

REGIONAL SEAWATER DESALINATION FEASIBILITY STUDY

GCWA PROJECT NO. 5993
US BUREAU OF RECLAMATION GRANT NO. R24AP00180-00
BLACK & VEATCH PROJECT NO. 419808

PREPARED FOR



Gulf Coast Water Authority

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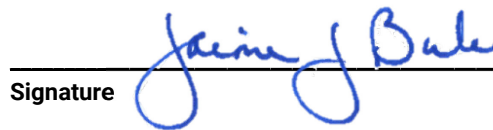
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Abbreviations List

ac-ft	Acre-feet
ac-ft/yr	Acre-feet per year
BCGCD	Brazoria County Groundwater Conservation District
BRA	Brazos River Authority
CBRA	Coastal Barrier Resources Act
CIP	Clean-in-Place
CMP	Coastal Management Program
CoA	Certificate of Adjudication
CWA	Clean Water Act
DAF	Dissolved Air Flotation
DWSRF	Drinking Water State Revolving Fund
EA	Each
EFH	Essential Fish Habitat
ENR	Engineering News-Record
EPA	Environmental Protection Agency
ERD	Energy Recovery Device
ESA	Endangered Species Act
°C	Degrees Celsius
FBSD	Fort Bend Subsidence District
ft	Feet
FRP	Fiberglass Reinforced Plastic
gal	Gallons
GCWA	Gulf Coast Water Authority
GCD	Groundwater Conservation District
gpm	Gallons per minute
GMF	Gravity Media Filtration
HGSD	Harris–Galveston Subsidence District
IPS	Industrial Pump Station
JEM	Joint Evaluation Meeting
LS	Lump Sum
MCL	Maximum Contaminant Limit
MGD	Million Gallons per Day
mg/L	Milligrams per liter
MF	Microfiltration
min	Minutes

MMPA	Marine Mammal Protection Act
µg/L	Micrograms per liter
µS/cm	Microsiemens per centimeter
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOFO	Notice of Funding Opportunity
NPSH	Net Positive Suction Head
NTU	Nephelometric Turbidity Unit
NWI	National Wetlands Inventory
O&M	Operations and Maintenance
OTN	Odor Threshold Number
ppt	Parts per Thousand
psi	Pounds per square inch
RO	Reverse Osmosis
SMCL	Secondary Maximum Contaminant Limit
SWIFT	State Water Implementation Fund for Texas
SWRO	Seawater Reverse Osmosis
S.U.	Standard Units
TCEQ	Texas Commission on Environmental Quality
TDS	Total Dissolved Solids
THC	Texas Historical Commission
TPDES	Texas Pollutant Discharge Elimination System
TMWTP	Thomas S. Mackey Water Treatment Plant
TOC	Total Organic Carbon
TWDB	Texas Water Development Board
UF	Ultrafiltration
USACE	US Army Corps of Engineers
USCG	US Coast Guard
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey
VFD	Variable Frequency Drive
WAM	Water Availability Model
WCID	Water Control and Improvement District
WRAP	Water Rights Analysis Package
WWTP	Wastewater Treatment Plant

1.0 Introduction

- (1) **Introductory Information.** Provide the following introductory information.
- (a) identification of the non-Federal project sponsor(s);
 - (b) a description of the study area and an area/project map; and
 - (c) a definition of the study area in terms of both the site-specific project area where the reclaimed water supply will be needed and developed, and any reclaimed water distribution systems.

1.1 Non-Federal Project Sponsor

Gulf Coast Water Authority (GCWA) located at 4243 Emmett F. Lowry Expressway, Texas City, Texas 77591, in Galveston County, was awarded the R24AP00180-00 - WaterSMART: Water Recycling and Desalination Planning Funding for the “Regional Seawater Desalination Feasibility Study” project and is the non-Federal project sponsor. GCWA is a wholesale water provider, established in 1965 by the Texas Legislature, serving agricultural, industrial, and municipal customers in Brazoria, Fort Bend, and Galveston counties in Texas. GCWA operates three divisions that are responsible for providing water supply. Two of these divisions, the Industrial and Water Treatment Divisions, depend upon supply from the Canal Division that currently provides the sole source of water to the GCWA area through diversion of raw water from existing water rights and contracts from the Brazos River.

GCWA operates and maintains 274 miles of canal infrastructure. Table 1-1 provides a summary of pump stations that includes GCWA’s water treatment plant, the Thomas S. Mackey Water Treatment Plant (TMWTP), while Table 1-2 summarizes the associated canals that are a part of the GCWA canal system. Figure 1-1 provides a map of GCWA’s canal and potable distribution system.

Table 1-1 Gulf Coast Water Authority Pump Stations

Pump Station	Water From	Water To
Darrell E. Shannon	Brazos River	American Canal Section 1
Second Lift	American Canal Section 1	American Canal Section 2
Briscoe	Brazos River	Briscoe Canal
William May	Brazos River	Juliff Canal
Chocolate Bayou	Chocolate Bayou	Chocolate Bayou Canal
Mustang Bayou	Mustang Bayou	Mustang Reservoir
Halls Bayou	Halls Bayou	Chocolate Bayou Canal
TMWTP	Industrial Canal	GCWA North and South Transmission System (Potable Water)
Joseph A. Wilhem Industrial Pump Station (IPS)	Industrial Canal	GCWA Industrial Distribution Pipeline (Raw Water)

Table 1-2 Gulf Coast Water Authority Canals

Canal	Water From (Method)	Delivered to (as of 2025)
American Canal Section 1 (A-1) <i>Also known as Jones and Oyster Creeks</i>	Brazos River (Darrell E. Shannon Pump Station)	Municipal Customers
American Canal Section 2 (A-2)	A-1 (Second Lift Pump Station)	Municipal and Interruptible Customers
American Canal New Extension (A-NE)	A-2 (Gravity Flow)	Ag and Interruptible Customers
Briscoe Canal (B)	Brazos River (Briscoe Pump Station)	Ag and Municipal Customers
Lateral 10 Canal (L10)	A-2 (Gravity Flow)	B Canal
Galveston Canal (G)	A-NE & B (Gravity Flow)	Ag Customers and Industrial Reservoir
Bypass Canal	G (Gravity Flow)	I Canal
Industrial Canal (I)	Industrial Reservoir (Gravity Flow)	Interruptible Customers, TMWTP, and IPS
Juliff Canal (J)	Brazos River (William May Pump Station)	Ag and Interruptible Customers
Chocolate Bayou (CB)	Chocolate Bayou (CB Pump Station)	Ag and Industrial Customers
Monsanto Canal	B Canal (Gravity Flow)	Industrial Customers and CB Canal
Ranch Canal	B Canal (Gravity Flow)	Ag Customers

GCWA's mission is to reliably deliver water to their customers. That mission is threatened by increasing demands on constrained water supplies. According to water demand projections developed as part of Texas Water Development Board's (TWDB) 2026 Region H Water Planning Process in Texas, between 2030 and 2050, municipal and industrial demands in these three counties will increase by approximately 90,000 acre-foot per year (ac-ft/yr), or just over 80 million gallons per day (MGD). By 2080, an additional increase of 110,000 ac-ft/yr, or 100 MGD, of municipal and industrial demand will occur. Based on existing supplies that are currently available in the three counties to meet water demands, identified needs for water to meet future municipal and industrial demands increases from approximately 70,000 ac-ft/yr (62 MGD) in 2030 to approximately 125,000 ac-ft/yr (110 MGD) in 2050. By 2080, the identified water need to meet future municipal and industrial water demands increases further to 200,000 ac-ft/yr (178 MGD). The TWDB's 2026 Region H Water Plan was used to assess future demands and needs. The plan and additional details can be found at <https://regionhwater.org/>.

GCWA is seeking to ensure a droughtproof, local water supply portfolio that contributes efficiently to the region's resilience against prolonged droughts. Seawater desalination is being evaluated for feasibility in this study. Desalinated water would be used primarily for municipal customers or other customers requiring treated water. With access to seawater and a robust water rights portfolio, GCWA is uniquely positioned to leverage these resources and benefit a larger (regional) customer base.

Depending on location of the desalination plant and commercial agreements with customers of the desalinated water, GCWA may be able to distribute desalinated water using the existing GCWA North & South Transmission System, currently used for potable water distribution from TMWTP. This option would require a blending study to review water quality impacts but may provide substantial savings over the installation of new desalinated water distribution infrastructure.

Brazos River Authority (BRA) is a stakeholder for the project and has provided a portion of the non-Federal funds for this study. BRA protects and manages the water resources within the Brazos River Basin, including the Brazos River itself. Water is supplied for agriculture, industry, mining, and municipal uses as it travels from West Texas to the Gulf of America near Freeport. In addition to having adjudicated Brazos River water rights that are permitted through Texas Commission on Environmental Quality (TCEQ), GCWA has stored water contracts with BRA that can be used to supply water to GCWA customers in the State of Texas.

Harris Galveston Subsidence District (HGSD) is a stakeholder in the project and provides a portion of the non-Federal funds for this study. HGSD is a special-purpose district created by the Texas Legislature to prevent further subsidence in Harris and Galveston counties through groundwater regulation, science and research programs, water conservation programs, and regional collaboration. Reducing reliance on groundwater is a vital component of preventing further subsidence, which is why HGSD encourages and supports the development of alternative water sources.

1.2 Description of Study Area

The study area includes the GCWA area, as shown on Figure 1-1. The development of desalinated seawater along the coast could potentially provide opportunities to free up stored water or other fresh water upstream of the GCWA area, so Figure 1-2 displays additional portions of the Brazos River Basin which are primarily managed by BRA.



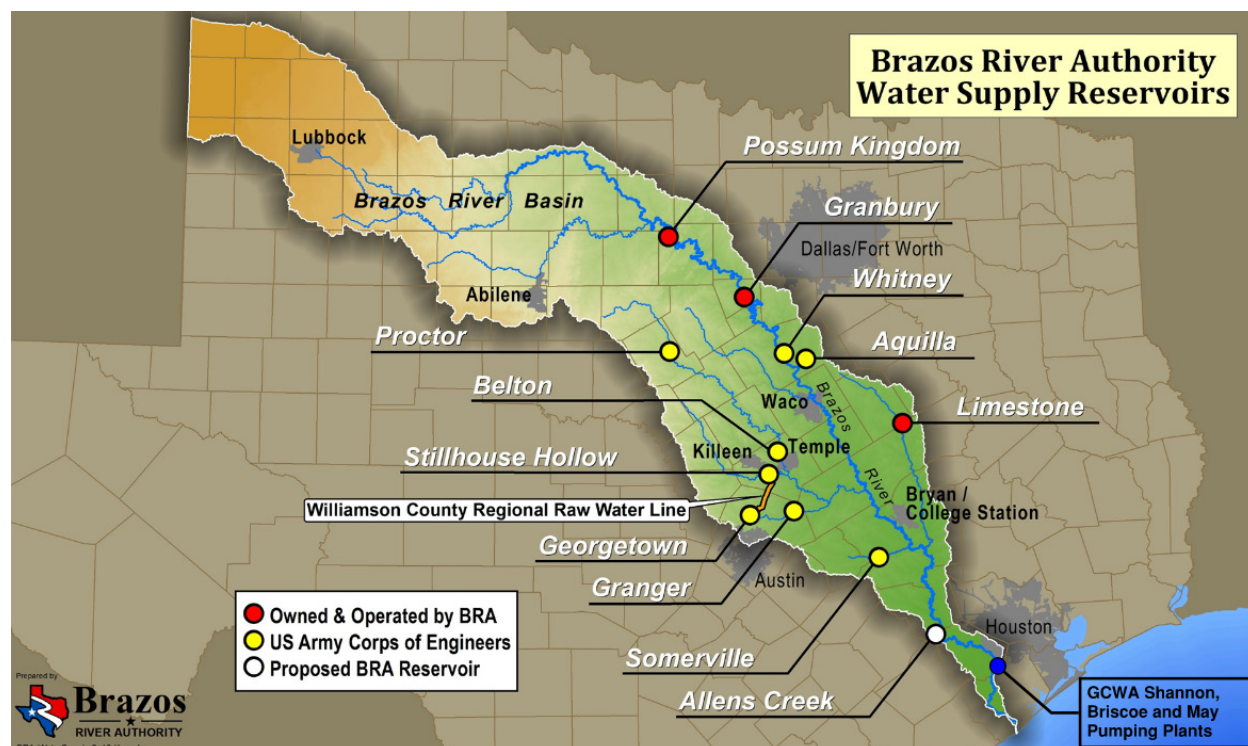


Figure 1-2 Lower and Central Sections of the Brazos River Basin

1.2.1 Site-Specific Project Area

As part of the effort for this feasibility study, a site selection evaluation was performed. The site screening effort began with the identification and mapping of five potential sites, with a sixth being added later in the process.

The six sites chosen were as follows:

1. Former P.H. Robinson Power Plant Site (Power)
2. Thomas S. Mackey Water Treatment Plant (Mackey or TMWTP)
3. Galveston/Pelican Island (Island)
4. Dickinson Bayou (Dickinson)
5. Moses Lake (Moses)
6. Southwestern Galveston County

Figure 1-3 shows the approximate location of all six sites.

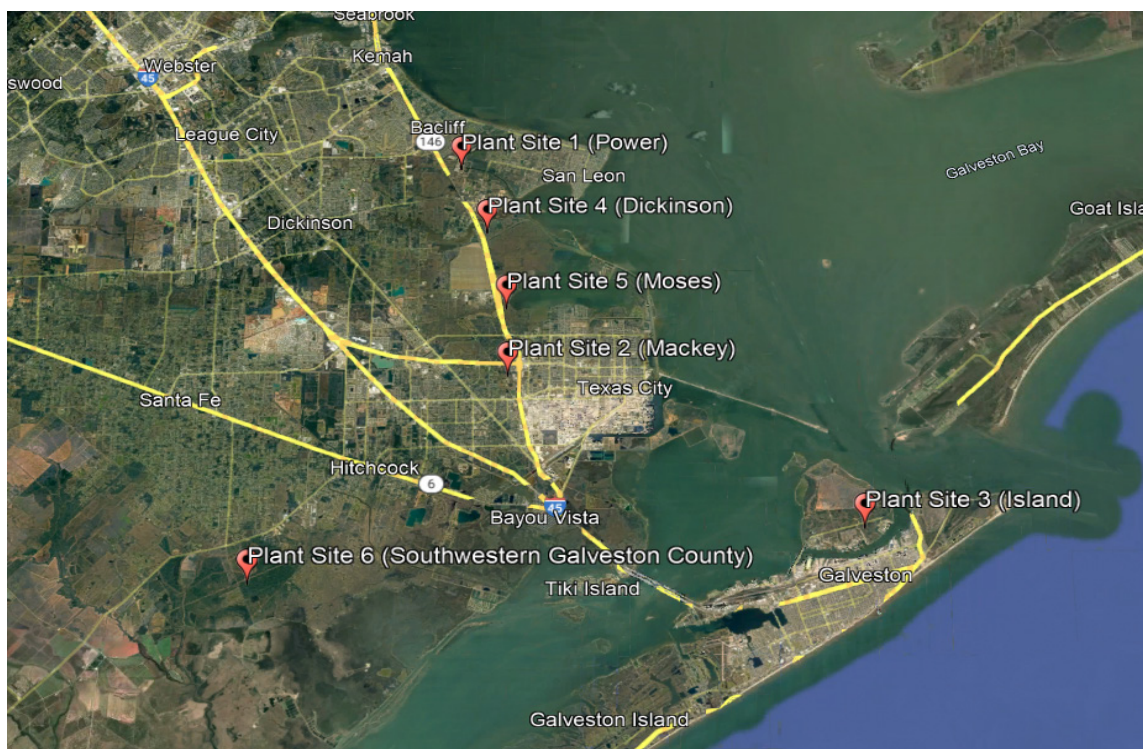


Figure 1-3 Preliminary Site Selection Locations

A workshop was held with all project stakeholders to review the available project site data and score each site using a determined weight associated with each criteria category. The goal of the workshop was to narrow the project sites down to two, although a third site was included after additional information was discussed. At this time, a single site location has not been selected for the project, but rather a preferred site area has been identified in southwestern Galveston County. The three final candidate sites are discussed below in more detail. Appendix A includes a Project Siting Technical Memorandum that details the site selection process.

1.2.1.1 Former P.H. Robinson Power Plant Site

This location is the site of a retired power plant, has an existing intake in Dickinson Bayou and discharge to Galveston Bay, as well as some water right permits, and is in proximity of the GCWA service area. This was originally GCWA's preferred site, but it is owned by another entity and is not an option for site development at this time.

1.2.1.2 Southwestern Galveston County Site

As the former P.H. Robinson Power Plant site is not currently available, a site location in Southwestern Galveston County is the chosen preferred option. While a specific site has not been identified, the area considered is west of Highway 6 and south of F.M. 2004 in Galveston County. This location area was chosen because of the expectation of new municipal and industrial growth in the area and the ability to meet those future demands, as well as having proximity to GCWA canals and their potable transmission system. Project costs are assumed based on a site location in this area.

1.2.1.3 Thomas S. Mackey Water Treatment Plant Site

A third site, adjacent to GCWA's existing TMWTP, is considered as a backup option. The land is already owned by GCWA, allowing the site to leverage existing utilities, infrastructure, and on-site staff.

1.3 Definition of Study Area

While the site-specific project area where the desalinated water will be developed has not been finalized, as mentioned above in Subsection 1.2.1.2, a site location in Southwestern Galveston County would be preferred. Figure 1-4 provides some additional detail of the preferred project area for the development of the desalinated seawater.

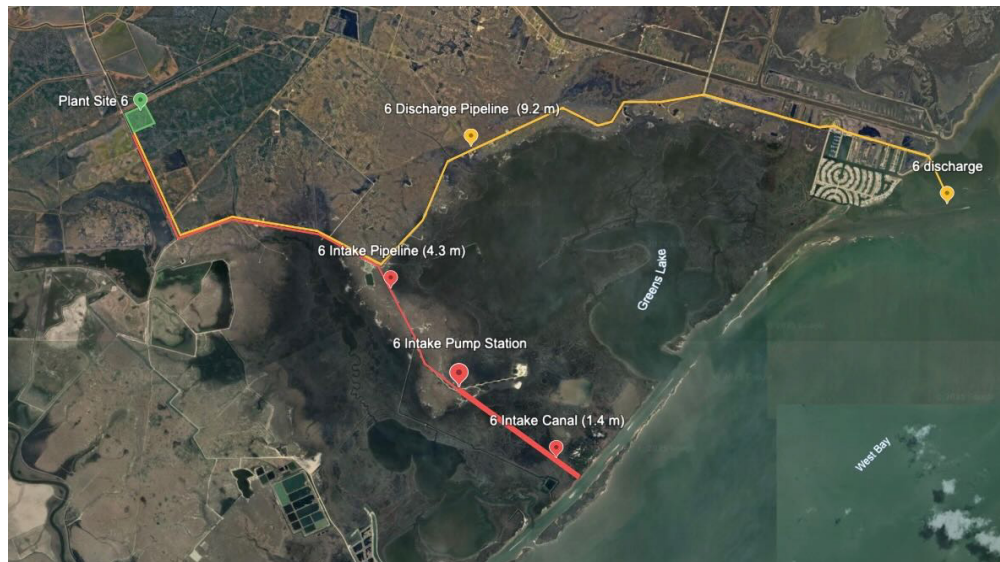


Figure 1-4 Site Location Map with Intake/Discharge for Southwestern Galveston County Site

The treated water will be pumped through a transmission line from the desalination plant site to connect with GCWA's existing potable water distribution system, shown in green in Figure 1.5. Transmission line alignment has not been determined at this time.

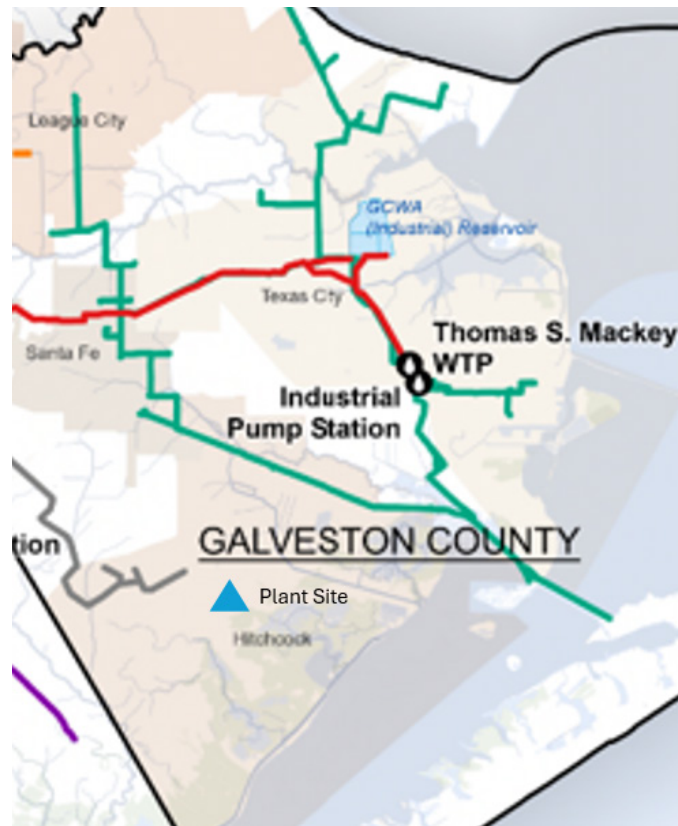


Figure 1-5 Preferred Site Location and GCWA Potable Distribution System (In Green)

2.0 Statement of Problems and Needs

(2) **Statement of Problems and Needs.** Describe key water resource management problems and needs for which a water reclamation, recycling or desalination project will provide a solution, including the following information. All projections shall be reasonable and applicable for a minimum of 20 years.

The State of Texas performs long-range water supply planning efforts every 5 years. It is known that the demand for water in Texas is increasing rapidly, while existing water supplies continue to be challenged by drought and other factors such as aging water infrastructure, water quality issues, groundwater depletion, and climate change. This is especially true in the metropolitan areas of Texas experiencing strong municipal and industrial growth.

GCWA has historically relied on its senior Brazos River water rights and BRA stored water contracts to meet the municipal, agricultural, and industrial water demands of its customers in Brazoria, Fort Bend, and Galveston counties. These sources have been the backbone of regional water security for decades. However, increasing variability in surface water, particularly during extended droughts, has exposed vulnerabilities in this traditional approach. GCWA is now seeking to ensure a droughtproof, local water supply portfolio that contributes efficiently to the region's resilience against prolonged droughts.

To address these challenges, GCWA is pursuing a drought-resilient, diversified water portfolio that strengthens regional resilience against prolonged dry periods. This strategy acknowledges that customer growth and rising water demands will continue as Southeast Texas experiences rapid population expansion and economic development.

2.1 Problem and Project Description

(a) Description of the problem and need for a water reclamation, recycling or desalination project.

As the State of Texas continues to grow, the demand for water is increasing as well. At the same time, existing water supplies are decreasing. Surface water sources are increasingly stressed during drought, and over-reliance on groundwater is unsustainable due to aquifer depletion and subsidence concerns. Groundwater use in the Houston metro area is being purposefully reduced to prevent land subsidence, which causes infrastructure damage, alters drainage patterns, and makes lowered land areas more vulnerable to flooding and storm surges. This limits groundwater as an option for future water supplies. The above realities underscore the need for innovative solutions, with seawater desalination emerging as a key component. Seawater offers a local, drought-proof source that can provide consistent supply regardless of climate variability, making it an attractive option for long-term planning.

GCWA's area covers the southern portion of the Houston metropolitan area, including Brazoria, Fort Bend, and Galveston counties. According to water demand projections developed as part of TWDB's 2026 Region H Water Planning Process in Texas, between 2030 and 2050, municipal and industrial demands in these three counties will increase by approximately 90,000 ac-ft/yr, or just over 80 MGD. By 2080, an additional increase of 110,000 ac-ft/yr, or 100 MGD, of municipal and industrial demand will occur. These projected demands will not be able to be met through existing supplies. Identified needs for water to meet future municipal and industrial demands increases from approximately 70,000 ac-ft/yr (62 MGD) in 2030 to approximately 125,000 ac-ft/yr (110 MGD) in 2050. By 2080, the identified water need to meet future municipal and industrial water demands increases further to 200,000 ac-ft/yr (178 MGD).

Three groundwater districts are within GCWA's service area. They include the following:

- Brazoria County Groundwater Conservation District (BCGCD)
 - New wells must be registered and permitted with the district. Permits specify allowable pumping rates and usage types. Large-volume wells are required to install meters.
 - Annual water usage reports must be provided to BCGCD for compliance monitoring.
 - Pumping limits may be restricted, specifically in areas subject to land subsidence. Limits may vary by aquifer and water use category.
 - BCGCD promotes conversion to surface water when feasible and requires conservation plans to reduce groundwater dependence.
 - Northern and western Brazoria County has experienced 2-5 feet of subsidence since the early 1900s.
- Fort Bend Subsidence District (FBSD)
 - All wells must be registered and permitted with FBSD. Permits specify allowable pumping rates and usage types. Large-volume wells are required to install meters.
 - Annual water usage reports must be provided to FBSD for compliance monitoring.
 - FBSD establishes conversion requirements for its permittees to reduce reliance on groundwater and utilize alternative water supplies to meet their total water demand.
 - FBSD monitors land elevation change, water use, and aquifer levels to monitor subsidence and ensure regulations are effective in reducing subsidence.
 - Northern and eastern Fort Bend County has experienced 2 to 3 feet of subsidence since the early 1900s.
- Harris-Galveston Subsidence District (HGSD)
 - All wells must be registered and permitted with HGSD. Permits specify allowable pumping rates and usage types. Large-volume wells are required to install meters.
 - Annual water usage reports must be provided to HGSD for compliance monitoring.
 - HGSD establishes conversion requirements for its permittees to reduce reliance on groundwater and utilize alternative water supplies to meet their total water demand. All groundwater users within the Subsidence District are required to limit groundwater use as specified in the Regulatory Plan.
 - HGSD monitors land elevation change, water use, and aquifer levels to monitor subsidence and ensure regulations are effective in reducing subsidence.
 - Portions of southeastern Harris and Galveston counties have experienced over 10 feet of subsidence since 1906.

In the greater Houston-Galveston region, land subsidence is the decrease in land-surface elevation caused by aquifer compaction due to abundant, long-term groundwater withdrawals. This consequence of groundwater use prompted the need for alternative water supply as groundwater is not a viable source as a long-term reliable water supply for GCWA. For example, the Galveston Canal was built in the late 1940s to bring surface water into Galveston County (Texas City) to combat land subsidence caused by the overuse of groundwater. GCWA purchased the canal in 1971.

Threats to GCWA's surface water supply are an additional consideration in the potential development of desalinated seawater. According to the 2026 Region G Water Plan ([2026 Regional Water Plans | Texas Water Development Board](#)), while the 1950s is still the official drought of record for the Lower Brazos Basin, additional droughts from 1993 to 2006 and 2008 to 2015 have seen significant low-flow periods for the Brazos River, with 2011 being considered the worst 1-year drought on record in Texas. Temperatures are trending upward, according to a report contracted by the TWDB and prepared by Freese & Nichols Inc. in 2021, entitled, *Assessment of How Trends in the Brazos River Basin May Affect Surface Water Availability and Attainment of Environmental Flow Standards*, resulting in increased evaporation from reservoirs and streams. During periods of low-flow in the Brazos River, the Brazos Alluvium Aquifer contributes base flow to the Brazos River. When irrigation or municipal users over-pump the aquifer during dry times, this reduces the baseflow to the river and makes the flow in the river less reliable.

As mentioned earlier, BRA and HGSD are stakeholders and partners for this feasibility study to look at the possibility of seawater desalination as a regional solution to water supply issues in Texas. Seawater desalination would both reduce the dependency on the reliability of the Brazos River during drought and prevent future demands for groundwater along the coast while also providing a reliable, local source of water. The addition of a desalinated seawater water supply could allow greater operational flexibility in the basin.

By integrating desalination into its portfolio, GCWA aims to:

- Reduce dependence on vulnerable surface water and groundwater sources
- Ensure reliable water for municipal, agricultural, and industrial needs
- Support economic growth while safeguarding environmental sustainability
- Partner with BRA to bring region-wide water relief through operational flexibility

This approach aligns with broader state trends: as Texas' population and industrial base expand, water demand will continue to rise, even as traditional sources face increasing constraints. Developing local, resilient water solutions such as desalination is critical to meeting future needs and maintaining regional competitiveness.

2.2 Current and Projected Water Supplies

(b) Description of current and projected water supplies, including water rights, and potential sources of additional water other than the proposed water reclamation, recycling or desalination project, and plans for new facilities other than the proposed project, if any.

GCWA provides raw or treated (potable) water on a wholesale basis to customers in Galveston, Fort Bend, and Brazoria Counties, Texas, including municipalities (e.g., Sugar Land, Missouri City), some agricultural users (irrigation), and several industrial users (e.g., Dow-UCC, Valero, INEOS, Marathon, Ascend). Natural streamflow variations and the water usage behavior of the upstream entities dictate the availability of GCWA's water. GCWA's water system infrastructure is predominately located in the Brazos River Basin, which is the second largest of the 15 major river basins in Texas. It has an area of 45,573 square miles. More than 1,000 water rights holders are in the Brazos River Basin. GCWA is one of the oldest water rights holders on the Brazos River and is one of the preeminent water rights holders in both primacy and volume.

2.2.1 Gulf Coast Water Authority Water Rights

Currently, all water delivered to customers by GCWA stems from stream systems within the Brazos and San Jacinto-Brazos watersheds as well as a system of canals operated by GCWA. Section 1.1 describes the canal system in detail.

GCWA owns multiple water rights authorizing the diversion of water from the Brazos River in Fort Bend County, Texas. These rights jointly authorize GCWA to divert up to a total of 379,932 ac-ft/yr at three diversion locations on the Brazos River, and with diversions having different priority dates under the Texas prior-appropriation doctrine. GCWA also has additional diversion rights totaling 57,500 ac-ft/yr from the Chocolate Bayou, Mustang Bayou, and Halls Bayou systems, as well as 12,000 ac-ft/yr (Certificate of Adjudication "CoA" 11-5169) from Jones and Oyster Creek. Combined, GCWA's water rights allow for annual diversions of up to 449,432 ac-ft/yr.

Table 2-1 describes the noted water rights.

Table 2-1 Gulf Coast Water Authority Water Rights Summary

GCWA Pumping Plants	Permit/CoA No.	Amount (Ac Feet)	Priority Date	Use Type	Notes
Shannon Plant (American Canal System)	CA No. 12-5168	99,932	1/15/1926	Industrial Municipal Irrigation	Can be diverted at either A or B
Briscoe Pumping Plant (Briscoe Canal System)	CA No. 12-5171	75,000	2/1/1939	Industrial Municipal Irrigation	Can be diverted at either A or B
		50,000	12/12/1950	Mining	Can be diverted at either A or B
Total Shannon and Briscoe Plants		224,932			
Jones and Oyster Creek	CA No. 11-5169 (Old 1467 Permit)	12,000	1985		GCWA
		18,000	1985		City of Sugar Land
Total Jones and Oyster Creek		12,000			
Total A, B and Jones and Oyster Creek		236,932			
William May Pumping Plant (formerly Juliff Plant)	CA No. 12-5322	40,000	2/8/1929	Industrial Irrigation	Can be diverted at J
		40,000	3/14/1955		
		75,000	7/25/1983		
Total Juliff River Permit		155,000			
Chocolate Bayou Halls Bayou Mustang Bayou	CA No. 11-5357	40,500	Multiple Dates	Industrial Irrigation	Chocolate Bayou
		4,000			Halls Bayou
		13,000			Mustang Bayou
Total CB/HB/MB		57,500			
Total River Permits		379,932			
Total All Permits		449,432			

2.2.2 Contract Water

GCWA also maintains contracts with other wholesale water entities for provision of water on a commercial basis. The bulk of the water available from these contracts is managed by BRA and relates to reservoir storage upstream of GCWA. Typically, these contracts are only utilized during periods of expected shortfalls in run-of-river supply and may only be used to satisfy municipal or industrial demands within the GCWA canal system. For the purposes of water supply availability modeling, Table 2-2 summarizes these contracts as follows:

Table 2-2 Gulf Coast Water Authority Contracts – Modeled Summary

No.	Total Contract Quantity Available (ac-ft/yr)	Notes
1	31,820	GCWA-BRA Long-Term Contract
2	9,335	GCWA-BRA Long-Term Contract
3	5,625	GCWA-BRA Long-Term Contract
4	3,100	Pecan Grove Contract
5	36,362	GCWA-BRA Long-Term Contract
6	10,000	NRG Short Term Contract

In summary, these water supplies are not projected to change significantly over the next 20 years. Other potential sources aside from the proposed desalination project include groundwater usage, reuse, or usage of alternative contract water sources, but have not yet been developed. Additional detail on supply modeling, not detailed further in this report, is included for reference in the US Bureau of Reclamation Funding Opportunity BOR-DO-19-F012 Report, dated September 2022, attached in Appendix B. Subsection 4.2.1 describes the alternatives that were considered in this report.

2.2.3 Water Availability Model Simulation

A potential desalination facility implemented within the GCWA system would positively affect the availability of other water supplies within the GCWA system. The GCWA system is hydrologically complex, and water availability is affected by many factors both environmental and contractual. To quantify this impact, and to examine impacts to reliability of water supplies, a Water Availability Model (WAM) evaluation was performed.

The TCEQ relies on WAM to evaluate and regulate surface water resources across the state's river basins. These models are essential tools for determining whether water is legally and physically available for new water rights or changes to existing ones. At the heart of the WAM system is the Water Rights Analysis Package (WRAP), a software program developed by Texas A&M University. WRAP simulates streamflows and the allocation of water under Texas's priority-based water rights system by processing historical data, return flows, diversions, reservoir operations, and other hydrologic inputs. Each river basin in Texas has its own WAM, developed using basin-specific data and tailored to its unique hydrologic and legal conditions.

Additionally, the Brazos Watermaster program monitors usage and water rights and acts to protect the water rights holders from over usage upstream. WAM simulations can evaluate and inform how potential changes or additions of rights results in a change in usage and the effect on the streamflow as well as other users.

This WAM evaluation aimed to bracket the volume of water that could be “freed-up” by implementation of a treated water desalination facility, and further to examine several scenarios to ascertain how available, and how reliable, such a volume of water would likely be. The modeling evaluation proceeded with the following assumptions, chosen to examine the feasibility of the ability of a future desalination plant to allow greater flexibility in operation and reliability in the region:

- It is assumed that future water produced by desalination will likely be allocated to serve treated water demands at the downstream end of the GCWA system, where existing fresh water supplies are under greater strain, and where proximity to both favorable sites for desalination and potential future users of water produced by desalination provides economic opportunities,
- By alleviating demands downstream, it is likely that implementation of future desalination will “free up” water to be allocated elsewhere. This “freed-up” water could be allocated either within the GCWA system, or to new or future users.
- To capture the impacts of either scenario, the volume of freed water was modeled as a diversion from existing water rights. This allows the WAM to examine the available volume and reliability of both the freed water and the remaining, un-diverted water under GCWA water rights and its BRA contracts. None of the water rights themselves are being split or otherwise modified.
- In this way, the WAM evaluations provide information about the reliability and availability of re-allocating the available water, examined through use of water rights, and examined at several locations. The WAM runs also provide a spectrum of scenarios and locations, ranging from highly reliable to moderately so. This information can be used to select scenarios for future study, and to support potential partnerships with other water users or water rights holders in the area.
- The WAM evaluations examined the impact of re-allocating a certain volume of water upstream and helps quantify how much water could reasonably be “freed up” or re-allocated by a future desalination project without impacting GCWA’s existing supply or intervening water rights holders, and how reliable this water might be.

The WAM simulation full report is included in Appendix C and is summarized here.

The WAM simulation examined a range of scenarios, including the following:

- Likely desalination facility sizing, including 10, 20, and 40 MGD.
- Freeing up water from several locations, including the Shannon, May, and Briscoe Pumping Plants.
- Allocation of “freed” water at two locations, including the Hempstead and Washington US Geological Survey (USGS) gauges. These locations are shown in Appendix C, Figure 2-1.

The simulation yielded the following conclusions about the studied scenarios:

- The Shannon Pumping Plant is an ideal location to free up water, as water from the Shannon water right(s) is very reliable in both amount and availability due to its priority date and volume.
- Simulation runs using the Shannon Pumping Plant also showed the least potential impact on other water rights holders, in terms of resulting available supply.
- Simulation runs using the May and Briscoe Pumping Plants displayed greater variability in the reliability and availability of water supply, from mid to low reliability. A full spectrum of results is available by combining these scenarios.

- Simulation runs using the Hempstead and Washington USGS gauges showed similar results for availability and reliability.
- Simulation runs using the Hempstead and Washington USGS gauges showed similar results for impacts to other water rights holders.

In conclusion, the WAM runs help demonstrate how GCWA's water supply availability can be affected by usage of water upstream. Further, the runs support the viability of the option of the desalination plant to provide an end-of-system water source, allowing water upstream of the plant to be used to mitigate over-usage on the Brazos and overall improve the resiliency of the watershed.

2.3 Current and Projected Water Demands

(c) Description of current and projected water demands, including a description of the current and projected water supply and demand imbalances.

2.3.1 Current Demands

As GCWA is a wholesale provider, it is not clear how many end-users obtain their water from GCWA sources. GCWA estimates that based on customer types and volumes, over 400,000 citizens are served over three counties. GCWA provides water to more than 45 entities, with the exact number fluctuating from year to year (due to varying annual agricultural contracts). Some GCWA customers hold "firm water" contracts in that they expect their water to be available 100% of the time. Other GCWA customers hold "interruptible water" contracts in that they recognize their access to water will be reduced during drought periods. For this evaluation, only "firm water" customer relationships were considered. Evaluations were performed on a conservative, worst-case basis, allowing for harshest predicted drought conditions and maximum "firm water" demands.

To determine water availability under various streamflow and system-operation scenarios, GCWA utilizes a numerical water accounting model named "GCWA Daily-Hydro." Since its initial development in 2010, the GCWA Daily-Hydro model has evolved to simulate many of the water resources of the Lower Brazos Basin, providing GCWA with greater opportunities to forecast water availability under possible climatic and management constraints.

The current and projected demands were modeled using GCWA's Daily-Hydro Model. Table 2-3 shows the modeled maximum demand for selected Lower Brazos Basin contracts for significant water users. In this model, the total modeled maximum demand for GCWA's contracts is 269,180 ac-ft/yr (240 MGD).

GCWA's maximum water rights total 449,432 ac-ft/yr (400 MGD). However, it is important to note that these water rights are geographically limited to their take points, as summarized in Section 1.0. This can affect how water right diversions are allocated, and both types of models, WAM and Daily-Hydro, attempt to take this into account. Seasonal drought also provides an element of unpredictability as to the actual amount of water that can be pulled from the river. Many of the water rights that GCWA holds are relatively senior, meaning that they are more likely to be successfully fulfilled. However, a few rights are more junior, and even senior rights can face depredations in the face of a strong drought.

Table 2-3 Brazos River Contracts Modeled Maximum Demand

	Entity	Amount (MGD)	Location
	DOW	328.96	Brazos- Dow
	NRG	55.25	Brazos- NRG
	Brazosport	62.157	Brazos- Dow
GCWA Customers	Ascend	17.87	Monsanto Canal
	Ashland	1	I Canal
	IPS	73.062	I Canal
	UGS	1.6	A Canal
	Fort Bend Water Control and Improvement Districts (WCID) No.2	10.5	A Canal
	Missouri City	15	B Canal
	Pecan Grove	2.35	A Canal
	Sugar Land	20	A Canal
	Pearland	20	A Canal
	Thomas S. Mackey	57.6	I Canal
	INEOS	24	CB Canal, Industrial Pipeline
	Galveston	6.2	AB Canal
	Texas City	8.7	AB Canal
	Topaz	0.137	I Canal

For historical context, the drought of record in the studied region occurred during 2011, and the 2011 historical streamflows were used for all GCWA Daily-Hydro model simulations to provide conservatism in comparing demands and supplies.

In 2011 GCWA provided customers with 316,297 ac-ft (282.4 MGD) of water, with 94,411 ac-ft (84.3 MGD), 96,346 ac-ft (86 MGD), and 125,540 ac-ft (112 MGD) for municipal, industrial, and agricultural purposes, respectively. Usage in 2011 was the highest ever achieved by GCWA, and usage in subsequent years has been reduced due to an overall reduction in irrigated acreage and general conservation measures by municipalities and industries. Several interruptible contracts were active in 2011 as well. However, to ensure a conservative approach, and align with take-or-pay contracts, modeling of demands proceeded with the assumption of maximum contract demands for municipal and industrial users.

To calibrate the model outputs, the available customer meter data for both raw and potable water customers for 2021-2023 were reviewed. These are tabulated in Appendix D and summarized in Table 2-4, which presents the average daily demands for 2021 to 2023 in MGD and ac-ft/day.

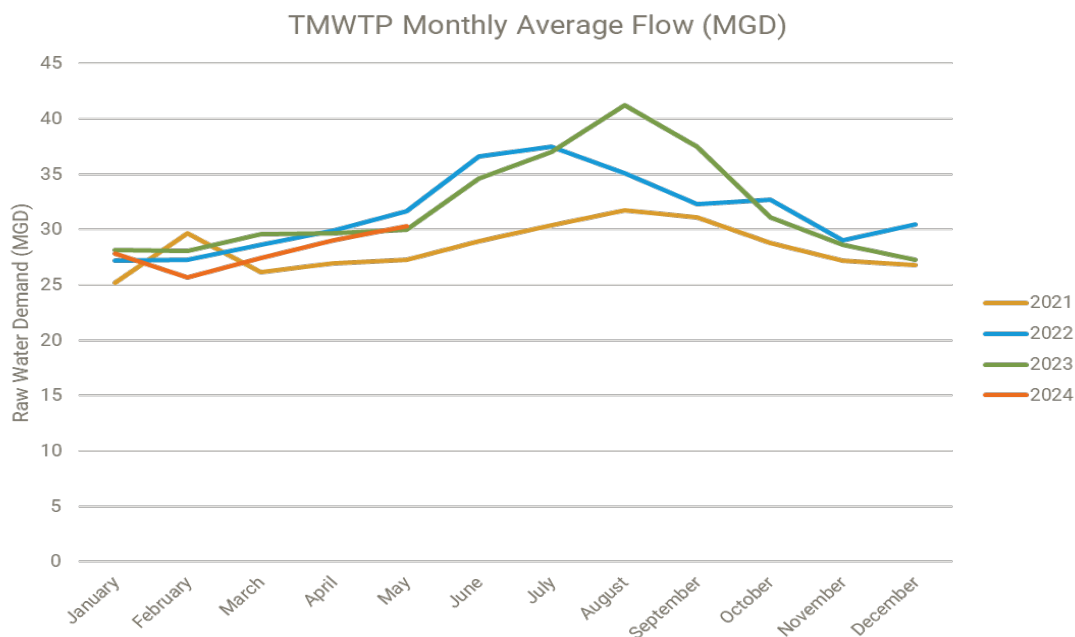
Table 2-4 Average Daily Demands Based on Customer Meter Data, 2021-2023

Year	Average Daily Demand (MGD)	Average Daily Demand (ac-ft/day)
2021	112.9	346.7
2022	126	386.9
2023	129.6	397.9

The total demand modeled for GCWA customers is the maximum contracted amount 269,180 ac-ft/yr (240 MGD), adjusted for in-canal losses. The modeled simulation follows the current water right allocation limitations, which means municipal and industrial demands not met by flows in Canals A or B cannot be satisfied by diversions from the GCWA J-Canal system.

The total average daily demand based on the raw and potable customer meter data for 2021 to 2023 totals approximately 123 MGD (377 ac-ft/day), which totals to 137,605 ac-ft/yr. The average customer meter demand is far below the maximum modeled demand. The usage in Table 2-4 is based on customer meters, while the above modeled demands are based on the actual contracts.

All potable water delivered by GCWA is produced by TMWTP. TMWTP historical production data for January 2021 through May 2024 were examined. TMWTP capacity is rated at 57.6 MGD, inclusive of ongoing improvement projects. TMWTP production peaked at 41 MGD in August 2023. Average demand over the period studied ranged from 30 to 35 MGD, as depicted on Figure 2-1.

**Figure 2-1 Average Monthly Raw Water Demand 2021 to 2023**

2.3.2 Projected Demands

A brief examination of future likely demands on the system was also undertaken. It is noted that in the future, new customers may seek contracted treated water supply from GCWA, either from population growth, groundwater usage reduction requirements, or a desire to explore additional reliable water

supplies. It is also noted that agricultural and other interruptible users experience high variation in supply and may face increasing demands.

Projections for future demands were modeled with the aid of the 2026 Region H Water Plan, as developed by the Region H Water Planning Group and the TWDB. Projected demands for current potable GCWA customers were compared and proportionally adjusted to the target timeframe at 2050 and 2080. For the sizing and timing of a proposed desalination plant, a two-stage approach was previously selected by GCWA, which calls for 20 MGD capacity by 2040 and 40 MGD capacity by 2070. This additional capacity was added into the GCWA Daily-Hydro Model, and runs were performed to simulate 2050 and 2080 water availability during a 2011 drought year. The future-demand projection modeling suggests an unmet increase of treated water demand of the following:

- 50.22 MGD (56,291 ac-ft/yr) by 2050
- 123.96 MGD (138,945 ac-ft/yr) by 2080

If these demands were to be fully passed on to GCWA, GCWA would be unable to meet the totality of demand even with full water rights usage and full contract usage. Serious shortfalls in water supply would occur. It is also possible that in such a scenario, the full contracted volume of water may not be available in the future due to reduced river flows or use by upstream customers. This potential shortfall underscores the need for reliable water sources in the region.

Demands for treated water will continue to rise. If this rise follows the Region H projections, additional demands must be met by development of additional water sources. The TMWTP cannot be expanded further. A desalination facility of moderate size (20 to 40 MGD) would provide additional capacity to meet near-term increases in treated water demands. Further, it would do so in a manner that could allow allocation of upstream water to other uses within the basin and increase the overall resiliency of both the GCWA water supply system and that of the region as a whole during an extended period of reduced Brazos River flows.

2.4 Water Quality Concerns

(d) Description of any water quality concerns for the current and projected water supply.

The GCWA May diversion point pulls from Segment 1202-01 of the Brazos River, known as the “Brazos River Below Navasota River.” Based on the Brazos River Basin Summary Report 2022, this segment shows a concern for elevated levels of Chlorophyll a, with a statistically significant increasing trend. Causes of elevated levels could be due to urban runoff, dogs, cattle, goats, sheep, horses, domestic and feral hogs, poultry, deer, wastewater, and rapid development. Total phosphorus and pH, while not showing elevated levels, are showing statistically significant increasing trends, while chlorides and sulfates are showing statistically significant decreasing trends. Increased phosphorus can lead to the requirement for enhanced coagulation or algal control measures during treatment. Increased pH can also impact coagulation efficiency and disinfection performance. Lower concentrations of chlorides and sulfates reduce corrosivity but change water chemistry. Drought-causing reductions in instream flows are likely to concentrate nutrient levels in the Brazos River. This results in increased risk for algal blooms, can impact coagulation and disinfection, and can require more chemicals for treatment.

Potable water treated and distributed by GCWA from the TMWTP is analyzed by laboratories contracted with TCEQ. The TMWTP staff monitors and performs water quality tests daily to ensure drinking water meets or exceeds state and federal regulations.

Seawater quality, which would be the source for the proposed seawater desalination project, is discussed in detail in Subsection 4.3.1.1 of this study.

3.0 Desalination Opportunities

(3) **Water Reclamation, Recycling or Desalination Opportunities.** Address the opportunities for water reclamation, recycling and desalination in the study area, and identify the sources of water that could be reclaimed or desalinated, including the following information.

With GCWA being right on the coast of Galveston Bay, the opportunity for seawater desalination could not be more optimal as the seawater from the bay provides a droughtproof water source. The State of Texas understands the existing and future demands for new sources of water, with desalinated seawater being one of the major ones. The “New Water Supply for Texas Fund” is a new special fund in the state treasury administered by the TWDB. The fund could provide financial assistance to political subdivisions of the state to develop water supply projects that create new water sources for the state, including seawater desalination, which will help reduce the State’s dependence on fresh groundwater sources that are being depleted and causing subsidence issues.

3.1 Desalinated Water Uses

(a) Description of all uses for reclaimed or desalinated water, or categories of potential uses, including, but not limited to, environmental restoration, fish and wildlife, groundwater recharge, municipal, domestic, industrial, agricultural, power generation, and recreation. Identify any associated water quality, and associated treatment requirements.

GCWA is a wholesale water provider and does not have the authority to provide wastewater treatment, so it is not authorized to provide reuse. The GCWA Regional Seawater Desalination project will provide potable water for municipal customers, both existing and future. Having an additional source of potable water may free up raw water for other customers. The desalination project in this study is proposed in two phases to support future growth at a reasonable pace that keeps up with demand. The seawater will be treated to drinking water standards prior to distribution.

3.2 Water Market Availability

(b) Description of the water market available to utilize reclaimed, recycled or desalinated water, including:

(i) Identification of existing and potential users, expected use, peak use, on-site conversion costs if necessary, desire to use reclaimed, recycled or desalinated water, including letters of intent if available.

(ii) Description of any consultation with potential reclaimed, recycled or desalinated water customers. Letters of intent must be included, if applicable.

Population and demand for water is increasing within the counties served by GCWA. Some GCWA customers hold “firm water” contracts in that they expect their water to be available 100% of the time. Other GCWA customers hold “interruptible water” contracts in that they recognize their access to water will be reduced during drought periods. It is anticipated that municipal and industrial need for water in Brazoria, Fort Bend, and Galveston counties will increase from approximately 70,000 ac-ft/yr (62 MGD) in 2030 to approximately 125,000 ac-ft/yr (110 MGD) in 2050. By 2080, the identified water need to meet future municipal and industrial water demands increases further to 200,000 ac-ft/yr (178 MGD). These numbers represent the need for water beyond currently available existing water supplies. These needs

include existing GCWA customers as well as potential future customers. GCWA provides water to more than 45 entities, with the exact number fluctuating from year to year (due to varying annual agricultural contracts). At the time of this feasibility study, no consultation with potential desalinated water customers has occurred. As water demands continue to grow, desalinated water will likely be the water source to supply the needs of existing and future customers.

The TWDB's 2026 Region H Water Plan was used to assess future demands and needs. The plan and additional details can be found at <https://regionhwater.org/>.

3.3 Desalination Project Considerations

(c) Discussion of considerations (for example: physical, converting systems for reused water, or public acceptance) which will prevent implementing a water reclamation, recycling or desalination project. Identify methods or community incentives to stimulate reclaimed, recycled or desalinated water demand, and methods to eliminate obstacles which will inhibit the use of reclaimed, recycled or desalinated water, including pricing.

Implementation of a large-scale seawater desalination project in the GCWA area must consider both technical and public acceptance factors. While physical constraints such as the need to construct new intake, treatment, and discharge facilities are being addressed through this feasibility study, public acceptance and long-term affordability remain key considerations.

Public outreach and education, supported by partnerships with BRA and HGSD, will be critical to communicate the benefits of seawater desalination. These efforts may include cost-sharing opportunities through stored water agreements, as well as programs that educate and incentivize responsible water use and conservation through grants and other initiatives. Emphasizing desalination's role in reducing dependence on the Brazos River will be a key message.

Obstacles to implementation may include public concern over energy use, brine discharge, or perception of higher costs. These can be mitigated through transparent cost comparisons with alternative water sources, clear environmental compliance strategies, and emphasizing the long-term water security benefits of diversifying GCWA's water portfolio.

3.4 Water and Wastewater Agencies Jurisdictions

(d) Identification of all the water and wastewater agencies that have jurisdiction in the potential service area or over the sources of reclaimed, recycled or desalinated water.

The proposed GCWA Regional Seawater Desalination Project lies entirely within the jurisdiction of GCWA. GCWA has both the legal authority and the operational responsibility for the development, treatment, and delivery of water produced by the proposed desalination facility.

GCWA does not provide retail potable water or wastewater services to individual households. Those services are provided by GCWA's contracted customers. There are no overlapping water or wastewater utility jurisdictions governing the production of desalinated water at the proposed project site.

Accordingly, GCWA is the sole agency with jurisdiction over the desalinated water supply and its delivery to end users under its existing wholesale contracts or any future customers. Downstream retail distribution and wastewater collection remain the responsibility of GCWA's customer entities.

3.5 Potential Desalination Water Sources and Source Water Facilities

(e) Description of potential sources of water to be reclaimed, recycled or desalinated, including impaired surface and ground waters.

(f) Description and location of the source water facilities, including capacities, existing flows, treatment processes, design criteria, plans for future facilities, and quantities of impaired water available to meet new reclaimed, recycled and desalinated water demands.

The proposed source of raw water for the GCWA Seawater Desalination Project is West Bay, located in Southwest Galveston County, Texas.

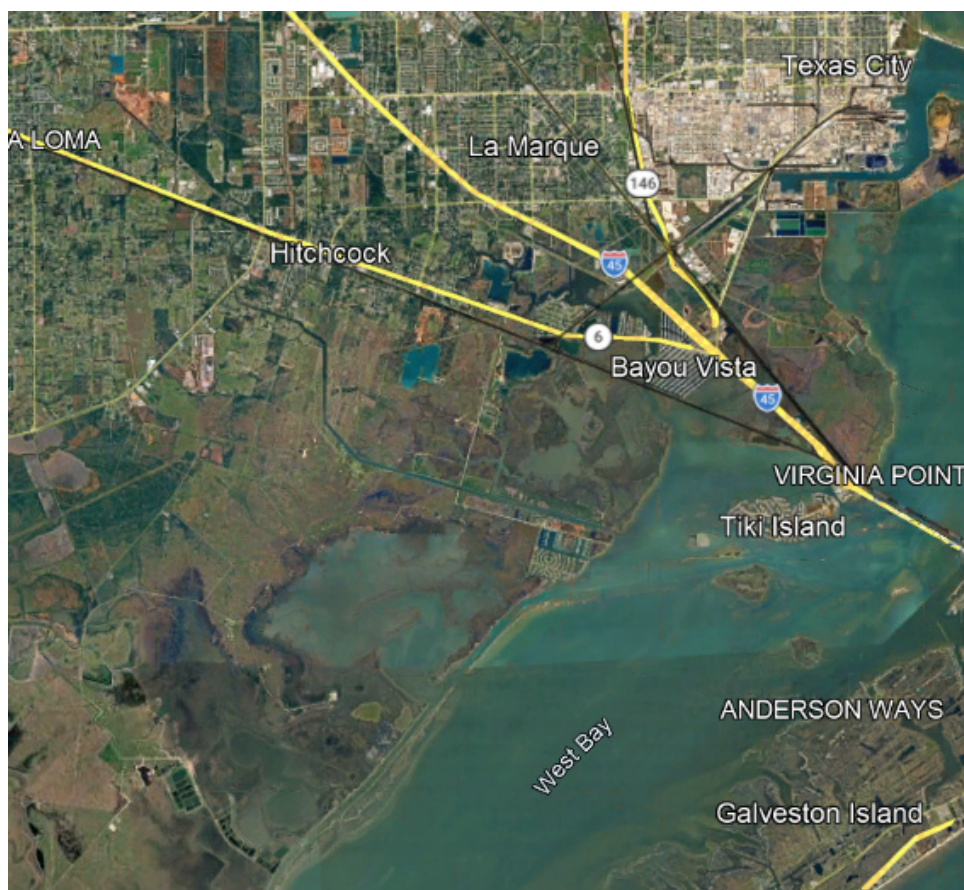


Figure 3-1 West Bay in Southwest Galveston County

The intake site under consideration is positioned to take advantage of existing industrial corridors (less impact to residential areas and city centers) and is sited to avoid environmentally sensitive areas such as oyster beds and seagrass habitats.

Preliminary intake capacity is estimated at approximately 88 MGD to support a projected desalinated product water output of 40 MGD. Sizing the intake infrastructure for full capacity when the plant may be built in phases minimizes the intake related permitting and construction required in future phases. Final capacities will be refined based on piloting results and detailed design. Intake design will include passive screening and low-velocity flow criteria to minimize entrainment and impingement of marine organisms.

There are currently no existing treatment facilities for this source water at the site; all treatment infrastructure will be new construction. The proposed treatment process will include pretreatment (likely using clarification and filtration), two pass seawater reverse osmosis (SWRO), and post-treatment stabilization. Design criteria and technology selection will be confirmed through pilot testing and in coordination with TCEQ. Conceptual design is provided in subsequent sections.

Future phases may allow for expansion of the treatment plant footprint to accommodate increased capacity or redundancy. No impaired water sources (water that does not meet water-quality standards set for its intended use) are currently integrated into this supply strategy; however, the use of a new, drought-resilient, and high-salinity source (seawater) is intended to reduce dependence on freshwater resources from the Brazos River Basin.

3.6 Existing Desalination Efforts

(g) Description of any current water reclamation, recycling or desalination taking place in the study area, including a list of reclaimed water uses, type and amount of reuse, and a map of existing pipelines and use sites.

There are currently no existing seawater desalination plants in the study area. At this time, a private utility has begun the permitting process for a new seawater desalination plant on Galveston Bay, which could bring up to 26.5 MGD of new water supply to Southeast Texas. The new facility could potentially be operational within five years or so if the permitting process is approved and the design and construction phases are allowed to proceed.

3.7 Existing and Projected Wastewater and Disposal Options

(h) Description of current and projected wastewaters and disposal options other than the proposed water reclamation, recycling or desalination project, and plans for new wastewater facilities, including projected costs, if any.

GCWA does not treat wastewater and does not have the authority to do so. Several municipal wastewater treatment plants (WWTPs) in the area including League City, Manvel, Missouri City, and Sugar Land have larger treatment capacities and are relatively near GCWA's canal system. One of the alternative projects evaluated in this feasibility study is for GCWA to purchase wastewater effluent from a local municipal WWTP that is normally discharged to a local creek and instead send it through GCWA's canal system for treatment at the TMWTP.

3.8 Existing Desalination Technologies and Opportunities for Improvement

(i) Summary of any water reclamation, recycling and desalination technology currently in use in the study area, and opportunities for development of improved technologies.

Local municipal and industrial WWTPs in the area currently treat to non-potable standards and discharge to local streams and creeks. Currently, desalination plants are not in the study area.

4.0 Description of Alternatives

(4) **Description of Alternatives.** The following information is required:

(a) Description of the non-Federal funding condition. The reasonably foreseeable future actions that the non-Federal project sponsor would take if Federal funding were not provided for the proposed water reclamation, recycling or desalination project, including estimated costs.

(b) Statement of the specific objectives all alternatives, including the water reclamation, recycling or desalination project, are designed to address.

(c) Description of the proposed water reclamation, recycling or desalination project including detailed project cost estimate; annual operation, maintenance, and replacement cost estimate; and life cycle costs shall be provided with sufficient detail to permit a more in-depth evaluation of the project, including non-construction costs. In this regard, the cost estimates shall clearly identify expenditures for major structures and facilities, as well as other types of construction and non-construction expenses and shall be based on calculated quantities and unit prices. (Per WTR-TRMR-128 – Large Scale Projects, this item is replaced as detailed in Section 5.0)

(d) The estimated costs shall also be presented in terms of dollars per million gallons (MG), and/or dollars per acre-foot of capacity, to facilitate comparison of alternatives described in Paragraph 4.B.(5) below. References, design data, and assumptions must be identified. The level of detail shall be as required for feasibility studies in RM D&S, *Cost Estimating* (FAC 09-01). (Per WTR-TRMR-128 – Large Scale Projects, this item is replaced as detailed in Section 5.0)

(e) Description of waste-stream discharge treatment and disposal water quality requirements, if applicable, for the proposed water reclamation, recycling or desalination project.

(f) Description of one or more alternative technologies that could be used in the proposed water reclamation, recycling or desalination project under consideration. Where a project only consists of reclaimed, recycled or desalinated water distribution, alternative plans for distribution or implementation will be provided. These alternatives must be approvable by the state(s) or tribal authorities in which the project will be located.

WTR-TRMR-128 – Large Scale Projects

(1) **Description of Alternatives.** WTR 11-01 Paragraph 3.B.(4) requires a description of the proposed project and a comparison to alternatives that would satisfy the same water demand as the proposed project. Feasibility studies for Large-Scale Water Recycling projects must also include the following additional requirements:

(a) A description of a reasonable range of viable alternatives that would satisfy the same water demand as the proposed project, including other water supply sources and/or project types that are practicable, feasible, and meet the planning objectives.

(b) A description of the baseline condition without the proposed project or any of the alternatives.

(c) Alternative plans must clearly identify and evaluate the trade-offs among stakeholders and resources. The viability of an alternative will be determined through an evaluation of its acceptability, efficiency, effectiveness, and completeness. Alternative plans will be formulated based on most likely future conditions expected with and without implementation of a plan.

4.1 Description of the Non-Federal Funding Condition

If federal funding was not an option for this project, GCWA would very likely look at state and local funding options, including deferred interest loan options through the TWDB including the State Water Implementation Fund for Texas (SWIFT), the Texas Water Development Fund, and the New Water Supply for Texas Fund, as GCWA cannot afford a seawater desalination project on their own. Additionally, alternative funding options such as public-private partnerships could be considered.

4.2 Statement of the Specific Objectives and Analysis of Alternatives

GCWA's mission is to continue to deliver water reliably to their customers. It is the objective of this project to ensure a droughtproof and local water supply portfolio that contributes efficiently to the region's resilience against climate change-driven droughts. As such, GCWA is considering several alternatives in addition to seawater desalination options of 20 MGD and 40 MGD. The other alternatives are no action (baseline condition), reuse, groundwater wellfield(s), and purchasing potable water from a third party.

4.2.1 Alternatives Analysis

A summary of the six alternatives being considered by GCWA is included in Table 4-1. Criteria considered include whether the alternative provides a reliable source of water during a drought, the volume of water that would be available, whether the alternative meets GCWA's long-term water need, whether it supports a regional water supply, is the supply resistant to climate change, how challenging permitting would be, and a relative comparison of the alternative's construction and operating costs.

Additional details for each alternative are included in the sections below and in Section 5.2.

Table 4-1 Summary of Criteria for Alternatives

Criteria	No Action	Reuse	Groundwater	Purchase Potable Water	Seawater Desalination (20 MGD)	Seawater Desalination (40 MGD)
Reliable Source During Drought?	No	Yes	Maybe	Yes	Yes	Yes
Volume of Water Available?	N/A	6.5 MGD	12-32 MGD	5 MGD	20 MGD	40 MGD
Meets Water Need Long-Term?	No	No	Unlikely	Unlikely	Yes	Yes
Supports Regional Water Supply?	No	No	Unlikely	Yes	Yes	Yes
Resistant to Climate Change	No	Yes	No	Maybe	Yes	Yes
Permitting	N/A	Moderate	Moderate	Minimal	Difficult	Difficult
Construction Cost	N/A	Low	Low	Low	High	High
Operational Cost	N/A	Low	Medium	Low	High	High

4.2.1.1 No Action (Baseline Condition)

The No Action alternative is that GCWA would take no action to increase supplies or resiliency for their service area. This alternative has \$0 cost but would restrict GCWA in supplying water to growing demands within their service area and would create less resiliency against climate-driven droughts by having their only source of water (Brazos River water) be subject to increasing droughts. This alternative is truly not feasible for addressing both growth and resiliency.

4.2.1.2 Reuse

Reuse is an alternative also being considered by GCWA. A potential reuse project would involve purchasing reclaimed water from one of League City's WWTPs, such as the Southwest Water Reclamation Facility, and discharging it into one of GCWA's canals near the wastewater facility to blend with surface water before being treated at the TMWTP. Figure 4-1 shows a potential path from the treatment plant to GCWA's G-Canal used for purposes of costing.

According to the City of League City's 2023 Wastewater Master Plan Update, it is anticipated that 8 MGD of average day wastewater flows will be treated (Type 1) at the Southwest Water Reclamation Facility once buildout is reached sometime after 2040. There is an existing 1.5 MGD commitment for a golf course which is anticipated to continue to be renewed, leaving approximately 6.5 MGD available for GCWA to purchase. The City of League City does not have a specific requirement in their permit for return flow quantities but is aware that it is a point of interest/concern with the TCEQ. This could potentially reduce the amount of reclaimed water that would be available for purchase.



Figure 4-1 Example Reuse Pipeline Path from League City WWTP to GCWA G-Canal

Cost assumptions include a capital cost for an 13,000-foot, 20-inch pipeline and pump station with power and backup generator to transfer the reclaimed water from the plant to the G-Canal, and annual costs that include debt service, operations and maintenance (O&M), and an assumed reclaimed water purchase cost of \$33/ac-ft.

Additional cost estimate details are included in Subsection 5.2.2.

4.2.1.3 Groundwater Wellfield(s)

In 2021, GCWA contracted a study by Ardurra to evaluate the ability of the existing Alta Loma Wellfield, owned by the City of Galveston but not in regular operation since 2000, in Galveston County to serve as an emergency supply to supplement their water system. Back in 2012, seven of nine wells were rehabilitated and have been exercised monthly since. The other two wells have not been in use. While the study was to look at using the wells in an emergency capacity, they could potentially be used on a more regular basis to supplement GCWA's water supply.

To develop this site as a source of water, all nine wells would require major or minor repairs. One option for connecting the wellfield to the GCWA system would be through a canal transmission option that would transport water from the wellfield to the G-Canal as a supplemental source. The water from the wellfield would be blended with water being conveyed in the canal for treatment at the TMWTP.

The Alta Loma Wellfield, using a canal transmission system, could provide up to 12 MGD, assuming the Base Phase (five wells), Phase 1 Expansion (two additional wells), and Phase 2 Expansion (two additional wells) are all developed. The wellfield is within HGSD Area 1, which means that GCWA can only pump 10% of their total water demand from that wellfield. Existing water demands for average daily use for raw and potable water are currently near 123 MGD (as described in Subsection 2.3.1), so the wellfield pumping meets that requirement. Planning level project components were taken from the Alta Loma study and input into the TWDB's Uniform Costing Model to develop costs in September 2023 dollars. Those costs were then updated to March 2025 dollars using the Engineering News-Record (ENR) Construction Cost Index.

The 2026 Region H Water Plan includes additional groundwater wells in the San Jacinto-Brazos Coastal Basin of Brazoria County as a water management strategy for GCWA. This strategy would develop up to 20 MGD of groundwater production capacity, by placing the wellfield facilities near the GCWA's canal system. Permitting would be required through the Brazoria County Groundwater Conservation District and GCWA could avoid export fees by using the groundwater for customers within Brazoria County. The project cost was taken from the 2026 Region H Water Plan in September 2023 dollars and was updated to March 2025 dollars using the ENR Construction Cost Index.

These two groundwater projects have been included together for this alternative and additional cost estimate details are included in Subsection 5.2.3.

While these two potential groundwater wellfields have the ability to provide up to 32 MGD, due to existing and likely future subsidence, the reliability of obtaining and keeping permits for a consistent volume of water for 20 years or longer is not high. As stated by the Brazoria County Groundwater Conservation District, all their permits are issued subject to any future production limits adopted by the District. As future pumping occurs, the potential for subsidence may have significant impacts on limits issued by the groundwater districts.

4.2.1.4 Purchase Potable Water From a Third Party

An additional alternative option to potentially increase water supply would be to purchase potable water from a third party. For this feasibility study, it is assumed that up to 5 MGD would be available for purchase by 2035. Estimated pricing for new sources of potable water in the study area is \$2,900 per ac-ft. No capital costs are assumed as any needed infrastructure to connect to GCWA's system would be expected to be included within the annual rate. Additional cost estimate details are included in Subsection 5.2.4.

One issue with this alternative is that it does not supply the full amount of water that GCWA is interested in developing to meet future needs in the area. The type of potable water that may be available to purchase in larger quantities is also expected to be quite expensive.

Additional research may be needed to look for wholesalers that GCWA could purchase from.

4.2.1.5 20 MGD Seawater Desalination Plant

This alternative includes building a 20 MGD desalination plant with intake and discharge designed for 40 MGD to allow the plant to expand in the future. The 20 MGD plant will allow demands to be met as growth occurs without oversizing too soon. The source water will be from West Bay. Seawater desalination is the only alternative GCWA is evaluating that can provide a droughtproof volume of 20 MGD for the local GCWA service area that also frees up surface water for BRA customers upstream in the Brazos River Basin that do not have access to seawater and that does not contribute to subsidence.

The assumed site location in southwestern Galveston County is the preferred location and would include both a 1.4 mile intake canal and 4.3 mile pipeline to bring the water to the plant, and a 9.2 mile pipeline to discharge the brine back to West Bay, as shown on Figure 4-2. A potable water delivery pipeline would also be constructed to connect the plant to the GCWA distribution system near Highway 6.

An alternative site location could be adjacent to the GCWA-owned TMWTP, which would require the intake and discharge pipelines to be constructed through open-cut methods under Texas City streets to Galveston Bay.

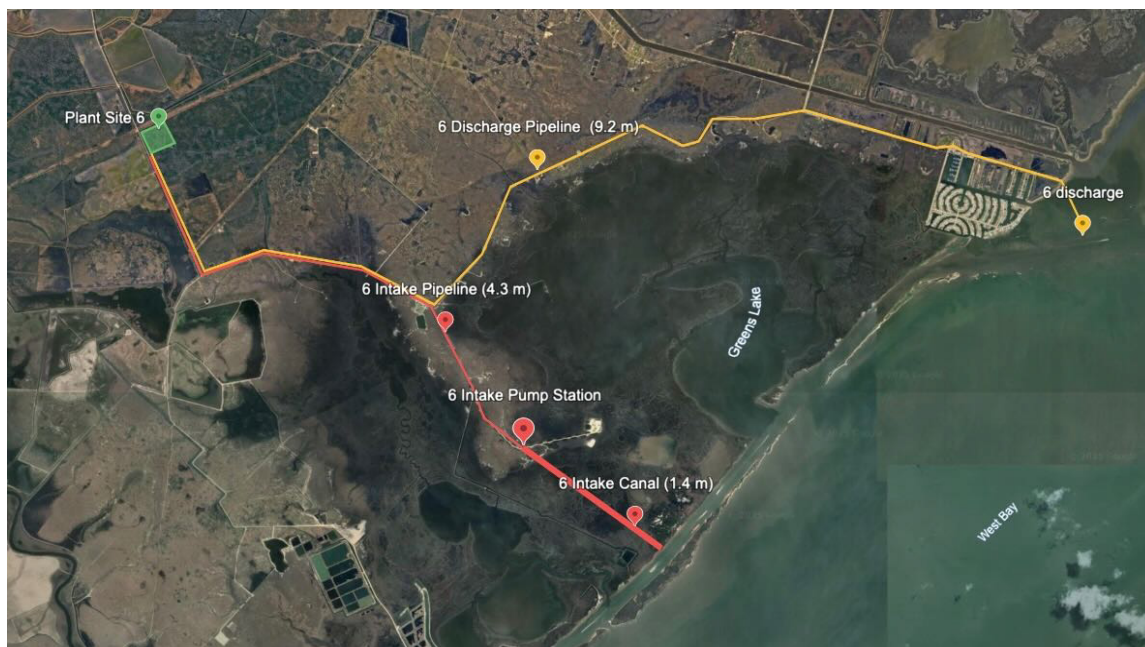


Figure 4-2 Site Location Map with Intake/Discharge for Southwestern Galveston County Site

The 20 MGD Seawater Desalination Plant is described in more detail in Section 4.3, with cost details included in Subsection 5.2.5.

4.2.1.6 40 MGD Seawater Desalination Plant

This alternative includes building a 40 MGD desalination plant with intake and discharge sized for this production capacity. The source water will be from West Bay. Seawater desalination is the only alternative GCWA is evaluating that can provide a droughtproof volume of 40 MGD for the local GCWA service area.

This project is very similar to the 20 MGD seawater desalination plant (Subsection 4.2.1.5) except that the plant itself is sized to 40 MGD during the initial construction, rather than being constructed in phases. One hindrance of building the 40 MGD plant all at once is that the plant may be oversized at an early stage, and thus operates below design capacity for many years.

Components that are similar to the 20 MGD seawater desalination plant alternative are described in more detail in Section 4.3, with cost details included in Subsection 5.2.6.

4.3 Description of the Proposed Desalination Project

In accordance to the TCEQ Seawater Desalination for Public Water Systems document, (<https://www.tceq.texas.gov/downloads/drinking-water/plan-technical-review/guidance/rq-640.pdf>) seawater is considered surface water and is subjected to primary and secondary maximum contaminant limits (SMCLs) listed in TCEQ's Title 30 Part 1 Chapter 290 Subchapter F.

Overall, the TCEQ potable water quality requirements are important for utilities to review and ensure compliance with to provide safe and aesthetically pleasing drinking water to the public. There are various disinfection-by-product precursors, inorganic, semi and volatile organic, and radionuclide contaminants that have enforceable maximum contaminant levels (MCLs). In addition, secondary drinking water standards have non-enforceable MCLs that have impacts to the taste, odor, and appearance of drinking water. These secondary parameters are still important, especially in a seawater desalination scenario when gaining the public's trust is crucial. Lastly, the proposed seawater desalination plant must ensure compliance with the log-removal requirements for *Cryptosporidium*, *Giardia*, and viruses, which can cause acute health effects to the public.

A non-exhaustive list of enforceable primary and secondary drinking water standards which are relevant to seawater desalination is provided in Table 4-2 and Table 4-3.

Table 4-2 Enforceable Primary Drinking Water Standards

Parameter	Primary MCL (mg/L unless otherwise specified)
2,3,7,8-TCDD (Dioxin)	3×10^{-8}
2,4,5-TP	0.05
2,4-D	0
Alachlor	0.002
Antimony	0.006
Arsenic	0.01
Atrazine	0.003
Barium	2
Benzopyrene	0.0002

Parameter	Primary MCL (mg/L unless otherwise specified)
Beryllium	0.004
Bromate	0.01
Cadmium	0.005
Carbofuran	0.04
Chlorite	1
Chlordane	0.002
Chromium	0.1
Cyanide	0.2 (as free Cyanide)
Dalapon	0.2
Di(2-ethylhexyl)adipate	0.4
Di(2-ethylhexyl)phthalate	0.006
Dibromochloropropane	0.0002
Dinoseb	0.007
Diquat	0.02
Endothall	0.1
Endrin	0.002
Ethylene dibromide	0.00005
Fluoride	4
Glyphosate	0.7
Heptachlor	0.0004
Heptachlor epoxide	0.0002
Hexachlorobenzene	0.001
Hexachlorocyclopentadiene	0.05
Lindane	0.0002
Mercury	0.002
Methoxychlor	0.04
Nitrate	10 (as Nitrogen)
Nitrate & Nitrite (Total)	10 (as Nitrogen)
Nitrite	1 (as Nitrogen)
Oxamyl (Vydate)	0.2
Pentachlorophenol	0.001
Picloram	0.5
Polychlorinated biphenyls	0.0005
Selenium	0.05
Simazine	0.004

Parameter	Primary MCL (mg/L unless otherwise specified)
Styrene	0.1
Turbidity	1.0 NTU
Tetrachloroethylene	0.005
Thallium	0.002
Total Organic Carbon (TOC)	Dependent on Source Water TOC
Toluene	1
Toxaphene	0.003
trans-1,2-Dichloroethylene	0.1
Trichloroethylene	0.005
Vinyl chloride	0.002
Xylenes (total)	10

Table 4-3 Secondary Constituents and Respective Maximum Contaminant Limits

Parameter	Secondary MCL (mg/L unless otherwise specified)
Aluminum	0.05 to 0.2
Chloride	300
Color	15 color units
Copper	1.0
Corrosivity	Non-corrosive
Fluoride	2.0
Foaming agents	0.5
Hydrogen sulfide	0.05
Iron	0.3
Manganese	0.05
Odor	3 Odor Threshold Number (OTN)
pH	> 7.0
Silver	0.1
Sulfate	300
Total Dissolved Solids (TDS)	1,000
Zinc	5.0

There are also treatment technique requirements for *cryptosporidium*, *giardia*, and viruses that public water systems must meet to provide drinking water to the public. According to TCEQ's Title 30 Section 290.111(b)(4), the log-removal requirements can be determined based on the *cryptosporidium* levels in the source water (i.e., seawater). A list of the log-removal requirements is provided in Table 4-4.

It is crucial for the proposed seawater desalination plant to ensure they meet the below log-removal requirements because of the acute risk of gastrointestinal diseases and other illness caused by these three microbial constituents. Generally, in seawater, high levels of *Cryptosporidium* oocysts are not observed and it is not expected that additional treatment for this is required specifically for *Cryptosporidium*. However, it is recommended to monitor these for pathogens during next stage of project development.

Table 4-4 Log-Removal Requirements

Average <i>Cryptosporidium</i> Level in Source Water	Bin Classification	<i>Cryptosporidium</i>	<i>Giardia</i>	Virus
<i>Cryptosporidium</i> < 0.075 oocyst/L	Bin 1	2.0-log	3.0-log	4.0-log
0.075 oocyst/L ≤ <i>Cryptosporidium</i> < 1.0 oocysts/L	Bin 2	4.0-log	3.0-log	4.0-log
1.0 oocysts/L ≤ <i>Cryptosporidium</i> < 3.0 oocysts/L	Bin 3	5.0-log	3.0-log	4.0-log
<i>Cryptosporidium</i> ≥ 3.0 oocysts/L	Bin 4	5.5-log	3.0-log	4.0-log

Table 4-5 provides the proposed treated water goals for the seawater desalination plant.

Table 4-5 Proposed Treated Water Goals for the Seawater Desalination Plant

Parameter	Unit	Value
Alkalinity (as CaCO ₃)	mg/L	>40
Aluminium	mg/L	0.05
Boron	mg/L	<1
Bromide	mg/L	0.2
Color	Pt. Co. Units	<15
Copper	mg/L	<1.3 (action level), 1.0 (SMCL)
Fluoride	mg/L	<2
Free residual chlorine	mg/L	4.0 (maximum residual disinfectant level)
Iron	mg/L	<0.015 (action level), 0.3 (SMCL)
Langlier Saturation Index	unitless	- 0.5 to + 0.5
Manganese	mg/L	<0.05
pH (at 25°C)	Standard Units (S.U.)	>7.0
Odor	OTN	<3
Total Coliforms & <i>E. coli</i>	Most probably number (MPN)	Absent
TDS	mg/L	<1,000
Total Hardness (as CaCO ₃)	mg/L	>40
Turbidity	NTU	<1
Viruses	Log	4.0-log (99.99%) reduction or inactivation

Parameter	Unit	Value
<i>Giardia</i> cysts (G)	Log	3.0-log (99.9%) reduction or inactivation

4.3.1 Treatment Process Overview

The anticipated treatment requirements are based on the raw water quality, treated water quality goals and the reliability of the plant required. The treatment requirements can be categorized into pretreatment, reverse osmosis (RO), post-treatment, disinfection, and waste treatment. The various options available for several of these treatment components and the overall treatment process adopted for the seawater desalination plant are described below. The following processes have been selected for the desalination plant:

- Marine growth control and coarse screening at the seawater intake structure
- Seawater intake pumping station
- Fine screening
- Coagulation and flocculation, including pH adjustment with sulfuric acid, followed by addition of ferric chloride and polymer for coagulation
- Dissolved air flotation (DAF)
- Gravity granular media filtration (GMF)
- Dechlorination through addition of sodium bisulfite
- Antiscalant and sulfuric acid addition (as needed) upstream of SWRO
- SWRO system with cartridge filters, high pressure feed pumps, and energy recovery system
- Post-treatment of RO permeate, using carbon dioxide, and lime
- Disinfection using hypochlorite

Ancillary processes include the following:

- Filter backwash system
- RO clean-in-place (CIP) system
- RO flushing system
- Filtered water storage and pumping
- Desalinated water storage
- Brine and waste collection
- Brine dispersion in the ocean

4.3.1.1 Seawater Quality

Proper characterization of the source water quality at the proposed seawater desalination facility intake site will provide insight on how to be compliant with TCEQ's potable water quality requirements. Table 4-6 provides a summary of the concentrations of various constituents in the seawater from a location near the proposed intake site. The analytical summary was provided from the port of Galveston and contains samples that were collected during the timeframe of 2021 to 2024. Data was also collected from the Environmental Protection Agency's (EPA's) How's My Water Way online tool (<https://mywaterway.epa.gov/>) and was sampled during the timeframe between 2015 to 2023. Table 4-6

provides a list of parameters that are relevant to seawater desalination operations because they can drive the treatment design and disposal technique requirements for the proposed seawater desalination facility. In instances where data from two sources are available, both are listed with number of samples (count column) from each data source. It should be noted that further sampling and analysis will help provide a more robust characterization of seawater quality.

Table 4-6 Summary of Seawater Quality Near the Proposed Intake Site

Analyte	Unit	Count	Avg	Standard Deviation	Min	Max	95th	5th
Aluminum, Total	µg/L	4	76.1	28.0	49.4	122.0	115.6	50.8
Ammonia Nitrogen	mg/L	4	0.2	0.0	0.2	0.2	0.2	0.2
Antimony, Total	µg/L	4	<5.3	<5.3	<5.3	<5.3	<5.3	<5.3
Arsenic, Total	µg/L	4	3.0	0.3	2.6	3.4	3.3	2.7
Barium, Total	µg/L	14	23.2	7.1	5.6	32.2	31.6	10.8
Beryllium, Total	µg/L	4	<0.91	<0.91	<0.91	<0.91	<0.91	<0.91
BOD ₅	mg/L	4	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Boron, Total	mg/L	14	4.0	1.0	0.7	5.0	4.9	2.4
Bromide	mg/L	12	34.4	17.3	7.0	52.1	52.0	8.2
Cadmium, Total	µg/L	4	<0.77	<0.77	<0.77	<0.77	<0.77	<0.77
Calcium	mg/L	12	368.8	102.7	77.0	482.0	482.0	198.0
CBOD ₅	mg/L	4	2.2	0.0	2.2	2.2	2.2	2.2
Chemical Oxygen Demand	mg/L	4	63.3	6.2	55.0	71.0	70.6	55.8
Chloride	mg/L	14	17,986	1,917	13,900	21,500	20,840	15,280
Chlorophyll-a	µg/L	229	13.2	8.5	0.9	66.6	30.6	3.8
Chromium, Hexavalent	µg/L	5	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51
Chromium, Total	µg/L	5	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51
Chromium, Trivalent	µg/L	5	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51
Cobalt, Total	mg/L	5	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Conductivity	µS/cm	948	30,008	11,715	281	57,100	48,865	8,838
Antimony, Total	µg/L	4	<5.3	<5.3	<5.3	<5.3	<5.3	<5.3
Beryllium, Total	µg/L	4	<0.91	<0.91	<0.91	<0.91	<0.91	<0.91
BOD (5-day)	mg/L	4	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Cadmium, Total	µg/L	4	<0.77	<0.77	<0.77	<0.77	<0.77	<0.77
Chromium, Hexavalent	µg/L	5	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51

Analyte	Unit	Count	Avg	Standard Deviation	Min	Max	95th	5th
Chromium, Total	µg/L	5	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51
Chromium, Trivalent	µg/L	5	<2.51	<2.51	<2.51	<2.51	<2.51	<2.51
Cobalt, Total	mg/L	5	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Copper, Total	µg/L	5	1.8	0.0	1.8	1.8	1.8	1.8
Cyanide, Available	µg/L	5	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Cyanide, Available	µg/L	5	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Depth	Feet	243	4.0	3.0	0.3	16.6	11.6	1.8
Dissolved Oxygen	mg/L	949	7.7	1.7	0.5	15.7	10.2	5.4
Fluoride	mg/L	14	2.3	0.9	1.1	3.3	3.2	1.3
Iron	mg/L	14	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Lead, Total	µg/L	5	<1.20	<1.20	<1.20	<1.20	<1.20	<1.20
Magnesium	mg/L	14	1,188	144	1,000	1,460	1,454	1,006
Manganese, Total	µg/L	14	6.4	5.1	1.1	15.5	14.8	1.2
Mercury, Total	µg/L	3	0.0	0.0	0.0	0.0	0.0	0.0
Molybdenum, Total	µg/L	5	9.5	0.8	8.9	10.9	10.7	8.9
Nickel, Total	µg/L	5	1.7	0.0	1.6	1.7	1.7	1.6
Nitrate (as nitrogen)	mg/L	14	2.1	0.4	1.6	2.6	2.6	1.6
Oil and grease	mg/L	14	2.8	0.3	2.5	3.3	3.2	2.5
pH	S.U.	14	8.1	0.2	7.8	8.4	8.3	7.8
pH	S.U.	949	8.2	0.2	6.8	8.9	8.5	7.9
Potassium	mg/L	12	348.2	97.0	74.4	460.0	449.5	186.2
Salinity	mg/L	949	18,821	7,868	100	37,800	31,980	4.9
Selenium, Total	µg/L	5	<8.60	<8.60	<8.60	<8.60	<8.60	<8.60
Silica, Dissolved	mg/L	10	0.8	0.8	0.2	3.2	2.1	0.2
Silver, Total	µg/L	5	<0.44	<0.44	<0.44	<0.44	<0.44	<0.44
Sodium	mg/L	12	9,925	1,118	8,200	12,000	11,550	8,655
Specific Conductance	µS/cm	12	60, 198.3	10,461	39,919	74,800	74,000	41,190
Strontium, Total	mg/L	10	6.7	2.0	1.3	8.6	8.5	3.2
Sulfate	mg/L	14	2,739.3	456.4	2,200	3,530	3,524	2,224
Sulfide	mg/L	4	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Temperature	°C	949	23.3	6.1	11.2	32.3	31.4	13.2
Thallium, Total	µg/L	5	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50

Analyte	Unit	Count	Avg	Standard Deviation	Min	Max	95th	5th
Tin, Total	µg/L	5	<0.58	<0.58	<0.58	<0.58	<0.58	<0.58
Titanium, Total	µg/L	5	6.7	0.0	6.7	6.7	6.7	6.7
Total Alkalinity (as CaCO ₃)	mg/L	14	119.6	21.9	48.9	146.0	145.4	85.6
TDS	mg/L	14	37,878	4,660	32,000	46,500	44,820	32,180
TOC	mg/L	14	2.1	0.3	1.2	2.6	2.4	1.5
TOC	mg/L	222	4.5	1.7	0.5	12.0	7.0	1.5
Total Organic Nitrogen	mg/L	4	0.9	0.4	0.6	1.3	1.3	0.6
Total Phosphorus	mg/L	4	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Suspended Solids	mg/L	14	16.0	9.4	3.9	40.9	33.5	5.6
Total Suspended Solids	mg/L	40	50.2	33.5	7.4	168	109	15.0
Zinc, Total	µg/L	5	<10	<10	<10	<10	<10	<10
1. Bold indicates the constituent's concentration does not meet proposed treated water quality goals.								

Based on the data summary, the feedwater at the proposed intake site requires robust pre-treatment prior to desalination to ensure reliability performance and meet the treated water quality goals listed in Table 4-5. In the subsequent sections, a list of unit processes that can effectively purify the feedwater will be discussed.

4.3.1.2 Seawater Intake

The proposed source water abstraction is discussed in Section 3.5.

Periodic shock chlorination is required to control biological growth in the intake pipeline and in the processes upstream of the SWRO system. Periodic shock chlorination using sodium hypochlorite is traditionally used for biofouling control in desalination plants; however, some desalination plants have also utilized sulfuric acid as an additional means for biofouling control and control of marine growth in the intake pipeline. Thus, provisions to feed sulfuric acid are included in the design. Sodium hypochlorite and sulfuric acid (optional) will be dosed at the offshore intake velocity cap to prevent marine growth in downstream systems. Both chemicals will be fed intermittently for approximately 5 to 7 hours on a weekly basis. The dose, duration, and frequency of each chemical application will ultimately depend on site-specific seasonal conditions, such as water temperature and the amount of organics and nutrients present in the water and will be optimized during operations.

4.3.1.3 Seawater Intake Pumping

The seawater intake pumping system will be located in a wetwell at the onshore intake structure. The seawater pumps will convey raw seawater to the fine screening facility at the SWRO plant. A summary of the design parameters for the seawater intake pumps is presented in Table 4-7.

Table 4-7 Seawater Intake Pump Design Parameters

Equipment/Description	Unit	20 MGD	40 MGD
Number	Nos.	4	8
Rated unit capacity	gpm	8454	8039
Rated head	psi	66	66
Pump type	-	Vertical turbine	
Material of construction	-	Super duplex stainless steel	
Drive type	-	Variable frequency drive (VFD)	
gpm – gallons per minute			

4.3.1.4 Fine Screens

The fine screens will remove large particles and other materials from raw water. Each screen will consist of a continuous band of mesh panels within a vertical self-supporting frame. The screens are designed for continuous operation. In normal operation, the screens remain static and water flows through them. As solids accumulate on the screens, the difference in water level across the screen increases. When it reaches a pre-set headloss value or after operator selected time interval, or when manually initiated, the screen will rotate to bring the fouled mesh up where they will be cleaned with screened seawater by a set of submersible spray wash pumps located downstream of the fine screens in a collection box. Debris collected on the screen mesh panels will be removed and collected in trash bins and will be hauled off-site for disposal.

Screen channels will be sized to achieve the minimum approach velocity (speed at which water flows toward the screen) that is necessary for effective screening and to minimize the potential for deposition of sediment in the screen channels. A means of isolating individual screen channels will be provided. Access will be provided for vehicles to collect the screenings waste from the trash bins. Design criteria are provided in Table 4-8.

Table 4-8 Screen Channel Design Criteria

Description	Unit	20 MGD	40 MGD
Number of units	No.	2 (1 duty, 1 standby)	3 (2 duty, 1 standby)
Screen type	-	Dual-flow travelling band screens or drum screens	
Maximum unit capacity	gpm	33,820	
Material of wetted parts	-	SDSS or 316L stainless steel with cathodic protection	
Screen openings	mm	3	

4.3.1.5 Pretreatment System

The objective of the pretreatment system is to remove foulants that adversely affect performance of the RO membranes and to minimize fouling potential. Pretreatment should consider provisions for removal of colloidal and suspended solids, oil and grease (if present), algae, and natural organic matter. Pretreatment systems typically consist of rapid mixing, flocculation, clarification, and filtration.

For seawater applications where algae is an issue, dissolved air flotation (DAF) clarification systems are recommended to address high concentrations of algae, oil and grease, and/or organics. They can also remove suspended solids to a great extent. While limited data is available, it is anticipated that high concentrations of algae and total suspended solids could occur and a DAF system is recommended at this stage of design. Additionally, GMF will be more cost-effective compared to pressure media filtration or membrane filtration. The primary advantage of pressure media filtration is off-site fabrication which makes it easy to maintain quality and relatively easier installation on concrete slab. However, the size of even the pressure vessels that can be transported to the site is relatively small requiring many of these vessels. In addition, MF/UF systems require a significantly larger number of valves and instruments as typical membrane skid capacity is smaller than that of a typical media filter. This can result in more maintenance for the MF/UF systems.

Membrane filtration provides consistently good quality feedwater to the SWRO system. However, the cost savings associated with reduced fouling of SWRO process do not offset the higher capital and operating costs of membrane filtration system.

Thus, the pretreatment system design consists of DAF followed by GMF.

4.3.1.5.1 Coagulant Chemical Addition

Static mixers will be provided immediately upstream of the DAF influent channel for sulphuric acid and coagulant addition. Ferric chloride is added for particle charge neutralization and allow floc formation and polymer (optional) is added as a coagulant aid. From the static mixers, flow will be distributed into the DAF influent channel and subsequently into the individual flocculation basins associated with each DAF unit. The flocculation basins will allow for agglomeration of particles and floc formation upstream of the DAF flotation basin.

4.3.1.5.2 Dissolved Air Flotation System

A DAF system will be provided to remove suspended material and floatable material such as algae, and any oil and grease present in the raw seawater. The DAF process is based on the principle that certain naturally occurring particles “float” better than settle after flocculation. In the DAF process, a portion of the clarified water is collected, pressurized, and saturated with air for recirculation back into the basin. The DAF system is expected to remove 80 to more than 95% of suspended solids. Provisions to bypass the DAF system are provided for periods when raw seawater quality has reasonably low concentrations of suspended solids and algae and can be directly treated by GMF, after coagulation.

Flocculated water enters the DAF unit under a baffle wall at the inlet riser. Recycled water that has been saturated with compressed air is introduced at the inlet of the basin via an array of distribution nozzles. The pressure drop across the recycle nozzles causes the air to come out of solution in the form of fine microbubbles (20 to 100 µm).

In the flotation basin, microbubbles are utilized to float low density algae and other solids to the water surface, forming a sludge layer that can be periodically removed by a float skimmer. The clarified water flows down to the filtration section in the lower part of the DAF structure. The sludge blanket is removed mechanically and is initiated automatically after a pre-set (adjustable) time interval. DAF solids will be pumped to the brine and waste collection tank.

Table 4-9 provides the design parameters for the dissolved air flotation basins.

Table 4-9 Dissolved Air Flotation Basin Design Parameters

Description	Unit	20 MGD	40 MGD
Number of units	No.	4	8
Maximum effluent flow rate	gpm	38,727	73,642
Nominal effluent flow rate	gpm	34,973	69,866
Flotation Basins			
Flotation basin loading rate with all units online (N)	gpm/ft²	8.9	
Flotation basin loading rate with one unit offline (N-1)	gpm/ft²	11.9	
Flocculation Basins			
Number of stages per basin	No.	2	
Number of cells per stage	No.	2	
Detention time per stage	min	10	
Total number of flocculators per unit	No.	4	
Flocculator type	-	Vertical axial flow	
Material of wetted parts	-	SDSS	
Recycle Pumps			
Number of units	No.	4	8
Percentage of influent flow	%	15%	
Pump rated head	psi	80	
Pump type	-	Centrifugal	
Drive type	-	VFD	
Material of wetted parts	-	SDSS	
Saturators			
Number of units	No.	4	8
Type	-	Packed bed	
Loading rate	gpm/ft²	35	
Saturator vessel material		Lined carbon steel	
Number of air compressors	No.	2 (1 duty,1 standby)	3 (2 duty, 1 standby)
Number of solids transfer pumps	No.	2 (1 duty, 1 standby)	3 (2 duty, 1 standby)

4.3.1.6 Gravity Media Filters

Gravity media filters (GMF) will be provided to remove suspended solids from the clarified water to provide high quality feedwater to the RO system. DAF effluent will flow into a filter influent channel and be distributed into the individual filter basins. The GMFs consist of a filter underdrain, gravel base layer,

sand, and anthracite. The sand layer provides effective removal of fine particles, and the anthracite layer removes larger particles and provides deeper solids penetration into the filter bed, enabling higher filter loading rates and longer filter runs. In the filtration process, solids are removed primarily at the surface of the filter media or through attachment to other solids that have already accumulated on the surface of the media.

As the filters begin to accumulate solids, headloss across the filter will begin to increase. Filter backwash will be triggered based on a pre-set value for headloss across the filter, filter run time, volume of water filtered, or filter effluent turbidity.

The filter backwash will be done with the reject stream from the SWRO process to minimize raw seawater intake flow. However, provisions for use of filtered seawater will also be provided. When a filter backwash is initiated, the filter will be drained to remove brine from the media bed. The filter backwashing process will consist of low and high rate backwashing with air scour. Following the backwash procedure, the filter will be put in “filter-to-waste” mode, where the filter effluent is diverted to the brine and waste collection tank until it reaches a specified filter effluent turbidity or setpoint on a timer. Once the filter-to-waste operation is complete, the filter can be returned to service.

