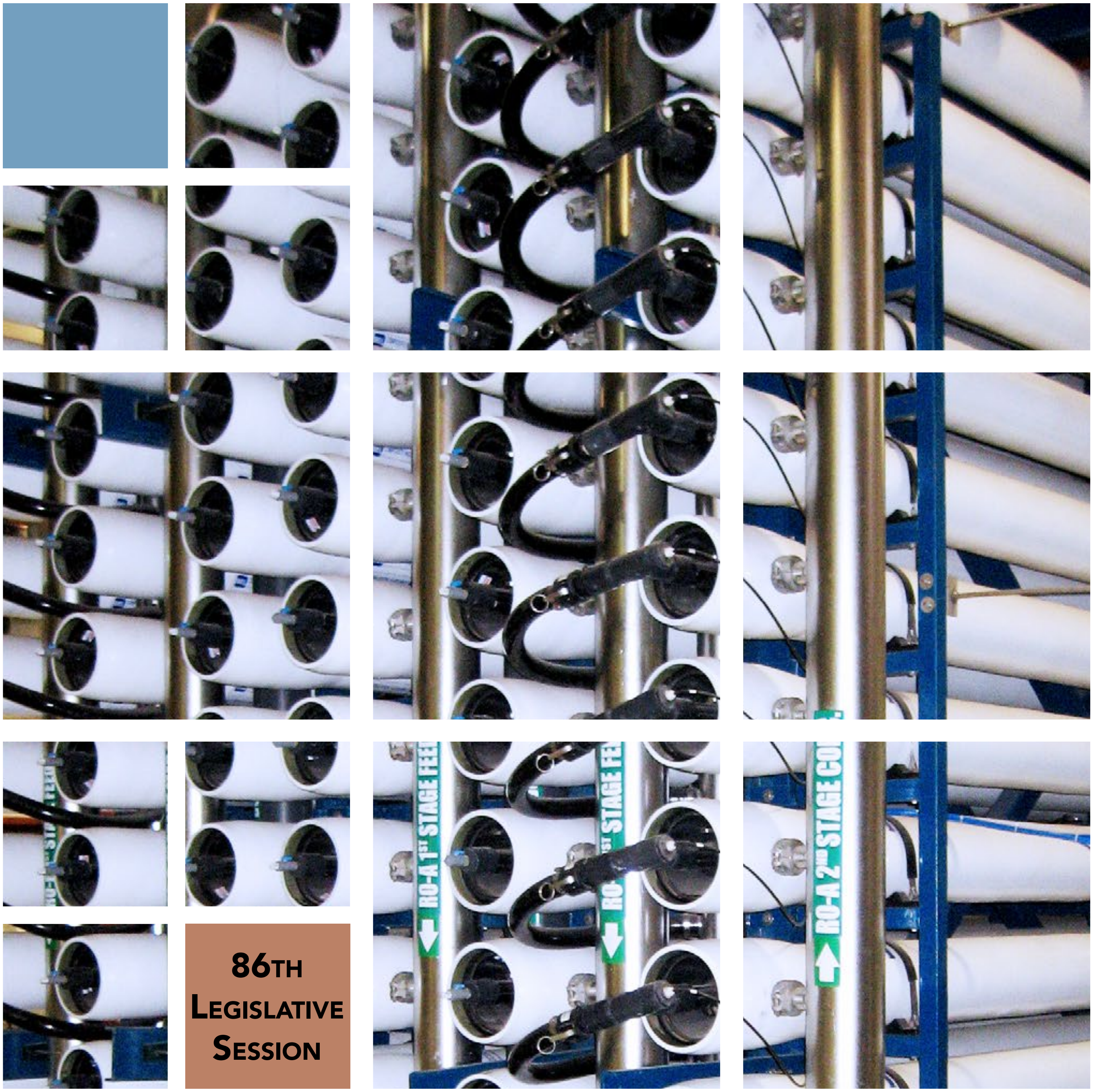
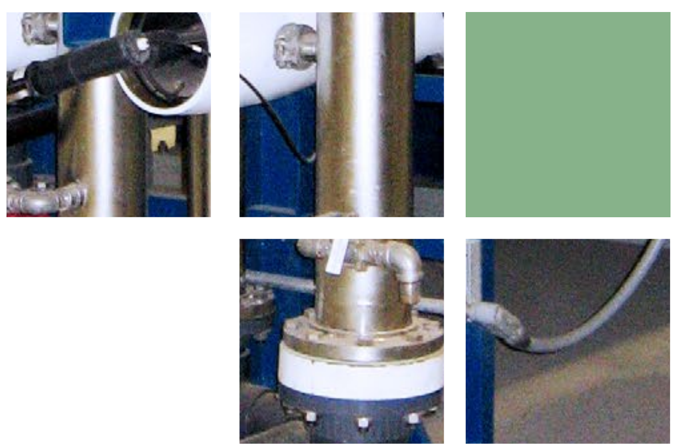


86th Legislative Session

The Future of Desalination in Texas



2018 Biennial Report on Seawater and Brackish Groundwater Desalination

Texas Water Development Board

The Future of Desalination in Texas

2018 Biennial Report to the 86th Texas Legislature on Seawater and Brackish Groundwater Desalination

Peter M. Lake, Chairman

Kathleen Jackson, Member

Brook T. Paup, Member

Jeff Walker, Executive Administrator

December 1, 2018

Texas Water Development Board

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Executive summary

Desalination is the process of removing dissolved solids and other minerals from saline water sources, which can include brackish groundwater and seawater. This important technology is used all around the world to produce new water supplies. In 2018, there were approximately 20,000 desalination plants (brackish groundwater and seawater) worldwide, with an equivalent installed capacity of 26.4 billion gallons per day (29.6 million acre-feet per year) (Sanz, 2018).

In the past decade, seawater desalination has become more prevalent in the United States. On the east and west coasts of the country, there are two large (capacity >25 million gallons per day or >28,000 acre-feet per year) operational seawater desalination facilities for municipal use: the Claude "Bud" Lewis Carlsbad Desalination Plant located in Carlsbad, California, and the Tampa Bay Seawater Desalination Plant located in Tampa Bay, Florida. While Texas does not have an operational seawater desalination facility, several feasibility studies have been conducted in the past few years and interest remains steady.

Brackish groundwater is also an important water source that can provide new water supplies and help reduce the demand on fresh water supplies. For the purpose of this report, brackish groundwater is considered groundwater that contains dissolved salts with total dissolved solid concentration ranging from 1,000 to 10,000 milligrams per liter. In the United States, there are 325 municipal brackish groundwater desalination plants—with the majority located in Florida (45 percent), California (14 percent), and Texas (9 percent) (Mickley and others, 2011).

Texas is estimated to have more than 2.7 billion acre-feet (880 trillion gallons) of brackish groundwater available in 26 of its major and minor aquifers (LBG-Guyton Associates, 2003). In summer 2016, the TWDB updated the desalination plant database that was developed to track the growth of desalination across the state. As of 2016, Texas had 49 municipal desalination plants that treat either brackish groundwater, surface water, or reclaimed water and in total have a design capacity of approximately 142 million gallons per day (159,040 acre-feet per year). Of these 49 facilities, 35 desalinate brackish groundwater and the facilities have a total capacity of 85 million gallons per day (95,200 acre-feet per year).

While the *2018 Biennial Report on Seawater and Brackish Groundwater Desalination* is the eighth report in the series, marking the completion of 16 years of advancing seawater desalination in Texas, it is the second report with an expanded scope that includes progress made in furthering brackish groundwater desalination, and identifying and designating brackish groundwater production zones in the aquifers of the state that fall under House Bill 30 (84th Texas Legislature, 2015).

Primary findings of the report are:

1. As of 2016, brackish groundwater desalination capacity and the number of desalination plants in the state continue to increase.
2. Certain plans for new seawater desalination plants have been discontinued. In October 2017, M&G Resins USA, LLC, filed bankruptcy, affecting plans to complete the full-production seawater desalination plant near Corpus Christi. Also, the Guadalupe-Blanco River Authority canceled its seawater desalination feasibility study to focus on near-term projects.
3. On July 20, 2017, the City of Corpus Christi received a $2.75 million loan from the Texas Water Development Board (TWDB) through the State Water Implementation Fund for Texas to continue conducting planning tasks for a seawater desalination plant that could be used for industrial and municipal use. In August 2018, the City of Corpus Christi issued a request for information for alternative water supplies projects that can produce 10 million gallons per day (11,200 acre-feet per day) of potable water over a 30-year period.
4. On March 7, 2018, the Port of Corpus Christi Authority initiated the permitting process for a seawater desalination facility and applied for a discharge permit through the Texas Commission on Environmental Quality (TCEQ).
5. State funds to support brackish aquifer studies were reduced in June 2017, delaying progress toward meeting the requirements of House Bill 30 (84th Texas Legislature, 2015), which include (1) modeling and calculating production volumes for 30-year and 50-year periods in the brackish groundwater production zones, and (2) completing the studies by December 1, 2022.
6. From October 2016 to August 2018, the TWDB provided $2.75 million in loan assistance to the City of Corpus for a seawater desalination project, and a $700,000 loan to Holiday Beach Water Supply Corporation and $200,000 to Commodore Cove Improvement districts for brackish groundwater desalination projects.

Results of the Board's studies and activities in desalination

The TWDB has a standalone desalination program under the Innovative Water Technologies Department. The Desalination Program was created in 2002 to initially cover activities for seawater desalination and two years later added brackish groundwater desalination.

For the Desalination Program, the TWDB has not had recent appropriations dedicated to support research, feasibility studies, or demonstration projects to advance seawater and brackish groundwater desalination in Texas. The Texas Legislature last appropriated funding for seawater desalination in 2005 and for brackish groundwater desalination in 2009. Between 2003 and 2006, the TWDB funded $3.2 million for seawater desalination studies through the Desalination

Program, including three feasibility studies, two pilot-plant projects, and several guidance and research studies. Between 2004 and 2010, the TWDB funded 11 brackish groundwater desalination projects and studies totaling $2.1 million through the Desalination Program, including the implementation of demonstration projects, preparation of guidance manuals, and completion of research studies.

More recently, the TWDB funded desalination activities through other internal grant and loan programs. The TWDB awarded a couple grants through the Regional Facility Planning Grant Program. The Barton Springs/Edwards Aquifer Conservation District conducted a feasibility study to treat saline groundwater from the Edwards Aquifer at a desalination facility and store the desalinated water at an aquifer storage and recovery system. The Rio Grande Regional Water Authority completed a study to evaluate alternative water sources for the region including seawater and brackish groundwater desalination. From October 2016 to August 2018, the TWDB provided a $2.75 million loan to the City of Corpus for a seawater desalination project, and a $700,000 loan to Holiday Beach Water Supply Corporation and $200,000 loan to Commodore Cove Improvement districts for brackish groundwater desalination projects.

The TWDB monitored other desalination activities including the construction of the seawater industrial desalination plant that M&G Resins USA, LLC, nearly completed, but ended up selling to a business venture when M&G filed for bankruptcy in 2017. Also, TWDB representatives attended the grand opening of and toured the San Antonio Water System's brackish groundwater desalination plant at the H2Oaks Center. The plant has been in operation since January 2017 and has a total design capacity of 12 million gallons per day (13,442-acre-feet-per-year).

Designation of brackish groundwater production zones

BRACS is a separate program from the Desalination Program, but also under the Innovative Water Technologies Department. BRACS was created in 2009 to map and characterize in detail the brackish aquifers in the state. The 81st Texas Legislature (2009) appropriated funding to implement the program and hire two staff members and fund research projects.

For BRACS, the TWDB funded three research projects totaling $449,500 in 2010 to support the initiation of the program. Subsequently, the TWDB completed four aquifer studies internally, which included the Pecos Valley Aquifer, the Gulf Coast Aquifer in the Corpus Christi Aquifer Storage and Recovery Conservation District, the Queen City and Sparta aquifers in Atascosa and McMullen counties, and the Gulf Coast Aquifer in the Lower Rio Grande Valley.

With the passing of House Bill 30 in 2015 (84th Texas Legislature), the TWDB funded seven contracts totaling over $1.7 million to identify and designate brackish groundwater production zones. House Bill 30 required the TWDB to designate brackish groundwater production zones in four aquifers by the statutory deadline of December 1, 2016, determine the volumes of water that a brackish groundwater production zone could produce over 30- and 50-year periods, and make recommendations on reasonable monitoring to observe the effects of brackish groundwater production within the zone. On October 20, 2016, the Board designated one zone in the Carrizo-Wilcox Aquifer, four zones in the Gulf Coast Aquifer, three zones in the Rustler Aquifer, and no zones in the Blaine Aquifer. All the zones contain brackish groundwater, with total dissolved solids concentration ranging from 1,000 to 10,000 milligrams per liter.

Contractors have since completed work and identified potential production areas for four additional aquifer studies (Trinity, Nacatoch, Blossom, and Queen City and Sparta), and TWBD staff completed one internal study (Lipan Aquifer). Staff is currently evaluating brackish groundwater production zones for three aquifers (Blossom, Nacatoch, and Northern Trinity) and is working on five other aquifer studies.

In the winter of 2018/2019, the Board will consider the Executive Administrator's recommendations for brackish groundwater production zone designations in the Blossom, Lipan, Nacatoch, and Northern Trinity aquifers. The TWDB will not be able to map brackish groundwater resources and designate zones in the remaining aquifers by the statutory deadline of December 1, 2022, even with restoration of funds.

Research, regulatory, technical, and financial impediments to implementation

For the past few biennium, the impediment to conducting research and pilot-scale testing is the lack of adequate funding. The Texas Legislature last appropriated funds to the TWDB to advance seawater and brackish groundwater desalination in Texas in 2009. The regulatory impediment for seawater desalination is that the permitting requirements will not be put in practice and established until a few seawater desalination plants have undergone the required permitting cycles. The relatively high cost and site specificity of desalination compared to the cost of developing conventional fresh water supplies continue to be technical and financial impediments to advancing desalination in Texas. Factors that affect the cost of desalination include permitting, treatment, brine disposal, and transmission pipelines. In general, desalination projects depend on site-specific conditions, so each project requires unique treatment and brine disposal analyses. However, as water resources become scarcer due to drought and growth, desalination becomes a more enticing option.

The role of the State in furthering the development of desalination projects

The role of the state is to continue technical efforts and to provide leadership and support to advance seawater and brackish groundwater desalination in Texas. The TWDB identified opportunities for continued state involvement which include: (1) appropriating funds to advance seawater and brackish groundwater desalination studies, (2) appropriating funds to continue designating brackish groundwater production zones, (3) facilitating meetings between water providers or municipalities and regulatory or planning agencies to facilitate the financial application and permitting processes, (4) providing financing through existing TWDB loan programs to entities interested in pursuing seawater and brackish groundwater desalination, and (5) working with private and public partners to advance the implementation of desalination in the state.

Anticipated appropriation from general revenues

As part of the 2020–2021 legislative appropriations request, the TWDB requested $2 million in funding for Brackish Resources Aquifer Characterization System (BRACS) to continue designating brackish groundwater production zones during the next biennium. The requested appropriations are necessary to continue progress toward meeting the requirements of House Bill 30 (84^{th} Texas Legislature, 2015). The TWDB did not request additional funding for the Desalination Program to advance seawater and brackish groundwater desalination activities.

1 Introduction

Desalination is an important water management strategy that has created new water supplies around the world. Desalination refers to the process of removing dissolved solids and other minerals from saline water sources, including brackish groundwater and seawater. Membranes are generally used to physically separate the dissolved solids from water. The most widely used commercial membrane technology is reverse osmosis, which uses high pressure to push water through the membranes.

The treatment process in a desalination plant typically consists of pretreatment, reverse osmosis, and post treatment. The raw (untreated) water enters the plant and goes through a series of filtration or membrane processes (such as strainers, cartridge filters, and microfiltration) to remove sand and suspended solids. Operators dose the water with antiscalant and acid to help prevent clogging the membranes. The operator then pumps the feed water to the reverse osmosis system, which results in two streams: (1) the permeate (the desalted water) and (2) the concentrate (or brine where the salts are accumulated). In post treatment, operators add chemicals to the permeate or blend the permeate with raw water to add minerals and make it less corrosive. The concentrate from brackish desalination can be discharged to an appropriate water body, sanitary sewer, injection well, or evaporation pond. For seawater desalination, the brine is typically discharged back to the ocean through an outfall. A reverse osmosis system generally operates with 75 to 85 percent recovery for brackish desalination (every 100 gallons desalinated produces 75 to 85 gallons of fresh water) and 50 percent recovery for seawater desalination. The higher the recovery of the system and the higher the total dissolved solids of the raw water, the more energy required to desalinate the water and the higher the costs.

In 2002, Governor Rick Perry announced his vision of meeting future water supply needs through seawater desalination and directed the TWDB to recommend a large-scale seawater desalination demonstration project. Thus, TWDB desalination efforts began with the identification of sites for a seawater desalination demonstration project. The first step was to issue a request for statements of interest to develop large-scale seawater desalination. In 2003, the TWDB selected three locations (cities of Corpus Christi, Brownsville, and Freeport) for feasibility studies. The 78th Texas Legislature subsequently appropriated $1.5 million to fund these studies. In 2005, the 79th Texas Legislature appropriated $2.5 million for seawater desalination pilot testing. Between 2006 and 2008, the TWDB contracted for two pilot-plant studies: one at the Brownsville Ship Channel by the Brownsville Public Utilities Board and the second on South Padre Island by the Laguna Madre Water District. In 2009 and 2010, the TWDB funded research studies on environmental permitting requirements to implement seawater desalination along the Texas Gulf Coast.

To build on the governor's desalination initiative, the TWDB established the Brackish Groundwater Desalination Initiative in 2004. The goal was to demonstrate the use of innovative and cost-effective desalination technologies and offer practical solutions to key challenges such as concentrate management and energy optimization. In 2005, the 79th Texas Legislature appropriated funds to support the first round of demonstration projects. In 2007, the Texas Legislature appropriated funds to support five new studies and, in 2009, additional funding was allocated to support four new demonstration projects. Texas Legislative appropriations for the Desalination Program ended in 2009.

In 2003, the 78th Texas Legislature passed House Bill 1370 directing the TWDB to pursue seawater desalination and to report progress in a biennial report due December 1 of each even-numbered year. The Texas Water Code §16.060 requires the TWDB to undertake necessary steps to further the development of cost-effective water supplies from seawater or brackish groundwater desalination in the state and report the results of its studies and activities to the governor, lieutenant governor, and House speaker no later than December 1 of each even-numbered year. The report includes:

1. the results of the Board's studies and activities related to seawater and brackish groundwater desalination during the preceding biennium;
2. an identification and evaluation of research, regulatory, technical, and financial impediments to implementing seawater or brackish groundwater desalination projects;
3. an evaluation of the role the State should play in furthering the development of large-scale seawater or brackish groundwater desalination projects in the state;
4. anticipated appropriation from general revenue necessary to continue investigating water desalination activities in the state during the next biennium; and
5. identification and designation of local or regional brackish groundwater production zones in areas of the state with moderate to high availability and productivity of brackish groundwater that could be used to reduce the use of fresh groundwater.

The 2018 biennial report is the second report to discuss both seawater and brackish groundwater desalination, as well as the identification and designation of local or regional brackish groundwater production zones. With respect to seawater desalination, this is the eighth report in the series and marks the completion of 16 years of activities toward advancing seawater desalination. The report also marks 14 years of activities furthering brackish groundwater desalination in Texas and the second time these activities have been described.

2 Current state of desalination

Desalination is the process of removing dissolved solids and other minerals from saline water sources, which can include brackish groundwater and seawater. This important technology is used all around the world to produce new water supplies. In 2018, there were approximately 20,000 desalination plants (brackish groundwater and seawater) worldwide, with an equivalent installed capacity of 26.4 billion gallons per day (29.6 million acre-feet per year) (Sanz, 2018).

2.1 Seawater desalination

Various countries around the world use seawater desalination to produce fresh water supplies, and this technology has gained momentum in the United States in the past decade. As of 2016, the installed global seawater desalination capacity was about 15.8 billion gallons per day (17.8 million acre-feet per year), or about 60 percent of total installed desalination capacity (Sanz, 2018). Seawater has a total dissolved solid concentration of about 35,000 milligrams per liter or greater.

In the United States, there are two large operational seawater desalination facilities for municipal use with design capacity greater than 25 million gallons per day (28,000 acre-feet per year): (1) the Claude "Bud" Lewis Carlsbad Desalination Plant located in Carlsbad, California, and (2) the Tampa Bay Seawater Desalination Plant located in Tampa Bay, Florida. Public-private partnerships were the financial mechanisms used to build these desalination plants. Texas does not have an operational seawater desalination facility, but several feasibility studies were conducted in recent years.

2.1.1 California

California currently has a total of 10 seawater desalination facilities along the Pacific Coast (Table 1). Of the seven seawater desalination facilities that are active, four are used for municipal purposes. The Sand City Coastal Desalination Facility became operational in May 2011 (Sand City, 2016), the Santa Catalina Island expansion and Carlsbad Desalination Plant became operational in December 2015, and the Charles Meyer Desalination Facility became operational in May 2017. There are eight proposals for future seawater desalination plants (Cooley, 2016). The next two projects currently in the permitting stages include the Huntington Beach Desalination Plant and the West Basin Municipal Water District's Ocean Water Desalination project. Additionally, there are two proposed plants in Baja California, Mexico.

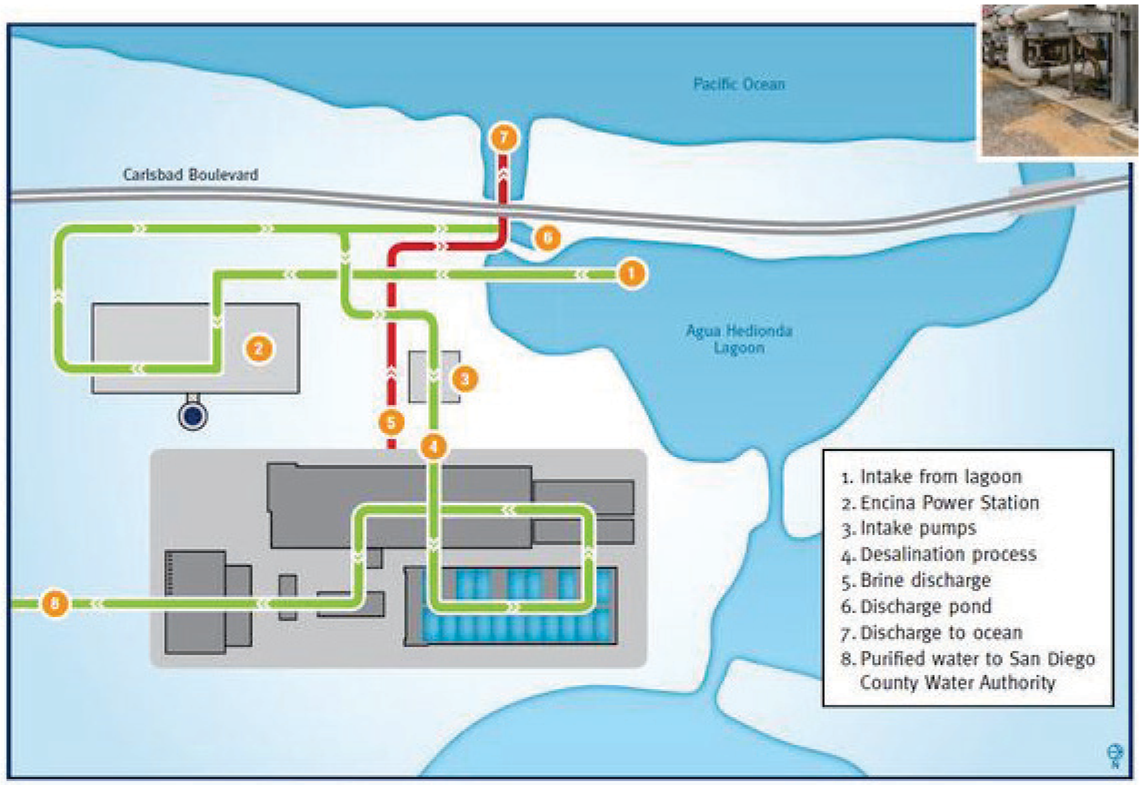
Table 1. **Existing seawater desalination facilities in California**

Status	Plant name	Size (million gallons per day)	Use	Operator
Active	Monterey Bay Aquarium	0.008	Commercial	Monterey Bay Aquarium
Active	Diablo Canyon Power Plant	0.580	Industrial	Pacific Gas & Electric
Active	Gaviota Oil Heating Facility	0.410	Industrial	Chevron Corporation
Active	Sand City Coastal Desalination Facility	0.300	Municipal	City of Sand City
Active	Santa Catalina Island	0.325	Municipal	Southern California Edison*
Active	Carlsbad Desalination Plant	50.000	Municipal	Poseidon Water
Active	Charles Meyer Desalination Facility	3.000	Municipal	City of Santa Barbara
Idle	Marina Desalination Plant	0.270	Municipal	Marina Coast Water District
Idle	Morro Bay Desalination Facility	0.600	Municipal	City of Morro Bay
Unknown	San Nicholas Island	0.024	Municipal	San Nicholas Island

*City of Avalon is co-operator of the facility with Southern California Edison. Source: (Cooley, 2016)

The Carlsbad Desalination Plant, which became operational on December 14, 2015, and has a design capacity of 50 million gallons per day (56,000 acre-feet per year), can serve approximately 400,000 people in San Diego County (San Diego County Water Authority, 2016c). The plant is the biggest seawater desalination plant in the United States. In 2020, seawater desalination will account for approximately 8 to 10 percent of the San Diego region's water supply and about one-third of all locally generated water in San Diego County (San Diego County Water Authority, 2016b; 2016c). The planning phase of this project started in 1998 and completion of the facility took a total of 14 years. The permitting process took nine years, from 2003 to 2009, and securing a water purchase agreement took an additional two years. In this scenario, Poseidon Water financed the desalination facility, IDE Technologies operates the facility, and the San Diego County Water Authority purchases the desalinated water. The Authority signed a 30-year water purchase agreement with Poseidon Water in 2017, with the cost of water estimated at $2,125 to $2,368 per acre-foot ($6.52 to 7.27 per thousand gallons) (San Diego County Water Authority, 2016a; Poseidon Water, 2016b).

