tx H2O

A Publication of the Texas Water Resources Institute

Fall 2016

TEXAS' EXTREME WEATHER

Inside: Why Texas has extreme floods and droughts, how a flood-prone community is adapting 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

This past summer was my first in College Station, and I cannot count the number of people who warned my wife and me to be ready for August, when daytime temperatures would top 100 degrees, with heat indices exceeding 110; when we would be spending quality time in indoor, air-conditioned Texas. August definitely started out that way, but we were pleasantly surprised when storms rolled in, temperatures dropped and we could spend a bit more time enjoying outdoor Texas.

While that change in weather was a welcome reprieve, it also resulted in extreme flooding in Louisiana that devastated many areas in and around Baton Rouge. This flooding came just months after severe flooding from Austin to Houston, where some areas received more than 1 foot of rain in a day. As pointed out in this issue of *txH2O*, those floods followed our wettest year ever (2015), which was preceded by a five-year drought.

This pattern reinforces the old saying: "If you don't like the weather, wait a few minutes." While the change in Texas weather took a bit longer than a few minutes, it is clear that Texas does experience extreme changes in weather patterns over short periods of time, best described by Dr. Nielsen-Gammon in this issue: "Texas weather is unusually abnormal."

While we know that weather extremes will occur, we still do not have the scientific tools to predict exactly when and where, which creates a water resource management challenge. Water managers have difficulty developing plans to prevent damage from extreme events, so the focus has been shifting to developing policies, plans and management strategies that focus on mitigating, responding to and recovering from extreme weather events. Instead of discussing "flood prevention," U.S. Army Corps of Engineers staff now discuss "flood risk management," and flood risk management is not a service provided by a governmental organization, but rather a shared responsibility between water resource managers, private organizations and individuals.

This issue of *txH2O* focuses on Texas weather extremes, the impacts these extreme events have on Texas' water resources and the ways in which water managers and individuals are preparing for these unexpected, but inevitable, events.

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

John C. Tracy, Ph.D.
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tx | H_2O

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On the cover:
Somerville Lake had historic flooding after Memorial Day weekend in 2016. Photo by Tommy Snow, Texas Parks and Wildlife Department.

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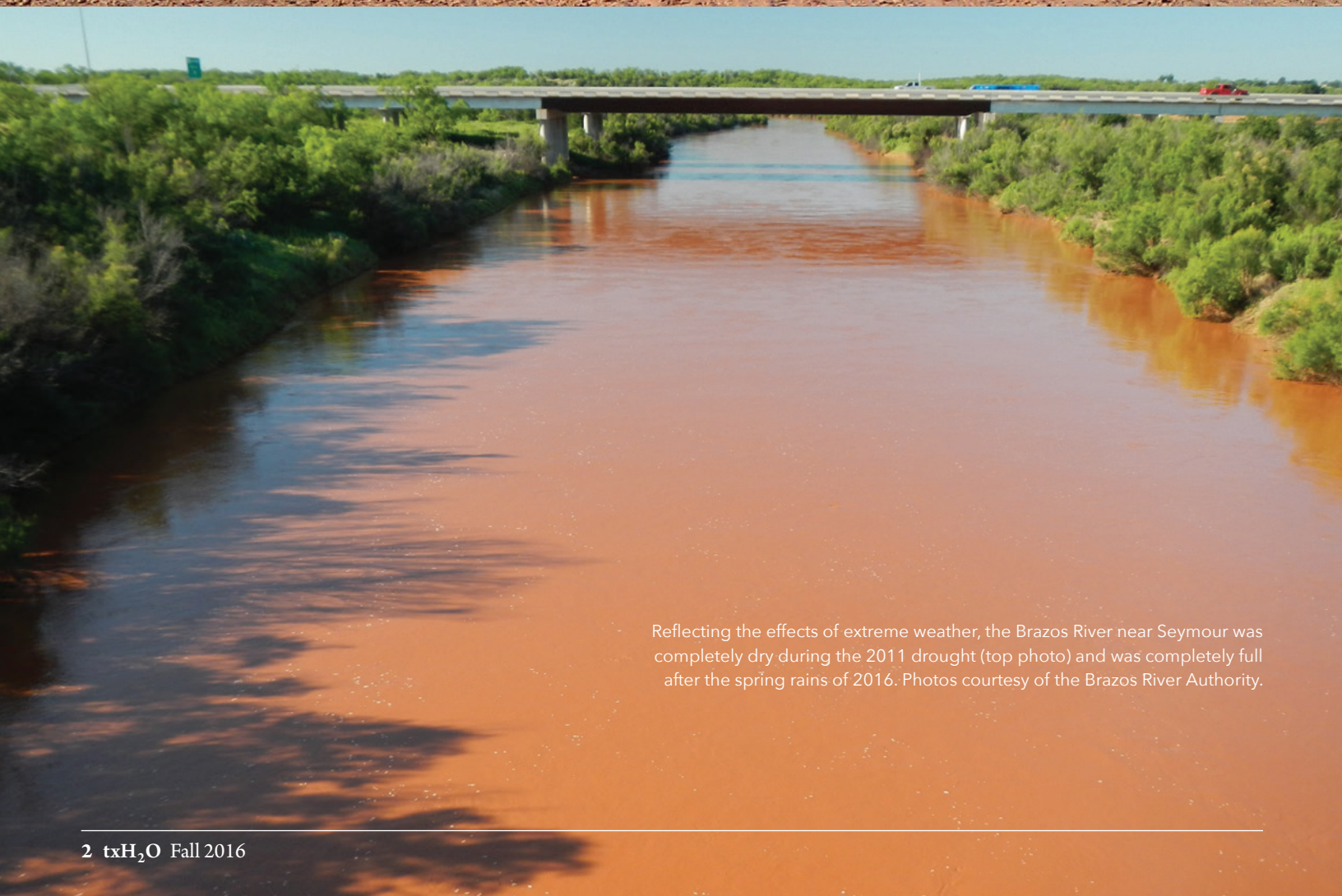
Texas Water Resources Institute
make every drop count

Volume 11, number 2, Fall 2016

The result of weather extremes can be seen in these photos of Nolan Creek at downtown Belton in Central Texas. The left photo was taken during the 2010 flash flood after Tropical Storm Hermine; the right photo was taken during the drought of 2011. Dr. June Wolfe, an AgriLife scientist in Temple, developed an automated weather station that sends text alerts to authorities of possible flooding of low-water crossings and danger to local communities. Right photo by June Wolfe, Texas A&M AgriLife Research.

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.



Reflecting the effects of extreme weather, the Brazos River near Seymour was completely dry during the 2011 drought (top photo) and was completely full after the spring rains of 2016. Photos courtesy of the Brazos River Authority.

EXTREMELY EXPECTED

Extreme is the new (and old) normal in Texas weather

In 2011 Texas experienced the driest year in its recorded history. 2015 was the wettest year on record with May 2015 the wettest month ever. Heading into fall 2016, experts were predicting a warm, dry winter.

Welcome to Texas weather.

This extreme variation in Texas weather is common, experts said.

Dr. Nelun Fernando, hydrologist for the Texas Water Development Board (TWDB), said historically drought and flood events in Texas do tend to follow each other. For instance, both the 1950s and the 2010-2015 droughts, and many other shorter duration drought events, ended in intense rainfall leading to flooding. "So, it is fair to say that is the norm," she said.

State Climatologist Dr. John Nielsen-Gammon, Regents professor in Texas A&M University's Department of Atmospheric Sciences, agreed that extreme weather changes are expected in Texas.

"I think it's fair to say Texas weather is unusually abnormal," he said. "We have a lot of variability in terms of rainfall, and also in the wintertime, temperatures vary a lot."

Climate change expert Dr. Bruce McCarl agreed that Texas' extreme weather is not new, although climate change will affect it.

"We've had a degree of variability for an awfully long time; in the end, we'll have it for a long time in the future. It's not purely a climate change phenomenon," said McCarl, distinguished professor, Regents professor and Texas A&M AgriLife Faculty Fellow in Texas A&M's Department of Agricultural Economics. "There are some rather major variability-causing things that come from the ocean, and climate change is likely to exacerbate that variability."

Extremes explained

The state's variable weather is caused, in part, because of its unique position globally. The state is at the crossroads of large-scale weather patterns, Nielsen-Gammon said.

"We're one of the few places on the globe that is affected by what's happening in both oceans," he said. "Our rainfalls are affected in the wintertime fairly strongly by what's happening in the Pacific Ocean. And in the summertime, there is a bit of an influence from the Atlantic Ocean."

In the Pacific, El Niño — warm waters near the ocean's center — and La Niña — cooler waters — influence Texas weather. El Niño and La Niña are phases of a recurring climate pattern across the tropical Pacific called the El Niño-Southern Oscillation, or ENSO. El Niño typically brings above-normal rainfall and below-normal temperatures to Texas during the cooler parts of the year. La Niña usually brings drier, warmer weather.

The La Niña pattern influenced the 2011 drought, Fernando said, causing reduced rainfall in late 2010 and early 2011. Nielsen-Gammon said predictions are that the state may have another La Niña in the winter of 2017. ⇨

"For a lot of the past few years, we've had both oceans working against rainfall in Texas at the same time and that helped contribute to the multiyear drought we experienced," Nielsen-Gammon said.

It is still unclear whether Texas is getting out of the drought cycle that it's been in for the past 20 years. "At this point, it's wait and see," he said. "But, it's possible we've gotten to the end."

Texas' susceptibility to both extreme drought and floods is somewhat unusual compared to other states.

"In Arizona, for example, it's sort of a permanent drought," he said. "You can get flooding happening locally, but it's not going to be anything major. In Vermont, you can get some pretty heavy floods, but you don't tend to get severe droughts. Here you get both."

Is extreme weather more frequent now?

Whether extreme weather in Texas is becoming more frequent remains to be seen.

Nielsen-Gammon said the state has seen more extremes than normal in recent years, but part of that is the randomness of weather. "For example, in May of 2015, we obliterated the statewide record for monthly rainfall, but the long-term trend for springtime rain in Texas is pretty much completely flat, so that doesn't seem to be part of the trend," he said.

Nielsen-Gammon said climate models do, however, predict a long-term upward trend in extreme rainfall events and temperatures for Texas. The warmer air over the warmer oceans will carry more water vapor to Texas, producing heavy rain.

His analysis of the past century shows a 20 to 40 percent increase in extreme rainfall. For example, a storm in late October 2015 produced the highest total rainfall amounts ever for one storm, he said.

Dr. Philip Bedient, Herman Brown professor of engineering in Rice University's Department of Civil and Environmental Engineering, said Houston is indeed experiencing more frequent and more extreme rainfall events in recent years, leading to more frequent and devastating floods.

Houston has seen seven major floods in the last 15 years, compared to six in the 25 years before, he said. "When you start seeing two events, one was a 100-year flood event and the other much greater than 100-year, over a vast part of the county in less than a year, I don't know if that has ever happened before," he said.

The Dallas-Fort Worth Metroplex is also seeing more extreme amounts of rainfall, according to Dr. Dong-Jun Seo of the University of Texas at Arlington (UT at Arlington) Department of Civil Engineering.

"In North Texas, over the last 50 years or so, the rainfall amounts from heavy precipitation events have increased about 15 percent," he said. "According to climate projections, the trend will continue and we may expect to see more extreme rainfall."

But the models are not nearly as consistent with overall annual rainfall amounts, Nielsen-Gammon said. For the next few decades, the natural variability of Texas weather will be a much larger influence on overall rainfall than any long-term trend from climate change, he said.

