. Testing generally includes nutrients and *E. coli* but can be expanded to include other constituents.
- **Instream Conditions:** A multiparameter water quality sonde is used to instantaneously measure temperature, pH, dissolved oxygen and specific conductance. These are important measures in gauging general water body health.
- **Flow data:** In shallow water, a hand-held Doppler flow meter is used. The team uses the floating river surveyor, which looks like a small boat, to measure flow when water is too deep to wade into.

Taking multiple flow readings provides a clearer picture of flow rates throughout the entire water body, which helps the researchers make an accurate bacteria or nutrient load estimate for the river.

- **Ambient Conditions:** The team records a number of ambient water body and watershed conditions during each monitoring event, including weather conditions, aesthetic metrics, physical water conditions and current water body usage.

This collection of photos shows TWRI's monitoring team collecting samples and measuring conditions along the Navasota River watershed and Big Elm Creek in the Little River watershed.

Beginning in 2002, the Texas Integrated Report of Surface Water Quality identified portions of the Navasota River and a number of its tributaries as having elevated levels of *E. coli* that do not comply with the state's recreational water quality criteria. Since then, *E. coli* levels have remained above the state's water quality standard.

TWRI has helped lead the Navasota River Water Quality Improvement project since 2014 and recently completed development of the Navasota River Below Lake Limestone Watershed Protection Plan. The plan was recently accepted by the U.S. Environmental Protection Agency.

The plan was informed by the data collected during dozens of water quality monitoring trips, such as those depicted here.

Clockwise beginning with top left: Dr. Lucas Gregory takes a water sample from the Navasota River. Photo by Leslie Lee. Ryan Pircher, student technician, conducts instantaneous stream flow measurements while Kirby Young, research assistant, records the data during water quality sampling in Big Elm Creek in the Little River watershed. Photo by Dr. Lucas Gregory. Once collected, the sample is labeled and will be delivered to an accredited lab for analysis. Photo by Leslie Lee. Young conducts instantaneous stream flow measurement in Big Elm Creek. Photo by Dr. Lucas Gregory.

Story by Kathy Wythe

Assistant research Cole Gray and Dr. Leslie Cizmas work in Cizmas' lab. She has identified a particular compound to use as a tracer molecule in her research on understanding what happens to PPCPs when water is intensively reused. Photo by Kathy Wythe.

SAFE WATER = SECURE WATER

Texas A&M researchers study ways to rid water of toxic chemicals

Photo by Freepik.com

What do Starbucks coffee, Chanel No. 5 perfume and Benadryl antihistamine have in common?

All three products are considered pharmaceutical and personal care products, or PPCPs, a broad and growing category of compounds.

Certain components of PPCPs are also part of another category of chemicals, called endocrine disruptor compounds (EDCs), which disrupt the endocrine system of animals and humans. PPCPs and EDCs together are considered contaminants of emerging concern because of their potential risks to public health and the environment.

Scientists across the Texas A&M University campus are studying some of these chemicals, their toxicity and methods to eliminate them from wastewater treatment systems before the treated wastewater is released into the environment.

Dr. Leslie Cizmas, assistant professor in Texas A&M School of Public Health's Department of Environmental and Occupational Health, said previous research has indicated that some PPCPs or EDCs released into the environment can affect animals, such as algae, fish and invertebrates.

She said while some people might not care about a small organism such as algae, they forget algae are primary producers that feed fish, which then feed other animals up the food chain.

For example, research has shown that environmental EDCs released in the water have caused male fish to develop intersex characteristics, leading to decreased reproductive success, according to Dr. Kung-Hui (Bella) Chu, associate professor in the Zachry Department of Civil Engineering at Texas A&M. "Then the fish production over the years will decline because it is not balanced," she said.

"We count on the environment to look normal," Cizmas said. "Even people who don't care about the environment would notice and be concerned if suddenly half the population of a species died."

In a recent journal article, Cizmas and her co-authors looked at existing research on PPCPs and their effects on the environment to help scientists better prioritize which compounds to study.

"There are so many pharmaceuticals out there and so little money," she said, "so prioritizing which compounds to look at is a huge deal. To start doing toxicity testing for each of those is too expensive."

One way to prioritize, Cizmas said, is to examine quantitative structure activity relationships, which is identifying a problematic compound, then finding related compounds and looking at that class of compounds more closely.

Focusing on compounds that are more frequently purchased and used, not taken out in the wastewater treatment process and more toxic are other ways to prioritize, she said.

Cizmas has identified a particular PPCP compound to use as a tracer molecule in her research on understanding what happens to PPCPs when water is intensively reused. The PPCP tracer is not removed during the wastewater treatment process and is relatively stable in the environment, she said. She recently submitted a proposal for funding such research with other Texas A&M scientists.

First line of defense

Wastewater treatment plants are the first line of defense for removing any harmful PPCPs or EDCs.

Cizmas said fat-loving chemical compounds naturally bind to sediment, or solids, and may be taken out of water by the wastewater treatment process. But other PPCPs may not be removed or degraded in the treatment process.

"Some pharmaceuticals do get taken out, and some go right through," she said. ⇨

> "Effective EDC removal during treatment will be the first gatekeeper for minimizing impacts on eco-health and potential harms to public health."

Chu said removing environmental EDCs during the treatment process was a logical focus for her research to make a difference and positive impact on water quality.

"Removing EDCs during the wastewater treatment process is an easier and effective way to minimize release of EDCs into the environment," she said. "Effective EDC removal during treatment will be the first gatekeeper for minimizing impacts on eco-health and potential harms to public health."

For much of her work, Chu works with bacteria already in wastewater that, under the right conditions, can break down these harmful EDCs into harmless chemicals.

