BETTER TECH FOR TOMORROW

THE FUTURE OF WATER IN TEXAS

WRITTEN BY
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February 2025

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KEY POINTS

- **Texas needs to substantially** increase water supply to meet the drought and economic growth challenges of the coming decades.
- **Delivering needed water** supplies for Texas is expensive, but the cost of insufficient action is much greater.
- **Although the state will continue** to be the major source of financing, innovative financing options—especially public-private partnerships—should be increasingly used.
- **While new sources of water** must be discovered and moved to ensure continued prosperity, traditional values such as private property rights must also be protected.
- **State, private, and academic institutions** must collaborate to fund and implement research to find and deliver water for municipal and industrial interests.

EXECUTIVE SUMMARY

Water access is critical to a prosperous future for Texas. Water fuels industry, powers next generation technologies, sustains reliable generation of electricity, satisfies thirsty communities, and maintains the natural beauty of the state. But Texas faces serious challenges: multiple droughts, uneven distribution of water resources, and the high cost of securing and delivering water to meet the needs of people and their industries. Texas cannot afford to ignore these challenges in order to maintain the Texas Miracle.

These challenges are already compounding. Consider the following: Texas' population will increase 73% by 2070 to 51.5 million. Over half that population growth will be in the planning regions that include the Dallas-Fort Worth and Houston metropolitan areas. During roughly the same time, water supplies are estimated to decrease by about 18%, mostly due to the depletion of aquifers in the High Plains and the Houston area. Moreover, water use shortages of 3 million acre-ft/yr in 2020 could rise to 6.9 million acre-ft/yr in 2070 in drought of record conditions (Texas Water Development Board, 2021). Inaction is not an option at this stage, and the window of proactive planning to address this mounting crisis is closing.

This paper will provide an overview of Texas' water resources and how the state will need to tackle the challenges of supplying water to meet the needs of its citizens. To ensure that Texas grows and prospers, the state must guarantee that sufficient water is available to sustain the economy during drought, must address the needs of both rural and urban areas, and must preserve the quality of natural resources that makes Texas an attractive place to live and work. Meeting the challenge of supplying water for Texas will require large financial investments by state and private entities, legislative modification and removal of barriers that

discourage cross-regional solutions, and adoption of new technologies that enable access to previously under-utilized water resources to development. Meeting this challenge is one in which Texas must, and will, succeed.

INTRODUCTION

Texans expect water production when they turn on the faucet. They expect fire hydrants to produce water when necessary to put out a fire. The idea that this might not be the case is unthinkable. Some may presume that water scarcity is only experienced in the developing world. Yet the short history of the American West reveals that this is not the case. In Texas, whether it be the safeguarded right to property or just genuine Texan pride, Texans know that water is something to be fought for. Because Texas is a desirable state to live, work, and raise a family, economic prosperity comes with no shortfall of growth of industry epicenters, populus cities, and even local barbecue restaurants.

Some associate water availability with geographic proximity or weather patterns. While this contributes a major role to the current state of water, there are also various social, political, and economic nuances happening below the surface that directly impact Texans. Water management frameworks, infrastructure, and funding tend to have more—if not the most—influence on water abundance and affordability than the actual amount of water available. These issues must be holistically and comprehensively addressed to properly meet our current and future water demands.

While the projected water resources are trending toward rapid depletion, the future can seem bleak, but it is not entirely pessimistic. Texas has virtually the same water resources as it had a century ago. Moreover, the capabilities to monitor watersheds and efficiently locate and generate additional supplies have advanced. Texas' water resources are in considerably greater shape today than in the prior century. Texas history is testament to the resilience of Texans. Accordingly, it is in our interest to draw upon the successes in Texas' ability to overcome challenges and integrate innovative approaches to adequately meet rapid demand growth. Our current local, regional, and state agencies can be utilized to create an efficient bottom-up approach. In addition, improved water sourcing techniques such as desalination, aquifer storage recovery, and produced water technology can help meet current and future needs.

In 2023, the Texas Legislature appropriated $1 billion to address this consequential issue. Through the Texas Water Fund, additional streams of funding were made available in the form of grants, revolving loan funds, and other financing opportunities. This paper offers analysis of the current state of water and discerns potential long-term policy solutions.

THE STATE OF WATER IN TEXAS

Water is essential to support Texas' growing population and its $2.1 trillion economy. In 2021, Texans used an estimated 14.7 million acre-feet[1] of water, divided between groundwater at about 55%, surface water at 42%, and reuse at nearly 3%, see **Figure 1** (TWDB, n.d.-a). The three types of water, surface, groundwater, and reuse water, referenced throughout the paper are defined as follows:

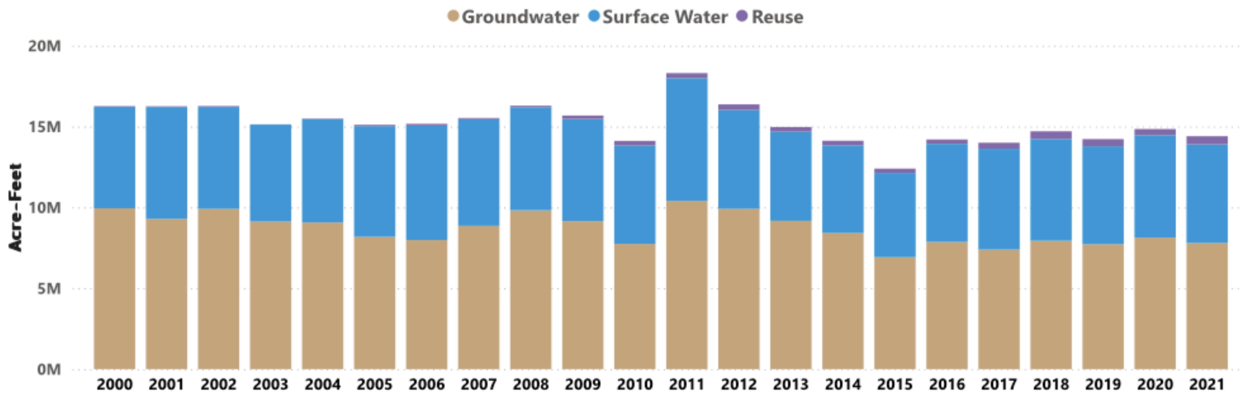
Surface water: Defined by the Texas Water Code Section 11.021 as "water of the ordinary flow, underflow and tides of every flowing river, natural stream, lake, bay, arm of the Gulf of Mexico, and storm water, floodwater or rainwater of every river, natural stream, canyon, ravine, depression, and watershed in the state is the property of the state."

Groundwater: Defined by the Texas Water Code Section 35.002 as "water percolating below the surface of the earth." Groundwater is found below

1 For reference, an acre-foot of water is 325,851 gallons, which is roughly half the volume of an Olympic swimming pool or about enough water to cover a football field to a depth of one foot.

Figure 1

Source of Water Used in Texas, 2000-2021



Note. From Texas Water Development Board, n.d.-f (https://www.twdb.texas.gov/waterplanning/waterusesurvey/dashboard/index.asp).

the surface of all land areas and is usually stored in an underground body of permeable rock, known as aquifers.

Reuse water: Defined by the Texas Administrative Code (TAC), reclaimed water is "domestic or municipal wastewater which has been treated to a quality suitable for beneficial use" (30 Tex. Administrative Code § 210.3). Depending on the desired use of the water, reuse water will be treated and recycled for future use.

As previously noted, the legal and policy aspects of surface water (e.g., rivers, streams, and lakes) and groundwater (e.g., underground aquifers) are critical to understanding how to secure water supplies for the future. Surface water is owned by Texas, while groundwater is owned by landowners and is a property right. These two ownership modes complicate Texas' capacity to balance multiple water needs to maintain secure and sustainable water resources, to promote economic prosperity and growth, to protect private property rights, and to ensure that Texas continues to be a desirable and attractive place to live (French, 2023).

Major water supply policy initiatives have typically followed on the heels of widespread or severe droughts. Thus, these initiatives have been reactive in nature. After the drought of the 1950s (often referred to as the "drought of record") the Texas Legislature in 1957 created the predecessor of the Texas Water Development Board (TWDB), which was the foundation for statewide water planning (Texas Water Development Board, 2012). A flurry of water infrastructure projects—mostly reservoirs—were underway by the late 1950s to address deficiencies in the state's water supply. Forty years later, another major drought prompted the legislature in 1997 to completely revise the water planning process such that citizen stakeholder groups for each of the 16 regional planning groups would now lead the way in developing a "bottom-up" approach to statewide water planning. The water planning process, as we know it today, is still utilizing the regional planning groups. Now, as the state is enjoying economic prosperity and population growth, the historically reactive nature of water planning does not appear to be capable of meeting the needs of the future. A proactive water planning approach—considering accelerated water demands for municipal needs, electric power generation, agricultural demands, and oil and gas development—is necessary if Texas is to ensure a prosperous and water-secure future. This proactive approach should support bold initiatives that include substantial funding for infrastructure, streamlined planning for traditional water sources, as well as innovative water supply projects, regulatory reforms that reflect the realities of regional hydrology and water demands, and protection of private property rights.

CURRENT REGULATORY FRAMEWORK

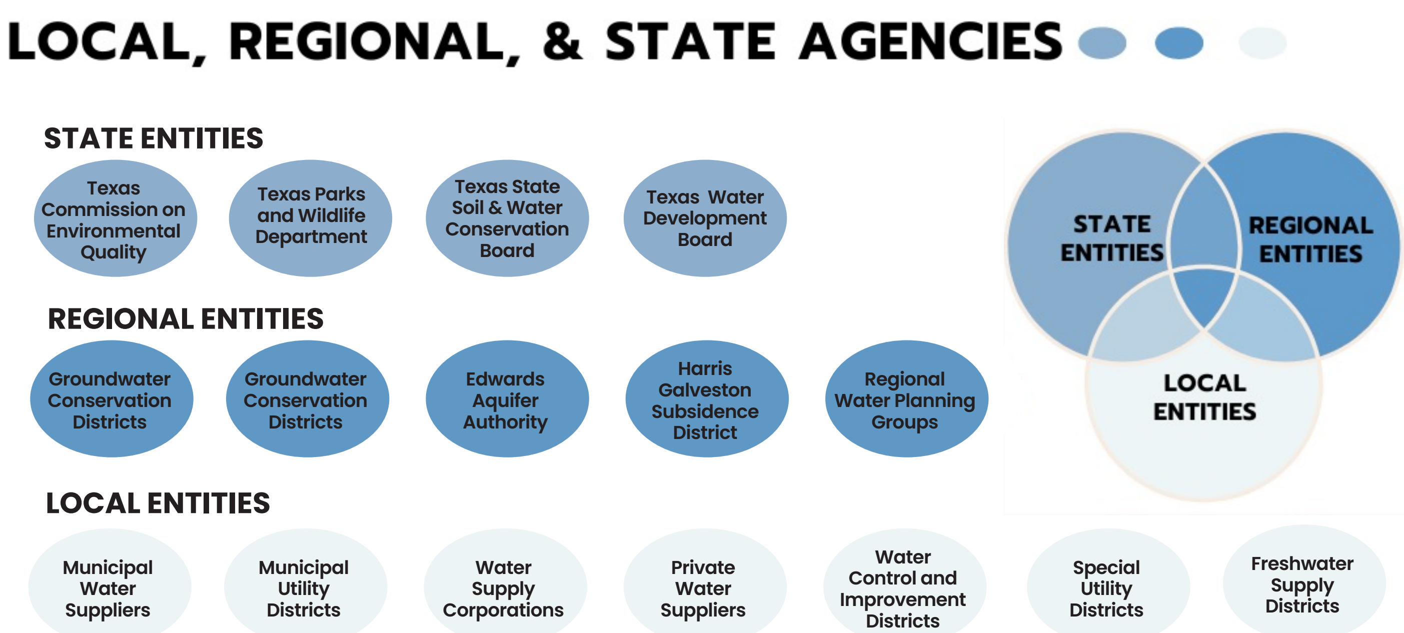
The regulation or management of water in Texas is divided into two separate legal environments: 1) surface water owned by the State of Texas and regulated on a statewide basis, and 2) groundwater owned by the landowner as a private property right and regulated by local or regional entities. The management and regulation of water resources in Texas involves several state agencies and local and regional entities. **Figure 2** illustrates some of the major Texas agencies and local and regional entities that have responsibilities and jurisdiction over water planning and management activities. The major state agencies include the Texas Commission on Environmental Quality (TCEQ) for both surface water and groundwater; the Texas Department of Licensing and Regulation (TDLR) for well construction standards; the TWDB for data collection, planning, and financing of water projects; and a multitude of river authorities and groundwater conservation districts. Other agencies have less direct roles in water supply, such as the Texas Railroad Commission, with its regulation of oil and gas production that generates huge quantities of produced water (about 256,000 acre-feet per year beyond that needed by the oil industry) (Texas Produced Water Consortium, 2022), and the Texas Parks and Wildlife Department (TPWD), through its management of environmental conditions tied to rivers and spring flows . In addition, while not directly involved with management and regulation, many organized interest groups exert influence on policymakers.

Surface Water

The overarching principle for regulating surface water use by the TCEQ is the doctrine of "first in time, first in rights." The TCEQ administers water rights, including issuing new and amended water rights and enforcement of water rights. Surface water availability is evaluated using surface water availability models developed and maintained by TCEQ. These models are used to assist the agency in permitting and compliance matters. The TCEQ is also involved in permitting for water conservation and drought response plans for public water systems.

Figure 2

Texas State Agencies and Local and Regional Entities Involved with Water Planning and Management



The Watermaster Programs within the TCEQ enforce water rights within their respective jurisdictions, and the TCEQ regional offices enforce water rights in all other areas of the state.

About 70% of the surface water rights are held by public river authorities, which then sell water to municipalities, water districts, and industry. When river authorities sell water to farmers or cities, the price is usually based on the costs of moving and treating the water, not competition or market economics. When water is scarce, the authorities often restrict supply to certain groups—just as the Lower Colorado River Authority did in 2012 to cut back water deliveries to agriculture—rather than rely on market pricing and allocation (Federal Reserve Bank of Dallas, 2013).

Furthermore, river authorities are political subdivisions that have the power to conserve, control, and distribute surface water in a designated region. There are more than 20 river authorities in Texas that operate infrastructure such as electricity-generating dams, flood control, and water supply reservoirs. River authorities' jurisdictions range from one to nineteen counties, but the majority cover an entire river basin or large portions of it. River authorities generate their own revenue by charging user fees for selling water, electricity, wastewater treatment, and other services. Customers of river authorities include cities, industry, agricultural users, and individual customers. River authorities are governed by their own enabling legislation, usually designated as a chapter of the Special District Local Laws Code.

The TCEQ also regulates public water supply corporations through reporting and notification requirements and monitoring of drinking water quality. To establish a public water supply system, the operator must work with the TCEQ regarding plans for pumps and pipelines that deliver drinkable water. The operator must submit plans for review to the TCEQ before construction. In addition, the owner or responsible official must provide written notification to the TCEQ of the startup of a new public water supply system or the reactivation of an existing public water supply system. Water quality standards for discharges from wastewater treatment plants are also regulated by the TCEQ.

Water supply and sewer service on a retail level are regulated by the Texas Public Utility Commission (PUC). These service providers must have a "Certificate of Convenience and Necessity" (CCN) as described in the Texas Water Code Chapter 13, Subchapter G and Chapter 24 of the Public Utility Commission Rules. The CCNs provide the exclusive right to serve every consumer within its certified area by providing continuous and adequate service. If conditions are not met, then the CCN may be subject to decertification. In addition, rates that the public water systems charge their customers fall under the authority of the PUC.

The TCEQ also manages activities related to groundwater quality. For example, TCEQ manages the Priority Groundwater Management Area (PGMA) program and produces reports detailing possible concerns with groundwater quality or supply within certain areas. The agency also directly regulates activities that could introduce pollution to the Edwards (Balcones Fault Zone) Aquifer, focusing on protection plans, maps, and rules to protect it. Statewide monitoring and evaluation of pesticide contamination in water is also a function of the TCEQ. The agency also has developed and hosts the Water Well Report Viewer, which includes information on over 800,000 online historical reports on water wells and their characteristics.

The Texas Legislature created several programs to ensure that sufficient surface water is available to meet environmental needs in Texas bays and estuaries. For example, the Texas Instream Flow Program was created in 2001 to determine how much water rivers need to maintain sound ecological environments. Three state agencies—the TCEQ, the TWDB, and the TPWD—administer the program. In addition, the Legislature passed Senate Bill 3 in 2007 to create a process for TCEQ to establish environmental flow standards for major river basins and bays. This basin-specific work is done by a statewide Environmental Flows Advisory Group (EFAG) and the statewide Science Advisory Committee.

Finally, several other state agencies and organizations that are not regulatory can, through their activities, influence and guide the management of surface water. For example, the TWDB conducts technical activities and research projects that feed into regulatory decisions. These efforts include reservoir surveys, coastal estuary studies, and the operation of the TexMesonet, a statewide water real-time monitoring program that collects data on precipitation, groundwater levels, soil moisture, and other parameters related to both flood and drought. Another organization that influences surface water management is the Water Conservation Advisory Council (WCAC), which is charged by the Legislature with researching and recommending actions related to water conservation. The WCAC consists of representatives from various state agencies and other organizations that conduct research and report directly to the Legislature on their activities.

Groundwater

Groundwater belongs to the landowner and is governed by the common law "rule of capture," which grants landowners the right to pump groundwater beneath their property. In the 2012 *Edwards Aquifer Authority v. Day* case, the Texas Supreme Court held that landowners own groundwater "in place" before it is captured, and the regulation of groundwater may be subject to takings. Section 36.002, Texas Water Code, acknowledges private ownership of groundwater but within the context of groundwater conservation districts (see **Figure 3**), which were made possible by the 51st Texas Legislature that passed the Texas Groundwater District Act of 1949. These districts have the authority to create and enforce rules for conserving, protecting, recharging, and preventing waste of groundwater. They develop groundwater management plans, adopt rules to implement them, and issue permits to pump water from wells.