The Carlsbad Desalination Plant is located adjacent to the Encina Power Station, which will be decommissioned in the near future (Figure 1). Nevertheless, the desalination plant can take advantage of existing infrastructure at the power plant. Seawater from the Pacific Ocean with a total dissolved solid concentration of approximately 33,500 milligrams per liter flows to the Agua Hedionda Lagoon (Poseidon Water, 2016b). Approximately 340,480 acre-feet per year (304 million gallons per day) of seawater is pumped from the lagoon to the power plant's cooling towers through an existing surface intake. About 224,000 acre-feet per year (200 million gallons per day) of cooling water is returned to a discharge pond and diluted with seawater and ultimately discharged back to the Pacific Ocean. The remaining 104 million gallons of cooling water is diverted to the desalination plant and treated. The treatment process includes multimedia filters and microfiltration, followed by reverse osmosis, and ends with mineralization and disinfection. Approximately 60,480 acre-feet per year (54 million gallons per day) of brine is also disposed to the discharge pond. The final product water is piped 10 miles to the San Diego County Water Authority Second Aqueduct.



Source: San Diego County Water Authority, 2018

Figure 1. Site layout for the Carlsbad Desalination Plant

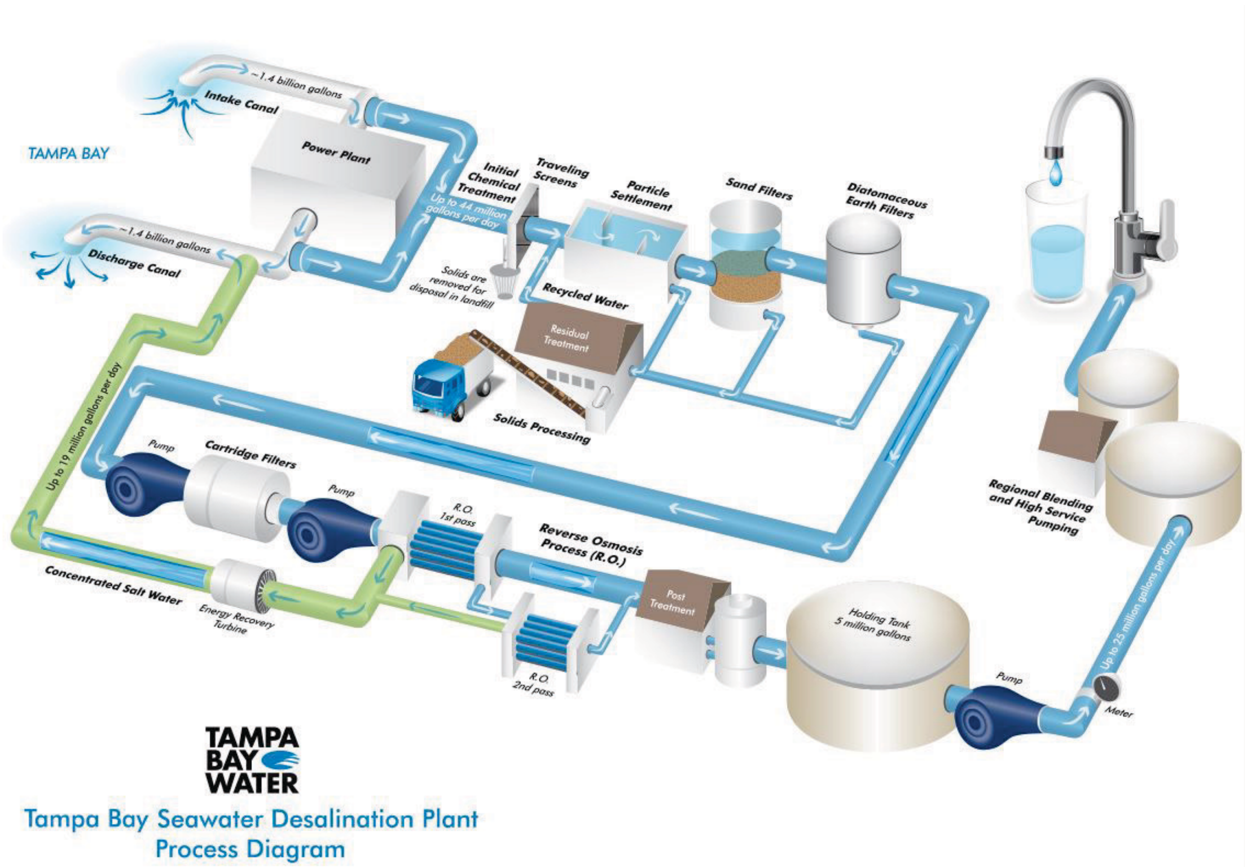
The Charles E. Meyer Desalination Facility in the City of Santa Barbara was built in 1991 to provide an emergency water supply during a drought. It operated for three months and was then placed in standby mode due to significant rainfall, in which it remained for over 25 years. In July 2015, the Santa Barbara City Council voted to reactivate the facility. In May 2017, the plant was recommissioned and began producing about 3,360 acre-feet per year (3 million gallons per day) of water. It can be expanded in the future to produce up to 10,000 acre-feet per year (8.9 million gallons per day) (City of Santa Barbara, 2018a). Seawater desalination will meet about 30 percent of the city's annual demands. The capital cost to reactivate the facility was $71 million and the annual operating cost is $4.1 million. The city owns the desalination plant and has a five-year contract with IDE Technologies to operate the facility. Overall, the cost of water was estimated at $2,750 per acre-foot in 2018 ($8.44 per thousand gallons); $1,400 per acre-foot ($4.30 per thousand gallons) was the cost to operate the plant and $1,350 ($4.14 per thousand gallons) was the cost of debt service (City of Santa Barbara, 2018b).

2.1.2 Florida

Florida has three operating seawater desalination facilities. The Florida Keys Aqueduct Authority operates two desalination plants that serve as emergency supplies to Lower and Middle Keys (FKAA, 2018a). The Kermit H. Lewin Reverse Osmosis Water Treatment Facility is a 2-million-gallon-per-day (2,240-acre-feet-per-year) desalination plant located on Stock Island and constructed in 1967. The Marathon Reverse Osmosis Water Treatment Facility is a 1-million-gallon-per-day (1,120-acre-feet-per-year) desalination plant located in Marathon and constructed in 1997. The Authority wants to upgrade the 51-year old plant on Stock Island and expand its capacity to 4 million gallons per day (4,480 acre-feet per year). On June 27, 2018, the Authority approved a contract with an engineering consulting firm to conduct a facility-planning assessment to upgrade the seawater desalination facility (FKAA, 2018b).

The Tampa Bay Seawater Desalination plant in Tampa, Florida, first became fully operational in December 2007 and has a design capacity of 25 million gallons per day (28,000 acre-feet per year). Water from the desalination plant currently provides up to 10 percent of the region’s needs (Tampa Bay Water, undated). The construction of the plant took 10 years (1997 to 2007), which included a four-year delay after two construction firms filed for bankruptcy and could not complete the plant. “The procurement of the desalination plant began as a Design Build Own Operate Transfer model, but eventually evolved into a model in which Tampa Bay Water would finance the construction, own the facility, and rely on a private operator for operations, management, and maintenance (Hughes, 2016).” The total cost to construct the plant was $158 million and operating costs can range from $2.20 to $4.00 per thousand gallons ($717 to $1,303 per acre-foot), depending on average demand (Hughes, 2016).

The plant is co-located with and uses electricity generated from Tampa Electric’s Big Bend Power Station (Figure 2). For source water, the seawater desalination plant uses approximately 49,280 acre-feet per year (44 million gallons per day) of water that has passed through the co-located power plant’s cooling tower (Tampa Bay Water, undated). The total dissolved solids concentration in the raw water averages 26,000 milligrams per liter, though it can range from 10,000 to 30,000 milligrams per liter. The treatment process includes pre-treatment, reverse osmosis, and post-treatment. Concentrate resulting from the reverse osmosis process (21,280 acre-feet per year or 19 million gallons per day) is returned to the Big Bend Power Station and blended with the cooling water stream. It is then discharged to a canal where it blends with seawater and eventually reaches Tampa Bay. The desalinated water produced at the Tampa Bay Seawater Desalination Plant is piped to a regional water facility located 14 miles away and blended with treated surface water at a rate based on demand.



Source: Tampa Bay Water, 2018

Figure 2. Treatment process of the seawater desalination plant

2.2 Brackish groundwater desalination

Brackish groundwater is becoming an important water source that can help reduce demand on fresh water sources. Globally, the contracted desalination capacity of brackish groundwater is about 4.6 billion gallons per day (International Desalination Association, 2017). Groundwater contains dissolved solids, often measured in units of milligrams per liter, and can be classified as fresh (0 to 1,000 milligrams per liter), slightly saline (>1,000 to 3,000 milligrams per liter), moderately saline (>3,000 to 10,000 milligrams per liter), very saline (>10,000 to 35,000 milligrams per liter), or brine (>35,000 milligrams per liter) (Winslow and Kister, 1956). For this report, brackish groundwater is considered groundwater that contains dissolved salts with total dissolved solid concentration ranging from 1,000 to 10,000 milligrams per liter.

In the United States, there are 325 municipal desalination plants primarily located in Florida (45 percent), California (14 percent), and Texas (9 percent). The majority (73 percent) of desalination plants in the nation employ reverse osmosis (Mickley and others, 2011). In South Florida alone, there are 38 brackish groundwater desalination plants with a total capacity of 279 million gallons per day (312,480 acre-feet per year) (South Florida Water Mangament District, 2018). In

California, there are 23 brackish groundwater desalination plants with a total capacity of 124 million gallons per day (139,627 acre-feet per year) (California Department of Water Resources, 2014). Most plants are located in Southern California, and the capacity of the largest plant is 15 million gallons per day (16,800 acre-feet per day).

2.2.1 Texas

Brackish groundwater is also an important water supply source in Texas. The state is estimated to have more than 2.7 billion acre-feet (880 trillion gallons) of brackish groundwater in 26 of its major and minor aquifers in Texas (LBG-Guyton Associates, 2003). In the last two decades, desalination capacity in Texas has increased steadily (Figure 3).

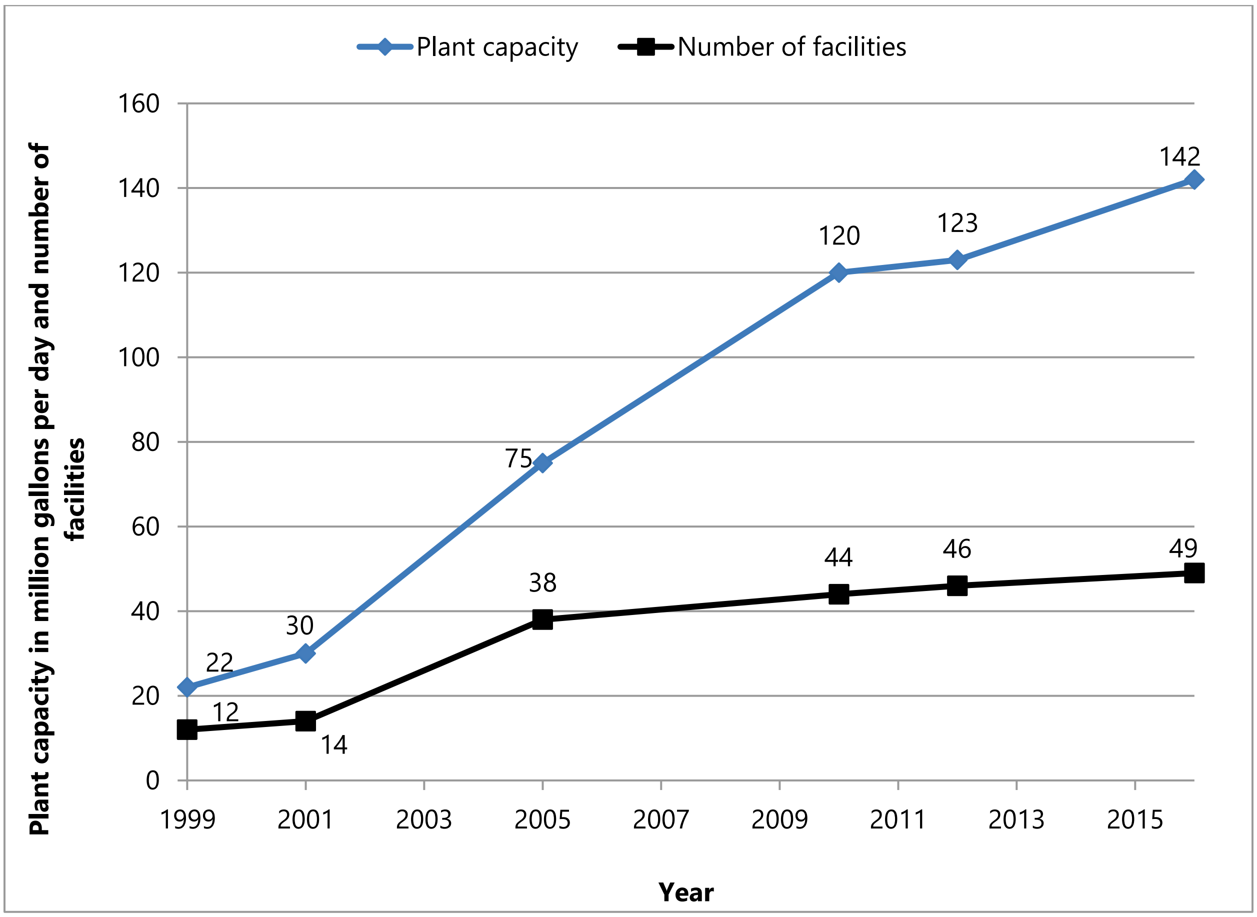


Figure 3. **The growth of municipal desalination facilities and installed design capacity in Texas, 1999 through 2016**

In 2005, the TWDB funded a project to develop an initial desalination plant database to track the growth of desalination across the state (Nicot et. al., 2005). In 2010 and 2016, staff updated the information and made it available online (www2.twdb.texas.gov/apps/waterdatainteractive/GroundwaterDataViewer/?map=desal).

As of 2016, there were 49 desalination plants for municipal use with a per-facility capacity greater than 23,000 gallons per day (Table 2). Of these facilities, 13 treat brackish surface water, 35 treat brackish groundwater, and 1 treats reclaimed water (Figure 4). In total, Texas has a desalination design capacity of approximately 142 million gallons per day (159,040 acre-feet per year) for municipal use. More specifically, the state has design capacity of 54 million gallons per day (60,480 acre-feet per year) for brackish groundwater desalination, 85 million gallons per day (95,200 acre-feet per year) for brackish surface water desalination, and 2.5 million gallons per day (2,800 acre-feet per year) for advanced treated reclaimed water. Reverse osmosis is the predominant desalination technology used in 47 of the 49 desalination facilities. The City of Sherman and Dell City use electrodialysis reversal. Additionally, the largest inland desalination plant in the state and nation is the Kay Bailey Hutchison Desalination Plant located in El Paso (27.5 million gallons per day or 30,937 acre-feet per day).

The desalination plant database relies on self-reported surveys and may not capture every plant in operation or plants constructed after 2016. For example, the City of Wolfforth began operating a 2.5 million-gallon-per-day (2,800-acre-foot-per-year) electrodialysis reversal (EDR) desalination plant in May 2017, and this plant is not included in the desalination plant database. Other entities with new desalination plants may include, but may not be limited to, the City of Ballinger, City of Roscoe, City of Rochester, Mitchell County Utilities, Port O'Connor Improvement District, and Wheeler Municipal Water System.

Table 2. Municipal brackish desalination facilities in Texas with a capacity greater than 0.023 million gallons per day (mgd)

Facility name	City	Water source	Facility startup year	Facility design capacity[1] (mgd)
Big Bend Motor Inn	Terlingua	Groundwater	1989	0.057
Bob Elder Water Treatment Plant	Milsap	Surface water	2014	1.000
Brazos Regional Public Utility Agency/Surface Water Advanced Treatment System	Granbury	Surface water	1989	15.000
City of Abilene (Hargesheimer Treatment Plant)	Tuscola	Surface water	2003	7.950
City of Bardwell	Bardwell	Groundwater	1980	0.252
City of Bayside	Bayside	Groundwater	1990	0.045
City of Beckville	Beckville	Groundwater	2004	0.216
City of Benjamin	Benjamin	Groundwater	2012	0.072
City of Brady	Brady	Surface water	2005	3.000
City of Clarksville City	White Oak	Groundwater	2006	0.288
City of Evant	Evant	Groundwater	2010	0.100
City of Fort Stockton Osmosis/Desalination Facility	Fort Stockton	Groundwater	1996	6.500
City of Granbury	Granbury	Surface water	2007[2]	0.462

Facility name	City	Water source	Facility startup year	Facility design capacity[1] (mgd)
City of Hubbard	Hubbard	Groundwater	2002	0.648
City of Kenedy	Kenedy	Groundwater	1995	2.858
City of Los Ybanez	Los Ybanez	Groundwater	1991	NA[3]
City of Robinson Reverse Osmosis Surfacewater Treatment Plant	Waco	Surface water	1994	2.400
City of Rule	Rule	Groundwater	2015	0.086
City of Seadrift	Seadrift	Groundwater	1998	0.610
City of Seymour	Seymour	Groundwater	1940	3.000
City of Sherman	Sherman	Surface water	1993	11.000
City of Tatum	Tatum	Groundwater	1999	0.324
Cypress Water Treatment Plant	Wichita Falls	Surface water	2008	10.000
Dell City	Dell City	Groundwater	1968	0.100
DS Waters of America, LP	Katy	Groundwater	1997	0.090
Fort Hancock Reverse Osmosis (RO) Plant No. 1	Fort Hancock	Groundwater	2012	0.430
H2Oaks Center	Elmendorf	Groundwater	2016	12.000
Holiday Beach Water Supply Corporation	Fulton	Groundwater	1960	0.150
Horizon Regional Municipal Utility District	Horizon City	Groundwater	2001	6.000
Kay Bailey Hutchison Desalination Plant	El Paso	Groundwater	2007	27.500
Longhorn Ranch Motel	Alpine	Groundwater	1990	0.023
Midland Country Club	Midland	Groundwater	2004	0.023
Mitchell County Desalination Plant	Colorado City	Groundwater	2017	0.025
North Alamo Water Supply Corporation (Doolittle)	San Juan	Groundwater	2008	3.500
North Alamo Water Supply Corporation (Lasara)	Edinburg	Groundwater	2005	1.200
North Alamo Water Supply Corporation (Owassa)	Raymondville	Groundwater	2008	2.000
North Cameron/Hidalgo Water Authority	Rio Hondo	Groundwater	2006	2.500
Oak Trail Shores	Granbury	Surface water	1985	1.584
Possum Kingdom Water Supply Corporation	Graford	Surface water	2003	1.000
Raw Water Production Facility	Big Spring	Reclaimed	2013	2.500
River Oaks Ranch	Pflugerville	Groundwater	1985[4]	0.115
Southmost Regional Water Authority	Brownsville	Groundwater	2004	11.000
Sportsman's World Municipal Utility District	Strawn	Surface water	1984	0.083
Study Butte Terlingua Water System	Terlingua	Groundwater	2000	0.140
The Cliffs	Graford	Surface water	1991	0.381
Valley Municipal Utility District #2	Olmito	Groundwater	2000	1.000
Veolia Water Treatment Plant	Port Arthur	Surface water	1992	0.245
Victoria Road Reverse Osmosis Plant #5	Donna	Groundwater	2012	2.250
Water Runner, Inc.	Midland	Groundwater	2001	0.028
			Total	**141.960**

Notes: MGD = million gallons per day
[1]Plant design capacity includes blending
[2]Plant constructed in 1984; reverse osmosis implemented in 2007
[3]Design capacity data not provided
[4]Plant rehabilitated in 2011

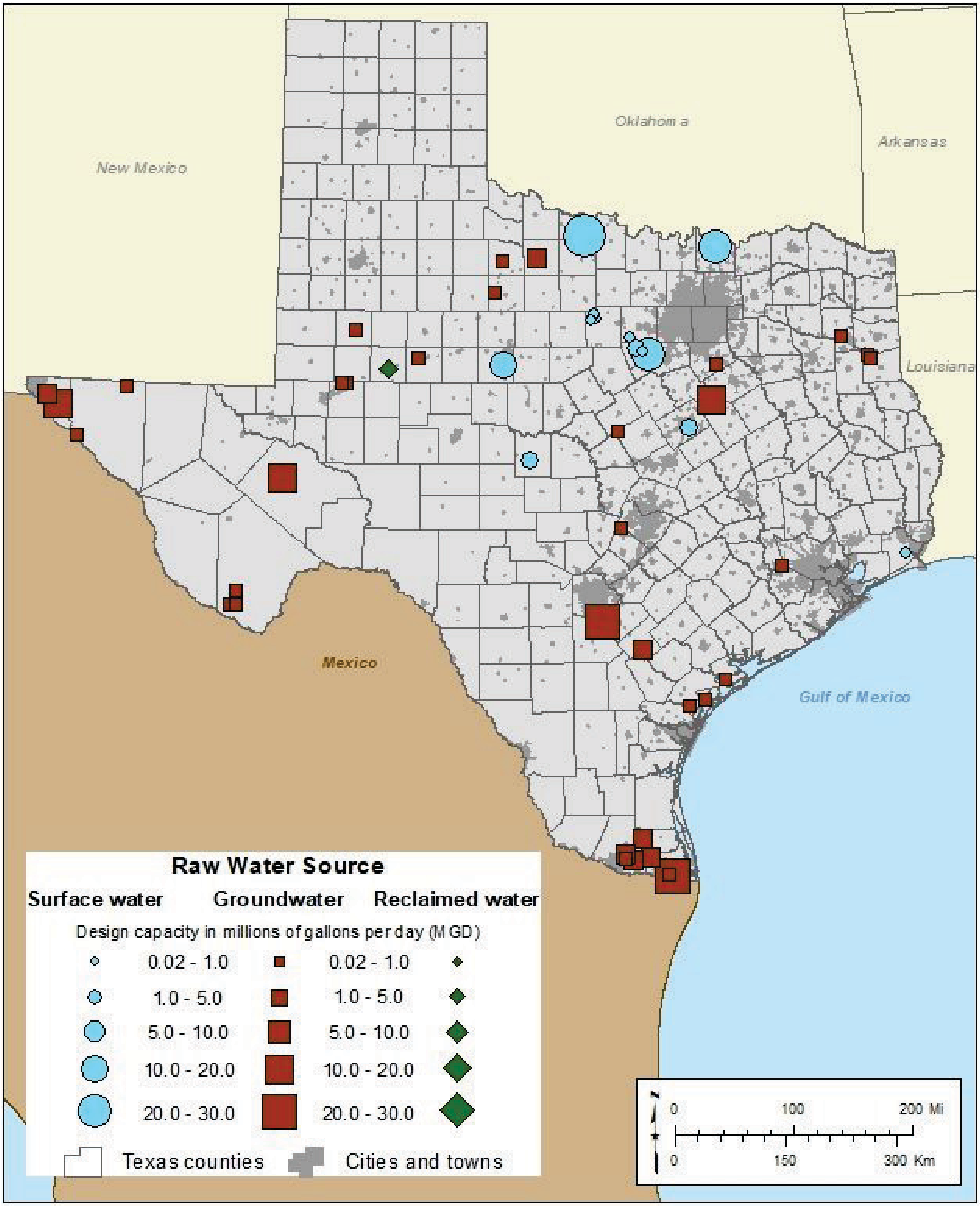


Figure 4. Distribution, size, and source water of municipal brackish desalination facilities in Texas with a design capacity of more than 0.023 million gallons per day, 2016

3 Results of the TWDB's studies and activities in desalination

In 2003, the 78th Texas Legislature passed House Bill 1370, directing the TWDB to undertake or participate in research, feasibility and facility planning studies, investigations, and surveys it considers necessary to further the development of cost-effective water supplies from seawater desalination. In 2015, the 84th Texas Legislature passed House Bill 30, directing the TWDB to also engage and report on brackish groundwater desalination in the state. This chapter describes desalination activities (1) funded through the Desalination Program, (2) in the 2017 State Water Plan, (3) and funded through other TWDB grant and loan programs.