A banned substance

One particular chemical Chu and her group have studied is triclosan, a compound used in more than 700 different industrial and consumer products, such as antibacterial soap, plastic cutting boards and even toys. In September 2016, the Federal Drug Administration (FDA) banned the use of triclosan and 18 other ingredients in antibacterial soap. But triclosan is still used in common household products, such as hairbrushes, sponges, computer keyboards and clothing.

According to the FDA, animal studies have shown that triclosan alters the way some hormones work in the body, and other studies have raised the possibility that triclosan contributes to making bacteria resistant to antibiotics.

In addition to triclosan being a weak endocrine disrupter that can interrupt thyroid function, Chu said with UV exposure, it can also potentially be transformed into compounds that are more toxic when released into the environment.

Using molecular techniques, Chu's research group determined that the bacterial strain KCY1 is normally present in wastewater and can degrade triclosan. The group correlated the needed amount of cell concentration of the strain to effectively degrade triclosan in wastewater. They have also defined optimal conditions for the bacteria to do its work during treatment.

"For example, this strain might prosper and work better in activated sludge without nitrification, since it is a fast-growing bacterium that can grow on organics," she said. "For wastewater treatment processes with nitrifying-activated sludge and lower abundance of this strain, other triclosan-degraders, both cultivated or uncultivated, would be responsible for triclosan removal. It will be case-by-case because biological treatment processes used by wastewater treatment plants create and shape different microbial ecology, leading to different removal efficiency for triclosan."

In her research, Dr. Kung-Hui (Bella) Chu works on identifying bacteria, naturally occurring in wastewater that can break down harmful compounds. Photo by Leslie Lee.

Chu said the next step could include some pilot-scale testing, but that testing would involve investment by the wastewater industry and that is unlikely to occur unless federal or state wastewater discharge regulations are imposed for triclosan or if more intensive water reuse dictates it.

Governmental oversight

The Safe Drinking Water Act requires the U.S. Environmental Protection Agency (EPA) to review compounds and develop a list of those that might need regulating. This list, called the Contaminant Candidate List, contains industrial chemicals and even naturally occurring elements, among other chemicals. But, because PPCPs are usually present in very low concentrations, there are currently no regulations concerning PPCPs.

EPA also has a human health risk database, called Integrated Risk Information System or IRIS. The agency has prioritized chemicals of concern found in the environment by reviewing human health and animal studies and has created a ranking in terms of carcinogenic and non-carcinogenic effects of the chemicals.

Bacteria to fight 1,4-dioxane

Another chemical Chu's group is researching is 1,4-dioxane. This known groundwater contaminant is a synthetic industrial chemical used widely as a stabilizer in certain chlorinated solvents, paint strippers, greases and waxes. It is also used in shampoos, detergents and deodorants. Although not yet banned or regulated, Chu said there is growing concern as it has recently been found in surface water in low concentrations. Classified by the EPA as "likely to be carcinogenic to humans," the agency has established drinking water health advisories but has not established a maximum contaminant level for drinking water.

Chu's research is using two bacterial strains that are known to produce certain enzymes that can degrade a co-contaminant, trichloroethylene (TCE), but under certain growing conditions can also degrade 1,4-dioxane.

"Our study is looking at effects of various growth substrates to induce the expression of different enzymes and determine the performance of those enzymes in degrading 1,4-dioxane," Chu said.

Chu said her research has found that using propane to grow these bacterial strains will produce the enzyme that degrades both 1,4-dioxane and TCE.

"But, because toxicity is produced during the degradation process of these compounds, particularly TCE, the bacteria can be damaged by the toxicity," she said. "Thus, it is a fine line to determine the certain conditions that will work best to degrade both chemicals or target one over the other."

Future regulation

Although multiple risk assessments have indicated that PPCPs and EDCs are not currently a risk or concern for humans, research into the compounds will continue to be an important area of study, the scientists said.

With more PPCPs being used, more water being reused and more droughts possible in the future, researchers said these products may eventually be regulated.

"My expectation is that the EDCs will be regulated sooner than any other PPCPs," Chu said. "Or something that falls in both categories might be regulated sooner."

Cizmas agreed the effects of these compounds might have a greater impact in the future.

"In the next 50 or 100 years, we are not only going to have bigger populations, but I think we are going to have more intensive water reuse," Cizmas said, attributing the increased reliance on water reuse to potentially more droughts.

"The key will be how many times does the water get reused and how well are those compounds being taken out before the next cycle of reuse," she said. "If we can treat them and they get removed, it is not a problem to keep reusing, but if we have some that make it through the treatment process and get reused, and these same compounds don't break down easily in the environment, then we could have build-up (of the compounds)."

Ensuring water safety

For both Chu and Cizmas, their work and the work of other scientists is needed to proactively understand and minimize the effects of these compounds even before they are possibly banned or regulated.

"We need to be good stewards of the water," Cizmas said. "Rather than hoping that water doesn't get contaminated, we need to be more proactive; it is extremely difficult to clean-up groundwater."