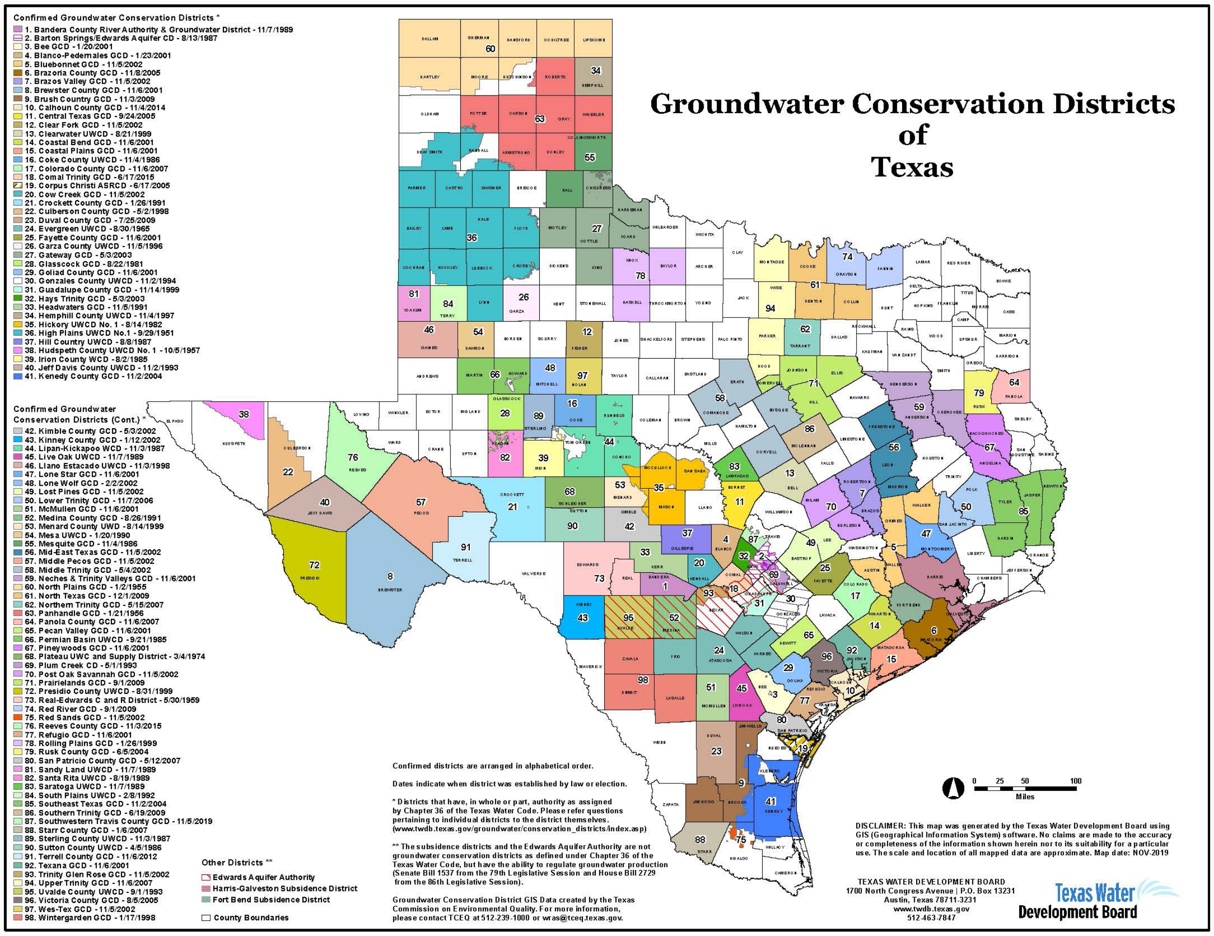
Nearly 100 groundwater conservation districts cover almost 70% of the state and 72% of the state's major and minor aquifers (Texas Water Development Board, n.d.-d). These districts are the "state's preferred method of groundwater management" (Texas Water Code, Section 36.0015(b)). While a foundational principle, the rule of capture can be modified by districts through rules that regulate well spacing, production limits, and other features. Furthermore, governing groundwater management can significantly change through the election of boards with differing perspectives. Wells installed to support the exploration and production of oil and gas are exempt from regulation by groundwater conservation districts. Neighboring districts, even those that share a common, connected aquifer, can also have significantly different policies related to groundwater development. Several neighboring districts in Central Texas had significant groundwater availability policy differences that were discussed during public meetings and documented in explanatory reports submitted for the most recent joint planning process in 2021 (Texas Water Development Board, n.d.-b).

Several districts have been established that differ in scope and function from groundwater conservation districts under the jurisdiction of Chapter 36, Texas Water Code. These include the Edwards Aquifer Authority in and west of the San Antonio area and two subsidence districts in the Houston area.

The Edwards Aquifer (Balcones Fault Zone segment in and west of San Antonio) has been the subject of numerous studies and investigations concerning its role in maintaining a critical environmental habitat due to springflow discharging from the aquifer. After much study and litigation, the Texas Legislature enacted a regulatory plan to limit withdrawals from the Aquifer or else the federal government would oversee the Aquifer under the Endangered Species Act (Eckhardt, n.d.-b). In May 1993, the Texas Legislature created the Edwards Aquifer Authority, giving it the authority to issue permits and regulate groundwater withdrawals from the Edwards.

Figure 3

Map of Groundwater Conservation Districts in Texas



Note. From the Texas Water Development Board, 2019a (https://www.twdb.texas.gov/mapping/doc/maps/GCDs_8x11.pdf).

This action transitioned groundwater management in the Edwards Aquifer from purely rule of capture to the hybrid framework for assigning permanent water rights to historical users (Votteler, 2023). It also created means to market groundwater rights by making permits transferable (with some restrictions), and it set a cap on permits at 450,000 acre-feet annually, reduced to 400,000 acre-feet in 2008. It also required the Authority to adopt a Critical Period Management Plan to reduce pumping during droughts and required the Authority to ensure continuous minimum springflows to protect the habitat of endangered species. However, permitted withdrawals from the aquifer greatly exceeded the scheduled 400,000 acre-feet per year cap so that the Texas Legislature in 2007 raised it to 572,000 acre-feet per year (Votteler, 2023). Stakeholders in the region developed the Edwards Aquifer Habitat Conservation Plan that provides for monitoring and measures to ensure that sufficient springflow is achieved for the protection of sensitive or endangered species that depend on minimum springflow levels.

Furthermore, the Legislature created the Harris-Galveston Subsidence District and the Fort Bend Subsidence District in the Houston area to mitigate continuing land subsidence attributable to groundwater pumping. To accomplish this, the districts regulate the spacing of wells and the production of groundwater. Owners or operators of wells must obtain a permit from the district, which uses a combination of mandatory planning and substantial permit fees to create financial incentives for water users to increase reliance on surface water and decrease groundwater pumping. Most of these areas have or are undergoing a transition of water supply sources from groundwater to surface water.

The Texas Groundwater Protection Committee (TGPC), an advisory, non-regulatory committee of nine state agencies and the Texas Alliance of Groundwater Districts, was created by the Texas Legislature to protect groundwater. The Executive Director of the TCEQ is the chair and the executive administrator of the TWDB is the vice chair. The purpose of the committee is to implement the state's groundwater protection policy which includes the non-degradation of groundwater quality, requires that discharges not harm public health or degrade water use, recognizes aquifer variability, and balances the long-term economic health of the state with the protection of the environment.

Finally, water well drilling and installation standards and practices are regulated by the Texas Department of Licensing and Regulation (TDLR). A license is required to drill a water well and install a pump in that well. Well records and construction details of wells must be included in the TDLR's Submitted Driller's Report Database. This database is hosted by the TWDB and contains water well reports submitted to TDLR dating back to February 2001. Older well records are available on the TCEQ website.

CURRENT STATE OF WATER IN TEXAS

The complexity of water management in Texas is closely tied to its large size and the range of climate and hydrologic conditions in the state. Texas' size introduces many challenges related to the availability and distribution of water resources.

As of 2024, rivers, reservoirs, and aquifers supply water for drinking, farming, and industry to nearly 30 million Texans. The amount of water that Texans use varies from year to year, with variations typically attributable to the overall state of drought or rainfall that affects agricultural (irrigation) demands. The geographic variability of water used is illustrated in **Figure 4**. For example, West Texas and areas along the Gulf Coast rely mostly on groundwater for irrigated agriculture, whereas the large metropolitan areas and East Texas depend more on surface water.

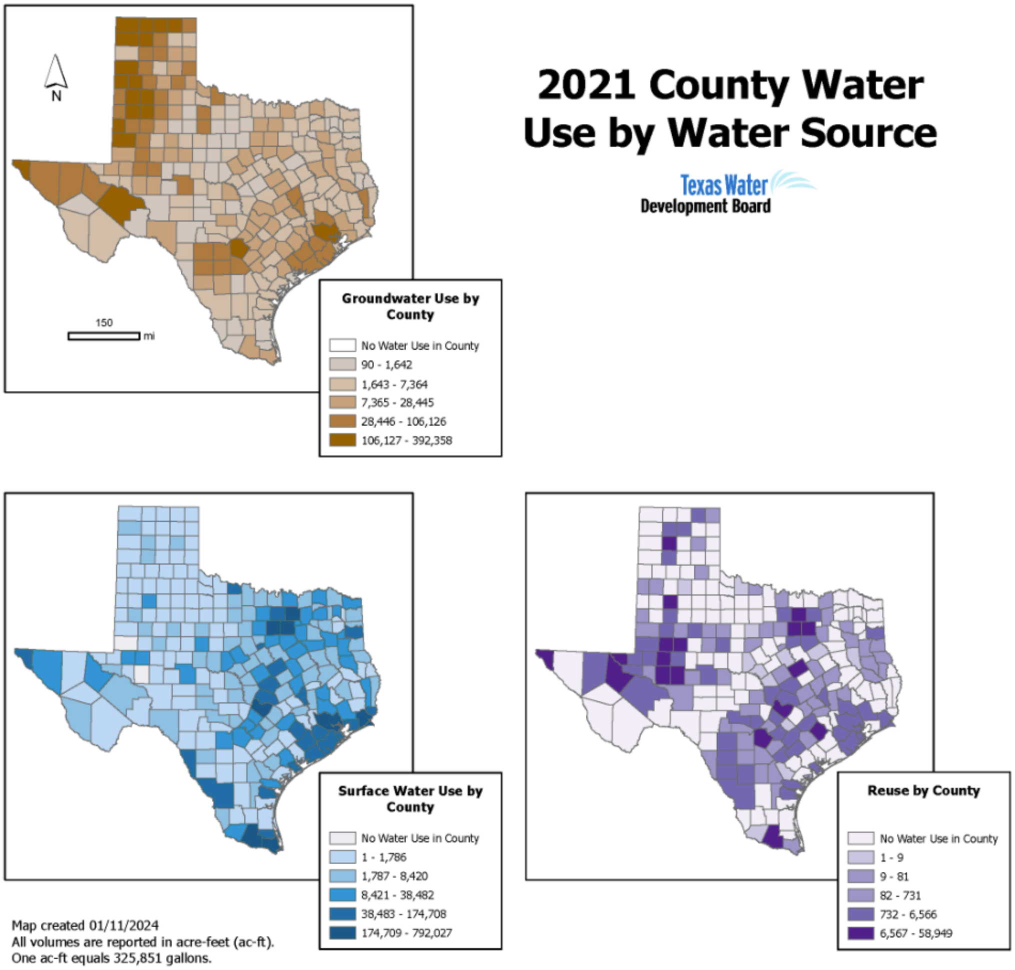
Figure 5 illustrates the historical use of both surface water and groundwater from 2000 to 2021. The overall water use trend is stable to slightly decreasing and does not mirror the 45% increase in population during the same period. These trends may be due to the emphasis on water conservation as well as implementation of various stages of drought restrictions on municipal water use. In addition, the graph for certain years reveals additional aspects of water use in Texas. For example, 2011 was an extremely hot and dry year—referred to as a "flash drought"—that shows a large increase in water usage driven primarily, and not surprisingly, by irrigation usage.

Existing water supplies in the state are projected to decrease from 16.8 million acre-feet in 2020 to 13.8 million acre-feet in 2070 (Texas Water Development Board, 2021). Notably, these projections concern total water supply volume; meaning, in accordance with the projected 9% increase in water demand over the same period, there will be an even greater decrease realized concerning water per capita. This decrease in water supply is primarily attributable to the projected depletion in groundwater supplies in the High Plains and the conversion of water supply from groundwater to surface water in the Houston area.

However, the water picture in Texas is more complicated when viewed regionally. For example, surface water resources are unequally distributed, *i.e.*, abundant in East Texas and scarce in West Texas. In an average year, El Paso receives less than 10 inches of rain, while Beaumont receives nearly 60 inches (see **Figure 6**). Most Texans live in areas that do not experience these precipitation extremes but tend to vacillate between drought and flood, as has been the case in Texas for centuries. Furthermore, aquifers underlie most of the state but vary considerably in their capacity to produce usable fresh water.

Figure 4

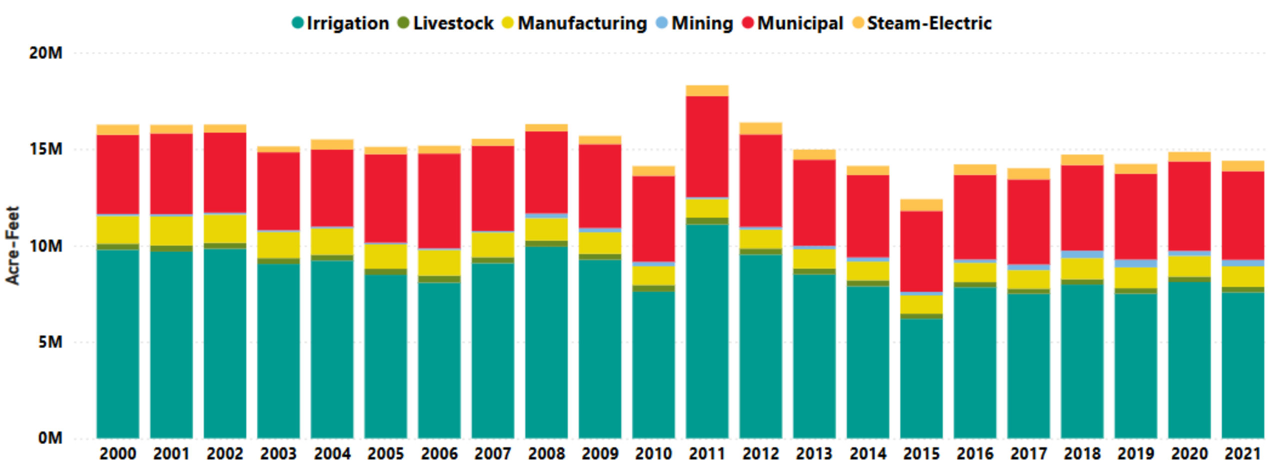
Maps of Groundwater, Surface Water, and Reuse Water Usage by County



Note. From the Texas Water Development Board, n.d.-f (https://www.twdb.texas.gov/waterplanning/waterusesurvey/dashboard/index.asp).

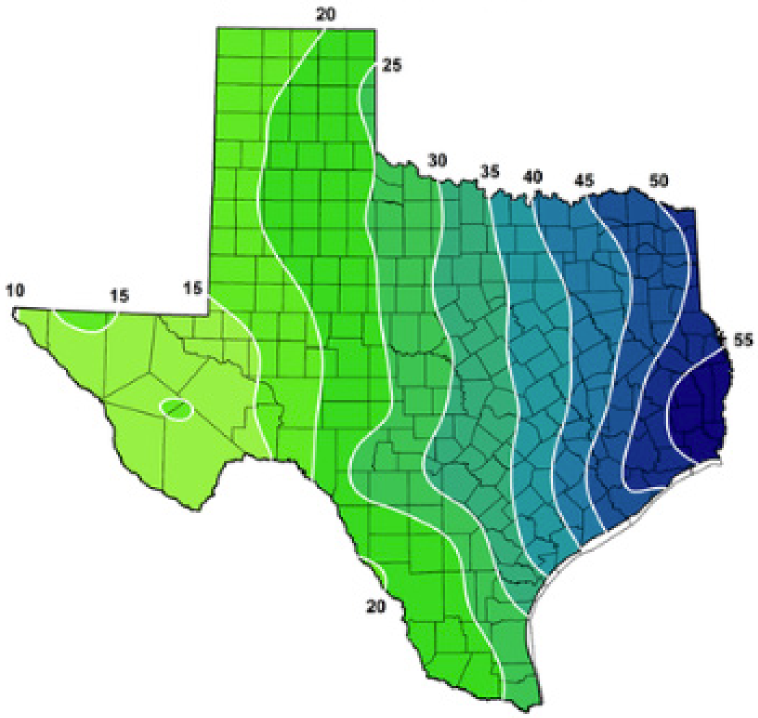
Figure 5

Graph of Historical Water Use by Category, 2000-2021



Note. From the Texas Water Development Board, n.d.-a (https://www.twdb.texas.gov/waterplanning/waterusesurvey/dashboard/2021CountyWUbyWaterSource.png).

Figure 6
Average Annual Rainfall (inches) in Texas for 1981-2018



Note. From the Texas Water Development Board, 2019 (https://twitter.com/twdb/status/1122863540539416577).

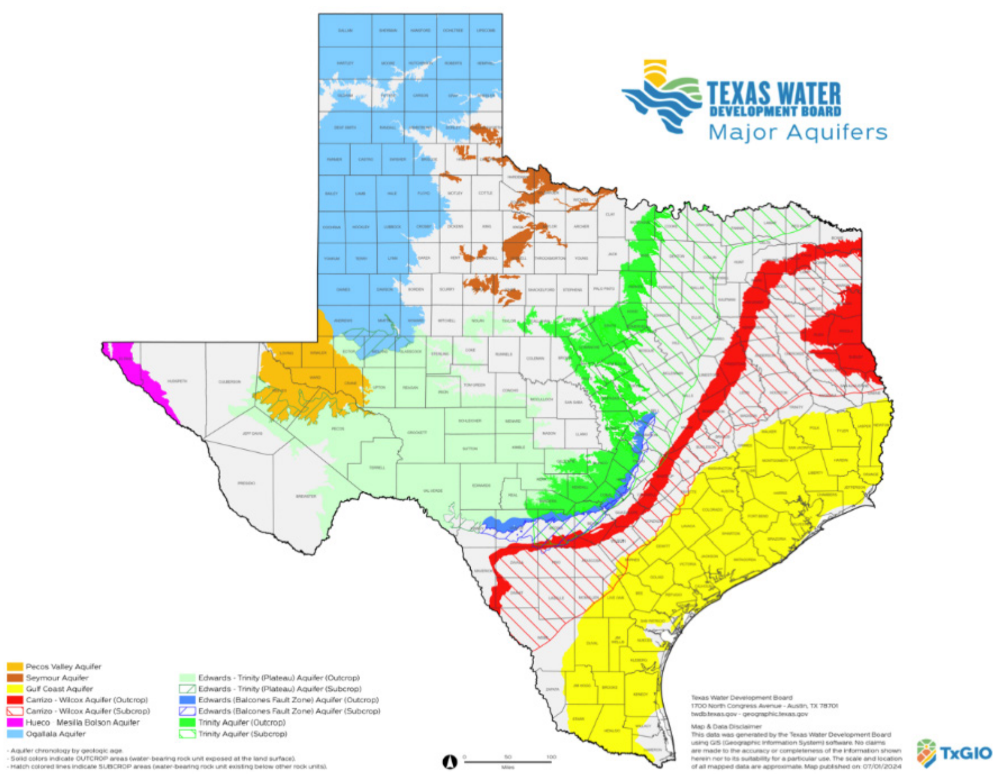
Generally, Texas is mostly in drought, going into drought, or emerging from one. The U.S. Drought Monitor defines several levels of drought, ranging from abnormally dry to exceptional drought (National Drought Migration Center, n.d.). Drought dominates the effort to plan for and secure reliable water supply. Because droughts happen gradually, it is difficult to recognize when a drought has started and when it will end.

Texas has about 191,000 miles of rivers and streams, 15 major river basins, eight coastal basins, and almost 200 major reservoirs (Texas Water Development Board, 2006). Major reservoirs are classified by obtaining at least 5,000 acre-feet of storage capacity at normal operating level. Furthermore, the average annual discharge of surface water to the Gulf of Mexico has varied throughout the years, "historically … from around 21 million acre-feet to 55 million acre-feet, depending on whether the state is in a wet or dry period" (Texas State Historical Association, 1995, para. 1). That discharge is significantly more than the amount of surface water and groundwater used in 2021. Furthermore, some surface water flows are dedicated to supporting ecological systems in the coastal bays and estuaries. Finally, flow in the Rio Grande depends on releases of water from Mexico in accordance with 1944 Treaty water delivery obligations (Texas Commission on Environmental Quality, 2024).