3.1 Desalination Program

The TWDB created the Desalination Program in 2002 in response to Governor Rick Perry announcing his seawater initiative and the 78th Texas Legislature passing House Bill 1370 that directed the TWDB to pursue seawater desalination and to report progress in a biennial report. Initially the program covered activities for seawater desalination and, in 2004, added brackish groundwater desalination. The Legislature last appropriated funding for seawater desalination in 2005 and brackish groundwater desalination in 2009.

3.1.1 Seawater desalination studies

Since 2002, the TWDB has funded $3.2 million in studies related to seawater desalination, including three feasibility studies, two pilot-plant projects, and several guidance and research studies (Table 3). In 2005, the 79th Texas Legislature made its last appropriation of $2.5 million for seawater desalination demonstration activities, which was spent by 2010. Since then, the TWDB has not funded additional seawater desalination studies.

Table 3. TWDB-funded reports on seawater desalination

Report title	Study location	Study type
Lower Rio Grande Valley, Brownsville Seawater Desalination Demonstration Project (Brownsville Public Utilities Board, 2004)	City of Brownsville	Feasibility study
Large-Scale Demonstration Desalination Feasibility Study (City of Corpus Christi, 2004)	City of Corpus Christi	Feasibility study
Freeport Seawater Desalination Project (Brazos River Authority, 2004)	City of Freeport	Feasibility study
Pilot Study Report, Texas Seawater Desalination Demonstration Project (Brownsville Public Utilities Board, 2008)	City of Brownsville	Pilot-plant study
Feasibility and Pilot Study, South Padre Island Seawater Desalination Project (Laguna Madre Water District, 2010)	South Padre Island	Pilot-plant study
Guidance Manual for Permitting Requirements in Texas for Desalination Facilities Using Reverse Osmosis Processes (R.W. Beck, Inc., 2004)	Not applicable	Guidance document
Lessons Learned from the Brownsville Seawater Pilot Study (Reiss Engineering Inc., 2009)	City of Brownsville	Guidance document
Texas Desal Project (Brownsville Public Utilities Board, 2011)	City of Brownsville	Guidance document

3.1.1.1 Brownsville feasibility and pilot-plant studies

From 2004 to 2011, the TWDB and the Brownsville Public Utilities Board conducted feasibility and pilot-plant studies, completed a scoping of permitting issues study, and completed a conceptual layout and cost estimate for a full-scale seawater desalination facility. The Brownsville Public Utilities Board has explored an increasingly smaller project to reduce the financial impact to its ratepayers and the state. In the 2010 and 2012 biennial seawater desalination reports, the TWDB reported that proposed plant capacity was reduced to 2.5 million gallons per day (2,800 acre-feet per year) with an estimated cost of $22.5 million. The amount of financial grant assistance requested from the 82nd Texas Legislature (2011) for this project was $9.5 million (TWDB, 2012). The project is on hold, pending procurement of funds by the Brownsville Public Utilities Board.

3.1.1.2 South Padre Island feasibility and pilot-plant studies

Although South Padre Island was not one of the three original sites selected for a feasibility study as part of the Seawater Desalination Initiative (TWDB, 2002), the Laguna Madre Water District completed a feasibility and pilot-plant study and was part of the environmental scoping study for seawater desalination (Brownsville Public Utilities Board, 2011). The amount of financial assistance (grant) requested from the 82nd Texas Legislature (2011) was $5 million for permitting and design to help initiate the implementation of the project (TWDB, 2012).

In May 2011, district voters approved two propositions. Proposition I was for the issuance of bonds in the amount of $23,750,000 for system improvements and for the levying of taxes to support payment of the bonds, and Proposition II authorized the Laguna Madre Water District to issue bonds in the amount of $15,655,000 to finance construction of a seawater desalination facility and to levy taxes for payment of the bonds.

In May 2014, the Laguna Madre Water District increased the total production capacity of its existing surface water treatment plant No. 2 by 2 million gallons per day (2,240 acre-feet per year) for a total production capacity of 7 million gallons per day (7,840 acre-feet per year). While this additional capacity strengthened the water supply system, it still relied on water from the Rio Grande, which is an unreliable source. The Laguna Madre Water District placed the seawater desalination project on hold while it explored potable reuse as an option (Laguna Madre Water District, 2014).

Deciding to pursue the potable reuse option, the District conducted a feasibility study for an advanced water treatment plant in March 2015. The District evaluated siting a water reclamation facility adjacent to the existing Port Isabel Wastewater Treatment Plant to treat wastewater effluent from the plant to augment surface water in Reservoir 3. The study also examined other alternatives, including a regional approach that involves receiving effluent from both Laguna Vista and Port Isabel wastewater treatment plants and treating the effluent at a single water reclamation facility. The feasibility study, which was completed in December 2015, concluded that the best location for a reclamation facility was near Water Treatment Plant 1 where wastewater effluent from both Laguna Vista and Port Isabel wastewater treatment plants would be treated and used to supplement water supplies in Reservoir 3. The next step for the District is to complete improvements to the Port Isabel Wastewater Treatment Plant in preparation for a future indirect potable reuse project. On June 14, 2016, the TWDB approved $5.8 million for the district to complete improvements to the wastewater treatment plant and continue pursuing indirect potable reuse.

3.1.1.3 Corpus Christi feasibility study

In 2004, the TWDB and the City of Corpus Christi completed a feasibility study that identified two sites, Barney Davis Power Plant and DuPont-OxyChem, as potential locations for a seawater desalination plant. Until recently, the city had not conducted additional work to pursue seawater desalination. On August 12, 2014, the city council passed a resolution recommending that the 84th Texas Legislature (2015) appropriate funds for Fiscal Year 2016 to implement seawater desalination projects (City of Corpus Christi, 2014c). The City of Corpus Christi also participated in two feasibility studies related to seawater desalination that are described in the Other Seawater Desalination Activities section of this report.

3.1.1.4 Freeport feasibility study

The Brazos River Authority reports that no additional work has been conducted since the TWDB-funded feasibility study was completed in 2004 (Brazos River Authority, 2016). The study concluded that seawater desalination was feasible and recommended that entities seek financial assistance and conduct pilot-scale testing. The proposed project consisted of the Brazos River Authority and Poseidon Water forming a private-public partnership and building a 10-million-gallon-per-day (11,200-acre-feet-per-day) demonstration facility.

The Brazos River Authority and City of Freeport have not completed additional work related to seawater desalination since completing the feasibility study in 2004 (Brazos River Authority, 2018).

3.1.2 Brackish groundwater desalination studies

The TWDB funded 11 projects and studies totaling $2.1 million related to brackish groundwater desalination, including the implementation of demonstration projects, preparation of guidance manuals, and completion of research studies (Table 4). Since 2009, the Texas Legislature has not appropriated funds to the TWDB for the Desalination Program to support brackish groundwater desalination projects.

Table 4. Brackish groundwater desalination studies funded through the Desalination Program

Report title	Contractor	Description	Study type	Year funded	Grant amount
Guidance Manual for Brackish Groundwater Desalination in Texas	North Cameron Regional Water Supply Corporation	The project prepared a brackish groundwater desalination guidance manual using desalination plant in Cameron County as an example.	Demonstration	2006	$150,000
Demonstration of Efficiencies Gained by Utilizing Improved Reverse Osmosis Technologies	City of Kenedy/San Antonio River Authority	The project demonstrated the efficiencies gained by installing a new reverse osmosis system in an existing brackish groundwater desalination plant.	Demonstration	2006	$150,000
Assessment of the Whitehorse Aquifer as a Potential Source of Water Supply for the City of San Angelo	City of San Angelo/Upper Colorado River Authority	The project assessed the feasibility of the Whitehorse Aquifer in Irion County as a source of brackish water for the City of San Angelo.	Demonstration	2006	$300,000
Evaluation of Concentrate Management and Assessment of the Vibratory Shear Enhanced Process	San Antonio Water System	The project conducted a pilot test to assess the cost and technical feasibility of the Vibratory Shear Enhanced Process as a tool for reducing	Demonstration	2007	$205,000

Report title	Contractor	Description	Study type	Year funded	Grant amount
		the volume of desalination concentrate.			
Improving Recovery: A Concentrate Management Strategy for Inland Desalination	The University of Texas at Austin	The study investigated anti-scalant precipitation and electrodialysis to increase recovery in desalination of brackish groundwater.	Demonstration	2007	$238,500
Pilot Study to Demonstrate Volume Reduction of Reverse Osmosis Concentrate	El Paso Public Utilities Board	The study evaluated silica reduction in reverse osmosis concentrate through the addition of lime, and application of the vibratory shear enhanced process. A second phase of the project tested the use of seawater reverse osmosis membranes to increase water recovery.	Demonstration	2007	$228,557
An Integrated Wind-Water Desalination Demonstration Project for an Inland Municipality	City of Seminole	The City of Seminole conducted pilot testing using wind energy to desalinate brackish groundwater.	Demonstration	2008	$300,000
Permitting Guidance Manual to Dispose Desalination Concentrate into a Class II Injection Well	CDM Smith, Inc.	The study developed an instruction manual and road map for permitting a Class II well for dual Class I-Class II purposes.	Demonstration	2010	$130,000
Upflow Calcite Contractor Design	Carollo Engineers, Inc.	The study developed design criteria for the post-treatment of permeate water using an upflow calcite contactor.	Demonstration	2010	$188,403
Demonstration of Fiberglass Well Casings in Brackish Groundwater Wells	North Alamo Water Supply Corporation	The project demonstrated the viability of using fiberglass well casing in water wells installed in brackish aquifers.	Demonstration	2010	$100,000
Demonstration of a High Recovery and Energy Efficient Reverse Osmosis System for Small-Scale Brackish Water Desalination	Texas Tech University	The study demonstrated the use of a reverse osmosis system with parallel elements for small-scale desalination with high recovery and energy efficiency.	Demonstration	2010	$101,597

3.2 2017 State Water Plan

The TWDB develops the state water plan every five years through a locally-driven planning process guided by 16 regional water groups. Each regional group assesses existing water supplies and future needs. If there are anticipated water shortages, the group identifies both recommended and alternative water management strategies and/or projects to create new water supplies. A water management strategy is a plan to meet a water need, whereas a project is the infrastructure required to implement the strategy. This section describes seawater and brackish groundwater desalination activities in the 2017 State Water Plan.

3.2.1 Seawater desalination

In the 2017 State Water Plan, four regional water planning groups (regions H, L, M, and N) included seawater desalination as a recommended water management strategy for a total of 10 recommended water management strategies (Appendix A, Table A-1). If implemented, these seawater desalination strategies will produce an estimated 116,000 acre-feet of new water supply by 2070. This constitutes about 1.4 percent of all recommended water management strategies in the state water plan.

The Rio Grande Regional Water Planning Group (Region M) included seawater desalination as an alternative water management strategy, which is a strategy that can replace a recommended strategy in the regional water plan, and consequently the state water plan, if it turns out the original recommended strategy cannot be achieved (Texas Administrative Code §357.10(1)). If implemented, the 28 strategies in Region M (Appendix A, Table A-2) would provide 81,000 acre-feet per year of water supplies by 2070.

To implement recommended or alternative water management strategies, water user groups may need to execute projects to obtain the new water supplies. The difference between a water management strategy and project is that a strategy is a plan to meet a water need and the project is the infrastructure required to implement the strategy. Projects would develop, deliver, or treat additional water supply volumes at a specified capital cost. One project may be associated with multiple water management strategies.

Regional water planning groups identified six recommended water management strategy projects and five alternative projects for seawater desalination (Table 5). Two of the recommended water management strategy projects in Region L are not assigned to serve a specific water user group (in other words, the projects are recommended but are not planned to provide water to users during the 50-year planning period). Guidelines for regional water plan development allow the water availability associated with a strategy or project to "remain unallocated, by associating the water volumes with an unassigned water volume entity that represents the entity that sponsored the development of the water" (TWDB, 2018). The statewide weighted-average[1] seawater desalination unit cost of recommended projects is $1,431 per acre-foot ($4.39 per thousand gallons). The projects are distributed along the Gulf Coast

[1] The weighted average is the average of values scaled by the relative volume of each strategy.

(Figure 5). For a few projects, sponsors have completed feasibility or pilot studies with the assistance of TWDB research funds.

Table 5. Seawater desalination projects in the 2017 State Water Plan

ID	Region	Project sponsor	Project name	Feasibility study completed	Pilot study completed	Project level recommendation type
1	H	Brazos River Authority	Freeport seawater desalination	Yes	--	Recommended
2	L	San Antonio Water System	Seawater desalination	--	--	Recommended
3	L	Guadalupe Blanco River Authority	Integrated water-power project	Yes	--	Recommended
4	M	Brownsville Public Utilities Board	Brownsville seawater desalination demonstration	Yes	Yes	Recommended
5	M	Brownsville Public Utilities Board	Brownsville seawater desalination implementation	Yes	Yes	Recommended
6	N	Corpus Christi	Seawater desalination	Yes	--	Recommended
7	M	Laguna Madre Water District	Laguna Madre seawater desalination	Yes	Yes	Alternative
8	M	RGRWA	RGRWA ocean desal - Phase I	--	--	Alternative
9	M	RGRWA	RGRWA ocean desal - Phase II	--	--	Alternative
10	M	RGRWA	RGRWA ocean desal - Phase III	--	--	Alternative
11	M	RGRWA	RGRWA ocean desal - Phase IV	--	--	Alternative

Note: RGRWA = Rio Grande Regional Water Authority

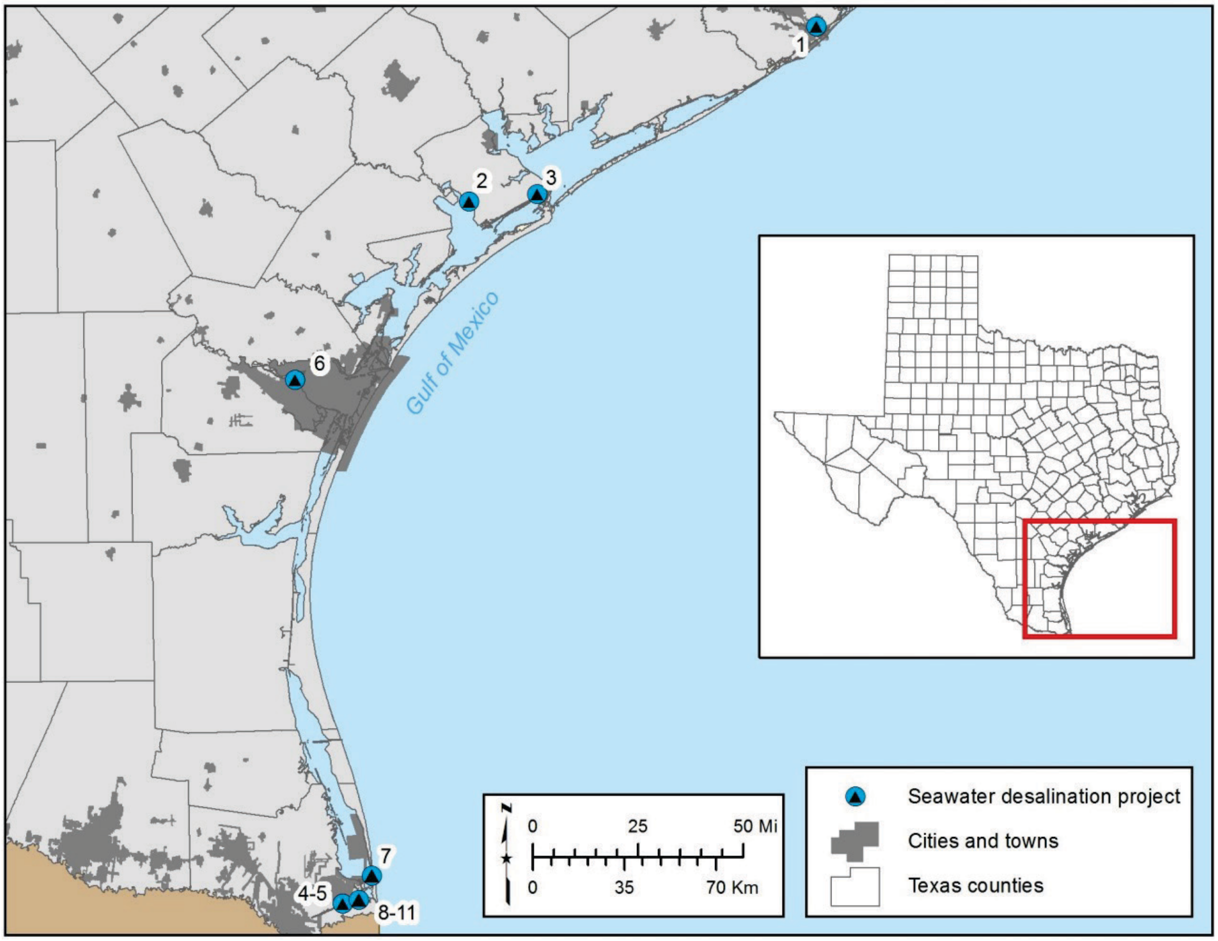


Figure 5. **Location of seawater desalination projects in the 2017 State Water Plan. Numbers refer to projects in Table 5.**

3.2.1.1 Region H Regional Water Planning Area

Seawater desalination is recommended as a water management strategy to meet manufacturing demands in Brazoria County by 2040 (Freese and Nichols, 2015). The Brazos River Authority proposes a seawater desalination plant with an initial capacity of 10 million gallons per day (11,200 acre-feet per year) at the Dow Chemical Company complex in the City of Freeport. The facility would use an existing intake and discharge outfall and Dow's withdrawal and discharge permits, which would reduce construction costs and environmental impacts. The estimated capital cost to build the plant is about $133 million.

3.2.1.2 South Central Texas (Region L) Regional Water Planning Area

The 2016 South Central Texas (Region L) Regional Water Plan includes two seawater desalination projects (HDR Engineering, Inc., 2015a). The San Antonio Water System proposes to build a seawater desalination plant adjacent to the San Antonio Bay near the City of Seadrift with a design capacity of 75 million gallons per day (84,000 acre-feet per year). A 126-mile-long pipeline would convey treated water to a location in southern Bexar County near the H2Oaks Center. The concentrate would be discharged 13 miles offshore to the Gulf of Mexico. The estimated total capital cost for the project is about $1.6 billion. The San Antonio Water System's 2017 Water Management Plan also identifies seawater desalination as a project that merits further consideration and would provide water supplies beyond 2070 (San Antonio Water System, 2017).

The Guadalupe-Blanco River Authority Integrated Water-Power Project would involve building an 89.3-million-gallon-per-day (100,000-acre-foot-per-year) seawater desalination plant near Port O'Connor in Calhoun County. Water would be conveyed via a 138-mile-long pipeline to Calhoun, Victoria, Gonzales, and Dewitt counties. The estimated total capital costs of the project are $1.6 billion.

3.2.1.3 Rio Grande (Region M) Regional Water Planning Area

The Brownsville Public Utilities Board proposes to locate a seawater desalination plant on the south shore of the Brownsville Ship Channel (Black & Veatch, 2015). The facility would come online by 2020 with an initial capacity of 2.5 million gallons per day (2,800 acre-feet per year) and would expand to 25 million gallons per day (28,000 acre-feet per year) by 2060. The estimated capital costs of the desalination plant are about $56 million for Phase I and about $310 million for Phase II.

3.2.1.4 Coastal Bend (Region N) Regional Water Planning Area

The City of Corpus Christi recommends a 20-million-gallon-per-day (22,400-acre-foot-per-year) seawater desalination project that would come online by 2030 (HDR Engineering, Inc., 2015b). The treatment plant, estimated to cost $248 million, could be located between Nueces and Corpus Christi bays or at the Inner Ship Channel adjacent to the Broadway Wastewater Treatment Plant near the northeast corner of Corpus Christi Bay. The plant would serve Nueces and San Patricio counties.

3.2.2 Brackish groundwater desalination

In the 2017 State Water Plan, eight regional water planning groups (regions E, F, H, J, L, M, N, and O) included groundwater desalination as a recommended water management strategy. In total, 78 recommended water management strategies would help meet the water needs of a water user group (Appendix A, Table A-3). If these recommended strategies are implemented, groundwater desalination would produce about 111,000 acre-feet per year of additional water supplies by 2070. This would constitute about 1.3 percent of all recommended water management strategies in the state water plan. Additionally, there are five water management strategies in regions F, L, and P not currently assigned to serve a specific water user group.

Four planning groups (regions K, L, M, and N) included groundwater desalination as an alternative water management strategy, for a total of 36 strategies (Appendix A, Table A-4). If implemented, these strategies would produce 32,449 acre-feet per year of new water supplies by 2070. Additionally, there are eight alternative water management strategies in regions F, K, and L not currently assigned to serve a specific water user group.

Regional water planning groups propose to implement 35 groundwater desalination projects (Table 6). The difference between a water management strategy and project is that a strategy is a plan to meet a water need and the project is the infrastructure required to implement the strategy. Projects would develop, deliver, or treat additional water supply volumes at a specified capital cost. One project may be associated with multiple water management strategies.

The proposed desalination projects are concentrated in the western, central, and southern parts of Texas (Figure 6). The statewide weighted-average[2] groundwater desalination unit cost of recommended projects is about $713 per acre-foot ($2.19 per 1,000 gallons). Project components may include pipelines, wells, new desalination plants, and expansions of existing plants. The implementation of the recommended water management strategies may lead to the development of 27 desalination plants (27 projects have a new treatment plant component).

Additional groundwater desalination may occur in the future as a result of implementing "groundwater wells and other" and "aquifer storage and recovery" recommended water management strategies.