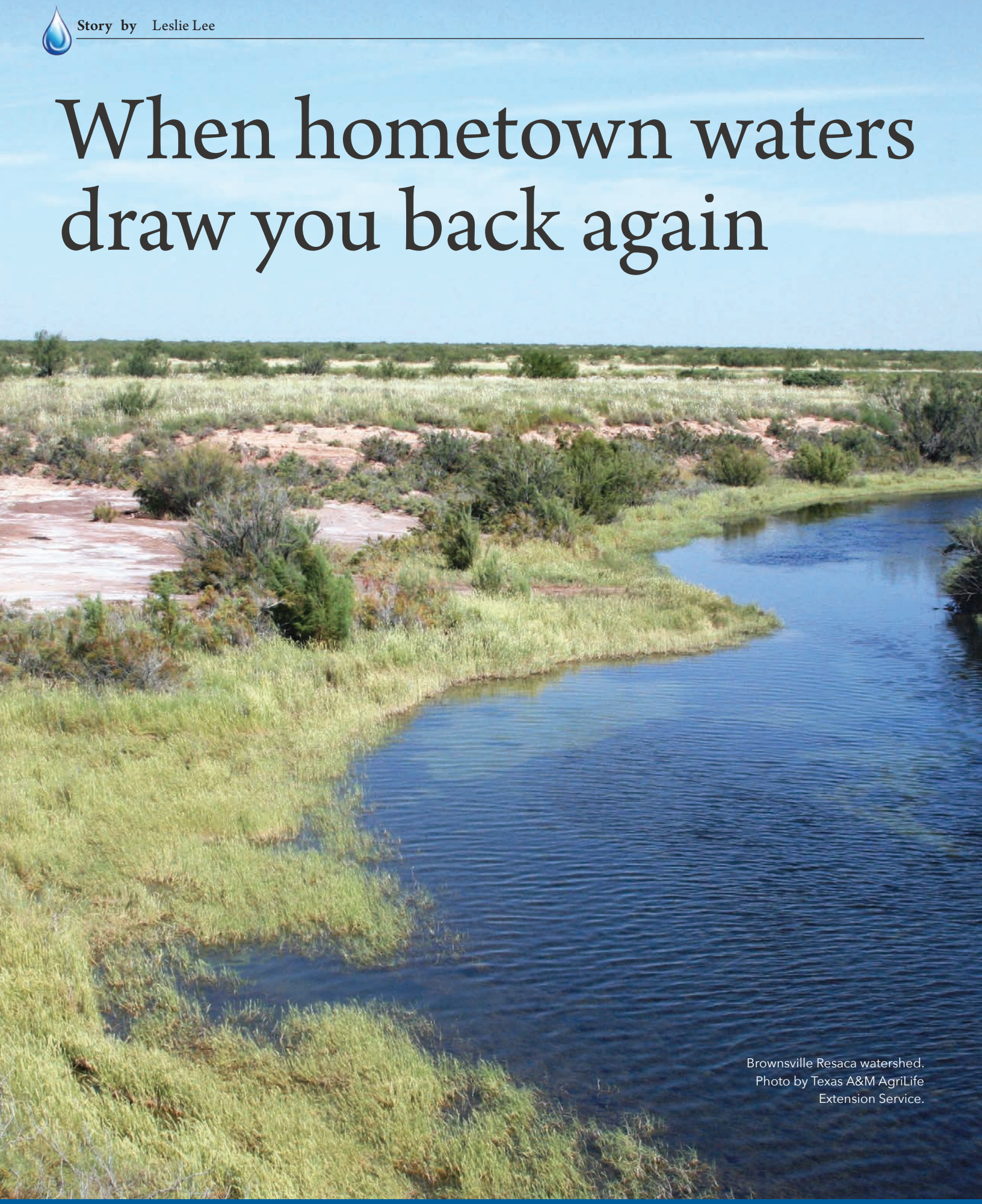
Chu agreed. "For drinking water safety, scientists and all the research community needs to be more proactive and find the best available technology for removing the contaminants, rather than waiting until these compounds are regulated," she said.

For example, Chu believes EDCs will eventually affect the human populations, but it will take time to collect the toxicology data to determine this.

"By the time we figure it out and try to find a solution, it will be too late," she said. "That is the whole concept with my research."

Story by Leslie Lee

When hometown waters draw you back again



Brownsville Resaca watershed. Photo by Texas A&M AgriLife Extension Service.

Rio Grande Valley native Dr. Jude Benavides shows that balancing public service and academic research is possible and impactful

Public service is the common thread winding through Dr. Jude Benavides' resume, even as he is still in the middle of his career as a professor and hydrologist.

Benavides grew up in the Rio Grande Valley and now serves as an associate professor in the School of Earth, Environmental and Marine Sciences at the University of Texas Rio Grande Valley (UTRGV).

"Growing up along the coast, I was always interested in the environment," Benavides said. "I grew up on a resaca and frequently went fishing as a young kid — I was always outdoors."

A mentor told teenage Benavides about the water and environmental opportunities that a civil engineering degree could open up to him, and that convinced him to pursue that field. After graduating from high school in Brownsville, Benavides headed to the University of Notre Dame to earn a bachelor's degree in civil engineering.

Choosing to apply to and join the U.S. Naval Reserve Officers Training Corps, or NROTC, at Notre Dame and committing to serve in the U.S. Navy after graduation was a major inflection point for his career and personal growth, Benavides said.

"After graduating from Notre Dame, I spent six years as an officer in the U.S. Navy, so I spent more time on the water," Benavides said. "Water has always been a part of my life."

Returning to hometown waters

When he concluded his time in active duty, Benavides went to graduate school at Rice University and focused on hydrology and flooding. He continued serving in the U.S. Naval Reserves until 2008. With Dr. Philip Bedient, a flood hydrology expert, as his advisor at Rice, Benavides eventually earned both his master's and doctorate in environmental science and engineering there. ⇨

Dr. Jude Benavides collects water quality samples within the tidal portion of the Arroyo Colorado.

"At Rice I developed my expertise in hydrology and specifically in flood alert systems, flood modeling and hydrologic modeling, as well as doing a little bit of GIS and water quality work," he said.

After leaving Rice, Benavides took a faculty position at UT Brownsville, returning to the Rio Grande Valley, where the 90-mile-long Arroyo Colorado runs through much of his childhood fishing and exploring spots. He was happy to return to kayaking and fishing in hometown waters, he said. Eventually he and his wife, Anne, an environmental consultant, would grow their family in the Valley and welcome a son in 2015 and a daughter in 2016.

But first, he would start a public service adventure he didn't see coming.