In 2021, surface water accounted for nearly 42% of the 14.3 million acre-feet of water used in Texas. As of August 2024, the TWDB's Water Data for Texas website reported that Texas reservoirs were 76% full compared with the historical median storage (since 1990) of about 80% (Water Data for Texas, 2024). The three biggest uses of surface water include municipalities, using nearly 50%, followed by irrigation at nearly 30%, and 15% for manufacturing. Other smaller users include (in descending order) power generation, livestock, and mining. The 2022 State Water Plan reported the total surface water availability—the maximum amount of water that could be withdrawn annually in a drought of record—is about 12.7 million acre-feet (Texas Water Development Board, 2021). However, surface water supply—that which today is connected to or legally available to water users—is about 7.2 million acre-feet per year. Millions of acre-feet of surface water are potentially available—that is, water that could be accessed—for use. However, nearly 100% of surface water supply is legally dedicated via long-term water delivery contracts. Accordingly, unless more storage capacity is added or surface water usage is decreased (via conservation), there is no additional surface water supply to satisfy future needs.

Texas has nine major aquifers and 22 minor aquifers as designated in the State Water Plan and illustrated in **Figures 7** and **8** (George et al., 2011). Aquifers are geologic formations such as sand, gravel, and limestone that can store and transmit economic quantities of groundwater. Major aquifers extend over large areas and can supply lots of groundwater. Minor aquifers vary in size and ability to provide water but are important local sources of water. Together, these aquifers are the state's primary suppliers of water, producing about 60% of the water that Texans use in an average year. That amount of groundwater varies from year to year—again, higher in drought times when surface water supplies are stressed and lower in periods of higher rainfall when agricultural demands are less (see **Figure 9**). According to the Texas Groundwater Protection Committee, groundwater supplies more than 98% of the drinking water to rural Texas (Texas Groundwater Protection Committee, n.d.). Furthermore, an estimated 30% of the river flows are attributable to discharge of groundwater (Bruun et al., 2016).

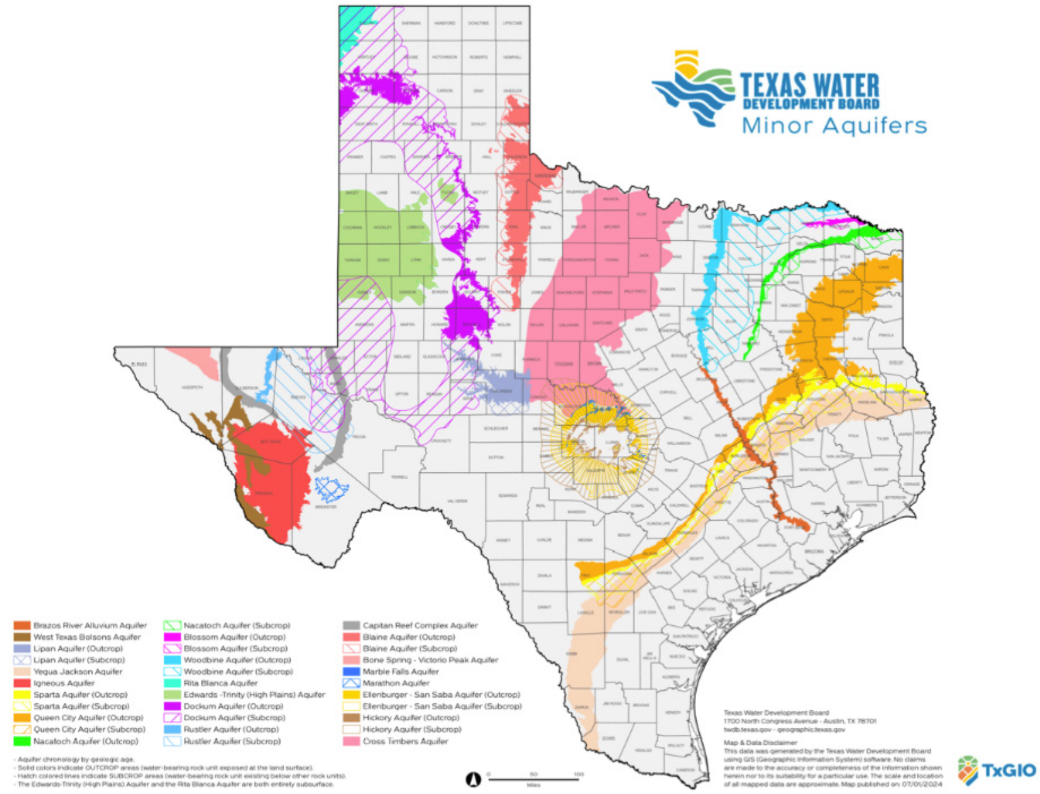
Figure 7
Map of Major Aquifers in Texas



Note. From the Texas Water Development Board, n.d.-h (https://www.twdb.texas.gov/groundwater/aquifer/major.asp).

Figure 8

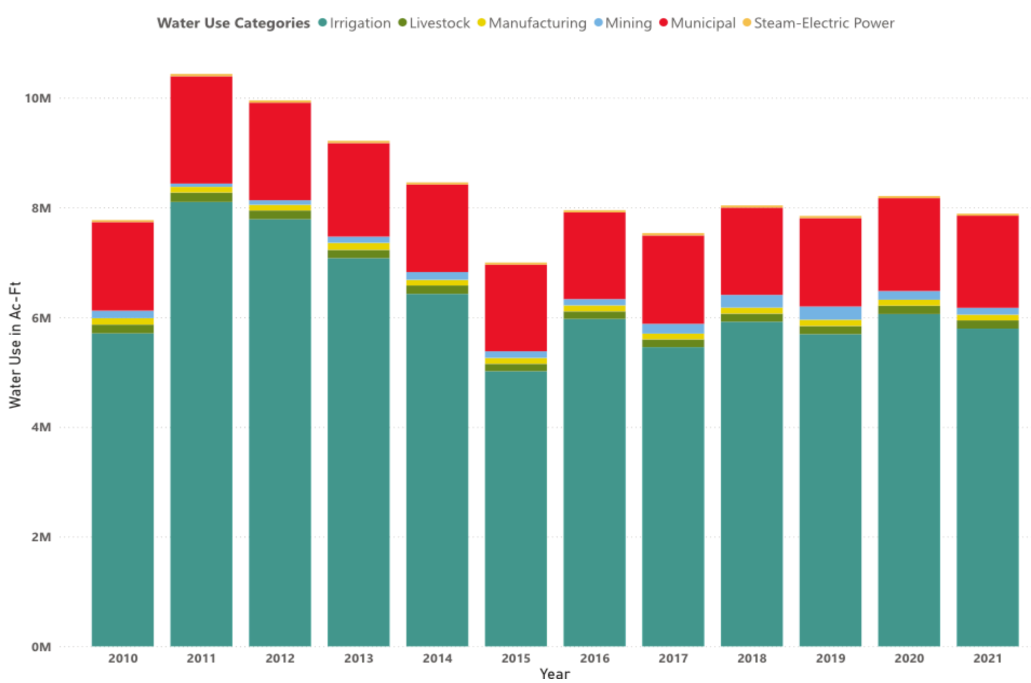
Map of Minor Aquifers in Texas



Note. From the Texas Water Development Board, n.d.-i (https://www.twdb.texas.gov/groundwater/aquifer/minor.asp).

Figure 9

Groundwater Use by Source, 2010-2021



Note. From the Texas Water Development Board, n.d.-f (https://www.twdb.texas.gov/waterplanning/waterusesurvey/dashboard/index.asp).

As illustrated in **Figure 9**, irrigation demands are by far the largest consumer of groundwater, generally in the High Plains (Ogallala Aquifer) region. Irrigation use has varied considerably but is generally decreasing over time as the Ogallala Aquifer is undergoing managed depletion. However, groundwater is a very important water source for municipal users; in fact, it is the "go-to" source of water during drought and is generally non-interruptible and critical to cities such as San Antonio and El Paso. Much of the Houston area—particularly high-growth suburban areas—rely on groundwater from the vast Gulf Coast Aquifer System. Furthermore, groundwater is increasingly important to the high-growth areas with limited options for additional surface water, including Austin, San Antonio, and much of the Texas Hill Country.

Emerging Role of Reuse Water

Reuse water currently represents about 3.5% of water used in the state, but it is becoming more popular as other traditional water sources have become limited or unavailable in some areas of the state.

Reuse water falls into two main categories: direct and indirect reuse (Health and Safety Code, Sec. 341.0391).

Direct-potable use involves first running wastewater through an advanced filtration process prior to releasing the water to the water treatment facility or the public water system. Indirect reuse typically sends wastewater to a natural water body where natural filtration takes place, and the water will eventually be diverted to potable or non-potable uses. The natural water body, either lakes or ponds, serves as environmental buffers before the water enters a treatment facility (Texas Water Development, 2021).

As of 2024, Texas has five indirect potable reuse operations (Texas Water Newsroom, 2024):

- El Paso Water Utilities operates the Fred Hervey Reclamation Plant.
- North Texas Municipal Water District operates the East Fork Raw Water Supply Project.
- Tarrant Regional Water District operates the George W. Shannon Wetland Water Reuse Project.
- The City of Abilene operates the Hamby Water Reclamation Facility.
- The City of Wichita Falls operates the Wichita Falls Resource Recovery Facility.

CURRENT STATE OF WATER INFRASTRUCTURE

As initially stated, water infrastructures' role in water availability and accessibility of surface, groundwater, and even reuse goes unnoticed. A well-designed, strategic water infrastructure landscape delivers water safely, efficiently, and reliably from the source to the point of need. This system frequently involves moving water from rural areas with relatively abundant resources to urban areas with focused needs.

There is no existing database that tracks water infrastructure and its condition. Most systems were installed in the early to mid-20th century with a lifespan of around 75-100 years. However, some utilities have aging systems that date to the 1800s. In 2022, the Texas Rural Water Association conducted a survey, and the average year of installation of small to midsized water systems was 1966 (Votteler, 2021). The combination of drought and wet cycles leads to the shrinking and expansion of soil that places stress on pipes and other structures within the system creating breaks and disruptions to water infrastructure. Pipes react differently depending on the material the system is made from and the condition of the surrounding soil of the system. For example, in the Trans-Pecos, there are well-drained, clay loams and sands that promote quick drainage. In contrast, the Blackland Prairies are made up of clays that are known as "cracking clays" due to their high shrink-swell properties. This soil can be neutral or acidic in character and raises major concerns about damage to infrastructure (Texas State Historical Society, 2014, p. 92). In many cases, this infrastructure has not undergone maintenance since installation and is responsible for mass water disruptions when pipes fail.

The American Society of Civil Engineers (ASCE), the oldest national engineering society which represents over 160,000 civil engineers worldwide, conducts a statewide infrastructure report card every four years. In its latest report card from 2021, Texas received a C- in drinking water and a D in wastewater infrastructure. Texas' score reflects a broader trend in drinking water systems. The drinking water systems in the United States received a C assessment and wastewater infrastructure received a D+ as the national average (Texas Section of the American Society of Civil Engineers, 2021). The severity of the current state of infrastructure was quickly realized in 2021 during Winter Storm Uri. During this time, the shared vulnerabilities in both the energy and water infrastructure surfaced because of power outages, frozen, inoperable pipes, water boil notices, and more. Since then, Texans have realized the prudence of increasing resiliency in critical infrastructure.

The 2022 water balance data from the TWDB provide statewide totals in Texas of all water resources in the treated distribution system ranging from input to consumption to loss. In partnership with the American Water Works Association (AWWA), the calculated water loss in Texas equated to approximately 151 billion gallons (Texas Water Development Board, 2024a). This water loss is more water than the entirety of Dallas County used in a year, according to the water use estimates summary conducted for 2021 (Texas Water Development Board, n.d.-d). In assessing the nearly 7,000 connections across Texas, the median water loss is quantified at 42.71 gallons per connection per day (GCD), updated as recently as July 2024. The water loss is broken down into apparent and real loss, where real loss makes up much of the unaccounted-for water. In 2022, the unreported loss was calculated at approximately 112 billion gallons, and reported breaks and leaks comprised approximately 16 billion gallons (Texas Water Development Board, n.d.-d).[2] The reported loss continues to increase year after year, predominantly because of expanding reporting requirements and the further degradation of infrastructure.

Deferred Maintenance

The biggest culprit in the overwhelming amount of infrastructure needing repair is deferred maintenance, which is any repair that was not completed or it was put off for later than when originally scheduled (DOE, 2020). Deferred maintenance may "save" money in the short term, but it has long term consequences, including an overall shorter life cycle, higher operational costs due to emergency repairs, and greater economic loss because deferred maintenance can create longer periods of downtime. Studies have shown that deferred maintenance costs can compound at 7% a year (Di Marco, 2018).

Deferred maintenance can also be viewed as a debt to the next generation. For example, an analysis was conducted by Jones Lang LaSelle in response to a group of real estate managers at a telecommunications firm who raised the concern that their companies' preventive maintenance was underfunded. The analysis sought to determine the return on investment (ROI). The analysis was held under three conditions: 1) zero dollars were spent on preventive maintenance, 2) half of the recommended benchmark standards for preventative maintenance were spent, and 3) the benchmark amount was spent.

The analysis concluded that where adequate preventive maintenance was spent, the investment did not just pay for itself but also produced a staggering ROI of 545%. Most of this return was generated from extending the life of equipment, with a small portion through energy savings (Koo & Van Hoy, n.d.).

A similar analysis can be applied to water infrastructure. The major considerations for investing in preventative maintenance of water systems and in determining whether to replace them entirely should involve the following:

2 To access the data, select "year" and "category" to populate the data.

Financial Impacts to Community: The cheapest time to address aging infrastructure is now. Costs for materials and services will increase and trend upward and will require greater capital from cities if left unaddressed. Repair and replacement in the present will relieve the community of future inflated financial burdens later.

Emergency Repair Repercussions: Left unaddressed or not properly planned for, failures of water systems result in quick-action solutions that typically leave little navigable room for choosing alternate cost-efficient or energy-efficient systems and fees acquired from the required expedited cost of labor and service (Lashley, n.d.).

Infrastructure Impacts Texas Cities: Large and Small

Reports often draw connections between small cities and the impact of limited resources and tax dollars to address infrastructure issues. While it is true that small towns throughout Texas require major infrastructure investment and simultaneously are burdened by generating the capital to do so, Texas' most populated cities also have aging systems comparable to the rest of the state. Texas' biggest cities, Houston, San Antonio, Dallas, Austin, Fort Worth, and El Paso, lost a combined total of nearly 87 billion gallons of water based on self-reported water loss audits in 2023 (Salinas II, 2024). In 2023, Houston alone received 500 calls a week to address water main breaks (Seedorff, 2023). Residents in Houston saw their water bills go from $89 a month to over $500 the next, with one resident receiving an $802 bill (Seedorff, 2023). Residents remain frustrated knowing these methods are not sufficient. For every gallon conserved by reducing household usage, millions of gallons of water are lost when a water main breaks somewhere else in the system. The current state of water infrastructure and the ASCE Texas water infrastructure grade as a C- is indicative of an aging system. Infrastructure for water municipalities, large or small, is now a statewide issue requiring major investment and using a dynamic approach to create a long-term solution.

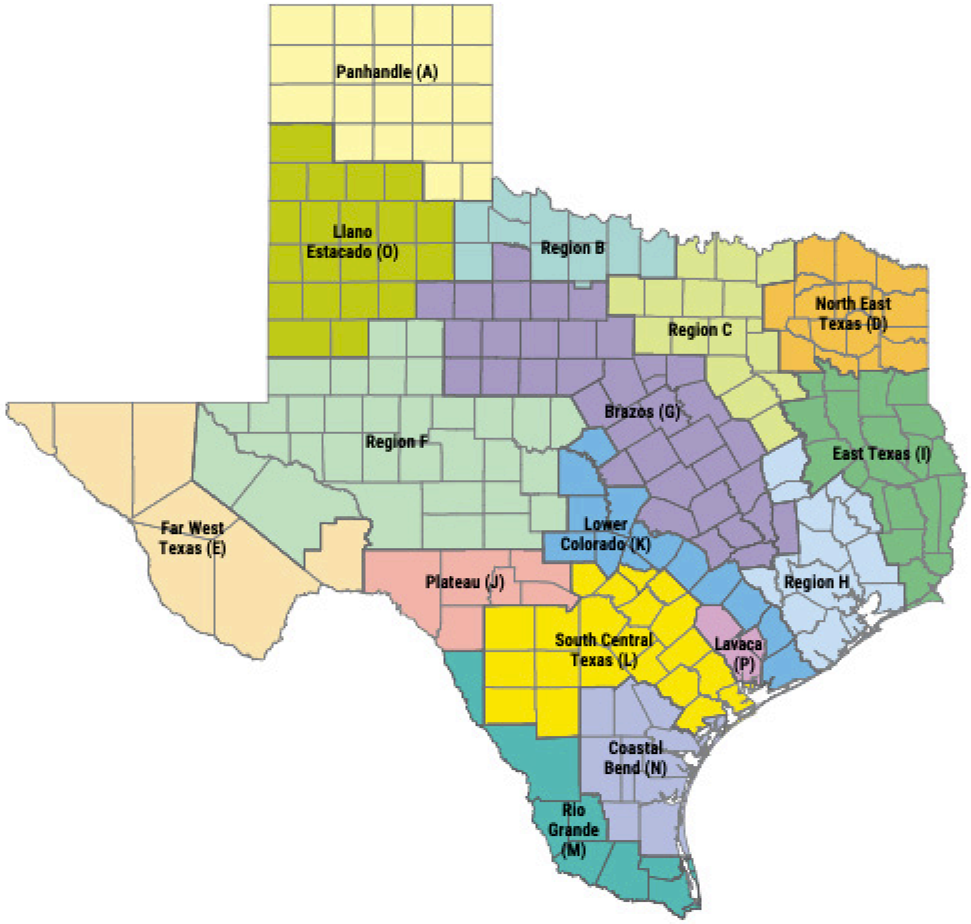
PLANNING TO ADDRESS FUTURE WATER NEEDS

Rapid population growth combined with an intense drought has applied pressure on limited water resources and catalyzed the development address water planning through a bottom-up approach. TWDB separates the state into 16 regional water planning groups (**Figure 10**). The 16 regions were determined based on many considerations; river basin and aquifer delineations, political boundaries, societal and economic factors all shaped the current planning area boundaries. The TWDB is required to review planning group boundaries every five years, and since the bottom-up framework was formed, no alterations have been made to the regional planning group boundaries (Texas Water Development Board, 2021).