Backwash water will be supplied by the RO concentrate header. The filter backwash tank will be located adjacent to the GMF facility and will share a common wall with the filtered water tank. The filter backwash tank is designed to store sufficient volume for a minimum of two backwashes. Design parameters for the backwash tank, backwash pumps and air scour blowers are summarized in Table 4-10.

Table 4-10 Gravity Media Filters Design Parameters

Description	Unit	20 MGD	40 MGD
Gravity Media Filters			
Number of units	No.	10	20
Loading rate with all filters in service (N)	gpm/ft ²	2.7	
Loading rate with one filter out of service (N-1)	gpm/ft ²	3	
Media	-	Anthracite Sand Gravel	
Backwash Supply Tank			
Number of backwash volumes stored	No.	2	
Tank usable volume	gal	644,160	
Tank material	-	Concrete tank	

Description	Unit	20 MGD	40 MGD
Backwash Operations			
Low rate backwash loading rate	gpm/ft ²	8	
Low rate backwash duration	min	10	
High rate backwash loading rate	gpm/ft ²	20.0	
High rate backwash duration	min	6	
Filter-to-waste duration	min	30	
Backwash Pumps			
Number of units	No.	2 duty 1 standby	
Pump rated flow	gpm	9000	
Pump type	-	Vertical turbine	
Drive type	-	VFD	
Air Scour Blowers			
Number of units	No.	1 duty 1 standby	2 duty, 1 standby
Drive type	-	Constant speed	

4.3.1.7 Filtered Water Storage and Pumping

Filter effluent will be collected in a common header and delivered to the filtered water tank. The filtered water tank is sized to provide sufficient hydraulic detention time of the filtered water at design flow as listed below. The filtered water pumps will deliver water from the filtered water tanks to the RO building. The filtered water pumps are sized based on the net positive suction head (NPSH) required by the RO high-pressure feed pumps, static lift between the filtered water tank and the RO building, equipment losses across the cartridge filters and static mixers, and hydraulic friction losses. Design parameters for the filtered water tank and filtered water pumps are summarized in Table 4-11.

Table 4-11 Filtered Water Storage and Pumping Design Parameters

Description	Unit	20 MGD	40 MGD
Filtered Water Tank			
Tank material		Concrete tank	
Detention time	min	15	

Description	Unit	20 MGD	40 MGD
Tank useable volume	gal	56,000	1,124,439
Filtered Water Pumps			
Number of units	No.	4	8
Rated capacity	gpm	31,404	
Rated head	psi	70	
Drive type	-	VFD	

4.3.1.8 First Pass Seawater Reverse Osmosis System

The first pass SWRO system consists of several SWRO trains. Each train consists of a high-pressure pump, SWRO skid, energy recovery device and a booster pump. The SWRO skid consists of several pressure vessels connected in parallel and house the SWRO membrane elements. The SWRO system plays a vital role in a seawater desalination facility, ensuring the effective treatment of seawater by removing dissolved salts and other impurities. In the SWRO treatment process, feedwater is first pumped from the SWRO feedwater holding tank and passed through cartridge filters located upstream of the SWRO system. The pressurized stream is then divided, with most of the flow directed to additional SWRO high-pressure feed pumps and the remainder sent to energy recovery devices (ERD). Each SWRO skid is equipped with a dedicated RO high-pressure feed pump and ERD, both of which will be equipped with variable frequency drives. The flow entering the ERD is pressurized by a booster pump and hydraulic energy recovered from the RO concentrate (Figure 4-3). The recovered flow is recirculated and mixed with the stream entering the RO modules for further processing.

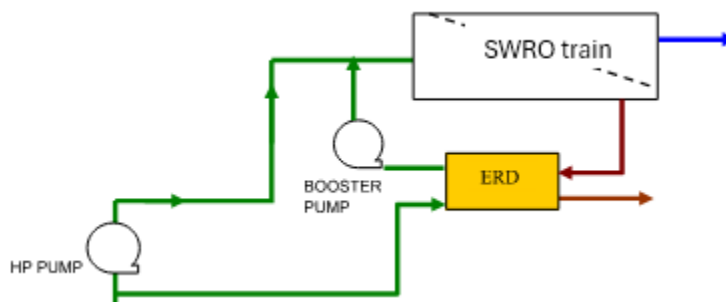


Figure 4-3 Arrangement of High-Pressure Pump, SWRO, and Energy Recovery Device

The high-pressure SWRO feed pumps adjust the RO feed pressure to achieve the necessary permeate flow (the high quality water that passes through the membrane) based on fluctuations in operating conditions such as water quality (salinity and temperature) and membrane age. In the RO train, the pressurized feedwater is distributed evenly across the pressure vessels. Some of the feedwater passes through the membrane elements and is discharged as SWRO permeate, while the rest is directed to the ERD after being collected and manifolded. The permeate is drawn from both ends of the SWRO vessels in the SWRO train. The permeate from the front end of the vessels is sent to post treatment while the permeate from rear end is sent to second pass brackish water RO system. This is because the front end permeate is of higher quality, while the lower quality permeate from rear of the vessels can be further treated by second pass. This reduces the size of second pass considerably. This type of arrangement is called Split Partial Two Pass System.

4.3.1.9 First Pass Seawater Reverse Osmosis Pretreatment Chemicals

Pretreatment chemicals, such as antiscalant, sulfuric acid, and sodium bisulfite, will be injected at desired concentrations at feed points located upstream and downstream of the RO cartridge filters. Antiscalant is utilized to minimize scaling on the RO membrane surfaces caused by inorganic substances. Additionally, sulfuric acid injection serves the purpose of pH adjustment and will help control calcium carbonate scaling. In case of shock chlorination at the intake, sodium bisulfite will be used to remove chlorine from the RO feed and protect the membranes from damage.

4.3.1.10 First Pass Seawater Reverse Osmosis Cartridge Filters

Prior to SWRO treatment, a series of cartridge filters will be implemented to ensure proper protection of the RO membranes. The main purpose of the cartridge filters is to act a safeguard against potential suspended solids and biofoulants (e.g., algae). Cartridge filters also provide an extra line of defense of deteriorated water quality due to failure of the upstream pretreatment process. The design parameters of the SWRO cartridge filters are provided in Table 4-12. The number of units can vary depending on the supplier and hence are not listed at this stage of design.

Table 4-12 Seawater Reverse Osmosis Cartridge Filter Design Parameters

Description	Unit	20 MGD and 40 MGD
Loading rate with all units online (N)	gpm/10" eq. length	3
Cartridge filter micron rating	µm	5 to 20

4.3.1.11 First Pass Seawater Reverse Osmosis Units

The SWRO system can be described by the number of units, capacity of each unit, flux, and recovery. The design parameters can determine the effectiveness of the SWRO treatment process. The design parameters of the SWRO system are provided in Table 4-13.

Table 4-13 Seawater Reverse Osmosis System Design Parameters

Description	Unit	20 MGD	40 MGD
Number of RO trains	No.	5 (4 duty, 1 standby)	9 (8 duty, 1 standby)
Design permeate flow with all units online	gpm	13,885	27,769
Membrane element description	-	8" diameter, 40" long	
RO recovery	%	48%	
Design flux at max permeate flow	gfd	7.1	
Active area per membrane element	ft ²	400	
Number of elements per vessel	No.	7	
Number of pressure vessels per unit	No.	276	

Proper sizing and quantity of the SWRO high-pressure pumps are important to consider due to the energy-intensive nature of desalinating seawater. The design parameters for the RO high-pressure pumps are listed in Table 4-14.

Table 4-14 Reverse Osmosis High-Pressure Pump Design Parameters

Description	Unit	20 MGD	40 MGD
Number of units	No.	5 (4 duty, 1 standby)	9 (8 duty, 1 standby)
Design flow rate with all units online	gpm	13,885	27,769
Estimated rated head	feet	2,066	
Expected NPSH required	feet	35	
Pump Type	-	Multistage split case centrifugal	
Drive type	-	VFD	

The ERDs used in the SWRO system provide potential reduction in energy requirements. The design parameters of the ERD are provided in Table 4-15.

Table 4-15 Energy Recovery Devices Design Parameters

Description	Unit	20 MGD	40 MGD
Energy Recovery Devices			
Number of units	No.	5 (4 duty, 1 standby)	9 (8 duty, 1 standby)
Type	-	Positive displacement	
Booster Pumps			
Number of units	No.	5 (4 duty, 1 standby)	9 (8 duty, 1 standby)
Design flow rate with all units online	gpm	16,579	33,158
Rated head	feet	131	
Pump type	-	Centrifugal	
Drive type	-	VFD	

4.3.1.12 Second Pass Brackish Water Reverse Osmosis System

The permeate from the rear elements of the first pass RO system is treated by second pass RO system. The rear permeate from first pass is collected in a tank and is supplied to the second pass RO trains as feedwater. The first pass rear permeate water is also used for service water and is supplied from the tank holding this water.

The reject from the second pass RO is low in TDS and other constituents and hence it is sent back to the feedwater tank of the first pass SWRO trains. The permeate from second pass RO is blended with the front permeate of first pass RO and conveyed to post treatment. Caustic soda is also added to raise the pH to enable higher rejection of boron. Antiscalant is added to the feedwater of second pass RO as this system is operated at high recovery and high pH and hence there is some scaling potential.

Details of the second pass RO system are provided in Table 4-16.

Table 4-16 Second Pass Reverse Osmosis System Details

Description	Unit	20 MGD	40 MGD
Number of RO trains	No.	5 (4 duty, 1 standby)	9 (8 duty, 1 standby)
Design permeate flow with all units online	gpm	9716	19,432
Membrane element description	-	8" diameter, 40" long	
RO recovery	%	90%	
Design flux at max permeate flow	gfd	18.9	
Active area per membrane element	ft ²	400	
Number of elements per vessel	No.	7	
Number of pressure vessels per unit	No.	66	

4.3.1.13 Reverse Osmosis Clean-in-Place (CIP) and Flushing System

A CIP system will be provided for periodic chemical cleaning of the RO membranes. A CIP will be initiated if the following occurs:

- The normalized permeate flux declines by 15%, or
- The pressure drop along the membrane (feed to concentrate) increases by 15% or higher, or
- Normalized permeate conductivity increases by 15%.

These limits may be adjusted based on the membrane manufacturer's recommendations. Cleaning of one SWRO skid may take on average 24 hours and up to 48 hours, depending on the type and degree of fouling and cleaning procedure required. Cleaning will typically occur every 3 to more than 6 months, depending on the raw water quality which can vary with seasons and also annually depending on climate variations and also on pretreatment performance during poor water quality conditions.

The major chemicals used for CIP are citric acid and surfactants with sodium hydroxide. The use of other chemicals in smaller quantities may be recommended by the membrane manufacturers as well. The major components of the CIP system are the CIP solution makeup tank, CIP pumps, neutralization basin, chemical feed systems (citric acid, caustic, and specialty chemicals), cartridge filter and associated CIP appurtenances.

Two CIP tanks will be provided, with one dedicated for acidic cleaning solutions and the other for basic cleaning solutions. Each tank will be equipped with heaters to raise the temperature of the CIP solution up to 40° C. A pair of CIP pumps (one duty and one standby), cartridge filter and associated appurtenances (piping, valves, and instruments) will be provided. The CIP pumps will be used to mix and recirculate the CIP solution.

The spent CIP waste will be neutralized in a neutralization basin using either sulfuric acid or sodium hydroxide and will be discharged by gravity to the Brine Tank and ultimately to the outfall. The tank contents will be mixed using top mounted mechanical mixers.

Design parameters for the CIP pumps are presented in Table 4-17.

Table 4-17 Clean-in-Place (CIP) System Design Parameters

Description	Unit	20 and 40 MGD
CIP Tanks		
Number of CIP tanks	No.	2 (1 acid, 1 base)
Tank useable volume, per tank	gal	35,679
Tank material	-	Fiberglass reinforced plastic (FRP)
CIP Pumps		
Number of pumps	No.	2 (1 duty, 1 standby)
Rated capacity	gpm	13,780
Rated head	ft	131
Pump type	-	Centrifugal
Drive type	-	VFD
CIP Cartridge Filters		
Design loading rate	gpm/10" eq. length	5.0
Cartridge filter micron rating	µm	5
Neutralization Tank		
Number of tanks	No.	1
Tank useable volume	gal	68901
Tank material	-	FRP or coated concrete

4.3.1.14 Reverse Osmosis Flushing System

When an RO unit is taken out of service, the RO unit must be flushed with permeate to remove the seawater from the system. If seawater is left in the membrane elements, biological growth will occur, which will result in the need for CIP cleaning shortly after returning the RO unit to service. The flush tank is designed to provide enough volume to perform flushing on all RO units. The RO flushing pumps are designed to flush one RO train at a time. The RO flushing pumps will be equipped with a VFD to allow flushing at different flow rates. Design parameters for the RO flushing system are presented in Table 4-18.

Table 4-18 Reverse Osmosis Flushing System Design Parameters

Description	Unit	20 MGD	40 MGD
RO Flushing Tank			
Tank useable volume	gal	432,568	865,230
Tank material	-	concrete tank	
RO Flushing Pumps			
Number of pumps	No.	2 (1 duty, 1 standby)	

Description	Unit	20 MGD	40 MGD
Maximum discharge flow per pump	gpm	8263	
Discharge pressure	ft	131	
Pump type	-	Centrifugal	
Drive type	-	VFD	

4.3.1.15 Post-Treatment and Disinfection

RO permeate water is often corrosive as it lacks mineral and alkalinity, and is low in pH. Post-treatment stabilization is required to condition the product water for it to be suitable for potable use as well as to protect distribution piping and plumbing systems.

Carbon dioxide will be added into the product water to increase carbonate species content in the water. After that, lime will be added to raise pH and to convert carbonate species into bicarbonate to provide a stable alkalinity level in the finished water.

Disinfection is achieved by providing the necessary CT value (disinfection concentration (mg/L) x contact time (minutes)) in the finished water tank which is partitioned to achieve appropriate residence time – the amount of time water remains in the tank to allow disinfectant to work- with necessary baffle factor. A disinfection tank's baffling factor quantifies how well it promotes "plug flow" (ideal, uniform water movement) versus "short-circuiting" (water bypassing treatment), calculated as the ratio of actual effective contact time (T_{10}) to the theoretical detention time ($T_{\text{theoretical}}$). T_{10} is the time it takes 10% of the water to exit the tank and represents the minimum contact time for disinfection while $T_{\text{theoretical}}$ is the hydraulic detention time (volume of tank divided by flow rate). Baffling factor determines the ratio of $T_{10}/T_{\text{theoretical}}$, depending on the degree of baffling provided in the tank to minimize dead zones and approach plug flow.

4.4 Description of Waste-Stream Discharge for Desalination Project

4.4.1 Waste Handling System

The waste handling system will consist of the following major components:

- DAF Solids Transfer Pump Station
- GMF Washwater Recovery Tank and Pump Station
- Thickeners Using Lamella Clarifiers
- Thickened Sludge Holding Tank
- Centrifuge for Dewatering
- Solids Disposal Pump Station

The GMF backwash water is treated in a thickener (lamella clarifiers) and sent to a thickened sludge holding tank. The sludge removed from the DAF process is also conveyed to this tank. The thickened sludge is then sent to centrifuges for dewatering.

4.4.2 Reverse Osmosis Brine Discharge

In the RO treatment process, a concentrated brine flow is generated and requires proper disposal due to its elevated amounts of dissolved salt concentrations. The brine can be generated at relatively large volumes; thus, it is important to understand the water quality (i.e., TDS) and the receiving water quality (i.e., seawater) to make ensure there is no impact due to brine disposal. Table 4-19 summarizes the TDS concentrations of seawater and RO concentrate brine, as well as the RO brine discharge volume.

Table 4-19 Summary of Brine Discharge

Description	40 MGD	Unit
Total Dissolved Solids		
Seawater (typical range)	33,000 to 38,000	mg/L
RO Concentrate Brine	63,000 to 73,000	mg/L
RO Concentrate Discharge Flow (daily average)	55.5	MGD

4.4.3 Disposal Permit Requirements

GCWA has not yet applied for a discharge permit for this desalination project. The City of Corpus Christi and Port of Corpus Christi have recently received desalination discharge permits from TCEQ that reflect similar water bodies. The Port of Corpus Christi has a 2 parts per thousand (ppt) rise in ambient salinity discharge limit that will likely be similar for GCWA.

Salinity dispersion modeling (CORMIX) and diffuser design will be developed in the next phase to demonstrate that discharge at the edge of the mixing zone will not exceed a salinity of 35 ppt or cause more than a 2 ppt rise in ambient salinity that are common benchmarks used by TCEQ, though not formal regulatory limits.

4.5 Description of One or More Alternative Technologies That Could be Used in the Proposed Desalination Plant

4.5.1 Pretreatment Alternatives

Pretreatment plays a crucial role in the seawater desalination process because it can safeguard the downstream treatment processes (i.e., RO) from potential biofoulants and suspended solids. Various pretreatment processes can be used individually, or in combination with each other. For example, DAF can be used with GMF as well as microfiltration (MF). It is helpful for utilities to have various alternatives to select from based on their specific source water quality and treatment and operational requirements. Below is a table that summarizes the various pretreatment alternatives for the DAF, GMF, and MF.

Use of MF as pretreatment upstream of SWRO is on the rise. However, majority of the seawater desalination facilities are still implementing media filtration as the filtration upstream of SWRO. The advantages of media filtration are extensive experience in hundreds of desalination plants around the world, lower capital and operating costs, and less maintenance. While the water quality from GMF is expected to be slightly lower than that from microfiltration/ultrafiltration (MF/UF), the benefits stated above outweigh the slightly higher frequencies of SWRO system cleaning events.

MF/UF provides consistently high quality water to the SWRO systems. However, many of the commonly used membranes do not have extensive experience. Further, the capital costs of MF/UF are higher than

that of conventional media filtration. Further, the energy, chemical and membrane replacement costs will be higher than media filters. The additional cost does not offset the reduced costs of cleaning the SWRO membranes. This alternative can be further evaluated in future.

5.0 Economic Analysis

WTR-TRMR-128 – Large Scale Projects

(e) In lieu of the cost information required in WTR 11-01 Paragraphs 3.B.(4) (c) and (d), Large-Scale Water Recycling Projects will be required to provide the cost information described in Paragraph 3.B.(2), below.

(2) **Economic Analysis.** For projects considered under the Large-Scale Water Recycling Program, the non-Federal project sponsor must submit the following information for the economic analysis as part of the feasibility study report in lieu of the information described in WTR 11-01 Paragraph 3.B.(5).

(a) Description of the conditions that exist in the area and provide projections of the future with, and without, the project. Emphasis in the analysis must be given to the contributions that the plan could make toward meeting the future water demand in an efficient and economically sound manner.

(b) Identification of all project-related costs for the selected water reclamation or recycling project and the alternatives identified. Costs must be provided for all planning, design, and construction activities as well as operations and maintenance costs. Cost estimates must be presented in terms of pay items, quantities, unit prices, contract costs, non-contract costs, and escalation. Cost estimates for the final analyzed alternatives shall be at a sufficient design level to conduct the comparisons required in subsection (d).

Cost estimates shall include:

(i) Pay Items – Abbreviated descriptions of work for which payments or charges to accounts are made. Pay items represent a logical and practical breakdown of the proposed work into separate and distinct classes of work.

(ii) Quantities – The quantities for pay items shall be presented by a number and a unit of measure such as pounds, cubic yard, or another unit that most appropriately represents the measurement for the particular pay item.

(iii) Unit Prices – Current unit prices shall be used in all estimates and identified.

(iv) Contract Cost – The contract cost represents the estimated cost of the contract at time of bid or award and will include allowances for design contingencies and for procurement strategies, but not construction contingencies.

(v) Non-Contract Cost – Costs associated with work or services provided in support of the project, these may include project management, investigations and data collection, construction management, environmental compliance, and archeological considerations.

(vi) Escalation – For projects that are to be developed over an extended period of time, or at some distant time in the future, estimates may account for escalation that may occur.

(c) Identification, quantification, and monetization of benefits, both direct use benefits and indirect use benefits, for the selected project and the alternatives identified. Benefits may include, but are not limited to, benefits related to water supply, recreational benefits, ecosystem benefits, water quality, energy efficiency, public health and other social benefits, and/or avoided costs.

(d) A comparison of the benefits and costs associated with the selected water reclamation or recycling project and the alternatives identified. The results of this comparison should be discounted to net present value. The alternative plan that reasonably maximizes net public benefits will be identified.

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- (ii) Discussion about the extent to which the selected project maximizes benefits must be included.
- (e) Some water reclamation, recycling or desalination project benefits will be difficult to quantify; for example, a drought tolerant water supply, reduced water importation, and other social or environmental benefits. These benefits shall be documented and described qualitatively as completely as possible. Any qualitative benefits will be considered as part of the justification for a water reclamation, recycling or desalination project in conjunction with the comparison of project costs described above.
- (f) A summary, in one table, of the net present value of monetized benefits and costs, and the listing and ranking of the benefits described qualitatively.

5.1 Existing and Projected Economic Conditions

- (a) Description of the conditions that exist in the area and provide projections of the future with, and without, the project. Emphasis in the analysis must be given to the contributions that the plan could make toward meeting the future water demand in an efficient and economically sound manner.

The State of Texas is growing, both in municipal population and in industrial demands, particularly in the metropolitan areas. The need for water is integral for that growth. Without a reliable water supply, economic growth in the State cannot happen. The State of Texas is now at a point where inexpensive reliable water options are generally not available. The development of new sources of water does cost money, but the cost of not developing these new sources of water may be greater. According to water demand projections developed as part of the 2026 regional water planning process in Texas, between 2030 and 2050, municipal and industrial demands in Brazoria County, Fort Bend County, and Galveston County, all served by GCWA, will increase by just over 80 MGD. By 2080, an additional increase of 100 MGD of municipal and industrial demand will occur. These projected demands will not be able to be met through existing supplies. Identified needs for water to meet future demands increases from approximately 62 MGD in 2030 to approximately 110 MGD in 2050. By 2080, the identified water need to meet future water demands increases further to 178 MGD. In addition, during times of drought, interruptible water for agriculture may be cut off, as it was in 2011 which resulted in no second crop. This impacts both the agricultural industry in the region as well as food resilience. As climate change continues to occur, these impacts may increase without a new supply of reliable water.

In support of the 2021 Region H Water Plan, the TWDB prepared a report called *Socioeconomic Impacts of Projected Water Shortages for the Region H Regional Water Planning Area*. The purpose of the report is to help evaluate the social and economic impacts of not meeting identified water needs in a given year under drought of record conditions. For this feasibility study, the impacts of not meeting future potential GCWA customer municipal water needs in Brazoria, Fort Bend, and Galveston counties were considered. The impacts were updated to 2025 dollars, using average annual inflation in the Houston area from 2018 to 2025 (<https://www.in2013dollars.com/Houston-Texas/price-inflation/2018-to-2025?amount=1>). Average GCWA customer municipal income losses per ac-ft of water need in 2025 dollars for the 2040 decade for Brazoria, Fort Bend, and Galveston counties are \$14,403. Other types of losses analyzed include GCWA customer municipal tax losses and municipal utility losses, which increase the overall cost per ac-ft of need. GCWA customer industrial (manufacturing) income and tax losses are also provided in the above-mentioned study by TWDB, which would increase the benefits of the project by \$13,347 per ac-

ft of water need. Job losses are also identified as an impact for both GCWA customer municipalities and industry.

If the desalination project were not to be implemented, it is likely that municipal and industrial growth in the area would be restricted due to limitations on future supplies from other potential sources, and drought impacts would have greater effects. In addition, agricultural demands may continue to be unmet during times of drought. If other less reliable sources of water were used as a supply instead of the desalination project, those sources would be less available during a drought of record and supplies would be reduced, causing needs to not be met.

5.2 Alternatives' Cost Comparison

(b) Identification of all project-related costs for the selected water reclamation or recycling project and the alternatives identified. Costs must be provided for all planning, design, and construction activities as well as operations and maintenance costs. Cost estimates must be presented in terms of pay items, quantities, unit prices, contract costs, non-contract costs, and escalation. Cost estimates for the final analyzed alternatives shall be at a sufficient design level to conduct the comparisons required in subsection (d).

Cost estimates for all the alternatives are included in the following sections. Because the desalination projects in this study are considered large-scale projects, the cost estimates include pay items, quantities, unit prices, contract costs, non-contract costs, and escalation to the year 2033 of 13.1%, using data from Global Insight. Pay item costs for the two desalination projects were developed specifically for this feasibility study using a Class 5 capital expenditures, while the pay item costs for the other alternatives were taken from previous project cost development for other studies.

- Contract costs represent the estimated cost of the contract at time of bid or award and will include allowances for design contingencies and for procurement strategies, but not construction contingencies.
- Non-contract costs include costs for planning and design costs associated with each project, including work or services provided in support of the project, these may include project management, investigations and data collection, construction management, environmental compliance, and archeological considerations.
- Direct costs are project-specific expenses for construction, including materials, labor wages, equipment rentals, and subcontractor fees easily traceable to the physical building process.
- Indirect costs include engineering and procurement, costs of shipping materials, spares, vendor rep time and travel, temporary facilities, construction management, and startup/commissioning costs.
- Contingency is also included at this level of cost estimation.
- Annual costs include debt service and operations and maintenance, with an assumed energy cost of \$0.10/kWh.

5.2.1 No Action (Baseline Condition) Cost Estimate

This alternative has \$0 cost associated with it but provides no water supply and no benefits.

5.2.2 Reuse Cost Estimate

Table 5-1 provides the cost estimate for the Reuse alternative, providing 6.5 MGD of water supply from League City's WWTP, such as the Southwest Water Reclamation Facility, and discharging it into GCWA's G-Canal. Total project cost is \$13.4 million, while annual costs are \$1.3 million.

Table 5-1 Cost Estimate Summary for the Reuse Alternative

Budget Item	Unit of Measure	Quantity	Unit Cost (\$)	Total (\$)
20" Pipeline	linear feet	13,000	317	4,121,000
Pump Station with Power Connection	ea	1	2,740,900	2,740,900
Backup Generator	ea	1	55,000	55,000
Direct Cost Subtotal				6,916,900
Indirect Contract Costs				1,175,873
Indirect Non-Contract Costs				1,590,887
Indirect Cost Subtotal				2,766,760
Direct Plus Indirect Cost Subtotal				9,683,660
Escalation				1,268,559
Contract Cost Subtotal				9,152,926
Non-Contract Cost Subtotal				1,799,293
Contingency				2,420,915
Total Project Cost				13,373,134
Annual Debt Service (3.5% for 20 yrs)				766,233
Annual O&M				275,429
Annual Purchase of Water (\$33/ac-ft)				240,240
Total Annual Costs (With Escalation)				1,281,902

5.2.3 Groundwater Wellfield(s) Cost Estimate

Table 5-2 provides the cost estimate for the Groundwater Wellfield(s) alternative, providing up to 12MGD at the Alta Loma wellfield rehabilitation and 20 MGD at a new wellfield in Brazoria County. Total project cost is \$58.3 million, while annual costs are \$3.8 million.

Table 5-2 Cost Estimate Summary for the Groundwater Wellfield(s) Alternative

Budget Item	Unit of Measure	Quantity	Unit Cost (\$)	Total (\$)
Well Rehabilitation (Alta Loma)	ea	9	79,830	718,500
Pipeline (Alta Loma)	linear feet	57,335	263	15,096,100
Wellfield (Brazoria County)	ea	1	14,332,679	14,332,700

Budget Item	Unit of Measure	Quantity	Unit Cost (\$)	Total (\$)
Direct Cost Subtotal				30,147,300
Indirect Contract Costs				5,125,041
Indirect Non-Contract Costs				6,933,879
Indirect Cost Subtotal				12,058,920
Direct Plus Indirect Cost Subtotal				42,206,220
Escalation				5,529,015
Contract Cost Subtotal				39,893,018
Non-Contract Cost Subtotal				7,842,217
Contingency				10,551,555
Total Project Cost				58,286,790
Annual Debt Service (3.5% for 20 yrs)				3,358,703
Annual O&M				477,352
Total Annual Costs (With Escalation)				3,836,055

5.2.4 Purchase Potable Water from a Third Party Cost Estimate

For this feasibility study, it is assumed that up to 5 MGD of potable water would be available for purchase by 2035. Estimated pricing for new potable water sources in the study area is \$2,900 per ac-ft, so for 5 MGD, annual costs would be \$18.4 million with 13.1% escalation. No capital costs would be needed as any connection infrastructure is assumed to be included in the annual rate.

5.2.5 20 MGD Seawater Desalination Plant Cost Estimate

Table 5-3 provides the cost estimate for the 20 MGD Seawater Desalination Plant alternative, providing up to 20 MGD of water supply from the southwestern Galveston County site. Total project cost is \$721.3 million, while annual costs are \$69.5 million.

Table 5-3 Cost Estimate Summary for the 20 MGD Seawater Desalination Plant Alternative

Budget Item	Unit of Measure	Quantity	Unit Cost (\$)	Total (\$)
Dissolved Air Flotation (DAF)	LS	1	14,578,383	14,578,383
Gravity Media Filtration (GMF)	LS	1	30,885,774	30,885,774
Chemical Area	LS	1	10,105,657	10,105,657
SWRO Process	LS	1	78,392,586	78,392,586
Clean-in-Place (CIP), Flushing	LS	1	3,438,333	3,438,333
Post Treatment	LS	1	3,591,974	3,591,974
Desalinated Water Tank	LS	1	5,358,724	5,358,724
Brine and Wastewater Collection Tank	LS	1	1,326,093	1,326,093

Budget Item	Unit of Measure	Quantity	Unit Cost (\$)	Total (\$)
Wastewater Equalization Tank	LS	1	797,071	797,071
Lamella Clarifier	LS	1	4,450,620	4,450,620
Sludge Holding Tank (not used)	LS	1	244,207	244,207
Thickening Centrifuges	LS	1	2,684,314	2,684,314
Desal Plant Substation	LS	1	0	0
Desal Plant Electrical Room	LS	1	15,708,013	15,708,013
Site Electrical	LS	1	6,180,000	6,180,000
Plant Control System	LS	1	5,803,500	5,803,500
Control and Administration Room	LS	1	4,620,000	4,620,000
Site Establishment	LS	1	0	0
Site Works	LS	1	4,100,000	4,100,000
Process Yard Pipe	LS	1	13,500,000	13,500,000
Utility Yard Pipe	LS	1	2,800,000	2,800,000
Intake Structure	LS	1	10,000,000	10,000,000
Intake Canal	LS	1	26,911,215	26,911,215
Screening and Wetwell Structure	LS	1	12,839,878	12,839,878
Outfall Pipeline (Onshore)	LS	1	62,413,825	62,413,825
Outfall Pipeline and Diffusers (Offshore)	LS	1	14,388,000	14,388,000
Delivery Point	LS	1	34,051,432	34,051,432
Electrical Transmission Line	LS	1	1,500,000	1,500,000
Electrical Substation	LS	1	2,500,000	2,500,000
Direct Cost Subtotal				369,075,902
Indirect Contract Costs				63,422,903
Indirect Non-Contract Costs				85,807,457
Indirect Cost Subtotal				149,230,361
Direct Plus Indirect Cost Subtotal				518,306,262
Escalation				68,422,120
Contract Cost Subtotal				493,680,149
Non-Contract Cost Subtotal				97,048,234
Contingency				130,576,566
Total Project Cost				721,304,948
Annual Debt Service (3.5% for 20 yrs)				41,246,000

Budget Item	Unit of Measure	Quantity	Unit Cost (\$)	Total (\$)
Annual O&M				28,250,000
Total Annual Costs (With Escalation)				69,496,000
LS – Lump Sum				

5.2.6 40 MGD Seawater Desalination Plant Cost Estimate

Table 5-4 provides the cost estimate for the 40 MGD Seawater Desalination Plant alternative, providing up to 40 MGD of water supply from the southwestern Galveston County site. Total project cost is \$991.6 million, while annual costs are \$102.3 million.

Table 5-4 Cost Estimate Summary for the 40 MGD Seawater Desalination Plant Alternative

Budget Item	Unit of Measure	Quantity	Unit Cost (\$)	Total (\$)
Dissolved Air Flotation (DAF)	LS	1	29,154,604	29,154,604
Gravity Media Filtration (GMF)	LS	1	52,573,490	52,573,490
Chemical Area	LS	1	13,007,360	13,007,360
SWRO Process	LS	1	135,131,551	135,131,551
Clean-in-Place (CIP), Flushing	LS	1	3,438,333	3,438,333
Post Treatment	LS	1	7,183,948	7,183,948
Desalinated Water Tank	LS	1	10,717,448	10,717,448
Brine and Wastewater Collection Tank	LS	1	1,326,093	1,326,093
Wastewater Equalization Tank	LS	1	797,071	797,071
Lamella Clarifier	LS	1	8,901,240	8,901,240
Sludge Holding Tank (not used)	LS	1	488,414	488,414
Thickening Centrifuges	LS	1	5,368,629	5,368,629
Desal Plant Substation	LS	1	0	0
Desal Plant Electrical Room	LS	1	31,416,027	31,416,027
Site Electrical	LS	1	10,300,000	10,300,000
Plant Control System	LS	1	10,446,300	10,446,300
Control and Administration Room	LS	1	4,620,000	4,620,000
Site Establishment	LS	1	0	0
Site Works	LS	1	4,920,000	4,920,000
Process Yard Pipe	LS	1	16,200,000	16,200,000
Utility Yard Pipe	LS	1	3,360,000	3,360,000
Intake Structure	LS	1	10,000,000	10,000,000
Intake Canal	LS	1	26,911,215	26,911,215

Budget Item	Unit of Measure	Quantity	Unit Cost (\$)	Total (\$)
Screening and Wetwell Structure	LS	1	12,839,878	12,839,878
Outfall Pipeline (Onshore)	LS	1	62,413,825	62,413,825
Outfall Pipeline and Diffusers (Offshore)	LS	1	14,388,000	14,388,000
Delivery Point	LS	1	34,051,432	34,051,432
Electrical Transmission Line	LS	1	2,600,000	2,600,000
Electrical Substation	LS	1	4,400,000	4,400,000
Direct Cost Subtotal				512,861,160
Indirect Contract Costs				87,186,397
Indirect Non-Contract Costs				117,958,067
Indirect Cost Subtotal				205,144,464
Direct Plus Indirect Cost Subtotal				718,005,624
Escalation				94,058,737
Contract Cost Subtotal				678,653,787
Non-Contract Cost Subtotal				133,410,574
Contingency				179,501,406
Total Project Cost				991,565,767
Annual Debt Service (3.5% for 20 yrs)				57,138,000
Annual O&M				45,200,000
Total Annual Costs (With Escalation)				102,338,000

5.3 Identification, Quantification and Monetization of Benefits

(c) Identification, quantification, and monetization of benefits, both direct use benefits and indirect use benefits, for the selected project and the alternatives identified. Benefits may include, but are not limited to, benefits related to water supply, recreational benefits, ecosystem benefits, water quality, energy efficiency, public health and other social benefits, and/or avoided costs.

Benefits were evaluated using the *Socioeconomic Impacts of Projected Water Shortages for the Region H Regional Water Planning Area* report by the TWDB as prepared for the 2021 Region H Water Plan. The report is included as a reference in Appendix E. The benefits identified in the report are essentially avoided costs and impacts that will occur if water needs are met.

The benefits that were identified and quantified for this feasibility study included avoided municipal income losses, avoided municipal tax losses, avoided municipal utility losses, as well as avoided municipal job losses, all for existing and potential future municipal customers of GCWA. Industrial (manufacturing) losses are also identified in the TWDB report but are not included for this feasibility study for conservative reasons as many industrial demands by GCWA customers may not require treated water, but rather raw water.

To monetize the benefits, municipal income, tax, and utility losses were pulled from the TWDB report for the three county area served by GCWA: Brazoria, Fort Bend, and Galveston counties. The losses were divided by the municipal needs in the three counties to develop a cost per ac-ft/yr of need for each of the benefit categories in 2018 dollars. Average inflation between 2018 and 2025 for the Houston area (2.81% per year) was then applied to calculate the cost per ac-ft/yr of need in 2025 dollars.

Job loss data was also pulled from the TWDB report and divided by the municipal needs in the three counties to calculate a job loss per ac-ft/yr of need. Job losses are estimated based on the economic impact of the water shortage. Municipal job loss is assumed to be from water-intensive commercial and institutional users included within the municipal water use category. This item was not monetized but is included as a separate qualitative benefit.

Each benefit category item per ac-ft/yr of need was then multiplied by the volume of water each project alternative would provide to calculate either the avoided dollars lost or the avoided jobs lost that would be provided by the project supplying the needed water. Benefits are quantified and summarized for each alternative in Table 5-5 in Subsection 5.4.2.

5.4 Cost-Benefit Comparison

(d) A comparison of the benefits and costs associated with the selected water reclamation or recycling project and the alternatives identified. The results of this comparison should be discounted to net present value. The alternative plan that reasonably maximizes net public benefits will be identified.

(i) This comparison must result in a benefit cost ratio that is provided for the selected project and the alternatives.

A cost-benefit comparison for the 20 MGD seawater desalination plant and the alternatives was performed, with costs being brought back to present value. Both monetized benefits and qualitative benefits were considered for all alternatives and are quantified and summarized for each alternative in Table 5-5 in Subsection 5.4.2.

5.4.1 Qualitative Benefits

(e) Some water reclamation, recycling or desalination project benefits will be difficult to quantify; for example, a drought tolerant water supply, reduced water importation, and other social or environmental benefits. These benefits shall be documented and described qualitatively as completely as possible. Any qualitative benefits will be considered as part of the justification for a water reclamation, recycling or desalination project in conjunction with the comparison of project costs described above.

As described in this feasibility study, the main qualitative benefit of the seawater desalination project is that it is a droughtproof source of water that supports resiliency for GCWA's customers and potentially the region by allowing operational flexibility in the Brazos River Basin. This seawater desalination project would not just serve local existing and future demands but could increase the water supply regionally.

The Galveston Canal was built in the late 1940s to bring surface water into Galveston County (Texas City) to combat land subsidence, or the gradual sinking of the Earth's surface due to subsurface movement, caused by the expanded development of the groundwater resources in the area. The canal was purchased by GCWA in 1971. An additional qualitative benefit of the seawater desalination project is the

ability to limit pressure on the local aquifer which reduces land subsidence. Land subsidence, particularly in Harris County, Galveston County and surrounding counties area, has contributed to increased flooding, as well as damage to roads and infrastructure. The issue of groundwater use and land subsidence is a major reason why groundwater is not a viable source of long-term reliable water supply for GCWA. Limiting future land subsidence will positively impact the population within the GCWA area.

As mentioned above, avoided job losses is another qualitative benefit that each of the alternatives (except No Action) have the ability to provide. Avoided job losses were determined using the *Socioeconomic Impacts of Projected Water Shortages for the Region H Regional Water Planning Area* report by the TWDB as prepared for the 2021 Region H Water Plan.

5.4.2 Cost-Benefit Summary

(f) A summary, in one table, of the net present value of monetized benefits and costs, and the listing and ranking of the benefits described qualitatively.

Table 5-5 provides a summary of the monetized costs and benefits based on net present value (rather than escalated), the cost-benefit ratio, and a list of qualitative benefits for each alternative. All of the alternatives, except for No Action (Baseline Condition), have a cost-benefit ratio greater than 1, which means the benefits are greater than the costs. The monetized benefits were calculated using the *Socioeconomic Impacts of Projected Water Shortages for the Region H Regional Water Planning Area* report by the TWDB as prepared for the 2021 Region H Water Plan and the methodology discussed in Section 5.3.

Groundwater has the highest cost-benefit ratio, but has limited qualitative benefits and would potentially lead to greater subsidence in the area, causing additional flooding and damage to roads and infrastructure. There is also a question of whether the supply would be available long-term, as the groundwater conservation districts (GCDs) in the area have the ability to limit future use beyond current restrictions.

Reuse has the next highest cost-benefit ratio and provides additional qualitative benefits that support some of the goals and objectives of the GCWA, but the volume of water that is potentially known to be available at the time of this study is limited to 6.5 MGD, which will not meet the anticipated future water demands for the GCWA area. Future efforts may be able to identify additionally available reclaimed water beyond the 6.5 MGD.

Purchasing potable water from a third party has the lowest cost-benefit ratio, but includes benefits that would reduce future dependence on the aquifer and would appear to be a droughtproof supply. One concern here is that it is unlikely that there would be enough of a new potable water supply for purchase that would meet GCWA's future needs.

While the cost-benefit ratios for the two seawater desalination plant alternatives (20 MGD and 40 MGD) are significantly lower than some of the others, they are still greater than 1 and thus supply greater benefit than cost. They also provide several qualitative benefits, including being a droughtproof water supply, reducing dependence on the aquifer, avoiding thousands of job losses, and supporting the GCWA's goal and objective by being a resilient supply for local customers and for the region. The 20 MGD seawater desalination plant alternative has a slightly lower cost-benefit ratio (6.9) than for the 40 MGD project (9.4) because the intake, discharge, and delivery system are sized for a full buildout of 40 MGD, allowing for a plant expansion in the future to size the plant to meet demands as they grow. The benefit

of the 20 MGD project is that the plant would not be oversized at an early stage, and thus partially unused, and would reduce the costs for the plant expansion by not requiring additional intake, discharge, and delivery infrastructure.

Therefore, the 20 MGD Seawater Desalination Plant alternative appears to maximize the benefits of all of the alternatives. Table 5-5 summarizes the cost and benefits for all alternatives.

Table 5-5 Summary of Costs and Benefits for all Alternatives

Alternative	Annual Costs ¹ (\$)	Annual Benefits ² (\$)	Cost-Benefit Ratio	Qualitative Benefits
No Action (Baseline)	0	0	N/A	None
Reuse (6.5 MGD)	\$1,056,000	\$138,071,000	131	• Droughtproof water supply • Reduces dependence on the aquifer, subsidence-neutral • 1,300 avoided job losses
Groundwater (32 MGD)	\$3,392,000	\$679,732,000	200	• May be reliable during drought • 6,400 avoided job losses
Purchase Potable Water (5 MGD)	\$16,240,000	\$106,208,000	6.5	• Droughtproof water supply, if available • Reduces dependence on the aquifer, subsidence-neutral • 1,000 avoided job losses
20 MGD Seawater Desalination	\$61,469,000	\$424,833,000	6.9	• Droughtproof water supply • Reduces dependence on the aquifer, subsidence-neutral • Supports resiliency in the region • Can expand to meet future needs as demands increase • 4,000 avoided job losses
40 MGD Seawater Desalination	\$90,520,000	\$849,666,000	9.4	• Droughtproof water supply • Reduces dependence on the aquifer, subsidence-neutral • Supports resiliency in the region • 8,000 avoided job losses
¹ Annual Cost estimation is shown in Section 5.2 and brought to present day value. ² Annual Benefits calculation methodology is discussed in Section 5.3.				

6.0 Selection of Desalination Project

6.1 Justification of Selected Project

(6) Selection of the Proposed Water Reclamation, Recycling or Desalination Project.

(a) Provide a justification of why the proposed water reclamation, recycling or desalination project is the selected alternative in terms of meeting objectives, demands, needs, cost effectiveness, and other criteria important to the decision.

The proposed GCWA 20 MGD Seawater Desalination project is the selected alternative for several reasons. GCWA's mission is to deliver a reliable, cost-effective quantity and quality of water to customers in the Texas Gulf Coast region. GCWA is seeking to ensure a droughtproof and local water supply portfolio that contributes efficiently to the region's resilience against prolonged droughts and supports future growth. Seawater desalination would both reduce the need for groundwater along the coast as well as provide a source of water locally.

Between 2030 and 2050, municipal and industrial demands in Brazoria, Fort Bend, and Galveston counties will increase by just over 80 MGD. Because these three counties are within GCWA's area, GCWA should plan to meet a large portion of this increase. Being on the Gulf Coast with a nearly limitless supply of seawater, close to Galveston Bay which has a nearly limitless supply of seawater, a seawater desalination plant makes the most sense with respect to responsibly managing the other water resources in the State and providing alternative sources for areas of demand that do not have seawater resources nearby.

While some of the other alternatives have higher cost-benefit ratios, each one does not meet certain criteria that are within the goals and objectives for GCWA. Reuse does not supply a sufficient volume of water and groundwater production has the ability to be cut back by the GCDs and can lead to additional subsidence in the region. Purchasing potable water from a third party has a lower cost-benefit ratio than either of the seawater desalination plant options.

The 20 MGD seawater desalination plant alternative has a slightly lower cost-benefit ratio (6.9) than for the 40 MGD project (9.4) because the intake, discharge, and delivery system are sized for a full buildout of 40 MGD, allowing for a plant expansion in the future to size the plant to meet demands as they grow. The benefit of the 20 MGD project is that the plant would grow as demands grow and not be oversized at an early stage, and thus partially unused, and would reduce the costs for the plant expansion by not requiring additional intake, discharge, and delivery infrastructure.

6.2 Selected Project Analysis

(b) Provide an analysis and, if applicable, an affirmative statement of whether the proposed water reclamation, recycling or desalination project would address the following:

- (i) reduction, postponement, or elimination of development of new or expanded water supplies;
- (ii) reduction or elimination of the use of existing diversions from natural watercourses, or withdrawals from aquifers;
- (iii) reduction of demand on existing Federal water supply facilities; and
- (iv) reduction, postponement, or elimination of new or expanded wastewater facilities.

The proposed GCWA 20 MGD Seawater Desalination Project offers a sustainable and drought-resilient source of potable water that directly supports the region's long-term water supply reliability. The project is designed to supplement existing supplies while reducing strain on freshwater sources, especially during periods of high demand or low surface water availability. The following analysis addresses the criteria set forth for water reclamation and desalination project benefits:

(i) Reduction, postponement, or elimination of development of new or expanded water supplies:

By introducing a new, independent source of supply from West Bay, the project offsets the need to develop additional surface or groundwater sources. It is not expected that other sources of water, such as groundwater or wastewater reused could satisfy future demands.

(ii) Reduction or elimination of the use of existing diversions from natural watercourses or withdrawals from aquifers:

Desalinated seawater could directly reduce GCWA's dependence on existing freshwater diversions, particularly from the Brazos River system. This contributes to more sustainable basin-wide water management and enhances regional drought resilience.

(iii) Reduction of demand on existing Federal water supply facilities:

GCWA currently does not rely heavily on federal water supply infrastructure; however, the introduction of a new, locally managed water source further ensures that no additional demand will be placed on existing federally developed resources, such as upstream reservoirs or inter-basin transfers.

(iv) Reduction, postponement, or elimination of new or expanded wastewater facilities:

The desalination project is not expected to significantly impact regional wastewater volumes, but by reducing peak demands on existing water sources, it may defer the need for expanded treatment capacity in some receiving systems. Additionally, the use of advanced treatment processes and brine discharge management ensures that no new municipal wastewater facilities will be required to support the desalination operations.

7.0 Environmental Consideration and Potential Effects

(7) Environmental Consideration and Potential Effects. The review of a water reclamation, recycling or desalination feasibility study report does not require National Environmental Policy Act (NEPA) compliance. The Department of the Interior categorical exclusion 1.11 “Activities which are educational, informational, advisory, or consultative to other agencies, public and private entities, visitors, individuals or the general public” applies to Reclamation’s consultative review, and preparation of the water reclamation, recycling or desalination feasibility study reports.

- (a) The water reclamation, recycling or desalination feasibility study report must include sufficient information on the proposed water recycling or desalination project to allow Reclamation to assess the potential measures and costs that will be necessary to comply with NEPA, and any other applicable Federal law. Accordingly, the following information is required.
- (i) Discussion whether, and to what extent, the proposed water reclamation, recycling or desalination project will have potentially significant impacts on endangered or threatened species, public health or safety, natural resources, regulated waters of the United States, or cultural resources.
 - (ii) Discussion whether, and to what extent, the project will have potentially significant environmental effects, or will involve unique or undefined environmental risks.
 - (iii) Description of the status of required Federal, state, tribal, and/or local environmental compliance measures for the proposed water reclamation, recycling or desalination project, including copies of any documents that have been prepared, or results of any relevant studies.
 - (iv) Any other information available to the study lead that would assist with assessing the measures that will be necessary to comply with NEPA, and other applicable Federal, state or local environmental laws such as the Endangered Species Act or the Clean Water Act.
 - (v) Discussion of how the proposed water reclamation, recycling or desalination project will affect water supply and water quality from the perspective of a regional, watershed, aquifer, or river basin condition.
 - (vi) Discussion of the extent to which the public was involved in the feasibility study, and a summary of comments received, if any.
 - (vii) Description of the potential effects the project will have on historic properties. Discussion must include potential mitigation measures, the potential for adaptive reuse of facilities, an analysis of historic preservation costs, and the potential for heritage education, if necessary.

7.1 The Water Desalination Feasibility Study Compliance with National Environmental Policy Act Assessment

An environmental review was performed to support this Feasibility Study (refer to Appendix F). The environmental initial review identified potential significant impacts on endangered and threatened species at both federal and state levels. This environmental review provides the results to identify baseline conditions, potential environmental constraints, and associated regulatory requirements for GCWA’s proposed Seawater Desalination Plant.

The project involves the design and construction of a Seawater Desalination Plant that would be constructed in Southwestern Galveston County, although a specific site has not yet been chosen. Additional details on project siting are included in Appendix A.

7.1.1 Waters of the United States, Including Wetlands

The National Wetlands Inventory (NWI) indicates approximately 7.4 acres of estuarine and marine wetlands, freshwater emergent wetlands, freshwater forested/shrub wetlands, and freshwater ponds occur within the project limits. Field investigations would need to be conducted to evaluate and delineate these NWI features. It is anticipated that the project could require authorization under a Standard Individual Permit under Section 404 of the Clean Water Act (CWA). The full extent of impacts to potential waters of the United States, including wetlands and special aquatic sites would need to be determined upon completion of field investigations.

7.1.2 Threatened and Endangered Species

A review of the US Fish and Wildlife Service (USFWS) Information for Planning and Consultation Official Species List and National Marine Fisheries Service (NMFS) Endangered Species Act (ESA) Section 7 Mapper concluded that while no designated critical habitat for federally listed species occurs within the proposed project limits, proposed critical habitat for the green sea turtle occurs within the tidal waters in the proposed project limits. Project components were sited to avoid mapped seagrass beds within Galveston Bay, which represent primary foraging habitat for green sea turtles, thereby reducing the likelihood of impacts to proposed critical habitat.

Based on desktop review of federally threatened or endangered species in Galveston County and the proposed project vicinity, potential habitat is indicated for seven bird species; three fish species; one insect species that is proposed for federal listing; eight mammal species and one mammal species that is proposed for federal listing; and six reptile species and one reptile species that is proposed for federal listing (Table 7-1). Federally listed species and their habitats are protected under the Endangered Species Act of 1973, as amended. Section 7 consultation with the USFWS and NMFS is anticipated to be required for the proposed project.

Table 7-1 Federal Threatened and Endangered Species Occurring in Galveston County, Texas

Federal Threatened and Endangered Species Occurring in Galveston County, Texas			
Taxon	Common Name	Scientific Name	Federal Status
Birds	Attwater's Greater Prairie-chicken	<i>Tympanuchus cupido attwateri</i>	Endangered
	Eastern Black Rail	<i>Laterallus jamaicensis ssp. jamaicensis</i>	Threatened
	Eskimo Curlew	<i>Numenius borealis</i>	Endangered
	Piping Plover	<i>Charadrius melodus</i>	Threatened
	Rufa Red Knot	<i>Calidris canutus rufa</i>	Threatened
	Whooping Crane	<i>Grus americana</i>	Endangered
	Yellow-billed Cuckoo	<i>Coccyzus americanus</i>	Threatened
Fishes	Giant Manta Ray	<i>Mobula birostris</i>	Threatened
	Oceanic Whitetip Shark	<i>Carcharhinus longimanus</i>	Threatened
	Smalltooth Sawfish	<i>Pristis pectinata</i>	Endangered
Insects	Monarch Butterfly	<i>Danaus plexippus</i>	Proposed Threatened
Mammals	Blue Whale	<i>Balaenoptera musculus</i>	Endangered
	Finback Whale	<i>Balaenoptera physalus</i>	Endangered
	Humpback Whale	<i>Megaptera novaeangliae</i>	Endangered
	North Atlantic Right Whale	<i>Eubalaena glacialis</i>	Endangered
	Rice's Whale	<i>Balaenoptera ricei</i>	Endangered
	Sei Whale	<i>Balaenoptera borealis</i>	Endangered
	Sperm Whale	<i>Physeter macrocephalus</i>	Endangered
	Tricolored Bat	<i>Perimyotis subflavus</i>	Proposed Endangered
	West Indian Manatee	<i>Trichechus manatus</i>	Threatened
Reptiles	Alligator Snapping Turtle	<i>Macrochelys temminckii</i>	Proposed Threatened
	American Alligator	<i>Alligator mississippiensis</i>	Threatened – similarity of appearance
	Atlantic Hawksbill Sea Turtle	<i>Eretmochelys imbricata</i>	Endangered
	Green Sea Turtle	<i>Chelonia mydas</i>	Threatened
	Kemp's Ridley Sea Turtle	<i>Lepidochelys kempii</i>	Endangered
	Leatherback Sea Turtle	<i>Dermochelys coriacea</i>	Endangered
	Loggerhead Sea Turtle	<i>Caretta caretta</i>	Threatened

In addition to the federally listed species, potential habitat for 20 state-listed threatened or endangered species occurs within or adjacent to the proposed project limits, as follows:

- Five birds: Reddish Egret (*Egretta rufescens*), Swallow-tailed kite (*Elanoides forficatus*), White-faced Ibis (*Plegadis chihi*), White-tailed Hawk (*Buteo albicaudatus*), and Wood Stork (*Mycteria americana*);
- Two fish: Great Hammerhead (*Sphyrna mokarran*) and Shortfin Mako Shark (*Isurus oxyrinchus*);
- 11 mammals: Atlantic Spotted Dolphin (*Stenella frontalis*), Bryde's Whale (*Balaenoptera edeni brydei*), Cuvier's Beaked Whale (*Ziphius cavirostris*), Dwarf Sperm Whale (*Kogia simus*), False Killer Whale (*Pseudorca crassidens*), Gervais' Beaked Whale (*Mesoplodon europaeus*), Killer Whale (*Orcinus orca*), Pygmy Killer Whale (*Feresa attenuata*), Rafinesque's Big-eared Bat (*Corynorhinus rafinesquii*), Roughtoothed Dolphin (*Steno bredanensis*), and Short-Finned Pilot Whale (*Globicephala macrorhynchus*);
- One reptile: Texas Horned Lizard (*Phrynosoma cornutum*); and
- One plant: Houston daisy (*Rayjacksonia aurea*).

State-listed species have limited regulatory protection. While these species cannot be taken, collected, held, or possessed without a permit, their habitat is afforded no regulatory protection, except on tracts managed by state, federal, or private interests for conservation purposes. Best management practices (BMPs) would be incorporated into the design of the proposed project to minimize impacts to these species.

Due to the presence of habitat for marine mammals in the proposed project area, provisions of the Marine Mammal Protection Act (MMPA); enacted on October 21, 1972, and amended in 1994, will apply. The MMPA authorized the USFWS to implement the act for the conservation and management of manatees and NMFS is authorized with the conservation and management of cetaceans.

7.1.3 Essential Fish Habitat

A review of information obtained from NMFS Essential Fish Habitat (EFH) GIS data inventory (2025) concludes that four Fishery Management Unit EFH designations exist in the vicinity of the proposed project. No designated Habitat Areas of Particular Concern exist in the vicinity of the proposed project. An EFH Assessment would need to be prepared for the proposed project and coordination with NMFS would be required.

7.1.4 Coastal Zone Management and Coastal Barrier Resources

Several coastal natural resource areas occur within the vicinity of the proposed project limits and would potentially be impacted by the construction of the proposed project. A consistency determination would be required to maintain compliance with the Texas Coastal Management Program (CMP). This determination would be included in the Section 404 USACE permitting process.

The proposed project is located within Galveston County but is not located within a designated Coastal Barrier Resources Act (CBRA) map unit; therefore, CBRA coordination with USFWS would not be required.

7.1.5 Cultural Resources

Based on the review of available cultural resources information for the project limits and surrounding areas, as well as the results of previous field investigations, the proposed project has moderate to high potential to impact shallowly and deeply buried cultural materials. Due to the alluvial formations

underlying the project limits, and the proximity to coastal wetlands and marshes, there is sufficient evidence that buried, intact archeological deposits could occur within the project limits. Coordination with the Texas Historical Commission (THC) would be required to determine the extent to which archeological field investigations would be needed for the proposed project prior to construction.

7.1.6 Hazardous Materials Screen

Based on review of available information from the Texas Railroad Commission, the proposed project lies within the Greens Lake well field, and active and abandoned oil and gas wells are common throughout the project area and along the proposed routes of the intake and discharge lines. In addition, a former TEPPCO Well Site (Texas No. 3) is located approximately half a mile to the east of the proposed intake line. The site is part of the Railroad Commission's Operator Cleanup Program (No. 2214) due to contaminated materials in the reserve pits. The Railroad Commission indicates the status of the remediation as closed; however, a more in-depth review is warranted to determine the potential for contaminated soils and groundwater to be encountered during construction.

7.1.7 Socioeconomic Conditions

The proposed GCWA Regional Seawater Desalination Project is in southwestern Galveston County. Although the plant site lies several miles southwest of Texas City, the project will influence a broader regional population. This includes communities near the site, as well as Texas City and La Marque, where GCWA maintains some operational presence and where some of the area's workforce resides. The majority of the GCWA staff comes from the broader region of South Houston in Brazoria and Galveston counties. The following sections summarize key socioeconomic indicators for the surrounding communities.

Table 7-2 provides a consolidated profile for the five communities most relevant to the project: Texas City, La Marque, Hitchcock, Santa Fe, and Bayou Vista. This is also shown on Figure 7-1.

Table 7-2 Regional Socioeconomic Summary (American Community Survey 2023 / 2024)

Community	Population	Median HH Income	Poverty Rate	Median Home Value	Median Age, yrs	Home Ownership	Key Characteristics
Texas City	~54,159	\$65,447	~16.5%	~\$190–205k	35	~54%	Largest labor base; industrial; GCWA HQ
La Marque	~18,000	~\$62,000	~17–18%	~\$175k	36	~67%	Residential + industrial commuting population
Hitchcock	~7,480	\$77,713	17.4%	~\$159,500	37	74.2%	Closest to the desal site; working-class/mid-skill
Santa Fe	~12,735	~\$80–85k	~10–12%	~\$230–260k	41	~82%	Stable residential community; family-oriented
Bayou Vista	~1,916	\$114,063	5.3%	\$364,400	59	86.3%	Affluent, older, waterfront; minimal labor contribution

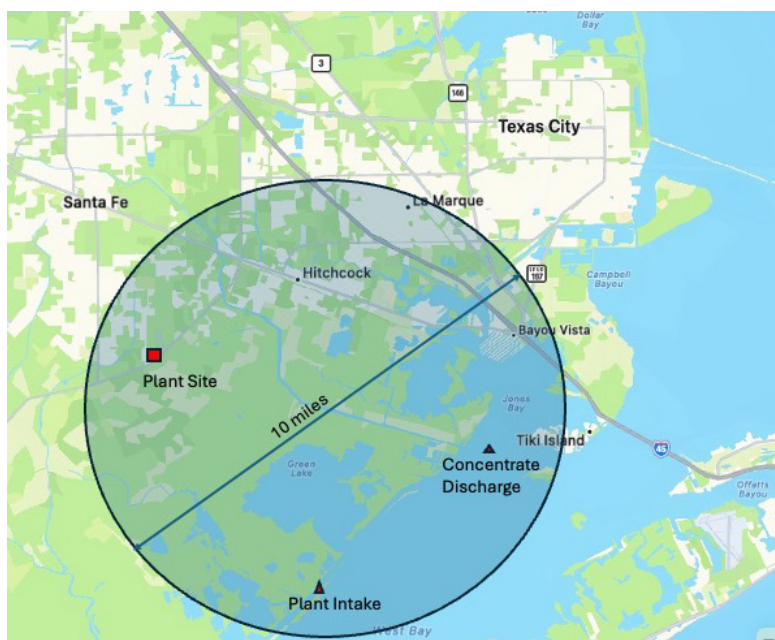


Figure 7-1 Local Communities Near the Proposed Project

Community Profiles

Texas City and La Marque

Texas City, the largest urban center in the study area, has a diverse population and an economy rooted in industrial, petrochemical, and port operations. Median household income is approximately \$65,447, with moderate housing values. GCWA's central office and operations are located here, making Texas City an important beneficiary of construction and long-term employment associated with the project.

La Marque, adjacent to Texas City, shares similar socioeconomic characteristics and serves as a significant residential base for workers employed throughout the industrial corridor. Together, these two communities represent the largest workforce pool available to support construction and operation of the desalination facility.

Communities Near the Project Site

Hitchcock is the closest municipality to the desalination site, with a median household income of \$77,713 and high rates of homeownership. The community includes a mix of blue-collar and mid-skill labor and may experience the most direct local economic effects from project development.

Santa Fe, located northwest of Hitchcock, is primarily residential with a stable population and higher household incomes. Santa Fe is likely to serve as a residential base for technical and professional staff associated with GCWA or the desalination plant.

Bayou Vista, while small, is an affluent and older community characterized by high home values and limited workforce availability. It forms part of the regional socioeconomic setting but is not expected to contribute significantly to project labor needs.

Racial and Ethnic Composition of the Regional Study Area

The regional study area includes communities with varying racial and ethnic composition. Larger population centers such as Texas City and La Marque are characterized by a relatively diverse population, with substantial White (non-Hispanic), Black (non-Hispanic), and Hispanic or Latino populations. In contrast, communities such as Santa Fe and Bayou Vista are predominantly White (non-Hispanic), with smaller minority populations.

Hitchcock, the community closest to the proposed desalination facility, reflects a mixed racial and ethnic profile, with no single racial or ethnic group comprising an overwhelming majority. Hispanic or Latino residents represent a meaningful portion of the population in Texas City, La Marque, and Hitchcock, consistent with broader demographic trends across Galveston County.

Table 7-3 summarizes the racial and ethnic composition of the primary communities considered in this socioeconomic analysis.

Table 7-3 Racial and Ethnic Composition of Regional Communities

Community	White (Non-Hispanic)	Black (Non-Hispanic)	Asian (Non-Hispanic)	Other / Multiracial (Non-Hispanic)	Hispanic or Latino (Any Race)
Texas City	~36%	~27%	~1%	~4%	~31%
La Marque	~35%	~31%	~2%	~3%	~29%
Hitchcock	~40%	~28%	~1%	~6%	~25%
Santa Fe	~78%	~0.4%	~0.4%	~4%	~17%
Bayou Vista	~83–85%	~2–3%	~1%	~3–4%	~10–12%
(2020 US Census with American Community Survey 2023 cross-checks where noted)					

Environmental Justice Screening

An initial environmental justice screening was conducted for the regional study area using available US Census data and American Community Survey estimates. This screening indicates that certain communities within the study area, particularly Texas City, La Marque, and Hitchcock, include minority populations that exceed regional or state averages.

The proposed desalination facility is located outside the incorporated limits of these communities, and no residential populations are located at the project site. While the project may result in localized construction and operational effects, these impacts are anticipated to be temporary and manageable through standard mitigation measures.

Based on the preliminary nature of this feasibility study, the project does not appear to pose disproportionate adverse environmental or human health effects to minority or low-income populations. Further environmental justice evaluation, if required, would be conducted as part of subsequent environmental review and permitting processes in accordance with applicable National Environmental Protection Agency (NEPA) and TCEQ requirements.

Regional Implications

The combined socioeconomic landscape presents a diverse mix of workforce availability, income levels, and residential conditions. Texas City and La Marque provide the largest labor pool, Hitchcock represents the most direct community interface with the project location, and Santa Fe and Bayou Vista contribute to the broader regional context for housing, commuting, and public engagement. Overall, the region is well positioned to support construction and long-term operational needs for the proposed desalination facility.

7.2 Potentially Significant Impacts

As part of this Feasibility Study, our scope was limited to a review of existing environmental literature and available data. A full Environmental Assessment was not included in this phase. The next step in the environmental process will involve conducting a comprehensive Environmental Assessment and initiating formal coordination with State and Federal agencies through a Joint Evaluation Meeting (JEM). This future work will address specific environmental concerns related to the proposed intake and discharge pipeline routes, associated structures, and plant construction.

A JEM is an early coordination step used in Texas, primarily along the coast, for projects requiring permits under Section 10 of the Rivers and Harbors Act and Section 404 of the CWA. It is coordinated by the USACE, Galveston District, and typically involves participation from several state and federal agencies.

The purpose of the JEM is to provide early feedback on potential environmental impacts before the applicant submits a complete permit application. In addition, resource concerns (wetlands, endangered species, essential fish habitat, cultural resources, etc.) are confirmed/identified. Permitting is streamlined by addressing issues upfront.

Participating agencies include, but are not limited to, the following:

- USACE (Galveston District)
- TCEQ
- Texas General Land Office
- Texas Parks and Wildlife Department
- NMFS
- USFWS
- EPA Region 6
- THC (for cultural resources)

Recognizing the project's location within a sensitive coastal and marine environment, additional environmental studies will be required to fully assess potential impacts. These studies are anticipated to include habitat mapping, benthic surveys, core mix analyses, salinity dispersion modeling, and targeted evaluations of wetlands, seagrasses, and oyster reef resources. The results of these investigations will inform the development of avoidance, minimization, and mitigation strategies necessary to meet regulatory requirements and environmental protection objectives.

The key components of the proposed project, along with their associated potential environmental impacts and basis for site selection, are summarized below:

Intake: The proposed intake structure is sited to minimize the risk of entrainment and impingement of aquatic organisms. Site selection criteria included proximity to stable marine conditions, avoidance of sensitive marine habitats, and integration within existing industrial corridors to minimize new disturbance.

Intake Channel/Pipeline: The intake pipeline corridor was evaluated to avoid wetlands, seagrass beds, and other submerged aquatic vegetation to the greatest extent practicable. The use of horizontal directional drilling or similar trenchless construction techniques will be evaluated during final design to further reduce temporary and permanent environmental impacts.

Discharge Pipeline: The discharge pipeline alignment has been preliminarily identified to avoid critical habitat areas and limit crossing of wetlands or jurisdictional waters. Construction BMPs will be implemented to manage turbidity and protect water quality during pipeline installation.

Discharge Outfall: The discharge outfall is sited to achieve rapid mixing and dilution within the receiving water body, consistent with applicable Texas Pollutant Discharge Elimination System (TPDES) permitting requirements. Detailed salinity and circulation modeling will be completed during the next phase to confirm dispersion performance and compliance with water quality standards.

Plant Site: The desalination plant is proposed within an existing industrial area, minimizing the need for clearing undeveloped land and reducing potential impacts to native coastal habitats. Site selection also considered proximity to existing utilities, roadways, and industrial services, further reducing the environmental footprint.

7.2.1 Potentially Significant Environmental Effects or Risks

Potentially significant environmental effects or risks include the following:

- Impacts to wetlands, seagrasses, and oyster beds from construction activities.
- Localized increases in salinity and temperature at the point of brine discharge.
- Temporary increases in turbidity and suspended solids during construction activities.
- Potential habitat disruption for species of concern, including federally listed threatened or endangered species.
- Cumulative environmental impacts associated with other industrial and marine operations within the Texas City coastal zone.

Comprehensive environmental field studies, detailed modeling efforts, and agency coordination will be conducted in subsequent project phases to fully characterize these potential impacts and develop effective mitigation strategies in accordance with federal, state, and local regulatory requirements.

7.3 Status of Required Federal, State, Tribal, and Local Environmental Compliance Measures

At this time, no formal environmental compliance measures have been initiated for the project. Preliminary discussions have taken place with the TCEQ regarding permitting requirements and potential options for brine discharge locations. Formal compliance processes, including environmental permitting, NEPA review, and other regulatory approvals, will commence during the next phase of project development.

7.4 Additional Environmental Information Available to the Study

No additional environmental studies, site investigations, or technical reports beyond the literature and data review completed as part of this Feasibility Study are available at this time. Future phases will include detailed field studies and environmental assessments to support permitting and compliance efforts.

7.5 Effect on Water Supply and Water Quality

This project proposes to utilize a currently untapped raw water source by drawing seawater from West Bay for desalination and public use. As such, the project will directly supplement existing freshwater diversions from the Brazos River. The use of seawater, a sustainable and drought-resistant source, will help protect existing freshwater resources and improve the long-term resiliency of the GCWA supply system.

From a water quality standpoint, desalination of West Bay seawater will provide a high-quality treated water source. Potential impacts to the receiving waters from brine discharge will be minimized through proper site selection, advanced dispersion modeling, and adherence to applicable discharge permit conditions.

This project is expected to align with public interest objectives by providing an environmentally sustainable source of water while maintaining the lifestyle, economy, and environmental quality associated with the GCWA service area.

While no formal environmental compliance activities have been initiated to date, the project team has actively monitored lessons learned from other SWRO projects currently underway in Texas. Observations have been made regarding the types of environmental, permitting, and operational questions being raised, and the potential implications for project development. Based on this knowledge, a list of frequently asked questions has been developed, along with available answers. Where answers are not currently known, these gaps have identified additional work needed during piloting, field investigations, and the environmental review process to ensure issues are addressed proactively.

The local economy within the GCWA service area is heavily dependent on reliable water supplies to support industry, commerce, and population growth. Shortages of water resources would have a significant and immediate negative impact on both existing jobs and future economic development. A reliable and drought-resilient water source is critical to maintaining and growing the region's economic stability.

The project team remains committed to working proactively to identify environmental issues early in the process. Through community involvement, early stakeholder outreach, strategic intervention, and rapid response to unforeseen challenges, the project aims to avoid, minimize, or fully mitigate environmental impacts. By doing so, the project can deliver new, sustainable water supplies while relieving pressure on the Brazos River Basin and minimizing disruption to the existing environmental and social fabric of the area.

In response to the question of potential impacts to historic properties: based on the information available to date, areas of potential historic significance have been identified and the project will seek to avoid or minimize impacts to these areas. Further cultural resource surveys will be conducted during the Environmental Assessment to confirm the absence of impacts or develop appropriate avoidance and mitigation strategies, as required.

In response to the question regarding future federal funding: it is understood by GCWA that if the Bureau of Reclamation provides funding for construction activities at a later date, all necessary environmental compliance under the NEPA, Section 106 of the National Historic Preservation Act (NHPA), and other applicable environmental and cultural resource laws must be completed prior to any ground-disturbing activities. GCWA acknowledges that full resolution of all outstanding environmental and cultural compliance requirements is a prerequisite to eligibility for future federal funding.

7.6 Extent of Public Involvement in the Feasibility Study and a Summary of Comments

At the beginning of the project, an article was written by Peter Warren in the Houston Chronicle newspaper, dated April 10, 2024, discussing the GCWA Desalination Feasibility Study and included quotes from both GCWA and BRA. The GCWA Desalination Feasibility Study has also been presented and discussed in multiple public forums throughout preparation of the report. These presentations include the following:

- Texas Desalination Association Legislative Workshop 2025 (March 4, 2025)
- Harris-Galveston Subsidence District 2025 Gulf Coast Water Conservation Symposium (May 21, 2025)
- American Society of Civil Engineers (ASCE) Environmental & Water Resource Institute (EWRI) 5th Annual Houston Conference (October 30, 2025)
- Southeast Texas American Water Works Association (TAWWA) / Water Environment Association of Texas (WEAT) Annual Seminar (February 17, 2026)

Appendix G contains some documentation of the public outreach efforts.

8.0 Legal and Institutional Requirements

(8) **Legal and Institutional Requirements.** The water reclamation, recycling or desalination feasibility study shall identify any legal or institutional requirements, or barriers to implementing the proposed project.

8.1 Analysis of Water Rights Issues

(a) Analysis of any water rights issues potentially resulting from implementation of the proposed water reclamation, recycling desalination project. All proposed water reclamation, recycling or desalination projects must comply with state water law.

This project does not require the purchase of water rights but does require approval of a water diversion for the seawater to be processed by the plant, and a discharge permit for the concentrate that is to be returned via the discharge. This project will contribute to a more sustainable Brazos River Basin and enhance regional drought resiliency.

8.2 Legal and Institutional Requirements

(b) Discussion of legal and institutional requirements (e.g., contractual water supply obligations, Indian trust responsibilities, water rights settlements, regional water quality control board requirements), state, and/or local requirements with the potential to affect implementation of the project. Water reclamation, recycling or desalination projects using Reclamation project water must address contractual requirements as described in RM D&S, *Reuse of Bureau of Reclamation Project Water* (PEC 05-09).

The GCWA Regional Seawater Desalination project will require GCWA to obtain permits and/or other forms of approval from federal, state, and local agencies as detailed in Sections 7.0 and 8.4 of this feasibility study. Permits have not been acquired yet for this project but will be pursued as early as possible during the design process. The Regional Seawater Desalination project will not use Bureau of Reclamation project water.

8.3 Need for Multi-Jurisdictional or Interagency Agreements

(c) Discussion of the need for multi-jurisdictional or interagency agreements, any coordination undertaken, and any planned coordination activities.

BRA and HGSD are stakeholders for the project and have provided a portion of the non-Federal funds for this study. As the project moves forward, there may be coordination and interagency agreements between these stakeholders. GCWA will continue to consider all potential partnerships and coordination as the project moves forward.

8.4 Permitting Procedures

(d) Discussion of permitting procedures required for the implementation of water reclamation, recycling or desalination projects in the study area, and any measures that the non-Federal project sponsor can implement that could speed the permitting process.

Seawater desalination projects are subject to numerous regulatory requirements and permitting processes to ensure their environmental impact is minimized and they comply with local, state, and federal regulations. This document identifies and describes the key water-related permits that are required for the implementation of this project.

1. Texas Pollutant Discharge Elimination System (TPDES) Permit

The TPDES permit is required under the CWA in Texas for any discharge of pollutants into Waters of the State. Desalination plants, which discharge concentrate (brine and other byproducts), must obtain this permit to ensure their discharges meet regulatory standards.

After consultation with TCEQ Water Quality Division, it was concluded that the Southwestern Galveston County site is likely an acceptable location for the discharge of brine into the Galveston Bay system. The outfall for the Southwestern Galveston County site is proposed to be in West Bay offshore south of the mouth of Highland Bayou Diversion Channel. Coordinates are approximately 29.463570 N, -94.946351 W.

Relevant criteria are as follows:

- Concentrate flow
- Concentrate quality
- Salinity
- Mixing
- Dilution opportunities
- Environmental consideration
- Permitting parameters

Likely effluent characteristics are average flow 50 MGD, salinity 70 ppt. The distance across the receiving water from the outfall is an important element. It needs to be at least 400 feet in all directions and not a dead-end channel to get the maximum benefit for the permit (largest Mixing Zone). The proposed site is in open water in West Bay and more than meets that criterion. It is also close to the dredged Intracoastal Waterway and has reasonable depth for mixing.

According to the TCEQ Surface Water Quality Monitoring (SWQM) database, average salinity in West Bay near this location is about 24 ppt. Typical sea water is 35 ppt, so this lower ambient value allows for more mixing and dilution. A typical "target" is to have a maximum of 35 ppt at the edge of the Mixing Zone. In addition, a maximum rise of 2 ppt at the edge of the Mixing Zone is another target. Neither of these are regulatory criteria, and not meeting them does not mean a permit will be denied, but a discharge meeting these will be more easily defended. The first target (35 ppt) is likely achievable, especially with a diffuser. The second target (2 ppt rise) is less likely to be achievable. The exact value at the edge of the Mixing Zone is unknown at this time. Permitting will likely require a multi-port diffuser at the outfall. The modeling associated with that will allow for more precise calculation of the value. This will allow greater

mixing of the effluent with the receiving water and avoid excessive concentrations at the edge of the Mixing Zone.

Seagrasses are to be avoided, but they are well southwest of the location under consideration. Oyster beds are also to be avoided and are not present in this area. These two items are unlikely to be factors.

The permitting process generally takes about a year, unless there are protests requesting a contested case hearing, in which case the time frame is uncertain.

2. Water Right Permit

The water right permit, obtained from TCEQ, is necessary for the intake and use of seawater. It regulates the quantity of seawater that can be withdrawn, ensuring sustainable use of marine resources. Salt water rights are usually easier to obtain than fresh water. The permitting process typically takes about a year.

3. US Army Corps of Engineers (USACE) Section 404 Permit

Structures below the high tide line (e.g., intake structures, discharge diffusers, buried pipelines crossing wetlands), a Section 404 permit for dredge or fill activities under the CWA will be required.

4. USACE Section 10 Rivers and Harbors Act Permit

For any structure in navigable waters (which West Bay is), Section 10 applies — intake pipes, discharge diffusers, etc. This is often bundled with Section 404 under a "Joint Permit" process.

5. Coastal Zone Consistency Certification

Since the project is in the Texas coastal zone, the project needs to be certified that it is consistent with the Texas CMP. The TCEQ Coastal Coordination Advisory Committee usually checks this during permitting.

6. Endangered Species Act (ESA) Consultation

If endangered species (e.g., sea turtles, certain shorebirds) may be affected by construction or operations, there could be a Section 7 Consultation with the USFWS or NOAA Fisheries.

At feasibility stage, the consultation *may* be required depending on final field surveys.

7. National Historic Preservation Act (NHPA) Section 106 Compliance

If any ground-disturbing activities occur, a Section 106 historic property review is needed and coordinated through the THC.

8. US Coast Guard Coordination

Given the proximity of project components to the Intracoastal Waterway, the USCG will be consulted during the Section 404/10 permitting process to evaluate potential impacts to navigation. If construction activities or structures are determined to impact navigable waters, appropriate USCG approvals, such as Private Aids to Navigation permits or obstruction evaluations, will be obtained. Coordination with the USCG will ensure compliance with applicable navigation safety requirements and minimize disruptions to marine traffic during construction and operation.

8.5 Unresolved Issues

(e) Discussion of any unresolved issues associated with implementing the proposed water reclamation, recycling or desalination project, how and when such issues will be resolved, and how the project would be affected if such issues are not resolved.

At this feasibility study stage of the Regional Seawater Desalination project, there are several still unresolved issues that need to be resolved to implement it.

1. Funding

Decisions and coordination related to applications for federal and state funding for the project have not yet occurred. This will be a key first step in moving the project forward. The inability to obtain funding would severely limit the ability of the project to move forward.

2. Site Selection

At this time, a final site location has not been determined or acquired. Next steps would be final site selection and negotiation of land acquisition. Currently, one of the preferred sites is the Southwestern Galveston County site. If, for some reason, land in that area cannot be acquired, there is a site adjacent to the GCWA-owned TMWTP that would also be an option for development of the desalination plant.

3. Permitting

While informal talks with TCEQ staff have occurred as part of the site selection evaluation process associated with this feasibility study, no permitting actions have been taken to date. Permitting applications for both the intake and discharge, as well as for the site development and connection to the delivery system, will need to be submitted and approved. The permitting process can be lengthy, and while GCWA will work with the permitting entities to ensure a smooth progression, slowdowns in the process could significantly delay the project.

4. Public Awareness

Public outreach activities related to the project have occurred as part of this feasibility study, as documented in Section 7.6. Additional outreach and efforts towards public awareness will be required as the project moves forward into planning, design, and construction.

8.6 Current and Projected Discharge Requirements

(f) Identification of current and projected wastewater discharge requirements resulting from the proposed water reclamation, recycling or desalination project (e.g., brine disposal).

The proposed GCWA Seawater Desalination Project will generate a concentrated brine stream as a byproduct of the reverse osmosis process. Current projections estimate an average brine discharge as listed in Subsection 4.4.2. This discharge will require a TPDES permit issued by the TCEQ.

Initial coordination with TCEQ has identified the site in Southwestern Galveston County connecting in West Galveston Bay as a potentially acceptable discharge location. The site offers sufficient depth, open-water conditions, and favorable mixing potential to support compliance with receiving water quality goals. Salinity dispersion modeling (CORMIX) and diffuser design will be developed in the next phase to demonstrate that discharge at the edge of the mixing zone will not exceed a salinity of 35 ppt or cause

more than a 2 ppt rise in ambient salinity that are common benchmarks used by TCEQ, though not formal regulatory limits.

The discharge location was selected to avoid sensitive ecological features such as seagrass beds and oyster reefs. A multi-port diffuser is expected to be incorporated into the final design to promote efficient mixing and minimize localized salinity impacts. Additional discharge requirements, including monitoring and reporting, will be defined during the permitting phase in coordination with TCEQ and other regulatory agencies.

8.7 Rights to Discharges

(g) Description of rights to wastewater discharges resulting from implementation of the proposed water reclamation, recycling or desalination project.

There are no ownership or property rights associated with brine or other concentrate streams generated by a seawater desalination facility. Brine is considered a waste stream, and its management is governed solely through state regulatory authorization, not market mechanisms or asset control.

For the GCWA Regional Seawater Desalination Project, the discharge of brine to Waters of the State will require a TCEQ TPDES permit. This permit specifies the following:

- Characterization of the brine effluent,
- Allowable discharge concentrations/limits,
- Receiving water mixing zone assumptions, and
- Monitoring and reporting requirements.

At the time of this feasibility study, GCWA has not yet initiated a formal discharge permit application. However, GCWA did conduct initial informal discussions with TCEQ during the site-selection process to confirm feasibility of the proposed discharge locations.

As the site-selection process progresses, GCWA will continue engagement with TCEQ regarding both intake and discharge requirements. Once a preferred site is finalized, GCWA will initiate the formal TCEQ TPDES application process.

Section 4.4 of this feasibility describes the anticipated waste-stream discharge for the GCWA Regional Seawater Desalination project.

9.0 Financial Capability of Sponsor

(9) **Financial Capability of Sponsor.** At the water reclamation, recycling or desalination feasibility study stage, Reclamation must request enough information to determine that the non-Federal project sponsor is likely to demonstrate financial capability if the project moves to construction. Reclamation will request more detailed information to make a determination that the non-Federal project sponsor is financially capable of funding the non-Federal share of the project's costs before a funding agreement covering construction can be executed. Accordingly, the following information is required to be included in the water reclamation, recycling or desalination feasibility study report.

9.1 Proposed Schedule

(a) Proposed schedule for project implementation.

GCWA has not currently identified how quickly they will begin moving forward with the Regional Seawater Desalination project, so the proposed project schedule, as shown on Figure 9-1, is based on a more generic timeline, assuming the project starts with funding research and site selection.

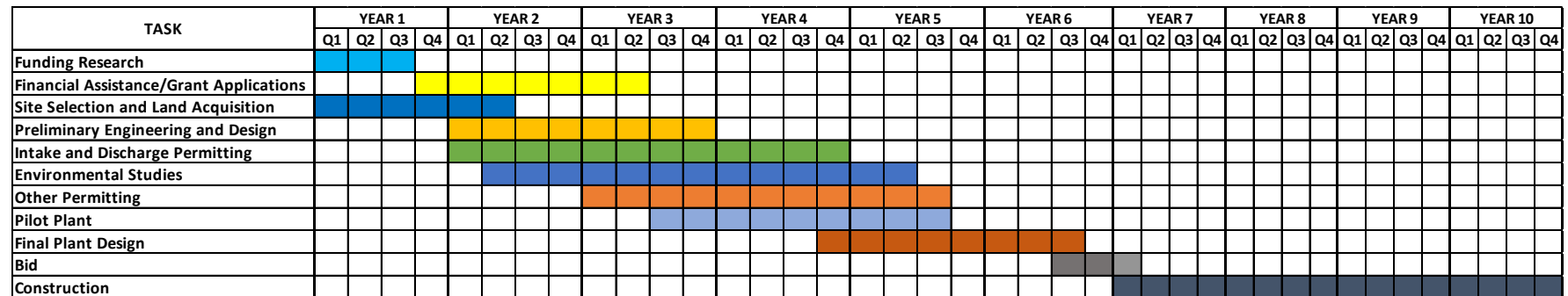


Figure 9-1 Proposed Project Schedule

9.2 Willingness to Pay

(b) Discussion of the willingness of the non-Federal project sponsor to pay for its share of capital costs and the full operation, maintenance, and replacement costs.

GCWA is committed to the implementation of the Regional Seawater Desalination project, including paying its share of the planning, design, construction, and full operation, maintenance, and replacement costs required for the life of the project. GCWA will take all actions as necessary to fund the project, with the funding plan being discussed in further detail in Section 9.3.

9.3 Funding Plan

(c) A plan for funding the proposed water reclamation, recycling or desalination project's construction, operation, maintenance, and replacement costs, including an analysis of how the non-Federal project sponsor will pay construction and annual operation, maintenance, and replacement costs.

GCWA anticipates funding the Regional Seawater Desalination project through a combination of federal and non-federal sources, with the hope of limiting the burden put on existing and future customers. GCWA will evaluate applicable sources based on eligibility criteria, funding availability, program and beneficial use goals and objectives, and/or program constraints to identify and prioritize funding and financing pursuits. Federal grant funding will be a goal of GCWA, and they will plan to incur costs upfront to research and apply for federal grant funding of either \$30 million or up to 25% of the cost of the project, depending on whether the \$30 million cap is eliminated in future Notice of Funding Opportunities, while understanding that federal grant funding is highly competitive.

Funding opportunities for seawater desalination projects are available from several state and federal sources. Potential funding and financing programs to be evaluated include, but are not limited to, the following.

Federal Programs

- Reclamation WaterSMART Title XVI Water Recycling and Desalination Projects
- Water Infrastructure Finance and Innovation Act (WIFIA) through the EPA

State Programs

- Texas Water Development Board - State Water Implementation Fund for Texas (SWIFT)
- Texas Water Development Board – New Water Supply for Texas Fund (NWSTF)
- Texas Water Development Board – Drinking Water State Revolving Fund (DWSRF)

In 2013, the Texas legislature passed House Bill 4 and Senate Joint Resolution 1, which created the SWIFT and the State Water Implementation Revenue Fund for Texas. Companion legislation, House Bill 1025, provided \$2 billion in initial funding for SWIFT from the state's Economic Stabilization Fund. In November 2013, Texas voters approved the funding to support the implementation of projects recommended by the State Water Plan.

In 2023, the Texas Legislature passed Senate Bill 28 and Senate Joint Resolution 75, which provided for the creation of the Texas Water Fund and the NWSTF. Additionally, Senate Bill 30 authorized a \$1 billion appropriation of revenue to the Texas Water Fund. In November of 2023, Texas voters approved

Proposition 6, which created the Texas Water Fund that will assist in financing water projects in Texas beginning in the fall of 2029. The Texas Water Fund may be used to transfer money to the following funds, among others, by the TWDB:

- NWSTF
- SWIFT
- Clean Water or Drinking Water State Revolving Funds

The NWSTF is a special fund in the state treasury administered by the TWDB. It will provide financial assistance to political subdivisions of the state to develop water supply projects that create new water sources for the state, including seawater desalination, which will help reduce the State's dependence on fresh groundwater sources that are being depleted and causing subsidence issues near the coast. There is no requirement that a project be in the State Water Plan to be eligible for the NWSTF financing.

Programs that have authorization for grants (or principal forgiveness) include the Clean Water and Drinking Water State Revolving Funds, and the NWSTF. Some programs, such as SWIFT, do not offer grants due to statutory or constitutional limitations.

Low interest loans would be assumed to cover any costs not covered by grant funding. The SWIFT fund from TWDB provides long-term fixed rate loans offered at below market rates, with maturities ranging from 20 to 30 years. Interest rates are based on the TWDB's cost of funds reduced by a subsidy established by TWDB each funding cycle. Debt service costs calculated for the alternatives in this study assumed 20 years at 3.5% interest.

GCWA will rely on ratepayers to fund costs associated with operations and maintenance of the Regional Seawater Desalination project through contracts with existing and future customers.

9.4 Sources of Funding

(d) Description of all Federal and non-Federal sources of funding and any restrictions on such sources, for example, minimum or maximum cost-share limitations. Generally, for water reclamation, recycling or desalination projects, the Federal cost share has been limited to 25 percent, or \$30,000,000, whichever is less.

Funding through outside state and federal programs has not been secured yet for the GCWA Regional Seawater Desalination project. GCWA is researching both grant and low interest loan opportunities to reduce project costs and potential impacts to its customers. The GCWA Regional Seawater Desalination project is included in the 2026 Region H Water Plan, which makes it eligible for SWIFT and other types of state funding, which have no cost-share limitations.

GCWA also anticipates pursuing federal funding through the Bureau of Reclamation's Title XVI Water Reclamation and Reuse Program for up to 25% of the project cost. If other federal funding options are pursued, the total federal funding share will not exceed 25% of the project cost.

10.0 Research Needs

(10) **Research Needs.** At a minimum, the report must include a statement on whether the proposed water reclamation, recycling or desalination project includes basic research needs, and the extent that the proposed project will use proven technologies and conventional system components. The following information is required only if further research is necessary to implement the proposed water reclamation, recycling or desalination project:

- (a) description of research needs associated with the proposed water reclamation, recycling or desalination project, including the objectives to be accomplished through research;
- (b) description of the basis for Reclamation participation in the identified research;
- (c) identification of the parties who will administer and conduct necessary research; and
- (d) identification of the timeframe necessary for completion of necessary research.

It is anticipated that additional research will be needed to implement this desalination project. Specifically, funding is one area of research that will be needed. As GCWA does not have project funding set up at this time, research related to the types of funding available will be a future part of the project process. Additionally, as of this feasibility study, a specific site has not been chosen. As part of the project process to move forward, a site will need to be identified and will require site-specific research such as environmental and cultural/historical analyses to be performed, as well as the potential for a pilot plant.

GCWA may submit future applications to Reclamation for funding assistance as the project progresses through the planning, design, and construction process, which would include funding assistance for the site-specific studies and the potential pilot plant.

GCWA will be responsible for administering and conducting the necessary research, either by GCWA staff or by hired technical consultants.

Once the desalination project is determined to move forward, the funding and site-specific research may take up to 2 years. A pilot plant analysis may take up to an additional 3 years once the site is determined.

11.0 Independent Peer Review

For projects considered under the Large-Scale Water Recycling Program, the following information is required:

- (a) Description of all independent peer review and/or quality assurance/quality control conducted on the analyses presented in the study and the scope and charge to the reviewers.
- (b) Identification of the number of technical reviewers and the technical expertise and affiliation of the independent reviewers.
- (c) Provide a comment disposition summary describing issues raised during peer review and/or quality assurance/quality control and how they were addressed.

In addition to internal quality assurance/quality control performed by Black & Veatch, a draft version of this study was independently peer reviewed by members of GCWA, HGSD, and BRA. Their scope and charge was to read the entire report and provide comments that could be incorporated into an appendix summary that includes how their comments were addressed. Throughout the project, feedback was received from the independent peer reviewers on various portions of the analyses, such as the site location determination and the WAM modeling, prior to being incorporated into the report.

Appendix H contains a log of the comments received and how those comments were addressed in the final version of the report.

11.1 Technical Reviewers and Their Expertise and Affiliation

Six independent peer reviewers provided comments on the draft report. The reviewers include four from GCWA (Robert Upton, Virginia Migl, Morgan Early, and David Hudson), one from HGSD (Ashley Greuter), and one from BRA (Aaron Abel). A description of their qualifications is provided below.

Robert Upton, GCWA:

Robert D. Upton, P.E. has been with Gulf Coast Water Authority since March 2023. As the District Engineer he oversees Engineering, Development Plan Review and Capital Improvement Program. Prior to GCWA, as the Director of Engineering and PW for the City of Pearland he guided the Engineering, Capital Projects, Water and Wastewater Utility Services and Internal Services Divisions. His experience includes water and wastewater design/construction, alternative contract procurement, project management, policy development and implementation. He has a Civil Engineering degree from Northern Arizona University and is a registered Professional Engineer in Texas and Arizona.

Virginia Migl, GCWA:

Virginia Migl holds a Bachelor of Science degree in Mathematical Biology from the University of Houston and has nine years of experience with the Gulf Coast Water Authority. She currently serves as a Project Manager II and is a certified Project Management Professional (PMP). Virginia has managed a diverse portfolio of water utility projects involving canals, pump stations, water treatment, and pipelines.

Morgan Early, GCWA:

Morgan R. Early, PMP, CPM, is a Project Manager II with the Gulf Coast Water Authority (GCWA). A graduate of the University of Houston's Construction Management program, she began her career more than 15 years ago as an underground utility contractor before transitioning into owner-side roles with

multiple municipalities. At GCWA, she leads the delivery of capital improvement projects that enhance regional water reliability and resilience.

David Hudson, GCWA:

David Hudson is currently the Director of Operations and Maintenance for Gulf Coast Water Authority. He brings over 25 years of dedicated service with the Gulf Coast Water Authority. Throughout his tenure, he has served in several key roles, including 14 years as a Heavy Equipment Operator, five years as Maintenance Superintendent, six years as the Canal Manager.

Ashley Greuter, HGSD:

Ashley Greuter is the Director of Research and Water Conservation for the Harris-Galveston Subsidence District (HGSD) where she oversees the research, monitoring, and water conservation programs to ensure that HGSD has the best available subsidence data and water conservation resources in the Texas Gulf Coast region. She proudly serves as the USA Affiliate for UNESCO's Land Subsidence International Initiative and is a licensed Professional Geoscientist in Texas. She has a Bachelor of Arts in Classical Studies and Bachelor of Science, summa cum laude, in Geology from the University of Florida as well as a Master of Science in Geological Sciences from the University of Massachusetts (Amherst).

Aaron Abel, BRA:

Mr. Abel has over 25 years of experience in water resources, private consulting and research. Prior to joining the BRA in 2008, he worked in private consulting and as a research assistant. As Water Services Manager, he and his staff oversee the BRA's daily raw water supply operations, customer relations, water supply contract management, provide water resources planning support to the organization, and project management.

Mr. Abel received a Bachelor of Science degree in Geological Sciences from The University of Texas at Austin and a Master of Science in Hydrology from the New Mexico Institute of Mining and Technology.

11.2 Summary of Comments Received

A summary of the comments received on the draft report and how they were addressed is included in Appendix H of this report. No major changes were made to the report as a result of the comments.

12.0 Summary and Conclusions

In conclusion, GCWA has historically relied on its senior Brazos River water rights and stored water contracts with the Brazos River Authority to meet municipal, agricultural, and industrial water demands across Brazoria, Fort Bend, and Galveston counties. Today, GCWA is committed to developing a drought-proof, locally sourced water supply portfolio that strengthens the region's resilience against prolonged drought conditions.

GCWA's area encompasses the southern portion of the Houston metropolitan region. Based on water demand projections from the TWDB's 2026 Region H Water Planning Process, municipal and industrial demands in Brazoria, Fort Bend, and Galveston counties are expected to increase by approximately 80 MGD between 2030 and 2050. By 2080, water demands will increase by an additional 100 MGD as compared to 2050. After accounting for existing water supplies, identified needs for water to meet future demands increases from approximately 62 MGD in 2030 to approximately 110 MGD in 2050. By 2080, the identified water need to meet future water demands increases further to 178 MGD. These projected needs cannot be met with existing water rights, contracts, or infrastructure.

While several alternatives offer favorable cost-benefit ratios, each falls short of meeting GCWA's strategic goals and objectives. For example:

- **Reuse** cannot provide sufficient volumes of water.
- **Groundwater production** is subject to potential reductions by GCDs and poses a risk of increased regional subsidence.
- **Purchasing potable water from third parties** remains uncertain in terms of long-term availability.