Jumping in feet-first

"I joined the UT Brownsville faculty in 2005, and I was quickly nominated and became chairman of the Arroyo Colorado Watershed Partnership (ACWP) in 2006," he said.

"I kind of did it a little backwards," Benavides said, because most academics wait until they have a little more experience under their belts to jump into public service roles. This career path would present some challenges and some big benefits.

"You have to spend a tremendous amount of time and energy listening to and working with stakeholders, focusing on organizing in the beginning of these projects. Fortunately, we have a really good watershed coordinator to work with," he said, referring to Jaime Flores, watershed coordinator for the Arroyo Colorado Watershed Partnership and Texas Water Resources Institute (TWRI) program coordinator.

Initially organized by two smaller groups of local stakeholders formed in 1998 as part of the State of Texas total maximum daily load process, the ACWP has since grown into an innovative group of local stakeholders and leaders. It collaboratively works with federal, state and private organizations to improve the health and function of the watershed.

Originally a stream channel of the Rio Grande that provided quality habitat for fish and wildlife, the modern Arroyo Colorado has been modified to carry to sea both commercial barges and, when necessary, flood waters. It empties into the Lower Laguna Madre (LLM) and is still a productive nursery for fish and other aquatic species and provides bird habitat, as well as premier recreational spaces for fishing, hiking and bird-watching. However, for decades, water quality data in the Arroyo have shown high levels of bacteria that exceed the state's standards for recreational contact.

"I've been lucky to be at a university that really emphasizes strong connections between education and outreach, and strong connections with the local region and area," Benavides said. "In 2006 the university trusted me, and I think that has paid multiple dividends down the road for everyone involved because we are seeing more grant funding come in for this work, and we are seeing a lot of positive action on the ground with water quality enhancement."

The ACWP focuses on the interrelated issues of water supply, flooding and drainage, fish and wildlife habitat, and water quality, particularly runoff pollution concerns. With support from Texas Sea Grant, the Texas Commission on Environmental Quality, the U.S. Environmental Protection Agency and TWRI, the group published the Arroyo Colorado Watershed Protection Plan in 2007.

Benavides has been instrumental in implementing it alongside local stakeholders.

"Years ago, local policy folks and stakeholders might not have turned to the university for help with these kinds of water issues — they might have gone to outside consultants or state agencies," he said. "But, if you're like me and you live in the watershed, then you really know it, and there is a lot of added incentive to work on issues in your own backyard."

Working in 'his own backyard,' Benavides has learned a lot about stakeholder engagement and organizing watershed efforts.

"My advice would be, have confidence in the voice and the requests of your stakeholders," he said. "Especially when I was a beginning academic, I had to be very mindful of that — just because you're educated and have a Ph.D., you don't really know that watershed or the needs of that watershed until you spend some time in it. I quickly realized I had a lot more to learn.

"And, through watershed protection planning and established education and outreach efforts like the ACWP, you grow relationships and build trust, which is far more beneficial than just addressing specific research or new technology issues."

Seeing watershed planning produce results

Flores and Benavides have spent much of the last 10 years putting their combined expertise in hydrology and local water bodies into action.

"We have leveraged the 2007 plan and the stakeholder relationships to the tune of several millions of dollars in grants that are helping address water quality issues in the Arroyo," he said.

Watershed stakeholders have accomplished many of the objectives of the original plan, including upgrading eight local wastewater treatment facilities

from outdated lagoon treatment plants to modern mechanical plants. This has reduced the contaminant loading into the Arroyo Colorado from continuous flow sources. Partnership funds also helped provide centralized wastewater service to 17,054 residents in 42 colonias.

The ACWP also helped landowners voluntarily implement best management practices to improve water quality on 130,000 acres of irrigated cropland. The partnership's education and outreach efforts have reached more than 100,000 residents at 221 events and installed approximately 8,000 informative storm drain markers throughout the watershed.

The partnership published an updated Arroyo Colorado Watershed Protection Plan in 2017, and Benavides said the revision will help give the local efforts a more accurate road map for implementing the plan and managing the watershed.

Helping another watershed

For the past few years, Benavides has also been involved with another local watershed restoration effort, this time for the Lower Laguna Madre/Brownsville Ship Channel watershed, called the Brownsville Resaca watershed by some. Like the Arroyo Colorado watershed, segments of water bodies within this watershed are also currently listed as impaired by the state for high bacteria levels.

"We are in the first stage of that watershed planning process, which is characterizing the watershed," he said. "That study has been going on for a couple of years. It involves very carefully detailing all the subbasins in the watershed so we can compile the necessary data to achieve the overall goal of identifying point and nonpoint sources of pollutants in the watershed."

The make-up of the Lower Laguna Madre/Brownsville Ship Channel watershed presents several challenges.

"It is very flat, and it is a very intricate network that consists of distributaries from the Rio Grande, drainage ditches, irrigation canals and coastal features such as bays, lagoons and saltwater flats," he said. "All of those water bodies kind of merge together, so any little thing can interrupt the flow or change the flow path. The water quality source tracking work we're coordinating now examines where the potential sources of the pollutants are, and whether they are a concern."

Benavides said one of the things he is most proud of in his career is bringing more academic and research attention to the Rio Grande Valley and to smaller waterways, such as resacas, the ship channel and the Arroyo. "One of the sayings here is that the Arroyo Colorado is a little waterway with a big job," he said, because it provides a badly needed freshwater environmental flow to the LLM, habitat for migrating birds, and serves as a nursery for juvenile shrimp, fish, crabs and wildlife.

"I'm proud that these regional hydrology and water quality efforts are now supported strongly by academics and the academic institutions here." ⇨

(left) Environmental Science program undergraduate students conduct streamflow and water quality sampling at the most downstream, non-tidally influenced monitoring station along the Arroyo Colorado as part of a bacterial source tracking grant funded by the TSSWCB.