Table 6. Brackish groundwater desalination recommended projects in the 2017 State Water Plan

ID	Region	Project sponsor	Project name	Capital cost (estimated)
1	E	Hudspeth County-other	Hudspeth County-other (Dell City) - brackish groundwater desalination facility	$1,299,000
2	E	El Paso	El Paso Water Utilities - expansion of the Kay Bailey Hutchison Desalination Plant	$37,200,000
3	E	El Paso	El Paso Water Utilities - brackish groundwater at the Jonathan Rogers Wastewater Treatment Plant	$65,865,000
4	E	Horizon Regional Municipal Utility District	Horizon Regional Municipal Utility District - additional wells and expansion of desalination plant	$56,443,000
5	E	Lower Valley Water District	Lower Valley Water District - groundwater from proposed well field - Rio Grande Alluvium Aquifer	$37,490,000
6	F	San Angelo	Desalination of other aquifer supplies in Tom Green County - San Angelo	$57,967,000

[2] The weighted average is the average of values scaled by the relative volume of each strategy.

ID	Region	Project sponsor	Project name	Capital cost (estimated)
7	F	Concho Rural Water Corporation	Desalination of other aquifer supplies in Tom Green County - Concho Rural Water Supply Corporation	$5,131,000
8	H	Conroe	Conroe brackish groundwater desalination	$40,691,342
9	H	Brazosport Water Authority	Brackish groundwater development	$34,016,950
10	L	San Antonio Water System	Brackish Wilcox groundwater for San Antonio Water System	$53,162,000
11	L	Canyon Regional Water Authority	Brackish Wilcox groundwater for Canyon Regional Water Authority	$62,787,000
12	L	Schertz-Seguin Local Government Corporation	Brackish Wilcox groundwater for Schertz-Seguin Local Government Corporation	$54,133,000
13	L	S S Water Supply Corporation	Brackish Wilcox groundwater for S S Water Supply Corporation	$16,864,000
14	L	San Antonio Water System	Expanded brackish Wilcox project - San Antonio Water System	$723,175,000
15	M	East Rio Hondo Water Supply Corporation; North Alamo Water Supply Corporation	North Cameron Regional Water Treatment Plant wellfield expansion	$1,881,000
16	M	Alamo	Alamo brackish groundwater desalination plant	$13,532,000
17	M	El Jardin Water Supply Corporation	El Jardin new brackish groundwater desalination plant	$8,272,000
18	M	Hebbronville	Hebbronville new brackish groundwater desalination plant	$8,275,000
19	M	La Feria	La Feria water well with reverse osmosis unit	$6,260,000
20	M	Lyford	Lyford brackish groundwater desalination	$6,950,000
21	M	McAllen	McAllen brackish groundwater desalination plant	$31,218,000
22	M	Mission	Mission brackish groundwater desalination plant	$31,914,000
23	M	Union Water Supply Corporation	Union Water Supply Corporation brackish groundwater desalination plant	$8,282,000
24	M	Laguna Madre Water District	Laguna Madre new brackish groundwater desalination plant	$22,564,000
25	M	North Alamo Water Supply Corporation	North Alamo Water Supply Corporation delta area reverse osmosis water treatment plant expansion	$22,709,000
26	M	Primera	Primera brackish groundwater desalination plant	$14,318,000
27	M	Sharyland Water Supply Corporation	Sharyland well and reverse osmosis at water treatment plant 2	$13,253,000
28	M	Sharyland Water Supply Corporation	Sharyland well and reverse osmosis at treatment plant 3	$13,253,000
29	M	San Juan	San Juan water treatment plant No. 1 expansion	$9,561,000

ID	Region	Project sponsor	Project name	Capital cost (estimated)
30	M	North Alamo Water Supply Corporation	North Alamo Water Supply Corporation La Sara reverse osmosis expansion	$13,260,000
31	N	Alice	Brackish groundwater development - Alice	$33,277,000
32	O	Seminole	Gaines County - Seminole groundwater desalination	$31,572,000
33	O	Abernathy	Hale County - Abernathy groundwater desalination	$10,100,000
34	O	Lubbock	Lubbock County - Lubbock brackish well field at the south water treatment plant	$34,531,740
35	P	Lavaca Navidad River Authority	Lavaca-Navidad River Authority desalination	$31,393,000
			Total	**$2,198,787,010**

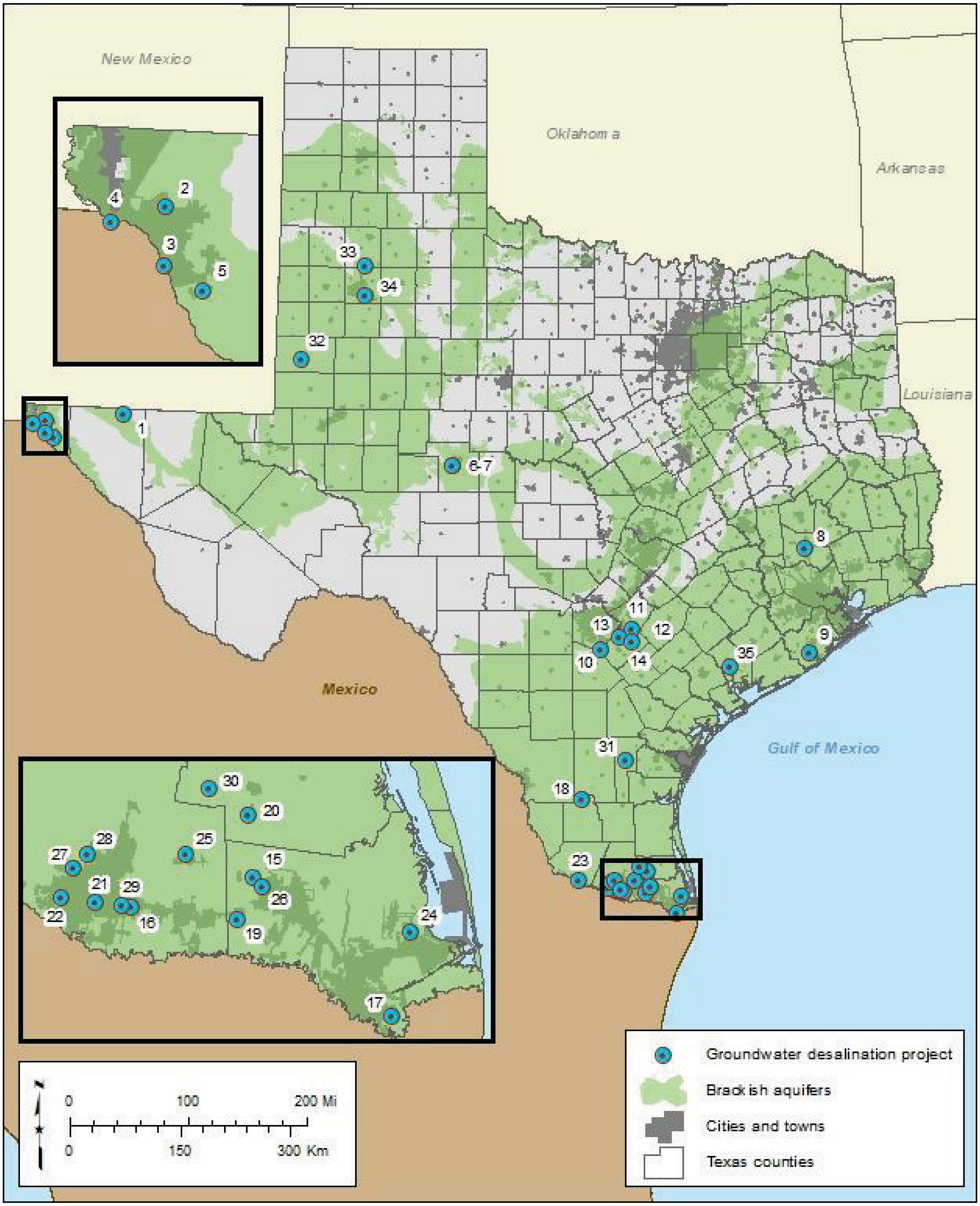


Figure 6. **Location of brackish groundwater desalination projects in the 2017 State Water Plan. Numbers refer to projects in Table 6.**

3.2.2.1 Far West Texas (Region E) Regional Water Planning Area

Brackish groundwater desalination is recommended as a water management strategy in the 2016 Far West Texas (Region E) Regional Water Plan to meet water demands starting by 2020. The desalination projects include the development of new wells, the construction of new desalination plants, and the expansion of existing facilities.

El Paso Water Utilities proposes developing 10 new wells and building a new desalination plant near the Jonathan Rogers Water Treatment Plant. The brine would be disposed via a deep injection well. The capital costs of the project are estimated at $65.8 million. El Paso Water Utilities also plans to expand the Kay Bailey Hutchison Desalination Plant from 27.5 to 32 million gallons per day (30,800 to 35,840 acre-feet per year). The project is planned to be completed in phases, which would include seven new wells and one new deep injection well, for a total capital cost of $37.2 million. The Utility also plans to import water from the Dell City area. Total capital costs would be $110 million, which would include purchasing land, rehabilitating 15 wells and a pump station, and building a 12-mile pipeline and an 18-million-gallon-per-day (20,160-acre-foot-per-year) desalination plant. However, this recommended project is associated with a "groundwater well development" water management strategy and not listed in Table 6. The TWDB provided a $50 million loan on December 2, 2015, and a $150 million multi-year loan on July 21, 2016, both from the State Water Implementation Fund for Texas to El Paso Water Utilities to purchase land and water rights above Bone Spring-Victorio Peak Aquifer. The project is ongoing, and land and water purchases are in progress.

The Lower Valley Water District proposes to develop a 10-million-gallon-per-day (11,200-acre-foot-per-year) plant along with a water storage tank, a disposal well, and seven new wells. Total capital costs would be $37.4 million and include the land purchase. The District proposes a similar project, with capital costs of $41.1 million, that would develop groundwater from the Hueco Bolson Aquifer instead of the Rio Grande Alluvium Aquifer.

The Horizon Municipal Utility District plans to expand its existing desalination plant from 6.0 to 21.4 million gallons per day (6,720 to 23,968 acre-feet per year). Expansion would include the development of nine new wells and project capital costs of $56.4 million. Dell City also plans to expand its existing plant by replacing the electrodialysis reversal system with reverse osmosis system at a capital cost of $1.29 million. In May 2013, the TWDB provided $244,450 in loan forgiveness to Dell City from the Drinking Water State Revolving Fund to complete the improvements to the desalination plant. The project is in the engineering design phase.

3.2.2.2 Region F Regional Water Planning Area

The City of San Angelo and the Upper Colorado River Authority propose a 7-million-gallon-per-day (7,840-acre-foot-per-year) desalination plant with six deep injection wells and a six-mile-long concentrate disposal pipeline. The project's capital costs are estimated at $79.1 million. The City of San Angelo also proposes to build a 10-million-gallon-per-day (11,201-acre-foot-per-year) desalination plant with four deep injection wells at total capital costs of $57.9 million.

The Concho Rural Water Corporation plans to build a 0.27-million-gallon-per-day (302-acre-foot-per-year) desalination plant and dispose of the concentrate in evaporation ponds. Capital costs would be $5.13 million.

3.2.2.3 Region H Regional Water Planning Area

The City of Conroe proposes to build a desalination facility and treat groundwater from the Catahoula Aquifer. Capital costs for the project are estimated at $40.7 million.

The Brazosport Water Authority plans to drill three groundwater wells and build a 6-million-gallon-per-day (6,720 acre-foot-per-day) desalination plant to treat the groundwater. In Phase II, they plan to drill two additional wells and expand the capacity of the plant to 12 million gallons per day (13,440 acre-feet per year). The concentrate would be discharged to a segment of the Brazos River below State Highway 332. The project's capital costs for Phase I and II would be $34 million.

3.2.2.4 Plateau (Region J) Regional Water Planning Area

The Upper Guadalupe River Authority and Eastern Kerr County propose to build a 1.2-million-gallon-per-day (1,344-acre-foot-per-year) facility using the Ellenburger Aquifer and dispose of the concentrate via evaporation ponds. Capital costs for the project are estimated at $14.5 million.

3.2.2.5 South Central Texas (Region L) Regional Water Planning Area

The S S Water Supply Corporation plans to pump brackish groundwater from the Wilcox Aquifer and treat it in a 2-million-gallon-per-day (2,240-acre-foot-per-year) desalination plant. The project would consist of three new groundwater wells, a two-mile-long pipeline, a storage water tank, and a deep injection well. Capital costs would be approximately $16.9 million.

The Schertz-Seguin Local Government Corporation plans to develop six groundwater wells that would pump water to a 5-million-gallon-per-day (5,600-acre-foot-per-year) desalination facility. The concentrate would be disposed via deep well injection. Capital costs of the project are estimated at approximately $69.6 million. On July 21, 2016, the TWDB approved a $66.5 million loan from the State Water Implementation Fund for Texas for the Corporation to develop a wellfield above the Wilcox and Carrizo aquifers and to build a water treatment facility and other project components. The project is ongoing, and TWDB staff have reviewed the engineering feasibility report and will issue an environmental finding.

The Canyon Regional Water Authority plans to develop up to 20 supply wells for a new brackish groundwater desalination plant. The project also includes separate water and concentrate pipelines and a deep injection well for concentrate disposal. Capital costs would be approximately $186.7 million.

The San Antonio Water System plans to expand the capacity of its existing desalination plant to 30 million gallons per day (33,600 acre-feet per year). The expansion will be completed in phases, which includes a 12-million-gallon-per-day (13,440-acre-foot-per-year) expansion in the second phase, and a 6-million-gallon-per-day (6,720-acre-foot-per-year) expansion in the third phase. The second phase includes the development of 12 wells and two deep injection wells at a proposed capital cost of approximately $96.5 million. The third phase includes the development of six wells and one deep injection well for a total capital cost of $42.8 million. Even though San Antonio Water System has plans to expand the desalination facility, as described above, it is restricted to the Modeled Available Groundwater (MAG) of 6,059 acre-feet per year (5.4 million gallons per day). The project would include the development of six wells, expansion of the plant, and installation of one concentrate injection well. Capital costs of the MAG constrained project would be $53.1 million.

The San Antonio Water System envisions another similar project that would include the development of two wellfields, with 32 wells in one wellfield and 19 wells in the other. The groundwater would be conveyed by a 36-mile-long pipeline to two new desalination plants with design capacities of 31.2 and 44.6 million gallons per day (34,944 and 49,952 acre-feet per year), respectively. Concentrate disposal would occur via nine deep injection wells. Capital costs of the project are estimated at approximately $723 million.

3.2.2.6 Rio Grande (Region M) Regional Water Planning Area

The Rio Grande Regional Water Planning Area has several desalination projects that include the construction of new plants and expansion of existing facilities. The capacity of the North Cameron Regional Water Supply Corporation desalination plant would be increased from 1.15 to 2.30 million gallons per day (1,288 to 2,576 acre-feet per year) with the addition of a water supply well. Capital costs of the project are estimated to be $1.9 million. Similarly, the North Alamo Water Supply Corporation plans to increase the capacity of the La Sara Desalination Plant by 1 million gallons per day (1,120 acre-feet per year) with the addition of groundwater wells and reverse osmosis systems. Capital costs are estimated at $13.3 million. The City of San Juan is also recommending the expansion of its existing brackish groundwater desalination facilities.

The City of El Jardin plans to build a new 0.5-million-gallon-per-day (560-acre-foot-per-year) desalination plant at a total capital cost of about $8.3 million. The City of La Feria also proposes to build a new desalination plant with capacity of 1.25 million gallons per day (1,400 acre-feet per year) and capital costs of approximately $6.3 million. Laguna Madre Water District recommends the building of a 2-million-gallon-per-day (2,240-acre-foot-per-year) desalination facility at a total capital cost of $22.4 million. Similarly, North Alamo Water Supply Corporation also plans to build a 2-million-gallon-per-day (2,240-acre-foot-per-year) desalination facility at a capital cost of $22.7 million. Other entities (Alamo, Hebbronville, Lyford, McAllen, Mission, Primera, Sharyland Water Supply Corporation, and Union Water Supply Corporation) also recommend the construction of new brackish groundwater desalination facilities to provide new water supplies for the region.

3.2.2.7 Coastal Bend (Region N) Regional Water Planning Area

The City of Alice proposes to build a 4-million-gallon per-day (4,480-acre-foot-per-year) desalination facility and two new wells that would pump groundwater from the Jasper Formation. The concentrate would be piped and discharged to San Diego Creek, which ultimately flows into San Fernando Creek. Capital costs for the project are estimated at about $33.3 million.

3.2.2.8 Llano Estacado (Region O) Regional Water Planning Area

The City of Abernathy plans to develop a 0.13-million-gallon-per-day (146-acre-foot-per-year) desalination facility with four production wells and one deep injection well. The City of Seminole proposes to develop a larger desalination plant with 11 production wells and 6 deep injection wells. The groundwater source for both projects would be the Santa Rosa Formation (Dockum Aquifer). Estimated capital costs are $10.1 million for the Abernathy project and $31.6 million for the Seminole project.

The City of Lubbock plans to build a 1.5-million-gallon-per-day (1,680-acre-foot-per-year) desalination plant with four wells that would also produce groundwater from the Santa Rosa Formation. Desalinated water would be blended with water from the South Water Treatment Plant, and the concentrate would be disposed through two deep injection wells. Capital costs would run approximately $34.5 million.

3.2.2.9 Lavaca (Region P) Regional Water Planning Area

The Lavaca-Navidad River Authority plans to develop a brackish groundwater desalination facility to provide water supplies for manufacturing at Formosa Plastics. The Authority plans to build a 5.8-million-gallon-per-day (6,497 acre-foot-per-year) desalination plant with three groundwater supply wells. Concentrate would be discharged to Lavaca Bay. The project’s capital costs are estimated at approximately $31.3 million.

3.3 Grant programs

Other TWDB funding sources for desalination activities include the Regional Facility Planning Grant Program and the Research and Planning Fund. The TWDB established these internal grant programs to fund projects related to a variety of topics (reuse, desalination, etc.). The Regional Facility Planning Grant Program was discontinued in 2016 and the Research and Research and Planning Fund in 2014, due to loss of funding. Table 7 lists past projects funded through these two grant programs, but is not all encompassing. Two projects are described in more detail below.

Table 7. Brackish groundwater desalination projects funded through grant programs

Report title	Contractor	Description	Study type	Year funded	Grant amount
Brackish Groundwater Manual for Texas Regional Water Planning Groups	LBG-Guyton Associates	The study identified potential brackish groundwater sources in Texas for future potable use.	Research	2003	$99,940
A Desalination Database for Texas	Bureau of Economic Geology at The University of Texas at Austin	The study developed a desalination database for Texas.	Research	2004	$75,000
Self-Sealing Evaporation Ponds for Desalination Facilities in Texas	Bureau of Economic Geology at The University of Texas at Austin	The study investigated regulatory requirements for developing a self-sealing evaporation pond.	Research	2005	$49,928
Assessment of Osmotic Mechanisms Pairing Desalination Concentrate and Wastewater Treatment	CH2M Hill	The study investigated the use of reverse osmosis concentrate as a draw solution in a forward osmosis process for recovering water from wastewater.	Research	2008	$90,000
Energy Optimization of Brackish Groundwater Reverse Osmosis Desalination	Affordable Desalination Collaboration	This study assessed and demonstrated energy optimization strategies for brackish groundwater desalination by reverse osmosis.	Research	2009	$496,783
Alternative to Pilot Plant Studies for Membrane Technologies	Carollo Engineers, Inc.	The project evaluated alternatives to the current regulatory requirements for pilot testing membranes.	Research	2011	$150,000

3.3.1 Barton Springs/Edwards Aquifer Conservation

On June 16, 2016, the TWDB awarded a $240,000 grant through the Regional Facility Planning Grant Program to the Barton Springs/Edwards Aquifer Conservation District to conduct a feasibility study to treat saline groundwater from the Edwards Aquifer at a desalination facility and store the desalinated water at an aquifer storage and recovery system (Carollo Engineers, 2018). Water quality sampling was conducted from the multiport monitoring well, and the salinity concentration of the groundwater was 17,000 milligrams per liter. Using membrane software, the reverse osmosis system for a 5.0 million-gallon-per-day (5,600 acre-foot-per-year) facility was modeled and predicted the salinity of the concentrate to be approximately 72,000 milligrams per liter. The concentrate would be disposed via deep well injection into the Trinity Aquifer. The 30-year life cycle cost for (1) the 5 million-gallon-per-day (5,600 acre-foot-per-year) desalination facility powered by the electrical grid with concentrate disposal in Trinity Aquifer injection wells would be $8.20 per thousand gallons ($2,673 per acre-foot) and (2) the aquifer storage and recovery system to store the desalinated water would run $0.38 per 1,000 thousand ($124 per acre-foot).

3.3.2 Rio Grande Regional Water Authority

On July 1, 2016, a regional water facility plan evaluating alternative water supplies for the Lower Rio Grande Valley was completed for the Rio Grande Regional Water Authority (Blandford and Jenkins, 2016). The purpose of the study was to evaluate alternative water sources for the region including seawater and brackish groundwater desalination. The study evaluated a 22,400-acre-foot-per-year (20-million-gallon-per-day) seawater desalination facility located at the Brownsville Navigation Channel with an approximate capital cost of $119 million or near the Gulf Coast for $229 million. The study concluded that seawater was a viable water supply for the region. The study also evaluated building: (1) a desalination plant and wellfield of 58 wells in Cameron County at a total capital cost of $249.7 million, and (2) a desalination plant and wellfield of 18 wells in Hidalgo County at a total capital cost of $86.9 million.

3.4 Loan assistance programs

The TWDB’s loan programs are available to public entities to fund the planning, design, and construction phases of seawater and brackish groundwater desalination plants. Since 1989, the TWDB has financed 36 desalination projects (Table 8) with a total value of approximately $322 million. Desalination projects are eligible for financing from various agency programs, including the Drinking Water State Revolving Fund, the State Participation Program, and the Texas Water Development Fund. Desalination projects in the state water plan are also eligible to benefit from the State Water Implementation Fund for Texas (SWIFT). To date, the TWDB has funded two seawater desalination projects (Corpus Christi and Guadalupe-Blanco River Authority) and one brackish groundwater desalination project (Brazosport Water Authority) through the SWIFT program. The Guadalupe-Blanco River Authority canceled its seawater desalination feasibility study to focus on near-term projects.