The 20 MGD seawater desalination plant alternative has a slightly lower cost-benefit ratio (6.9) compared to the 40 MGD option (9.4), primarily because the intake, discharge, and delivery systems are designed for a full 40 MGD buildout. This design enables future expansion without additional major infrastructure investments. The 20 MGD approach offers flexibility by allowing incremental growth aligned with demand, avoiding premature oversizing and reducing future expansion costs.

The proposed GCWA 20 MGD Seawater Desalination Project represents a sustainable, drought-resilient source of potable water that enhances long-term regional water supply reliability. This project is designed to supplement existing resources while alleviating pressure on freshwater sources, particularly during periods of high demand or limited surface water availability.

Appendix A. Project Siting Technical Memorandum

GCWA DESALINATION FEASIBILITY STUDY – CANDIDATE SITE EVALUATION

Technical Memorandum

GCWA PROJECT NO. 5993
US BUREAU OF RECLAMATION GRANT NO. R24AP00180-00
BLACK & VEATCH PROJECT NO. 419808

PREPARED FOR



Gulf Coast Water Authority

19 MAY 2025



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1.0 Background

Gulf Coast Water Authority (GCWA) has historically relied on its senior Brazos River water rights and Brazos River Authority stored water contracts to meet the municipal, agricultural, and industrial water demands in Galveston, Brazoria and Fort Bend Counties. GCWA is now seeking to ensure a droughtproof water supply portfolio that contributes efficiently to the region’s resilience against climate change-driven droughts. The goal of this project is to prepare a feasibility study report that will define and assess the viability of implementing a large-scale seawater/brackish desalination project in accordance with Reclamation Manual WTR 11-01 as part of the WaterSMART Title XVI Program.

Task 4 of the contract is named Project Siting Recommendation with the purpose being to select a preferred site for the proposed seawater desalination facility. The siting recommendation process included the identification of five initial sites, with a sixth site added after the initial screening process, followed by selection of four candidate sites and then the preferred site location. The deliverable for Task 4 is this siting technical memorandum detailing the siting strategy to include potential site identification and screening of five sites (plus a sixth after initial screening), selection of four candidate sites, and a description of the tasks and data required to make a final site selection in the project’s future planning phase.

2.0 Potential Site Screening

The potential site screening effort began with the identification and mapping of five potential sites that were focused in Galveston County based on the following criteria as identified in the project scope:

- Proximity to water demand center(s),
- Site acreage and availability,
- Land use,
- Environmental considerations,
- Source water quality,
- Intake considerations,
- Concentrate discharge considerations, and
- Power supply considerations.

The five sites chosen were as follows:

1. Former P.H. Robinson Power Plant Site (Power)
2. Thomas S. Mackey Water Treatment Plant (Mackey)
3. Galveston/Pelican Island (Island)
4. Dickinson Bayou (Dickinson)
5. Moses Lake (Moses)

A sixth site (Southwestern Galveston County) was considered after the initial screening effort. It is included in Figure 2-1 and is discussed in more detail in Section 3.4, but is not included in the criteria scoring shown in Table 2-1.

Figure 2-1 identifies the location of the five sites chosen for initial screening, plus the sixth site added later in the evaluation process.

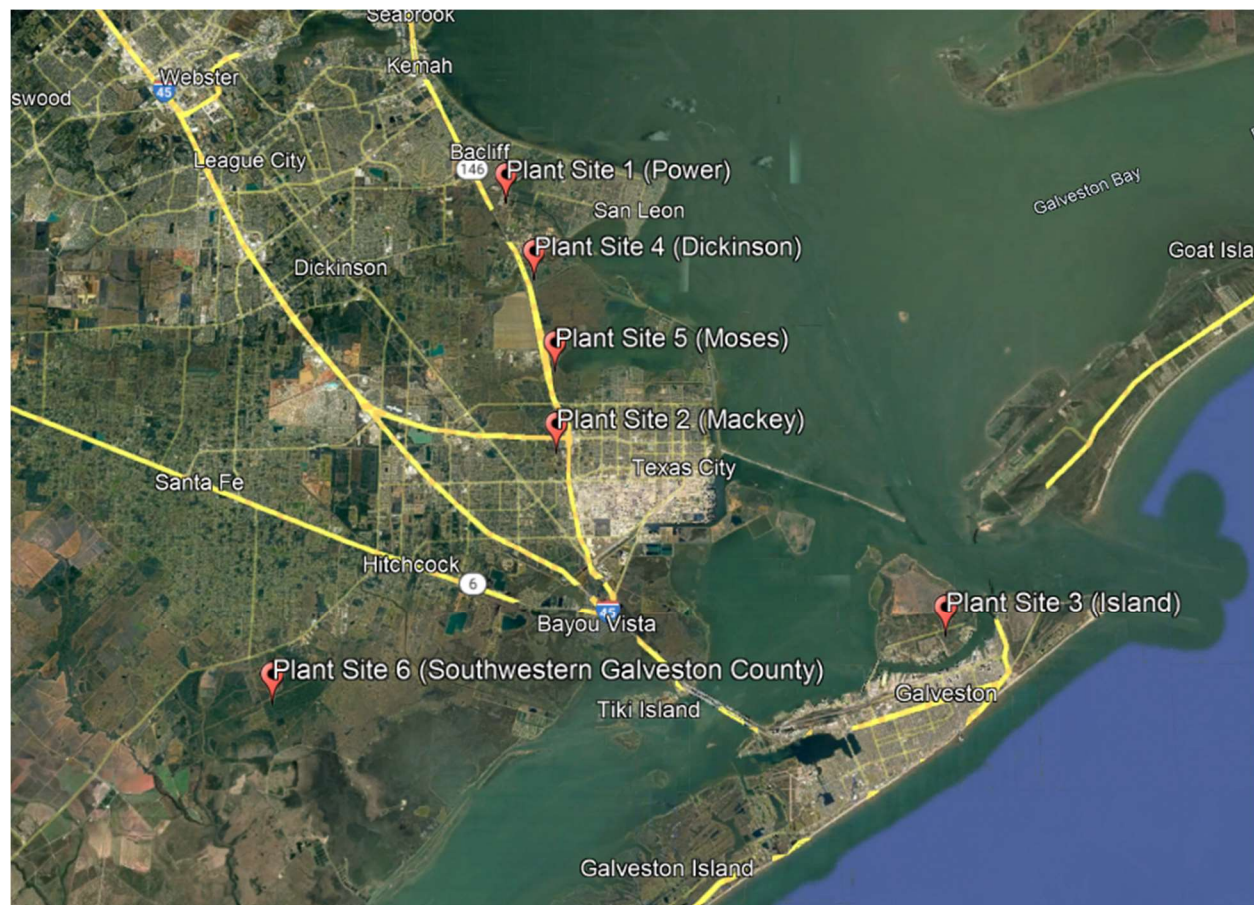


Figure 2-1 Site Location Map for Sites 1 Through 6

On November 19, 2024, Workshop 2 was held with all project stakeholders to review the available project site data and score each site using a determined weight associated with each criteria category. The goal of the workshop was to narrow the project sites down to two. The categories included Site Favorability (weighted 30%), Environmental (weighted 30%), Social (weighted 20%), Risk of Hazards (weighted 15%), and Water Quality and Availability (weighted 5%). The Site Favorability category included criteria such as proximity to the service area, intake, discharge, and utilities, as well the ability to co-locate utilities, site accessibility, and land acquisition. The Environmental category considered environmental concerns, discharge impacts, and regulatory compliance. The Social category considered community acceptance and environmental justice. The sites were scored for each category through consensus.

Table 2-1 provides the weighted scoring for each of the five sites. The top scoring and preferred site was Site 1 (Former P.H. Robinson Power Plant) due to the presence of existing intake and discharge canals, proximity to GCWA's service area and proximity to existing utilities including power, which contributed to high scores in the Site Favorability, Environmental and Social categories. However, this site has already been purchased by another party for development and is currently not available as a desalination facility site for GCWA. As a result, Site 1 was not considered for further analysis. This site may become an option for GCWA to purchase treated water but is not an option as a potential development site for this feasibility study. The next top two scoring sites were Site 4 (Dickinson) with a score of 4.0, and Site 2

(Mackey) with a score of 3.7. Site 4 (Dickinson) scored the highest in the Site Favorability and Social categories due to its location along Dickinson Bayou near industrial areas, while Site 2 (Mackey) scored the highest in the Social and Risk of Hazards categories due to its inland location near the existing water treatment plant. These two sites were chosen to move forward with the Candidate Site Evaluation process to determine the preferred site location.

Table 2-1 Weighted Selection Criteria Scoring for Sites 1 Through 5

Category	Criteria	Scoring Range	Weight	Site 1 Power	Site 2 Mackey	Site 3 Island	Site 4 Dickinson	Site 5 Moses
Site Favorability	Proximity to Service Area	1-5	30%	5	3	2	5	3
	Proximity to Intake							
	Proximity to Discharge							
	Proximity to Utilities							
	Co-location Opportunities							
	Site Accessibility							
	Land Cost and Acquisition							
Environmental	Environmental Concerns	1-5	30%	5	3	5	3	1
	Discharge Impact							
	Regulatory Compliance							
Social	Community Acceptance	1-5	20%	5	5	1	5	1
	Environmental Justice							
Risk of Hazards	Risk of Natural Hazards	1-5	15%	3	5	2	3	5
Water Quality & Availability	Water Supply	1-5	5%	3	3	5	3	1
Total Score			100%	4.6	3.7	2.85	4	2.2

3.0 Candidate Site Evaluation

At the Monthly Progress Meeting, held on December 17, 2024, an update was presented on the progress related to the evaluation of Site 2 (Mackey) and Site 4 (Dickinson), specific to the intake and discharge pipelines. The length of the discharge pipeline for Site 4 is a concern, and GCWA requested that Site 3 (Island) be considered in more detail again.

GCWA also requested further investigation of potential sites in southwestern Galveston County. As a result, a new Site 6 (Southwestern Galveston County) was included in evaluation.

Hence, the Candidate Site Evaluation included four sites – Site 2 (Mackey), Site 3 (Island), Site 4 (Dickinson), and the new Site 6 (Southwestern Galveston County). The evaluation for the four sites was presented at Workshop 3, held on February 3, 2025, and is discussed in detail below.

3.1 Site 2 (Mackey)

Site 2 (Mackey) is located in Texas City, Texas, next to the existing GCWA Thomas S. Mackey Water Treatment Plant, as shown on Figure 3-1.

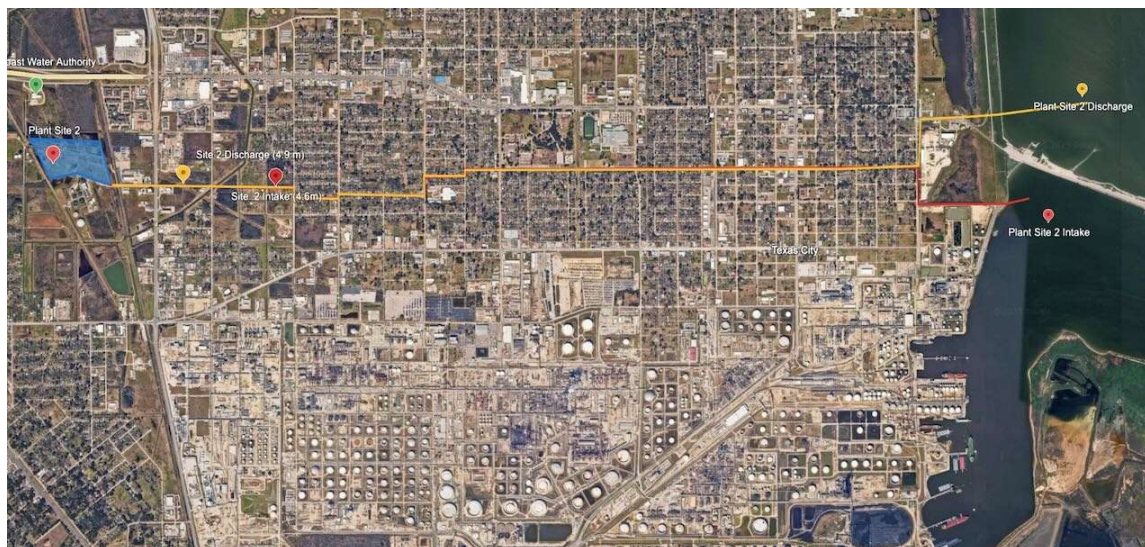


Figure 3-1 Site Location Map for Site 2 (Mackey)

3.1.1 Land Availability

A benefit of Site 2 is that it is co-located with the existing Mackey Water Treatment Plant. The land is already owned by GCWA and the site would be able to take advantage of existing storage and pumping facilities, utilities and operational personnel.

3.1.2 Environmental Constraints

Endangered species include the following: West Indian Manatee, Attwater's Greater Prairie Chicken, Eastern Black Rail, Piping Plover, Rufa Red Knot, Whooping Crane, Green Sea Turtle, Hawksbill Sea Turtle, Kemp's Ridley Sea Turtle, Leatherback Sea Turtle, and Monarch Butterfly (proposed threatened). This list indicates that suitable habitat is likely present and not whether these species actually occur within the site footprint.

Minimal impacts to seagrass, oysters, and tidal wetlands are expected, due to the anticipated locations for the intake and discharges, and because the site itself is inland.

3.1.3 Intake and Discharge Locations, Bathymetry, and Permitting

As shown on Figure 3-1, an open cut pipeline trench would need to be constructed across Texas City to carry both the intake and the discharge pipelines for the majority of their lengths. The intake is proposed for south of the Texas City Dike, while the discharge would be on the north side of the Texas City Dike. Water depths in the locations of the intake and the discharge appear to be in the 0 to 12 feet range. Permitting could have high complexities for the pipelines, due to the need for open cut through Texas City, and medium complexities for environmental impacts and fair quality of discharge mixing.

3.1.4 Source Water Quality

Water quality data was obtained through the EPA ([EPA's My Waterway Tool](#)) from samples taken near Site 3 (Island), since sample data was not available near the Site 2 intake and discharge locations. It is

expected that the water quality is similar to the Site 3 water quality since the water body overall is well connected. The salinity of the water is close to seawater. Refer to Table 3-1 for the water quality parameters and Figure 3-2 for sample site locations.

Table 3-1 Source Water Sample Data for Water Quality Parameters for Sites 2, 3, and 6

		Sample 1 (2023-2024)				Sample 4 (2004)				Sample 5 (2015-2020)			
Parameter	Units	Count	Average	Min	Max	Count	Average	Min	Max	Count	Average	Min	Max
Conductivity	µS/cm	23	44,530	24,500	55,100					30	33,362	7,870	46,900
Salinity	mg/L	23	28,770	14,500	36,400	3	25,633	24,050	27,200	30	20,887	4,400	30,500
Chlorophyll a	µg/L	3	13	5	24	8	4.48	0.00	7.40	6	13.15	8.85	19.10
Depth	Feet	4	39	27	45					6	37.51	29.53	45.28
Dissolved oxygen	mg/L	23	6	5	10	2	5.45	5.20	5.71	30	7.63	4.00	10.20
pH	S.U.	23	8	8	9	3	7.88	7.87	7.90	30	8.20	8.00	8.40
Temperature	°C	23	26	21	32	3	31.26	31.13	31.44	30	21.15	15.20	30.50
Total suspended solids	mg/L	2	11	10	11	6	21.33	13.00	28.00	6	19.32	10.90	26.00
Total organic carbon	mg/L	3	3	2	3					4	4.25	3.00	5.00

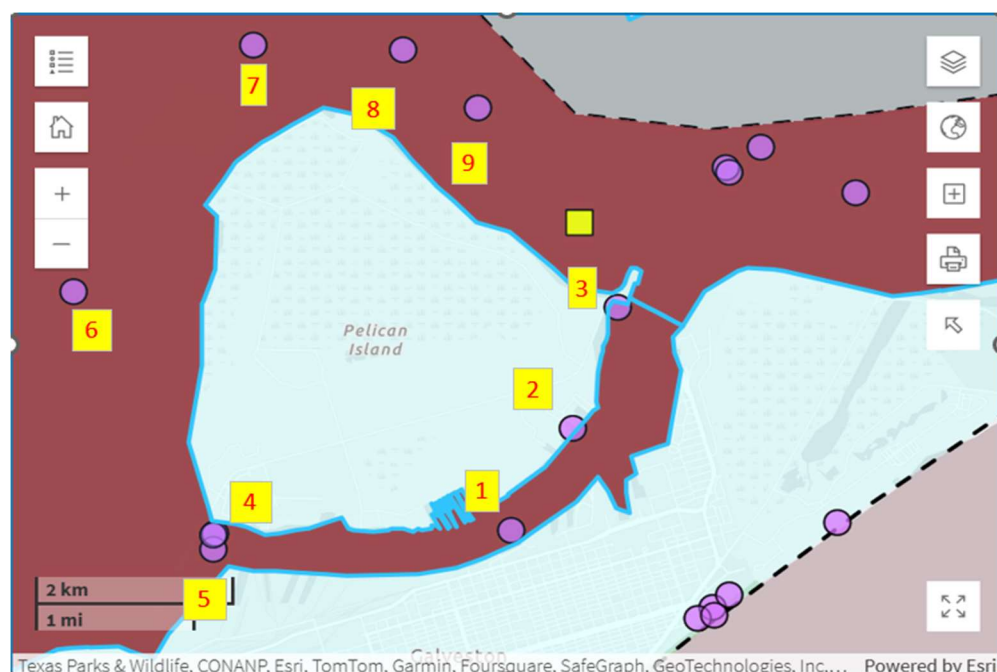


Figure 3-2 Water Quality Data Sample Location Map for Sites 2, 3, and 6

3.1.5 Planning Level Cost Estimate

Planning costs were developed for each site to include intake, discharge, and water delivery. Plant costs were not included as it was assumed plant costs would be very similar regardless of site location. The intake costs assumed a 4.6-mile open cut trench with pipeline, as well as a screen/pump wetwell. The discharge costs assumed a 4.6-mile pipeline included in the same open cut trench for most of the way to the open water, and then a 0.5-mile pipeline offshore with a diffuser. The water delivery costs are low because it was assumed that only an 1,800-foot pipeline would be needed to connect to the current distribution system. Refer to Table 3-2 for the Site 2 costs.

Table 3-2 Planning Costs for Site 2 (Mackey) for Intake, Discharge, and Water Delivery (\$M)

Intake Cost (\$M)	\$70.8 M
Discharge Cost (\$M)	\$47.9 M
Delivery Cost (\$M)	\$1.9 M
Total Intake/Outfall/Delivery Point Costs (\$M)	\$120.6 M
Note: The costs presented above are direct construction costs only and do not include construction indirects or contingency.	

3.2 Site 3 (Island)

Site 3 (Island) was chosen as a potential option because of the deeper water that may ease the permitting of the intake and discharge. It would also provide an additional source point for potable water for Galveston Island, although the costs associated with the desalination facility would need to be passed on to new customers on the mainland.

3.2.1 Land Availability

Vacant land is potentially available on Pelican Island, near some industrial facilities. Wetlands mitigation would likely be needed as part of the development of the land. Refer to Figure 3-3 for additional information.



Figure 3-3 Site Location Map with Intake/Discharge for Site 3 (Island)

3.2.2 Environmental Constraints

Endangered species include the following: West Indian Manatee, Attwater's Greater Prairie Chicken, Eastern Black Rail, Piping Plover, Rufa Red Knot, Whooping Crane, Green Sea Turtle, Hawksbill Sea Turtle, Kemp's Ridley Sea Turtle, Leatherback Sea Turtle, and Monarch Butterfly (proposed threatened). This list indicates that suitable habitat is likely present and not whether these species actually occur within the site footprint.

Minimal impacts to seagrass, oysters, and tidal wetlands are expected, due to the location of the site and the proposed intake and discharge locations in the deeper water.

3.2.3 Intake and Discharge Locations, Bathymetry and Permitting

As shown on Figure 3-3, Site 3 is located on Pelican Island, across the channel from Galveston Island. The intake would be at the channel itself, while the discharge would be near the jetty at the mouth of the bay, on the northeast side of Pelican Island where there is good mixing. The water depths in this area range from 20 to 40 feet deep. Permitting could have low complexities for the pipelines, and medium complexities for environmental impacts and good quality of discharge mixing.

3.2.4 Source Water Quality

Water quality data was obtained through the EPA ([EPA's My Waterway Tool](#)) from samples taken near Site 3, as shown in Table 3-1 and on Figure 3-2. The salinity maximum is similar to seawater, as expected. The total suspended solids (TSS) are moderately high, requiring clarification process in the pretreatment. While the data for chlorophyll a is limited, the available data indicates moderately high concentrations. The chlorophyll a concentrate, often used as surrogate for algae. For seawater sources that are susceptible to algal blooms, a flotation process is preferred, as algae tends to rise than settle. Hence, a dissolved air flotation (DAF) clarification process will be required.

3.2.5 Planning Level Cost Estimate

The intake costs assumed a 0.5-mile shoreline intake canal, as well as a screen/pump wetwell. The discharge costs assumed a 1.1-mile open cut pipeline and then a 0.5-mile pipeline offshore with a diffuser. The water delivery costs only include the costs required to distribute the treated water to the ground storage tanks on Galveston Island near the railway, including tunneling beneath the channel between Galveston Island and Pelican Island as well as multiple train tracks servicing Galveston Yard. They do not include the necessary infrastructure to move the water over the Causeway to the mainland. Refer to Table 3-3 for the Site 3 costs.

Table 3-3 Planning Costs for Site 3 (Island) for Intake, Discharge, and Water Delivery (\$M)

Intake Cost (\$M)	\$29.5 M
Discharge Cost (\$M)	\$24.1 M
Delivery Cost (\$M)	\$196.3 M
Total Intake/Outfall/Delivery Point Costs (\$M)	\$249.9 M
Note: The costs presented above are direct construction costs only and do not include construction indirects or contingency.	

3.3 Site 4 (Dickinson)

Site 4 (Dickinson) was chosen because of its proximity to Dickinson Bayou, which could provide water with a lower salinity that may save on treatment costs. The potential site area is on the east side of Highway 146, just south of Dickinson Bayou.

3.3.1 Land Availability

Land next to Dickinson Bayou appears to be available.

3.3.2 Environmental Constraints

Endangered species include the following: West Indian Manatee, Attwater's Greater Prairie Chicken, Eastern Black Rail, Piping Plover, Rufa Red Knot, Whooping Crane, Green Sea Turtle, Hawksbill Sea Turtle, Kemp's Ridley Sea Turtle, Leatherback Sea Turtle, Monarch Butterfly (proposed threatened), and Tricolored Bat (proposed endangered). This list indicates that suitable habitat is likely present and not whether these species actually occur within the site footprint.

Minimal impacts to seagrass, oysters, and tidal wetlands are expected, due to the anticipated locations for the intake and discharges. There are various environmental concerns, though, for the route needed for the discharge pipeline.

3.3.3 Intake and Discharge Locations, Bathymetry and Permitting

As shown on Figure 3-4, Site 4 is located along Highway 146 in Texas City, adjacent to the Dickinson Bayou. The intake would be a short channel from Dickinson Bayou (shown as a blue line on Figure 3-4), while the discharge would follow a private road, Beach Drive, and Skyline Drive until it reaches an area north of the Texas City Dike (shown as a red line on Figure 3-4). The water depths in this area generally range from 0 to 12 feet deep, although a channel runs through the area that may be deeper. Permitting could have high complexities for the pipelines, and high complexities for environmental impacts and fair quality of discharge mixing.

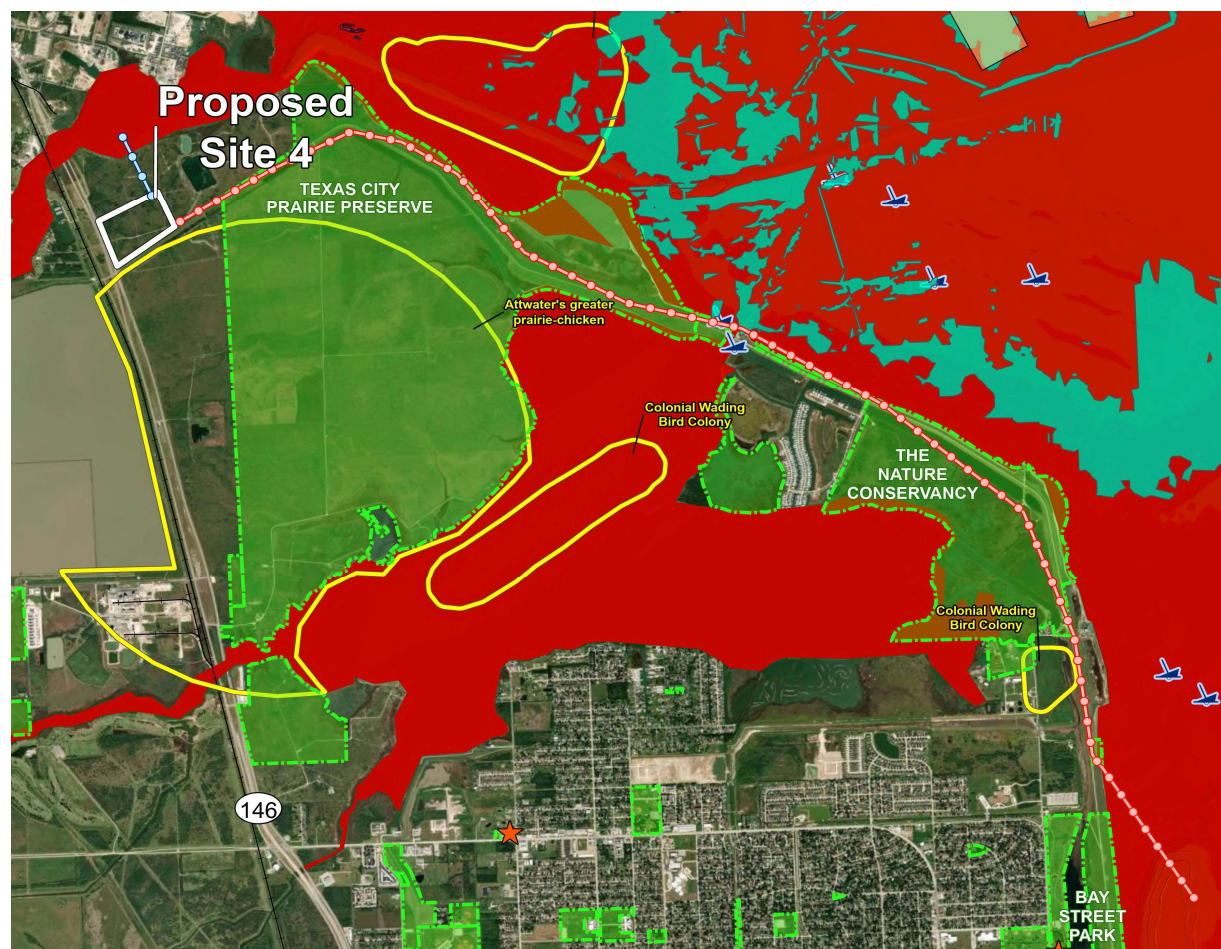


Figure 3-4 Site Location Map with Intake/Discharge for Site 4 (Dickinson)

3.3.4 Source Water Quality

Water quality data was obtained from samples taken near Site 4, as shown in Table 3-4 and on Figure 3-5. The salinity maximum is significantly lower than seawater, due to runoff. The limited data available indicates that the TSS can be high. Since algal blooms is a possibility, the DAF process will be required to remove organics and algae. However, the DAF process is not capable of removing very high concentrations of suspended solids. Hence, a pre-sedimentation may be required and would need to be confirmed by further testing.

Table 3-4 Source Water Sample Data for Water Quality Parameters for Site 4 (Dickinson)

Parameter	Units	Sample 1 (1984-2012)				Sample 2 (1997)				Sample 3 (2015-2023)				Sample 4 (1984)				Sample 5 (1997)			
		Ct	Avg	Min	Max	Ct	Avg	Min	Max	Ct	Avg	Min	Max	Ct	Avg	Min	Max	Ct	Avg	Min	Max
Conductivity	µS/cm	12	11,018	8,400	13,890	3	16,633	16,400	16,800	38	15,459	282	38,800	13	17,190	14,000	20,100	3	17,833	17,800	17,900
Salinity	mg/L	0	N/A	N/A	N/A	3	9,700	9,600	9,900	33	10,600	2,100	24,600	0	N/A	N/A	N/A	3	10,567	10,500	10,600
Chlorophyll a	µg/L	1.00	26.00	26.00	26.00	0	N/A	N/A	N/A	0	N/A	N/A	N/A	1	10.00	10.00	10.00	0	N/A	N/A	N/A
Depth	Feet	0.00	N/A	N/A	N/A	1	4.92	4.92	4.92	36	2.25	0.33	4.92	0	N/A	N/A	N/A	1	8.53	8.53	8.53
Dissolved oxygen	mg/L	11.00	10.26	9.00	12.30	3	6.00	5.90	6.10	37	7.64	4.50	11.20	12	11.17	10.30	12.80	3	6.17	6.10	6.20
pH	S.U.	12.00	8.02	7.90	8.10	3	7.80	7.80	7.80	38	8.01	7.30	8.50	13	8.21	8.00	8.30	3	7.90	7.90	7.90
Temperature	°C	22.00	14.41	11.78	26.57	3	30.40	30.40	30.40	38	23.09	8.30	32.20	24	34.65	11.60	57.90	3	30.23	30.20	30.30
Total suspended solids	mg/L	1	18	18	18	0	N/A	N/A	N/A	36	54	14	168	1	63	63	63	0	N/A	N/A	N/A
Total organic carbon	mg/L	0.00	N/A	N/A	N/A	0	N/A	N/A	N/A	0	N/A	N/A	N/A	0	N/A	N/A	N/A	0	N/A	N/A	N/A

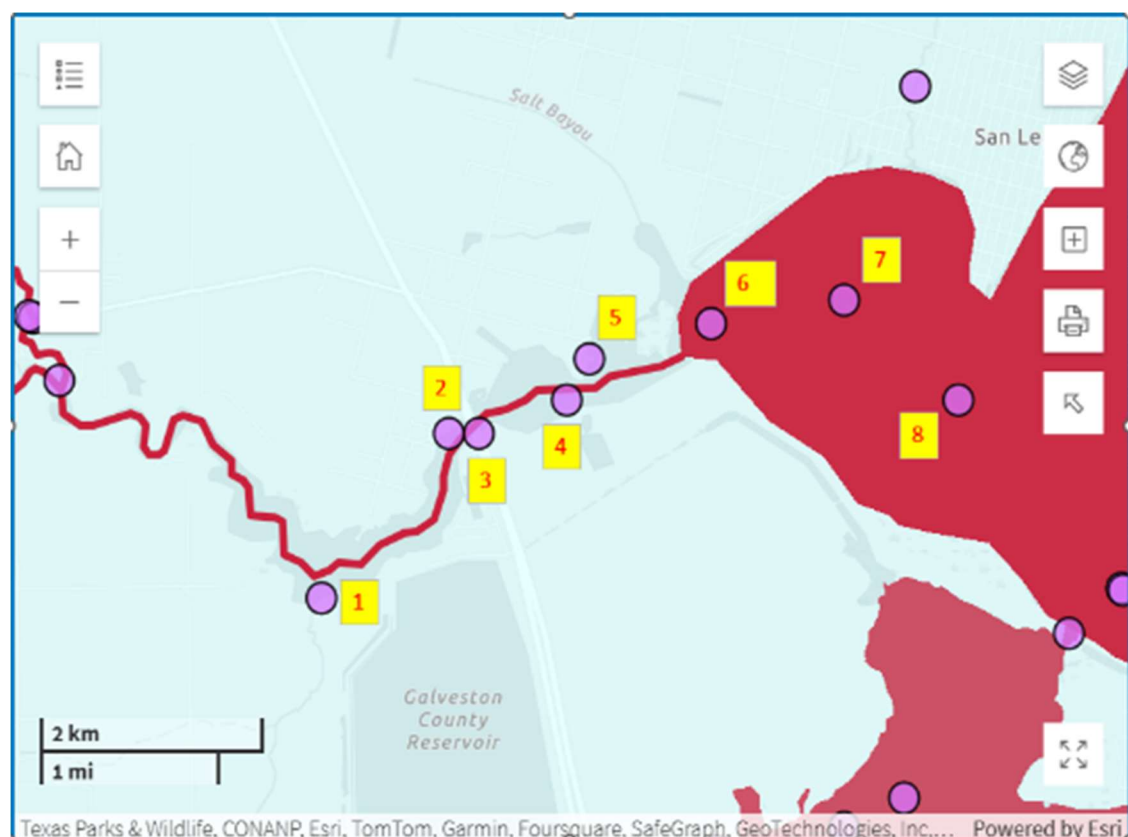


Figure 3-5 Water Quality Data Sample Location Map for Site 4 (Dickinson)

3.3.5 Planning Level Cost Estimate

The intake costs assumed a 0.4-mile shoreline intake canal, as well as a screen/pump wetwell. The discharge costs assumed a 7-mile overland pipeline and then a 0.5-mile pipeline offshore with a diffuser. The water delivery costs looked at two potential options for connecting with the existing distribution system. Option 1 would be to connect to the North Transmission – Bayshore Line and North Transmission – San Leon Spur Intersection, near Highway 146. The second option would be to connect to the North Transmission – Bayshore Line Near the Galveston County Industrial Water Reservoir. For costing purposes, the second option was assume as it was further from the site (3.3 miles). Refer to Table 3-5 for the Site 4 costs.

Table 3-5 Planning Costs for Site 4 (Dickinson) for Intake, Discharge, and Water Delivery (\$M)

Intake Cost (\$M)	\$29.4 M
Discharge Cost (\$M)	\$74.2 M
Delivery Cost (\$M)	\$27.4 M
Total Intake/Outfall/Delivery Point Costs (\$M)	\$131.0 M
Note: The costs presented above are direct construction costs only and do not include construction indirects or contingency.	

3.4 Site 6 (Southwestern Galveston County)

Site 6 (Southwestern Galveston County) was chosen as a potential option because of the location and expectation for new growth and demand for water in the area. The area looked at is west of Highway 6 and south of Camp Wallace Road in Galveston County.

3.4.1 Land Availability

The area looked at for Site 6 has a lot of open land that is privately owned. Wetlands in the area limit how close to West Bay the site can be developed.

3.4.2 Environmental Constraints

Endangered species include the following: West Indian Manatee, Attwater's Greater Prairie Chicken, Eastern Black Rail, Piping Plover, Rufa Red Knot, Whooping Crane, Green Sea Turtle, Hawksbill Sea Turtle, Kemp's Ridley Sea Turtle, Leatherback Sea Turtle, and Monarch Butterfly (proposed threatened). This list indicates that suitable habitat is likely present and not whether these species actually occur within the site footprint.

Impacts to seagrass, oysters, and tidal wetlands in the area of the intake and discharge would need to be avoided or mitigated.

3.4.3 Intake and Discharge Locations, Bathymetry and Permitting

When looking at intake and discharge locations for Site 6 (Southwestern Galveston County), options include the Gulf Coast Intracoastal Waterway and West Bay. Two options for intake/discharge were considered. As shown on Figure 3-6, the preferred option would be to use an intake canal from the Intracoastal Waterway with a pipeline and pump station to the plant, and a discharge pipeline north and east near the Harborwalk Yacht Club with the outfall in West Bay (Option 1). Figure 3-7 shows an alternative option where the intake and discharge locations are reversed. The Intracoastal Waterway is approximately 12 feet deep, while West Bay is shallower, but more open. Permitting could have low complexities for the pipelines, and medium complexities for environmental impacts and fair quality of discharge mixing.

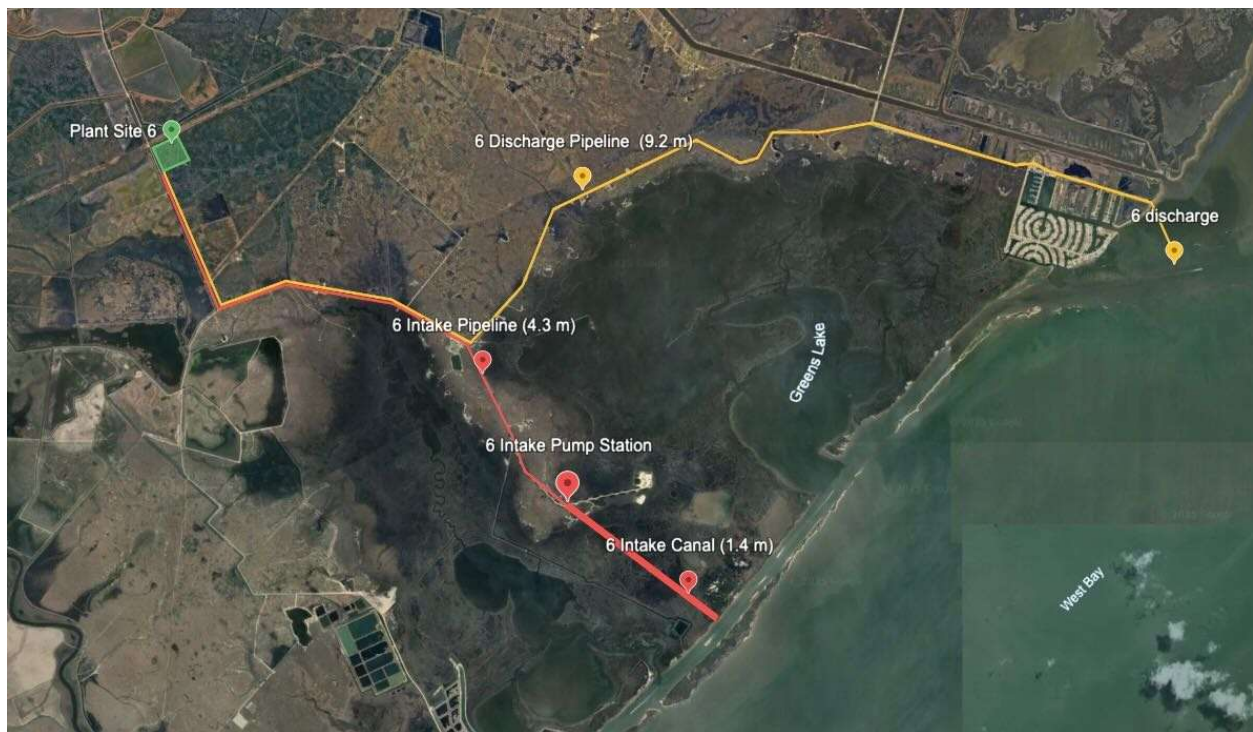


Figure 3-6 Site Location Map with Option 1 Intake/Discharge for Site 6 (Southwestern Galveston County)



Figure 3-7 Site Location Map with Option 2 Intake/Discharge for Site 6 (Southwestern Galveston County)

3.4.4 Source Water Quality

The source water quality for Site 6 (Southwestern Galveston County) should be similar to Site 2 (Mackey) and Site 3 (Island). The salinity maximum is similar to seawater. The TSS is moderately high, requiring pretreatment. The chlorophyll a is also moderately high, which requires DAF.

3.4.5 Planning Level Cost Estimate

The intake costs for the preferred Option 1 assumed a 1.4-mile shoreline intake canal, as well as a pump station and 4.3-mile intake overland pipeline. The discharge costs assumed a 9.2-mile overland pipeline and then a 0.5-mile pipeline offshore with a diffuser. The water delivery costs assumed a delivery point along Highway 6 northeast of the plant (6.2 miles). Refer to Table 3-6 for the Site 4 costs.

Table 3-6 Planning Costs for Site 6 (Southwestern Galveston County) for Intake, Discharge, and Water Delivery (\$M)

Intake Cost (\$M)	\$45.7 M
Discharge Cost (\$M)	\$76.8 M
Delivery Cost (\$M)	\$34.1 M
Total Intake/Outfall/Delivery Point Costs (\$M)	\$156.6 M
Note: The costs presented above are direct construction costs only and do not include construction indirects or contingency.	

4.0 Preferred Site Selection

As part of the evaluation, cost was considered, assuming the desalination plant cost would be the same for all four sites and therefore was not included in the costs.

Table 4-1 Summary of Planning Costs for All Sites for Intake, Discharge, and Water Delivery (\$M)

Site	Site 2 (Mackey)	Site 3 (Island)	Site 4 (Dickinson)	Site 6 (Southwestern Galveston County)
Total Cost (\$M)	\$120.6 M	\$249.9 M	\$131.0 M	\$156.6 M

At Workshop 3, held on February 3, 2025, the four candidate site evaluations were presented for discussion and consideration. An important part of the discussion identified that future population growth should be considered as part of the selection criteria to allow GCWA to provide water to new customers. As a result, Site 6 (Southwestern Galveston County) was determined to be the preferred site selection, even though the intake, discharge, and delivery costs were not the lowest. Site 2 (Mackey) was chosen as a potential backup preferred site in case Site 6 (Southwestern Galveston County) was not able to continue to be considered in the future.

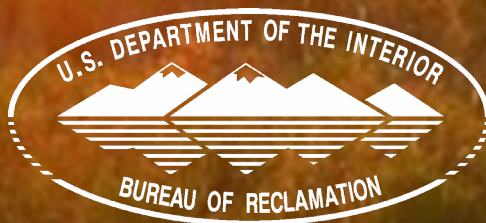
The feasibility study will move forward with consideration of Site 6 (Southwestern Galveston County) as the preferred site and Site 2 (Mackey) as an alternate choice. It should be noted that during the site screening, the preferred site was Site 1 (Former P.H. Robinson Power Plant); however, this site has already been purchased by another party for development and is currently not available as a desalination facility site for GCWA.

Appendix B. US Bureau of Reclamation Funding Opportunity BOR-DO-19-F012 Report

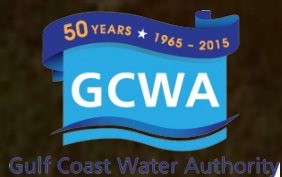
GULF COAST WATER AUTHORITY DROUGHT CONTINGENCY PLAN UPDATE

MARCH 31, 2019

PREPARED FOR



**UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION**



in conjunction with



Gulf Coast Water Authority Drought Contingency Plan Update

Prepared for:

UNITED STATE DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

March 2019

Under Agreement Number:

R16AC00114

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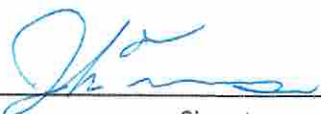


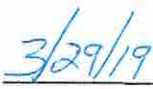
Geoscientist and Engineer Seals

To complete this Drought Contingency Plan Update, the Gulf Coast Water Authority contracted with LRE Water, LLC, a licensed professional geoscientist firm (Texas License No. 50516) and licensed professional engineering firm (Texas License No. 14368). This report documents the work of the following licensed professional geoscientists and licensed professional engineers in the State of Texas:

Jordan Furnans, Ph.D., P.E., P.G.

Dr. Furnans was the Project Manager for this work and was responsible for the entirety of the project, including data analysis, plan development, holding public/stakeholder meeting, and numerical water availability modeling. His work also involved final report review and acceptance.

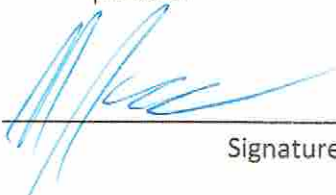

Signature

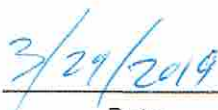

Date



Michael Keester, P.G.

Mr. Keester was responsible for assessing the viability of local groundwater usage to supplement surface water flows during drought periods.


Signature


Date

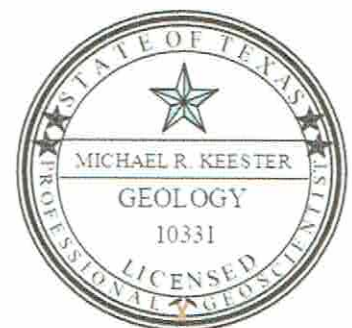


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Gulf Coast Water Authority

Drought Contingency Plan Update

Introduction

Scope and Purpose of Drought Contingency Plan Update

The Gulf Coast Water Authority (“GCWA”) provides water on a wholesale basis to customers in Galveston, Fort Bend, and Brazoria Counties (TX), including municipalities (e.g. Galveston, Sugarland, Missouri City) as well as petro-chemical industries (e.g. Dow-UCC, Valero, INEOS, Marathon, Ascend). The majority of GCWA’s water is diverted from the Brazos River, and the location of its diversions in the Lower Brazos basin cause GCWA’s water availability to be dictated both by natural streamflow variations and the water usage behavior of upstream entities. Texas regulations require that GCWA develop and routinely update basic drought contingency plans to aid in mitigating the effects of drought on customers. The existing GCWA plan, however satisfying state criteria, does not include all standard drought contingency practices as endorsed by the US Bureau of Reclamation (“Reclamation”). Through this project, GCWA has updated its plan to better satisfy its customer’s needs and expectations, and meets or exceeds standard practices required by the Bureau of Reclamation. The plan integrates four critical components:

1. Drought severity assessment through data gathering and analysis,
2. Planning to conjunctively utilize available groundwater during periods of drought,
3. Developing/implementing infrastructure monitoring and mitigation activities to reduce water loss, and
4. Incorporating standard drought contingency planning elements into GCWA’s existing plan.

GCWA’s Response and Mitigation Actions include a detailed evaluation of the availability of locally-sourced groundwater suitable for supplementing surface water sources during periods of drought. Additionally, GCWA has refined water loss monitoring procedures, geared to minimize demands for additional Brazos River water, thereby making such water available for other users within the Brazos Basin.

This updated DCP was developed by GCWA over the course two years (November 2016-December 2018) and describes how GCWA will operate to ensure water availability to customers through future droughts. The project was managed by LRE Water, LLC in close coordination with GCWA management and engineering staff. GCWA solicited and received plan input from its municipal, agricultural, and industrial clients, and many such clients readily served as members of the project Drought Task Force (“DTF”) that continually guided plan development during the project.

Through this plan update process with the Reclamation, GCWA also revised and updated its DCP for submission and approval by the Texas Commission on Environmental Quality (TCEQ). This updated DCP (Appendix A) utilized the research and components of the Reclamation DCP, yet is contains formatting and content consistent with Texas standards.

Planning Area

As water availability to GCWA is dictated by hydrologic conditions throughout the Brazos Basin, the planning area for this project must include the majority of the Brazos River Basin. However, with the creation of the Brazos Basin Watermaster program in 2015, the TCEQ effectively separated the Brazos Basin into upper and lower portions, with the lower portion under the jurisdiction of the Watermaster. As such, the overall planning area for this project includes the Brazos Basin watershed downstream of and including Possum Kingdom Lake (Figure 1). This region encompasses 21,903 square miles, and provides water to 1,227 water right holders authorized to divert by the TCEQ. Within the region there exist 47 active USGS streamflow gauges, as well as 21 reservoirs capable of storing at least 5,000 acre-ft of water. All drought monitoring activities, as well as some vulnerability assessment efforts and mitigation activities derived under this project cover the entire project planning area as shown in Figure 1.

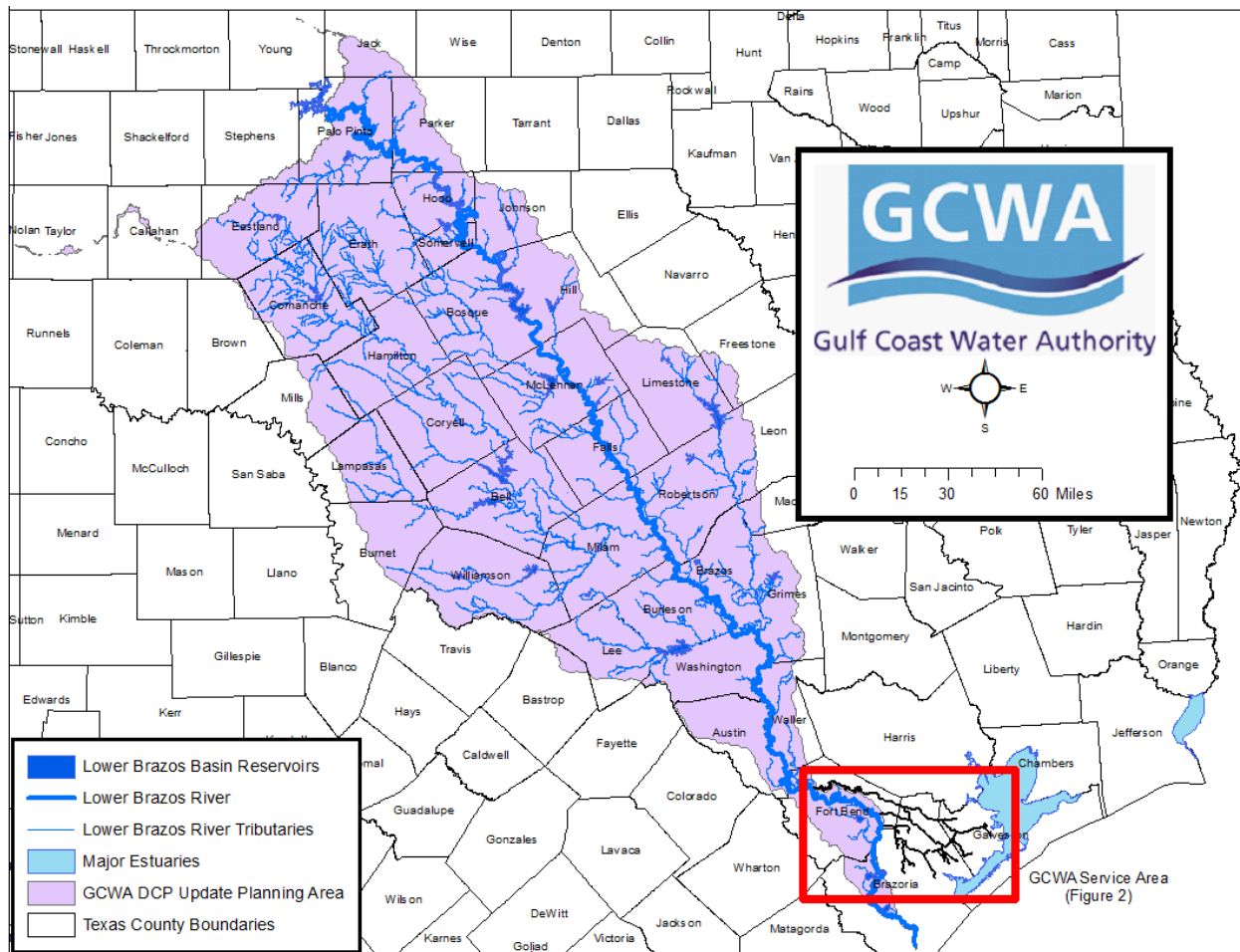


Figure 1 - Brazos Basin Map showing the full extent of the GCWA DCP Update Planning Area, as well as the GCWA Service Area at the downstream end of the Brazos.

Figure 2 provides details of GCWA's service area within Fort Bend, Brazoria, and Galveston Counties, and is visible in the lower-right hand corner of Figure 1. GCWA's response actions developed during this project are limited in geographic scope to the areas shown in Figure 2. Some vulnerability assessment

efforts and mitigation actions are also limited in scope to the areas shown in Figure 2. The majority of mitigation and response actions included within this DCP are limited to areas adjacent to GCWA and GCWA's customers, including water conveyance infrastructure utilized by GCWA and its customers. Through this project, however, GCWA also investigated mitigation actions potentially to be undertaken by GCWA outside of GCWA's immediate service area (Figure 2).

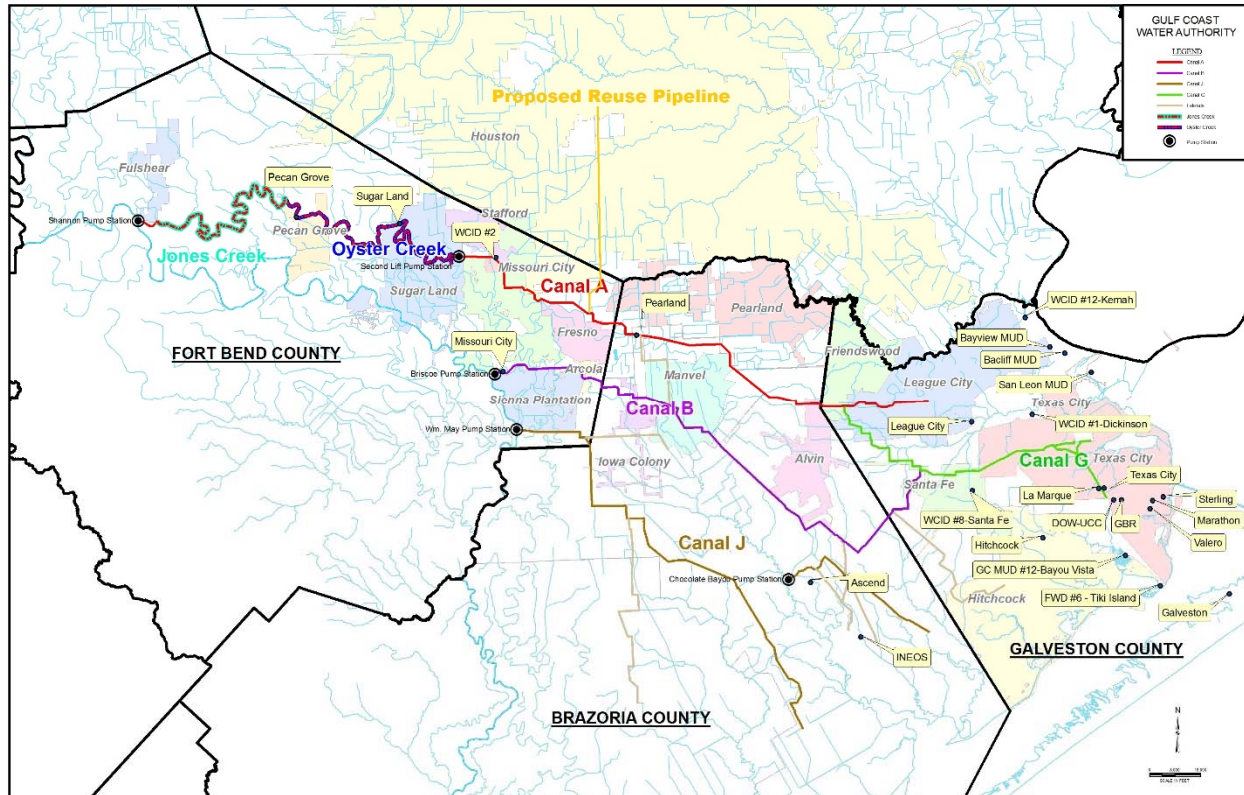


Figure 2 – GCWA's Service Area showing canals and customer locations

Background

As required by TCEQ, GCWA's drought contingency plan must provide TCEQ, GCWA customers, and the general public with basic information regarding actions to be undertaken in the case of Brazos Basin drought and/or a reduction in water availability to GCWA. GCWA has maintained a drought contingency plan throughout its years of operation, and the last plan update (prior to this project) occurred in 2012. This "Previous Plan" satisfies all plan requirements stipulated by the Texas Administrative Code (§288.20-§288.22). Under the Previous Plan, the general manager of GCWA was given the authority to impose voluntary and mandatory water usage reductions on its customers, based upon unspecified drought forecasts/triggers and specified water usage rate values. The Previous Plan defined only four stages of drought response, with increases in curtailment required with increases in drought severity. The Previous Plan also addressed public/stakeholder involvement in the planning process, obtaining variances from plan requirements, penalties for non-compliance, and how the plan was to be periodically updated and reviewed. The Previous Plan was sufficiently general in that GCWA retained great flexibility in deciding how to implement drought responses, and exactly what actions were to be undertaken at each plan stage.

Through this project, GCWA developed two separate planning documents: 1) a Drought Contingency Plan Update (“Reclamation Plan”) meeting Reclamation requirements, and 2) a Drought Contingency Plan update meeting only TCEQ requirements (“TCEQ Plan”) yet based entirely on the elements of the Reclamation Plan. The TCEQ Plan (Appendix A) was approved for use by the GCWA Board of Directors on December 6, 2018. This document is the Reclamation Plan, and will serve as the research basis from which all GCWA drought contingency planning efforts will be undertaken. GCWA will update both plans continuously based on observations of plan implementation, analysis results, and continued development of water resources infrastructure and monitoring systems, implemented by GCWA and other entities within the Brazos Basin. GCWA will formally update the TCEQ Plan every 5-years, with the next formal update due to the TCEQ in 2024.

GCWA– Reclamation Planning Approach

Through the development of the TCEQ Plan and the Reclamation Plan, GCWA was guided by the plan requirements stipulated by Reclamation. These plan requirements, including the six essential elements (“Drought Monitoring,” “Vulnerability Assessment,” “Mitigation Actions,” “Response Actions,” “Operational & Administrative Framework,” and “Plan Update Process”) are addressed in detail below in the following Plan sections. The next section describes the Drought Task Force (“DTF”) formed to guide the Plan update process, and details the DTF-GCWA interactions throughout the project duration.

Drought Task Force & Guiding the DCP Update Process

To ensure that the updated DCP would be accepted by GCWA customers, GCWA formed a Drought Task Force (DTF) that would meet periodically throughout the project and provide feedback on the project progress and plan development. The DTF consisted of interested stakeholders committed to aiding GCWA in the drought contingency planning update. DTF membership was open to the public, yet GCWA direct customers as well as local regulators and officials were specifically invited to participate. Membership in the DTF was not fixed, and meeting attendance (while recorded) was not required. DTF members were kept informed of the plan progress via a website developed for the project, linked to the main GCWA website. DTF members were able to provide feedback directly to GCWA or LRE Water via email or via a comment section on the DCP Update website. When comments were provided, the comments were discussed at the subsequent DTF meeting.

Table 1 lists the dates of the DTF meetings conducted during this project effort, as well as provides a brief summary of the main topics of discussion of each meeting. All meetings were held at GCWA facilities, with the exception of the first and last meetings which were held at a large venue to accommodate the expected number of participants. Entities were also always able to participate online and via conference call, as each meeting was broadcasted via a GoToMeeting Invitation to interested participants. Presentations made at each meeting were posted to the DCP website immediately after the meeting, to aide in participant review and comments. Participant surveys were also conducted via “SurveyMonkey.com” to determine levels of “acceptable” curtailment DTF member organizations could accept, as well as to gauge interest in a proposed curtailment-trading scheme designed to minimize the potential impacts of curtailments on certain GCWA customers.

Table 1 – Drought Task Force Meetings – Dates and Topics

Meeting #	Date	Topic
1 - Kickoff	1/12/2017	Project Description, Solicit ideas/interest
2	4/17/2017	Detailed Work Plan Development, Review Existing DCP from GCWA, Customers, and BRA
3	7/17/2017	Project Website, Planning Dashboard, Water Loss Monitoring
4	10/17/2017	Climate Change Analysis, Flow Prediction Tool, Curtailment Rules
5	2/26/2018	Basin Hydrology, US Drought Monitor Review, Curtailment Survey Results, Curtailment Modeling, Canal Losses, Groundwater Usage
6	5/7/2018	Basin WAM Modeling, Groundwater Availability, Existing DCP Contents, Draft DCP Preparation & Review
7 -- TCEQ Plan Discussion	8/14/2018	Presentation of TCEQ Plan – V. 9, Hydrology Discussion, Request for Review & Comment

All communications between GCWA, LRE Water, and the project stakeholders (DTF members and other interested parties) were initiated based on terms of the Reclamation-approved Communications & Outreach Plan (“C&O Plan”) developed for this DCP update project. The C&O plan was designed to optimize stakeholder and public engagement in preparation of the GCWA DCP update. The C&O plan directed how information regarding the update will be made available to stakeholders and the public (via the DCP project website), how meetings will be announced (via the DCP project website and email reminders to DTF members and past meeting attendees), and how parties may provide information or comments during the project (via email to GCWA, LRE Water, or via the DCP project website).

The DCP project website was available during the duration of the project at the following URL:

<http://gcwa.lrewater.com/>

It was updated periodically through the project, and served as a central repository for all information regarding the project. The DCP project website will be active and accessible at the above address until 12/31/2019, at which time the website contents will be archived and possibly transferred to another GCWA website for GCWA continued maintenance. LRE Water, LLC will retain all archived website contents, including all correspondence, for a minimum of 3-years and will make all project information available upon receipt of written request. Material generated during this DCP update process will prove invaluable during the upcoming 2024 DCP update.

Upon adoption of the Reclamation and TCEQ Plans by GCWA, both plans will be available from the GCWA website at the following URL:

<http://gulfcoastwaterauthority.com/reports-studies-data/conservation/>

This URL will also contain updated drought stage triggers and response actions (compared to the 2012 TCEQ Plan currently posted), thus serving as the resource for GCWA customers working under the GCWA DCP.

Table 2 provides a list of the DTF members not employed by GCWA and who actively provided input during the DCP update process. DTF members guided the update process through answering surveys

regarding potential DCP components and offering insights into the benefits and difficulties to arise from the proposed actions. Survey results and DTF insights were always discussed at the next DTF meeting and were used to dictate meeting contents and ultimately the DCP components.

Table 2 – DTF Members & Affiliations

First Name	Last Name	Email	Affiliation
Bill	Alcorn	mud12@comcast.net	MUD 12
Robert	Gadbois	robert.gadbois@missouricitytx.gov	City of Missouri City
Shashi	Kumar	shashi.kumar@missouricitytx.gov	City of Missouri City
Chris	Cruz	ccruz@marathonpetroleum.com	Marathon Petroleum
David	Anton	dwanto@ascendmaterials.com	Ascend Materials
David	Davalos	ddavalos@dow.com	Dow Chemical Co.
Jerry	Dobbs	jerry.dobbs@valero.com	Valero
Kevin	Moore	kevinmoore@eastman.com	Eastman
Dennis	Stark	starkden@cityofgalveston.org	City of Galveston
Doug	Kneupper	dkneupper@texas-city-tx.org	City of Texas City
Jody	Hooks	jody.hooks@leaguecity.com	City of League City
San Leon MUD		slmud1@slmud.org	San Leon MUD
Scott	Elmer	elmer@missouricitytx.gov	City of Missouri City
Kyle	Jung	kjung@cityofmanvel.com	City of Manvel
Bobby	Gervais	BGervais@cityofmanvel.com	City of Manvel
Delores	Martin	dmartin@cityofmanvel.com	City of Manvel
Kirby	Brown	kbrown2@ducks.org	Ducks Unlimited
Glen	Lord	mglord@dow.com	Dow Chemical Co.
Dennis	Stark	dstark@galvestontx.gov	City of Galveston
Ross	Blackketter	rblackketter@galvestontx.gov	City of Galveston
Tim	Samford	tsamford@texas-city-tx.org	City of Texas City
Keith	Morgan	kmorgan@wcid1.com	Fort Bend WCID #1
John	Mitchiner	jmitchiner@wcid1.com	Fort Bend WCID #1
Terri	Gale	tlsgale@gmail.com	GCWCID #12
Nancy	McDonald	nancymcd@aol.com	WCID #12
Roselle	Bleile	calongrf@dow.com	Dow Chemical Co.
Angelo	Grasso	agrasso@galvestontx.gov	City of Galveston
James	McWhorter	jmcwhorter47@yahoo.com	City of Texas City
Nancy	Ragland	nancy.ragland@tceq.texas.gov	TCEQ
Katie	Clayton	kclayton@sugarlandtx.gov	City of Sugar Land
Debra	Davison	ddavison@cityofmanvel.com	City of Manvel
Daniel	McGraw	Daniel.McGraw@missouricitytx.gov	City of Missouri City
Les	Rumburg	l.rumburg@cityoflamarque.org	City of La Marque
Christopher	Dorow	christopher.dorow@basf.com	BASF
Andrew	Miller	amiller@slmud.org	SL MUD
Venkat	Venkatasubbiah	vvenkatasubb@marathonpetroleum.com	Marathon Petroleum
Richard	Matthews	rmatthews6490@gmail.com	Galveston County MUD12

Public Participation Opportunities within the DCP Update

GCWA always strives to conduct its operations in an open and transparent manner. All DTF meetings were open to anyone who wished to attend, and meetings were announced a minimum of two weeks prior to the meeting date. In preparation for the project kickoff meeting (1/12/2017), GCWA invited (via email) all individuals and entities with previous interactions regarding GCWA operations. During each meeting, participants selected the date of the next meeting, and this information was included in the meeting minutes which became immediately available upon the DCP project website. At each meeting, participants were encouraged to contact either GCWA or LRE Water directly with comments or information regarding the project. Comments were generally provided only by a select few of the DTF members (Table 2), and these comments were addressed privately via email prior to the next DTF meeting and then publically at the next DTF meeting. The majority of comments were received after the last DTF meeting, at which a draft DCP was presented. The provided comments highlighted many concerns the DTF members had with the draft DCP, and these concerns led to draft DCP revisions and ultimately the final DCP version as presented herein and in Appendix A. Each entity that submitted a comment after the last DCP meeting received a detailed email discussing the comment and how the comment led to any modifications between the draft and final DCPs. Copies of these emails will be included in the project archive.

Over the course of the project, two separate surveys were sent to DTF members and past meeting attendees. The first survey contained questions which were designed to gauge GCWA customer abilities to reduce their current demands during a drought period. Customers were asked if they could maintain basic operations with a 5%, 10%, 15%, 20% or greater reduction in available water. Customers were also asked about their notification preferences, specifically how long prior to implementing the reduction would they like to receive notice of the reduction. This information directly led to the development of the water use reduction goals included in the DCP (See discussion on Essential Element #4 – Response Actions) as well as in setting the 2-week flow prediction window incorporated into GCWA’s Flow Prediction Tool (FTP – See Essential Element #2 – Vulnerability Assessment). The second survey was designed to determine GCWA customer interest in the development and administration (by GCWA) of a “Cap-and-Trade” type system in which certain GCWA customers might be avoid (or lessen) reducing their water usage during a drought, while other customers would reduce usage to a greater extent to make the overall water usage meet the reduction goals. Under this scheme, the entities who reduced less than the desired goal would compensate those entities who reduced more than the desired goal. This scheme was favorably discussed during the 5/7/2018 DTF meeting, yet was found to be un-tenable based on the survey results. As such, the scheme was abandoned and not included as part of the final DCP presented herein.

The final DCP presented herein was ultimately crafted by LRE Water based on direct input from GCWA and the DTF. The DCP evolved over the course of the project, and the evolution was largely directed by input received during and as a result of the DTF meetings. Receiving stakeholder input (and acceptance) was crucial to the DCP development process. Future revisions to GCWA’s DCP will also include stakeholder and public input processes, as GCWA recognizes the importance of customer and public acceptance of proposed GCWA drought management actions.

Essential Element #1 – Drought Monitoring

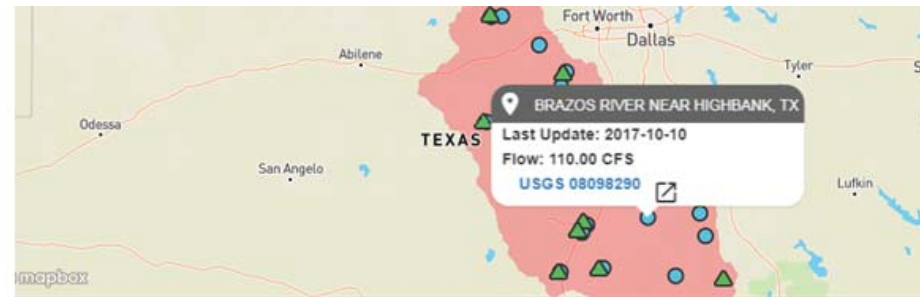
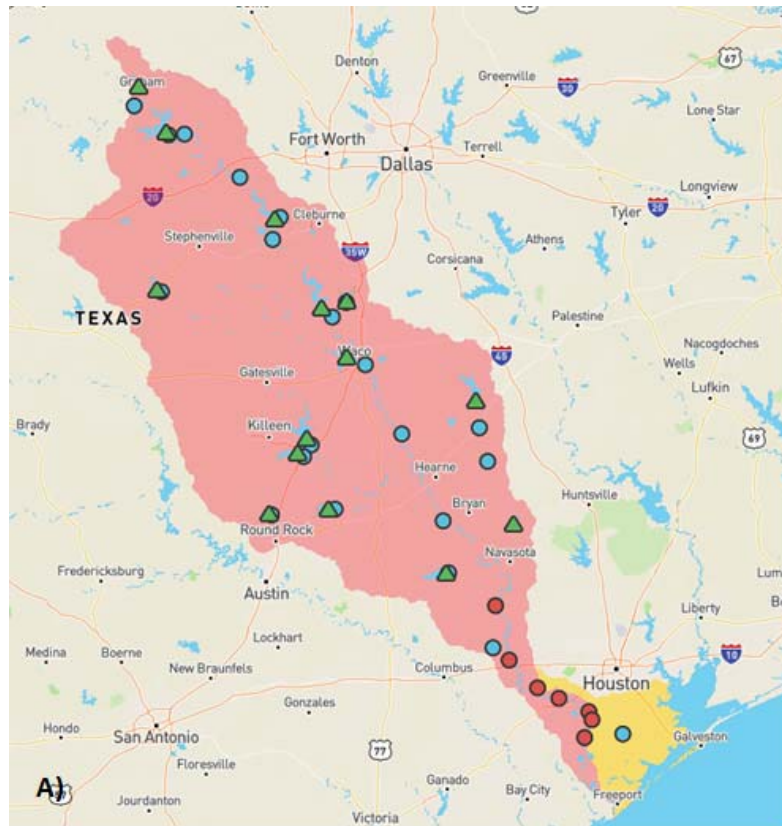
The purpose of the Drought Monitoring actions described herein is to provide information to GCWA to allow for informed assessment of available water supplies and demands within the GCWA service area. Such provided information will be used by the GCWA General Manager (or designee) in assessing hydrologic conditions and in consideration of the need to increase drought stages (and stage responses). As described in the Response Actions and Operational and Administrative Framework sections, information gathered through drought monitoring activities is to be used only to suggest drought responses. The GCWA General Manager (or designee) will CONSIDER such information when deciding whether or not to implement a higher or lower drought stage response; such decisions will not be made automatically based only on the drought monitoring information.

As described within the Detailed Work Plan for this DCP, efforts undertaken under the drought monitoring task were to include the development of an online data repository for Brazos Basin streamflow that would aide GCWA in analyzing and predicting drought conditions. The dashboard was created and made accessible at the URL:

<http://www.gcwa-dashboard.com>

The dashboard provided a map-based interface to Brazos Basin streamflow and reservoir water level gauges, and would update daily through the executing of a Matlab program which obtained data from USGS websites, processed data into usable formats, stored the data in GCWA databases, and displayed the data through the dashboard (Figure 3). Aside from displaying streamflow data, the dashboard also displays reservoir water level time-histories and time-histories of reservoir storage (total storage and storage as a percentage of conservation storage).

Along with real-time and historical data, the GCWA dashboard also displays predicted stream flow at certain locations within the study area. These predicted streamflows were created utilizing the “Flow Prediction Tool (FPT)” (Appendix B), designed to assess streamflows up to 2-weeks (14 days) into the future and compare those flows against the expected water needs of all permitted water diverters in the Lower Brazos Basin (including GCWA, Dow Chemical Company, and NRG Energy). Figure 4 shows sample results from the FPT for the period from 9/15/18 to 10/6/18. Specifically, the FPT routes downstream known releases from water supply reservoirs within the Brazos Basin, and then determines streamflows to be expected at select locations, including at the USGS gauge locations (Hempstead, Richmond, and Rosharon) as well as at the locations of GCWA pump stations. The FPT tool relies upon travel time and conveyance loss data provided by the Brazos River Authority, and is most accurate under dry (low flow, low rainfall) conditions. As shown in Figure 4, the FPT results contain 3-weeks of data. The first week of displayed results corresponds to the week prior to the date of execution of the FPT program. During this time, it is possible to compare real-time streamflow gauge data (shown in GREEN) against the predicted streamflow (shown in RED), thus providing an assessment of the potential validity of the FPT’s predictions. The 2nd and 3rd weeks of data provided by the FPT are predicted streamflows. Figure 4 also shows the monthly streamflow target(s) representing the minimum streamflow needed to satisfy the needs of all Lower Basin water right holders (black lines). The monthly streamflow targets are discussed in the “Vulnerability Assessment” Section. FPT graphical output, like Figure AC, can be utilized by GCWA



Selected Results



Figure 3– GCWA Dashboard for Storing & Displaying Brazos Basin Watershed conditions (streamflow and reservoir information). A) Map view showing the entire contributing area for GCWA, as well as stream gauges, reservoir gauges, the GCWA canal system, and location

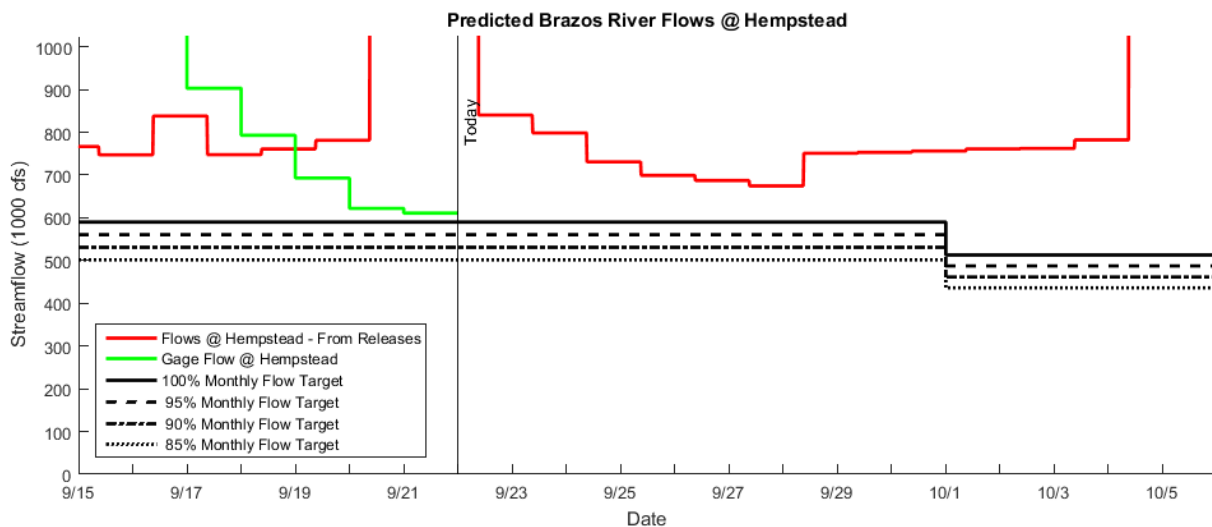


Figure 4– Flow Prediction Tool (FPT) results for the Brazos River at Hempstead, showing observed (green) and predicted (red) flows for the period 9/15/18-10/6/18. Also shown are the computed GCWA Monthly Flow Targets (Discussed in the Vulnerability Assessment Section). FPT results provide a visual assessment of the likelihood that near-term future stream flows will be lower than those needed to satisfy the needs of GCWA customers and other water users in the Lower Brazos Basin.

staff to quickly assess whether it is necessary to implement any of the drought response measures discussed in the “Response Actions” section.

Additional drought monitoring activities developed during this DCP update include monitoring methods utilizing data from the US Drought Monitor (Appendix C). The US Drought Monitor data for Texas is obtainable at:

<http://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?TX>

Drought Monitor data is maintained by National Drought Mitigation Center (University of Nebraska at Lincoln), the US Department of Agriculture, and the National Oceanic and Atmospheric Administration. Data is produced nationwide and updated every Thursday. Drought data is produced graphically and in ArcGIS format, allowing visual and quantifiable assessment of drought conditions in specific regions of interest. GCWA decided to utilize US Drought Monitor data in its assessment of the onset of Stage 1 drought conditions under its revised DCP. Routinely reviewing US Drought Monitor data has become common amongst GCWA staff and customers in charge of water usage and operational decisions, which led to inclusion of the drought monitor data with the GCWA DCP. Figure 5 shows how GCWA utilizes the US Drought monitor data to assess drought conditions within its “contributing watershed.” Specifically if GCWA determines that over 50% of its contributing watershed is classified as a “D1-Moderate Drought” or higher by the US Drought Monitor, then GCWA will consider entering Stage 1 of its DCP.

Along with the dashboard, FPT results, and data from the US Drought Monitor, GCWA requested additional information regarding basin streamflow in order to make operational decisions regarding water diversions, contract water releases, and possible demand curtailment. Specifically GCWA staff requested the creation of a drought monitoring system which automatically obtains data, processes data, and formats the data into an easily understandable customized summary. Staff desired such data to be automatically emailed to select GCWA email addresses, and that the data/email be easily readable from mobile devices as well as desktop or laptop computers. This utility was developed in conjunction with the Matlab program used to update and populate the GCWA dashboard with data for points of interest in the Brazos River basin. Figure 6 shows the tabular data emailed to GCWA accounts, and Figure 7 presents a graphical representation of Brazos Basin reservoir storage contents; this graphic accompanies the tabular emailed data as an emailed attachment. Figure 8 is another graphic attached to the email detailing expected releases from Brazos Basin reservoirs based on the reservoir operating rules; this graphic is only created and emailed if at least one of the reservoirs is above conservation pool elevation.

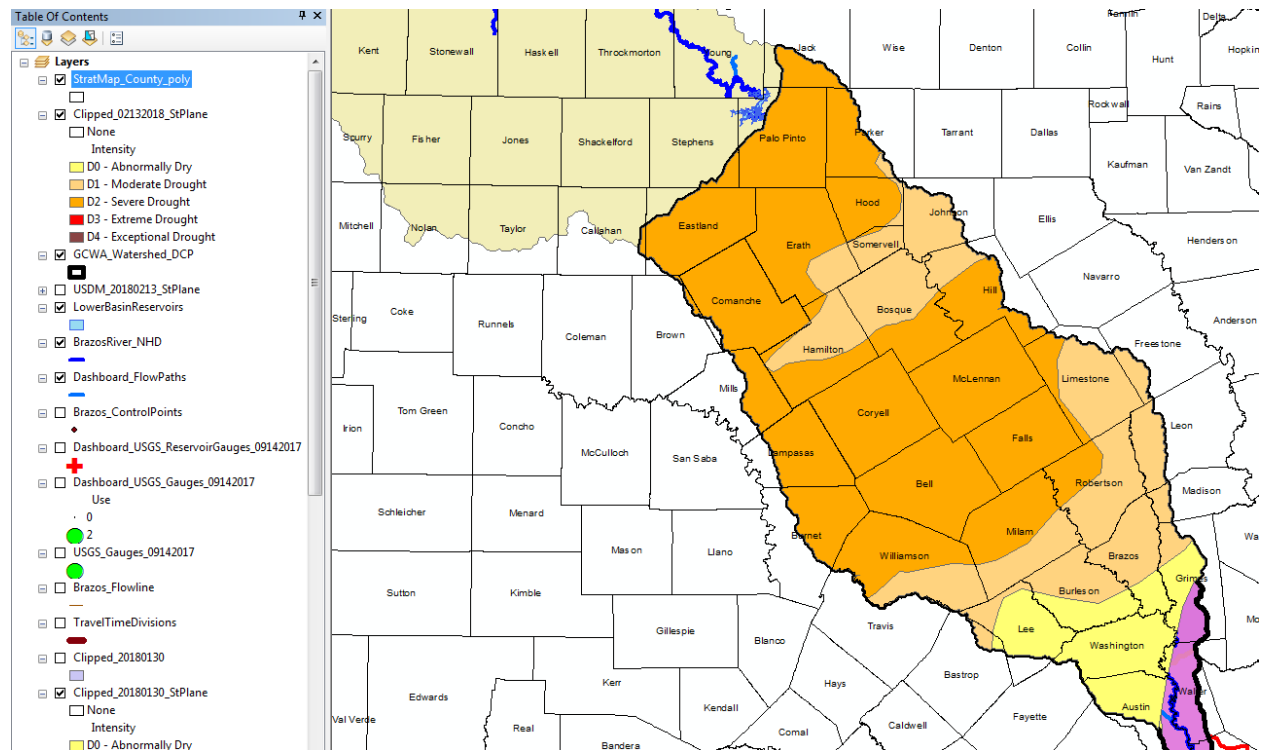


Figure 5 – Usage of US Drought Monitor Data to assess conditions within the GCWA “Contributing Watershed” – within ArcGIS, GCWA clips the nation-wide drought monitor data to the watershed upstream from GCWA, and determines what percentage of the watershed is experiencing what levels of drought. If over 50% of the GCWA contributing watershed is experiencing D1-Moderate Drought or greater, then GCWA will consider entering Stage 1 Drought Conditions.

RESERVOIR	STORAGE	%	STATUS	CHANGE FROM PREVIOUS DAY
Possum Kingdom	= 527,803 acre-ft	(100.75%)	INCREASING	1,803 acre-ft
Granbury	= 125,433 acre-ft	(100.18%)	INCREASING	378 acre-ft
Whitney	= 553,521 acre-ft	(99.88%)	INCREASING	5,664 acre-ft
Aquilla	= 46,826 acre-ft	(105.07%)	INCREASING	1,552 acre-ft
Stillhouse Hollow	= 284,716 acre-ft	(124.97%)	INCREASING	4,750 acre-ft
Belton	= 463,310 acre-ft	(106.45%)	INCREASING	10,412 acre-ft
Proctor	= 55,834 acre-ft	(100.68%)	INCREASING	189 acre-ft
Granger	= 62,364 acre-ft	(122.82%)	INCREASING	8,296 acre-ft
Georgetown	= 40,415 acre-ft	(109.51%)	INCREASING	1,807 acre-ft
Somerville	= 166,437 acre-ft	(113.14%)	INCREASING	17,267 acre-ft
Limestone	= 211,924 acre-ft	(101.88%)	INCREASING	3,768 acre-ft

System-Wide:				
Current	= 2,538,583 acre-ft	(105.37%)		
Yesterday	= 2,482,699 acre-ft	(103.05%)	Change =	55,884 acre-ft
One Week Ago	= 2,532,527 acre-ft	(105.12%)	Change =	6,056 acre-ft
Three Months Ago	= 1,965,454 acre-ft	(81.58%)	Change =	573,130 acre-ft
One Year Ago	= 2,167,261 acre-ft	(89.96%)	Change =	371,322 acre-ft
Recent Low	= 1,447,266 acre-ft	(60.07%)	Change =	1,447,266 acre-ft (8/10/2011)

Streamflow Records (cfs):				
	Current Flow	12/7/2018 Average Flow		
Whitney	= 618 cfs	522 dcfs		
Waco	= 4,860 cfs	2,180 dcfs		
HighBank	= 10,900 cfs	4,180 dcfs		
Bryan	= 23,800 cfs	15,800 dcfs		
Hempstead	= 36,100 cfs	13,400 dcfs		
San Felipe	= 26,900 cfs	13,100 dcfs		
Richmond	= 21,300 cfs	13,900 dcfs		
Rosharon	= 25,700 cfs	13,700 dcfs		

Figure 6 – Sample Daily Text Emailed Automatically to GCWA Staff – detailing basin reservoir storage content, changes from the previous day, recent trends in reservoir storage, current streamflow and streamflow from the previous day. For users familiar with the locations of each reservoir and stream gauge, this information allows for easy assessment of watershed conditions, aiding GCWA staff in system management and drought monitoring.

As shown in Figure 6, the daily email provided to select GCWA staff contains information regarding status of water resources in the basin. All data is based on data provided by the US Geological Survey. The upper section of the email contains the current quantity of water stored in the basin reservoirs from which GCWA may receive BRA contract water. This information is obtained from USGS published water level data, translated into storage data using the most updated reservoir elevation-area-capacity curves published by the Texas Water Development Board. Along with the current storage, the reader is informed how the storage level changed from the previous day, and by how much. The middle section of the email provides a historical look at the combined water storage in all listed reservoirs, and provides the change in combined storage over time. The third email section contains streamflow at the USGS gauges on the Brazos River within the GCWA watershed. Gauges are listed in geographical order from North to South, and provided as current flow (at the time the program is executed) and as a daily averaged flow from the previous day. Recipients can utilize this information to assess the likely future quantity of water to arrive at GCWA pumping stations (located between the San Felipe, Richmond, and Rosharon gauges).

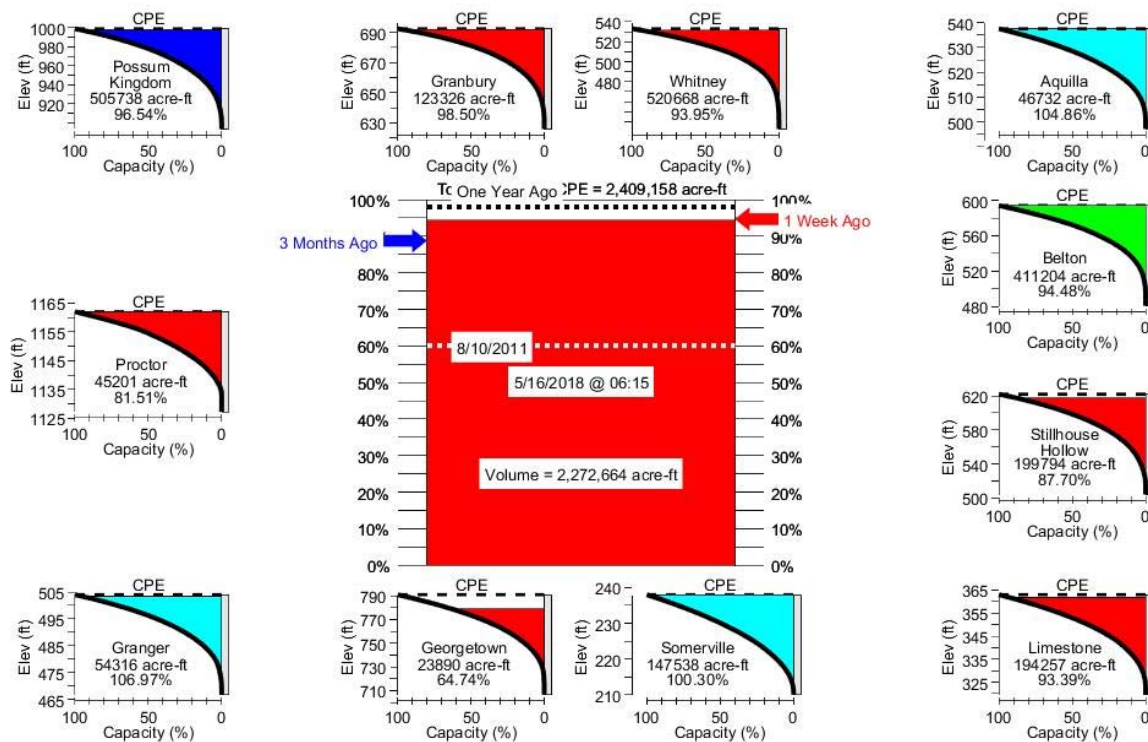


Figure 7 – Graphic Emailed to GCWA Staff depicting storage contents and trends of BRA reservoirs. Individual reservoirs are shown around the perimeter, with the composite storage shown in the center. Dark blue indicates storage increased from the previous day; red indicates storage decreased from the previous day. Cyan indicates that the reservoir is currently storing more than conservation storage and is releasing water from the flood pool. Green indicates no change from the previous day (usually due to a gauge malfunction).

Figure 7 displays the graphical representation of reservoir storage content in the Brazos River basin, as emailed to GCWA staff on a daily basis. Recipients can quickly assess the capacity of the basin's reservoirs, as well as the day-to-day storage trends for individual reservoirs. Daily, 1-week, 3-month, and 1-year trends in composite reservoir storage are also provided. Colors within the graphic indicate trends in reservoir storage as follows:

- Dark Blue – Increasing Storage from Previous Period (ex. Possum Kingdom Reservoir in figure)
- Red – Decreasing Storage from Previous Period (ex. Lake Limestone in figure)
- Cyan – Reservoir is releasing water from the flood pool (ex. Granger Lake in Figure)
- Green – Reservoir storage is steady from the Previous Period (ex. Belton Lake in Figure)

As it is rare that reservoir inflows exactly balance evaporative losses and outflows on a given day, the green color in such graphics typically indicates a gauge malfunction or missing data in the USGS files.

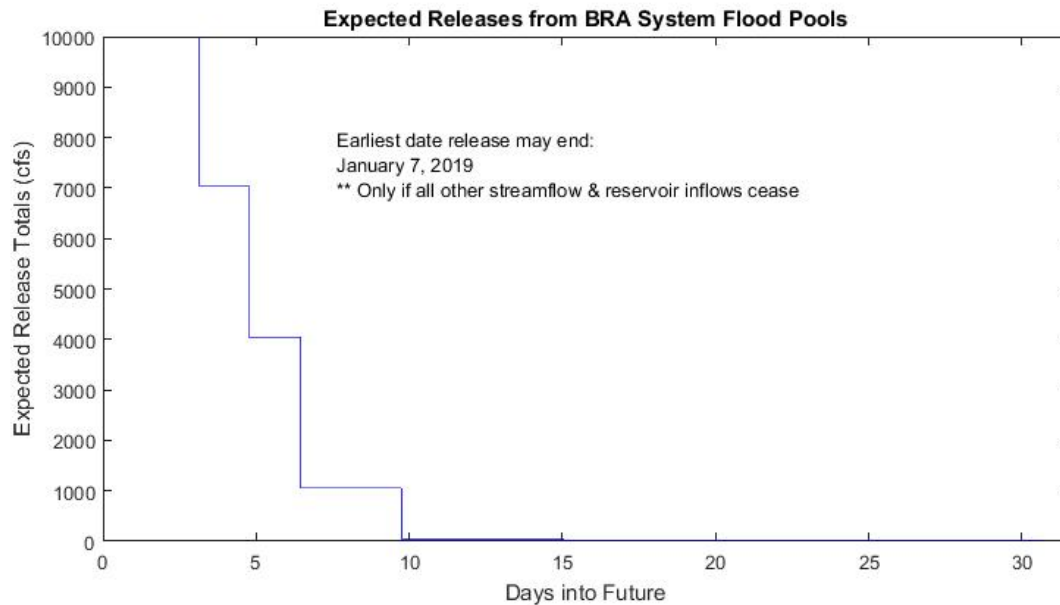


Figure 8 – Expected Releases from Brazos River Authority (BRA) reservoirs based on reservoir operating rules. Releases are determined for each reservoir with storage currently in the flood pool. Releases are shown cumulatively for all reservoirs in the flood pool, and are predicted into the future based on the current storage in each reservoir, downstream flow conditions in the basin, and the reservoir release rules developed by the BRA and US Army Corps of Engineers.

Figure 8 depicts a second graphic emailed to GCWA staff, yet this graphic is only created when one or more of the basin reservoirs is releasing water from its flood pool. When a reservoir's storage exceeds its conservation storage capacity and water is within the reservoir flood pool, reservoir releases are dictated by published operating rules. These rules specify the release rates based on downstream conditions and the quantity of water within the reservoir flood pool. Release rates for all applicable reservoirs are computed into the future and combined into the graphic shown above, providing the recipient with a predicted duration of releases. This data provides GCWA staff with knowledge regarding how long streamflows are likely to remain elevated. In Figure 8, releases are to exceed 1000 cfs for the next 5 days, after which they will continue for another 10 days yet at a much lower release rate. The graphic also provides the future date at which releases will end, assuming no further reservoir inflows occur and other basin conditions do not change. Figure 8 is only created and emailed to GCWA staff when one or more reservoirs is in flood stage; during prolonged drought periods this graphic is not likely to be created. However the graphic does provide GCWA with useful knowledge about the watershed conditions and can assist in water resources management by GCWA.

Essential Element #2 – Vulnerability Assessment

In general, the purpose of the “Vulnerability Assessment” is for GCWA to understand the risks to its water supply under threat of drought. As originally envisioned, work under this heading was to involve statistical assessment the hydrologic data from the dashboard, with a goal to predict likely streamflow condition up to six months in advance. This section will outline the streamflow prediction methods developed for GCWA, as well as the modeling efforts undertaken to help GCWA understand its ability to reliably provide water to its customers.

As of January 2019, GCWA has committed to delivering to customers firm customers 274,319.52 acre-ft/yr (244.88 MGD). To determine the actual water volume diverted by GCWA, it becomes necessary to increase delivered quantities by canal loss factors, which vary depending upon the location of the GCWA customer diversion along the canal system. For modeling purposes, GCWA assumes canal losses amount to 24% at the end of its canal system, and lower percentages for diversions located upstream from the end of the canal system (See “Mitigation Actions” Section). By including canal losses, GCWA calculated that their needed diversions (from the Brazos River and other water sources) must total approximately 342,424 acre-ft/yr (305.68 MGD) to meet the demands of firm customers. Additional water demands for interruptible customers (mostly for rice irrigation) may also be satisfied by GCWA, yet interruptible supplies are determined annually and are reduced based on firm customer demands.

Historically, GCWA customers have not used all of the water they have under contract with GCWA. Figure 9 presents the usage of GCWA firm customers in 2017 as a percentage of their contracted water quantities. As shown, only Ashland utilized over 70% of its firm contract quantity in 2017, and some customers (Pearland, Galveston, and Texas City) did not use any of their contract quantities. Most GCWA firm contract holders have simply reserved more water than currently needed in order to ensure sufficient future water supplies to meet their anticipated future needs. In total, GCWA’s 2017 usage by firm customers amounted to 154,600 acre-ft (138 MGD).

GCWA requested that efforts to assess the vulnerability of its water supplies be tailored to determine its ability to obtain sufficient water to meet both historical usage quantities (as in Figure 9) and its contractually obligated supplies to firm customers.

Vulnerability Assessments via Water Balance Modeling

To assess vulnerability of its water supplies, GCWA utilizes water availability models which are essentially mass-balance accounting models that divide available water among eligible water users according to State of Texas water allocation rules. For this purpose, the State of Texas has developed a monthly-timestep Water Availability Model (WAM). GCWA has also developed a daily-timestep model (“GCWA Daily-Hydro”) which applies water allocation rules to water users in the Lower Brazos Basin downstream of Hempstead. GCWA favors utilizing this daily-timestep model because it factors into the allocation process items such as GCWA pumping limitations, daily fluctuations in Brazos River water levels, and greater customization (allowing GCWA to experiment with different water management scenarios and options). For this project, GCWA utilized Version 7 of the GCWA Daily Hydro model (“V7”) to assess water reliability and various curtailment strategies. The V7 model is also preferable over the available WAM model because it runs on non-naturalized streamflow data, which is readily available for the period 1939-Present. As such the model is capable of simulating water availability for GCWA during the most severe dry years, including 1956 and 2011.