For nearly 25 years, water planning has centered on these 16 regional water planning areas which develop custom plans that are combined by the Board into a comprehensive state water plan. Regional water planning groups work on a five-year cycle and are composed of a cross-section of water users and interest groups. These groups evaluate supplies and demands to project needs on a 50-year planning horizon and outline water management strategies to meet those demands. Little (if any) consideration is given to coordinating those items with other regional water planning groups. The TWDB then compiles the plans and issues the state water plan. The TWDB's role is essentially passive because it is up to public entities to come to the TWDB to fund specific projects that have already been incorporated into the state water plan. The TWDB does not propose projects or strategies that address either regional or statewide needs; those proposals originate in the regions. Therefore, it is no surprise that when all regional

Figure 10

Map of Regional Water Planning Areas



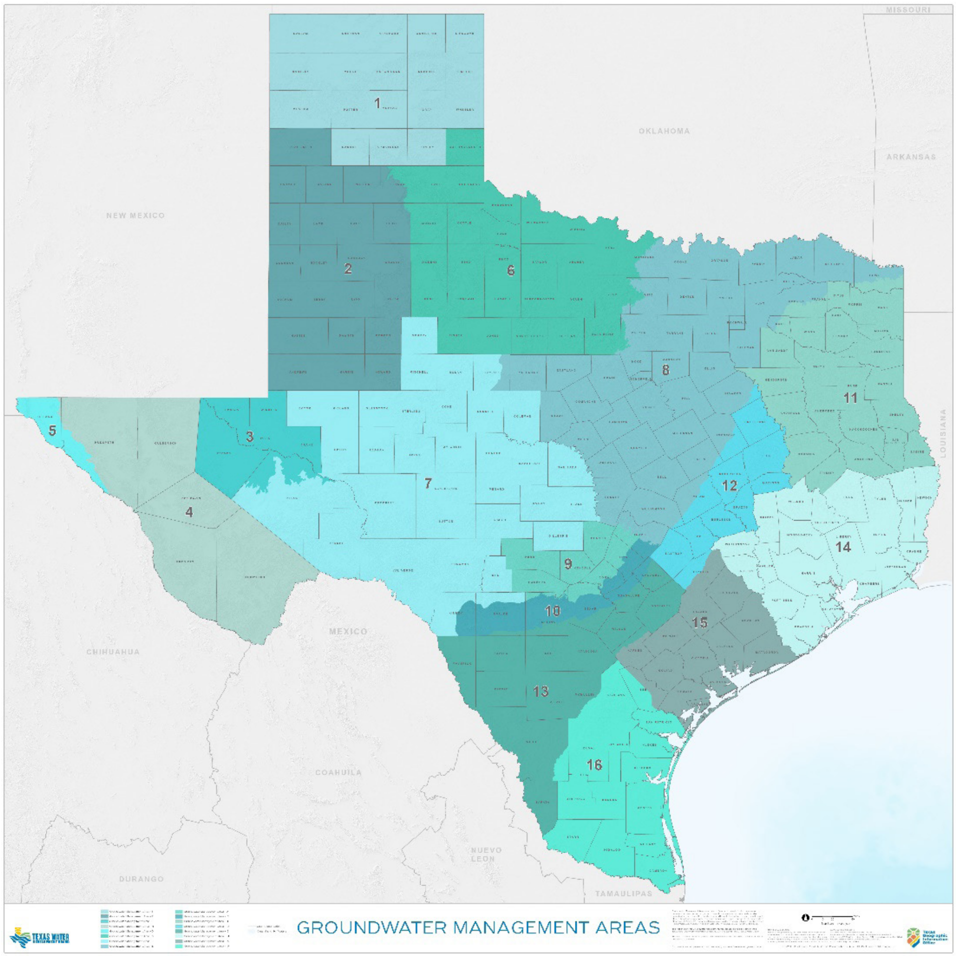
Note. From the Texas Water Development Board, n.d.-j (https://www.twdb.texas.gov/waterplanning/rwp/regions/).

plans are "rolled up," statewide water needs continue to be identified, but there is little incentive or reason for regional water planning groups to address needs beyond their borders. Each region is basically "on its own" by design. Yet before the passage of Senate Bill 1 (1997), the legislation that created the current system, the TWDB would take a more proactive development stance—at least for groundwater—by identifying areas for favorable groundwater development based on aquifer conditions. This proactive effort no longer happens.

In a process separate from regional water planning, groundwater conservation districts engage in joint planning to determine groundwater availability and input those availability numbers into regional plans. The districts that share common major aquifers in one of the 16 groundwater management areas (**Figure 11**) are required to work together to adopt aquifer management goals called "desired future conditions." They consider various technical factors and must balance conservation with the maximum practicable groundwater production, as well as protect private property rights. A desired future condition is "the desired, quantified condition of groundwater resources (such as water levels, springflows, or volumes) within a management area at one or more specified future times" (Texas Administrative Code, 2021, Section 356.10(9)). The desired future conditions are input into groundwater availability models (which are developed and run by the TWDB) to determine

Figure 11

Map of Groundwater Management Areas



Note. From the Texas Geographic Water Office, n.d. (https://data.geographic.texas.gov/e60d98b1-8e64-412a-a9b8-1ec78ae8e413/assets/thumbnail.jpg).

groundwater availability, termed "modeled available groundwater." Modeled available groundwater is the annual volume of groundwater that can be pumped to achieve the desired future condition of an aquifer. Districts consider modeled available groundwater, along with other parameters, in the implementation of management plans, permitting decisions, and management strategies to achieve the desired future conditions. These groundwater availability values are then included in the regional plans.

The 2022 State Water Plan notes the following concerns for current and future water conditions:

- Texas' population will increase 73% by 2070 to 51.5 million. Over half that population growth will be in the planning regions that include the Dallas-Fort Worth and Houston metropolitan areas.
- Water supplies are estimated to decrease by about 18% between 2020 and 2070, mostly due to the depletion of aquifers in the High Plains and the Houston area.
- Water use shortages of 3 million acre-ft/yr in 2020 could rise to 6.9 million acre-ft/yr in 2070 in drought of record conditions.

- About 5,800 water management strategies have been identified in the SWP to address water shortages. They would provide 1.7 million acre-ft/yr in 2020 and 7.7 million acre-feet/yr in 2070. Conservation strategies represent about 29% or 2.2 million acre-ft/yr in 2070 (Texas Water Development Board, 2021).

The strategies and projects identified by these planning efforts may be moved forward and financed by the State Water Implementation Fund for Texas (SWIFT) or other financial programs at the Board. With some notable exceptions, most of the projects and associated financing over the last 20 years were directed toward a "plug the leaks" effort or moving water within basins over relatively short distances. For example, most of the recent financing commitments made by the TWDB have been for projects such as wastewater treatment systems, infrastructure improvements, drainage projects, flood control and mitigation, and technical studies. While those are necessary and worthwhile projects, relatively few projects to bring new sources of water online have been brought to the TWDB for financing. That work has largely been done by the private sector, in the direction of local governments, to meet the needs of growing cities and suburbs.

A more proactive approach is needed. For example, **Figure 12** shows that at least two-thirds of the water management strategies, such as "demand management" and "other surface water," do not generate "new water" but reallocate water or make water systems more efficient. According to the 2022 State Water Plan, describing "other surface water," the Plan notes:

> These strategies generally do not require further development of surface water resources and new water right permits but simply convey previously developed and permitted surface water to users. In addition to pipelines, the types of projects associated with these strategies may include, but are not limited to, constructing pump stations, adding water treatment capacity, or lowering the elevation of a reservoir intake to allow a water provider to continue to draw water when lake levels are low. (Texas Water Development Board, 2021, p. 105)

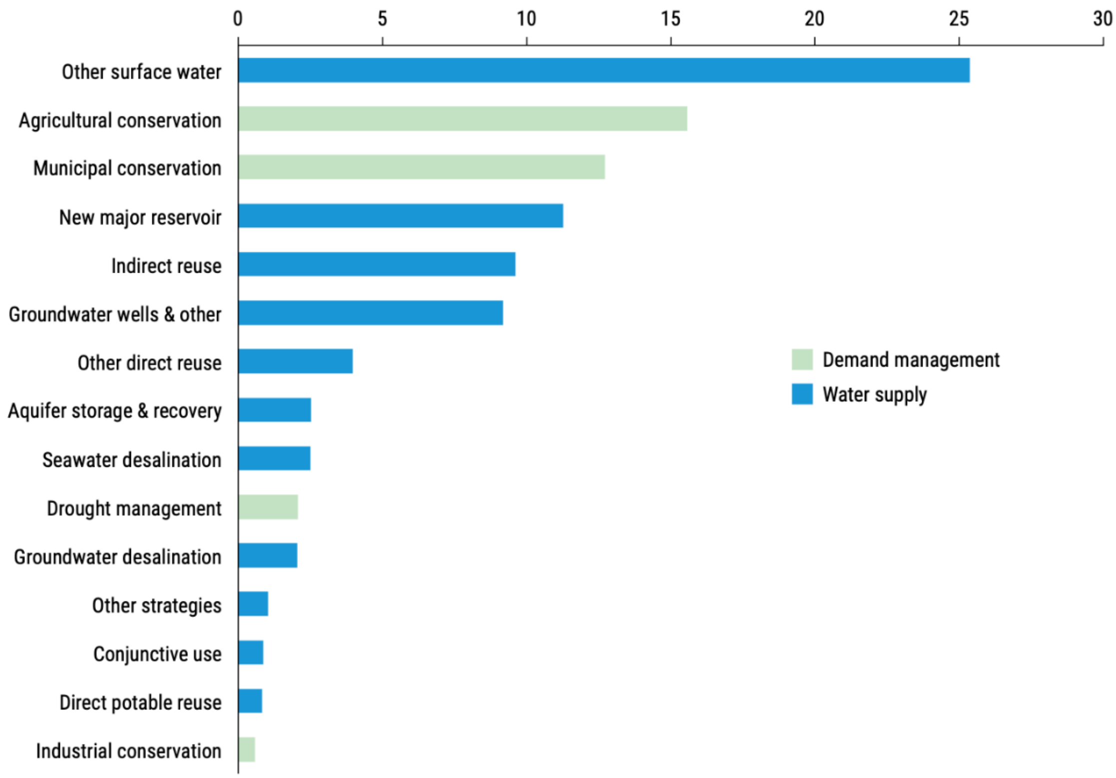
FUNDING WATER PROJECTS

One of the challenges facing Texas is how to pay for water supply projects. Water supply financing options have been expanding and changing to address these challenges. To underscore the scope of current financial needs in the state, the TWDB approved more than $3 billion for various projects at their July 2024 meeting. The 2022 State Water Plan documents the demands for and supply of water and identifies projects and costs to address those demands over a 50-year planning period (Texas Water Development Board, 2021). About $80 billion will be needed to fund the more than 2,400 water management strategy projects identified in the 2022 State Water Plan to address water demands. Decision makers are faced with several questions: "Should we make that investment?" And, if so, "where will that money come from?"

Not all water projects are included in the regional plans or the state water plan. Therefore, the state water plan does not completely describe the scope and scale of water projects that will be undertaken to address local or regional needs. The costs for these projects may be locally funded through bond initiatives or public-private partnerships such that the local taxpayers and ratepayers—rather than state taxpayers—foot the bill. However, rural areas and economically disadvantaged areas will continue to gravitate toward the financial programs and resources offered by the state.

The 2022 State Water Plan lays out both the costs of recommended projects to address water management strategies as well as the regions that will require the most investment dollars to complete those projects. Based on an inspection of the projected costs (not adjusted for inflation) over the next 50 years, the 2020-2030 decades will see the greatest project costs: an estimated nearly $45

Figure 12
Percentage of Water Needs that Will Be Met by Strategies in the 2022 State Water Plan



Note. From the Texas Water Development Board, 2021, p. 11 (https://www.twdb.texas.gov/waterplanning/swp/2022/index.asp).

billion to fund all proposed projects—with declining costs over the following 30 years (see **Figure 13**). This projection assumes that all projects would be funded and constructed—an assumption that is unlikely to be realized as new supply and demand projects in future regional plans will likely modify the existing plans.

In addition to the projected costs over the 50-year planning horizon, it is also instructive to understand where those projects and costs will occur. **Figure 14** illustrates how the project costs will be distributed across the state by decade. The geographic distribution of the estimated costs will be heavily tilted to two of the regional planning areas: Region C (Dallas area) and Region H (Houston area). Together, Regions C and H account for more than 50% of the estimated costs for water projects in the 2020-2030 planning period.

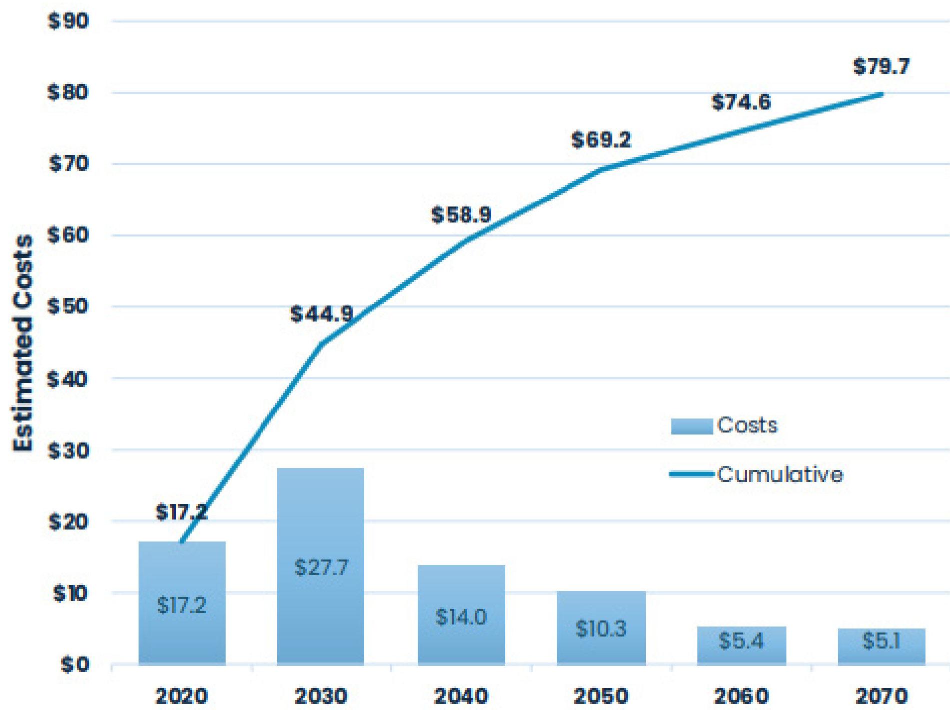
The methods to pay for water projects are varied. Federal funding, in the form of grants and transfers to the state, and state funding through various programs and initiatives constitute the bulk of financing available to construct water supply projects. Other financing options, such as municipal bonds or public-private partnerships, are considered in certain cases. Ultimately, the water utility ratepayers and taxpayers pay for the projects.

State Water Implementation Fund for Texas (SWIFT)

The State Water Implementation Fund for Texas (SWIFT) and State Water Implementation Revenue Fund for Texas (SWIRFT) programs were established after voters approved Proposition 6 in 2013 to provide affordable state financial assistance for projects identified in the 2012 State Water Plan (SWP). The SWIFT does not directly fund water

Figure 13

Projected Estimated Costs (in billions of dollars) by Decade of Recommended Projects to meet Water Management Strategies Listed in 2021 Regional Water Plans



Note. Chart reproduced by the author from data in 16 regional water plans from 2021 Regional Water Plans, by the Texas Water Development Board, 2021 (https://www.twdb.texas.gov/waterplanning/rwp/plans/2021/index.asp).

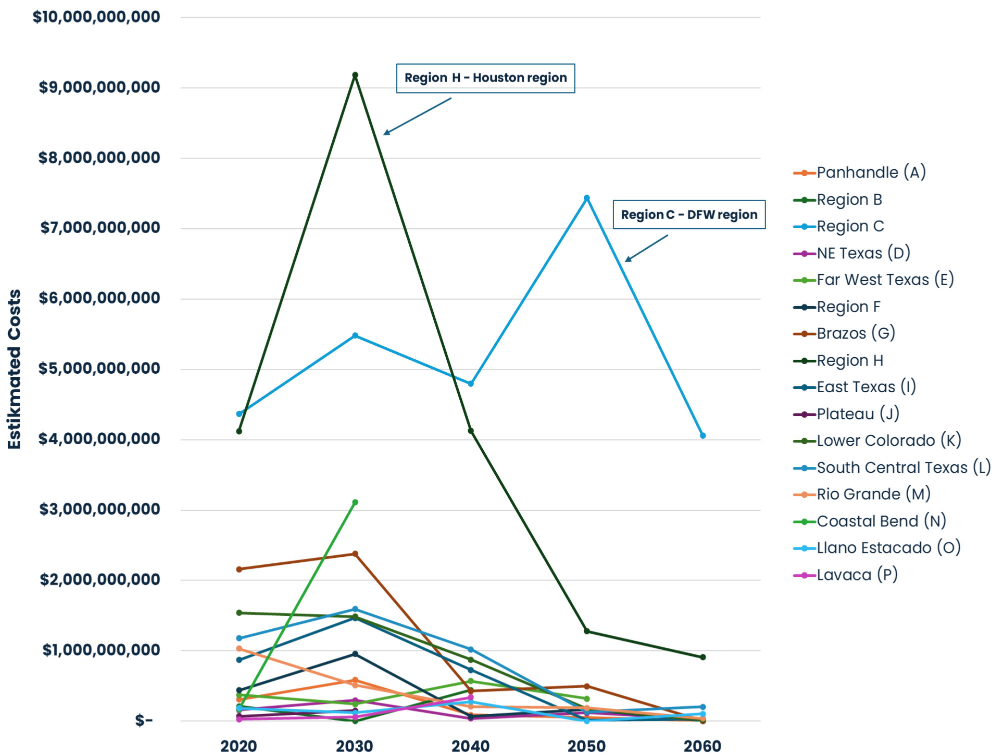
projects. Instead, it subsidizes loans that are made through the SWIRFT. The SWIRFT fund issues revenue bonds to finance water projects. **Figure 15** illustrates the relationship between the funds and how money moves from these funds to borrowers. Since the SWIFT was implemented with $2 billion in initial funding from the state's Economic Stabilization Fund, nearly $11.5 billion has been loaned from the SWIRFT fund to public entities to design and construct water projects identified in the SWP. The 2022 report to the Legislature indicated that 55 projects have been funded, representing 68 water management strategies (Texas Water Development Board, n.d.-c). The projects have added more than 1.6 million acre-feet to the state's water supply. Most of the SWIFT projects to date have been centered in the Dallas-Fort Worth and Houston areas. The TWDB has indicated that the SWIFT will be primarily focused on funding large infrastructure projects whereas relatively smaller projects will be funded with other financial vehicles. The Legislature required that at least 20 percent of its funding be directed to general water conservation and reuse and 10% of the funding be directed to rural areas for agricultural water conservation. Lawmakers should review if that approach—that is, funding primarily large, urban projects—or more direct investments in smaller projects is important to the state as a whole.