"We don't know how much of the monthly or annual rainfall variations we've seen so far are part of a long-term trend," Nielsen-Gammon said. "But the temperature changes and the short duration rainfall amounts are pretty clearly part of a trend."

McCarl agreed that while climate models are projecting hotter temperatures, the projections for annual rainfall for Texas are not as certain.

"If it gets several degrees warmer, there will be more evaporation that happens over the ocean, and that's going to mean more total rainfall," he said. "But most people think Texas is going to be substantially drier," he said, citing Columbia University research showing that normal conditions in Texas by 2080 will be equivalent to those of the most recent drought. "That's (the normal conditions) not drought; that's just the average."

McCarl said most climate models are projecting more extreme weather worldwide — more droughts, more floods, perhaps a higher frequency of hurricanes — with more severity.

"There have been some arguments made, although it's not really settled, that El Niño and La Niña events would become more frequent, and more severe, so that would mean more frequent and more severe droughts in Texas," McCarl said.

Future scene for Texas agriculture

A hotter Texas will change the agricultural industry and land use, McCarl said.

There will be more evaporation from reservoirs and less soil moisture, he said. "So even if it rains the same amount, agriculture production will suffer because of the drying soil moisture," he said.

McCarl predicted a hotter Texas will see a conversion of crop land into grassland — as much as a 25 percent decrease in crop acreage — as well as a decline in livestock numbers. Studies show that livestock appetites will be depressed and there will be lower calving rates and higher incidents of various diseases as well as longer feeding periods to get the animal to an equivalent weight.

As typical of many boat ramps during drought, a boat ramp in 2012 reflects the lower water levels in Cypress Creek. Photo courtesy of the Lower Colorado River Authority.

McCarl has also analyzed crop yields and crop yield variability in a changing climate. "We showed substantially more variable crop yields due to the fluctuating weather conditions, and for most crops, we show lower crop yields."

McCarl said the state will need to figure out ways to adapt.

To maintain the past rate of yield growth, he said, the state would have to substantially increase its research investments.

"We need to make crops that can grow with less water, change our crop mix away from heavily water dependent crops, use water more efficiently and perhaps manage water a little better, so we would have lower evaporation losses and bigger supplies."

Preparing for future conditions

Considering these predictions of a hotter, drier Texas that still sees extreme, flood-inducing rainfall events, what can the state do to manage resources and prepare for these extremes?

After the 1950s drought, Texas began tackling drought solutions by initiating a state water plan specifically to address water needs in times of drought. In the newly released 2017 plan, the 10th such plan, there are more than 5,500 water management strategies, which, if implemented, would provide 8.5 million acre-feet of additional water supplies per year by 2070.

On the heels of the driest year in the state in 2011, the Texas Legislature in 2013 passed and voters approved, the State Water Implementation Fund for Texas (SWIFT) program. Managed by TWDB, SWIFT provides state financial assistance for the water management strategies in the state water plan.

More recently, there has been more attention on possible solutions for flood preparedness and management.

For example, researchers at Rice University, UT at Arlington and the University of Texas in Austin all developed more sophisticated flood alert systems to help alleviate damage or loss of lives. In addition, Texas A&M AgriLife Research scientists in Temple developed a flood alert system for Fort Hood and the city of Belton.

In November 2015, Gov. Greg Abbott transferred $6.8 million from the state's Disaster Contingency Account to TWDB for development of better and more stream gauges and more technical assistance ⇨

and outreach for floodplain management and planning. The board also developed Texasflood.org to provide flood information and resources to the public.

"Hopefully, the actions taken will pay off in terms of less damage or less life lost the next time we have extreme flooding," Nielsen-Gammon said.

Dr. Robert Mace, TWDB's deputy executive administrator for water science and conservation, said Texas does plan for both ends of the weather spectrum. "On the water planning side, we plan for a very severe drought. And then on the flooding side, we're also planning for severe floods. Does that mean there aren't going to be worse droughts than the drought of record? Or worse floods than the 100-year flood? No," he said. "But, given that we are planning for those edges, it helps make us better prepared."

For Mace the biggest issue is the complacency that happens between droughts and between floods. "People think that, 'Oh, we just had a major five-year drought; that was a fluke. We won't have one of those again for a while,' and they get complacent," he said. "But, almost assuredly we will."

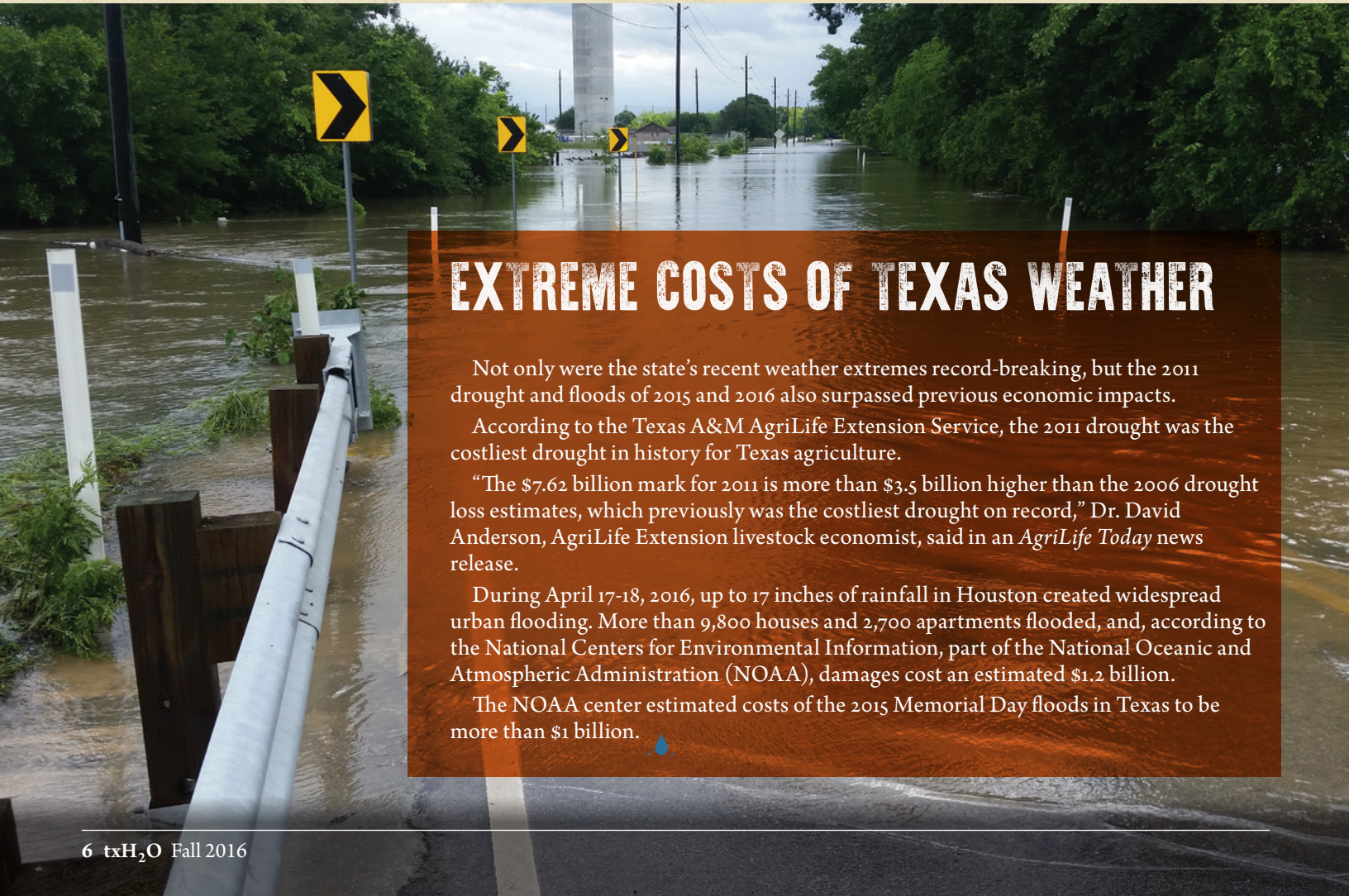
The same complacency happens about floods, he said, with people thinking, "that was a once in a 100- or 500-year flood, so we'll never have to worry about that again.

"In actuality, the statistics show that you will see that happen again," Mace said. "So, the important part is to help people be prepared for those extreme events."

The challenge to responding to Texas' weather extremes, Nielsen-Gammon said, is that people must think outside the box.

"People often say the army is always preparing to fight the previous war rather than the next war," he said. "Weather extremes are sort of the same way. We react to weather extremes when they happen. But it's difficult to prepare for them, because we haven't yet experienced the future extremes that will happen.

The truly extreme weather, the things that only happen maybe every 50 or 100 years, that's beyond most people's memory; they haven't been able to see what the weather can do."



Flooding in Cypress, Texas, near Houston on April 20, 2016. Photo by Tom Pistillo, U.S. Geological Survey.

EXTREME COSTS OF TEXAS WEATHER

Not only were the state's recent weather extremes record-breaking, but the 2011 drought and floods of 2015 and 2016 also surpassed previous economic impacts.

According to the Texas A&M AgriLife Extension Service, the 2011 drought was the costliest drought in history for Texas agriculture.

"The $7.62 billion mark for 2011 is more than $3.5 billion higher than the 2006 drought loss estimates, which previously was the costliest drought on record," Dr. David Anderson, AgriLife Extension livestock economist, said in an *AgriLife Today* news release.

During April 17-18, 2016, up to 17 inches of rainfall in Houston created widespread urban flooding. More than 9,800 houses and 2,700 apartments flooded, and, according to the National Centers for Environmental Information, part of the National Oceanic and Atmospheric Administration (NOAA), damages cost an estimated $1.2 billion.

The NOAA center estimated costs of the 2015 Memorial Day floods in Texas to be more than $1 billion.

Story by Leslie Lee

Do you live in Flash Flood Alley?

Experts explain the Central Texas phenomenon and what residents should know

For many Texans, the Hill Country is not just a region but a way of life: beautiful vistas of rocky hillsides, small towns with live music and quaint festivals, and, of course, hot summer days spent diving into spring-fed swimming holes or floating down iconic rivers.

Those same rivers can tell another story about the Hill Country, however. Those rivers run through Flash Flood Alley, one of the most flood-prone regions on the continent. Following the curve of the Balcones Escarpment through Texas' middle — from Waco south to Uvalde — Flash Flood Alley's weather and landscape distinctively work together to produce rapid flood events.

A unique phenomenon

Major flash floods are common along the Balcones Escarpment because of two factors prevalent in the region, according to experts: intense rainfall events and efficient drainage off the landscape.

"The region has some of the highest flood discharge per unit area of a drainage basin in the country," said Dr. Richard Earl, professor in Texas State University's Department of Geography. Earl, who joined the department in 1991, has studied flooding hazards for decades and has experienced numerous floods in San Marcos.

High rainfall intensities are common in the region because there's an infinite source of moist air from the Gulf of Mexico, he said.

Over Texas, these moist, warm air masses from the Gulf collide with cool air masses from the north and moisture flow from the Pacific, said Dr. Nelun Fernando, hydrologist at the Texas Water ⇨

The Memorial Day flood of 2015 left widespread damage along the Blanco River in Wimberley. Photo by Paul Jordan.

Development Board (TWDB). When warm and cool air masses combine, it results in instability as the warm air rises above the cool air. Additionally, the Balcones Escarpment's hilly terrain acts as a "ramp" for the fronts and "enhances what was already taking place between the two air masses," she said.