(right) UTRGV professors Dr. Jude Benavides (right) and Dr. Alejandro Fierro (middle) discuss water quality and benthic sampling techniques to high school teachers who volunteered to help sample local area resacas. Photos courtesy of Dr. Jude Benavides.

> "The water challenges we have today in the Valley are going to be nothing like we will see 25 to 50 years from now, but I'm confident that together we will develop the necessary, stakeholder-driven solutions to meet them."

Interdisciplinary water research in the Valley

"In the beginning of my career, I was one of the few hydrologists at UT Brownsville and UT Pan America for many years before we merged into UT Rio Grande Valley," he said.

Helping lead the ACWP so early in his career helped Benavides understand local water problems.

"It forced me to learn the watershed in a different way," he said. "It got me out of the office, off campus and tuned-in to a lot of different stakeholders' needs."

As UTRGV has grown, the number of faculty members doing water research has grown as well, Benavides said, and the abundance of interdisciplinary water research now happening at the university serves the region's unique needs well.

"When you are looking at an area of Texas, or even the world, that is in a semi-arid, sub-tropical area, and in a coastal area, and in an international basin or water basin, and that is multicultural and rapidly changing from an agricultural area to a rapidly growing urban industrial area, that presents a whole host of interdisciplinary challenges," he said. "From engineering to science, to policy, to agriculture, to environmental water and flows, to flooding, to coastal issues — you name it, the Valley and Rio Grande River delta have it.

"Brownsville is often referred to as 'on the border, by the sea,' and as a result, we have grown and need to continue to grow our team of environmental scientists, civil engineers, marine biologists, ecologists and others who are studying a little bit of everything — hydrology, groundwater, surface water and how these water resources connect with and support the environmental and human systems in the area."

The rapid population growth and urbanization occurring in the Rio Grande Valley also heightens the need for interdisciplinary water research and outreach.

"These quickly urbanizing watersheds have been terribly understudied," Benavides said. "I think that at UTRGV we are helping meet that need by partnering across systems, such as with TWRI and the Texas A&M University System, to together focus on regional water needs."

"The water challenges we have today in the Valley are going to be nothing like we will see 25 to 50 years from now, but I'm confident that together we will develop the necessary, stakeholder-driven solutions to meet them."

Dr. Jude Benavides (left) and UTRGV student Monica Delgado and Robert Figueroa-Downing, a visiting student, prepare to collect water quality samples for hydrodynamic modeling of the tidal zone along the Arroyo Colorado.

Story by Claire Corley

EARNING HIGH MARKS

AgriLife scientist finds LID practices reduce runoff, improve water quality

Texas' urban areas are growing, and that means more impervious surfaces, less natural filtration of water through soils and more stormwater carrying pollutants into streams. Studies in recent years at the Texas A&M AgriLife Research and Extension Center in Dallas have proven the effectiveness of low impact development (LID) practices in reducing these negative environmental impacts of urban growth.

Dr. Fouad Jaber, Texas A&M University associate professor and Texas A&M AgriLife Extension Service specialist at the Dallas center, has been designing and testing several LID practices including green roofs, permeable pavements and rain gardens through a Clean Water Act grant funded by the U.S. Environmental Protection Agency through the Texas Commission on Environmental Quality.

Urban areas are mostly paved or covered by other structures, so water filtration and purification typically done by the soil is not possible, Jaber said. As a result, many times urban pollutants flow directly into streams and lakes, degrading their water quality.

"When you urbanize an area, instead of rainwater infiltrating, runoff goes into stormwater pipes and that results in a lot of damage downstream," he said.

Urban watersheds also cause increased flooding and reduced groundwater recharge. However, Jaber said LID practices use natural elements to minimize negative environmental impacts of urbanization.

"One of the benefits of the structures is that they encourage water filtration and retention," Jaber said.

Each LID structure at the Dallas center collects the first two inches of rain, getting rid of settling dirt from the last rain, or as Jaber calls it, 'the first flush,' to reduce pollutants flowing into water bodies.

Green roofs

One of the practices Jaber has tested is the green roof, which can provide a more aesthetically appealing look to concrete buildings.

Green roofs refer to roofs partially or completely covered by topsoil and planted with vegetation. The roofs have a waterproof membrane and drainage area and are planted with native plants. By adding these touches, some of the rainwater will be caught in the soil for the plants, allowing only a portion of the runoff to end up in the gutters, Jaber said.

The green roof of the Botanical Research Institute of Texas in Fort Worth. Photo by Dr. Fouad Jaber.

The experimental green roof study at the Dallas center captured 75 percent of runoff on a yearly basis. Photo courtesy of the Ecological Engineering Program at the Texas A&M AgriLife Research and Extension Center in Dallas..

"Green roofs are basically a way to green up the footprint of buildings," he said.

He said in his tests at the Dallas center, 75 percent of the runoff on a yearly basis was captured by a green roof, alleviating added pollution to stormwater.

"We have a famous green roof in the Dallas area even though people don't identify it as such," Jaber said, referring to Klyde Warren Park, a popular ⇨

urban park in Dallas that is on top of a section of the Woodall Rodgers Freeway and serves as green roof.

The 5.2-acre park, composed of 37 native plant species and 322 trees, includes walking trails, a dog park, a children's park and game areas.

Permeable pavement

Jaber has also tested four permeable pavement types to see which reduces runoff the most. Out of the four — permeable concrete, interlocking concrete, gravel paver and grass paver — the grass paver performed the best, with a total volume reduction rate of 93 percent.

The idea with these pavers is that rainwater and sediment pass through the surface allowing for the sediment and pollutants to be trapped before the water reaches outlet pipes that lead to a sewer or stream, Jaber said.

One challenge is there are limited areas where grass pavers can be installed, he said.

"They are really intended for overflow and occasional parking," Jaber said. "Football stadiums, where you park once a week for four months, or churches just on Sunday, those would be good for grass pavers."