Table 8. Desalination projects funded through TWDB's financial programs, as of August 2018

No.	Entity	Funding program	Funding amount*	Funding date	Project name
1	Holiday Beach Water Supply Corporation	DWSRF	$700,000	1/22/2018	Urgent Need Request: Hurricane Harvey
2	Corpus Christi	SWIFT	$2,750,000	7/20/2017	Seawater Desalination
3	Commodore Cove Improvement District	DWSRF	$200,000	12/15/2016	Reverse Osmosis Treatment
4	Wellman	DWSRF	$1,122,654	05/05/2016	Nitrate and fluoride removal
5	Seymour	DWSRF	$4,140,476	04/11/2016	Water system improvements
6	Loop Water Supply Corporation	DWSRF	$170,000	12/14/2015	Water treatment plant improvements
7	Brazosport Water Authority	SWIFT	$28,300,000	07/23/2015	Brackish groundwater reverse osmosis water treatment plant and water wells
8	Guadalupe-Blanco River Authority	SWIFT	$2,000,000	07/23/2015	Integrated Water and Power Plant project
9	Granbury	DWSRF	$16,430,000	03/26/2015	City of Granbury water treatment plant
10	Baylor Water Supply Corporation	DWSRF	$500,000	02/25/2015	Urgent need - Bufkin well field development
11	San Antonio Water System	DWSRF	$75,920,000	11/06/2014	Water Resources Integration pipeline
12	Raymondville	DWSRF	$3,800,000	09/19/2013	Well and reverse osmosis system
13	Dell City	DWSRF	$244,450	05/16/2013	Reverse osmosis treatment plant
14	Montgomery County Municipal Utility District #8 and #9	WDF	$5,450,000	09/22/2011	Walden conjunctive use water treatment plant design
15	Roscoe	DWSRF	$1,765,000	05/04/2011	Reverse osmosis water treatment plant
16	Stephens Regional Special Utility District	DWSRF; WDF	$5,800,000	01/20/2011	Water treatment plant and transmission lines
17	Fort Hancock Water Improvement Control District	EDAP	$3,012,990	04/22/2010	Water well and RO treatment facility
18	Fort Griffin Special Utility District	DWSRF	$2,355,000	10/15/2009	Throckmorton County water lines
19	Millersview-Doole Water Supply Corporation	DWSRF	$10,857,148	10/15/2009	Surface water treatment plant and distribution lines
20	San Antonio Water System	WIF	$109,550,000	07/16/2009	Brackish groundwater desalination
21	Greater Texoma Utility Authority	WIF	$835,000	12/15/2008	Northwest Grayson County Water Improvement Control District #1 Surface water treatment plant

No.	Entity	Funding program	Funding amount*	Funding date	Project name
22	Possum Kingdom Water Supply Corporation	DWSRF	$1,625,000	07/18/2006	Water treatment plant expansion
23	East Rio Hondo Water Supply Corporation	RWAF	$4,150,000	11/15/2005	North reverse osmosis plant transmission line
24	Clarksville City	WDF	$1,530,000	02/15/2005	George Richey Road water wells
25	Ballinger	DWSRF	$3,865,000	06/16/2004	Lake Ballinger water line
26	El Paso	WAF; SAAP	$1,240,000	03/20/2002	Eastside desalination plan
27	Horizon Regional Municipal Utility District	WDF	$7,780,000	11/14/2001	Reverse osmosis treatment plant
28	Burleson Co Municipal Utility District #1	DWSRF	$1,560,000	09/19/2001	Reverse osmosis treatment facility
29	Holiday Beach Water Supply Corporation	WDF	$470,000	11/15/2000	Reverse osmosis water plant
30	Harlingen	CWSRF	$1,845,000	04/19/2000	Wastewater treatment plant #2 sludge process
31	Brady	DWSRF	$9,405,000	03/09/2000	New surface water treatment plant and storage tank
32	Palmer	DWSRF	$1,405,000	07/14/1999	Reverse osmosis plant
33	Possum Kingdom Water Supply Corporation	DWSRF	$4,700,000	12/17/1998	Regional water system
34	Lorena	WDF	$3,335,000	10/16/1997	Robinson transmission line
35	Haciendas del Norte Water Improvement District	WDF	$1,725,000	08/20/1997	East Montana transmission and RO unit
36	Harlingen	WAF	$2,000,000	04/20/1989	Wastewater treatment plant #2 expansion

Note: *Funding amount = final funded amount after all withdrawals and alterations
CWSRF = Clean Water State Revolving Fund
DWSRF = Drinking Water State Revolving Fund
EDAP = Economically Distressed Areas Program
RWAF = Rural Water Assistance Fund
SWIFT = State Water Implementation Fund for Texas
WIF = Water Infrastructure Fund
WAF = Water Assistance Fund
WDF = Water Development Fund

3.4.1 Guadalupe-Blanco River Authority

On December 1, 2015, the Guadalupe-Blanco River Authority received a $2 million loan from the TWDB through the State Water Implementation Fund for Texas to further study integration of a seawater desalination plant as a supplemental supply and to continue project development. Project tasks included preliminary site selection and project sizing criteria, completing environmental surveys, and much more. However, the Authority canceled the feasibility study to focus on near-term projects, but the TWDB outstanding loan may be used toward their project with Schertz-Seguin Local Government Corporation.

3.4.2 Brazosport Water Authority

On July 23, 2015, the TWDB approved a $28.3 million loan through the State Water Implementation Fund for Texas to the Brazosport Water Authority to design and build a brackish groundwater desalination plant. The proposed 6-million-gallon-per-day (6,720-acre-foot-per-year) desalination facility would pump groundwater using three wells located in the Gulf Coast Aquifer. The concentrate would be discharged to an impaired segment of the Brazos River. A cultural resources survey and wetland delineation of the project area has been completed. The Authority has begun the environmental permitting process with the Texas Historical Commission, Local Floodplain Administrator, U.S. Army Corps of Engineers, and Texas Parks and Wildlife Department. Most of these permitting agencies concluded there was no environmental impact to the surrounding area. To abide by the Migratory Bird Treaty Act, the Brazosport Water Authority will need to comply with conditions provided by the Texas Parks and Wildlife Department when site clearing begins. Recently, the Authority installed a demonstration and monitoring well to obtain water quality and aquifer-specific data. The testing indicated higher salinity and lower water yields than expected. As a result, the Authority will complete two additional test wells at depths of 850 feet and 1,250 feet and conduct testing for several months.

3.4.3 City of Corpus Christi – Industrial desalination project (Phase II)

On July 20, 2017, the City of Corpus Christi received a $2.75 million loan to continue conducting planning tasks for a seawater desalination plant through the TWDB's State Water Implementation Fund for Texas. Before initiating procurement and implementation (Phase II) of the desalination plant, the stakeholder group determined that additional information was needed. Project tasks include establishing a cost allocation methodology and water rate strategy, recommending a plant site and brine management options, and developing a water characterization plan. Phase I of this project is discussed in 4.1.3. Currently, the city and the consultant are working on cost allocation and utility rate strategy for the project. In August 2018, the City of Corpus Christi issued a request for information on alternative water supplies projects that will produce 10 million gallons per day (11,200 acre-feet per year) of potable water over a 30-year period. Responses are due by October 12, 2018 (Pankratz, 2018a and b). The City hosted a pre-bid meeting on August 30, 2018.

4 Other desalination activities

This chapter describes desalination activities not funded by the TWDB. Several public entities have completed or have ongoing seawater and brackish groundwater desalination studies that were funded by the entity themselves and possibly by a grant from other state or federal agencies. Recently enacted legislation and the permitting process are addressed. In addition, some active desalination organizations are also discussed.

4.1 Seawater desalination activities

Several public entities have completed or are conducting feasibility studies in support of seawater desalination projects. These activities are described in more detail below. Recent legislation passed by the Texas Legislature and its effects on regulations are also discussed.

4.1.1 *Guadalupe-Blanco River Authority*

The Guadalupe-Blanco River Authority, in partnership with the Texas General Land Office and the Texas Sustainable Energy Research Institute at The University of Texas at San Antonio, conducted a feasibility study to determine the best co-location for a seawater desalination plant and a power plant for their Integrated Water-Power Project. The river authority obtained a $450,000 grant from the U.S. Bureau of Reclamation through the Title XVI Water Reclamation and Reuse Program to cover part of the study costs.

The feasibility study evaluated siting a 25- to 250-million-gallon-per-day (28,000- to 280,000-acre-foot-per-year) seawater desalination plant with a 500- to 3,000-megawatt co-located power plant (Guadalupe-Blanco River Authority, 2014). The study area extended from Freeport to Corpus Christi along the Gulf Coast. Possible site locations were identified in San Patricio, Calhoun, Matagorda, and Brazos counties. The Authority obtained a loan from the TWDB, which is discussed in the Loan assistance programs section of this report.

4.1.2 *City of Corpus Christi variable salinity desalination program*

In 2013, the City of Corpus Christi contracted with an engineering firm to conduct a 30-month study to design, build, and operate a demonstration seawater desalination plant (City of Corpus Christi, 2014a). The City allocated funds to conduct the study and received a $400,000 grant from the U.S. Bureau of Reclamation through the Desalination and Water Purification Research program. The study consisted of four major components: literature review, desalination plant siting, pilot testing criteria, and pilot testing protocol. The team compiled water quality data from 17 locations and analyzed water samples only from 15 locations (Cocklin, 2016). The proposed site for the 12-month-long pilot is located next to the existing Broadway Wastewater Treatment Plant near the inner harbor. The team finalized the protocol and technical criteria for the pilot study. The City of Corpus Christi, however, decided not to move forward with the pilot testing.

4.1.3 *Industrial seawater desalination facility economic feasibility – Phase I*

A group of 15 stakeholders consisting of industries, water providers, and regional authorities located in and around Corpus Christi has joined forces to conduct a feasibility study on seawater desalination for industrial purposes. Since they use 50 percent of the region’s municipal water supplies, the industrial stakeholders are considering developing seawater desalination water supplies to ensure service continuity in the event of extreme drought. The Industrial Seawater Desalination Facility Economic Feasibility Study consists of two phases. The first phase will evaluate locations, water sources, water delivery methods, and brine disposal for a seawater desalination plant. If the stakeholders decide to implement the project, the second phase will procure and implement the facility. Study participants include the City of Corpus Christi, Corpus Christi Regional Economic Development Corporation, San Patricio Municipal Water District, Port of Corpus Christi, DuPont, OxyChem, Sherwin Alumina Company, LyondellBassell Industries, Citgo, Flint Hills Resources, Valero, Topaz Power, AEP Texas, Cheniere Energy, and Voestalpine Texas.

Funding for the study is provided by Corpus Christi Regional Economic Development Corporation ($150,000), Port Industries of Corpus Christi ($150,000), and the City of Corpus Christi ($50,000) (City of Corpus Christi, 2014b). Phase I of the study concluded that stakeholders prefer to build two seawater desalination plants, each with a capacity of 10 million gallons per day (11,200 acre-feet per year) (Freese and Nichols, 2016). One plant could be located in Corpus Christi on the Inner Harbor Ship Channel and the other in Ingleside on the La Quinta Channel. The desalinated water would be delivered using the Corpus Christi Regional System, and funding would be pursued through the TWDB's State Water Implementation Fund for Texas (Arroyo and Paulison, 2016).

4.1.4 *Port of Corpus Christi Authority – Discharge permits*

On March 7, 2018, the Port of Corpus Christi Authority submitted an application for a water quality permit for the disposal of up to 19 million gallons per day (21,280 acre-feet per year) of brine via pipeline to multi-port diffuser to the La Quinta Channel in the Corpus Christi Bay (Port of Corpus Christi Authority, 2018). The seawater desalination plant would be constructed on land owned by the port authority and located in Portland, Texas. The port authority's plan is to obtain the necessary permits for the 50-million-gallon-per-day (56,000-acre-foot-per-year) desalination plant and have a public entity, such as the City of Corpus Christi, develop it. The TCEQ required the port authority to conduct a mixing zone analysis of the brine being discharged to the bay using CORMIX. The modeling concluded that discharging brine with a total dissolved solid concentration of 66,000 milligram per liter would cause less than 1 percent increase of the ambient salinity in the Corpus Christi Bay. The total dissolved solids concentration in the bay is 41,252 milligrams per liter.

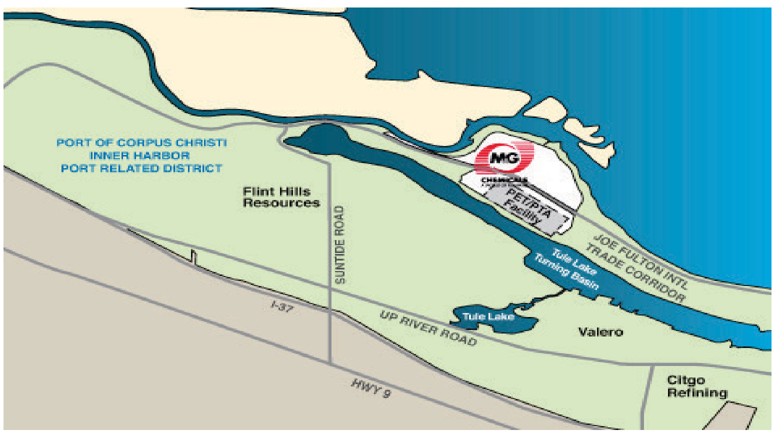
On May 7, 2018, the TCEQ issued a public notice and will begin the technical review of the application (TCEQ, 2018). While in process, the public was able to submit comments or request a public meeting or a contested case hearing. Based on news articles, there is public opposition to the construction of the desalination plant.

4.1.5 *City of Ingleside*

In August 2018, the City of Ingleside signed a memorandum of understanding with Poseidon Water to evaluate the technical and economic feasibility of constructing a seawater desalination plant (Pankratz, 2018a).

4.1.6 *M&G Resins USA, LLC*

M&G Resins USA, LLC, an Italian chemical company, is a producer of polyethylene terephthalate. Polyethylene terephthalate is used to make plastic packaging such as bottles and containers. In 2012, M&G Resins announced plans to build the world's largest polyethylene terephthalate plant, along with an integrated terephthalic acid plant in Corpus Christi. The plants were to be located at a site between Nueces Bay and the Viola Channel (Figure 7).



Source: Gruppo Mossi & Ghisolfi (M&G) Polymers

Figure 7. Location of the polyethylene terephthalate and terephthalic acid plant in Port of Corpus Christi Inner Harbor.

The two chemical plants would require about 8,960 acre-feet per year (8 million gallons per day) of water for the manufacturing process (M&G Resins USA, 2014). To meet this requirement, the chemical company was building a seawater desalination plant onsite to supply 6,720 acre-feet per year (6 million gallons per day) of water and recover 2,240 acre-feet per year (2 million gallons per day) of water from their internal process. Approximately 80 percent of the water consumption in the manufacturing plant would be for cooling purposes while the rest would be used in the manufacturing process.

The seawater desalination plant would ensure that a reliable source of water was always available for use at the plants. Additionally, by locating a desalination plant onsite, the quality of water produced could be controlled to meet the requirements of the chemical plants. The desalination plant would be initially designed to suit M&G Resins' needs but could be expanded to divert up to 24,640 acre-feet per year (22 million gallons per day) of raw water in the future. The planned seawater desalination plant was expected to require about 16,800 acre-feet per year (15 million gallons per day) of raw seawater from the Viola Channel. About 10,080 acre-feet per year (9 million gallons per day) of brine produced during the desalination process would be discharged back into the channel.

The company filed for a water permit in February 2013, and the water permit and wastewater discharge permit were granted in September 2014 (M&G Resins USA, 2014). The construction of the desalination plant began (Figure 8), and the plant was supposed to be operational in the last quarter of 2017 (M&G Resins USA, LLC, 2016). TWDB staff toured the unfinished seawater desalination facility on July 11, 2017. The company filed for bankruptcy in October 2017 and sold the unfinished project to an international business venture. The Port of Corpus Christi Authority placed a bid on the project on behalf of the City of Corpus Christi but was unsuccessful.

Source: Gruppo Mossi & Ghisolfi (M&G) Polymers

Figure 8. Image showing construction of the M&G Resins industrial seawater desalination plant, as of October 14, 2016.

4.1.7 *Legislative Committees*

On November 4, 2015, the speaker of the Texas House of Representatives assigned various interim committee charges to the House Committee on Natural Resources. On April 26, 2016, the committee conducted a hearing focused on water quality (Interim Charge 9) and desalination (Interim Charge 4) in Brownsville. More specifically, Interim Charge 4 consisted of evaluating the progress of seawater desalination near the Texas coast, building on the work of the Joint Interim Committee to Study Water Desalination (83rd Texas Legislative Session, 2015). The TWDB Chairman and staff provided testimony on the status of desalination in Texas.

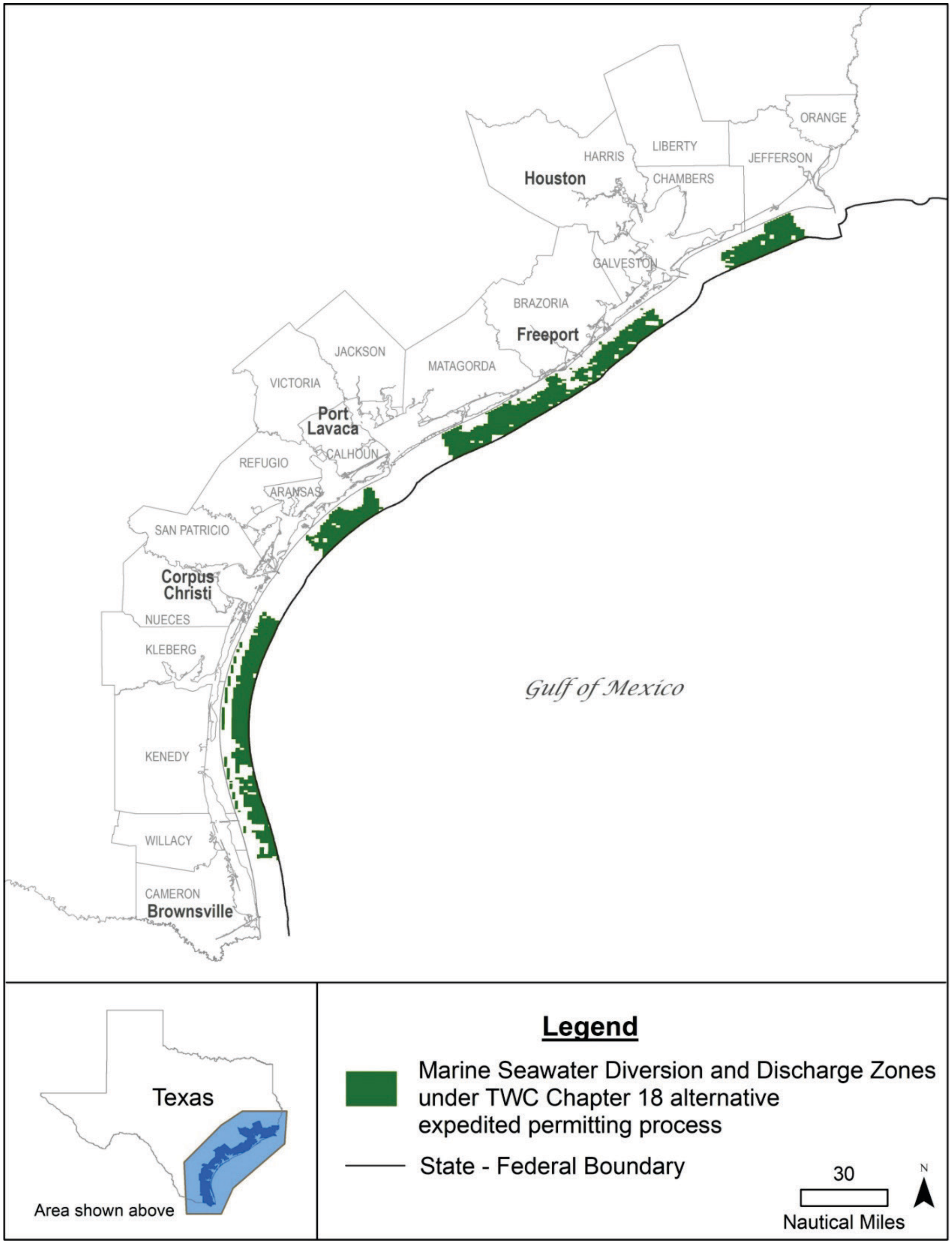
4.1.8 House Bill 2031

In 2015, the 84th Texas Legislature passed House Bill 2031 relating to the diversion, treatment, and use of marine seawater and the discharge of treated marine seawater and brine resulting from the desalination of marine seawater. The overall goal was to streamline and expedite the regulatory and permitting processes associated with seawater desalination. House Bill 2031 created Chapter 18 in the Texas Water Code, which requires entities to:

- Obtain a permit to divert and use seawater if the point of diversion is located within three miles or less of the Gulf Coast, or if the yearly average of total dissolved solids concentration of the seawater is less than 20,000 milligrams per liter. The total dissolved solids concentration is required to be calculated based on monthly sampling for a year, and data must be provided to the TCEQ (Texas Water Code §18.003(a) and (c)). If the point of diversion is more than three miles offshore, a permit is not required.
- Obtain a bed and bank permit to discharge and convey treated seawater via a lake, reservoir, flowing stream, or other impoundment. The desalinated water must be of the same quality of the receiving water body (Texas Water Code §18.004).

The bill also directed the Texas Parks and Wildlife Department (TPWD) and General Land Office (GLO) to identify zones in the Gulf of Mexico where an entity can divert seawater for desalination and discharge waste from the desalination process. The TCEQ is required to designate zones by September 1, 2020 (Texas Water Code §18.003(i)). On November 16, 2016, the TCEQ adopted the proposed rulemaking for House Bill 2031. The TCEQ also created a marine seawater desalination permit application and instructions for completing the form (TCEQ, 2016a and b).

To meet the above legislative requirements, the TPWD and GLO completed a joint study by the statutory deadline of September 1, 2018, and identified zones for both diversion of marine seawater and discharge of the desalination waste, also known as the brine (TPWD and GLO, 2018). Results from the study will inform a new, expedited permit application process currently under development at the TCEQ. The TPWD created a map that shows the zones for diversion and discharge that are only applicable when using the expedited permitting process for seawater desalination (Figure 9). No zones are located within the state’s bays and estuaries. Both agencies will work together to update the map periodically due to the dynamic nature of the Gulf of Mexico. The map will be available at the GLO Resource Management Code Viewer (glo.maps.arcgis.com/home/webmap/viewer.html?webmap=c65754a74de84eee8dec3197213eee6c). The study also included recommendations and evaluations that should be considered during the planning and design of a seawater desalination plant.



Source: TPWD and GLO, 2018

Figure 9. Zones recommended for diversion of marine seawater and discharge of desalination waste

4.1.9 House Bill 4097

The Texas Legislature in 2015 also passed House Bill 4097 relating to the use of seawater desalination for industrial purposes. The bill amended the Texas Water Code to allow an entity to divert and desalinate seawater for industrial purposes by obtaining the appropriate permits from the TCEQ (Texas Water Code §11.1405). The bill authorizes the disposal of water treatment residuals produced by desalination of seawater used for industrial purposes (Texas Water Code §26.0272). The bill also stipulates that a general permit may authorize the use of Class I injection wells for the disposal of nonhazardous brine produced by desalination of seawater and must meet requirements of the federal underground injection control program administered by the TCEQ (Texas Water Code §27.025). On November 16, 2016, the TCEQ adopted proposed rulemaking for House Bill 4097.

House Bill 4097 also (1) directs the Public Utility Commission of Texas (PUC), in cooperation with the Electric Reliability Council of Texas (ERCOT) and other transmission and distribution utilities, to study and determine if existing transmission and distribution planning processes can provide adequate infrastructure for seawater desalination projects, and (2) directs the PUC and ERCOT to study the potential for seawater desalination projects to participate in existing demand response opportunities in the electric market.

The PUC and EROCT submitted a report to the Texas Legislature in January 2017. They concluded that the existing transmission and distribution planning processes are sufficient to provide adequate infrastructure for seawater desalination projects and that desalination projects can participate in demand response opportunities in the ERCOT market. Demand response programs help preserve system reliability, and provide economic benefits to participating electric consumers. In general, seawater desalination plants have participated in demand response programs on a limited basis. To participate in these programs, seawater desalination plants need to be designed to meet key operational parameters of demand response programs such as response time, recovery time, and operational flexibility. “Costs associated with additional plant design specifications, need for excess capacity and storage to make up for lost production during demand response deployment, operational costs resulting from interruptions to plant processes, and potential financial penalties if demand response deployment results in failure to meet contract demands (PUC, 2017).”

4.2 Brackish groundwater desalination activities

Several public entities are conducting feasibility studies in support of brackish groundwater desalination projects. These activities are described in more detail below. Recent modifications to regulations related to groundwater desalination and active desalination organizations are also discussed.

4.2.1 North Alamo Water Supply Corporation

In 2017, the North Alamo Water Supply Corporation was awarded a $90,000 grant through the Reclamation's Title XVI Research and Feasibility Study Grants. The study is evaluating the replacement of existing reverse osmosis membranes with new nanofiltration membranes to reduce the energy consumption and operating costs. The specific energy consumption for two existing plants was evaluated and concluded that pumping groundwater and treating it through the reverse osmosis membrane system are the two processes that use the most energy. They propose installing a nanofiltration membrane system and running the system in parallel with the existing reverse osmosis to obtain direct comparison on energy and system performance.