"The rising air condenses and that creates rainfall," Fernando said. "That effect gets concentrated over the Balcones Escarpment, and if very slow-moving frontal systems come through, such as what happened with the 2015 Memorial Day storms, then this constant stream of moisture from the Gulf will produce many inches of rainfall over a short period."

This is called an orographic effect, where a change in elevation causes moisture-laden winds to deflect upwards and cool, resulting in rainfall, said Dr. Robert Mace, TWDB deputy executive administrator for water science and conservation.

"The transition between the Gulf Coastal Plain and the Hill Country is recognized nationally as a place where topographic changes cause these intense, localized floods," he said.

"In 1921, just on the other side of Austin, 39 inches fell in 24 hours," Earl said. "In 1935, 22 inches in less than three hours fell near Uvalde. And, in the 1998 flood, one station had 19 inches in 24 hours and a number of stations had 16-18 inches in 24 hours."

Combined with its propensity for intense rainfall, the region's rocky topography makes it flood-prone.

"The Hill Country is karst terrain, so it's limestone that tends to erode in beautiful ways, but along with that beauty you get thin soils, hard surfaces and steep hills, and that all serves to funnel rainfall very quickly into restricted valleys," Mace said.

This property was damaged in Wimberley after the 2015 Memorial Day flood. Photo by Chase Fountain, Texas Parks and Wildlife Department.

Such terrain is created by the Balcones Fault zone, expressed on the surface by the Balcones Escarpment, which "goes through the heart of Texas," Mace said. Along the escarpment and in areas just north and west of it, almost the entire landscape is sloped.

"It is fluvially dissected, which means that when it rains, the water doesn't sit there — it runs off into the streams," Earl said. "That's hydrologically efficient drainage. When it rains, it just rushes into the streams and you get really intense increases in the amount of flow in the stream."

Clay-rich soil types in the region are another contributing factor because once they are wet, clay soils have low infiltration and high runoff.

"And, much of the rural landscape is overgrazed," Earl said. "Combine that with the fact that there's increased impervious cover around cities and suburban areas — all of these things work together, almost in perfect combination to result in extreme floods."

A tragic history

Unfortunately, this unique hydrology in Flash Flood Alley has produced a tragic history of flooding events.

A tropical storm resulted in extreme rainfall in South Texas beginning Sept. 8, 1921, and a wave 12 feet deep flooded downtown San Antonio Sept. 9, killing 51 people. Heavy rains continued, and 38.2 inches of rainfall were recorded from the morning of Sept. 9 to the morning of Sept. 10 in Thrall, northeast of Austin, while 87 people drowned in nearby Taylor.

On Aug. 2, 1978, 27 people died in the Hill Country during flooding caused by Tropical Storm Amelia, when the Guadalupe River at Comfort crested at 40.90 feet, flowing 240,000 cubic feet per second (cfs).

The Shoal Creek Flood on May 24, 1981, was caused by a slow-moving storm directly over Austin; 13 people drowned.

Another terribly perfect storm of conditions led to the Blanco River rapidly rising and raging out of its banks on the Memorial Day weekend in 2015, producing floods that killed 11 people near Wimberley.

May 2015's record-setting rains had saturated soils throughout the Hill Country; so when rain began falling Saturday, May 24, most of it ran off, and the Blanco River began to swell.

According to the National Weather Service, at 9 p.m. Saturday the Blanco River at Wimberley was at 5 feet. By 1 a.m. the river was rushing through at 40.3 feet, destroying bridges, homes and lives. The previous record was 33.3 feet.

"The Balcones Escarpment just happens to be at the headwaters of the Blanco, where the landscape has very thin soil and exposed bedrock, so all of that rainfall just goes down the watershed very rapidly," Fernando said.

"Something that is just mind-boggling is that the discharge at Wimberley during the May 24 storm was more than a fourth of the discharge flow of the Mississippi River at New Orleans, which is about 600,000 (cfs)," Earl said. "And the Blanco's drainage basin is only 355 square miles, whereas the Mississippi drains almost half of the United States."

How to plan ahead in Flash Flood Alley

Such tragedies highlight the importance of residents actively monitoring conditions, just as the region's long history of flooding catastrophes demonstrates a need for continued improvements in flood planning and management, the experts said. Residents and decision-makers alike can help mitigate future disasters.

In 2015, Gov. Greg Abbott transferred $6.8 million to TWDB from the Disaster Contingency Account to provide additional technical assistance and outreach for floodplain management and planning and to develop a high-tech network of stream gauges. As part of that $6.8 million, TWDB issued a $2 million request for communities to apply for grants to implement early warning systems or develop flood response measures.

The governor's funding initiative has also paid for additional stream gauges installed throughout Central Texas in the past year, including on the Blanco.

Residents are increasingly signing up for flash flood warnings and emergency notifications to be sent to their cell phones, sometimes referred to as "reverse 911," which is one positive effect of recent floods, Earl said.

"Those changes are sort of the good news," Earl said. "The bad news is that the local decision-makers have been reluctant to say no to developers."

Various scientific definitions affect how municipalities' city planning officials balance development with flood safety.

Floodplain designations are affected by 100-year storm rainfall levels, and floodplains are a major part of city planning. For Federal Emergency Management Agency (FEMA) flood insurance purposes, official FEMA maps define 100-year ⇨

floodplains, also known as areas that have a 1-percent chance of flooding in any given year.

For planning purposes, cities sometimes define their own floodplains. "Cities might choose to plan for a new 100-year floodplain that isn't yet accepted by FEMA or plan for greater floodplains," Mace said.

"Many cities around here use 10-11 inches in 24 hours as the '100-year storm,'" Earl said. "However, a climatologist in the department and I did a study after the 2002 flood, and we concluded that the 100-year storm or 1-percent probability storm should be defined as more like 12-13 inches. What that means is you have to make floodplains bigger, and therefore that's less land that can be developed."

Integrating retention and detention ponds into developments, using floodplains for green space or parks that will hold and spread out water during floods, and limiting impervious cover are some planning strategies that can reduce flooding.

Building developments in floodplains on top of man-made taller pads or foundations might appear to be a flooding solution, Earl said, but this practice can actually cause flooding to be worse in adjacent neighborhoods and areas.

San Marcos, Austin and many other cities in the Interstate-35 corridor are facing the need to balance rapid population growth with sustainable development. For the last three years, San Marcos was the fastest growing city in the United States.

"I would recommend that, first, areas that have been previously flooded should not have new development," Earl said. "And second, there should be floodplain noticing requirements for both owner-occupied and rental properties. Presently, I do not believe that property owners are required to notify renters that they're renting a place in a floodplain."

Mace urged Flash Flood Alley residents to get educated about local flooding risks, sign up for automated weather warnings sent to cell phones, consider purchasing a National Weather Service radio and read about flood preparation on texasflood.org, a site TWDB developed in 2016 with state funds.

"We have a saying here: 'everybody lives in a floodplain,'" he said. "Even local circumstances can cause flooding. There's always a chance."

Cypress trees and homes were badly damaged along the Blanco River in Wimberley after the 2015 Memorial Day flood. Photo by Paul Jordan.

Story by Leslie Lee

HOW TO DEAL WITH EXTREMES

When Texas weather gets intense, count on these resources for help

FLOODING

1

Drive informed: drivetexas.org
The Texas Department of Transportation provides Texas drivers with the most accurate, up-to-date and real-time road conditions, including roads closed due to floodwaters.

2

Get educated: texasflood.org
Learn what to do before, during and after a flood, thanks to the Texas Water Development Board's website. Texasflood.org can help you determine if you live in a floodplain, learn about flood insurance, learn how to deal with property damage from floods and more.

3

Sign up for alerts: warncentraltexas.org
If you live in Flash Flood Alley, flood alerts can literally be a life-saver. Register at warncentraltexas.org to get emergency warnings for your neighborhood by text, email or phone.

4

Get trustworthy advice: texashelp.tamu.edu
Powered by the Texas A&M AgriLife Extension Service, the Texas Extension Disaster Education Network (EDEN) flood information page has science-based, reliable materials on everything from repairing on-site wastewater treatment systems after floods, to managing mosquitoes and fireants after floods. It also covers livestock preparedness and recovery.

5

Follow these experts:

- Federal Emergency Management Agency Flood information: ready.gov/floods
- Association of State Floodplain Managers: floods.org
- Texas Floodplain Management Association: tfma.org
- U.S. Army Corps of Engineers Institute for Water Resources Flood Risk Management Program: www.iwr.usace.army.mil/Missions/Flood-*Risk-Management/*

Story by Leslie Lee

HOW TO DEAL WITH EXTREMES

When Texas weather gets intense, count on these expert resources for help

DROUGHT

1

Study up: twri.tamu.edu/resources/drought
If you're looking for some Texas drought-related information, chances are the Texas Water Resources Institute (TWRI) can help. The drought resources page is a clearinghouse for agricultural and residential drought help. You can also contact TWRI with further questions at twri@tamu.edu.

2

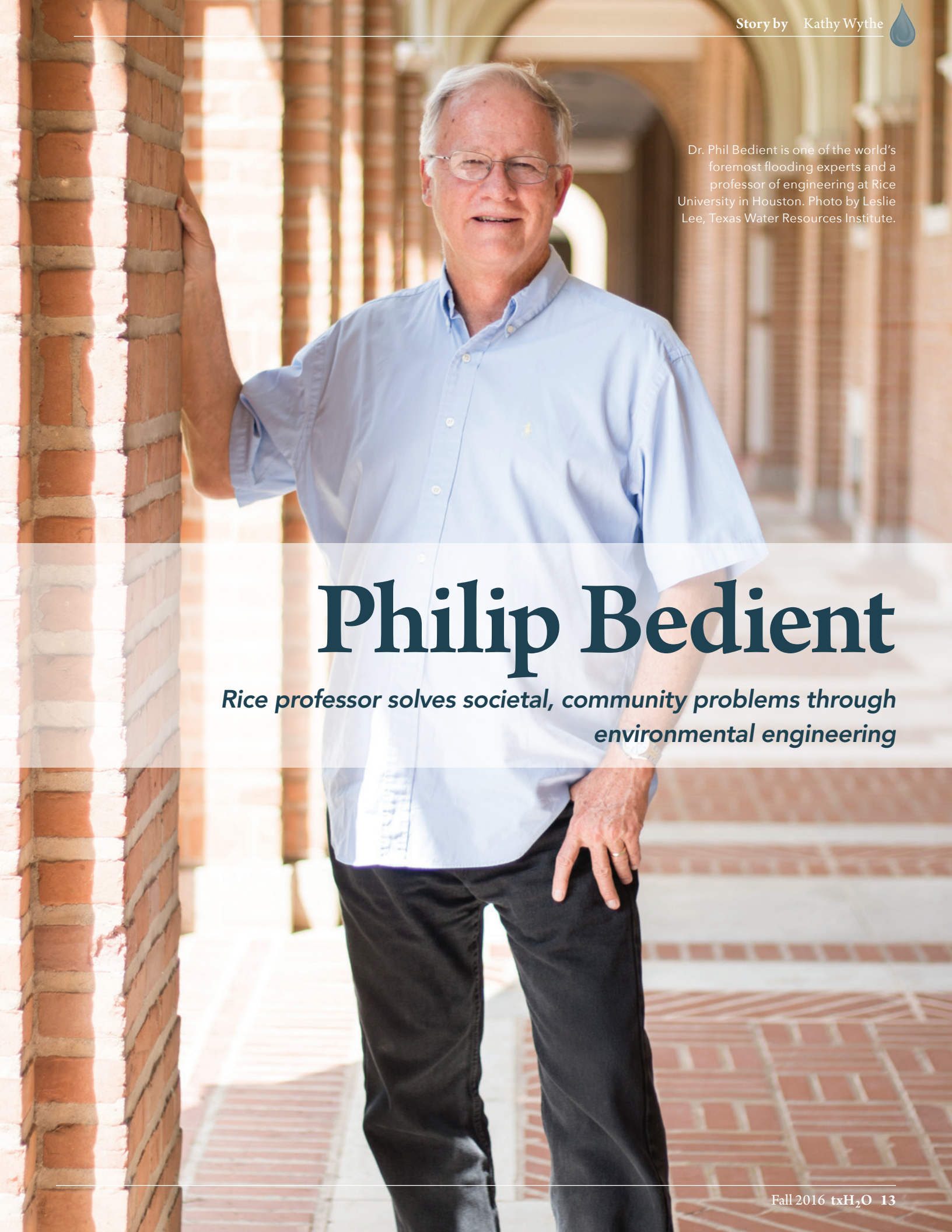
Prepare your landscape: earth-kind.tamu.edu/drought
Keeping residential and commercial landscapes healthy during drought is possible, and Earth-Kind® landscaping resources can help. Developed by the Texas A&M AgriLife Extension Service and Department of Horticulture, Earth-Kind provides materials on irrigating trees, conserving water, using mulch and much more.