On the other hand, the other three pavement types performed equally and could replace any parking lot, since they are made up of concrete or gravel material, he said. While there was not a performance difference in the three, there are aesthetic and price differences. Based on an informal poll of the many visitors that toured the center's site over the past few years, Jaber said it appears that people preferred the interlocking concrete pavers more, but they are more expensive than the gravel pavers.

"You have an option here to go with cheap and less aesthetic or expensive and more aesthetic for the same technical performance," Jaber said.

Rain gardens

Rain gardens or bioretention areas are full ecological systems that work to reduce the total runoff volume from either residential or commercial areas, Jaber said.

Residential rain gardens are planted in yards to alleviate runoff problems. Typically 6 to 8 inches deep, the rain garden is heavily planted so the runoff has no place to go but to infiltrate into the soil or evaporate from the plants, he said. Commercial rain gardens can be used in road medians or alongside parking lots.

At the Dallas center, the rain garden, which collects runoff from a 37,000-square-foot parking area on the center's grounds, reduced stormwater volume by 49 percent.

Rain gardens also address high levels of pollutants. "They break down nitrate into nitrogen gas that reduces nitrogen pollution. They also reduce phosphorus pollution and pesticide pollution," Jaber said.

> "Economic benefits can result due to less costly water treatment, smaller stormwater systems and reduced flooding."

Dr. Fouad Jaber studied a rainwater harvesting system as a stormwater best management practice at the Dallas center. Photo courtesy of the Ecological Engineering Program at the Texas A&M AgriLife Research and Extension Center in Dallas.

Story by Claire Corley

Ahead of the curve

Hill Country stakeholders proactively create Upper Llano River Watershed Protection Plan

Added benefits

Along with environmental benefits, he said these LID practices also positively affect the economy.

"Economic benefits can result due to less costly water treatment, smaller stormwater systems and reduced flooding," Jaber said.

Another economic benefit can be found with green roofs. In addition to reducing runoff, green roofs can also reduce energy costs for cooling and heating a building because they provide insulation.

Jaber said studies have shown green roofs greatly reduce inside temperature as compared to conventional roofs, and temperatures can be even lower than ambient air during the morning time. Conventional roof temperatures can exceed 90 degrees on a sunny day, and most of that heat transfers to the inside of the building below the roof.

These practices are used throughout Texas, but Jaber's project in Dallas was one of the first when it began in 2012.

The Dallas center's ongoing education program on LID stormwater management teaches cities, consulting firms and Master Naturalist and Master Gardener chapters how to deal with stormwater in an environmentally friendly way.

After completing testing, Jaber saw more and more LID practices pop up around the Dallas area.

"People have called me to help design them, so I've been part of at least 15 rain gardens built here in the Dallas area," he said.

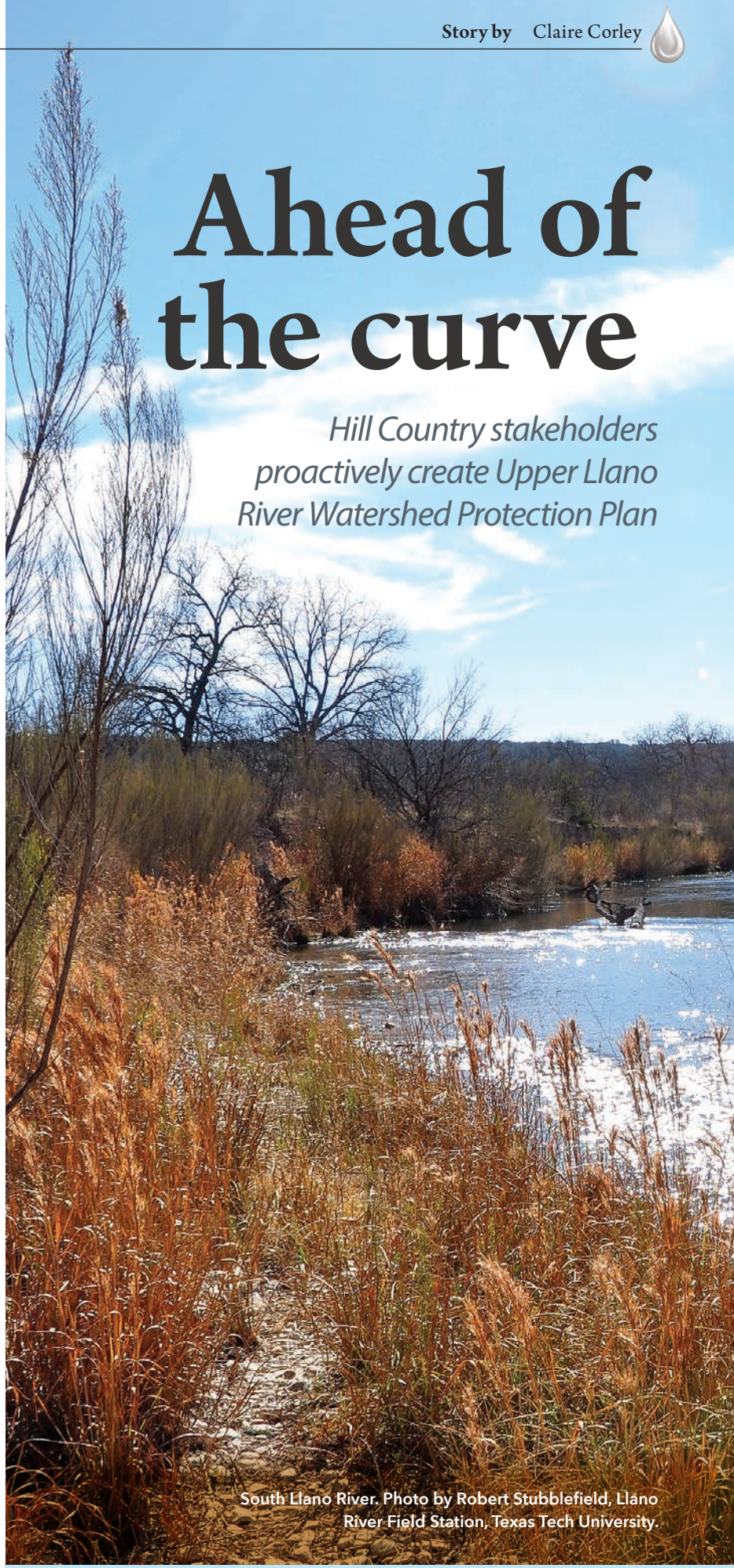
Jaber said all the LID practices at the Dallas Center were monitored and tested for small rain events but could be built to withstand larger storms.