4.2.2 Southmost Regional Water Authority

In 2015, the Southmost Regional Water Authority was awarded a grant through the U.S. Bureau Reclamation's Drought Response Program to study the groundwater conditions of the well field that sources water to the existing desalination plant (R W Harden & Associates, 2018). The study consisted of several tasks. Well field monitor equipment such as transducers and conductivity probes were installed at each well. The pump and motor of a well were upgraded. The Authority also completed 21 well pumping tests and observed moderate to significant capacity reduction in the transmissivity of existing wells compared to the initial data collected in 2004. A SCADA system was installed and a program developed to store aquifer performance and well maintenance data, and to provide the user real-time and historical data. Finally, a groundwater model of the existing well field was created and several groundwater production case scenarios including subsidence were analyzed. The results of the study will help the Authority to proactively manage the groundwater production of the well field.

4.2.3 Rio Grande Regional Water Authority

The Rio Grande Regional Water Authority, in collaboration with the U.S. Bureau of Reclamation, completed a basin study that encompassed an eight-county area. The study was completed in December 2013 and concluded that brackish groundwater desalination should be evaluated further as a viable water supply source for the area. The study recommended expanding existing groundwater desalination facilities and developing four new regional desalination plants. The U.S. Bureau of Reclamation provided $214,655 for the study through the WaterSMART Program. A more recent planning study was conducted in 2016 and discussed further in the Grant programs section of this report.

4.2.4 San Antonio Water System

San Antonio Water System completed Phase I of its desalination plant in January 2017. The facility has an initial design capacity of 12 million gallons per day (13,440 acre-feet per year) and will be expanded in two phases to add 12 million gallons per day (13,440 acre-feet per year) in the second phase and 6 million gallons per day (6,720 acre-feet per year) in the third phase. The first well field consists of: (1) 12 supply wells with a total dissolved solids concentration ranging from 1,300 to 1,500 milligrams per liter, and (2) two deep injection wells. For the first phase, capital costs are $118 million, and the unit cost of the treated water is $1,177 per acre-foot ($3.61 per thousand gallons). Total capital costs for all three phases, including land acquisition, are $411.4 million (San Antonio Water System, 2016)

4.2.5 Alternatives to pilot-plant testing

In November 2015, the TCEQ adopted rules to allow the use of computer models from membrane manufacturers for reverse osmosis systems used to treat secondary contaminants in groundwater as an alternative to conducting pilot testing. Two years before, the TWDB had funded a study to compare computer model outputs to pilot- and demonstration-scale testing data and determine the accuracy and precision of the models (Mancha et. al, 2014a and 2014b). The study concluded that computer models could effectively demonstrate membrane performance of reverse osmosis systems operated under normal conditions. As a result, the TCEQ's subsequent rule adoption provides a more expedited path for approving brackish groundwater desalination facilities.

4.2.6 South Central Membrane Association

The South Central Membrane Association (SCMA) was created in 1997, and its members are primarily membrane operators in Arkansas, Louisiana, New Mexico, Oklahoma, and Texas. The association has a strong presence in Texas and is slowly expanding its membership in Oklahoma. The primary objective of the association is to provide training on membranes (both low pressure and desalting membranes) to operators. The association host an annual conference and multiple workshops throughout the year that provide a space for operators to share their experiences running membrane plants. At the annual conference, awards are given to a small and a large membrane plant, an operator, and the best tasting membrane water.

The SCMA's Training & Certification Committee put forth a great deal of effort to create materials such as manuals, presentations, and speaker notes for the various training events and to obtain TCEQ approval for the courses. Courses available include introduction to membrane systems, advanced training of reverse osmosis and nanofiltration, and low-pressure membrane systems. In August 2016, the TCEQ required all operators of reverse osmosis and nanofiltration systems to complete a TCEQ-approved 8-hour course. The association was able to put together course materials and get on the TCEQ's approved training list. Overall, membrane operators are engaged within the association and serve on the SCMA board. The TWDB participates as an "ex-officio director" on the SCMA Board and is a member of various subcommittees.

4.2.7 U.S. Bureau of Reclamation Collaboration

In absence of research funding, the TWDB established a method to continue advancing the Desalination Program by creating a partnership with the U.S. Bureau of Reclamation (Reclamation) and its Oklahoma-Texas Area Office. The TWDB has collaborated with Reclamation on eight projects related to desalination and reuse through its Science and Technology and Planning programs since 2013 (Table 9). Once a year both agencies meet, and TWDB staff shares research needs for the Innovative Water Technologies Department. Then Reclamation determines if it has the in-house expertise to conduct the research and apply for internal funding through its programs. The TWDB will continue to foster this partnership.

Table 9. Ongoing and completed projects in collaboration with the U.S. Bureau of Reclamation

Project title	Status/date completed
Refining interpretation techniques for determining brackish aquifer water quality	Ongoing
Development of Triple Bottom Line methods to analyze the economic, environmental, and social benefits of water reuse projects	Ongoing
An innovative constructed wetland design for attenuating endocrine disruptor compounds (EDCs) from reclaimed wastewater	Project terminated
Developing a deterministic model for cleaning reverse osmosis membranes	June 2015
Comparing the performance of nanofiltration and reverse osmosis membranes for desalting brackish groundwater in Texas	May 2015
Developing a cost curve for brackish groundwater desalination in Texas	July 2014
Variable source salinity desalination	January 2014
State of Texas – tool for planning temporary water supply response in drought emergencies	January 2013

In addition, through its federal grant programs, Reclamation has funded a variety of studies and projects related to desalination, drought, water reuse, and conservation. Since 2010, Reclamation has awarded 21 projects in Texas through the Desalination and Water Purification Research Program (Table 10), 5 projects through the Drought Response Program (Table 11), 1 basin study through the WaterSMART Program, 15 studies through Title XVI Research and Feasibility Study Grants (Table 12), and 29 projects through Water and Energy Efficiency Grants (Table 13).

Table 10. Texas studies funded through Reclamation's Desalination and Water Purification Research Program

Project title	Entity	Report status/ publication date
Emerging Ion Concentration Polarization for Brackish Desalination	Texas Tech University	Ongoing
Activated Sludge Aeration Waste Heat for Membrane Evaporation of Desalination Brine Concentrate	University of Texas at San Antonio	Ongoing

Project title	Entity	Report status/ publication date
Microfiltration System for Indirect Potable Reuse Water Treatment	Texas A&M University	Ongoing
Advanced Pretreatment for Nanofiltration of Brackish Surface Water: Fouling Control and Water Quality Improvements	Texas A&M University	April 2017
Demonstration of Zero Discharge Desalination (ZDD)	University of Texas at El Paso	September 2014
Aluminum Electrocoagulation and Electroflotation Pretreatment for Microfiltration: Fouling Reduction and Improvements in Filtered Water Quality	University at Houston	September 2014
High Recovery of Silica-Saturated RO Concentrate Using a Batch Treatment Seawater RO System	University of Texas at El Paso	March 2012
Wind Power and Water Desalination Technology Integration	Texas Tech University	July 2009
Reduced Membrane Fouling Potential by Tailored Fluid/Structure Interaction	Heat Transfer Research, Inc.	May 2008
Novel Fouling Resistant Membranes for Water Purification	University of Texas at Austin	September 2008
Cost-Effective Volume Reduction of Silica-Saturated RO Concentrate	University of Texas at El Paso	February 2008
Electrocoagulation Pretreatment for Microfiltration: An Innovative Combination to Enhance Water Quality and Reduce Fouling in Integrated Membrane Systems	University of Houston	September 2007
Using Oil Fields for the Disposal of Concentrate from Desalination Plants: Please Pass the Salt	Texas Water Development Board	September 2005
Volume Reduction of High-Silica RO Concentrate Using Membranes and Lime Treatment	University of Texas at El Paso	March 2004
Zero Waste Brine Management for Desalination Plant	University of Texas at El Paso	December 2002
Solar and Waste Heat Desalination by Membrane Distillation	University of Texas at El Paso	April 2004
Thermal Desalination Using MEMS & Salinity-Gradient Solar Pond Technology	University of Texas at El Paso	April 2002
Salinity and TOC Removal Using Nanofiltration	University of Texas at El Paso	August 2002
Brackish Groundwater Treatment and Concentrate Disposal for the Homestead Colonia El Paso, Texas	University of Texas at El Paso	April 1999
Wastewater Recovery from a Textile Bleach and Dye Operation, Bench Scale Evaluation	Rice University	December 1998
Halophyte Crops and a Sand-Bed Solar Concentrator to Reduce and Recycle Industrial, Desalination and Agricultural Brines	Texas A&M University in El Paso	December 1998

Table 11. Texas studies funded through Reclamation's Drought Response Program

Project title	Entity	Funding fiscal year
Water reuse storage tank	Little Elm, Texas	2016
Drought contingency plan update	Gulf Coast Water Authority	2015
Early warning drought tool	Texas Water Development Board	2015

Project title	Entity	Funding fiscal year
Well field monitoring project	Southmost Regional Water Authority	2015
Drought contingency and water supply resiliency plan	McLennan County	2015

Table 12. Texas studies funded through Reclamation's Title XVI Research and Feasibility Study Grants

Project title	Entity	Funding fiscal year and amount
Feasibility study of energy-efficient alternatives for brackish groundwater desalination	North Alamo Water Supply Corporation	2017 / $90,000
Aquifer storage-recovery with reclaimed water to preserve Hueco Bolson using enhanced arroyo infiltration for wetlands, and secondarily reducing local power plant reclaimed water demand	El Paso Water Utilities	2017 / $150,000
Feasibility of Water Recovery from Filter Backwashing and Rewashing Operations	El Paso Water Utilities	2016 / $10,600
Potable water reuse research pilot study	City of San Angelo	2016 / $300,000
McAllen Public Utility water reuse feasibility study	City of McAllen	2015 / $150,000
Feasibility study of water reclamation and reuse	City of Hudson Oaks	2015 / $147,600
Potable water reuse implementation feasibility study	City of Lubbock	2015 / $150,000
Collection, storage, recharge and recovery of conserved source waters for advanced purified treatment (apt) of reclaimed water	El Paso Water Utilities	2014 / $150,000
Feasibility study of industrial water management and reclamation for the Permian Basin	Gulf Coast Waste Disposal Authority	2014 / $150,000
Port Isabel water reclamation facility	Laguna Madre Water District	2014 / $150,000
The integrated water and power project: a drought-proof water supply for Texas	Guadalupe-Blanco River Authority	2014 / $450,000
Feasibility study of augmenting regional water supply system for Tarrant Regional Water District and Wichita Falls with impaired groundwater supplies	Tarrant Regional Water District	2014 / $150,000
Williamson County, Water Recycling and Reuse Project	City of Round Rock	2012 / $954,083
Central Fort Worth Reclaimed Water Delivery System Feasibility Study	City of Fort Worth Water Department	2012 / $150,000
City of Kyle, Water Reuse Feasibility Study	City of Kyle	2011 / $132, 290

Table 13. Texas construction grants funded through WaterSMART Program, 2010 to 2017

Project title	Entity	Funding fiscal year and amount
Installation of Water Efficient Fixtures	Brownsville Public Utilities Board	2017 / $74,868
Automation of the Lateral B and C Canal Head Gate	Hidalgo County Irrigation District No. 2	2017 / $74,798
Conversion of Lateral "8" from Open Canal to Pipeline	Cameron County Irrigation District No. 2	2017 / $299,731

Project title	**Entity**	**Funding fiscal year and amount**
Conversion of Canal "E" from Open Canal to Pipeline	Cameron County Irrigation District No. 2	2017 / $299,674
Conversion of Lateral "F" from Open Canal to Pipeline	Cameron County Irrigation District No. 2	2017 / $277,283
Conversion of Lateral "JN-1" from Open Canal to Pipeline	Cameron County Irrigation District No. 2	2017 / $173,311
Conversion of Lateral "J" from Open Canal to Pipeline	Cameron County Irrigation District No. 2	2016 / $288,652
Leak Detection and Smart Metering	City of Arlington	2016 / $300,000
Canal conversion to pipe and construction of aerial crossing and solar-powered second lift pump	Cameron County Irrigation District #6	2016 / $300,000
Shotcrete lining of the canal, installing a variable frequency drive, and construction of a wind-powered pump to provide auxiliary power to lift station	Santa Cruz Irrigation District #15	2015 / $300,000
Relining and retrofit of the two existing check gate structures	Hidalgo County Irrigation District #2	2016 / $288,652
Water measurement and control project	Cameron County Irrigation District No. 2	2013 / $224,889
Surge valve collaborative for on-farm water conservation	Rio Grande Regional Water Authority	2013 / $77,500
Main flume, wind powered pump, and canal lining.	United Irrigation District	2013 / $1,333,901
Install smart meters to implement leak detection program	Cedar Hill	2012 / $300,000
Natural gas and wind powered pumps	Adams Garden Irrigation District	2011 / $300,000
Replacement of plumbing fixtures, graywater and rainwater collection systems	Edwards Aquifer Authority	2011 / $300,000
Installation of flume gates and solar-powered SCADA	Hidalgo County Irrigation District #2	2011 / $300,000
Automated gates/solar-powered SCADA	Hidalgo County Irrigation District #2	2011 / $300,000
Conversion of open canal to pipeline	Delta Lake Irrigation District	2011 / $296,446
Conversion of mortar joint to PVC pipe	Hidalgo County Irrigation District #3	2011 / $286,794
Conversion of open canal to pipeline	Cameron County Irrigation District No. 2	2011 / $286,265

Project title	**Entity**	**Funding fiscal year and amount**
Canal lining and rehabilitation	Hidalgo County Irrigation District #6	2010 / $300,000
Direct, non-potable water reuse	Laguna Madre Water District	2010 / $300,000
Gulf Coast Irrigation Division gate rehabilitation	Lower Colorado River Authority	2010 / $256,296
Conveyance system improvements	Brownsville Irrigation District	2010 / $300,000
Direct, non-potable water reuse	Harlingen Water Works	2010 / $142,425
System Optimization Review - measuring past water conservation improvements to prioritize future projects	Harlingen Irrigation District	2010 / $73,022
Climate analysis on drought in the High Plains Ogallala Aquifer	University of Texas at Austin	2010 / $199,999

5 Designation of local or regional brackish groundwater production zones

In 2015, the 84th Texas Legislature passed House Bill 30, directing the TWDB to conduct studies to identify and designate brackish groundwater production zones in the state. This chapter describes the BRACS program, completed and ongoing studies, the House Bill 30 implementation process, and the status of brackish groundwater production zone designation.

5.1 Brackish Resources Aquifer Characterization System Program

In 2009, the 81st Texas Legislature provided funding to the TWDB to establish the BRACS program. The goal of the program is to map and characterize the brackish portions of the aquifers in Texas in sufficient detail to provide useful information and data to regional water planning groups and other entities interested in using brackish groundwater as a water supply.

For each BRACS study, the TWDB collects as much geological, geophysical, and water-well data as is available in the public domain and uses the information to map and characterize both the vertical and horizontal extents of the aquifers in great detail. Groundwater is classified into five salinity classes: fresh, slightly saline, moderately saline, very saline, and brine (Winslow and Kister, 1956). The volume of groundwater in each salinity class is estimated based on three-dimensional mapping of the salinity zones. The project deliverables, both the data and report, are available to the public on the TWDB website. All project data is compiled into the BRACS Database, which is in Microsoft Access format and described in a detailed data dictionary (Meyer, 2014). Digital geophysical well logs used for the studies may be downloaded from the TWDB Water Data Interactive website (www2.twdb.texas.gov/apps/waterdatainteractive/groundwaterdataviewer).

5.2 Studies on brackish aquifers

Mapping of Texas' saline water resources dates back to 1956 (Winslow and Kister, 1956). In 1970, the TWDB funded a study "to make a reconnaissance and inventory of the principal saline aquifers in Texas that discussed the salinity, the productivity, and the geology of the aquifers" (Core Laboratories, 1972). In 2003, the TWDB funded a study to map the brackish aquifers of the state and calculate the volume of brackish (slightly to moderately saline) groundwater available in these aquifers (LBG-Guyton Associates, 2003). The study was done to support the regional water planning process and to help identify alternative sources to meet water demands. It estimated that there are 2.7 billion acre-feet (880 trillion gallons) of brackish groundwater in the aquifers of the state. While the study demonstrated that brackish groundwater is an important resource, it also highlighted the need for detailed aquifer studies.

In total, the TWDB has funded 10 contracts in the BRACS program (Table 14). In 2010, with the aid of legislative funding, the TWDB funded three research projects totaling $449,500 to support the initiation of the BRACS program. With passage of House Bill 30 (84th Legislature, 2015), the TWDB funded seven contracts totaling under $1.7 million.

Overall, The TWDB has completed nine studies (Figure 10) and has eight ongoing studies (Figure 11**).** TWDB staff completed five aquifer studies internally, which included the Pecos Valley Aquifer (Meyer, et al., 2012), Gulf Coast Aquifer in Corpus Christi Aquifer Storage and Recovery Conservation District (Meyer, 2012), Queen City and Sparta aquifers in Atascosa and McMullen counties (Wise, 2014), the Gulf Coast Aquifer in the Lower Rio Grande Valley (Meyer et. al, 2014), and Lipan Aquifer (Robison, et al., 2018). Contractors completed work for four additional aquifers (Blaine, Carrizo-Wilcox, Gulf Coast, and Blaine aquifers) and staff completed an evaluation of these studies. Staff is currently evaluating brackish groundwater production zones for three aquifers (Blossom, Nacatoch, and Northern Trinity) and is working on five other aquifer studies.

Table 14. TWDB-funded projects of the Brackish Resources Aquifer Characterization System Program

Report title	Description	Contractor	Study type	Year funded	Grant amount
Geophysical Well Log Data Collection Project	Geophysical well logs from brackish aquifers in the state were collected from multiple sources, digitized, and entered into a database.	Bureau of Economic Geology at The University of Texas at Austin	Research	2010	$300,000
Brackish Groundwater Bibliography Project	The project developed a comprehensive bibliography of Texas brackish aquifers.	INTERA, Inc.	Research	2010	$99,500
An Assessment of Modeling Approaches to Brackish Aquifers in Texas	The study assessed groundwater modeling approaches for brackish aquifers.	INTERA, Inc.	Research	2010	$50,000
Identification of Potential Brackish Groundwater Production Areas – Carrizo-Wilcox Aquifer and Queen City and Sparta aquifers	The project mapped and characterized the aquifer and evaluated the aquifer for potential production areas.	Bureau of Economic Geology at The University of Texas at Austin	Research	2016	$181,446*
Identification of Potential Brackish Groundwater Production Areas – Gulf	The project mapped and characterized the aquifer and evaluated the aquifer for potential production areas.	INTERA, Inc.	Research	2016	$500,000

Report title	Description	Contractor	Study type	Year funded	Grant amount
Coast Aquifer					
Brackish Groundwater in the Blaine Aquifer System, North Central Texas	The project mapped and characterized the aquifer and evaluated the aquifer for potential production areas.	Daniel B. Stephens & Associates, Inc.	Research	2016	$200,000
Identification of Potential Brackish Groundwater Production Areas – Rustler Aquifer	The project mapped and characterized the aquifer and evaluated the aquifer for potential production areas.	INTERA, Inc.	Research	2016	$200,000
Identification of Potential Brackish Groundwater Production Areas – Blossom Aquifer	The project mapped and characterized the aquifer and evaluated the aquifer for potential production areas.	LBG-Guyton	Research	2016	$50,000
Identification of Potential Brackish Groundwater Production Areas – Nacatoch Aquifer	The project mapped and characterized the aquifer and evaluated the aquifer for potential production areas.	LBG-Guyton	Research	2016	$150,000
Identification of Potential Brackish Groundwater Production Areas – Trinity Aquifer	The project mapped and characterized the aquifer and evaluated the aquifer for potential production areas.	Southwest Research Institute	Research	2016	$400,000

*One intra-agency contract that covers two aquifer projects

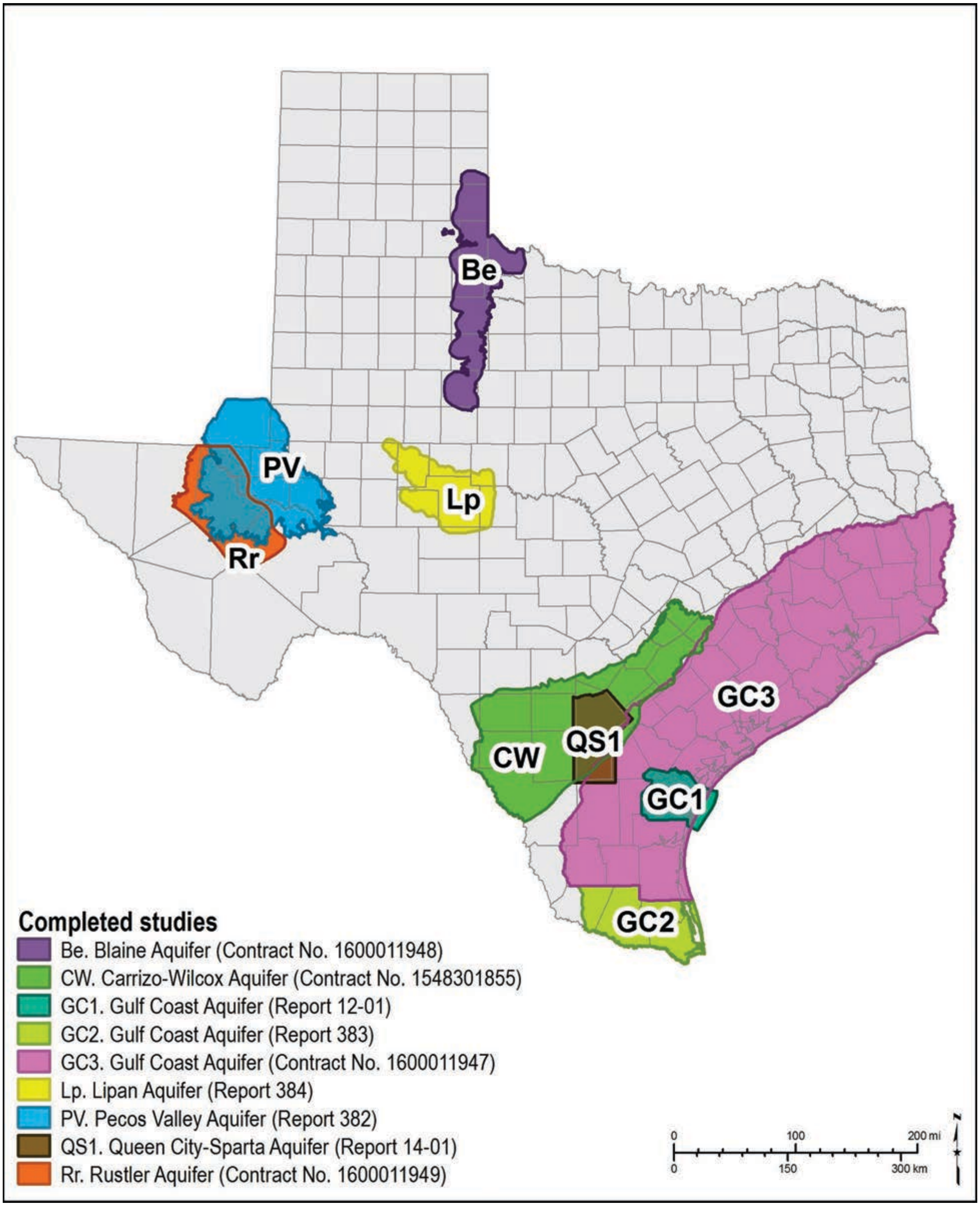


Figure 10. **Completed studies of the Brackish Resources Aquifer Characterization System Program**