3

Keep up with drought data: droughtmonitor.unl.edu
The United States Drought Monitor is a weekly map showing drought occurrence and severity. Follow Texas' map to see how drought conditions in your county change from week to week. The monitor is produced by the National Oceanic and Atmospheric Administration, the U.S. Department of Agriculture and the National Drought Mitigation Center.

Cut out and save these pages for reference in case of extreme weather.

Story by Kathy Wythe



Dr. Phil Bedient is one of the world's foremost flooding experts and a professor of engineering at Rice University in Houston. Photo by Leslie Lee, Texas Water Resources Institute.

Philip Bedient

Rice professor solves societal, community problems through environmental engineering

Dr. Phil Bedient and colleagues developed a flood warning system for the highly urbanized, flood-prone Brays Bayou around the Texas Medical Center. When water gets to certain level in the bayou, the medical center is able to "shut down, like a castle." Photo by Leslie Lee, Texas Water Resources Institute.

In the early 1970s, when the environmental movement was just beginning and the U.S. Environmental Protection Agency (EPA) was newly established, a college student in Florida began studying environmental engineering and water issues. Little did he know that for the next 40 years he would live and work in the "flood mecca of the United States" and eventually be called "one of the world's foremost flooding experts."

Dr. Philip Bedient, Herman Brown professor of engineering in Rice University's Department of Civil and Environmental Engineering, has studied floods throughout the United States, developed a flood alert system for the 1,345-acre Texas Medical Center in Houston and organized a multiuniversity center focused on severe storms along the Gulf Coast. He also co-authored one of the top-selling textbooks on hydrology and floodplains.

Initially interested in the space program, he received his undergraduate degree in physics from the University of Florida. But after the 1969 manned moon landing, future space program funds and jobs became limited, so Bedient, who had been exposed to hurricanes and flooding growing up in Florida, switched to environmental engineering.

He received his masters and doctorate in environmental engineering from Florida. While there, he met his mentor, Dr. Wayne Huber, one of the main authors of EPA's Storm Water Management Model. "We joined forces and started studying rivers in Florida, and I never looked back," Bedient said.

In 1975, Bedient accepted a position at Rice, unaware of the water and flooding issues of his newly adopted state.

"As I was leaving Florida to come to Texas, I went into Wayne's office and said, 'I am really worried about going to Texas because Florida has so many wonderful water problems. I am worried there won't be any water problems in Texas,'" he said, breaking into a huge laugh.

He found plenty of water problems in Texas and more than plenty in the Houston-Galveston area.

Four decades of flood-related research

Bedient has built a career of teaching and research focused on surface water and groundwater hydrology, flood prediction and warning systems, and water quality assessments.

Upon arriving at Rice, he initially worked on water quality and stormwater studies for The Woodlands, a master-planned community north of Houston.

"It was a wonderful place to learn as a young professor," Bedient said. "There was a lot of field work and a lot of computer modeling going on at the same time."

During the 1990s, Bedient collaborated with colleagues from Rice and the University of Oklahoma to develop a flood warning system using radar rainfall for the highly urbanized, flood-prone area around the Texas Medical Center. The Flood Alert System (flood-alert.org) is an integrated system using radar, rain gauge information, bayou stage data and hydrologic modeling to predict the overall threat of out-of-bank flooding of the nearby bayou. National Weather Service (NWS) radar data gives the system rainfall information every five minutes for every 1-square-kilometer area within the Brays Bayou Watershed.

After Hurricane Ike in 2008 devastated Galveston Island, Dr. Phil Bedient determined to study the impacts of Ike and do everything possible engineering-wise to prevent similar future devastation. Photos courtesy of Texas Parks and Wildlife Department.

"It's like having hundreds of rain gauges, so it's very accurate," Bedient said.

After Tropical Storm Allison flooded Houston in 2001, Bedient and his colleagues were funded by the Federal Emergency Management Agency to improve the alert system. The system is now in its third iteration and has also been adapted for use in other locations, including the Houston suburb of Sugar Land and by the Texas Department of Transportation.

"We predicted the 2015 Memorial Day flood more accurately and more closely than any other flood that we have worked on," he said. "We absolutely nailed it."

Solving problems through engineering

Bedient said he enjoys environmental engineering because it uses engineering to solve major societal and community problems.

"Floods and disasters bring a lot of data from which we are able to try to come up with better plans, better schemes and engineering solutions," he said. "You are working on infrastructure problems that people need to have solved."

One of the most devastating disasters to ever hit the United States and the New Orleans area in particular — Hurricane Katrina in 2005 — motivated Bedient even more to pursue his passion for solving engineering problems affecting society. The destructive storm caused more than $150 billion in damages and more than 1,800 deaths.

A month after Katrina, Bedient traveled to New Orleans.

"I never saw such devastation on Planet Earth — ever," he said. "You would drive 15 miles and not see a single house with any windows. It was unbelievable devastation. I got a real taste of severe hurricane surge damage and what it can really do to an entire community, and I brought those memories back to Houston."

Those memories led Bedient to organize a multiuniversity research and education center focused on severe storms and their impacts on the Gulf Coast.

Bedient recalled a meeting in which experts from universities along the Texas-Louisiana Gulf Coast were together discussing post-Katrina strategies. It was at this meeting that he realized the group of 15 experts should establish a research center. After approval by the Texas Legislature and the Governor, the Severe Storm Prediction, Education and Evacuation from Disasters (SSPEED) Center was launched in 2007. A small training grant from the state allowed the center to organize and host a conference.

Then the next one hits

A year after the SSPEED Center's launch, Hurricane Ike hit, causing an estimated $33 billion in damages in the U.S., with $29 billion Texas. More than an estimated 112 people died with 28 deaths in Harris County and 17 in Galveston County.

"Just like Tropical Storm Allison in 2001, Hurricane Ike in 2008 changed my life for the next decade," Bedient said. He determined to study the impacts of Ike and do everything possible engineering-wise to prevent similar future devastation. ⇨

With the SSPEED team assembled, he went to the Houston Endowment with a $1.6 million proposal in early 2009, a little more than three months after Ike. The endowment funded the center and has continued that funding, which now totals $8 million through 2017.

The center is now composed of active university researchers from Rice, the University of Houston, the University of Texas, Texas A&M University, Texas A&M at Galveston and Louisiana State University.

Bedient, who serves as the center's director, said its early mission was focused on learning from Hurricane Ike; its first product was a book published by the Texas A&M University Press, Lessons Learned from Hurricane Ike. Later the center became focused on mitigation strategies and plans on how to protect this vulnerable region, especially the Houston Ship Channel, from impacts of severe storms.

A regional surge protection system

One of Bedient's proudest and perhaps most rigorous endeavors is gaining steam, and he is most optimistic that it will succeed, while acknowledging it may take years to complete.

The SSPEED Center has been working to develop a regional surge protection system for the Galveston Bay area, the industrial complex along the Houston Ship Channel and the preservation of the barrier islands, which include Galveston Island and Bolivar Peninsula.

Its Houston-Galveston Area Protection System Phasing Plan recommends protection components that would be implemented in phases.

Phase I would provide the most protection for the least cost and includes a mid-bay storm surge gate across the Houston Ship Channel, in-bay containment berms along the east and west sides of the Houston Ship Channel, a Galveston levee, other small sand dunes and raising Highway 87 and Farm-to-Market 3005 to a 10-to-17-foot elevation.

Phase II includes building gates in the lower part of Galveston Bay and raising the Texas City levee.

Bedient said the team believes that some of the components can be built with state and local funding for about $3 billion, with some built as soon as within five years. But the proposed lower bay gates that would stretch across the 10,000-foot wide Bolivar Roads inlet will need to be a federal project, with a $5-6 billion price tag.

"Protecting the Houston Ship Channel is extremely important," Bedient said. "If we get a direct hit to the Houston Ship Channel, such as a 20- to 25-foot storm surge, you are looking at anywhere from $60 to $100 billion in damages and a major impact to the national economy with the ship channel down."

Bedient now leverages his years of research and experience to advocate for the protection plan by meeting with decision-makers, city and state leaders, industry professionals, Port of Houston authorities and others.

"We have done our job as researchers; now it is someone else's turn at the state or federal level to step in and begin to take this seriously. If we just sit and wait until the next big one, that is very fool hardy."

While he doesn't enjoy the hot Houston summers and vacations in Colorado or Florida when he can, Bedient said he is glad he decided to change from physics to environmental engineering and leave his native state for Texas and Rice.