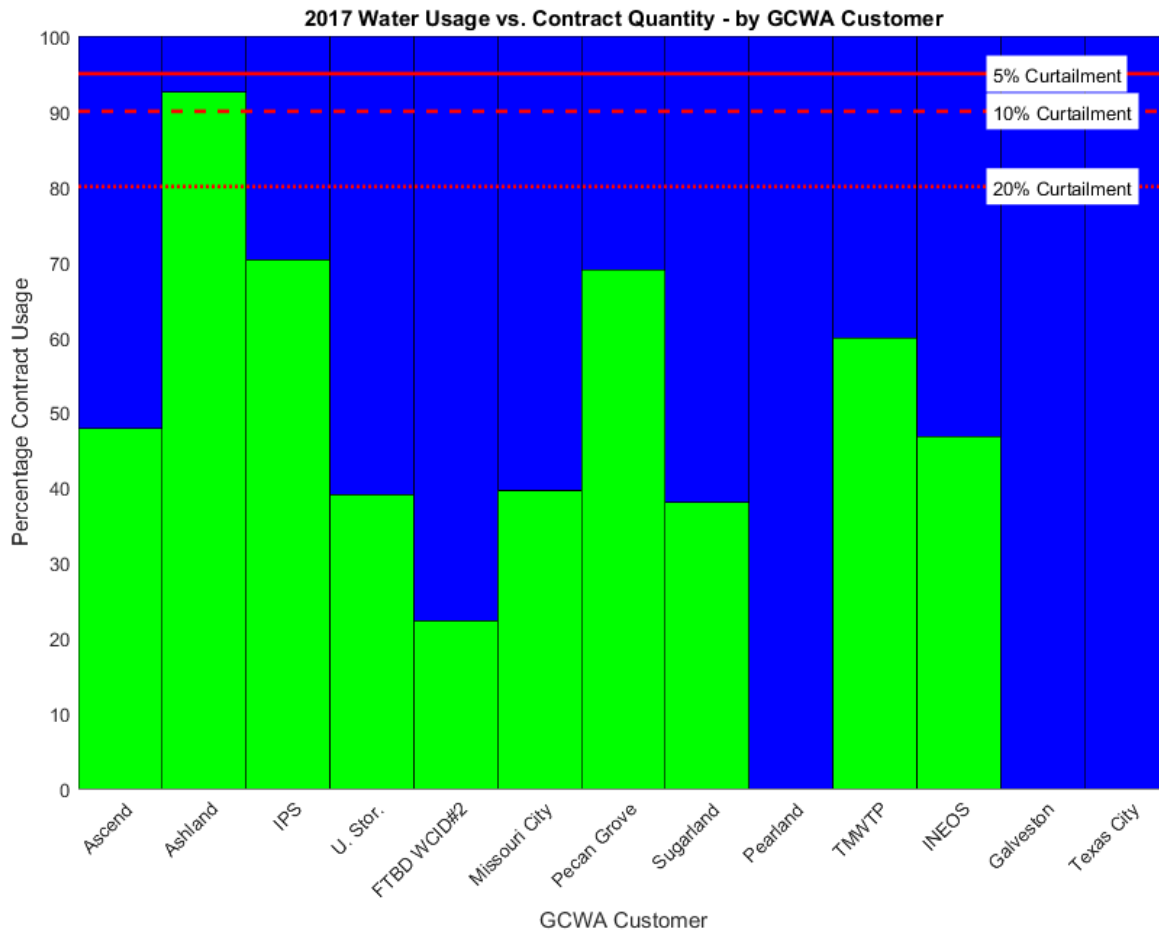


Figure 9 – 2017 Water usage by GCWA firm customers, showing that nearly all customers used less than 70% of their contractual allotment.

Another benefit of the V7 model over the WAM model is that within V7, any shortages incurred by GCWA may be satisfied through the usage of water supplied under contract with the Brazos River Authority (BRA). This “contract water” essentially serves as insurance for GCWA as it is used when GCWA is unable to obtain water under its own water rights. GCWA maintains numerous long-term contracts with BRA, each with differing rules regarding water usage, contract quantities, Brazos River delivery losses, etc. The V7 model considers all these rules when utilizing the contract to satisfy shortages in diversions made under GCWA’s own water rights. The V7 model can also simulate the impact of any short-term contract water GCWA may obtain from BRA or other entities. However for assessing vulnerability in this effort, the V7 model only utilized the long term contracts GCWA has with BRA, totaling 44,569 acre-ft/yr as delivered to the GCWA pump stations along the Brazos River. The BRA, through WAM modeling performed on its behalf (not presented here) has determined that GCWA’s contract water is 100% reliable and will always be available for GCWA usage.

To assess the vulnerability of its water supply, including the sufficiency of GCWA’s contract water with BRA, the V7 model was set to simulate two years of severe drought – specifically with river flows from 2011 followed by stream flows from 1956. This approach is fairly conservative, as historical hydrology in the Brazos Basin has rarely included two consecutive extremely low-flow years.

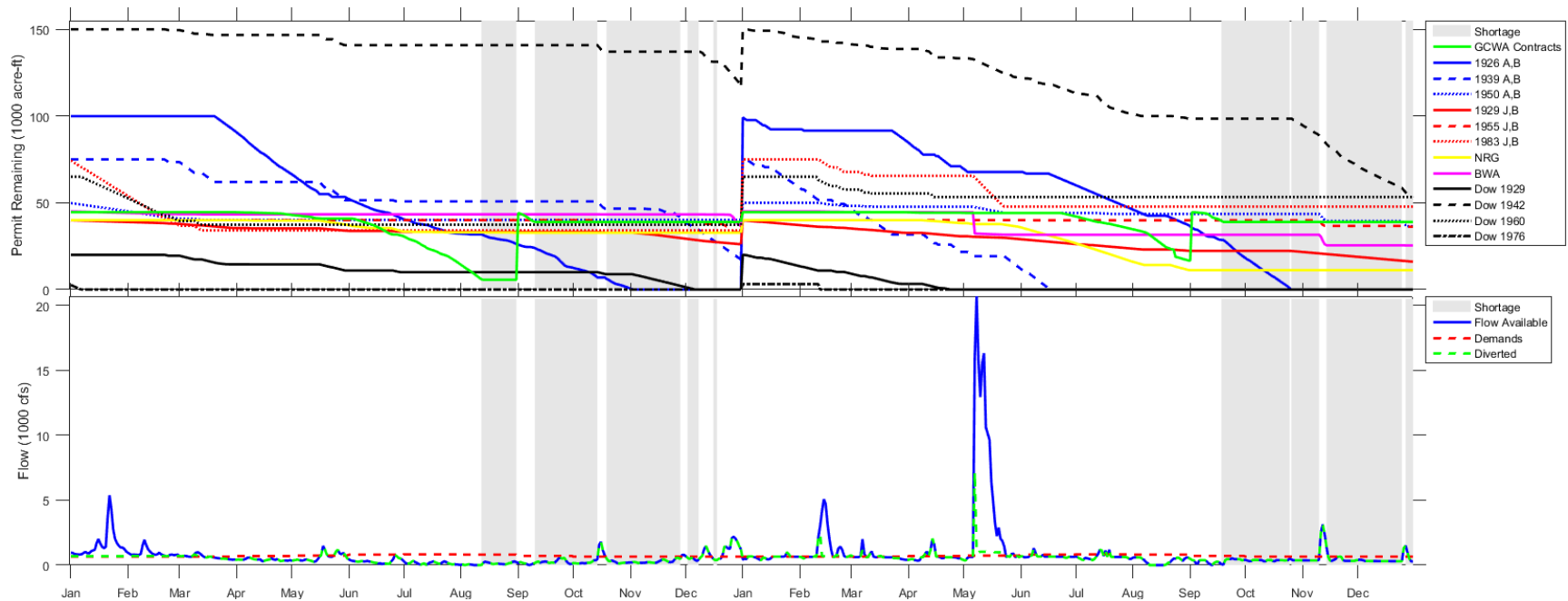


Figure 10 – GCWA Daily Hydro (V7) modeling of water availability in the Lower Brazos Basin, simulating two consecutive extremely dry years (2011 followed by 1956), with GCWA attempting to satisfy full firm contract demands and associated canal-system losses.

Results from the V7 modeling (Figure 10) indicate that GCWA will experience shortages when attempting to meet all firm customer demands. The shortages occur at the end of the calendar year (August-December), and result from the fact that streamflow is extremely low during these periods. Shortages are eliminated when streamflow temporarily increased, as evident in mid-October 2011 and mid-November 1956. Based on the modeling presented in Figure 10, GCWA would have experienced shortage of 39,440 acre-ft in simulated 2011, followed by 42,255 acre-ft in simulated 1956. These shortages amounted up to 350 cfs per day.

Figure 11 presents V7 results for an identical simulation, yet with GCWA having the freedom to utilize its BRA contract water whenever needed. In the V7 simulations generating Figure 10, GCWA was prohibited from using some of its BRA contracts from September-December, in an effort to conserve those contracts for use in the summer of the following year. This conservation is necessary as the majority of the GCWA contracts with BRA renew on a fiscal-year basis, defined by the BRA as September-August. As such, if GCWA were to use up contract water in October, the

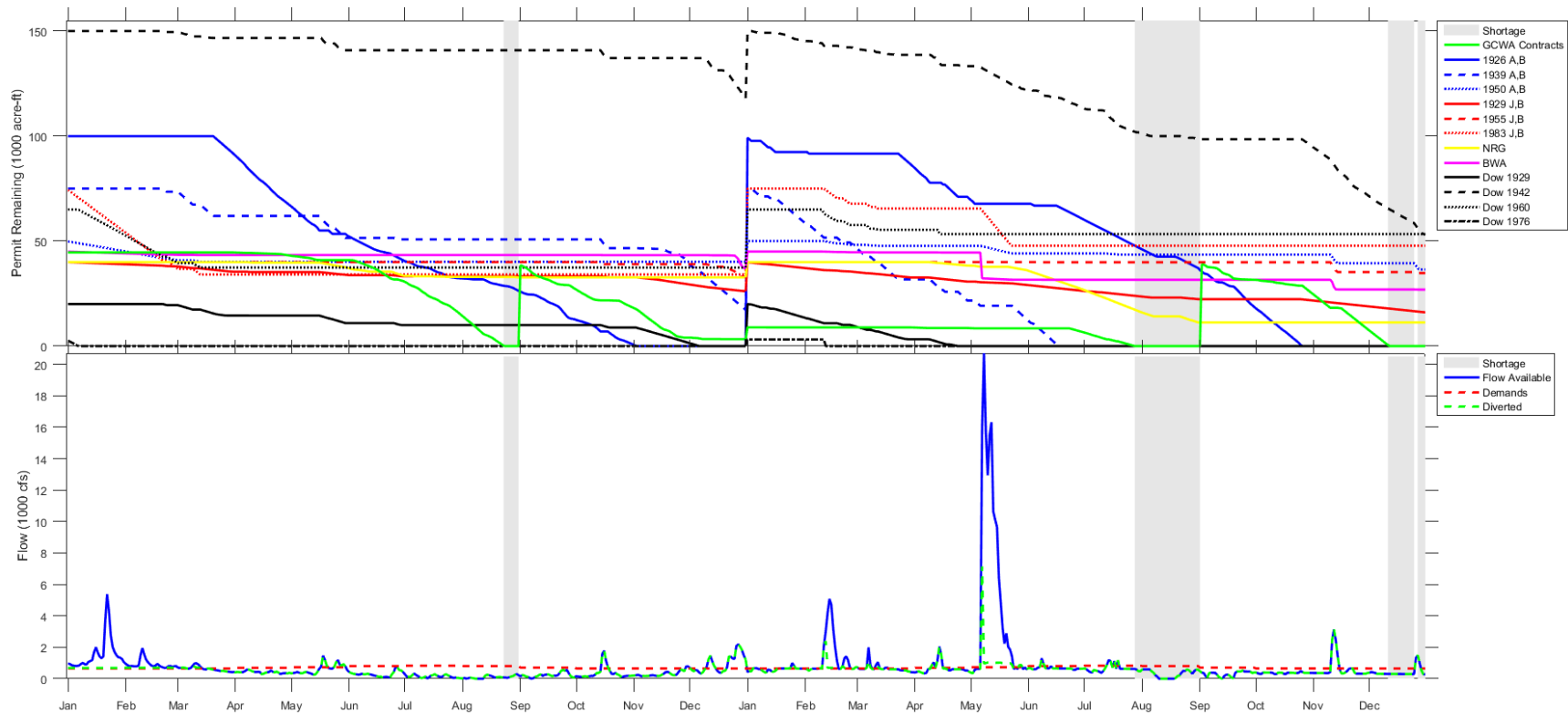


Figure 11 – GCWA Daily Hydro (V7) modeling of water availability in the Lower Brazos Basin, simulating two consecutive extremely dry years (2011 followed by 1956), with GCWA attempting to satisfy full firm contract demands and associated canal-system losses. In this simulation, GCWA could utilize available BRA contract water whenever needed, resulting in reduced shortages.

water would not be available until the contracts had renewed the following September, thus putting GCWA potentially at risk if the June-August months were low streamflow periods.

As shown in Figure 11, freedom to utilize BRA contracts when needed greatly reduces the times at which modeled shortages occurred. Total shortages amounted to only 3,776 acre-ft in 2011 and 25,355 acre-ft in 1956. The maximum daily shortage, however, increased to 400 cfs. More troubling, however, is the observation that by the end of 1956 (the second modeled year), GCWA's available contract water from BRA was depleted. Thus if the modeled drought extended into a third year, GCWA's shortages would have likely increased, possibly significantly.

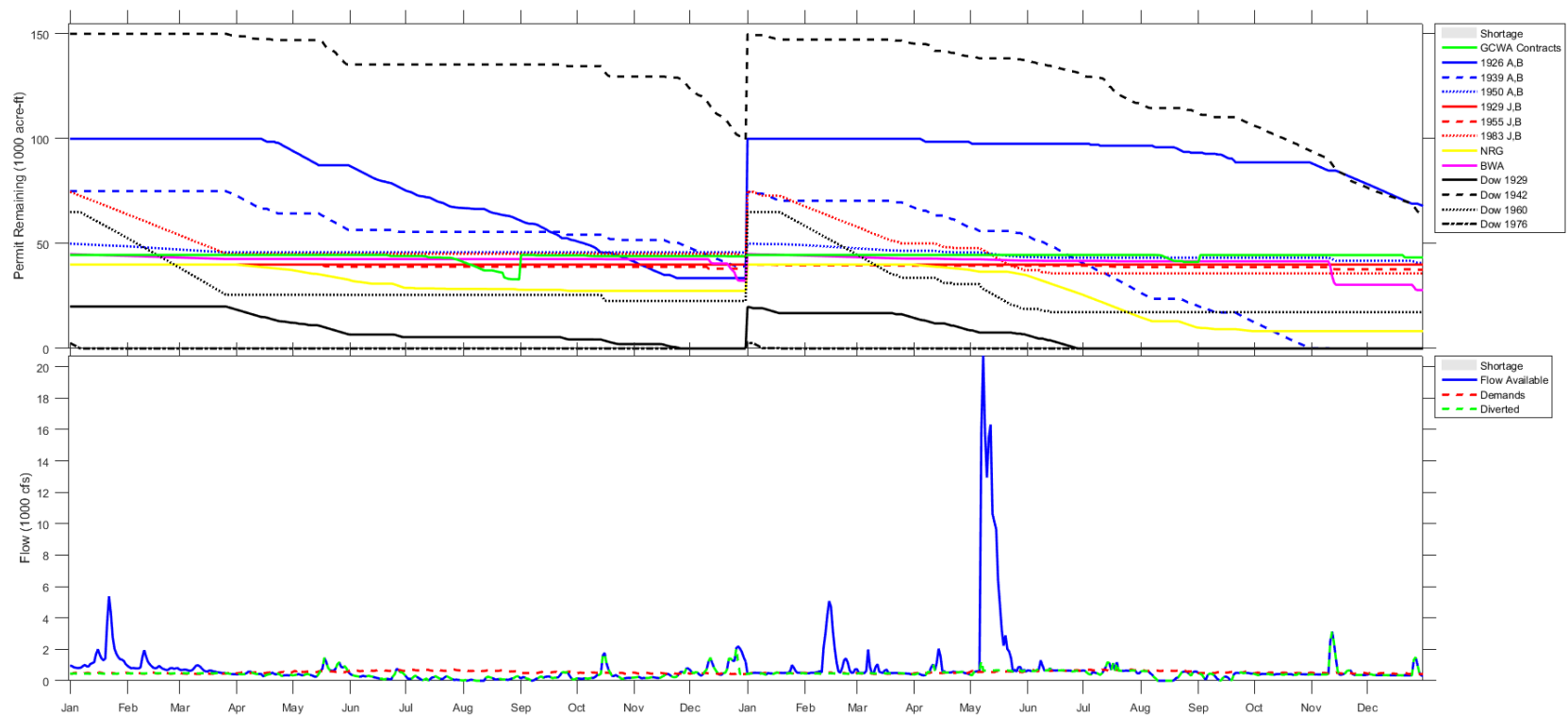


Figure 12 – GCWA Daily Hydro (V7) modeling of water availability in the Lower Brazos Basin, simulating two consecutive extremely dry years (2011 followed by 1956), with GCWA attempting to 2017 firm customer demands and associated canal-system losses. In this simulation, GCWA did not experience shortages, and only minimally utilized contracts with BRA.

As shown in Figure 12, GCWA will not experience shortages if attempting only to meet 2017 firm customer demands, and it does so without using very much of its contract water with BRA. This indicates that until GCWA firm customer usage approaches full contractual obligations, shortages can generally be avoided and BRA contract water is generally sufficient to make up any differences between demand and run-of-river supplies available to GCWA.

In assessing the modeling results shown in Figure 10-Figure 12, it is necessary to consider that assumptions inherent in the V7 algorithms will not necessarily reflect the management actions of GCWA, the BRA, or the Brazos Basin Watermaster (who has ultimate responsibility for making

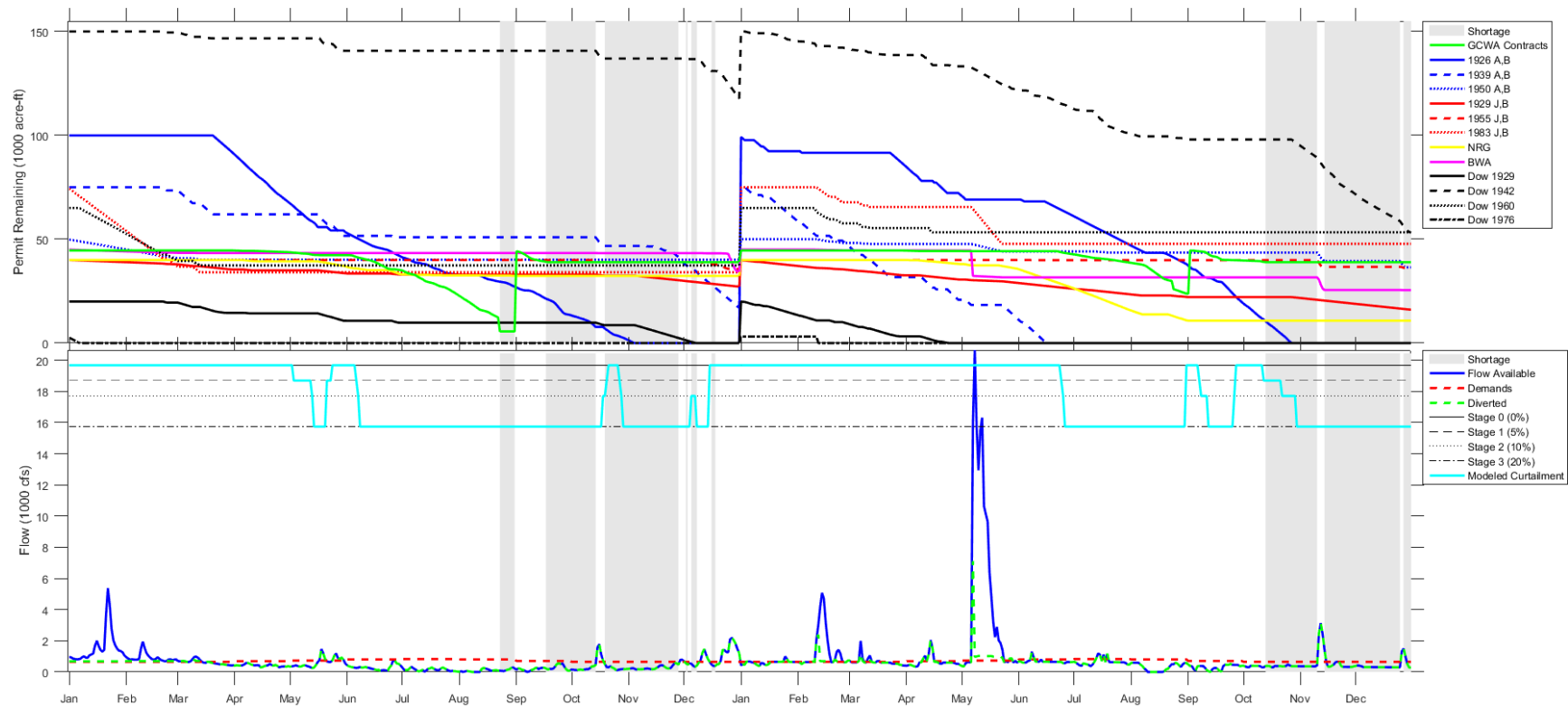


Figure 13 – GCWA Daily Hydro (V7) Modeling of water availability in the Lower Brazos Basin, simulating two consecutive extremely dry years (2011 followed by 1956), with GCWA attempting to satisfy full firm contract demands and associated canal-system losses. In this simulation, GCWA implements the demand curtailment rules in place per its existing 2012 Drought Contingency Plan. Shortages are diminished but not eliminated.

water allocations during drought periods). For instance, the V7 model assumes allocation decisions will always be made based on the priority system, yet the Watermaster may implement alternate allocation methods that could reduce water to GCWA during drought periods.

In Figure 13, the V7 model results are presented assuming GCWA must limit BRA contract usage in September-December, and assuming firm contract demands can be curtailed according to the existing 2012 GCWA Drought Contingency Plan. Under the 2012 plan, Stage 3 droughts

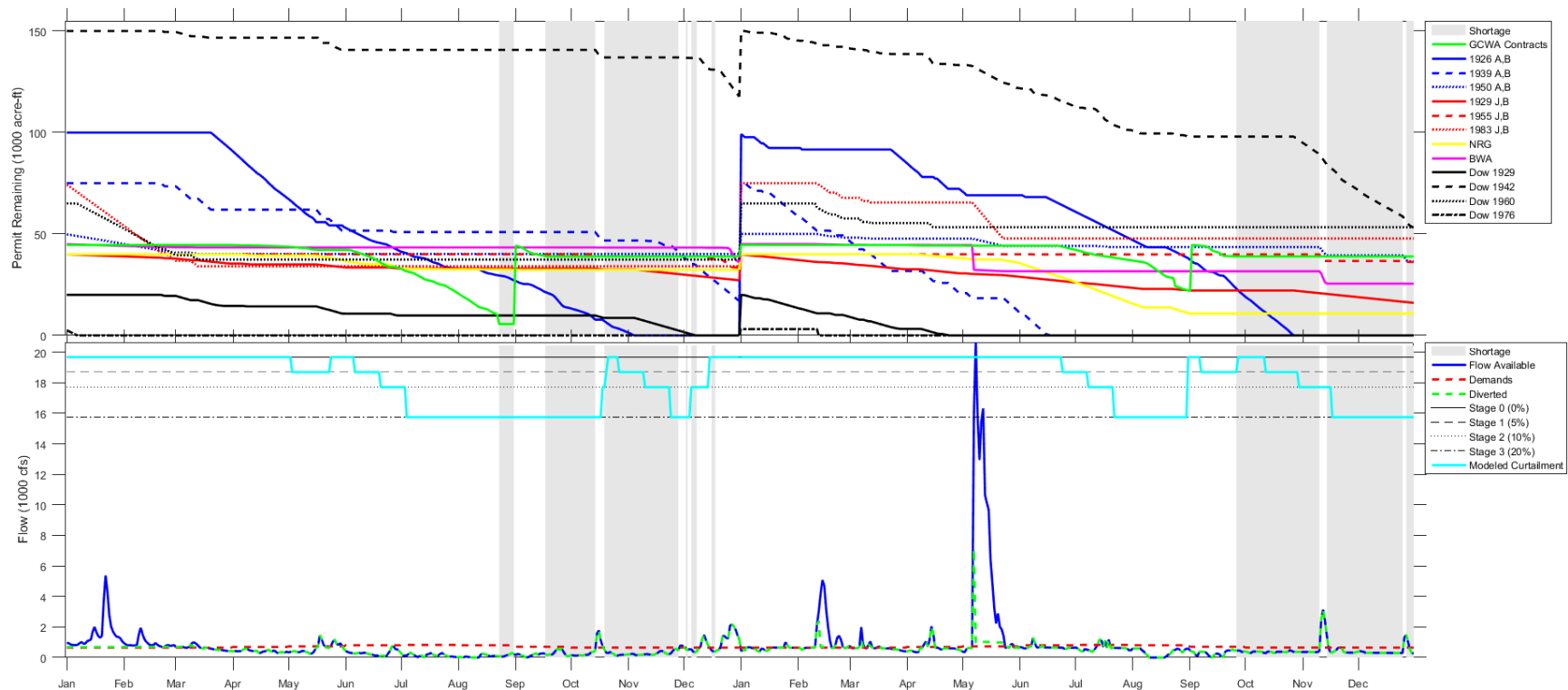


Figure 14 – GCWA Daily Hydro (V7) Modeling of water availability in the Lower Brazos Basin, simulating two consecutive extremely dry years (2011 followed by 1956), with GCWA attempting to satisfy full firm contract demands and associated canal-system losses. In this simulation, GCWA implements the demand curtailment rules in place per its existing 2012 Drought Contingency Plan, yet with the requirement that 2-weeks must pass before a higher drought stage can be implemented. This requirement, while beneficial to GCWA customers, leads to an increase in annual shortages compared to results shown in Figure 13.

request a 20% reduction in firm demand, with lower reductions requested at lower drought stages. As shown in Figure 13, through the 2-year simulation, it was often necessary to enter Stage 3 drought status, with generally rapid transitions from Stage 0 (Normal operations) to Stage 3. Such rapid transitions would likely be difficult to implement for GCWA firm customers. Through the demand curtailment, shortages are reduced to 21,554 acre-ft in 2011 (from 39,440 acre-ft, See Figure 10) and to 31,794 in 1956 (from 42,255 acre-ft, See Figure 10). These reductions are beneficial, yet it is evident that the existing DCP does not provide full drought protection under these modeled circumstances.

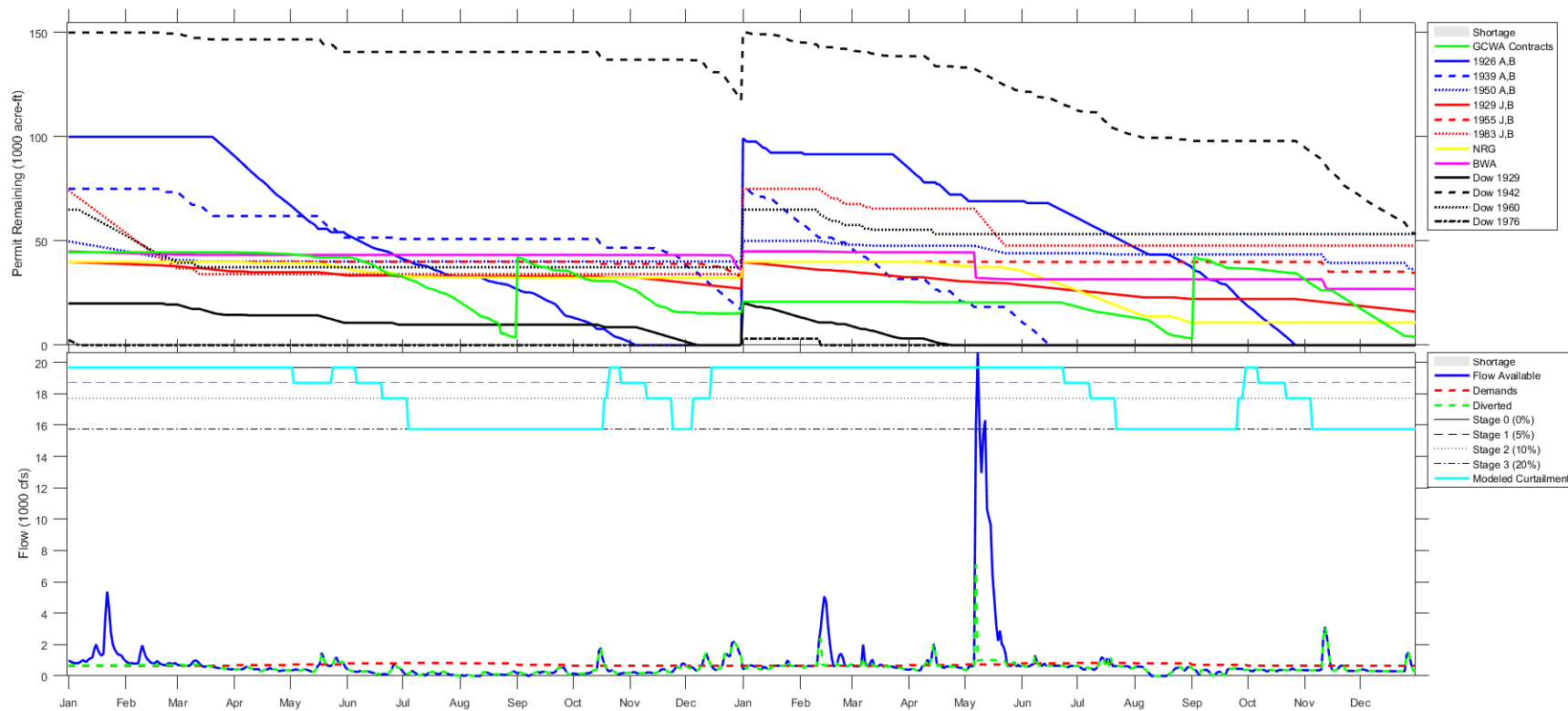


Figure 15 – GCWA Daily Hydro (V7) Modeling of water availability in the Lower Brazos Basin, simulating two consecutive extremely dry years (2011 followed by 1956), with GCWA attempting to satisfy full firm contract demands and associated canal-system losses. In this simulation, GCWA implements the demand curtailment rules in place per its existing 2012 Drought Contingency Plan and has full freedom regarding usage of BRA contract water. Under these modeled circumstances, shortages are eliminated and some contract water is conserved for use in an extended drought.

In Figure 14, results are shown from the V7 model using 2012 Drought Contingency Plan rules, yet requiring a minimum of 14-days at each drought stage before entering a higher drought stage (with increased curtailment). This scenario would allow GCWA customers to better adjust their processes and operations in order to tolerate less water availability. Modeling results still indicate shortages incurred later in the year, with

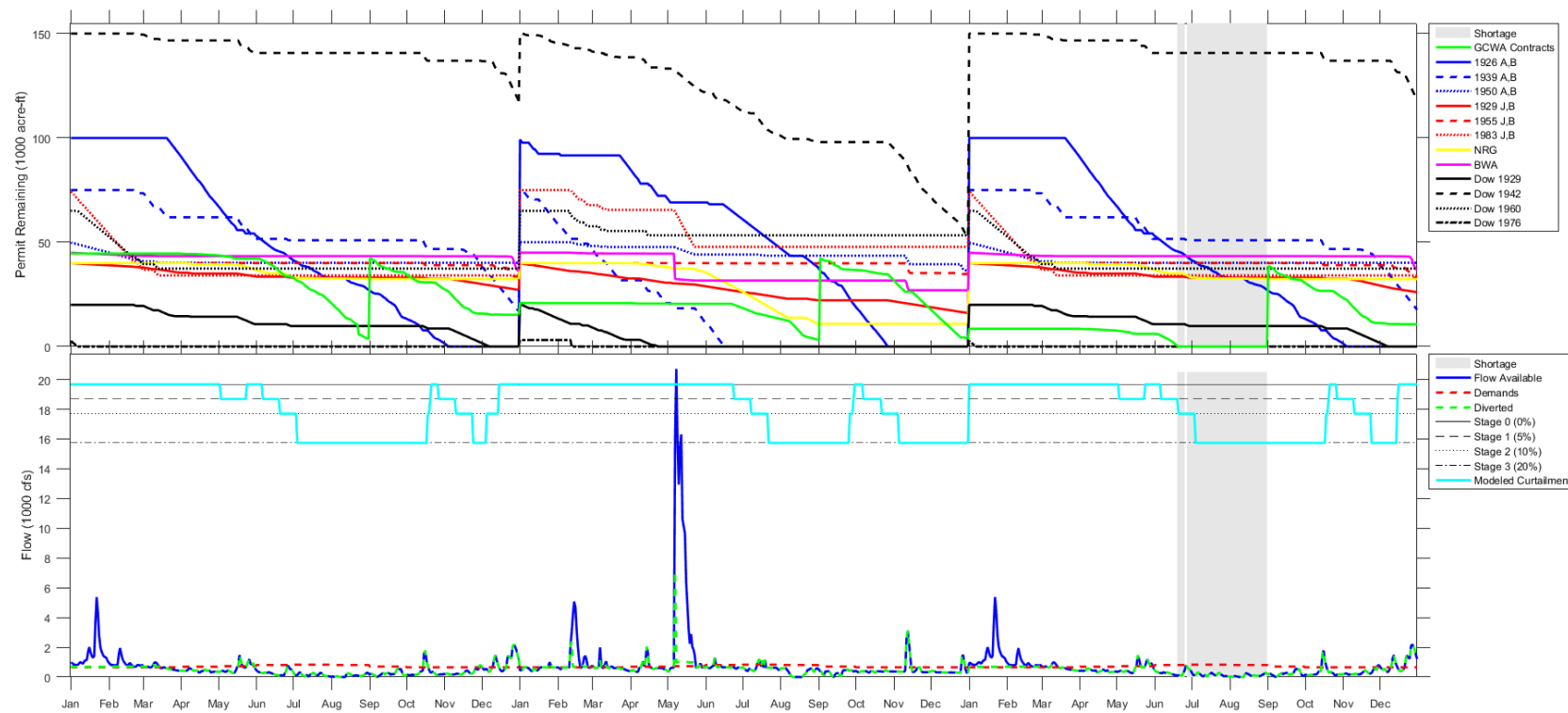


Figure 16 – GCWA Daily Hydro (V7) Modeling of water availability in the Lower Brazos Basin, simulating three consecutive extremely dry years (2011, 1956, and 2011 again), with GCWA attempting to satisfy full firm contract demands and associated canal-system losses. In this simulation, GCWA implements the demand curtailment rules in place per its existing 2012 Drought Contingency Plan and has full freedom regarding usage of BRA contract water. Under these modeled circumstances, shortages are eliminated only in the first two modeled years, and shortages occur in the third year once contract water has been fully utilized.

the total modeled shortages of 23,704 acre-ft/yr in modeled 2011, with a 33,734 acre-ft shortage in modeled year 1956. These shortages are larger than those computed without the 14-day requirement prior to transitioning to higher drought stages (Figure 13).

Figure 15 presents V7 results including the existing curtailment rules (from GCWA's 2012 DCP) and assuming GCWA may freely use BRA contract water whenever needed. As shown, Stage 3 curtailment is still common, yet all modeled shortages have been eliminated. At issue here, however, is the relative lack of remaining contract water GCWA retains at the end of the 2nd modeled year, thus making it likely that shortages would occur if the following year were also dry. This assertion is presented in Figure 16, which shows results from 3 consecutive years of dry conditions (2011, 1956, and 2011 again).

Figure 16 presents results from a 3-year simulation (2011, 1956 and 2011 repeated), with a modeled shortage of 29,000 in the third year. This demonstrates that GCWA's current level of contract water with the Brazos River Authority is insufficient to avoid shortages during an extended drought, even with implementation of the 2012 drought contingency plan. This suggests GCWA would benefit from obtaining additional water sources other than those currently available. It should be noted, however, that for the period 1940-2018, the Lower Brazos Basin has not experienced three consecutive years of severe drought as simulated in Figure 16.

Table 3 presents the model-computed shortages for the scenarios depicted in Figure 10-Figure 16. It is evident that GCWA, based on historical hydrology, should be able to satisfy recent customer demands as well as full contract demands through efficient operation of its canal system and management of available contract water from BRA. Obtaining additional contract water would be beneficial if GCWA were to experience a prolonged severe drought of duration longer than two years. Limiting restrictions on contract water usage is a key component to reducing shortages to be experienced by GCWA.

Table 3 – GCWA Daily Hydro (V7) Modeled Shortages

Figure	Years	Notes	Shortage
10	2011 1956	Full Demands Limited Contract Usage Without 2012 DCP	39,440 acre-ft 42,255 acre-ft
11	2011 1956	Full Demands Freed Contract Usage Without 2012 DCP	3,776 acre-ft 25,355 acre-ft
12	2011 1956	2017 Demands Limited Contract Usage Without 2012 DCP	0 acre-ft 0 acre-ft
13	2011 1956	Full Demands Limited Contract Usage With 2012 DCP	21,554 acre-ft 31,879 acre-ft
14	2011 1956	Full Demands Limited Contract Usage With 2012 DCP & 14-day Stage Minimum	23,704 acre-ft 33,737 acre-ft
15	2011 1956	Full Demands Free Contract Usage With 2012 DCP & 14-day Stage Minimum	0 acre-ft 0 acre-ft
16	2011 1956 2011	Full Demands Free Contract Usage With 2012 DCP & 14-day Stage Minimum	0 acre-ft 0 acre-ft 29,000 acre-ft

Figure 17 presents computed annual shortages for the period 1940-2018 using the GCWA Daily-Hydro model (V7), set so that contract water quantities at the end of one model year are available at the beginning of the next model year. As shown, only in two out of the 79 modeled years did GCWA experience a shortage. Model simulations utilized full customer demands, free contract usage, and the 2012 DCP with the 14-day stage duration minimum. Figure 17 demonstrates that at least for the period of record of the V7 model, severe droughts of durations exceeding 2 years are extremely rare.

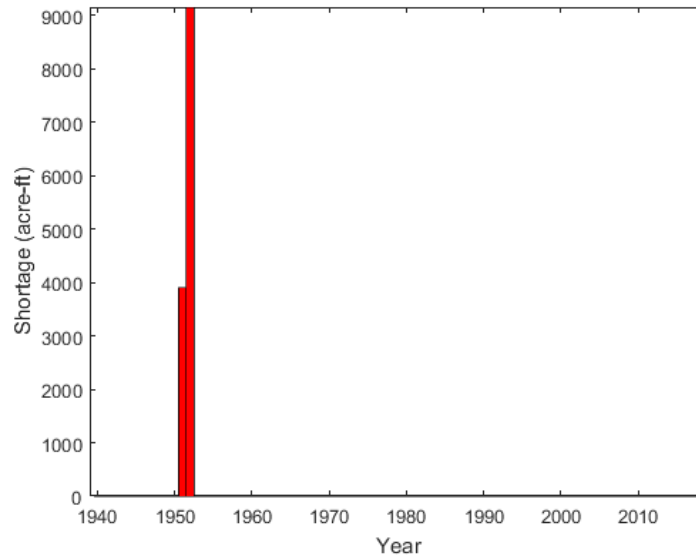


Figure 17 – Modeled Annual Shortage for 1940-2018 from the GCWA Daily-Hydro Model (V7), assuming full demands, free contract usage, the 2012 drought contingency plan in-place yet modified to include a 14-day required transition period prior to increasing drought stages. Only in 1951-1952 would GCWA not been able to satisfy demands per the 2012 Drought Contingency Plan.

Vulnerability Assessment using the Flow Prediction Tool (FPT)

As detailed in the Drought Monitoring Section, GCWA created a “Flow Prediction Tool” (FPT) which was designed to predict Brazos River streamflow at GCWA pump stations for up to 2 weeks into the future. The FPT is detailed in Appendix B of this plan, but is detailed here with respect to how it is used to assess immediate drought vulnerability for GCWA.

Statistical analysis of lower basin hydrology (gauge records, and reservoir water levels) indicated that while some seasonal trends are evident, the trends are not reliable enough to utilize in the prediction of long-term basin streamflow or reservoir contents. However shorter term predictions in streamflow did prove viable, especially under the assumptions used in the FPT. Based on a survey of the drought task force members (DTF), it was found that most GCWA customers would prefer longer advanced notice of curtailment measures to be implemented under the DCP. As such GCWA strived to develop the FPT so that it could provide up to two weeks (14 days) of advanced notice for when stream flows were likely to be insufficient to meet customer needs. DTF members also were not confident that any “sophisticated, statistically based” prediction algorithms would provide meaningful Brazos River streamflow predictions with any greater accuracy than simpler methods or common guesswork. As such, GCWA abandoned all efforts to statistically predict streamflows and reservoir storage contents, in favor of a simple routing model based on travel times and loss rates published by the Brazos River Authority.

Specifically the FPT tool predicts streamflow within the Lower Brazos Basin by routing known releases from upstream reservoirs downstream through the Brazos flow network (i.e. the Brazos River and its tributaries). Travel times between reservoirs and the downstream prediction locations are fixed by BRA, and do not vary based on flow rate. In addition, flow losses are fixed along the flow network, and also do not vary with flow rate. Losses are assumed even though numerous studies and statistical analyses have

proven that the Brazos River is often a “gaining” stream, with flows increasing in the downstream direction due to watershed contributions and groundwater influxes. Hence the FPT is likely to provide the most accurate predictions of future Lower Brazos streamflow only when the entire basin is in drought conditions, with little to zero flow contribution from the watershed or underlying aquifer.

Results of the FPT, shown in Figure 4 and reproduced in Figure 18, include a graphical depiction of the time-series of observed and predicted flows at a given location. From the figure, it is possible to compare 1-week of measured and predicted streamflow data, which allows GCWA to assess how well the assumptions inherent in the FPT reflect actual basin conditions. This assessment may help GCWA in evaluating the “accuracy” of the predicted streamflow for the future 2-week period. However, the key result of the FPT, for the purposes of the vulnerability assessment, is the comparison between the predicted streamflow and the “Monthly Flow Targets” shown in the graphic.

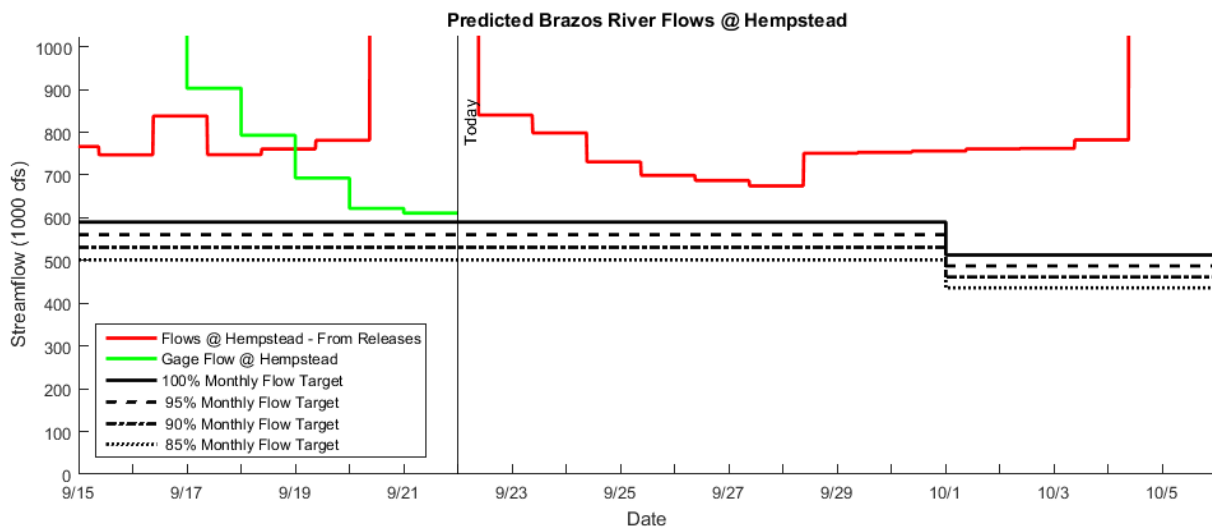


Figure 18 – Flow Prediction Tool (FPT) results for the Brazos River at Hempstead, showing observed (green) and predicted (red) flows for the period 9/15/18-10/6/18. Monthly Flow Targets reflect the computed needs of Lower Brazos water users, and can be compared against the predicted streamflow assess immediate drought vulnerability. Reproduced from Figure 4.

In utilizing the FPT predictions to make demand management/curtailment decisions as part of this revised DCP, GCWA needed to compare the predictions to some base level of streamflow. The “Monthly Flow Targets” represent the monthly-averaged streamflow needed to meet the diversion needs of all Lower Brazos water users, including GCWA customers. The targets include the channel losses within the GCWA canal system, as well as an averaged monthly estimate of water needed by each GCWA customer. To compute the average customer water needs, GCWA utilizes its historical diversion records, and takes an average of the monthly diversions for the past three years. For example, if Customer X diverted 10, 20, and 18 acre-ft in July of 2016, 2017, and 2018, respectively, then GCWA would estimate that they will require 16 acre-ft in July of 2019 (i.e. 16 acre-ft is the average of the customer’s diversions for the three previous Julys). GCWA would then adjust this estimate upward based on a canal loss factor (relative to the customer’s location on the GCWA canal system), and sum the total customer needs (along with needs from Dow Chemical Company and NRG Energy) to compute the Monthly Flow Target. As such, if the FPT predicts that streamflows over the next two weeks are likely to dip below the

monthly flow target, GCWA can consider implementing a higher stage in its drought contingency plan, or it can take other measures to ensure sufficient water supplies are being delivered to customers.

Vulnerability Assessment Using Climate Change Analysis for GCWA

In Texas, water availability is officially determined, for permitting purposes, using the State of Texas Water Availability Models (WAMs). Water availability for GCWA is determined based on the Brazos & San Jacinto-Brazos WAM model, referred to herein as “bwam3.” The bwam3 model simulates water availability according to the Texas prior-appropriation system, and determines the monthly amount of water available for each water right holder in the basin. The simulation “period of record” for the bwam3 model is from 1940-1998. GCWA owns three separate water rights on the Brazos River, with each right having between 1 and 3 separate diversion quantities and priority dates. Therefore GCWA’s Brazos River water rights are modeled as 6 different water rights within the bwam3 model. To determine the quantity of water available to GCWA on a monthly basis, it is necessary to add up the diversions made under each of GCWA’s 6 modeled water rights.

To assess the impacts of climate change on water availability for GCWA, it is necessary to expand the modeled period of record for the bwam3 model. To expand the period of record to time periods prior to 1940, a statistical correlation analysis was performed using PDSI data from tree ring studies (Cleaveland et al, 2011). To expand the period of record to time periods after 1998, correlations were attempted using precipitation and temperature predictions from downscaled Global Climate Models (GCMs) and measured streamflow from 1940-1998. Neither the tree-ring analysis nor GCM analysis yielded highly-confident correlations, yet the modeling results are still useful in assessing the potential severity of droughts likely to be experienced by GCWA.

Water Availability Modeling Using Tree-Ring Data – 1500 to 1999

In their 2011 paper “Extended Chronology of Drought in South Central, Southeastern, and West Texas,” Cleaveland et. al detailed their utilization of tree rings to re-construct the Palmer Drought Severity Index (PDSI) for the period 1500-2011. Figure 19 presents the extended the PDSI data as annual values and as a 5-year rolling average. As shown, the PDSI values are highly variable, and the period from 1500 to 1940 (pre-WAM model period of record) indicates that there were numerous instances when the climate was both wetter and drier than in the modeled period of record. Also based on the 5-year rolling PDSI averages, there appear to have been numerous moderate drought periods for the Lower Brazos Basin, including many prolonged drought periods that are longer in duration than the 1950’s drought period (which is recognized as the drought of record for the Brazos Basin. It is notable that the recent drought period (2005-2016) appears to be the most severe, based on the 5-year rolling average PDSI values.

The PDSI data from Figure 19 was used to develop a correlation between PDSI and naturalized streamflow in the Brazos River near Rosharon. The correlation yielded a reasonable fit ($R^2 = 0.6$) between the naturalized flows in the bwam3 model (1940-1998) and predicted flows based on the PDSI for the same time period. This correlation was then utilized to determine the naturalized streamflow at Rosharon for the period 1500-1940. Naturalized streamflow was then created for the entire Brazos River basin for the period 1500-1940 by applying a separate relation between the Rosharon naturalized flows and all other naturalized flows within the model. Any resulting negative streamflows were set to zero. Figure 20 presents modified bwam3 model results for the period 1500-1998, showing water reliability for GCWA over this period.

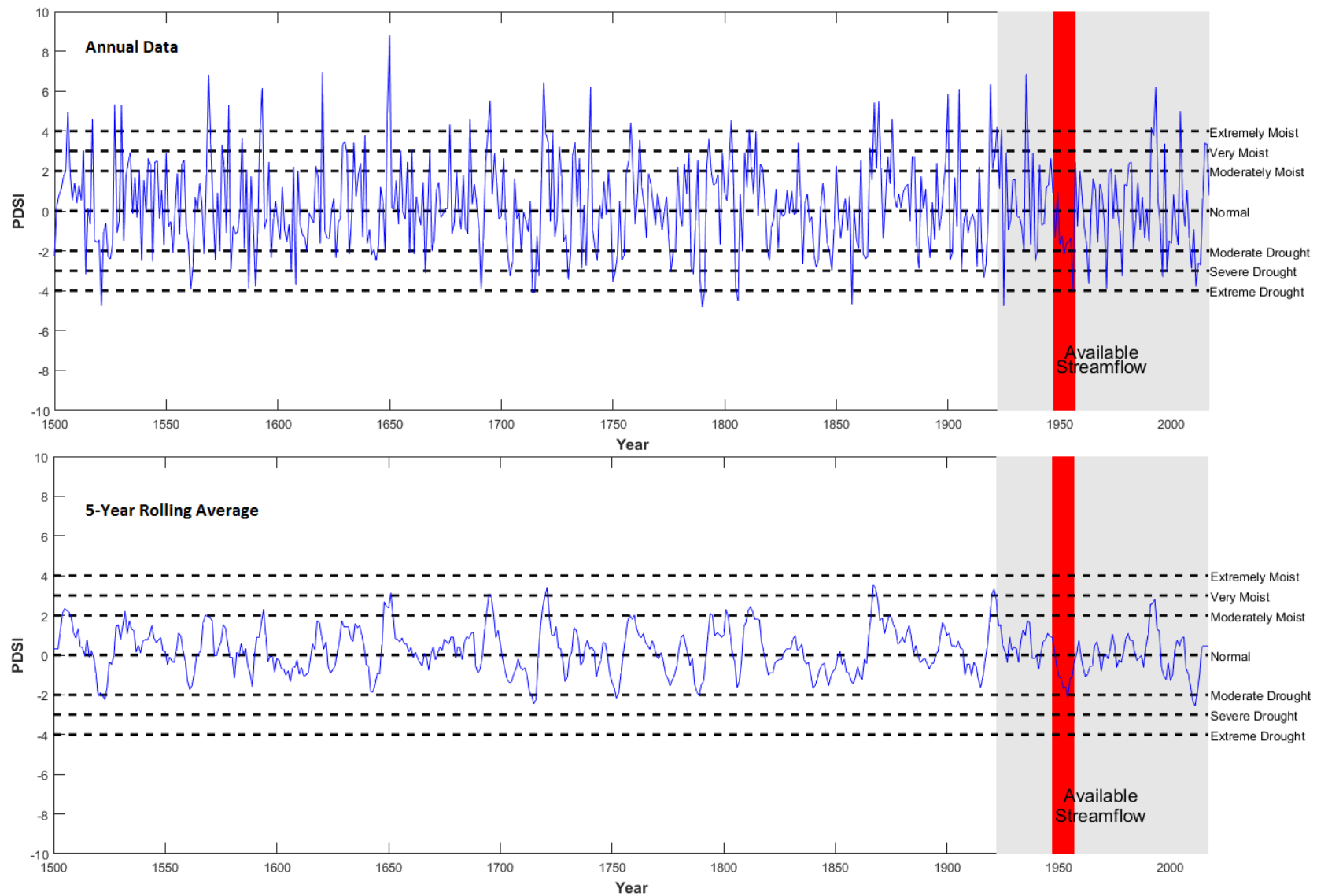


Figure 19 – PDSI Values for the Lower Brazos Basin – 1500 to 2017

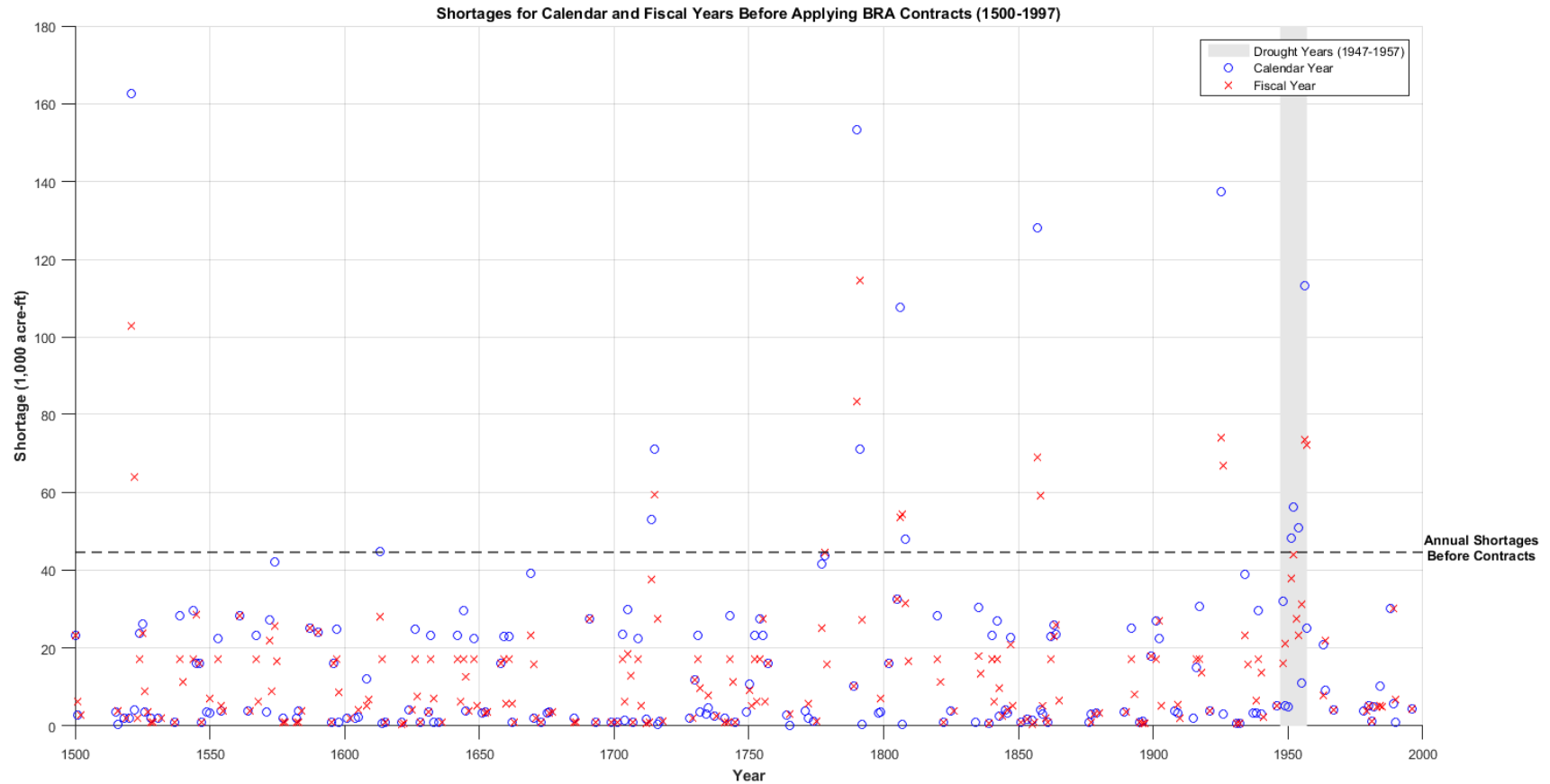


Figure 20 – Modeled shortages by year for GCWA, based on full contractual demands (337,150 acre-ft/yr). Shortages are determined monthly, and may be reduced or eliminated through the use of GCWA contract water from the BRA. While shortages existed in most modeled years, in only 9 of the 499 modeled calendar years (1.8%) were shortages in excess of GCWA’s contract quantities from BRA.

As shown in Figure 20, GCWA was routinely unable to divert sufficient water quantities under its water rights in order to avoid monthly water shortages. However, in only 9 of the 499 modeled calendar years (1.8%) was GCWA unable to eliminate shortages through the use of contract water from the BRA (based on currently held long-term contracts between GCWA and BRA). Similarly, in only 13 of the 499 fiscal years modeled was GCWA unable to fully meet full contract customer demands through both Brazos River diversions and BRA contract water usage.

Water Availability Modeling Using Global Climate Models – 1950 to 2099

To assess how future climate change may affect GCWA's ability to satisfy customer demands, attempts were made to utilize results of Global Climate Models and correlate those results to available naturalized streamflow data. GCM results were obtained for the period 1950-2099 using a variety of available datasets. Results included predicted average temperatures and precipitation depths for the area around the Lower Brazos Basin. This correlation was attempted in a fashion similar to that for the correlation between PDSI and streamflow used in developing the 1500-1940 period of record. Unfortunately, meaningful correlations were unattainable, between either temperature and streamflow or precipitation and streamflow using data from a variety (20+) GCMs. The greatest obtained correlation ($R^2 = 0.23$) was insufficient to justify creating a revised naturalized flow dataset and running the bwam3 model into the future.

Figure 21 presents typical GCM results obtained for the Lower Brazos Basin, showing a definite increasing trend in average July temperatures between 2000 and 2099. GCM results shown in Figure 21 are from the RGRD3 GCM, showing results from three separate emissions scenarios.

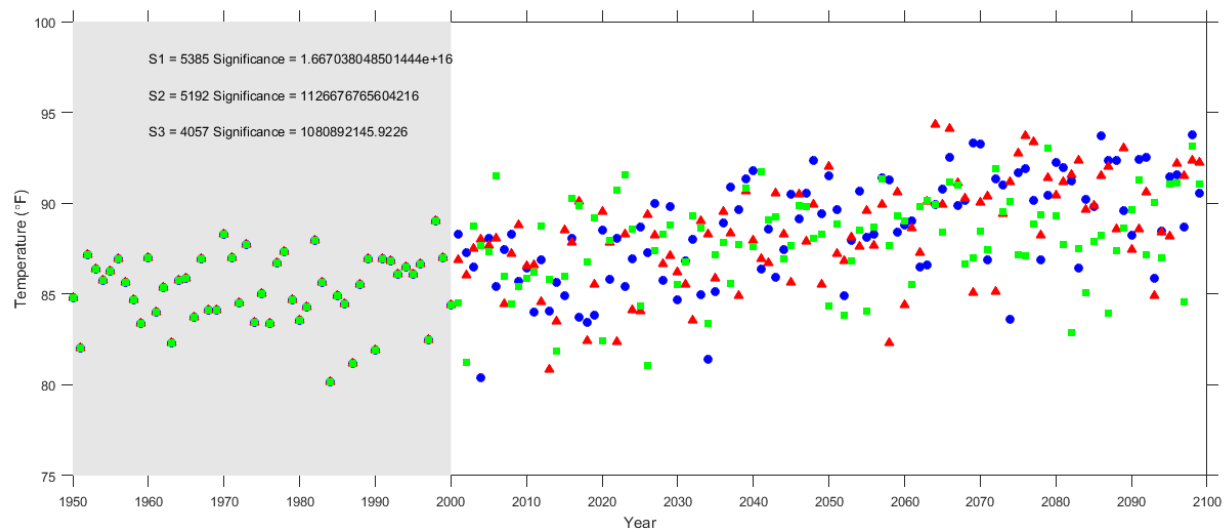


Figure 21– Average July Temperatures for the Lower Brazos Basin – from GCM RGRD3. Results show a statistically significant increasing temperature trend for each emission scenario, as computed using a standard Mann-Kendall analysis.

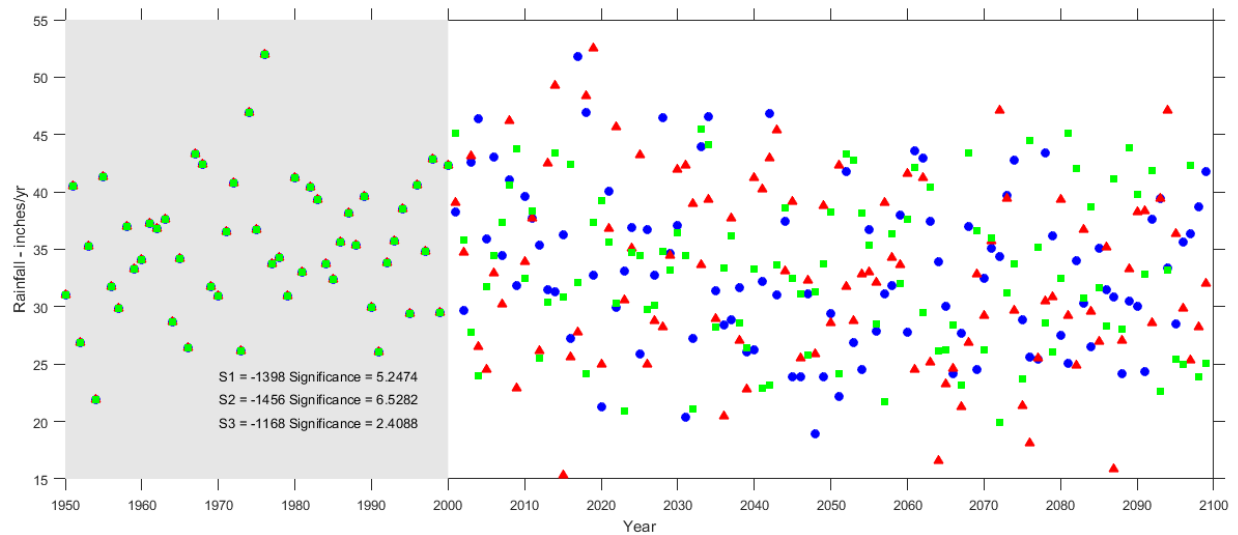


Figure 22 – Total Annual Precipitation Results for the Lower Brazos Basin – from the GCM BC3 model with standard emission scenarios. Decreasing trends are indicated, yet wide annual variations are evident, and variations are evident by emission scenario for most given years.

Figure 22 presents annual precipitation results from the BC3 GCM, utilizing the standard 3 emission scenarios. As shown, there is a statistically significant decreasing trend in total annual precipitation, yet the trend is not as strong as for the temperature data (Figure 21). There is also a wide annual variation in total precipitation, and a large variation in total precipitation by emission scenario.

Taken in general, the results of the majority of GCMs reviewed for this effort suggest that the Lower Brazos Basin will experience lower annual precipitation and higher average temperatures by the year 2099. This would suggest that less streamflow would be generally available over this time period, yet it is difficult to quantify any streamflow decreases with any real certainty.

Based on this climate change analysis, it is likely that GCWA will be able to obtain sufficient water to meet customer demands for the vast majority of months and years. Depending upon actual future climate change impacts on local hydrology, however, it remains possible that GCWA would experience an increase in the likelihood of not being able to satisfy customer demands in the future. As such, it is recommended that GCWA continue efforts to obtain additional water supplies to supplement run-of-river water available from the Brazos Basin. Such supplies could take the form of local groundwater usage, increasing contracts with BRA, desalination, or importing water from other surrounding river basins. Reducing GCWA demands (through customer demand reduction, canal loss reduction, or by other means) is also recommended.

Vulnerability Assessment Summary and Conclusions

Based on the assessments presented in this section, GCWA is well suited to provide sufficient water for its customers through repeats of droughts experienced historically in the Lower Brazos Basin region. GCWA's water rights are generally reliable, and when properly supplemented with water available under contracts with BRA, are largely sufficient to meet historical and contractual water needs. GCWA will need to make operational decisions regarding the usage of BRA contract water, especially in the months of September to December, in order to best ensure that contract water is available when needed by GCWA customers. Obtaining additional contract water, or other reliable sources of water, will certainly increase GCWA's ability to meet customer needs.

Through the Flow Prediction Tool, GCWA has developed a useful tool for assessing immediate drought risk and providing customers with sufficient lead-time to implement water saving and conservation measures to counter such risk. The FPT is simplistic in concept, yet useful in implementation for GCWA. However GCWA wisely did not require usage of the FPT in defining drought triggers in its approved TCEQ DCP (Appendix A). This allows GCWA to consider tool output when making water availability and drought stage response decisions.

The true uncertainty inherent in GCWA's drought vulnerability lies in the future climate change analysis. If temperatures increase in the Lower Brazos basin coupled with decreases in precipitation, then the impact on water availability for GCWA could be significant. Further efforts, outside the scope of the DCP update, would be necessary to better quantify this uncertainty and incorporate it in GCWA's ongoing efforts to increase water reliability and augment its Brazos River water supplies.

Essential Element #3 – Mitigation Actions

Efforts under this essential element were to include the identification, analysis, and implementation of drought mitigation actions. Mitigation activities addressed in this GCWA DCP update, as detailed within the approved "Detailed Work Plan" were to include: 1) maximizing delivery percentage in the GCWA canals and client distribution systems, and 2) assessing the conjunctive use of groundwater and surface water at times when surface water is scarce. Over the course of the project effort, a third mitigation action was identified and implemented, specifically monitoring and tracking reservoir inflows to ensure that streamflow is properly passed downstream to senior water right holders (such as GCWA) rather than illegally storing the inflows in upper basin reservoirs. This section details GCWA's analysis of each of these mitigation actions and how they have been implemented over the course of this DCP update.

Mitigation through Canal Delivery Efficiency Enhancement

The goal of this mitigation effort is to increase the delivery efficiency of the GCWA canal system, thereby ensuring that a greater percentage of water entering the canal system is delivered to GCWA customers. For this discussion, the terms "water losses" and "un-accounted water" are used interchangeably, each meaning water entering the GCWA system yet not delivered to GCWA customers. Water losses within the canal system may be due to: 1) evaporation to the atmosphere, 2) transpiration through vegetation along the canal banks, 3) seepage and/or leaks into the canal banks and underlying soils, and 4) illegal or unpermitted diversions from the canal system. Water delivery efficiency is also affected by changes in water storage within the canal system, including water needed to fill-in the canals prior to water being diverted by GCWA customers. Mitigation activities designed to minimize loss through each of these

causes are discussed individually below, after a discussion of the current water loss rates applied to portions of the GCWA canal system.

Quantification of Current Loss Rates within the GCWA Canal System

GCWA currently does not have a scientifically defensible quantified loss rate that is applicable for its canal system. The losses included within the GCWA Daily-Hydro (V7) model are such that 24% of Brazos River diversions are lost between the river and the Industrial Pump Station at the canal end. Loss rates to intermediate locations within the canal system vary based on the distance between the canal system entrance and the intermediate location. The 24% loss rate is essentially a conservative loss estimate based loosely on a combination of canal flow measurements from 2013 and annual water budget analyses utilizing GCWA reported diversions and water deliveries to customers.

Annual water budgets for 2014-2017 were analyzed by GCWA canal section in order to estimate canal losses. Table 4 presents the water budget results and quantifies the percentage of “un-Accounted” water by section and year. For this analysis, “un-Accounted” water is defined as water introduced into the GCWA canal system yet not delivered to GCWA customers. The data contained in Table 4 do not take into account changes in water storage within the various canal systems, with the exception of calculations related to the Canal A2-Briscoe-G-I system. For this canal subsystem, water storage changes in Texas City Reservoir are included in the calculations, but changes in storage within the actual canal system are not included.

Table 4 – Computed Gains and Losses by GCWA Canal Section via Annual Water Budget

	Un-Accounted Water by Calendar Year				
	2014	2015	2016	2017	Average
Canal Section					
Entire System	-33%	-8%	-13%	-21%	-19%
Jones & Oyster Creek (Canal A1)	11%	28%	14%	23%	19%
Canal A2-Briscoe-G-I	-22%	-6%	-17%	-20%	-16%
Juliff Canal System	NA	NA	-34%	-17%	-26%

As shown in Table 4, results are highly variable by year and canal section. Percentages shown for the “Entire System” are calculated by dividing the total delivery to GCWA customers by the total system inflows, and include inflows and deliveries made from all other listed canal systems. It is also notable that for every year, outflows from the Jones & Oyster Creek (Canal A1) system exceed measured inflows to the system. Outflows for this reach include GCWA pumping at the Second Lift pump station, as well as water diversions by the City of Sugar Land, Pecan Grove, Flour Daniels, First Colony, Southwyck Country Club and Riverbend Country Club as well as leakage through the Amil Gates within the City of Sugar Land. The routinely positive values shown in Table 4 for this section indicate that the watershed of the canal section is clearly contributing inflows to the section. Percentages for the Canal A2-Briscoe-G-I system include the remainder of the GCWA canal system with the exception of the Juliff system and the Monsanto Canal/Chocolate and Mustang Bayou systems. It is probable that some of the Un-Accounted water attributed to the Canal A2-Briscoe-G-I system was transported via the Monsanto Canal into the Chocolate and Mustang Bayou systems. Any such water transported via the Monsanto Canal and subsequently delivered to customers would be captured within the “Entire System” analysis, however.

Un-accounted water for the Juliff system was determined by comparing the water delivered to farmers (based on GCWA Mace Meter data) with water diverted from the Brazos River at the May Pumping Station. Data is unavailable for 2014 and 2015 as GCWA did not commence metering all irrigation diversions until mid-2015.

Conclusions to be drawn from the data presented in Table 3 are:

- Water loss rates (or Un-accounted water rates) are variable between canal sections and over different years
- The modeled 24% loss rate for the GCWA Canal system may be appropriate, but is likely overstating actual rates
- Better quantification of losses or un-accounted water would enhance GCWA's ability to manage available water supplies.

Recommended Canal System Improvements to Better Control Water Losses

GCWA is considering various options for improving the operational efficiency of its canal system in order to:

1. Increase water delivery efficiency to customers,
2. Increase water storage capacity within the canal system, and
3. Decrease staff time spent manually monitoring canal operations and status

All options for addressing the three objectives listed above will also provide GCWA with data and knowledge about where water is located within their canal systems, and how quickly that water is moving through the canal systems. The following options will each enhance GCWA's ability to monitor canal operations and reduce water loss.

Recommendation #1 – Canal Storage Monitoring Devices

GCWA maintains over 275 miles of canals used to transport water throughout its distribution system. Canal dimensions vary over the entire system, as well as canal slopes and conveyance capacities. Currently GCWA does not actively track and record how much water is within each section of the canal system at any given time. Tracking such information would enhance GCWA's ability to track water movement through the canals over time, and would better allow GCWA to assess the true time-averaged water gains or losses through the canal system.

Figure 23 provides approximate information regarding the potential storage capacity of the GCWA canal system. Figure 23A depicts the cross-sectional dimensions of a portion of the Briscoe canal system, as included in a HEC-RAS model describing water flow through the system. For this analysis, it was assumed that the entire 275 miles of GCWA canals followed this cross-section. Figure 23B shows the computed storage within this approximated GCWA canal system, based on the maximum water depth within the system. As shown, under these gross system simplifications, the GCWA canal system could be capable of storing up to nearly 18,000 acre-ft of water.

The computed canal system capacities shown in Figure 23B are provided not as "truth" but rather to illustrate the fact that the GCWA canal system can potentially store a significant amount of water. Knowledge of where this stored water is located within the canal system would better allow GCWA to manage water deliveries and track water gains and losses throughout the system and over-time.

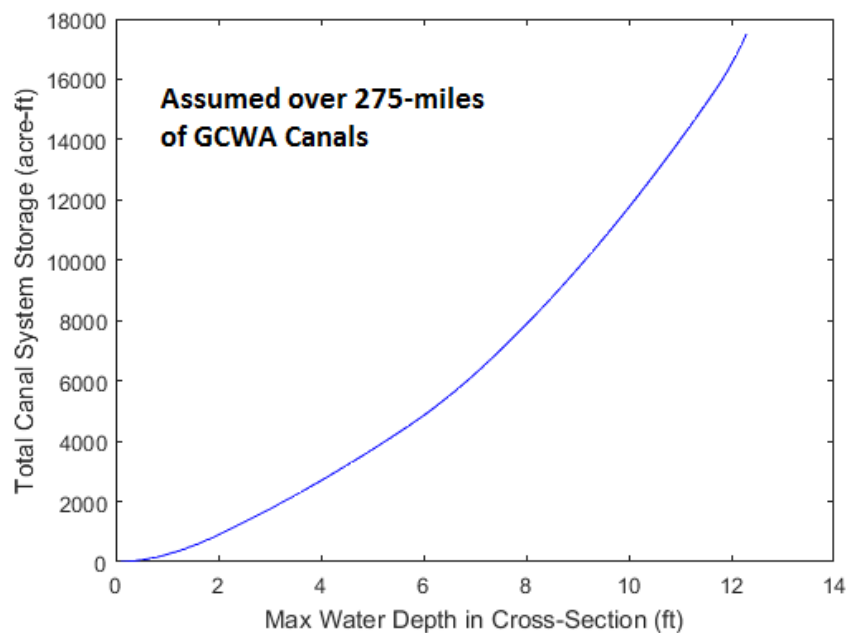
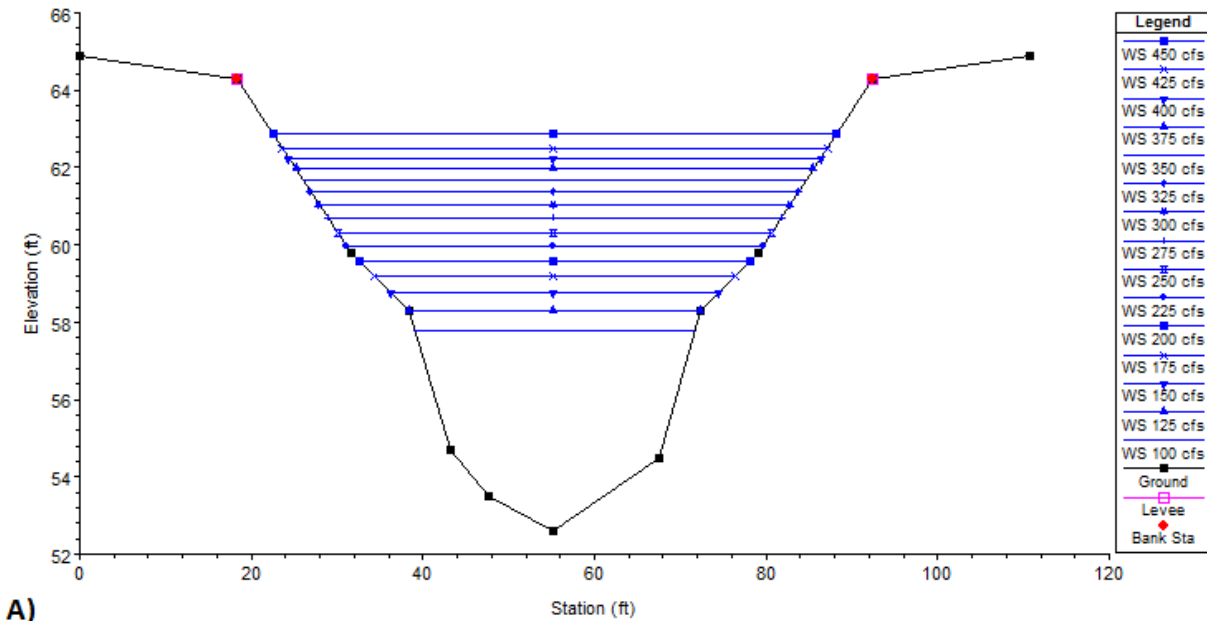


Figure 23 – A) Canal cross-section dimensions from a HEC-RAS model of the Briscoe canal system, B) computed total-system storage capacity assuming a constant cross-section over the entire 275 mile canal system, and neglecting the effect of canal slope, obstructions, and other features. The true potential canal system storage capacity may be larger or smaller depending upon cross-sectional area changes over the entire system length.

The canal storage computations shown in Figure 23B are likely overstated in that canal cross-sections differ at different locations within the system, the canal bottom has a slight slope (allowing for free-flowing water downstream, and the existence of structures within the canal (check structures, gates, siphons, etc.) also impact water storage. Given these limitations, however, it is possible to use available information from existing canal HEC-RAS models to determine the storage capacity of the canal system, assuming the HEC-RAS models are accurate. For example, there are numerous “check” structures, gates, and culverts located throughout the GCWA canal system (Figure 24), and these structures are points at which the canal system could be considered “divided.” If GCWA had detailed knowledge of the canal system cross-sections upstream of each division point, then by measuring water levels at the division points would allow for the determination of both canal flow and water storage within the canal section.



Figure 24 – Structures within the GCWA canal system – A) Gates, B) Culverts, and C) Check stations. Recording water levels at each structure would allow for the computation of flow past the structure as well as water stored in the canal section immediately upstream of the structure.

GCWA could install water level loggers/recorders at every structure within its canal system, and then continuously record water levels at each location. Using knowledge of the canal system geometry (either from direct measurement or from existing HEC-RAS canal system models), the water level readings could be translated into local flow rates and water storage quantities within the canal section. The loggers can be mounted to SCADA data control and telemetry systems, operated on battery and solar power, and be largely self-sustainable without requiring significant servicing by GCWA staff. Staff

could then collect all data from the SCADA units from their central office, and be able to continuously monitor flow and storage (as well as logger performance) throughout the system. Accuracy of the computed flows would depend upon the accuracy of the HEC-RAS models used to translate the recorded water levels into flow rates. These HEC-RAS models would likely need periodic revision and spot checking – yet the data from the water level loggers could become useful in identifying when and where a HEC-RAS model would need updating. For example, consider three sections of the GCWA canal system, each defined at the downstream end by one of the control structures shown in Figure 24. If the flow through sections 1, 2, and 3, were each 100 ± 1 cfs, then GCWA would conclude that this stretch of the canal system was not gaining or losing water. If, however, water levels at the section 2 division point reported 110 cfs, then GCWA staff would be able to notice the discrepancy and attempt to explain it. Possible explanations could be:

- Local influx of flow to the system within section 2
 - Yet if section 3 still showed only 100 cfs, this would be unlikely
- Accumulation of sediment/debris within section 2 that would increase measured water depth for the same flow rate (possibly requiring sediment removal)
- Changes to the canal cross-section (possibly due to bank failure, illegal dumping, or vegetation over-growth)
- Faulty water level readings.

Each of the above-listed explanations could warrant an inspection of the section 2 area by GCWA staff, who could look for and fix causes for the reading discrepancy. Conversely, if the section 2 water level logger were reading 90 cfs, and if logger #3 downstream were also reading 90 cfs, then this might indicate that the canal section 2 developed a leak, or that known (or unknown) entities are diverting water in the section. GCWA could use the data from all of the SCADA readings to pinpoint their canal inspection and maintenance operations.

Having knowledge of the water storage content within each section of GCWA's canal system would also provide useful data for the over-all water budget calculations used to estimate canal system losses (See Table 3). It would become possible to perform water budget calculations on each section of the canal system, with greater accuracy achieved through better tracking of the stored volume changes over time.

The installation of water level loggers and SCADA equipment at each GCWA in-canal structure would require significant capital investment, as well as staff time in developing and enhancing HEC-RAS models of the canal system. One mechanism of funding available to GCWA would be through an Agricultural Water Conservation Grant from the Texas Water Development Board. GCWA utilized such a grant to partially fund the development of the irrigation diversion metering system currently used to measure and track water usage rates for GCWA irrigation customers.

Recommendation #2 – Increasing in-canal water levels

Storing more water in the canal system segments (defined as the portion of the canal between in-canal structures such as checks, gates, and culverts) would have three main benefits:

- It would reduce the amount of canal “charging” needed to efficiently divert water, such that less water would be needed to add to a segment so that diversions could be made in the segment or downstream

- Less vegetation growth would occur along the canal banks and bottom, thereby increasing the ease with which water can flow through the segment (reducing roughness) and reducing the amount of water lost to transpiration through the vegetation, and
- The stored water could be made available to downstream customers during periods when water from GCWA sources (the Brazos River, Chocolate, Halls and Mustang Bayou) are low.

Storing water within the GCWA canal system could provide water supply benefits, without the need for large infrastructure outlays (at least in comparison to the efforts undertaken to obtain new reservoirs). This could be a significant benefit to GCWA, however a more detailed canal-system study would be needed to fully address these benefits. Potential detractors of increased water storage in the canal system include:

- Increased evaporative losses from the canal system, as the free-surface area is greater
- Potentially increased leakage from the canal system, as the canal walls would be retaining more water and hence subject to more weight/pressure
- Decreased canal freeboard, which could lead to canal over-topping during heavy rainfall events, especially where stormwater is discharged into the canal system. Decreased canal freeboard could also pose a public safety concern, despite the notion that the canals are not supposed to be accessible to the public.
- Increased need for canal systems operation to ensure water is stored while sufficient flow is passed through to meet diversion needs.

To more efficiently manage the canal system while retaining greater on-canal storage, it would be beneficial to install automated gates and check structures within each canal section. The gates could be either battery/solar powered, or could be connected to the local power grid. SCADA control sensors would allow the gates to be operated from GCWA headquarters, eliminating the need for manual gate operation and the expenditure of staff time/effort. The gates could be operated from the same SCADA network used to transmit water level data.

Recommendation #3 – Increasing Flow Monitoring and Canal Spot-Checks

This recommendation follows largely from the previous recommendations, yet would be beneficial with or without implementation of the previous recommendations. GCWA owns an Acoustic Doppler Current Profiler (ADCP) which is setup to allow easy and accurate flow measuring along the GCWA canal system. The ADCP could be used to spot-check modeled predicted flows (based on measured water level data), and could be used to continuously refine the canal HEC-RAS models. The ADCP could also be used repeatedly over a canal section to identify where water may be leaking from (or entering into) the canal section. In 2013 and 2014, GCWA utilized its ADCP as well as additional ADCP units to perform a gain-loss study of the canal system. That study was largely inconclusive as to the overall water loss rate across the entire GCWA system. The study was, however, beneficial in indicating locations where losses were observed, and where further study was warranted to pinpoint the cause of the loss.

Figure 25 shows the locations along the GCWA Briscoe Canal where ADCP measurements were made in 2013. The measured flow values (RED) indicate that between 121 cfs and 127 cfs were occurring in the canal, yet flows decreased to 112 cfs closer to the confluence with the Lateral-10 canal. Flows entering the Briscoe Canal from Lateral-10 were not measured. Subsequent flow measurements at this location

in later months confirmed there was a decrease in flow along this stretch of canal. Additional measurements, made along a regular schedule and at locations along this stretch could lead to pinpointing the cause of the flow decrease.

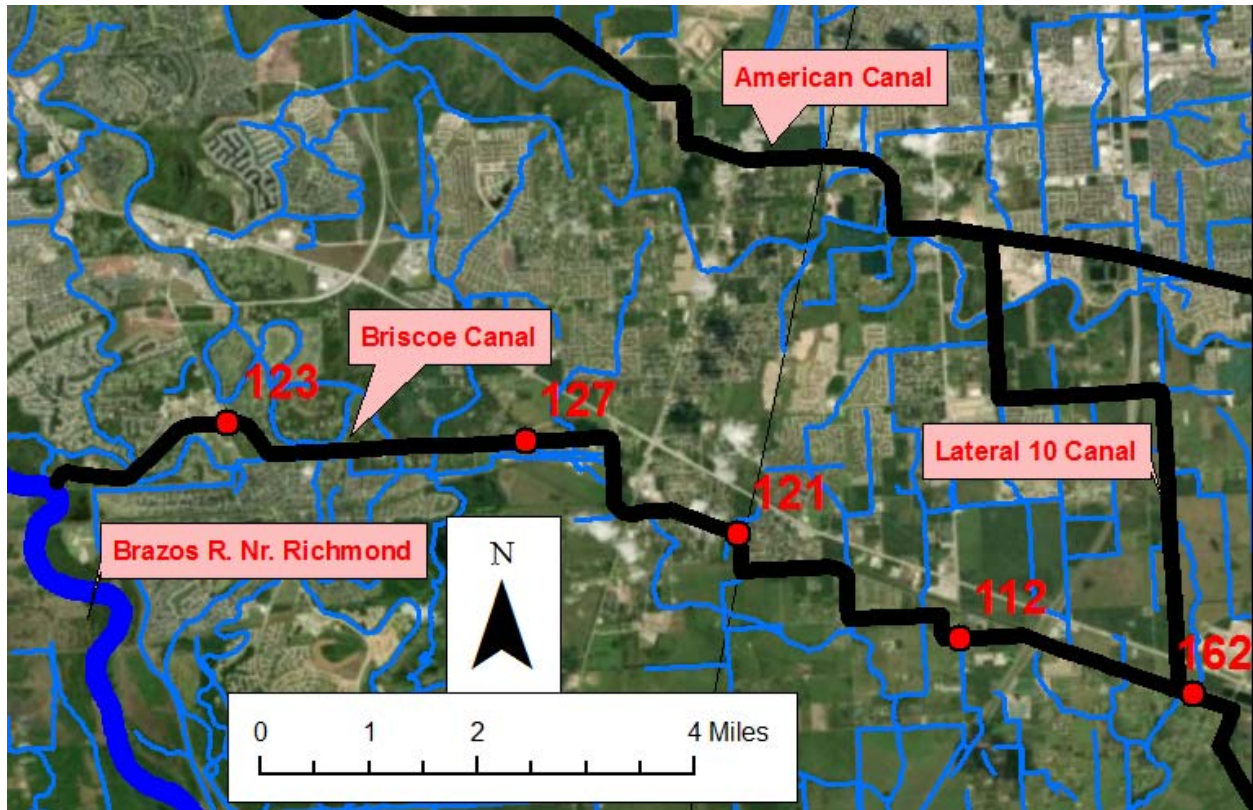


Figure 25 – GCWA flow measurements from the ADCP on 4/16/2013 along the Briscoe Canal during a period of steady pump operation and river levels. The apparent loss of 9 cfs along the mid-section of the canal segment was observed with repeated measurements

The ability of GCWA to maintain a regular flow measurement and monitoring program using its ADCP is contingent upon staff availability. The accuracy of spot flow measurements is also dependent upon the skill and experience of the field technician. Efficiently collecting measurements to assess gains and losses within the canal system could require two field crews of 2 people each, each with their own ADCP and associated equipment. This would allow for the simultaneous flow measurement at downstream and upstream portions of a reach, thus providing accurate gains or loss data if the flow is steady along the reach. Given the staff effort and the difficulty with maintaining steady canal flows, it is recommended that GCWA utilize its ADCP to aid in the development and updating of HEC-RAS models and continuously defining the relationship between flow and water depth along GCWA's canal systems. This will ensure that the water level measurement network (Recommendation #1) accurately produces a detailed picture of water movement through the GCWA canal system. Large and small scale flow gains or losses suggested by the water level monitoring network could then be further investigated by GCWA field technicians using the ADCP unit, on a periodic or as-needed basis.

Mitigation through Supplemental Groundwater Usage

A parallel option for mitigating drought risk is for GCWA to utilize groundwater supplies to supplement available surface water supplies during drought periods. GCWA investigated two potential groundwater sources during this DCP update project, and determined each had significant pros and cons with respect to availability, price, environmental impacts, and political impacts. The following options were reviewed, and each option is discussed separately below:

- **Groundwater Option #1** – Transporting Groundwater to GCWA from the Upper Brazos River Basin via the Brazos River, and
- **Groundwater Option #2** – Using groundwater pumped from new or existing wells in the immediate vicinity of the GCWA canal system

Groundwater Option #1 – Regional Groundwater Transport and Usage

Under this mitigation action, GCWA would purchase groundwater leases located on land upstream of the GCWA service area and not too distant from the Brazos River. GCWA would then pump groundwater from these leases and deliver the groundwater via pipeline to the Brazos River, where it would travel downstream to GCWA pump stations. GCWA has previously identified possible sites for the leased groundwater and groundwater wells, yet has not actively pursued the projects based on project costs (initial capital outlay and operation and maintenance fees). The following aspects are considered “Pros” for GCWA in exercising this groundwater option:

- Pro #1. Groundwater is readily available, and could be available either continuously or on an as-needed basis during drought periods
- Pro #2. Infrastructure and accounting mechanisms are already in place to handle diverting the groundwater from the Brazos River into the GCWA canal system
- Pro #3. Groundwater usage from outside of the immediate vicinity of the GCWA service area will not exacerbate land subsidence within the GCWA service area

The following “Cons” are also under consideration with respect to GCWA’s decision in exercising this groundwater option:

- Con #1. High Initial & Ongoing costs for lease setup, well setup, maintenance & operation, and pipelines between the wellhead(s) and Brazos River (including easements), especially if the groundwater is only used to supplement surface water during drought
- Con #2. Many groundwater conservation districts upstream of GCWA have water export fees GCWA would need to pay in order to transport the groundwater outside of the district’s service area. Permits for exported water are also not politically popular in many districts.
- Con #3. Many of the groundwater conservation districts issue permits on an annual yet renewable basis, limiting the assurance that the groundwater supply will be available continuously into the future.
- Con #4. Additional accounting measures would need to be developed between GCWA and the Brazos Watermaster, and GCWA would need to obtain a “Bed and Banks” permit to transport water via the Brazos River. Such a permit would require potentially expensive environmental studies to determine the impact to aquatic fauna and flora of discharging groundwater (at potentially high temperatures) into the Brazos River.

Based on these relative Pros and Cons, GCWA has decided to “table” all further considerations of regional groundwater as a supplemental drought mitigation water source. This option may be re-considered in the future should situations change to make such actions more favorable and less costly.

Groundwater Option #2 – Local Pumping into the GCWA Canal System

A more favorable option for GCWA is to use locally sourced groundwater supplies to supplement surface water supplies during times of drought. This option is favorable because it does not require interaction with the Watermaster, does not require additional Bed-and-Banks permitting, and does not require a large amount of infrastructure to get the water into the GCWA canal system. This option is also beneficial in that many GCWA customers have existing groundwater wells that they could use to supplement their own diversions from GCWA, and reduce their demands on the GCWA system. Within its TCEQ DCP (Appendix A), GCWA has requested that customers utilize other water sources (including groundwater sources) when GCWA enters Drought Stages 2-5. GCWA has not considered using customer groundwater supply wells to supplement water distributed through the GCWA canal system. This option would require compensation agreements between GCWA and the individual customer(s), and may be feasible yet was not explored explicitly as part of this DCP update project. A review of well records held by TCEQ indicates that GCWA firm customers own 74 public water supply wells that have a combined total production capacity of 88,185 GPM (approximately 196 cfs). It is unknown how often these wells are used by GCWA customers, and whether the wells are well maintained and capable of currently producing water at these production rates.

Figure 26 depicts the known groundwater wells in the immediate vicinity of the GCWA canal system, and provides reported indications of the well productivity. As shown, many wells exist near the GCWA system that are capable of producing in excess of 1,000 GCP. The largest portion of these wells exist within Fort Bend County around the upstream end of the GCWA canal system. The well capacities displayed in Figure 26 are likely reflective only of the well characteristics and design; many of the wells shown with lower production capabilities would likely produce more if they were refurbished or re-developed. Each of these wells is located within the Gulf Coast Aquifer (or perhaps the Brazos River Alluvial Aquifer), which is generally known to be a high production aquifer across Texas.

One significant obstacle for local use of groundwater from the Gulf Coast Aquifer is that the aquifer is recognized as a high-risk aquifer for land subsidence due to groundwater pumping (LRE, 2017). GCWA’s canal system travels through portions of the Fort Bend Subsidence District and Harris-Galveston Subsidence District, and both districts have the authority to regulate groundwater production to minimize subsidence risk. Therefore any groundwater pumping within those district’s jurisdictions would require a permit from the district, as well as strict monitoring of the diverted quantities in comparison to overall used quantities. For example, the Harris-Galveston subsidence district requires that groundwater

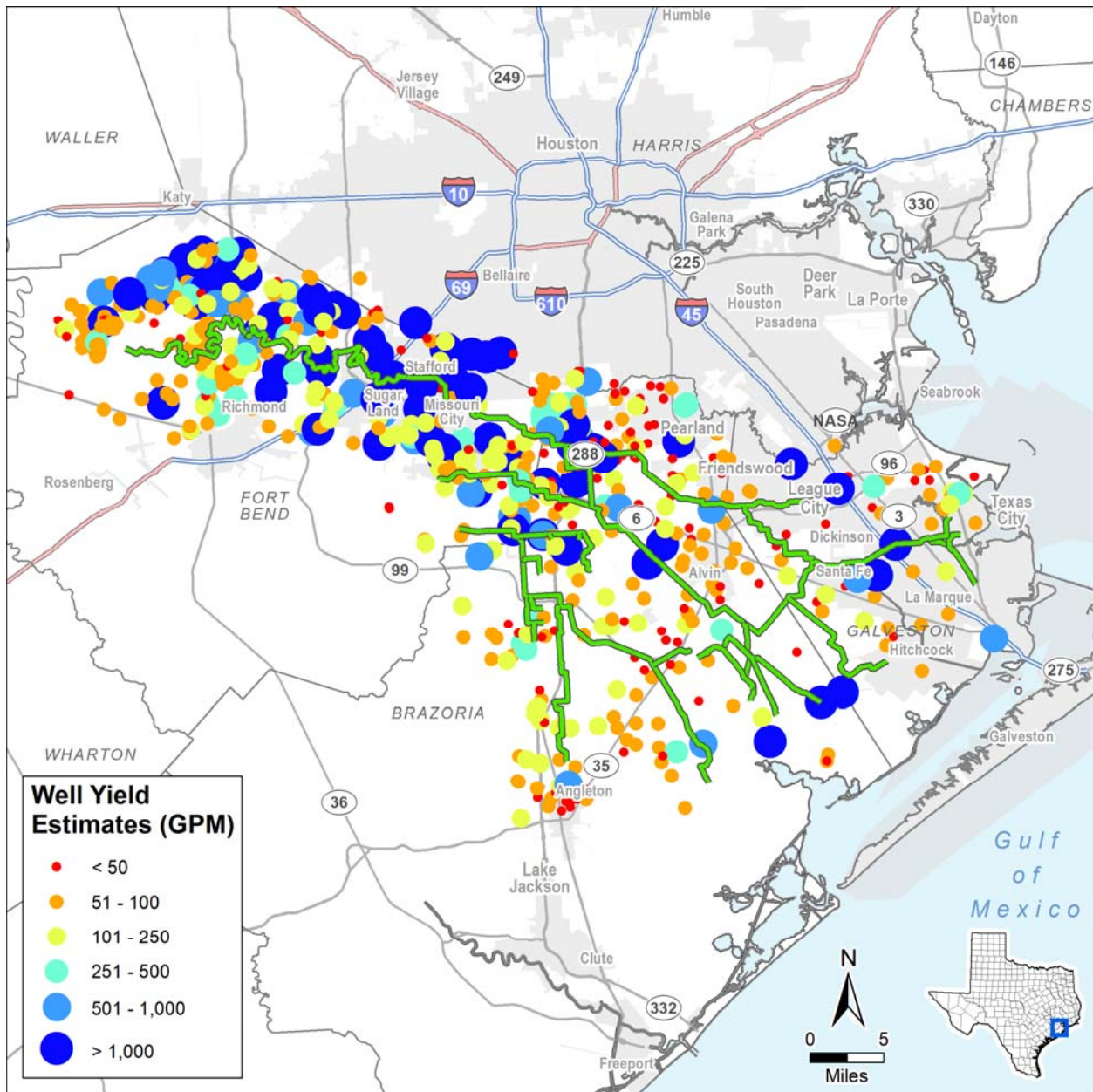


Figure 26 – Known well productivities (Gallons-per-minute “GPM”) in the immediate vicinity of the GCWA canal system, based on TWDB databases.

usage make up no more than 10% or 20% of a customer’s annual water usage, depending on the groundwater location within the district boundaries. Most entities within subsidence district boundaries rely nearly entirely upon surface water sources in order to comply with district rules. Thus using groundwater to supplement surface water sources would be numerically feasible, in only for a limited period over the course of a calendar year. Accounting for the groundwater usage would have to be approved by the subsidence district, yet this is not likely to be a significant obstacle to groundwater usage.