"Typically, LID structures are designed to capture the first flush (less than 2 inch storms) to reduce pollution and are small scale and can be integrated within a development or a landscape without using additional space," Jaber said. "But, in most cases, flooding is a result of extreme rain events.

"To reduce flooding from extreme events using LID, there is a little bit of design and planning, and a little bit of critical thinking in eventually being able to install enough structures to reduce flooding and improve water quality."

This planning might require integrating rain gardens in all road medians, installing a rainwater harvesting system on most houses and using permeable pavement on most parking spaces.

Jaber said the hope is that these practices will help improve overall water quality in urban areas.



South Llano River. Photo by Robert Stubblefield, Llano River Field Station, Texas Tech University.

Composed of the North and South Llano rivers, the Upper Llano River is known as a Hill Country treasure. Its near-pristine flows provide a healthy ecosystem supporting a variety of aquatic communities and numerous recreational opportunities.

To sustain the river's pristine condition, local stakeholders partnered with the Texas State Soil and Water Conservation Board (TSSWCB), soil and water conservation districts, groundwater conservation districts, Texas Tech University Llano River Field Station, Texas Water Resource Institute (TWRI), Texas Parks and Wildlife Department and the Llano River Watershed Alliance to develop a watershed protection plan (WPP).

Typically, a WPP is developed in a watershed that is impaired and needs restoration; the Upper Llano River WPP is an exception.

Dr. Kevin Wagner, former TWRI deputy director of engagement, said that in impaired watersheds, water quality criteria have been exceeded and WPPs are then developed to achieve needed reductions. Since the Upper Llano River's water quality did not exceed any regulatory standards, stakeholders had great flexibility to develop their vision for the watershed and identify what they wanted to see implemented over the next five to 10 years.

Landowners got it started

Wagner said landowners and landowner associations were already working on improving the watershed prior to this planning effort, which generated great interest in possible collaborative opportunities among a variety of state agencies, nongovernmental organizations and university programs, including TWRI.

Dr. Tom Arsuffi, Llano River Field Station director, agreed the stakeholders were the driving force behind the WPP.

"To address complex issues requires a 'bridging of silos' approach," Arsuffi said. "That is why this plan is effective; it brings together expertise from Texas Tech University and Texas A&M University, landowners and ranchers, county judges and mayors, state and federal agencies, and others."

Stakeholders such as County Judge Delbert Roberts and Llano Springs Ranch owner Tom Vandivier know how important the well-being of the river is to everyday life.

"It is easier to prevent something than to reinvent it or clean it up, so anything we do is better than nothing or allowing it to get worse," Roberts said.

Vandivier said the citizens of Texas have a responsibility to help protect the natural resources of the state, including rivers such as the North and South Llano.

"What we do on private property to protect and enhance the habitat in our watersheds is critical to protecting that resource for everyone," Vandivier said. "Good land stewardship practices are vital to this protection and enhancement."

Model for the Hill Country

The plan was funded by a federal Clean Water Act Nonpoint Source Grant administered by the TSSWCB from the U.S. Environmental Protection Agency (EPA).

Tyson Broad, Llano River Field Station watershed coordinator, said two and a half years of water quality and biological monitoring and analysis went into informing stakeholders about potential issues in the river and opportunities for improving and sustaining it.

Findings showed potential problems related to the river's low flow in 2011–2012 and an overpopulation of wildlife impeding growth of young woody plants along the riparian area, Broad said. ⇨

Clockwise starting with top left: Dr. Preston Bean (left) and Dr. Emily Seldomridge (right) take stream discharge measurements on North Llano River. Seldomridge, a field assistant and Bean take aquatic sampling using backpack shocker. Seldomridge and Bean take water quality measurements on the North Llano River. Photos courtesy of Llano River Field Station, Texas Tech University.

> "Stewardship education is likely the most important thing we can do to protect our land, habitat, water and wildlife. How will people understand how to protect the river if we don't teach them?"

The Upper Llano River WPP proactively addresses emerging water quality concerns, invasive species, aquatic habitat loss and altered water flows through voluntary, non-regulatory watershed management strategies.

Because of its proactive, non-regulatory approach, Arsuffi said the Upper Llano River WPP is a model for the rest of the Hill Country.

Implementation begins

Since approval by EPA in September 2016, the implementation phase of the WPP has made great progress through efforts by the stakeholders, Arsuffi said.

To start implementing the WPP, Broad said range management and restoration programs, as well as demonstrations at the field station, have been funded.

"We are starting a streambank restoration project at the Llano River Field Station and a brush control demonstration project as well," Broad said.

He said the city of Junction has applied to the Texas Water Development Board for financial assistance to install water conservation projects in the city. These efforts include smart meters, identifying line leaks in water distribution networks and low-flow toilets.

Arsuffi said with the better watershed management upstream, the Upper Llano River WPP is not only ensuring the water quality and quantity of the North and South Llano rivers, but also improving flows and water quality for downstream aquatic ecosystems and cities, including the city of Austin and the Highland Lakes.