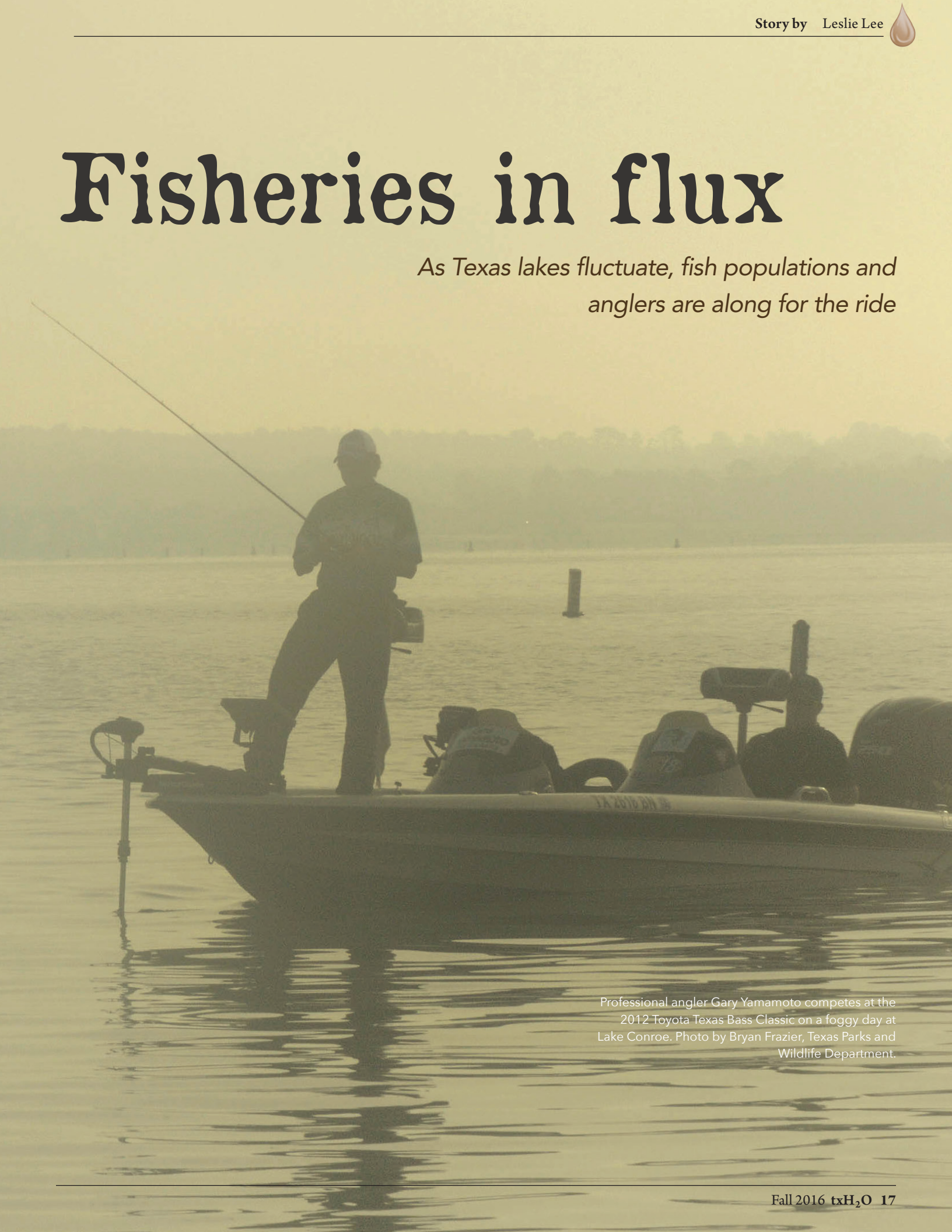
"What makes environmental engineering an interesting study for me is it combines the physics and the complex fluids with impact to society and impact to community. So it's a wonderful sort of area in which to learn and to make predictions with real-time forecasting.

We try to help folks, and try to save lives. It's a very rewarding field."

Story by Leslie Lee

Fisheries in flux

As Texas lakes fluctuate, fish populations and anglers are along for the ride



Professional angler Gary Yamamoto competes at the 2012 Toyota Texas Bass Classic on a foggy day at Lake Conroe. Photo by Bryan Frazier, Texas Parks and Wildlife Department.

Lake Fork is one of Texas' most famous bass fishing destinations. Every year the East Texas reservoir hosts multiple professional tournaments and draws recreational fishing crowds most every spring and fall weekend.

When the Sabine River Authority created the lake in the early 1980s, standing timber was left in place on much of the flooded land, creating ideal fish habitat. In the three decades since, of the 50 biggest largemouth bass ever caught and recorded in the state, 33 were caught at Lake Fork — including the five biggest.

Texas Parks and Wildlife Department (TPWD) fisheries biologist Kevin Storey has helped maintain Lake Fork's fishing reputation for 17 years. Through every season and change, he watched the lake's water levels stay as steady as could be.

"Drought is not a pattern we're accustomed to seeing in East Texas," said Storey, who serves as inland fisheries management supervisor for TPWD's Tyler North District.

Lake Fork's conservation pool level is 403 feet above mean sea level, and since it filled in 1985, it has never been more than 8 feet low, according to U.S. Geological Survey data.

For a frame of reference for how widely other Texas lakes fluctuate — Lake Travis near Austin was at least 50 feet below its conservation pool level from 2011 to 2015. But with heavy rains in May and June 2015, it rose significantly, to only 10 feet below its conservation pool. In June 2016, it reached its flood pool stage and then remained full into the beginning of fall.

"Because of our higher rainfall amounts, we normally assume Lake Fork will remain stable and stay within 2 feet of its conservation pool," Storey said. "I've been in this job for a while now, and I can remember when I first started, if the lake was 2 feet low, anglers thought the world was going to end."

But when the intense statewide drought of 2011 set in, Storey saw the lake drop to 395.4 feet for the first time. It would remain more than 3 feet low until spring 2015.

How droughts affect fish

As a lake goes down, recreational users have to deal with a shrinking lake, but changing water levels can also change fish behavior. It is self-evident that when a lake lowers, there's a smaller pool of water for the fish to share, but less obvious effects also take place.

Competition between predators and prey can change as the amount of structures where fish can hide or hunt from changes. Largemouth bass and many other species use vegetation or other types of cover to hide behind while hunting prey.

"If you don't have either aquatic vegetation or structures in that deep water for habitat, then the predatory fish will be forced to adapt to a new environment without adequate ambush sites," said Steven Bardin, fisheries biologist and owner-operator of Texas Pro Lake Management. Bardin received his master's degree from the Texas A&M University Department of Wildlife and Fisheries Sciences in 2011.

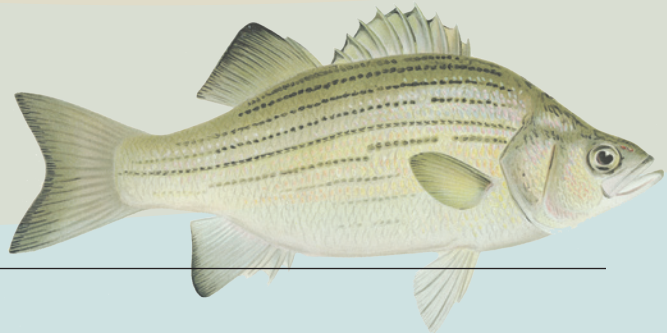
"If that happens, then the predators have to change how they feed and what they're eating; if they are not able to adapt long-term, they may not survive," he said.

Toward the end of the most recent drought, Bardin observed that fish populations in many clients' ponds were clearly down. In a smaller amount of water and with less habitat, predatory fish had been able to consume many of the forage species and young fish.

Drought recovery leads to fisheries recovery

Although droughts do create smaller and less-productive lakes, low-rainfall periods can provide an opportunity for near-shoreline habitat to improve, said Dave Terre, TPWD chief of inland fisheries management and research.

Fish illustrations by iStock.com



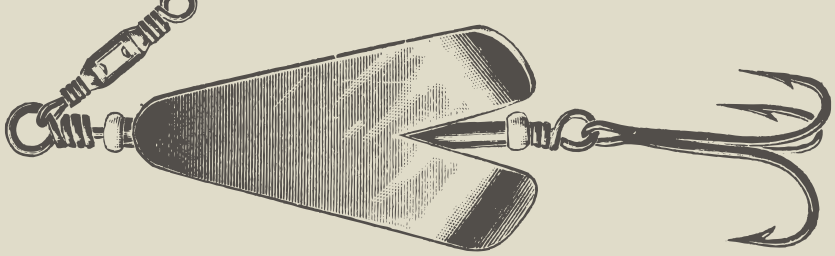


Illustration by RetroVectors.com

"Picture this: say a lake goes down a couple feet every year for a long time — 10 or 15 years, getting down to 50-feet low," he said. "What's occurring during that time is growth of terrestrial plants around the reservoir.

"And then, if a hurricane system pulls up into the region or a flash flood occurs, all of a sudden the lake catches a lot of water, comes up 20 or 30 feet, then the lake inundates all that plant growth. Now you have a 'new lake' situation — all those plants and terrestrial growth, around the lake, all of that becomes habitat for fish."

And a 'new lake,' is a very, very good thing for anglers.

"It creates a huge boom in the fishing," Terre said. "It creates a boom in not only habitat but also in the forage species base — the fish that bass depend on for food sources."

Lake Fork has benefited from this phenomenon in 2015 and 2016. After decades of being perennially stable, the lake's low levels from 2011 to 2015 allowed terrestrial plants to grow on the shoreline and exposed sediment for the first time in its history.

Once the rains came and the lake rose back up, the fish population numbers quickly reflected the increased amount of aquatic vegetation and water. Aquatic plant cover allows fish to reproduce more often, survive at higher rates and grow faster.

"This spring we saw significant increases in the bass and sunfish numbers," Storey said. "There are more places for the fish to be and hide. We saw real increases in abundance in our samples, and other lakes around the state saw this as well."

TPWD staff at Lake Fork use electrofishing to sample fish and estimate population data. In electrofishing, fish are immobilized temporarily by electric currents entered into the water, and then surveyors in a boat count and record the fish that float to the surface. Bardin saw high reproductive rates in his clients' fisheries this spring and summer, according to his data also gathered by analyzing electrofishing surveys.

"Many lakes filled up quickly, and all of a sudden we saw second and third reproduction — fish spawning multiple times," he said. "There's all this flooded terrestrial habitat, and the offspring survive really well."

Lunkers lag behind

Although fish populations can recover in a few months after lakes fill back up, occurrences of trophy bass catches don't necessarily correlate, the experts said.

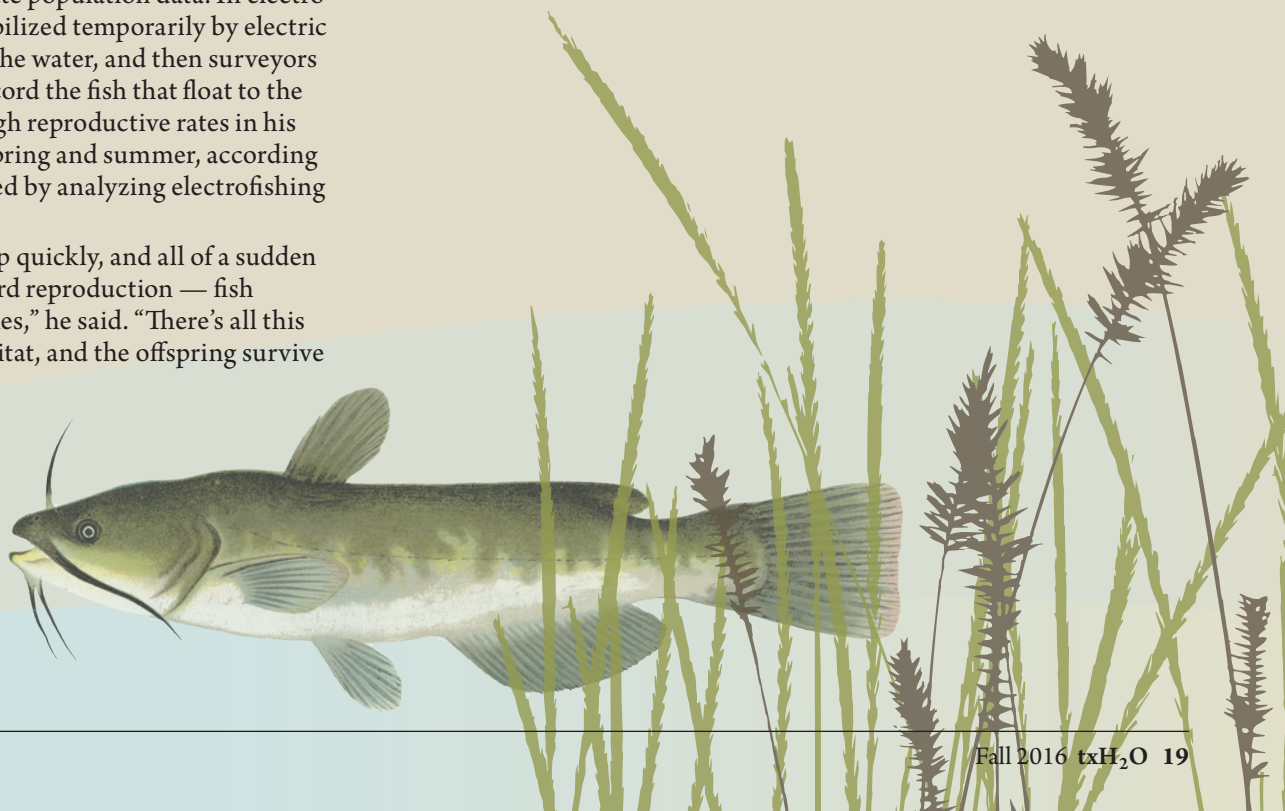
"Your chances of catching a trophy bass can sometimes actually be greater when a lake is low," Terre said. "When a lake recedes, generally there's less cover in the lake, which initially means that the catchable fish in a lake become concentrated under a smaller amount of cover, making them more accessible."