As Brazoria County does not have a subsidence district, groundwater withdrawals in that county are not as stringently regulated with respect to subsidence impacts. However the Brazoria County GCD does have numerous rules regarding groundwater pumping, and they charge large fees if pumped groundwater is transported out of Brazoria County. Therefore there would be potentially large financial penalties if GCWA were to pump groundwater from wells in Brazoria County and have that water travel down the canal system into Galveston County for use by other GCWA firm customers. In addition, even though Brazoria County is not part of an official subsidence district, it was recognized as being at high-risk of subsidence in the recent statewide subsidence risk assessment published by the TWDB (LRE, 2017). Therefore it is likely that Brazoria County GCD may become a subsidence district in the future, and that action may alter the benefits of using Brazoria County groundwater to supplement surficial sources during drought.

Figure 27 details a proposed groundwater project designed for this DCP Update, where GCWA would locate up to twelve wells along the GCWA G-Canal system upstream from where the G-Canal and B-Canals converge. These wells would be located within the Harris-Galveston Subsidence District Area-2 and therefore be subject to the 20% customer annual water usage requirement. Well production was simulated within the official Houston Area Groundwater Model (HAGM) in order to assess resulting drawdown and subsidence risk. Simulated production levels included 4 MGD, 8 MGD, and 16 MGD with production assumed constant and continuous in time (due to the limitations of the HAGM model). Resulting drawdown and subsidence risk varied based on model parameters, well location, and subsidence calculation methodologies. It was estimated that subsidence of up to 1 ft would occur by 2070 if these wells were pumped at 16 MGD continuously. Significantly less subsidence would be expected if the wells were only to be used periodically to supplement surface water supplies during drought.

If GCWA were to move forward with the groundwater development project depicted in Figure 27, it would be necessary to determine through negotiations with the Harris-Galveston Subsidence District exactly what type of well permitting and accounting would be required. Based on this investigation, it was unclear whether HGSD would consider the water user to be GCWA or whether the user would be considered GCWA's individual customers. The distinction is potentially important as it relates to the HGSD rule regarding a maximum of 20% of a customer's annual usage be derived from groundwater sources. If, for example, GCWA was considered the customer, then 20% of GCWA's annual water usage would be upwards of 50,000-70,000 acre-ft/yr. Alternatively if the water user were considered the HGSD customer, then groundwater usage by GCWA would have to be added to any other groundwater usage by the individual customer, and then compared against the surface water usage by that customer for the given year. The accounting tasks involved are not insurmountable, yet through discussion with HGSD staff it has become evident that the tasks have not yet been considered and the water accounting methods have yet to be developed.

Total cost estimates for the 12 wells shown in Figure 27 were determined based on the TWDB's Unified Costing Model utilized in the Regional Water Planning process. Based on this model, the initial construction costs for the 12 wells is likely to be approximately \$18M, and operation and maintenance costs will be \$2.7M per year depending upon how often the wells are pumping.

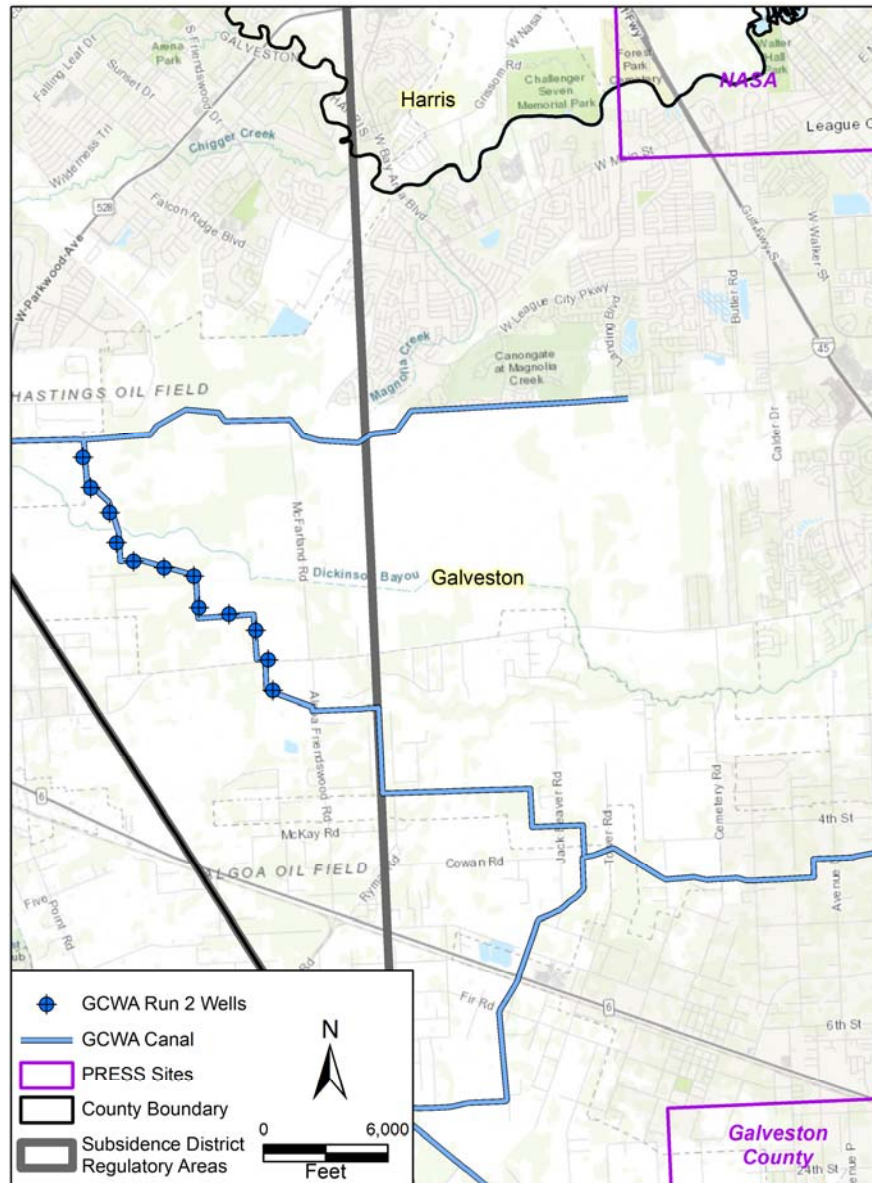


Figure 27 – Proposed groundwater wells along the GCWA G-canal within the Area-2 of the Harris-Galveston Subsidence District. Pumping from these wells could provide 16 MGD with limited effect on area subsidence.

Additional groundwater projects under consideration by GCWA include the installation of wells along the Monsanto Canal within Brazoria County. These wells would be used to supply water to GCWA customer INEOS, and could reduce GCWA's Brazos River demands by up to 24 MGD. Using pumped groundwater within the Monsanto Canal system would also eliminate the groundwater export fee imposed by the Brazoria County GCD.

Within its TCEQ DCP, GCWA provides financial compensation to customers who successfully reduce their demand for GCWA water, potentially through the use of their own groundwater supplies. This financial incentive was intended by GCWA to offset the costs of well maintenance and operation by the GCWA

customer. Customers only receive the incentive, however, if they reduce demands for GCWA water by certain percentages prescribed in the DCP.

Mitigation through Reservoir Inflow Analysis

As a senior water right holder in the lower Brazos Basin, GCWA is entitled to priority-access to water from the Brazos River basin. In theory, only entities holding water rights with priority dates senior to those of GCWA should be able to divert water before GCWA, as long as GCWA has a demonstrated need for the water and sufficient water would not be available to GCWA should the water first be diverted by others. The same is true for water impounded in reservoirs – namely any reservoir owner/operator with a storage right junior to GCWA’s active water right(s) should not be allowed to impound inflows to the reservoir if those inflows are needed to satisfy GCWA’s demands under its water rights. It is the job of the Brazos Watermaster to monitor all movement of water through the Brazos River basin, and to authorize diversions such that all entities (reservoir owner/operators and water right holders) are behaving fairly according to the Texas prior-appropriation system. The watermaster has been active in the Brazos Basin since June 2015, yet only over the summer of 2018 did the watermaster have to make water allocation decisions to mitigate drought impacts for the Lower Brazos Basin. In general, the Brazos Watermaster has worked cooperatively with GCWA, the BRA, and other basin water right holders to manage available water supplies.

Near the beginning of June, 2018 there was a period when the flows in the lower Brazos River were decreasing to the point where GCWA was considering initiating releases of contract water from BRA reservoirs. During this same period, drought monitoring tools developed during this DCP update (Figure 6, Figure 7) indicated that reservoirs within the BRA system were typically increasing in storage on a day-to-day basis. This, in turn, indicated that the BRA was storing water at a time when GCWA was in need of water downstream under its senior water right. GCWA discussed the observations with BRA and the Brazos Watermaster, and it was determined that BRA would begin releasing more of the inflow, and not charging the releases against GCWA’s contract quantities.

As part of its reservoir management operations, the BRA has developed a daily water accounting plan in which it calculates inflows to each of its system reservoirs. The inflows are calculated according to the equation:

$$I = \Delta S + O + E - P + D$$

Where “I” is the inflows, “ΔS” is the change in reservoir storage, “O” is the gauged outflows, “E” is water lost to evaporation, “P” is water gained due to precipitation, and “D” is water lost to diversions made along the lake boundaries. The BRA regularly tracks and records this information at each of their reservoirs, and it updates the official accounting spreadsheet monthly or weekly depending on the drought status. During the summer of 2018, the Brazos Watermaster used inflow calculations made by BRA to aid in its decisions regarding how much (if any) of the inflows needed to be passed downstream to senior water right holders (including GCWA).

GCWA decided to modify its dashboard and Flow Prediction Tool in order to compute and track inflows to BRA’s reservoirs. The purpose of the action was not necessarily to challenge BRA’s or the Watermaster’s management of reservoir inflows, but rather to provide GCWA with a means to independently assess the actions of the BRA and Watermaster with regard to reservoir operation during

drought. As such, the various Matlab scripts that run the dashboard, FPT, and emailing tools created for Drought Monitoring and Vulnerability Assessment were modified to include approximate daily calculations of reservoir inflows, outflows, and water lost to evaporation. GCWA's methods included using the same base equation as BRA, yet assuming lakeside diversions ("D") were negligible. GCWA also made the assumption that evaporative loss rates would be approximately equal to the 5-year averaged historical loss rates for the reservoir area, as reported by the Texas Water Development Board. Both the diversion and evaporation assumptions were needed as actual real-time information is not available to GCWA. GCWA could obtain the real, measured data from BRA yet doing so would necessitate time delays in computing inflows and assessing water management practices by BRA and the Watermaster. As such, GCWA recognizes that its inflow estimates are not exact, yet also assumes that they are "close enough" to demonstrate to the Watermaster that the BRA should or should not be passing inflows at a given time.

Streamflow Records (cfs):

		Current Flow	12/8/2018 Average Flow
Whitney	=	382 cfs	660 dcfs
Waco	=	2,410 cfs	5,190 dcfs
HighBank	=	13,500 cfs	13,300 dcfs
Bryan	=	42,400 cfs	39,700 dcfs
Hempstead	=	47,100 cfs	38,400 dcfs
San Felipe	=	50,700 cfs	33,500 dcfs
Richmond	=	41,300 cfs	24,100 dcfs
Rosharon	=	37,600 cfs	27,000 dcfs

BRA Reservoir Inflows vs. Outflows & Evaporation: 12/8/2018

		Inflow	Outflow	Evaporation
Possum Kingdom	=	1,341 acre-ft	580 acre-ft	106 acre-ft
Granbury	=	988 acre-ft	1,545 acre-ft	47 acre-ft
Whitney	=	5,051 acre-ft	870 acre-ft	144 acre-ft
Aquilla	=	2,411 acre-ft	52 acre-ft	20 acre-ft
Stillhouse Hollow	=	6,282 acre-ft	117 acre-ft	46 acre-ft
Belton	=	10,262 acre-ft	153 acre-ft	81 acre-ft
Proctor	=	147 acre-ft	69 acre-ft	31 acre-ft
Granger	=	5,774 acre-ft	61 acre-ft	29 acre-ft
Georgetown	=	1,132 acre-ft	14 acre-ft	8 acre-ft
Somerville	=	29,002 acre-ft	458 acre-ft	76 acre-ft
Limestone	=	14,631 acre-ft	14,124 acre-ft	88 acre-ft
Total	=	77,020 acre-ft	18,043 acre-ft	676 acre-ft

Figure 28 – Portion of Sample Daily Text Emailed Automatically to GCWA Staff – detailing current Brazos River streamflow and computed BRA reservoir inflows, outflows, and evaporative losses from the previous day. This text is amended onto the text presented in Figure 6.

Figure 28 shows the results of the inflow calculations for 12/9/2018 as included in the daily email sent from the Dashboard to select GCWA staff. As shown, the text contains inflows and outflows computed

for each reservoir, and also provides the total inflows and outflows. For 12/9/2018, computed inflows (77,020 acre-ft) greatly exceeded outflows (18,043 acre-ft). GCWA would not complain that BRA was improperly storing inflows in this instance, however, because Brazos River streamflows are higher than GCWA's customer demands or the Monthly Flow Target for December. In this instance, GCWA would not protest BRA's storing of water, as this water could be available to GCWA at a later date (as contract water).

Figure 29 depicts the results of the Flow Prediction Tool (FPT) for June 9, 2018, showing predictions based on both releases from the reservoirs (gauged observations) AND from reservoir inflows computed by GCWA. As shown during this period predicted flows at Hempstead due to reservoir inflows (blue line) occasionally exceeded predicted inflows due to the actual gauged releases (red line). However for the majority of the second week of the prediction, flows from releases exceeded flows predicted from inflows. GCWA could have used this information in deciding whether to request that the Watermaster direct BRA to release rather than store more of its inflows. Figure 26 is also notable as it often shows disagreement between the observed and predicted flows at Hempstead. There were two dates, however, when observed and predicted flows due to releases were nearly identical (6/6 and 6/9).

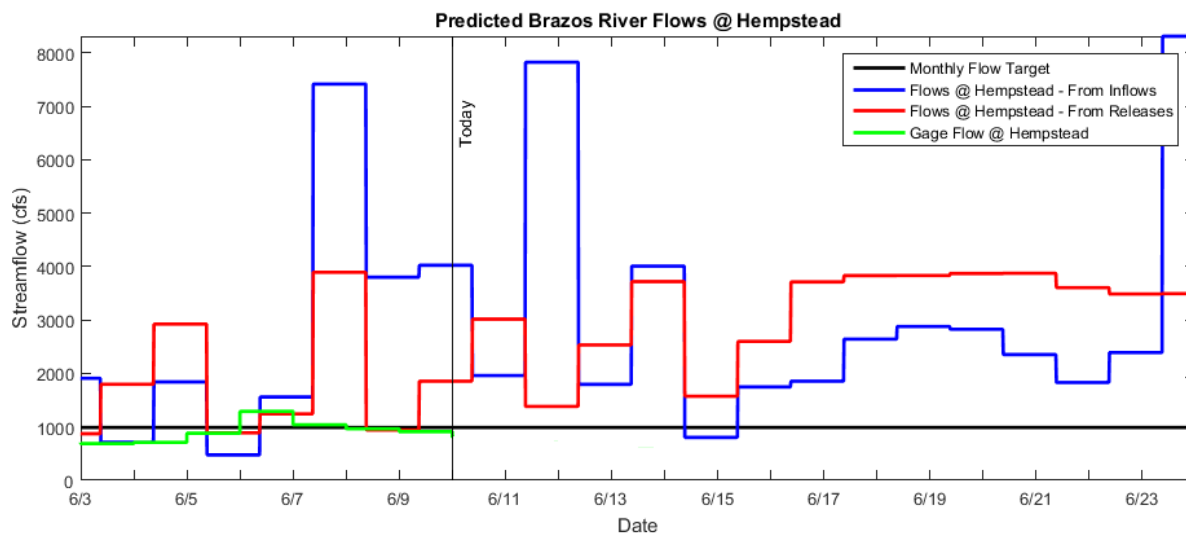


Figure 29 – Flow Prediction Tool Results for 6/9/2018 – Showing output for actual reservoir releases (Red) and passage of inflows to BRA reservoirs (Blue).

Results of the FPT (similar to that shown in Figure 28 and Figure 29) are emailed to select GCWA staff on a daily basis, and can therefore help inform operational decisions with regard to drought planning. No formal mention of the FPT or the reservoir inflows calculation is made in the GCWA DCP developed for submission to the TCEQ. However both tools form part of the mitigation and analysis framework used by GCWA to ensure its customers obtain their desired water quantities.

Prioritization of Mitigation Actions

Drought resiliency projects discussed in this section (Essential Element #3 – Mitigation Actions) were prioritized based on their ease of implementation and expected effectiveness. Table 5 presents each resiliency project in priority order. With the exception of the “Regional Groundwater Transport and

Usage” project, GCWA intends to implement each mitigation action as soon as possible, depending upon funding and staff abilities.

Table 5 – Prioritization of Drought Resiliency Projects (Mitigation Actions)

Priority	Mitigation Action
1	Reservoir Inflow Analysis
2	Canal Flow Monitoring & Spot Checks
3	Local Groundwater Usage
4	Increasing In-Canal Water Levels
5	Canal Storage Monitoring Devices
6	Regional Groundwater Transport and Usage

The “Reservoir Inflow Analysis” mitigation action was assigned the priority rank #1 as this action was implemented during the development of this DCP Update, and has already provided benefits to GCWA and its customers. GCWA used the automated analyses during the summer of 2018 in discussions between the Brazos Watermaster and the Lower Basin User’s Group (See Concept #4 in the Response Actions section). This mitigation action required little cost and staff time to develop and implement, and requires minimal effort to maintain.

The “Canal Flow Monitoring & Spot Checks” mitigation action was assigned the 2nd priority rank as this action can be implemented with existing GCWA-owned equipment and by allotting staff time to the effort. The action is likely to identify water loss locations within the GCWA canal system, which will lead to canal repairs and delivery efficiency improvements.

The “Local Groundwater Usage” mitigation action was assigned the 3rd priority rank as this action is already being implemented, with GCWA discussing with customers the availability of groundwater from customer wells. GCWA is also developing detailed plans for the design and construction of GCWA-owned wells adjacent to portions of its canal system. GCWA is discussing with customers potential compensation measures for customer usage of groundwater sources during drought periods.

The “Increasing In-Canal Water Levels” mitigation action was given the 4th priority ranking as the method will increase supplies through on-canal storage of water. GCWA is investigating the availability of numerous grants which will allow for the upgrading of in-canal gates and structures, allowing for improved water delivery efficiency.

The “Canal Storage Monitoring Devices” mitigation action was given the 5th priority ranking, although the strategy is under GCWA development and closely tied to the “Increasing In-Canal Water Levels” strategy. GCWA is investigating the availability of numerous grants which will allow for the purchase and installation of water level monitors and SCADA networks, to work in conjunction with the upgraded in-canal gates, thus allowing GCWA to better manage and operate its canal system.

The “Regional Groundwater Transport and Usage” mitigation action was given the lowest priority ranking due to the numerous (and onerous) permitting requirements associated with such a strategy. GCWA is not actively pursuing this strategy at this time, yet some GCWA customers have expressed interest in developing this strategy in collaboration with GCWA.

Essential Element #4 – Response Actions

The Response Actions to be undertaken by GCWA during a future drought are encoded within the DCP prepared for submission and approval by the TCEQ. This DCP, included as Appendix A herein, was created during the larger Reclamation DCP update process, and incorporates knowledge and concerns presented by the DTF. The GCWA board of directors formally adopted the DCP for TCEQ on December 6, 2018 as GCWA board resolution #2018-013.

The GCWA DCP contains 5 drought stages, with stages 1-4 depending upon severity of the lack of water within the Brazos River (and other GCWA sources). Stage 5 is an emergency water stage, and is reflective of situations where GCWA infrastructure is not capable of conveying sufficient water to its customers; Stage 5 conditions do not require a lack of water available to GCWA. Stage 5 conditions are likely to occur if GCWA pump stations fail, if canal systems sustain large leaks, or if the source water were to become contaminated (for example). In November of 2018, GCWA's pipeline transferring water to the City of Galveston sustained a significant rupture, causing the City of Galveston to receive reduced water supplies. Under this situation, had GCWA's DCP been adopted, it would have declared a Stage 5 condition for the City of Galveston, yet would not have declared such a stage response for other customers. The City of Galveston did implement its emergency drought response at the suggestion of GCWA, and both entities were able to sustain operations until the pipeline leak was repaired.

Per the approved Detailed Work Plan (DWP), the "Response Actions" portion of the DCP was to include discussions of existing drought contingency plans, rules for use of supplemental groundwater, rules for implementation of other mitigation strategies, and "Last-Resort" Curtailment Rules implementation. During the DCP update process, however, each of these topics intermingled such that they are not easily distinguishable in the final GCWA DCP to be submitted to TCEQ. The following 4 sections detail investigations into each of the topics required in the DWP. Subsequent sections detail GCWA's staged drought responses as included in the DCP for TCEQ.

Review and Summary of Existing Drought Contingency Plans

This task involved the collecting and analyzing of the drought contingency plans of entities serviced by GCWA, as well as the drought contingency plan developed by the Brazos River Authority. These plans were analyzed to determine if any proposed changes to GCWA's DCP would necessitate significant changes to the DCPs of GCWA customers and supplier (the Brazos River Authority) during drought periods. The DCPs were also reviewed to assess whether any components of those implemented DCPs would provide viable benefit to GCWA and its customers if included in the GCWA DCP.

Table 6 lists the entities who's DCPs were reviewed during this process.

DCP for the Brazos River Authority – A GCWA Supplier

As the owner of three upstream reservoirs and holder of numerous Brazos River water rights, the Brazos River Authority (BRA) is able to provide its customers with a reliable water supply during all times (drought, normal conditions, or wet conditions). GCWA is a customer of the BRA, and holds long-term contracts requiring BRA to provide water to GCWA when insufficient water is available under GCWA's various water rights. GCWA had initially wished to use BRA's adopted drought triggers, stages, and responses when developing its DCP. However upon review of the BRA DCP, it was concluded that GCWA

could not rely on the concepts included in the BRA DCP in order to protect GCWA customers during drought periods.

Table 6 – Entities with DCPs Reviewed During this Project

Entity	Type	DCP Plan Adoption Date
Brazos River Authority	Supplier to GCWA	10/29/2012
City of Galveston	Customer of GCWA	3/2003
Bacliff MUD	Customer of GCWA	Unknown
Bayview MUD	Customer of GCWA	4/16/2009
City of Hitchcock	Customer of GCWA	Unknown
City of La Marque	Customer of GCWA	April, 2009
City of League City	Customer of GCWA	May 2012
City of Texas City	Customer of GCWA	August 2009
Galveston County Fresh Water Supply District No. 6	Customer of GCWA	May 10, 2005
Galveston County MUD No. 12	Customer of GCWA	December 17, 2012
Galveston County Water Control and Improvement District No. 1	Customer of GCWA	January 20, 2010
Galveston County Water Control and Improvement District No. 8	Customer of GCWA	September 16, 2010
Galveston County Water District No. 12	Customer of GCWA	April, 2009
San Leon MUD	Customer of GCWA	September 1999

The BRA DCP defines “drought severity triggers” based entirely upon stored water contents of its 11 system reservoirs. It can define different drought stages for customers served by each reservoir, and for GCWA (which is downstream and can thus receive BRA water from each of the 11 BRA source reservoirs) drought stages are based upon the total water storage within all BRA system reservoirs. Figure 30 shows the time-history of storage within BRA reservoirs, relative to the various stage triggers included in the BRA DCP.

As shown in Figure 30, since 1980 when the last of the 11 system reservoirs was completed, system storage has periodically approach the “Stage 1- Watch” level, and was below the watch-level during the 2011 and 2013-2014 drought periods. System storage has never been sufficiently low to cause BRA to implement its “Warning,” “Emergency,” or “Pro-Rata Curtailment” clauses within its DCP. Note: the storage time history shown in Figure 30 is approximate, as it assumes Lake Whitney always contained the 50,000 acre-ft of water that BRA has access to per agreement with the US Army Corps of Engineers (USACE); the actual amount of water within Lake Whitney to which BRA has access at any given time is not readily published by the BRA, USACE, or US Geological Survey (USGS).

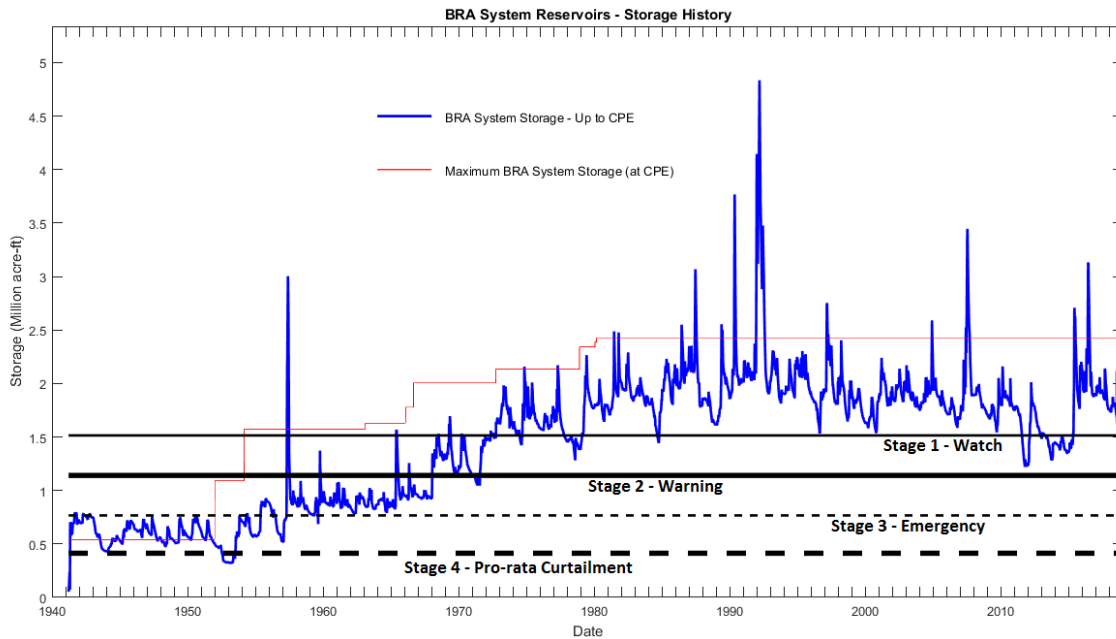


Figure 30 – Time-history of BRA reservoir storage relative to the defined drought stages within the BRA DCP.

The significant difference between the BRA and GCWA in terms of water supply is that GCWA owns “run-of-river” rights to water, and does not maintain its own reservoirs to provide water during drought conditions. As such, directly linking GCWA’s DCP stages to those of BRA may not necessarily accurately reflect streamflow conditions, as BRA will not alter its drought stages based on streamflow. For this reason, it was decided that while GCWA may use information provided by BRA (including BRA’s potential declaration of drought stages) in its assessment of river conditions, GCWA’s DCP will not directly “link back” to any decisions made by BRA.

DCP for the City of Galveston – A GCWA Customer

The City of Galveston receives 100% of its water as treated water via pipeline from the GCWA Thomas S. Mackey Treatment Plant. The City has contracted with GCWA for 21.0 MGD, and recently uses an average of 14 MGD, with higher usage during summer tourist seasons. The City also maintains a groundwater wellfield capable of producing up to 10.3 MGD, yet this wellfield has not been utilized since the City switch to GCWA for its main water supply. The City of Galveston’s DCP was approved in March of 2003, and staff have begun updating the DCP to reflect more recent conditions and better coincide with GCWA’s revised DCP. The main object of the City of Galveston’s DCP is to codify how the city will work to conserve water during drought stages. Conservation measures, such as prohibition of outdoor car washing, mid-day lawn irrigation, etc. are explicitly expressed within the DCP, and violations for non-compliance are also included. As the City passed the DCP rules into law as a city ordinance, the City then had the legal authority to enforce water reduction requirements based on prescribed drought stages.

Insights based on Existing DCP Review

While some insights were obtained through analysis of BRA's and GCWA Customer DCPs, the greatest insight was that GCWA's DCP must be materially different in that its water source is not a reservoir (or system of reservoirs), and that it is not a retail water provider with direct control over the water demands of end-users. For these reasons, it was determined that GCWA's DCP would be similar in form to that of BRA and its customers, yet would rely upon different analyses and triggers when assessing drought stages. GCWA would consider the drought stages declared by BRA and its customers when making its own drought declarations, but the various drought declarations do not have to be identical. For example, GCWA could declare a stage-3 drought based on streamflow, yet BRA may not declare even a stage 1 drought if their system reservoirs were still sufficiently full. GCWA recommends to each of its customers that the customer's DCP utilize GCWA drought stage determination as one criteria for implementing their own stage declarations. This notion has been incorporated into the revised (and yet-to-be-adopted) City of Galveston DCP.

GCWA's Adopted TCEQ DCP – Drought Stage Triggers & Response Actions

The purposes of the GCWA DCP are as follows:

- To conserve the available water supply in times of drought and emergency;
- To maintain supplies for domestic water use, industrial use, sanitation, and fire protection;
- To protect and preserve public health, welfare, and safety;
- To minimize the adverse impacts of water supply shortages;
- To minimize the adverse impacts of emergency water supply conditions; and
- To satisfy the requirements set forth by the Texas Commission on Environmental Quality (TCEQ) and other agencies, including the US Bureau of Reclamation.

For GCWA's DCP, a drought is generally defined as an extended period of time when an area receives insufficient amounts of rainfall to maintain or replenish the water supply, thereby causing temporary water supply shortages. In the absence of drought response measures, water demands tend to increase during a drought due to the need for additional outdoor irrigation and cooling water. The severity of a drought depends on the degree of depletion of supplies and on the relationship of demand to available supplies. The GCWA DCP defines four drought stages, with an increase in drought severity with an increasing drought stage number. The Stage 5 drought condition defined by GCWA is reserved for when emergency conditions occur that are related to GCWA's ability to deliver usable water supplies, not based on the quantity of supply available for delivery.

This GCWA DCP addresses periods of time when: (i) the quantity of water in the Brazos River available to GCWA under its water rights, and its alternative sources of water (including contracts for stored water from the Brazos River Authority [BRA]) is insufficient to meet the demands of GCWA's water supply customers; or (ii) the capacity of GCWA's pump stations, canals or water treatment plants is insufficient to meet the demands of any water supply customers dependent on such facilities, or both. The GCWA General Manager (GM), or his/her designee, is to be

responsible for implementing all applicable provisions of this DCP upon determination that such implementation is necessary to protect public health, safety, and welfare. GCWA's general strategy is to monitor hydrologic conditions within the Brazos Basin, and utilize alternative water supplies when insufficient streamflow is available. Only when available streamflow and alternative supplies are insufficient to meet GCWA customer needs will GCWA consider moving up to the next stage within its DCP.

Table 7 provides an outline of GCWA's defined drought stage triggers and responses. GCWA decided to implement water use reduction "goals" under Stage 1-4 responses, and to implement surcharges and credits in order to incentivize water conservation during drought periods. The following sections detail GCWA triggers and response actions for each defined drought stage.

Table 7- Summary of Drought and Emergency Response Stages

	Stage 1 Response	Stage 2 Response	Stage 3 Response	Stage 4 Response	Stage 5 Water Emergency Response
Minimum percentage of Contributing Watershed in "Moderate Drought" or higher per the US Drought Monitor to declare Stage Response	50%	NA	NA	NA	NA
System Demand Exceeds [A]% of Deliverable Capacity to declare Stage Response :	85%	90%	95%	98%	NA
Run-of-River Supplies plus GCWA Alternate Water Supplies are less than [A]% of the Monthly Flow Target through August 31 to declare Stage Response	NA	95%	90%	85%	NA
Lower Basin User's Group recommendations**	NA	YES	YES	YES	NA
Water Use Reduction Goal	95%	90%	85%	80%	GM discretion
Potential Surcharge	NA	2.5x	2.5x	5.0x	10.0x
Potential Credit	NA	1.0x	1.0x	1.0x	1.0x

"NA" signifies "Not Applicable". [A] references percentage values listed in Table rows.

**The Lower Basin User's Group may recommend entering a Stage 2, 3, or 4 drought based on their review of hydrologic conditions.

General Concepts Included in the GCWA Response Actions

While specific details are provided below pertinent to each GCWA defined drought stage, there are several key concepts inherent to each stage that must first be explained. These concepts form the backbone of the GCWA DCP, and are rather unique among DCPs developed for Texas entities.

Concept #1 – GCWA does not wish to impose curtailment rules, and will strive to meet customer demands through usage of all available water sources. Through each drought stage, GCWA will encourage customers to use alternate water sources available to them, possibly including local groundwater sources, before requesting that the customer reduce their demands. GCWA will also carefully utilize its own alternate water sources to supplement available supplies from the Brazos River.

Concept #2 – GCWA will not automatically enter (or leave) a given drought stage when any stage entrance/exit criteria are satisfied. The GCWA General Manager will CONSIDER changing from one stage to another based on the criteria stated in this DCP. This provides GCWA with desired flexibility in its actions. GCWA intends to follow the guidelines listed in this DCP, yet reserves the right to deviate from them under unforeseen circumstances not anticipated during the development of this DCP.

Concept #3 - GCWA's water use reduction goals are targets, and are not mandatory requirements. Customers will be given monetary credit for achieving the goals, and will be penalized/assessed a water surcharge on their monthly bills if water usage exceeds their monthly target amount.

Concept #4 - Monthly target water usage is based on an individual customer's actual usage during the same month during the three previous calendar years, excluding any reductions in usage as a result of implementing a Stage Response. In this way, GCWA is basing water usage reductions on historically used quantities, rather than on the quantity GCWA is contractually obligated to provide for the customer (a quantity that is often higher than the actual customer usage).

Concept #5 – Water management during drought cannot be heavily prescribed, and must be sufficiently flexible to allow GCWA staff to optimally allocate available water resources. GCWA, at the discretion of the GM, will consult the advice of a "Lower Basin User's Group" made up of experienced professionals who will jointly assess the hydrologic conditions and make recommended actions with respect to drought stages. The GM is not required to implement drought stages because one of the particular stage triggers is achieved; Discretion is to be utilized, and rapid consensus amongst participating entities is to be expected. The Lower Basin User's Group may recommend entering (or leaving) Stage 2, 3, and 4 based on their review of hydrologic conditions within the region.

Concept #6 - The GCWA DCP pertains to only water obtained by GCWA and delivered to customers. It does not pertain to water procured by customers and delivered (by prior agreement) through GCWA infrastructure. This allows customers to obtain additional supplies for their sole use, subject to GCWA's ability to deliver the water under drought conditions.

The six drought management response concepts listed above were each heavily debated by GCWA staff and members of the Drought Task Force through the duration of this project. The resulting benefits from their inclusion are expected to be that they provide sufficient notice for customers to deal with impending drought conditions, yet also provide flexibility for all to maintain operations using alternate water supplies and proper, flexible water management. Each of these concepts is intertwined in the individual drought response stages discussed below.

Stage #1 – Mild Water Shortage (“TCEQ Watch Level”)

Under Stage 1 drought conditions, GCWA’s main goal is to make customers aware of the developing dry conditions, and to have them internally prepare for potential periods in the future where water supplies are diminished. Stage 1 conditions are achieved when the US Drought Monitor classifies over 50% of the GCWA contributing watershed to be in or exceed “Moderate Drought” conditions. This assessment is made by GCWA staff skilled/trained in the use of GIS and geospatial analysis. Training material for this assessment is provided in Appendix C. Stage 1 conditions can also be achieved if GCWA’s customer demands exceed 85% of the deliverable capacity of GCWA. This could mean that GCWA can only divert streamflow to meet 85% of customer demands, or GCWA is only able to convey (through its canal system) enough water to meet 85% of demands. Under Stage 1 conditions, customers are encouraged to begin water conservation efforts, and to reduce their usage to only 95% of their monthly targets.

Water usage under Stage 1 conditions is not eligible for customer credits or surcharges. Stage 1 conditions are expected to occur rather frequently, and as such GCWA customers are expected to operate often while considering the constant benefits of water conservation. Figure 31 depicts when Stage 1 conditions would occur based on the US Drought Monitor, from January 2000 to August 2018. As shown, Stage 1 conditions were common, with both 2006 and 2011 experiencing the condition for most of the calendar year. In contrast, there are years (2001 and 2016) when Stage 1 conditions were never experienced. Stage 1 conditions are also likely to yield Stage 2 conditions (or higher). As such, the GCWA GM is likely to recommend entering Stage 1 conditions often, even if hydrologic conditions are ambiguous. By entering Stage 1 conditions, it is hoped that transitions to Stage 2 conditions will be more easily achieved by GCWA customers, should stage 2 conditions become necessary.

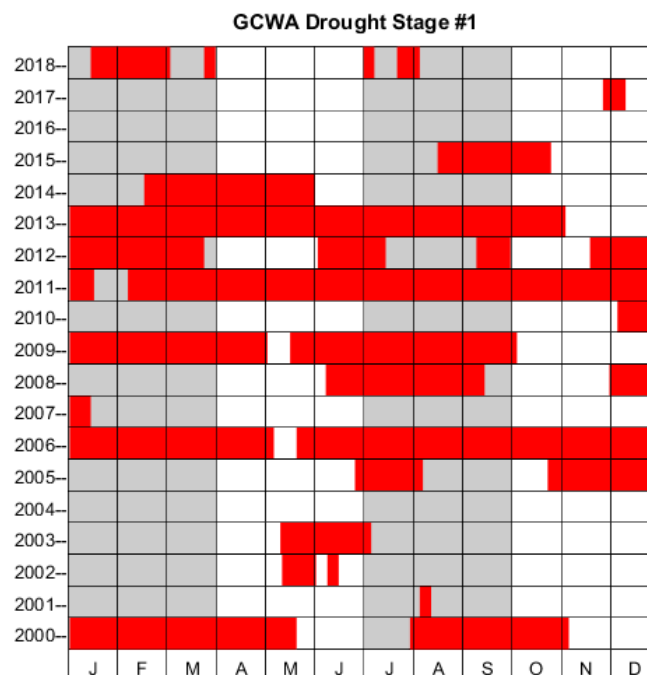


Figure 31 – Time history of when GCWA Stage 1 conditions would have occurred, based on the US Drought Monitor data criterion.

Stage #2– Moderate Water Shortage (“TCEQ Concern Level”)

Under Stage 2 drought conditions, GCWA requests greater voluntary reductions in water usage, and offers credits for entities who meet the usage reduction targets. They also impose surcharges if the customer fails to reduce usage to less than their monthly target. GCWA determined, through consultation with the DTF members, that surcharges would only be imposed on entities with monthly usages greater than their individual monthly targets (referred to as “Base Water Usages” in the GCWA DCP for TCEQ – see Appendix A), and that the surcharge would only apply to the quantity of water used in excess of their target. Implementing this policy required the development of a daily accounting method for assessing usage in a month, recognizing that in all likelihood GCWA would enter or exit various drought stages in the middle of a month rather than only at the beginning or end of a month. Monthly assessments of water usage were desired in order to conform to GCWA’s customer billing process.

Prior to entering Stage 2 drought conditions, GCWA has the option of utilizing both alternative and available streamflow to meet customer needs. GCWA has the flexibility to determine which alternative sources to utilize, yet will likely first utilize water available from the BRA prior to other sources, such as local groundwater sources. The decision to enter a Stage 2 drought condition is made by the GM, and per the DCP the GM must CONSIDER making such a stage declaration when at least one of the following triggers is met:

- 1) System Demand exceeds 90% of Deliverable Capacity within GCWA’s conveyance system for three consecutive days (applicable to any portion thereof).
- 2) The Lower Basin User’s Group recommends further water conservation based on its collective experience managing river operations.
- 3) Water available from Run-of-River Supplies and GCWA Alternate Water Supplies is determined to be insufficient to satisfy 95% of GCWA’s Monthly Flow Target through August 31 of the current year (if date is on or after January 1) or through August 31 of the next year (if date is on or after September 1 of the current year).

Within the three criteria listed above, GCWA has intertwined water availability, conveyance capacity, and user recommendations/experience into the decision-making process. The Lower Basin User’s Group, as further described in the “Operational and Administrative Framework” section, consists of water management professionals from GCWA, BRA, TCEQ, Dow Chemical, and NRG Energy who each of water provision responsibilities in the lower Brazos basin. These professionals, in 2018, decided that the best way to manage diminished resources during drought periods was to collectively discuss and decide courses of action that would be of the greatest benefit to the group. During the dry summer of 2018, this group met up to 3x weekly via conference call or in person to discuss the water supply and each entity’s needs, with each discussion leading to a decision regarding water allocation over the coming few days (until the next informal meeting/discussion). This process, while not originally part of the GCWA DCP, was so successful in 2018 that GCWA decided to include the Lower Basin User’s group formally within its DCP. It should be noted, however, that this user’s group is not a formal group, can have fluid membership, and relies upon the good-faith efforts of the members to effectively allocate available water. During periods of extreme drought, it is possible that this group may behave differently and make different water allocation decisions. This is largely driven by the fact that GCWA maintains the senior water right in the lower Brazos Basin, and therefore has priority access to available water should it wish to assert this priority

under the lowest of flow conditions. DTF members expressed this desire during DCP development and negotiations.

The third criterion listed above also intertwines the notion of run-of-river supplies and alternate water supplies available to GCWA. Ideally GCWA will be able to meet 100% of its customer demands by diverting only run-of-river supplies, defined as streamflow available for diversion under the State of Texas prior-appropriation system. During times of drought, however, it is possible that streamflows decrease to levels less than that required to meet the cumulative monthly flow targets of GCWA customers. In such instances, GCWA will utilize alternative water supply sources to supplement run-of-river flows and fully satisfy customer needs. However if GCWA determines that its available alternative water supply sources, when combined with expected run-of-river supplies, are insufficient to meet needs through August 31, then they may consider entering a Stage 2 drought. As shown in criterion #3 above, to enter a Stage 2 drought, the combined run-of-river and alternate water supplies must be less than 95% of the expected GCWA customer water demand. The 95% quantity is based on the implementation of the 5% reduction goal included in the Stage 1 response actions.

To assess criterion #3, GCWA had to develop an accounting mechanism to predict run-of-river supplies and the availability of alternate water supplies up until the August 31 calendar date. This prediction was incorporated into the Flow Prediction Tool (Figure 29), as well as within an Excel spreadsheet used by GCWA staff for tracking flow and water usage. The August 31 date was selected as a target date because it represents the end of the Texas summer, and is also when most of GCWA's available alternate water supplies from the BRA renew. For example, if GCWA was utilizing backup water from BRA and on August 30 they had fully depleted their annual allotment, BRA would have to cease releasing water for GCWA. However, as GCWA's annual allotment renews on September 1, GCWA would only have to wait until September 1 before requesting and receiving more released water from GCWA. As such, GCWA's standard policy is to not utilize BRA releases for as long possible within the calendar year, thus keeping water available to supplement run-of-river supplies in the summer months. Similar supply limitations will be implemented if GCWA utilizes local groundwater supplies to supplement run-of-river flows during drought conditions. Such limitations are not yet included in the Flow Prediction Tool or GCWA Excel spreadsheet, as wells are not yet available and their limitations (specified by the Harris Galveston Subsidence District, Fort Bend Subsidence District, or Brazoria County Groundwater Conservation District) are not yet known.

Within the Flow Prediction Tool and Excel spreadsheet, it is necessary to essentially forecast run-of-river flows into the future. This is achieved using the release rates and travel times for BRA reservoirs, and then assuming that run-of-river conditions remain constant through the remaining period between the calculation date and August 31. GCWA utilizes the aggregate monthly flow target for all its customers as the desired demand to be met, and then subtracts the estimated run-of-river flows from the aggregate monthly flow target. Resulting positive values represent the quantity of GCWA alternate water supplies needed to satisfy GCWA customers. If sufficient alternate supplies are available to satisfy needs through August 31, then GCWA either continues or initiates usage of the alternate supplies, and does not likely enter into a Stage 2 drought condition. However if sufficient alternate supplies are not available, the GCWA GM will consider entering into a Stage 2 drought condition. Figure 32 presents an approximate time-history of when GCWA would possibly enter Stage 2 drought conditions, assuming current monthly target usage rates by GCWA customers, and assuming GCWA's current alternate supply quantities from

BRA. Figure 32 does not include any planned or possible additional alternate water supplies such as local groundwater usage.

As shown in Figure 32, there are many recent years in which GCWA would not have entered into Stage 2 drought conditions (when considering only criterion #3). Recently dry years included 2009, 2011, 2013 and 2014, and correspondingly those years indicated greater frequencies of entering in or remaining in Stage 2 drought conditions. It is also notable that Stage 2 drought conditions do not only occur in the summer months, when streamflow is lower and demand is generally higher. This is because of how GCWA rations the use of its alternate water supplies over the course of the year. For example, if streamflow happened to be low in September, the calculation method would attempt to divide the alternate water supply over a large number of days, making it last until August 31 of the following year. Thus low streamflows in September are more likely to trigger Stage 2 drought declarations than identical streamflows in July, assuming alternate supplies had not already been used-up in the time preceding July. It must be noted that the results shown in Figure 32 only consider criterion #3 for entering a Stage 2 drought, and GCWA may not have made such a decision identically as predicted mathematically using historical streamflow data. The Lower Basin User's Group (criterion #2) could have used some other hydrologic criterion or other means to decide that entering Stage 2 drought was not warranted.

GCWA Drought Stage #2 - Criterion #3

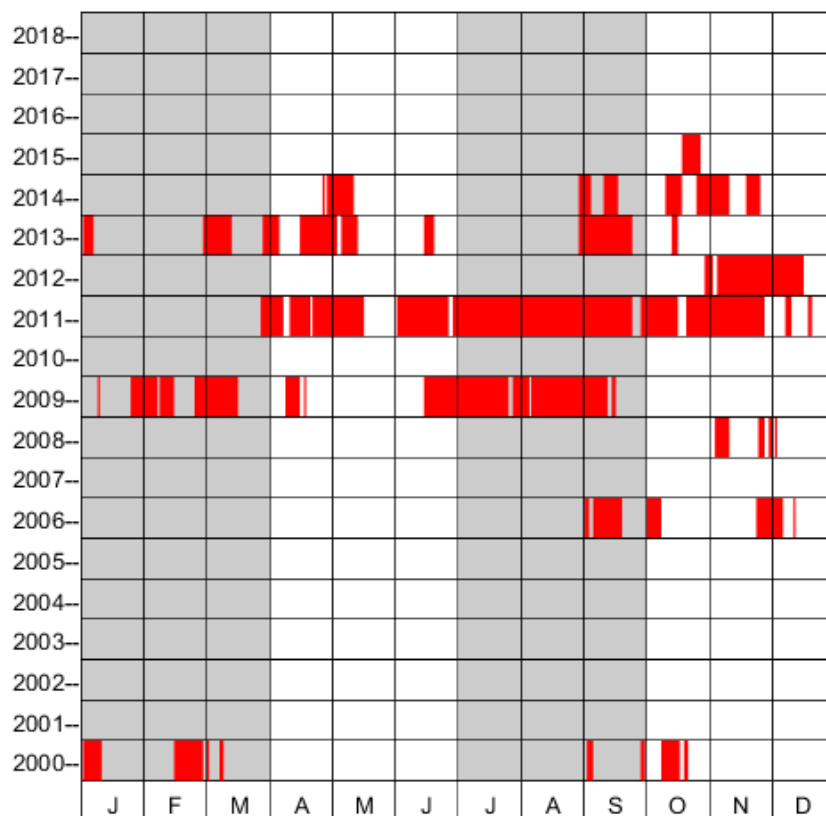


Figure 32 – Modeled time-history of when GCWA would possibly enter a Stage 2 drought based only on criterion #3 (run-of-river flows and alternate water supplies).

Figure 33 presents the time-history of GCWA's alternate water supplies from the BRA as calculated when assessing the Stage 2 drought condition criterion #3 (Figure 32). Shown are the remaining volumes of supply from both fiscal-year (September-August) and calendar-year (January-December) contracts GCWA maintains with BRA. As shown, in both 2009 and 2011, GCWA would have fully utilized its alternate water supplies from BRA along with available run-of-river water to meet customer demands. Figure 33 also demonstrates that in most years, GCWA maintains an abundant alternative water supply.

Figure 34 demonstrates the time history of when Stage 2 demand reductions (modeled as 10% reductions) combined with available run-of-river flows and GCWA alternate water supplies would not have been sufficient to meet customer demands. Such instances occurred only in late summer, and would have likely necessitated GCWA's entering a Stage 3 drought condition. Using supplemental groundwater during 2009 and 2011 may have resulted in GCWA having avoided entering a Stage 3 drought condition. Obtaining additional alternate water supplies from BRA would have also provided sufficient relief; GCWA did purchase additional alternate water supplies in 2011.

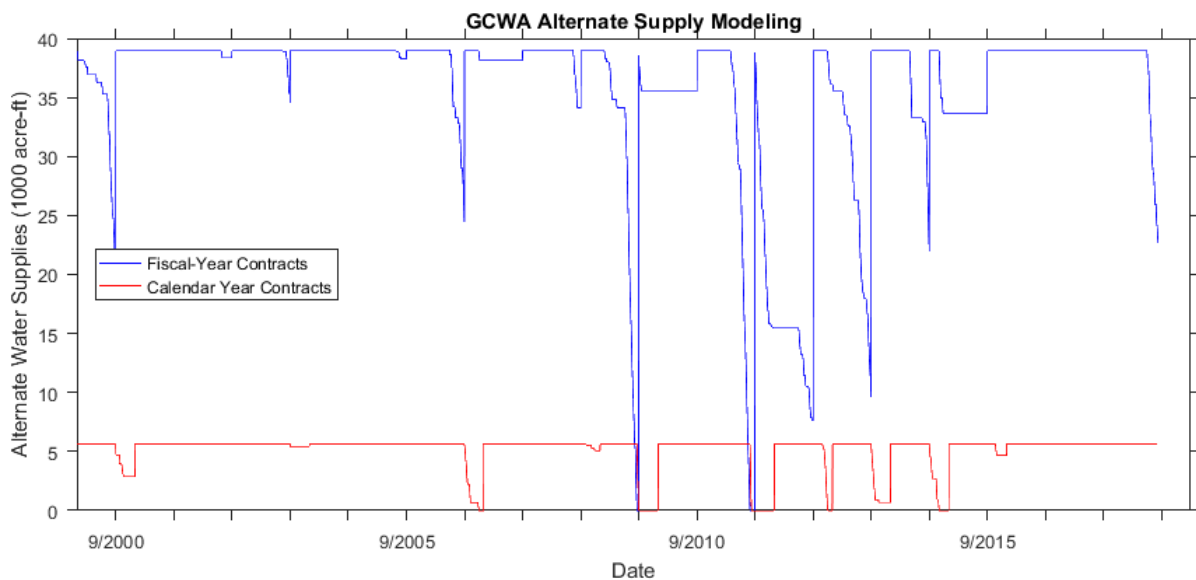


Figure 33 – Time series of GCWA available alternate supplies from the BRA, as modeled in assessing Stage 2 conditions (Figure 32).

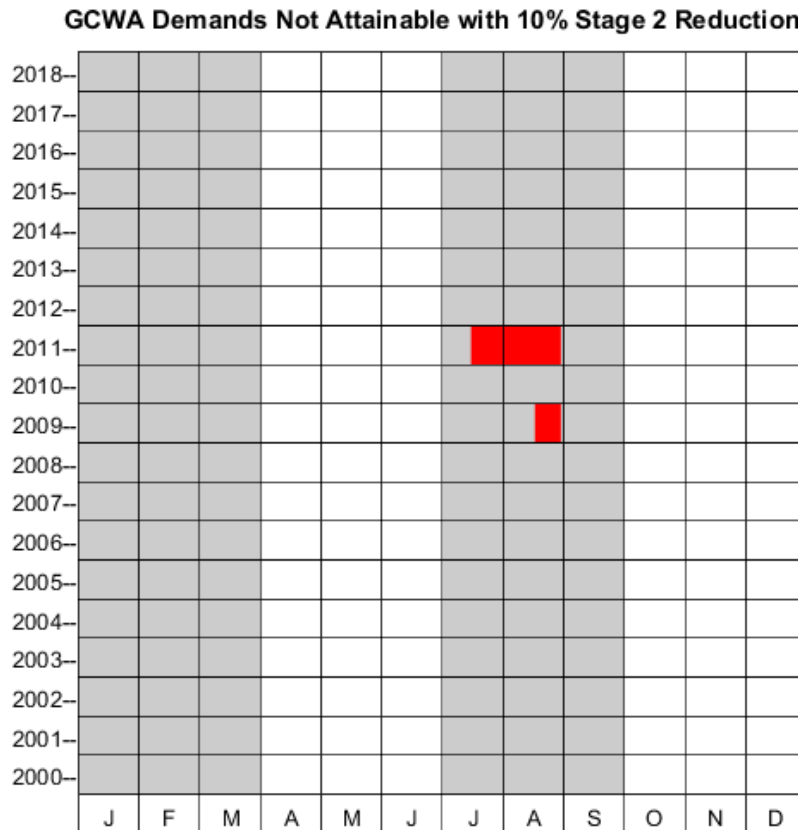


Figure 34 – Time-history of when GCWA customer demands would have been un-satisfied with available run-of-river flows and alternate water supplies after implementing a Stage 2 demand reduction of 10%.

Upon declaring a Stage 2 drought condition, GCWA may take the following actions to reduce demands to levels that are achievable given available supplies:

- Continue or initiate any actions available under Stage 1;
- Notify all Affected Customers that a Stage 2 Response condition exists;
- Initiate or continue usage of GCWA Alternate Water Supplies to augment Run-of-River Supplies;
- Request all Affected Customers to initiate Stage 2 or other appropriate stage in their drought contingency plans;
- Request voluntary reductions in water use by Affected Customers;
- Meet with Affected Customers to determine water use on a as needed basis, identify Affected Customers exceeding 95% of their Base Water Use or Interruptible Water Use and encourage them to reduce their usage;
- Cease issuance of new short-term or Interruptible Customer contracts with the exception of contracts needed under emergency conditions;
- Terminate water deliveries to existing Interruptible Customers without Backup;
- Increase public awareness of drought condition and measures to reduce demand; and
- Notify the Brazos Watermaster, NRG, and Dow that a Stage 2 Response Condition exists
- Implement water rate surcharges and credits based on individual customer water usage

All of the measures listed above are designed to convey to water users the severity of the water shortage and to encourage water conservation. The most impactful measure is the termination of water deliveries to interruptible customers. These customers have only short-term contracts for water delivery from GCWA, and are typically used for agricultural crop irrigation. Ceasing deliveries for interruptible customers can significantly reduce GCWA's overall water demand, especially during the summer months when irrigators use the most water. By terminating interruptible customer deliveries under Stage 2, GCWA is vastly decreasing the likelihood of necessitating a Stage 3 drought declaration. However removing interruptible demands during 2011 would not have eliminated the water shortages shown in Figure 34. This is because the run-of-river streamflow during the late summer of 2011 was virtually non-existent, and GCWA would use up its alternate supplies prior to the September 1 renewal date. Shortages for 2009, however, would have been eliminated through the termination of the interruptible customer water deliveries. By eliminating interruptible customer demands under Stage 2 drought conditions, GCWA is making it more likely that all "firm" customer demands will be met.

Stage #3 & Stage 4— Severe & Extreme Water Shortage ("TCEQ Priority & Emergency Levels")

Stage 3 and Stage 4 droughts, as defined in the GCWA DCP, are really just more severe versions of a Stage 2 drought. They have similar triggers as defined under the Stage #2 description, yet with different percentages used. For example, per criterion #3 for a Stage 2 drought, GCWA cannot meet 95% of demands with available supplies. For a stage 3 drought, the target is lowered to 90% of demands being met. The lower trigger corresponds to the targeted demand reduction from the next lower drought stage.

Water use reduction goals for Stage 3 and Stage 4, respectively, are set to 85% and 80% of the customer's monthly target. These amounts generally exceed "acceptable" reduction quantities identified by GCWA customers and DTF members over the course of this project. GCWA intends to work with individual customers to devise means of reducing water usage through further best management practices, where possible. This includes aiding customers in obtaining alternate water supplies, possibly including assisting to maintain customer groundwater wells which are only to be used during severe or worse drought conditions. Under Stage 4 conditions, GCWA commits to requesting relief from the Brazos Watermaster, asserting GCWA's generally senior priority water rights for preferential use of water during drought conditions. It is only under Stage 4 conditions that GCWA will specifically ask for relief from the Brazos Watermaster.

Stage #5 – Water Emergency Response (“TCEQ Emergency Level”)

A Stage 5 drought condition is only to be declared when GCWA is not physically able to convey sufficient water to customers, or if the water is of poor quality due to a contamination event. It is not foreseen that a Stage #5 condition will be in anyway related to the quantity of water available from GCWA sources. Examples of potential causes of Stage #5 conditions include:

- Canal system failure/leakage/damage
- Damage to GCWA pump stations and other infrastructure
- Chemical contamination making available water unsuitable for desired purpose of use.

Depending upon the location of the cause of the Stage #5 declaration, it is possible that certain GCWA customers would be able to continue operations as normal when other customers would be forced to severely diminish water usage. For example, a failure of the GCWA industrial pump station would result in a Stage 5 drought emergency for only those customers receiving water from the pump station; Customers upstream of the failed pump station would not be affected and would be allowed to continue operations as hydrologic conditions dictate.

GCWA strives to avoid Stage #5 conditions by continuously monitoring the operation of all canal conveyance infrastructure, and immediately solving small infrastructure issues before they become cataclysmic.

Under Stage #5 conditions, GCWA customers do not have defined water use reduction goals, but rather are allotted a pro-rata share of any available water. The pro-rata share is based on the individual customer’s monthly target usage rate. Customers who unfairly utilize more water than their allotted quantity during a Stage #5 declaration will be assessed a 10x surcharge on the excess water. GCWA determined that such a financial penalty would provide customers with sufficient incentive to comply with GCWA’s water allocation decisions during water supply emergencies.

Essential Element #5 – Operational and Administrative Framework

GCWA's objective in developing and implementing this DCP is to effectively and fairly manage available water during periods of drought so that customers have the water they need and are provided sufficient time to adjust water usage practices to avoid short-term water shortages due to drought conditions. It is GCWA's intention to administer the DCP in an open manner, and as such GCWA welcomes input and participation from interested parties.

Through discussions between GCWA staff, members of the GCWA Board of Directors, and Drought Task Force members, the operational and administrative framework for the GCWA DCP was established. Responsibility for implementing the DCP lies with the GCWA General Manager (GM), currently Ivan Langford. The GM may delegate responsibilities to GCWA staff members, who will report back to the GM with both data and recommendations for action regarding the drought status. Water accounting tasks, including tracking customer monthly usage and running the Flow Prediction Tool, will be accomplished by GCWA staff otherwise tasked with performing water accounting functions. Analysis of the US Drought Monitor data (for assessing Stage 1 drought conditions) will be performed by GCWA staff trained in geospatial analysis using ArcGIS or similar software.

GCWA staff will coordinate the informal meetings of the Lower Basin User's group as needed. During 2018, this group (organized and lead by GCWA's Assistant General Manager Mr. David Sauer) met as needed either in person, by phone, or via online video conferencing to discuss hydrologic conditions and local water needs. The group then jointly made decisions regarding water allocation, with each participating entity occasionally modifying their diversion requests in order to fairly make water available to other members of the group. During 2018, the Lower Basin User's group consisted of representatives from GCWA, the Dow Chemical Company of Freeport, TX, and NRG Energy, Inc. Other participating members included the Brazos Watermaster, representatives of the TCEQ (including watermaster staff), and representatives of the Brazos River Authority. Their participation was especially important during the summer months when streamflow was low and allocation decisions became especially important. GCWA will consistently organize the informal meetings of the Lower Basin User's group, and decisions will be made based on the desires of the entities participating in each meeting. The Lower Basin User's group membership is designed to be fluid as needed to incorporate the views of all entities interested in contributing to the water allocation decision making process. Expected primary members will be representatives of the three large diverters in the Lower Brazos Basin (GCWA, NRG Energy, Inc. and the Dow Chemical Company of Freeport, TX), with GCWA representing the interests of its customers. Secondary members will be representatives of the TCEQ (including the Brazos Watermaster) as well as representatives of the Brazos River Authority. Tertiary members will be other lower basin water right holders or GCWA customers who wish for more active participation. Such customers are likely to be those who obtain "Alternate Water Supplies" to be managed by GCWA. All members will contribute to group decisions, yet formal operating rules will not be implemented.

Upon deciding to implement a certain drought stage, the GCWA GM will notify customers following their accepted notification procedures, developed through the contracting process between GCWA and each customer. Notice will also be provided on the GCWA website, and will be made via standard GCWA

communication protocols to the media and general public. GCWA did not wish to include these protocols and standard methods of communication here in this DCP document, as the methods are subject to change by agreement of the GCWA Board of Directors and customer representatives.

Imposition of monthly surcharges and credits, according to the DCP, will be incorporated into the GCWA normal customer billing process. Customers will have the ability to review and contest water accounting practices developed by GCWA and used to implement the DCP. Per State of Texas general practices, GCWA's water accounting spreadsheets and methods will be available for review at the GCWA office during normal business hours, or at other times/locations by special permission granted by the GCWA GM.

As part of the DCP implementation process, GCWA will initiate and maintain an ad-hoc Drought Contingency Advisory Committee. The Committee will be administered by GCWA. The Committee will be comprised of representatives from each of the industrial customers, major municipal treated water customers and agricultural customers of GCWA. The Brazos River Watermaster will be an ad-hoc member. The Committee will meet with GCWA twice each year to:

- Review information on river flow and BRA reservoir levels, and drought conditions in the Brazos River Basin.
- Monitor the running computation of water use for each customer.
- Receive information on water use, conservation and drought contingency planning by GCWA, NRG, and Dow.
- Provide feedback to GCWA on the implementation of the Plan.
- Receive information from GCWA on its acquisition of Alternate Water Supplies.

The ad-hoc Drought Contingency Advisory Committee will not be a formal committee established by GCWA, and will not be subject to the legal requirements for formal committees performing business for the State of Texas. Members of the public are eligible to participate in the informal committee meetings, and may learn of meeting dates and times by contacting the GCWA administration office.

Per Section XI of the GCWA DCP (TCEQ version – Appendix A), GCWA customers may request variances to aspects of the DCP. Variances may relate to the surcharges or credits to be obtained, to the water use target to be achieved by each customer, or to some other aspect of the plan. Variances are to be submitted in writing to the GCWA GM, who has the authority to grant or deny each variance request. Any denied variance request may be appealed to the GCWA Board of Directors, who have the final decision regarding any appealed request. The GCWA Board of Directors may uphold or overrule the variance decision made by the GM.

Essential Element #6 – DCP Update Process

The GCWA DCP will be formally updated every 5 years. The update process will culminate with a GCWA Board of Directors resolution adopting the revised DCP, and the submission of the DCP to the Texas Commission on Environmental Quality (TCEQ) and Texas Water Development Board (TWDB). Current DCP was formally adopted by the GCWA Board of Directors on December 6, 2018. It will be submitted to TCEQ and TWDB upon acceptance of this DCP by Reclamation, or by May 1, 2019 (whichever is earlier). The next required update of the GCWA DCP will be completed by May 1, 2024.

During the period leading up to the next GCWA DCP update, GCWA staff, stakeholders, members of the Lower Basin User's Group, and the ad-hoc Drought Contingency Advisory Committee will continuously track, observe, and scrutinize the methods employed to administer the DCP. The GCWA GM will document any observations regarding the effectiveness of the DCP, including any observed benefits and deficiencies of the plan. These observations will be utilized when developing the plan revision.

The DCP presented in this document will be in place for 5 years, between 2019 and 2024. This 5-year "implementation period" period will be GCWA expects to used year 1 and year 2 of the implementation period to observe the efficacy of the DCP and note aspects that should be improved during the next revision process. Potential revisions are to be recorded by GCWA staff (as delegated by the GM), and revision methods are to be developed and discussed by the ad-hoc Drought Contingency Advisory Committee during years 3 and 4 of the implementation period. During year 5 of the implementation period, GCWA will formally revised the DCP based on the recommendations of the ad-hoc Drought Contingency Advisory Committee (and other recommendations received by GCWA, if any). GCWA will then offer the draft revised DCP for review and public comment, holding at least one public meeting at which GCWA may receive public (including stakeholder or customer) input regarding the DCP. After the public meeting, GCWA will address any issues raised from the meeting discussion, and will present a revised DCP for review and potential adoption by GCWA Board of Directors. After formal adoption, GCWA will submit the revised DCP to the TCEQ and TWDB. The revised DCP will contain all content and format requirements (if any) specified by TCEQ and TWDB. These requirements may change over time, and GCWA will coordinate with TCEQ and TWDB to ensure the updated DCP meets all updated requirements.

GCWA, at the discretion of the Board of Directors, may update the DCP at any time within the 5-year implementation period, and the updates will take effect upon formal adoption of the revised DCP by the GCWA Board of Directors. After the DCP is formally updated and adopted, the revised DCP will be submitted to TCEQ and TWDB.

References

Cleaveland, M.K, Votteler, T.H, Stahle, D.K, Casteel, R.C., and Banner, J.L (2011) "Extended Chronology of Drought in South Central, Southeastern, and West Texas." Texas Water Journal, Texas Water Resources Institute Volume 2, Number 1, pg. 54-96. December.

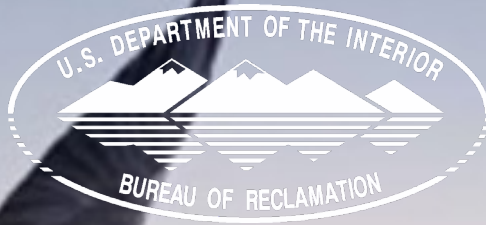
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<http://www.twdb.texas.gov/groundwater/models/research/subsidence/subsidence.asp>

Appendix A

Gulf Coast Water Authority Drought Contingency Plan

For the
Texas Commission on Environmental Quality



Gulf Coast Water Authority

in conjunction with



LREWater, LLC



Appendix C. Water Availability Model Simulation Report

TECHNICAL MEMORANDUM

Prepared for:

[Gulf Coast Water Authority](#)

4243 Emmett F Lowry Expressway

Texas City, TX 77591

Subject:

[Water Availability Model Simulation Report](#)

Regional Seawater Desalination Feasibility Study

GCWA PROJECT NO. 5993

US BUREAU OF RECLAMATION GRANT NO. R24AP00180-00

BLACK & VEATCH PROJECT NO. 419808

Prepared by:

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March 6, 2026

Texas Registered Engineering Firm F-4991

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1 Introduction

Civitas Engineering Group, Inc. (Civitas), in conjunction with Black and Veatch, inc. (B&V) were asked to conduct a Regional Seawater Desalination Feasibility Study for the Gulf Coast Water Authority (GCWA). This study is a multi-part effort to consider aspects of feasibility of a desalination facility in the Texas Gulf Coast region, including regional supplies and demands, hydrologic availability, impacts on the Brazos river, and others. A potential desalination facility implemented within the GCWA system would positively affect the availability of other water supplies within the GCWA system. The GCWA system is hydrologically complex, and water availability is affected by many factors both environmental and contractual. To quantify this impact, and to examine impacts to reliability of water supplies, a Water Availability Model (WAM) evaluation was performed. This memo details the simulation.

2 Water Availability Model (WAM) Simulation

The TCEQ relies on Water Availability Models to manage and evaluate surface water resources across the state's river basins. These models are essential tools for determining whether water is legally and physically available for new water rights or changes to existing ones. TCEQ staff use the models in evaluating water rights applications to help determine if water would be available for a newly requested water right or amendment, or if an amendment might affect other water rights. Two kinds of models are published. A Full Authorization simulation models all water rights utilized to their maximum authorized amounts. This is used to evaluate applications for perpetual water rights and amendments. In contrast, a Current Conditions simulation model includes flows that are returned to the river, and current water use. This is used to evaluate applications for term water rights. For the Brazos River Basin, the WAM is considered a "Full Authorization" dataset, which examines cases where the maximum water rights are diverted. This is considered a conservative modeling assumption. At the heart of the WAM system is the Water Rights Analysis Package (WRAP), a software program developed by Texas A&M University. WRAP simulates streamflows and the allocation of water under Texas's priority-based water rights system by processing historical data, return flows, diversions, reservoir operations, and other hydrologic inputs. Each river basin in Texas has its own WAM, developed using basin-specific data and tailored to its unique hydrologic and legal conditions. Additionally, the Brazos Watermaster program monitors usage and rights and acts to protect the water rights holders from over usage upstream. WAM simulations can inform potential results of a change in usage. If water is available, these models estimate how often water would be available. For example, this would help inform stakeholders if a potential source would be available only during very wet times, or if it might also be available during very dry times. Applicants may also use the models when preparing to apply for a new water right or an amendment. WAMs are widely used for long-range planning, environmental impact assessments, and drought contingency evaluations. By simulating how water is used and flows through a basin under varying hydrologic conditions, WAMs support informed decision-making and sustainable water management across Texas.

This WAM evaluation in this report aimed to bracket the volume of water that could be "freed-up" by implementation of a treated water desalination facility, and further to examine several scenarios to ascertain how available, and how reliable, such a volume of water would likely be. The modeling evaluation proceeded with the following assumptions, chosen to examine the feasibility of the ability of a future desalination plant to allow greater flexibility and reliability in the region:

- It is assumed that future water produced by desalination will likely be allocated to serve treated water demands at the downstream end of the GCWA system, where existing fresh water supplies are under greater strain, and where proximity to both favorable sites for desalination and potential future users of water produced by desalination provides economic opportunities,
- By alleviating demands downstream, it is likely that implementation of future desalination will “free up” water to be allocated elsewhere. This “freed-up” water could be allocated either within the GCWA system, or outside of it.
- To capture the impacts of either, the volume of freed water was modeled as a diversion from existing water rights. This allows the WAM to examine the available volume and reliability of both the freed water and the remaining, un-diverted water under GCWA water rights and its BRA contracts. None of the water rights themselves are being split or otherwise modified.
- In this way, the WAM evaluations provide information about the reliability and availability of re-allocating the available water, examined through use of water rights, examined at several locations. The WAM runs also provide a spectrum of scenarios and locations, ranging from highly reliable to moderately so. This information can be used to select scenarios for future study, and to support potential partnerships with other water users or water rights holders in the area.
- The WAM evaluations examined the impact of re-allocating a certain volume of water upstream and helps quantify how much water could reasonably be “freed up” or re-allocated by a future desalination project without impacting GCWA’s existing supply or intervening water rights holders, and how reliable this water might be.

The WAM simulation examined a range of scenarios, including the following:

- Likely desalination facility sizing, including 10, 20, and 40 MGD.
- Freeing up water from several locations, including the Shannon, May, and Briscoe Pumping Plants.
- Allocation of “freed” water at two locations, including the Hempstead and Washington US Geological Survey (USGS) gauges. These locations are shown for reference in Figure 2-1.

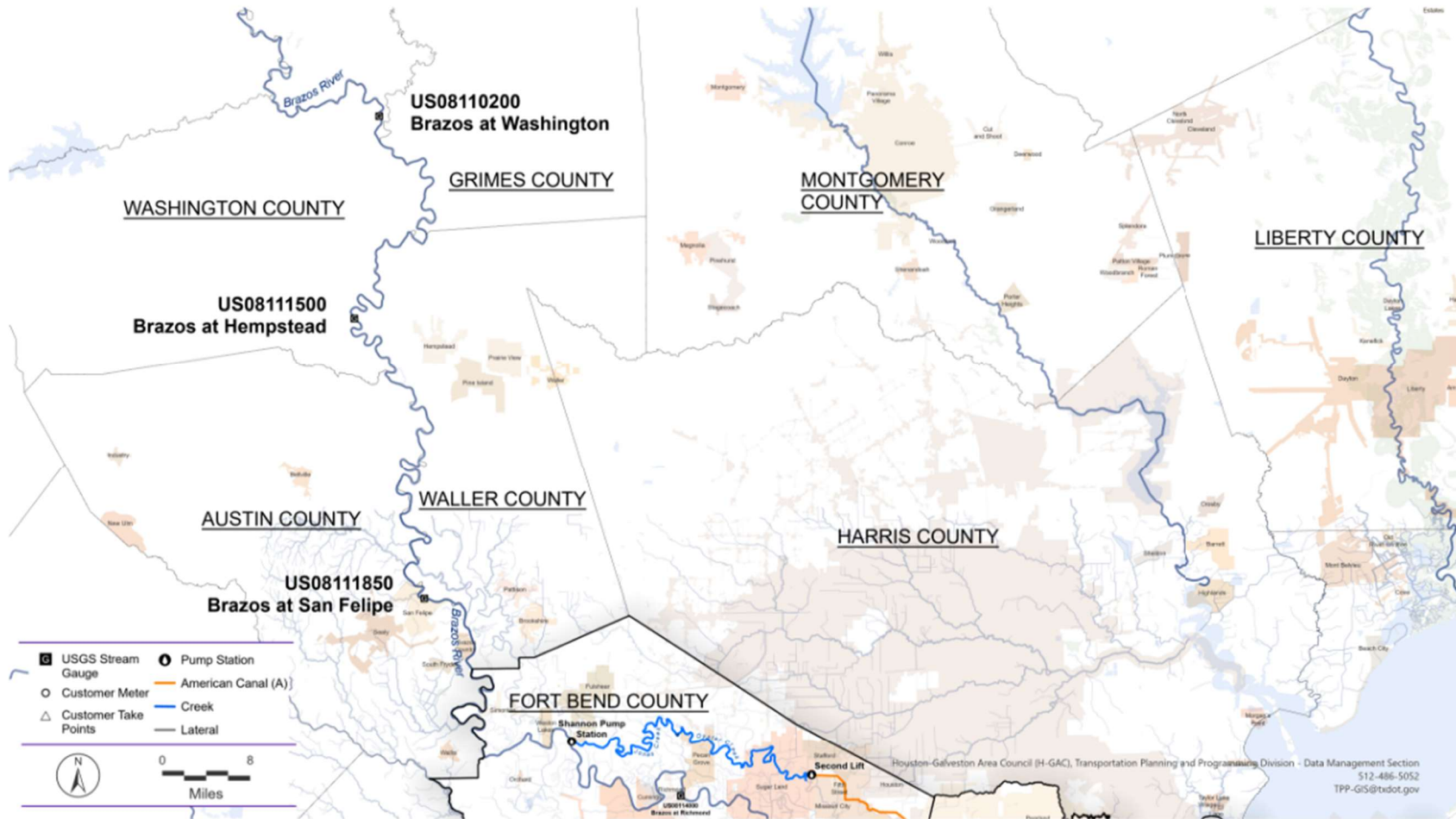


Figure 2-1 Upstream USGS Gauges

For the purposes of this exercise, any water “freed-up” is considered as a diversion from a water right. This is not intended to reflect the splitting of a water right or any other legal modification, but is instead intended to allow examination of the hydrologic impacts of both the diversion volume and the remaining volume. This informs likely outcomes for re-allocation of freed water by examining resulting availability and reliability of impacted water supplies.

To that end, the objective of this exercise was to evaluate different scenarios for implementation of a desalination facility. The objectives of the WAM analysis are as follows:

- Execute the WAM on a monthly timestep and output water availability for GCWA diversions at the Shannon, Briscoe, and May Pump Stations. These locations were chosen to reflect the GCWA take points from the Brazos River
- Identify key scenarios to evaluate using the Brazos WAM model.
- For volume of “freed” water examined, account for hydrologic effects of re-allocating water upstream and estimate the quantity of water made available at the upstream USGS Hempstead and Washington gauges. These gauges were identified as useful control points to serve as a comparison point to BRA operations that may impact GCWA. The location of these gauges is included in Figure 1-1.
- Determine any positive or negative impact on any individual water rights as a result of these scenarios.

3 Methodology

An overview of the WAM methodology is explained below. In the beginning of the execution of a WAM simulation, basic information about the river basin is prepared. Naturalized flows, meaning original streamflows without modification, are identified for primary control points. Basin geometry and net evaporation rates for reservoirs were previously published by TCEQ, and are read from the WAM input dataset. Naturalized flows are then distributed to secondary control points and all other sites based on the watershed characteristics. Prior appropriation doctrine dictates that priorities for allocations are based on dates specified in the permits reflecting when the right was established. Water rights are sorted into priority order. Within each sequential month, water accounting computations are performed as each set of water use requirements (water right) is considered in priority order. Water allocation and management are modeled by accounting procedures within the water rights priority loop.

As each water right is considered in priority order, the following four tasks are performed:

1. The diversion, instream flow, or hydropower target is set starting with an annual amount and 12 monthly distribution factors provided as input.
2. The amount of streamflow available to the water right is determined considering available flows at the control point of the water right and all downstream control points.

3. Water use requirements are met subject to water availability following specified system operating rules. Water accounting computations are performed to determine the diversion, diversion shortage, end-of-month storage, and related quantities.
4. The available streamflow is adjusted for the control point of the water right and all downstream sites to reflect the effects of the water right.

The latest version of the WAM input dataset for the Brazos River were obtained from TCEQ in May 2024. Modeling simulations specific to this project were planned with respect to the proposed changes in diversion strategy. The three main pumping stations of May, Briscoe, and Shannon plants were chosen as diversion points of study for the GCWA system. To evaluate upstream impacts, the US Geological Survey (USGS) streamflow gauges at Hempstead and Washington were chosen as control points to evaluate streamflow at two likely upstream locations. Under these conditions, the WAM simulations examine water availability in the river at each of the chosen diversion and control points. Multiple simulations were run using the WRAP software. These include the following:

1. Base WAM Run at William May, Briscoe, and Shannon plants, which acts as a control, or unchanged, water availability simulation.
2. 10 MGD diversions at William May, Briscoe, and Shannon plants effects on or at Hempstead and Washington gauges, which examines water availability assuming a 10 MGD desal plant.
3. 20 MGD diversions at William May, Briscoe, and Shannon plants effects on or at Hempstead and Washington gauges, which examines water availability assuming a 20 MGD desal plant.
4. 40 MGD diversions at William May and Shannon plants effects on or at Hempstead and Washington gauges, which examines water availability assuming a 40 MGD desal plant.

These runs examine run-of-river flows within and upstream of GCWA. No direct evaluation of stored water was made in these runs. Rather, the WAM runs seek to inform the availability and reliability of water under several scenarios. These volumes could then potentially be used for storage, re-allocation, or other uses.

To set up these model runs, the Base WAM Run contains input files for Brazos River Basin from TCEQ. No diversions were added to the input files. Table 3-1 lists the identifiers used for the above control points.

Table 3-1 Water Availability Model Control Points

Name	Water Right / Control Point ID	Priority Date
William May Plant	C_5322_6	07/25/1983
Briscoe Plant	C_5171_4	02/01/1939
Shannon Plant	C_5168_6	01/15/1926
Hempstead Gauge	BRHE68	
Washington Gauge	528611	

The next sections describe the model simulations, important parameters, and results.

4 Model Runs

4.1 Base WAM run

This first WAM simulation was run based on the Brazos River Basin WAM obtained from TCEQ without any modifications. The results of this simulation are used to compare the results from other simulations where the input files are modified to account for diversions. For this run, target flows were limited to a representative portion of each diversion point's available water rights, in order to facilitate future comparisons. Table 4-1 describes this run.

Table 4-1 Water Availability Model Base Run Parameters

Plant Name	Water Right ID	Target (ac-ft/yr)
William May	C5322_6	75000
Briscoe	C5171_4	33750
Shannon	C5168_6	49966

4.2 Diversions to Hempstead and Washington gauges

This section describes how the simulation is modified to evaluate the potential changes to diversion strategies. Base WAM targets are modified for diversions and remaining water right volumes with underscore D are added for the diverted water. Table 4-2 identifies the diversion parameters.

Table 4-2 Water Availability Model Diversion Targets

Plant	WRID	Target (ac-ft/yr)			
		Base WAM Run	10 MGD Diversion	20 MGD Diversion	40 MGD Diversion
William May	C5322_6	75000	63795	52590	30180
	C5322_D	-	11205	22410	44820
Briscoe	C5171_4	33750	22545	11340	N/A
	C5171_D	-	11205	22410	N/A
Shannon	C5168_6	49966	38761	27556	5146
	C5168_D	-	11205	22410	44820

This table allows comparison of the proposed diversion against the remaining water right flow. At 40 MGD, for example, diverting the full 40 MGD from the senior Briscoe right is in excess of the selected

right and is not allowable. Further, a 40 MGD diversion from either the William May or the Shannon water right would constitute the majority of the right and would negatively impact the water available to GCWA customers downstream, requiring any proposed desal plant to provide water to the impacted GCWA customers.

For the simulation inputs, input datasets for each of the diversions are modified before running the simulations. For example, if 10 MGD is diverted from William May Plant, the target for William May Plant is reduced by 10 MGD from Base WAM Run target ($C5322_6 = 75000 - 11205 = 63795$ ac-ft/yr) and a water right name C5322_D is added with a target of 10 MGD (11205 ac ft/yr). This simulates the addition of another diversion at this point, and is used to reflect the loss of water to GCWA that results from an upstream diversion.

5 Results

Over 50 runs were made examining different aspects and combinations of water right diversions across the historical time period provided by the TCEQ WAM, which is limited to 1940 to 2018. These are tabulated in Appendix C. Selected runs are presented here for clarity. These runs represented illustrative points that demonstrated clear differences between run categories, and are generally the “best” run of that category, as measured by highest reliability and least potential impact to other water users. Water supply availability is a key aspect of the run evaluation and is tracked two ways. The WAM examines the historical streamflow during the period, models the demands exerted, and then outputs the percentage of those historical periods where streamflow would exceed the specified target under the specified conditions. Both a monthly and yearly basis are considered. A monthly basis allows a more granular timestep to be examined, and is useful to examine scenarios where a dry month would invite a shortage in streamflow and thus water right. A yearly basis allows direct comparison to historical drought years, and is a good marker to detect if a certain diversion would allow a shortage at any point in the year. In the model output, the flow of the modeled diversion is compared to the target diversion flow, and cutoff thresholds of 75% and 95% are established to more concisely illustrate how reliable the diversion becomes. Selected runs are presented in Table 5-1.

Table 5-1 Select WAM Run Results

Diversions	Percentage of Months		Percentage of Years		Total Diversion Impact (Acre-ft/yr)
	With Diversions Equaling or Exceeding Percentage of Target Diversion Amount				
	95%	75%	95%	75%	
40 MGD from William May to Hempstead	83.5	83.5	44.3	70.9	(3507.63)
40 MGD from Shannon to Hempstead	99.3	99.4	94.9	100	(928.62)
	99.4	99.4	94.9	100	(1131.53)

Diversions	Percentage of Months		Percentage of Years		Total Diversion Impact (Acre-ft/yr)
	With Diversions Equaling or Exceeding Percentage of Target Diversion Amount				
	95%	75%	95%	75%	
20 MGD each from Briscoe and Shannon to Hempstead	96.9	97	82.3	96.2	
40 MGD from William May to Washington	90.4	90.4	57	81	(3252.19)
40 MGD from Shannon to Washington	98.9	99.1	93.7	98.7	(780.14)
20 MGD each from Briscoe and Shannon to Washington	99.2	99.3	94.9	100	(1209.10)
	96.7	96.8	82.3	94.9	

The above table lists six model runs that showed high availability. To explain the diversion reliability more clearly, consider the model run for diversion of 40 MGD from Shannon to Hempstead. This run examines the reliability and impacts of diverting 40 MGD from the Shannon water right before it enters the GCWA system. For this run, these impacts are evaluated at the upstream Hempstead gauge.

The model outputs that during 99.3% of the months studied, the modeled diversion amount equaled or exceeded 95% of the target amount. Similarly, during 99.4% of the months studied, the modeled diversion amount equaled or exceeded 75% of the target amount. This indicates that this scenario scores very highly for reliability, and is not overly sensitive to variations in the target amount. On a yearly basis, 94.9% of the years studied yielded a modeled diversion amount that equaled or exceeded 95% of the target amount, and 100% of the years studied yielded a modeled diversion amount that equaled or exceeded 75% of the target amount. This indicates a uniform and reliable diversion that is not overly affected by seasonal dips in water supply availability.

By contrast, the model run for 40 MGD from William May pump station, again measured at the Hempstead gauge, posts lower reliabilities across the board, indicating that the position (and age of the water right) of William May has potential negative impacts on how often the target diversion can successfully be met. A diversion from this location will be more heavily subject to drought impacts and more likely to submit to more senior water rights before it can be fulfilled.

A third category of scenarios were studied, to examine a split diversion between the Shannon and the Briscoe water rights. As expected, runs in this category display middling reliabilities. Similar results were obtained for all three runs when comparing examination points between the Hempstead and Washington gauges.

A final category of model outputs, represented in the far column of Table 5-1, examined and evaluated the potential of impacts to other water right holders. GCWA is not the only holder of water rights in the studied basins, and the WAM can capture to a certain extent the impact of changes to the streamflow on additional water right holders. Runs were configured to examine the water supply availability to the users in-between the modeled diversion point and the studied USGS gauge. This allows a quantification of any positive or negative change to the water supply of these point users due to the diversion. In general, almost all runs demonstrated a slight but consistent potential negative impact to these users. The diversion of water from upstream, as modeled by these WAM runs, in effect reduced the amount available to other users under most circumstances. Naturally, the water rights represented by these users must be satisfied in the event of any change to stream diversions. In most of the time period studied, this resulted in small shortfalls of the modeled available water, compared to the point user's usual or "base" projected flows available for use.

The next step in a model run evaluation is to calculate the final potential water made available, representing the modeled amount of flow that could be put to beneficial use in a given scenario. The target amount resulting from an upstream diversion is reduced by the diversion impact amount, which is the amount needed to withhold from the diverted flow to ensure that downstream user rights are protected. In the example of the run diverting 40 MGD from Shannon to Hempstead, the final potential water made available would be 40 MGD (~44,835.46 acre-ft/yr) less the 928.62 acre-ft/yr needed to reserve for impacted rights holders, for a total of approximately 43,906.84 acre-ft/yr.

In summary, of the runs studied, the 40 MGD diversion from Shannon demonstrated the most favorable characteristics of high diversion reliability and low diversion impact, resulting in a diversion with the most likelihood to deliver the highest amount of water made available. The 40 MGD diversion from Briscoe demonstrated the least reliable diversion.

6 Conclusions

- Percentage of months with diversions equaling or exceeding the percentage of target diversion amount was the highest for moving the 40 MGD diversion from Shannon plant to Hempstead gauge.
- Period Reliability and Volume Reliability was also the highest for 40 MGD diversion from Shannon plant to Hempstead gauge.
- Diversion potential impact on other water rights holders was the least for 40 MGD diversion from Shannon plant to Washington gauge.

These results indicate that the Shannon water rights are the most reliable water right to divert 40 MGD with the least diversion impacts. Older water rights are better options for diversion modifications because they are more reliable. Reliability decreases with newer priority dates. If a take point associated with a water right is moved upstream, TCEQ will ensure other rights are not impacted and environmental flows are also protected, which may impact actual flows available to allocate. Location of a take point also affects reliability, due to increased mainstem flows from tributaries and flow accumulations further down the basin.

This supports the feasibility of the ability of a future desalination plant to allow greater flexibility and reliability in the region in the following manner;

- It is assumed that future water produced by desalination will likely be allocated to serve treated water demands at the downstream end of the GCWA system, where existing fresh water supplies are under greater strain, and where proximity to both favorable sites for desalination and potential future users of water produced by desalination provides economic opportunities,
- By alleviating demands downstream, it is likely that implementation of future desalination will “free up” water to be allocated elsewhere upstream. This “freed-up” water could be allocated either within the GCWA system or outside of it.
- To capture the impacts of either, the volume of freed water has been modeled as a diversion from existing water rights. This allows the WAM to examine the available volume and reliability of both the freed water and the remaining, un-diverted water.
- In this way, the WAM evaluations provide information about the reliability and availability of re-allocating the available water, examined through use of water rights, examined at several locations. The WAM runs also provide a spectrum of scenarios and locations, ranging from highly reliable to moderately so. This information can be used to select scenarios for future study, and to support potential partnerships with other water users or water rights holders in the area.
- The WAM evaluations examined the impact of re-allocating a certain volume of water upstream, and helps quantify how much water could reasonably be “freed up” or re-allocated by a future desalination project without impacting GCWA’s existing supply or intervening water rights holders, and how reliable this water might be.

In conclusion, the WAM runs help demonstrate the viability of the option of the desalination plant to allow upstream water to be used to meet other demands upstream and overall improve the resiliency of the watershed.