Texas Water Fund and New Water Supply Fund for Texas

In 2023, Texas voters approved Proposition 6 by a wide margin, creating the Texas Water Fund with $1 billion that will be administered by the TWDB (TWDB, 2024b). This money will be directed to existing TWDB financing programs (see **Figure 16**) in accordance

Figure 14

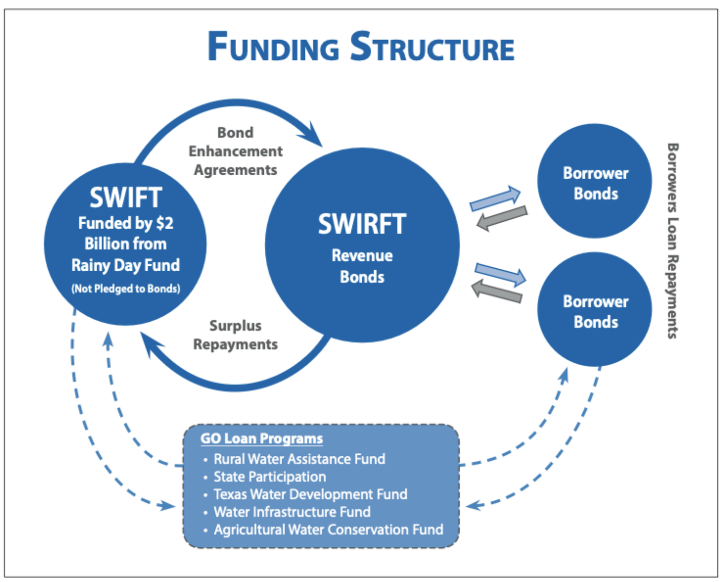
Graph of Projected Estimated Costs by Decade of Recommended Projects in Planning Regions to Meet Water Management Strategies Listed in 2021 Regional Water Plans



Note. Data from the Texas Water Development Board, 2021 (https://www.twdb.texas.gov/waterplanning/data/rwp-database/index.asp).

Figure 15

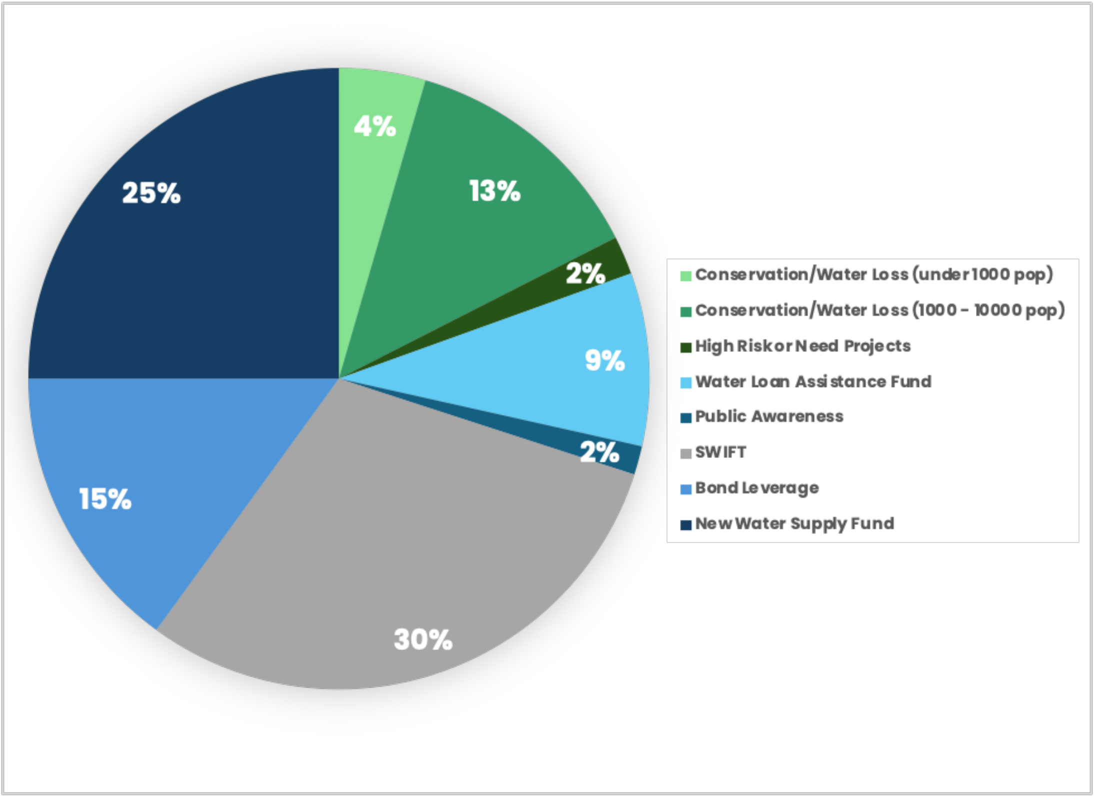
SWIFT and SWIRFT Funding Structure



Note. From Texas Comptroller (Hegar, 2016) (https://comptroller.texas.gov/economy/docs/96-1790.pdf) and Texas Water Development Board, 2021 (https://www.twdb.texas.gov/waterplanning/swp/2022/index.asp).

Figure 16

Implementation Plan for Texas Water Fund Financing



Note. Data from the Texas Water Development Board, 2024c (https://www.twdb.texas.gov/financial/programs/TWF/doc/2024-07-23-Brd02.pdf?d=3427.5999999940395).

with the implementation plan published in July 2024 (Texas Water Development Board, n.d.-e) and honoring the priorities established by the Legislature. The TWDB has approved an implementation plan to transfer the funds to various financing programs. Twenty-five percent of that money—$250 million—will be directed to the New Water Supply Fund for Texas that will finance projects that generate "new water" for the state. The TWDB rules governing this fund are still in development, but based on direction from the Legislature, the goal is to generate 7 million acre-feet of new water supply over the next 10 years. However, the New Water Supply Fund would not be for projects that move water from one region of the state to another (Perry, 2024). Nor would this fund be used to finance conservation programs of existing water sources. The specific intent of the legislation includes funding for brackish groundwater and marine desalination, produced water treatment, aquifer storage and recovery projects, and acquiring water through regional and nationwide partnerships with other states.

Federal Financial Assistance Programs (through State Revolving Funds)

The federal government funds water projects directly and indirectly by providing designated funds to state governments. Many federal projects are funded through the Bureau of Reclamation's WaterSMART program. This program is for projects in the western United States, including Texas. The eligible project types include water recycling and desalination programs, environmental water resources projects, water and energy efficiency grants, small-scale water efficiency projects, and water marketing strategy grants.

In addition, the federal government, through direct budget allotments, as well as programs such as the 2021 Infrastructure Investment and Jobs Act (IIJA), provides funds to the state for the Clean Water State Revolving Fund (CWSRF) and the Drinking Water State Revolving Fund (DWSRF). The CWSRF is primarily for wastewater projects, and the DWSRF is used for systems to comply with federal drinking water standards. These programs are administered by the TWDB. Over a five-year period, Texas will receive about $2.5 billion, which is more money than was used to capitalize the State Water Implementation Fund for Texas (SWIFT) program in 2013.

Peña (2024) reported that the DWSRF currently has $435 million available, including $95 million in principal forgiveness. It subsidizes interest rates and includes special allocations for disadvantaged communities, green projects, very small systems, and systems with "urgent needs." The DWSFR also includes programs for lead service line replacement funds (about $354 million in funding available) and emerging contaminants (about $58 million in funding is available). The CWSRF currently has $460 million available, including $55.3 million in principal forgiveness. It subsidizes interest rates and includes special allocations for disadvantaged communities, green projects, and "urgent needs." It also includes more than $3 million in funding for emerging contaminants. More broadly, revolving loan funds play a crucial role in providing targeted support to underserved and economically disadvantaged rural communities across Texas. Rural areas with limited access to capital for major water infrastructure projects can leverage programs like the CWSRF, SWIFT, or DWSRF to secure reliable, long-term funding for essential water system improvements system improvements.

State Financial Assistance Programs

Since 1957, when the TWDB was established, more than $35.4 billion has been loaned or granted to political subdivisions to develop and deliver water supplies. The principal state financial assistance programs include the SWIFT, the TWDB Fund (DFund), and the Economically Disadvantaged Assistance Program (EDAP). The TWDB uses federal funds, along with proceeds from bond sales, to provide low-interest rate loans and grants to water supply providers. This approach allows Texas to use loan repayments to build a permanent, sustainable funding source. Federal funding allows the state revolving funds to offer discounted interest rates, which can save borrowers up to 75% in interest payments compared to municipal bonds. However, in recent years, the amount of federal funding available to Texas has been diminishing (Howe et al., 2024). In fact, both the clean water and drinking water revolving fund programs are "significantly oversubscribed" (Texas Water Development Board, 2024c) as shown on **Figure 17**.

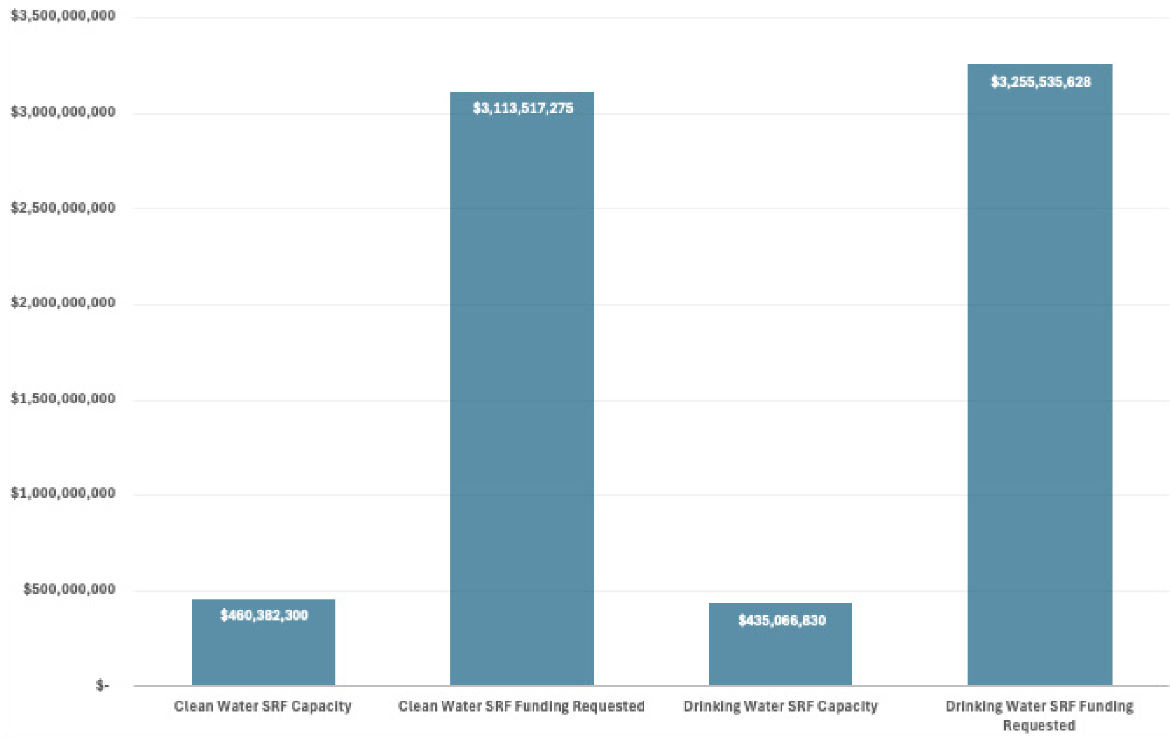
Other sources of funding that are coordinated through the Texas Water Infrastructure Coordinating Committee (TWICC) include programs of the Texas Department of Agriculture (Community Development Fund and State Urgent Need Fund), Communities Unlimited, the North American Development Bank (Loan Program, Border Environment Infrastructure Fund, and Community Assistance Program), and the U.S. Department of Agriculture Rural Development.

Private-Public Partnerships

Depending on the needs of a project, municipalities or water authorities may choose to issue bonds or employ other commercial financial mechanisms such as private-public partnerships. Perhaps the best-known example is the City of San Antonio's Vista Ridge project (San Antonio Water System). The $3.4 billion project delivers a maximum of 50,000 acre-feet of groundwater per year from a well field in Burleson County (San Antonio Water System, n.d.). All costs of construction and pipeline right-of-way acquisition were covered by privately raised debt and equity capital. The San Antonio Water System pays only for the water that is delivered and for some operating and maintenance costs. Capital markets were tapped for debt financing, totaling more than $852 million.

Figure 17

Demand for Clean Water and Drinking Water State Revolving Funds Far Exceed Program Capacity In 2024



Note. Data from the Texas Water Development Board, 2024 c (https://www.twdb.texas.gov/financial/programs/TWF/doc/2024-07-23-Brd02.pdf?d=3427.5999999940395).

NEW WATER SUPPLY SOURCES

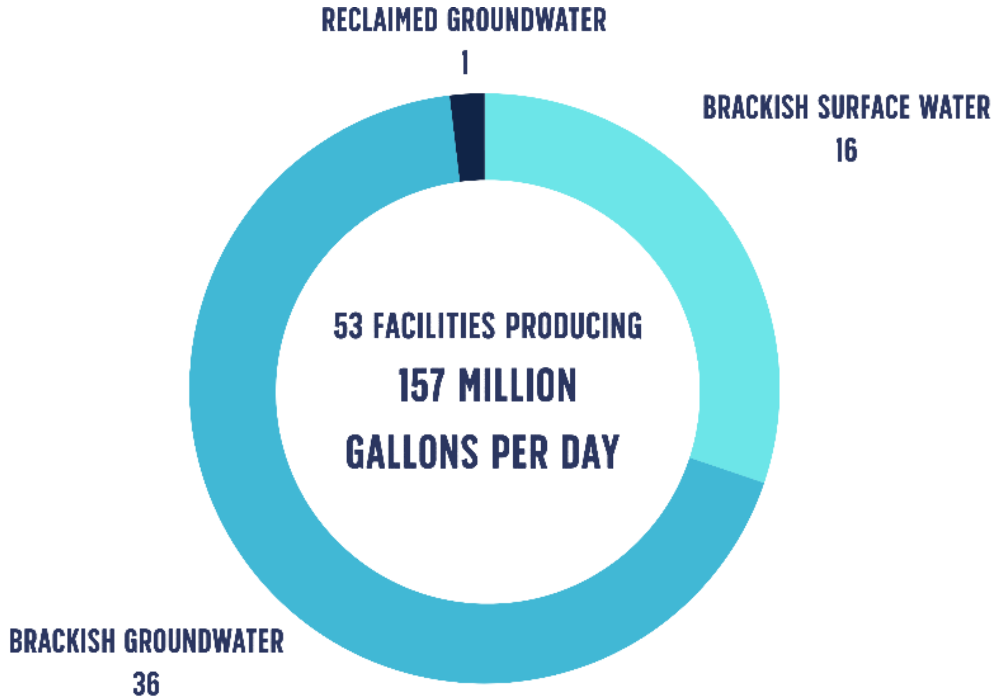
Texas is accelerating its search for water beyond the traditional surface water and potable groundwater sources. This search is increasingly focused on new water supply sources, *i.e.*, those sources that are historically unconventional for Texas but, in most cases, have been proven to be viable sources of water in other states and countries. The passage of Proposition 6 in 2023 gave further stimulus to exploring new sources; in fact, at least $250 million in the Texas Water Fund is specifically dedicated to new water supplies. These supplies have been identified as seawater and groundwater desalination, produced water from oil and gas operations, and aquifer storage and recovery projects. The infrastructure needed to move water from these sources to the points of need is also included in the funding made possible by Proposition 6. The following sections summarize the current state and possibilities of using these new sources to meet Texas' water needs.

Desalination

Desalination efforts date back centuries, although large-scale treatments incorporating desalination did not make headway until the 1950s (Angelakis et al., 2021). The process utilizes naturally occurring brackish or saltwater that runs through filtration technology to purify and remove excess minerals and salt, resulting in potable water. In desalination, there is a product and by-product. The product is referred to as permeate, which is just the pure water produced by the treatment process. The by-product is the rejected particulates from the fresh water, which become more concentrated as the treatment process filters multiple times with the aim of recovering the greatest amount of water. Depending on whether the facility filters brackish water or seawater, reverse osmosis (RO), thermal, or a combination of both are used in desalination processes. Reverse osmosis is the gold standard and the most widely used technology in desalination. The natural process

Figure 18

Desalination Facilities in Texas and Combined Total Production Capacity



Note. Data from Texas Comptroller, 2022 (https://comptroller.texas.gov/economy/economic-data/water/2022/desalination.php).

of osmosis is essentially a lower concentrated liquid moving towards a higher concentrated liquid; in this case, freshwater would naturally gravitate towards saltwater. Reversing this process involves applying energy, or pressure, to saline water which then promotes the flow of water to pure water. As this occurs, the water is passed through a semi-permeable membrane that removes 95–99% of all dissolved solids, particles, bacteria, and more from the originally sourced water (Puretec, n.d.). Reverse osmosis is so effective at removing dissolved solids that after the treatment process, minerals must be added back into the water for taste and nutrients.

Brackish water and saltwater are classified using the total dissolved solids concentration (TDS). Brackish water has a TDS range of 1,000 to 10,000 mg/L, where water with more than 10,000 mg/L is classified as saline. Water with a TDS concentration of less than 1,000 mg/L is classified as fresh water. EPA regulations recommend no more than 500 ppm of TDS in drinking water (Woodward, 2024).

There are currently 53 municipal desalination facilities in Texas, all of which treat groundwater or surface water. The combined capacity equals 157 million gallons per day (see **Figure 18**). Of the 53 facilities, 16 are sourced from brackish surface water, generating a combined capacity of 65 million gallons a day. Thirty-six facilities use brackish groundwater, with a generating capacity of 90 million gallons a day. One facility is sourced from reclaimed groundwater and generates 2.5 million gallons per day. The three largest groundwater desalination facilities are located in Bexar, Cameron, and El Paso counties (Texas Comptroller, n.d.).

Here are the three largest brackish groundwater desalination facilities in Texas:

1. **Kay Bailey Hutchison Desalination Plant, El Paso:**
   Capacity: 27.5 million gallons per day (mgd)
   Operational: 2007

   World's largest inland desalination plant, 83% recovery rate with remainder being brine concentrate. Potable water is piped to a storage tank for distribution and the brine is disposed through deep-well injection (El Paso Water, 2022).

2. **H2OAKS Center, San Antonio:**
   Capacity: 12 mgd
   Operational: 2016

   Brackish desalination, aquifer storage, and water recovery facility serving nearly 2 million customers. The total recovery rate is 90%. Brine is disposed through deep-well injection at 5,000 feet deep into the Georgetown, Edwards, and Upper Glen Rose limestones (Texas Water Development Board, 2017).

3. **Southmost Regional Water Authority, Rio Grande Valley:**
   Capacity: 10 mgd
   Operational: 2004

   Meets nearly 40% of the area's water needs and the plant significantly reduced the area's dependency on the Rio Grande River (Norris, n.d.). The recovery rate is 75%. Brine is disposed via surface water drainage system that flows through a ditch that directs the concentrate into the Brownsville ship channel.

A significant challenge for facilities is how brine, a by-product of any desalination process, is managed. Brine is a highly concentrated mixture of primarily salt. Depending on where water is sourced, brine may include concentrations of heavy metals, nutrients, solids, and other contaminants. Both seawater and brackish water desalination facilities face the same consideration in brine disposal. Brackish water has a greater recovery ratio when compared to seawater desalination facilities because of the lower TDS ratio.

Existing strategies of brine discharge involve surface water discharge, deep well injection, land applications, or evaporation ponds. In a review of management strategies for waste management of desalination facilities, a survey conducted by TWDB showed that 36% of Texas desalination plants discharge brine through surface water discharge, 28% discharge into to a sanitary sewer, 15% store in an evaporation pond, 11% utilize onsite land application, and 4% dispose using deep well injection (Rose, 2023). The other 9% of desalination plants surveyed did not provide information on the facilities' disposal process (Rose, 2023). The disposal methods and processes are as follows:

- **Surface water (sea, lakes, rivers, etc.) discharge** disposal is one of the most common discharge methods due to the availability of this option to any facility and being the lower cost option. In an effort to minimize impacts from the input of brine mixture into a water body, this discharge method either relies on diffusers at the end of the discharge pipe or the natural tidal zone of the receiving water body to assist in diluting the discharge (Lenntech, n.d.-b).