But, that good news doesn't last.

"Long term, dropping lake levels are not good for fish or for anglers, because survival and recruitment goes down, and therefore the supply of future trophy fish is smaller," Terre said. "Our Sharelunker Program has seen a down year the last couple of years, which doesn't surprise me. That's an effect of the prolonged drought we've now come out of."

TPWD's Sharelunker Program, currently sponsored by Toyota, encourages anglers who have caught largemouth bass that weigh 13 pounds or more to lend or donate the fish to TPWD for spawning purposes. The program is housed at the Texas Freshwater Fisheries Center in Athens.

Since 1986, at least one Sharelunker fish, and usually multiples of them, has been caught at Lake Fork. But so far in 2016, no such fish has been pulled from the lake. ⇨



"Soon, but maybe as long as a couple of years from now, I think we'll see things ramp up again statewide with Sharelunker catches," Terre said.

How lakes weather ups and downs

Statewide, TPWD uses three main fisheries management tools: enforcing regulations, stocking fish from the states' five fish hatcheries and enhancing habitat, Terre said.

Fishing harvest regulations limit the size and number of fish that can be kept by anglers and serve to protect populations.

"We use those strategies all the time — in drought and in high water," he said. "We want to make sure we have good adult populations of fish in our reservoirs, and then when the timing is right and the lakes come up, we'll have adult fish populations there and they'll spawn."

TPWD actively assesses and works to improve fish habitat in many lakes.

"Most reservoirs in Texas were built in the 1950s and 1960s, so some of those reservoirs' habitats are now degrading," Terre said. "So, we are working on technologies to improve aquatic habitat in some of our aging reservoir systems."

Bardin said management techniques he uses in his clients' lakes and ponds include "everything from fish stocking to vegetation control to electrofishing, lake mapping, habitat restoration or setting up a fish feeding program.

"There is constant cause and effect in pond management — you have to be very aware of everything that you do," Bardin said.

Periodic draw-downs can actually be an effective fisheries management tool. Pumping down a pond can help manage vegetation or manipulate a fish population, he said. The important part is to make sure it's filled back up within a few months.

When ponds are down or in construction, Bardin plants aquatic vegetation, uses natural materials such as rocks or large logs, and installs artificial structures in ponds to ensure fish habitat and ambush cover during future droughts.

It is also critical that landowners prepare for floods, Bardin said.

"I had one client in Comanche County whose lake breached its dam this spring; so in a matter of hours, it went from a full lake to an empty lake," he said. "On the extreme side, if you're not prepared, floods can cause you to lose everything and start over. You must have the proper spillway or drainage pipe installed on the pond to be fully prepared."

Whether it's keeping a close eye on dam erosion or drought conditions, small fisheries require greater attention to detail than large water bodies, Bardin said.

"One of my favorite parts about private waters is that they are small; most of the time these fisheries are 100 acres or less," he said. "So, the smaller they are, the bigger difference small changes can make."

For a very small pond, even something as minor as which direction a landowner mows their grass can matter. If the grass clippings go into the water body, an algae bloom can result, Bardin said.

Another major concern to monitor for when floods rapidly fill a lake or pond is the possibility of it "turning over," which usually results in a fish kill, Bardin said.

"Fish kills are caused by changes in oxygen content, turbidity, pH and other water quality parameters," he said.

Especially if the lake is stratified, meaning the warm and cool water are separated, too much water flushing into the water body at one time can cause a turnover. Luckily this year's heavy rains came in early spring when waters were still cool, and Bardin observed few fish kills.

Monitoring pH and oxygen is a best management practice for pond owners, but especially when water levels go down and there is less water per fish. An aerator located at the bottom of the pond is an effective solution for this, he said. It creates more oxygen, makes more of the water column usable and prevents stratification.

"The good news is this spring I didn't have a lot of clients with breached dams or fish kills; instead we saw a lot of lakes' fish populations rebound very quickly," he said.

Decreased access hampers fishing

Another key to managing recreational fishing in drought-prone Texas lakes is maintaining their access points.

Preserving quality shoreline access is key for private ponds and lakes, and that involves thinking ahead about erosion and sedimentation risks. Especially in West Texas, where draw-downs are

Illustration by RetroVectors.com

In February 2012, the National Park Service, Texas Parks and Wildlife Department and Del Rio Home Depot worked together to place a fish attractor made of Christmas trees into Amistad Reservoir. Photo by Larry D. Hodge, Texas Parks and Wildlife Department.

inevitable, Bardin recommends that landowners consider shoreline stability early and often.

"As that lake drops, how are we going to make sure that we don't get erosion and sedimentation from soil that is now exposed?" he said.

When constructing a new pond in West Texas or other drought-prone areas, Bardin preemptively stabilizes the soil using ground cover, such as rock or other erosion prevention products well into the middle of the planned pond, even though that soil will sometimes be below 3-4 feet of water.

Terre and his inland fisheries colleagues usually focus on managing fish populations, but in 2011 their focus expanded to lake access.

"In 2011, about 25 percent of our Texas reservoirs were without public boat ramps because of the drought," he said. "A lot of our reservoirs in the state had dropped to a point at which ramps were high and dry, out of the water. So, when anglers can't even get their boats out on the water — that opened up our eyes here at TPWD."

Future water demands, future droughts and effects of climate change could all make lake fluctuations more frequent in Texas. To prepare for that, TPWD is working with the river authorities and other partners managing lakes to enhance boat ramps and access points so that they will still function in low-water conditions.

"Looking down the road, we will have more droughts, so we are going to be proactive about lake access," Terre said.

More than just a lake

One reason proactive lake management is important to the state is its huge economic impact. Freshwater sportfishing's total annual economic impact on Texas was estimated at about $3 billion in 2008. And, TPWD records show that the sales of fishing licenses and taxes on fishing-related items generate millions of dollars for conservation work.

When fisheries are managed well and can quickly recover from droughts once rains return, local economies benefit.

"We've got data on the economics of a fishery before and after one of these flood events," Terre said. "The economic value of the fishery just tripled, it was amazing. Direct expenditures by anglers just went through the roof."

He said it is important for Texans to know the economic impacts of recreational activities such as fishing and boating. TPWD studies show that Lake Fork alone generates in excess of $25 million a year for the local economy.

"Our fish populations were thriving this spring and summer," Terre said. "Unfortunately, the Texas Parks and Wildlife Department does not control rainfall or water releases in Texas. But, what we can do is collect information on how water level changes do impact fish populations, how important those changes are to recreation and how economically valuable recreation is."

During the spring of 2016, Somerville Lake's shoreline rose to unprecedented levels, closing its gates to recreational users and visitors. Photo by Tommy Snow, Texas Parks and Wildlife Department.

Story by Eva Vigh

RISING TO THE CHALLENGE

Somerville Lake reaches historic levels, prevents downstream flood damages

Weeks after record floods, Somerville Lake still sat at its flood pool storage level. Photo by Eva Vigh, Texas Water Resources Institute.

If Russell Meier had not been a U.S. Army Corps of Engineers natural resource specialist, he might have been more worried about the rising flood waters at Somerville Lake during the 2016 Memorial Day weekend. For days, the weather across southeast and Central Texas had gone from bad to worse, with severe storms bringing huge amounts of rain to the regions.

Inside his office, Meier calmly watched the rain pour down. He knew Somerville Lake could take the floods.

The storms hit northwest of Brenham, Texas, just before the weekend. Somerville Lake's shoreline nearly disappeared as water levels continued to climb. Park benches and tables were completely submerged. By May 29, the lake had not only risen past its total water storage capacity but also shattered the previous record level set in March 1992.

Encompassing nearly 18 square miles, Somerville Lake, built and operated by the Corps Fort Worth District since 1967, is a reservoir in the Brazos River Basin designed to provide flood control as well as water for downstream communities, lake recreation, fisheries and wildlife.

While the lake reached record levels in May 2016, it also prevented major flood damage in nearby Burleson and Washington counties.

"If the water is too high, the lake is designed to hold that water back to prevent further flooding downstream," Meier said.

The reservoir is built to hold a specific amount of water in its conservation pool and also have the additional capacity to hold a certain amount of floodwater. Its conservation pool water level is 238 feet above mean sea level, and its flood pool storage level is between 238 and 258 feet.

Without the lake's flood storage, nearby communities would be more susceptible to flooding from Yegua Creek or the Brazos River, Meier said. If water levels reach more than 258 feet, water is released through an uncontrolled spillway and the lake is considered to be in flood status.

"Think of a 5-gallon bucket," said Stanford, a Corps hydraulic engineer. "When Somerville is at the top of its conservation pool, the bucket is about 30 percent full. When it's at the top of its flood pool, the bucket is completely full. Once it gets completely full, it starts to spill over the bucket. That's what's happening with the uncontrolled spillway."

Except during times of extreme rain, the flood storage pool is usually empty, Stanford said.

However, the May rainstorms were nothing short of extreme.

Flooding at Somerville Lake, in May 2016 (left photo), and in spring 2015 (right photos), when the lake's water level also went over the spillway crest. Photos by Russell Meier, U.S. Army Corps of Engineers, and Tommy Snow, Texas Parks and Wildlife Department.

From May 14 to June 5, 14.5 inches of rainfall accumulated over the drainage basin that flows into Somerville Lake, he said. On May 27 alone, rainfall measured 6.3 inches.

"On May 29, when the lake reached peak flood storage, at 113 percent of its flood storage capacity, the flood water stored was 393,000 acre-feet," Stanford said. "To put that in perspective, that's enough to cover a 614-square-mile area 1-foot deep, which is about the area of Washington County."

In its nearly 50 years of operation, there have only been two other times the water level went over the spillway crest in an uncontrolled release — March 1992 at 259.61 feet and May 2015 at 258.33 feet. In May 2016 the lake set a pool of record at 259.82 feet.

"It's not an inexhaustible supply of flood storage space because it's not possible to build a lake that would contain every conceivable flood," Stanford said. "So at that point, Somerville has an uncontrolled spillway."

Once the water level drops below the spillway crest, the floodgates can be activated to release more water at a controlled rate.

So, why did Somerville Lake remain flooded for months after reaching those historic levels?

The answer lies downstream. Releasing too much water, too soon, could flood the Yegua and Brazos, and damage nearby communities, Stanford said. The lake must be drained slowly.

The maximum nondamaging release out of Somerville Lake is 2,500 cubic feet per second (cfs); flow rates above that can lead to flooding in Yegua Creek, Meier said. During the 1992 floods, flow rates hit 5,000 cfs. Meier saw those rates nearly double in the recent floods, reaching about 9,400 cfs. Those were large amounts, but they were significantly lower than if the dam had not been there, he said.

"That's why it takes so long to drain the lake," Stanford said. "We could push more water out, but if you push more water out into the downstream and rivers, and then they get local rain, it's that much quicker for them to experience flood damages."

Reflecting on the lake's performance, Meier said Somerville operated according to its design.