Appendix D. GCWA Customer Meter Usage Data 2021-2023

Appendix D- GCWA Customer Usage Data 2021-2023
(From Meter)

<u>Customers with confirmed location</u>	<u>Average Monthly Demand (MG)</u>	<u>Average Annual Demand (2021-2023) (MG)</u>	<u>Average Daily Demand based on Annual Avg Demand (2021-2023) (MGD)</u>	<u>Average Daily Demand based on Annual Avg Demand (2021-2023) (ACF)</u>
30" Virginia Point (01)	177.0	2124.2	5.8	17.85
36" Virginia Point (02)	158.0	1895.8	p	#VALUE!
Ascend Customer Meter	280.9	3371.1	9.2	28.34
Ashland	8.1	97.5	0.3	0.82
Bacliff MUD	17.6	211.0	0.6	1.77
Bait Camp	30.5	366.3	1.0	3.08
Bayou Vista	6.3	75.5	0.2	0.63
Bayview	3.6	43.1	0.1	0.36
Blanchard	864.5	10373.9	28.4	87.20
Calder Meter Station	47.2	566.0	1.6	4.76
Detention Center	12.8	153.5	0.4	1.29
Diamond K	0.3	4.0	0.0	0.03
Dickinson #2 Plant	16.5	197.6	0.5	1.66
Eastman	65.4	785.2	2.2	6.60
Ecure Meter (Dickinson #1)	52.8	633.3	1.7	5.32
First Colony / Bakerland	0.0	0.4	0.0	0.00
Flour Daniel	2.6	31.5	0.1	0.26
FM 1764	33.7	404.8	1.1	3.40
Golf Course	1.4	17.3	0.0	0.15
Hitchcock	24.3	291.1	0.8	2.45
INEOS	436.2	5234.7	14.3	44.00
Magnolia Creek Golf Course	4.7	57.0	0.2	0.48
Mainland Concrete	0.0	0.4	0.0	0.00
Missouri City	228.6	2743.1	7.5	23.06
Orchid (La Margue 1)	86.8	1042.1	2.9	8.76
Pecan Grove	39.3	471.3	1.3	3.96
Residential	0.0	0.1	0.0	0.00
Residential	0.0	0.0	0.0	0.00
Residential- Humble Camp	15.7	187.9	0.5	1.58
RiverBend	4.1	48.8	0.1	0.41
San Leon	18.3	219.8	0.6	1.85
Santa Fe 11th Street Meter	2.6	30.7	0.1	0.26
Sante Fe residential	0.0	0.1	0.0	0.00
Silver Ridge HOA	1.3	16.2	0.0	0.14
Sugar Creek	11.1	133.5	0.4	1.12
Sugar Land	247.8	2974.0	8.1	25.00
TC East	147.1	1765.4	4.8	14.84
TC FM 517	1.9	22.9	0.1	0.19
TC West	101.2	1214.8	3.3	10.21
Texas City - Hwy 146	-	0.0	0.0	0.00
Tiki Island	6.3	75.5	0.2	0.63
Topaz	4.9	58.8	0.2	0.49
TX City 24" HC Road	79.5	953.5	2.6	8.01
UCC/DOW	251.1	3012.9	8.3	25.32
Underground Storage	5.2	62.7	0.2	0.53
Valero	147.5	1769.7	4.8	14.88
WCID #12 (Kemah)	21.8	262.0	0.7	2.20
WCID #2 Stafford	55.8	669.8	1.8	5.63
WCID 8 Meter- Santa Fe	13.9	167.1	0.5	1.40
Williams Farm	0.0	0.2	0.0	0.00

Appendix D- GCWA Customer Usage Data 2021-2023

<u>Customers with confirmed location</u>	<u>2021 (MG)</u>												<u>2021 Total</u>
	<u>January</u>	<u>February</u>	<u>March</u>	<u>April</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>August</u>	<u>September</u>	<u>October</u>	<u>November</u>	<u>December</u>	
30" Virginia Point (01)	121.8	132.8	143.0	148.3	170.3	175.8	181.6	178.5	153.5	139.2	132.3	129.1	1806.2
36" Virginia Point (02)	149.4	157.3	143.2	150.1	167.2	179.5	189.0	187.0	186.7	180.2	162.5	167.3	2019.4
Ascend Customer Meter	243.7	145.1	257.7	316.5	324.9	326.2	324.5	342.3	307.7	320.1	296.5	331.1	3536.4
Ashland	7.0	5.8	5.9	5.5	6.3	9.1	9.1	9.1	12.3	6.2	6.1	6.3	88.6
Bacliff MUD	18.0	17.9	17.7	17.4	17.8	17.9	18.1	18.6	17.6	17.6	16.9	16.6	212.1
Bait Camp	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.0	0.3	291.9	255.1	24.1	573.4
Bayou Vista	5.6	6.9	5.7	5.7	5.9	6.2	6.2	5.8	8.2	1.8	8.1	4.8	70.9
Bayview	3.0	3.6	3.2	3.4	3.5	3.6	4.0	4.0	2.7	3.8	3.1	2.3	40.1
Blanchard	786.2	576.6	589.6	779.8	908.3	860.9	925.6	934.8	937.5	863.0	755.5	976.9	9894.8
Calder Meter Station	32.9	30.0	7.6	0.0	0.1	0.3	13.9	54.8	62.4	68.9	35.5	41.4	347.7
Detention Center	9.9	6.3	7.5	11.3	9.1	8.9	10.7	12.7	11.1	12.8	14.2	11.6	126.2
Diamond K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dickinson #2 Plant	8.0	8.9	12.5	14.1	12.2	18.0	33.5	12.6	14.6	11.5	10.6	16.8	173.2
Eastman	65.0	68.5	62.7	60.5	62.8	60.8	61.7	62.1	58.1	59.5	54.1	54.8	730.7
Ecret Meter (Dickinson #1)	50.5	52.0	47.1	48.6	47.9	50.9	56.9	60.4	0.0	0.0	0.0	195.2	609.5
First Colony / Bakerland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flour Daniel	1.5	1.3	2.3	3.3	2.7	1.4	1.0	3.1	2.9	2.9	2.5	0.7	25.5
FM 1764	20.8	21.3	19.1	20.2	21.1	18.5	26.6	31.5	35.9	44.0	42.3	31.3	332.5
Golf Course	1.0	0.5	0.6	0.5	0.3	4.1	4.5	6.0	0.0	0.6	0.6	1.6	20.3
Hitchcock	24.7	24.9	23.7	23.2	23.6	20.3	25.9	22.1	22.2	24.9	20.7	20.1	276.3
INEOS	440.0	358.8	258.3	449.6	409.7	543.1	468.0	514.4	462.3	450.5	425.1	244.0	5023.8
Magnolia Creek Golf Course	1.2	1.9	0.8	1.9	3.1	2.9	2.7	9.9	3.7	1.9	1.5	1.3	32.9
Mainland Concrete	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.3
Missouri City	130.7	141.1	147.3	202.7	199.2	218.1	207.7	262.7	228.2	202.2	187.1	160.9	2287.9
Orchid (La Margue 1)	64.9	73.8	70.3	67.8	69.2	68.5	71.3	70.7	59.4	36.9	34.3	37.5	724.7
Pecan Grove	28.6	28.7	43.8	50.9	49.8	44.1	44.7	51.3	52.4	49.3	49.9	45.3	538.8
Residential	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Residential	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Residential- Humble Camp	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.2
RiverBend	0.1	2.2	2.1	4.8	3.0	3.7	2.6	5.4	4.0	3.3	2.0	1.2	34.4
San Leon	15.7	16.7	15.6	16.2	17.0	18.5	18.2	17.9	16.8	16.4	15.6	13.8	198.4
Santa Fe 11th Street Meter	1.6	3.1	2.2	3.2	3.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	14.7
Sante Fe residential	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Silver Ridge HOA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sugar Creek	0.0	0.0	5.3	17.1	11.7	7.2	5.6	15.7	12.4	8.3	5.3	12.3	101.1
Sugar Land	246.8	201.6	263.5	182.8	253.0	248.3	242.3	262.8	267.3	273.2	239.0	209.0	2889.8
TC East	87.3	98.7	89.0	90.3	88.6	86.2	90.8	94.7	93.2	94.2	85.8	89.7	1088.6
TC FM 517	0.3	0.7	0.7	0.7	1.0	1.0	0.5	1.0	1.4	0.9	0.4	0.6	9.3
TC West	49.4	59.7	61.1	39.9	44.9	50.6	52.4	54.2	44.6	51.0	50.0	49.5	607.2
Texas City - Hwy 146													0.0
Tiki Island	4.5	6.2	4.7	5.5	6.3	6.3	7.2	6.6	6.2	3.9	6.8	4.2	68.5
Topaz	0.0	0.0	0.0	0.0	0.0	0.0	8.6	9.6	4.8	6.0	1.8	1.9	32.8
TX City 24" HC Road	28.1	13.7	24.7	38.0	48.0	51.2	46.2	52.5	53.3	47.8	38.9	34.9	477.3
UCC/DOW	204.4	238.0	219.5	213.5	205.7	312.7	321.6	339.2	289.3	390.4	416.9	203.6	3354.6
Underground Storage	0.8	9.4	0.4	0.4	0.2	0.1	0.1	0.8	1.2	2.0	3.5	4.2	23.4
Valero	133.0	100.9	150.2	150.6	143.9	149.3	142.3	142.9	137.2	131.9	133.1	139.1	1654.4
WCID #12 (Kemah)	17.3	16.7	18.6	21.9	23.1	22.7	20.9	21.6	20.5	19.9	18.1	18.1	239.4
WCID #2 Stafford	66.9	41.8	50.4	60.1	71.6	64.4	76.3	80.5	78.2	76.8	63.6	53.5	784.2
WCID 8 Meter- Santa Fe	15.0	14.6	13.9	12.6	13.4	10.2	13.6	11.1	11.6	13.1	12.2	11.3	152.5
Williams Farm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

Appendix D- GCWA Customer Usage Data 2021-2023

<u>Customers with confirmed location</u>	<u>2022</u>												<u>2022 Total</u>
	<u>January</u>	<u>February</u>	<u>March</u>	<u>April</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>August</u>	<u>September</u>	<u>October</u>	<u>November</u>	<u>December</u>	
30" Virginia Point (01)	133.8	116.5	153.2	164.1	193.0	221.6	343.7	222.9	191.5	192.8	156.5	185.8	2275.4
36" Virginia Point (02)	143.6	135.3	148.8	157.4	177.2	209.4	104.7	172.9	172.3	178.3	139.6	140.7	1880.3
Ascend Customer Meter	307.3	269.2	234.9	274.8	256.3	294.2	308.8	313.1	282.5	215.6	252.8	213.1	3222.5
Ashland	5.9	5.4	6.3	6.0	6.1	6.0	5.6	6.2	6.1	5.4	11.5	15.8	86.1
Bacliff MUD	16.5	15.0	16.6	17.3	3.9	20.2	21.2	19.5	18.5	19.0	16.6	18.6	202.9
Bait Camp	24.0	21.0	35.2	33.5	36.7	33.1	39.0	33.1	31.0	29.7	24.7	42.0	382.9
Bayou Vista	5.4	4.4	5.2	6.0	7.1	8.2	8.5	6.7	6.0	6.5	5.2	10.3	79.6
Bayview	3.5	2.7	3.4	3.2	3.9	5.2	4.9	4.1	3.4	3.7	2.9	3.4	44.4
Blanchard	869.8	682.2	975.1	983.6	1077.2	1032.6	1102.1	237.8	915.2	983.7	870.3	927.6	10657.2
Calder Meter Station	62.3	52.1	74.2	47.9	49.9	64.7	57.5	63.1	46.3	60.2	50.0	17.9	646.1
Detention Center	10.7	8.2	10.3	9.7	12.8	15.5	17.6	20.6	15.0	9.4	15.2	16.3	161.2
Diamond K	0.0	0.0	0.0	2.7	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	5.1
Dickinson #2 Plant	15.6	14.0	14.9	15.3	17.8	16.4	18.3	13.8	18.6	23.7	18.7	16.6	203.8
Eastman	54.1	49.4	60.7	62.5	54.5	71.2	47.8	79.6	70.7	68.4	53.9	55.4	728.2
Ecret Meter (Dickinson #1)	51.6	45.5	49.2	49.0	57.1	57.3	59.1	53.2	53.1	43.4	53.1	64.9	636.6
First Colony / Bakerland	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.5
Flour Daniel	0.4	2.1	0.3	0.4	3.7	5.3	5.3	3.4	3.3	2.5	1.5	2.7	31.0
FM 1764	33.0	28.5	48.6	46.9	53.2	60.4	50.1	35.1	32.4	50.9	50.3	46.9	536.1
Golf Course	0.0	0.0	0.0	1.6	0.9	2.0	2.2	1.8	1.0	0.2	0.0	0.0	9.7
Hitchcock	22.4	18.9	21.5	22.1	23.3	27.8	30.3	26.7	24.6	29.2	24.0	22.1	292.9
INEOS	379.1	359.5	534.7	487.9	495.8	549.0	473.2	436.5	525.6	455.8	441.3	330.7	5469.2
Magnolia Creek Golf Course	1.2	0.8	2.6	4.1	9.1	15.9	13.3	5.1	7.8	6.5	1.0	1.8	69.2
Mainland Concrete	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Missouri City	142.2	121.9	160.9	215.5	303.4	334.4	365.2	300.6	294.6	279.8	162.1	178.5	2859.1
Orchid (La Margue 1)	724.7	44.8	36.2	32.6	42.1	43.1	34.3	57.1	77.8	58.9	53.4	43.3	1248.3
Pecan Grove	38.6	35.4	34.1	27.4	32.2	36.9	41.3	39.1	41.2	35.4	39.0	42.8	443.5
Residential	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Residential	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Residential- Humble Camp	1.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	38.0	41.2	28.7	109.9
RiverBend	0.6	0.8	3.5	5.7	7.0	9.4	8.2	4.6	6.2	6.9	1.1	0.4	54.4
San Leon	18.1	15.3	16.3	18.4	18.3	21.7	24.2	21.0	18.7	20.0	17.4	20.8	230.2
Santa Fe 11th Street Meter	14.7	0.0	0.0	0.0	0.0	0.0	3.5	3.6	3.1	2.5	2.7	2.6	32.8
Sante Fe residential	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Silver Ridge HOA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Sugar Creek	6.8	9.9	16.2	15.5	22.7	25.3	26.3	3.6	21.3	14.2	1.2	0.9	163.9
Sugar Land	193.2	167.0	229.2	242.8	293.4	291.5	304.6	285.1	283.3	295.1	270.4	245.9	3101.7
TC East	1088.6	87.5	72.1	85.2	92.8	97.2	91.5	96.4	89.7	93.6	95.3	85.1	2075.2
TC FM 517	9.3	1.4	1.2	1.4	1.4	1.5	1.3	1.4	1.4	1.4	1.5	1.3	24.5
TC West	607.2	46.5	49.2	45.7	46.4	51.0	68.7	86.3	78.9	81.8	82.8	73.8	1318.3
Texas City - Hwy 146													0.0
Tiki Island	4.9	4.0	5.0	6.3	6.6	8.2	8.2	6.9	6.4	7.4	5.0	6.0	75.0
Topaz	3.9	4.9	6.7	10.5	12.4	14.0	12.3	7.6	6.6	1.5	6.2	5.1	91.5
TX City 24" HC Road	477.3	34.5	34.1	51.7	67.6	87.5	65.3	96.3	63.1	31.1	41.4	28.8	1078.7
UCC/DOW	251.9	262.6	225.0	167.6	151.9	205.2	311.5	97.6	250.0	200.6	199.0	173.0	2495.9
Underground Storage	33.0	28.7	23.7	12.5	31.6	3.0	3.4	2.0	0.6	1.9	1.8	2.7	144.9
Valero	139.2	104.2	135.1	143.2	149.1	147.7	158.3	156.3	157.2	165.9	151.4	161.3	1768.9
WCID #12 (Kemah)	18.9	17.3	20.5	23.1	23.3	25.9	28.3	23.5	21.9	25.1	20.5	20.7	269.1
WCID #2 Stafford	21.3	45.5	14.0	50.8	57.5	68.0	79.6	66.2	75.4	68.4	29.3	41.3	617.4
WCID 8 Meter- Santa Fe	13.8	11.1	13.9	13.1	13.2	11.5	14.1	15.3	14.6	14.7	13.7	18.4	167.3
Williams Farm	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2

Appendix D- GCWA Customer Usage Data 2021-2023

Customers with confirmed location	2023												2023 Total
	January	February	March	April	May	June	July	August	September	October	November	December	
30" Virginia Point (01)	138.3	150.3	310.9	294.8	168.3	199.6	221.9	211.0	177.0	151.3	135.3	132.2	2291.0
36" Virginia Point (02)	142.2	94.7	0.0	0.0	160.7	196.5	228.8	232.6	217.0	199.0	161.2	155.2	1787.9
Ascend Customer Meter	226.5	198.8	264.6	256.6	288.0	297.1	312.0	309.1	297.0	305.6	293.2	305.9	3354.4
Ashland	10.9	8.2	3.4	10.0	12.9	11.3	4.8	9.7	8.8	8.0	16.2	13.3	117.7
Bacliff MUD	16.5	14.8	17.6	16.0	17.3	18.3	19.8	21.9	19.1	17.8	19.4	19.5	218.0
Bait Camp	20.9	21.4	44.3	25.3	28.6	0.3	0.3	0.3	0.4	0.3	0.3	0.3	142.6
Bayou Vista	4.3	4.5	5.4	5.6	5.8	6.9	8.8	9.5	7.5	5.8	5.6	6.0	75.9
Bayview	3.1	2.9	3.4	3.2	3.5	4.2	4.8	5.7	4.5	3.0	3.5	2.9	44.6
Blanchard	902.4	767.1	889.5	907.1	987.5	942.5	944.2	833.0	768.1	920.6	827.6	880.1	10569.7
Calder Meter Station	48.1	44.0	55.3	65.9	49.2	56.5	50.2	88.9	86.4	54.8	50.0	54.7	704.0
Detention Center	12.9	12.8	11.7	16.9	20.5	14.9	14.4	18.9	12.4	9.1	14.5	14.0	173.1
Diamond K	0.0	0.0	2.4	0.0	0.0	2.4	0.0	1.9	0.0	0.0	0.0	0.0	6.8
Dickinson #2 Plant	17.2	15.4	15.9	18.6	16.8	16.7	22.2	24.0	20.8	13.9	11.9	22.3	215.6
Eastman	60.5	51.2	63.7	56.8	84.7	100.4	110.6	96.8	75.8	61.6	69.9	64.6	896.6
Ecret Meter (Dickinson #1)	49.4	48.8	55.4	53.1	59.8	50.6	59.8	73.2	56.9	53.4	52.5	40.9	653.7
First Colony / Bakerland	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.5
Flour Daniel	1.1	0.9	1.9	1.9	1.2	3.3	4.7	5.3	8.5	5.1	2.6	1.4	37.9
FM 1764	45.3	46.8	39.1	30.4	27.6	17.5	18.8	9.7	27.8	25.3	25.9	31.6	345.8
Golf Course	0.0	0.0	0.0	0.0	0.0	3.5	7.8	5.5	2.8	1.5	0.0	0.7	21.8
Hitchcock	21.2	20.8	21.5	23.9	22.3	23.5	27.3	30.4	28.3	25.5	28.9	30.4	304.1
INEOS	430.1	387.2	464.7	375.3	425.3	494.2	480.4	486.7	479.2	407.3	412.7	367.9	5211.0
Magnolia Creek Golf Course	1.0	0.6	4.0	4.4	5.4	18.9	15.7	9.4	4.5	4.5	0.3	0.1	68.8
Mainland Concrete	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0.5
Missouri City	126.4	138.0	211.0	193.6	244.8	229.4	308.4	351.0	476.5	396.3	223.8	183.1	3082.2
Orchid (La Margue 1)	69.0	592.5	53.0	39.6	39.2	32.2	30.2	46.1	52.6	63.6	75.4	59.9	1153.2
Pecan Grove	42.3	40.0	38.8	29.4	37.4	24.9	34.2	40.6	48.9	29.3	35.4	30.4	431.7
Residential	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Residential	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Residential- Humble Camp	61.1	169.7	38.3	37.3	49.1	45.1	51.0	0.1	0.2	0.4	0.2	0.1	452.7
RiverBend	0.0	0.8	4.0	1.5	3.9	7.9	8.7	14.8	9.1	4.1	1.6	1.2	57.6
San Leon	16.1	15.8	17.1	17.3	19.3	20.0	25.1	25.8	23.1	17.4	17.2	16.7	230.8
Santa Fe 11th Street Meter	1.8	19.9	3.1	3.0	3.1	2.7	3.4	3.0	3.3	0.9	0.5	0.0	44.6
Sante Fe residential	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Silver Ridge HOA	0.0	0.0	0.1	0.1	0.0	7.0	7.3	13.4	10.6	6.1	3.9	0.0	48.5
Sugar Creek	0.0	1.1	9.5	1.3	7.7	8.8	28.7	34.5	25.9	7.4	6.1	4.5	135.4
Sugar Land	216.7	184.9	284.2	245.0	248.3	273.4	269.8	303.2	246.7	203.5	234.3	220.7	2930.6
TC East	98.8	1085.4	92.4	79.8	89.0	84.3	87.3	91.2	103.1	117.3	105.9	98.0	2132.4
TC FM 517	1.7	16.9	1.5	1.6	1.8	1.3	1.4	1.4	1.7	2.0	1.8	1.6	34.8
TC West	85.8	796.9	80.4	69.6	77.8	74.1	77.1	80.4	92.0	104.0	93.8	87.1	1719.0
Texas City - Hwy 146													0.0
Tiki Island	3.7	3.6	5.4	5.5	6.4	7.6	10.8	11.2	10.6	6.8	6.2	5.1	82.9
Topaz	2.4	3.2	3.5	6.3	9.2	5.7	5.4	6.1	4.0	2.2	2.6	1.4	52.0
TX City 24" HC Road	61.0	662.4	39.2	37.2	49.6	44.8	50.9	68.5	80.0	83.6	67.3	60.0	1304.4
UCC/DOW	199.6	199.9	215.9	147.6	181.9	216.4	296.9	440.4	446.6	266.3	290.0	286.7	3188.1
Underground Storage	0.5	1.1	0.7	0.1	0.0	1.2	2.9	3.1	3.2	3.6	1.6	1.8	19.9
Valero	142.7	145.1	164.4	148.9	160.4	160.8	170.6	154.8	168.4	169.7	148.7	151.3	1885.8
WCID #12 (Kemah)	18.3	16.3	21.1	20.7	23.8	25.9	30.6	34.1	26.2	21.6	19.6	19.1	277.3
WCID #2 Stafford	62.9	36.1	51.4	22.1	77.9	44.5	48.1	52.5	48.3	49.6	46.0	68.6	608.0
WCID 8 Meter- Santa Fe	11.6	11.9	13.2	13.5	13.1	12.3	15.4	20.8	19.5	16.7	16.4	17.0	181.5
Williams Farm	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2

Appendix E. Socioeconomic Impacts of Projected Water Shortages for the Region H Regional Water Planning Area

Socioeconomic Impacts of Projected Water Shortages for the Region H Regional Water Planning Area

Prepared in Support of the 2021 Region H Regional Water Plan



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Texas Water Development Board

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Executive Summary

Evaluating the social and economic impacts of not meeting identified water needs is a required analysis in the regional water planning process. The Texas Water Development Board (TWDB) estimates these impacts for regional water planning groups (RWPGs) and summarizes the impacts in the state water plan. The analysis presented is for the Region H Regional Water Planning Group (Region H).

Based on projected water demands and existing water supplies, Region H identified water needs (potential shortages) that could occur within its region under a repeat of the drought of record for six water use categories (irrigation, livestock, manufacturing, mining, municipal and steam-electric power). The TWDB then estimated the annual socioeconomic impacts of those needs—if they are not met—for each water use category and as an aggregate for the region.

This analysis was performed using an economic impact modeling software package, IMPLAN (Impact for Planning Analysis), as well as other economic analysis techniques, and represents a snapshot of socioeconomic impacts that may occur during a single year repeat of the drought of record with the further caveat that no mitigation strategies are implemented. Decade specific impact estimates assume that growth occurs, and future shocks are imposed on an economy at 10-year intervals. The estimates presented are not cumulative (i.e., summing up expected impacts from today up to the decade noted), but are simply snapshots of the estimated annual socioeconomic impacts should a drought of record occur in each particular decade based on anticipated water supplies and demands for that same decade.

For regional economic impacts, income losses and job losses are estimated within each planning decade (2020 through 2070). The income losses represent an approximation of gross domestic product (GDP) that would be foregone if water needs are not met.

The analysis also provides estimates of financial transfer impacts, which include tax losses (state, local, and utility tax collections); water trucking costs; and utility revenue losses. In addition, social impacts are estimated, encompassing lost consumer surplus (a welfare economics measure of consumer wellbeing); as well as population and school enrollment losses.

IMPLAN data reported that Region H generated more than \$510 billion in GDP (2018 dollars) and supported roughly 4.1 million jobs in 2016. The Region H estimated total population was approximately 7 million in 2016.

It is estimated that not meeting the identified water needs in Region H would result in an annually combined lost income impact of approximately \$4.6 billion in 2020, increasing to \$13.8 billion in 2070 (Table ES-1). In 2020, the region would lose approximately 29,000 jobs, and by 2070 job losses would increase to approximately 149,000 if anticipated needs are not mitigated.

All impact estimates are in year 2018 dollars and were calculated using a variety of data sources and tools including the use of a region-specific IMPLAN model, data from TWDB annual water use

estimates, the U.S. Census Bureau, Texas Agricultural Statistics Service, and the Texas Municipal League.

Table ES-1 Region H socioeconomic impact summary

Regional Economic Impacts	2020	2030	2040	2050	2060	2070
Income losses (\$ millions)*	\$4,600	\$8,521	\$10,313	\$11,301	\$12,437	\$13,784
Job losses	28,805	66,183	95,862	110,604	127,869	148,164
Financial Transfer Impacts	2020	2030	2040	2050	2060	2070
Tax losses on production and imports (\$ millions)*	\$507	\$815	\$944	\$1,021	\$1,115	\$1,226
Water trucking costs (\$ millions)*	\$4	\$3	\$8	\$10	\$13	\$258
Utility revenue losses (\$ millions)*	\$72	\$626	\$1,134	\$1,403	\$1,722	\$2,085
Utility tax revenue losses (\$ millions)*	\$1	\$12	\$22	\$27	\$33	\$40
Social Impacts	2020	2030	2040	2050	2060	2070
Consumer surplus losses (\$ millions)*	\$59	\$515	\$878	\$1,469	\$2,980	\$4,359
Population losses	5,289	12,151	17,600	20,307	23,477	27,203
School enrollment losses	1,012	2,324	3,366	3,884	4,491	5,203

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero (\$0) indicate estimated income losses less than \$500,000.

1 Introduction

Water shortages during a repeat of the drought of record would likely curtail or eliminate certain economic activity in businesses and industries that rely heavily on water. Insufficient water supplies could not only have an immediate and real impact on the regional economy in the short term, but they could also adversely and chronically affect economic development in Texas. From a social perspective, water supply reliability is critical as well. Shortages could disrupt activity in homes, schools and government, and could adversely affect public health and safety. For these reasons, it is important to evaluate and understand how water supply shortages during drought could impact communities throughout the state.

As part of the regional water planning process, RWPGs must evaluate the social and economic impacts of not meeting water needs (31 Texas Administrative Code §357.33 (c)). Due to the complexity of the analysis and limited resources of the planning groups, the TWDB has historically performed this analysis for the RWPGs upon their request. Staff of the TWDB's Water Use, Projections, & Planning Division designed and conducted this analysis in support of Region H, and those efforts for this region as well as the other 15 regions allow consistency and a degree of comparability in the approach.

This document summarizes the results of the analysis and discusses the methodology used to generate the results. Section 1 provides a snapshot of the region's economy and summarizes the identified water needs in each water use category, which were calculated based on the RWPG's water supply and demand established during the regional water planning process. Section 2 defines each of ten impact assessment measures used in this analysis. Section 3 describes the methodology for the impact assessment and the approaches and assumptions specific to each water use category (i.e., irrigation, livestock, manufacturing, mining, municipal, and steam-electric power). Section 4 presents the impact estimates for each water use category with results summarized for the region as a whole. Appendix A presents a further breakdown of the socioeconomic impacts by county.

1.1 Regional Economic Summary

The Region H Regional Water Planning Area generated more than \$510 billion in gross domestic product (2018 dollars) and supported roughly 4.1 million jobs in 2016, according to the IMPLAN dataset utilized in this socioeconomic analysis. This activity accounted for nearly 30 percent of the state's total gross domestic product of 1.73 trillion dollars for the year based on IMPLAN. Table 1-1 lists all economic sectors ranked by the total value-added to the economy in Region H. The manufacturing and mining sectors (including oil and gas extraction and petroleum refineries) generated more than 25 percent of the region's total value-added and were also significant sources of tax revenue. The top employers in the region were in the public administration, health care, and retail trade sectors. Region H's estimated total population was close to 7 million in 2016, comprising 25 percent of the state's total.

This represents a snapshot of the regional economy as a whole, and it is important to note that not all economic sectors were included in the TWDB socioeconomic impact analysis. Data

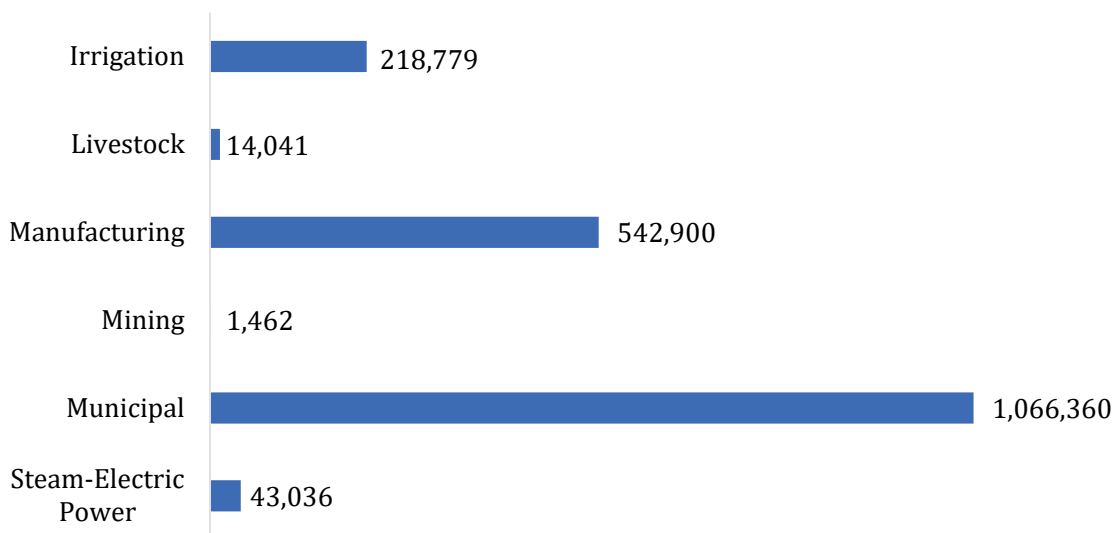
considerations prompted use of only the more water-intensive sectors within the economy because damage estimates could only be calculated for those economic sectors which had both reliable income and water use estimates.

Table 1-1 Region H regional economy by economic sector*

Economic sector	Value-added (\$ millions)	Tax (\$ millions)	Jobs
Manufacturing	\$77,054.9	\$2,445.7	245,107
Mining, Quarrying, and Oil and Gas Extraction	\$53,253.7	\$4,778.1	134,003
Real Estate and Rental and Leasing	\$49,060.4	\$5,941.4	181,440
Professional, Scientific, and Technical Services	\$43,742.8	\$829.6	347,563
Wholesale Trade	\$41,208.9	\$5,398.2	183,641
Public Administration	\$37,764.0	\$(116.3)	405,515
Construction	\$34,660.2	\$357.4	323,162
Health Care and Social Assistance	\$24,613.3	\$295.0	377,106
Finance and Insurance	\$22,571.0	\$947.7	202,699
Retail Trade	\$22,251.1	\$4,857.3	360,968
Administrative and Support and Waste Management and Remediation Services	\$19,943.8	\$416.7	311,499
Transportation and Warehousing	\$18,819.0	\$1,509.6	183,611
Utilities	\$14,459.5	\$1,798.7	18,945
Other Services (except Public Administration)	\$13,458.3	\$1,253.2	284,129
Accommodation and Food Services	\$13,036.2	\$1,874.1	321,732
Management of Companies and Enterprises	\$8,740.2	\$133.9	47,545
Information	\$8,620.3	\$2,064.9	45,803
Educational Services	\$3,388.3	\$114.5	73,245
Arts, Entertainment, and Recreation	\$3,025.3	\$374.5	62,813
Agriculture, Forestry, Fishing and Hunting	\$660.5	\$27.8	29,892
Grand Total	\$510,331.9	\$35,301.9	4,140,419

*Source: 2016 IMPLAN for 536 sectors aggregated by 2-digit NAICS (North American Industry Classification System)

Figure 1-1 illustrates Region H's breakdown of the 2016 water use estimates by TWDB water use category. The categories with the highest use in Region H in 2016 were municipal (56 percent) and manufacturing (29 percent). Notably, more than 50 percent of the state's manufacturing water use occurred within Region H.

Figure 1-1 Region H 2016 water use estimates by water use category (in acre-feet)

Source: TWDB Annual Water Use Estimates (all values in acre-feet)

1.2 Identified Regional Water Needs (Potential Shortages)

As part of the regional water planning process, the TWDB adopted water demand projections for water user groups (WUG) in Region H with input from the planning group. WUG-level demand projections were established for utilities that provide more than 100 acre-feet of annual water supply, combined rural areas (designated as county-other), and county-wide water demand projections for five non-municipal categories (irrigation, livestock, manufacturing, mining and steam-electric power). The RWPG then compared demands to the existing water supplies of each WUG to determine potential shortages, or needs, by decade.

Table 1-2 summarizes the region's identified water needs in the event of a repeat of the drought of record. Demand management, such as conservation, or the development of new infrastructure to increase supplies, are water management strategies that may be recommended by the planning group to address those needs. This analysis assumes that no strategies are implemented, and that the identified needs correspond to future water shortages. Note that projected water needs generally increase over time, primarily due to anticipated population growth, economic growth, or declining supplies. To provide a general sense of proportion, total projected needs as an overall percentage of total demand by water use category are also presented in aggregate in Table 1-2. Projected needs for individual water user groups within the aggregate can vary greatly and may reach 100% for a given WUG and water use category. A detailed summary of water needs by WUG and county appears in Chapter 4 of the 2021 Region H Regional Water Plan.

Table 1-2 Regional water needs summary by water use category

Water Use Category		2020	2030	2040	2050	2060	2070
Irrigation	water needs (acre-feet per year)	84,455	84,455	84,455	84,455	84,455	84,538
	% of the category's total water demand	25%	25%	25%	25%	25%	25%
Livestock	water needs (acre-feet per year)	1,276	1,659	1,913	1,912	1,911	1,919
	% of the category's total water demand	9%	12%	14%	13%	13%	14%
Manufacturing	water needs (acre-feet per year)	31,431	62,474	63,994	65,314	65,339	65,405
	% of the category's total water demand	5%	9%	9%	9%	9%	9%
Mining	water needs (acre-feet per year)	3,340	4,236	4,034	4,048	4,248	4,582
	% of the category's total water demand	22%	26%	26%	28%	30%	34%
Municipal*	water needs (acre-feet per year)	24,239	217,667	386,593	474,367	578,028	694,876
	% of the category's total water demand	2%	16%	26%	29%	33%	36%
Steam-electric power	water needs (acre-feet per year)	4,968	4,968	4,968	4,968	4,968	4,968
	% of the category's total water demand	5%	5%	5%	5%	5%	5%
Total water needs (acre-feet per year)		149,709	375,459	545,957	635,064	738,949	856,288

* Municipal category consists of residential and non-residential (commercial and institutional) subcategories.

2 Impact Assessment Measures

A required component of the regional and state water plans is to estimate the potential economic and social impacts of potential water shortages during a repeat of the drought of record. Consistent with previous water plans, ten impact measures were estimated and are described in Table 2-1.

Table 2-1 Socioeconomic impact analysis measures

Regional economic impacts	Description
Income losses - value-added	The value of output less the value of intermediate consumption; it is a measure of the contribution to gross domestic product (GDP) made by an individual producer, industry, sector, or group of sectors within a year. Value-added measures used in this report have been adjusted to include the direct, indirect, and induced monetary impacts on the region.
Income losses - electrical power purchase costs	Proxy for income loss in the form of additional costs of power as a result of impacts of water shortages.
Job losses	Number of part-time and full-time jobs lost due to the shortage. These values have been adjusted to include the direct, indirect, and induced employment impacts on the region.
Financial transfer impacts	Description
Tax losses on production and imports	Sales and excise taxes not collected due to the shortage, in addition to customs duties, property taxes, motor vehicle licenses, severance taxes, other taxes, and special assessments less subsidies. These values have been adjusted to include the direct, indirect and induced tax impacts on the region.
Water trucking costs	Estimated cost of shipping potable water.
Utility revenue losses	Foregone utility income due to not selling as much water.
Utility tax revenue losses	Foregone miscellaneous gross receipts tax collections.
Social impacts	Description
Consumer surplus losses	A welfare measure of the lost value to consumers accompanying restricted water use.
Population losses	Population losses accompanying job losses.
School enrollment losses	School enrollment losses (K-12) accompanying job losses.

2.1 Regional Economic Impacts

The two key measures used to assess regional economic impacts are income losses and job losses. The income losses presented consist of the sum of value-added losses and the additional purchase costs of electrical power.

Income Losses - Value-added Losses

Value-added is the value of total output less the value of the intermediate inputs also used in the production of the final product. Value-added is similar to GDP, a familiar measure of the productivity of an economy. The loss of value-added due to water shortages is estimated by input-output analysis using the IMPLAN software package, and includes the direct, indirect, and induced monetary impacts on the region. The indirect and induced effects are measures of reduced income as well as reduced employee spending for those input sectors which provide resources to the water shortage impacted production sectors.

Income Losses - Electric Power Purchase Costs

The electrical power grid and market within the state is a complex interconnected system. The industry response to water shortages, and the resulting impact on the region, are not easily modeled using traditional input/output impact analysis and the IMPLAN model. Adverse impacts on the region will occur and are represented in this analysis by estimated additional costs associated with power purchases from other generating plants within the region or state. Consequently, the analysis employs additional power purchase costs as a proxy for the value-added impacts for the steam-electric power water use category, and these are included as a portion of the overall income impact for completeness.

For the purpose of this analysis, it is assumed that power companies with insufficient water will be forced to purchase power on the electrical market at a projected higher rate of 5.60 cents per kilowatt hour. This rate is based upon the average day-ahead market purchase price of electricity in Texas that occurred during the recent drought period in 2011. This price is assumed to be comparable to those prices which would prevail in the event of another drought of record.

Job Losses

The number of jobs lost due to the economic impact is estimated using IMPLAN output associated with each TWDB water use category. Because of the difficulty in predicting outcomes and a lack of relevant data, job loss estimates are not calculated for the steam-electric power category.

2.2 Financial Transfer Impacts

Several impact measures evaluated in this analysis are presented to provide additional detail concerning potential impacts on a portion of the economy or government. These financial transfer impact measures include lost tax collections (on production and imports), trucking costs for imported water, declines in utility revenues, and declines in utility tax revenue collected by the

state. These measures are not solely adverse, with some having both positive and negative impacts. For example, cities and residents would suffer if forced to pay large costs for trucking in potable water. Trucking firms, conversely, would benefit from the transaction. Additional detail for each of these measures follows.

Tax Losses on Production and Imports

Reduced production of goods and services accompanying water shortages adversely impacts the collection of taxes by state and local government. The regional IMPLAN model is used to estimate reduced tax collections associated with the reduced output in the economy. Impact estimates for this measure include the direct, indirect, and induced impacts for the affected sectors.

Water Trucking Costs

In instances where water shortages for a municipal water user group are estimated by RWPGs to exceed 80 percent of water demands, it is assumed that water would need to be trucked in to support basic consumption and sanitation needs. For water shortages of 80 percent or greater, a fixed, maximum of \$35,000¹ per acre-foot of water applied as an economic cost. This water trucking cost was utilized for both the residential and non-residential portions of municipal water needs.

Utility Revenue Losses

Lost utility income is calculated as the price of water service multiplied by the quantity of water not sold during a drought shortage. Such estimates are obtained from utility-specific pricing data provided by the Texas Municipal League, where available, for both water and wastewater. These water rates are applied to the potential water shortage to estimate forgone utility revenue as water providers sold less water during the drought due to restricted supplies.

Utility Tax Losses

Foregone utility tax losses include estimates of forgone miscellaneous gross receipts taxes. Reduced water sales reduce the amount of utility tax that would be collected by the State of Texas for water and wastewater service sales.

2.3 Social Impacts

Consumer Surplus Losses for Municipal Water Users

Consumer surplus loss is a measure of impact to the wellbeing of municipal water users when their water use is restricted. Consumer surplus is the difference between how much a consumer is

¹ Based on staff survey of water hauling firms and historical data concerning transport costs for potable water in the recent drought in California for this estimate. There are many factors and variables that would determine actual water trucking costs including distance to, cost of water, and length of that drought.

willing and able to pay for a commodity (i.e., water) and how much they actually have to pay. The difference is a benefit to the consumer's wellbeing since they do not have to pay as much for the commodity as they would be willing to pay. Consumer surplus may also be viewed as an estimate of how much consumers would be willing to pay to keep the original quantity of water which they used prior to the drought. Lost consumer surplus estimates within this analysis only apply to the residential portion of municipal demand, with estimates being made for reduced outdoor and indoor residential use. Lost consumer surplus estimates varied widely by location and degree of water shortage.

Population and School Enrollment Losses

Population loss due to water shortages, as well as the associated decline in school enrollment, are based upon the job loss estimates discussed in Section 2.1. A simplified ratio of job and net population losses are calculated for the state as a whole based on a recent study of how job layoffs impact the labor market population.² For every 100 jobs lost, 18 people were assumed to move out of the area. School enrollment losses are estimated as a proportion of the population lost based upon public school enrollment data from the Texas Education Agency concerning the age K-12 population within the state (approximately 19%).

² Foote, Andrew, Grosz, Michel, Stevens, Ann. "Locate Your Nearest Exit: Mass Layoffs and Local Labor Market Response." University of California, Davis. April 2015, <http://paa2015.princeton.edu/papers/150194>. The study utilized Bureau of Labor Statistics data regarding layoffs between 1996 and 2013, as well as Internal Revenue Service data regarding migration, to model the change in the population as the result of a job layoff event. The study found that layoffs impact both out-migration and in-migration into a region, and that a majority of those who did move following a layoff moved to another labor market rather than an adjacent county.

3 Socioeconomic Impact Assessment Methodology

This portion of the report provides a summary of the methodology used to estimate the potential economic impacts of future water shortages. The general approach employed in the analysis was to obtain estimates for income and job losses on the smallest geographic level that the available data would support, tie those values to their accompanying historic water use estimate, and thereby determine a maximum impact per acre-foot of shortage for each of the socioeconomic measures. The calculations of economic impacts are based on the overall composition of the economy divided into many underlying economic sectors. Sectors in this analysis refer to one or more of the 536 specific production sectors of the economy designated within IMPLAN, the economic impact modeling software used for this assessment. Economic impacts within this report are estimated for approximately 330 of these sectors, with the focus on the more water-intensive production sectors. The economic impacts for a single water use category consist of an aggregation of impacts to multiple, related IMPLAN economic sectors.

3.1 Analysis Context

The context of this socioeconomic impact analysis involves situations where there are physical shortages of groundwater or surface water due to a recurrence of drought of record conditions. Anticipated shortages for specific water users may be nonexistent in earlier decades of the planning horizon, yet population growth or greater industrial, agricultural or other sector demands in later decades may result in greater overall demand, exceeding the existing supplies. Estimated socioeconomic impacts measure what would happen if water user groups experience water shortages for a period of one year. Actual socioeconomic impacts would likely become larger as drought of record conditions persist for periods greater than a single year.

3.2 IMPLAN Model and Data

Input-Output analysis using the IMPLAN software package was the primary means of estimating the value-added, jobs, and tax related impact measures. This analysis employed regional level models to determine key economic impacts. IMPLAN is an economic impact model, originally developed by the U.S. Forestry Service in the 1970's to model economic activity at varying geographic levels. The model is currently maintained by the Minnesota IMPLAN Group (MIG Inc.) which collects and sells county and state specific data and software. The year 2016 version of IMPLAN, employing data for all 254 Texas counties, was used to provide estimates of value-added, jobs, and taxes on production for the economic sectors associated with the water user groups examined in the study. IMPLAN uses 536 sector-specific Industry Codes, and those that rely on water as a primary input were assigned to their appropriate planning water user categories (irrigation, livestock, manufacturing, mining, and municipal). Estimates of value-added for a water use category were obtained by summing value-added estimates across the relevant IMPLAN sectors associated with that water use category. These calculations were also performed for job losses as well as tax losses on production and imports.

The adjusted value-added estimates used as an income measure in this analysis, as well as the job and tax estimates from IMPLAN, include three components:

- **Direct effects** representing the initial change in the industry analyzed;
- **Indirect effects** that are changes in inter-industry transactions as supplying industries respond to reduced demands from the directly affected industries; and,
- **Induced effects** that reflect changes in local spending that result from reduced household income among employees in the directly and indirectly affected industry sectors.

Input-output models such as IMPLAN only capture backward linkages and do not include forward linkages in the economy.

3.3 Elasticity of Economic Impacts

The economic impact of a water need is based on the size of the water need relative to the total water demand for each water user group. Smaller water shortages, for example, less than 5 percent, are generally anticipated to result in no initial negative economic impact because water users are assumed to have a certain amount of flexibility in dealing with small shortages. As a water shortage intensifies, however, such flexibility lessens and results in actual and increasing economic losses, eventually reaching a representative maximum impact estimate per unit volume of water. To account for these characteristics, an elasticity adjustment function is used to estimate impacts for the income, tax and job loss measures. Figure 3-1 illustrates this general relationship for the adjustment functions. Negative impacts are assumed to begin accruing when the shortage reaches the lower bound 'b1' (5 percent in Figure 3-1), with impacts then increasing linearly up to the 100 percent impact level (per unit volume) once the upper bound reaches the 'b2' level shortage (40 percent in Figure 3-1).

To illustrate this, if the total annual value-added for manufacturing in the region was \$2 million and the reported annual volume of water used in that industry is 10,000 acre-feet, the estimated economic measure of the water shortage would be \$200 per acre-foot. The economic impact of the shortage would then be estimated using this value-added amount as the maximum impact estimate (\$200 per acre-foot) applied to the anticipated shortage volume and then adjusted by the elasticity function. Using the sample elasticity function shown in Figure 3-1, an approximately 22 percent shortage in the livestock category would indicate an economic impact estimate of 50% of the original \$200 per acre-foot impact value (i.e., \$100 per acre-foot).

Such adjustments are not required in estimating consumer surplus, utility revenue losses, or utility tax losses. Estimates of lost consumer surplus rely on utility-specific demand curves with the lost consumer surplus estimate calculated based on the relative percentage of the utility's water shortage. Estimated changes in population and school enrollment are indirectly related to the elasticity of job losses.

Assumed values for the lower and upper bounds 'b1' and 'b2' vary by water use category and are presented in Table 3-1.

Figure 3-1 Example economic impact elasticity function (as applied to a single water user's shortage)

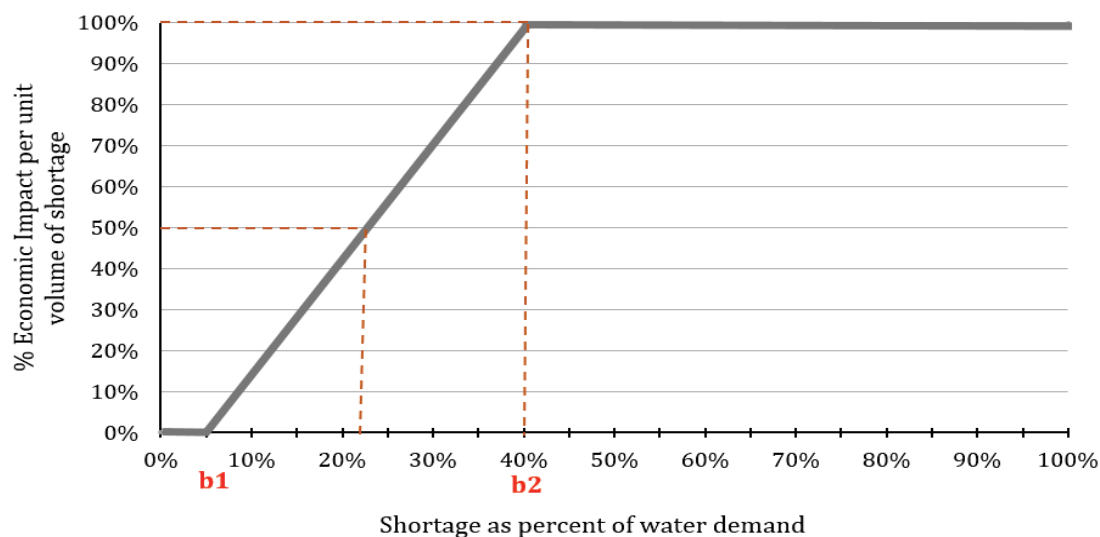


Table 3-1 Economic impact elasticity function lower and upper bounds

Water use category	Lower bound (b1)	Upper bound (b2)
Irrigation	5%	40%
Livestock	5%	10%
Manufacturing	5%	40%
Mining	5%	40%
Municipal (non-residential water intensive subcategory)	5%	40%
Steam-electric power	N/A	N/A

3.4 Analysis Assumptions and Limitations

The modeling of complex systems requires making many assumptions and acknowledging the model's uncertainty and limitations. This is particularly true when attempting to estimate a wide range of socioeconomic impacts over a large geographic area and into future decades. Some of the key assumptions and limitations of this methodology include:

1. The foundation for estimating the socioeconomic impacts of water shortages resulting from a drought are the water needs (potential shortages) that were identified by RWPGs as part of the

regional water planning process. These needs have some uncertainty associated with them but serve as a reasonable basis for evaluating the potential impacts of a drought of record event.

2. All estimated socioeconomic impacts are snapshots for years in which water needs were identified (i.e., 2020, 2030, 2040, 2050, 2060, and 2070). The estimates are independent and distinct “what if” scenarios for each particular year, and water shortages are assumed to be temporary events resulting from a single year recurrence of drought of record conditions. The evaluation assumed that no recommended water management strategies are implemented. In other words, growth occurs and future shocks are imposed on an economy at 10-year intervals, and the resulting impacts are estimated. Note that the estimates presented are not cumulative (i.e., summing up expected impacts from today up to the decade noted), but are simply snapshots of the estimated annual socioeconomic impacts should a drought of record occur in each particular decade based on anticipated water supplies and demands for that same decade.
3. Input-output models such as IMPLAN rely on a static profile of the structure of the economy as it appears today. This presumes that the relative contributions of all sectors of the economy would remain the same, regardless of changes in technology, availability of limited resources, and other structural changes to the economy that may occur in the future. Changes in water use efficiency will undoubtedly take place in the future as supplies become more stressed. Use of the static IMPLAN structure was a significant assumption and simplification considering the 50-year time period examined in this analysis. To presume an alternative future economic makeup, however, would entail positing many other major assumptions that would very likely generate as much or more error.
4. This is not a form of cost-benefit analysis. That approach to evaluating the economic feasibility of a specific policy or project employs discounting future benefits and costs to their present value dollars using some assumed discount rate. The methodology employed in this effort to estimate the economic impacts of future water shortages did not use any discounting methods to weigh future costs differently through time.
5. All monetary values originally based upon year 2016 IMPLAN and other sources are reported in constant year 2018 dollars to be consistent with the water management strategy requirements in the State Water Plan.
6. IMPLAN based loss estimates (income-value-added, jobs, and taxes on production and imports) are calculated only for those IMPLAN sectors for which the TWDB’s Water Use Survey (WUS) data was available and deemed reliable. Every effort is made in the annual WUS effort to capture all relevant firms who are significant water users. Lack of response to the WUS, or omission of relevant firms, impacts the loss estimates.

7. Impacts are annual estimates. The socioeconomic analysis does not reflect the full extent of impacts that might occur as a result of persistent water shortages occurring over an extended duration. The drought of record in most regions of Texas lasted several years.
8. Value-added estimates are the primary estimate of the economic impacts within this report. One may be tempted to add consumer surplus impacts to obtain an estimate of total adverse economic impacts to the region, but the consumer surplus measure represents the change to the wellbeing of households (and other water users), not an actual change in the flow of dollars through the economy. The two measures (value-added and consumer surplus) are both valid impacts but ideally should not be summed.
9. The value-added, jobs, and taxes on production and import impacts include the direct, indirect and induced effects to capture backward linkages in the economy described in Section 2.1. Population and school enrollment losses also indirectly include such effects as they are based on the associated losses in employment. The remaining measures (consumer surplus, utility revenue, utility taxes, additional electrical power purchase costs, and potable water trucking costs), however, do not include any induced or indirect effects.
10. The majority of impacts estimated in this analysis may be more conservative (i.e., smaller) than those that might actually occur under drought of record conditions due to not including impacts in the forward linkages in the economy. Input-output models such as IMPLAN only capture backward linkages on suppliers (including households that supply labor to directly affected industries). While this is a common limitation in this type of economic modeling effort, it is important to note that forward linkages on the industries that use the outputs of the directly affected industries can also be very important. A good example is impacts on livestock operators. Livestock producers tend to suffer substantially during droughts, not because there is not enough water for their stock, but because reductions in available pasture and higher prices for purchased hay have significant economic effects on their operations. Food processors could be in a similar situation if they cannot get the grains or other inputs that they need. These effects are not captured in IMPLAN, resulting in conservative impact estimates.
11. The model does not reflect dynamic economic responses to water shortages as they might occur, nor does the model reflect economic impacts associated with a recovery from a drought of record including:
 - a. The likely significant economic rebound to some industries immediately following a drought, such as landscaping;
 - b. The cost and time to rebuild liquidated livestock herds (a major capital investment in that industry);
 - c. Direct impacts on recreational sectors (i.e., stranded docks and reduced tourism); or,
 - d. Impacts of negative publicity on Texas' ability to attract population and business in the event that it was not able to provide adequate water supplies for the existing economy.

12. Estimates for job losses and the associated population and school enrollment changes may exceed what would actually occur. In practice, firms may be hesitant to lay off employees, even in difficult economic times. Estimates of population and school enrollment changes are based on regional evaluations and therefore do not necessarily reflect what might occur on a statewide basis.
13. **The results must be interpreted carefully. It is the general and relative magnitudes of impacts as well as the changes of these impacts over time that should be the focus rather than the absolute numbers.** Analyses of this type are much better at predicting relative percent differences brought about by a shock to a complex system (i.e., a water shortage) than the precise size of an impact. To illustrate, assuming that the estimated economic impacts of a drought of record on the manufacturing and mining water user categories are \$2 and \$1 million, respectively, one should be more confident that the economic impacts on manufacturing are twice as large as those on mining and that these impacts will likely be in the millions of dollars. But one should have less confidence that the actual total economic impact experienced would be \$3 million.
14. The methodology does not capture “spillover” effects between regions – or the secondary impacts that occur outside of the region where the water shortage is projected to occur.
15. The methodology that the TWDB has developed for estimating the economic impacts of unmet water needs, and the assumptions and models used in the analysis, are specifically designed to estimate potential economic effects at the regional and county levels. Although it may be tempting to add the regional impacts together in an effort to produce a statewide result, the TWDB cautions against that approach for a number of reasons. The IMPLAN modeling (and corresponding economic multipliers) are all derived from regional models – a statewide model of Texas would produce somewhat different multipliers. As noted in point 14 within this section, the regional modeling used by TWDB does not capture spillover losses that could result in other regions from unmet needs in the region analyzed, or potential spillover gains if decreased production in one region leads to increases in production elsewhere. The assumed drought of record may also not occur in every region of Texas at the same time, or to the same degree.

4 Analysis Results

This section presents estimates of potential economic impacts that could reasonably be expected in the event of water shortages associated with a drought of record and if no recommended water management strategies were implemented. Projected economic impacts for the six water use categories (irrigation, livestock, manufacturing, mining, municipal, and steam-electric power) are reported by decade.

4.1 Impacts for Irrigation Water Shortages

Five of the 15 counties in the region are projected to experience water shortages in the irrigated agriculture water use category for one or more decades within the planning horizon. Estimated impacts to this water use category appear in Table 4-1. Note that tax collection impacts were not estimated for this water use category. IMPLAN data indicates a negative tax impact (i.e., increased tax collections) for the associated production sectors, primarily due to past subsidies from the federal government. However, it was not considered realistic to report increasing tax revenues during a drought of record.

Table 4-1 Impacts of water shortages on irrigation in Region H

Impact measure	2020	2030	2040	2050	2060	2070
Income losses (\$ millions)*	\$16	\$16	\$16	\$16	\$16	\$16
Job losses	398	398	398	398	398	398

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero (\$0) indicate estimated income losses less than \$500,000.

4.2 Impacts for Livestock Water Shortages

Five of the 15 counties in the region are projected to experience water shortages in the livestock water use category one or more decades within the planning horizon. Estimated impacts to this water use category appear in Table 4-2.

Table 4-2 Impacts of water shortages on livestock in Region H

Impact measure	2020	2030	2040	2050	2060	2070
Income losses (\$ millions)*	\$47	\$66	\$79	\$79	\$79	\$79
Jobs losses	1,818	2,425	2,831	2,831	2,831	2,831
Tax losses on production and imports (\$ millions)*	\$3	\$3	\$4	\$4	\$4	\$4

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero (\$0) indicate estimated income losses less than \$500,000.

4.3 Impacts of Manufacturing Water Shortages

Manufacturing water shortages in the region are projected to occur in seven of the 15 counties in the region for at least one decade of the planning horizon. Estimated impacts to this water use category appear in Table 4-3.

Table 4-3 Impacts of water shortages on manufacturing in Region H

Impacts measure	2020	2030	2040	2050	2060	2070
Income losses (\$ millions)*	\$1,214	\$3,190	\$3,262	\$3,332	\$3,334	\$3,342
Job losses	5,997	16,195	16,518	16,841	16,840	16,860
Tax losses on production and imports (\$ millions)*	\$89	\$220	\$225	\$230	\$230	\$231

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero (\$0) indicate estimated income losses less than \$500,000.

4.4 Impacts of Mining Water Shortages

Mining water shortages in the region are projected to occur in nine of the 15 counties in the region for one or more decades within the planning horizon. Estimated impacts to this water use type appear in Table 4-4.

Table 4-4 Impacts of water shortages on mining in Region H

Impacts measure	2020	2030	2040	2050	2060	2070
Income losses (\$ millions)*	\$2,947	\$3,317	\$3,067	\$3,062	\$3,109	\$3,182
Job losses	18,787	21,185	19,706	19,787	20,176	20,760
Tax losses on production and Imports (\$ millions)*	\$406	\$456	\$419	\$415	\$419	\$426

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero (\$0) indicate estimated income losses less than \$500,000.

4.5 Impacts for Municipal Water Shortages

Nine of the 15 counties in the region are projected to experience water shortages in the municipal water use category for one or more decades within the planning horizon.

Impact estimates were made for two sub-categories within municipal water use: residential and non-residential. Non-residential municipal water use includes commercial and institutional users, which are further divided into non-water-intensive and water-intensive subsectors including car wash, laundry, hospitality, health care, recreation, and education. Lost consumer surplus estimates were made only for needs in the residential portion of municipal water use. Available IMPLAN and TWDB Water Use Survey data for the non-residential, water-intensive portion of municipal demand allowed these sectors to be included in income, jobs, and tax loss impact estimate.

Trucking cost estimates, calculated for shortages exceeding 80 percent, assumed a fixed, maximum cost of \$35,000 per acre-foot to transport water for municipal use. The estimated impacts to this water use category appear in Table 4-5.

Table 4-5 Impacts of water shortages on municipal water users in Region H

Impacts measure	2020	2030	2040	2050	2060	2070
Income losses¹ (\$ millions)*	\$116	\$1,672	\$3,630	\$4,552	\$5,639	\$6,906
Job losses¹	1,805	25,979	56,408	70,747	87,624	107,315
Tax losses on production and imports¹ (\$ millions)*	\$9	\$137	\$297	\$372	\$461	\$564
Trucking costs (\$ millions)*	\$4	\$3	\$8	\$10	\$13	\$258
Utility revenue losses (\$ millions)*	\$72	\$626	\$1,134	\$1,403	\$1,722	\$2,085
Utility tax revenue losses (\$ millions)*	\$1	\$12	\$22	\$27	\$33	\$40

¹ Estimates apply to the water-intensive portion of non-residential municipal water use.

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero (\$0) indicate estimated income losses less than \$500,000.

4.6 Impacts of Steam-Electric Water Shortages

Steam-electric water shortages in the region are projected to occur in two of the 15 counties in the region for one or more decades within the planning horizon. Estimated impacts to this water use category appear in Table 4-6.

Note that estimated economic impacts to steam-electric water users:

- Are reflected as an income loss proxy in the form of estimated additional purchasing costs for power from the electrical grid to replace power that could not be generated due to a shortage;
- Do not include estimates of impacts on jobs. Because of the unique conditions of power generators during drought conditions and lack of relevant data, it was assumed that the industry would retain, perhaps relocating or repurposing, their existing staff in order to manage their ongoing operations through a severe drought.
- Do not presume a decline in tax collections. Associated tax collections, in fact, would likely increase under drought conditions since, historically, the demand for electricity increases during times of drought, thereby increasing taxes collected on the additional sales of power.

Table 4-6 Impacts of water shortages on steam-electric power in Region H

Impacts measure	2020	2030	2040	2050	2060	2070
Income Losses (\$ millions)*	\$260	\$260	\$260	\$260	\$260	\$260

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero (\$0) indicate estimated income losses less than \$500,000.

4.7 Regional Social Impacts

Projected changes in population, based upon several factors (household size, population, and job loss estimates), as well as the accompanying change in school enrollment, were also estimated and are summarized in Table 4-7.

Table 4-7 Region-wide social impacts of water shortages in Region H

Impacts measure	2020	2030	2040	2050	2060	2070
Consumer surplus losses (\$ millions)*	\$59	\$515	\$878	\$1,469	\$2,980	\$4,359
Population losses	5,289	12,151	17,600	20,307	23,477	27,203
School enrollment losses	1,012	2,324	3,366	3,884	4,491	5,203

* Year 2018 dollars, rounded. Entries denoted by a dash (-) indicate no estimated economic impact. Entries denoted by a zero (\$0) indicate estimated income losses less than \$500,000.

Appendix A - County Level Summary of Estimated Economic Impacts for Region H

County level summary of estimated economic impacts of not meeting identified water needs by water use category and decade (in 2018 dollars, rounded). Values are presented only for counties with projected economic impacts for at least one decade.

(* Entries denoted by a dash (-) indicate no estimated economic impact)

County	Water Use Category	Income losses (Million \$)*						Job losses					
		2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070
AUSTIN	MINING	-	\$17.00	\$11.45	\$4.98	-	-	-	134	91	39	-	-
AUSTIN	MUNICIPAL	-	\$0.07	\$0.85	\$2.58	\$4.96	\$6.85	-	1	13	40	77	106
AUSTIN Total		-	\$17.07	\$12.30	\$7.56	\$4.96	\$6.85	-	136	104	80	77	106
BRAZORIA	IRRIGATION	\$12.64	\$12.64	\$12.64	\$12.64	\$12.64	\$12.66	315	315	315	315	315	316
BRAZORIA	MANUFACTURING	\$808.53	\$1,206.91	\$1,206.91	\$1,206.91	\$1,206.91	\$1,211.99	3,556	5,307	5,307	5,307	5,307	5,330
BRAZORIA	MINING	-	\$19.93	\$70.72	\$148.21	\$203.02	\$270.15	-	149	529	1,109	1,520	2,022
BRAZORIA	MUNICIPAL	-	\$2.58	\$27.93	\$77.52	\$119.17	\$164.21	-	40	434	1,205	1,852	2,552
BRAZORIA Total		\$821.17	\$1,242.07	\$1,318.20	\$1,445.29	\$1,541.75	\$1,659.01	3,871	5,812	6,586	7,937	8,994	10,219
CHAMBERS	IRRIGATION	\$0.21	\$0.21	\$0.21	\$0.21	\$0.21	\$0.21	6	6	6	6	6	6
CHAMBERS	MANUFACTURING	\$279.79	\$392.92	\$392.92	\$392.92	\$392.92	\$392.92	1,414	1,986	1,986	1,986	1,986	1,986
CHAMBERS	MUNICIPAL	\$2.12	\$6.90	\$13.68	\$18.72	\$24.34	\$30.28	33	107	213	291	378	471
CHAMBERS	STEAM ELECTRIC POWER	\$72.71	\$72.71	\$72.71	\$72.71	\$72.71	\$72.71	-	-	-	-	-	-
CHAMBERS Total		\$354.84	\$472.74	\$479.53	\$484.57	\$490.19	\$496.13	1,453	2,099	2,204	2,283	2,370	2,462
FORT BEND	MANUFACTURING	-	\$345.35	\$345.35	\$345.35	\$345.35	\$345.35	-	1,948	1,948	1,948	1,948	1,948
FORT BEND	MINING	\$0.03	\$1.21	\$0.74	\$0.50	\$0.54	\$0.16	0	11	6	4	5	1
FORT BEND	MUNICIPAL	\$20.07	\$722.38	\$973.25	\$1,133.02	\$1,263.81	\$1,379.76	312	11,226	15,125	17,607	19,640	21,442
FORT BEND Total		\$20.11	\$1,068.94	\$1,319.34	\$1,478.87	\$1,609.70	\$1,725.27	312	13,184	17,079	19,559	21,592	23,391
GALVESTON	IRRIGATION	\$1.58	\$1.58	\$1.58	\$1.58	\$1.58	\$1.58	40	40	40	40	40	40
GALVESTON	LIVESTOCK	\$7.03	\$7.03	\$7.03	\$7.03	\$7.03	\$7.03	315	315	315	315	315	315
GALVESTON	MANUFACTURING	-	\$740.73	\$745.90	\$750.90	\$756.31	\$761.33	-	3,104	3,126	3,147	3,169	3,190
GALVESTON	MINING	\$206.20	\$221.23	\$243.48	\$262.72	\$281.35	\$300.59	1,621	1,739	1,914	2,065	2,212	2,363
GALVESTON	MUNICIPAL	\$43.85	\$63.34	\$65.09	\$68.35	\$73.34	\$79.13	681	984	1,012	1,062	1,140	1,230
GALVESTON Total		\$258.66	\$1,033.90	\$1,063.08	\$1,090.57	\$1,119.61	\$1,149.66	2,657	6,182	6,406	6,629	6,876	7,138

County		Water Use Category		Income losses (Million \$)*							Job losses						
		2020	2030	2040	2050	2060	2070	2020	2030	2040	2050	2060	2070				
HARRIS	LIVESTOCK	\$24.22	\$43.39	\$56.20	\$56.20	\$56.20	\$56.20	767	1,375	1,781	1,781	1,781	1,781				
HARRIS	MANUFACTURING	-	\$84.55	\$159.34	\$231.81	\$231.81	\$231.81	-	421	793	1,154	1,154	1,154				
HARRIS	MINING	\$2,740.78	\$2,723.10	\$2,674.73	\$2,644.96	\$2,621.70	\$2,603.09	17,166	17,056	16,753	16,566	16,420	16,304				
HARRIS	MUNICIPAL	\$24.06	\$729.84	\$2,241.51	\$2,721.03	\$3,325.02	\$4,032.88	374	11,342	34,834	42,285	51,672	62,672				
HARRIS	STEAM ELECTRIC POWER	\$187.72	\$187.72	\$187.72	\$187.72	\$187.72	\$187.72	-	-	-	-	-	-				
HARRIS Total		\$2,976.78	\$3,768.60	\$5,319.50	\$5,841.72	\$6,422.46	\$7,111.71	18,308	30,193	54,160	61,786	71,027	81,911				
LEON	MANUFACTURING	-	\$9.25	\$9.25	\$9.25	\$9.25	\$9.25	-	74	74	74	74	74				
LEON Total		-	\$9.25	\$9.25	\$9.25	\$9.25	\$9.25	-	74	74	74	74	74				
LIBERTY	IRRIGATION	\$1.46	\$1.46	\$1.46	\$1.46	\$1.46	\$1.46	37	37	37	37	37	37				
LIBERTY	LIVESTOCK	\$15.29	\$15.29	\$15.29	\$15.29	\$15.29	\$15.29	735	735	735	735	735	735				
LIBERTY	MINING	-	-	-	\$0.30	\$2.41	\$8.40	-	-	-	2	20	70				
LIBERTY	MUNICIPAL	-	\$0.01	\$0.12	\$0.35	\$0.69	\$1.15	-	0	2	5	11	18				
LIBERTY Total		\$16.75	\$16.75	\$16.87	\$17.40	\$19.84	\$26.30	773	773	775	781	803	860				
MADISON	MINING	-	\$334.73	\$66.03	-	-	-	-	2,096	414	-	-	-				
MADISON Total		-	\$334.73	\$66.03	-	-	-	-	2,096	414	-	-	-				
MONTGOMERY	MANUFACTURING	\$125.73	\$410.57	\$401.83	\$394.63	\$391.76	\$388.91	1,028	3,356	3,284	3,225	3,202	3,179				
MONTGOMERY	MUNICIPAL	\$25.06	\$143.84	\$302.37	\$523.97	\$817.63	\$1,197.57	389	2,235	4,699	8,143	12,706	18,610				
MONTGOMERY Total		\$150.78	\$554.41	\$704.21	\$918.60	\$1,209.39	\$1,586.48	1,417	5,591	7,983	11,368	15,908	21,789				
WALLER	MUNICIPAL	\$0.97	\$2.77	\$5.03	\$6.93	\$9.54	\$13.78	15	43	78	108	148	214				
WALLER Total		\$0.97	\$2.77	\$5.03	\$6.93	\$9.54	\$13.78	15	43	78	108	148	214				
REGION H Total		\$4,600.06	\$8,521.23	\$10,313.32	\$11,300.76	\$12,436.69	\$13,784.42	28,805	66,183	95,862	110,604	127,869	148,164				

Appendix F. Environmental Review

Draft Environmental Evaluation

in support of the

Feasibility Study for a
Desalination Plant
in Galveston County, Texas

on behalf of

NorrisWater

and the

Gulf Coast Water Authority

Prepared by



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1.0 Introduction

This Draft Environmental Evaluation provides the results of desktop environmental reviews conducted to identify baseline conditions, potential environmental constraints, and associated regulatory requirements for the Gulf Coast Water Authority's proposed desalination plant in Galveston County, Texas. This assessment will be used as part of the Feasibility Study being prepared for the proposed project.

2.0 Project Description

The project involves the design and construction of a desalination plant that includes the following components:

- Raw Water Intake Structure
- Raw Water Intake Line
- Desalination Plant
- Concentrate Discharge Line

3.0 Environmental Setting

3.1 Topography

The project limits are located in Galveston County south of Texas City, Texas (**Appendix A, Figures 1 and 2**). The site location is on the Hitchcock, Lake Como, Sea Isle, and Virginia Point 7.5-minute United States Geologic Survey (USGS) Topographic Quadrangles. The topography is gently sloped with elevations ranging from 0–5 feet above mean sea level (**Figure 2**).

3.2 Geology

The geology within the project limits (**Appendix A, Figure 3**) is primarily alluvial deposits of Holocene age and Beaumont Formation of Holocene and Pleistocene age. Mapped alluvium consists of clay, silt, and sand organic matter, including point-bar, natural levee, stream channel, backswamp, coastal marsh, mud flat, and narrow beach deposits. The Beaumont Formation is mostly clay, silt, and sand, including mainly stream channel, point-bar, natural levee, backswamp, coastal marsh, and mud flat deposits (BEG 2002).

3.3 Soils

Information for soils found within the project limits (**Figure 3**) was obtained from the U.S Department of Agriculture (USDA) Web Soil Survey. Results from the soil survey (USDA 2025) are shown in **Table 1** below.

Table 1. Soils within the Project Limits	
Map Unit Symbol	Map Unit Name
Be	Bernard clay loam, 0 to 1 percent slopes
Bn	Bernard-Edna complex, 0 to 1 percent slopes
Fr	Francitas clay loam, 0 to 1 percent slopes, rarely flooded
LetA	Leton loam, 0 to 1 percent slopes, occasionally flooded, frequently ponded
Mc	Mocarey-Cieno frequently flooded complex, 0 to 1 percent slopes
Na	Narta fine sandy loam, 0 to 1 percent slopes, rarely flooded
Pd	Francitas clay, 0 to 1 percent slopes, frequently flooded, occasionally ponded

Table 1. Soils within the Project Limits

Map Unit Symbol	Map Unit Name
Tc	Tracosa clay, 0 to 1 percent slopes, low, very frequently flooded
Vx	Veston complex, 0 to 1 percent slopes, frequently flooded
W	Water

3.4 Ecoregion

The project limits are situated within the Northern Humid Gulf Coastal Prairies (Griffith et al. 2007). This area is characterized by a gently sloping, mostly flat, coastal plain. Vegetation is typically prairie grassland with clusters of oaks (oak mottes) or maritime woodlands. The climate is humid with 37–58 inches of annual precipitation. Almost all of the coastal prairies have been converted to cropland, rangeland, pasture, or urban and industrial uses (Griffith et al. 2007).

3.5 Water Resources

3.5.1 Surface Water

The proposed project lies within the watershed boundaries of Dickinson Bayou and Halls Bayou (TPWD 2025). The northern portion of the project limits drains to Jones Bay; the southern portion of the project limits drains to West Bay.

3.5.2 Groundwater

The Gulf Coast Aquifer is the major groundwater aquifer underlying the project site. The Gulf Coast Aquifer consists of several aquifers, including the Jasper, Evangeline and Chicot aquifers, which are composed of discontinuous sand, silt, clay, and gravel beds. Areas of increased salinity along the central and eastern Gulf Coast may be associated with saltwater intrusion in response to groundwater pumping or to brine migration in response to oil field operations and natural flows from salt domes intruding into the aquifer (TWDB 2025).

3.6 Land Use

Land use within and adjacent to the project limits is mostly undeveloped, with oil and gas wells and pipelines throughout the Greens Lake Well Field. The Harborwalk Yacht Club and Marina and the Flamingo Isles waterfront neighborhood lie along the coast with an outlet to Jones Bay. Texas City and other smaller municipalities lie to the north of the proposed project site, with Galveston and Galveston Island to the east across West Bay.

4.0 Waters of the U.S., Including Wetlands

Section 404 of the Clean Water Act (CWA) authorizes the U.S. Army Corps of Engineers (USACE) to issue permits for the discharge of dredged or fill material into waters of the U.S., including wetlands. Discharges into waters of the U.S. must be in accordance with Section 404(b)(1) guidelines developed by the Environmental Protection Agency (EPA) in conjunction with the USACE. Permits issued by the USACE are required for activities that would result in the discharge of dredged or fill material into waters of the U.S. Regulated activities may be permitted through USACE via Standard Individual Permits, Regional General Permits, or Nationwide Permits.

National Wetland Inventory (NWI) maps and the National Hydrography Dataset (NHD) were consulted to assess the potential for water features that may be subject to regulation under Section 404 of the CWA to occur within the project limits. The NWI maps and NHD depict wetlands and other water features that have been identified using aerial photographs and other available mapping data; such features can include ponds, lakes, rivers, and streams. Potential wetland features are shown in **Figures 4-1** through **4-4**, in **Appendix A**, and **Table 2** below.

Table 2. Potential Water Features within the Project Limits			
Water Feature Type	NWI Code	Description	Acres within Project Limits
Estuarine and Marine Wetland	E2EM1P	Estuarine (E), Intertidal (2), Emergent (EM), Persistent (1), Irregularly Flooded (P)	0.02
Estuarine and Marine Wetland	E2EM1N	Estuarine (E), Intertidal (2), Emergent (EM), Persistent (1), Regularly Flooded (N)	1.86
Estuarine and Marine Deepwater	E1UBL	Estuarine (E), Subtidal (1), Unconsolidated Bottom (UB), Subtidal (L)	0.17
Freshwater Emergent Wetland	PEM1C	Palustrine (P), Emergent (EM), Persistent (1), Seasonally Flooded (C)	0.09
Freshwater Emergent Wetland	PEM1Ch	Palustrine (P), Emergent (EM), Persistent (1), Seasonally Flooded (C), Diked/Impounded (h)	0.02
Freshwater Emergent Wetland	PEM1A	Palustrine (P), Emergent (EM), Persistent (1), Temporarily Flooded (A)	1.79
Freshwater Emergent Wetland	PEM1Ah	Palustrine (P), Emergent (EM), Persistent (1), Temporarily Flooded (A), Diked/Impounded (h)	0.55
Freshwater Emergent Wetland	PEM1J	Palustrine (P), Emergent (EM), Persistent (1), Intermittently Flooded (J)	0.06
Freshwater Forested/Shrub Wetland	PSS1A	Palustrine (P), Scrub-Shrub (SS), Broad-Leaved Deciduous (1), Temporarily Flooded (A)	1.28
Freshwater Pond	PUSA	Palustrine (P), Unconsolidated Shore (US), Temporarily Flooded (A)	0.68
Freshwater Pond	PUBFx	Palustrine (P), Unconsolidated Bottom (UB), Semipermanently Flooded (F), Excavated (x)	0.13
Freshwater Pond	PUSCh	Palustrine (P), Unconsolidated Shore (US), Seasonally Flooded (A), Diked/Impounded (h)	0.94
Total			7.6

As shown in **Table 2**, the NWI indicates approximately 7.6 acres of estuarine and marine wetlands, freshwater emergent wetlands, freshwater forested/shrub wetlands, and freshwater ponds occur within the project limits. Field investigations would need to be conducted to evaluate and delineate these NWI features. It is anticipated that the project would require authorization under a Standard Individual Permit. The full extent of impacts to potential waters of the U.S., including wetlands and special aquatic sites would need to be determined upon completion of field investigations.

5.0 Threatened and Endangered Species

The U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) have authority for the protection of threatened and endangered species as provided by the Endangered Species Act (ESA) of 1973 and subsequent amendments and can list species for protection and monitoring that are

considered imperiled. Vulnerable species that qualify for listing are categorized as candidates that have been deferred from the listing process pending further status review. The vulnerability decision is based upon many factors affecting the species within its range and is linked to the best current scientific data available. Species listed as Endangered (E) or Threatened (T) by the USFWS or NMFS are provided full protection under the ESA. This protection includes a prohibition on direct take of the listed species in addition to indirect take such as destruction of habitat.

The Texas Parks & Wildlife Department (TPWD) oversees endangered resources through the Wildlife Division's Wildlife Diversity Program. This program is responsible for maintaining county occurrence records of state and federal endangered and threatened species and also maintains the Texas Natural Diversity Database (TXNDD) that provides specific site information and other species status tracking information on listed or rare animal and plant species including unique or declining vegetation communities of concern. State-listed species have limited regulatory protection. While these species cannot be taken, collected, held, or possessed without a permit, their habitat is afforded no regulatory protection, except on tracts managed by State, federal, or private interests for conservation purposes.

Federal and State-listed endangered and threatened species that could occur in Galveston County and the proposed project limits were determined by referencing existing county lists maintained by the TPWD, the Information for Planning and Consultation (IPaC) database maintained by the USFWS, and the ESA Section 7 Mapper for the Southeast Region maintained by NMFS. Information provided from these databases is summarized in **Table 3**. The TPWD and USFWS lists vary due to differences in the procedures for collecting and disseminating data on recorded occurrences.

Table 3. Threatened and Endangered Species of Potential Occurrence in Galveston County, Texas			
Species	Federal Status	State Status	Description of Suitable Habitat
Birds			
Attwater's Greater Prairie-Chicken <i>Tympanuchus cupido attwateri</i>	E	E	Open prairies of mostly thick grass one to three feet tall; sandhill country with bunch grass, sage, and shinnery oak. From near sea level to 200 feet along coastal plain on upper two-thirds of Texas coast; males form communal display flocks during late winter – early spring; booming grounds important; breeding February–July.
Black Rail <i>Laterallus jamaicensis</i>	T	T	The county distribution for this species includes geographic areas that the species may use during migration. Time of year should be factored into evaluations to determine potential presence of this species in a specific county. Salt, brackish, and freshwater marshes, pond borders, wet meadows, and grassy swamps; nests in or along edge of marsh, sometimes on damp ground, but usually on mat of previous year's dead grasses; nest usually hidden in marsh grass or at base of Salicornia.
Eskimo Curlew <i>Numenius borealis</i>	E	E	Historically, shortgrass plains and prairies, but more recently (1960s) in old fields, closely grazed pastures, burned prairies, and marshes; beaches and sand flats. Nonbreeding: grasslands, pastures, plowed fields, and less frequently, marshes and mudflats.
Piping Plover <i>Charadrius melodus</i>	T	T	Beaches, sandflats, and dunes along Gulf Coast beaches and adjacent offshore islands. Also spoil islands in the Intracoastal Waterway. Algal flats appear to be the highest quality habitat. Some of the most important aspects of algal flats are their relative inaccessibility and their continuous availability throughout all tidal conditions. Sand flats often appear to be preferred over algal flats when both are available, but large portions of sand flats along the Texas coast are available only during low-very low tides and are often completely unavailable during extreme high tides or strong north winds. Beaches appear to serve as a secondary habitat to the flats associated with the primary bays, lagoons, and inter-island passes. Beaches are rarely used on the southern Texas

Table 3. Threatened and Endangered Species of Potential Occurrence in Galveston County, Texas			
Species	Federal Status	State Status	Description of Suitable Habitat
			coast, where bayside habitat is always available, and are abandoned as bayside habitats become available on the central and northern coast. However, beaches are probably a vital habitat along the central and northern coast (i.e., north of Padre Island) during periods of extreme high tides that cover the flats. Optimal site characteristics appear to be large in area, sparsely vegetated, continuously available or in close proximity to secondary habitat, and with limited human disturbance.
Reddish Egret <i>Egretta rufescens</i>	NL	T	Resident of the Texas Gulf Coast; brackish marshes, shallow salt ponds and tidal flats; nests on ground or in trees or bushes, on dry coastal islands in brushy thickets of yucca and prickly pear.
Rufa Red Knot <i>Calidris canutus rufa</i>	T	T	The county distribution for this species includes geographic areas that the species may use during migration. Time of year should be factored into evaluations to determine the potential presence of this species in a specific county. Habitat: Primarily seacoasts on tidal flats and beaches, herbaceous wetlands, and tidal flats/shores. Bolivar Flats in Galveston County, sandy beaches on Mustang Island, few on outer coastal and barrier beaches, tidal mudflats and salt marshes.
Swallow-tailed Kite <i>Elanoides forficatus</i>	NL	T	The county distribution for this species includes geographic areas that the species may use during migration. Time of year should be factored into evaluations to determine potential presence of this species in a specific county. Lowland forested regions, especially swampy areas, ranging into open woodland; marshes, along rivers, lakes, and ponds; nests high in tall tree in clearing or on forest woodland edge, usually in pine, cypress, or various deciduous trees.
White-faced Ibis <i>Plegadis chihi</i>	NL	T	The county distribution for this species includes geographic areas that the species may use during migration. Time of year should be factored into evaluations to determine the potential presence of this species in a specific county. Prefers freshwater marshes, sloughs, and irrigated rice fields, but will attend brackish and saltwater habitats; currently confined to near-coastal rookeries in so-called hog-wallow prairies. Nests in marshes, in low trees, on the ground in bulrushes or reeds, or on floating mats.
White-tailed Hawk <i>Buteo albicaudatus</i>	NL	T	Near coast on prairies, cordgrass flats, and scrub-live oak; further inland on prairies, mesquite and oak savannas, and mixed savanna-chaparral; breeding March–May.
Whooping Crane <i>Grus americana</i>	E	NL	The whooping crane breeds, migrates, winters and forages in a variety of habitats, including coastal marshes and estuaries, inland marshes, lakes, open ponds, shallow bays, salt marsh and sand or tidal flats, upland swales, wet meadows and rivers, pastures and agricultural fields.
Wood Stork <i>Mycteria americana</i>	NL	T	The county distribution for this species includes geographic areas that the species may use during migration. Time of year should be factored into evaluations to determine potential presence of this species in a specific county. Prefers to nest in large tracts of baldcypress (<i>Taxodium distichum</i>) or red mangrove (<i>Rhizophora mangle</i>); forages in prairie ponds, flooded pastures or fields, ditches, and other shallow standing water, including saltwater; usually roosts communally in tall snags, sometimes in association with other wading birds (i.e., active heronries); breeds in Mexico and birds move into Gulf States in search of mud flats and other wetlands, even those associated with forested areas; formerly nested in Texas, but no breeding records since 1960.
Yellow-billed Cuckoo <i>Coccyzus americanus</i>	E	T	In Texas, the populations of concern are found breeding in riparian areas in the Trans Pecos (known as part of the Western Distinct Population Segment [DPS]). It is the Western DPS that is on the ESA threatened list and includes the Texas counties Brewster, Culberson, El Paso, Hudspeth, Jeff Davis, and Presidio. Riparian woodlands below 6,000 feet in elevation consisting of cottonwoods and willows are prime habitat. This species is a long-distant migrant that summers in Texas, but winters mainly in South America. Breeding birds of the Trans Pecos populations typically arrive on their breeding grounds possibly in late April, but the peak arrival time is in May. Threats to preferred habitat include hydrologic changes that don't promote the regeneration of

Table 3. Threatened and Endangered Species of Potential Occurrence in Galveston County, Texas			
Species	Federal Status	State Status	Description of Suitable Habitat
			cottonwoods and willows, plus livestock browsing and trampling of sapling trees in sensitive riparian areas.
FISHES			
Giant Manta Ray <i>Mobula birostris</i>	T	NL	The giant manta ray has a worldwide distribution but is currently limited to several highly fragmented populations. It is the largest species of ray with a wingspan of up to 29 feet. The giant manta ray is a filter feeder that forages primarily on microscopic organisms but is known to consume some small fish. Common occurrences are in oceanic waters, offshore, and near protective coastlines. The species has been documented in the Gulf of Mexico, including juvenile nursery grounds at Flower Garden Banks National Marine Sanctuary off the coast of Texas. This species also occasionally occurs in estuarine waters near ocean inlets at potential nursery grounds.
Great Hammerhead <i>Sphyrna mokarran</i>	NL	T	Occurs in warm temperate and tropical seas worldwide. Highly migratory species. May be found in both inshore and offshore waters. Typically found over the continental shelf, near islands and reefs, and in lagoons.
Oceanic Whitetip Shark <i>Carcharhinus longimanus</i>	T	T	This pelagic shark ranges from Argentina to Maine, including the Gulf of Mexico, the Pacific Ocean, and the Caribbean Sea. It is generally a surface-dwelling species, but it can also be found in water depths up to 183 meters. The oceanic whitetip shark generally remains offshore in the open ocean or along the outer continental shelf but is occasionally found near oceanic islands. It prefers water temperatures greater than 20 degrees Celsius.
Shortfin Mako Shark <i>Isurus oxyrinchus</i>	NL	T	This species of shark prefers the surface of open warm seas in the Gulf of Mexico. It feeds primarily on schooling fishes like mackerels and herrings.
Smalltooth Sawfish <i>Pristis pectinata</i>	E	E	Different life history stages have different patterns of habitat use: young of year Age 1 and Age 2 are dependent upon shallow (1 meter), euryhaline waters with red mangrove lined shoreline. These age classes are often found very close to shore over muddy and sandy bottoms in sheltered bays, on shallow banks, and in estuaries or river mouths. These age classes can tolerate a wide range of salinities but will move in and out of protected areas (estuaries) due to changes in flow and salinity. Larger juveniles may occupy greater depth strata in areas further from shore as they consistently occupy marine waters. Adult sawfish are encountered in various habitat types (mangrove, oyster reef, seagrass, and coral), in varying salinity regimes and temperatures, and at various water depths, feed on a variety of fish species. Adult female sawfish return to protected estuarine areas to give birth.
INSECTS			
Monarch Butterfly <i>Danaus plexippus</i>	C	NL	Found statewide. Adults are found in a variety of habitats including native prairies, pastures, open woodlands and savannas, desert scrub, roadsides, and other habitats with abundant nectar plants, including urbanized areas. Although adults may be present year-round, they are primarily encountered between March and November and are most commonly observed in the summer and fall during breeding and migration. Caterpillars are found on various species of the family <i>Asclepiadaceae</i> (occasionally treated as a subfamily of <i>Apocynaceae</i>). Common host plants in Texas include milkweeds (<i>Asclepias</i> spp.), milkweed vines (<i>Matelea</i> spp.), climbing milkweed (<i>Funistrum</i> spp.), swallowworts (<i>Cynanchum</i> spp.), and anglepod (<i>Gonolobus suberosus</i>). Caterpillars are most frequently observed between April and September.
MAMMALS			
Atlantic Spotted Dolphin <i>Stenella frontalis</i>	NL	T	Inhabits warm tropical, subtropical, and temperate waters throughout the Atlantic Ocean, including the Gulf of Mexico. Commonly found along the continental shelf and coastal waters that are 65–820 feet deep, usually inside or near 185-meter contour (within 250–350 kilometers of coast); occasionally found in deeper waters. Often dive to 30–200 feet preying upon fish, invertebrates, and cephalopods.

Table 3. Threatened and Endangered Species of Potential Occurrence in Galveston County, Texas			
Species	Federal Status	State Status	Description of Suitable Habitat
Blue Whale <i>Balaenoptera musculus</i>	E	E	Inhabits tropical, subtropical, temperate, and subpolar waters worldwide, but are infrequently sighted in the Gulf of Mexico. They migrate seasonally between summer feeding grounds and winter breeding grounds, but specifics vary. Commonly observed at the surface in open ocean.
Bryde's Whale <i>Balaenoptera edeni brydei</i>	NL	E	Bryde's whales are found in warm, temperate oceans including the Atlantic, Indian, and Pacific. Some populations of Bryde's whales make short migratory movements with the seasons, while others do not migrate, making them unique among other migrating baleen whales.
Cuvier's Beaked Whale <i>Ziphius cavirostris</i>	NL	T	Inhabits tropical, subtropical, and temperate waters worldwide, including the Gulf of Mexico. Commonly found in water over 3,300 feet deep near the continental shelf near steep slopes or canyons, avoiding coastal areas. Mostly pelagic apparently confined by the 1,000-meter bathymetric contour; frequently make deep dives to capture prey (squids and fishes).
Dwarf Sperm Whale <i>Kogia simus</i>	NL	T	Inhabits tropical and temperate waters worldwide, commonly found in deep waters near the continental shelf and rarely seen at the surface but may be more coastal than the pygmy sperm whale (<i>Kogia breviceps</i>). Dives to great depths (1,000 feet) to hunt for squid, fish, and crustaceans. Migration patterns are unknown.
False Killer Whale <i>Pseudorca crassidens</i>	NL	T	False killer whales generally prefer offshore tropical to subtropical waters that are deeper than 3,300 feet. False killer whales occur in tropical, subtropical, and temperate waters of all ocean basins. In the United States, they are found around Hawaii, in all Pacific Remote Island Areas, the Mariana Archipelago, and in American Samoa, as well in the Gulf of Mexico and in the warm Gulf Stream waters off the East Coast.
Finback Whale <i>Balaenoptera physalus</i>	E	E	Inhabits tropical, subtropical, temperate, and subpolar waters worldwide, but are less common in the tropics preferring cooler water. Commonly found in deep, offshore waters and migrate in the open ocean from the poles (feeding grounds) to warmer waters in the winter to give birth. They feed on krill, squid, and small schooling fish sometimes with other baleen whale species. They are very rare in the Gulf of Mexico and reported sightings are likely vagrants.
Gervais's Beaked Whale <i>Mesoplodon europaeus</i>	NL	T	Inhabits tropical, subtropical, and temperate waters of the northern Atlantic Ocean, Gulf of Mexico, and Caribbean. Commonly found in deep water and open ocean where they prey upon squids. They are difficult to distinguish from others in their family (<i>Mesoplodon</i>) and are cryptic and skittish, but are the most commonly stranded species on the U.S. southeastern coast. Migration patterns are unknown.
Humpback Whale <i>Megaptera novaeangliae</i>	E	NL	Inhabits tropical, subtropical, temperate, and subpolar waters worldwide. Migrate up to 5,000 miles between colder water (feeding grounds) and warmer water (calving grounds) each year. They will use both open ocean and coastal waters, sometimes including inshore areas such as bays, and are often found near the surface; however, this species is rare in the Gulf of Mexico. The northwest Atlantic/Gulf of Mexico distinct population segment is not considered at risk of extinction and is not listed as Endangered on the ESA.
Killer Whale <i>Orcinus orca</i>	NL	T	Inhabits tropical, subtropical, temperate, and polar waters worldwide. In the Gulf of Mexico, they are commonly found in oceanic waters ranging from 256–2,652 meters deep beyond the 1,000-meter isobath and a very rarely found over the continental shelf and may be entirely absent from nearshore waters. May come in contact with pelagic longline fisheries targeting tunas and billfishes.
North Atlantic Right Whale <i>Eubalaena glacialis</i>	E	E	Inhabits subtropical and temperate waters in the northern Atlantic. Commonly found in coastal waters or close to the continental shelf near the surface. They migrate from feeding grounds in cooler waters (Canada and New England) to warmer waters of the southeast U.S. (South Carolina, Georgia, and Florida) to give birth in the fall/winter - both areas are identified as critical habitat by NOAA-NMFS. Nursery areas are in shallow, coastal waters. This species is very rare in the Gulf of Mexico and the few reported sightings are likely vagrants.

Table 3. Threatened and Endangered Species of Potential Occurrence in Galveston County, Texas			
Species	Federal Status	State Status	Description of Suitable Habitat
Pygmy Killer Whale <i>Feresa attenuata</i>	NL	T	Inhabits tropical and subtropical waters worldwide, including the Gulf of Mexico. Commonly found in deeper, offshore waters where they dive for their prey (squids and fishes), but may occasionally occur close to shore. They are very rare, and migration patterns are unknown.
Pygmy Sperm Whale <i>Kogia breviceps</i>	NL	T	Inhabits tropical, subtropical, and temperate waters worldwide. Commonly found in deep water over the continental slope and rarely seen at the surface. Dives to great depths (over 1,000 feet) to hunt for squid, fish, and crustaceans. Migration patterns are unknown.
Rafinesque's Big-eared Bat <i>Corynorhinus rafinesquii</i>	NL	T	Historically, lowland pine and hardwood forests with large hollow trees. roosts in cavity trees of bottomland hardwoods, concrete culverts, and abandoned manmade structures.
Rice's Whale <i>Balaenoptera ricei</i>	E	E	Research indicates Rice's whales are resident and live year-round in the Gulf of Mexico. They are the only species of baleen whale that regularly occurs in the Gulf. Most sightings of Rice's whales have been concentrated in 100–400-meter water depths in the northeastern Gulf of Mexico and the west coast of Florida. Sightings have been documented less frequently in the western Gulf, offshore of Louisiana and Texas.
Roughtoothed Dolphin <i>Steno bredanensis</i>	NL	T	Inhabits tropical, subtropical, and temperate waters worldwide, including the Gulf of Mexico. Records in Texas are only known from strandings. Commonly found in deep, oceanic water over 1,500–2,000 meters deep and ranging in temperature from 17–25 degrees Celsius. May associate with other cetaceans. Prey on squids and fish. No known migration patterns.
Sei Whale <i>Balaenoptera borealis</i>	E	E	The sei whale is a baleen species that inhabits subtropical, temperate, and subpolar waters worldwide. It prefers deeper waters offshore where it feeds on plankton, small schooling fish, and cephalopods. This species has annual migrations from subtropical, temperate waters during the winter (breeding) to subpolar, cool waters in the summer.
Short-finned Pilot Whale <i>Globicephala macrorhynchus</i>	NL	T	Inhabits tropical, subtropical, and temperate waters worldwide, including the Gulf of Mexico. Commonly found in deeper waters (1,000 feet) and continental shelf where they make deep dives to capture squid, but may come closer to shore. Migration patterns unknown.
Sperm Whale <i>Physeter macrocephalus</i>	E	E	Inhabits tropical, subtropical, and temperate waters worldwide, avoiding icy waters. Distribution is highly dependent on their food source (squids, sharks, skates, and fish), breeding, and composition of the pod. In general, this species migrates from north to south in the winter and south to north in the summer; however, individuals in tropical and temperate waters don't seem to migrate at all. Routinely dive to catch their prey (2,000–10,000 feet) and generally occupies water at least 3,300 feet deep near ocean trenches.
Tricolored Bat <i>Perimyotis subflavus</i>	PE	NL	Suitable summer habitat consists of a wide variety of forested/wooded habitats where this species roosts, forages, and travels and may include some adjacent and interspersed non-forested habitats such as emergent wetlands and adjacent edges of agricultural fields, old fields, and pastures. This includes forests and woodlots containing trees with potential roost substrate (i.e., live and dead leaf clusters of live and recently dead deciduous trees, Spanish moss [<i>Tillandsia usneoides</i>], and beard lichen [<i>Usnea trichodea</i>]), as well as linear features such as fencerows, riparian forests, and other wooded corridors. Tricolored bats will roost in a variety of tree species, especially oaks (<i>Quercus</i> spp.), and often select roosts in tall, large diameter trees, but will roost in smaller diameter trees when potential roost substrate is present (e.g., 4-inch [10-centimeter]). In the southern portion of the range, where this species exhibits shorter torpor bouts and remains active and feeds year-round, tricolored bats may roost in culverts, bridges, cavities in live trees, live and dead leaf clusters, and/or Spanish moss during the winter.

Table 3. Threatened and Endangered Species of Potential Occurrence in Galveston County, Texas			
Species	Federal Status	State Status	Description of Suitable Habitat
West Indian Manatee <i>Trichechus manatus</i>	T	T	Large rivers, brackish water bays, coastal waters. Warm waters of the tropics, in rivers and brackish bays but may also survive in saltwater habitats. Very sensitive to cold water temperatures. Rarely occurring as far north as Texas. Gulf and bay system; opportunistic, aquatic herbivore.
REPTILES			
Alligator Snapping Turtle <i>Macrochelys temminckii</i>	PT	T	Aquatic: Perennial water bodies; rivers, canals, lakes, and oxbows; also swamps, bayous, and ponds near running water; sometimes enters brackish coastal waters. Females emerge to lay eggs close to the water's edge.
American Alligator <i>Alligator mississippiensis</i>	SAT	NL	Aquatic: Coastal marshes; inland natural rivers, swamps and marshes; manmade impoundments.
Atlantic Hawksbill Sea Turtle <i>Eretmochelys imbricata</i>	E	E	Inhabit tropical and subtropical waters worldwide, in the Gulf of Mexico, especially Texas. Hatchling and juveniles are found in open, pelagic ocean and closely associated with floating algae/seagrass mats. Juveniles then migrate to shallower, coastal areas, mainly coral reefs and rocky areas, but also in bays and estuaries near mangroves when reefs are absent; seldom in water more than 65 feet deep. They feed on sponges, jellyfish, sea urchins, mollusks, and crustaceans. Nesting occurs from April to November high up on the beach where there is vegetation for cover and little or no sand. Some migrate, but others stay close to foraging areas; females are philopatric.
Green Sea Turtle <i>Chelonia mydas</i>	T	T	Inhabits tropical, subtropical, and temperate waters worldwide, including the Gulf of Mexico. Adults and juveniles occupy inshore and nearshore areas, including bays and lagoons with reefs and seagrass. They migrate from feeding grounds (open ocean) to nesting grounds (beaches/barrier islands) and some nesting does occur in Texas (April to September). Adults are herbivorous feeding on sea grass and seaweed; juveniles are omnivorous feeding initially on marine invertebrates, then increasingly on sea grasses and seaweeds.
Kemp's Ridley Sea Turtle <i>Lepidochelys kempii</i>	E	E	Inhabits tropical, subtropical, and temperate waters of the northwestern Atlantic Ocean and Gulf of Mexico. Adults are found in coastal waters with muddy or sandy bottoms. Some males migrate between feeding grounds and breeding grounds, but some don't. Females migrate between feeding and nesting areas, often returning to the same destinations. Nesting in Texas occurs on a smaller scale compared to other areas (i.e., Mexico). Hatchlings are quickly swept out to open water and are rarely found nearshore. Similarly, juveniles often congregate near floating algae/seagrass mats offshore, and move into nearshore, coastal, neritic areas after 1–2 years and remain until they reach maturity. They feed primarily on crabs, but also snails, clams, other crustaceans and plants, juveniles feed on sargassum and its associated fauna; nests April through August.
Leatherback Sea Turtle <i>Dermochelys coriacea</i>	E	E	Inhabits tropical, subtropical, and temperate waters worldwide, including the Gulf of Mexico. Nesting is not common in Texas (March to July). Most pelagic of the sea turtles with the longest migration (10,000 miles) between nesting and foraging sites. Are able to dive to depths of 4,000 feet. They are omnivorous, showing a preference for jellyfish.
Loggerhead Sea Turtle <i>Caretta caretta</i>	T	T	Inhabits tropical, subtropical, and temperate waters worldwide, including the Gulf of Mexico. They migrate from feeding grounds to nesting beaches/barrier islands and some nesting does occur in Texas (April to September). Beaches that are narrow, steeply sloped, with coarse-grain sand are preferred for nesting. Newly hatched individuals depend on floating algae/seaweed for protection and foraging, which eventually transport them offshore and into open ocean. Juveniles and young adults spend their lives in open ocean, offshore before migrating to coastal areas to breed and nest. Foraging areas for adults include shallow continental shelf waters.

Table 3. Threatened and Endangered Species of Potential Occurrence in Galveston County, Texas

Species	Federal Status	State Status	Description of Suitable Habitat
Texas Horned Lizard <i>Phrynosoma cornutum</i>	NL	T	Terrestrial: Open habitats with sparse vegetation, including grass, prairie, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky; burrows into soil, enters rodent burrows, or hides under rock when inactive. Occurs to 6,000 feet, but largely limited below the pinyon-juniper zone on mountains in the Big Bend area.
PLANTS			
Houston Daisy <i>Rayjacksonia aurea</i>	NL	T	Grasslands and mesquite-dominated shrublands on various soils ranging from heavy clays to lighter textured sandy loams, mostly over the Beaumont Formation on the Coastal Plain; in modified unplowed sites such as railroad and highway rights of way, cemeteries, mowed fields, erosional areas along small creeks; Perennial; Flowering July–November.
E – Endangered; T – Threatened; C – Candidate for Listing; PE – Proposed for Listing as Endangered PT – Proposed for Listing as Threatened; NL – Not Listed			

Sources:

National Oceanic and Atmospheric Administration (NOAA). <https://www.fisheries.noaa.gov/species/brydes-whale>. Accessed April 7, 2025

National Marine Fisheries Service (NMFS). ESA Section 7 Mapper. NOAA Fisheries Southeast Region (v2a). Last updated April 15, 2025. <https://noaa.maps.arcgis.com/apps/webappviewer/index.html?id=b184635835e34f4d904c6fb741cfb00d>. Accessed April 15, 2025.