- **Sanitary sewer brine disposal** relies on a nearby wastewater system. Given the desalination facility is under the right conditions, this method is also a low-cost option and the second most utilized discharge method. This method is best used by smaller capacity facilities that discharge into a wastewater system that is a large capacity wastewater treatment plant. Larger wastewater treatment plants are equipped to handle greater volumes of waste so the treatment methods can also handle higher TDS (Lenntech, n.d.-a).

- **Evaporation ponds** are the process of using a built pond, designed to prevent any seepage of the by-product, to allow for the natural evaporation process to occur and leave behind the remaining salt. This method is best used by desalination facilities in a drier climate with land available (Rose, 2023).

- **Land application** is also a cost-effective option for facilities with low volumes of brine by-product. This method primarily relies on spray irrigation on crops or plants that are able to handle high salinity environments (Rose, 2023).

- **Deep well injection** is one of the least used methods in brine disposal but there is feasibility where desalination facilities are located with favorable geologic conditions. For example, the H2Oaks facility, located in San Antonio, uses deep well injection to dispose of residual brine about 5,000 feet below the surface into the saline zone of the Edwards Aquifer (Zachry Construction, n.d.). A large capacity desalination facility will likely pursue this option because of the barriers of limited disposal in the alternate methods. The process involves using an injection system to pipe the discharge past the groundwater aquifer and into the confined layer below. The confined aquifer is a saline environment where discharge can be injected without meeting the groundwater sources above (Rose, 2023).

No seawater desalination facilities currently exist in Texas. This reality is primarily due to the challenges with higher salinity water requiring a more intensive filtering process, and this process comes with additional costs and waste considerations. However, a facility in Corpus Christi is slated to begin construction in 2025 (Hami, 2024).

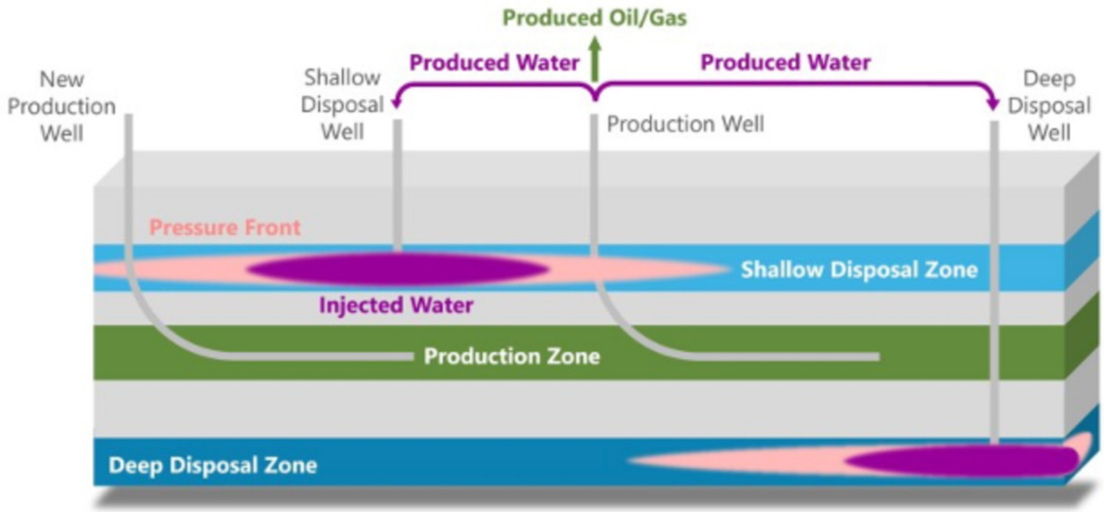
Corpus Christi provides the pilot program and a case study for the challenges and opportunities arising in implementing a saltwater desalination facility. Corpus Christi's water is supplied to about 500,000 residents from four reservoirs, including Choke Canyon, Lake Corpus Christi, and Lake Texana, all of which are treated by one facility (City of Corpus Christi, n.d.). Considering drought conditions and growing water demands that have resulted in these reservoirs at only 24% capacity in August 2024, Corpus Christi has sought to diversify and expand water generating capacity by pushing the construction of the Inner Harbor Desalination project. The facility would have the capacity to generate 30 million gallons of water per day. The facility faces the continued challenge of high capital costs that desalination projects seek to overcome. With a price tag expected to approach $1 billion, the discussion has centered around how costs are apportioned to rate payers, particularly the costs reflected on residential utility bills. Costs are a much of a concern for the community as the potential environmental impacts. Corpus Christi residents have also expressed concern that the facility has been projected to generate just as much wastewater as it can produce. The decision on where the 30 million gallons of wastewater will be discharged has yet to be determined. In a TCEQ hearing, members of the community discussed the current permit under consideration on the ability to discharge this waste into the inner harbor ship canal. The community expressed concern about the brine sinking to the bottom of the closed bay, creating a "dead zone" where an ecological system could not survive. Piping the brine further into the open Gulf was considered, and it ultimately came down to a matter of cost (Davis, 2024).

Future of Desalination

The Global Strategic Business Report tabs the global desalination technologies market as a nearly $17 billion industry in 2023 and projected it to approach $34 billion by 2030. This is an annual growth rate close to 11% by the end of the decade (Global Industry Analysts, Inc., 2024). Looking forward, Texas can look to proven technologies and aim to replicate the most effective processes and systems here. For example, Israel employs some of the most advanced water technologies in the world and relies heavily on desalination to meet its water needs. Desalinated drinking water makes up a mere 1% globally. However, desalinated water in Israel accounts for over 80% of water consumption and produces nearly 160 billion gallons of water annually (Serim, 2024). While desalination technology and processes remain the same, Israel has the advantage of attractive financing options and lower labor costs (Aggarwal, 2023).

Figure 19

Diagram of Permian Basin Oilfield Water Production and Disposal Operations



Note. From Bruant, 2023 (https://jpt.spe.org/the-growing-pressures-of-produced-water-disposal).

Produced Water

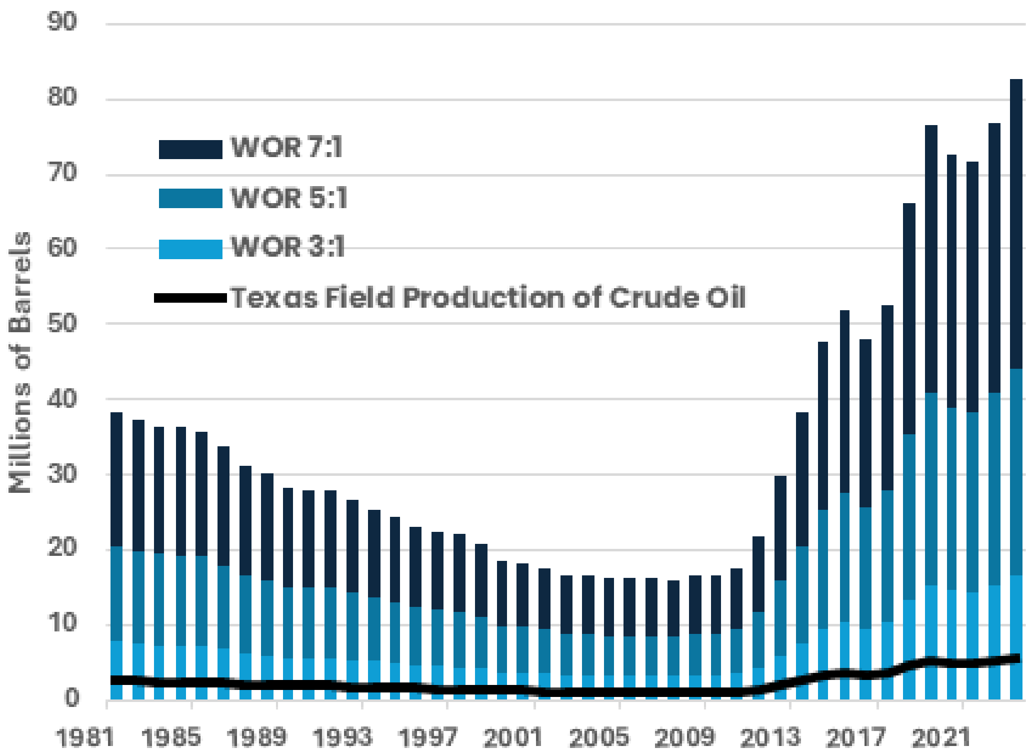
In the last 15 years, the Permian Basin of West Texas has transitioned from a declining conventional oil basin to a "super basin," which is defined as a basin that has a cumulative production of more than 5 billion barrels of oil equivalent (Zartler, 2017). Unconventional oil and gas production—characterized by the widespread application of hydraulic fracturing, or "fracking"—has opened previously untapped oil resources that are now accessed through horizontal drilling resulting in long lateral wells (see **Figure 19**). In the month of August 2024, Texas produced an average of 5.8 million barrels of oil each day (EIA, 2024). In every barrel of oil produced, sometimes three to twelve times the amount of water is also produced as a by-product. Depending on where the oil production occurs, depth of well, and the use of either conventional versus unconventional oil or gas production, different amounts of wastewater are generated. Volumes are dependent on the formation and basin of the oilfield, but also vary based on the producing well age, where produced water generally increases over the lifetime of a well (Texas Produced Water Consortium, 2024). This water, referred to as produced water, is defined in Texas statute as "[f]luid oil and gas waste" (Texas Natural Resources Code, Section 122.001(2)). Estimates vary, but in 2020, the United States generated an estimated 240 billion gallons of produced water from oil and gas operations. In Texas, there is an estimated 33 million barrels of produced water generated every day. The common consensus among researchers is that the oilfields in the Permian Basin in Texas alone generate more produced water than all other U.S. oilfields combined (Luedke, 2024). Produced water was previously seen as a liability as producers were responsible for disposing. However, emerging methods to treat produced water, discussed below, provide opportunities to reuse what would otherwise be wasted water. Indeed, as the demand for new water supply intensifies, Texas and its industries have a real opportunity to not only capitalize on previously unusable water, but to completely revolutionize the future water supply, creating a substantial new source for the state.

WHERE DOES PRODUCED WATER COME FROM?

Some produced water originates from the water that is used to drill and frack a well—an average of 14.3 million gallons per well, or more than 340,000 barrels (Valder et al., 2021). Another source component of produced water is the water that originates from the oil-bearing formations and is pumped up with

Figure 20

Annual Total of Texas Field Production of Crude Oil compared the Produced Water Generated based on Common Water to Oil Ratios (WOR)



Note. From EIA, 2024 (https://www.eia.gov/dnav/pet/hist/leafhandler.ashx?n=pet&s=mcrfptx2&f=m).

the oil and frack water. Between 3 and 7 barrels (or more) of produced water are typically generated for every barrel of oil. This process results in large quantities of produced water that must be handled; for context, about 20 million barrels of produced water were produced each dayin 2024 in the Permian Basin (Bennett, 2023). This produced water has high concentrations of salts, oil, grease, and organic and inorganic materials.

HOW IS PRODUCED WATER USED?

The oil industry has increasingly used produced water in place of fresh water (which is nearly always groundwater) to meet the water demands for drilling and fracking operations (ALL Consulting, 2022). Using produced water helps conserve scarce fresh water (usually groundwater) for drinking water and irrigation uses in the arid Permian Basin. This practice has been important to conserve scarce fresh water in the Permian Basin. Water-handling companies have developed networks of centralized water treatment facilities to handle the produced water and then to deliver the water to drilling sites for fracking uses. For example, Baddour (2022) reported that XRI Holdings anticipated the increased demand for use of produced water for fracking purposes as it planned to increase its 450-mile pipeline network with an additional 230 miles of extensions. The expanded pipeline network will help move to transport produced water from recycling facilities to oilfield operations in the Permian Basin.

HOW IS PRODUCED WATER DISPOSED?

Even with an increased use of recycled produced water, there is a considerable amount of excess produced water that must be disposed of (see **Figure 20**). The principal option for disposal is injection into the deep subsurface. However, this option, while being the most economical, is becoming subject to regulatory restrictions. The restrictions are in response to the increasing frequency of seismic activity attributable to saltwater disposal. The Railroad Commission of Texas conducts a seismicity review which includes evaluation of fault hazards, monitoring of borehole pressures, seismicity monitoring, and other activities as part of the permit approval process for injection wells (Railroad Commission of Texas, 2024). In recent years, the Texas Railroad Commission has identified several "seismic review areas" where injection wells are either prohibited or restricted in terms of injection volumes or target injection zones. Disposal of produced water into surface water is also possible. For example, in 2024, there were two pending permit applications to the TCEQ for the surface disposal of treated produced water into the Pecos River (Pskowski & Baddour, 2024).

HOW CAN PRODUCED WATER BE TREATED?

Currently, there are efforts underway to evaluate the possible application of treatment technologies capable of providing produced water for beneficial use (Scanlon et al., 2020). Recycling produced water could reduce the amount of water disposed via injection wells and mitigate projected shortfalls in regional fresh water supplies. Although research indicates that most produced water is not yet economically treatable to drinking water standards (Texas Produced Water Consortium, 2024), it is possible that treated produced water may be usable for agricultural or other purposes.

Treatment of produced water is complicated by the general quality of the source water and the resultant need to undergo considerable treatment to reduce the concentrations of oil and suspended solids, as well as the occurrence of various dissolved solids, metals, and organic compounds. Furthermore, the costs of treatment escalate with increasing salinity of the produced water.

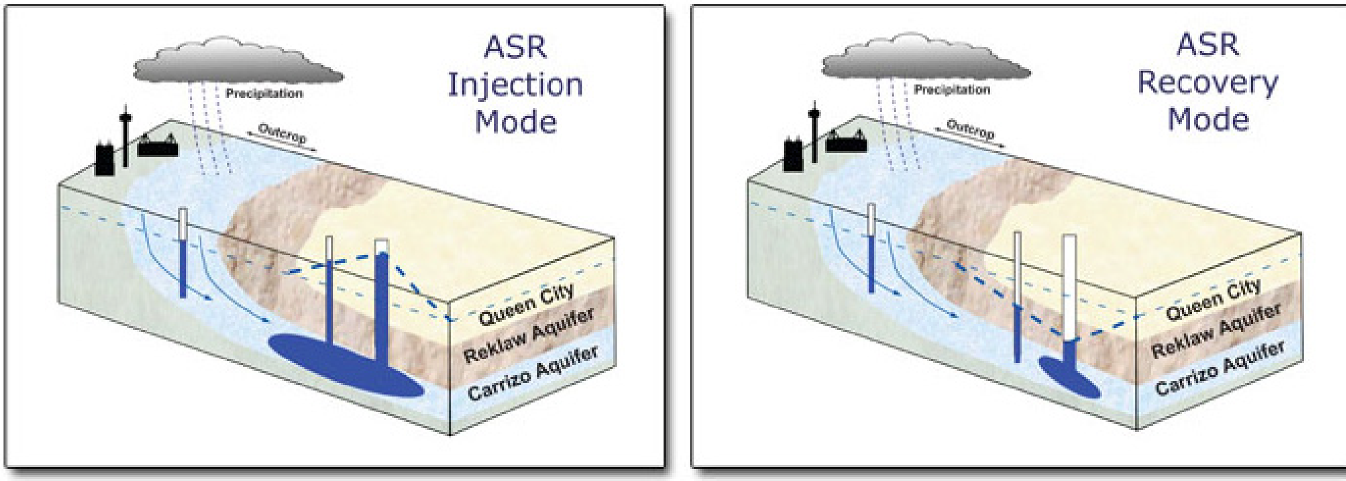
There are two general types of treatment: 1) membrane technologies and 2) thermal technologies. Membrane technologies include electrodialysis, electrodialysis reversal, nanofiltration, and reverse osmosis. Reverse osmosis requires significant pre-treatment to remove silt and solids. Thermal technologies include multiple-effect distillation, mechanical vapor compression, and recompression. All these technologies involve heating and evaporating the feed water followed by condensation of pure water.

Considering the large amounts of produced water generated where freshwater is scarce, produced water may represent a new, currently untapped water supply for specific uses, such as irrigation. For example, the Texas Produced Water Consortium (2022) has estimated that 256,000 acre-feet per year of produced water may be recoverable for treatment and beneficial use. Much of this water would be generated in the Region F water planning area, which is the West Texas region that has a projected annual water shortage of 102,000 acre-feet by 2070 (Texas Water Development Board, 2021). Most of this shortage is connected to irrigation use. Various treatment technologies being evaluated might be economically applied to address this projected shortage. Ultimately, using excess produced water to meet actual and projected water supply shortfalls for irrigation would require that the treatment technologies be economically feasible for agriculture. The "willingness to pay" costs of irrigation water are estimated to range between $227 and $347 per acre-foot (WestWater Research, 2024). In contrast, municipalities are generally willing to pay over $3,000 per acre-foot for water.

Any widespread use of treated produced water to help mitigate water shortages will be expensive to both treat to acceptable standards and transport to points of need. In 2023, the 88th Texas Legislature recognized the potential application of produced water to help alleviate water shortages by passing legislation to create a funding mechanism for such water projects. This legislation created Proposition 6, which voters approved by a wide margin in November 2023 to establish the Texas Water Fund with $1 billion in funding. Proposition 6 also dedicated $250 million to the new water supply for Texas Fund,

Figure 21

H2Oaks Wells Used to Both Inject or Extract Water Stored in the Carrizo Aquifer



Note. From Eckhardt, n.d.-a (https://edwardsaquifer.net/asr.html).

which will support the development of new water sources, including produced water treatment projects and the development of infrastructure to transport water made available by these projects (Texas Water Development Board, 2024).

Aquifer Storage and Recovery

In 2020, aquifers supplied 55% of water used in Texas (Texas Water Development Board, n.d.-e). The heavy reliance on aquifers brought about a new era of water challenges when aquifers' pumping rates began to surpass the rate of recharge. One solution, aquifer storage and recovery (ASR), is the process of capturing water in times of water excess to then store within an aquifer to later be recovered when needed (Texas Water Code, Section 27.151). **Figure 21** illustrates the basic operations of the San Antonio Water System's (SAWS) H2Oaks ASR facility, the largest ASR operation in Texas. ASRs are likely to be used in areas that already are experiencing a heavy reliance on groundwater and increasing population. The three ASRs in Texas in 2024 include:

1. **The City of San Antonio**, which injects 60 million gallons per day (mgd) from the Edwards Aquifer into injected 400 to 600 feet into the Carrizo Aquifer.
2. **The City of El Paso**, which injects 10 mgd of treated wastewater into aquifers 300 to 835 feet below the ground.
3. **The City of Kerrville**, which injects 2.5 mgd of water from the Guadalupe River is injected into wells 500-600 feet deep.

Managed aquifer recharge, also known as artificial recharge, artificial aquifer recharge, or artificial recharge and recovery, are similar in premise of ASRs but have different objectives. ASRs are different because instead of managed recharge of one aquifer, an ASR will carefully extract water, usually from one aquifer and often during wet seasons, and inject excess water into a separate aquifer.