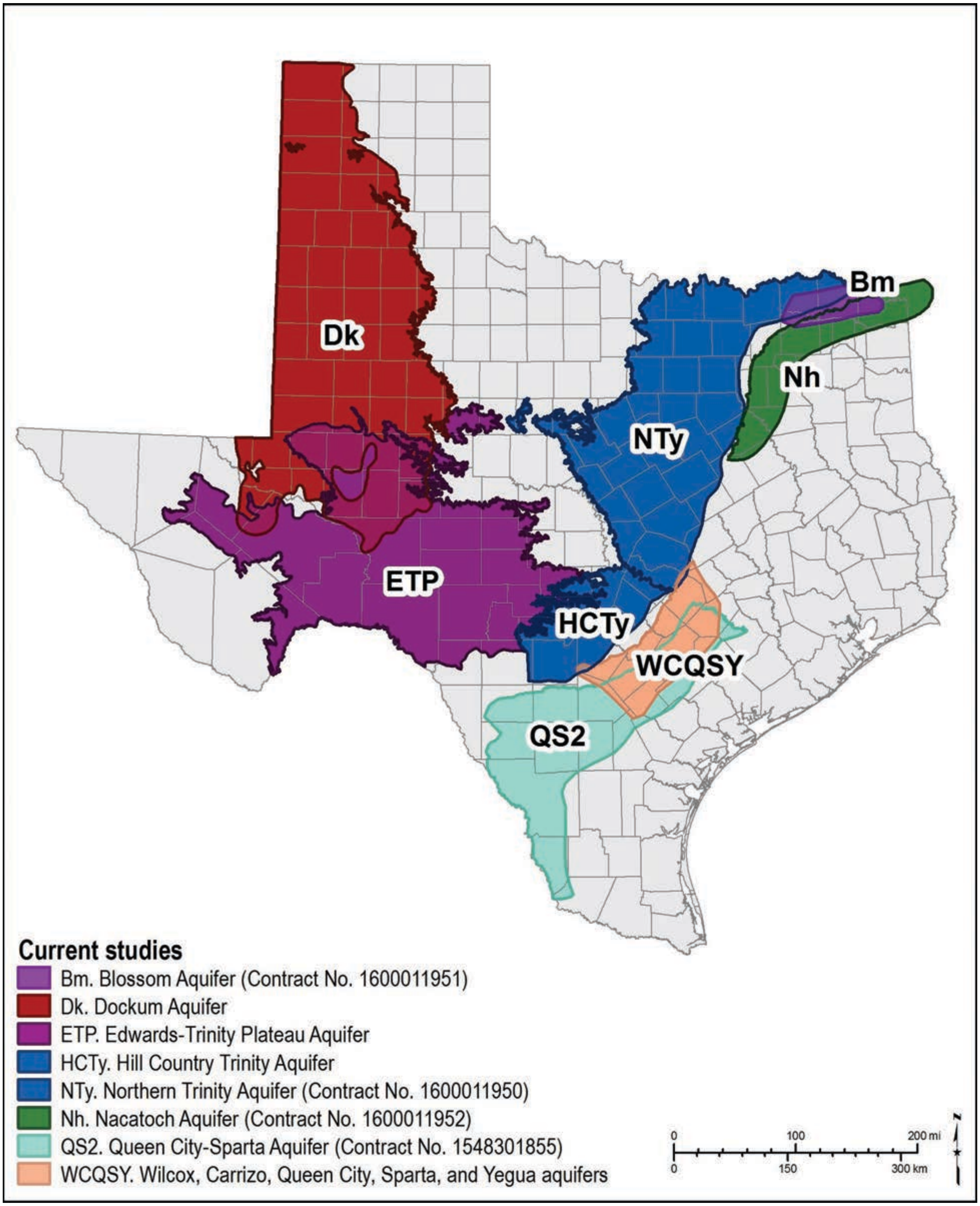


Figure 11. Ongoing studies of the Brackish Resources Aquifer Characterization System Program

5.3 House Bill 30

In 2015, the 84th Texas Legislature passed House Bill 30, directing the TWDB to conduct studies to identify and designate brackish groundwater production zones in the state. The legislation directed the TWDB to make designations in four aquifers—the Carrizo-Wilcox Aquifer located between the Colorado River and the Rio Grande, the Gulf Coast Aquifer and sediments bordering that aquifer, the Blaine Aquifer, and the Rustler Aquifer—and to report the designations to the Legislature by December 1, 2016. The legislation further required the TWDB to identify and designate brackish groundwater production zones in the remaining aquifers before December 1, 2022.

House Bill 30 requires that brackish groundwater production zones are located in areas with moderate to high availability and productivity, and separated by hydrogeologic barriers sufficient to prevent significant impacts to water availability or water quality in geologic strata that have average total dissolved solids concentrations of 1,000 milligrams per liter or less. For each zone, the TWDB was required to determine the amount of brackish groundwater that a zone is capable of producing over 30- and 50-year periods without causing a significant impact to water availability or water quality in surrounding aquifers. The TWDB was also required to make recommendations on reasonable monitoring to observe the effects of brackish groundwater production within the zone and to work with groundwater conservation districts and various stakeholders on the studies in general.

House Bill 30 excluded certain areas from zone designation:

- The Edwards (Balcones Fault Zone) Aquifer located within the jurisdiction of the Edwards Aquifer Authority;
- Areas within the boundaries of the Barton Springs-Edwards Aquifer Conservation District, the Harris-Galveston Subsidence District, and the Fort Bend Subsidence District;
- Aquifers, subdivisions of aquifers, or geologic strata that have an average total dissolved solids concentration of more than 1,000 milligrams per liter and serve as a significant source of water supply for municipal, domestic, or agricultural purposes; and
- Geologic formations that are designated or used for wastewater injection through the use of injection or disposal wells permitted under Texas Water Code Chapter 27.

To assist the TWDB in making designations, the legislature appropriated $2 million in 2015 for contracts and administrative costs (House Bill 1, General Appropriations Act, 2015 Legislature, Regular Session, pages IX-88, Sec. 18.30). The TWDB funded seven contracts for eight aquifers. One of the contracts was an interagency contract, in which the scope of an ongoing TWDB-funded study was expanded to cover two aquifers (Carrizo-Wilcox Aquifer and Queen City-Sparta aquifers). State funds to support brackish aquifer studies were discontinued in 2017.

5.3.1 Implementation process

To achieve the goals of House Bill 30, the TWDB undertook the following process and will use the same process for each study:

1. Contractors compiled and assessed available geologic and hydrologic information to identify proposed production areas.
2. Contractors assessed the hydrologic effects of pumping in the proposed production areas.
3. TWDB staff reviewed information from the contractors and information associated with exclusions (such as existing pumping, water quality, injection wells, impacts from pumping brackish groundwater in the proposed production zones) and developed possible zones for designation.
4. The Executive Administrator recommended proposed brackish groundwater production zones to the agency's Board for possible approval.

Each step of the implementation process provided ample opportunities for stakeholder review and comment. On October 26, 2015, staff held the first stakeholder meeting in Austin to explain the TWDB's approach to implementing House Bill 30, solicit feedback on key terms in the bill (for example, significant impact), and receive comments on implementation of the legislation. Throughout the studies, the TWDB gave presentation at local meetings within the vicinity of each aquifer and notified stakeholders of the meetings in advance via email. Between February and November 2017, staff held 10 aquifer-specific stakeholder meetings to request data, share results, and solicit feedback. Details of the meetings are as follows:

- Blossom and Nacatoch aquifers:
    - Mount Pleasant, TX, February 8, 2017
    - Commerce, TX, April 18, 2017
    - Mount Pleasant, TX, October 25, 2017
- Dockum Aquifer:
    - Midland, TX, August 16, 2017
    - Lubbock, TX, November 15, 2017
- Edwards-Trinity (Plateau) Aquifer:
    - Midland, TX, August 16, 2017
    - Fredericksburg, TX, October 19, 2017
- Trinity Aquifer:
    - Austin, TX, May 8, 2017
    - Waco, TX, November 1, 2017
- Queen City and Sparta aquifers:
    - Pleasanton, TX, June 6, 2017

Information pertaining to all stakeholder meetings, including announcements and presentations, were posted on the TWDB website (www.twdb.texas.gov/innovativewater/bracs/HB30.asp) in a timely manner.

Staff also worked closely with contractors throughout the various stages of the projects. Early in each project, contractors submitted interim reports on the project methodology, which staff reviewed, provided written comments on, and discussed during meetings with contractors to address issues and concerns. Staff also reviewed draft reports and data deliverables and provided written comments to the contractors. Additionally, staff met with the contractors several times during the course of the project to discuss comments, request changes, and correct errors. Contractors delivered the final reports and datasets to the TWDB, and the agency posted the final reports on the TWDB website.

Staff is conducting a thorough review of contract deliverables and these may require staff to modify stratigraphy, augment well data, and calculate salinity, when necessary. Staff will evaluate the contractor-identified potential production areas for: (1) Class II injection well data using a 15-mile buffer around each well, (2) presence of domestic, municipal, and agricultural water wells using a 2- to 3-mile buffer around each well, (3) Class I, Class III, Class IV, and Class V injection wells, and (4) hydrogeologic barriers. If other injection wells (Class I, III, IV, and V) are located in the potential zones, we will also place buffers around them. Staff will continue to thoroughly review the results in the final reports and datasets to ensure that the requirements of and exclusion criteria in House Bill 30 are properly implemented.

TWDB staff will finalize the areas and provide them to the Executive Administrator with a recommendation for the Board to designate the areas as brackish groundwater production zones. The Board memo containing the Executive Administrator's recommendation will be posted on the TWDB website before the Board meeting, and stakeholders will be notified via email about its availability for review and comment. If comments are received, they will be provided to the Board before the meeting.

5.3.2 Key challenges

In the ongoing process of conducting the aquifer studies, TWDB staff and project contractors encountered the same three challenges as in the 2016 aquifer studies, which included water well and injection well data availability, groundwater model accessibility, and injection well buffer applicability.

The first key challenge is that there is not a single database in Texas that has complete records of all installed water wells (domestic, municipal, and agricultural) and injection wells (Class I, II, III, IV, and V). Datasets that are available are located in different agencies and in different formats and often have incomplete information. Since House Bill 30 excludes designation of brackish groundwater production zones in specific areas, identifying water wells and injection wells within proposed production areas is critically important in our evaluation process.

The second challenge is that the agency does not have the modeling expertise or appropriated funding to create a calibrated groundwater model for each zone to estimate the volume of brackish groundwater production that will account for simultaneous well fields and regional water pumping. As a result, contractors only conducted a simple, desktop analysis of groundwater production within a zone to estimate the impact to fresh water resources. Similarly, staff used a simple analysis to determine groundwater volume based on aquifer parameters and simulated drawdown.

The third challenge is that we do not know the distance that injected fluids may have traveled both laterally and vertically from Class II injection wells. Determining the distance that injected fluids travel is important, as TWDB staff discovered that several Class II injection zones are installed above, below, lateral to, or overlapping with geologic stratum containing brackish groundwater. We will continue to adopt a conservative approach and place a 15-mile buffer around injection wells as in past studies. In the future, we may revise zone designations if the buffer is reduced.

As of July 2017, the TWDB began collaborating with the Groundwater Advisory Unit of the Railroad Commission (RRC) to discuss different aspects of their programs and to hold monthly meetings. On January 23, 2018, the RRC provided a presentation on its Underground Injection Control Permit program, and TWDB staff learned of a recent project the RRC had completed that is relevant to the BRACS program. On February 27, 2018, the TWDB submitted a request for and subsequently obtained the report for the State of Texas Aquifer Exemption Project, the internal searchable database of injection wells, and the geographic information system files and metadata developed for this project. TWDB staff will use this data when evaluating brackish groundwater production zones. Staff from both agencies met an additional three times (March 3, April 23, June 27) on the same topic and will continue discussions.

It is essential that TWBD staff have a thorough understanding of the Class II injection well data and methodology so they can accurately use the data when evaluating and delineating brackish groundwater productions zones. It is also important for RRC staff to understand the requirements of House Bill 30 and to learn how TWDB uses their information to support the BRACS program. Key topics for continued discussion include: (1) the methodology RRC applies to determine the geologic separation between the Underground Source of Drinking Water (groundwater less than 10,000 milligram per liter of total dissolved solids) and top of the injection zone, and (2) specific injection wells that may not be within mapped aquifer exemption boundaries.

5.4 Results of studies

To date, the Board has designated brackish groundwater production zones in the following aquifers: no zones in the Blaine Aquifer, one zone in the Carrizo-Wilcox Aquifer south of the Colorado River, four zones in the Gulf Coast Aquifer and bordering sediments, and three zones in the Rustler Aquifer (Figure 12). In winter 2018/2019, the Board will consider the Executive Administrator's recommendations for possible brackish groundwater production zone designations in the Blossom, Lipan, Nacatoch, and Northern Trinity aquifers.

In the 2018-2019 biennium, the TWDB did not receive appropriations to continue implementing the requirements of House Bill 30 (84th Texas Legislature, 2015). As a result, the TWDB is not currently able to meet the full requirements of legislation, which include: (1) modeling and calculating production volumes for 30-year and 50-year periods in brackish groundwater production zones, and (2) completing studies by December 1, 2022. The TWDB will continue mapping brackish aquifers with current resources at a slower pace than would have been possible with continued program funding. This scientific work is a process that first requires that brackish groundwater in an entire aquifer is analyzed, characterized, and mapped before zones within the aquifer can be delineated. It is important that this work proceed to continue progress toward achieving the objectives of the BRACS program. The TWDB has requested appropriations for the 2020-2021 biennium that would restore the $2 million to support the BRACS program and work on House Bill 30. If approved, the funding would enable the TWDB to make faster progress toward meeting the HB 30 requirements. However, the TWDB will not be able to map brackish groundwater resources and designate zones in the remaining aquifers by the statutory deadline of December 1, 2022, even with restoration of funds.

5.4.1 Texas House Committee on Natural Resources

In October 2017, the speaker of the Texas House of Representatives announced the interim committee charges for the House Committee on Natural Resources, which included Interim Charge 3 generally related to groundwater policy in Texas. On June 5, 2018, the TWDB provided testimony at the committee hearing in Palo Duro Canyon State Park on Interim Charges 3(e) and (f) related to the designation of brackish groundwater production zones and related research and groundwater data and science needs, respectively. TWDB staff provided an update to the committee on the progress of the BRACS studies and the status of designation of brackish groundwater production zones.

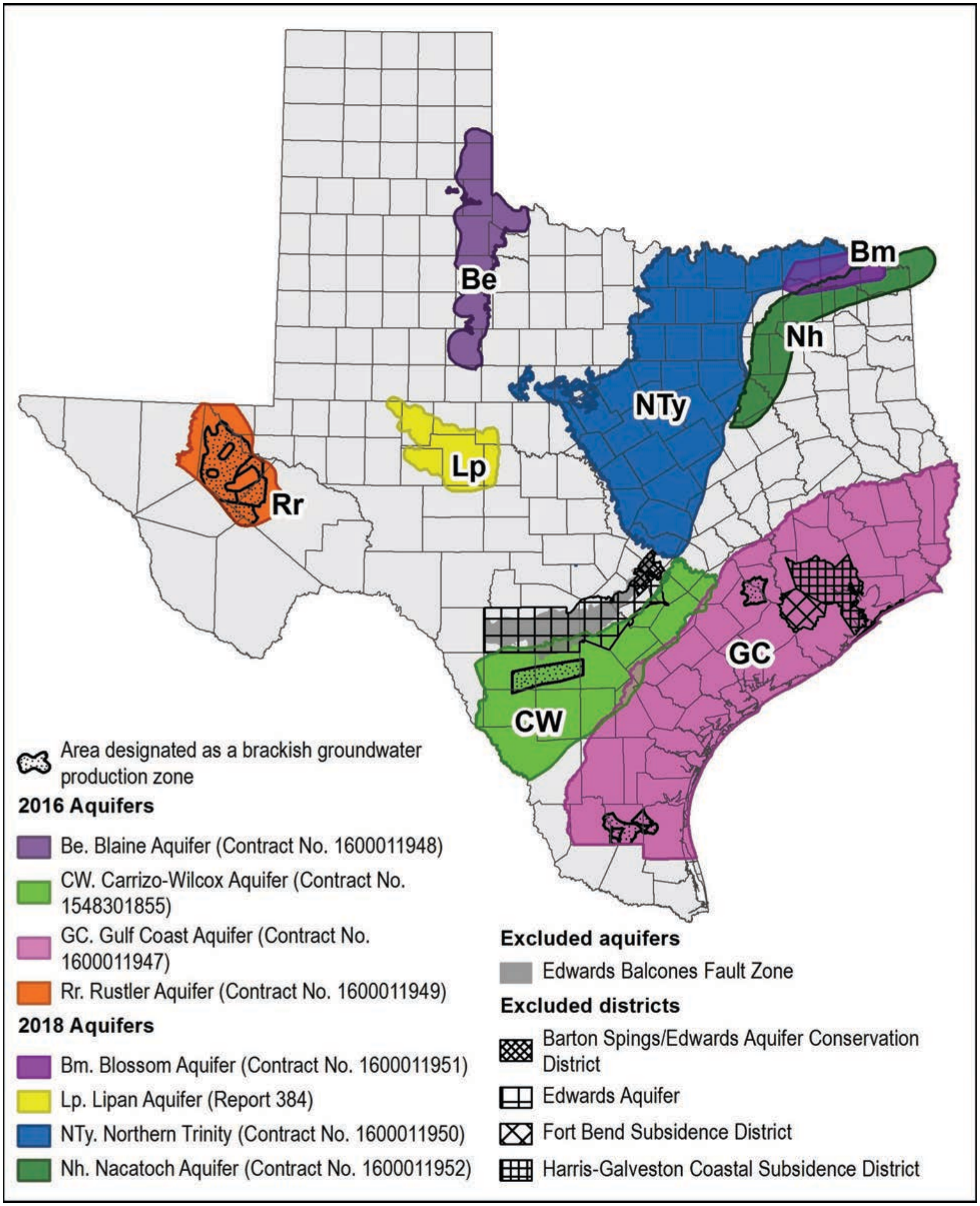


Figure 12. **House Bill 30 project area boundaries and excluded aquifer and districts**

6 Identification and evaluation of research, regulatory, technical, and financial impediments to implementing seawater or brackish groundwater desalination projects

Desalination projects, both seawater and brackish groundwater, are driven by site-specific conditions. Source water quality, permitting requirements, construction costs, and operation costs are all dependent on local site conditions. Thus, impediments for desalination projects can be different for each project.

6.1 Research

A common obstacle to conducting research is the lack of adequate funding. The Texas Legislature last appropriated funds to the TWDB to advance seawater and brackish groundwater desalination in Texas in 2009. Should funding become available, potential research topics specific to Texas have been identified in past TWDB studies and biennial reports (Brownsville Public Utilities Board, 2011; TWDB, 2010; Carollo Engineers, 2014; U.S. Environmental Protection Agency, 2014). These research topics include:

- characterizing benthic fauna in areas that will be affected by concentrate discharges;
- determining the salinity tolerance of key aquatic species along the Texas Gulf Coast that may potentially be affected by desalination concentrate discharges;
- modeling currents and tides to determine impact on concentrate dispersion;
- improving thin-layer mixing models as part of far-field plume modeling;
- integrating desalinated seawater into existing drinking water distribution networks;
- revising regulatory bacteria and virus removal credits for reverse-osmosis membranes;
- studying subsurface intakes, including subsurface infiltration galleries, for entrainment data;
- quantifying construction impacts of subsurface intakes;
- quantifying differences in energy use and greenhouse gas emissions between open and subsurface intakes; and
- determining mitigation for impacts due to intake structures.

There is also a need to assess the relevance of the above research topics and develop a current desalination research agenda that contains research topics and tangible pilot- and demonstration-scale projects that would help advance the implementation of desalination. Guidance documents also need to be updated, such as the permit decision model (roadmap) developed by the TWDB in 2004, to reflect the new streamlined and flexible permitting process adopted as a requirement of House bills 2031 and 4097 (84th Texas Legislature, 2015).

6.2 Regulatory

In general, the permitting process can be a barrier to public entities pursuing desalination. For seawater desalination, the TCEQ and other agencies' permitting requirements will not be put in practice and established until a few seawater desalination plants have been built and undergone the required permitting cycles. When desalination initiatives began, there was a need to develop a permitting roadmap that allowed entities to determine the permits required to build a seawater or brackish groundwater desalination plant. As a result, the TWDB funded a study to develop a permit-decision model that identifies major requirements through a decision tree analysis (R.W. Beck, Inc., 2004). The model can be applied to either a seawater or brackish water desalination facility that uses a reverse osmosis system. The model has three main categories: (1) raw water source, (2) facility, and (3) concentrate disposal. The study also provides an example of how to apply the permit decision model to a seawater desalination plant co-located with a power plant.

As feasibility studies and pilot testing were completed for seawater desalination, there was a need to determine the specific permits required to build the desalination plant. A TWDB-funded study determined that a total of 26 federal and state permits may be required to implement a seawater desalination project along the Gulf Coast (Brownsville Public Utilities Board, 2011). The study also included information about the timeframe and costs associated with each permit, and the regulatory agency responsible for the permits.

As listed in the research section above, there is a research need to update the permit decision model, along with a corresponding guidance document for desalination, and include case studies to become more familiar with the regulatory process.

6.3 Technical

The Brownsville and the South Padre Island pilot-plant studies conducted from 2008 to 2010 tested treatment technologies that are now six to eight years old. Recent advances in desalination technology make the results of these pilot tests dated. Consequently, additional piloting of technologies may be needed to pursue seawater desalination. Since brackish groundwater desalination is currently implemented in Texas, targeting entities that have conducted feasibility studies and providing these entities funding for pilot-scale testing and demonstration-scale testing may help advance the implementation and construction of desalination plants. Although there are 35 brackish groundwater desalination facilities in state, desalination is dependent on site-specific parameters such as water quality and water yield that require installing monitoring wells and conducting other pilot- and demonstration-scale testing for a successful project.

California offers a funding model to advance the construction of desalination plants. The California Department of Water Resources has a Water Desalination Grant program that provides grants for: (1) the planning, design, and construction of brackish groundwater and seawater desalination facilities, and (2) the piloting, demonstrating, and researching of projects (California Department of Water Resources, 2018a). The department conducted four rounds of funding in 2005, 2006, 2014, and 2017. Funding came from two sources: Proposition 50 for rounds 1, 2, and 3, and Proposition 1 for Round 4. Proposition 50 provided $50 million for grants when voters passed the Water Security, Clean Drinking Water, Coastal, and Beach Protection Act in 2002. Proposition 1 provided $725 million for grants and loans for water reuse and advance treatment, of which $100 million was allocated for desalination. The department received 30 applications for Round 4 and funded 8 projects for a grand total of $34 million (California Department of Water Resources, 2018b). The department announced its selection in March 2018, which included three construction projects, two design pilots, two feasibility studies, and one research pilot. The department created a “Continuous Application Process” for the remaining funds, which began accepting applications on March 9, 2018, and will award funds on a first-come basis until exhausted.

6.4 Financial

Despite improvements to reverse osmosis membranes and the increased cost competitiveness of desalination, creating a new water supply from seawater and brackish groundwater is still relatively more expensive than developing supplies from existing fresh sources, if available. Desalinating seawater and brackish groundwater is more costly for a number of reasons, with salinity concentration (about 1,000 to 35,000 milligrams per liter) being the key driver. Higher-salinity water requires more pressure in the treatment process, which increases the energy costs. Other factors that affect cost include the type and location of intake and outfall structures, the size and depth of water supply wells, the pre-treatment process, the brine disposal method, and the length of distribution pipelines. Additionally, the permitting process can increase the cost by requiring entities to obtain numerous permits and conduct environmental studies.

Due to the uncertainties associated with developing uniform cost estimates for projects across the state, the TWDB funded a study to develop the Unified Costing Model for the 16 regional water planning groups (TWDB, 2013). The costing tool allows the user to employ a standardized costing framework for desalination plants. The groups first used the tools in the fourth regional water planning cycle from 2011 and 2016. The costing model is being updated and will be used for the 2022 State Water Plan.

The greatest challenge to constructing large-scale seawater and brackish groundwater desalination facilities in Texas is the relatively high cost, compared to less expensive conventional supplies. Additionally, public entities implementing the first seawater desalination plant may face greater risks due to permitting, treatment, and water quality uncertainness and may adopt a more conservative approach.

Therefore, public entities may need financial assistance from the state to implement seawater desalination projects. For the recommended 2.5-million-gallon-per-day (2,800-acre-foot-per-year) seawater desalination plant in Brownsville, the TWDB requested a $9.5 million financial grant from the 83rd Texas Legislature (TWDB, 2012). Entities constructing brackish groundwater desalination plants would also benefit from state assistance to help drill monitoring wells and run geophysical well tools to characterize the water source.