Texas Parks & Wildlife Department (TPWD). Annotated County Lists of Rare Species: Galveston County, last update January 15, 2025. <http://tpwd.texas.gov/gis/rtest/>. Accessed April 7, 2025.

U.S. Fish and Wildlife Service (USFWS). Official Species List for project location in Galveston County, Texas. <http://ecos.fws.gov/ipac/>. Accessed April 7, 2025

A review of the USFWS IPaC Official Species List and NMFS ESA Section 7 Mapper concluded that while no designated critical habitat for federally listed species occurs within the proposed project limits, proposed critical habitat for the green sea turtle occurs within the tidal waters in the proposed project limits.

Based on desktop review of federally threatened or endangered species in Galveston County and the proposed project vicinity, potential habitat is indicated for seven bird species; three fish species; one insect species that is proposed for federal listing; eight mammal species and one mammal species that is proposed for federal listing; and six reptile species and one reptile species that is proposed for federal listing. Federally listed species and their habitats are protected under the ESA of 1973, as amended. Section 7 consultation with the USFWS and NMFS is anticipated to be required for the proposed project.

In addition to the federally listed species, potential habitat for twenty State-listed threatened or endangered species occurs within or adjacent to the proposed project limits. These include five birds: Reddish Egret (*Egretta rufescens*), Swallow-tailed kite (*Elanoides forficatus*), White-faced Ibis (*Plegadis chihi*), White-tailed Hawk (*Buteo albicaudatus*), and Wood Stork (*Mycteria americana*); two fish: great hammerhead (*Sphyrna mokarran*) and shortfin mako shark (*Isurus oxyrinchus*); eleven mammals: Atlantic spotted dolphin (*Stenella frontalis*), Bryde's whale (*Balaenoptera edeni brydei*), Cuvier's beaked whale (*Ziphius cavirostris*), dwarf sperm whale (*Kogia simus*), false killer whale (*Pseudorca crassidens*), Gervais's beaked whale (*Mesoplodon europaeus*), killer whale (*Orcinus orca*), pygmy killer whale (*Feresa attenuata*), Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), rough-toothed dolphin (*Steno bredanensis*), and short-finned pilot whale (*Globicephala macrorhynchus*); one reptile: Texas horned lizard (*Phrynosoma cornutum*); and one plant: Houston daisy (*Rayjacksonia aurea*). State-listed species have limited regulatory protection. While these species cannot be taken, collected, held, or possessed without a permit, their habitat is afforded no regulatory protection, except on tracts managed by state, federal, or private interests.

for conservation purposes. Best Management Practices (BMPs) would be incorporated into the design of the proposed project to minimize impacts to these species.

The Marine Mammal Protection Act (MMPA) was enacted on October 21, 1972, and amended in 1994 to protect the populations of marine mammals from declining beyond that which is required to maintain a stable population. The MMPA establishes a moratorium on the importation of marine mammals and marine mammal products into the United States and prohibits the “taking” of marine mammals (though some exceptions are authorized through an authorization or permitting process). The MMPA authorized USFWS to implement the act for the conservation and management of sea otters, walrus, polar bears, dugong, and manatees. The NMFS is authorized with the conservation and management of cetaceans and pinnipeds other than the walrus. Additionally, the MMPA established the Marine Mammal Commission to provide independent oversight of the conservation policies and programs implemented by USFWS and NMFS. Due to the presence of habitat for marine mammals in the proposed project area, provisions of the MMPA will apply.

6.0 Essential Fish Habitat

The Magnuson-Stevens Fishery Conservation and Management Act, as amended in 1996 and reauthorized in 2007, requires that Essential Fish Habitat (EFH) be identified for all federally managed fisheries. For the purposes of conservation and management, federally managed species are grouped into fishery management units. These units are identified on the basis of geographical, scientific, technical, recreational, and economic characteristics and then managed under a fishery management plan (FMP). EFH is determined for each unit and is defined by the Act as “...those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” Additionally, the Act further delineates areas of EFH into Habitat Areas of Particular Concern (HAPC). These areas are defined as subsets of EFH which are rare, particularly susceptible to human-induced degeneration, especially ecologically important, or located in an environmentally stressed area.

Projects that are funded, permitted, or implemented by federal agencies are required to consult with NMFS regarding potential adverse impacts on EFH. A review of information obtained from NMFS EFH GIS data inventory (2025) concludes that four Fishery Management Unit EFH designations exist in the vicinity of the proposed project (**Appendix A, Figure 5**). No designated HAPC exists in the vicinity of the proposed project. An EFH Assessment would be prepared for the proposed project and coordination with NMFS would be required.

7.0 Coastal Zone Management and Coastal Barrier Resources

7.1 Coastal Zone Management Program

Section 306 of the Federal Coastal Zone Management Act of 1972 allows coastal states to submit for approval of state coastal management plans. Approval of these state plans makes the state eligible for federal grant funds for coastal issues and enables the states to review federal actions and permits for consistency with the coastal plan. Texas has an approved Coastal Management Program (CMP), which was developed and adopted and is currently being administered by the General Land Office (GLO) and by the Texas Land Commissioner. The GLO is charged with making more effective and efficient use of public funds and providing for more effective and efficient management of coastal resources. Under the CMP, agency actions that are within the coastal boundaries are subject to the CMP and must comply with the applicable goals and policies of the CMP.

The proposed project is located within Galveston County, which is within the Texas CMP Boundary as defined in §503.1 of Title 31 in the Texas Administrative Code (TAC). Section 33.001 of the Texas Natural Resources Code implements policies for the management of coastal public land. Section 33.001(b) states “The natural resources of the surface estate in coastal public land shall be preserved. These resources include the areas in their natural state for the protection and nurture of all types of marine life and wildlife.” Several coastal natural resource areas (CNRAs) occur within the vicinity of the proposed project limits and would potentially be impacted by the construction of the proposed project. These CNRAs include the following:

- Waters under tidal influence;
- Submerged land (regardless of whether the land is owned by the state or a person other than the state);
- Coastal wetlands;
- Submerged aquatic vegetation;
- Oyster reefs;
- Coastal shore areas—all areas within 100 feet landward of the high water mark on state submerged land; and
- Special hazard areas (100-year floodplain).

A consistency determination would be required to maintain compliance with the CMP. This determination would be included in the Section 404 USACE permitting process.

7.2 Coastal Barrier Resources Act

The Coastal Barrier Resources Act (CBRA) was enacted in 1982 to protect coastal barriers along the Atlantic and Gulf coasts from development by making these designated areas ineligible for financial assistance from the federal government. The CBRA was reauthorized in 1990 with the passage of the Coastal Barrier Improvement Act and expanded to include the Florida Keys, Great Lakes, Puerto Rico, and the U.S. Virgin Islands.

The proposed project is located within Galveston County but is not located within a designated CBRA map unit; therefore, CBRA coordination with USFWS would not be required.

8.0 Cultural Resources

This section evaluates the potential occurrence of archeological and historic resources within the project limits. The environmental setting of the project limits is discussed, including soils and geology, along with previously recorded sites and surveys, geoarcheological potential of encountering intact cultural resources, and potential impacts of the proposed project.

8.1 Environmental Setting

Soils and Geology

According to the USDA’s Natural Resources Conservation Service (NRCS) Web Soil Survey for Galveston County (2025), ten soil types occur within the proposed project limits, as illustrated in **Figure 3**. These include Bernard clay loam, 0 to 1 percent slopes (Be); Bernard-Edna complex, 0 to 1 percent slopes (Bn); Francitas clay loam, 0 to 1 percent slopes, rarely flooded (Fr); Leton loam, 0 to 1 percent slopes, occasionally flooded, frequently ponded (LetA); Mocarey-Cieno frequently flooded complex, 0 to 1 percent

slopes (Mc); Narta fine sandy loam, 0 to 1 percent slopes, rarely flooded (Na); Francitas clay, 0 to 1 percent slopes, frequently flooded, occasionally ponded (Pd); Tracosa clay, 0 to 1 percent slopes, low, very frequently flooded (Tc); Veston complex, 0 to 1 percent slopes, frequently flooded (Vx); and Water (W) (see **Table 1**).

Geologically, the project limits are situated over Holocene age Alluvium (Qal), and Beaumont Formation deposits (Qb and Qb-stippled) of Holocene and Pleistocene age (BEG 2002) (**Figure 3**). These deposits are mostly clay, silt, and sand, with backswamp, coastal marsh, mud flat, and narrow beach deposits (BEG 2002).

8.2 Background Records Review

A records search was conducted utilizing the Texas Historical Commission's (THC's) online Texas Archeological Sites Atlas (Atlas) to locate any previously conducted archeological surveys within one kilometer of the project limits (**Appendix A, Figure 6**). The results of this search indicated seven previous investigations conducted between 1990 and 2016; one additional survey is noted in the Atlas, although the date of the survey along with other details are unknown. Information regarding previous investigations in the vicinity of the project limits can be found in **Table 4**.

Table 4. Previous Archeological Investigations within One Kilometer of the Project Limits						
Project Type	Project Name	Antiquities Permit No.	Date of Investigations	Agency/Sponsoring Entity	Investigative Firm	Principal Investigator
Survey	Corps of Engineers-Galveston District (1990)	Unknown	1990	USACE-Galveston District	Unknown	Unknown
Survey	Corps of Engineers-Galveston District (1990)	Unknown	1990	USACE-Galveston District	Unknown	Unknown
Survey	Unknown	Unknown	1998	COE-VD	Unknown	Unknown
Survey	Unknown	Unknown	1998	COE-VD	Unknown	Unknown
Survey	Unknown	Unknown	1998	COE-VD	Unknown	Unknown
Survey	Corps of Engineers-Galveston District (2012)	6246	2012	USACE-Galveston District	HRA Gray & Pape	Tony Scott
Survey	Texas A&M University, United States Army Corps of Engineers (2016)	7470	2016	Texas A&M University, USACE	HRA Gray & Pape	T. Aaron Kotlensky
Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

The majority of the previous investigations occurred north of the project limits. Three surveys by the USACE in 1998 occurred along the Intercoastal Waterway in the vicinity of the proposed intake location.

Geoarcheological Potential

Data from the Potential Archeological Liability Map (PALM), created for the Texas Department of Transportation (TxDOT), indicates moderate to high potential of encountering buried intact archeological deposits throughout a majority of the project limits (**Appendix A, Figure 7**). This model utilizes geologic, soils, landform (including distinct breaks in slope), topography, floodplain, and land use data to predict the likelihood of an area to contain eligible archeological deposits and organizes these data into different categories to rank probability for the occurrence of potentially eligible archeological sites. Each category grades this potential as either low, moderate, or high for depths below the surface of up to one meter (shallow) and below the surface greater than one meter (deep), or as negligible. It should be noted that the PALM is applicable to prehistoric archeological sites, and more recent historic deposits and their eligibility are not reliably predicted by this model (Abbott 2013). Also, the PALM is not intended to be solely relied upon and is intended to be utilized in concert with other data to make informed recommendations regarding the level of effort that may be required in archeological investigations prior to construction of a project.

8.3 Anticipated Impacts and Recommendations

Based on the review of available cultural resources information for the project limits and surrounding areas, as well as the results of previous field investigations, the proposed project has moderate to high potential to impact shallowly and deeply buried cultural materials. Due to the alluvial formations underlying the project limits, and the proximity to coastal wetlands and marshes, there is sufficient evidence that buried, intact archeological deposits could occur within the project limits. Coordination with the THC would be required to determine the extent to which archeological field investigations would be needed for the proposed project prior to construction.

9.0 Hazardous Materials Screen

Based on review of available information from the Railroad Commission of Texas, the proposed project lies within the Greens Lake Well Field, and active and abandoned oil and gas wells are common throughout the project area and along the proposed routes of the intake and discharge lines. In addition, a former TEPPCO Well site (Texas No. 3) is located approximately half a mile to the east of the proposed intake line. The site is part of the Railroad Commission's Operator Cleanup Program (OCP# 2214) due to contaminated materials in the reserve pits. The Railroad Commission indicates the status of the remediation as closed; however, a more in-depth review is warranted to determine the potential for contaminated soils and groundwater to be encountered during construction.

10.0 Summary

This Draft Environmental Evaluation was performed to identify baseline conditions, potential environmental constraints, and associated regulatory requirements for the Gulf Coast Water Authority's proposed desalination plant in Galveston County, Texas. Based on an evaluation of the existing data, the findings are summarized in **Table 5** below.

Table 5. Summary of Expected Environmental Conditions and Constraints	
Resource Feature	Findings
Waters of the US; including Wetlands	– 7.6 acres of wetlands potentially occur within the project limits.
Threatened and Endangered Species	– Proposed critical habitat for the green sea turtle occurs within the tidal waters of the project limits. – Potential habitat for federally threatened, endangered, and candidate species occurs within the vicinity of the project. – Potential habitat for State-listed threatened and endangered species occurs within the vicinity of the project. – Marine mammals are known to occur within the vicinity of the project limits.
Essential Fish Habitat	– Four Fishery Management Unit EFH designations exist within the vicinity of the project limits.
Coastal Zone Management Program/Coastal Barrier Resources Act	– Several CNRAs occur within the vicinity of the project limits and would potentially be impacted by construction. – The project limits do not fall within a designated CBRA map unit.
Cultural Resources	– No historic structures are anticipated to be directly or indirectly impacted by the project. – Moderate to high potential to impact buried prehistoric cultural materials.
Hazardous Materials	– Former TEPPCO Well site (Texas No. 3) is located approximately half a mile to the east of the proposed intake line.

In summary, this project would require:

- A permit under Section 404 of the CWA to address project impacts to waters of the U.S.;
- Section 7 consultation with the USFWS and NMFS to address potential impacts to federally listed species protected under the ESA of 1973; BMPs would need to be incorporated to minimize impacts to listed species;
- Compliance with the provisions of the MMPA;
- An EFH Assessment and coordination with NMFS to address EFH within the project limits;
- A consistency determination for the CNRAs to maintain compliance with the CMP;
- Coordination with the THC to determine the need for archeological field investigations; and
- A hazardous materials management plan if contaminated soil or other hazardous materials are encountered during construction.

11.0 References

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<https://www.fws.gov/program/national-wetlands-inventory> Accessed April 7, 2025.
- U.S. Geological Survey (USGS). 2022. Hitchcock, Texas 7.5-minute topographic quadrangle map.
- _____. 2022. Lake Como, Texas 7.5-minute topographic quadrangle map.
- _____. 2022. Sea Isle, Texas 7.5-minute topographic quadrangle map.
- _____. 2022. Virginia Point, Texas 7.5-minute topographic quadrangle map.

Appendix A

Figures

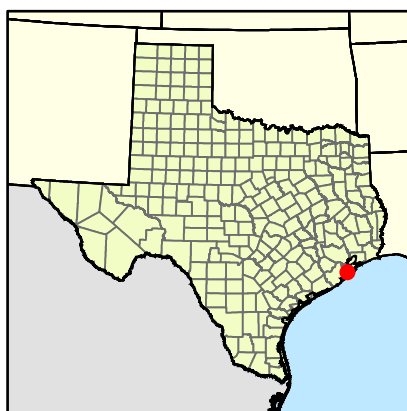
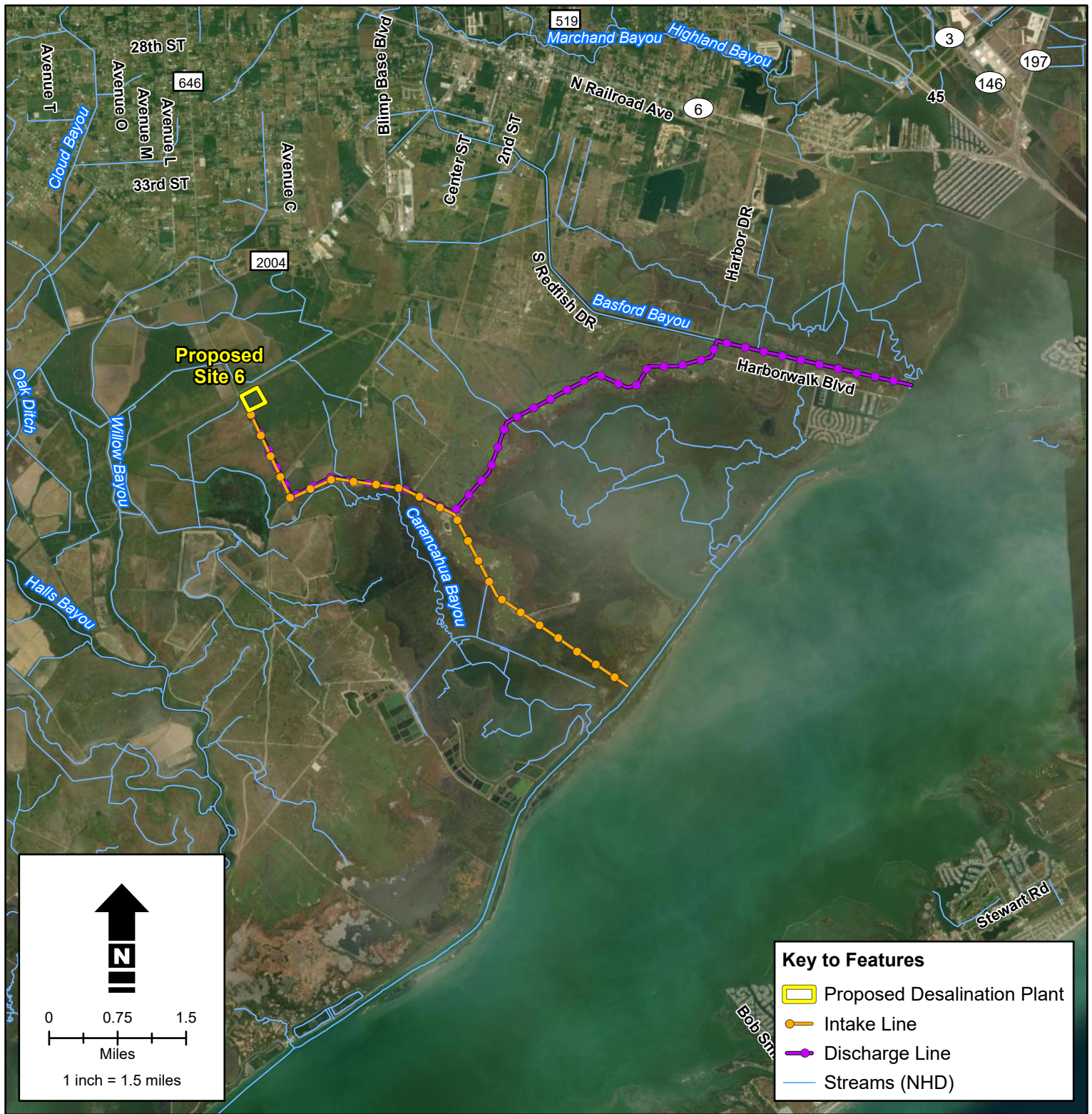


Figure 1

**Project Location
(Aerial)**

Gulf Coast Water Authority Feasibility Study
Galveston County, TX

ESRI World Imagery (2023);
USGS National Hydrography Dataset (2025)



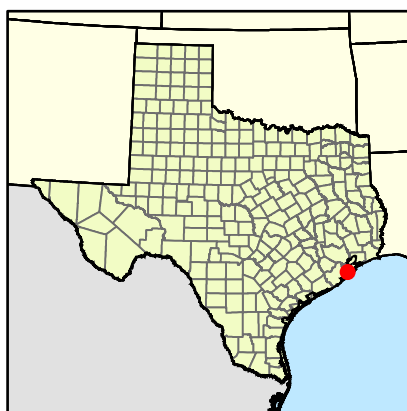
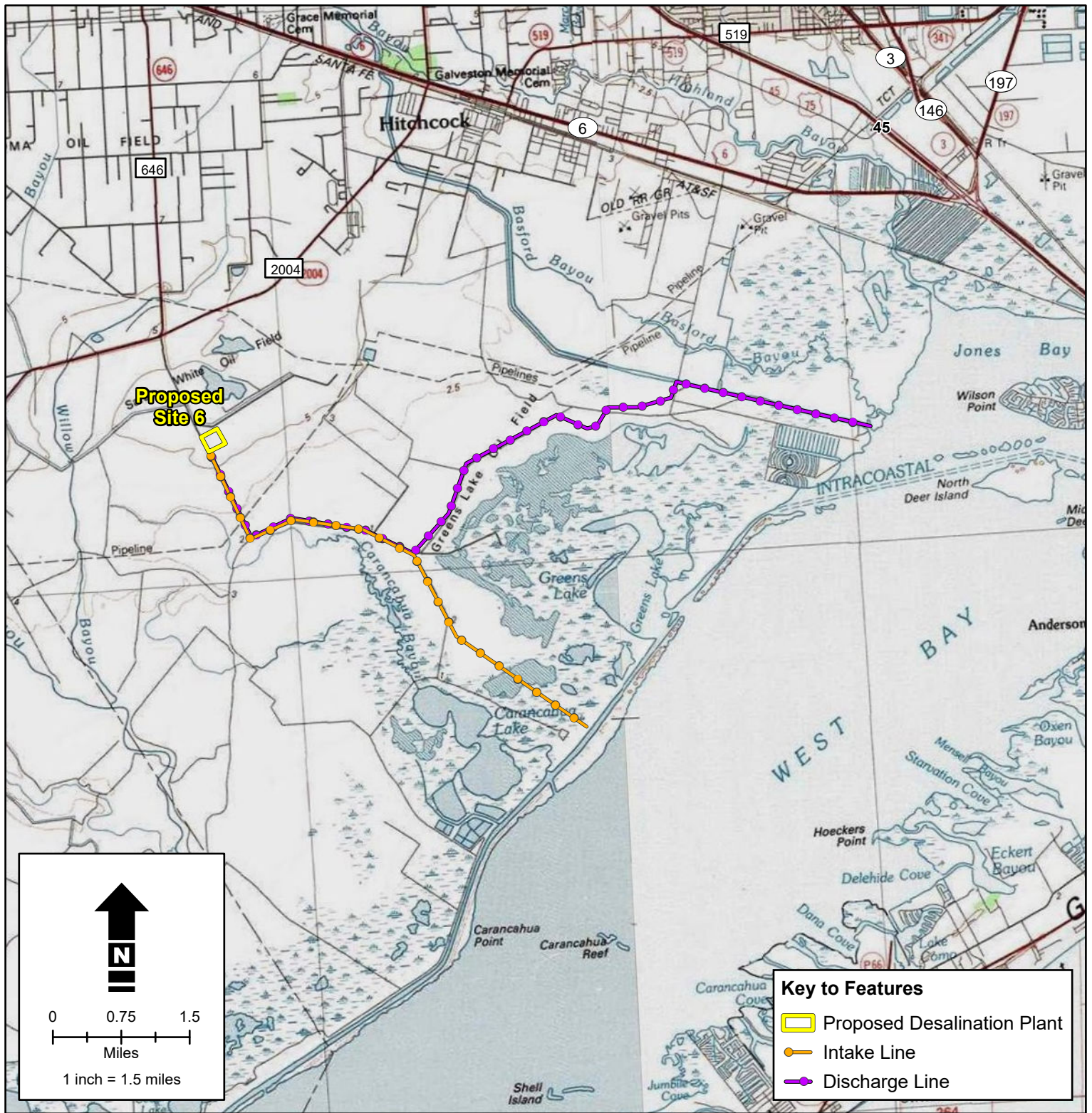


Figure 2

**Project Location
(Topographic)**

Gulf Coast Water Authority Feasibility Study
Galveston County, TX

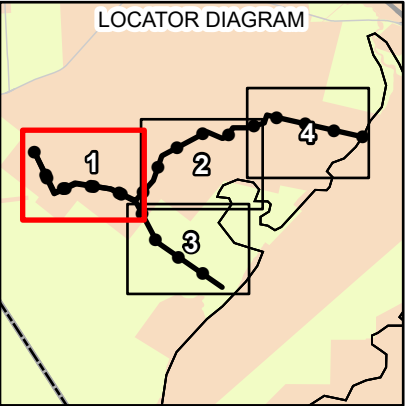
USGS 7.5-minute Topographic Quadrangles:
Hitchcock (20296-C1), Lake Como (29094-B8),
Sea Isle (29095-B1), Virginia Point (29094-C8)



Figure 3-1

Soils and Geology

Gulf Coast Water Authority
Feasibility Study
Galveston County, TX



Key to Features

- Proposed Desalination Plant
- Soil Series Boundaries
- Intake Line
- Discharge Line
- Streams (NHD)

Geologic Formations (1:250,000)

- F S - Fill and Spoil
- Qal - Alluvium
- Qb - Beaumont Formation
- Qb-stipled - Beaumont Formation
- Wa - water

ESRI World Imagery (2023);
Natural Resources Conservation Service (NRCS) (2022);
Texas Water Science Center (USGS TWSC). Geologic Database of Texas, 2014-02-01;
USGS National Hydrography Dataset (2025)



0 500 1,000
Feet

1 inch = 1,000 feet

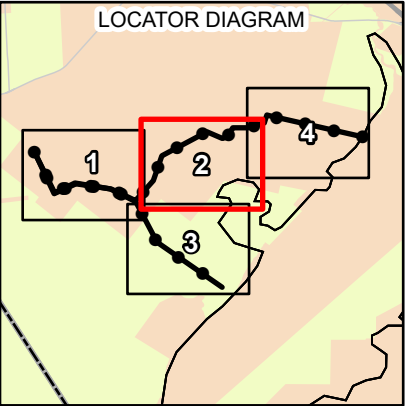
Intersecting Soil Series

- Be- Bernard clay loam, 0 to 1 percent slopes
- Bn- Bernard-Edna complex, 0 to 1 percent slopes
- Fr- Francitas clay loam, 0 to 1 percent slopes, rarely flooded
- Mc- Mocarey-Cieno frequently ponded complex, 0 to 1 percent slopes
- Na- Narta fine sandy loam, 0 to 1 percent slopes, rarely flooded
- Pd- Francitas clay, 0 to 1 percent slopes, frequently flooded, occasionally ponded

Figure 3-2

Soils and Geology

Gulf Coast Water Authority
Feasibility Study
Galveston County, TX



Key to Features

- Soil Series Boundaries
- Discharge Line
- Streams (NHD)

Geologic Formations (1:250,000)

- F S - Fill and Spoil
- Qal - Alluvium
- Qb - Beaumont Formation
- Qb-stipled - Beaumont Formation
- Wa - water

ESRI World Imagery (2023);
Natural Resources Conservation Service (NRCS) (2022);
Texas Water Science Center (USGS TWSC). Geologic Database of Texas, 2014-02-01;
USGS National Hydrography Dataset (2025)



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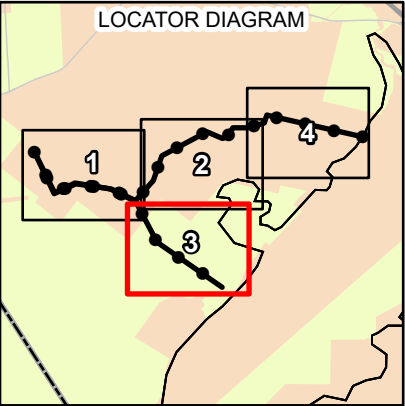
1 inch = 1,000 feet

Intersecting Soil Series
LetA- Leton loam, 0 to 1 percent slopes, occasionally flooded, frequently ponded
Na- Narta fine sandy loam, 0 to 1 percent slopes, rarely flooded
Tc- Tracosa clay, 0 to 1 percent slopes, low, very frequently flooded
W- Water

Figure 3-3

Soils and Geology

Gulf Coast Water Authority
Feasibility Study
Galveston County, TX



Key to Features

Soil Series Boundaries

Intake Line

Streams (NHD)

Geologic Formations (1:250,000)

F S - Fill and Spoil

Qal - Alluvium

Qb - Beaumont Formation

Qb-stipled - Beaumont
Formation

Wa - water

ESRI World Imagery (2023);
Natural Resources Conservation Service
(NRCS) (2022);
Texas Water Science Center
(USGS TWSC). Geologic Database of
Texas, 2014-02-01;
USGS National Hydrography Dataset
(2025)



0 500 1,000
Feet

1 inch = 1,000 feet

Qb-stipled

Pd

Qb

Na

Pd

Tc

Qal

Vx

FS

Wa

Intersecting Soil Series

Na- Narta fine sandy loam, 0 to 1 percent slopes, rarely flooded

Pd- Francitas clay, 0 to 1 percent slopes, frequently flooded, occasionally ponded

Tc- Tracosa clay, 0 to 1 percent slopes, low, very frequently flooded

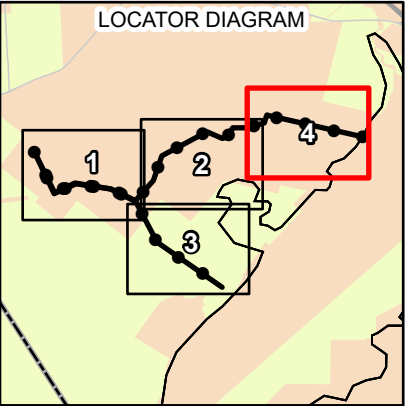
Vx- Veston complex, 0 to 1 percent slopes, frequently flooded

W- Water

Figure 3-4

Soils and Geology

Gulf Coast Water Authority
Feasibility Study
Galveston County, TX



Key to Features

- Soil Series Boundaries
- Discharge Line
- Streams (NHD)

Geologic Formations (1:250,000)

- F S - Fill and Spoil
- Qal - Alluvium
- Qb - Beaumont Formation
- Qb-stipled - Beaumont Formation
- Wa - water

ESRI World Imagery (2023);
Natural Resources Conservation Service (NRCS) (2022);
Texas Water Science Center (USGS TWSC). Geologic Database of Texas, 2014-02-01;
USGS National Hydrography Dataset (2025)



0 500 1,000
Feet

1 inch = 1,000 feet

Intersecting Soil Series

LetA- Leton loam, 0 to 1 percent slopes, occasionally flooded, frequently ponded
Na- Narta fine sandy loam, 0 to 1 percent slopes, rarely flooded
Tc- Tracosa clay, 0 to 1 percent slopes, low, very frequently flooded
W- Water

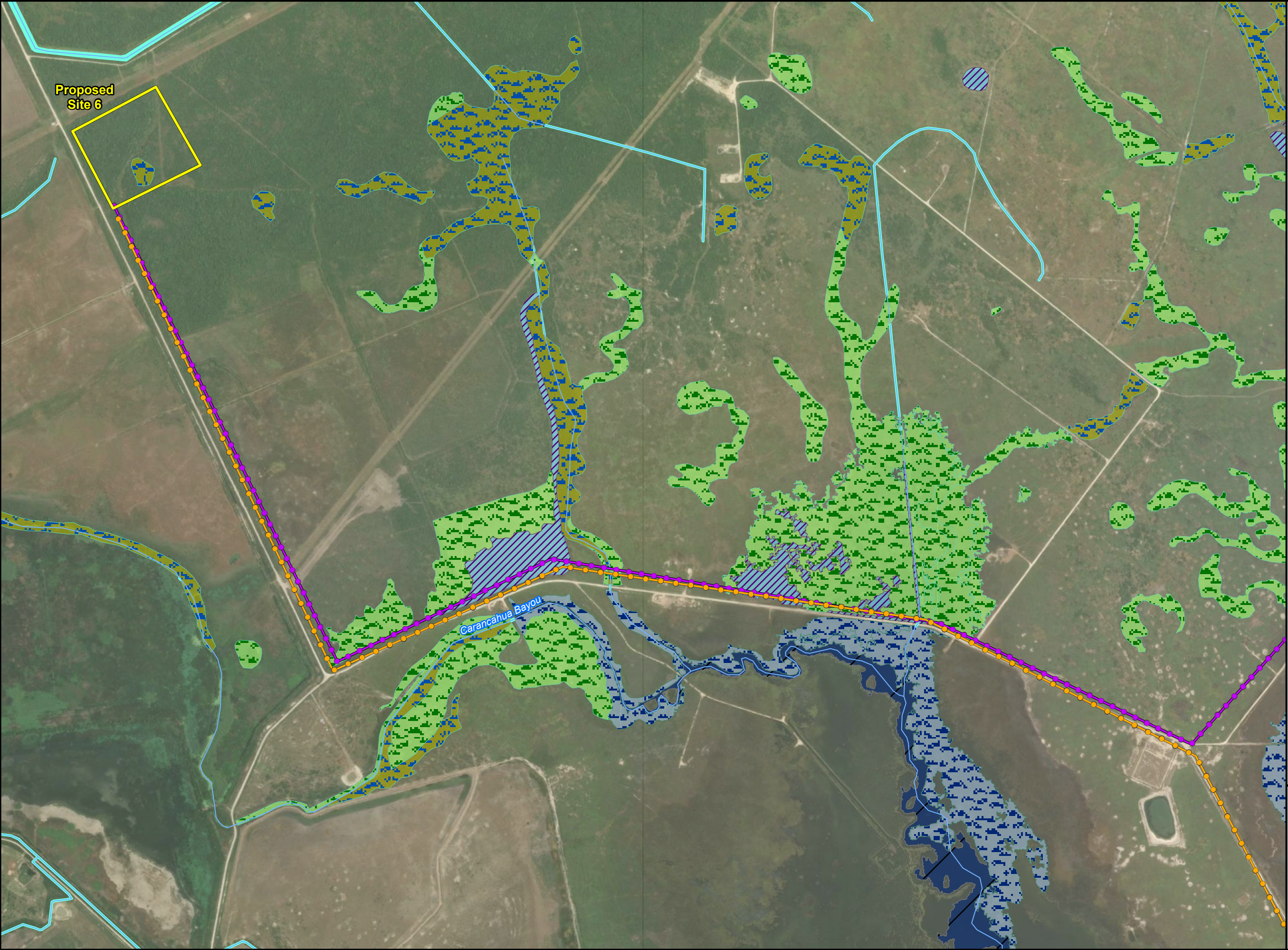
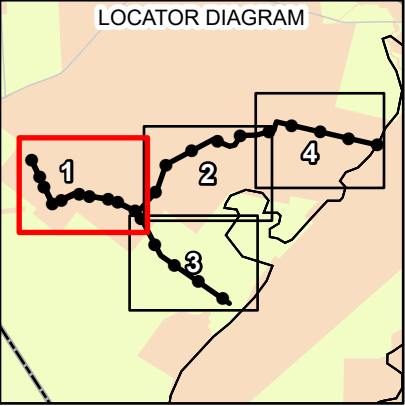


Figure 4-1

National Wetland Inventory

Gulf Coast Water Authority
Feasibility Study
Galveston County, TX



Key to Features

- Proposed Desalination Plant
- Intake Line
- Discharge Line
- Streams (NHD)
- Wetlands (NWI)
 - Estuarine and Marine Deepwater
 - Estuarine and Marine Wetland
 - Freshwater Emergent Wetland
 - Freshwater Forested/Shrub Wetland
 - Freshwater Pond
 - Riverine

ESRI World Imagery (2023);
US Fish and Wildlife Service
(USFWS) (2024);
USGS National Hydrography Dataset
(2025)

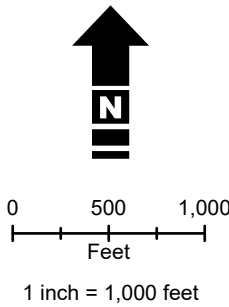
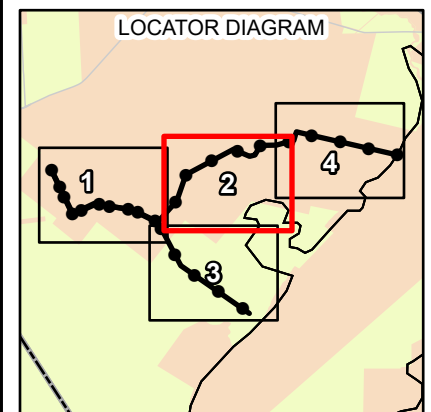


Figure 4-2

National Wetland Inventory

Gulf Coast Water Authority
Feasibility Study
Galveston County, TX



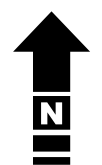
Key to Features

- Discharge Line
- Streams (NHD)

Wetlands (NWI)

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Riverine

ESRI World Imagery (2023);
US Fish and Wildlife Service
(USFWS) (2024);
USGS National Hydrography Dataset
(2025)



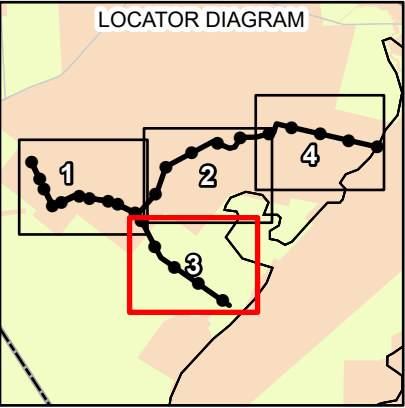
0 500 1,000
Feet

1 inch = 1,000 feet

Figure 4-3

National Wetland Inventory

Gulf Coast Water Authority
Feasibility Study
Galveston County, TX



Key to Features

- Intake Line
- Streams (NHD)

Wetlands (NWI)

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland

ESRI World Imagery (2023);
US Fish and Wildlife Service
(USFWS) (2024);
USGS National Hydrography Dataset
(2025)



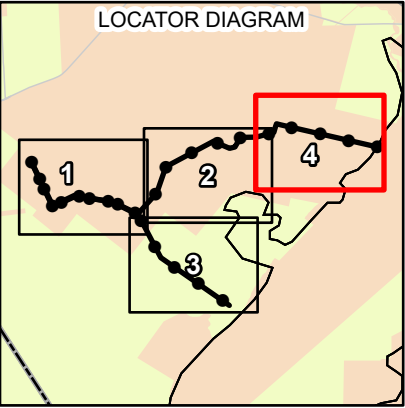
0 500 1,000
Feet

1 inch = 1,000 feet

Figure 4-4

National Wetland Inventory

Gulf Coast Water Authority
Feasibility Study
Galveston County, TX



Key to Features

- Discharge Line
- Streams (NHD)

Wetlands (NWI)

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Pond
- Lake
- Riverine

ESRI World Imagery (2023);
US Fish and Wildlife Service
(USFWS) (2024);
USGS National Hydrography Dataset
(2025)



0 500 1,000
Feet

1 inch = 1,000 feet

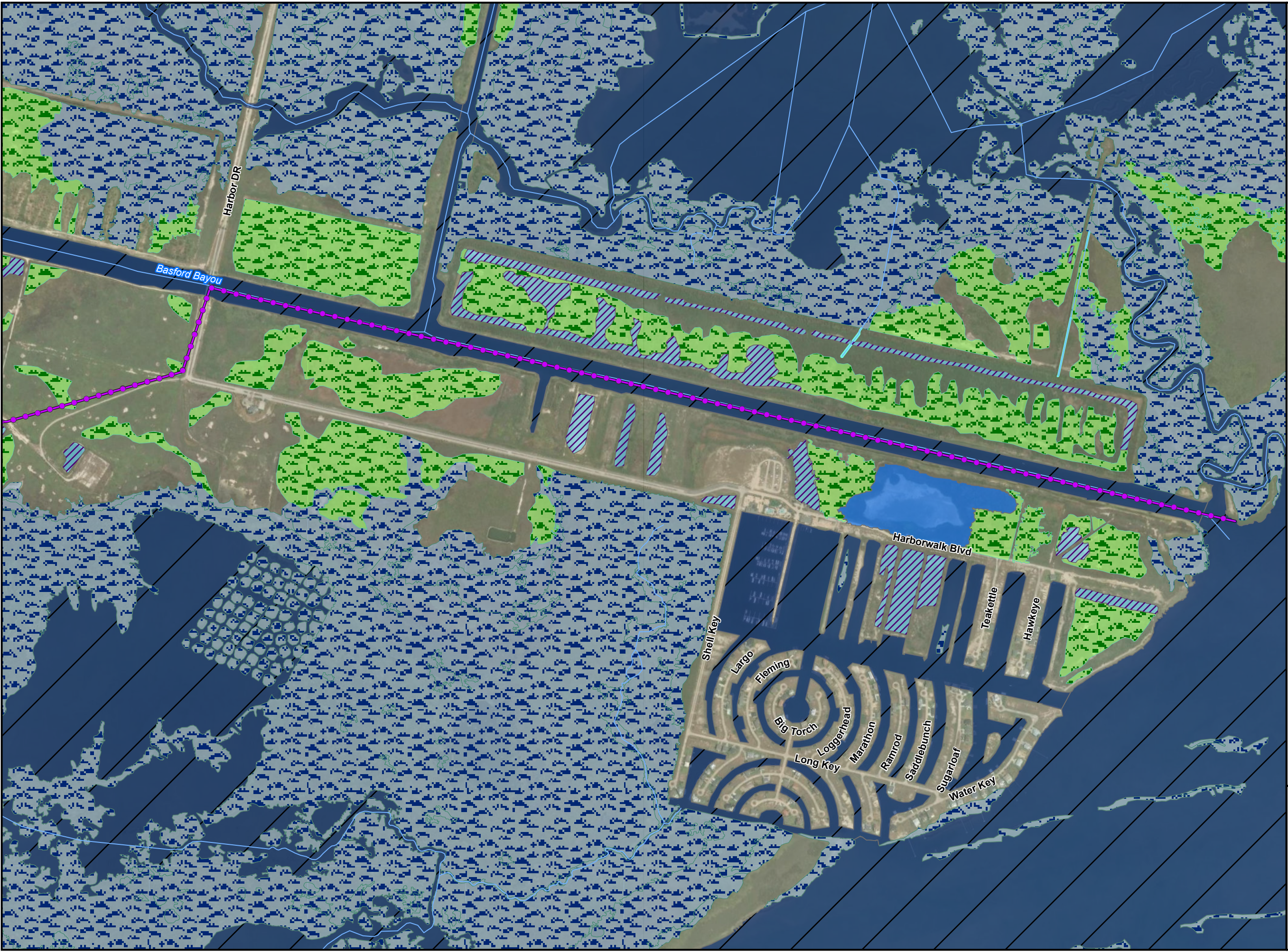




Figure 5

Essential Fish Habitat

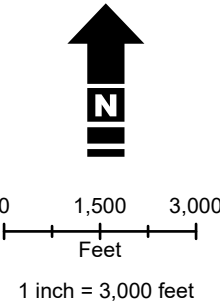
Gulf Coast Water Authority
Feasibility Study
Galveston County, TX



Key to Features

- Proposed Desalination Plant
- Intake Line
- Discharge Line
- Essential Fish Habitat
- Streams (NHD)

ESRI World Imagery (2023);
US Fish and Wildlife Service
(USFWS) (2024);
USGS National Hydrography Dataset
(2025)



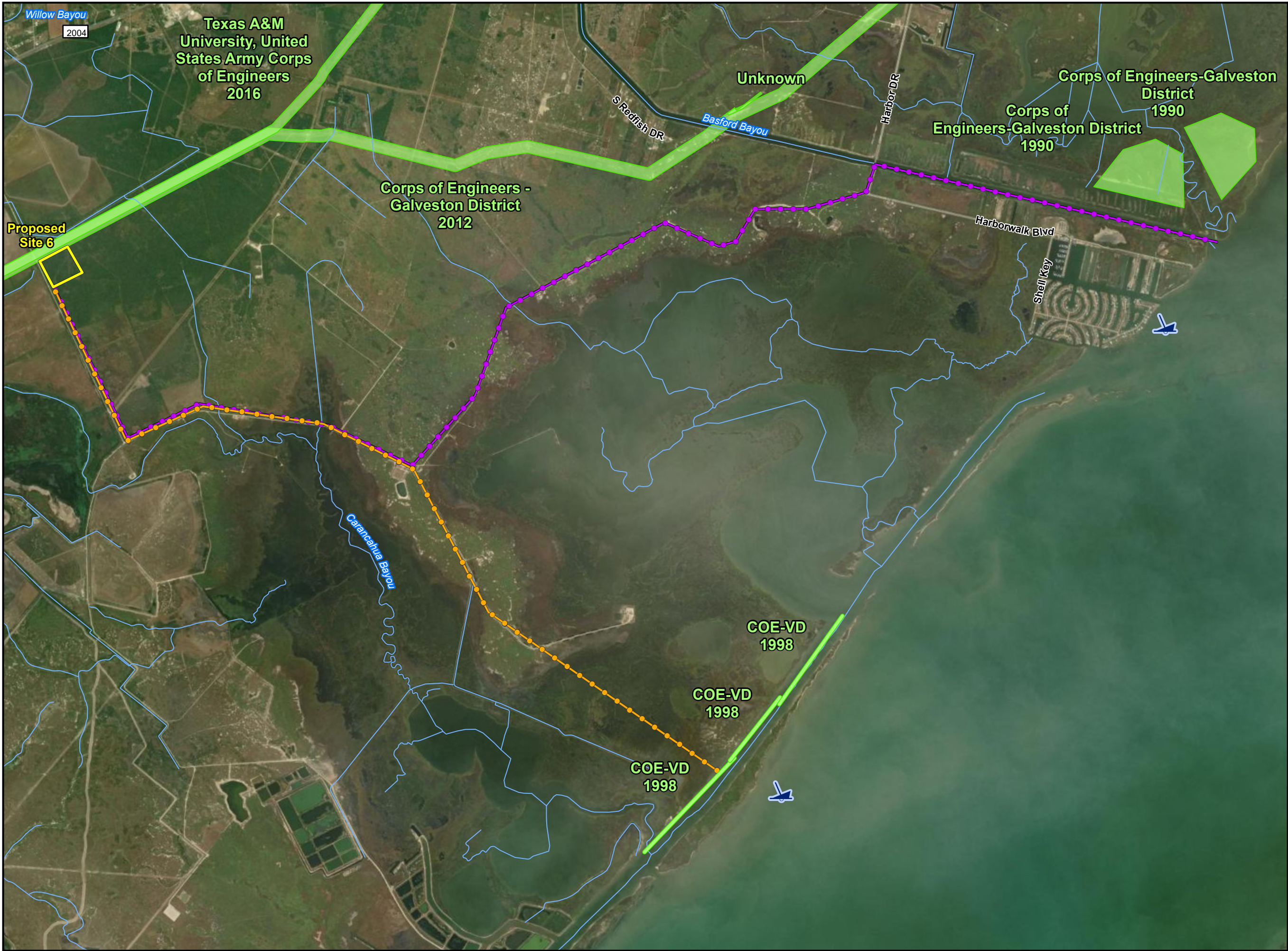
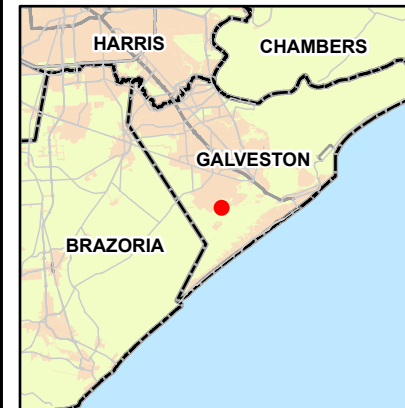


Figure 6
Previous Archeological Surveys & Cemeteries within One Kilometer of the Project Limits

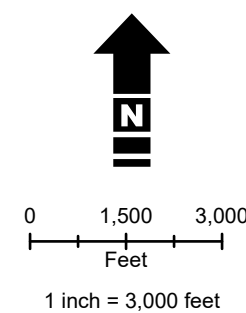
Gulf Coast Water Authority
Feasibility Study
Galveston County, TX



Key to Features

- Proposed Desalination Plant
- Intake Line
- Discharge Line
- Archeological Surveys (Areal)
- Archeological Surveys (Linear)
- Shipwrecks
- Streams (NHD)

ESRI World Imagery (2023);
Texas Archeological Research Lab (2024);
USGS National Hydrography Dataset (2025)



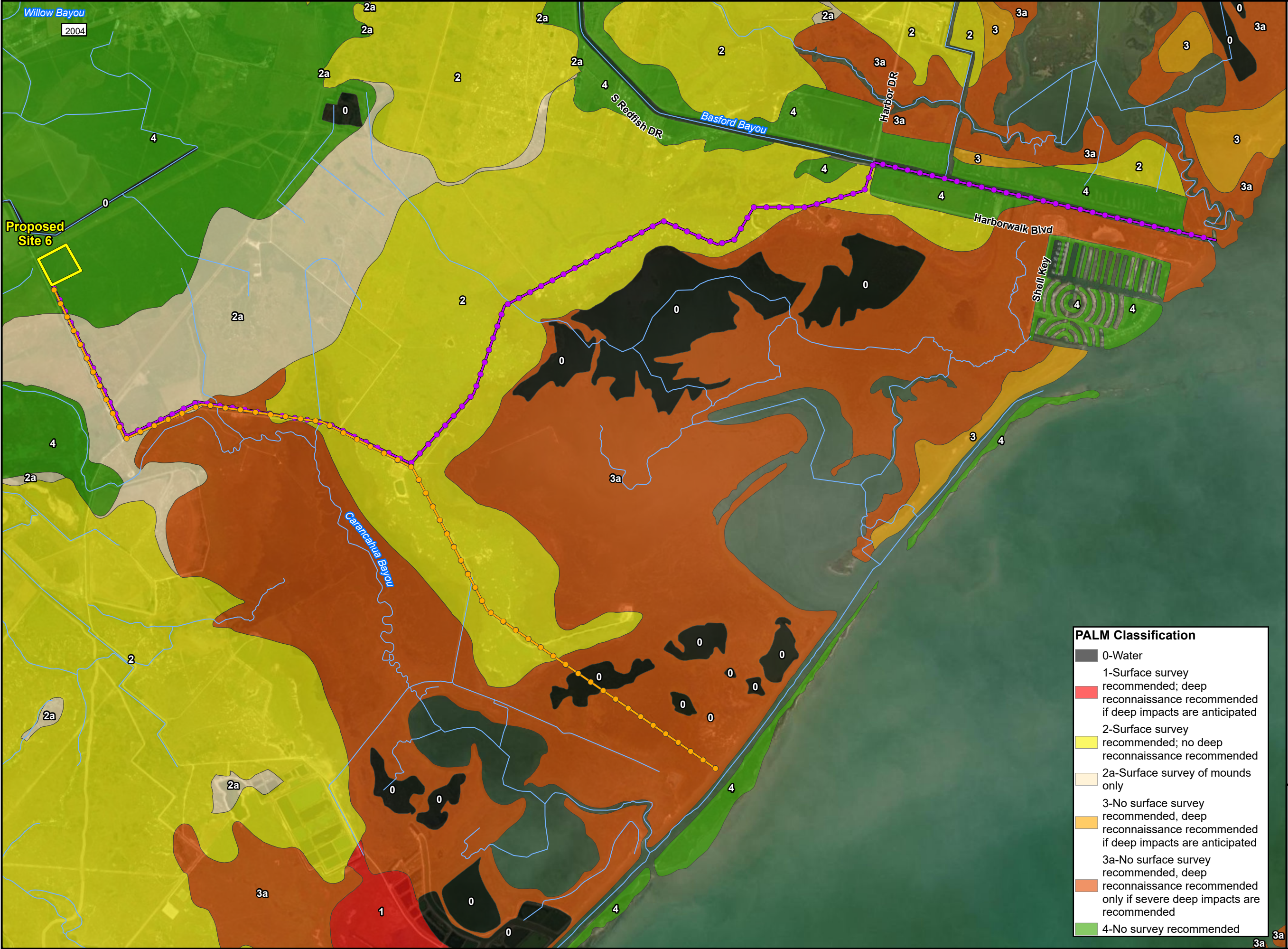


Figure 7
Potential Archeological Liability Map

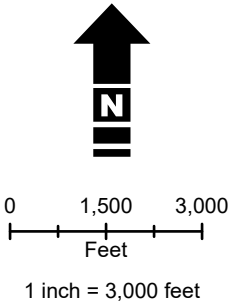
Gulf Coast Water Authority
Feasibility Study
Galveston County, TX



- Key to Features**
- Proposed Desalination Plant
 - Intake Line
 - Discharge Line
 - Streams (NHD)

- PALM Classification**
- 0-Water
 - 1-Surface survey recommended; deep reconnaissance recommended if deep impacts are anticipated
 - 2-Surface survey recommended; no deep reconnaissance recommended
 - 2a-Surface survey of mounds only
 - 3-No surface survey recommended, deep reconnaissance recommended if deep impacts are anticipated
 - 3a-No surface survey recommended, deep reconnaissance recommended only if severe deep impacts are recommended
 - 4-No survey recommended

ESRI World Imagery (2023);
TPWD, Houston TXDOT District (2023);
USGS National Hydrography Dataset (2025)



Appendix G. Public Outreach Documentation



Texas Desal Legislative Workshop 2025

Tuesday, March 4, 2025

GCWA Desalination

Brandon Wade



GCWA
Desalination:
~~It's Complicated~~
Is It Possible?

~~Don't~~ Need It!

^
Might

~~Can't~~ Afford It!

^
Can We

Best Location!





History of GCWA

- Multiple Names
 - Cane and Rice Belt Irrigation Co. (1905)
 - Brazos Valley Irrigation Co. (1926)
 - American Canal Co. (1940)
 - American Canal Co. of Texas (1959)
- Briscoe Canal System
 - Briscoe Irrigation System (1940s)
- Industrial Water Co. (1948)
- Galveston County Water Company (1965)
- Chocolate Bayou Water Co. (2006)

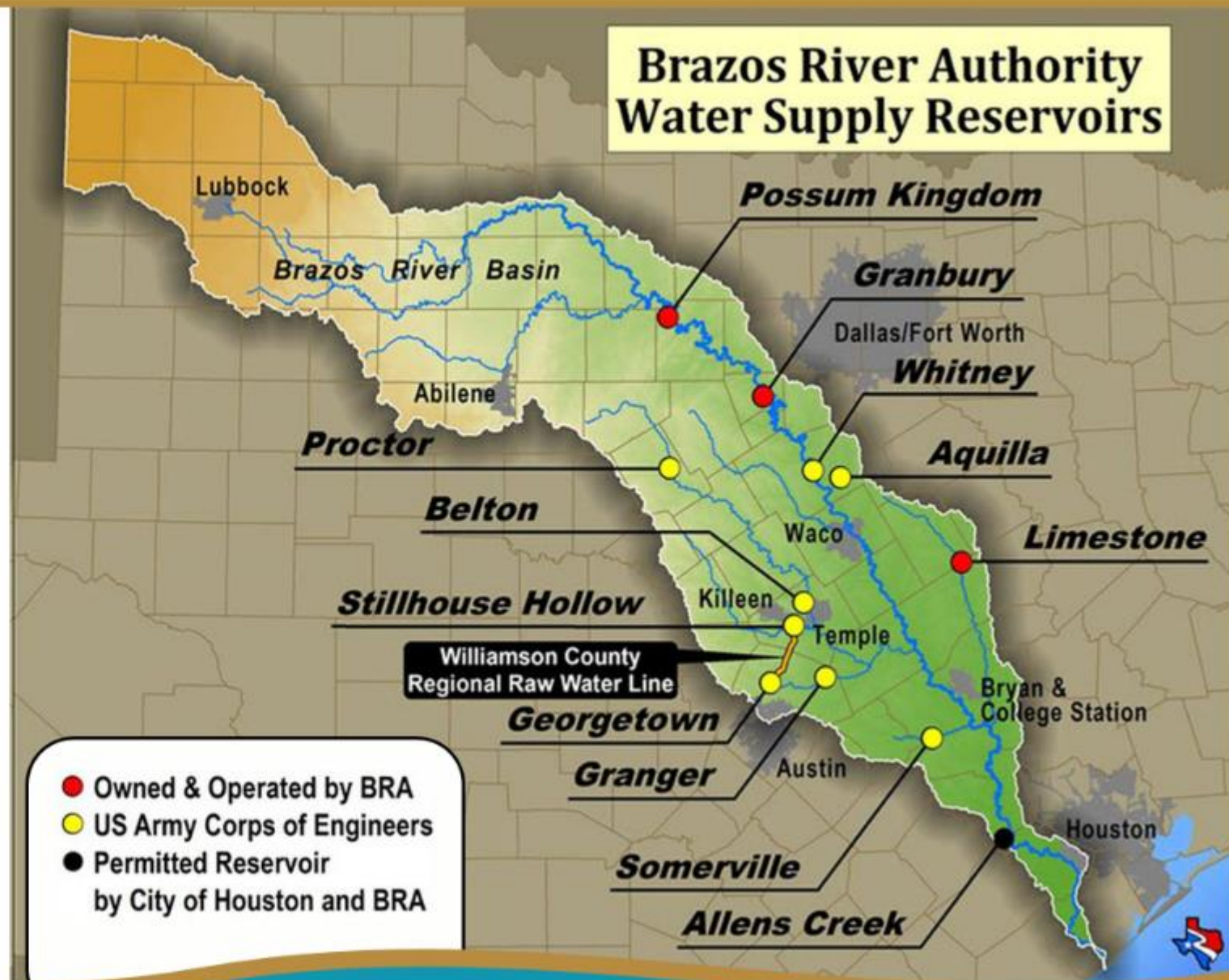
Water For...

- Industry
 - Marathon
 - Ineos
 - Valero
 - Others
- 16,000 acres of rice fields
- 600,000 people
- Raw Water - Sugar Land & Pearland
- 58 MGD Water Treatment Plant - Galveston County
- S.E. Plant – Co-participant

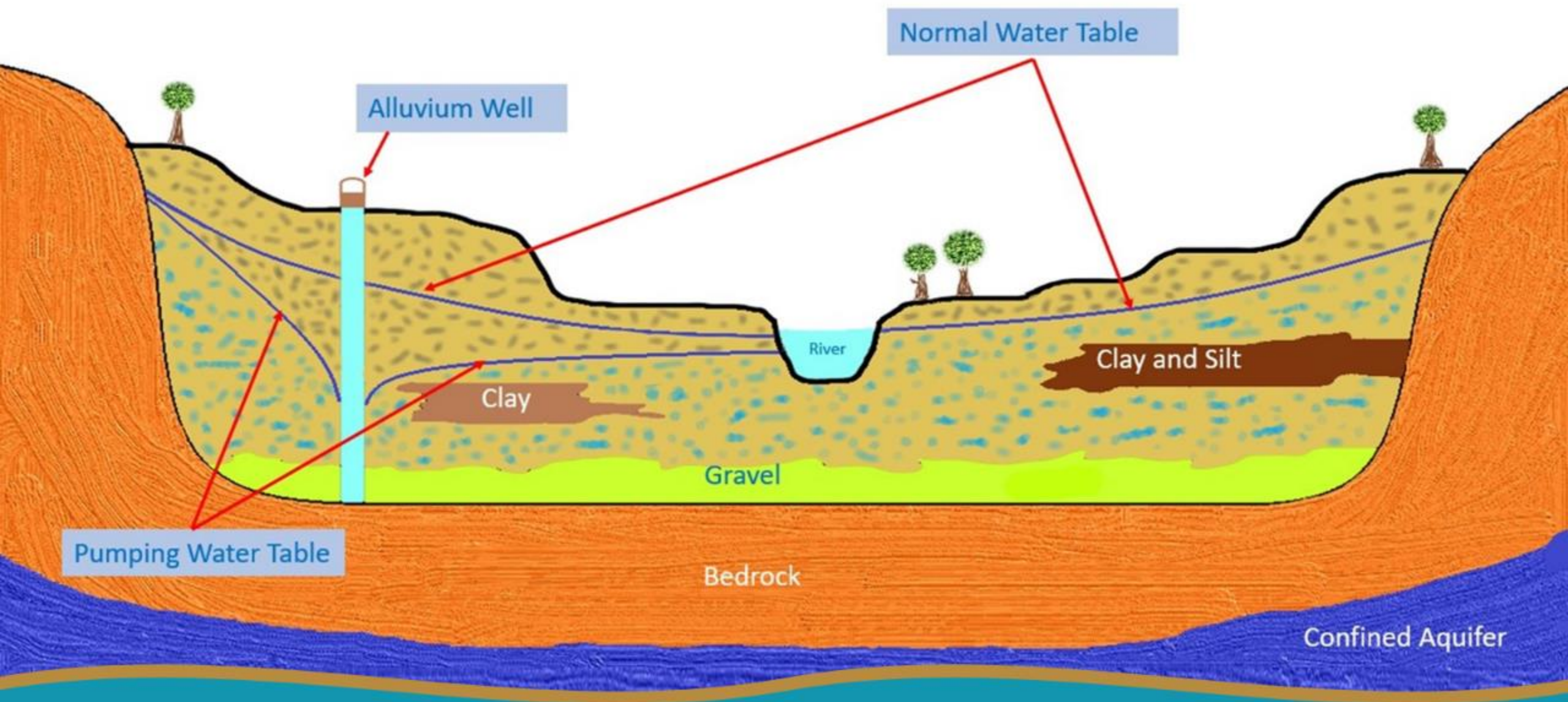


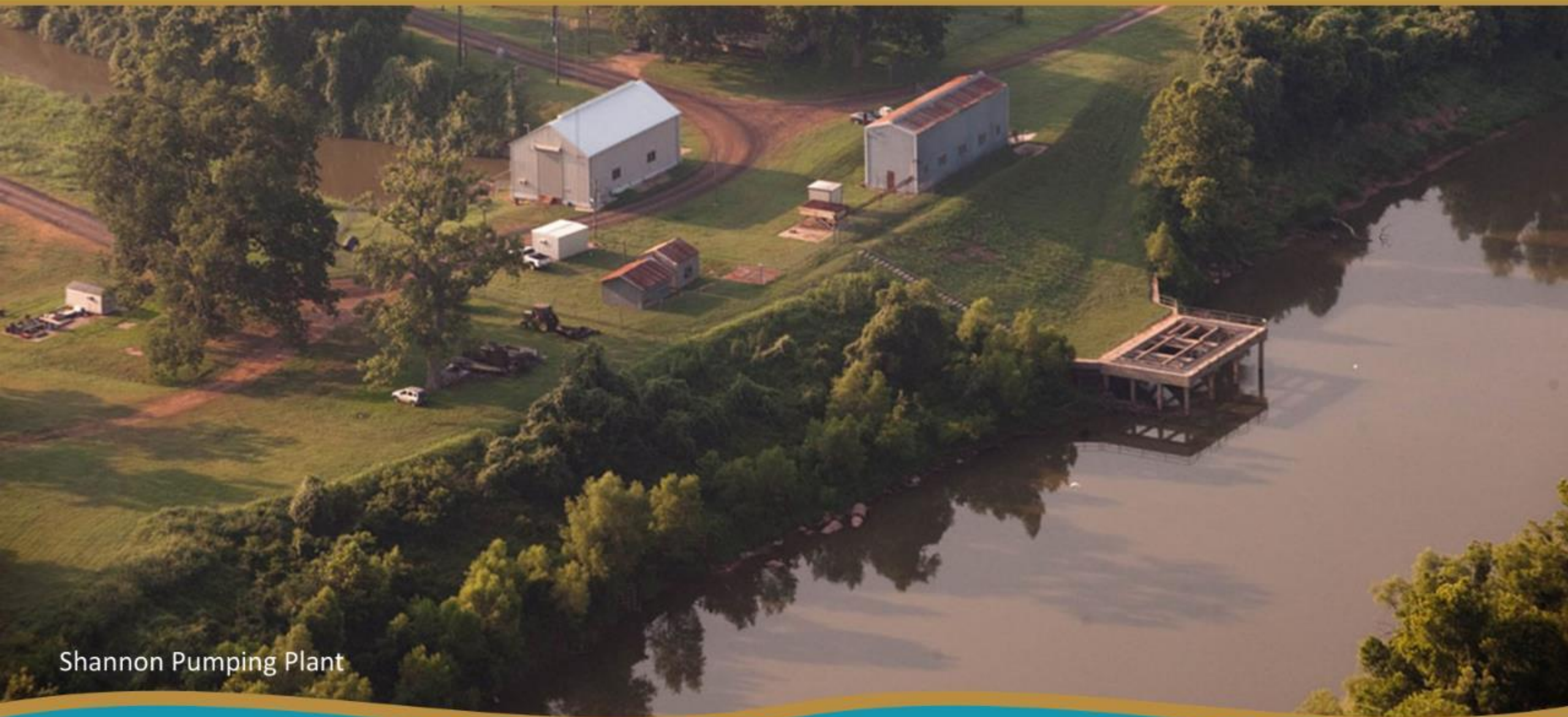
Water Source

- 380,000 acre-feet Run of the River
- 80,000 acre-feet BRA Reservoirs (Reserve)
- Houston S.E. Plant (Trinity River)









Shannon Pumping Plant



Shannon Pumping Plant

William J May Pumping Plant – Brazos River

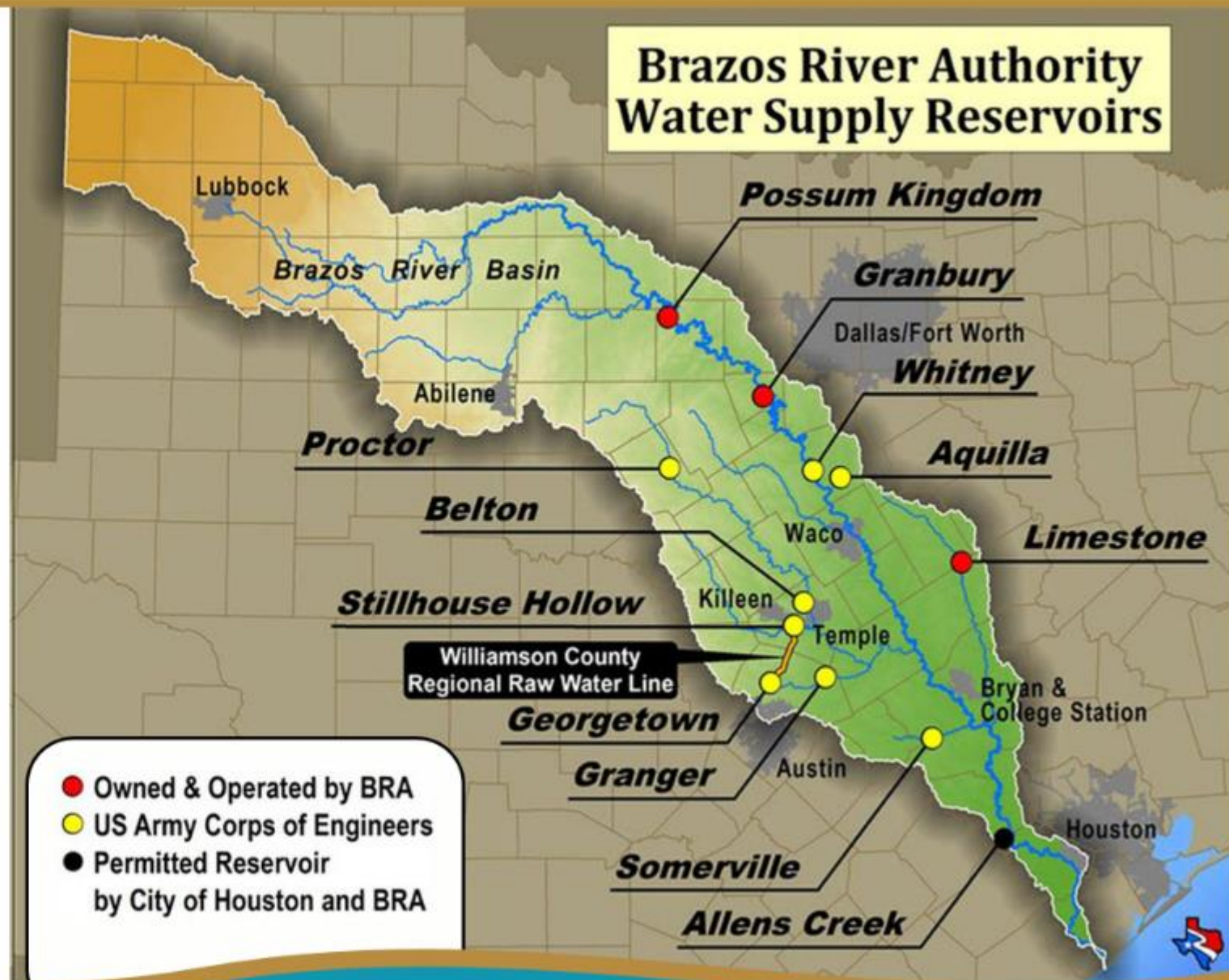


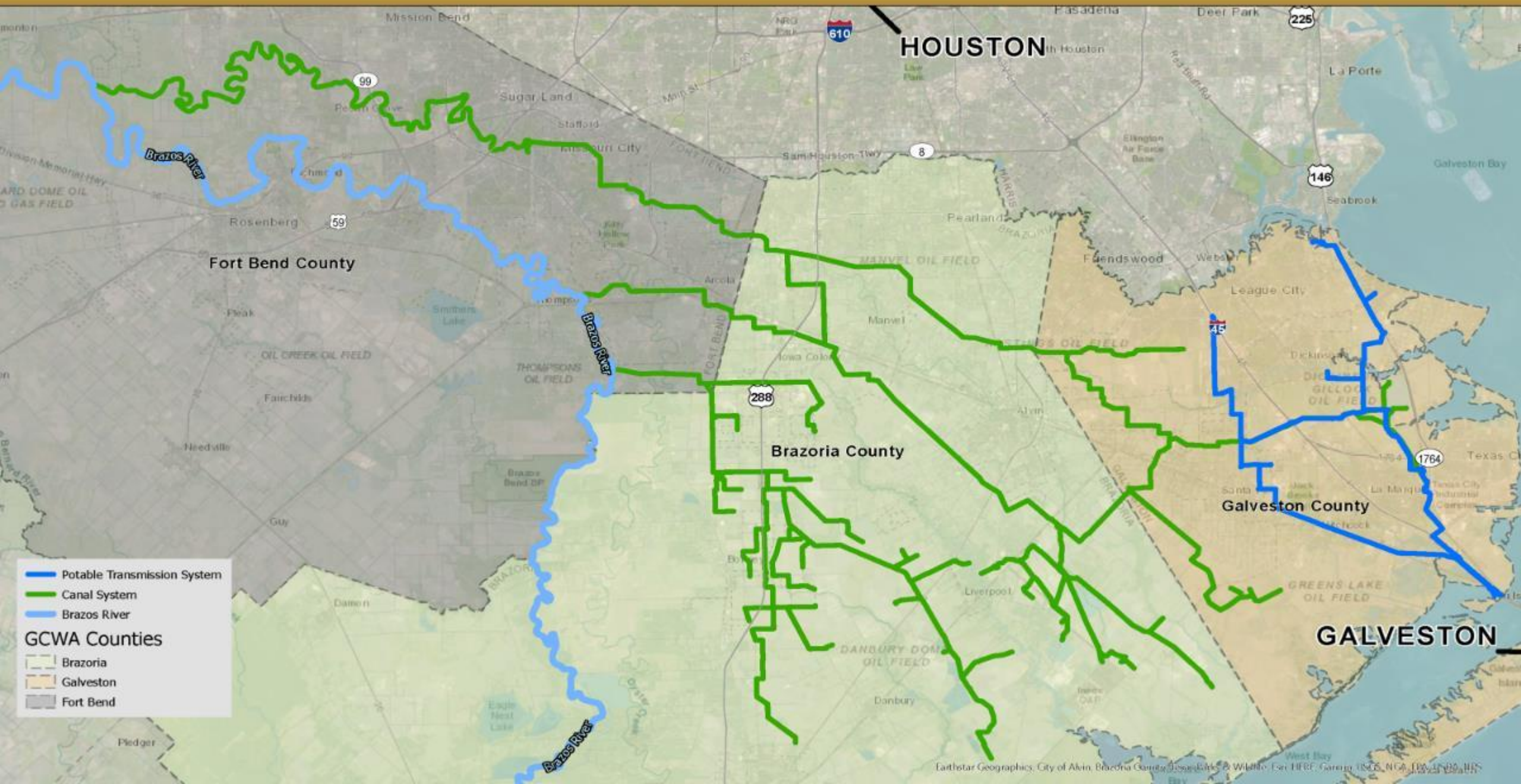
William J May Pumping Plant – Brazos River

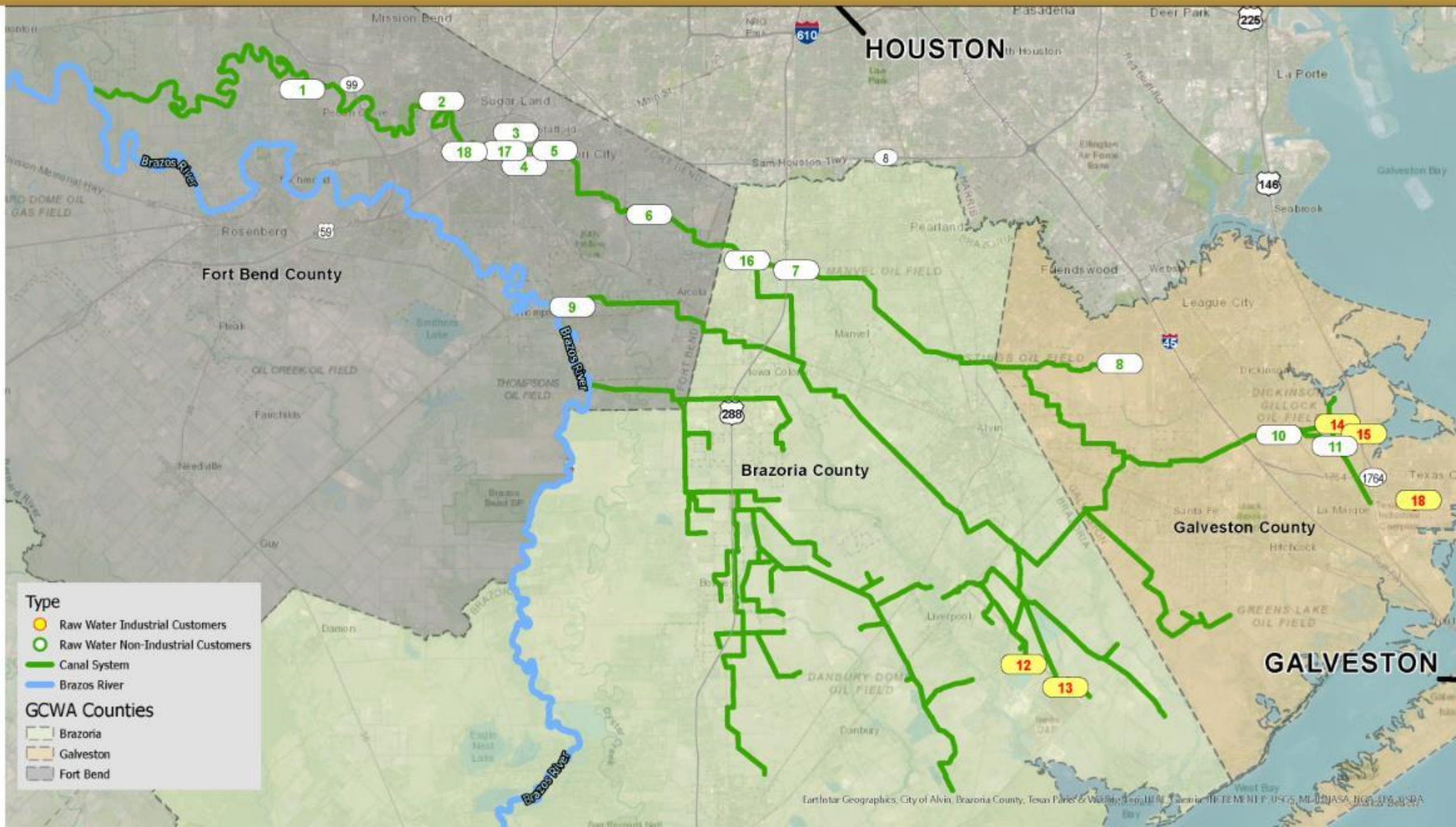


Water Source

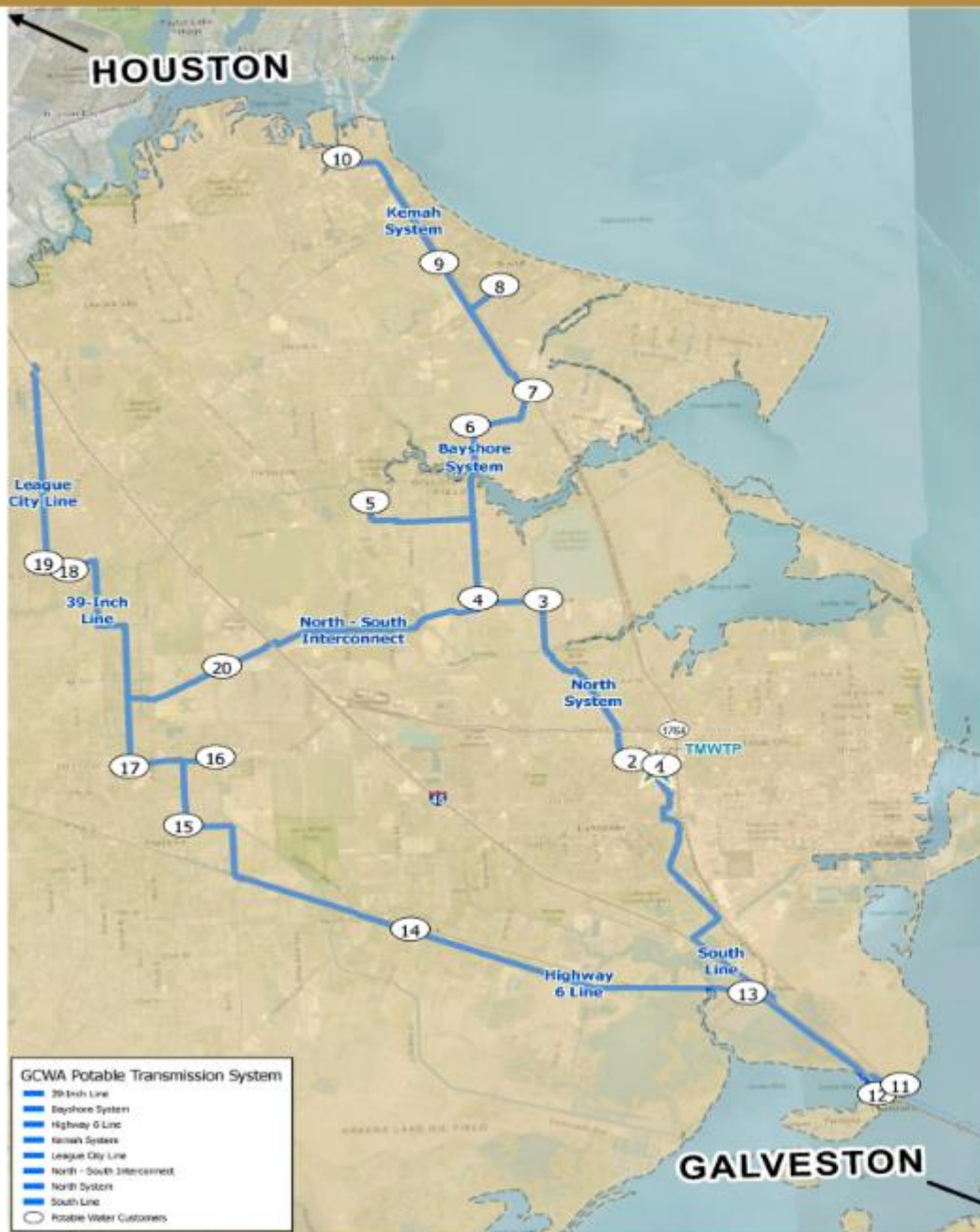
- 380,000 acre-feet Run of the River
- 80,000 acre-feet BRA Reservoirs (Reserve)
- Houston S.E. Plant (Trinity River)







Potable Water Customers



- 1 City of Texas City (East/West)
- 2 City of La Marque
- 3 City of Texas City
- 4 City of Texas City
- 5 GC WCID No. 1 - Dickinson
- 6 GC WCID No. 1 - Dickinson ISD
- 7 San Leon MUD
- 8 Bacliff MUD
- 9 Bayview MUD
- 10 GC WCID No. 12 - Kemah
- 11 City of Galveston
- 12 GC FWSD No. 6 - Tiki Island
- 13 GC MUD No. 12 - Bayou Vista
- 14 City of Hitchcock
- 15 GC WCID No. 8 - Santa Fe
- 16 City of La Marque
- 17 GC WCID No. 8 - Santa Fe
- 18 GC WCID No. 1 - Dickinson
- 19 City of League City
- 20 GC MUD No. 56 - Lago Mar



Sugar Land
Water Treatment Plant



Pearland
Water Treatment Plant



Galveston County Water Treatment Plant

Threats

- Lowest Wholesale Water Rate
- Contract Based
- “Pragmatic” CCN



GCWA Desalination Past Work

- In 2022 completed a Business Case report for Desalination
- 40 MGD plant in two 20 MGD stages (seawater-based design)
- Bureau of Reclamation WaterSMART program opened to applications
- Partners: Harris Galveston Subsidence District, Brazos River Authority

GCWA Feasibility Study

BOR Study Requirements

- Statement of Problem and Needs
- Project Planning and Analysis
- Evaluation of Project Alternatives
- Stretching Water Supplies
- Environment and Water Quality
- Economic Analysis
- Selection of Proposed Seawater Desalination Project
- Legal and Institutional Requirements
- Financial Capability of Sponsor



Carlsbad Desalination Plant (50MGD)

GCWA's Progress

- Bathymetry
- Environmental Constraints

Key to Features

□ Proposed Desalination Sites

— Proposed Discharge Line

— Proposed Intake Line

● NDO Occurrences

— Rude Red Knot Proposed Critical Habitat

— Historical Seagrass (1956-1996)

— TPWD Seagrass

— TPWD Christmas Bay West Bay Seagrass (2015)

— Oysters

— Texas Coastwide Oyster Restorations 2000-2022

— Private Oyster Leases (2020)

— Conservation Easements (NCE)

— Industrial Hazardous Waste Corrective Action (TCEQ IHWCA)

□ TCEQ Cleanup Sites

▲ Brownfield Sites (EPA)

◆ VCP Sites

★ National Register of Historic Properties (Listed)

★ Recorded Texas Historic Landmark (RTHL)

★ State Archeological Landmark (SAL)

★ Official Texas Historical Marker (OTHM)

— Shipwrecks

— Railroads

Bathymetric Depth (Feet)

— -6.27 - 0

— -12.55 - -6.27

— -18.82 - -12.55

— -25.09 - -18.82

— -31.36 - -25.09

— -37.64 - -31.36

— -43.91 - -37.64

— -50.18 - -43.91

— -56.45 - -50.18



- Site Challenges
- Environmental
- Intake
- Discharge

Plant Site
4 Discharge
Plant Site
2 Discharge

Site	Site 1 (Bacliff)	Site 2A (TMWTP) - tunnels	Site 2B (TMWTP) – above ground pipe (if feasible)	Site 3 (Pelican Island)	Site 3B (Galveston Island)	Site 4 (Dickinson)	Site 6 (Southwest)
Water Intake Assumption	Modifications to former PP intake, screen/pump wetwell	Shoreline intake, tunnel from Texas City Dike (4.3 mile), screen/pump wetwell	Shoreline intake, canal (4.7 mile), screen/pump wetwell	Shoreline intake, canal (0.5 mile), screen/pump wetwell	Shoreline intake, canal (0.5 mile), screen/pump wetwell	Shoreline intake, canal (0.4 mile), screen/pump wetwell	Shoreline intake, canal (5 mile), screen/pump wetwell
Intake Cost (\$M)	\$18.8 M	\$255.8 M	\$37.6 M	\$29.5 M	\$29.5 M	\$29.4 M	\$38.1 M
Water Outfall Assumptions	600 ft overland pipeline, 0.4-mile offshore pipeline and diffuser	4.3-mile tunnel to Texas City Dike, 0.5-mile offshore pipeline and diffuser	6.5-mile overland pipeline, 0.5-mile offshore pipeline and diffuser	1.1-mile overland pipeline, 0.5-mile offshore pipeline and diffuser	1.1-mile overland pipeline, 0.5-mile offshore pipeline and diffuser	7-mile overland pipeline, 0.5-mile offshore pipeline and diffuser	11-mile overland pipeline, 0.5-mile offshore pipeline and diffuser
Outfall Cost (\$M)	\$15.0 M	\$244.2 M	\$81.2 M	\$24.1 M	\$24.1 M	\$74.2 M	\$86.0 M
Water Delivery Assumption	Hwy 146 southwest of former PP (0.5 miles)	1800 ft to current distribution system	1800 ft to current distribution system	Tanks near Railway (4.1 miles)	Tanks near Railway (4.1 miles)	Near Industrial Water Reservoir (3.3 miles)	Hwy 6 northeast of the desal plant (6.2 miles)
Delivery Cost (\$M)	\$2.7 M	\$1.9 M	\$1.9 M	\$92.4 M	\$37.4 M	\$27.4 M	\$34.1 M
Notes	Existing intake and outfall from former Power Plant	Over 8 miles of tunneling beneath Texas City required by this option	Tunneling beneath major highways and railroads	Tunneling beneath the Galveston channel as well as multiple train tracks servicing Galveston Yard	Short intake and outfall, delivery point would require routing through Galveston	Overland outfall pipeline drives cost, could reduce by reducing length of pipeline	Delivery point is assumed
Total Intake/ Outfall / Delivery Point costs (\$M)	\$36.5 M	\$501.9 M	\$120.7 M	\$146.0 M	\$91.0 M	\$131.0 M	\$158.2 M
Permitting Complexity	Not Applicable	Piping – Low Complexity Discharge – Fair mixing	Piping – High Complexity Discharge – Fair mixing	Piping – Low Complexity Discharge – Good mixing	Piping – Medium Complexity Discharge – Good mixing	Piping – High Complexity Discharge – Fair mixing	Piping – Low Complexity Discharge – Fair mixing

Planning Cost Comparison

GCWA's Progress

- Modeling of the water supplies
- Site selection and criteria

	Criteria	Description	Scoring Range	Weight	Site 1 Bacliff	Site 2 Mackey	Site 3 Island	Site 4 Dickinson	Site 5 Moses
Site Favorability	Proximity to Service Area	Distance to primary service area; closer proximity minimizes distribution costs.	1-5	30%	5	3	2	5	3
	Proximity to Intake	Distance to seawater intake site; closer proximity reduces conveyance infrastructure costs.	1-5						
	Proximity to Discharge	Distance to a viable discharge point; closer proximity simplifies discharge infrastructure.	1-5						
	Proximity to Utilities	Access to power, roads, and other essential infrastructure.	1-5						
	Co-location Opportunities	Possibility of co-locating with power plants, wastewater treatment plants, or other facilities.	1-5						
	Site Accessibility	Ease of access for construction, operations, and maintenance, including road or port access.	1-5						
	Land Cost & Acquisition	Cost and ease of acquiring land; regulatory or permitting challenges related to the land.	1-5						
Environmental	Environmental Concerns	Impact on sensitive ecosystems, protected areas, or endangered species in the vicinity.	1-5	30%	5	3	5	3	1
	Discharge Impact	Potential environmental impact of brine discharge on local marine ecosystems.	1-5						
	Regulatory Compliance	Feasibility of obtaining permits and meeting regulatory requirements for desalination operations.	1-5						
Social	Community Acceptance	Potential for public support or opposition in the local community and nearby residential areas.	1-5	20%	5	5	1	5	1
	Environmental Justice	Considers potential impacts on vulnerable or disadvantaged communities, ensuring fair distribution of risks and benefits.	1-5						
Risk of Hazards	Risk of Natural Hazards	Vulnerability to natural hazards such as flooding, and hurricanes.	1-5	15%	3	5	2	3	5
Water Quality & Availability	Water Supply	Suitability of raw seawater quality for treatment, including salinity and contaminant levels.	1-5	5%	3	3	5	3	1
				100%	4.6	3.7	2.85	4	2.2

Next Steps

- Two more workshops to evaluate the selected sites in more detail.
- Develop site configurations and cost estimates.
- Develop the draft Feasibility Study in accordance with the USBR program.



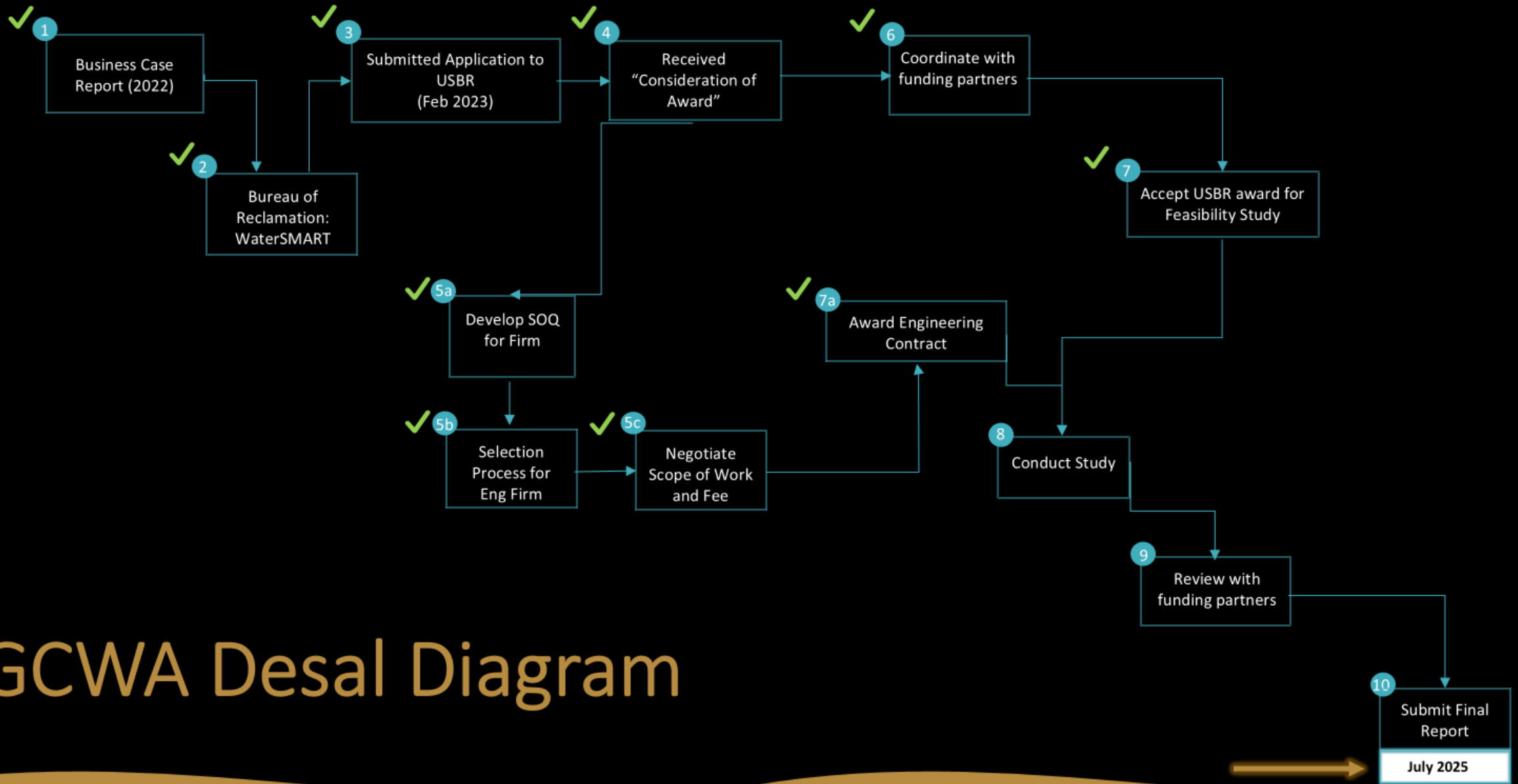
— BUREAU OF —
RECLAMATION



Brazos
— ★ —
RIVER AUTHORITY



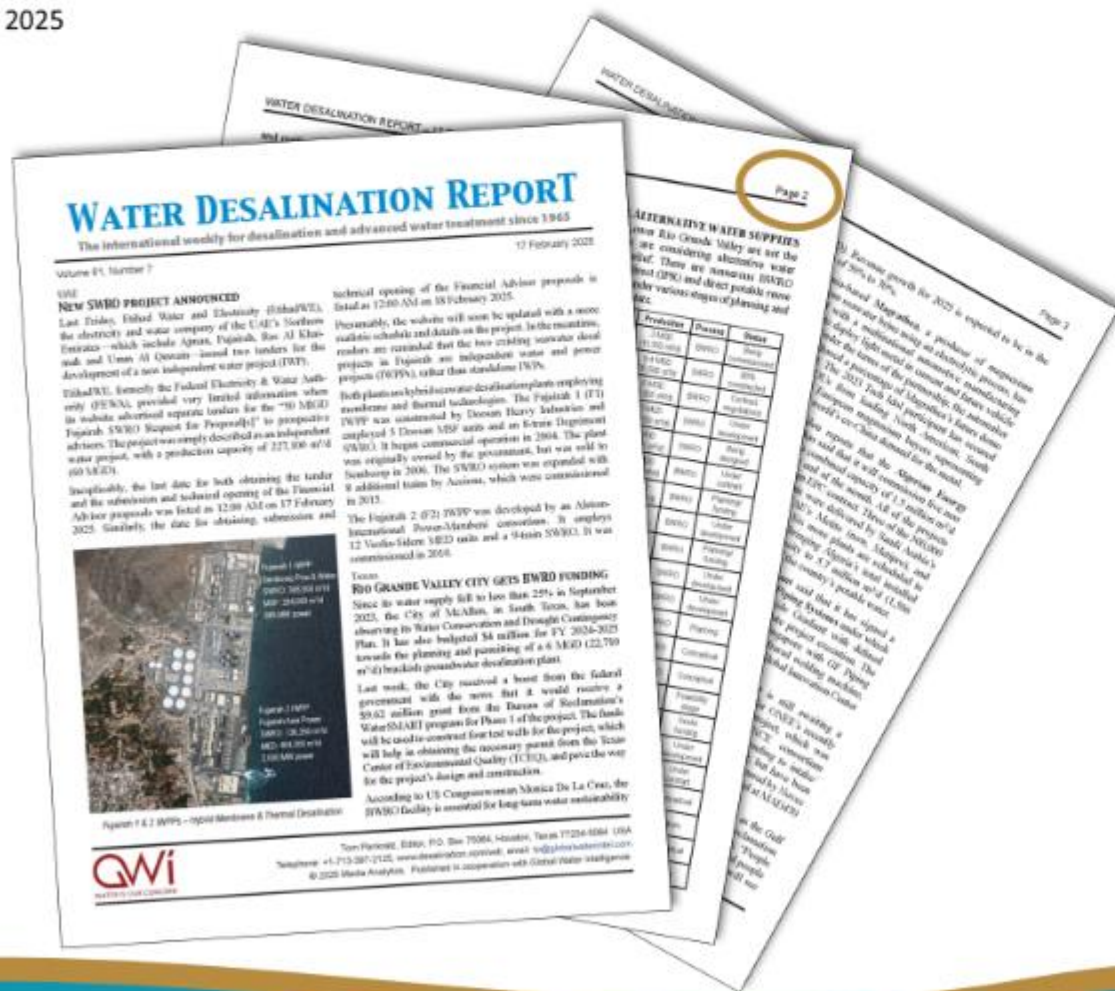
HARRIS-GALVESTON
SUBSIDENCE
DISTRICT
— 1975 - 2025 —



GCWA Desal Diagram

Water Desalination Report

February 17, 2025



and resilience, adding, "Drought conditions and Mexico's refusal to comply with the 1944 Water Treaty have devastated water supplies in [Texas' border] communities."