The successful implementation efforts ultimately depend on effective education and outreach to landowners in the watershed.

"Stewardship education is likely the most important thing we can do to protect our land, habitat, water and wildlife," Vandivier said. "How will people understand how to protect the river if we don't teach them?"

Brad Littrell on the South Llano River. Photo by Tyson Broad, Llano River Field Station, Texas Tech University.

South Llano River. Photo by Robert Stubblefield, Llano River Field Station, Texas Tech University.

Wagner leaves TWRI to become director of Oklahoma water center

Dr. Kevin Wagner, former deputy director of engagement for the Texas Water Resources Institute (TWRI), became director of the Oklahoma Water Resources Center at Oklahoma State University (OSU) in Stillwater on July 31.

As director of the center, he works with faculty from 11 academic departments at OSU, including the Division of Agricultural Sciences and Natural Resources' nine departments, Extension experts and other universities throughout the state to help address the state's critical water resources issues. He also serves as the Thomas E. Berry Professor of Integrated Water Research and Management and as an associate professor in the university's Plant and Soil Science Department.

Both TWRI and the Oklahoma Water Resources Center are part of the National Institutes for Water Resources, established by the federal Water Resources Research Act and supported by the U.S. Geological Survey.

Wagner, who served in various positions at TWRI for 12 years, had a tremendous impact on advancing watershed planning and water quality issues in the state, according to Dr. John C. Tracy, TWRI's director.

Tracy said Wagner also increased engagement with the water resources community across Texas and the nation during his time at the institute.

"Dr. Wagner was hugely responsible for the institute's increased work with state water agencies, and, as a result, the institute and stakeholders in watersheds throughout the state were able to make significant progress in addressing water quality impairments," Tracy said. "He also provided effective leadership and administration of the institute's numerous water programs."

TJ Helton, Texas State Soil and Water Conservation Board (TSSWCB) Nonpoint Source Program coordinator, said Wagner continually demonstrated his leadership in tackling the magnitude of water quality issues faced by Texans.

"Dr. Wagner was a fundamental partner to TSSWCB for the past 12 years," he said. "Through this partnership, there were multiple initiatives developed and implemented to address water quality issues across the state."

For example, Helton said, TSSWCB worked alongside Wagner and others to develop the Texas Bacterial Source Tracking Library, making it one of the first of its kind.

The library, a joint program of TWRI, Texas A&M AgriLife Research and The University of Texas Health Science Center at Houston School of Public Health in El Paso, is used to identify and also rule-out significant sources of *E. coli* pollution in watersheds.

"This library will continue to be used as a tool for future watershed planning efforts," Helton said.

Wagner also led the Texas A&M University System's work with the Ogallala Aquifer Program

(OAP), a research-education consortium finding solutions to declining water availability from the Ogallala Aquifer in the Texas High Plains and western Kansas. The consortium is led by the U.S. Department of Agriculture's Agricultural Research Service (ARS) and partners with three other universities.

"Dr. Wagner was an inspirational leader guiding the Texas A&M AgriLife Research and Texas A&M AgriLife Extension Service portion of the OAP," said Dr. David Brauer, OAP's program manager and a research agronomist for ARS. "Dr. Wagner's leadership was responsible for the OAP receiving an award for excellence from the U.S. Secretary of Agriculture."

Wagner said he really appreciated his time at TWRI and believes his work at TWRI prepared him to lead the Oklahoma Water Resources Center.

"I do look forward to using all the knowledge and experience gained at TWRI to lead the Oklahoma center and enhance collaborations in the region," he said.

Wagner received his doctorate in agronomy from Texas A&M University, his master of science in environmental science from Oklahoma State University and his bachelor of science from Howard Payne University.

Institute adds to water team

The Texas Water Resources Institute's (TWRI) water team continues to increase its expertise and capabilities, adding three members within the last year: Ed Rhodes, Kirby Young and Nathan Glavy.

Rhodes joined TWRI as a research associate in 2017. In this position, he provides leadership for the institute's various water quality monitoring projects and assists with quality assurance activities associated with primary and secondary data collection efforts.

His research interests include GIS applications in water quality assessments and monitoring and implications of land use/ cover on water quality and watershed assessment.

Rhodes received his bachelor's degree in rangeland ecology and management from Texas A&M University and his master's in rangeland ecology and management from Oregon State University.

Prior to joining the institute, Rhodes worked as a research associate for Texas A&M AgriLife Research in Vernon, Temple and College Station.

As a research assistant, Young works on various watershed protection, management and research projects with university faculty; state, local and federal governments; and stakeholders to address statewide water-related issues.

Young initially joined TWRI as a graduate student researcher in 2016. She received her bachelor's degree in geosciences with a minor in Spanish from Trinity University in San Antonio and is currently pursuing a master's degree in Texas A&M's Water Management and Hydrological Science Program.

Young is a certified Texas geoscientist-in-training, and her research interests include hydrology, hydrogeology and water quality.

Glavy is an extension program specialist for the institute and works on watershed planning projects and trainings, as well as water quality and riparian education. He also provides leadership for various research and extension projects, working with university faculty; state, local and federal government agencies; and stakeholders to address statewide water-related issues.

Glavy initially joined the institute as a graduate research assistant in 2017. He received his master's in water management and hydrological sciences from Texas A&M University, and his bachelor's degree in environmental studies with a minor in geography from Texas A&M University as well.

His research interests include water conservation and education and public health issues associated with drinking water quality.

Ed Rhodes, Kirby Young and Nathan Glavy. Photo by Kathy Wythe.

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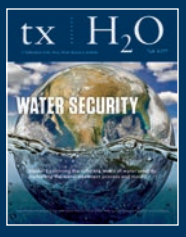

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