7 Evaluation of the role the State should play in furthering the development of large-scale seawater or brackish groundwater desalination projects

The purpose of the Seawater and Brackish Groundwater Desalination Initiatives was to accelerate the development of cost-effective desalination water supplies and innovative technologies in Texas. Since their inceptions in 2002 and 2004, the ultimate goal had been to install desalination plants—with particular focus on a full-scale seawater desalination facility—to demonstrate the potential of desalination as a new water source. However, both initiatives have stalled due to the lack of appropriations.

The role of the State (Texas Legislature) is to continue providing leadership and supporting the advancement of desalination in Texas. The State has taken first steps by identifying and addressing past and current challenges to seawater and brackish groundwater desalination. Fulfilling this role during the upcoming biennium would require consideration of the following:

- <u>Supporting the advancement of science</u>
  The State can assist by appropriating funds to advance seawater and brackish groundwater desalination studies and continue designating brackish groundwater production zones. The TWDB can continue to support entities by providing data and technical support through its existing programs and staff resources.

- <u>Facilitating an efficient permitting process</u>
  The permitting process can be challenging for entities pursuing seawater desalination for the first time. The State can assist in the permitting process by participating in and facilitating meetings between water providers or municipalities and regulatory agencies. The TCEQ is the state agency that has regulatory authority over public drinking water quality and treatment requirements. It also oversees the issuance of permits for water diversions and waste discharges.

- <u>Informing the public of funding opportunities</u>
  Political subdivisions such as cities, counties, utility districts, and authorities are eligible for TWDB loan and grant programs. The low-interest loans provide funding for water supply projects, including desalination projects. The State should continue to inform public entities of these and other funding opportunities.

- Seeking opportunities for partnerships with the private sector
  Public-private partnership is one method of implementing a large-scale desalination project. Existing TWDB funding programs can accommodate public-private partnerships as long as the project meets eligibility requirements. However, the TWDB can only provide funding to a political subdivision in the partnership. The new Center for Alternative Finance and Procurement at the Texas Facilities Commission can also help public entities learn more about this financing mechanism.

8 Anticipated appropriation from general revenues necessary to continue investigating water desalination activities during the next biennium

As part of the legislative appropriations request for the 2020-2021 biennium, the TWDB requested baseline funding of $2 million for the BRACS program to continue mapping brackish groundwater in the state. The appropriations would be used for contracts and administrative costs associated with hiring two full-time equivalents.

The TWDB did not request funds for the Desalination Program and will continue to monitor desalination activities with current limited resources. At present, one staff member covers the Desalination Program in the Innovative Water Technologies Department.

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Appendix A: Tables

Table A-1. Recommended water management strategies for seawater desalination in the 2017 State Water Plan

Region	Water management strategy	Water user group	Water supplies by decade (acre-feet per year)					
			2020	2030	2040	2050	2060	2070
H	Freeport seawater desalination	Manufacturing, Brazoria County	0	0	11,200	11,200	11,200	11,200
L	Integrated water-power project	Guadalupe Blanco River Authority*	-	-	-	-	-	-
L	Seawater desalination	San Antonio Water System*	-	-	-	-	-	-
L	Seawater desalination	San Antonio	0	0	12,319	23,337	37,364	48,278
L	Seawater desalination	San Antonio Water System	0	0	5,700	5,700	5,700	5,700
M	Brownsville seawater desalination	Brownsville	2,603	2,603	2,603	2,603	26,022	26,022
M	Brownsville seawater desalination	El Jardin Water Supply Corporation	108	108	108	108	1,081	1,081
M	Brownsville seawater desalination	Manufacturing, Cameron County	56	56	56	56	565	565
M	Brownsville seawater desalination	Steam electric power, Cameron County	33	33	33	33	332	332
N	Seawater desalination	Manufacturing, Nueces County	0	9,000	9,000	9,000	9,000	9,000
N	Seawater desalination	Manufacturing, San Patricio County	0	9,000	9,000	9,000	9,000	9,000
N	Seawater desalination	Steam electric power, Nueces County	0	4,420	4,420	4,420	4,420	4,420
		Total	**2,800**	**25,220**	**54,439**	**65,457**	**104,684**	**115,598**

Notes: *Unassigned water volumes to specific water user group. The strategy is currently not assigned to serve a specific water user group (in other words, the strategy is recommended but is not planned to provide water to users during the 50-year planning period).

Table A-2. Alternative water management strategies for seawater desalination in the 2017 State Water Plan

Region	Water management strategy	Water user group	Water supplies by decade (acre-feet per year)					
			2020	2030	2040	2050	2060	2070
M	Laguna Madre seawater desalination	Laguna Vista	390	390	390	390	390	390
M	Laguna Madre seawater desalination	Port Isabel	213	213	213	213	213	213
M	Laguna Madre seawater desalination	South Padre Island	517	517	517	517	517	517
M	RGRWA regional facility project – seawater desalination	Agua Supply Utility District	0	69	43	467	1,282	2,176
M	RGRWA regional facility project – seawater Desalination	Alamo	183	147	137	475	1,017	1,508
M	RGRWA regional facility project – seawater desalination	Brownsville	0	0	31	1,224	4,222	7,864
M	RGRWA regional facility project – seawater desalination	Donna	0	15	40	201	502	822
M	RGRWA regional facility project – seawater desalination	East Rio Hondo Water Supply Corporation	0	5	40	209	557	925
M	RGRWA regional facility project – seawater desalination	Edinburg	762	623	571	1,957	4,222	6,202
M	RGRWA regional facility project – seawater desalination	Harlingen	0	0	68	564	1,686	2,981
M	RGRWA regional facility project – seawater desalination	Hidalgo	86	78	75	258	571	840
M	RGRWA regional facility project – seawater desalination	Hidalgo County Municipal Utility District #1	64	44	34	105	223	326
M	RGRWA regional facility project – seawater desalination	La Feria	0	5	12	64	167	274
M	RGRWA regional facility project – seawater desalination	Laguna Vista	183	123	102	338	711	1,028
M	RGRWA regional facility project – seawater desalination	McAllen	934	1,256	1,335	4,889	10,966	16,500
M	RGRWA regional facility project – seawater desalination	Mercedes	54	69	71	258	585	874

Region	Water management strategy	Water user group	Water supplies by decade (acre-feet per year)					
			2020	2030	2040	2050	2060	2070
M	RGRWA regional facility project – seawater desalination	Military Highway Water Supply Corporation	236	201	189	669	1,463	2,193
M	RGRWA regional facility project – seawater desalination	Mission	1,428	1,094	975	3,278	6,995	10,177
M	RGRWA regional facility project – seawater desalination	North Alamo Water Supply Corporation	0	172	192	1,410	3,442	5,808
M	RGRWA regional facility project – seawater desalination	Olmito Water Supply Corporation	0	0	0	16	70	137
M	RGRWA regional facility project – seawater desalination	Pharr	4	201	258	1,015	2,397	3,684
M	RGRWA regional facility project – seawater desalination	Port Isabel	97	64	53	177	362	531
M	RGRWA regional facility project – seawater desalination	Rancho Viejo	0	0	0	0	28	86
M	RGRWA regional facility project – seawater desalination	San Benito	0	0	0	0	167	428
M	RGRWA regional facility project – seawater desalination	San Juan	376	280	242	846	1,825	2,690
M	RGRWA regional facility project – seawater desalination	Sharyland Water Supply Corporation	226	422	478	1,804	4,375	6,117
M	RGRWA regional facility project – seawater desalination	South Padre Island	236	162	137	443	934	1,371
M	RGRWA regional facility project – seawater desalination	Weslaco	601	442	385	1,281	2,731	3,958
		Total	**6,590**	**6,592**	**6,588**	**23,068**	**52,620**	**80,620**

Note: RGRWA = Rio Grande Regional Water Authority

Table A-3 Groundwater desalination recommended water management strategies in the 2017 State Water Plan

Region	Water management strategy	Water user group	Water supplies by decade (acre-feet per year)					
			2020	2030	2040	2050	2060	2070
E	Additional groundwater wells - Rustler Aquifer	Mining, Culberson County	590	590	590	590	590	590
E	Additional groundwater well - West Texas Bolsons Aquifer	Mining, Culberson County	590	590	590	590	590	590
E	Dell City - brackish groundwater desalination facility	County-other, Hudspeth County	111	111	111	111	111	111
E	Brackish groundwater at the Jonathan Rogers Wastewater Treatment Plant	El Paso	0	0	11,000	11,000	11,000	11,000
E	Expansion of the Kay Bailey Hutchison Desalination Plant	El Paso	1,260	2,520	2,520	2,520	2,520	2,520
E	Hudspeth County Conservation and Reclamation District #1 - additional groundwater wells	Irrigation, Hudspeth County	230	230	230	230	230	230
E	Additional wells and expansion of desalination plant	Horizon City	0	1,457	3,195	4,923	6,562	8,107
E	Additional wells and expansion of desalination plant	Horizon Regional Municipal Utility District	8,652	8,652	8,652	8,652	8,652	8,652
	Additional wells and expansion of desalination plant	Horizon Regional Municipal Utility District	8,652	8,652	8,652	8,652	8,652	8,652
E	Mining - additional groundwater well	Mining, Hudspeth County	30	30	30	30	30	30
E	Groundwater from proposed well field – Rio Grande Alluvium Aquifer	Lower Valley Water District	6,800	6,800	6,800	6,800	6,800	6,800
F	Desalination of other aquifer supplies in Tom Green County	Concho Rural Water Supply Corporation	150	150	150	150	150	150
F	Desalination of other aquifer supplies	County-other, Tom Green County	0	0	0	96	105	115
F	Desalination of other aquifer supplies	Manufacturing, Tom Green County	0	0	0	312	366	425
F	Desalination of other aquifer supplies	San Angelo	0	0	0	2,928	2,600	2,973
F	Desalination of other aquifer supplies	San Angelo*	-	-	-	-	-	-
H	Brackish groundwater supplies	County-other, Montgomery	0	0	0	0	3,622	10,000

Region	Water management strategy	Water user group	Water supplies by decade (acre-feet per year)					
			2020	2030	2040	2050	2060	2070
		County						
H	Brackish groundwater supplies	Dobbin-Plantersville Water Supply Corporation	153	327	570	890	1,337	1,930
H	Conroe brackish groundwater desalination	Conroe	5,600	5,600	5,600	5,600	5,600	5,600
H	New / expanded contract with Brazosport Water Authority - brackish groundwater	County-other, Brazoria County	1,147	1,063	1,003	937	865	800
H	Panorama and Shenandoah Joint Group	Shenandoah	0	0	472	472	472	472
H	San Jacinto River Authority Catahoula Aquifer supplies	County-other, Montgomery County	3,920	3,920	3,920	3,920	3,920	3,920
H	San Jacinto River Authority Catahoula Aquifer supplies	Steam-electric power, Montgomery County	3,920	3,920	3,920	3,920	3,920	3,920
J	Livestock - additional groundwater wells	Livestock, Kinney County	22	22	22	22	22	22
L	Brackish Wilcox Aquifer groundwater	Canyon Regional Water Authority*	-	-	-	-	-	-
L	Brackish Wilcox Aquifer groundwater	County Line Water Supply Corporation	0	0	0	251	440	641
L	Brackish Wilcox Aquifer groundwater	Green Valley Special Utility District	0	0	0	0	0	619
L	Brackish Wilcox Aquifer groundwater	Alamo Heights	796	848	820	807	805	805
L	Brackish Wilcox Aquifer groundwater	Atascosa Rural Water Supply Corporation	1,167	1,446	1,708	1,970	2,218	2,448
L	Brackish Wilcox Aquifer groundwater	County-other, Bexar County	0	0	0	1,898	2,113	1,823
L	Brackish Wilcox Aquifer groundwater	Kirby	137	207	181	172	169	169
L	Brackish Wilcox Aquifer groundwater	Leon Valley	97	147	196	254	317	377
L	Brackish Wilcox Aquifer groundwater	San Antonio	3,425	2,974	2,717	521	0	0
L	Brackish Wilcox Aquifer groundwater	S S Water Supply Corporation	0	0	0	0	0	234
L	Brackish Wilcox Aquifer groundwater	Schertz-Seguin Local Government Corporation*	-	-	-	-	-	-
L	Expanded brackish Wilcox Aquifer	San Antonio Water System*	-	-	-	-	-	-

Region	Water management strategy	Water user group	Water supplies by decade (acre-feet per year)					
			2020	2030	2040	2050	2060	2070
	groundwater							
M	Alamo brackish groundwater desalination plant	Alamo	1,000	1,000	1,000	1,000	1,000	1,000
M	El Jardin new brackish groundwater desalination plant	El Jardin Water Supply Corporation	560	560	560	560	560	560
M	Hebbronville new brackish groundwater desalination plant	Hebbronville	560	560	560	560	560	560
M	La Feria water well with reverse osmosis unit	La Feria	1,120	1,120	1,120	1,120	1,120	1,120
M	Laguna Madre new brackish groundwater desalination plant	Laguna Vista	780	780	780	780	780	780
M	Laguna Madre new brackish groundwater desalination plant	Manufacturing, Cameron County	1	1	1	1	1	1
M	Laguna Madre new brackish groundwater desalination plant	Port Isabel	425	425	425	425	425	425
M	Laguna Madre new brackish groundwater desalination plant	South Padre Island	1,034	1,034	1,034	1,034	1,034	1,034
M	Lyford brackish groundwater well and desalination	Lyford	1,120	1,120	1,120	1,120	1,120	1,120
M	McAllen brackish groundwater desalination plant	McAllen	2,688	2,688	2,688	2,688	2,688	2,688
M	Mission brackish groundwater desalination plant	Mission	2,688	2,688	2,688	2,688	2,688	2,688
M	North Alamo Water Supply Corporation delta area reverse osmosis water treatment plant expansion	County-other, Hidalgo County	0	0	0	0	2	2
M	North Alamo Water Supply Corporation delta area reverse osmosis water treatment plant expansion	Edinburg	0	0	0	0	4	4
M	North Alamo Water Supply Corporation delta area reverse osmosis water treatment plant expansion	Military Highway Water Supply Corporation	0	0	0	0	1	1
M	North Alamo Water Supply Corporation delta	North Alamo Water Supply	0	0	0	0	1,410	1,410

Region	Water management strategy	Water user group	Water supplies by decade (acre-feet per year)					
			2020	2030	2040	2050	2060	2070
	area reverse osmosis water treatment plant	Corporation						
M	North Alamo Water Supply Corporation delta area reverse osmosis water treatment plant expansion	Primera	0	0	0	0	4	4
M	North Alamo Water Supply Corporation delta area reverse osmosis water treatment plant expansion	San Juan	0	0	0	0	800	800
M	North Alamo Water Supply Corporation delta area reverse osmosis water treatment plant expansion	San Perlita	0	0	0	0	19	19
M	North Alamo Water Supply Corporation La Sara reverse osmosis plant expansion	County-other, Hidalgo County	0	0	0	0	0	37
M	North Alamo Water Supply Corporation La Sara reverse osmosis plant expansion	Edinburg	0	0	0	0	0	2
M	North Alamo Water Supply Corporation La Sara reverse osmosis plant expansion	Manufacturing, Hidalgo County	0	0	0	0	0	1
M	North Alamo Water Supply Corporation La Sara reverse osmosis plant expansion	Manufacturing, Willacy County	0	0	0	0	0	1
M	North Alamo Water Supply Corporation La Sara reverse osmosis plant expansion	Military Highway Water Supply Corporation	0	0	0	0	0	1
M	North Alamo Water Supply Corporation La Sara reverse osmosis plant expansion	North Alamo Water Supply Corporation	0	0	0	0	0	997
M	North Alamo Water Supply Corporation La Sara reverse osmosis plant expansion	Primera	0	0	0	0	0	2
M	North Alamo Water Supply Corporation La Sara reverse osmosis plant expansion	San Juan	0	0	0	0	0	70
M	North Alamo Water Supply Corporation La	San Perlita	0	0	0	0	0	9

Region	Water management strategy	Water user group	Water supplies by decade (acre-feet per year)					
			2020	2030	2040	2050	2060	2070
	Sara reverse osmosis plant expansion							
M	North Cameron regional water treatment plant wellfield expansion	County-other, Hidalgo County	1	1	1	1	1	1
M	North Cameron regional water treatment plant wellfield expansion	Edinburg	1	1	1	1	1	1
M	North Cameron regional water treatment plant wellfield expansion	Manufacturing, Hidalgo County	160	160	160	160	160	160
M	North Cameron regional water treatment plant wellfield expansion	Manufacturing, Willacy County	85	85	85	85	85	85
M	North Cameron regional water treatment plant wellfield expansion	Primera	1	1	1	1	1	1
M	North Cameron regional water treatment plant wellfield expansion	San Juan	52	52	52	52	52	52
M	North Cameron regional water treatment plant wellfield expansion	San Perlita	7	7	7	7	7	7
M	Primera reverse osmosis plant with well	Primera	1,120	1,120	1,120	1,120	1,120	1,120
M	San Juan water treatment plant upgrade and expansion to include brackish groundwater desalination	San Juan	1,792	1,792	1,792	1,792	1,792	1,792
M	Sharyland Water Supply Corporation well and reverse osmosis unit at water treatment plant #2	Alton	189	189	189	189	189	189
M	Sharyland Water Supply Corporation well and reverse osmosis unit at water treatment plant #2	Palmhurst	90	90	90	90	90	90
M	Sharyland Water Supply Corporation well and reverse osmosis unit at water treatment plant #2	Sharyland Water Supply Corporation	621	621	621	621	621	621
M	Sharyland Water Supply Corporation well and reverse osmosis unit at water treatment plant #3	Alton	171	171	171	171	171	171
M	Sharyland Water Supply Corporation well and	Palmhurst	72	72	72	72	72	72

Region	Water management strategy	Water user group	Water supplies by decade (acre-feet per year)					
			2020	2030	2040	2050	2060	2070
	reverse osmosis unit at water treatment plant #3							
M	Sharyland Water Supply Corporation well and reverse osmosis unit at water treatment plant #3	Sharyland Water Supply Corporation	657	657	657	657	657	657
M	Union Water Supply Corporation brackish groundwater desalination plant	Union Water Supply Corporation	560	560	560	560	560	560
N	Brackish groundwater development - Alice	Alice	3,363	3,363	3,363	3,363	3,363	3,363
O	Gaines County - Seminole groundwater desalination	Seminole	500	500	500	500	500	500
O	Hale County - Abernathy groundwater desalination	Abernathy	150	150	150	150	150	150
O	Lubbock County - Lubbock brackish well field at the south water treatment plant	Lubbock	1,120	1,120	1,120	1,120	1,120	1,120
P	Lavaca Navidad River Authority desalination - brackish groundwater	Lavaca Navidad River Authority*	-	-	-	-	-	-
		Total	**70,137**	**72,944**	**86,337**	**91,906**	**99,706**	**110,773**

Note: *Unassigned water volumes to specific water user group

Table A-4. Groundwater desalination alternative water management strategies in the 2017 State Water Plan

Region	Water management strategy	Water user group	Water supplies by decade (acre-feet per year)					
			2020	2030	2040	2050	2060	2070
F	Midland - development of groundwater in Midland County (previously used for mining)	Midland*	-	-	-	-	-	-
F	Odessa - develop Capitan Reef Complex Aquifer supplies in Ward County	Odessa*	-	-	-	-	-	-
F	Odessa - develop Edwards-Trinity and Capitan Reef Complex Aquifer supplies in Pecos County - I & II	Odessa*	-	-	-	-	-	-
K	City of Austin - brackish groundwater desalination	Austin	0	5,000	5,000	5,000	5,000	5,000
K	Brackish groundwater desalination	Lower Colorado River Authority*	-	-	-	-	-	-
L	Brackish Wilcox	S S Water Supply Corporation	0	0	0	0	0	1,120
L	Brackish Wilcox groundwater	San Antonio Water System*	-	-	-	-	-	-
L	Brackish Wilcox groundwater	Canyon Regional Water Authority*	-	-	-	-	-	-
L	Expanded brackish project	San Antonio Water System*	-	-	-	-	-	-
L	Brackish Wilcox	Schertz-Seguin Local Government Corporation*	-	-	-	-	-	-
M	New brackish groundwater desalination plant	Agua Supply Utility District	0	0	0	1,212	1,212	1,212
M	Agua Supply Utility District new brackish groundwater desalination plant	County-other, Hidalgo County	0	0	0	14	14	14
M	Agua Supply Utility District new brackish groundwater desalination plant	La Joya	0	0	0	40	40	40
M	Agua Supply Utility District new brackish groundwater desalination plant	Mission	0	0	0	7	7	7
M	Agua Supply Utility District new brackish groundwater desalination plant	Palmview	0	0	0	160	160	160
M	Agua Supply Utility District new brackish groundwater desalination plant	Penitas	0	0	0	130	130	130
M	Agua Supply Utility District new brackish groundwater desalination plant	Sullivan City	0	0	0	117	117	117

Region	Water management strategy	Water user group	Water supplies by decade (acre-feet per year)					
			2020	2030	2040	2050	2060	2070
M	New brackish groundwater desalination plant	Combes	0	0	0	125	125	125
M	New brackish groundwater desalination plant	Donna	700	700	700	1,000	1,000	1,000
M	New brackish groundwater desalination plant	Eagle Pass	0	0	0	560	560	560
M	New brackish groundwater desalination plant	Elsa	560	560	560	560	560	560
M	Harlingen new brackish groundwater desalination plant	Combes	0	0	21	21	21	21
M	Harlingen new brackish groundwater desalination plant	County-other, Cameron County	0	0	10	10	10	10
M	Harlingen new brackish groundwater desalination plant	East Rio Hondo Water Supply Corporation	0	0	14	14	14	14
M	New brackish groundwater desalination plant	Harlingen	0	0	888	888	888	888
M	Harlingen new brackish groundwater desalination plant	Manufacturing, Cameron County	0	0	12	12	12	12
M	Harlingen new brackish groundwater desalination plant	Military Highway Water Supply Corporation	0	0	9	9	9	9
M	Harlingen new brackish groundwater desalination plant	Palm Valley	0	0	19	19	19	19
M	Harlingen new brackish groundwater desalination plant	Primera	0	0	26	26	26	26
M	New brackish groundwater desalination plant	La Villa	560	560	560	560	560	560
M	New brackish groundwater desalination plant	Laredo	0	0	0	5,000	5,000	5,000
M	New brackish groundwater desalination plant	Mercedes	0	0	435	435	435	435
M	New brackish groundwater desalination plant	Olmito Water Supply Corporation	560	560	560	560	560	560
M	Rio Grande City new brackish groundwater desalination plant	County-other, Starr County	0	43	43	43	43	43
M	New brackish groundwater desalination plant	Rio Grande City	0	469	469	469	469	469
M	Rio Grande City new brackish groundwater desalination plant	Rio Water Supply Corporation	0	48	48	48	48	48
M	New brackish groundwater	Santa Rosa	0	560	560	560	560	560

Region	Water management strategy	Water user group	Water supplies by decade (acre-feet per year)					
			2020	2030	2040	2050	2060	2070
	desalination plant							
M	Valley Municipal Utility District 2 new brackish groundwater desalination plant	Brownsville	0	0	0	0	10	10
M	Valley Municipal Utility District 2 new brackish groundwater desalination plant	County-other, Cameron County	0	0	0	0	3	3
M	Valley Municipal Utility District 2 new brackish groundwater desalination plant	Rancho Viejo	0	0	0	0	87	87
M	New brackish groundwater desalination plant	Weslaco	0	1,630	1,630	1,630	1,630	1,630
N	Brackish groundwater desalination - regional	Manufacturing, Nueces County	0	0	4,000	4,000	4,000	4,000
N	Brackish groundwater desalination - regional	Manufacturing, San Patricio County	0	0	4,000	4,000	4,000	4,000
N	Brackish groundwater desalination - regional	Steam-electric power, Nueces County	0	0	4,000	4,000	4,000	4,000
		Total	**2,380**	**10,130**	**23,564**	**31,229**	**31,329**	**32,449**

Note: *Unassigned water volumes to specific water user group