The total estimated EPC cost for the facility is \$180 million, and McAllen Public Utilities (MPU) plans to build on its momentum by applying for an additional \$20 million federal grant from Reclamation for engineering design, environmental assessment and installation of permanent wells. It also plans to seek funding assistance through a loan from the Texas Water Development Board to complete the project.

With projections showing that water demands would exceed supplies between 2030 and 2035, MPU hired Phammer to evaluate water supply strategies to meet supply shortages and diversify its water portfolio. Nine water strategies were initially considered, before a screening workshop with the City reduced the list to one direct potable reuse option, two groundwater BWRO options, and a hybrid option. The four options were then evaluated in detail, with the City deciding on BWRO with groundwater blending.

Editor's note: Under a 1944 international treaty, Mexico must deliver 1.75 million acre-feet (2.16 billion m³) of water to the US from six tributaries every five years, or an average of 350,000 AFY (43 million m³/yr). But Mexico still has a balance of more than 1.3 million AF (1.6 billion m³) of water it that needs to deliver by October 2025, and is at a high risk of not meeting that deadline. A 2024 amendment allows Mexico to meet its obligations by giving up some of its allotments, and transferring water from other rivers.



Locations on Map correspond to project numbers in Table

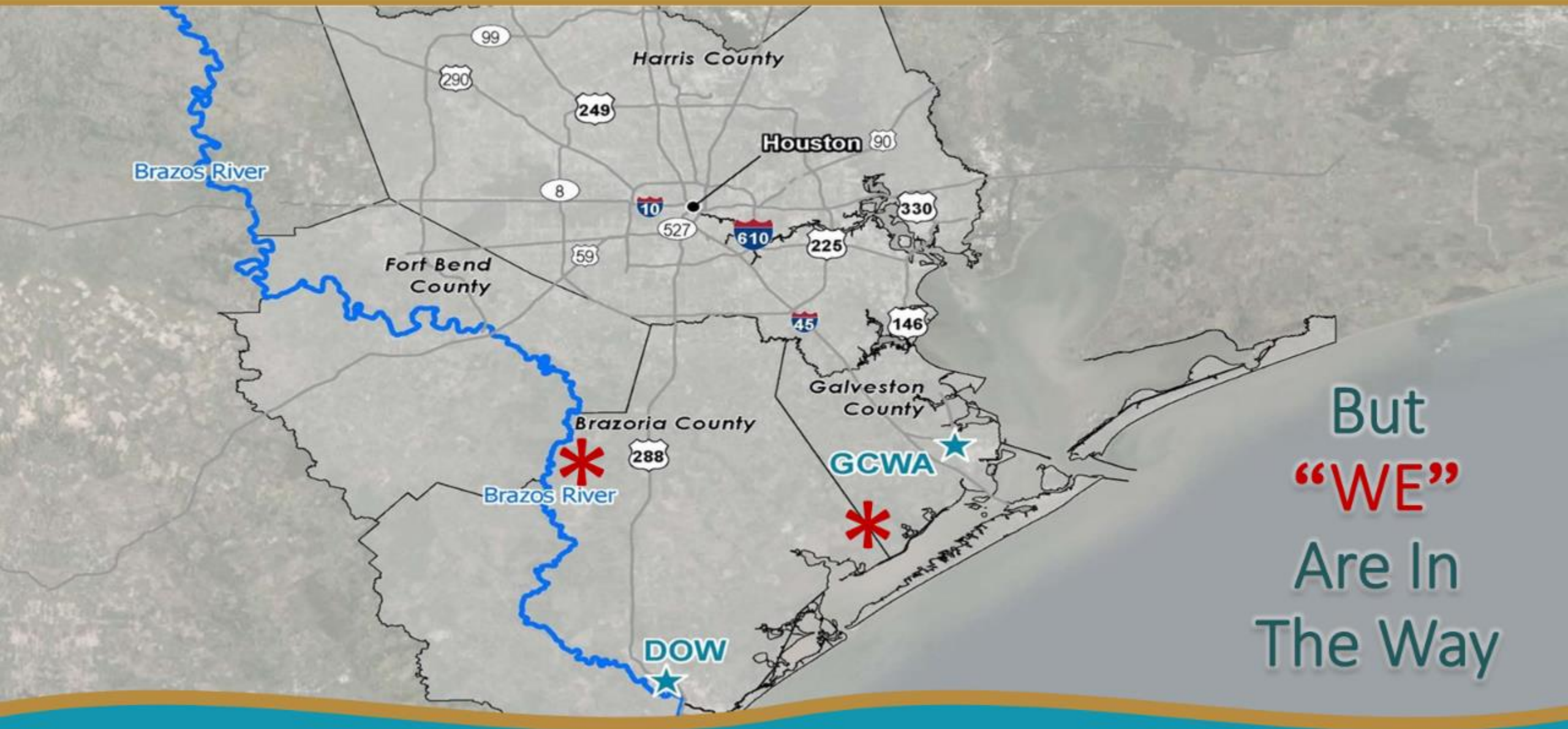
MORE CITIES SEEK ALTERNATIVE WATER SUPPLIES
Communities in the Lower Rio Grande Valley are not the only Texas cities that are considering alternative water supplies for drought relief. There are numerous BWRO and SWRO projects, indirect (IPR) and direct potable reuse (DPR) projects, that are under various stages of planning and development around the state.

Key	Offtaker/Project	Production	Process	Status
1	City of Alice	3 MGD (11,250 m ³ /d)	BWRO	Being commissioned
2	OC Polyweb - Corpus Christi	8.4 MGD (26,580 m ³ /d)	SWRO	SOI constructed
3	Crescenta Mesa Water Supply - Buda	5 MGD (26,520 m ³ /d)	BWRO	Contract negotiations
4	Inner Harbor Canal - City of Corpus Christi	30 MGD (112,500 m ³ /d)	SWRO	Under development
5	Laguna Madre Water District - Port Isabel	5 MGD (26,520 m ³ /d)	SWRO	Being designed
6	Legacy Water Supply - Webb County/Laredo	6.5 MGD (24,000 m ³ /d)	BWRO	Under contract
7	Brownsville PWS - Southwest Water Authority	10 MGD (37,500 m ³ /d)	BWRO	Planning/funding
8	City of McAllen	6 MGD (22,710 m ³ /d)	BWRO	Under development
9	H&H plant expansion El Paso Water	3 MGD (12,255 m ³ /d)	BWRO	Planning/funding
10	Hartford Water Corp - Huachuca River Authority	100 MGD (375,000 m ³ /d)	SWRO	Under development
11	La Grana Channel - City of Corpus Christi	30 MGD (112,500 m ³ /d)	SWRO	Under development
12	SAWS ASR treatment plant expansion	30 MGD (112,500 m ³ /d)	BWRO	Planning
13	Banney Davis Plant - City of Corpus Christi	100 MGD (375,000 m ³ /d)	SWRO	Conceptual
14	Freeport - Freeport Water Authority	25 MGD (84,025 m ³ /d)	SWRO	Conceptual
15	Salinas River treatment - Gulf Coast Water Authority	TBD	BWRO, SWRO	Feasibility stage
16	Emergency system - City of Bexley	100	BWRO	Seeking funding
17	El Paso Water	10.7 MGD (40,500 m ³ /d)	DPR	Under development
18	Weatherford Reuse Project	2 MGD (7,570 m ³ /d)	IPR	Under contract
19	City of San Antonio	7.5 MGD (26,520 m ³ /d)	IPR	Conceptual
20	South Lake Water Treatment Plant	5.1 MGD (26,520 m ³ /d)	IPR	Future
21	City of Cedar Park (northwest Austin)	TBD	DPR or BWRO	Conceptual
22	City of Mission	7.5 MGD (26,520 m ³ /d)	DPR	Future

Best Location

- Multiple Locations
- Bureau of Reclamation Study
- Partners:
 - BRA
 - HGSD





But
“WE”
Are In
The Way

GCWA Future Surface Water

- Near Mustang Reservoir
- West Brazoria J System



Opportunities

- Basin Water Rights “Loan” (To Central Texas)
- TWDB Loan
- State Participation
- Federal Money?
- GCWA- Resilience (Alluvium)





Summary of Delivery Points

Entry	Flow Delivery	
	K AF/Yr	MGD*
Amarillo/Lake Meredith	572	511
Austin/Lake Travis	1,275	1,138
Brownsville	75	67
Bryan/College Station	100	89
Dallas/Fort Worth	100	89
Lubbock	173	156
Mckinney	75	67
Midland	100	89
NTMWD	250	223
San Antonio	150	134
San Antonio/Spence Reservoir	392	354
San Antonio	100	179
Starr County	150	134
UTMWD	250	223
Waco	325	290
Wichita Falls	408	362
Sum of Delivery Points	4,600	4,105

*K AF/Yr is 1,000s of acre-foot/year

MGD is millions of gallons/day







2025
GULF COAST
WATER CONSERVATION
Symposium

May 21, 2025 | Houston, Texas

PROGRAM

Schedule

8:30 AM REGISTRATION

Pre-Function Area

Please show your photo ID or registration confirmation to pick up your name badge, welcome pack, and parking validation at the registration table. Your name badge must be worn at all times.

**We recommend that you store your validated parking ticket inside your name badge for safekeeping.*

8:30 AM CONTINENTAL BREAKFAST

Salon B

After you have completed the registration process, enjoy a continental breakfast before the morning speaking sessions begin.

9:30 AM MORNING SPEAKING SESSIONS

Salon A

WELCOME REMARKS

MIKE TURCO



General Manager, Harris-Galveston Subsidence District & Fort Bend Subsidence District
Michael J. Turco obtained his Bachelor of Science degree in Geology and a Master of Science in Geology (Hydrogeology) from the University of Nebraska and began his career in the water industry with the U.S. Geological Survey, working on many water data collection and research projects throughout Iowa and Nebraska. In 2004, he moved to Houston, Texas, to be the Chief Hydrologist of the Gulf Coast Program unit accepting the position of General Manager of the Harris-Galveston Subsidence District (HESD) and Fort Bend Subsidence District (FBSD). In 2013, with the goal of supporting our region's growth by protecting groundwater resources with reasonable and effective regulation backed by the best available science to ensure a sustainable water future, free from the impacts of subsidence, he is involved in many influential water groups, such as the Region H planning group, Region 6 Flood Planning Group, the Texas Water Association, and UNESCO's International Symposia on Land Subsidence.

WHY WATER ISSUES ARE THE HIGHEST PRIORITY

COMMISSIONER TOM RAMSEY, P.E.



Harris County Commissioner - Precinct 3
Commissioner Tom Ramsey holds over 45 years of experience as a Professional Engineer. He served as the Mayor of Spring Valley Village for 8 years and is now on his second term as County Commissioner for Precinct 3. As County Commissioner, he's responsible for 75% of unincorporated Harris County, which has more residents than the City of Houston. His office is responsible for the maintenance of 6,800 miles of roads, 72 parks, and 10 Community and Nature Centers. In 2023, he was named Engineer of the Year by Houston area engineering societies and received the Distinguished Graduate Award from Zachry Department of Civil and Environmental Engineering at Texas A&M University. He was also named the 2024 Public Official of the Year by ASCE National.

DESALINATION - IS IT POSSIBLE?

CHRIS MUNSON, P.E.



Project Director - Black & Veatch
Chris Munson, P.E., is responsible for leading Black & Veatch's water team in Houston. He has over 25 years of experience in the evaluation and design of water and wastewater treatment facilities and is well-versed in managing large, multi-disciplinary project teams to successfully execute complicated water and wastewater projects throughout both design and construction. He received a Bachelor's Degree in Civil Engineering in 1997 and a Master's Degree in Environmental Engineering in 1998, both from Penn State, and is a registered Professional Engineer in Texas and Louisiana.

ROBERT D. UPTON, P.E.



District Engineer - Gulf Coast Water Authority
As the District Engineer at the Gulf Coast Water Authority, Robert D. Upton, P.E., oversees Engineering, Development Plan Review, and the Capital Improvement Program. Before GCWA, as the Director of Engineering and Public Works for the City of Pearland, he guided the Engineering, Capital Projects, Water and Wastewater Utility Services, and Internal Services Divisions. His experience includes water and wastewater design and construction, alternative contract procurement, project management, policy development, and implementation. He received a Civil Engineering degree from Northern Arizona University in 1996 and is a registered Professional Engineer in Texas and Arizona.

MORNING SPEAKING SESSIONS (Continued)

Salon A

PROTECTING TOMORROW'S WATER: UTILIZING LOCAL RESOURCES FOR LASTING CONSERVATION

DENISE MA



Water Conservation Program Coordinator, Harris-Galveston Subsidence District
Denise earned her Bachelor of Science in Environmental Science from St. Mary's University and her Master of Arts in Education from Relay Graduate School of Education. She began her career as a high school Biology and AP Environmental Science teacher. Wanting to make a bigger impact in conservation and environmental sustainability, Denise joined the Harris-Galveston Subsidence District in 2023, where she supports the District's award-winning water conservation programs.

CONSERVATION BY WAY OF SEA - MUNICIPAL DESALINATION FOR A TEXAS GULF COAST CITY

DREW MOLLY, P.E.



Chief Operating Officer - City of Corpus Christi
Drew Molly obtained his Civil Engineering degree from Texas A&M University and is a licensed engineer in the state of Texas who maintains a Class A water license and Class D wastewater operations license. Drew has dedicated his career to ensuring safe and sustainable water resources, which has earned him the American Water Works Association's George Warren Fuller Award and Engineering News-Record's Top 25 Newsmaker.

REDUCING CONSUMPTION IN THE GULF COAST BY THE BILLIONS

JULIA FRANKOVICH, P.E.



Project Manager - BGE / North Fort Bend Water Authority
Julia has over a decade of engineering experience encompassing a variety of projects from planning to design. Her primary focus is water planning for North Fort Bend Water Authority with an emphasis on reducing groundwater consumption through surface water delivery and promotion of reclaimed water use and water conservation to the northern Fort Bend County area.

WHITNEY MILBERGER



Project Manager - BGE / North Fort Bend Water Authority
Whitney primarily serves as the conservation and communications manager for the Authority. Her quest for over two decades has been to help educate the industry and community about actual plant water needs versus common perception. She also serves as the State's landscape, irrigation, and Horticultural representative for the Texas Water Development Board's Water Conservation Advisory Council.

12:00 PM LUNCH

Salon B

Enjoy a delicious lunch buffet while networking with symposium participants. Be sure to check each table for participants' favorite water-saving tips and resource submissions!

Thank you to our Luncheon Sponsor, the Fort Bend Subsidence District!



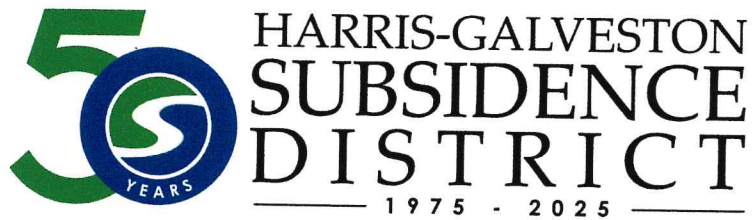
**FORT BEND
SUBSIDENCE DISTRICT**

1:00 PM AFTERNOON SPEAKING SESSIONS

Salon A

Continue to next page for more information about the afternoon speaking sessions.

The 2025 Gulf Coast Water Conservation Symposium is presented by:



The Harris-Galveston Subsidence District (HGSD) is a special-purpose district created by the Texas Legislature in 1975, authorized as a groundwater regulatory agency to cease ongoing and prevent future subsidence in Harris and Galveston counties. In addition, HGSD provides water conservation, education, and outreach programs to underscore the importance of reducing reliance on groundwater and promote water efficiency best practices in our communities.

The District's goal is to protect and conserve the groundwater resources in order to prevent subsidence in Harris and Galveston counties. Part of that goal includes equipping permittees, residents, businesses, and educators with water conservation tips, tools, and resources. Wasting water not only affects individual households and their budgets, but also puts a strain on our natural and infrastructure resources.

HGSD's award-winning Water Conservation Program includes H2O Lab!, a school program offering water education to local 3rd-6th grade students, a grant program funding water efficiency projects, Smarter About Water - a dedicated platform for sharing water conservation tools and resources, and WaterMyYard, an irrigation program collaborating with several entities to provide watering recommendations for yards in the region.

Learn more by scanning the QR codes below and follow us on our social channels:



ABOUT HGSD



WATER
CONSERVATION
PROGRAM



SMARTER ABOUT
WATER

Gulf Coast Water Conservation Symposium

Wednesday, May 21, 2025

GCWA Desalination – Is It Possible?

Robert Upton, P.E.
Chris Munson, P.E.





GCWA
Desalination:
~~**It's**~~
~~**Complicated**~~
Is It Possible?

~~Don't~~ Need It!

^
Might

~~Can't~~ Afford It!

^
Can We

Best Location!





History of GCWA

- Multiple Names
 - Cane and Rice Belt Irrigation Co. (1905)
 - Brazos Valley Irrigation Co. (1926)
 - American Canal Co. (1940)
 - American Canal Co. of Texas (1959)
- Briscoe Canal System
 - Briscoe Irrigation System (1940s)
- Industrial Water Co. (1948)
- Galveston County Water Company (1965)
- Chocolate Bayou Water Co. (2006)

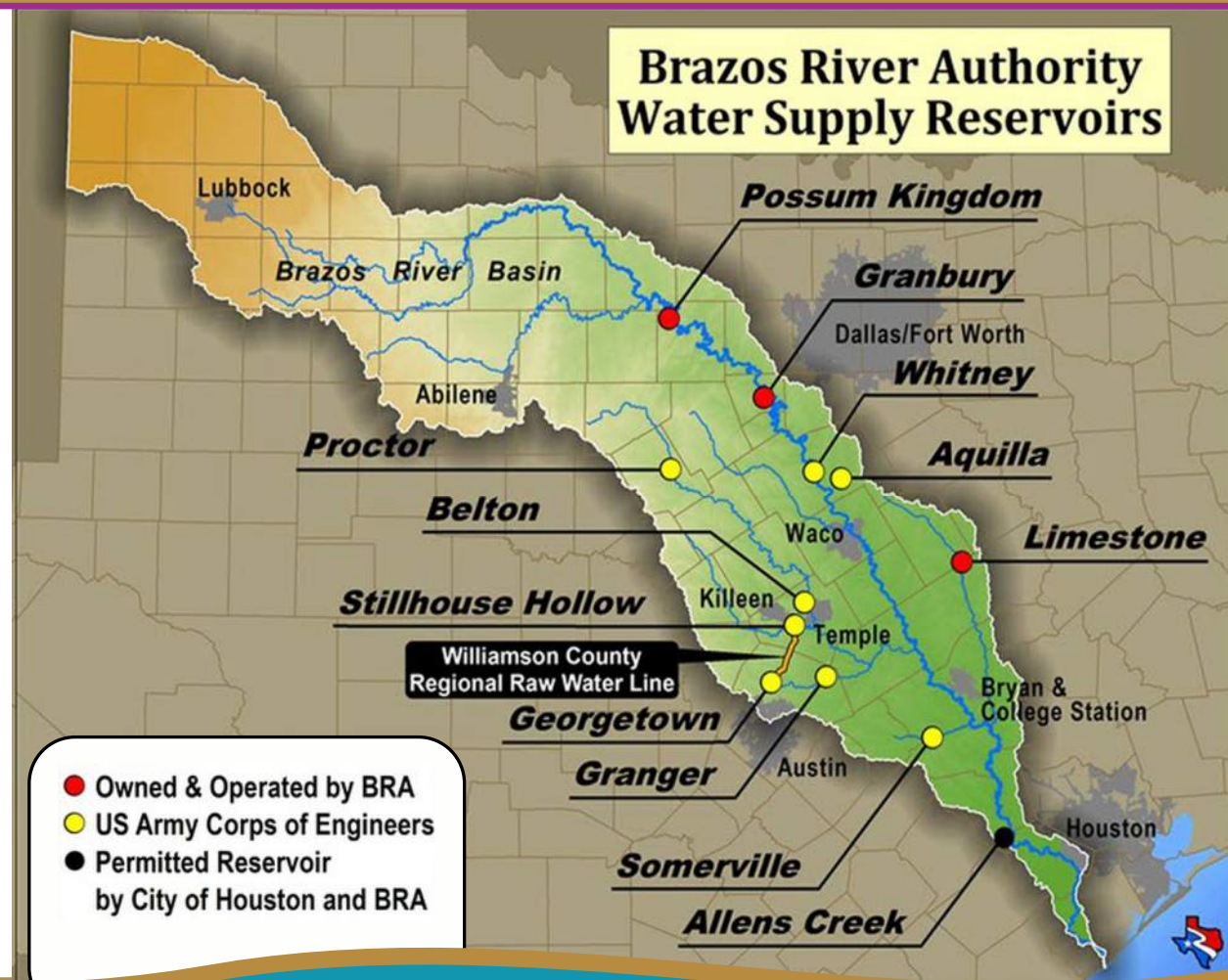
Water For...

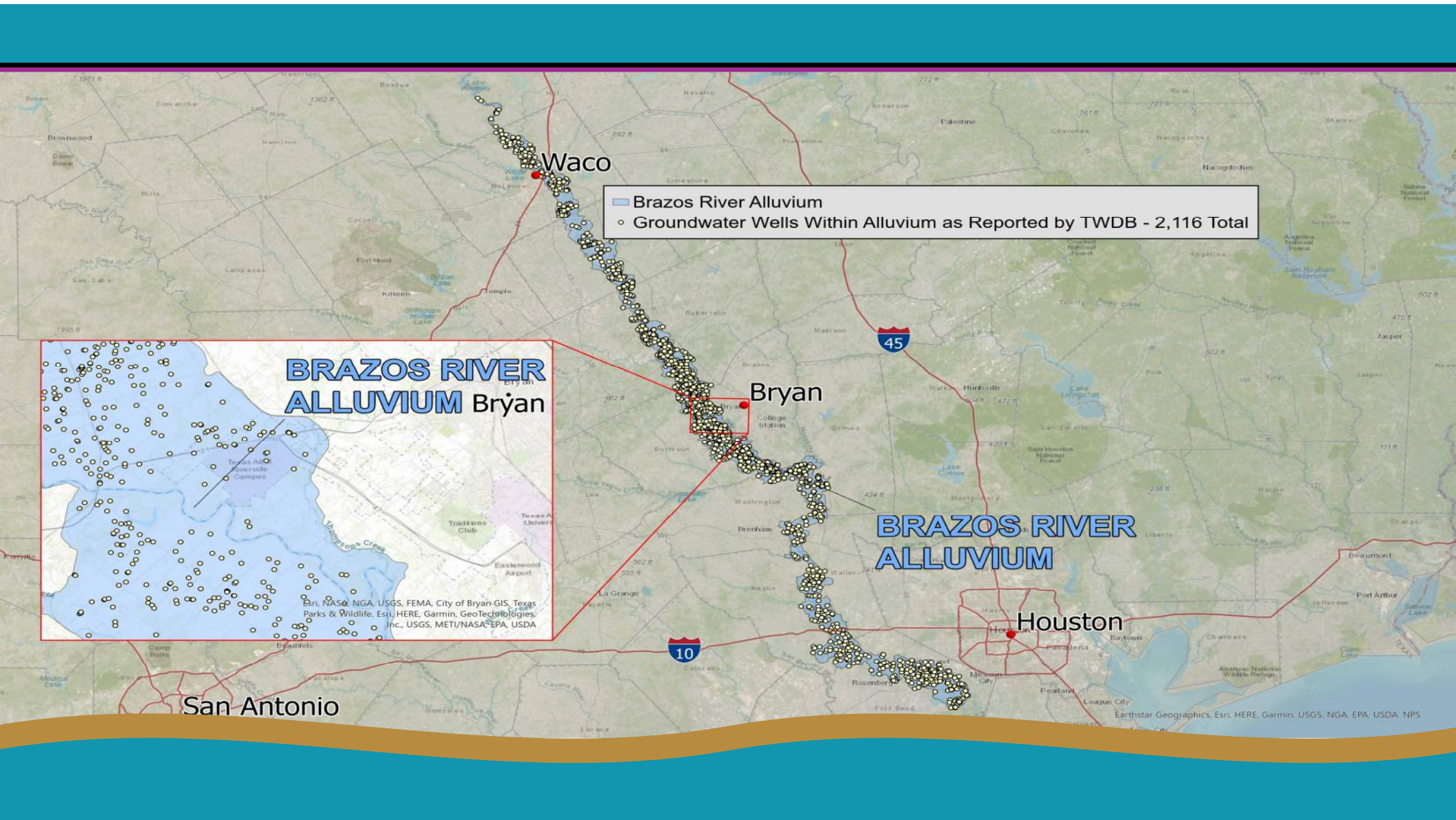
- Industry
 - Marathon
 - Ineos
 - Valero
 - Others
- 16,000 acres of rice fields
- 600,000 people
- Raw Water - Sugar Land & Pearland
- 58 MGD Water Treatment Plant - Galveston County
- S.E. Plant – Co-participant

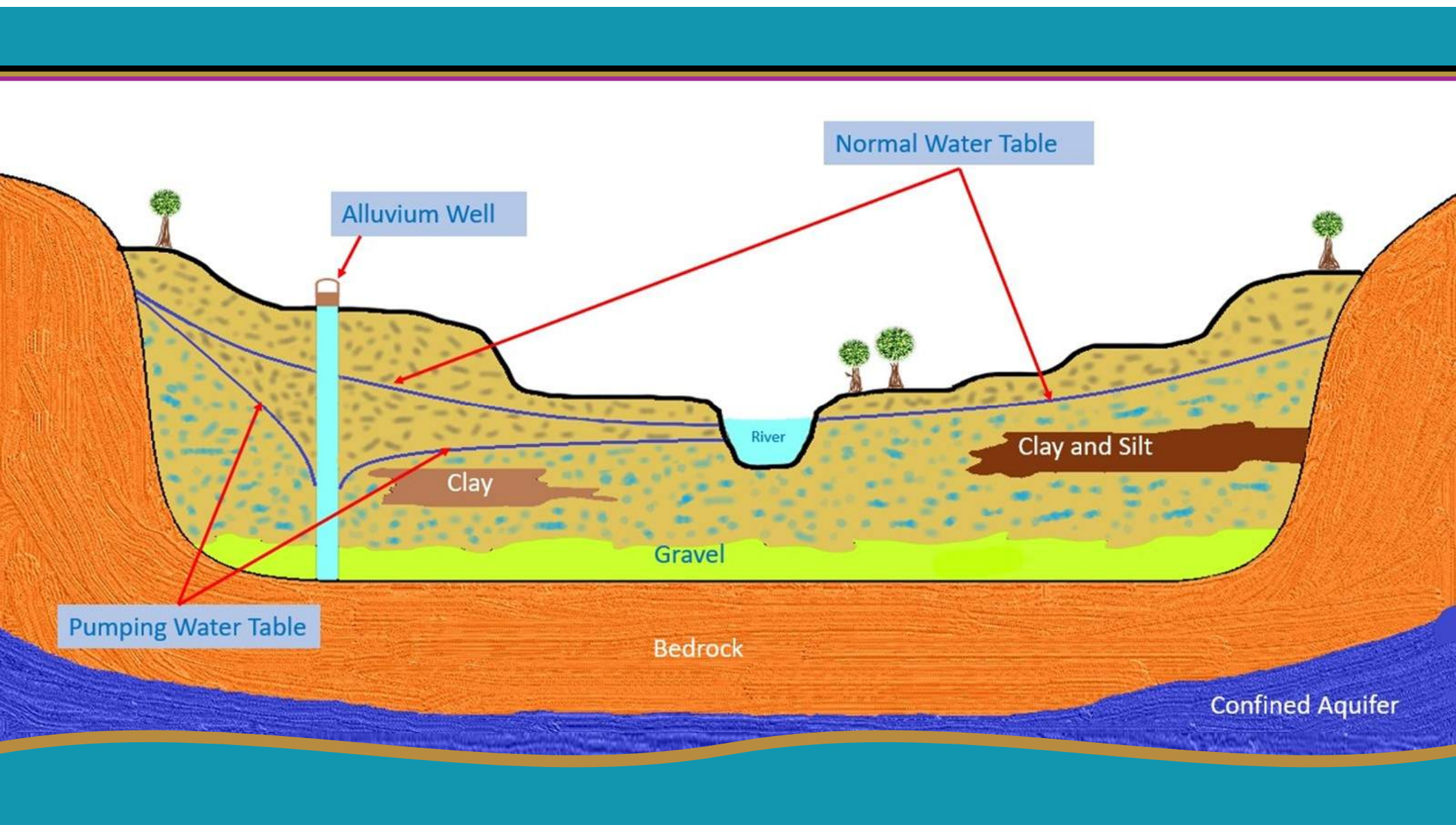


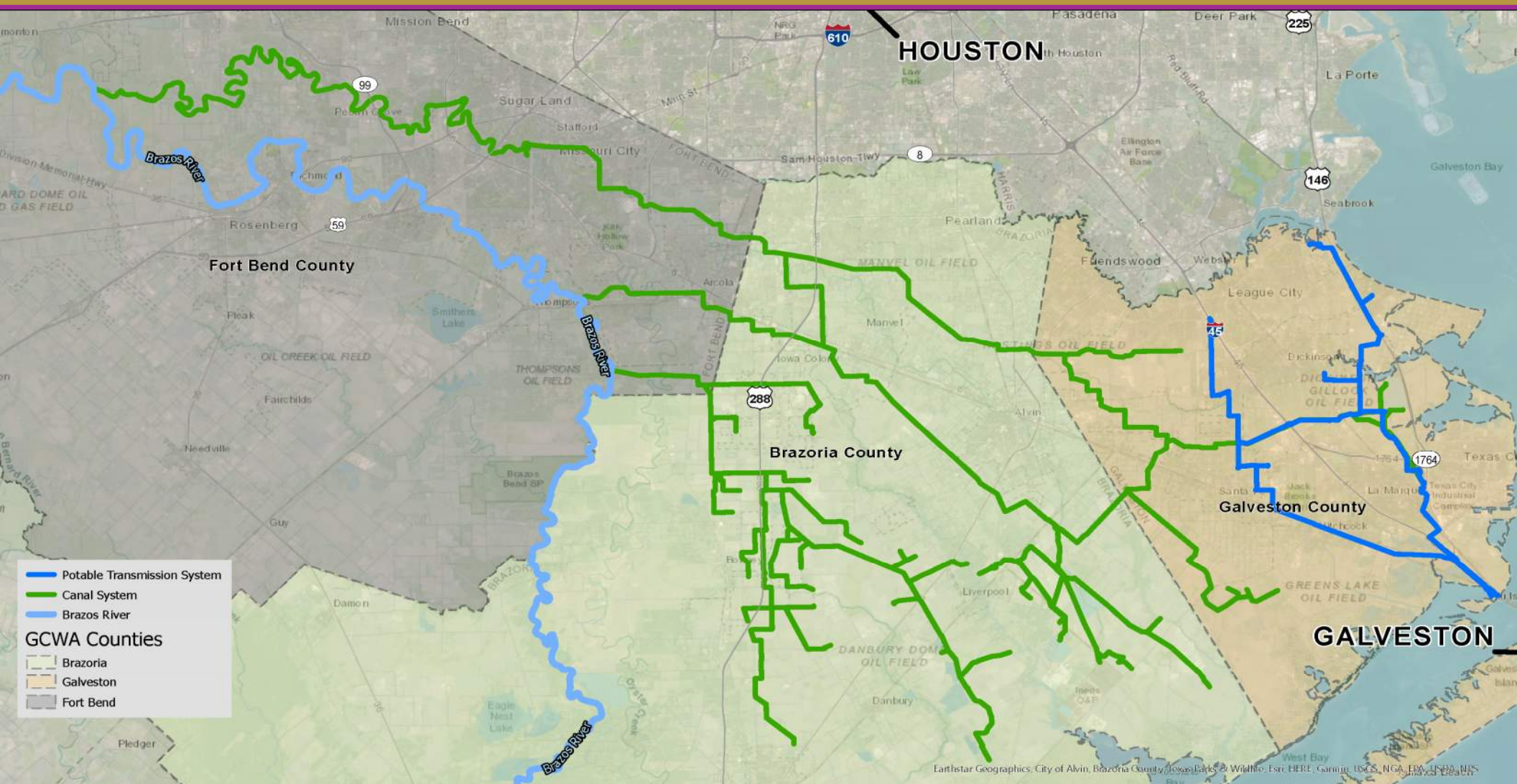
Water Source

- 380,000 acre-feet
Run of the River
- 80,000 acre-feet
BRA Reservoirs
(Reserve)
- Houston S.E. Plant
(Trinity River)









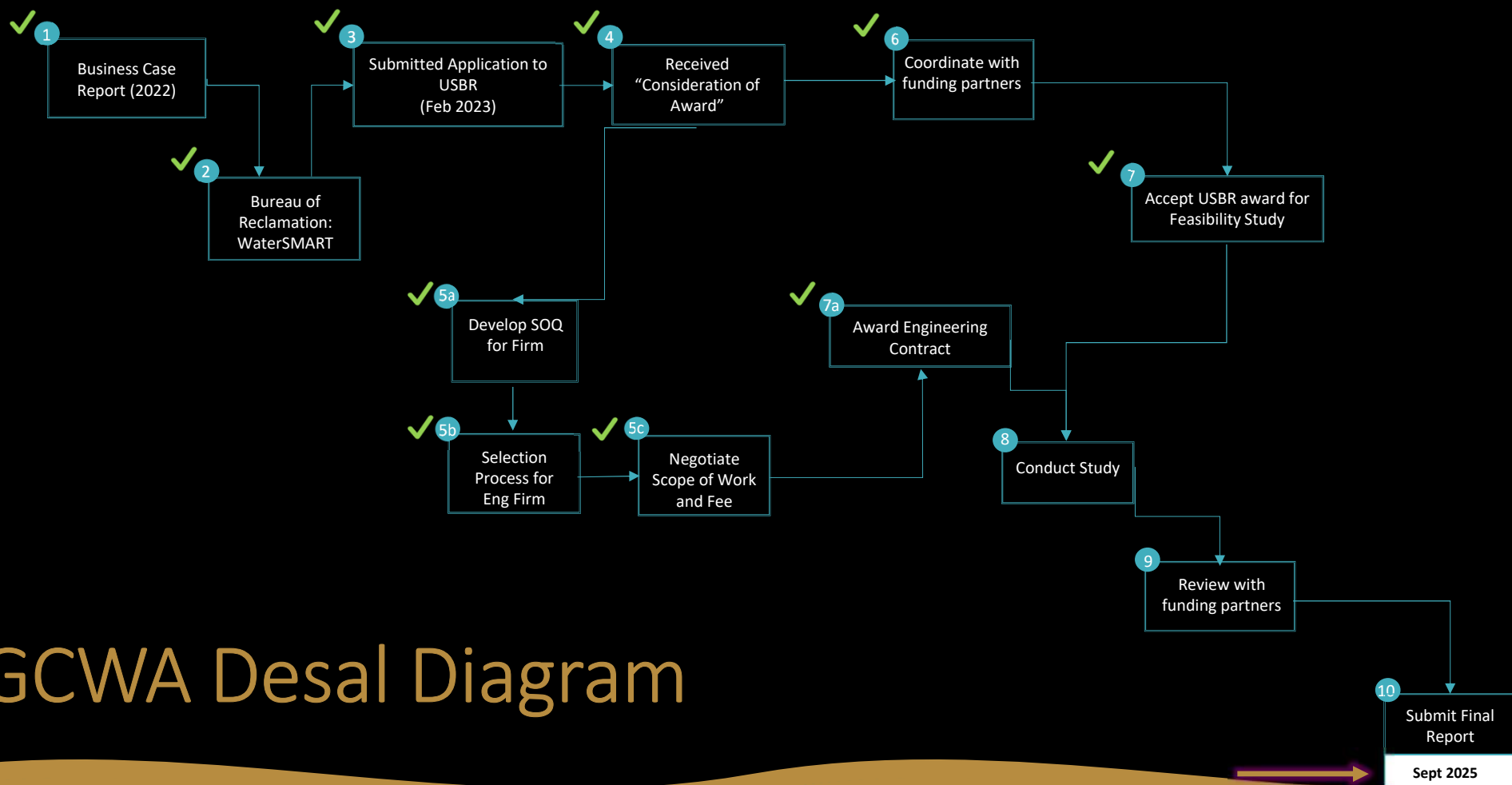
Threats

- Lowest Wholesale Water Rate
- Contract Based
- “Pragmatic” CCN



GCWA Desalination Past Work

- In 2022 completed a Business Case report for Desalination
- 40 MGD plant in two 20 MGD stages (seawater-based design)
- Bureau of Reclamation WaterSMART program opened to applications
- Partners: Harris Galveston Subsidence District, Brazos River Authority

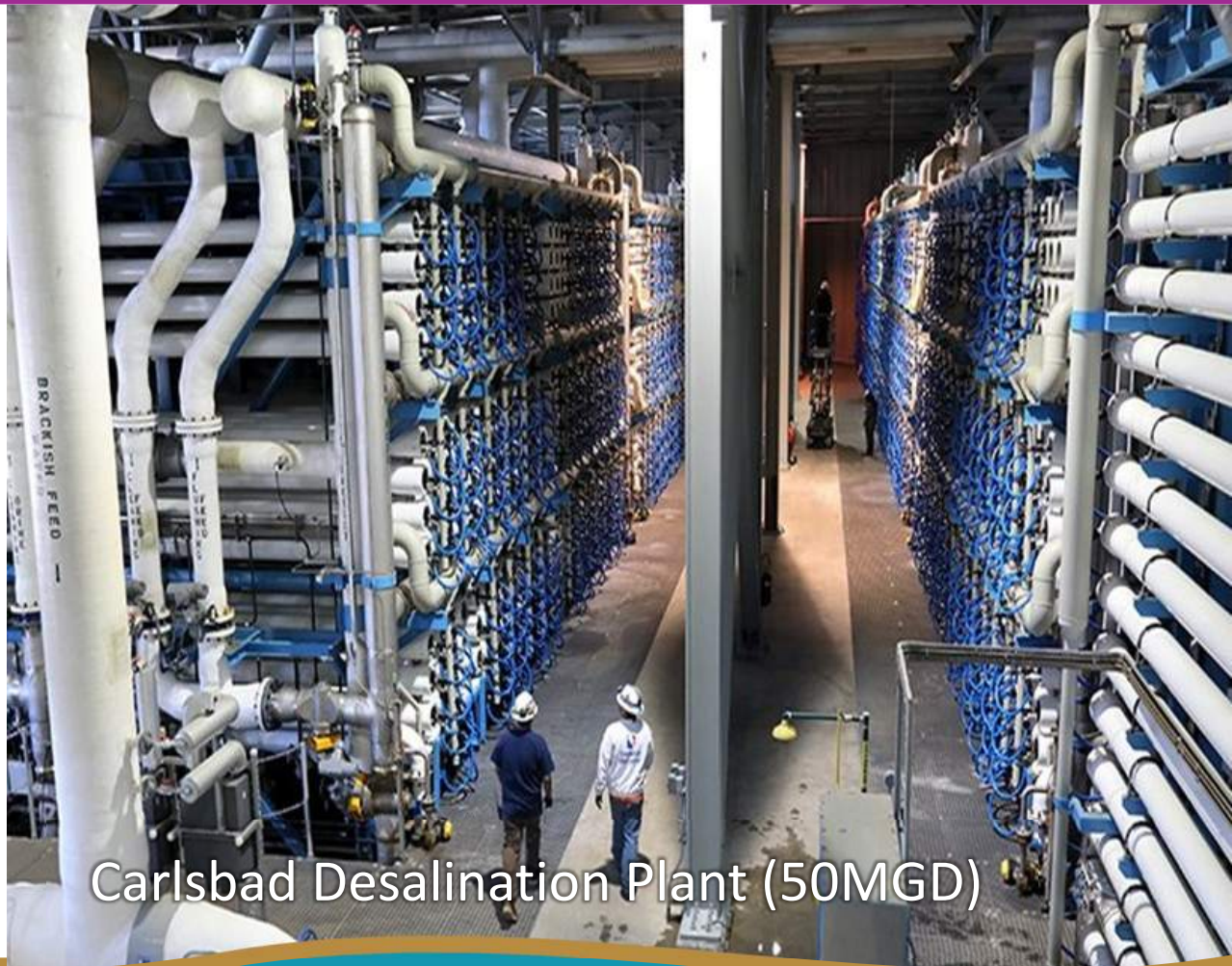


GCWA Desal Diagram

GCWA Feasibility Study

Title XVI Study Requirements

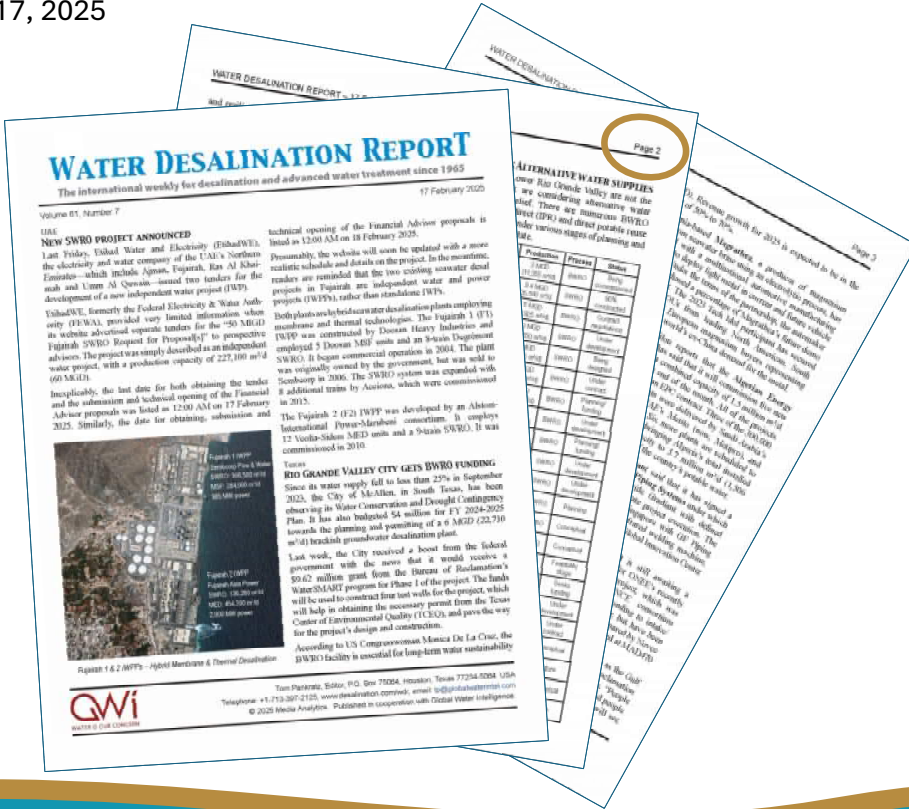
- Statement of Problem and Needs
- Project Planning and Analysis
- Evaluation of Project Alternatives
- Stretching Water Supplies
- Environment and Water Quality
- Economic Analysis
- Selection of Proposed Seawater Desalination Project
- Legal and Institutional Requirements
- Financial Capability of Sponsor



Carlsbad Desalination Plant (50MGD)

Water Desalination Report

February 17, 2025

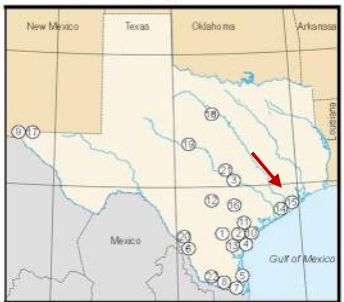


and resilience, adding, “Drought conditions and Mexico’s refusal to comply with the 1944 Water Treaty have devastated water supplies in [Texas’ border] communities.”

The total estimated EPC cost for the facility is \$180 million, and McAllen Public Utilities (MPU) plans to build on its momentum by applying for an additional \$20 million federal grant from Reclamation for engineering design, environmental assessment and installation of permanent wells. It also plans to seek funding assistance through a loan from the Texas Water Development Board to complete the project.

With projections showing that water demands would exceed supplies between 2030 and 2035, MPU hired Plummer to evaluate water supply strategies to meet supply shortages and diversify its water portfolio. Nine water strategies were initially considered, before a screening workshop with the City reduced the list to one direct potable reuse option, two groundwater BWRO options, and a hybrid option. The four options were then evaluated in detail, with the City deciding on BWRO with groundwater blending.

Editor’s note: Under a 1944 international treaty, Mexico must deliver 1.75 million acre-feet (2.16 billion m³) of water to the US from six tributaries every five years, or an average of 350,000 AFY (43 million m³/yr). But Mexico still has a balance of more than 1.3 million AF (1.6 billion m³) of water it that needs to deliver by October 2025, and is at a high risk of not meeting that deadline. A 2024 amendment allows Mexico to meet its obligations by giving up some of its allotments, and transferring water from other rivers.



Locations on Map correspond to project numbers in Table

MORE CITIES SEEK ALTERNATIVE WATER SUPPLIES

Communities in the Lower Rio Grande Valley are not the only Texas cities that are considering alternative water supplies for drought relief. There are numerous BWRO and SWRO projects, indirect (IPR) and direct potable reuse (DPR) projects, that are under various stages of planning and development around the state.

Key	Offtaker/Project	Production	Process	Status
1	City of Alamo	3 MGD (11,355 m ³ /d)	BWRO	Being commissioned
2	CC Polymers – Corpus Christi	9.4 MGD (35,580 m ³ /d)	SWRO	90% constructed
3	Crescenta Mesa Water Supply – Buda	5 MGD (18,925 m ³ /d)	BWRO	Contract negotiations
4	Inner Harbor Desal – City of Corpus Christi	30 MGD (113,550 m ³ /d)	SWRO	Under development
5	Laguna Madre Water District – Port Isabel	5 MGD (18,925 m ³ /d)	SWRO	Being designed
6	Legacy Water Supply – Webb County/Laredo	6.5 MGD (24,625 m ³ /d)	BWRO	Under contract
7	Brownsville PUB – Southernmost Water Authority	10 MGD (37,850 m ³ /d)	BWRO	Planning/ funding
8	City of McAllen	6 MGD (22,710 m ³ /d)	BWRO	Under development
9	H&H plant expansion El Paso Water	3 MGD (11,355 m ³ /d)	BWRO	Planning/ funding
10	Harbort Isle Corpus Christi – Nueces River Authority	100 MGD (378,500 m ³ /d)	SWRO	Under development
11	La Quinta Channel – City of Corpus Christi	30 MGD (113,550 m ³ /d)	SWRO	Under development
12	SAWS AQR treatment plant expansion	30 MGD (113,550 m ³ /d)	BWRO	Planning
13	Barney Davis Plant – City of Corpus Christi	100 MGD (378,500 m ³ /d)	SWRO	Conceptual
14	Freeport – Brazosport Water Authority	25 MGD (94,625 m ³ /d)	SWRO	Conceptual
15	Galveston, Harris counties – Gulf Coast Water Authority	TBD	BWRO, SWRO	Feasibility stage
16	Emergency system – City of Beaville	TBD	BWRO	Seeks funding
17	El Paso Water	10.7 MGD (40,500 m ³ /d)	DPR	Under development
18	Weatherford Reuse Project	2 MGD (7,570 m ³ /d)	IPR	Under contract
19	City of San Angelo	7.5 MGD (28,385 m ³ /d)	IPR	Conceptual
20	South Laredo WWTP – Laredo	5.1 MGD (19,350 m ³ /d)	IPR	Future
21	City of Cedar Park (northwest Austin)	TBD	DPR or BWRO	Conceptual
22	City of Mission	7.5 MGD (28,385 m ³ /d)	DPR	Future

GCWA's Progress - Modeling

- Regional Solution
- Water Supply Portfolio Modeling
 - 50+ WAM runs
 - 25+ Daily Hydro runs
- Desal Volume and Timing
 - Current / Future Demands
 - Confirmed Phased 40 MGD Capacity

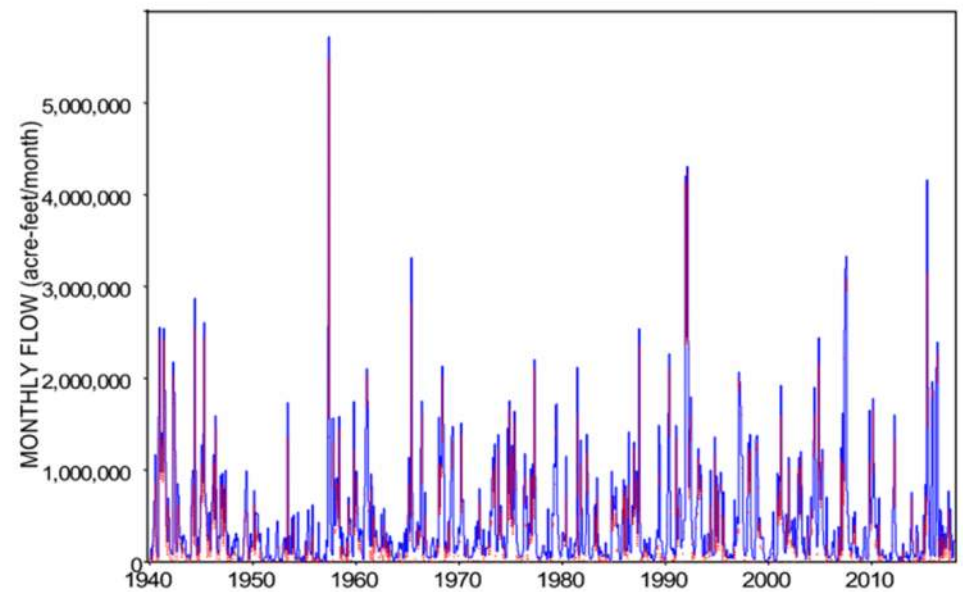


Figure 4.1 Naturalized (blue solid line) and Unappropriated (red dotted line)
Monthly Flow Volumes at Control Point HEMP

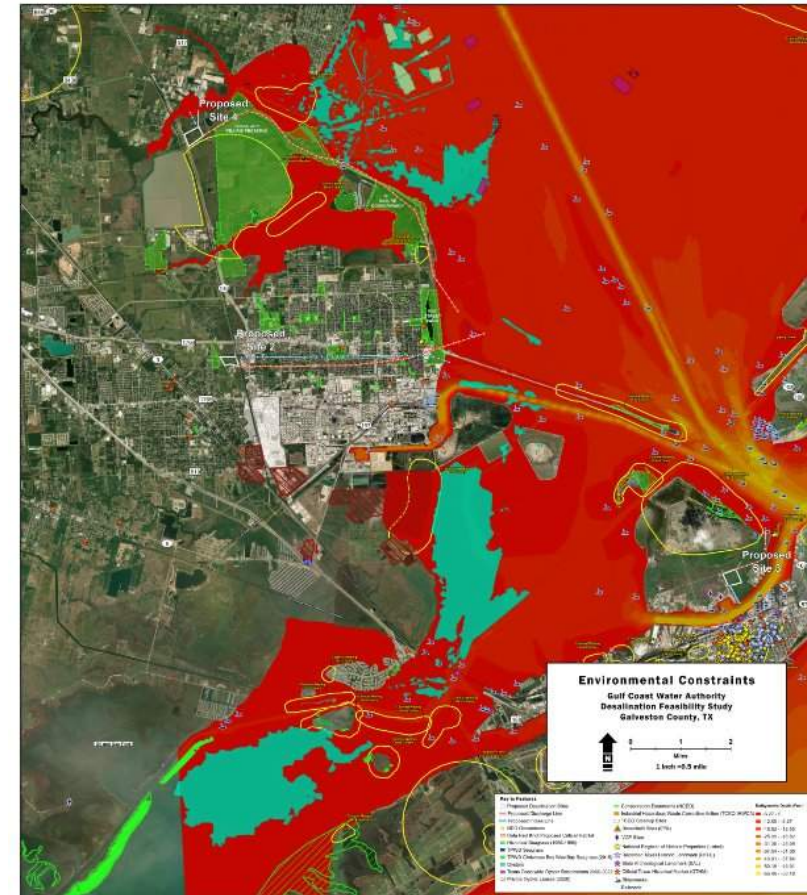
GCWA's Progress – Site Screening

- Site Screening
 - Established High Level Criteria
 - Screened 6 Sites
 - 2 Sites for Evaluation

Category	Criteria	Scoring Range	Weight	Site 1	Site 2	Site 3	Site 4	Site 5
Site Favorability	Proximity to Service Area	1-5	30%	5	3	2	5	3
	Proximity to Intake							
	Proximity to Discharge							
	Proximity to Utilities							
	Co-location Opportunities							
	Site Accessibility							
Environmental	Land Cost & Acquisition							
	Environmental Concerns	1-5	30%	5	3	5	3	1
	Discharge Impact							
	Regulatory Compliance							
Social	Community Acceptance	1-5	20%	5	5	1	5	1
	Environmental Justice							
Risk of Hazards	Risk of Natural Hazards	1-5	15%	3	5	2	3	5
Water Quality & Availability	Water Supply	1-5	5%	3	3	5	3	1
Total Score			100%	4.6	3.7	2.85	4	2.2

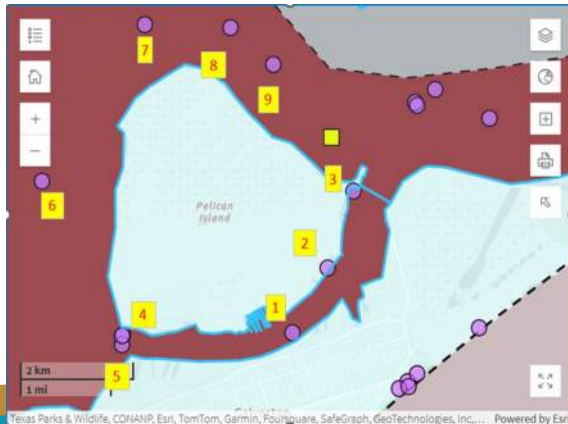
GCWA's Progress – Site Selection

- Site Selection Criteria
 - Land Availability
 - Product Water Delivery
 - Potential Impacts to Seagrass, Oysters, Tidal Wetlands
 - Federally Listed Species
 - Source Water Quality
 - Bathymetry
 - Concentrate Management Strategies
 - Permit Overview
 - Planning Level Cost Estimates
- Selected “Preferred” Site and an Alternative Site Location



GCWA's Progress – Conceptual Design

- Source Water Quality
 - EPA's My Waterway Tool
 - Salinity Similar to Seawater
 - TSS Moderately High
 - Chlorophyll (Algae)



Parameter	Units	Sample 1 (2023-2024)				Sample 4 (2004)				Sample 5 (2015-2020)			
		Count	Average	Min	Max	Count	Average	Min	Max	Count	Average	Min	Max
Conductivity	µS/cm	23	44,530	24,500	55,100					30	33,362	7,870	46,900
Salinity	mg/L	23	28,770	14,500	36,400	3	25,633	24,050	27,200	30	20,887	4,400	30,500
Chlorophyll a	µg/L	3	13	5	24	8	4.48	0.00	7.40	6	13.15	8.85	19.10
Depth	Feet	4	39	27	45					6	37.51	29.53	45.28
Dissolved oxygen	mg/L	23	6	5	10	2	5.45	5.20	5.71	30	7.63	4.00	10.20
pH	S.U.	23	8	8	9	3	7.88	7.87	7.90	30	8.20	8.00	8.40
Temperature	°C	23	26	21	32	3	31.26	31.13	31.44	30	21.15	15.20	30.50
Total suspended solids	mg/L	2	11	10	11	6	21.33	13.00	28.00	6	19.32	10.90	26.00
Total organic carbon	mg/L	3	3	2	3					4	4.25	3.00	5.00

GCWA's Progress – Conceptual Design

- Desalination Facility

- Pretreatment

- Dissolved Air Flotation (DAF)
 - Media Filters

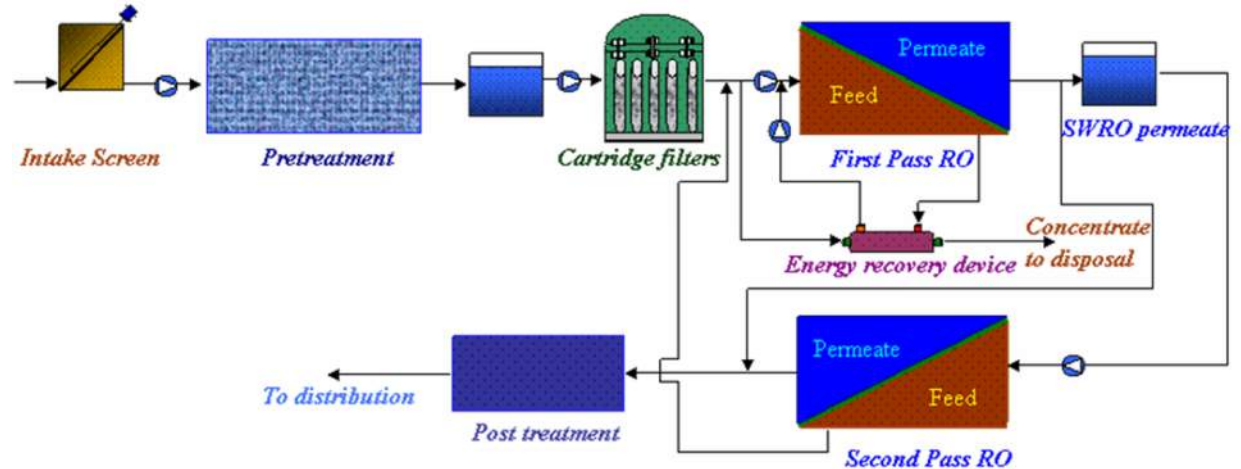
- Reverse Osmosis (Two Pass)

- Post Treatment

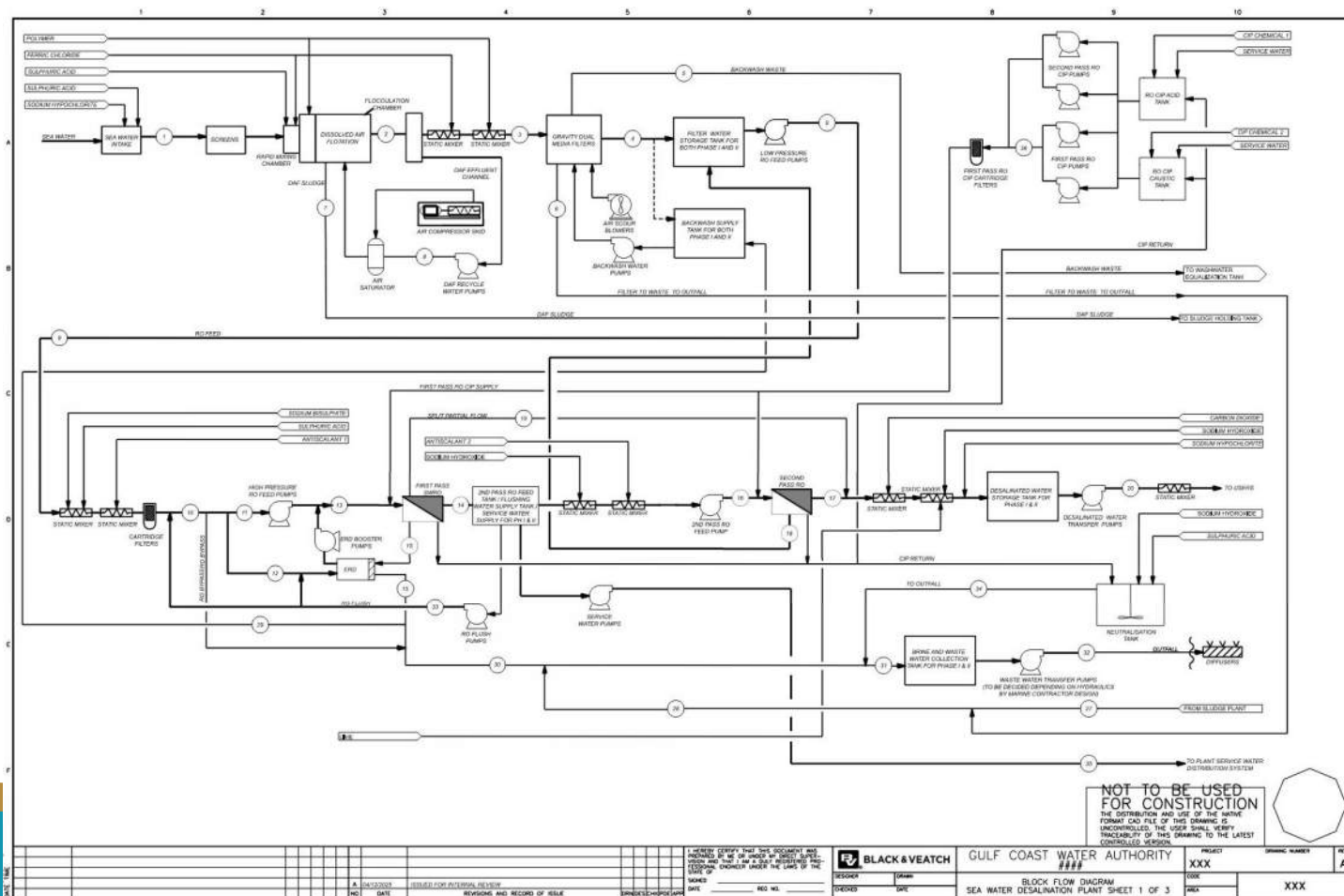
- CO₂ and Lime

- Solids Handling

- Lamella Clarifier
 - Centrifuge / Belt Press



GCWA's Progress – Conceptual Design



Next Steps

- Develop site configurations and cost estimates
- Develop the Draft Feasibility Study in accordance with the USBR program



— BUREAU OF —
RECLAMATION



Brazos
— ★ —
RIVER AUTHORITY



HARRIS-GALVESTON
SUBSIDENCE
DISTRICT
— 1975 - 2025 —

Opportunities

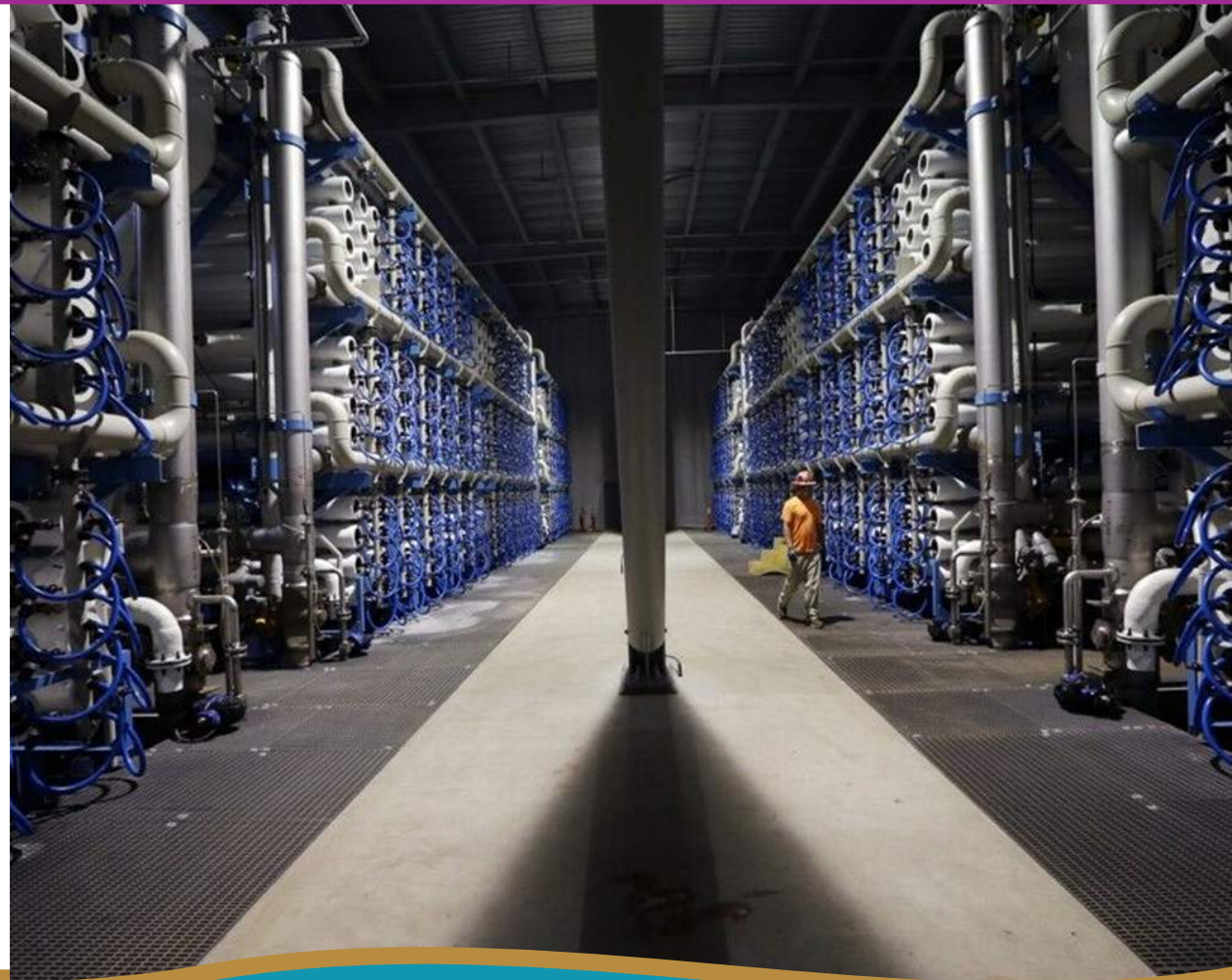
- Basin Water Rights “Loan” (To Central Texas)
- TWDB Loan
- State Participation
- Federal Money?
- GCWA – Resilience (Alluvium)

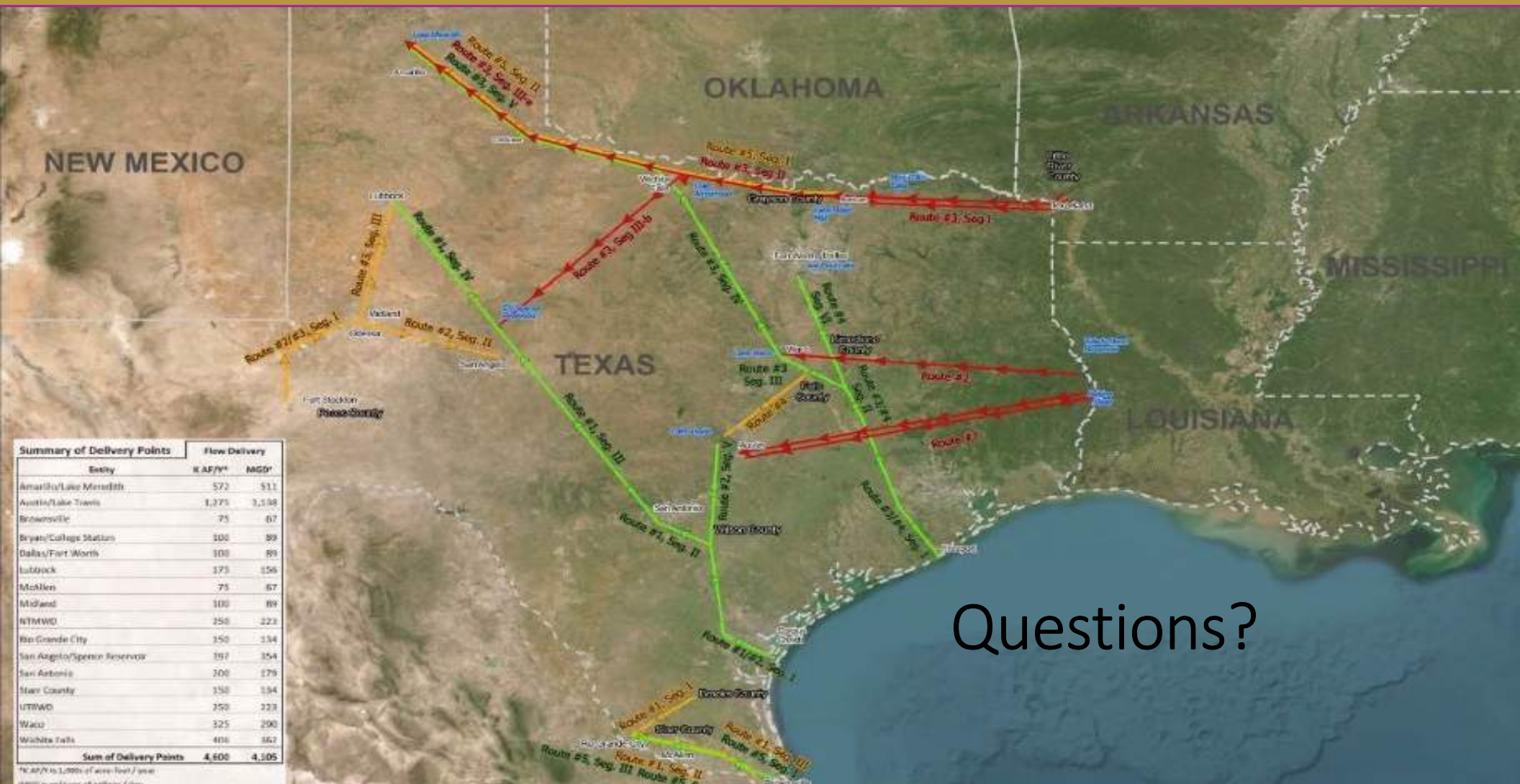


Best Location

- Multiple Locations
- Bureau of Reclamation Feasibility Study
- Partners:
 - BRA
 - HGSD

Is It Possible?







ENVIRONMENTAL &
WATER RESOURCES
INSTITUTE
Houston Chapter

5TH ANNUAL HOUSTON CONFERENCE

Houston, Texas | October 30, 2025

Connected by Water: From Local Projects to Regional Progress



ascehouston.org/EWRI

LinkedIn®

Desalination: Is it Possible?

Water rights, forecasted water needs, drought and water supply resiliency are hot topics throughout Texas. As GCWA seeks to add resiliency to their own water supply portfolio, they have asked the question - can seawater desalination be a part of a regional or statewide solution for water supply? As a step towards answering that question, GCWA was granted a U.S. Department of the Interior Bureau of Reclamation grant to conduct a Title XVI Feasibility Study for a seawater desalination plant. This presentation will center around a brief history of GCWA, the grant requirements, status of the study, and our next steps.



Robert Upton, PE has been with the Gulf Coast Water Authority (GCWA) since March 2023. As District Engineer, he oversees Engineering, Development Plan Review, and the Capital Improvement Program. Prior to GCWA, as the Director of Engineering and Public Works for the City of Pearland, he oversaw the Engineering, Capital Projects, Water and Wastewater Utility Services and Internal Services divisions. His experience includes water and wastewater design and construction, alternative contract procurement, project management, policy development and implementation.

Flood Control Maintenance: Reinvesting for Tomorrow

On November 4, 2024, the voters of Harris County approved a ballot measure for the reinvestment of funding towards the maintenance of its drainage system infrastructure. The Harris County Flood Control District is using this vote of confidence to address its deferred maintenance, increase services to the citizens of Harris County, expand its operational footprint, and transform its maintenance operations with forward-looking and holistic thinking in mind. Please join Jason Krahn as he explains the Flood Control District's journey of addressing the maintenance issues of today, while focusing on a more sustainable tomorrow.



Jason Krahn, AC, PMP is the Chief Infrastructure and Operations Officer for the Harris County Flood Control District (HCFCD). His career has spanned more than 22 years with HCFCD, managing the design and construction of more than 250 million dollars of gray-blue-green drainage infrastructure maintenance and improvement projects. He focuses on providing stormwater quality benefits, enhancing flood defense and community resilience, and prolonging the useful life of critical drainage infrastructure.



Appendix H. Independent Peer Review Comment Log

Project Name: Desalination Feasibility Study
Consultant Firm: Black & Veatch
Submittal % or #: Draft Study

USBR Grant No.
Project Number:
Submittal Date:

R24AP00180-00
5993
1/16/2026

Comment #	Page	Section	Reference	Comments Review Meeting Comments	Commentor	Responder	Consultant Response
1		General		Are we leaving the WTR 11-01 boxes in the report? The boxes are to remain in the report.	V. Migl	JB	Boxes will stay in the report to aid the USBR reviewers.
2		Abbreviations List		Add GCD.	V. Migl	VAF	GCD added.
3		1.0	Introduction	1C is not answered. Robert is asking for clarity about reuse vs desal. Jaime will ask for clarification from Luis.	R. Upton	JB	Luis confirmed the section applies to desalination. Section 1.3 has been added to address item 1c.
4	1-1	1.1	1st paragraph, last sentence	The sentence should end "...water rights and contracts <u>from</u> the Brazos River."	Aaron Abel, BRA	VAF	Addressed.
5	1-1	1.1	2nd paragraph, first sentence	Verify 300 miles of canal. David Hudson confirmed 274 miles of canal.	R. Upton	JB	Modified sentence to say "274 miles of canal infrastructure."
6	1-1	1.1	2nd paragraph	Add comma after (TMWTP).	R. Upton	VAF	Addressed.
7	1-1	1.1	Table 1-1	Tables 1-1 and 1-2 interchange "Pump Station" and "Pumping Plant". Standardize "Pump Station".	V. Migl	VAF	Addressed.
8	1-2	1.1	Table 1-2	In the canal column, standardize whether the word canal will be used or not. i.e. Briscoe vs. Briscoe Canal. Juliff vs. Juliff Canal.	V. Migl	VAF	Addressed.
9	1-2	1.1	Paragraph 3	GCWA's mission statement is "To reliably deliver water to our customers".	V. Migl	JB	Mission statement has been corrected.
10	1-2	1.1	Paragraph 3	Verify Region H water plan from now to 2080. Water demand will increase by approximately 110,000 af/year or just over 90 MGD.	R. Upton	JB	Added demand statement through 2080. Also added statement on water needs for the area, based on currently available existing supplies, showing how much of the future demand still needs to find a water supply in order to be met.
11	1-3	1.1	Last paragraph in 1.1	Revise entire paragraph to: Harris Galveston Subsidence District (HGSD) is a stakeholder in the project and provides a portion of the non-Federal funds for this study. HGSD is a special-purpose district created by the Texas Legislature to prevent further subsidence in Harris and Galveston counties through groundwater regulation, science and research programs, water conservation programs, and regional collaboration. Reducing reliance on groundwater is a vital component of preventing further subsidence, which is why HGSD encourages and supports the development of alternative water sources.	HGSD	VAF	Addressed.
12	1-3	1.2	Last sentence	Not all of the area within Figure 1-2 is managed by BRA. Recommend that this sentence be modified. "...the Brazos River Basin which are <u>primarily</u> managed by BRA."	Aaron Abel, BRA	VAF	Addressed.
13	1-4	1.2	Figure 1-1	Legend is not correct.	V. Migl	CAS	Updated
14	1-4	1.2	Figure 1-1	Juliff Canal and Chocolate Bayou canal should be different colors. The green portion of the chocolate bayou canal should be the same color as the rest of the chocolate bayou canal. Show Brunner Ditch as part of CB system instead of showing as a lateral.	V. Migl	CAS	Updated

Project Name: Desalination Feasibility Study
Consultant Firm: Black & Veatch
Submittal % or #: Draft Study

USBR Grant No.
Project Number:
Submittal Date:

R24AP00180-00

5993

1/16/2026

Comment #	Page	Section	Reference	Comments Review Meeting Comments	Commentor	Responder	Consultant Response
15	1-5	1.2	Figure 1-2	Should we show some BRA customers to help show that GCWA is towards the bottom of the Brazos River and downstream of most BRA. This is a factor in why modeling was done to see the potential of GCWA water being received upstream. Aaron will provide a map of BRA system and it's reservoirs. B&V should identify GCWA location on the map.	V. Migl	VAF/Chris	Figure 1-2 has been replaced with a map provided by BRA. GCWA location has been identified on the map.
16	1-6	1.2.1.2		Camp Wallace Road is better known as F.M. 2004.	V. Migl	VAF	Addressed.
17	1-6	1.2.1.2		This site also has proximity to GCWA canals and the potable transmission system.	V. Migl	JB	This information has been added to Section 1.2.1.2.
18	2-1	2.1	2nd paragraph	Verify the Region H numbers.	R. Upton	JB	Region H demand numbers have been verified. Additional statements on the amount of needed water to meet future demands is also included.
19	2-2	2.1	FBSD - 3rd bullet point	Replace bullet point with: FBSD establishes conversion requirements for its permittees to reduce reliance on groundwater and utilize alternative water supplies to meet their total water demand.	HGSD	VAF	Addressed.
20	2-2	2.1	FBSD - 4th bullet point	Replace with: FBSD monitors land elevation change, water use, and aquifer levels to monitor subsidence and ensure regulations are effective in reducing subsidence.	HGSD	VAF	Addressed.
21	2-2	2.1	HGSD - 3rd bullet point	Replace bullet point with: HGSD establishes conversion requirements for its permittees to reduce reliance on groundwater and utilize alternative water supplies to meet their total water demand. All groundwater users within the Subsidence District are required to limit groundwater use as specified in the Regulatory Plan.	HGSD	VAF	Addressed.
22	2-2	2.1	HGSD - 4th bullet point	Replace with: HGSD monitors land elevation change, water use, and aquifer levels to monitor subsidence and ensure regulations are effective in reducing subsidence.	HGSD	VAF	Addressed.
23	2-2	2.1	HGSD - 5th bullet point	Replace with: Portions of southeastern Harris and Galveston counties have experienced over 10 feet of subsidence since 1906.	HGSD	VAF	Addressed.
24	2-2	2.1	Last paragraph on page 2-2	Revise first sentence to: In the greater Houston-Galveston region, land subsidence is the decrease in land-surface elevation caused by aquifer compaction due to abundant, long-term groundwater withdrawals. This consequence of groundwater use prompted the need for alternative water supply as groundwater is not a viable source as a long-term reliable water supply for GCWA.	HGSD	VAF	Addressed.

Project Name: Desalination Feasibility Study
Consultant Firm: Black & Veatch
Submittal % or #: Draft Study

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Project Number:
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R24AP00180-00
5993
1/16/2026

Comment #	Page	Section	Reference	Comments Review Meeting Comments	Commentor	Responder	Consultant Response
25	2-2	2.1	Last paragraph on page 2-2	Consider removing the culprit (Texas City Industries) in the second sentence as there were other users like municipal and agricultural. This would end the sentence after "overuse of groundwater".	HGSD	JB	Addressed.
26	2-2	2.1	Last paragraph on page 2-2	Consider revising second sentence to: For example, the Galveston Canal was built in the late 1940s to bring surface water into Galveston County (Texas City) to combat land subsidence caused by the expanded development of the groundwater resources in the area.	HGSD	VAF	Addressed.
27	2-4	2.2.1	2nd paragraph, last sentence	Define CoA. Certificate of Adjudication.	Aaron Abel, BRA	VAF	Addressed.
28	2-4	2.2.1	Table 2-1	Remove " Old 1040 Permit, Originally A Plant).	B. Johnson	VAF	Addressed.
29	2-4	2.2.1	Table 2-1	Remove "Old 1299 Permit, Originally Plant B".	B. Johnson	VAF	Addressed.
30	2-4	2.2.1	Table 2-1	Replace "Currently, can only be used at May Pumping Plan. Accounting plan in development for diversion at Briscoe Pumping Plant" with "Can be diverted at J".	B. Johnson	VAF	Addressed.
31	2-5	2.2.2	Table 2-2	Remove 5-11 as these contracts have expired and weren't renewed.	B. Johnson	VAF	Addressed.
32	2-5	2.2.2	Table 2-2	Add NRG Short Term Contract with 10,000 ac-ft/yr.	B. Johnson	VAF	Addressed.
33	2-6	2.2.3	Second Paragraph	Replace "additions of rights results of a change" to "additions of rights results in a change".	R. Upton	VAF	Addressed.
34	2-6	2.2.3	First Bullet	Section 1 didn't provide much of an introduction to the treated water system.	V. Migl	CAS	Updated.
35	2-6	2.2.3	Third bullet	Maybe specify that "un-diverted water" is un-diverted water under GCWA water rights and its BRA contracts?	Aaron Abel, BRA	VAF	Addressed.
36	2-7	2.3.1	First Paragraph	Remove" GCWA serves different types of customers including..." as this sentence gets redundant.	V. Migl	VAF	Addressed.
37	2-7	2.3.1	Third Paragraph	344,115 ac-ft/yr (307 MGD) doesn't align with table 2-3.	V. Migl	CAS	Corrected, in accordance with edits to Table 2-3
38	2-8	2.3.1	Table 2-3	1. Ascend is located on the Monsanto Canal. 2. Ashland is located on the I Canal. 3. IPS amount is 73.062 MGD. 4. IPS is located on the I Canal. 5. TMWTP is located on the I Canal . 6. Galveston is a customer of TMWTP so the amount would be included in the 57.6MGD. 7. Texas City is a customer of TMWTP so the amount would be included in the 57.6 MGD. 8. Missing Topaz, amount 0.137 MGD, located on the I Canal. 9. Robert will send out updated numbers.	V. Migl	VAF	Addressed.
39	2-9	2.3.1	Second Paragraph	Where is 344,115 ac-ft/yr from?	V. Migl	CAS	This was direct from the source files of the latest iteration of daily-hydro model, as provided by GCWA. Updated to reflect updated Table 2-3. Model not re-run, but conclusions unaffected.

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40	2-9	2.3.1	Second Paragraph	How are the in-canal losses calculated? We can show only 5% loss. Report shows 2-3% losses, GCWA claims 5% losses.	R. Upton	CAS	Text updated, but model has not been re-run.
41	2-9	2.3.1	Fourth Paragraph	TMWTP capacity is rated at 57.6 MGD.	V. Migl	VAF	Addressed.
42	2-10	2.3.2	Table 2-5	Should we show demands of other GCWA customers outside of the TMWTP and outside of GCWA since we mention the potential to allocated water upstream to other customers? Show growth expected in Brazoria and Fort Bend Counties.	V. Migl	CAS	The original approach to develop Section 2.3.2 was more limited in assumptions of which customers would affect GCWA's demand, compared to the approach developed in Section 1. Section 2.3.2 has been revised to match.
43	2-10	2.3.2	Table 2-5	Are we rounding to 2 decimals or 3?	V. Migl	CAS	Table 2-5 was removed as part of update to Section 2.3.2.
44	2-11	2.3.2	Table 2-5	Peaking factor not discussed.	M. Early	CAS	Table 2-5 was removed as part of update to Section 2.3.2.
45	2-11	2.3.2	Second Paragraph	Throughout report: Region H estimates 80 MGD increase needed by 2050. Table shows only 10 MGD short by 2080. Section does not depict Need. Is there a way to connect these figures to the Region H figures used in the report?	M. Early	CAS	The original approach to developed Section 2.3.2 was more limited in assumptions of which customers would affect GCWA's demand, compared to the approach developed in Section 1. Section 2.3.2 has been revised to match.
46	2-11	2.3.2	Third Paragraph	Remember, as long as BRA has water, GCWA has water.	R. Upton	CAS	Text in Section 2.3.2 has been modified.
47	3-1	3.0	First Paragraph	Don't focus on texas city, focus on GCWA being on the Gulf Coast.	V. Migl	JB	Changed from "Texas City" to "GCWA"
48	3-1	3.0	Last Sentence	Is subsidence only happening near the coast?	V. Migl	JB	No, it's not. "near the coast" has been removed from the sentence.
49	3-1	3.1	First Sentence	Clarify that no WW treatment = no reuse.	M. Early	VAF	Addressed.
50	3-1	3.1	Second Sentence	Change "free up raw water for industrial customers and potential even agricultural customers" to "free up raw water for other customers."	V. Migl	VAF	Addressed.
51	3-1	3.2	Second Sentence	increase by another 100MGD by 2080, I don't think so.	R. Upton	JB	Demands have been changed to "needs", and the numbers from the Region H plan have been updated.
52	3-1	3.2	Last sentence	This sentence belongs in the introduction, "Some GCWA customers hold "firm water" contracts...."	V. Migl	VAF	Addressed.
53	3-2	3.2	Last Sentence	TWDB 2026 Region H has been mentioned multiple times already. This reference should come much earlier in the report.	V. Migl	JB	This reference is included here to document the water market availability analysis, but has been added to Section 1.1 as well.
54	3-2	3.4	Second sentence	Remove - Redundant as GCWA has already been introduced. "GCWA is a wholesale water supplier...."	V. Migl	VAF	Addressed.
55	3-2	3.4	Second paragraph	Replace the first sentence with "GCWA does not provide potable water or wastewater services to individual households."	V. Migl	VAF	Addressed.
56	3-3	3.5	First Sentence	West Bay is located in Southwest Galveston County, not south of Texas City. An image may be helpful here.	V. Migl	VAF	Addressed. Figure 3-1 added.

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57	3-3	3.5	Third Paragraph	Why would the preliminary intake capacity be for 40 MGD when we are phasing from 20MGD to 40MGD. This should better describe the intent.	V. Migl	JB	Added sentence stating: Sizing the intake infrastructure for full capacity when the plant may be built in phases minimizes the intake related permitting and construction required in future phases.
58	3-3	3.5	Last Paragraph	What is an impaired water source?	V. Migl	JB	Added "(water that does not meet water quality standards set for its intended use)" to the sentence.
59	3-3	3.6	Last Paragraph	PH Robinson site "could be operational in five years" from permit or date of report or?	M. Early	JB	Revised sentence to say: "The new facility could potentially be operational within five years or so if the permitting process is approved and the design and construction phases are allowed to proceed." This information is from a news report and EPCOR's Bayshore website.
60	4-1			4-c and 4-d are discussed in section 5 instead of 4.	V. Migl	JB	Added an explanation to 4c and 4d in the box at the beginning of Section 4.0)
61	4-3	4.2.1.2	Figure 4-1	Another option - The treatment plant sits adjacent to a GCWA canal. A pipeline can be ran west along gcwa canal to the Head of the G Canal. This way we stay in existing GCWA easements.	R. Upton	JB	The Reuse alternative has been revised to assume the pipeline runs west along the GCWA canal.
62	4-5	4.2.1.4	"GCWA will need"	We need to discuss this as what do you mean. Need where? The water needed for the non-WUGs in the area or that TWTP is not going to be expanded? We have the water just not treatment.	R. Upton	JB	Modified sentence to say "...GCWA is interested in developing to meet future needs in the area."
63	4-5	4.2.1.6	Last Sentence	Remove, "that also frees up surface water for BRA customers upstream in the Brazos River Basin that do not have access to seawater and that does not contribute to subsidence"	V. Migl	VAF	Addressed.
64	4-14	4.3.1.3		Would we build the structure for 40MGD then only install pumps for 20MGD?	V. Migl	VV	Ideally the intake structure would be built for the entire flow rate, but would only install pumps for 20 MGD. It is less expensive that way overall. No change proposed to the report.
65	4-15	4.3.1.5	Second Paragraph, last sentence	Missing text.	R. Upton	VV	Revised sentence to say: In addition, MF/UF systems require a significantly larger number of valves and instruments as typical membrane skid capacity is smaller than that of a typical media filter. This can result in more maintenance for the MF/UF systems.
66	4-23	4.3.1.13		Should Clean-in-Place have (CIP) following it?	V. Migl	VAF	Added.
67	4-26	4.4.3	1 st paragraph, last sentence	"2 parts per trillion (ppt)". I think the units should be "parts per thousand" instead of parts per trillion.	Aaron Abel, BRA	JB	This has been corrected.
68	5-2	5.1	First Paragraph	Verify the Region H information.	R. Upton	JB	Verified and added "Needs" numbers.

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69	5-3	5.1	Last Paragraph, First Sentence	Do not understand statement "If the desalination project were not to be implemented, it is likely that GCWA's municipal and industrial customer growth would slow, and potentially impact growth upstream in the Brazos River Basin as well."	R. Upton	JB	Revised sentence to say: "If the desalination project were not to be implemented, it is likely that municipal and industrial growth in the area would be restricted due to limitations on future supplies from other potential sources, and drought impacts would have greater effects."
70	5-4	5.2.2	Table 5-1	Need to fix alignment.	R. Upton	JB	Costs from update to reuse has been incorporated.
71	5-4	5.2.2	Table 5-1	Current contract w/ Alvin is \$0.10 per thousand gallons.	R. Upton	JB	Cost of water has been adjusted to reflect this number.
72	5-4	5.2.3	First Sentence	12MGD at Alta Loma and 20 MGD at a new wellfield in Brazoria County.	R. Upton	VAF	Addressed.
73	5-10	5.4.1	First paragraph	Consider revising first sentence to: The Galveston Canal was built in the late 1940s to bring surface water into Galveston County (Texas City) to combat land subsidence caused by the expanded development of the groundwater resources in the area.	HGSD	VAF	Addressed.
74	5-10	5.4.1	First paragraph	Consider replacing "realistic source" to "viable source" in the second sentence.	HGSD	VAF	Addressed.
75	5-10	5.4.2	Third Paragraph	Volume of water is limited to 6.5 MGD, we are only looking at cost correct?	R. Upton	JB	This paragraph has been revised to acknowledge that there may be additionally available reclaimed water in the area that could be identified in the future.
76	5-11	5.4.2	Table 5-5	In the qualitative benefits column, replace all instances of "creating less subsidence" to "subsidence-neutral".	HGSD	VAF	Addressed.
77	6-1	6.1	First Paragraph, Last Sentence	leave out "so that surface water within the Brazos River Basin would have greater operational flexibility".	V. Migl	VAF	Addressed.
78	6-1	6.1	Second paragraph, second sentence	Should state "Because these three counties are within GCWAs service area".	V. Migl	VAF	We have previously been requested not to use the phrase "service area", so we have been consistent with that throughout the report. Suggest leaving as-is.
79	6-1	6.1	Second paragraph third sentence	State, "Being on the Gulf Coast with a nearly limitless supply of seawater..."	V. Migl	VAF	Addressed.
80	6-1	6.1	Third paragraph	What is GCD?	V. Migl	VAF	Groundwater Conservation District, which has been defined in earlier sections and has been added to the Abbreviations List

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81	7-1	7.1	First Paragraph	"Initial review identified potential significant impacts on endangered and threatened species". This sounds very concerning, is this true?	V. Migl	Norris	The "significant impacts" language comes from the National Environmental Policy Act (NEPA), and although the feasibility study is not a NEPA document, it is intended to allow for a transition into a NEPA process if applicable. At this stage of the project, there is not enough information to say that endangered species will not be adversely affected, nor is there enough information to say that they will. Therefore, potentially significant is standard terminology pointing to the likelihood of needing to prepare an Environmental Assessment if the project moves forward with federal funding. Endangered species are present in the study area and are therefore a cause for concern at this stage; however, we will follow the regulatory process of avoiding, minimizing, and mitigating adverse impacts to obtain the necessary permits and approvals to allow the project to move forward. No change proposed.
82	7-2	7.1		Are there maps to go along with the subsections of 7.1?	V. Migl	Norris	The shapes and layers make it not conducive to putting them on a paper map for the report; however, the spatial and regulatory information have been accounted for and included in the report.
83	7-2	7.1.2	First paragraph, last sentence	A proposed critical habitat for the green sea turtle occurs within the tidal water in the proposed project limits. Is there a map of this? How does this affect our project?	V. Migl	Norris	Language added: Project components were sited to avoid mapped seagrass beds within Galveston Bay, which represent primary foraging habitat for green sea turtles, thereby reducing the likelihood of impacts to proposed critical habitat.

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84	7-6	7.1.7	Texas City and La Marque	Most GCWA employees do not come from Texas City and La Marque. GCWA staff comes from all over South Houston in Brazoria and Galveston Counties.	V. Migl	Norris	Language revised: GCWA maintains significant some operational presence and where of the some of the area's workforce resides. The majority of the GCWA staff comes from the broader region of South Houston in Brazoria and Galveston counties. The following sections summarize key socioeconomic indicators for the surrounding communities.
85	9-2	9.1	Figure 9-1	1. Concern of so short bid time. This was misinterpreted as months instead of quarters. 2. May need to consider thought on CMAR in the future.	R. Upton	JB	No change anticipated.
86	12-1	12.0	Second Paragraph	Concern on Region H sentence because it's not what I see in the next Region H plan. See a total of 90MGD.	R. Upton	JB	The Region H data summaries by county have been pulled and totaled for the three counties based on both demands and needs.
87	N/A	App. C, WAM Simulation Report, Section 2	Third bullet of modeling assumptions	Never saw in the report an explanation on why volume and reliability may vary from GCWA's location on the bottom end of the revier versus other locations upstream. Such as, inflow may occur upstream of GCWA but still downstream of other desired locations.	V. Migl	CAS	This is intended to reflect the variability of GCWA customer's actual take volume.
88	N/A	App. C, WAM Simulation Report, Section 2	Third bullet of modeling assumptions	Is un-diverted water, water that is not diverted under GCWA water rights only? Or does it also include water that is not diverted under GCWA's stored water contracts with BRA? (Similar comment from Page 2-6, Section 2.2.3.	Aaron Abel, BRA	CAS	Updated as in the similar comment.
89	N/A	App. C, WAM Simulation Report, Section 2	Last bullet of model assumptions	"....without impacting GCWA's existing supply or intervening water rights holders...." Did the evaluation of impacts to intervening water rights only include water rights below the Hempstead gage?	Aaron Abel, BRA	CAS	Correct. While operations further upstream of this limit (especially reservoirs) may have an effect on water supply to GCWA, the selected area was evaluated to be the region of most interest to the study.
90	N/A	Appendix C, Section 2	Third bullet of the objectives of the WAM analysis	"Foy" should be "For".	V. Migl	CAS	Updated
91	N/A	App. C, WAM Simulation Report	Multiple instances	Multiple "Error! Reference source not found" are within the text of Appendix C.	Aaron Abel, BRA	CAS	Updated
92	N/A	Appendix C Section 4.2	Second Paragraph	"A diversion of the full amount from the Briscoe right"? What is Briscoe right.	R. Upton	CAS	This is intended to refer to the 1939 priority date of CA No. 12-5171. Text updated
93	N/A	Appendix C Section 5	Fifth Paragraph	"A third category of scenarios were studied, to examine a split diversion between the Shannon and the William May water rights." Does this mean Shannon and Briscoe? Table 5-1 shows 20MGD each from Briscoe and Shannon to Washington.	V. Migl	CAS	Clarified

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94	N/A	App. C, WAM Simulation Report	Page 4 of 7	This sentence isn't clear. There may be a word missing. "A <i>final category of model outputs, represented in the far column of Error! Reference source not found. , examined and evaluated the potential deals with impacts to other water right holders.</i> " What is meant by "...examined and evaluated the potential deals with impacts to other water rights."?	Aaron Abel, BRA	CAS	Clarified
95	N/A	Appendix C Section 6	"This freed-up water could be allocated either within the GCWA system or without"	Should this state "either within the GCWA system or outside"?	V. Migl	CAS	Updated
96	3	Appendix F Environmental Review	4.0, last paragraph	"Feld investigations would need to be conducted"... should be "Field".	V. Migl	Norris	Corrected
97	13	Appendix F 8.2	Table 4	What is the purpose of a full row of "unknown"?	V. Migl	Norris	The explanation is noted in 8.2 of the report "one additional survey is noted in the Atlas, although the date of the survey along with the other details are unknown" The information for the table comes directly from the THC archeological sites atlas, which shows a record of a previous survey having been performed with no useful information included in the THC database. This note is included in the environmental report for clarification.