"It performed perfectly. We got up to that level, we engaged the uncontrolled spillway and water went out of it. Once we got back down to below that, we were able to open the flood gates and release water that way."

Story by Leslie Lee

Equipping a resilient community

Flood-vulnerable Houston neighborhood collaborates with Texas A&M researchers

Left: Texas A&M graduate student Marccus Hendricks trains Furr High School Green Ambassadors in how to perform infrastructure assessments, in Harrisburg-Manchester. Photo courtesy of RCCCP.

Right: Texas Target Communities helps RCCCP collaborate with residents and students in Harrisburg-Manchester.

The Houston Ship Channel is a huge part of the Texas and national economy. Its 52 miles of winding waterways are lined with industrial terminals and plants, providing an enormous amount of jobs for the region.

Families also live, work and play in neighborhoods along the ship channel.

Southeast of downtown Houston, Harrisburg-Manchester is one such neighborhood. The flood-prone, under-resourced community is bordered by industrial plants, Sims Bayou and the ship channel, with Loop 610 crossing through its center. Its stormwater should drain into the Sims Bayou Watershed, but average rainfall often results in large pools and ponds held in the streets for much of the year.

Flooding threats from multiple causes — sea level rise, inland flooding and coastal flooding — are a reality for much of the region around Houston. But in Harrisburg-Manchester, where the infrastructure already cannot handle even a normal rainfall event, Texas A&M University experts have found these threats to be especially serious.

"The neighborhood faces average flooding on a regular basis, because the stormwater infrastructure just doesn't work well," said Dr. Philip Berke, director of the Institute of Sustainable Coastal Communities, part of the Texas A&M College of Architecture and Texas A&M University at Galveston. "And at just a moderate projection of sea level rise, the neighborhood will be significantly impacted; so what is a small flood now will be even worse in the future. The infrastructure that's already not working there will not be sufficient."

To help Harrisburg-Manchester deal with current environmental risks and prepare for future challenges, Berke and a team of Texas A&M experts from various academic disciplines have helped create a partnership with the community. The Resilience and Climate Change Cooperative Project (RCCCP) is housed under the institute and is a multiyear, interdisciplinary, collaborative research and engagement venture with residents of Harrisburg-Manchester, as well as other neighborhoods and communities in Texas.

RCCCP combines university research, community engagement and service learning opportunities, which involve Texas A&M students in applied-research classes studying and addressing real problems for the neighborhood. About 20 faculty members, 10 graduate students and 30 undergraduate students are working on RCCCP efforts. Berke, RCCCP principal investigator, spoke to *txH2O* on behalf of the many projects, teams and individuals that make up RCCCP.

Berke came to Texas A&M in 2014 specifically for the opportunity to begin a program connecting university research with an under-served community.

"Texas A&M allowed me to do something I'd wanted to do for a very long time," he said.

So far the research has addressed water quality, stormwater infrastructure, reliability of citizen scientist data and more.

The project has been such a success that Texas A&M has made it the university-wide Environmental Grand Challenge, part of the Provost's Grand Challenges program that tackles big societal problems through academic research and outreach.

Listening to locals' experiences

The cooperative began with the guidance of Texas Target Communities (TTC), a program within the architecture college that "has a long history of successfully serving under-served communities," Berke said. "TTC understands that when we're engaging communities where there is distrust, you have to build trust."

A team of Texas A&M experts arranged listening events with community leaders, interest groups and Harrisburg-Manchester residents so that their concerns, personal experiences, observations and informal data could inform the research moving forward. These events also create a line of communication for research results to be better implemented, Berke said.

"We could do technical analysis and research, and then just throw that data over the fence, or we can work with them, listen to the issues and try to match the science and research that we do to serve the real issues."

At least eight research projects resulted from the initial meetings with the community in the spring of 2015; the partnership flourished and the RCCCP team at Texas A&M grew, Berke said. For the last two years the team has met every other week over lunch to continue collaborating on the projects and updating each other on ongoing work.

The RCCCP team is made up of faculty and graduate students from Texas A&M's Department of Landscape Architecture and Urban Planning, Department of Civil Engineering, Department of Geography, School of Public Health, Department of Sociology and the Bush School of Government and Public Service, as well as the Department of Sociology at Louisiana State University.

The team collaborates with TTC, as well as the organization Texas Environmental Justice Advisory Services (TEJAS), which was founded in Harrisburg-Manchester, is still officed there and now does statewide advocacy. The TEJAS groups' experience and relationships in Harrisburg-Manchester made it possible for RCCCP to begin to build relationships with the community, Berke said. He said that TEJAS deserves much of the credit for the cooperative's success.

"We didn't just walk into the neighborhood," he said. "We're doing science, but we're also delivering the science in a way that is framed based on how the community defines their needs and concerns."

Equipping students with science

A key part of RCCCP's community-led work has been collaborating with a group of Furr High School students who have been incredibly helpful to the community, Berke said. He credited much of RCCCP's collaborative success to the leadership and teachers at Furr, which is part of the Houston Independent School District. RCCCP has worked with the Green Institute at Furr, which includes the Green Ambassador Woodsy Owl Conservation Corps, sponsored by the U.S. Forest Service.

"The Green Ambassadors are 30 amazing students," he said. "These students are really the core of the participatory-based research in the neighborhood. They have participated with locating and identifying pooled water locations, applied and tested an infrastructure assessment tool, and assisted in collecting health and perceptions data by administering door-to-door surveys."

Funded by a National Science Foundation (NSF) grant, a RCCCP team recently began working with the Green Ambassadors to use cell phone applications to measure and track infrastructure and water quality issues in the neighborhood, building on previous infrastructure assessment efforts by Furr students. ⇨

Ponding and pooling are types of flooding that aren't always tracked by official agencies, so this data could better equip local authorities in addressing Harrisburg-Manchester's infrastructure needs, he said.

"Our group from civil engineering, public health and urban planning is running this project to test the validity of the data that's being collected on local infrastructure in the neighborhood against expert-driven data collection, which is much more expensive," Berke said.

The NSF-funded project will run for three years, and it has already included trips to Texas A&M for the students to experience university life for themselves, Berke said. David Salazar, one of Furr's science teachers, is so invested in RCCCP's work that he recently began graduate school in Texas A&M's Department of Landscape Architecture and Urban Planning.

"He is a great role model for the neighborhood, and we hope to continue recruiting undergraduate and graduate students from there," Berke said.

Examining water quality

RCCCP scientists initially collected water quality data in Harrisburg-Manchester.

"The reason our team chose to study surface water quality there was that the residents mentioned the flooding issues, and they were worried about polluted water and effects of being in contact with it," Berke said.

Air quality and water quality were both frequently discussed at the community meetings RCCCP held as well as in a door-to-door public health survey the RCCCP researchers conducted, he said.

RCCCP's surface water quality study was conducted by faculty and graduate student researchers in the School of Public Health. They began by splitting the neighborhood into 30 zones and then taking one surface water sample in each zone, Berke said. The samples were tested for arsenic, barium, chromium, lead and mercury, along with other heavy metals.

"Our researchers found that a few of the samples had very elevated levels of arsenic, barium, chromium, lead and mercury," he said.

Barium, which is used in many refinery processes and products, was found in every zone.

"Worrisomely high" lead levels were found in standing water about two blocks away from Harrisburg-Manchester's main park, Berke said. The study's findings have recently been published in a public health journal.

An upcoming RCCCP study will examine drinking-water quality in the neighborhood.

The causes of environmental vulnerability in Harrisburg-Manchester are multifaceted, he said.

"There's poor water quality and poor air quality," he said. "They have stressed relationships with nearby industry. The infrastructure is poor. The neighborhood has very narrow streets, but huge industrial 18-wheelers are driving through all the time."

Facing long-term risks, together

Although the individual research projects will be completed in a few years, the RCCCP team is committed to engaging and serving in Harrisburg-Manchester long-term.

"A key core principle that we're going to follow is: we're sticking with these neighborhoods for the long haul," Berke said. "And we'll begin working with other under-served neighborhoods to continue this work, including the Sunnyside neighborhood."

One reason this committed approach is important is that the flooding and infrastructure problems are projected to only get worse.

In the Sims Bayou Watershed, 26,180 people live in the 100-year floodplain. According to RCCCP data, if moderate projections of sea level rise happen, the watershed's floodplain would then include 35,354 people, and that's not even accounting for likely population growth.

Moving forward, RCCCP is going to continue building its team's research capacity, while helping Harrisburg-Manchester's residents build theirs. This includes educating the community on local flooding and its causes, including development and increased impervious surfaces in the Sims Bayou Watershed.

According to RCCCP research, development was shown to grow by 10 percent from 1980 to 2000, which led to increases in streamflow within Sims Bayou and a 15 percent larger flooding area.

Educating local and regional decision-makers on these approaching risks as well as the current insufficiencies in the neighborhood's infrastructure is one area of work RCCCP will continue to expand, Berke said. They want to inform policymakers about the challenges facing Harrisburg-Manchester's residents.

"Someone has to look at the broader policies affecting these people," he said. "They need to account for them. They have been under-served for decades."

Story by Eva Vigh

Breaking barriers

Restoration project returns tidal flow and aquatic life to marsh

Old timers say Magic Ridge Marsh in Magnolia Beach, Texas, used to be a great fishing spot. But for the past 50 years, it's gotten harder and harder to land a bite.

The saltwater marsh covers roughly 14 square miles, stretching from Magnolia Beach to Indianola in Calhoun County, and had been steadily degrading for years, experts said. Although the wetlands were historically connected to Matagorda Bay, blocked tidal flow at several points in the channel network caused large vegetative and ecosystem losses over time.

To restore tidal flow to the marsh complex, Dr. Rusty Feagin, coastal scientist in Texas A&M University's Department of Ecosystem Science and Management, led work to remove the two primary barriers blocking the inlets.

The Texas A&M AgriLife Research Magnolia Beach to Indianola Marsh Restoration project, which began June 2013 and ended this year, was funded by a Texas Coastal Management Program grant and a Coastal Erosion Planning and Response Act grant from the Texas General Land Office, as well as a Hydrological Restoration grant from the National Oceanic and Atmospheric Administration and the Gulf of Mexico Sea Grant consortium. In 2016, it earned the state's highest environmental honor, a Texas Environmental Excellence Award, from the Texas Commission on Environmental Quality.

Feagin and his team of AgriLife researchers determined both the northern, bigger inlet, which flows into west Matagorda Bay, and the southern, smaller inlet — the "back door" — were blocked by manmade barriers.

The barriers were remnants of berms and roads built by immigrants who landed on Magnolia Beach and migrated to Central Texas in the early 1800s, Feagin said. As they headed toward the Hill Country in their covered wagons, they built structures using shell hash, or tiny pieces of shells, to cross the marsh.

The additional buildup of oysters growing and dying on the structures further obstructed the inlets, and the barriers acted like small dams, he said, preventing water from flowing into the marsh. During the hot, dry months of summer, evaporation would increase and water levels would drop below the berms. As the water evaporated, salinity levels rose.

"The water leaves, but the salt stays, and it just gets more and more salty," Feagin said. "Even if you bring more tidal water in and you block it up again, over time you're just making it hypersaline."

The team measured salinity levels of 160 parts per thousand (ppt) in some areas of the marsh, compared to Matagorda Bay's 15 to 40 ppt levels.

"Some spots were more salty than the ocean," he said. "But it should have been half the ocean strength."

A fishing pole reflects that, after years of clogged channels, fish are following the tide back to Magic Ridge Marsh. Photo by Dr. Rusty Feagin, Texas A&M University Department of Ecosystem Science and Management.