The ASR components include the subsurface aquifer storage system, recharge facilities, extraction facilities, and the source water (**Figure 21**). An aquifer storage system is the storage site where the water will be held until it is ready to be extracted, usually during a drought. The recharge facilities then focus on recharging the aquifer. Typical methods include injection wells (a pipe system that pumps water into the storage aquifer) or infiltration basins that direct the water to the designated area (EPA, 2024). These four systems, when working in unison, can mitigate periods of floods and droughts, restore aquifers, and decrease reliance on one water source . Since an ASR is not the water source itself, to develop an ASR system, an original source water is required. The first step in assessing a suitable site for ASR projects is determining an excess water source that can supply the stored water. Whether surface water, groundwater, reclaimed water, or harvested water, all sources of water have been used within an ASR project (Texas Water Development Board, n.d.-e).

The biggest advantage to ASRs is that underground storage of water can protect stored water from contamination and evaporation. From an environmental perspective, ASRs also offer a massive reservoir without condemning any land or property at the surface (Eckhardt, n.d.-a). The H2Oaks facility is an example of the success of operating an ASR facility while still allowing the original landowners to continue using the property. SAWS operates one of the biggest ASR facilities in the United States. Several different locations and aquifers were considered prior to the final decision of the current site of the ASR. The ultimate siting decision of the Carrizo-Wilcox Aquifer was made in 2004 based off several factors, including topographical features, transmission costs, and project development needs. The facility is located south of San Antonio where wet months offer excess water that the facility can collect from the Edwards Aquifer to be treated to drinking water standards and then injected in the Carrizo-Wilcox aquifer on the property. The system is made up of 29 ASR wells, and seven Carrizo-Wilcox aquifer pumping wells, all of which can reverse circulate the process to either pump or inject water.

Siting of ASR Facilities

However, ASRs are not without challenges, including degradation of water quality while in storage, the ability to physically recover stored water, and land acquisition costs. In 2019, the Texas Legislature enacted HB 721 (2019) which conducted an analysis that would determine suitable aquifers for ASR projects. It is a complex process in determining if a site is feasible for an ASR facility. Factors include proximity to a water supply, permeable soil, aquifer with sand, silt, or clay, and even an ideal gradient of topography. **Figure 22** illustrates the locations of existing and proposed ASR projects.

Water Treatment Processes and Technology

Whether desalination, ASR, or produced water treatment, specific technology—membrane or thermal—is required to treat water to drinking water standards.

Membrane Technology

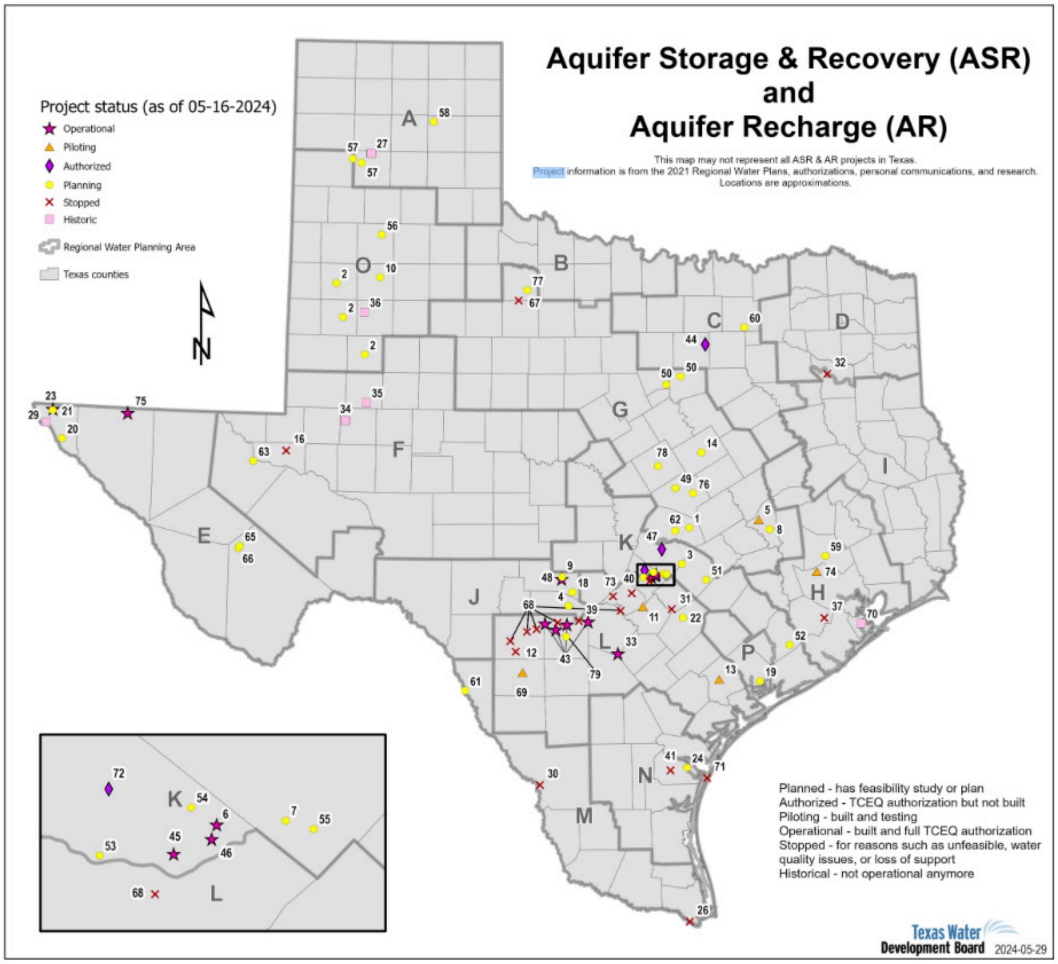
Membrane technologies make up the most popular methods in water treatment technology primarily due to the lower costs and energy requirements. The different membrane treatments are defined by the membrane material and the applied force used in the process. For example, reverse osmosis (RO) uses hydraulic pressure to overcome the natural osmotic pressure of water and pass water through a semi-permeable membrane and fresh water will flow through as solutes are rejected (Krishna, n.d.). While energy may be required for applying hydraulic pressure for RO, the natural pressure per square inch of brackish water is around six times the amount of standard water found in a home, which offsets some of the energy needs for this technology (Scavetta, n.d.).

Nanofiltration (NF) is also a type of membrane treatment technology and is like RO as both use pressure to pass water through membranes. Nanofiltration can filter nearly all microbes and organic matter other than dissolved compounds that RO can remove. While RO removes 99.9% of all minerals, this also removes healthy minerals that are added back to water. Nanofiltration has selectivity abilities in the compounds rejected, allowing for a greater recovery ratio (Safe Drinking Water Foundation, n.d.).

Furthermore, electrodialysis (ED) utilizes the existing charge of the source water and voltage to remove solute in water. Depending on whether the existing ions in water are positively or negatively charged (*e.g.*, sodium (+) and chloride (-)), voltage is

Figure 22

Map of Existing and Proposed ASR Projects



Note. From the Texas Water Development Board, n.d.-h (https://www.twdb.texas.gov/innovativewater/asr/index.asp).

applied and electrically charges the system causing dissolved ions to migrate to opposite electrodes, only allowing certain ions to pass through (Rana et al., 2024).

Thermal Technology

Thermal technology is a process that uses heat to collect vapor as condensation, also known as distillation. It has higher costs and energy demands than membrane technology. There are two major types of thermal technologies commonly used. The first type, multi-Stage Flash Distillation (MSF), is the most used thermal water treatment technology. Due to saline solutions MSF heats the source water to near boiling and feeds water into multiple stages of "flash" chambers where each following chamber has a lower pressure than the previous. As near boiling water enters the first chamber and pressure is released, this causes rapid evaporation or known as "flashing," and this water is collected as condensate through each stage (Krishna, n.d.). The second type, multi-effect flash distillation (MED), involves utilizing the principles of evaporation and condensation. The boiling point of water decreases as pressure decreases. So, MED involves a series of vessels that create a low-pressure system that produces water through evaporation effects. As water passes through the first system, the residual heat is used for the next vessel. The more vessel stages there are, the higher the recovery ratio of the system (Krishna, n.d.).

ELECTRICITY GENERATION REQUIRES DEPENDABLE WATER SUPPLIES

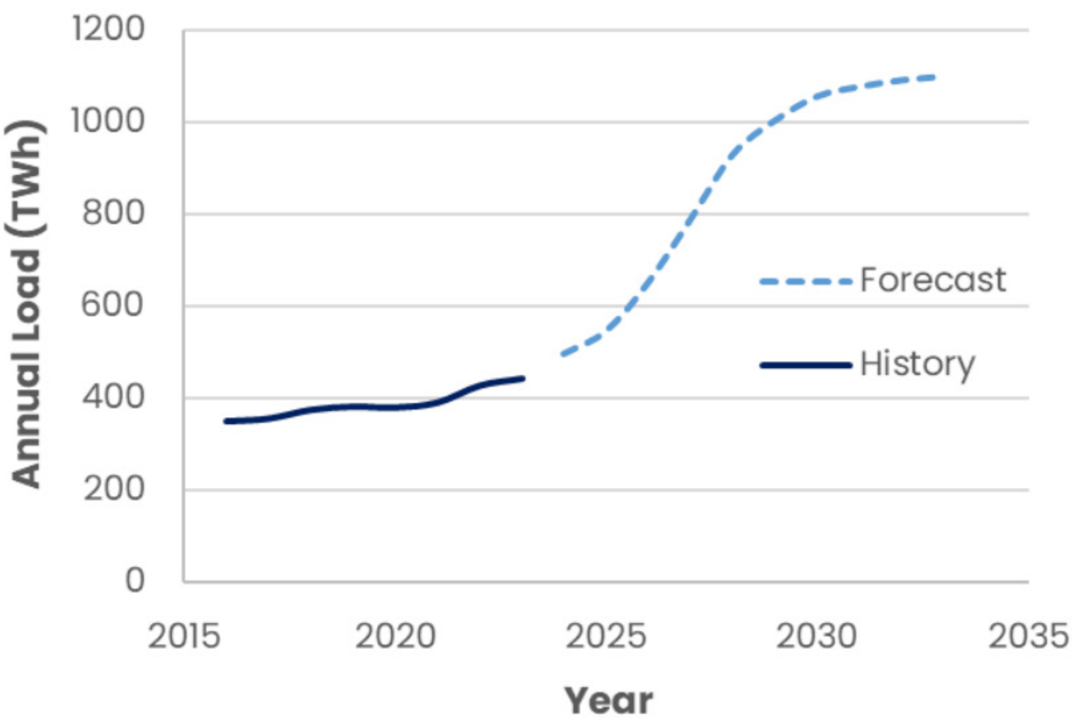
Water and electricity are linked. It takes electricity to operate pumping stations to move water from sources to points of need. And it takes water—lots of it—to produce electricity (primarily for cooling operations) from steam electric power plants. Until recently, the conversation regarding electricity and water has been completely disjointed. The electricity sector focused on methods to meet current and future demands whereas the water sector centralized efforts on properly allocating existing resources to meet current and future needs. The luxury of an undivided focus on either electricity or water no longer exists. The strategy for meeting the demands of one sector requires harmonizing with the strategy of the other. As the population of Texas grows, the demand for electricity and water grows. However, these demands are not simply to satisfy municipal growth; they are also driven in part by forecasts for significant demands for large electricity and water-hungry digital data centers and other industrial complexes being located in the state. Yet the 2022 State Water Plan does not project a significant increase in demand for water to meet the needs of electricity generation over the next five decades (Texas Water Development Board, 2021). In contrast, the Electric Reliability Council of Texas (ERCOT) forecasts that demand for energy is expected to double from 2023 to 2029, see **figure 23** (ERCOT, 2024, p. 4). Regional water plans due in 2026 that are currently in development may reveal an increased demand for water to satisfy the growth of the electric power generation .

Recent droughts have exposed the vulnerabilities of steam-powered generating facilities to shortages of water. For example, in 2014 and 2015, the R.W. Miller generating station on Lake Palo Pinto was temporarily shut down due to low lake levels (Collins, 2024). Furthermore, ERCOT noted that in the hot summer of 2023, the electricity grid could have been vulnerable to curtailments if drought conditions had persisted in reducing critical water supplies to power generating facilities (Collins, 2024).

Whether sourcing or transporting water, the technology is energy intensive. At the same time, to produce energy, consistent and uninterruptable water sources are required to operate. Water sources, specifically, are huge restraints in planning, designing, and constructing energy systems. Now more than ever, there is a real potential hindrance to Texas' growth. Not only are water demands a deterrent to community growth at the most basic level, but they are also a major consideration in whether to finance electricity generation and build out infrastructure. Looking at the long term, decision-makers, businesses, and communities will face competing water needs ranging from powerplant cooling to drinking water for growing communities. Producing energy requires water, and this water-for-energy side of the nexus is well understood. As new, energy-intensive technologies arise to treat water on larger scales, the other side of the nexus, energy-for-water, is receiving attention. Across Texas municipal water facilities' largest expense is the energy costs. The range varies, but drinking water and wastewater facilities can account for 30-40% of total energy consumption of energy consumed (EPA, 2024).

For example, the Tarrant Regional Water District (TRWD) supplies water to over 30 wholesale customers covering 11 counties and is one of the largest water suppliers in North Texas. Even at this economy of scale, nearly 40% of the operating costs were energy related (North Central Texas Council of Governments, 2019). Energy-related costs reflect the costs of operating pump stations, valves, reservoir balancing equipment, and any chemical treatment systems. Within the 11 counties, TRWD operated over 100 facilities with operating costs ranging from $15 million during wet seasons to $30 million during drought periods, the latter becoming the norm in recent years. The average annual energy costs were calculated at $29 million and this accounted for nearly 90% of overall energy consumption in the area (Tarrant Regional Water District, 2020).

Figure 23
Historical and Forecasted ERCOT Annual Load



Note. Data from 2024 ERCOT System Planning Long-Term Hourly Peak Demand and Energy Forecast, Electric Reliability Council of Texas, 2024 (https://www.ercot.com/files/docs/2024/01/18/2024_LTLF_Report.docx).

POLICY CONSIDERATIONS

Water supply policy addresses the types and locations of water resources; the current and projected water demands; the regional needs and challenges that agricultural, municipal, and industrial users face; and the legal frameworks that govern extraction and delivery of water from source to customer. These water policy considerations stem from the concept of resource stewardship—that is, policies that protect water resources that make Texas a desirable and attractive place to live, that promote the development of water supplies that ensure that drinking water, irrigation water, and industrial uses are met now and in the future, and that ensure that the fundamental rights of property owners and consumers are protected and safeguarded now and in the future.

Texas' existing water supplies are projected to decline by about 18% by 2070—from 16.8 million to 13.8 million acre-feet per year. The state water plan depends heavily on conservation (29%, or 2.2 million acre-feet per year, recommended water management strategies by 2070) and legal and contractual mechanisms to access available water to meet the state's water needs. To implement the 2,400 water management strategy projects by 2070, the projected cost totals $80 billion based on prices in 2018. If Texas fails to implement those projects, the Texas Water Development Board has estimated that there will be $153 billion in economic losses during a severe drought (Texas Water Development Board, 2021). As noted above, the state water plan depends heavily on conservation and the use of legal and contractual mechanisms to access available water to meet the state's water needs. While these are necessary and important, relatively few major projects have been proposed to generate new water supplies.

Still, there are workable options to inform sound water policy to address water supply needs for the state.

First, generating new water supply is the highest priority, but Texas must also recognize that we need to protect the flowing rivers and springs that contribute to the quality of life and make Texas an attractive place to live and work. Second, Texas' reliance on groundwater pumping to meet municipal needs should decrease as aquifers are being depleted and are very slow to recover. Examples include decreasing groundwater pumping to mitigate land subsidence or to preserve springflow, which is necessary to sustain rivers, tourism, and ensure future economic viability of certain areas. Third, private property rights related to groundwater need to be honored. Finally, while use of water for electric power generation is projected to be much smaller than agricultural or municipal needs, the assumptions for water use by power generators should be verified to ensure that adequate resources are identified to meet the rapidly increasing needs for electricity in Texas.

New Water Supply

Ultimately, Texas needs more water. Conservation measures and demand management of existing water resources are critical components of the plan for water security during drought, but those alone are not enough. By 2070, the 2022 State Water Plan projects that the state will need an additional 1.5 million acre-feet of water per year (a 9% increase from 2020) during a severe drought. However, this projection is not a complete picture: municipal demand is expected to increase by 3.5 million acre-feet per year while agricultural demand decreases. New sources of water (i.e., from desalination, produced water, aquifer storage and recovery) are projected by regional planning groups to provide a very small percentage of new water supplies (Texas Water Development Board, 2021). These strategies presented by the regional water planning groups need to be re-evaluated in future planning cycles, given the significant progress now being made to make these sources more attractive and economically feasible. New water supplies will also come from the expansion of these proven technologies on a much larger scale than currently used. Generating new water supplies will also require a re-thinking of some existing practices that inhibit the movement of water from areas of water surplus to areas of water deficit.

Financing

Water is expensive, and large projects are required to develop new water supplies and move that water to places in need. To tackle future water supply needs, Texas policymakers need to determine whether and how to finance these projects. The Foundation supports the judicious use of public funds via the New Water Supply Fund (approved by Texas voters in November 2023) and the SWIFT program to expedite the development of new water supplies. These new water supply projects should have the highest priority. Furthermore, projects funded via loans will generate a revenue stream capable of funding additional projects. However, state funding is not and should not be the only funding source as private-public partnerships have already been implemented. Texas regulatory agencies should provide streamlined regulatory approval so that these projects that involve non-traditional approaches can successfully bring water to consumers.

The use of state funds for water projects must be accompanied by metrics related to accountability and transparency that focus on the actual benefits achieved. For example, what is the expected unit cost of the volume of water generated (i.e., dollars per acre-foot delivered)? Other issues to be explored could include the degree to which new projects are developing new water sources or simply replacing existing supplies.

Conservation and Aging Infrastructure

Water conservation is a common-sense component of the water supply picture in Texas. The State Water Plan estimates that over the next 50 years municipal and agricultural water conservation strategies will save an estimated 2.2 million acre-feet of water per year, representing about 29% of the water management strategies in the Plan. There has been meaningful progress in municipal and agricultural conservation, including addressing aging infrastructure and repairing and replacing leaking pipes and inefficient plumbing (Water Conservation Advisory Council, 2022). The TWDB has published a list of prioritized water loss mitigation projects, totaling approximately $481 million, and focuses on small- and medium-sized and rural communities that will be prioritized for financial support from the Texas Water Fund. Continued efforts on conservation should be motivated by economic incentives and public education as the priority rather than government mandates.

Movement of Water

Throughout history, great civilizations have moved water. Even today, surface water transport across basin boundaries is routine in other states and should happen in Texas. River basins in East Texas have water availability that exceeds anticipated demands, and with willing customers in other areas of Texas, this method should be a strategy to address future needs. Those entities with surface water rights in the source basins should be appropriately compensated according to the market value of the water. Implementing market-driven solutions to surface water allocation can reduce pressure on local groundwater resources in drier, faster-growing areas in other parts of the state. Trans-regional transport of groundwater and surface water will continue to be needed to ensure there is sufficient water to sustain and grow economically. Other than costs, there are few physical impediments to implementation for groundwater as its transfer on a large scale is already taking place. Landowners are compensated for the sale of their groundwater while those who share common aquifers will need to be protected through mitigation programs to ensure that all have access to water. Surface water transport faces more legal and regulatory headwinds, and it will require both legislative action and political will to move water across basin boundaries.