The Texas A&M AgriLife Research team did extensive post-restoration testing to determine the project's success. Results confirmed salinity levels had significantly gone down. Photo by Dr. Rusty Feagin, Texas A&M University Department of Ecosystem Science and Management.

More than just physical barriers

Years of blocked channels and stagnant, salty waters caused the marsh to degrade. Vegetation and aquatic organisms died, in part because of decreased oxygen levels and poor water quality, he said. Even when fish weren't turning up dead in big kills, the once lucrative fishing habitat suffered. The community looked on as redfish, sea grass and other species disappeared.

"Everyone had been seeing this place go downhill," Feagin said. "All the marshes were disappearing, and it was just turning into open water."

After years of watching the land vanish and not acting to protect the marsh, the community was able to come together and address the marsh's issues with the Texas A&M team's help.

"Maybe they just didn't want to talk, or they didn't want to cross particular social barriers within the community, but we could step in and say 'you need to do this,'" he said. "They saw us as a third party that wouldn't have conflicting interests. We could put the pieces together to best serve everybody."

Return of the tide

With the community's support and guidance, the research team got to work. Working with several stakeholders, including private landowners and county officials, the team began groundwork to remove the two barriers. It first used a large backhoe to excavate the southern barrier and reopen the small flow into nearby canals and creeks. It was, as Feagin described it, like opening a small pet door and letting fresh air into a stagnant house.

Although water — and with it, aquatic life — immediately poured through the inlet, the flow was a trickle compared to what the salty marsh needed.

"You could see fish running through the channel, and tons of birds came as well. So it was doing something," he said. "But when we really looked at all our salinity, water quality and vegetation measurements, we didn't see a lot of change."

It became clear the other barrier had to be removed to restore the marsh completely, Feagin said. In several days, the team dug out the northern barrier and dumped the sediment on the shoreline of a nearby lake, creating a submerged breakwater. This "artificial reef" will help protect the lakeshore from eroding and provide habitat for oysters, he said.

More than 100 truckloads later, the northern barrier was gone, the inlet was opened and tidal flows returned. The marsh was reborn.

Successful restoration

When Feagin stood at the marsh's edge and gazed out at the landscape two days after removing the barrier, he was stunned at the transformation.

"Immediately you could see the water flowing," he said. "It was really shocking because this place I had seen for a couple years, the water was always at the same level. But now that we took that barrier out, water could get out."

The return of the water brought new plant growth and animals, including marsh grass and red fish.

Because marsh grass grows at the waterline, Feagin said as the marsh tide goes out further with the increased water, plant growth is already expanding and covering quite a bit more land.

"Now that the waterline is out, the grass is migrating out, and we are gaining a ton of marsh," he said. "We'll get back a lot of the marsh we lost in the last 50 years."

Post-restoration water quality samples are indicative of success as well.

"We have water level gauges all over the marsh in different places, and salinity has dropped," Feagin said. "Our water level data confirms what you see with your eyes."

To test further its restoration efforts, the team drove along the marsh shoreline, rolled down its vehicle's windows and asked the fishermen if they were getting any bites — but the answer was already obvious. Feagin said he could see the anglers, backs to the sun, filleting dozens and dozens of red fish.

The project's success helped set the standard for future restoration projects, Feagin said. Simply removing the barriers, rather than attempting to build more marshland, was a very economical approach, he said. "Now the Texas General Land Office wants to fund hydrological restoration-type projects, as they're so cost effective."

Although the project is completed, Feagin said future testing could be done to assess the long-term results and success of the restoration efforts.

"You find a place that is dying or dead, go to one spot on that landscape and do something relatively simple, and you can fix the whole thing. So that's what we did."

Story by Kathy Wythe

85th TEXAS LEGISLATURE

Committees discuss water issues as they prepare for next session

Photo by Leslie Lee, Texas Water Resources Institute.

Are you curious what water topics will be discussed, debated and voted on during the upcoming 85th Texas legislative session? While it is still early, the following information will help you stay current on legislative activities.

Facts about the upcoming session:

- The 85th Texas legislative session begins Jan. 10, 2017, and ends May 29, 2017.
- Bill pre-filing begins Nov. 14, 2016, and March 10, 2017, is the deadline for filing bills and joint resolutions other than local bills, emergency appropriations and bills that have been declared an emergency by the governor.

Interim charges related to water

In between sessions, interim charges are issued to both House and Senate legislative committees. The committees hold meetings during the interim, hearing testimony and receiving written testimony about the issues the committees are studying. Before the session begins, each committee will issue a report about its findings and recommendations. Those reports will be on the Legislative Reference Library of Texas website: www.lrl.state.tx.us/committees/lrlhome.cfm.

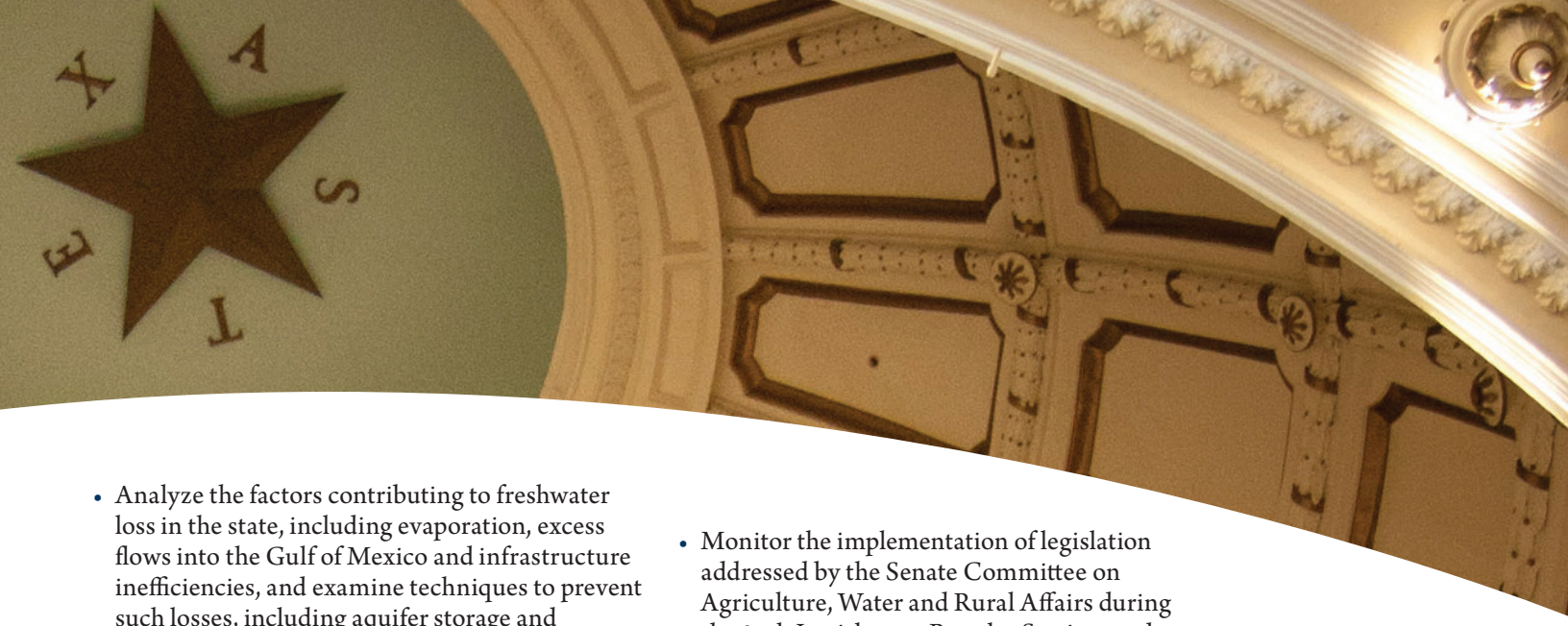
In November 2015, House of Representatives Speaker Joe Straus issued numerous charges to various House committees. A few of the water-related charges are listed by committee.

House Committee on Agriculture and Livestock

- Evaluate policy challenges to the state's agriculture and livestock industry, including long-term impacts of price declines in oil and natural gas; the availability of natural resources, including water, necessary to operate the industries; and the mitigation of and preparation for potential future hazards to the industries caused by natural disaster, drought or disease.
- Determine the sources of water used by Texans in the production of food and fiber, and examine current water delivery methods and water conservation goals for agricultural use. Evaluate whether there are more efficient and effective water-usage management practices that could be employed in the agricultural industry, and determine the impact of crop insurance requirements on producers (Joint charge with the House Committee on Natural Resources).

House Committee on Natural Resources

- Examine the regional and state water planning processes, with emphasis on the following:
  - the integration of HB 4 (83R);
  - the appropriate role of the state in ensuring that the process both supports regional goals and priorities and the water needs of the state as a whole, and how the state might encourage strategies to benefit multiple regions;
  - the structure and operation of the regional planning groups;
  - the interaction between the planning process and groundwater management;
  - whether the "drought of record" remains the appropriate benchmark for planning; and
  - any impediments to meeting the conservation, agricultural and rural project goals set by HB 4 (83R), and possible new approaches to help meet these goals.
- Evaluate the status of water markets in Texas and the potential benefits and challenges of expanded markets for water. Include an evaluation of greater interconnections between water systems through both engineered and natural infrastructure. Examine opportunities for incentives from areas receiving water supplies to areas providing those supplies that could benefit each area and the state as a whole.



- Analyze the factors contributing to freshwater loss in the state, including evaporation, excess flows into the Gulf of Mexico and infrastructure inefficiencies, and examine techniques to prevent such losses, including aquifer storage and recovery, off-channel storage and infrastructure enhancements.
- Evaluate the progress of seawater desalination projects near the Texas coast as a means of increasing water supplies and reducing strain on existing supplies, building on the work of the Joint Interim Committee to Study Water Desalination (83rd session). Examine the viability of the use of public-private partnerships and of methods by which the state might facilitate such a project.
- Evaluate the status of legislation to encourage joint groundwater planning, including HB 200 (84R), and monitor ongoing legal developments concerning ownership and access to groundwater and the impact of these developments on property rights and groundwater management.
- Determine if sufficient safety standards exist to protect groundwater contamination from disposal and injection wells (Joint charge with the House Committee on Energy Resources).

The House's interim charges are available in full at: www.house.state.tx.us/_media/pdf/interim-charges-84th.pdf.

The House Committee on Agriculture and Livestock, the House Committee on Natural Resources and other committees' video/audio broadcasts are available at: http://www.house.state.tx.us/video-audio/committee-broadcasts/.

Lt. Gov. Dan Patrick issued charges in October 2015 to the Senate Committee on Agricultural, Water and Rural Affairs on water-related issues:

Senate Committee on Agriculture, Water and Rural Affairs

- Study and make recommendations regarding the ownership, production and transfer of surface water and groundwater in the state of Texas.
- Study and make recommendations on improving the process of developing and executing the State Water Plan.
- Monitor the implementation of legislation addressed by the Senate Committee on Agriculture, Water and Rural Affairs during the 84th Legislature, Regular Session, and make recommendations for any legislation needed to improve, enhance and/or complete implementation. Specifically monitor the Texas Water Development Board's process in the identification and designation of brackish groundwater zones.

The Senate's interim charges concerning water are available at: http://www.senate.state.tx.us/assets/pdf/Senate_Interim_Charges_84_pt1.pdf.

Video/audio recordings of the committee's meetings are available at: http://www.senate.state.tx.us/75r/senate/commit/c505/c505.htm.

Useful websites

- Texas Legislature Online: www.legis.state.tx.us/.
- Legislative Reference Library of Texas: www.lrl.state.tx.us/.

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