Water Markets

Water markets need transport infrastructure to fully develop and create an optimal value of water for suppliers and consumers. Markets should be encouraged to ensure that water is appropriately valued. It has often been undervalued, which discourages conservation and underfunds needed infrastructure. Texas' water laws should be reformed to remove current legal barriers that discourage the development of private water markets. Texas law should not impede private investment in water supply projects, hamper voluntary transfers of water, block inter-basin transfers, or bureaucratize approval of water right amendments. Instead, Texas water law should be updated to embrace free market transactions that have been incorporated into other Texas statutes governing markets such as electricity, telecommunications, and insurance.

Desalination

Brackish groundwater is abundant. The TWDB estimates that about 3.2 billion acre-feet of brackish groundwater (less than 10,000 parts per million total dissolved solids) occurs in Texas. While that storage estimate does not represent the volume of brackish groundwater that can be produced, it is nevertheless a substantial resource. Due to advances in the cost of recovery and treatment of brackish groundwater, this resource is a good option for larger consumers such as water supply corporations, municipalities, and industry. Depending on the quality of the source water, the disposal of treatment residuals (either via a brine line to the deep waters of the Gulf or that line and a combination of industrial uses that could derive value from the separated minerals) is likely to be the biggest impediment to large-scale implementation. Site-specific studies will be required, and groundwater conservation districts need to implement reasonable regulatory approaches to encourage the use of this resource.

Produced Water

Produced water may represent a new, untapped water supply for some uses. The Texas Produced Water Consortium (2022) has estimated that 256,000 acre-feet of produced water may be recoverable for treatment and beneficial use. Much of this water would be generated in the Region F water planning area—the West Texas area that has a projected water shortage that increases to 102,000 acre-feet by 2070. Unfortunately, the regional plans and the 2022 State Water Plan ignore produced water as a possible water management strategy. Considering that the options for management of produced water—particularly subsurface disposal—are being limited, the possibility of using excess produced water to meet actual and projected shortfalls is very attractive. The Foundation is encouraged by the initiatives of the Texas Produced Water Consortium and various companies engaged in research and application of water treatment and transport options.

Three converging developments—excess produced water, regional water shortages, and state-backed financing that prioritizes treatment and transport of produced water—favor a serious effort to make produced water a potential supply to mitigate some water shortages in West Texas. Produced water is both an asset and a waste, requiring a combination of the above strategies and innovations to approach how Texas should best manage the resources to ensure the continuing success of the Texas oil industry. The Foundation supports and encourages the combination of industry, academia, and state resources that will cooperate to make produced water an asset that benefits Texans.

Aquifer Storage and Recovery

Aquifer storage and recovery does not generate "new water" but is an attractive option for addressing drought challenges when other approaches, such as surface reservoirs, are unavailable or too costly. Aquifer storage and recovery demonstrates technology that is working well in Texas. One challenge is finding suitable subsurface conditions and working within the regulatory framework of the local groundwater conservation districts.

CONCLUSION

Water is essential to support Texas' growing population and a $2.1 trillion economy. Yet securing needed water supplies is complicated by two simple facts: surface water (i.e., rivers, streams, and lakes) is owned by the state of Texas, while groundwater (i.e., underground aquifers) is owned by landowners and is a property right. These two ownership modes complicate Texas' capacity to balance multiple water needs to maintain secure and sustainable water resources, promote economic prosperity and growth, protect private property rights, and ensure that Texas remains a desirable and attractive place to live. These are tall but very achievable orders. Cities, farms, and industry need water—lots of it—and must plan and work together with state policymakers to ensure that Texas continues to succeed.

Investing in statewide water solutions, supported by both public and private funding, will ensure that Texas has the resources to address immediate water shortages and plan for future needs. These investments will also create the foundation for supporting and sustaining the growth of Texas' economy while improving the resilience of the state's water systems against challenges such as drought and population growth. A true dynamic approach is needed by the Legislature so that the state works alongside regional groups to ensure planning works collaboratively throughout Texas. Texas should promote and embrace the innovative water solutions available and foster public-private partnerships to build out these projects. Having a keen focus on making the proper infrastructure upgrades will instill a sense of urgency and support by the Legislature so that municipalities can have access to the foundation to build out the required water resources to meet demands. ■

Decades-Long West Texas Water War

Challenges in depleting water supply existed in Texas well before the regained interest in addressing water demands became a top priority issue for the Legislature in the last few years. Originating in the 1950s, a small, rural town in Texas began a fight that would eventually unfold over the last decade. The fight erupted over a family's ability to pump water from their property in Fort Stockton and sell it to Midland-Odessa. The Williams family and the small town of Fort Stockton, ensued what many refer to as the decades long "water war."

West Texas is known for periods of oil booms and 2019 brought about another rapid economic boom (Collier, 2018). This time, on a larger scale than any oil boom prior, the Midland-Odessa area was referred to by *The Wall Street Journal* as having the fastest job and labor-force growth rates compared to the rest of the nation (Matthews & Elliott, 2019). The unemployment rate fell to 2%, almost half of a record-low national unemployment rate of 3.6% (Isidore, 2019; Tappe, 2019). When the market shifted and prices for oil dipped, the unemployment rate in Midland was still competitive. In any market, there is a variable that eventually brings climbing expansion to a halt. In the oil industry, it can be water. The Midland-Odessa region relied heavily on the Permian Basin and the outlook was not bright as water usage was quickly outpacing supply from the Colorado River reservoirs. Clayton Williams sought to supply this critical water resource from his property, sitting atop a portion of the Edwards-Trinity Aquifer, and sell it to the Midland-Odessa region to support the industry (Aguilar, 2010a).

It was an understood concept by Texas landowners that if you own the land, you own the rights to the water below it. The Williams family's 18,000 acre-ft property in Fort Stockton sat atop multiple large aquifers. In accordance with Texas groundwater law, the Williams family had the right to pump water and use it for any purpose they sought fit. However, the rule of capture was contested in this case. This first began in 1951, when the Pecos County Water Control and Improvement District filed a lawsuit against Williams. Three years later, in 1954, an appeals court ruled that the rule of capture would be upheld. This allowed the Williams family to pump up to 47,418 acre-feet of water from the aquifer annually based on historic permits. In 2010, the Williams family sought to expand their permit to allow for broader use cases. Previously, water was only allowed for use in irrigation, the new permit would allow for use of water for transport and sale (Beauvais, 2017). Based on the Texas Supreme Court ruling in *Guitar Holding Company v. Hudspeth County Underground Water Conservation District* (2008), amending a pre-existing permit causes the permit to lose its priority or potentially face forfeiture. This ignited a series of legal battles spanning over the years. Arguments made in opposition to the expanded permit application involved the recharge capabilities of the aquifer while taking into consideration the neighboring communities who rely on their wells to support themselves. Williams believed that the water could be used for a variety of uses. Williams claimed that water stunted growth if restricted or limited to one purpose or one region (Beauvais, 2017). The main argument made by the Williams family is that Fort Stockton Holdings (FHS) was not requesting to pump more water, but rather to expand the allowable uses of the water. The family already obtained the permit to pump the water (Aguilar, 2010b).

Fast forward another decade, the case remains the same for West Texas cities. There was and still is a perpetual search for resolving the challenge of limited water availability and growing demand. For nearly ten years, council members in Midland have been seeking a solution that can be integrated into the 100-year water plan (Fortunato, 2024). In 2020, Midland, Abilene, and San Angelo were able to acquire a contract with FHS, owned by the Williams' family. The public announcement made in 2020 broadcasts a new timeline for the future that involves a series of phases that determine what this water acquisition will look like for each of these three cities (NewsWest 9, 2024). There is still a long road ahead until residents in Midland, Abilene, or San Angelo will be drinking water owned by the Williams family. In the latest update as of 2024, news sources reported that the cities are in the process of the beginning phases of constructing test wells and infrastructure planning (Fortunato, 2024). The debate continues, primarily on a case-by-case basis, on whether it is sound policy to transport and move private water resources across the state. It is to be expected that this conversation will be more frequent when the price for transported water becomes more comparable to other methods of water sourcing.

Edward's Aquifer: Journey from Federal Intervention to Local Management

Known as the home of the Alamo, South Texas represents the strive for independence and ultimately, what it means to be Texan. This essence carries into the grit of a group of Texans who face the reality of their water being overseen by someone other than those closest to it.

Located 650 feet below the surface of San Antonio is the Edwards Aquifer (Patoski, n.d.). Edwards Aquifer supplies irrigation to farmers as well as the drinking water for over two million people (The Nature Conservancy, n.d.). Like the majority of Texas, groundwater pumping was guided by the "rule of capture" and surface water was regulated by the state. The Edwards Aquifer was no different. Meeting population needs as a city rapidly grows is a significant factor in the aquifer's management. There was a complex hydrologic connection between the Nueces, River, Comal, and San Marcos Springs. The Nueces River basin was responsible for recharging the Edwards Aquifer that would then feed into the Comal and San Marcos springs. This interconnection meant that the water passes through multiple jurisdictions of unregulated to regulated, naturally creating a complex issue in managing water users with access to different water sources (Votteler, 2023).

The Edwards Aquifer was regarded as one of the most diverse groundwater ecosystems in the world, as a habitat for 35 to 40 species (Longley, 1981). Between the Comal and San Marcos discharge points, six species were listed as endangered, one species listed as extinct, and three deemed as warranted for listing (Votteler, 2023). In 1991, the Sierra Club joined with Professor Clark Hubbs, a zoology professor at the University of Texas at Austin, to file an Endangered Species Act (ESA) lawsuit in the U.S District Court in Midland, Texas. The Sierra Club filed against the Secretary of the Interior and the United States Fish and Wildlife Services (USFWS). The suit alleged that the USFWS did not adequately ensure water levels in the aquifer that determined the state of the Comal and San Marcos habitats, placing endangered species in jeopardy. The language in the lawsuit stated that the withdrawals of the Edwards Aquifer caused "takings" of species under the ESA. Under the ESA, the term "take" is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (16 U.S.C. § 1532(19)). As water was being pumped from the aquifer, the flow of surface water to springs was reduced, increasing the threat to species already listed. The Sierra Club garnered the support of like-minded parties, such as the Guadulupe-Blanco River Authority (GBRA), who joined in pursuant of the goal to protect surface water. In 1993, the district court ruled in favor of the plaintiff and required the USFWS to create a minimum spring discharge requirement. Additionally, it was ruled that under the circumstances that the Texas Legislature did not establish a plan to minimize pumping from the aquifer by the close of the next session, the Sierra Club and associated parties could require additional relief.

Texas now faced the reality of legal takeover by the federal government if the aquifer dispute was not adequately addressed by the state. By May 30, 1993, the Texas Legislature established the Edwards Aquifer Authority (EAA). The EAA was created to act as a political subdivision of the state and exist as a regional agency. The main purpose of the EAA was to regulate groundwater withdrawals and ensure minimum flow requirements required by federal law. This was done through a transition away from the previously held "rule of capture" system to now incorporate a permit-based system that acknowledged historic trends of groundwater use amongst the eight incorporated counties using the Edwards Aquifer. The EAA Act went into effect in 1996, after years of delays on the debate of constitutionality. The permits were issued based on the hybrid approach and after groundwater pumping right permits were issued, totaling 549,000 acre-feet, the EAA was still above the required 400,000 acre-feet withdrawal limits. The Texas Legislature sought to add an amendment that would then require the EAA to meet the permitted withdrawal requirement by 2008. By 2007, there was still a real threat of another ESA litigation battle. In 2006, USFWS Director Dave Hall met with the GBRA General Manager Bill West. West consulted with USFWS senior staff to develop a recovery implementation program (RIP). Stakeholders of the Edwards Aquifer were encouraged to participate in the voluntary RIP program. The stakeholders would create a comprehensive plan highlighting activities, timelines, and measures of success with the go being to find the balance of water use and federal ESA requirements. Texas Legislature urged stakeholders to enter an RIP as the last opportunity to create a compromise to maintain the aquifers management. In 2007, the Texas Legislature passed SB 3, raising the withdrawal requirement to 572,000 acre-feet to avoid the risk of cutting off rights, and directed state, municipal, and the EAA to participate in the Edwards Aquifer Recovery Implementation Program (RECON Environmental, Inc. et al., 2012). Early in the process, it was clear that no decisions would be made until every issue was addressed. A steering committee, constituted of 26 environmental, water authority, and other agency interests, was established by SB 3 and hosted monthly meetings. In between meetings, workshops were held for stakeholders to analyze issues and provide recommended solutions.

Through the multi-year process, EARIP established the Edwards Aquifer Habitat Conservation Program (EAHCP). In March 2013, the EAHCP went into effect, resolving and effectively mitigating complex issues that regulatory frameworks were unable to in past. The EAA Act successes are largely attributed to the bottom-up approach, where stakeholders are engaged and actively participating in the decision-making processes. Edwards Aquifer serves as an example of a process that resulted in an effective long-term solution through active stakeholders, not the pure dictates of the federal government.

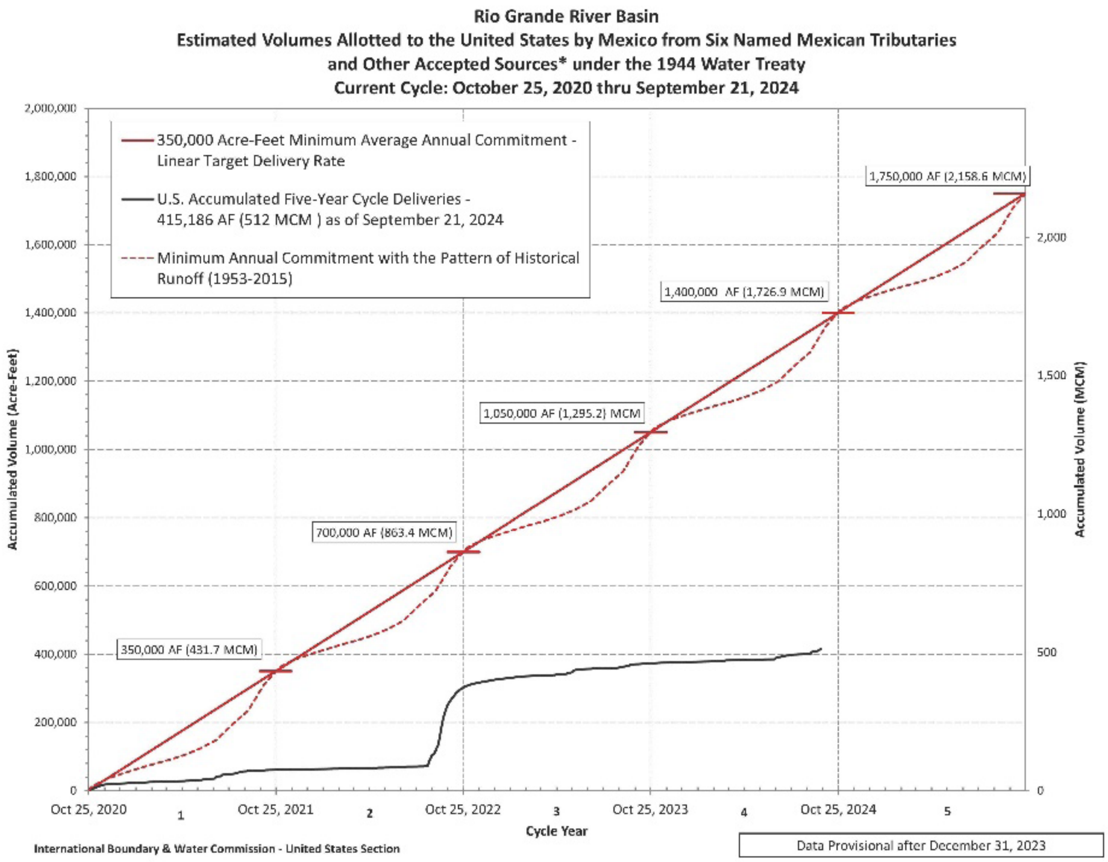
State of Emergency for South Texas

The United States and Mexico share the Amistad and Falcon reservoirs, a part of the Rio Grande River basin. To serve the interests of both Mexico and the United States, the 1944 treaty sought to reach an agreement in how to manage the Rio Grande and Colorado River. The treaty was and still is considered one of the world's leading examples of binational cooperation in management of transboundary water resources. This is complex due to incorporating multiple basins within one treaty. Due to the co-existence of three rivers—the Rio Grande, Colorado, and Tijuana Rivers—the treaty could be seen as three treaties combined into one. Of note, the treaty requires Mexico to provide 1,750,00 acre-feet of water from the Rio Grande over a five-year cycle. In exchange, the United States provides 1.5 million acre-feet from the Colorado River. The U.S consistently meets this obligation while Mexico is consistently falling well below the average 350,000 acre-feet per year annually. The International Boundary & Water Commission (IBWC), who oversee treaties between the United States and Mexico, reported that the Mexico is 700,000 acre-feet behind on its deliveries to the U.S. In **Figure 16**, trends assume that Mexico will not be able to fulfill the deliveries by the end of the current five-year cycle.

This is not going unfelt by residents who rely on this water for agriculture operations. South Texas is requesting to declare the water shortage occurring in the Rio Grande as a state of disaster for the region. In February 2024, a 51-year-old sugar mill closed, and 500 workers lost their jobs. The closure of the Lone Star Sugar Mill, only one of three nationally, is a major hit for the sugarcane industry in the United States. The sugar mill was one of the largest employers in the district and this closure precedes a

Figure 23

Water Deliveries to the United States from Mexico



Note. From the International Boundary & Water Commission, 2024 (https://ibwcsftpstg.blob.core.windows.net/wad/WeeklyReports/Current_Cycle.pdf).

trend of more industry closures that is forecasted to come if South Texas does not secure a water source.

Historic lows of reservoirs combined with the unfulfillment of the 1944 U.S.-Mexico water treaty is forcing Rio Grande Valley into a water crisis and causing the region to enact drought contingency plans. As summer ends, Texas' residents remain amidst a water crisis that only continues to worsen. In May 2024, Governor Abbott amended a drought disaster declaration constituting 38 counties listed under the threat of imminent disaster due to the conditions (Office of Governor Greg Abbott, 2024). The Texas Farm Bureau interviewed Tudor Uhlhorn, a sugar mill operator in the Rio Grande Valley, where he stated, "if Mexico had delivered water like they're supposed to, we wouldn't be standing here today, I'd be raising sugarcane and the mill would be operating normally" (Texas Farm Bureau, 2024).

As tensions rise in South Texas, this issue also comes at a time of tenuous relations with Mexico, predominately due to the Texas-Mexico border. This is not the first time Mexico has fell behind on water deliveries and according to Rio Grande Valley farmers—indeed, this has been happening for decades (Rio Grande Valley Sugar Growers, 2024).

The solution here is multifaceted. There is no expectation as to when Mexico will be able to deliver this water supply. At the federal level, action has been taken to withhold USAID or prohibiting U.S. trade and Development Agency funds to Mexico. While federal actions apply pressure on Mexico to determine a solution to fulfill water requirements, Texas needs to find creative solutions to address its current and future water needs—as Texas has often done, on its own.

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